

Singular vectors and extratropical transition of tropical cyclones

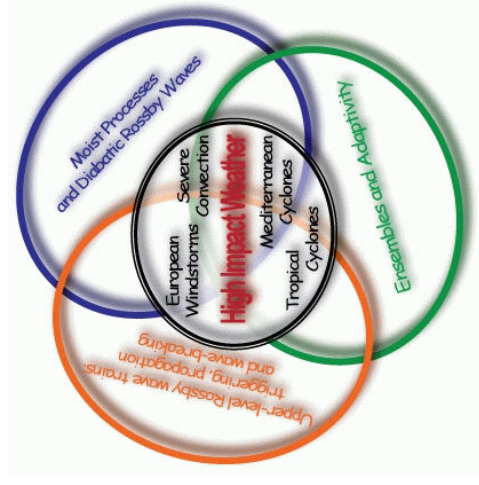
Simon Lang¹, Sarah Jones¹, Martin Leutbecher²

¹Universität Karlsruhe / Forschungszentrum Karlsruhe

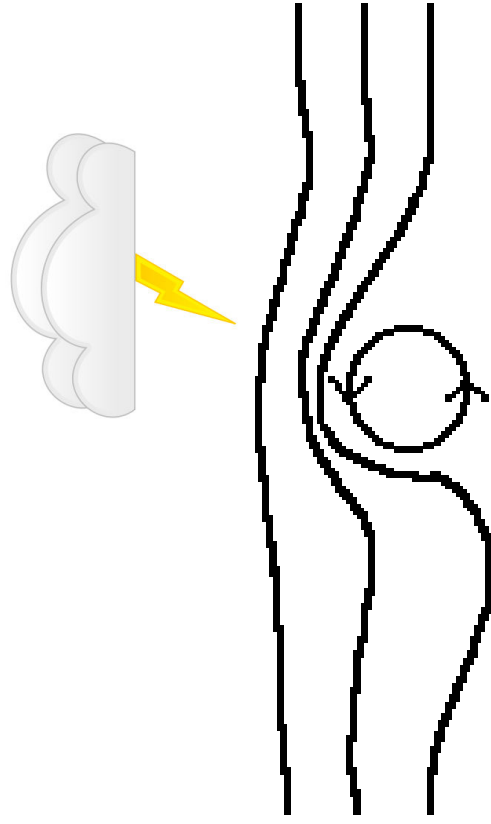
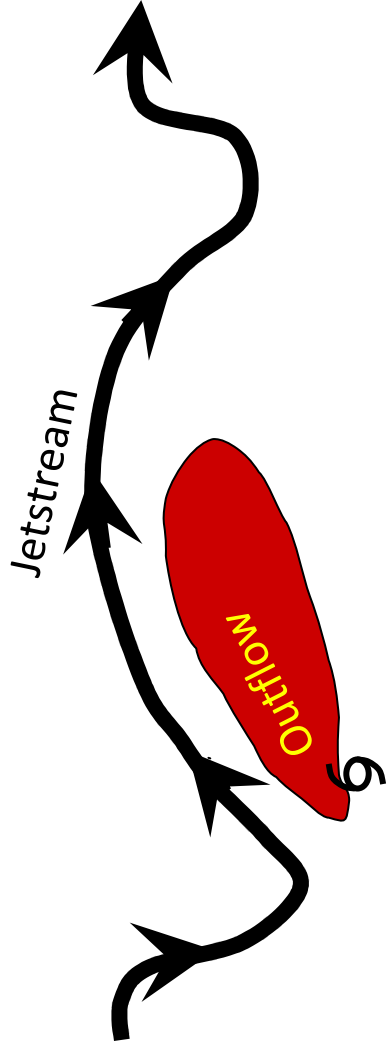
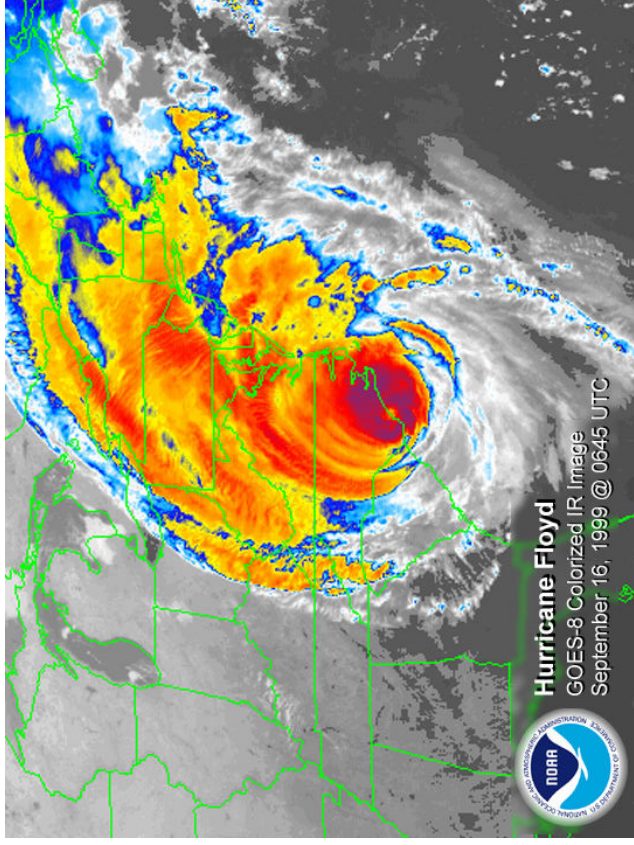
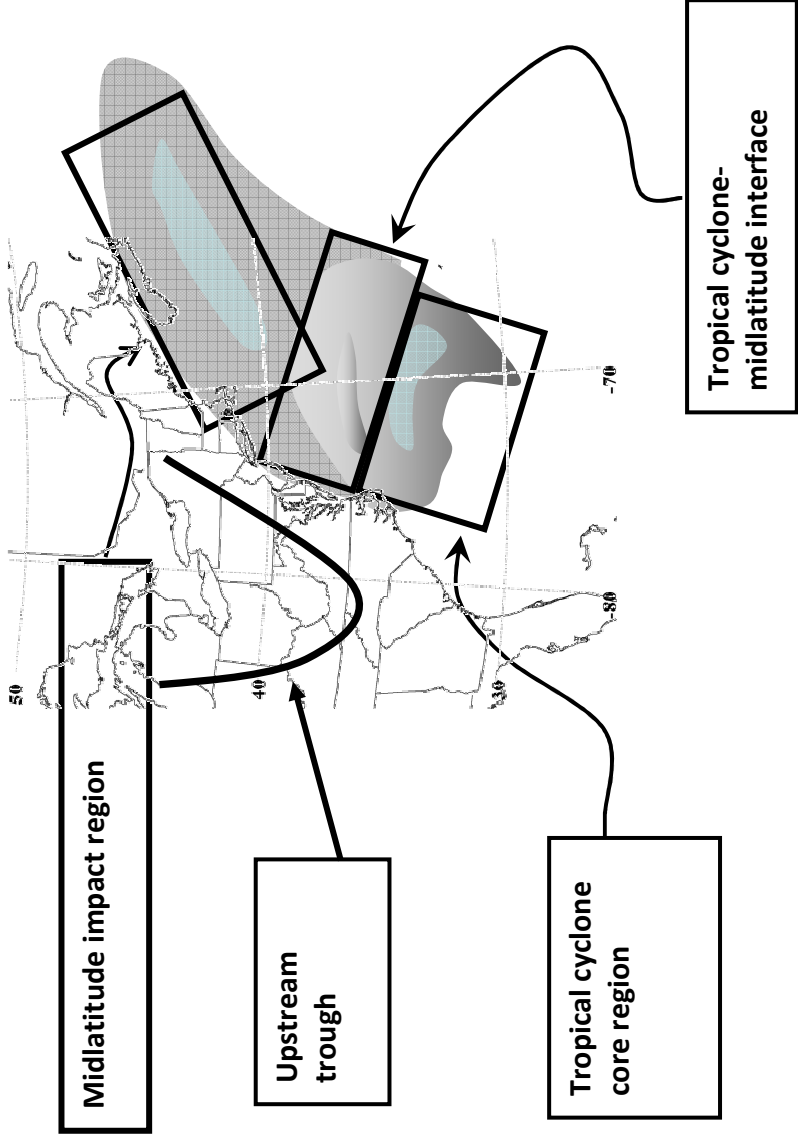
²European Centre for Medium-Range Weather Forecasts



Karlsruhe Institute of Technology

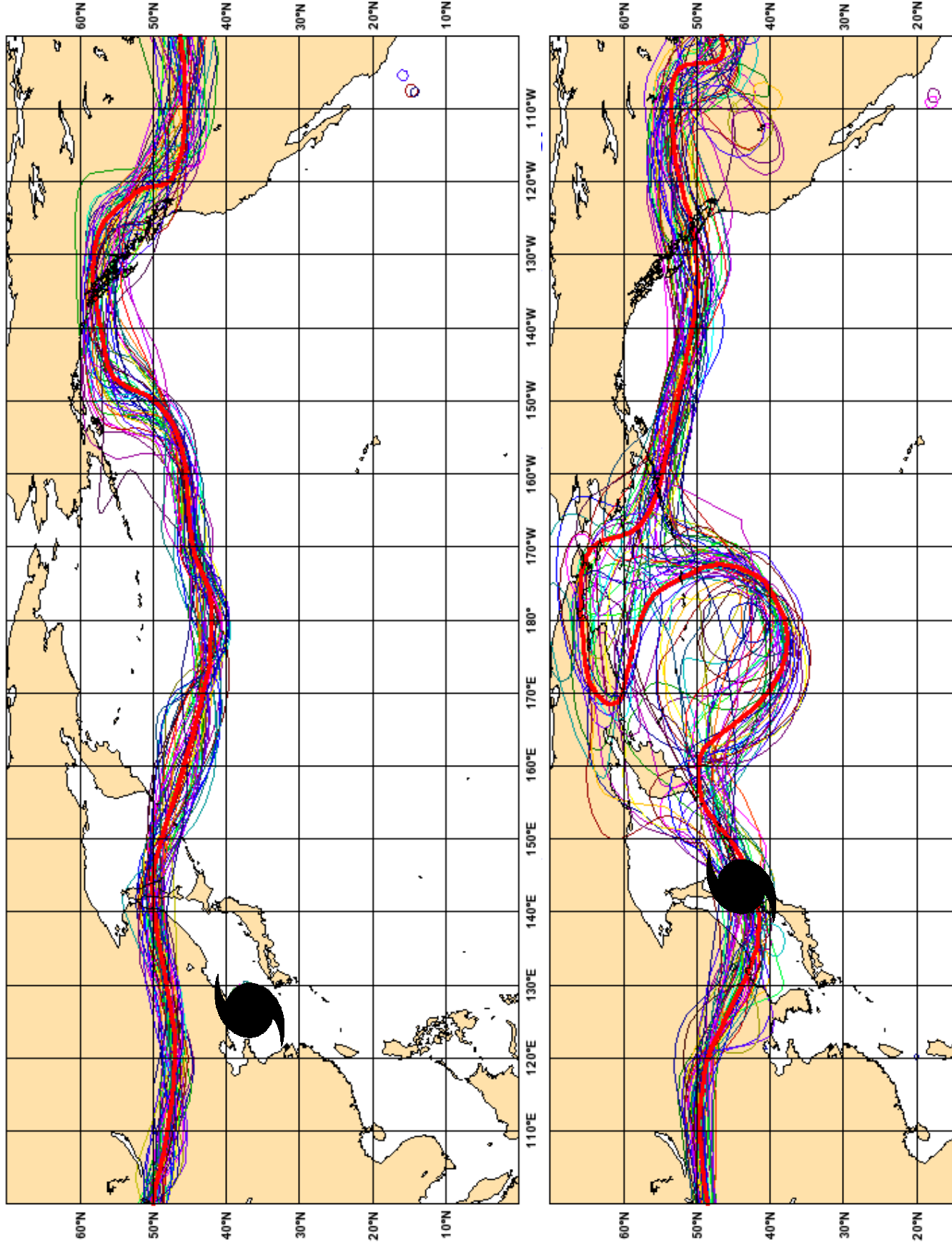


Extratropical Transition (ET)



Maemi 2005

IT: 2003-09-10 12UTC ECMWF FC t+60 VT:2003-09-13 00 - Geopot. Ensemble 500hPa
Red : Control Forecast, Coloured: Ensemble Forecast, 51 members, for 568 gpdm



Singular Vectors and ET

The operational resolution of singular vectors targeted on tropical cyclones at the ECMWF is rather low (T42) - too low to represent the tropical cyclone (TC) properly

We want to investigate the sensitivity of the singular vector calculations to spatial resolution

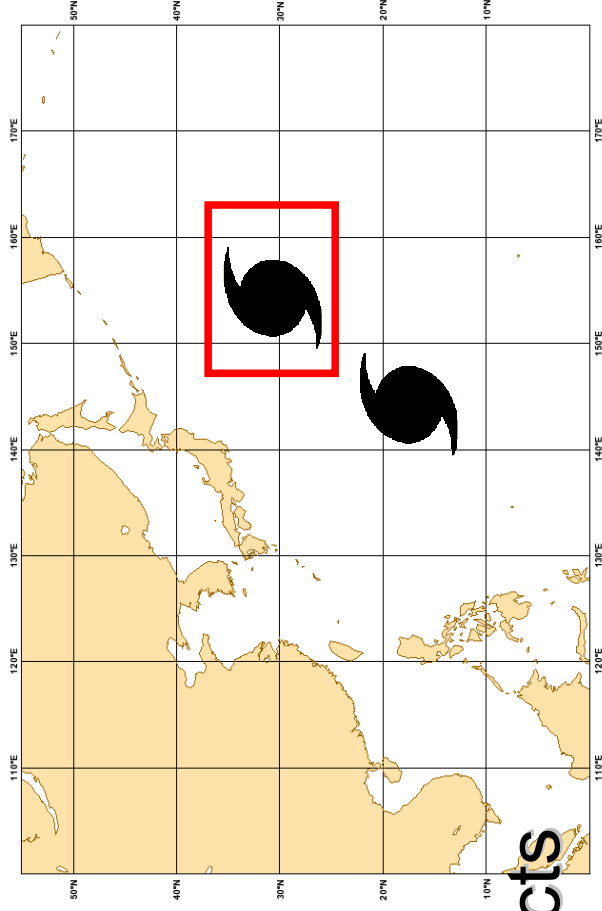
What impact do higher resolution singular vectors targeted on TCs have on the ensemble prediction system?

What can we learn from higher resolution singular vectors about the important physical and dynamical processes during an ET event?

Targeted Moist Singular Vectors

SVs targeted on TCs are calculated with linearised physics:

- Vertical diffusion
- Large-scale condensation
- Deep convection
- Long-wave radiation
- Subgrid-scale orographic effects



Growth is measured by a Total Energy Norm:

$$\vec{x}' C \vec{x}'^T = \frac{1}{2} \int_{P_0}^{P_1} \int^S (u'^2 + v'^2 + \frac{c_p}{T_r} T'^2) dp ds + \frac{1}{2} R_d T_r p_r \int_S \ln^2(p'_{sfc}) ds$$

Experiments

Implemented experiments with the IFS of the ECMWF:

- calculate SVs targeted on one specific tropical cyclone without operational constraints
- Output time evolution of trajectory and SVs

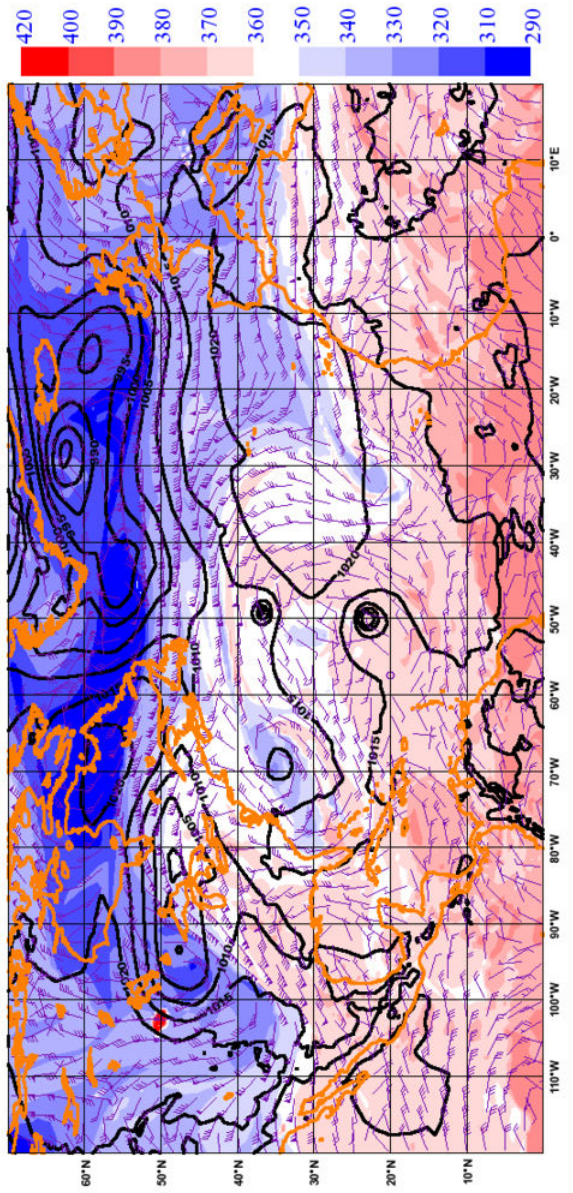
3 experiments with different resolution:
(48h Optimization Time)

T42	~ 2.81° (operational resolution for SVs for
EPS)	
TL95	~ 1.89°
TL159	~ 1.13°

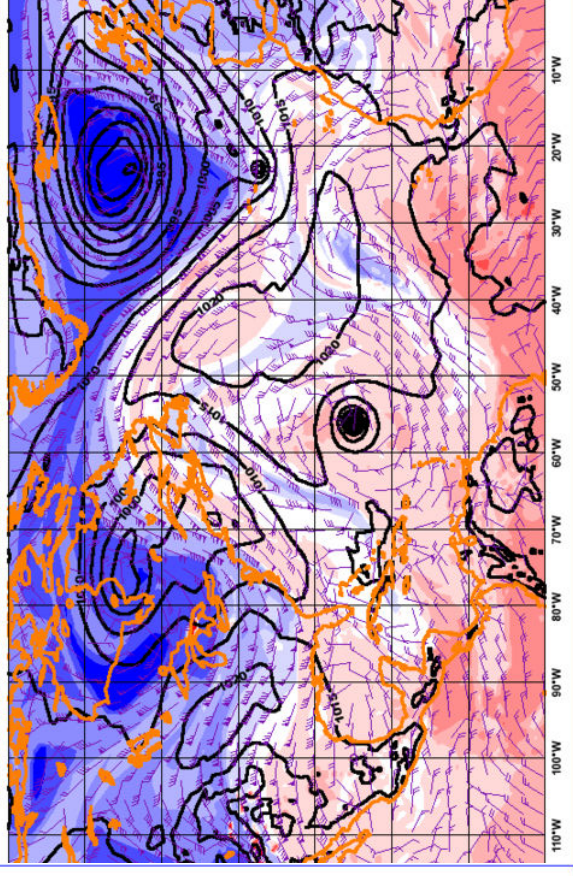
Heleene 2006

Potential Temperatur on 2 PVU Surface (colored)
MSLP (black contour)

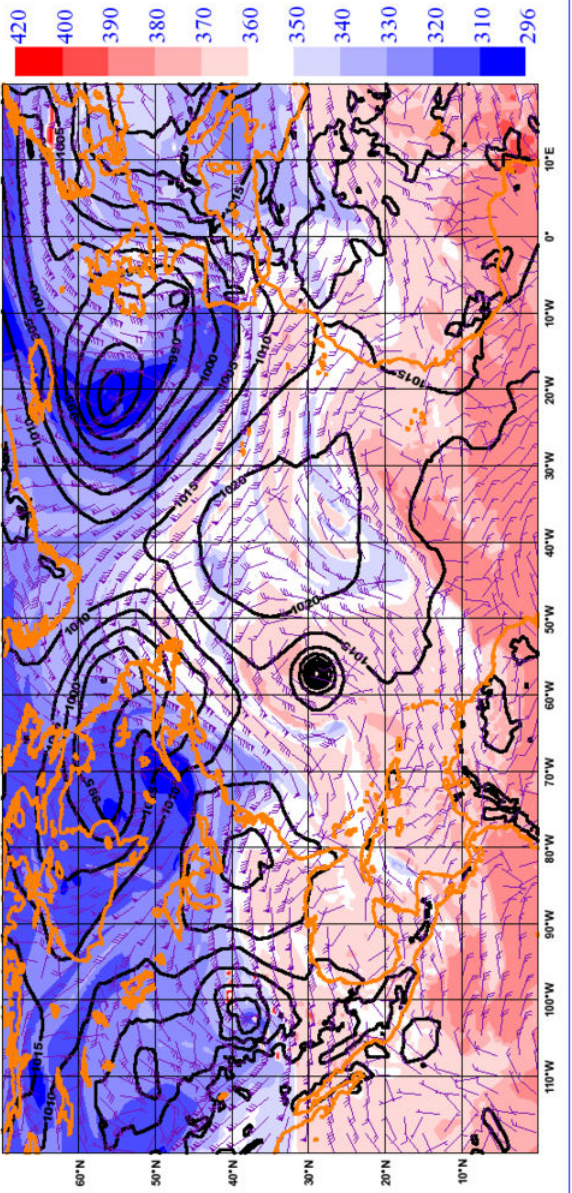
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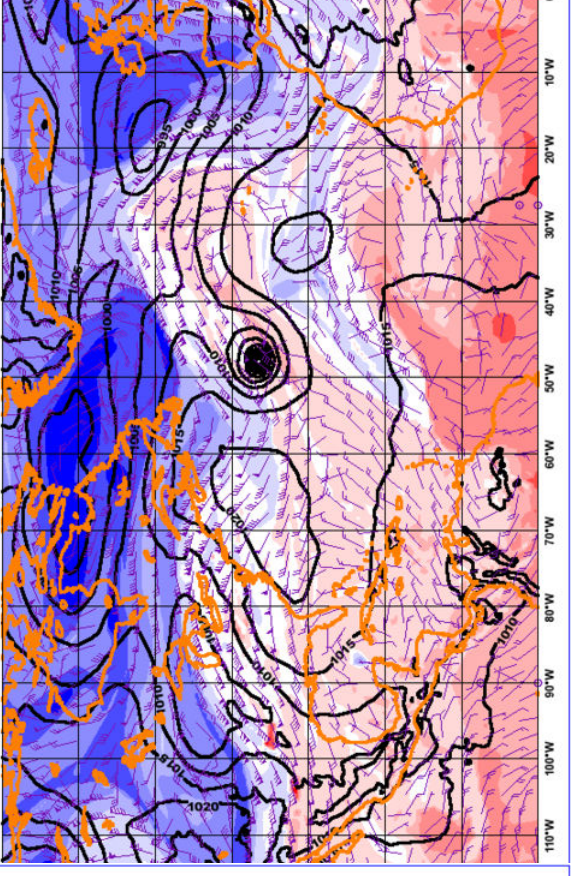
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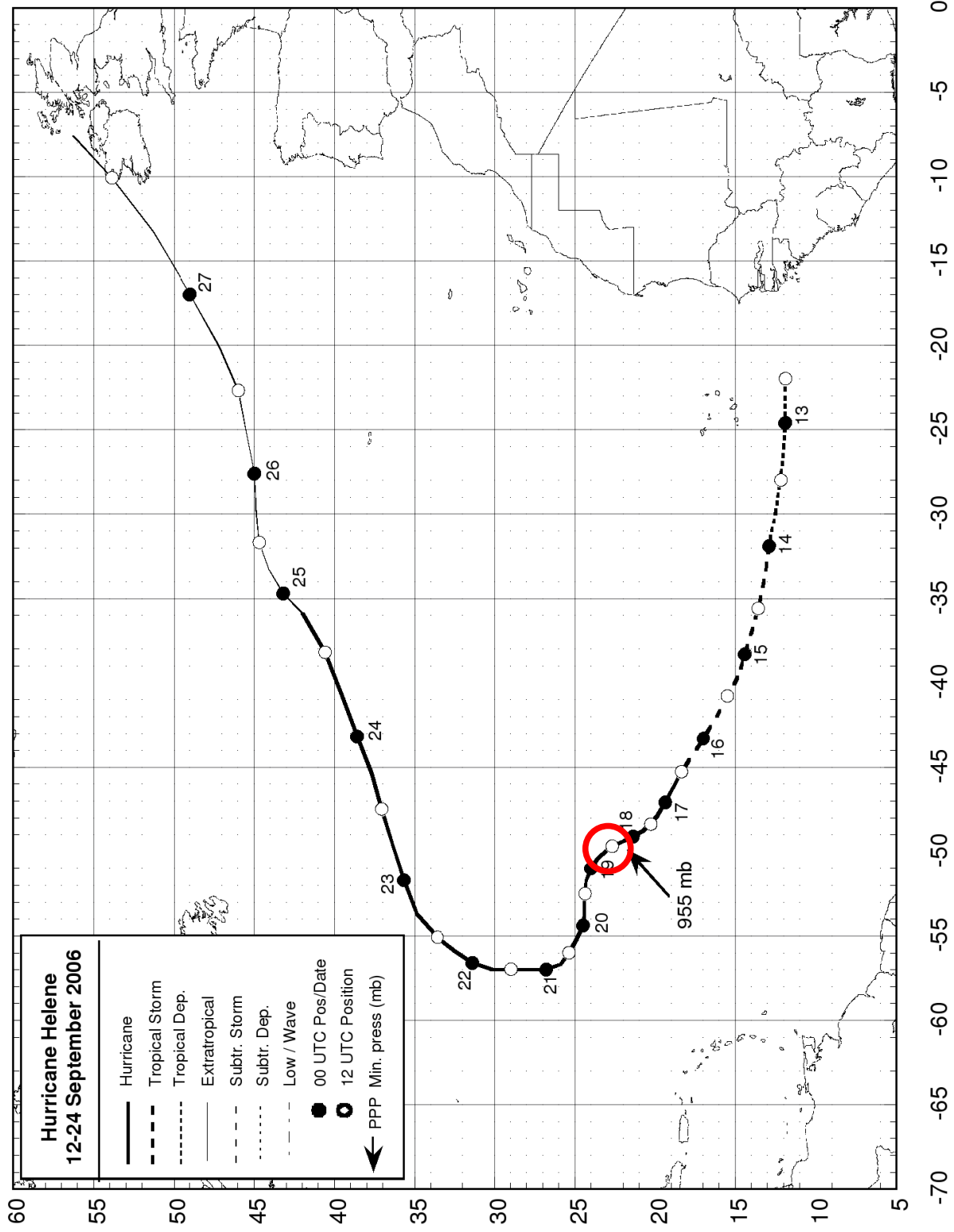
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Helene 2006



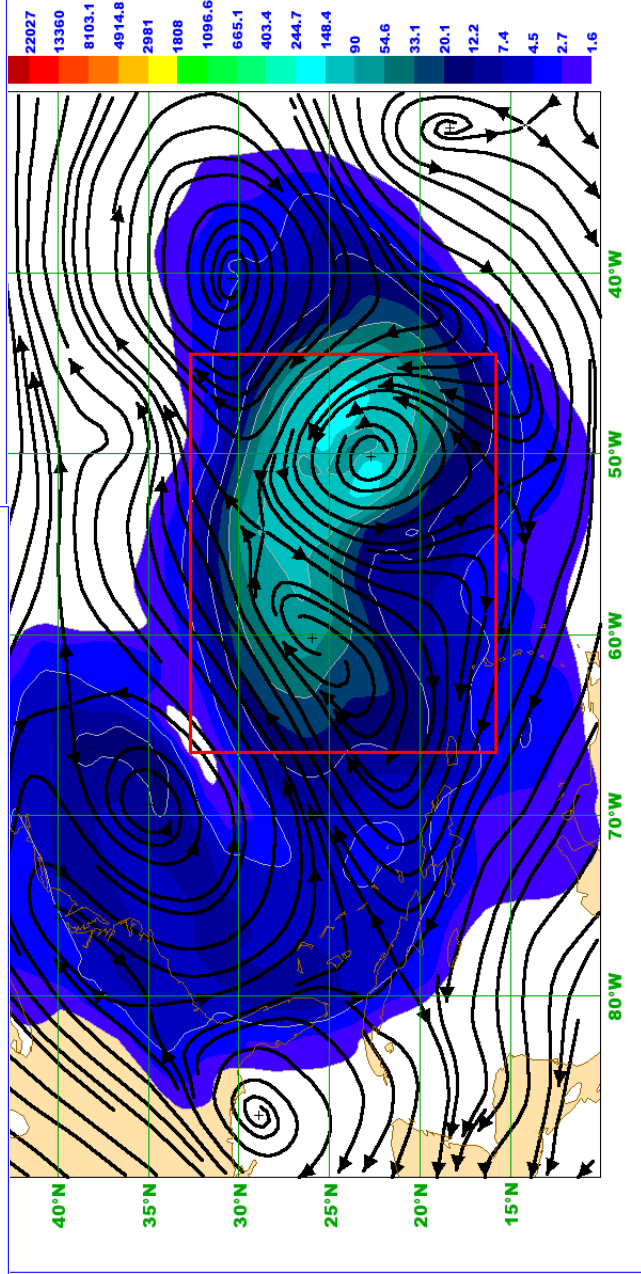
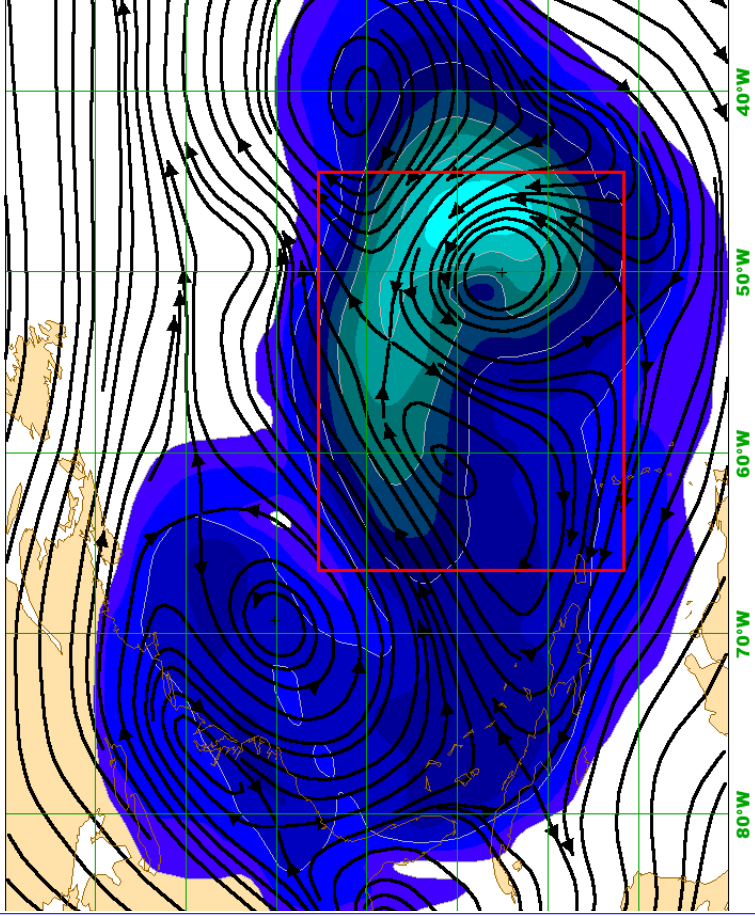
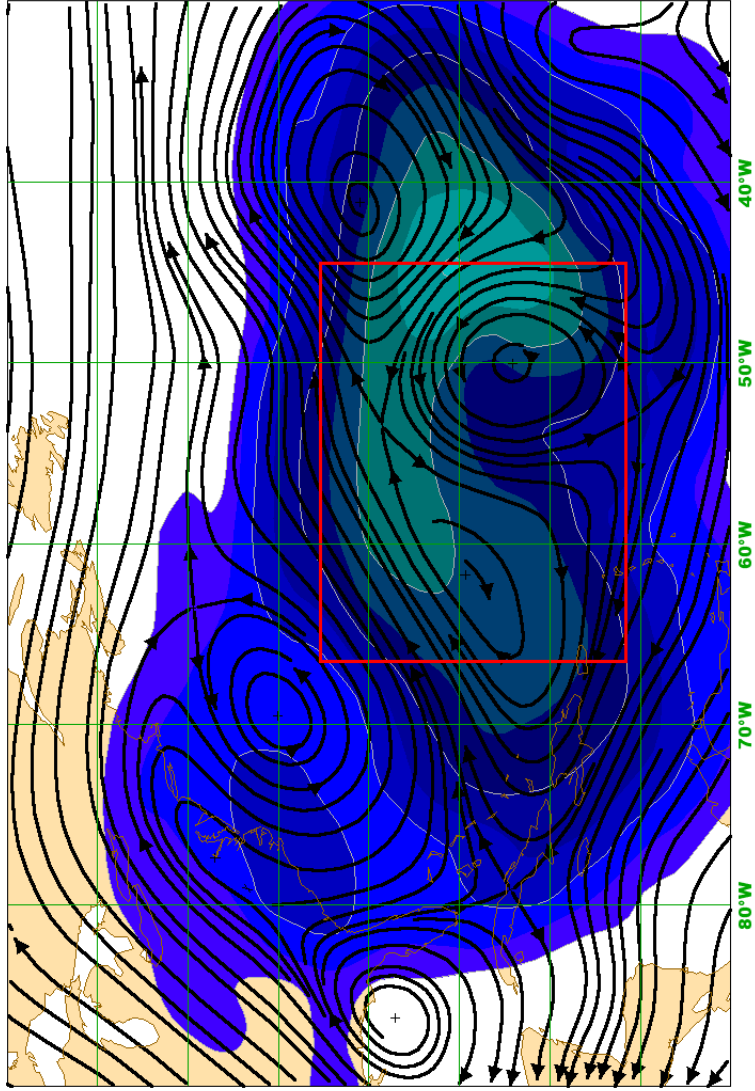
18.09.2006 12:00

