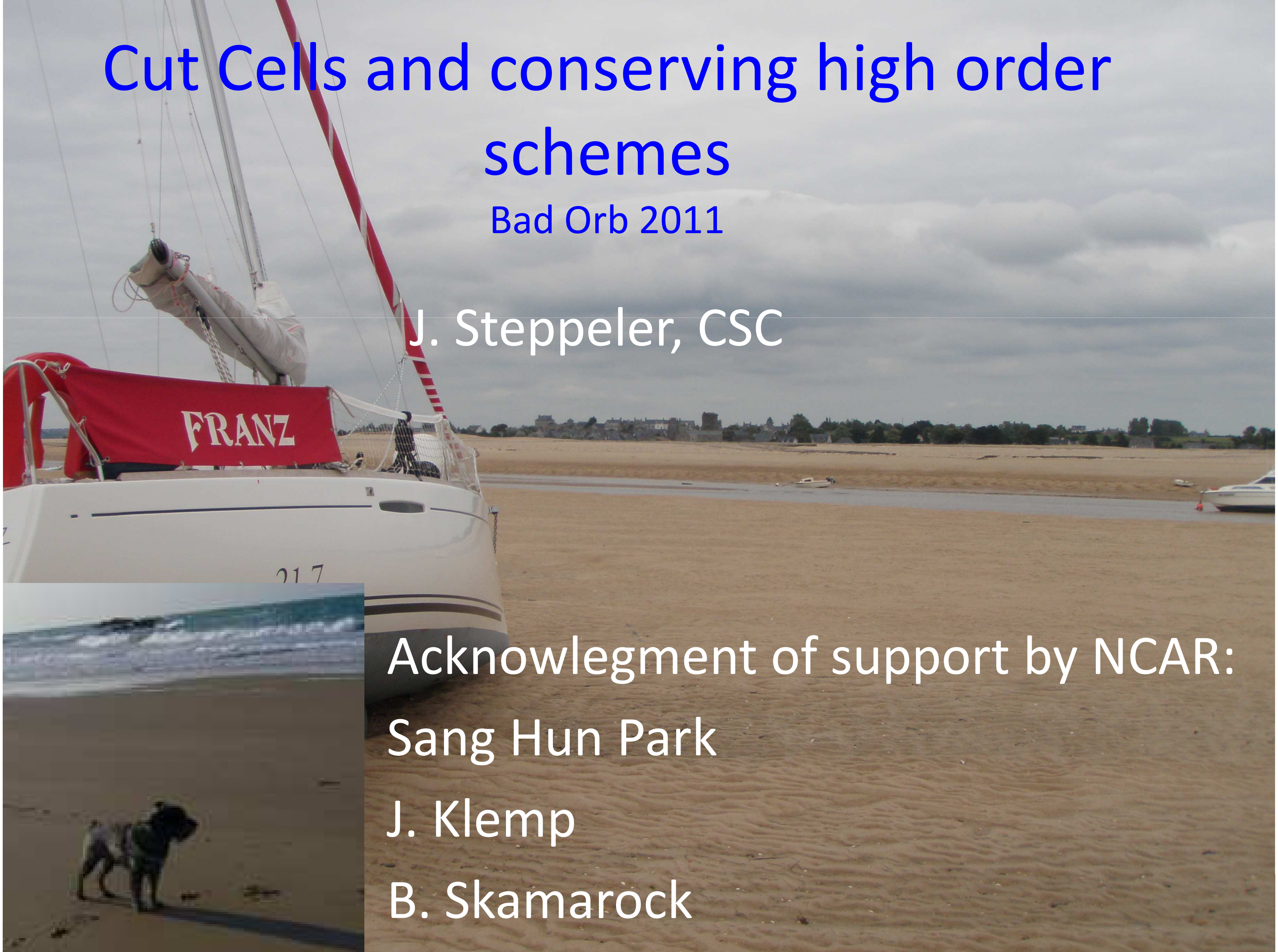
Cut Cells and conserving high order schemes

Bad Orb 2011

J. Steppeler, CSC



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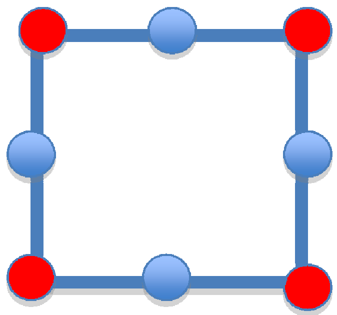
Sang Hun Park

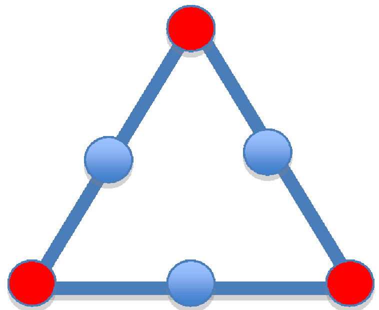
J. Klemp

B. Skamarock

Serendipity Local-Galerkin Schemes with and without Interpolation

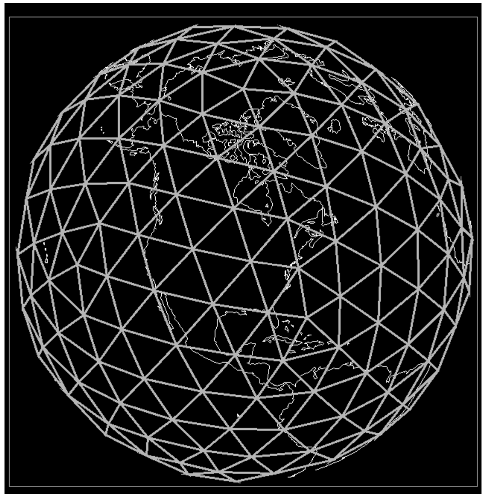
- Are conservative of „high“ order
- Arakawa schemes are a special case: O2 grid with o1 interpolation
- O3 grid without interpolation results into a third order conserving scheme
- O2 grid without interpolation is conserving and second order on irregular grids. For regular grids Super-convergence gives third order.
- L-Galerkin avoids the use of a mass matrix and is local
- The non-interpolating versions are spectral element schemes

