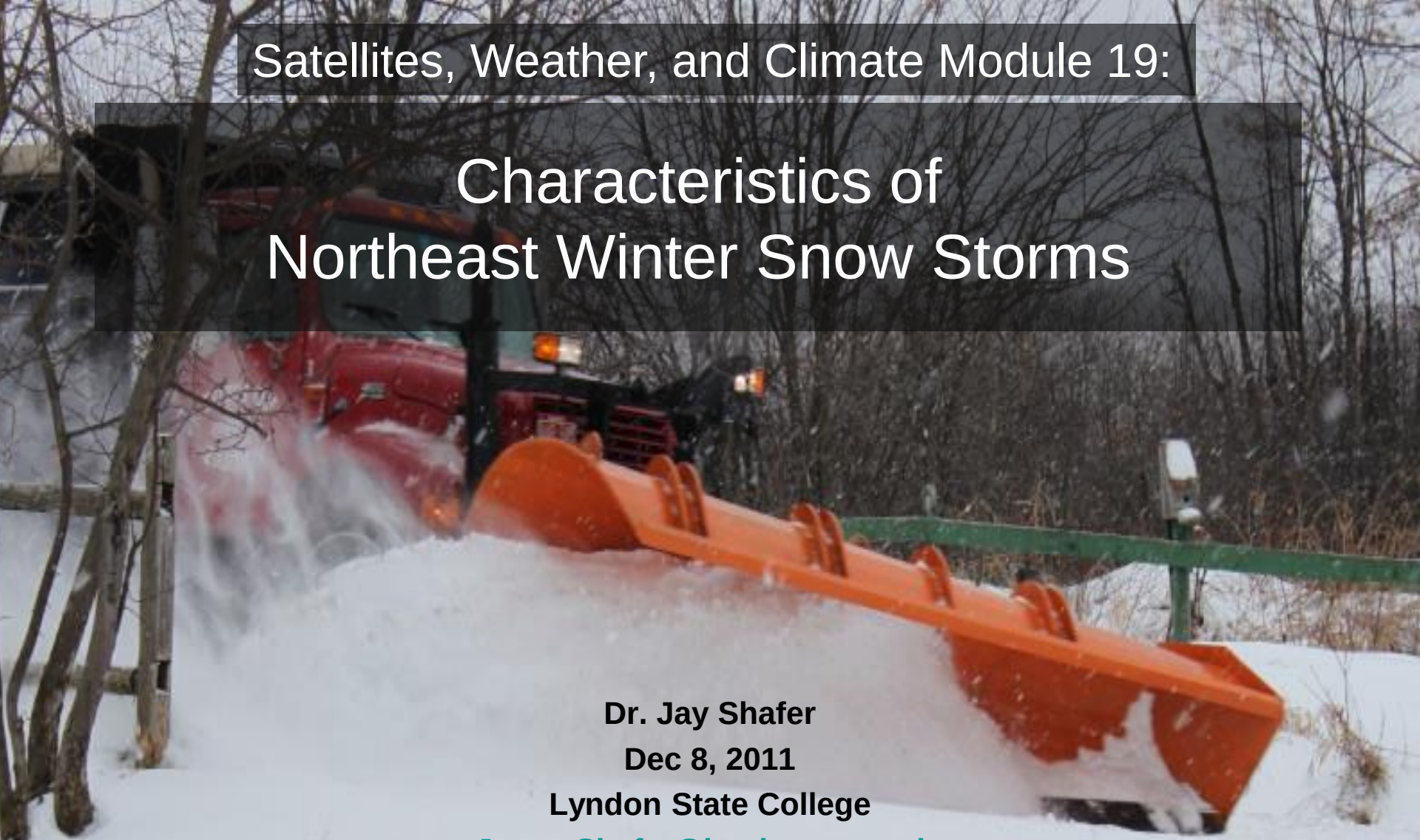
Satellites, Weather, and Climate Module 19:

Characteristics of Northeast Winter Snow Storms



Dr. Jay Shafer

Dec 8, 2011

Lyndon State College

Jason.Shafer@lyndonstate.edu

SWAC

The UNIVERSITY of VERMONT

NSF

VERMONT

Outline

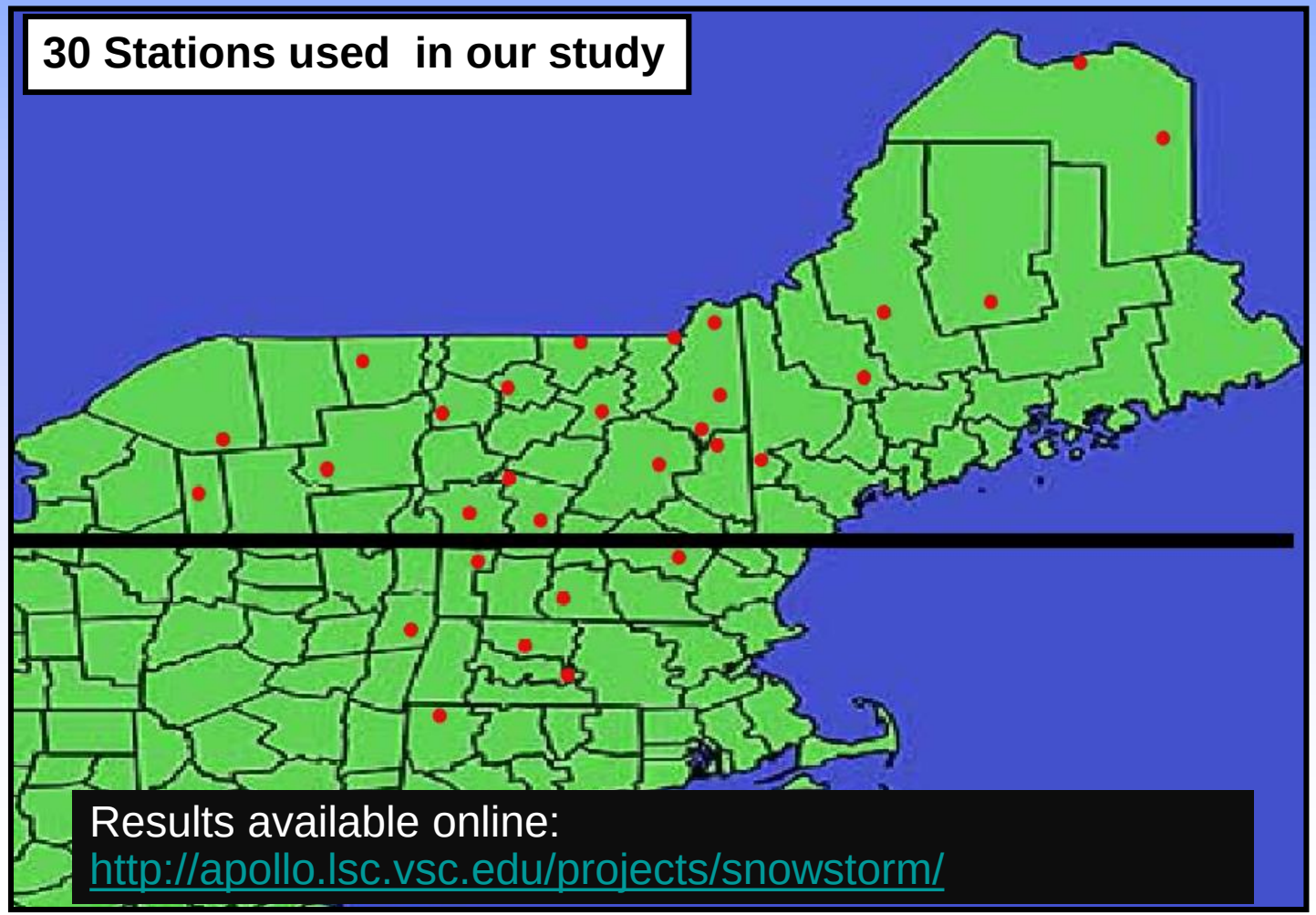
- Large scale structure of Northeast Snow Storms
  - Surface pressure patterns
  - Moisture patterns
  - Frontal patterns
- Forecasting storms: tools meteorologists used to predict today's snow storm

Learning Outcomes

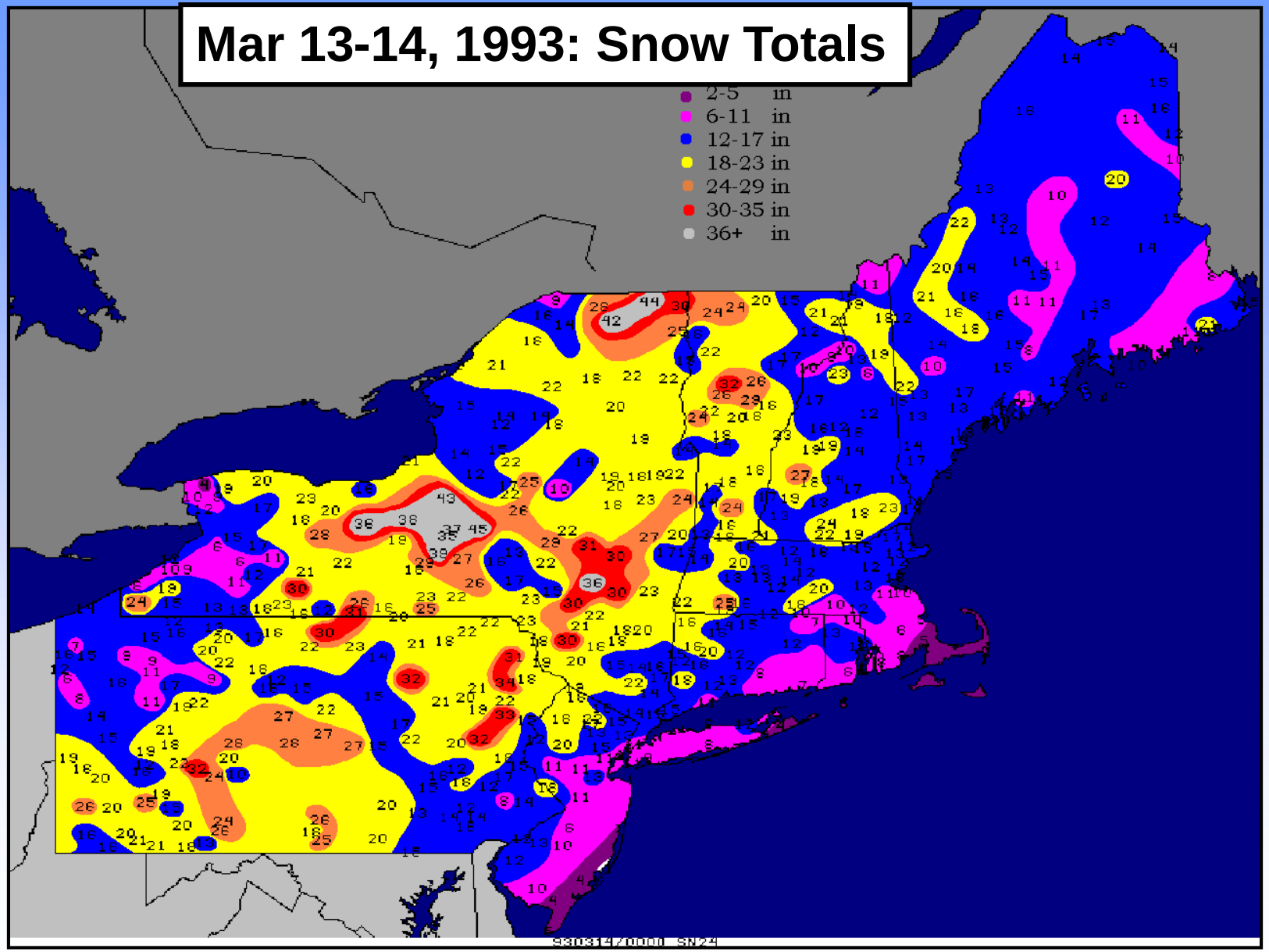
1. Improve understanding of the typical lifecycle of mid-latitude cyclones
2. Improve understanding of the structure of Nor'easters and how they produce heavy snowfall
3. Develop a basic understanding of how weather forecast models can be used to predict these events

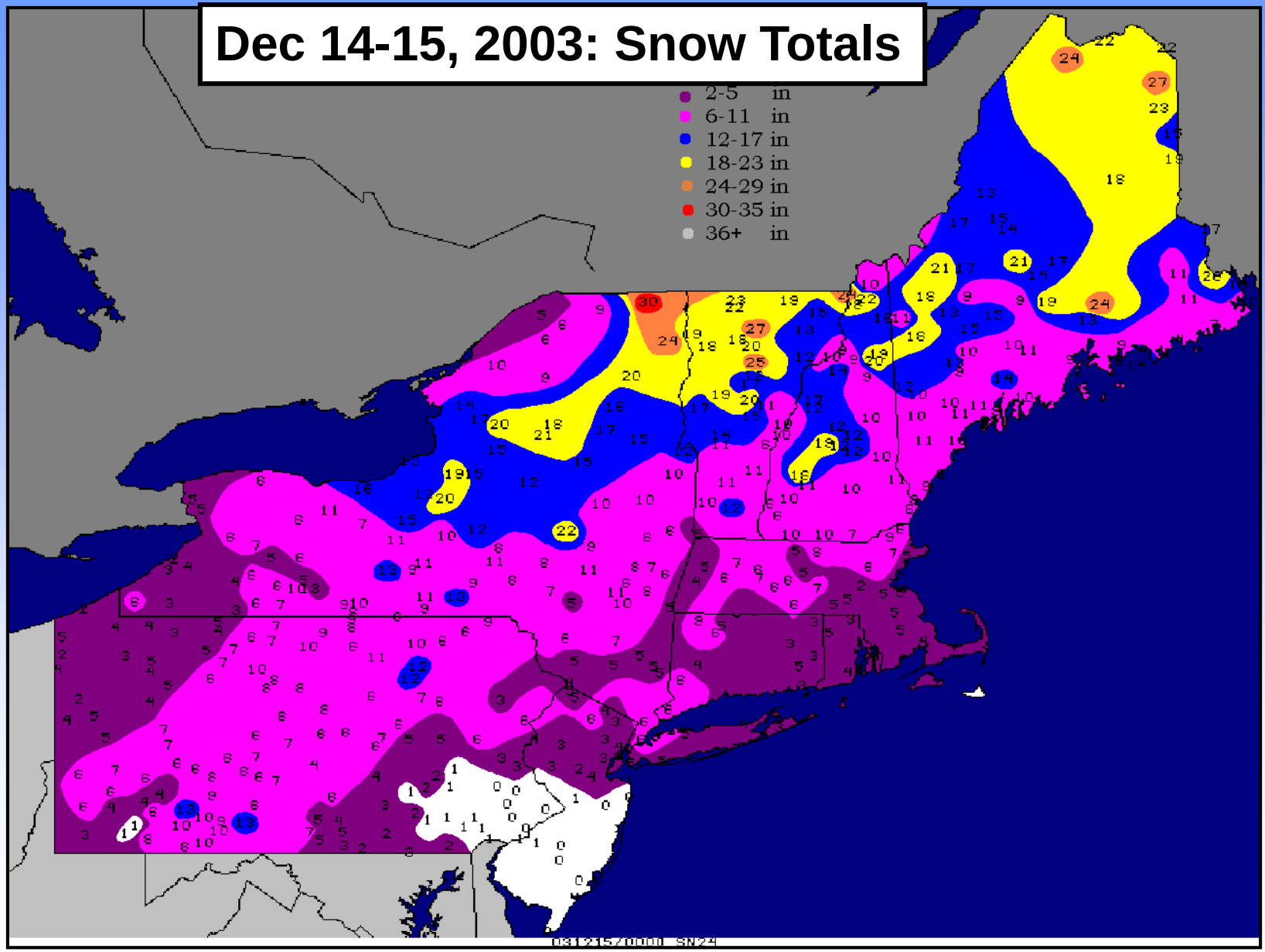
Northeast Snow Storm Project

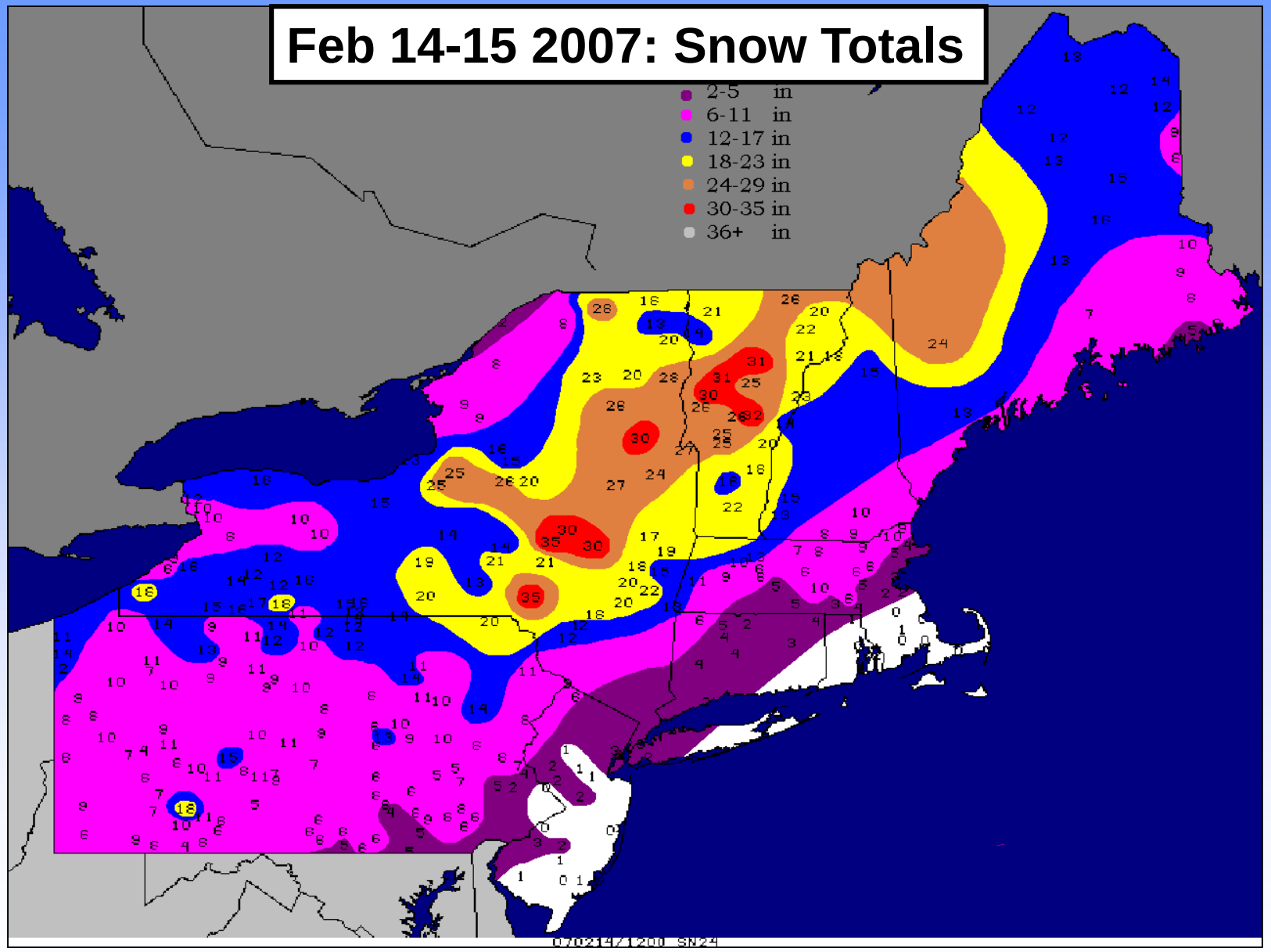
- Identified top 30 snow storms 1977-2007 using area-averaged weighing of daily snow amounts



Mar 13-14, 1993: Snow Totals




Dec 14-15, 2003: Snow Totals
2-5 in
6-11 in
12-17 in
18-23 in
24-29 in
30-35 in
36+ in
031215/0000 SN24