T42

TL95

Ritz Values 7.5766 7.209 4.441 4.0231 3.8048

Ritz Values 30.3131 22.3968 15.8357 11.4496 8.3076



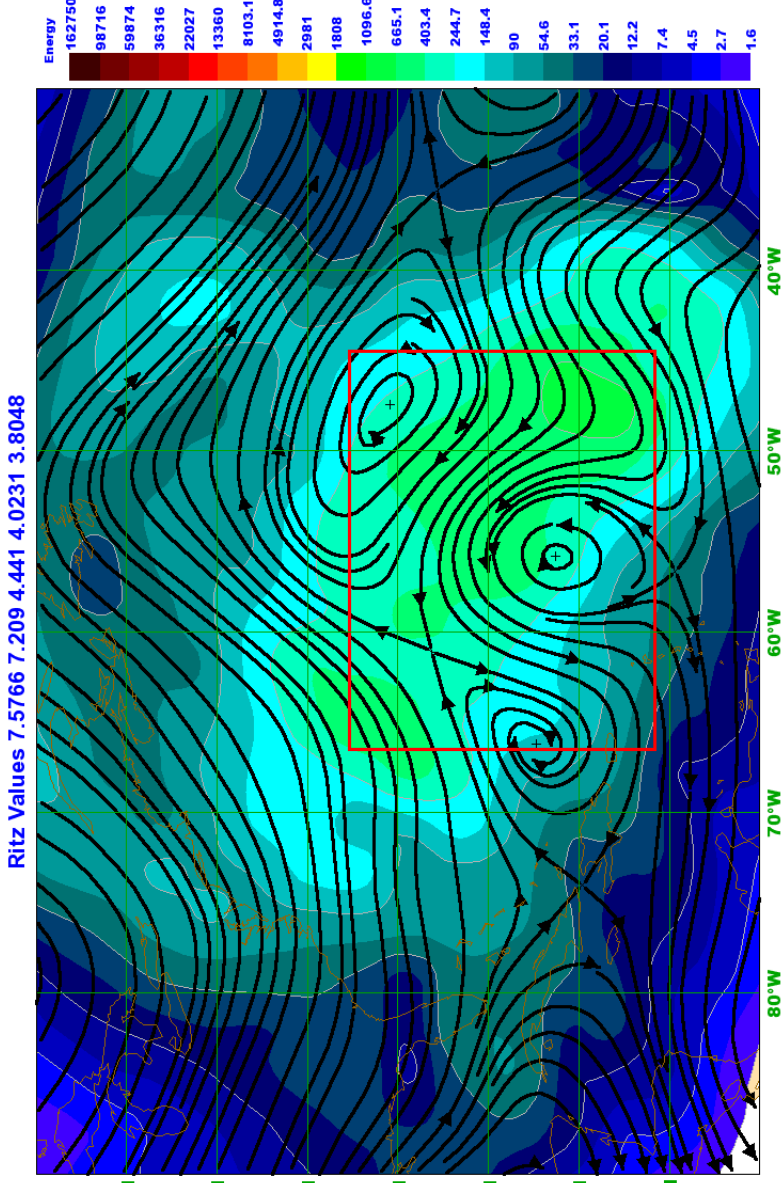
TL159

18.09.2006 12:00 + 48 h

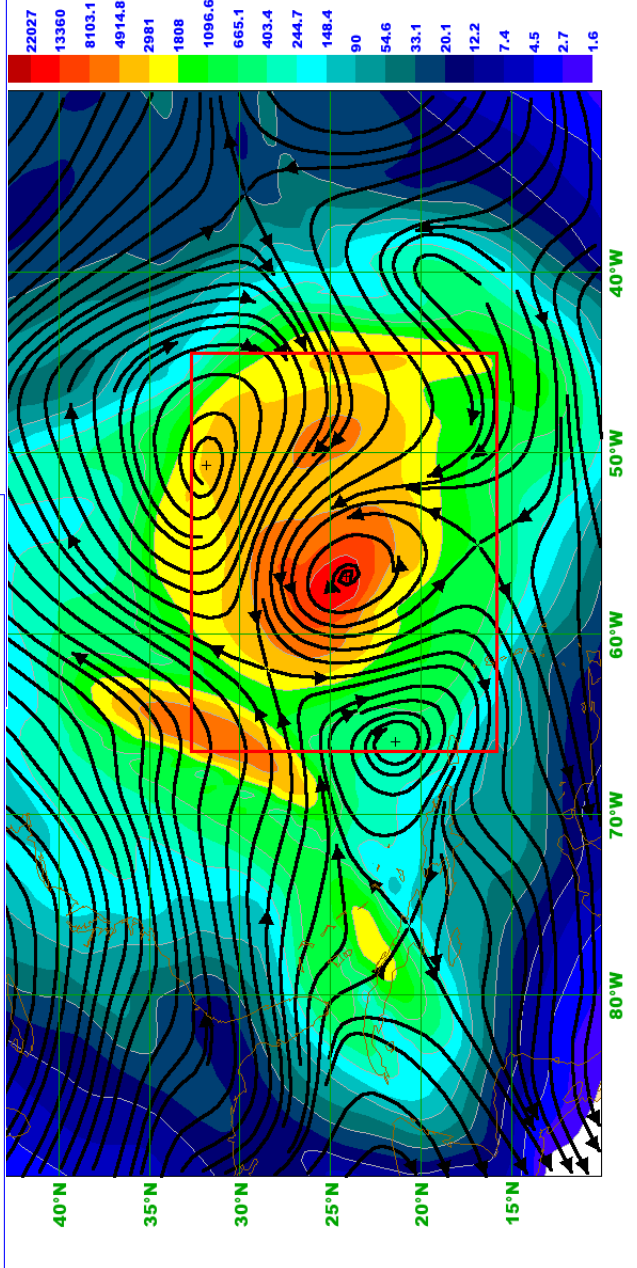
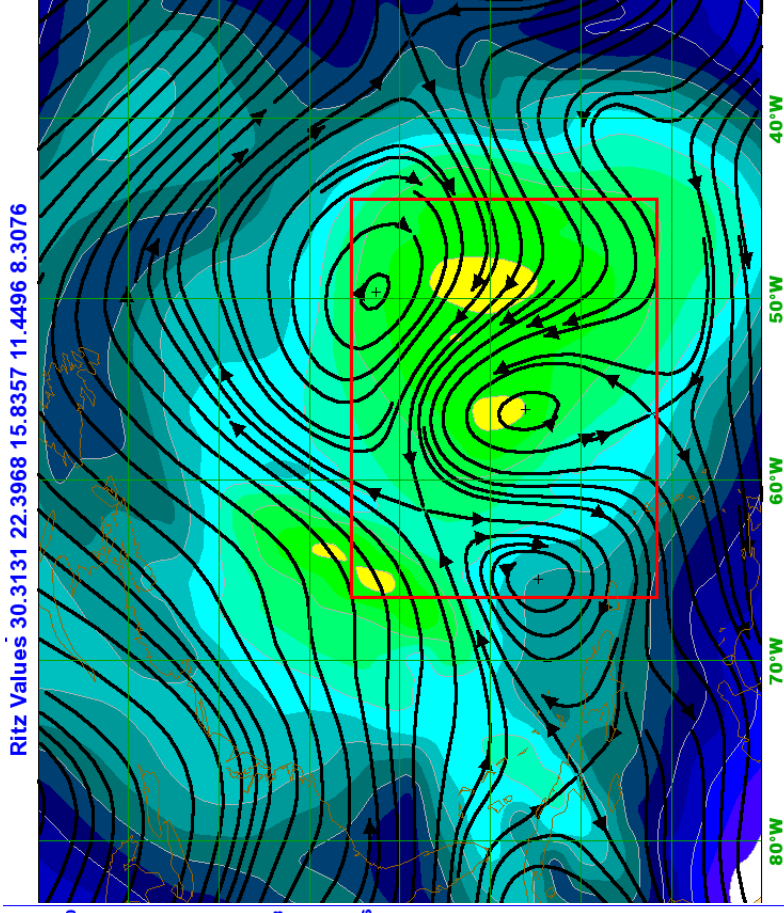
T42

TL95

Ritz Values 7.5766 7.209 4.441 4.0231 3.8048

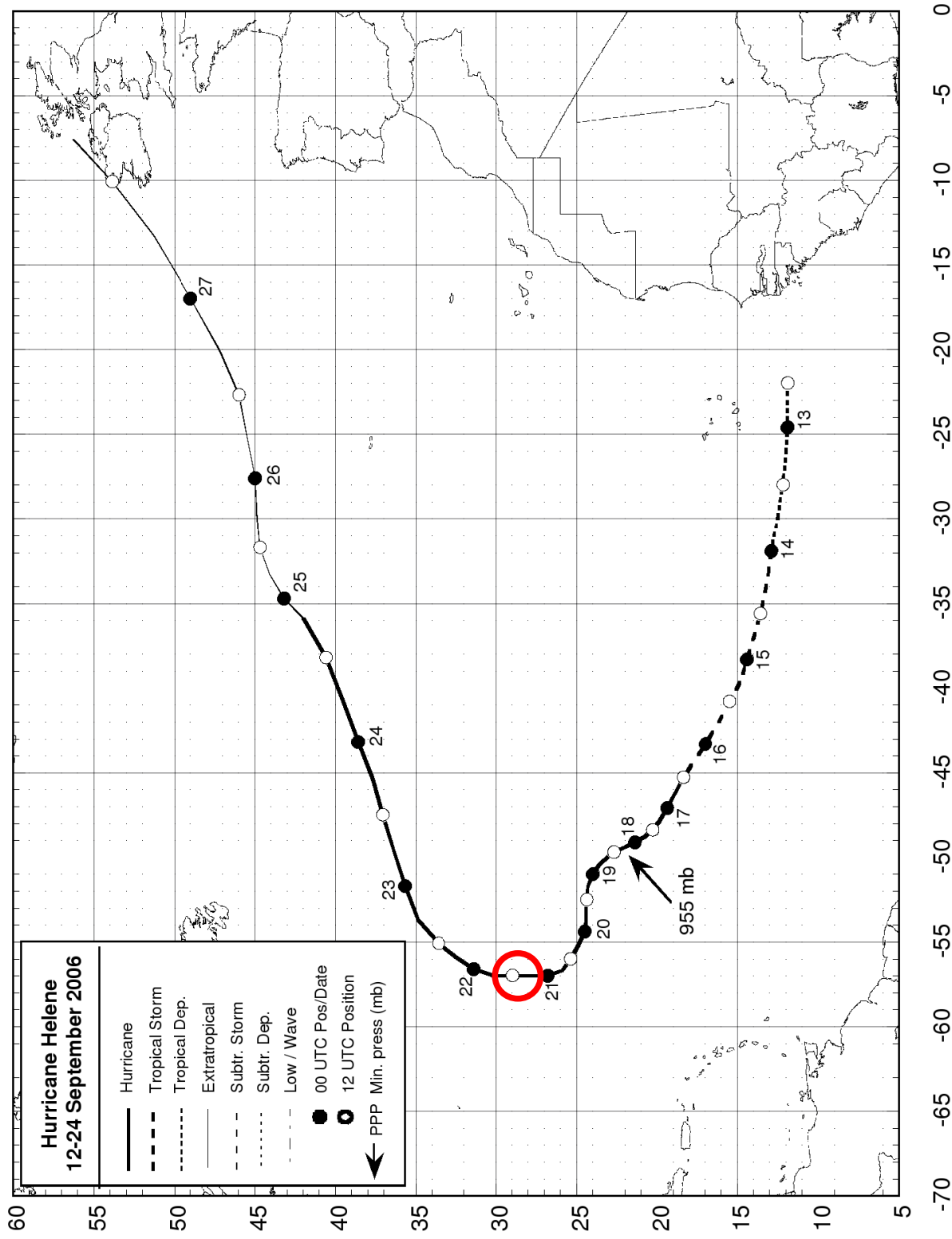


Ritz Values 30.3131 22.3968 15.8357 11.4496 8.3076



TL159

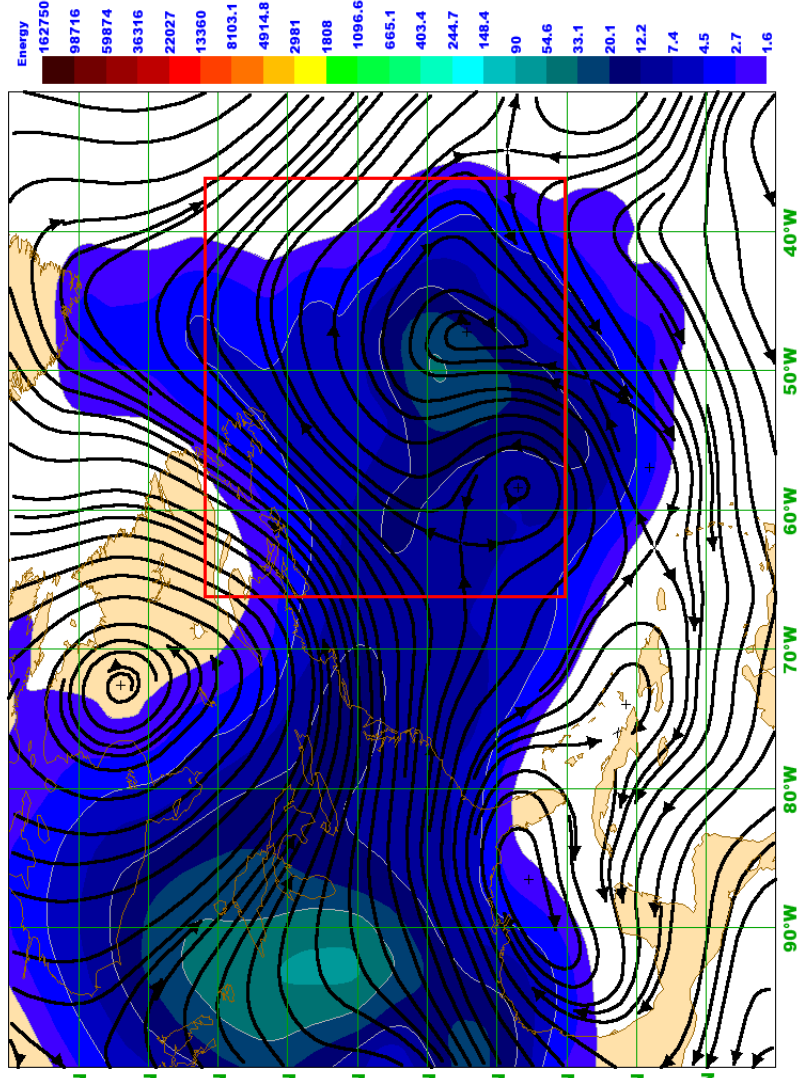
Helene 2006



21.09.2006 12:00

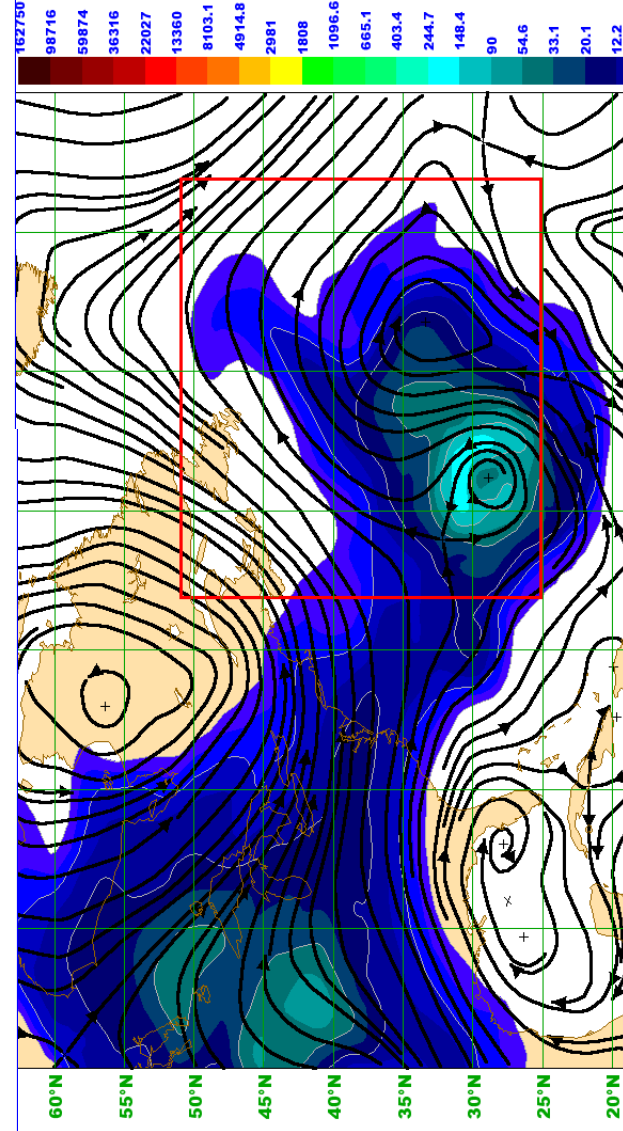
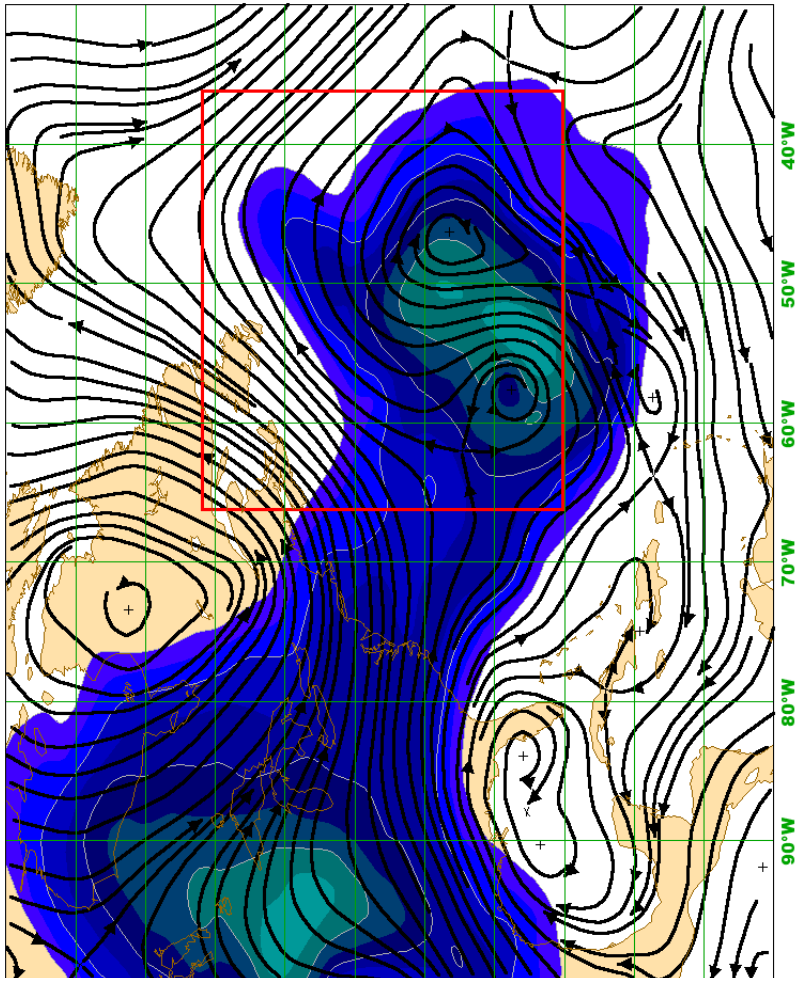
T42

Ritz Values 64.579 39.279 19.4884 15.6104 12.9837



TL95

Ritz Values 304.385 88.277 44.207 39.064 32.227

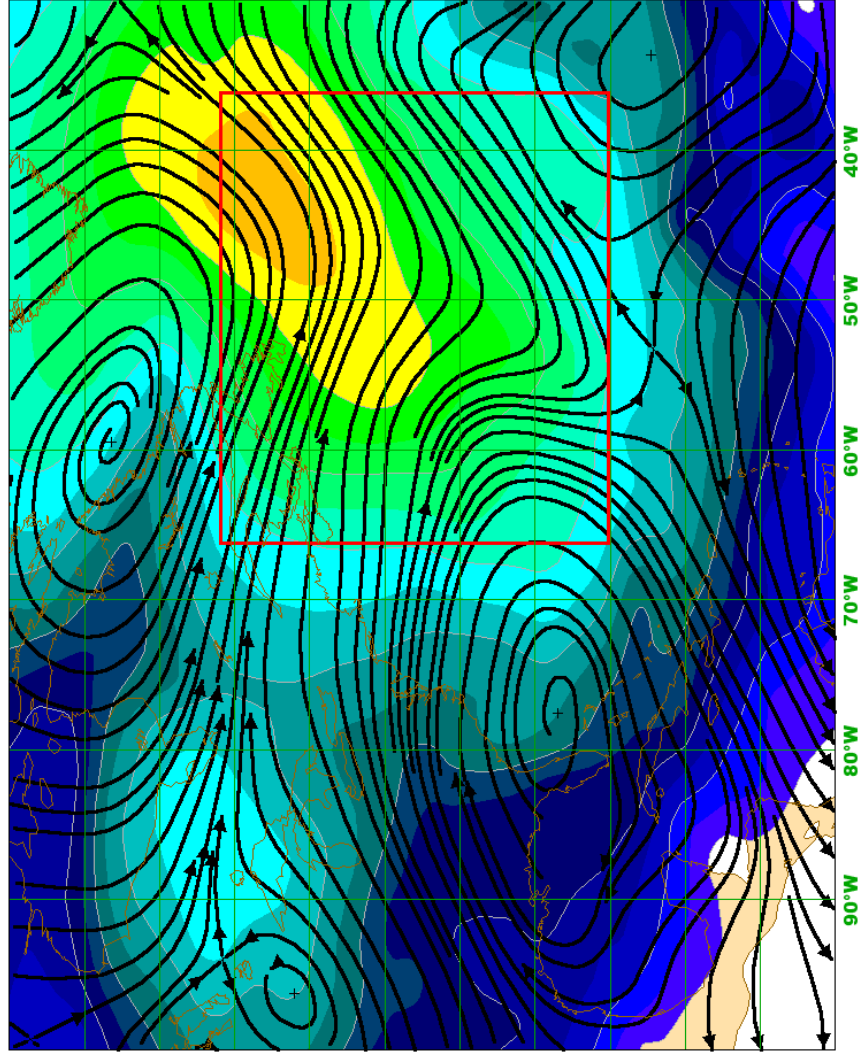


TL159

21.09.2006 12:00 + 48h

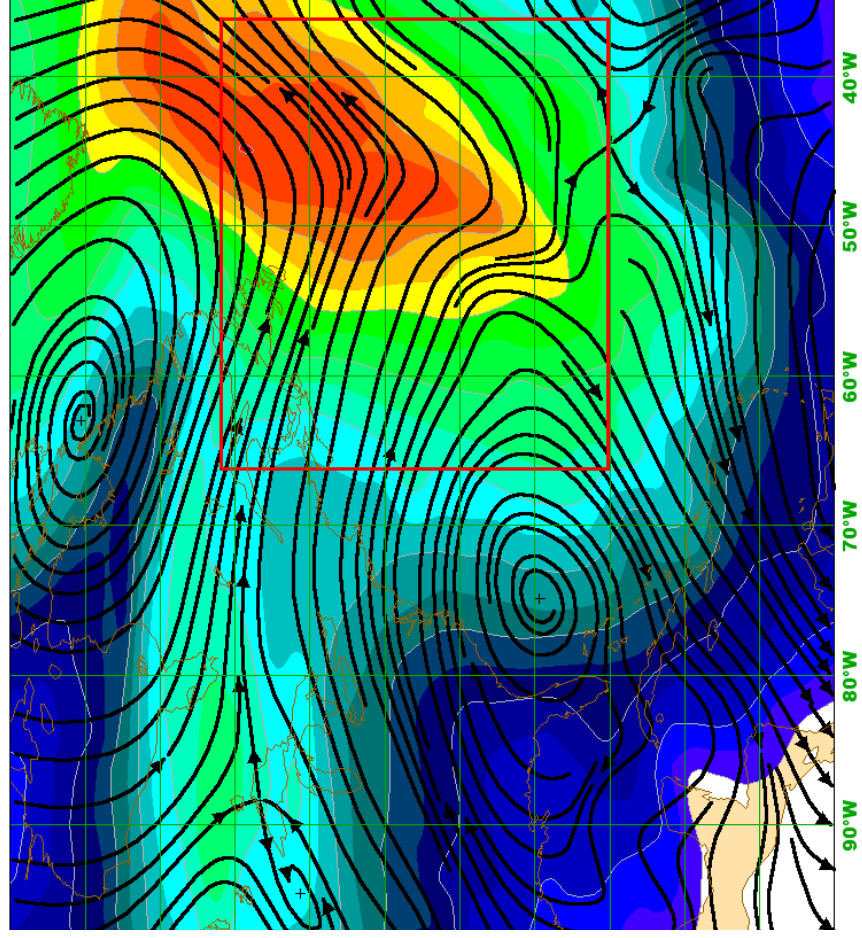
T42

Ritz Values 64.579 39.279 19.4884 15.6104 12.9837

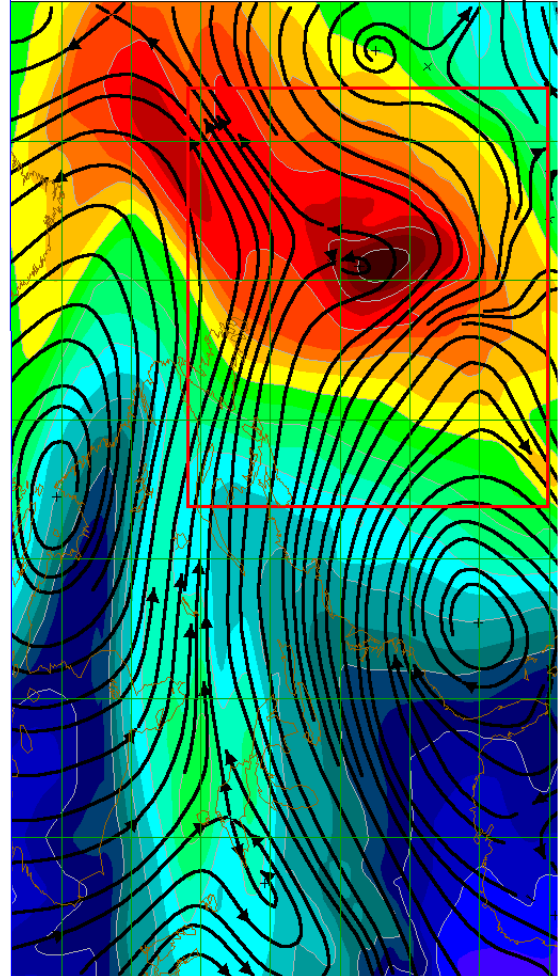


TL95

Ritz Values 304.385 88.277 44.207 39.064 32.227



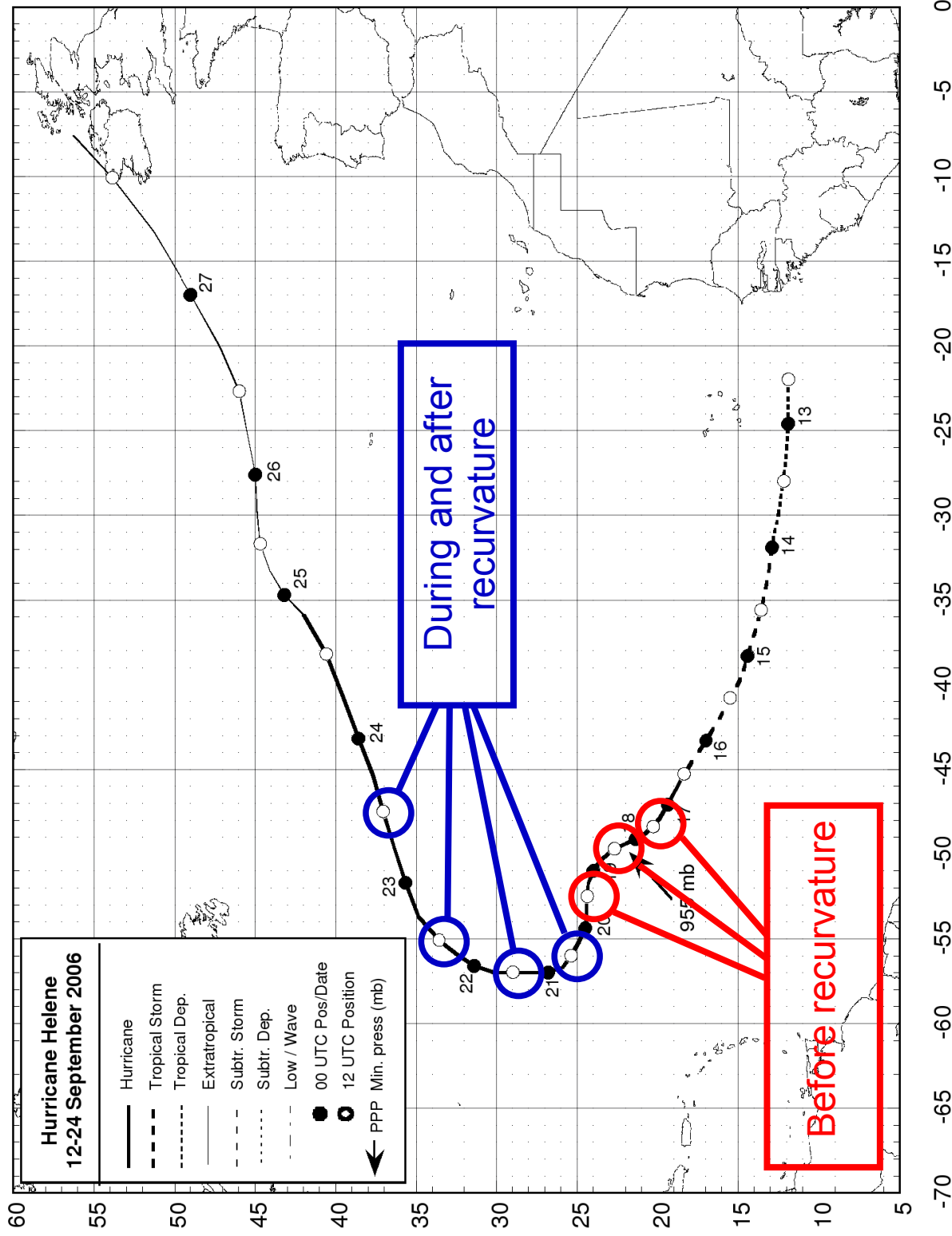
60°N
55°N
50°N
45°N
40°N
35°N
30°N
25°N



TL159

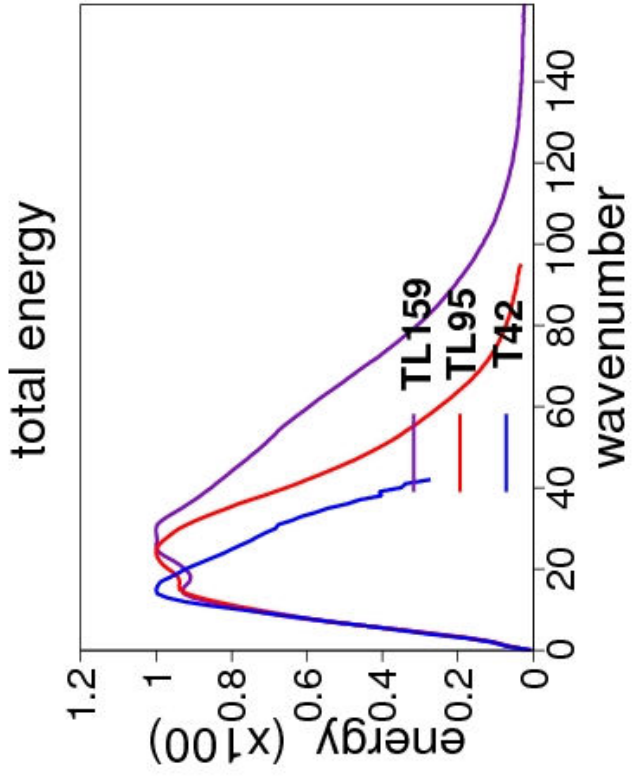
162750
98716
59874
36316
22027
13360
8103.1
4914.8
2981
1808
1096.6
665.1
403.4
244.7
148.4
90
54.6

Helene 2006



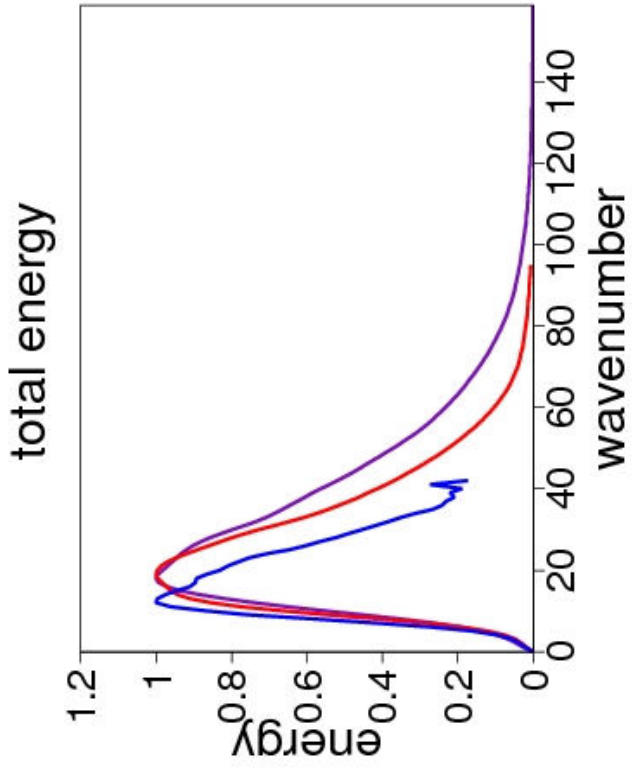
Spectra of Vertical Integrated Total Energy

