The single most important thing to thunderstorm forecasting is listen to your gut feeling over anything else

Remember, this is a guide only - the second most important thing to thunderstorm forecasting is experience! That is something that no books or guides can ever teach - it can only be taught from hard work and patience.

Part One - The Basics

Part Two - Skew-T s

Downunder Chasing - Thunderstorm Forecasting Guide http://www.downunderchase.com/storminfo/stormguide/

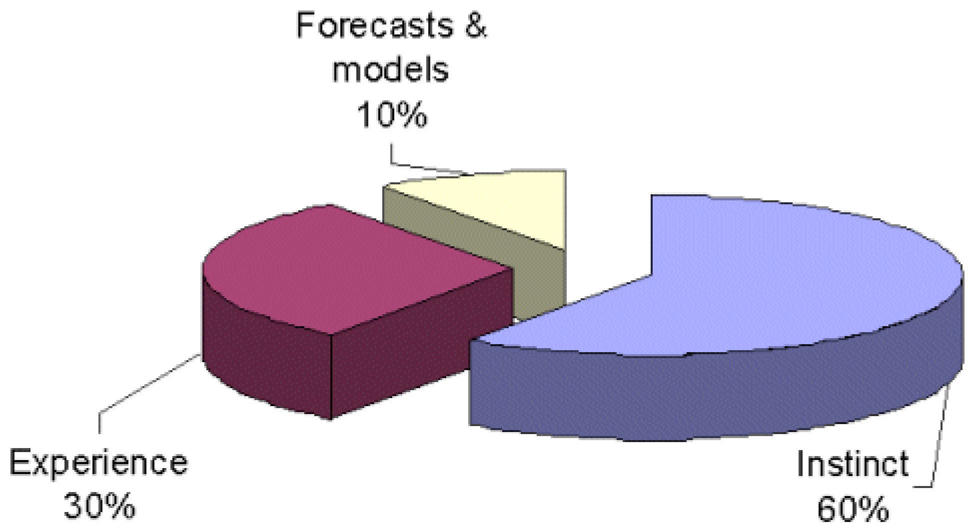
Part Three - More On Shear

Part Four - Thinking Outside The Square

I would also like to strongly recommend Jimmy Deguara's guide on "Weather Observation Techniques" for learning about "reading the sky." I believe it is an excellent supplement to this guide! The above sections are simply my own thoughts and opinions on thunderstorms and forecasting thunderstorms. There are many different ways of forecasting thunderstorms - this is just a guide with my advice. I hold no responsibility for the actions you may take in the course of reading this.

How do you forecast storms?

This is the question I get asked the most, and this is what this guide is for! To help give an overview on how to forecast storms. The second most frequently asked question is "what is the best way?" Well, a lot of people don't like the answer I give - because the "best way" is not really the easiest way! And few people believe me when I tell them, but here's (in my opinion) the "best way" to forecast storms!



This may give a bit of a shock - only 10% for forecasts and models! Yet chances are, people (including myself) will still look at them fairly extensively. The thing is, computers can't think! We can, and we're lucky enough to be able to learn things. Instinct is so important! How does the day look? Feel? Smell even!? Or if the day(s) in question haven't arrived yet, how are the days before feeling and looking? There's a certain "feel" when it comes to thunderstorms (and all aspects of weather) - some days don't quite feel right, even though the models look great!
Downunder Chasing - Storm Chasing 2000 - 2001

Sometimes days feel great, even though he models don't look that crash hot - yet time after time, your feeling will often win ahead of the models.
Experience and instinct work hand in hand - you develop your gut feeling and instinct by experience, by learning things it helps you get a better feel for what's happening around you. Hence, I often lump them in together and think that 90% of storm forecasting really is instinct and experience! So don't be afraid to listen to your gut feeling - trust it further and you might be surprised about how much you already know. Learning about weather is not something you can read in a guide or read in a book - it's something that you need to learn and "nurture" so to speak. So this guide is not going to teach you all there is to know about storms (and first and foremost, that's because I don't know everything there is to know about storms - only a small part in an endless tangle of web!) But I hope that it helps people have a better understanding of what they're looking at so that they may gather more experience and develop their gut feeling and instinct better.

The other aim of this is to help teach people exactly what some of the thunderstorm indicies do. While it's nice to look at a LI chart and see nice big splotch of -6 over you, what does it really mean? We know it's "good" - but what else? It reminds me somewhat of going into a computer store and a salesperson is trying to sell a computer. They ratter off lots of impressive specs, and all they know is "that's good" - but they don't know why it's good, or perhaps it's going to give them something they don't really need or want. Think about it - if you know what you're looking at, then perhaps you might be able to choose the "specifications" of your thunderstorm too! Do you want lightning? Structure? Hail? A tornado? Or do you just want any thunderstorm? Knowing what you're looking at can certainly help you decide which type of storm you're after! It's all very nice having a DVD player on the computer, but is it worth sacrificing that CD writer that you really want? This is why it's important to know what you're looking at, as opposed to just knowing "that's good!"

So in brief...look at the data to give you an idea, then let your senses guide you...

What do thunderstorms require?

Lets think about this question for a bit. What do you notice on typical thunderstorm days? Are there features of days that tend to characterise thunderstorm days from other days? Well - yes! We tend to associate thunderstorm days with warm or hot, humid days. This guide will explain why - but also, it will look at how thunderstorms are also possible (and occur regularly in states such as Western Australia and Victoria), on those very cold days!

Alright, so we have in our mind of a "typical" thunderstorm day. Well, here's the list of ingredients that are essential for thunderstorms:

1. Heat (some form of heat is needed, even on those cold days!)
2. Moisture (after all, thunderstorms are made of water...)
3. Trigger (need something to start the storms).
4. Relatively colder air aloft (key word is relative here...more about this later sections).

Now - your heat will take a while to build up. There's two ways you can get heat, either through advection (ie, winds blowing hot air into the area), and the other through the Sun. The latter is preferable but a combination of the two works well. Why do we need heat? Well, heat is the key to our mixture here - that mixture is instability. Air will only rise on its own accord if it is lighter than the surrounding air - for that to happen, it must be warmer as warm air is less dense that cold air. So if we have some warm/hot air at the ground - it'll (in theory) rise. And why do we want most of the heat to come from the sun? Convection starts off as small pockets of air that rise as they become warmer than the surrounding air. We want the ground to become hot too, that also helps retain the heat and helps get those thermals (pockets of air) rising. As opposed to a cloudy, but hot day - those thermals never really have the same potential. Typically, I'd prefer 30C and sunny over 35C and cloudy.

Meanwhile, while our heat is starting to do some work - lets assume it can ascend up into the atmosphere. What happens? Absolutely nothing! Woops, we forgot to add some moisture, given that thunderstorms are full of billions of little water droplets and hail/ice nuclei - it makes sense that we're going to need a lot of moisture. We want this moisture at the surface, not in the upper levels though. There are two ways we can get moisture, either through left over rain bands, or advected through by winds on the ocean (the latter is preferable, but some storms systems can "recycle" moisture from previous rain/storms over the same area over and over - especially in inland Australia, and can produce some beautiful storm systems from it!) Moisture is really what a thunderstorm consists of - a column of water suspended up in the atmosphere. But the other reason why this is handy as it again is another vital ingredient in our instability mixture. Moist air contains latent (hidden) heat, basically - I won't go into the reasons, but when water condenses, it releases heat! So if we have an updraft that is condensing water, then there's additional heat being released in the updraft. The significance of this is that the updraft parcel cools due to expansion as it ascends into the atmosphere.

The addition of heat through to this process means it doesn't cool as quickly, so a parcel is more likely to be warmer than its surroundings as it ascends in the atmosphere, so it's more likely to rise and helps with our instability! The thing to remember here, is we want the moisture in a layer at the surface (it's no good if the surface DP is 20, and 100m above that the DP crashes to 5), the moist layer is too shallow. You want the lower 1km or so (approx 100mb) to be moist. More on moisture thickness in later parts.

Ok - so we've got our heat and moisture. It's 34 degrees and the DP is 25 - but we're staring at clear skies, why??? Lets add a trigger…after all, something has to break through the cap in the lower atmosphere, right? A 'cap' acts as a lid on convection, it's sometimes incorrectly referred to as an inversion (where air warms with height), but a cap can occur without an inversion. In fact, if you look at how a parcel of air will rise in its dry rate, and its wet rate you can soon see that a cap is a naturally occurring phenomenon in most cases. So this small stable layer has to be broken, to allow our updraft parcels to continue to ascend into the atmosphere. A cap may be broken by the shear force of an updraft parcel without any other influence, but often there is some sort of low pressure area around that. So ways to break the cap may include ranges (forcing air upwards, and elevated heating) and fronts/troughs/low pressure systems where air is converging/confluencing in an area and moving upwards into the lower atmosphere. So essentially all up, we're just trying to force the air parcel through a small stable layer.

The other ingredient is highly relative (so is much of the above), you need cooler air aloft. You don't necessarily need a great big upper level trough, but just air that is cold enough to allow your surface obs to create an unstable air parcel. If the air in the upper atmosphere is too warm, then you might find that no matter how much moisture/heat/triggers you have - that you won't get anything. Upper level ridges can be killers - they can suppress strong updrafts in some cases!

If we put all of these ingredients together…we should have instability and a trigger and in *theory* have a storm developing. I stress - in theory, there is obviously much more to it. This has touched on the absolute basics and has used a lot of generalisations (and as they say, all generalisations are false!)

Introduction to Forecasting Thunderstorms

We've established that we need instability as one of our essentials to thunderstorm development. But how do we measure instability? There's a few ways. The best way is to open a Skew-T and look, but for the moment it will be easier to use a few other methods. And these methods generally work well too - especially on a broad scale, I often look at things on a broad scale before going back in for a closer look with a few Skew-Ts and other information.
One of the most popular ways of deriving instability is using the lifted index (LI). So what is it? Well, basically - if you ascended a parcel of air at the surface and then compared it to the actual environmental temperature at the 500mb level of the atmosphere (approximately 18,000ft), then that gives you your LI! Quite simple really, and quite a good little way of deriving instability. The actual formula if you're interested is:

LI = Environmental temperature - temperature of ascending parcel

So lets say our environmental temperature was -15C, and the temperature of our ascending parcel is -5C, then:

LI = -15 - 5
LI = -10

Ok...so our LI is -10C, that's great! Right? Err...what does it mean? Well...as a guide I tend to think of the LI as potential as opposed to what will and won't happen. Keep in mind that these "magic numbers" assume that other things are adequate (eg, trigger for storms, shear and other factors for severe storms).:

LI Value/Result

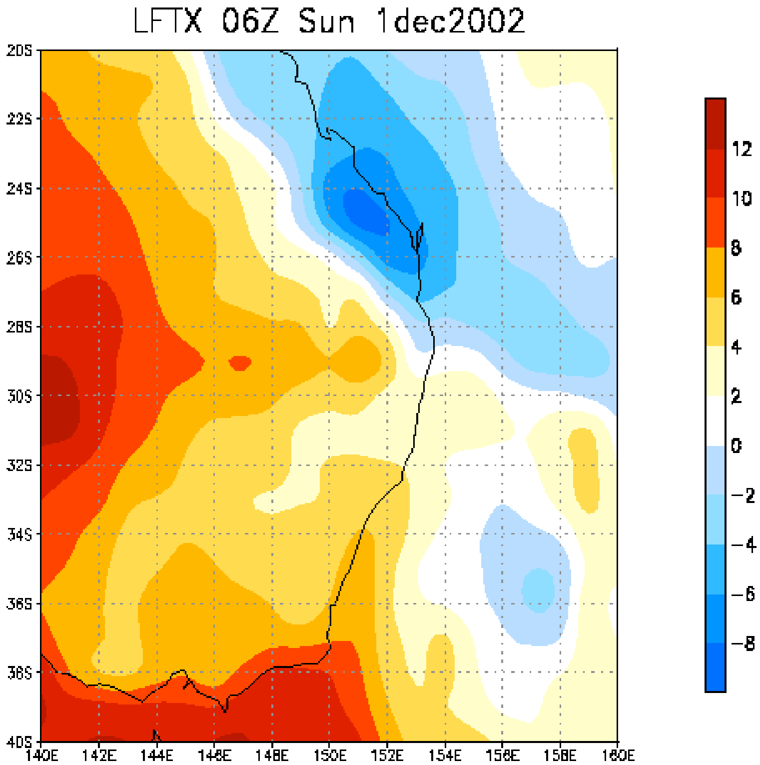
- +2 or higher The 500mb level looks relatively stable, might get some showers if the lower levels are cool enough though. Storms unlikely.
- 0 to +2 Possible showers, low risk of storms (but storms in more unstable areas might move into this region and survive).
- -2 to 0 Weak instability, potential for some showers and storms.
- -4 to -2 Moderate instability, ample potential for storms - starting to become favourable for severe storms if other conditions are right.
- -4 to -6 Strong instability, more than ample potential for storms and severe storms.
- -6 and below Very strong instability, same as above.

One thing quite a few people do is load the LI and then see if it's nicely negative or horrendously positive and then immediately say yay or nay to storms for that area. To be honest, quite a few times you're going to be right - the LI is certainly a very good index for instability! But also remember that there's a lot more to just looking at the LI, and if you want to become more accurate you'll need to look at other things than the LI, such as CAPE, or better still - Skew-Ts!

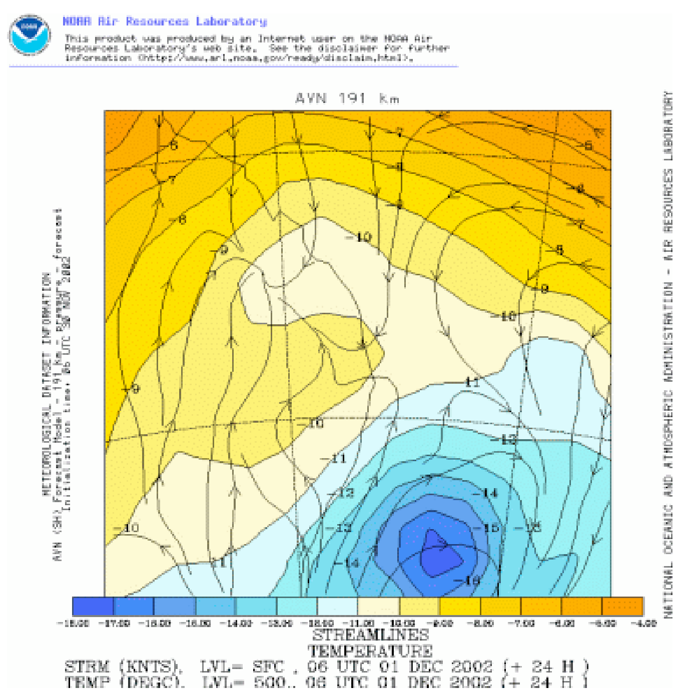
Also remember something else - the LI only tells you if one level is unstable! Think about it...what if the 500mb level instability is not representitive of the remainder of the instability in the atmosphere? We could have a warm layer at 500mb, so the LI is quite high, or we could have a cold layer at 500mb so the LI is quite low (ie strongly negative).

Where can you find LI forecasts? There's a few models that do it, it's a case of personal preference, but I use AVN when I look at LIs. Select the latest forecast set, then choose "LFTX," and then select your date and time (time is in UTC, add 10hrs for EST, 8hrs for WST). After some experience you can fiddle around with the contour interval, and perhaps even pull out a map of your area and look at zooming in using the custom option! I use 140, 20, -40, 20 respectively in the four longitude/latitude boxes and that gives me the southern half of Queensland and most of NSW.

A few last thoughts about the LI though...lets look at an LI chart...

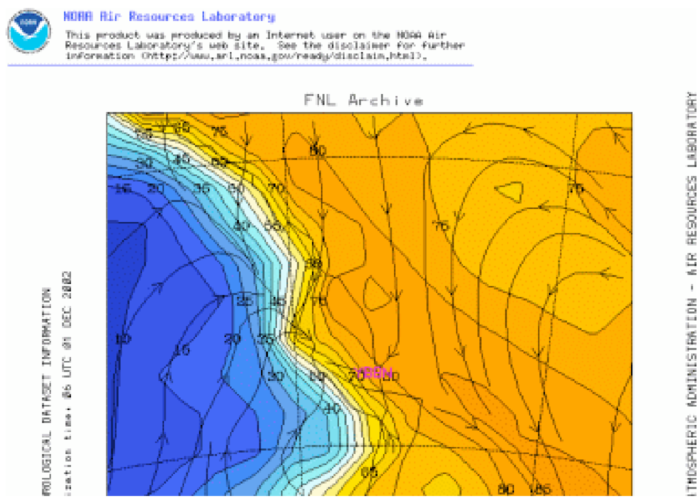


Wowzers! Some nice -8 to -10 LIs over Capricornia - lets head to the middle of it, right! Right...? Right??? Hmmm...lets have a think about it first. If we ignore shear (read about that here), and assume that our other main thunderstorm features are shear and cap, and they're all equal over the area. Would we really want to head to the LI bullseye? Why does the LI increase so quickly when you shift to the west? Is it because of an upper trough? Well, lets look at our 500mb temperatures and see...



Ok, this is a good way of looking at things - 500mb temperatures are a great little way of checking on our LIs to see what they're doing, are they decreasing because there's an extremely sharp and cold upper level cold cool, or is it because of large amounts of heat and moisture? Well, we've also overlaid the surface streamlines here, so we can automatically see two things! First, yes there is an upper trough (a quite nice one too, we're in Capricornia here which is the southern edge of the tropics, so -10C @ 500mb is quite considerable!) A good way to see the strength is compare the temperature in that area, against other areas of the same latitude. You can see that if you drift E or W you'd run into -7C 500mb temperatures, so that's not too bad (again, this is the southern tropics now!) But the upper level trough isn't that sharp, and certainly not enough to cause our LIs to increase rapidly into the positives as we drift was of the LI max. What about heat and moisture? Well, I'm going to concentrate on moisture here, and if you take the chance to read about Skew-Ts, then you'll see what I mean about how much moisture can effect the LI! Look at the winds, lovely northerly winds coming straight off the tropical Coral Sea meeting a trough (line of convergence and where the streamlines meet), where we have southerly winds. Those southerly winds have traveled 1000s of kilometres over land! So while they may not be very cool, they're certainly going to be very dry!

Unfortunately there are no "pure" dewpoint maps for Australia, you have to convert them from specific humidity. What's that you might ask? Probably best not to introduce it at this stage, it will get too confusing. But the other way you can look at surface moisture is actually using surface relative humidity (this has some limitations, but it's good enough for the descriptive purpose here). So lets look at a map...



Ok then! We can see a lovely tongue of moisture right along the coast - but look what happens once you cross that trough and push into those southerlies - the humidity plummets! Right, well since surface moisture is a critical thing to LIs, we've deducted one critical thing - once we hit the LI max, it's going to dry out and stabilise rapidly after. We also know that the LI max is very close to the trough, so things may very well initiate there first. But do you really want to sit underneath the trough line? You can't really see what's happening! It's personal preference, but I like to sit a little ahead of the trough line so I can take into account what's happening. The other thing you will want to take note of is how will thunderstorms move? More about how to decide where they will move in later sections. But on this day, storms were likely to move E or NE, so it would make sense to sit E or NE of the troughline so that you are ahead of the storms and don't get left behind. When it comes to storms though, I like being on the northern edge of them too - that's the most interesting part and where you can see most of the structure (not to mention a tornado if one develops!)

Ok, so we have learnt some things about the LI. Don't always rush for the LI max, but we want strongly negative values ideally. We'll learn a bit more about the limitations of the LI later if you keep reading. I'll also talk about other factors - ie if we want strong or severe thunderstorms, instability and the LI aren't anything.

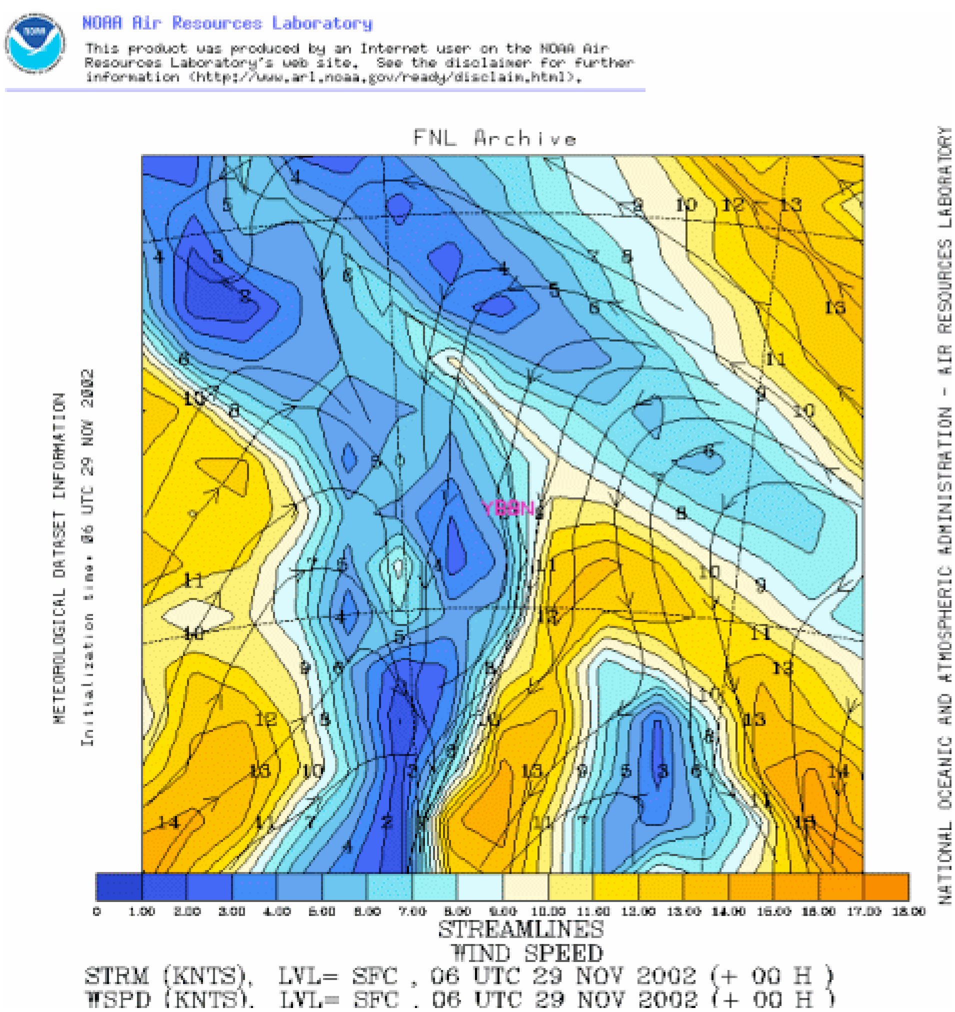
First, one of the limitations of the LI that I mentioned before! The LI only tells us if one level is unstable. Is there another way of knowing if other levels are unstable (short of opening a Skew-T diagram). Yes there is! It's called CAPE (Convective Available Potential Energy). It's another very common and popular way of forecasting instability potential for thunderstorms. However I'm not going to explain it...yet - I think to really understand CAPE you need to know what a Skew-T looks like. So we'll continue onto a few other aspects of storm development first before going onto CAPE!

Triggers

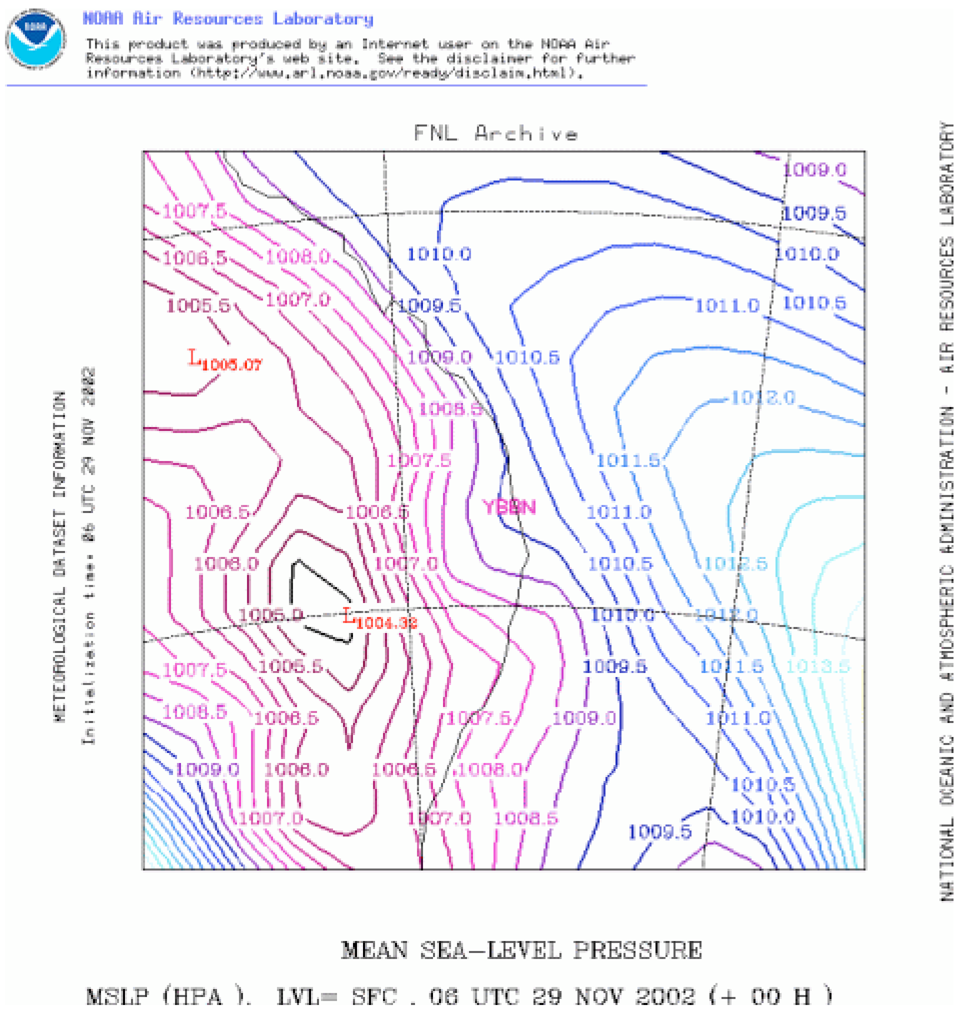
Ok, so next we need a trigger. As mentioned in our thunderstorm ingredients before, triggers are needed to initiate thunderstorm development! Triggers include:

- Troughs
- Cold fronts
- Mountains/ranges

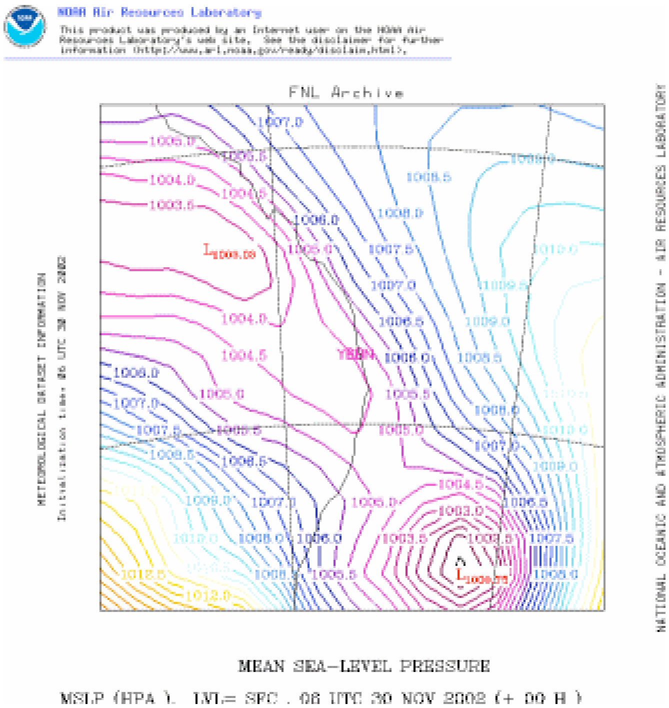
All three are relatively common in Australia, especially with the ranges along the east coast (and often cause the first storms to develop on storm days). Although troughs can be a little more favourable than cold fronts (unless in the higher latitudes of the southern states), as cold fronts have a tendency to dry out a little further north (probably more so a concern because the air isn't as cold in the upper levels which enhances instability). Cold fronts can easily be identified from a wind change bringing significantly cooler temperatures (eg, NW winds swinging to the SW and dropping the temperature rapidly) - this is fairly common in states like Victoria and South Australia. SW'ly winds tend to dry out and warm as they travel across several thousand kilometres of land though, so they are not always that favourable (more so if the SW'ly change is a gusty one) - as I said, they can dry out the situation. But some excellent storm situations have developed in those situations! A more typical situation though is to have a pre-frontal trough (ie a trough ahead of the front). An example of this (not the best example in the world, if I see another one I will swap it over!) is listed below, with a weak front behind a pre-frontal trough - the pre-frontal trough an 800km long squall line developed bringing widespread damage to some of the northern inland NSW communities.

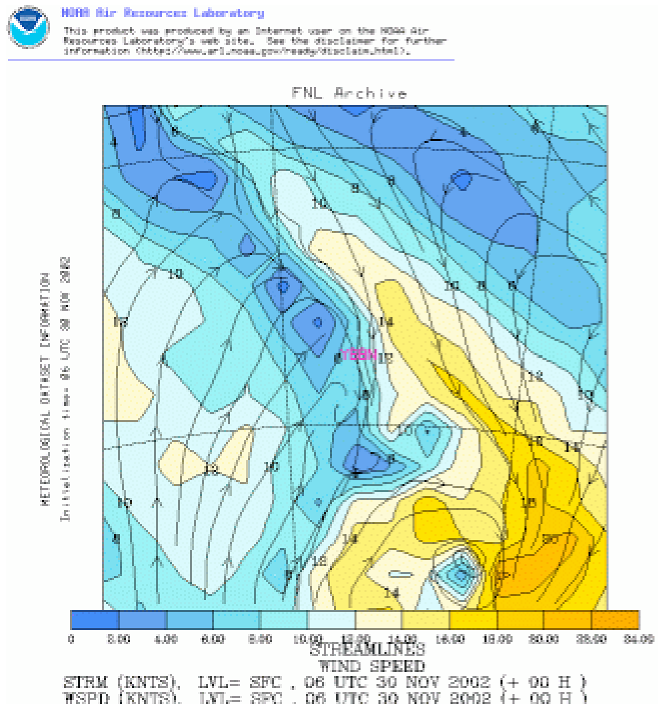


There are two points of interest here, the first is the pre-frontal trough - this can be seen just to the left of the middle, here NNE and NNW winds converging in the centre, signifying the trough. These winds meet at the centre, and collide. There is nowhere for the air to go but up, so that helps force the air upwards and can help break any cap that might be suppressing the convection. Further to the west, there is a wind change and the winds suddenly get a lot stronger. They swing around from the NW to the SW and increase in speed from the SW. This is the remnants of a weakening cold front, although the cold front itself is just another trough! To extent, this cold front is so weak it's almost just a trough by itself, so the trough ahead is almost a "pre-trough trough" instead of a pre-frontal trough! Troughs are essentially elongated areas of low pressure and can be seen either on streamlines or using pressure charts. Streamlines are probably a good way to see boundaries (especially now that there are higher resolution models such as FNL that offer more detail now - it seems to have had a revamp from recent years (previously AVN), it even seems to pick up things like seabreezes on the Australian coast, where as previously it never did). To see the same thing, you can look at BoM charts or the same model will also give you analysis/forecast pressure charts.



You can pick the main trough/weak cold front on this quite well - but you can't really see the pre-frontal trough. So that's where streamlines can be handy - but don't use them as law! Often if you look at the satellite images you can see where the boundaries are and would be more accurate than streamlines. I like streamlines as they do give you a good guide where the main boundaries will lie for storm development - but don't use them as law!
Obviously sometimes you only have the one boundary (ie just a trough), for instance, the following day has just a trough along the coast and that was pretty much picked by streamlines and the pressure!





Another great way if the boundaries aren't showing on the satellite images though is to look at the observations around the place. If you're not up to scratch on your geography - a road atlas could be handy to help you put things into perspective. Say the SE QLD area all has NE'lies, but in NE NSW everywhere by the northern most observation station (Byron Bay) as SE'lies, then you know that there's a boundary/trough just south of Byron Bay. If it extends inland, you might be able to pick up the trough by changes on the Northern Tablelands and Darling Downs too (eg, Warwick might have N'lies but Stanthorpe could be reporting a SE'ly). One little note - sometimes when it's quite warm, a weak SE change may push up the coast. But it will lag inland - these can be prime storm areas! The October 9 supercell was testimony to this!

Ok - so there we have it, we know how to make a thunderstorm using instability (heat, moisture, relatively cooler air aloft), and a trigger! What about severe thunderstorms? That's a little more involved...

Introduction to Forecasting Severe Thunderstorms

Ok, we've baked our cake (made a thunderstorm) using some instability and a trigger. Not only that, we know what some of the ingredients actually mean. How about some icing on that cake? Fancy some:

- 2cm+ hail?
- 90km/h+ winds?
- Flash flooding?
- Tornadoes???

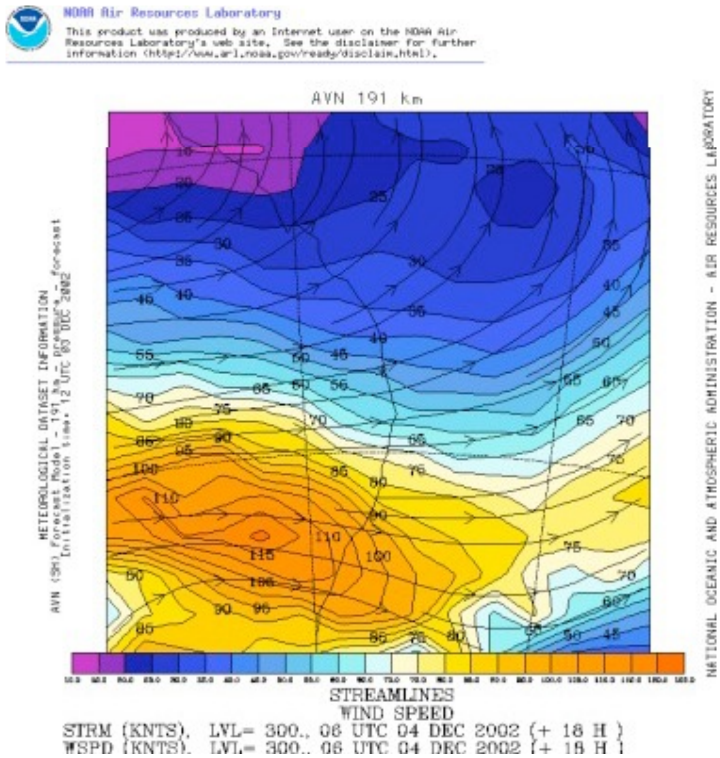
Well, we need to add a little bit extra to the environment, depending on what we want. I'm going to generalise here - I'm going to say you need good wind shear for severe thunderstorms. This however is not always true! (Remember, all generalisations are false! :) But it is true for the majority of cases - for more information on severe storms in no shear, see severe thunderstorms - breaking all the rules! In order to simplify, I'm going to take the majority of cases.

Lets think about how a storm might move, and lets also think about the structure of a thunderstorm! A thunderstorm contains vast quantities of water - if we put all of this water up in the atmosphere, it has to go somewhere! Some of it falls back as rain or hail, but some of it remains as cloud. Remember - what goes up, must come down!
Updrafts can only hold a finite amount of water - it can either fall back on the updraft, or move elsewhere as cloud and perhaps fall to the ground clear of the updraft. If the precipitation falls back on, or too close to the updraft then the updraft will "suffocate" and die! Windshear helps keep updrafts clear of rubbish and allows the updrafts to continue uninhibited:
For instance, lets start at the 300mb (approximately 30,000ft) level. Think of this windshear as an "exhaust" - it has to blow all of the waste anvil cirrus away. What typical speeds would be adequete for this? Here's a rough guide based on my observations in Australia...opinions will differ no doubt, but these are my thoughts.

300mb Winds

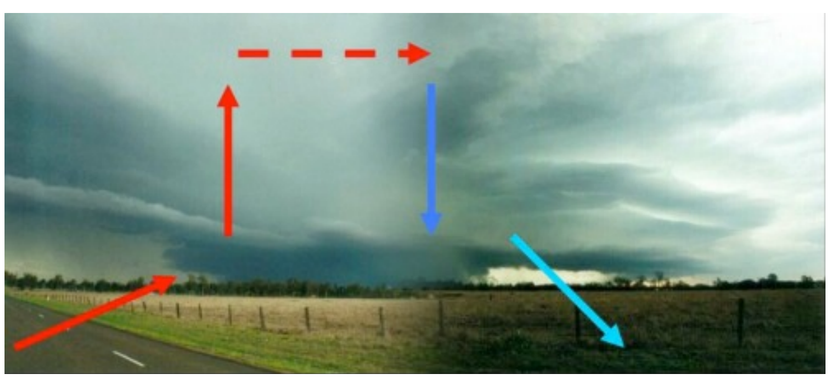
Wind	Strength Effects
< 20 knots	It is unlikely that there will be enough wind shear at this level to help blow away the cirrus and other high cloud that is produced from storms. Storms would probably collapse on themselves unless the mid level shear is relatively strong.
20 - 30 knots	This is marginal, it should allow enough shear for thunderstorms, and the risk of some severe pulses but you will need some strong instability to offset this, or at least some good shear in the mid levels.
30-45 knots	Adequete but not good, this should allow enough shear for thunderstorms and even severe thunderstorms providing there's some moderate instability too
45 - 70 knots	Good shear, allows reasonable outflow for thunderstorms at the 300mb level, including supercells and severe storms.
70 - 100 knots	Very good shear, ample outflow for all storms.
100 knots >	Very strong shear, perhaps too strong for weak storms, but fantastic for other storms!

Ok, so we have organised our thunderstorm's "exhaust" - we can use differing charts to see this. For instance, FNL is a great way of looking at winds:

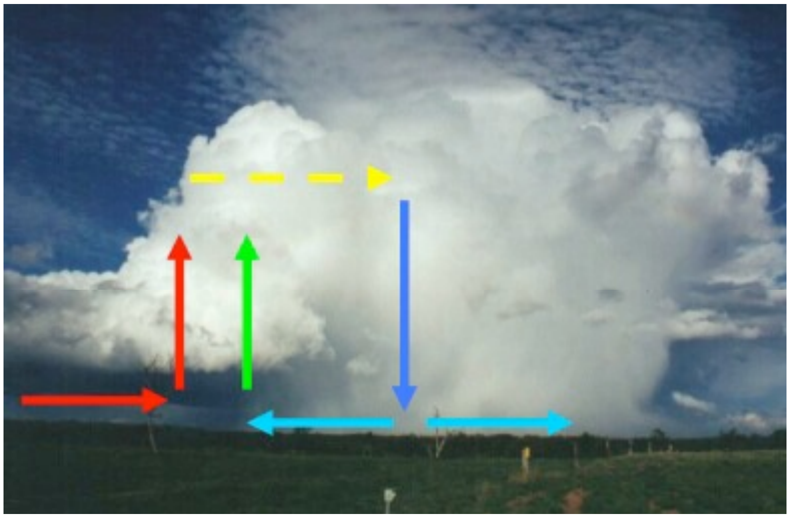


This is a plot of the 300mb winds from the December 4 supercell through south Brisbane in 2002. Brisbane (the asterix) has 50 knot WNW winds at 300mb, which fits in nicely with our table above. A much stronger jetstream was lying to the south (110-120 knots!) but unfortunately there was no instability there.

So we've completed looking at 300mb (well, the basics anyway). Lets do this differently, and think about the surface. Think about an updraft - all of that air moving upwards! It has to come from somewhere, so where? Well, the surrounding surface air forms the basis for our updraft, but what happens when that air moves into the updraft? It has to draw in more air from its surroundings. That's a lot of work for our poor little updraft that has only just begun its life in our world! It's not going to have a very long lifespan if it has to keep producing its own inflow! What's a way to speed this process up? We could have a low level jet (say at the surface, or even 925mb, which is about 1km above the surface). That would certainly help things a lot! A well organised storm will have very defined inflow and outflow regions, for instance here's a photo of a supercell SW of Brisbane on November 4, 2000:



This photo is taken to the NW of the storm. You can see a small inflow band coming in from the NE, and then the outflow coming from around the back at the SW. This was a high precipitation supercell, but weakened significantly before moving over the western suburbs of Ipswich, however it gave extensive hail damage south of Ipswich near Warrill View. The inflow into this storm was well organised with a 15-20 knot NE'ly into the storm which helped it survive. Lets look at another situation when the inflow is too weak:



Here you can see the inflow area into the updraft on the left. However the downdraft is still above to push against the inflow area and the updraft is sucking up some of the cooler outflow. This is a photo of a dying storm in the Capricornia region. This should hopefully give you an idea on the advantages of having reasonable inflow, but what speeds are we looking at? Well, as a guide...

Surface Winds

Wind	Strength Effects
< 5 knots	Negligible
5 - 10 knots	Light inflow, helps storms a little but not really ideal
10 - 15 knots	Moderate inflow, helps storms organise themselves near the surface, in Australia we lack a low level jet a lot of the times and if I had a 10-15 knot surface flow I'd be very happy!
15-25 knots	Strong inflow, probably only experienced around frontal systems in Australia, or near the coast from seabreeze fronts - great for severe storms and supercells!
25 knots >	Very strong inflow!

Remember, these are the pre-existing winds, not the winds around storms! Winds around storms are often stronger, for instance inflow on the November 4, 2000 supercell above was in excess of 35 knots further south of my location! However had there not been a pre-existing 15-20 knot NE'ly, then the overall inflow may have only been around 20 knots and the storm may not have become as large or severe.

What about low to mid level shear? There are certain (somewhat arbitrary) levels that are normally used, we've looked at two of them (surface, or 1000mb, and 300mb) already. Other levels that are normally used are 850mb, 700mb and 500mb. We want moderately strong winds at 850mb, and then a good flow at 700 and 500mb is preferable. These winds (especially 700mb and 500mb) are often referred to as the steering winds, the stronger these winds are then the faster storms will move. Storms that move relatively quickly normally gather good inflow - it's important that a storm moves as if it stays still, it might exhaust all of the energy around it (ie it could cool the surface area around it, therefore stabilising the immediate atmosphere). Or we might encounter the problem we've discussed - the updraft and downdrafts may not be well separated and the updraft may begin to draw in some of the cooler air from the downdraft which certainly is not what we want for strong or severe thunderstorms!

On the other hand, while having something like 30 knots @ 850mb, 50 knots @ 700mb and 80 knots @ 500mb seems fantastic! You're going to have storms moving at around 70-90km/h! Great if you're in the immediate path of a storm (well, sort of - and you can stay ahead on the one road), not so great otherwise. And from experience, the "otherwise" constitutes 90% of chases. A fast moving storm is not good to chase because it's too difficult, on the other hand if it moves too slow it might weaken or worse, collapse! So what type of winds do we want at these levels? Trying to decide this can be quite difficult because it really depends on the speed of winds at the other levels, eg if the 700mb and 500mb levels are quite strong, then if the 850 winds are weak it won't matter as much as if all of them were weak.

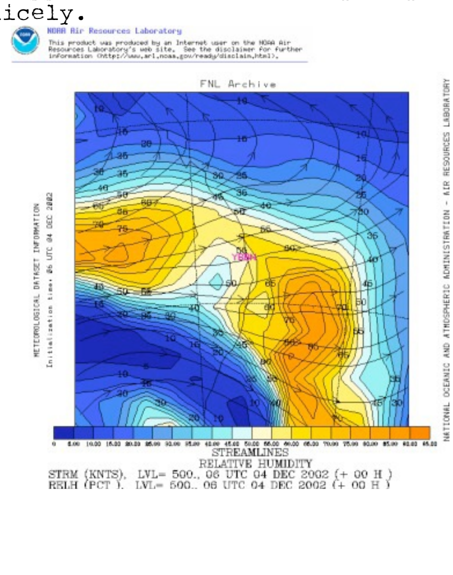
But anyway, here's a rough guide of what to look for in a "warm cored" situation (eg spring/summer setup). If you look at winds a bit more you'll begin to notice what I mean by if one or two level is lacking, it's not as bad as if they're all lacking. In a way, shear in other levels can "make up" for poor shear elsewhere. Remember though - we're only looking at single levels here! Essentially we're choosing 5 levels in the atmosphere to represent the entire shear profile! This is where something like a Skew-T diagram comes in handy, as that shows you immediately 20-30 levels which gives you a much better representation of what shear is really like! Anyway, here's an approximate guide (again, focusing on Australian situations). I've also thrown in 1000mb and 300mb as a reference point.\

Wind Strength Guide

	Poor	Marginal	Adequate	Good	Very Good
1000mb	< 5 Knots	5-10 knots	10-15 knots	15-25 knots	> 25 knots
850mb	< 7 knots	7-10 knots	10-17 knots	17-30 knots	> 30 knots
700mb	< 10 knots	10-15 knots	15-20 knots	20-40 knots	> 40 knots
500mb	< 15 knots	15-20 knots	20-30 knots	30-50 knots	> 50 knots
300mb	< 20 knots	20-30 knots	30-45 knots	45-70 knots	> 70 knots

This is a table that gives an idea of what type of winds you would be wanting for strong to severe thunderstorms - at least, this is what I look for at a general rule. Ok, that's the first part of shear (yes, first part...there's more to shear! There's also divergence, convergence, diffluence and convergence to look at and directional shear too! But this is enough for the moment and to help understand the basics).

There's another important aspect of severe thunderstorms - that is upper level moisture. It might seem odd, but in the mid-high levels (eg, above 700mb), you don't want much moisture! In fact, the drier the better! There are several reasons, but one of them is that dry air means that waste anvil cirrus, and the edges of storms will evaporate. That provides cooling of the air around it and also means that cloud is unlikely to develop around the storms. Cloud will block out the sun and therefore block out heat! So it's good to have low levels of moisture if possible in the upper levels. Anything below 70% is reasonable, below 50% not bad and below 30% even better - especially at the 500 and 300mb levels (probably the more critical levels to have dry air at). Dry air in the mid levels also increases the chances of microburst activity which is often severe. Assessing moisture in the upper levels is extremely easy! A 500 or 300mb moisture chart from FNL will do the trick nicely.



This shows 50% RH over Brisbane at 500mb for our December 4, 2002 supercell, not bad! A word of warning when looking at forecast charts of RH. You're looking for broad sweeping bands of large moisture, the model is also going to pick up moisture from the storms themselves in the upper levels, so it may not be unusual to see "splotches" of large RH in small areas, don't automatically assume that you're going to get a big cloud area there. To be honest, I don't look at RH maps at the mid-upper levels very often, I prefer to look at the satellite image as I think that's going to give you a much better idea of whether there is going to be cloud or not, and a Skew-T.

Probably the last thing (and very important) for the best severe storms, is a cap. A cap is a small stable layer in the low levels that inhibits convection. You might be surprised that we want something to inhibit convection! Well, the best severe storms occur when the heat of the day is at its maximum. If storms were to start developing at 11am, then that uses some of our heat energy and converts it into storms. Now, if they started developing at say 3-4pm, then that heat energy has been building up all day and it is ready to all be used up by the storms then and there! The best days that I have chased have actually had a strong cap that broke late - although it does add some suspense to it, as sometimes you begin to wonder if anything will develop! (If the cap is too strong, then that's no good either as then you get no storms!) I'm not going to say much more at this stage on capping, except that I often look at 850mb temperatures to get an idea on the cap. But the problem is that it is difficult to give an idea on what type of 850mb temperature you need as this is strongly relative to the surface temperature and the time of year. The best way to learn is to look at a Skew-T, but for now, if I were looking at a "typical summer situation" then I'd be thinking the following:

Temperature Effect

Temperature	Effect
<15°C	Weak cap, development likely early.
15-17°C	Moderate cap, not really ideal but should hold convection off until midday or early afternoon - later if the trigger is weak.
17-19°C	cap, should hold convection off until the afternoon but will require areasonable trigger to break.
19-21°C	Strong cap, will need a good trigger to break.
21-23°C	marginal - the trigger will need to be very strong or it's going to need to getvery hot to break the cap!
>23°C	approaches the limit of thunderstorm development in most situations.

Remember, cap is very relative to the surface temperatures! When I explain Skew-Ts you'll see what I mean. Until then, lets use our knowledge to "forecast" a real storm day...

Forecasting Severe Storms - A Practical Look

Lets look at a typical situation and see how we can apply this. I dug up some forecast charts that I saved from the December 4, 2002 Brisbane supercell. Lets have a look at the charts and see what we can apply...

This day was actually my last chase day on my annual chase holiday "Thunder Downunder 2002." It ended up being one of the best chases of the year! James (my chase partner) and I were up early but were quite tired from the night before, we had travelled 1100km the day before and didn't get to sleep until well after midnight. We decided to get some McDonalds for breakfast, then sat down to have a look at the situation.

I'm doing this in order of how I remember going through this. Because I was on a laptop connection using my mobile - everything was slow! Furthermore, we had to get ready early as we did a tyre the day before and had to try and find a new one and didn't want to start out too late! So we had to look at everything quickly, so I decided to load everything up at once. The first thing that loaded for us was the forecast:

SOUTHEAST COAST CITIES PRECIS
for Wednesday

	WEATHER FORECAST	MAX	UV FORECAST
Brisbane	Late shower/storm	34	15
Ipswich	Late shower/storm	39	15
Gold Coast	Late shower/storm	32	15
Sunshine Coast	Late shower/storm	33	16

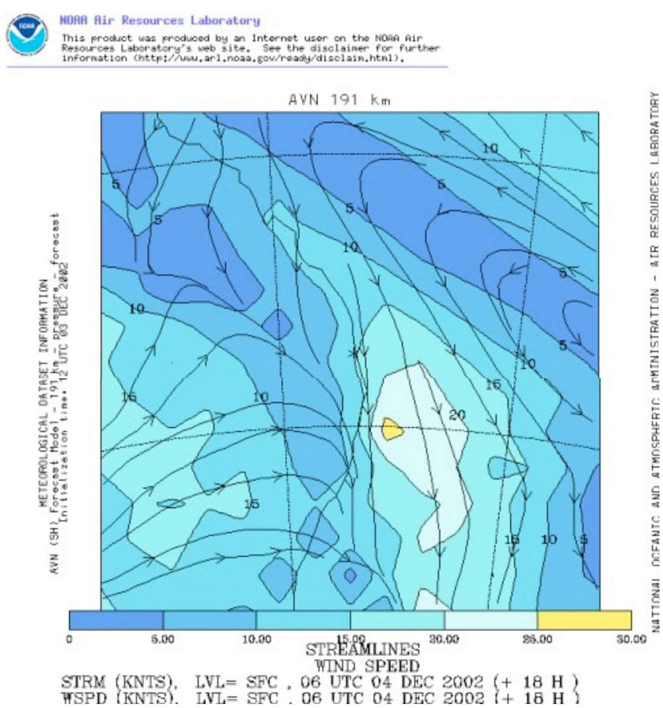
A hot day was forecast! Taking the BoM's word for it, we were going to need a reasonable cap was in the back of my mind. The other thing that struck me was "NW winds gusty at times." Any situation with NW winds automatically grants a chance of becoming too dry. So the next thing I loaded up were some obs to get an idea on things:

Station Name	Current Observations										
	Date Time (AEST)	Temp (deg C)	Dew Point (deg C)	Rel Hum (%)	Wind Dir	Wind Speed (km/h)	Wind Speed (knots)	Wind Gust (km/h)	Wind Gust (knots)	Press (hPa)	Rain since 9am (mm)
Brisbane *	04 07:05	28.4	21.2	66	NNW	7	4	11	6	1009.9	0.0
Brisbane Airport *	04 07:05	28.2	21.8	68	N	30	16	33	18	1010.4	0.0
Archerfield *	04 07:05	27.2	21.5	72	N	11	6	13	7	1010.0	0.0
Amberley *	04 07:05	29.0	20.9	61	NNW	28	15	31	17	1010.0	0.0
Gatton UQ	04 07:00	27.0	20.6	68	CALM			6	3	-	0.0
Toowoomba Airport	04 07:00	25.5	17.2	60	WNW	17	9	24	13	1015.2	0.0
Oakey	04 07:00	26.5	17.6	58	NNW	11	6	13	7	1013.4	0.0
Coolangatta	04 06:30	23.7	22.5	93	N	17	9	24	13	1009.4	0.4
Gold Coast Seaway	04 07:00	25.5	22.4	83	NNW	17	9	24	13	1009.9	0.0
Cape Moreton	04 07:00	24.5	22.6	89	N	44	24	54	29	1011.8	0.0
Spitfire Channel	04 07:00	-	-	-	N	37	20	48	26	-	-
Inner Beacon	04 07:00	-	-	-	N	43	23	52	28	-	-
Banana Bank	04 07:00	-	-	-	N	37	20	48	26	-	-
Maroochydore	04 07:00	25.2	22.5	85	NNW	17	9	26	14	1012.9	0.0
Tewantin	04 07:00	25.5	20.3	73	NNW	15	8	22	12	1012.3	0.0
Nambour	04 07:00	24.9	20.6	77	N	13	7	24	13	1011.9	0.0
Beerburrum	04 07:00	25.9	22.8	83	N	11	6	17	9	-	0.0
Toolara AWS	04 07:00	24.6	20.9	80	NW	15	8	28	15	-	0.0
Jimna Forestry	04 07:00	25.9	18.6	64	SE	2	1	13	7	-	0.0
Gympie	04 07:00	24.1	21.6	86	NW	17	9	26	14	1013.0	0.0
Double Is Pt	04 07:00	25.2	21.7	81	NNW	33	18	39	21	1012.3	0.0

Wow - what an impressive set of obs! DPs in the low 20s throughout, 28/22 at the airport at 7am!!! 29/21 at Amberley too! Mostly northerly winds, although it's a little drier on the Downs (Oakey and Toowoomba with DPs around 17-18). That's not too bad because they're both elevated (Oakey 500m, Toowoomba 650m) - you'll learn why that isn't a concern in the Skew-T section. What is a concern are those WNW winds at Toowoomba! Although Oakey is NNW which is OK. To get a better idea on things, (ie what the conditions were like further west), we loaded up the southern inland Queensland obs:

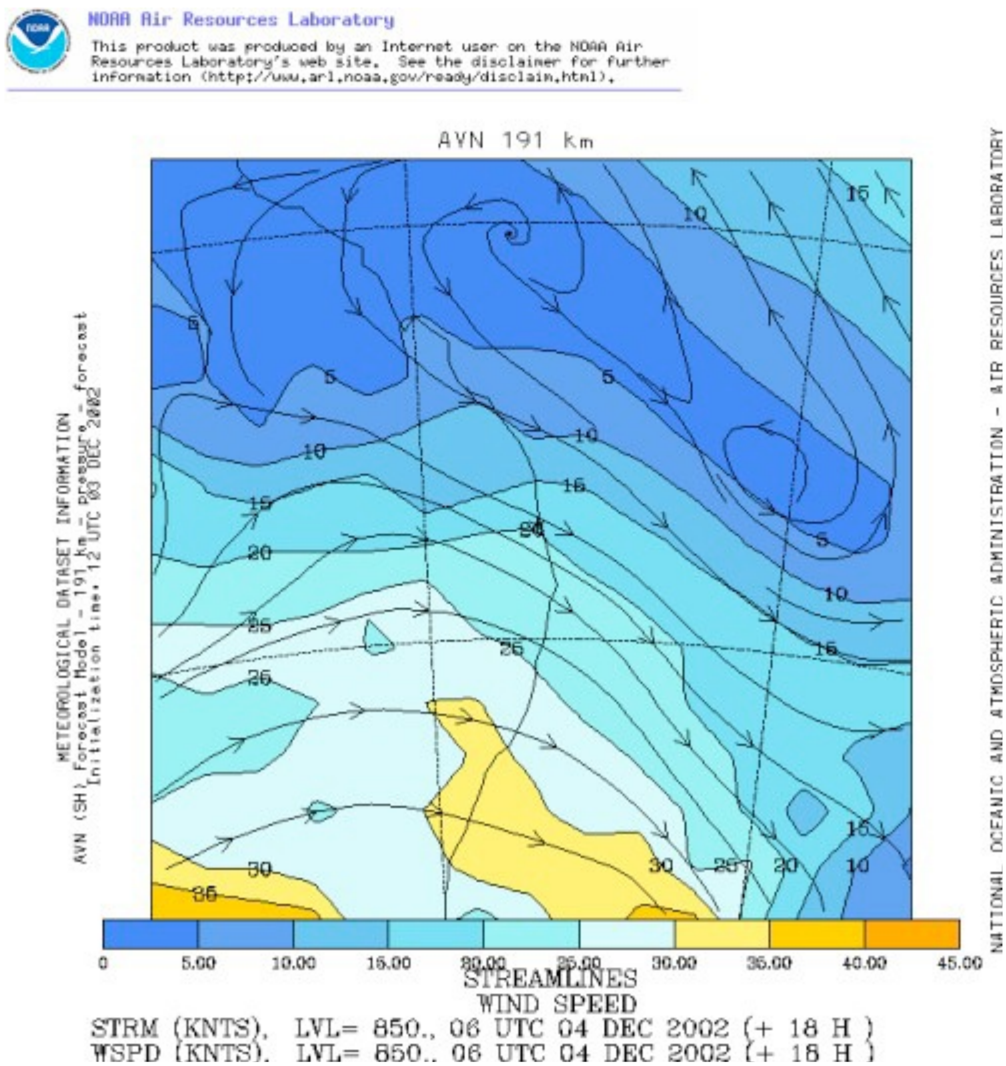
Station Name	Current Observations										
	Date Time (AEST)	Temp (deg C)	Dew point (deg C)	Rel Hum (%)	Wind dir	Wind speed (km/h)	Wind speed (knots)	Wind gust (km/h)	Wind gust (knots)	Press (hPa)	Rain since 9am (mm)
Gayndah *	04 06:00	22.0	21.2	95	E	6	3	-	-	1012.0	0.0
Inglewood Forest	04 07:00	28.7	17.3	50	N	17	9	22	12	-	0.8
Goondiwindi *	04 06:00	27.0	20.1	66	NE	15	8	-	-	1009.1	0.0
Miles *	04 06:00	26.9	18.1	59	NNE	11	6	-	-	1010.8	0.0
Roma	04 07:00	30.9	13.3	34	N	28	15	37	20	1011.6	0.0
St George	04 07:00	27.0	18.1	58	NNE	15	8	20	11	1009.3	3.2
Injune *	04 06:00	26.7	15.0	49	NNW	6	3	-	-	1009.5	0.0
Emerald	04 07:00	25.9	20.0	70	NNE	22	12	28	15	1013.2	0.0
Biloela *	04 06:00	22.4	20.2	87	CALM			-	-	1012.8	0.0
Charleville	04 07:00	31.6	15.3	37	N	18	10	28	15	1010.0	0.0
Cunnamulla *	04 06:00	29.5	8.8	27	SW	4	2	-	-	1007.3	0.0
Blackall AP	04 07:00	31.3	15.3	38	N	20	11	30	16	1011.6	0.0
Quilpie *	04 06:00	30.4	7.0	23	S	2	1	-	-	1007.7	0.0
Thargomindah	04 06:59	30.0	-1.6	13	SW	20	11	28	15	1012.0	0.0
Windorah *	04 06:00	28.5	8.5	29	SW	4	2	-	-	1009.1	0.0
Birdsville	04 07:00	27.7	-3.3	13	SSE	26	14	33	18	1011.7	0.0
Stanthorpe	04 07:00	24.3	15.9	59	NNW	15	8	24	13	1015.1	13.6
Toowoomba	04 07:00	25.5	17.2	60	WNW	17	9	24	13	1015.2	0.0
Oakey	04 07:00	26.5	17.6	58	NNW	11	6	13	7	1013.4	0.0

Alright, lets have a look at this. Dalby didn't fit on this (w of Oakey), but its 6am observation was 26/19. Inglewood 29/17, Goondiwindi (300km WSW of Brisbane), 27/20, Miles (350km WNW of Brisbane) 27/18. Looking good...Roma, 31/13 - aha! That's a bit low, although St George is 27/18 and is 200km S of Roma (this is where your geography comes in handy). Charleville is OK too, 32/15 - but you can see it's getting a bit dry out there, and the main SW boundary is back towards Cunnamulla (30/9 with SW'lies). Is it going to dry out? Just going by this, moisture doesn't look like it's going to be a problem! Lets get a second opinion though by loading a 1000mb shear chart. It'll also give us a good opportunity to check where the model thinks the trough will lie in the afternoon (don't get put off by its positioning, you might disagree and think it will lie somewhere else - go by your instinct).



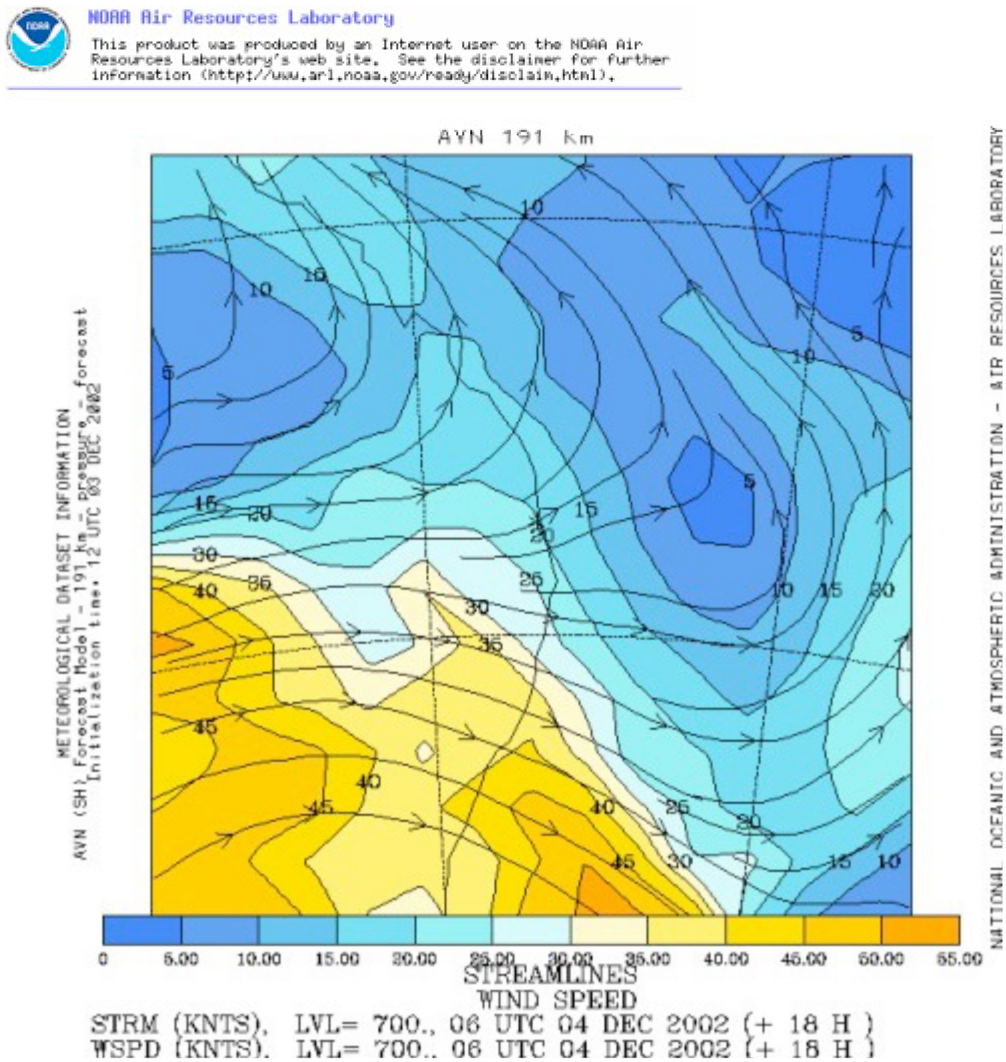
This shows a trough to our west which is good, sitting on the eastern side of the trough is the unstable area generally and is where the air is generally rising (air rises ahead of troughs). It shows those NW'ly winds too, but look where they're coming from - they're actually originating over the Coral! Certainly not going to dry out here I think! While we're looking at shear, lets look at the surface shear. 10-15 knots over SE QLD, getting up to 15-20 knots on the coast. Going back through our "magic numbers" this gives us moderate to strong inflow at the surface, off to a good start!

Lets look at 850...



