General order for discussion

- Does balance matter?
- What kinds of metric should be used to measure imbalance?
- Algorithm details
- Other types of balance
- What about unbalanced flow?
- Use of “toy models”.
- Anything else?

Metrics

- What kind of metric should be used to measure imbalance?
  - Separate by scale?

Measuring gravitational “noise”

An ”energy” metric applied to the linearly unbalanced fields

$$E = \frac{1}{2}\sum_k g_k g_k^* = \frac{1}{2A}\int \left[u'^2 + v'^2 + \frac{C_p}{T_r}T'^2 + \frac{RT_r}{p_{sr}^2}p_s'^2\right]\, dA\, d\sigma$$

The same applied to the linearly unbalanced time tendencies

$$B = \frac{1}{2}\sum_k \dot{g}_k \dot{g}_k^* = \frac{1}{2A}\int \left[\dot{(}u'^2 + \dot{v}'^2 + \frac{C_p}{T_r}\dot{T}'^2 + \frac{RT_r}{p_{sr}^2}\dot{p_s}'^2\right]\, dA\, d\sigma$$

An E–weighted mean period of the linearly unbalanced fields

$$T = 2\pi\sqrt{E/B}$$

Does balance matter?

- Does a balanced analysis matter, or can we just initialise?

- Does a balanced background matter?
  - Used to estimate background error covariances

Algorithm details

- Are some flavours of EnKF inherently better for balance?
  - Perturbed obs, single vs double, ETKF vs EnSRF vs EAKF, sequential vs all-at-once, …
- Are some control variable choices better for balance in Var systems?

Other types of balance

- Balance issues concerning moisture
- Balances on the mesoscale
- Tropical cyclones

