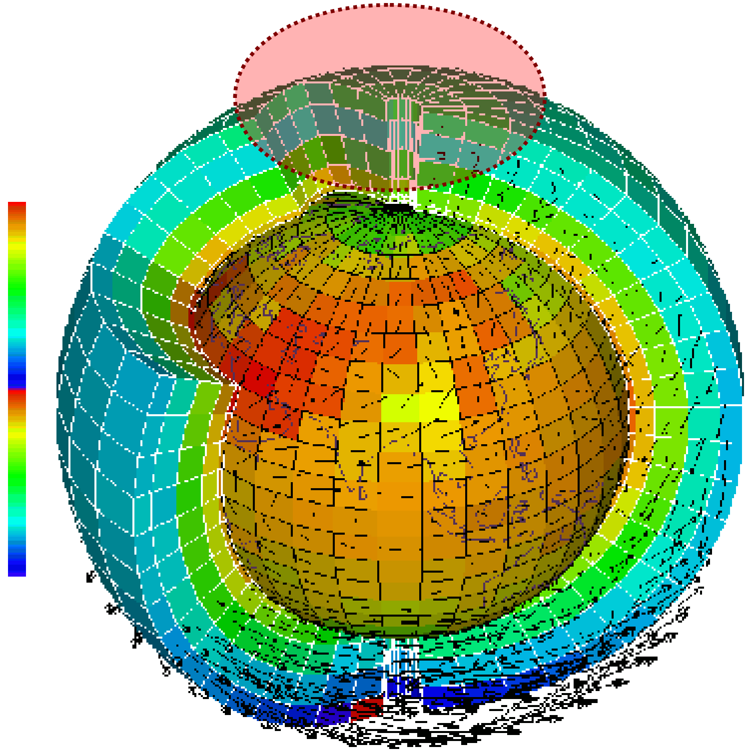
DYNAMICO

Status and outlook

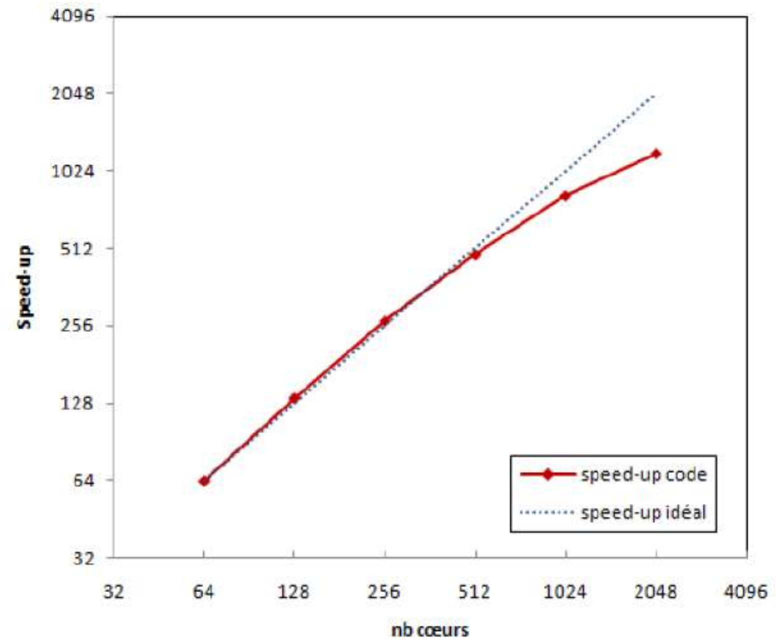
Thomas Dubos
École Polytechnique, LMD/IPSL

*with F. Hourdin, A. Traore, M. Tort, E. Millour, A. Spiga & co (LMD/IPSL),
J. Gattas (IPSL), Y. Meurdesoif, J. Servonnat, M. Kageyama, P. Braconnot (LSCE/IPSL),
S. Dubey (IIT Delhi),E. Kritsikis (LAGA/Paris XIII), ...*

The pole problem : FFT filters around the pole for stability => global dependency (Williamson, 2007)



