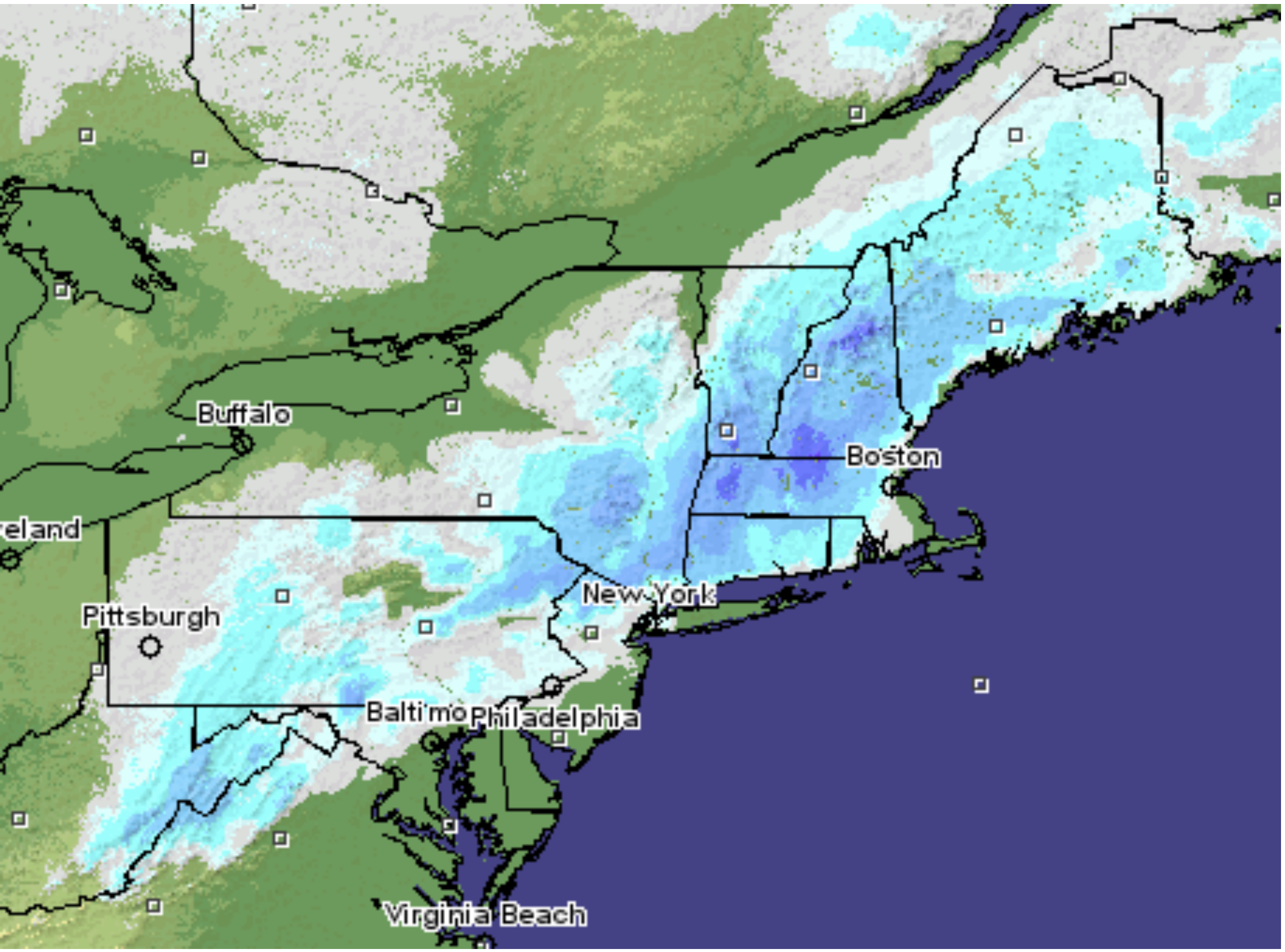
MET 3502/5561 Synoptic Meteorology
Lecture 8: Interpreting Weather Maps

Case Study: October 2011 Nor'easter

A Mid-latitude Cyclone (October 2011 Northeaster): Snowfall totals



- Forecasters knew this was coming!!!!
- Why & How? We'll analyze the weather maps using this case to show how to do weather discussion & forecasts in the next ~20 slides (Slide#3-21).
- This lecture should be very helpful for lab 1 (weather discussion video).

“Top-down” model analysis

- **300 mb: Jet stream** (Jet streams are relatively narrow bands of strong wind in the upper levels of the atmosphere)
- **500 mb: Vorticity** (Vorticity is a clockwise or counterclockwise spin/rotation in the troposphere; by convention, counterclockwise vorticity is positive, which is also referred to as “cyclonic vorticity”)
- **700 mb: Vertical Motion**
- **850 mb: Temperature**
- **Surface: Pressure, Precipitation**

- Note: this example only considers one time period at the height of the storm, the evolution of these features through time is important also

What to look for at 300 mb

- **Jet stream pattern** (zonal, split flow, blocking)
  - Note: Use 200 mb for subtropical jet, especially in summer
- **Ridges and troughs**: location and tilting (+ or -)
- Location of upper level highs and lows
- **Jet streaks (or Jet Max):** A "jet streak" refers to a portion of the overall jet stream where winds along the jet core flow are stronger than in other areas along the jet stream.
  (a) Trough will amplify (deepen) if a jet streak is on the left side of the trough axis
  (b) 4-quadrant model for rising/sinking motion
- **Upper-level divergence** = rising motion (especially if there is low-level WAA also)

Positively or Negatively Tilted Trough

- **A positively tilted trough:** indicates the low pressure will develop/amplify
- **A negatively tilted trough:**

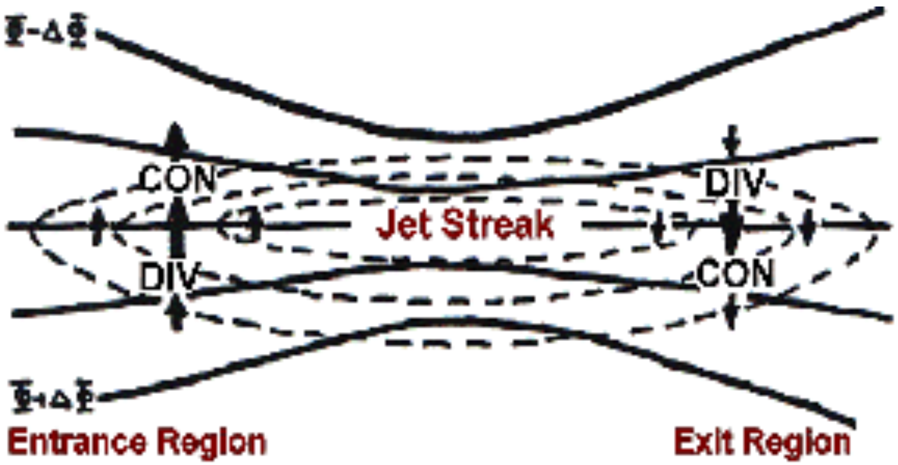
(1) indicates a low pressure has reached **maturity**,

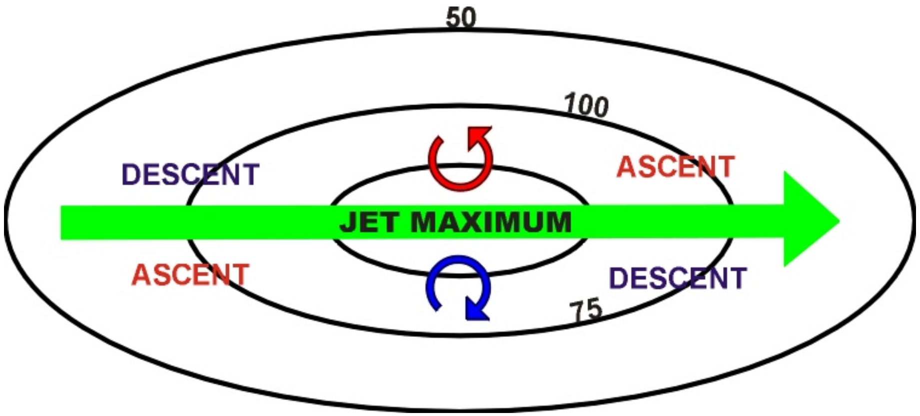
(2) indicates strong differential advection (middle and upper level cool air advecting over low level warm air advection). This increases thermodynamic instability.

(3) Indicates good vertical wind shear.

(4) A deep low pressure, a negatively tilted trough, and a warm and moist warm sector combination east of the Rockies often produces a severe weather outbreak.

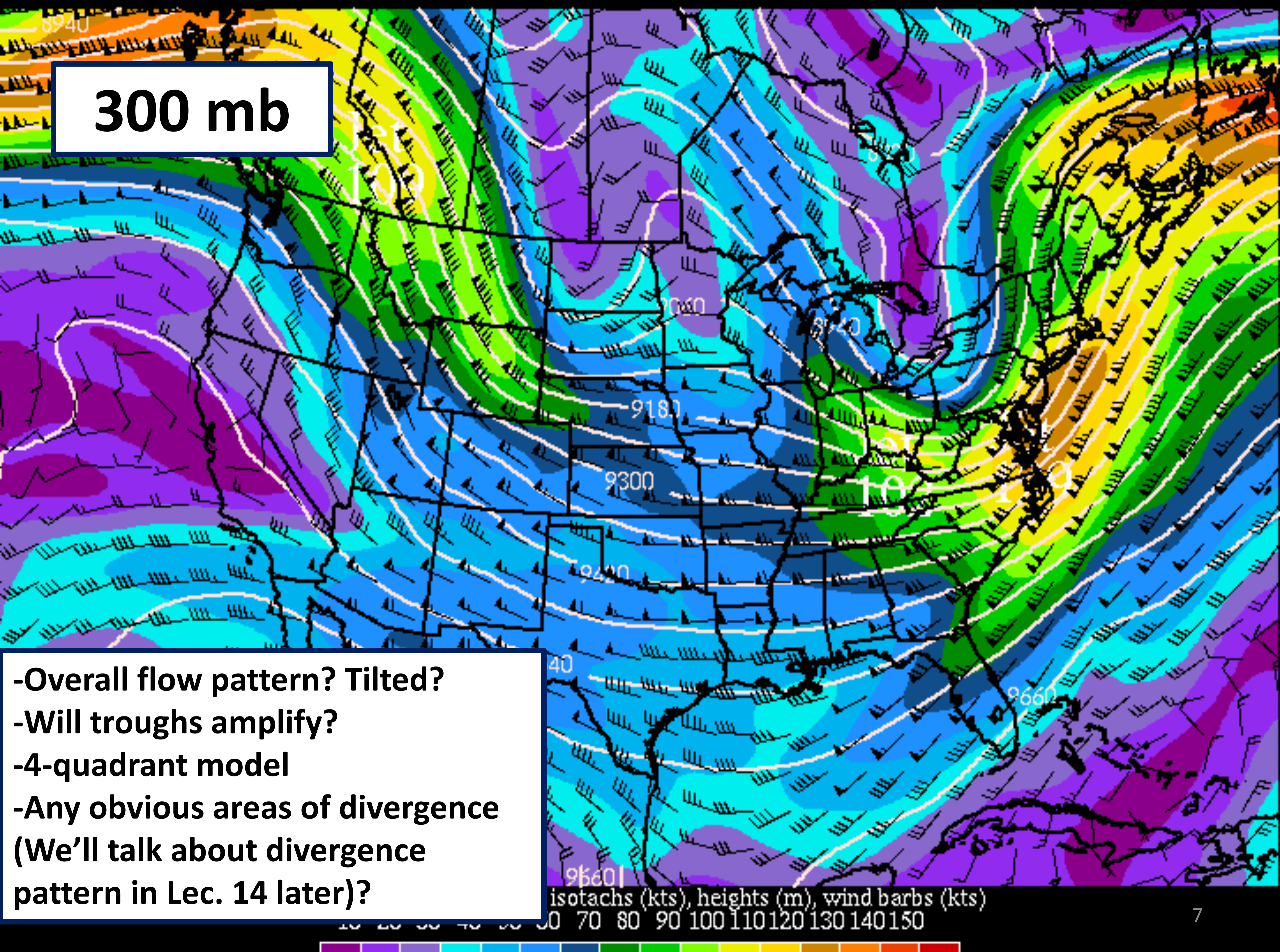
4-Quadrant Jet Model





- Rising motion is located at: Right Entrance and Left Exit
- Sinking motion is located at: Left Entrance and Right Exit
- Rising motion for a curved jet stream: **north of jet axis if jet is in a highly curved flow**

