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Model physics influences on tropical cyclone size

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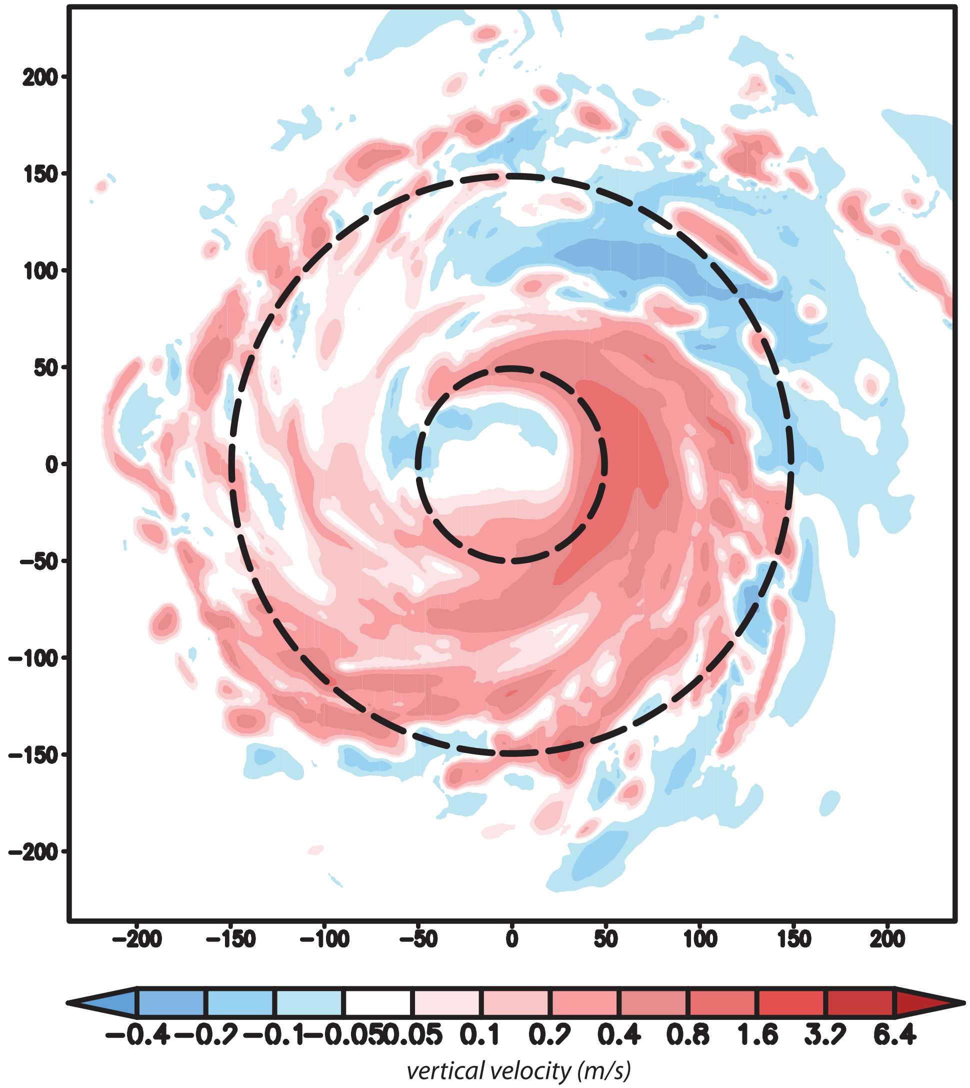
Introduction

- Hurricane storm size is an important forecast metric
  - Directly and indirectly influence motion, intensity, storm surge, evacuation zones, etc..
- Size measures include R34 (radius of 34-kt wind), ROCI (radius of outer closed isobar), etc..
- Size can be profoundly influenced by model physics (Cao et al. 2011)
- Hurricane Weather Research and Forecasting (HWRF) model, in “semi-idealized” mode
  - No land, constant SST, initially calm winds
- How and why model physics influences storm size
  - Cloud-radiative forcing (Bu et al. 2014; Fovell et al. 2015)
  - Planetary boundary layer (Bu 2015)

Cloud-radiative forcing (CRF)

Fovell et al. (2010)
Bu et al. (2014)
Fovell et al. (2015)



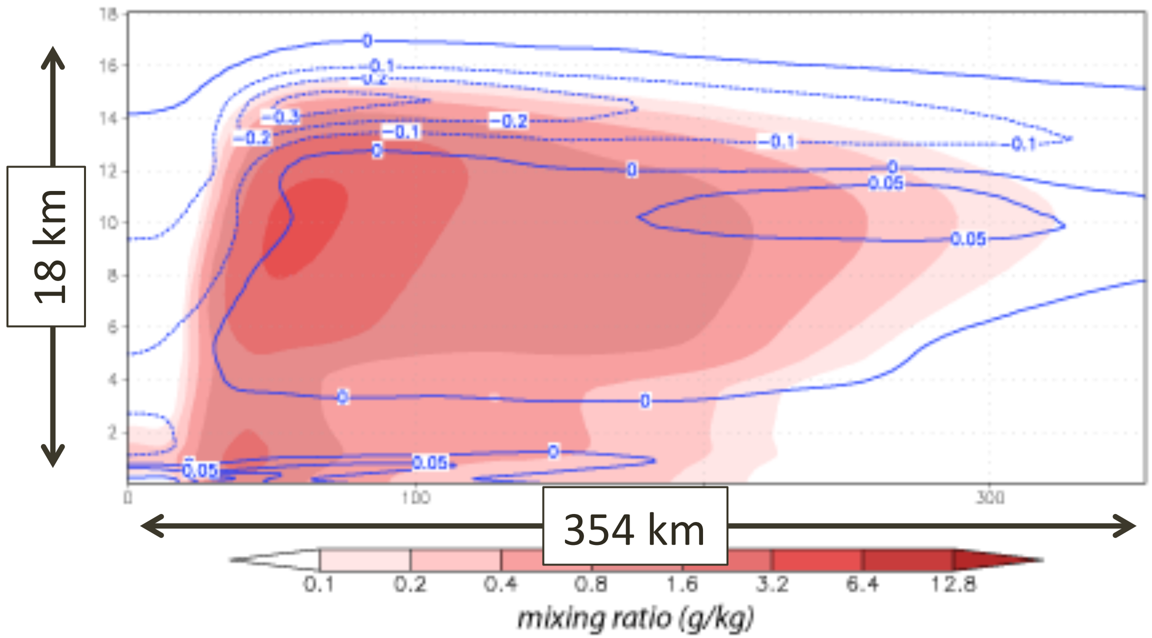
480 km x 480 km

Vertical velocity (time-averaged)

HWRF (2013 version)
Thompson microphysics
GFS PBL scheme (α = 0.7)
RRTMG radiation

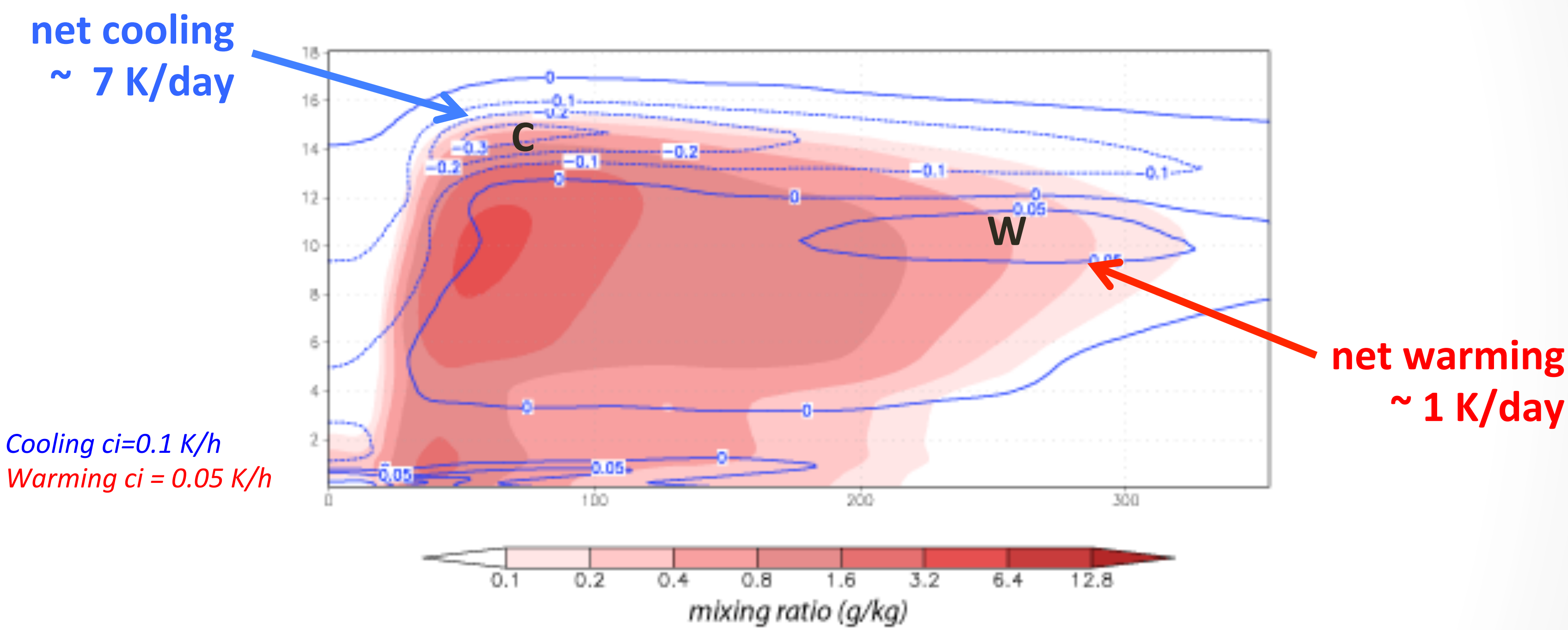
Semi-idealized

Cloud-radiative forcing (CRF)



Condensate (shaded) and net radiative forcing (K/h)

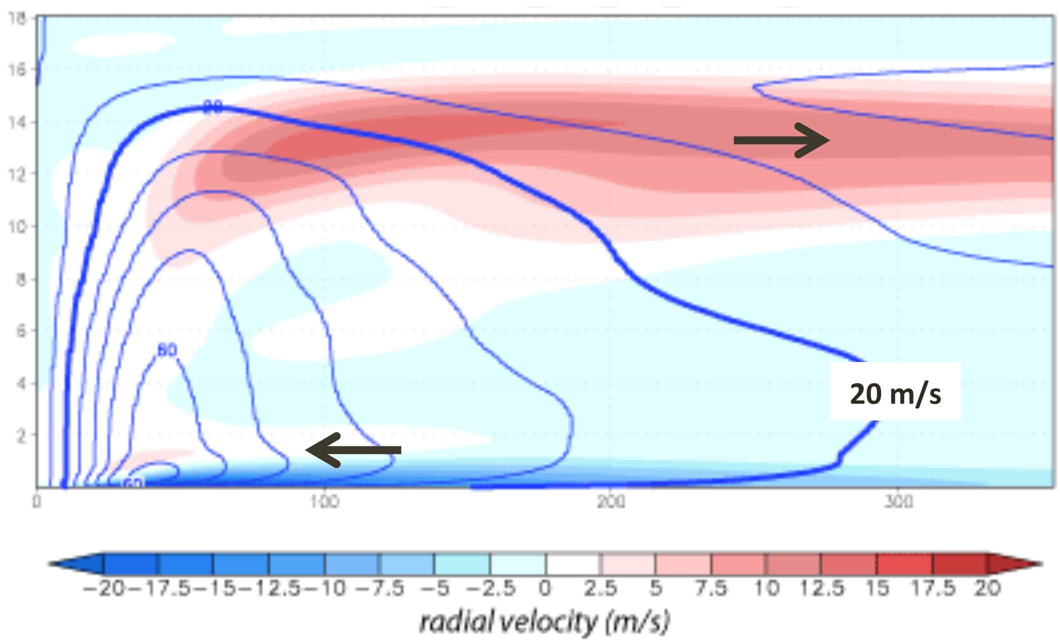
Cloud-radiative forcing (CRF)



Condensate (shaded) and net radiative forcing (K/h)

Net radiation = LW + SW and includes background (clear-sky) forcing
Radiation contour interval differs for positive and negative values

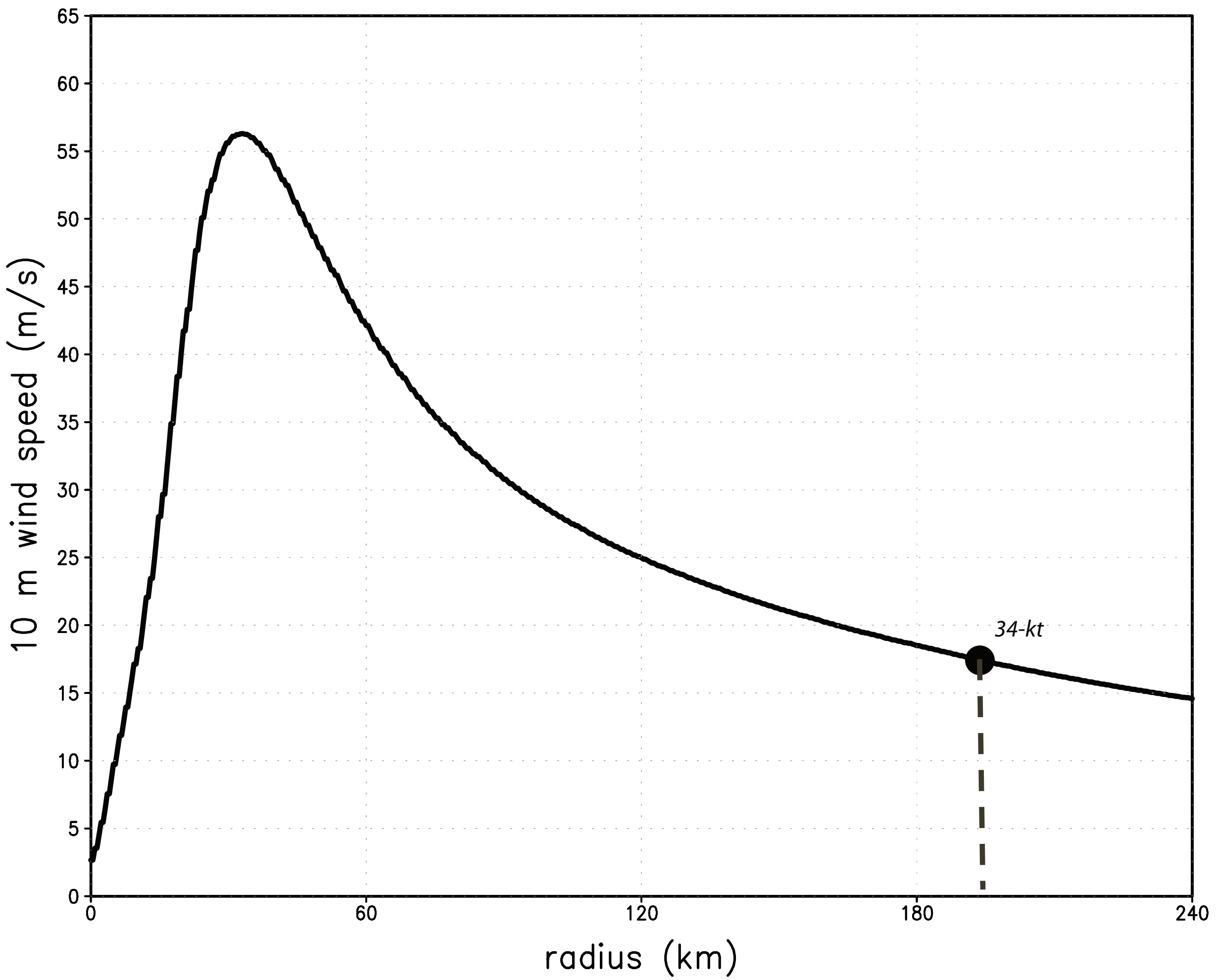
Radial and tangential winds



Radial (shaded) and tangential velocity (m/s)

