Diabatic Balance for the Canadian Continental LAM-4D-Var

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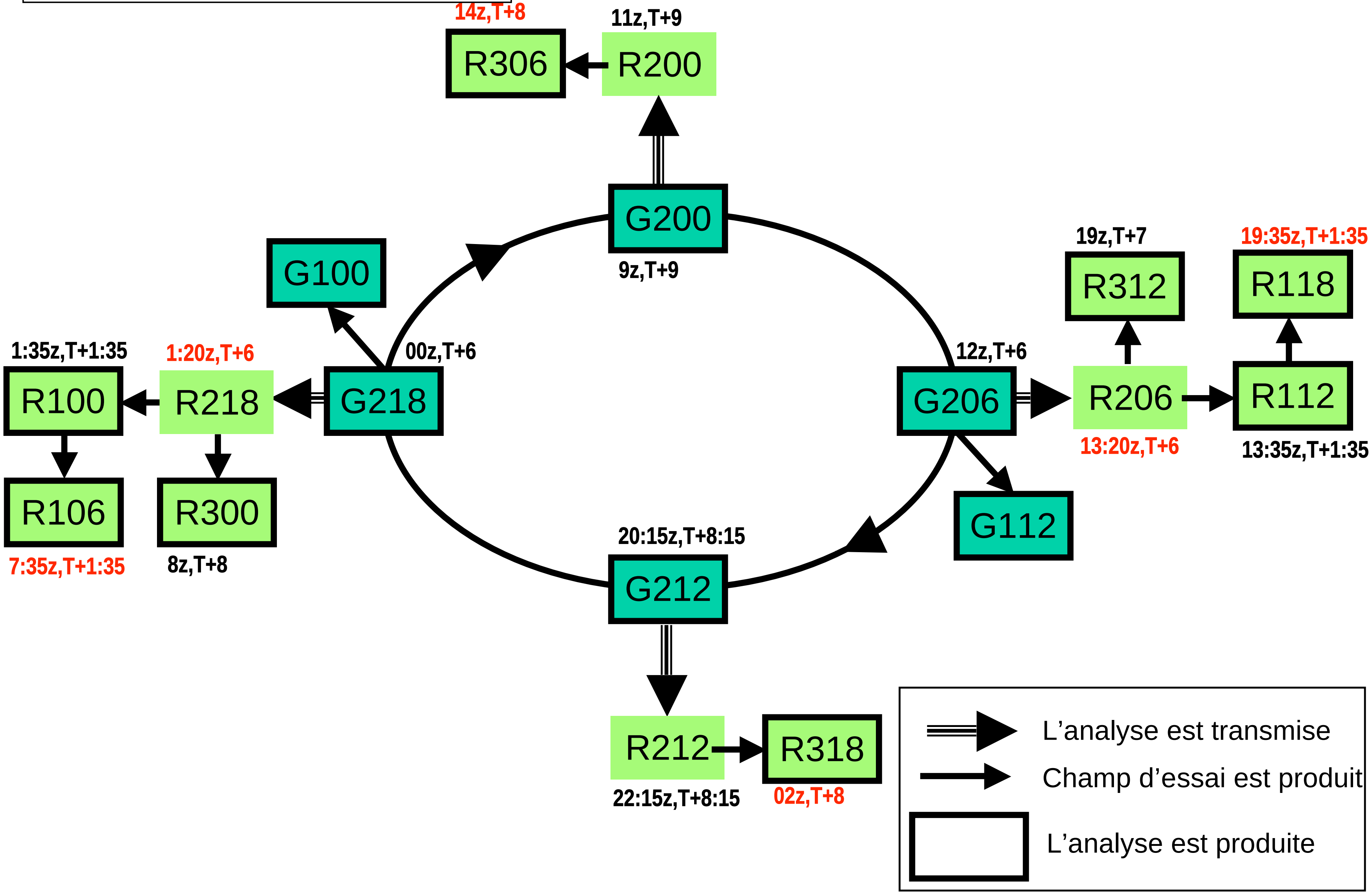
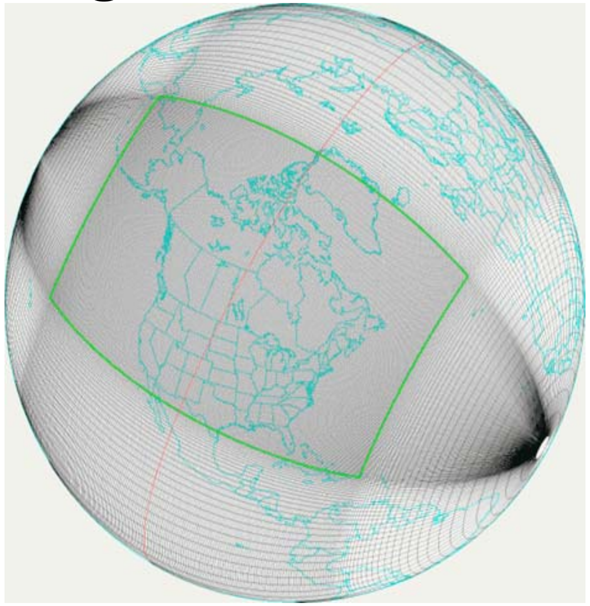
Cycle régional 6 heures



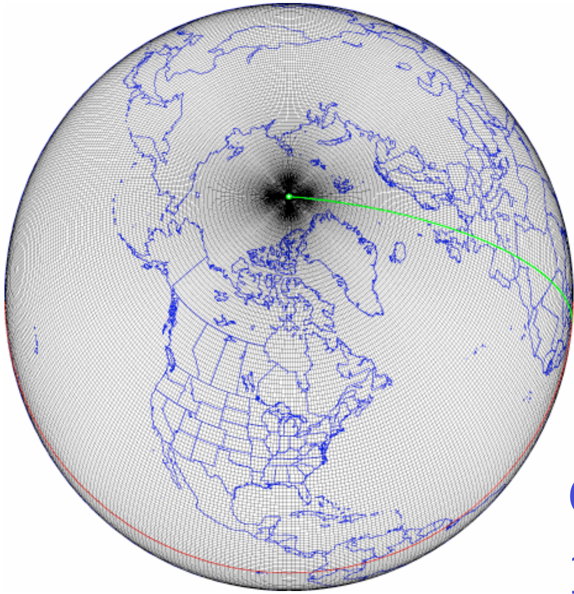
48hr Forecast model | **Analysis increments**

