Frontogenesis II

Nuerical simulation of the development of a baroclinic perturbation of a jet and associated frontogenesis

Rotunno, Skamarock & Snyder, 1994, J. Atmos. Sci., 51, pp. 3373-3398

Diagnostic of frontogenesis

The horizontal gradient of potential temperature $\nabla_H \theta$ *(we do not use the buoyancy* b *) is given, from primitive equations, as*

$$D_t \vec{\nabla}_H \theta = \vec{Q} - \partial_z \theta \vec{\nabla}_H w$$

with

$$\vec{Q} = \begin{pmatrix} -\partial_x u & -\partial_x v \\ -\partial_y u & -\partial_y v \end{pmatrix} \vec{\nabla}_H \theta$$

$\vec{v} = (u, v)$ *is teh horizontal velocity and is expanded as* $\vec{v} = \vec{v}_g + \vec{v}_a$.
Similarly, we split $\vec{Q} = \vec{Q}_g + \vec{Q}_a$

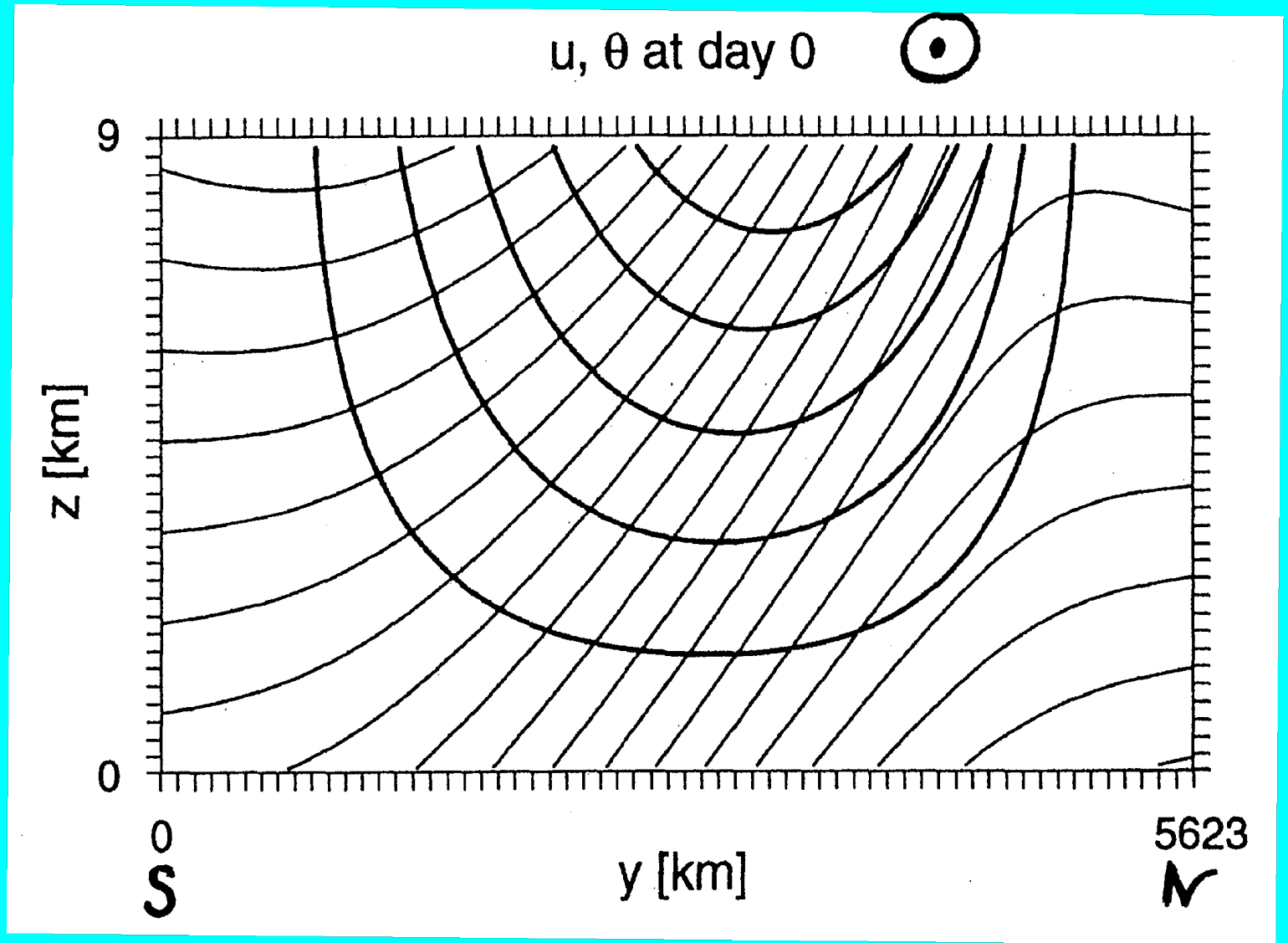
Frontogenesis is characaterizes by

$$\frac{1}{2} D_t \left(\vec{\nabla}_H \theta \cdot \vec{\nabla}_H \theta \right) = F_g + F_a + F_{tilt} = F$$