Initial Singular Vectors

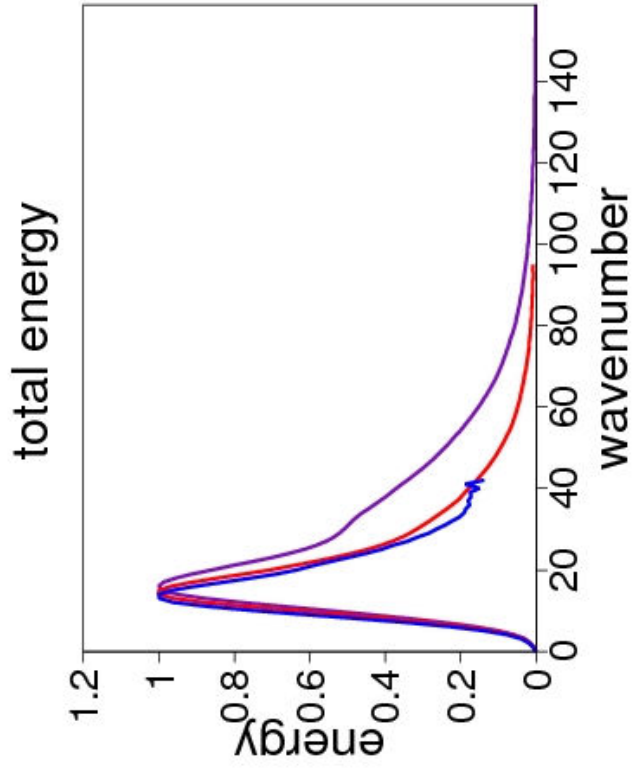
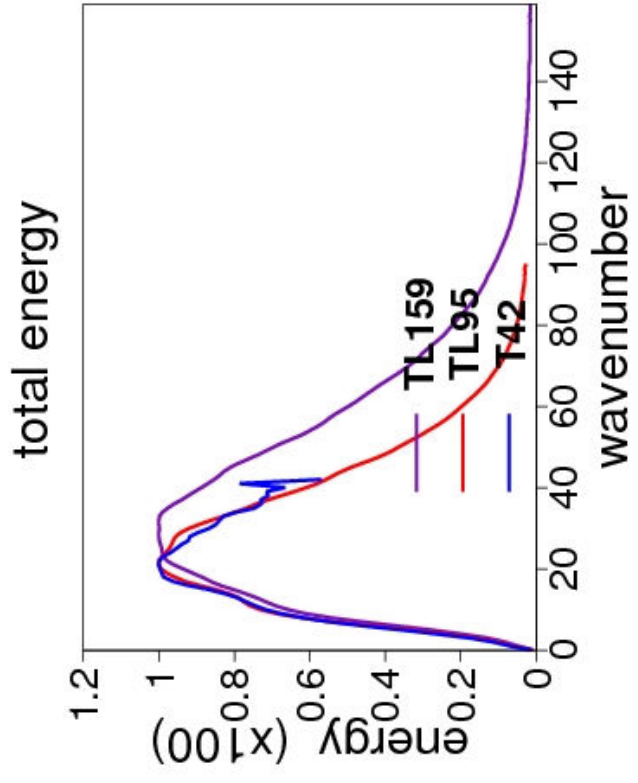


before recurvature

evolved Singular Vectors

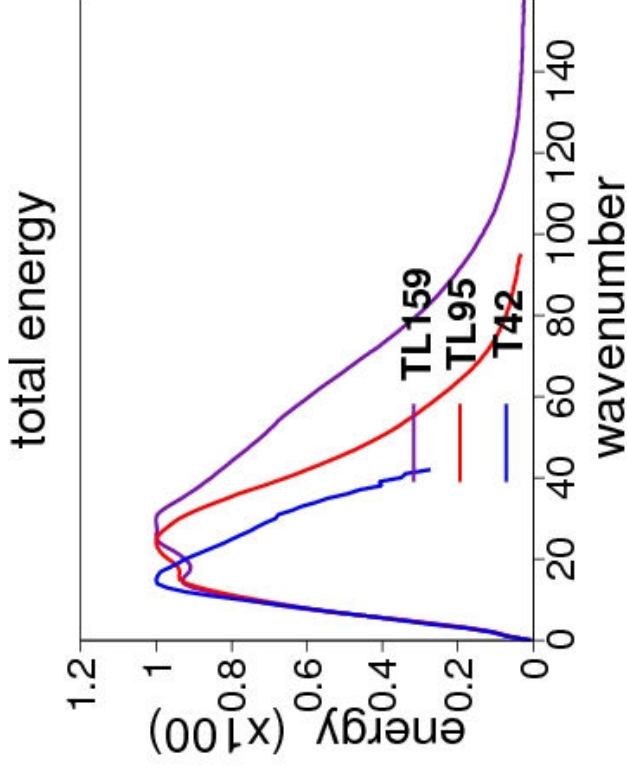


during / after recurvature



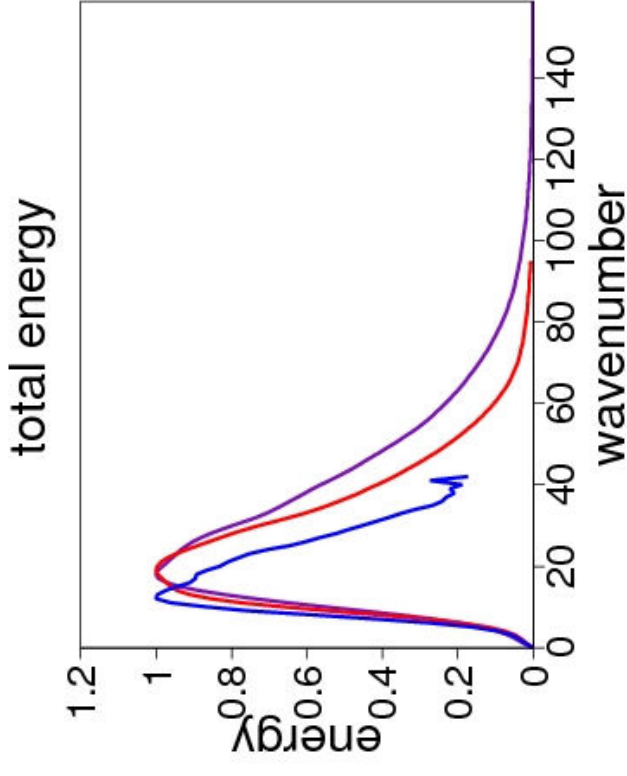
Spectra of Vertical Integrated Total Energy

Initial Singular Vectors



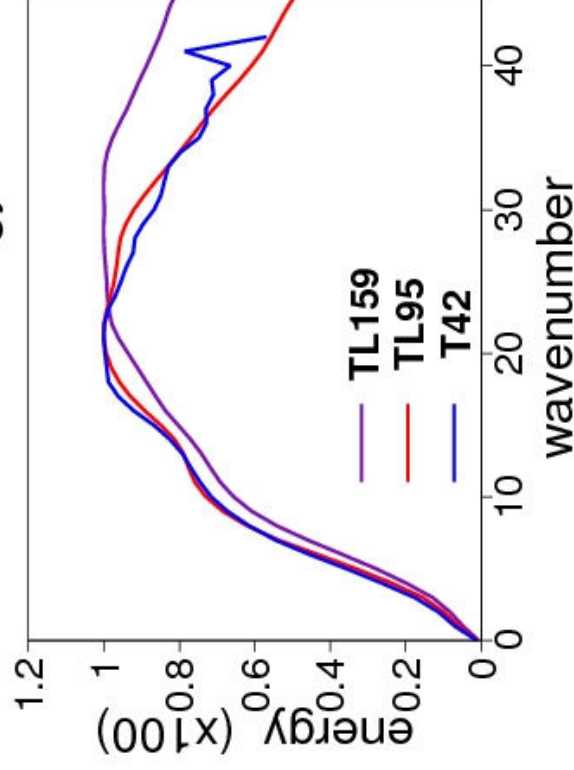
before
recurvature

evolved Singular Vectors

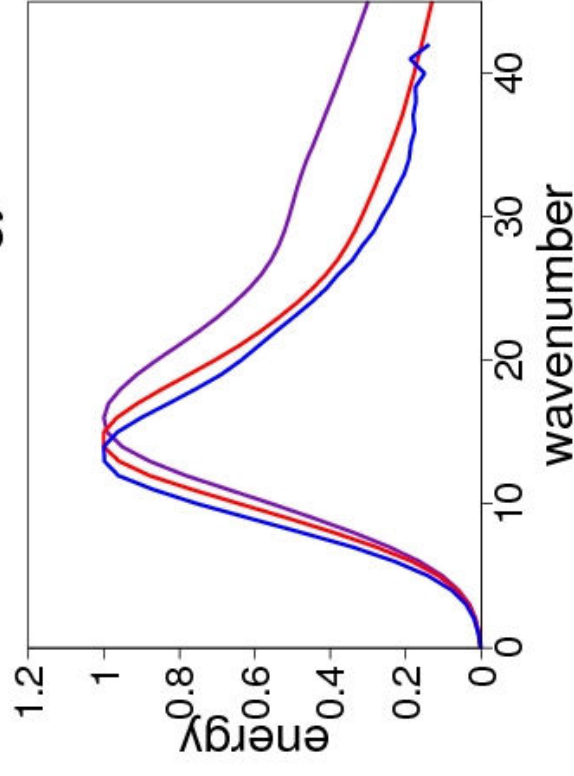


during / after
recurvature

total energy



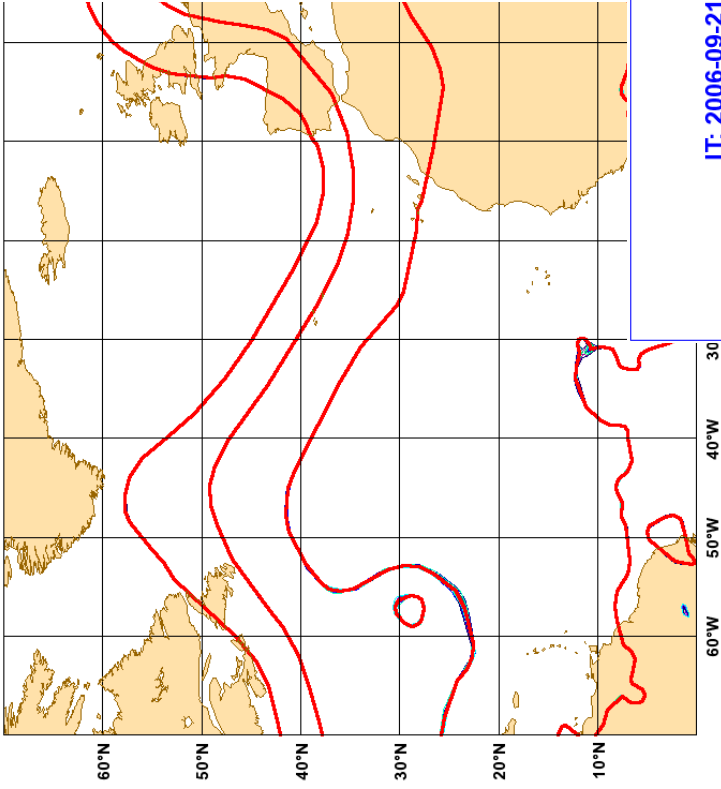
total energy



EPS-Experiments

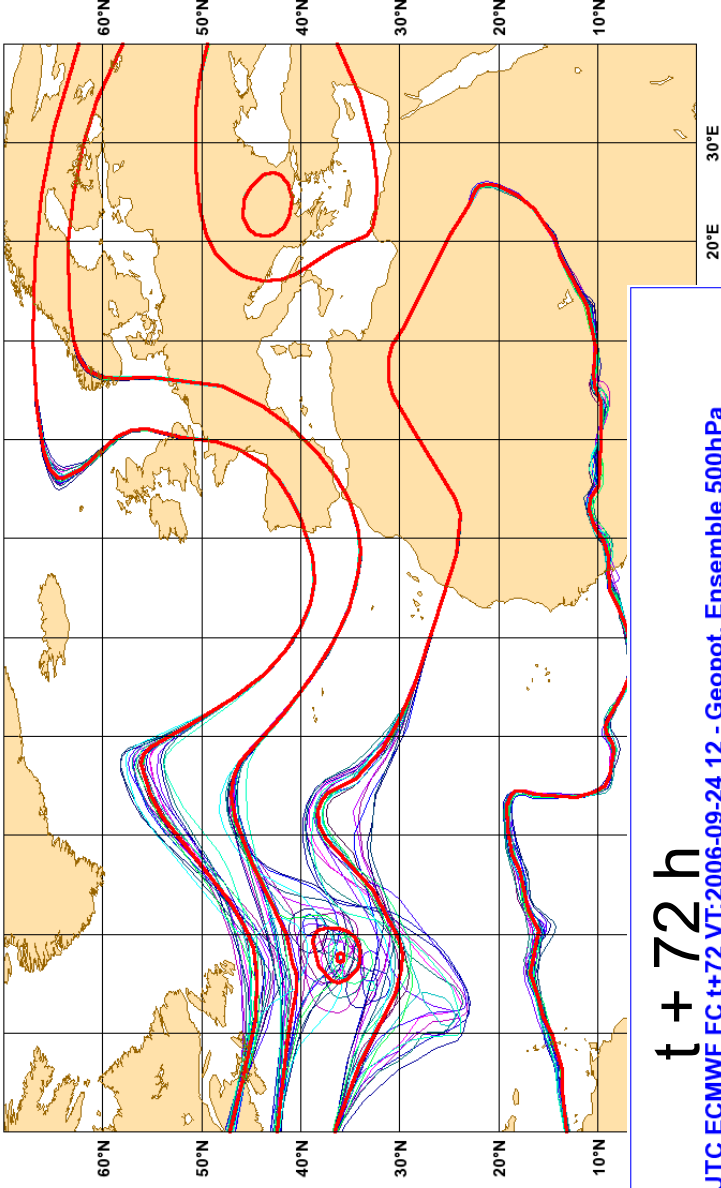
t + 0 h

IT: 2006-09-21 12UTC ECMWF FC t+0 VT:2006-09-21 12
Red : Control Forecast, Coloured: Ensemble Forecast, 20 members



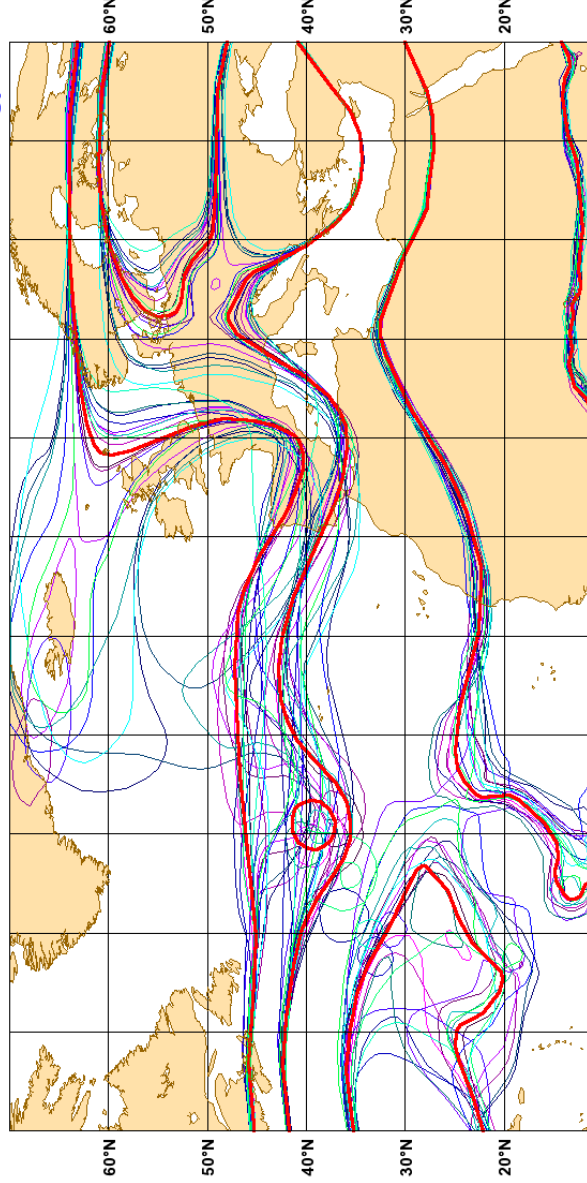
t + 36 h

IT: 2006-09-21 12UTC ECMWF FC t+36 VT:2006-09-23 00 - Geopot. Ensemble 500hPa
Red : Control Forecast, Coloured: Ensemble Forecast, 20 members, for 564, 576, 588 gpdm

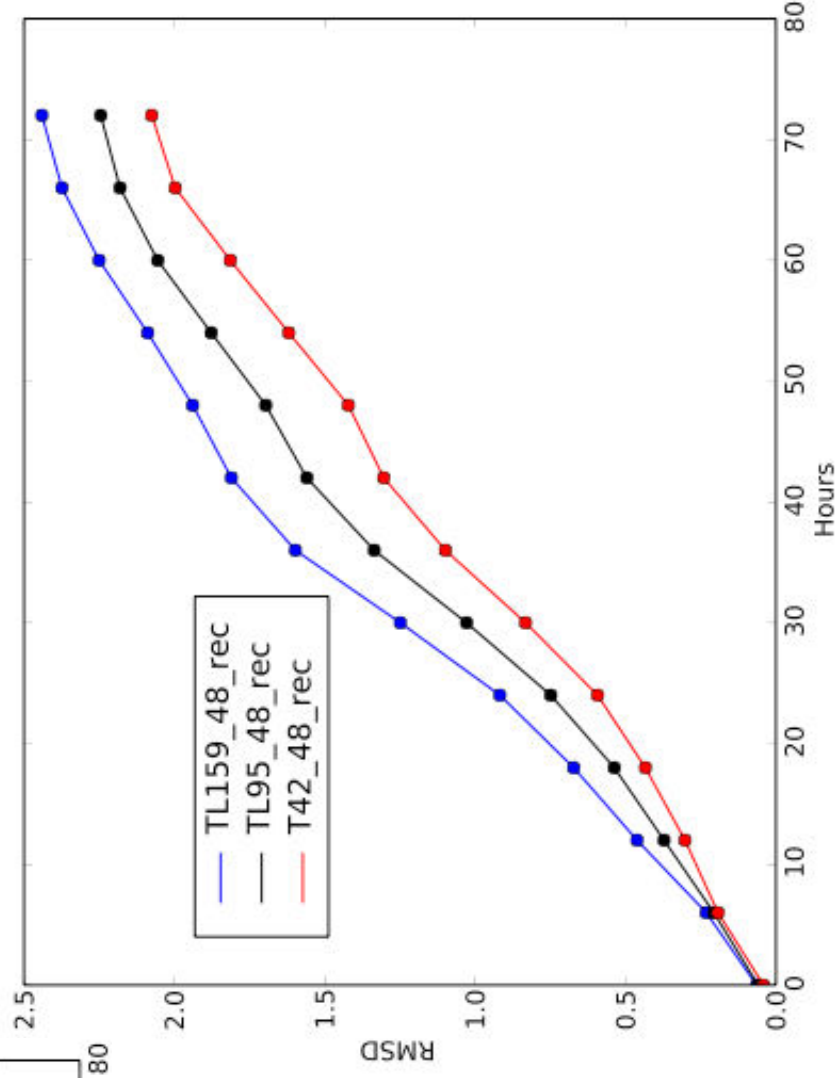
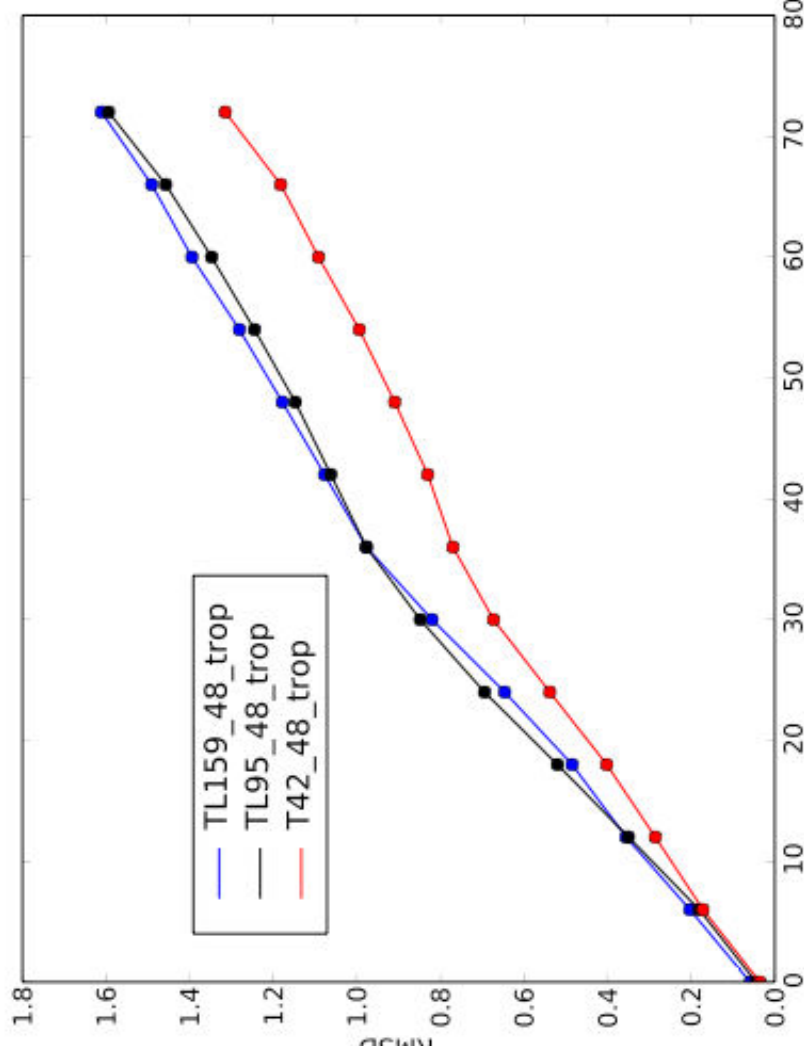


t + 72 h

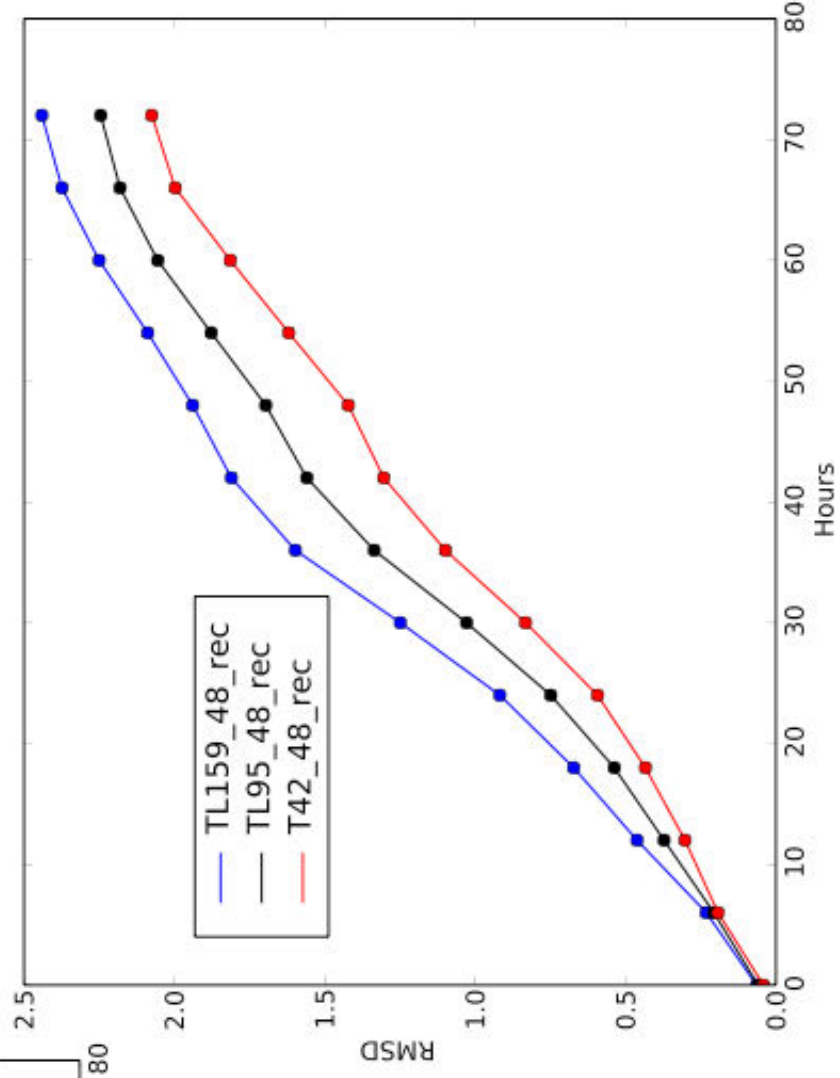
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Red : Control Forecast, Coloured: Ensemble Forecast, 20 members, for 564, 576, 588 gpdm



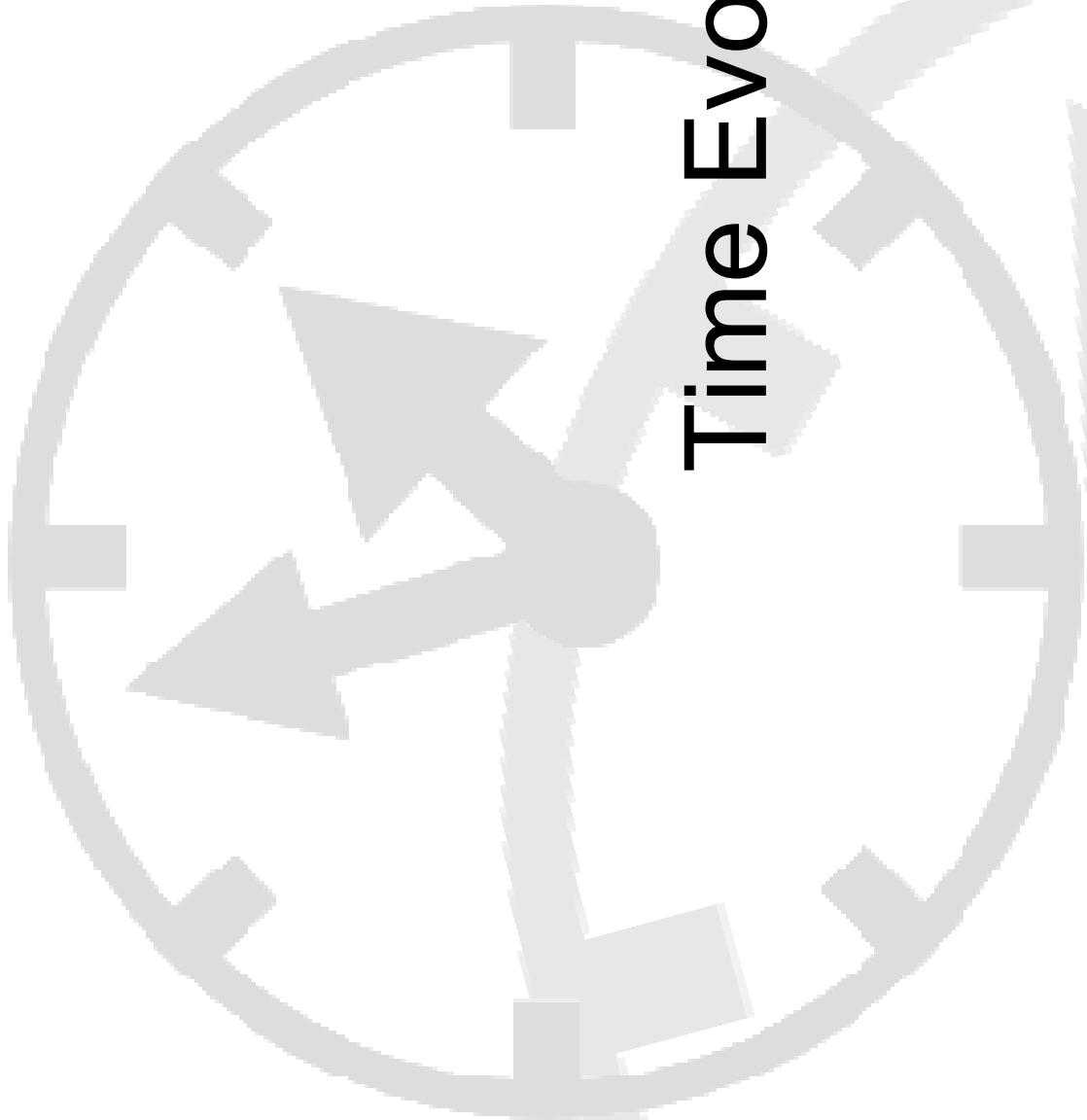
Before recurvature



During / after recurvature

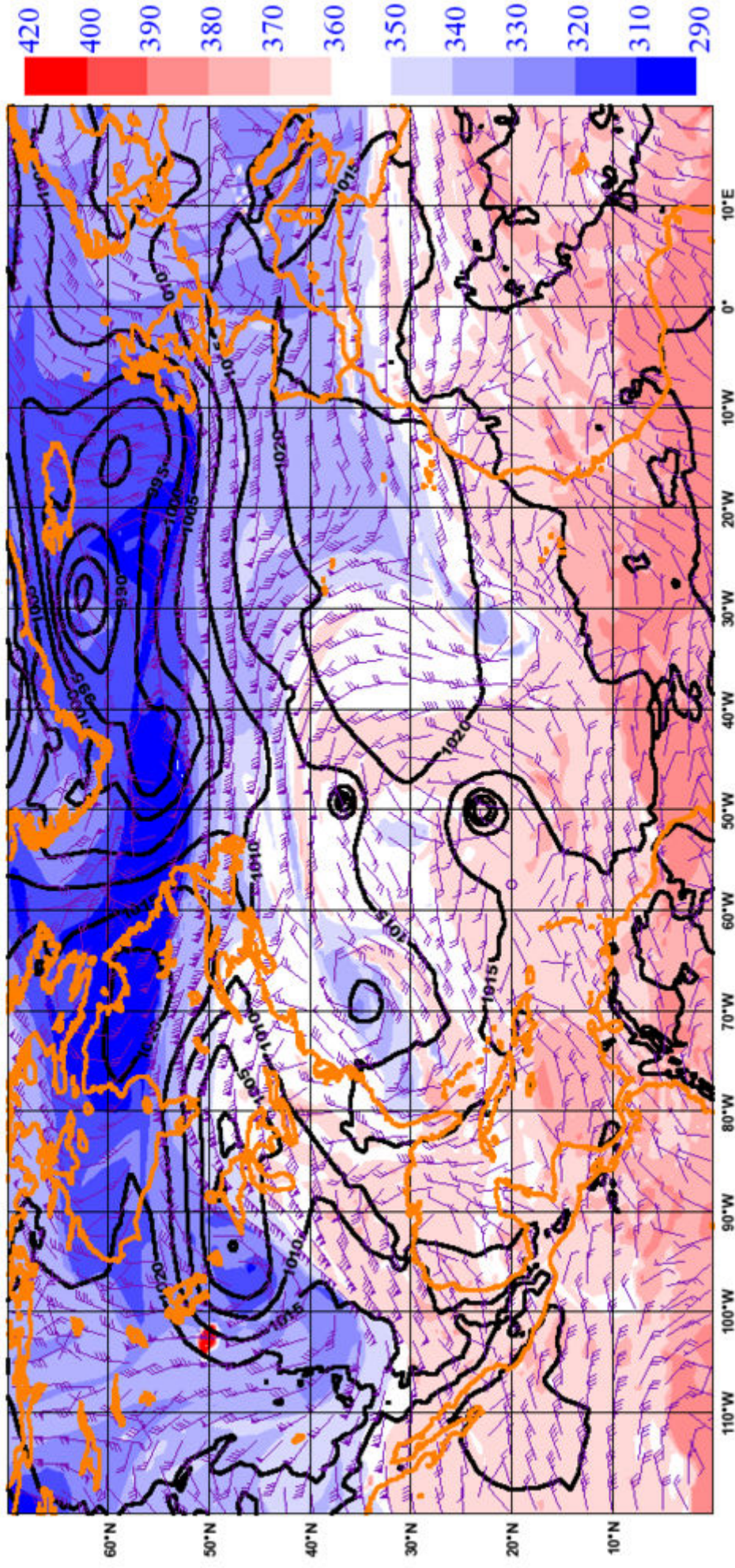


Time Evolution of SV 1



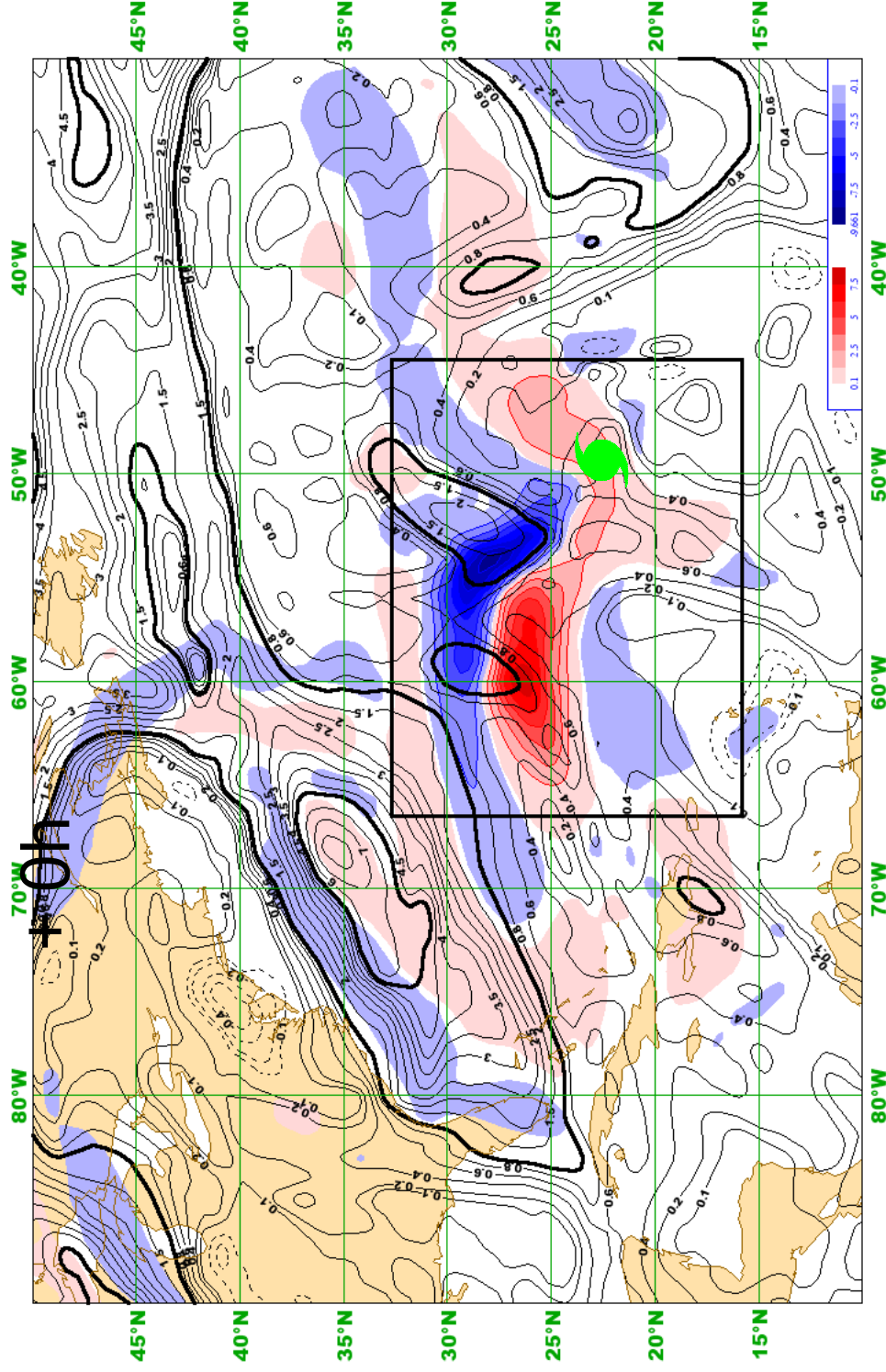
18.09.2006

IT: 2006-09-18 12UTC ECMWF FC t+0 VT:2006-09-18 12 - 2PVU PotT / Wind / Pmsl



TL159

Level 20 ~ 200hPa



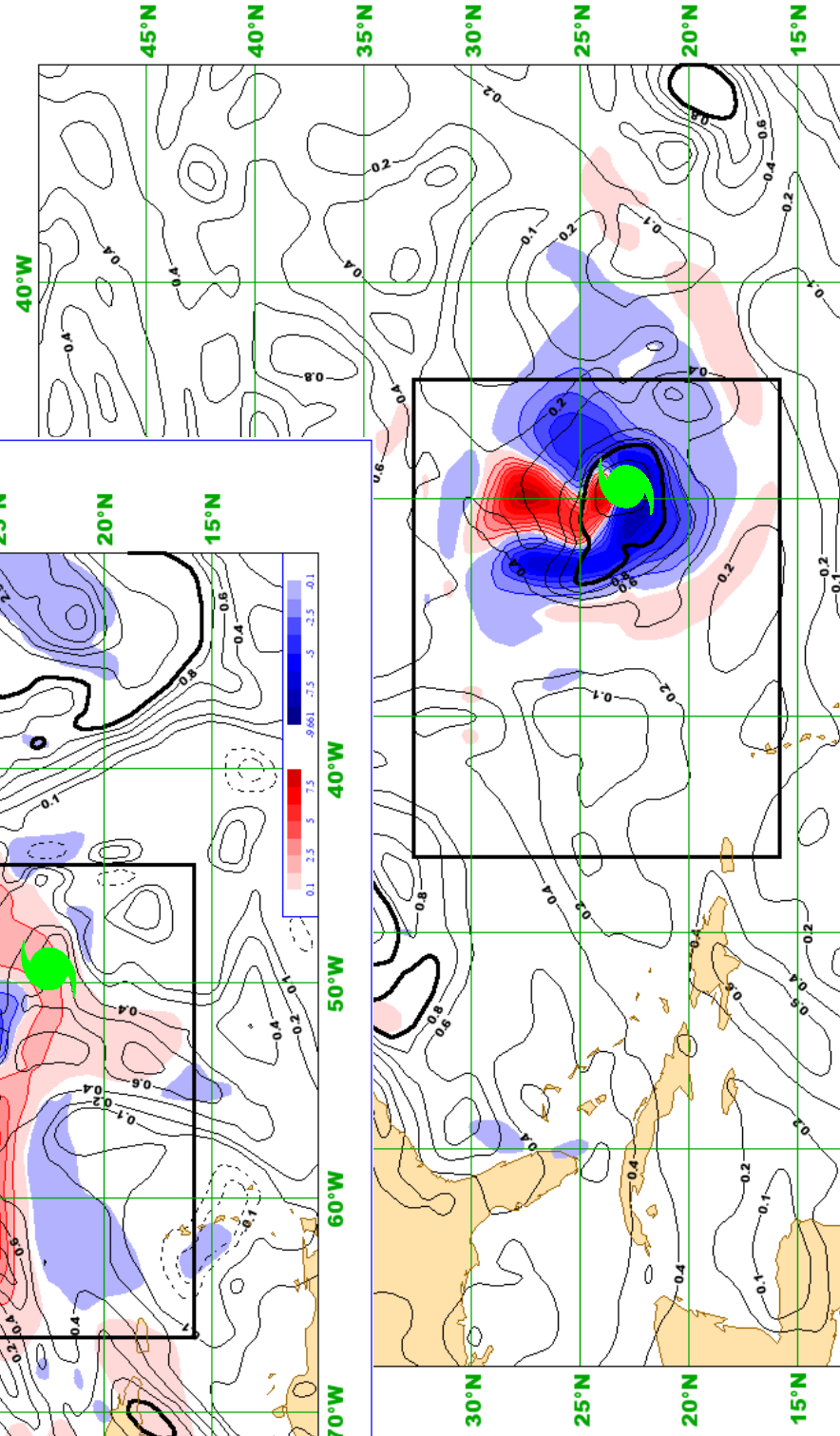
Contours:

Black : PV Traj.

