Luca Bonaventura

Development of a nonhydrostatic dynamical core for climate and NWP

Outline of the talk

- **Description of the MPI-DWD project**
- **Outline of future model characteristics**
- **Current (early!) stage of the development (project start: April 2002)**

Aims and nature of the project

- **DWD (NWP): unificate local and global forecasting system, use improved physical parameterizations**

- **MPIM (climate): develop new GCM as atmospheric part of an Earth system model (+ ocean, full chemistry, mesosphere and upper atmosphere), need of a data assimilation system**

- **Deliver state of the art, unified model and investigate advanced research targets**

ICON: Outline of the dynamical core

- **Finite volume spatial discretization on a hierarchy of geodesic, icosahedral grids**

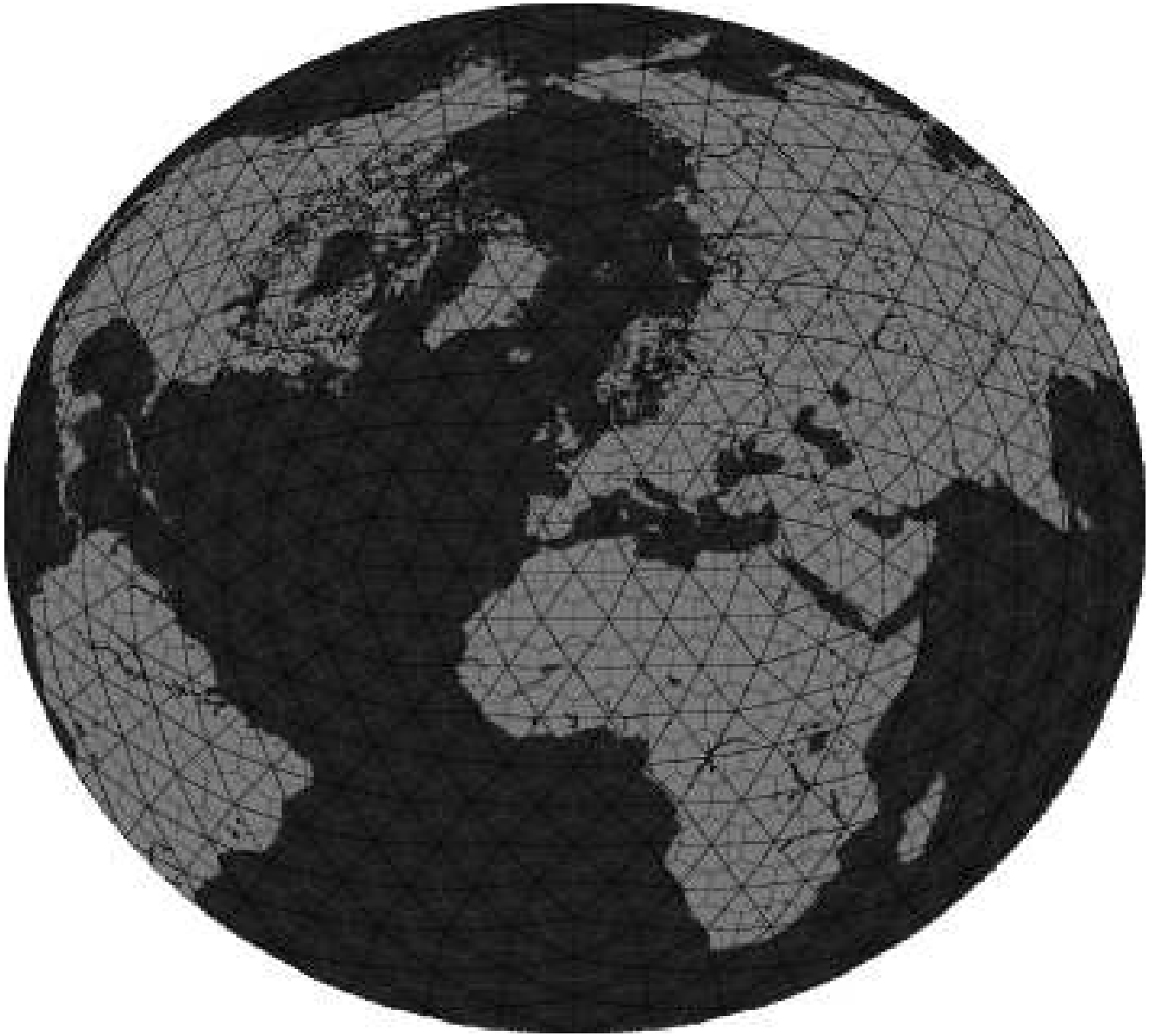
- **Consistent mass conservative discretization of continuity equation and tracer transport**