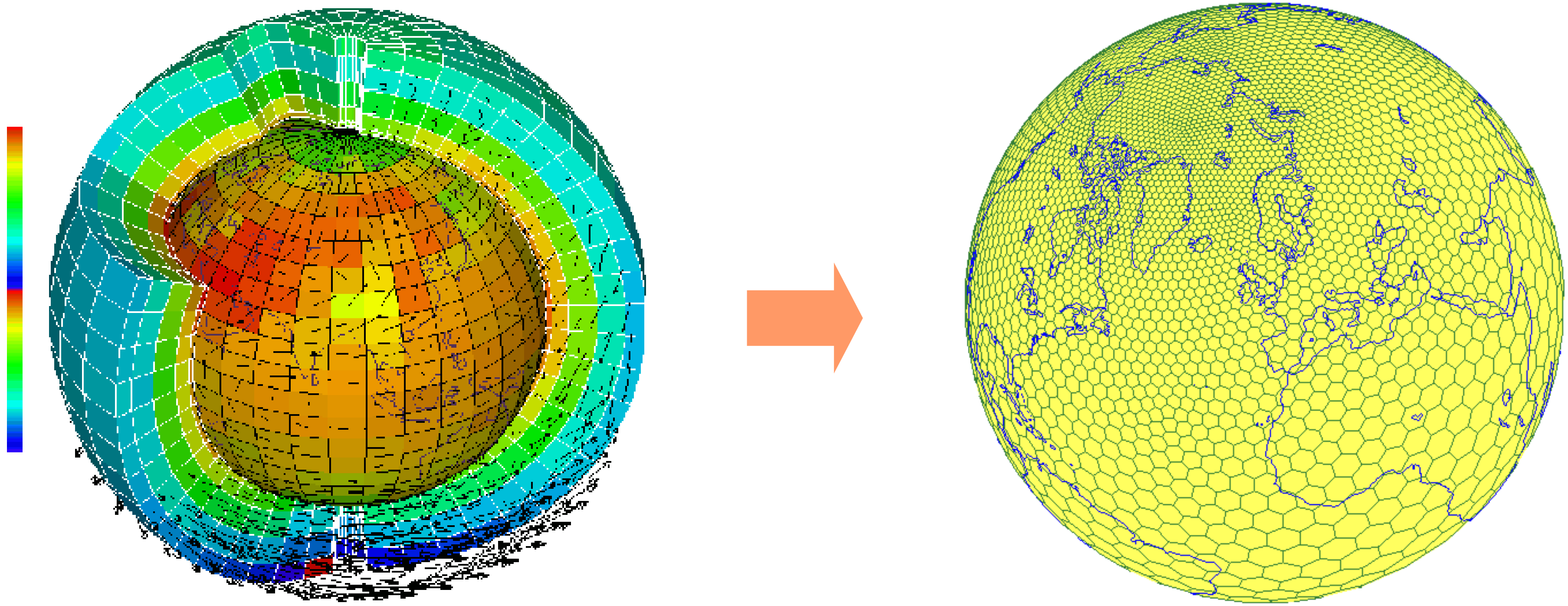
LMD-Z lon-lat core

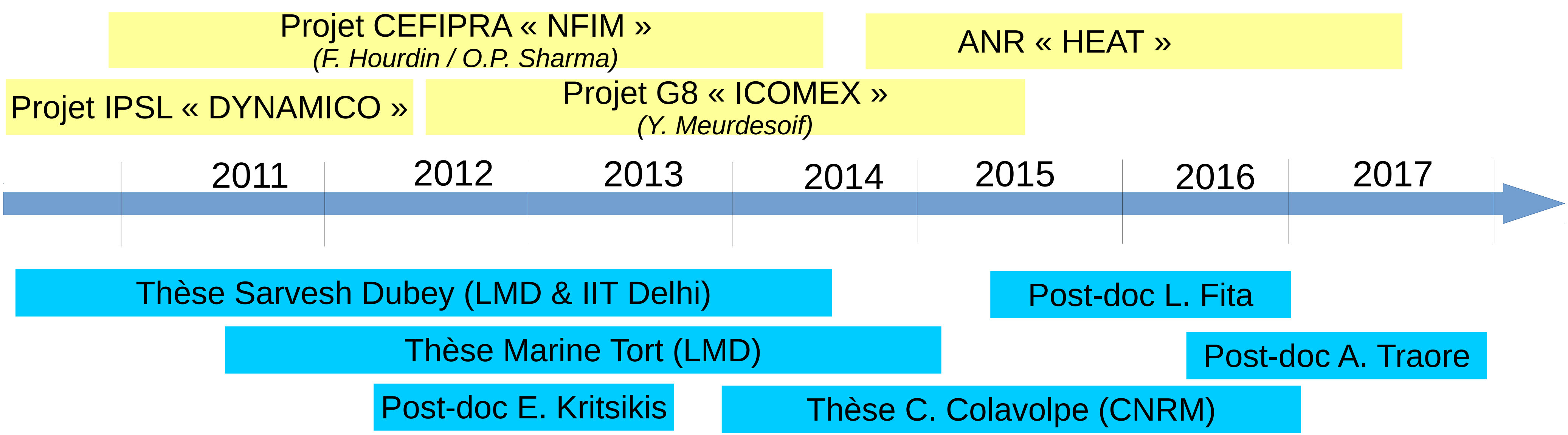


Y. Meurdesoif (2010, 1/4 degree)

Enstrophy-conserving finite differences on lon-lat mesh (Sadourny, 1975)

Positive definite finite-volume transport (Hourdin & Armengaud, 1999)




Projet CEFIPRA « NFIM »
(F. Hourdin / O.P. Sharma)
ANR « HEAT »
Projet IPSL « DYNAMICO »
Projet G8 « ICOMEX »
(Y. Meurdesoif)
2011
2012
2013
2014
2015
2016
2017
Thèse Sarvesh Dubey (LMD & IIT Delhi)
Post-doc L. Fita
Thèse Marine Tort (LMD)
Post-doc A. Traore
Post-doc E. Kritsikis
Thèse C. Colavolpe (CNRM)

Références

- T. Dubos, S. Dubey, M. Tort, R. Mittal, Y. Meurdesoif and F. Hourdin (2015) *DYNAMICO, a hydrostatic icosahedral dynamical core designed for consistency and versatility* Geosci. Mod. Dev.
- S. Dubey, T. Dubos, F. Hourdin, H.C. Upadhyaya (2015) *On the inter-comparison of two tracer transport schemes on icosahedral grid*s Applied Math. Mod. 39(16) 4828-4847 doi:10.1016/j.apm.2015.04.015
- E. Kritsikis, M. Aechtner, Y. Meurdesoif, and T. Dubos *Conservative interpolation between general spherical meshes* Geosci. Mod. Dev.
- T. Dubos and M. Tort (2014) *Equations of atmospheric motion in non-Eulerian vertical coordinates : vector-invariant form and Hamiltonian formulatio*n Mon. Wea. Rev. 142(10) : 3860-3880

- http://forge.ipsl.jussieu.fr/dynamico/wiki
- https://forge.ipsl.jussieu.fr/heat/wiki

Google Agenda | python - Passin | Typed Memory | aller lecce bari | Aqua-Planet Ex | [DYNAMICO] | Timeline - Dyna | Timeline - Dyna | program.pdf on

forge.ipsl.jussieu.fr/dynamico/timeline

Applications | Agenda | Biblio | DYNAMICO | HEAT | AIMES | X | LMD | Medecine | Famille | Comptes | Importés depuis Fir...