Red : Pos. Pert.

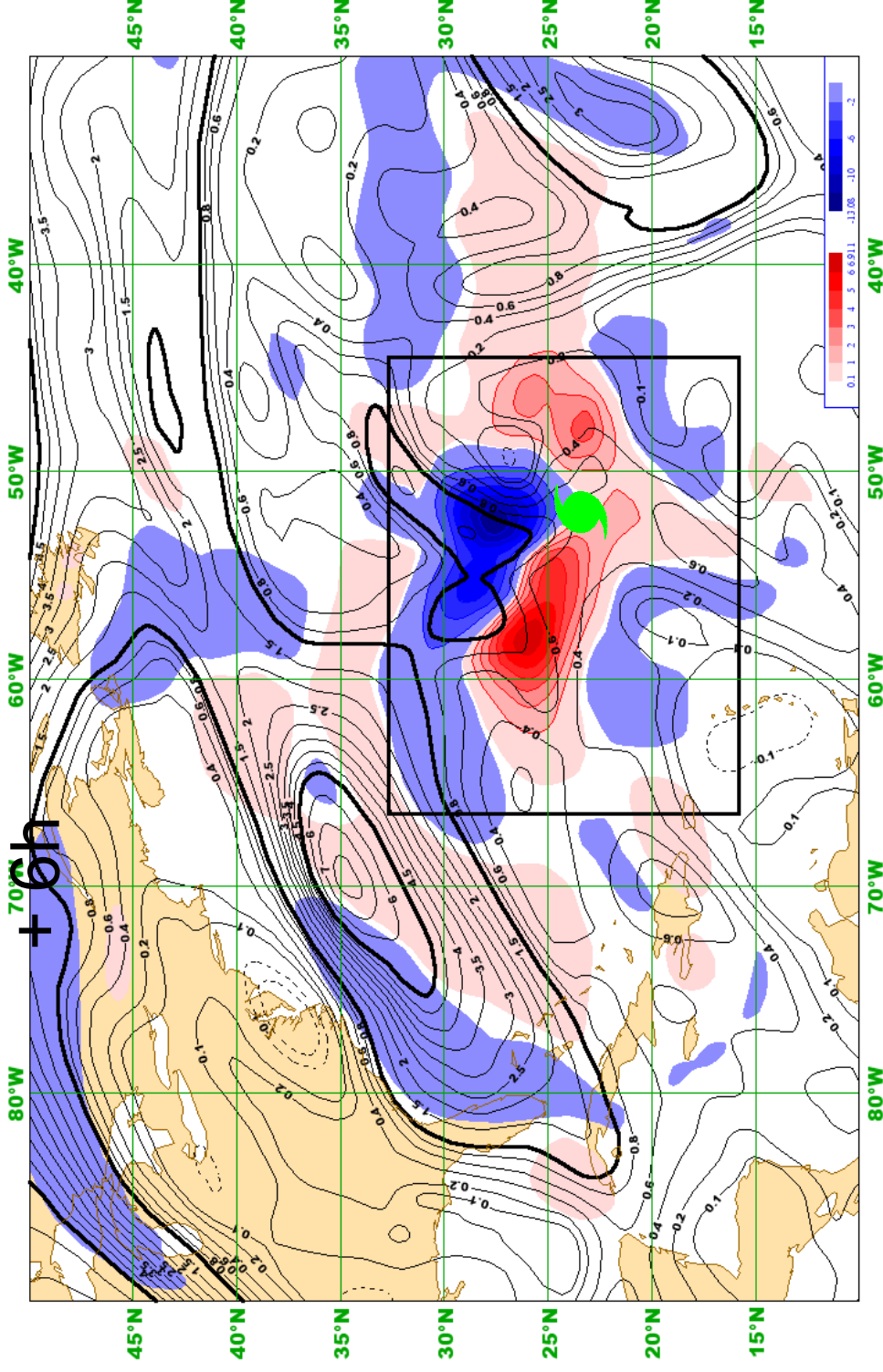
Blue : Neg. Pert.

Level 30 ~ 370hPa



TL159

Level 20 ~ 200hPa



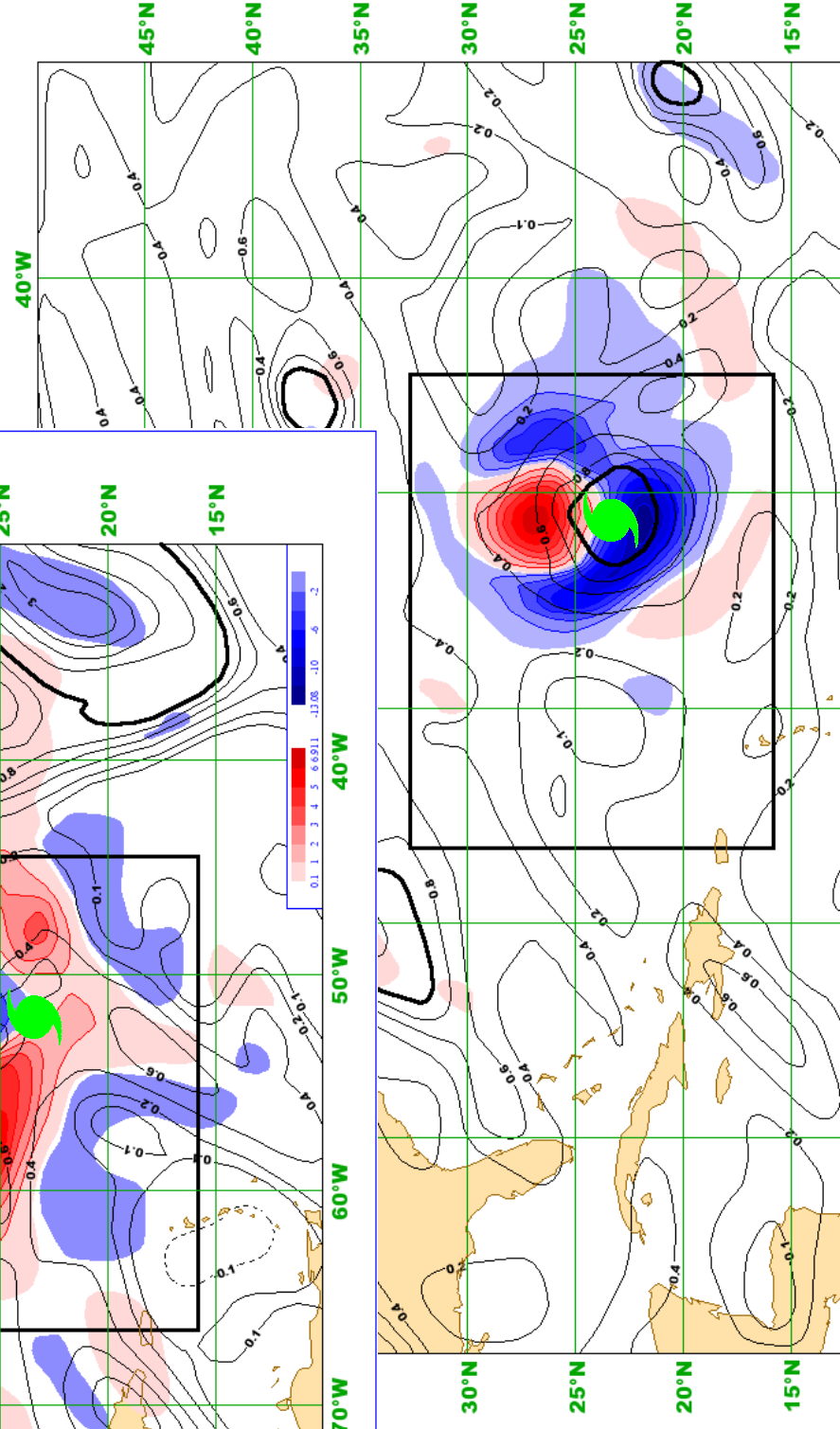
Contours:

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Red : Pos. Pert.

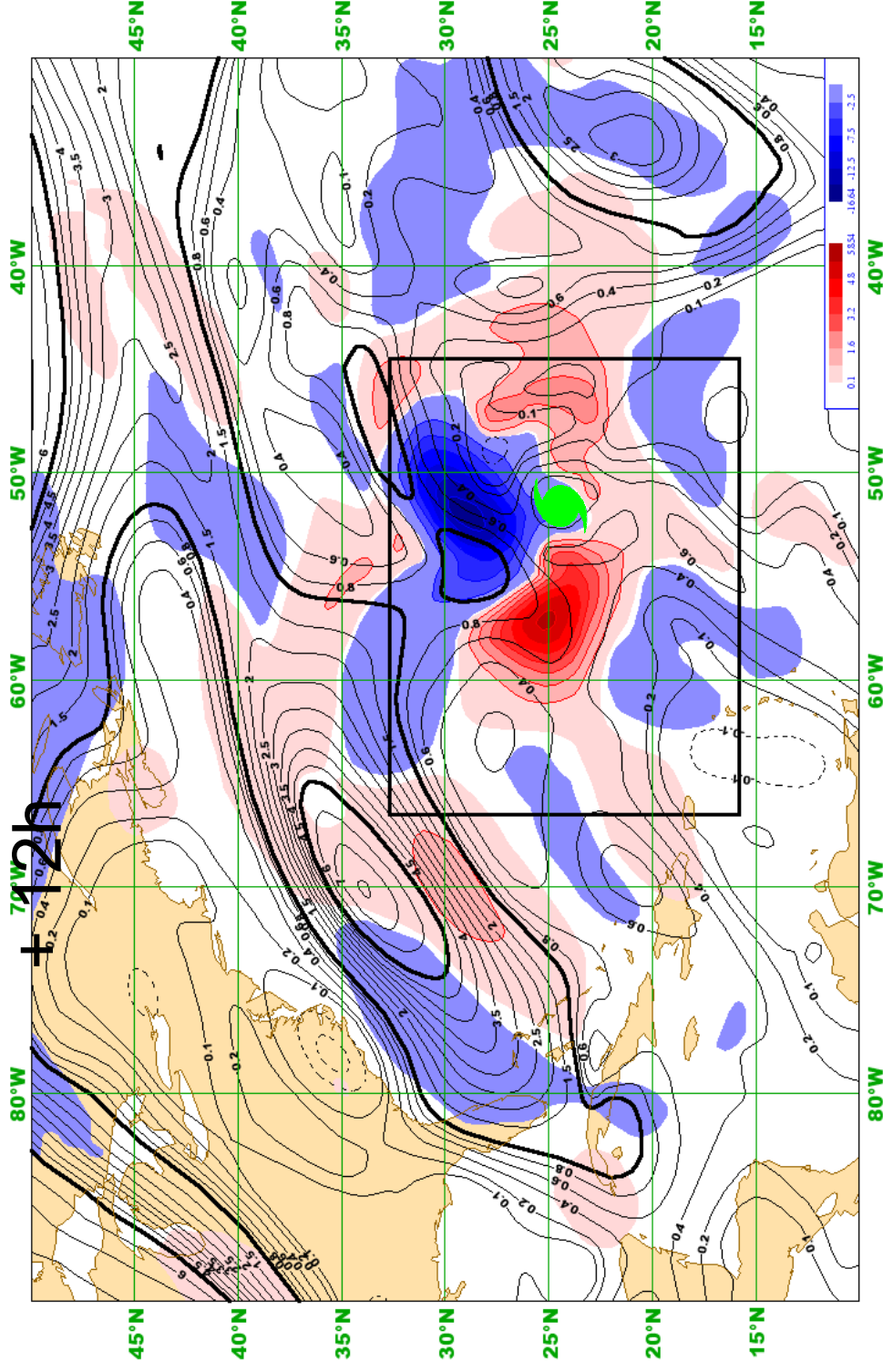
Blue : Neg. Pert.

Level 30 ~ 370hPa



TL159

Level 20 ~ 200hPa



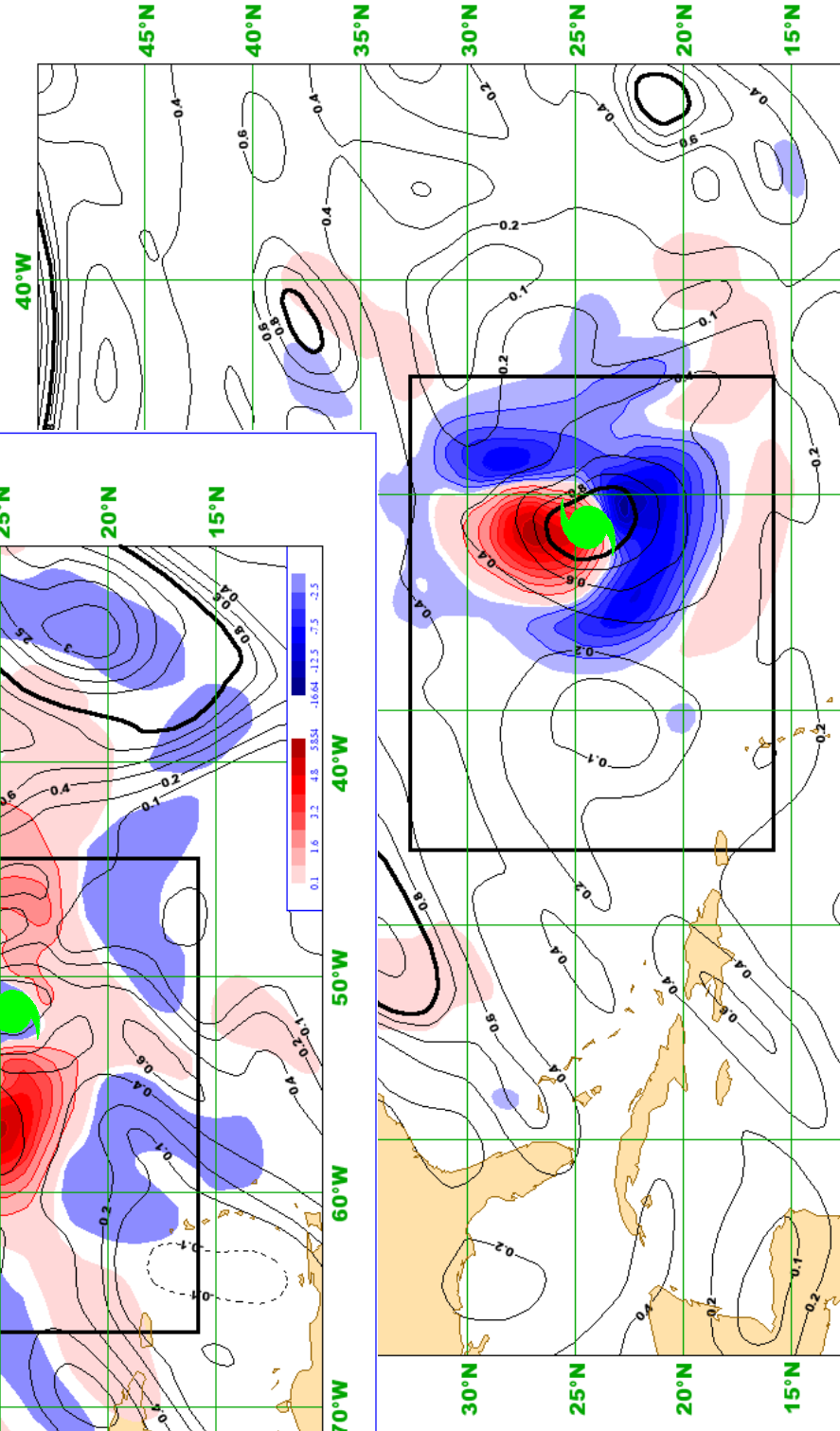
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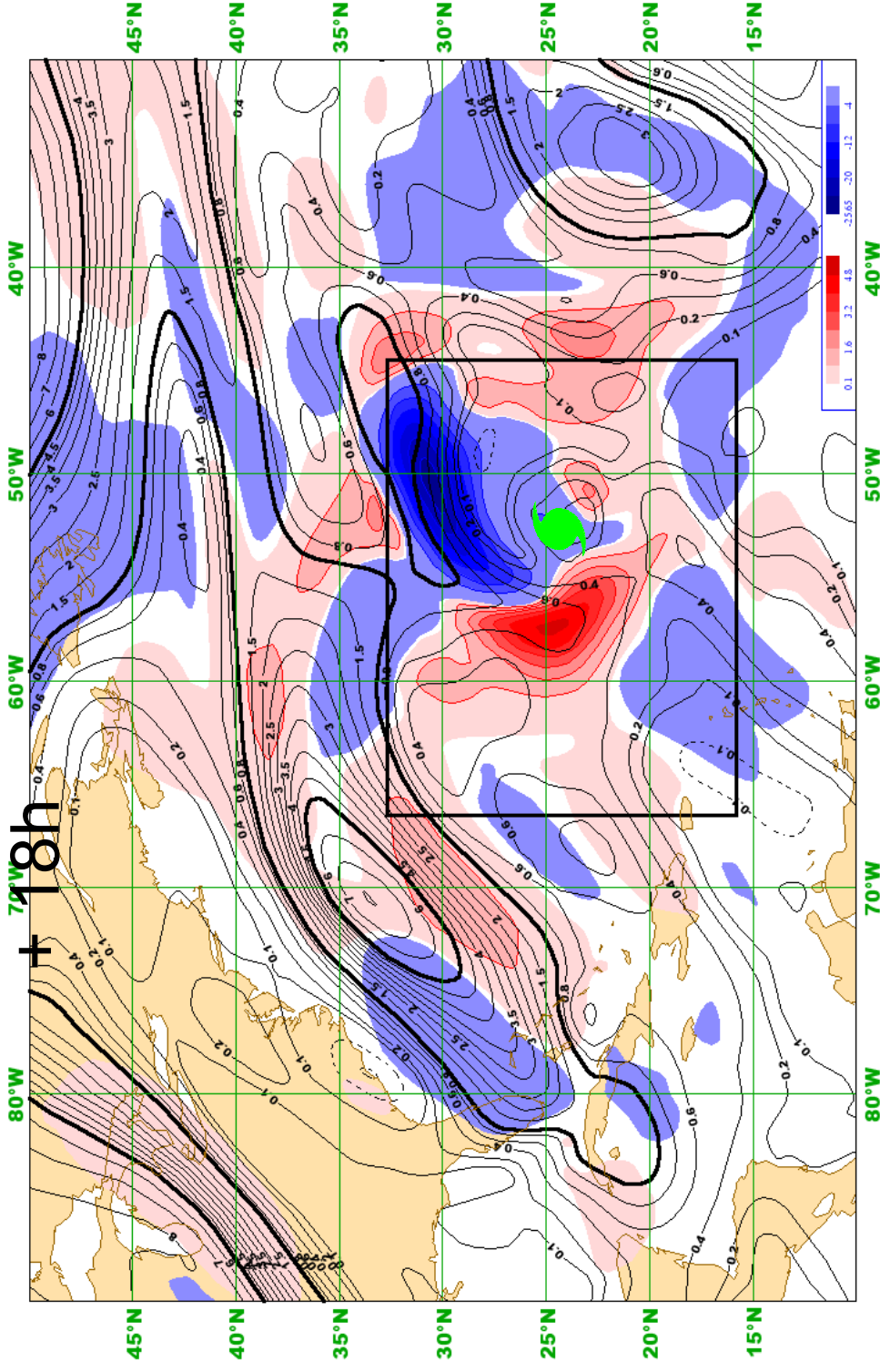
Blue : Neg. Pert.

Level 30 ~ 370hPa



TL159

Level 20 ~ 200hPa



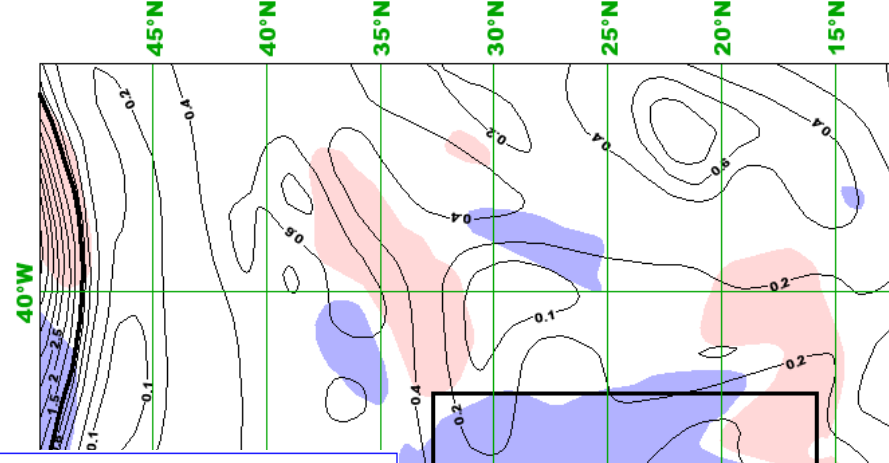
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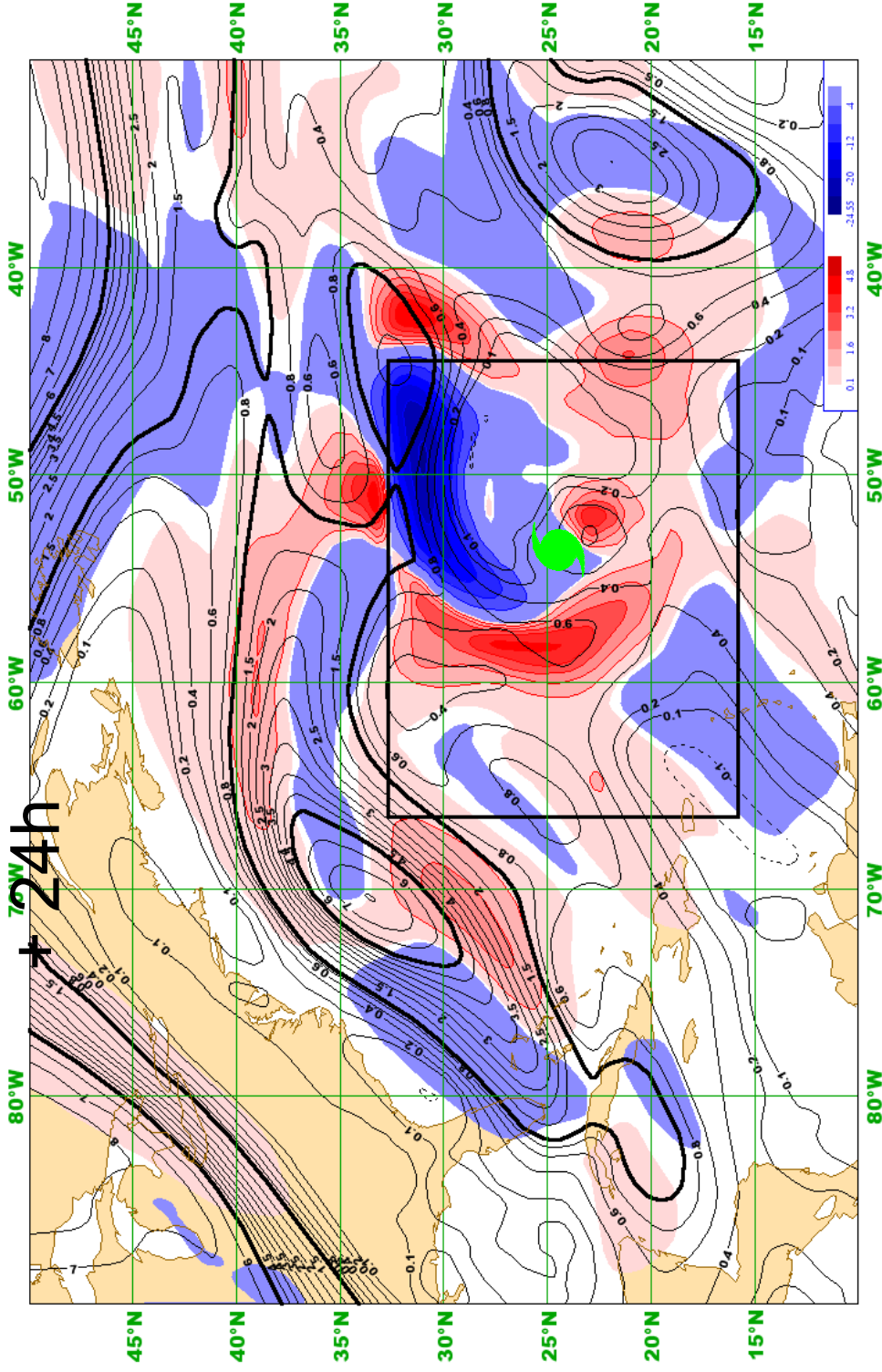
Blue : Neg. Pert.

Level 30 ~ 370hPa



TL159

Level 20 ~ 200hPa



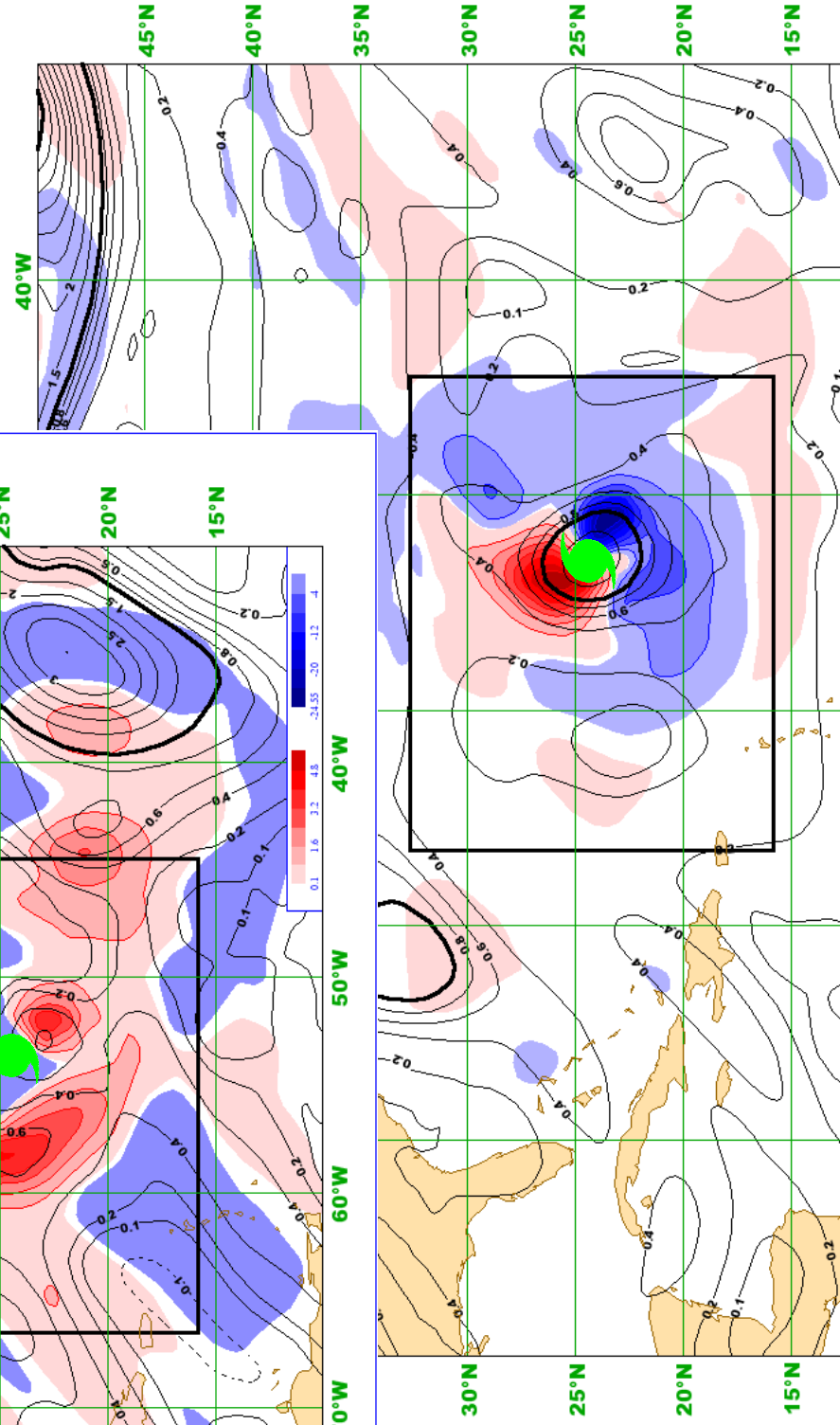
Contours:

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Red : Pos. Pert.

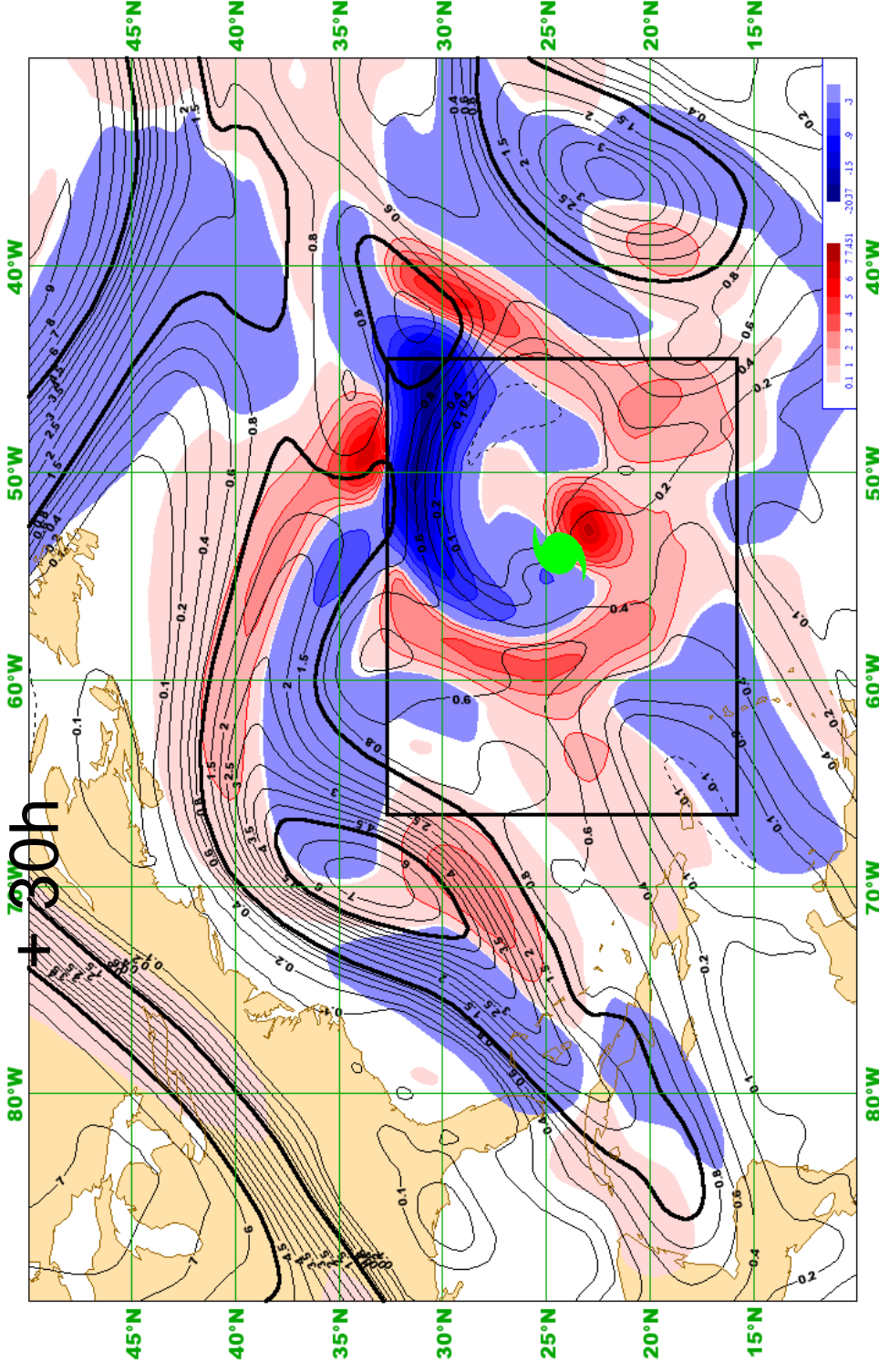
Blue : Neg. Pert.

