Early results from the GFDL ARM Corroboration: A Bridge between ARM Data and GCM Evaluation and Improvement

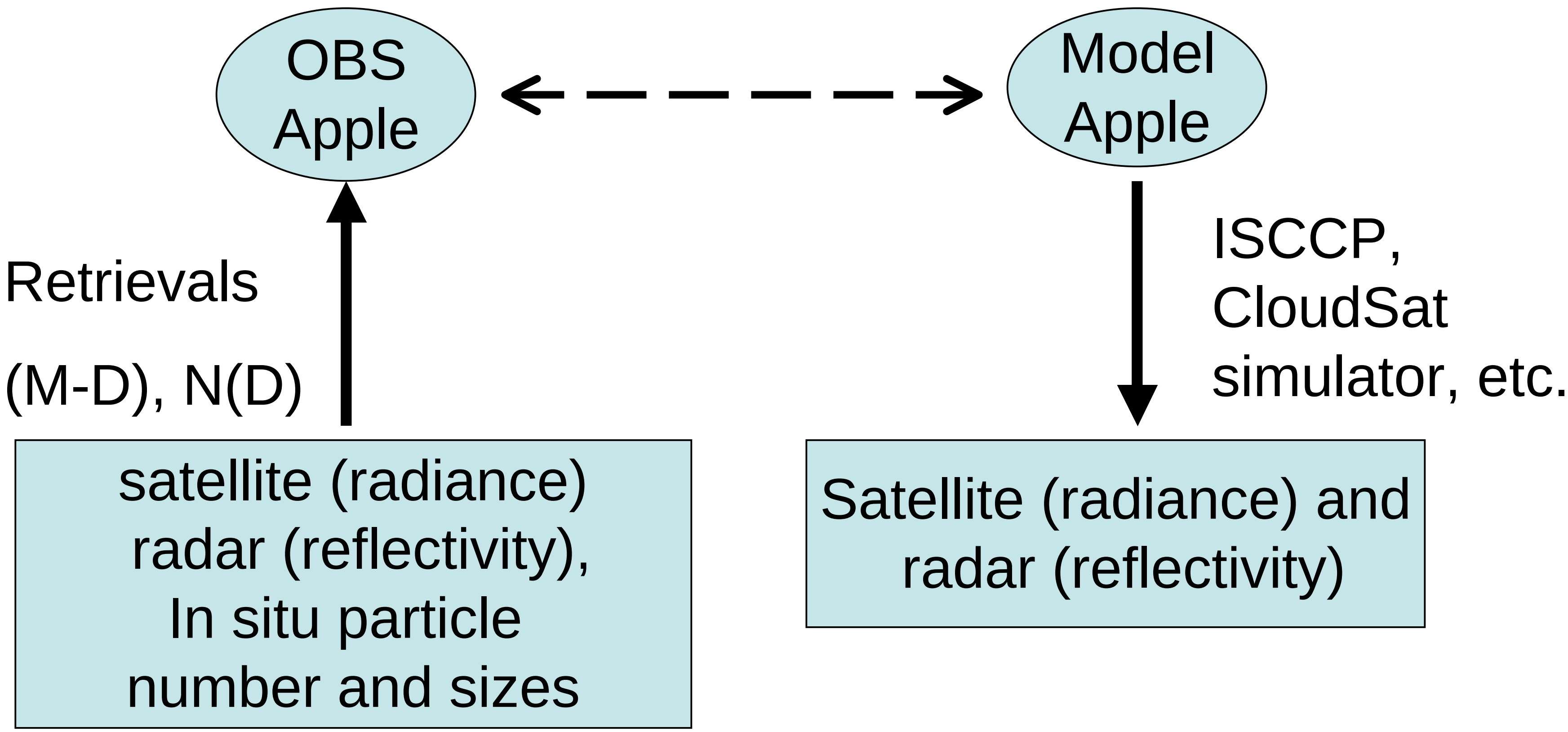
Yanluan Lin,
Leo Donner, Chris Golaz, Ming Zhao,
Steve Klein, Shaocheng Xie,
Min Deng, Gerald Mace