- **Fully compressible nonhydrostatic equations with semi-implicit time discretization, ‘deep’ atmosphere**

Modelling issues to be investigated

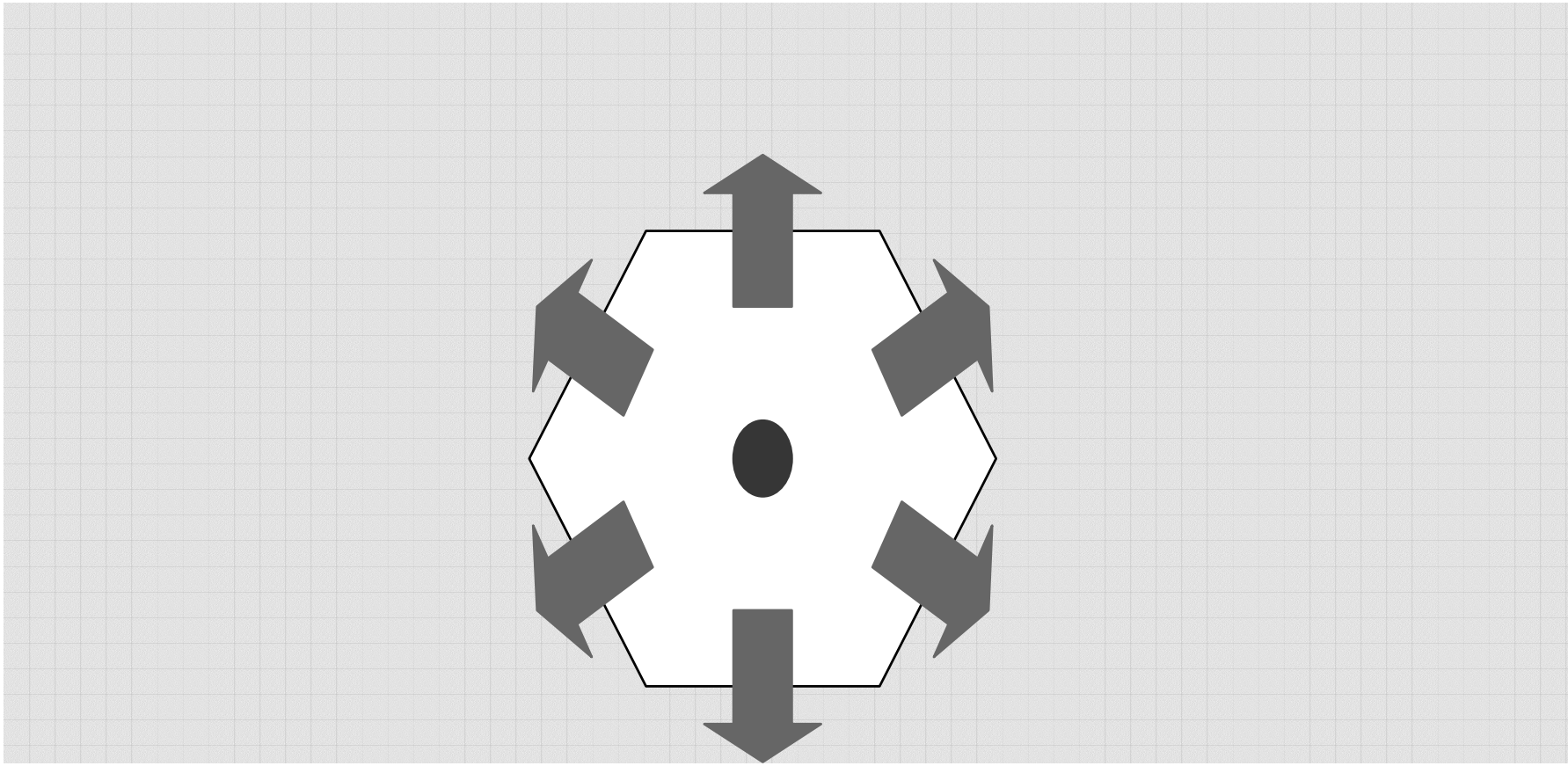
- **Numerical schemes good in the low Mach number limit (efficient, free of spurious pressure modes) and good for geostrophic adjustment**
- **Accurate conservative schemes (discontinuous Galerkin, flux form semi-lagrangian)**
- **Height and hybrid isentropic vertical coordinate**
- **Standard and cascadic multigrid solvers**

