A Proposed Test Suite for Atmospheric Model Dynamical Cores

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Motivation

- Test cases for 3D dynamical cores on the sphere
  - are hard to find in the literature
  - are often not fully documented
  - have (often) not been systematically applied by a large number of modeling groups
  - lack standardized & easy-to-use analysis techniques
- Idea: Establish a collection of test cases that finds broad acceptance in the modeling community
- Test suite that clearly describes the initial setups and suggests evaluation methods like the
  - Test suite for the SW equations (Williamson et al. 1992)
  - Proposed test suite for non-hydrostatic NWP dynamical cores (Bill Skamarock, NCAR, under development)

Goals of the Test Suite

Test cases should

- be designed for hydrostatic and non-hydrostatic dynamical cores on the sphere
- be easy to apply
- be easy to evaluate
- be relevant to atmospheric phenomena
- reveal important characteristics of the numerical scheme (with increasing complexity)
- have an analytic solution or converged reference solutions

The Proposal (I)

A) 3D advection experiments:

Schär et al. (2002)
Zubov et al. (1999)

B) Steady-state test case:

Jablonowski and Williamson (2006a,b)
Balanced state at rest, Bill Putman ?

C) Evolution of a baroclinic wave:

Jablonowski and Williamson (2006a,b)
Polvani et al. (2004)

D) Mountain-induced Rossby wave train

Smolarkiewicz et al. (2001)
Tomita and Satoh (2004)

E) 3D Rossby-Haurwitz wave with wavenumber 4:

Monaco and Williams (1975)
Giraldo and Rosmond (2004) (typo in the formulation)

The Proposal (II)

F) 3D Mountain Waves (irrotational):

hydrostatic & non-hydrostatic, linear & non-linear

Tomita and Satoh (2004)

Qian et al. (1998)

G) Acoustic Waves and Gravity Waves (irrotational):

Tomita and Satoh (2004)

H) Dycore tests with real orography (Mark Taylor)

I) Idealized tropical cyclone with simplified moisture processes:

Jablonowski, Held and Garner (in preparation)

- Prescribed tropical vortex embedded in an easterly flow
- Balanced initial data, ocean-covered surface
- Specific humidity
- Large-scale condensation with latent heat release
- Simple boundary layer formulation (evaporation)

The Proposal (III)

J) Long-term climate assessments:

* **Dry dynamical core tests:**

Held and Suarez (1994)
Boer and Denis (1997)

*** Moist dynamical core tests:**

- Aqua-planet simulations with full physics, Neale and Hoskins (2001)

