Dynamical Frameworks Talks

- Joon-Hee - Progress report on the development of a Q3D MMF
- Celal - Atmospheric dynamical cores
- Ross - Recent developments with the icosahedral grid model
- Don - Status of SUZI tests
- Dave - Next steps

Next steps

What CMMAP models will get finished in the time available?

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Multiscale modeling of the moist-convective atmosphere — A review

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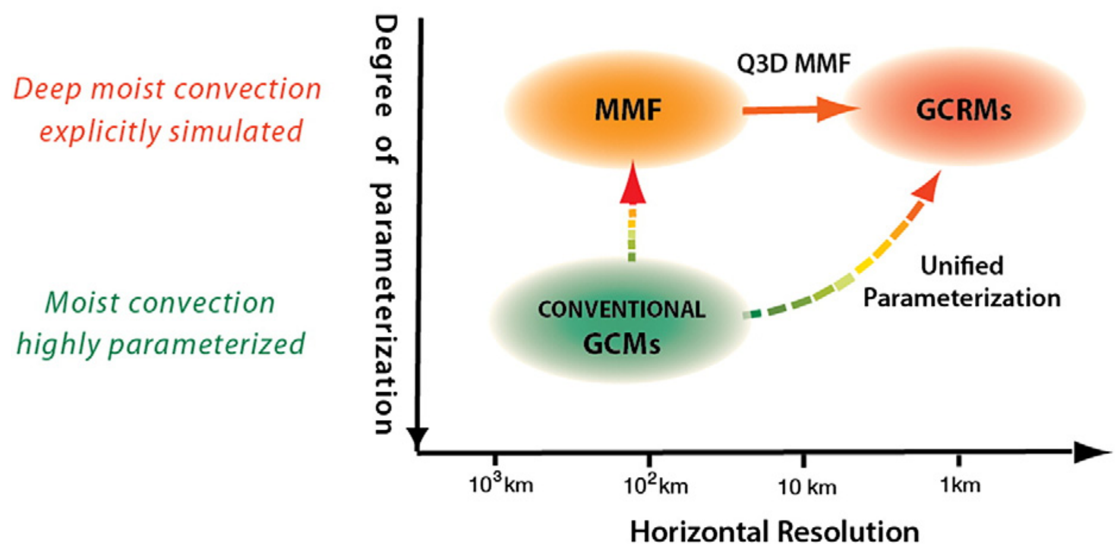
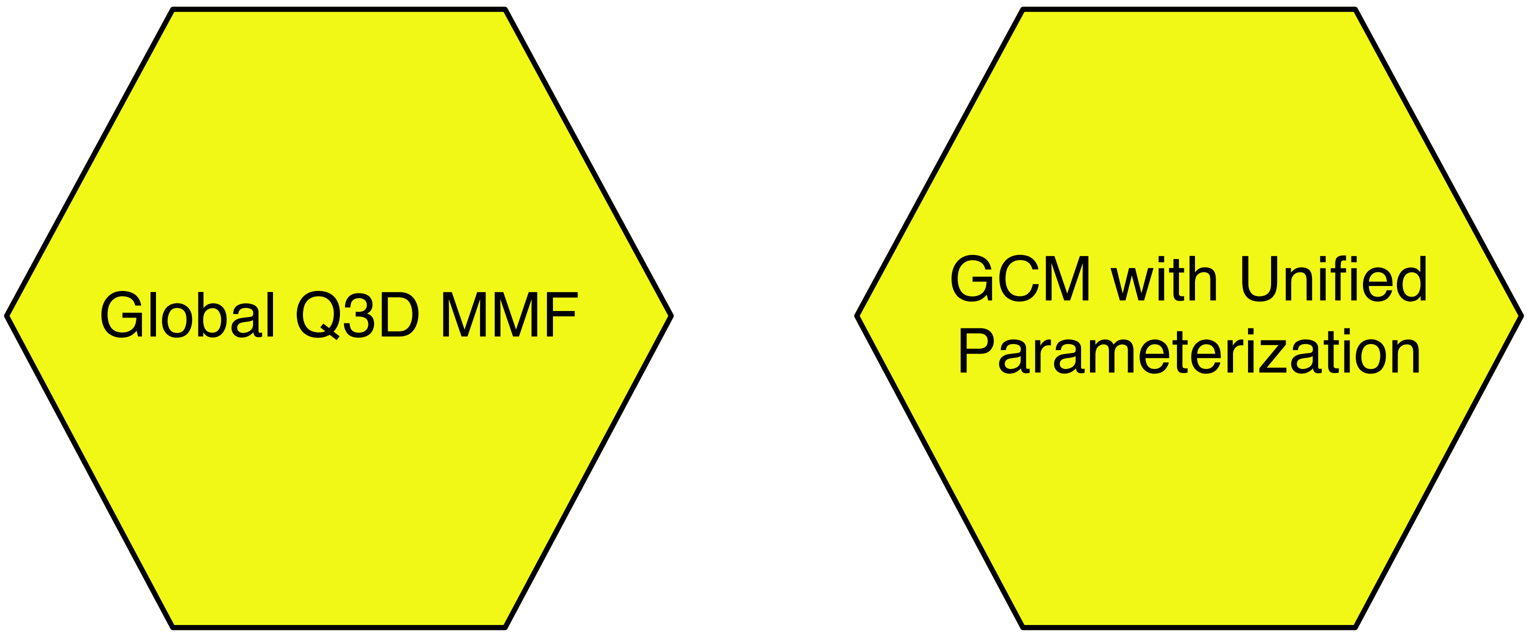