The icosahedral grids



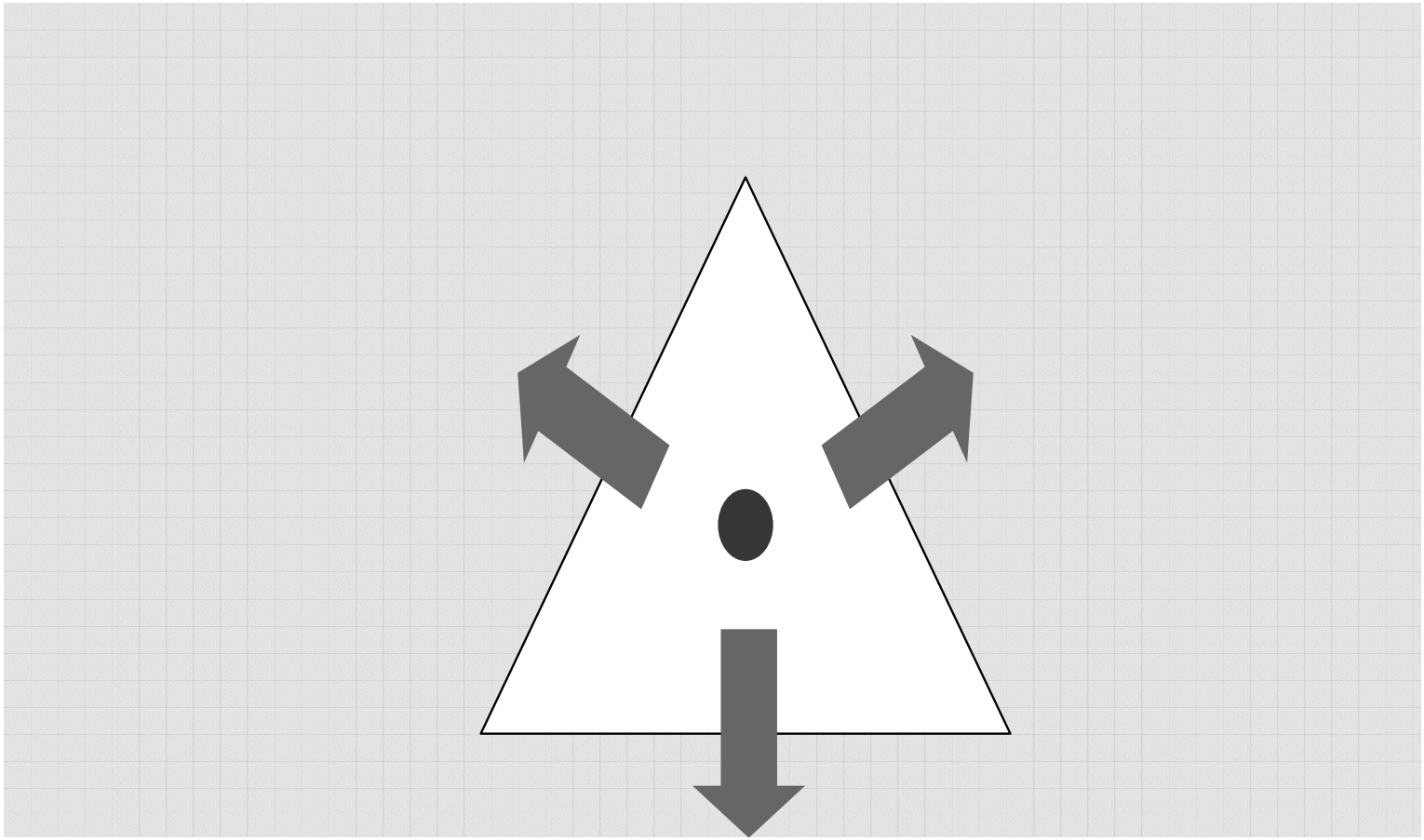
C grid staggering on hexagons

pressure **Normal velocity component**



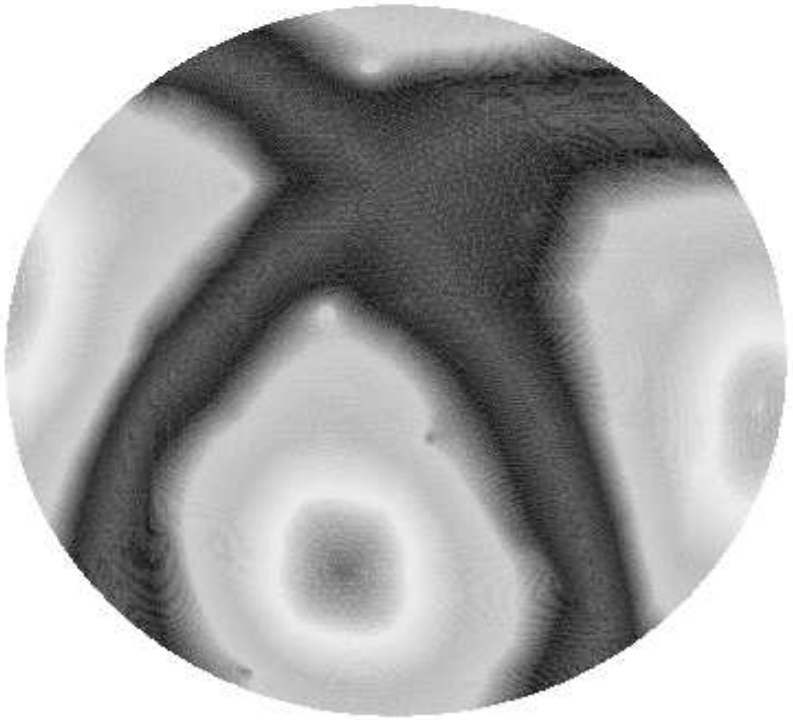
C grid staggering on triangles

pressure **Normal velocity component**



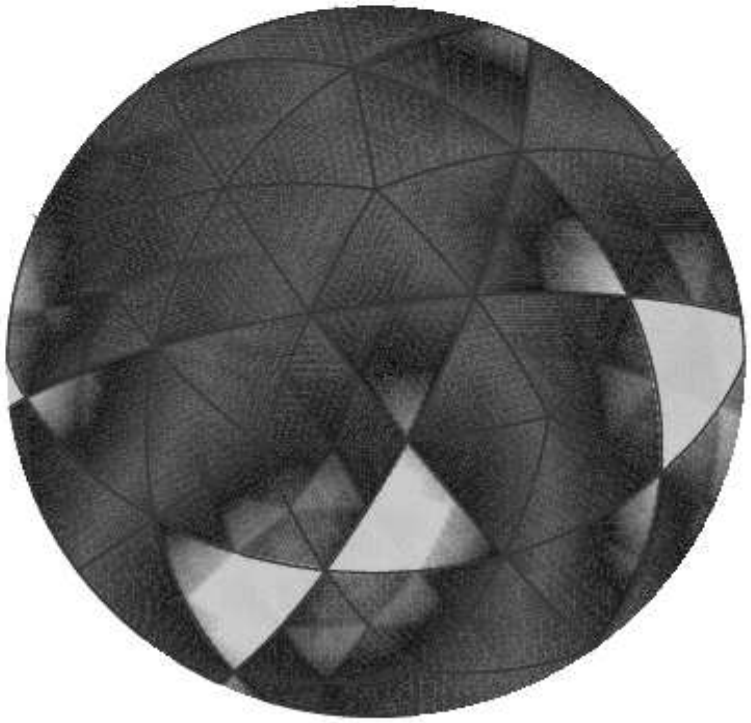
Preliminary work

- **Assess accuracy of standard discretization of Laplace operator and need for grid optimization**
- **Hackbusch 1989: standard discrete Laplacian on hexagons coincides with that of linear finite elements discretization**
- **Order of accuracy in solution of Poisson equation depends on discretization of right hand side**