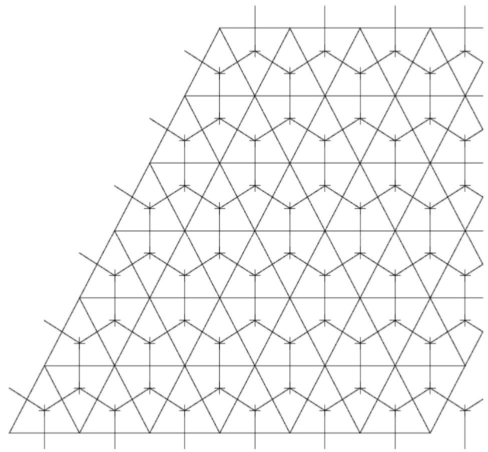


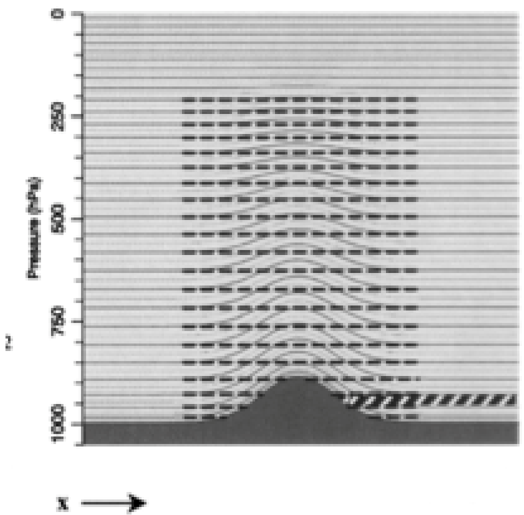


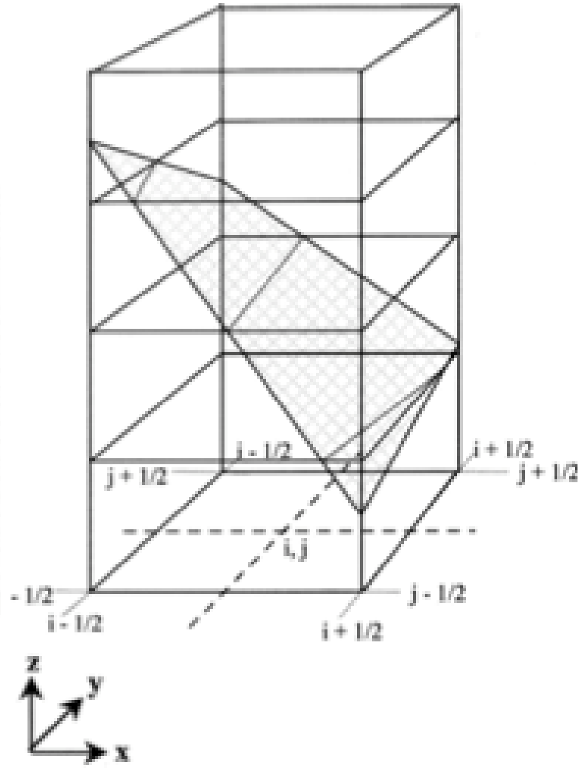
Grids to be used

- Triangular/hexagonal grids also irregular and patching with grid fault lines
- Cut cell grids/shaved cells/z-co-oordinate: very irregular near the surface
- 1-d schemes can be carried over to the 2-d/3-d case and irregular grids. Superconvergence properties will not always carry over
- A minimum “order by consruction” will carry over to 2-d and irregular grids.

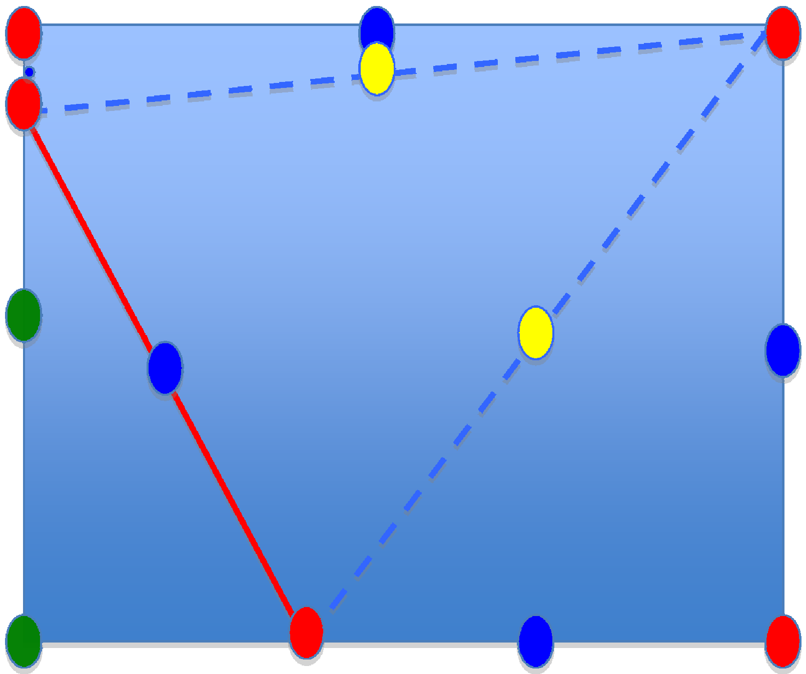








Triangulation



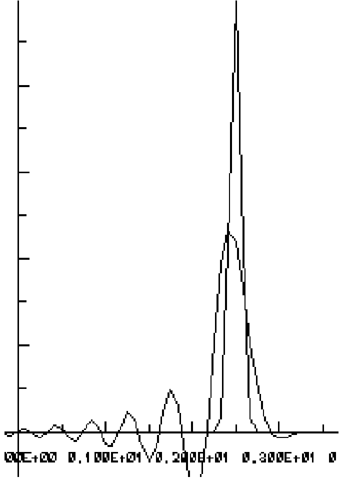
Transfer of 1-d schemes to irregular and 2-d/3-d meshes

- A popular method of choice is **finite volumes**: naturally conserving, o2 or o4 on **regular grids.** No o2 schemes are known **for irregular grids**. This problem exists already for **1-d.**
- The combination of o2 or o3 with conservation is an **open problem even in 1-d**
- **Finite elements/spectral elements** are not popular, naturally conserving and can be of any order on irregular/polygonal girds
- Local Galerkin Serendipity schemes use no mass matrix. They use local difference stencils.

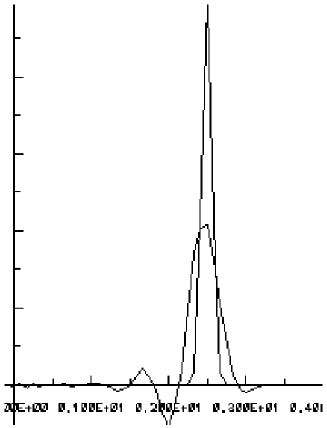
Schemes considered

- **Serendipity grid-o2 with linear interpolation** (Arakawa C) approximation order o2 for regular grid, generalises to polygonal irregular case, approximation order drops to o1: **play models**
- **Serendipity grid-o2 with interpolation-o2** or **non-interpolating,** approximation o3 by super-convergence on regular grids, o2 for irregular grids, o3 is retained for slightly irregular hexogonal grids: **play models**
- **Serendipity grid-o3 non-interpolating,** approximation o3 for irregular polygonal grids: **play models**
- **Cut cells for Arakawa C**, approximation o2 for regular part of grid, o1 for irregular cells near surface: **3-d real life model with actual data**

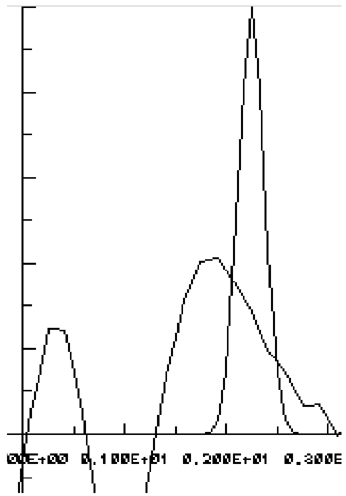
1-d o2 non-interpolating scheme with super-convergence leading to order o3



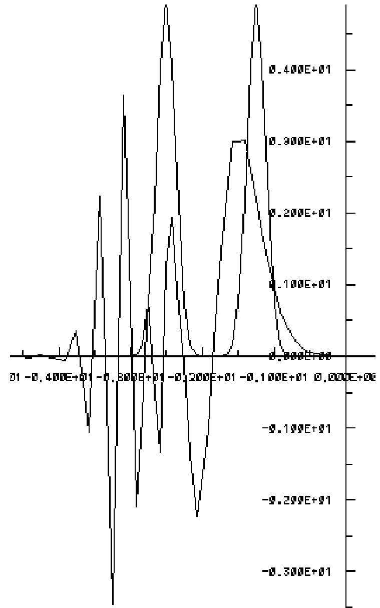
Classic o4



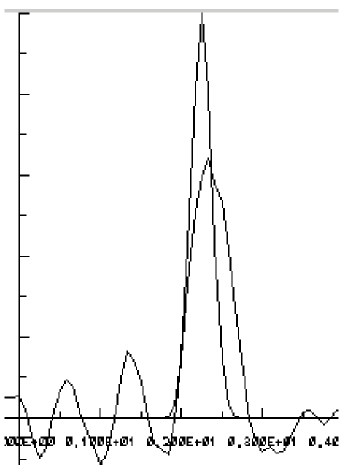
O2-serendipity, **not interpolating (spectral elements)**
3rd order by super-convergence



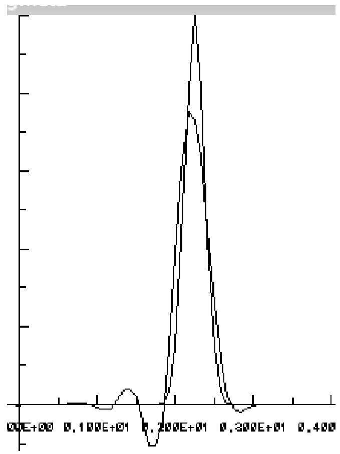
As Below and lower left, for **classical Arakawa** scheme



Top: computational mode of classical Arakawa:
The initial values, the exact solution and solution by classical Arakawa: Strong waves of **negative group velocity** are seen.