where

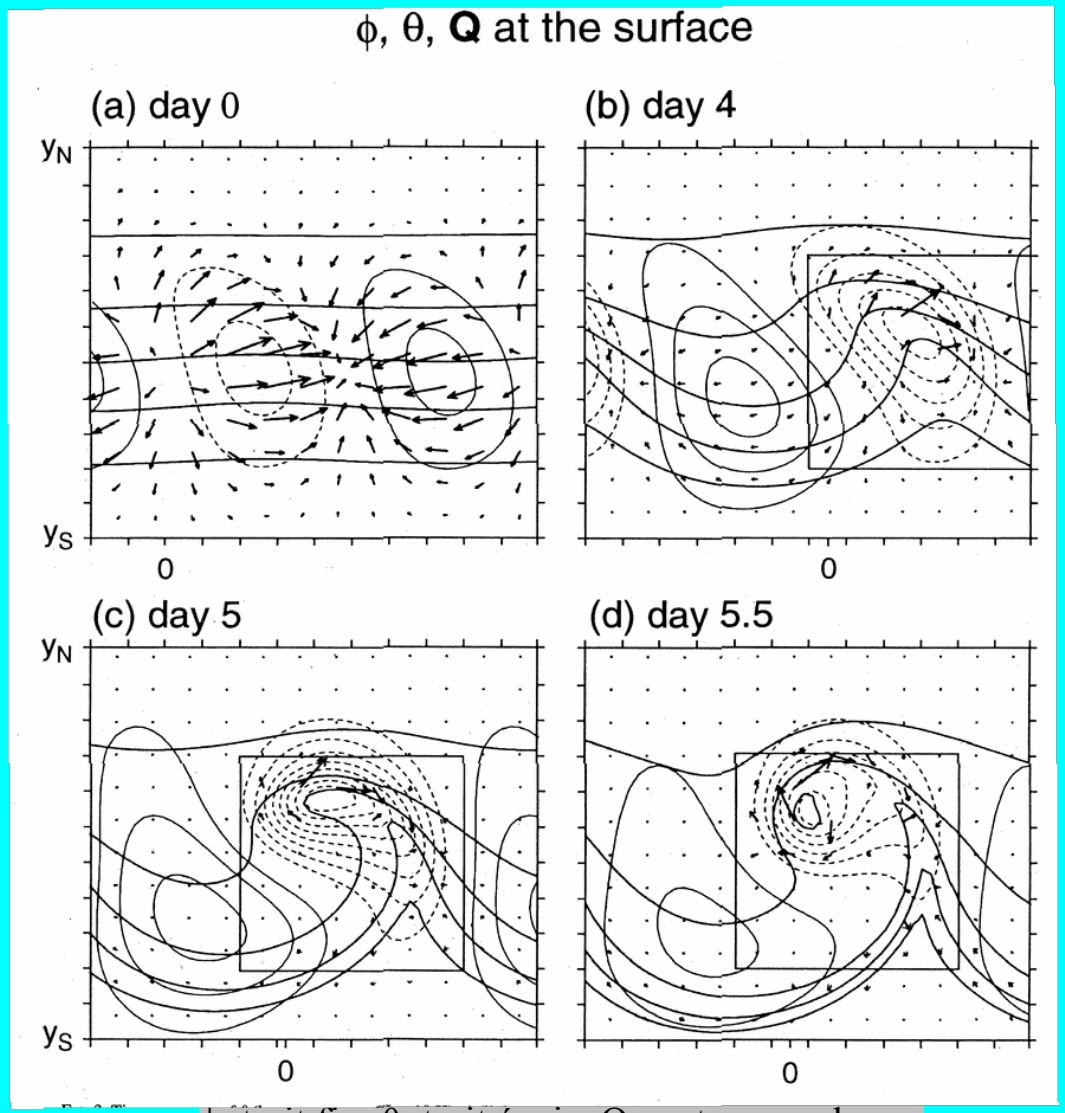
$$F_g = \vec{Q}_g \cdot \vec{\nabla}_H \theta$$
$$F_a = \vec{Q}_a \cdot \vec{\nabla}_H \theta$$
$$F_{tilt} = -\left(\vec{\nabla}_H w \cdot \vec{\nabla}_H \theta \right) \partial_z \theta$$

Numerical simulation of barocinic instability and frontogenesis
From a baroclinic jet. First case: rigid top boundary.
Initial conditions of the jet and of the temperature distribution.

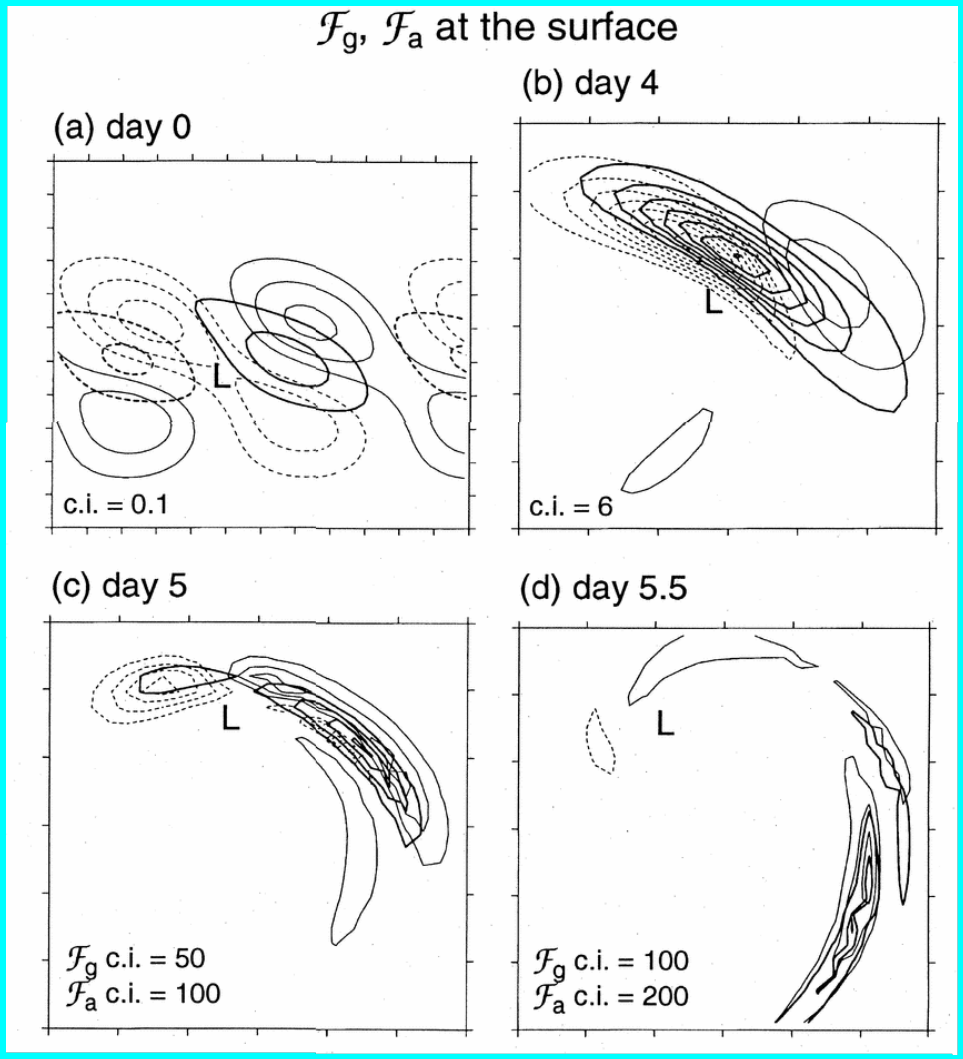


Development of the surface instability

- Anticyclonic migration to the south and cyclonic migration to the north.
- Initial development in the difflent region of the flow.
- Ageostrophic forcing dominates the geostrophic forcing (except at the very beginning)
- War front develops first (until day 5)



