Model physics influence on hurricane track, structure (& intensity)

Robert Fovell

University of California, Los Angeles

rfovell@ucla.edu

Collaborators: Kristen Corbosiero, Yang Cao, Hung-Chi Kuo, Hui Su, Axel Seifert, Don Boucher, Kuo-Nan Liou, Travis Wilson

HFIP Physics Workshop, Clinton, MD 10 August 2011

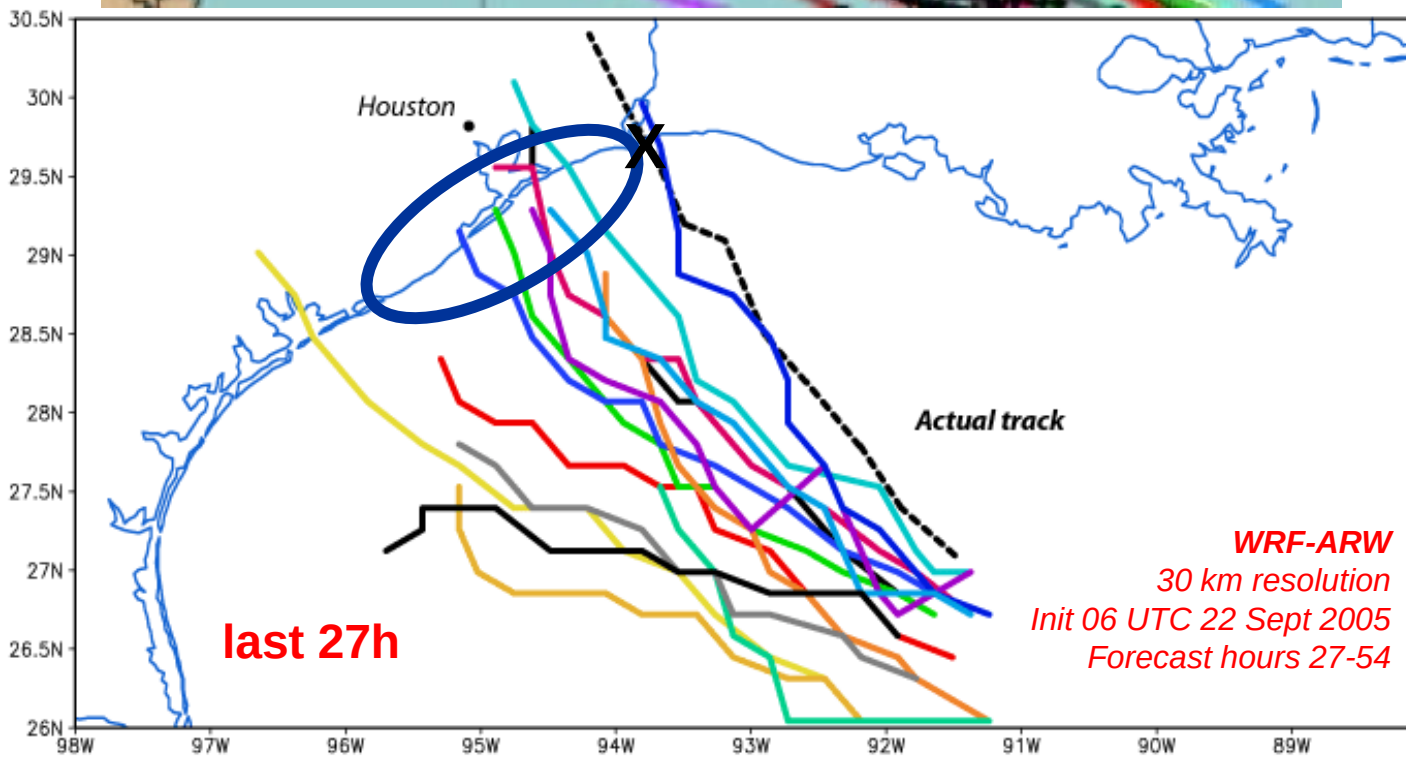
Rita (2005)

NHC
Multi-model
Consensus
06 UTC 22 Sept

[courtesy J. Vigh]

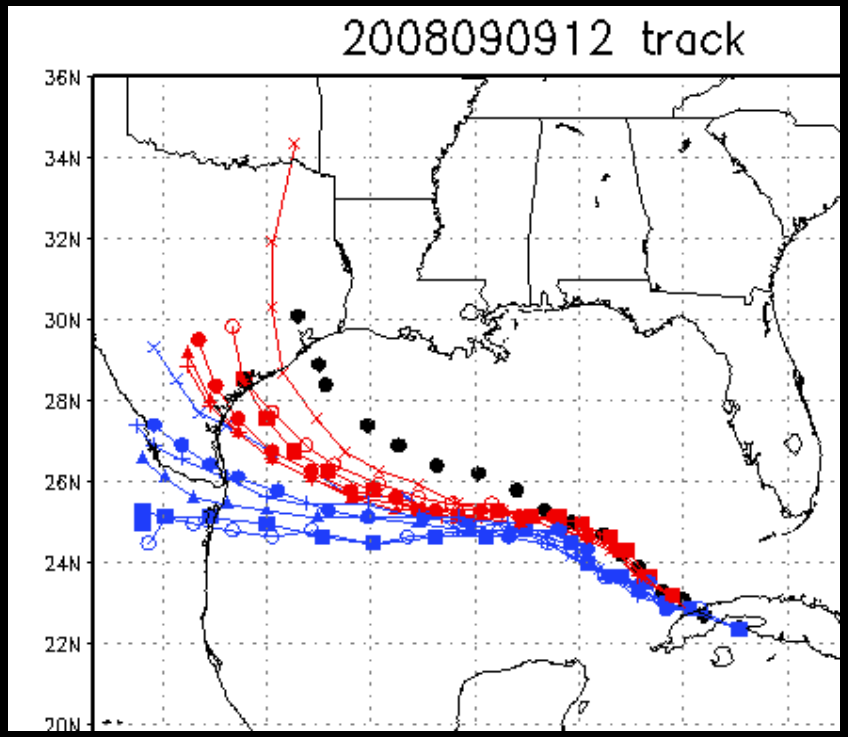
One model
One initialization
Vary model physics
(CP and MP)

Fovell and Su (2007)
[replotted]

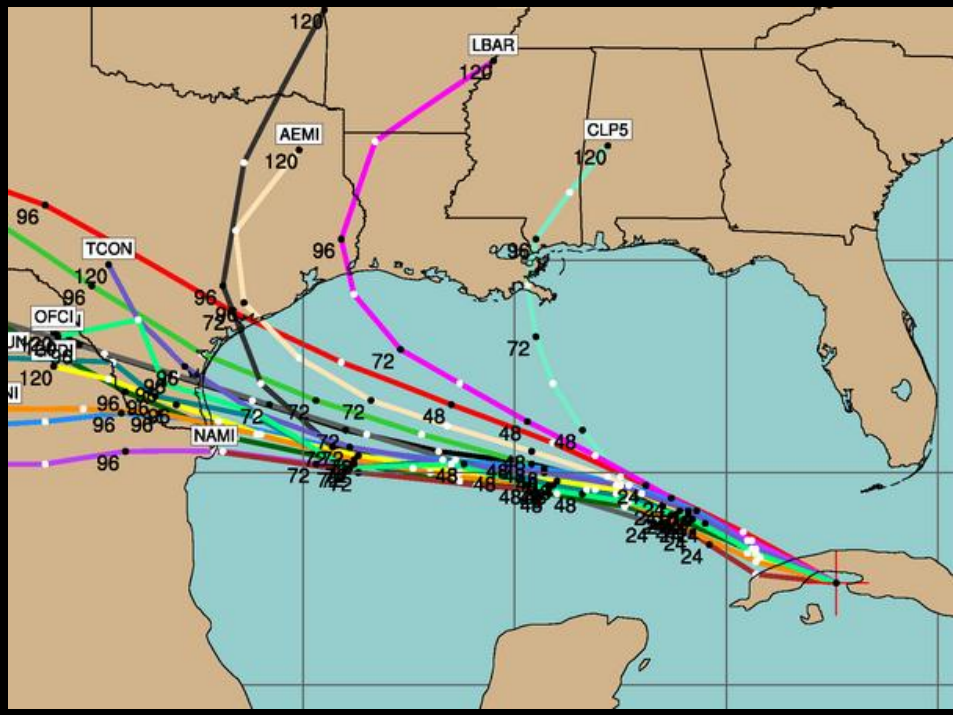


Hurricane Ike - 12 UTC 9/09/08

36 km WRF-ARW ensemble



NHC multi-model ensemble



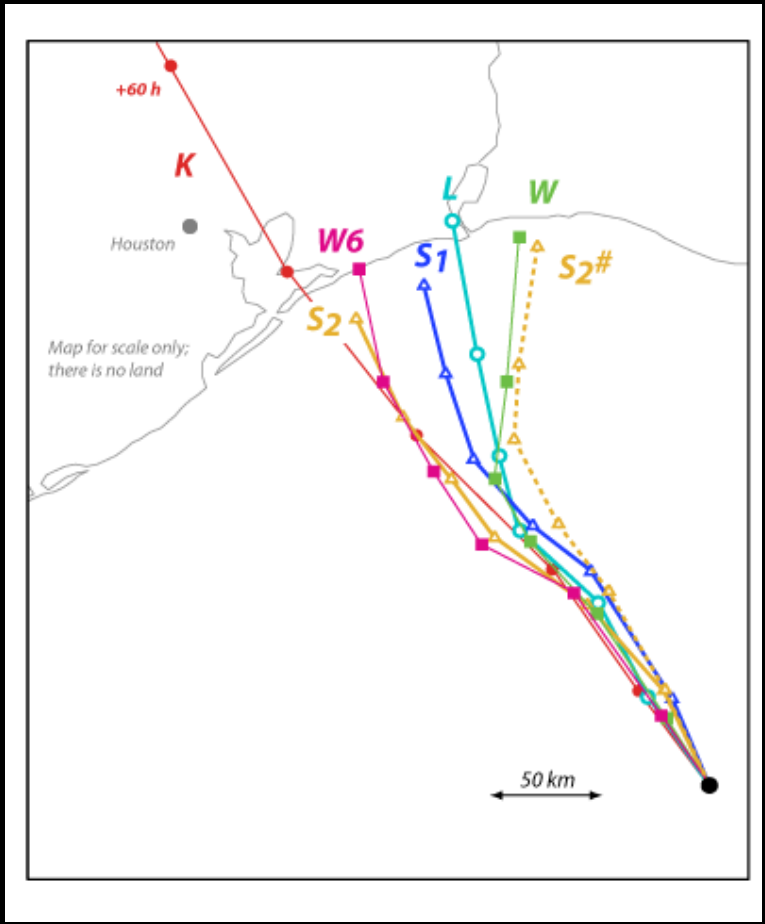
J. Vigh

Black dots - actual positions

One of 68 ensemble events of 5 Atlantic landfalling storms [816 runs total] for 2008 - Fovell and Boucher (2009)
[36 km WRF-ARW]

Semi-idealized TC tracks

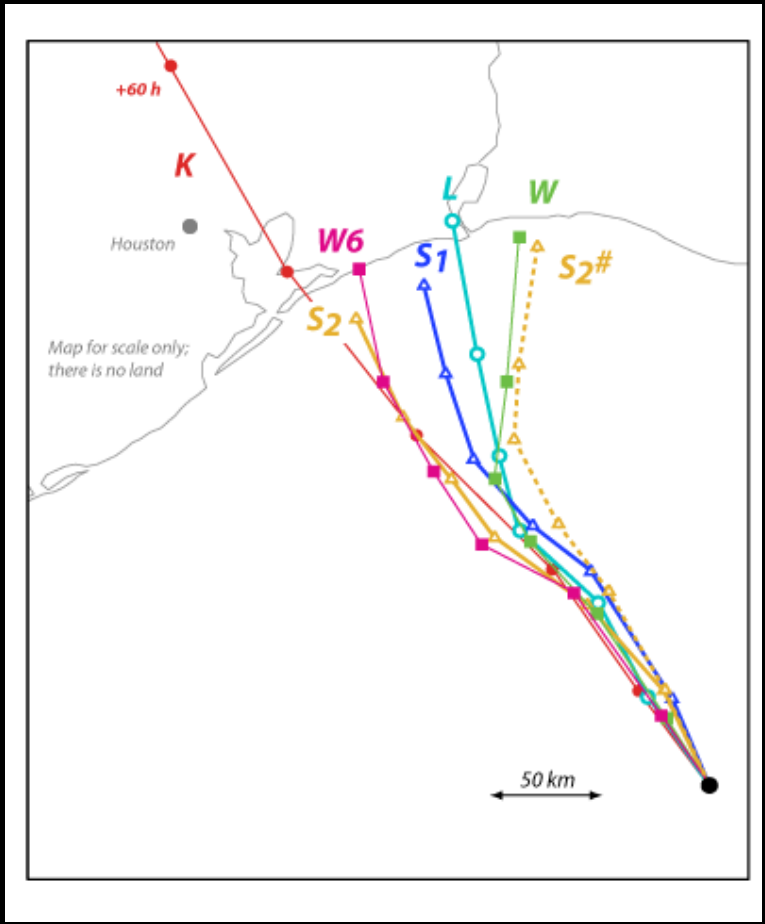
very small part of domain shown



- *Real-data* WRF-ARW @ 3 or 4 km
- 72 h
- Uniform SST
- No initial flow
- **NO LAND**
- 7 microphysics schemes
- **One initial condition**
- “bubble” initialization

Fovell et. al. (2009, JAS)
Fovell et al. (2010, GRL)