ARM/GFDL

3/31/2009

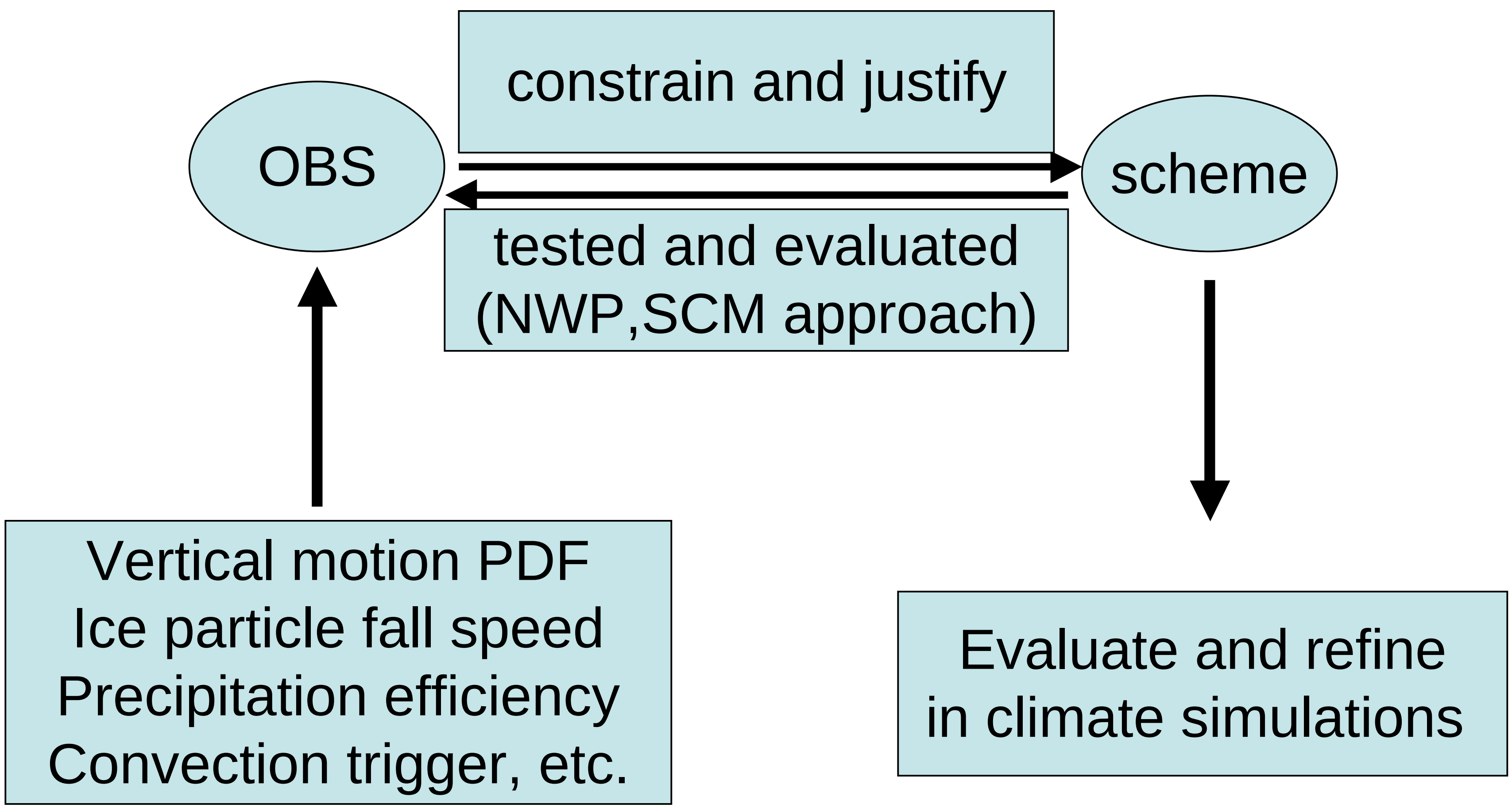
For model evaluation

1. Compare the same quantity
2. Go beyond the mean
3. Useful diagnostics (not readily available from model or OBS)



For scheme development

1. Focus on process level
