DEVELOPMENT OF THE UNIFIED PARAMETERIZATION

— AN UPDATE —

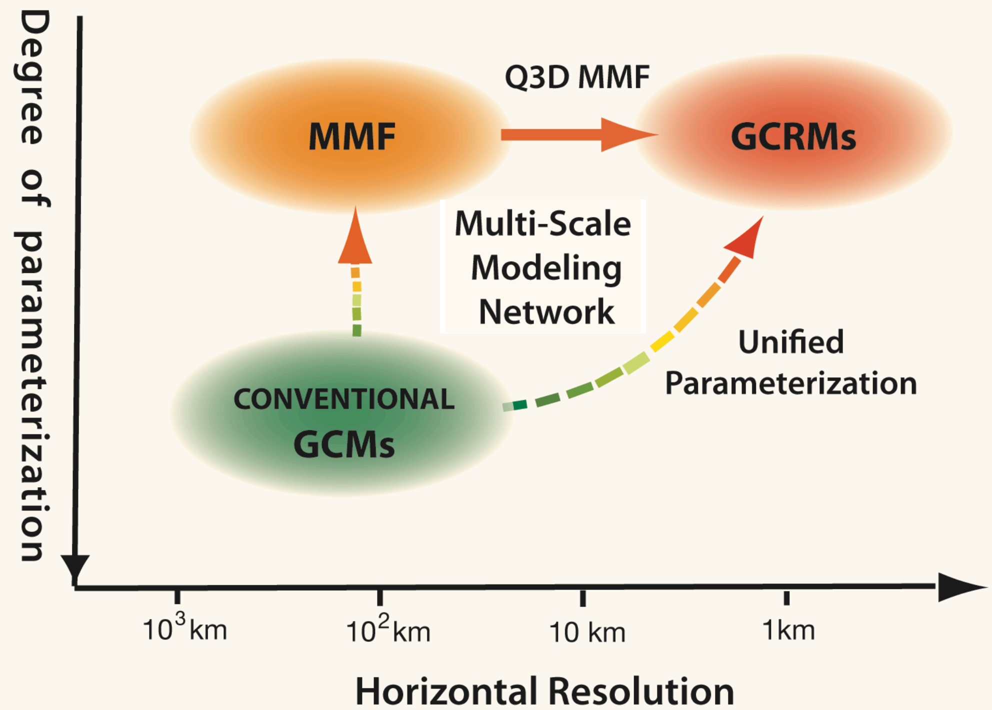
Akio Arakawa and Chien-Ming Wu

SUMMARY AND CONCLUSION

- GCMs and GCRMs should be unified so that we can freely choose a resolution without changing formulation of model physics.

- The unified parameterization can achieve the unification through a relatively minor modification of the existing parameterizations.

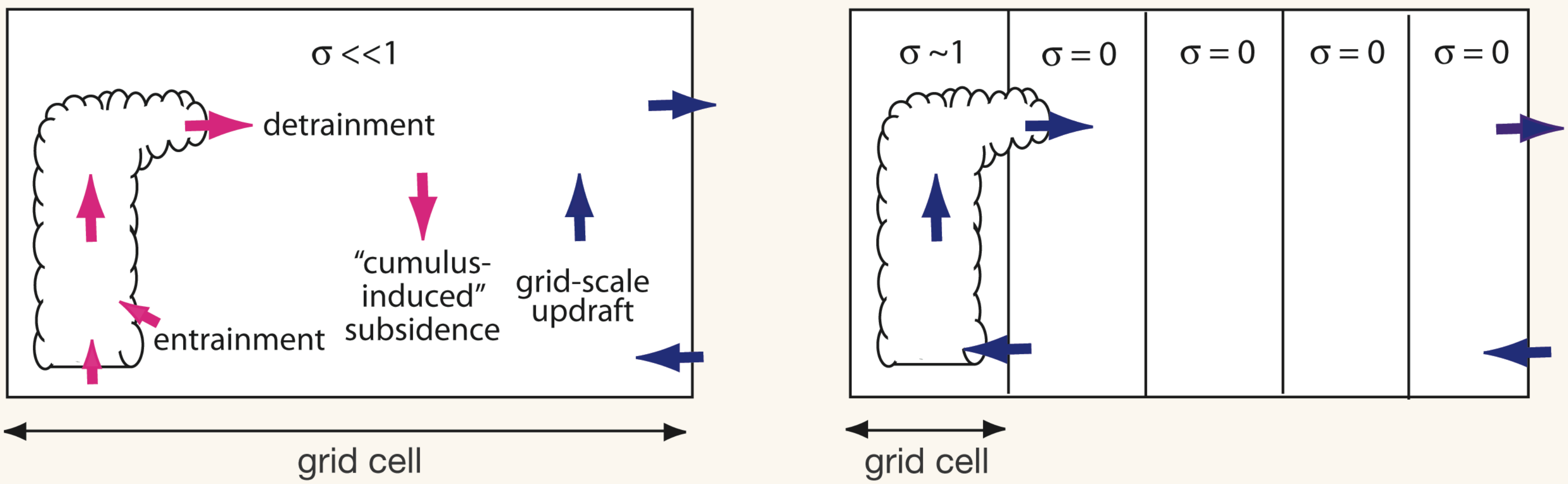
- The third approach that bridges conventional GCMs and the Q3D MMF can also be constructed.