(please configure the [header_logo] section in trac.ini)

Search

logged in as dubos | Logout | Preferences | Help/Guide | About Trac

Wiki | **Timeline** | Roadmap | Browse Source | View Tickets | New Ticket | Search

← Previous Period | Next Period →

Timeline

View changes from 11/20/17
and 90 days back
done by

- [ ] Milestones reached
- [ ] Tickets opened and closed
- [x] Repository changesets
- [ ] Wiki changes

Update

11/19/17: Yesterday

00:18 Changeset [607] by dubos
trunk : added AAM_tot to detailed AAM budget

10/25/17:

17:00 Changeset [606] by dubos
trunk : new disvert strato_custom

10/24/17:

01:46 Changeset [605] by dubos
trunk : backported r600 from devel

01:32 Changeset [604] by dubos
trunk : backported r600-603 from devel

01:22 Changeset [603] by dubos
devel : output theta and momentum fluxes

01:20 Changeset [602] by dubos
devel : make sure le_de is 0 for 6th edge of pentagons

10/23/17:

```
    END DO
    !
    DO l = ll_begin, ll_end
       !DIR$ SIMD
       DO ij=ij_begin, ij_end
          du_trisk=0.
          du_trisk = du_trisk + wee(ij+u_right,1,1)*hflux(ij+u_rup,l)*(qu(ij+u_right,l)+qu(ij+u_rup,l))
          du_trisk = du_trisk + wee(ij+u_right,2,1)*hflux(ij+u_lup,l)*(qu(ij+u_right,l)+qu(ij+u_lup,l))
          du_trisk = du_trisk + wee(ij+u_right,3,1)*hflux(ij+u_left,l)*(qu(ij+u_right,l)+qu(ij+u_left,l))
          du_trisk = du_trisk + wee(ij+u_right,4,1)*hflux(ij+u_ldown,l)*(qu(ij+u_right,l)+qu(ij+u_ldown,l))
          du_trisk = du_trisk + wee(ij+u_right,5,1)*hflux(ij+u_rdown,l)*(qu(ij+u_right,l)+qu(ij+u_rdown,l))
          du_trisk = du_trisk + wee(ij+u_right,1,2)*hflux(ij+t_right+u_ldown,l)*(qu(ij+u_right,l)+qu(ij+t_right+u_ldown,l))
          du_trisk = du_trisk + wee(ij+u_right,2,2)*hflux(ij+t_right+u_rdown,l)*(qu(ij+u_right,l)+qu(ij+t_right+u_rdown,l))
          du_trisk = du_trisk + wee(ij+u_right,3,2)*hflux(ij+t_right+u_right,l)*(qu(ij+u_right,l)+qu(ij+t_right+u_right,l))
          du_trisk = du_trisk + wee(ij+u_right,4,2)*hflux(ij+t_right+u_rup,l)*(qu(ij+u_right,l)+qu(ij+t_right+u_rup,l))
          du_trisk = du_trisk + wee(ij+u_right,5,2)*hflux(ij+t_right+u_lup,l)*(qu(ij+u_right,l)+qu(ij+t_right+u_lup,l))
          du(ij+u_right,l) = du(ij+u_right,l) + .5*du_trisk
          du_trisk=0.
          du_trisk = du_trisk + wee(ij+u_lup,1,1)*hflux(ij+u_left,l)*(qu(ij+u_lup,l)+qu(ij+u_left,l))
          du_trisk = du_trisk + wee(ij+u_lup,2,1)*hflux(ij+u_ldown,l)*(qu(ij+u_lup,l)+qu(ij+u_ldown,l))
          du_trisk = du_trisk + wee(ij+u_lup,3,1)*hflux(ij+u_rdown,l)*(qu(ij+u_lup,l)+qu(ij+u_rdown,l))
          du_trisk = du_trisk + wee(ij+u_lup,4,1)*hflux(ij+u_right,l)*(qu(ij+u_lup,l)+qu(ij+u_right,l))
          du_trisk = du_trisk + wee(ij+u_lup,5,1)*hflux(ij+u_rup,l)*(qu(ij+u_lup,l)+qu(ij+u_rup,l))
          du_trisk = du_trisk + wee(ij+u_lup,1,2)*hflux(ij+t_lup+u_right,l)*(qu(ij+u_lup,l)+qu(ij+t_lup+u_right,l))
          du_trisk = du_trisk + wee(ij+u_lup,2,2)*hflux(ij+t_lup+u_rup,l)*(qu(ij+u_lup,l)+qu(ij+t_lup+u_rup,l))
          du_trisk = du_trisk + wee(ij+u_lup,3,2)*hflux(ij+t_lup+u_lup,l)*(qu(ij+u_lup,l)+qu(ij+t_lup+u_lup,l))
          du_trisk = du_trisk + wee(ij+u_lup,4,2)*hflux(ij+t_lup+u_left,l)*(qu(ij+u_lup,l)+qu(ij+t_lup+u_left,l))
          du_trisk = du_trisk + wee(ij+u_lup,5,2)*hflux(ij+t_lup+u_ldown,l)*(qu(ij+u_lup,l)+qu(ij+t_lup+u_ldown,l))
          du(ij+u_lup,l) = du(ij+u_lup,l) + .5*du_trisk
          du_trisk=0.
          du_trisk = du_trisk + wee(ij+u_ldown,1,1)*hflux(ij+u_rdown,l)*(qu(ij+u_ldown,l)+qu(ij+u_rdown,l))
          du_trisk = du_trisk + wee(ij+u_ldown,2,1)*hflux(ij+u_right,l)*(qu(ij+u_ldown,l)+qu(ij+u_right,l))
          du_trisk = du_trisk + wee(ij+u_ldown,3,1)*hflux(ij+u_rup,l)*(qu(ij+u_ldown,l)+qu(ij+u_rup,l))
          du_trisk = du_trisk + wee(ij+u_ldown,4,1)*hflux(ij+u_lup,l)*(qu(ij+u_ldown,l)+qu(ij+u_lup,l))
          du_trisk = du_trisk + wee(ij+u_ldown,5,1)*hflux(ij+u_left,l)*(qu(ij+u_ldown,l)+qu(ij+u_left,l))
          du_trisk = du_trisk + wee(ij+u_ldown,1,2)*hflux(ij+t_ldown+u_lup,l)*(qu(ij+u_ldown,l)+qu(ij+t_ldown+u_lup,l))
          du_trisk = du_trisk + wee(ij+u_ldown,2,2)*hflux(ij+t_ldown+u_left,l)*(qu(ij+u_ldown,l)+qu(ij+t_ldown+u_left,l))
          du_trisk = du_trisk + wee(ij+u_ldown,3,2)*hflux(ij+t_ldown+u_ldown,l)*(qu(ij+u_ldown,l)+qu(ij+t_ldown+u_ldown,l))
          du_trisk = du_trisk + wee(ij+u_ldown,4,2)*hflux(ij+t_ldown+u_rdown,l)*(qu(ij+u_ldown,l)+qu(ij+t_ldown+u_rdown,l))
          du_trisk = du_trisk + wee(ij+u_ldown,5,2)*hflux(ij+t_ldown+u_right,l)*(qu(ij+u_ldown,l)+qu(ij+t_ldown+u_right,l))
          du(ij+u_ldown,l) = du(ij+u_ldown,l) + .5*du_trisk
       END DO
    END DO
    !---------------------------- coriolis ------------------------------------
    !
```

