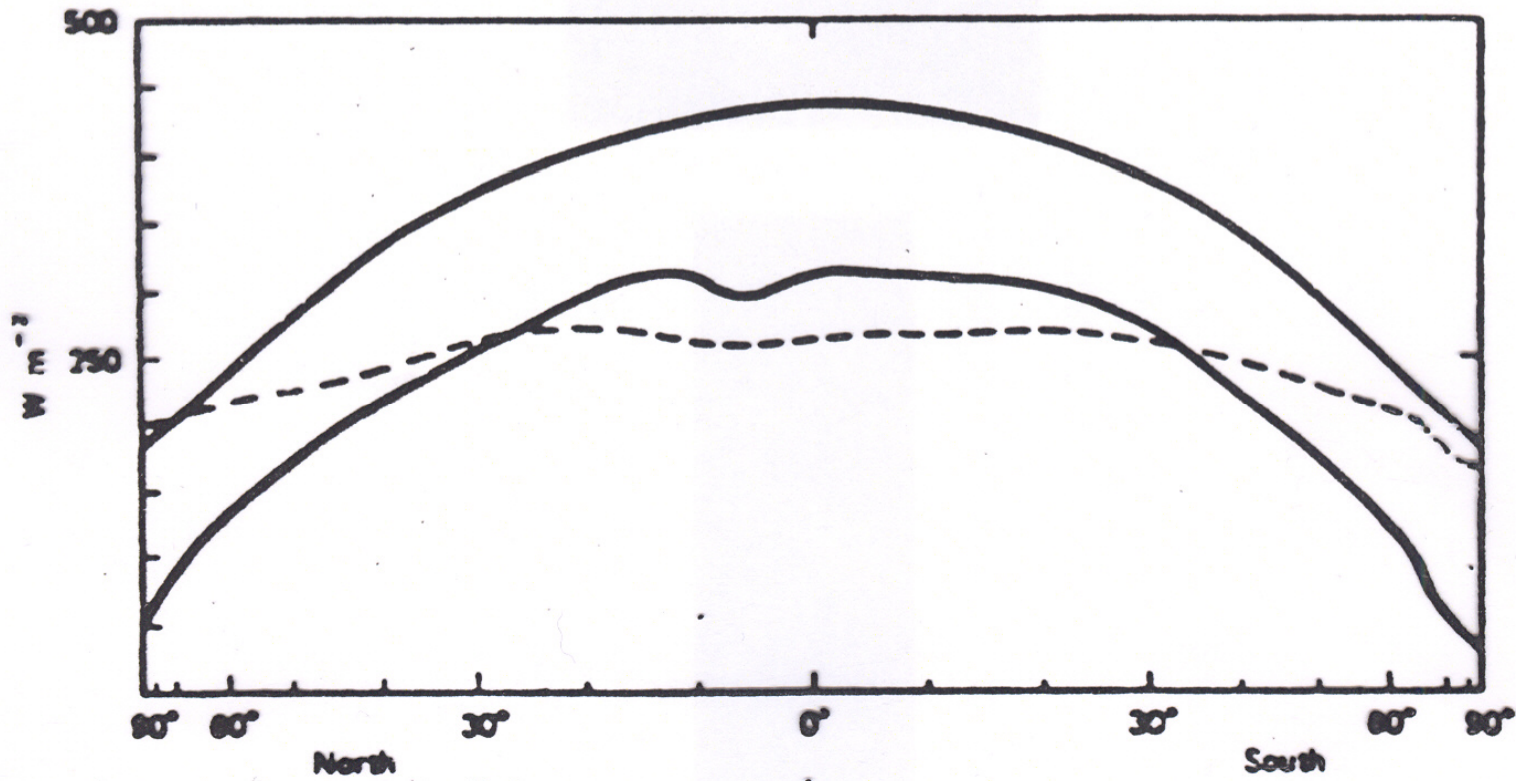


École Doctorale des Sciences de l'Environnement d'Île-de-France  
Année Universitaire 2011-2012

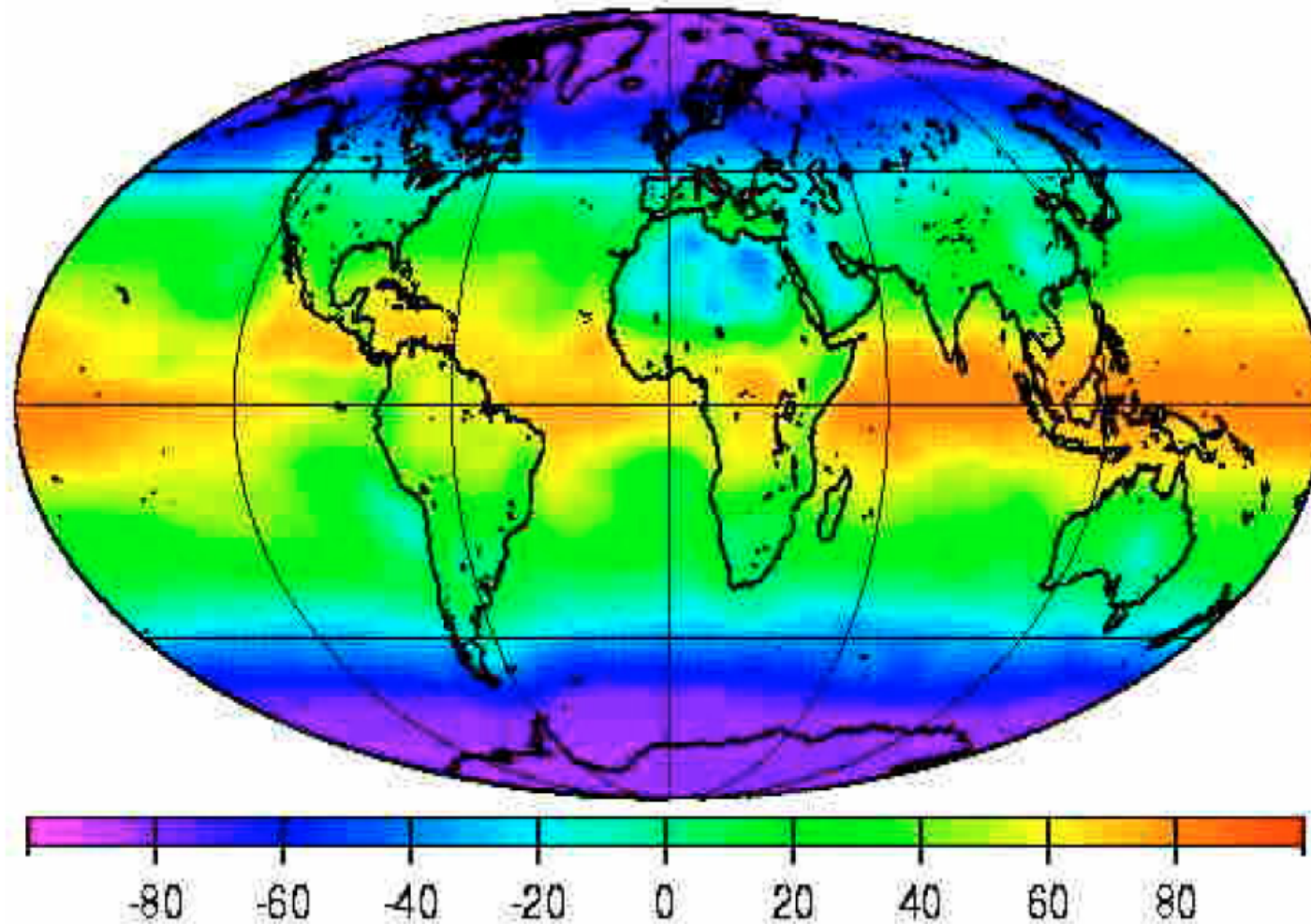
Modélisation Numérique  
de l'Écoulement Atmosphérique  
et Assimilation de Données