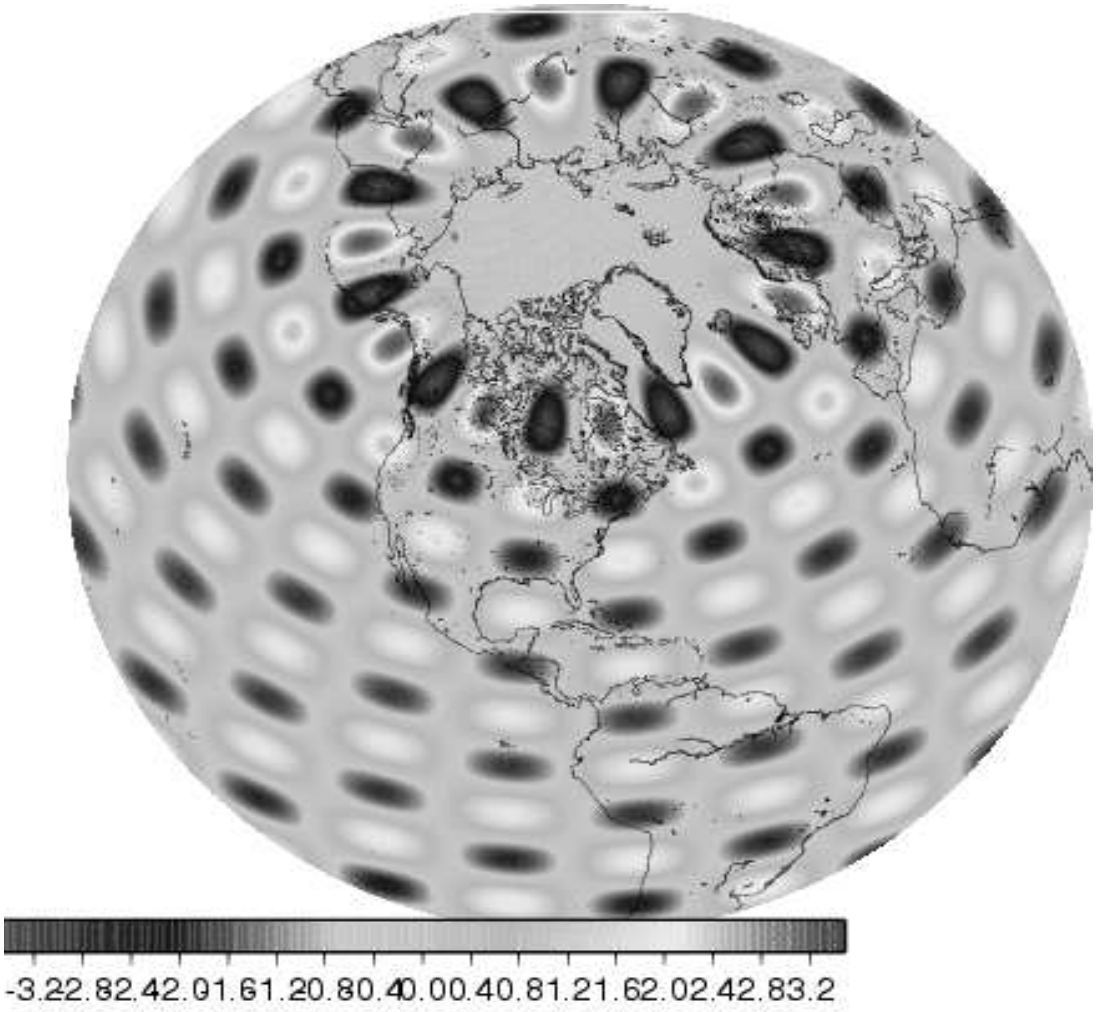
Sup norm error for Helmholtz equation, unoptimized hexagonal grid 5

(bright red= 1.e-3)