2. Gain insights and new ideas



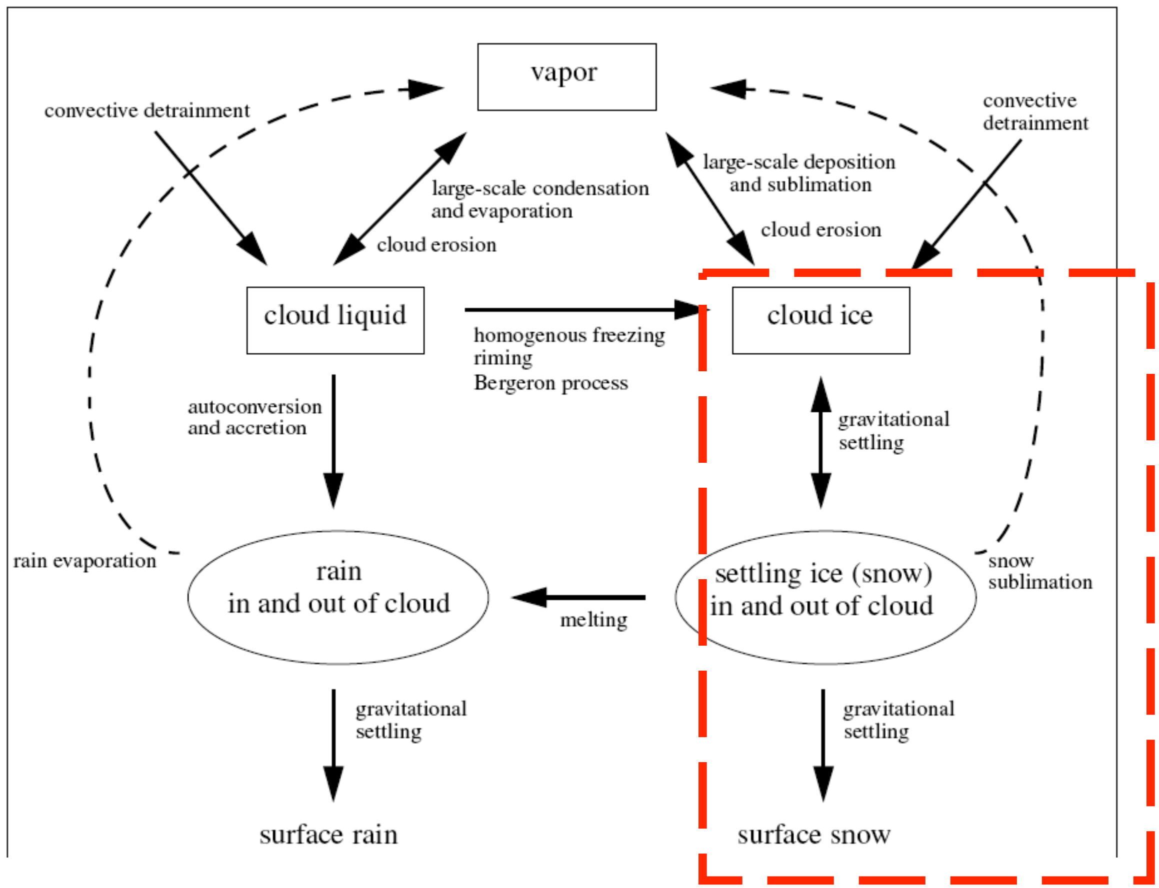
Outline

- An ice fall speed considering riming and its test and evaluation in GFDL AM3
- Another look at summer dryness over Great Plains
- Ongoing work (TWP-ICE NWP, vertical motion PDF, etc.)