Convection and Gravity-Wave Generation

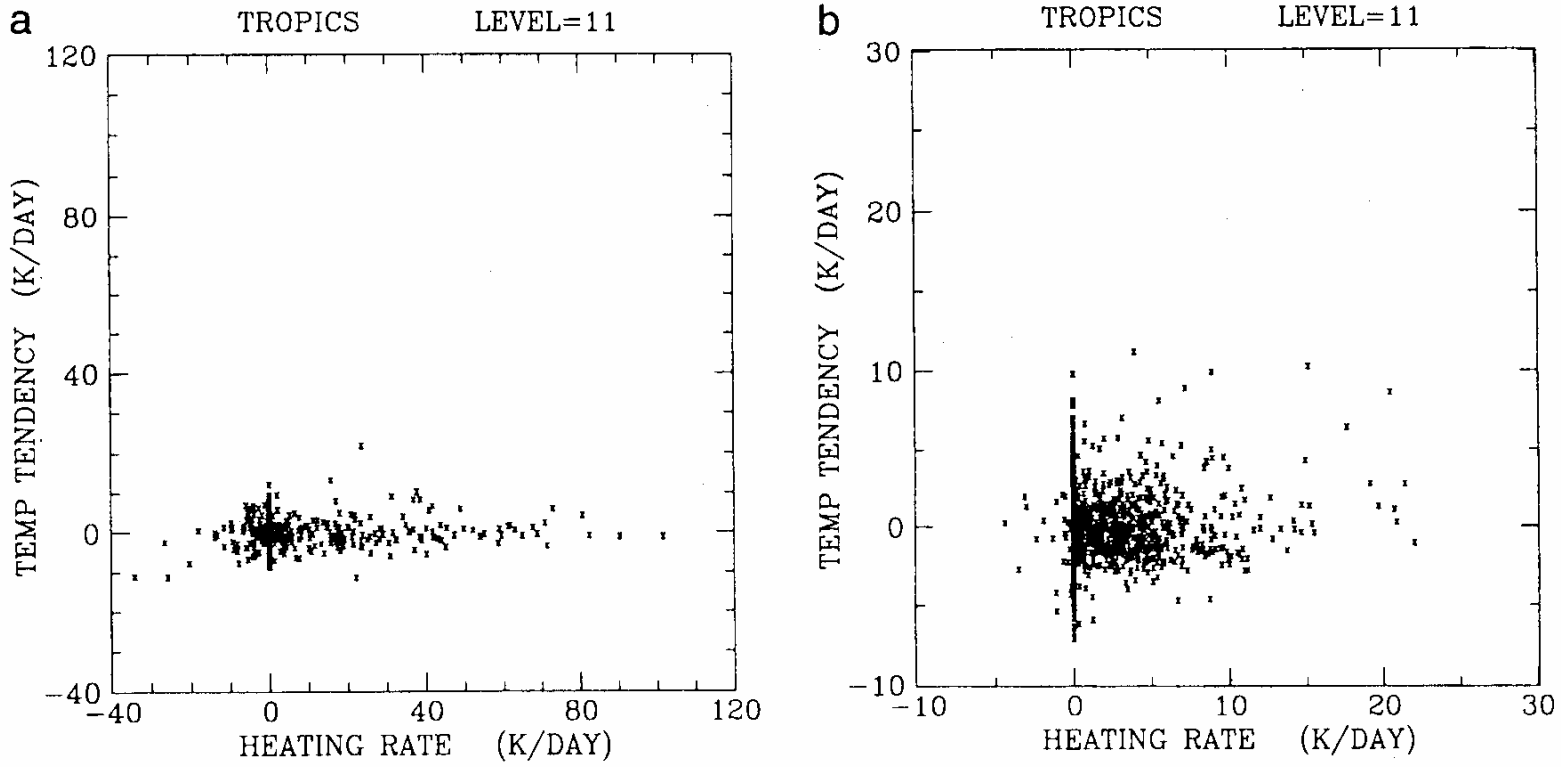


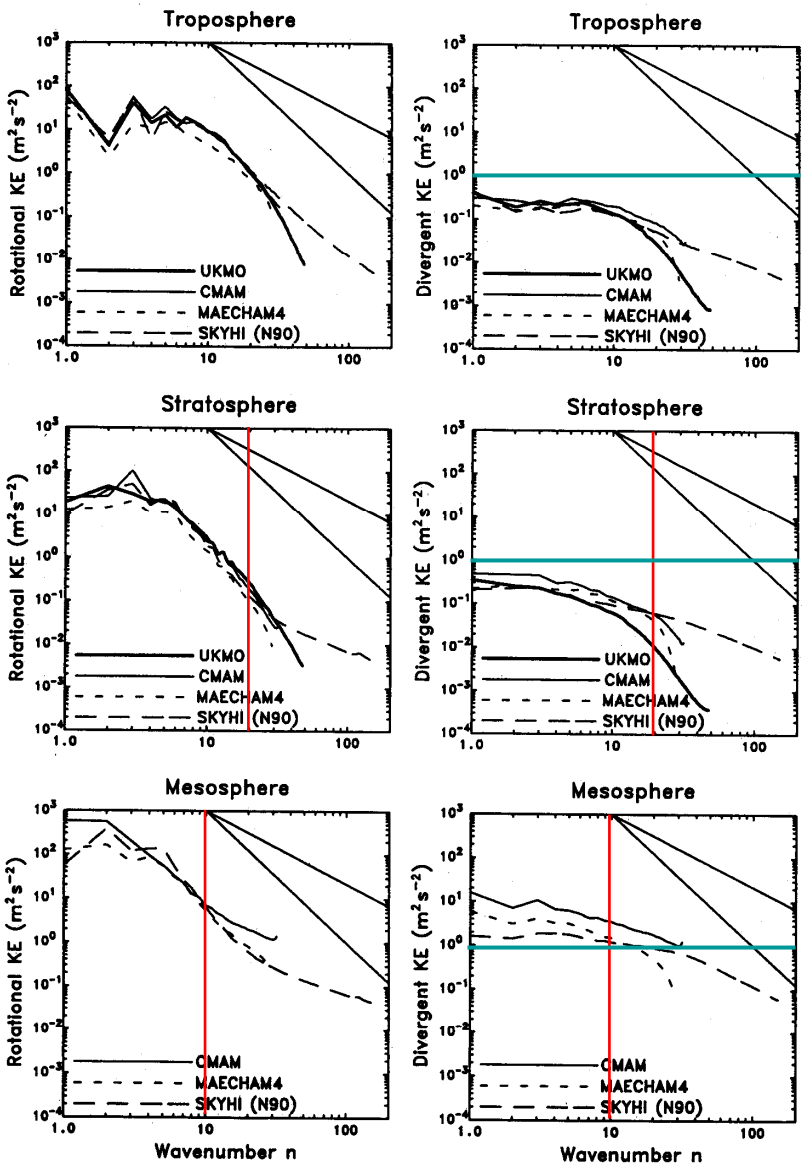
Fig. 4. Scatter diagrams of the diabatic rate heating due to condensation and moist convective processes vs. the time tendency of temperature for all grid points within the tropics on model level 11 at 1 time step during a climate simulation with (a) the Hack scheme and (b) the Relaxed Arakawa-Schubert scheme. Units are K/day.

What about unbalanced flow?

- Models can simulate several regimes, e.g
- Mesosphere
- Mesoscale
- Tropics

Kinetic energy spectrum changes with height

Rot KE Div KE



troposphere

stratosphere

RotKE = DivKE around n=20

mesosphere

RotKE = DivKE around n=10

Figure 4. Rotational and divergent parts of the monthly mean kinetic energy per unit mass versus total horizontal wavenumber for January data from the UKMO assimilation, CMAM, MAECHAM4, and SKYHI (N90) models. The curves represent vertically averaged values over the troposphere (top), stratosphere (middle), and mesosphere (bottom), as described in Figure 1.