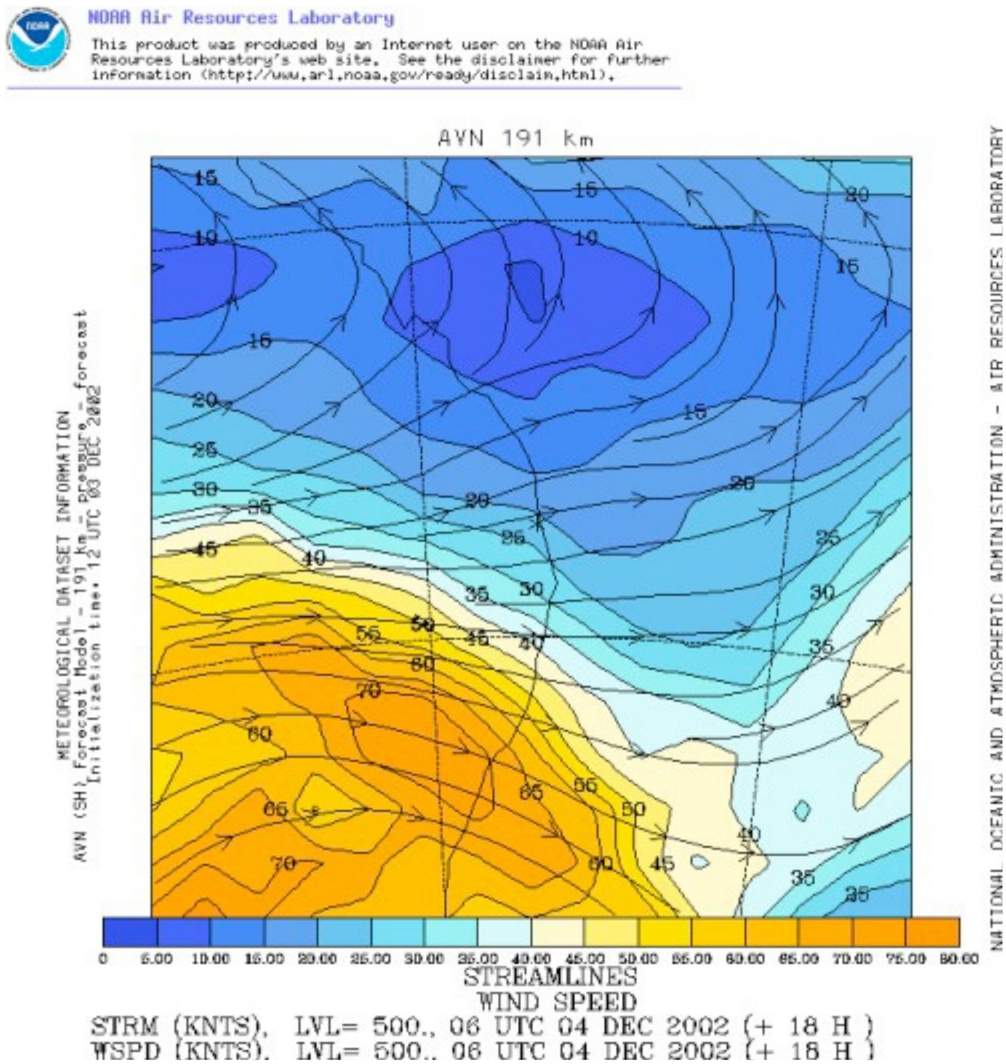
Ok, here we have NW winds at around 20 knots at the 850mb level...remember that direction, we're going to need it to work out which way storms are going to move! Referring to our magic numbers we see that 20 knots sits in the "good" category for 850mb.

And now 700..



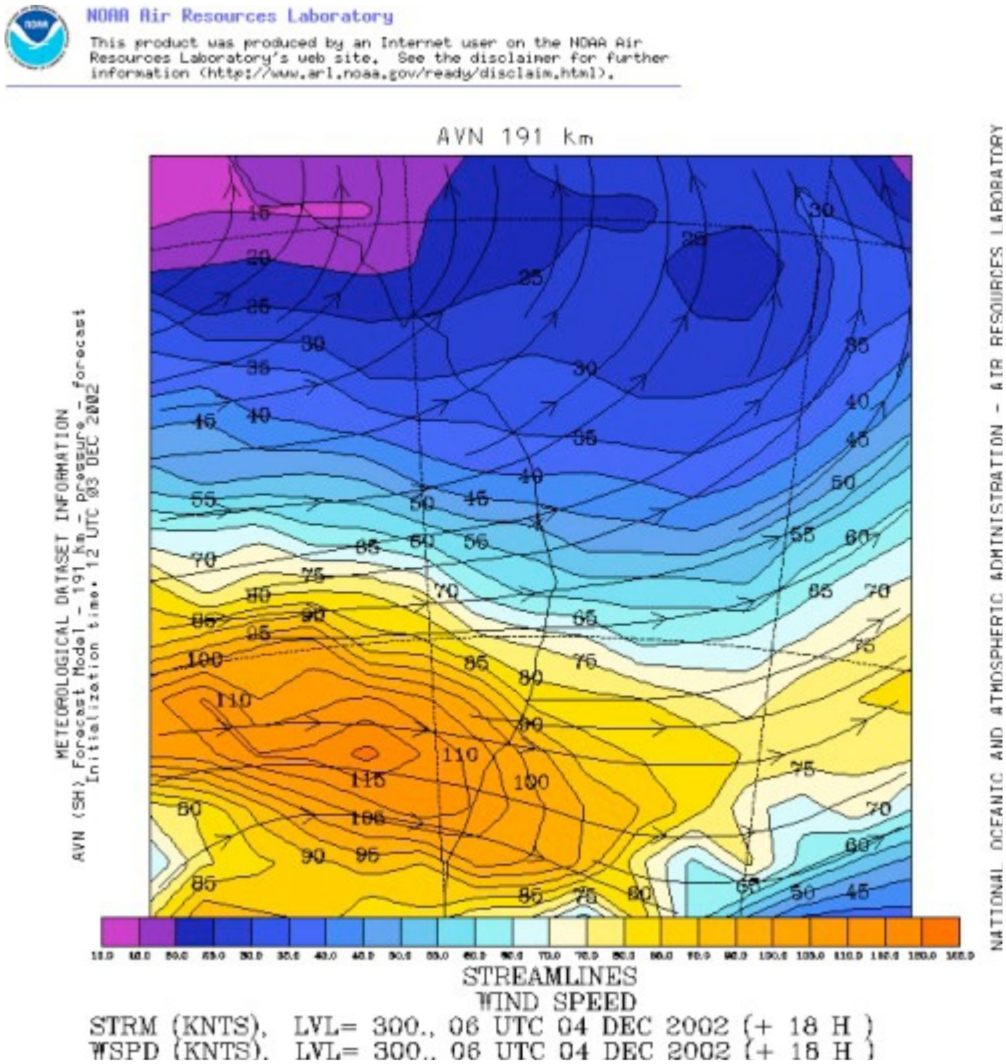
Here's our 700mb chart, those winds have swung towards the west. This was interesting in both ways, it added directional shear too! (You guessed it...explained in the Skew-T section). The wind speed is 20-25 knots (oh, the little asterix is Brisbane in case you were wondering...to the SW the latitude/longitude intersection is 30S, 150E). Once again, referring to our magic numbers this sits in the "good category" - doing well so far!

On to 500mb…

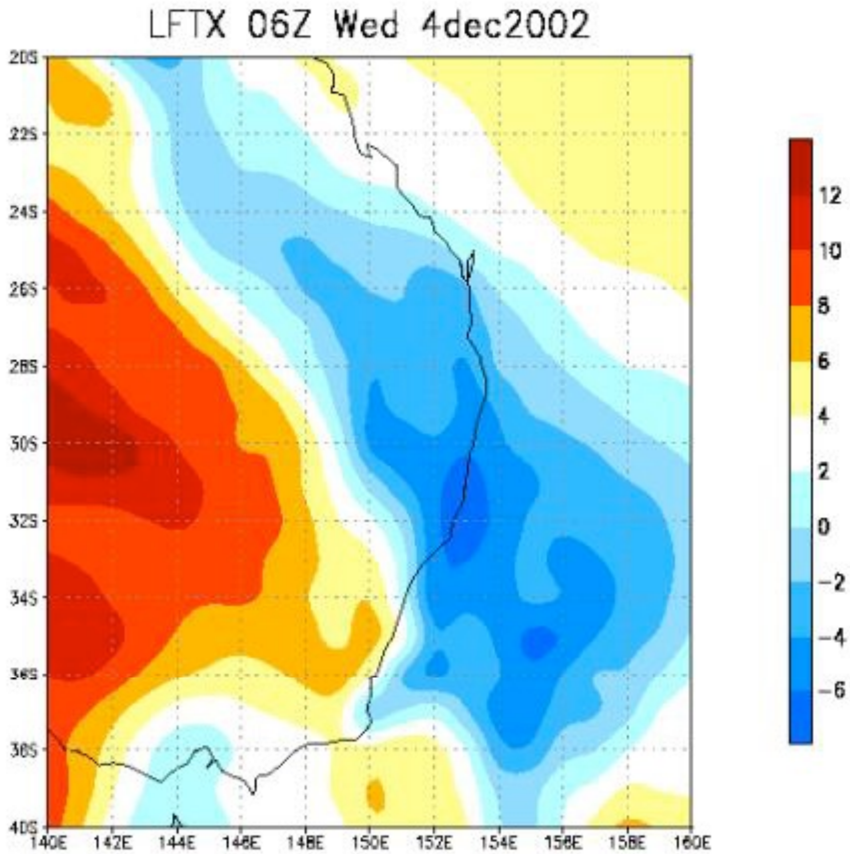


Here's the 500mb winds, from the WSW now and again at around 20-30 knots. However if we check our magic numbers table, it only sits as "adequete." Remember, these are not concrete numbers and are relative to what the other shear is. Sure the 500mb winds aren't ideal, but hey - the 850 and 700mb winds aren't bad, and the 1000mb winds are quite strong for our area. Lets check the 300mb level before we start panicking...

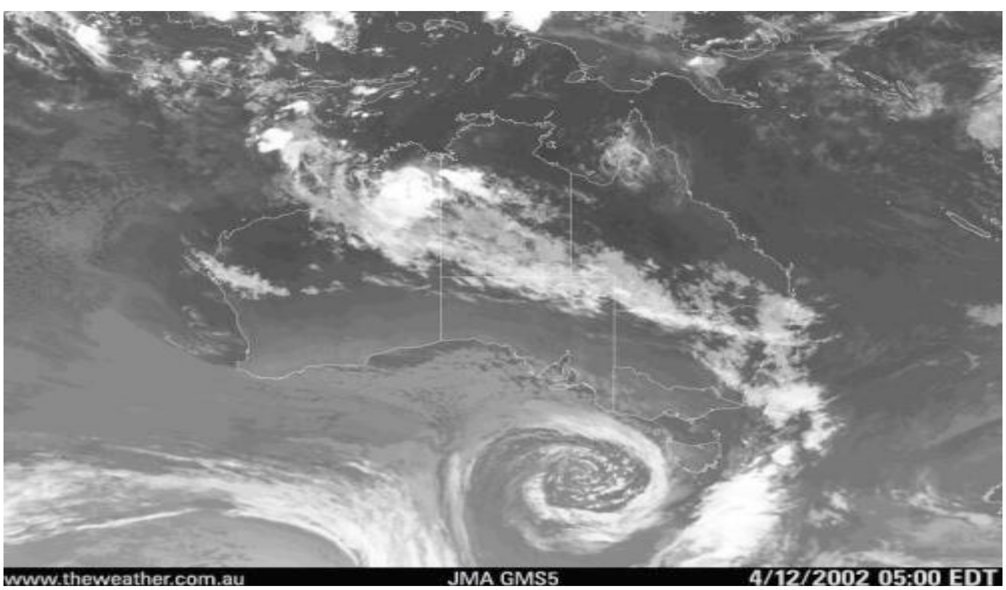
Finally, 300mb…



The 300mb chart shows 50-60 knot winds from the WSW through SE QLD, which once again sits in our "good category." So as a quick summary, the shear - it's not fantastic, but it's pretty reasonable and I'd be relatively happy with this for severe storms providing there was some decent instability. Oops, no point in having shear if there's no instability! Lets check it, we're low on time so we'll just check the LIs...



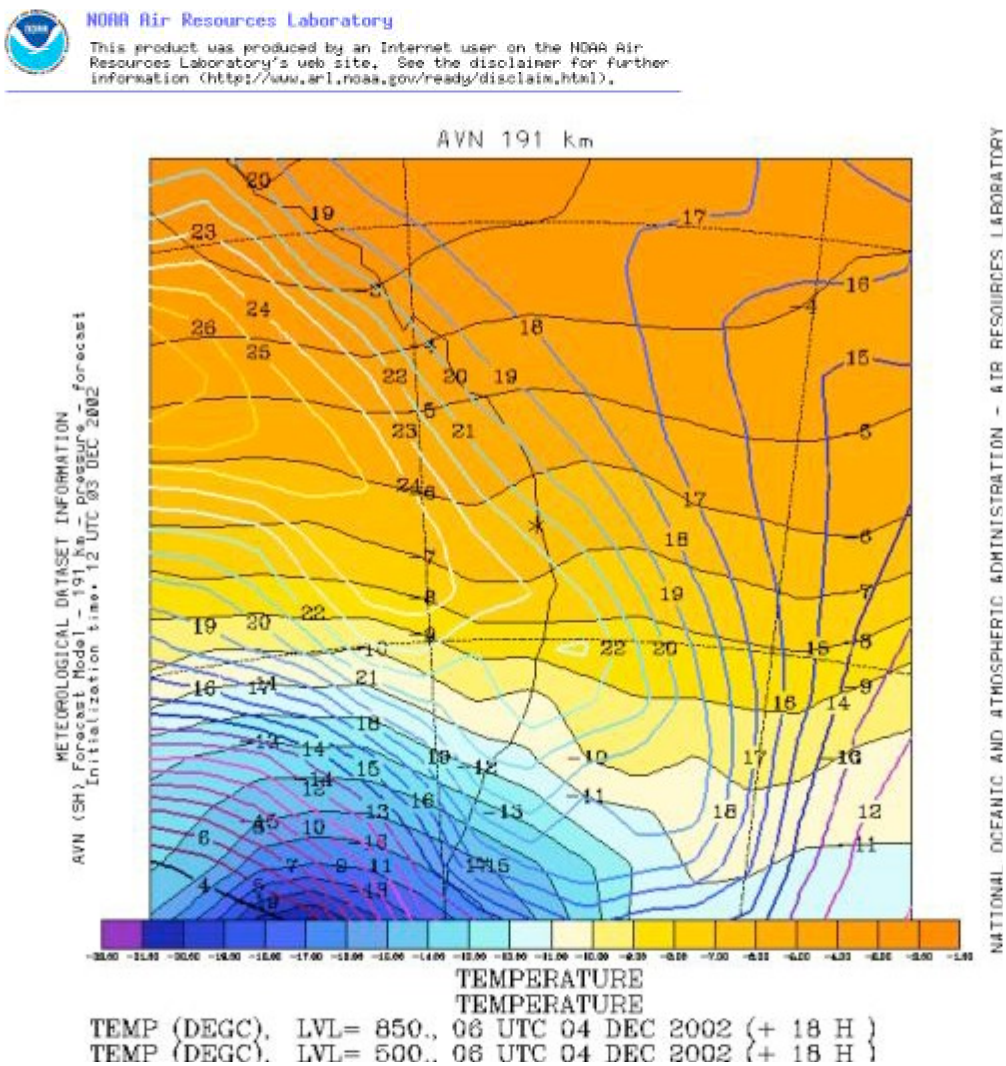
Alright! Some nice instability poking into SE QLD there, -4 to -6 LIs is certainly nothing to be sneezed at. Ok...before we continue, have a look at what I've presented. I've concentrated on describing the setup in SE QLD, but look at the instability and the shear. The instability and shear actually gets stronger further south!!! Well, there is one thing I didn't show in order. One of the first things I load up automatically is the satellite image! Lets have a look at it..



This is the 5am EDT (4am EST) satellite image. From Stanthorpe the cloud was just clearing off, but have a look at the line of cloud off to the west. There's more cloud lining up for NE NSW than SE QLD, so that in itself is a deterrent. Have a look at the LIs and then have a look at the 1000mb winds too. The instability is right on the coast, but tends more inland further north. The trough is very close to the coast in NE NSW, perhaps too close. No point in having storms develop 20km inland from the coast and then having them move out to sea! It's nice to have storms develop at least a little inland so you can chase them to the coast. Speaking of which, which way are storms going to move? I generally try and "average" out the wind speeds and directions in my head. We have 20 knot NW'ly @ 850mb, 20-25 knot W'ly @ 700mb and 20-30 knot WSW @ 500mb. Averaging these out gives a generally easterly flow, but I'm about to throw a spanner into the works...

Storms tend to move to the left of the steering flow (ie equatorward), this is to do with the positioning of the updrafts, they like to feed on the warm northerly winds, so the updrafts are often orientated so that they are more favoured on the northern (equatorward) edge. They will move even more left if the winds are weaker, but not so much if the winds are stronger. And stronger thunderstorms tend to move even further left of the mean steering flow. It's not unusual to see larger storms move to the left of other storm movement either, for instance weaker storms might be moving ENE, but stronger storms NE, or sometimes even NNE and even N!

Anyway, back to December 4! We've established that while in theory our instability and shear is better south, it may not actually be the best area due to other factors. Lets look at one other thing - the cap, and we can use 850mb temperatures to help...



I often like to overlay the 850mb and 500mb temperatures, lets ignore the 500mb temps for the moment (although they're kinda warm...-6 to -7C @ 500mb, but it's quite moist and very hot so that's bringing the instability!) But check out those 850 temps, yeouch!!! 21 to 22 over SE

QLD, solid 22 over NE NSW, and 23-24 further west. Given that NE NSW has to contend with some cloud (even if it's just for the first few hours in the morning), when you've got those types of 850mb temperatures you need all the heat you can get! Even at 21-22C I was concerned the cap was going to be too strong, the only thing we could try and bank on was it was going to get hot. Hot was a bit of an understatement...James and I were sitting at Warrill View when it was 42/18!!! Anyway, to cut a long story short, if you want to see what happened - check out the December 4 supercell chase report! The result was one very nice supercell through south Brisbane, it interacted with the seabreeze front. A squall line developed behind it and gave some severe winds to the Downs, but nothing in SE QLD. The squall line developed on the main trough and moved over.

Introduction to Skew-T Diagrams

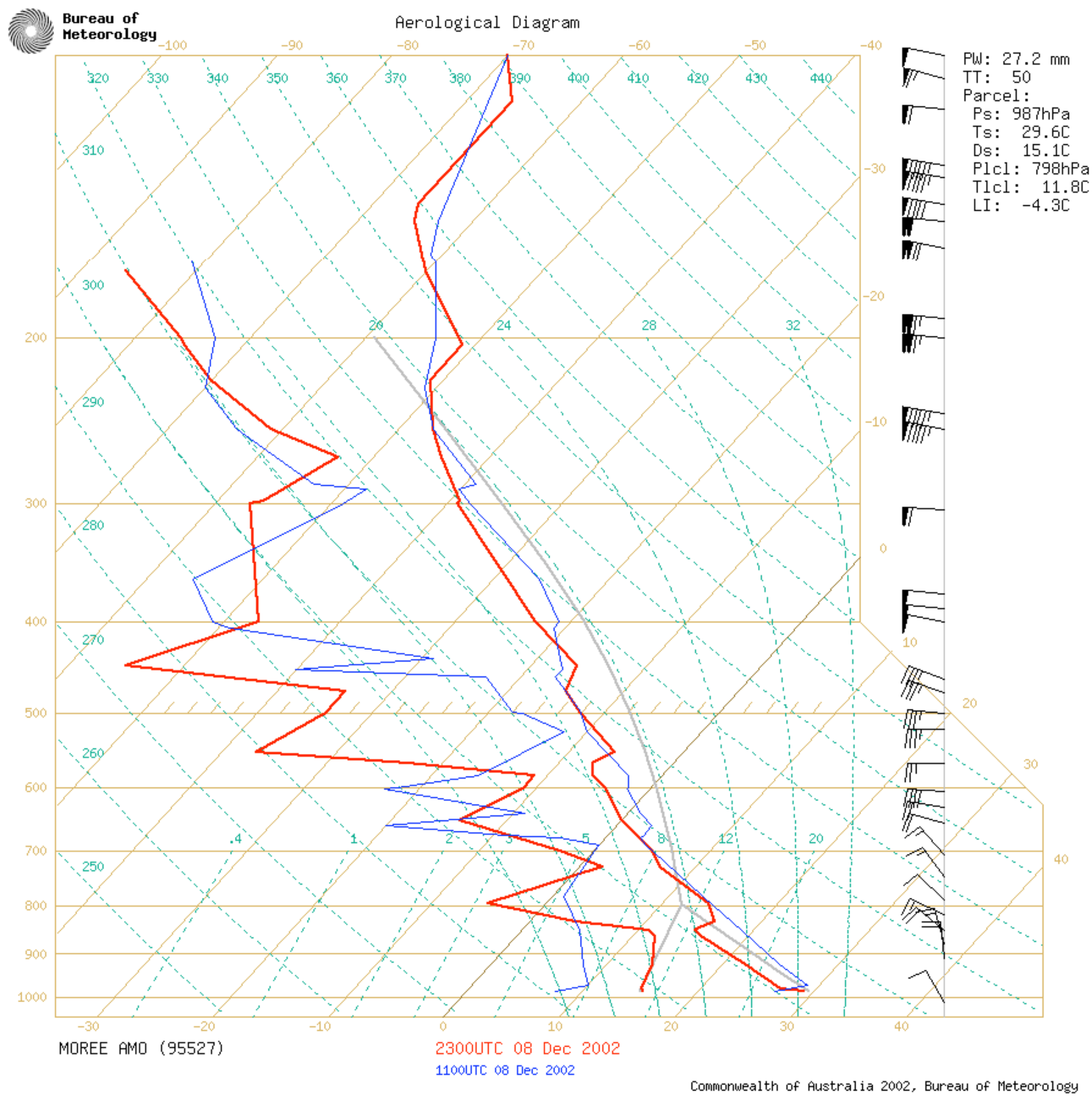
Have a think about a few things I'm going to throw to you…it will hopefully make you think a little outside the square!

- **LIs of -15 can give you clear skies**
- **LIs of 0 can give you tornadoes**

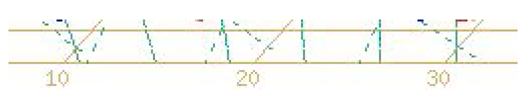
This may seem odd, but it makes a lot of sense when you really understand what LIs are in the overall picture of stability and instability. We only know if one level is stable or unstable - but what about the rest of the atmosphere, what is it doing? Perhaps it's very unstable to the 550mb level, but then stable higher then this? If the air is extremely cold, storms may not reach the 500mb level! Conversely, what about caps? Sure we can look at the 850mb temperatures, but what about other levels? What if the main cap is at 900mb? 800mb? 700mb? Are you going to load up each individual chart for each of the levels forecast in the atmosphere? If so, you're going to waste a lot of time! Surely there's an easier and better way! I've mentioned these diagrams throughout the first part, but here I'll describe what I mean and point out the limitations of using some of the common thunderstorm indicies, and how they can better be used as a guide, and perhaps show a better way of determining the local potential for the day using Skew-Ts.

While daunting and somewhat menacing by their unusual appearance, Skew-T's are an extremely effective method of reading a vertical slice of the atmosphere. Just by glancing at a Skew-T, one can tell the amount of moisture, the lapse rates, see inversions, see shear profiles, and see the potential for the coming day by making adjustments to the surface measurements. While charts generally give you a horizontal layer of the atmosphere, Skew-T's able you to see the vertical component, which is essential in forecasting. So often horizontal charts appear to suggest great storm activity, with fantastic shear, high CAPE, low LIs and low upper level moisture. But they don't tell you whether the LI's have been 'corrupted' through too much low level moisture (eg rain area) or whether there's a strong cap just above that will not let a hint of convection through, or whether there's dry air immediately aloft (thus upsetting any surface CAPE calculations). Not to mention, the most common indicies (LI and CAPE) rely heavily on the temperature and dewpoint at and near the surface. So in order to calculate the LI and CAPE for an area, a forecast model must also forecast temperature and dewpoint. But in my experience, models can sometimes have inaccurate dewpoints or temperatures, being either too high or too low. This is especially the case for AVN (one of the most widely used LI/CAPE models in Australia), it tends to under-forecast surface temperatures, but also has a tendancy to over-forecast dewpoints (for Australia at least!) Normally they're pretty good and indicies such as LI and CAPE give a good idea of instability potential, but **just because there's a bullseye of -6 or +2 LIs doesn't mean you're definitely going to get storms, or there are no storms on the cards for you whatsoever!**

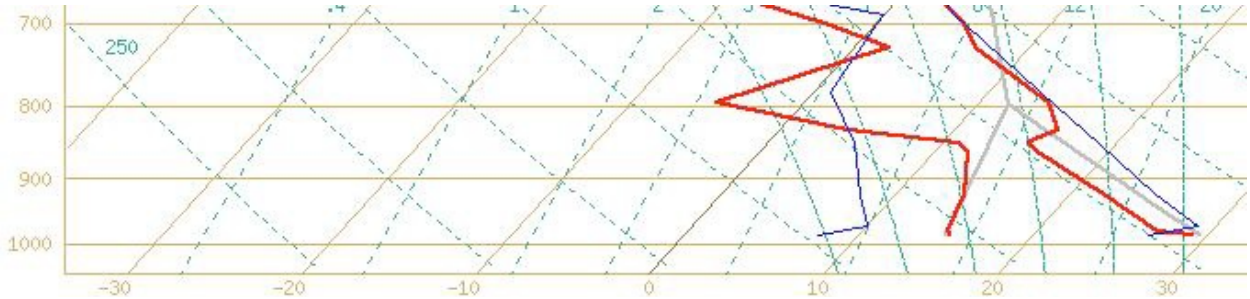
The downside of using Skew-T's is that they can only give a general 'accurate' approximation for the area around them of about 200km. None the less, they can still be very useful if you are forecasting for the immediate area around a sounding station. I hope that people can find this part of the guide useful, but I would also like to emphasize that this guide is my interpretation of Skew-T's and how I personally read them. Each person will have their own ideas on how a Skew-T should be interpreted, and all of them are not necessary the correct or incorrect method. I originally made this using the University of Wyoming soundings, and even though they're world wide - they've since changed to a (much worse) format. So I'll use the Australian BoM soundings in the examples, however the BoM normally plots the maximum potential on their soundings, and we don't want that quite yet...so I had to settle for this example:



The pale yellow/brown lines that originate from the bottom of the Skew-T and travel diagonally upwards to the right are the temperature lines. The scale is on the bottom of the Skew-T. This increases by 10C increments.



Upon learning this, we can now interpret part of the Skew-T. The large thick red line on the right, is the temperature line. The red line on the left, is the dew point line. The temperature line is always to the right of the dew point, although in very moist situations, they can be overlaid over each other, indicating 100% humidity at a particular level(s). The red lines correspond to the time in red on the bottom of the Skew-T. The blue lines are the previous sounding (normally around 12 hours before), and corresponds to the time in blue at the bottom of the Skew-T. There is one other line, the grey line, which is the theoretical air parcel line, it is probably the most important line in the Skew-T, however it's behaviour and interpretation is somewhat more complex and less straight-forward, we will deal with this a little later on.



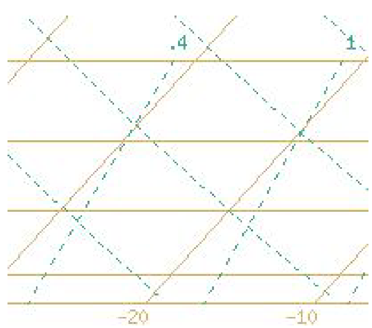
The horizontal dark yellow lines are the height and pressure lines. These are fair uniform, however if you look closely, they dip in slightly towards the left of the graph. This is where the colder temperatures are, and denote how cold air causes the air to be more dense, hence heights are lower. This is the same as geopotential height, where colder air above, has a smaller geopotential height - as cold air is denser then warm air, and therefore causes a lowering in height with pressure. Unfortunately, the BoM soundings don't display the height, but if you look at University of Wyoming soundings then you will see the height (in metres) at which these levels occur in the atmosphere. Remember that these heights are not constant, and only apply to the particular atmosphere the sounding was taken in! It's also important to note that pressure decreases with height. So that 700mb is actually higher than say 800mb. The reason for this is because air becomes compressed at the surface with the weight of all the air above it. So the pressure at the surface is greater then a few kilometres up in the atmosphere.

Ok, in knowing that we're ready to interpret part of our Skew-T. Lets read some temperatures off it and get an idea on what it's trying to tell us! Lets look for the 800mb temperature, see where the red line crosses the 800mb line? The temperature at 800mb there is around 14C, simply follow the diagonal lines down to read the temperature off. What about dewpoint? We use the same method! Here we can tell that the dewpoint is around -5C at 500mb. The surface dewpoint is around 15 degrees (bottom part), note that the surface is not 1000mb here because Moree is actually around 200m above sea level, so the surface pressure here is actually closer to around 980mb. Remember this, it will come in handy for later! One of the advantages the BoM Skew-Ts do give us though is the previous sounding before hand, here we can see that the surface DP has increased from around 7.5C to 15C in the last 12 hours! Scroll back up and have a look at the temperatures too - what can we tell about the atmosphere? Lets compare...

Level	Current Temp.	Previous Temp.	Temp. Difference
700mb	6°C	6°C	0°C
600mb	-4.5°C	-2°C	-2.5°C
500mb	-12°C	-12°C	0°C
400mb	-23°C	-21°C	-2°C
300mb	-39°C	-38°C	-1°C

When you get used to looking at Skew-Ts, you won't have to do this - you'll see it straight away (perhaps you already can), that the overall trend in the upper atmosphere is a cooling one. And from what we learnt in the previous section, upper atmospheric cooling will enhance instability!

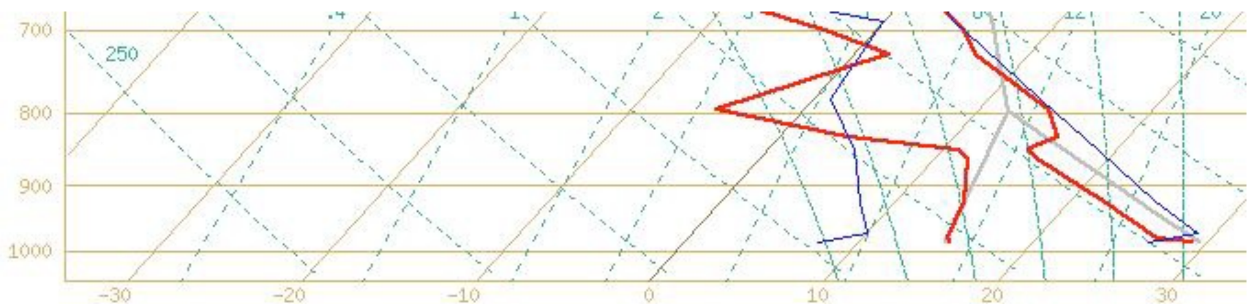
Ok, so we can read temperatures and dewpoints off the Skew-T, what else? How about those dashed green lines that rise diagonally to the right, but not quite parallel to the temperature lines? They are the saturated mixing ratio lines. This is expressed in terms of grams of water vapor, per saturated kg of air, or g/kg. The importance of these will be highlighted later.



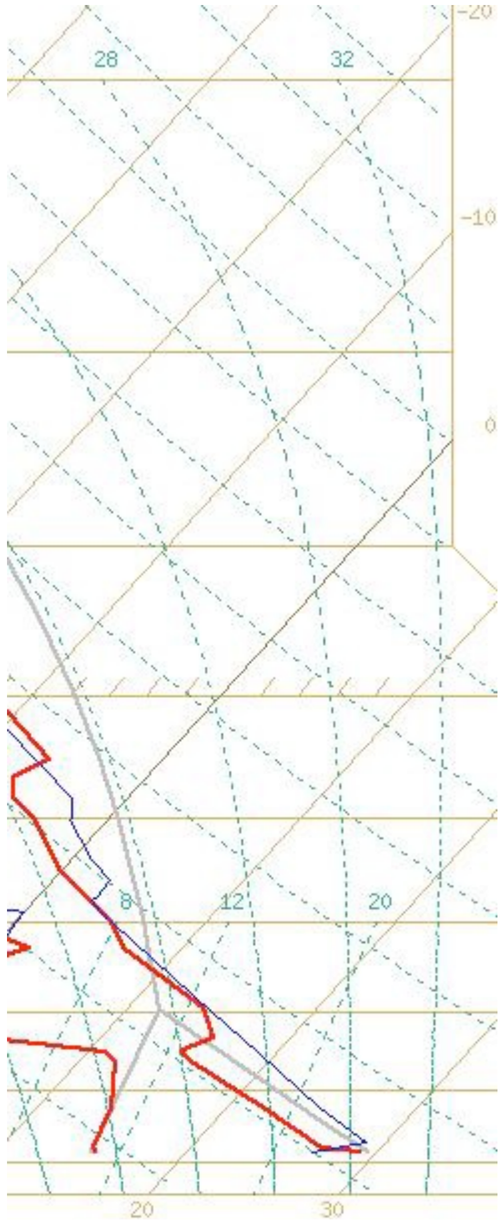
Still with me? Ok, this is going to get wordy now...but it's important to understand these concepts...

The dashed green lines that originate from the bottom, and rise diagonally to the left, represents the Dry Adiabatic Lapse Rate - abbreviated DALR. That is, the path that a parcel of unsaturated air will rise in the atmosphere. Unsaturated is air of which the humidity is less then 100%. As air rises, the pressure is less, and thus air being a gas obeys the gas law and expands under lower pressure. This expansion causes the air to cool - the air does not cool due to temperature exchange with its surroundings, in fact very little of this occurs as air is a poor conductor of heat. Hence, we arrive at the term "adiabatic," which essentially means without any exchange of heat. The reason why the air cools as it expands is because there is no heat added into it, yet the overall size of the parcel is increased. So the heat that was spread in the small parcel near the surface, now has to be distributed into a much larger parcel higher in the atmosphere. Thus, the heat is less concentrated, and causes the air to become cooler. An analogy that could be used, would be the Difference between a 1000W heater in a small bedroom, compared to a 1000W heater in an open lounge room. The same amount of heat is present, but the lounge room will be cooler (assuming the air mixes well), as there's more space to heat than in the bedroom.

Unsaturated air cools rather quickly, 9.8C/km and frequently will become colder then its surroundings if it rises at this rate for a long period of time. And, as soon as it becomes colder then the surrounding air, it begins to descend as cold air is denser than warm air, it sinks. Given this, we could already begin to make the assumption that dry air (unsaturated air), will cool very quickly, and descend back to the ground without traveling very far into the atmosphere. This indicates that dry air is not conductive of convective environments, although there are always exceptions and these will be discussed later. The lines that represent the DALR are in 10C increments and start at the same point the temperature lines do.

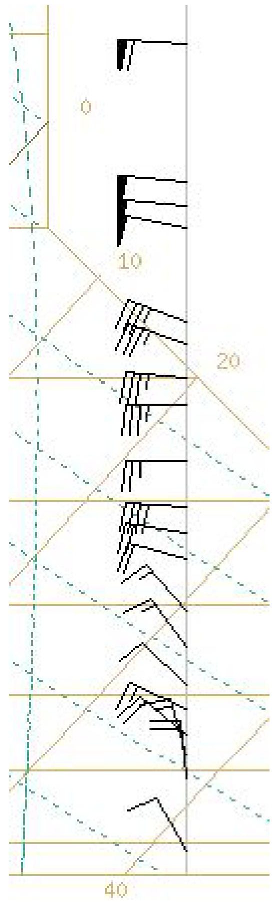


The dashed green lines that originate at the bottom of the Skew-T, but appear to go almost straight up first before veering towards the left is the Saturated Adiabatic Lapse Rate - abbreviated SALR. That is, the path that a parcel of saturated air will rise in the atmosphere. Saturated air is air that has 100% humidity. It also cools as it rises in the atmosphere, it loses heat just as quickly as an unsaturated parcel, however it also has heat added into it by the process of water vapour condensing into droplets. The reason for this is because in order to create water into water vapor or steam, we need to add heat to it (imagine boiling water on a stove). The water vapour in the air, exists because heat was added to cause it to 'vaporise.' Now, heat is simply a form of energy, and energy must always be conserved - i.e., it cannot be destroyed. Condensing is the opposite of vaporising, and thus as it condenses, it releases heat. This is called "latent heat" - essentially meaning "hidden heat." As soon as a parcel of air hits 100% saturation, if it cools any further, it'll begin to condense moisture. So - as it expands, it cools, but there's also heat added into the parcel as it condenses, but the rate of expansion cooling is still greater then the latent heat added to it, this is why it stills cools, however not quite as fast. The warmer the condensed parcel of air is, then the more heat that is released by this process occurs. This is a an important note, as it explains why in very moist surface situations, just a small fluctuation in moisture can have significant impacts on CAPE, LI and instability.

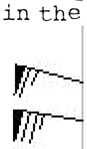


Notice on the Skew-T, how the SALR lines tend to 'bulge' out, at first glance it looks like the air is actuallygetting warmer as the air rises! However, remember that the temperature lines are diagonal, so the SALR lines are skewed somewhat. If you look at it closely, you can see that they are still cooling, just much slower. Also, notice how the SALR lines begin to follow the shape of the DALR lines as height increases? This is because as water gets condensed out, the parcel of air begins to lose its moisture, eventually the small amount of water that is condensing is so insignificant, that the air parcel begins to cool at the DALR.

On the right hand side of the Skew-T, you'll see flags along the side at different levels. This tells you the wind direction and strength at that level (just follow the pressure line and read the level that wind is on). When looking at the wind flags, the direction is quite easy to read, but might be a little difficult to comprehend for the first time. The part of the flag with the barbs points to the direction the wind is coming from. The end point (pointy section) points to the direction the wind is travelling to. On a skew-t, if the barb section points towards the top of the page, then the wind is coming from the direction of 0 degrees. If it points towards the right of the page, the wind is coming from 90 degrees. And so forth. Effectively, imagine you have a 360 degree compass on the page, with the top of the page being north/0 degrees. The direction can be a combination, so can point in any one of the 360 divisions.

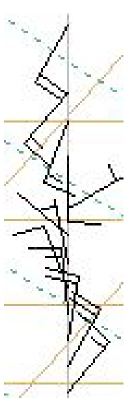


The barbs tell you how fast the wind is travelling. Half a barb stands for 5kn, a full barb stands for 10kn, and a bold barb stands for 50kn. Simply add all the barbs up together to get the wind speed. The direction from the bottom wind barb in the above example is NW at a speed of 10 knots.



Here's an example. The top wind flag has a wind speed of 65 knots (one bold barb, one full barb and one half barb), and then the bottom has a wind speed of 75 knots (one bold barb, two full barbs and one half barb). Both of the winds here are from the WNW (almost W).

Still not sure? Here's another example:



Winds at the bottom are from the NE at 15 knots here, and towards the top they're from the SW at 20 knots. It's easy once you get the hang of it!

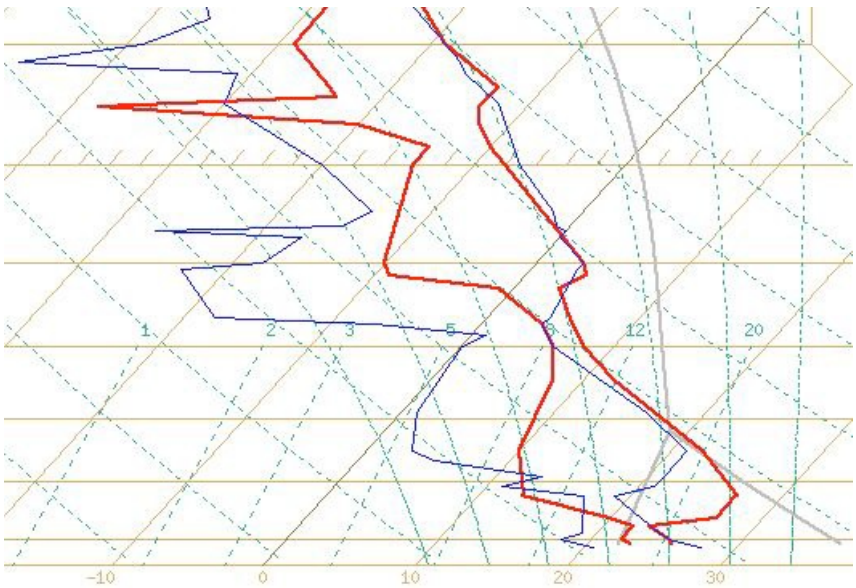
That's the basics of Skew-Ts - once you get the hang of it you'll be able to read them in seconds! Ok, but how do we tell whether the atmosphere is stable or unstable? I think that needs a new section...

Interpreting Skew-Ts (Part One)

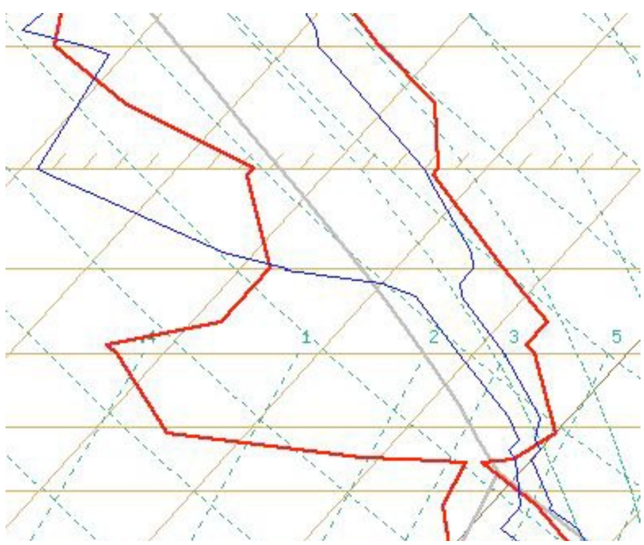
Now that the basics of a Skew-T are understood, we can now talk about how to put all of it together, and learn how to interpret a Skew-T. It's important to have a firm grasp on what the parts of a Skew-T mean before continuing into this section

One of the most frequently asked questions when reading a Skew-T and interpreting the information is, how do you know if air will rise or not, thus be unstable or stable? The answer to this question is very simple - there's one more line that is drawn on a Skew-T that was not described (although mentioned) before. That is the **Theoretical Air Parcel Plot line (TAPP).** This is the grey line that can be seen on the Skew-T. This indicates how a parcel of air will move, however it is imperative that the word theoretical is taken into account. As with many applications of meteorology, what works in theory does not always work in a practical situation. This will be explored in the next section further.

If the TAPP lies to the right of the temperature line (environmental lapse rate, or the ELR), then that section of the atmosphere is unstable...



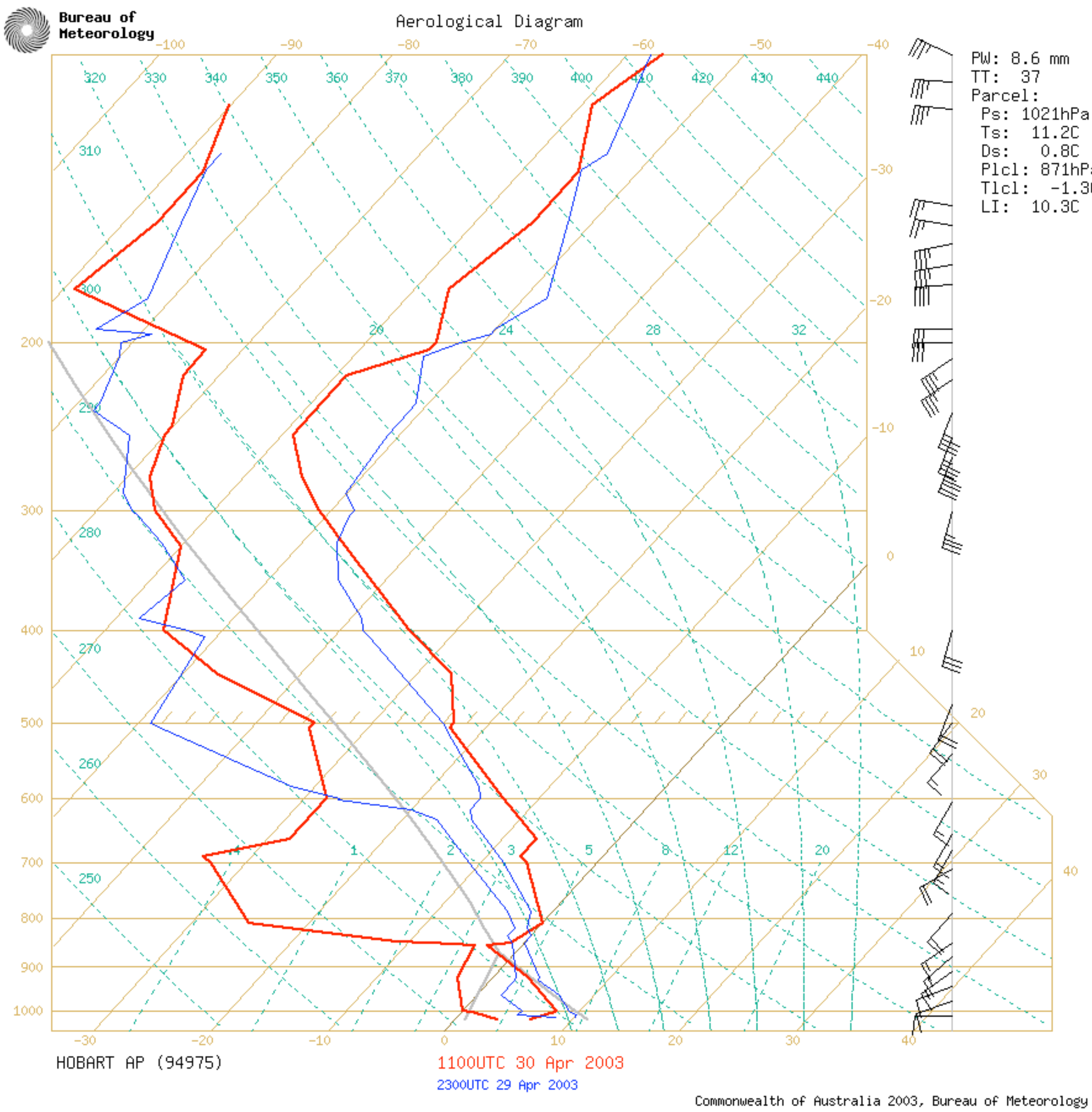
If the TAPP lies to the left of the temperature line, then that section of the atmosphere is stable...



Remembering that the Theoretical Air Parcel Plot line informs you how a parcel of air will rise in the atmosphere. Basically, it tells you the temperature at which it'll proceed if it's allowed to rise in theatmosphere. So if the temperature if the **TAPP** is warmer than the **ELR**, then it'll become positively buoyant and rise past that point (if allowed to reach that point). It's warmer, because if you read the temperature along the horizontal axis, you'll see that the **TAPP** will achieve a higher temperature then the **ELR**.

If the temperature at the **TAPP** is cooler than the **ELR**, then it'll become negatively buoyant. This does not necassarily mean it will not rise past this point though, and this will be explained in the next section. It will either slow down, or not be allowed past this point.

However - it is not quite as easy as this all the time. Quite often, we have times when the atmosphere has inversions, caps or sometimes the atmosphere is conditionally unstable, or completely unstable. Below, is an example of different Skew-T's and an explanation on "deciphering" them for the relevant information to "read" what the atmosphere is doing.



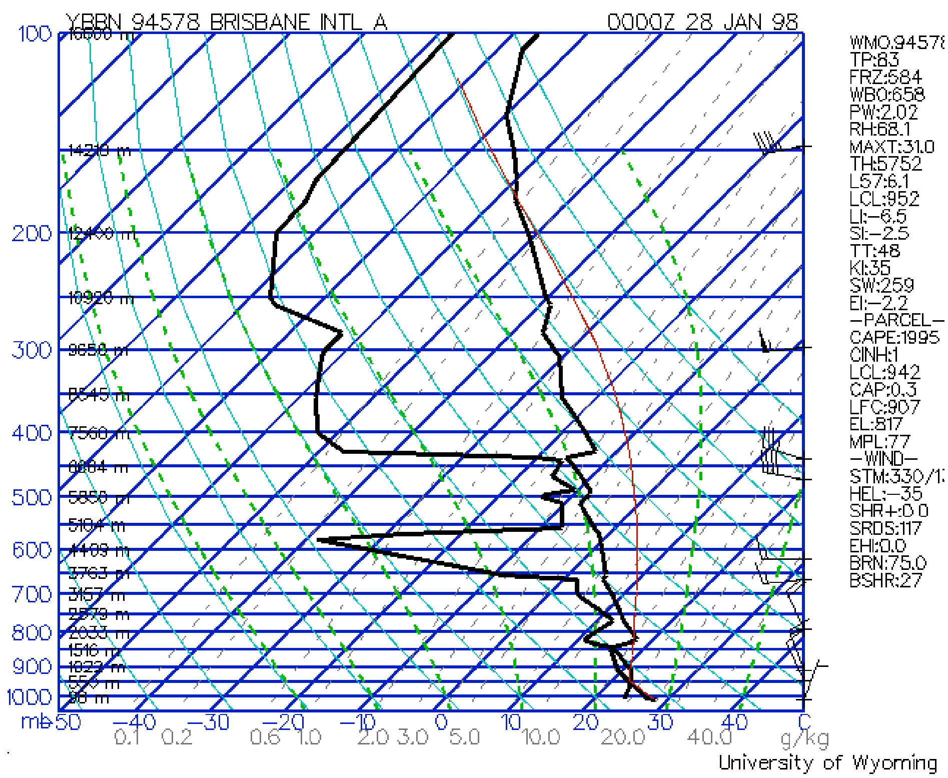
Notice how far away the air parcel line is from the **ELR**? There is no way you can even hope to achieve convection here! But it's important to note that the atmosphere at the exact moment that the skew-T plot was taken was completely stable. There are other factors that can change. For example, the upper atmosphere might suddenly become extraordinarily cold, or the surface heat and/or moisture might increase, or possibly even a combination of both might occur. Being able to monitor, and forecast the effects these changes will have on the environment, and your skew-T plot will be discussed later. So for the purpose of this example, this skew-T plot is completely stable, as the ELR is much warmer then what the TAPP would be if it attempted to rise, and thus the TAPP would begin to sink back to the surface.

There is one small section where the air parcel is slightly warmer then the ELR however, up until around the 850mb, so we might expect some very small Cu (probably stratocumulus!) But then no other convective clouds above that level as the atmosphere goes from marginally unstable, to strongly stable, and this layer will prevent any air from rising.

A few other comments that can be made, is the dryness of the overall atmosphere. Notice how far the DP and the temperature lines are apart? This is a sign of a dry atmosphere. The further the DP and the temperature lines are apart, the drier the atmosphere. Sometimes you can have differing moist and dry layers throughout the atmosphere, during that case you'll see the DP line 'jump' around a fair bit, but you'll distinctly see moist and dry layers.

Another feature on this is the presence of a large inversion in the upper levels (between the 250mb and the 200mb levels). An inversion is vertical section of the atmosphere where the temperature increases with height. You can see the that the 250mb temperature is approximately -59C. But the 200mb temperature, is -54C. So the temperature has increased with height, and this is therefore an inversion. The size and strength of the inversion depends on how sharply the temperature line veers to the right (temperature gradient increase), and for how long it does so (the size of the inversion). Another inversion is present between 850mb and 800mb which actually commences the start of our stable layer!

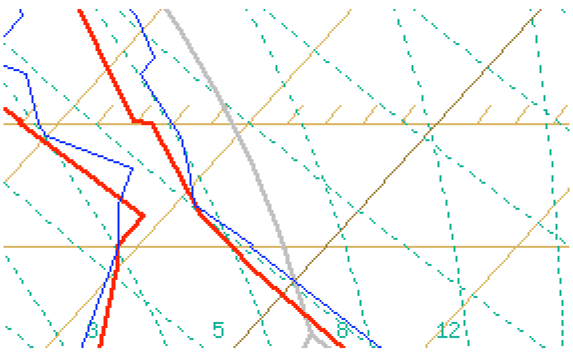
Lets look at another example, only this is a different Skew-T. Well, not really different - just different colours and format, it still tells you the same. It's just that this particular situation I want to illustrate is quite rare, and I saved this image back in 1998 when the BoM soundings weren't available. If you really have trouble understanding, I've written a quick page introducing the colour scheme of this particular Skew-T here.

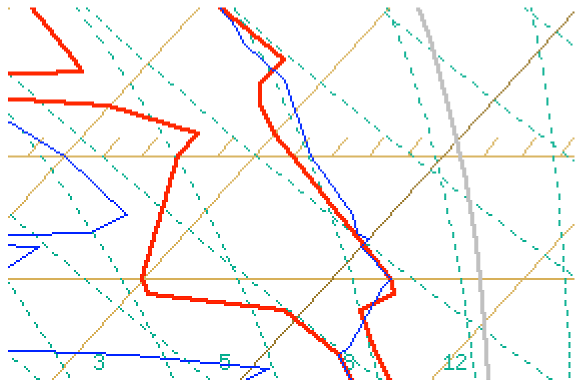


Notice that for the entire plot, the TAPP equals, or exceeds that of the temperature line? Except for two areas, there's a very small cap near 800mb, and at the top of the Skew-T (around 13,200m) the air parcel line crosses to be on the left of the ELR. The cap is so small though, that it will not make a difference - considering the uneven surface heating, you can almost bet that there would be areas with convection well above this level.

A cap is considered as a 'lid' on convection. A cap is an area where the TAPP crosses to the left of the ELR, and then eventually crosses back to the right of the ELR. So in between, you'll have an area of stability that suppresses convection. A cap is not to be confused with an inversion, which is simply a descriptive term on what the ELR does, it has nothing to do with the TAPP. However, because of an inversion's properties, a cap often occurs near, or on an inversion. This is a reason why these two terms are often confused to have analogous meanings.

This may now become a little confusing, as if the cap is a stable layer, and the particular sounding used in this example is a representation of a completely unstable atmosphere, how is the atmosphere completely unstable? There's are few other things that must be noted when looking at instability. The larger the difference between the TAPP and the ELR, then the stronger the stability, or instability is in that area. For example, if a parcel of air is 5C warmer than its surroundings, it'll ascend faster than air that is 2C warmer than its surroundings. Here's what I mean:





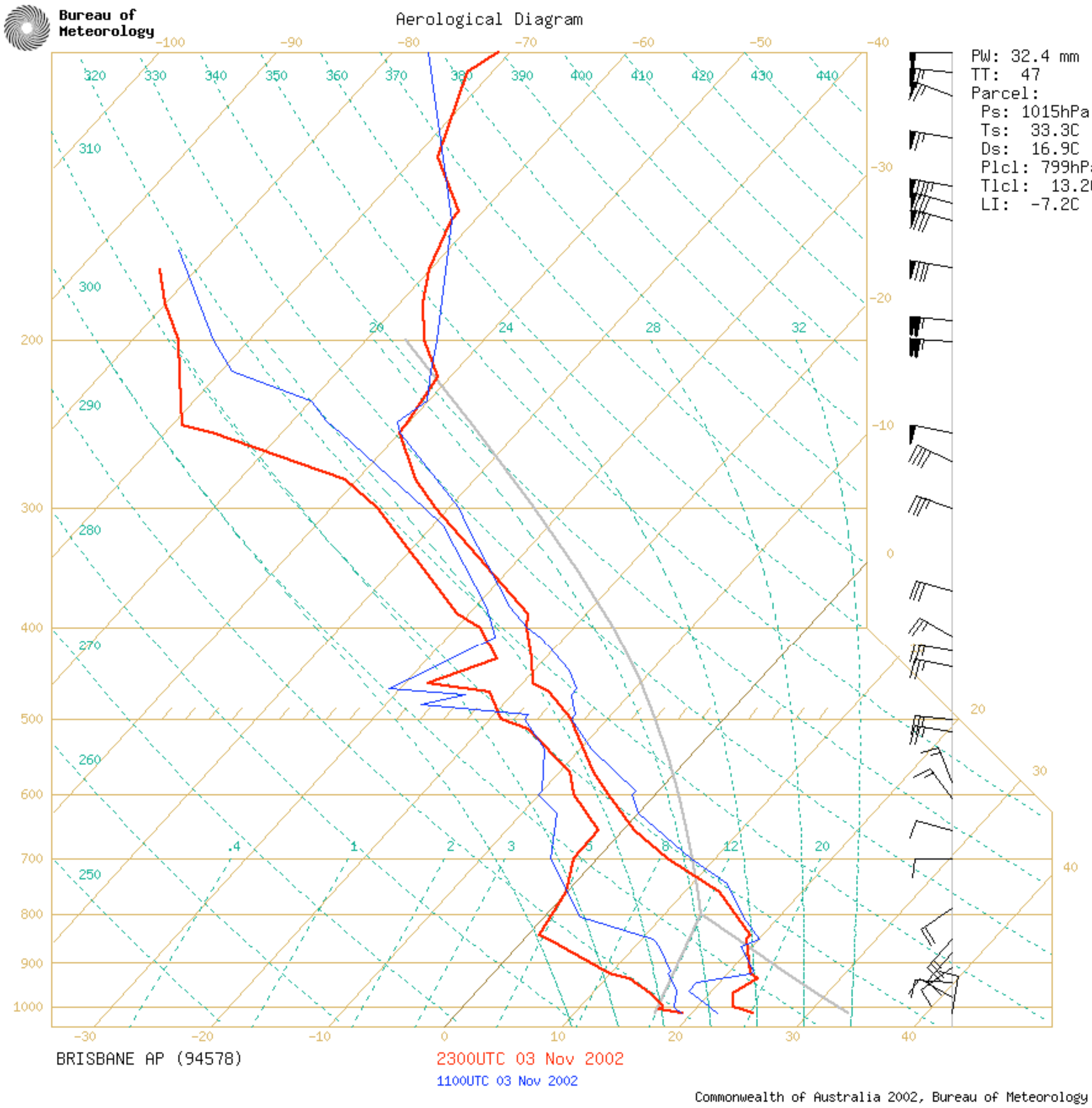
Both of these parts of the atmosphere are unstable, but the one on the right is more unstable than the left. That can be seen even just looking at the LIs. -4 LIs on the first sounding vs -9 LIs on the second sounding.

Similarly, if air is 5C colder than its surroundings, it'll descend OR reduce speed faster than a parcel of air 2C colder. As air rises, it gains momentum, updrafts can often gain speed very quickly, reaching 40-60km/h and sometimes as high as 150km/h. When an updraft, or a parcel of air that is ascending reaches a stable layer (eg, a cap), it begins to slow down, but it doesn't stop immediately. A useful analogy that can be used, is the example of a ball rolling down a hill. The steep the decline (the warmer the parcel of air is to its surroundings), the faster the ball will roll down the hill (the faster the parcel of air will ascend). The opposite can occur when a ball rolling down a slope, reaches an incline. What happens when a ball rolling down a slope suddenly reaches an incline? Will it stop immediately? It certainly will not! It'll roll up the incline and slow down. The steeper the incline, the faster the ball will slow down (the faster a parcel of air will reduce its speed), and if a ball is placed at the bottom of an incline, it simply won't move at all (a parcel of air will not ascend, therefore is stable).

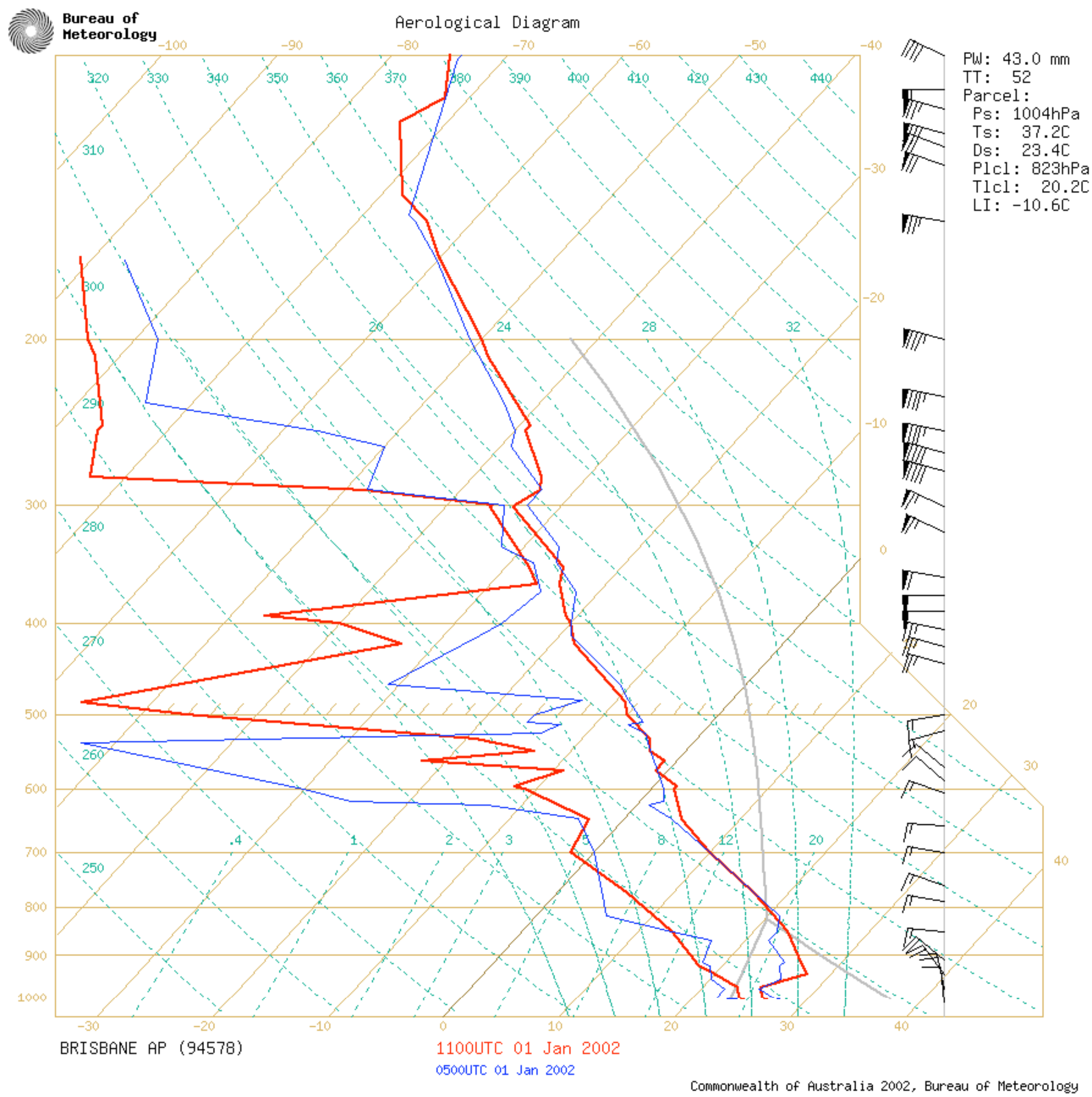
The small cap that can be seen on the sounding will easily be 'broken' from the momentum of air gained from below it, where it's slightly unstable. Basically, this stable layer is so negligible, that in our rolling ball example, this will be seen as a very small incline on a declining slope. The ball would have been given an opportunity to already gain speed, and will slow down at the incline, but still proceed over the incline, and will travel down the rest of the slope without hinderence. Similarly, our parcel of air that is rising in the atmosphere that this skew-T represents will see this cap as a small hindrance, and will slow down at this point, and continue rising. For this reason, small caps in the lower atmosphere are easily broken - often without any other assistance. Now you can understand why before, the cap mentioned in the Skew-T could easily be broken, as the air gathered momentum, it was able to break such a small cap. Anything under 0.5C can easily be broken by this method.'

Here is a good place to introduce CAPE, (Convective Available Potential Energy). CAPE is, as the name suggests, the amount of available convective potential energy in the atmosphere. Crudely, but simply - it is the measure of the area between the air parcel line and the ELR where the air parcel is to the right of the ELR. The larger the CAPE, the more unstable the atmosphere is. Air will rise faster if it is significantly warmer then its surroundings, this results in stronger, and more sustained updrafts. With CAPE being a measure of this instability, it is fairly explanatory why large CAPE's often correspond with severe thunderstorm development.

Think of CAPE this way in regards to the atmosphere. If CAPE is simply a measure of the amount of area that the air parcel line lies to the right of the ELR, then the larger the CAPE the larger the temperature differences between these two lines. Time for some more examples, lets look at two soundings - both having large areas of instability, but one being more unstable than the other.



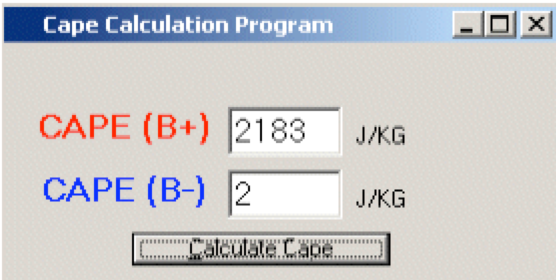
Here's a lovely unstable sounding above 700mb, -7 LIs too - this is the sounding of the morning of the November 4 Brisbane Valley Supercell. The BoM have plotted the day's maximum potential on it though, but I'll explain that a bit more in a future section. All we need to note here is that the CAPE is calculated (using a complex mathematical formula) from the unstable area of this Skew-T above the LCL. That means from approximately 720mb to 225mb is unstable. Compare that with the below sounding during the December 29 2001, January 1 2002 storm outbreak (including the December 30, 2001 South Brisbane Supercell).