300 mb

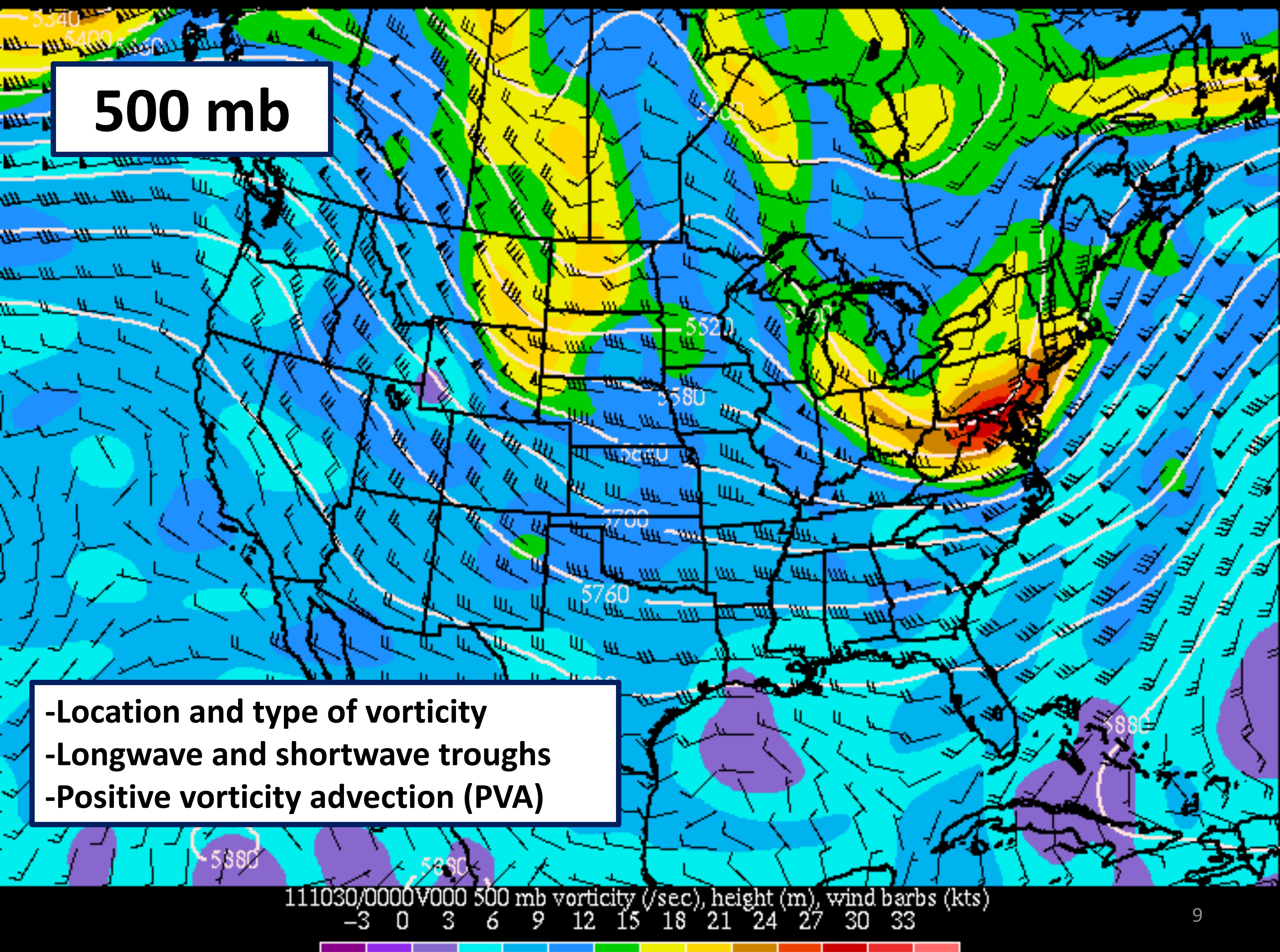


- -Overall flow pattern? Tilted?
- -Will troughs amplify?
- -4-quadrant model
- -Any obvious areas of divergence (We'll talk about divergence pattern in Lec. 14 later)?

What to look for at 500 mb

- **Vorticity**: location and type
  - Shear, Curvature, Earth (Coriolis) (we'll talk about shear vorticity, curvature vorticity & earth vorticity in details in Lec. 15 later. To preview Lec. 15, go to here: https://faculty.fiu.edu/~hajian/MET3502/MET3502_Synoptic_Lec17.pdf)
- **Longwave and shortwave troughs**
  - Both associated with positive vorticity
- **Positive Vorticity Advection** (PVA or CVA)
  - High areas of vorticity being advected by strong winds (i.e. wind blows across vorticity contours; similar to warm/cold advection in Lec. 5)
  - Causes vertical motion (QG Omega equation)

500 mb

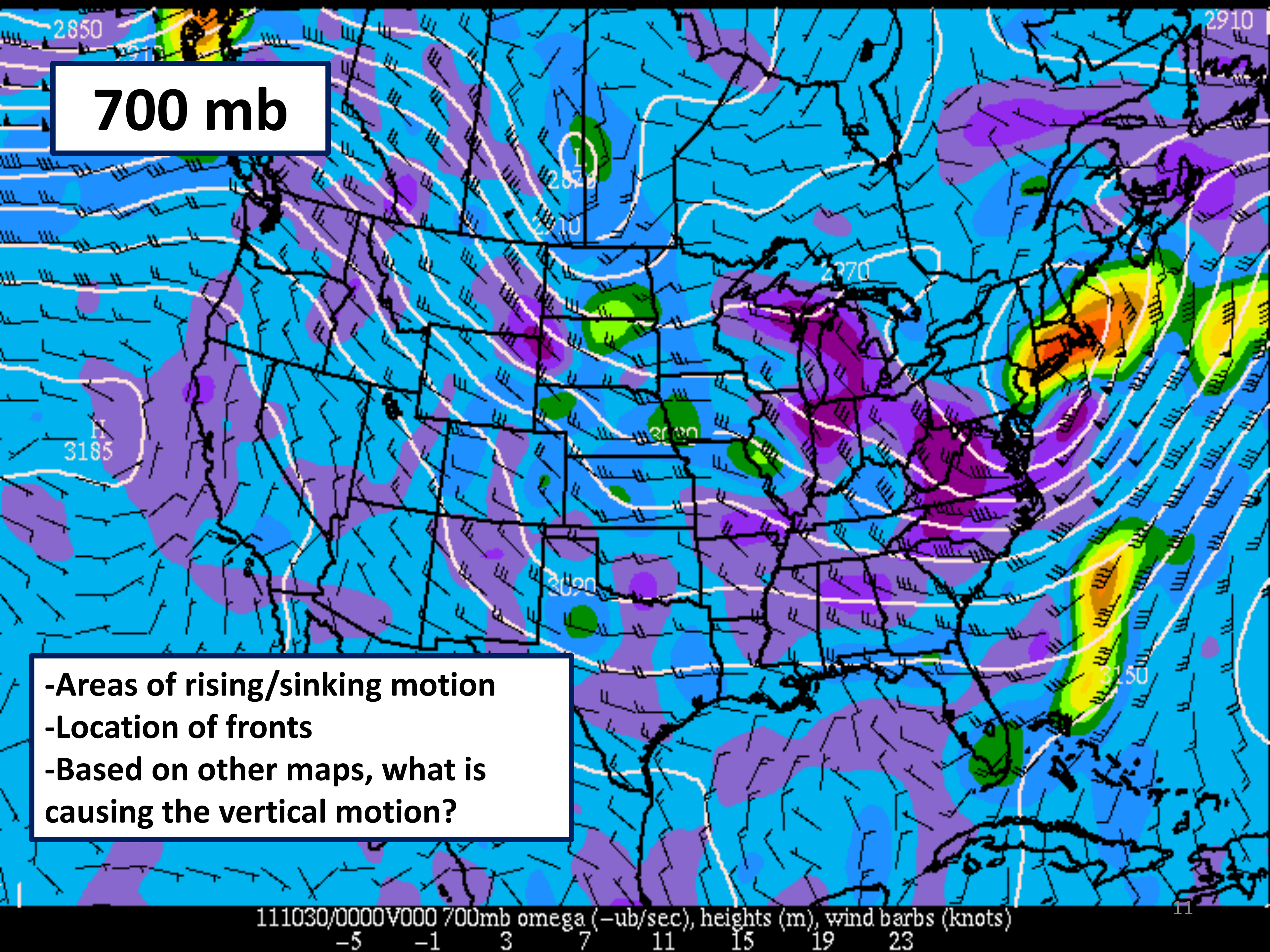


- Location and type of vorticity
- Longwave and shortwave troughs
- Positive vorticity advection (PVA)

What to look for at 700 mb

- **Vertical Motion**
  - Should match up fairly well with our diagnostics from the other levels
  - Precipitation is likely in areas of upward motion, but moisture is necessary also
- **Location of fronts** (at 700 mb)
  - Look for a "kink" in height contours at the bottom of a trough, usually only works for strong cold fronts
- Note: Vertical motion is not always synoptically forced
  - Mountains can create "couplets" of upward/downward motion
  - Unusually high upward motion is common in convection

700 mb

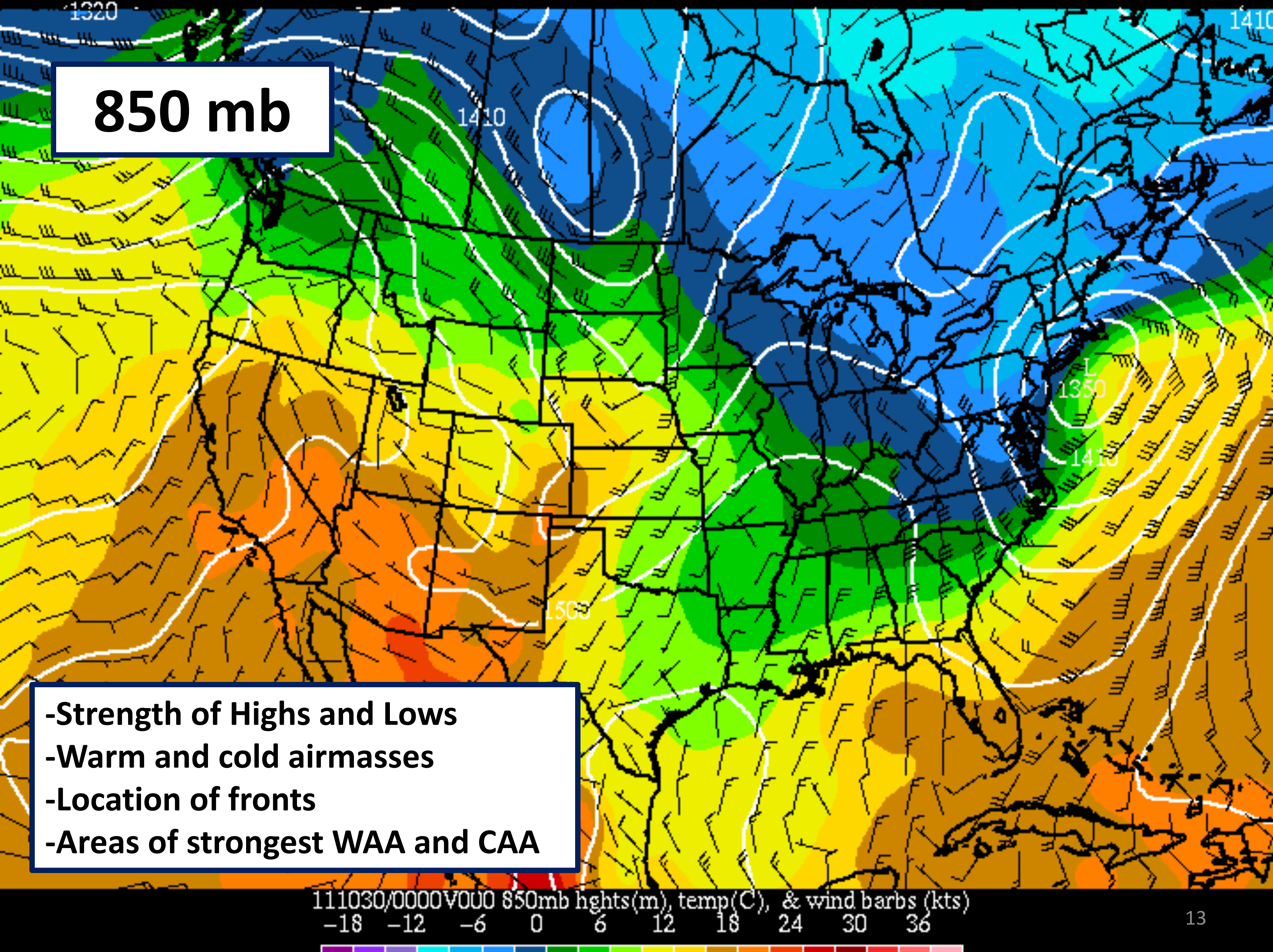


- -Areas of rising/sinking motion
- -Location of fronts
- -Based on other maps, what is causing the vertical motion?