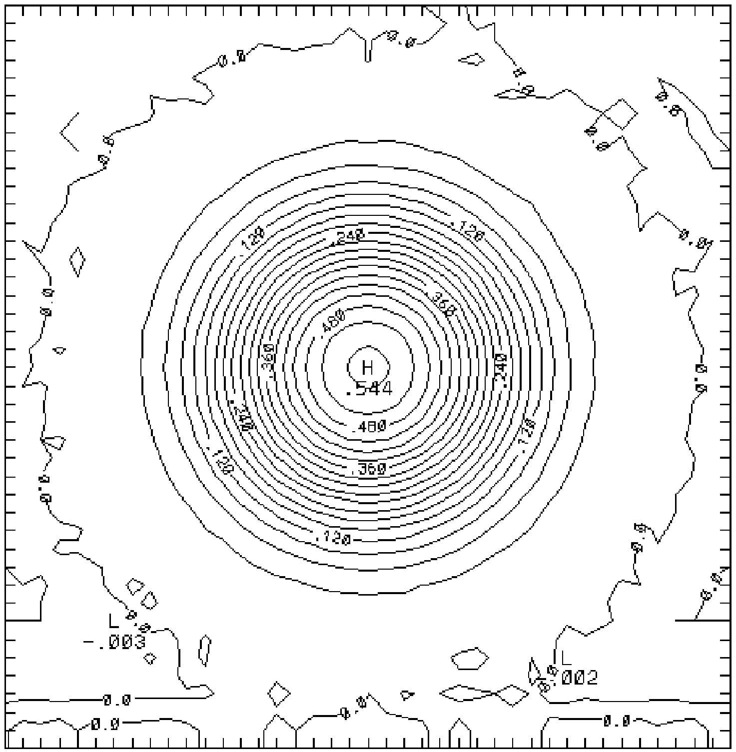
O2-serendipity **interpolating** 3rd order by super-convergence
Double resolution, strong computational mode



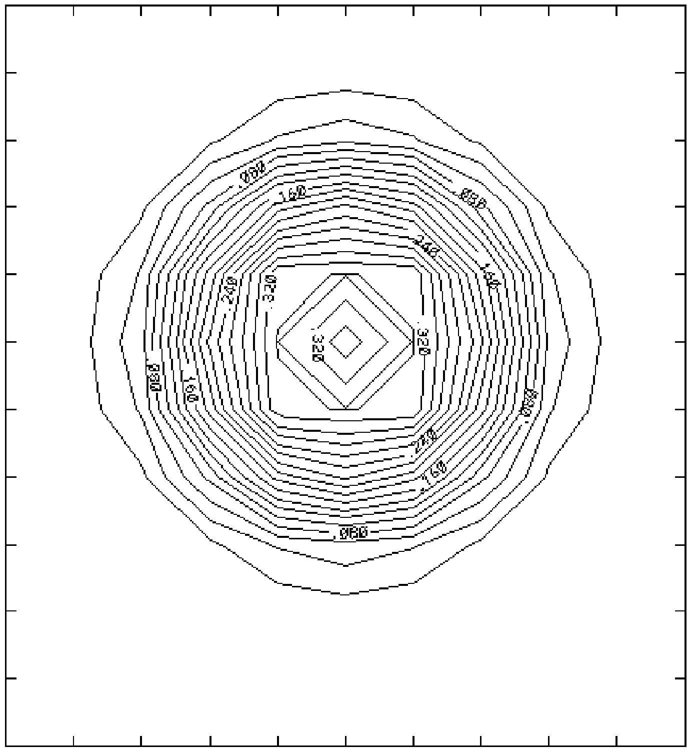
As left (equivalent resolution), for **non interpolating (spectral elements)** scheme

Rotational symmetric gravitational wave by third order conserving scheme (on o3 grid)

120 points

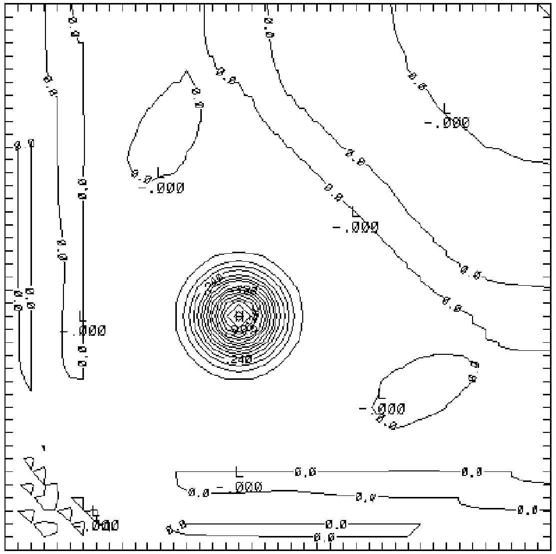


30 points

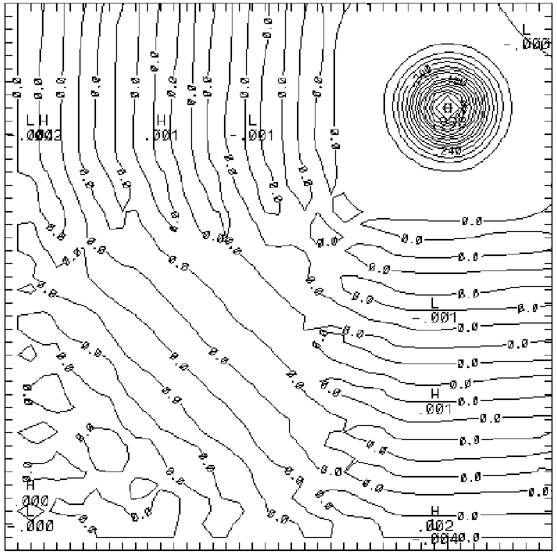


Irregular resolution (order 3): linear homogeneous advection

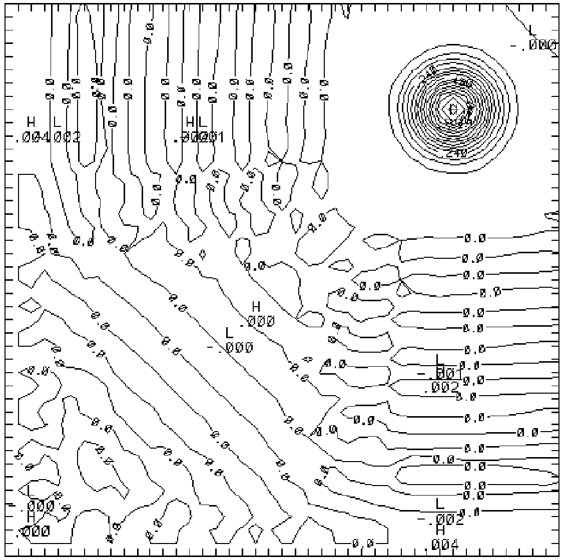
Initial



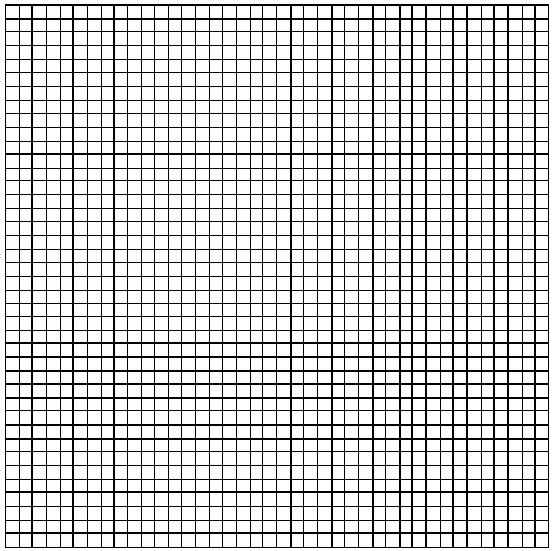
reg. Res.