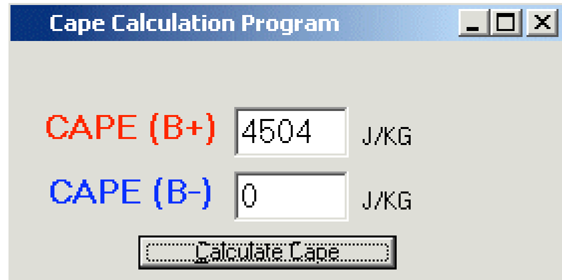


See how much more unstable it is? Clearly there is going to be more CAPE in the second sounding
because there is more area between the theoretical air parcel plot line and the environmental lapse rate. How much more CAPE? Well, I have a little program that calculates CAPE, you can't really calculate it by hand or in your hand. What I do recommend is going through the Wyoming soundings and then you canguestimate CAPE simply by looking at the amount of area under the curve. I rarely look at CAPE values on soundings though, I just look at the instability and think there's "lots of it," "a little bit" "a reasonable amount" etc - and so forth. Once you get a grip on soundings, the actual CAPE values won't really mean as much - although they're good training wheels to start with. You can actually use CAPE charts to forecast though, and CAPE is better than the LI when it comes to instability! Remember how the LI just tells you whether it's unstable at one level? Well CAPE takes the overall instability across all levels, so it's a little more reliable there! BUT!!! Unless you're from the US (well, I don't know about Europe/Asia/Africa...) forget CAPE forecasts!!! I'm yet to see decent CAPE forecast for Australia - occasionally it's ok, but for some reason it's very dodgy and tends to have a strong bullseye area. In reality, CAPE should occur in "bands" as opposed to circles - furthermore, LIs and CAPE don't seem to match up very well. My recommendation is to forget it...it's honestly not worth it. Use LIs if you want to use horizontal charts in Australia! But if you do use it, I strongly recommend you use it with a grain (in fact a bottle...) of salt! As I said,

this is just my opinion and recommendation, and if you find looking at CAPE useful - by all means do so!

Anyway, back to CAPE - I said the second sounding had more CAPE than the first...I better give some proof of that, here are the figures:





As you can see, there's much more CAPE in the second sounding compared to the first! Hopefully that helps give you an idea and a concept about what CAPE is! I'll give a set of "magic numbers" for CAPE too. Keep in mind that, you can get tornadic supercells in CAPE of just 100-200 in the right conditions! If you continue to read on in this guide, you'll discover why. I've also included some typical LI values you might see with these CAPEs. Keep in mind that while there is a correlation with CAPE and LI values, there can be significant differences! Hence there is some overlap in the figures. These magic numbers are assuming the cap breaks:.

CAPE (LIs)	Description
< 500 (-1 to 2)	Very weak instability, showers likely with some isolated storms. If shear is absolutely fantastic, then there is the chance of severe storms.
500 -1000 (0 to -3)	Weak instability, showers and storms likely but generally weak unless shear is good.
1000-1750 (-2 to -5)	Moderate instability, storms (possibly severe with pulses), becoming quite severe if shear is very good, updrafts may be strong enough to sustain large hail (2cm+)
1750-2500 (-4 to -8)	Strong instability, possible severe pulse storms in weak shear - probable severe storms in good shear, large enough to sustain large (2cm+) to very large hail (5cm).
2500-4000 (-6 to -12)	Very strong instability, severe pulse storms likely in weak shear. Good shear will result in severe to very severe storms with updrafts strong enough to sustain very large (5cm+) to extreme (8cm+) hail.
4000 > (-10 to -16)	Extreme instability, severe pulse storms likely in weak shear. If you have good shear - watch out! Updrafts strong enough to sustain hail in excess of 10cm.

We have now seen two examples of skew-T's representing completely stable, and completely unstable atmospheres. However, more often the not, we'll see that the atmosphere is neither. Sometimes the atmosphere is unstable in the lower levels, but stable in the upper levels (eg, low-mid topped showers). Unstable in the mid-upper levels, but very stable in the low levels (generally sunny, occasionally some Altocumulus Castellatus). Or sometimes it's generally unstable, but stable in other areas - all of these give differing results. But importantly, we have to remember that a skew-T is a vertical slice of the atmosphere at the time the sounding was taken. During that time, a myriad of factors can change, cold air can come through in the upper levels, or an upper level ridge may move through. Alternatively, moisture in the upper levels may suddenly increase or decrease. But the most common change that occurs is the change at the surface. The change that results in the surface conditions is often so great that it frequently alters what a seemingly stable, or unstable atmosphere will actually produce. So how can the skew-T be adjusted to represent the change in at the surface? It's quite simple, but rather long-winded and is explained in the next section.

Interpreting Skew-Ts (Part Two)

We're going to look atsome more examples soon, but first lets learn a little more about this new line - after all, it's probably the most important line of the Skew-T, but you can control it too! Remember a few things we learnt in the first part of this guide about instability:

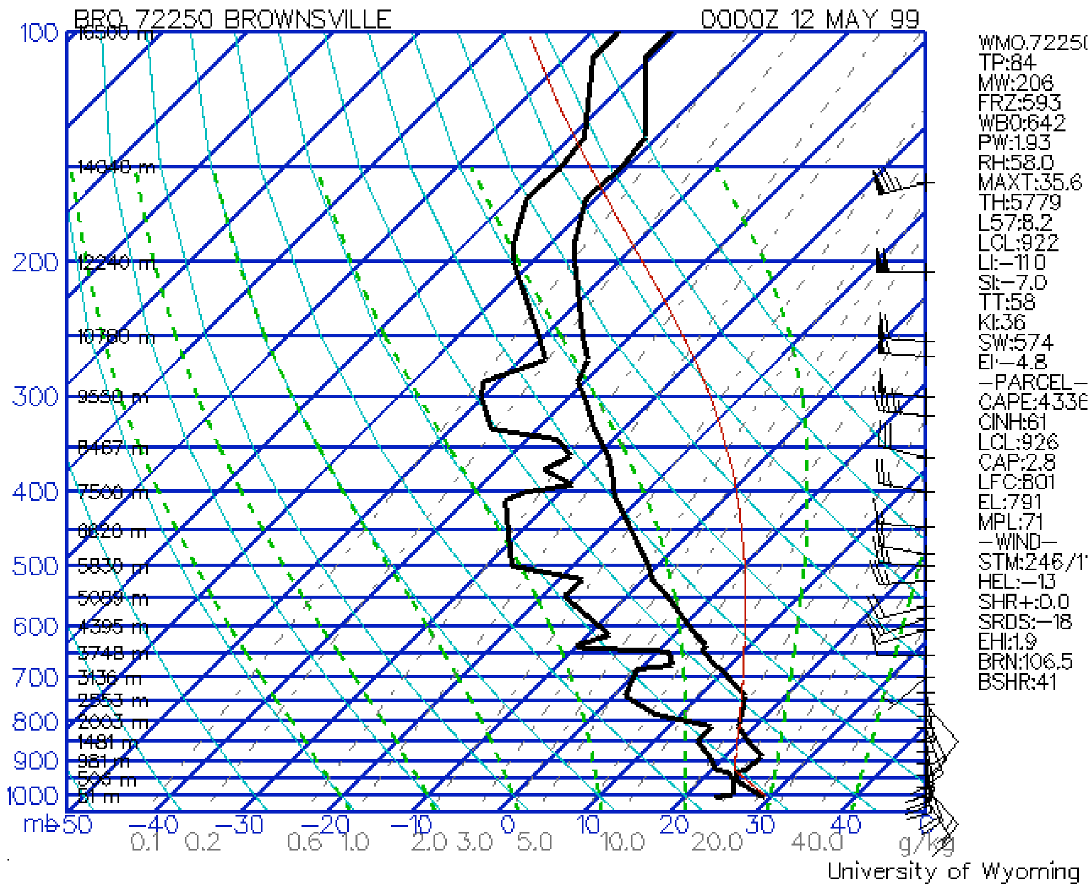
- Higher surface temperatures = higher instability (or less stability)
- Higher surface moisture = higher instability (or less stability)
- Colder upper level temperatures = higher instability (or less stability)

Conversely, the opposite is also true for all of these (eg lower surface temperatures produce lower instability and an increase in stability and so forth).

Keeping this in mind, we also know that our TAPP line not only tells us whether the atmosphere is stable orunstable, but also how stable and unstable it is.

So then - do you think that the TAPP line and the surface temperature and moisture, and the upper level temperatures could be related? If you think yes - you're right! In fact, if you know the surface temperature and dewpoint, you can plot the TAPP line! This is extremely important, knowing how to do this gives you full control over Skew-Ts - I know it's a bit of work, but trust me - you'll understand things a lot more if you understand exactly how it works!

Once again, an archived Wyoming sounding is the best illustration of this (I'll get back to the proper BoM soundings the next time - I promise!)



Look how far to the right the air parcel line is to the ELR!!! The CAPE is calculated at 4336 and LIs -11 - the atmosphere at first glance appears **EXTREMELY** unstable. However, technically it isn't! Look at the cap near 900mb, that's a fairly large cap!

Looking at the air parcel line and ELR, air is not going to rise above 950mb, all that CAPE above will simply go to waste. The atmosphere at this point is "stable." However - if certain conditions occur, that cap could 'break,' for this reason, the correct terminology is "conditionally unstable." Rather - it is conditional upon other variables to whether or not it will be unstable or not. If cooler air comes aloft near 900mb (and assuming that the warm, humid air at the surface prevails) the cap will decrease significantly, until eventually air at the surface will be allowed free passage through the atmosphere. Conditionally unstable atmosphere's generally cause the most severe thunderstorms. The reason for this, is that all the heat of the day is kept at the surface, and then when the cap suddenly breaks, you have an entire day's heat energy from the Sun to utilise in energy and 'fuel' for thunderstorms. There are a multitude of other ways the cap can be broken, quite frequently it is by added heat at the surface. If you heat the air up further at the surface, it is more likely to be warmer then the rest of the atmosphere as it rises. A trigger will also help break the cap, in many situations just heating a conditionally unstable atmosphere isn't quite enough to break the cap, you still need some forcing to help get the initial parcels of air rising. Here we come into the basics of nowcasting and forecasting CAPE during situations such as these.

We learnt before that air will cool at the DALR (Dry Adiabatic Lapse Rate) until it reaches 100% humidity (ie saturated), and then from that point it will cool at the SALR (Saturated Adiabatic Lapse Rate). The point at which this changes is the LCL (Lifted Condensation Level) - ie the base of the clouds. However, this path changes as heat and moisture at the surface changes. As heat and/or moisture at the surface increases, the air parcel line is "shifted" to the right. The LCL also changes as heat and moisture changes. Both of these points are critical. But using this information that's been presented, do you think if we added enough heat (or moisture) into the atmospheric situation described by the sounding that we might be able to break the cap?

What do we need to know here to work it out? Well...we need to know:

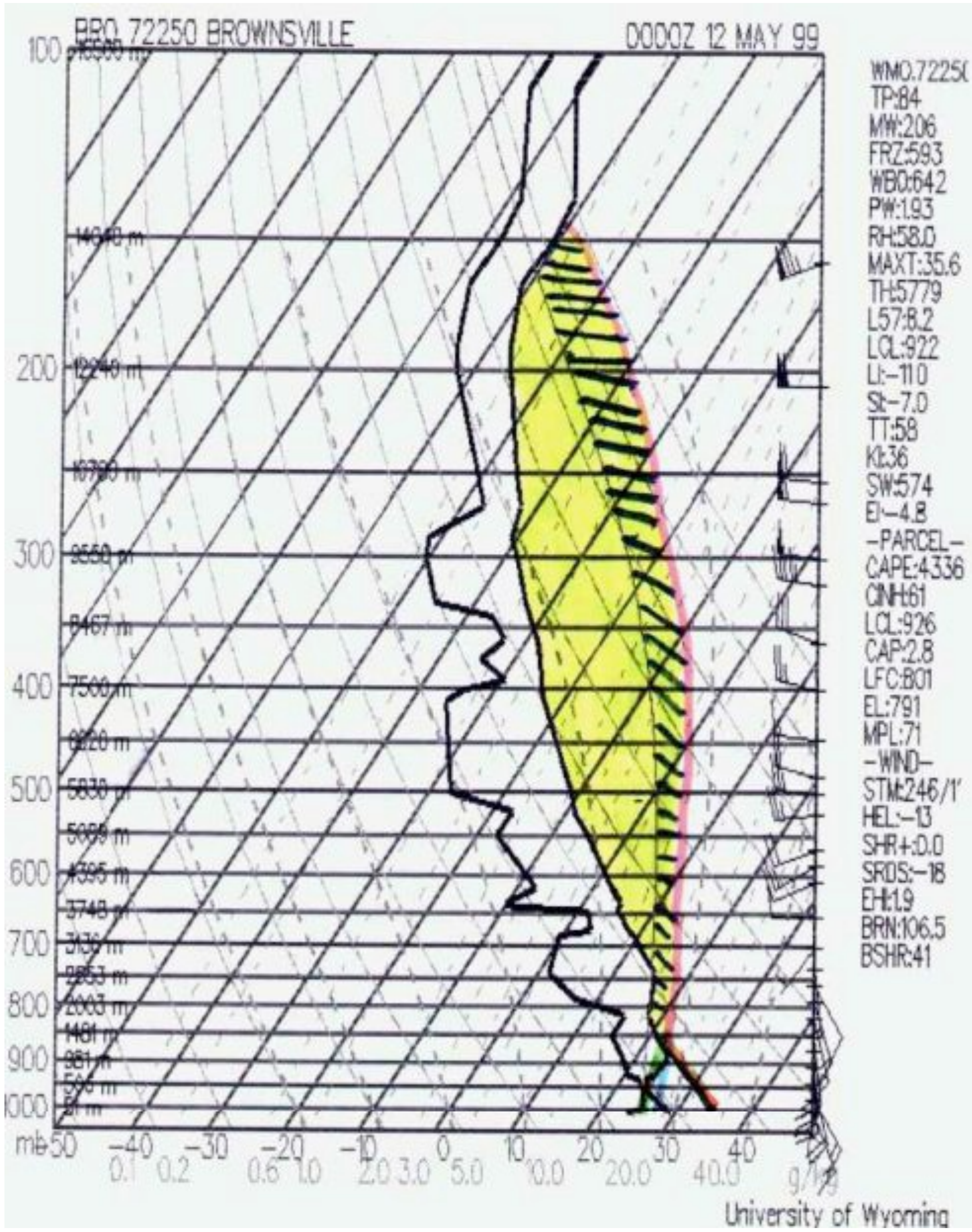
a) by how much is the theoretical air parcel plot shifted to the right? And...
b) where is the new LCL?

The relationship can be related by "Normands Theorem." This simply states this::
That the LCL is where the following lines intersect:

- The DP (Dewpoint) from 1000mb, taken up through the atmosphere following the pattern of a mixing ratio line.
- The T (Temperature) at 1000mb, taken up through the atmosphere following the pattern of a DALR line.

Where these two intersect, is where the LCL will lie. Lets assume that the DP remains the same, but the temperature rises to 35C during the day.

From the DP, follow a mixing ratio line upwards for a few centimetres. From the temperature, follow a DALR up for a few centimetres, see where the two intersect? Tadah!. We have now just found our new LCL! We can now plot the rest of the Skew-T. We can now clearly see that the atmosphere has become unstable! We have also added more CAPE, as we can see the area between the air parcel line, and the ELR has increased considerably. Our CAPE is now well in excess of 5000! Not to mention the atmosphere is now unstable, we can now expect some very large (and severe) thunderstorms.

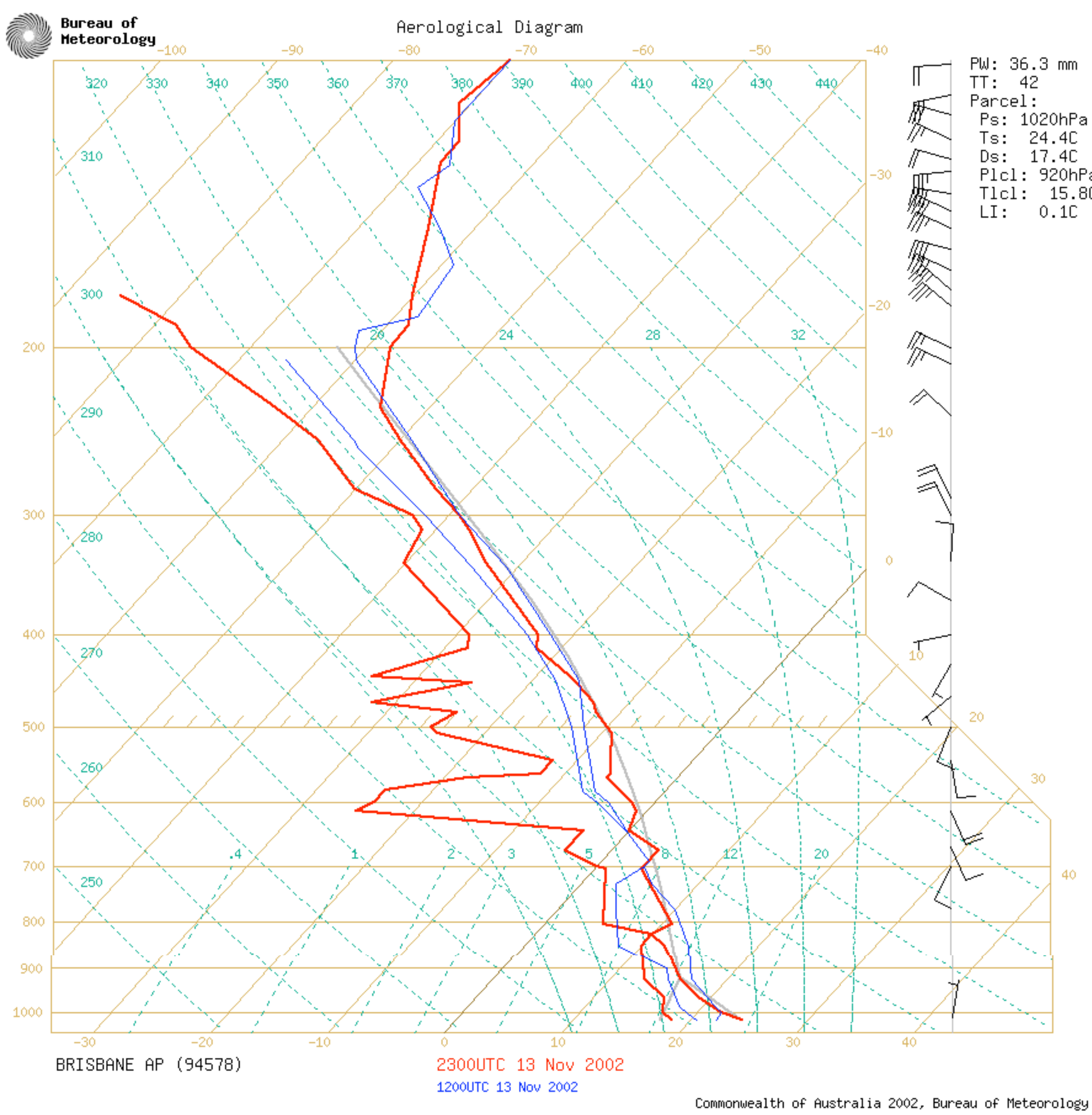


Above is the new Skew-T with the added heat at the surface. The green line is from the DP, following a mixing ratio line. The orange line is the air parcel line from the temperature, following a DALR line, and the red-pink line is a continuation of the air parcel line, after the LCL has been reached, and the air is cooling at the SALR. The shaded yellow is the CAPE, with the stripped yellow indicating the new CAPE added by increasing the surface temperature. (NB - Ignore the middle dark black line, this was the old ELR, the new ELR is on the right - as the bottom part of the atmosphere changes temperature somewhat during the day. Also ignore the blue line drawn in - knowing what this is now obsolete).

You may be wondering about the changes in temperature in the atmosphere. Anything above 850mb, is not effected by diurnal temperature changes at the surface. Providing our upper atmosphere remains the same (and fluctuations are common, but generally aren't significant. They only occur by temperature advection, and this can be forecasted well in advance by looking at forecast Skew-T's <which will be mentioned later>
and seeing the expected changes in the atmosphere.) Anything below the 850mb line that changes, is most likely to follow a DALR line. This means that air will rise slowly at this point, but as soon as it passes the broken cap, it will rise very quickly, and convection will "explode."

There are limitations of “Normands Theorem” – during very dry situations, and inversions right above the surface, the LCL does not exactly follow this plot. Because of these limitations, many people tend to alter this process a little. The next section illustrates how that process is changed to give a more accurate representation of the atmosphere. Don't worry, it's not difficult at all – in the long run it'll take an extra half a second, but it'll probably save you hours of bust stormchasing!

Finally we have an example of a potentially unstable atmosphere. That is, it can potentially be unstable if a few things happen. You might be wondering if this is the same as a conditionally unstable atmosphere. However a conditionally unstable atmosphere is generally an unstable atmosphere with a moderate to large cap that could potentially be broken. However, a potentially unstable atmosphere is an atmosphere that is almost completely stable – but only just stable or very marginally unstable (but overall because there's too many stable points, it's generally considered stable. But a few normal changes that occur during the day could easily cause the atmosphere to become unstable. Below is a Brisbane sounding for November 14:



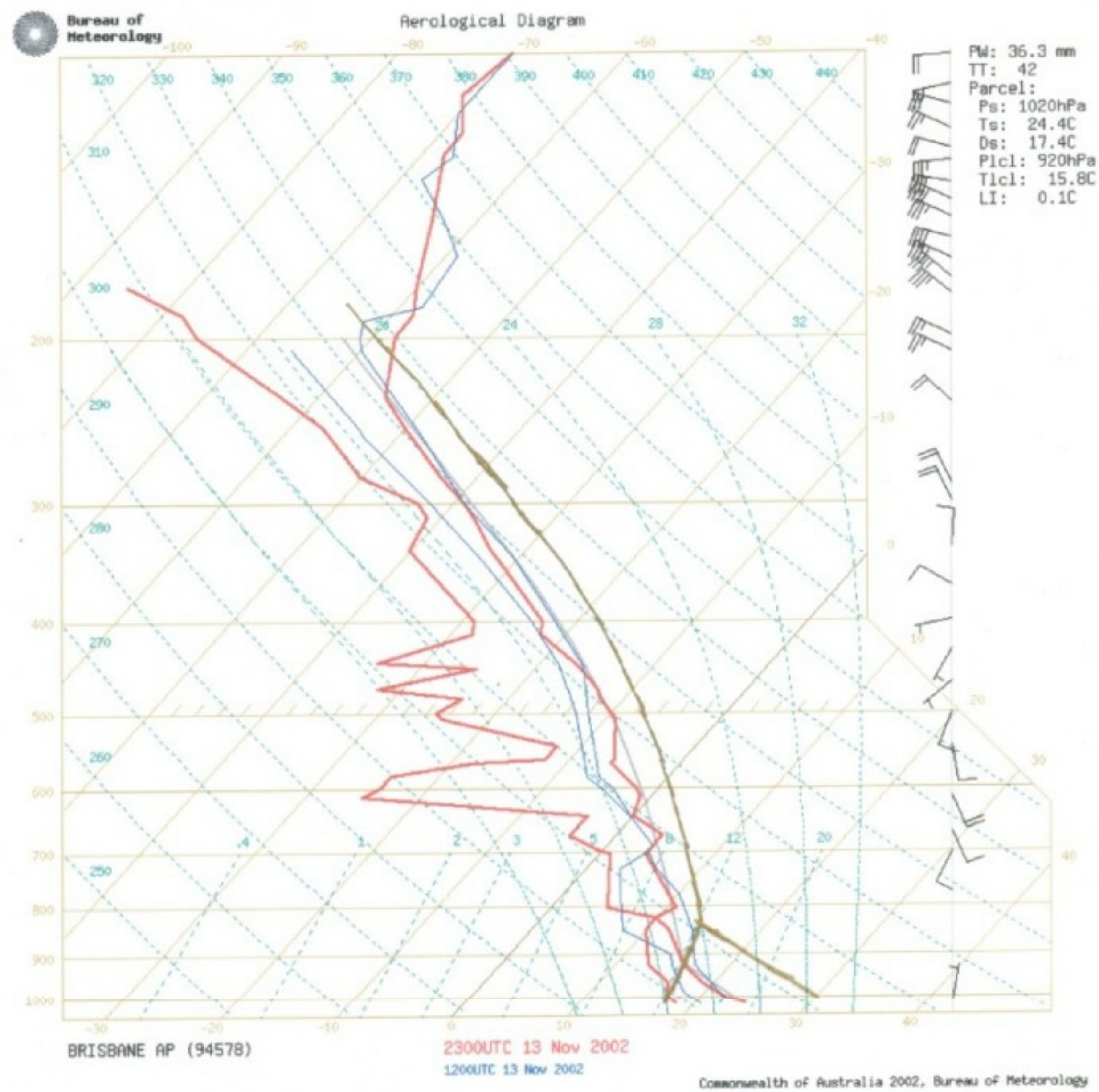
Look at the ELR and air parcel line, oh no! A fair chunk of the air parcel line is to the left or the ELR! So there's quite a few stable areas with some marginally unstable regions. Not to fear though! This Skew-T is taken on Nov 13 at 23z, (Nov 14, 9am local time), but 9am in November (summer in Bris Vegas for those northern hemispheric folk reading this) means there's oodles and oodles of potential heating from sunlight (providing it's not cloudy) yet to come. We can see here that the plot is taken at approximately 24.4C with a dewpoint of 17.4C. How did I know it so exact? Ok, lets look at another thing briefly on the sounding before we go further...

```
PW: 36.3 mm
TT:  42
Parcel:
 Ps: 1020hPa
 Ts:  24.4C
 Ds:  17.4C
 Plcl: 920hPa
 Tlcl:  15.8C
 LI:   0.1C
```

Right, lets make some sense of this (you may have already guessed some of them already going by their abbreviations).

PW	Precipital water. If you condensed all the water in the atmosphere above you, then you would get 36.3mm of water (in this example). The higher this is, the more moisture in the atmosphere.
TT	Total total values, click here for more information. Parcel Below is the parcel information
Ps	Pressure at the surface (1020hPa)
Ts	Temperature plotted at the surface for the TAPP line (24.4C)
Ds	Dewpoint plotted at the surface for the TAPP line (17.4C)
Plcl	Pressure at which the LCL occurs (920hPa), the higher the pressure the lower the bases of convective development.
Tlcl	Temperature at which the LCL occurs (15.8C)
LI	Lifted index value, click here for more information.

Now that that is out of the way, lets look at replotting our sounding! We know it's going to be warmer than 24.4C! Moisture? Hmm...lets keep it constant for now for simplicity, but remember that moisture can also change! Lets say it gets to 30 degrees and moisture stays the same. If we follow our rules of Normands Theorem as before, we can arrive with a new air parcel plot, that has all of the air parcel line to the right of the ELR!



You can now see that the atmosphere is clearly unstable. Not hugely unstable (LIs are -2 at 500mb, remember the rule to calculating them? If not, click here. But if we work out the maths: -10C - -8C = -2LIs

Also note that it is fairly consistently unstable throughout the atmosphere - that's good, there's some good moderate instability here! Not too bad given the sounding initially didn't suggest any convection! That's a critical thing to remember, and I'll discuss that more in the following section. Were there severe storms? A little further south there were some one foot hail drifts - in SE QLD not so much, look at the shear, barely 20 knots until above 300mb! The shear section of this guide helps describe why it's difficult to get severe storms in that type of shear and proposes some better shear values that we might want to look for. Check out the chase report of this day though if you're not convinced there were storms! Now that we have learnt how to re-plot skew-t's with different surface conditions, and read instability/stability - we can now continue to really let Skew-Ts do some work for us!

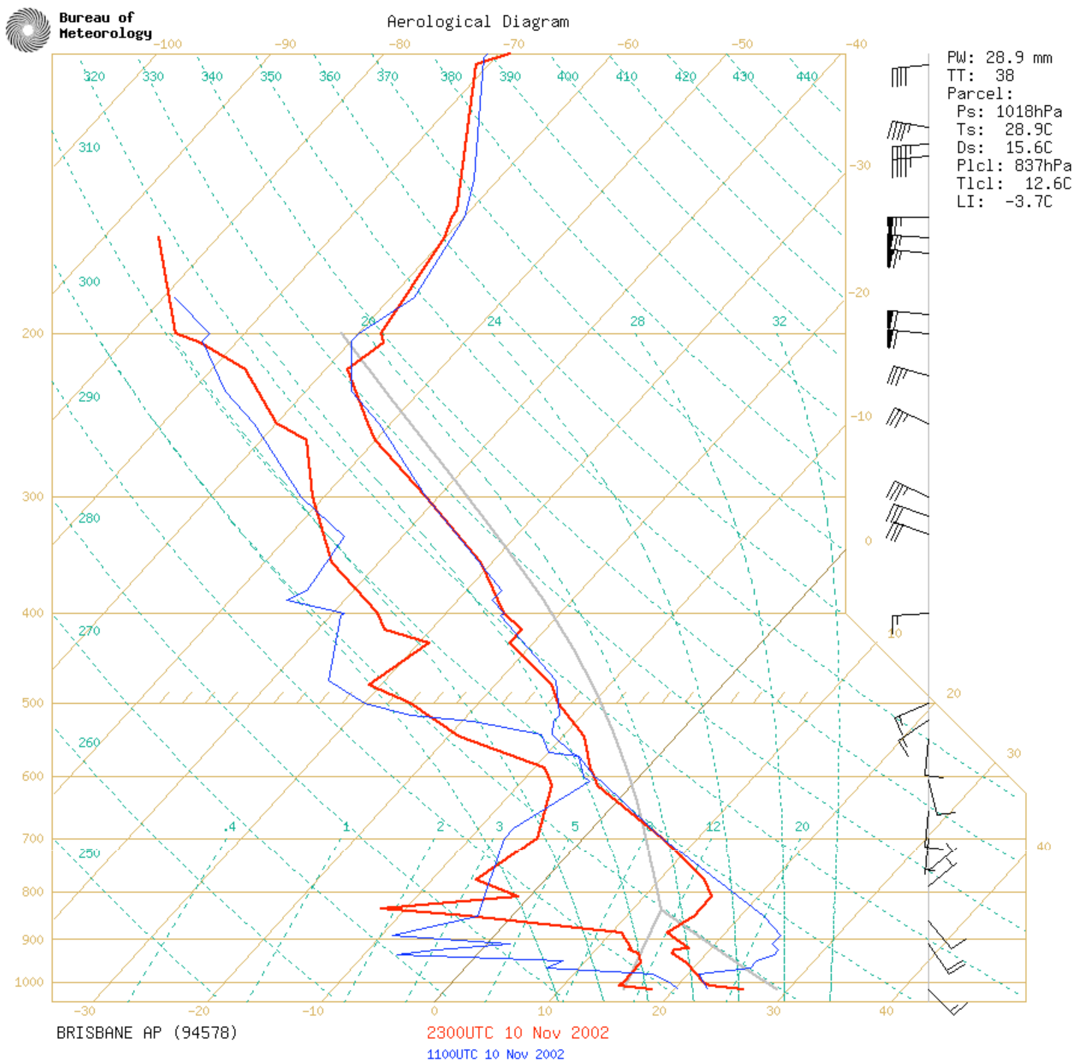
Interpreting Skew-Ts (Part Three)

Understanding Skew-Ts and some of the information previously presented now allows us to learn a few more things. Have you ever noticed that storms have a tendancy to favour the ranges? Why is this? Most people think that this is due to the extra convergence (ie, additional lift as wind climbs the ranges), this is somewhat true, it does help break the cap and initiate convection. But what about those really marginal days when there's barely enough energy for storms to develop - the ranges still fire, but storms then weaken or sometimes die as they come off the ranges. Why is this?

This brings about the concept of elevated heating and another concept I (somewhat colloquially call) pressure heating. Don't ask me how I derived the second one! But essentially, it is this:

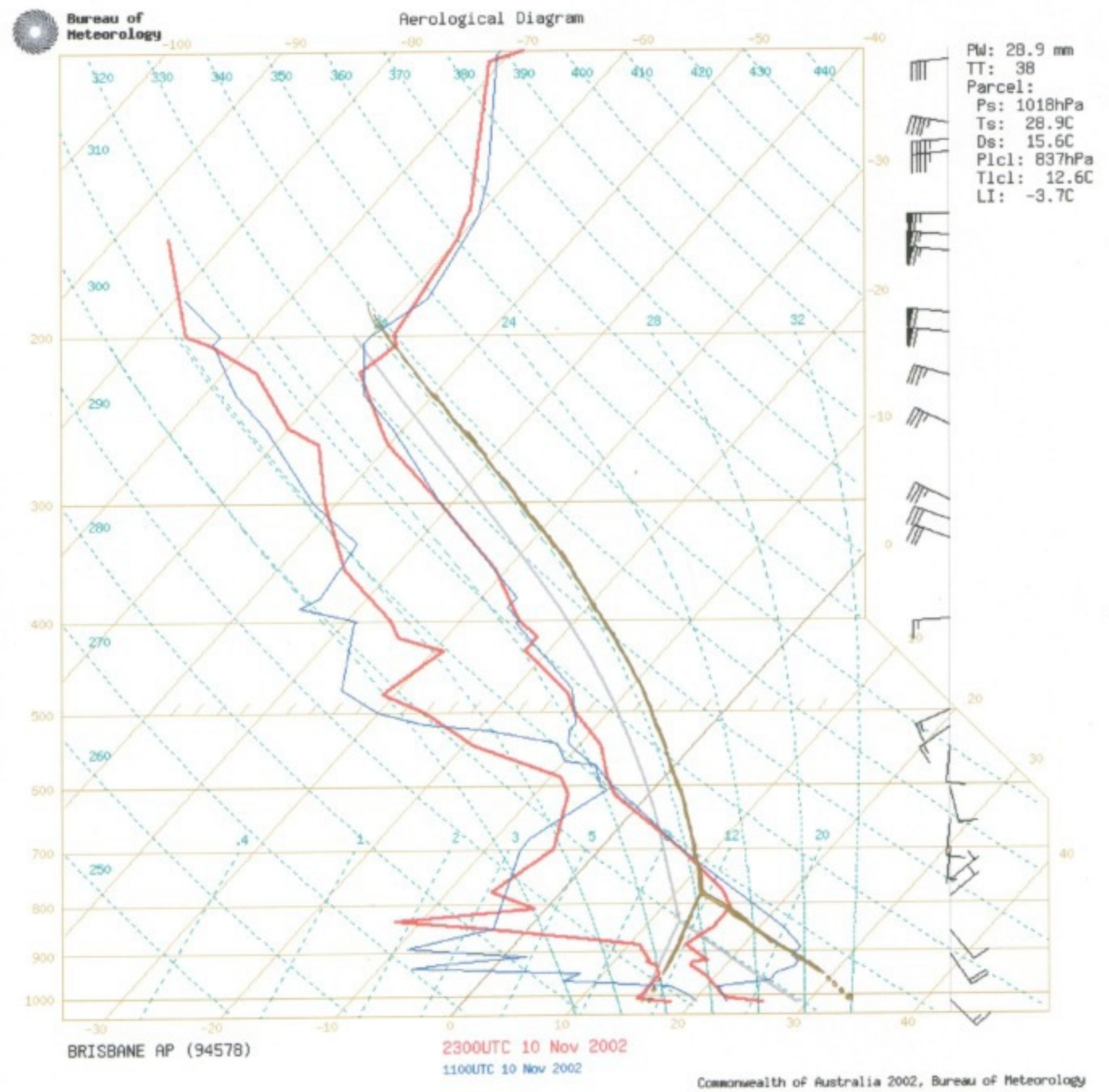
- Elevated heating results in an effective higher temperature and dewpoint (therefore increasing instability).
- Pressure heating results in an effective higher temperature and dewpoint (therefore increasing instability).

Make sense? Probably not...so lets get some examples on the way!



Here we have a sounding on the morning of November 11. There is a fair bit of instability if it reaches close to 30 degrees with a DP of around 16C. (Notice that in this example that a DP drier than the surface was chosen? I'll explain why that's the case soon - but it's to do with averaging the low level moisture). The problem is that there is a massive cap! Unfortunately on this day, while it actually got into the low 30s on some of the plains of the SE Coast region, nothing happened. In fact, one storm that did move into the region died as it came off the ranges. If you're not familiar with the topography of SE QLD (where I live), then here's a quick run down. SE QLD is surrounded by ranges to the south and to the west. Ranges to the south are along the border of NSW and QLD and get up to 1300m. Ranges to the SW get up to 1200m and to the west they get up to 800m. To the west is what is referred to as the "Darling Downs" - a large farming region that goes several hundred kilometres inland. The Downs is one of my favourite playgrounds - not just because it's flat and few trees either! But because it's elevated, in fact most of the Downs is around 500m high!

So what's so important about height? Well - what happens as you ascend? The pressure drops! In the bottom 1-2km, the pressure drops at approximately 1hPa every 10m. So say the pressure is 1000hPa at the surface, if you ascend 100m then the pressure is now 990hPa. If you ascend 500m the pressure is 950hPa and if you ascend 1000m the pressure is 900hPa. Remember how we used Normand's Theorem to plot our Skew-T, and we started at the surface? Normally the surface is taken to be around 1000hPa, but what if it were say 950hPa? We would then have to plot our temperature and dewpoint commencing from the 950hPa level! Normally as you ascend, the temperature and dewpoint decrease (in fact, this should be at around 1C/100m), but that isn't actually the case over land! For instance, at an elevation of 600m, about 20km south of Toowoomba on November 11, I measured a temperature of 29 degrees. The sea level
pressure at the time was around 1010hPa, which meant the actual pressure I was experiencing was around 950hPa. The dewpoint was hovering around 15-16C. Essentially, at 600m it was the same temperature and dewpoint as plotted at 0m (sea level) on the above Skew-T. So we're going to get a good idea on how increasing the altitude can really help increase the instability!

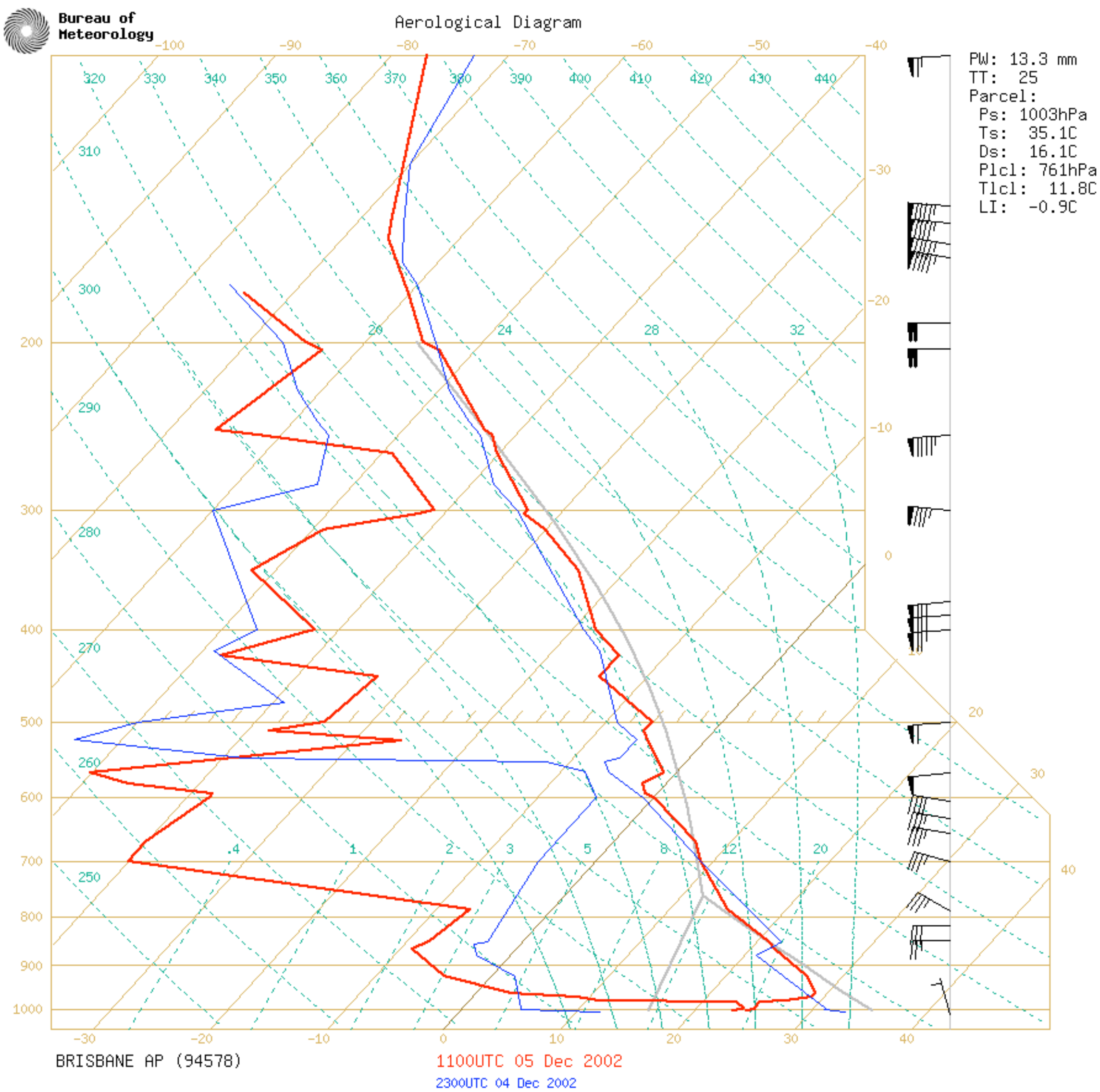


Here we are with our new plot, plotted at 600m (or in this case 950hPa), look how much more instability we have! Just going by LIs along we've gone from -4 to -7! That cap has weakened a lot too, much more breakable then before. I've also drawn (well attempted, it didn't work too well) to draw in some dashed lines from 950hPa to 1010hPa to illustrate the equivalent surface potential. Had I had a steady hand, you would see that the surface potential of 29C at 600m is around 35C! (ie 1C per 100m), and the DP ended up being around 17C from 15C. So you can clearly see here how elevated heating increases the instability and can also help to break the caps. This is a major thing to realise if you're chasing say on the Tablelands (large areas over 1000m) or the slopes and plains that lie to the west of these areas. So what happened on this day? A storm I chased gave cricket ball hail and severe winds that destroyed several sheds and barns. I missed the hail (fortunately!) There were some even stronger storms in the northern Downs but few people live there. Check the chase report anyway if you're interested!

This also brings about "pressure heating." Think about it if the pressure is 1000hPa vs 1020hPa. For every 10hPa higher that the pressure is over your area, then that's the equivalent of 1C cooler when you look at it in terms of instability potential. This is another reason why lower pressure is good - winter storms can struggle because the pressure can be in excess of 1020hPa - that means that it is effectively 2C cooler at the surface already then the same situation in summer at 1000hPa (even ignoring the summer/winter temperature differences). So areas of low pressure also help increase the instability - while areas of high pressure decrease it. Not to mention the fact the areas of low pressure often have already rising air and areas of high pressure have sinking air which surpresses updrafts.

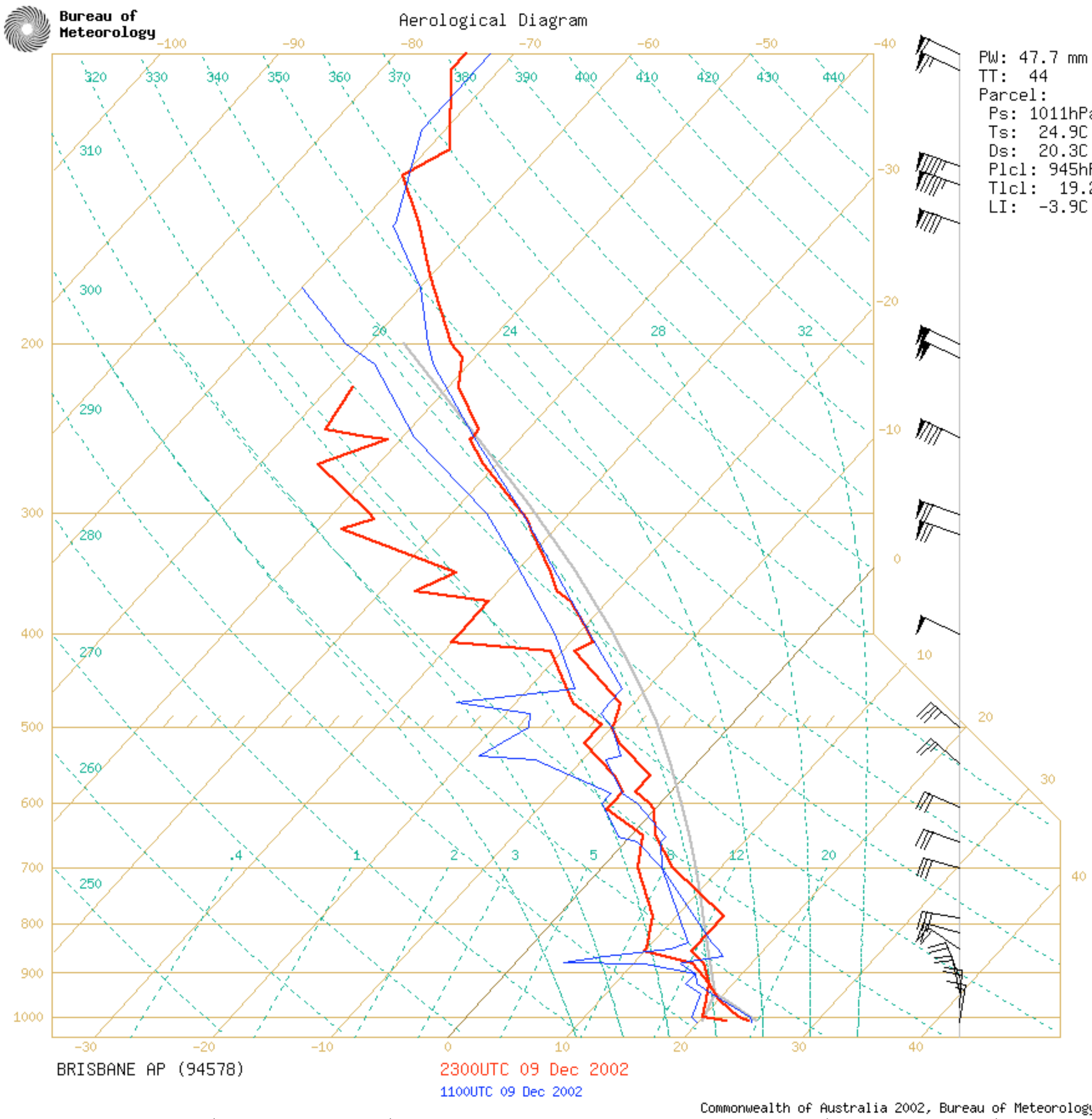
I mentioned that the BoM often takes an average of the surface moisture - in fact, a lot of sites that plot soundings do this. There is a good reason for this, it's to do with mixing during the day. Lets think about our convective process. The initial convective process occurs in rolls, in lower 1-2km of the atmosphere you tend to have air rise from heating, and then cooler air around it sinks. This cooler air is then heated in the lower atmosphere by the sun and the ground. Already we can see two things here! Our convective "roll" will not go past the initial cap, so if the cap is say at around 2km, then our convective roll won't go past 2km and then all our heat energy is "trapped" underneath the cap. If there is a weaker cap, then a lot of our heat energy can escape into the upper atmosphere as convective clouds - not what we want if we want stronger thunderstorms.

The other thing we can see is, if the surrounding air in the lower atmosphere is dry - what is going to happen when it mixes in the surrounding air? For instance, lets say there is a DP of 20C at the surface - lovely and moist! But 500m up the DP is only 10C, then that dry air will eventually mix down towards the surface and give a combined DP much lower than 20C! So our convective potential is subsequently diminished. Lets look at some more examples. Here is an example of what I call very shallow moisture:



Look at the surface - lovely DP of around 24C! But then look up - look how much it dries out! Lets assume that the inversion wasn't there, and we were able to allow a parcel of air to rise - what is going to happen when the surrounding air just above the surface begins to sink and mix in with the surface air? It's going to dry out the surface very rapidly! Hence why in this sounding you can see that the TAPP has been plotted at a much lower DP than the DP at the surface. In fact, I would personally say the potential here would have a DP of around 10C - it's way too dry just above the surface. It's important to know if the air is dry just above the surface, you want a nice deep surface moisture layer so the moisture doesn't "mix out" and ruin your storm potential! And no there were no storms on this day!

On the other hand, lets look at a slightly moister situation at the surface:

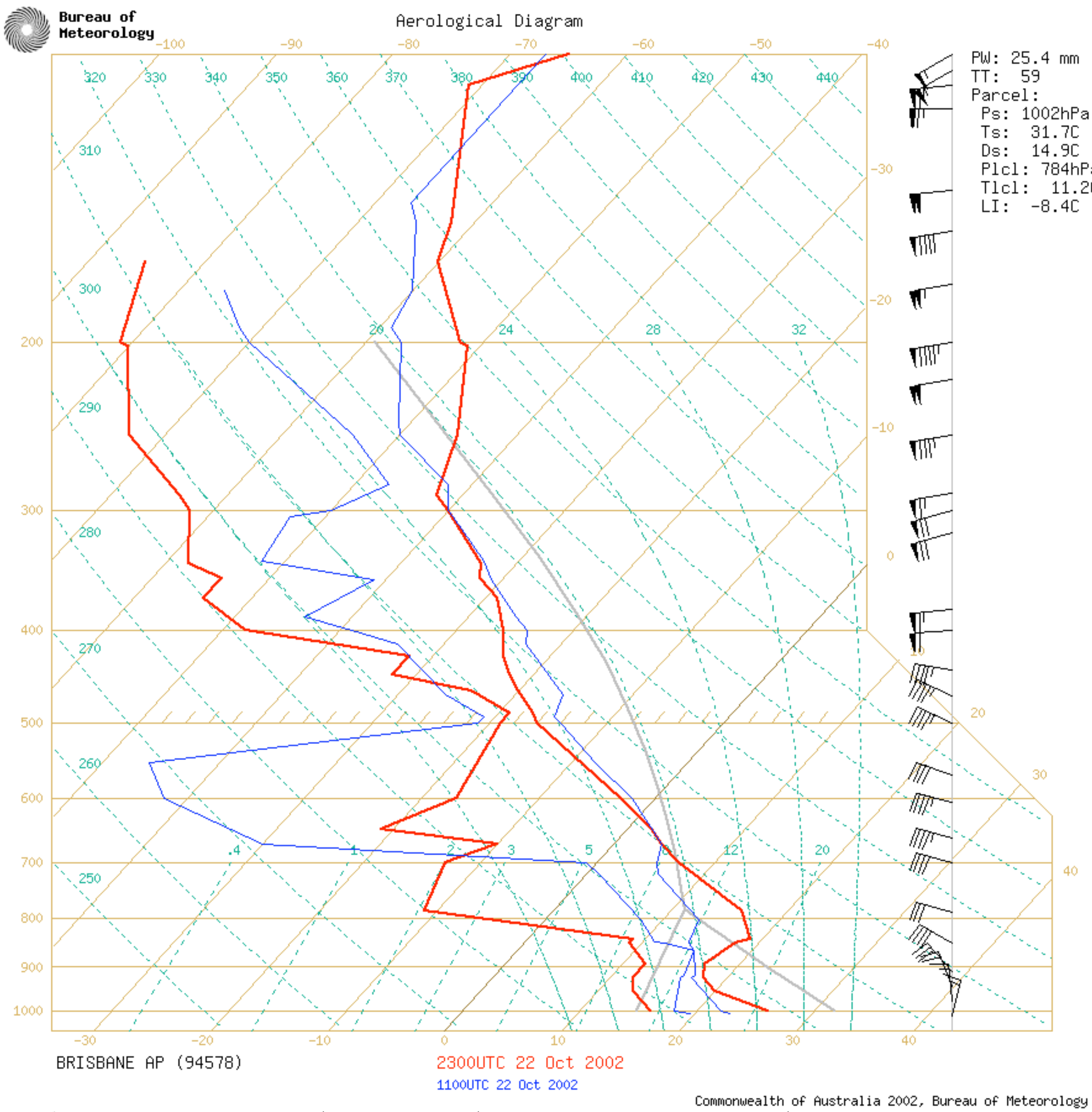


Here's a sounding on the morning of the December 10, 2002 squall line through Brisbane. Nice moisture again! Dp at the surface of around 23C, but it drys out (just a little), but then the moisture remains relatively constant. I often take an average of the lower 1km. I want to see the lower 1km (eg below the 900mb level) to be nice and moist, ideally up to 750-800mb should be relatively moist too before beginning to rapidly dry out above 700mb (anything above around the 850mb level doesn't influence the surface directly).

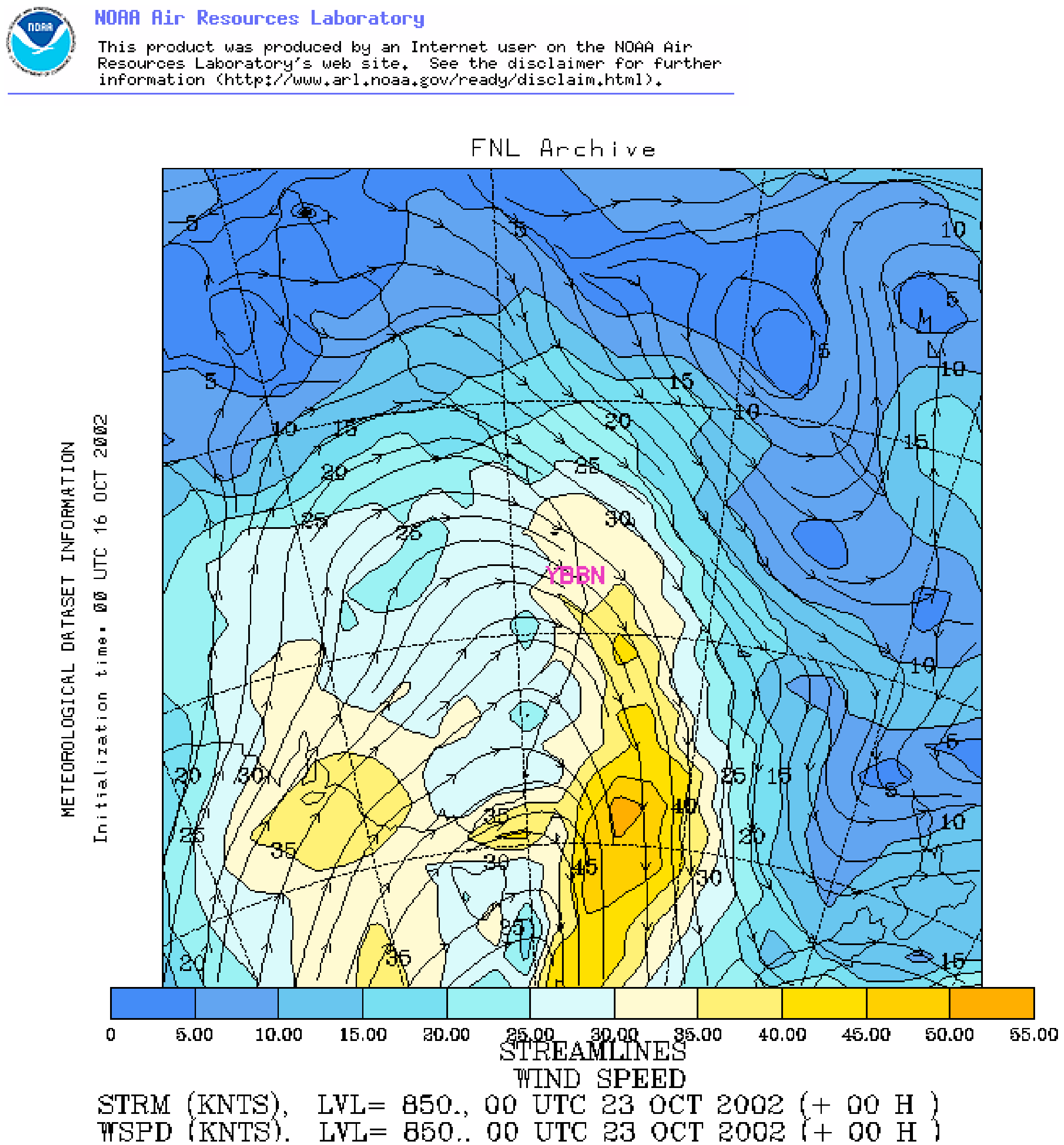
I consider deep moisture critical to not only severe thunderstorms, but thunderstorms in general. Shallow moisture depths can still produce thunderstorms, but only to an extent - this is something only your instinct and experience of the region can really decide, and even then it's very hard. There are some situations that are more likely to "mix out" than others. Situations to becareful of:

- When the low levels (925-850mb) turn back to the W (or even NW) very quickly and become strong. This Is fairly common in early spring, and if moisture is going to be a problem this will make it even worse! (Ideally,
- winds should not go too much west of NW until 850 in general situations though, otherwise it will bring too much dry air into the low levels - always exceptions to the rule though).
- When there are hot, dry W'lies behind the pre-frontal trough it's generally not a good thing, as they have a tendancy to move through and dry out the low levels.

Lets look at an example of what I mean - the October 23, 2002 duststorm through Brisbane is a good (but
extreme) example of this. Here's the sounding on the morning:

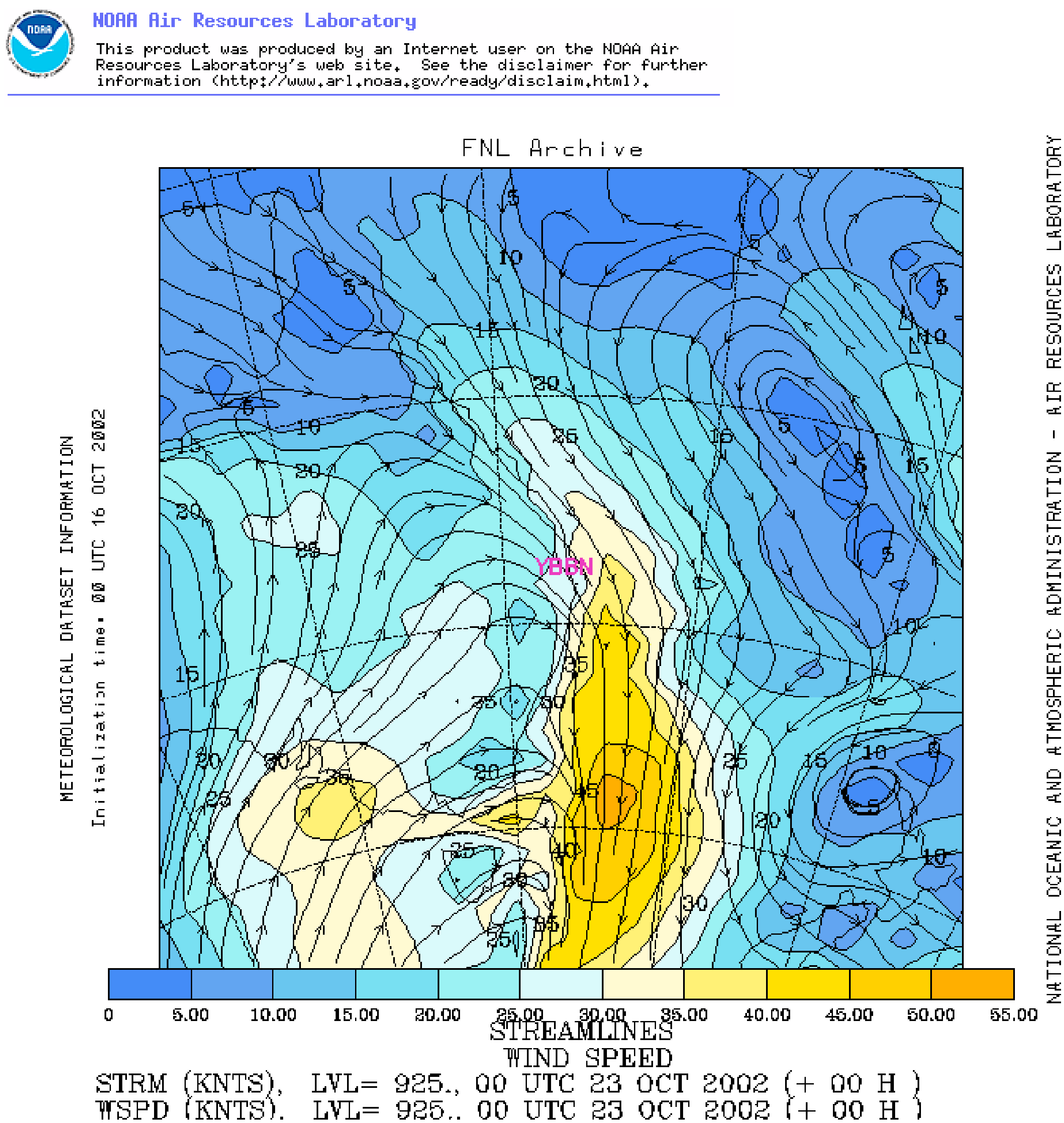


Ok, here we have a sounding plotted with the day's expected maximum temperature and the current DP. If it gets to 32C with an average DP of 15C, we're going to get -8 LIs!!! That's pretty hefty - there's some beautiful cold air in the upper levels (you can see that the 400-600mb levels have cooled down a fair bit in the past 12 hours too). The moisture depth is pretty good too - but it's already dried out compared to the sounding the previous night a fair bit, but if it were to stay around that then it'd be ok. Will it stay? Just looking at the sounding I'm getting nervous already - those winds are becoming W'ly very quickly, and they're strong. 30 knot NW'ly at 925mb and 40 knot NW at 850mb...hmmm...I guess it's *ok* (speed wise the shear is excellent!) I guess it really depends of the origin of those NW'lies - that's the key. Lets look...



Yikes! Those NW'lies are originating from SW'lies over South Australia and NSW - not good!!! No doubt there's going to be some dry air behind them...

lets see if 925mb has anything better...

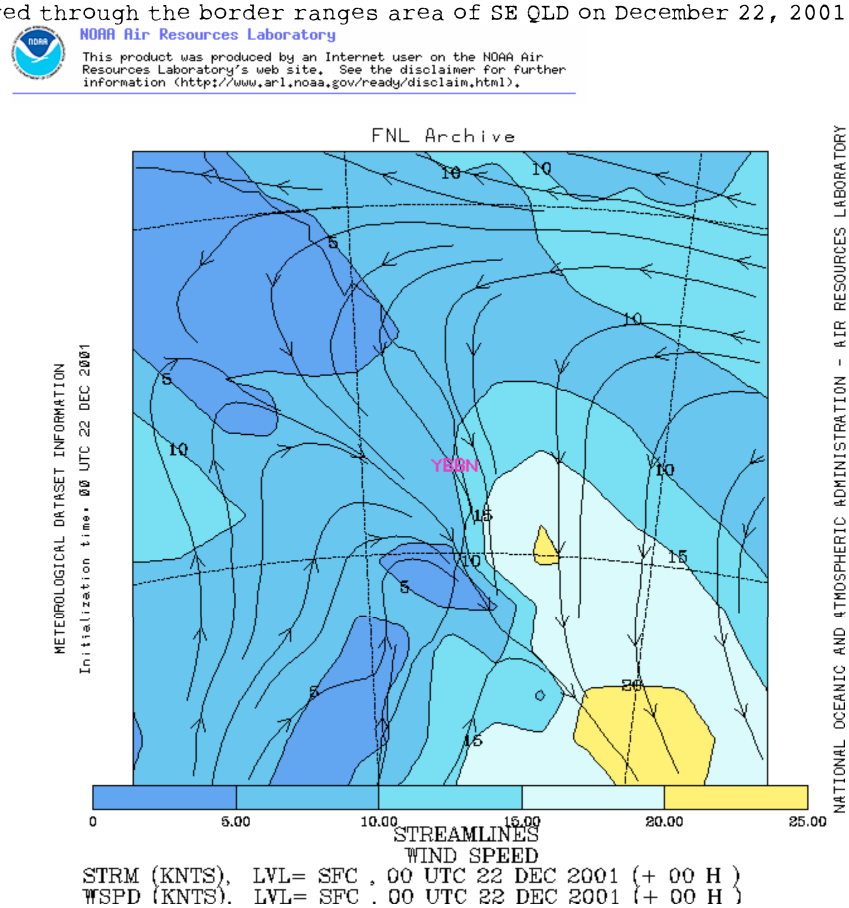


Hmm...nope!!! Still originating from NSW and South Australia - but can you see the critical line? There are two types of NW'lies here, some originate from north Queensland/tropics - others originate from NSW and South Australia. This is a common situation - while NW'lies don't always equate to bad news, in this case they are - I nick name this the "critical line" - note though that where the critical line becomes diffuse is the danger point, because here there is an slow transition of moist, tropical NW'lies to dry NW'lies (pseudo-SW'lies). Where as further north it becomes more defined it's less unlikely to dry out. I find knowing where this is essential...I hate being in the diffuse area, I want it to be defined. If you're in a difuse area you're in real strife and you're going to struggle. Still, there were storms though on this day - very weak ones though and only within about 15km of the coast due to the dryness. The line became more defined along the coast due to the seabreeze boundary. Have a look at how defined it became right along the coast!