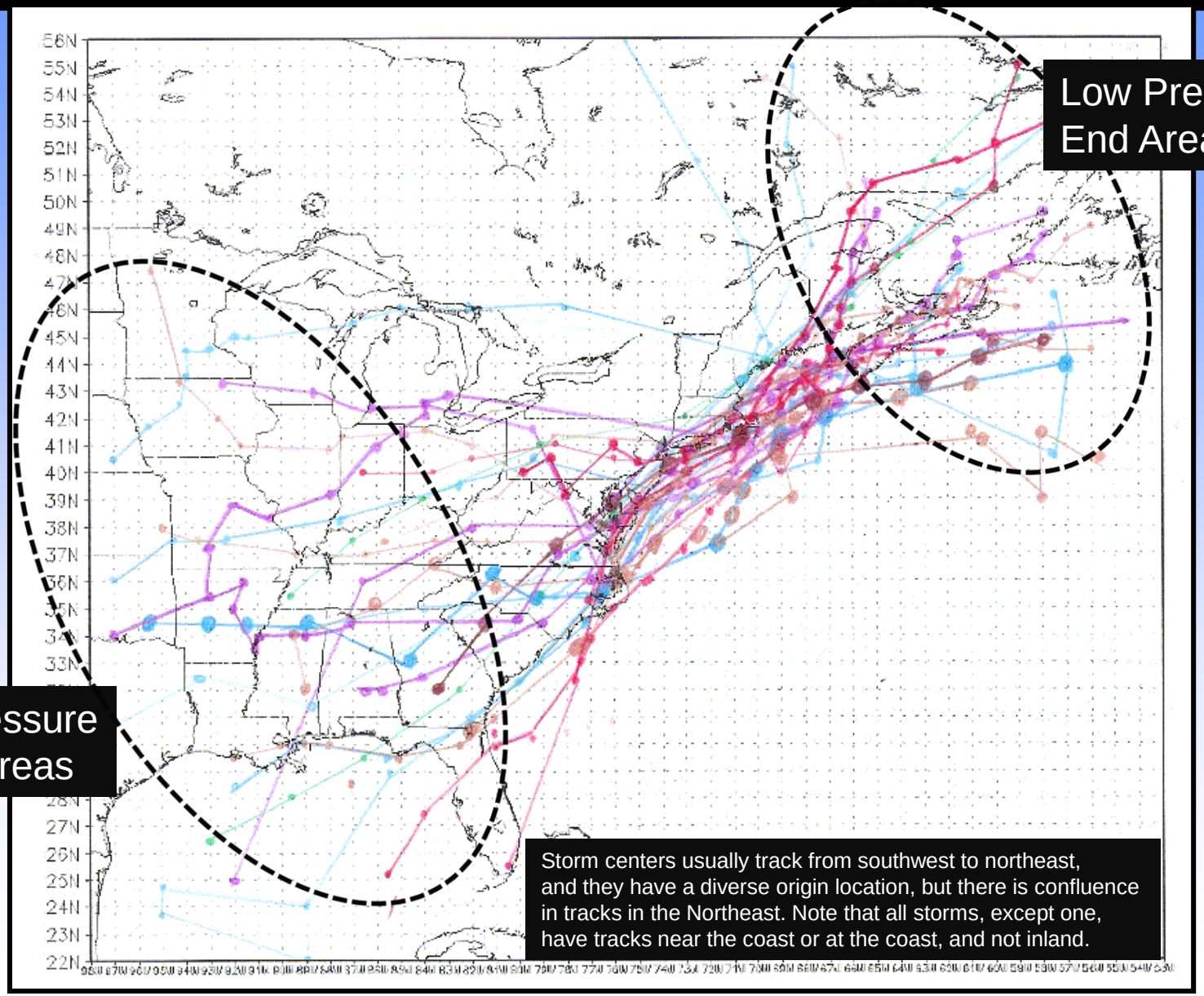

Feb 14-15 2007: Snow Totals
2-5 in
6-11 in
12-17 in
18-23 in
24-29 in
30-35 in
36+ in
070214/1200 SN24

Surface Pressure Patterns

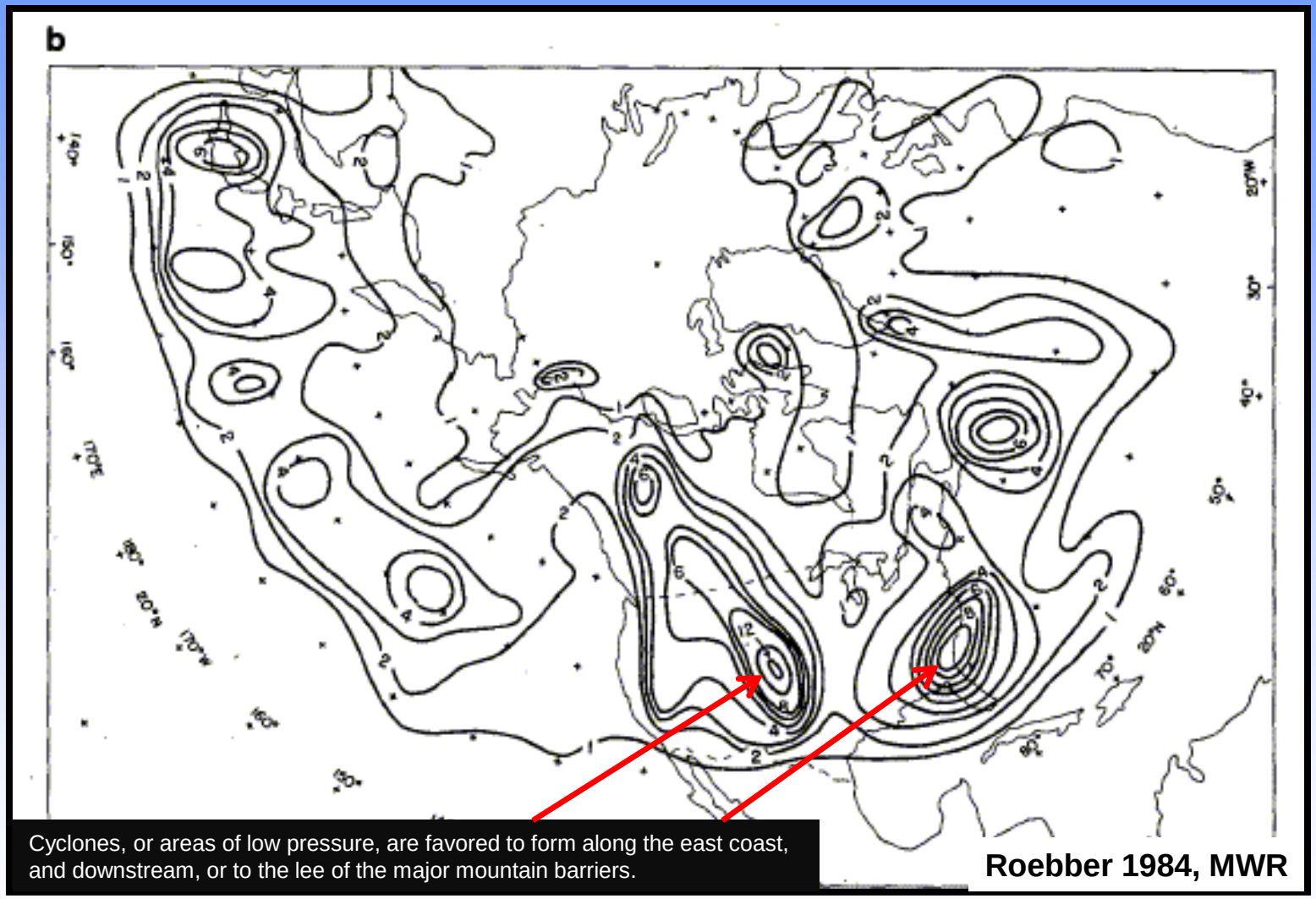
Valentine's Day Blizzard, February 14 2007

Photo credit: Alexander Jacques

Surface low pressure tracks for major NE Snow Storms



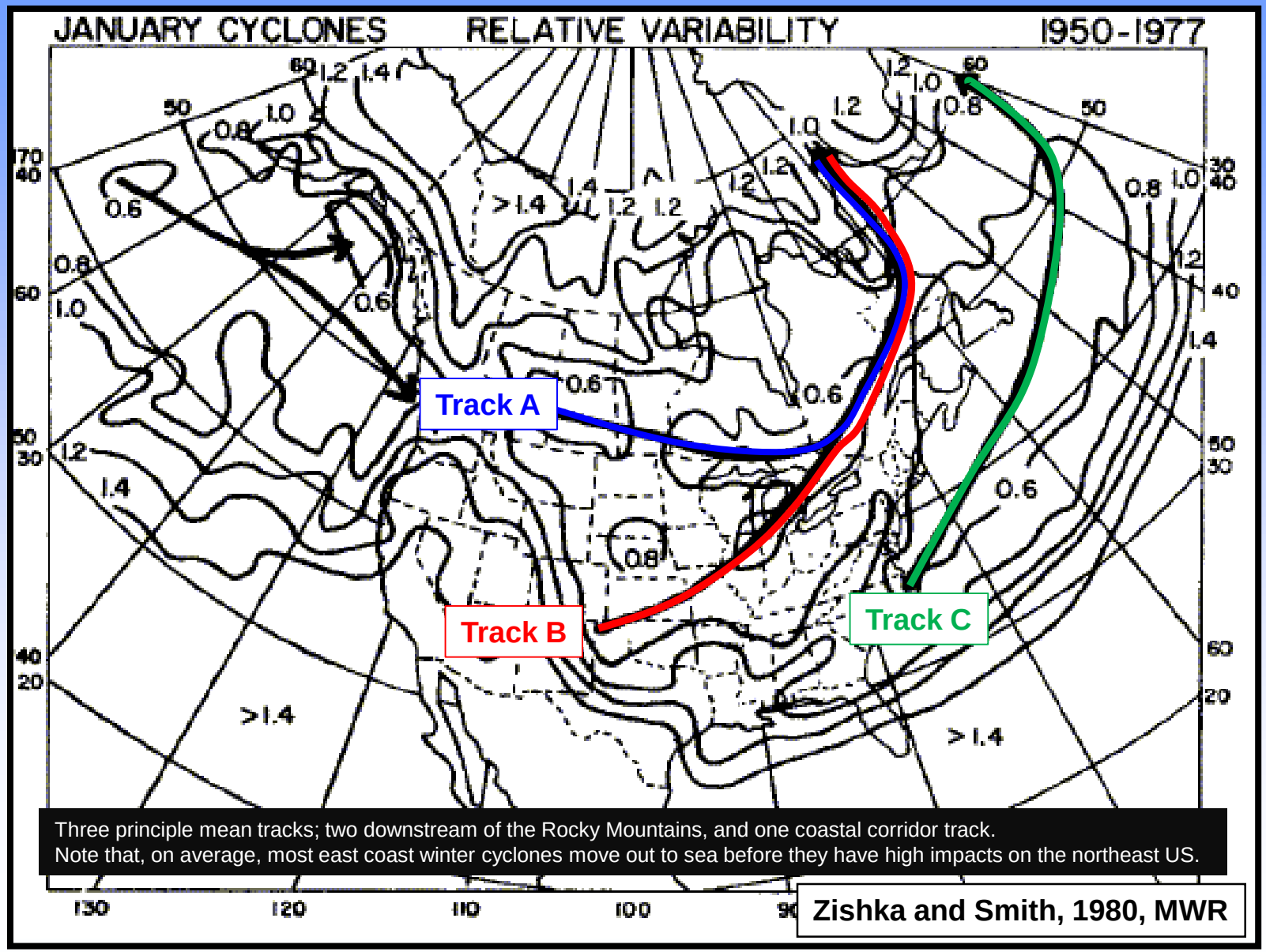
Storm Development "Cyclogenesis" Climatology



Cyclones, or areas of low pressure, are favored to form along the east coast, and downstream, or to the lee of the major mountain barriers.

Roebber 1984, MWR

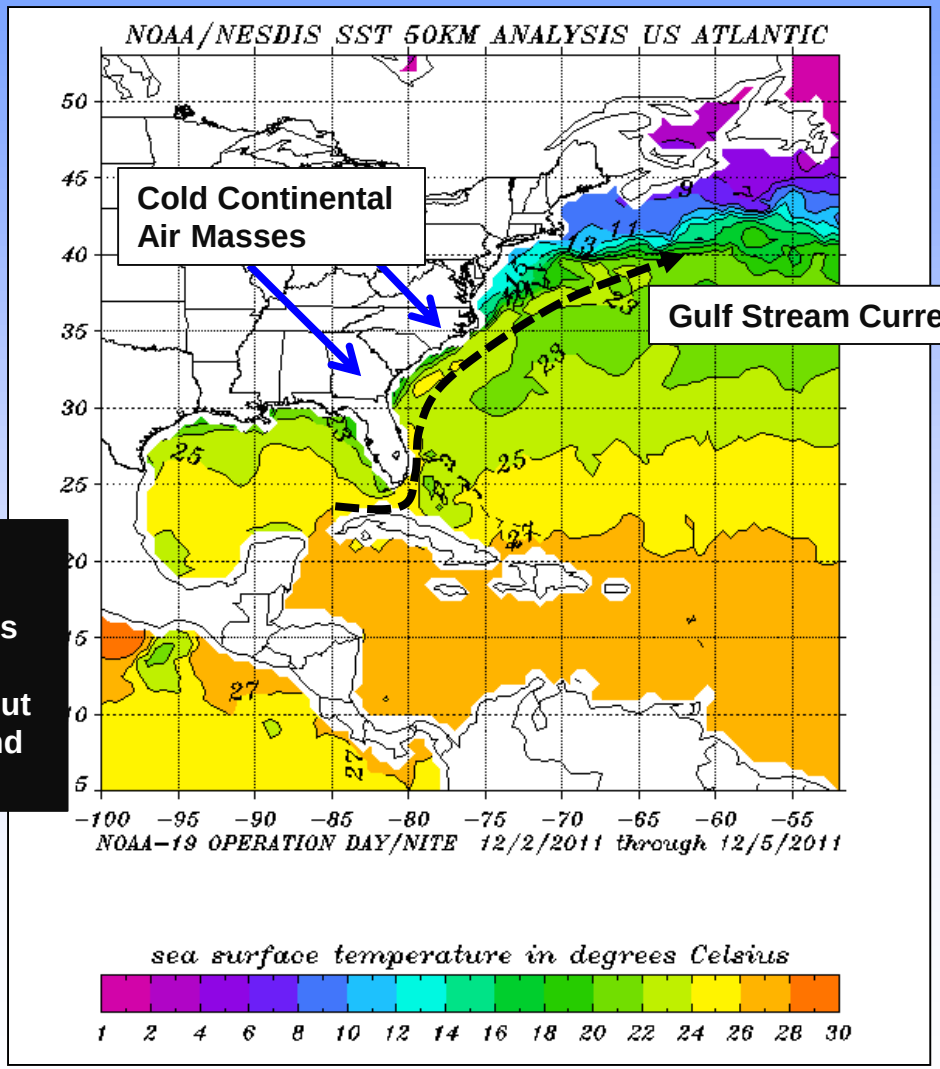
Principle January Cyclone Tracks



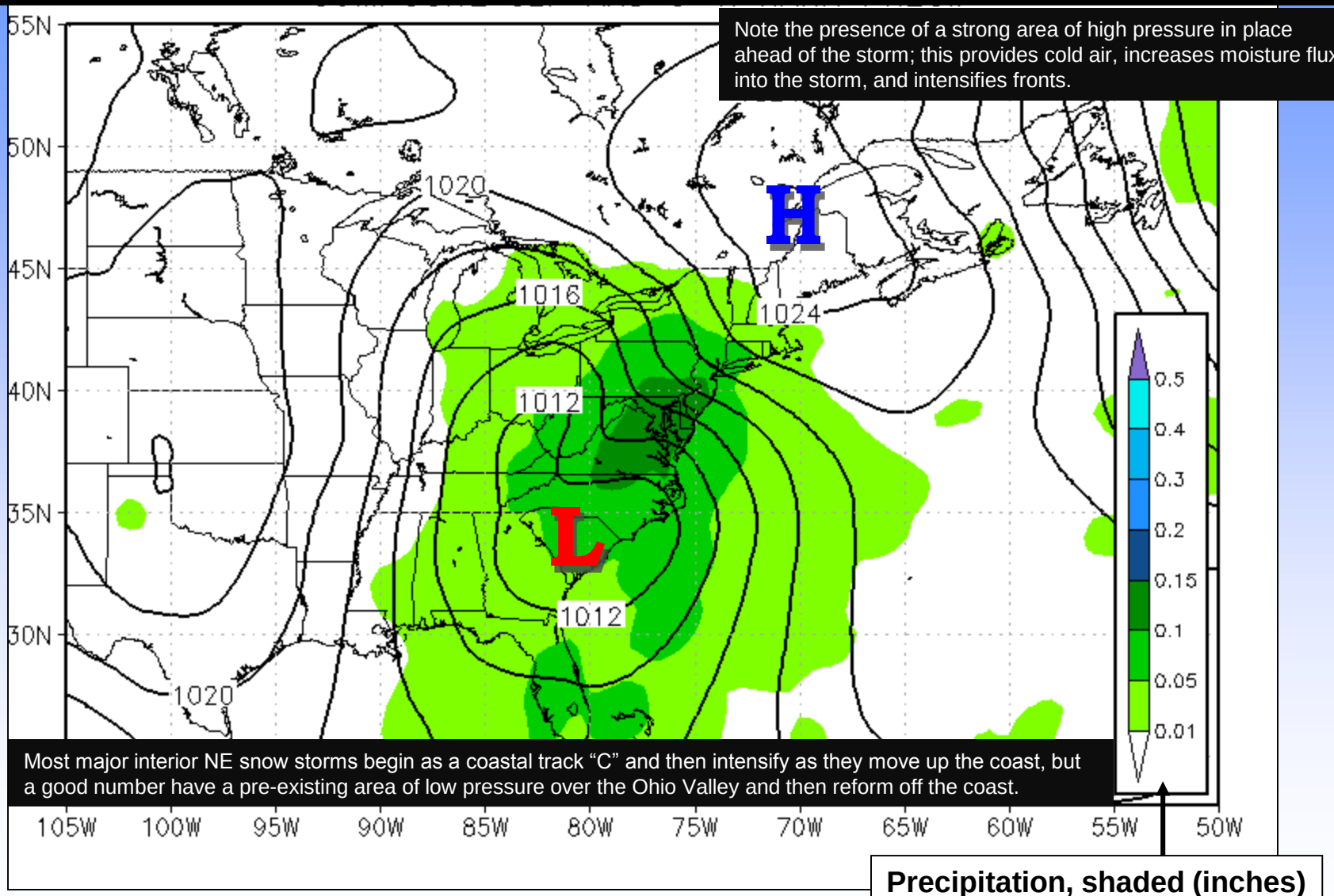
Why is the east coast favored for cyclone or low pressure formation?

Juxtaposition of cold air masses and warm temperatures related to Ocean temperatures creates a strong temperature gradient or "frontal zone"

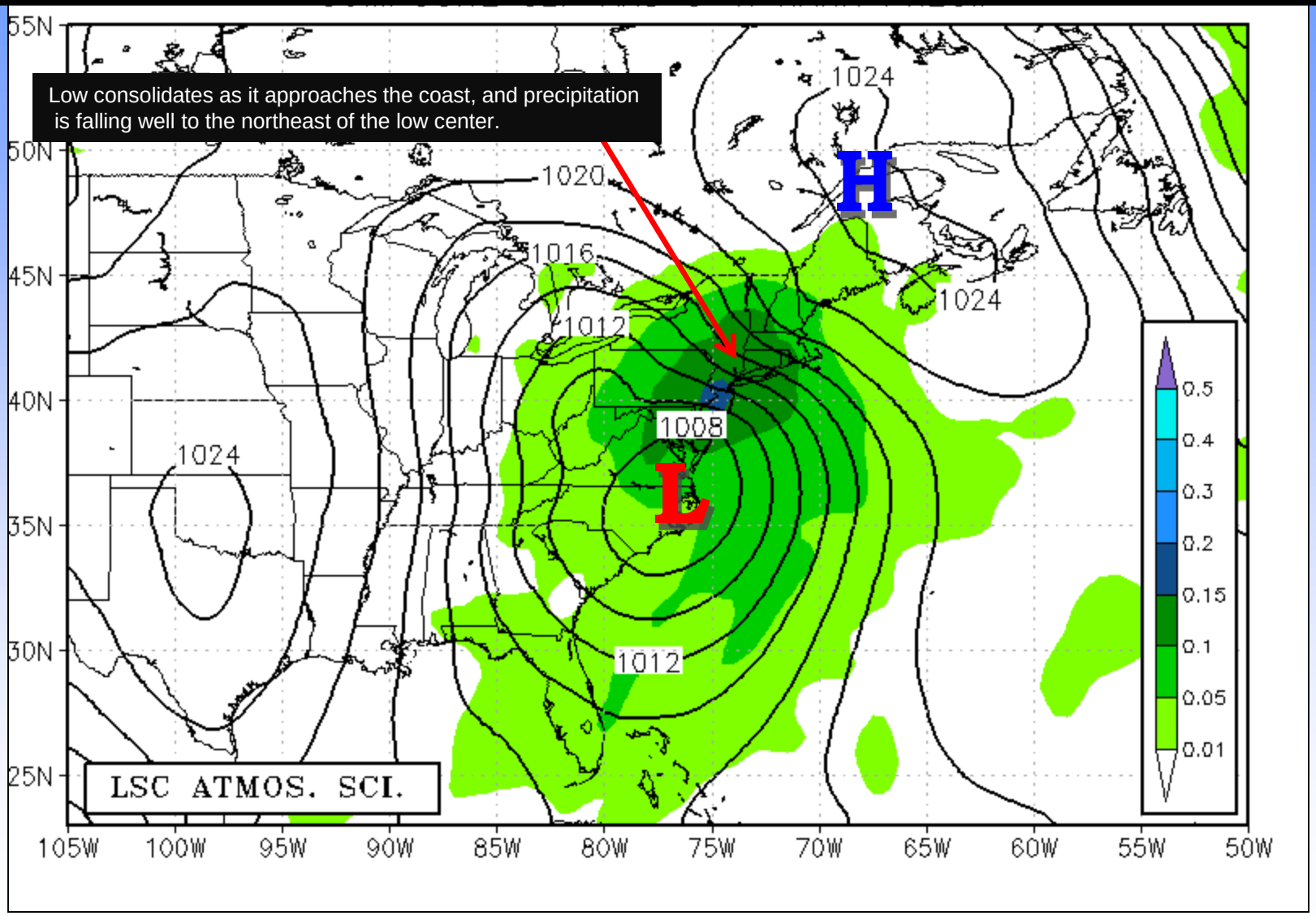
This creates baroclinic instability, which is an instability resulting from a strong temperature gradient; Mother Nature does not like strong temperature gradients, so a midlatitude cyclone develops to even out this gradient and bring warm air north and cold air south.