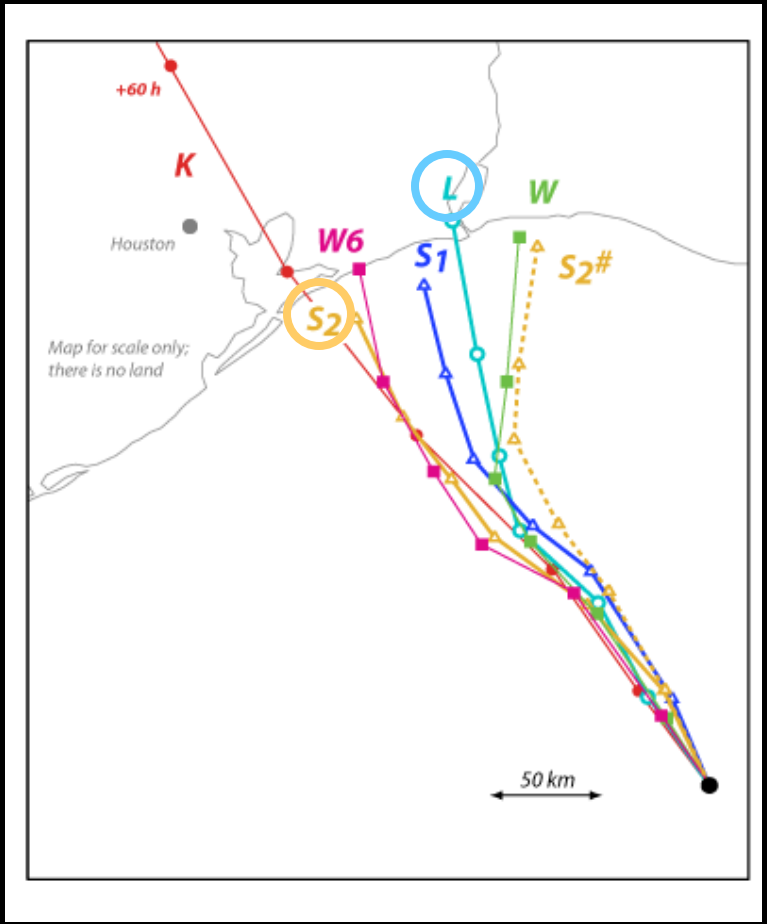
Semi-idealized TC tracks



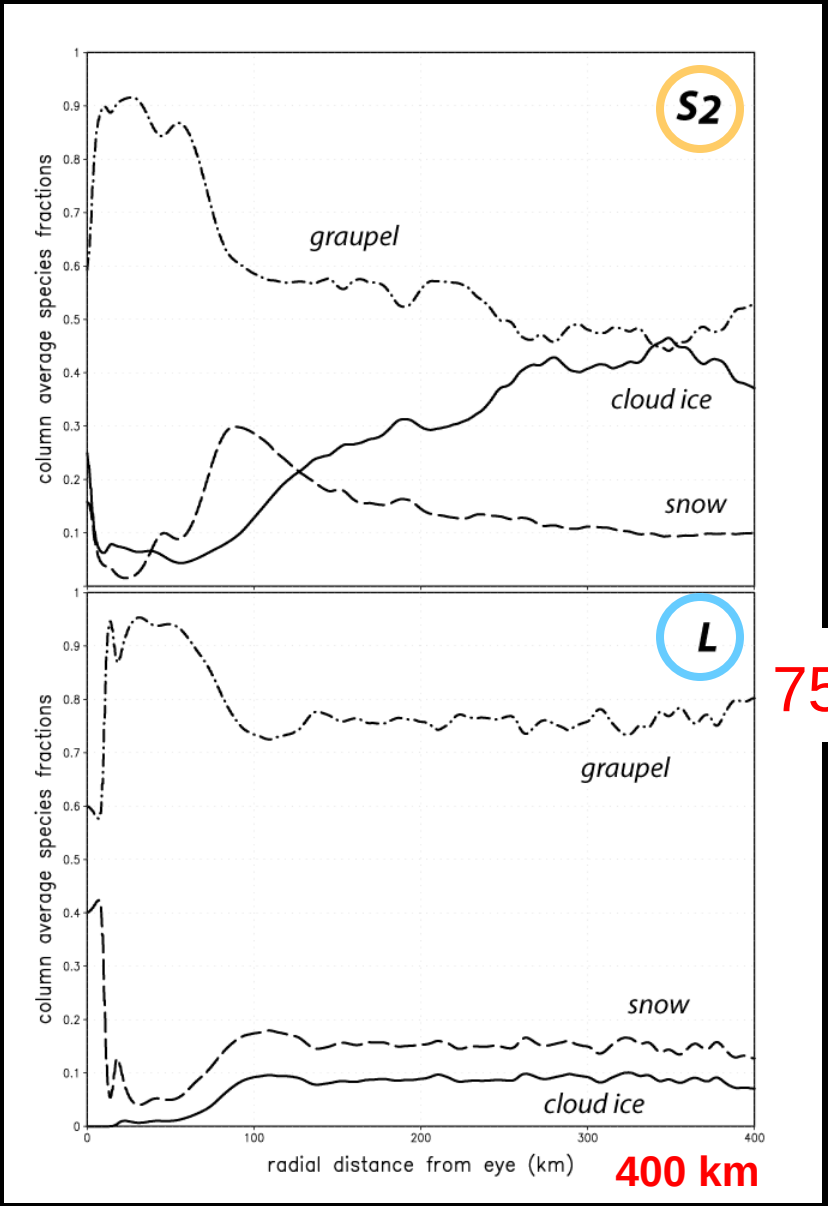
- MPs produce *different hydrometeor amounts, distributions*
  - L: 75% ice is graupel
  - S_2: significant cloud ice
- MPs result in different *symmetric* and *asymmetric* storm structures

Fovell et al. (2010, GRL)

Condensate fraction



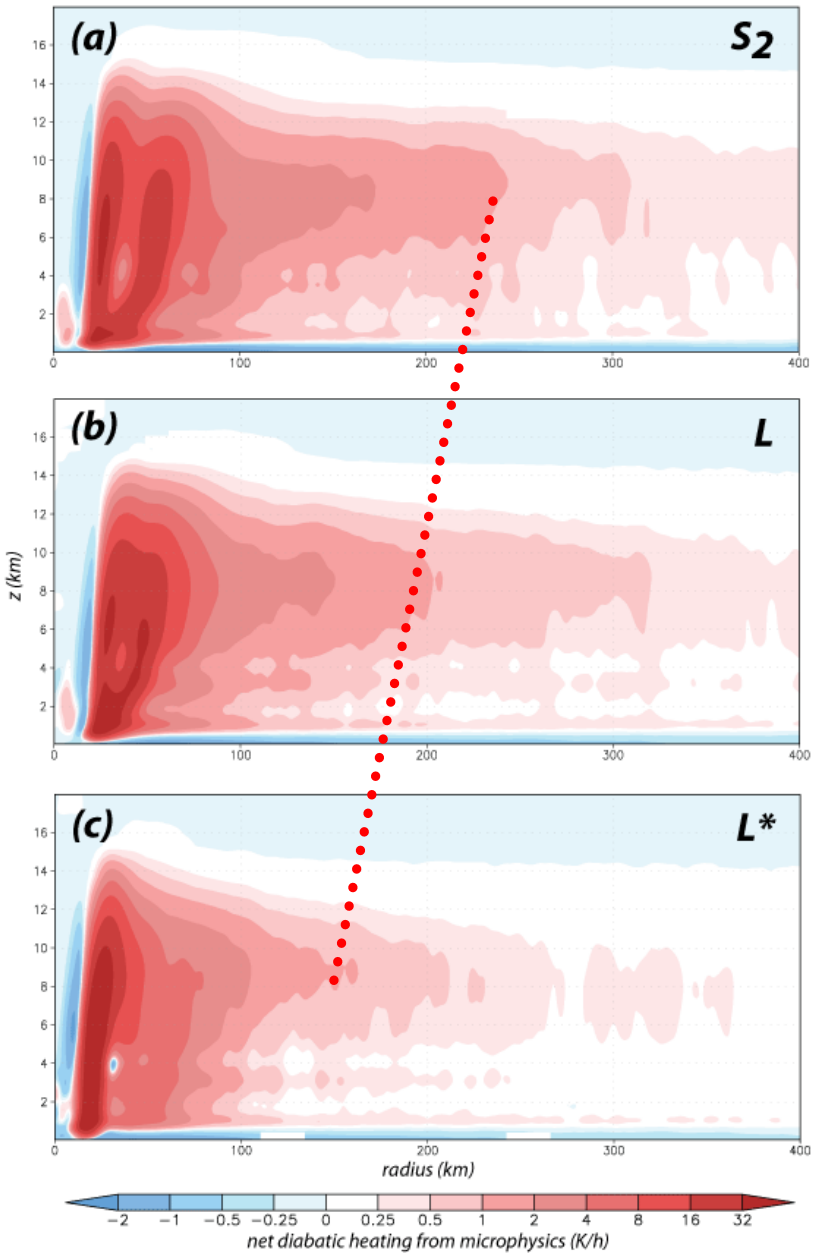
Fovell et al. (2010, GRL)



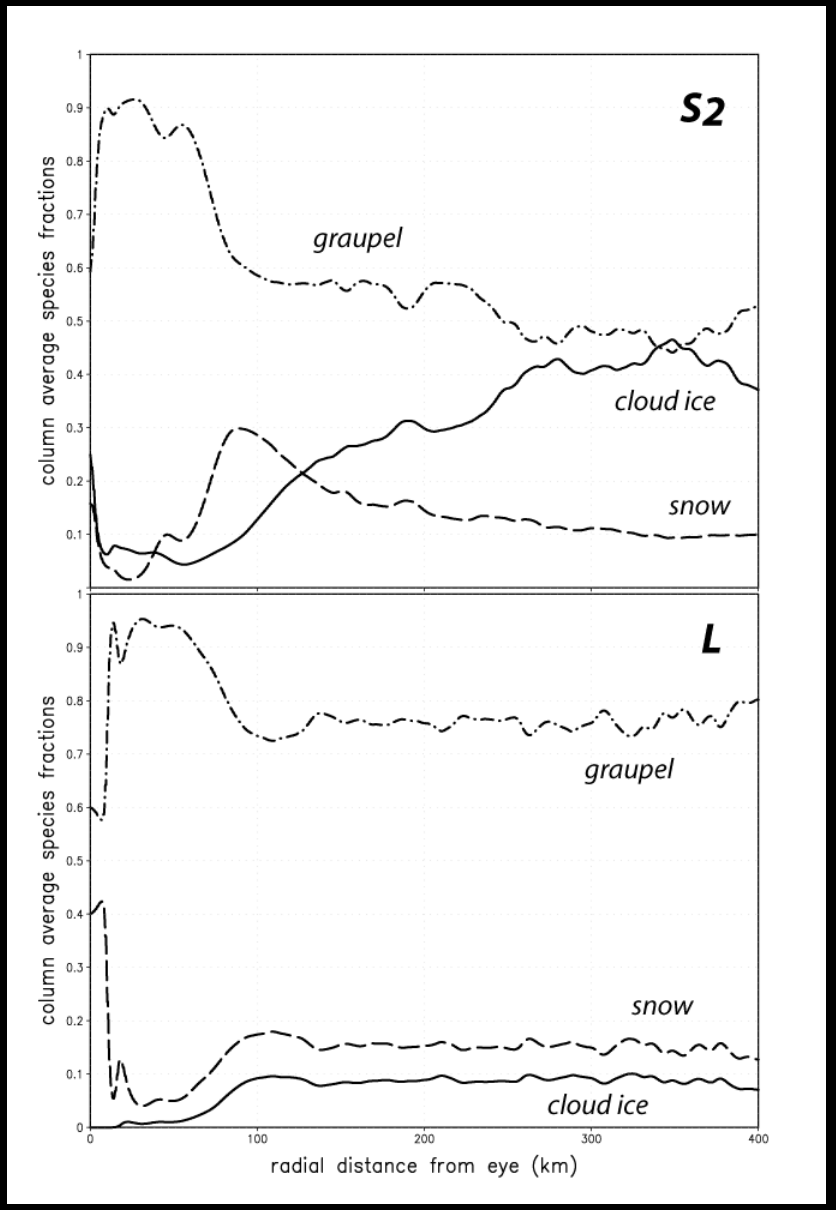
75%

Fovell et al. (2010, 29th H)