Station Name	Current Observations										
	Date Time (AEST)	Temp (deg C)	Dew Point (deg C)	Rel Hum (%)	Wind Dir	Wind Speed (km/h)	Wind Speed (knots)	Wind Gust (km/h)	Wind Gust (knots)	Press (hPa)	Rain since 9am (mm)
Brisbane *	23 16:14	36.8	8.6	19	WNW	15	8	18	10	992.8	0.2
Brisbane Airport *	23 16:15	26.8	20.7	69	NNE	41	22	54	29	993.5	-
Archerfield *	23 16:15	36.9	6.0	16	NNW	33	18	41	22	992.3	0.0
Amberley *	23 16:14	37.1	1.5	10	WNW	50	27	57	31	992.1	0.0
Gatton UQ	23 16:05	36.6	-4.7	7	W	41	22	61	33	-	0.0
Toowoomba Airport	23 15:56	31.4	-6.8	8	W	46	25	67	36	998.6	0.0
Oakey	23 16:10	32.4	-10.8	6	W	50	27	70	38	997.2	0.0
Coolangatta	23 16:00	24.0	20.7	82	N	26	14	33	18	993.1	0.0
Gold Coast Seaway	23 16:00	27.8	20.4	64	NNW	33	18	48	26	992.9	0.0
Cape Moreton	23 16:00	23.9	20.2	80	N	70	38	83	45	995.7	0.0

27/21 at the airport, but the city barely 10km away was 37/9! Weak storms developed on the boundary, but with such dry air encroaching, there was no way storms could sustain themselves. If you're interested, check out the chase report from the weak afternoon storms and the amazing duststorm that followed though!

Heres another example. Here are some analysed surface streamlines from the morning of a supercell that moved through the border ranges area of SE QLD on December 22, 2001.



Here you can see there are NW winds over SE QLD - but look where they're originating from - originally over the Coral Sea! As long as you're ahead of this point you're fine, but look in NE NSW where it's getting a bit diffuse and the transition is starting to get ill-defined to the other NW'lies originating from the SW - that's the danger point where it's likely to dry out. The end result were some rather spectacular pyro-Cbs in NE NSW, but this was more due to the fires, had they not been there it perhaps would not have been as interesting. Although later that evening a SE change pushed through and returned moisture for lightning! The most severe storms on this day though appeared to be in SE QLD with tens of millions of dollars damage, especially to areas of the Gold Coast and the Border Ranges area from the afternoon supercell ahead of a squall line.

Skew-Ts certainly provide the edge over other methods such as LIs because you can modify them to suit your needs. You can replot temperatures and dewpoints to get a better indication of the day's potential, and you can see caps and moisture trends much easier too! I hope this Skew-T section has helped clear up how to read and interpret them and it helps you in your forecasting. Until then, lets use our new knowledge of Skew-Ts to forecast a real day

March 30, 2003 Case Study

Ok, time for another practical example I think! But also a few new things that might come in handy. That is confirming the forecasts. What do I mean by that? Well - this is where a bit of experience and intuition can come in handy, but most of us can do this even on a basic level. For instance, lets look at the following forecast:

```
IDQ1008003
TOOWOOMBA
Hot with an afternoon or evening shower or thunderstorm. NE winds becoming fresh
and gusty ahead of a SE change late this evening.
MAX    53
UV INDEX - 15 [Extreme]
Outlook for Thursday    ... Fine.
```

Look ok? What about the max temp? Bit high? Of course! Perhaps they meant 35? Or perhaps something else totally different! But here you just used your weather knowledge, experience and intuition to tell you that this forecast is incorrect! It doesn't look right, and it's not going to happen - that's what I mean by confirming forecasts, however we can do this at a number of levels. I've seen day 8 forecast models effectively forecast snow in north Queensland before - but you know that this is not right!

Taking this into account - think about this...

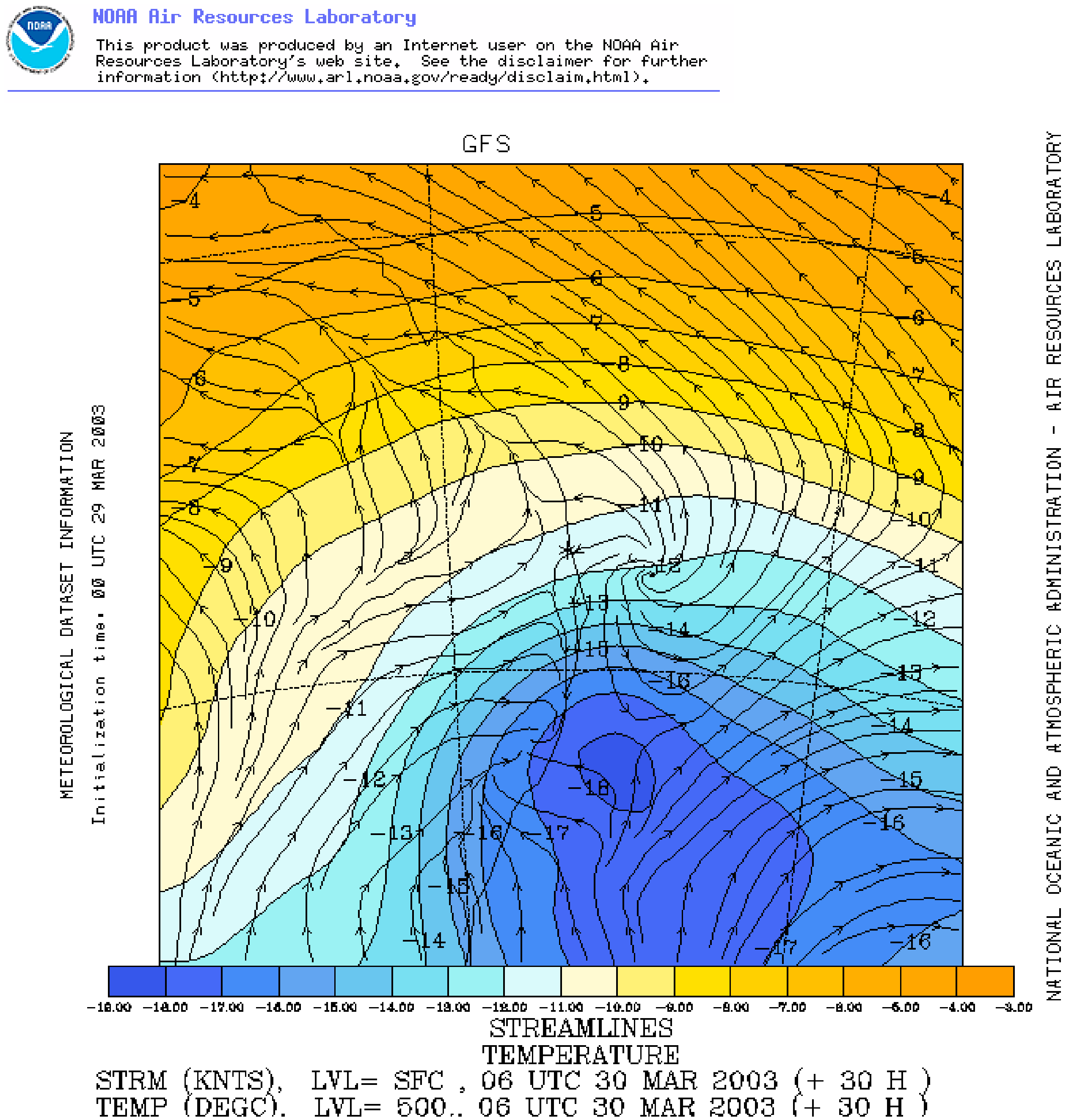
Why should forecast models just a day or two out be any different???

Just because it's day one or two, doesn't mean it's right! Sure it's got a better accuracy than day seven or eight, but don't believe everything you see if you don't think it's right! Those LIs of -10 or LIs of +2 - are they correct? LIs rely on quite a few things, surface temperatures, low level moisture and upper level temperatures. Just three things, right? Not quite...what influences temperature? Wind strength, wind direction, moisture, cloud cover, elevation, vegetation...and the list goes on. What influences moisture? Wind strength, wind direction, proximity to the coast, types of winds (ie seabreeze) etc. What influences the temperature influences? Well, winds rely on pressure, positions of highs and lows, seabreeze and coastal effects, then there's cloud cover - that relies on upper temperatures upper winds, upper moisture! And I could go on again about what effects all of those.

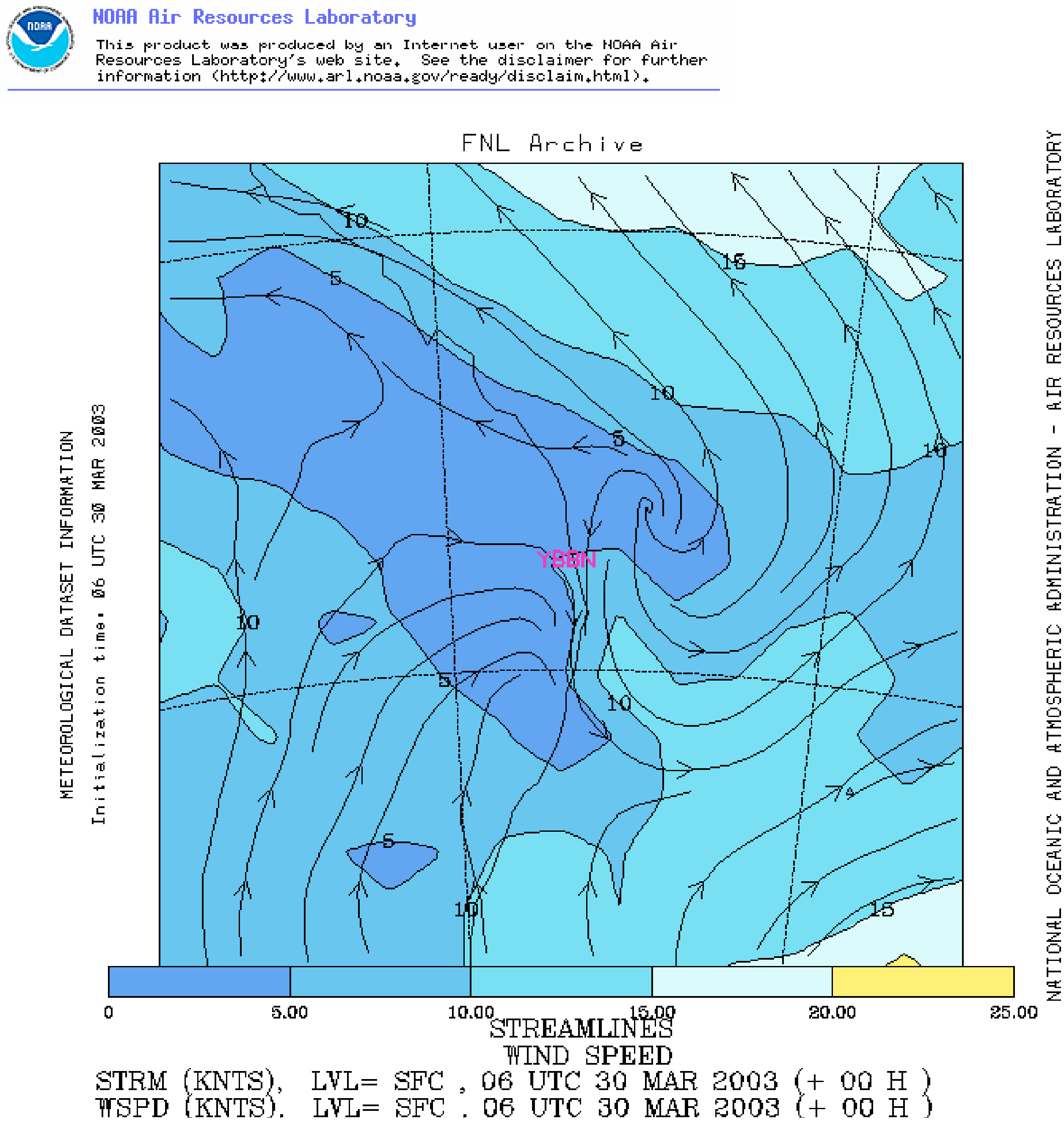
Can you see what I'm getting at here? Look at how many factors we need to go through to get a stability index such as the LI. That's a lot of things that our model has to get right...what happens if our model is a little off in a couple of those? We can effectively get big changes, a small change in some of the earlier influences can have phenomenal changes on the end product. This is why I think it is important to take all models with a grain of salt - look at it. Is it right? I'm going to illustrate one method I use a lot when I don't think the LIs look quite right. I'm going to use the March 30, 2003 NE NSW/SE QLD supercell outbreak as an example. I'm also going to try and incorporate some of the techniques at the end of the first part so that you can see that they're still important. The March 30 outbreak comes with a bit of a story...stay with me and we'll see if we can get through it!

On March 29, one of my best friends went chasing into S NSW (also using a very similar technique). Essentially the LIs were underprogged, and looked at soundings to trace where the cold pool would lie and look at the instability potential. To put a long story short, he rang me later that afternoon after playing in one foot golfball haildrifts!

Anyway, I was watching the satpic, I was interested in the upper low, it didn't look like it was going to go E (it actually looked to be going NNE or even N still). The previous progs had showed LIs of around +2 over NE NSW. The first chart I loaded up was a 500mb chart, I was curious to see where the model was progging the positioning of the cold pool. The results were so astounding I actually saved some of the forecast progs!

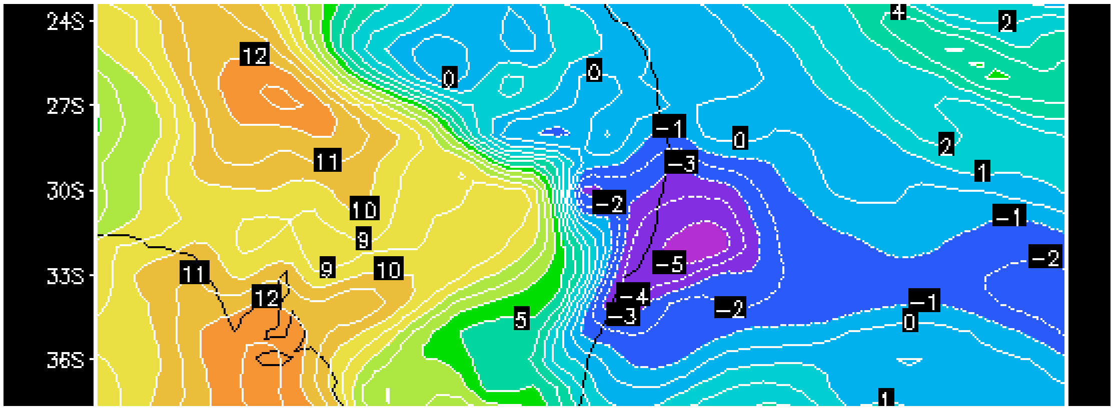


I must say, I nearly fell off my chair as I saw the cold pool just off the coast, and a large area of very cold air along the coast! My main concern looking at this was it could dry out, but I was encouraged by the SE change pushing behind it, I had a feeling it might stop the W'lies encroaching too close to the coast (like this shows it here). Well - it wouldn't quite stop it, rather the SE'ly winds would push inland and turn westerly - which isn't too bad, it provides a boundary with a pseudo-SE'ly as opposed to a real westerly. The analysis actually showed this happened in the long run:



Unfortunately due to the resolution of the FNL analysis, the boundary isn't as defined here - but you can see what I mean by SE'lies tending towards the W. I was also thinking a weak high which was on the BoM charts would help keep the trough inland - it pushed it maybe an extra 50km inland, but this probably became critical as the day progressed.

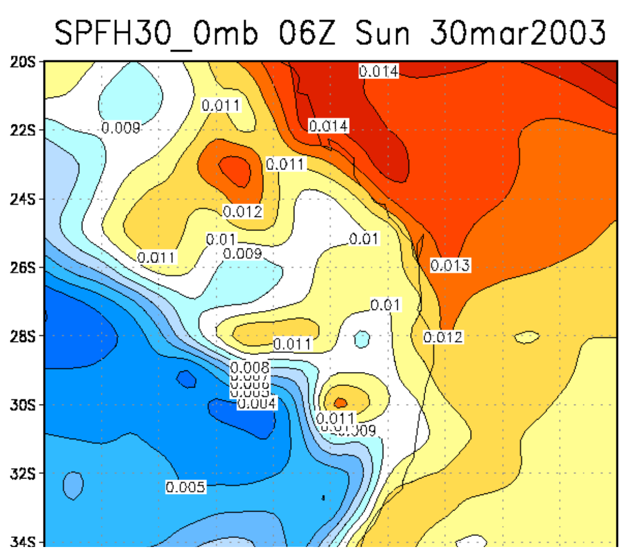
I then proceeded to look at the LI charts again...unfortunately I didn't save them - but Ben Quinn was kind enough to download a forecast plot for me from this day using GRADS:



Now this plot actually doesn't show bad potential in some areas...especially the Mid North Coast (south of around 30S). But look at the Northern Rivers area...-2 to -3 around Grafton, -1 to -2 around Casino...positive LIs in SE QLD! Things aren't really looking quite right...I wonder what the model is forecasting? Here's a way we can check. Perhaps the model thinks it's going to dry out? Lets have a look. Earlier I used relative humidity to show moisture, but there's a better way if you want the dewpoint (which is probably more handy), and that's specific humidity. I won't go into the details of what it is (it's actually the forecast for the mixing ratio lines), but I'll give an approximate chart of how to convert (I worked out this chart by looking at a Skew-T and typed it out and it's actually across the top of my monitor, I use it religiously! I never worked out 21+ though as DPs beyond 26 are very rare):

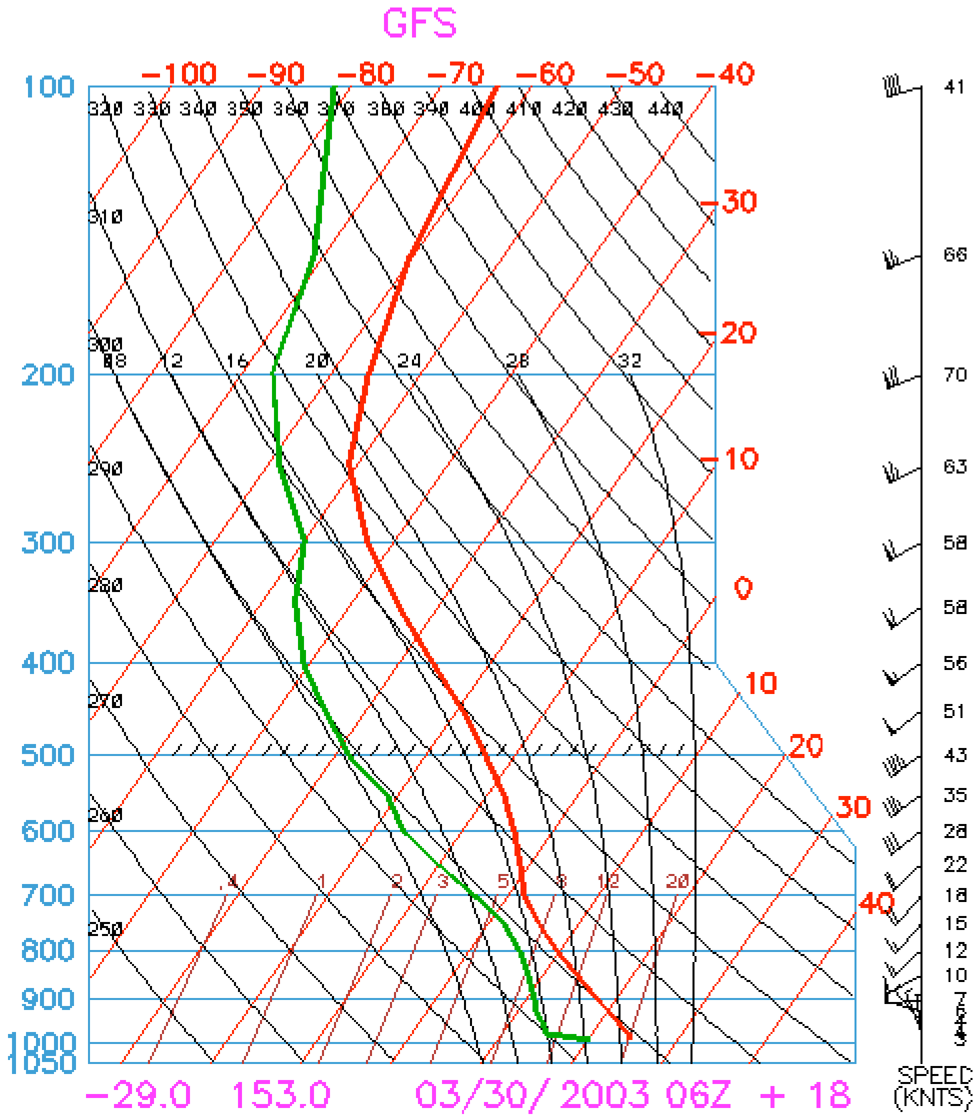
Specific Humiv.	Dew Point	Specific Humid	Dew Point	Specific Humid	Dew Point
2	-9	9	12	16	21
3	-3	10	14	17	22
4	0	11	15.5	18	23
5	4	12	17	19	24
6	6	13	18	20	25
7	8	14	19	21	26
8	10	15	20		

This little conversion table comes in very handy for Australia given (for some unknown reason!) no models forecast DPs straight out. Anyway, lets look at a specific humidity map. There are two types (both from AVN), one is the surface, the other is the surface 30mb (bottom 300m of the atmosphere). I always choose the surface-30mb one as it helps give a better idea on the moisture depth. Here's the forecast on that day:

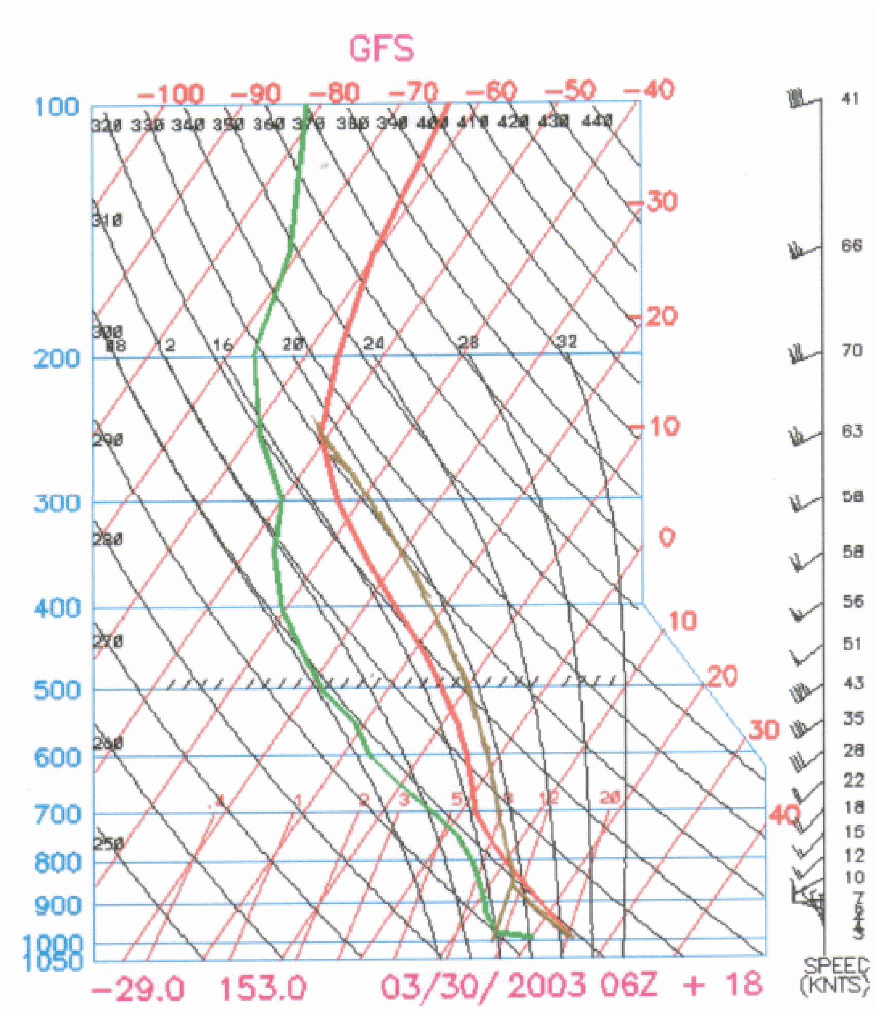


Ok, here we can see a nice tongue of moisture along the coast, specific humidity of 11-12 (Dps of 16-17) on the coast area...not too bad! Is it right? Well, I was a bit dubious because I was thinking that the moisture would actually be higher...but it might be thinking of a snip of dry air pushing into the low levels but not the surface...certainly not out of the question though! But what about the seabreeze? Unfortunately this model doesn't have the resolution to pick up seabreezes...but any seabreeze in this situation was going to have DPs in the low 20s, and they would be (well mixed) DPs of low 20s.

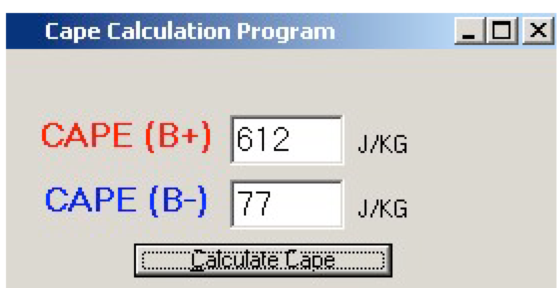
Lets look at a forecast sounding (available from READY). This would be the best way to tell what the model is forecast now and we can start confirming our forecasts too! Especially the LI.



This is for Casino (well, 10km west of - close enough). Aha! There's a bit of dry air being forecast there, but it's not too bad, it's moist after that. The winds back around the NW very quickly, that's a concern...so we know that moisture is perhaps going to be a danger on this day...it's going to depend on how close the trough comes to the coast...there is a weak high out to sea, so it might help keep it just a little inland (this is something you have to decide for yourself - remember, instinct and experience!) But lets assume moisture is going to be ok...so we're going to plot it as it is with 24/15 as the maximum potential.

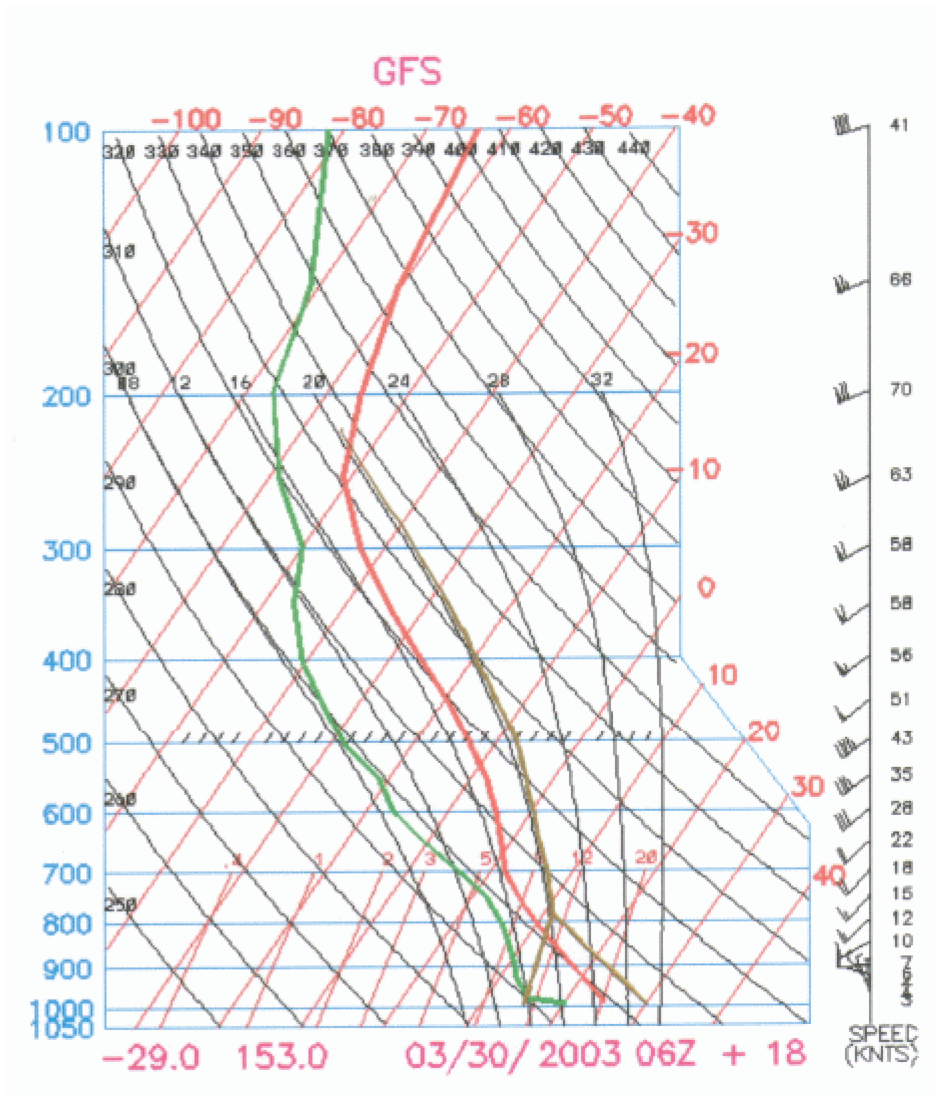


Here's our plot - hmm...the instability is pretty broad which is good! Do we agree with our forecast LIs of -2 to -3? Well plotting it like we have, we get LIs of around -3 - so they match up. I calculated CAPE too, lets look at what we got:

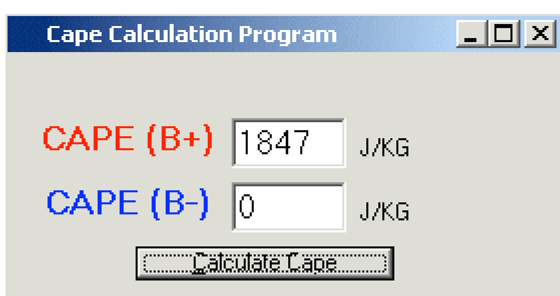


612...so there's some instability, not great...but there's some!

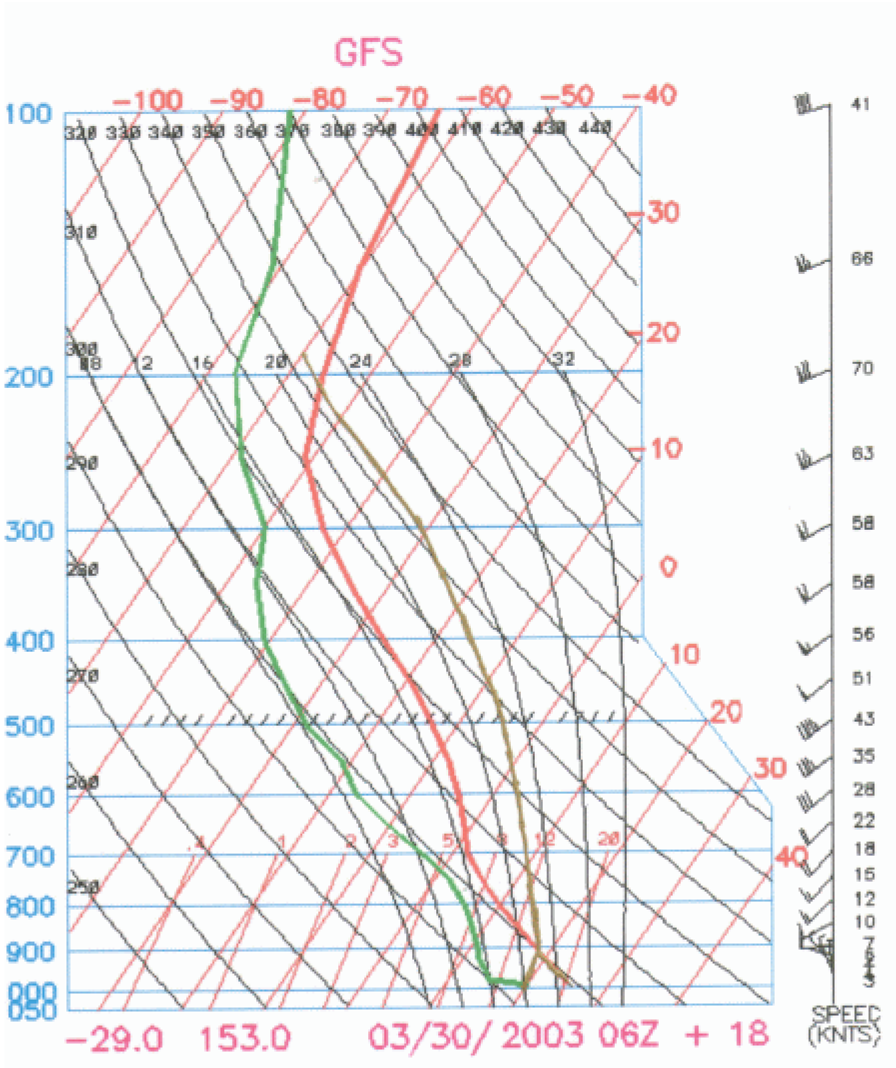
So...here comes the fundamental question...are the LIs "correct?" Using the data (500mb temp, surface temp and low level DP) that the model has provided us - then yes. But I'd like to point out one thing (you might have already thought of it. What's the date? It's March 30...in sub tropical NE NSW/SE QLD. At 6Z we expect the temperature to be around its maximum. Is there going to be a maximum of 24C? Erm...NO!!! The maximum is going to be closer to 30 degrees! (If not higher again, this is Casino, it gets hot there!!) Ok...we're starting to think that the model might be under-forecasting the surface temperatures. So what are the effects of this? Lets replot for say 30/15.



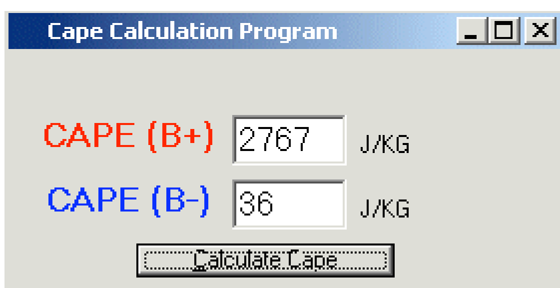
Hey now! This is getting more interesting here, -5 to -6 LIs looking at the sounding, and this is the minimum likely potential (ie 30/15). I calculated CAPE too:



Looking better!!! One thing that I haven't mentioned (and I won't go into too much detail, more so because I don't have the data to show it properly), and that is seabreeze fronts. Seabreeze fronts can make some monsters in NE NSW and SE QLD, it's quite an interesting boundary to be on. Sometimes storms can ride along seabreeze fronts, normally a seabreeze creates an inversion and caps off development. But if a storm is already surviving, then it can draw in the warm, moist air and strengthen rapidly - especially if there is an marked increase of moisture. Lets look at the potential in a seabreeze situation...say, 24/20:

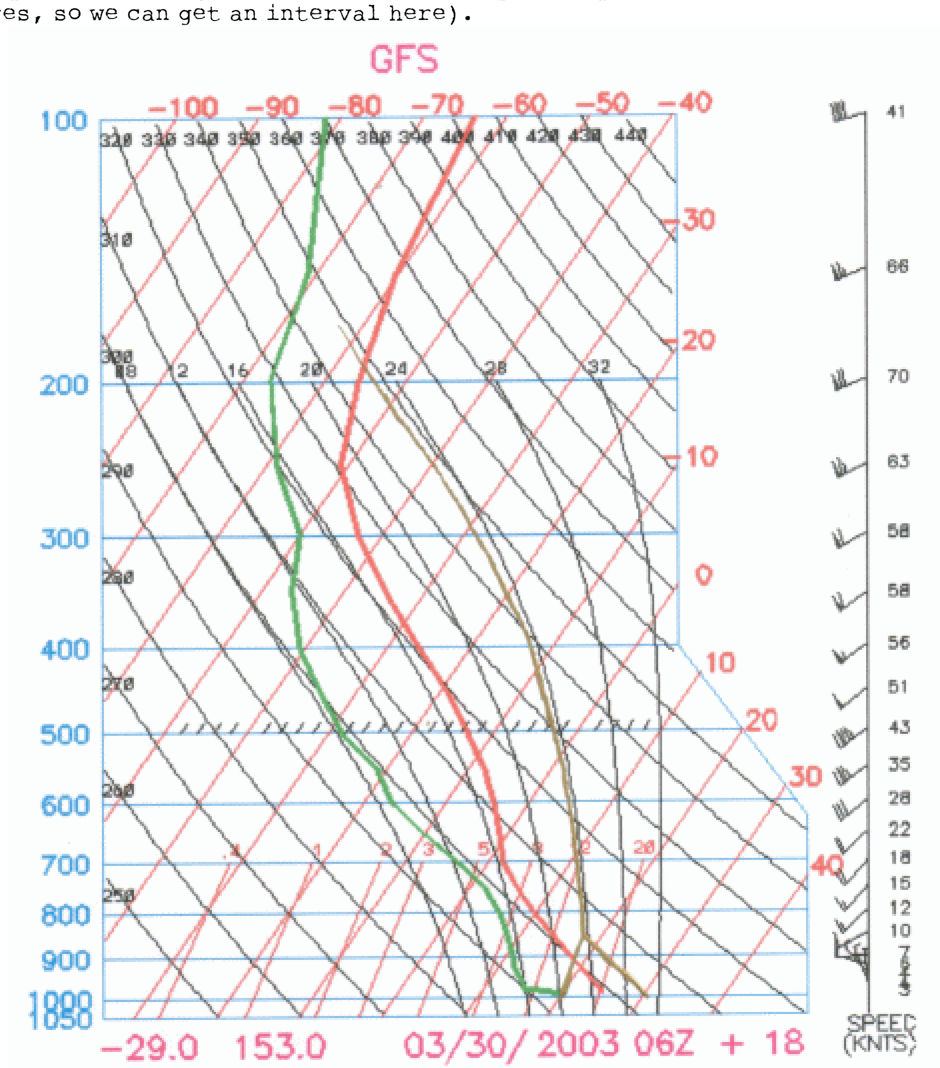


And CAPE:

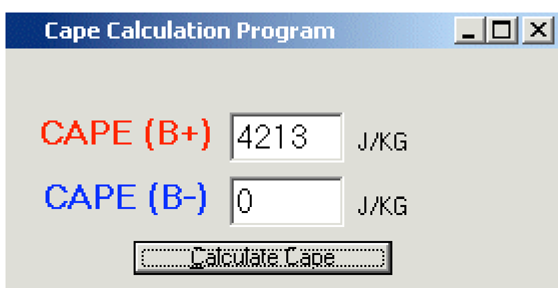


That's getting pretty unstable!!! LIs up towards -7 and -8 and CAPE of nearly 2800 - that's some nice potential storms can tap into if they get going. But notice how far we've come from our LIs of around -2? Just by looking at a forecast Skew-T and applying our own observations and forecasts, we're coming up with more accurate and realistic forecasts that truly illustrate the potential of what was an awesome day. This can work the other way too though...those -8 to -10 LIs that you might see in a forecast could actually be suffering from an over forecast of surface moisture for example - this is why confirming these types of situations and seeing if the outcome is realistic or not can be so helpful!

Ok, we've looked at the minimum realistic potential...what about maximum realistic potential? One of the obs I got told was that it was 30/20 at Casino at one point...lets assume that there was plenty of moisture (the actual result was probably less than 20, but more than 15 in the 30C temperatures, so we can get an interval here).



And CAPE once again:



Not bad eh? -10 to -11 LIs and CAPE of around 4200!!! So that's our maximum potential...it won't get there, but it's nice to know. Realistically, I think the day probably saw a maximum mixed potential of 31/17 at Casino...that gives a CAPE of just under 3000! So there was a lot of instability there...the thing is, the surface temperatures were similar, but the upper level temperatures even colder down towards Grafton, so there was even further potential to the south!!!

I'm hoping that this example will give you an idea on how LIs can be unreliable and misleading if you're not careful. Check them - make sure they're correct (ie understand what LIs are too, I've described it thoroughly in earlier sections). As I said before, if you understand what they actually mean, then you have a much greater chance of being successful with them and using them to your advantage.

So what was the shear like? We can just read it straight off the sounding for this location! I often round up or down to the nearest 5 knots to make it easier...but 850mb 10 knots, 700mb 20 knots, 500mb 45 knots, 300mb 60 knots...and if you look at the horizontal shear maps you'd actually see the shear was stronger just south of Casino!!! And as always, the end results? See for yourself - not bad for those -2 LIs forecast eh?

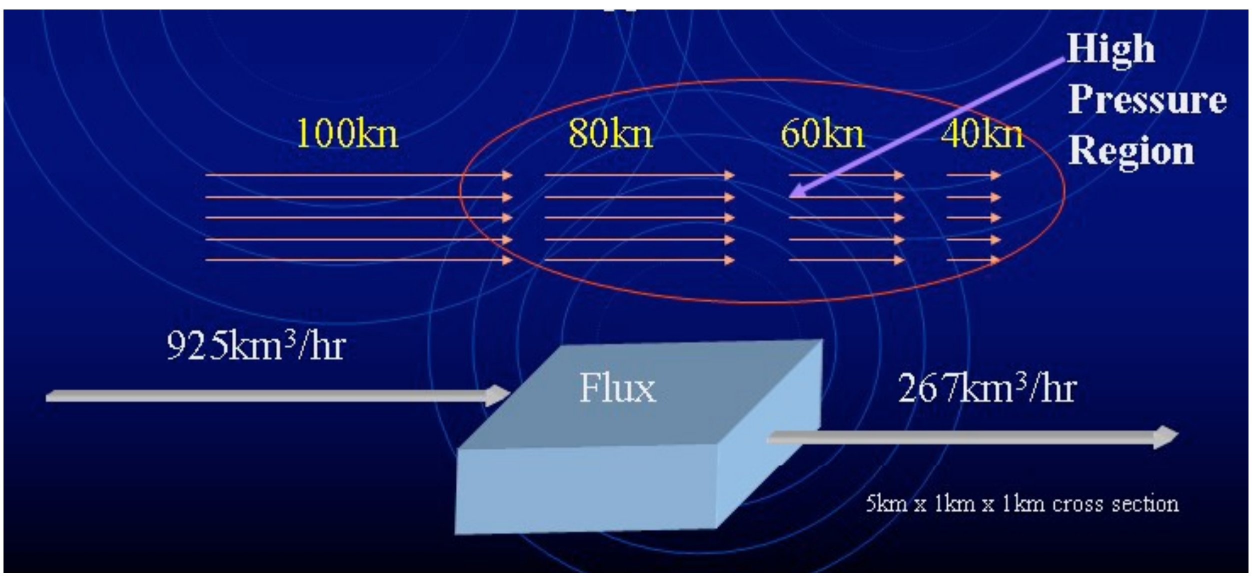
Classic supercell just NE of Grafton (80-100km S of Casino), unfortunately another supercell developed nearby and moved over the highway...my vehicle was pounded my winds in excess of 100km/h (trees falling down near the car) and hail up to golfballs as this other storm (I only saw the edge of being running into it).

Shear - It's Not All the Same!

Earlier in this guide I talked about the different shear strengths that can help organise our storms and give us what we want to see (whatever that may be! Often it's a well structured, and/or photogenic storm). But there are some other parts of shear that can come in handy. For instance, the way the winds are moving over a broad area can help enhance or suppress updrafts. They're often termed into two terms (convergence and divergence), but when people talk about these two they often mean confluence and diffluence. They're actually quite different - except for their overall meaning (ie winds coming together and moving away from each other).

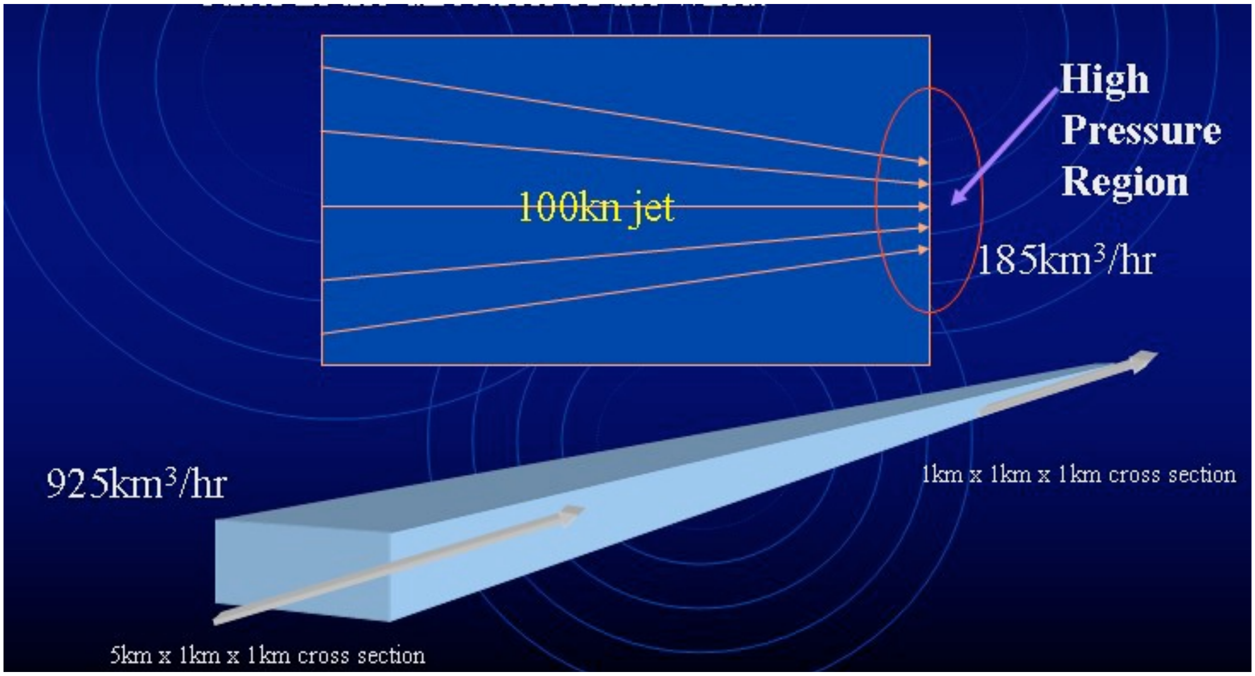
So what do I mean? Well, here are the definitions:

Convergence: This is air that is slowing down to reach a point, so as you progress along the direction of the wind, the wind strength may go from 100 knots to 80 knots to 60 knots and so forth. This is analogous to traffic and say roadworks. Traffic will bank up at roadworks because people have to slow down - and people behind them moving at say 110km/h have to slow down to the roadworks limit (say 60km/h). As you can see, if you timed both points, more cars could move through the 110km/h zone then the 60km/h zone per hour. This causes cars to bank up - and eventually, cars begin to find other ways of getting around the area when the build up gets too big (ie take another road). This is the same with convergence, as the wind slows down it builds a small high pressure region - air then has to move away from this point, often moving up and down. So imagine an updraft underneath a convergent zone in the upper atmosphere, it's ascending along happily but then it approaches this point, and it begins to slow down because there is pressure being forced upon it from above. For example:



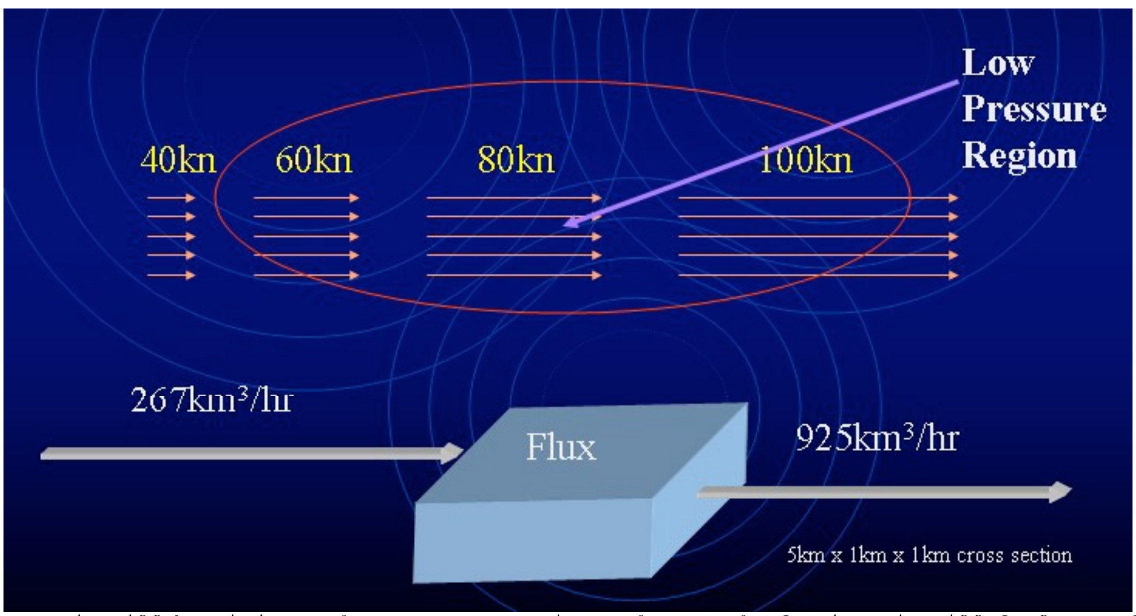
More air is entering the region then leaving - so this then pushes down on the updrafts. Convergence isn't all bad - for example, it's good in the low levels (surface-850mb, even 700mb sometimes). Keeping in mind that close to the surface, air here has no choice but to go upwards because air can't go below the ground surface!

Confluence: Confluence means that the wind directions (streamlines) are coming in together and meeting up. This often occurs near troughs (at the surface), and is good because it allows the air to rise up into the atmosphere given it can't sink into the ground! Think of our traffic example from before, (the M1 comes into mind here, soon after the M6 interchange the M1 <stupidly!> goes from 8 lanes to 6 lanes). Often in the morning, going into the city this area banks up because where were lots of lanes, there are fewer lanes so cars begin to back up. Either all the cars have to be patient and just go through slower, or they need to start looking for alternative routes. Once again, if we have confluence in the upper atmosphere it will surpress updrafts because of the higher pressure region and general sinking air:



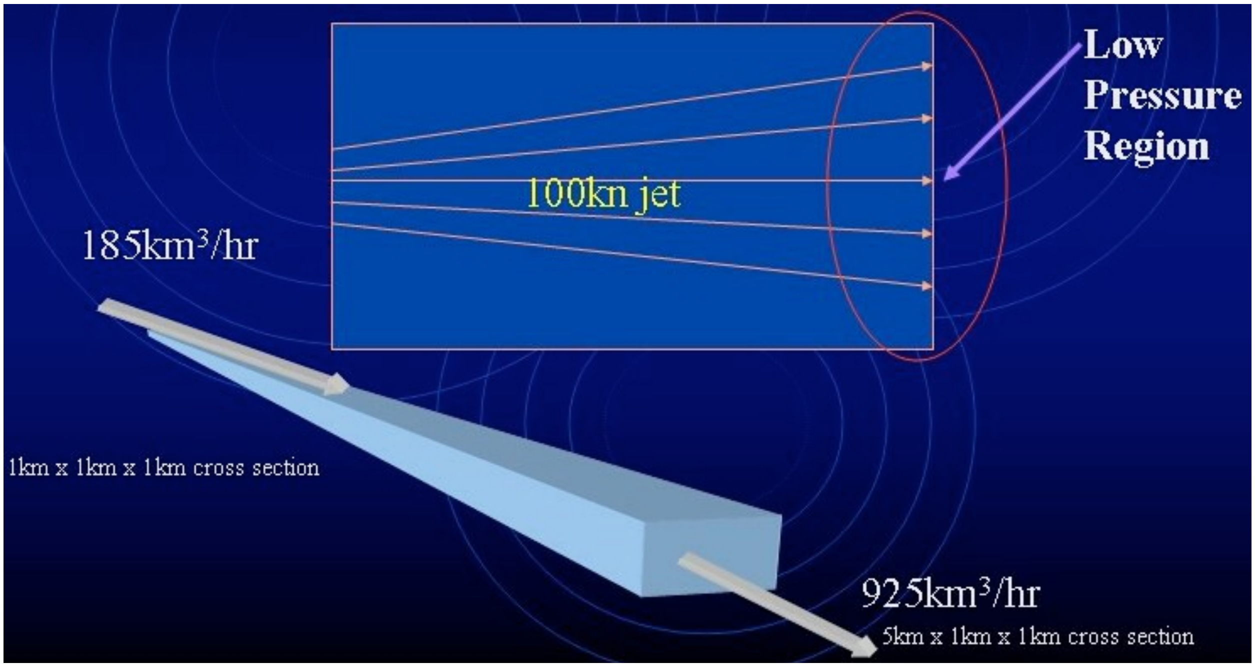
Ok - now lets look at the opposite...

Divergence: The opposite of convergence, this is air speeding up in the direction of the winds. This could also be modeled from our cars coming out of the roadworks zone and now able to do 110km/h once again! You will see the cars become well separated from this area as cars are effectively able to leave faster than they arrive, hence the spacing. For instance:



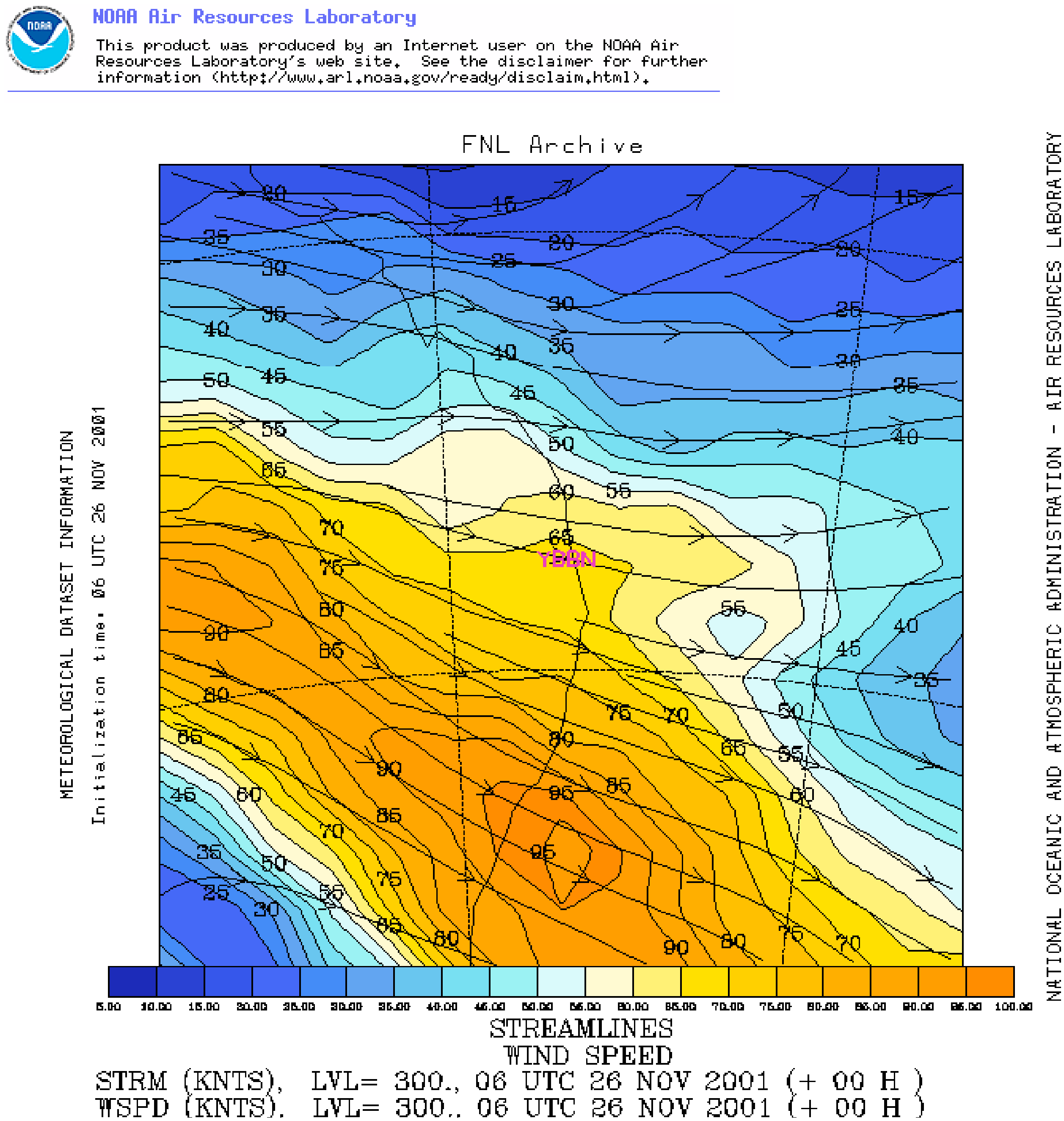
Here air will be rising underneath the region and any updrafts in this will feel the effects of it and be able to rise even faster! This helps enhance the instability if its in the mid to upper levels (500mb and above), but it's not a good thing to see at the low levels.

Diffluence: Once again the opposite to confluence, this is where the wind directions (streamlines) begin to spread out. Taking our M1 example, as you come out of the city in peak hour and you're slowly going along, then just prior to the M6 interchange you will enjoy some extra lanes and cars will be able to spread out and it will be effectively able to carry more traffic. In the case of the atmosphere, it will create a low pressure region because there's more air moving out of the region then entering the region, and once again will help enhance instability:

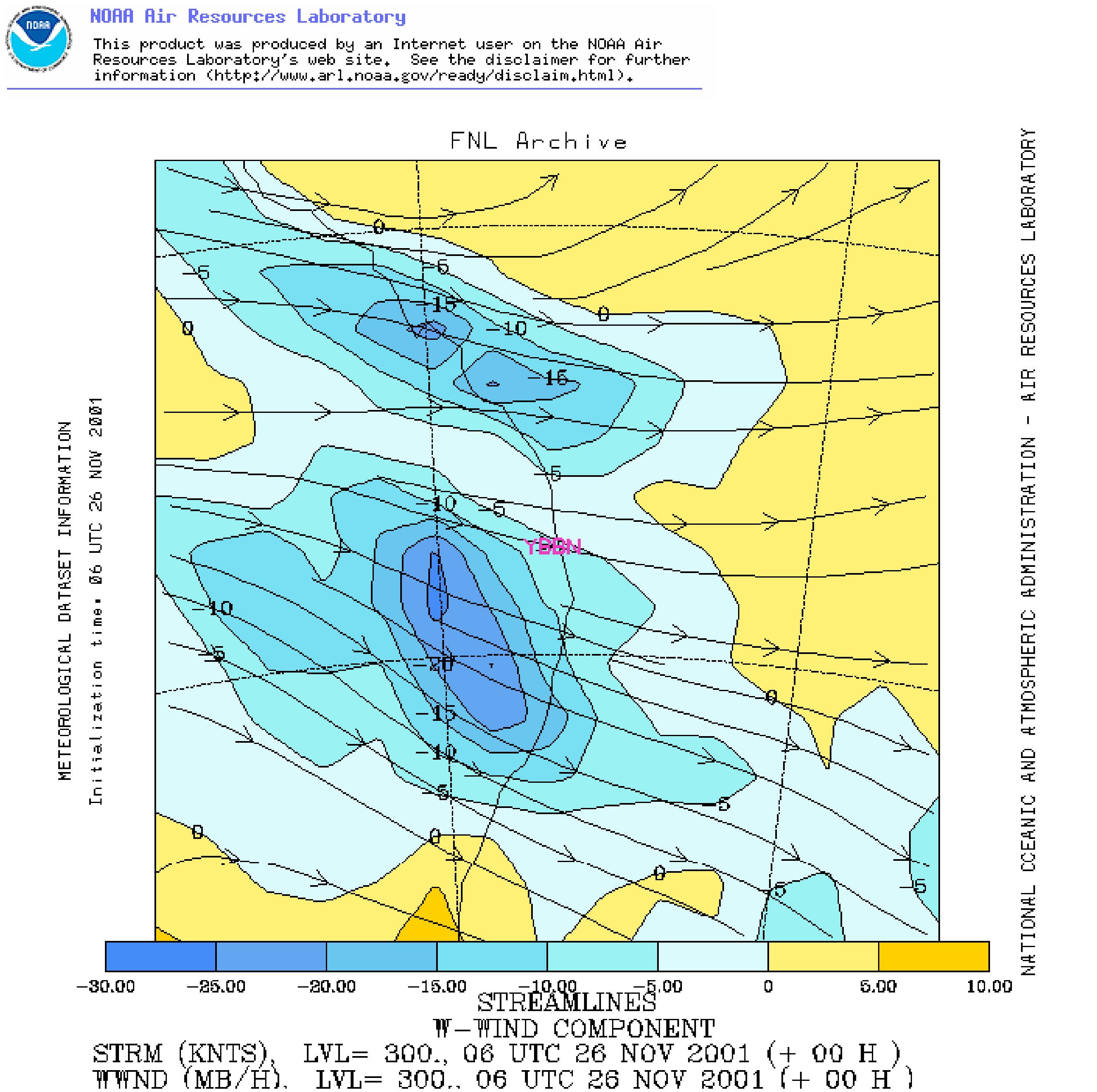


In my experience, I actually look out for confluence at the surface and diffluence in the mid to upper levels more than convergence and divergence, because I tend to find the former gives better results, but even I'm still learning about the effects of different shear setups on storm days!