What to look for at 850 mb

- **Warm/cold airmasses**: location and strength
- **High/low pressure systems**: location and strength
  - Look for magnitude of height gradient
- Strong thermal gradient = possible front
- **Temperature advection** (associated with fronts and cyclones):
  - WAA = wind blowing from warm to cold
    - WAA = rising motion (2nd term in QG omega equation)
  - CAA = wind blowing from cold to warm
    - CAA = sinking motion
- Temperature advection is strongest with:
  1. Closely spaced isotherms
  2. Closely spaced height contours (stronger winds)
  3. Isotherms nearly perpendicular to height contours
- Note: 850 mb is essentially a surface map at high elevations

850 mb

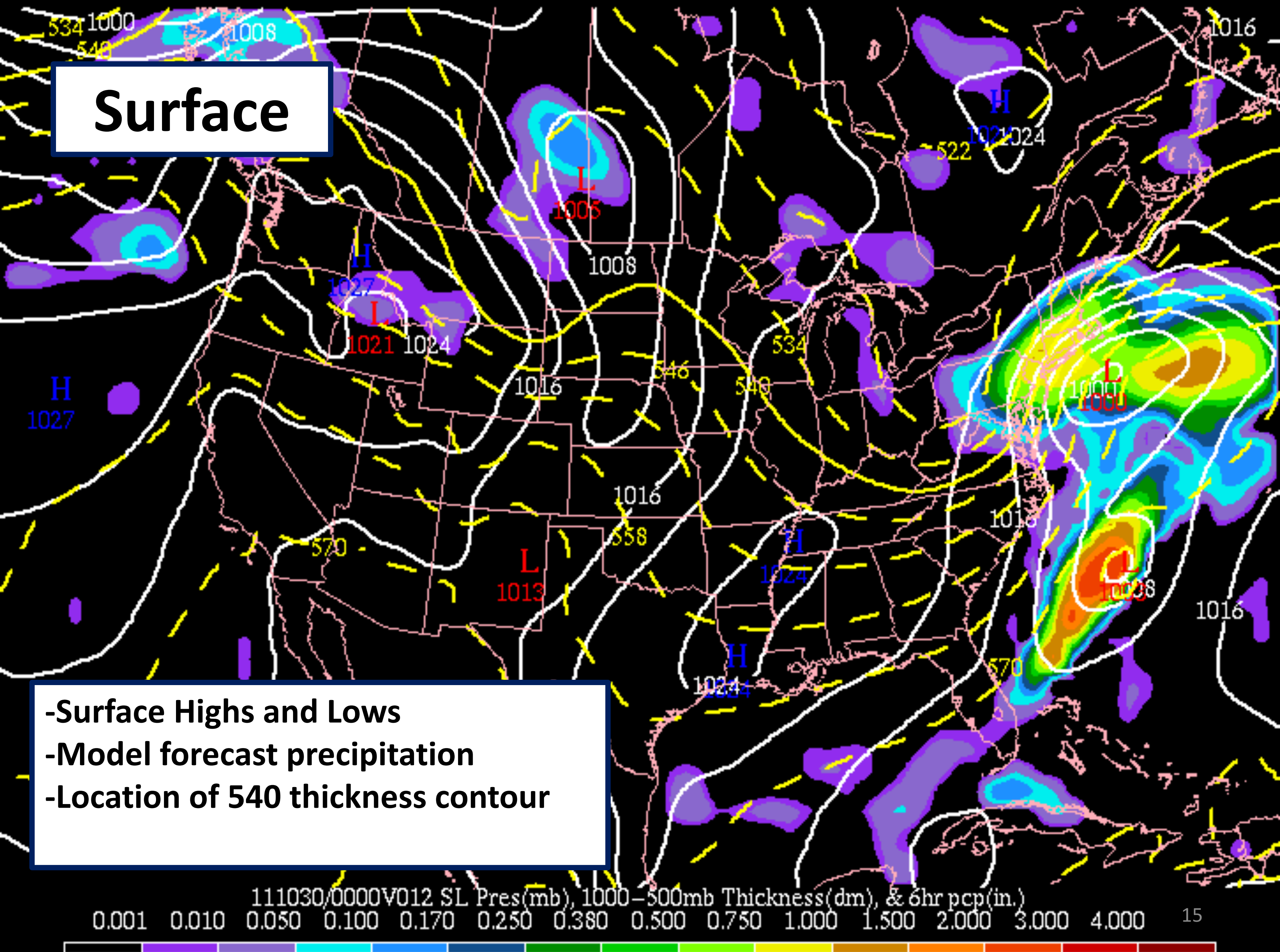


-Strength of Highs and Lows
-Warm and cold airmasses
-Location of fronts
-Areas of strongest WAA and CAA

What to look for at the surface

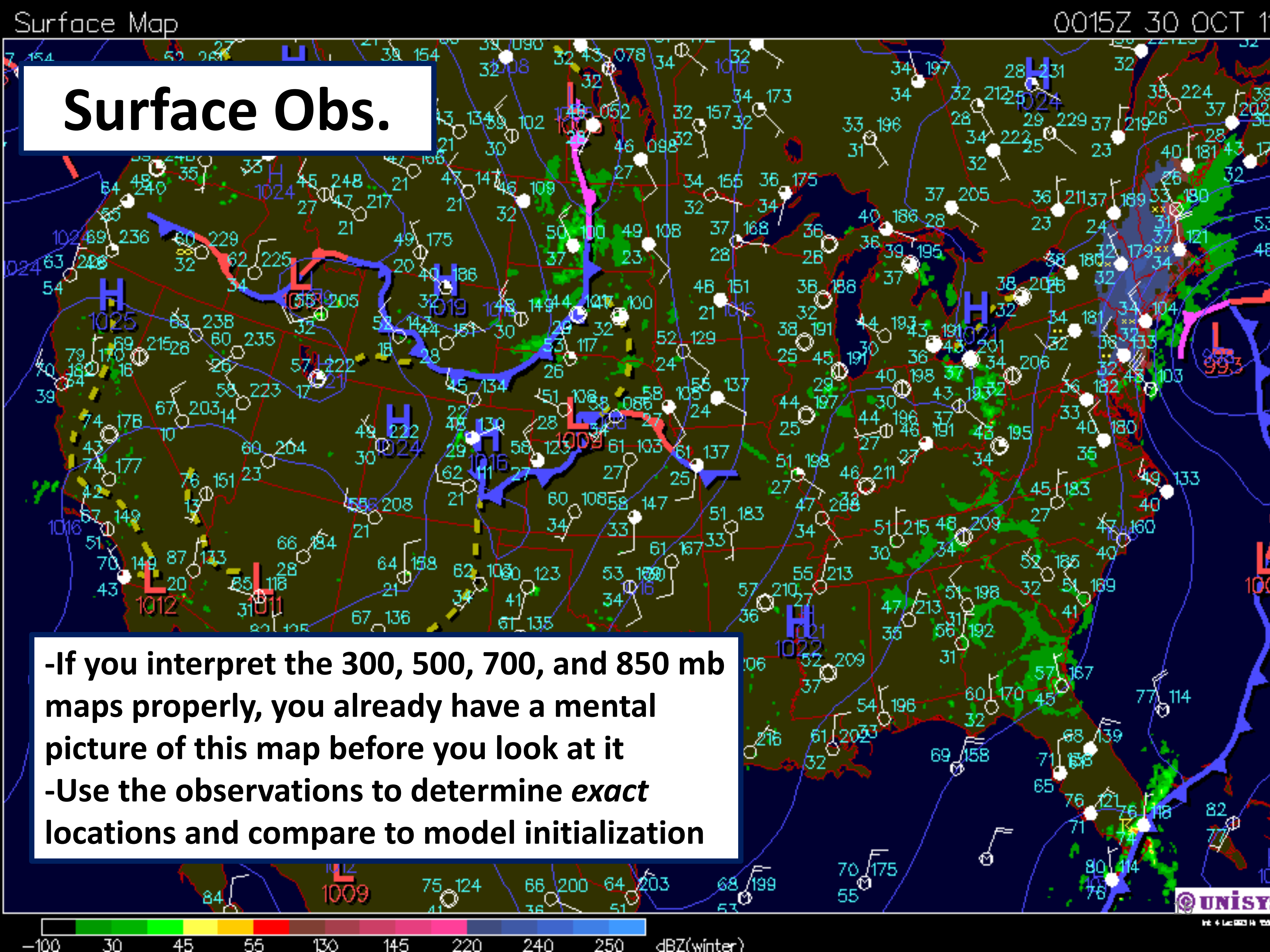
- Surface **Highs, Lows, Fronts**
- **Model forecast precipitation**
  - Not necessarily accurate, especially for mesoscale features!!!
- **1000-500 mb thickness**: 540 dm contour often approximates the rain/snow line
- **Regions of divergence, convergence, confluence, diffluence** (We'll talk about divergence pattern in Lec. 14 later. To preview Lec 14, go to here: https://faculty.fiu.edu/~hajian/MET3502/MET3502_Synoptic_Lec16.pdf)
  - Convergence = upward vertical motion

Surface



- Surface Highs and Lows
- Model forecast precipitation
- Location of 540 thickness contour

Surface Obs.