Diabatic heating

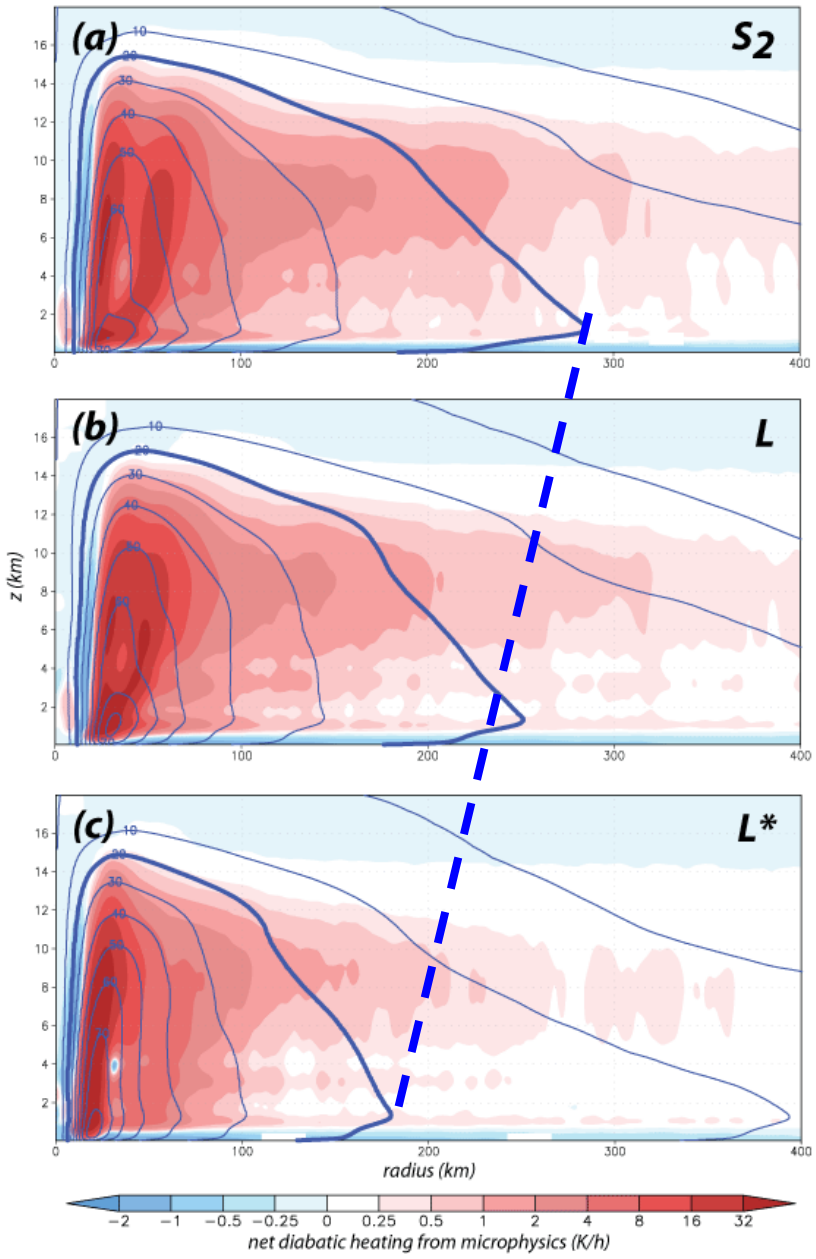


Condensate fraction

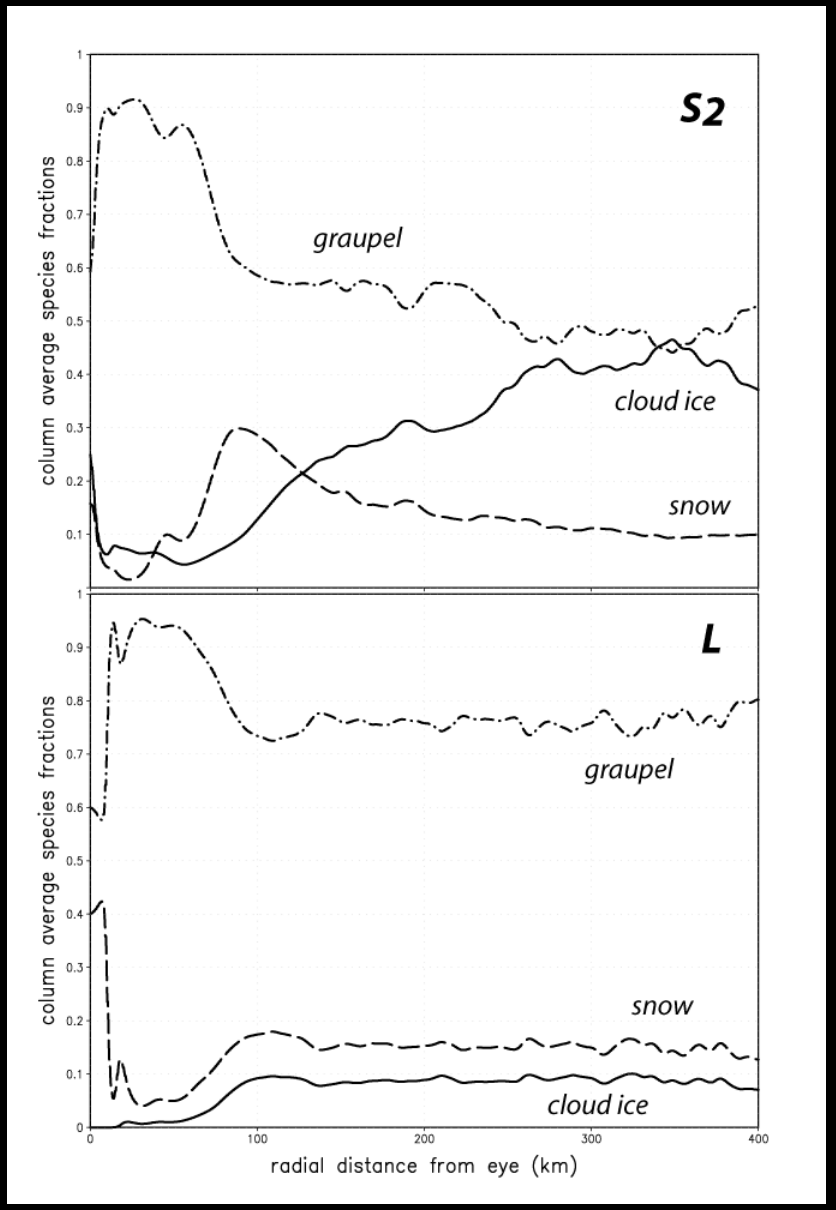


400 km x 18 km

Diabatic heating & tangential winds

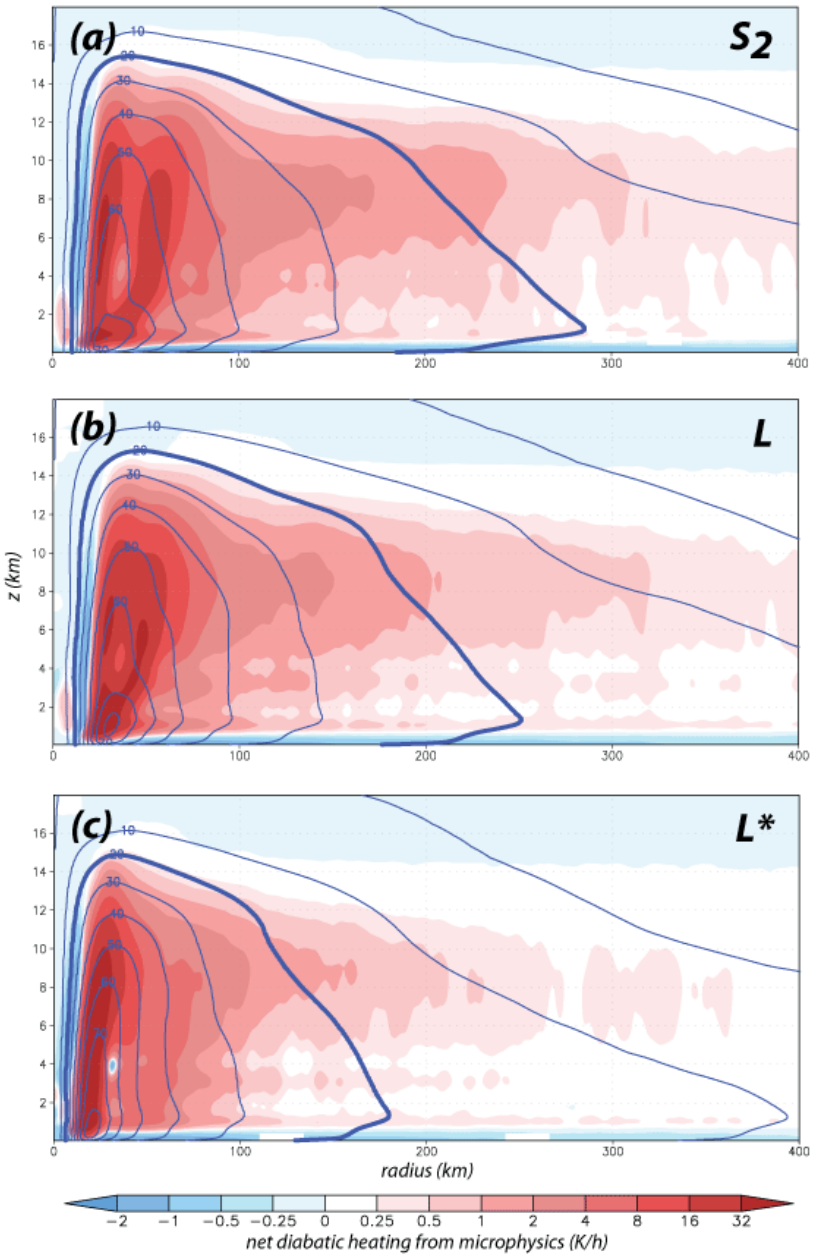


Condensate fraction

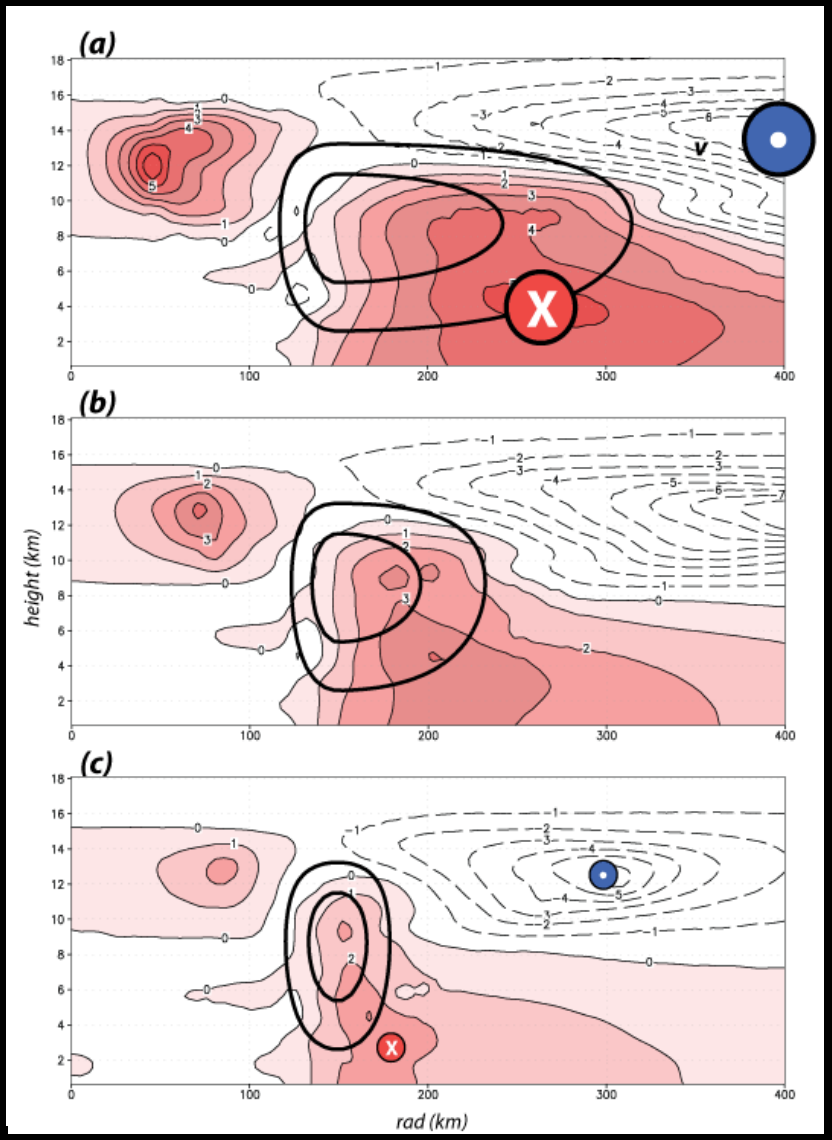


400 km x 18 km

Diabatic heating & tangential winds



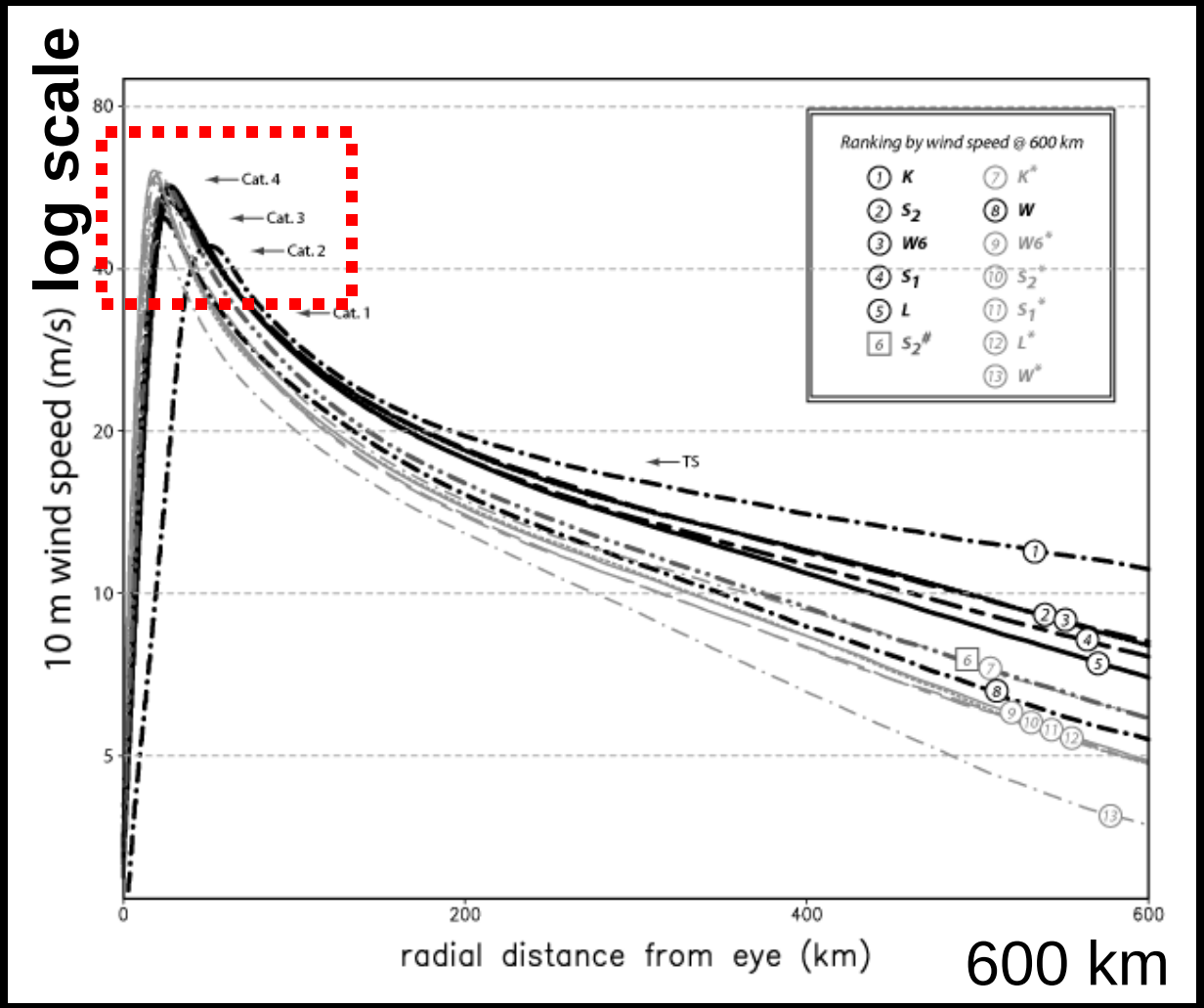
400 km x 18 km



Dry axisymmetric model response to outer-core heating

10 m wind:

time-averaged symmetric component

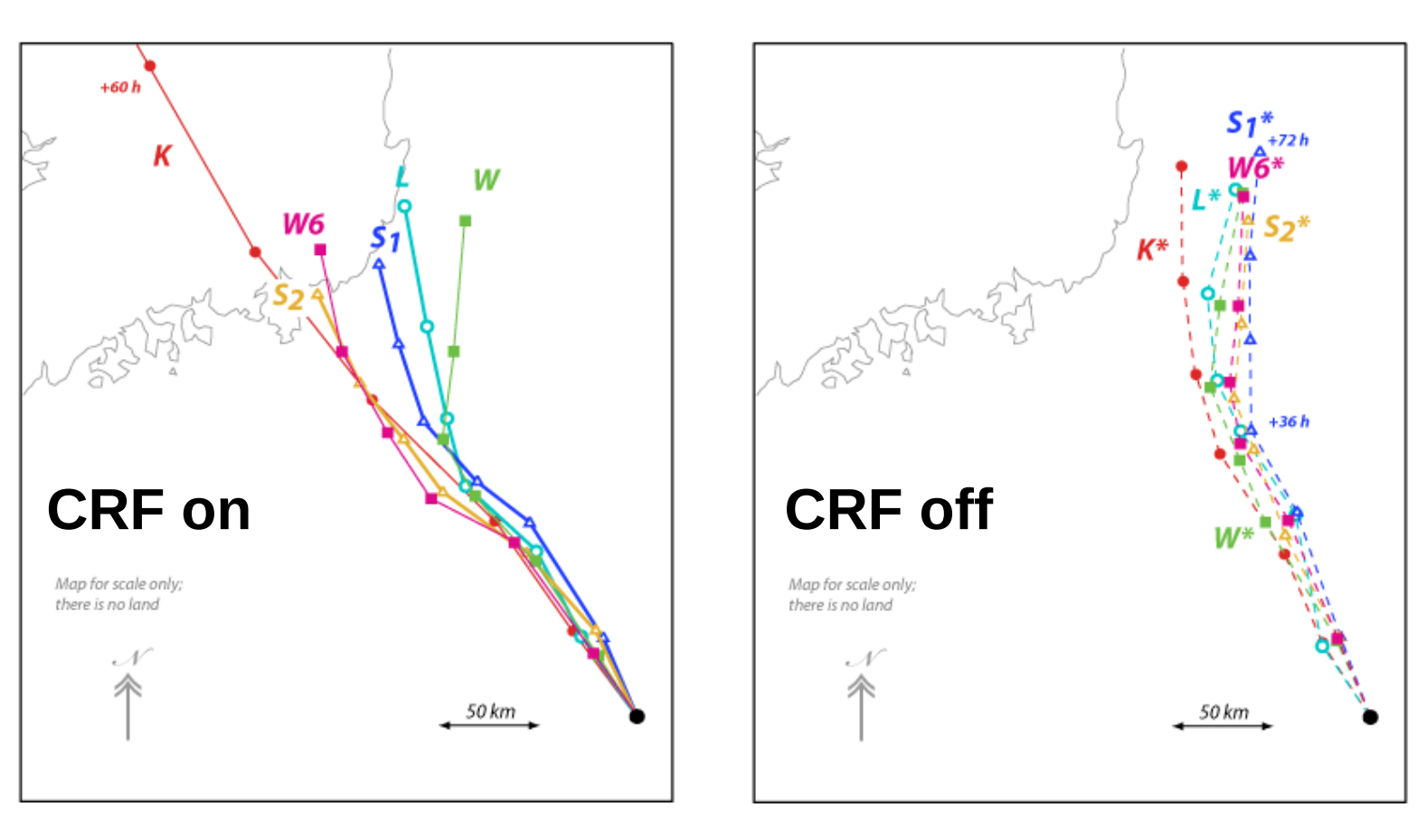


One model
One initial condition

One consequence: storms will have different beta drifts (cf. Chan and Williams 1987)