Lets look at some examples of what these things might look at if we saw them on charts:

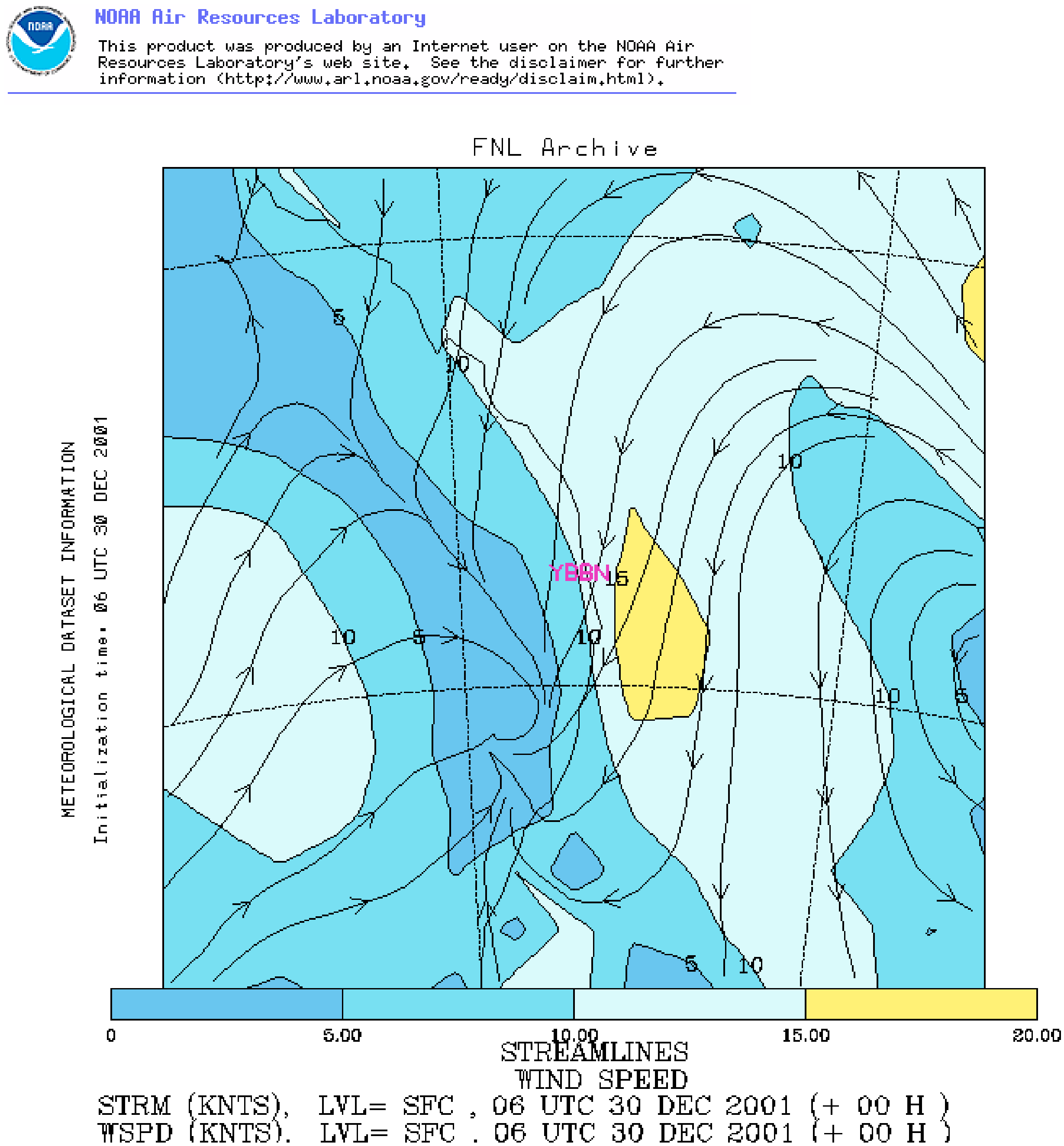


Here's a 300mb analysis chart from the Millmeran Tornadic Supercell. Notice the diffluent jet to the west and south of Brisbane (YBBN)? Here the streamlines are spreading apart and that can help enhance the instability that updrafts will "feel." Here's some "proof:"

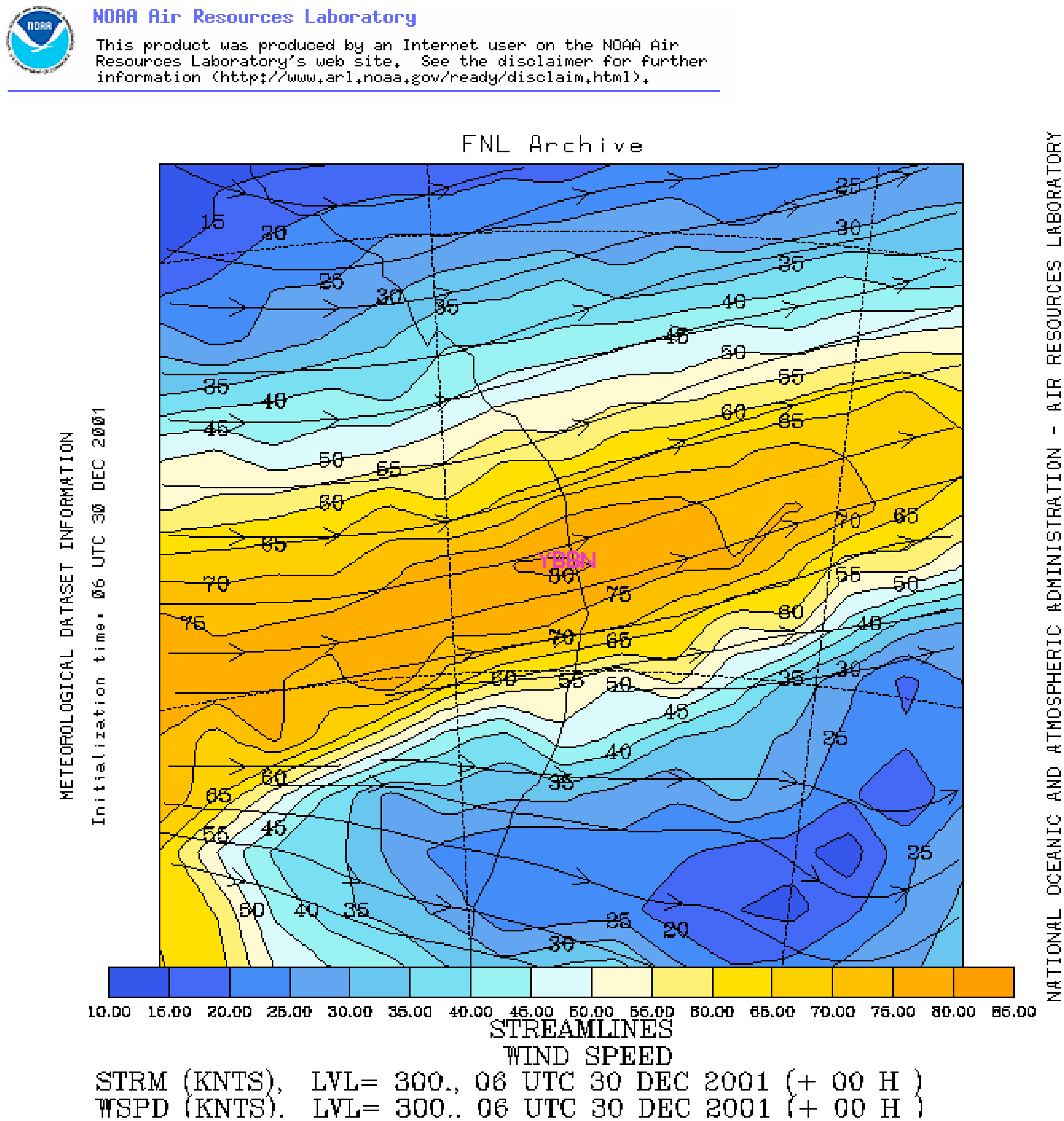


What's this chart? Well, I've overlayed the pressure vertical velocity over the streamlines at 300mb. In simple terms...it is a measure of how fast the air is rising. Remember, we have horizontal winds (north, south, east and west). Winds also move up and down!!! This is essentially what the upper level shear can help cause from divergence, diffluence, convergence and confluence - it can help create the vertical winds. Here, negative means that the air is ascending and positive values indicate descending air. Notice our nice cluster of rising air around the point where the diffluence starts? The maximum potential normally occurs where diffluence commences. Don't forget to have a look at the chase report from this day with photos of a small tornado from a very nice supercell!

Here is another example from the December 30, 2001 Brisbane supercell. This is the surface and shows a defined line of confluence just to the west of Brisbane marking the trough line where air can rise and help break the cap:



Here NE winds are meeting W to NW winds along a trough line and helping to lift the air. Also note that air is converging on the trough line too? There reasonable winds of 10-15 knots at the surface, but it's slowing down at the trough line and that's also helping lift the air ahead of the trough line in the low levels. Lets look at the 300mb chart too, because it has "fake convergence" - and I want to emphasize something:



Nice jet right over SE QLD! Ok, look north of Brisbane (YBBN), see how the winds decrease as you push north? 70 knots to 40 knots across a relatively short distance. Don't get this confused, this is not convergence! Remember, the winds have to slow down in the direction of the wind - so remember that. There is however some convergence in the far SW of this plot where the wind speeds slow down in the direction of the wind.

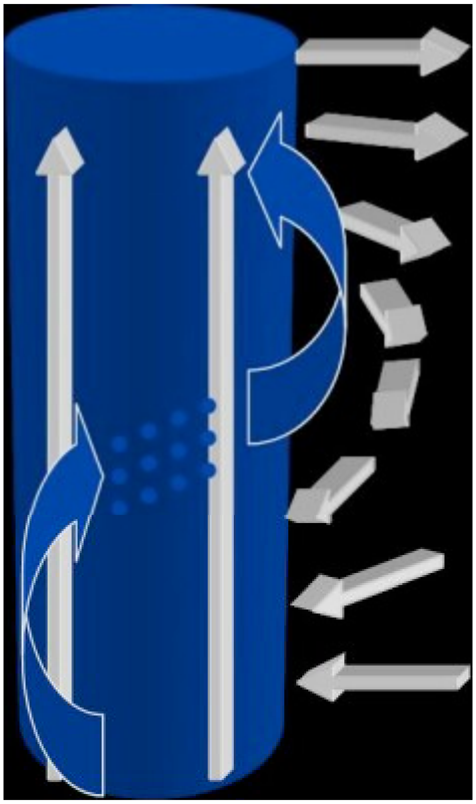
The key thing from this section is that vertical winds (partially derived from horizontal winds), can really help updrafts along, or alternative surpress them. Think of going out for a swim in the ocean. Ignoring any rips of sweeps - it can be quite hard to wade out into the ocean because the waves keep pushing you back. This is what our updrafts feel if the air is already sinking over its position. It has to work harder to get to the same area, and we don't want that! We want the journey for our updraft in the upper atmosphere to be an easy one. Similarly, if we're at the beach and already in the water, then it's much easier to wade or swim back to shore because the waves help push you back to land! Likewise, our updrafts find it much easier if the air around them is moving in the same direction they are!

Supercellular Shear

Shear is quite a diverse subject when you look into it quite deeply. There's another concept (and it's often thought to be quite a critical concept for supercells, especially in the US - although in Australia you'll probably find that storms don't require it *quite* as much). Anyway...directional shear, what do I mean by that? Remember when we looked at Skew-Ts, we could see the wind strengths and directions of the winds above that point. Essentially, in the southern hemisphere, you want the shear to back (turn anti-clockwise with height). In the northern hemisphere, you want the shear to veer (turn clockwise with height). For example, the southern hemisphere might have a shear profile like this:

Height	Direction& Speed
Surface	NE @ 15 knots
	NNE @ 20 knots
	NNW @ 30 knots
	NW @ 45 knots
	W @ 60 knots
	WSW @ 100 knots

Why do we need it? Well, stretching of an updraft already provides some vorticity, but further vorticity can be enhanced by directional shear, for instance a diagram of what this might look like:



This might help conceptualise how directional shear can help with updrafts. Of course, this then helps develop supercells (which is simply defined by the presence of a sustained mesocyclone, and a mesocyclone is simply a rotating updraft!) Here's a photo of the January 25, 1999 Oakey supercell I took from the Warrego Hwy, you can see the rotation and wrapping around in the updraft! It's one of the best examples of a mesocyclone I've personally seen to date (physically).

So how much is needed? Well...normally it's taken over the lower 6km (say surface-500mb). The threshold for supercellular development is thought to be 90 degrees (eg, NE to NW). Anything further is a bonus, and 180 degrees is considered ideal (but in my experience, rarely achieved). But generally most shear will back NE to at least NW, and often even further towards the W by 500mb.

I once was fortunate enough to attend a presentation by Harald Richter who discussed the concept of "0-6km shear strength." Essentially, it seems that the stronger the shear is - the less you need it to back with height. Harald mentioned that the 0-6km shear should be 40 knots. What does this mean? Well, lets say there is a NE'ly at the surface of 10 knots. Lets then say that at 500mb, the winds are from the SW at 35 knots. Because they are exactly 180 degrees from each other, add them up and you get 45 knots, which is within the threshold for supercellular shear. What about if you have a 10 knot NW'ly, and at 500mb it's 50 knots NW'ly too? Because the shear is all in the same direction, you don't get any "bonuses" here - but the 0-6km shear is considered to be 50-10 knots, which is 40 knots and is the threshold. It's a bit tricky to get your head around, but from my experience it does seem to be a fairly accurate threshold.

There isn't much more to say except how this might look like on a Skew-T, but I think that the case study for this part will explain this well!

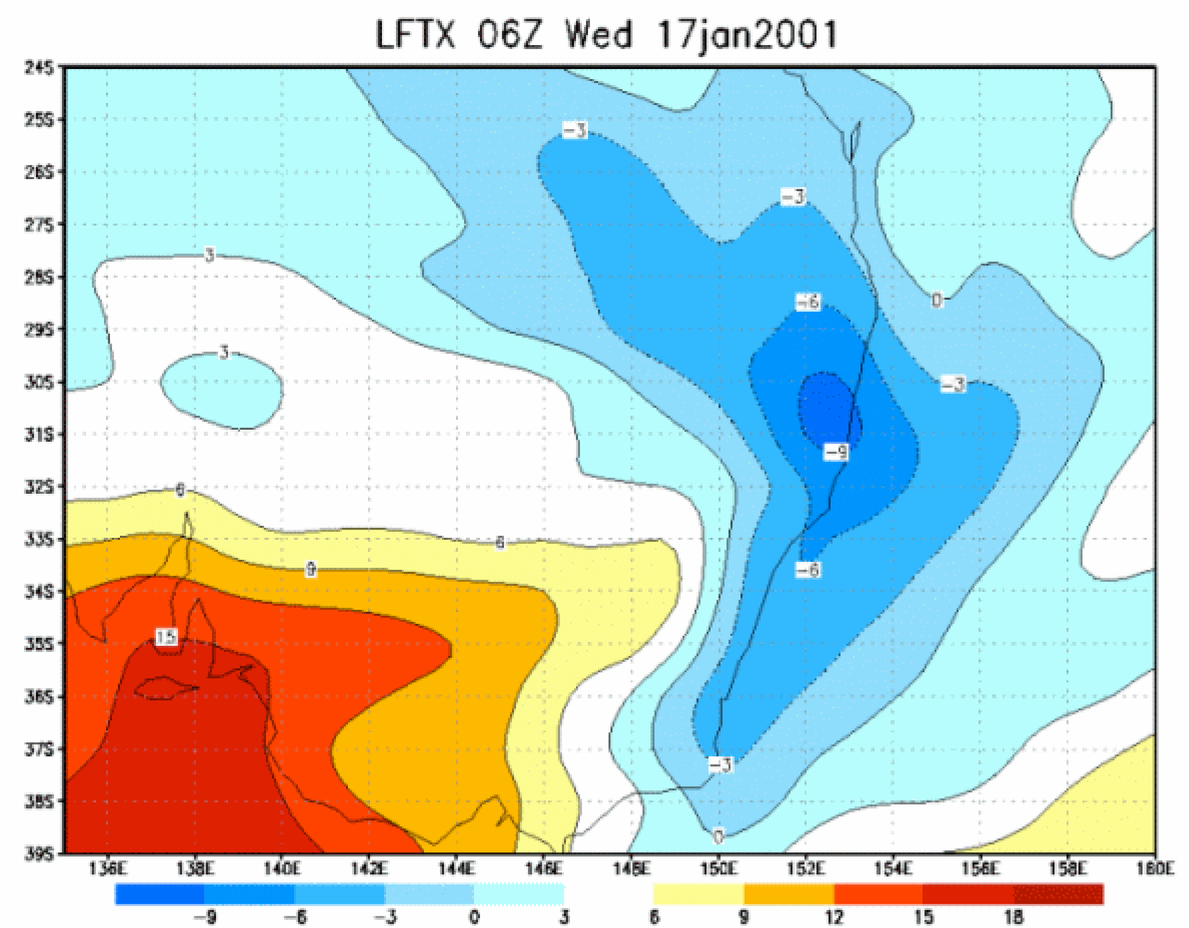
January 17-18 2001 SE QLD/NE NSW

Supercell Outbreak Case Study

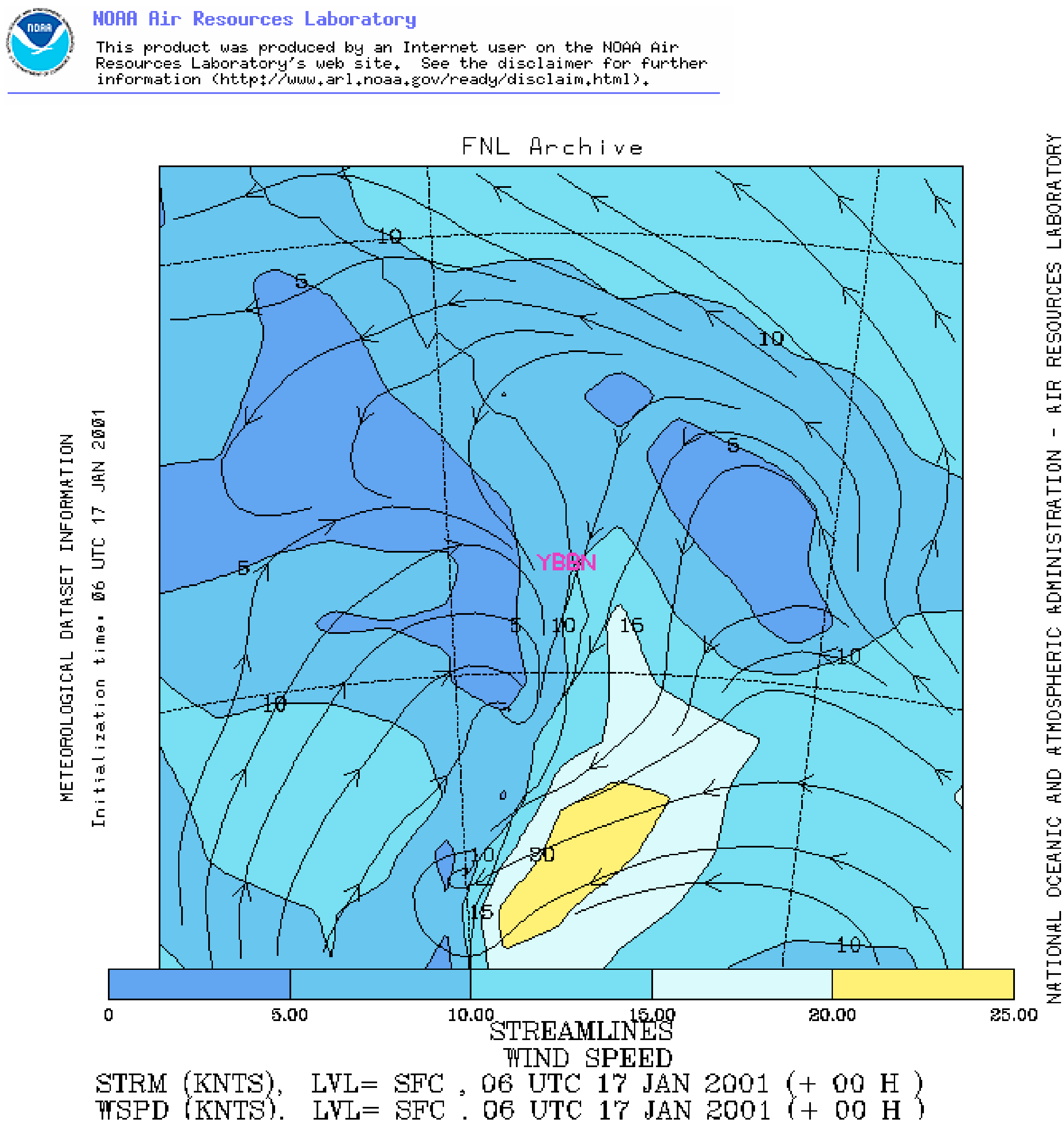
I'm going to do this a little differently...more so an analysis of this event as opposed to a forecast as such. I don't have any forecast charts either, so it makes it difficult - only analysis charts. I'm going to talk about the supercells that developed late in the afternoon on January 17, and also look at how storms were able to support tennis ball hail at 3-4am in the morning, despite it being cooler with much lower instability by then! More so the latter, because that is the focus I want to give for this section.

January 17 was a big learning curve for me...it was interesting because I had never paid a significant attention to things such as capping before. It also taught me a little about the potential for drying out and the importance of shear.

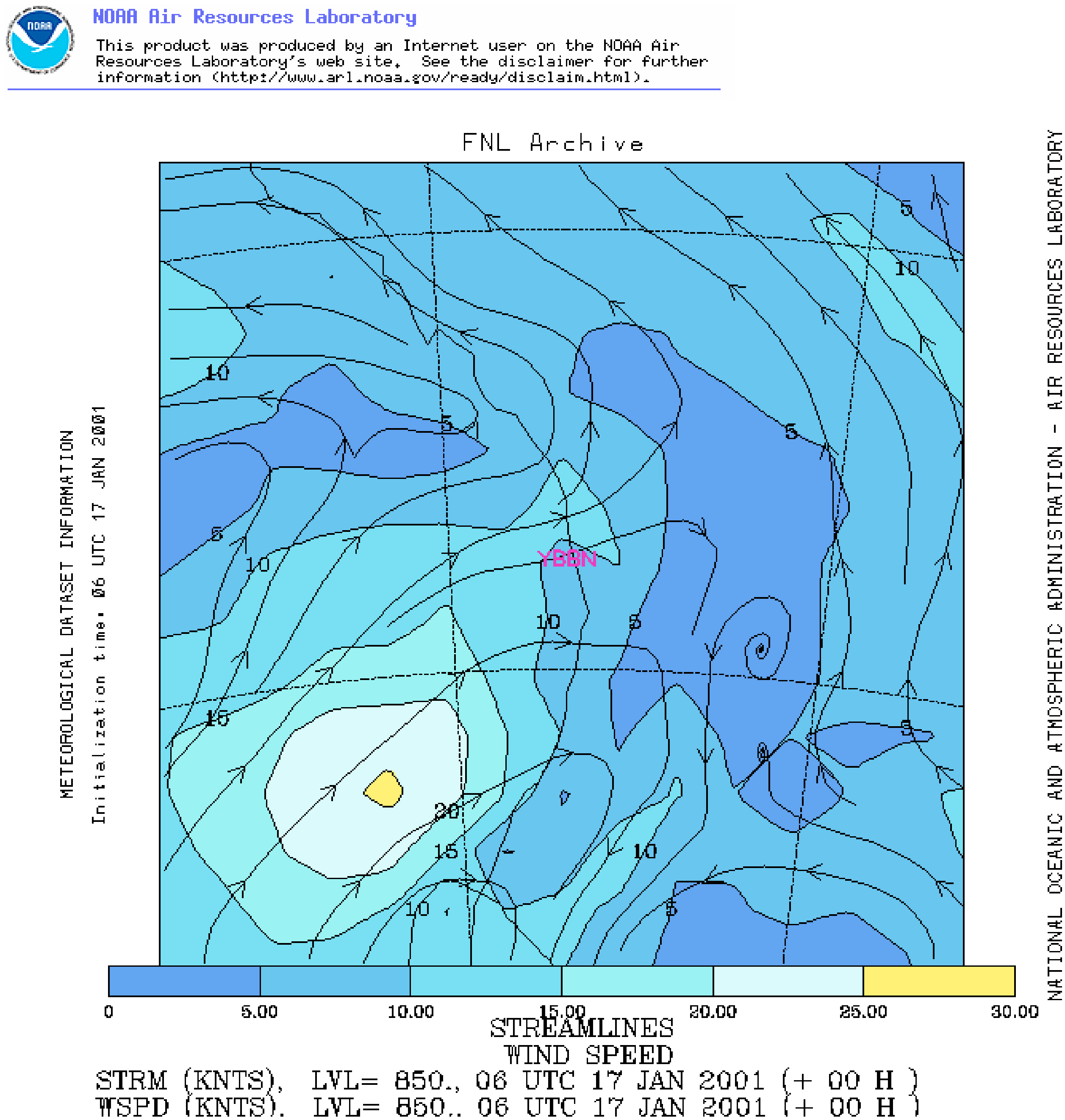
Anyway, lets start having a look at some sharts! First...instability...



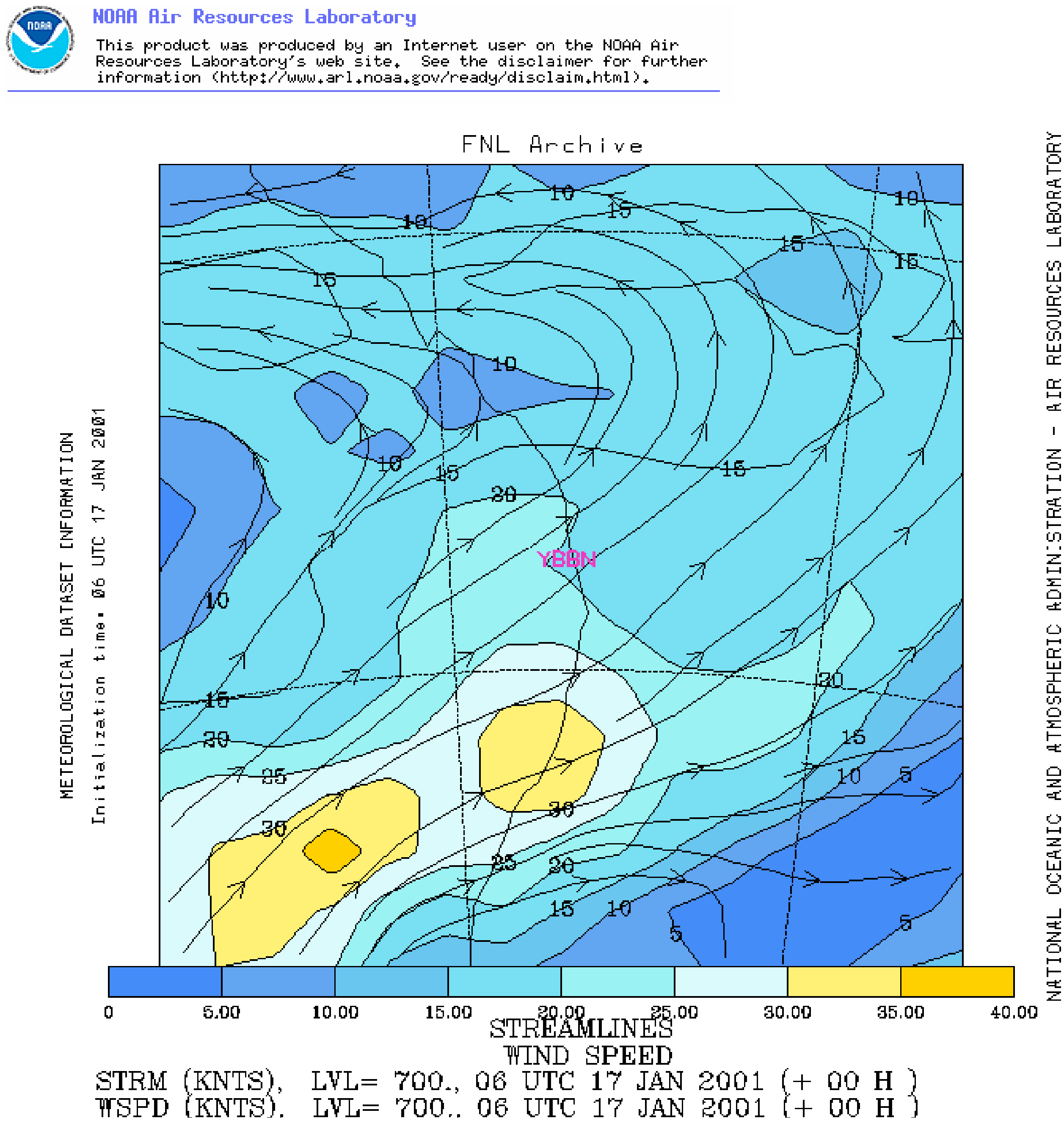
As you can see there was no shortage of instability on this day! -3 to -6 through much of SE QLD, approaching -6 towards the border with a solid region of -6 to -9 over NSW, decreasing even further to -9 to -12 over the Grafton-Coffs Harbour region. You might be surprised to know that virtually all storms during the day were coastal! Storms developed a little further inland that night though. However a quick look at the surface winds will help reveal why that was the case:



A defined dryline was present across the eastern areas, with moisture pushing into the Sydney and upper Hunter region and into the Mid North Coast. (Being defined is important...remember, if it's illdefined or not-formed properly then the two boundaries will tend to mix and the transition will become gradual). The shallow region of moisture was back towards NE NSW and SE QLD - however this ended up most probably interacting with the seabreeze front to give some of the best storms of the day! The other thing to note was the fairly reasonable NNE flow...with relatively strong winds off the coast.
While we're on the subject of winds, lets look at some other maps to get an idea of things!

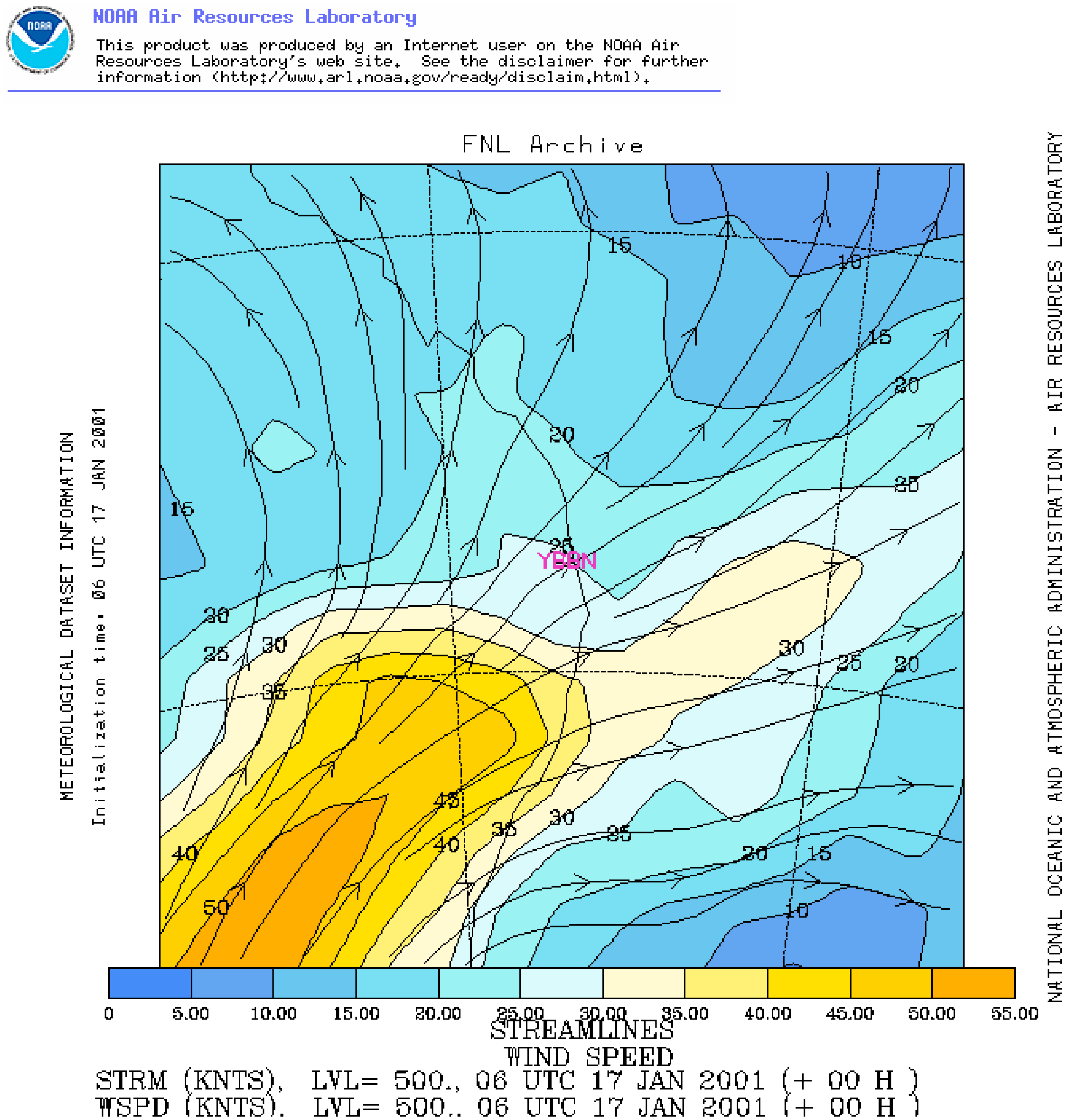


The 850 winds were analysed surprisingly weak...I have an inkling that suggests these were stronger (as per the 12z Brisbane sounding), but perhaps they just increased rapidly towards the evening (which is possible). But here you can see that the winds have already backed around from the NE to the west...we've nearly done all the directional turning required here alone! 850 winds were around 10 knots in the region



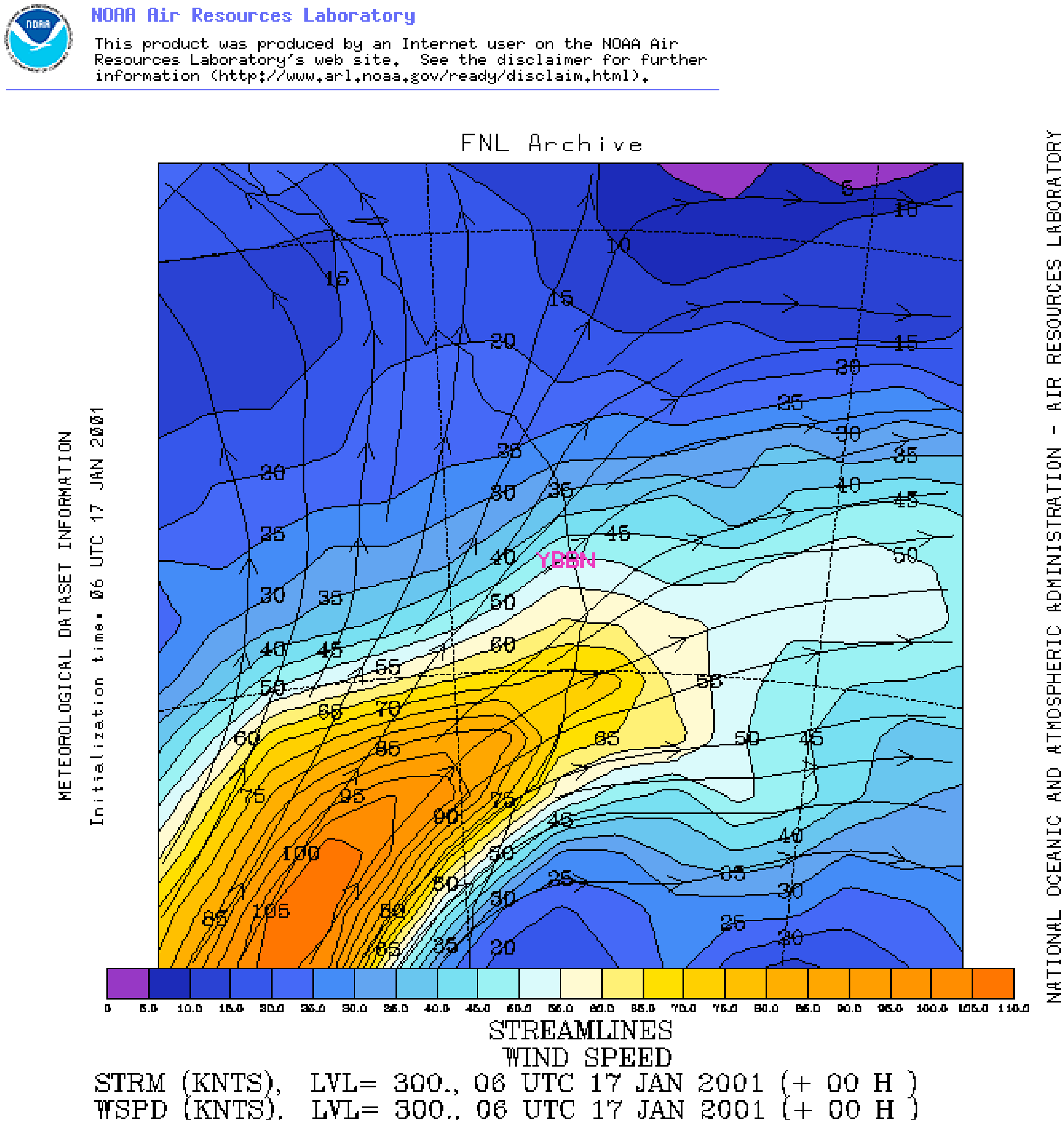
Here the 700mb winds have backed around to the SW - talk about awesome directional shear! The 700 winds are quite reasonable too...20-25 knots, reaching 25-30 knots over the NE NSW region. Quite reasonable!

Lets look at 500mb...

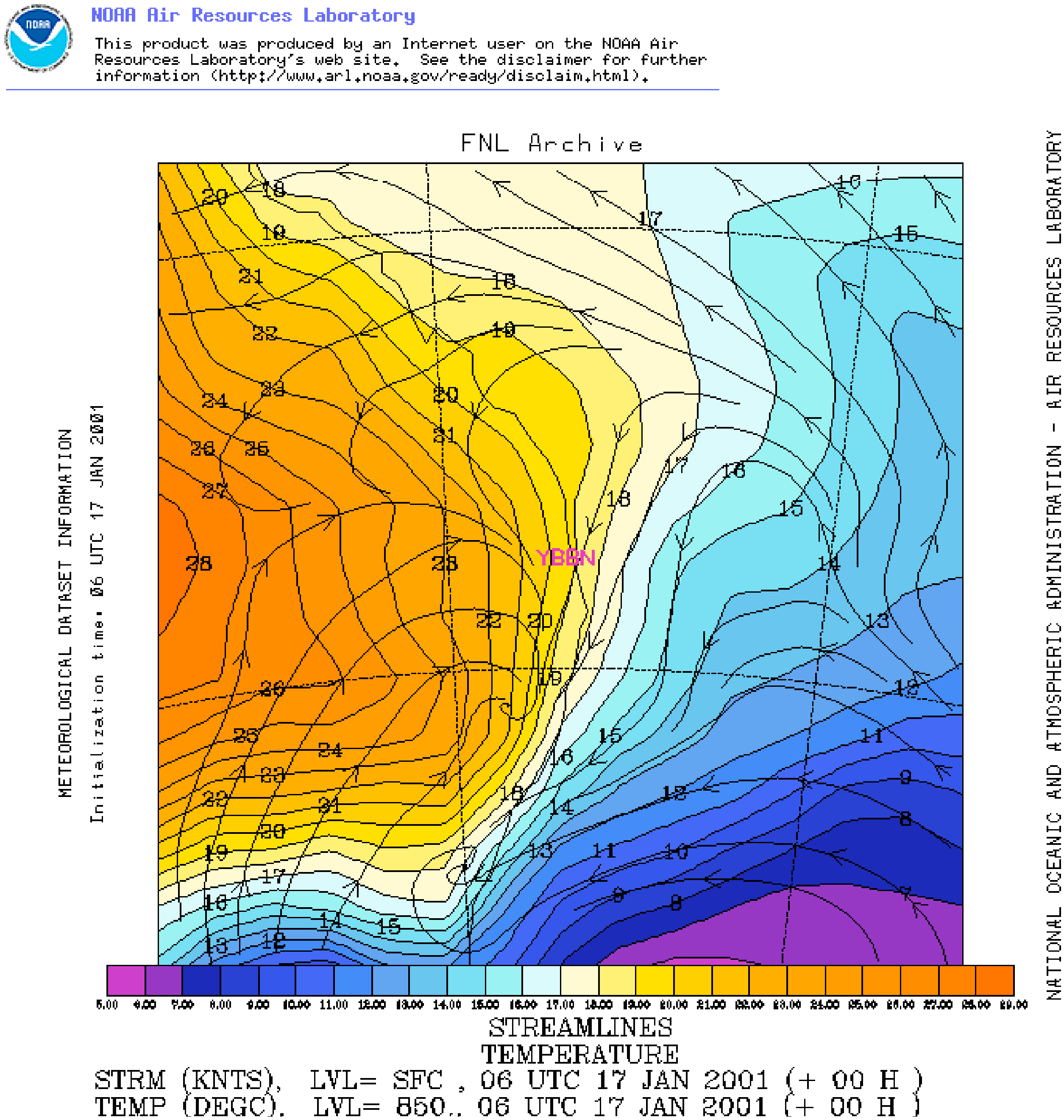


Ok...here things get a little more interesting! A good 500mb jet is rapidly pushing into the region...not only that though, look at some of the nice diffluence that has developed on the edge! A solid 30-40 knots over NE NSW too. Now this brings us to thinking about the supercell threshold of shear. Keeping in mind that with the seabreeze, NE winds were around 15-20 knots. So 30-40 knots SW'ly at 500mb provides us with 0-6km shear of between 45 and 60 knots - which fits in nicely with our supercellular threshold!

For good measure we'll look at the 300mb jet too...

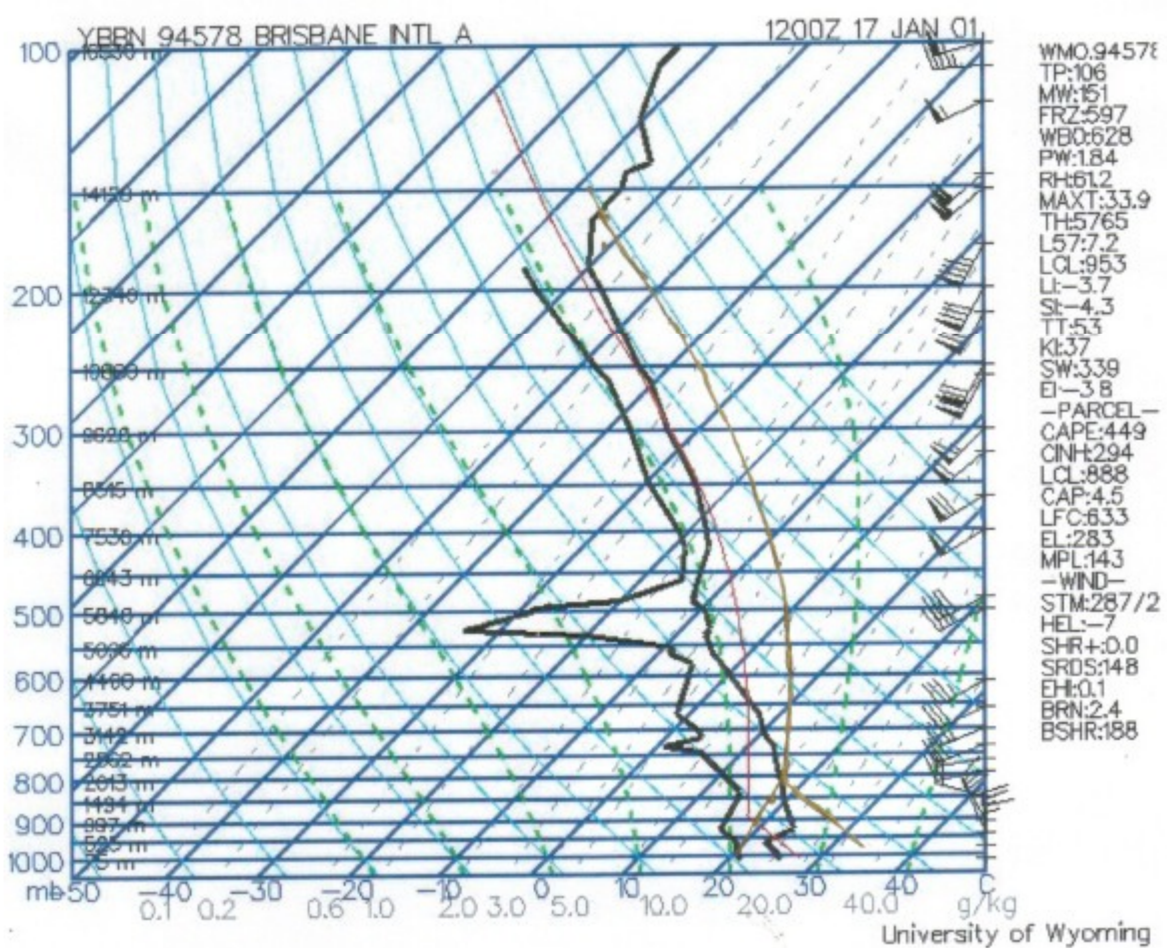


Once again some lovely diffluence over NE NSW and a good jet (50-60 knots in SE QLD, 70-80 knots over NE NSW). So shear is certainly supportive of supercells...so is instability...everything is perfect! And well...it pretty much is the perfect setup (which is why I've included it!) But lets look at the cap too using 850mb temperatures as a guide...

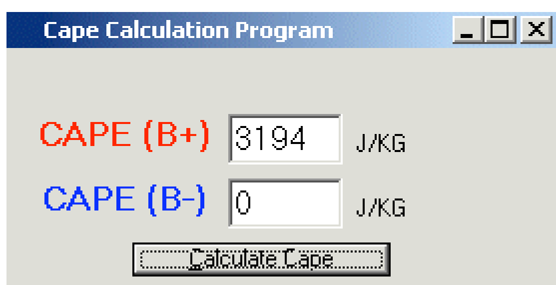


The cap was a key factor in making this day more interesting! The 850 temps were quite warm...19C right on the coast, getting to 20C along the dryline. 850 temperatures were even higher towards the NW along the dryline (hence why there were no storms to the NW, the cap was too strong!)

Can you guess which way storms were going to move? The shear gave a NE'ly steering flow, but you might be interested to know that most storms moved N or NNE! This is because as mentioned before, stronger storms (especially supercells) in the southern hemisphere have a tendancy to move to the left of the mean steering flow...which is what happened on this day! In fact there was a spectacular supercell in Casino that produced some softball sized hail...check out Michael Bath's and Dave Ellem's report. I scored another supercell in SE QLD...it was an active day! But there were a few things that really enhanced it. Perhaps what was really memorable was the fantastic night development that took place...even at 3am in the morning! In fact there was tennis ball hail while CAPE was only a few hundred - how did this happen? Well, this is where the shear analysis gets interesting! And here is a classic case where horizontal shear can enhance instability! Lets look at a modified sounding...I've used the Brisbane sounding here (12z for this day), and plotted the maximum potential for Casino (34/20) on it...

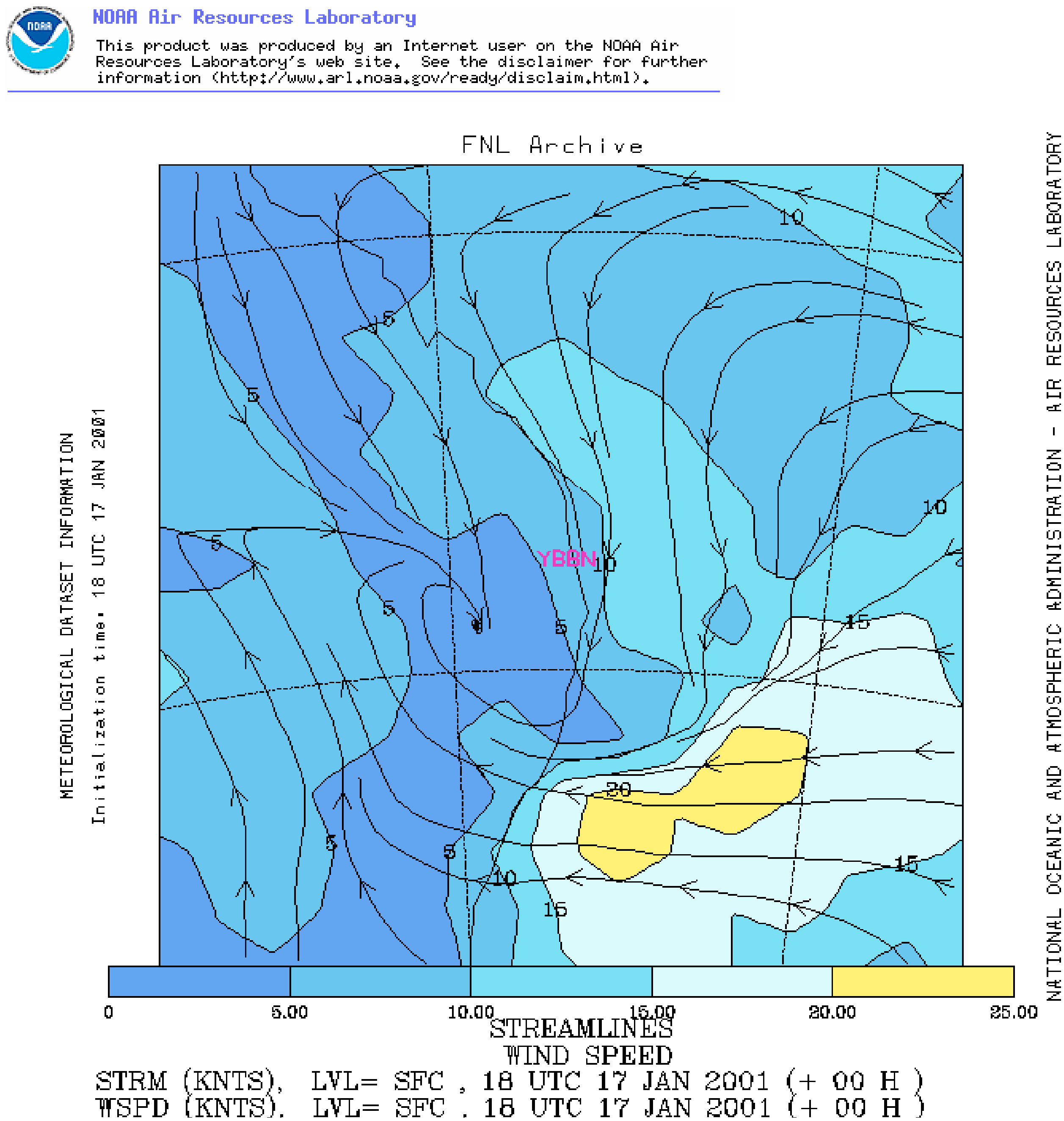


You can see how unstable it was - especially in the mid levels with that upper trough pushing through! LIs were well towards -10 as we saw in the forecast. A quick check of CAPE in the afternoon reveals some impressive instability too!



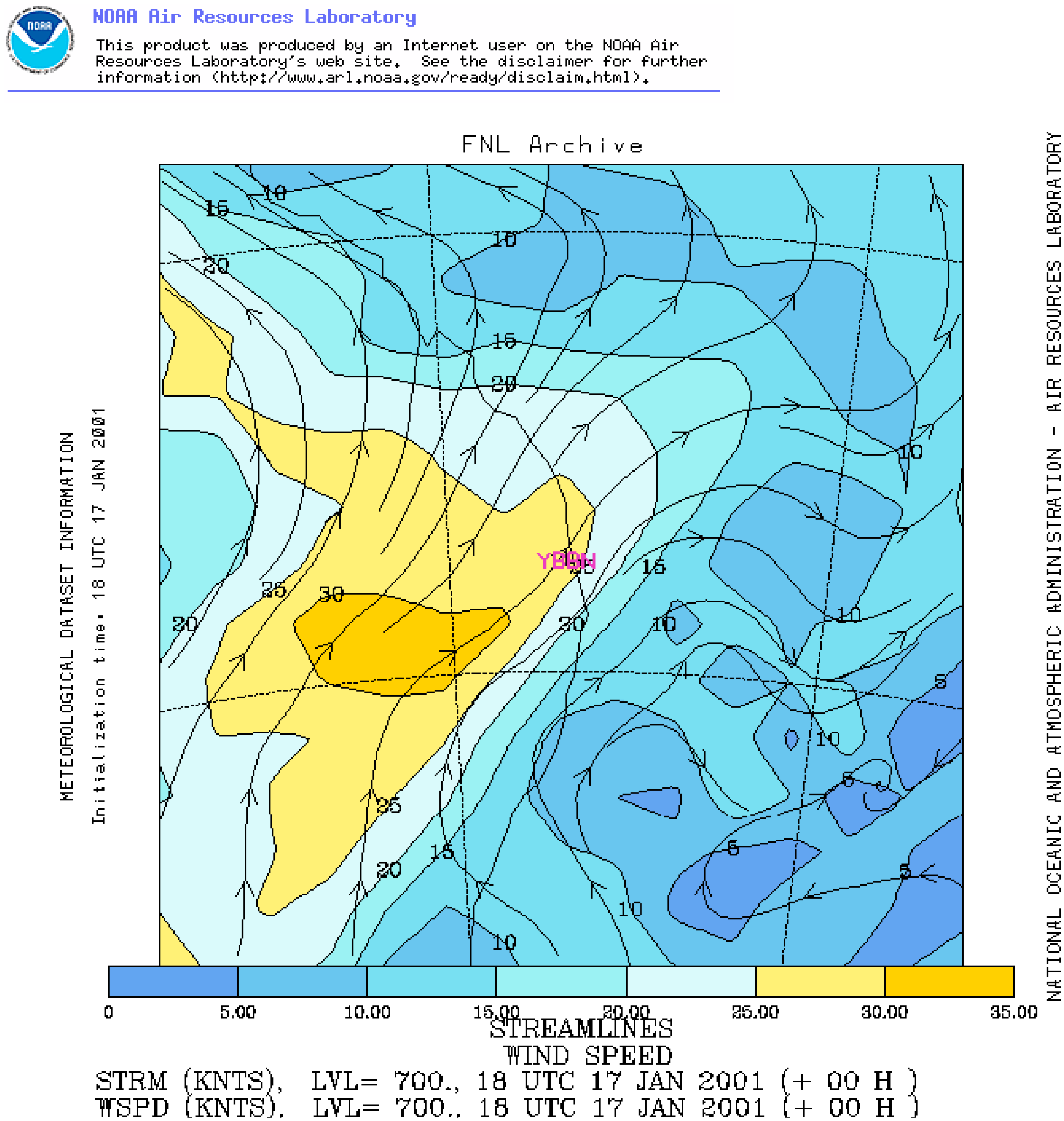
Plenty of instability to support powerful updrafts with large hail...no wonder there was some massive hail! But what about in the evening? At 10pm there was a severe squall line that moved through NE NSW and SE QLD...ok...there would have been some residual instability leftover and that squall line actually developed west of the dryline (amazingly!) and moved across and sustained itself...once storms develop, it's easier to maintain them...the hard work is often forming them in the initial stage. But then at 1-2am, storms developed in the Downs and moved over north Brisbane bringing tennis ball hail! But it didn't finish there...at 4:30am more storms began to develop on the border ranges and they moved over Brisbane becoming severe yet again! Yet if we look at the above sounding (the red line is the unmodified night sounding), we see unstable mid levels - but not much else! CAPE is only 449, how does that work to produce tennis ball hail!!! Well, the key can be having a look at a few more charts - namely shear.

Lets look at a surface chart for 4am...

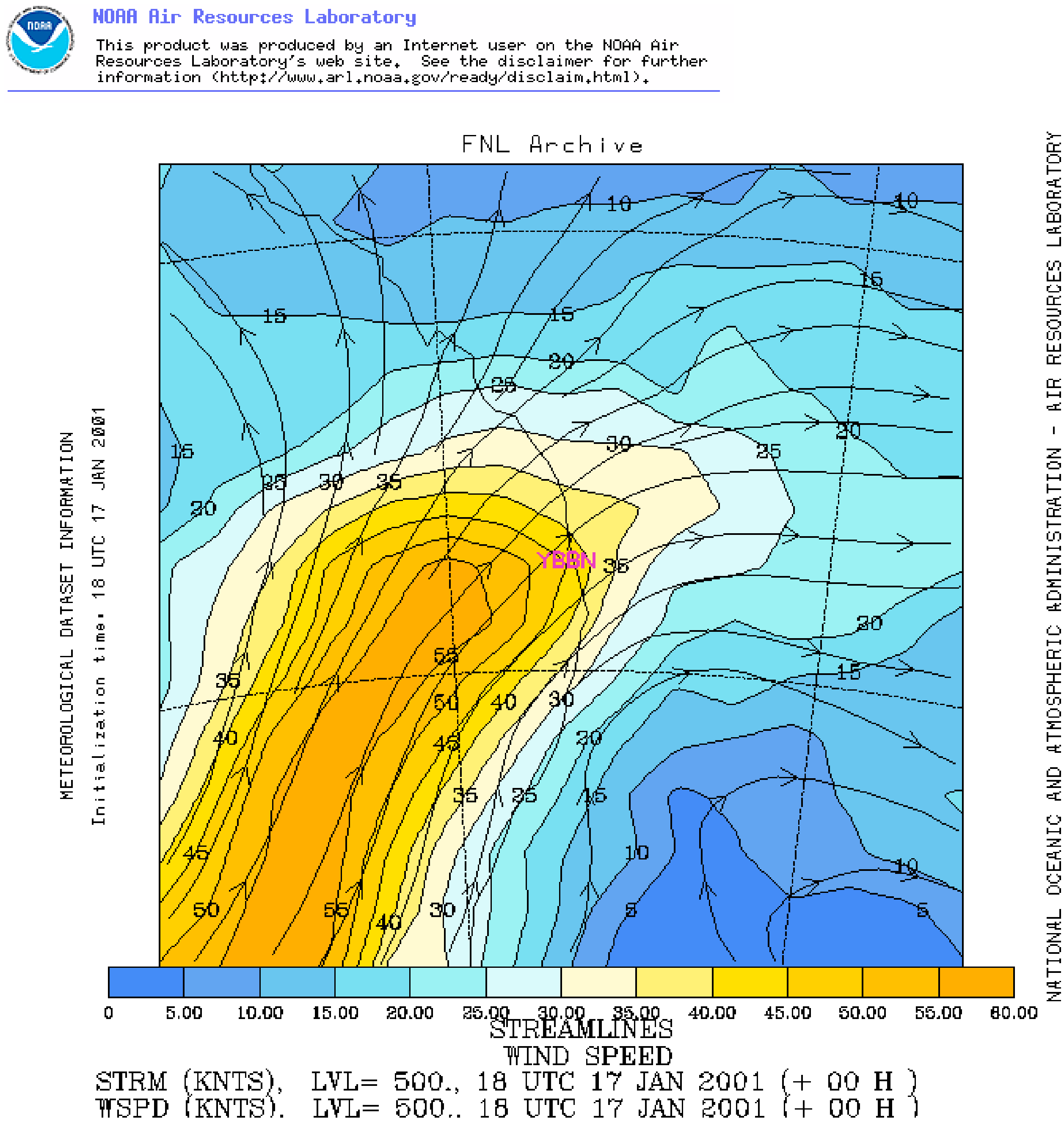


This is a big change from 12 hours ago! Our dryline has actually disappeared...but the trough remains. Note along the trough (spiralling inwards, indicating a low), that we have confluence. But also note that there are effectively NE'lies feeding into both sides of this through! First there are the northerlies on the northern side, but also note that the SE'lies are really pseudo NE'lies because that is their point of origin. Further west along the trough there are true southerlies as that is their origin. So this is interesting...a lot of moisture has been pumped into this trough in a small amount of time...one thing that potentially happened is this moisture mixed with the heat on the Downs leftover from the day before and this helped produce additional instability. But it still doesn't quite explain the Brisbane stuff - which was cooled by storms already!

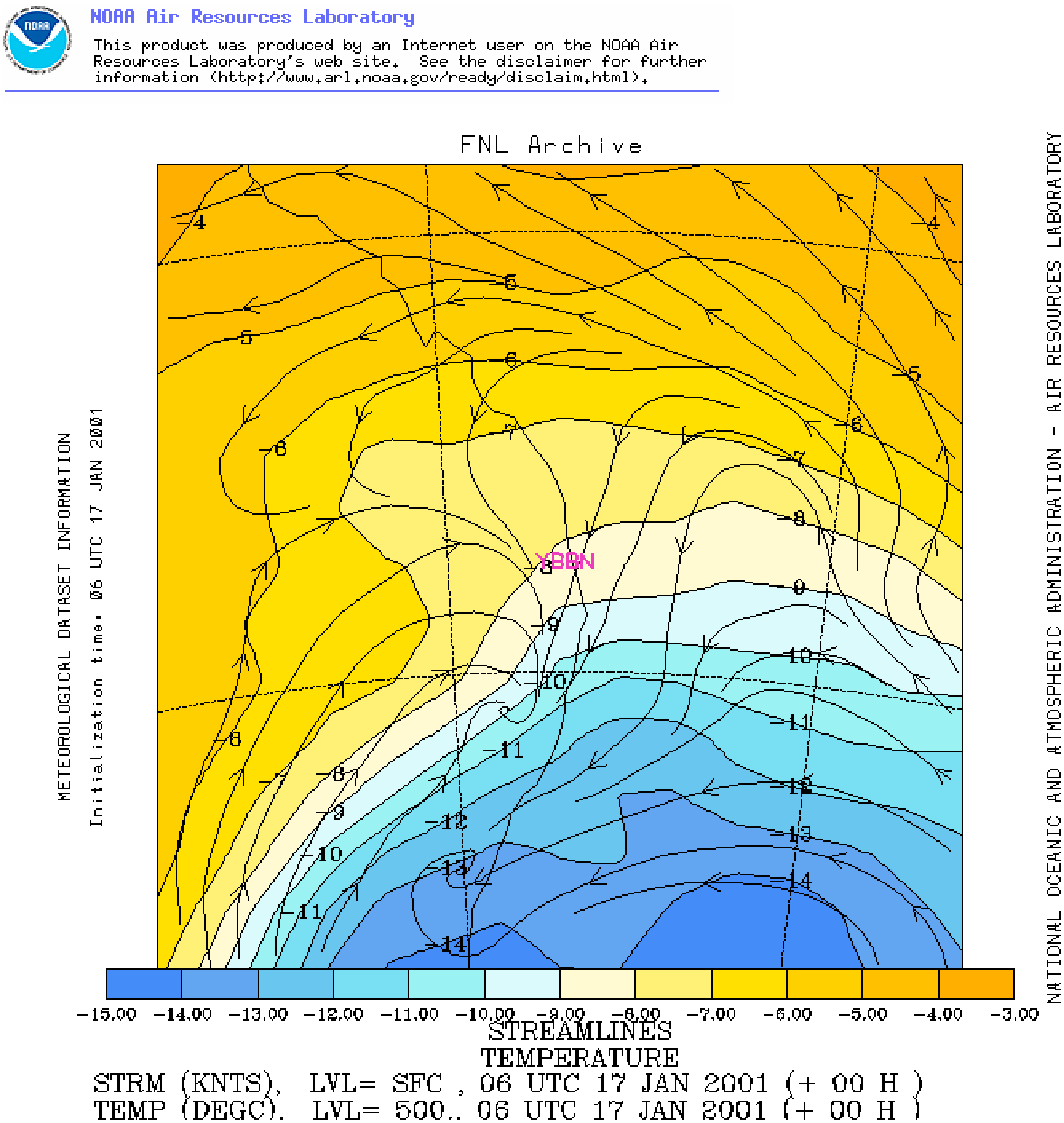
Lets delve a bit deeper...



I've skipped 850...but it was W'ly at 15 knots if you're interesting...so we still have strong
directional turning. Here the 700mb chart gets a little interesting...25-30 knot SW'ly...fantastic directional shear is persisting! Notice a little diffluence west of Brisbane?
Interesting...lets go up another level to 500mb...



A very nice mid level jet here! Pushing 40-45 knots and getting up to 50 knots over the Downs. But also notice something else - notice how the area is nicely diffluent? Also note that here, we're on the right exit region of the jet...due to the structure of jetsteams, air tends to rise on the right exit region (in the southern hemisphere, in the northern hemisphere it's the left exit region). So how much air is rising? Well, before we look...lets look at a 500mb temperature chart...both at 6z and 18z...


NOAA Air Resources Laboratory
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FNL Archive
METEOROLOGICAL DATASET INFORMATION
Initialization time: 06 UTC 17 JAN 2001
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION - AIR RESOURCES LABORATORY
YBBN
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STREAMLINES
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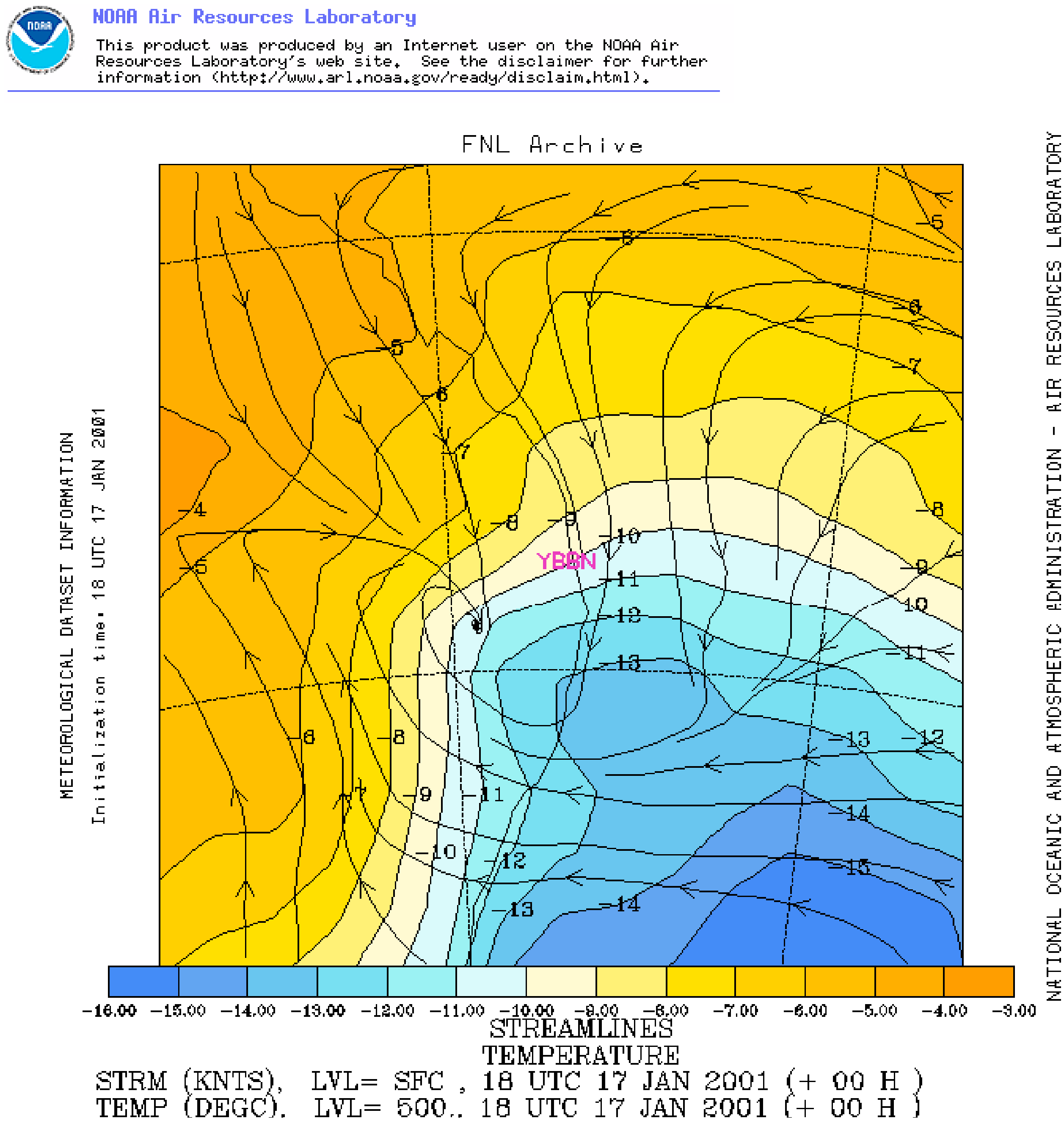
STRM (KNTS), LVL= SFC , 06 UTC 17 JAN 2001 (+ 00 H)
TEMP (DEGC), LVL= 500., 06 UTC 17 JAN 2001 (+ 00 H)



Wow - that's a nice little upper level trough pushing into SE QLD and NE NSW there! That's contributing to the destabilisation of the mid levels quite nicely - swift moving upper trough are good at doing that...but not only that, they also help to lift the air in general around them. So if we have two things (diffluent 500mb jet) and the upper trough moving in the region then we would expect to see this in the vertical wind charts. Do we? Lets look!