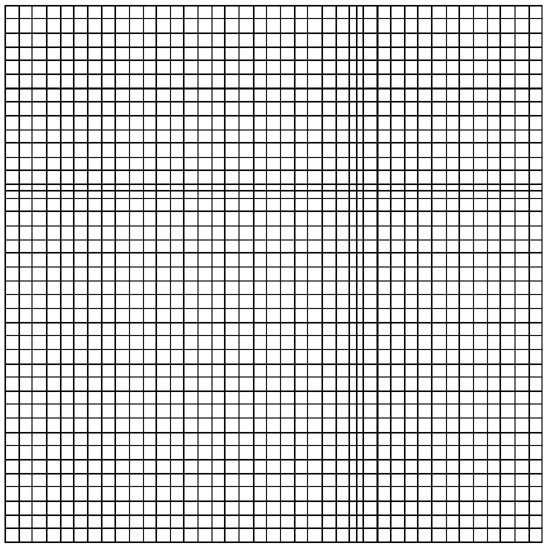


Irreg. res

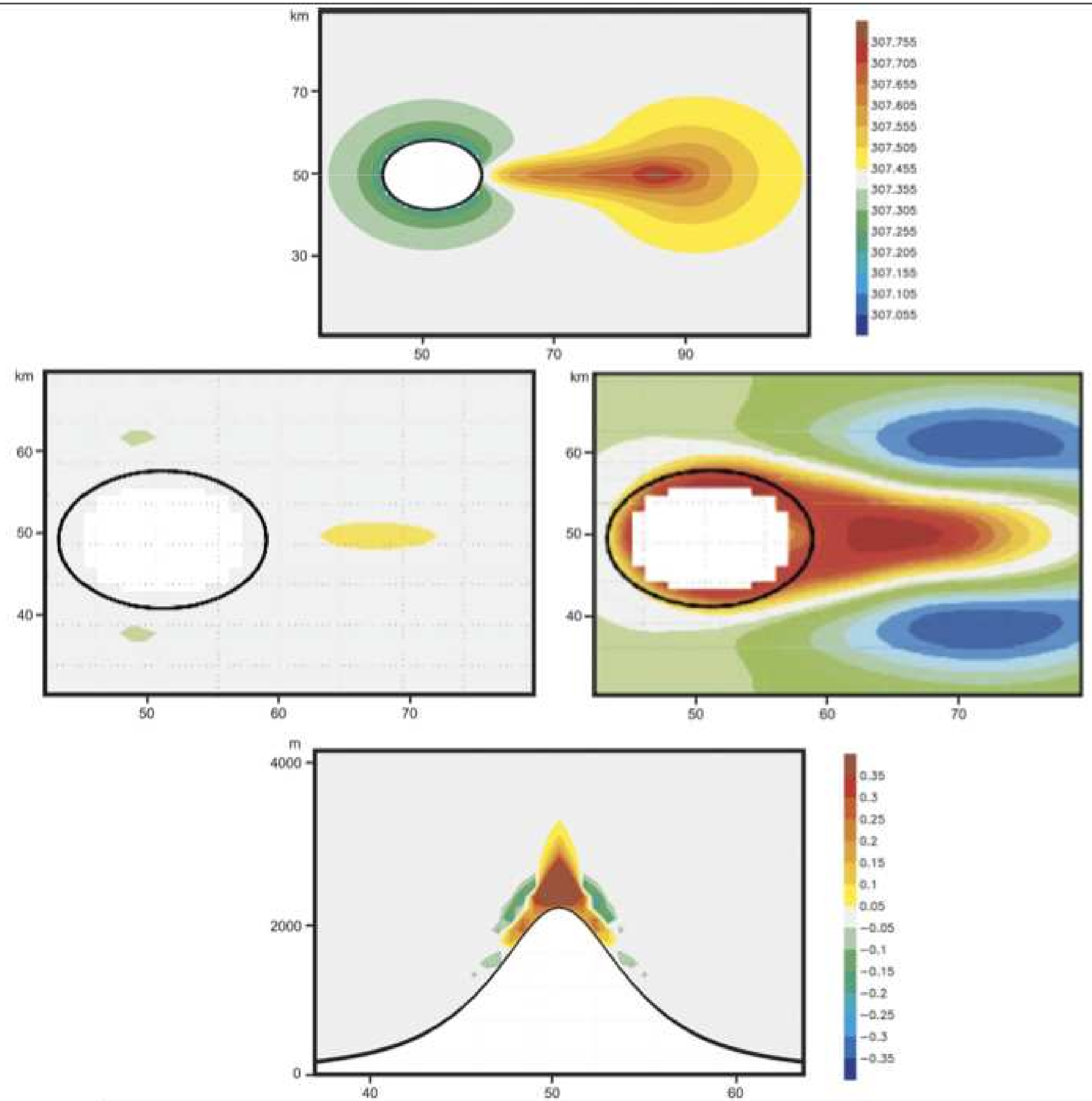


120 points
In x and y