Regional 15 km



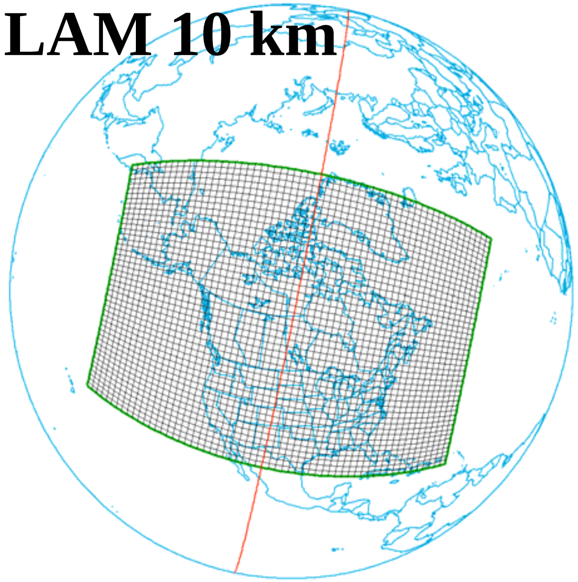
x 12

Global T108 240x120 ~185 km



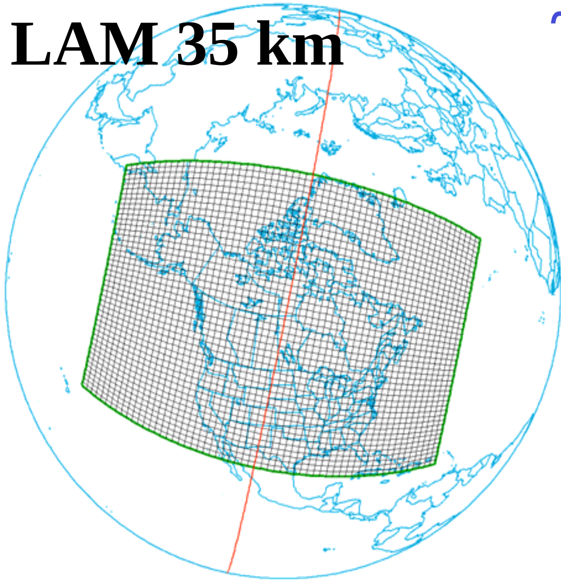
Global T571
1140 x 570 x 22
~ 35 km

LAM 10 km



x 3.5

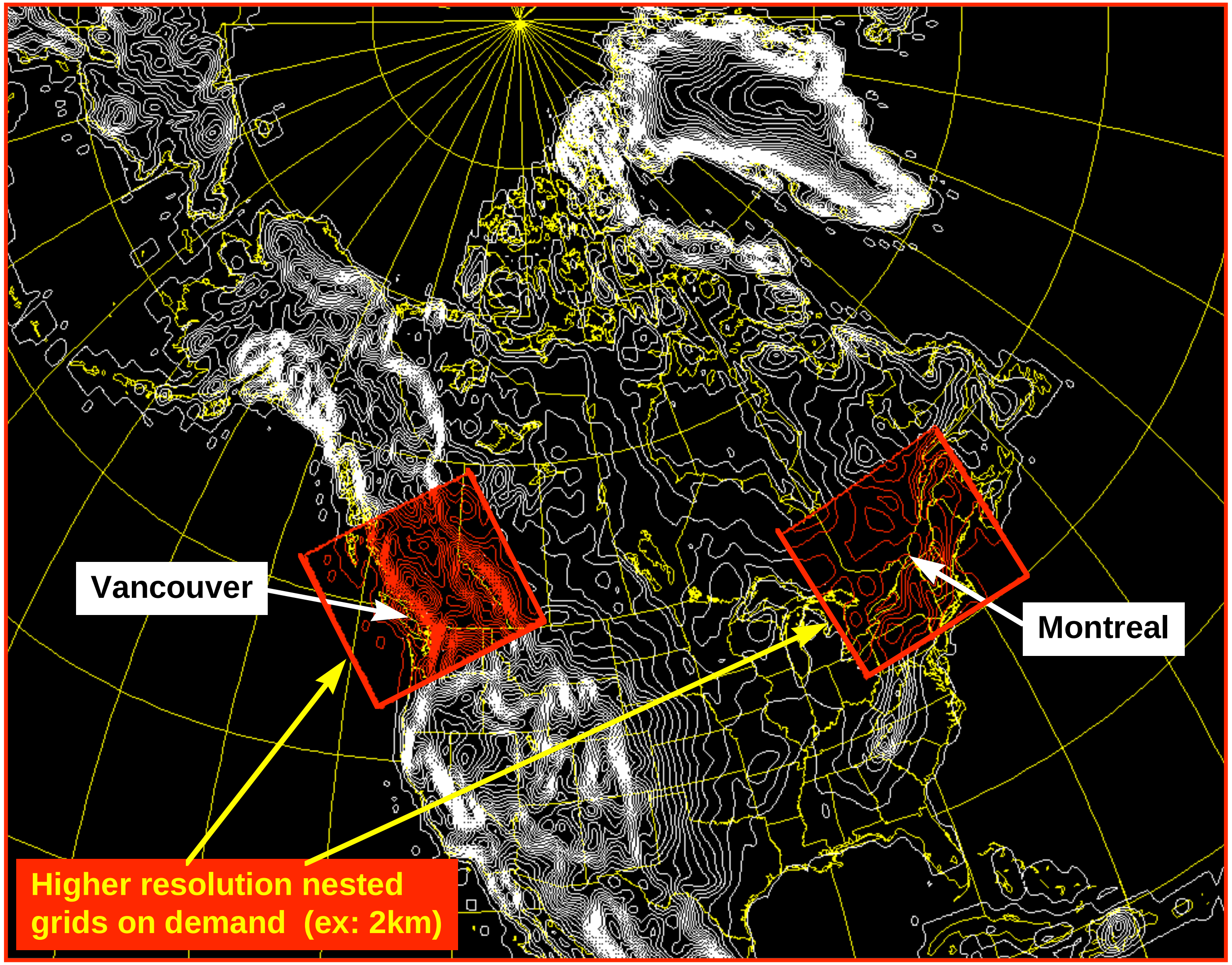
LAM 35 km



225x300 x 2

LAM4D-Var_C: Continental

Target Grid for Regional 48H Forecast at 10 km using GEM_LAM



LAM4D-Var_L :Local

$$\Delta\mathbf{x} \equiv \overbrace{(\Delta\psi, \Delta\chi_{\mathrm{b}}, \Delta\mathrm{T}_{\mathrm{b}}, 0, \Delta\mathrm{p}_{\mathrm{sb}})^{\mathrm{T}}}^{Balanced} + \overbrace{(0, \Delta\chi_{\mathrm{u}}, \Delta\mathrm{T}_{\mathrm{u}}, \Delta\mathrm{q}, \Delta\mathrm{p}_{\mathrm{su}})^{\mathrm{T}}}^{Unbalanced}$$

- Construction of P_b from ψ using Local Balance Equation:

$$\nabla^2 \Delta P_b = -\nabla \bullet (f\,\mathbf{k} \times \Delta\mathbf{v}_{\psi})$$

- Regression matrix to derive T_b and p_{sb}: $\left[\Delta \mathrm{T}_b \,, \Delta \mathrm{p}_{sb}\right] = \mathbf{V}\,\Delta P_b$

- Diabatic Balance to control Vertical motion

$$\mathbf{\Omega}\,\delta\omega = \mathbf{A}_{\bar{\psi}}\delta\psi + \mathbf{A}_{\bar{T}}\delta T - \frac{R}{p^{*}\sigma}\nabla^2\,\mathbf{K}_{\bar{T},\bar{q}}(\delta T, \delta q)$$

Nonlinear Normal Mode Initialization and Quasi-Geostrophic Theory

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ABSTRACT

The first iteration of the recently developed nonlinear normal mode initialization procedure for primitive equation models leads to quasi-rotational dynamical and diagnostic equations agreeing with those of quasi-geostrophic theory in a simple Boussinesq *f*-plane model. The proper initialization of a quasi-rotational model, however, requires a nonlinear modification of the geostrophic state traditionally used. Various generalizations are discussed briefly.

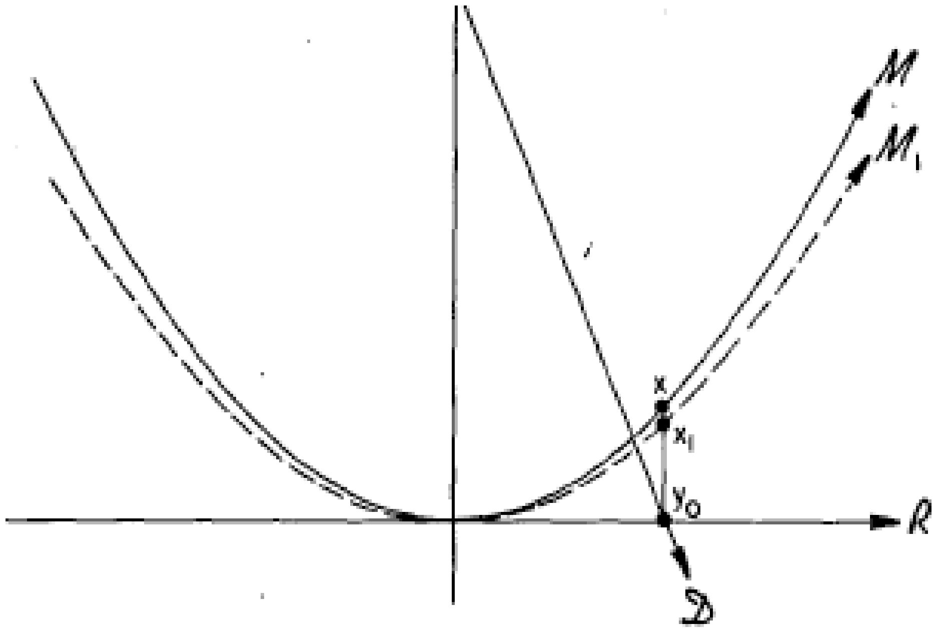


FIG. 1. Schematic diagram showing linear and nonlinear manifolds in dynamical phase space: $\mathcal{R}$, rotational; $\mathcal{G}$, gravitational; $\mathcal{D}$, data; all linear; and $\mathcal{M}$, slow nonlinear with first approximation $\mathcal{M}_1$.