NOAA Air Resources Laboratory

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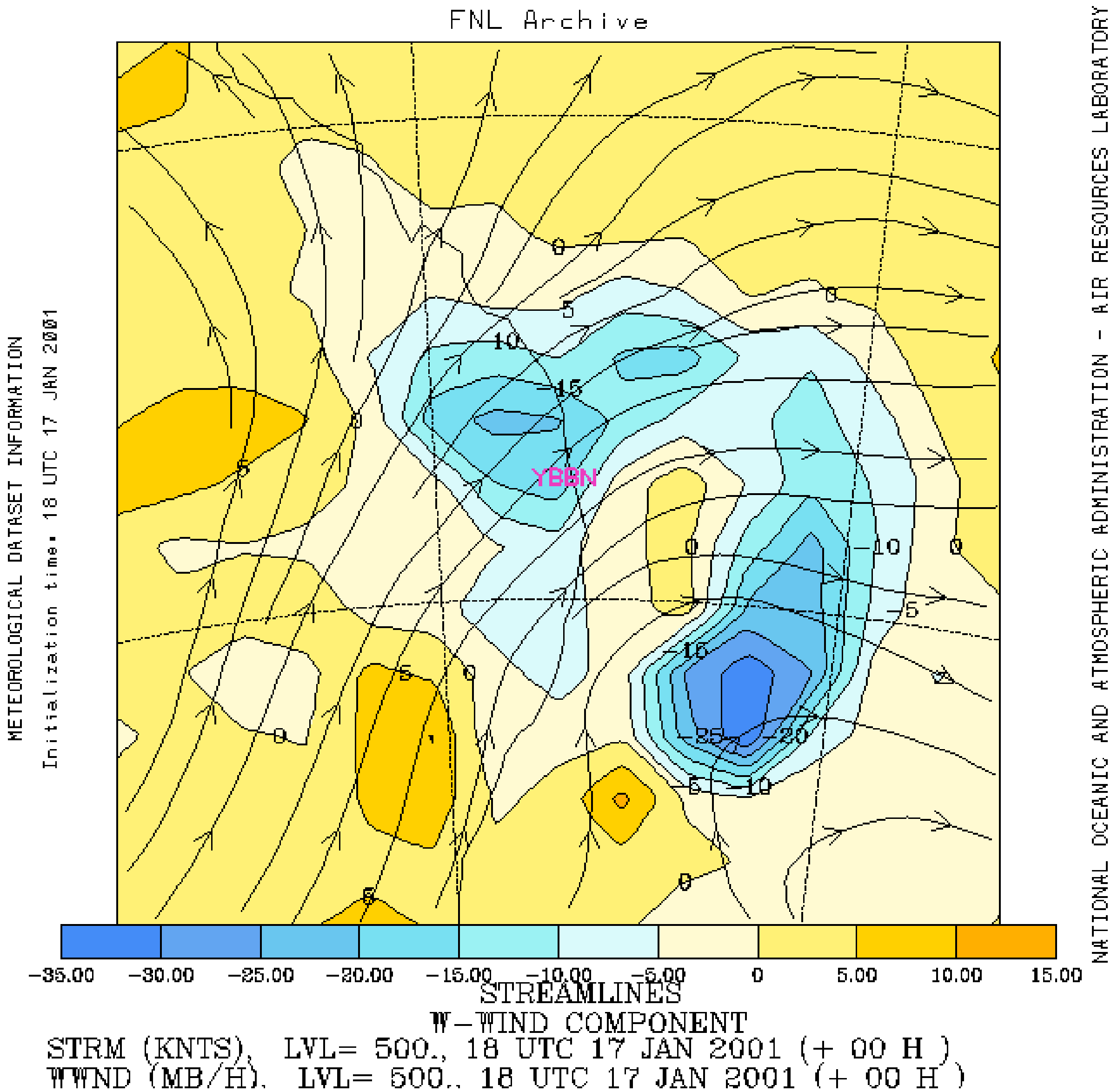
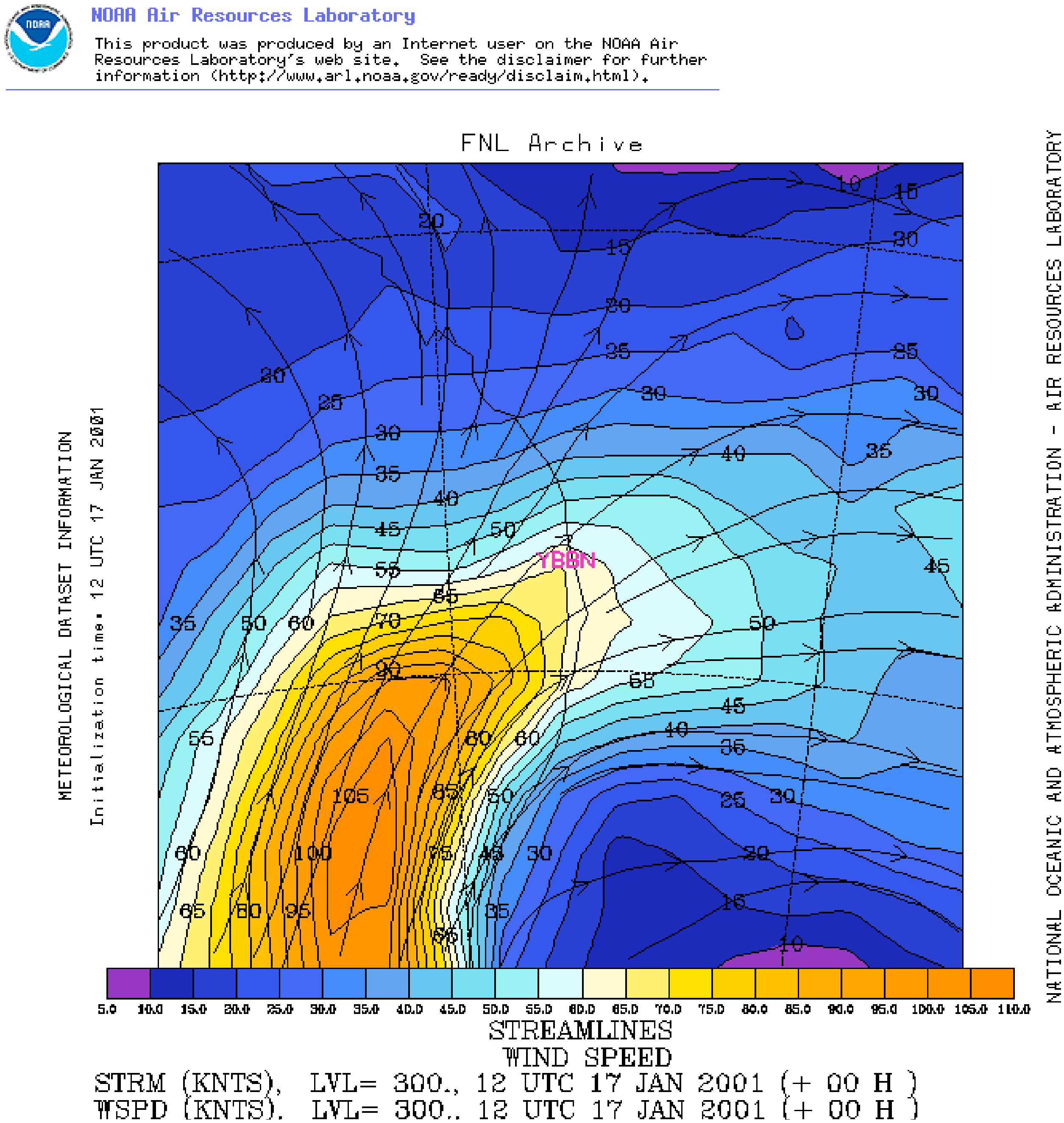
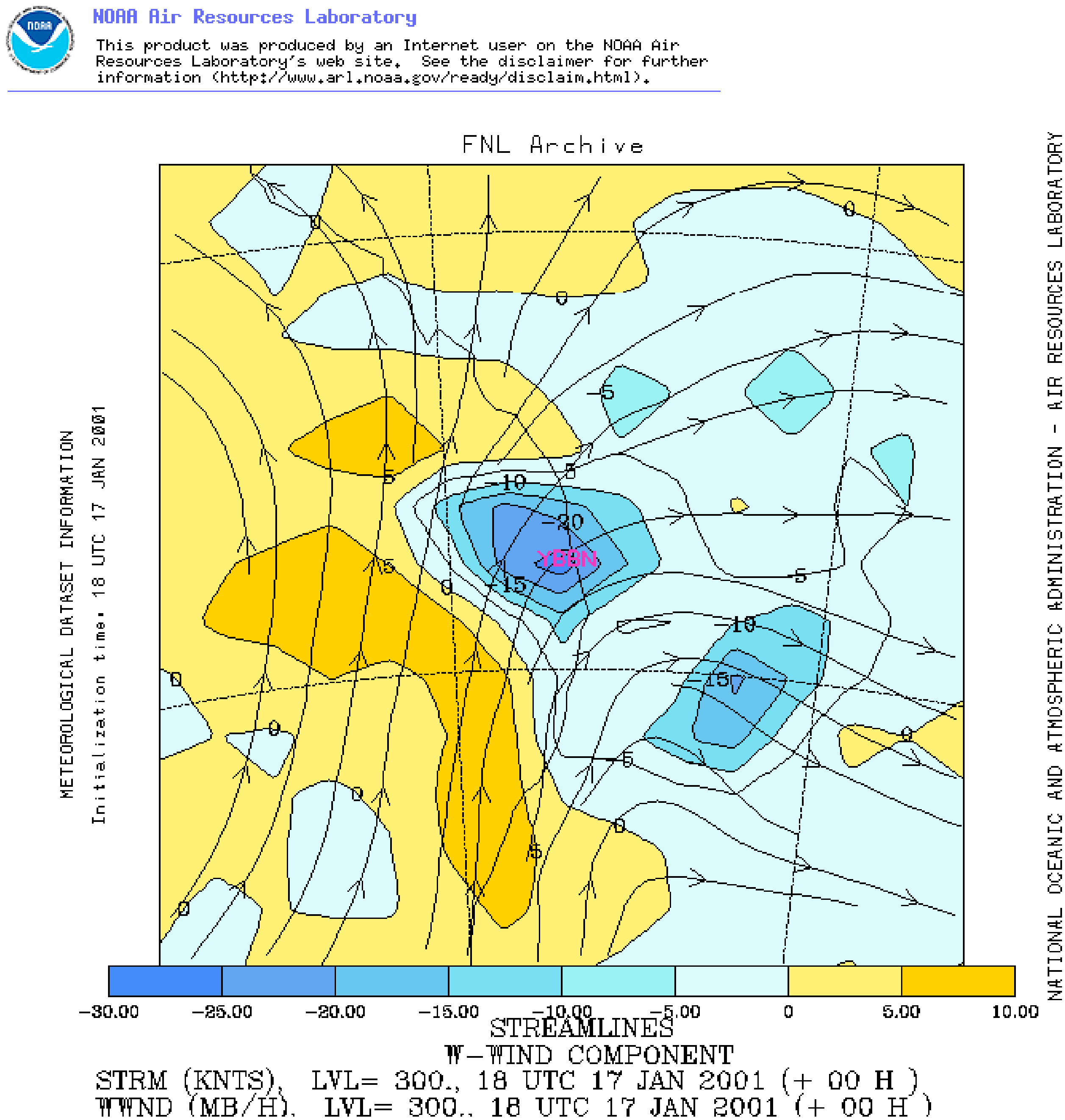


Hmm...solid -15 to -20 VV's (vertical velocities) over the Brisbane region...certainly quite nice and quite supportive!

Lets check 300mb...



There is some awesome diffluence happening here! And Brisbane is right under the right exit region too. Just without looking at the upper temperatures, you can see there must be a sharp 300 trough pushing into the Mid North Coast (31-32S) area because of where the winds suddenly slacken (due to the weaker temperature gradient). Once again...a look at VVs...



Even better here! Solid -20 to -25 and even -25 to -30 VVs over the Brisbane region. So just by a few proccesses:

- Horizontal shear arranging itself in such a way it induces favourable vertical shear
- Swift movement of cold air into the upper levels inducing favourable vertical shear

We can see that while the atmosphere is not hugely unstable...when you combine it with the awesome horizontal shear (supportive of supercells) you can get severe storms. Also, the vertical shear has helped enhance the current instability there is there now (so perhaps it might have the equivalence of a CAPE of 1000 instead of 450 due to the vertical shear. It's not quite that figure...I've never calculated it, but I'm just giving you an example!) This concludes this part, but ties into the last part which discusses storms and severe thunderstorms when you probably wouldn't pick it!

Magic Numbers Summary

This is a summary of the magic numbers used in this guide for thresholds of storm and severe thunderstorm development. Please note that the worst thing you could do is continually refer to this page and look for the thresholds and apply them to the current situation that you are currently experiencing!!! The atmosphere extremely dynamic and these thresholds can only be considered as a guide and not law. Just because something is outside a threshold, or in another does not in anyway mean that is what will happen. I strongly suggest that you read all sections of this guide in order to obtain a better idea on what these thresholds actually mean and how they can best be used. For example, just because a CAPE of 950 falls in one category and a CAPE of 1050 falls in another does not mean that the latter is significantly better than the former!

Instability Figures
Lifted Index

LI Value	Result
+2 or higher	The 500mb level looks relatively stable, might get some showers if the lower levels are cool enough though. Storms unlikely.
0 to +2	possible showers, low risk of storms (but storms in more unstable areas might move into this region and survive).
-2 to 0	Weak instability, potential for some showers and storms.
-4 to -2	Moderate instability, ample potential for storms - starting to become favourable for severe storms if other conditions are right.
-4 to -6	Strong instability, more than ample potential for storms and severe storms.
-6 and below	Very strong instability, same as above.

CAPE & LIs

CAPE (LIs)	Description
< 500 (-1 to 2)	Very weak instability, showers likely with some isolated storms. If shear is absolutely fantastic, then there is the chance of severe storms.
500 -1000 (0 to -3)	Weak instability, showers and storms likely but generally weak unless shear is good.
1000-1750 (-2 to -5)	Moderate instability, storms (possibly severe with pulses), becoming quite severe if shear is very good, updrafts may be strong enough to sustain large hail (2cm+).
1750-2500 (-4 to -8)	Strong instability, possible severe pulse storms in weak shear - probable severe storms in good shear, large enough to sustain large (2cm+) to very large hail (5cm).
2500-4000 (-6 to 12)	Very strong instability, severe pulse storms likely in weak shear. Good shear will result in severe to very severe storms with updrafts strong enough to sustain very large (5cm+) to extreme (8cm+) hail.
4000 > (-10 to -16)	Extreme instability, severe pulse storms likely in weak shear. If you have good shear - watch out! Updrafts strong enough to sustain hail in excess of 10cm.

Shear Figures - 300mb Winds

Wind Strength	Effects
< 20 knots	unlikely that there will be enough wind shear at this level to help blow way thecirrus and other high cloud that is produced from storms. Storms would probablycollapse on themselves unless the mid level shear is relatively strong
20 - 30 knots	marginal, it should allow enough shear for thunderstorms, and the risk of somesevere pulses but you will need some strong instability to offset this, or at least some good shear in the mid levels.
30 - 45 knots	Moderate but not good, this should allow enough shear for thunderstorms and even severe thunderstorms providing there's some moderate instability too.
45-70 knots	Good shear, allows reasonable outflow for thunderstorms at the 300mb level, including supercells and severe storms.
70-100 knots	Very good shear, ample outflow for all storms.
100 knots +	Very strong shear, perhaps too strong for weak storms, but fantastic for other storms!

Shear Figures - Surface Winds

Wind Strength	Effects
< 5 knots	Negligible
5 - 10 knots	Light inflow, helps storms a little but not really ideal
10 - 15 knots	Moderate inflow, helps storms organise themselves near the surface
15 - 25 knots	Strong inflow, great for severe storms and supercells!.
25 knots +	Very string inflow!

Wind Strength Guide

Height	Poor	Marginal	Adequate	Good	Very Good
1000mb	< 5 knots	5-10 knots	10-15 knots	15-25 knots	25 knots +
850mb	< 7 knots	7-10 knots	10-17 knots	17-30 knots	30 knots +
700mb	< 10 knots	10-15 knots	15-20 knots	20-40 knots	40 knots +
500mb	< 15 knots	15-20 knots	20-30 knots	20-50 knots	50 knots +
300mb	< 20 knots	20-30 knots	30-45 knots	45-70 knots	70 knots +

Cap (summer)

Temp.	Effects
<15°C	Weak cap, development likely early.
15-17°C	Moderate cap, not really ideal but should hold convection off until midday afternoon - later if the trigger is weak.
17-19°C	Good cap, should hold convection off until the afternoon but will require a reasonable trigger to break
19-21°C	Strong cap, will need a good trigger to break.
21-23°C	marginal - the trigger will need to be very strong or it's going to need to get very hot to break the cap!
23°C+	approaches the limit of thunderstorm development in most situations.

Breaking All The Rules

Alright...we've gone through the first three sections now. Hopefully it's given you a bit of an idea on what type of things severe storms need and what to look for for severe storms. I'm now going to tell you to forget all that!!! Well - not quite. But what I want your mindset to be from this section stems from a little saying of mine...

The golden rule of weather is there are no rules!

This especially applies to thunderstorms! You don't always need instability and shear for severe thunderstorms, and similarly, severe thunderstorms don't always develop in areas of good instability and shear! There is probably a better way of putting shear and instability into context...that is:

- The greater the instability, the higher chance of severe thunderstorms
- The greater the shear, the higher chance of severe thunderstorms
- The greater "extra" enhancements (such as good cap, favourable shear patterns) are, the higher chance of severe thunderstorms

But this also allows us to draw implications, especially with the first two. What happens if instability is very high but shear is low? What happens if shear is very high but instability is low? Generally these two work together, but what you'll actually find if you look at events is that there can be a "trade off" between the two. So the higher the instability, the less shear you actually need and vice-versa for severe storms! In Australia, we tend to lack shear in some situations - but we make up for this sometimes by additional instability present. Darwin and the Top End is a classic example of this. The area is in the tropics and generally exhibits poor shear...but the instability is very great. Hence it is not unusual to see severe storms through the region (in fact, if there was a higher population density you would probably find they're relatively common!)

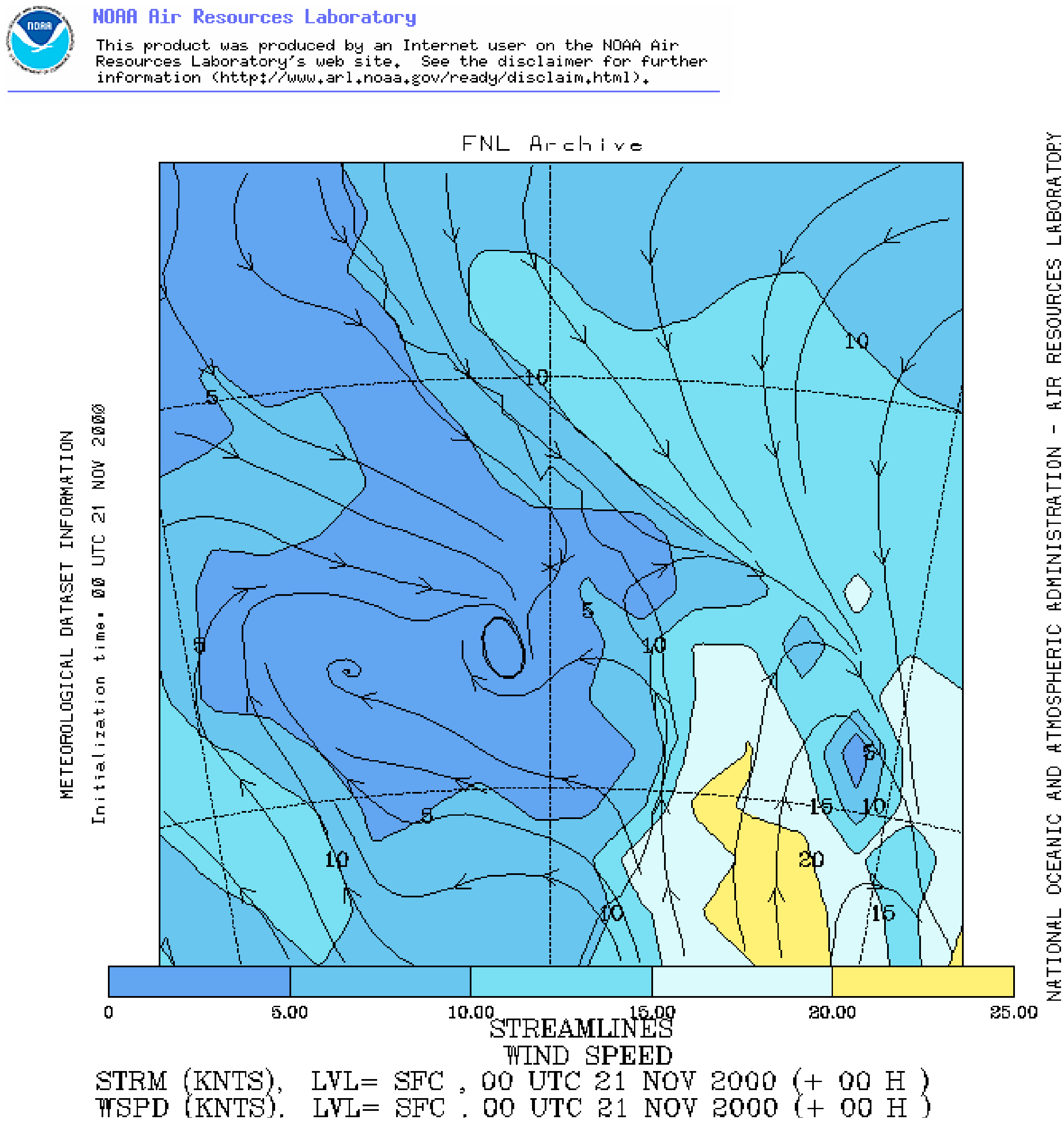
I've used some examples (they quite actually a lot easier to find than the "perfect setups" I used to describe some of the previous events!) So they're very common...so it's important to note that. Those marginal days are not always as marginal as they look...that's for sure. You'll see from the examples too that these are not days you would rush out and chase on. Yet if you didn't chase on them...well, you would have missed out on a bit! Most of the examples are once again more so of an analysis than an actual forecast of the event...I hope that it gives you some further insight into storms and see that it's really never a clear-cut situation. The majority of events tend to straddle boundaries so to speak...but that just makes it all the more challenging!

Severe Thunderstorms In Low Shear

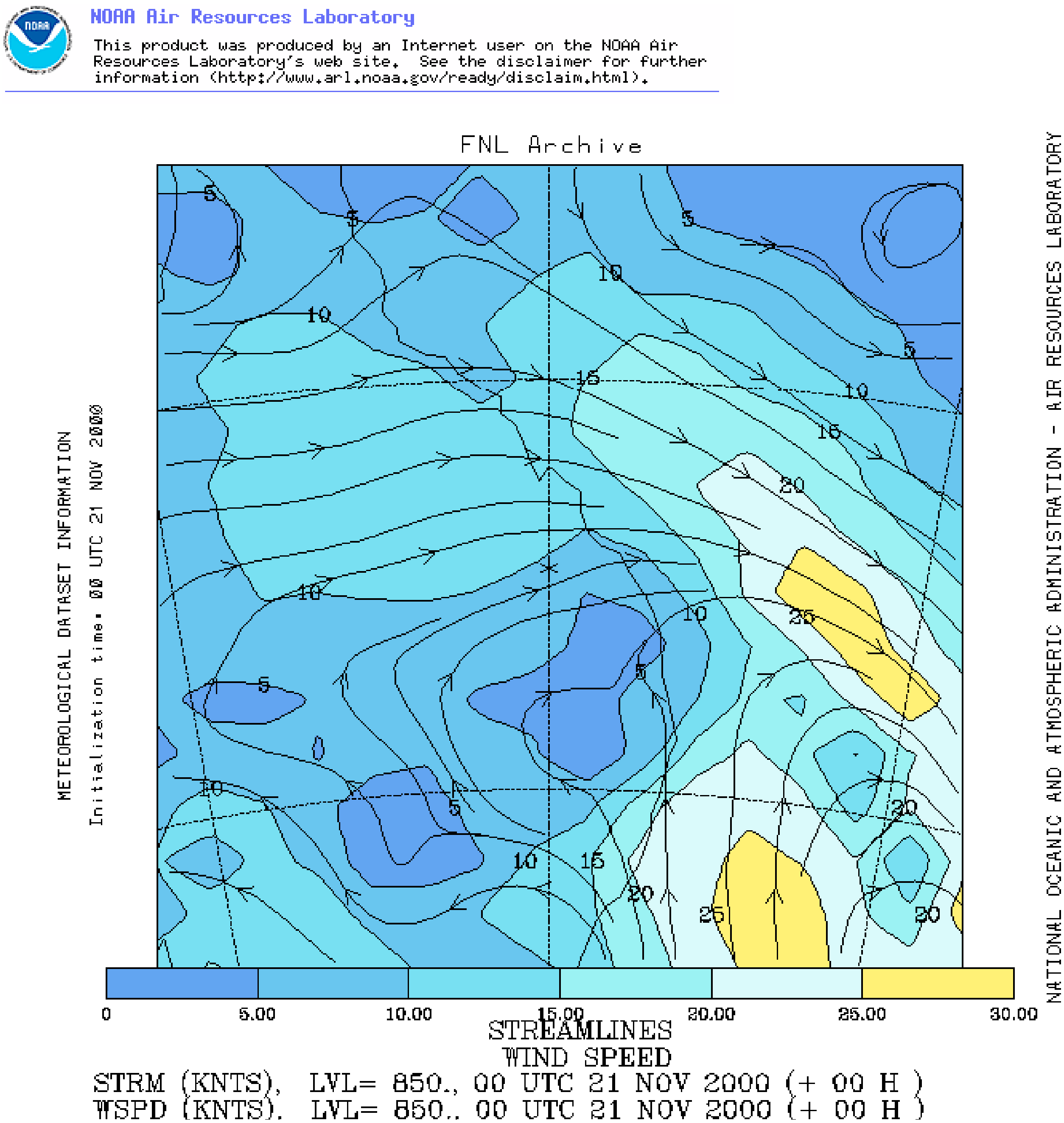
Banana Supercell Case Study - Nov 21, 2000

One of the favourite supercells that I chased was the November 21, 2000 Banana Supercell. A horrible name! But it was quite memorable - one of the best wall clouds that I've seen and some of the most defined rotation that I've seen too. In fact, you would have thought this was a day of plenty of shear...here's the wall cloud I mentioned:

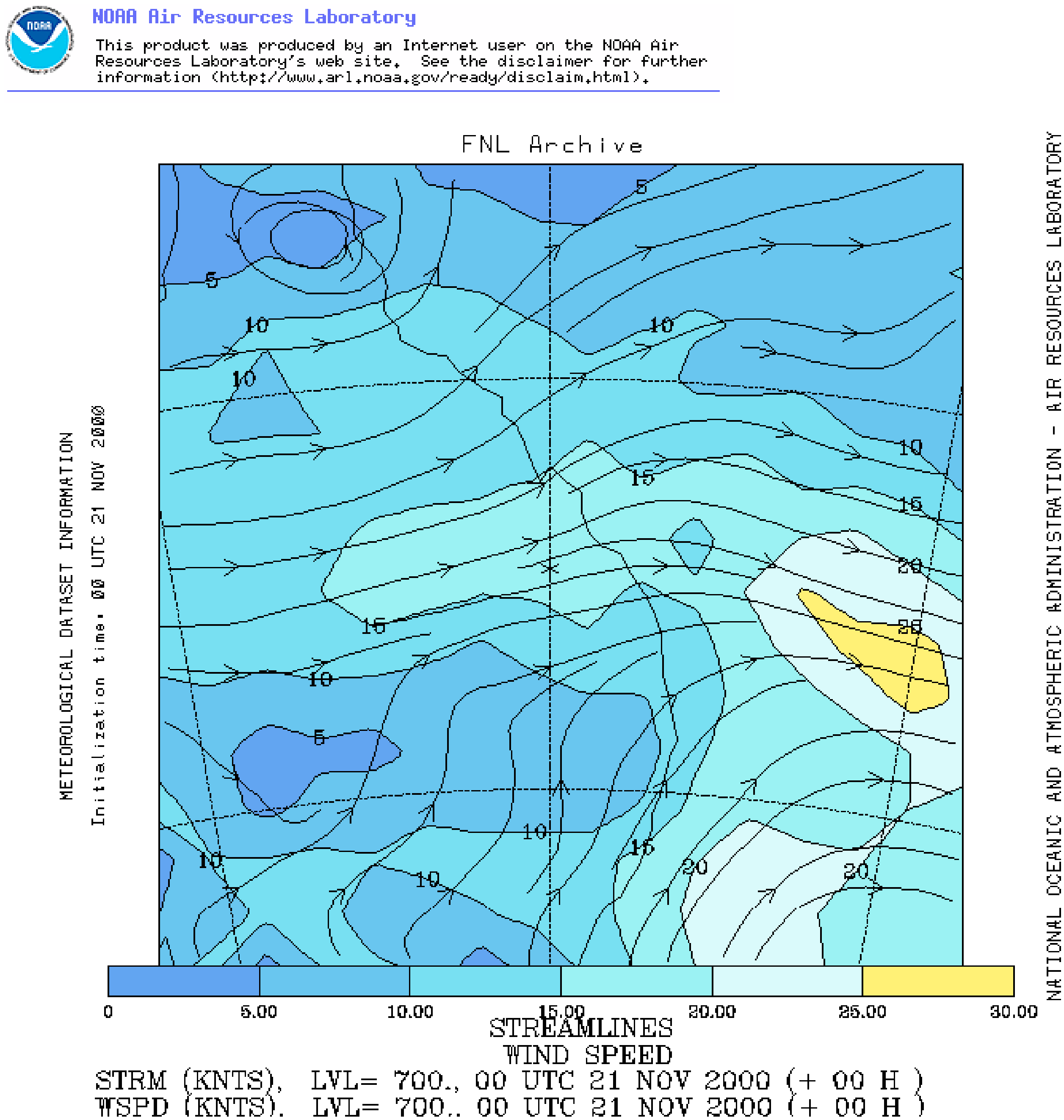
This supercell moved nearly parrallel with the highway (seen in the photo - that's a major Australian highway I might add!) so it was good chasing. The other thing is, the storm developed in a higher region (ie around 400-500m high), and as we learnt before...this increases the instability in the area. But first, lets look at the shear - keep in mind the shear on this day really wasn't that bad at all. But for strong rotation, you often expect good shear - especially in the low levels, but that didn't happen...so lets analyse why we got we we got!



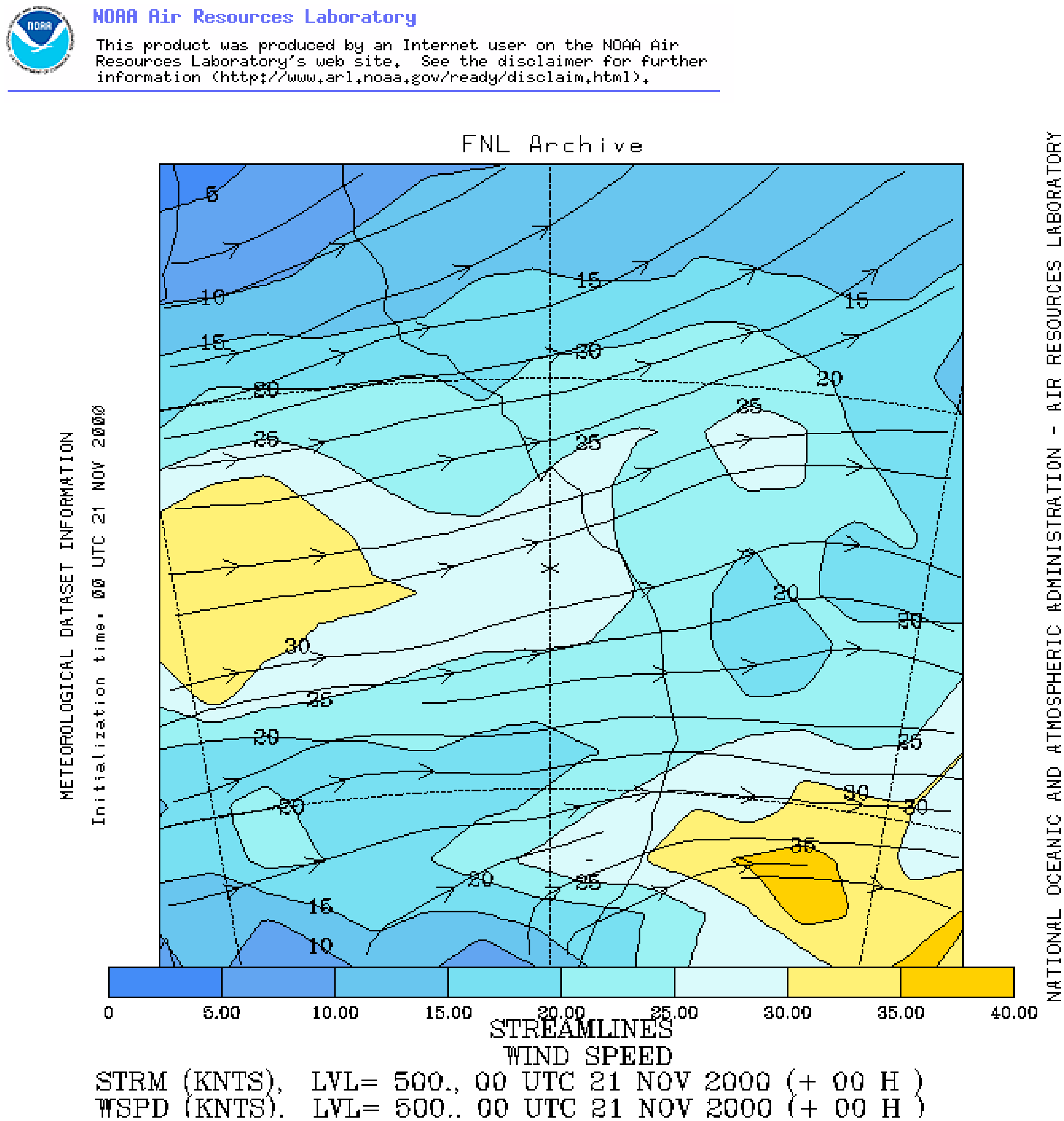
Where's Banana you ask? (It's not exactly a major location...) well, it's NW of Brisbane...I decided to plot these maps with Banana in the middle (so Banana is the asterix). The storm started about 40-50km SW of Banana though. Note one other thing...I've used 00z maps instead of 06z maps. That's because the main storm was early in the afternoon (1-2pm, or 3-4z), yes 06z is closer but looking at this, I think that the 00z maps give a better representation of what was happening in the area. (In case you're wonder, 06z shear is a lot weaker than 00z shear! So we could probably deduct some wind strength off the speeds...but we won't). Here we can see a (poor) NW'ly flow just north of a low. There was plenty of moisture due to widespread storm activity over the last week over western Queensland, so the NW'lies were of no concern. The low was moving quite quickly northwards, and was bringing with it a SE'ly change...one thing that I feel is that the Banana supercell "rode" the SE'ly change north - this would certainly have added another uplift point for confluence and also given additional directional shear!



We can see here that the directional shear here is quite good...straight away it's gone to 5-10 knots from the WSW! (Speed shear is bad <poor to marginal>...directional shear is good...well it's something!)

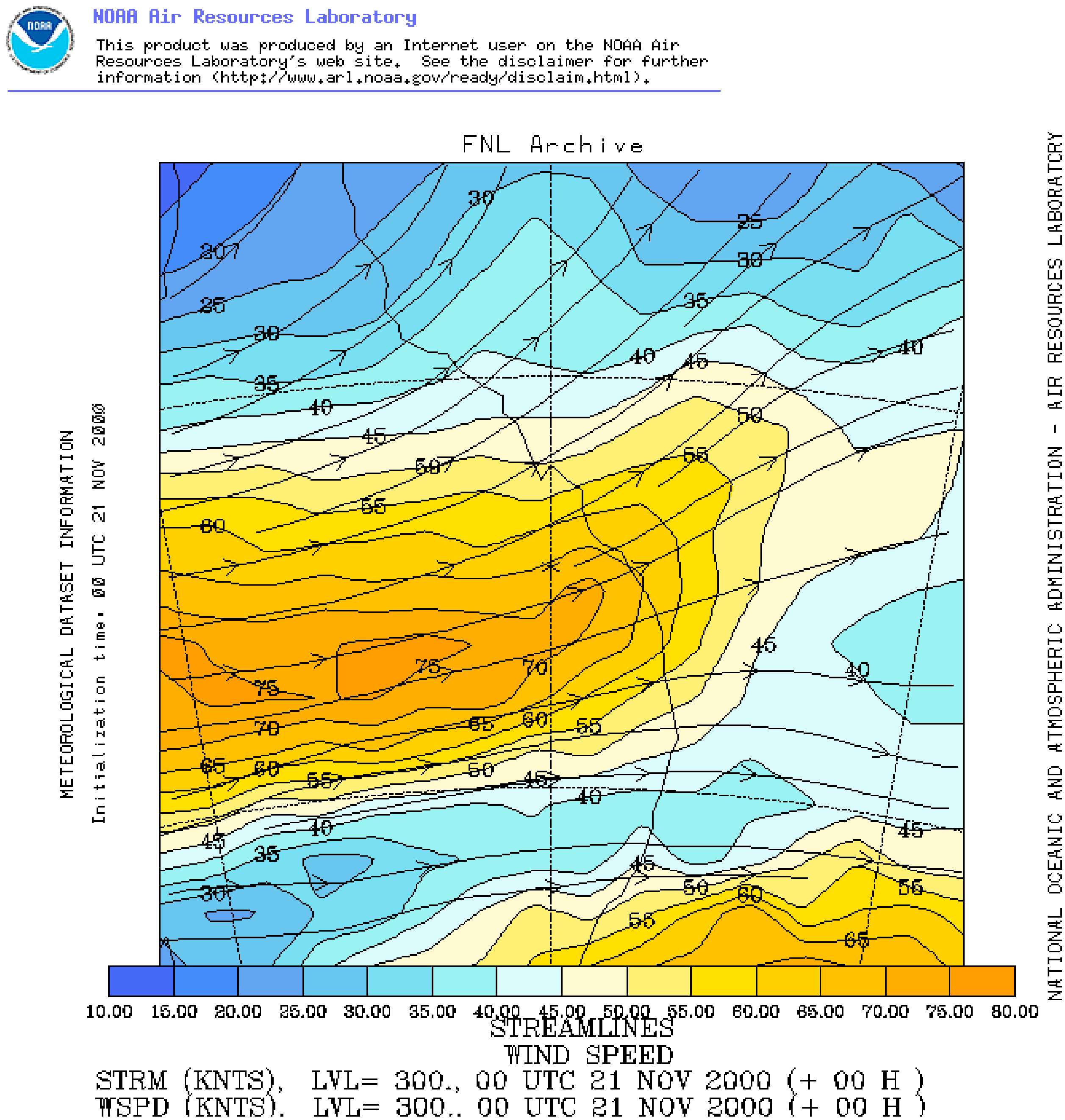


700 winds are OK here...around 15 knots (marginal) (remember, to the SW of Banana...and the shear is weakening over time). Still from the WSW too.

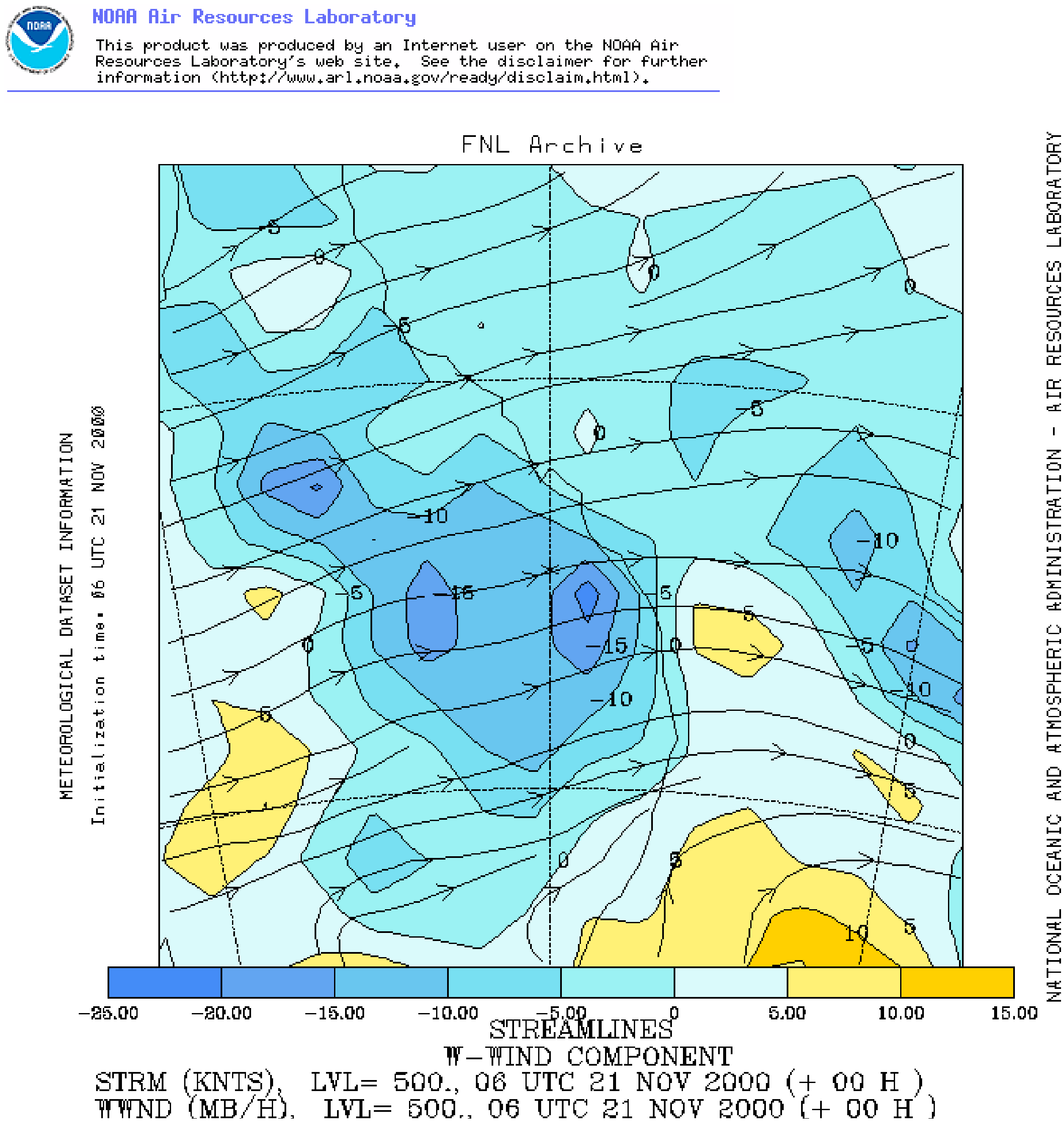


Here we have 25 knots @ 500mb from the WSW (adequate). We also had <5 knot NW'lies and then there were SE'lies pushing from behind it. However, do the maths and you'll see we're not going to reach our 40 knot 0-6km supercell threshold! In fact we're going to struggle to reach 30 knots in the 0-6km threshold...yet still we can see that we had supercells!

Lets keep going...



Alright at 300mb!!! Too bad this was weakening during the day...but here we see around 65-70 knots (good) at 300mb. One other thing I want to show...both the 500 and 300 jets were in the process of becoming diffluence, so I'm going to show the 06z VVs of these two levels to see how much the air was rising. At 00z, these values were 0 to -5.
First 500...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FNL Archive
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STREAMLINES
W-WIND COMPONENT
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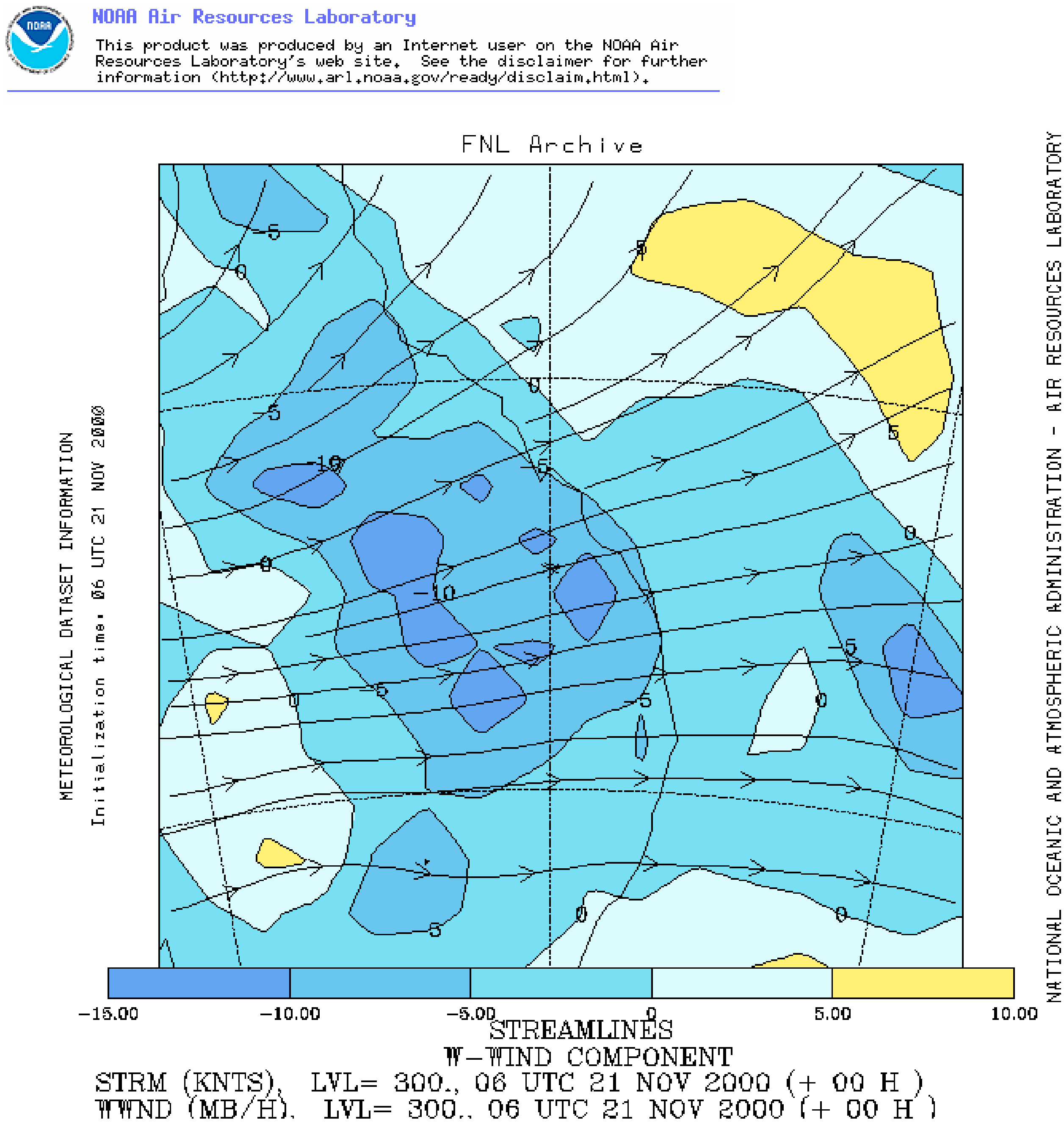
WWND (MB/H), LVL= 500., 06 UTC 21 NOV 2000 (+ 00 H)

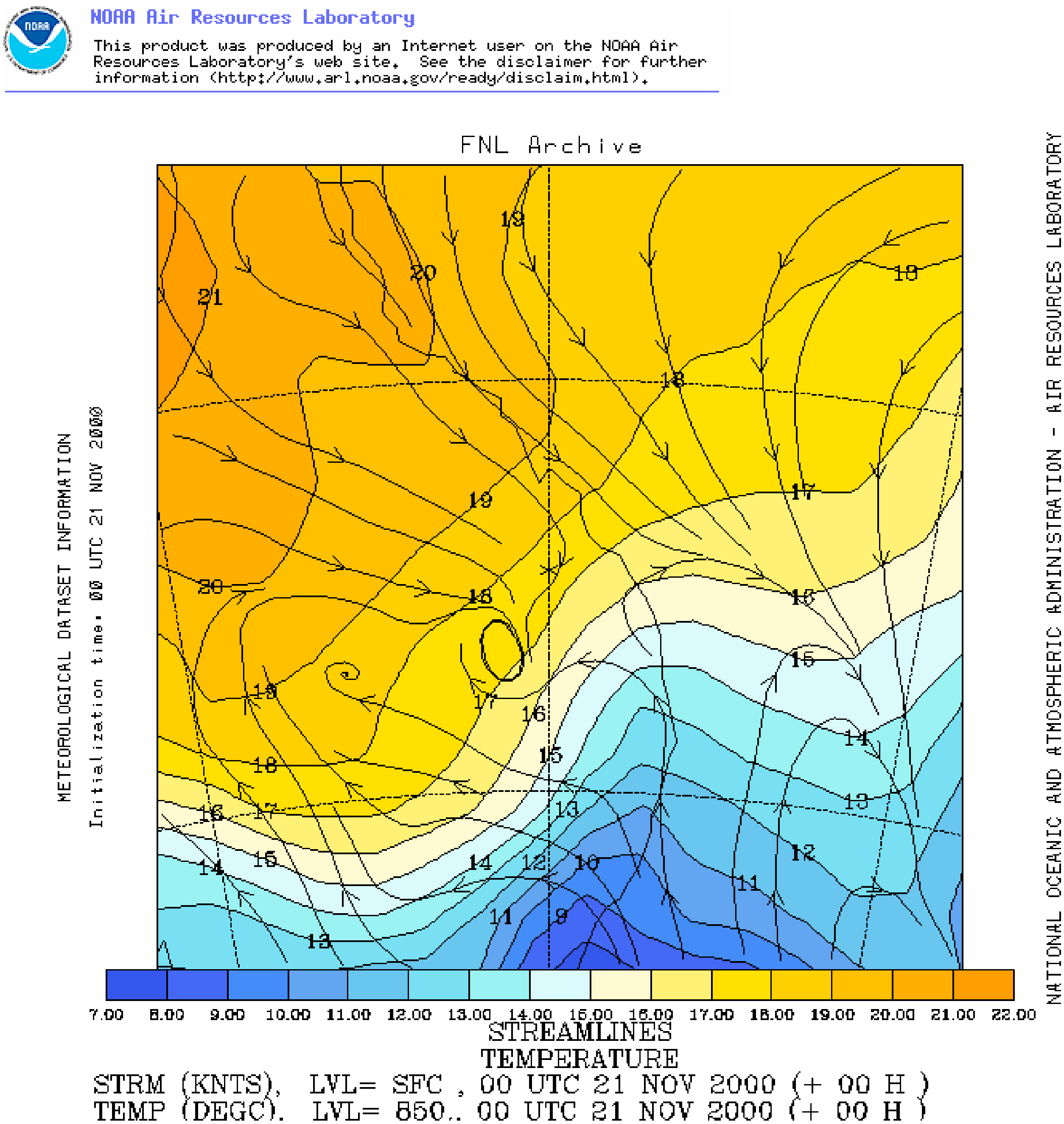
And 300...



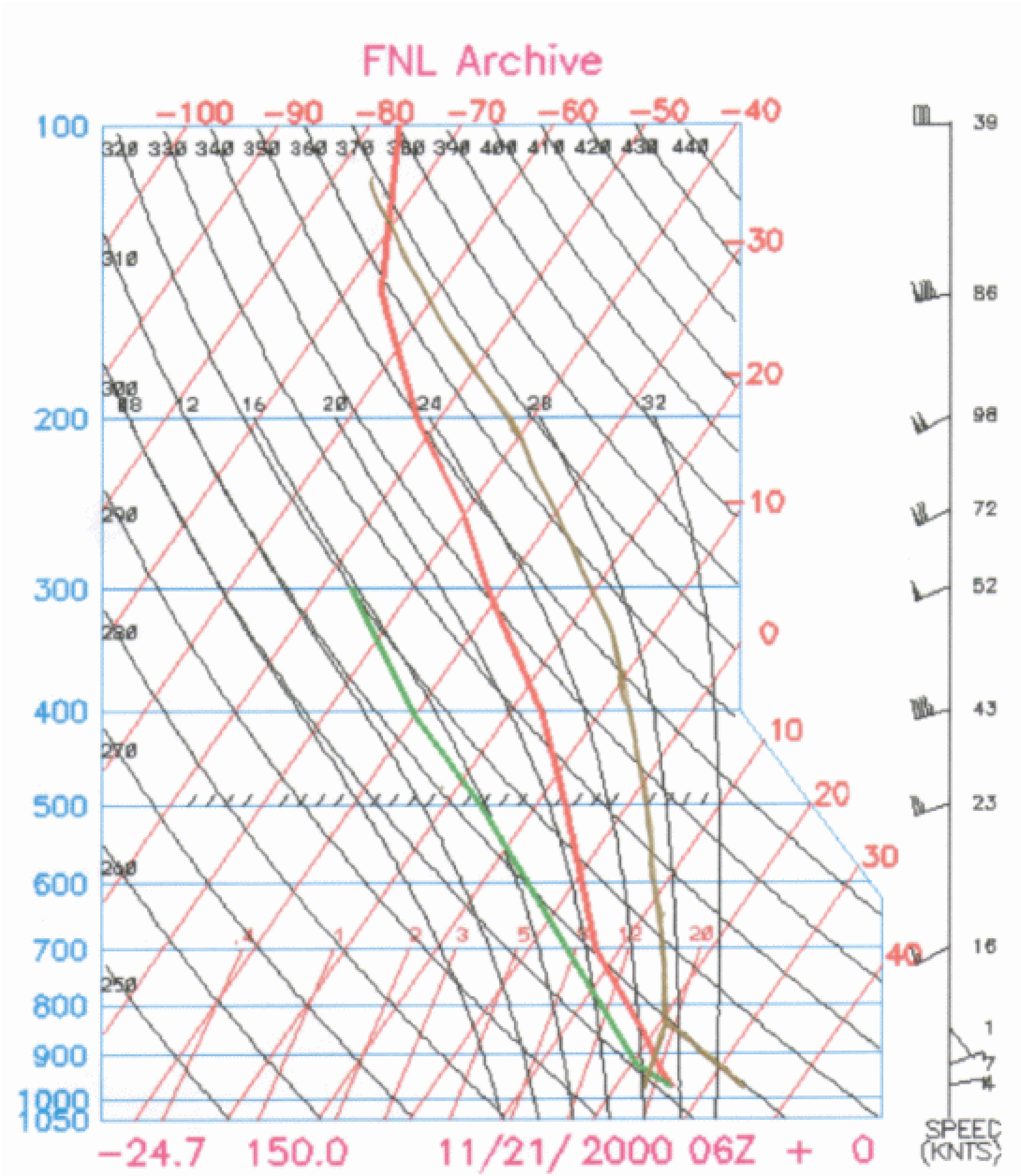
Not bad! We can see that due to a weak upper trough pushing into the region (allowing the air to rise), and the help of some diffluence we have some vertical upmotion happening, so this is going to enhance our instability. But before we look at the instability (the key on this day), lets re-assess our shear categories. I'm going to purposely apply the techniques from certainl thresholds. The reason why is to prove that they don't always work if you use them this way, they're meant as a guide...not as strict rules!)

Surface - poor (1)
850mb - poor-marginal (1.5)
700mb - marginal (2)
500mb - adequate (3)
300mb - good (4)
Total rating: 2.3 (marginal)

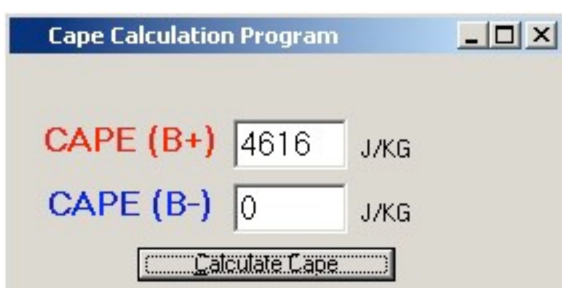
Our shear rating really isn't all that good...it's not horrible, but we could do a lot better in the shear ratings! Alright, so lets look at some other things...given shear isn't everything. But remember our cap didn't do us any favours (storms were roaring along not long after 11am...so the cap was quite weak). No surprise why when you look at the 850 temps either...



Storms started well south of that location and you can see cold air at 850 pushing into the region weakening the cap. One thing we haven't looked at is the instability. Keep in mind that we had nearly a week of storms...DPs were sky-high! In the low-mid 20s, and there was a very moist slab of air at the surface which was well mixed. Furthermore, temperatures quickly reached into the 30s by late morning...and we also had some elevated heating. So you might have already guessed we're going to have some nice instability...so lets look at a sounding!



Wowzers!!! That's some instabilty there!!! LIs of around -9 to -10...and CAPE of...



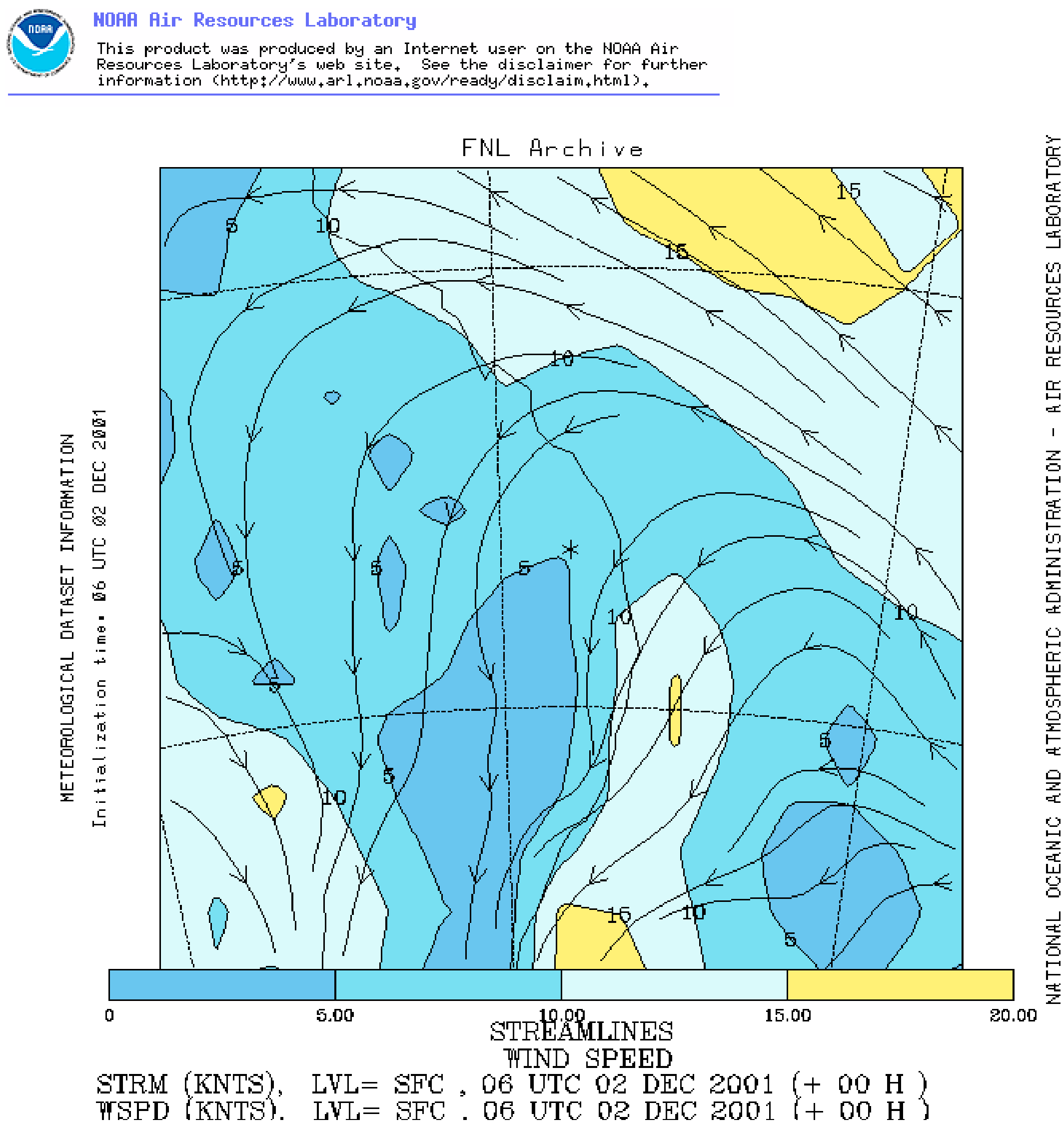
4600!!! The atmosphere is massively unstable! And this was the key to this day...we had marginal shear, but we had absolutely awesome instability. That allowed for severe storms to develop (and this supercell)...this is just one example of how the "tradeoff" can work, and how you have to look at the overall picture, not just a few things! I'll continue on now with some even "more marginal" situations...

Severe Thunderstorms in Low Shear

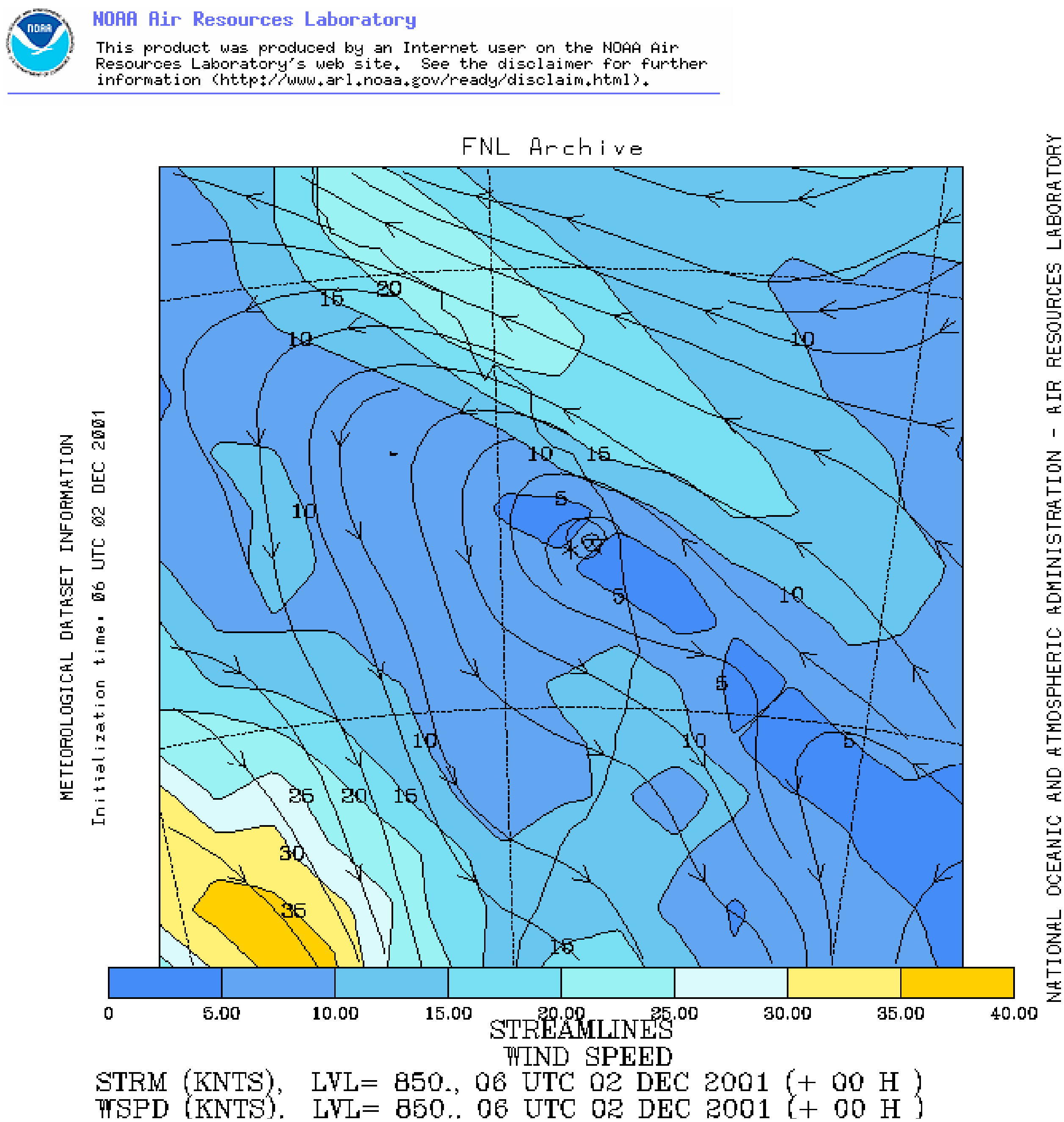
Wide Bay Case Study - Dec 2, 2001

We've just seen a great example of how instability can help offset shear. This is another example...no supercells on this day, but some roads were closed in the Brisbane Valley/Wide Bay region from trees over them! So certainly no shortage of severe weather. The day was forecast and also analysed very poorly from models...the models grossly nderforecasted moisture (hence the forecast was for -1 LIs!) But there was plenty of moisture with a fairly thick moist layer too as a deep easterly flow developed. Once again we'll look at shear and give them ratings like before to prove the ratings incorrect! Oh, before a quick snapshot of what happened. Check out the chase report of this day...for us, the best stuff was photogenic really. But notice the powerful updrafts? We can already see that the real LIs were not -1 on this day!