Sup norm error for Helmholtz equation, unoptimized triangular grid 5

same scale as previous



Higher spherical harmonics: P_{21}^{10}

sup norm error about 1.e-2 on grid 6

Features of shallow water model, I

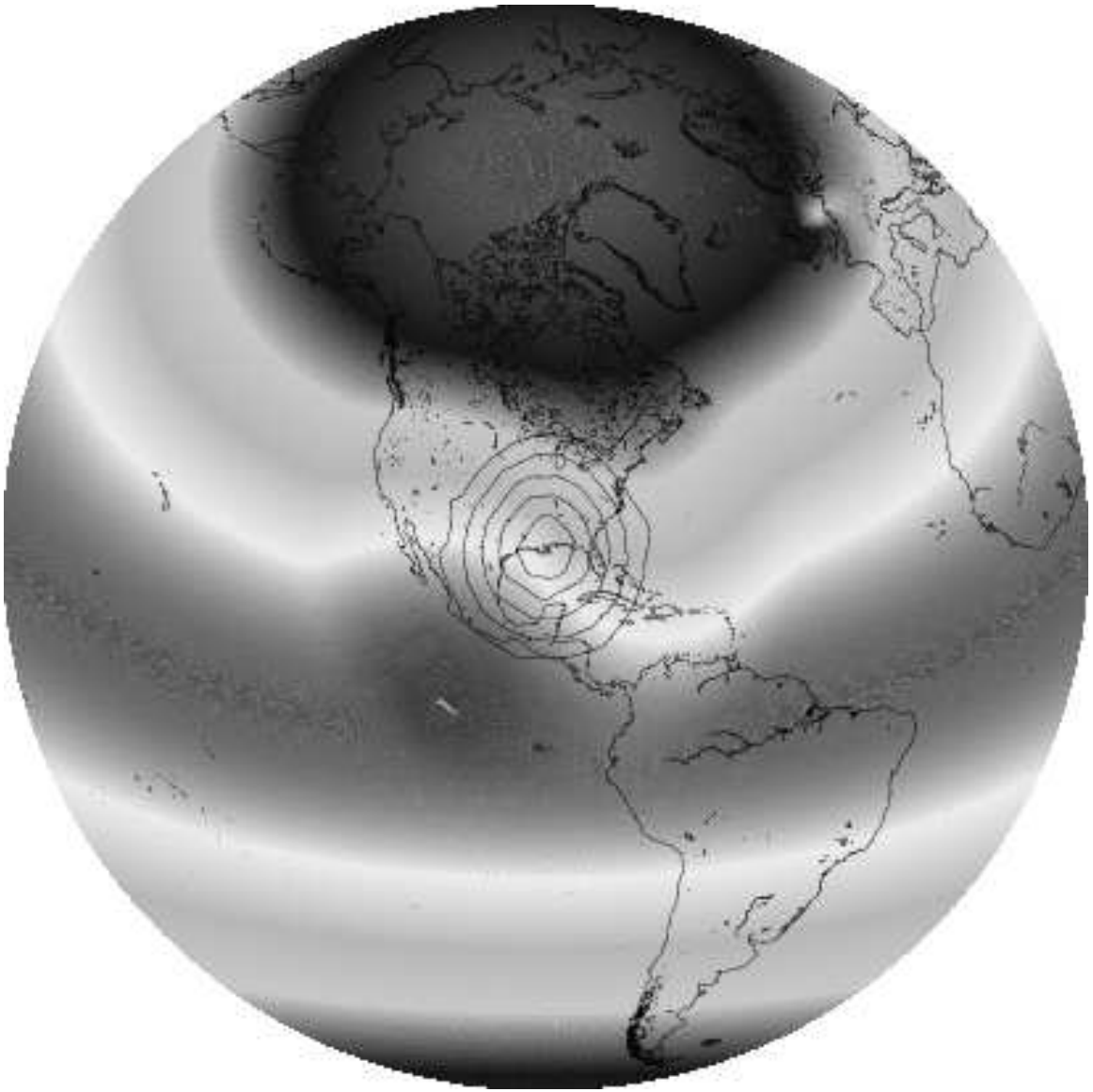
- **Spurious geostrophic modes on hexagonal C grid (Nickovic)**

- **Possible solution: at each timestep solve linear balance equation on the dual grid, compute geostrophically balanced geopotential field**

- **Well balanced momentum equation, all terms left are of the same order of magnitude**

Features of shallow water model, II

- **Semi-implicit, mass conservative scheme, predictor-corrector approach (Lin-Rood, Thuburn)**
- **Semi-lagrangian methods in the predictor step**
- **No spurious production of vorticity**



TEST 5, early stage: semi-implicit scheme on triangles, upwind advection

Conclusions and deadlines

- **ICON: a nonhydrostatic, unified climate AGCM and NWP model using the icosahedral grid is under construction**

- **An intensive research effort is required to achieve some of the targets**

- **A shallow water and x-z slice code by the end of 2003, a new dynamical core by 2005**