Olivier Talagrand  
Cours 1  
1 Mars 2012

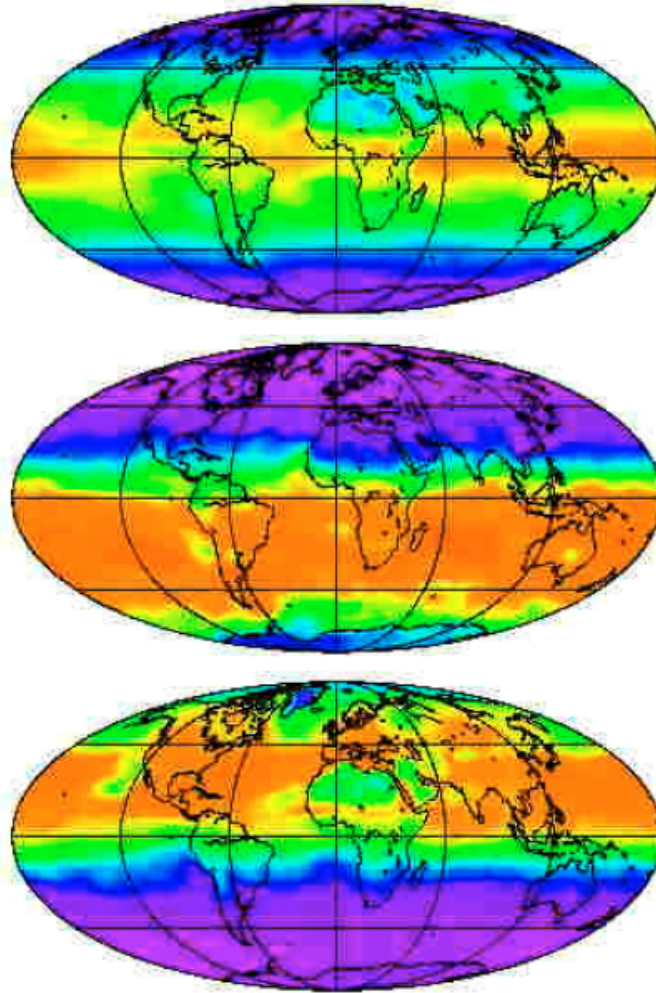


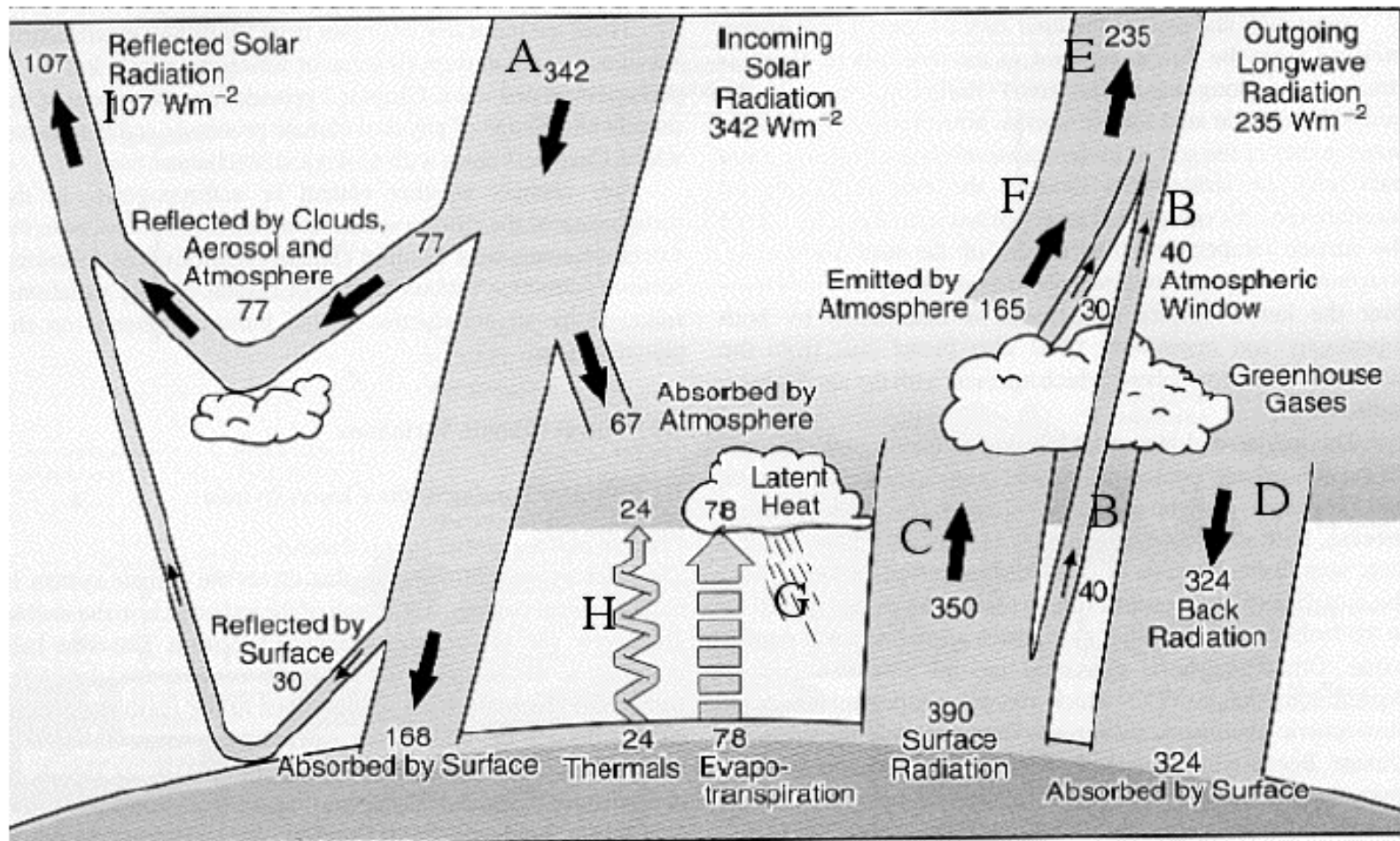
Bilan radiatif de la Terre, moyenné sur un an

## Bilan radiatif au sommet de l'atmosphère (en $\text{W m}^{-2}$ )



# Variations saisonnières du bilan radiatif





D'après K. Trenberth

Particle moves on sphere with radius  $R$   
under the action of a force lying in meridian  
plane of the particle

→ Angular momentum wrt axis of rotation  
conserved.

$$(u + \Omega R \cos\varphi) R \cos\varphi = \text{Cst}$$

On Earth,  $\Omega \approx 2\pi \cdot 10^{-5} \text{ s}^{-1}$ ,  $R \approx 6.4 \cdot 10^6 \text{ m}$ .

If  $u = 0$  at equator,  $u = 329 \text{ ms}^{-1}$  at latitude  $\varphi = 45^\circ$ . If  $u = 0$  at  $45^\circ$ ,  $u = -232 \text{ ms}^{-1}$   