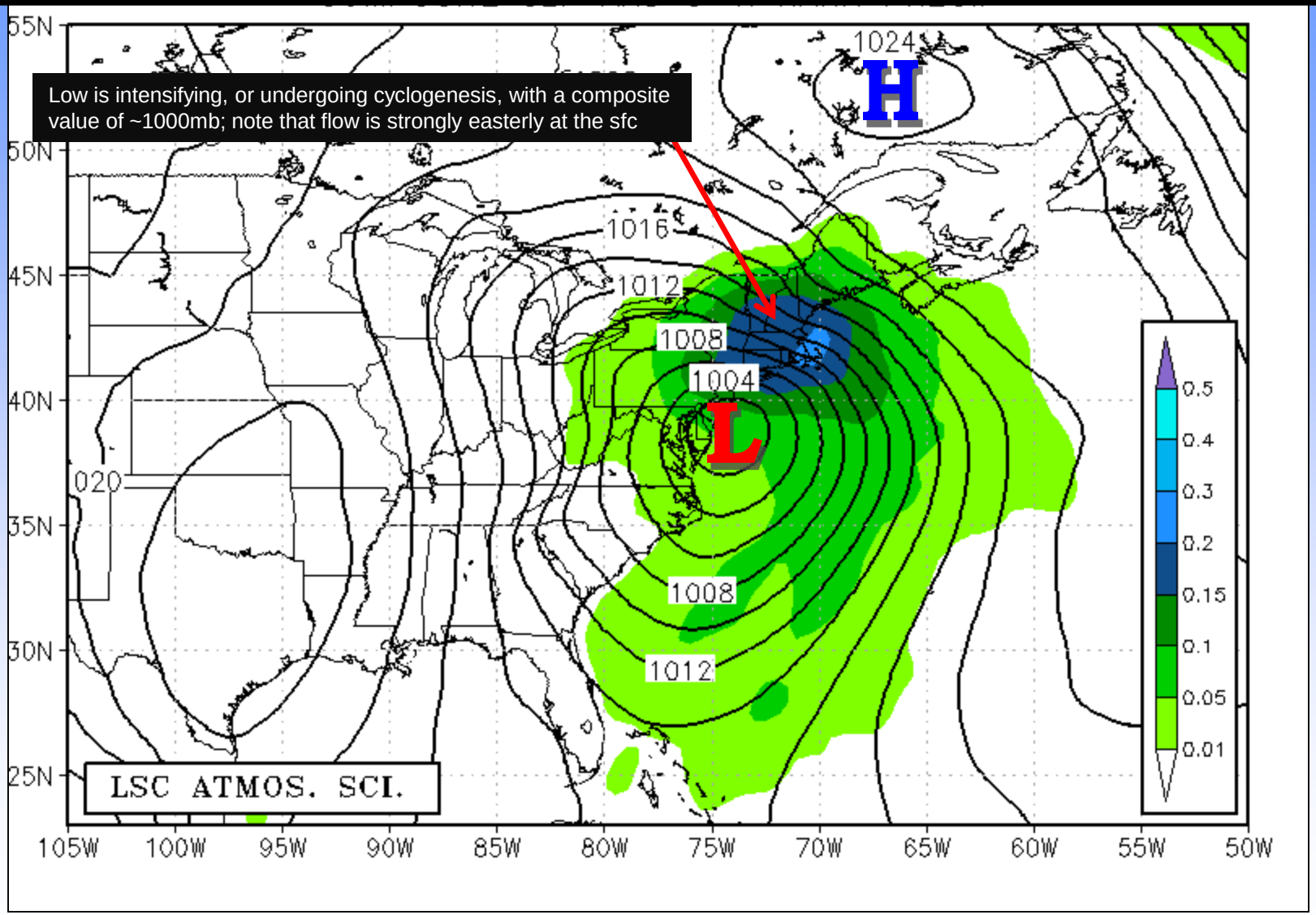
Average Pressure and Observed 3-HR Precipitation: Hour -18



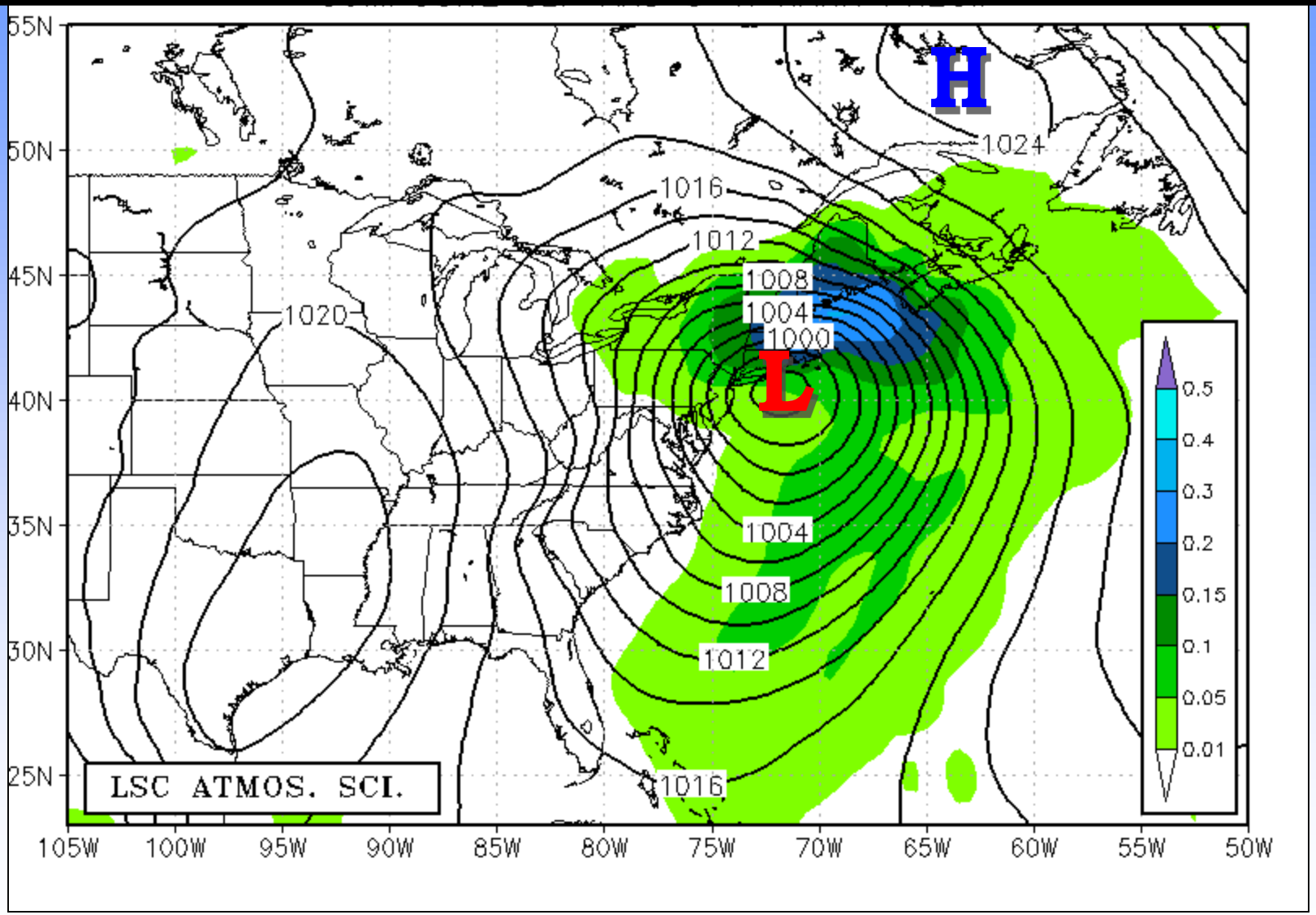
Average Pressure and Observed 3-HR Precipitation: Hour -12



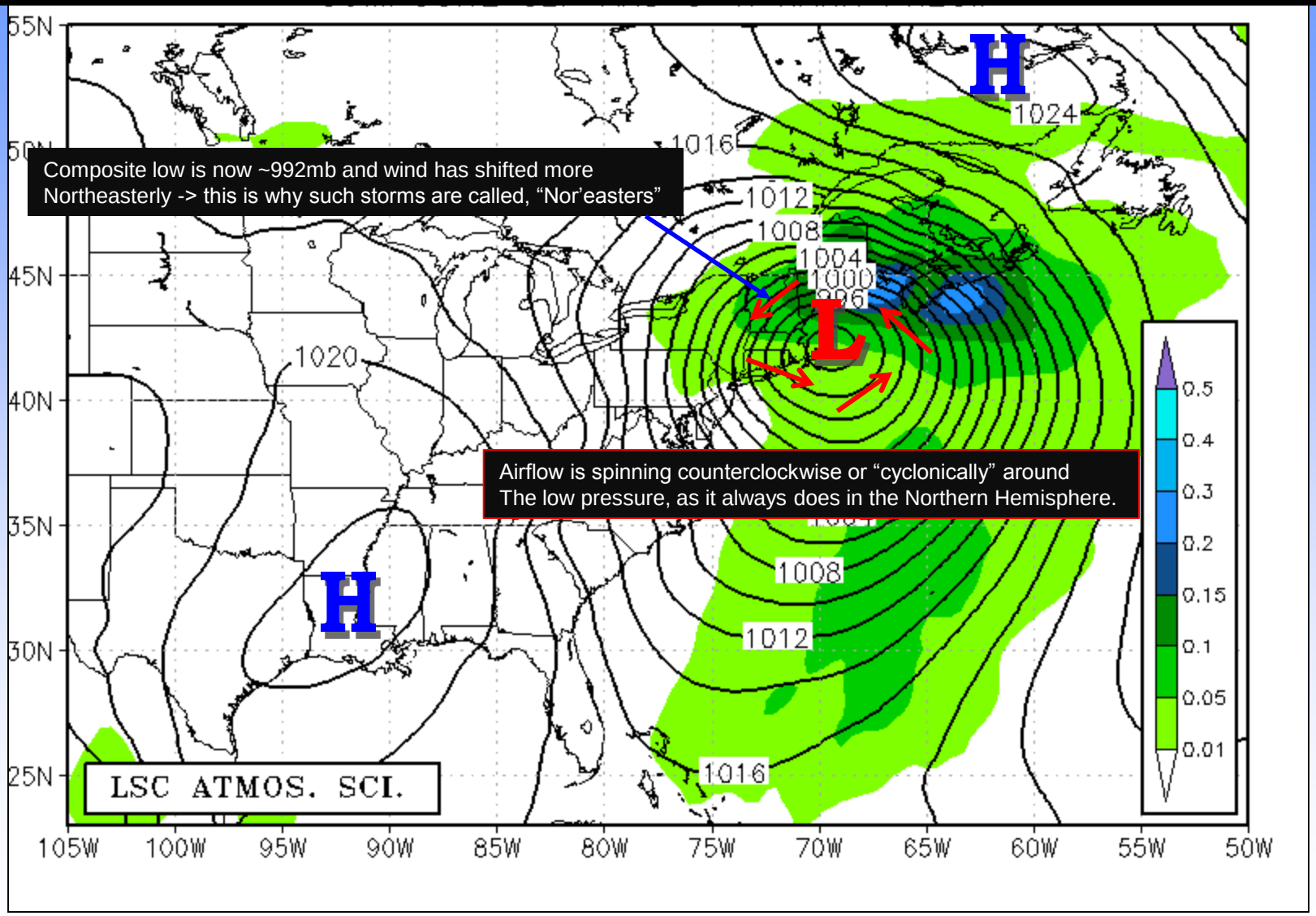
Average Pressure and Observed 3-HR Precipitation: Hour -06



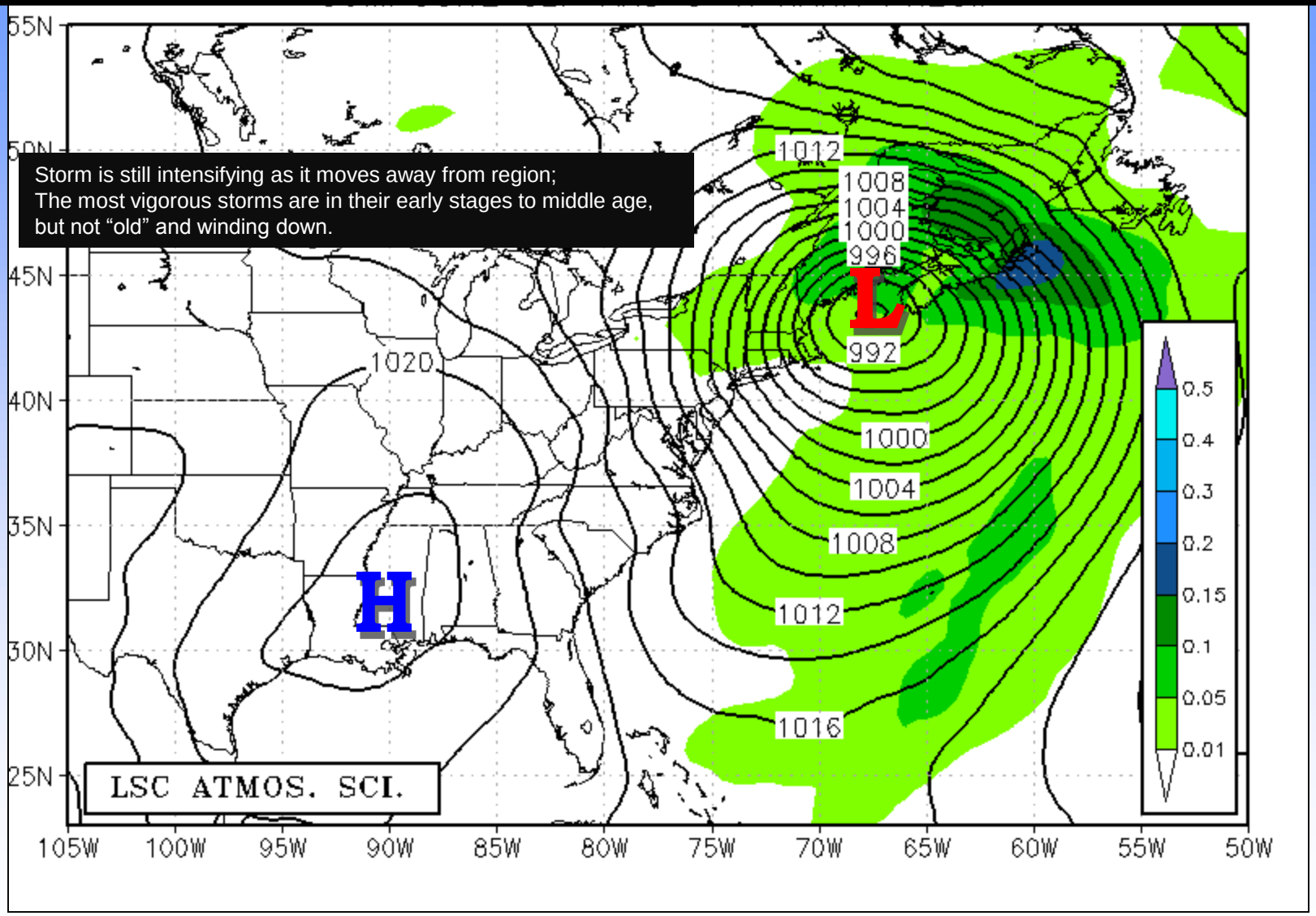
Average Pressure and Observed 3-HR Precipitation: Hour 0