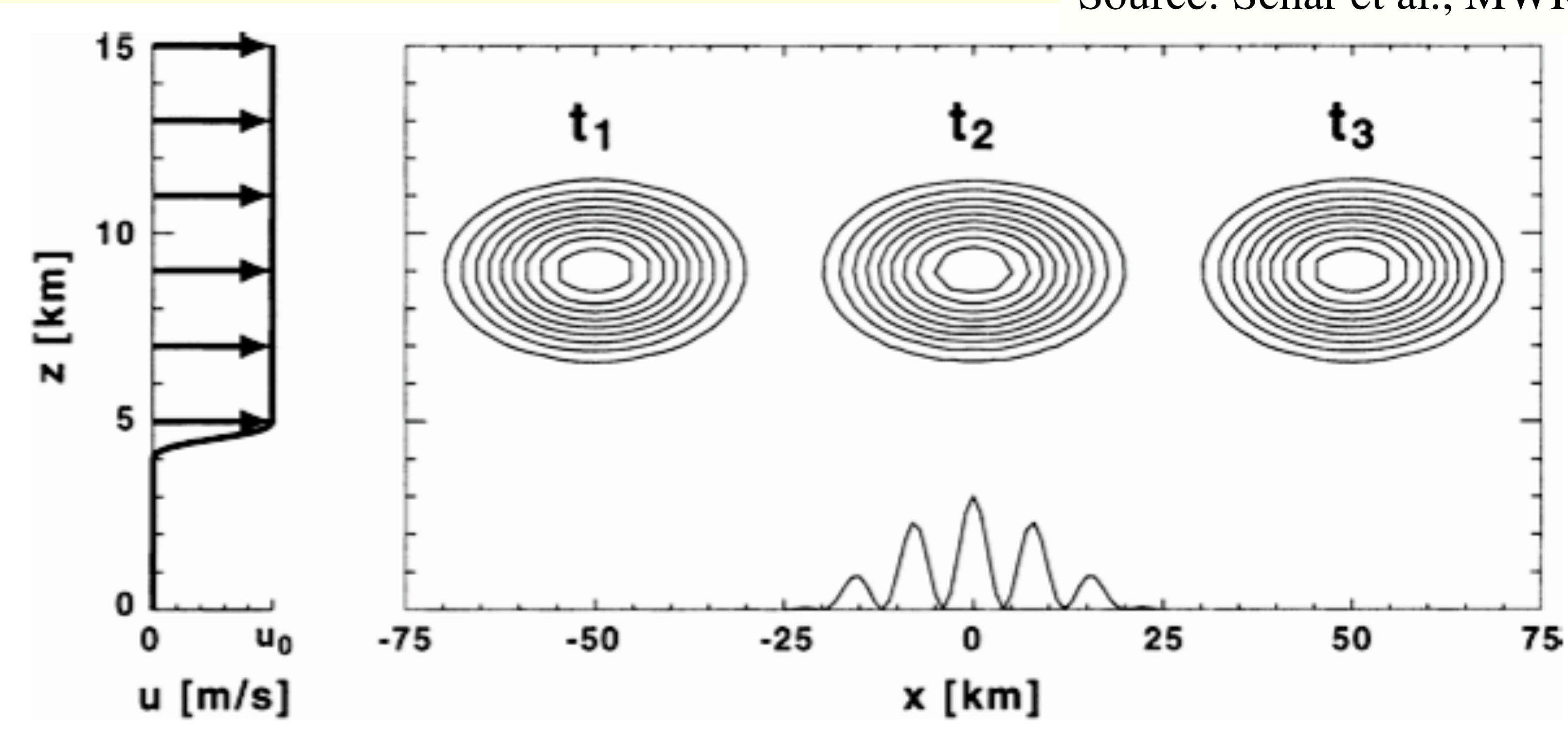
- Held-Suarez test with moisture, prescribed evaporation, model-generated precipitation without latent heat release Galewsky et al. (2005)

- Moist Held-Suarez ?

- Simplified Aqua-Planet simulations (Frierson et al., 2006)

