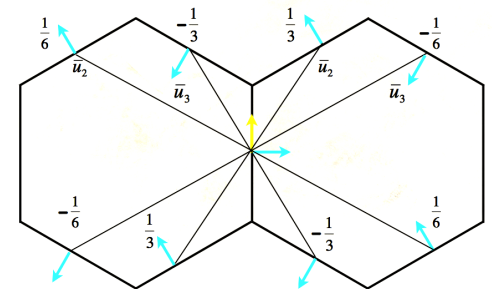
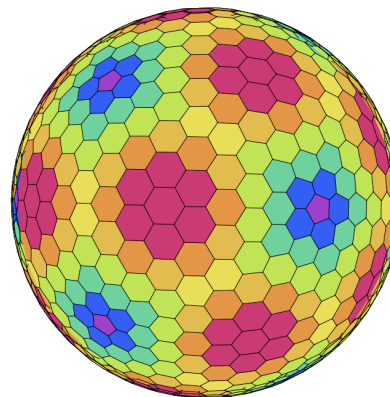
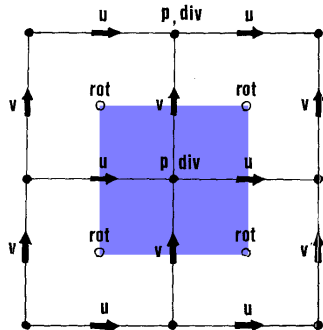


Nouvelle dynamique *principe, où on en est, stratégie*

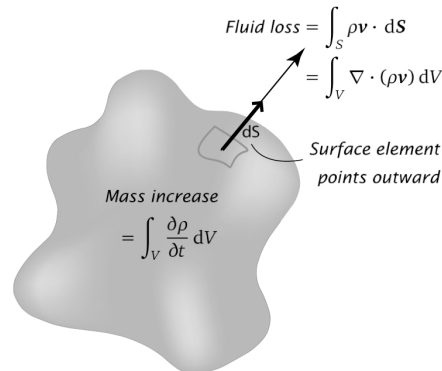
Thomas Dubos,
LMD/IPSL, Ecole Polytechnique



Dynamique vs physique

$$\frac{D\phi}{Dt} = \frac{\partial\phi}{\partial t} + \mathbf{v} \cdot \nabla\phi$$

Conservation de la masse (air, eau, espèces chimiques)



$$\frac{D\rho}{Dt} + \rho \nabla \cdot \mathbf{v} = 0, \quad \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0$$

$$\frac{\partial \phi}{\partial t} + \nabla \cdot (\phi \mathbf{v}) = Q[\phi]$$

Changement de phase, précipitation
 Cinétique chimique
 Diffusion

Thermodynamique : loi d'état + conservation de l'énergie / second principe

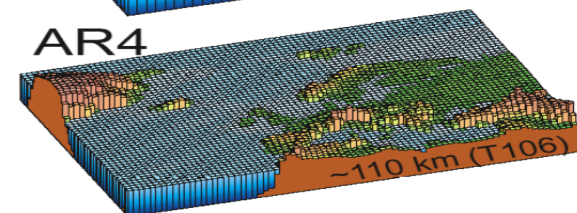
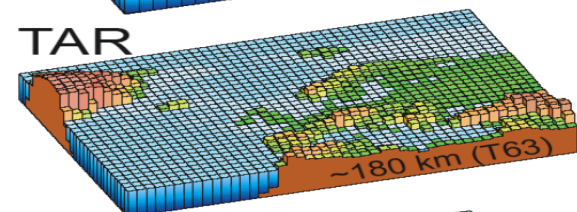
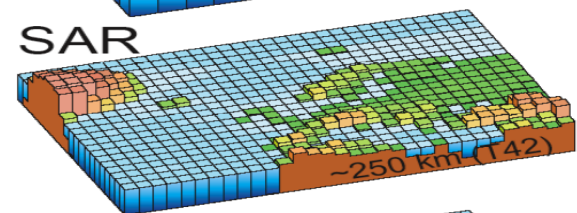
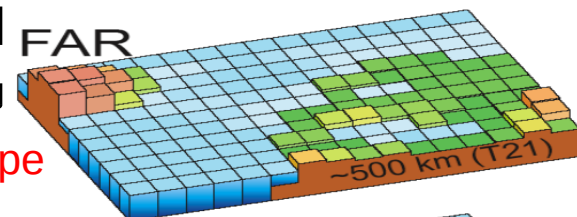
$$\frac{DI}{Dt} + RT \nabla \cdot \mathbf{v} = T \frac{D\eta}{Dt} = |\dot{Q}|$$