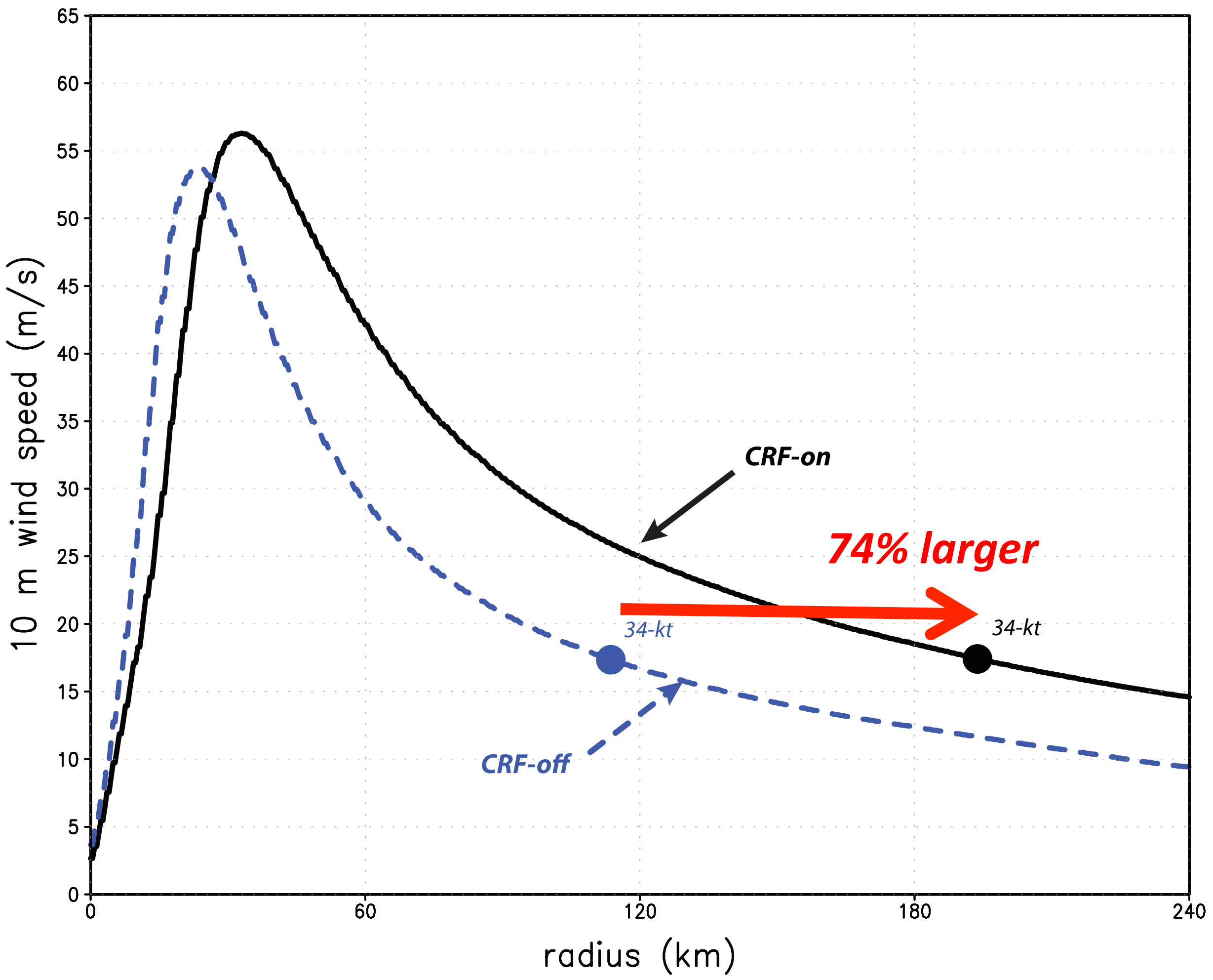
Temporally and azimuthally averaged

10-m winds



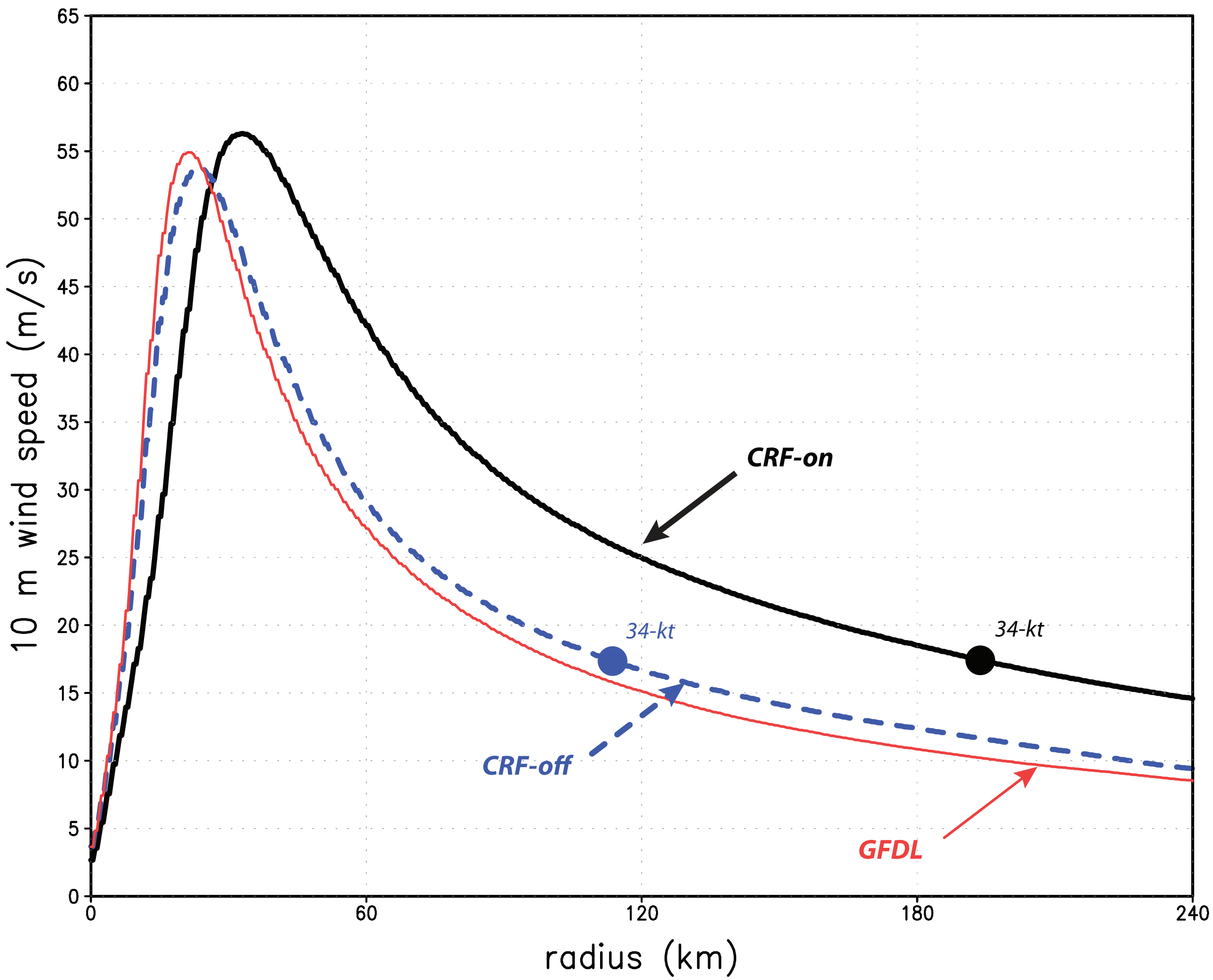
65
60
55
50
45
40
35
30
25
20
15
10
5
0
10 m wind speed (m/s)
34-kt
0
60
120
180
240
radius (km)

10-m winds



CRF-on
74% larger
34-kt
34-kt
CRF-off
10 m wind speed (m/s)
radius (km)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
0
60
120
180
240

10-m winds



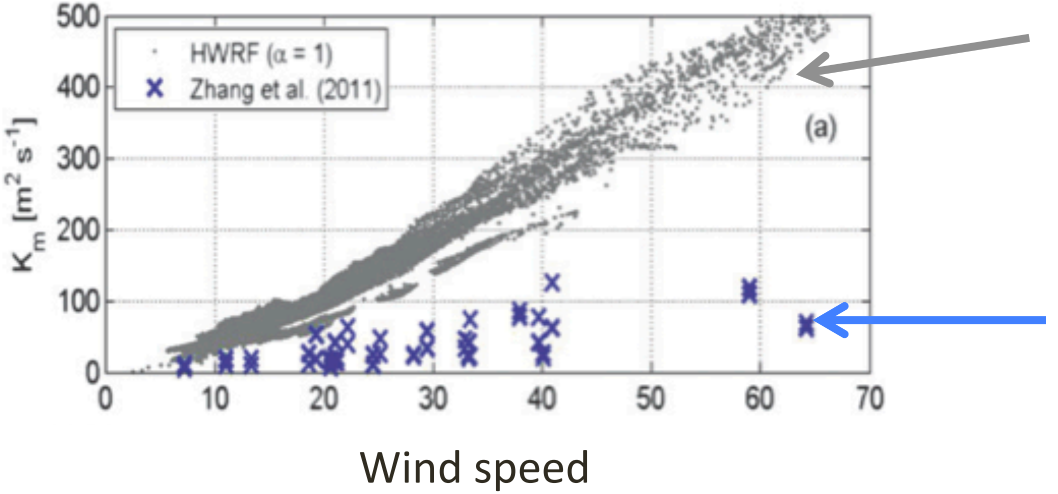
operational version
(until this season)

CRF and HWRF

- Bu et al. (2014) showed that **longwave warming** within the anvil cloud -> gentle ascent -> enhanced outer convection -> expanded wind field
- Operational model's radiation scheme was lacking (effective) cloud-radiative forcing
- Implementing improved radiation scheme in the model *degraded* forecast skill in DTC's experiments
- **Why?**

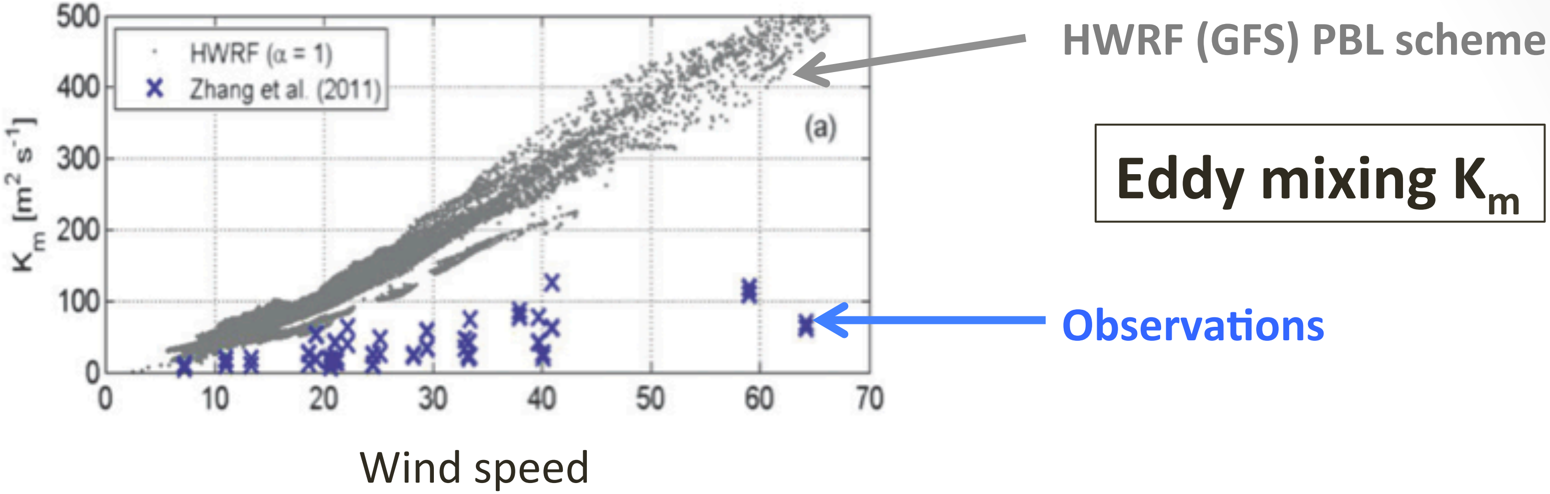
Planetary boundary layer (PBL) influences

Bu (2015)



Eddy mixing K_m

Gopalakrishnan et al. (2012)



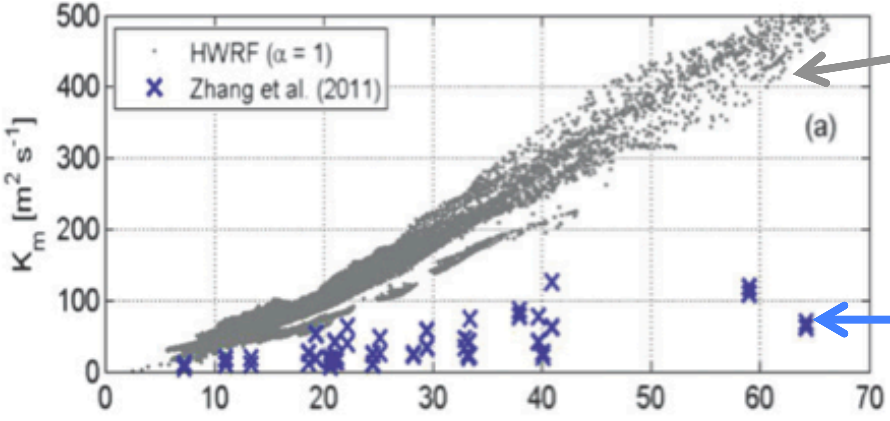
Eddy mixing K_m

$$K_m = k(U_*/\phi)Z[\alpha(1 - Z/h)^2]$$

Gopalakrishnan et al. (2012)