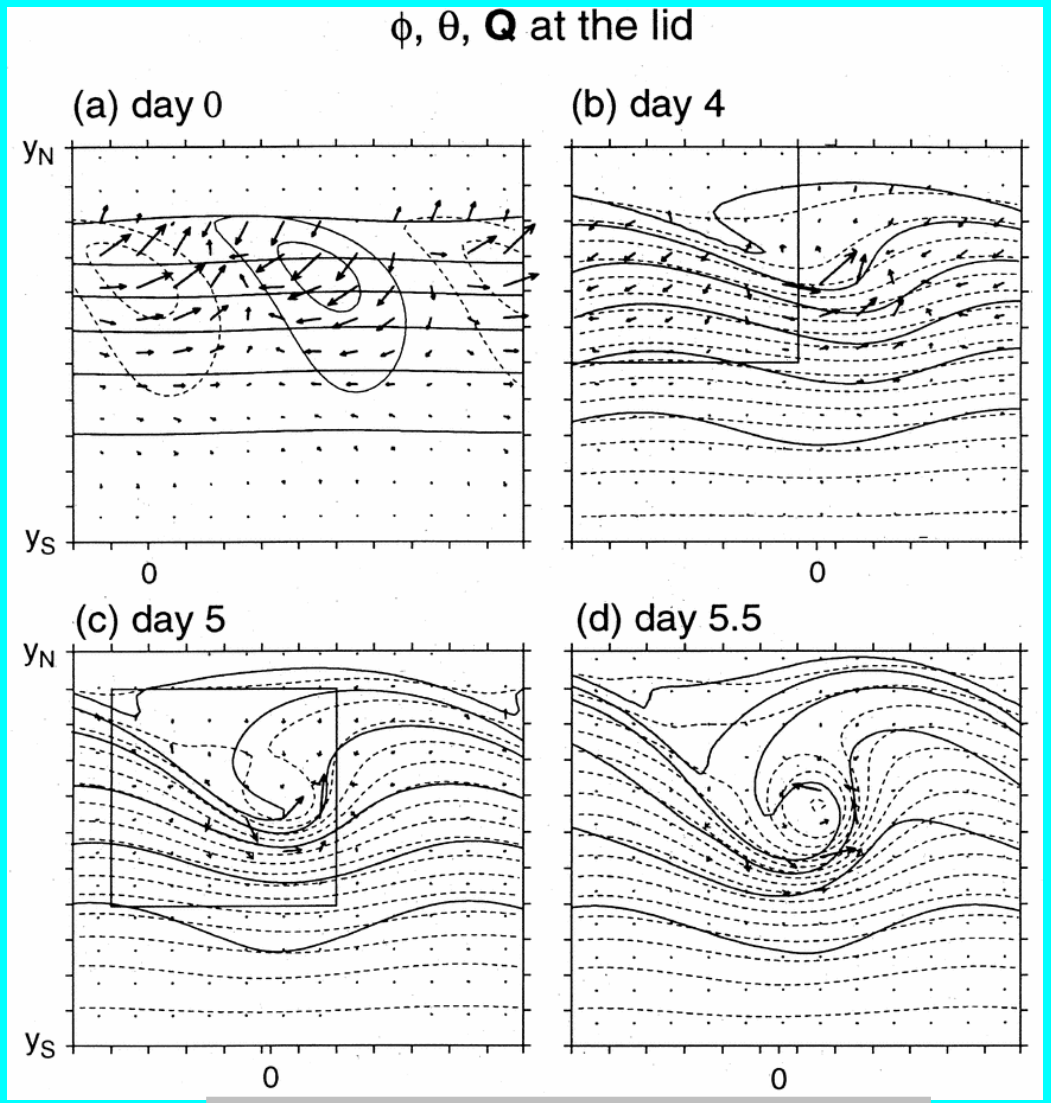
ϕ: trait fin; θ: trait épais; Q:vecteurs; valeurs négatives en tiretés