Chauffage radiatif
 Chaleur latente

Conservation de la quantité de mouvement dans un référentiel tournant

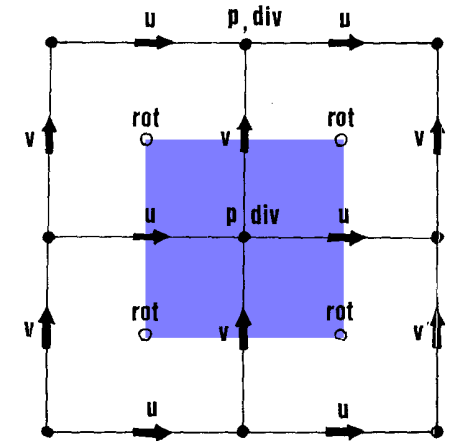
$$\frac{D\mathbf{v}}{Dt} + 2\boldsymbol{\Omega} \times \mathbf{v} = -\frac{1}{\rho} \nabla p - \nabla \Phi + \mathbf{F}'$$

Friction
 Turbulence



Le schéma de Sadourny (1975)

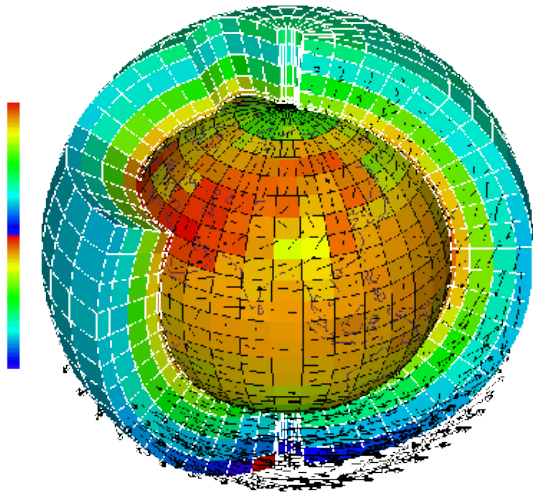
- Reproduire au niveau discret les relations entre opérateurs continus.
- Exemples : $\text{grad}(p^2) = 2p \cdot \text{grad}(p)$, $\text{div} = \text{adjoint}(\text{grad})$, $\text{curl grad} = 0$
- Permet de conserver des invariants intégraux, en particulier l'*enstrophie*



Résolution $\sim \frac{1}{2}^\circ$ 720x360x19
(Y. Meurdesoif)



Maillage cartésien latitude-longitude : limitations et alternatives



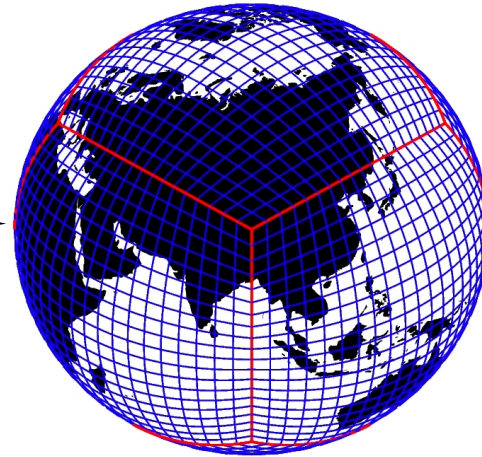
« problème du pôle »