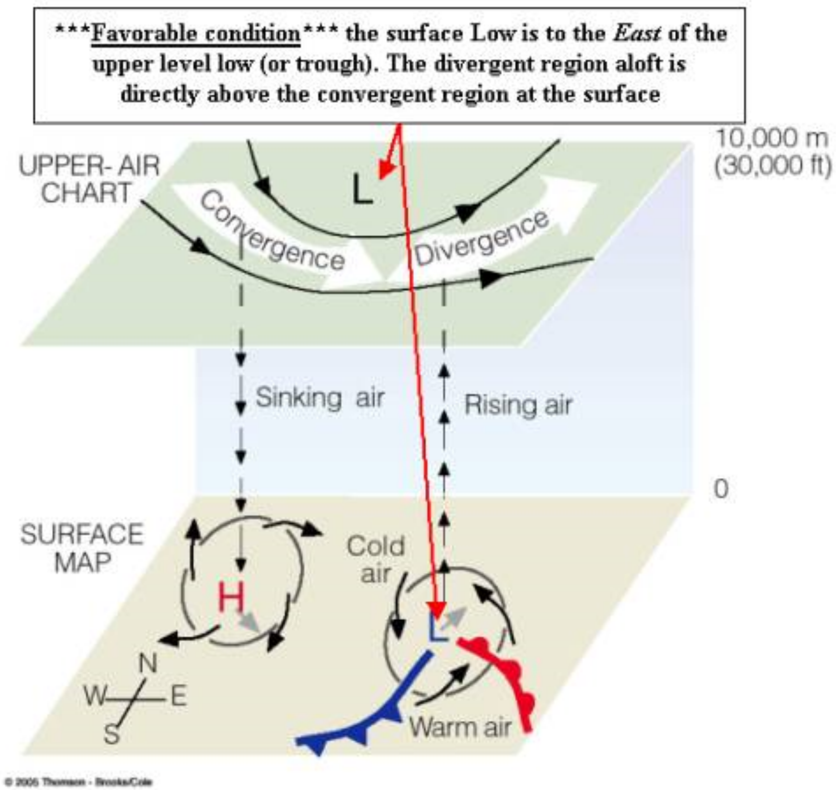


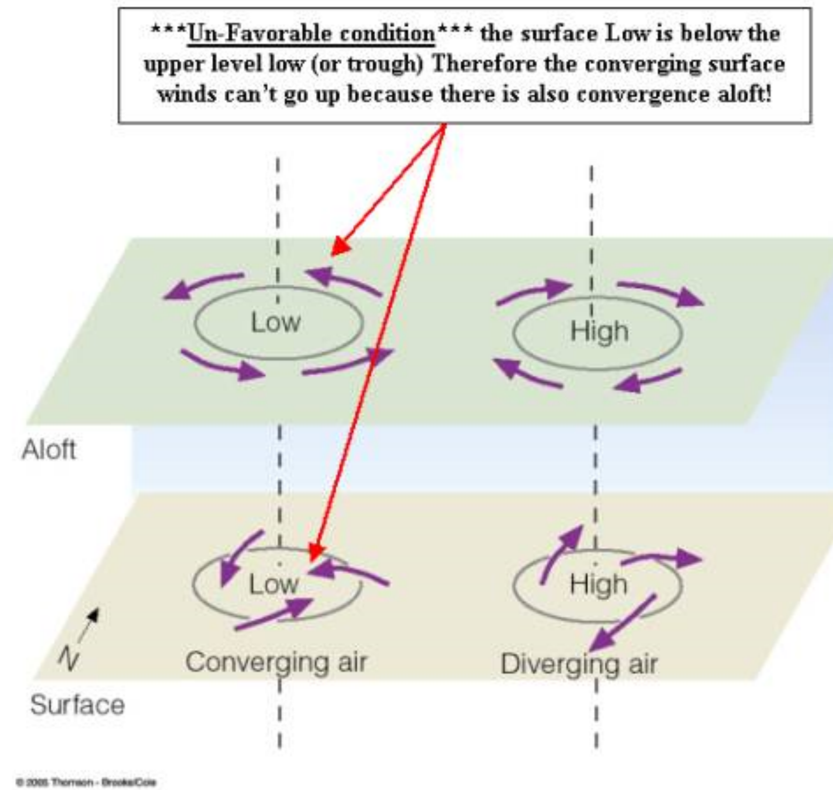
- If you interpret the 300, 500, 700, and 850 mb maps properly, you already have a mental picture of this map before you look at it
- Use the observations to determine *exact* locations and compare to model initialization

Multi-level analysis

- Is the low pressure system **vertically stacked**?
  - Compare trough location at 500/300 mb to 850/700 mb
  - Developing low: vertical tilt to NW with height
  - Occluded low: vertically stacked
- **Tilting of fronts with height**
  - Important for determining location of frontal precipitation
  - Use surface, 850, and 700 mb
- Forecasting thunderstorms/convection
  - Use synoptic overview combined with vertical sounding

How do upper-level conditions help surface cyclone develop?





- At perturbation stage, in the center of this circulation, there is mass convergence. When all that air hits the center, we have rising motion because it has nowhere else to go. If the upper levels are favorable for cyclone development, then there is a region of divergence aloft above the developing Low-pressure center. This will help pull the air that is converging at the surface upward and continue to develop the surface cyclone. The upper levels also steer the system and make it progress east.

Summary: Contributing factors to vertical motion over Northeaster

- Upper level divergence due to region being located in right entrance + left exit region of two jet streaks
- 500 mb Positive Vorticity Advection (PVA)
- 850 mb Warm Air Advection (WAA)
- Surface low pressure system continuing to deepen due to NW tilting creating divergence over surface low

Other factors to consider for predicting exact snowfall totals:

- Warm Soil temperature
  - May limit snowfall accumulation due to melting
- Warm ocean temperature
  - Limiting factor if flow is onshore
- Rising motion in “Dendritic Growth Zone”
  - Snowflakes grow fastest in -12 to -18°C range
- If snow falls during daytime, the high sun angle may melt snow off dark surfaces
- Note: in a borderline rain/snow case, heavy snowfall rates will cancel out limiting factors due to high rates of adiabatic cooling (from intense rising motion) and latent heat of fusion (from flakes melting as they fall into warmer air)

Sources/Notes

- Information on interpreting weather maps can be found at: http://www.theweatherprediction.com

  --***reading assignment:***
  http://www.theweatherprediction.com/charts/

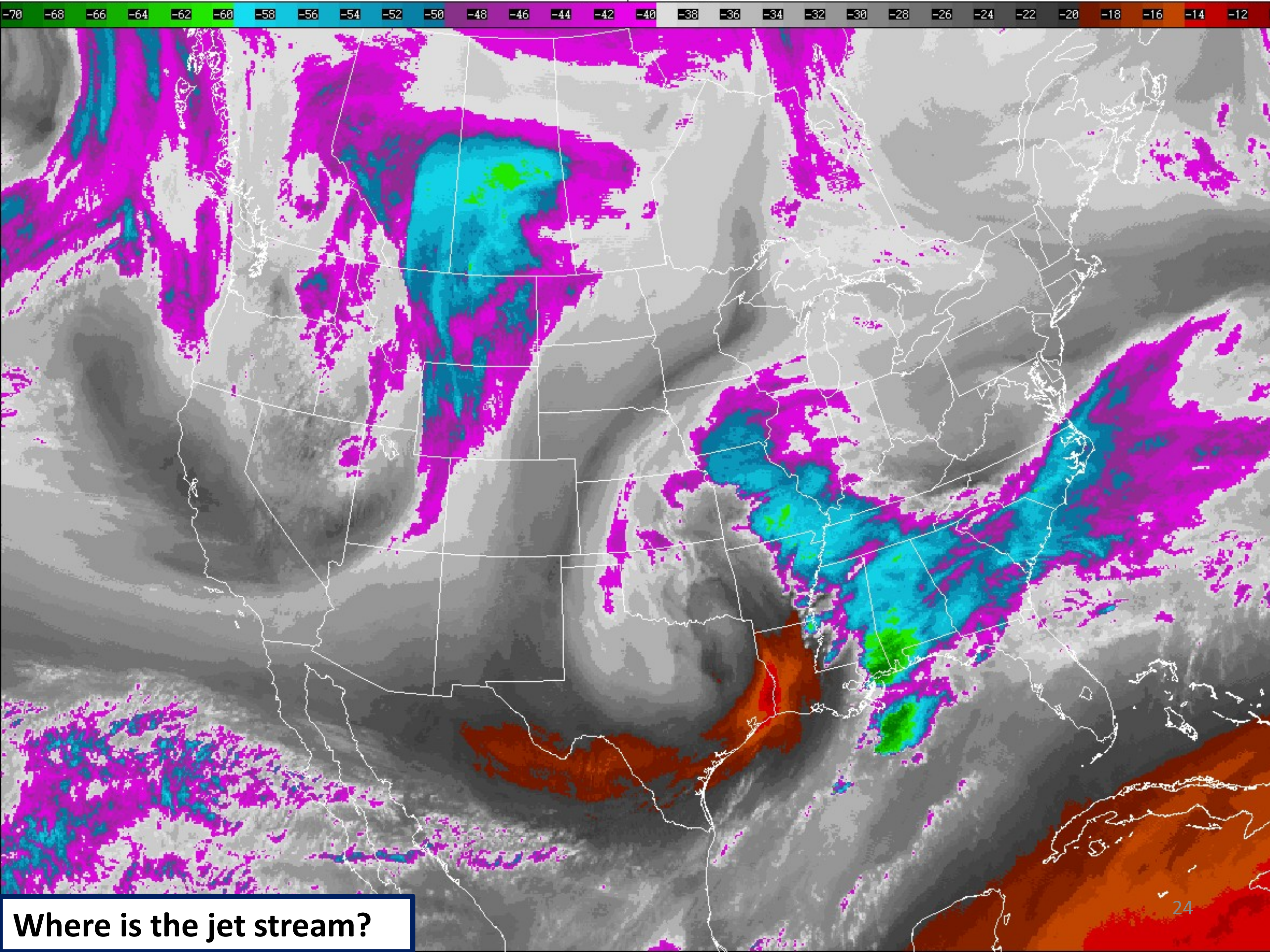
- Mathematical derivations and interpretations are in Martin (2006)

- Weather maps like this can be found at: http://sol.aos.wisc.edu
- Disclaimer: All vertical motion diagnostics are filled with assumptions. The omega terms can also cancel each other out in some cases. It is usually easy to diagnose a strong system, it is the weaker cases that are more challenging.