Average Pressure and Observed 3-HR Precipitation: Hour +06

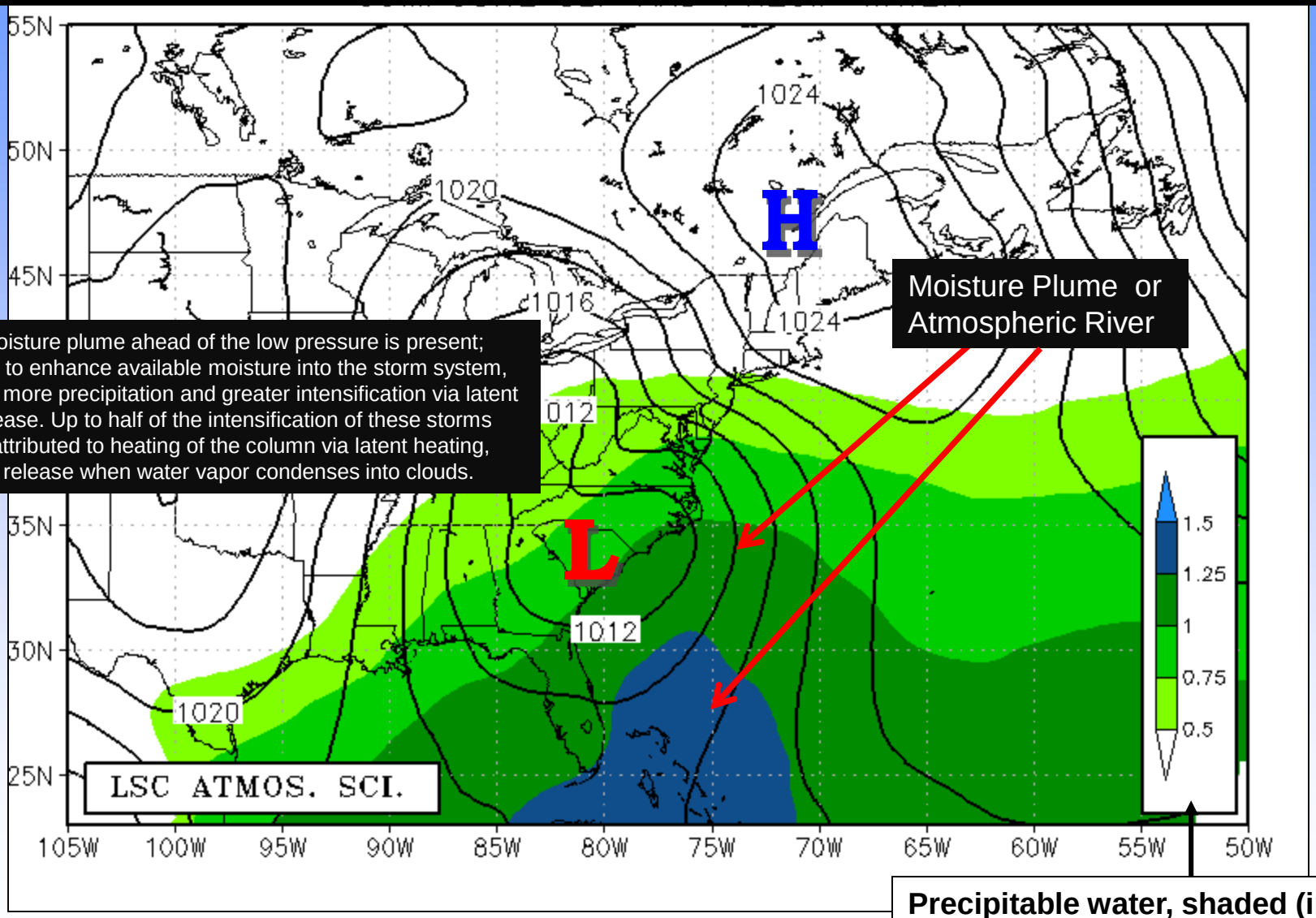


Average Pressure and Observed 3-HR Precipitation: Hour +12



Moisture Source and Evolution

Average Pressure and Precipitable Water (Inches) Hour: -18

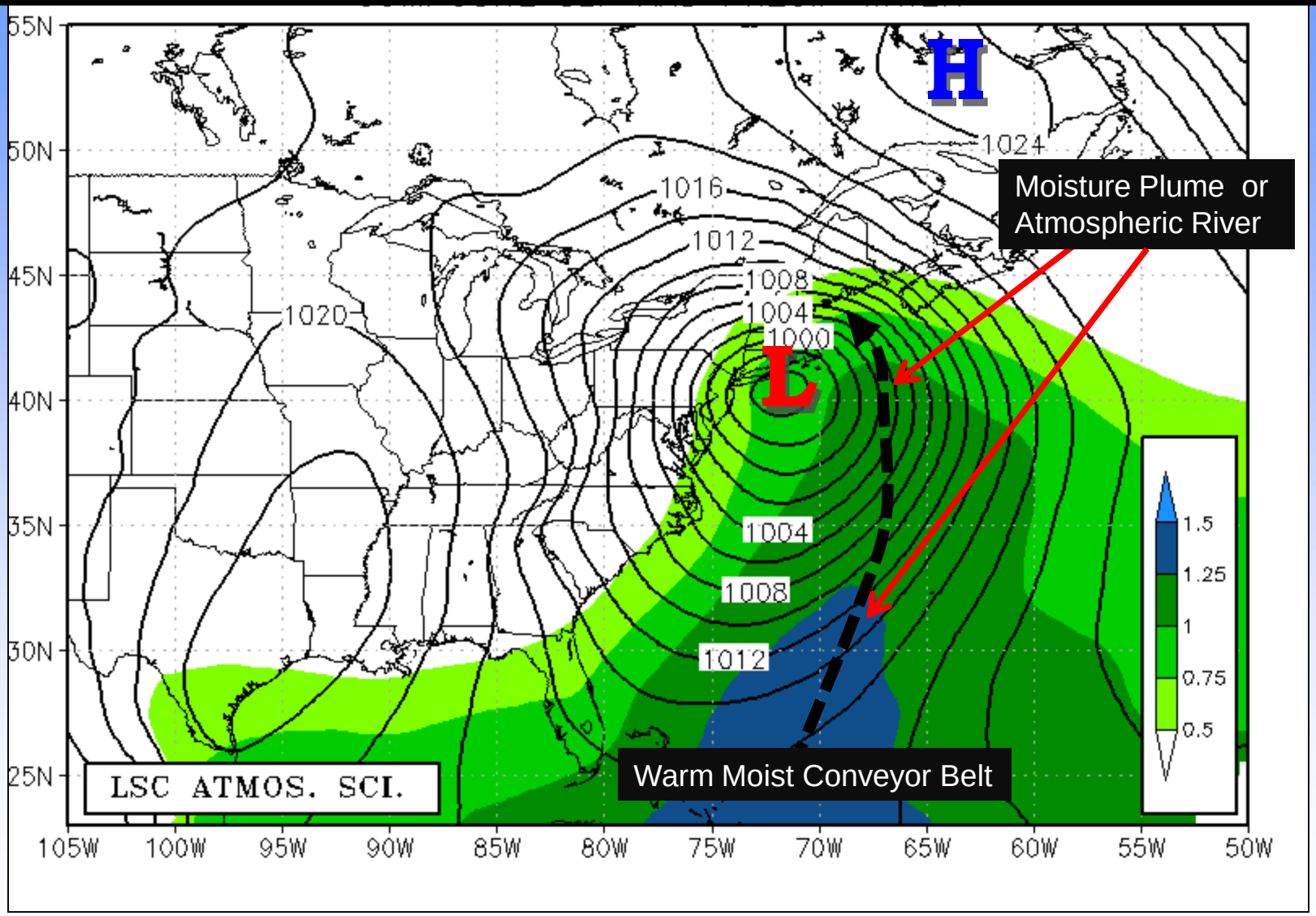


Deep moisture plume ahead of the low pressure is present; this acts to enhance available moisture into the storm system, creating more precipitation and greater intensification via latent heat release. Up to half of the intensification of these storms can be attributed to heating of the column via latent heating, which is release when water vapor condenses into clouds.

Moisture Plume or Atmospheric River

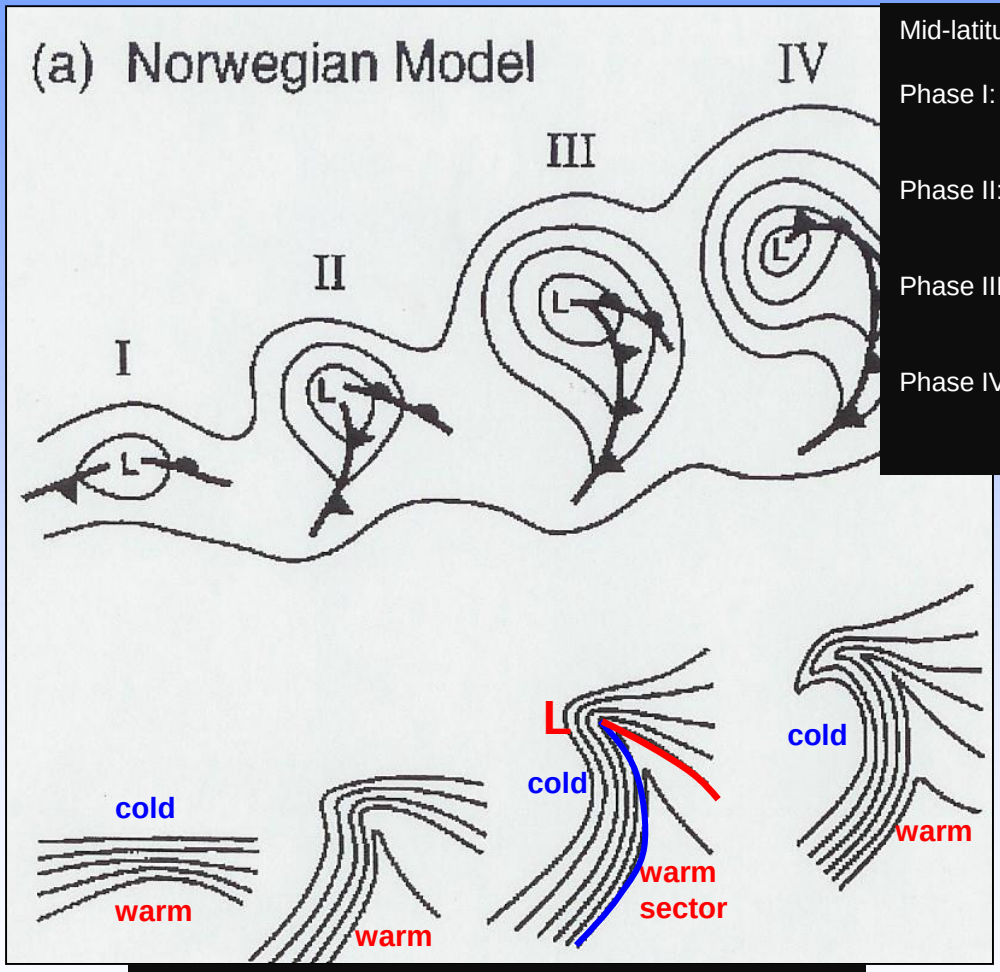
Precipitable water, shaded (inches)

Average Pressure and Precipitable Water (Inches) Hour: 0



Temperature Pattern

Mid Latitude Cyclone Lifecycle



Isotherms: Lines of Constant Temperature

Mid-latitude cyclones evolve through different phases:

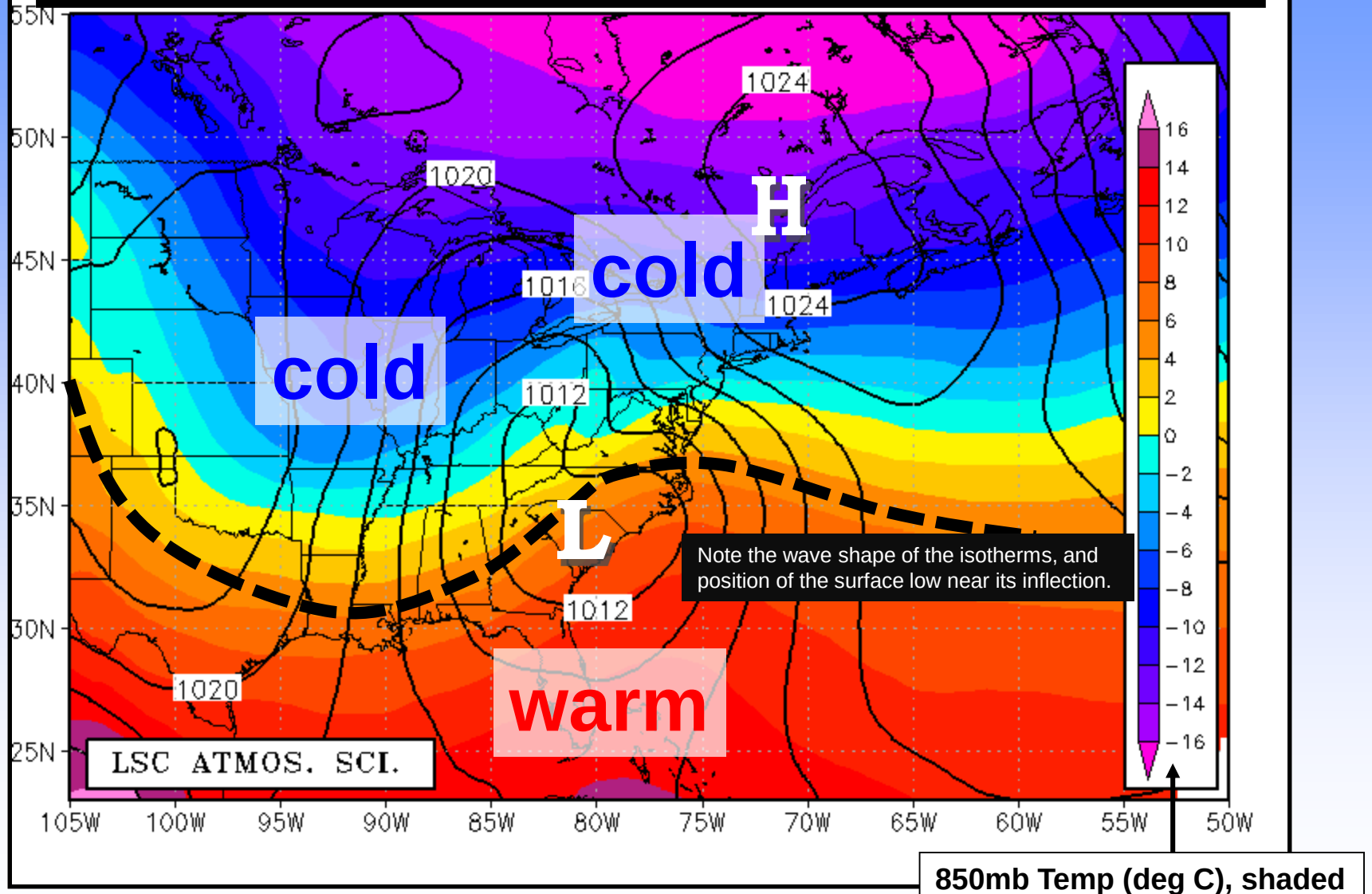
Phase I: East-west stationary frontal zone with warm air south and cold air north strong temperature gradient is present

Phase II: A kink develops on the isotherms (lines of constant temperature) as warm and cold fronts develop and move.

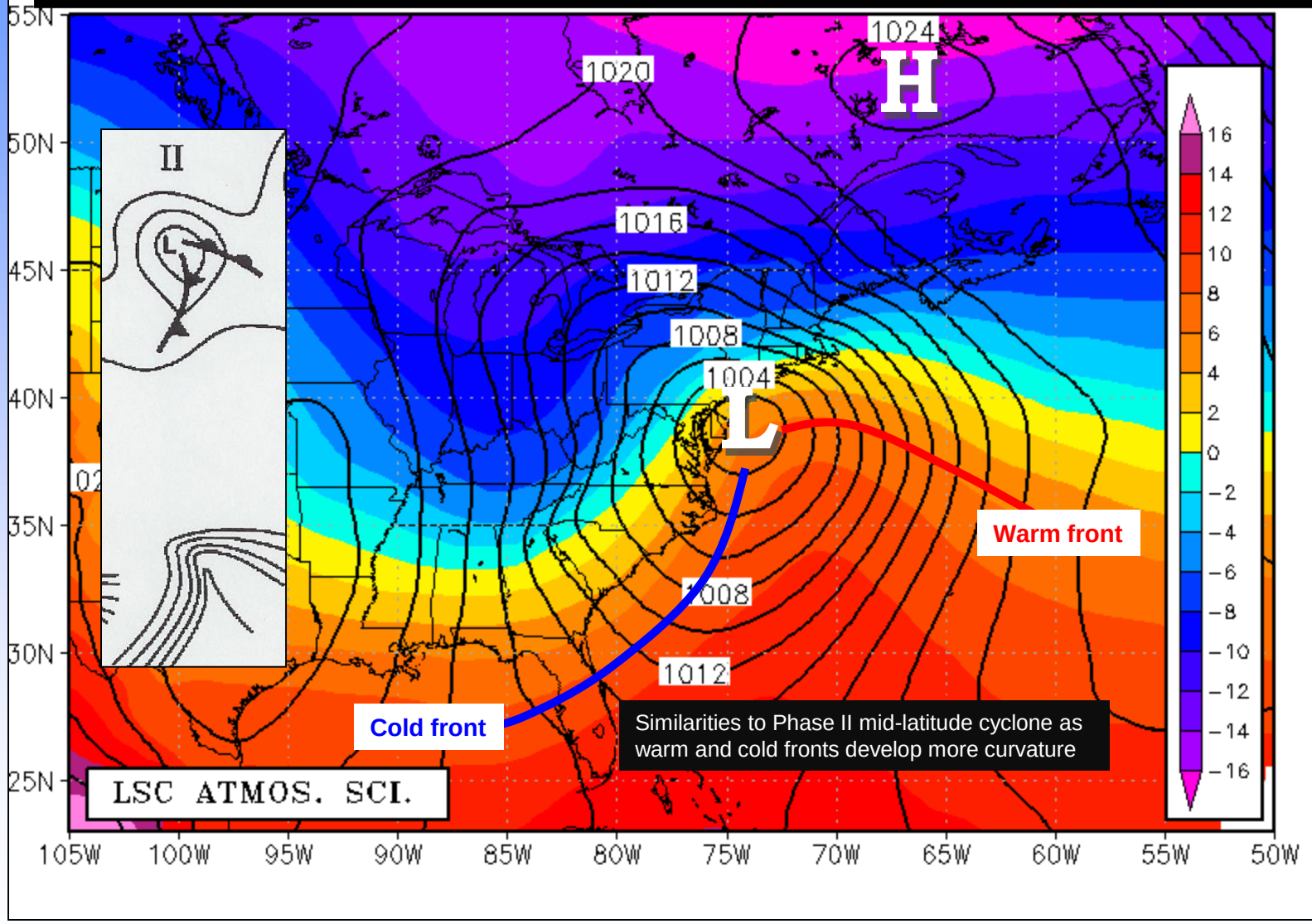
Phase III: Wave on the isotherms amplifies and cold front advances faster than warm front; cyclone is nearing maturity

Phase IV: Occlusion develops as cold front catches up with warm front; this process does not always occur with every cyclone; ridge of warm temperatures extends back toward the low center; storm is weakening

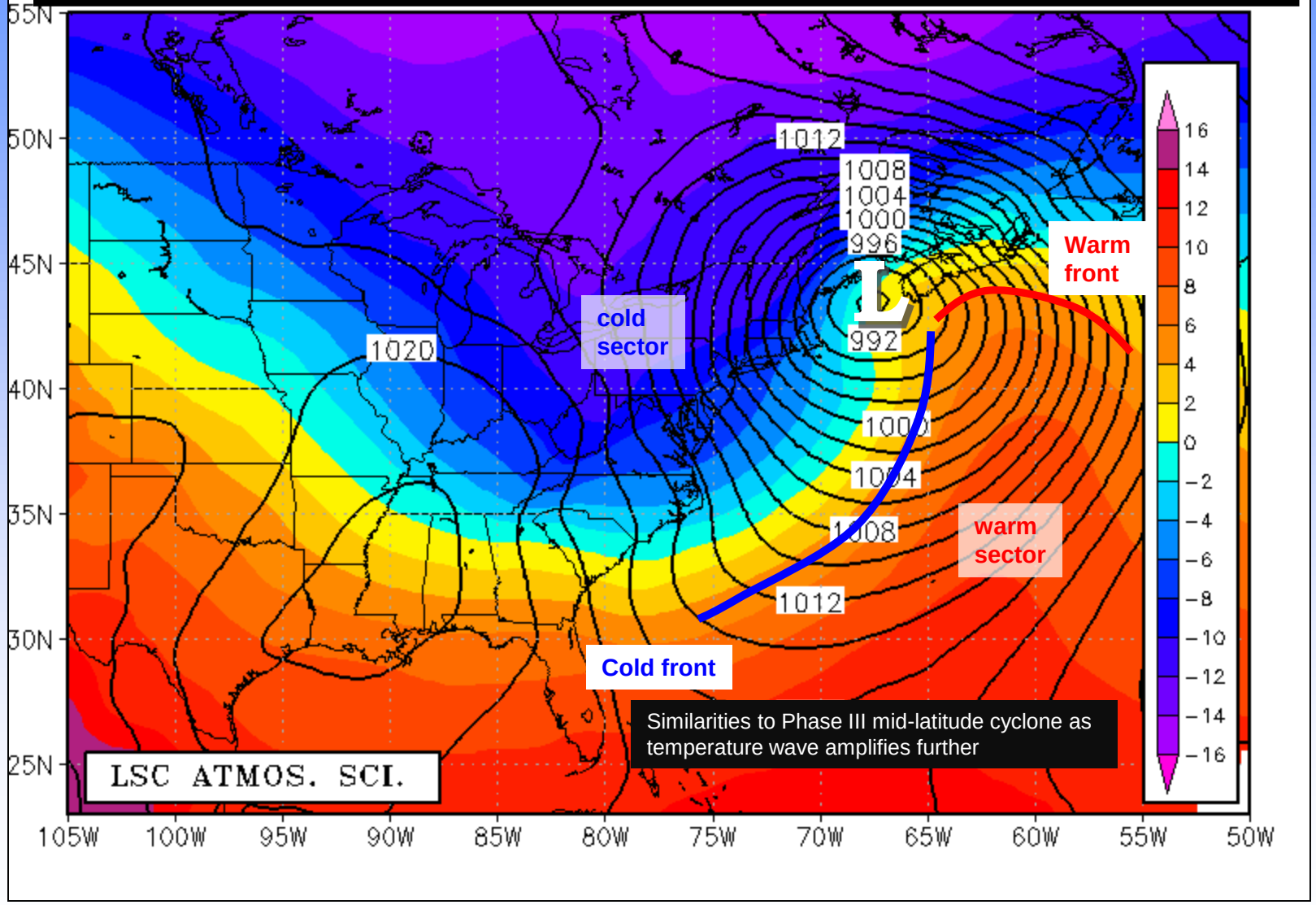
Average Pressure and 850-MB Temperature Hour: -18