OPENING A ROUTE FOR UNFIED PARAMETERIZATION

σ : the fractional area covered by all ***convective*** clouds in a grid cell.

- Conventional parameterizations assume $\sigma << 1$, either explicitly or implicitly.
- Then the temperature and water vapor to be predicted are essentially those for the cloud environment.



- But, if cloud occupies the entire cell, there is no "environment" within the cell.

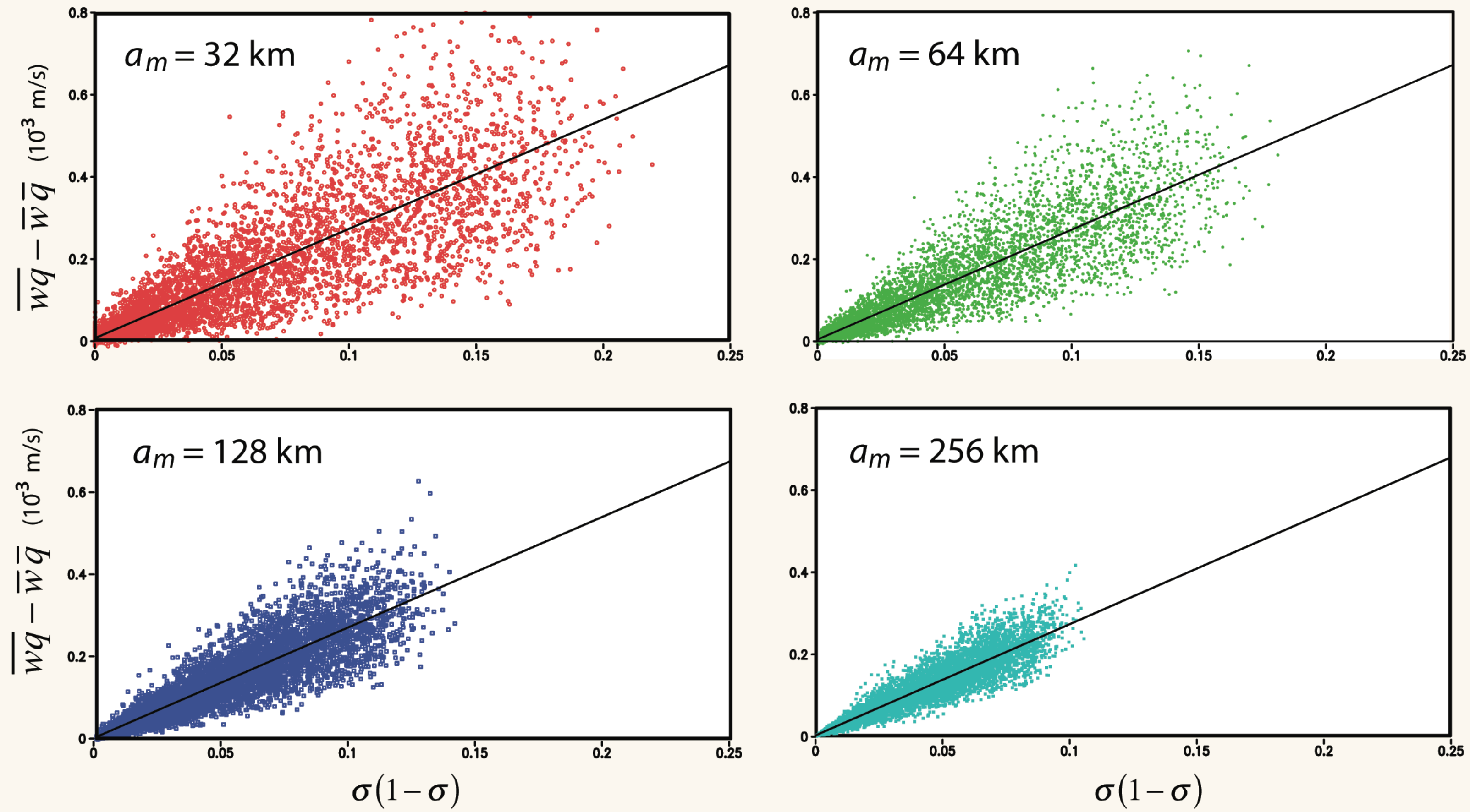
A key to open this route is eliminating the assumption of $\sigma << 1$.

THE GOAL OF THE UNIFIED PARAMETERIZATION

To formulate the vertical eddy transport

in a way that is applicable to any value of σ including $\sigma = 1$.