at equator.

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at equator.

*The general circulation*

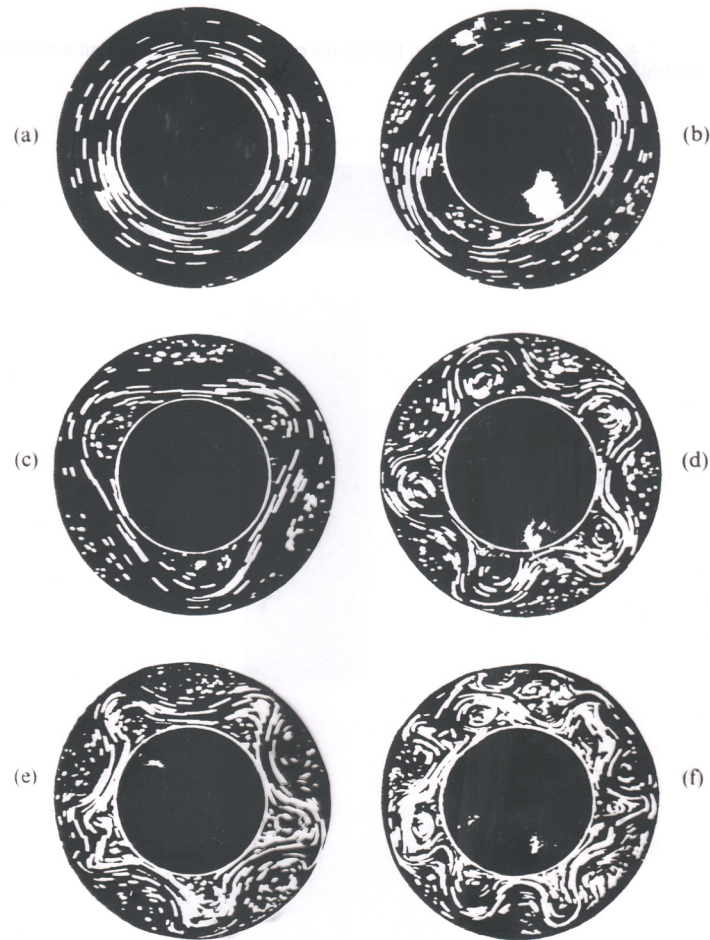


Fig. 10.1. Streak photographs illustrating the dependence of the flow type on rotation rate  $\Omega$  for a laboratory 'dishpan' experiment. The values of  $\Omega$  in  $\text{rad s}^{-1}$  are (a) 0.41; (b) 1.07; (c) 1.21; (d) 3.22; (e) 3.91; (f) 6.4. Working fluid was a water-glycerol solution of mean density  $1.037 \text{ g cm}^{-3}$  and kinematic viscosity  $1.56 \times 10^{-2} \text{ cm}^2 \text{ s}^{-1}$ . The streak photographs show the flow at a depth of 0.5 cm below the free upper surface (see also problem 10.1.) (From Hide & Mason, 1975)