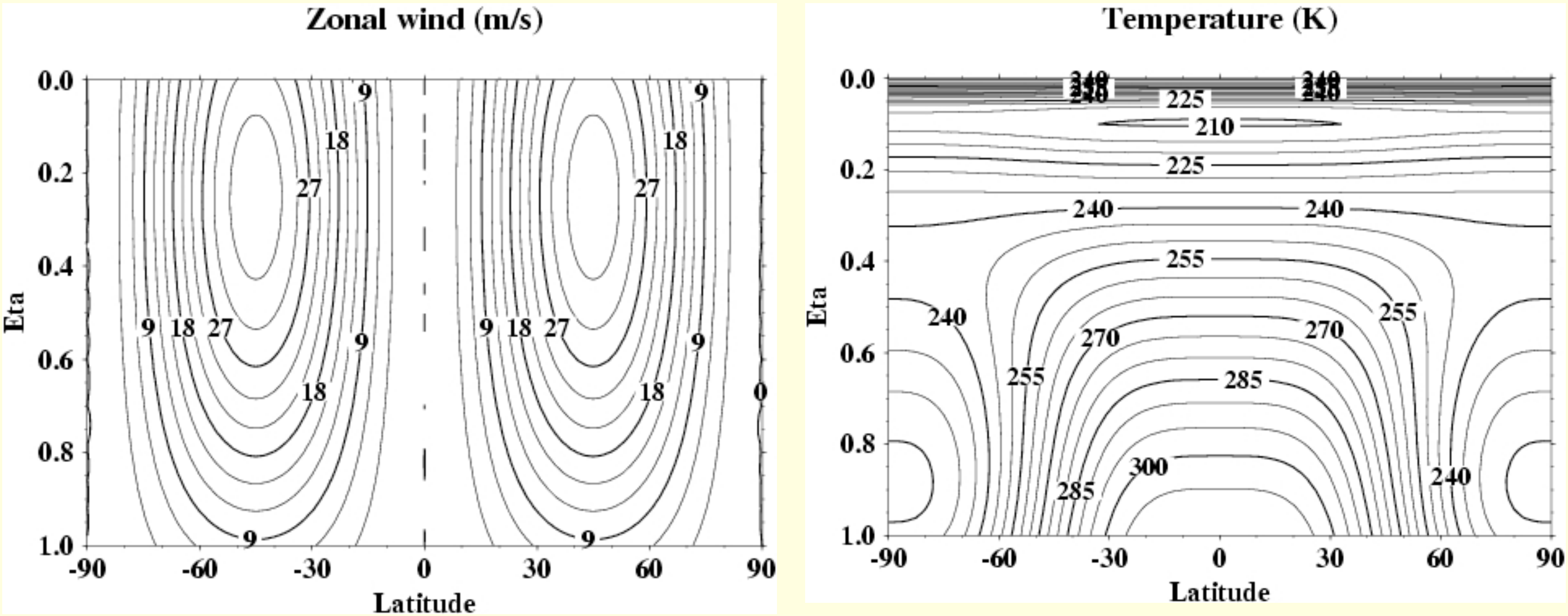
A) 3D Advection

Source: Schär et al., MWR 2002



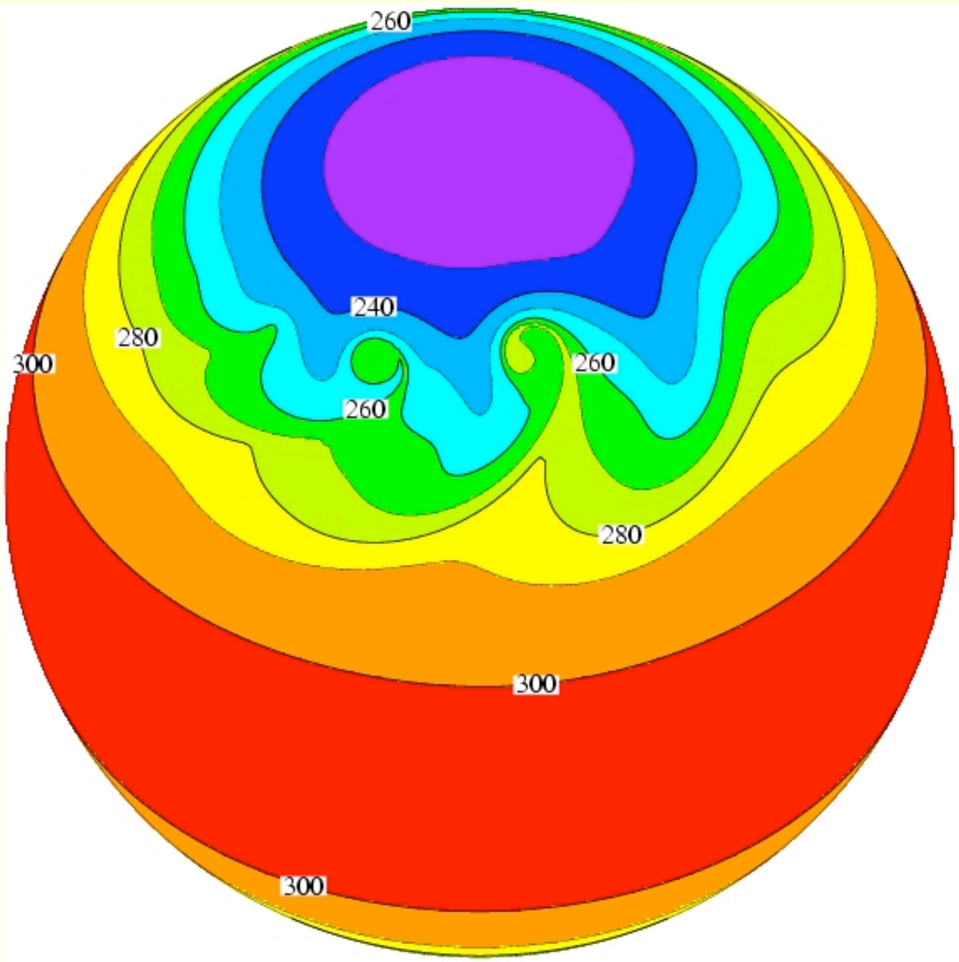
A) Advection of a tracer around the sphere with prescribed nondivergent wind fields and idealized topography. A 3D version of the 2D Schär et al. 2002 approach is under development. The initial state is the analytic solution after one revolution.