Fovell et al. (2010, 29th H)

Influence of cloud-radiative feedback (CRF)



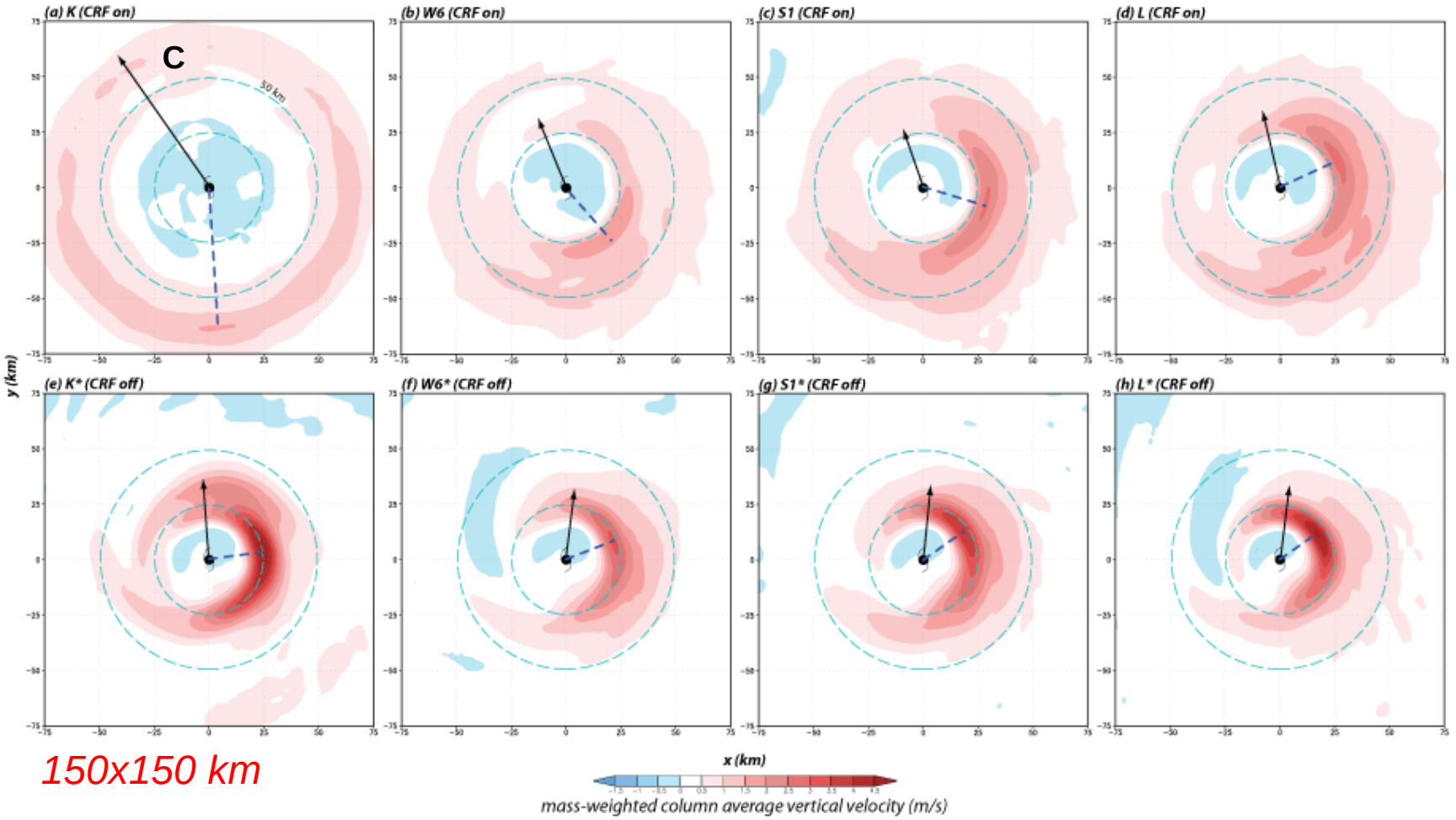
Fovell et al. (2010, GRL)

Fovell et al. (2010, GRL)

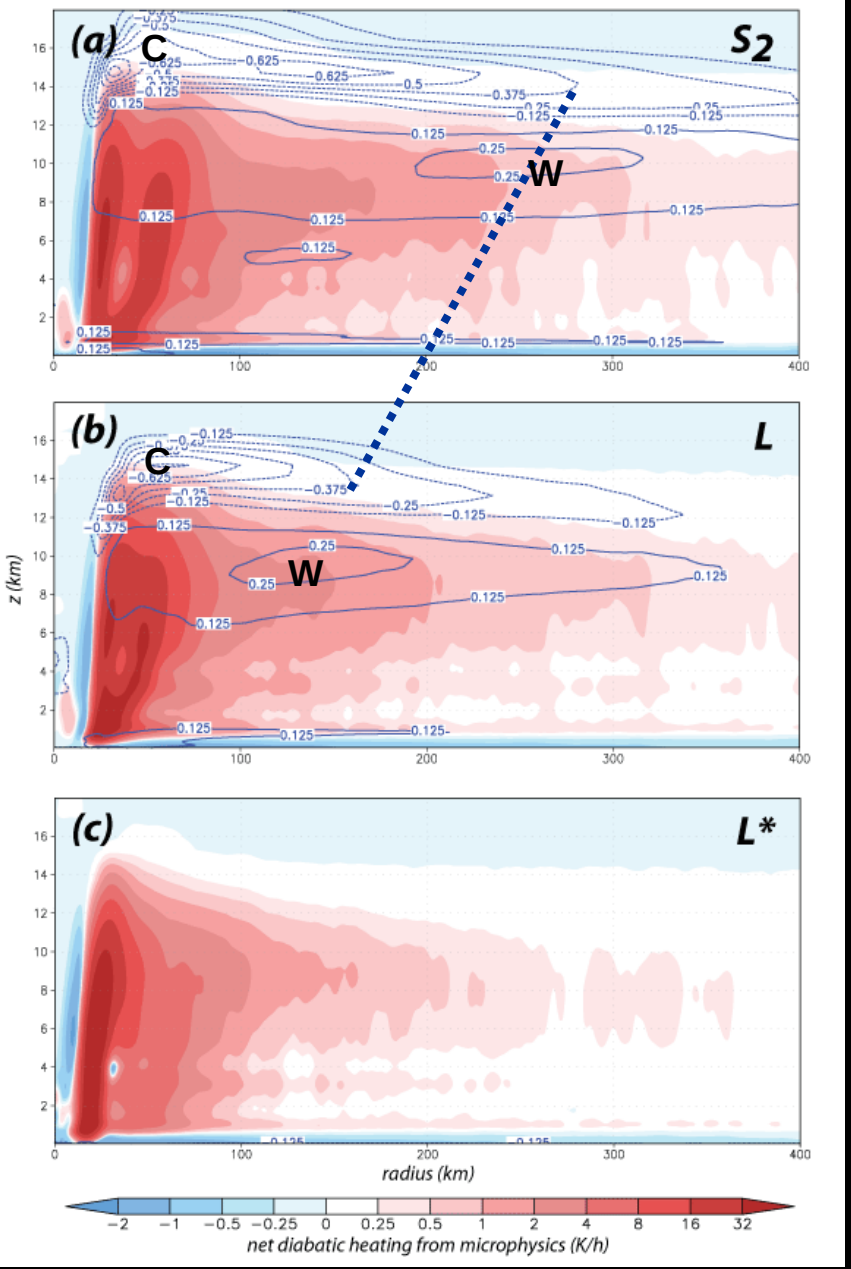
Average vertical velocity

CRF ON

CRF OFF



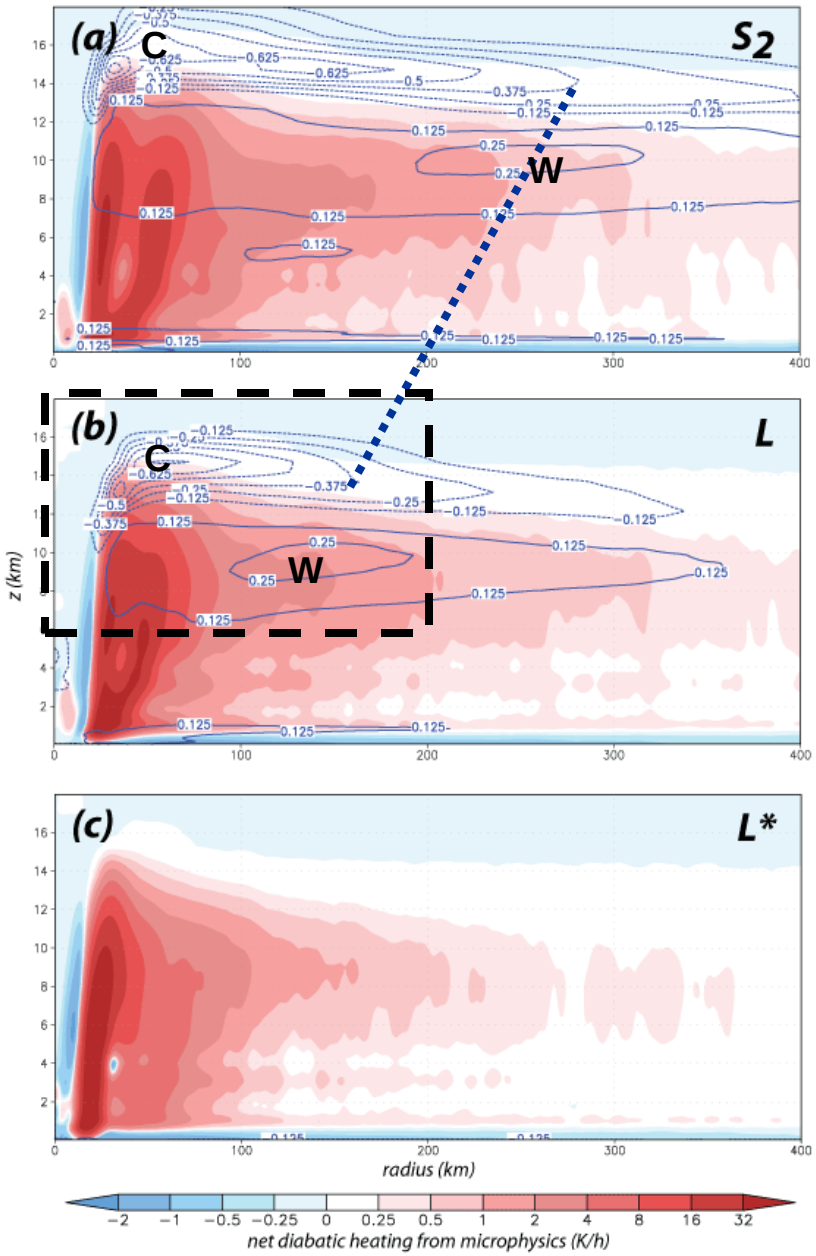
Diabatic heating & radiative forcing



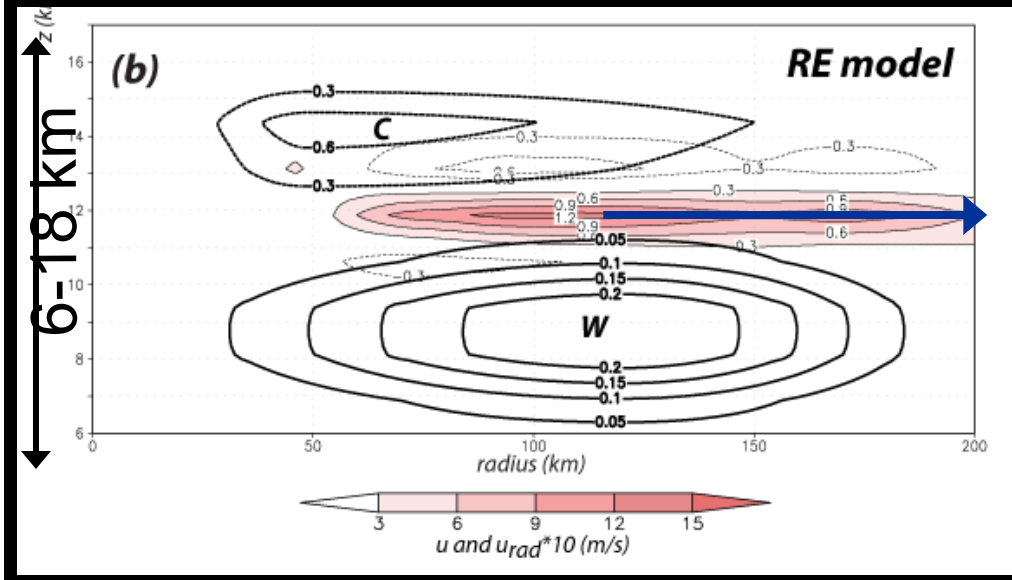
400 km x 18 km

Fovell et al. (2010, 29th H)

Diabatic heating & radiative forcing



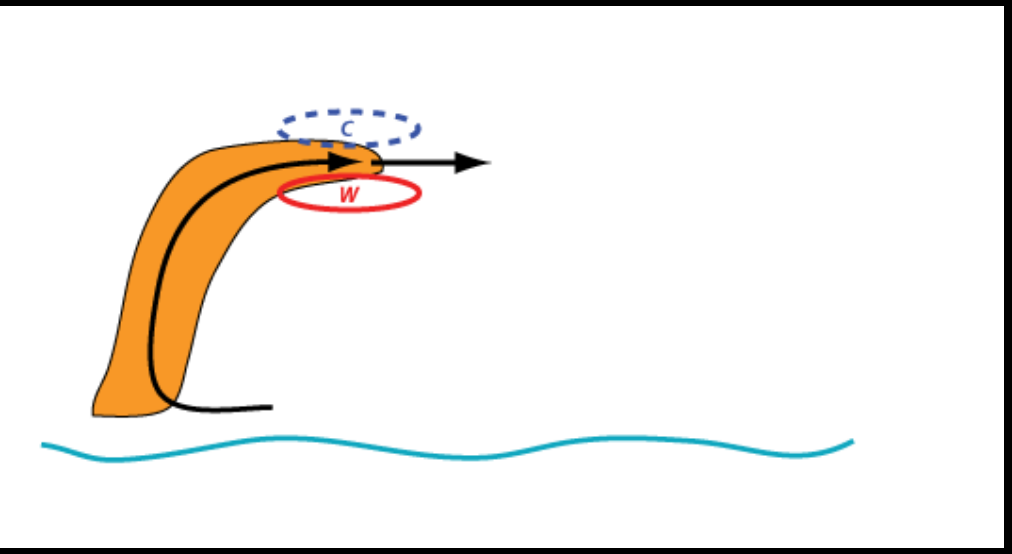
Dry axisymmetric model response to dipolar radiative forcing