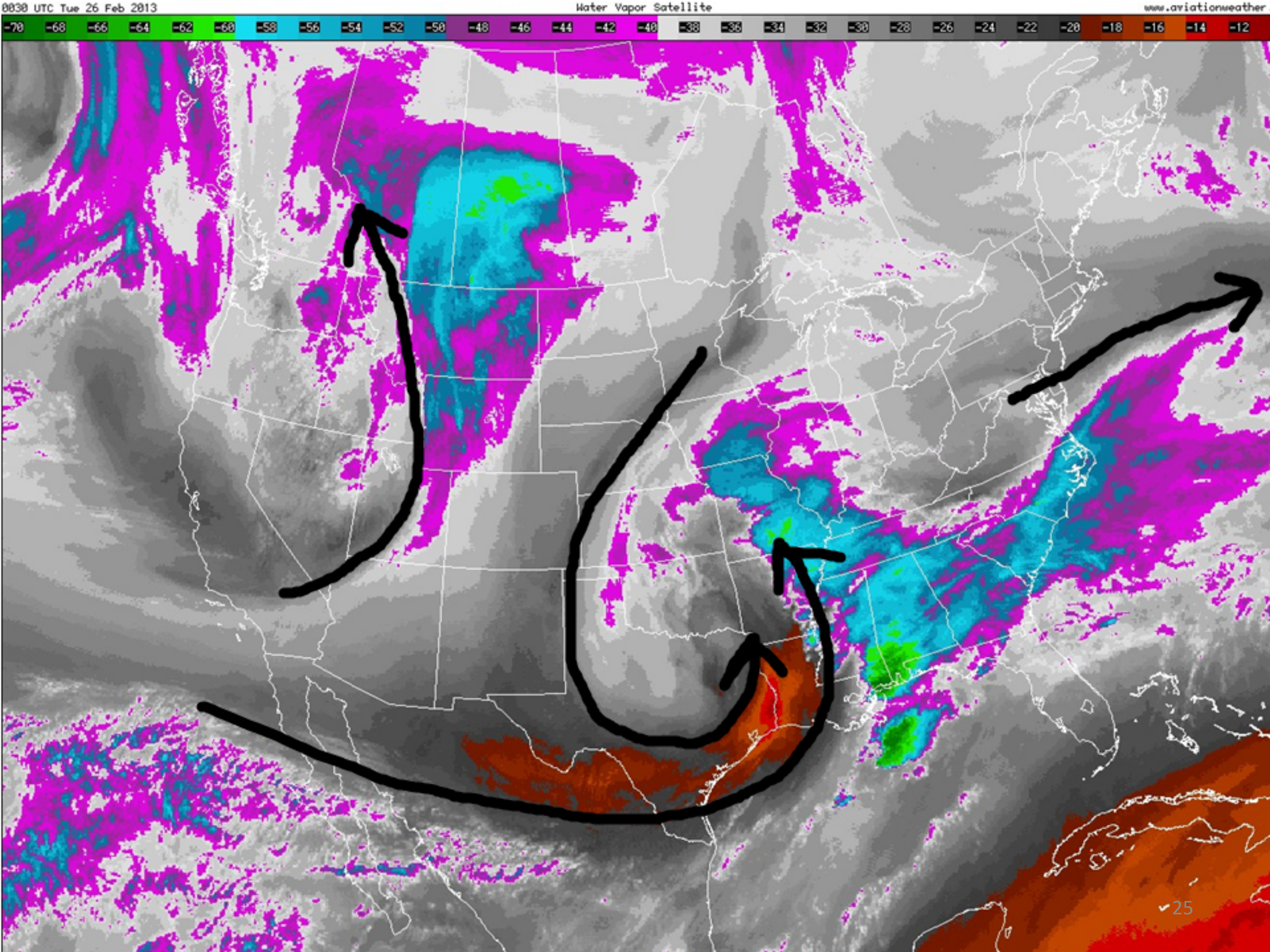
Jet stream analysis

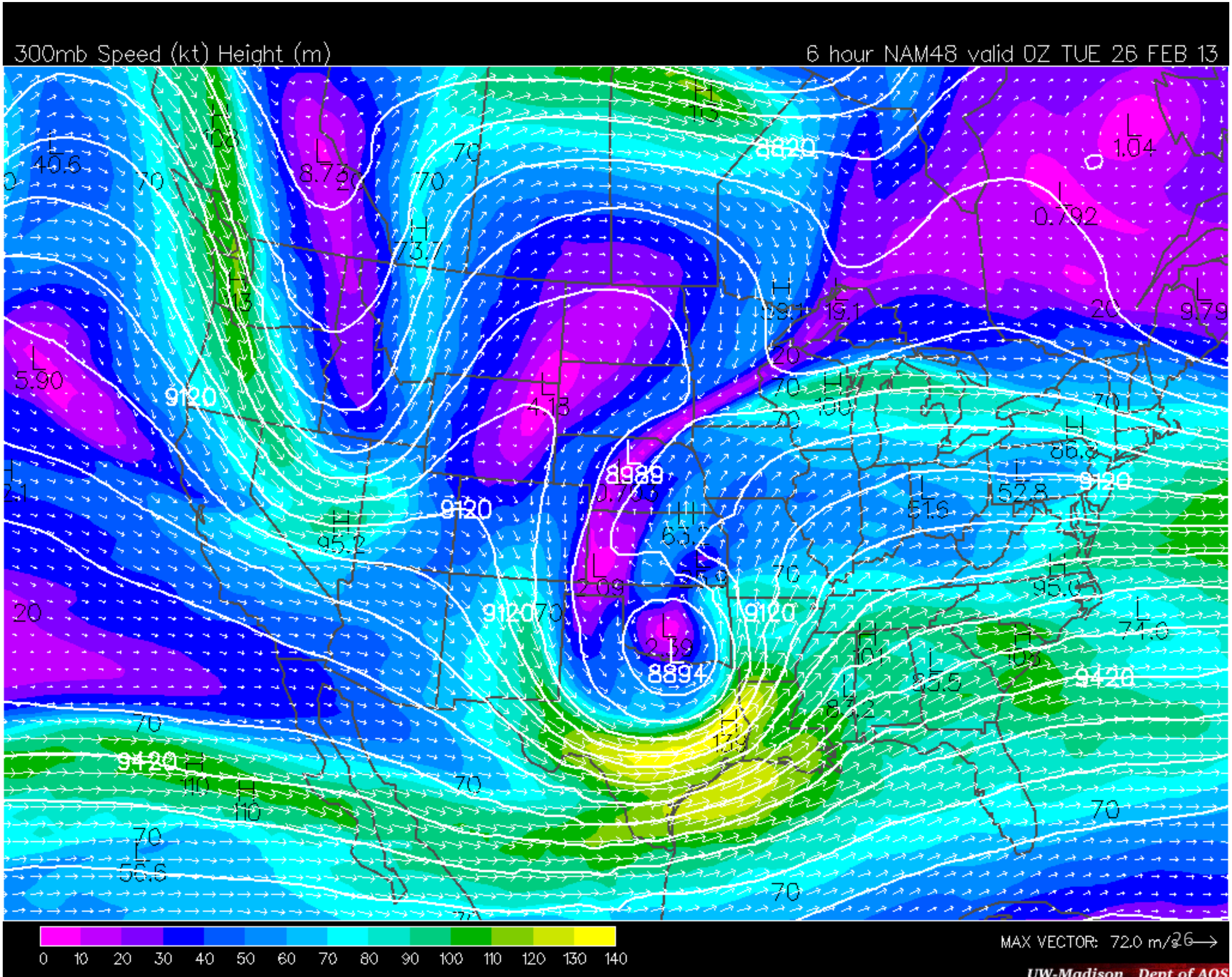
Identifying the jet stream on water vapor imagery

- The 6.7 µm water vapor channel is sensitive to moisture in the upper atmosphere (above 500 mb), which makes it especially useful in identifying the jet stream
- Jet streams are often found:
  - Where water vapor features are moving rapidly (streaky features)
  - Near moisture gradients
  - In the vicinity of developing fronts or cyclones



Where is the jet stream?


0030 UTC Tue 26 Feb 2013
Water Vapor Satellite
www.aviationweather
-70 -68 -66 -64 -62 -60 -58 -56 -54 -52 -50 -48 -46 -44 -42 -40 -38 -36 -34 -32 -30 -28 -26 -24 -22 -20 -18 -16 -14 -12

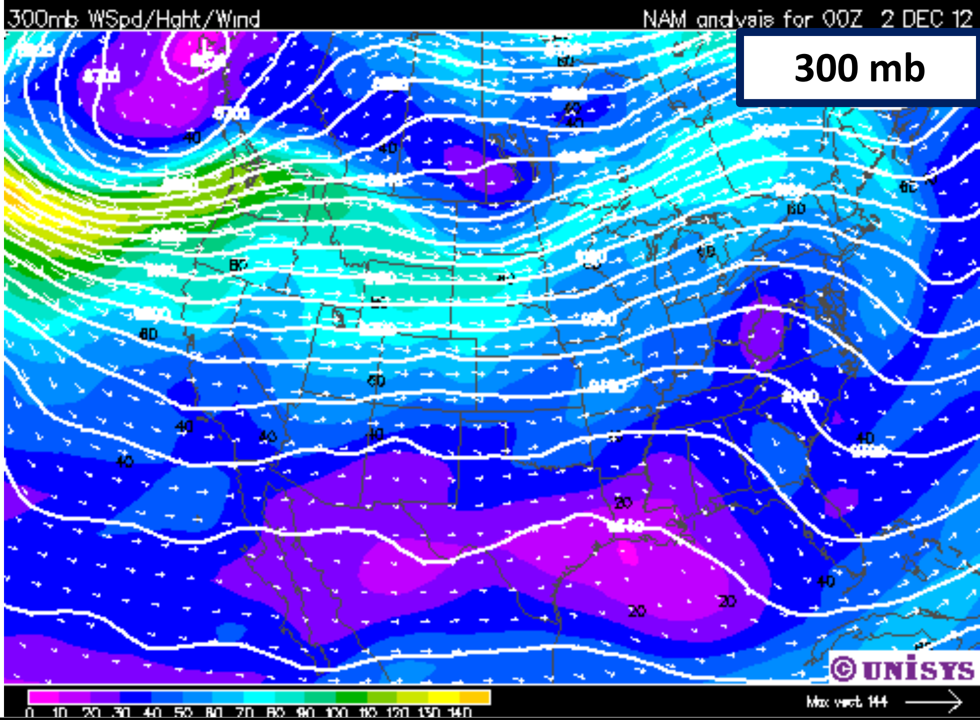

300mb Speed (kt) Height (m)
6 hour NAM48 valid 0Z TUE 26 FEB 13
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
MAX VECTOR: 72.0 m/s
UW-Madison Dept of AOS

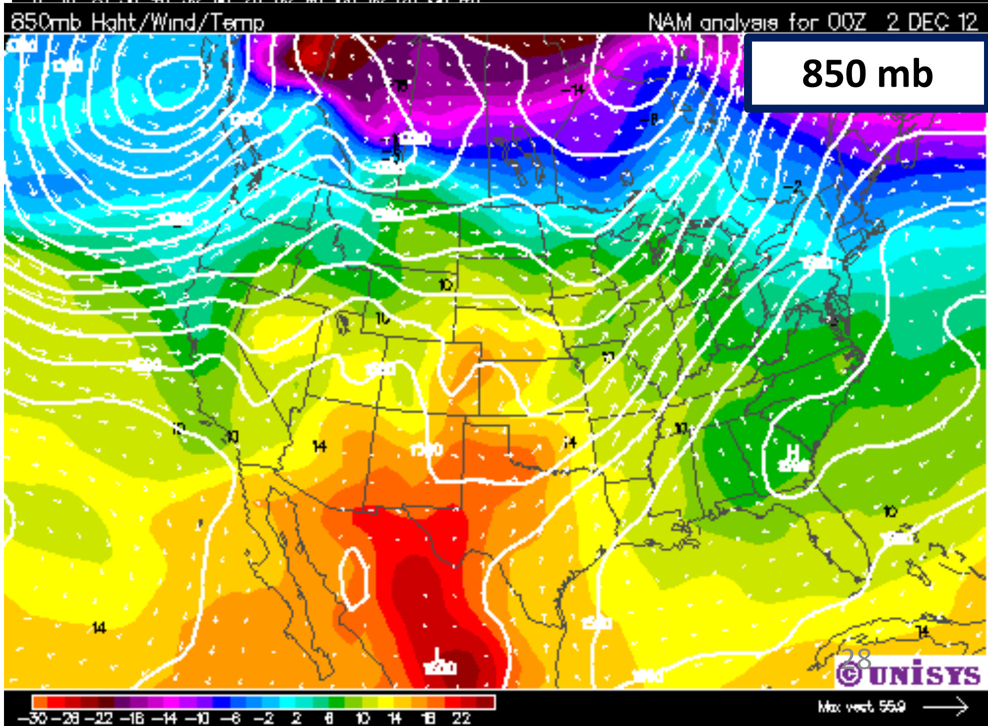
Common types of jet stream patterns

- Zonal Flow
- Meridional Flow
- Split Flow
- Cutoff Low
- Blocking High
- Omega Block
- Rex Block
- Pineapple Express

Zonal Flow

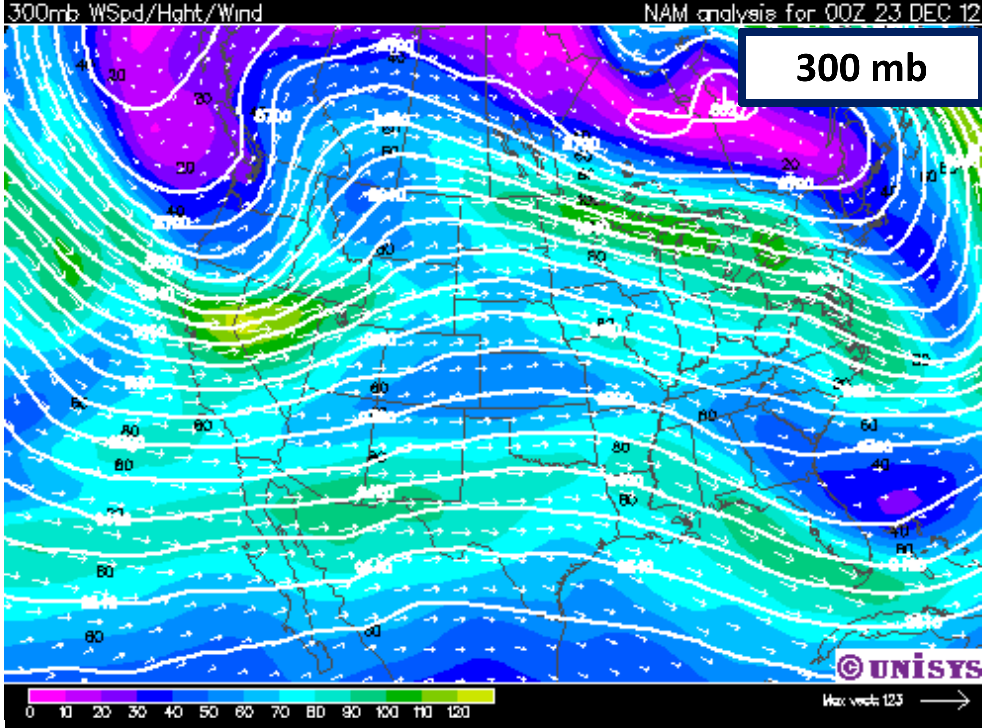
- Dominant west to east flow pattern
- Low pressure systems are generally weak and move quickly
- Weather is generally quiet with few extremes