HWRF (GFS) PBL scheme

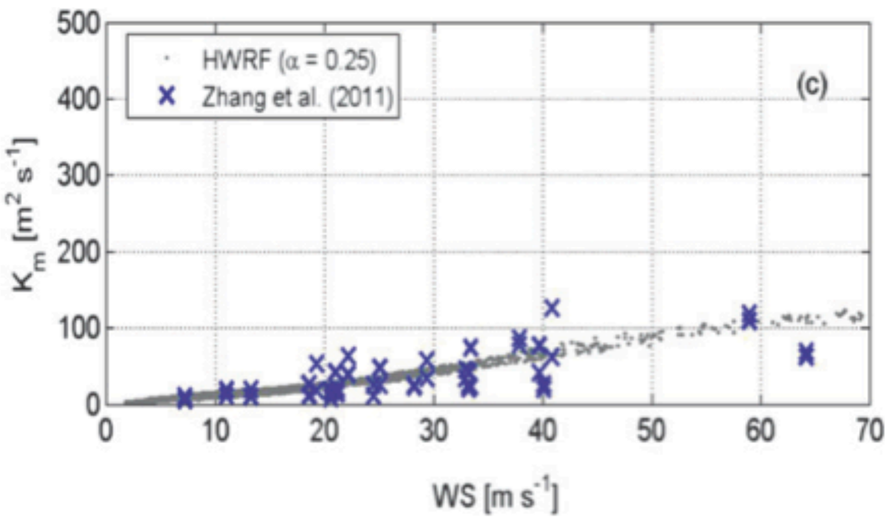
Eddy mixing K_m



Observations

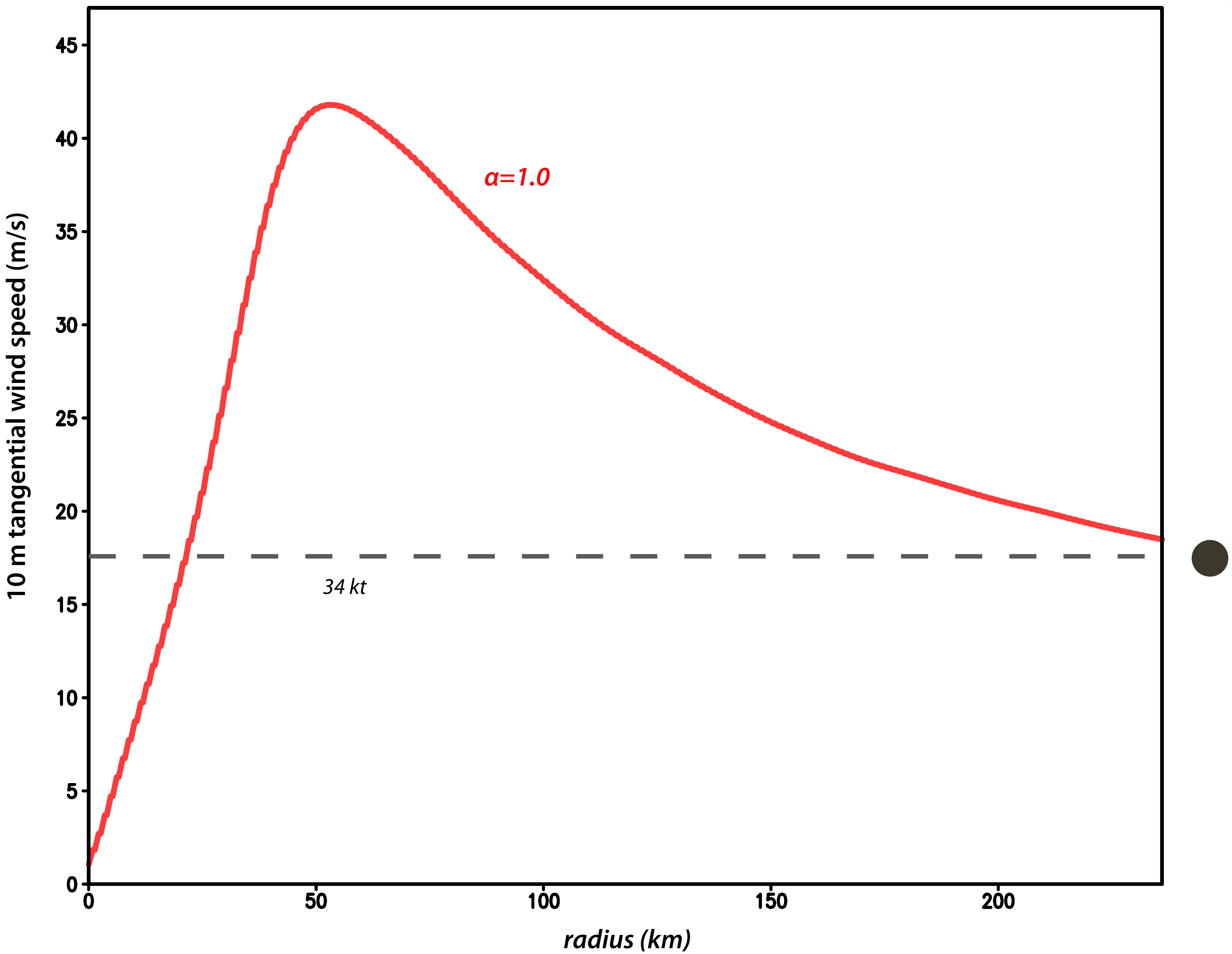
Wind speed

$$K_m = k(U_*/\phi)Z[\alpha(1 - Z/h)^2]$$



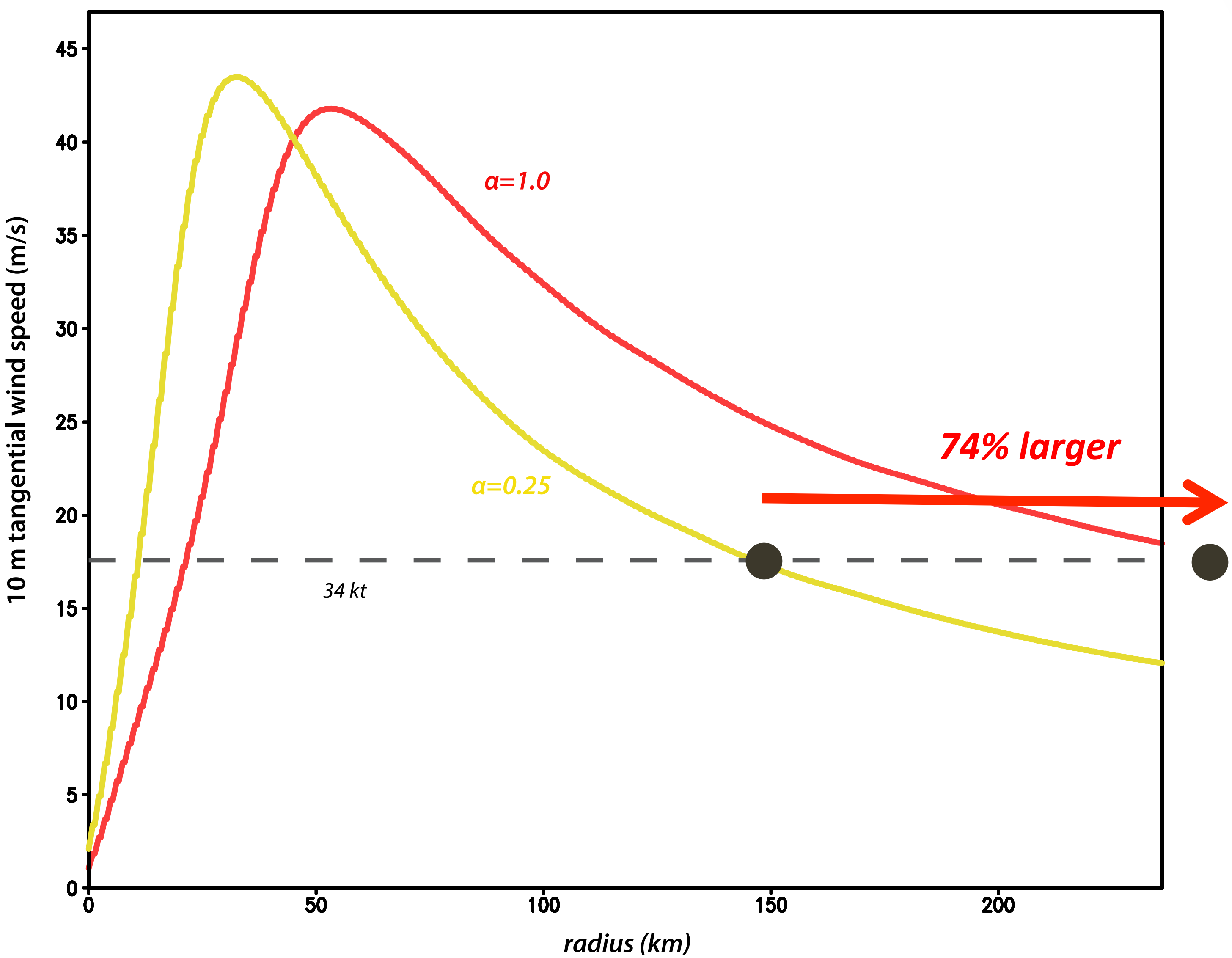
$\alpha = 0.25$

Gopalakrishnan et al. (2012)