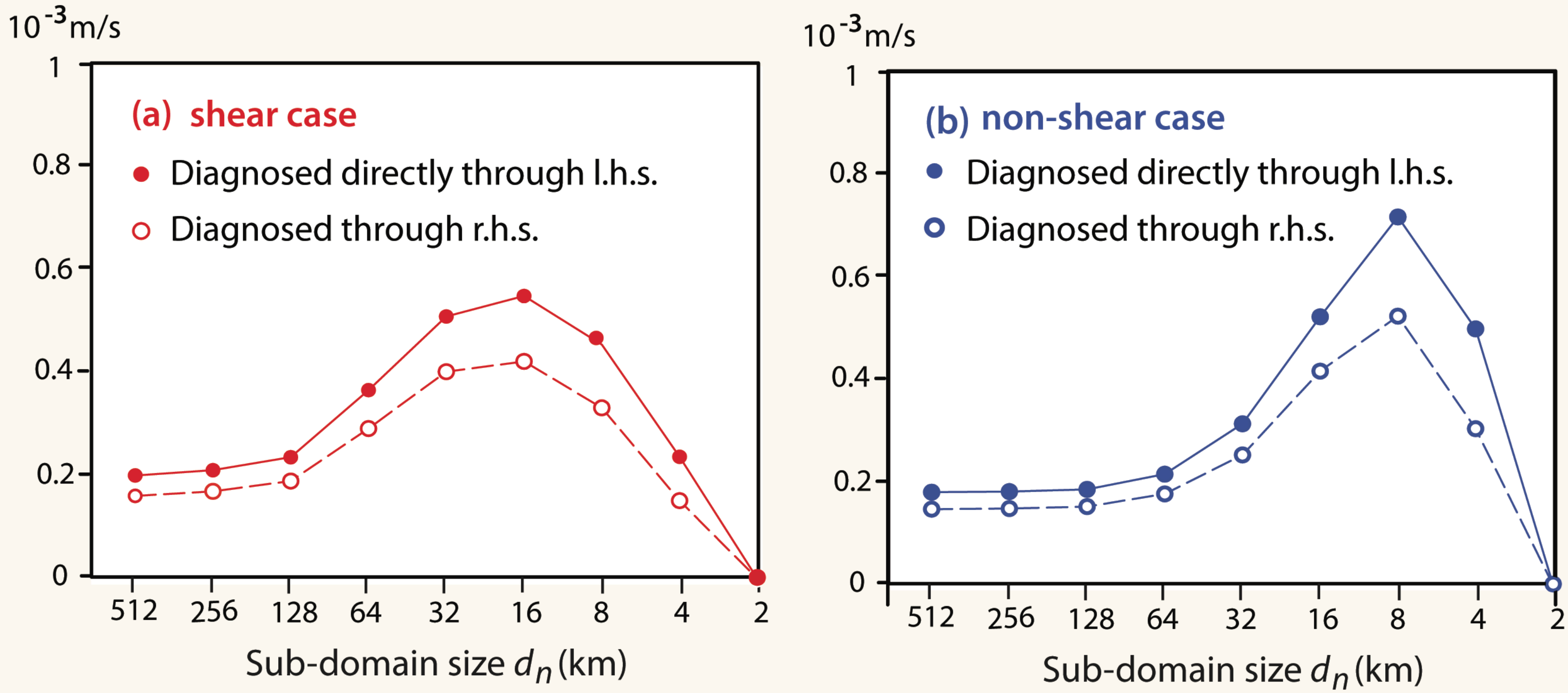
SCATTER PLOTS OF $\overline{wq} - \bar{w}\,\bar{q}$ AGAINST $\sigma(1-\sigma)$ WITH $d_n = 16$ km FOR VARIOUS AVERAGING SIZES a_m



- The ratio of the scatter to the mean value does not significntly depend on sigma.
- The ratio depends on the averaging length as expected.

WEIGHTED AVERAGE OF $\overline{\mathrm{wq}} - \overline{\mathrm{w}}\,\overline{\mathrm{q}}$ OVER SUB-DOMAINS

$$\left\langle \overline{wq} - \overline{w}\,\overline{q} \right\rangle = \frac{\left\langle \sigma\,(1-\sigma) \right\rangle}{\left\langle (1-\sigma)^2 \right\rangle} \left\langle \left(w_c - \overline{w}\right)\left(q_c - \overline{q}\right) \right\rangle$$



Simulations of Extratropical Cyclogenesis with the Unified, Quasi-Hydrostatic and Anelastic Dynamical Cores

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Tenth CMMAP Team Meeting, 11-13 January 2011, Berkeley, CA
Dynamical Framework Working Group

A dynamical core based on the unified (UN) system has been constructed. The preliminary results are very encouraging