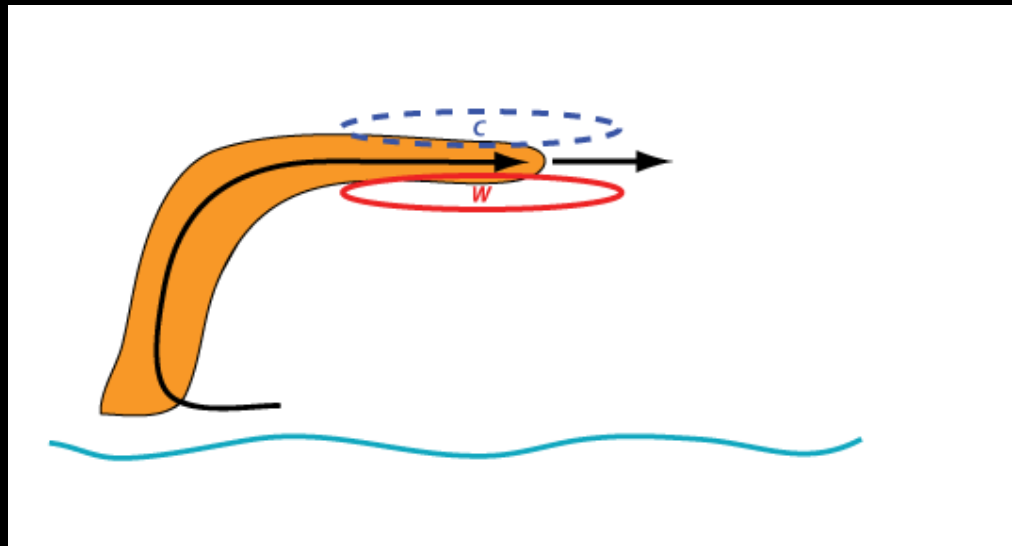


400 km x 18 km

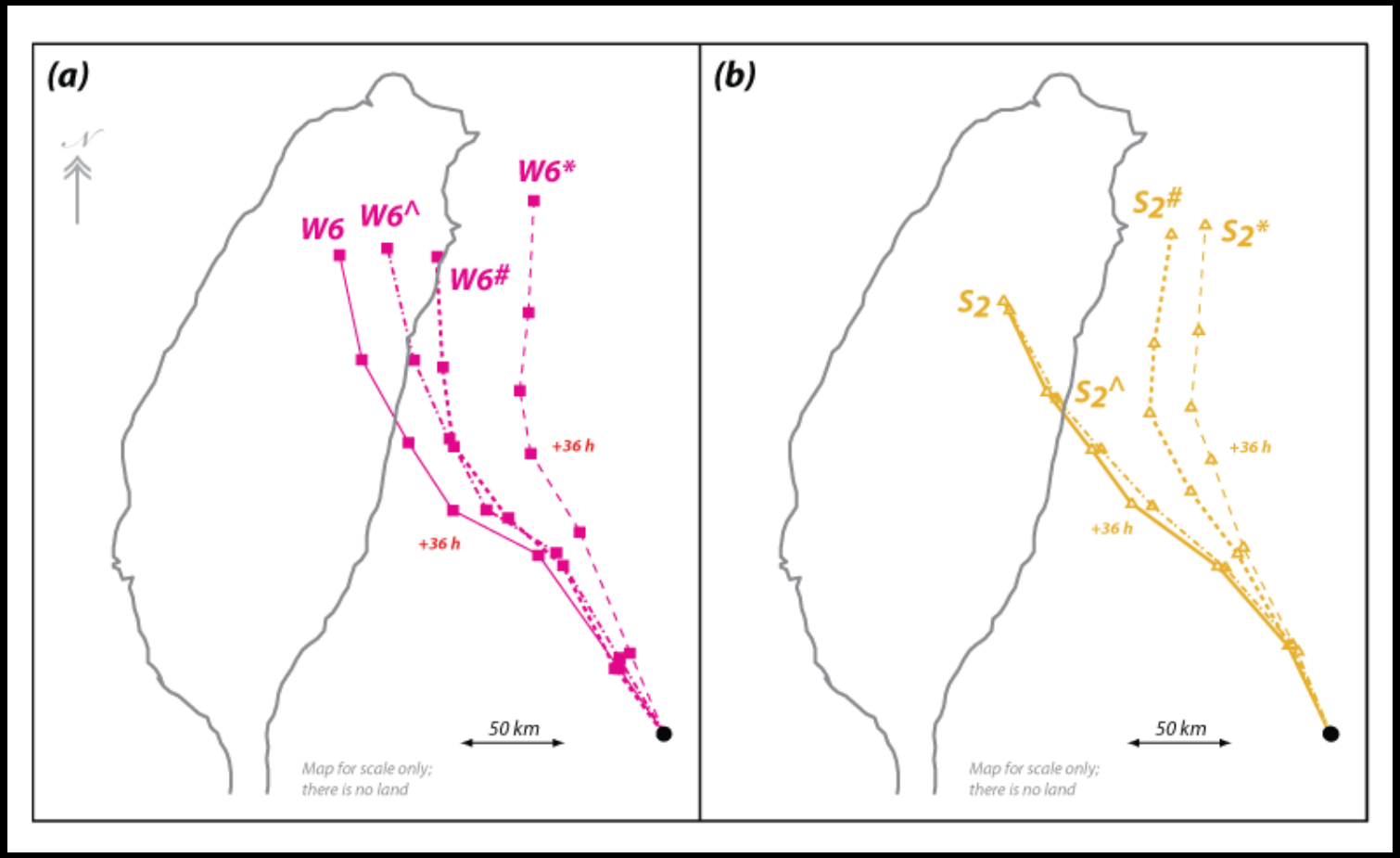
Fovell et al. (2010, 29th H)

Anvil self-expansion



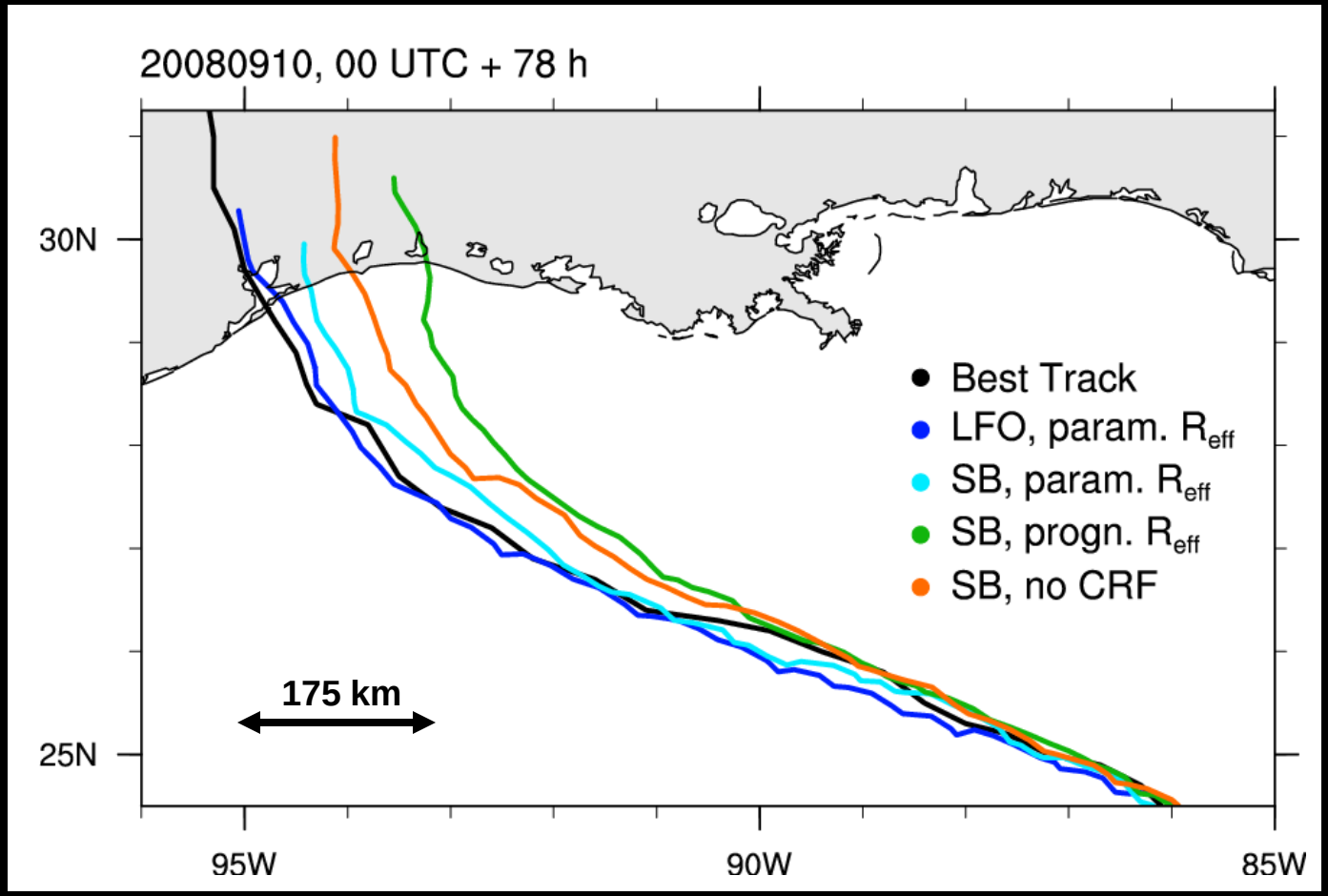


CRF manipulations



Fovell et al. (2010, GRL)

CRF influence on Hurricane Ike (2008) hindcast



Operational COSMO model (German Weather Service)

7 km resolution

Courtesy of Axel Seifert, German Weather Service

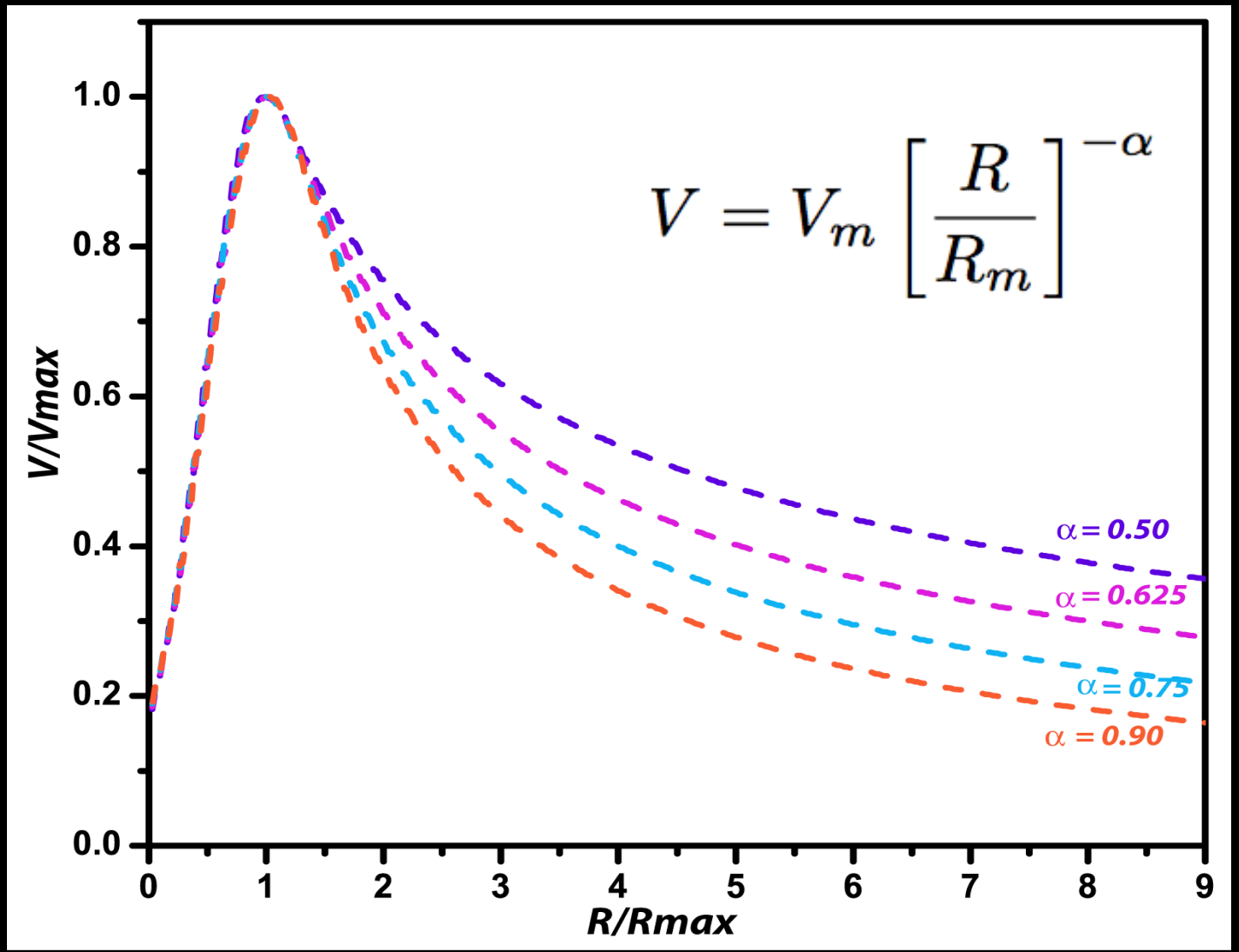
Model physics vs. model initialization

Cao et al. (2011, TAO Morakot issue)

Yang Cao (2011, MS thesis)