B) 3D Steady-state



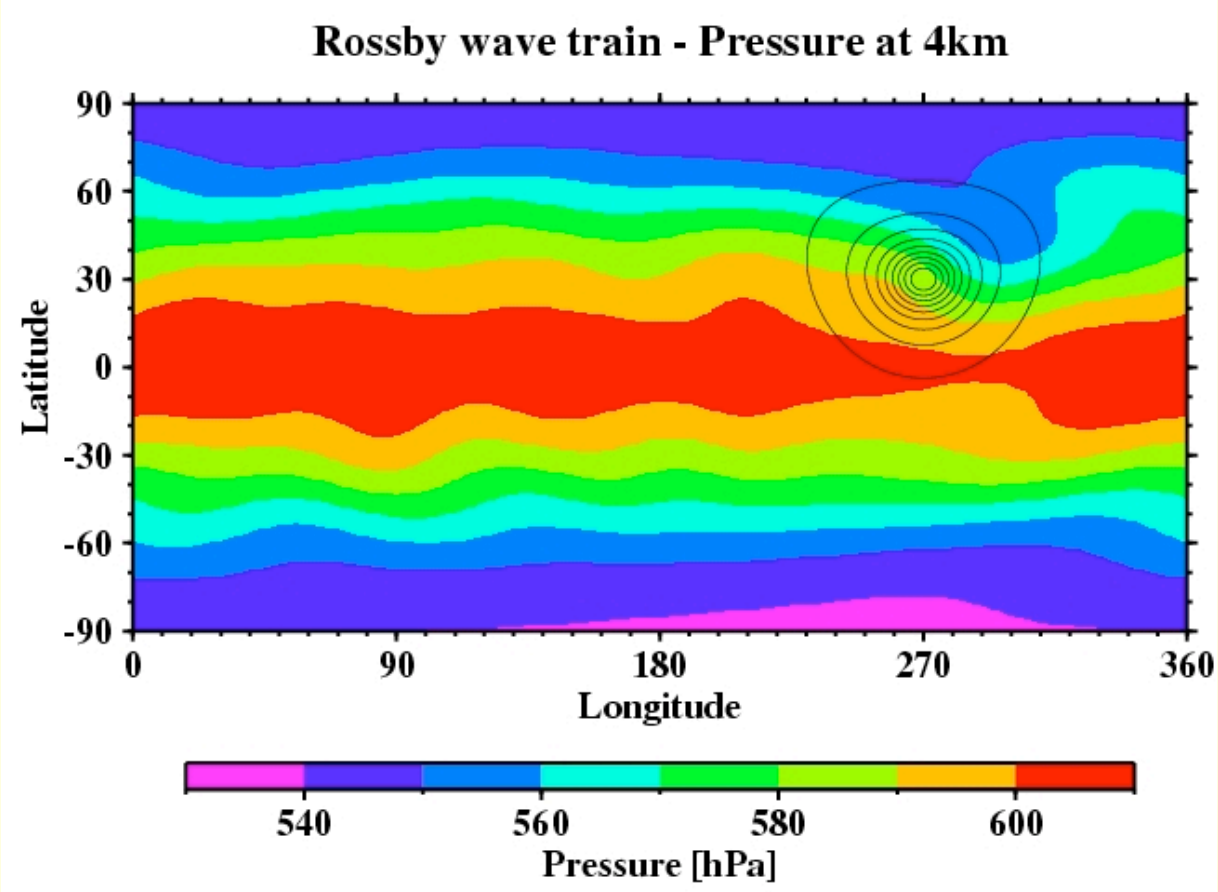
B) Steady-state initial conditions that are an analytic solution to the inviscid primitive equations. Models should maintain the steady-state for at least 10 days. Global error norms can be assessed (Jablonowski and Williamson 2006a,b).