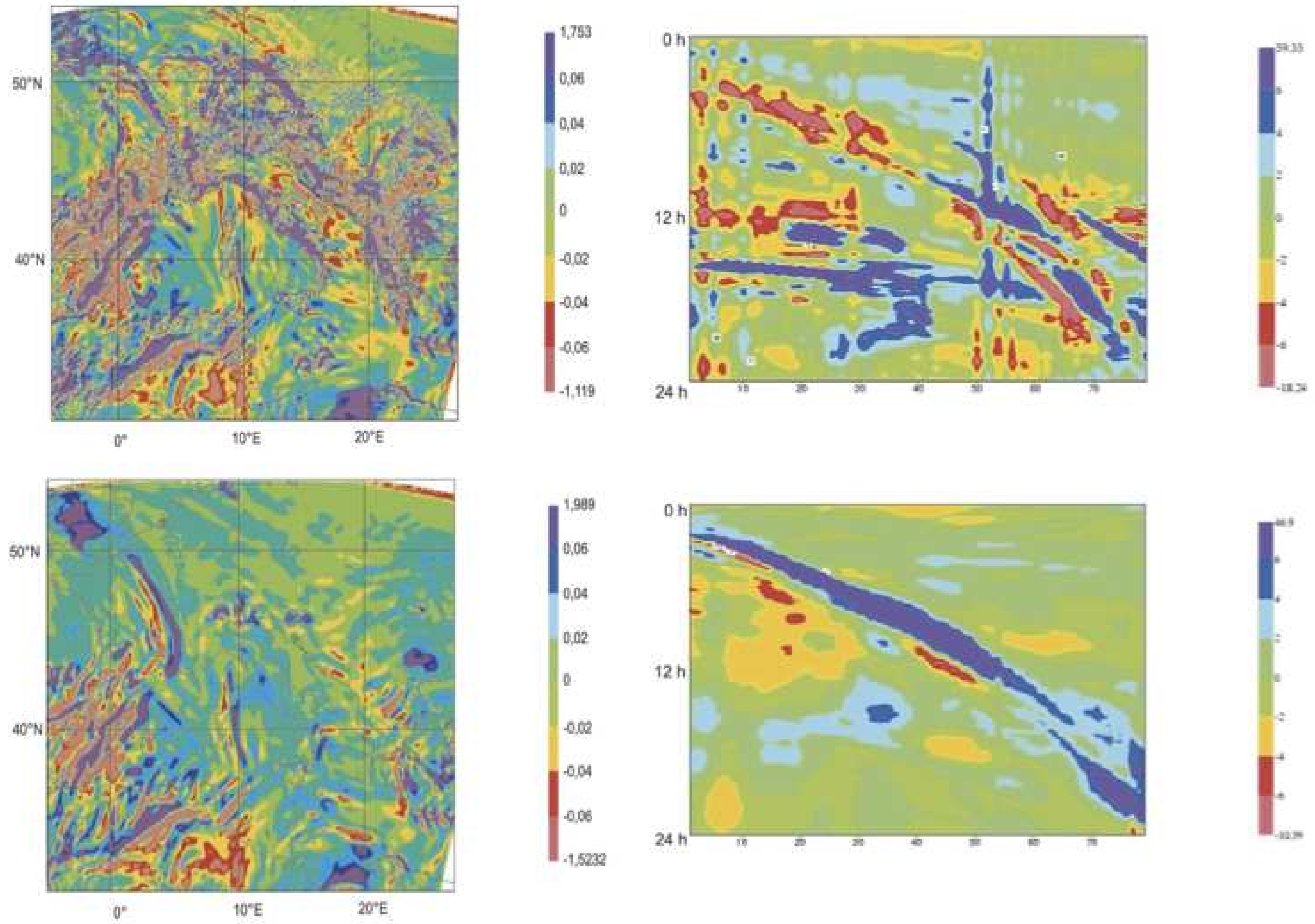




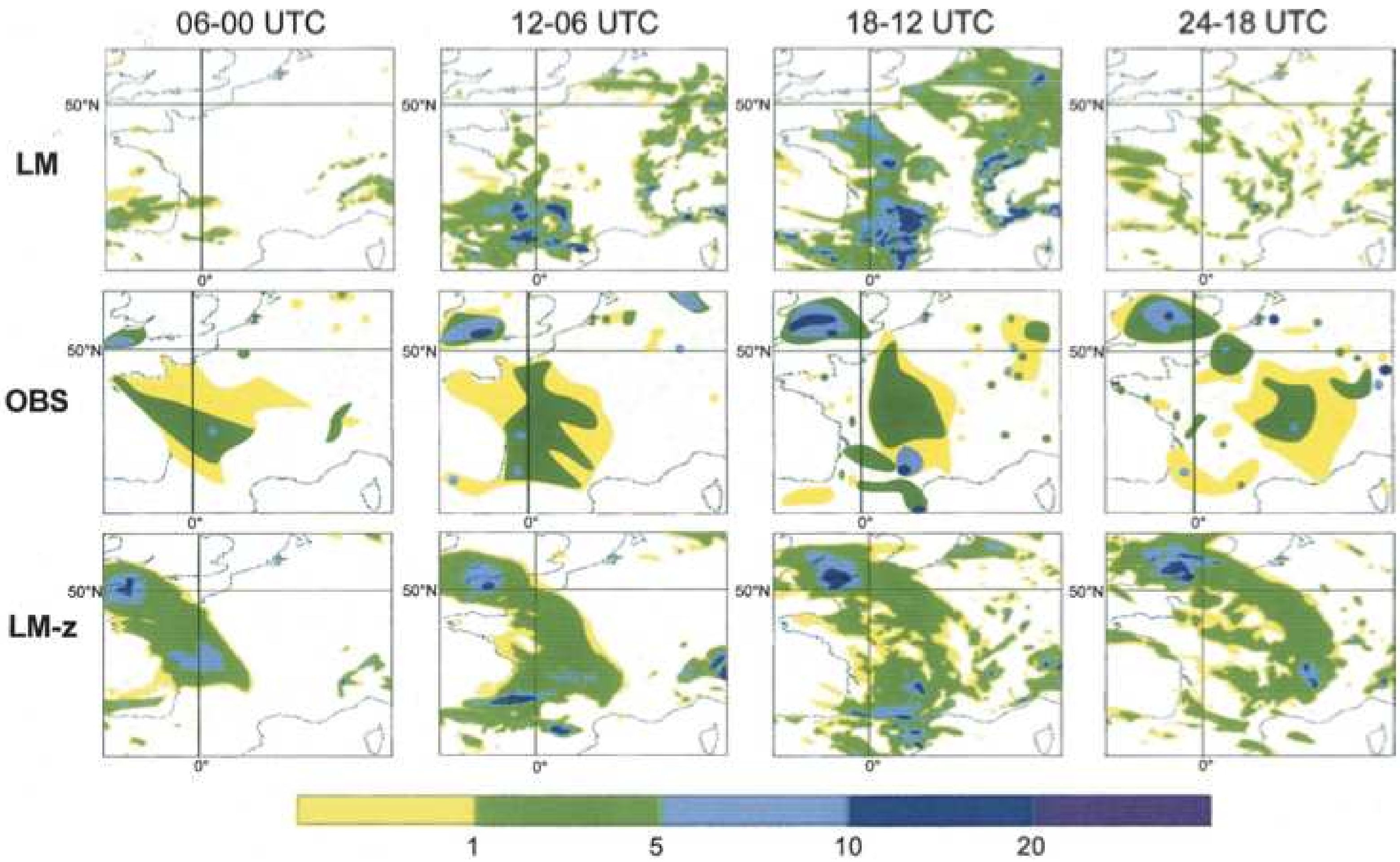
Convection with dry stable atm. with terrain following coordinates