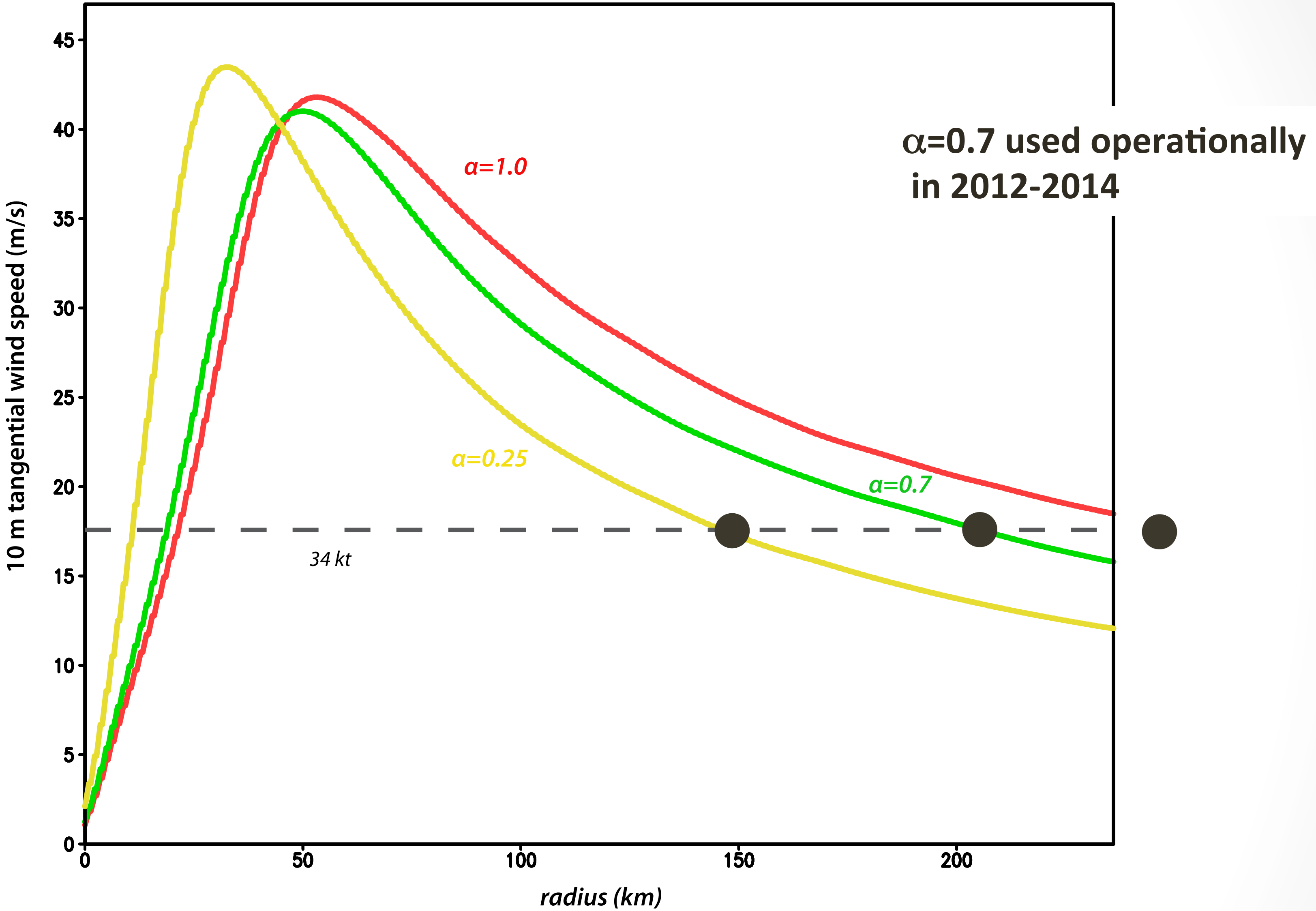
10-m wind speed

$$K_m = k(U_*/\phi)Z[\alpha(1 - Z/h)^2]$$



10-m wind speed

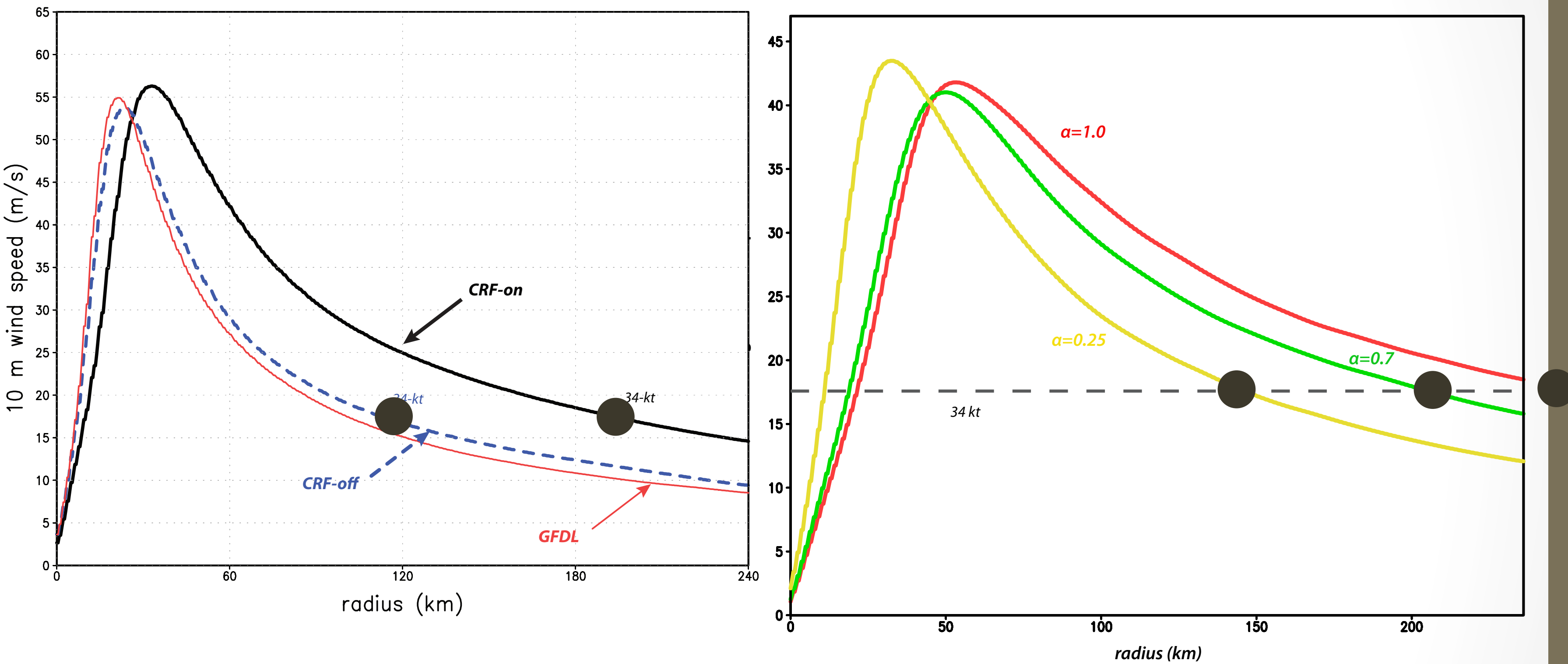
$$K_m = k(U_*/\phi)Z[\alpha(1 - Z/h)^2]$$



10-m wind speed

$$K_m = k(U_*/\phi)Z[\alpha(1 - Z/h)^2]$$

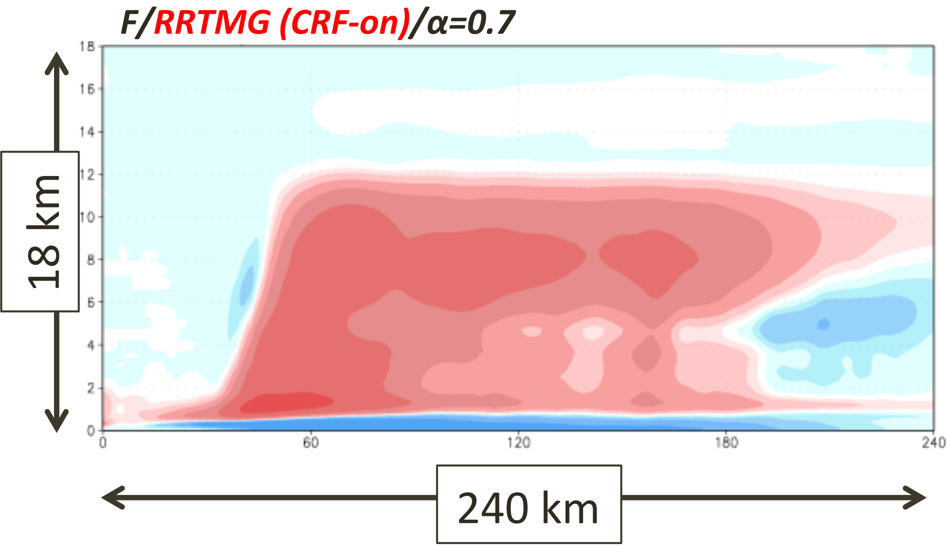
Comparison



Both CRF and PBL mixing strongly influence storm size.
Excessive mixing could have been compensating
for cloud transparency.

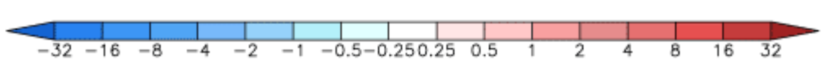
How CRF and PBL influence storm size

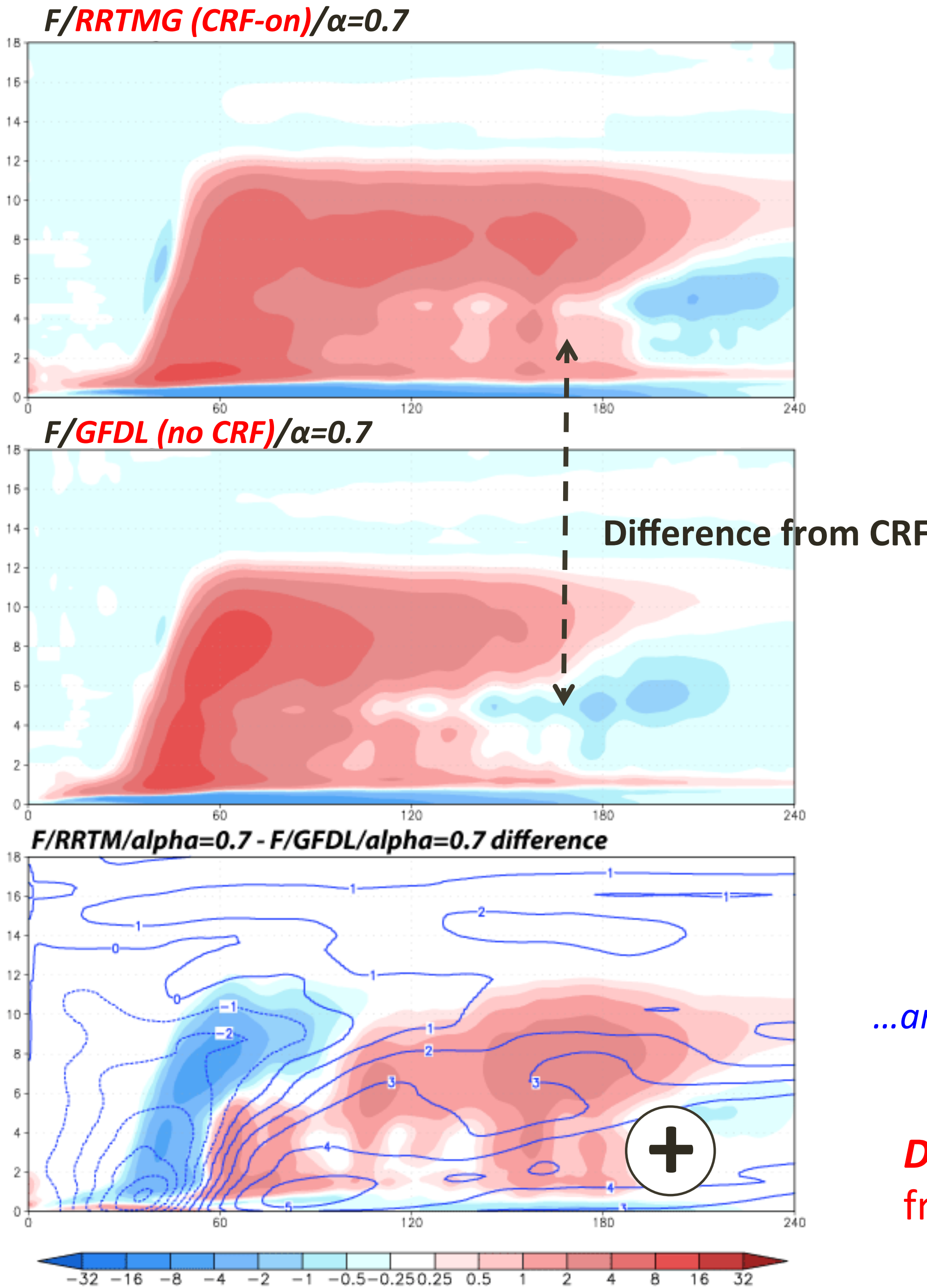
Bu et al. (2014)
Fovell et al. (2015)
Bu (2015)



- Modified configuration
  GFS_alpha (α= 0.7)
  RRTMG radiation (CRF-on)

Diabatic forcing (colored, K/hr)
from microphysics



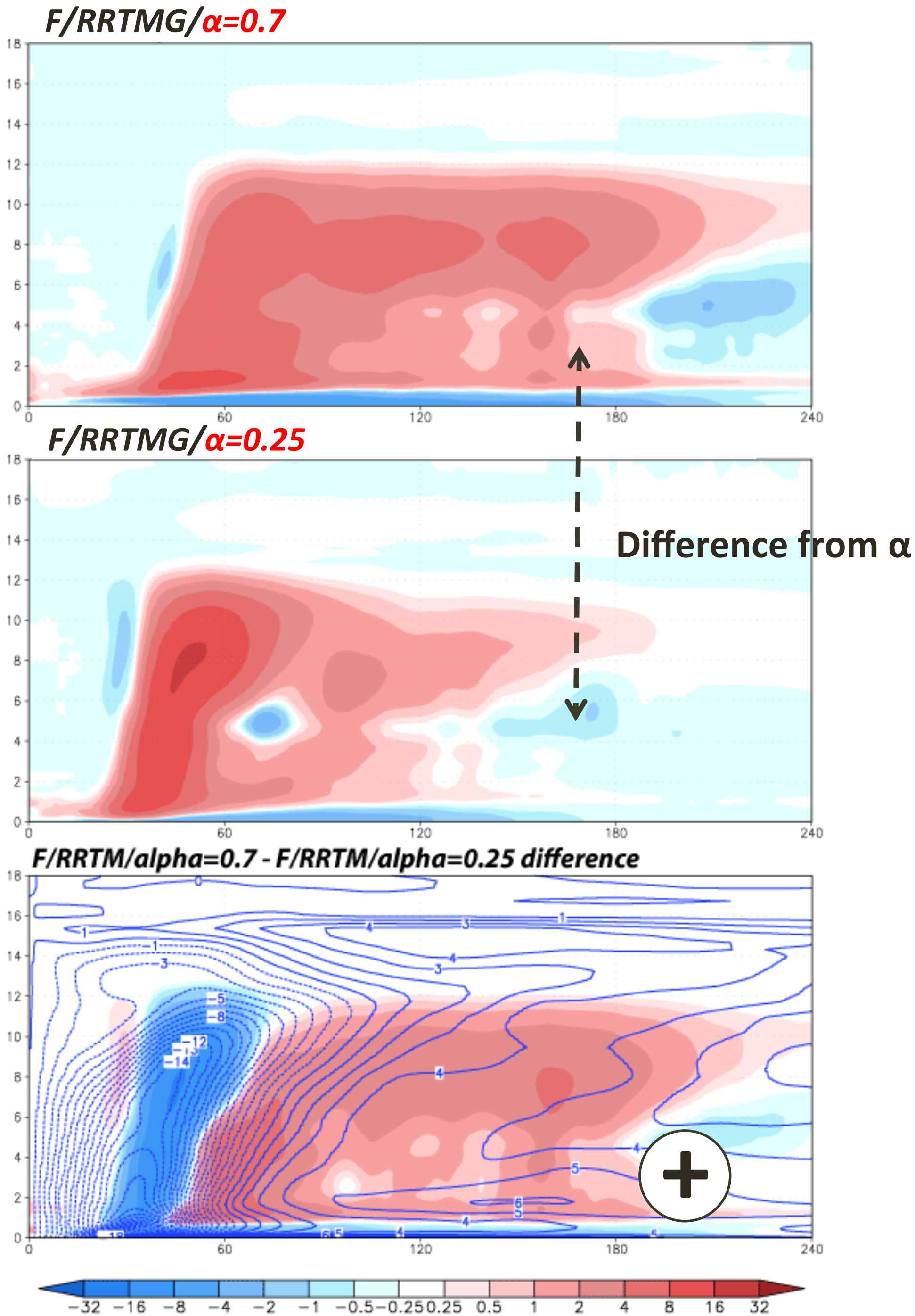


- Modified configuration
  GFS_alpha (α= 0.7)
  RRTMG radiation (CRF-on)

- **Operational configuration**
  GFS_alpha (α= 0.7)
  GFDL radiation (no CRF)

…and wind field difference

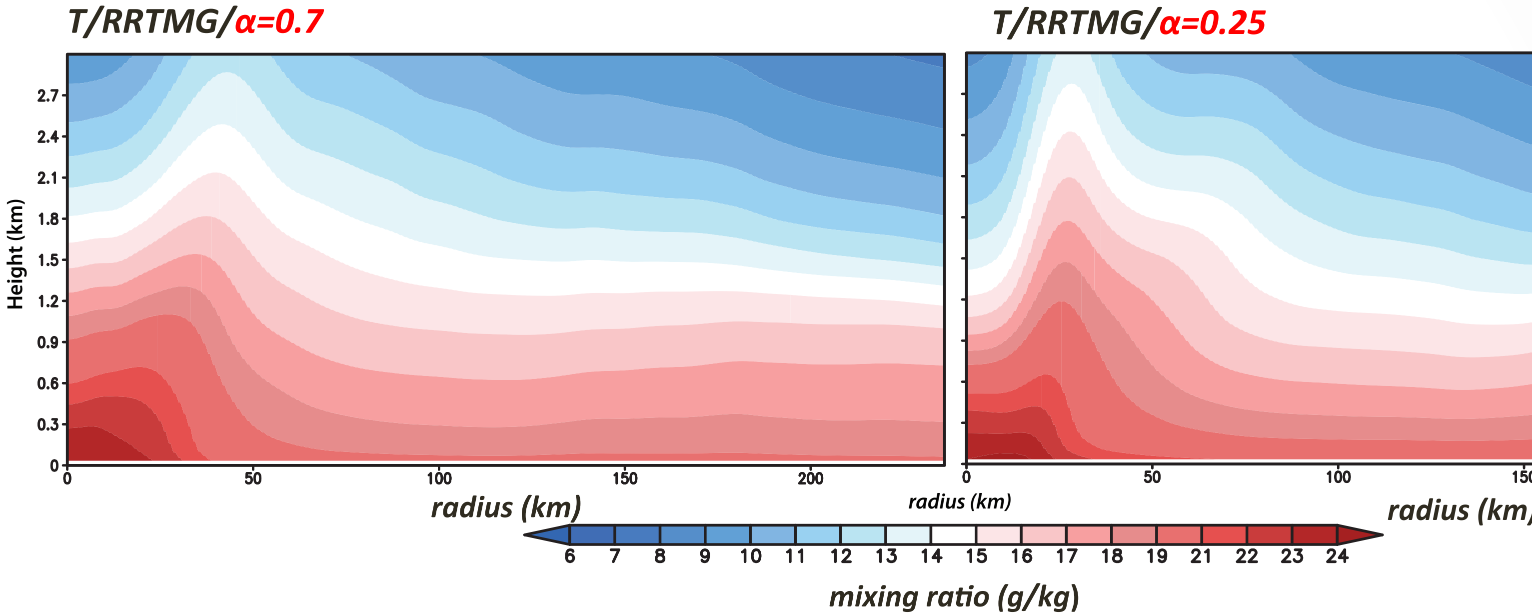
Diabatic forcing (colored, K/hr) from microphysics



