Low frequency oscillations in the atmosphere induced by SST front

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- The most prominent SST fronts found in the upwelling zones and across major oceanic currents.
- Midoceanic thermal fronts such as the Gulf Stream and Kuroshio current extension, are permanent features in the midlatitude ocean-circulation.

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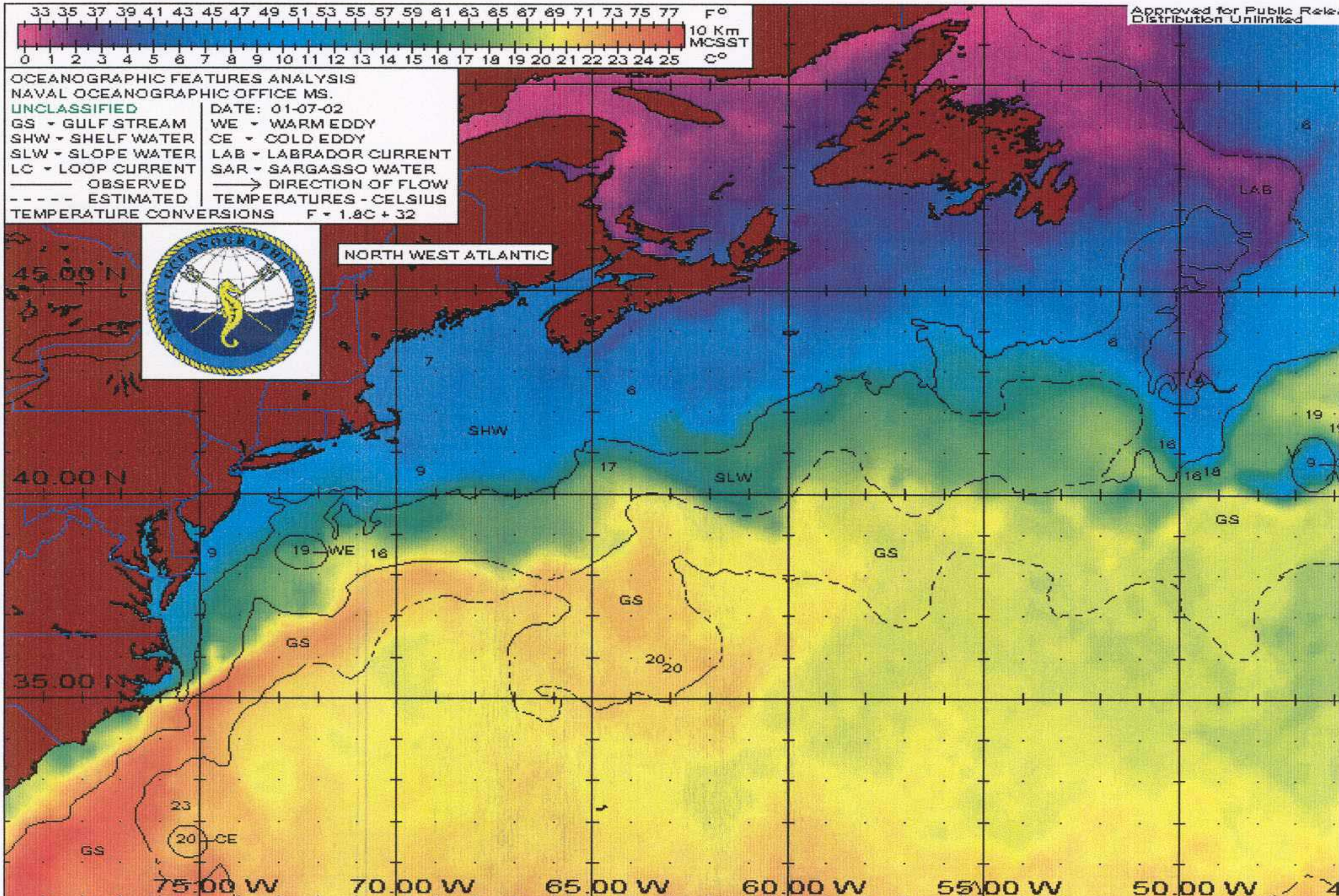
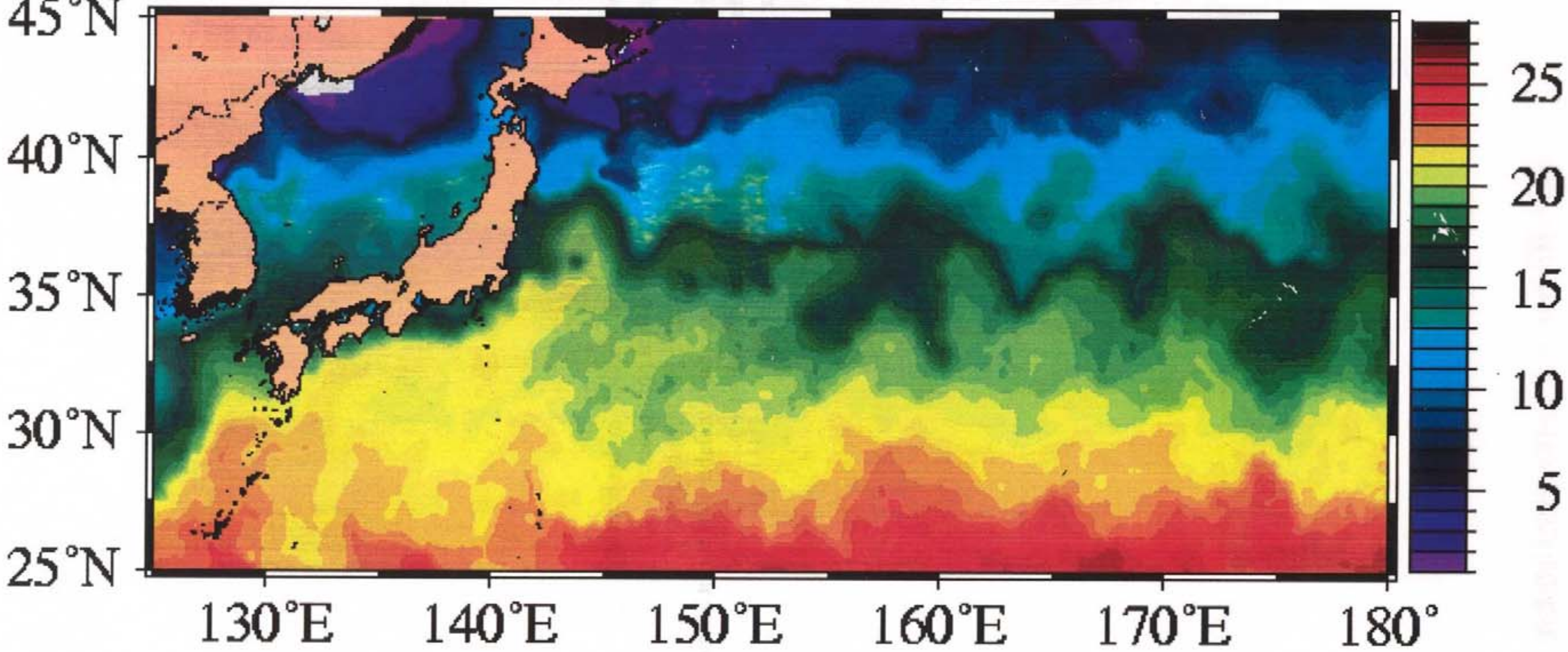


MCSST OI: Sea Surface Temperature (C)
1/8° MODAS2D 01-04-2002



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Response of the AMBL to oceanic fronts

- Most of the studies concentrated on steady-state AMBL solutions or short time evolution (of order of 12-24hours).
- The circulation in the AMBL adjusts to changes in the oceanic surface conditions in several hours. The AMBL reaches heights of 600-1200m.

