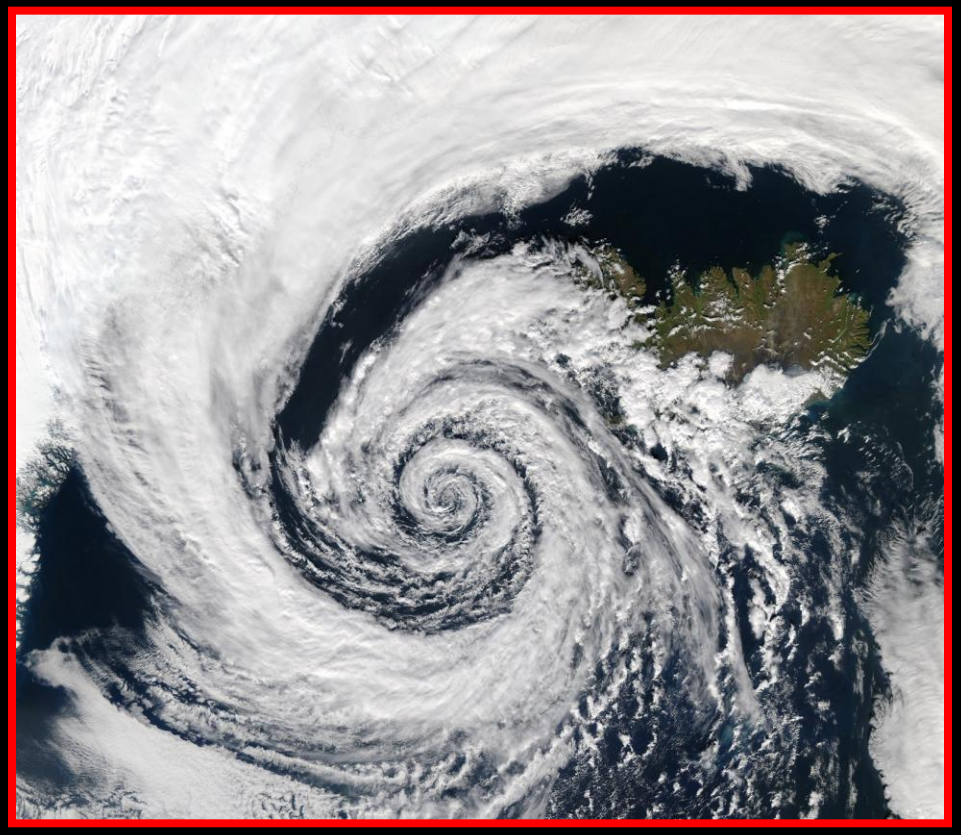
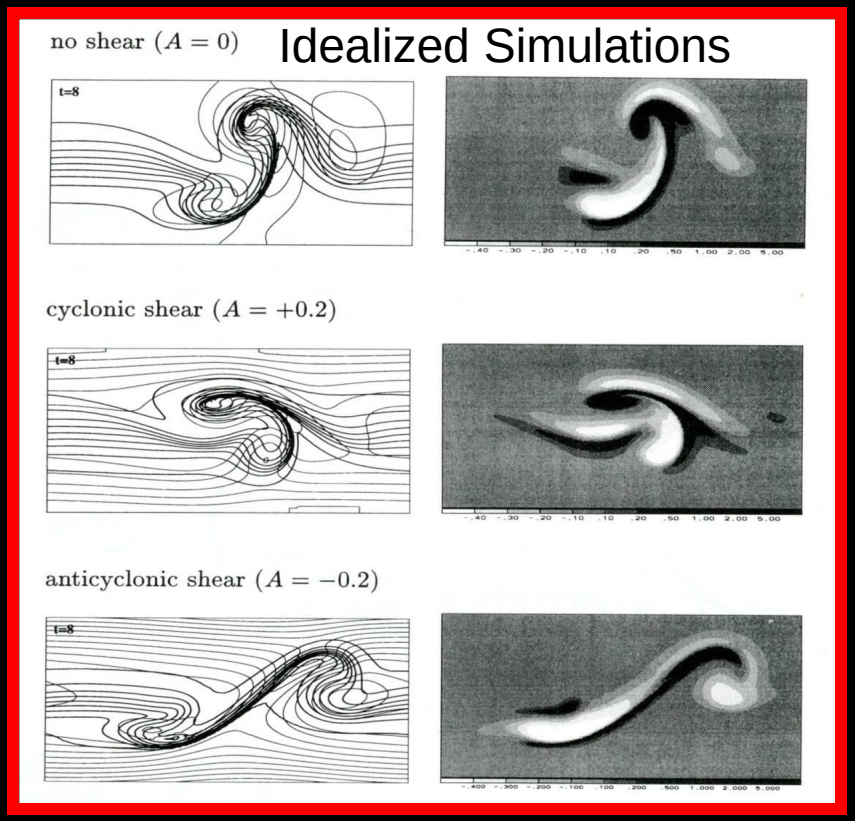
The influence of low-frequency variability on the life cycles of high-impact weather: simulations, predictions and observations



European Polar Low Working Group
Oslo Polar Low Workshop, Oslo Norway 21-22 May 2012

Mel Shapiro *National Center for Atmospheric Research, Boulder CO USA*
University of Bergen, Norway

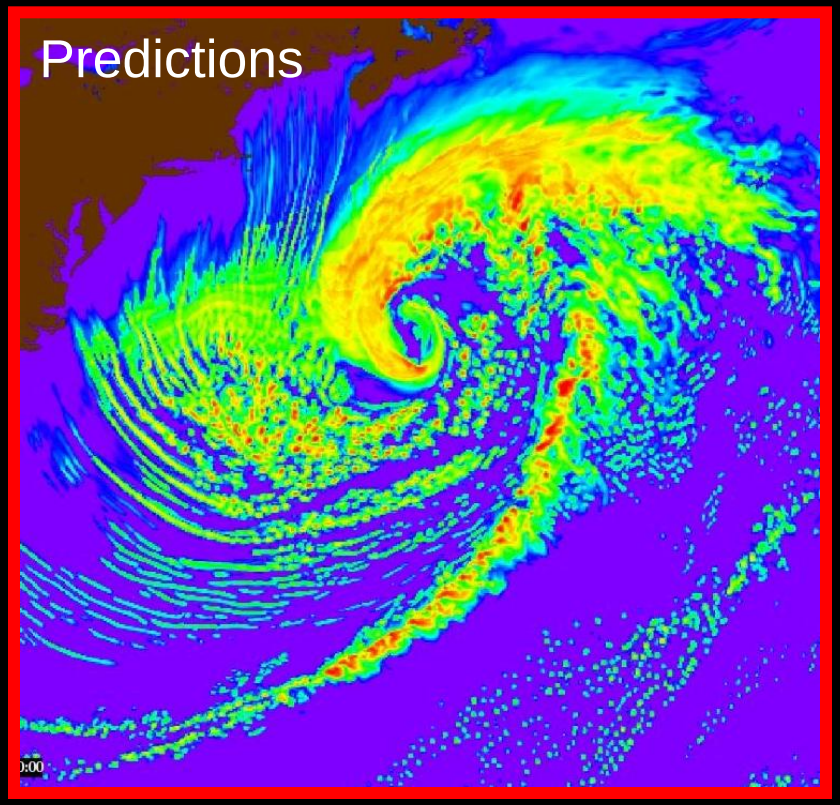
The influence of low-frequency variability on the life cycles of high-impact weather: simulations, predictions and observations



Mel Shapiro; Joseph Tribbia; Thomas Galarneau; Julio Bacmeister; Alan Norton
National Center for Atmospheric Research, Boulder CO USA
Ryan Maue; Rolf Langland
Naval Research Laboratory, Monterey CA USA

World Climate Research Program (WCRP) Open Science Conference 2011
Denver CO, 24-28 October 2011

The influence of low-frequency variability on the life cycles of high-impact weather: simulations, predictions and observations



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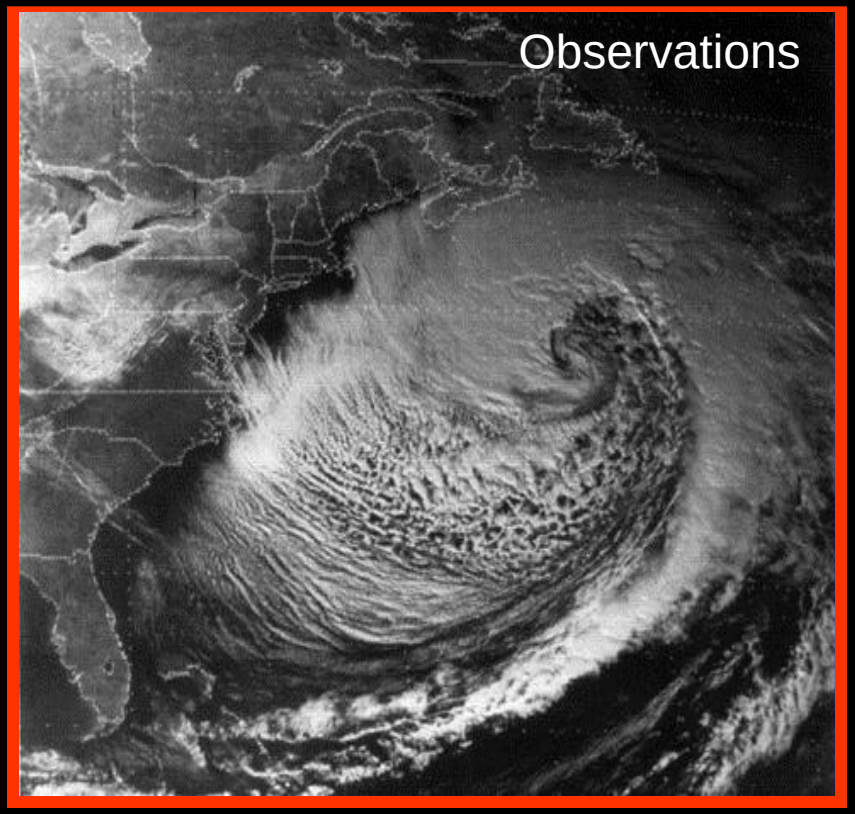

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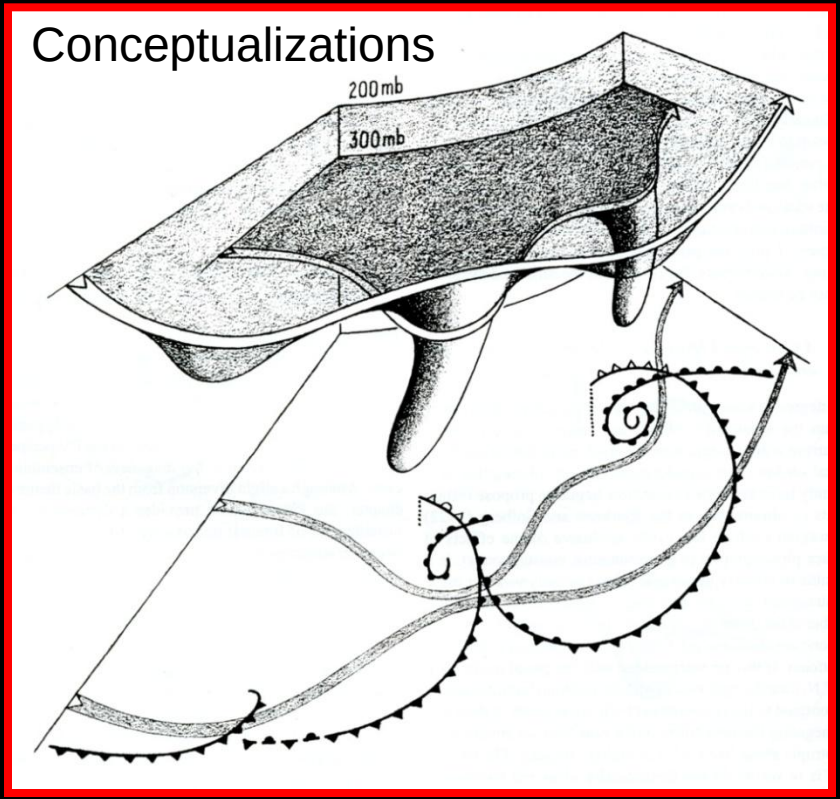

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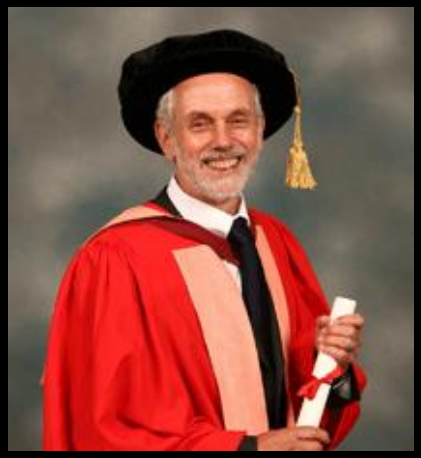
The influence of planetary barotropic shear on idealized extratropical baroclinic life cycles



Brian Hoskins

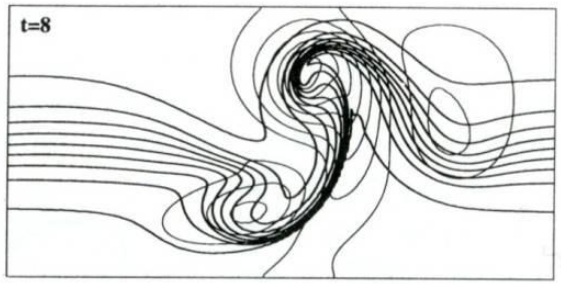
Adrian Simmons

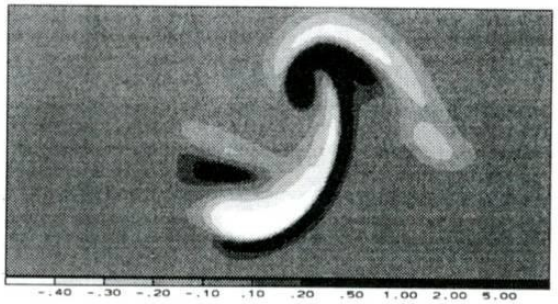
John Methven

Huw Davies

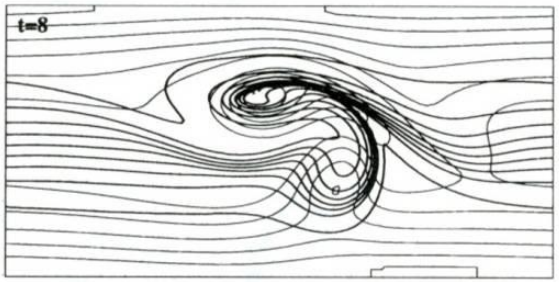
Heini Wernli

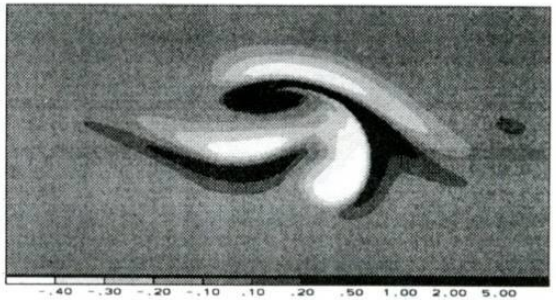
no shear $(A = 0)$ **Life Cycle 1 (LC1)**



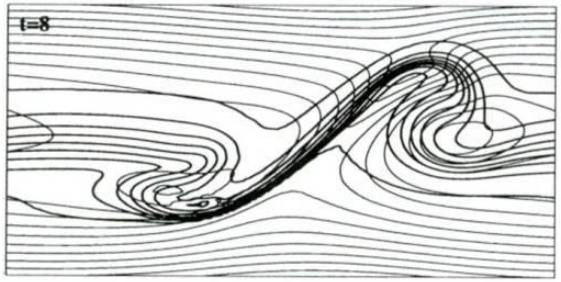


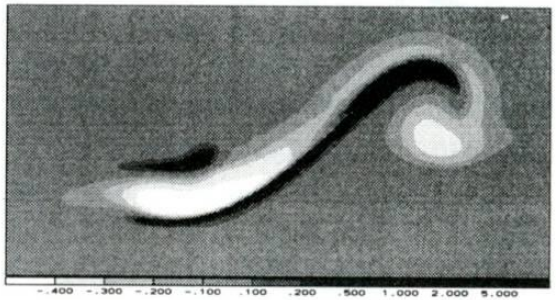
cyclonic shear $(A = +0.2)$ **LC2**





anticyclonic shear $(A = -0.2)$ **LC3**





LC1 **LC2**

Surface Temperature

Surface Vorticity

Potential Vorticity at 300 K

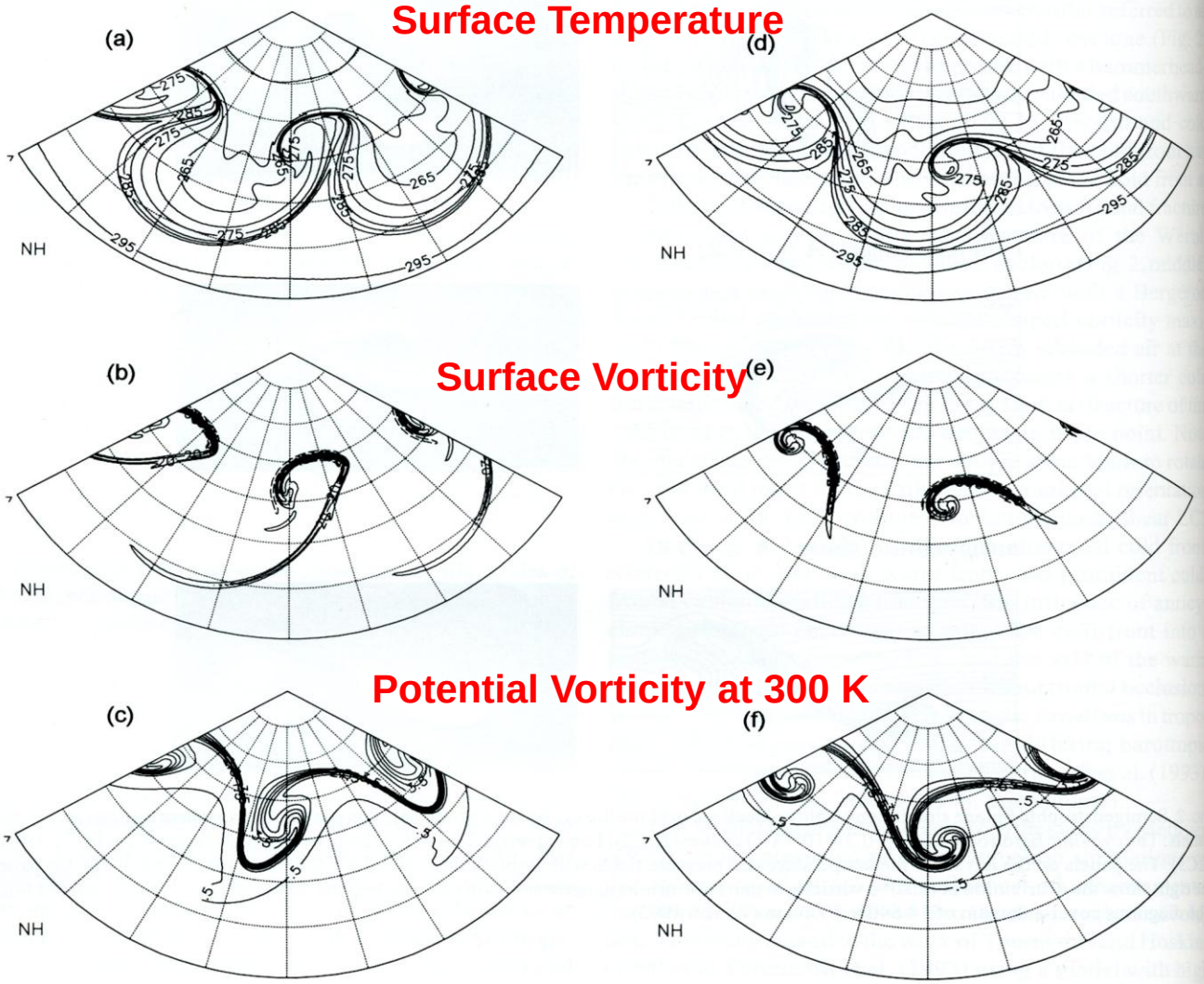
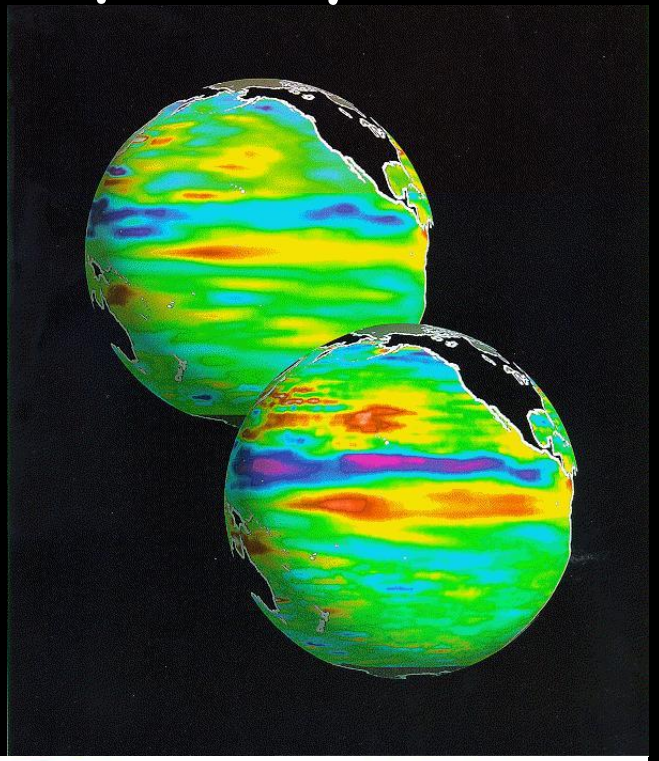


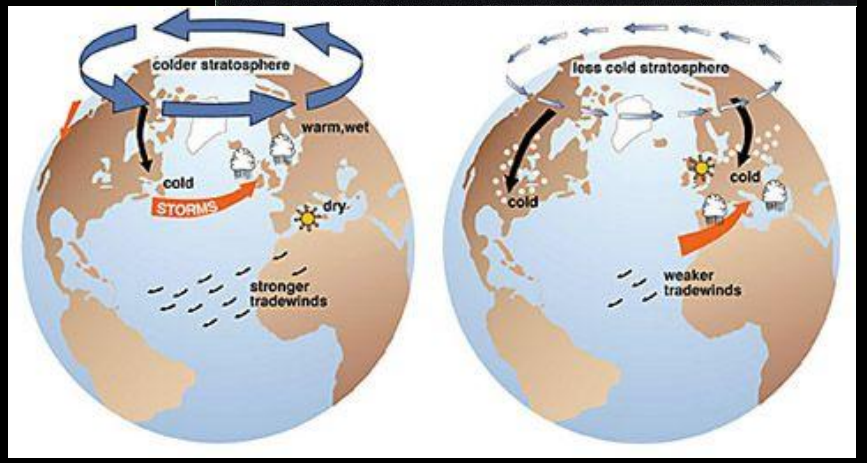
FIG. 3. Primitive-equation, spherical-domain simulations of two idealized cyclone life cycles at ~day 6. Left panels (a–c): The nonshear cyclone (LC1). Right panels (d–f): The cyclonic barotropic-shear (~0.2×10^{-4} s^{-1}) cyclone (LC2). Upper panels (a, d): Surface potential temperature at 5-K intervals. Middle panels (b, e): Surface relative vorticity at 10^{-4} s^{-1} intervals. Lower panels (c, f): Potential vorticity on the 300-K isentropic surface at 0.5-PVU intervals (Methven 1996).

The influence of low-frequency variability

El Nino Southern Oscillation

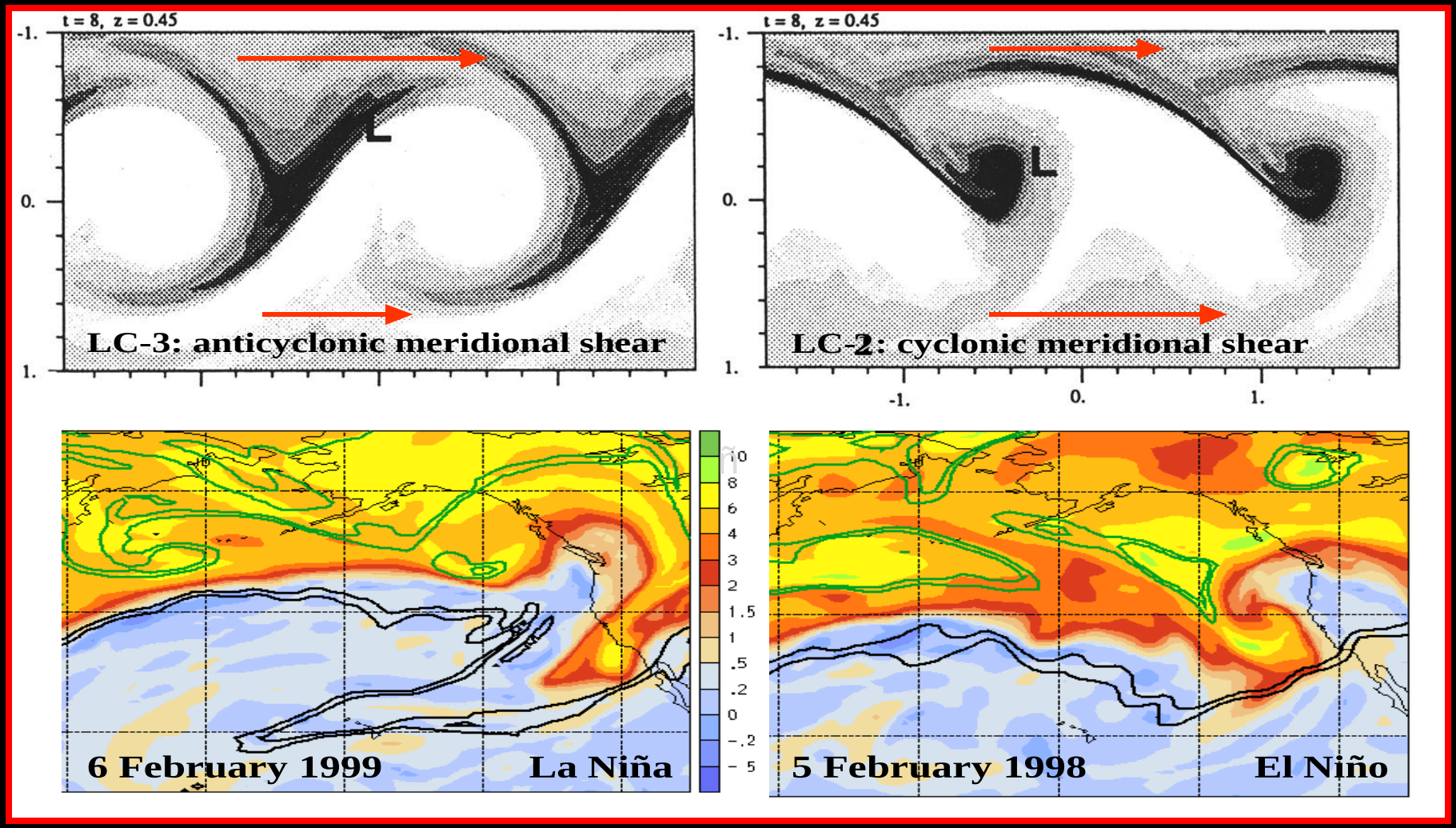


Arctic Oscillation



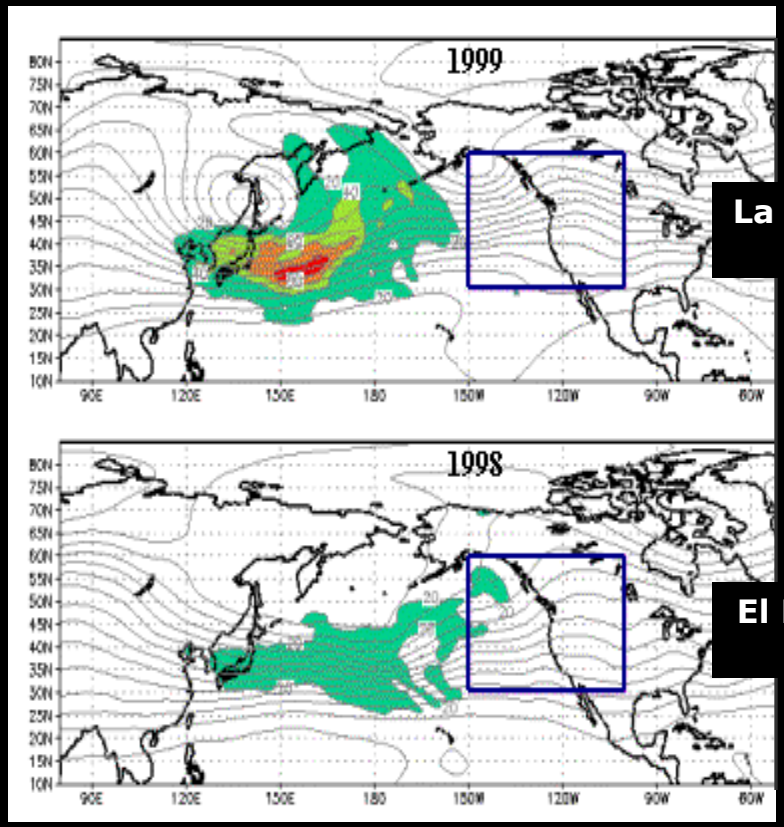
The influence of planetary time-mean flows on Rossby wave breaking

Idealized and Observed Potential Vorticity (PV)



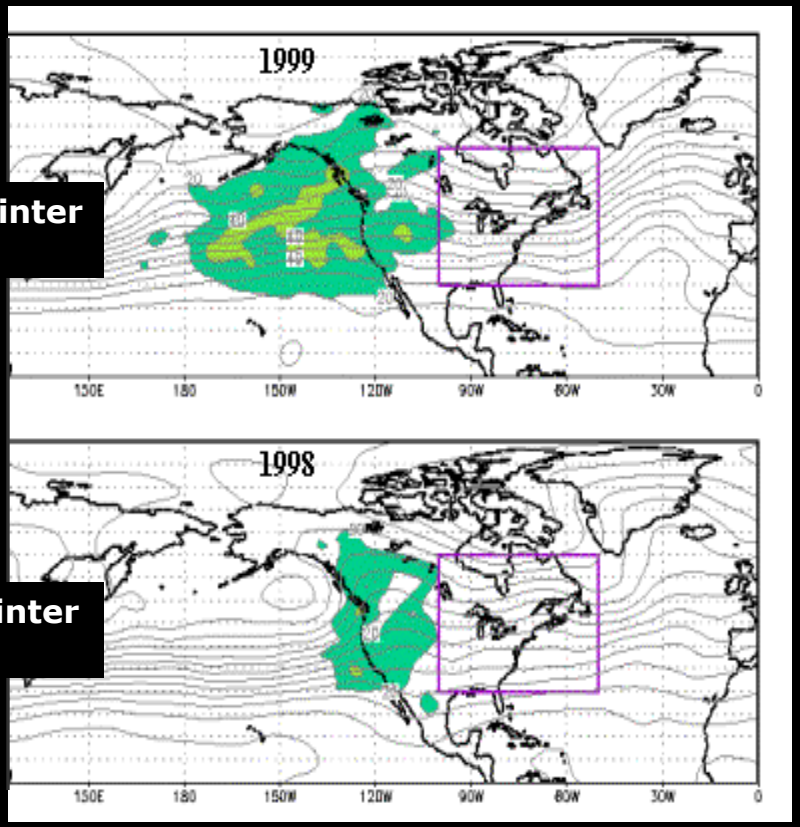
***Upper panels*: idealised simulations under the influence of anticyclonic (*left,* LC3) and cyclonic (*right,* LC2) time-mean meridional barotropic shear (from Davies *et al* 1991). *Lower panels*: ECMWF observed PV at three isentropic levels for the cold and warm phases of ENSO, respectively; Shapiro *et al.* 2001 *QJRMS*.**