Average Pressure and 850-MB Temperature Hour: -06

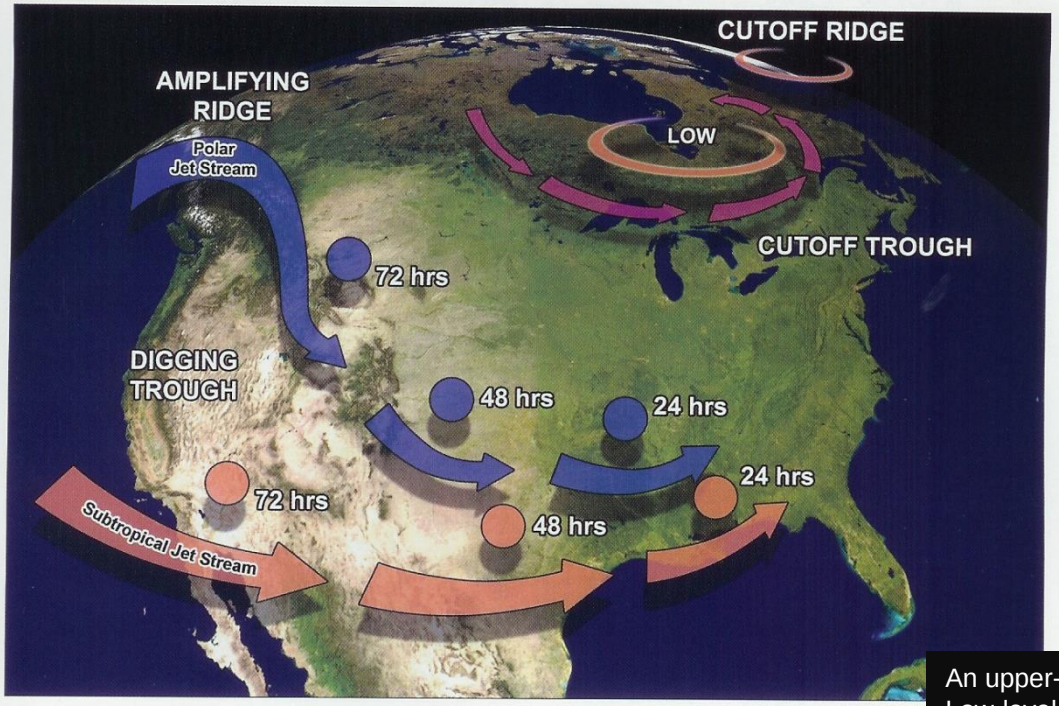


Average Pressure and 850-MB Temperature Hour: +12



Upper-level Evolution:
Major Interior Northeast Snow Storms

COMMON UPPER-LEVEL SIGNATURES
3,2 and 1 DAYS PRIOR TO NOTHEAST SNOWSTORMS



Kocin and Uccellini 2004

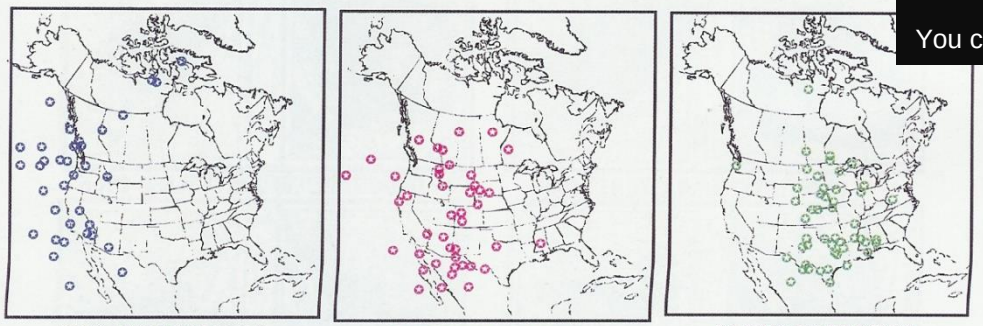
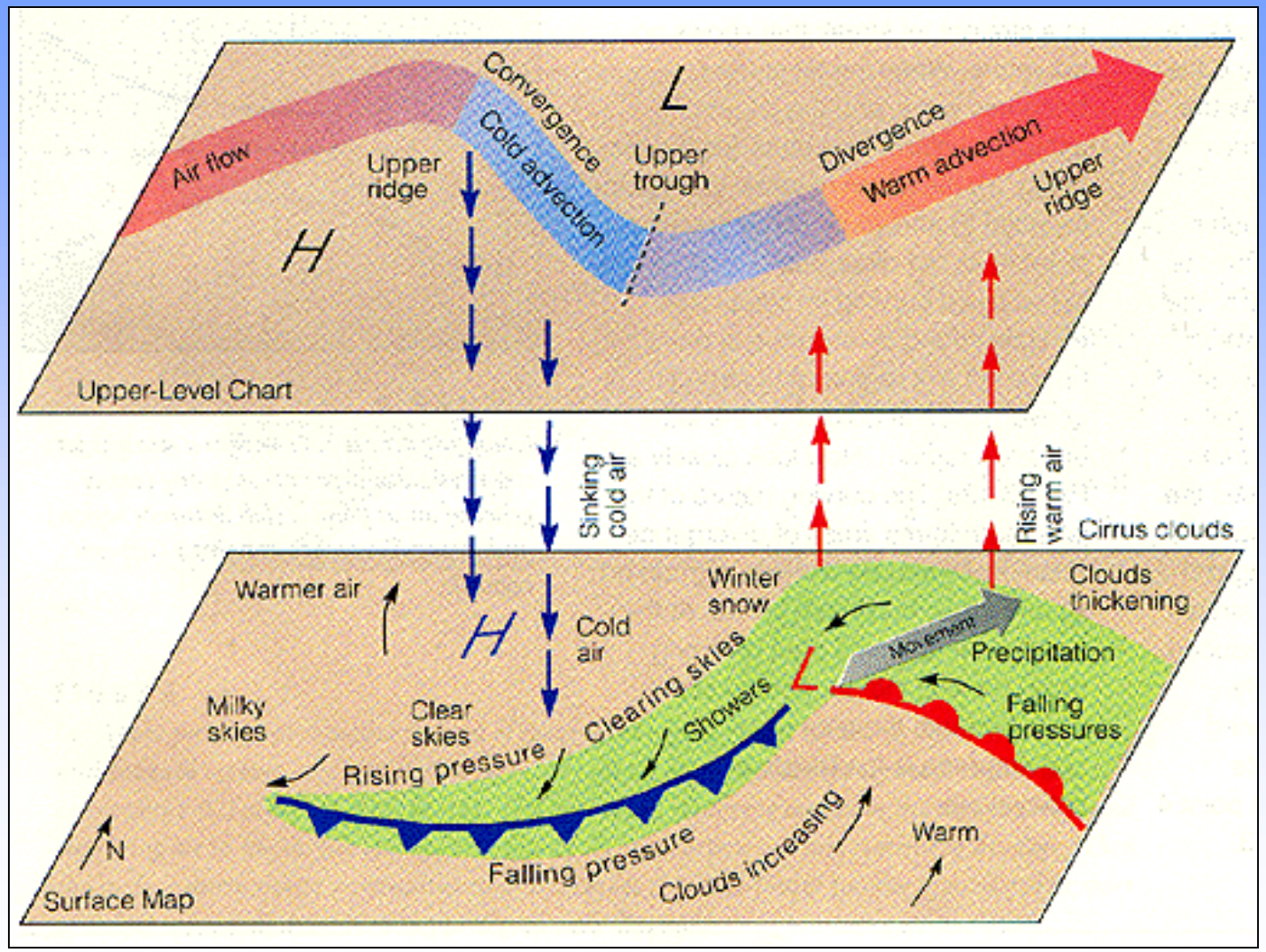


FIG. 4-4. Summary of upper-level signatures 3, 2, and 1 days prior to Northeast snowstorms, including summary of 500-hPa vorticity associated with Northeast snowstorms.

An upper-level disturbance is needed to perturb the Low-level temperature gradient to produce a cyclone; these are usually coherent features traceable days upstream

You can think of the jet stream as producing these features.

Vertical Structure



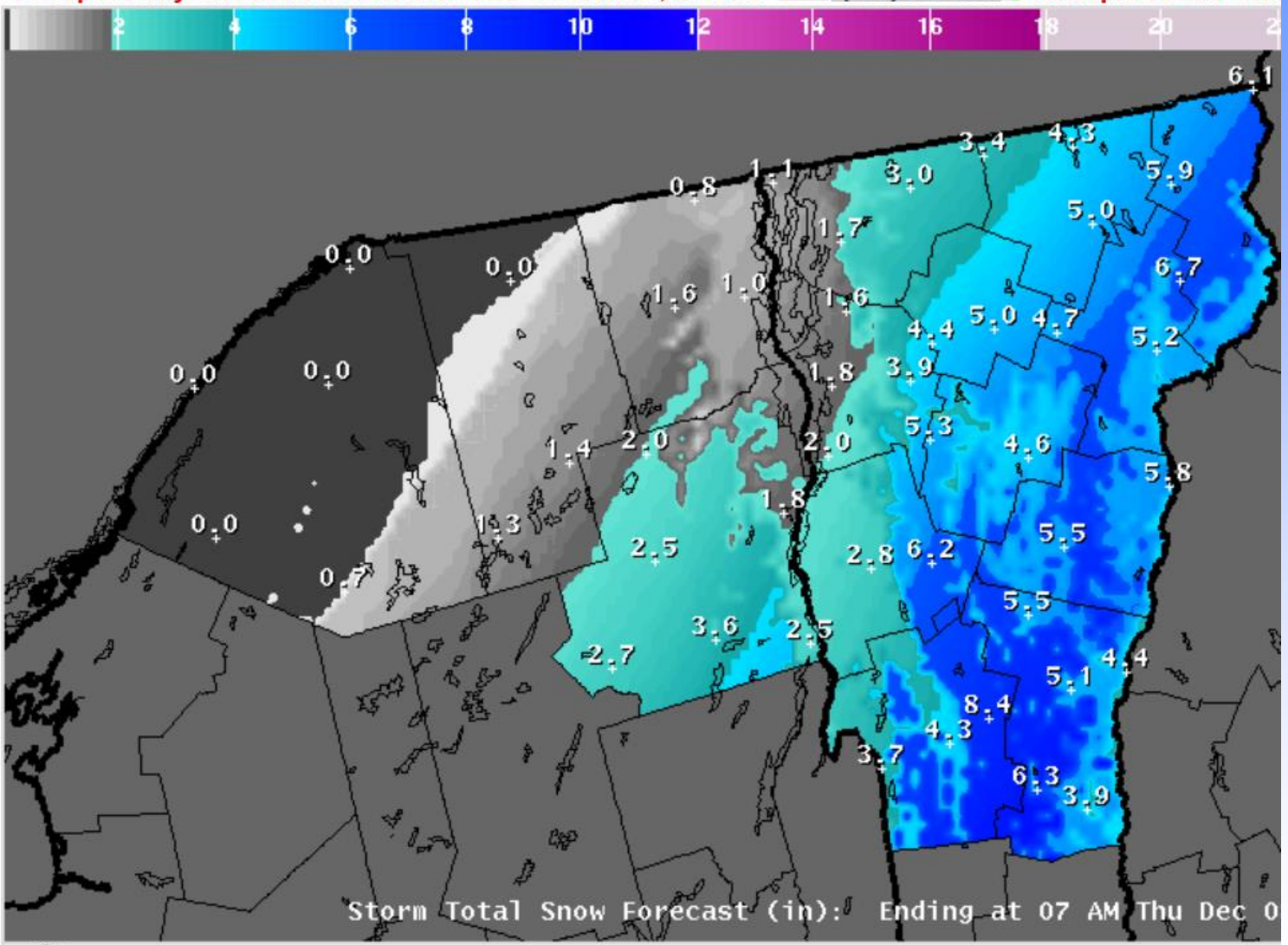
Ahrens 2006

Forecasting East Coast Snow Storms

Storm Total Snow Forecast

Note: The map above displays the expected **average** accumulation. Some locations will receive less snow, while others wi
more.

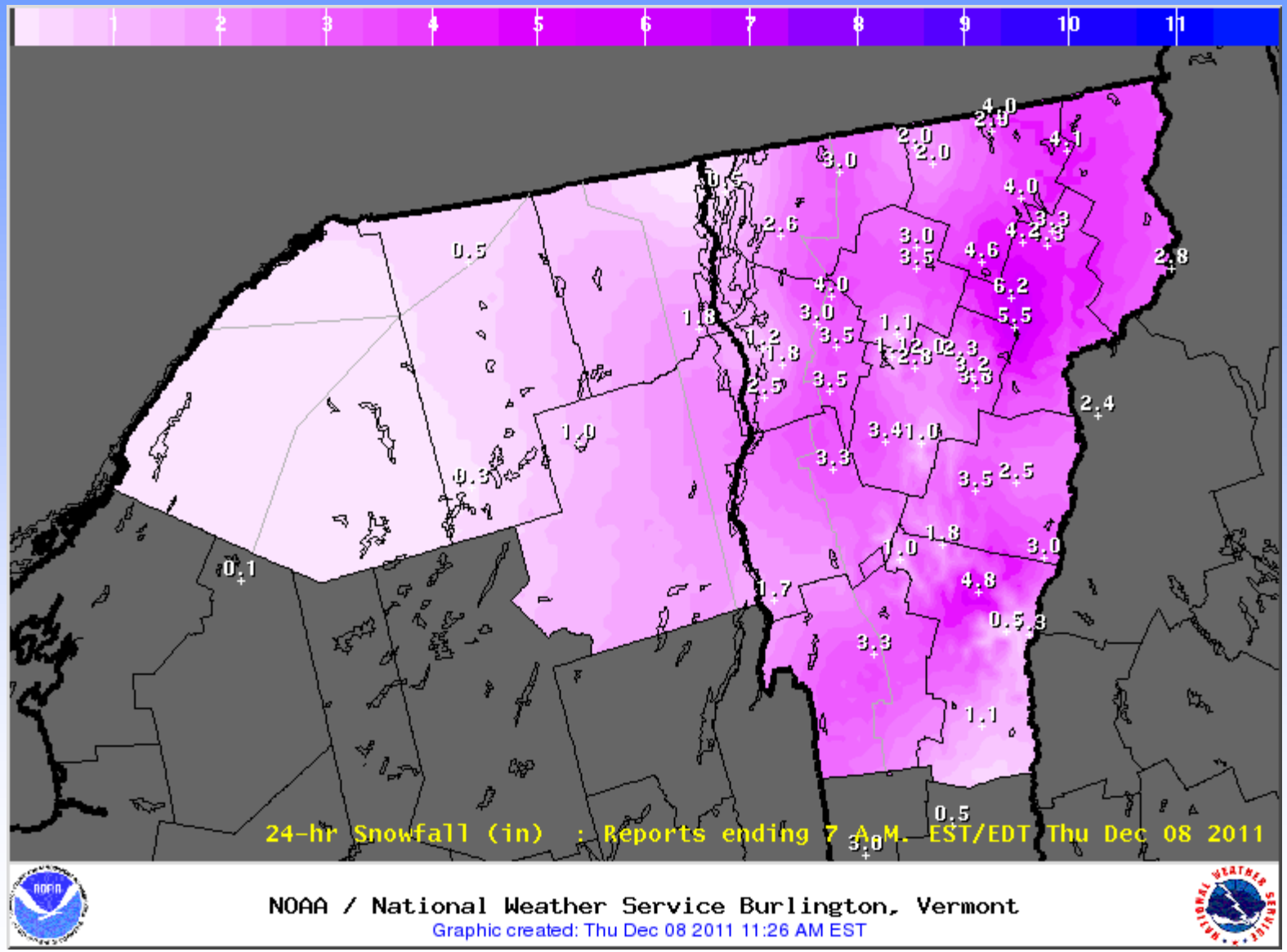
To report any snowfall accumulations click here, or call (802)862-2475 and press the sta



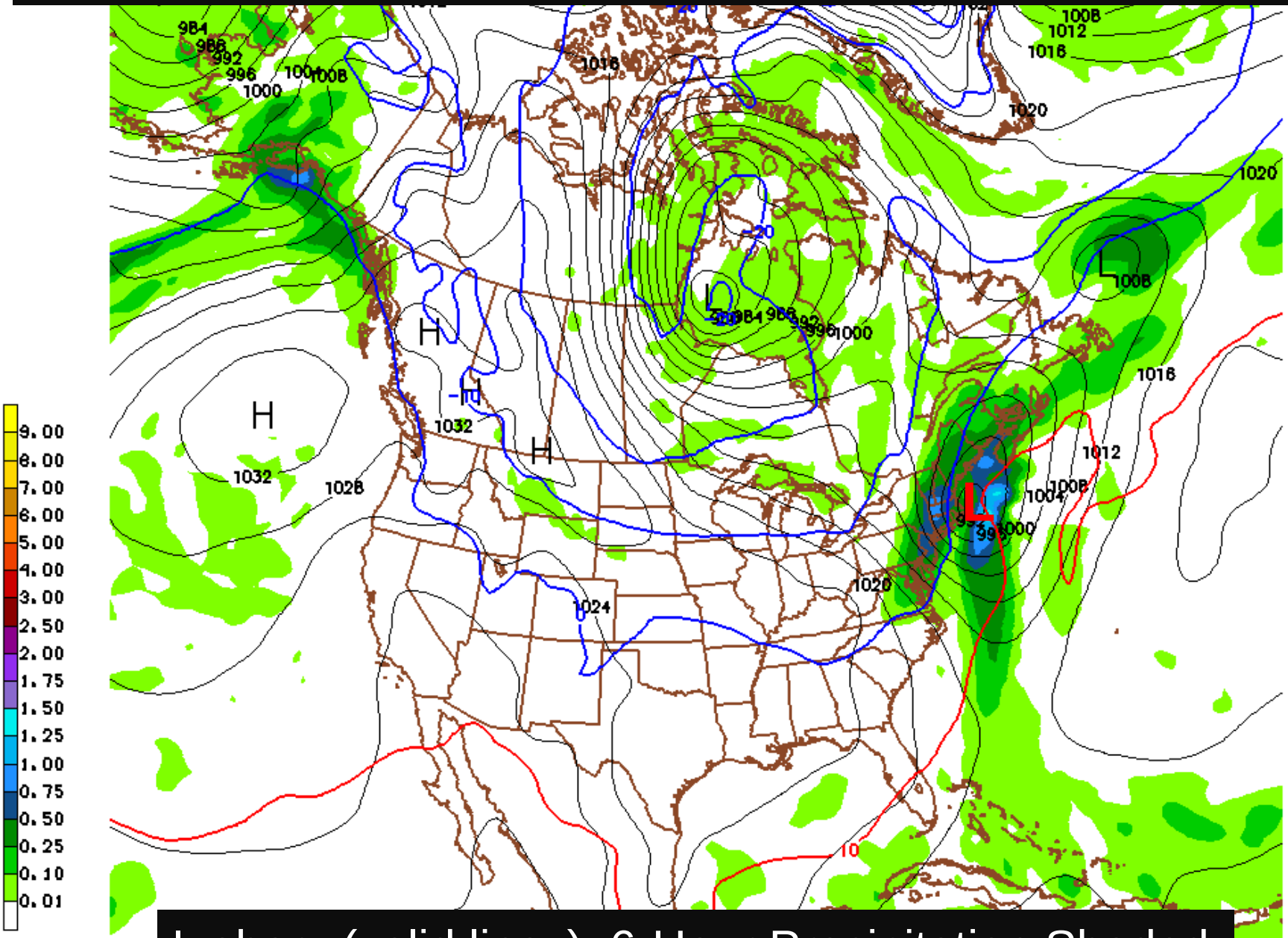
NOAA / National Weather Service Burlington, VT