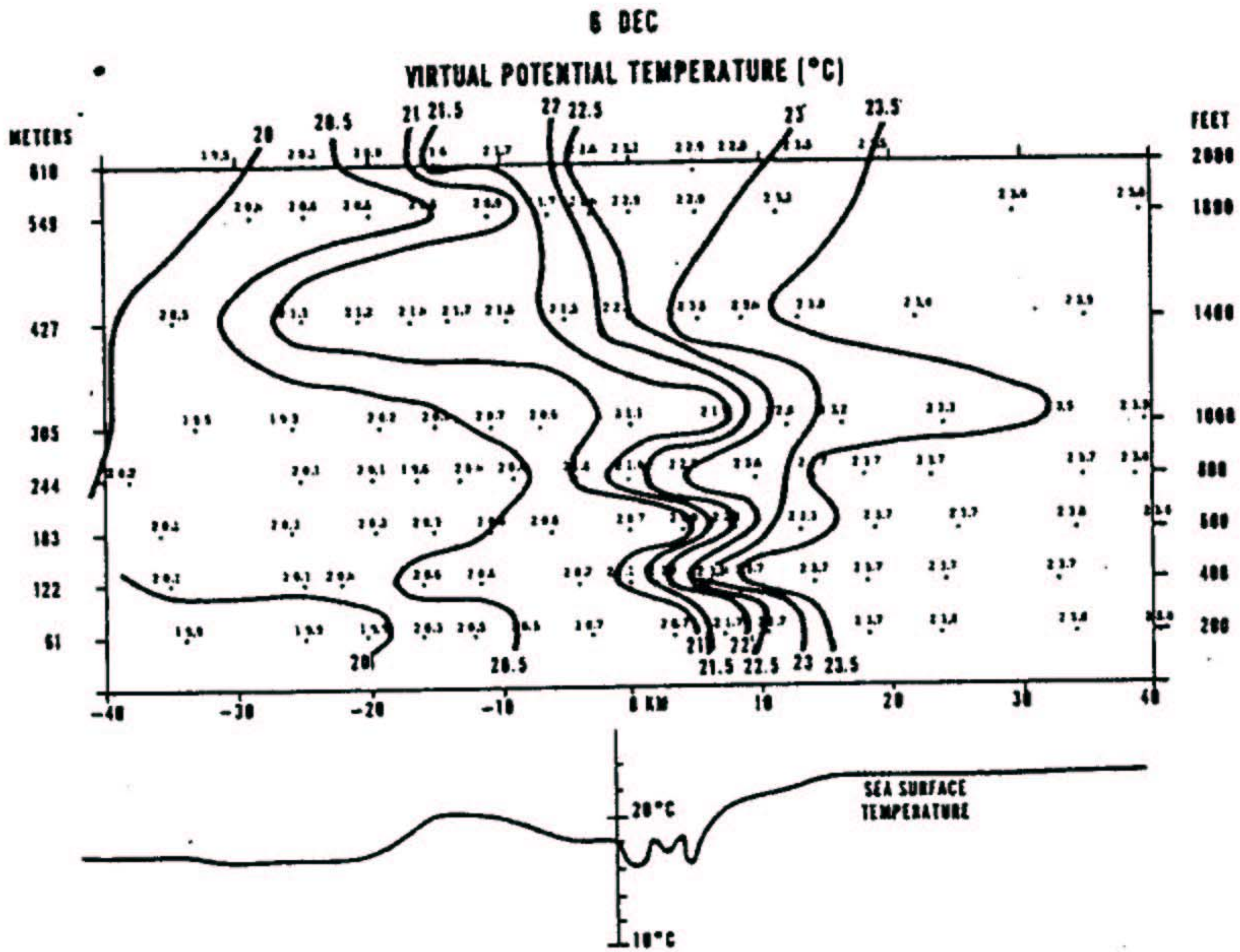


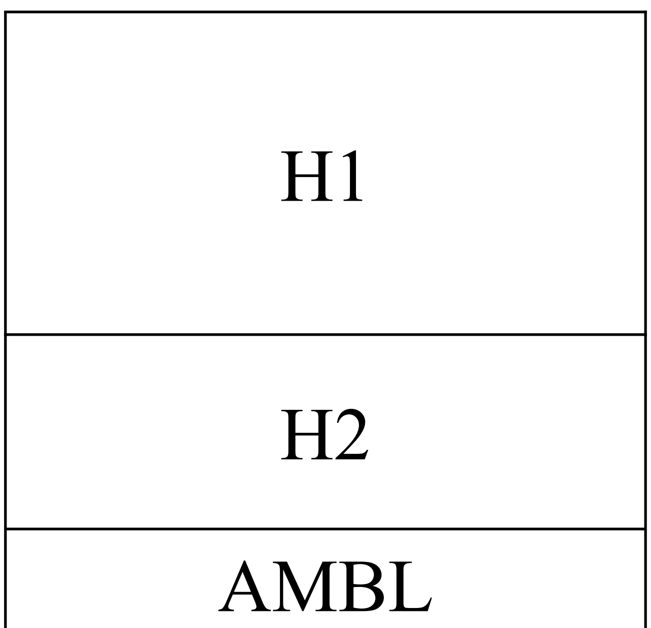
FIG. 14. Vertical cross section of virtual potential temperature, 6 December 1979.

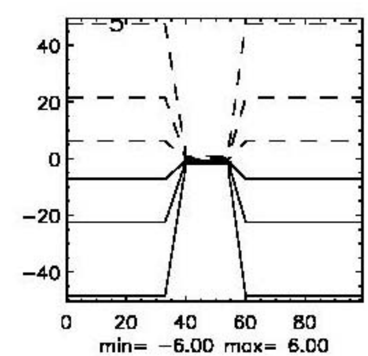
- We study the flow induced by an east-west oriented SST front of finite zonal extent (600km). The SST front has the pattern:

  - $T(y)=-T^{*}\tanh(y/50km)$

- The atmospheric model composed of a steady, analytical AMBL and a time dependent, QG, baroclinic model has two modes in the vertical, corresponds to two layers.

- The computational domain size is 5000km x 5000km with grid spacing of 50km.