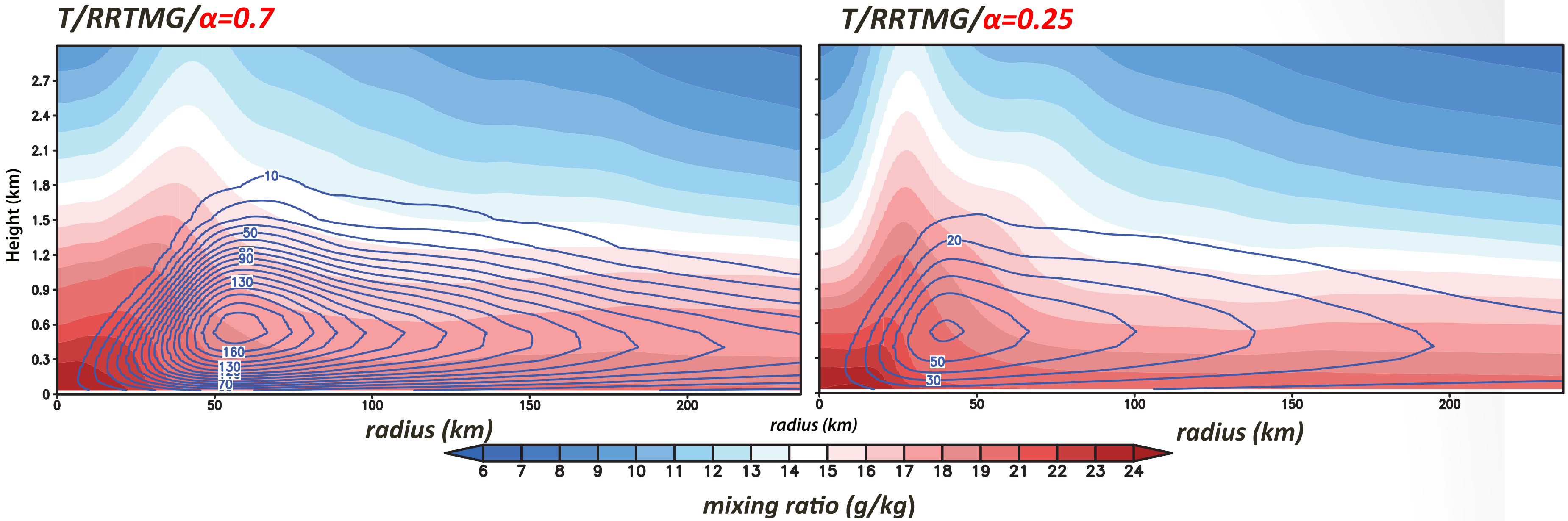
- Modified configuration
  GFS_alpha (α)= 0.7
  RRTMG radiation

- Modified configuration
  GFS_alpha (α)= 0.25
  RRTMG radiation

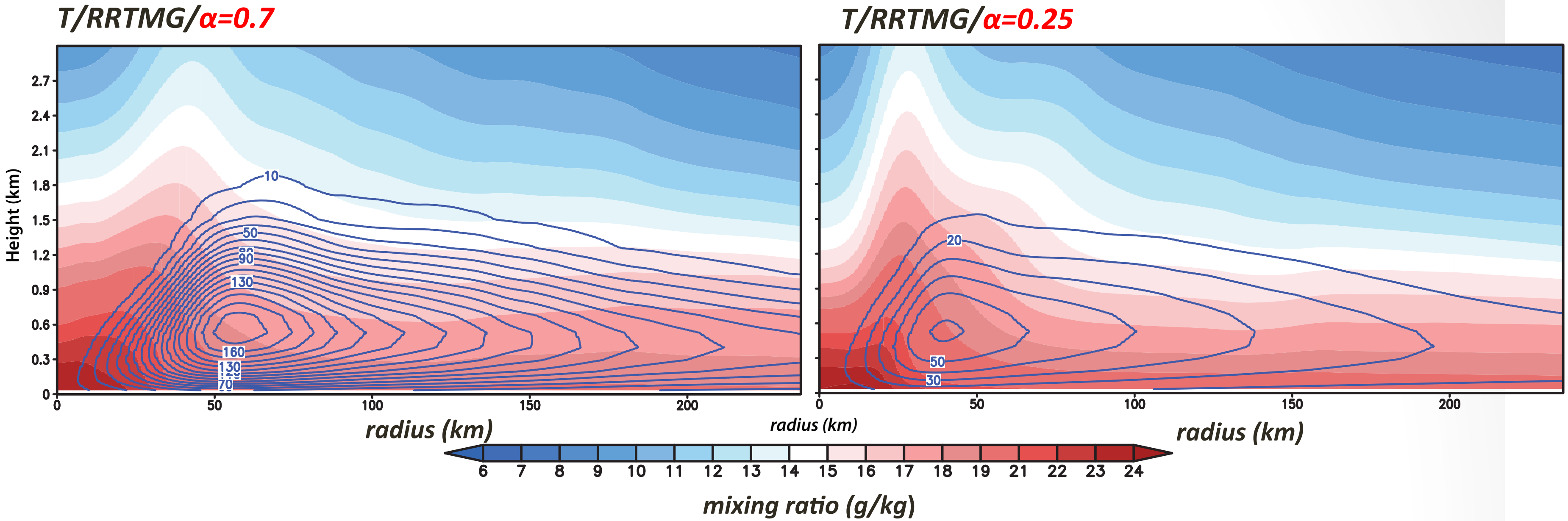
Diabatic forcing (colored, K/hr) from microphysics

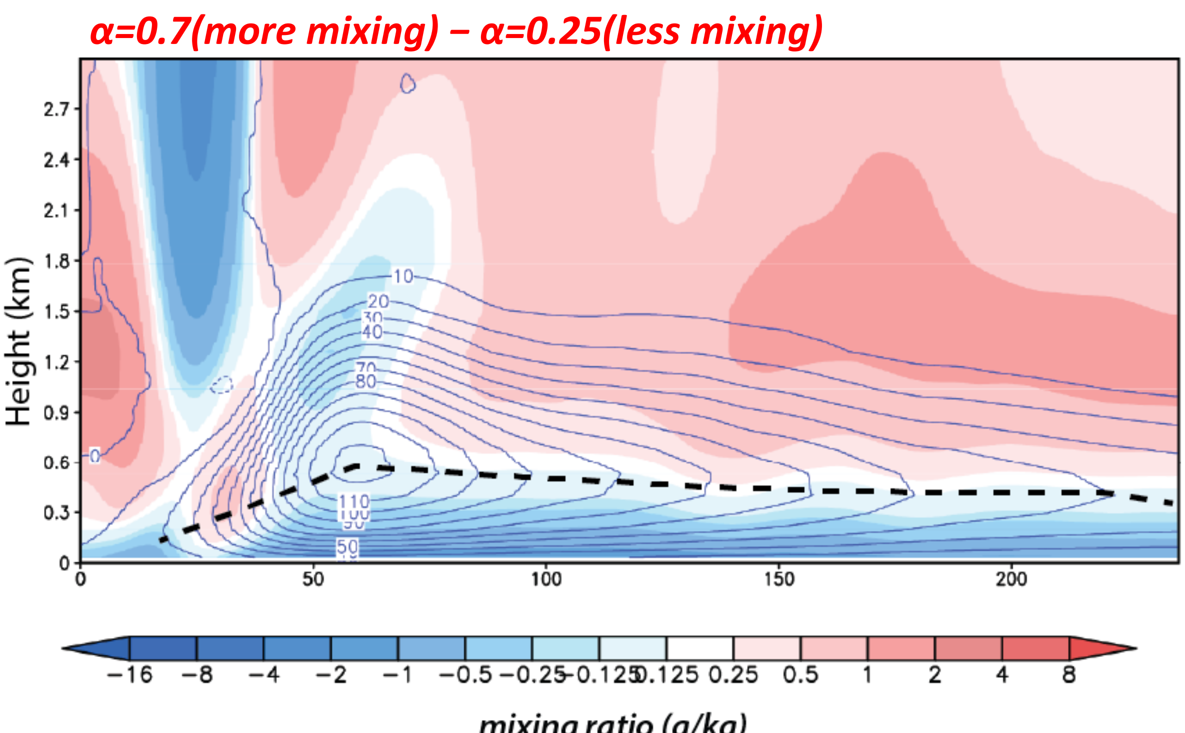


Water vapor
(colored, g/kg)



Water vapor (colored, g/kg) & ***eddy diffusivity*** (contour)



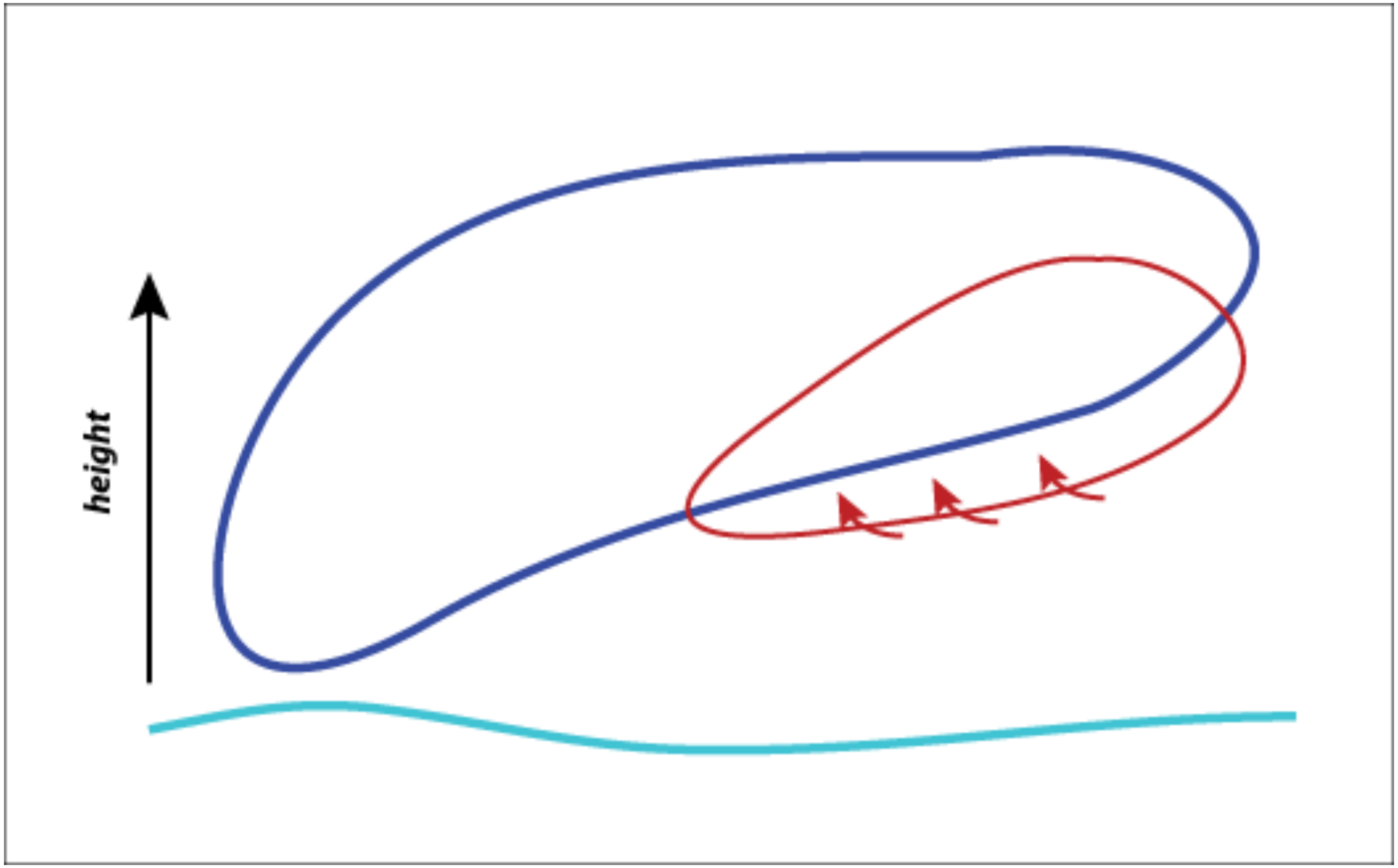


Water vapor (colored, g/kg) & ***eddy diffusivity*** (contour) difference fields due to α