Koshyk et al. (1999)

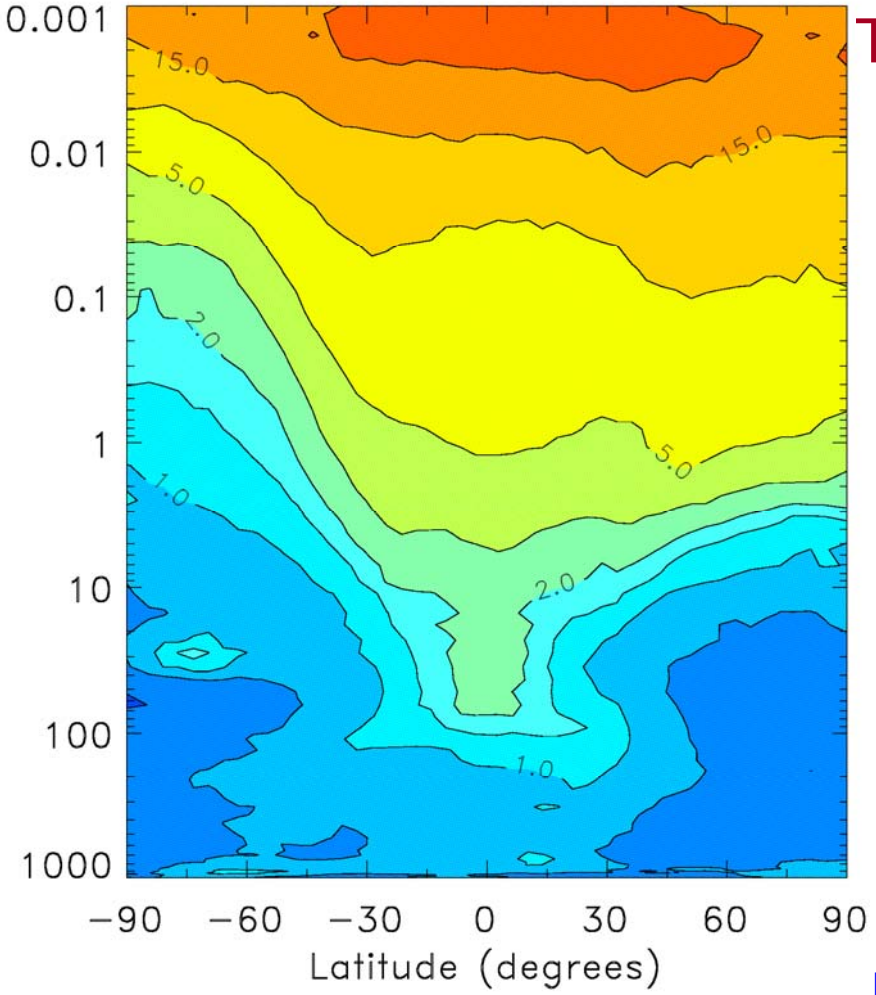
Toy models

- What are the desirable properties of a toy model for studying balance in an assimilation system?

Anything else?

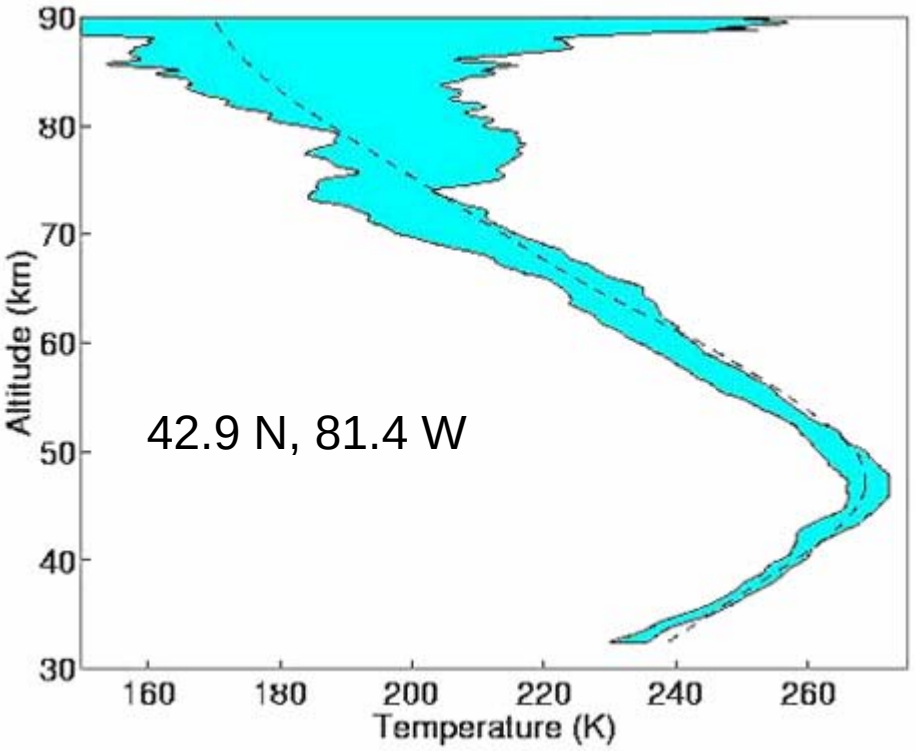
Forecast and obs error variances increase with height

CMAM ens-based T forecast error std



Nezlin et al. (2008)

T profiles over one night from lidar



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http://pcl.physics.uwo.ca/science/temperature/