Sensitivity of Large 72-hr Forecast Errors to Initial Conditions in Two Winters

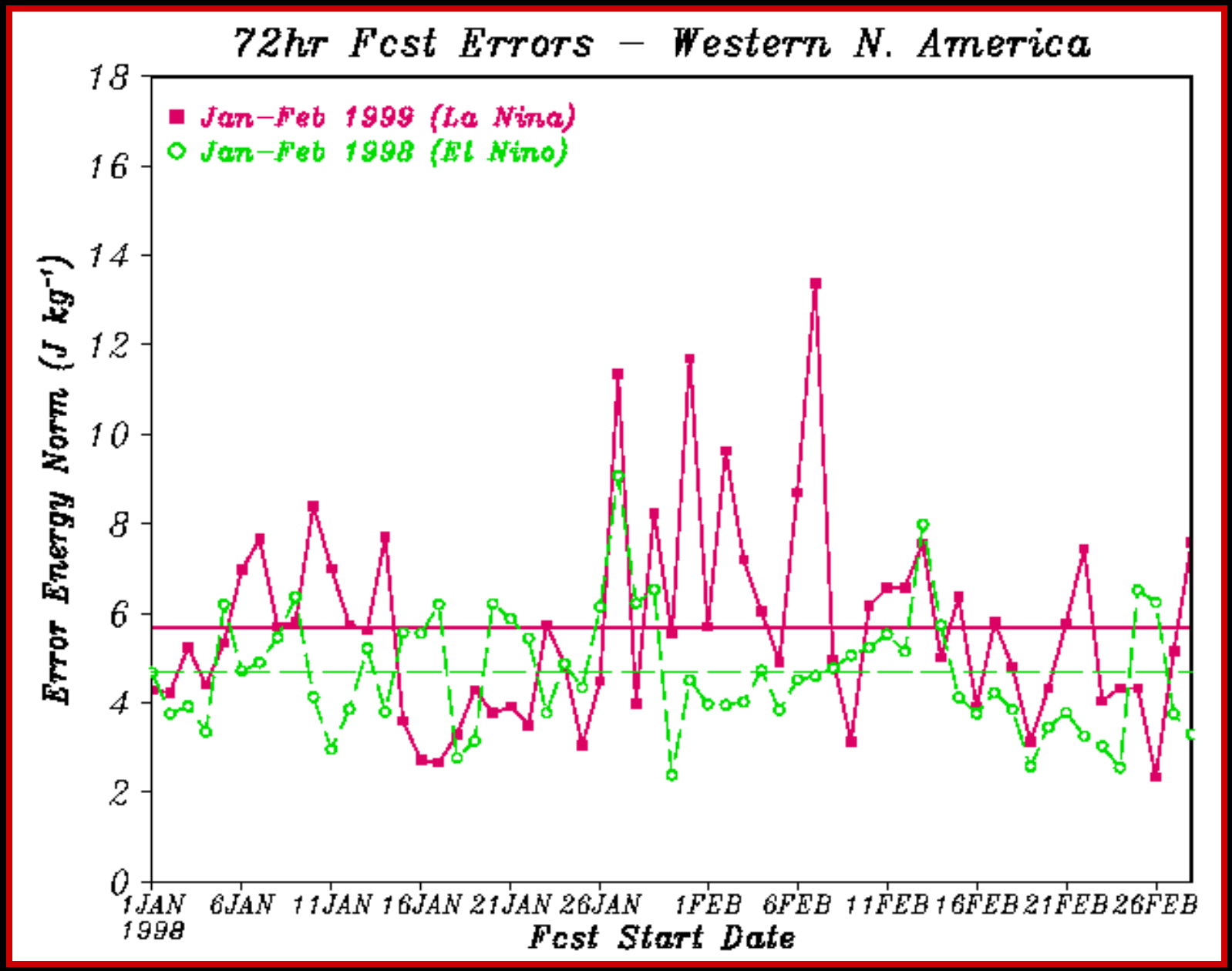


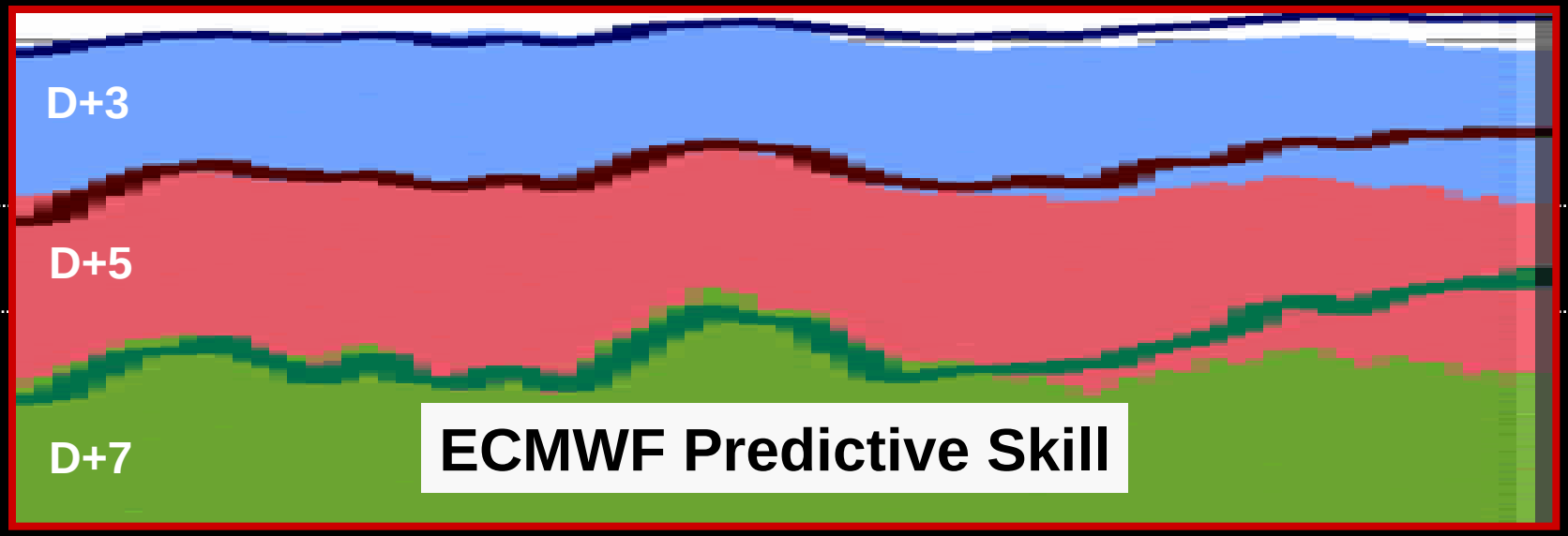
La Niña winter 1999

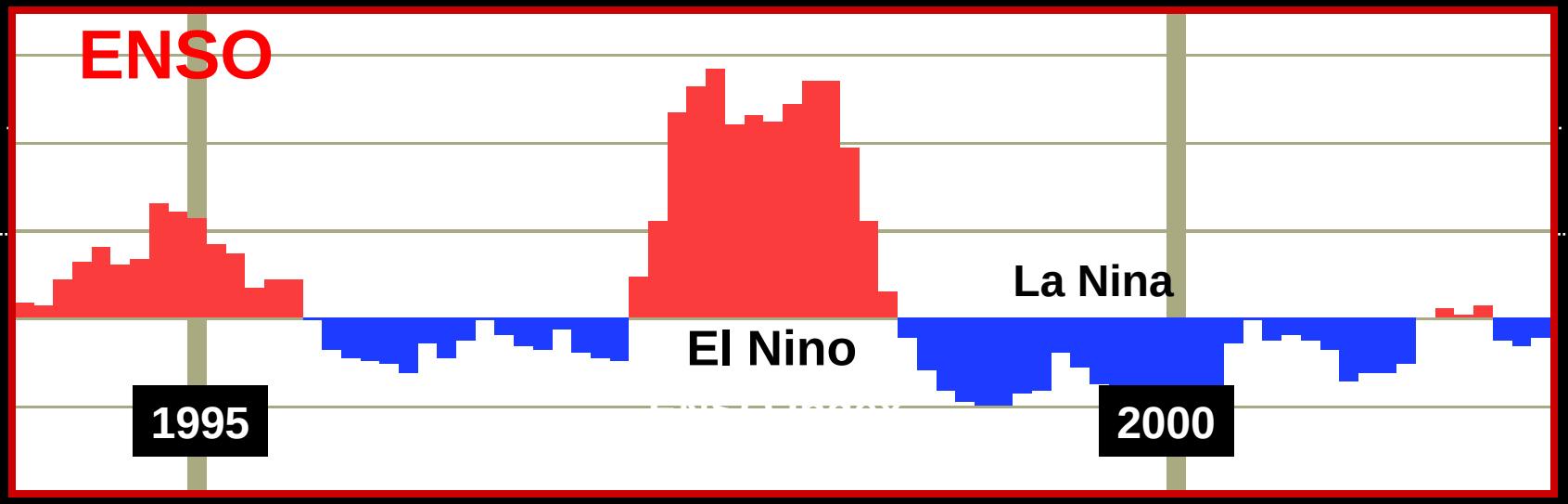
El Niño winter 1998



Shading is the sensitivity calculated using the NOGAPS forecast and adjoint models. Contours are mean 500-mb ht. for January & February (courtesy Rolf Langland (NRL/Monterey).

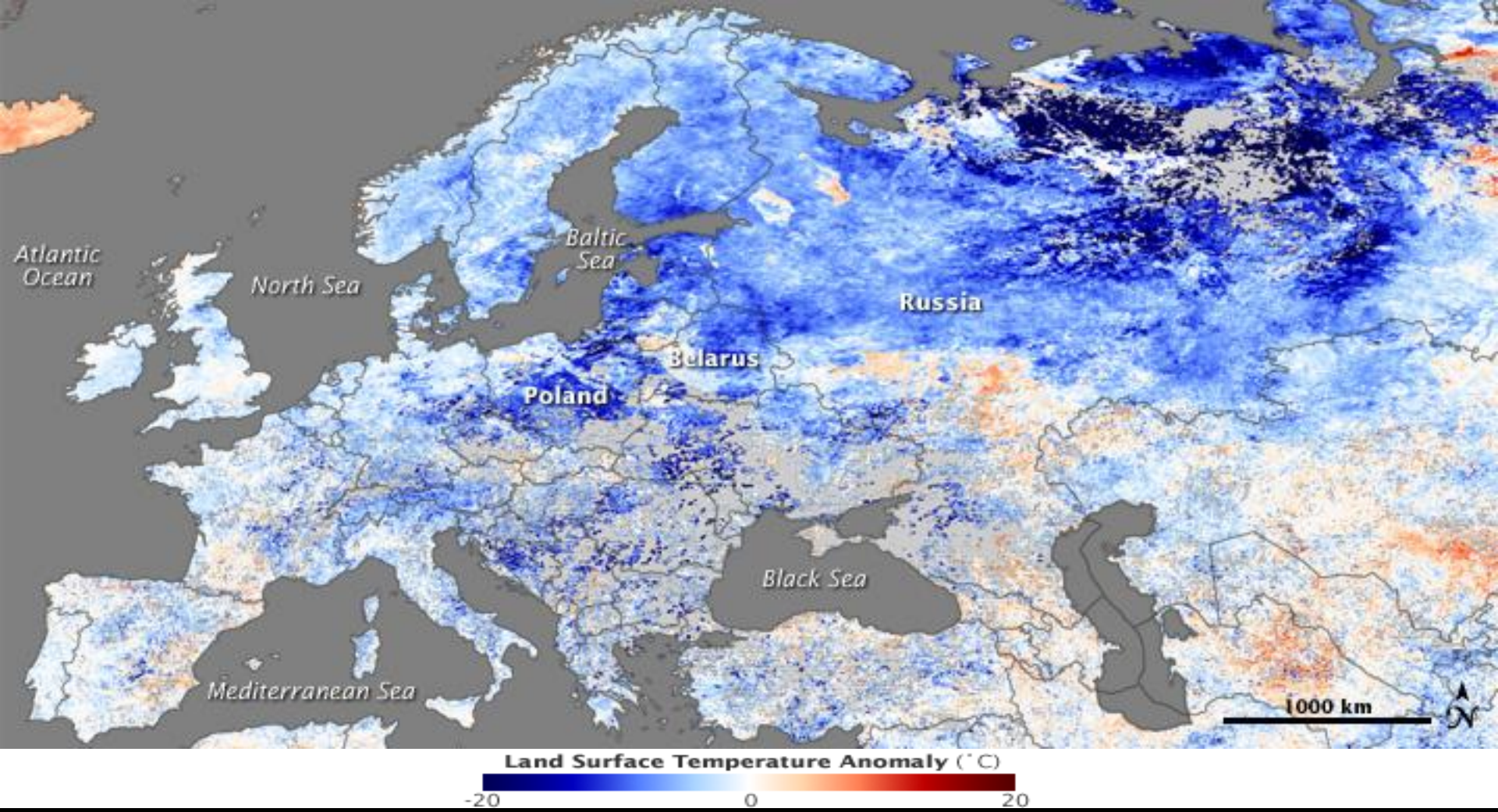

72hr Fcst Errors – Western N. America
Jan–Feb 1999 (La Nina)
Jan–Feb 1998 (El Nino)
Error Energy Norm (J kg-1)
0
2
4
6
8
10
12
14
16
18
1JAN 1998
6JAN
11JAN
16JAN
21JAN
26JAN
1FEB
6FEB
11FEB
16FEB
21FEB
26FEB
Fcst Start Date


D+3
D+5
D+7
ECMWF Predictive Skill

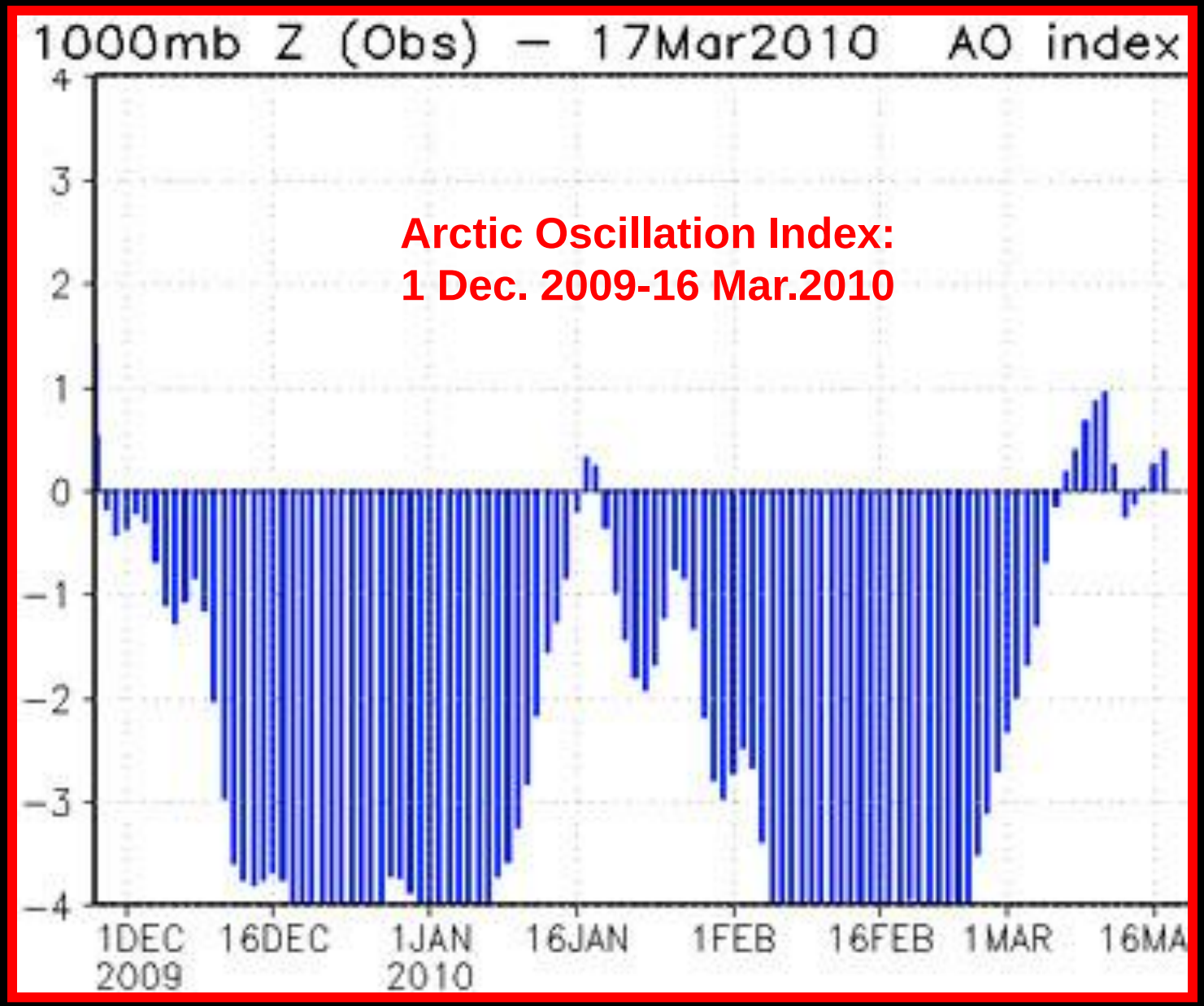

ENSO
La Nina
El Nino
1995
2000

Preliminary indications continue to suggest that winter temperatures are likely to be near or above average over much of Europe including the UK Winter 2009/10 is likely to be milder than last year for the UK, but there is still a 1 in 7 chance of a cold winter

Britain facing one of the coldest winters in 100 years, experts predict Britain is bracing itself for temperatures hitting minus 16 degrees Celsius, forecasters have warned.

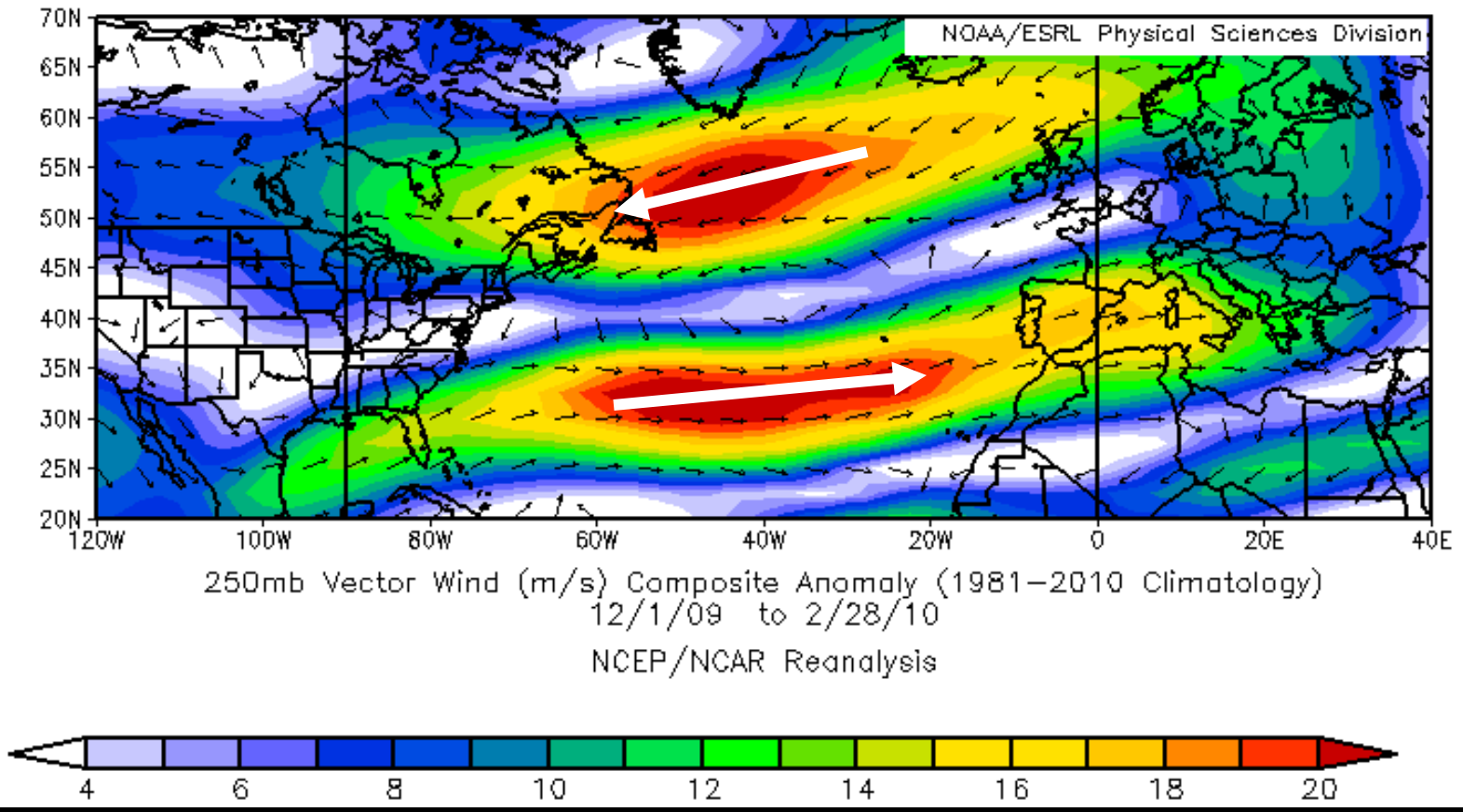


A wave of frigid air spilled down over Europe and Russia from the Arctic in mid-December, creating a deadly cold snap. According to BBC.com, at least 90 people had died in Europe, including 79 people, mostly homeless, in Poland. In places, the bitter cold was accompanied by heavy snow, which halted rail and air traffic. This image shows the impact of the cold snap on land surface temperatures across the region from December 11–18, 2009, compared to the 2000–2008 average.


1000mb Z (Obs) – 17Mar2010 AO index
Arctic Oscillation Index:
1 Dec. 2009-16 Mar.2010
4
3
2
1
0
−1
−2
−3
−4
1DEC 2009
16DEC
1JAN 2010
16JAN
1FEB
16FEB
1MAR
16MA

250-mb Vector Wind Anomaly

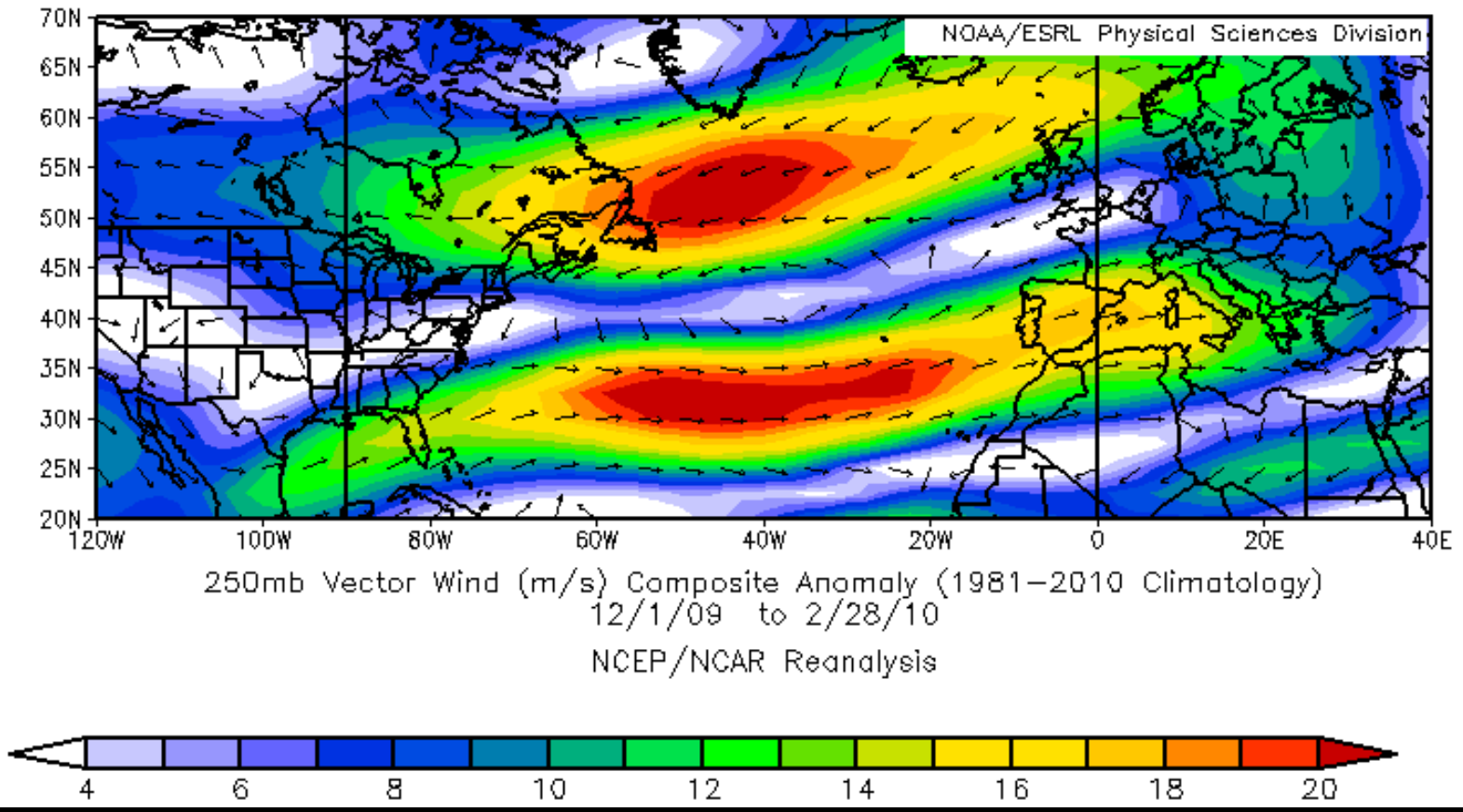
Negative AO regime



1 Dec 2009–28 Feb 2010

250-mb Vector Wind Anomaly

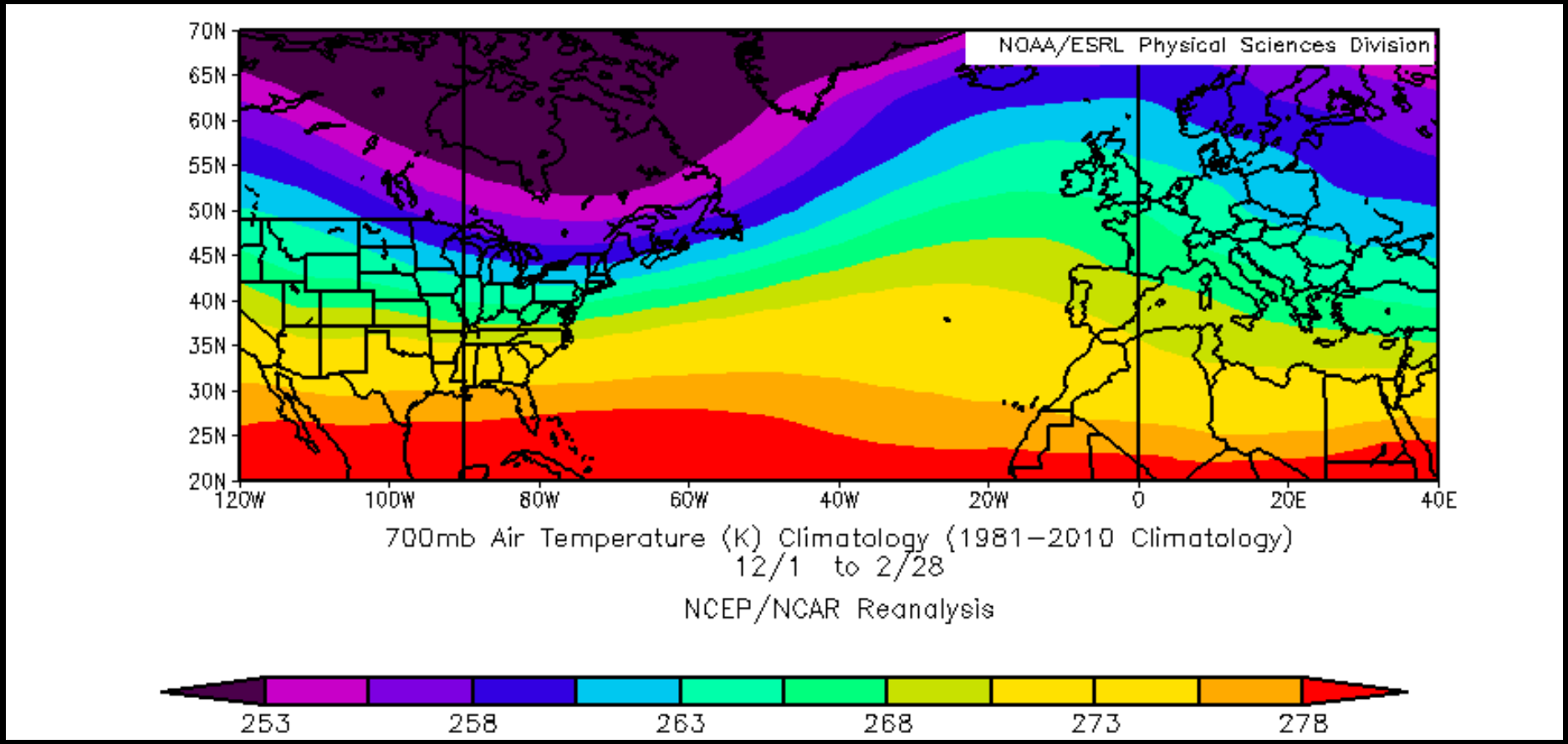
Negative AO regime



1 Dec 2009–28 Feb 2010

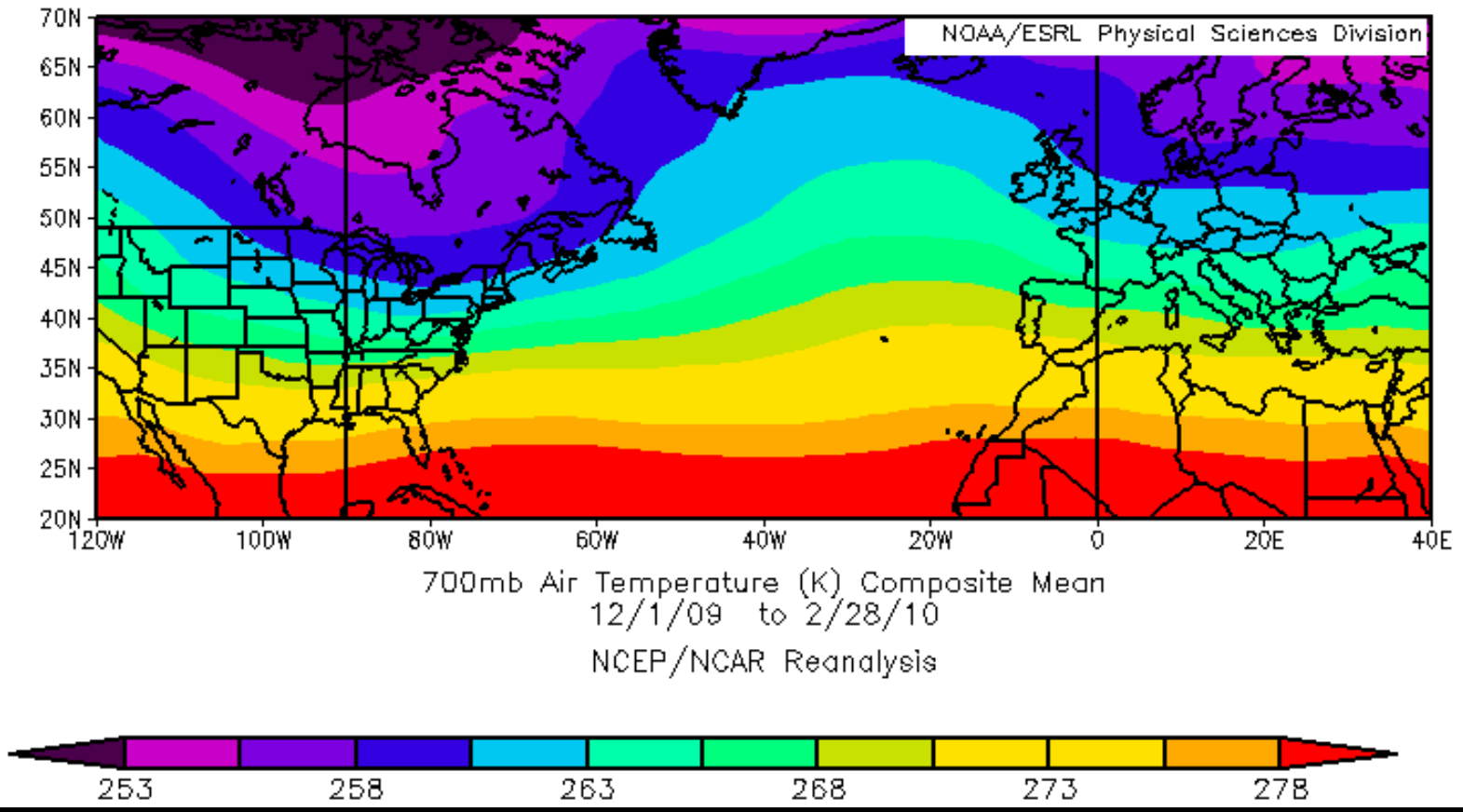
700-mb Temperature Long-Term Climatology