DYNAMICO

Equations of motion	*shallow-water* *shalllow-atmosphere, hydrostatic*
Conservation properties	*Mass (air and species)* *Energy*
Formulation	*Mass : flux-form* *Momentum : vector-invariant form*
Vertical coordinate	*Terrain-following mass-based* *(often conflated with pressure-based)*
Numerics	*Mass : finite volume* *Momentum : low-order* ***mimetic finite difference*** *Mesh :* ***icosahedral-hexagonal C-grid*** *Time : (additive) Runge-Kutta (HEVI)*
Computing	*MPI / OpenMP* *XIOS I/O server* *Scales at least to O(10^4), including* ***I/O***

Physical space

$$\lambda, \varphi, \Phi, g$$

$$u, v, w$$

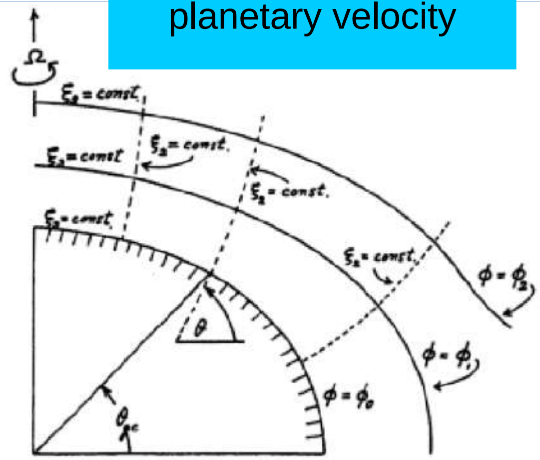
$$\alpha = 1/\rho,\ s,\ r$$

Thermodynamics

$$p, T, \chi$$

Geopotential Coordinates

Metric, gravity, planetary velocity



Surfaces of constant ξ_2 and constant ξ_3

Computational space $S^2 \times [0,1]$

$$\mathbf{v} = \mathbf{G}(\mathbf{n}, \Phi) \cdot \dot{\mathbf{n}} + \mathbf{R}(\mathbf{n}, \Phi)$$

$$\Phi(\mathbf{n}, \eta, t), \mu,$$

$$\mathbf{n} \qquad \eta$$

Horizontal mesh

Icosahedral-hex C-grid

Vertical mesh

Lorenz

Discrete space

$$m_{ik} = \int\int\int \mu \mathrm{d}\mathbf{n}\mathrm{d}\eta$$

$$W_{il} = \int\int \mu\dot{\eta}\mathrm{d}\mathbf{n}$$

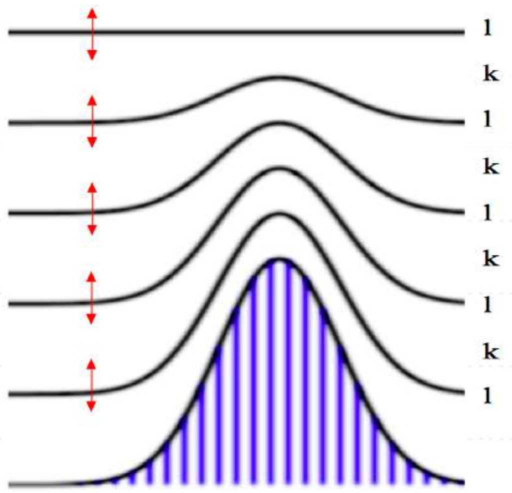
$$v_{ek} = \int \mathbf{v} \cdot \mathrm{d}\mathbf{n}$$

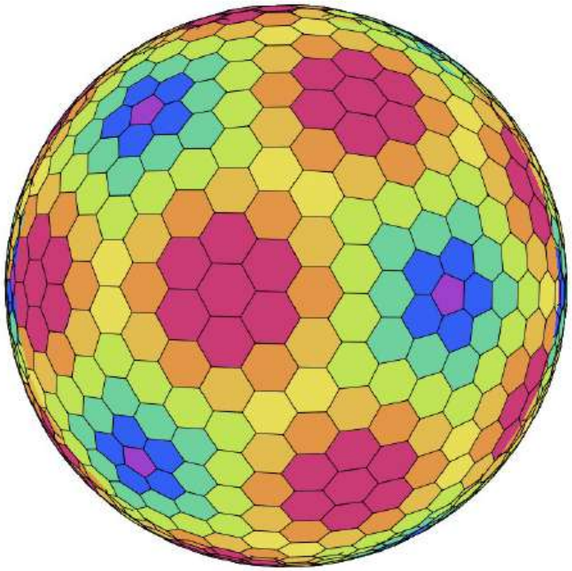
$$\alpha_{ik} = \alpha(p_{ik}, s_{ik}),$$