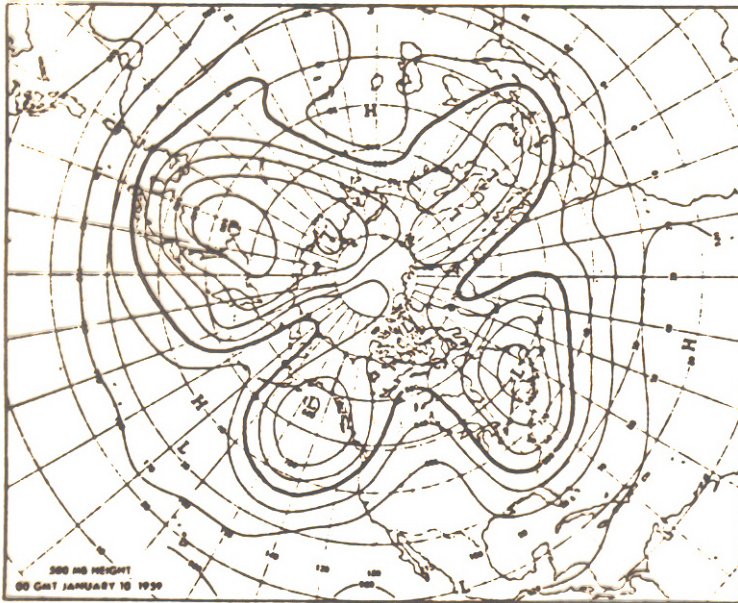
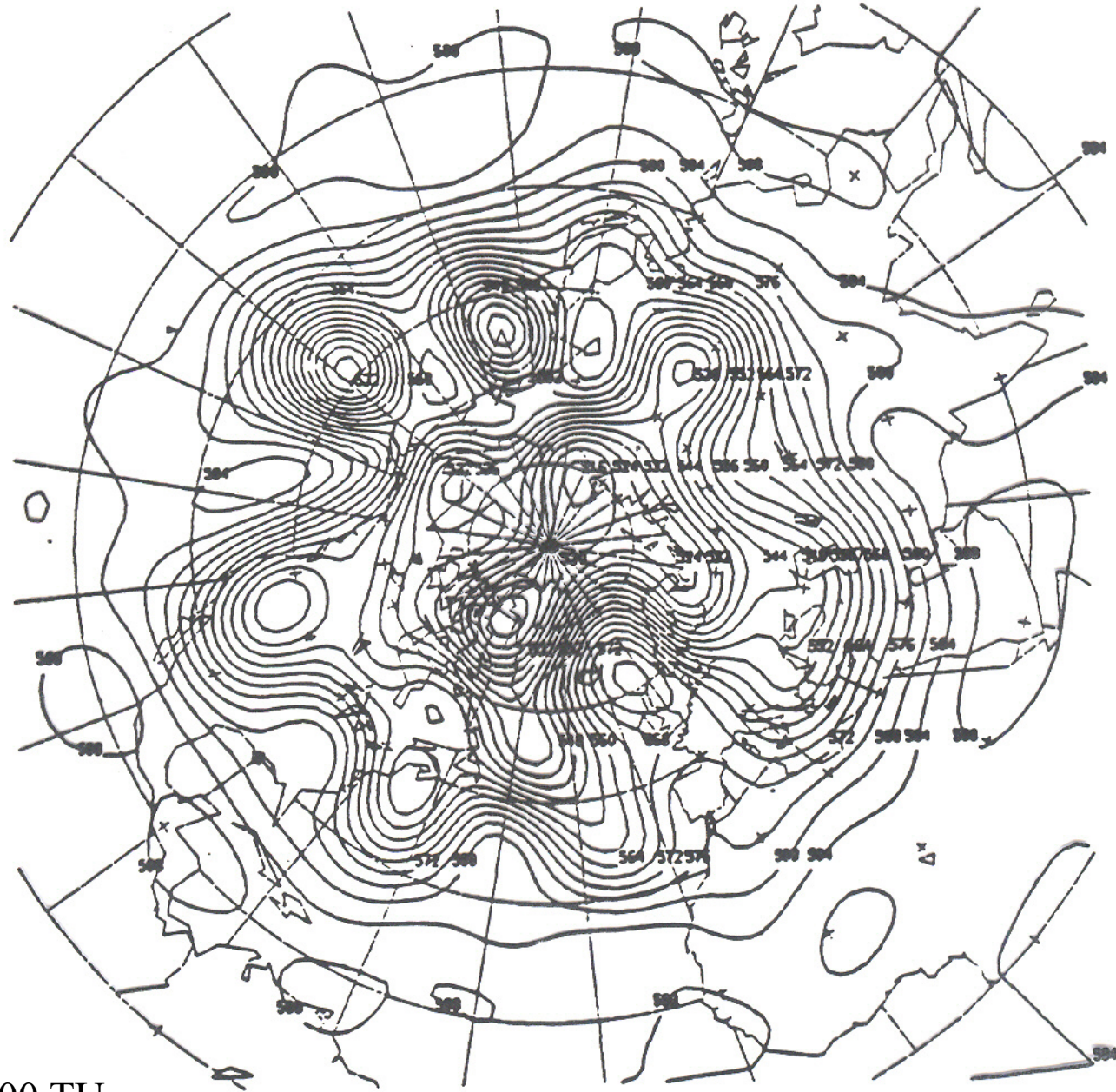


Figure 2. Comparison shows similarities between the global 500 mb pressure pattern in the upper atmosphere of the Northern Hemisphere and a four-wave pattern in the laboratory.