Ok...surface flow



We're off to an OK start...5-10 knots puts it in our marginal range...but so often I see weak winds at the surface for storm events (which is unfortunate). You can see the exstensive northerlies coming off the Coral Sea too...so plenty of moisture at the surface!



850mb doesn't really strengthen at all...we hover around the same 5-10 knots (poor-marginal)...once again we can see that we have extensive northerlies with the origin over the Coral Sea...hence our backing for a deep moist layer (also it was very visible by the amount of low level cu early in the day). Note the anticyclonic rotation over the Wide Bay area? (Asterix)...hmmm...I normally associate that with fairly warm 850 levels, lets have a quick squiz at the 850 temps!

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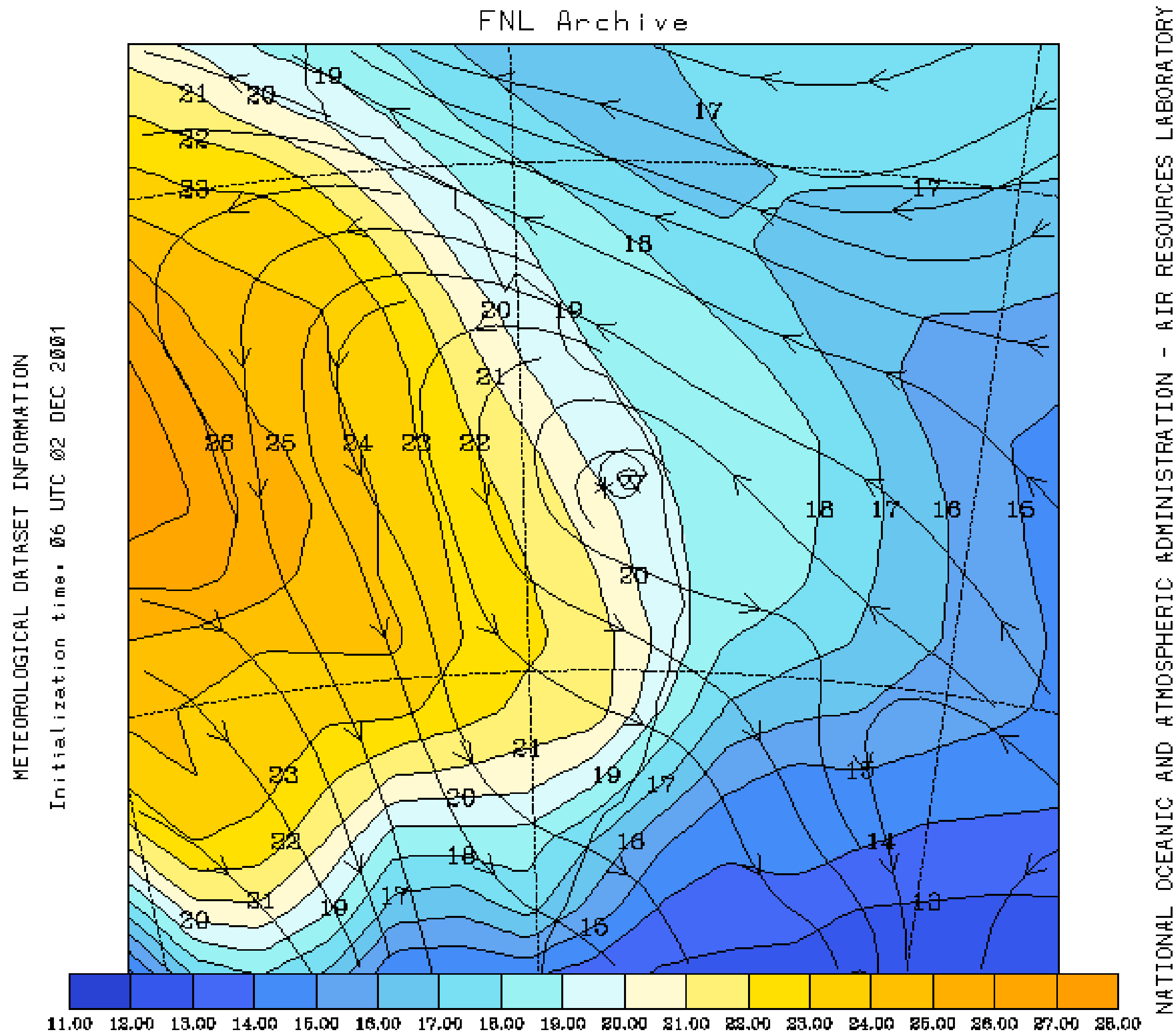
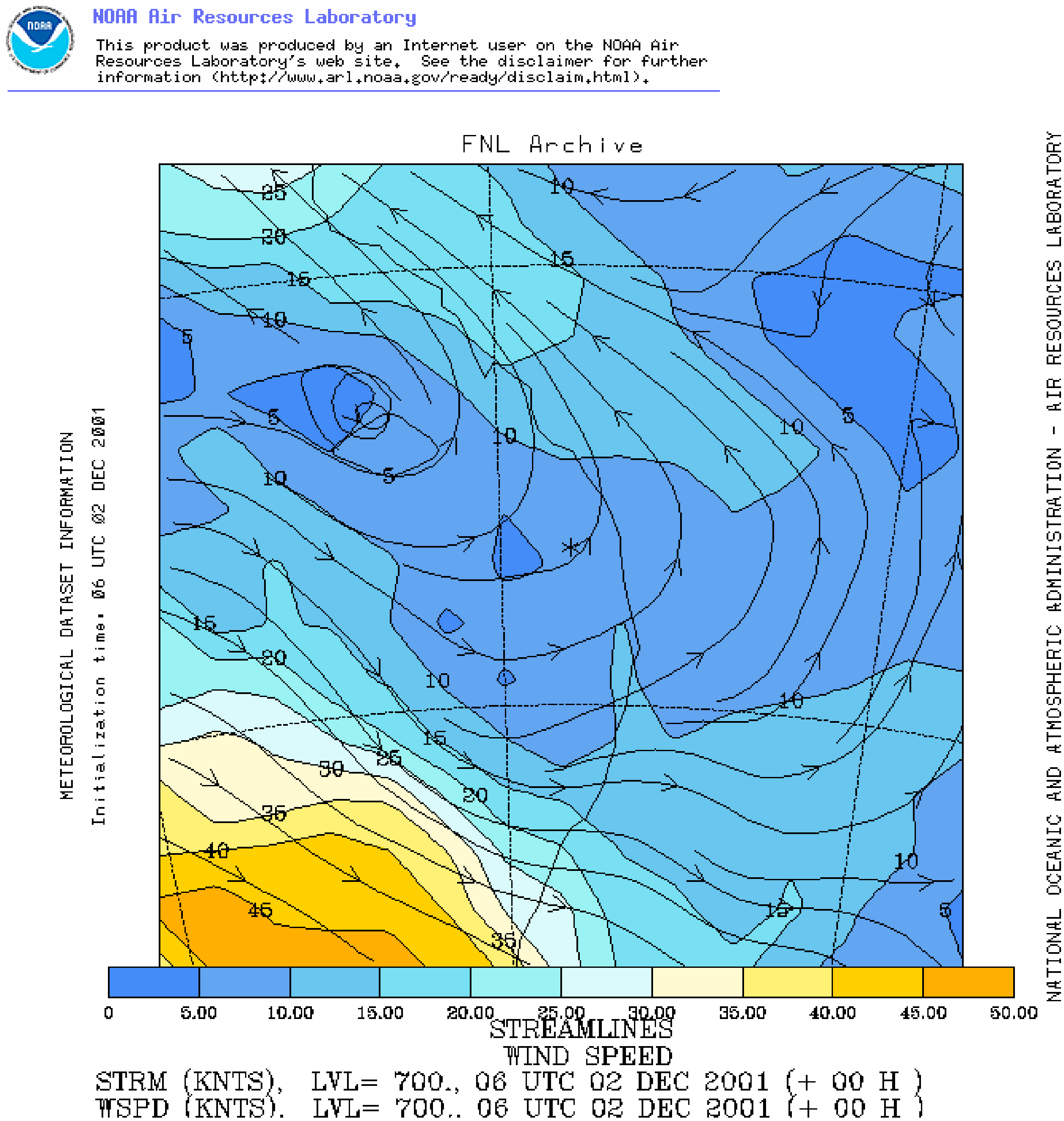


STREAMLINES
TEMPERATURE
STRM (KNTS), LVL= 850., 06 UTC 02 DEC 2001 (+ 00 H)
TEMP (DEGC), LVL= 850., 06 UTC 02 DEC 2001 (+ 00 H)

That's not too bad...850 temps of around 20C, so the cap is fairly strong, but it could be broken. Development on the Downs was during the afternoon...but the main Wide Bay development exploded late in the afternoon after 4pm...here we see that the cap held the convection until late in the day when it was able to release all of the energy! Had the cap broken earlier, then things may have become cluttered (they sometimes can in low cap, low shear, high instability situations - but not always as before in the previous example). Lets look at 700mb to see if shears gets any better there!



Urk! This is clearly not looking good for shear, 5-10 knots (poor) at 700! What about 500 and 300...

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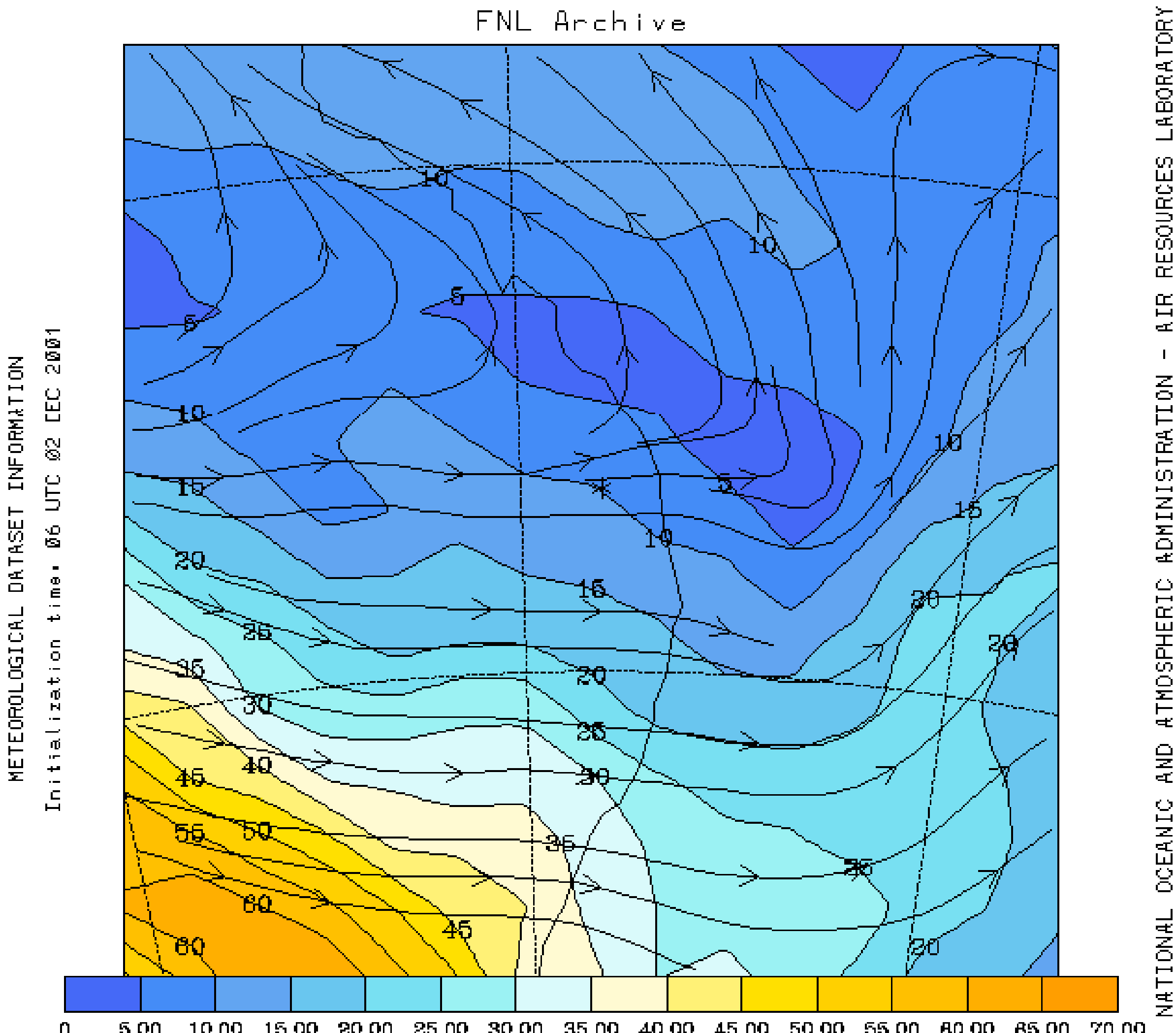
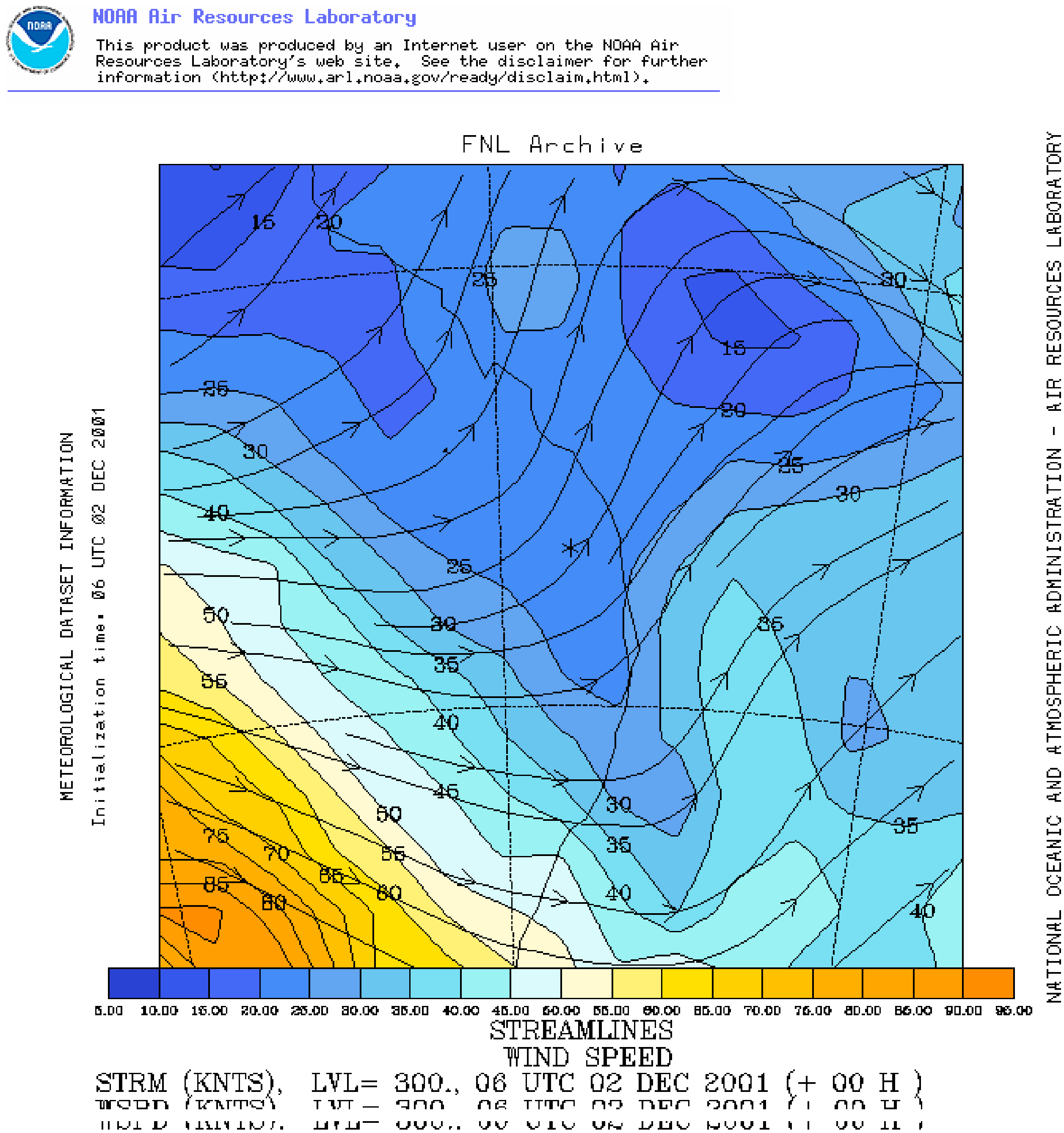


STREAMLINES
WIND SPEED

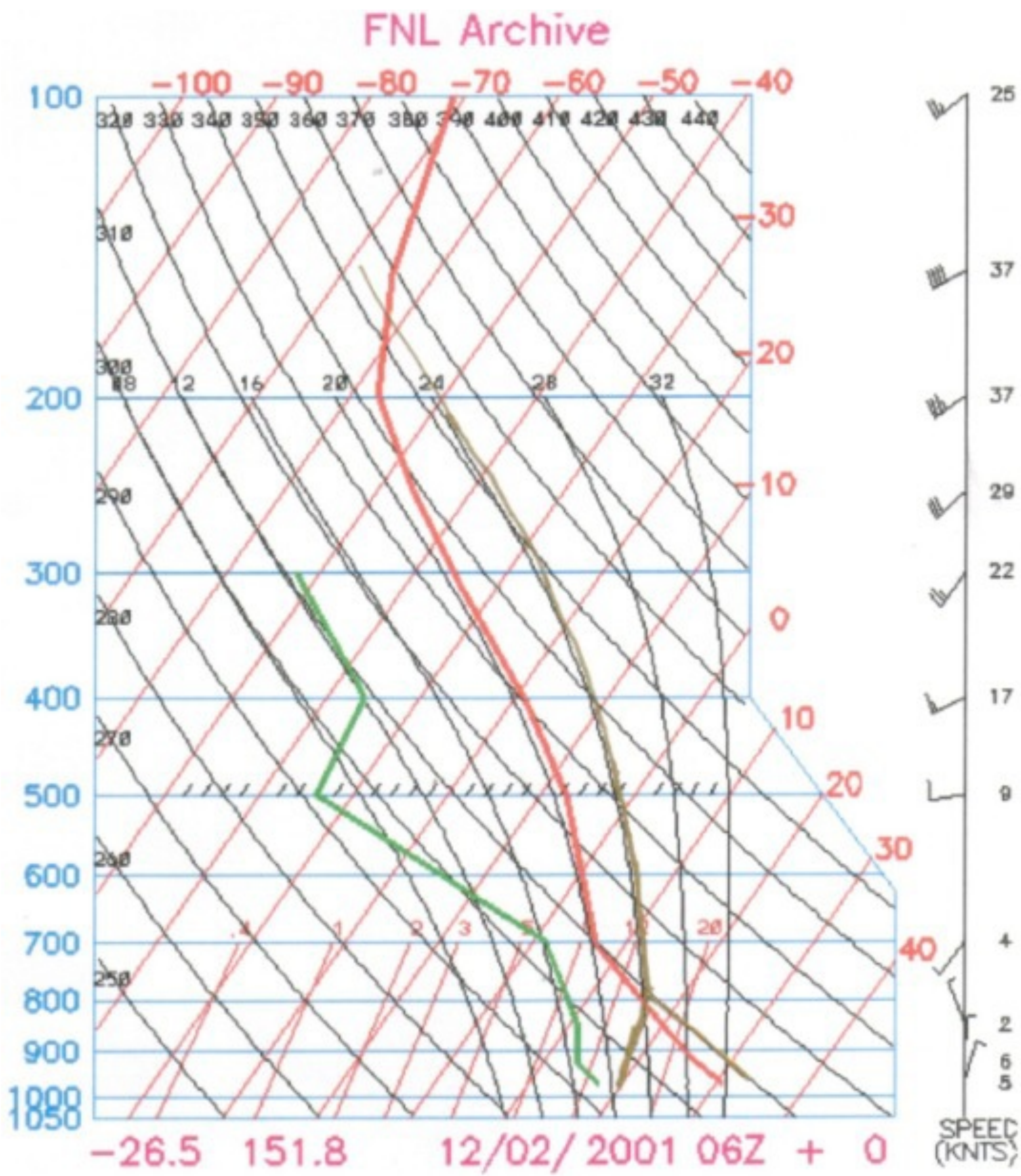
STRM (KNTS), LVL= 500., 06 UTC 02 DEC 2001 (+ 00 H)
WSPD (KNTS), LVL= 500., 06 UTC 02 DEC 2001 (+ 00 H)



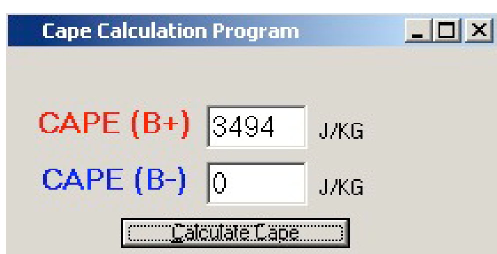
No good really...500 is 10-15 knots (poor) and 300 is 20-25 knots (marginal). We do have some good directional shear though...turning from the NNE towards the W in the lower 6km which is something! But really, shear is bad...again, lets look at the cutoffs in strict terms:

Surface - marginal (2)
850mb - poor-marginal (1.5)
700mb - poor (1)
500mb - poor (1)
300mb - marginal (2)
Total: 1.5 (poor-marginal)

We can't even attain marginal status here! What hope do we have of severe storms you might ask? Well they still happened! Once again, lets look at a Skew-T and plot some instability...I've adjusted for maximum potential on the day with a much deeper PBL than was analysed (to something more accurate).



Some nice instability once more! Sure, not as much as Banana, but lets look at CAPE, it's bound to be impressive again!

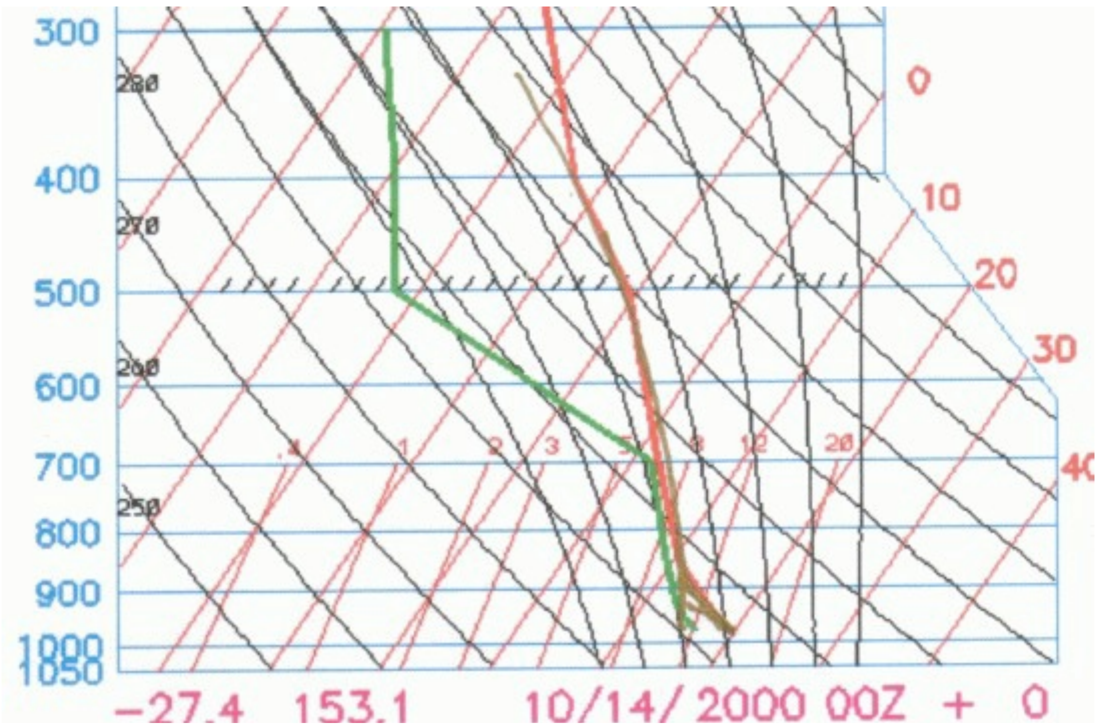


Nearly 3500!!! That's still some awesome instability! The instability and the strong cap is what helped develop severe storms on this day despite the absoutely horrible shear! Another example where in theory severe storms shouldn't have happened but they did! So lets look into a different type of setup...what about lots of shear and little instability?

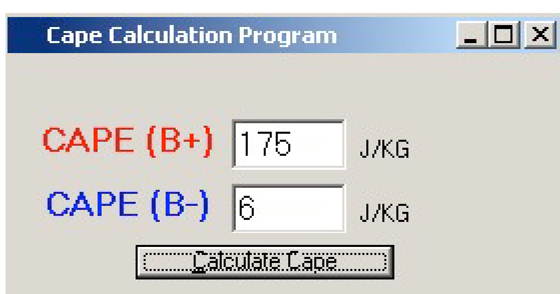
Severe Thunderstorms in Low Instability

Ipswich Tornado - Oct 14, 2000

This was an interesting little day. It produced a small tornado through the southern edge of Ipswich, with other possible tornadoes reported in Brisbane (only weak also thankfully!) The tornado I encountered was rain-wrapped and it actually passed within metres of the car! (My car nearly got pushed off the road)...once again, check the chase report to get an idea on what happened on this day. This was an interesting day...don't see too many of them up here in Brisbane. You'll see what I mean...first lets look at some instability.

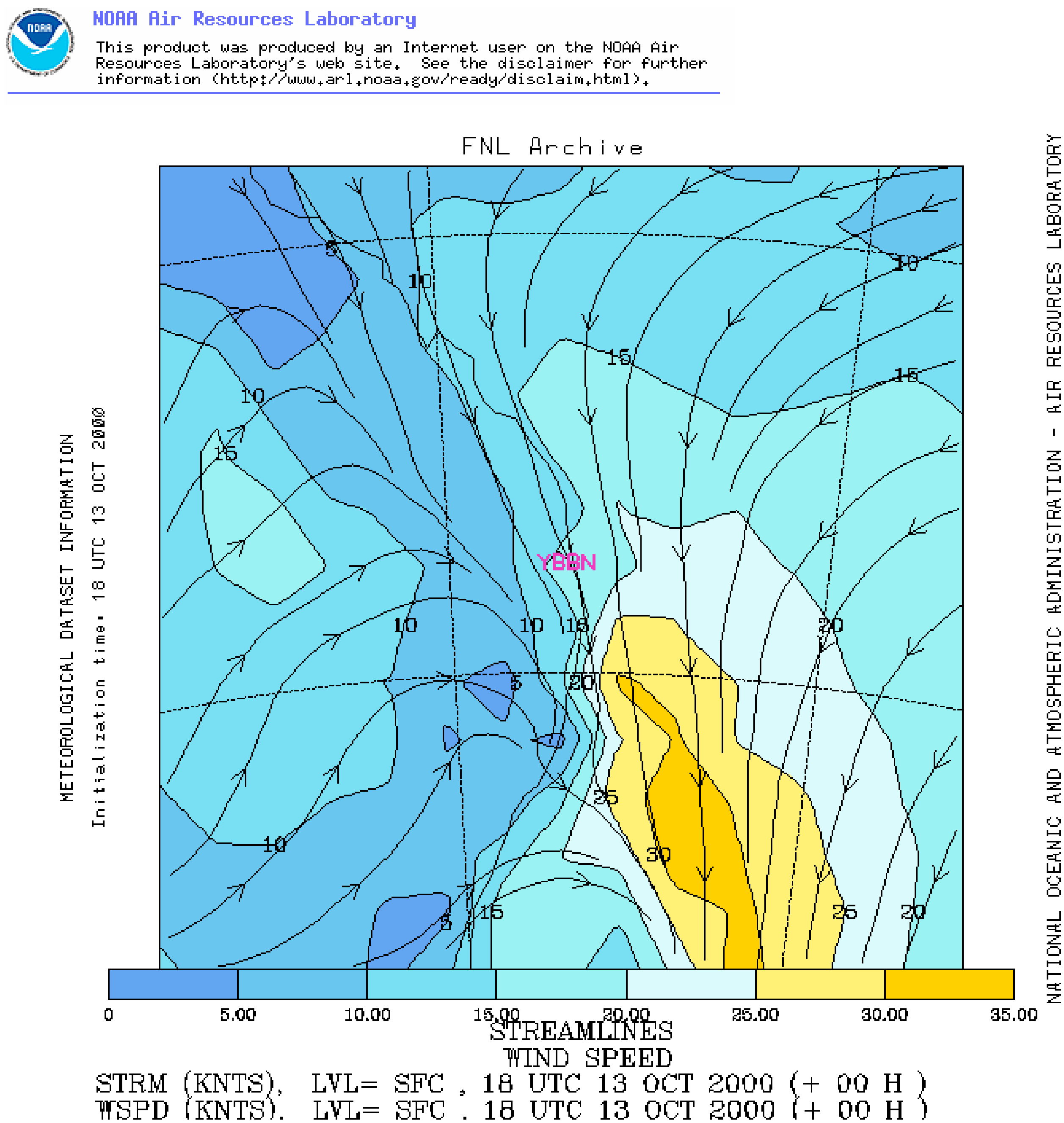


Interesting plot here...do I have the right day? Yeah I do! Did I plot the right temp/DP on it...well, it got a lot warmer than 20C...but the squall line was pretty much all over by 10am! I've plotted an archived FNL sounding here...if you see the chase report there's a sounding at 10am which was plotted with even less potential than this! So I'm perhaps even over-estimating the instability! But it did dry out a tad by the time the sounding went up. Lets check the CAPE...



175!!! And there was a tornado!!!!! (Possibly more than one) - what on Earth is going here!!! These tornadoes are what (Victorians) call "cold air tornadoes." It can be a bit of a misnomer because tornadoes can form in similar situations in "warm air" - but essentially "cold air tornadoes" develop in high shear profiles with limited instability. So if shear was that good lets get cracking! Although I want to point something else out - it's not just the shear, it's the dynamics. The air around the area was rising fast and that was helping storms - and also keep in mind that this situation actually developed the day before and became a squall line. Sometimes you can get high shear days with low instability that just don't work because the updrafts just aren't strong enough to stand up to the shear. So it can take a bit of discression to try and work out these "boundaries."

I'm going to use an 18z surface map to get an idea what the surface was like prior to the event, and then use 00z 850mb and above maps because they're more relevant to the time when the squall line and tornado went through SE Queensland.



You can see the trough/front just to the west of Brisbane giving a probable dryline along the periphery...the day before we had some rain, so plenty of moisture ahead of the front. Also, some fairly strong northerly winds, 15-20 knots over Brisbane...decreasing closer to the front, but prior to the front, northerlies were quite strong! 20-25 knots or so which were very nice! A quick look at surface moisture will show that the main dry air is sitting just behind the trough (so along the front). Note how SE QLD/NE NSW stays relatively moist, even though how in previous sections it was taught that an ill-defined boundary can cause dry-air mixing? We were lucky that we had rain the day before...it kept things moist and delayed the dry air somewhat!

Onto 850mb...

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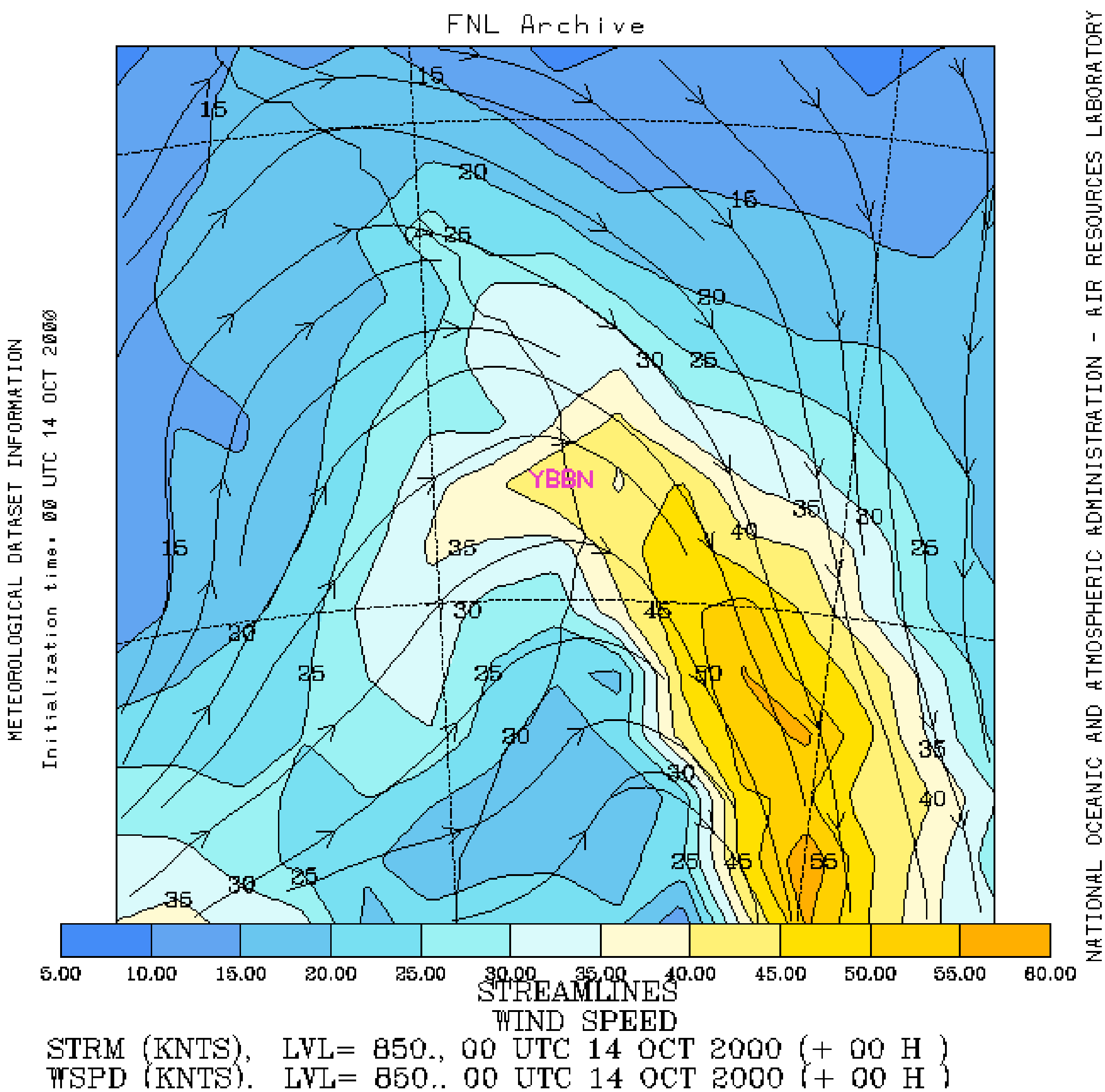
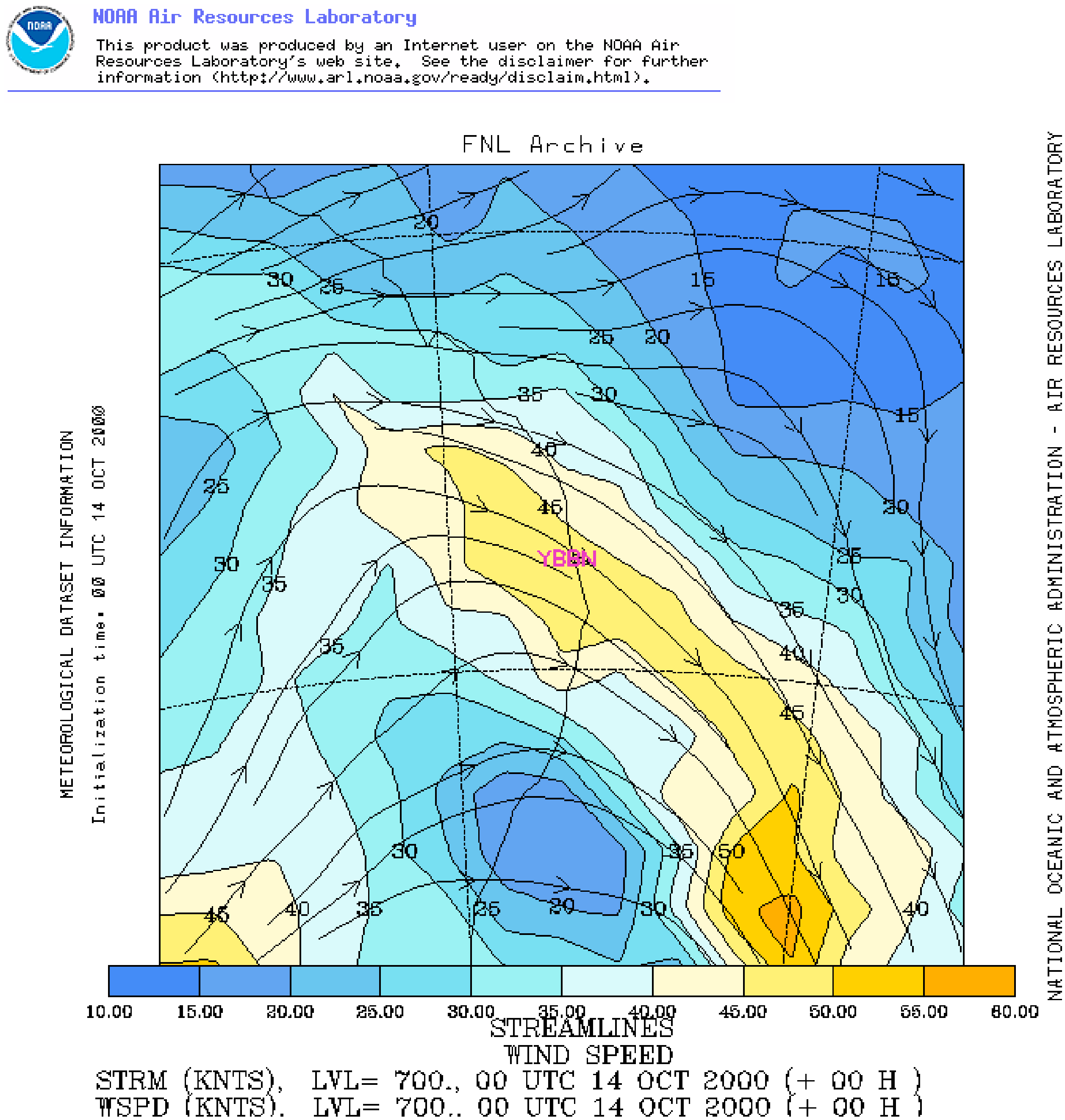
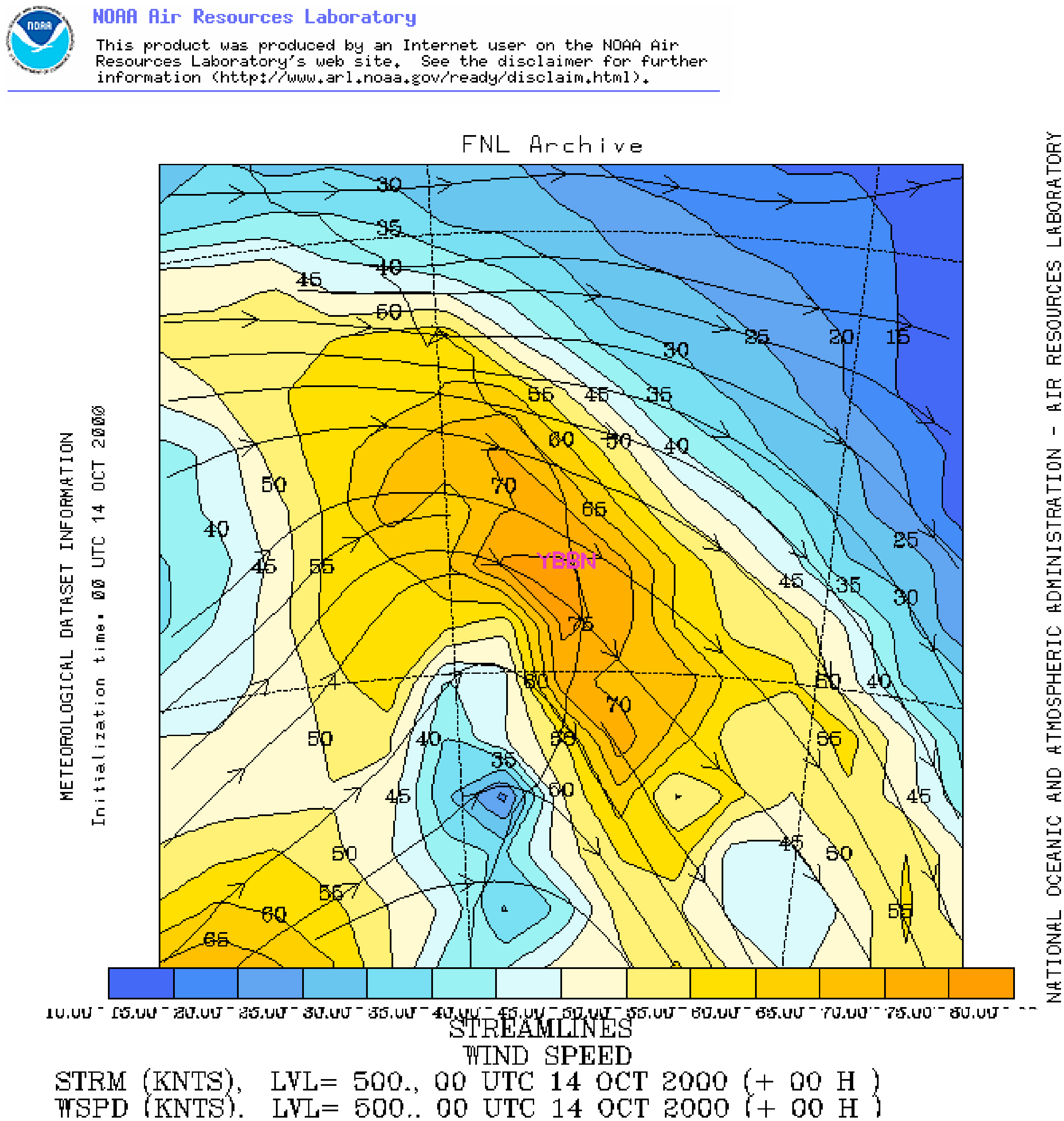


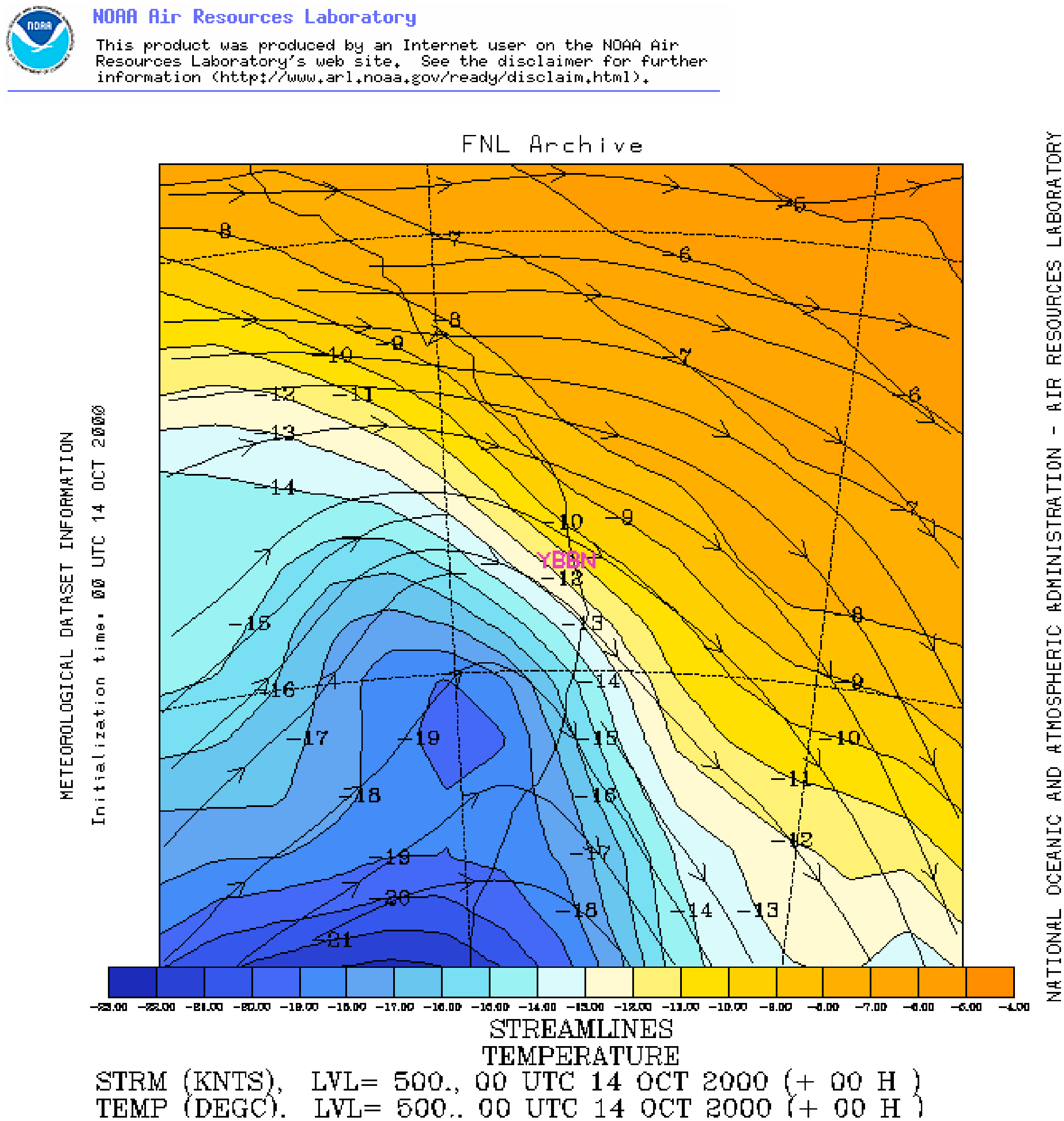
Our directional and speed shear wastes no time either when you check out 850mb! 40-45 knots over Brisbane...very impressive!!! In fact, if you were to look at our approximate supercell threshold, it's pretty much just been satisfied already going from the surface to 850mb...yet we're going to expect even stronger shear as we go higher in the atmosphere...



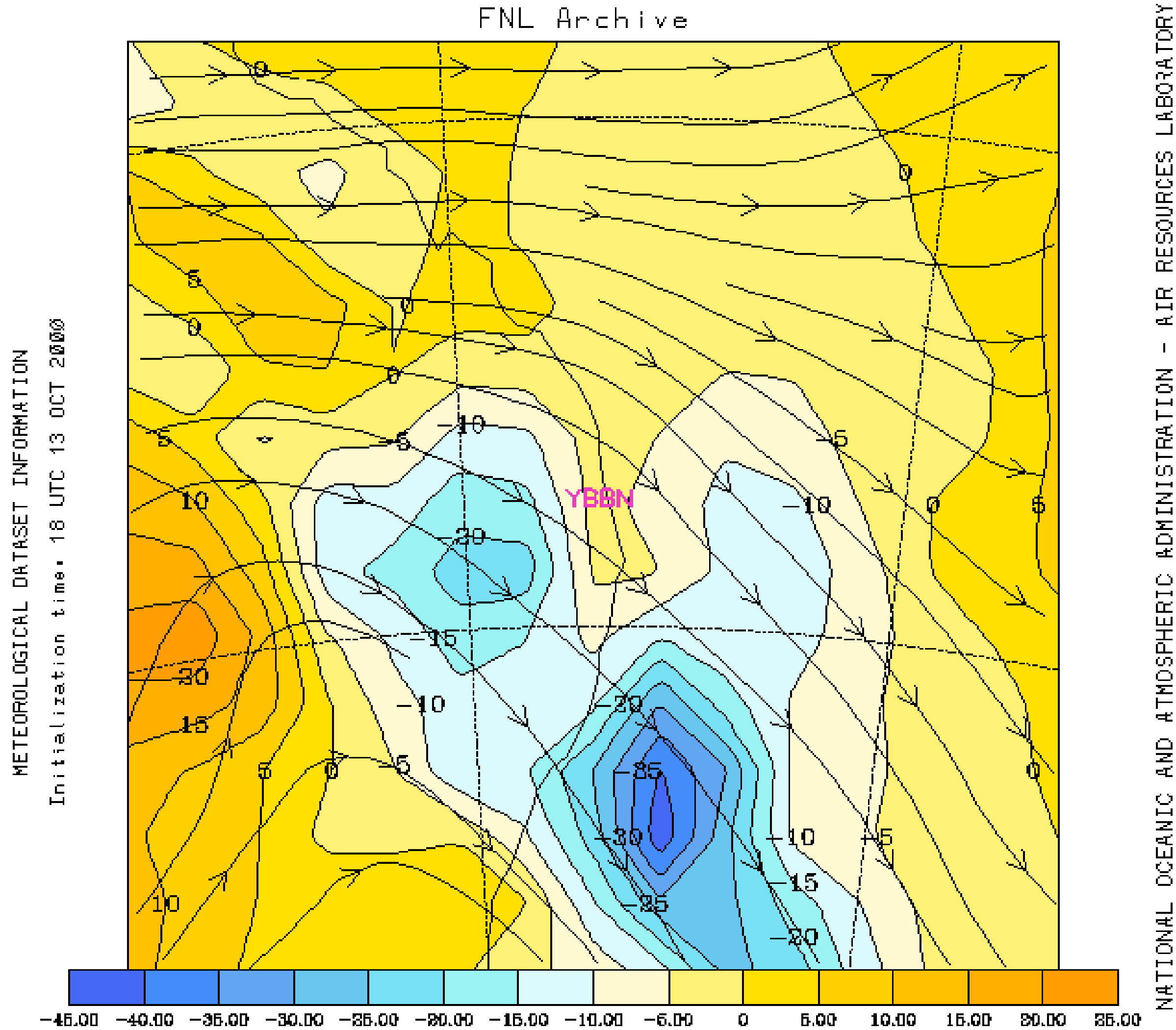
Interesingtly, the 700mb shear tilts back towards the NW - it's in response to a cold pool pushing into NSW. Oh, 45-50 knot NW'lies too!



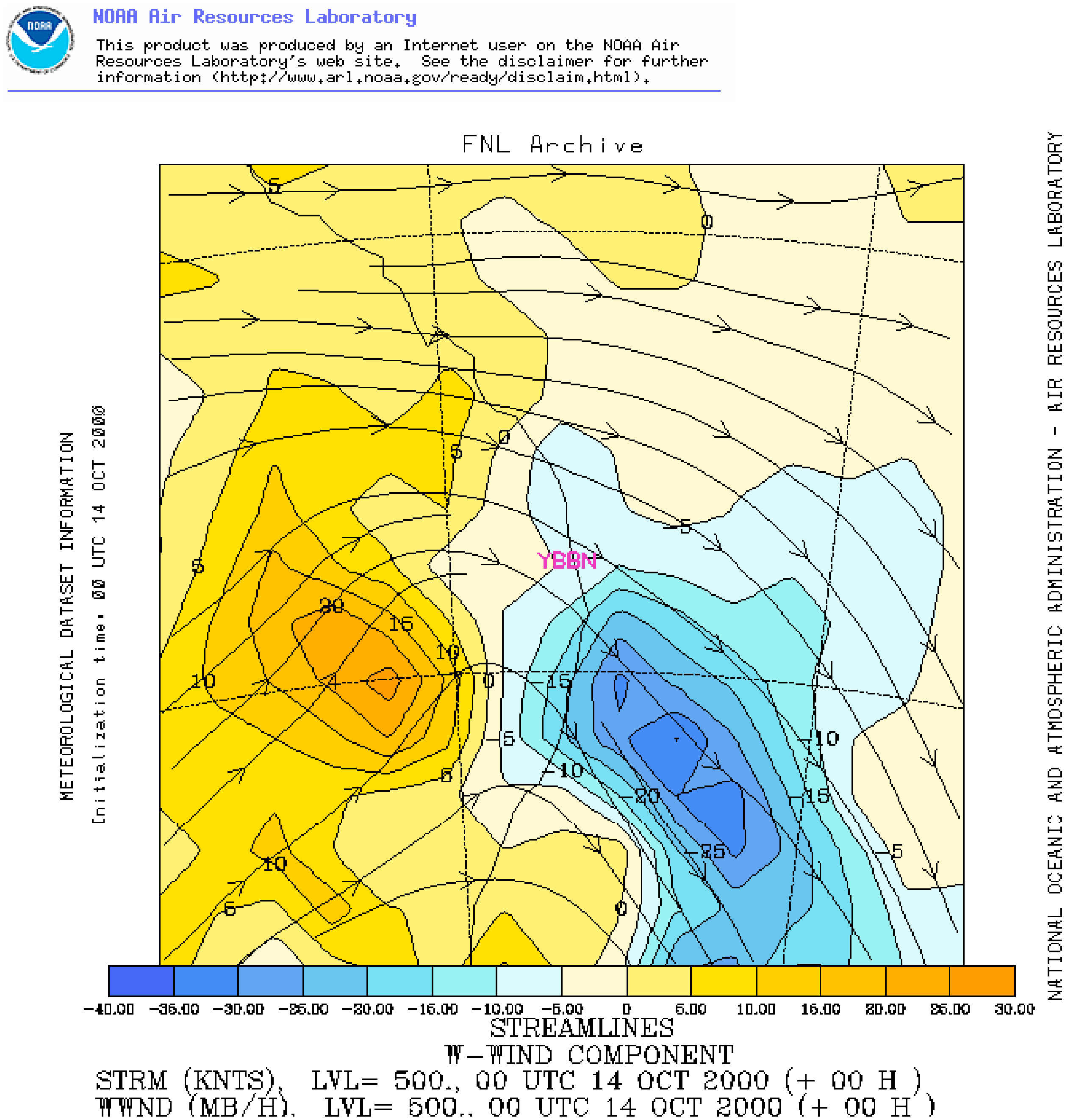
The 500mb shear was nothing short of awesome either...solid 75 knot WNW'ly over Brisbane and SE Queensland! Certainly looking good shear wise...lets check that cold pool which is responsible for the shear!



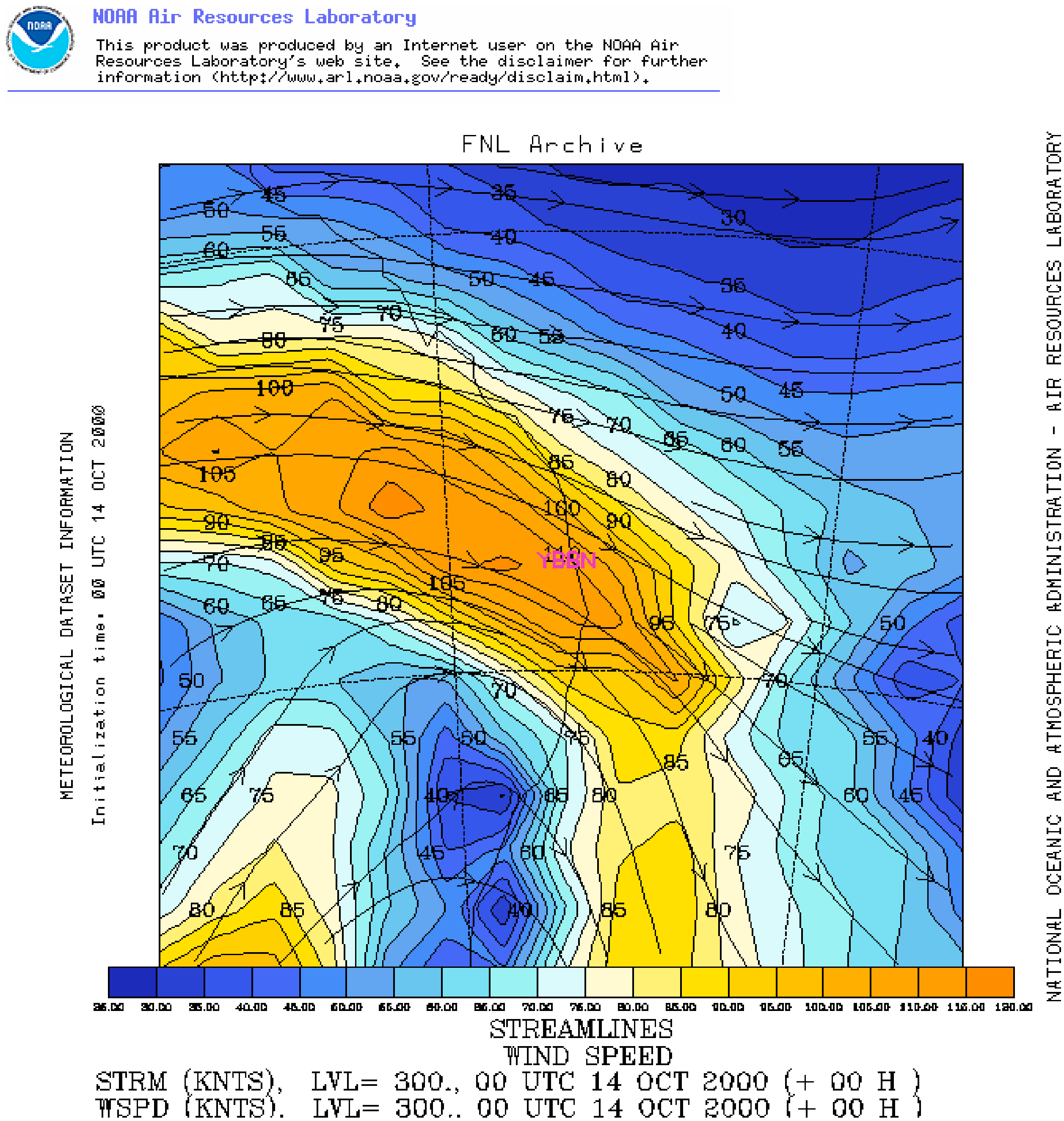
That's a great cold pool down in S NSW, and there's a small extension pushing northwards which is providing the shear. Remember how the strength of upper cold pools/troughs can be seen by looking at how much colder the air is to the relative surrounding regions of the same latitude? Have a look to the east of the -19 cold pool...getting down to -9/-10 there! So we know it's pretty considerable (although the -9 to -10 is quite warm for that region in October). But just seeing how much the cold air protrudes into warmer air should give you some idea about its strength. We also know that strong temperature gradients cause strong pressure gradients in the upper levels and therefore causes strong shear...and this certainly shows it well! Lets check the vertical motion at 500mb to! I'll do 18z and 00z, because during those terms the favourable vertical motion moved over SE QLD...



STREAMLINES
W-WIND COMPONENT
STRM (KNTS), LVL= 500., 18 UTC 13 OCT 2000 (+ 00 H)
WWND (MB/H), LVL= 500., 18 UTC 13 OCT 2000 (+ 00 H)



You can see here how fast this system was moving with favourable VVs moving quickly off the coast (although still hugging the coast at 00z)...some nice upmotion though, -15 to -20! So the vertical motion is enhancing the updrafts, possibly contributing to additional "effective CAPE." And finally 300mb shear...



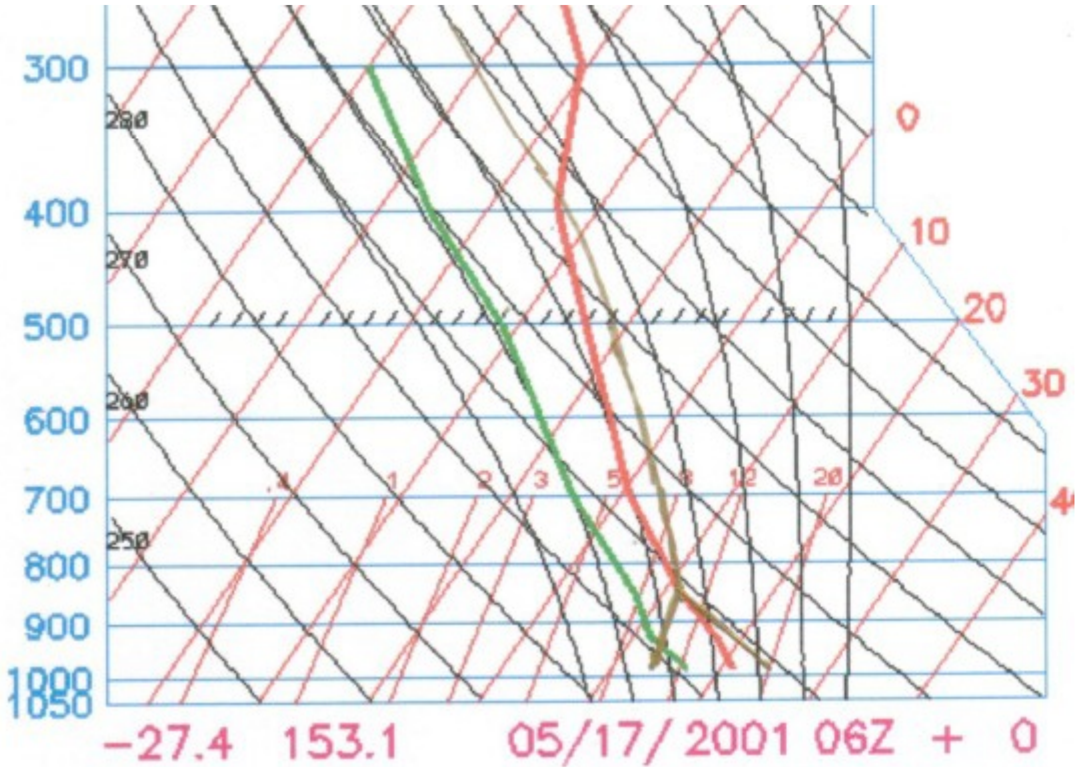
300mb didn't disappoint either...110 knots over Brisbane...this is some fantastic speed shear and directional shear is pretty good too! This is primarily the reason that such an event (ie tornado) developed on this day, even though instability was extremely poor (CAPE of 175, LIs barely negative!) Certainly it shows that just how shear isn't everything, neither is instability - and it demonstrates how one can offset the other. And it's just yet another situation where thunderstorms decide to break the rules!

Severe Thunderstorms In Low Instability

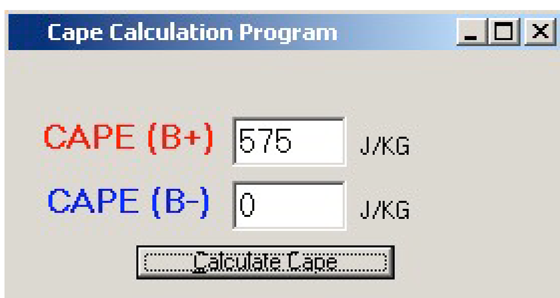
Amberley-Warrill View Severe Storm - May 17, 2001

Ok...time for another situation, this was a nice day with a storm moving rapidly SE between Amberley and Warrill View bringing one foot hail drifts and plenty of trees down! Perhaps the most impressive things were that the storm moved quickly yet brought so much hail! Check out the chase report if you're interested! A few captures...