GFDL AM3 cloud and convection schemes

Donner deep convection

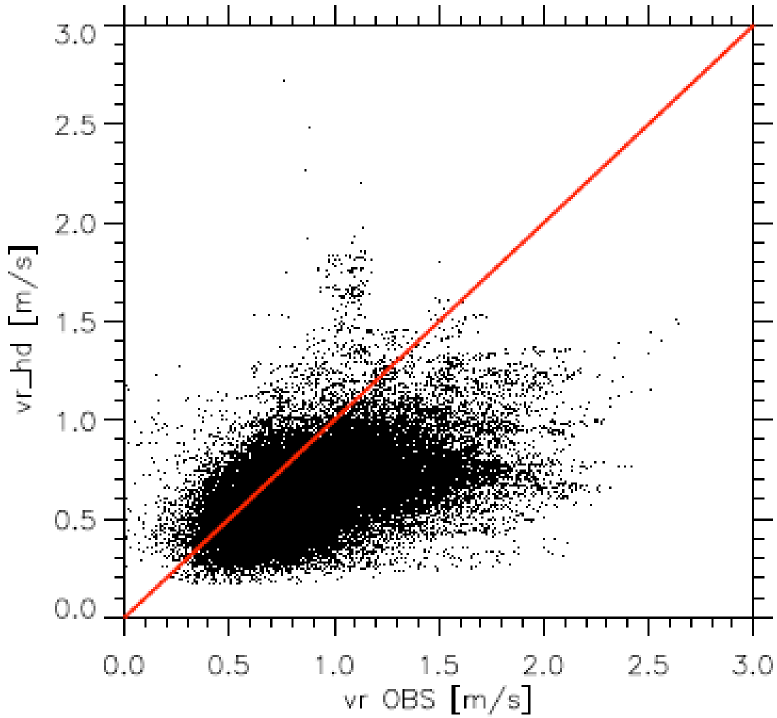
UW shallow convection



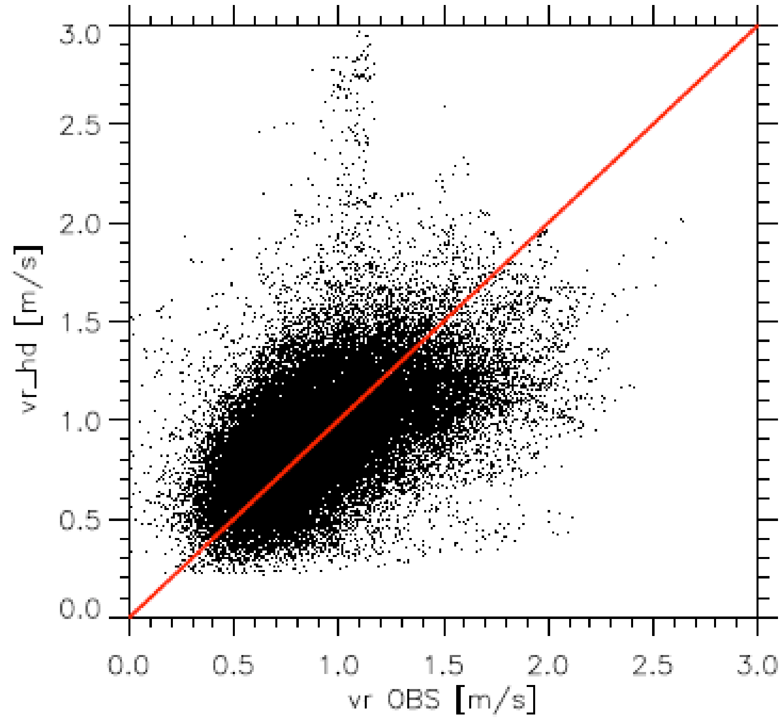
Tiedtke-Rotstayn-Klein large-scale cloud

A new ice fall speed considering riming

Heymsfield and Donner 1990 (JAS)



Ri approach



MMCR radial velocity at SGP

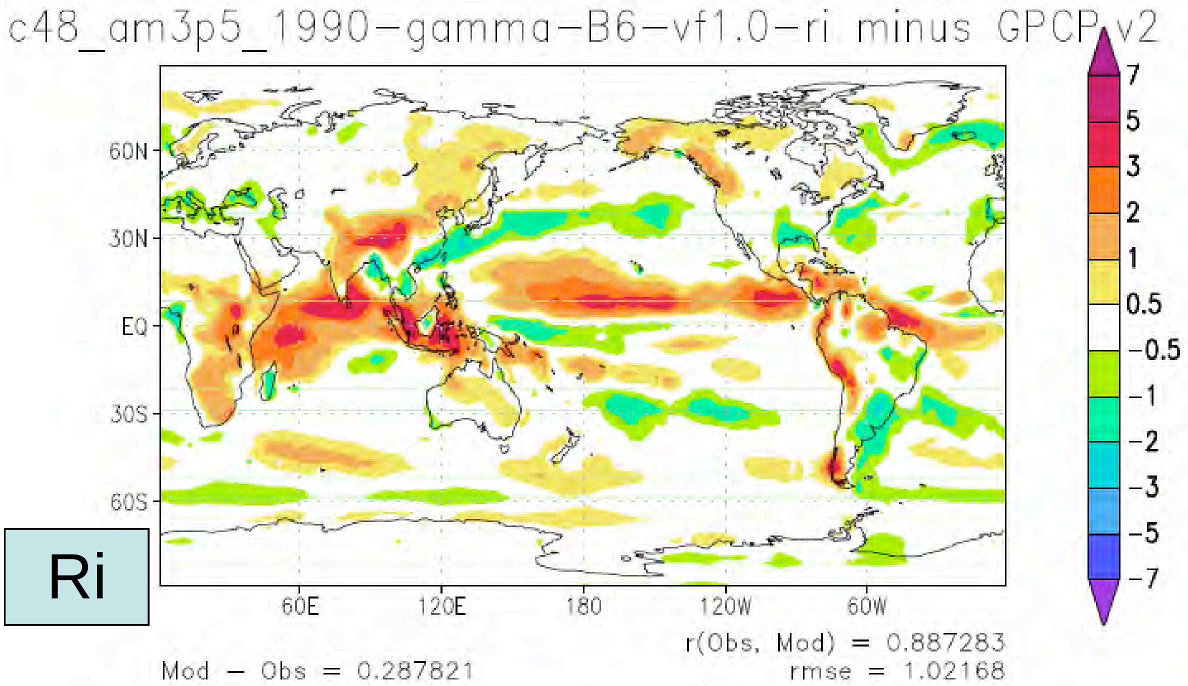
$$Vi = 3.29 IWC^{0.16} \quad V_g = 19.3 IWC^{0.37}$$

$$V_{Ri} = V_i IWC(1 - R_i) + V_g IWC R_i$$

Using Mace et al. 2006 (JGR)