1st Order Baer-Tribbia Balanced State

$$\dot{\mathbf{x}} = i\mathscr{L}\mathbf{x} + \epsilon\mathscr{N}(\mathbf{x}), \qquad (2.1)$$

$$\mathbf{x}_1 = \mathbf{y}_0 + \mathbf{z}_1 = \mathbf{y}_0 + i\epsilon(\mathscr{L}\mathscr{G})^{-1}\mathscr{G}\mathscr{N}(\mathbf{y}_0), \qquad (2.4a)$$

The addition of a physical forcing term $\epsilon\mathscr{F}(\mathbf{x})$ on the right side of the dynamics equation (2.1) does not change the balancing procedure since $\epsilon\mathscr{N}(\mathbf{x})$ may simply be replaced by $\epsilon\mathscr{N}(\mathbf{x}) + \epsilon\mathscr{F}(\mathbf{x})$ in the analysis. The slow manifold $\mathscr{M}$, of course, will be modified. In the quasi-rotational dynamics the balancing circulation will be the sum of contributions from nonlinear and physical forcing. Those physical processes depending on vertical velocity, of course, will not be treated well in the lowest-order quasi-rotational dynamics.

Diabatic TL-INMI Balance

$$\dot{\mathbf{x}} = i\,\mathbf{L}\,\mathbf{x} + \varepsilon\, N(\mathbf{x})$$

$$\delta\dot{\mathbf{x}} = i\,\mathbf{L}\,\delta\mathbf{x} + \varepsilon\,\mathbf{N}_{\bar{x}}\,\delta\mathbf{x}$$

$$\mathbf{G}\,\delta\dot{\mathbf{x}} = i\,\mathbf{G}\mathbf{L}\,\delta\mathbf{x} + \varepsilon\,\mathbf{G}\mathbf{N}_{\bar{x}}\,\delta\mathbf{x}$$

$\mathbf{G}\,\delta\dot{\mathbf{x}} \approx 0$ generalization of *Ballish* (*NMC* : *MWR* – 92)

$$\Rightarrow \quad \mathbf{G}\mathbf{L}\,\delta\mathbf{x} = i\,\varepsilon\,\mathbf{G}\,\mathbf{N}_{\bar{x}}\,\delta\mathbf{x} \quad \textit{TL Balance Manifold } \mathrm{B}$$

Use *Andersen* (1977) forward timestep trick to get :

$$\mathbf{L}\,\Delta(\delta\mathbf{x})_G = i\,(\delta\dot{\mathbf{x}})_G$$

Use *Temperton's* (1988) physical space $\mathbf{G}$ – projectors.

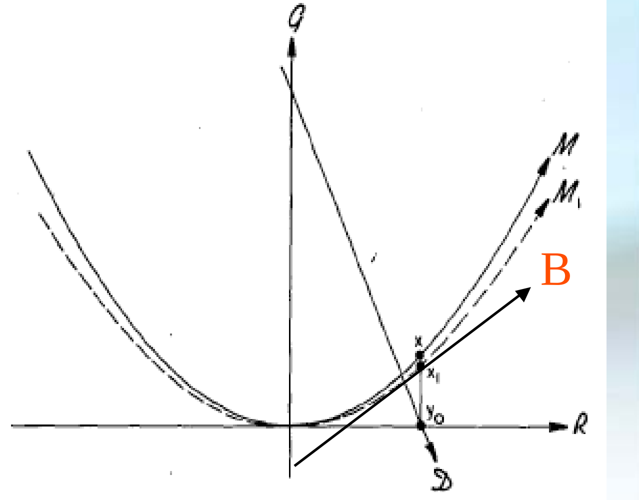


FIG. 1. Schematic diagram showing linear and nonlinear manifolds in dynamical phase space: ℛ, rotational; 𝒢, gravitational; 𝒟, data; all linear; and ℳ, slow nonlinear with first approximation ℳ₁.

SW-INMI (Temperton, MWR-1988)

$$\frac{\partial}{\partial t}\begin{bmatrix}\varsigma \\ D \\ \phi\end{bmatrix} = \begin{bmatrix} 0 & \Im & 0 \\ -\Im & -\mathrm{B} & \nabla^2 \\ 0 & \Phi\nabla^2 & 0 \end{bmatrix}\begin{bmatrix}\varsigma \\ D \\ \phi\end{bmatrix} + \begin{bmatrix} Q_\varsigma \\ Q_D \\ Q_\phi \end{bmatrix}$$

$$\Im \equiv \nabla \bullet (f\nabla)\ ;\ \mathrm{B} \equiv J(f,\ )\quad s.t.\ \ f = f(\lambda,\theta)\ here$$

$$\begin{bmatrix} 0 & \Im & 0 \\ -\Im & - & \nabla^2 \\ 0 & \Phi\nabla^2 & 0 \end{bmatrix}\begin{bmatrix}\Delta\varsigma \\ \Delta D \\ \Delta\phi\end{bmatrix} = \begin{pmatrix} \delta_t \zeta \\ \delta_t D \\ \delta_t \phi \end{pmatrix}_G$$

Baroclinic-INMI (Temperton, MWR-1988)

1) Run the model for one forward timestep to obtain

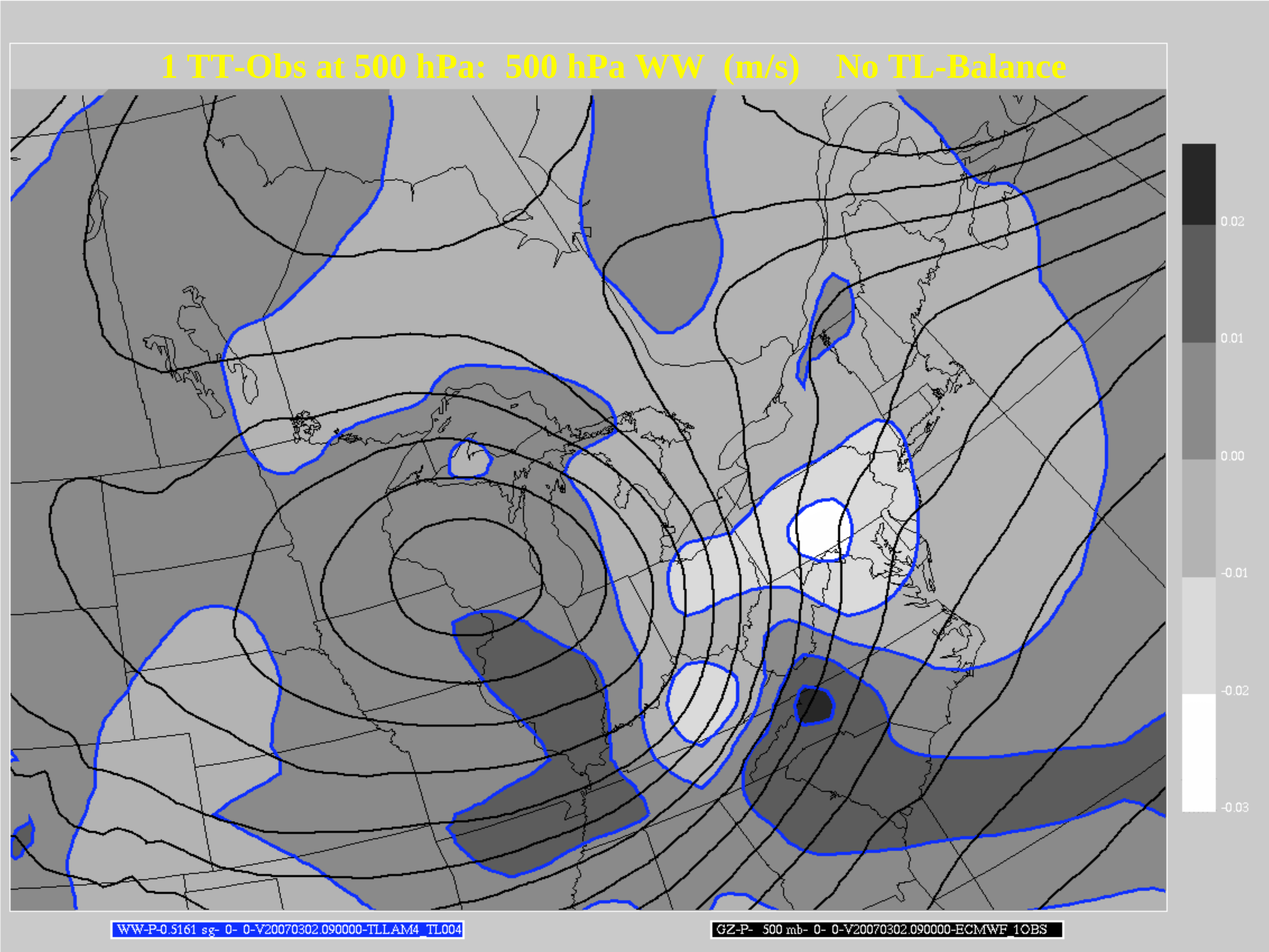
$$(\delta_t \zeta)_o \, , (\delta_t D)_o \, , (\delta_t T)_o, (\delta_t \ln p_s)_o \rightarrow (\delta_t \hat{\zeta})_o \, , (\delta_t \hat{D})_o \, , (\delta_t \hat{P})_o ,$$