The vertical velocity, w, at the top of the AMBL, H_E

$$w(H_E) = -\int_0^{H_E} \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right) dz = \gamma \nabla^2 \psi - \alpha \nabla^2 T$$

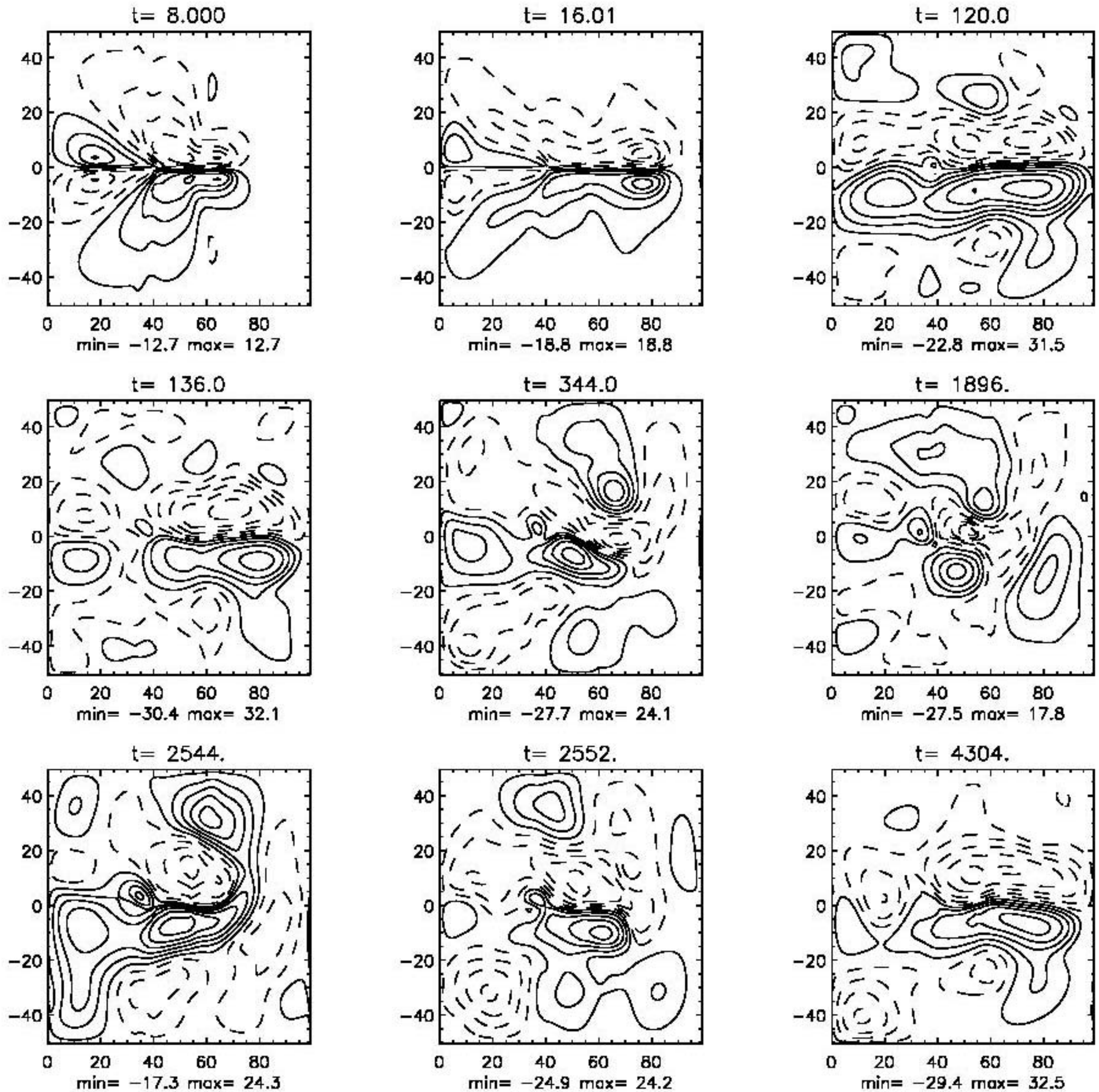
Thermal component

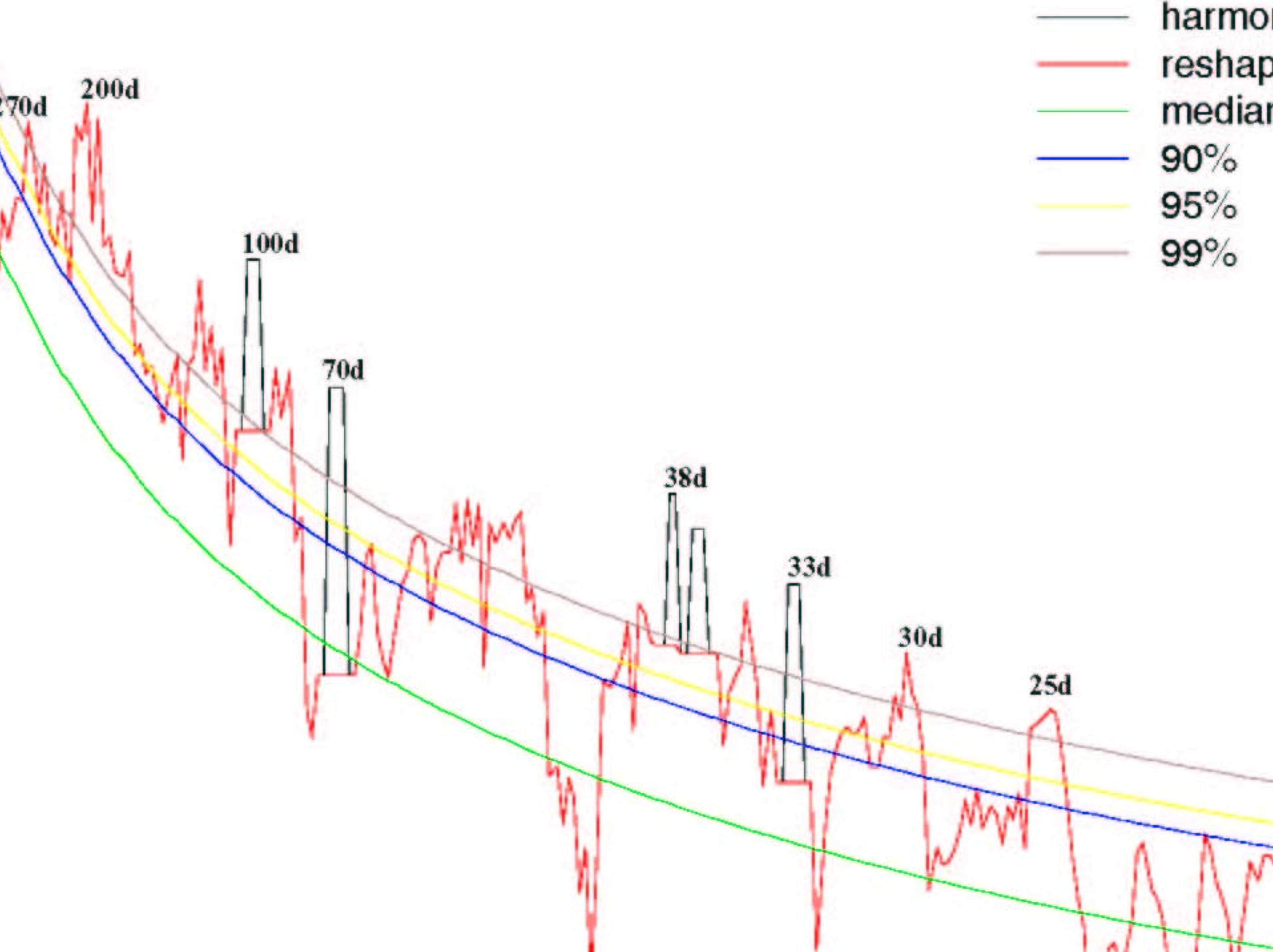
Mechanical component

The nondimensional constant

$$\alpha = \frac{1}{2\pi}\left(1 - \frac{1}{2\pi}\right) \frac{g H_E^{\ 2}}{H_a V^2} \frac{T^*}{\theta_0} = \frac{1}{2\pi}\left(1 - \frac{1}{2\pi}\right) \frac{H_E}{H_a} \frac{1}{Fr^2} \qquad (5)$$

determines the strength of the vertical velocity component at the top of the AMBL