Level 30 ~ 370hPa



TL159

Level 20 ~ 200hPa



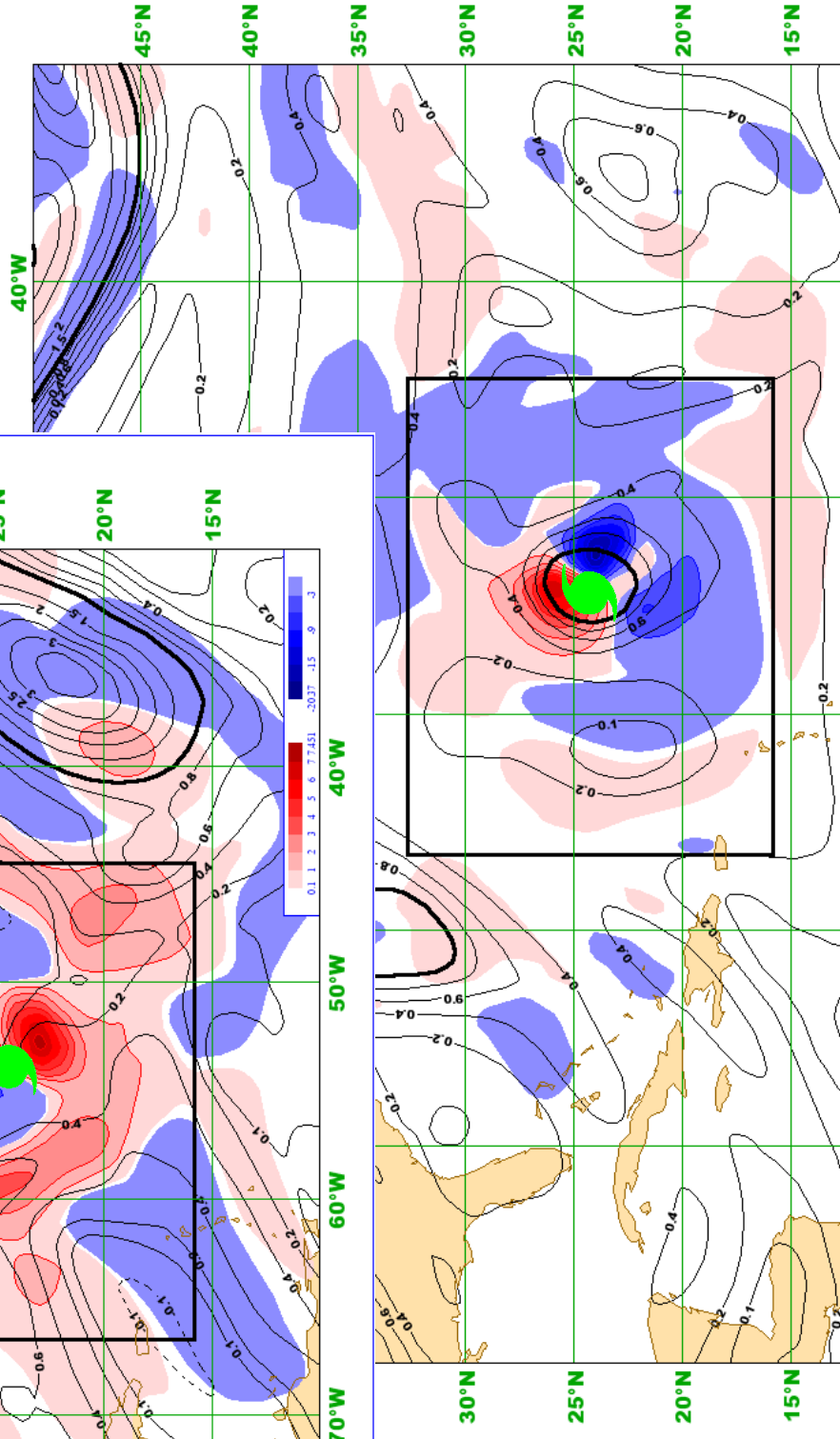
Contours:

Black : PV Traj.

Red : Pos. Pert.

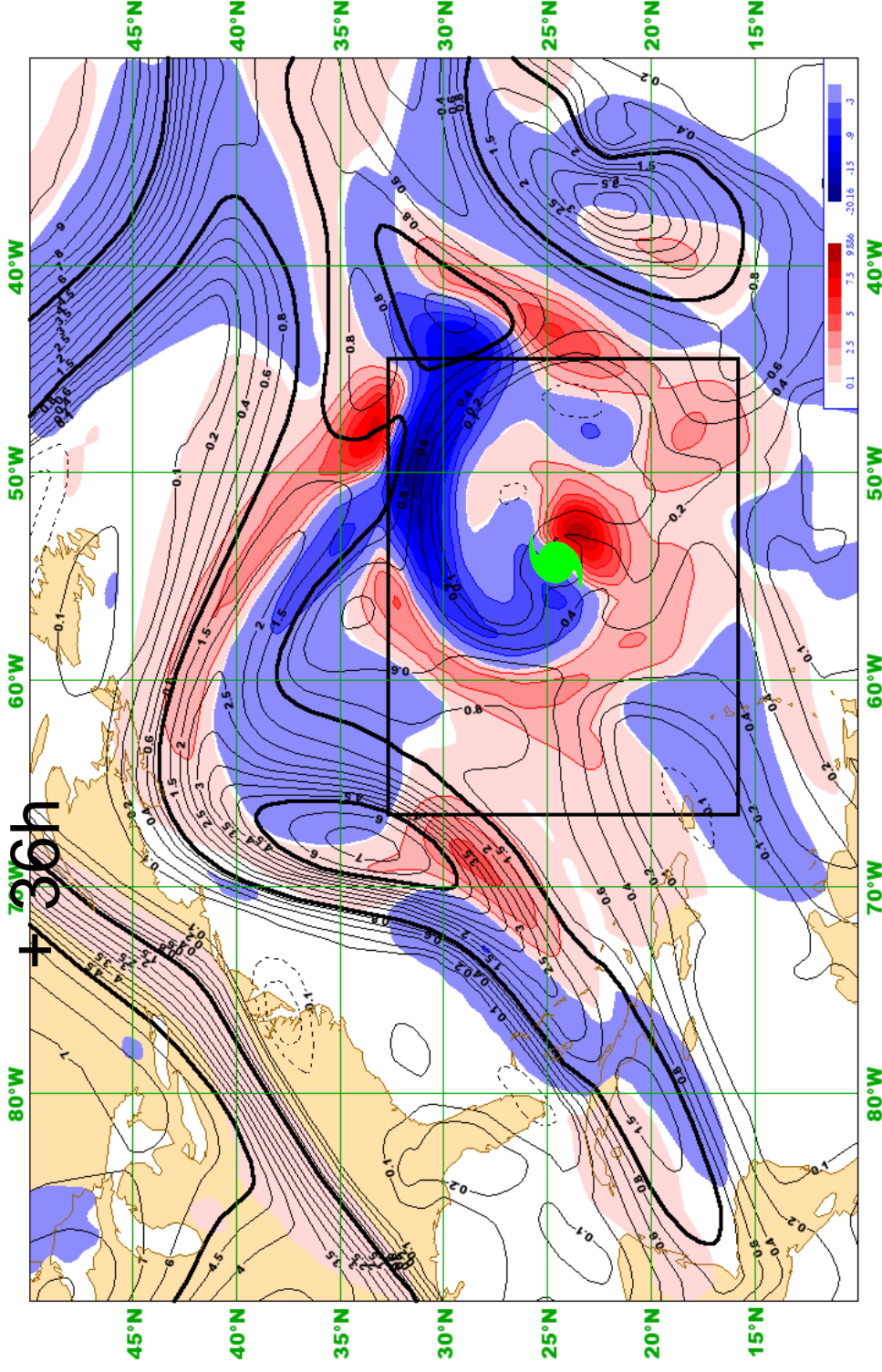
Blue : Neg. Pert.

Level 30 ~ 370hPa



TL159

Level 20 ~ 200hPa



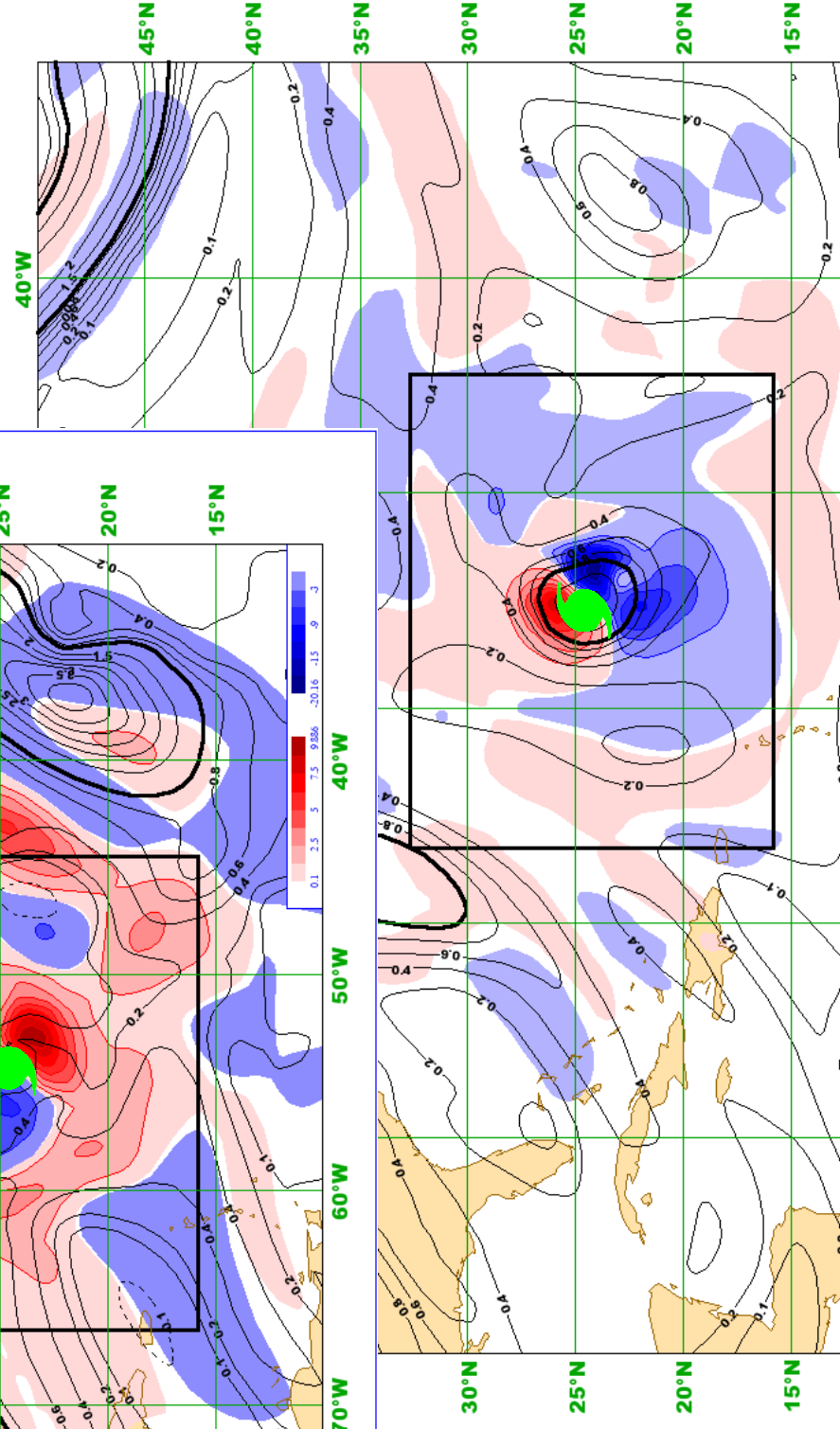
Contours:

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Red : Pos. Pert.

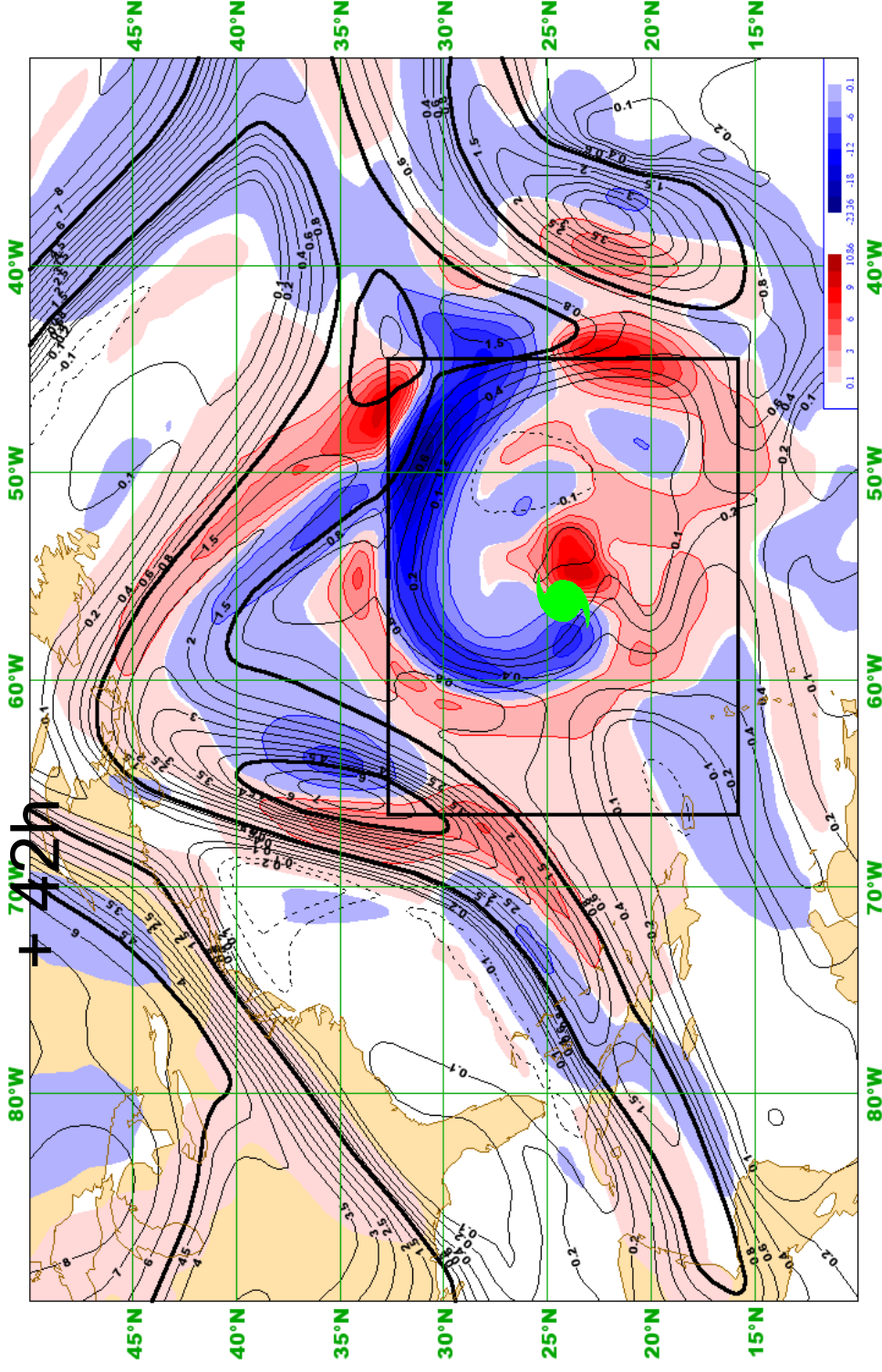
Blue : Neg. Pert.

Level 30 ~ 370hPa



TL159

Level 20 ~ 200hPa



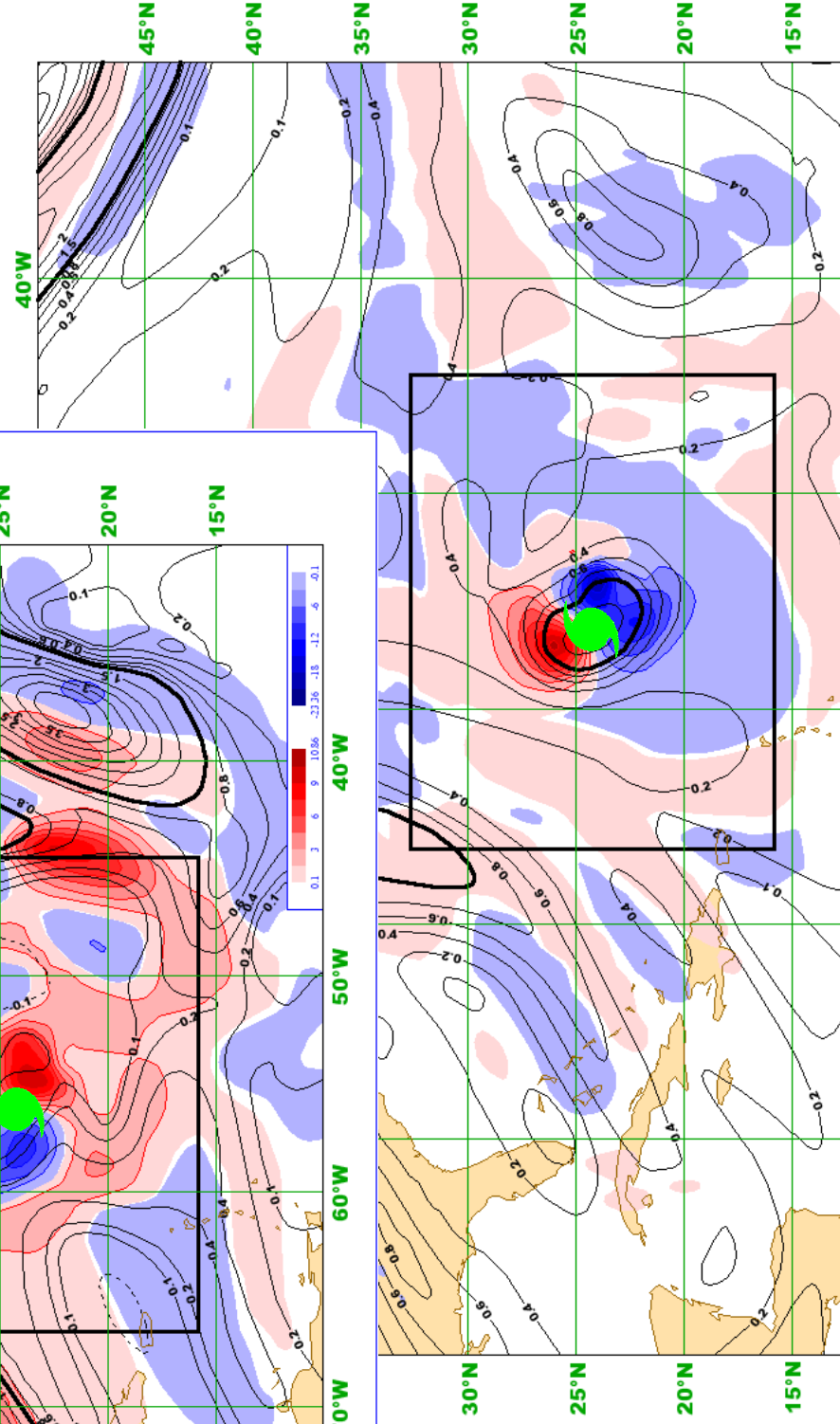
Contours:

Black : PV Traj.

Red : Pos. Pert.

Blue : Neg. Pert.

Level 30 ~ 370hPa



40°W

45°N

40°N

35°N

30°N

25°N

20°N

15°N

30°N

25°N

20°N

15°N

80°W

70°W

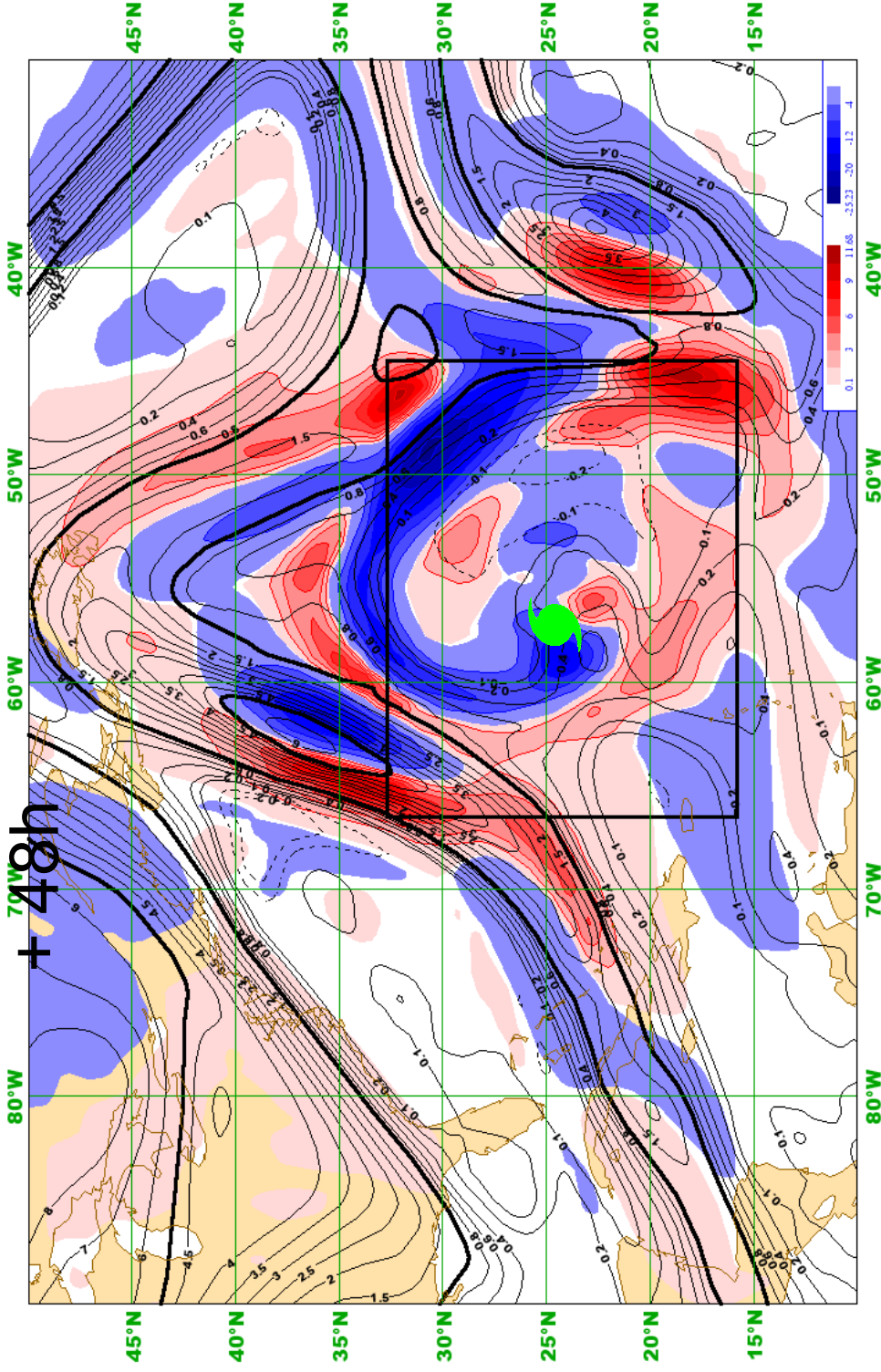
60°W

50°W

40°W

TL159

Level 20 ~ 200hPa



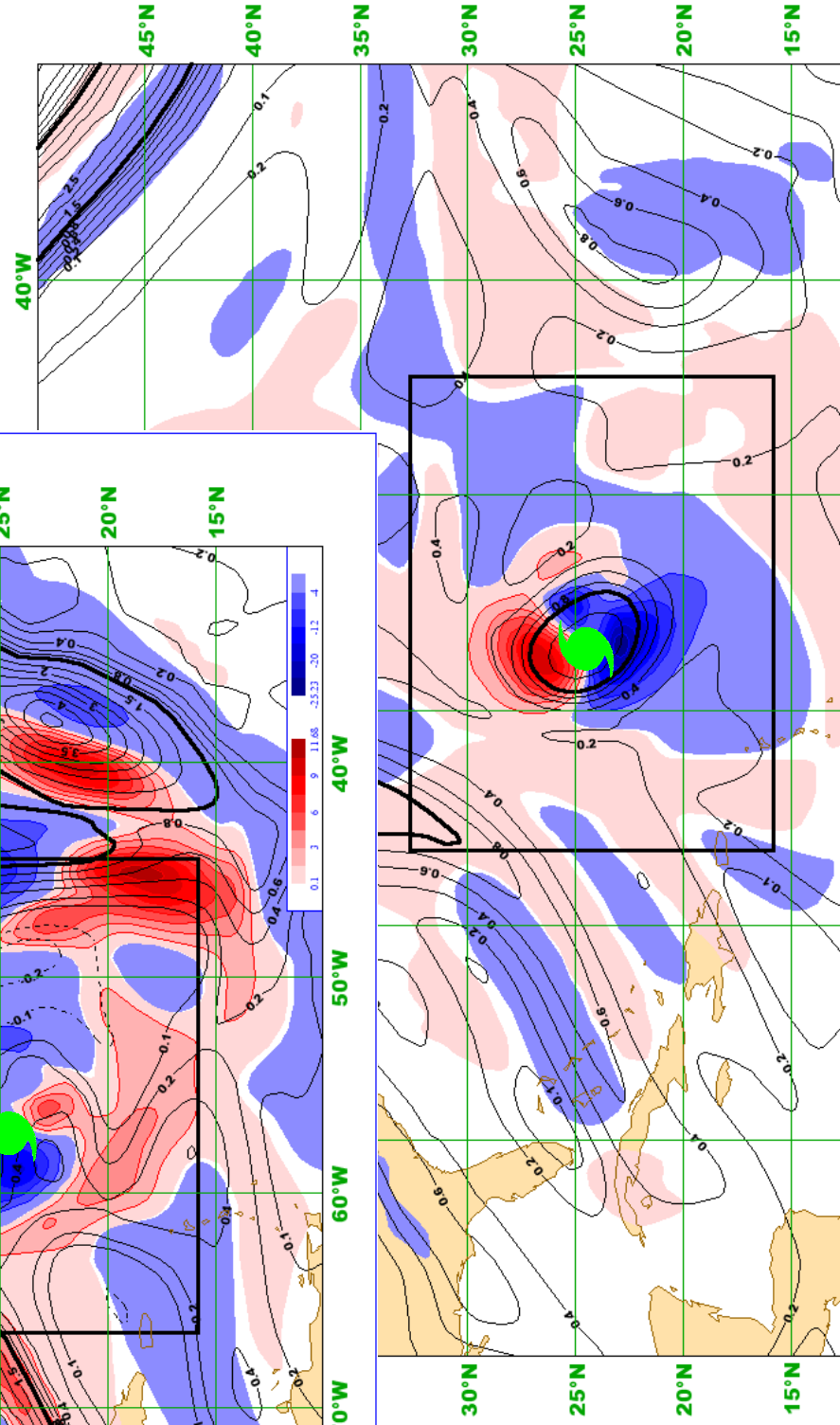
Contours:

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Red : Pos. Pert.

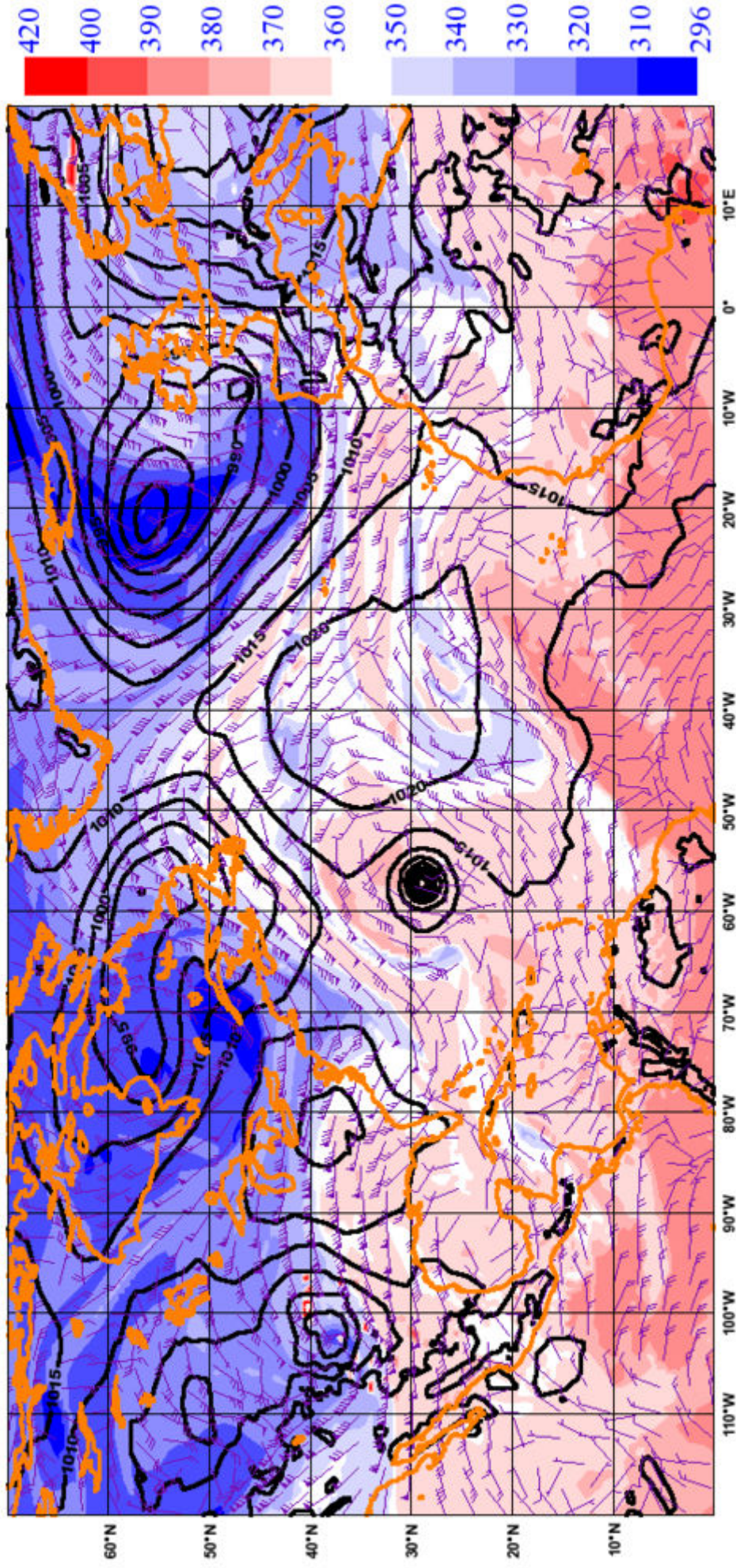
Blue : Neg. Pert.