Graphic created: Wed Dec 07 2011 3:59 PM EST

Snowfall Verification

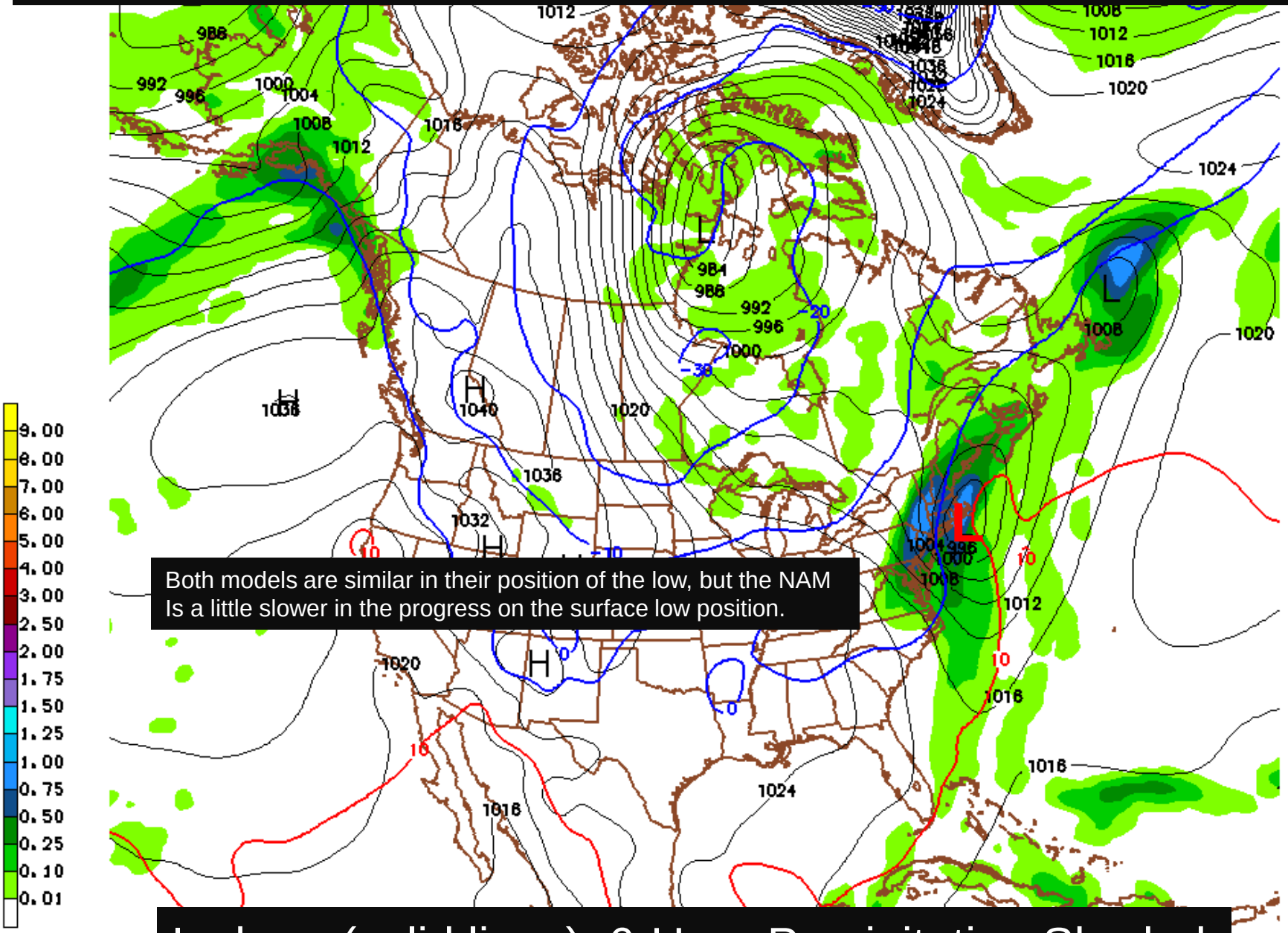


GFS Model Forecast: 39 Hour Forecast Valid 4:00AM Thursday



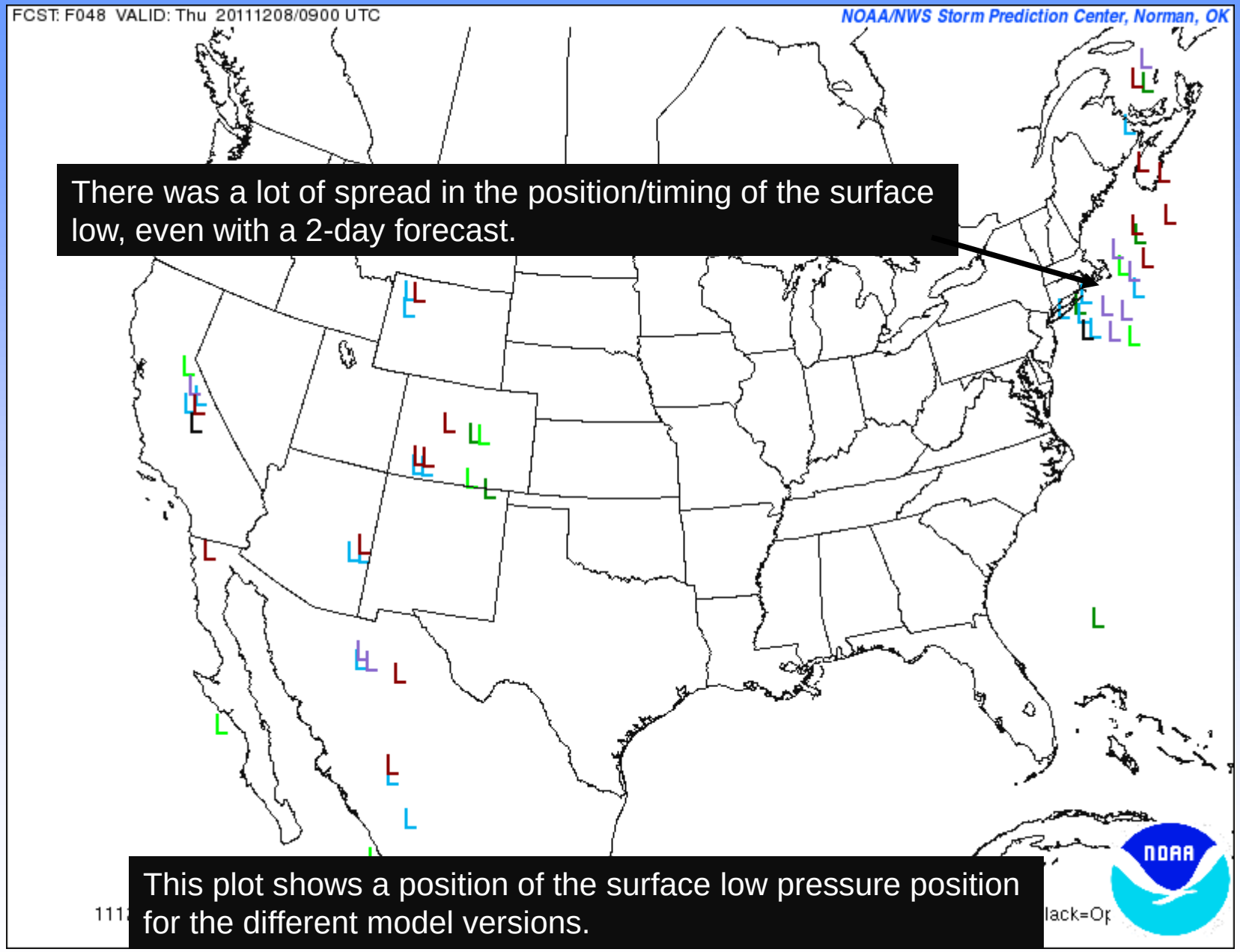
Isobars (solid lines), 6-Hour Precipitation Shaded

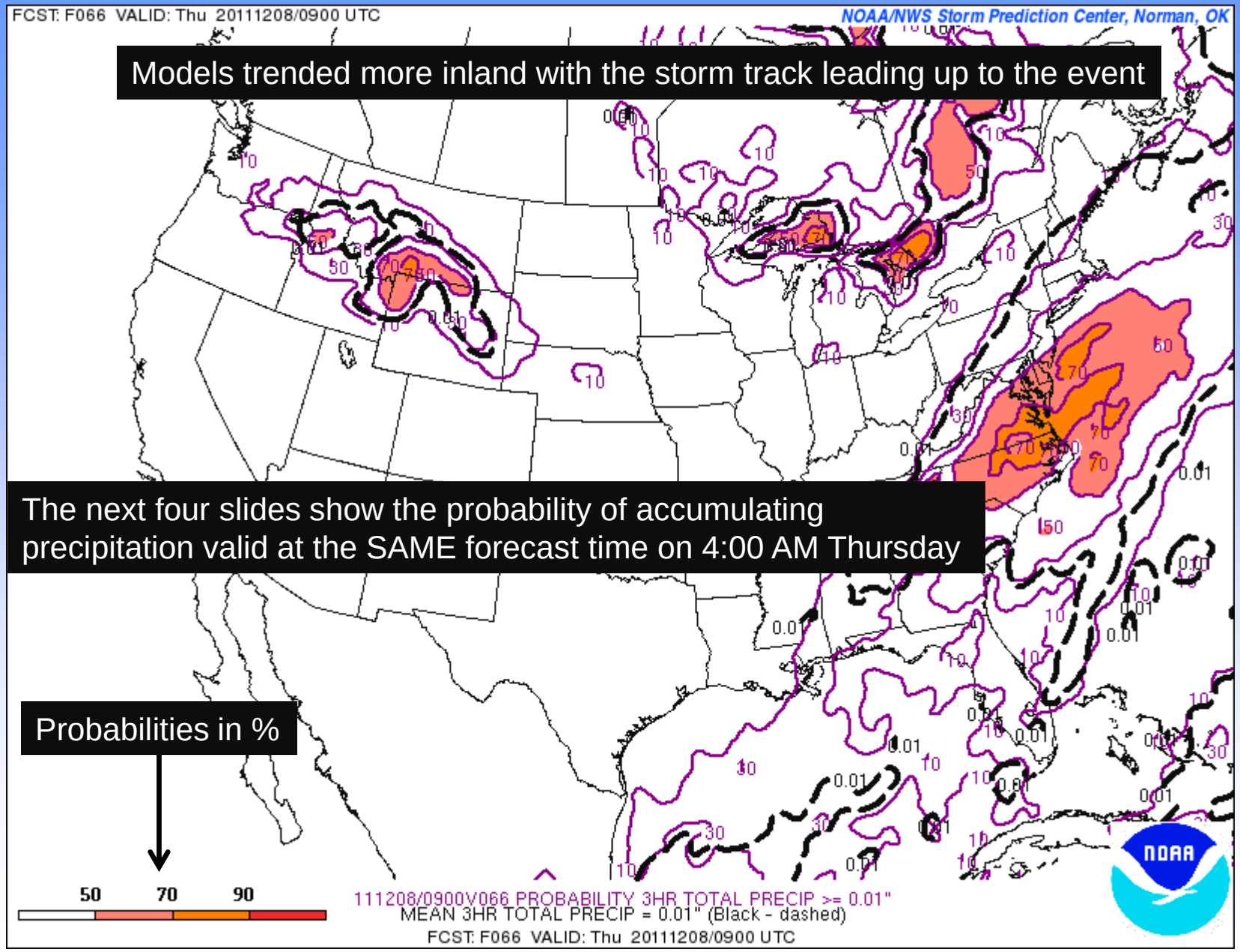
NAM Model Forecast: 39 Hour Forecast Valid 4:00AM Thursday

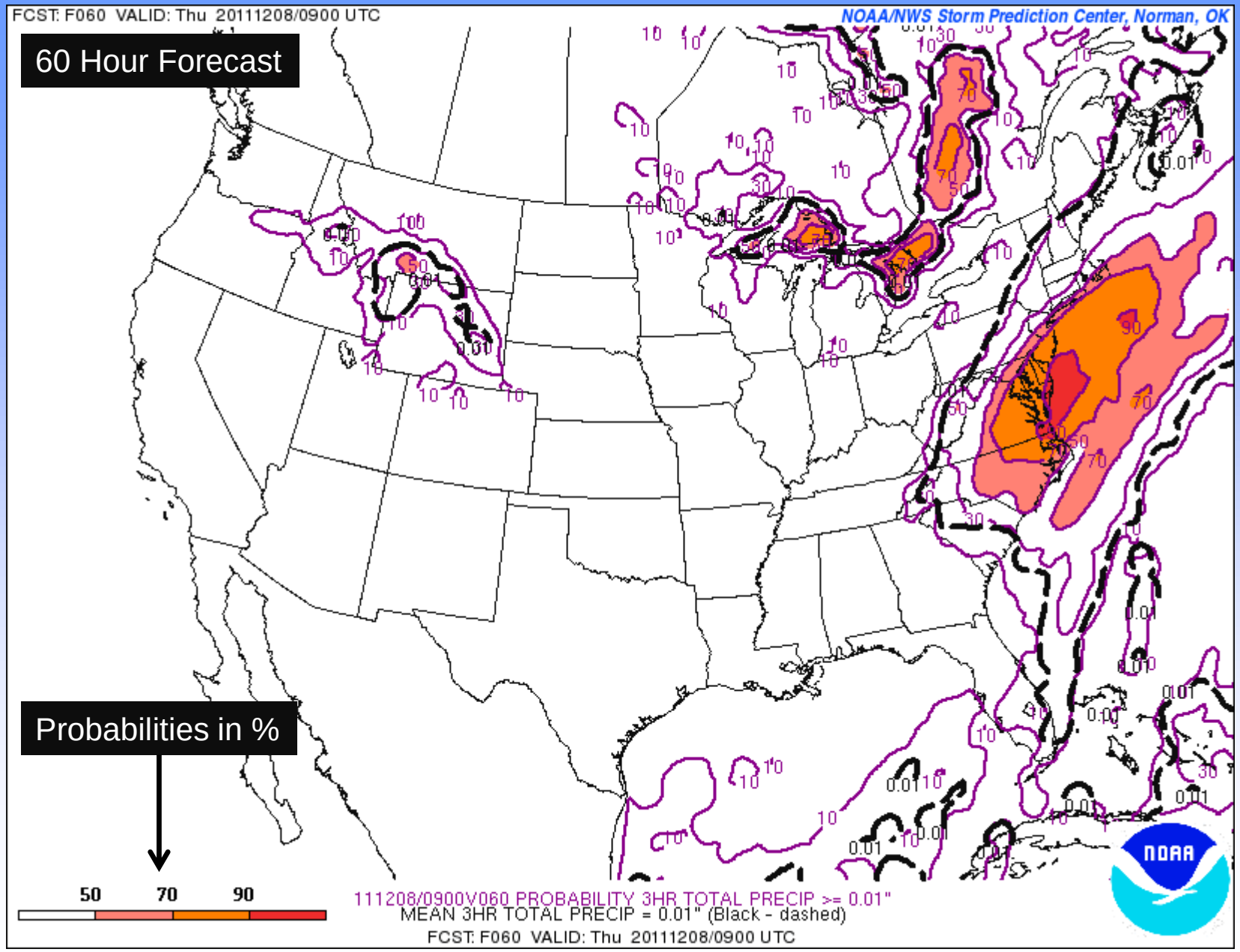


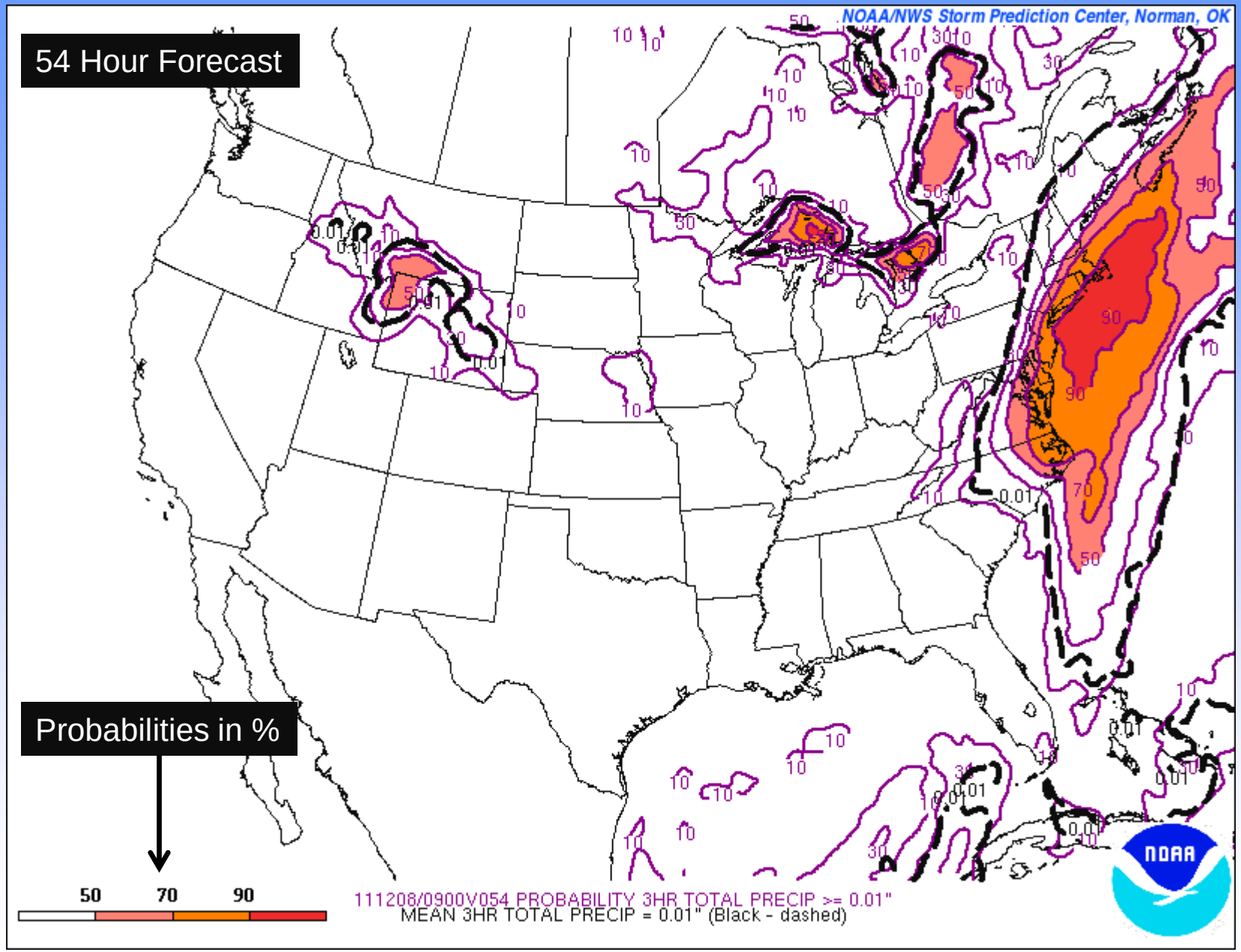
Isobars (solid lines), 6-Hour Precipitation Shaded

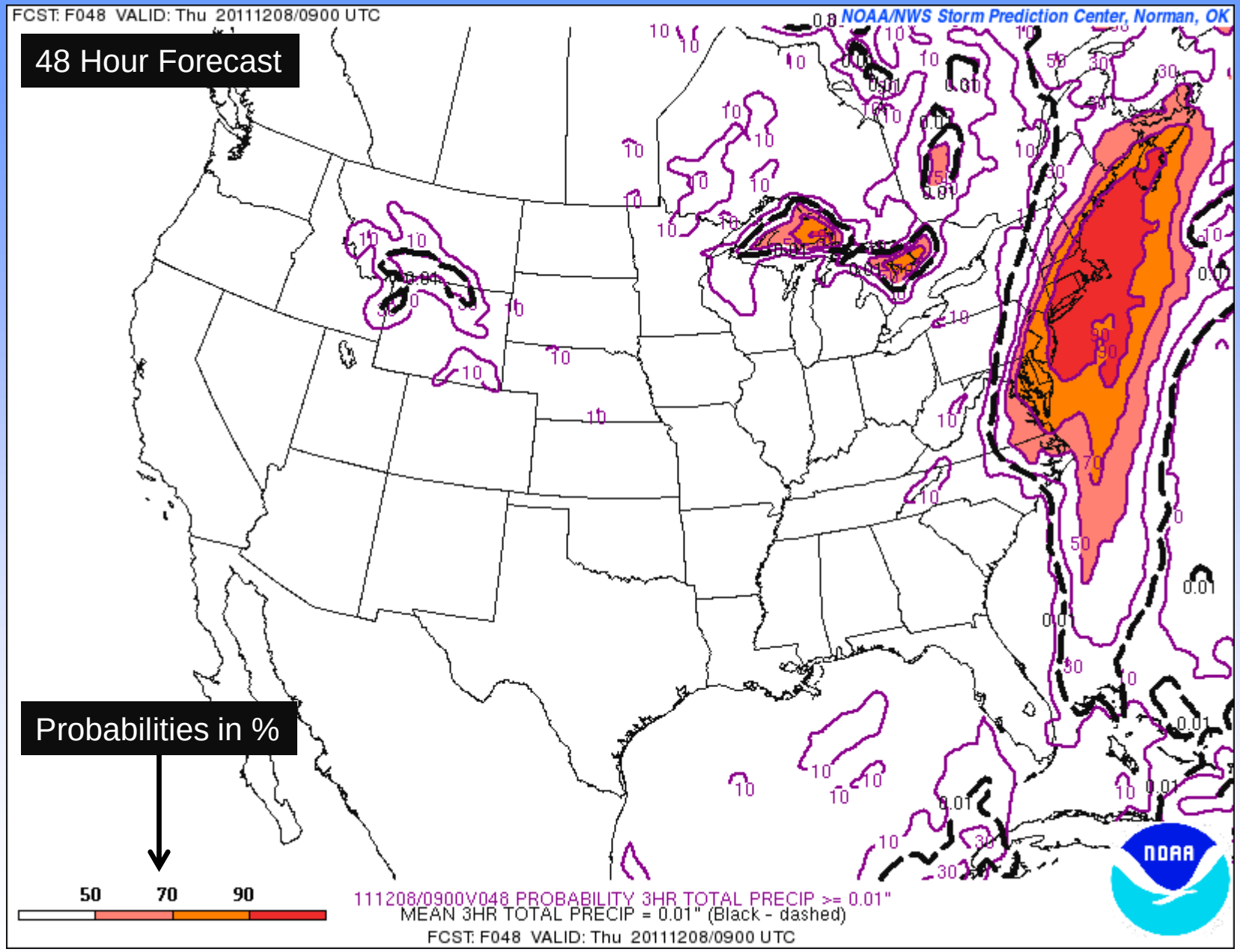
Assessing Forecast Uncertainty

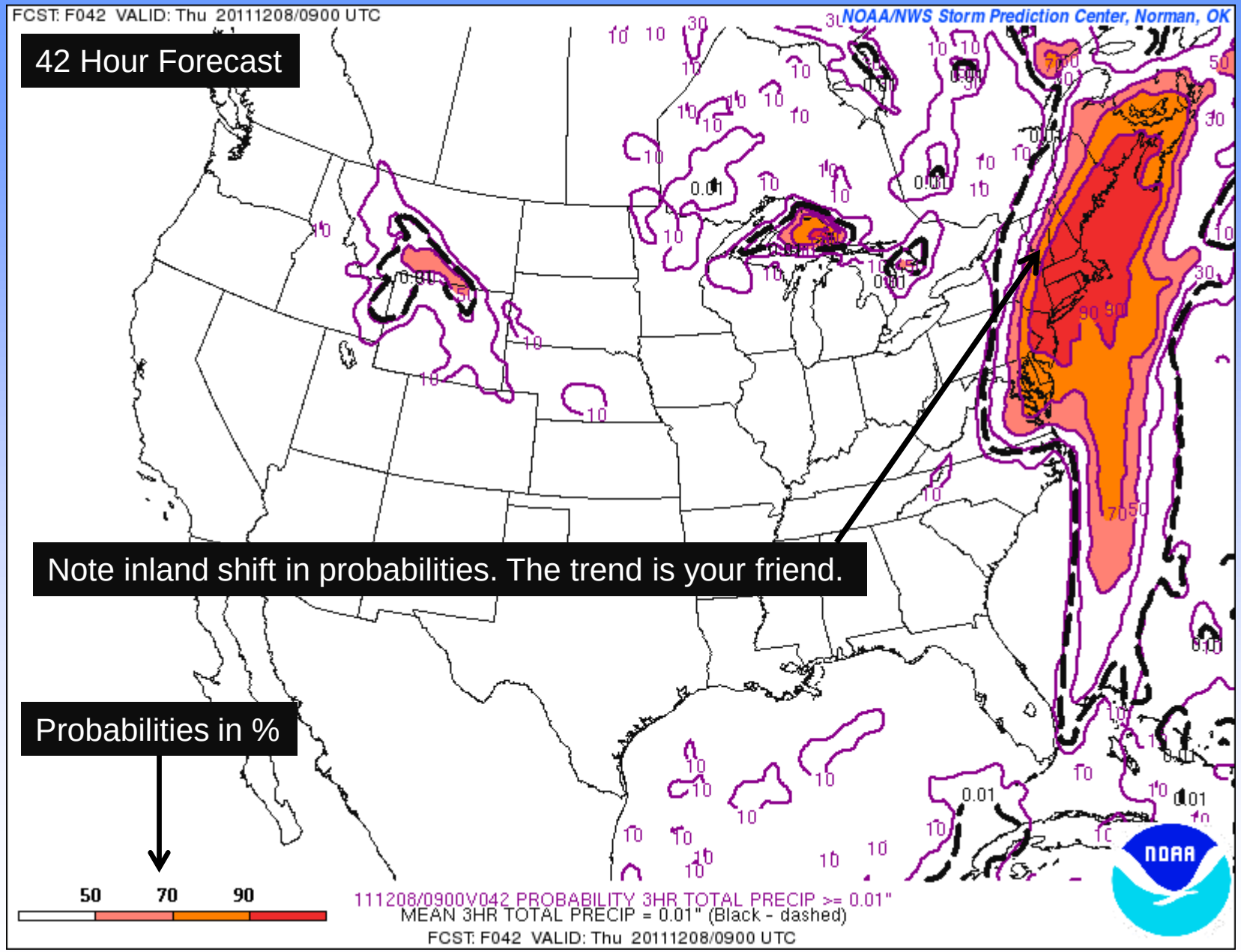

FCST: F048 VALID: Thu 20111208/0900 UTC
NOAA/NWS Storm Prediction Center, Norman, OK
There was a lot of spread in the position/timing of the surface low, even with a 2-day forecast.
This plot shows a position of the surface low pressure position for the different model versions.
NOAA