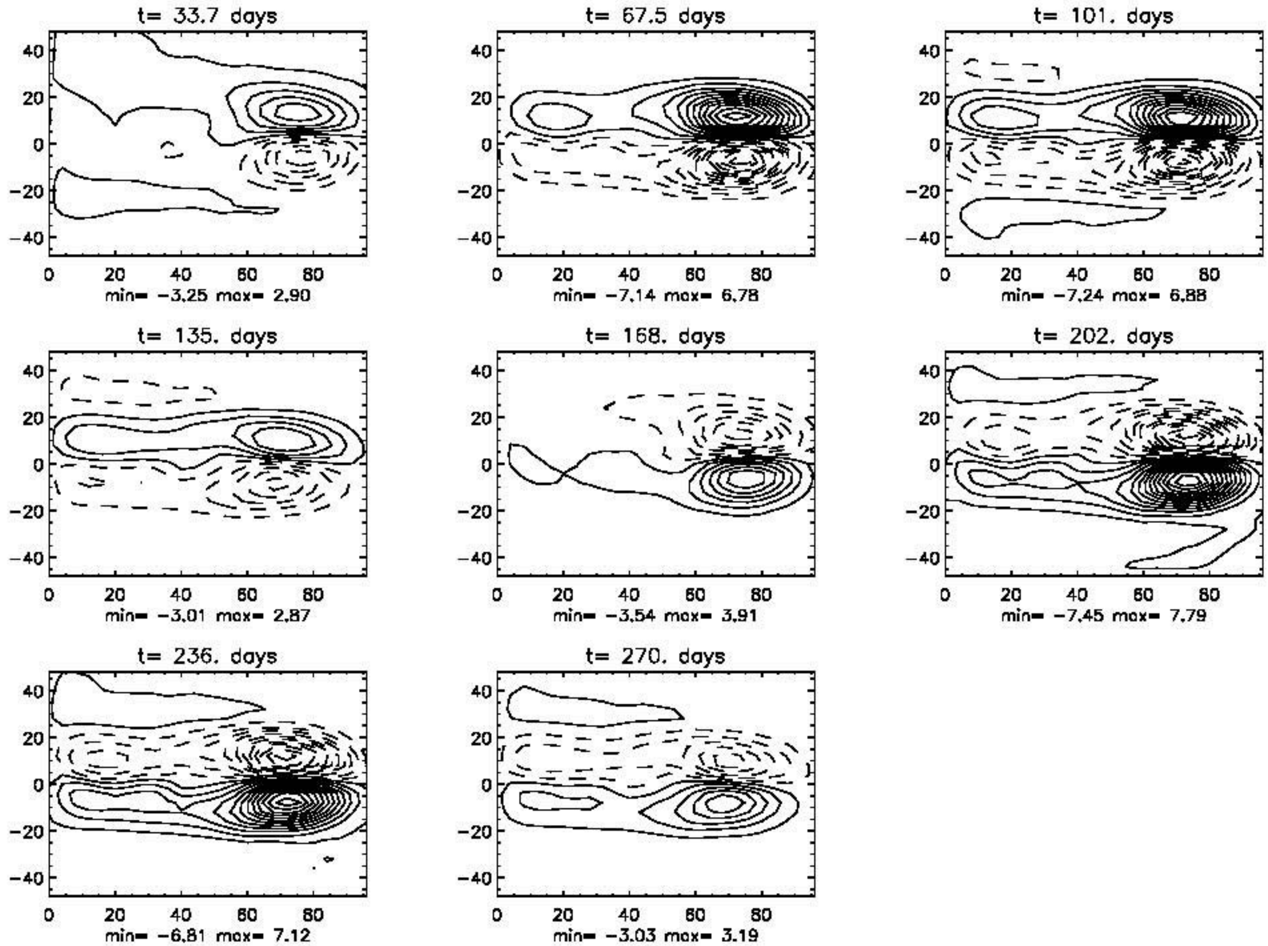

t= 8.000
min= −12.7 max= 12.7
t= 16.01
min= −18.8 max= 18.8
t= 120.0
min= −22.8 max= 31.5
t= 136.0
min= −30.4 max= 32.1
t= 344.0
min= −27.7 max= 24.1
t= 1896.
min= −27.5 max= 17.8
t= 2544.
min= −17.3 max= 24.3
t= 2552.
min= −24.9 max= 24.2
t= 4304.
min= −29.4 max= 32.5