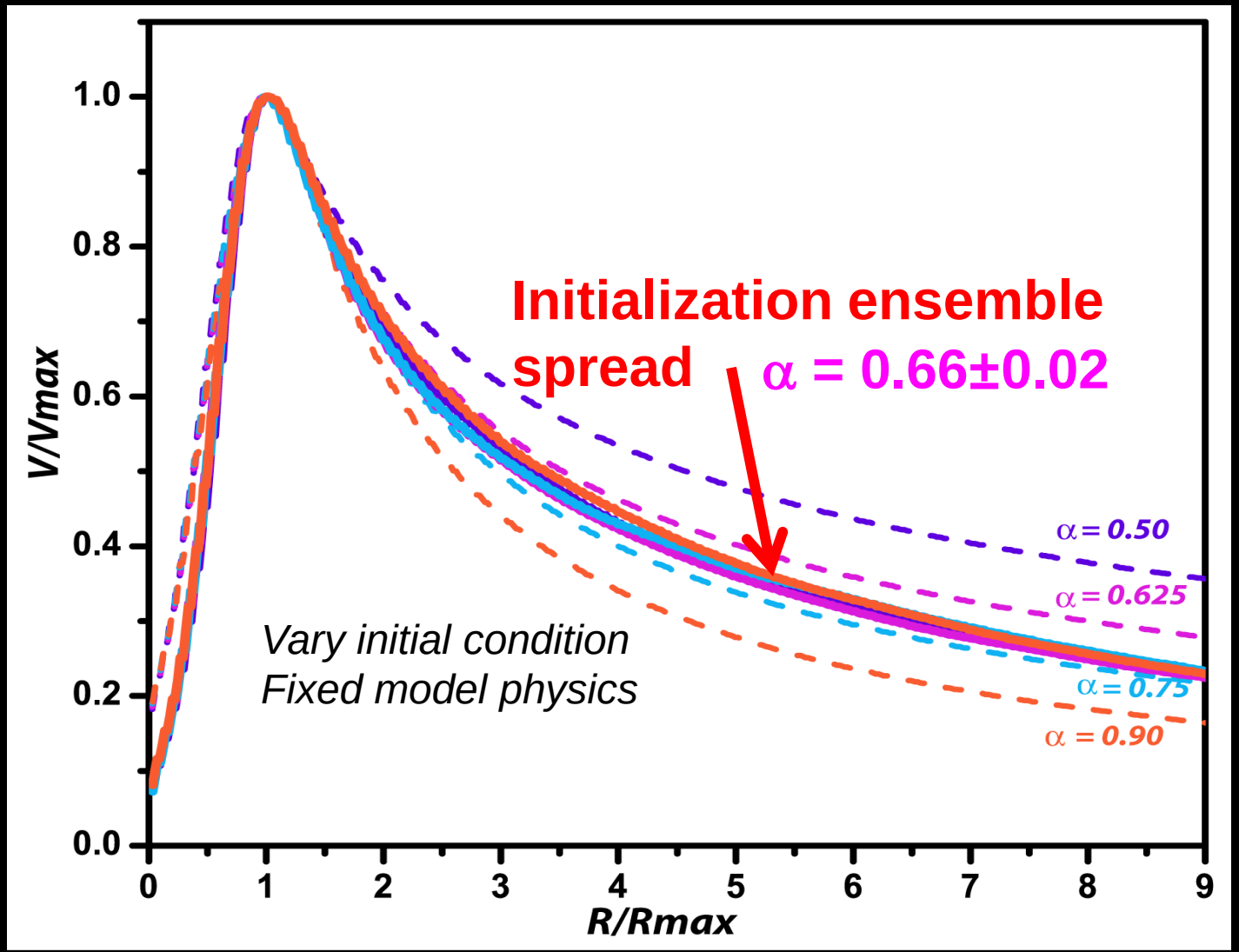
Cao et al. (2011)

Normalized initial wind profiles
(bogussed TCs)



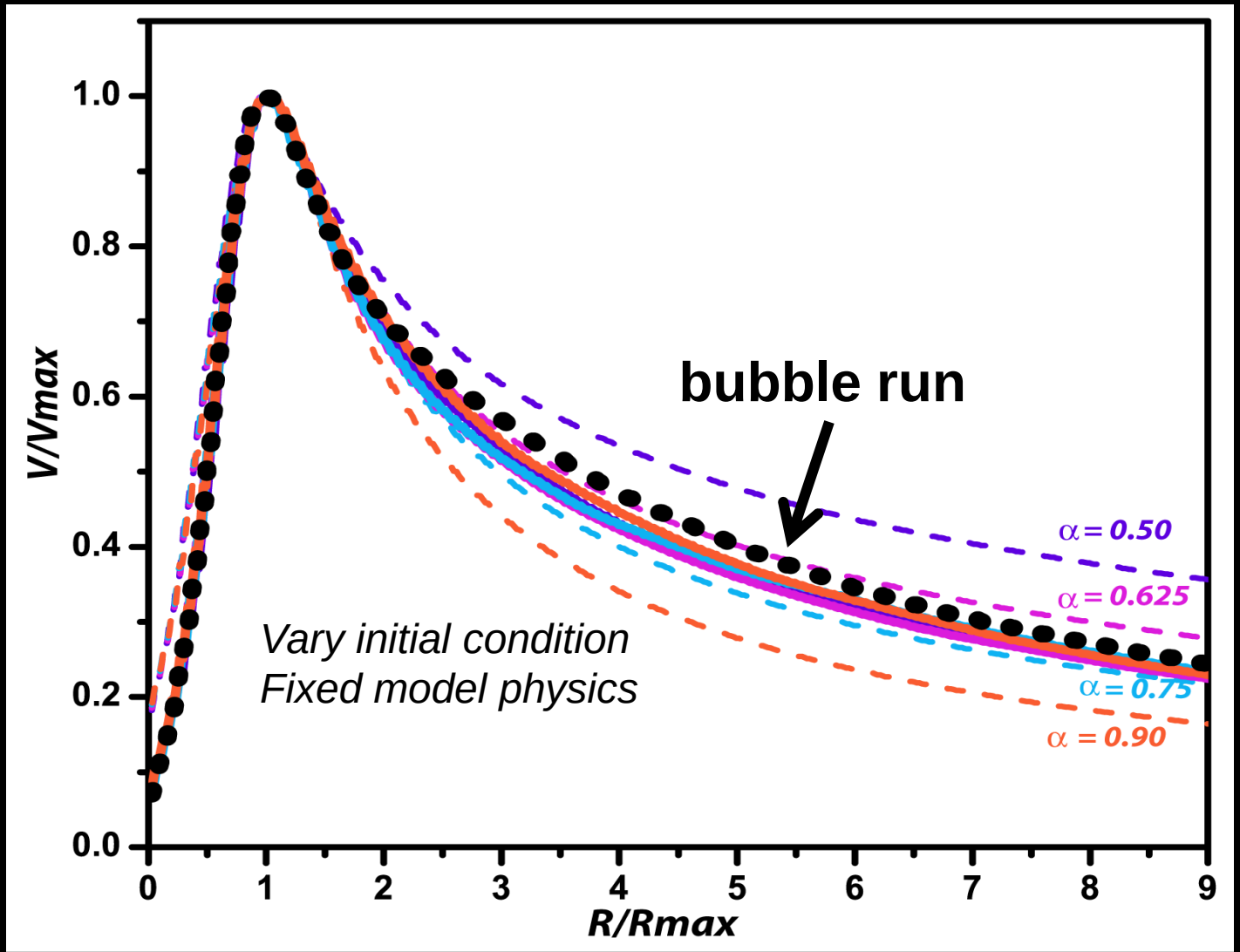
Cao et al. (2011)

Normalized final wind profiles

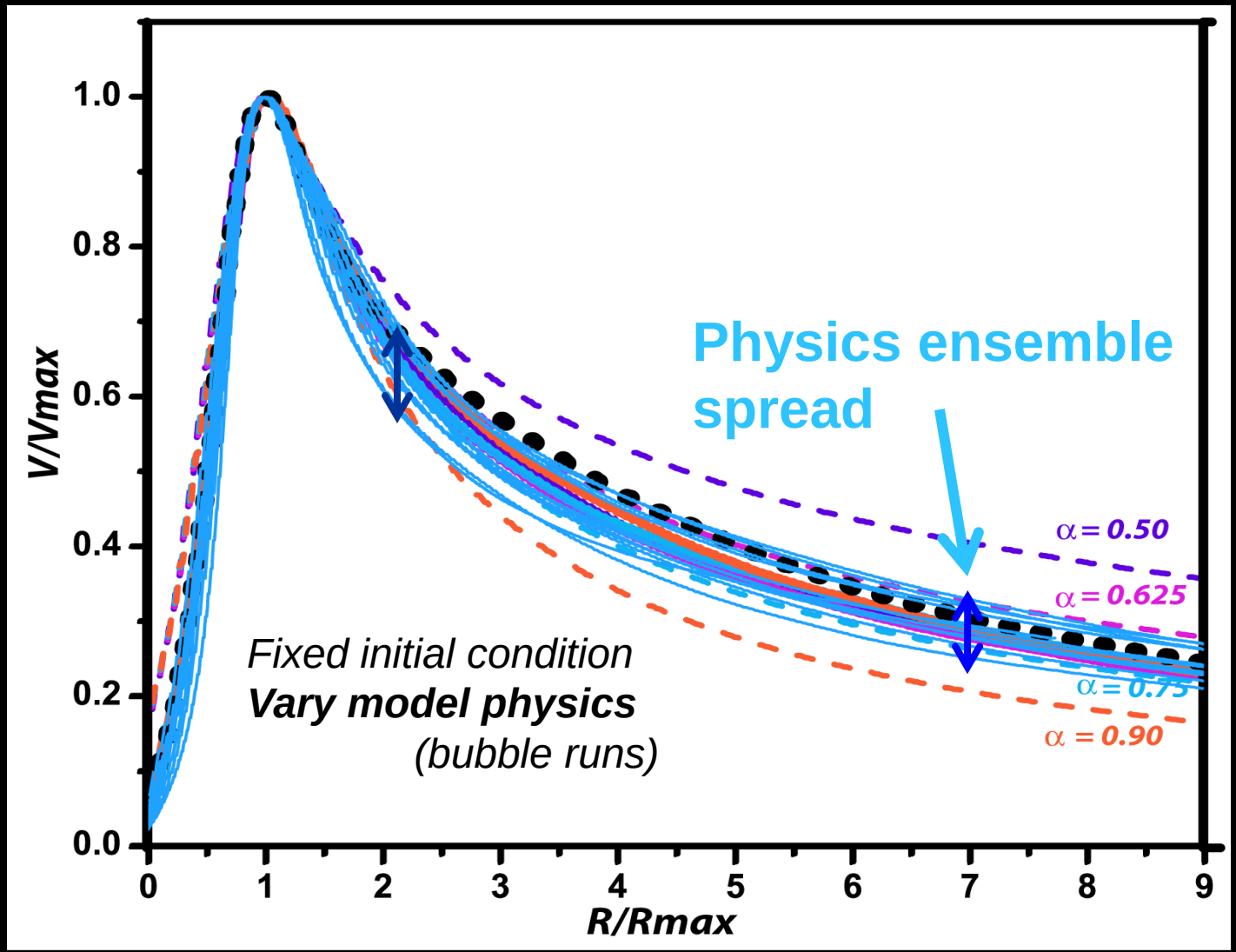


Cao et al. (2011)

Normalized final wind profiles
(with bubble run)



Normalized final wind profiles
(varying model physics)



PV tendency analysis

$$\frac{\partial PV}{\partial t} = \Lambda_1 \left[HA + VA + DH + R \right]$$

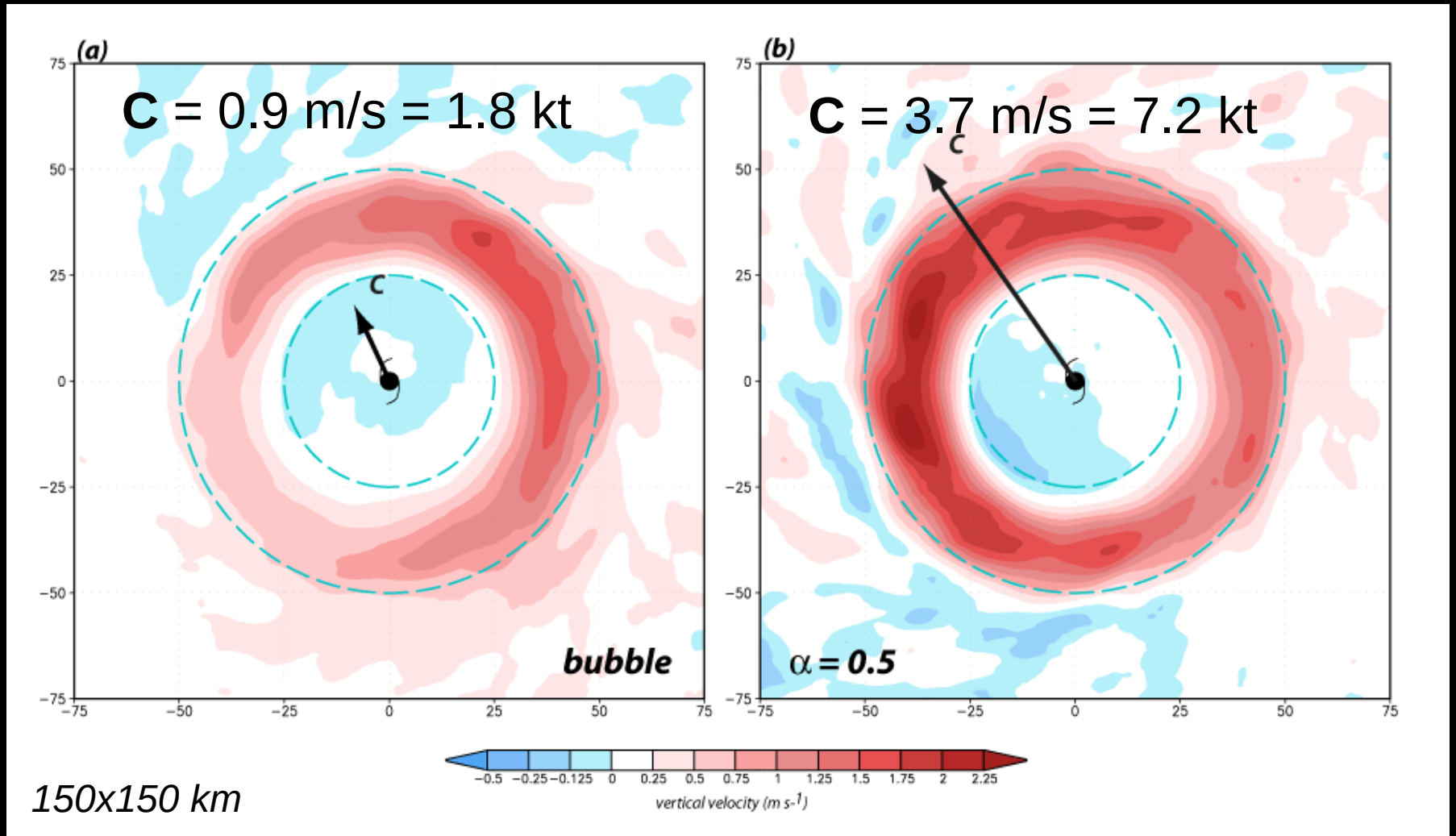
$$= \Lambda_1 \left[HA + DH* \right]$$

HA = horizontal advection
VA = vertical advection
DH = diabatic heating term
Λ_1 extracts wavenumber 1 component

Cao et al. (2011)