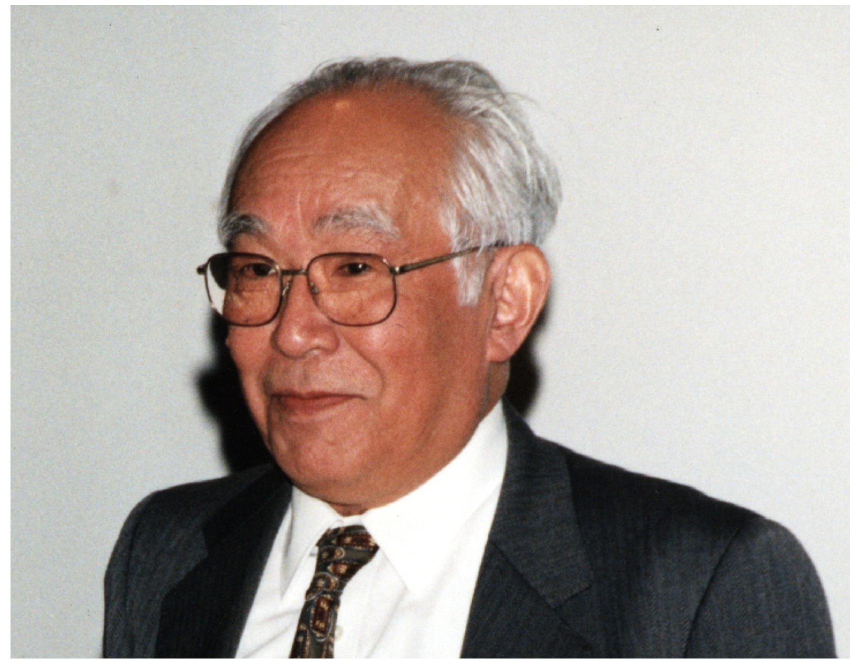
GCMs with very flexible resolution



Models don’t get finished. They just get better.