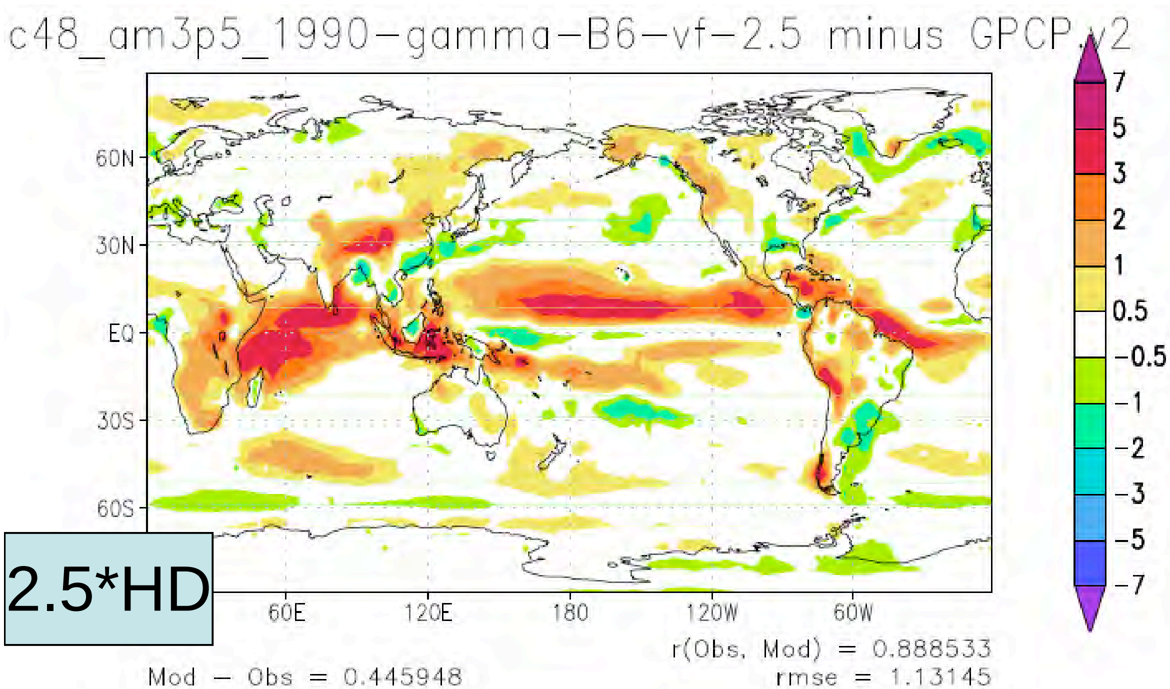
$$R_i = \frac{LWC}{LWC + IWC}$$

Precipitation difference