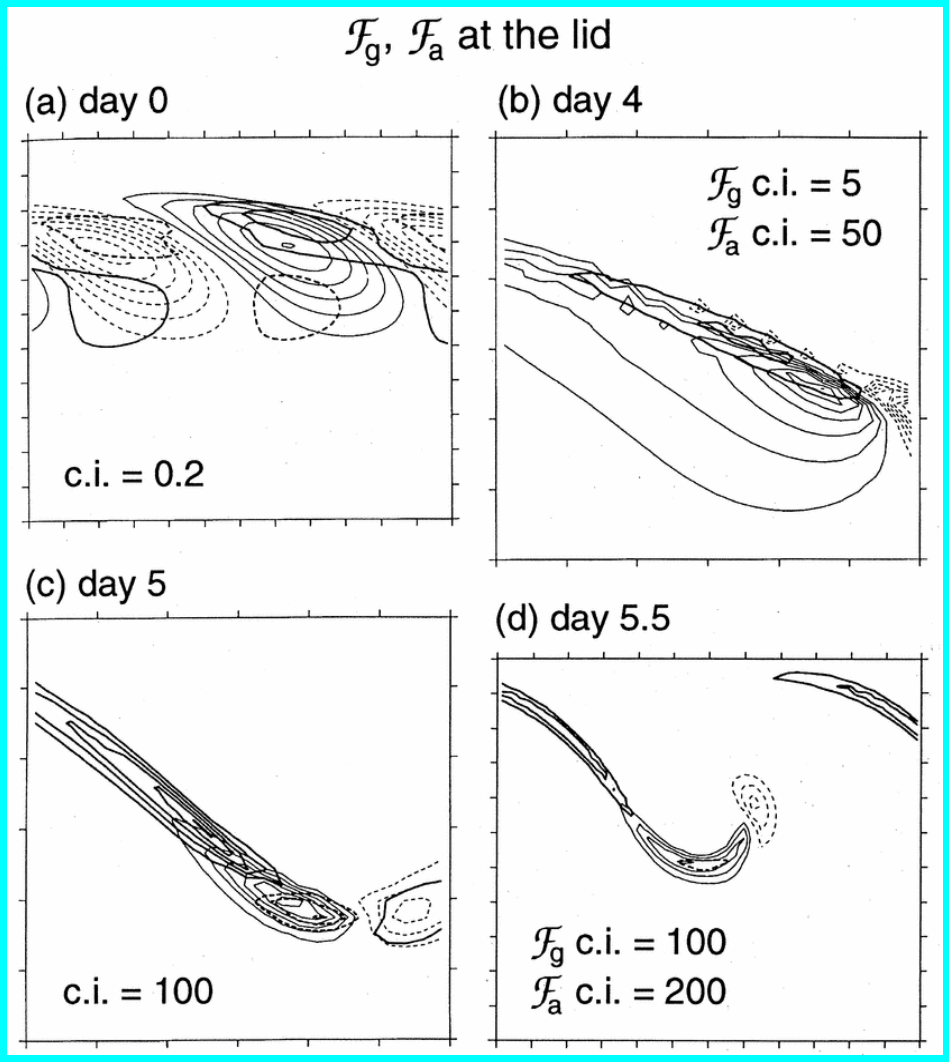
Fg: trait fin; Fa: trait épais; valeurs négatives (frontolyse) en tiretés

Dévelopment of the instability at the rigid top

- Same initial structure than at the ground
- Dévelopment of a unique front conecting cyclone and anticyclone
- Fast intensification of the front
- Quasi-rectilinear front except wrapping in the core of the cyclone



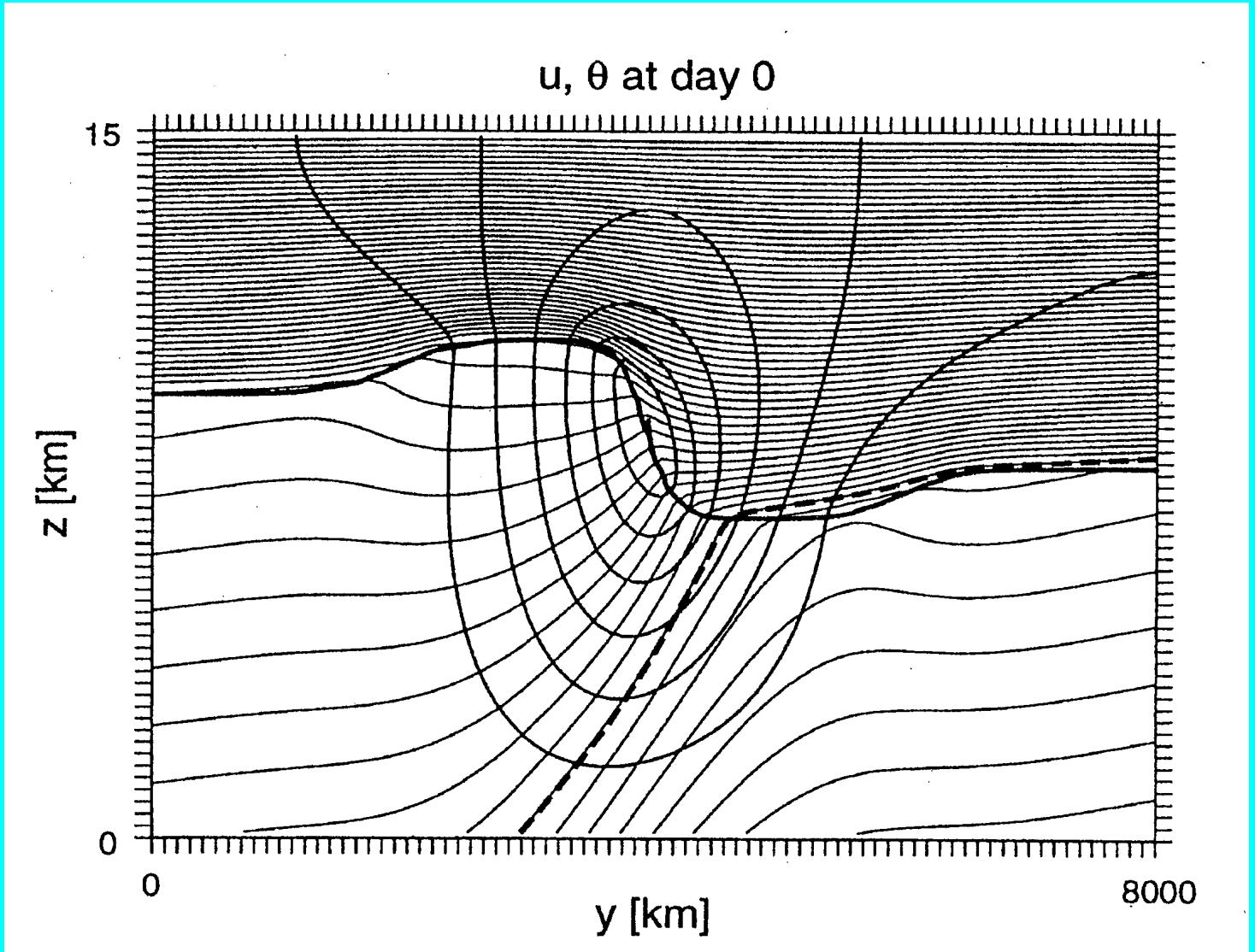
ϕ: thin; θ: thick ; Q:vectors; negatives values are dashed



Fg: thin; Fa: thick; negative values (frontolysis) are dashed

Numerical simulation of baroclinic instability and frontogenesis.
Second cas: tropopause séparating the troposphere fro the stratosphere,
Both with unifor potential vorticity.