1 Dec–28 Feb



700-mb Temperature Mean

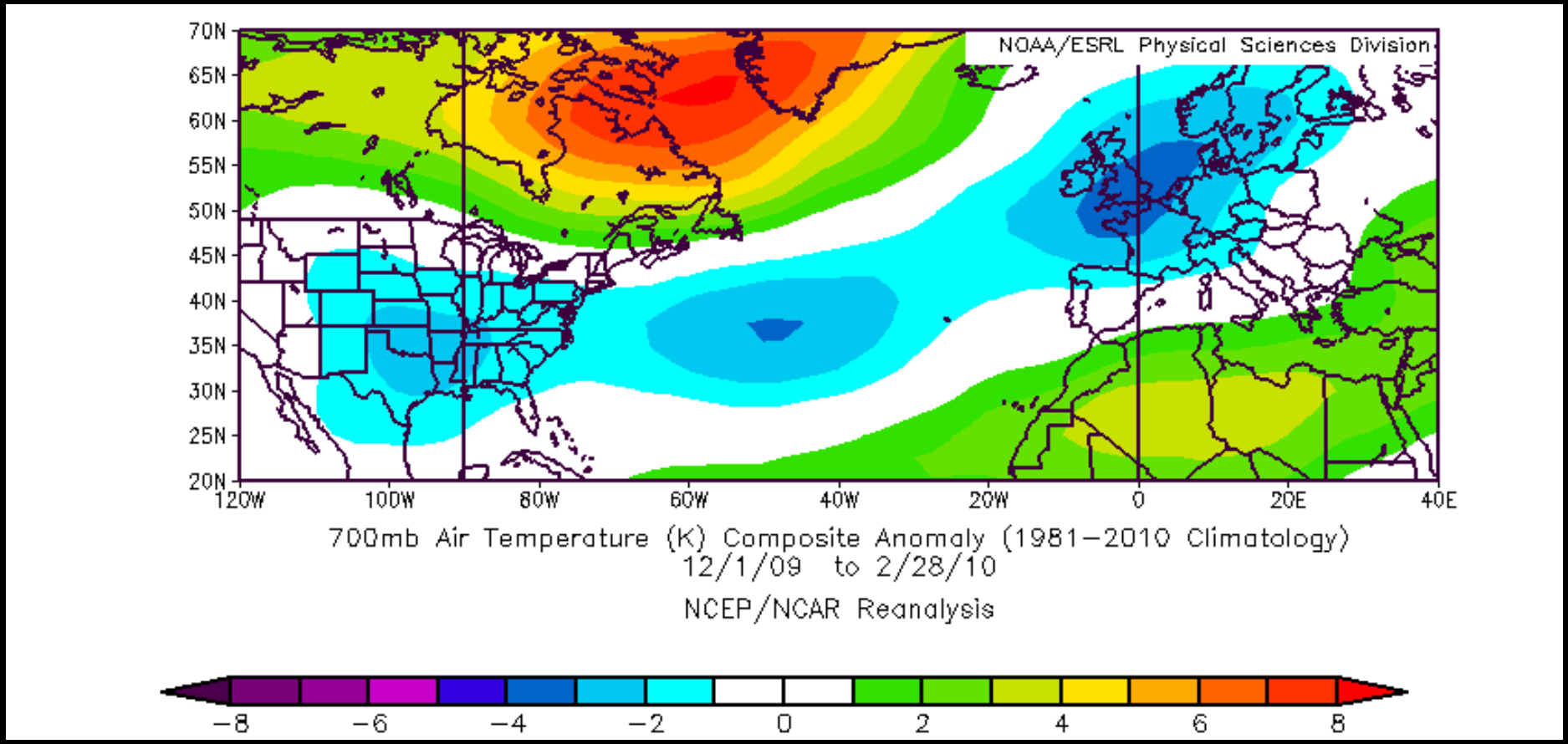
1 Dec 2009–28 Feb 2010



Negative AO regime

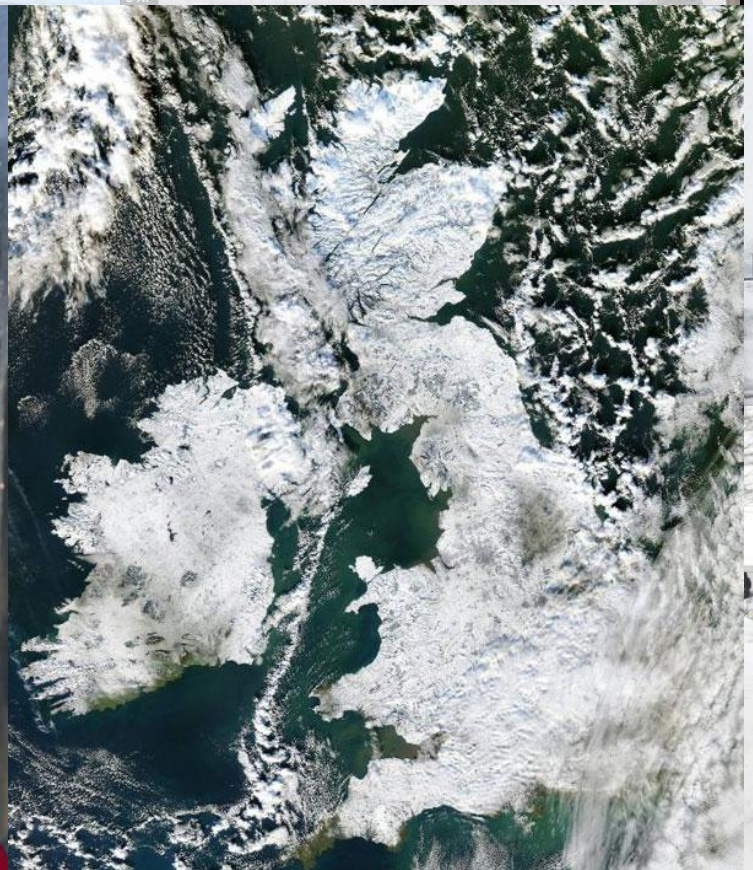
700-mb Temperature Anomaly

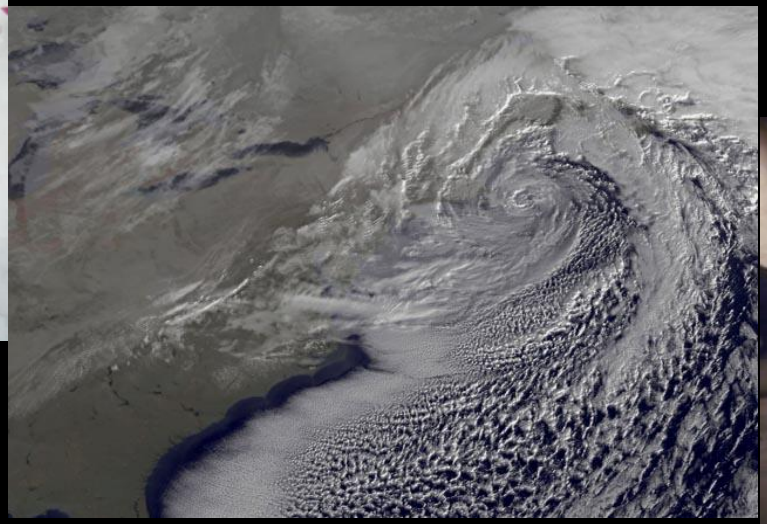
1 Dec 2009–28 Feb 2010



Negative AO regime

“Snow causes travel chaos in the UK, as the cold snap continues”
December 2010



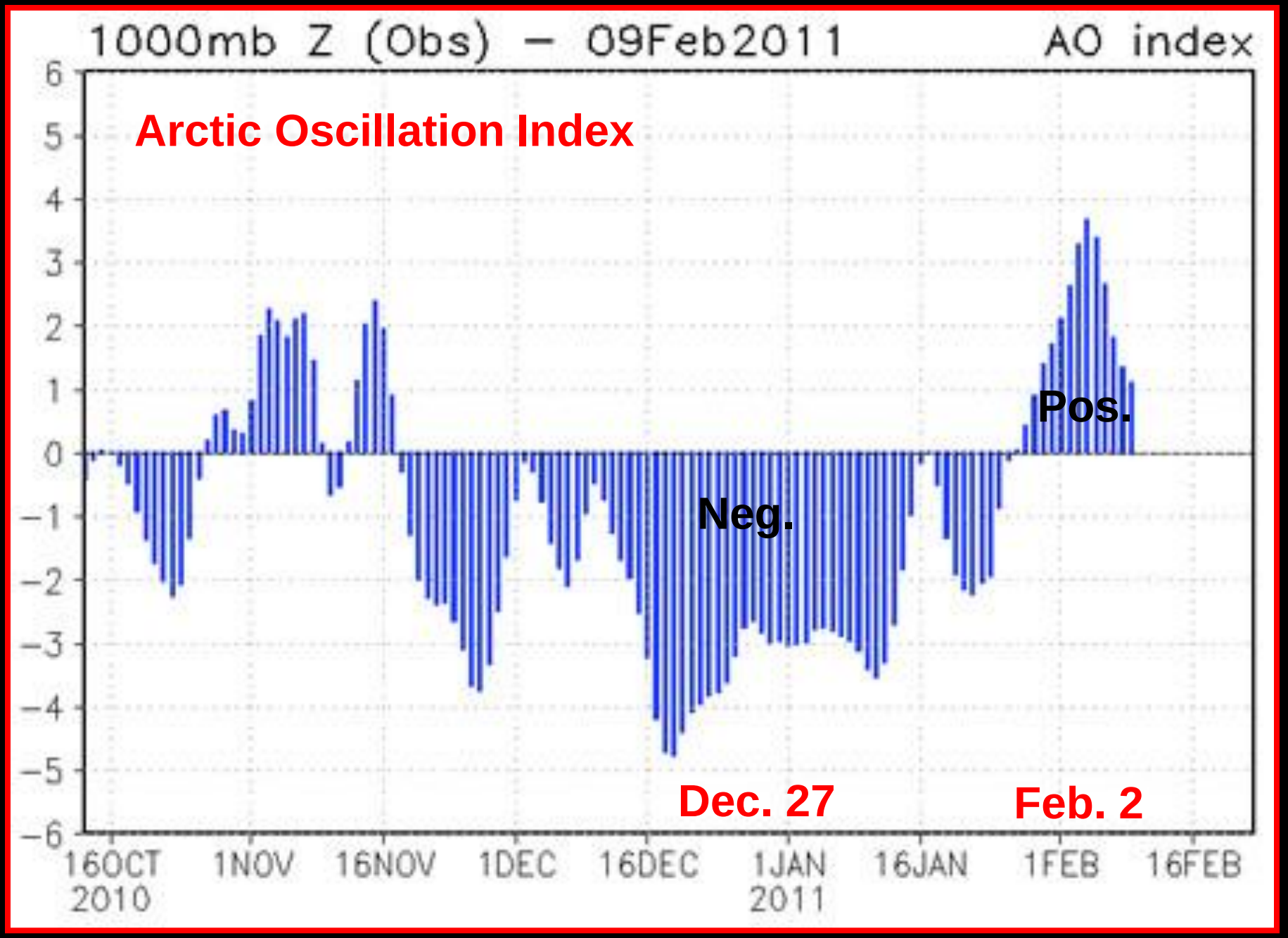


26-27 December 2010

Northeastern US

Snow storm

2-3 February 2011
New England Snow Storm


1000mb Z (Obs) – 09Feb2011
AO index
Arctic Oscillation Index
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
−6
Pos.
Neg.
Dec. 27
Feb. 2
16OCT
2010
1NOV
16NOV
1DEC
16DEC
1JAN
2011
16JAN
1FEB
16FEB

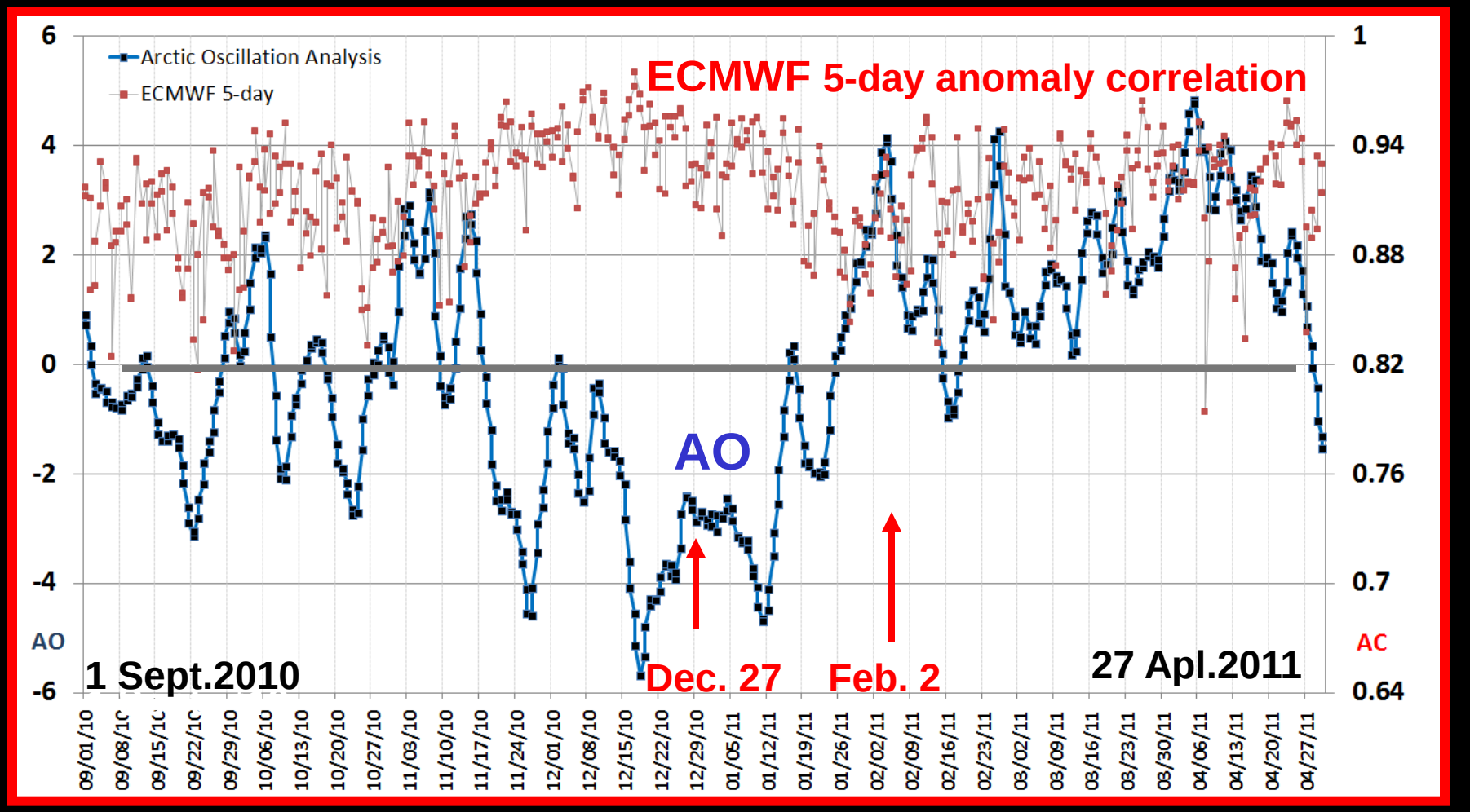
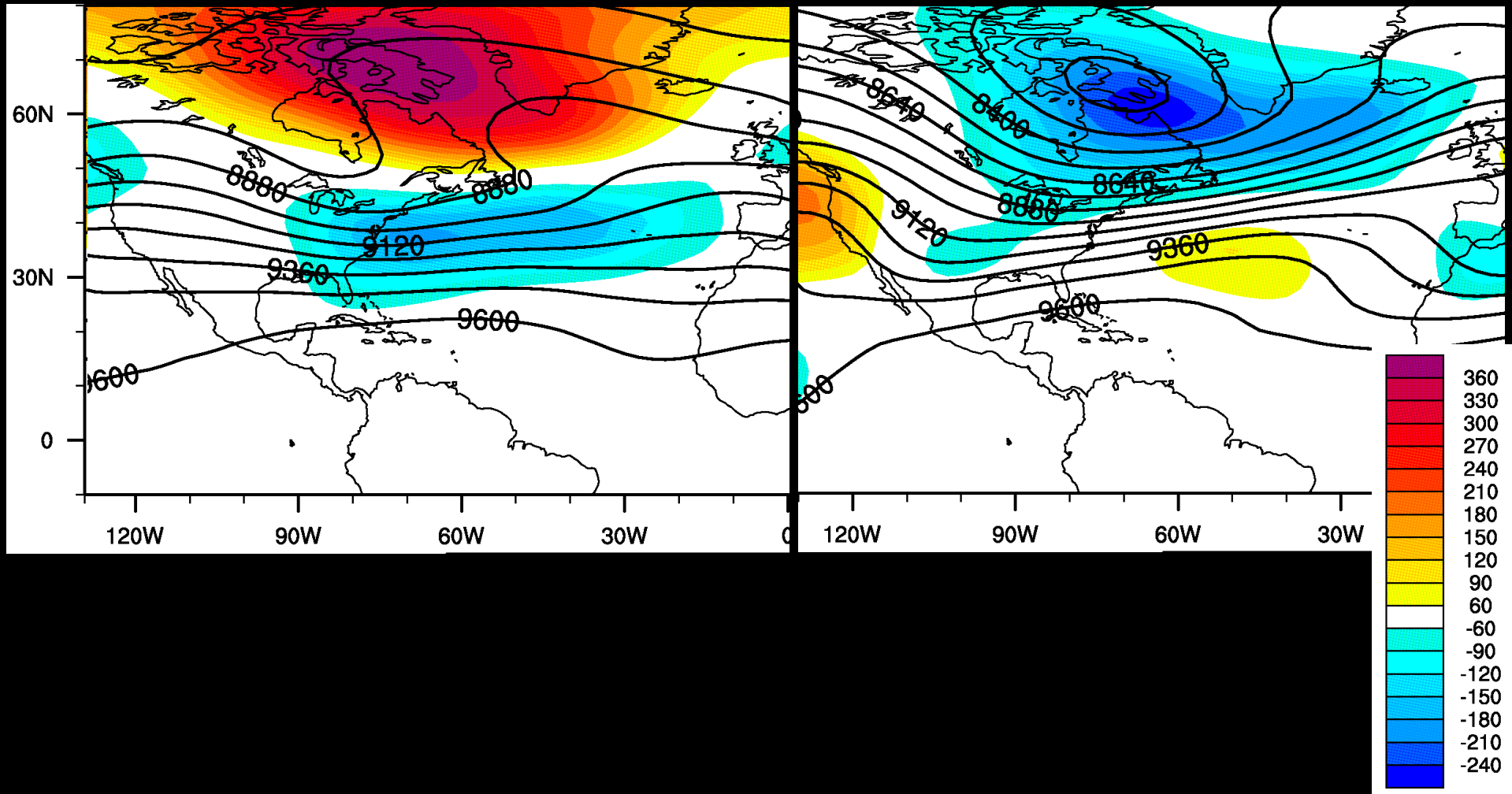


Figure 1: **Arctic Oscillation (AO)** and **ECMWF** **5-day anomaly correlation** of 500hPa height in the northern hemisphere (20°N-80°N), from 1 Sept 2010 to 27 Apr 2011. Note the period of high skill from mid-November to mid-January associated with negative AO phase. Forecast dropouts (low skill) occur during periods with positive AO phase and transitions between positive and negative AO phase; **Langland and Maue, NRLMRY**

North Atlantic 300-mb Height Mean and Anomaly (m)

11 Dec 2010–15 Jan 2011 (AO−)

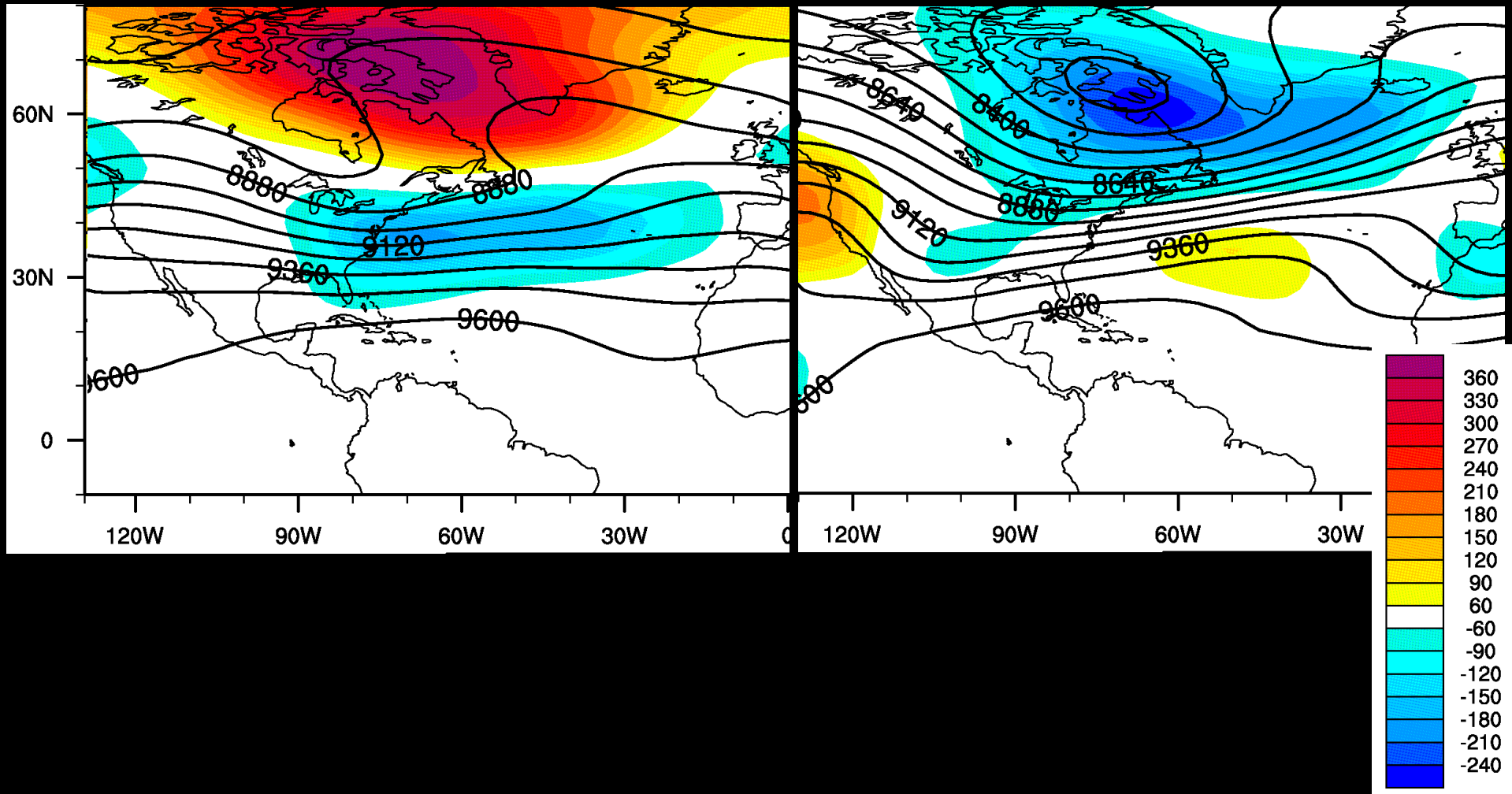
28 Jan–14 Feb 2011 (AO+)



North Atlantic 300-mb Height Mean and Anomaly (m)

11 Dec 2010–15 Jan 2011 (AO−)

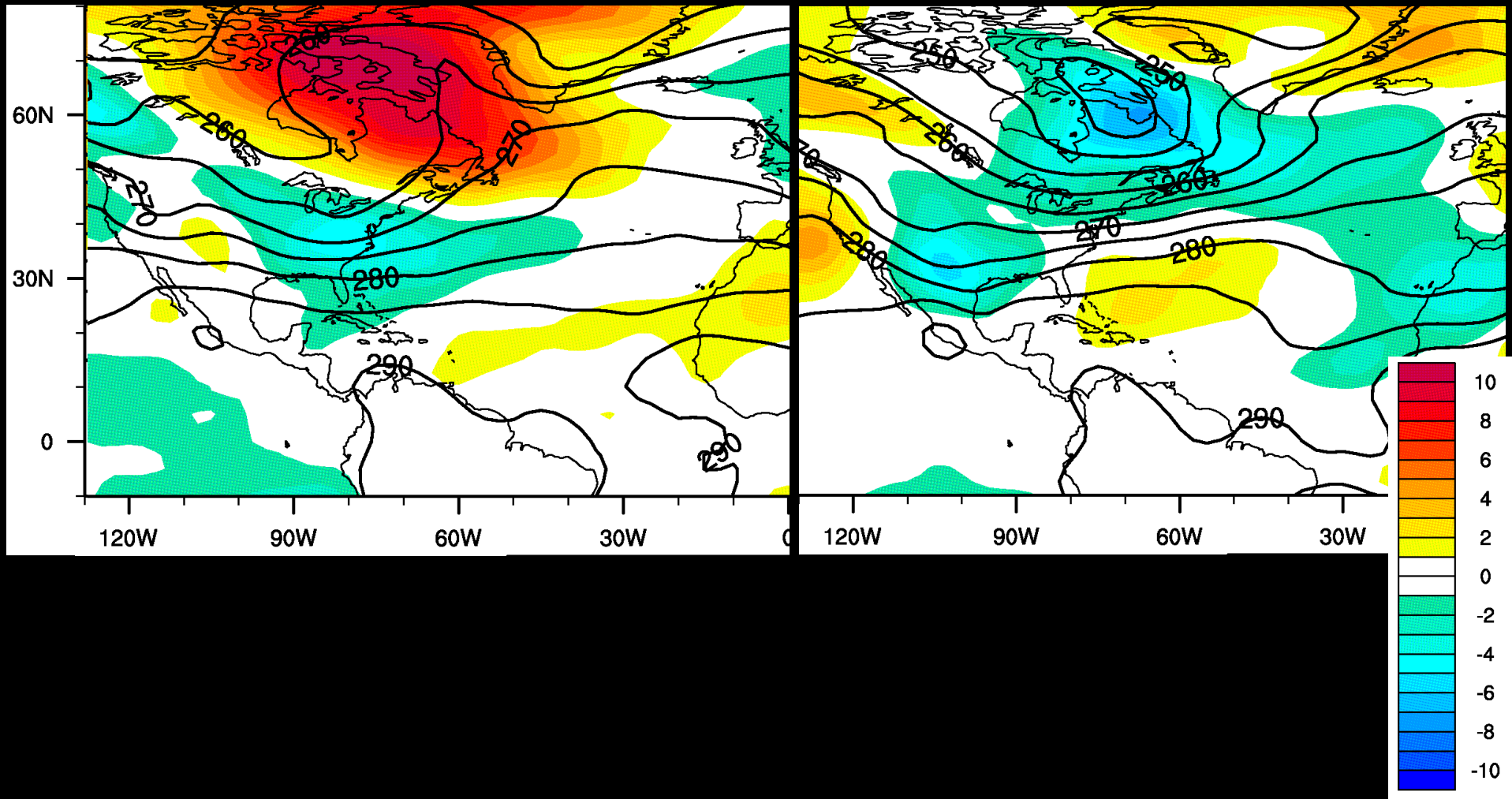
28 Jan–14 Feb 2011 (AO+)



North Atlantic 850-mb Temperature Mean and Anomaly (K)

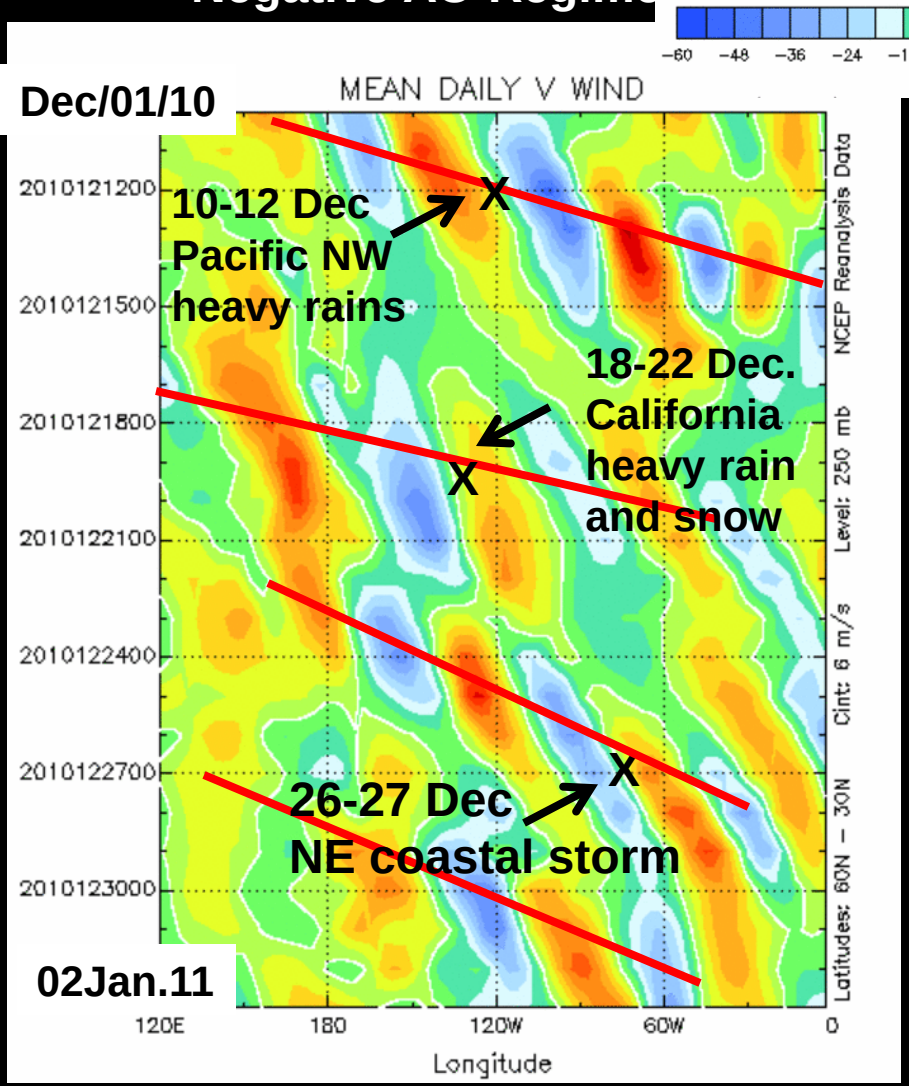
11 Dec 2010–15 Jan 2011 (AO−)

28 Jan–14 Feb 2011 (AO+)



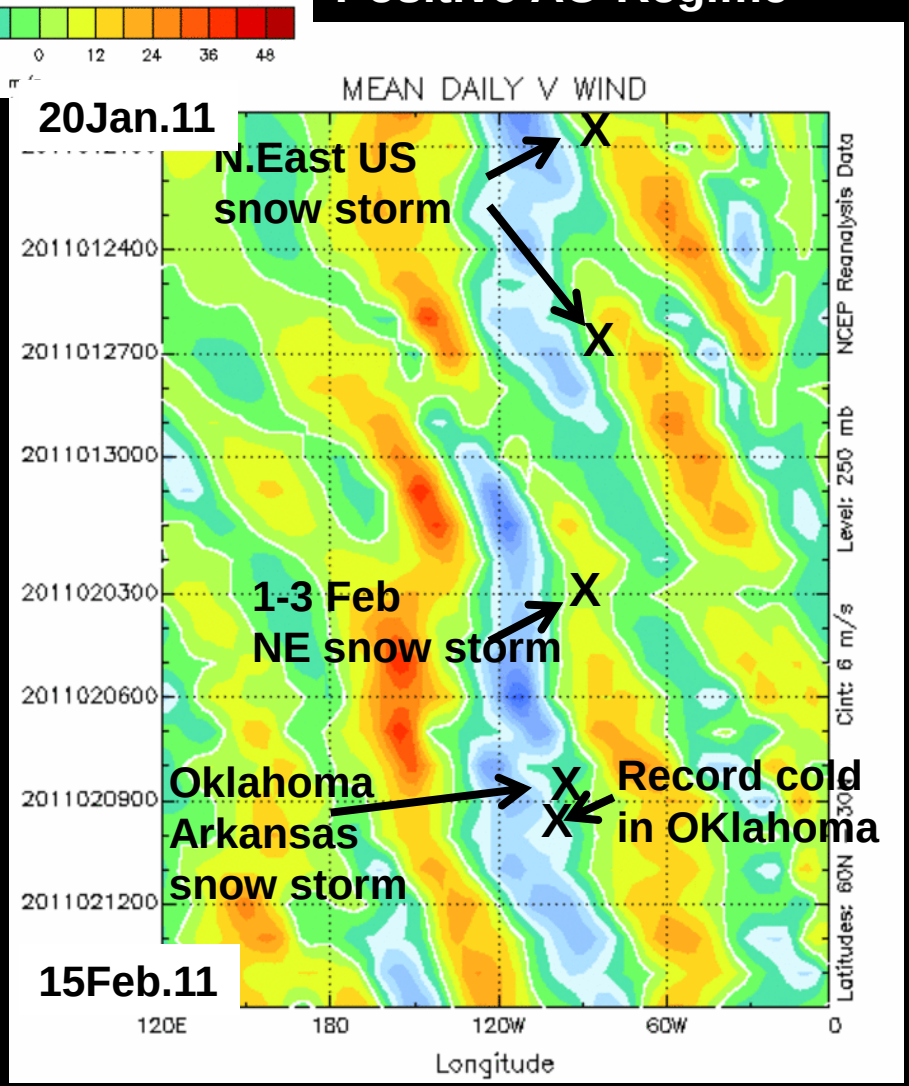
250-hPa Meridional Wind Component (lat avg 30–60˚ N.)