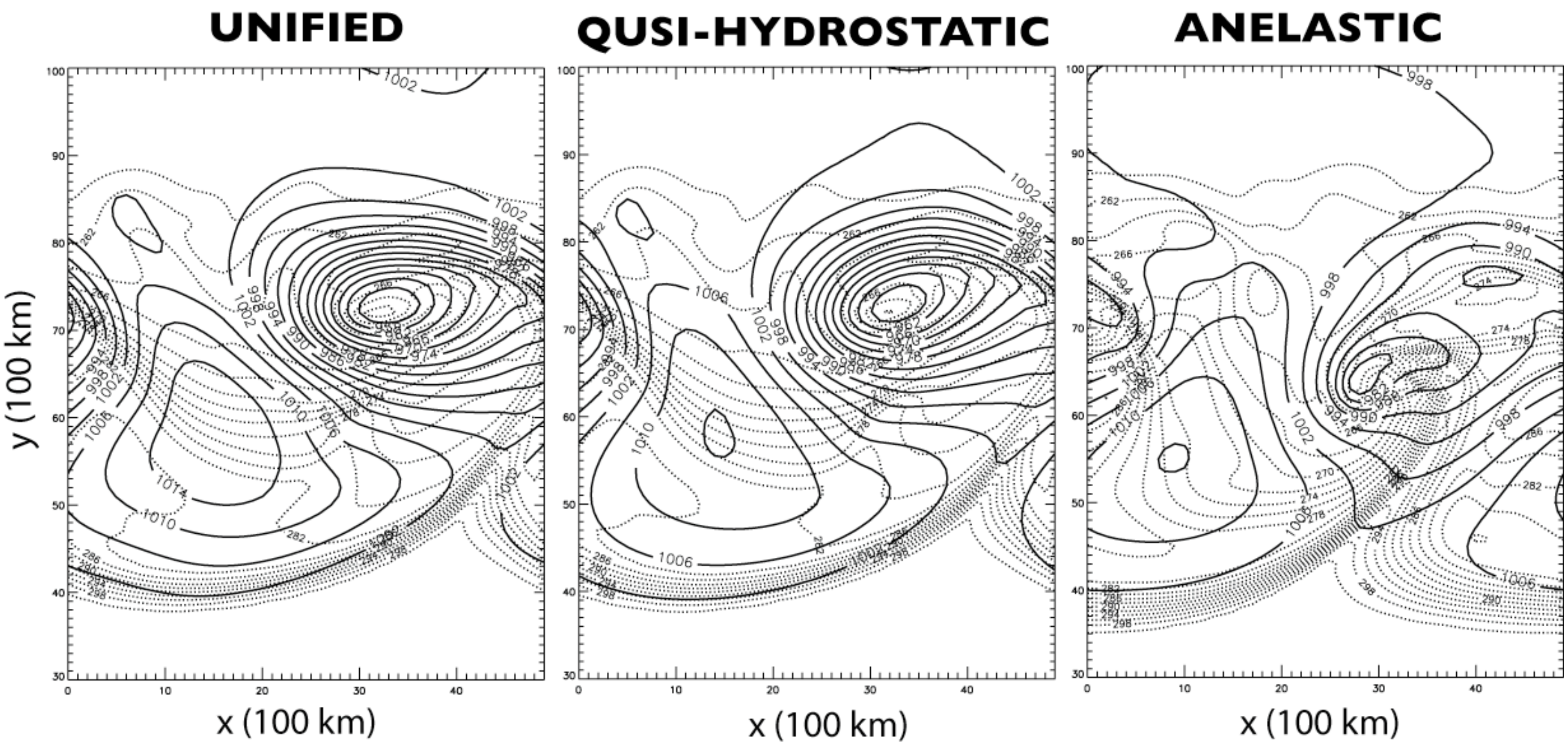
Outline

- A descriptive comparison of the unified (UN), quasi-hydrostatic (QH) and anelastic (AN) dynamical cores
  - Continuous equations
  - Important aspects of discretization of the UN dynamical core
- Simulations of extratropical cyclogenesis on midlatitude β- and f- planes
- A comparison of the results obtained by the three models
- Conclusions

Comparison of the β-Plane Results (Cont.)

- Surface low pressure in the AN simulation does not get as deep as that in the UN and QH simulations

Surface qh-pressure (mb) for UN and QH (and surface pressure (mb) for AN) and potential temperature (K) for day 15



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Progress Report

Research Objective 1:
Development of a Q3D MMF

The quasi-3D multi-scale modeling framework (Q3D MMF) is an attempt to include 3D cloud effects in a GCM without necessarily using a fully three-dimensional global cloud-resolving model (GCRM).

Joon-Hee Jung and Akio Arakawa

January 2011 CMMAP Team Meeting

A Q3D algorithm based on a "gappy" grid has been developed and evaluated

Publications:

Jung, J.-H., and A. Arakawa, 2010:
Development of a quasi-3d multiscale modeling framework: motivation, basic algorithm and preliminary results.
J. Adv. Model. Earth Syst., **2**, Art. #11, 31pp.

A. Arakawa, J.-H. Jung, and C.-M. Wu:
Toward unification of the multiscale modeling of the atmosphere
submitted to Atmos. Chem. Phys.

A. Arakawa, J.-H. Jung, and C.-M. Wu:
Toward unification of general circulation and cloud-resolving models
submitted to ECMWF conference proceeding

Completed Tasks

- Forming a primary structure of Q3D MMF: coded & tested

  (coupled structure of GCM and CRM, I/O, individual channel calculation, elliptic solver, handling channels located in different direction, and so on)

- Inclusion of Q3D algorithm: almost coded & tested

  (channel coupling, bg field calculation, ghost point calculation, and so on)

Near Future Tasks

- Completion of the parallelized code
- Test of the code through a complete simulation

  (serial *vs.* parallelized calculations, efficiency check, and so on)

Continued development of the Vector Vorticity Model on the Icosahedral Geodesic Grid

Ross Heikes, C.S. Konor, Joon-Hee Jung and D. Randall

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CMMAP team meeting
University of California, Berkeley