Unique Elements

- Super-parameterization
- Geodesic Z grid
- Unified System of equations
- Vector vorticity model
- Q3D super-parameterization
- Unified parameterization




Z

The Z-Grid

$$\frac{\partial \zeta}{\partial t} = -f\delta$$

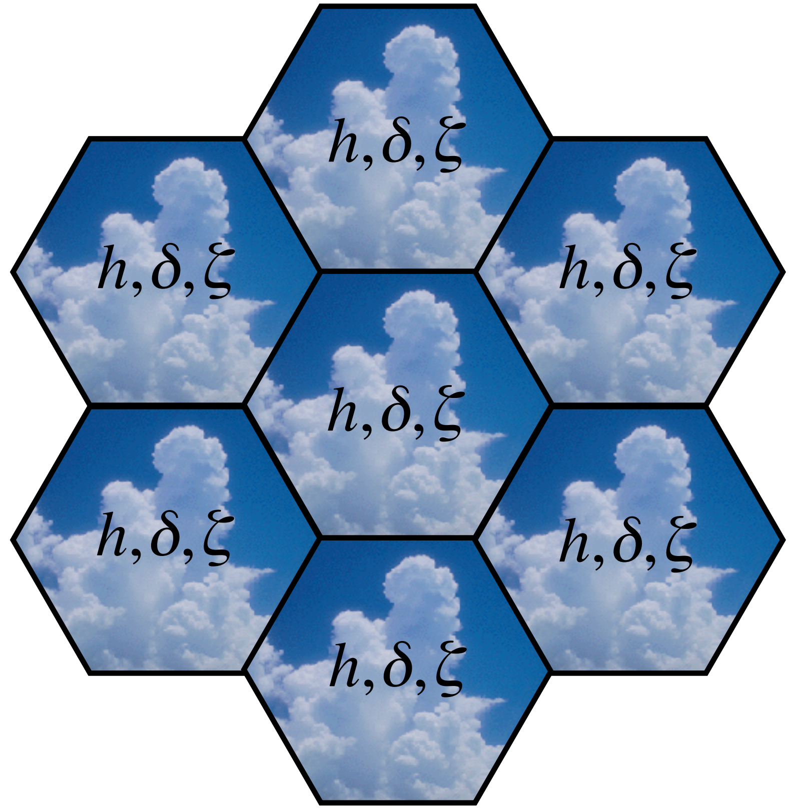
$$\frac{\partial \delta}{\partial t} = f\zeta + g\nabla^2 h$$

$$\frac{\partial h}{\partial t} = -H\delta$$

$$\zeta = \nabla^2 \psi$$

$$\delta = \nabla^2 \chi$$

$$\mathbf{V} = \nabla\chi + \mathbf{k} \times \nabla\psi$$



We use a multigrid method
to solve the 2D Poisson equations.

No computational modes
Excellent dispersion properties
Direct prediction of the vertical component of the vorticity vector

The unified system of equations

Arakawa and Konor (2009)

- Yields elastic solutions for large-scale quasi-hydrostatic motion and anelastic solutions for small-scale nonhydrostatic motion.
- Filters vertically propagating acoustic waves.
- Does not introduce approximations to the thermodynamic and momentum equations. The continuity equation uses the quasi-hydrostatic density.
- Does not need a basic (or mean) state.
- Conserves total energy.
- Covers a wide range of horizontal scales from turbulence to planetary scales so that it is suitable for the use in global cloud resolving models.

3D Poisson Equation for Pressure

$$\nabla_H \cdot \left(\rho_{qs} c_p \theta \nabla_H \delta\pi\right)^{(n+1)} + \frac{\partial}{\partial z}\left(\rho_{qs} c_p \theta \frac{\partial \delta\pi}{\partial z}\right)^{(n+1)} =$$

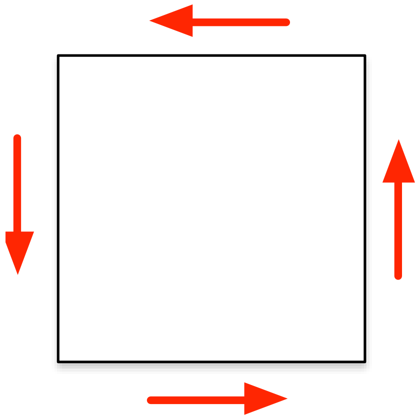
$$-\nabla_H \cdot \left(\rho_{qs} c_p \theta \nabla_H \pi_{qs}\right)^{(n+1)} + \left(\frac{\partial^2 \rho_{qs}}{\partial t^2}\right)^{(n+1)} + G^{(n+1/2)}$$

$$\left(\frac{\partial \delta\pi}{\partial z}\right)_S = \left(\frac{\partial \delta\pi}{\partial z}\right)_T = 0$$

Neumann boundary conditions

Solver performance is poor with Neumann boundary conditions.