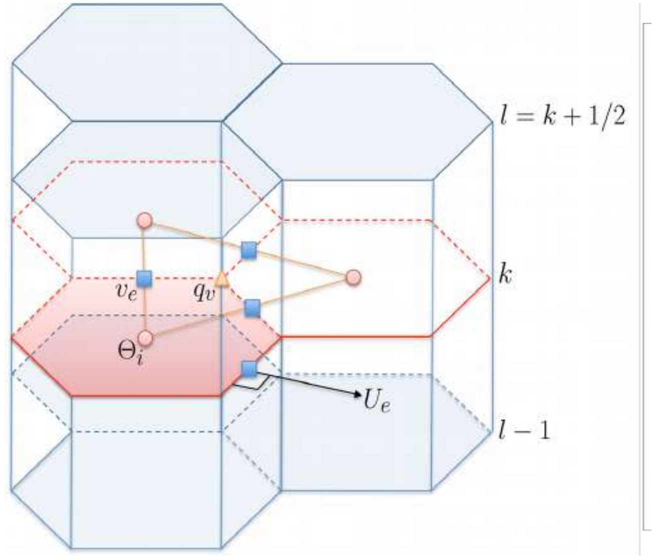
- Discrete integration by parts (Bonaventura & Ringler, 2005 ; Taylor, 2010)
- Energy- and vorticity- conserving Coriolis discretization (TRiSK : Thuburn et al., 2009 ; Ringler et al., 2010)

Energy-conserving 3D core

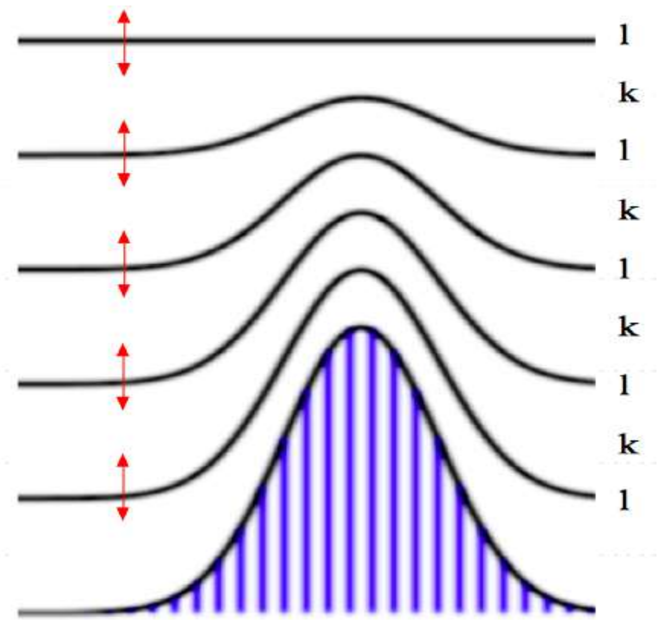
Computational mesh







Mesh partitioning for parallel computing



Hydrostatic balance couples all layers strongly

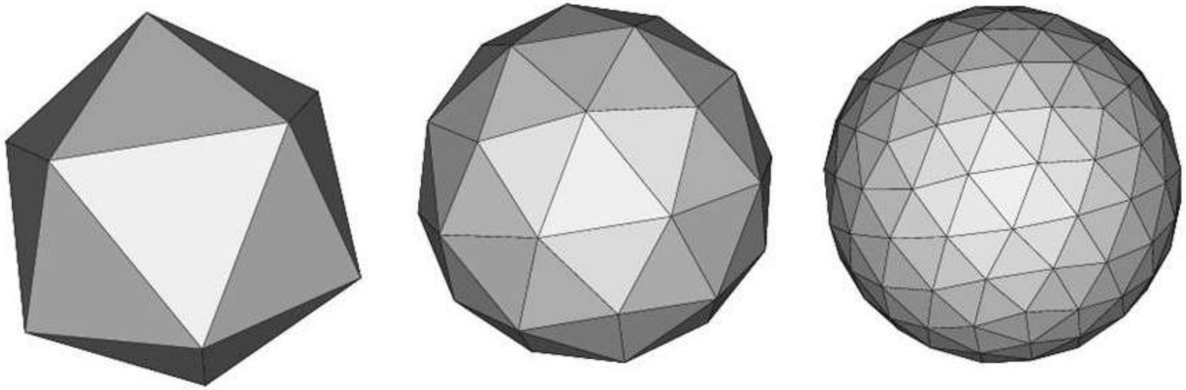
=> distribute vertical direction among OpenMP threads with shared memory

Similar to LMDZ :

- llm=39 vertical levels => 4 OpenMP threads
- llm=79 vertical levels => 8 OpenMP threads

Mesh partitioning for parallel computing

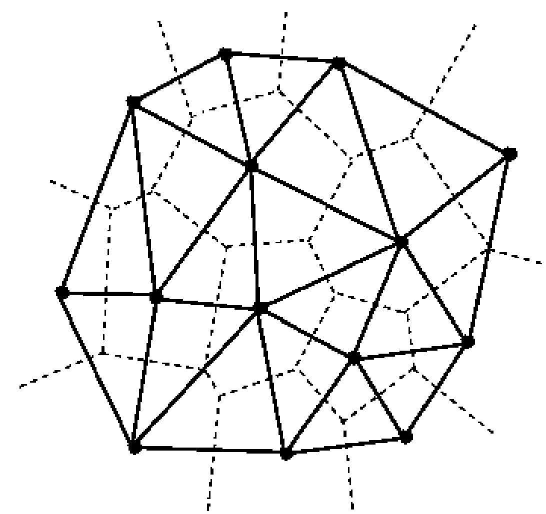
nbp=1 *nbp=2* *nbp=4*

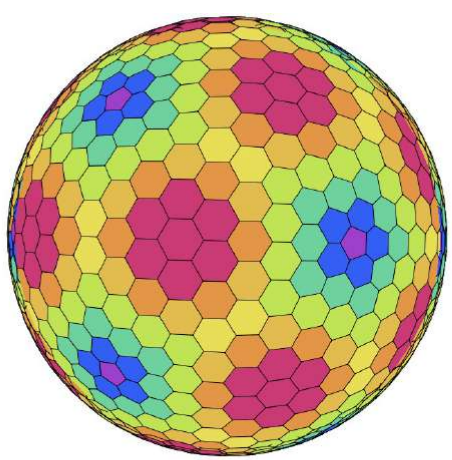


Icosahedral-triangular mesh
$10*nbp^2+2$ *vertices*

Icosahedral-hexagonal mesh
$10*nbp^2+2$ *cells*

Voronoi dual





- Easy to partition into 10 x $nsplit^2$ domains
- About $(nbp/nsplit)^2$ cells per domain = MPI process
- Nbp/nsplit>10 for performance