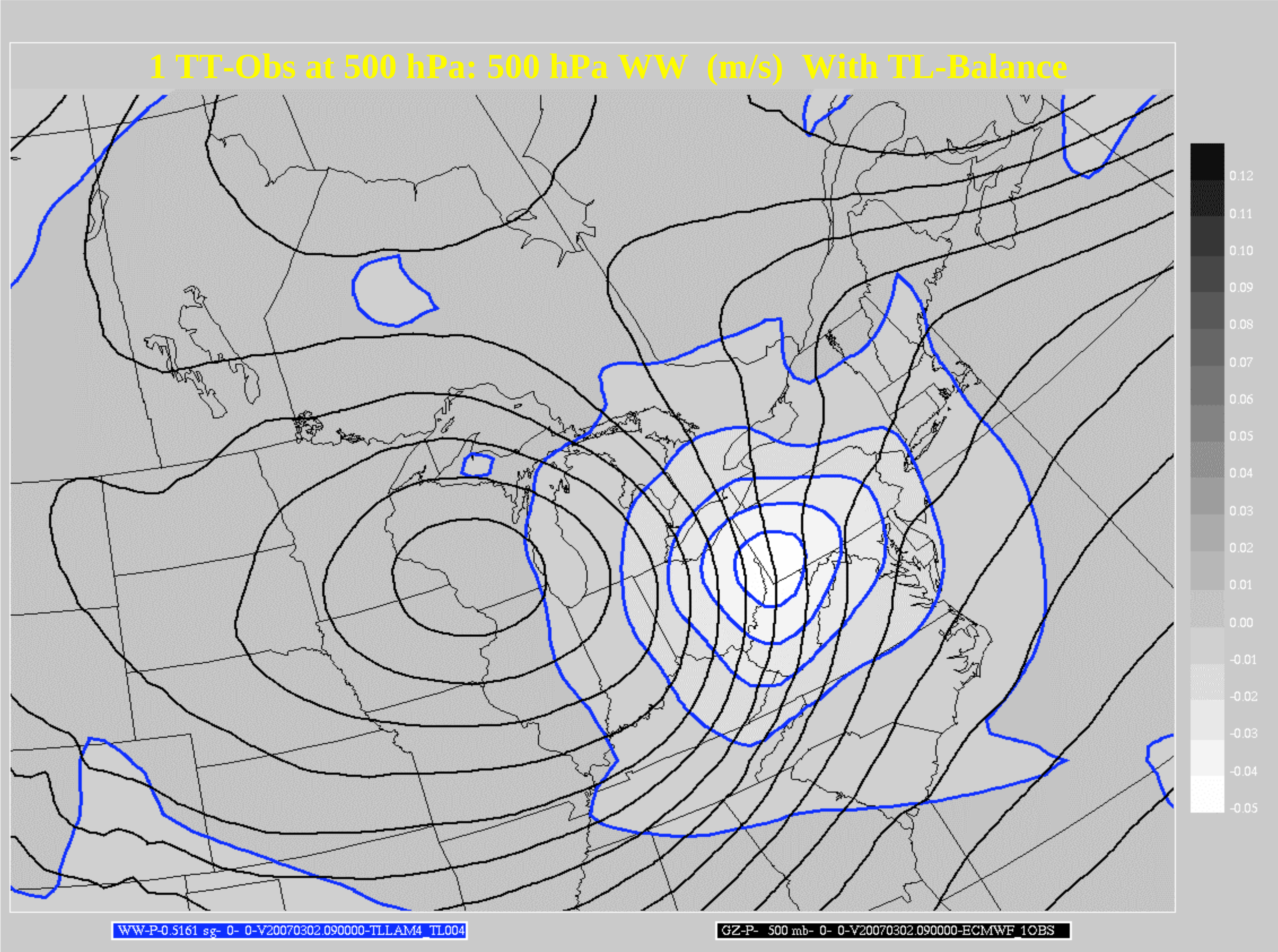
2) Solve $$(\nabla^2 - \frac{f^2}{\Phi_l}) \; \Delta \hat{P}_l = \left(\delta_t \hat{D}_l \right)_o \quad ; \quad l = 1, \dots, N \quad (N = 50 \; here)$$

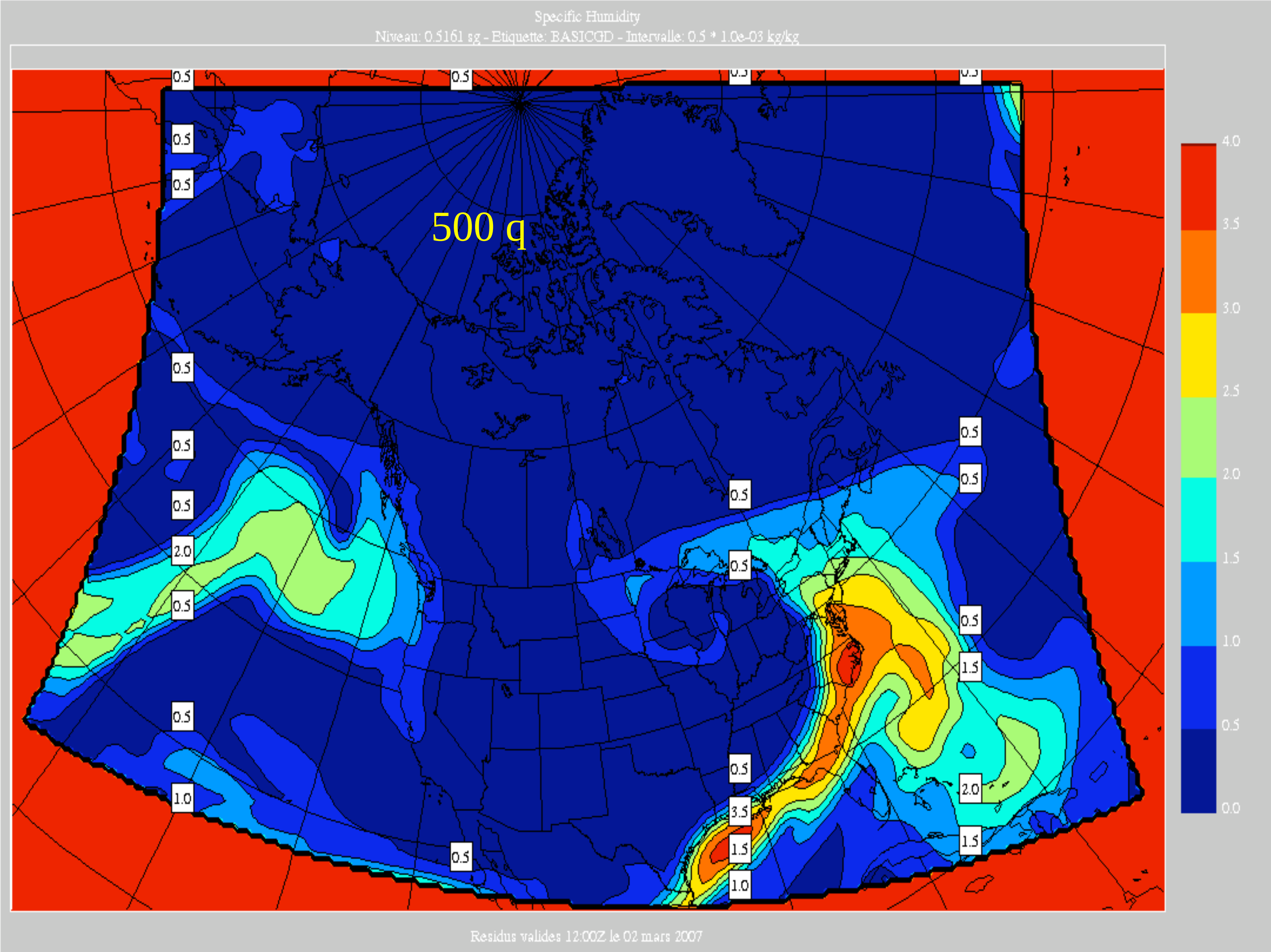
3) Solve $$(\nabla^2 - \frac{f^2}{\Phi_l}) \left(\delta_t \hat{P}_l \right)_G = \left[\nabla^2 \left(\delta_t \hat{P} \right)_o - f \, \nabla^2 \left(\delta_t \hat{\zeta} \right)_o \right]_l ; \quad l = 1, \dots, N$$