Asymmetry differences

lower tropospheric average vertical velocity



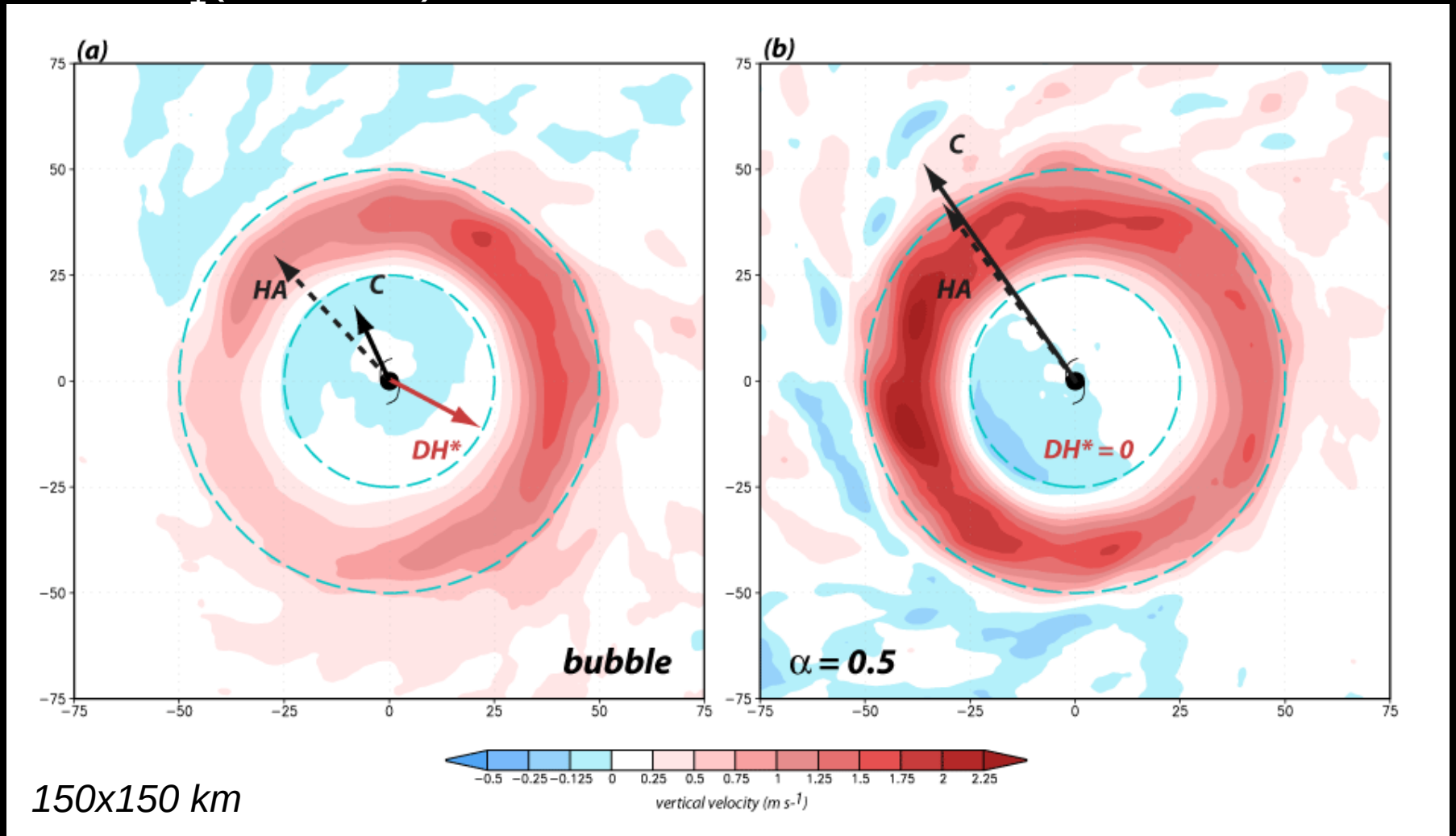
150x150 km

Cao et al. (2011)

Asymmetry differences

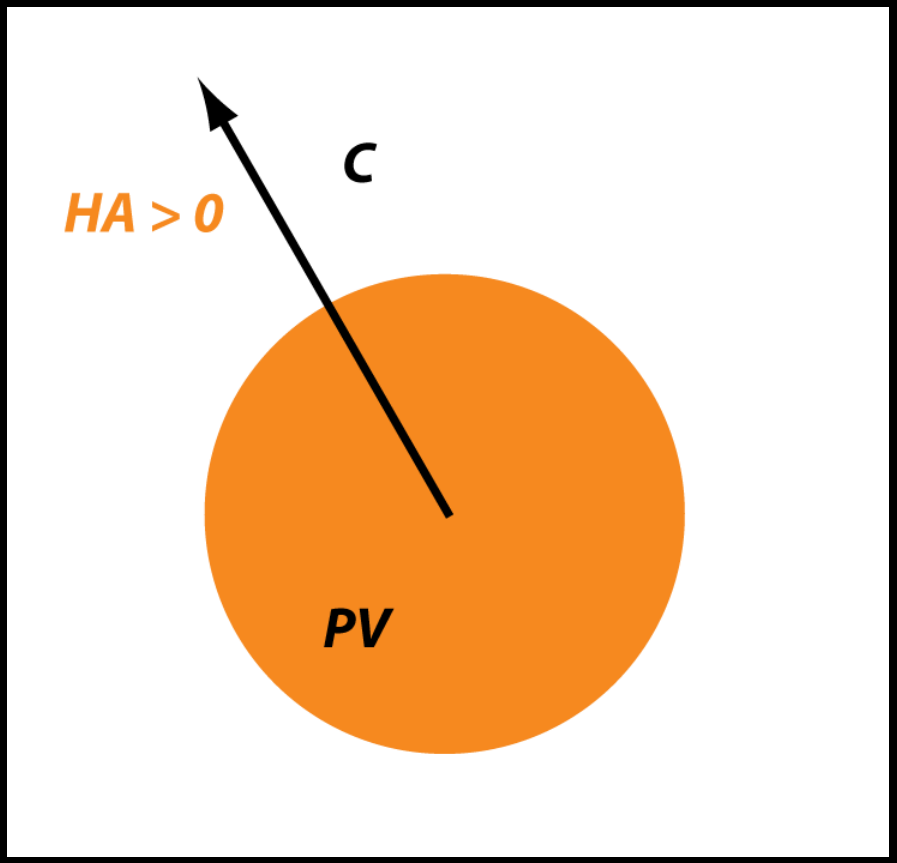
lower tropospheric average vertical velocity

PVT ~ Λ_1(HA+DH*)

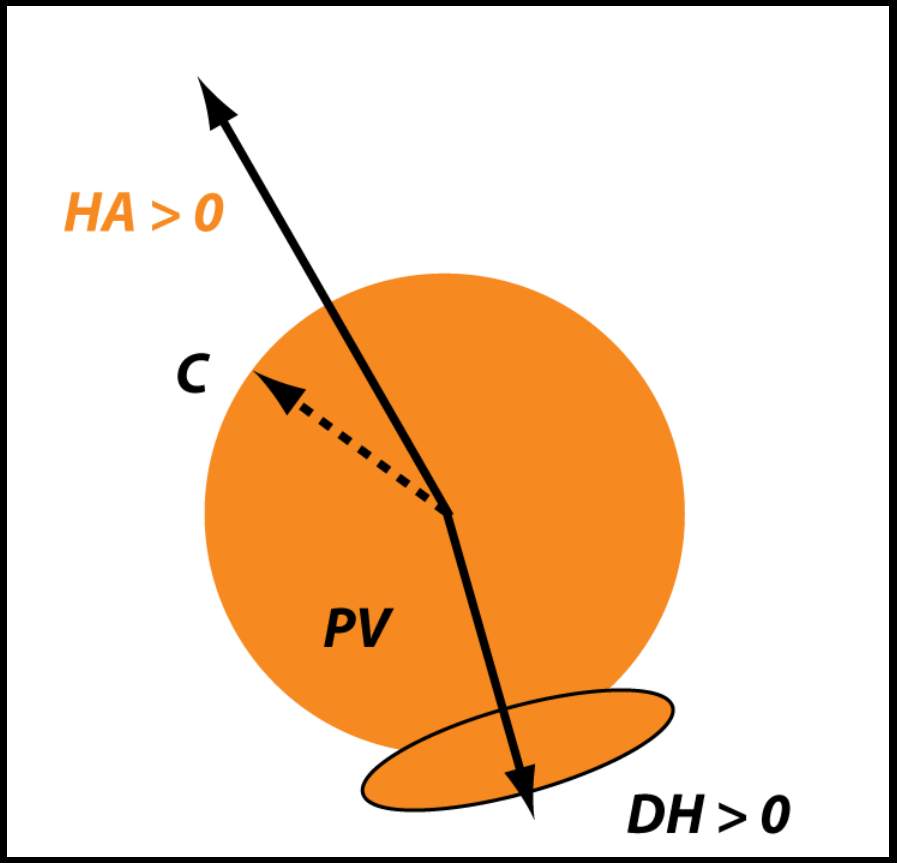


150x150 km

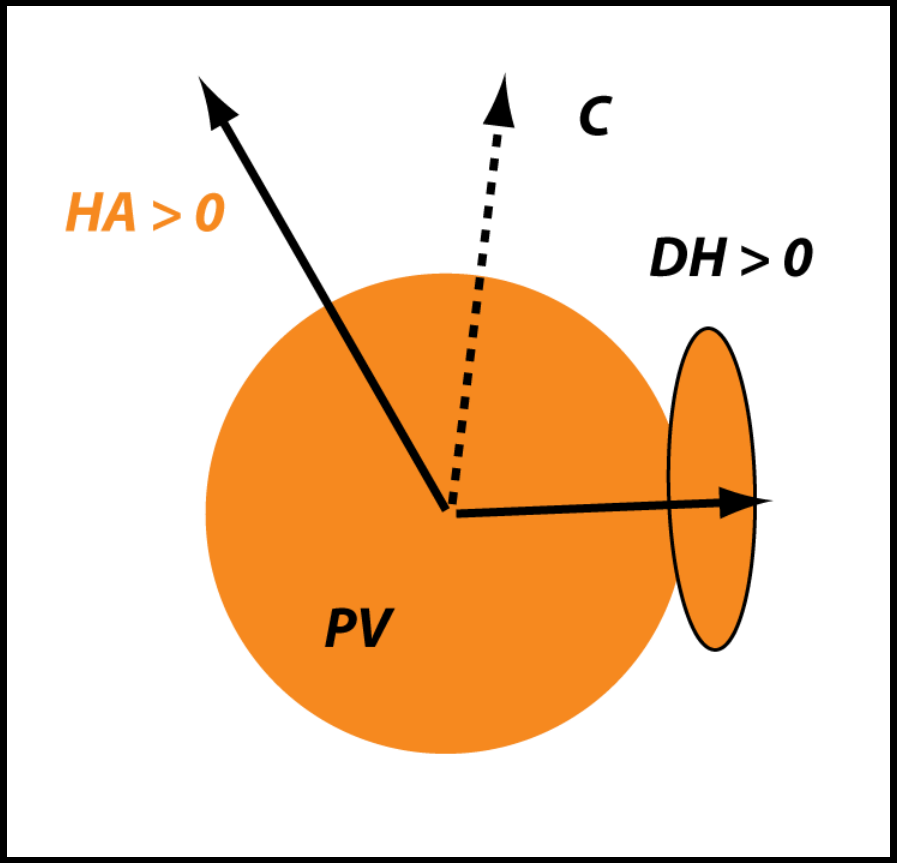
PV advection by ventilation flow (beta gyres)



PV advection by ventilation flow (beta gyres)

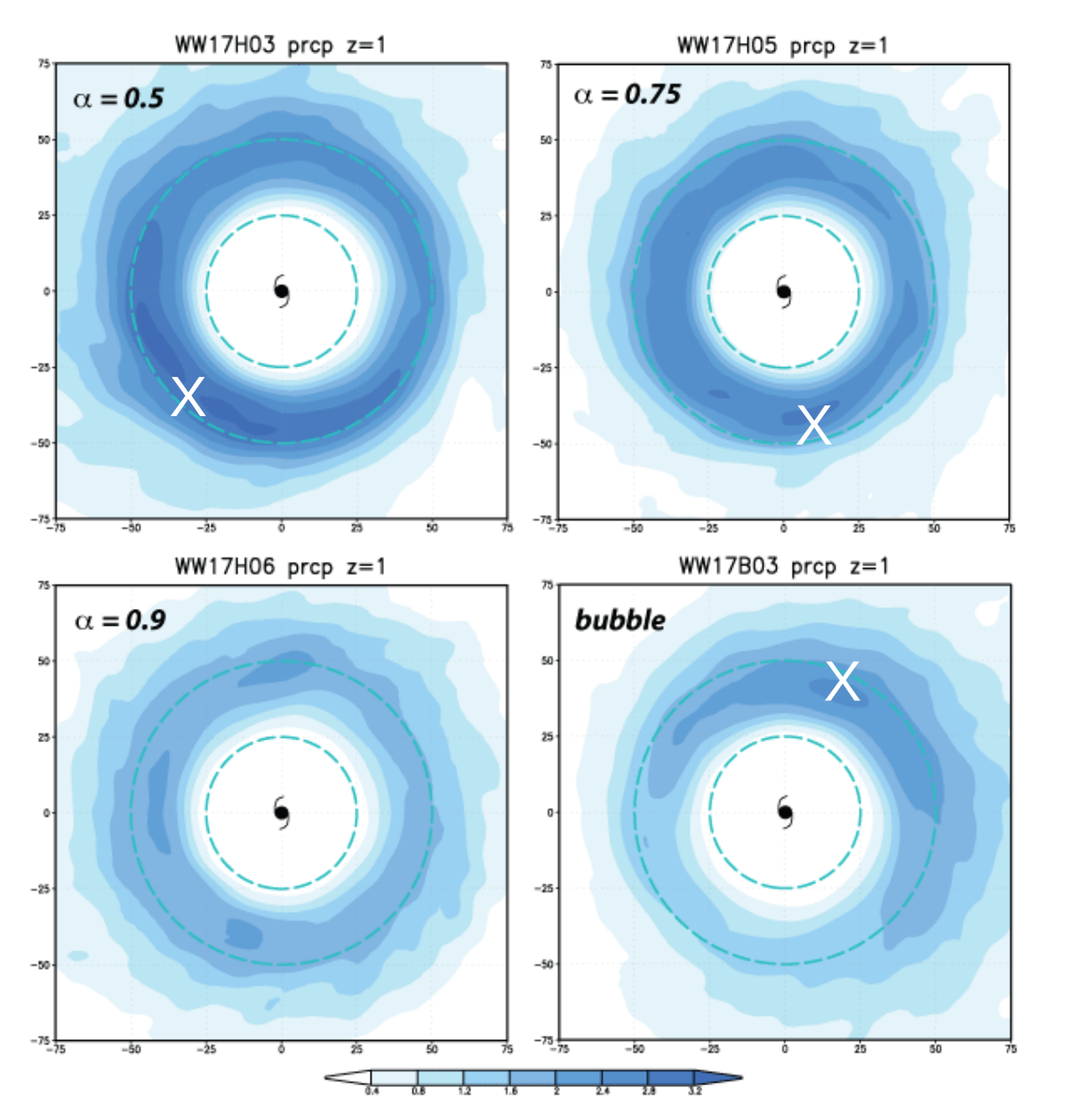


PV advection by ventilation flow (beta gyres)