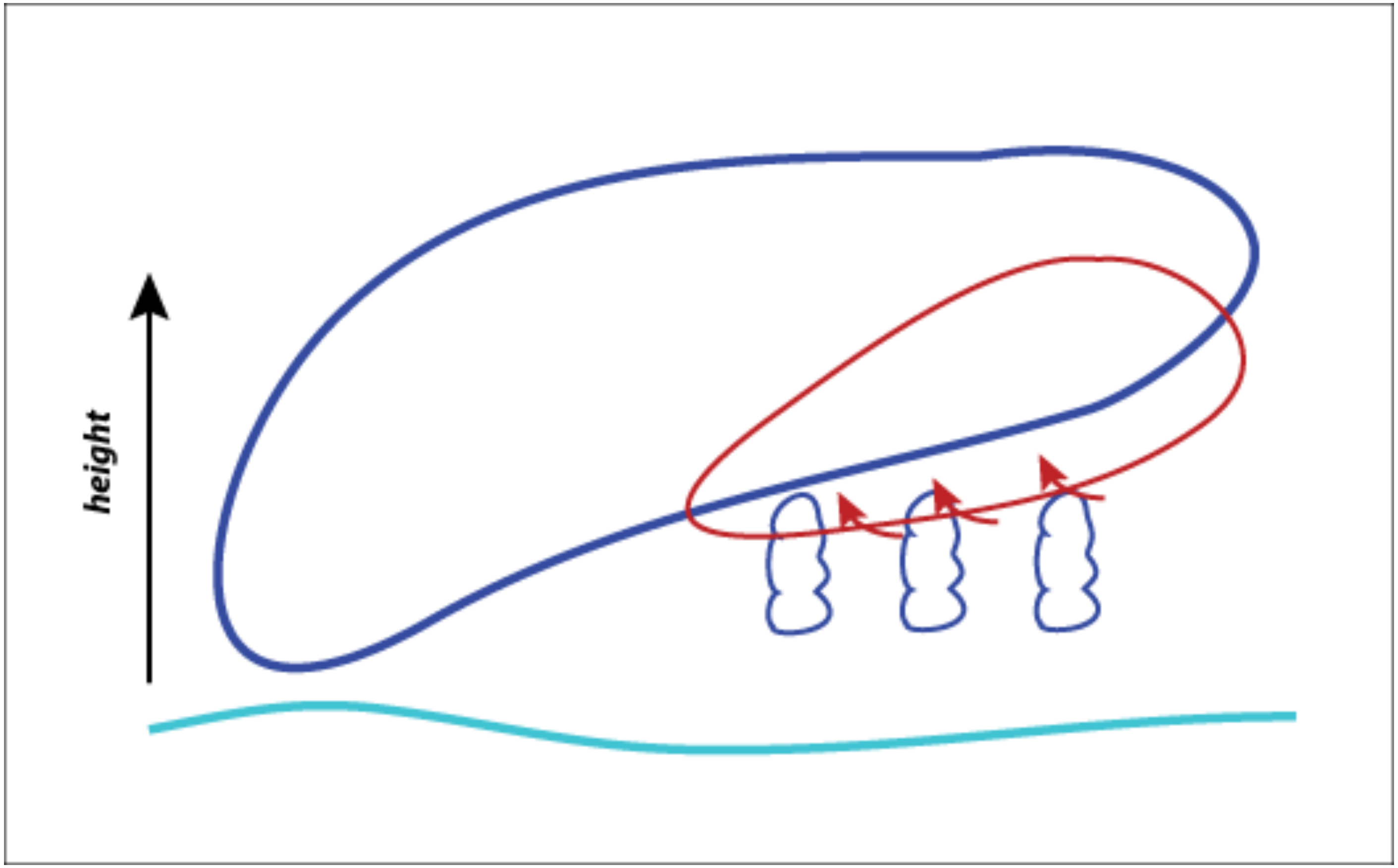
$$\left[\frac{\partial q}{\partial t}\right]_{mix} = \frac{\partial}{\partial z} K_h \frac{\partial q}{\partial z}$$

TC central dense overcast

CRF LW warming

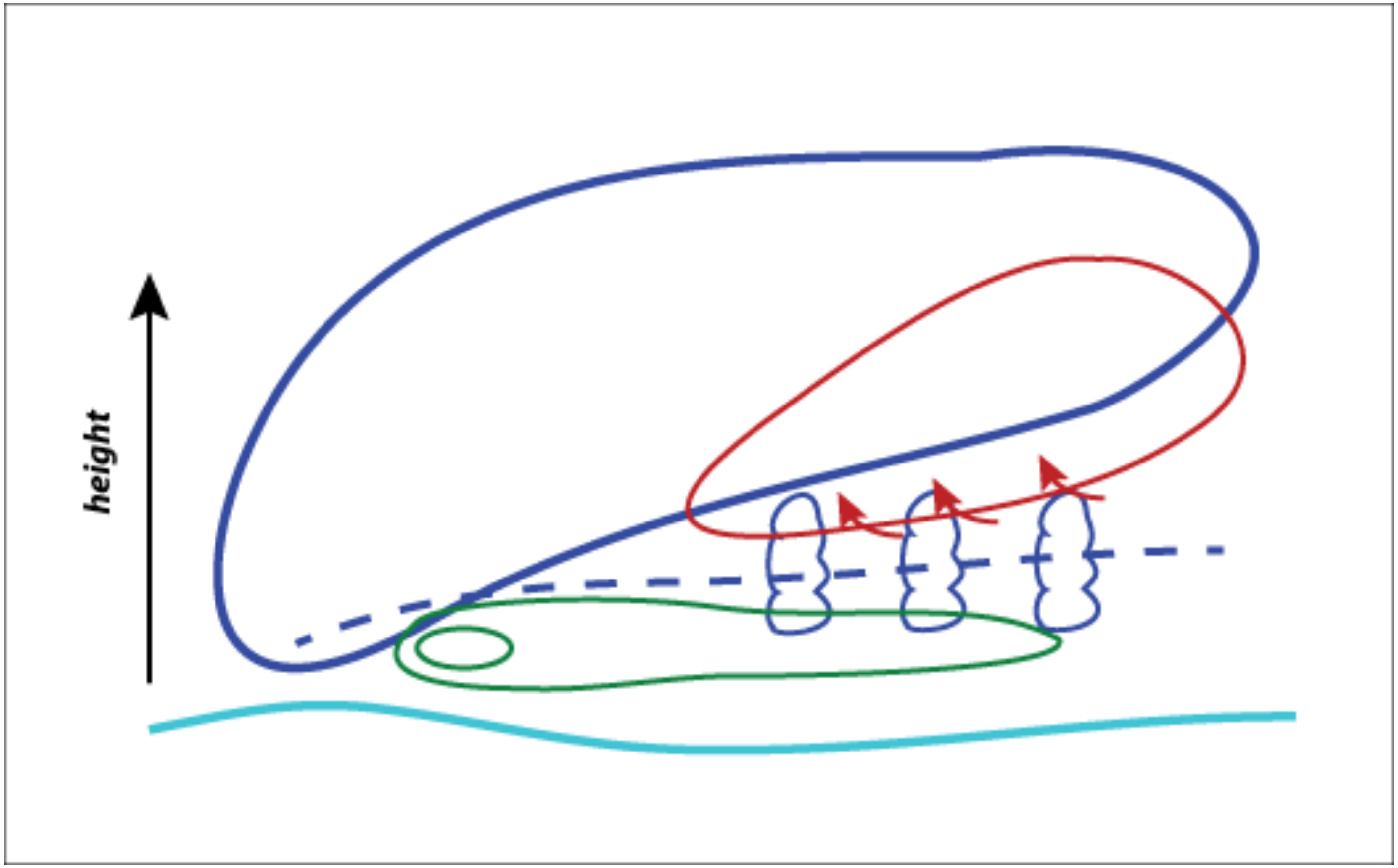


Enhanced outer-core convection

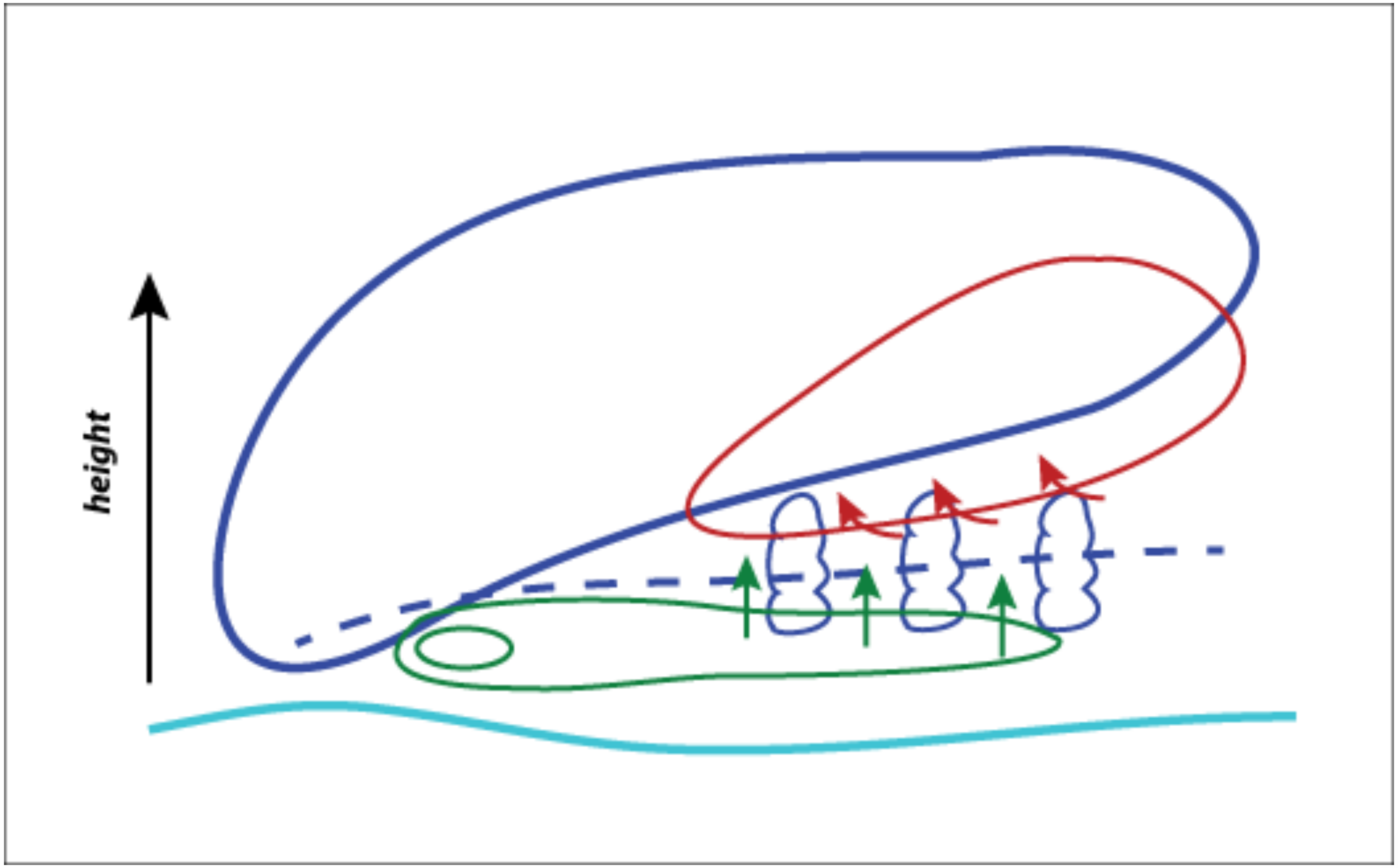


Bu et al. (2014)
Fovell et al. (2015)

