Departures from gradient wind balance during secondary eyewall formation

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Take home message:
Axisymmetric balanced dynamics of Shapiro and Willoughby (1982) are unable to capture SEF spin-up

Background

It has been proposed that the **essential dynamics of secondary eyewall formation (SEF)** are related to departures of (gradient wind) balance in the boundary layer (Huang et al. 2012; Abarca and Montgomery 2013). In this view there is a progressive boundary layer control that includes the development of supergradient flow. The latter is crucial for SEF in:

a) The establishment of the sustained deep convection
   Result of the strong horizontal convergence (agradient force pointing outward in a region of inflow)
b) The emergence of the wind maximum
   Result from mean influx of absolute vorticity surpassing the depletion of absolute angular momentum

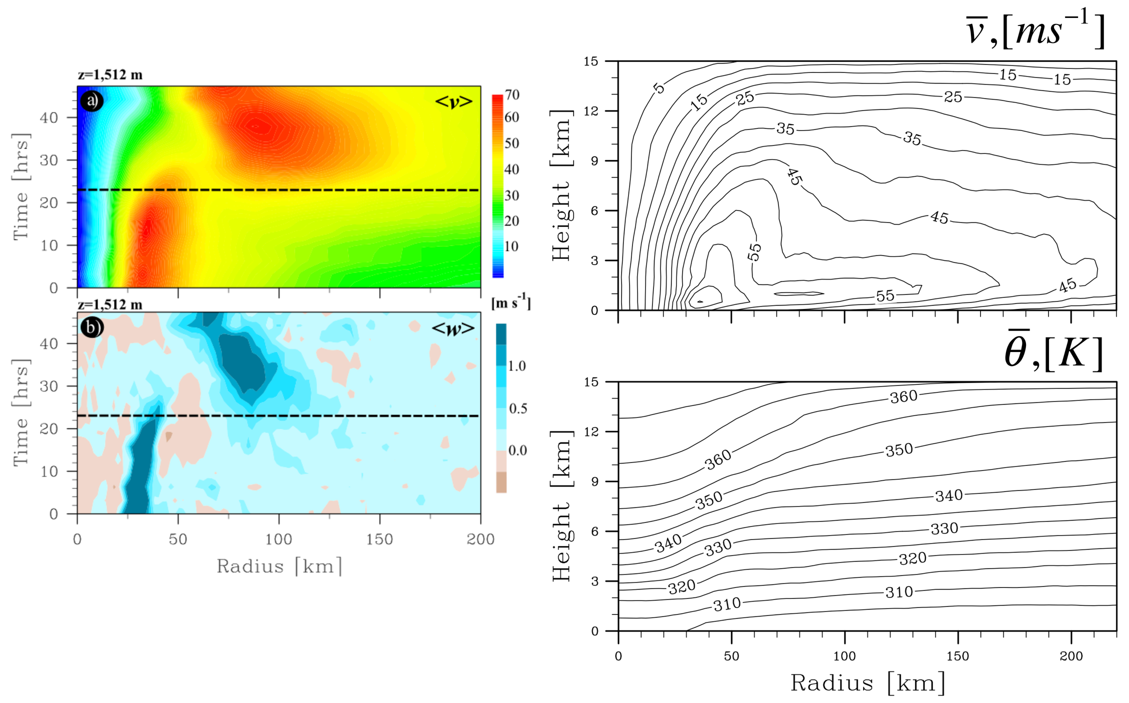
To what extent do full-physics numerical simulations undergoing SEF depart from axisymmetric balance evolution as defined by Shapiro and Willoughby (1982)?

Methodology

Compare:
- Radial velocity
- Vertical velocity
- Tangential velocity tendency

RAMS Vs Sawyer-Eliassen

RAMS
- Full-physics, mesoscale integration
- Exhibited a canonical SE
- Described in Terwey and Montgomery (2008) and Abarca and Montgomery (2013)



Sawyer-Eliassn

$$\frac{\partial}{\partial r}\left[-g\frac{\partial\chi}{\partial z}\frac{1}{\rho r}\frac{\partial\psi}{\partial r}-\frac{\partial(\chi C)}{\partial z}\frac{1}{\rho r}\frac{\partial\psi}{\partial z}\right]+$$
$$\frac{\partial}{\partial z}\left[\left(\xi\chi\zeta_a+C\frac{\partial\chi}{\partial r}\right)\frac{1}{\rho r}\frac{\partial\psi}{\partial z}-\frac{\partial(\chi C)}{\partial z}\frac{1}{\rho r}\frac{\partial\psi}{\partial r}\right]=$$
$$g\frac{\partial(\chi^2 Q)}{\partial r}+\frac{\partial(C\chi^2 Q)}{\partial z}-\frac{\partial(\chi^2\xi F_\lambda)}{\partial z}$$

- Integrated using the successive overrelaxation scheme (Press *et al.* 1992)

Ellipticity condition

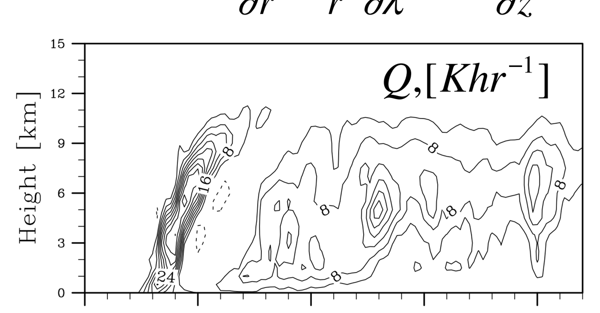
Met when $D<0$, where:

$$D=B^2-4AC \qquad \chi=\frac{1}{\theta}$$
$$A=-g\frac{\partial\chi}{\partial z}$$
$$B=\frac{\partial\left[\chi\left(\frac{v^2}{r}+f_c v\right)\right]}{\partial z}$$
$$C=\left(\frac{2v}{r}+f_c\right)\chi\zeta_a+\left(\frac{v^2}{r}+f_c v\right)\frac{\partial\chi}{\partial r}$$