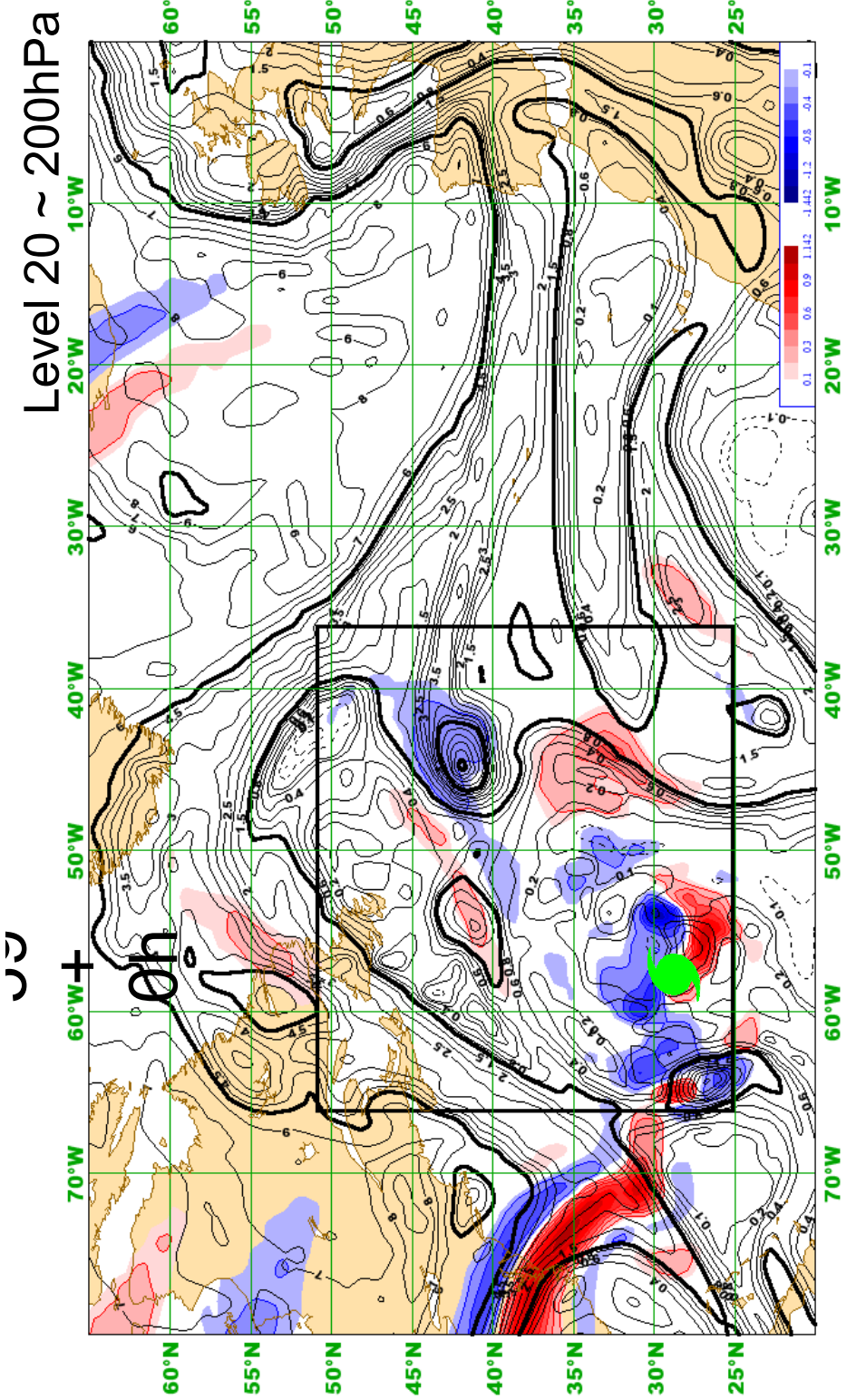
Level 30 ~ 370hPa



21.09.2006

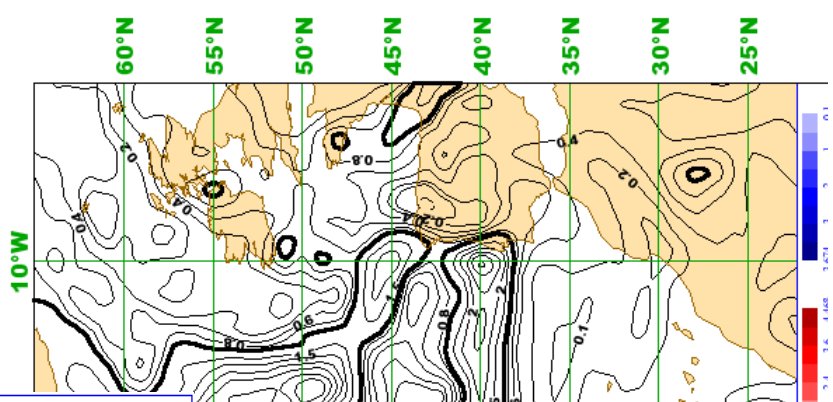
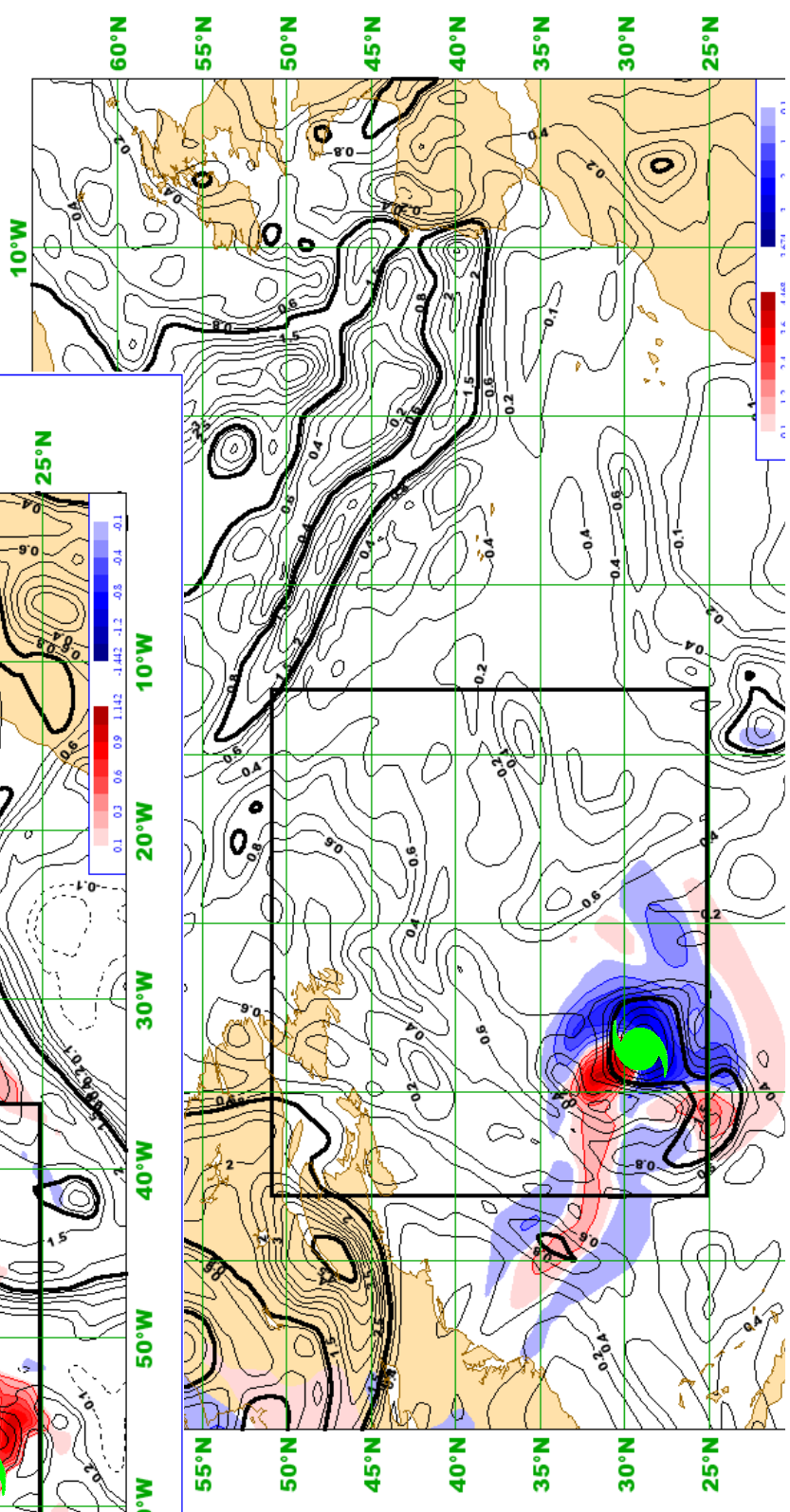
IT: 2006-09-21 12UTC ECMWF FC t+0 VT:2006-09-21 12 - 2PVU PotT / Wind / Pmsl

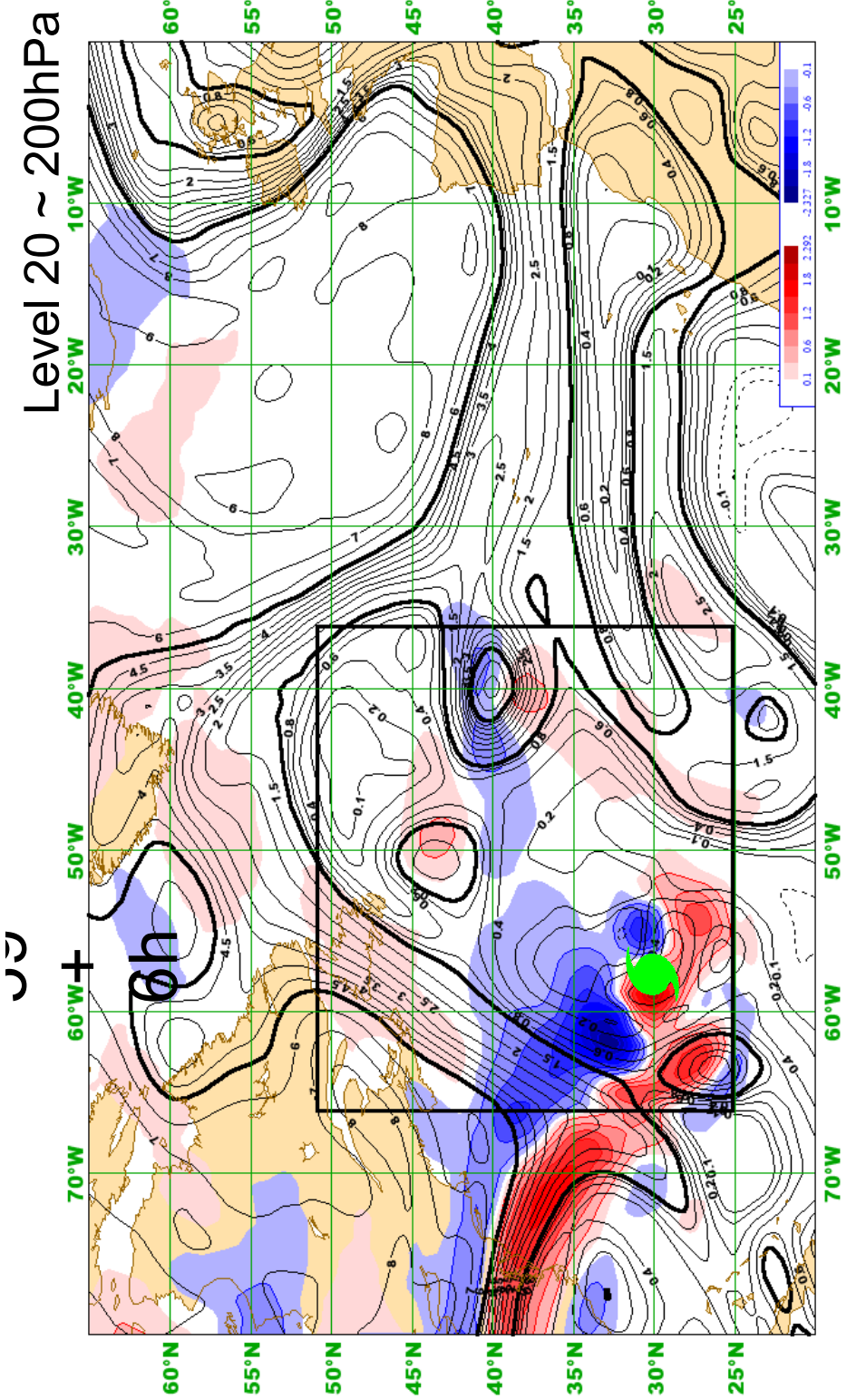




Contours:
 Black : PV
 Red : Pos. Pert.
 Blue : Neg. Pert.

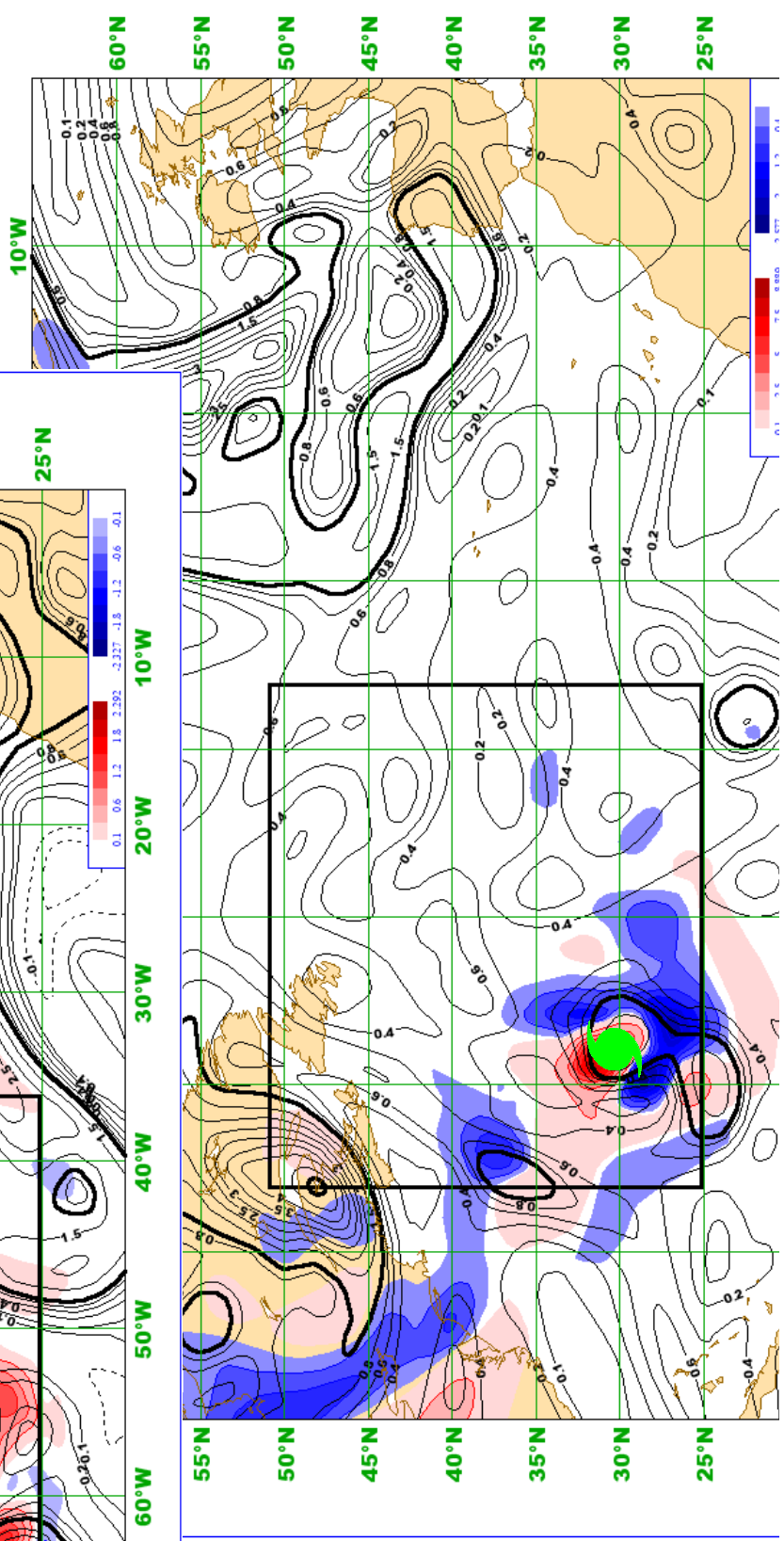
Level 30 ~ 370hPa





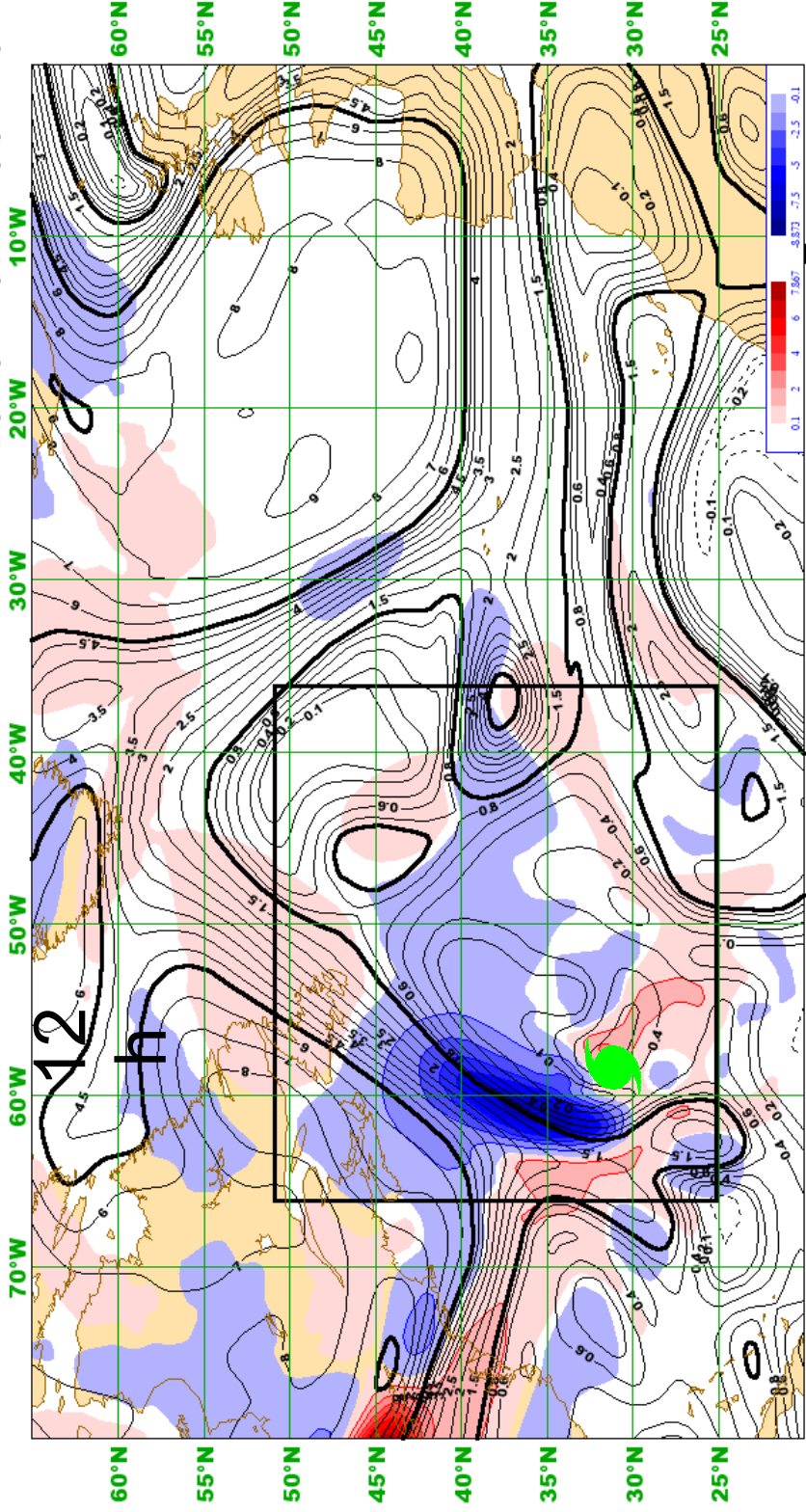
Contours:
 Black : PV
 Red : Pos. Pert.
 Blue : Neg. Pert.

Level 30 ~ 370hPa



Level 20 ~ 200hPa

+



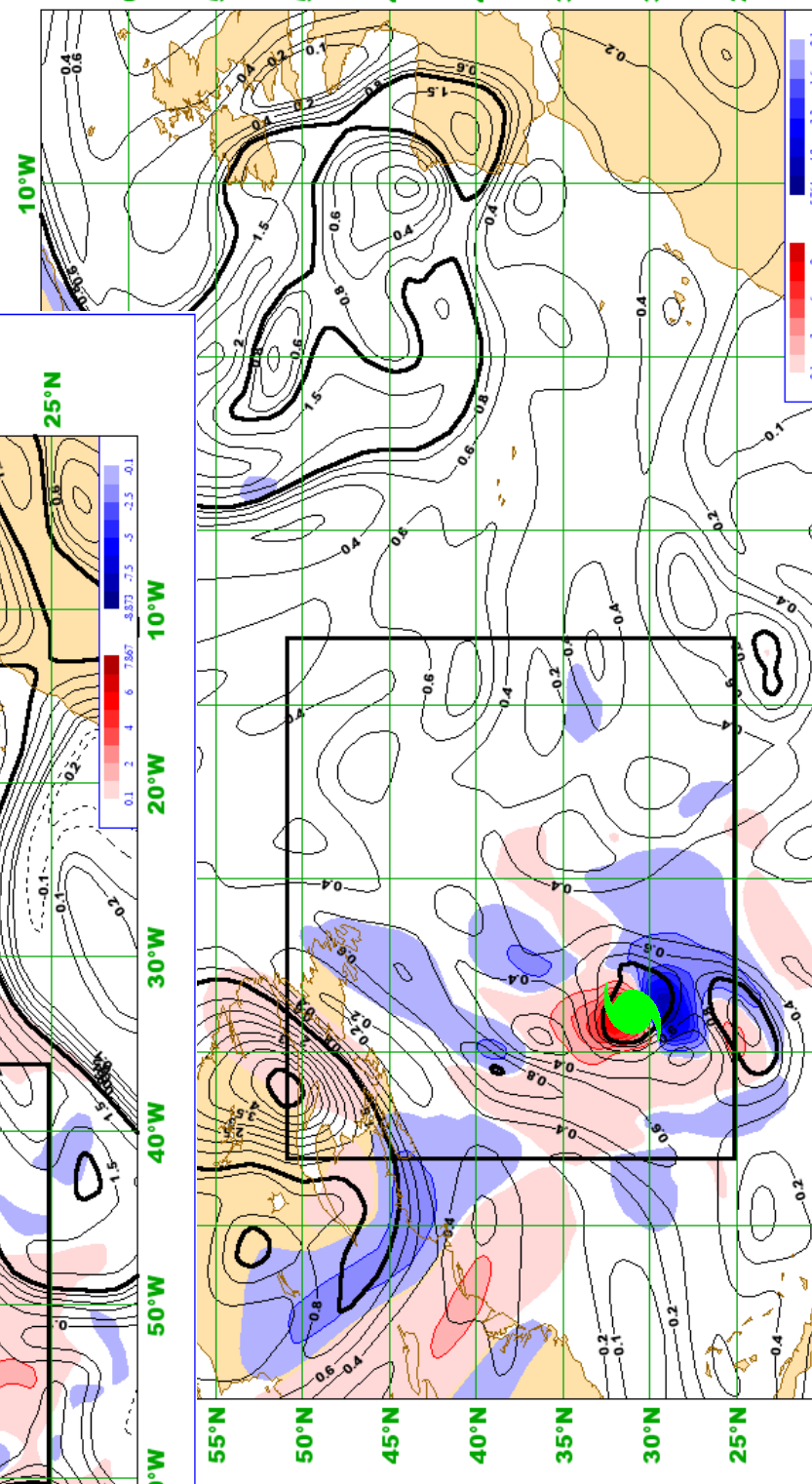
Contours:

Black : PV

Red : Pos. Pert.

Blue : Neg. Pert.

Level 30 ~ 370hPa



10°W

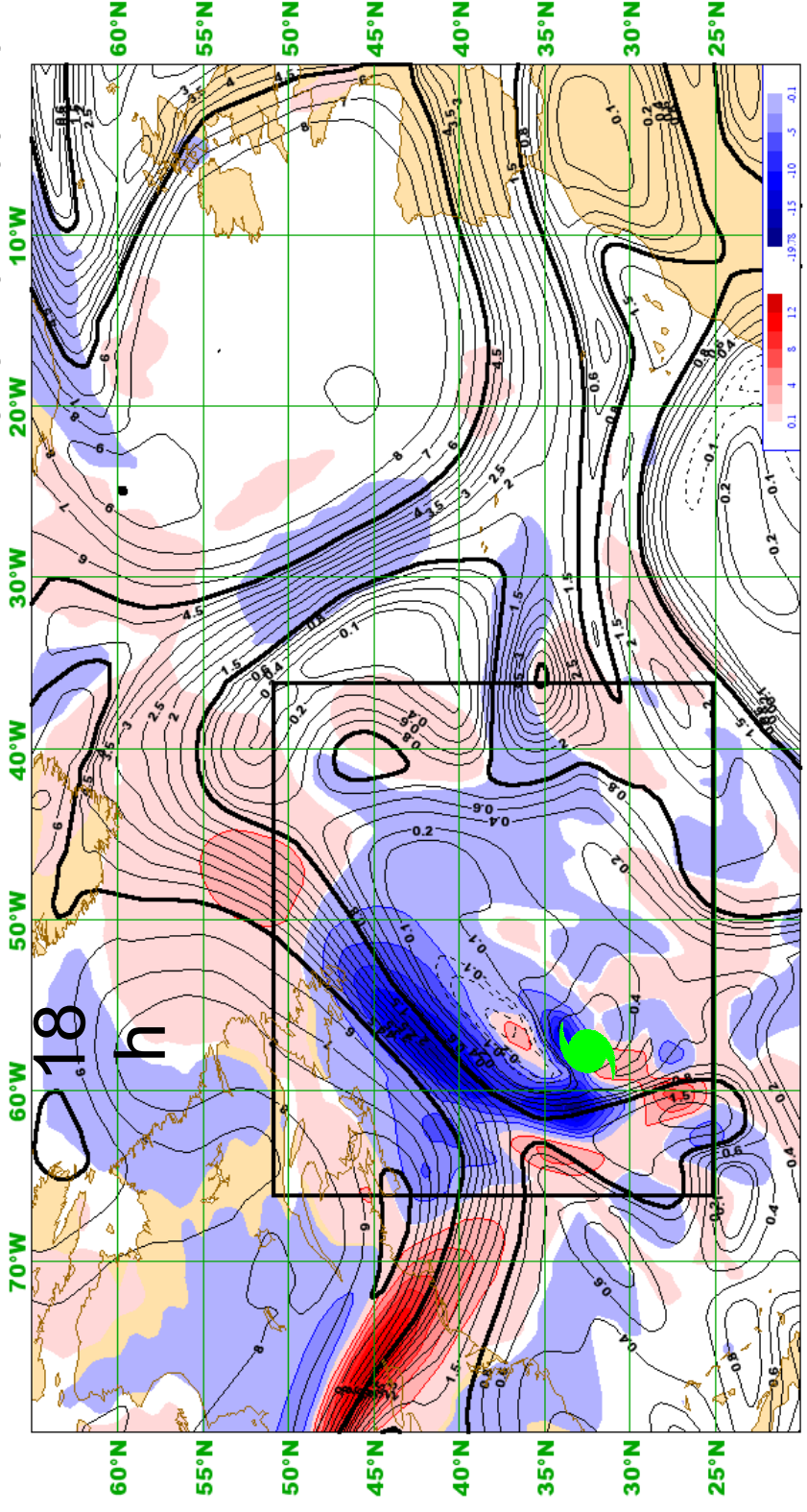
60°N
55°N
50°N
45°N
40°N
35°N
30°N
25°N

70°W
60°W
50°W
40°W
30°W
20°W
10°W

55°N
50°N
45°N
40°N
35°N
30°N
25°N

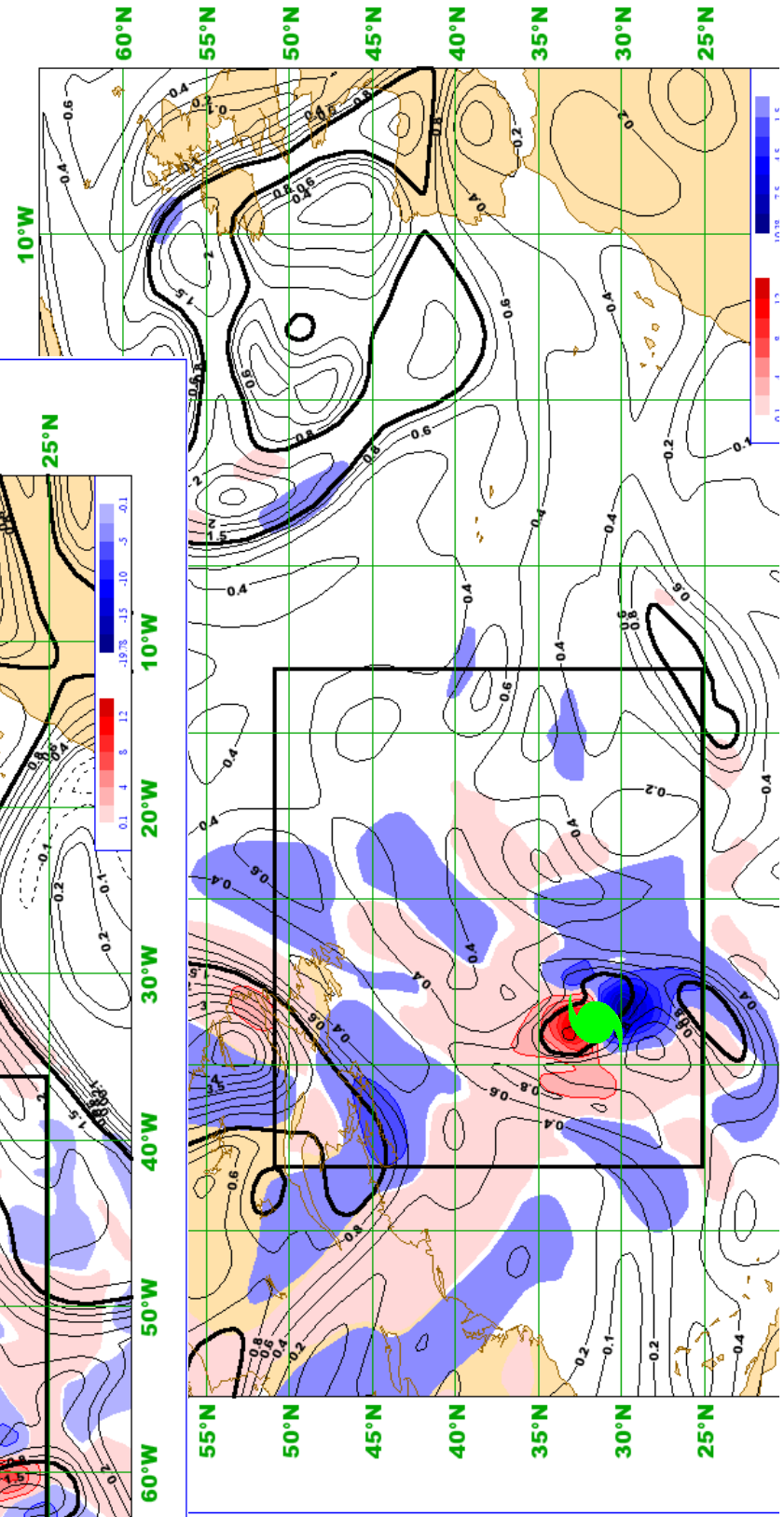
Level 20 ~ 200hPa

+



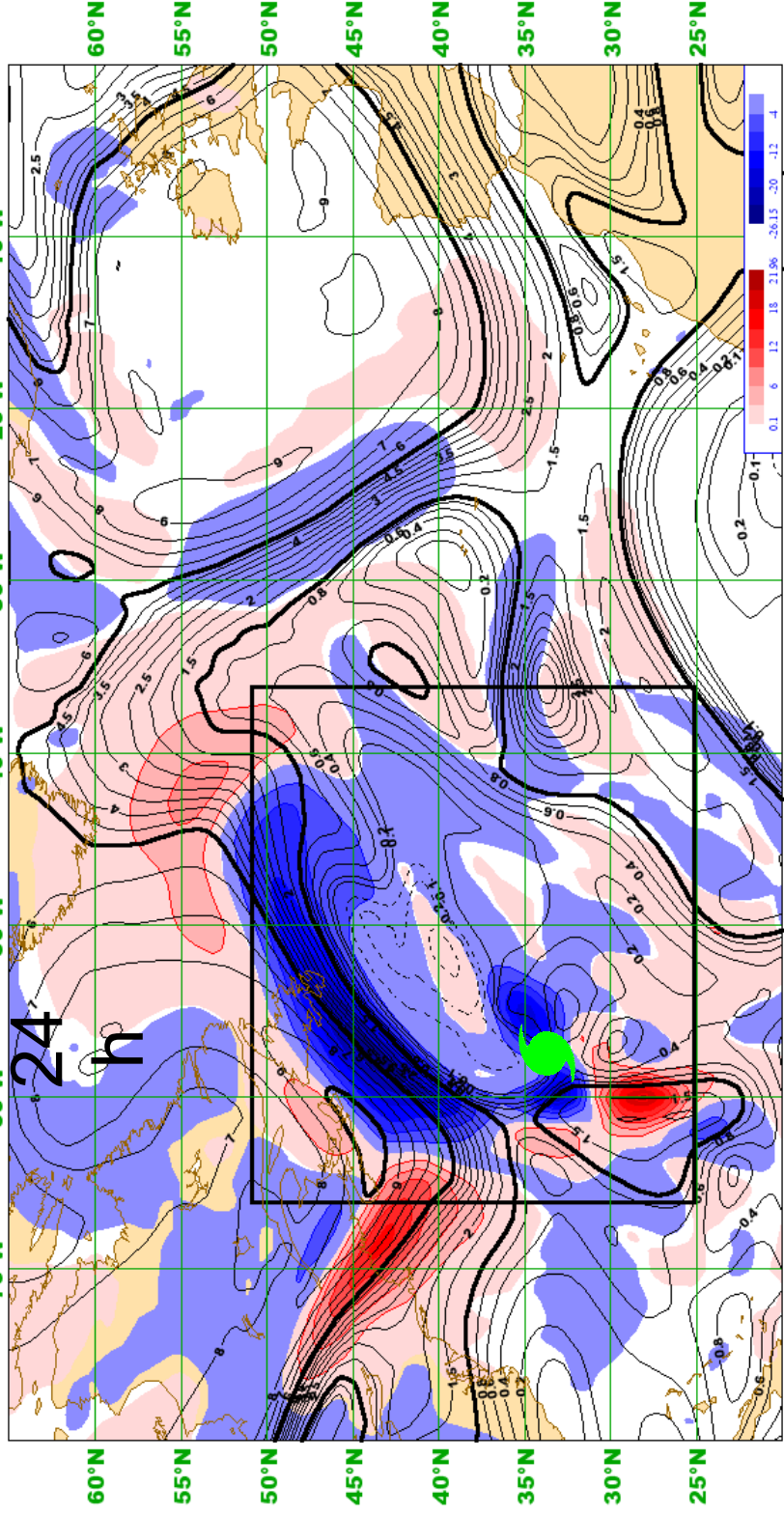
Contours:
Black : PV
Red : Pos. Pert.
Blue : Neg. Pert.