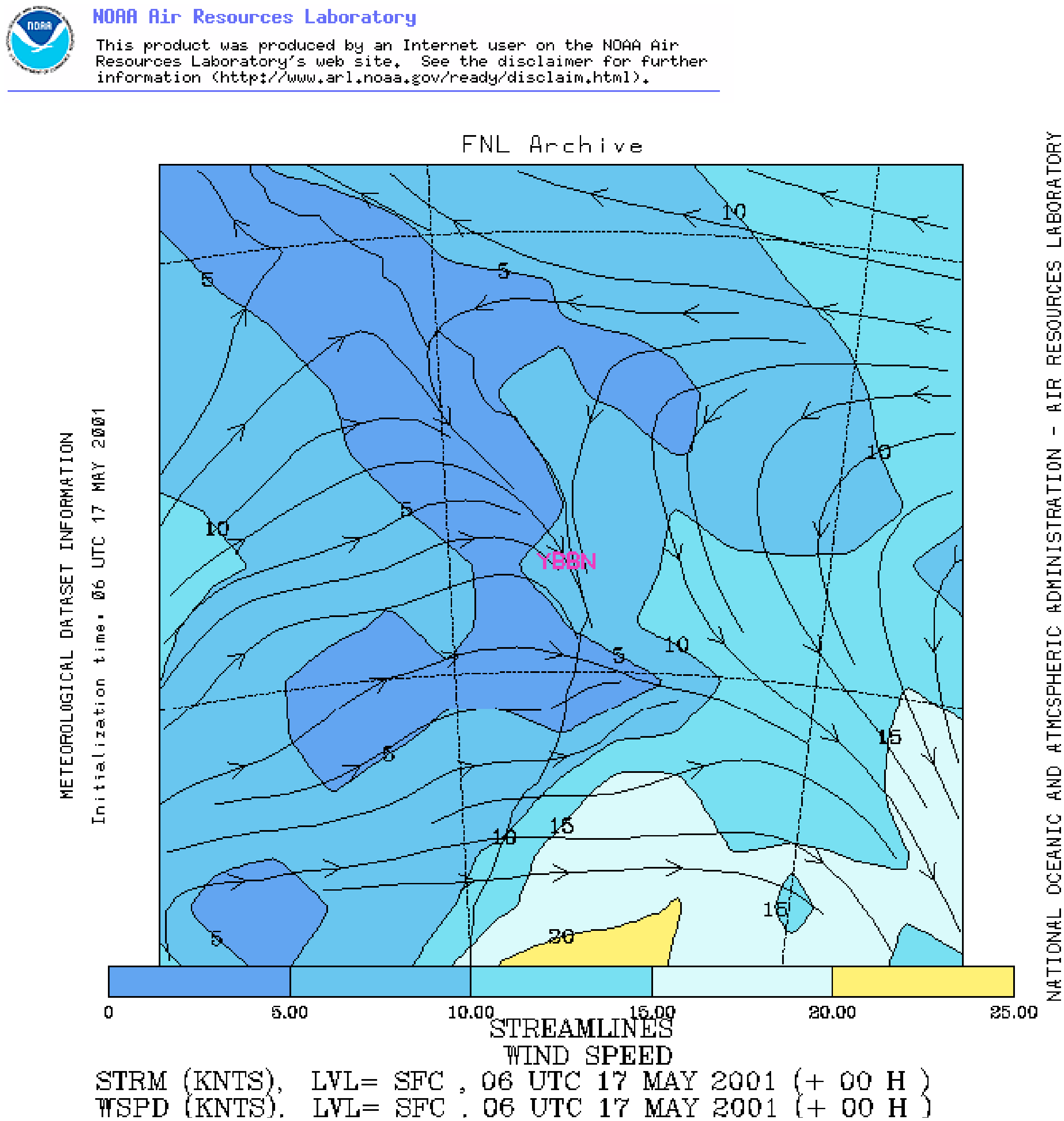
(No it's not snow, it's all hail!)
Anyway...onto the analysis...first some instability, lets have a gander at a Skew-T!



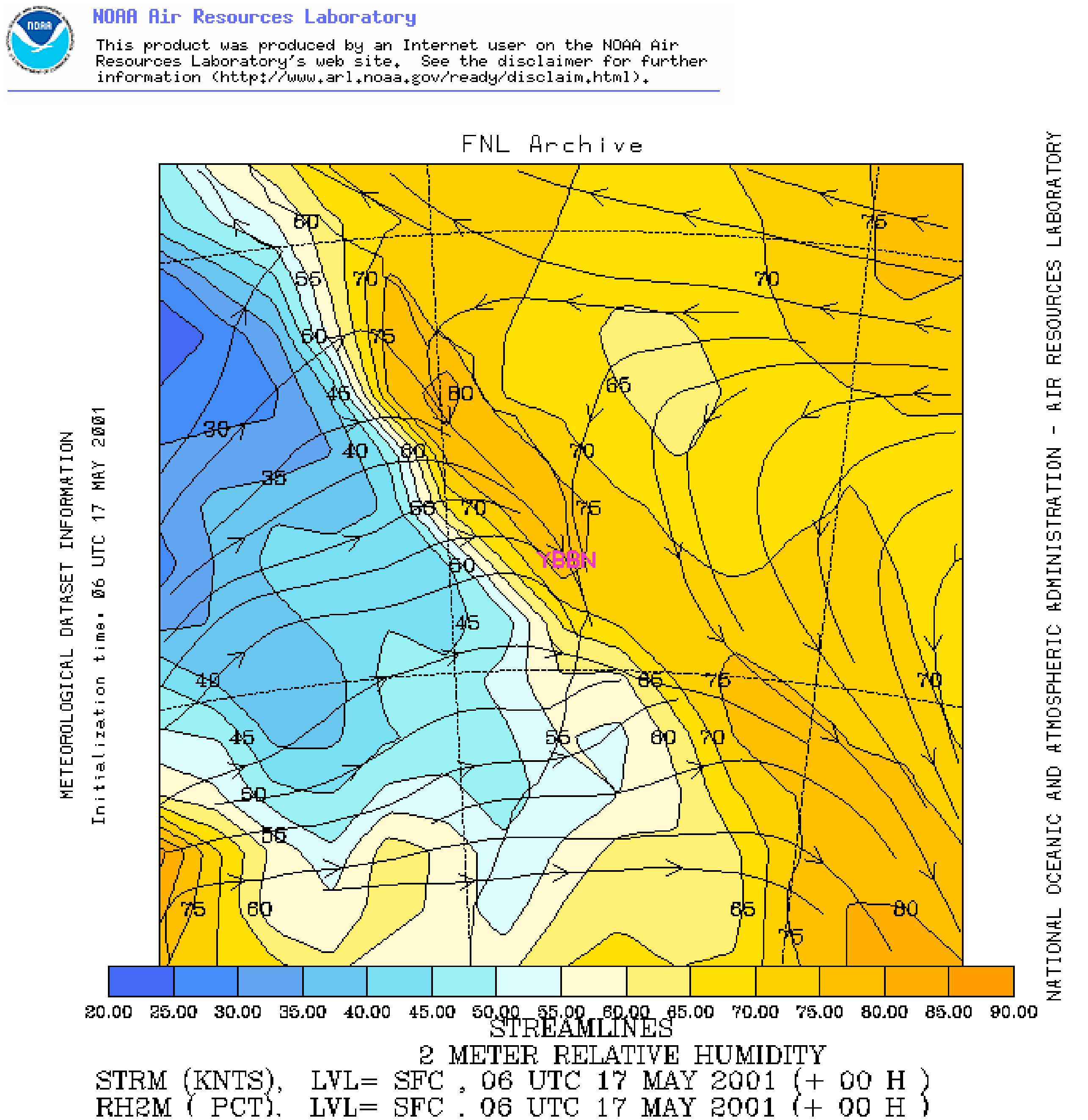
Hmmm...well, we have a bit more instability than the last situation at least! Still not that great, LIs are -2 though...but they're fairly consistently -2 throughout the instability region. One thing that is important is how the instability is stretched out, for instance lets see what CAPE is like...



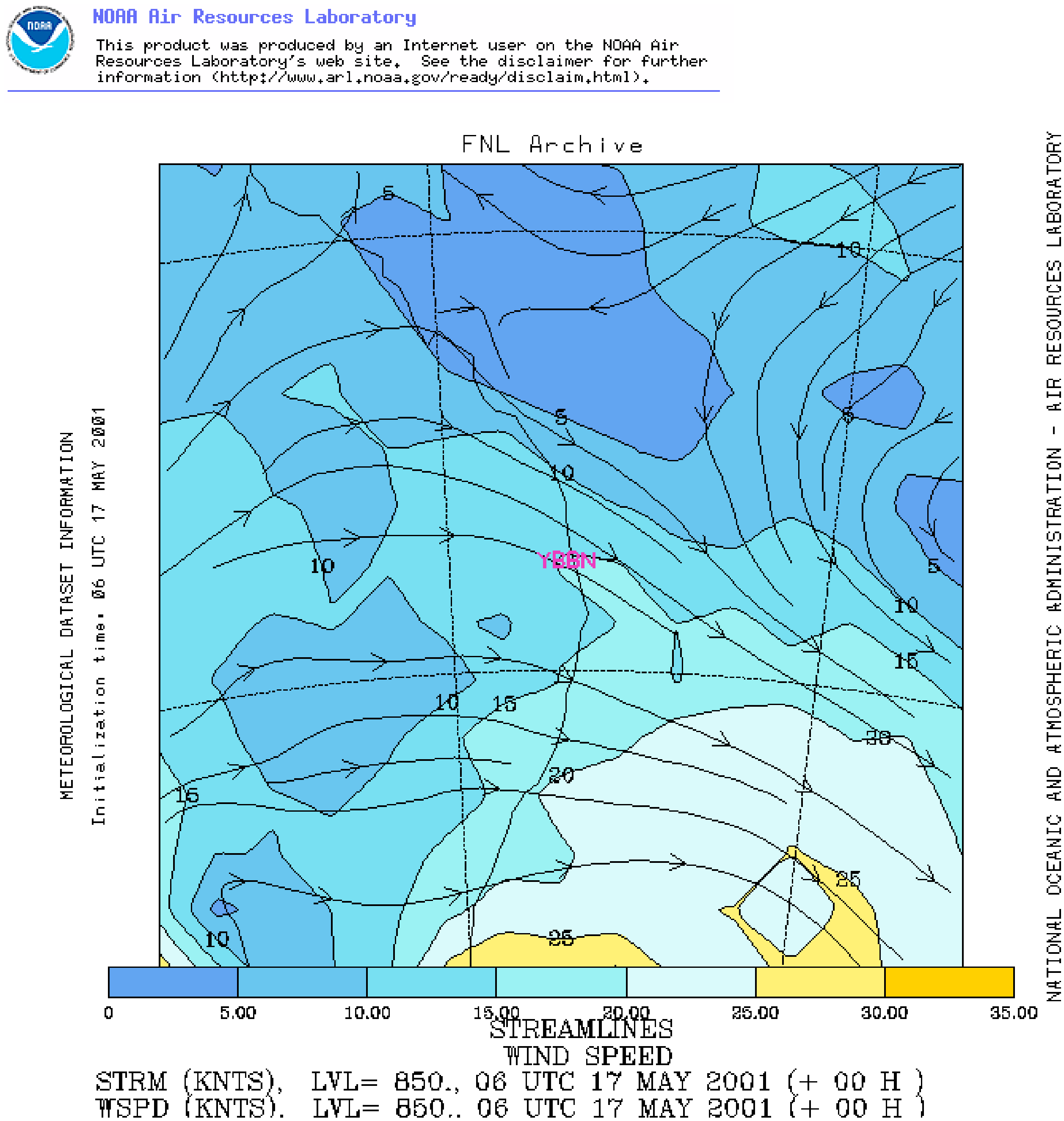
575...not exactly fantastic! But most of the CAPE is between 800mb and 400mb, and that actually helps us a bit. How? Well, the CAPE is "compressed." For instance, say the CAPE was spread from 900mb to 300mb, well because CAPE is simply a function of area underneath the Skew-T, if we make the length longer (depth of instability), we must make the width shorter (strength of instability at a given point). See what I mean? So you can have two situations where CAPE is the same, but the situation that has the CAPE in a more confined area tends to be the one that would give you stronger storms! Ok...so the shear and setup...



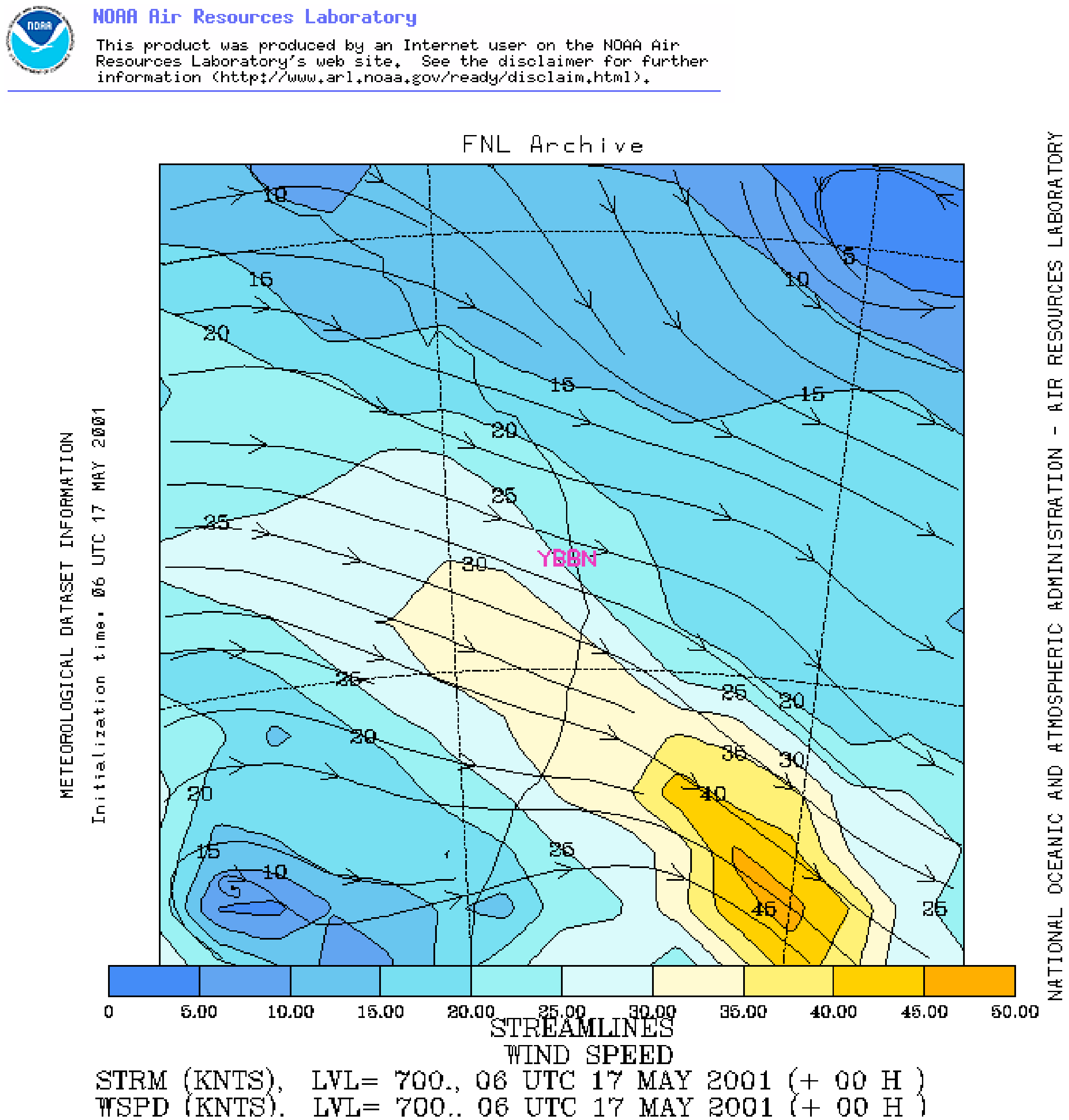
Wozers...trough is right over Brisbane and there's some nasty westerly winds pushing in...already not looking that crash hot! But still...we've seen the proof and we know what happened! However westerlies aren't always bad...it's often important to look at the surface moisture too. I didn't save any specific humidity charts, so we'll have to look at an archived surface humidity one!



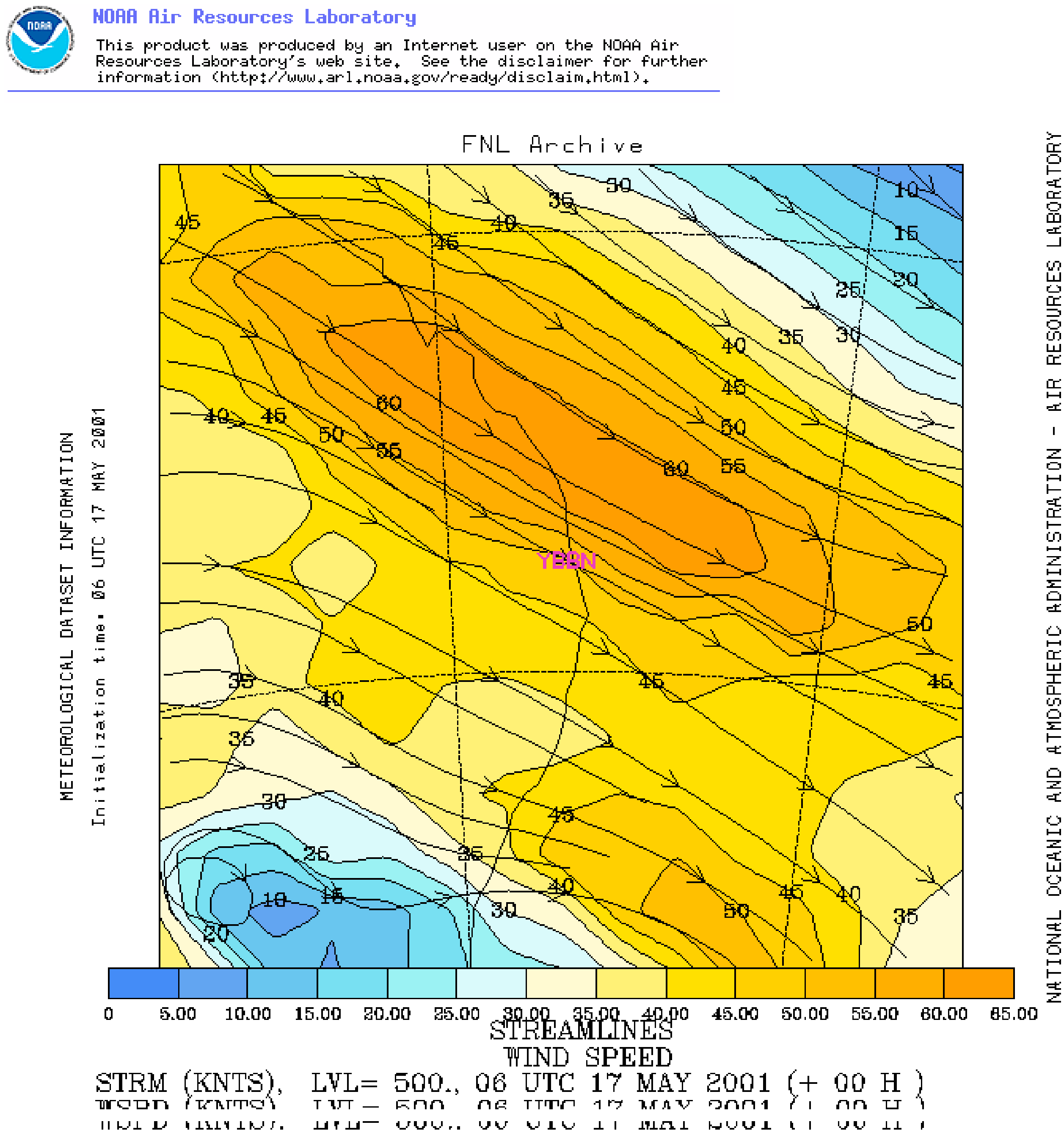
You can see it does dry out just behind the main trough, so this was a big help to us! It didn't dry out straight on the trough like it often can. So with that, lets look at the remainder of the levels.



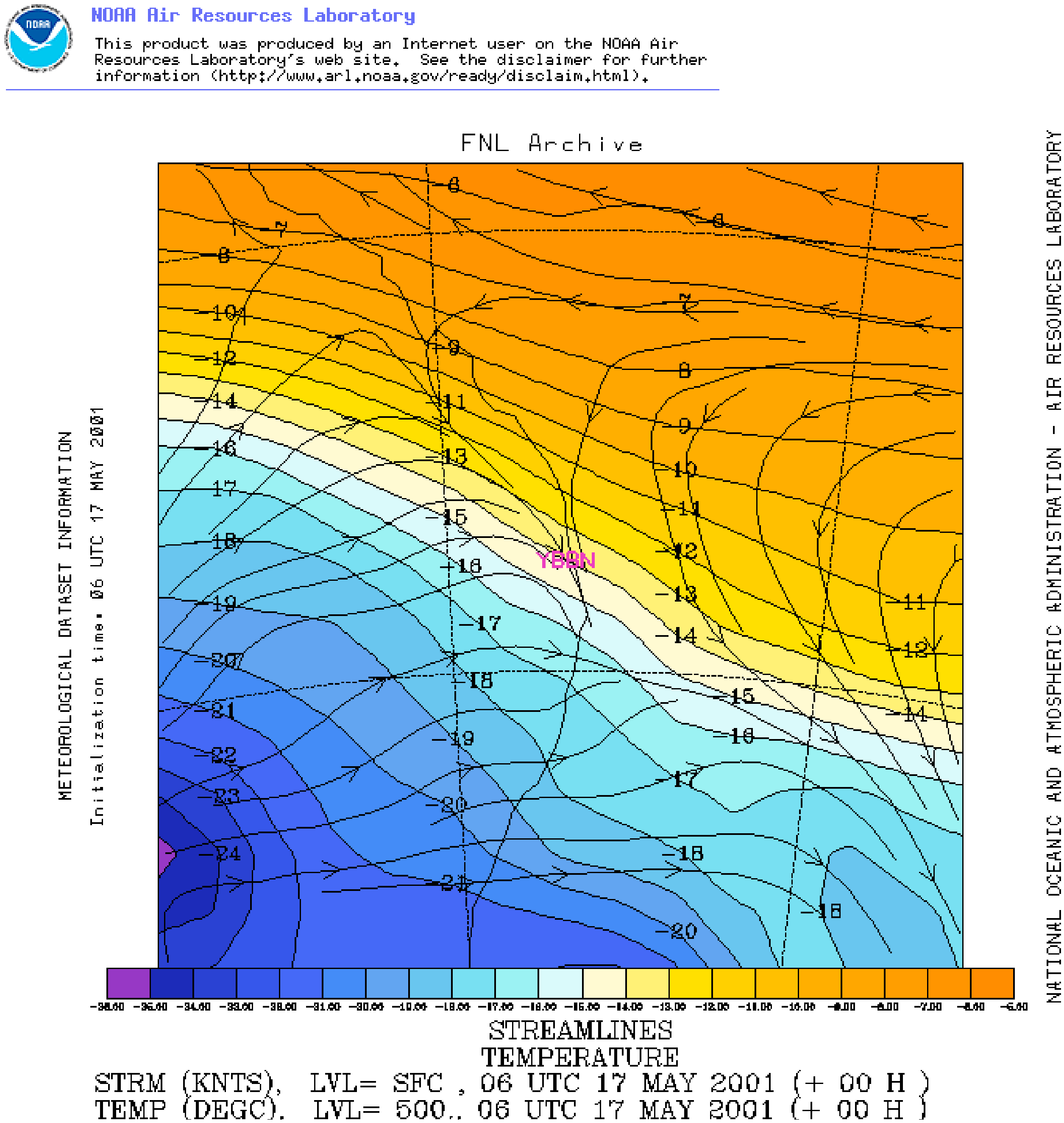
850 level is OK, around 10-15 knots...not fantastic, so the shear here hasn't done any favours to our little instability, so lets continue upwards!



Ok, the 700 level is more favourable! 25-30 knot WNW'ly over us and 30 knots nearby...looking better! Lets continue!

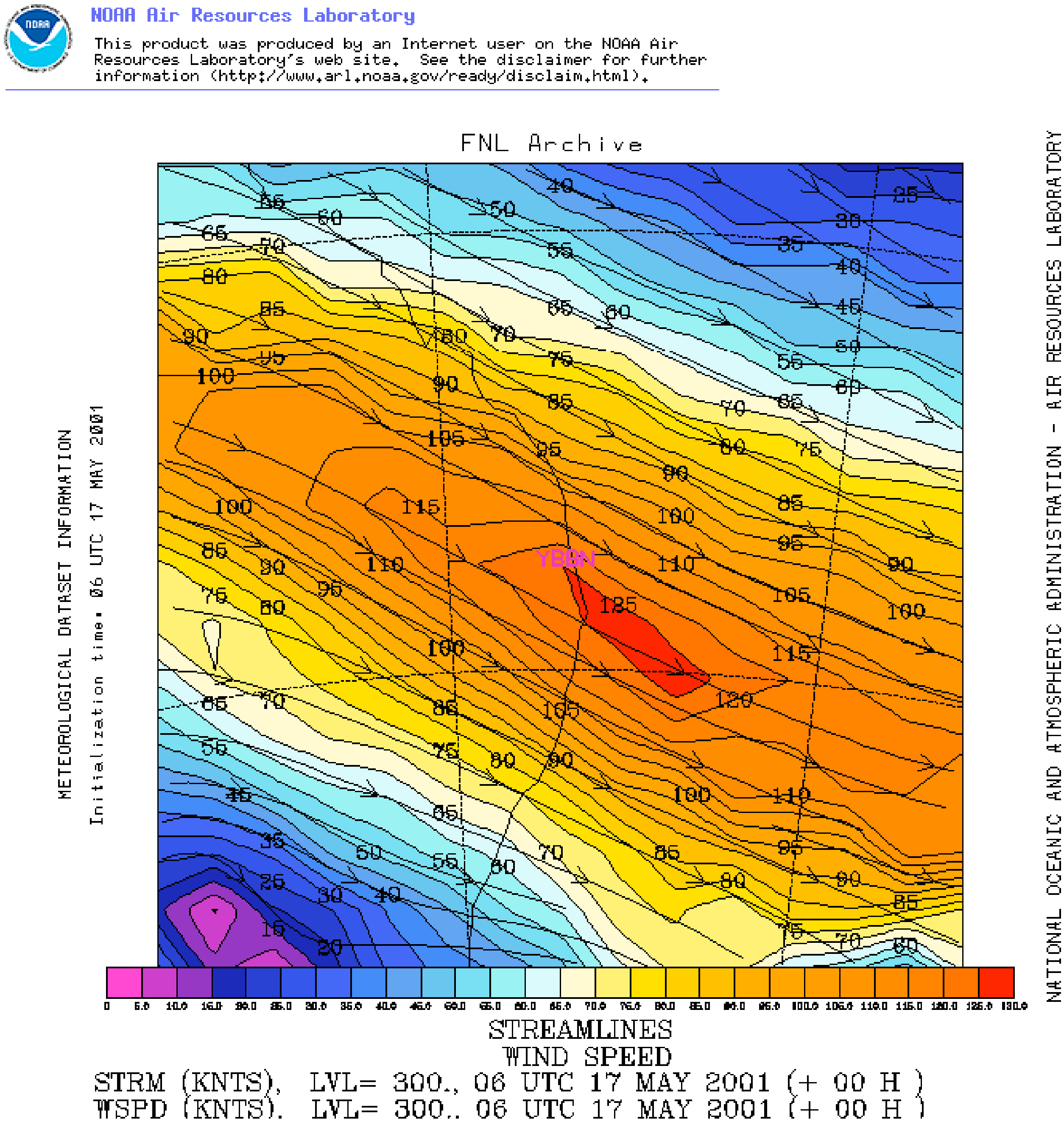


Now we're talking! Solid 50 knot jet over the region, stronger to the north though. Still, fairly reasonable and you can see now that we're also somewhat making up for the lower shear too - not just the instability! Lets have a look at the nice cold pool producing this too, you can see the closed circulation in the far SW of the plot, so we can probably expected a cold pool there, not just an upper trough!

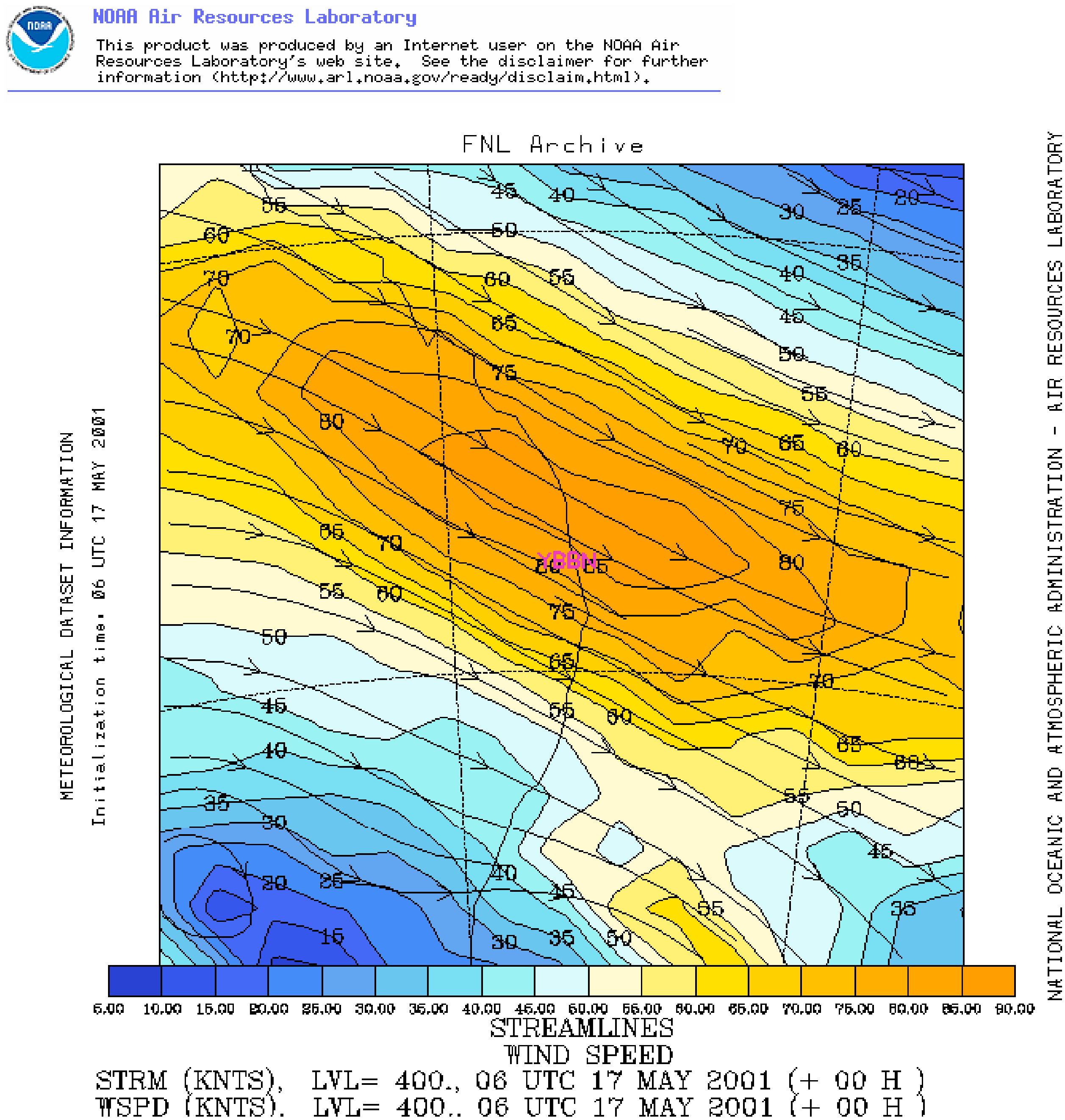


Yep! Pretty close anyway, just west of the region (the geopotential heights would be slightly different). You can see that the strongest temperature gradient is just north of Brisbane too...no surprise that that is where our strongest get is!

One more chart...



120 knots!!! Mega-strong...keep in mind though that our storms probably wouldn't have reached that high! Check the Skew-T, the instability ends at 400mb, so really a 400mb chart would be more appropriate in this situation. Strong upper shear though can assist in vorticity which helps lift the air, even if it doesn't directly influence the updraft. So lets look at 400mb and think that it was 300mb...



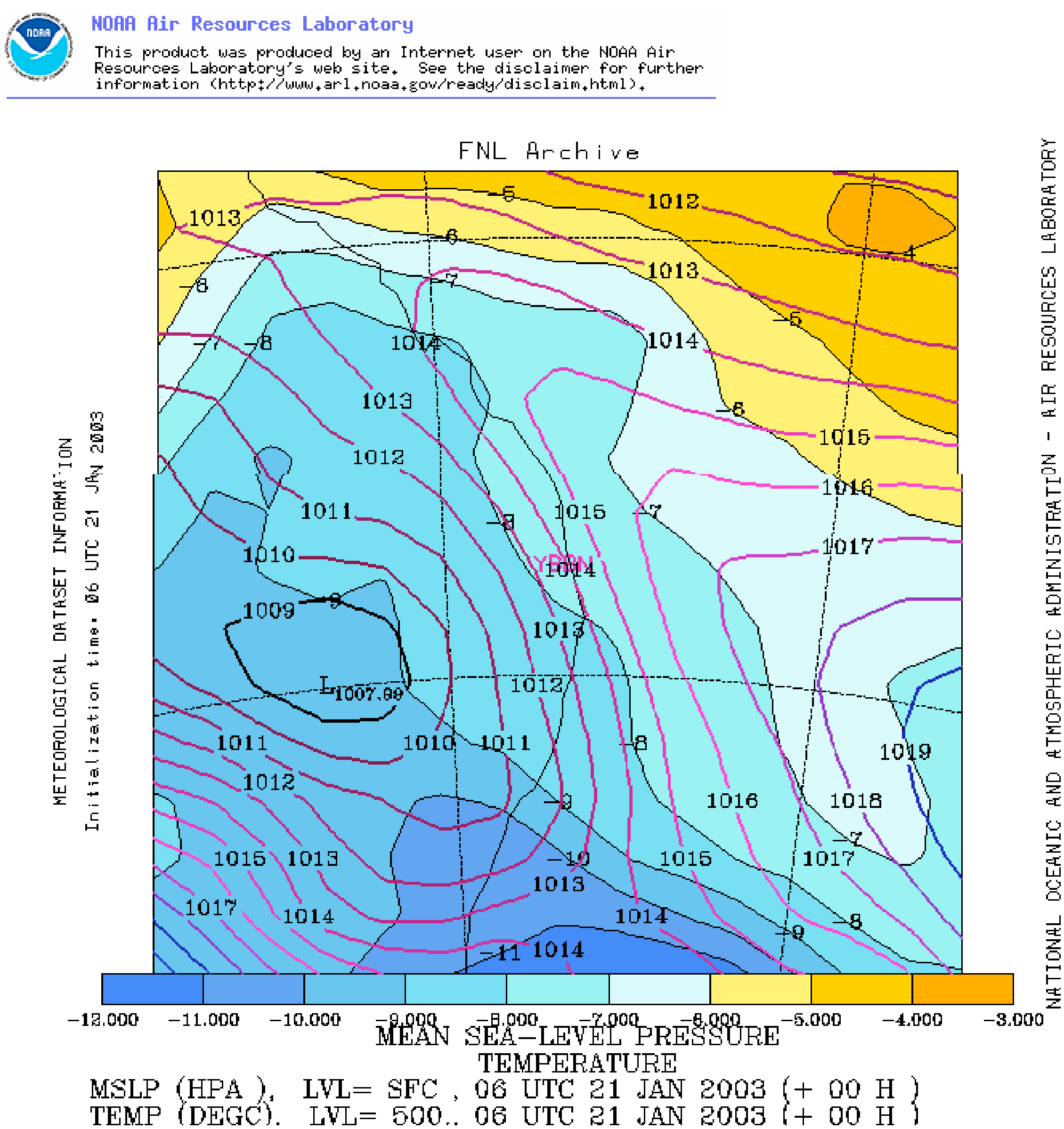
80-85 knots, still some very nice shear! Most of the shear here was NW'ly, so not much in directional shear. Still, it managed to produce a nasty little storm. These are just situations that I went through in my chase reports and found them to be "not ideal" (well, remembered them to be). There are so many examples when you can have non-ideal situations, yet it becomes quite fruitful! It's not just a cut and dry situation where you look at instability and shear and say "there'll be this, this this and this" - much more complicated than this, and hopefully these 4 examples illustrate that to you. I have one more example though! And this time we're going to bump up the "odds" with OK instability and absolutely no shear!

Severe Thunderstorms in Poor Conditions

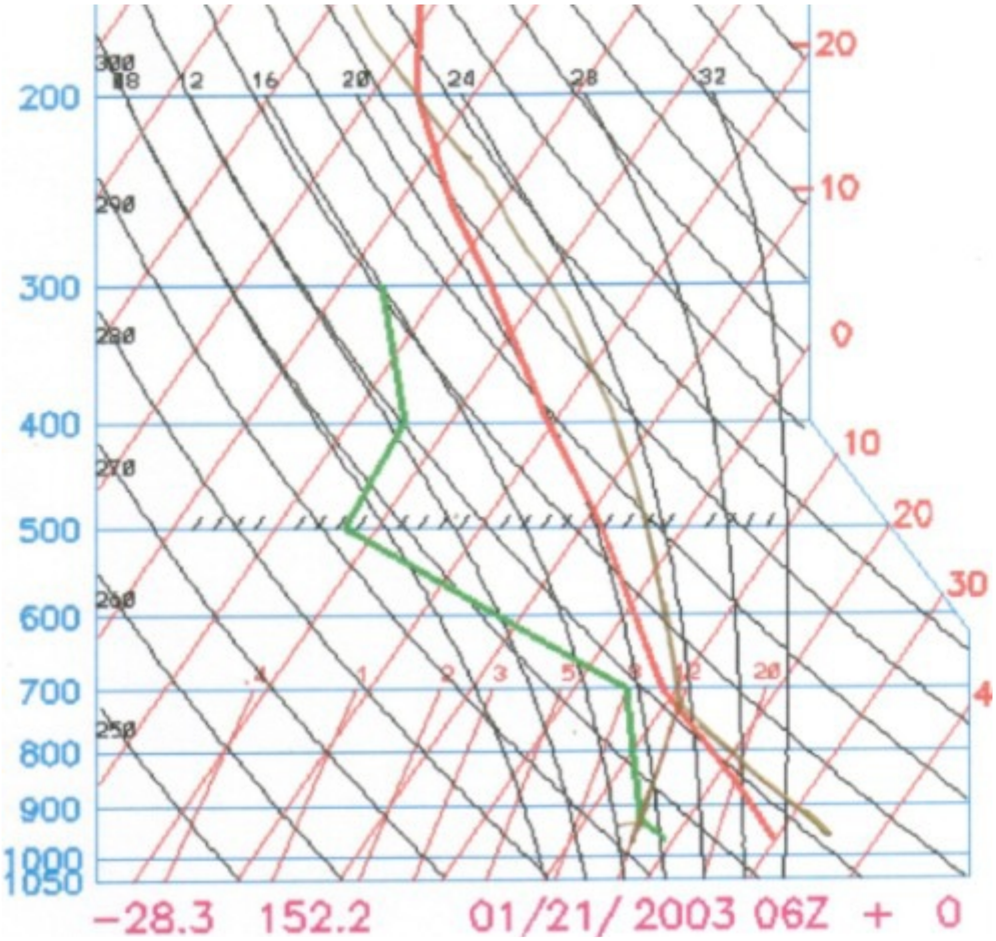
Southern Downs Microbursts - Jan 21, 2003

This is quite a good example of storms breaking the rules I think! One of the worst shear days in the history of storm chasing (almost...) producing some severe storms! There were a couple of factors for this. Once again I encourage you to check out the chase report of this day to get an idea on what happened (other than my car nearly having a tree fall on it in a rare treed area of the Downs!)

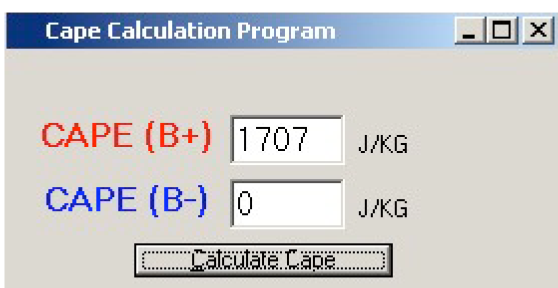
The setup...



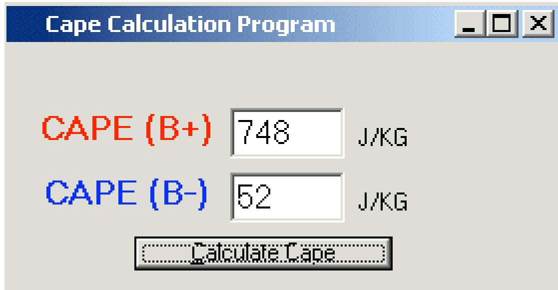
Yes I do look at MSL charts! I just haven't used them much in this guide, but I always look at MSLs too! Anyway...the charts showed a low through the eastern Warrego and western Maranoa regions, this was extending a trough across into the Downs, with most of the confluence developing over the western Downs. A weak general upper trough pushed into the region giving a broad region of instability. However moisture was becoming a problem, not so much surface moisture, but the moisture depth - it was getting a little shallow. So the ranges and elevated regions looked to be the best areas I thought. So lets look at instability...one thing that really made this work of the ranges was the fact that at 500m it was the same temperature as it was at the surface! So this really helped with the instability!



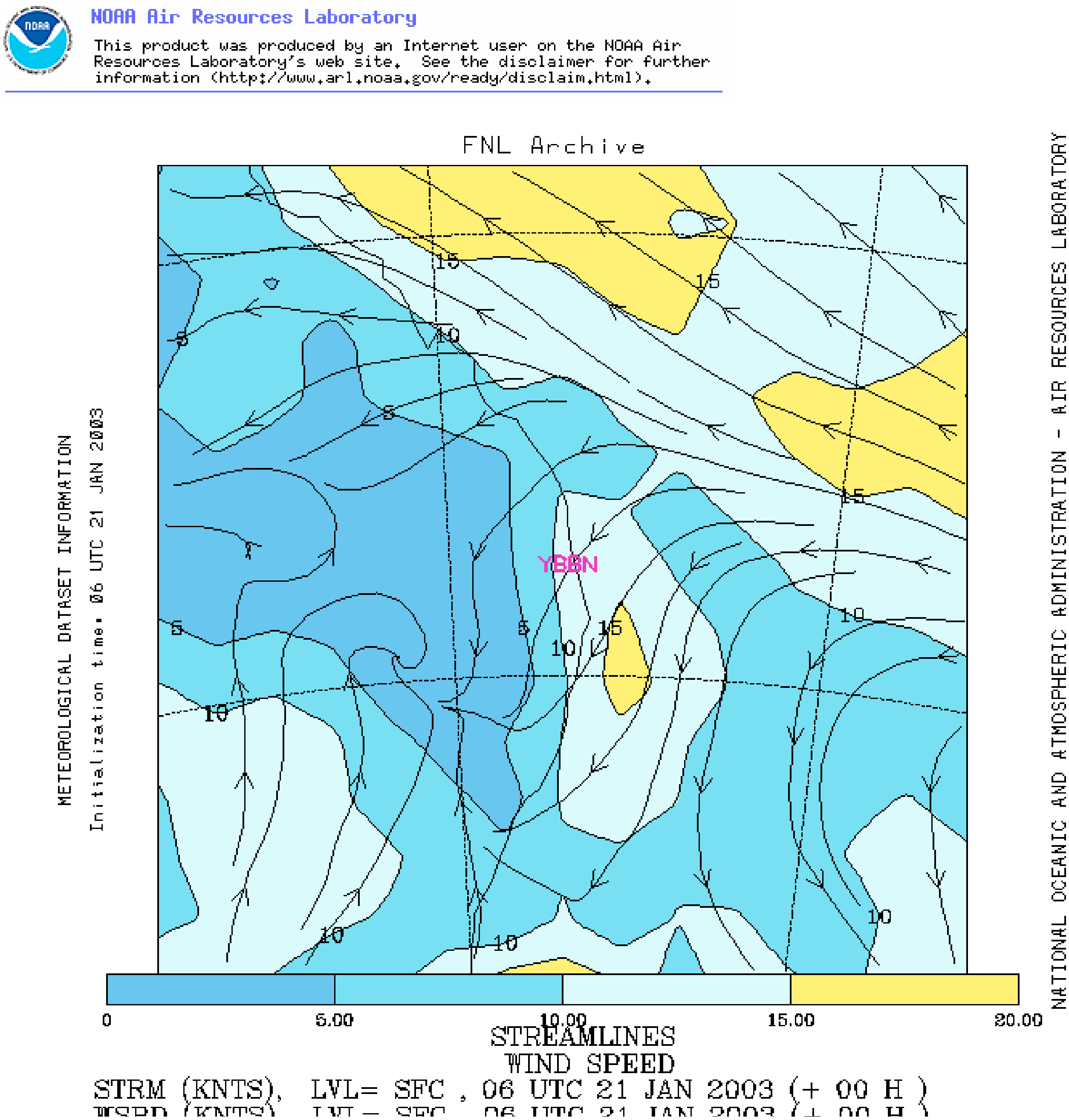
Even on the low resolution of an archived sounding you can already see the dry air in the low levels. The day didn't see much happen near sea level...most of it was along the ranges in the nearby area and on the Downs. Notice how high the LCL was too? A sig of dryness. Never the less, there's a reasonable amount of instability there! Not oodles and oodles, but pretty strong! Lets look at CAPE...



Not bad, 1700 is pretty good really! Although we'll need some shear to back that up. Interestingly, lets also calculate CAPE for around the sea level...I'll even compensate for some extra moisture by increasing the DP by a degree...



Nearly a 1000 CAPE deduction! So far it looks the ranges could be a good option, as we're going going to need every ounce of instability we can get...I'm sure you'll agree with me when you see shear.



The surface flow wasn't too bad, 5-10 knot NNE'ly over the Downs (SW of Brisbane), once again I'm going to use the rigid scale I gave earlier to try and demonstrate how shear isn't always necessary. So this gives us a marginal surface flow.

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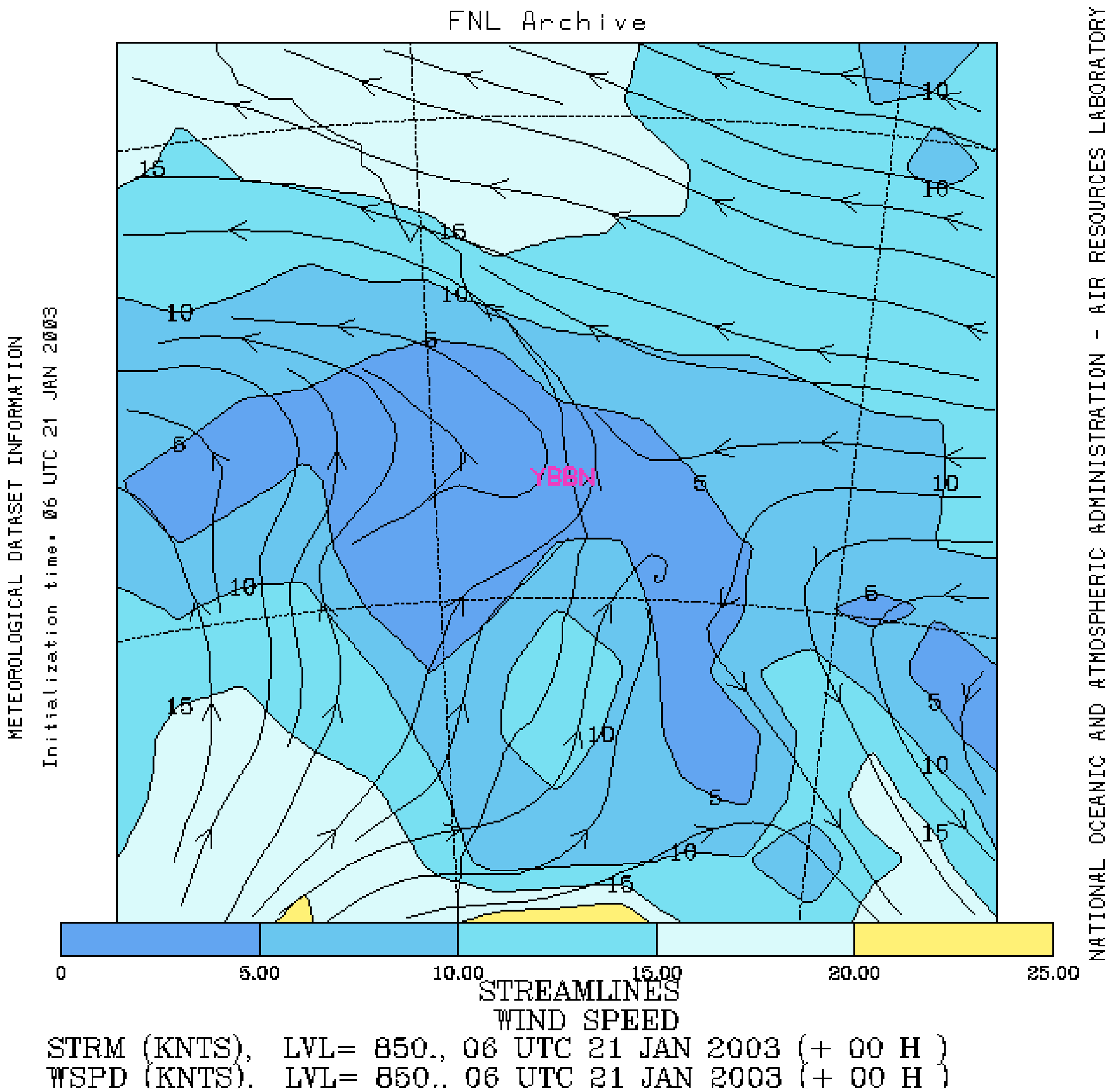
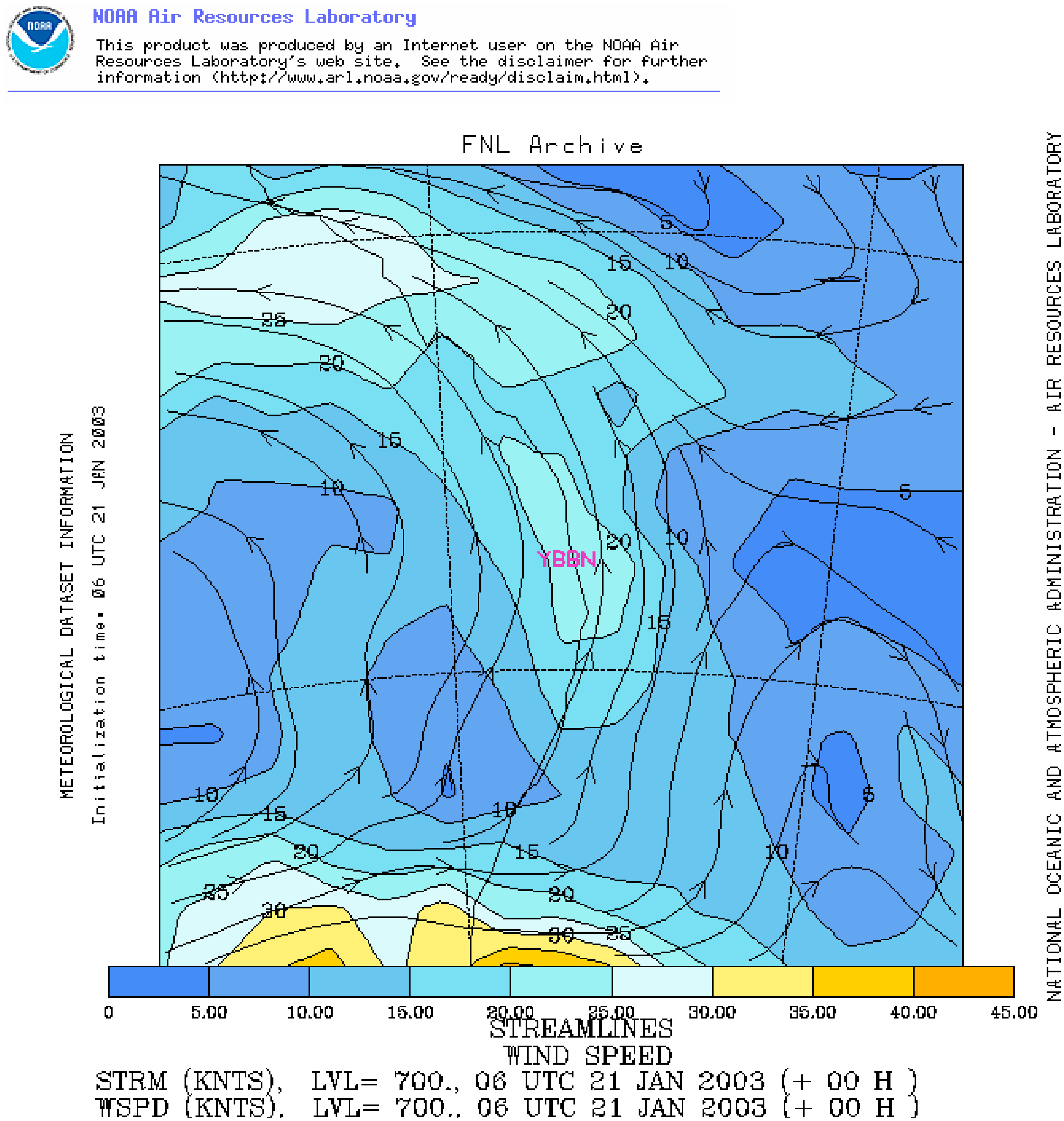
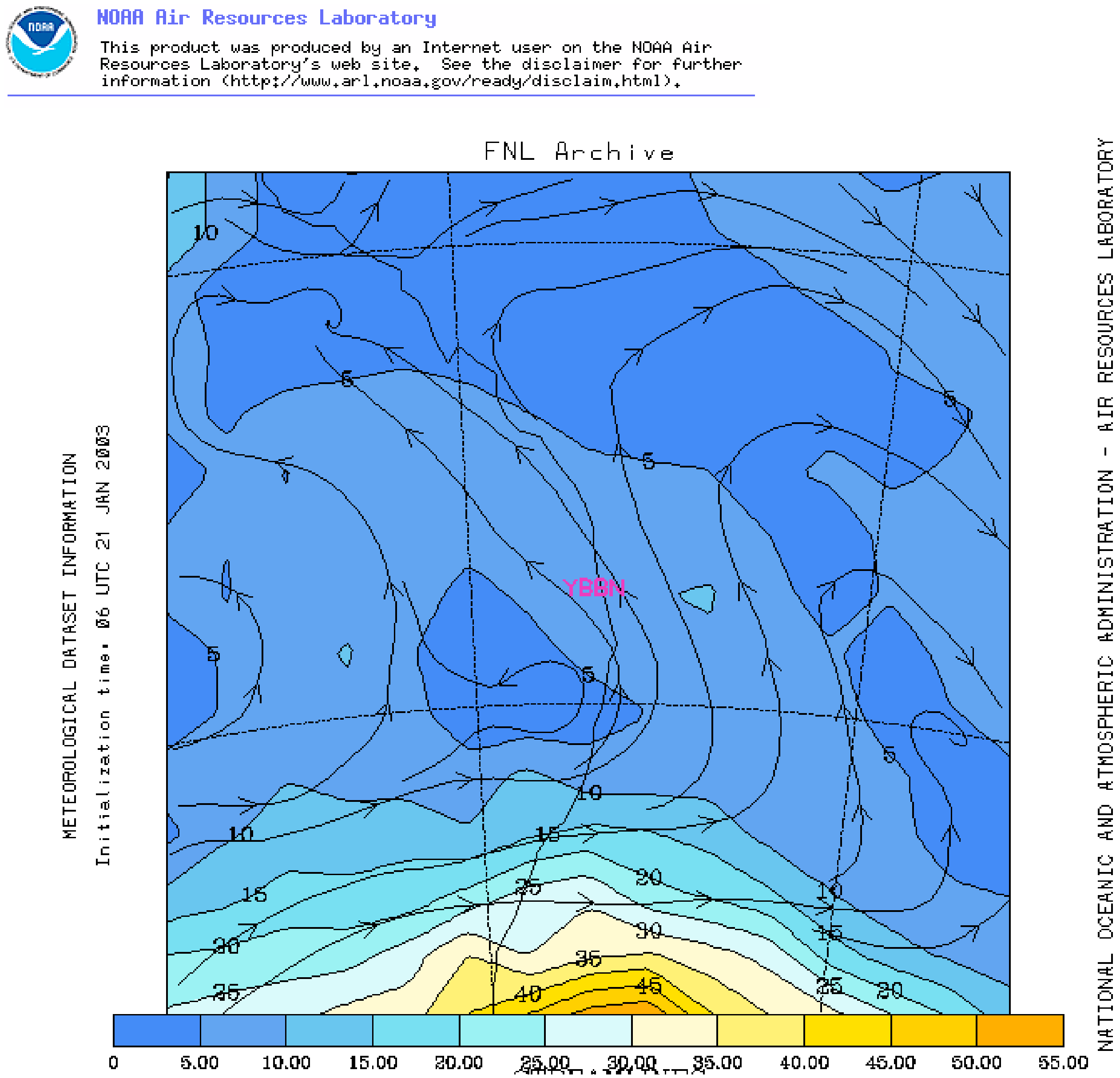


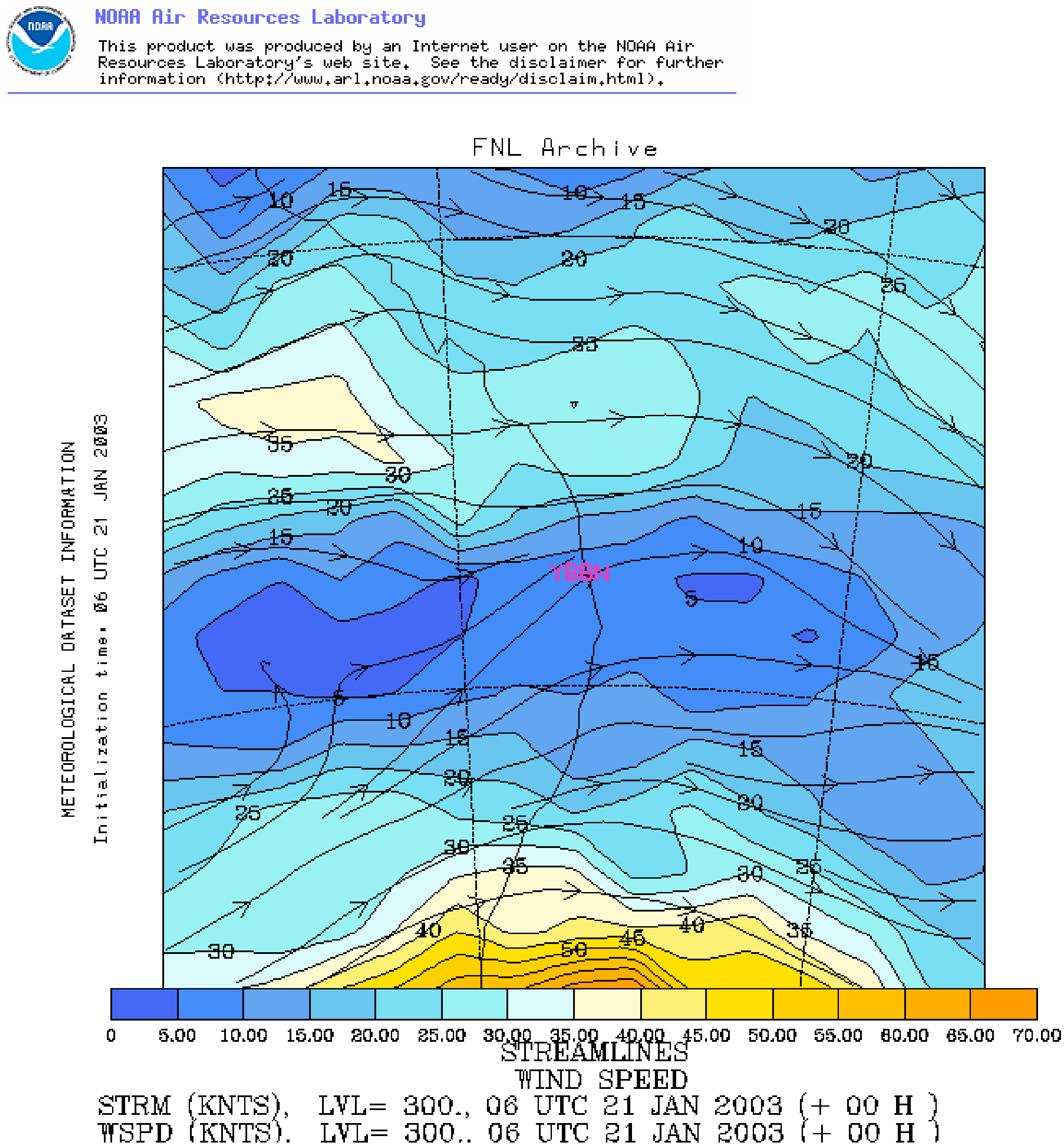
Yick...not really what we were hoping to see, <5 knots (poor) over a broad area! No good, lets continue...



700 is certainly a bit more of an improvement! 20 knots or so (adequate), so things are suddenly looking up! Maybe we can compensate for the 850 levels as we go up! Lets see...



Right...well, after a brief bit of OK shear we've gone from bad to worse! 5-10 knots at 500mb (poor), this is looking hopeless!!!



And again!!! Geez...why even bother chasing on this type of day??? I'll explain my madness soon...but lets summarize our shear!

1000mb - marginal (2)
850mb - poor (1)
700mb - adequate (3)
500mb - poor (1)
300mb - poor (1)
Total: 1.6 (poor-marginal)

To put it bluntly...shear is hopeless. We do have some OK instability though, but how will that work with no shear? Well, this is partly where the dryness was going to give us an advantage (see, weather really does have no rules...after so much stuff on being concerned of it drying out, we find an area where the dryness actually helped us!) There a few reasons...the microbursts are no real mystery at all. Dry microbursts develop when rain evaporatively cools in the low-mid levels. You can see it's relatively dry in these levels, so we'd expect that to happen. As it cools, it's forced to sink (because it becomes heavier), but as it sinks it'll warm at the SALR (because it's

saturated)...while the atmosphere around it warms at the ELR (which in dry situations is often the DALR). So once this parcel gets to the surface, it's going to be a LOT cooler than the surroundings! Remember how updrafts become really strong if they're significantly warmer than the surroundings? Downdrafts and microbursts are exactly the same - only opposite! (Does that make sense!) What I mean is, downdrafts that are significantly cooler than their surroundings will also be really strong. And once they hit the ground, there's no where for the air to go but spread out! I was standing on the edge of a dry microburst and nearly got
blown over from the winds! (~115km/h!)

The other thing dry air can help with is one of the reasons why storms like shear is it helps with organisation and it stops storms and updrafts from being "cluttered." If it is dry though, this will mean updrafts and upper moisture will evaporate into the surroundings, decreasing the chance for the situation to become cluttered!

The last thing is - it really depends what you want. I wanted lightning (and I got it!) Dry air storms are normally good lightning produces, and if you check the chase report there's a few nice captures/photographs from it! Bottom line...what looked like a hopeless day was an enjoyable chase afternoon and evening!

Concluding Remarks

Well that about wraps it up for this guide. I hope that it has been of some use to you and that you've learnt something from it! Remember though...it's a guide! You can never categorise weather into sections and say "unless it falls within these boundaries it won't happen" - sure it might be the case a lot of the time, but it's not always the case! And that is a big thing that I've tried to demonstrate in this guide, especially in part four!

I also hope that it has given you a better idea on things such as LI and shear, and they're no longer numbers...but something meaningful too (as in a physical understanding of what they really mean).

I really encourage you to look at some of the storm days you've remembered. I've got links throughout this guide...also have them in the acknowledgements. Going through and seeing how a storm day worked or what made it special from another can really teach you a lot! It'll help you gain additional experience too. I actually learnt a lot myself just by going back through events I'd never looked at in detail from doing this guide! There is ALWAYS something to learn, you can never learn it all! Remember...instinct and experience will help you more than any of this guide can. Effectively all this guide has been is what I've learnt in my experience...little has come from textbooks and the like. I'm not trying to make myself sound good - I'm just trying to point out that to really learn weather, you can't just read books (or even just look at this guide). You need to experience it!

Good luck and all the best with your storms! Feel free to email me with any questions or thoughts on or about this guide!