Negative AO Regime



Transient “wave packets” associated with high-impact weather

Positive AO Regime

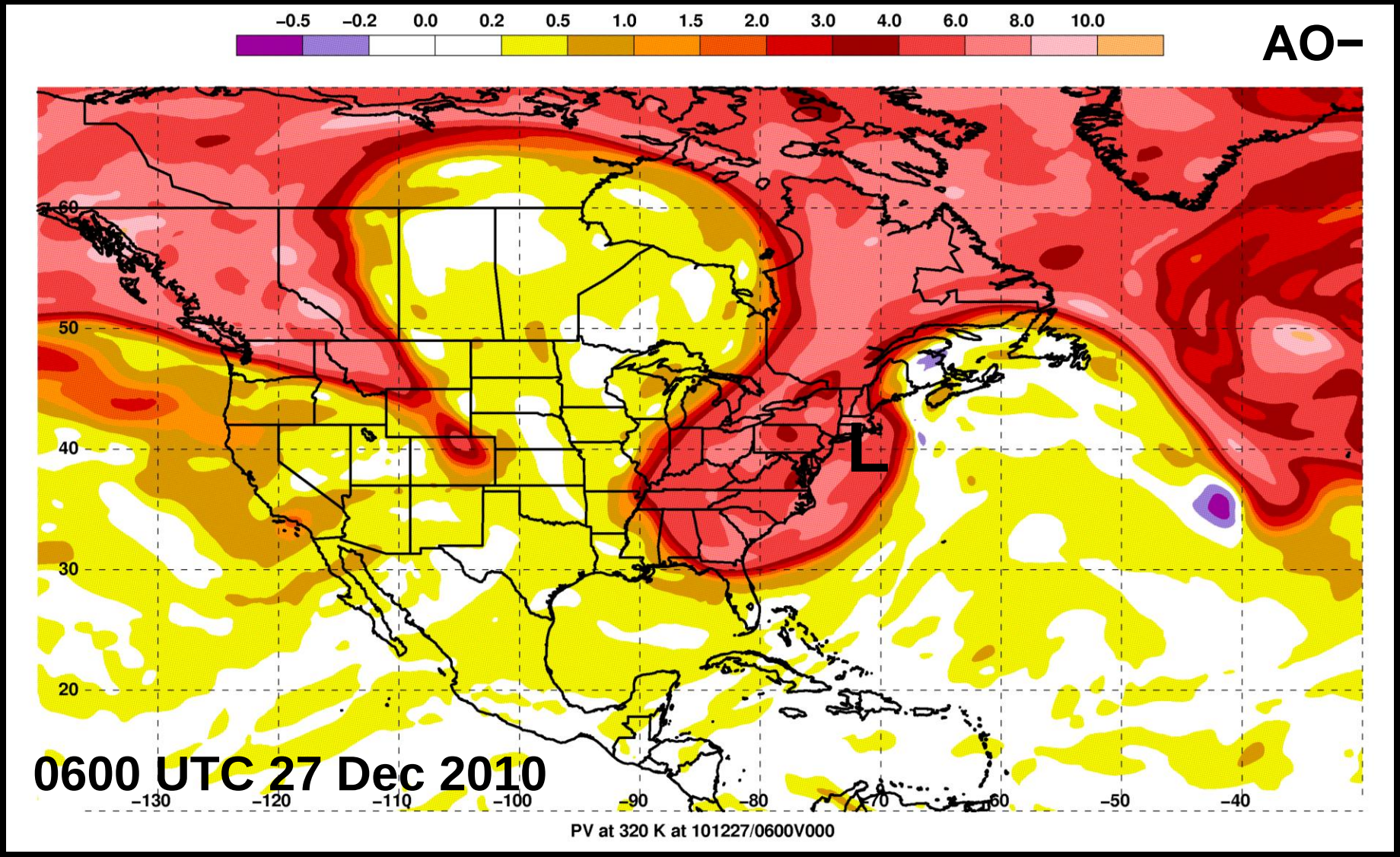


Persistent blocking pattern associated with high-impact weather

Hovmoller diagrams were computed using the NOAA/ESRL Physical Sciences Division Interactive Plotting and Analysis website

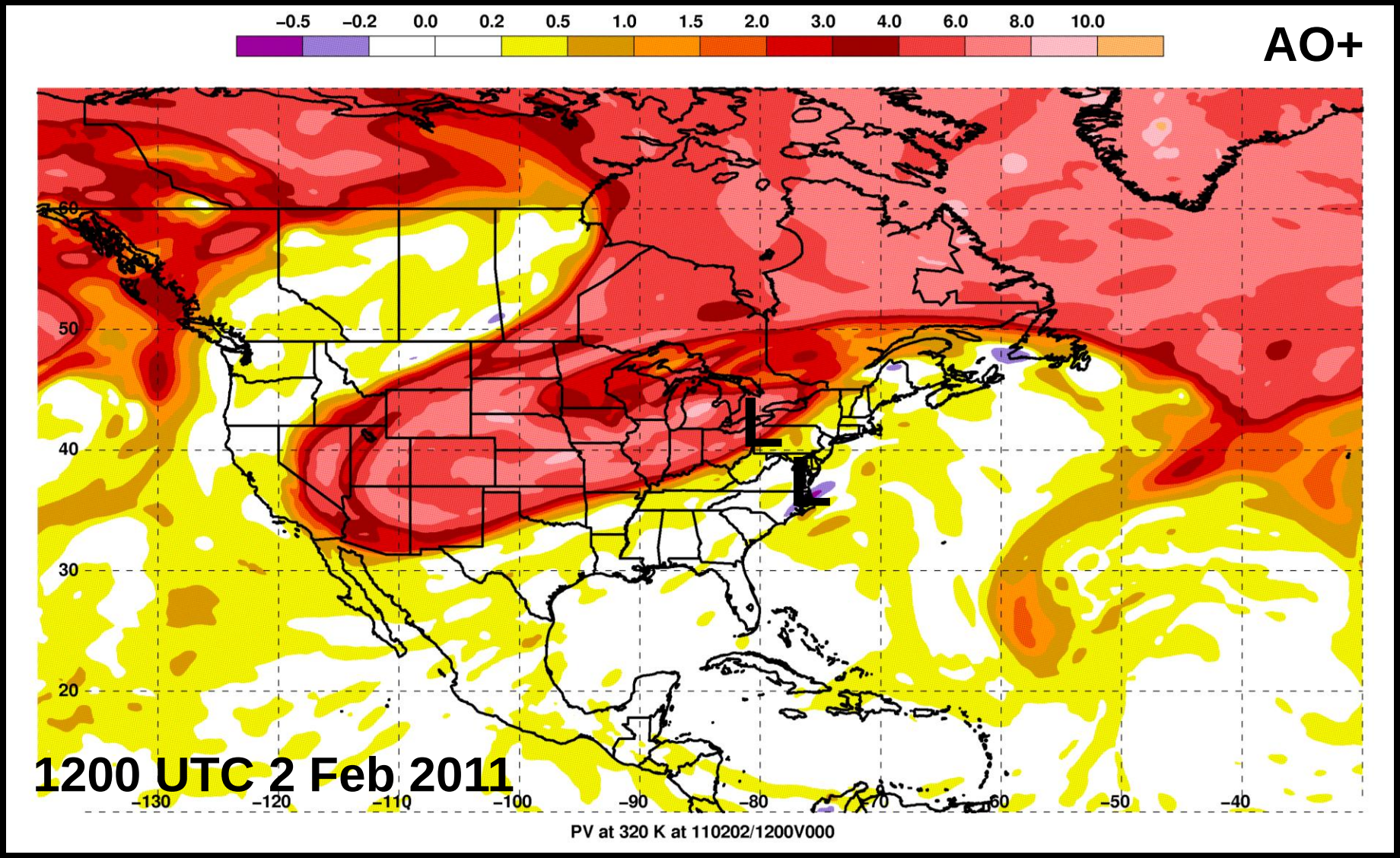
PV on 320 K Surface

Negative Phase AO



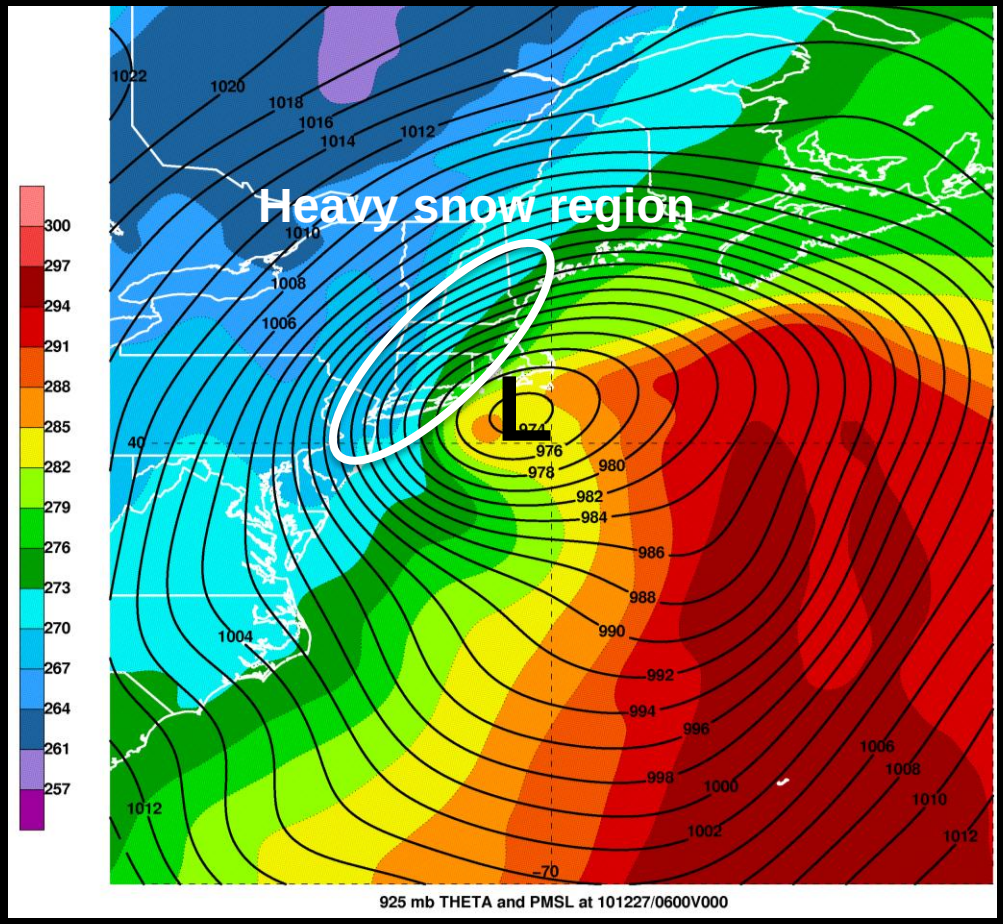
PV on 320 K Surface

Positive Phase AO



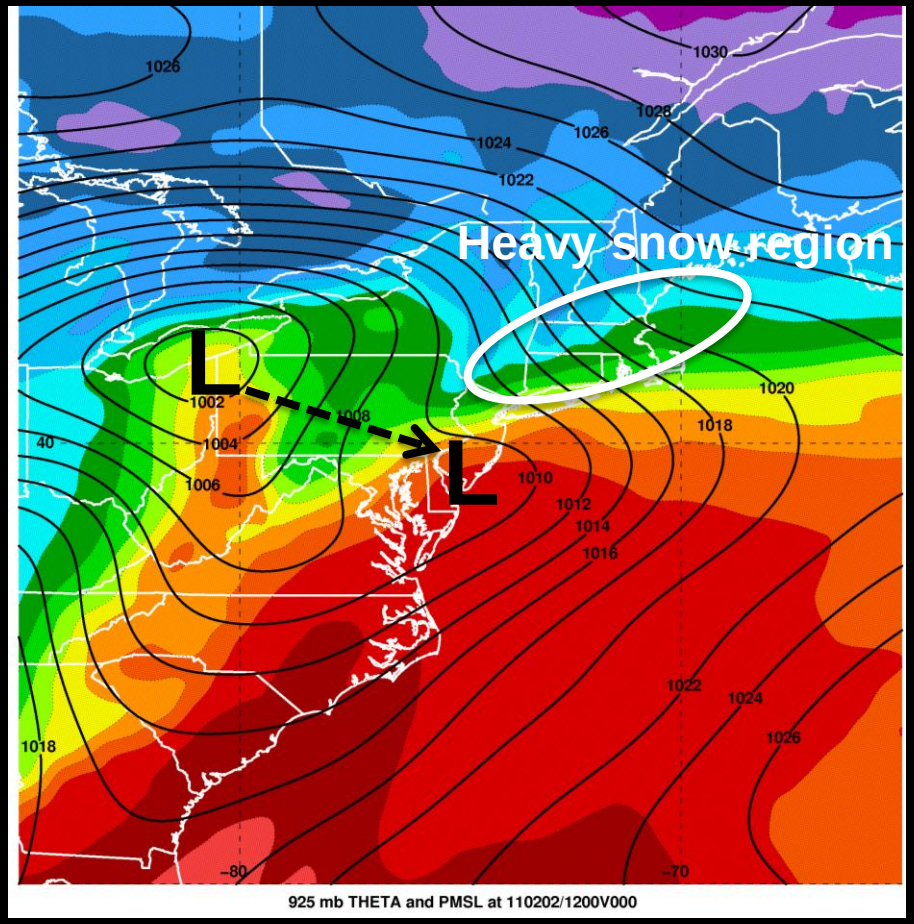
925-mb θ (K) and MSLP (mb)

0600 UTC 27 Dec 2010



Negative AO Phase

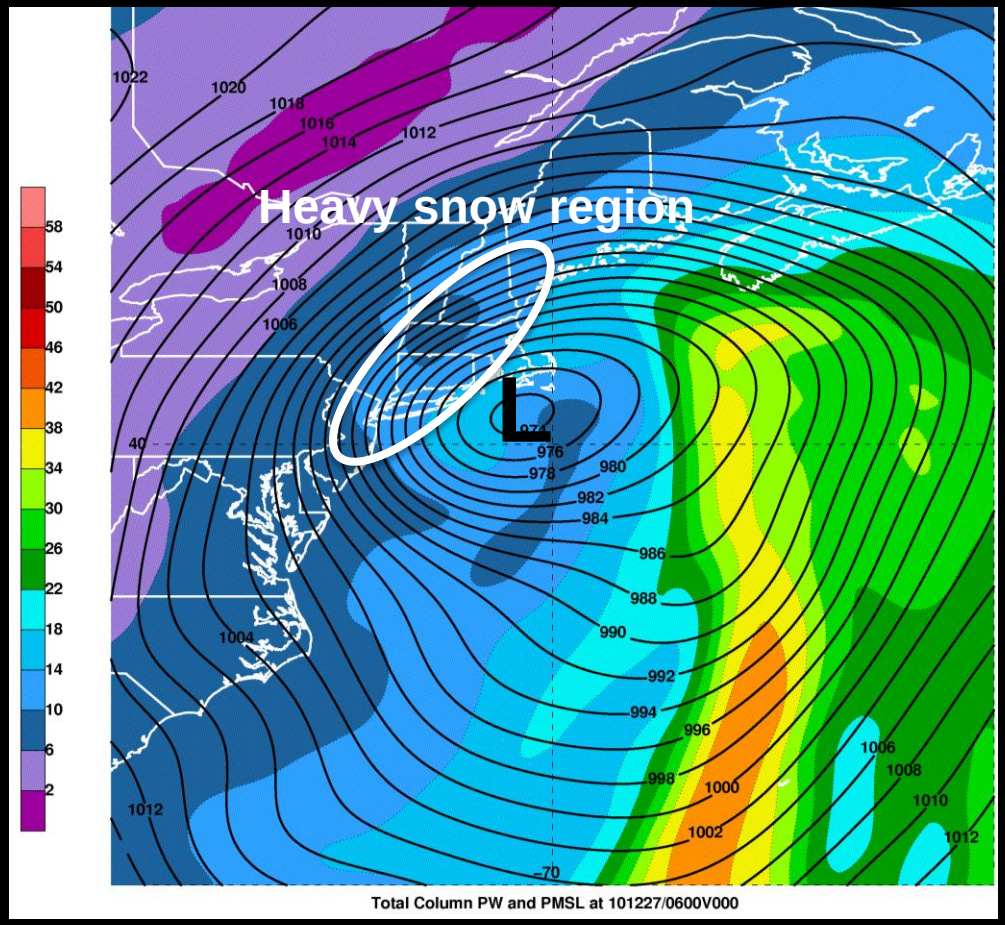
1200 UTC 2 Feb 2011



Positive AO Phase

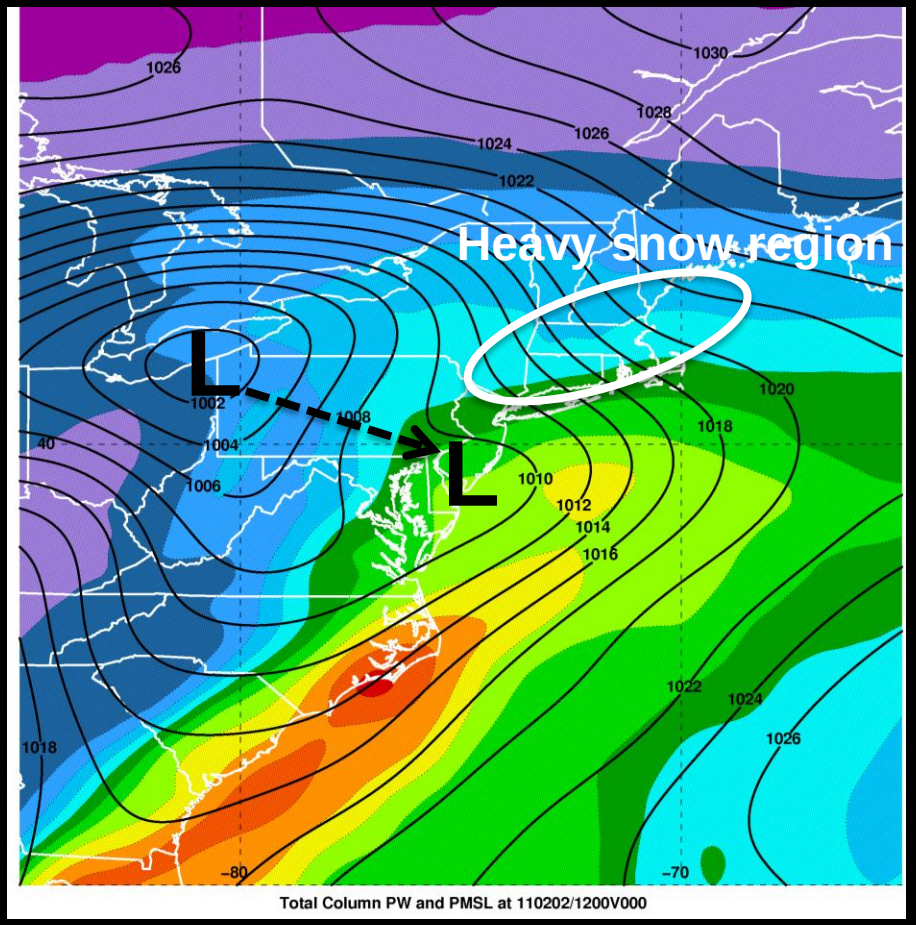
Precipitable Water (mm) and MSLP (mb)

0600 UTC 27 Dec 2010



Negative AO Phase

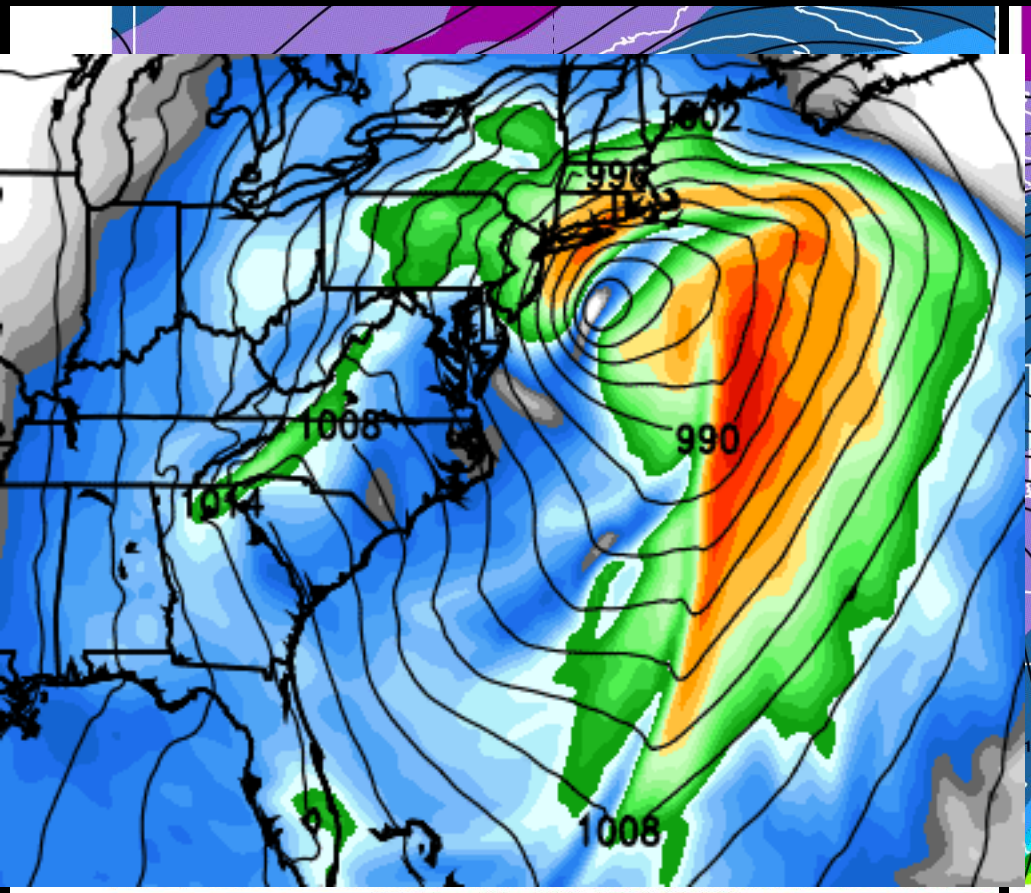
1200 UTC 2 Feb 2011



Positive AO Phase

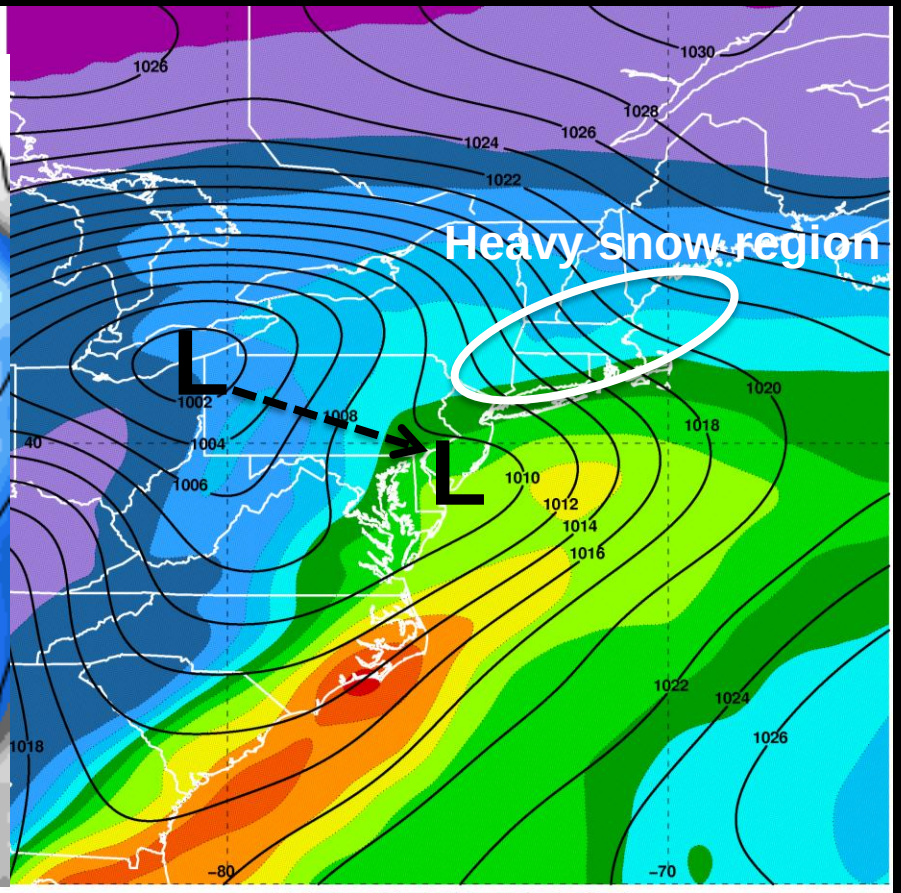
Precipitable Water (mm) and MSLP (mb)

0600 UTC 27 Dec 2010



Negative AO Phase

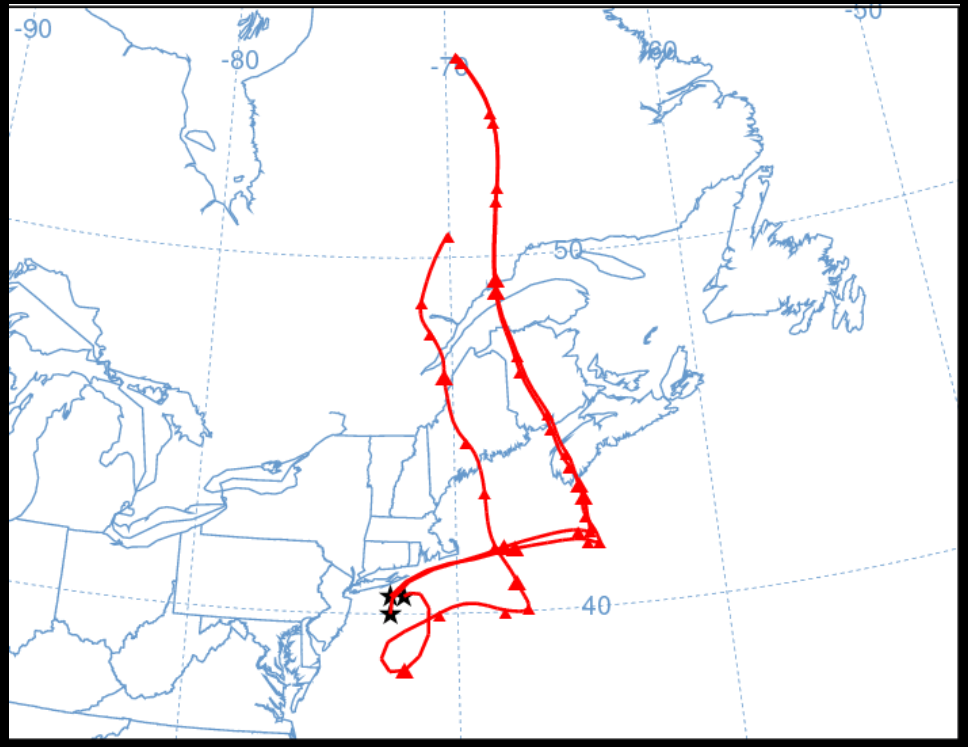
1200 UTC 2 Feb 2011



Positive AO Phase

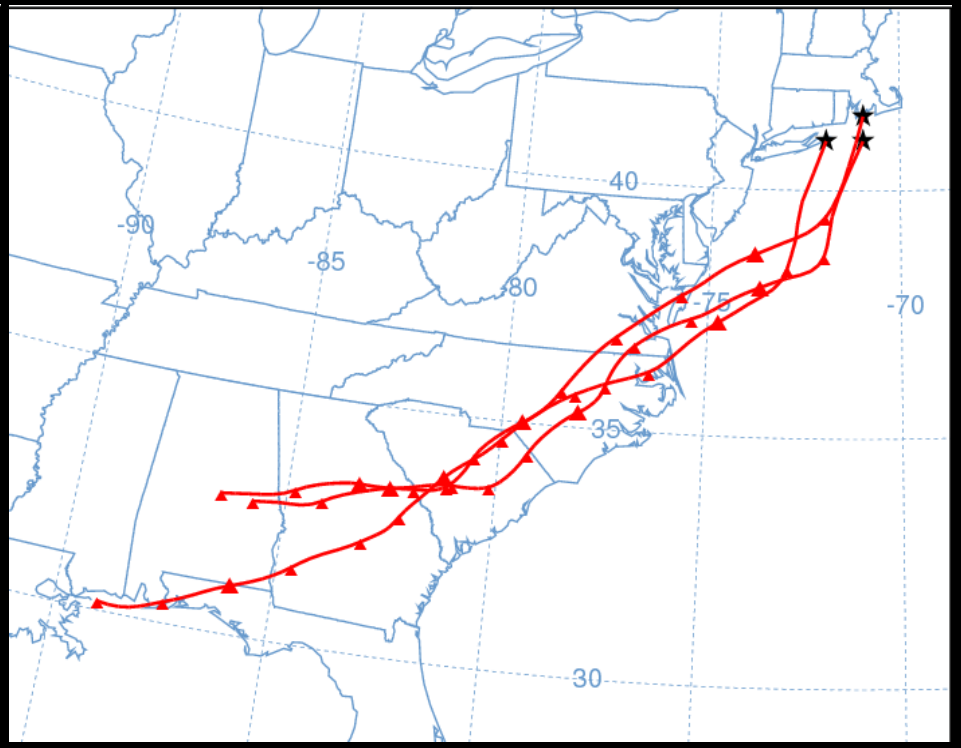
72-h Backward trajectories starting at 1500 m. MSL