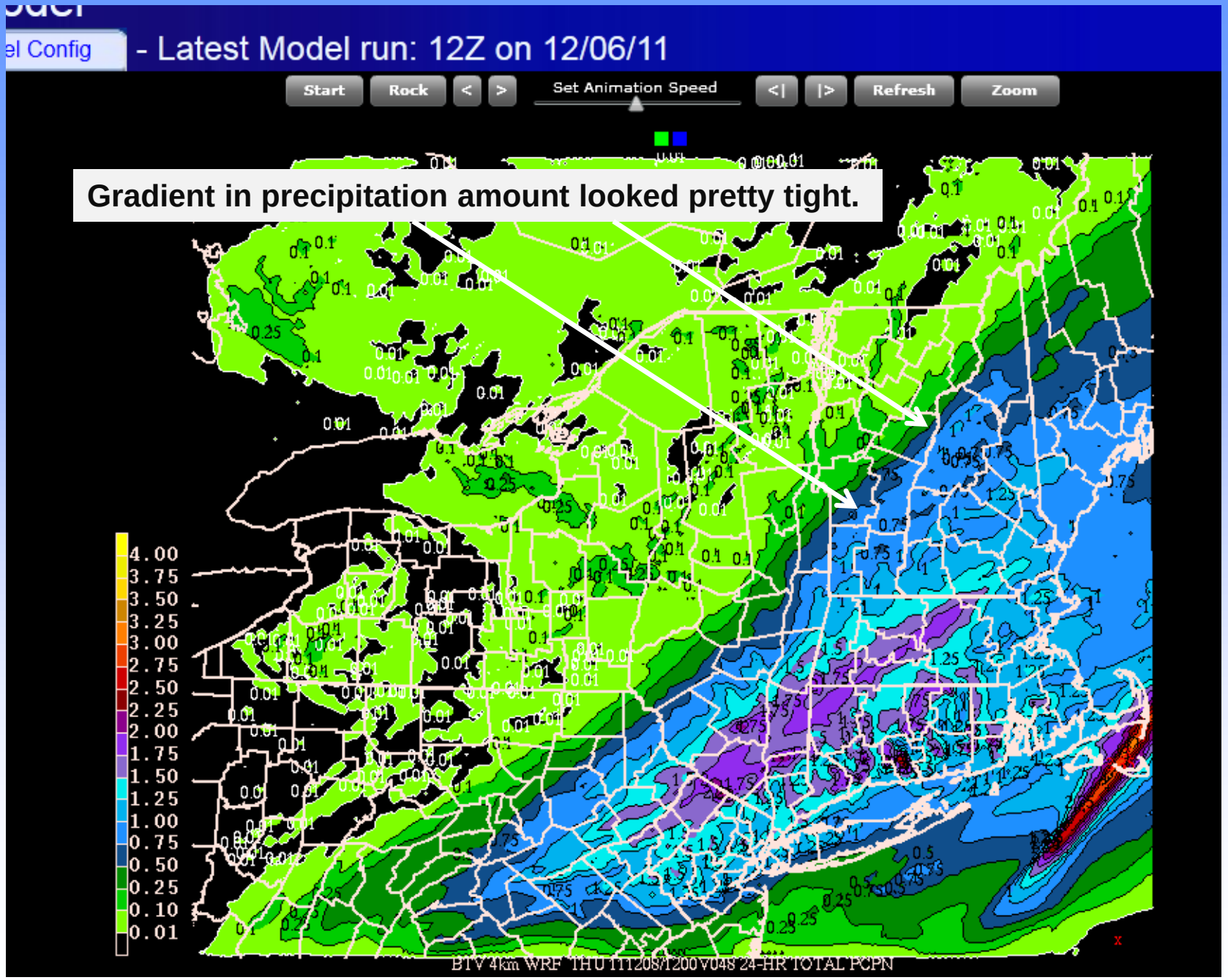

FCST: F066 VALID: Thu 20111208/0900 UTC
NOAA/NWS Storm Prediction Center, Norman, OK
Models trended more inland with the storm track leading up to the event
The next four slides show the probability of accumulating precipitation valid at the SAME forecast time on 4:00 AM Thursday
Probabilities in %
50
70
90
111208/0900V066 PROBABILITY 3HR TOTAL PRECIP >= 0.01"
MEAN 3HR TOTAL PRECIP = 0.01" (Black - dashed)
FCST: F066 VALID: Thu 20111208/0900 UTC
NOAA


FCST: F060 VALID: Thu 20111208/0900 UTC
NOAA/NWS Storm Prediction Center, Norman, OK
60 Hour Forecast
Probabilities in %
50
70
90
111208/0900V060 PROBABILITY 3HR TOTAL PRECIP >= 0.01"
MEAN 3HR TOTAL PRECIP = 0.01" (Black - dashed)
FCST: F060 VALID: Thu 20111208/0900 UTC
NOAA

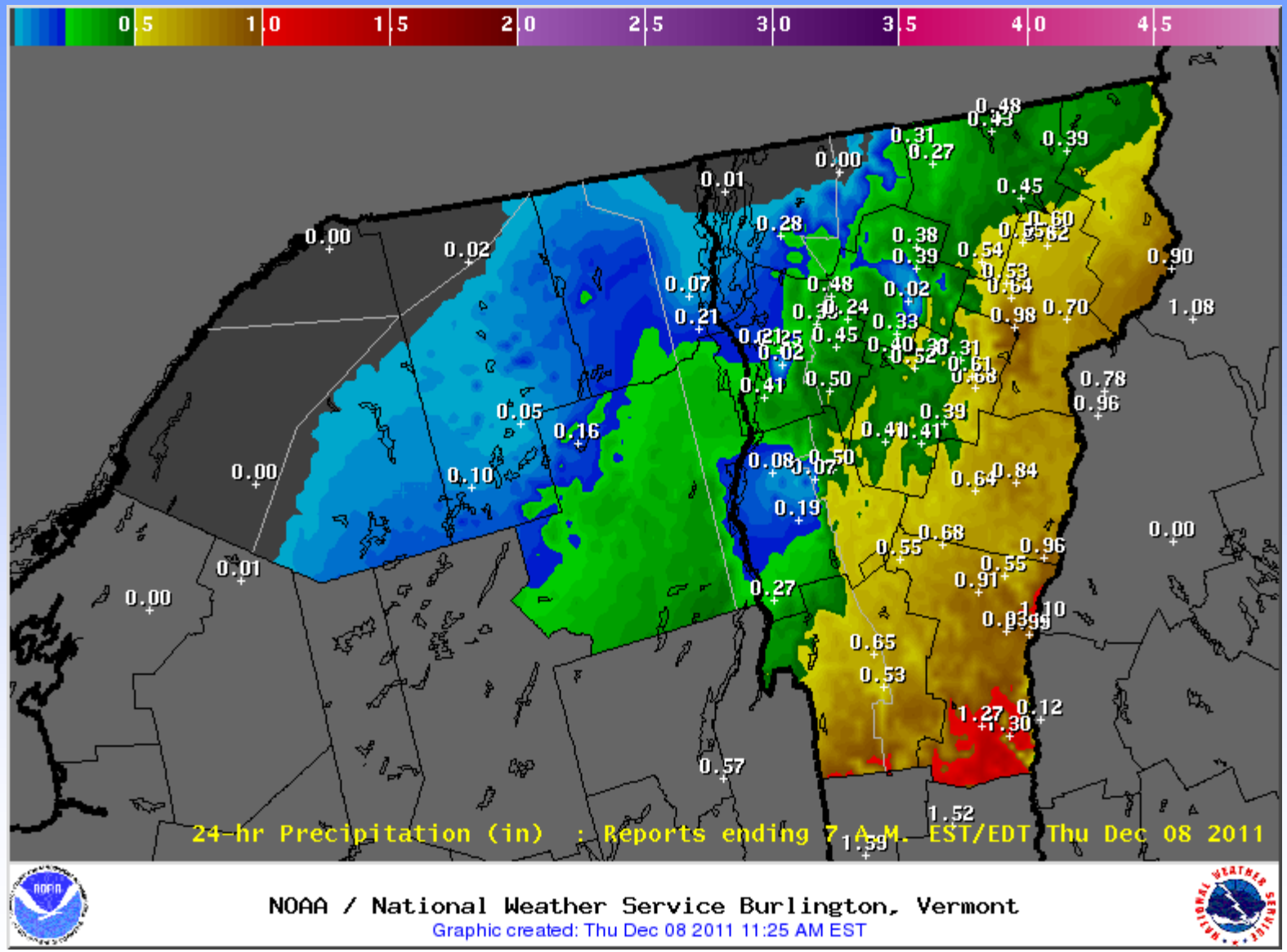

54 Hour Forecast
NOAA/NWS Storm Prediction Center, Norman, OK
Probabilities in %
50
70
90
111208/0900V054 PROBABILITY 3HR TOTAL PRECIP >= 0.01"
MEAN 3HR TOTAL PRECIP = 0.01" (Black - dashed)
NOAA


FCST: F048 VALID: Thu 20111208/0900 UTC
NOAA/NWS Storm Prediction Center, Norman, OK
48 Hour Forecast
Probabilities in %
50
70
90
111208/0900V048 PROBABILITY 3HR TOTAL PRECIP >= 0.01"
MEAN 3HR TOTAL PRECIP = 0.01" (Black - dashed)
FCST: F048 VALID: Thu 20111208/0900 UTC
NOAA


FCST: F042 VALID: Thu 20111208/0900 UTC
NOAA/NWS Storm Prediction Center, Norman, OK
42 Hour Forecast
Note inland shift in probabilities. The trend is your friend.
Probabilities in %
50
70
90
111208/0900V042 PROBABILITY 3HR TOTAL PRECIP >= 0.01"
MEAN 3HR TOTAL PRECIP = 0.01" (Black - dashed)
FCST: F042 VALID: Thu 20111208/0900 UTC
NOAA

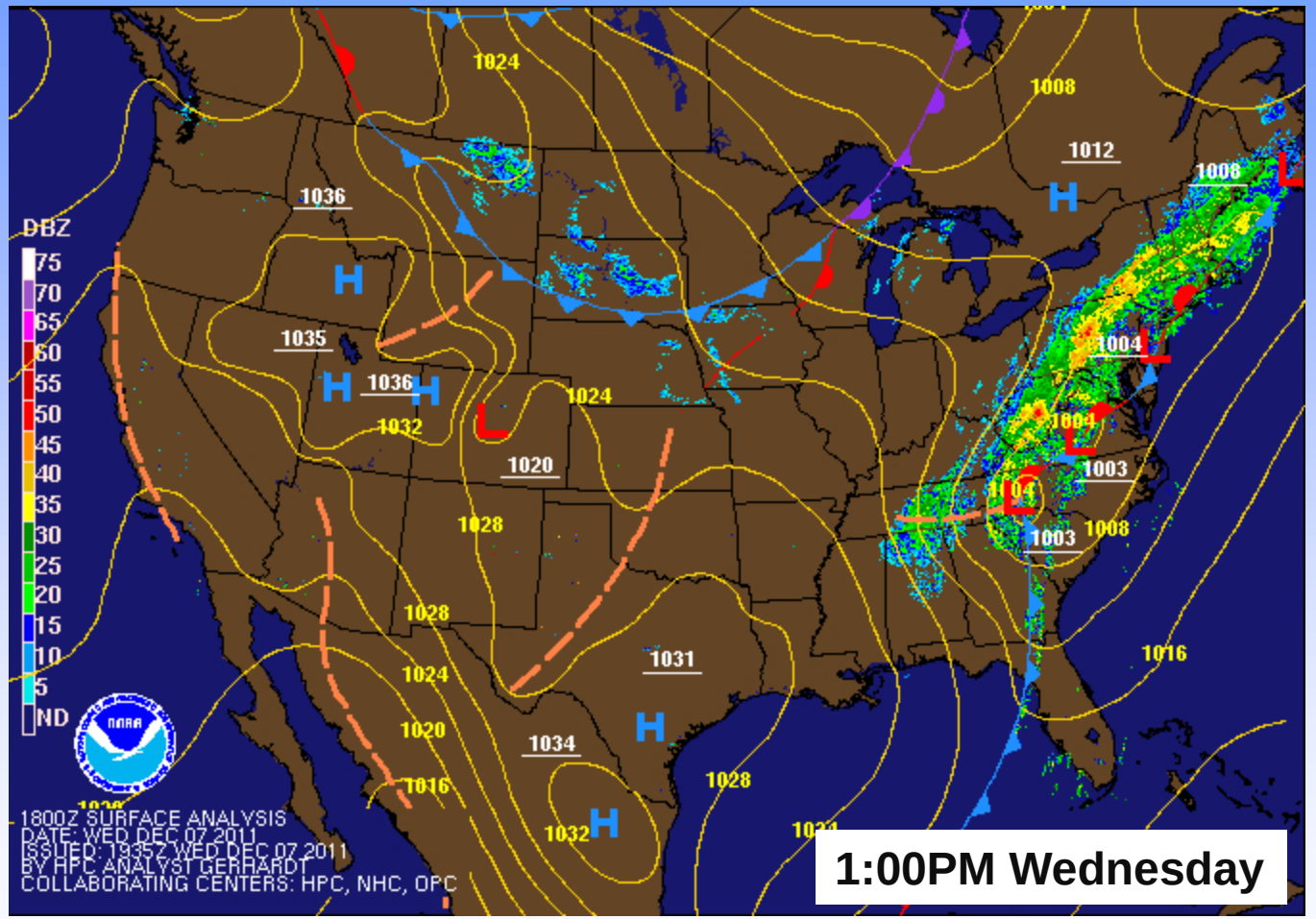

el Config
- Latest Model run: 12Z on 12/06/11
Start
Rock
<
>
Set Animation Speed
<|
|>
Refresh
Zoom
Gradient in precipitation amount looked pretty tight.
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.10
0.01
BTV 4km WRF THU 111208/1200 V048 24-HR TOTAL PCPN

Precipitation Verification



Activity

- Plot the surface low position every 3 hrs over the last day for today's storm
  - How did the track of the storm compare to other snow storms?
- Annotate the surface low strength in (mb) to each low position
  - Was the surface low intensifying, decaying, or remaining the same strength as it passed the Northeast?
- Compare frontal development to the typical midlatitude cyclone model
  - What stage or stages did today's snow storm evolve through?


DBZ
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70
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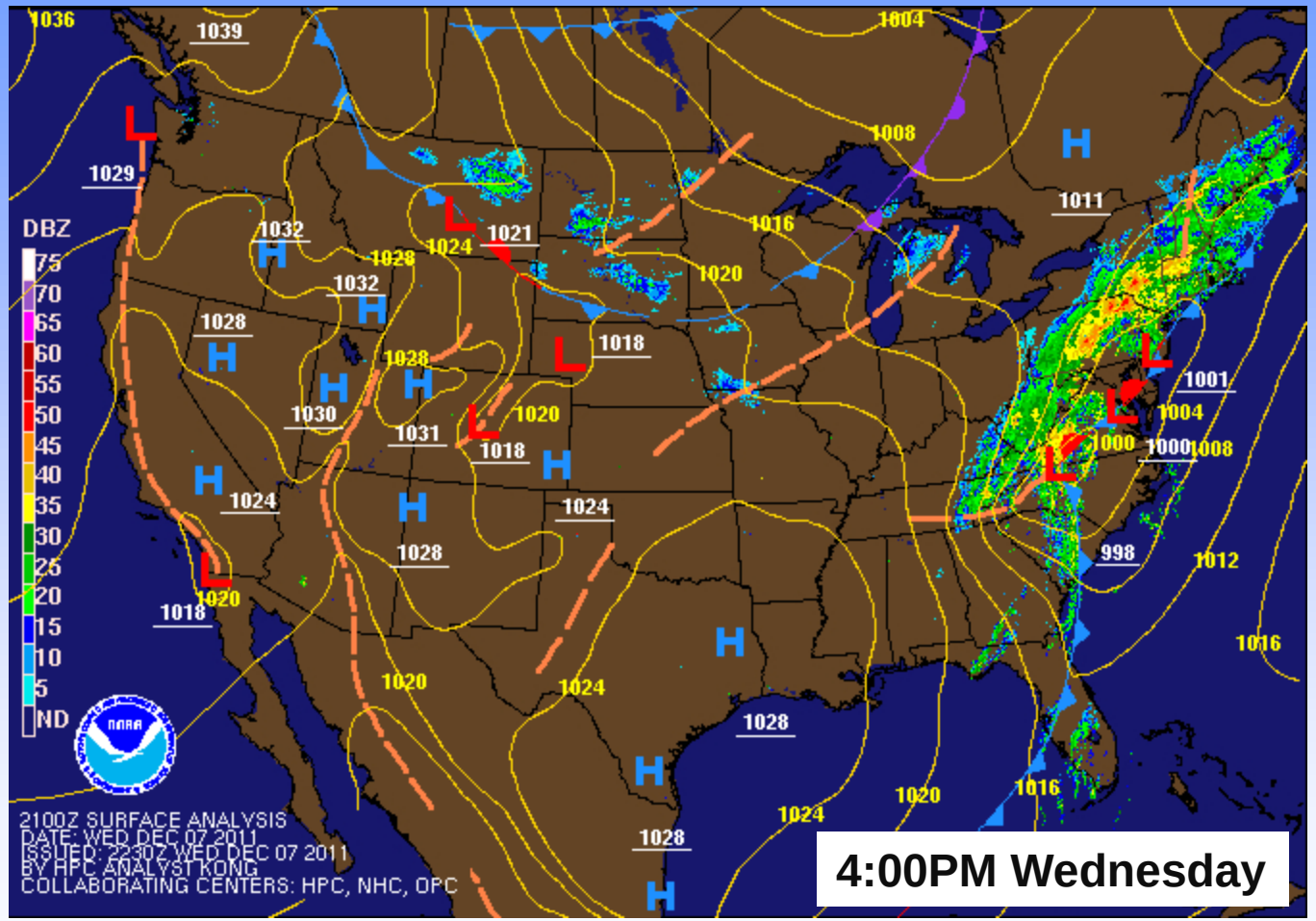
25
20
15
10
5
ND
1800Z SURFACE ANALYSIS
DATE: WED DEC 07 2011
ISSUED: 1835Z WED DEC 07 2011
BY HPC ANALYST GERHARDT
COLLABORATING CENTERS: HPC, NHC, OPC
1:00PM Wednesday