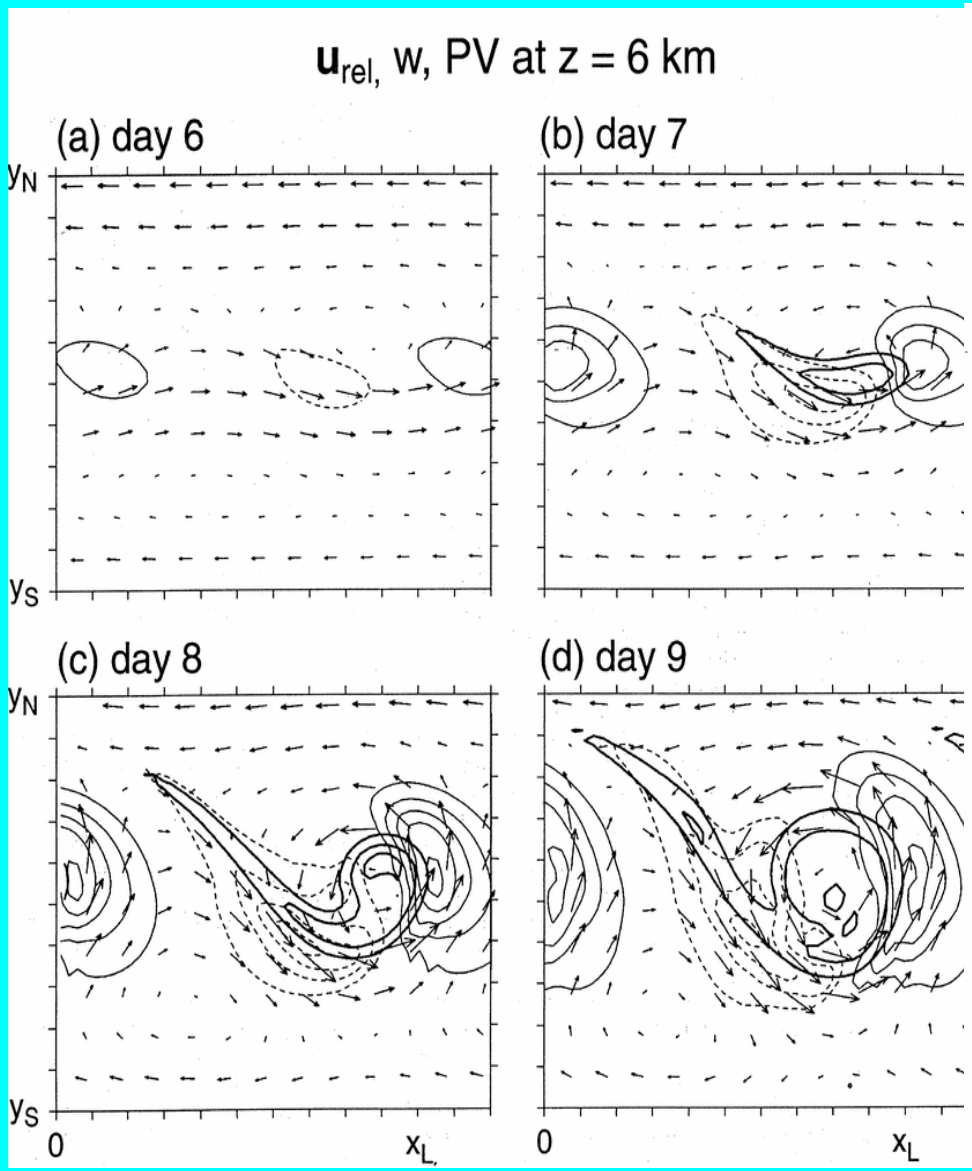
Initial conditions of the jet and temperature