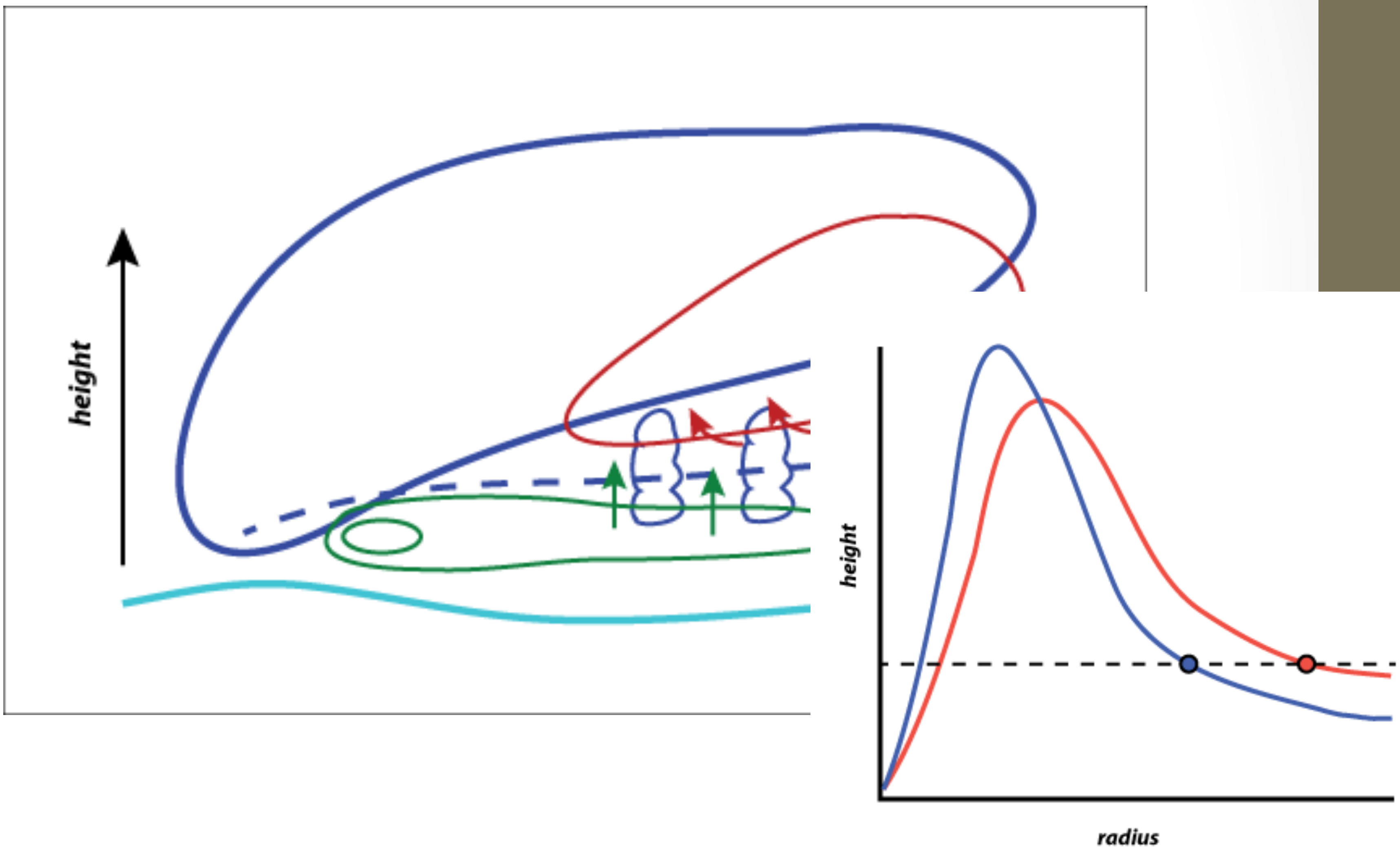
PBL eddy mixing



Vertical moisture diffusion



Vertical moisture diffusion

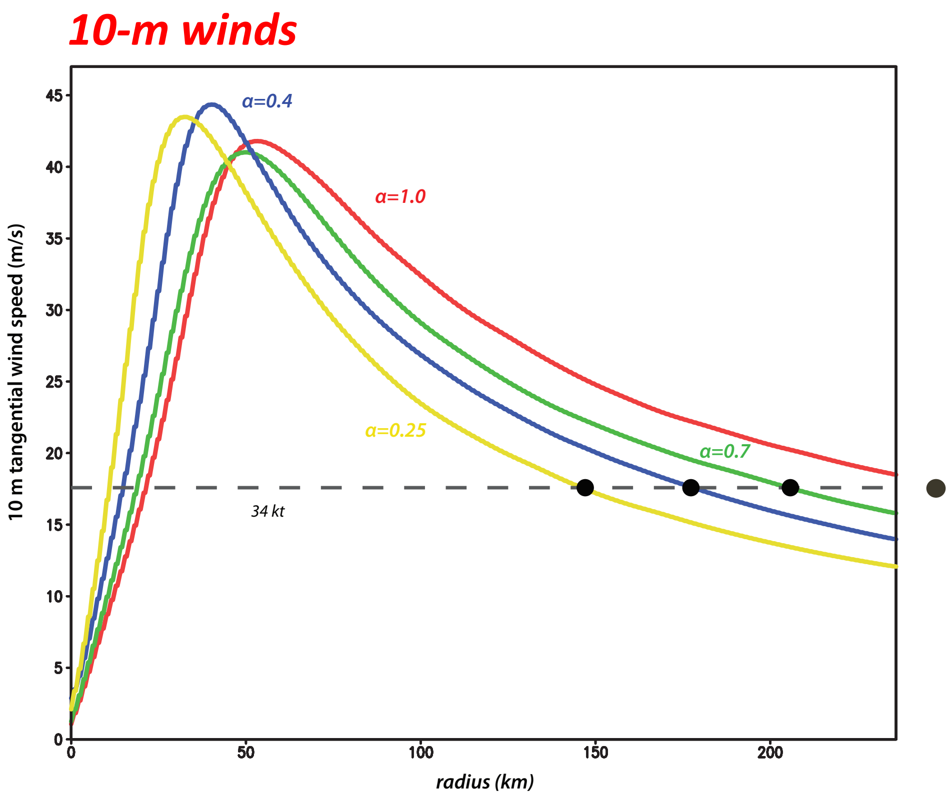


HWRF and ARW comparisons…

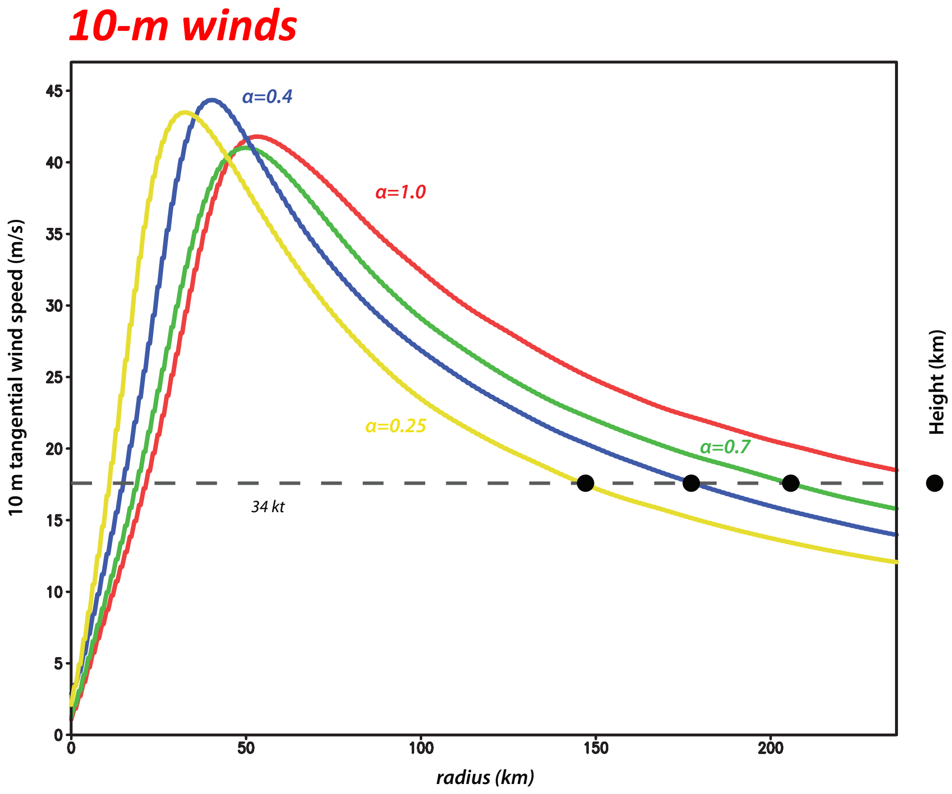
GFS vs. YSU PBL

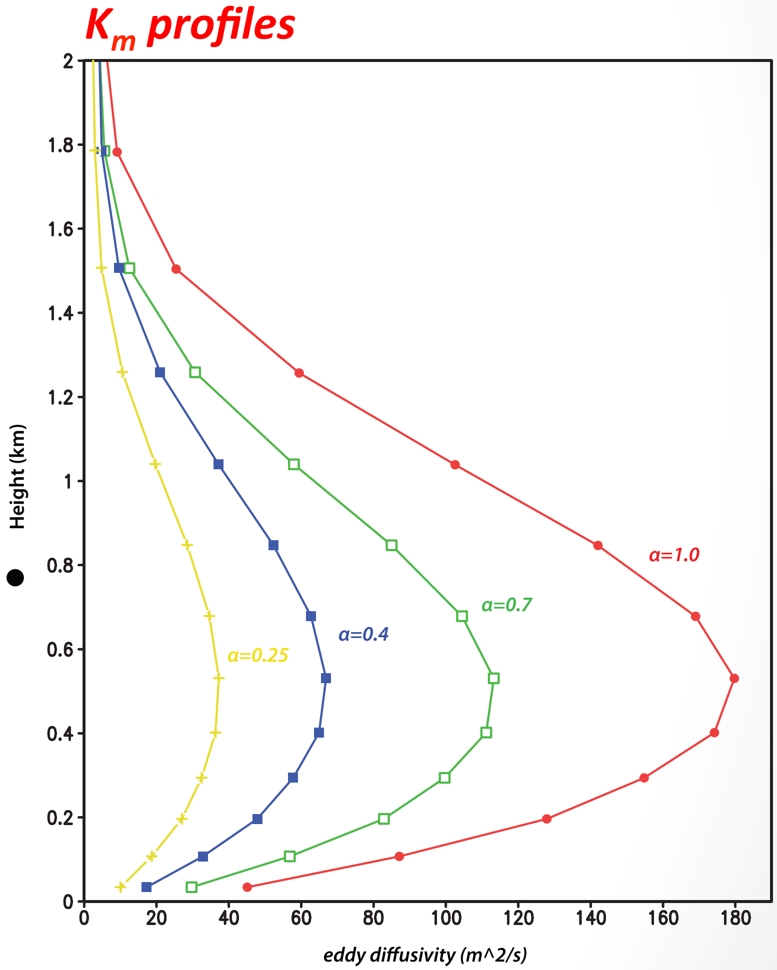
Bu (2015)