12 January 2011

The Vector-Vorticity Dynamical Core (VVDC) on the Icosahedral Grid

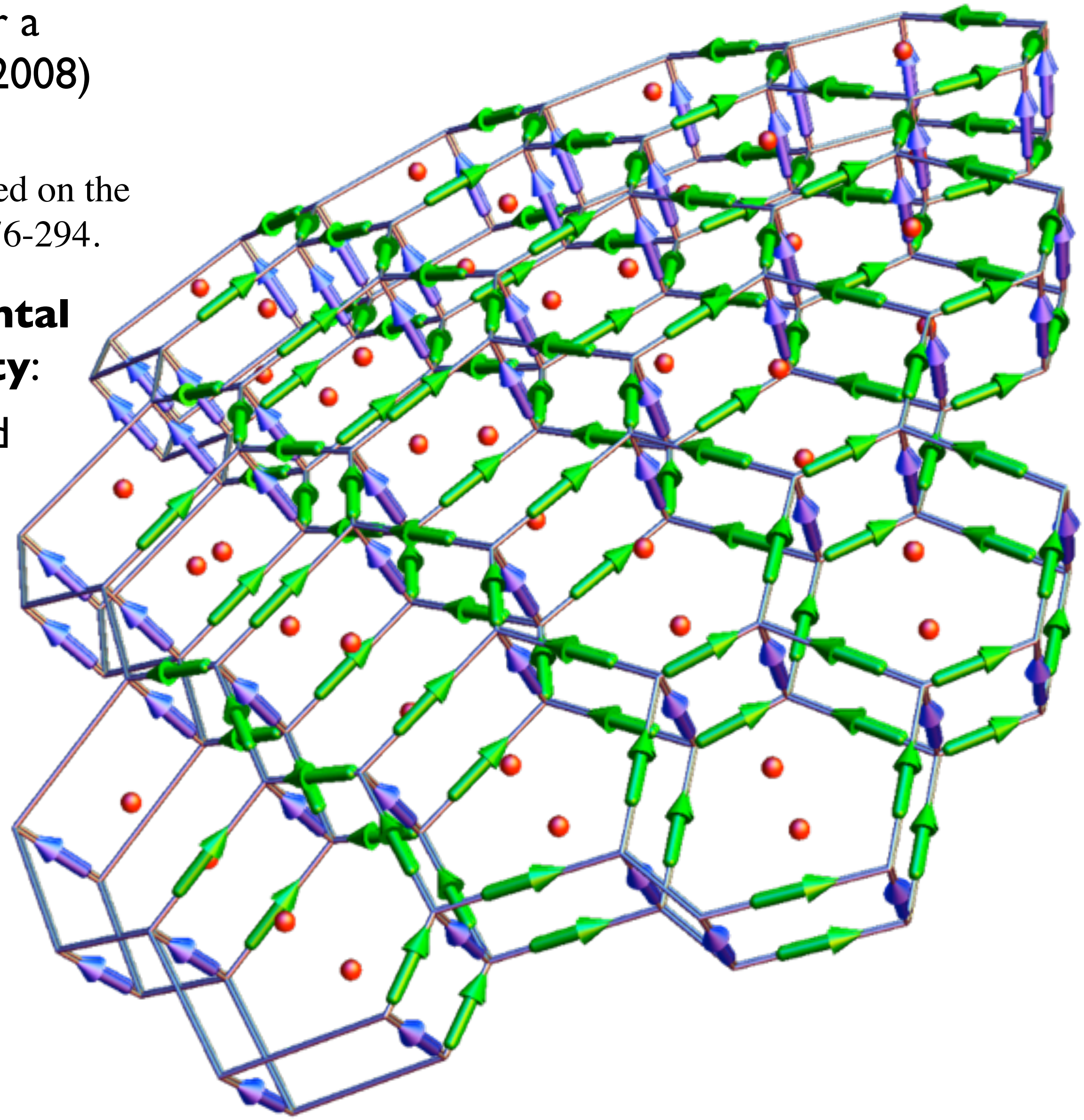
✦ The VVDC was originally designed for a Cartesian grid by Jung and Arakawa (2008)

Jung, J.-H., and A. Arakawa, 2008:
A Three-Dimensional Anelastic Model Based on the Vorticity Equation. *Mon. Wea. Rev.*, **136**, 276-294.

✦ The model predicts both the **horizontal** and **vertical** components of **vorticity**:

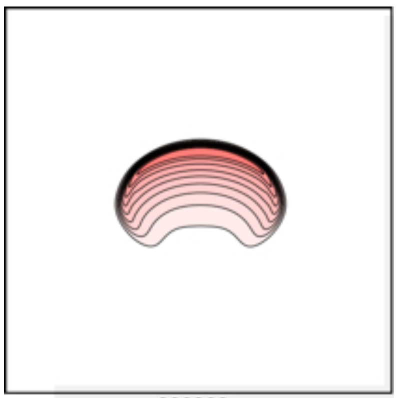
- Horizontal (green arrows) is defined at cell edges and layer interfaces
- Vertical (purple arrows) is defined cell corners and within a layer

✦ The model predicts **Potential Temperature** (red dots) defined at layer interfaces



Rising bubble test case with the VVDC sphere

- This animation shows cross section of temperature through a rising warm bubble
- Contour interval 0.1 K



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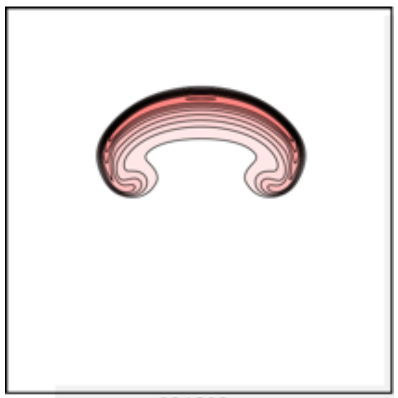