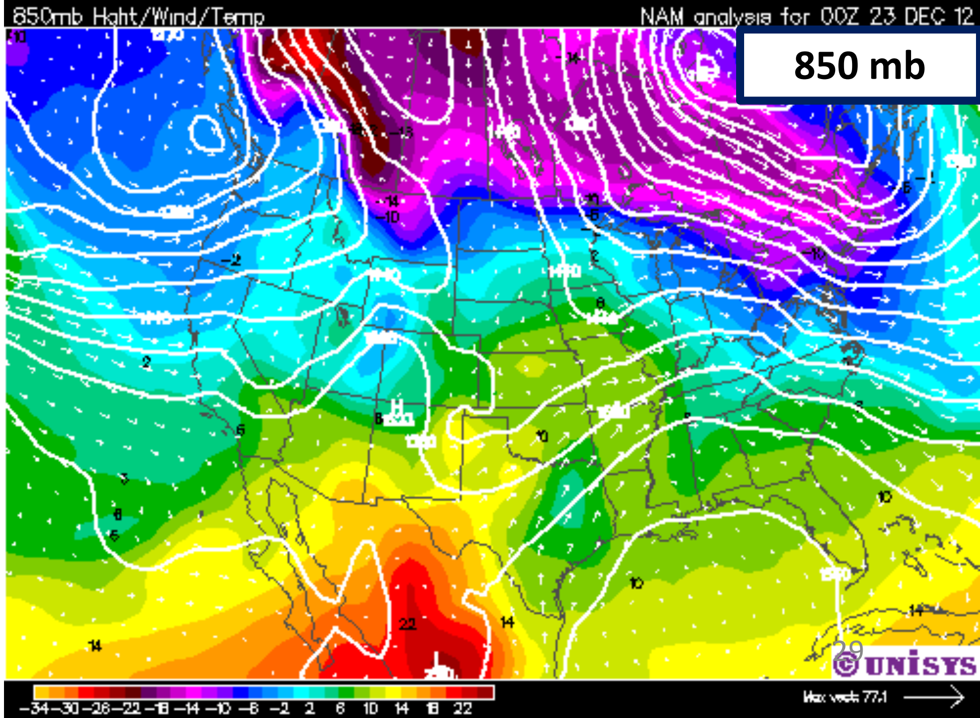




Split Flow

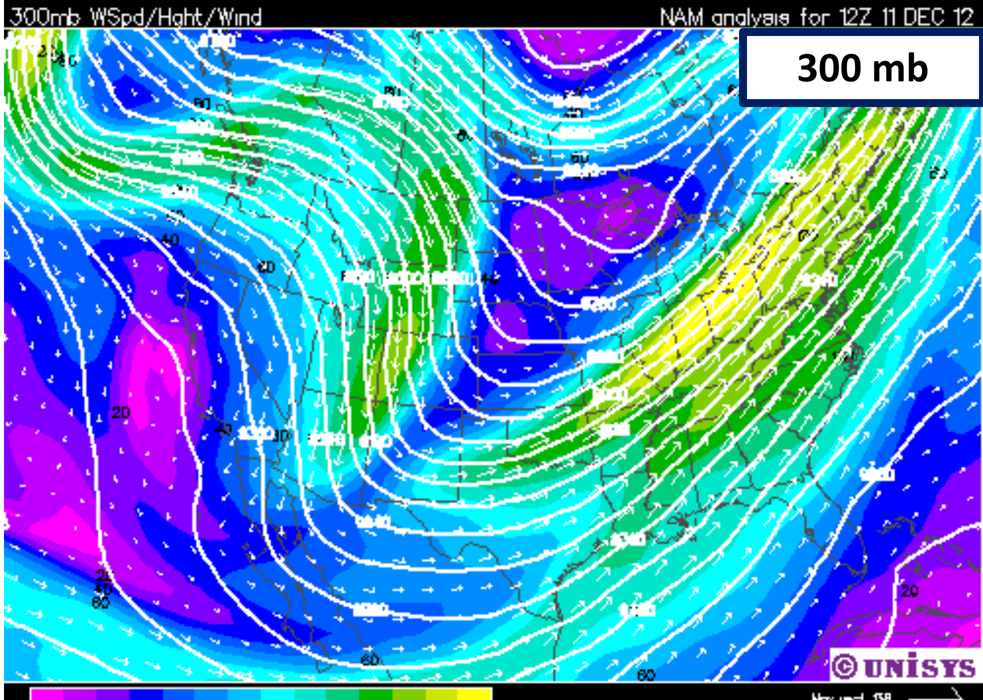
- Similar to zonal flow except with distinctly separate polar and subtropical jets
- Quiet weather between jets
- Fast moving, active weather elsewhere

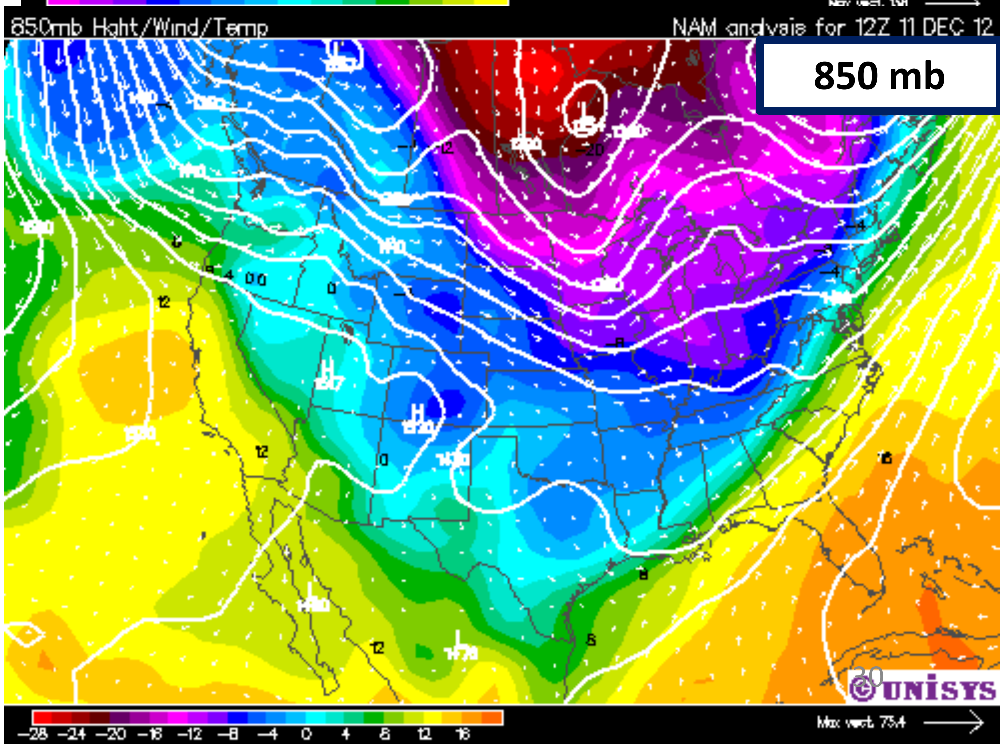




Meridional Flow

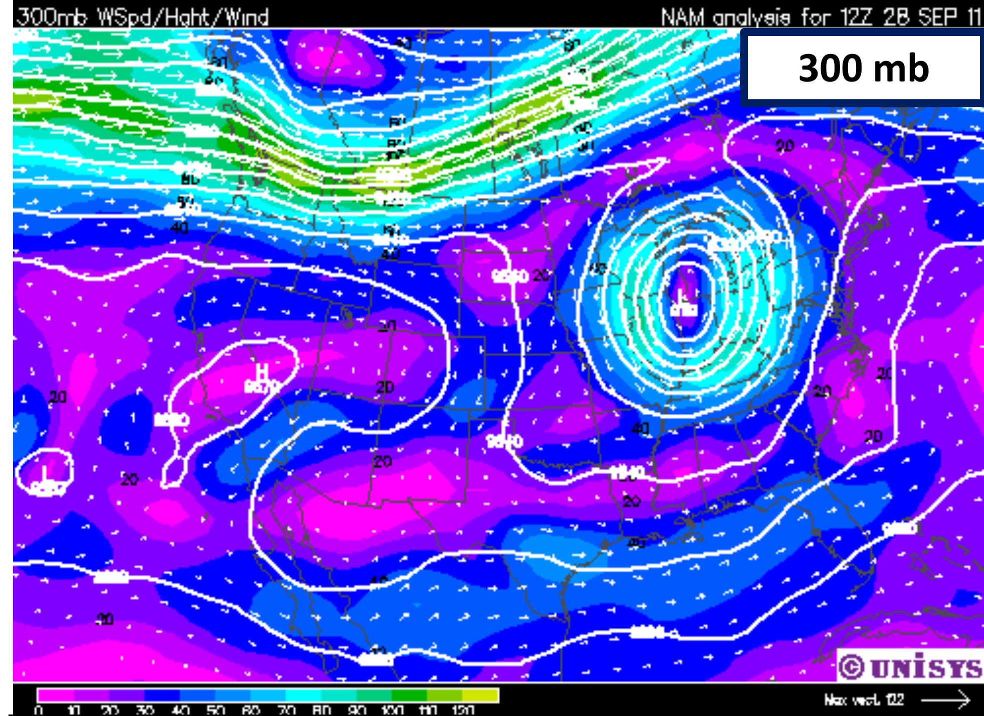
- Dominant north-south flow pattern
- Low pressure systems are stronger and move slower than zonal flow
- Associated with temperature extremes

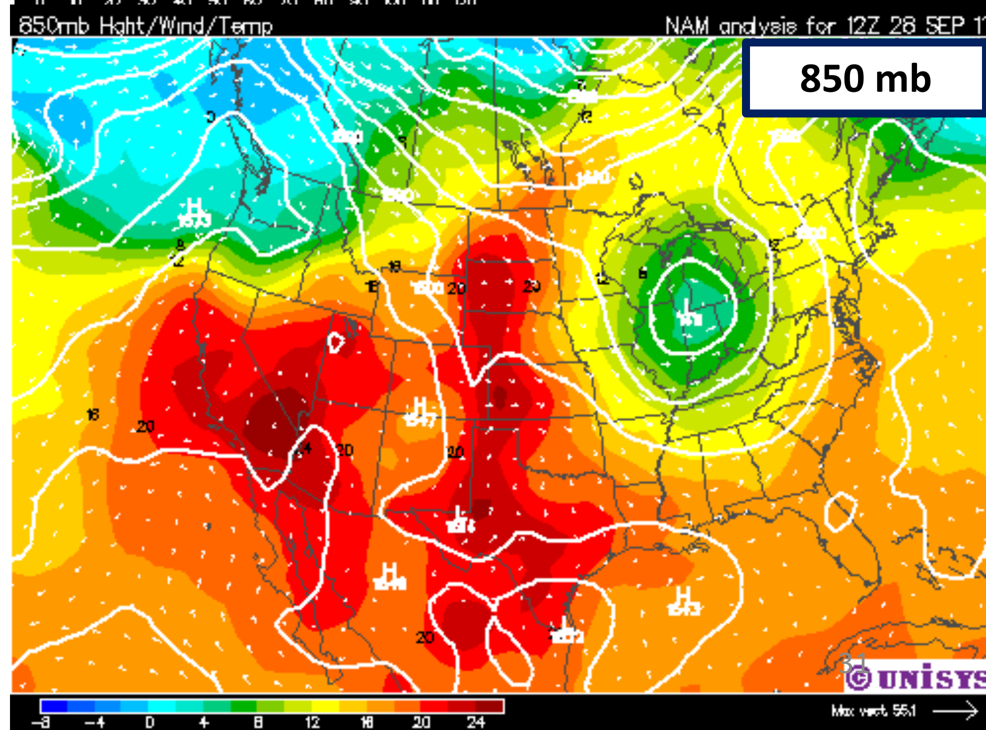




Cutoff low

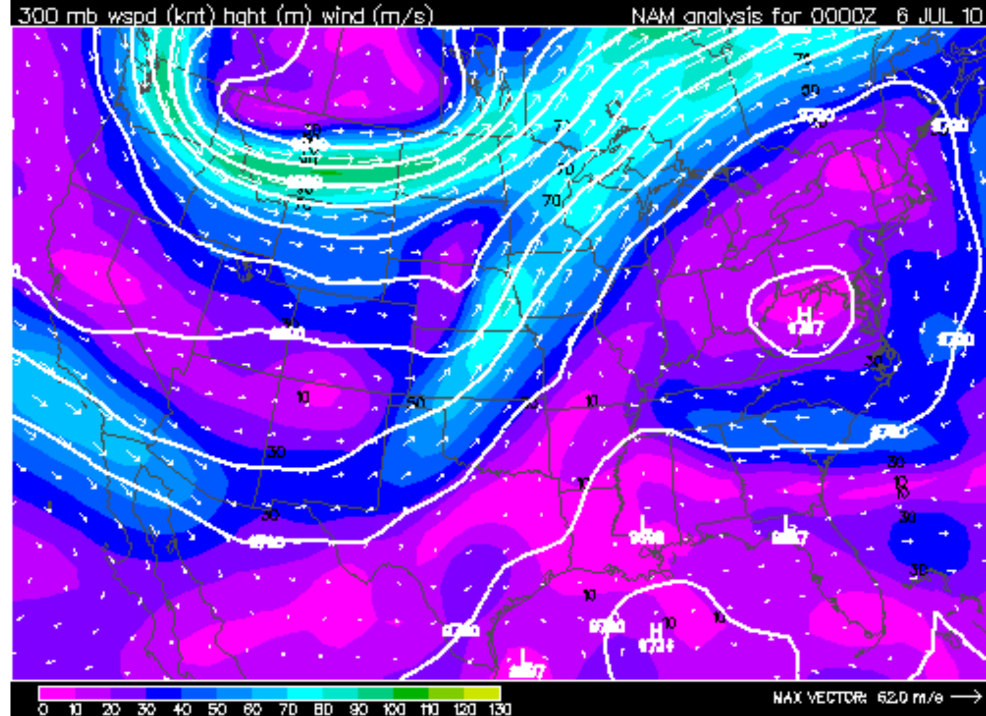
- Starts as a normal trough, persists when trough continues to “dig” while rest of jet stream resumes ridging or zonal flow
- Associated with persistent cold, cloudy weather