Vertical velocities for t=12h and as time space diagram



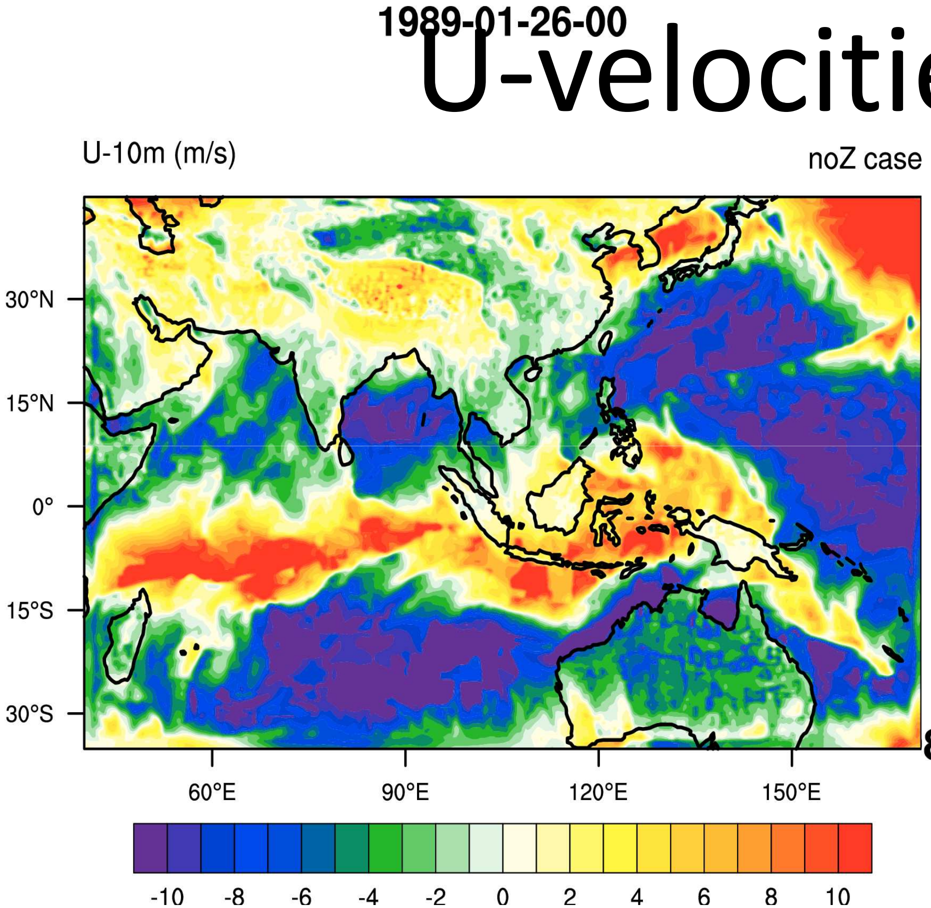
Precipitation

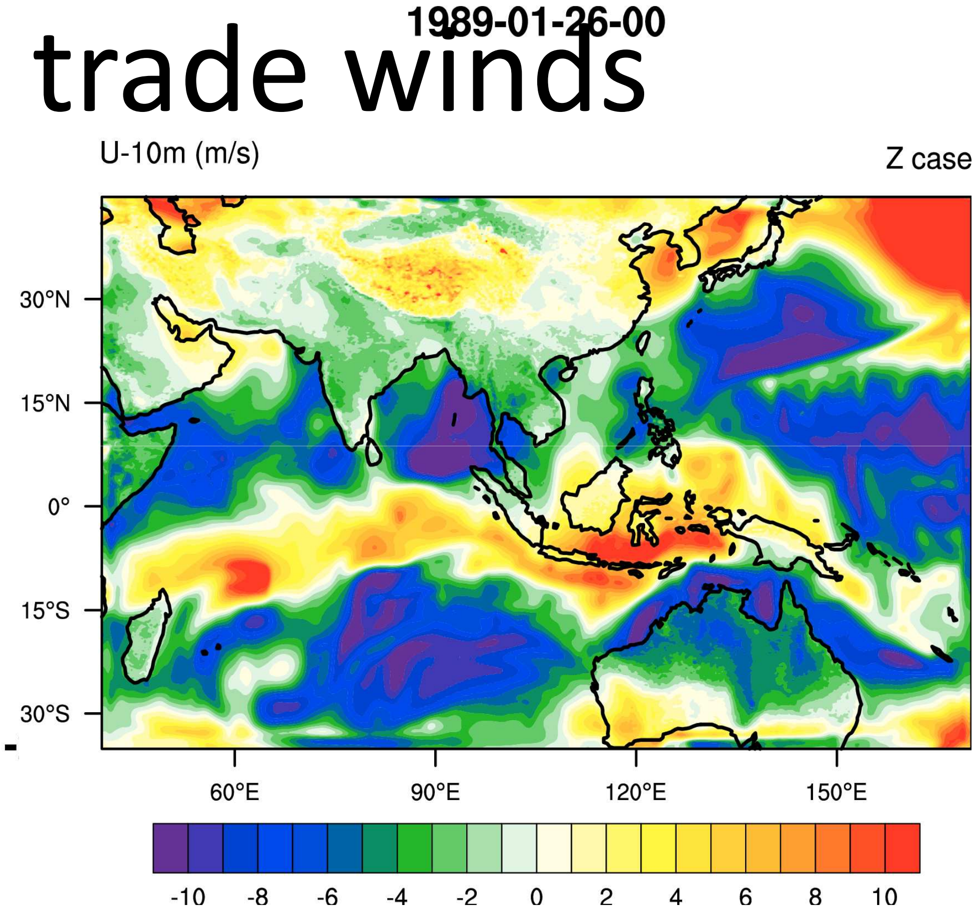


A preliminary indication: Longer Range and Climate

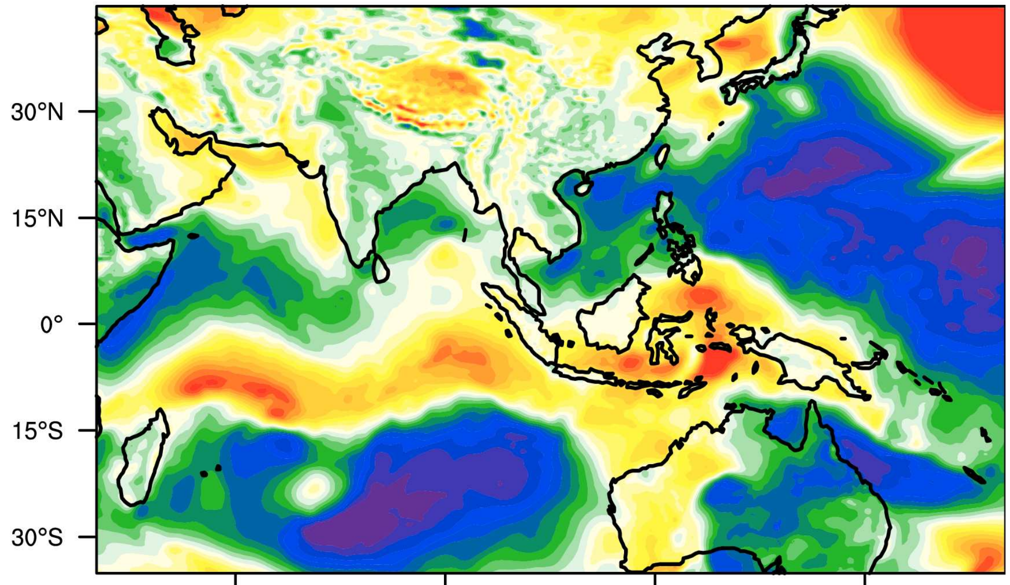
- January 1989:
- 5-day forecasts, dx =25 km, large area
- ERA interim data for initial and lateral boundary values
- Old version of LM for control and LMZ
- Filtered orography for both LM and LMZ
- Same time step
- Special point: basic value 0 rather than .5 in Kessler scheme for moisture