- Problème modèle : équation des ondes

$$\partial_{tt}p + c^2 \Delta p = 0$$

$$c \delta t \leq \delta x = R \cos(lat) \delta \lambda$$

- Au pôle le critère CFL impose $dt=0$
- Pour relaxer le critère CFL : **filtre passe-bas éliminant les hautes fréquences spatiales en longitude**



Sphère « cubée »

MITgcm (MIT), HOMME (NCAR)
GFDL-CM3 (GFDL), GEOS (NASA)



Maillage icosaédrique

NICAM (JAMSTEC, Japon)
ICON (DWD/MPI-M, Allemagne)
DYNAMICO (IPSL)
MPAS (NCAR), CSUgcm (Colorado U)

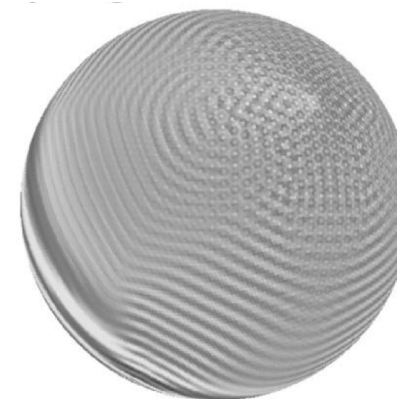
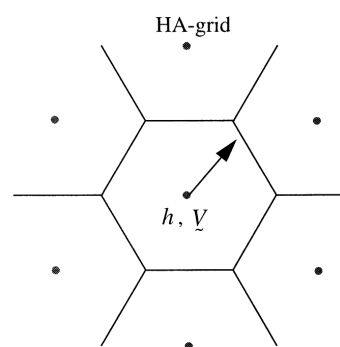
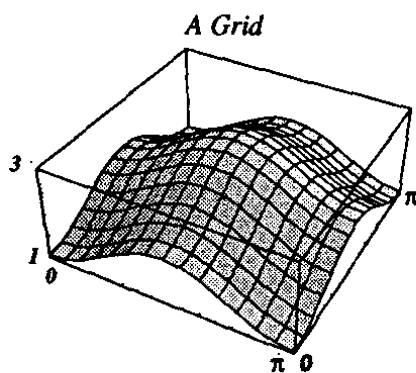
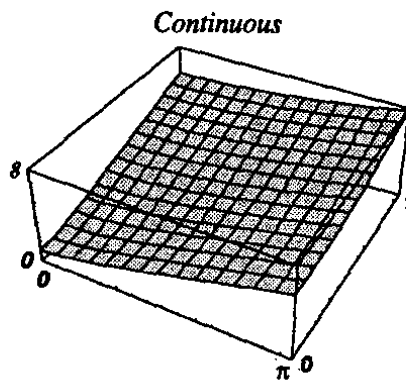
Élimination des singularités artificielles aux pôles