Example configurations

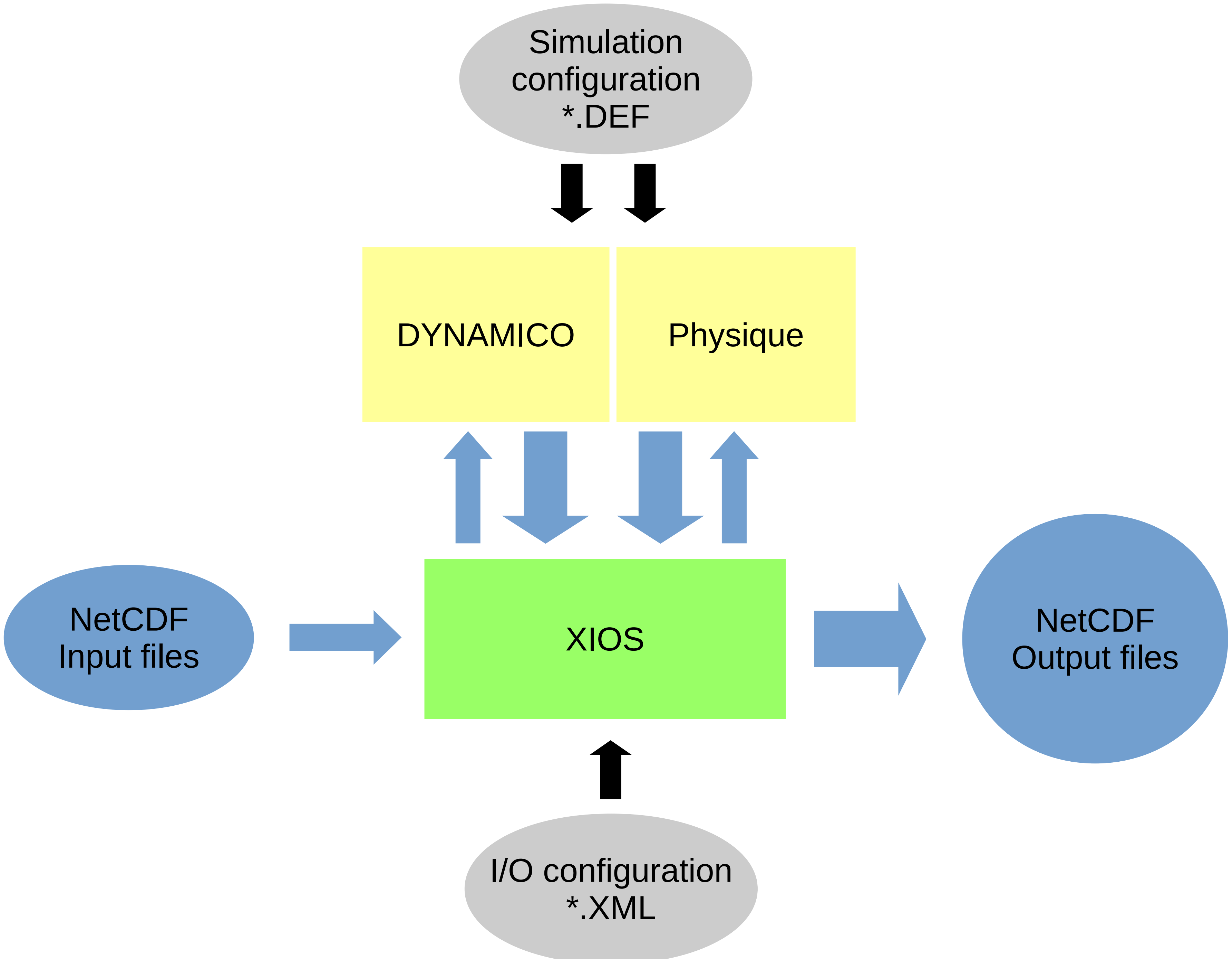
LMDZ

		MPI
3°	96x95	48
2°	144x142	72
(2/3)°	512x360	180

DYNAMICO

		MPI	SYPD (no phys)	SYPD* (CMIP5a)	Mh per 100 yr*
2°	10x40x40	160	300	120	0,01
1°	10x80x80	640	150	40	0,15
(1/2)°	10x160x160	2560		18	1,4
(1/4)°	10x320x320	*2560*		12	2

**assuming 4x with 4 OpenMP threads, no attempt to optimize/tune MPI or XIOS, very few runs*


Simulation configuration *.DEF
DYNAMICO
Physique
NetCDF Input files
XIOS
NetCDF Output files
I/O configuration *.XML

Couplage DYNAMICO – physique de LMDZ

Ehouarn Millour, Yann Meurdesoif (LSCE)