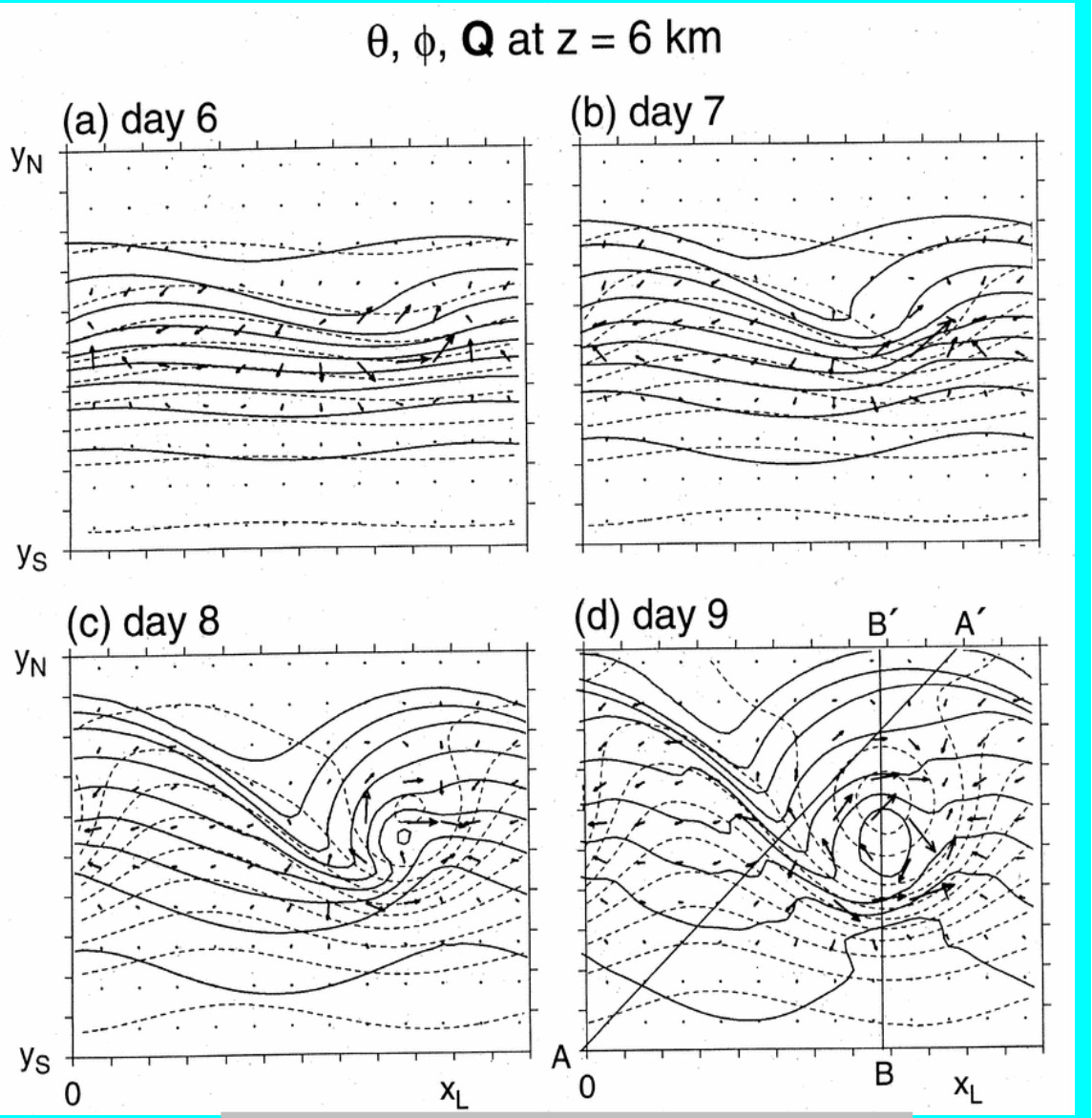
Dvelopment of the instability at 6 km

Development of a potential vorticity anomaly due to the descent of stratospheric air in the depression

Formation of a rectilinear front and wrapping. This latter is stronger than in the rigid lid case.