Calculs locaux => parallélisme

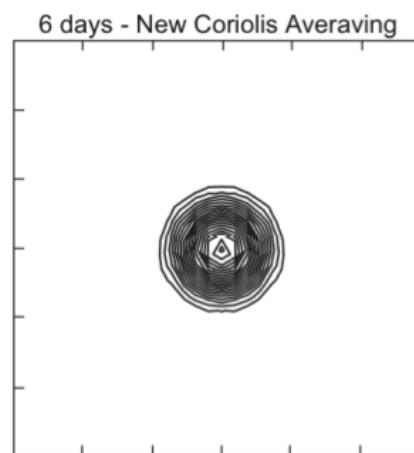
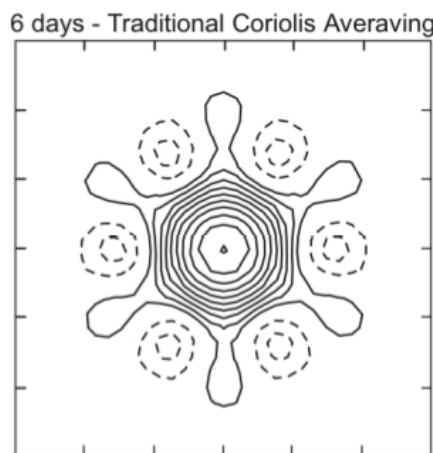
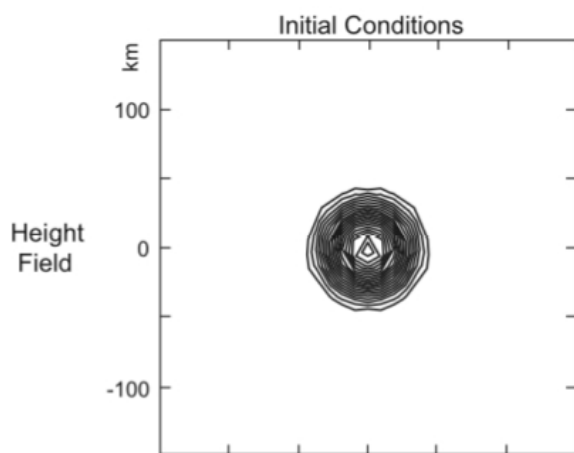
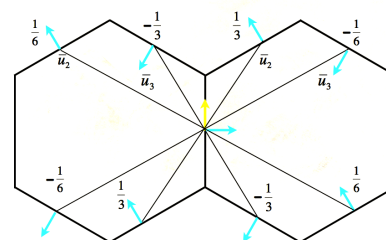
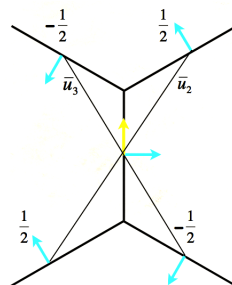
Repenser les schémas numériques

Ondes de gravité (couplage vitesse-pression)

Collocation vitesse-pression => mode numérique



Équilibre géostrophique (couplage Coriolis-pression)



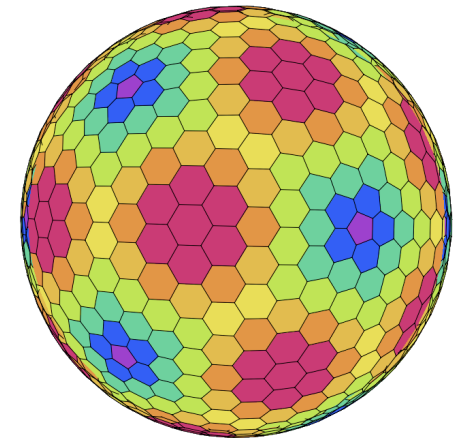
Équilibres géostrophiques violés
Pas de conservation de l'entropie

Équilibres géostrophiques préservés
Conservation de l'entropie

Etat des lieux

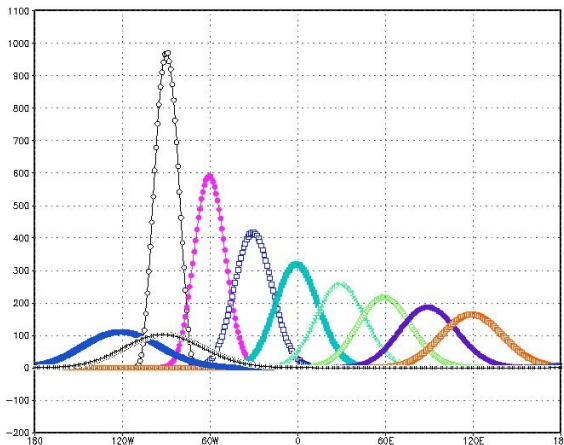
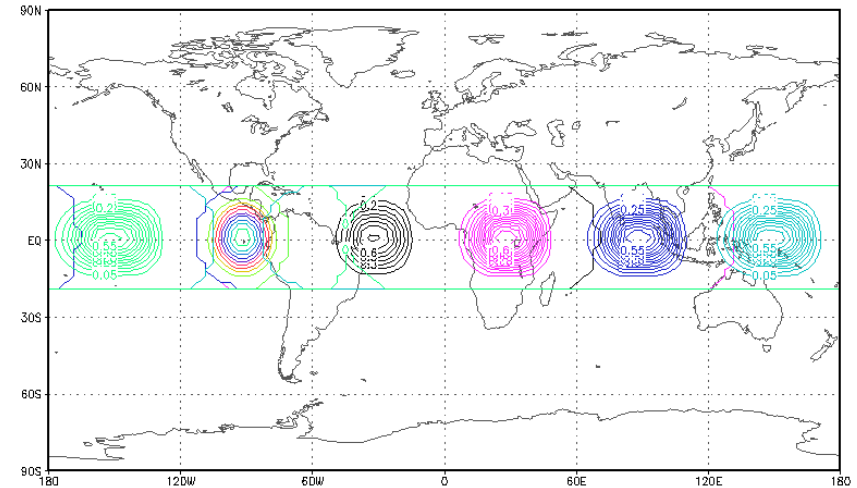
LMD-Z (lat-lon)