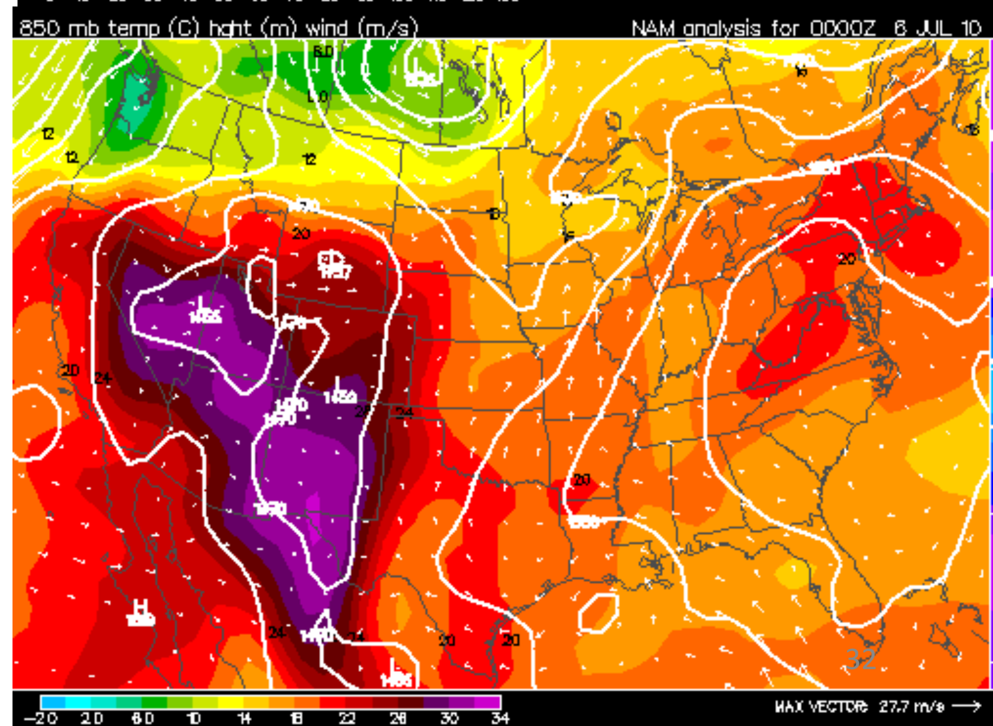




Blocking High

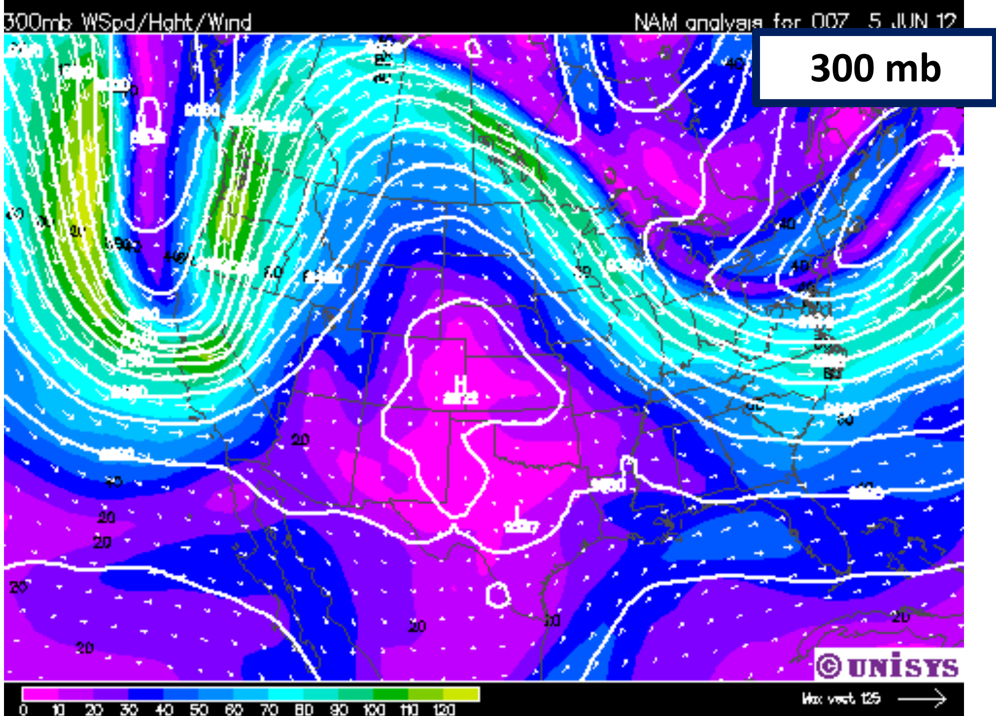
- Forms from a ridge when warm advection wraps around to the poleward and west sides of the high
- Associated with summer heat waves in eastern US
- Example: The Bermuda High is a semi-permanent blocking high

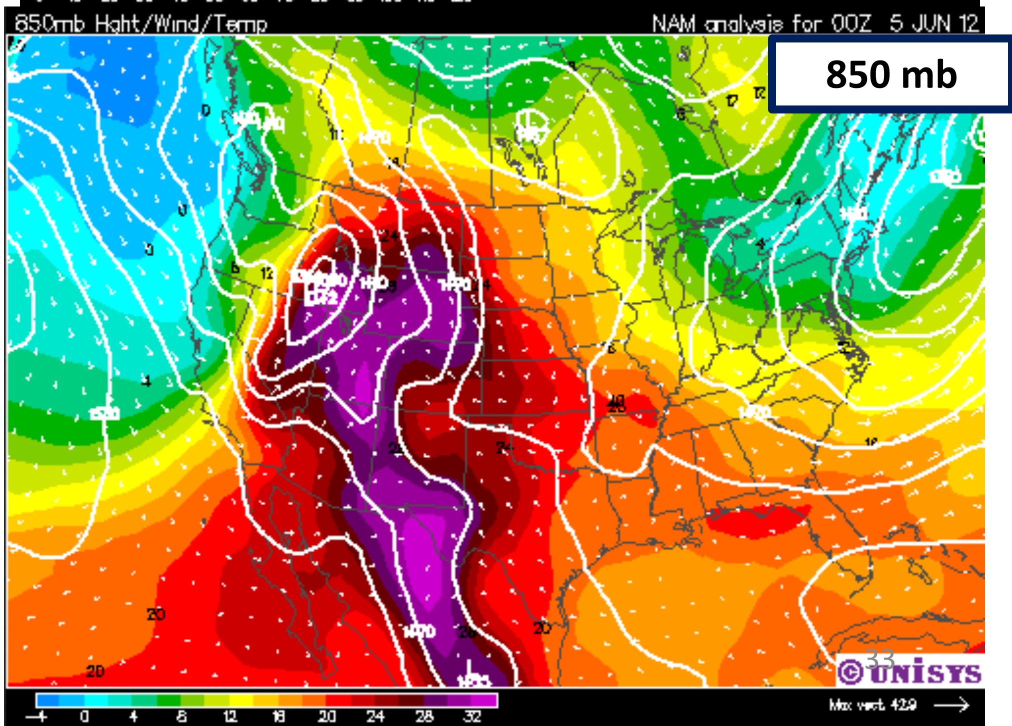




Omega Block

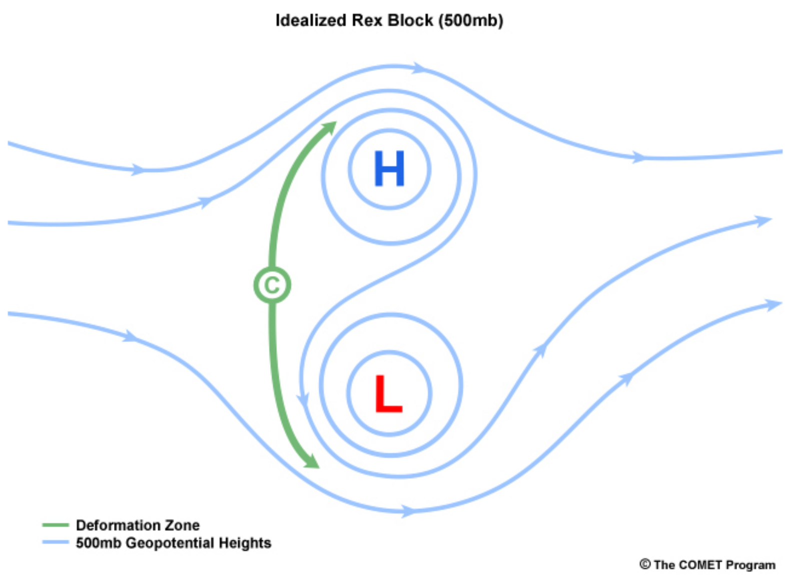
- Jet stream takes shape of omega: Ω (low-high-low)
- Largest and least common blocking pattern, usually seen in summer
- Associated with most persistent/extreme droughts