(Laboratory flow conditions were similar to those in Fig. 1, except  $\Omega = 1.95$  radians per sec.) In the atmosphere the flow is approximately parallel to the isobars (the flow is to the right,

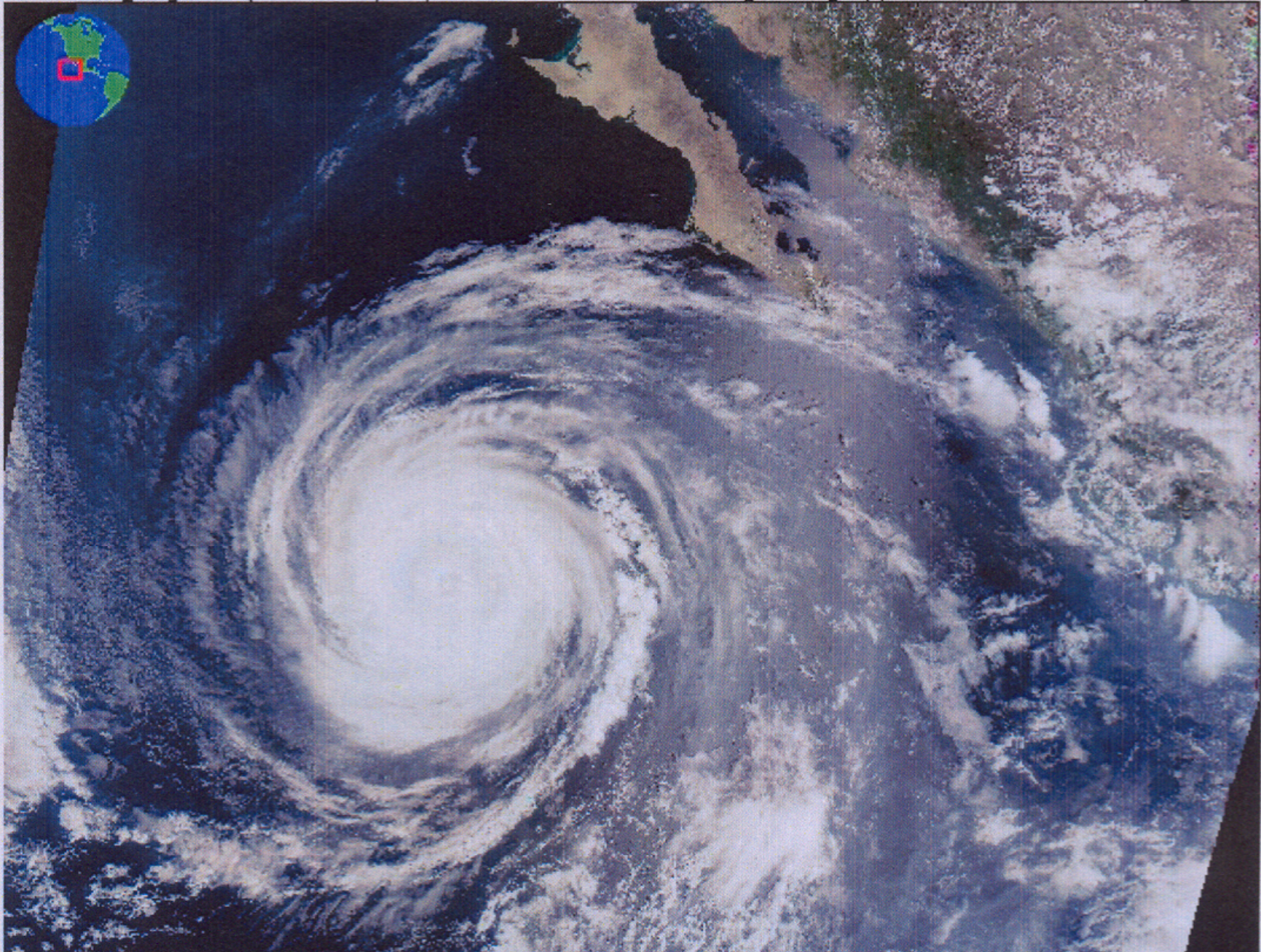


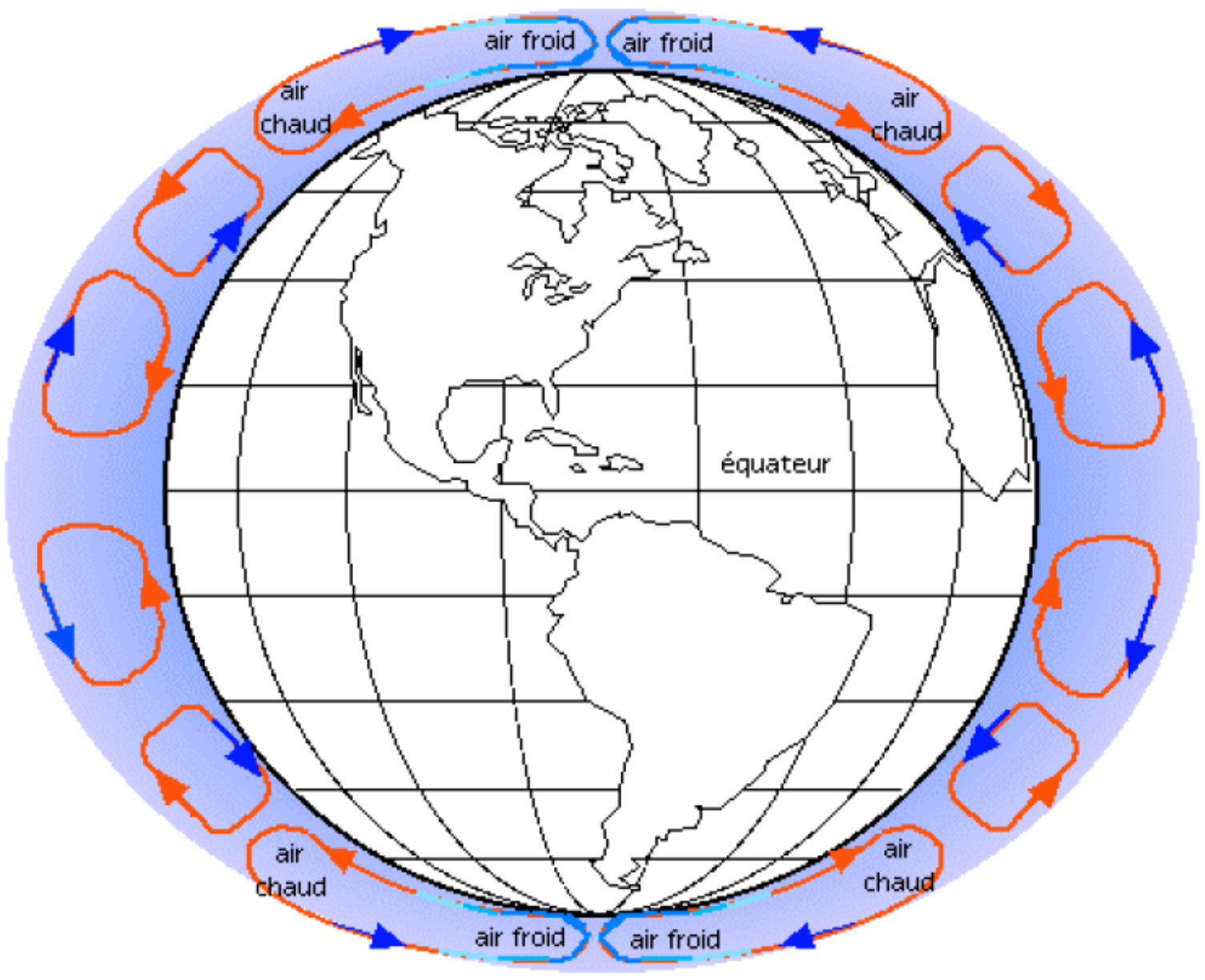
from high to low pressure), with speed inversely proportional to the spacing. Changes in the wave pattern have a significant effect on large-scale weather and climate.