Starting at 0600 UTC 27 Dec 2010

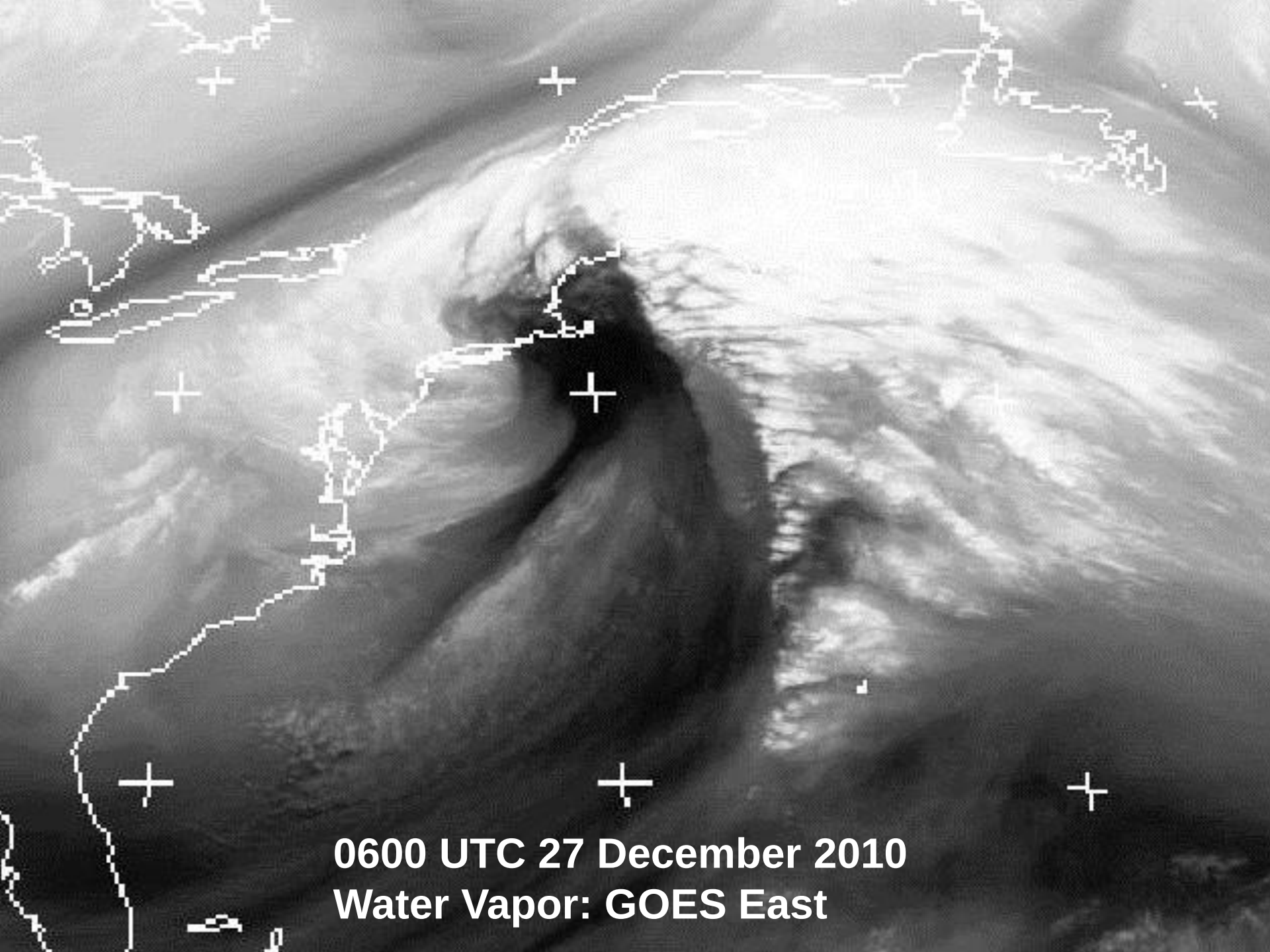


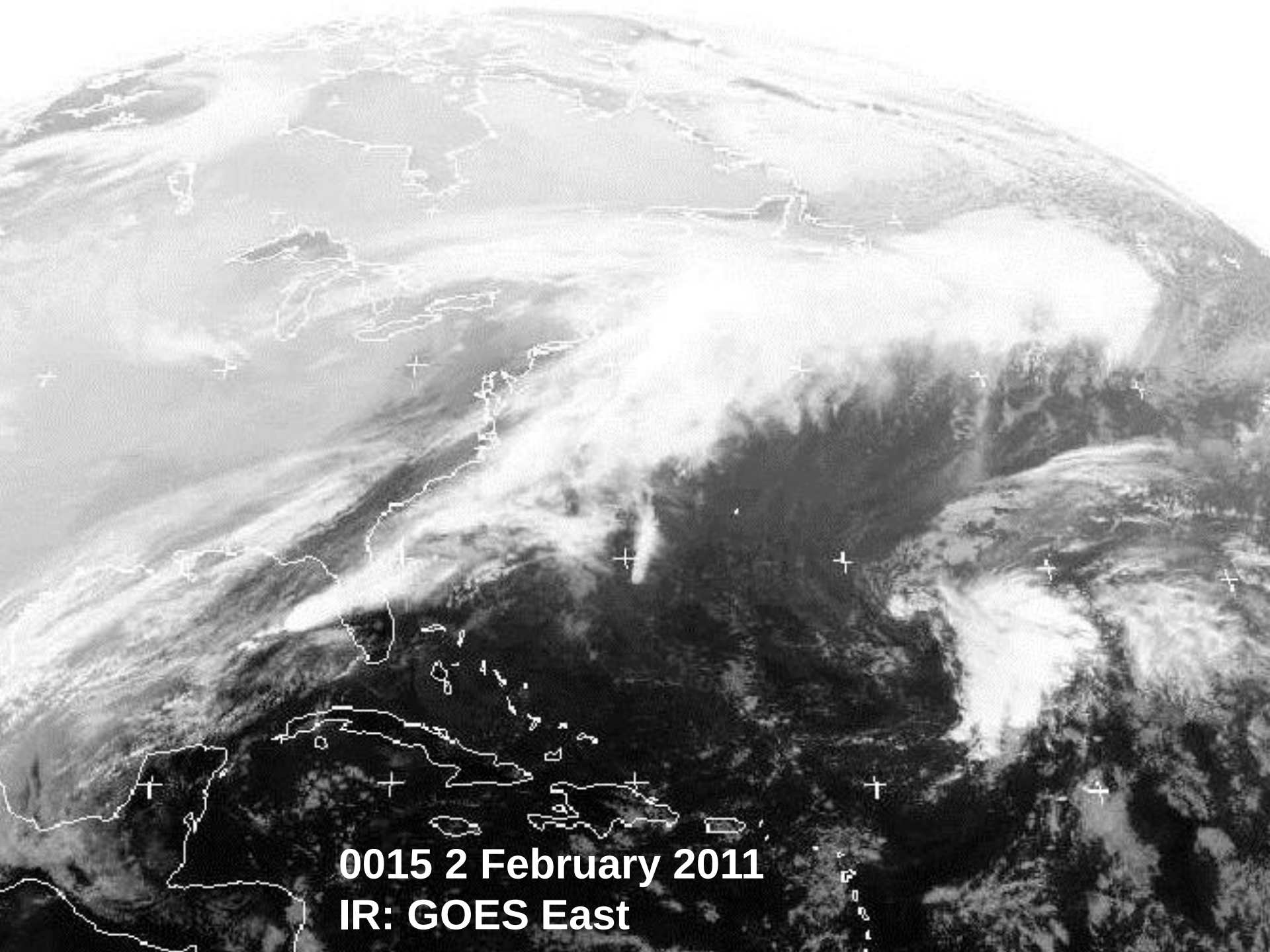
- LC2 during negative AO phase
- Air parcels near heavy snow region originate well north of warm front

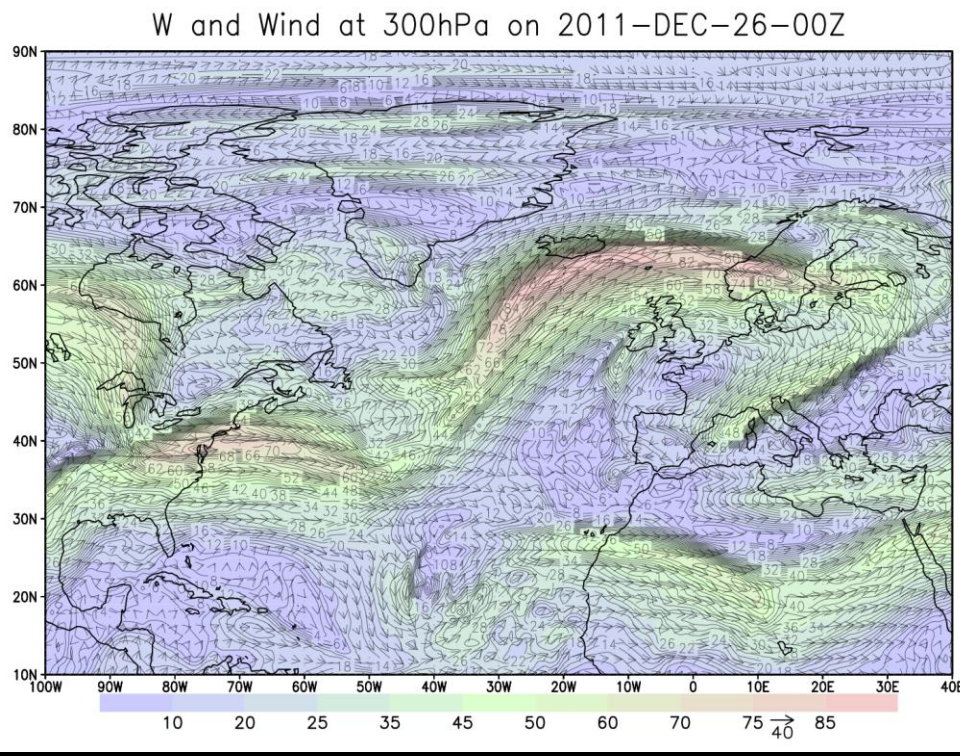
Starting at 1200 UTC 2 Feb 2011

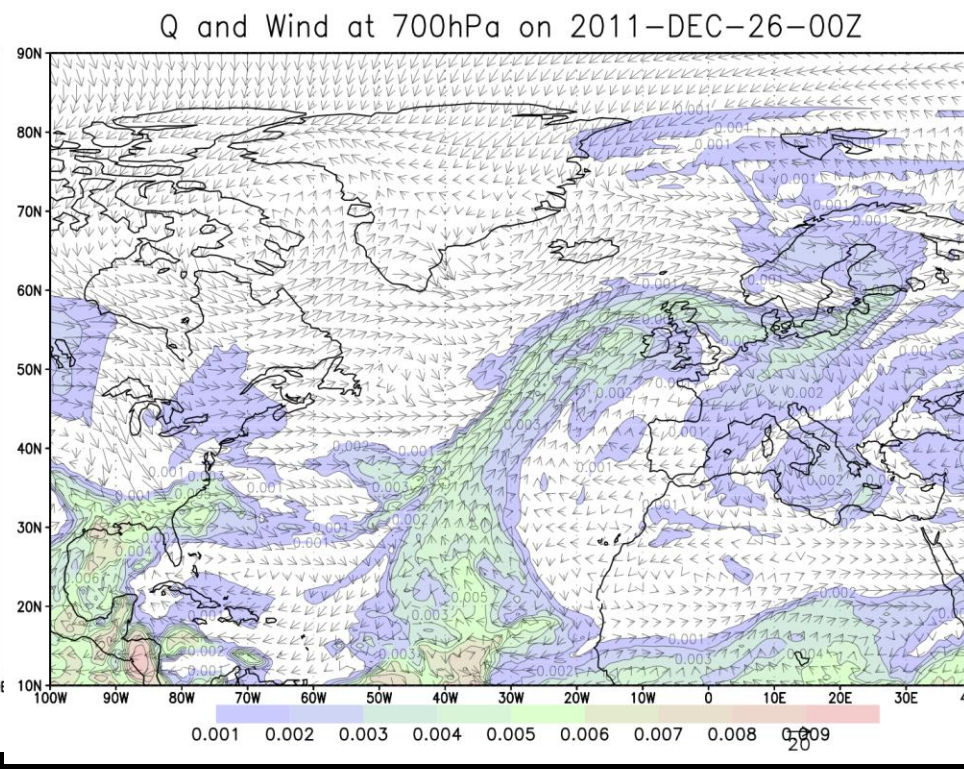


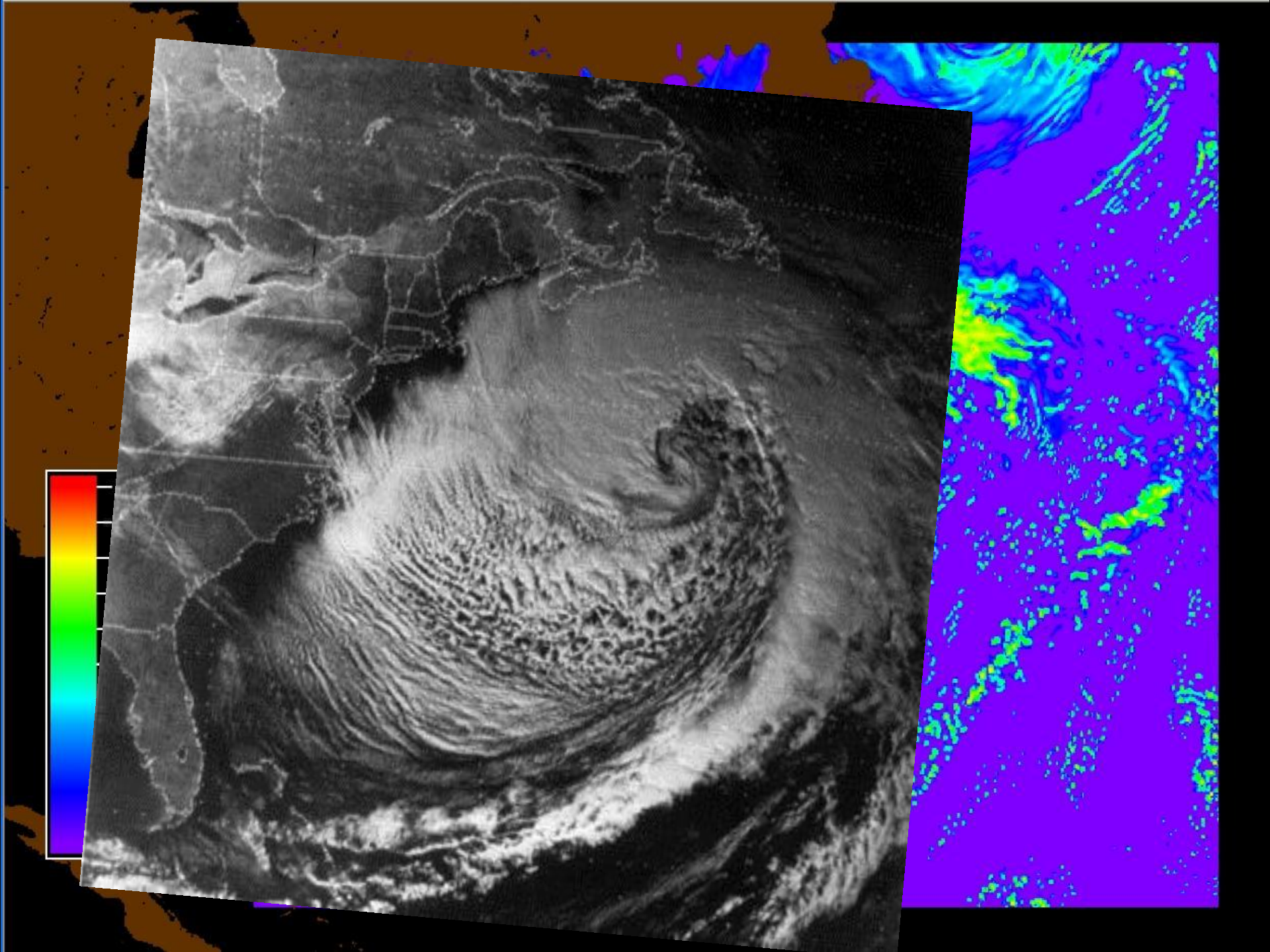
- LC1 during positive AO phase
- Air parcels near heavy snow region originate in cyclone warm sector
- Direct tropical moisture feed


0600 UTC 27 December 2010
Water Vapor: GOES East

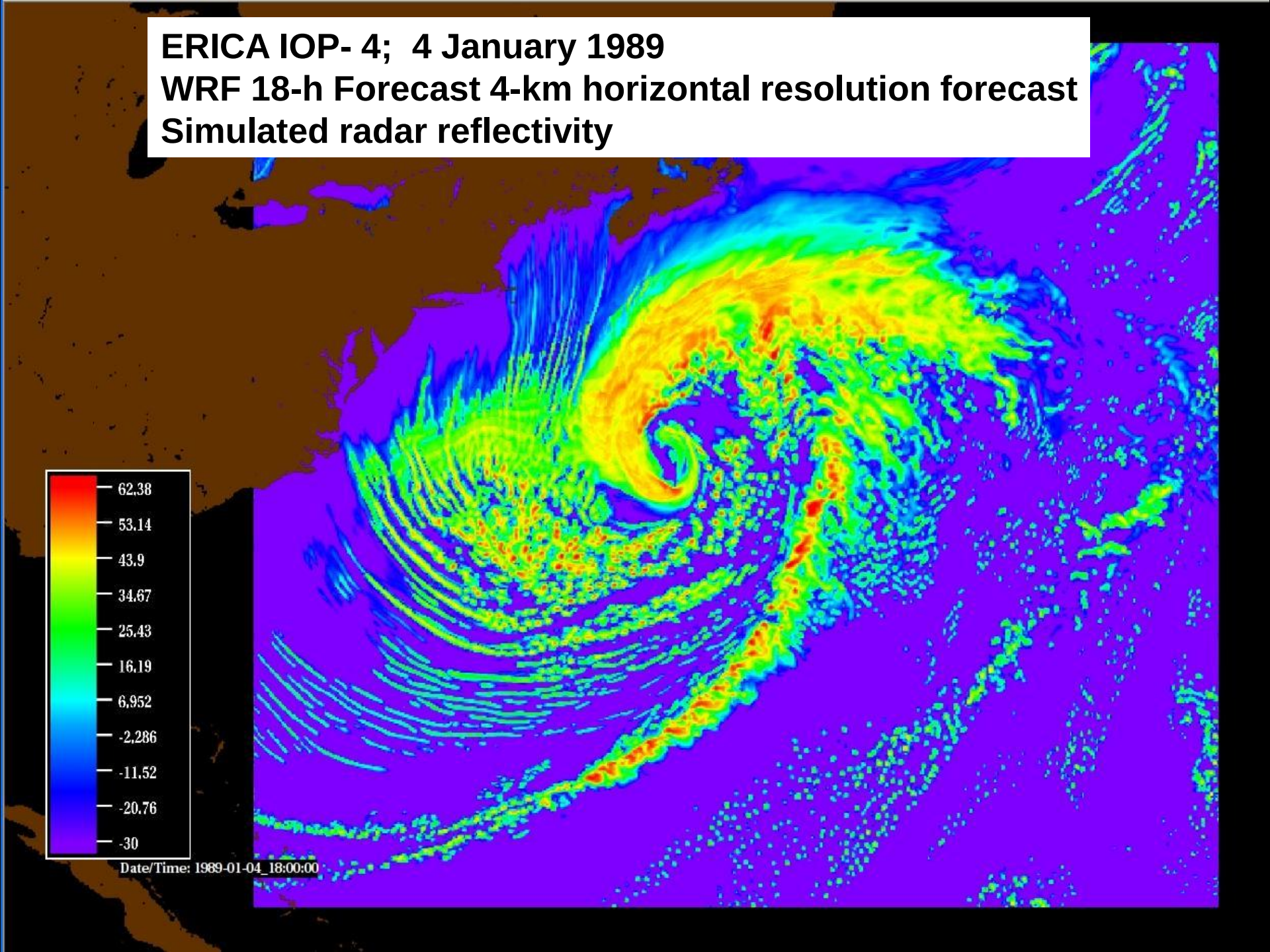

0015 2 February 2011
IR: GOES East

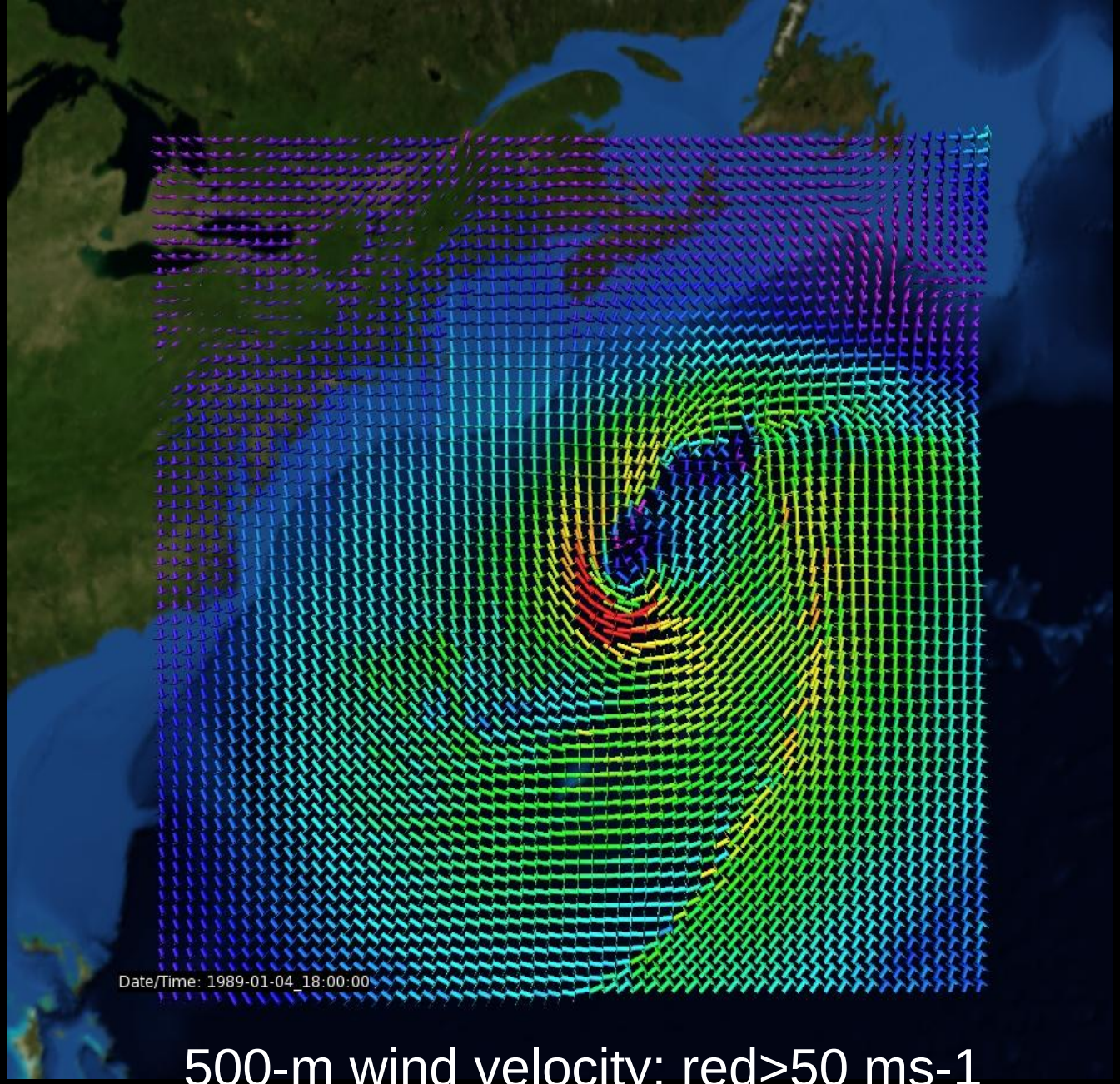

W and Wind at 300hPa on 2011-DEC-26-00Z
90N
80N
70N
60N
50N
40N
30N
20N
10N
100W 90W 80W 70W 60W 50W 40W 30W 20W 10W 0 10E 20E 30E
10 20 25 35 45 50 60 70 75 40 85


Q and Wind at 700hPa on 2011-DEC-26-00Z
90N
80N
70N
60N
50N
40N
30N
20N
10N
100W 90W 80W 70W 60W 50W 40W 30W 20W 10W 0 10E 20E 30E
0.001 0.002 0.003 0.004 0.005 0.006 0.007 0.008 0.009 20

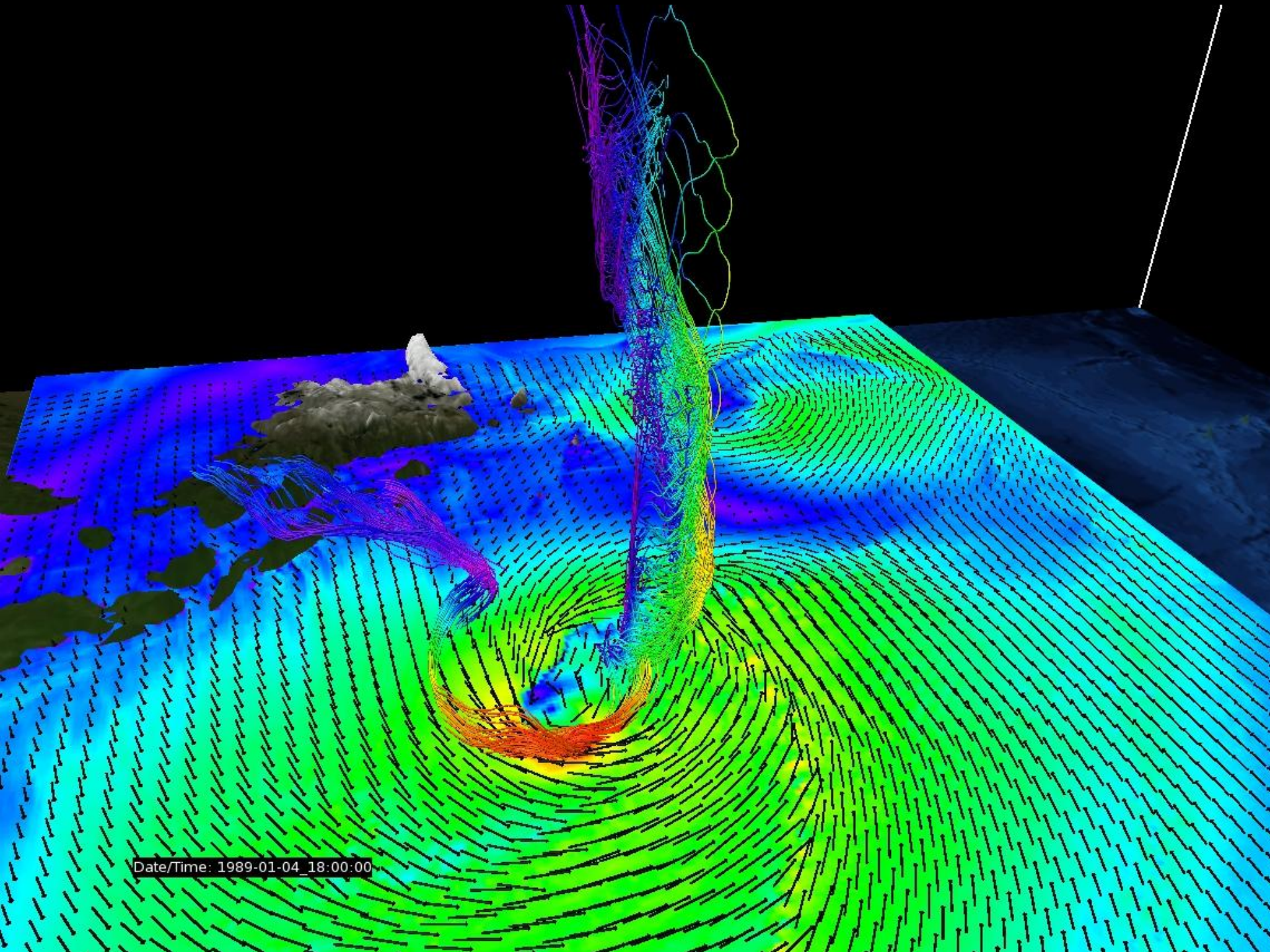


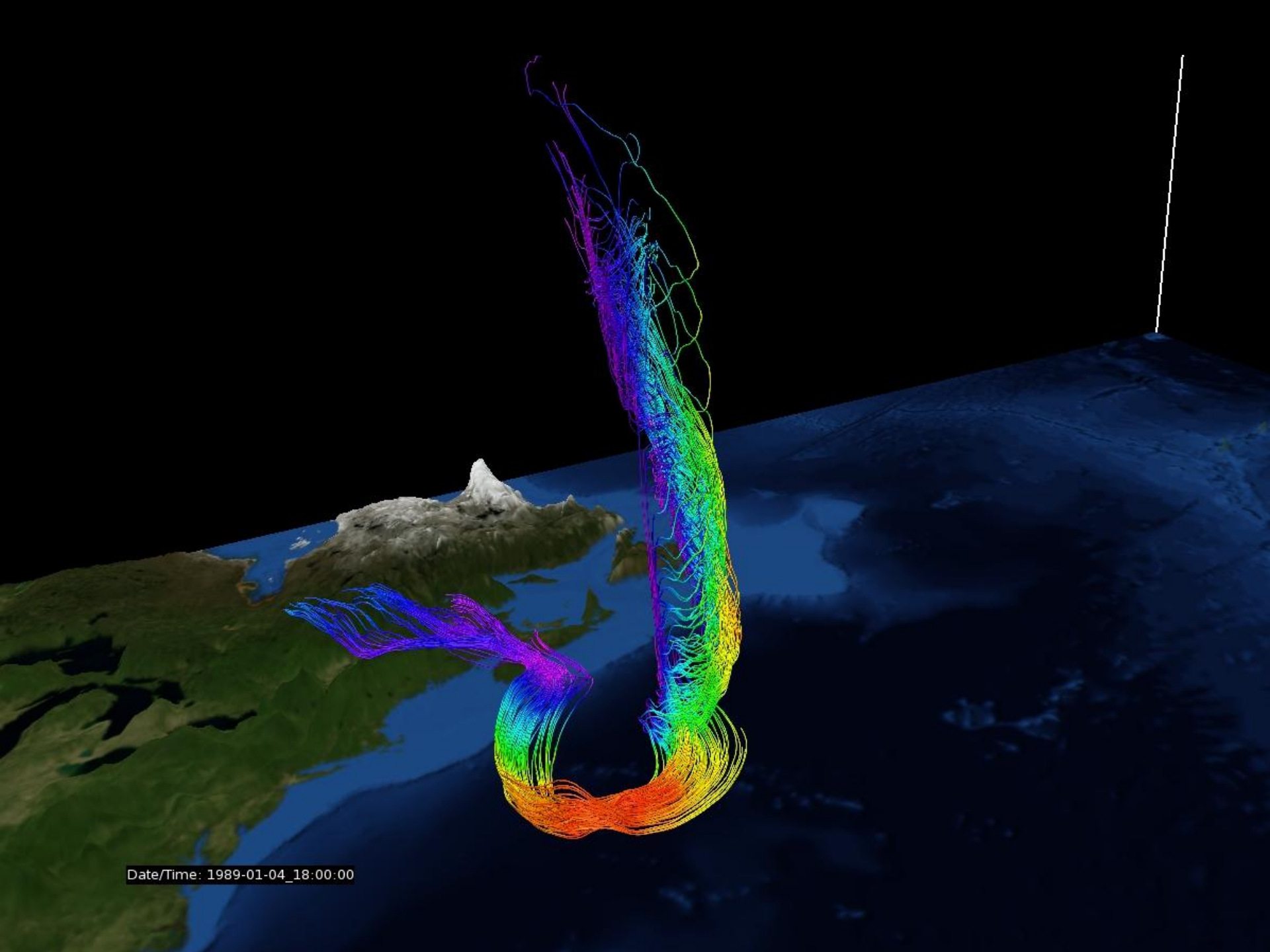
ERICA IOP- 4; 4 January 1989
WRF 18-h Forecast 4-km horizontal resolution forecast
Simulated radar reflectivity