between AM3 and GPCP



Ri

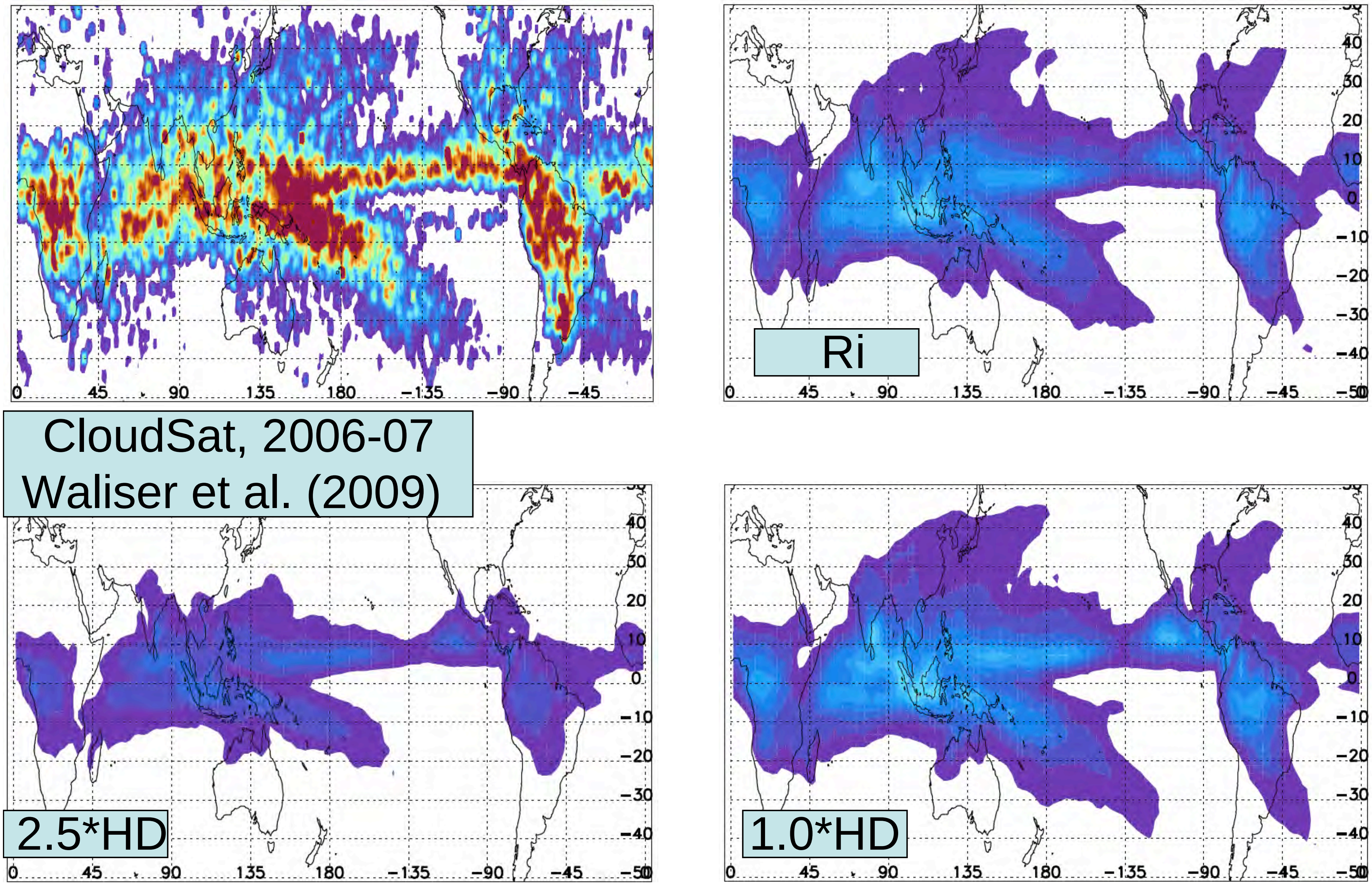
RMSE=1.02