Level 30 ~ 370hPa



Level 20 ~ 200hPa

+



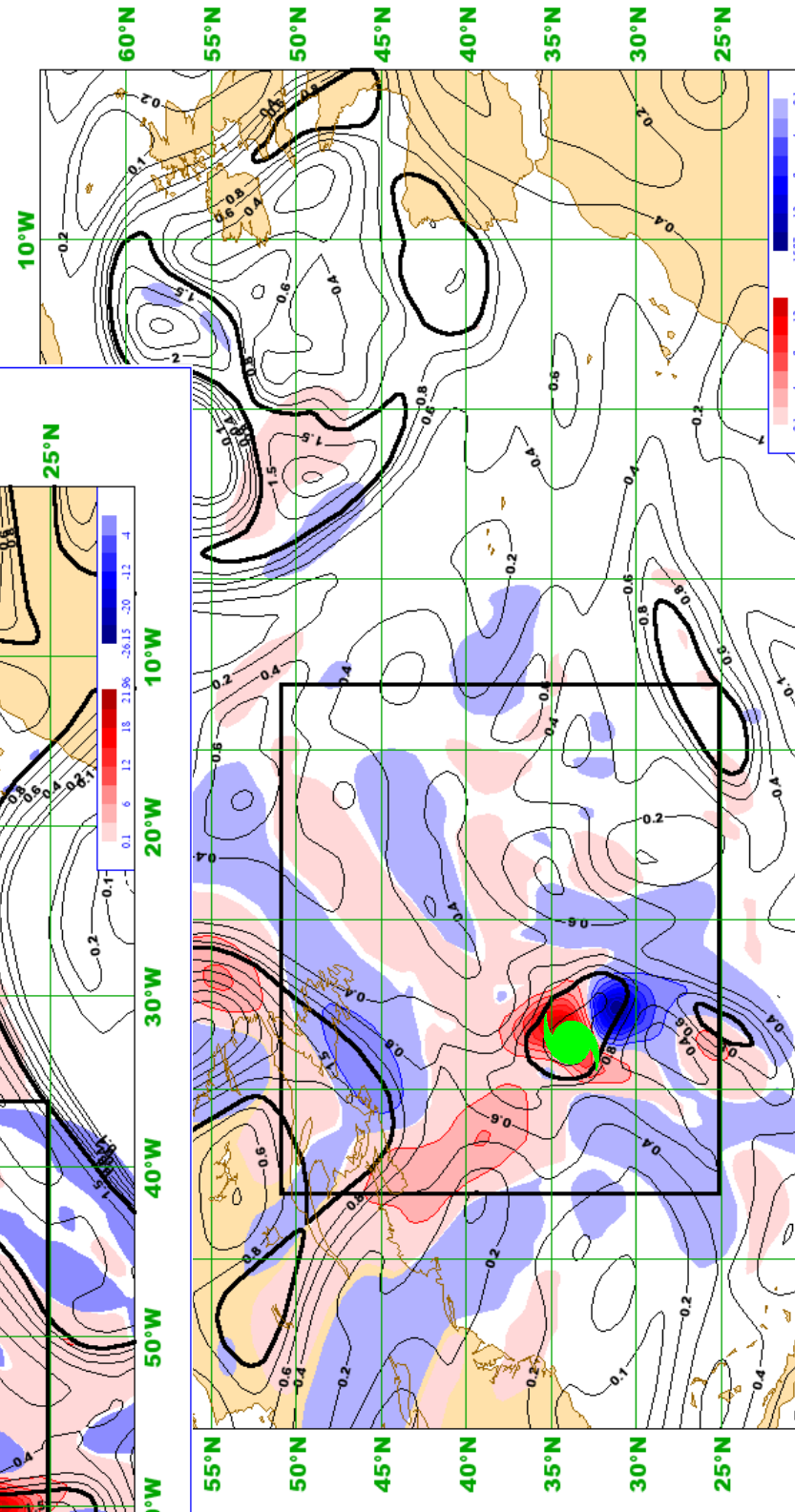
Contours:

Black : PV

Red : Pos. Pert.

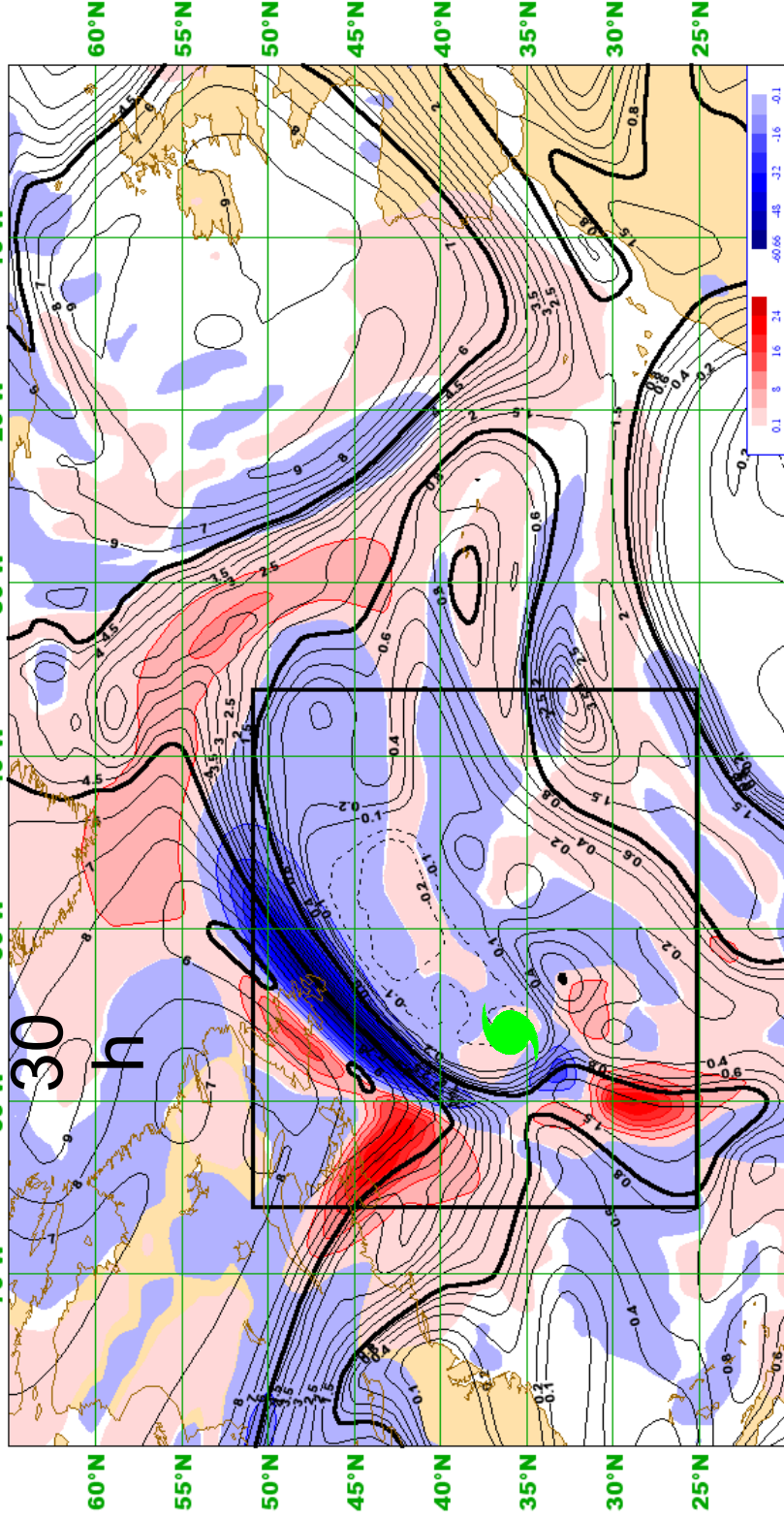
Blue : Neg. Pert.

Level 30 ~ 370hPa



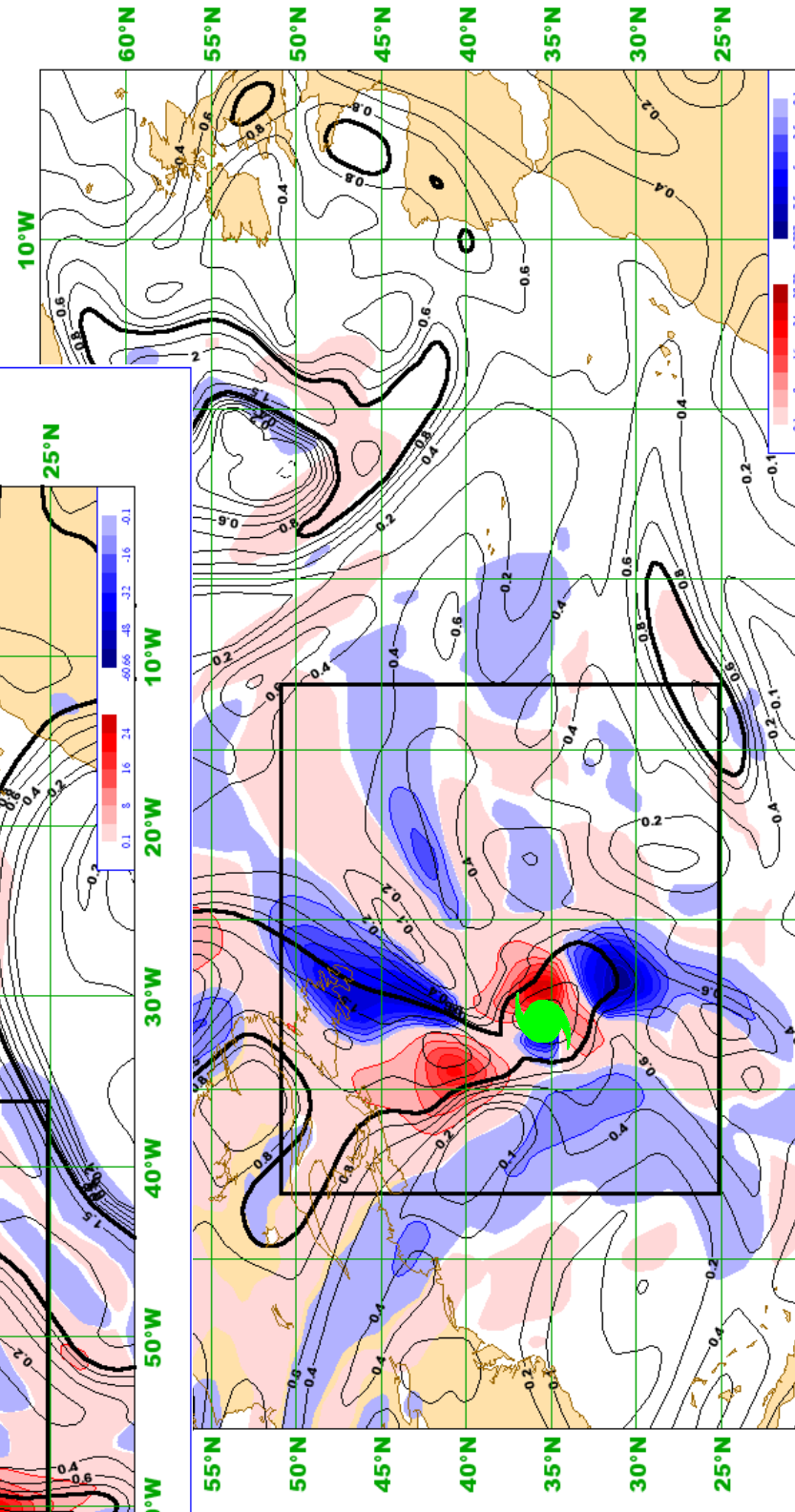
Level 20 ~ 200hPa

+



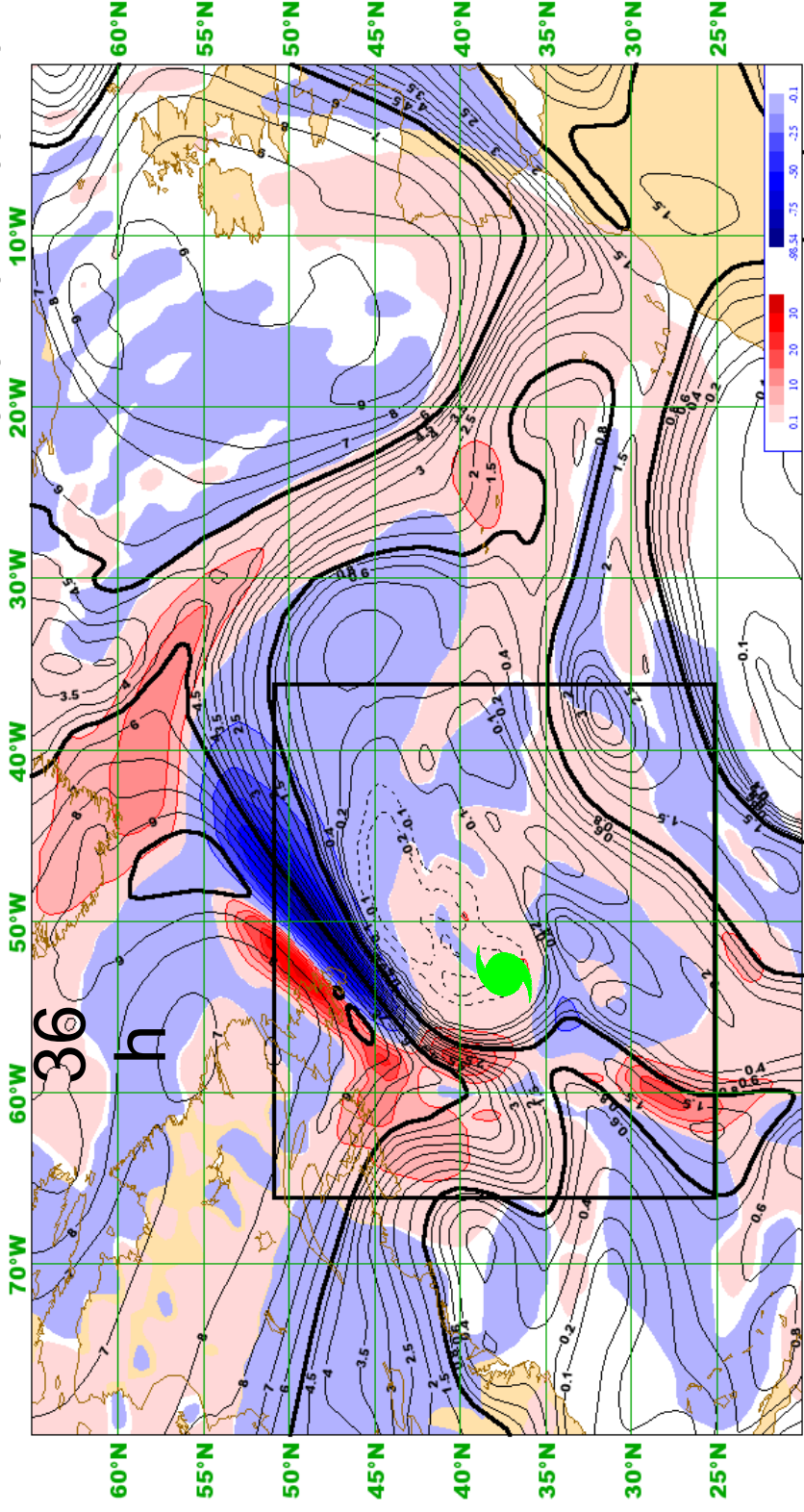
Contours:
Black : PV
Red : Pos. Pert.
Blue : Neg. Pert.

Level 30 ~ 370hPa



Level 20 ~ 200hPa

+



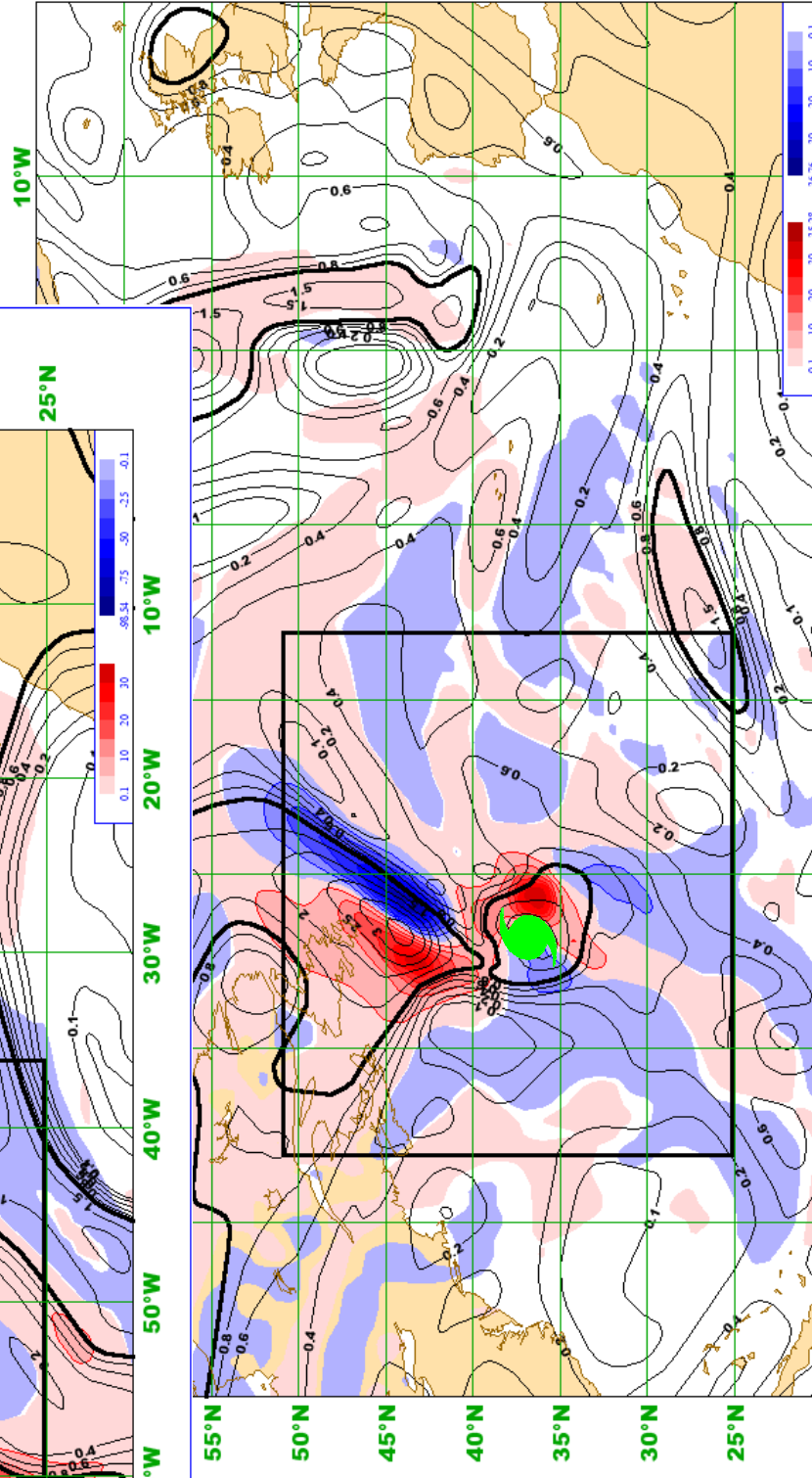
Contours:

Black : PV

Red : Pos. Pert.

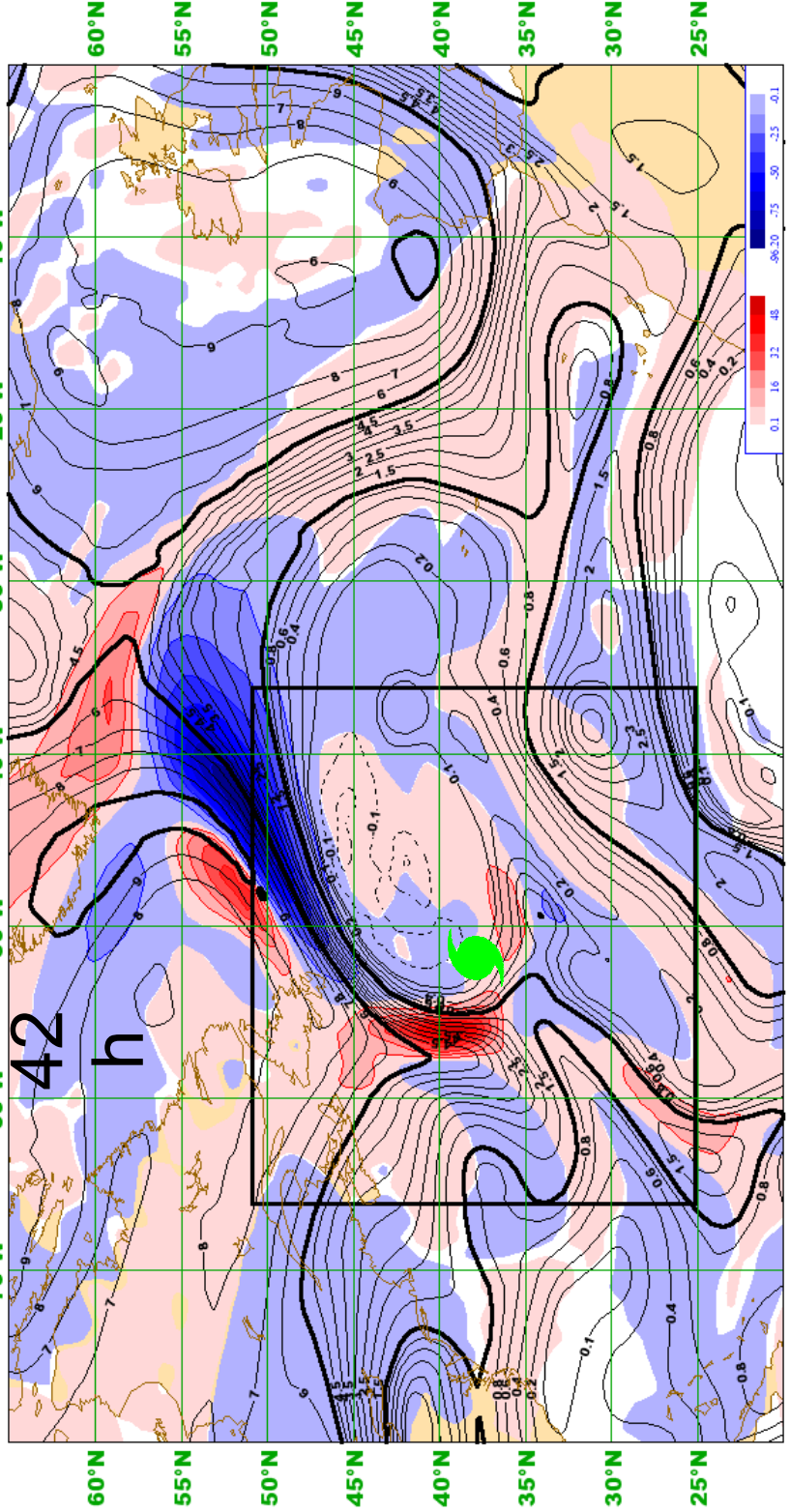
Blue : Neg. Pert.

Level 30 ~ 370hPa



Level 20 ~ 200hPa

+



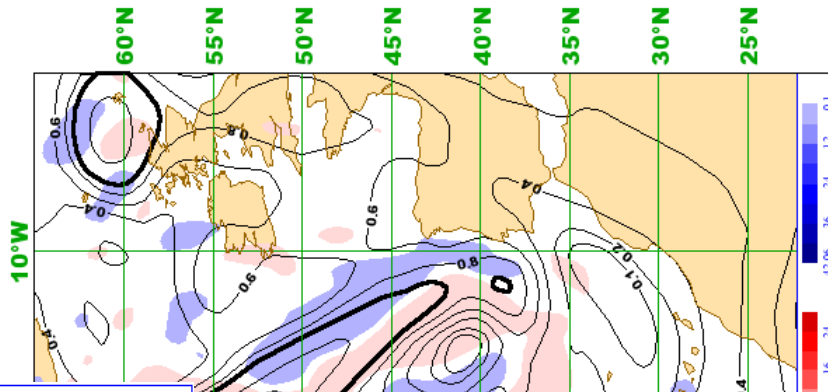
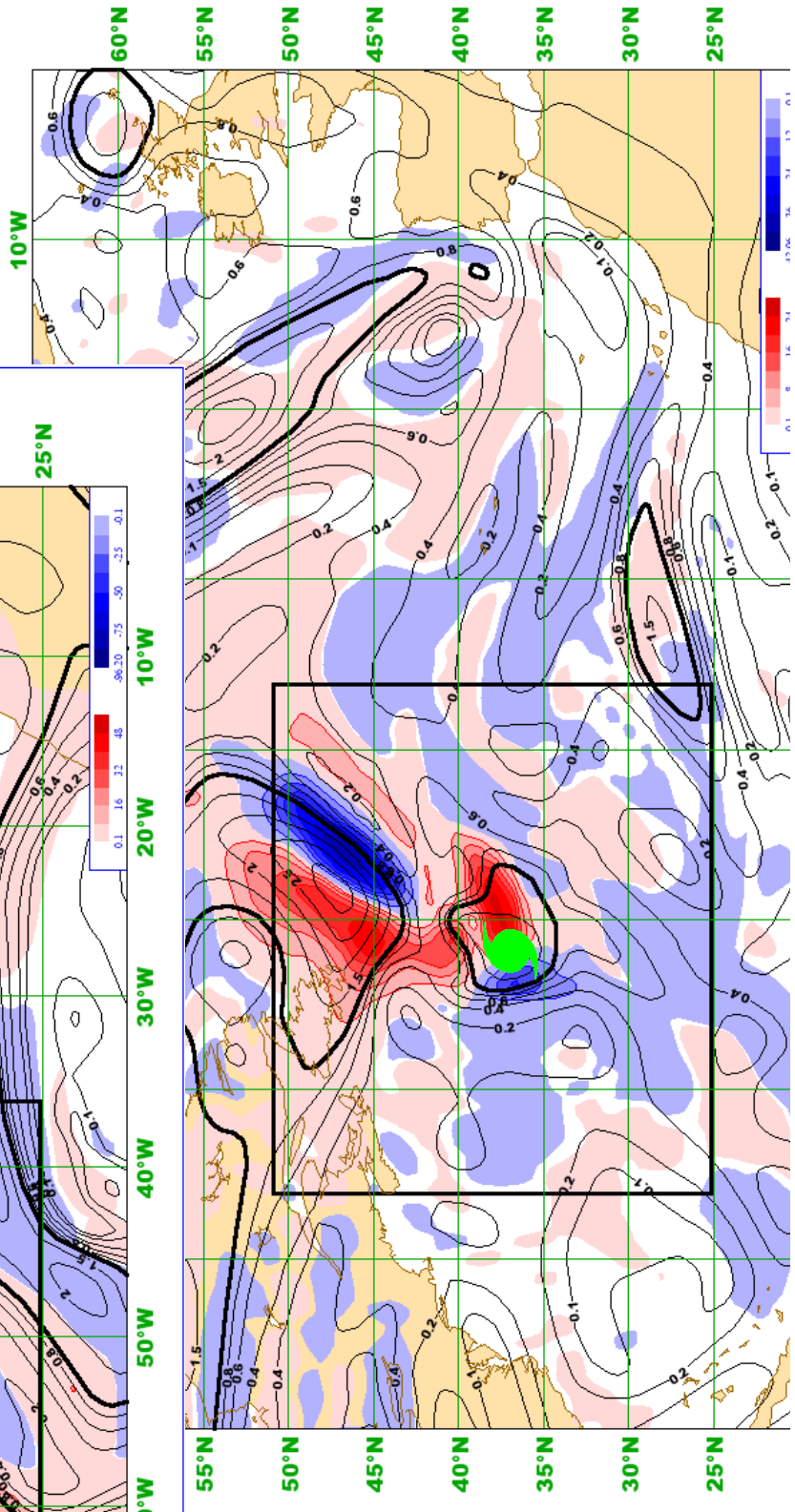
Contours:

Black : PV

Red : Pos. Pert.

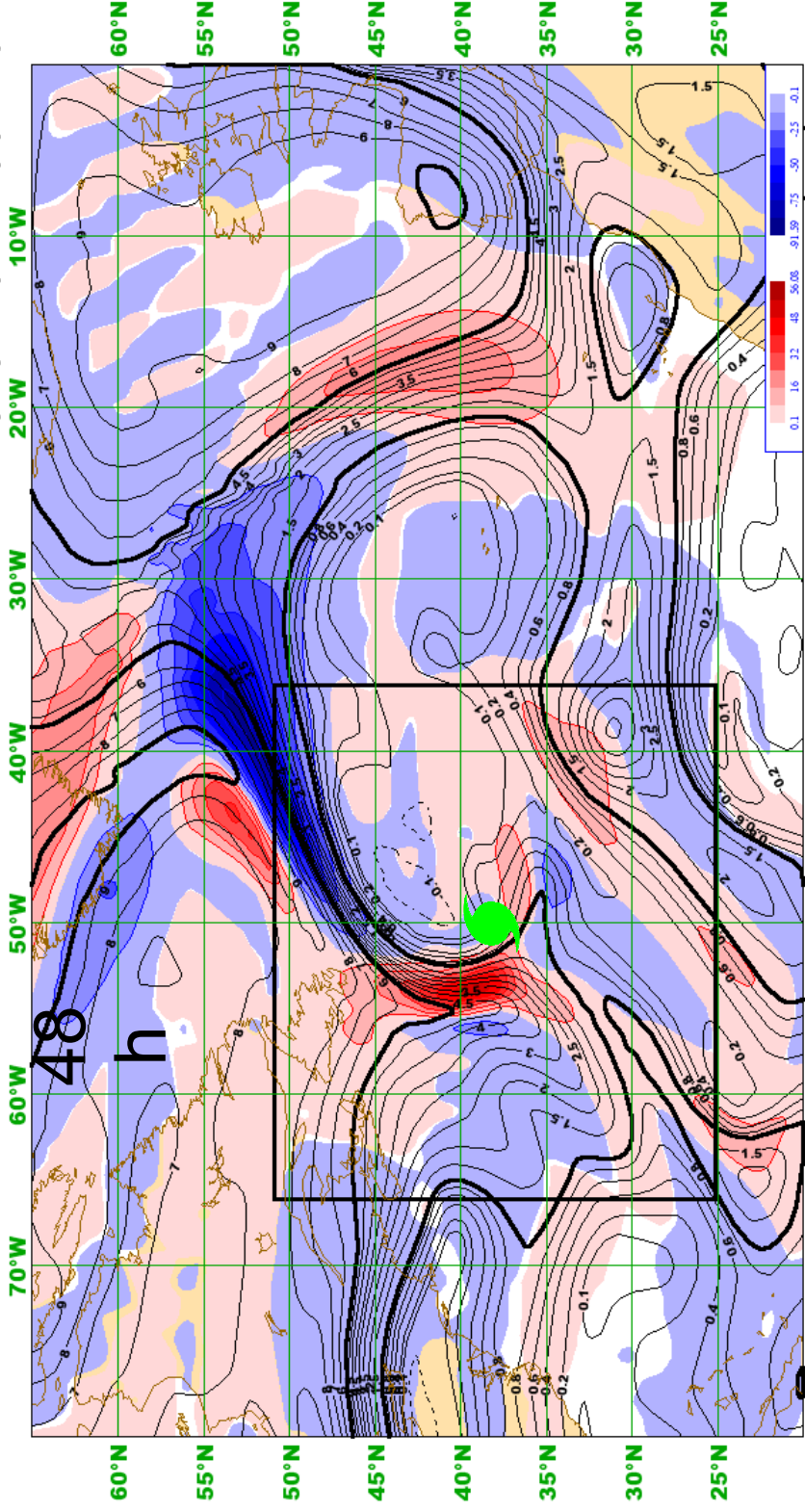
Blue : Neg. Pert.

Level 30 ~ 370hPa



Level 20 ~ 200hPa

+



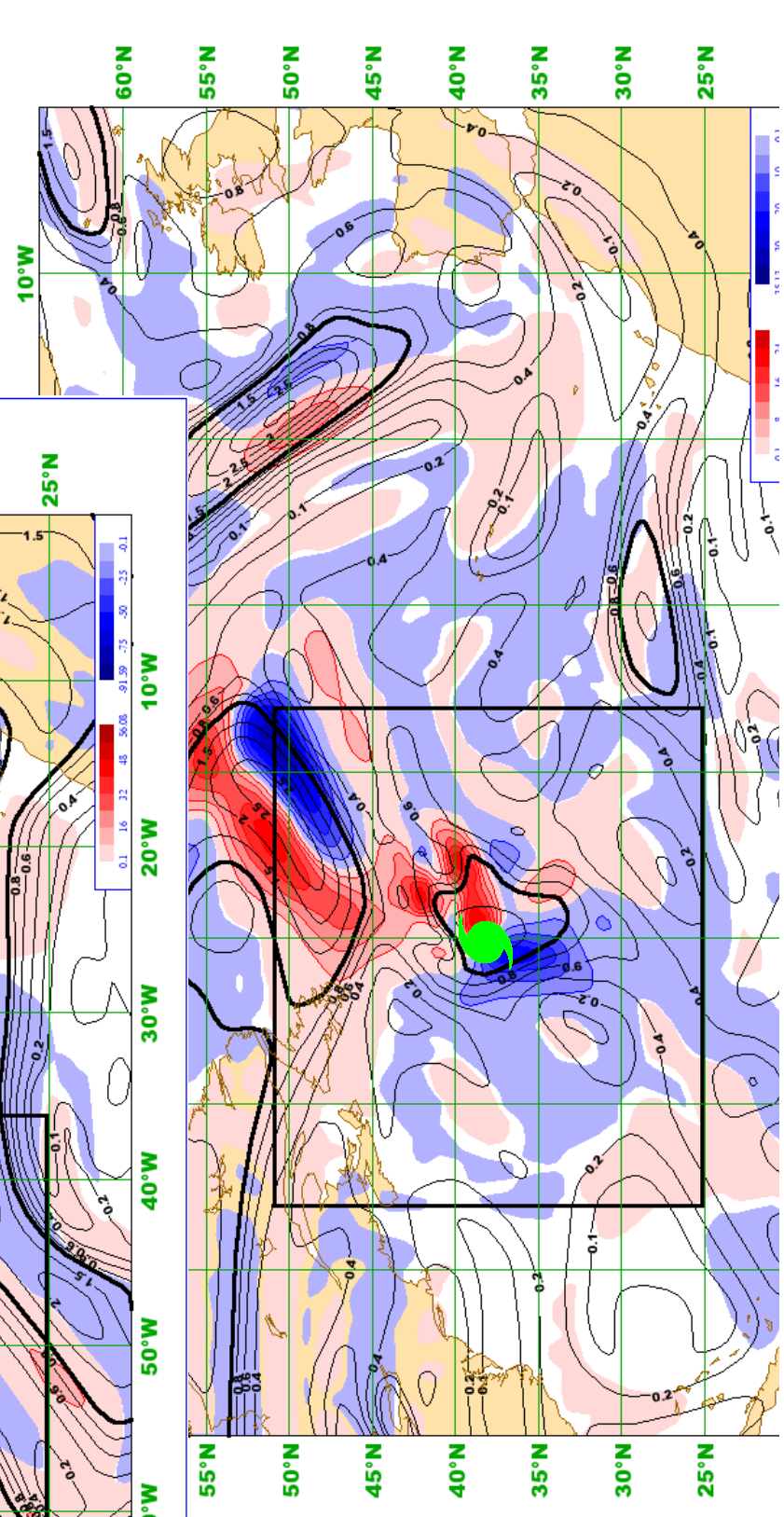
Contours:

Black : PV

Red : Pos. Pert.