VVM

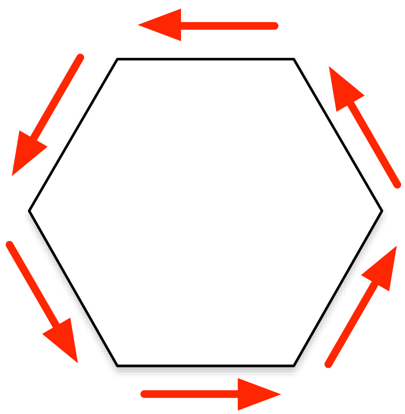


h = 0 at the upper boundary.

g_T is predicted for the top layer.

Upper boundary condition is $w = 0$.

$\mathbf{v}_n$ is determined from streamfunction and velocity potential. Mean velocity is predicted.



h is predicted at interior interfaces.

g is diagnosed from g_T and h at layers.

w is solved from a 3D elliptic equation.

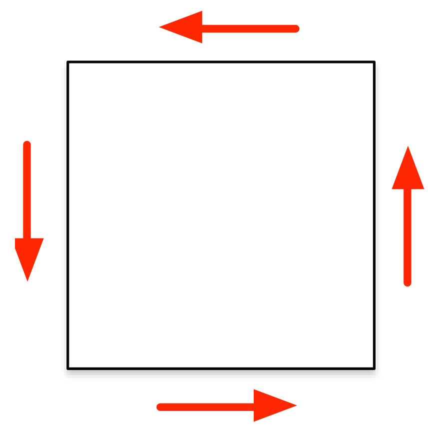
$\mathbf{v}_n$ is determined from h and w.

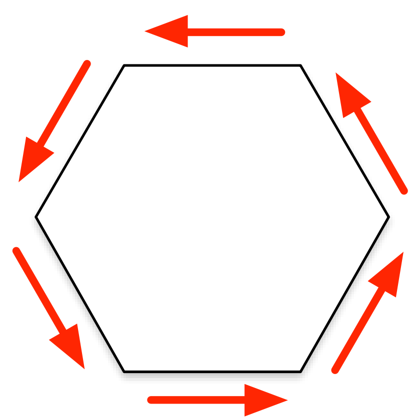
i is predicted at every interface.

h = 0 at the lower boundary (frictionless case).

Lower boundary condition is $w = 0$.

This is a C grid.