GFS vs. YSU PBL



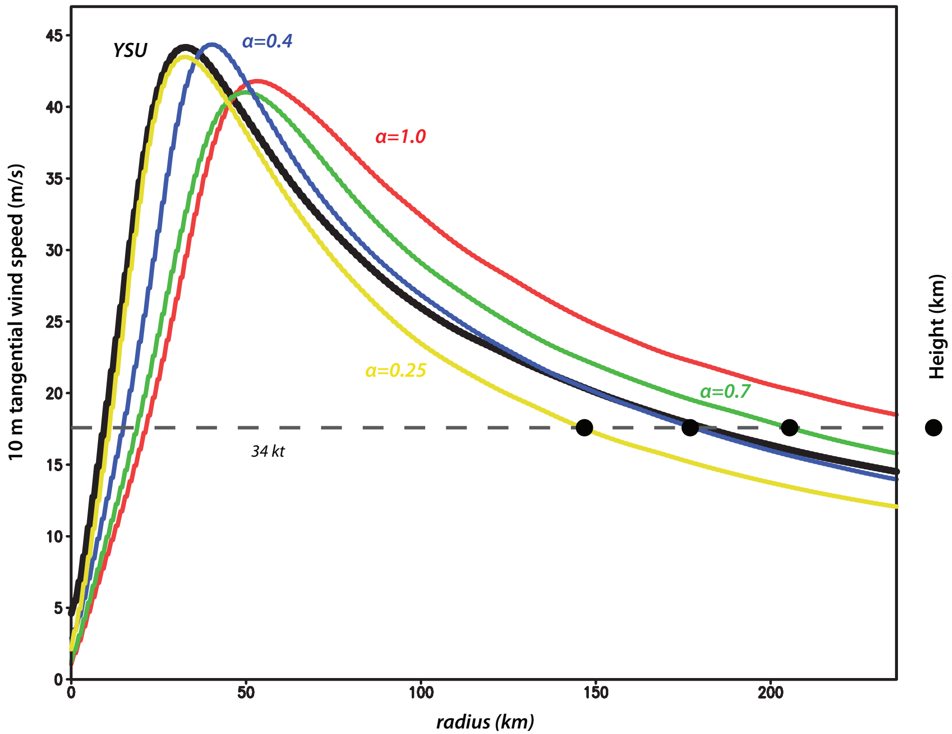
GFS vs. YSU PBL



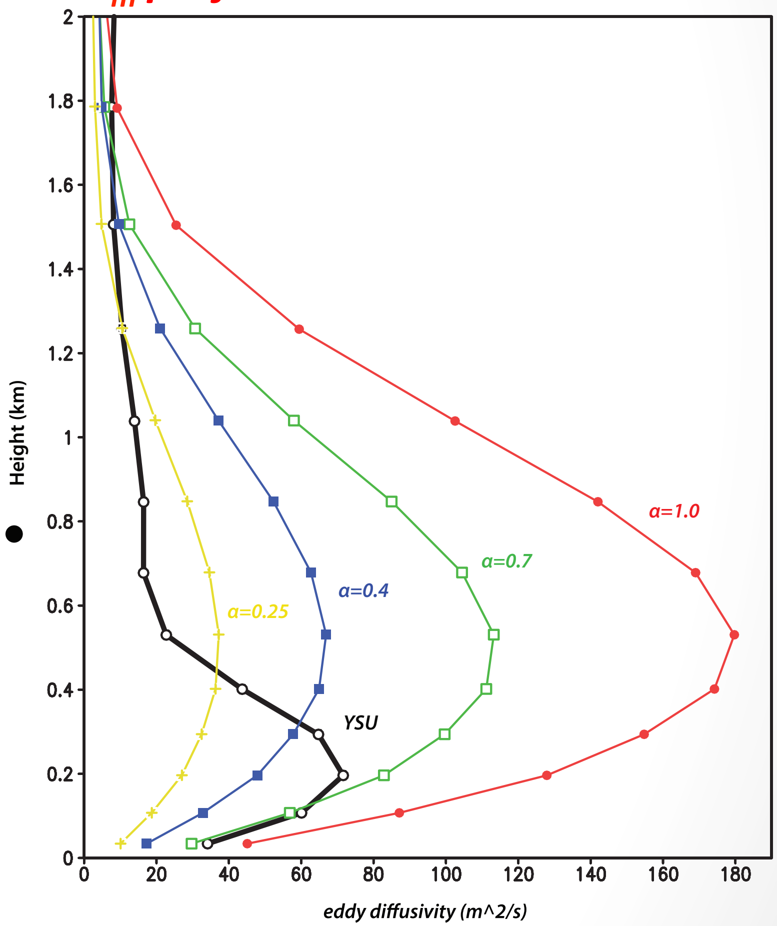


GFS vs. YSU PBL

10-m winds

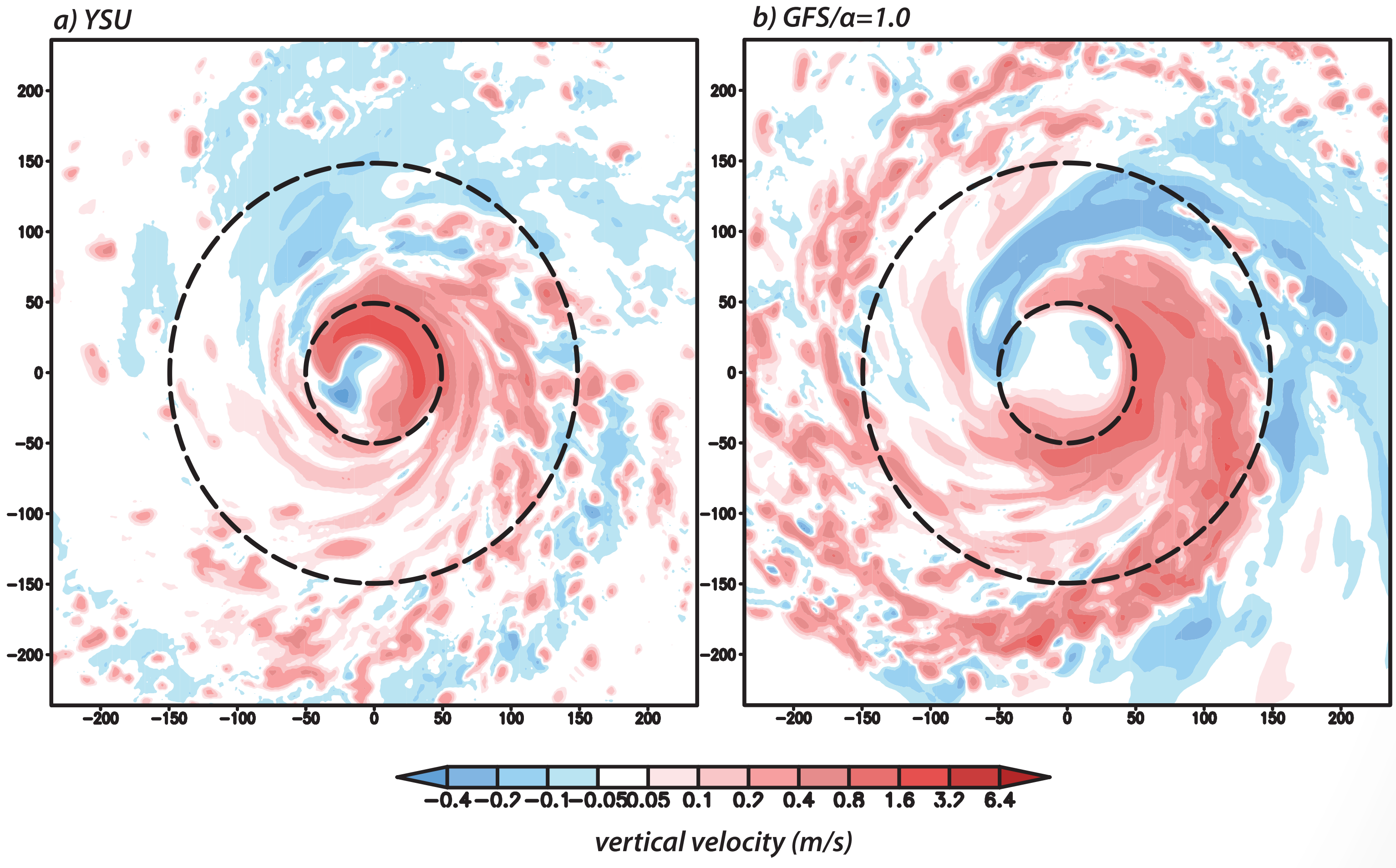


K_m profiles



PBL depths differ due to different critical Richardson numbers

GFS vs. YSU PBL



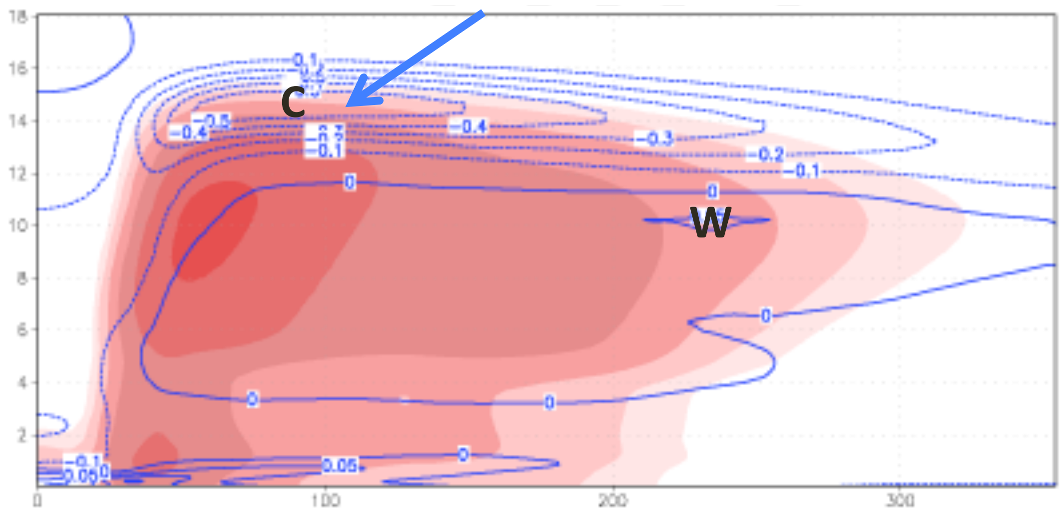
Summary

- Model physics profoundly influences storm size
- Radiation/microphysics and PBL vertical moisture mixing make storms wider
- Radiation problem in HWRF – fixed (also, see next talk)
- Conceptually different approach to limiting hurricane inner-core mixing in 2015 HWRF (Fovell and Bu)
- PBL influence on hurricanes – known to be important
- PBL influence on *forecast skill* – <u>next task</u>
- Research supported by NOAA/HFIP and DTC Visitor Program

[end]

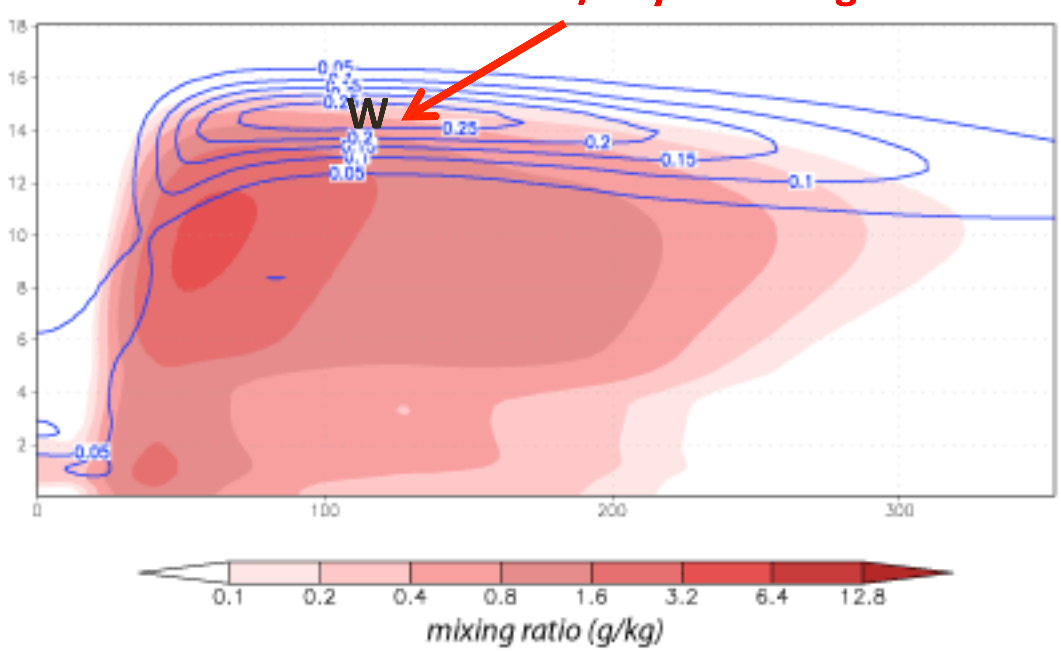
~ 13 K/day cooling

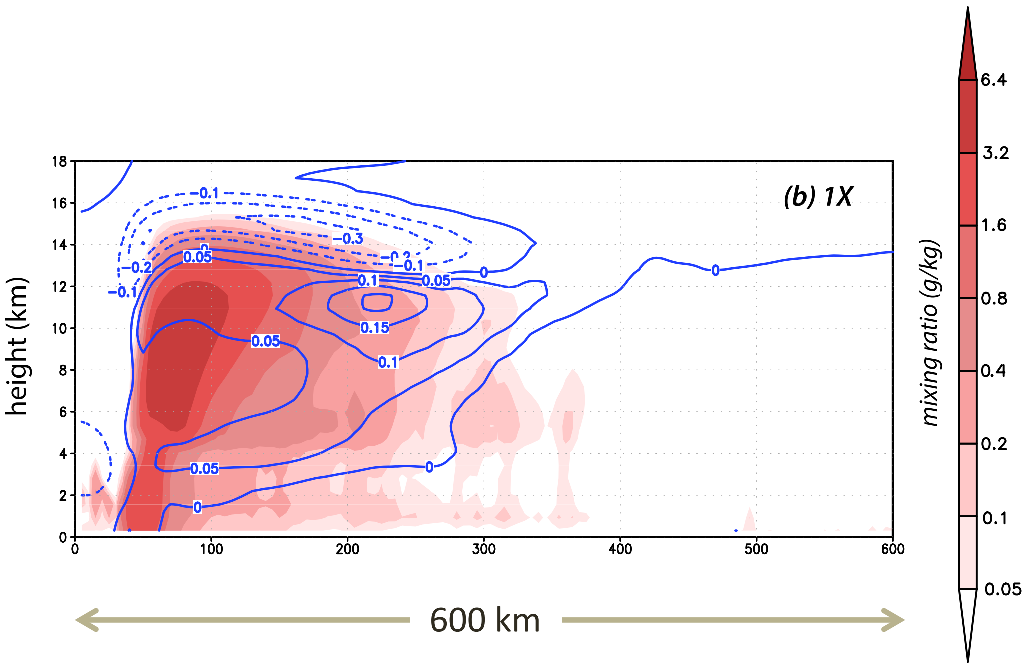
LW only



~ 6 K/day warming

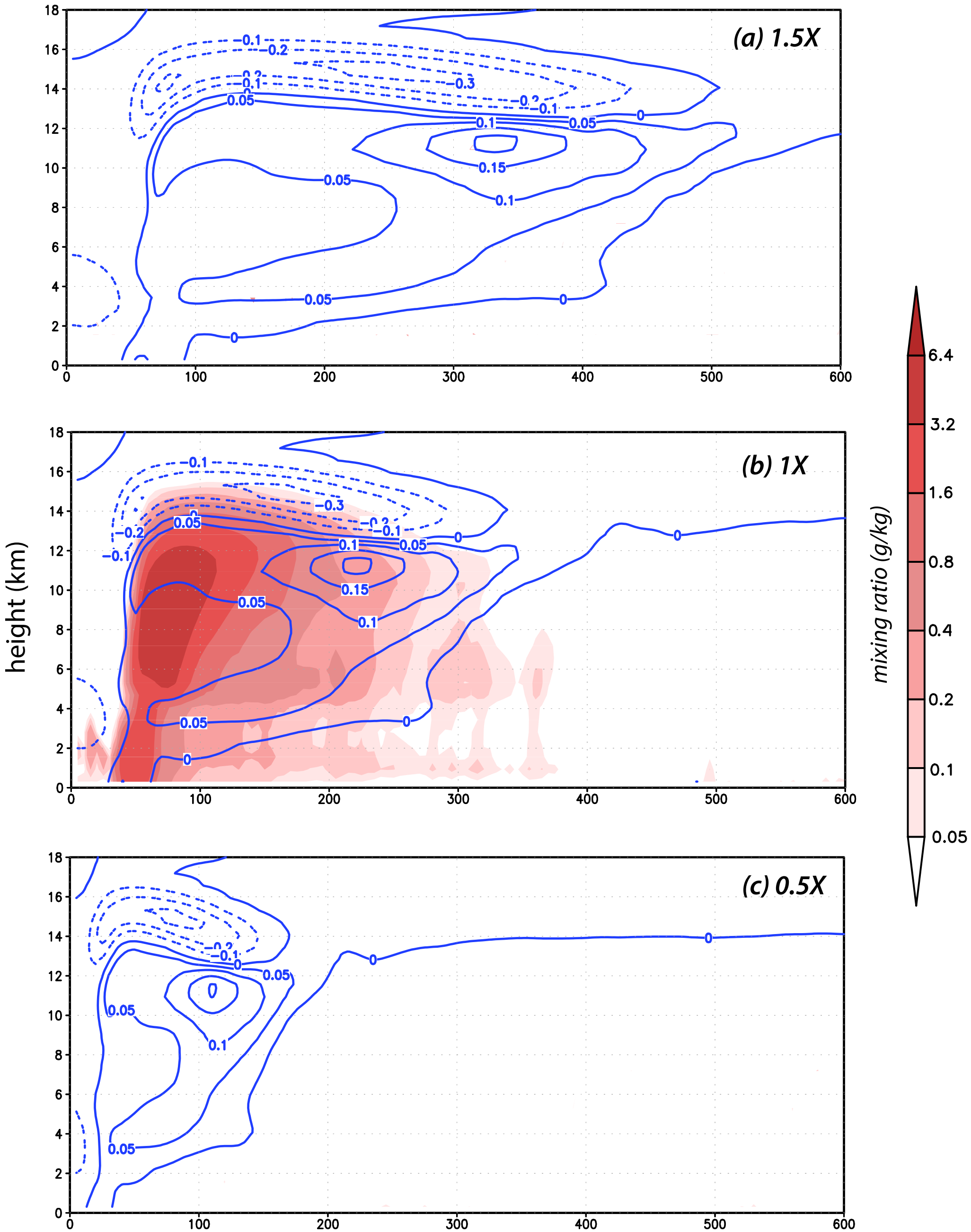
SW only





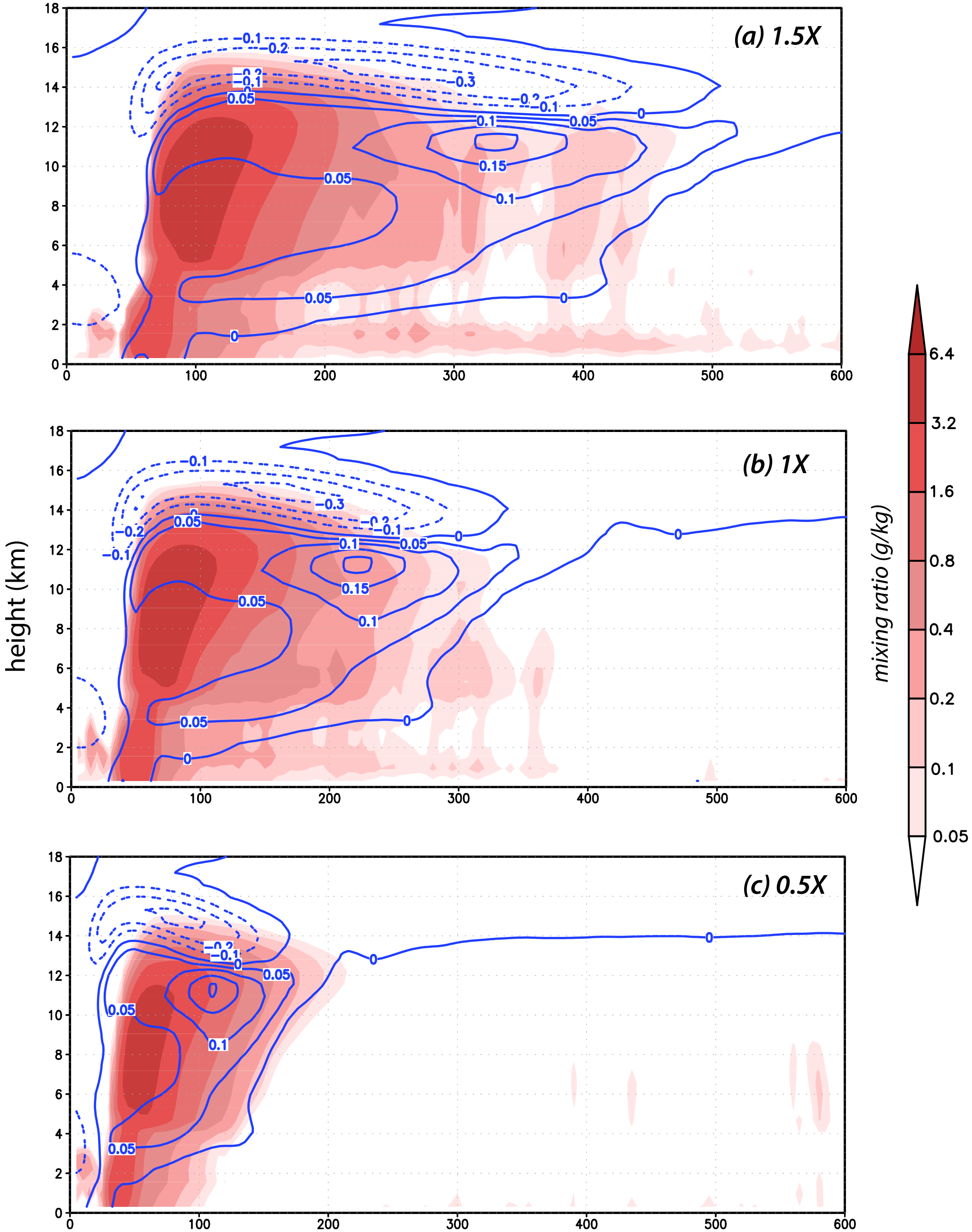
- Standard CRF-fixed

Bu et al. (2014)
Fovell et al. (2015)



- **Expanded** radiation field
- Standard CRF-fixed
- **Contracted** radiation field

Bu et al. (2014)
Fovell et al. (2015)



- **Expanded** radiation field
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