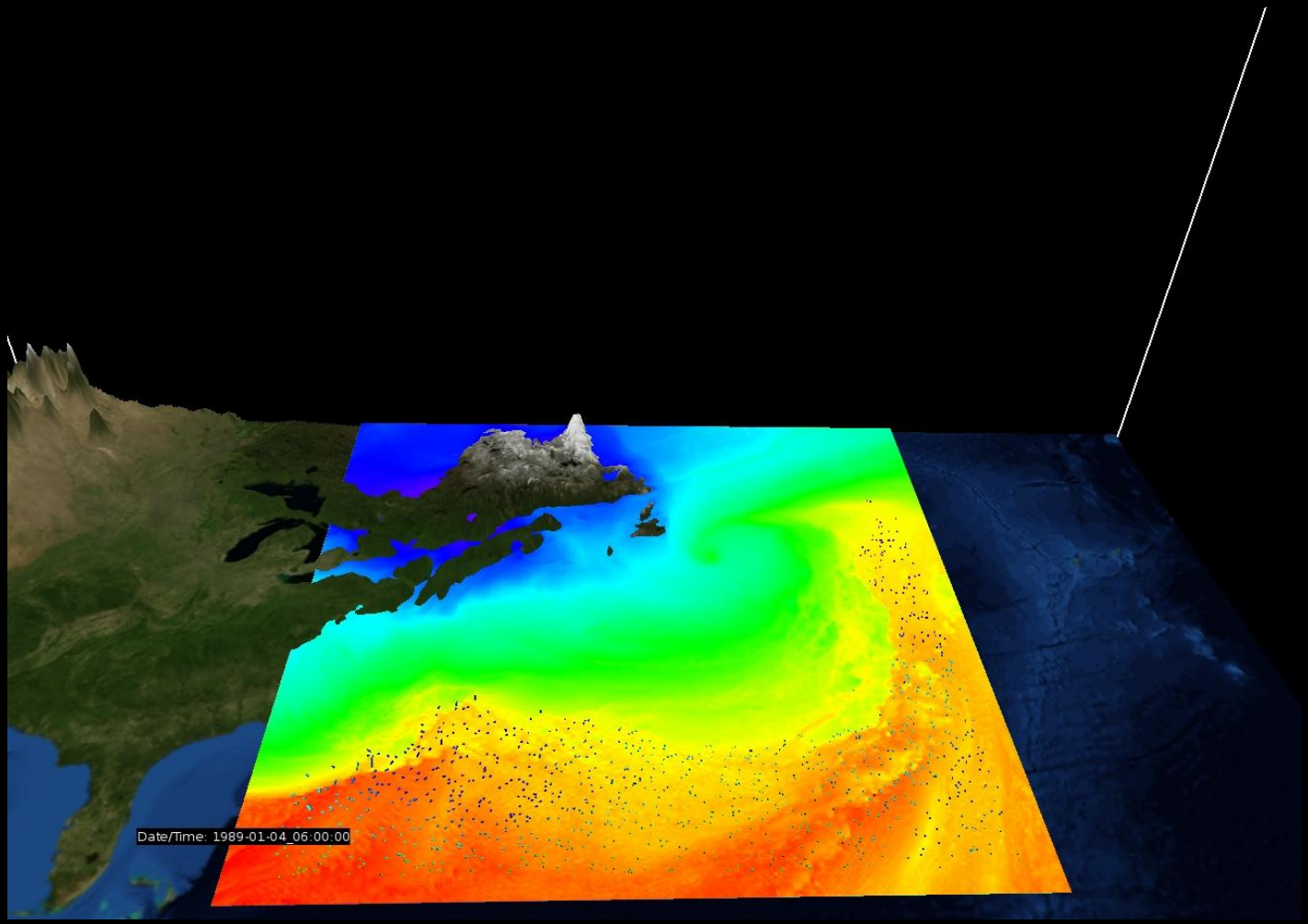


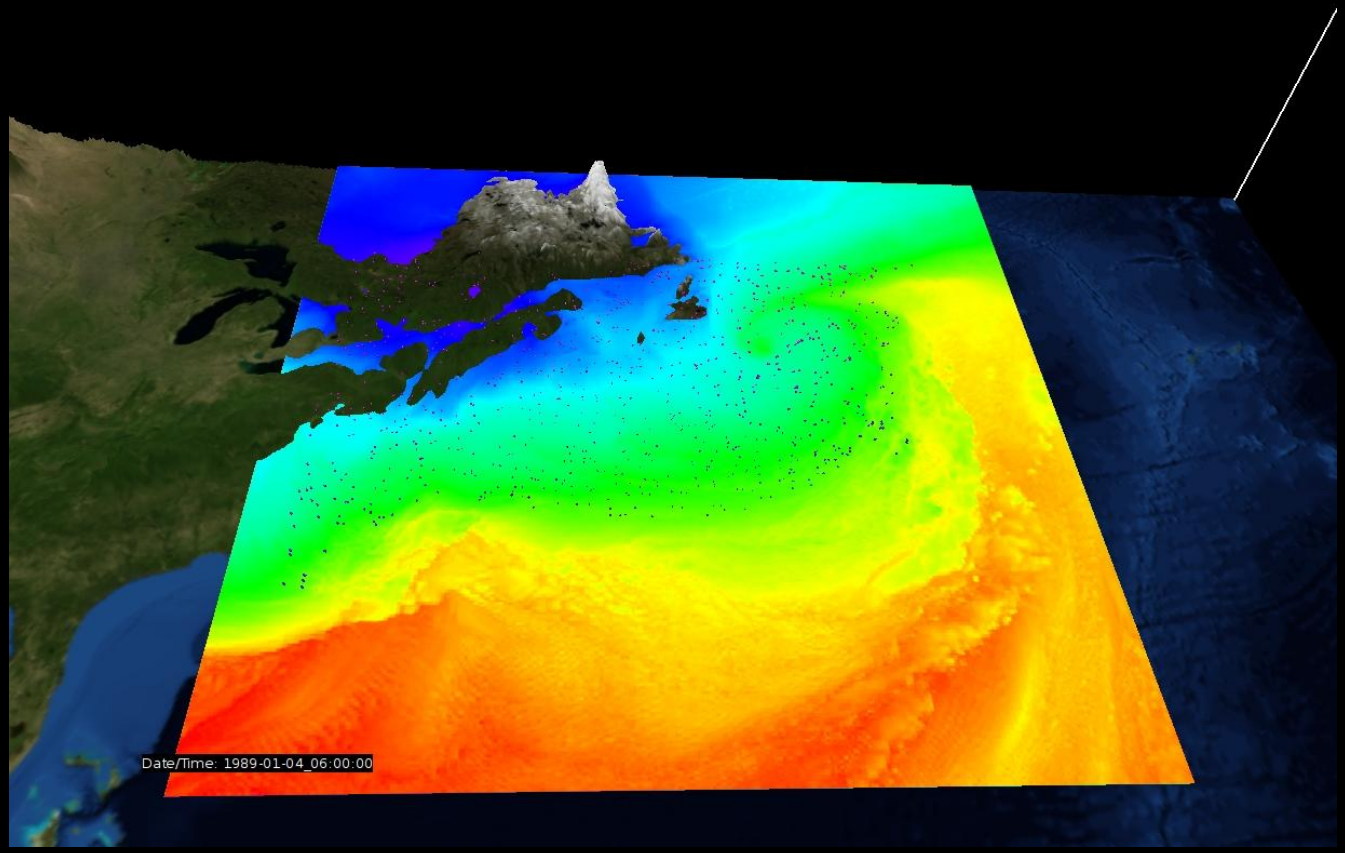


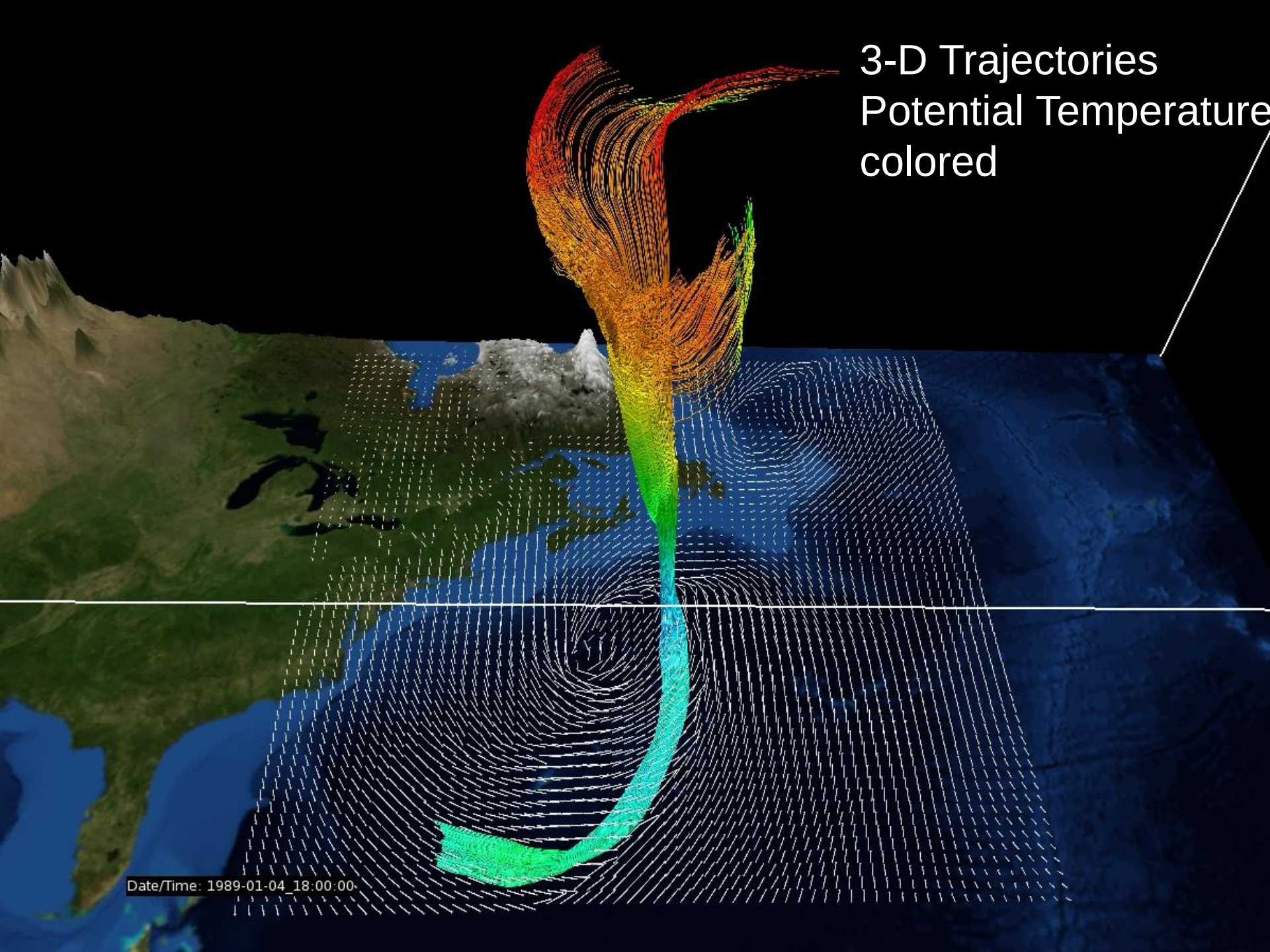
500-m wind velocity; red>50 ms-1

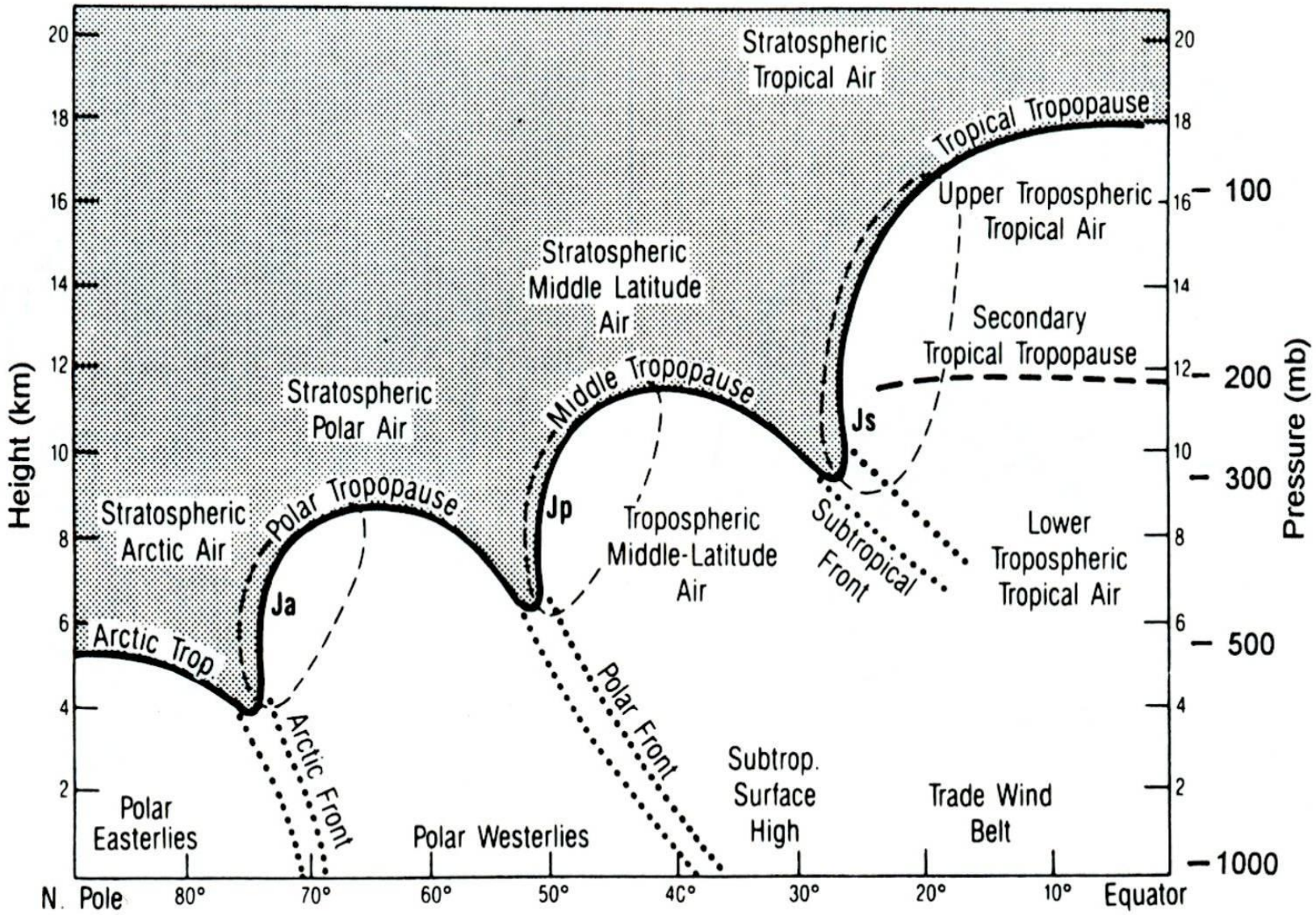

Date/Time: 1989-01-04_18:00:00

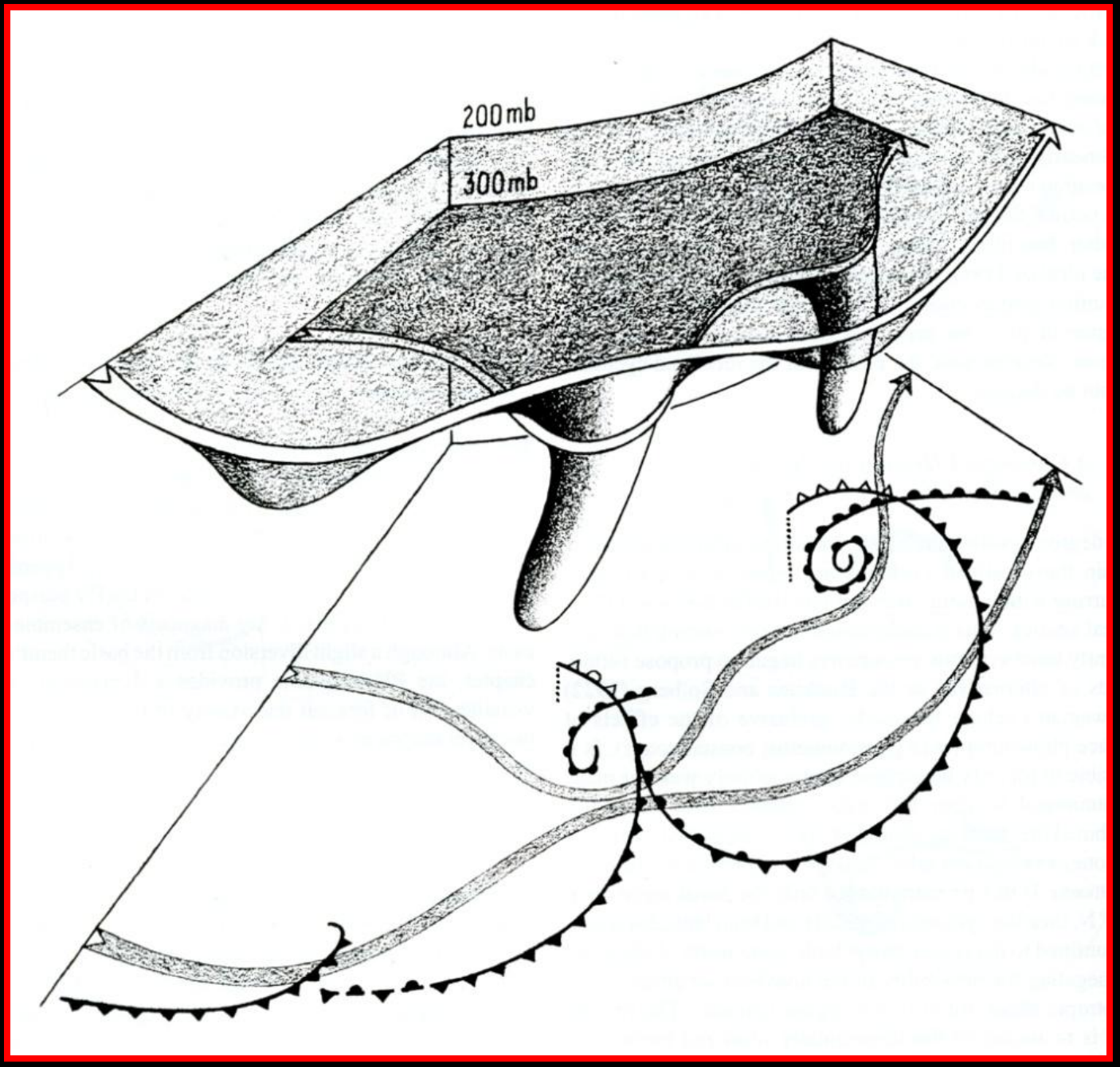

Date/Time: 1989-01-04_18:00:00

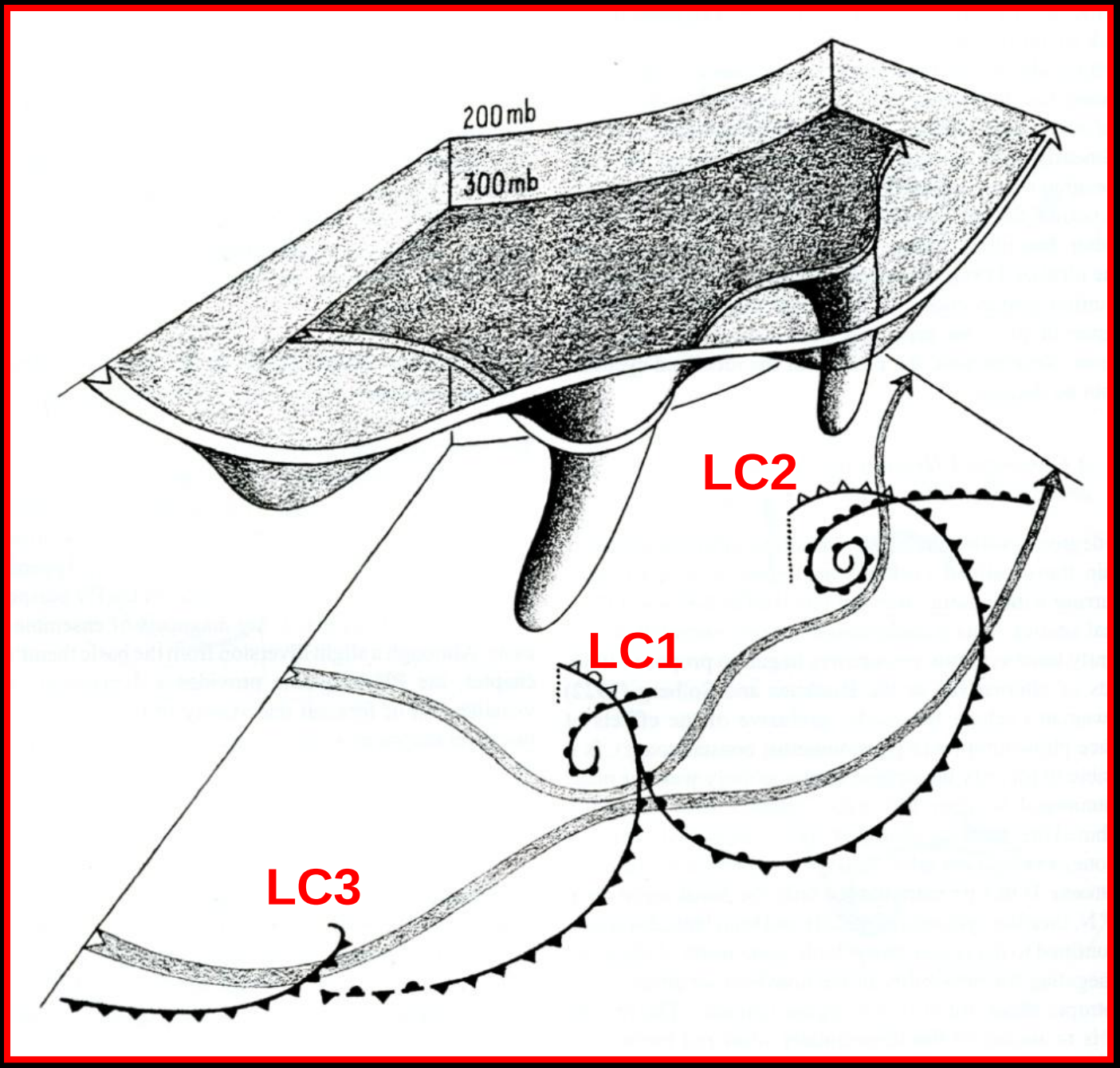

Date/Time: 1989-01-04_06:00:00


Date/Time: 1989-01-04_06:00:00


3-D Trajectories
Potential Temperature
colored
Date/Time: 1989-01-04_18:00:00

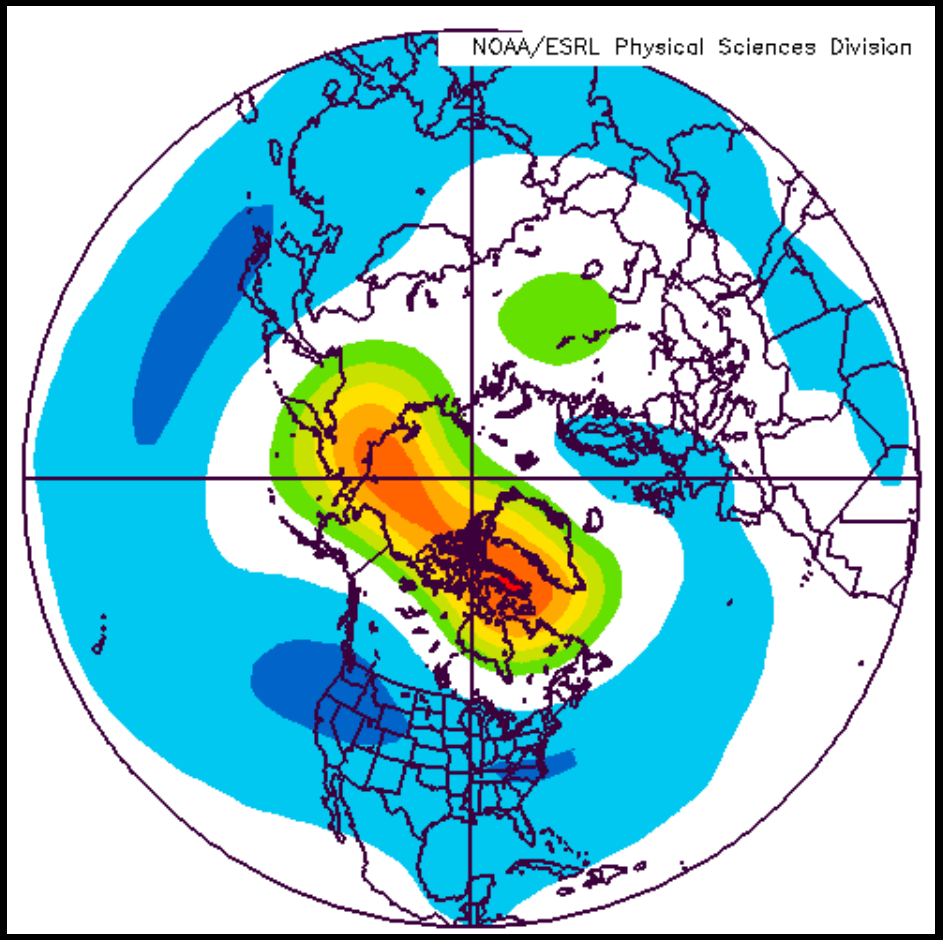

Stratospheric Tropical Air
Tropical Tropopause
Upper Tropospheric Tropical Air
Secondary Tropical Tropopause
Stratospheric Middle Latitude Air
Middle Tropopause
Stratospheric Polar Air
Polar Tropopause
Stratospheric Arctic Air
Arctic Trop
Ja
Jp
Js
Tropospheric Middle-Latitude Air
Subtropical Front
Lower Tropospheric Tropical Air
Arctic Front
Polar Front
Subtrop. Surface High
Trade Wind Belt
Polar Easterlies
Polar Westerlies
N. Pole
80°
70°
60°
50°
40°
30°
20°
10°
Equator
Height (km)
Pressure (mb)
20
18
16
14
12
10
8
6
4
2
100
200
300
500
1000


200 mb
300 mb

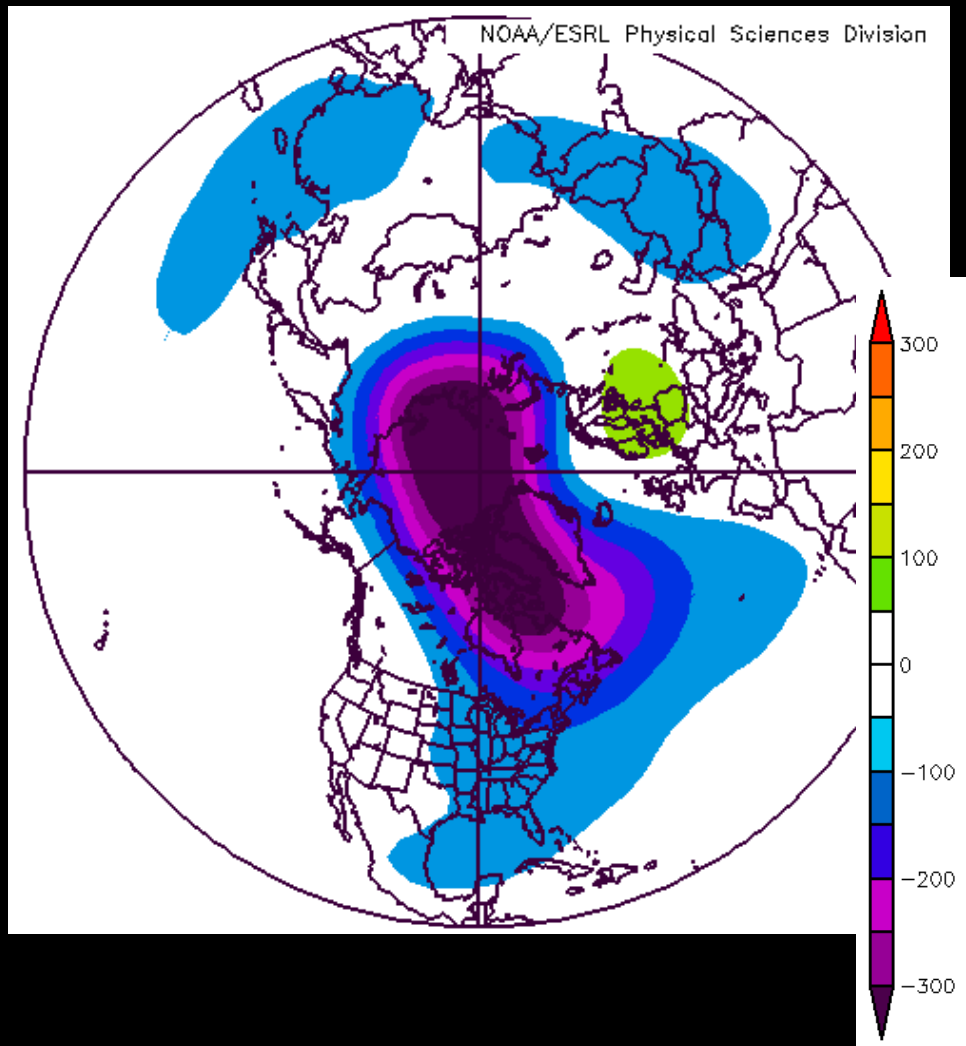

200 mb
300 mb
LC2
LC1
LC3

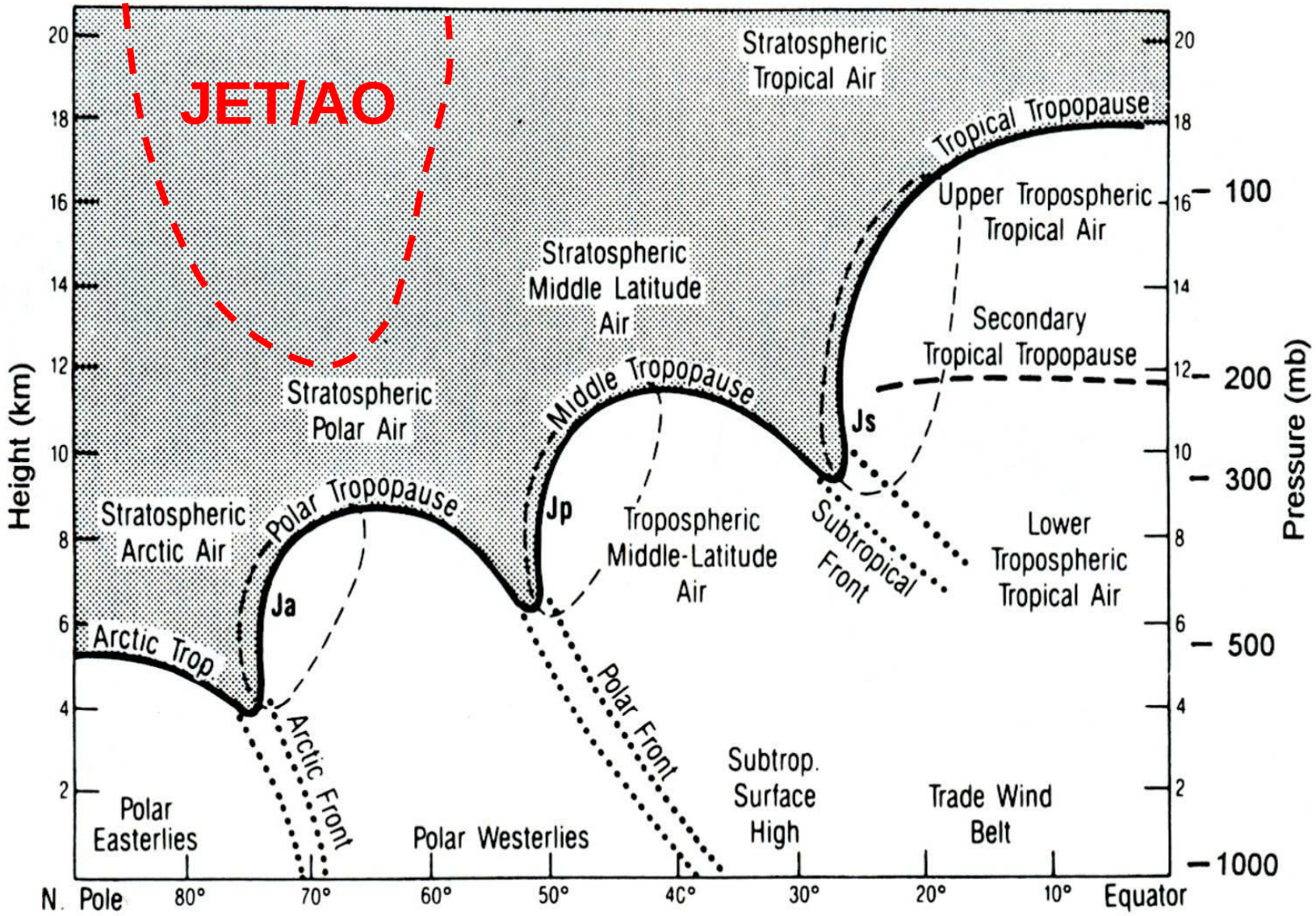
50-mb Height Anomaly (m)

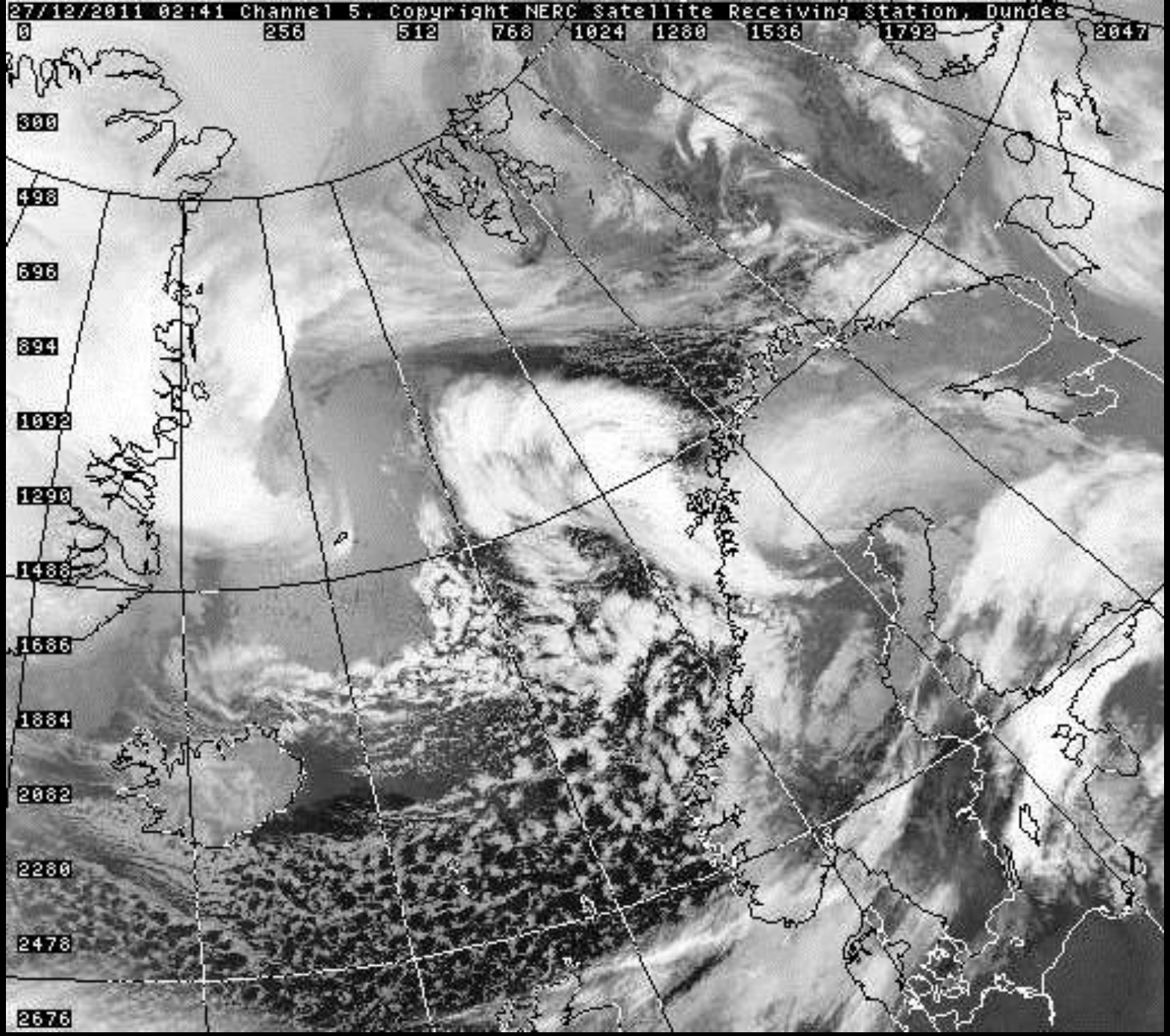
11 Dec 2010–15 Jan 2011 (AO−)