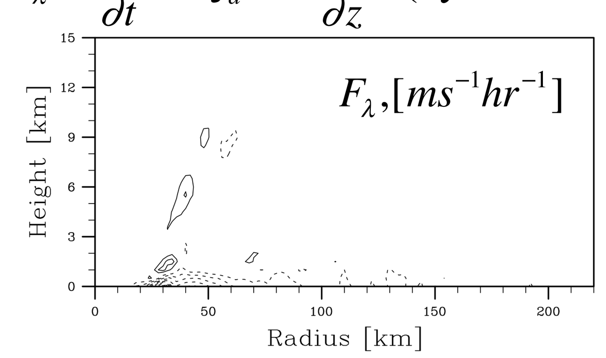
- Regularization procedure

Forcing Functions

$$Q=\dot{\bar{\theta}}-\overline{u'\frac{\partial\theta'}{\partial r}}-\overline{\frac{v'}{r}\frac{\partial\theta'}{\partial\lambda}}-\overline{w'\frac{\partial\theta'}{\partial z}}$$



$$F_\lambda=\frac{\partial\bar{v}}{\partial t}+\bar{u}\zeta_a+\bar{w}\frac{\partial\bar{v}}{\partial z} \quad \text{(by residual)}$$



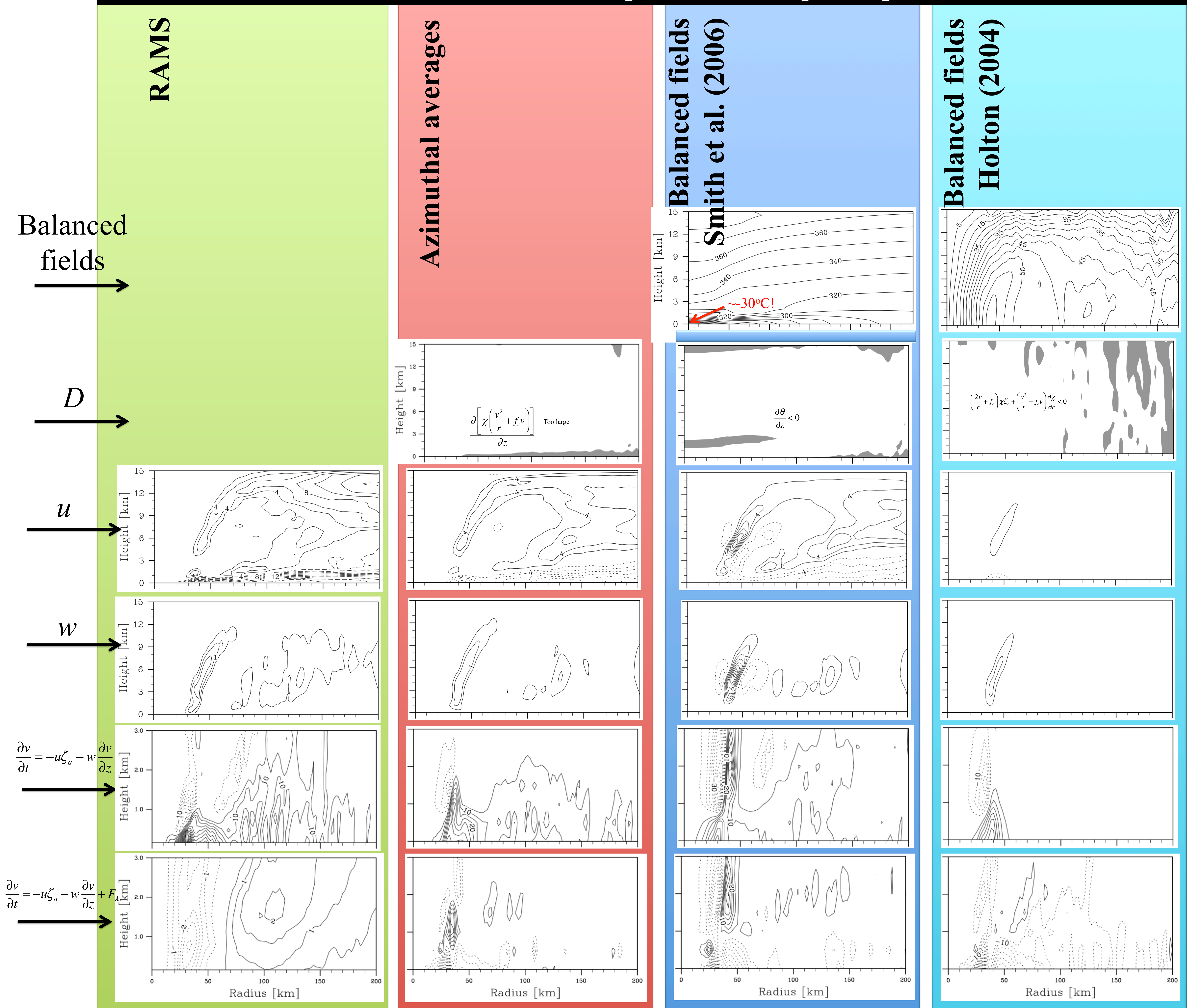
Definition of balance

Three options:

a) Azimuthal averages
   As performed before (e.g. Persing and Montgomery 2003), but not in balance

a) Smith et al. (2006)
   Use azimuthal average tangential wind field and derive the temperature field in balance with it

a) Holton (2004)
   Use azimuthal average temperature field and derive the tangential wind field in balance with it



References

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