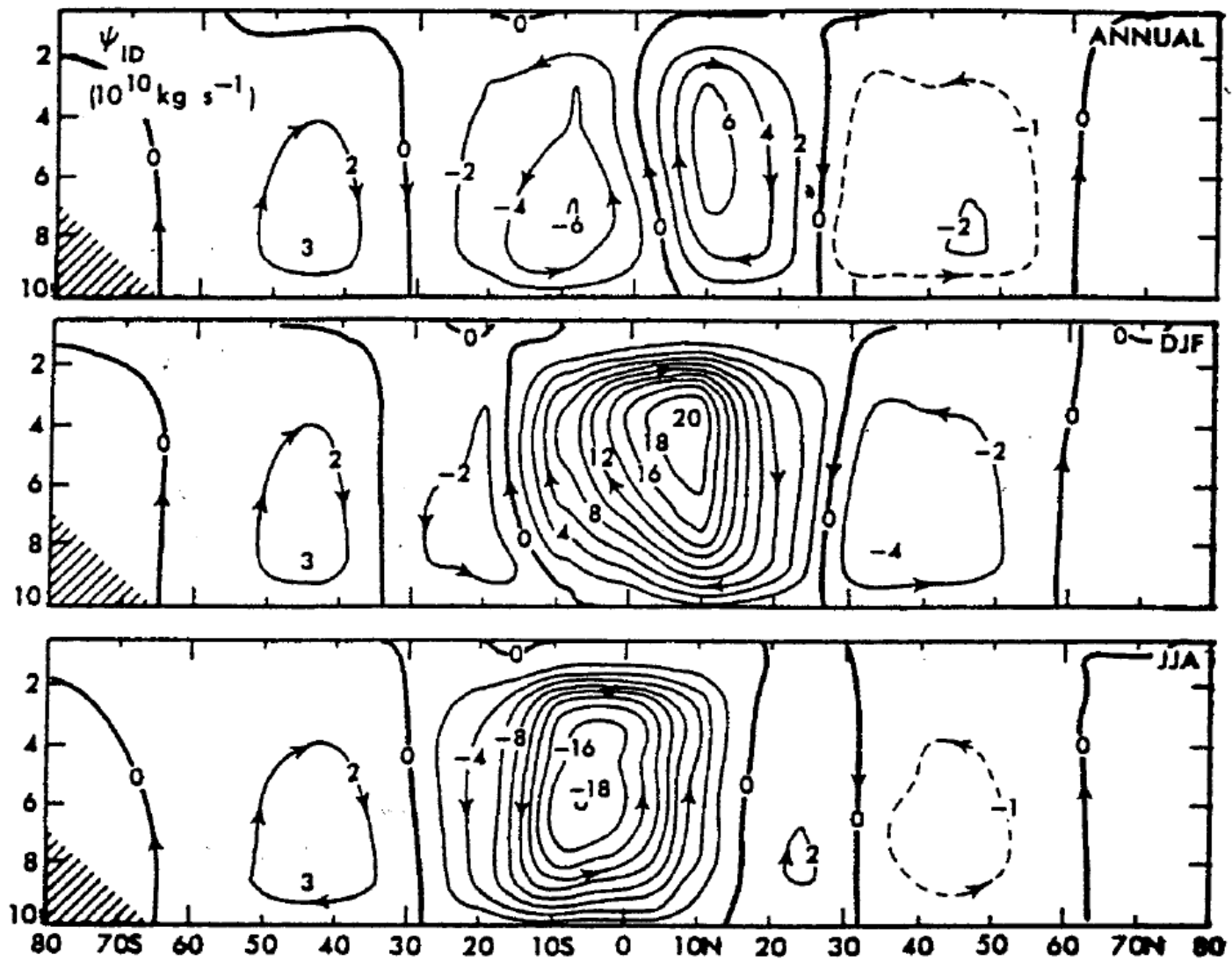


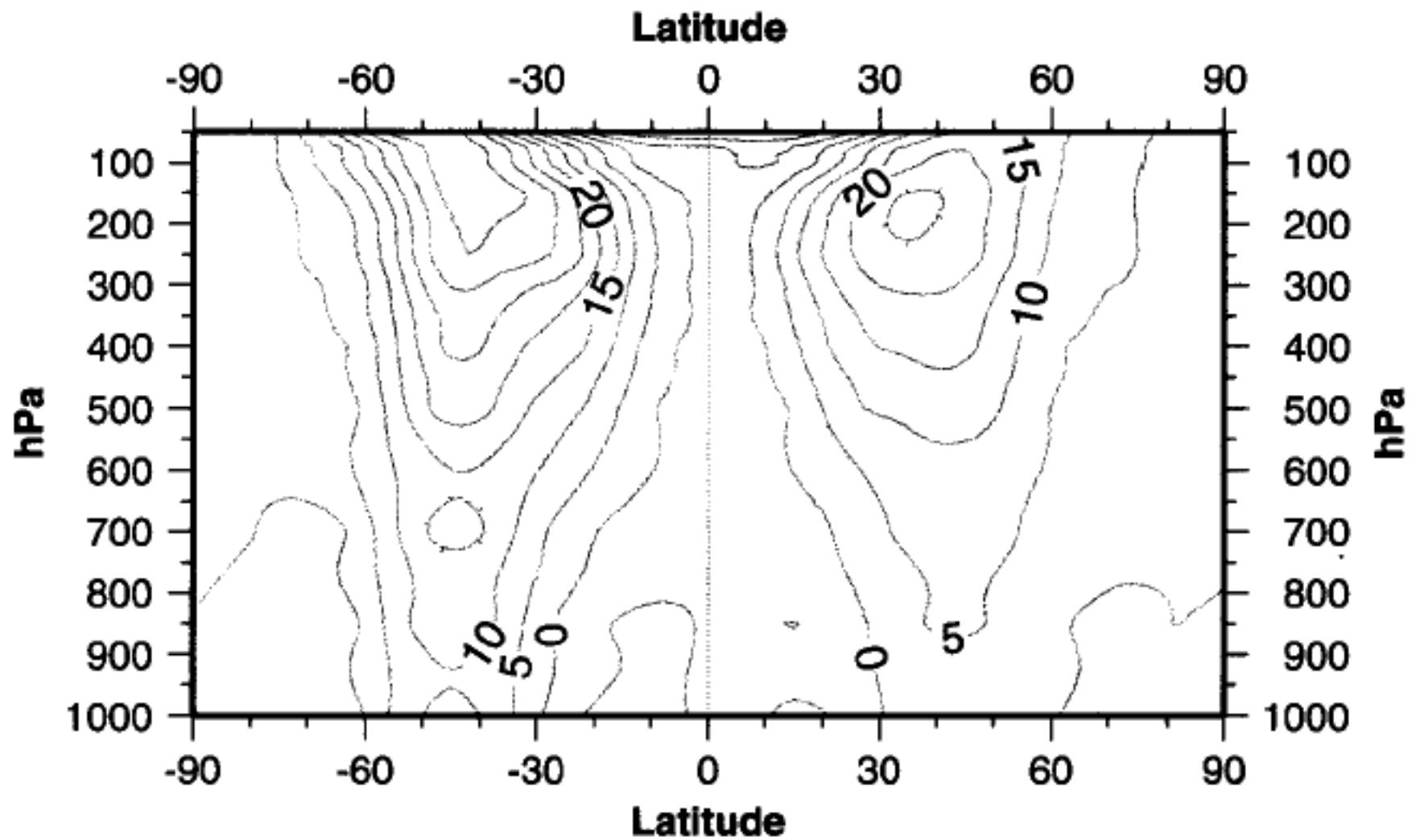
26/04/1984, 00/00 TU

. HDFLook project (LOA-USTL) (MODIS October 2 2002 [18h10]) (Hurricane Hernan (Baja Cali









Distribution moyenne latitude-altitude du vent zonal (m.s<sup>-1</sup>)  
(cours H. Le Treut)

## Lois physiques régissant l'écoulement

- Conservation de la masse

$$D\rho/Dt + \rho \operatorname{div}\underline{U} = 0$$

- Conservation de l'énergie

$$De/Dt - (p/\rho^2) D\rho/Dt = Q$$

- Conservation de la quantité de mouvement

$$D\underline{U}/Dt + (1/\rho) \underline{\operatorname{grad}}p - \underline{g} + 2 \underline{\Omega} \wedge \underline{U} = \underline{F}$$

- Equation d'état

$$f(p, \rho, e) = 0 \qquad (p/\rho = rT, e = C_v T)$$

- Conservation de la masse de composants secondaires (eau pour l'atmosphère, sel pour l'océan, ...)

$$Dq/Dt + q \operatorname{div}\underline{U} = S$$

Les modèles globaux, qui couvrent la totalité du volume de l'atmosphère, sont construits sur l'hypothèse *hydrostatique*

Dans la direction verticale :