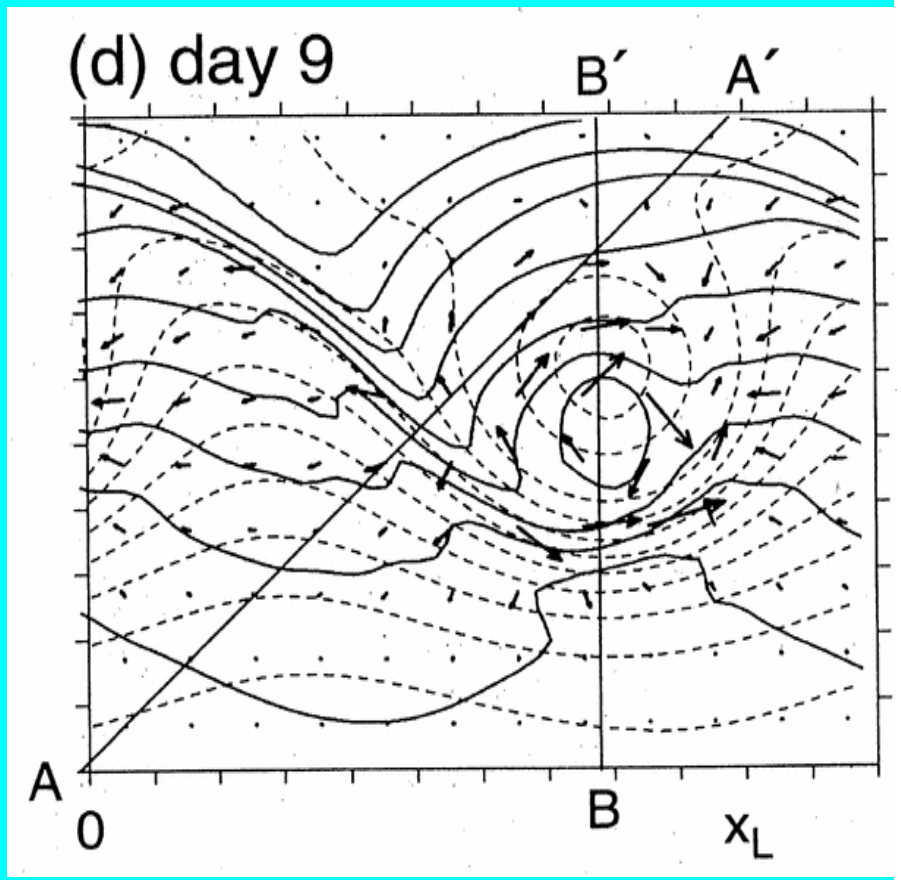
PV: thick; w: thin; u: vectors,

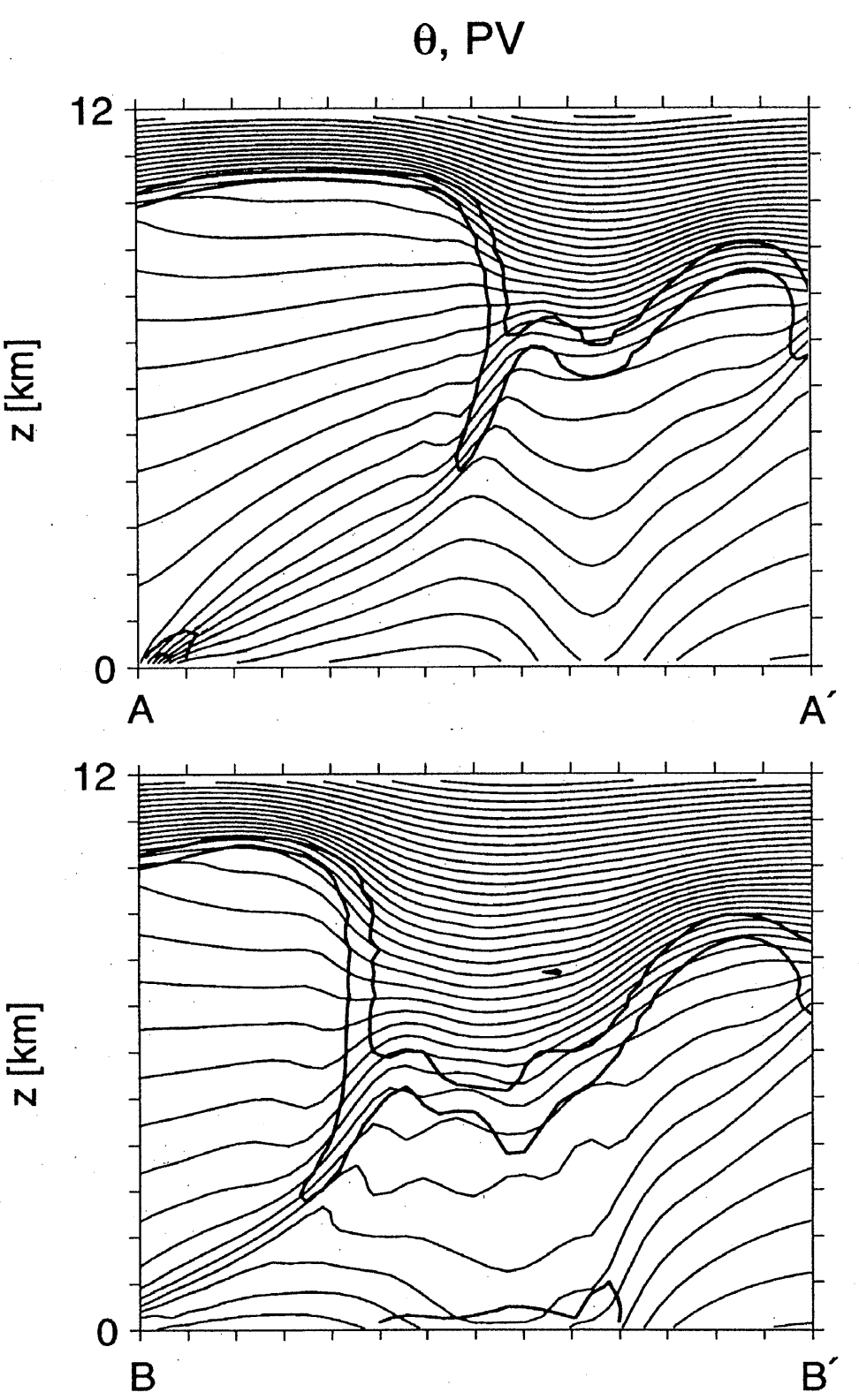


ϕ: thin; θ: thick; Q:vectors; negative values are dashed

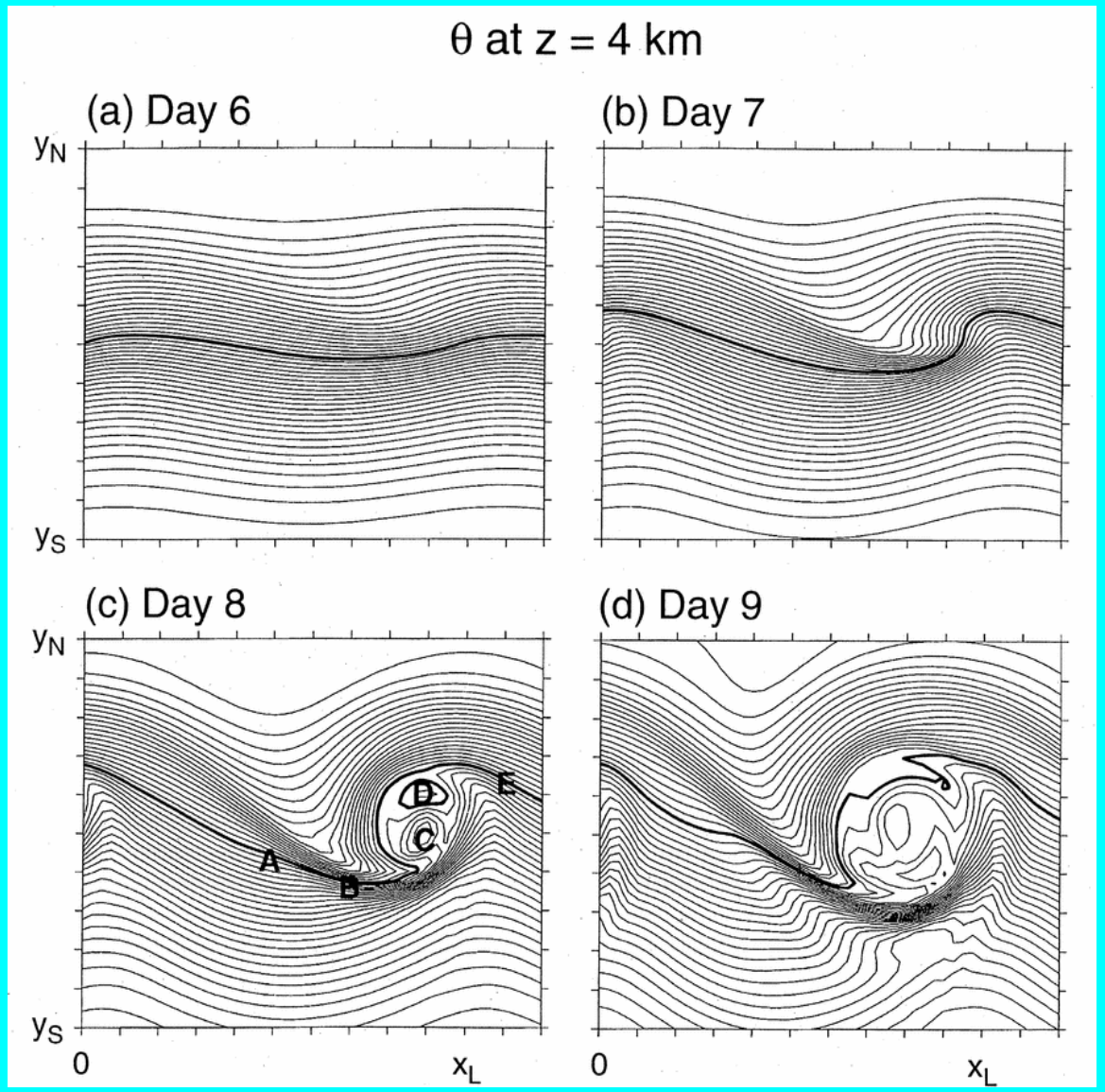
Sections of the frontal s system

Upper level front wraps inside the depression core

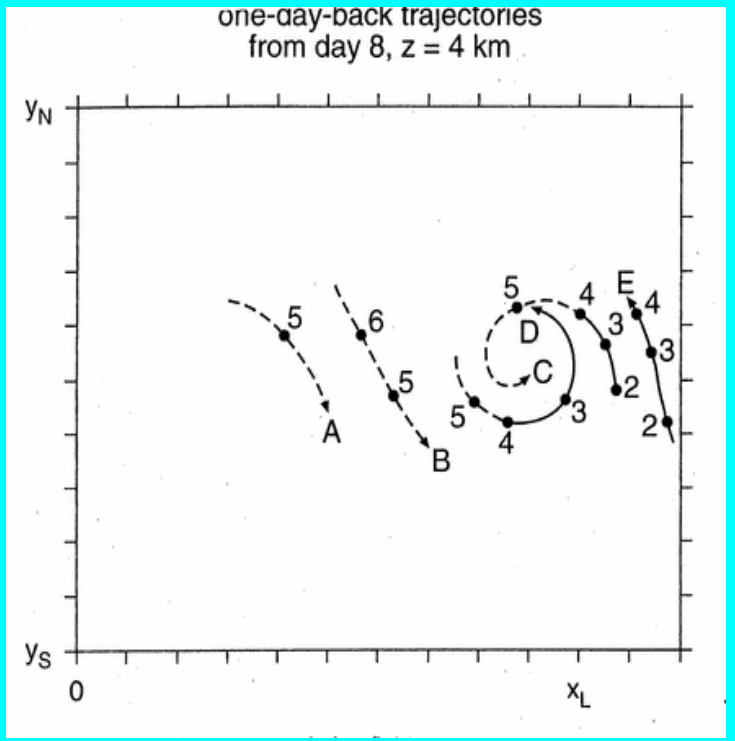




Wrapping of ascending warm air and descending clod air at 4 km in the core of the perturbation