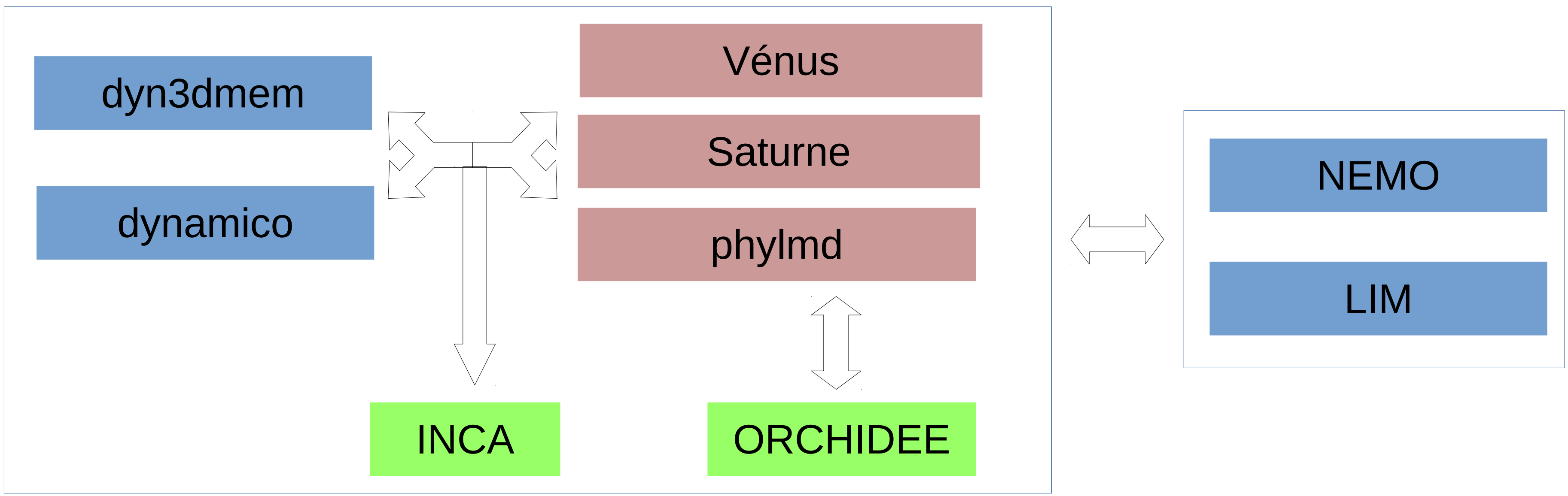
Precipitable water in an aquaplanet experiment (IPSL-CM5a physics, 1/4 degree)

Ongoing : ORCHIDEE+routing

Lluis Fita, Jan Polcher

Outlook

2018 target for IPSL Earth System Model



- *Projet ANR HEAT 2014-2018*
- *HighResMIP (CMIP6) : 2x50 years AMIP at 1/4 degree*

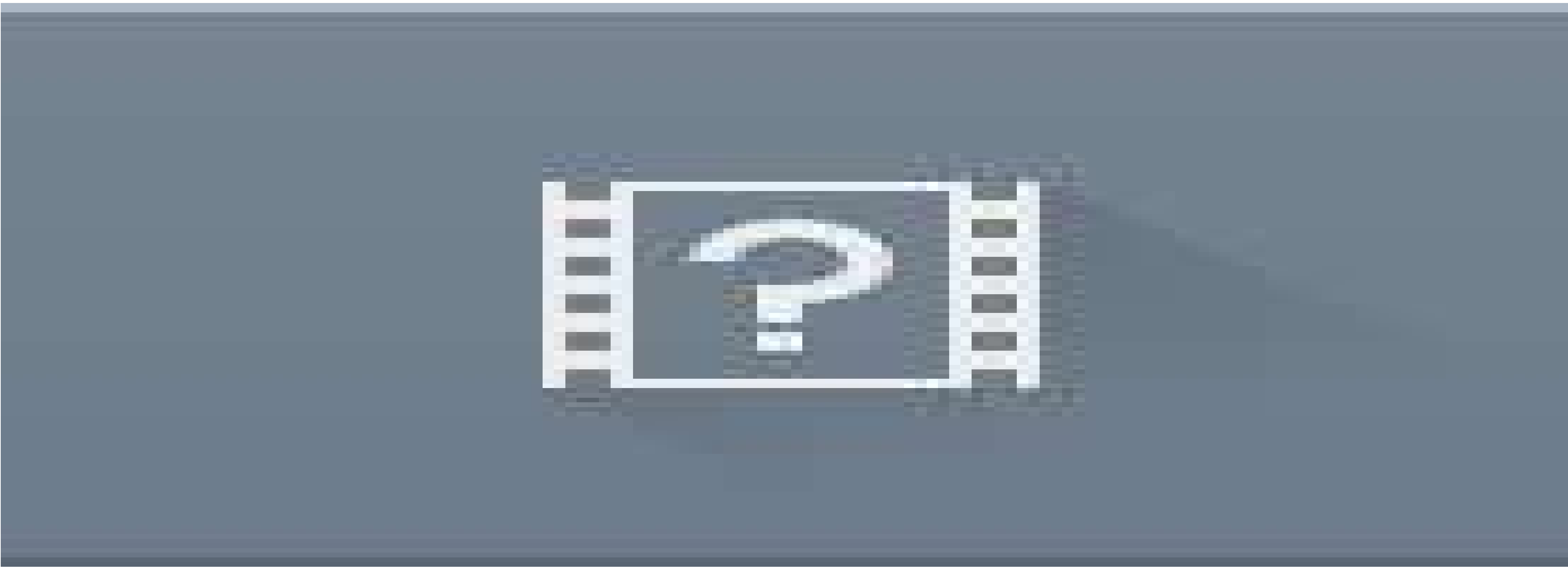
DYNAMICO-NH : non-hydrostatic, (fully compressible) dynamics

T. Dubos, F. Voitus, C. Colavolpe (CNRM-GAME)

Subsidence of a zonally-symmetric cold pool

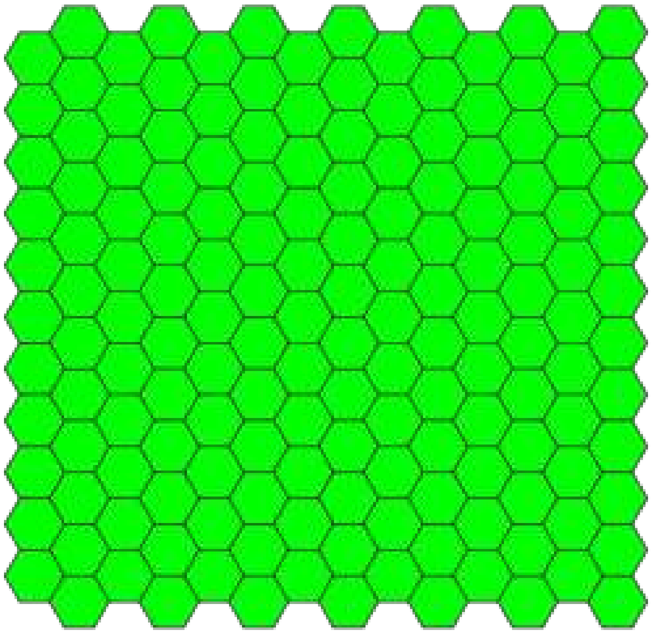
Status :