DBZ
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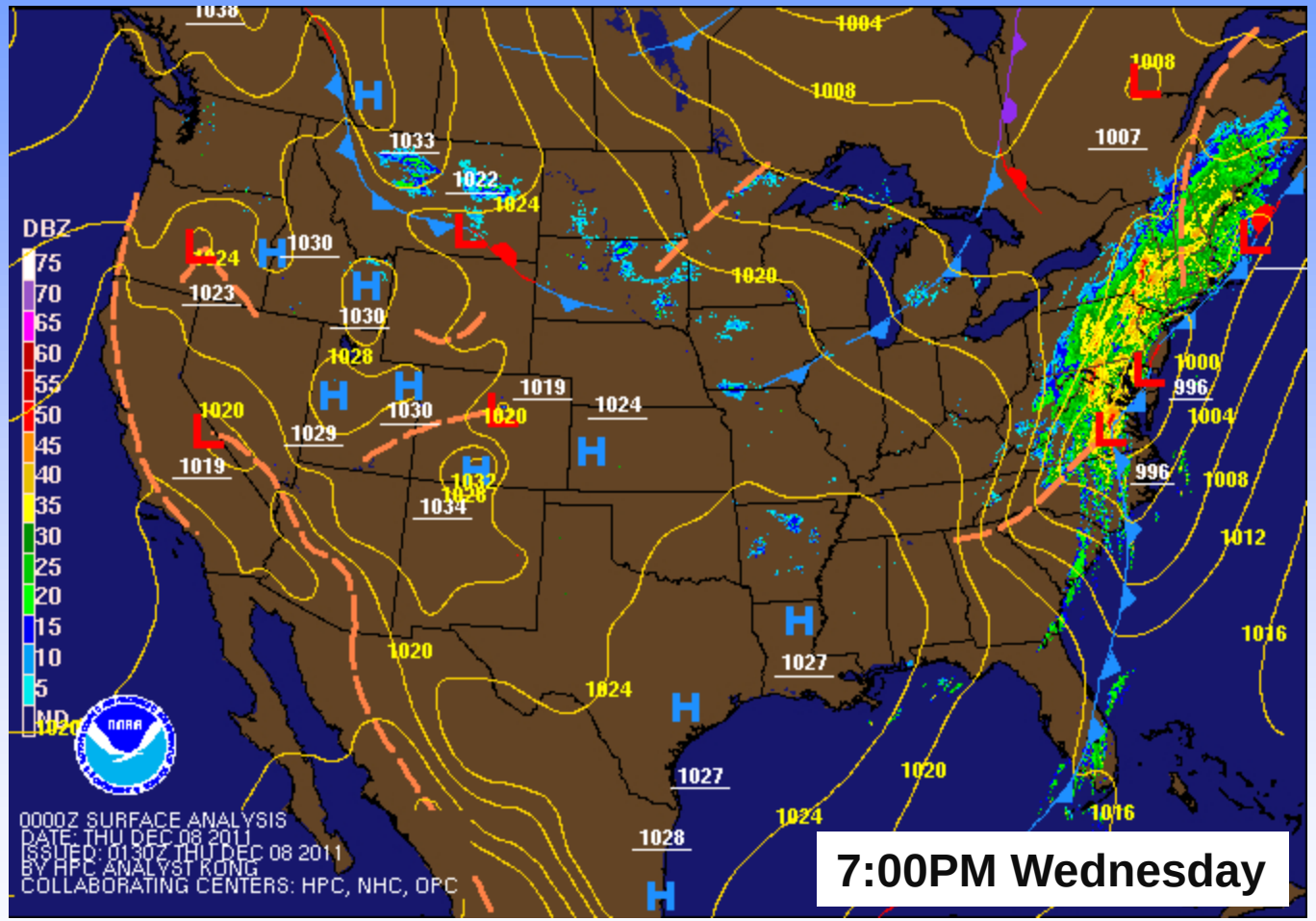
ND
2100Z SURFACE ANALYSIS
DATE: WED DEC 07 2011
ISSUED: 2230Z WED DEC 07 2011
BY HPC ANALYST KONG
COLLABORATING CENTERS: HPC, NHC, OPC
4:00PM Wednesday


DBZ
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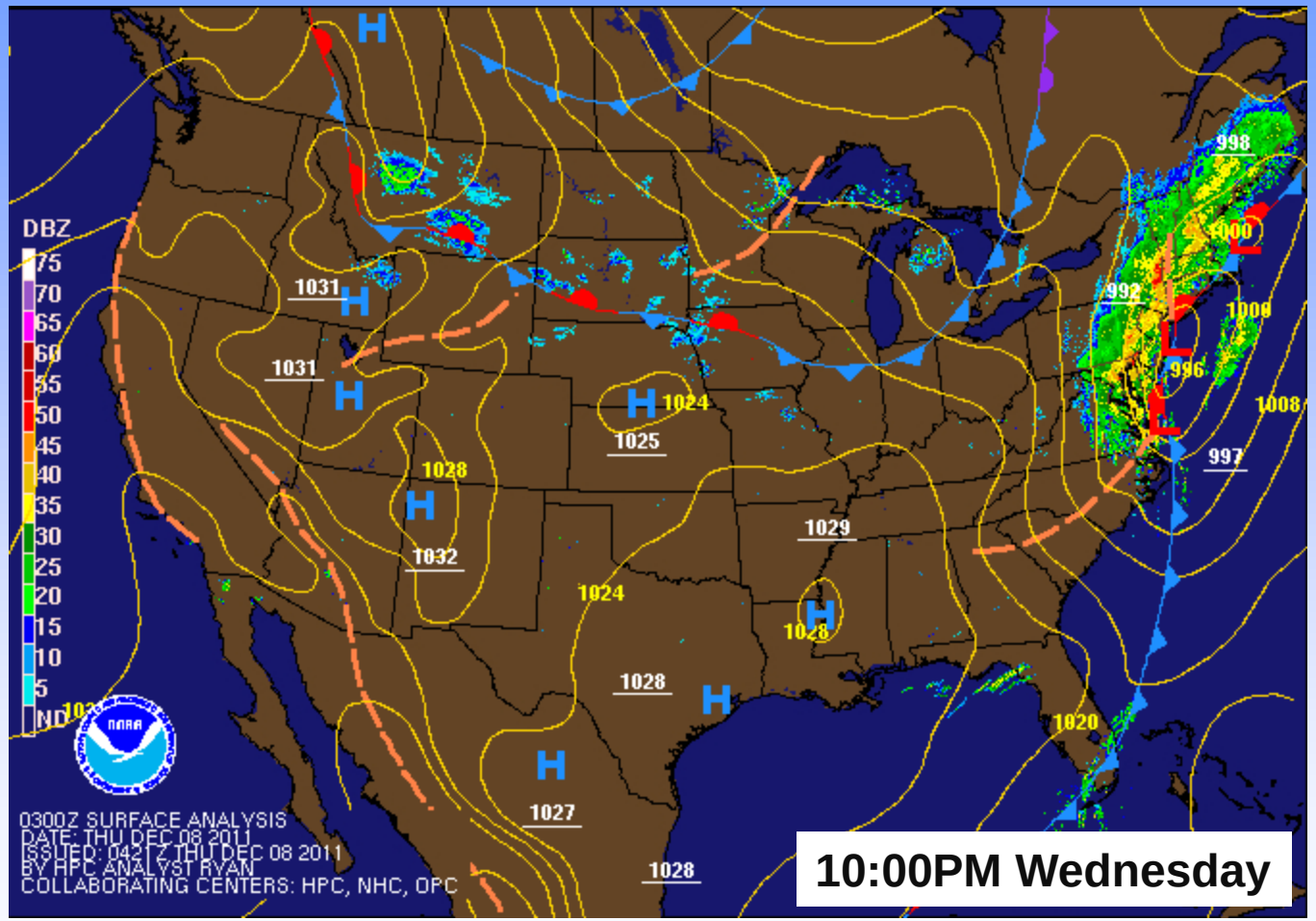
ND
0000Z SURFACE ANALYSIS
DATE: THU DEC 08 2011
ISSUED: 0130Z THU DEC 08 2011
BY HPC ANALYST KONG
COLLABORATING CENTERS: HPC, NHC, OPC
7:00PM Wednesday


DBZ
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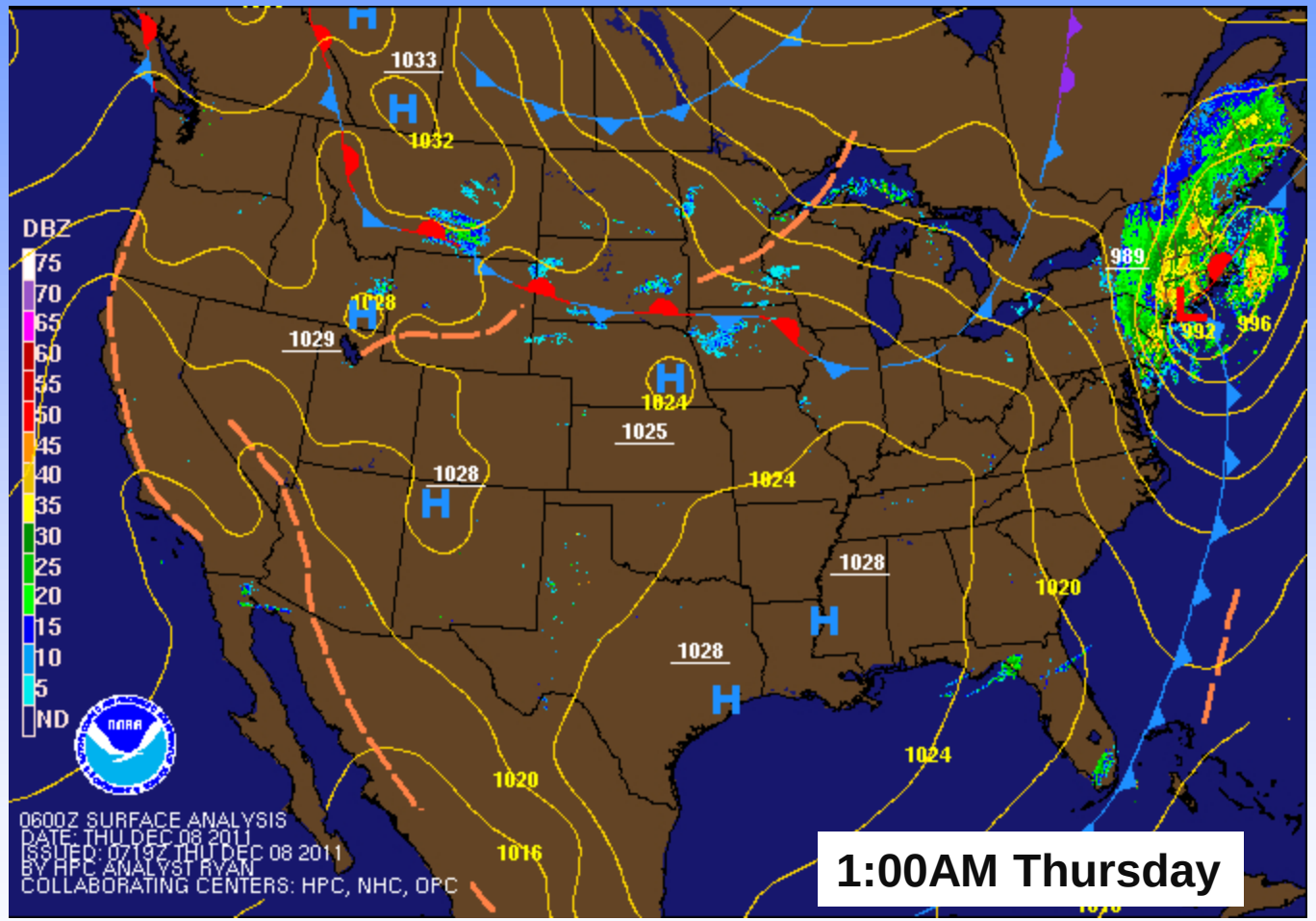
ND
0300Z SURFACE ANALYSIS
DATE: THU DEC 08 2011
ISSUED: 0421Z THU DEC 08 2011
BY HPC ANALYST RYAN
COLLABORATING CENTERS: HPC, NHC, OPC
1031
1031
1024
1025
1028
1032
1024
1029
1028
1028
1027
1028
1020
998
1000
992
1000
996
1008
997
10:00PM Wednesday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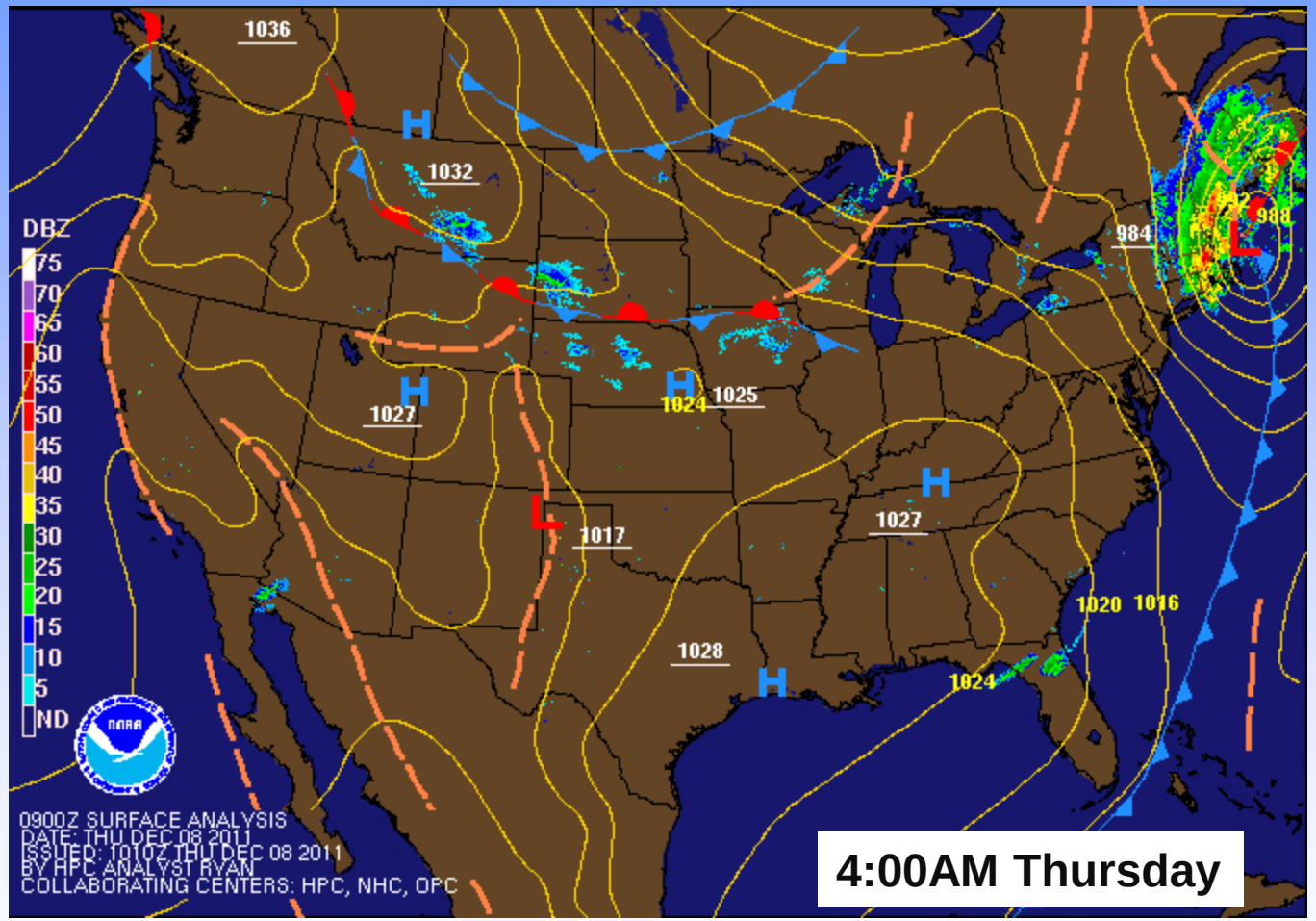
996
0600Z SURFACE ANALYSIS
DATE: THU DEC 08 2011
ISSUED: 0719Z THU DEC 08 2011
BY HPC ANALYST RYAN
COLLABORATING CENTERS: HPC, NHC, OPC
1:00AM Thursday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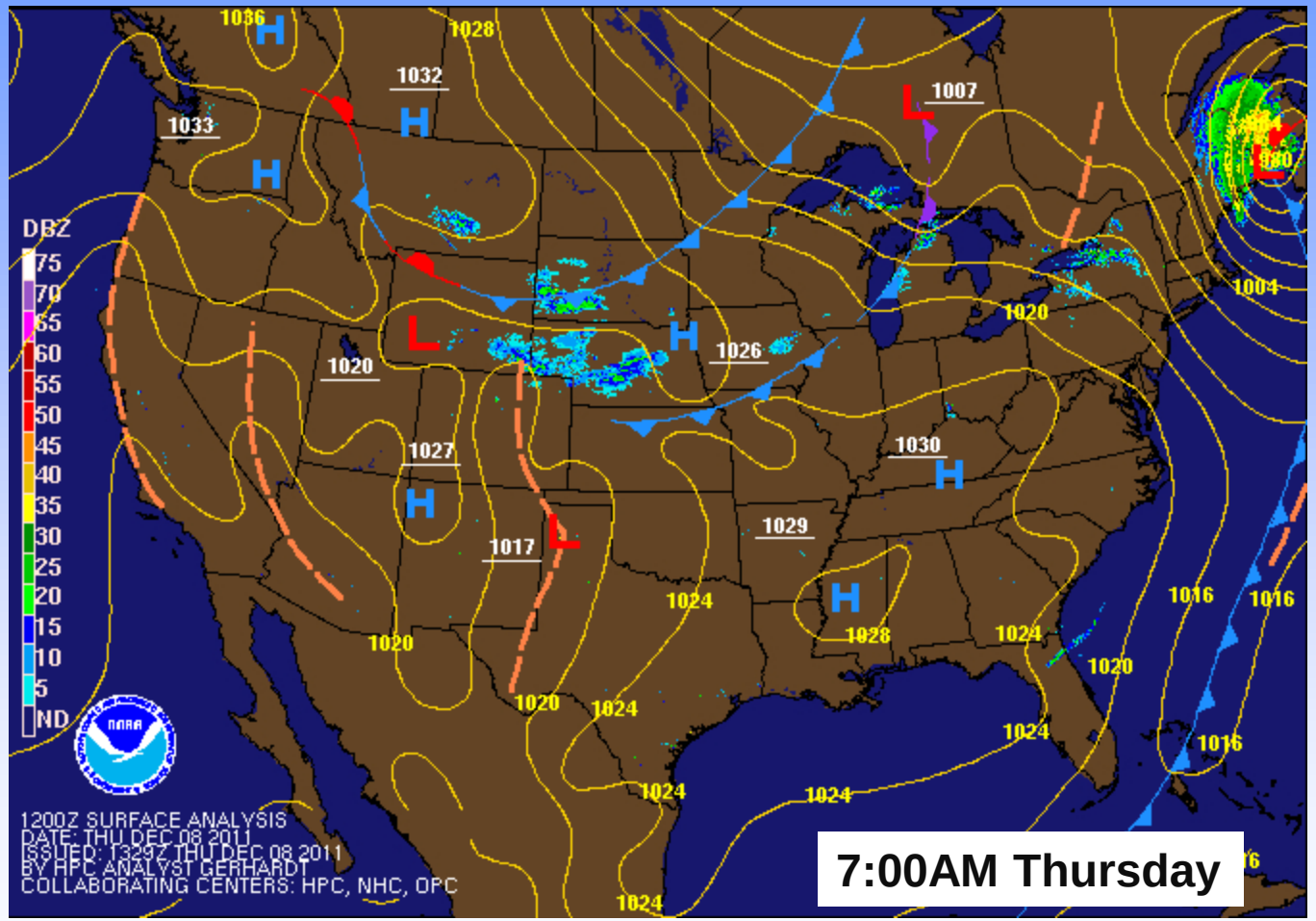
0900Z SURFACE ANALYSIS
DATE: THU DEC 08 2011
ISSUED: 1010Z THU DEC 08 2011
BY HPC ANALYST RYAN
COLLABORATING CENTERS: HPC, NHC, OPC
4:00AM Thursday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DATE: THU DEC 08 2011
ISSUED: 1329Z THU DEC 08 2011
BY HPC ANALYST GERHARDT
COLLABORATING CENTERS: HPC, NHC, OPC
7:00AM Thursday

Resources

- Lyndon Snow Storm Project: http://apollo.lsc.vsc.edu/projects/snowstorm/
- NOAA Weather Forecast Models: http://mag.ncep.noaa.gov/NCOMAGWEB/appcontroller?prevpage=index&MainPage=index&cat=MODEL+GUIDANCE&page=MODEL+GUIDANCE
- Burlington Weather.com: http://www.burlington-weather.com/models.php
- NWS Burlington: http://www.erh.noaa.gov/er/btv/
- Daily Observed Temperatures and Precipitation via NWS: http://www.erh.noaa.gov/btv/html/climatemaps/

- Contact: jason.shafer@lyndonstate.edu