4) Compute $$\Delta \hat{D}_l = \frac{\left(\delta_t \hat{P} \right)_{lG}}{\Phi} \quad ; \quad \Delta \hat{\zeta} = \frac{f \, \Delta \hat{P}_l}{\Phi_l} \; ; \; l = 1, \dots, N$$

5) Project back to gridpoint space

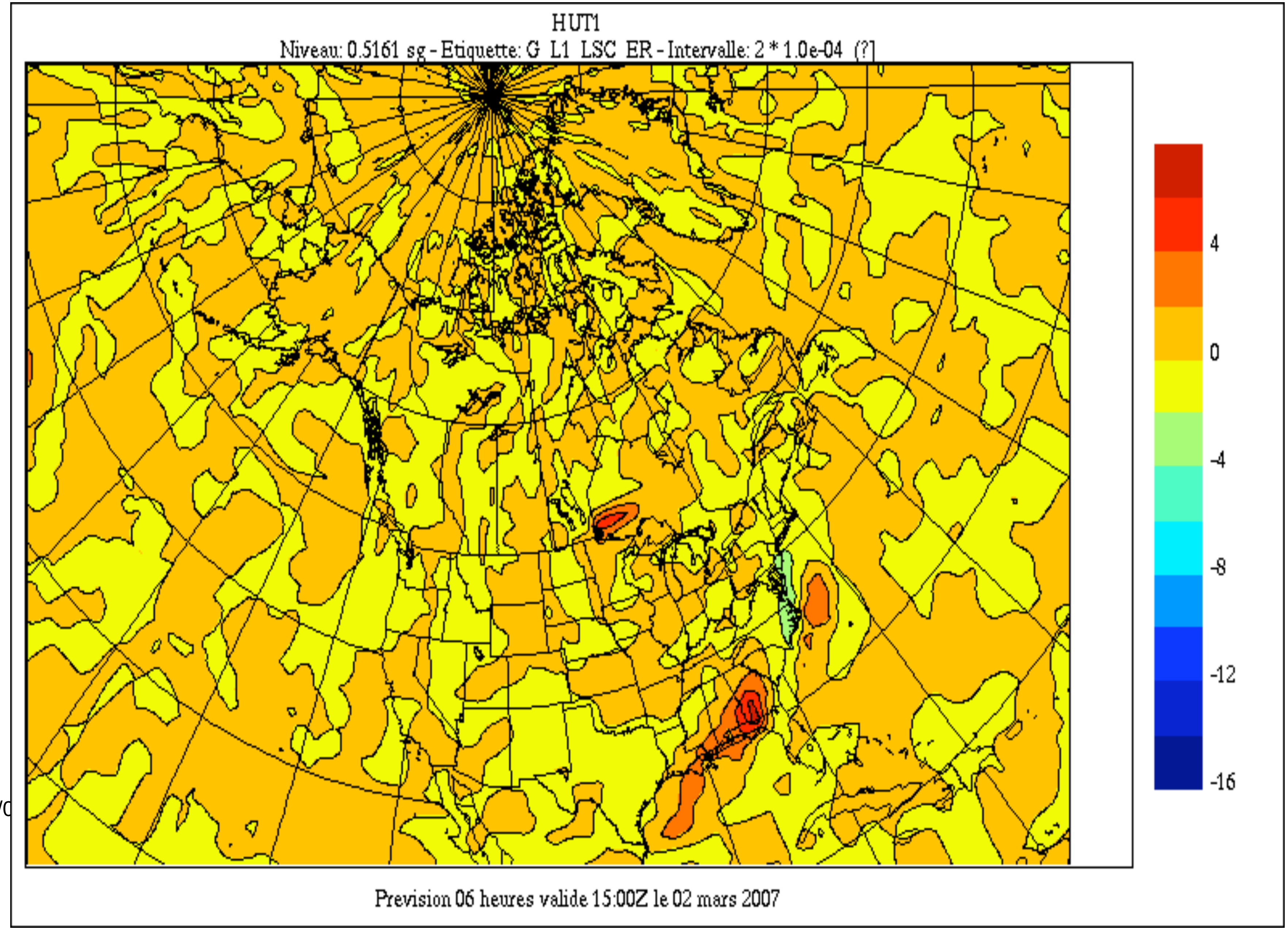

1 TT-Obs at 500 hPa: 500 hPa WW (m/s)   No TL-Balance
0.02
0.01
0.00
-0.01
-0.02
-0.03
WW-P-0.5161 sg- 0- 0-V20070302.090000-TLLAM4_TL004
GZ-P- 500 mb- 0- 0-V20070302.090000-ECMWF_1OBS


1 TT-Obs at 500 hPa: 500 hPa WW (m/s) With TL-Balance
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
WW-P-0.5161 sg- 0- 0-V20070302.090000-TLLAM4_TL004
GZ-P- 500 mb- 0- 0-V20070302.090000-ECMWF_1OBS

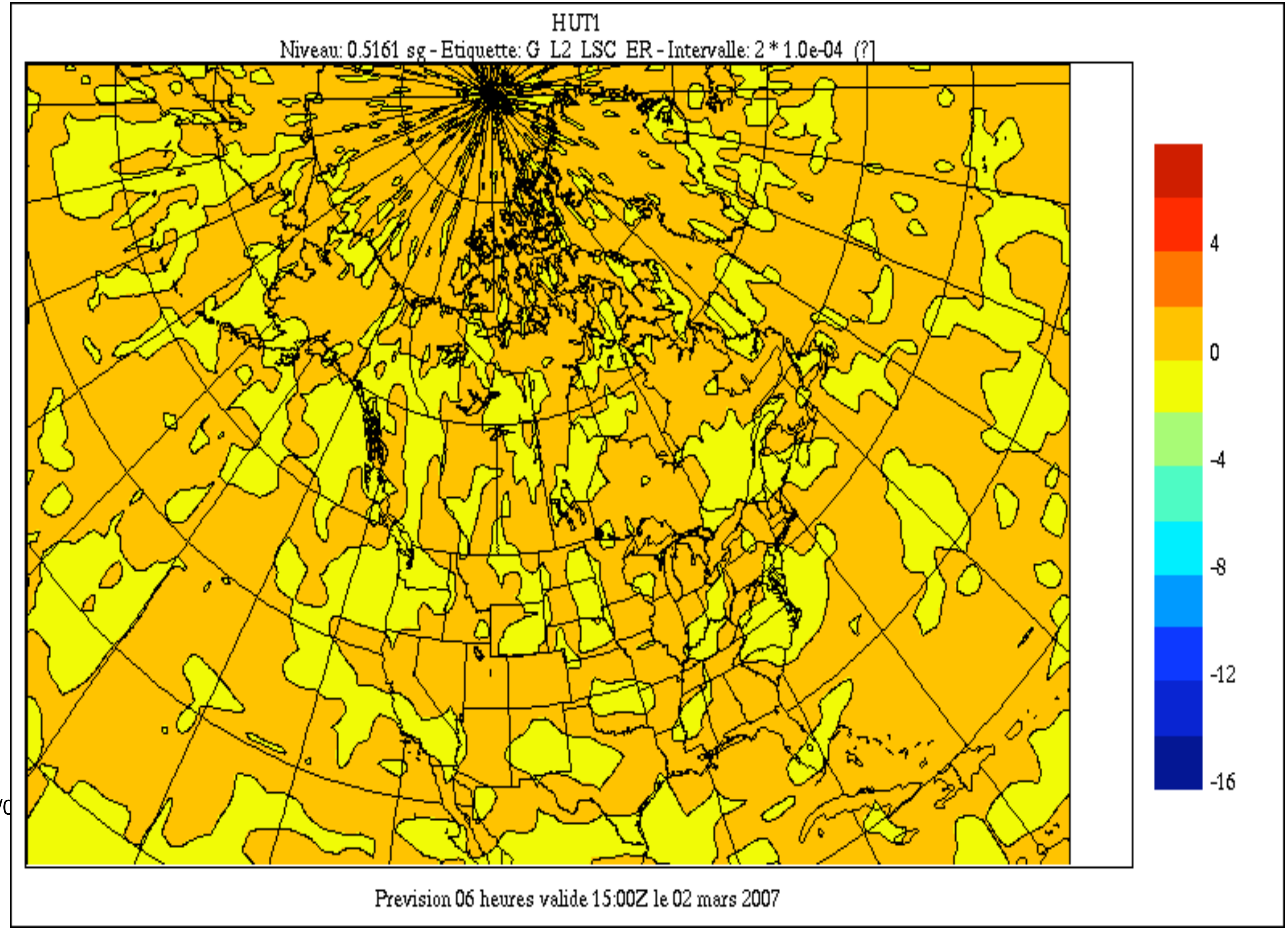

Specific Humidity
Niveau: 0.5161 sg - Etiquette: BASICGD - Intervalle: 0.5 * 1.0e-03 kg/kg
500 q
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Residus valides 12:00Z le 02 mars 2007