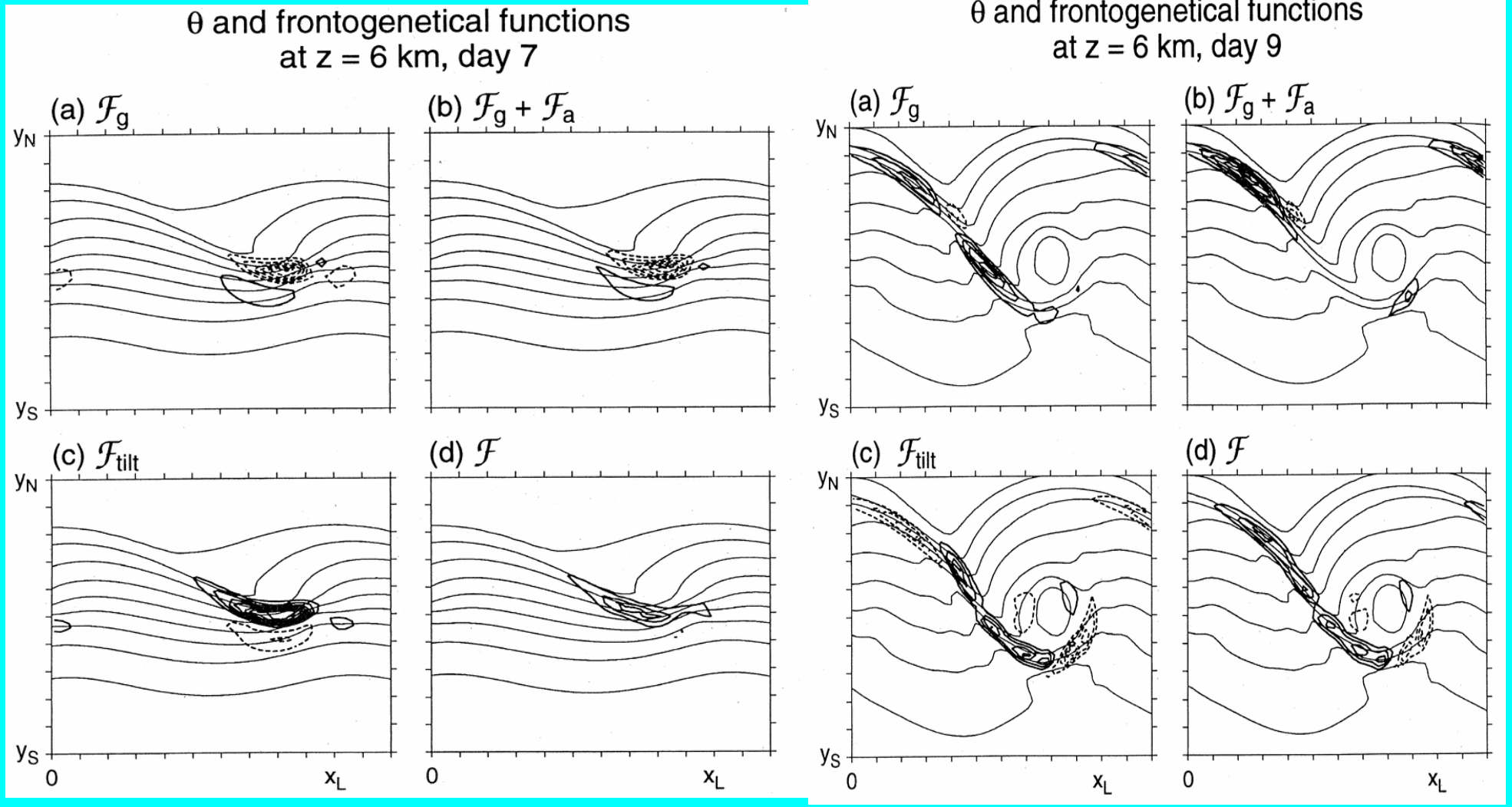


Trajectories of parcels.
Dash: air below 4 km.
Solid: air above 4km
Wrapping of an ascending spiral and a descending spiral.



Frontogenesis at 6 km

- Domination of F_{tilt} when the perturbatio depens and the
- upper-level front intensifies



θ: thin, interval 5K; F: thich, negative avlues are dashed, inerval 20 $(K/100\ km)^2/10^5$ s