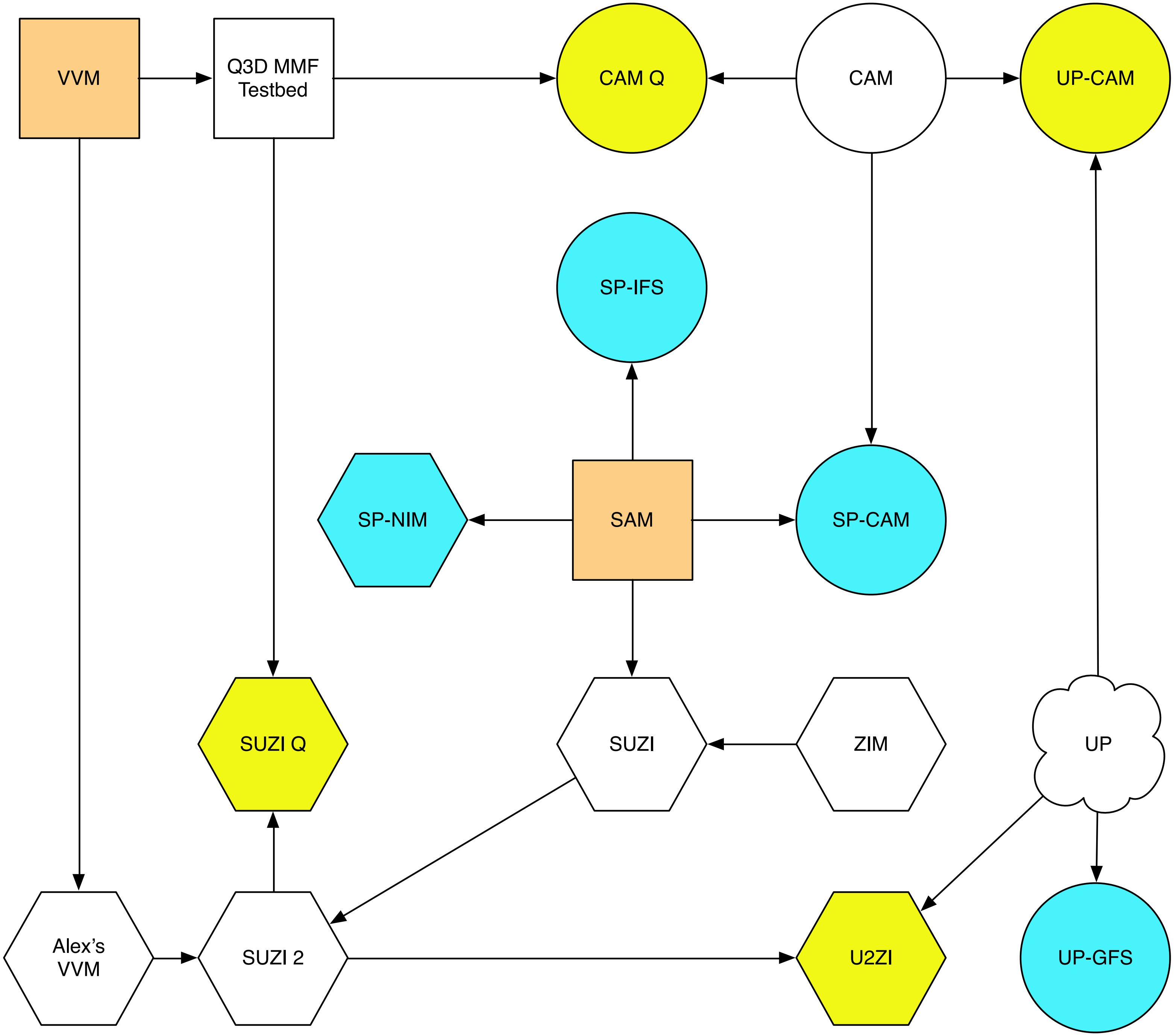
Geodesic VVM

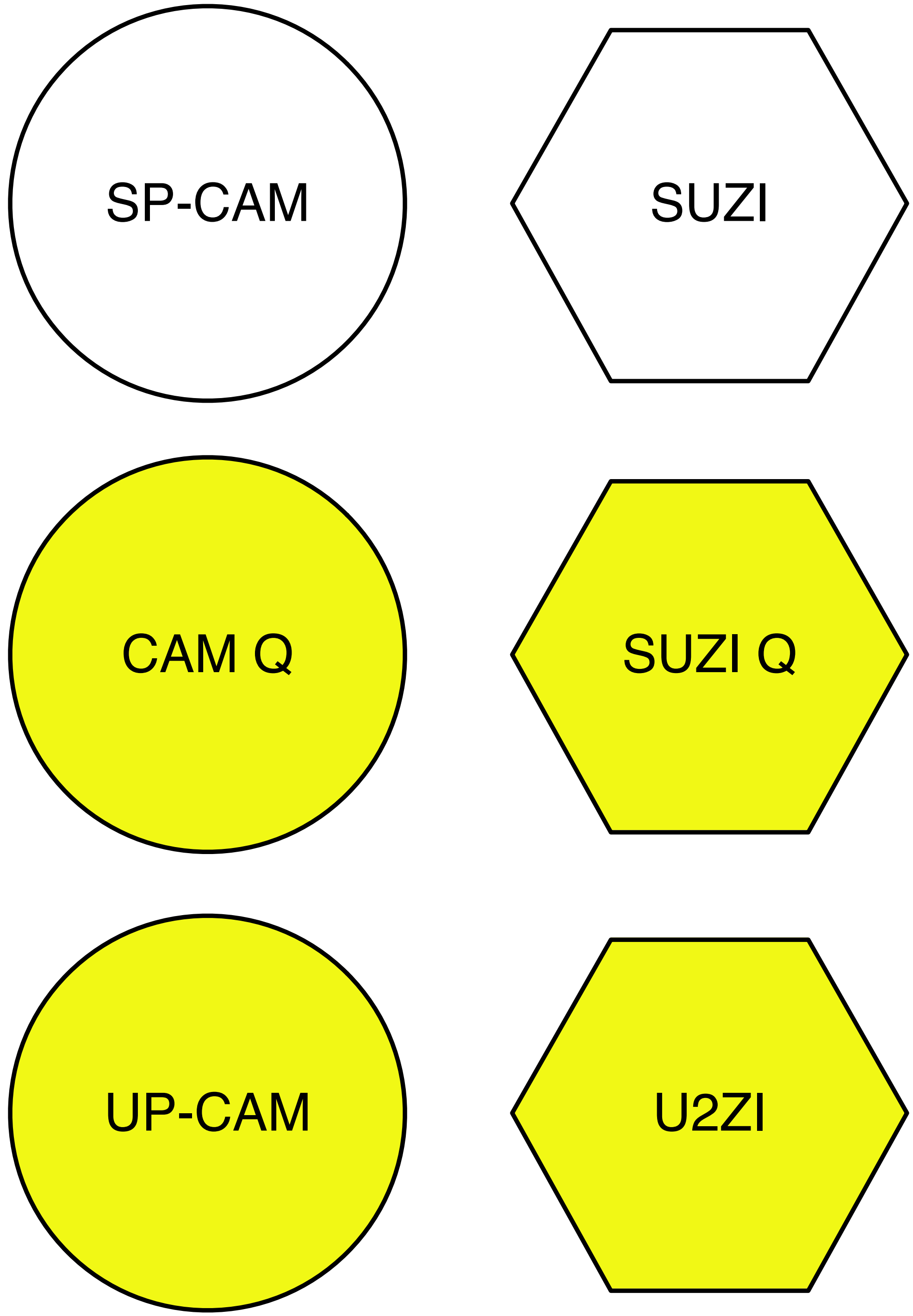
- Mismatch of degrees of freedom — three horizontal vorticities per mass point → computational mode.
- Filter computational mode by predicting curl and div of horizontal vorticity, then recovering horizontal vorticity vector by solving 2D Poisson equations.
- Predict the curl of the horizontal vorticity vector at the cell centers. *Palinstophy*.
- Predict the vertical component of the vorticity at the cell centers, displaced vertically by half a level.
- Divergence of the horizontal vorticity is minus d/dz of the vertical component of the vorticity.
- Divergence and curl can be used to reconstruct both normal and tangential components of the horizontal vorticity vector on cell walls.
- Strategy:
  - Predict curl(eta) and zeta
  - Diagnose horizontal vorticity vector
  - Compute w and horizontal winds as in original VVM
  - 3D Poisson equation is for w, not p

Alex Goodman is working on this in a limited-area framework.

Summary

- Unified system entails 3D Poisson equation.
- With current version of SUZI, the Poisson equation governs pressure, with Neumann boundary conditions.
- Geodesic VVM motivated by need for Dirichlet boundary conditions, which are used with solution for w.
- Prediction of curl and div of horizontal vorticity vector motivated by need to avoid computational mode.


VVM
Q3D MMF Testbed
CAM Q
CAM
UP-CAM
SP-IFS
SP-NIM
SAM
SP-CAM
SUZI Q
SUZI
ZIM
UP
Alex's VVM
SUZI 2
U2ZI
UP-GFS


SP-CAM
SUZI
CAM Q
SUZI Q
UP-CAM
U2ZI