- *available in the « trunk» branch*
- *Runs DCMIP2016 test cases*
- *OpenMP, restarts and orography to be consolidated in 2018*



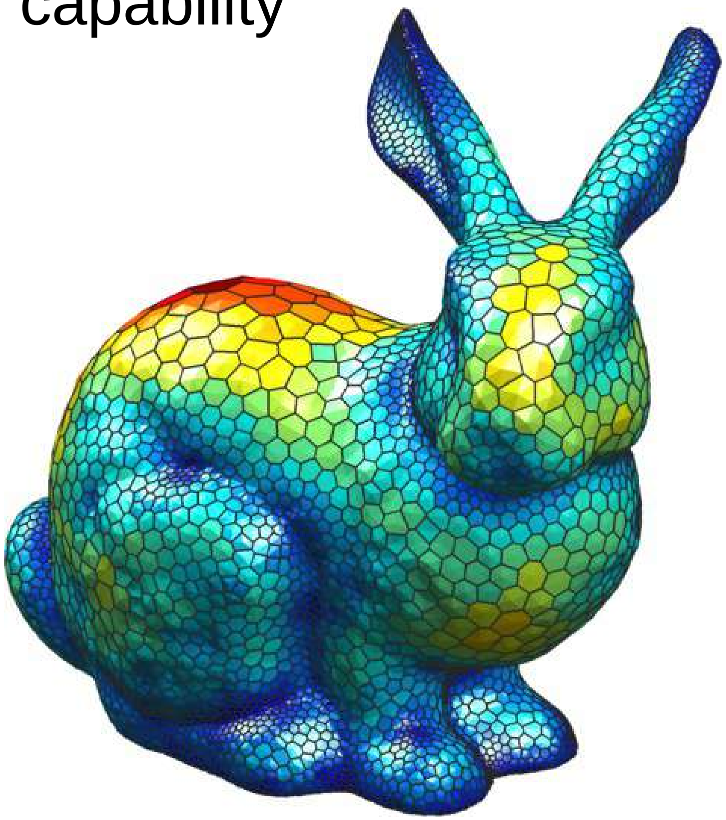
« Supercell » on a tiny planet (400km around the Equator)
Résolution 1°~ 1km
Explicit convection, Kessler microphysics

Unstructured-mesh capability



Structured mesh

- Quasi-uniform resolution
- Zoom possible but limited
- Regular data access / compute pattern



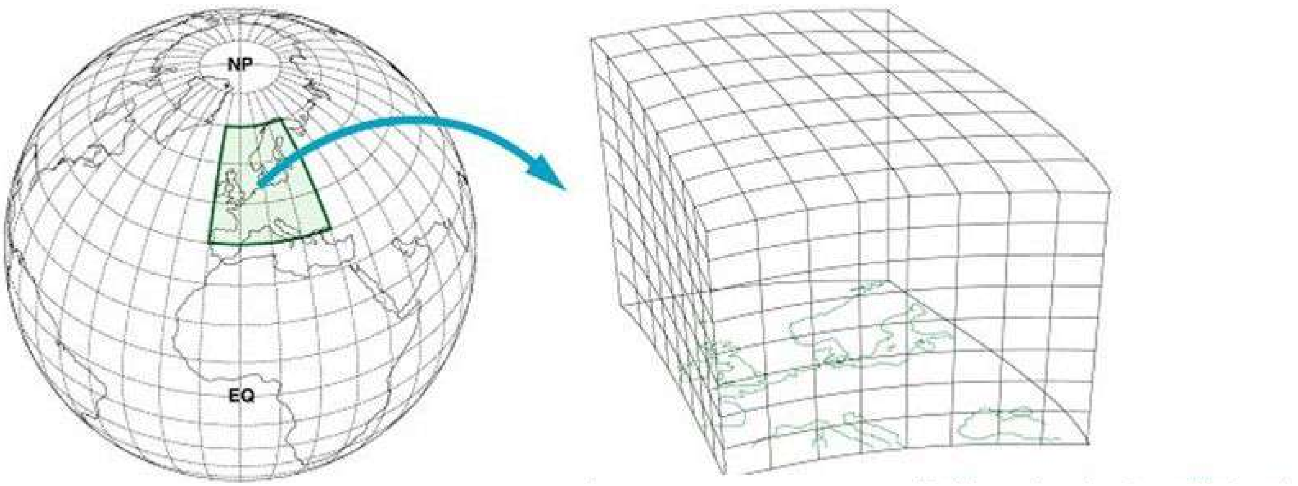
Unstructured mesh

- Variable resolution
- Very flexible zoom capability
- Irregular data access / compute pattern
- Needs scale-aware physics

Status :

- *Prototype available in the « devel» branch*
- *Needs MPI parallelism, transport scheme, ...*
- *Work continues in 2018 (PhD), cf S. Mailler*

Limited-area capability



Status :

- Not started
- IPSL Labex funding (12-month post-doc) to build **convection-resolving demonstrator** by mid 2019
- Physics will initially be LMDZ with convection shut down

Roadmap

- Build periodic-box DYNAMICO, either from structured or unstructured code
- Use already developed coupling to LMD-Z
- Davies relaxation at lateral domain boundaries
- Build workflow to get boundary data through XIOS

Mid-term outlook :
Towards a global-regional IPSL ESM