- Only the *asymmetric* component of heating influences motion…

Rainfall patterns



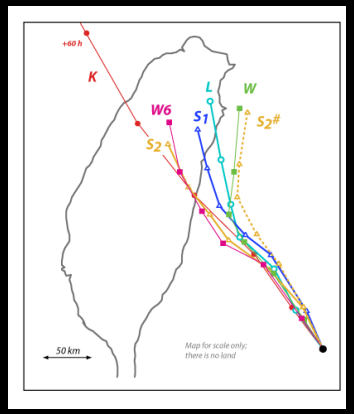
150x150 km

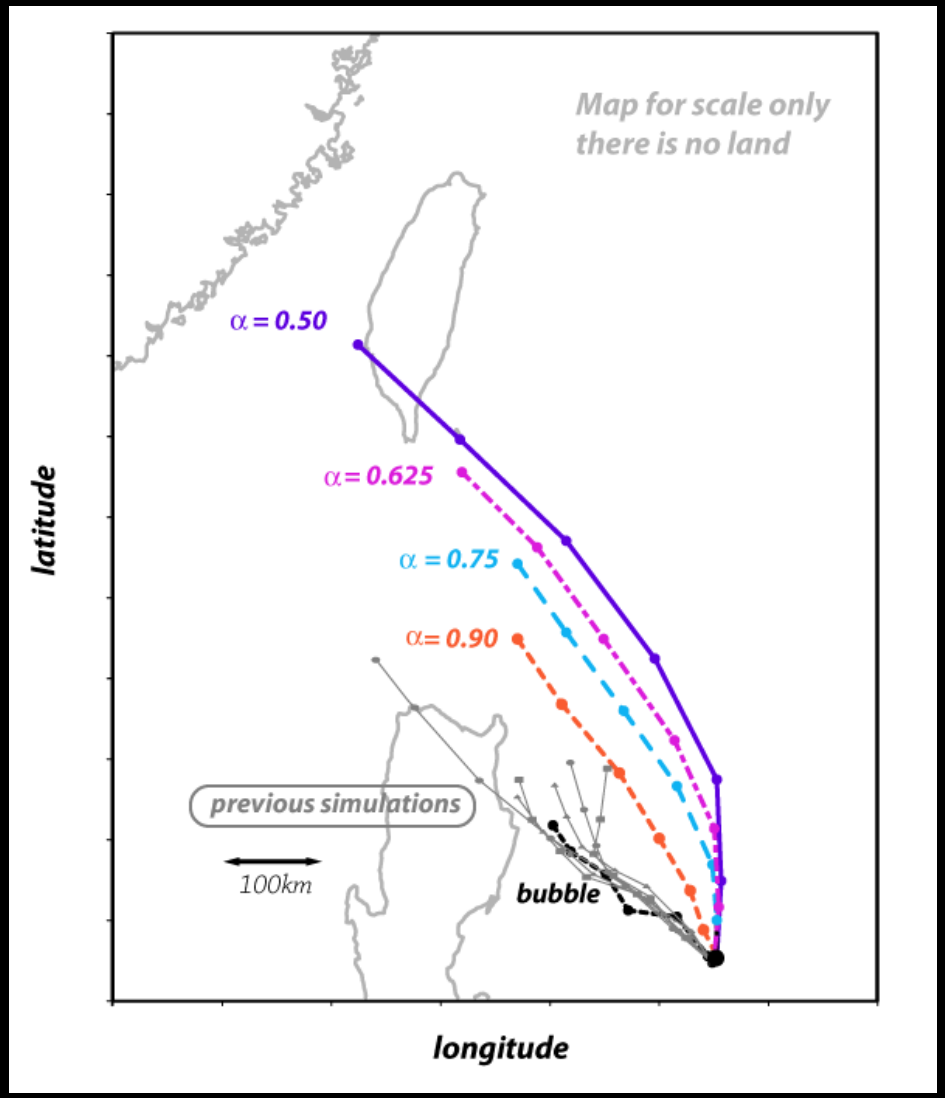
Summary

- Model physics (relating to convection) influences hurricane track and structure (and intensity)
- Cloud-radiation feedback worthy of closer examination (in real-data and semi-idealized frameworks)
- Structural variations (symmetric wind profiles, asymmetries) may provide clues for physics selection, tuning

Cao et al. (2011)

Semi-idealized tracks





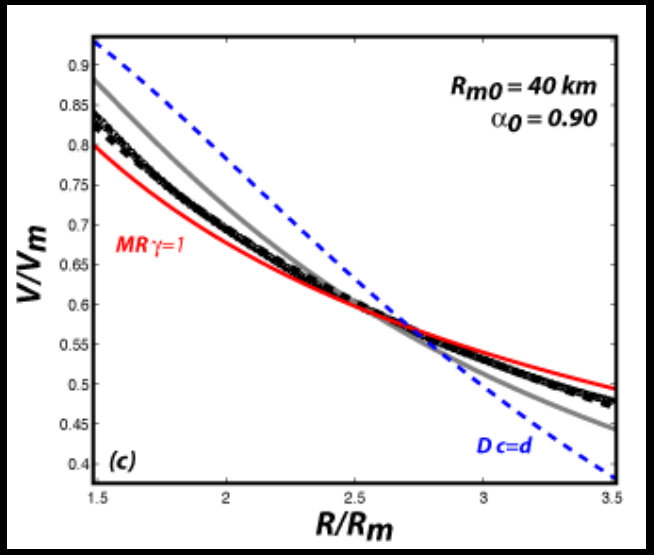
3 km moving nest

NO LAND

Fixed model physics

Vary initial vortex

Inner region ($1.5 \leq R/R_m \leq 3.5$)



- Mallen et al. (2005): $0.2 \leq \alpha \leq 0.7$, mean 0.5 in *near core*
- Modified Rankine (MR) fits better after adjustment ($\gamma \sim 1.06$)
- DeMaria (1987) profile fits best (if c ≠ d)

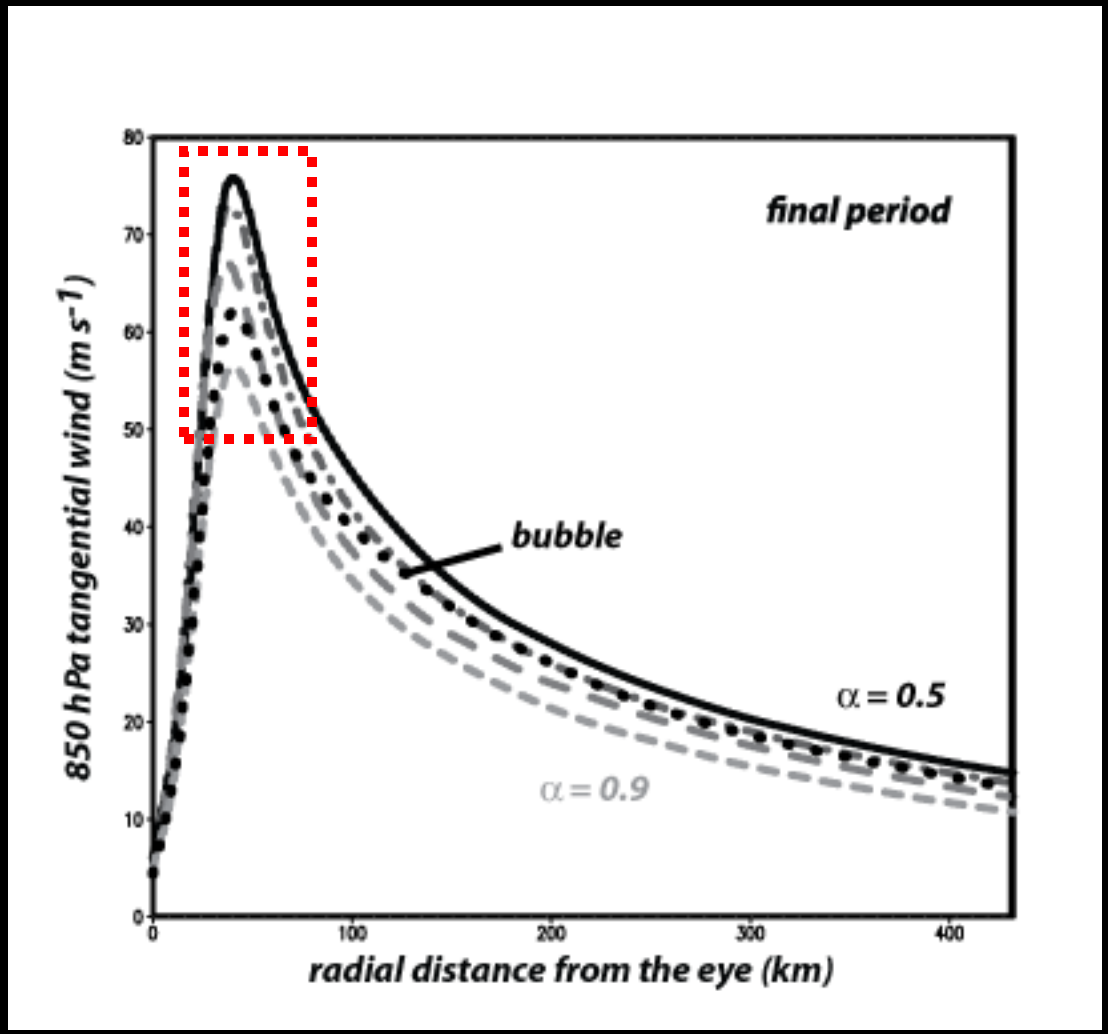
Modified Rankine

$$\frac{V}{V_m} = \gamma \left[\frac{R}{R_m}\right]^{-\alpha}$$

DeMaria (1987)

$$\frac{V}{V_m} = \left(\frac{R}{R_m}\right) \exp\left\{\frac{1}{d}\left[1 - \left(\frac{R}{R_m}\right)^{c}\right]\right\}$$

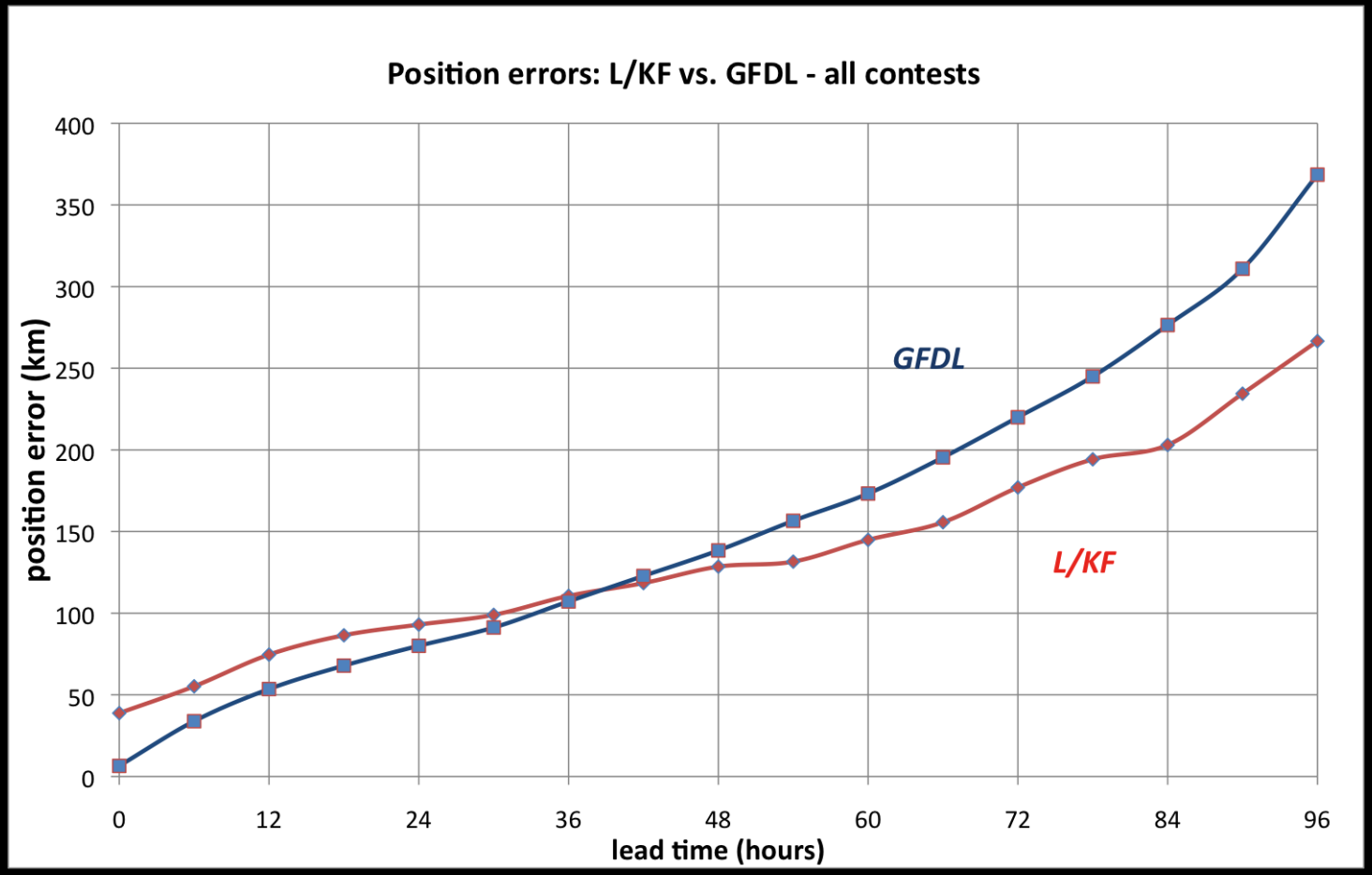
Unnormalized final wind profiles

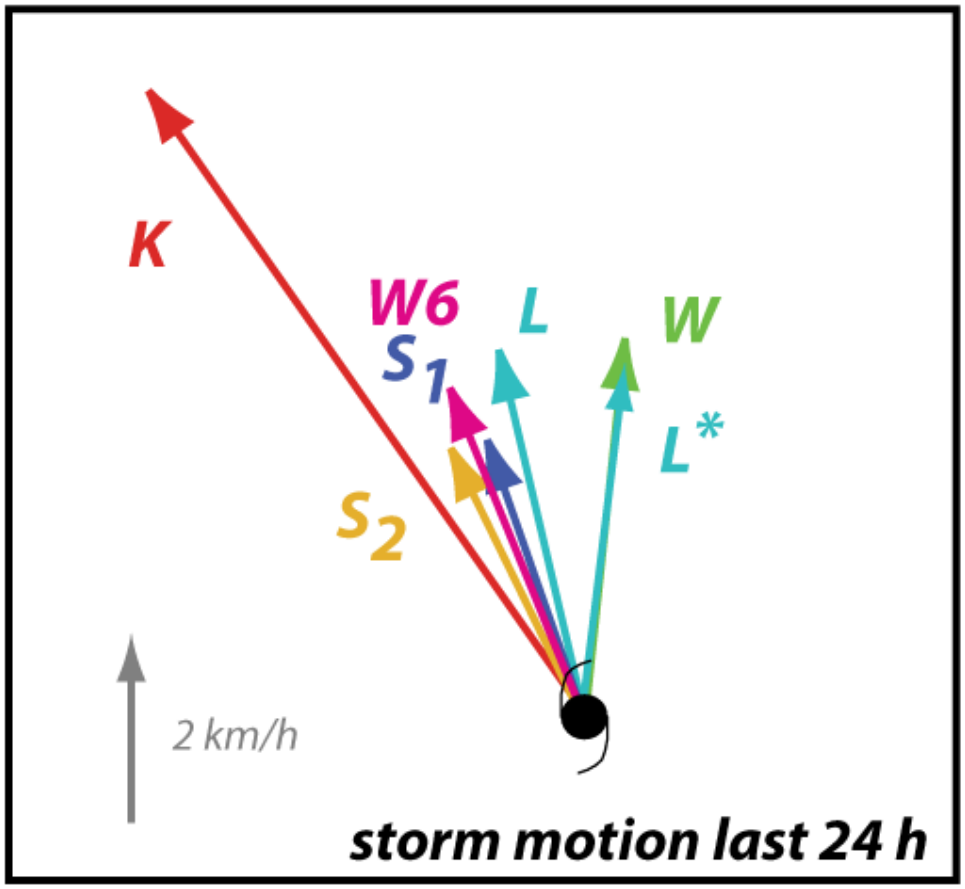


Maximum 850 mb winds (symmetric components): 56-77 m/s

[Cats 2-4 at 10 m]

L/KF vs. GFDL: all 65 contests 2008 ATL




K
W6
S1
L
W
L*
S2
2 km/h
storm motion last 24 h