2nd March, 2007 Storm, Montreal

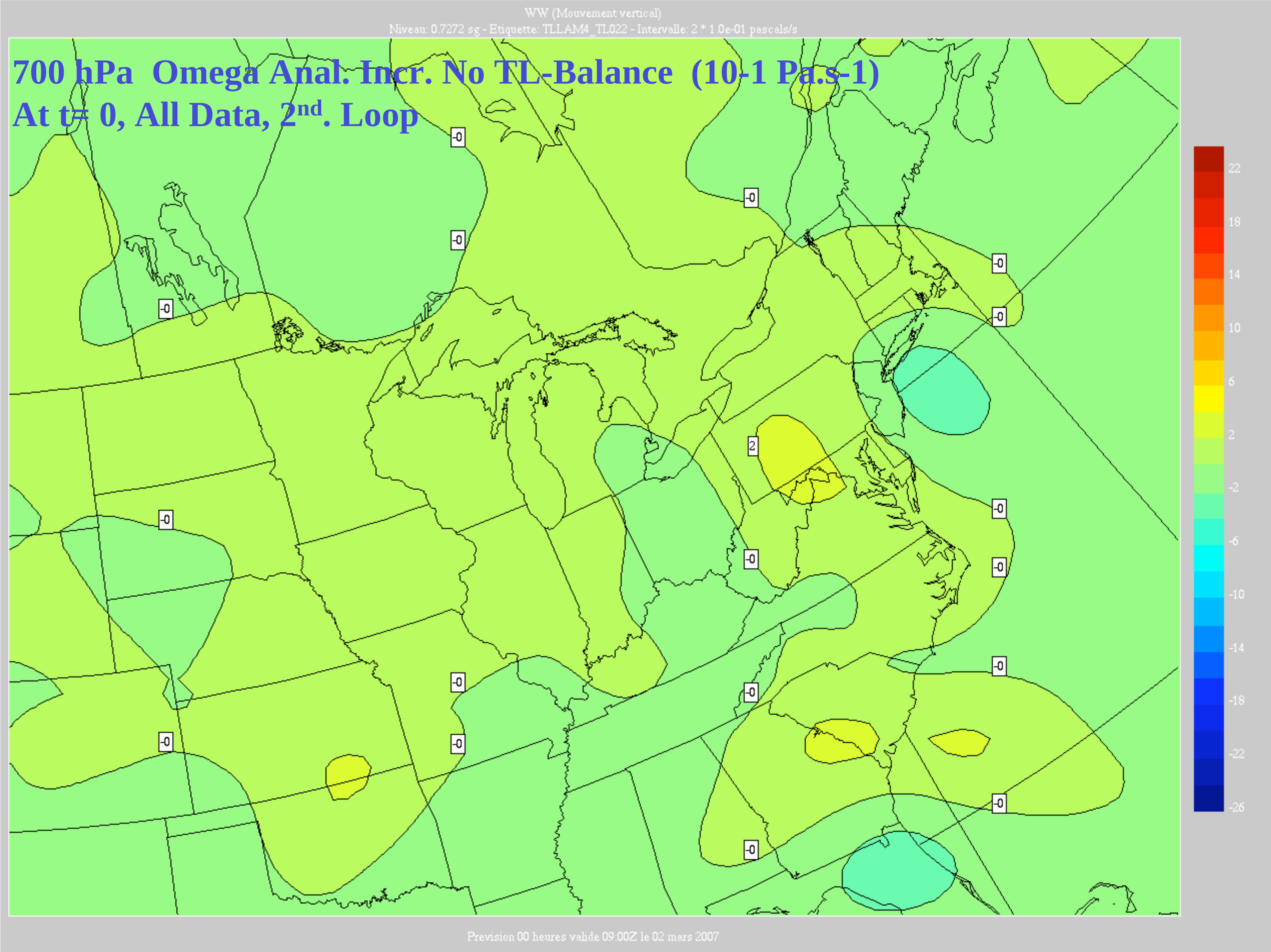
[(NL2-NL1) - TL] Global HU T=6hr (LOOP1)