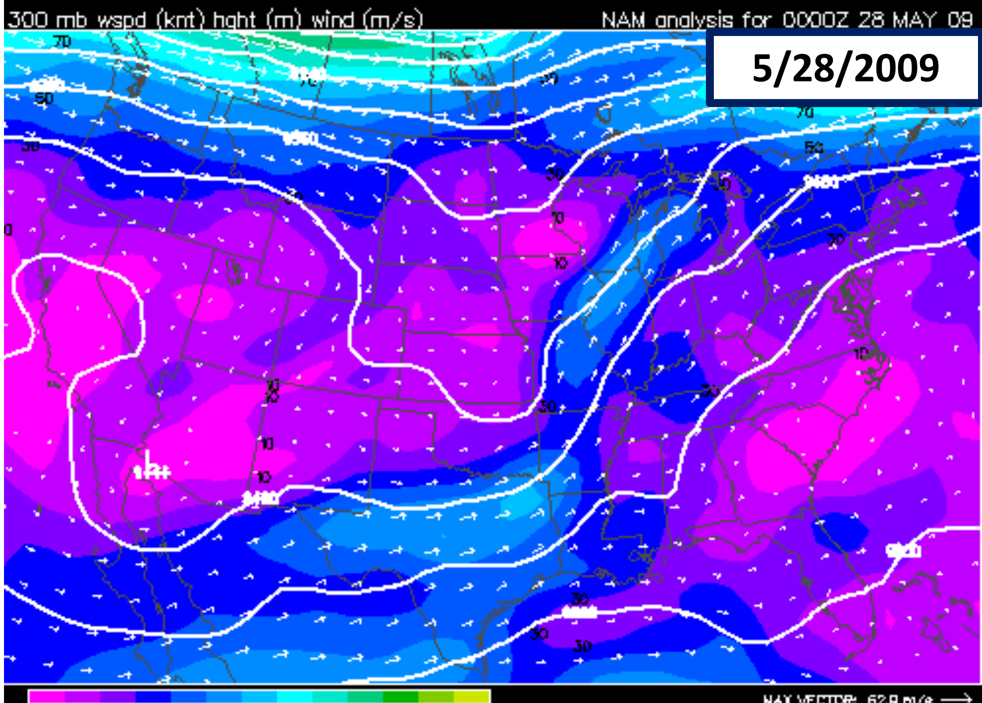


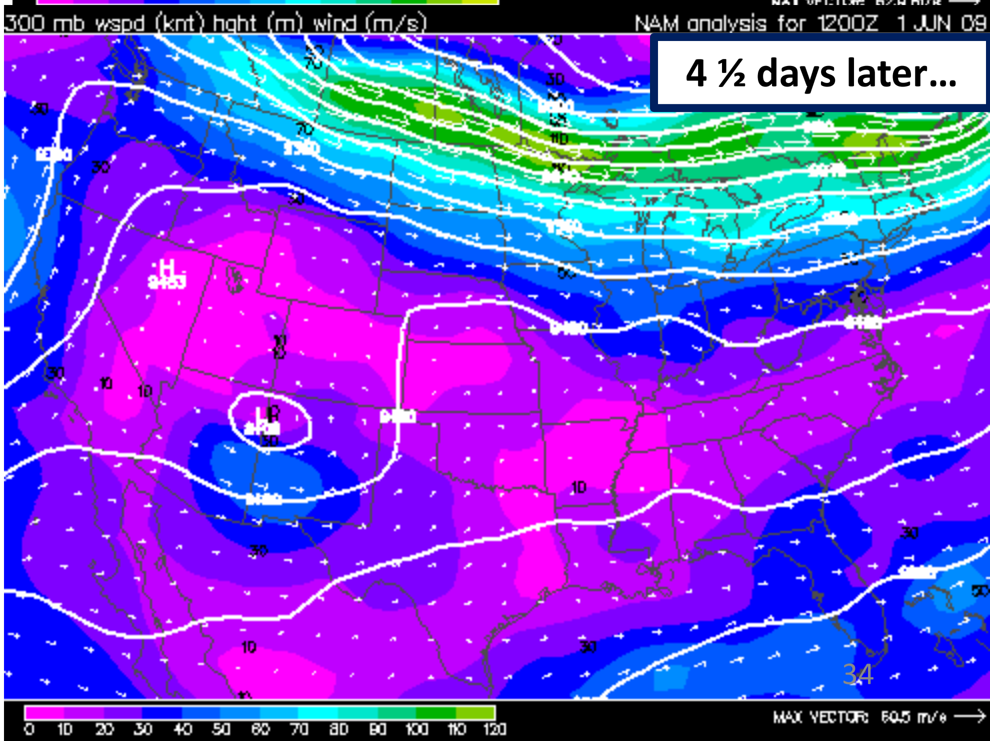


Rex Block

- Blocking high on top of cutoff low
- Associated with persistent ridging (dry/warm weather) over most of US





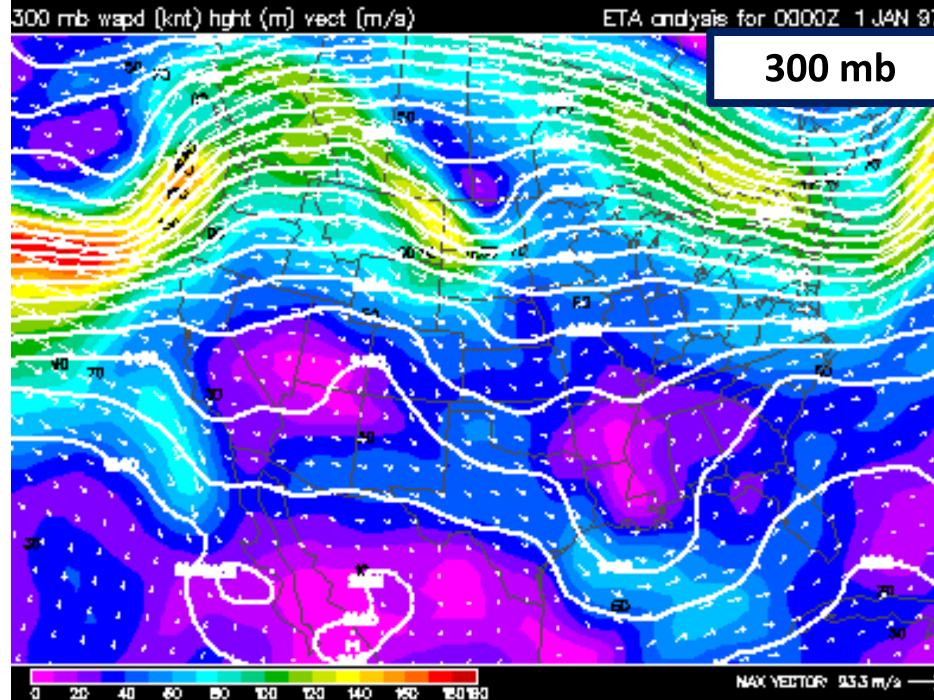


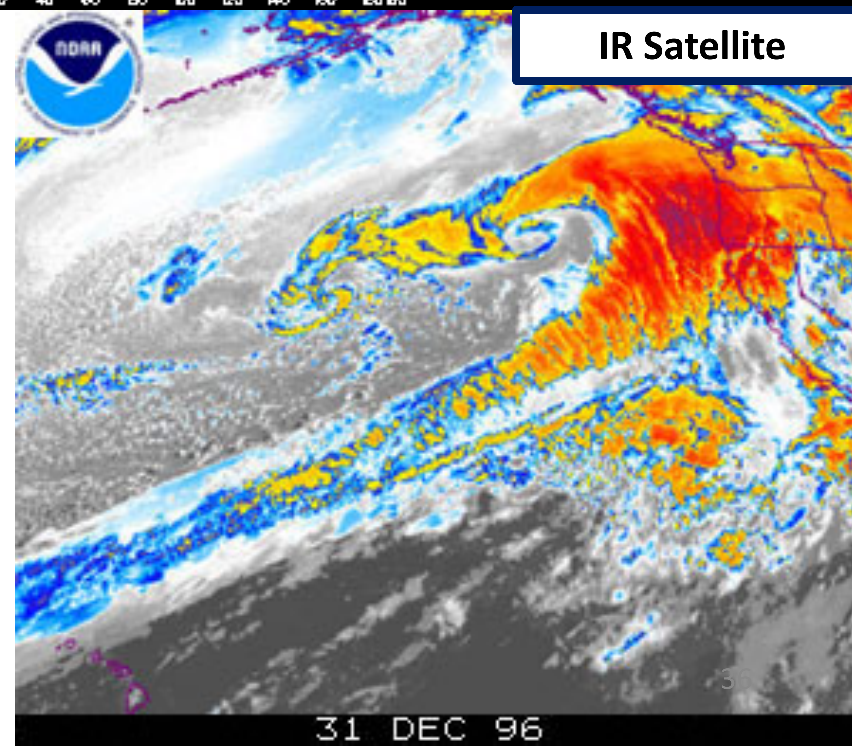
Dissipating a blocking pattern

- Deformation zone upstream (west) of block is the key to maintaining the blocking feature
  - Flow travels around block, either to the north or south
  - Deformation zone appears as a strong moisture gradient in water vapor imagery
- Numerical models tend to break down blocking patterns too quickly

Pineapple Express

- Strong jet stream from Hawaii to Pacific coast creates persistent moist flow to US Pacific coast
- Associated with very heavy rainfall
- More common in El Nino years

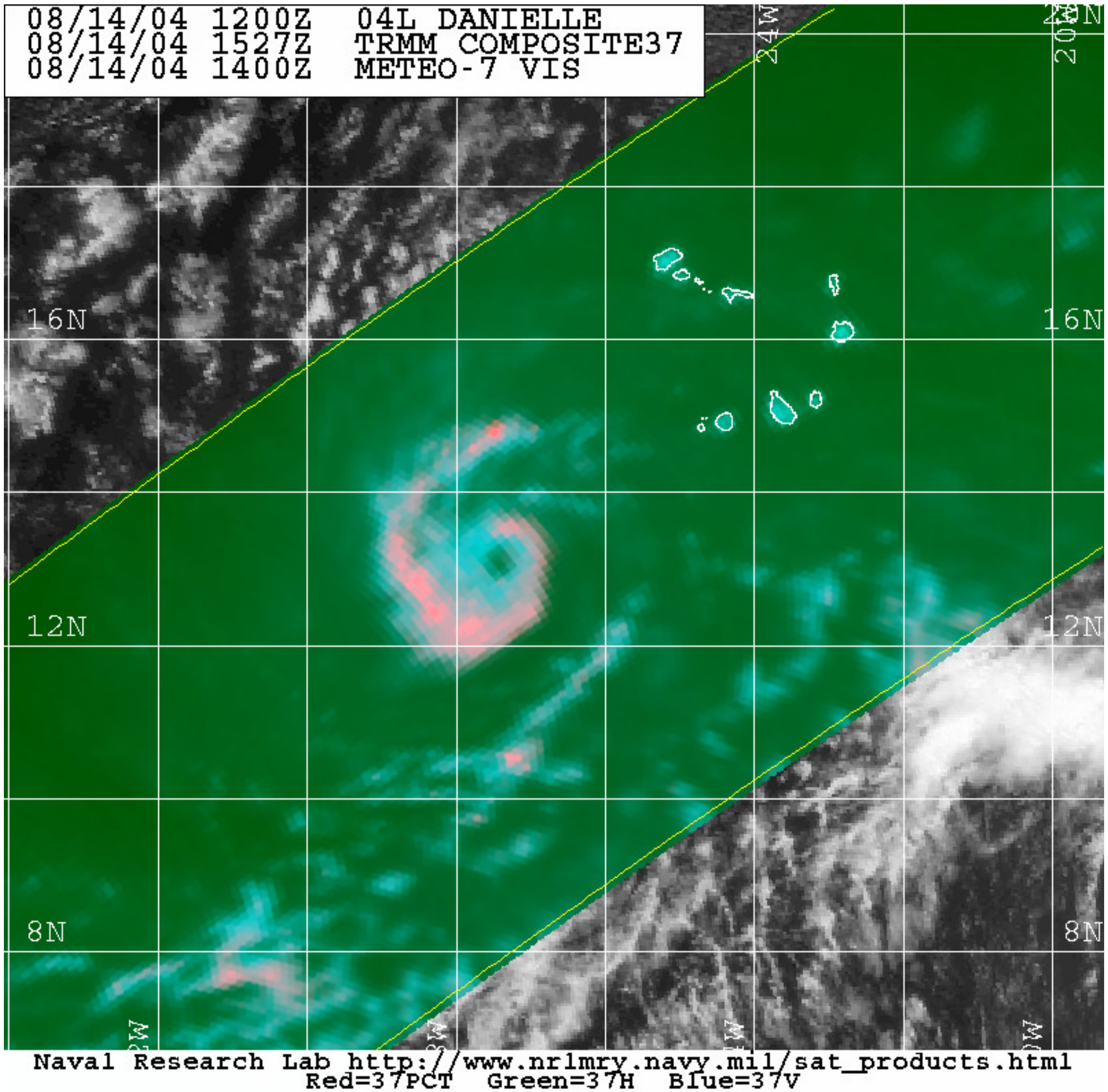




Hurricane Forecasts

- Genesis: on large scale weather maps or satellite images, look for tropical waves (Africa easterly waves)
- Tropical storm or hurricane development:
  - Environmental conditions (CIMSS TC website):
    - High SST: >= 26 degree C
    - Low vertical wind shear: <= 5-10 m/s is favorable
    - High moisture: total precipitable water >= 50mm, SAL
  - Internal conditions:
    - Organized convection on IR image; deep convection (85 GHz) near center; ring formed in 37 GHz color image indicating RI (NRL TC website)
    - Upper level (200mb or 300 mb) outflow: anti-cyclonic (CIMSS TC website)

37 GHz Ring and TC Rapid Intensification (RI)



- RI is defined as 30 kt intensity increases during 24 hours (Kaplan and DeMaria 2003)
- A cyan and pink ring pattern around storm center on 37 GHz color images is a good indicator for future 24 hour RI

- In the image above, Danielle's intensity was 40 kt and increased 33 kt in the next 24 hours (RI)