harmo
reshap
median
90%
95%
99%
270d
200d
100d
70d
38d
33d
30d
25d

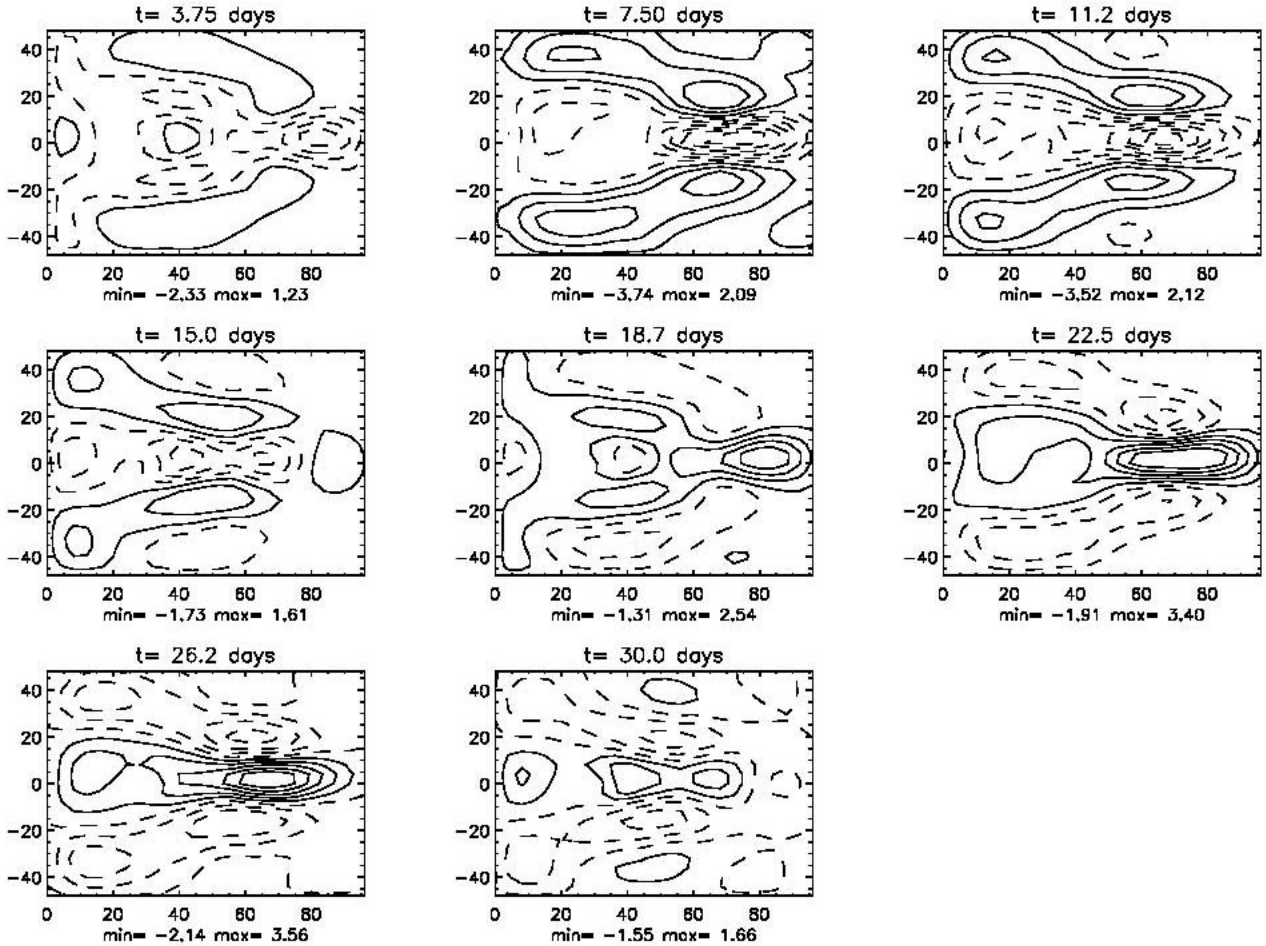
Three kinds of unstable oscillatory modes are obtained

- First, antisymmetric instabilities that correspond to baroclinic instabilities have a standing oscillating dipole structure.
- The most dominant modes have period of 270 days.

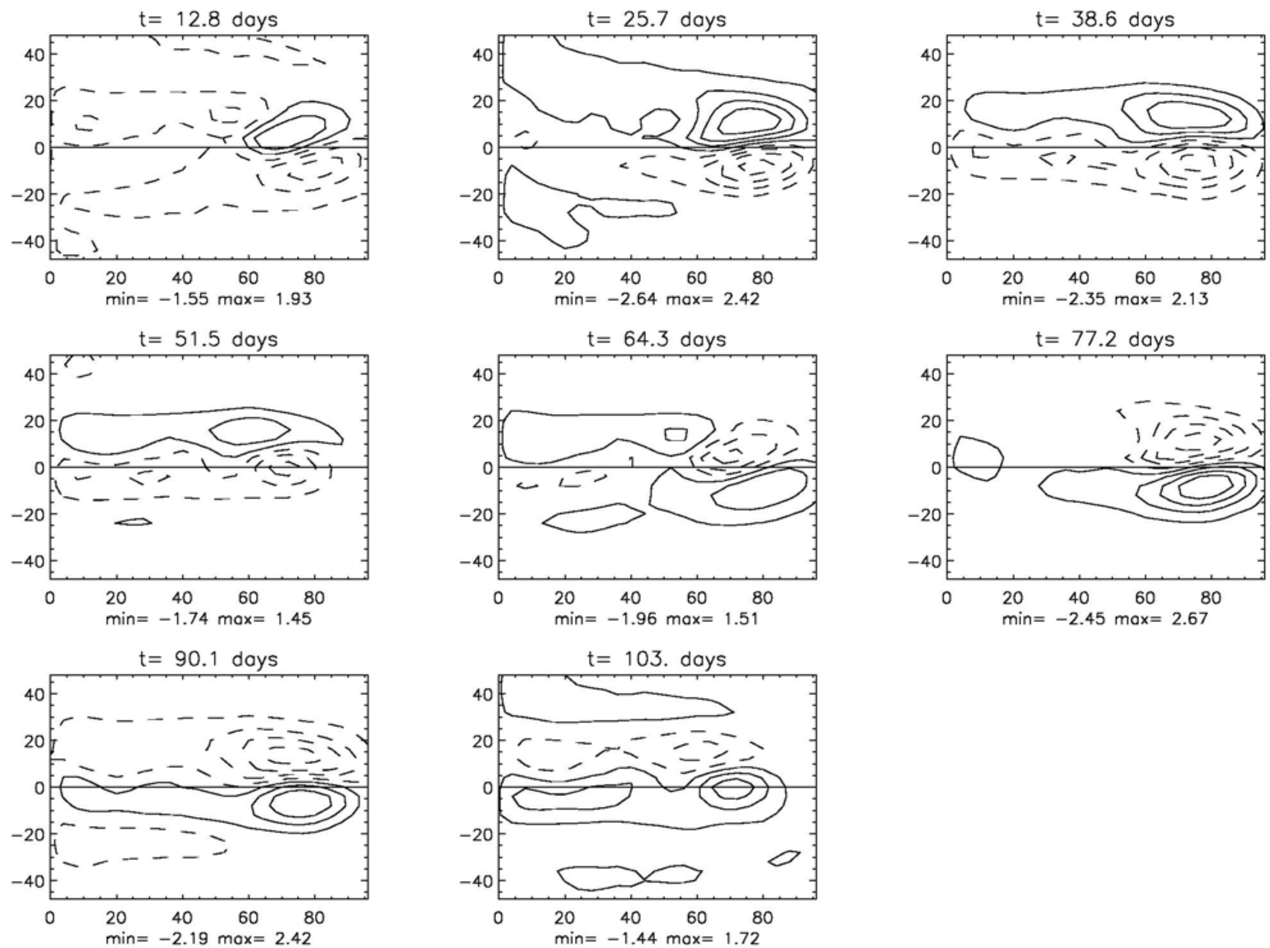


t= 33.7 days
min= -3.25 max= 2.90
t= 67.5 days
min= -7.14 max= 6.78
t= 101. days
min= -7.24 max= 6.88
t= 135. days
min= -3.01 max= 2.87
t= 168. days
min= -3.54 max= 3.91
t= 202. days
min= -7.45 max= 7.79
t= 236. days
min= -6.81 max= 7.12
t= 270. days
min= -3.03 max= 3.19