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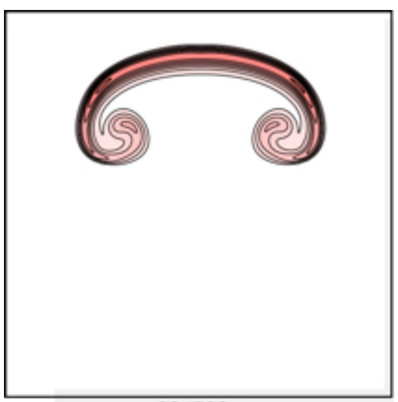

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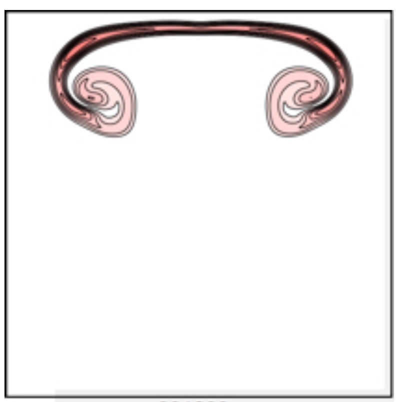

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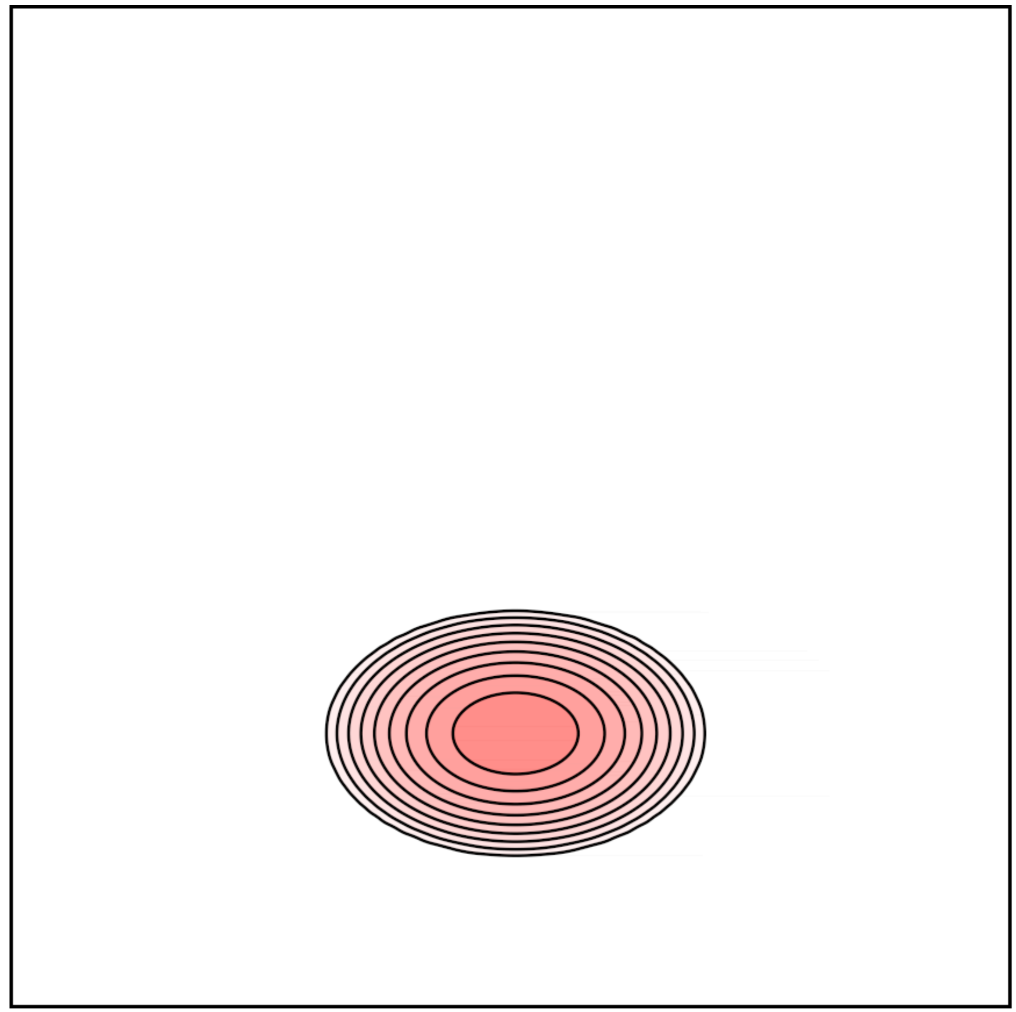