C) Baroclinic Waves



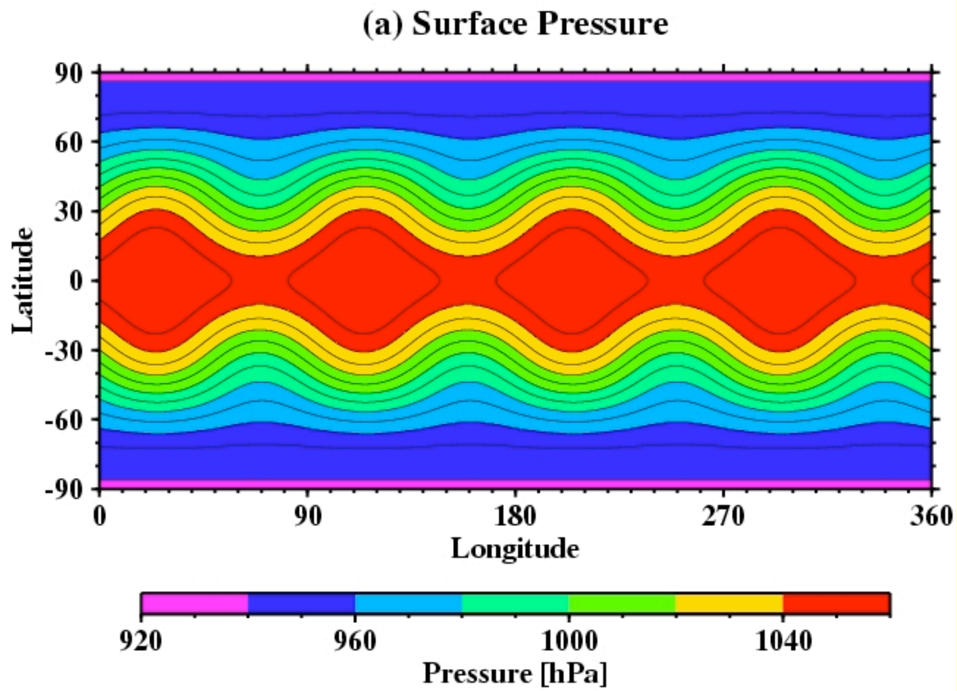
C) 850hPa temperature field (in K) of an idealized baroclinic wave at model day 9. The initially smooth temperature field develops strong gradients associated with warm and cold frontal zones. High-resolution reference solutions of this test case along with their uncertainties are assessed in Jablonowski and Williamson (2006a,b). See also Polvani et al. (2004).