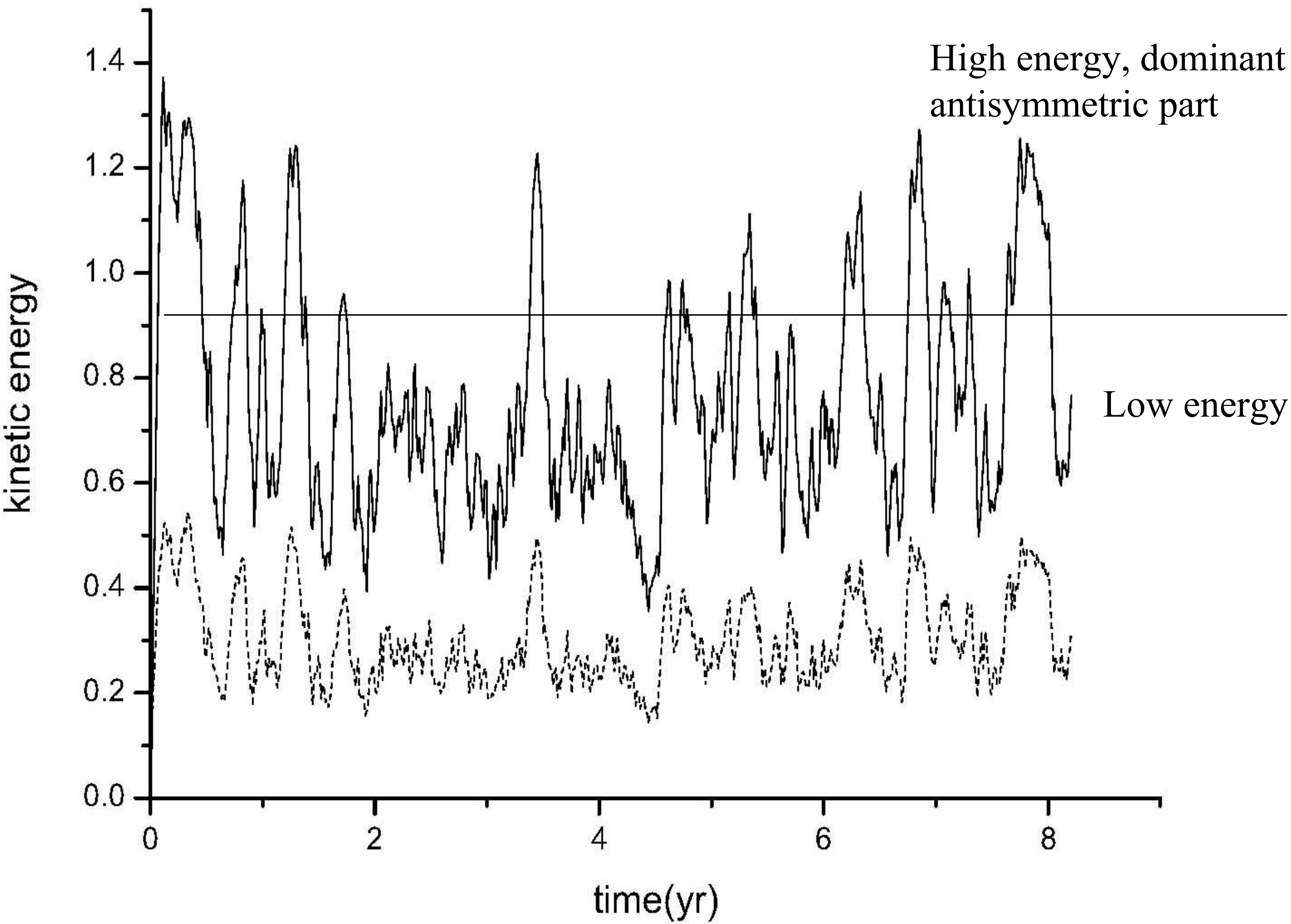
- Second, symmetric instabilities that correspond to barotropic instabilities develop at the eastern edge of the eastward jet and propagate slowly westward. This mode also obtained in equivalent barotropic model.
- The most dominant mode has period of 30 days.

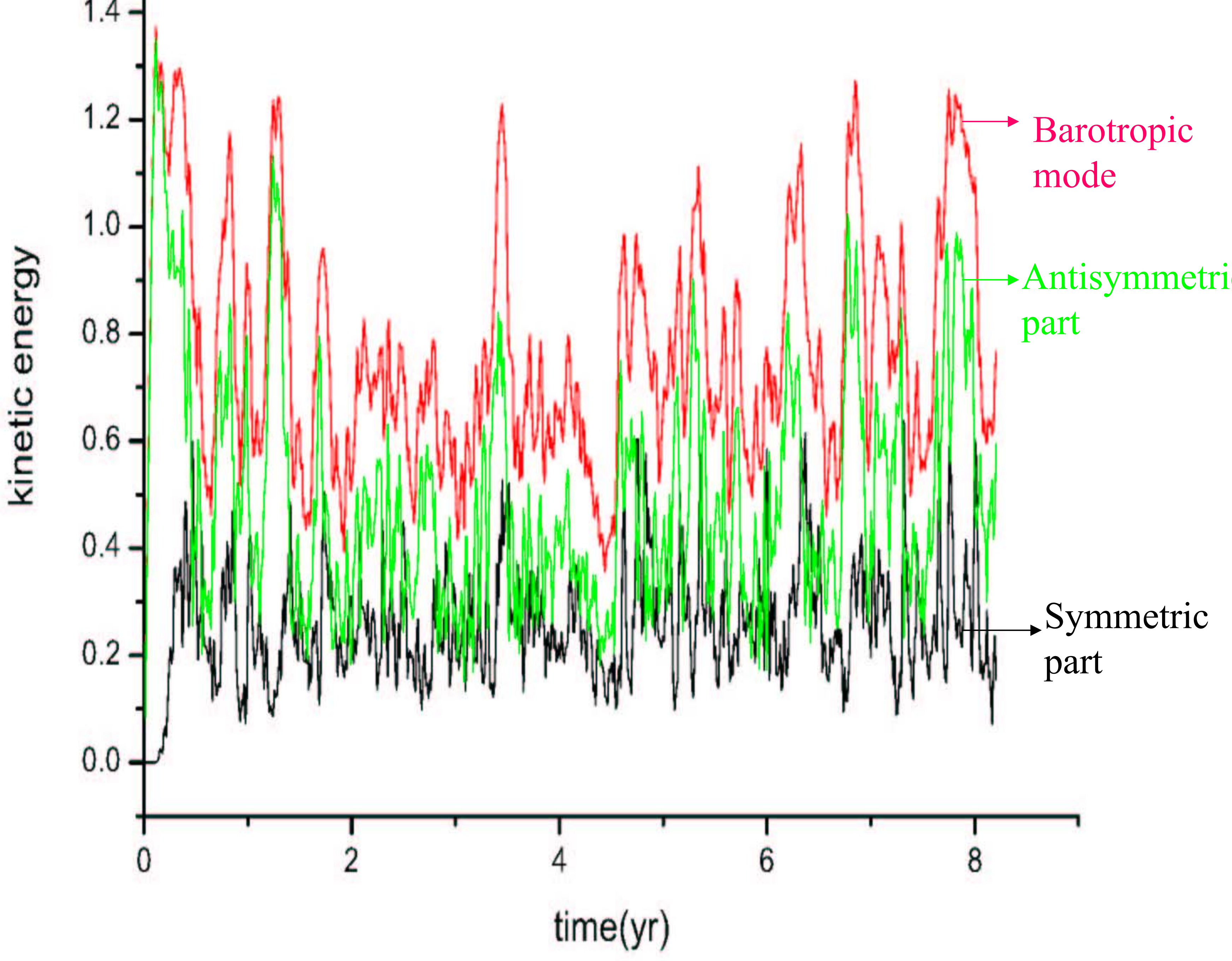

t= 3.75 days
min= -2.33 max= 1.23
t= 7.50 days
min= -3.74 max= 2.09
t= 11.2 days
min= -3.52 max= 2.12
t= 15.0 days
min= -1.73 max= 1.61
t= 18.7 days
min= -1.31 max= 2.54
t= 22.5 days
min= -1.91 max= 3.40
t= 26.2 days
min= -2.14 max= 3.56
t= 30.0 days
min= -1.55 max= 1.66