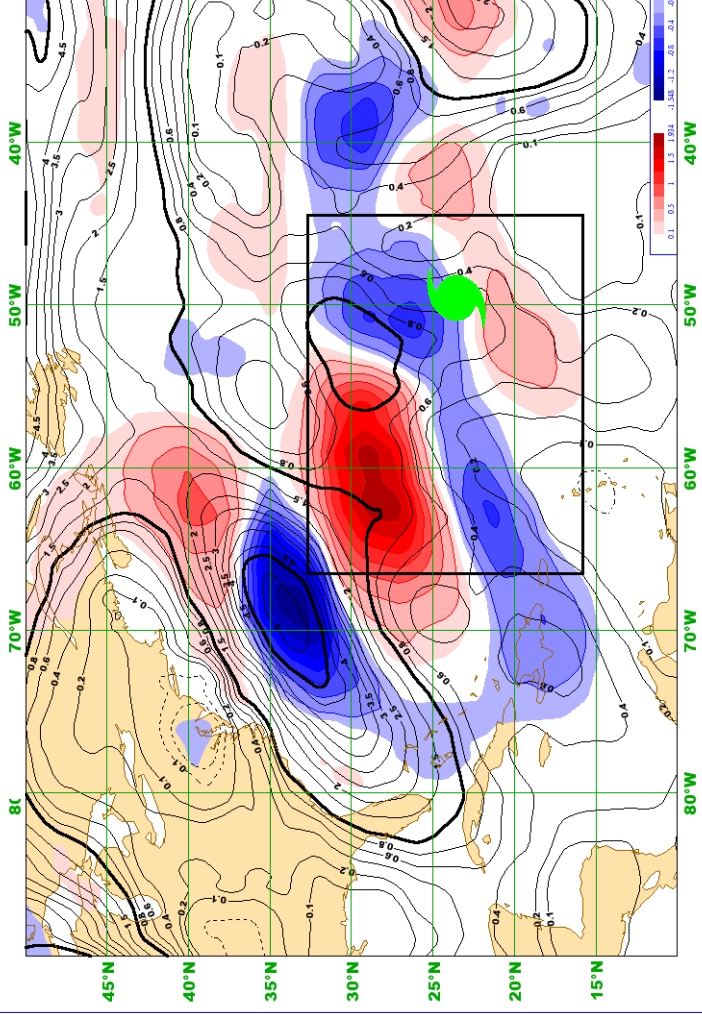
Blue : Neg. Pert.

Level 30 ~ 370hPa

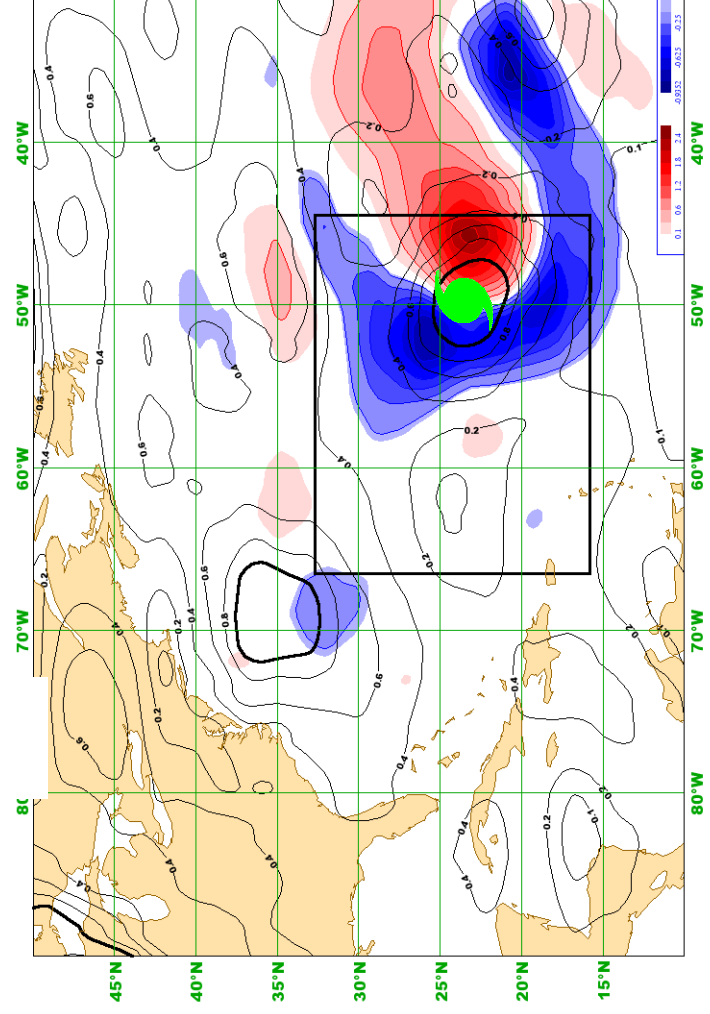


TL159 vs. T42

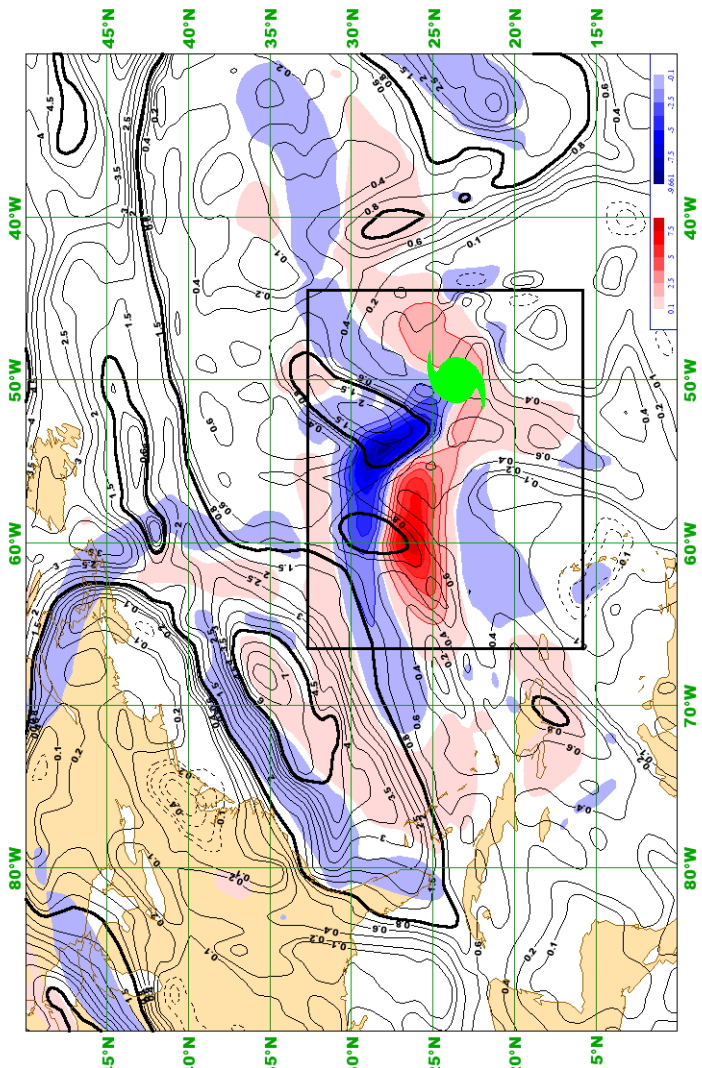
T42 Level 20 + 0h



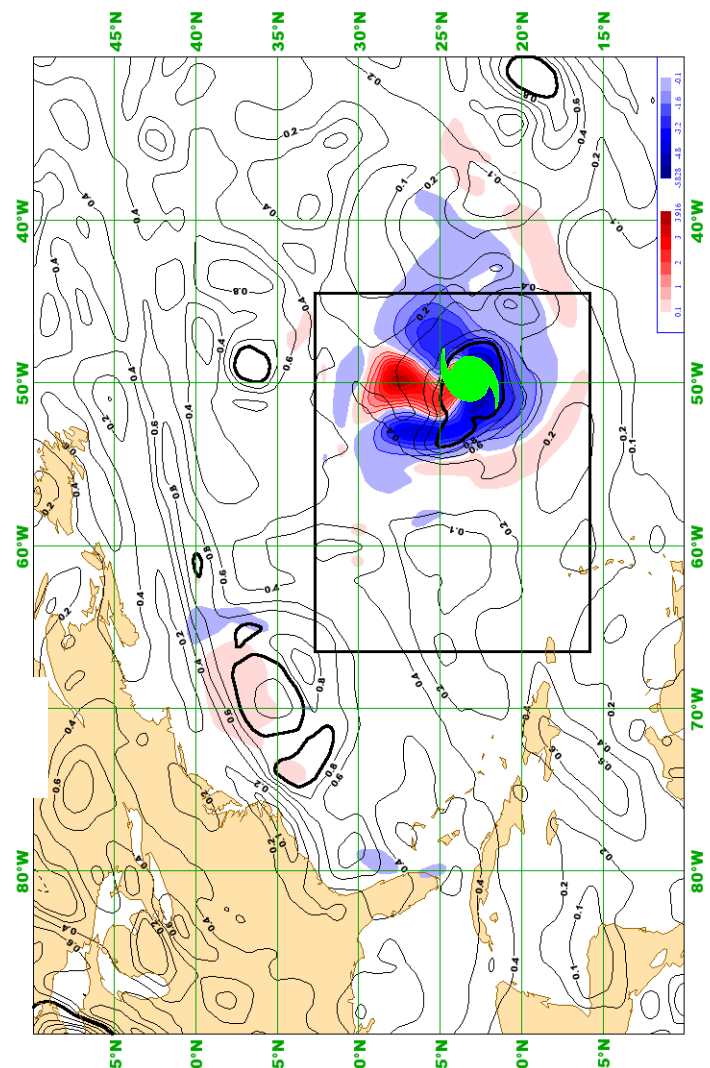
T42 Level 30 + 0h



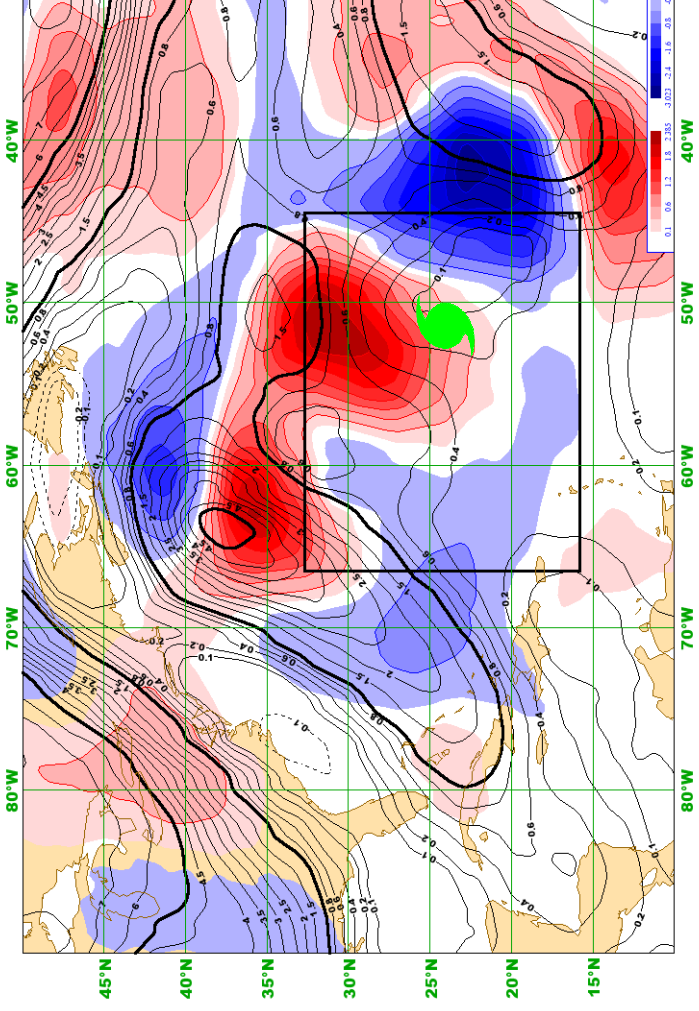
TL159 Level 20 + 0h



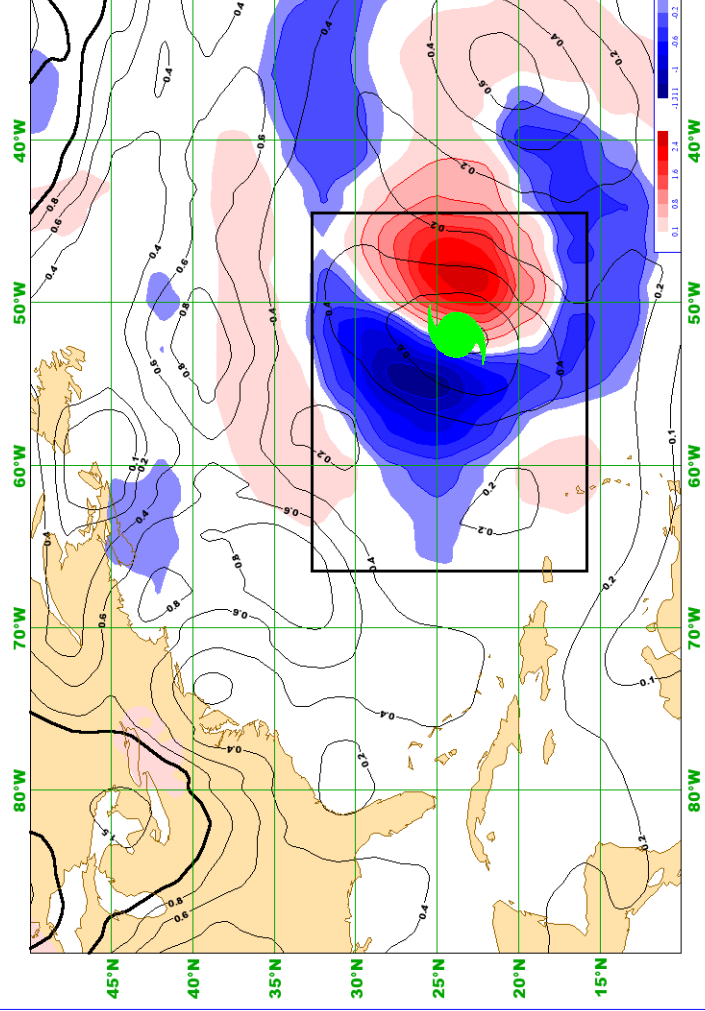
TL159 Level 30 + 0h



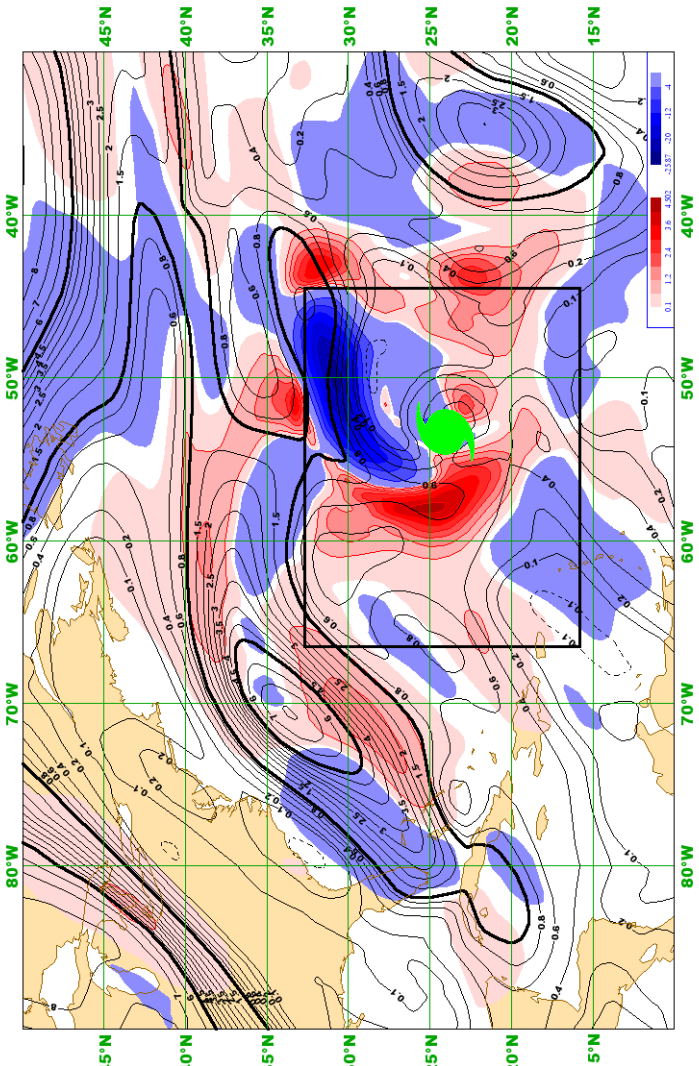
T42 Level 20 + 21h



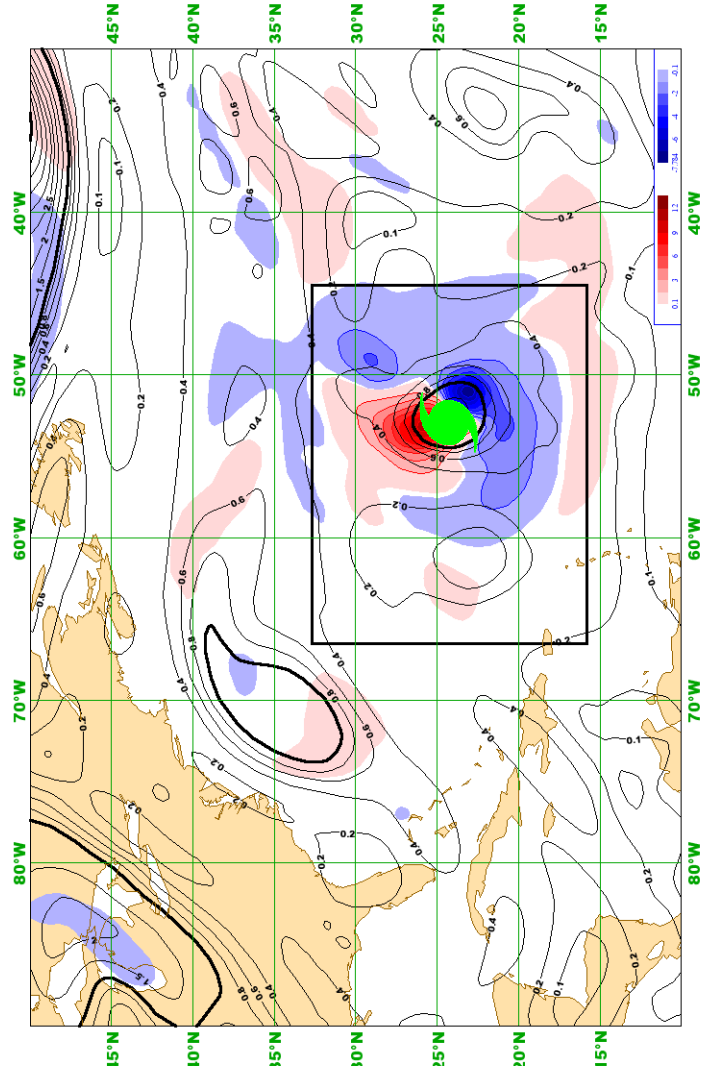
T42 Level 30 + 21h



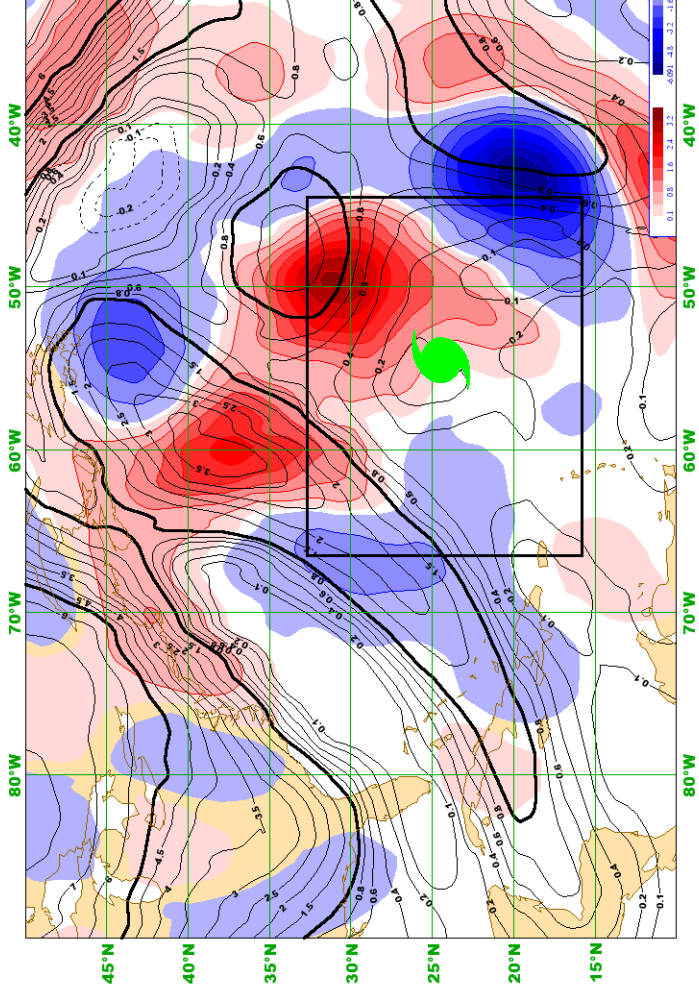
TL159 Level 20 + 21h



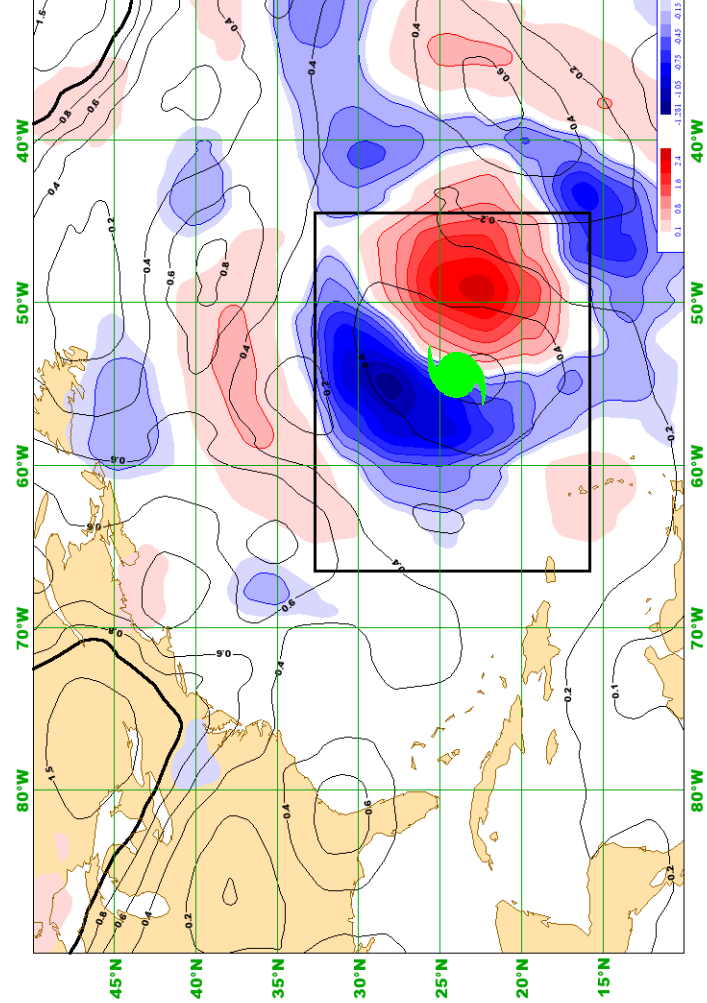
TL159 Level 30 + 21h



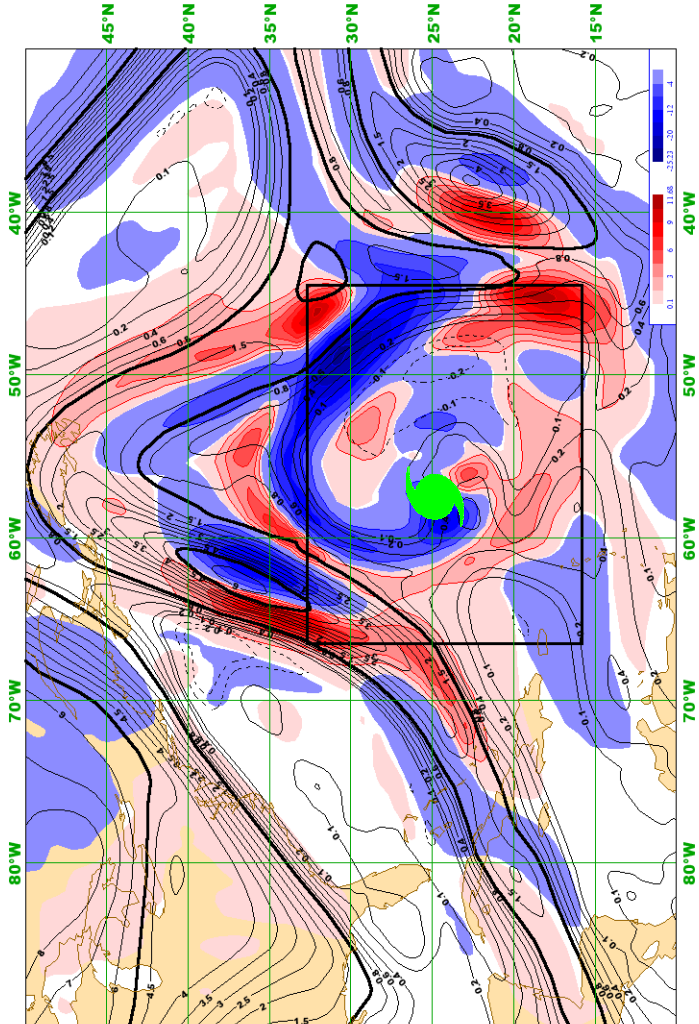
T42 Level 20 + 48h



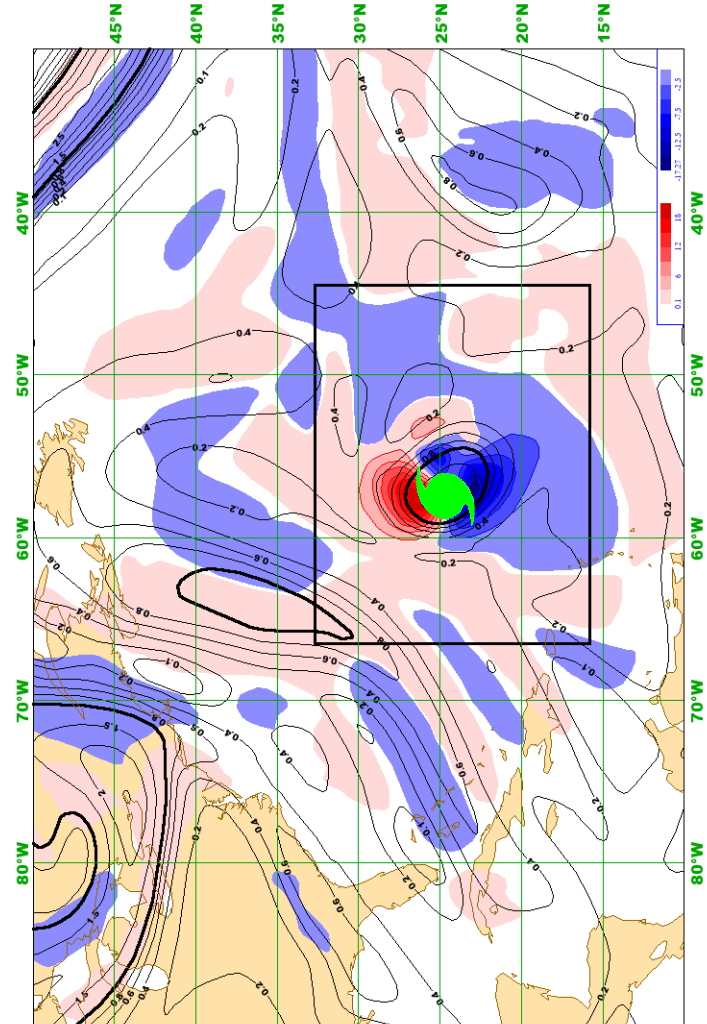
T42 Level 30 + 48h



TL159 Level 20 + 48h

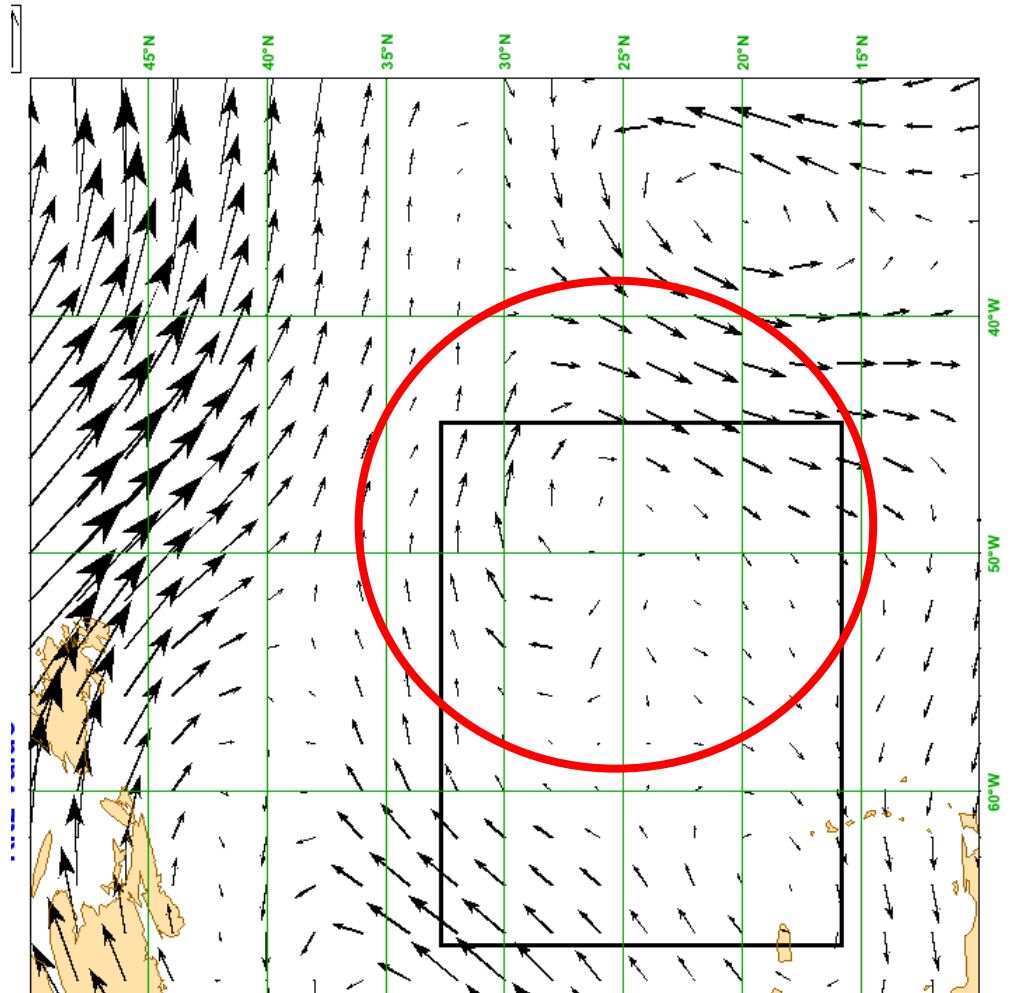


TL159 Level 30 + 48h

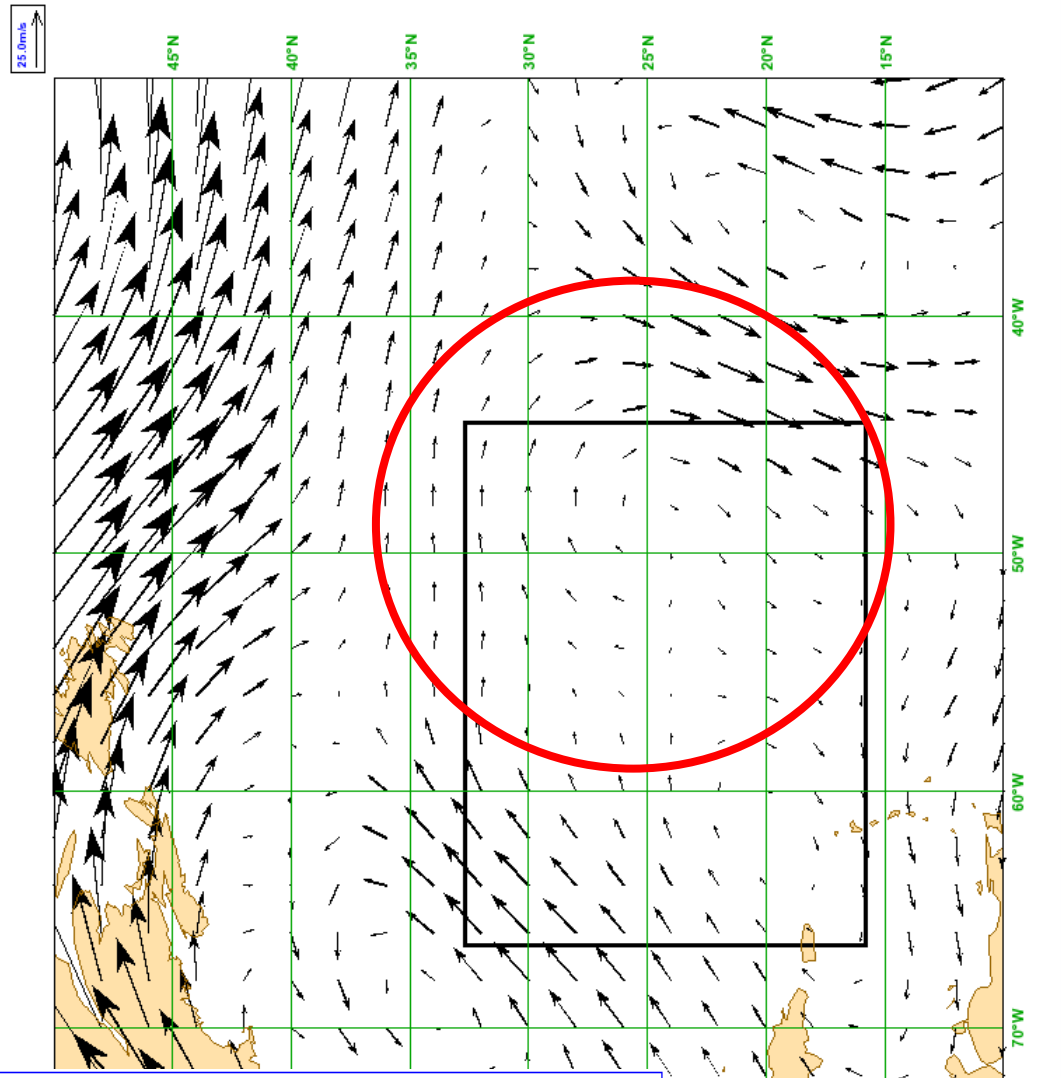


Outflow Channel

TL159 Level 20 + 24h



T42 Level 20 + 24h



Summary & Outlook

First Case Study:

- Higher resolution ➡ higher growth rates and more small scale structures
- At higher resolution structures closer to the centre of the TC experience the strongest growth (and SVs capture Outflow Channel)
- When the TC approaches the mid-latitudes higher resolution is needed to capture perturbations directly related to the TC

Outlook:

- More cases
- Explore impact of high resolution SVs on EPS
- Investigate validity of the tangent linear approximation in case of tropical cyclones
- Examine the role of tendency perturbations in the EPS (a revised version of the stochastic physics is in preparation.)

Thank you for your attention!