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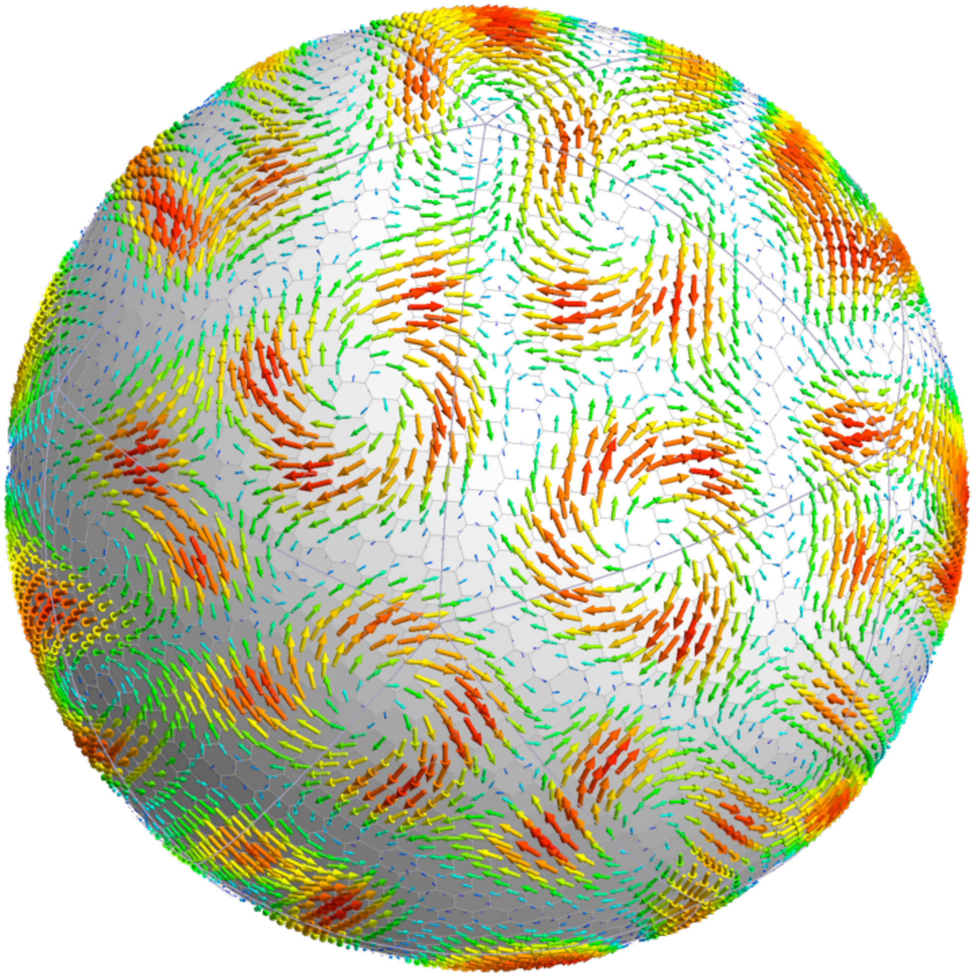
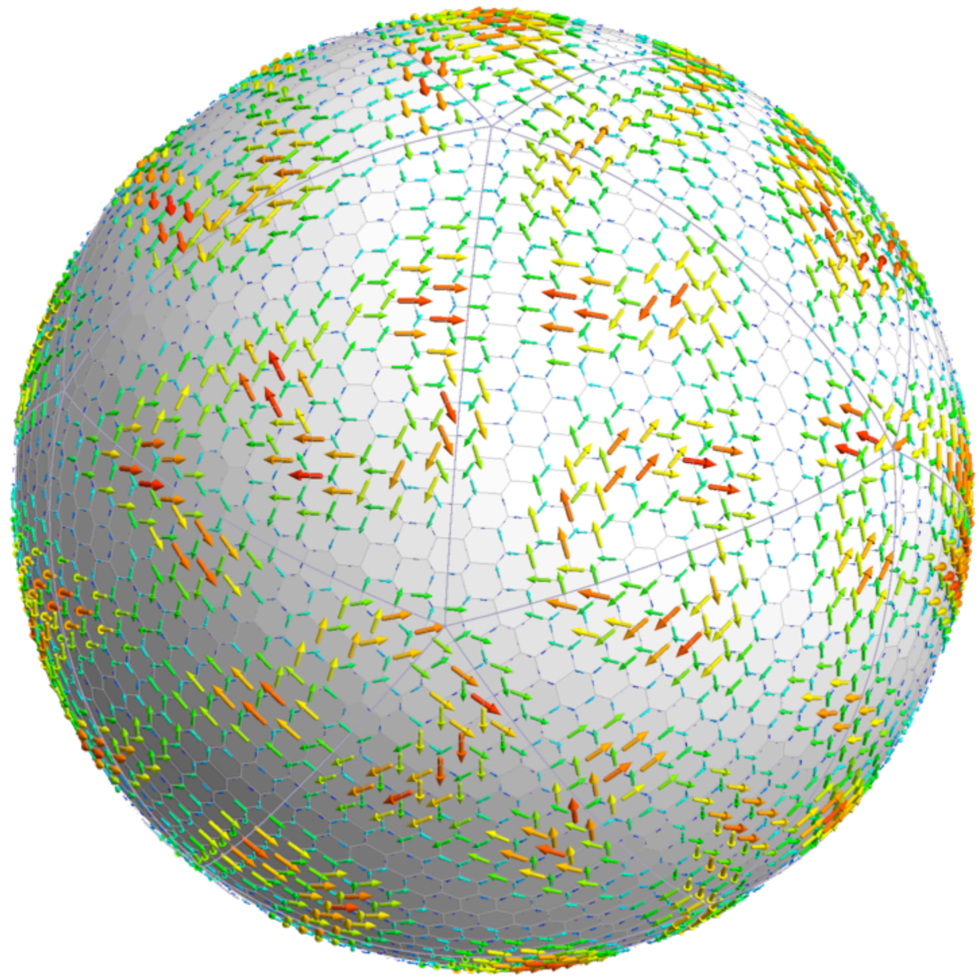
Radial basis functions -- motivation

✦ Current improvements to the model focus on aspects that are unique to the icosahedral grid

Consider a fully 3D field (tangent to surface of the sphere) defined at cell edges.