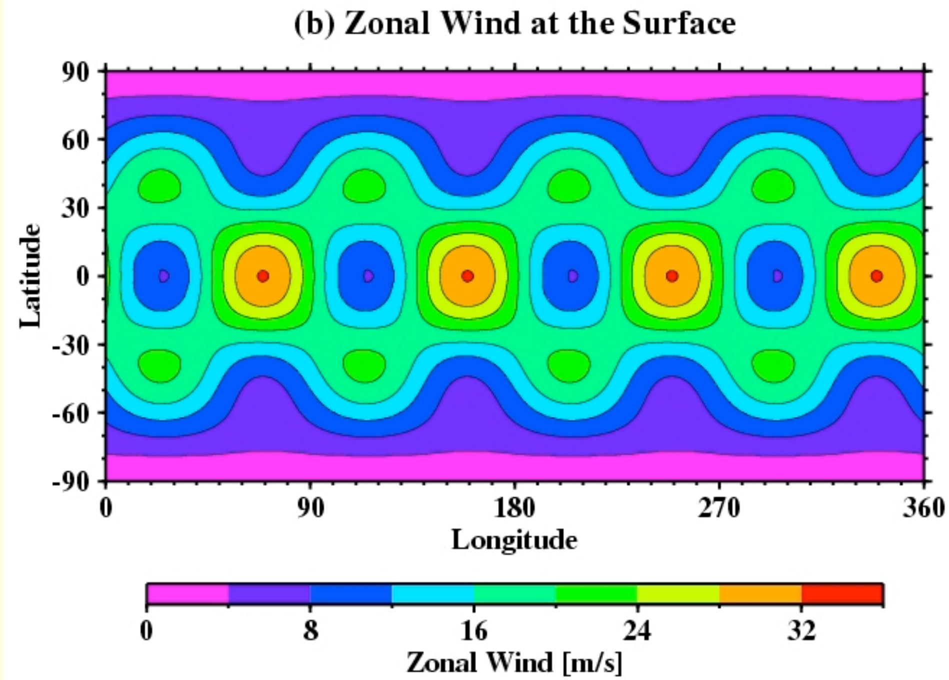
D) Mountain-Induced Rossby Wave Train



D) Pressure field at 4 km of a Rossby wave train at day 15. The wave is triggered by an idealized mountain. This Witch-of-Agnesi mountain profile follows Tomita and Satoh (2004). See also Smolarkiewicz et al. 2001 for an alternative setup.