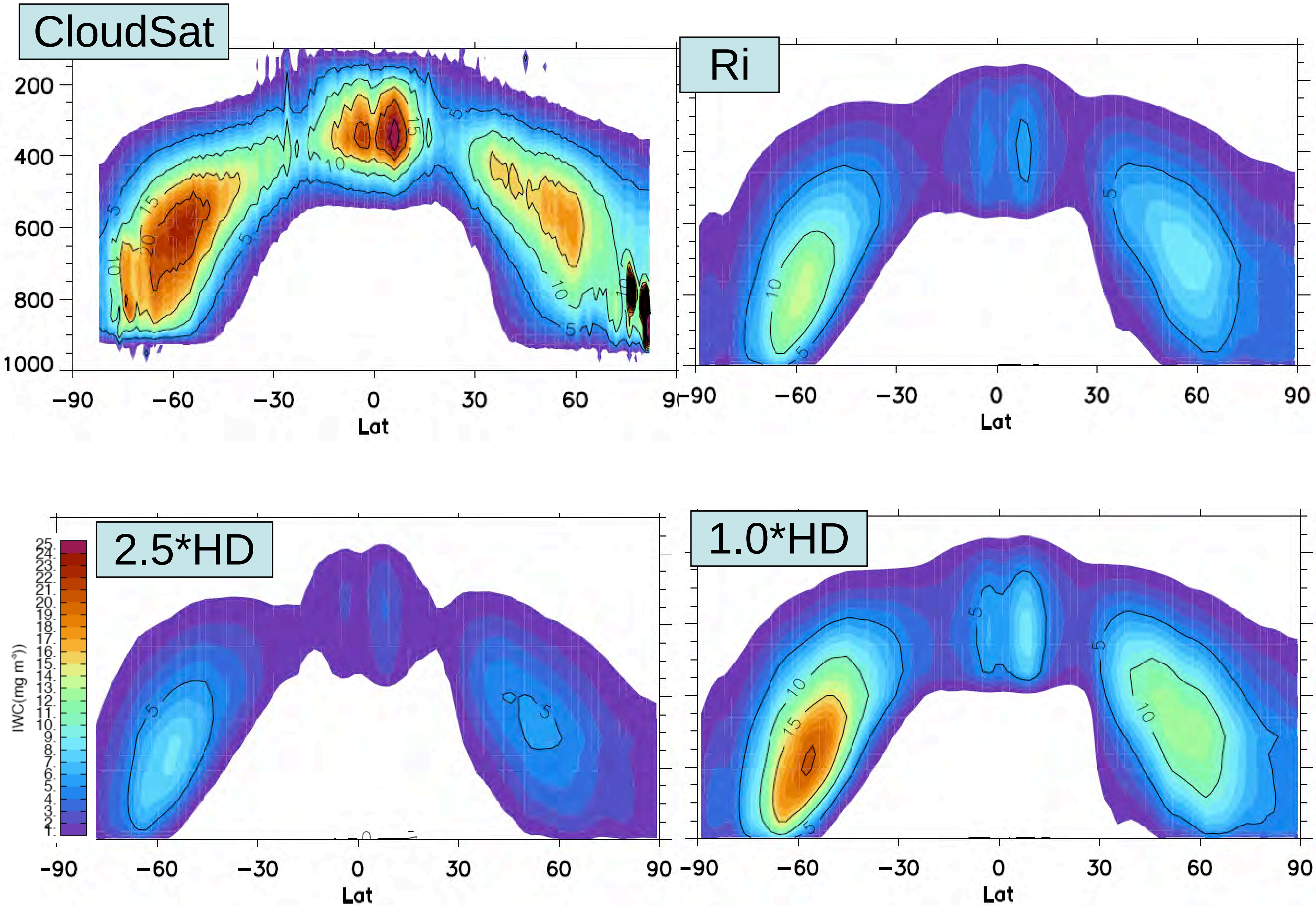
2.5*HD

RMSE=1.13

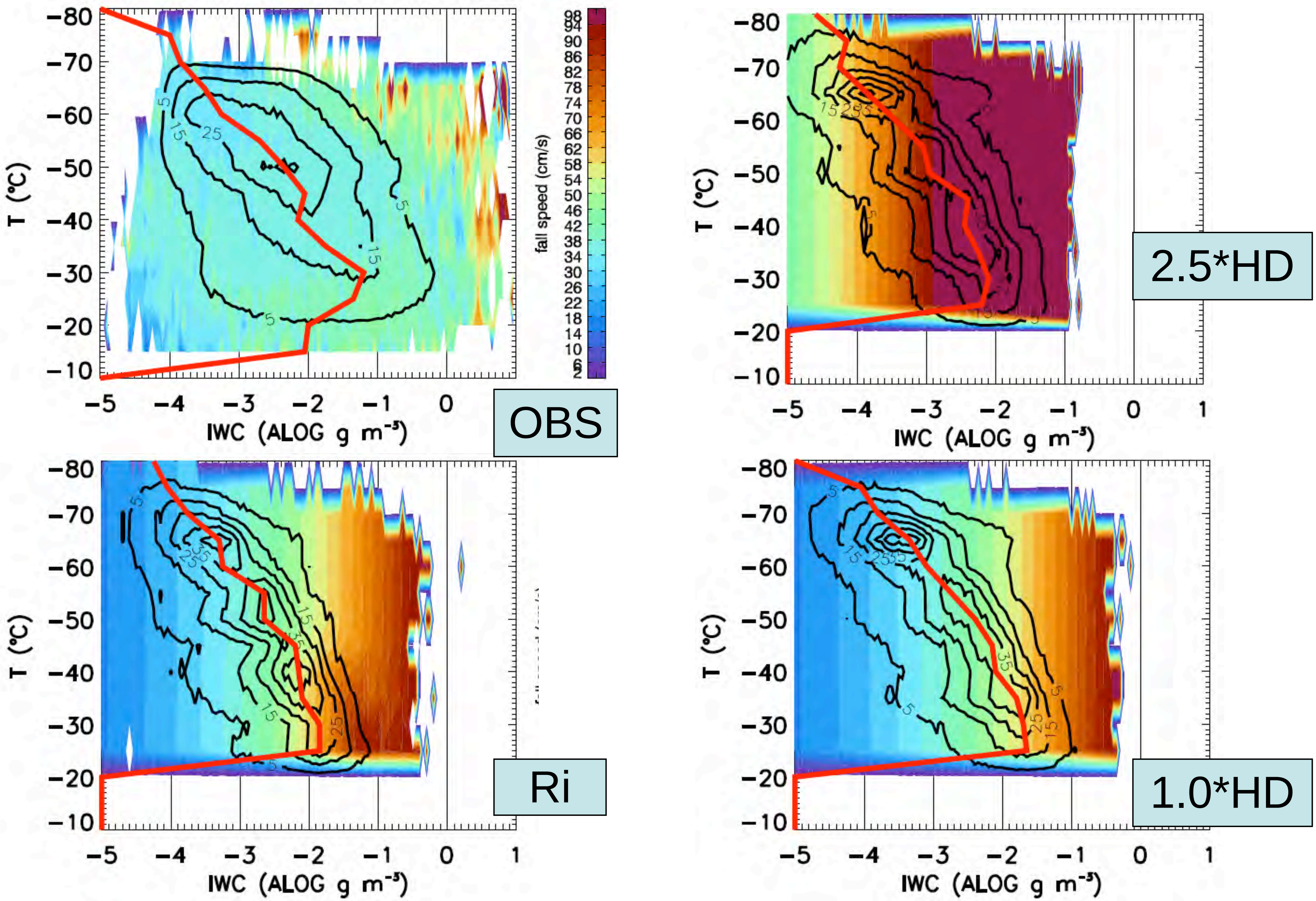