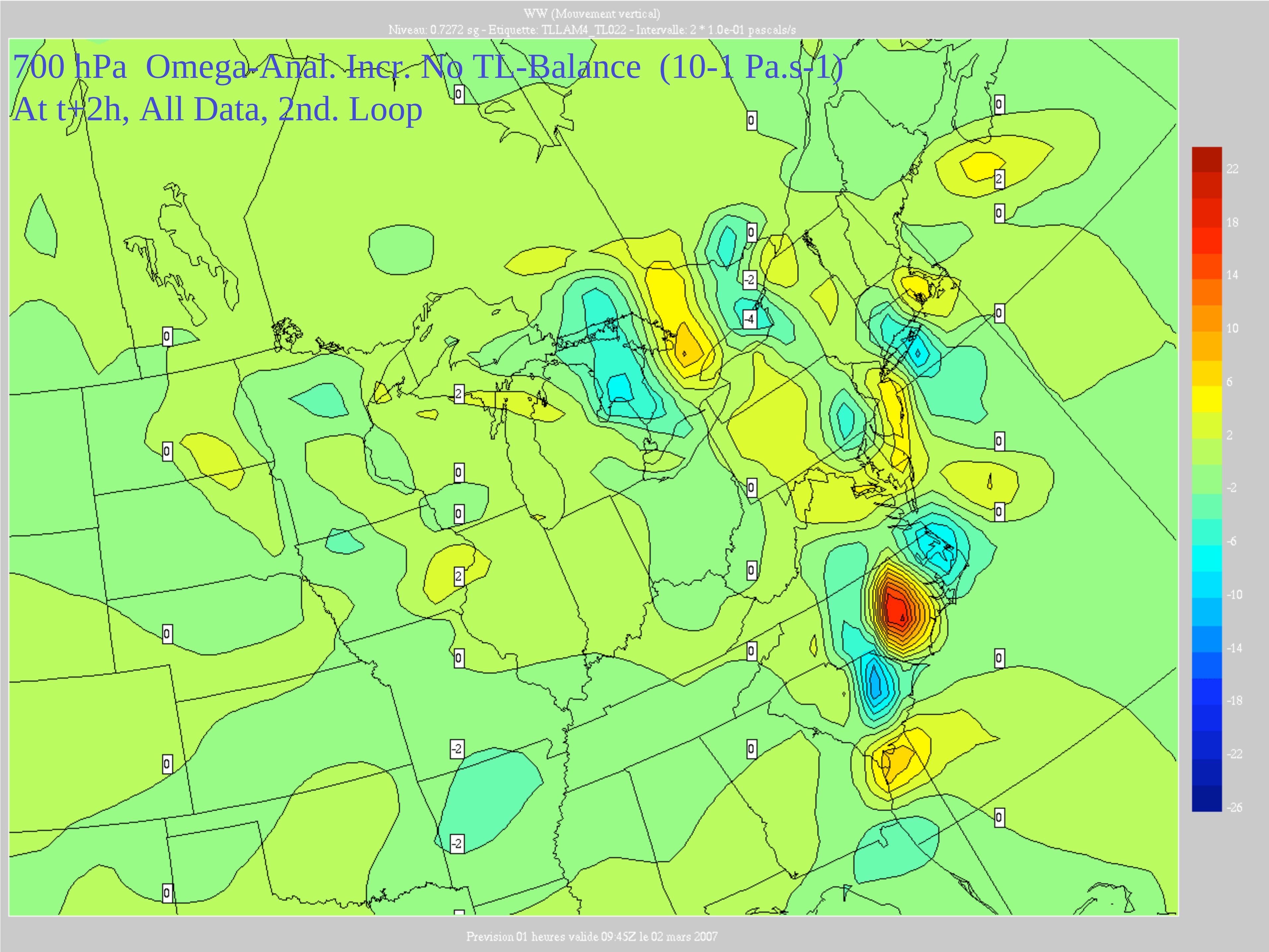


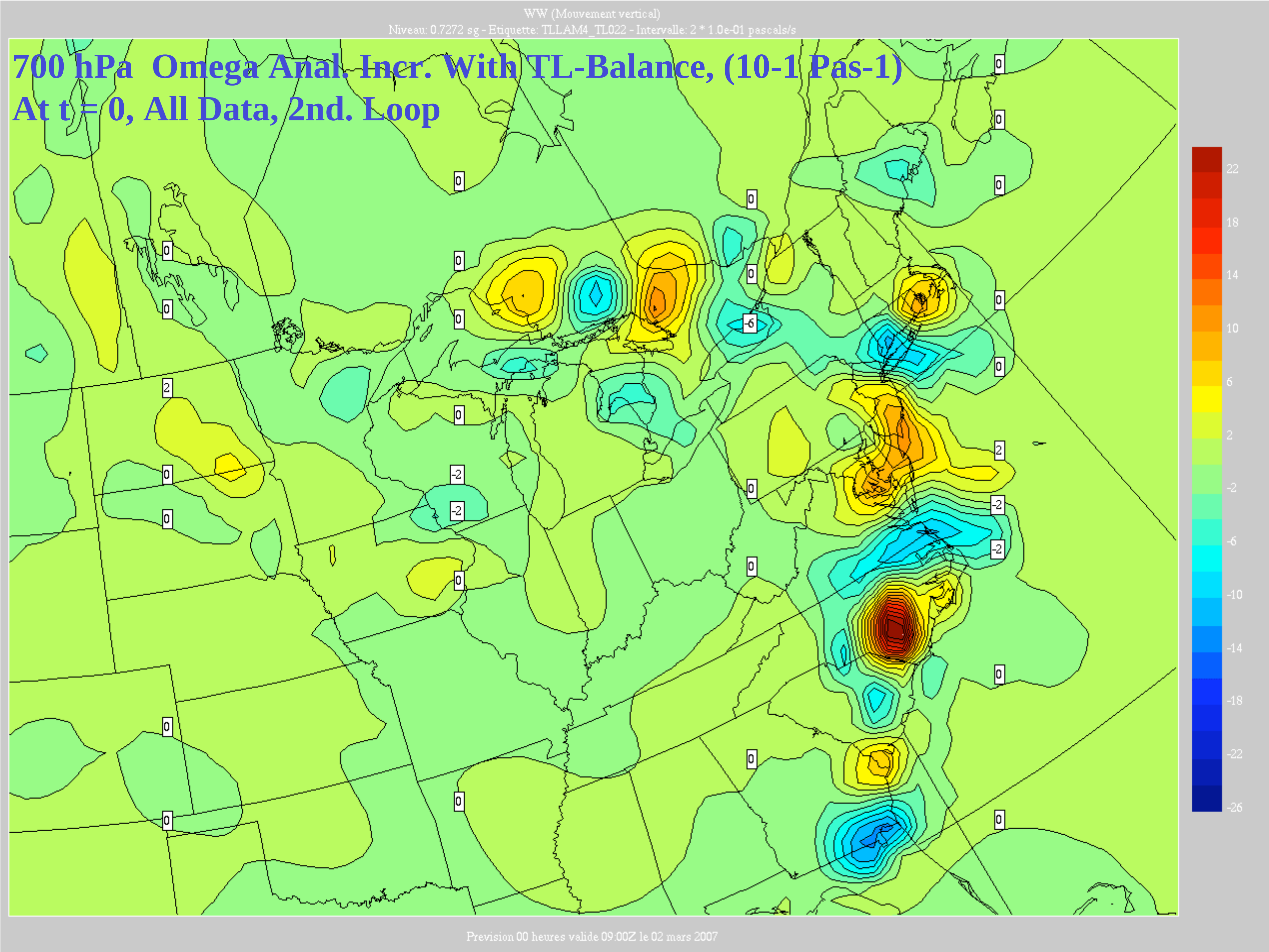
[(NL2-NL1) - TL] Global HU T=6hr (**LOOP2**)