- Third, instabilities propagating northward are found that can be decomposed into two standing parts, an antisymmetric part and a symmetric part.
- The most dominant mode has period of 103 days.
- This mode can be relate to the observed 70-days oscillation that propagate from Cape Hatteras to Greenland in a direction roughly perpendicular to the Gulf Stream path (Plaut and Vautard, 1994).



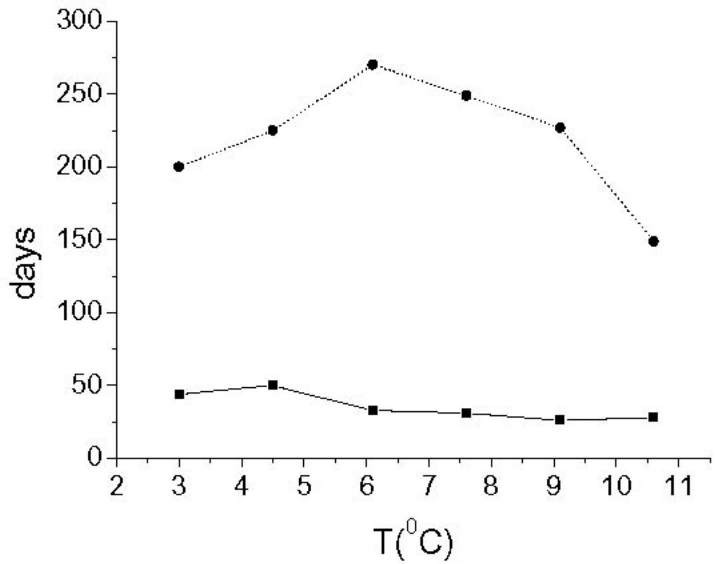
t= 12.8 days
min= −1.55 max= 1.93
t= 25.7 days
min= −2.64 max= 2.42
t= 38.6 days
min= −2.35 max= 2.13
t= 51.5 days
min= −1.74 max= 1.45
t= 64.3 days
min= −1.96 max= 1.51
t= 77.2 days
min= −2.45 max= 2.67
t= 90.1 days
min= −2.19 max= 2.42
t= 103. days
min= −1.44 max= 1.72


High energy, dominant antisymmetric part
Low energy
kinetic energy
time(yr)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0
2
4
6
8



1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
kinetic energy
0
2
4
6
8
time(yr)
Barotropic mode
Antisymmetri part
Symmetric part

Period of the dominant oscillatory mode of symmetric (solid) and antisymmetric (dashed) components as function of the SST front's strength.

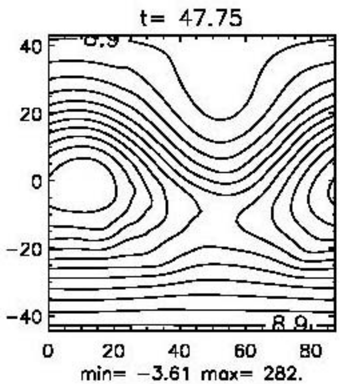


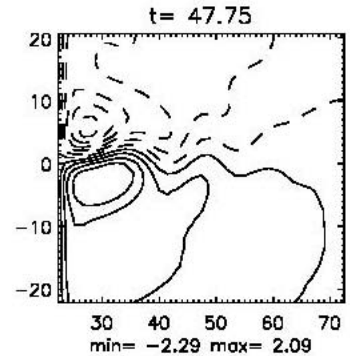
Conclusion:

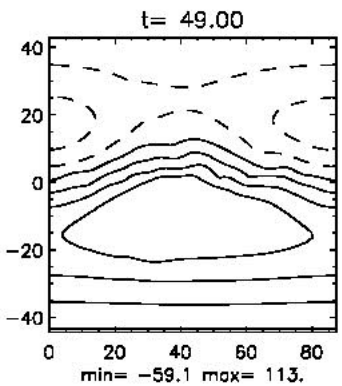
- The SST front spinup an eastward jet in the free atmosphere.
- Three kinds of unstable oscillatory modes are obtained: (1) antisymmetric due to baroclinic instability, the period is 6-8 months. (2) Symmteric structure due to barotropic instability, the period is 30 days. (3) propagating northward that can be decomposed into two standing parts, an antisymmetric part and a symmetric part, the period is 2-3 months.

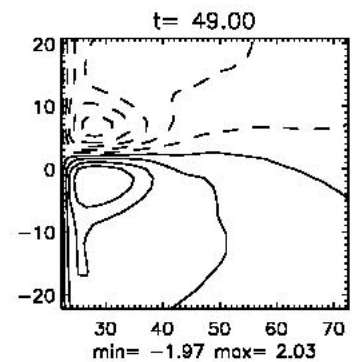
- The dependence of the atmospheric dynamics on the strength of the oceanic SST show:
- T*<1.5C (T*<4C in the equivalent barotropic model) the flow is steady.
- T*>3C (T*>5C in the equivalent barotropic model) the solution became chaotic.
- The baroclinic jet and the symmetric anomalies in the upper layer are two times stronger than in the equivalent barotropic model.
- A dynamical coupling with a double-gyre ocean within QG framework indicates that even more complex low-frequency dynamics are involved.