U-velocities trade winds



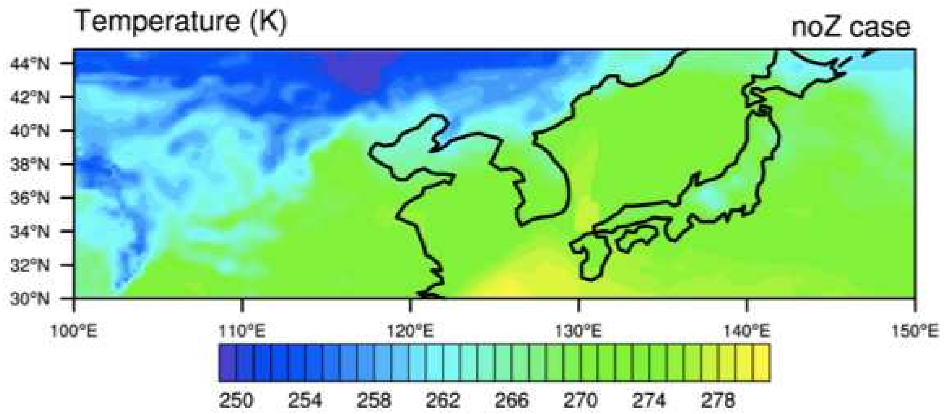


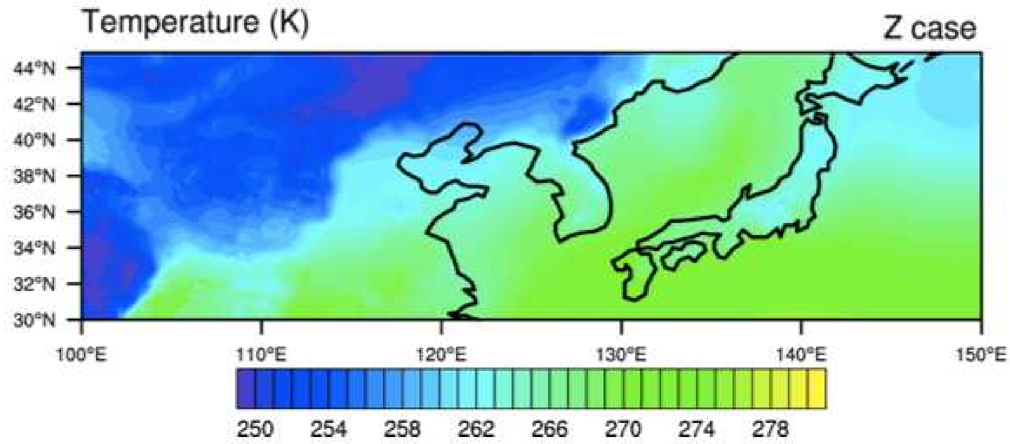
89-01-



Temperatures at level 20

1989-01-26-00





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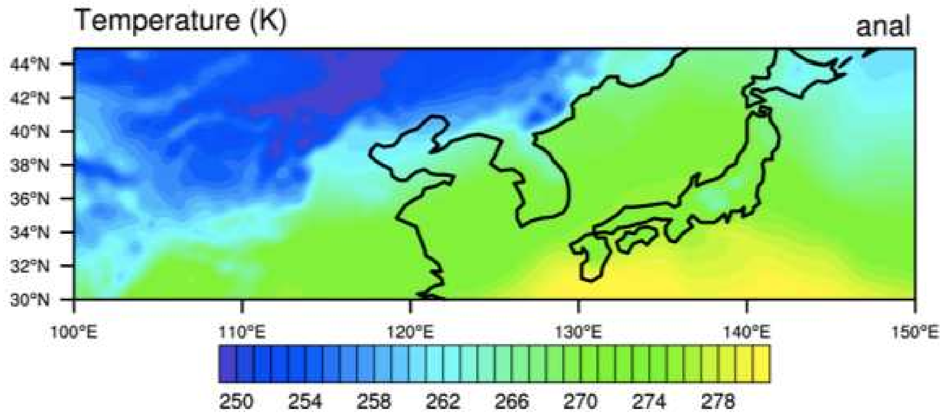
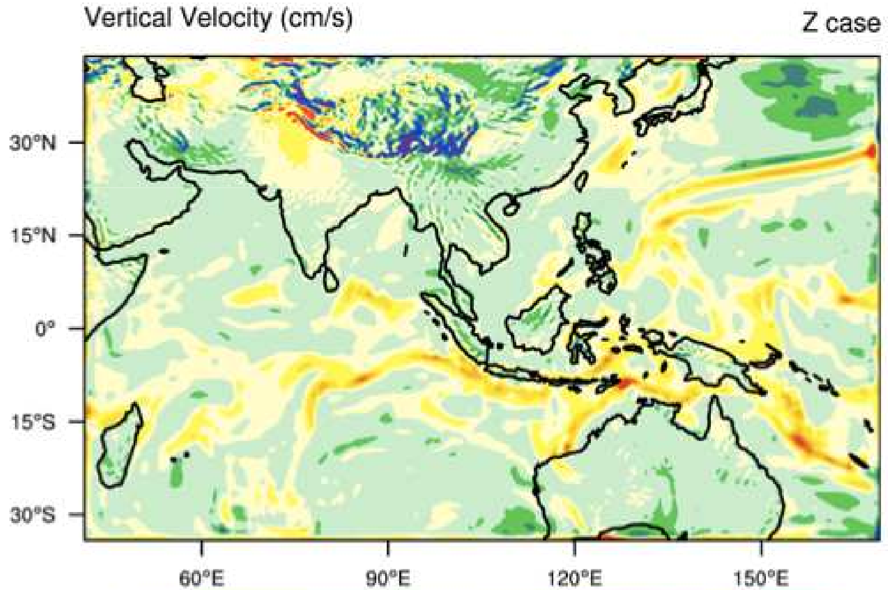
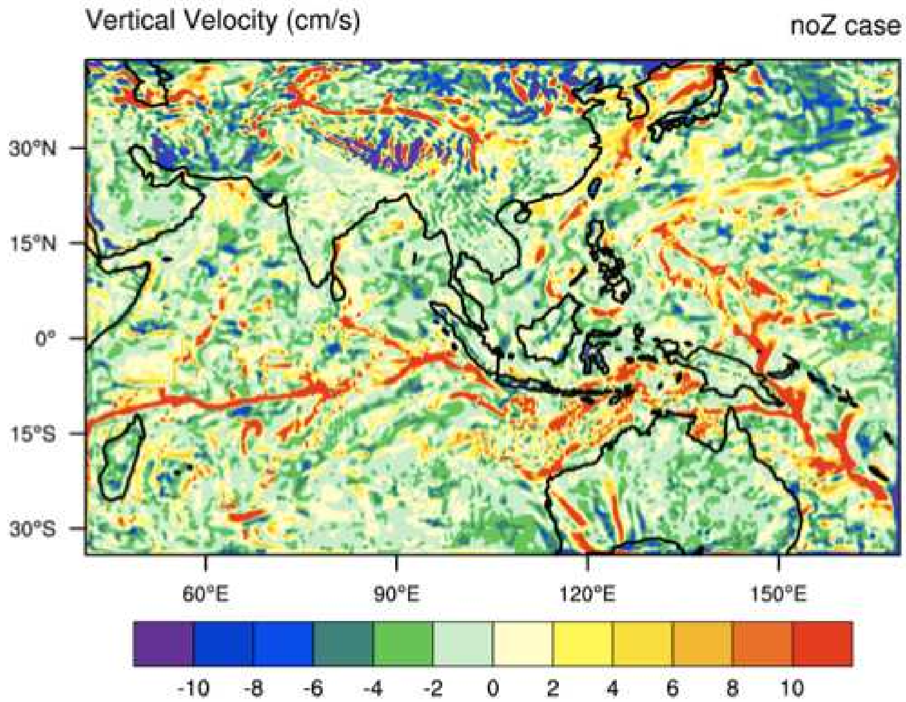
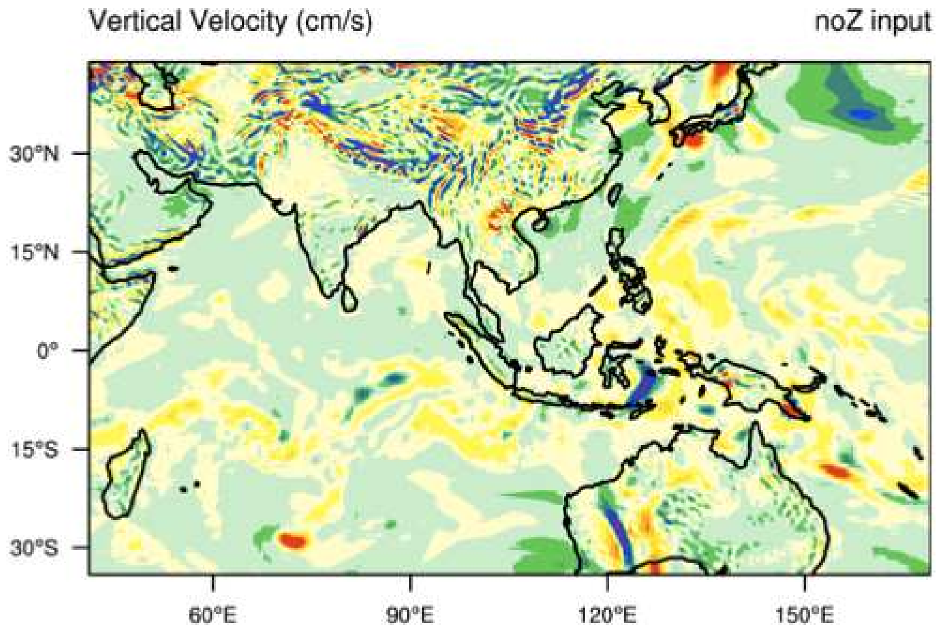