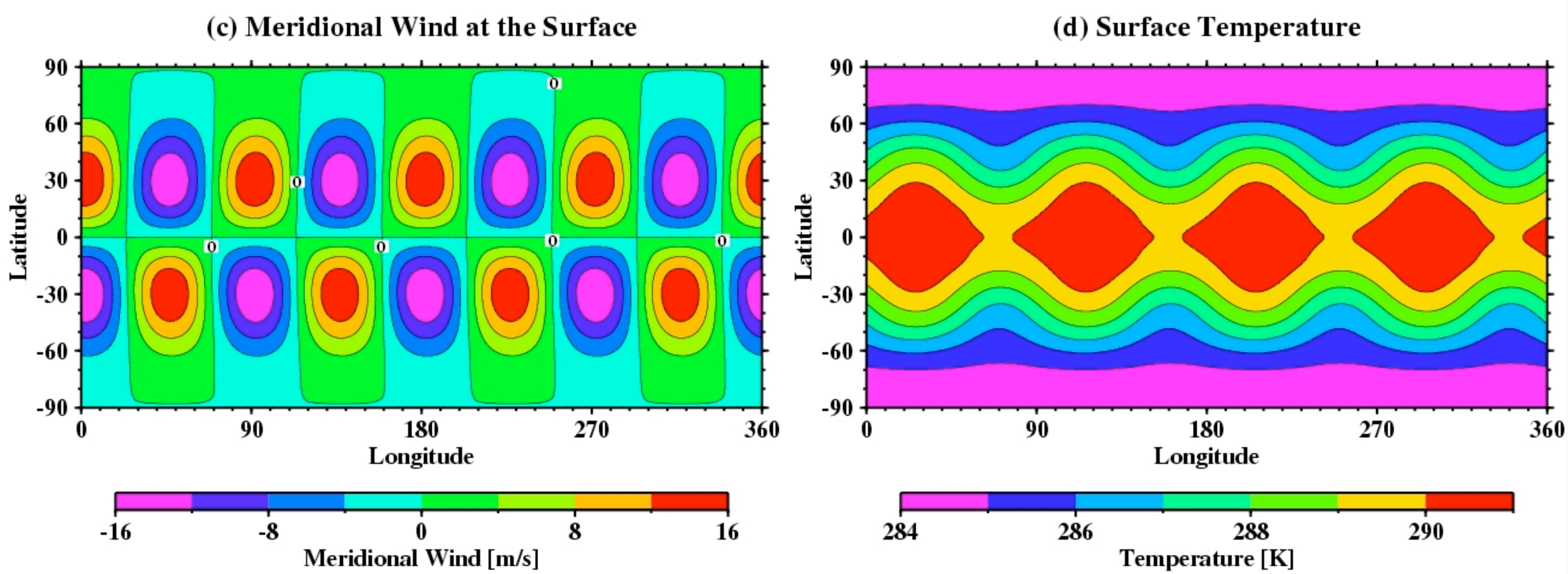
E) 3D Rossby-Haurwitz Wave





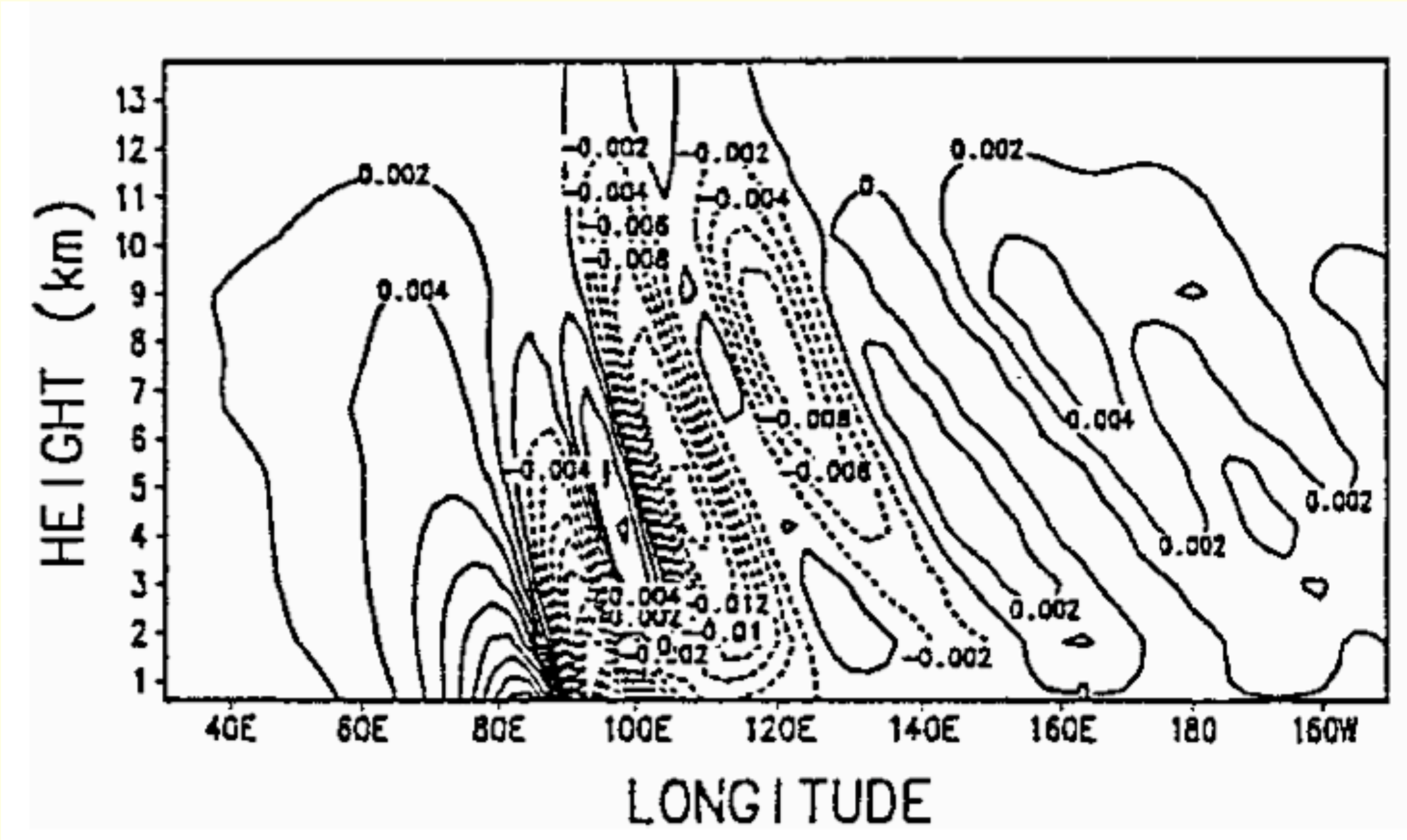
E) (a) Surface pressure and (b) zonal wind near the surface (lowest model level) at day 10. This Rossby-Haurwitz wave with wavenumber 4 pattern moves from east to west without change of shape.

E) 3D Rossby-Haurwitz Wave



E) (c) Meridional wind and (d) temperature fields near the surface (lowest model level) at day 10. The initial conditions are a variant of the Giraldo and Rosmond (2004) and Monaco and Williams (1975) formulation.

F) 3D Mountain Wave (Irrotational)



F) Vertical velocity of a mountain-induced wave at day 5 (source: Qian et al. (1998)).

The Invitation

Modeling groups are invited

- to test and adjust the proposed test suite using their dynamical cores
- to provide feedback on the existing test cases. Suggestions for other test cases are highly appreciated (email: cjablono@umich.edu)
- to propose standardized diagnostics

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