atmosphere ocean

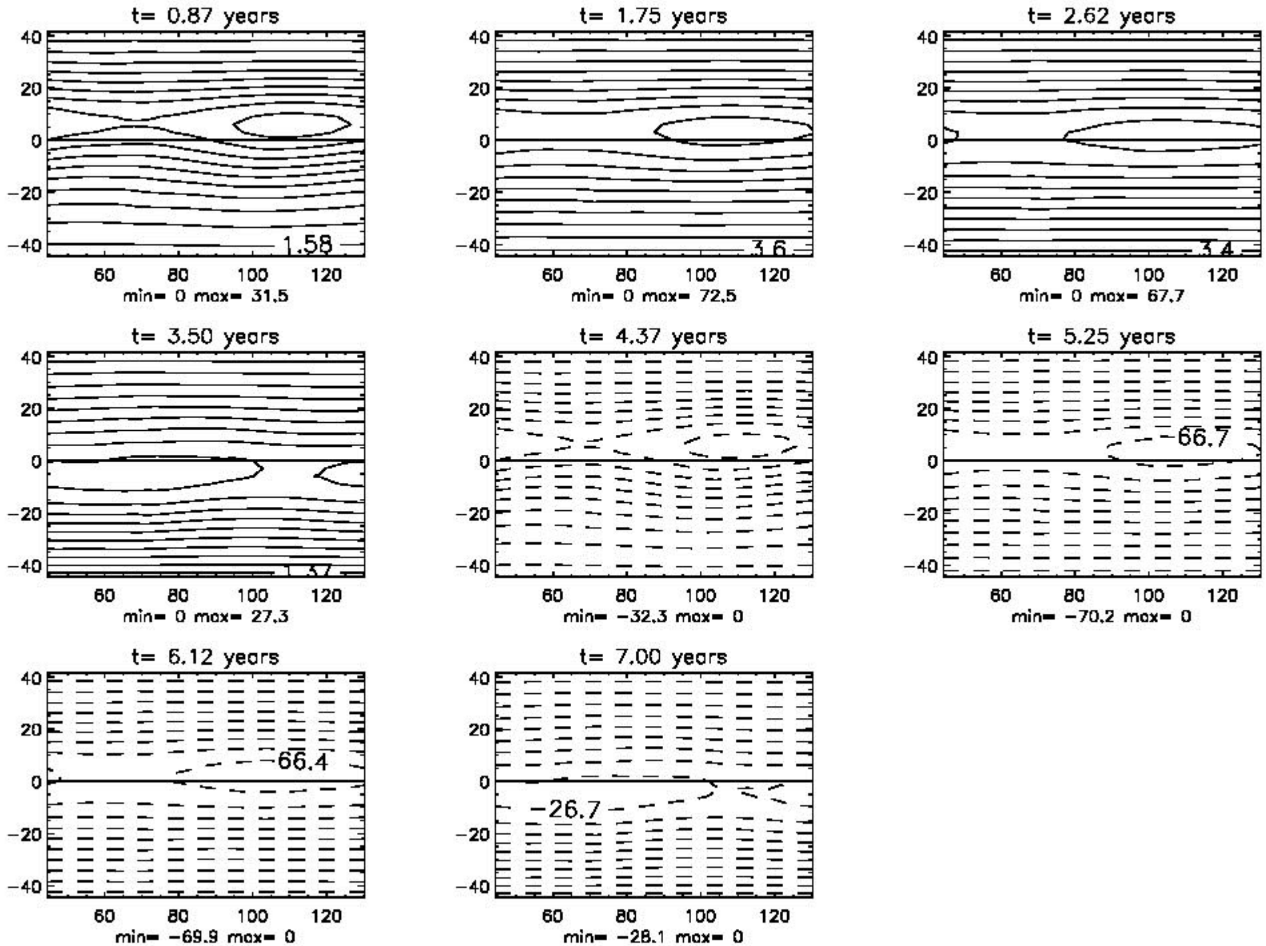




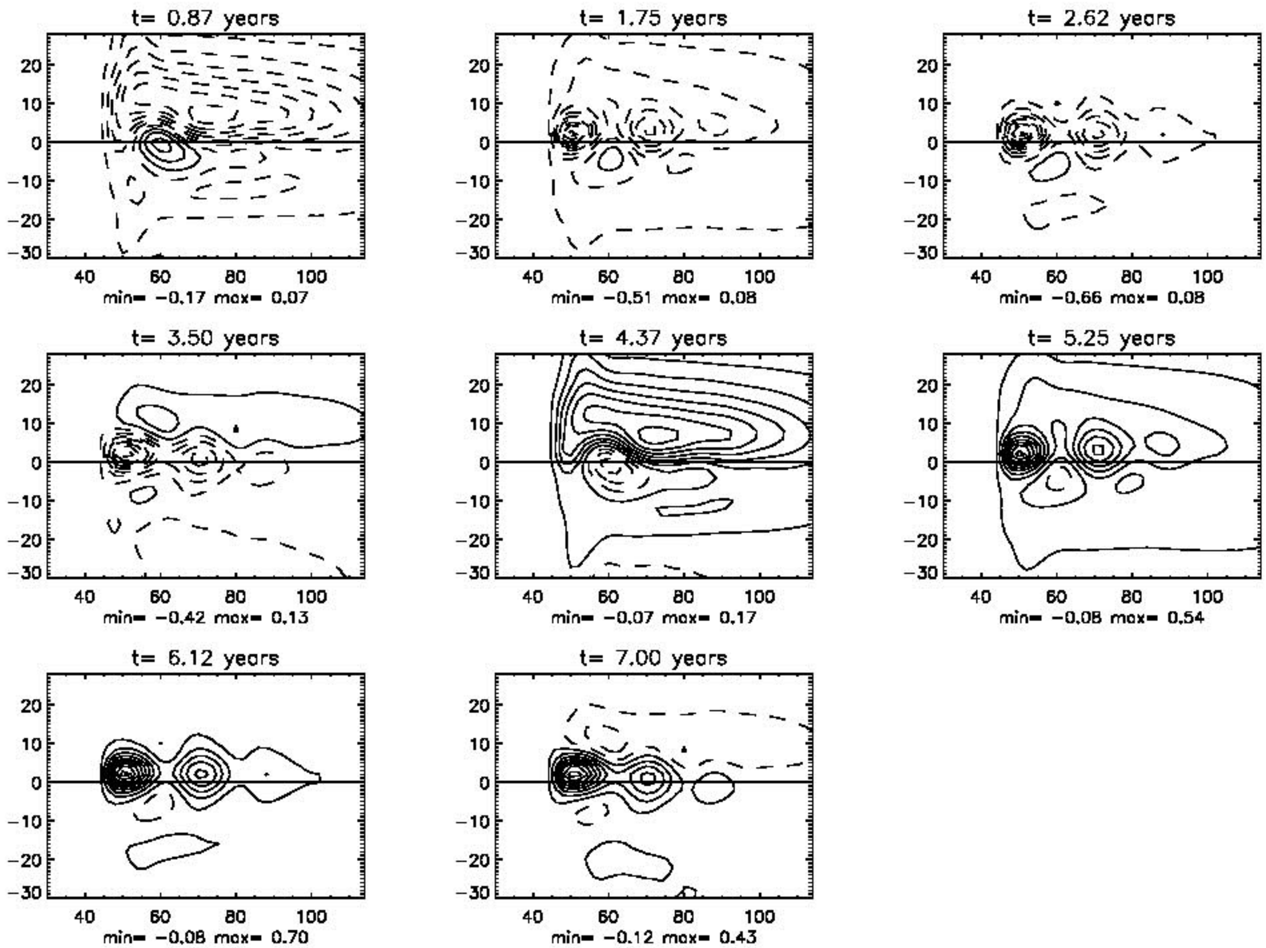




Atmospheric 7-years anomaly



Oceanic 7-years anomaly



- These studies strongly suggest that mid-latitude oceans might very well influence the low-frequency variability in the atmosphere above them, provided oceanic fronts like the Gulf Stream and Kuroshio current are sufficiently well-resolved spatially.