5 day forecasts of vertical velocities to 26 Jan 1989







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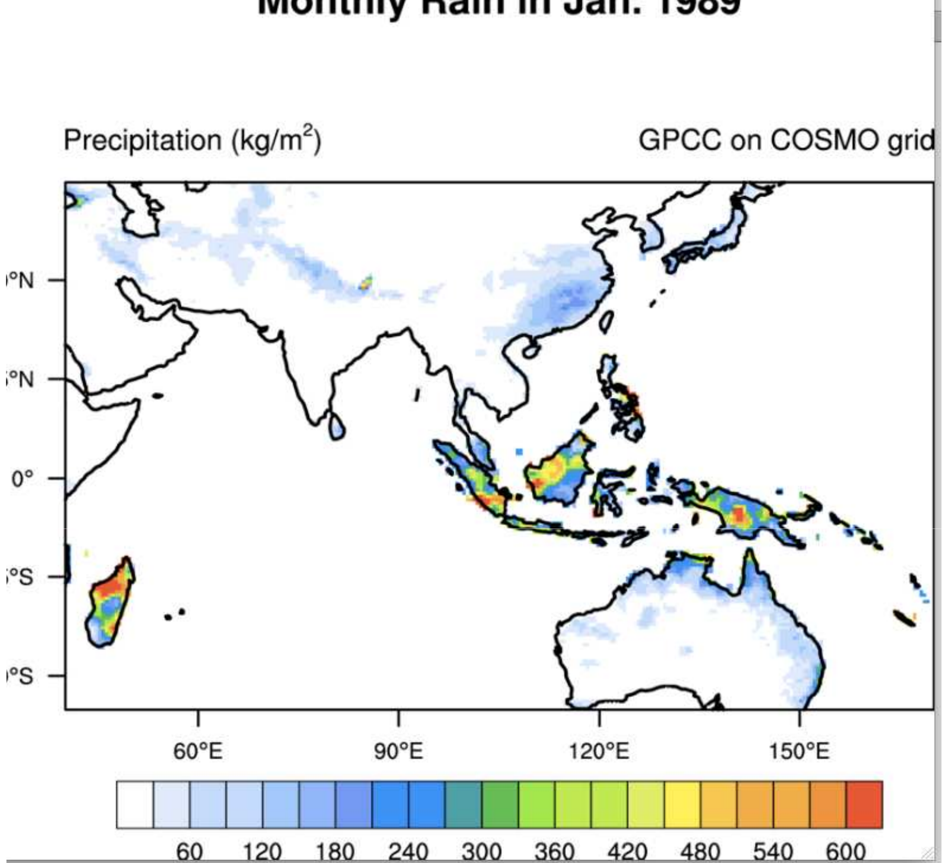
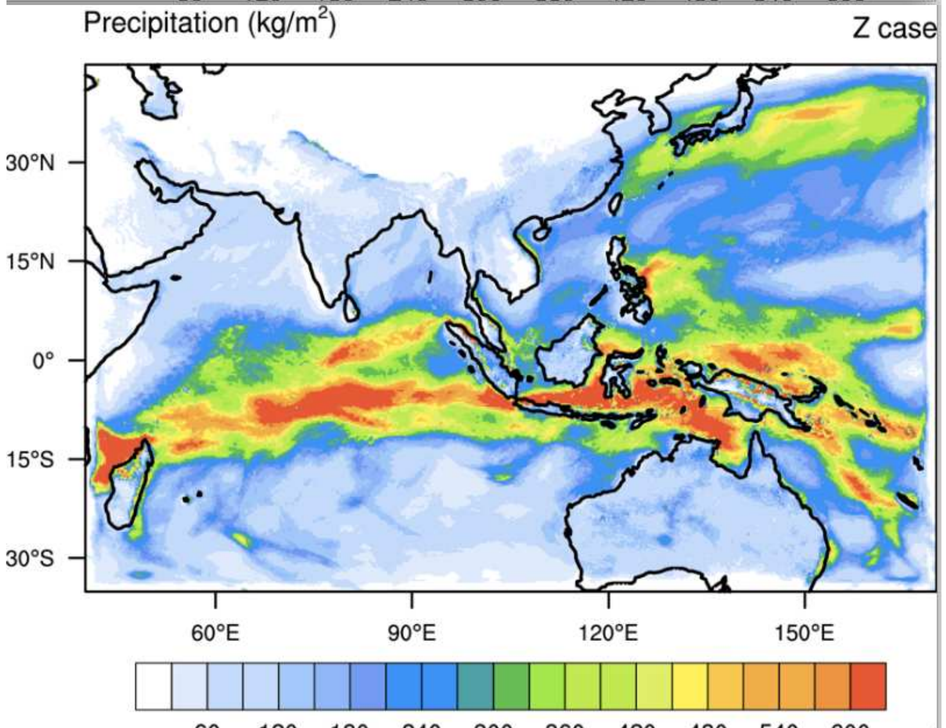
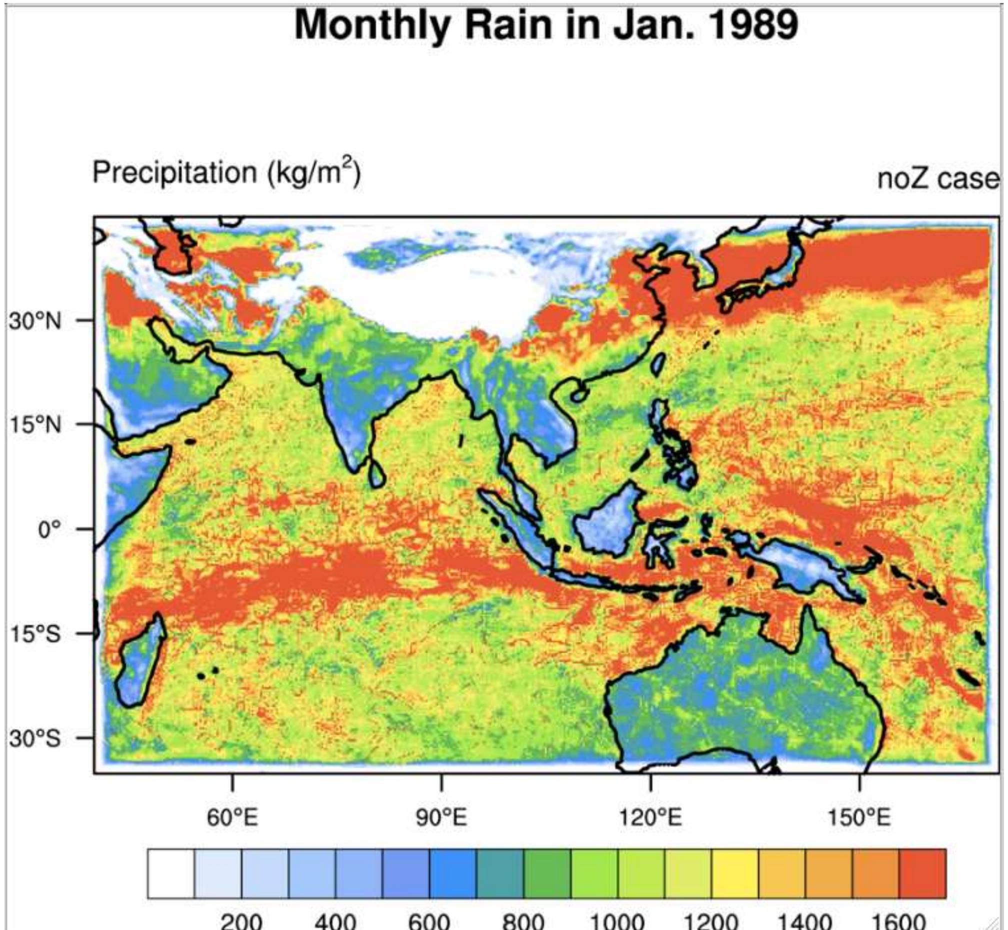


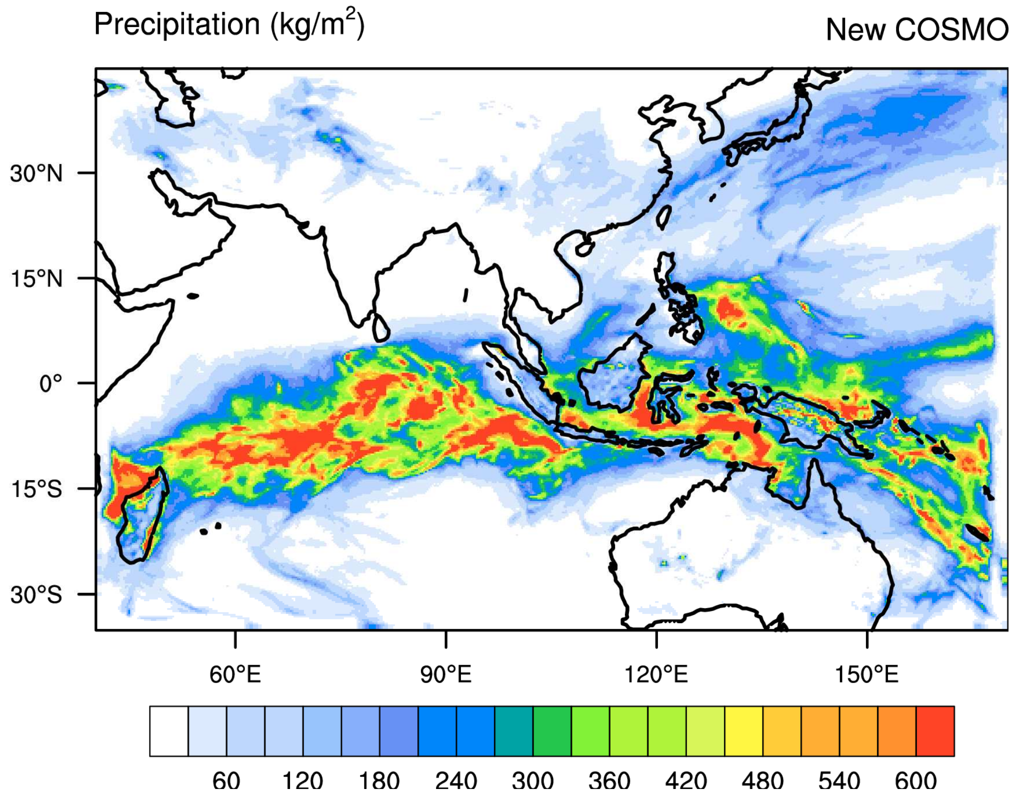




The End, further questions welcome

CLM-new

Monthly Rain in Jan. 1989



Cut cell LMZ

- LMZ uses the cut cell <u>finite volume </u>method being 1rst order near mountains: MWR (2006),**134,** pp 3626.
- Known deficiencies of terrain following coord., such as convection in stable conditions are avoided
- More work: **1.** Climatological testing **2.** Transition to second and third order **3.** Transfer to REMO