28 Jan–14 Feb 2011 (AO+)




JET/AO
Stratospheric Tropical Air
Tropical Tropopause
Upper Tropospheric Tropical Air
Secondary Tropical Tropopause
Stratospheric Middle Latitude Air
Middle Tropopause
Stratospheric Polar Air
Js
Jp
Ja
Polar Tropopause
Stratospheric Arctic Air
Tropospheric Middle-Latitude Air
Subtropical Front
Lower Tropospheric Tropical Air
Arctic Trop
Arctic Front
Polar Front
Subtrop. Surface High
Trade Wind Belt
Polar Easterlies
Polar Westerlies
N. Pole
80°
70°
60°
50°
40°
30°
20°
10°
Equator
Height (km)
Pressure (mb)
100
200
300
500
1000


27/12/2011 02:41 Channel 5. Copyright NERC Satellite Receiving Station, Dundee
0
256
512
768
1024
1280
1536
1792
2047
300
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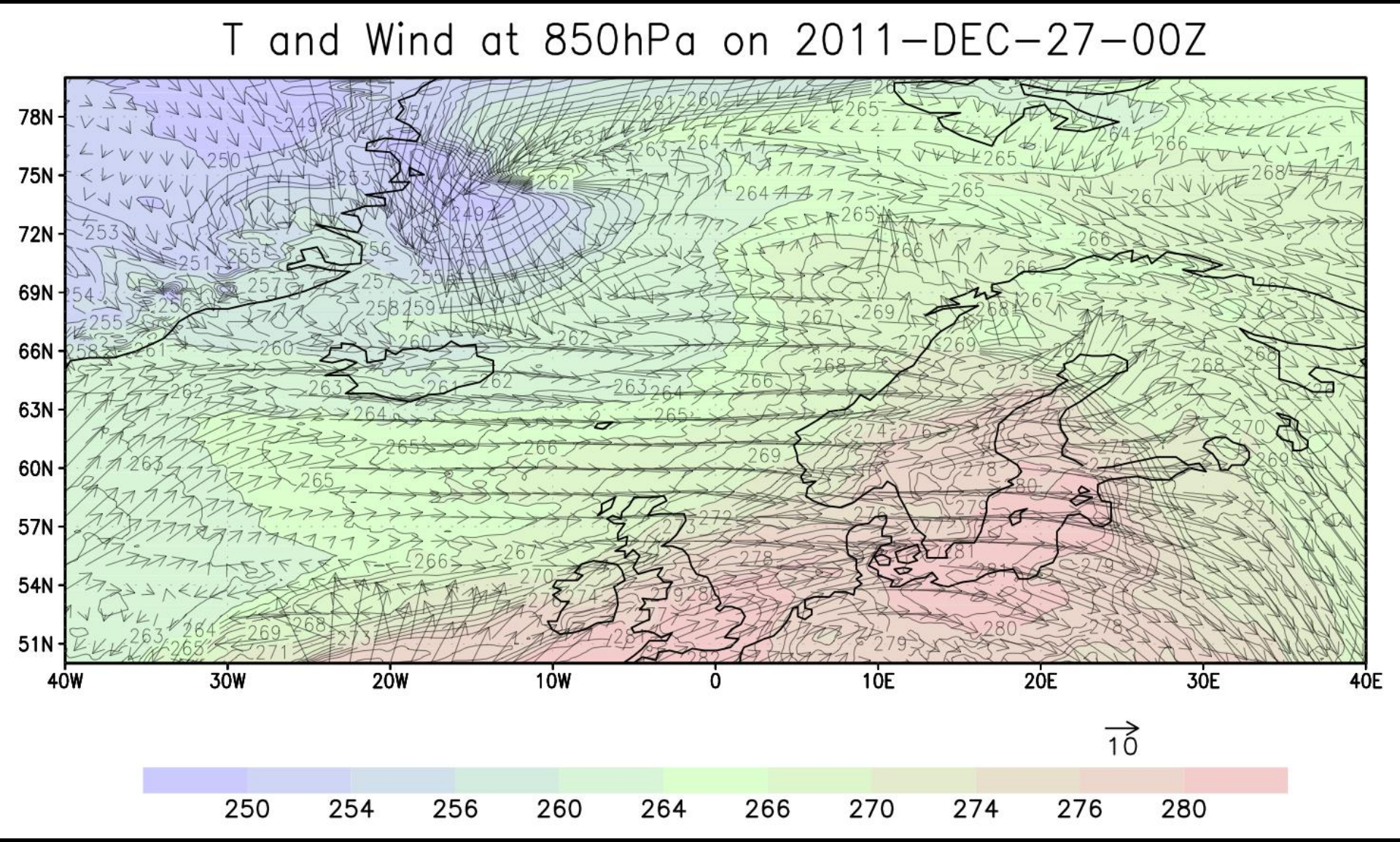
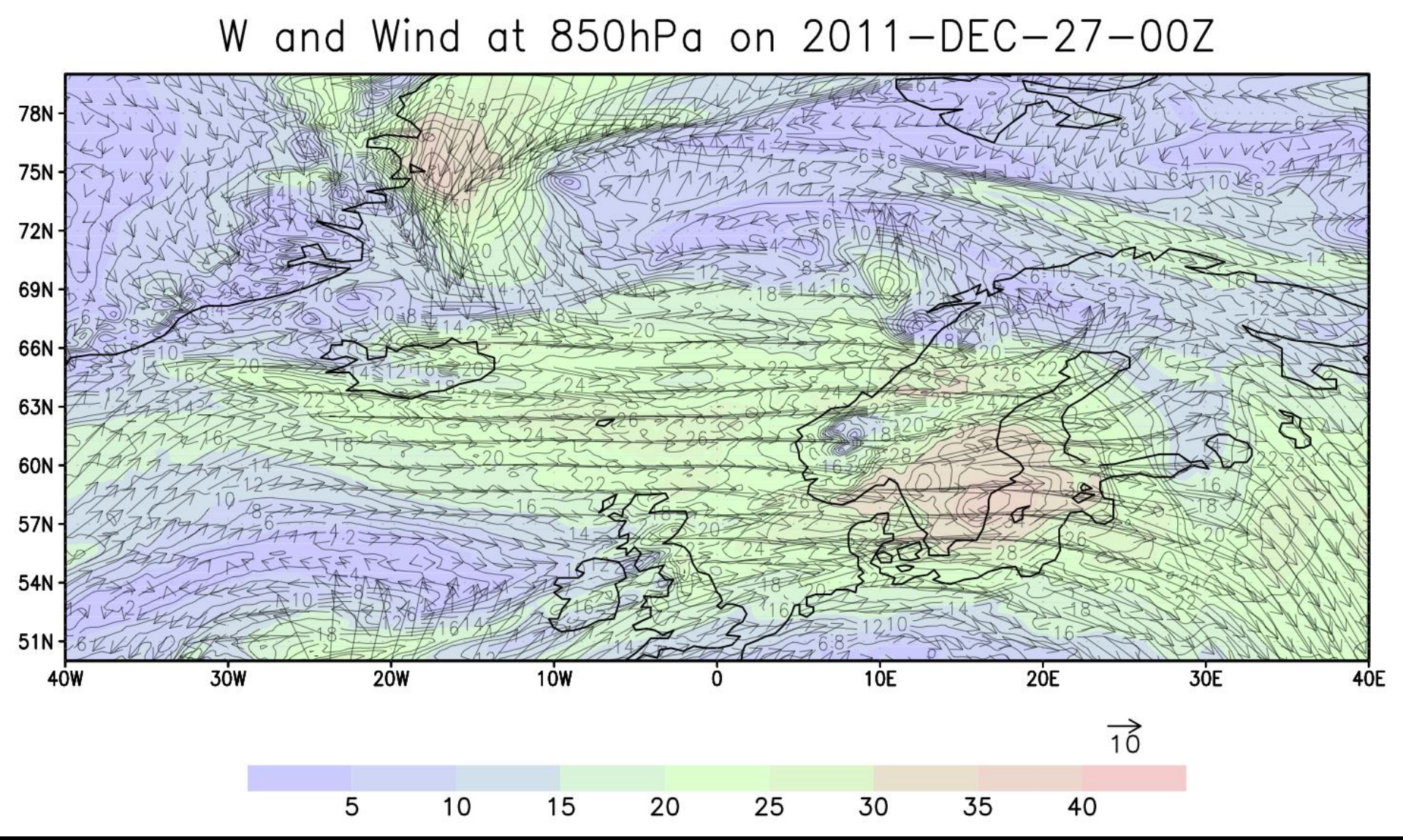
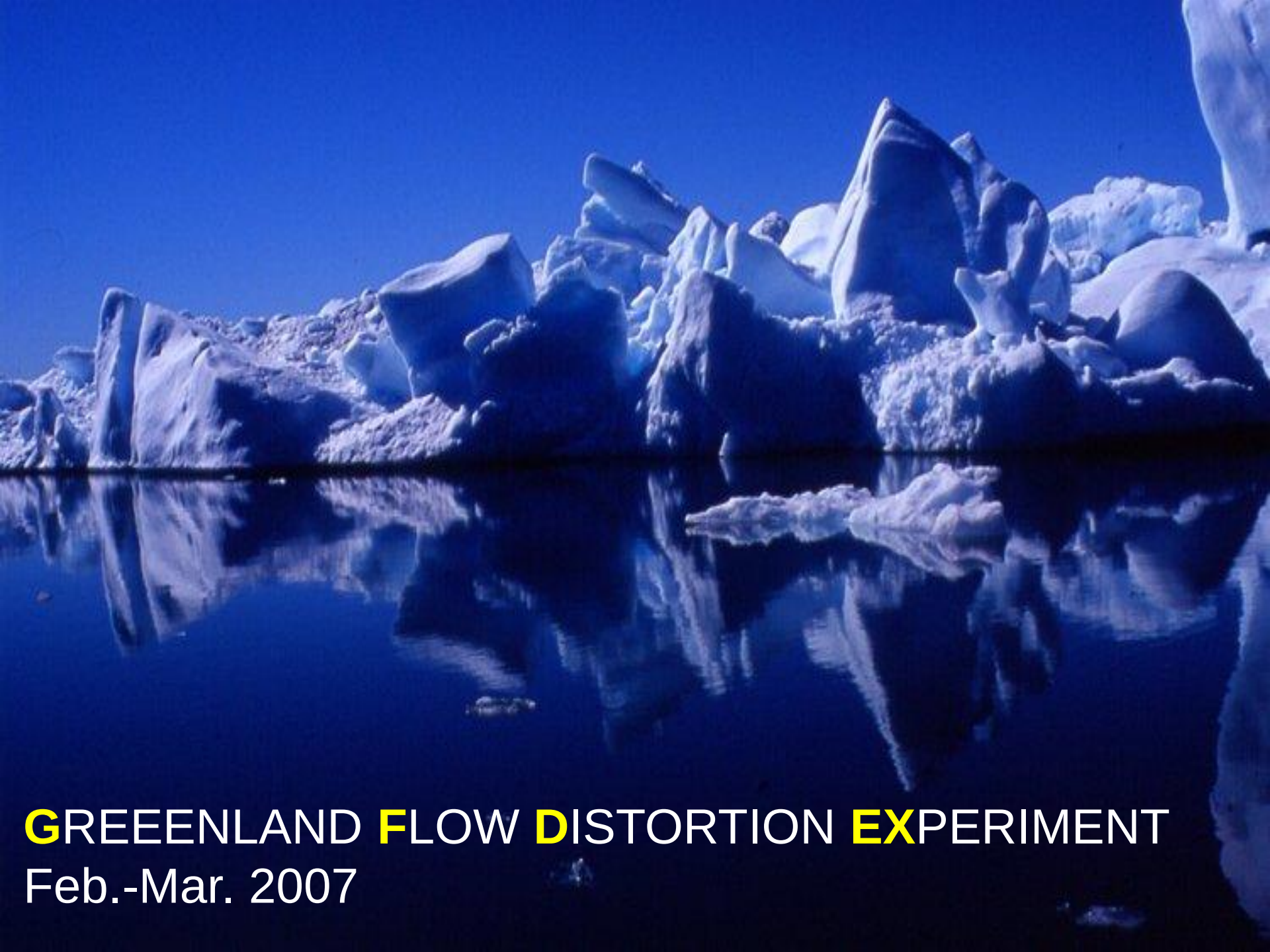
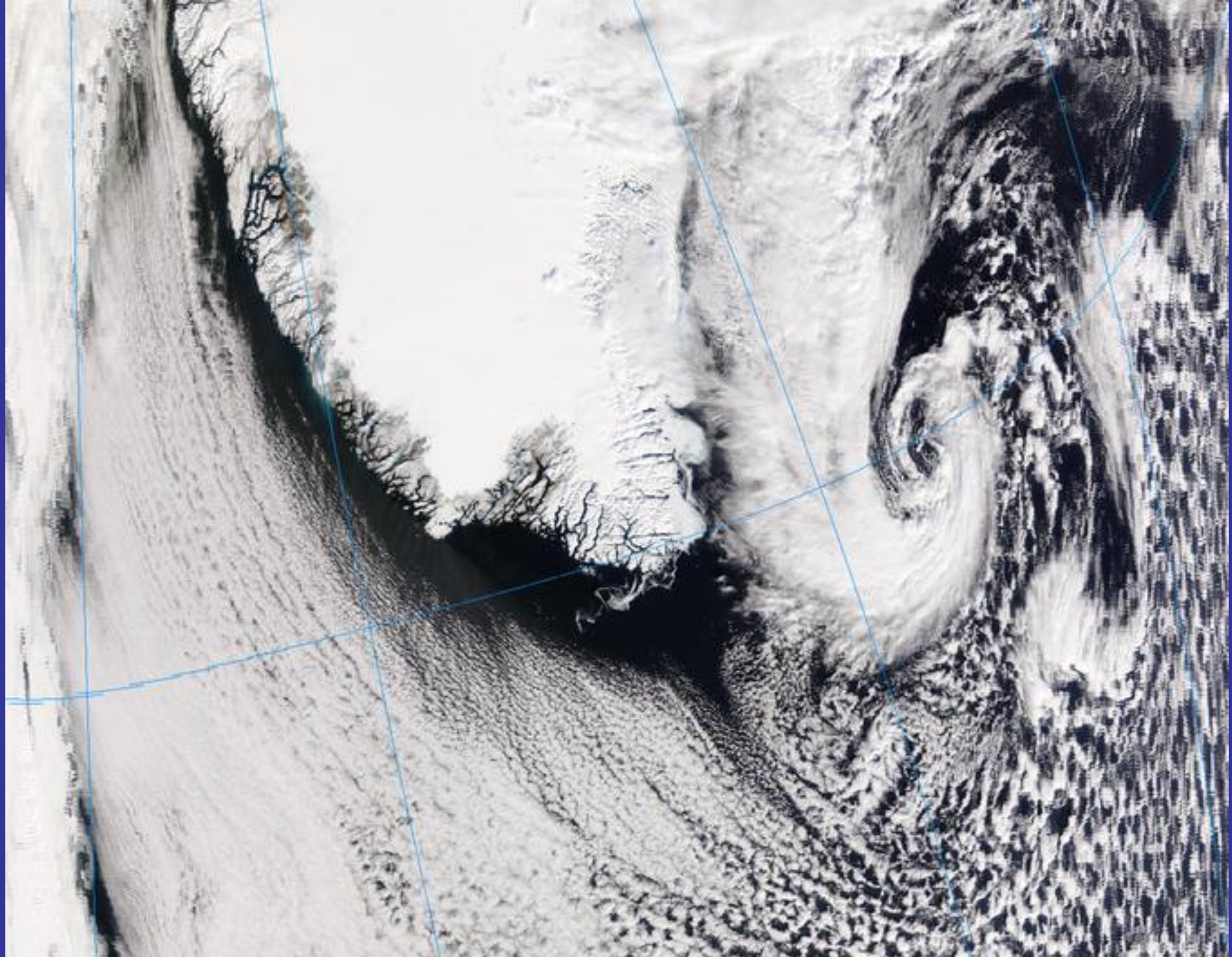
1488
1686
1884
2082
2280
2478
2676


T and Wind at 850hPa on 2011-DEC-27-00Z
78N
75N
72N
69N
66N
63N
60N
57N
54N
51N
40W
30W
20W
10W
0
10E
20E
30E
40E
10
250
254
256
260
264
266
270
274
276
280

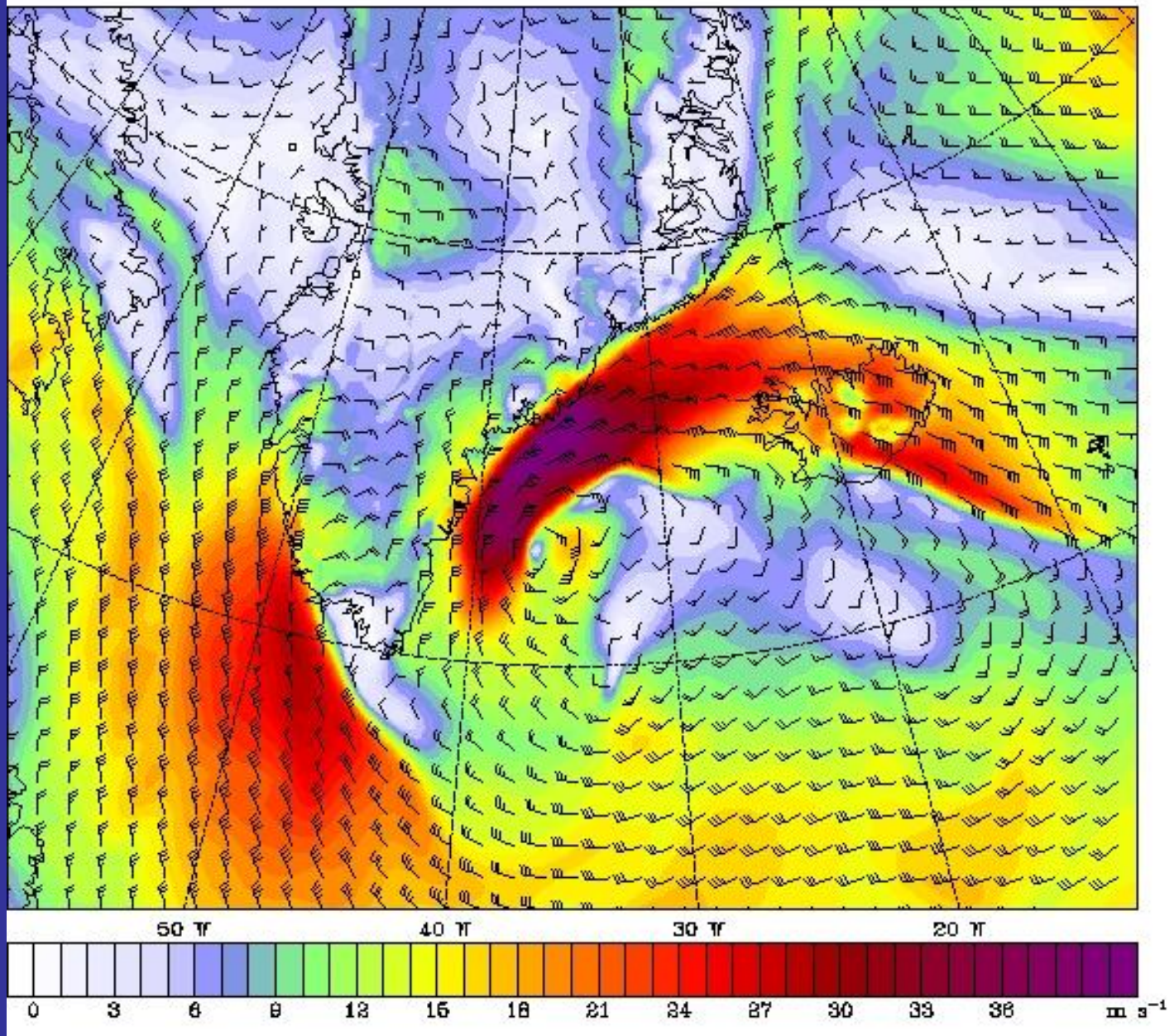

W and Wind at 850hPa on 2011-DEC-27-00Z
78N
75N
72N
69N
66N
63N
60N
57N
54N
51N
40W
30W
20W
10W
0
10E
20E
30E
40E
10
5
10
15
20
25
30
35
40


GREEENLAND FLOW DISTORTION EXPERIMENT
Feb.-Mar. 2007



Init: 0000 UTC Sat 03 Mar 07

Fcst: 0.00 Valid: 0000 UTC Sat 03 Mar 07 (0100 LST Sat 03 Mar 07)



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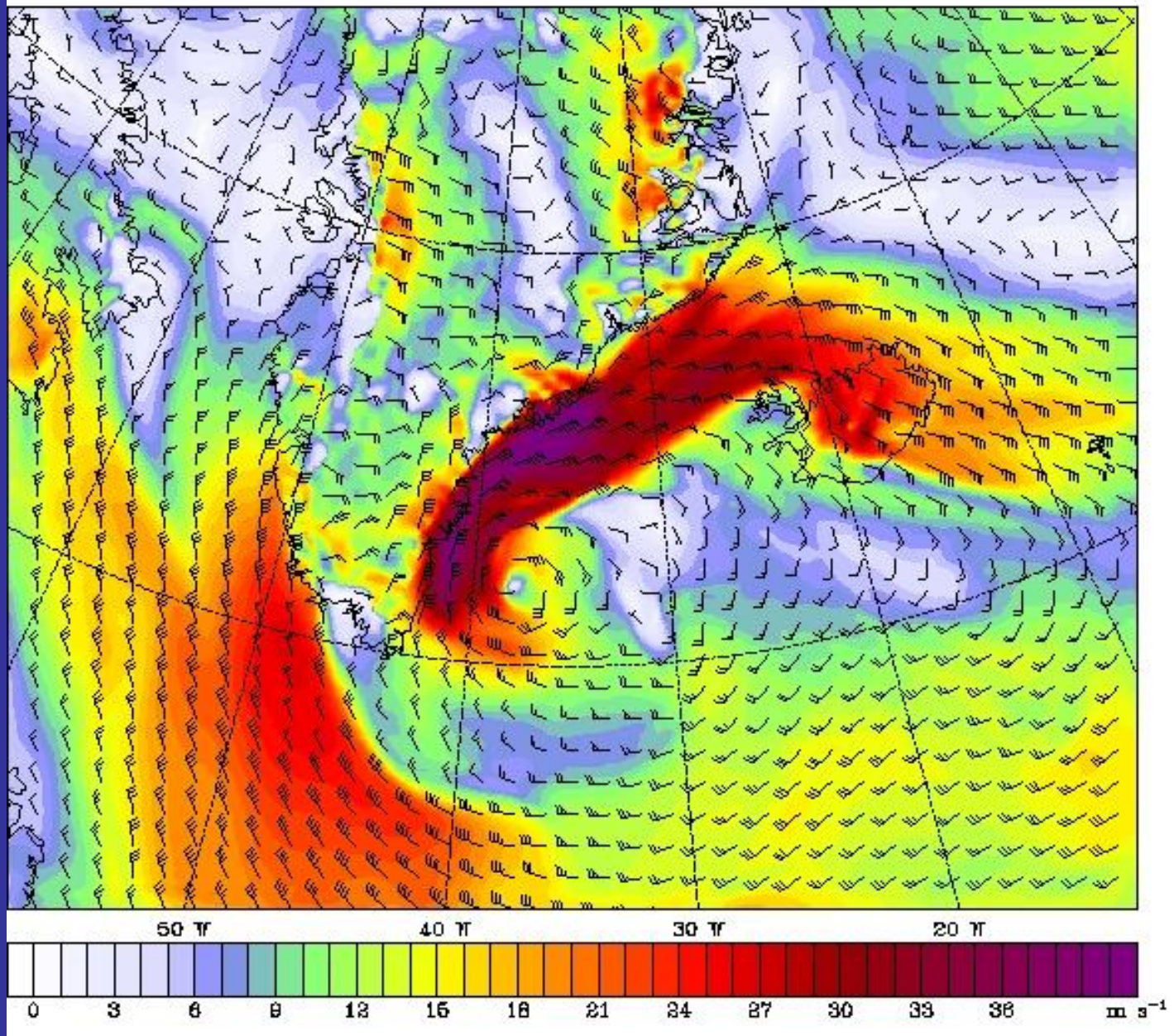

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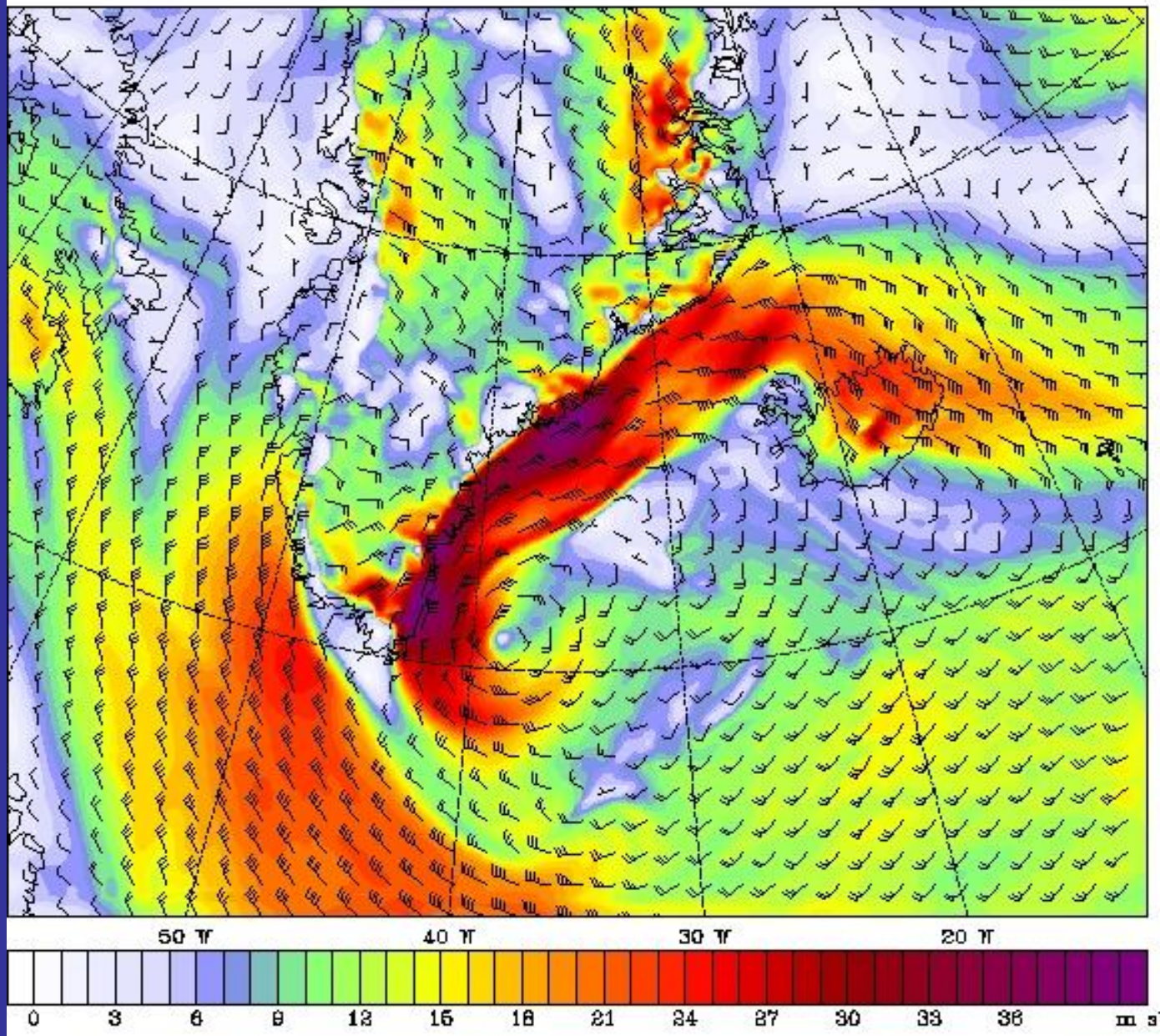
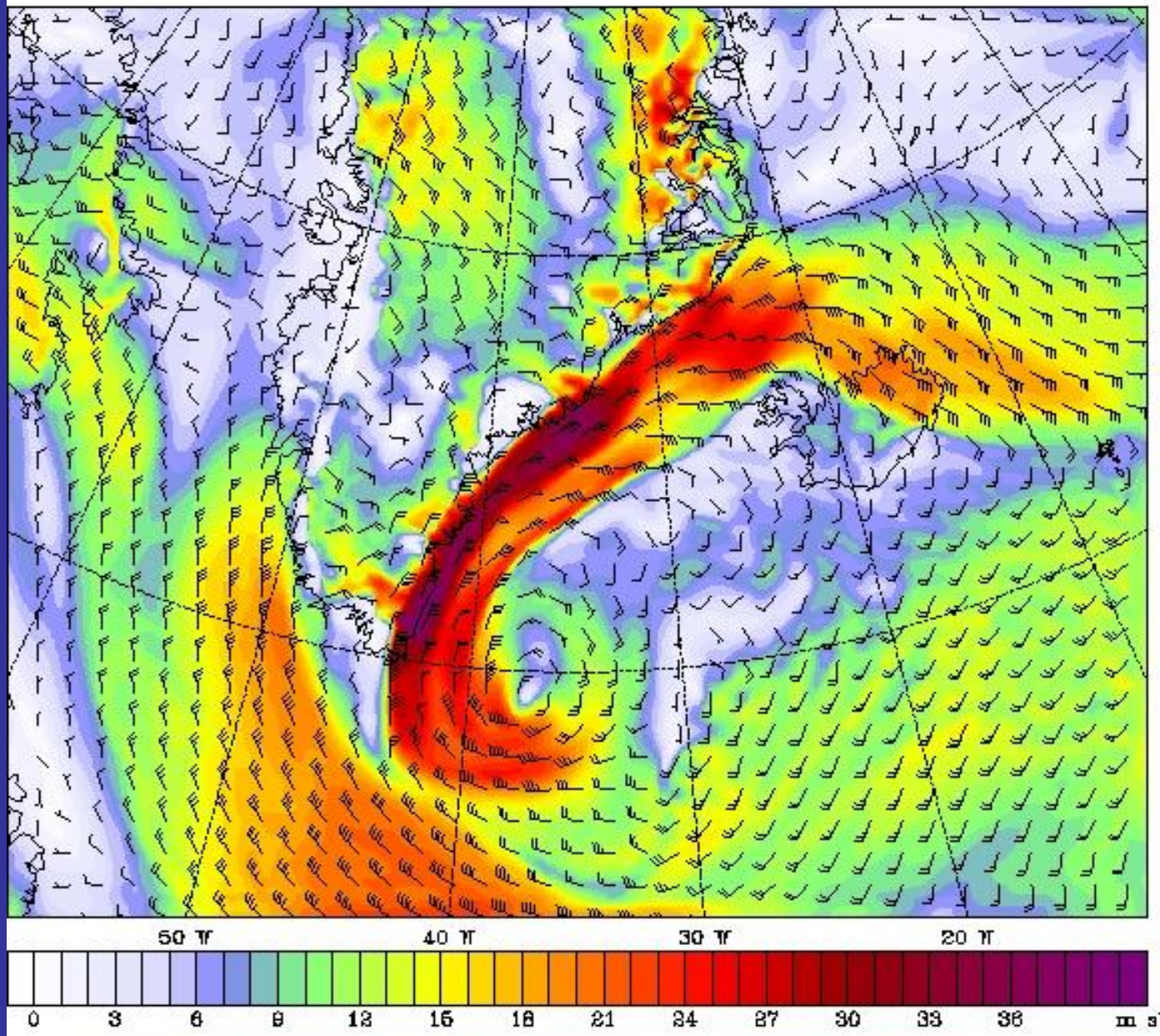
Fcst: 12.00 Valid: 1200 UTC Sat 03 Mar 07 (1300 LST Sat 03 Mar 07)