$$\partial p / \partial z + \rho g = 0$$

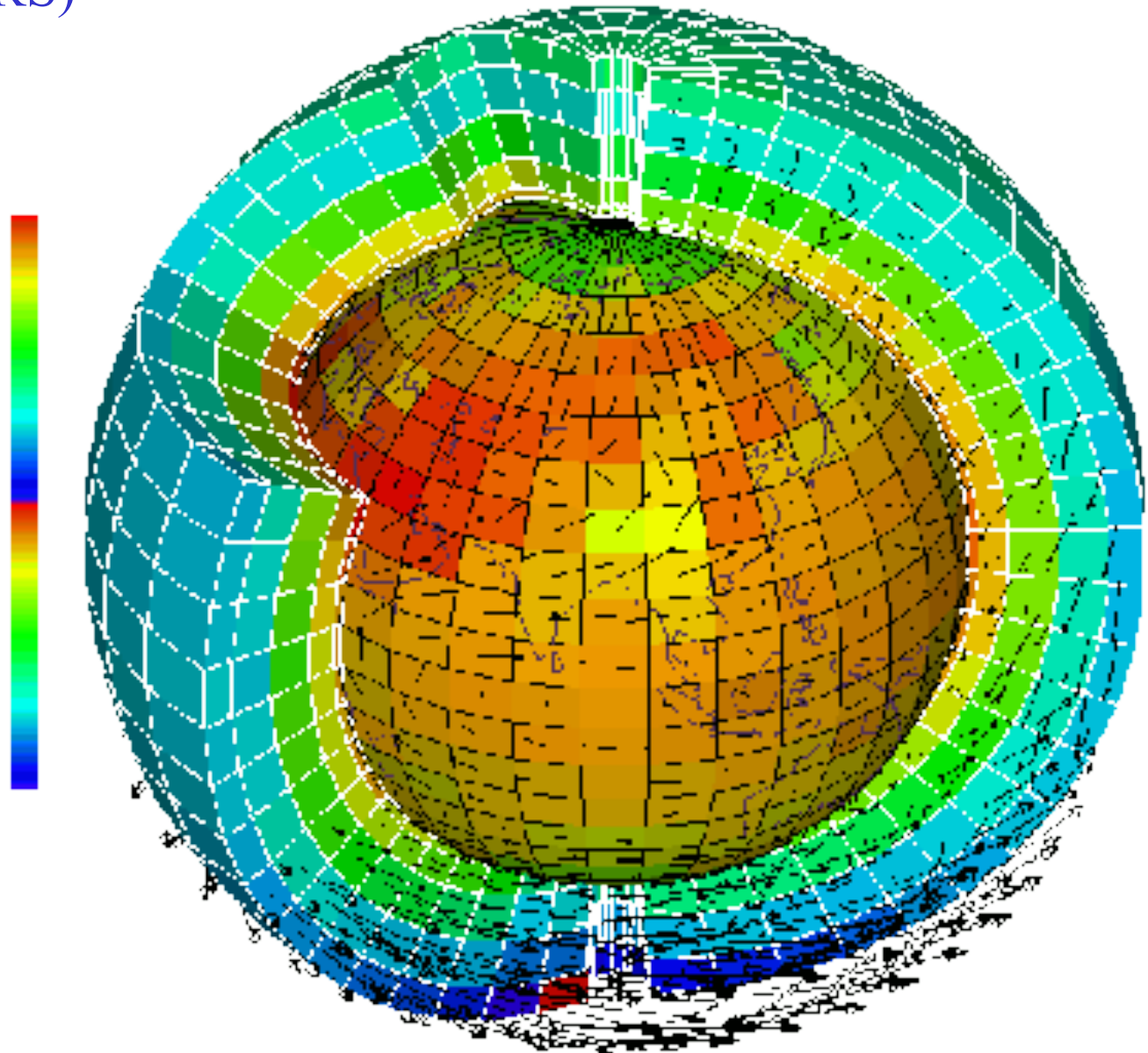
Élimine l'équation du mouvement pour la direction verticale; en outre, l'écoulement est incompressible dans les coordonnées  $(x, y, p) \Rightarrow$  nombre d'équations diminué de deux unités.

Approximation hydrostatique valide pour échelles horizontales  $> 20-30$  km

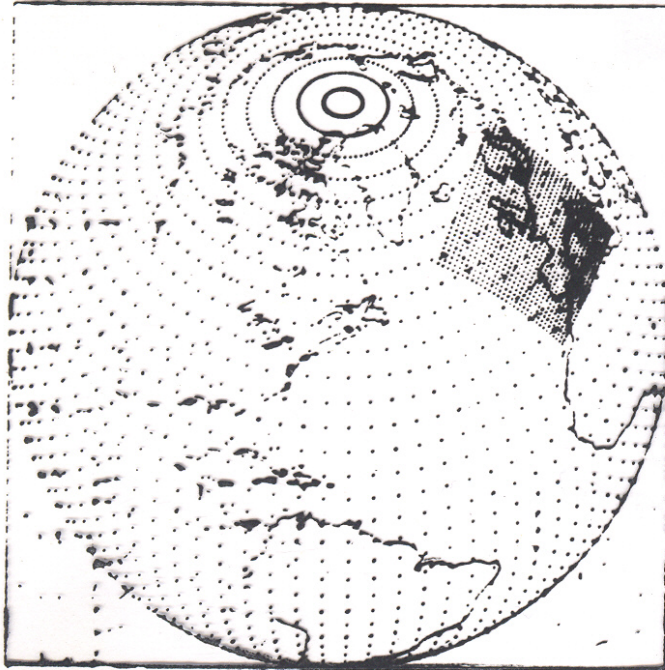
Modèles non-hydrostatiques, plus coûteux, sont utilisés pour la météorologie de petite échelle.



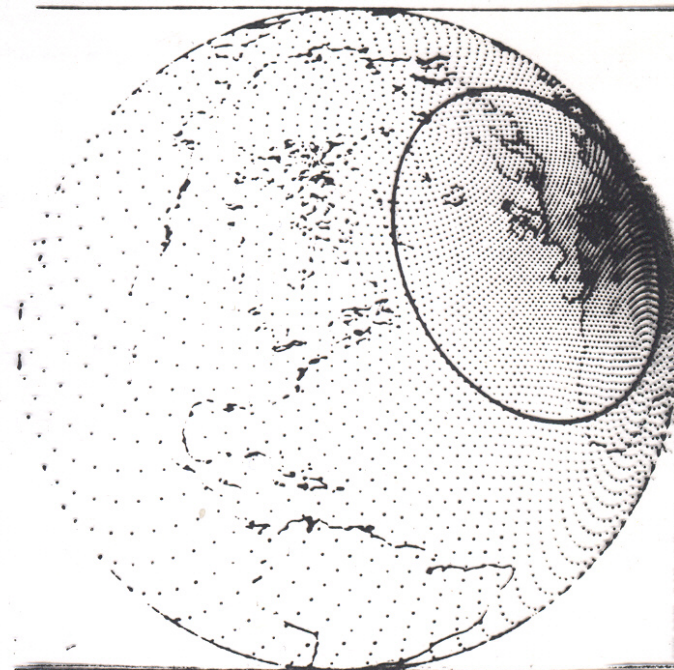
A schematic of an Atmospheric General Circulation Model (L. Fairhead /LMD-CNRS)



Grille Emerald-Péridot



Grille Arpège



Grilles de modèles de Météo-France (*La Météorologie*)