Projection into the direction tangent to each cell wall. **Can we reconstruct the 3D field from this information?**

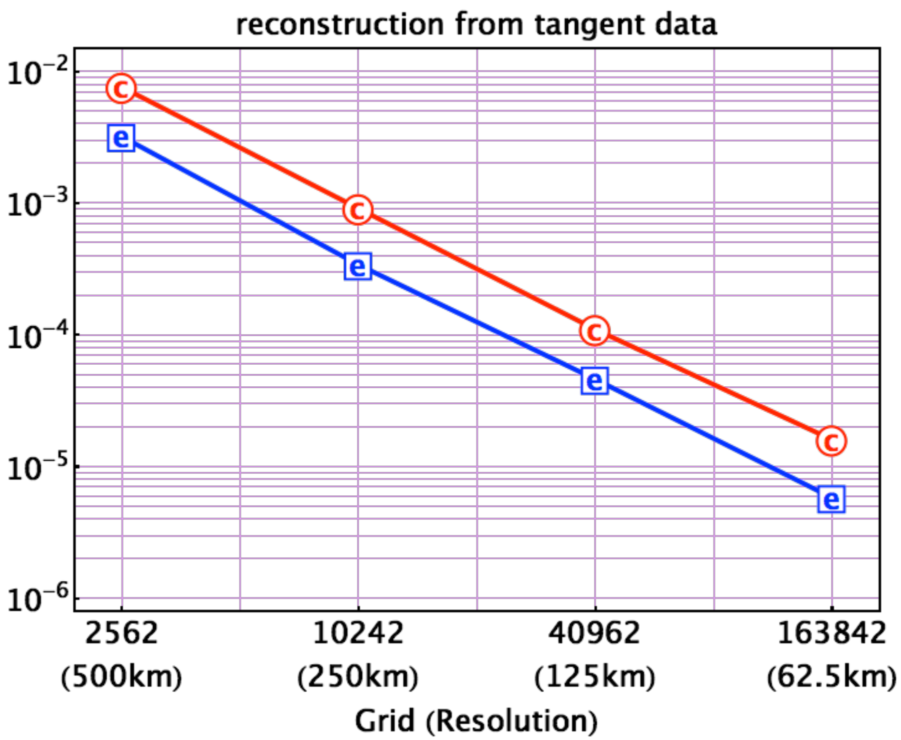


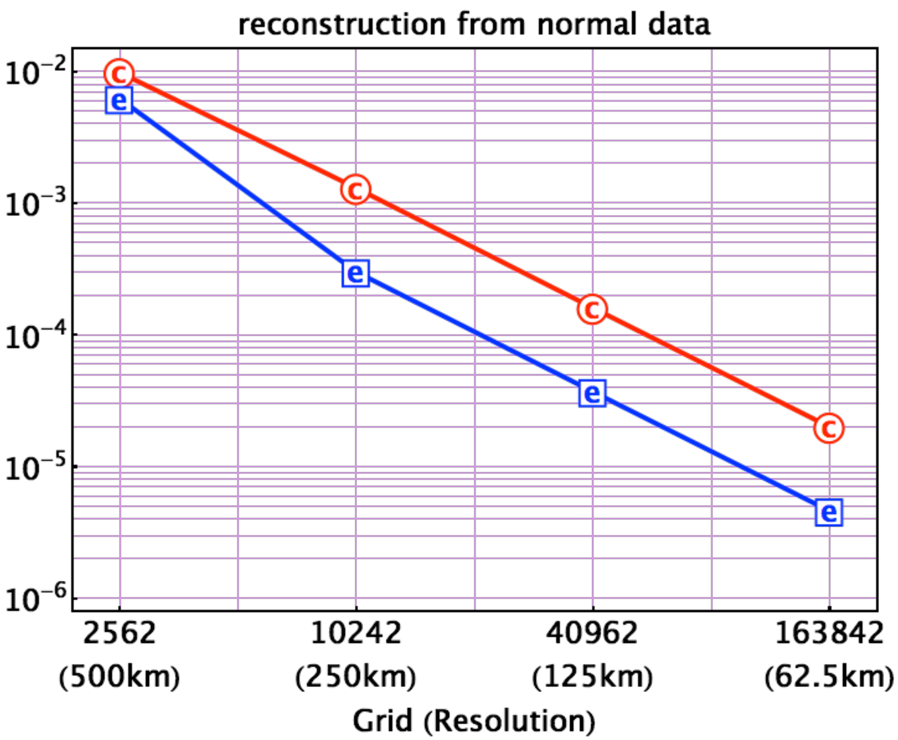
Radial basis functions -- error

- ✦ Given an analytic test case plot the L∞-norm error

$$error = \max\left\{\left\|\mathbf{x}_{appx} - \mathbf{x}_{true}\right\|_2\right\}$$

- ✦ With input data defined tangent and normal to cell walls
- ✦ The plots show the 3D reconstruction at:
  - cell corners (red lines)
  - cell edges (blue lines)





Conclusions

- The use of RBFs offers a dramatic improvement over the previous representation of the 3D fields.
- RBFs can be used to improve various parts of the model.