Init: 0000 UTC Sat 03 Mar 07

Fcst: 18.00 Valid: 1800 UTC Sat 03 Mar 07 (1900 LST Sat 03 Mar 07)



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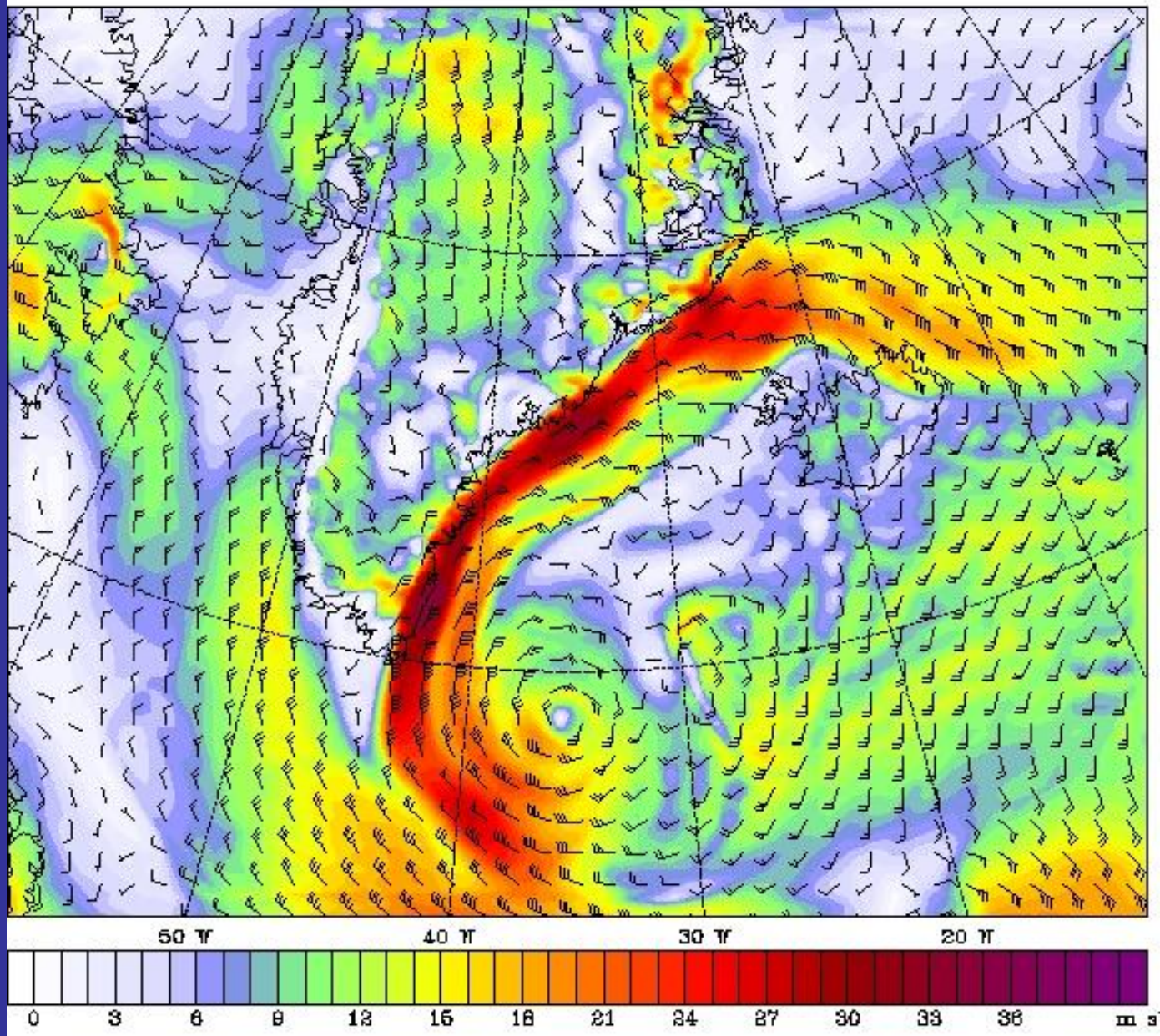
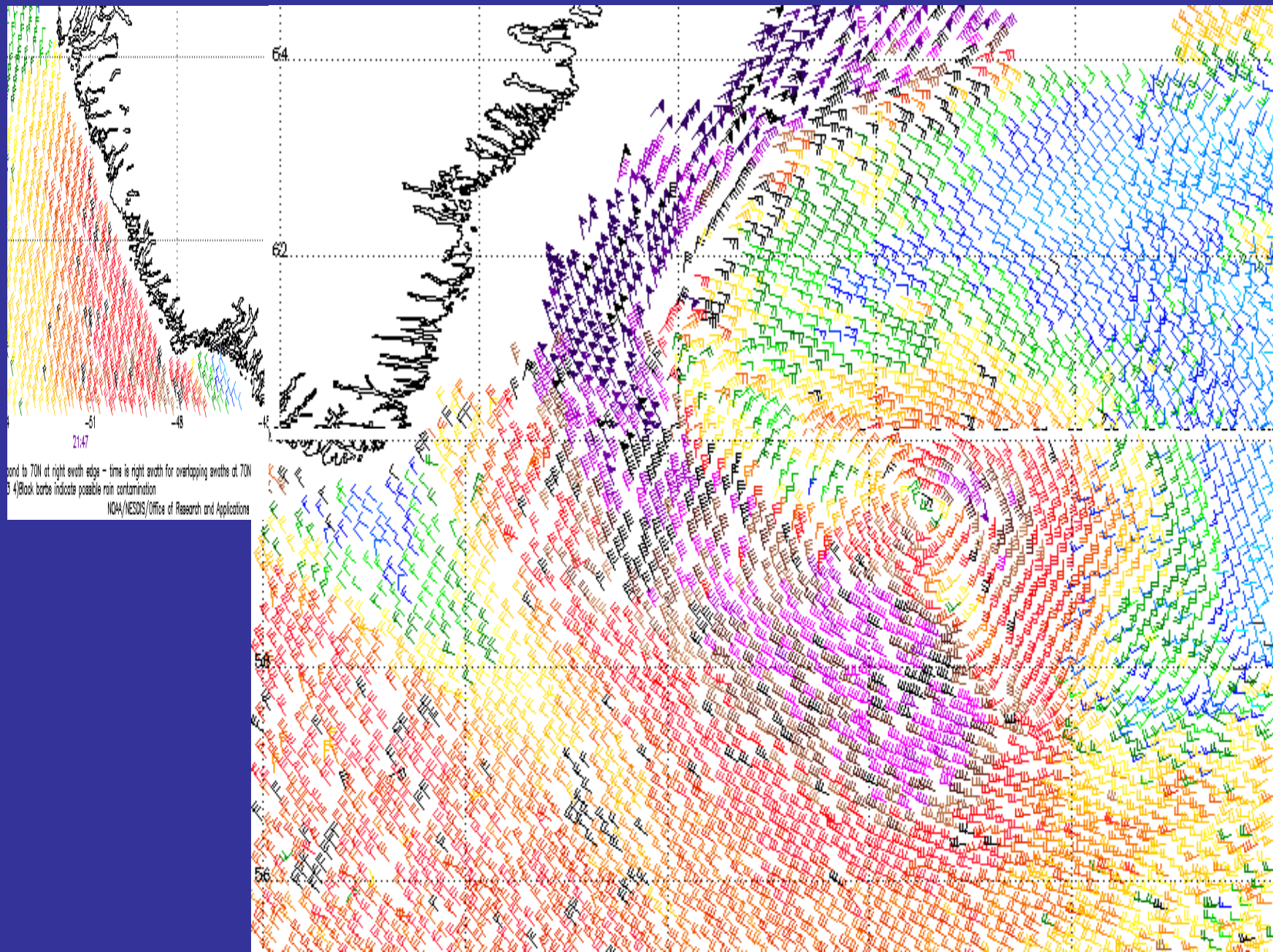
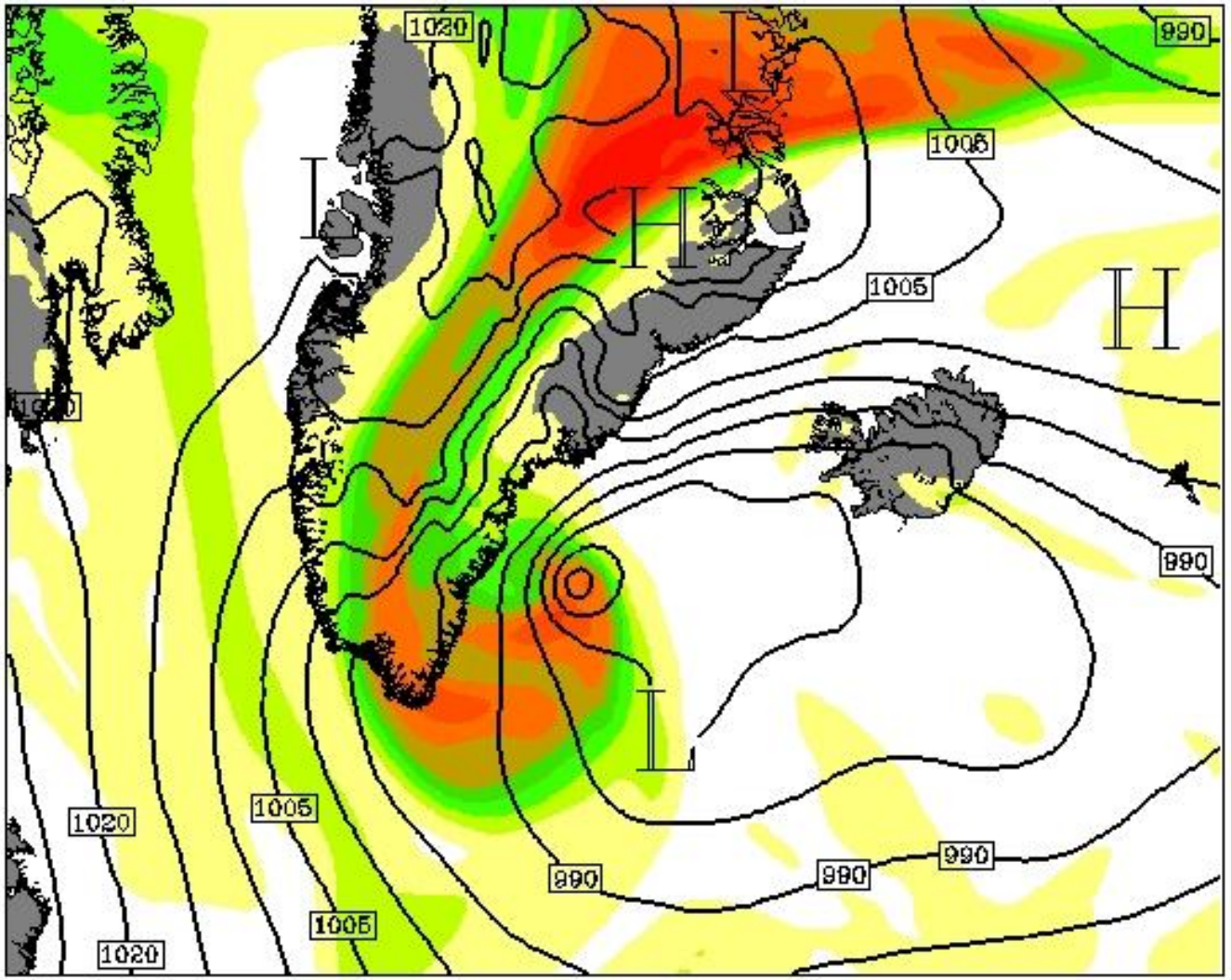
Fcst: 24.00 Valid: 0000 UTC Sun 04 Mar 07 (0100 LST Sun 04 Mar 07)

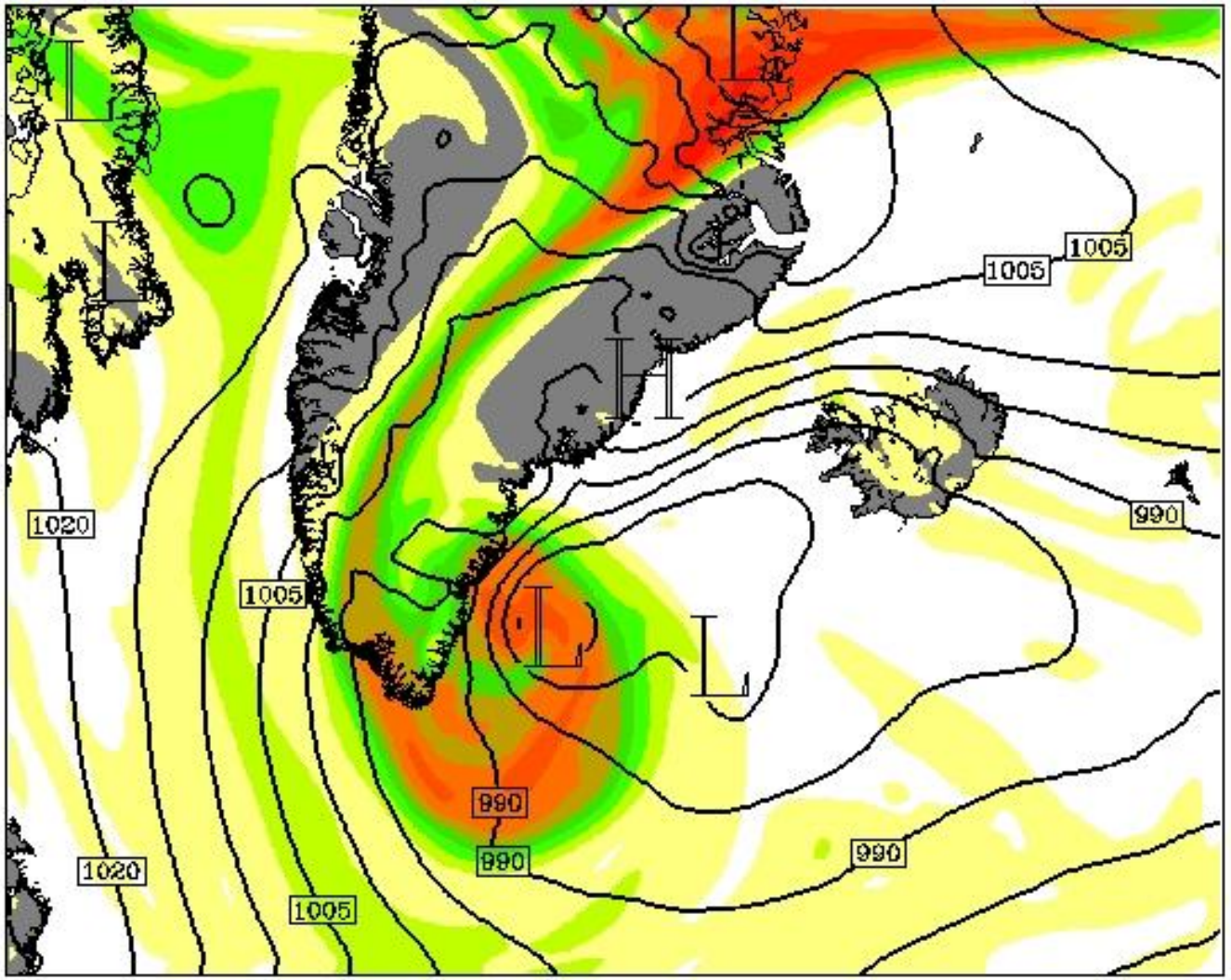


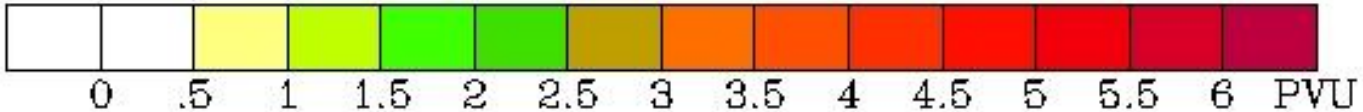

64
62
56
56
-51
-48
21:47
cond to 70N at right swath edge – time is right swath for overlapping swaths at 70N
3 4)Black barbs indicate possible rain contamination
NOAA/NESDIS/Office of Research and Applications

STORM WEATHER CENTER MM5 RUN
Init: 0000 UTC Sat 03 Mar 07
Fcst: 0.00
Valid: 0000 UTC Sat 03 Mar 07 (0100 LST Sat 03 Mar 07)



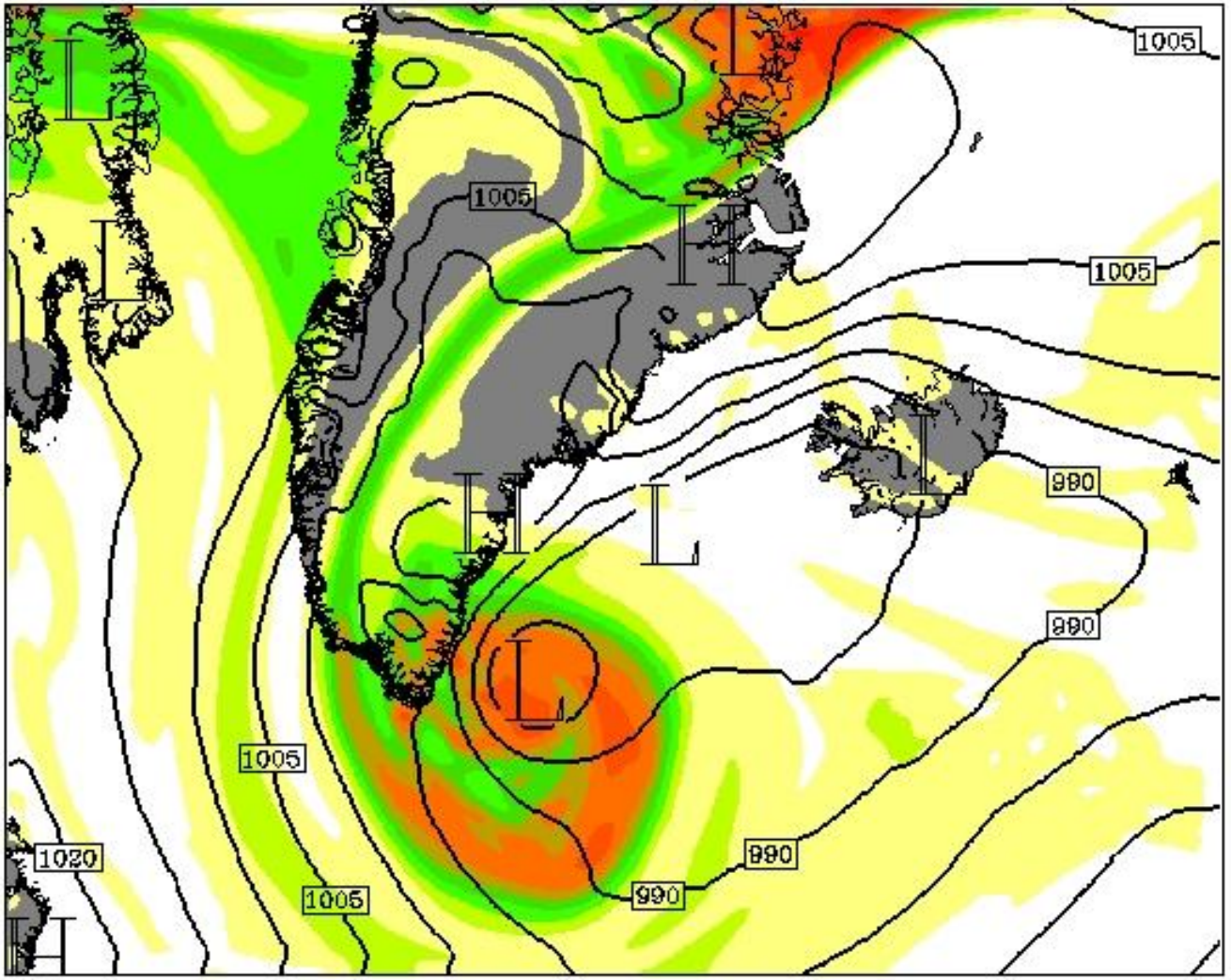
STORM WEATHER CENTER MM5 RUN
Init: 0000 UTC Sat 03 Mar 07
Fcst: 6.00
Valid: 0600 UTC Sat 03 Mar 07 (0700 LST Sat 03 Mar 07)



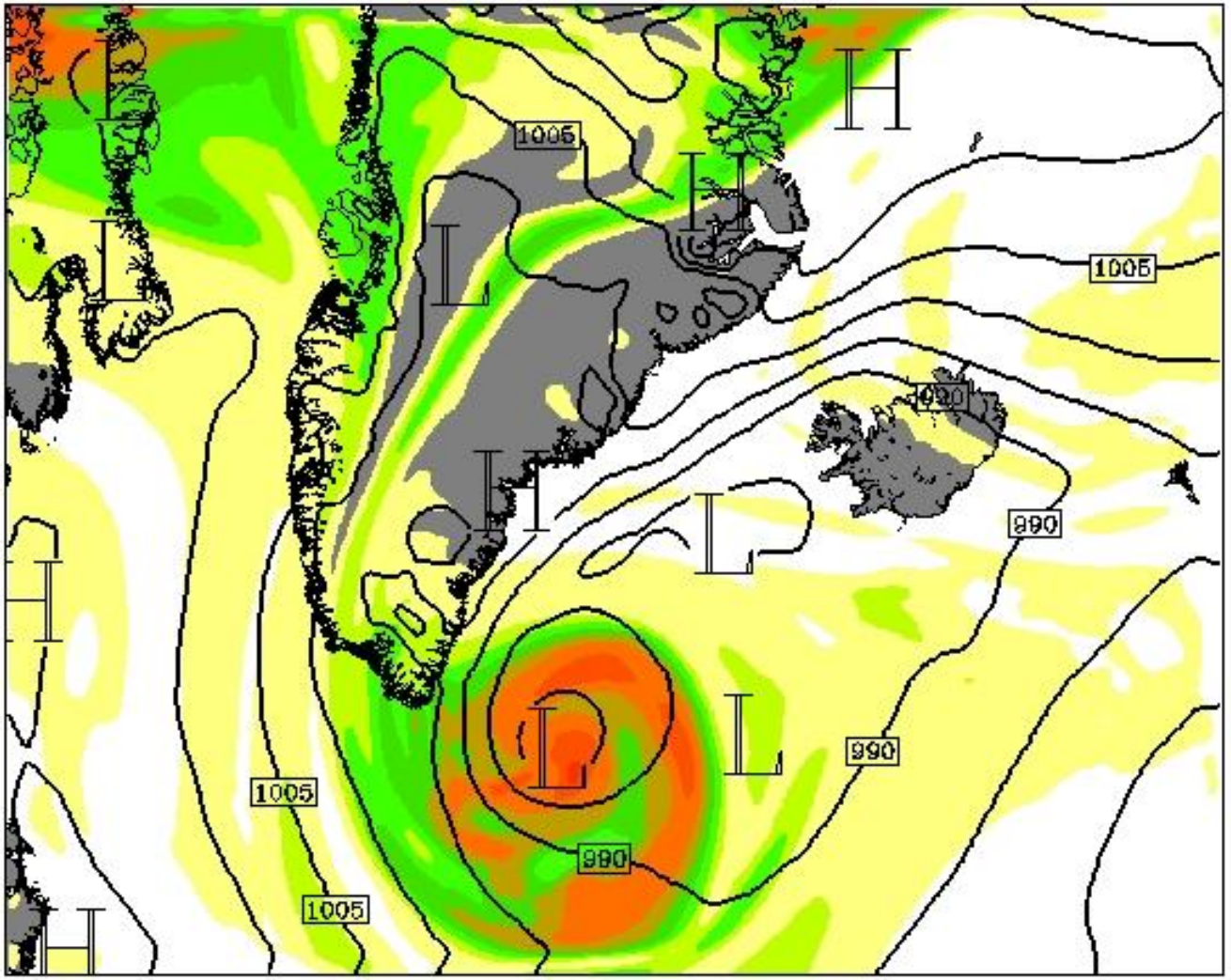


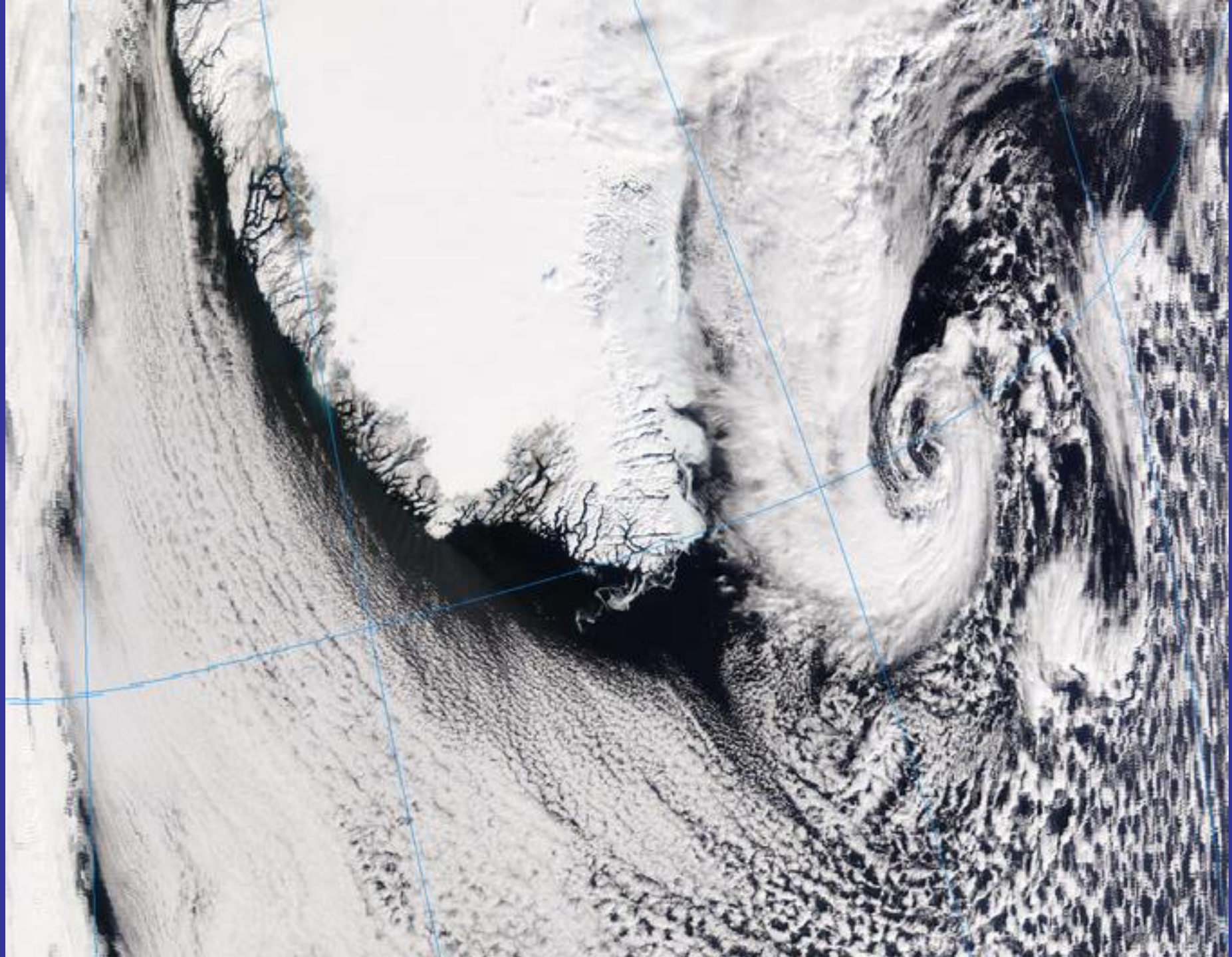
STORM WEATHER CENTER MM5 RUN
Fcst: 12.00

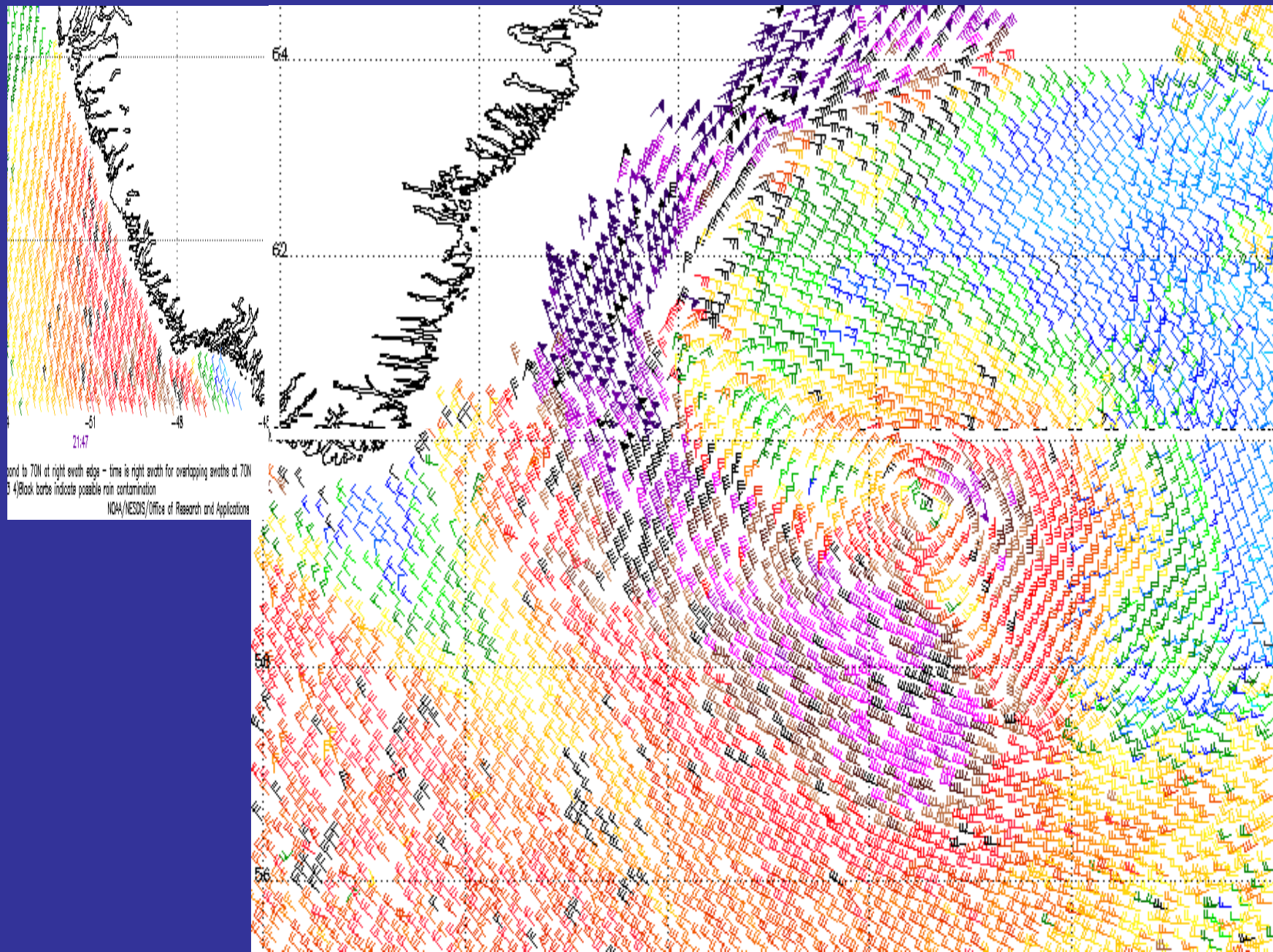
Init: 0000 UTC Sat 03 Mar 07
Valid: 1200 UTC Sat 03 Mar 07 (1300 LST Sat 03 Mar 07)



STORM WEATHER CENTER MM5 RUN
Fcst: 18.00
Init: 0000 UTC Sat 03 Mar 07
Valid: 1800 UTC Sat 03 Mar 07 (1900 LST Sat 03 Mar 07)






64
62
56
56
-51
-48
21:47
cond to 70N at right swath edge – time is right swath for overlapping swaths at 70N
3 4)Black barbs indicate possible rain contamination
NOAA/NESDIS/Office of Research and Applications