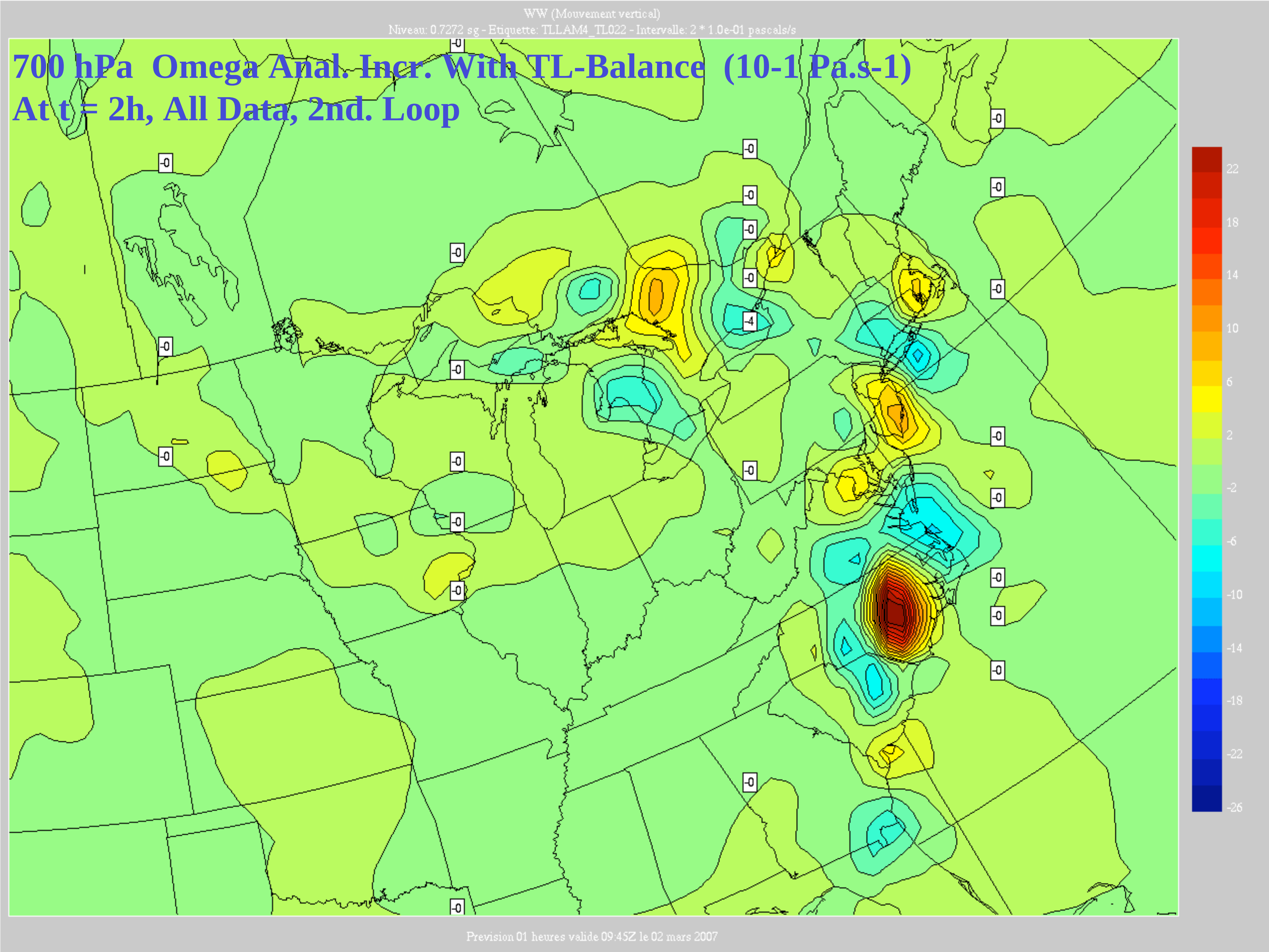


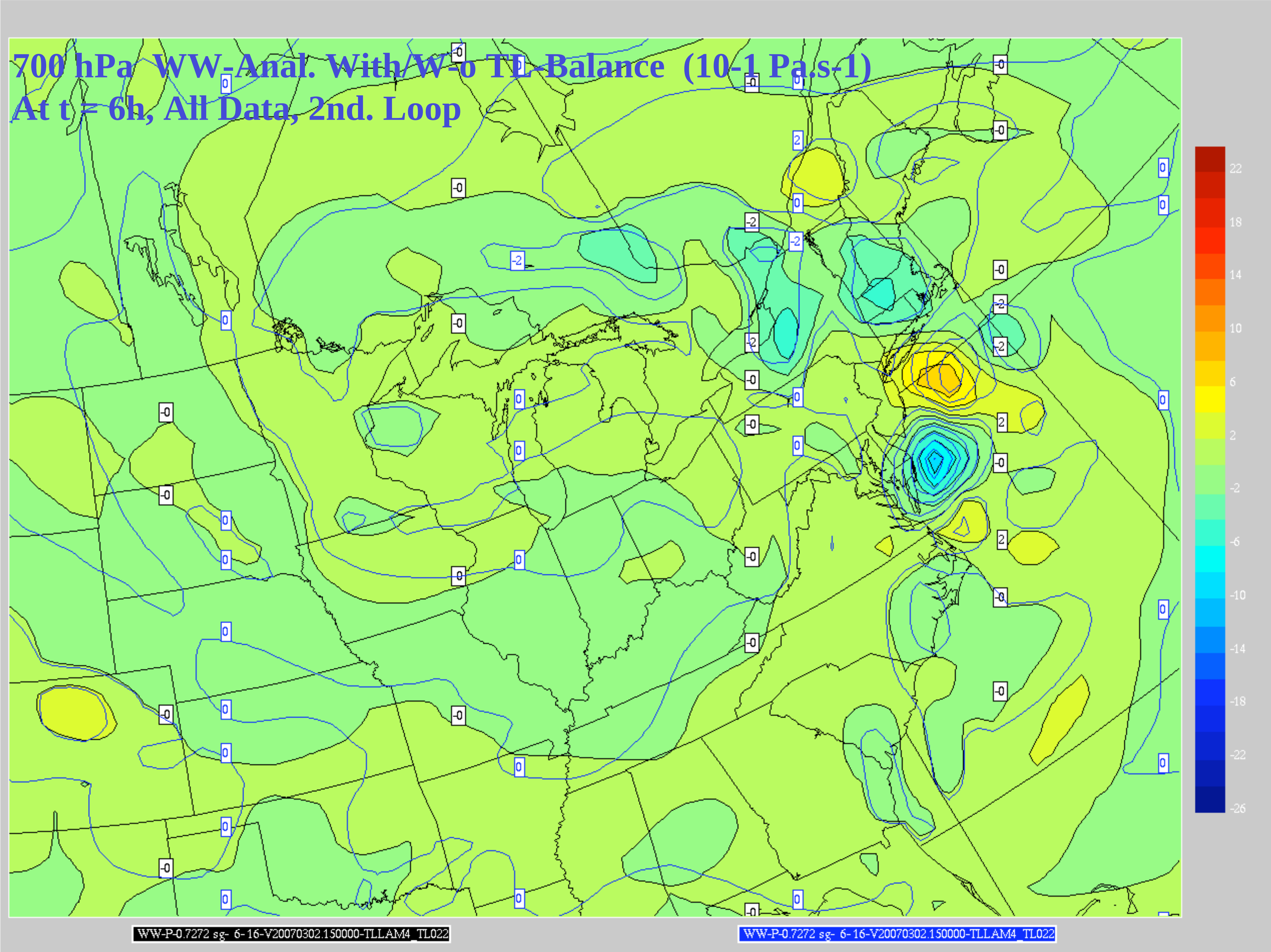
700 hPa Omega Anal. Incr. No TL-Balance (10-1 Pa.s-1)
At t= 0, All Data, 2nd. Loop

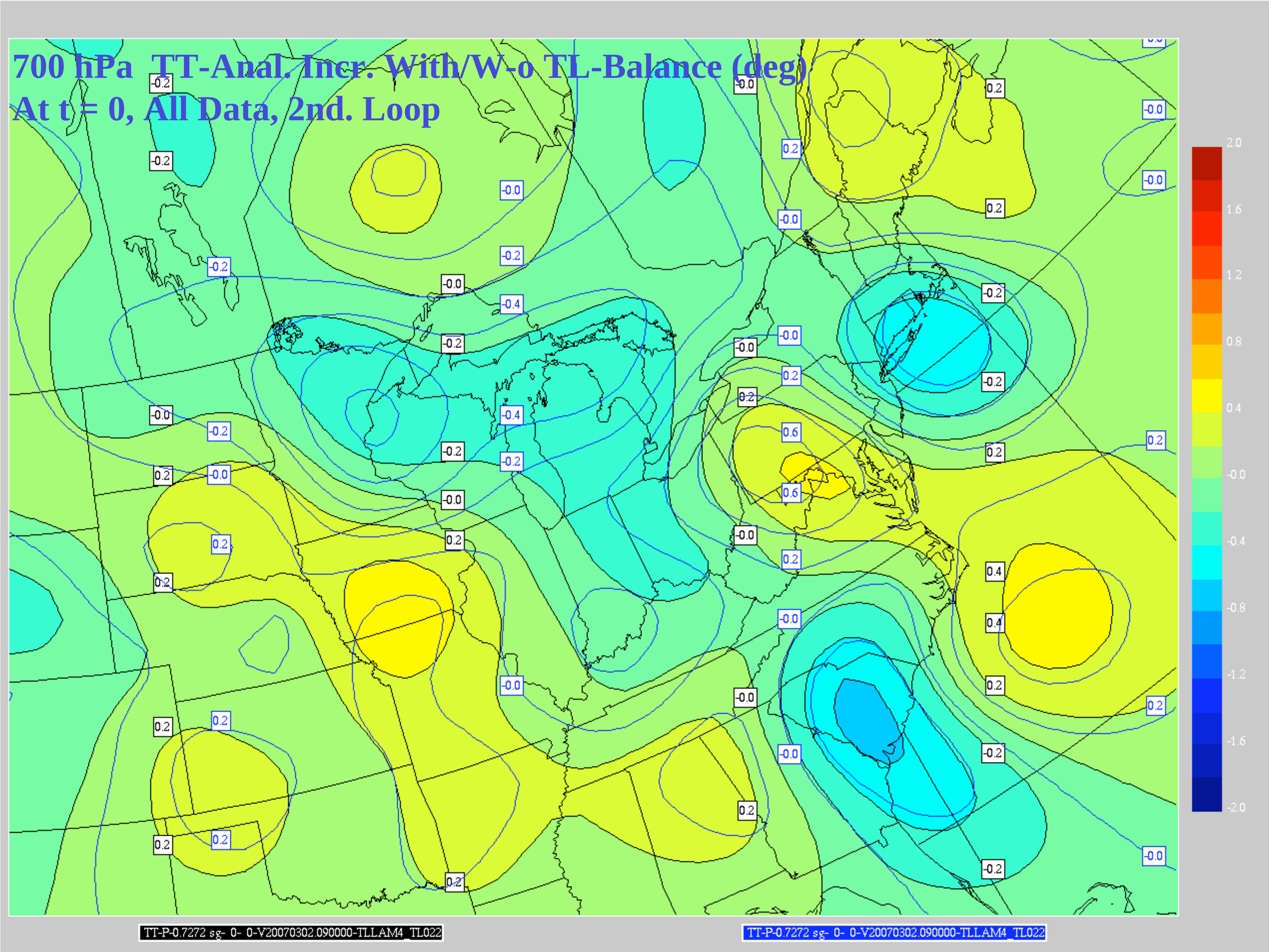



WW (Mouvement vertical)
Niveau: 0.7272 sg - Etiquette: TLLAM4_TL022 - Intervalle: 2 * 1.0e-01 pascals/s
700 hPa Omega-Anal. Incr. No TL-Balance (10-1 Pa.s-1)
At t+2h, All Data, 2nd. Loop
22
18
14
10
6
2
-2
-6
-10
-14
-18
-22
-26
Prevision 01 heures valide 09:45Z le 02 mars 2007


WW (Mouvement vertical)
Niveau: 0.7272 sg - Etiquette: TLLAM4_TL022 - Intervalle: 2 * 1.0e-01 pascals/s
700 hPa Omega Anal. Incr. With TL-Balance, (10-1 Pas-1)
At t = 0, All Data, 2nd. Loop
22
18
14
10
6
2
-2
-6
-10
-14
-18
-22
-26
Prevision 00 heures valide 09:00Z le 02 mars 2007


WW (Mouvement vertical)
Niveau: 0.7272 sg - Etiquette: TLLAM4_TL022 - Intervalle: 2 * 1.0e-01 pascals/s
700 hPa Omega Anal. Incr. With TL-Balance (10-1 Pa.s-1)
At t = 2h, All Data, 2nd. Loop
22
18
14
10
6
2
-2
-6
-10
-14
-18
-22
-26
Prevision 01 heures valide 09:45Z le 02 mars 2007


700 hPa WW-Anal. With/W-o TL-Balance (10-1 Pa.s-1)
At t = 6h, All Data, 2nd. Loop
22
18
14
10
6
2
-2
-6
-10
-14
-18
-22
-26
WW-P-0.7272 sg- 6-16-V20070302.150000-TLLAM4_TL022
WW-P-0.7272 sg- 6-16-V20070302.150000-TLLAM4_TL022


700 hPa TT-Anal. Incr. With/W-o TL-Balance (deg)
At t = 0, All Data, 2nd. Loop
2.0
1.6
1.2
0.8
0.4
-0.0
-0.4
-0.8
-1.2
-1.6
-2.0
TT-P-0.7272 sg- 0- 0-V20070302.090000-TLLAM4_TL022
TT-P-0.7272 sg- 0- 0-V20070302.090000-TLLAM4_TL022

Thank you!