- Shallow water 1 couche en standard
- Cas-test standard (Williamson)
- Convergence
E. Millour

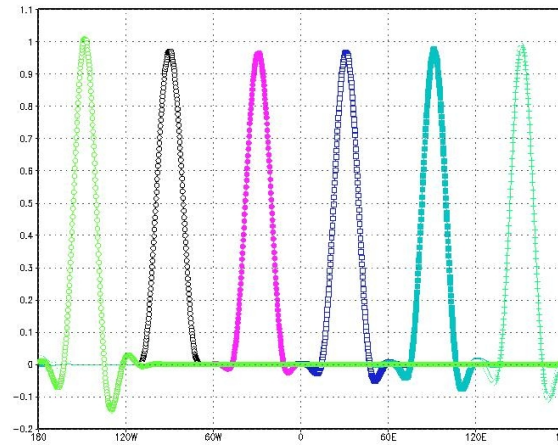


Icosaèdre

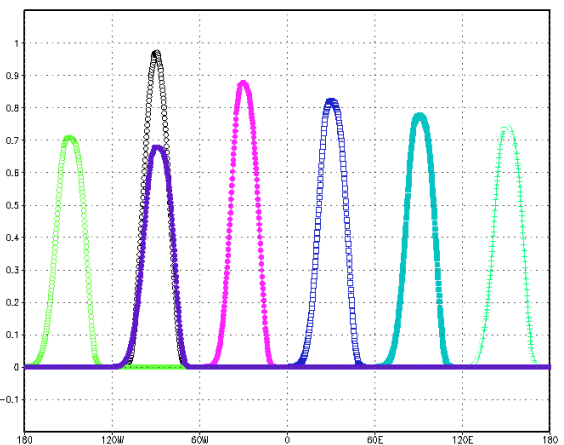
- squelette pour calcul parallèle *Y. Meurdesoif*
- outils de visualisation *P. Brockmann*
- schémas de transport définis positifs
Sarvesh Dubey, Rashmi Mittal, LMD/IIT Delhi
- schémas à la Sadourny (mi-2011)
(Thuburn et al., JCP 2009 ; Klemp et al., JCP 2010).
- équations primitives (début 2012 ?)



2010-07-15-11:30 @#DS: COLA/DES



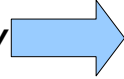
2010-11-24-11: @#DS: COLA/DES



2010-11-05-12:48

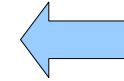
Feuille de route

*Projet franco-indien
(IFCPAR)
Thèse Sarvesh Dubey
2010-2013*



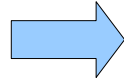
Schémas sur l'icosaèdre :

volumes finis (transport),
différences finies conservatives
volumes finis « well-balanced »



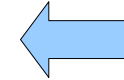
*ANR SVENO
2010-2013*

*Thèse Marine Tort
2011-2014
S. Lebonnois,
A. Spiga*



Atmosphères profondes :

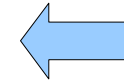
Titan, planètes gazeuses



*V. Zeitlin, F. Bouchut
(LAMA), G. Lapeyre*

Calcul intensif

Parallélisme massif, GPU
I/O parallèles avec post-traitement



*Projet G8 ICOMEX
2011-2014*