Ice water content (IWC) at 225 hPa

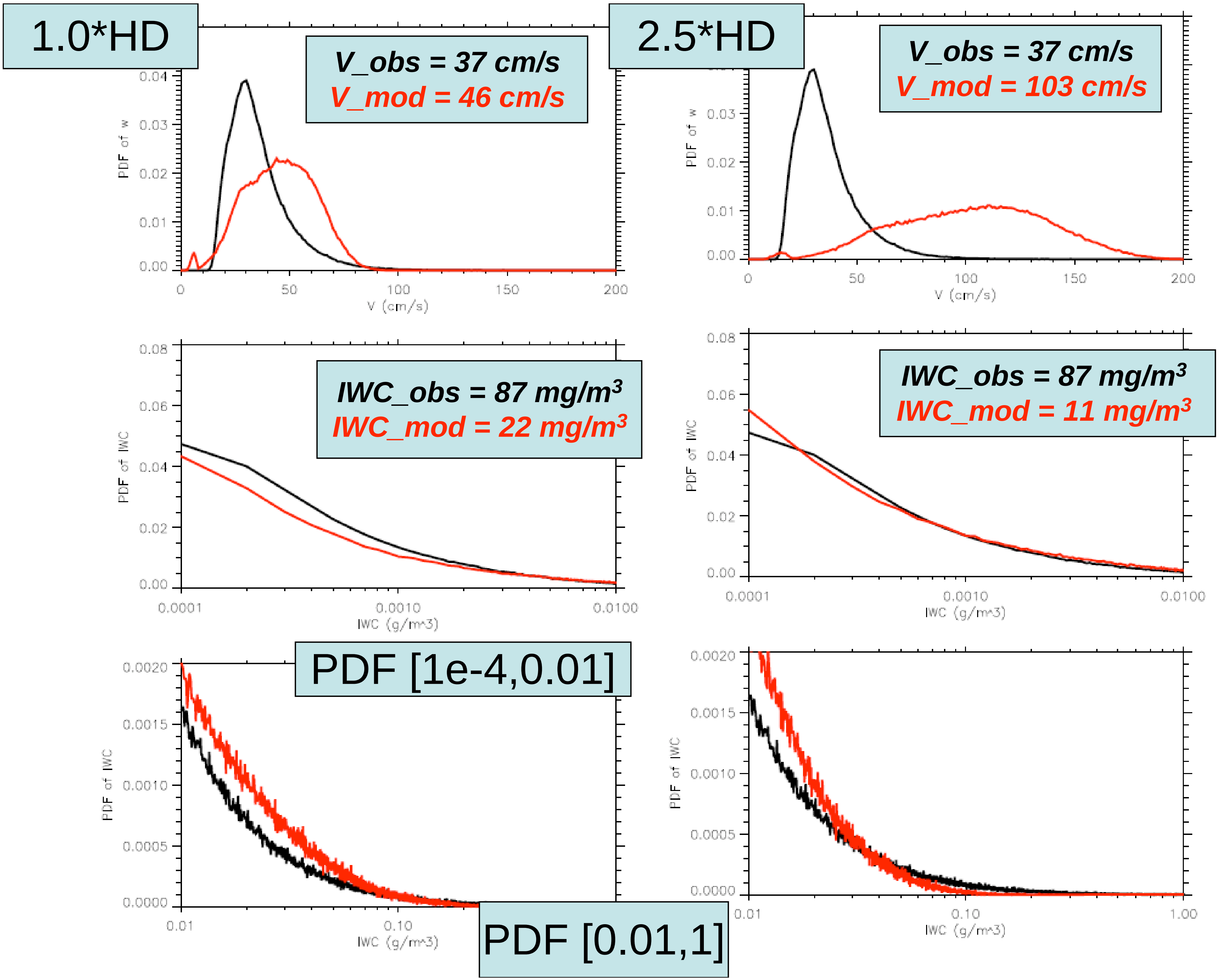


Zonal mean IWC

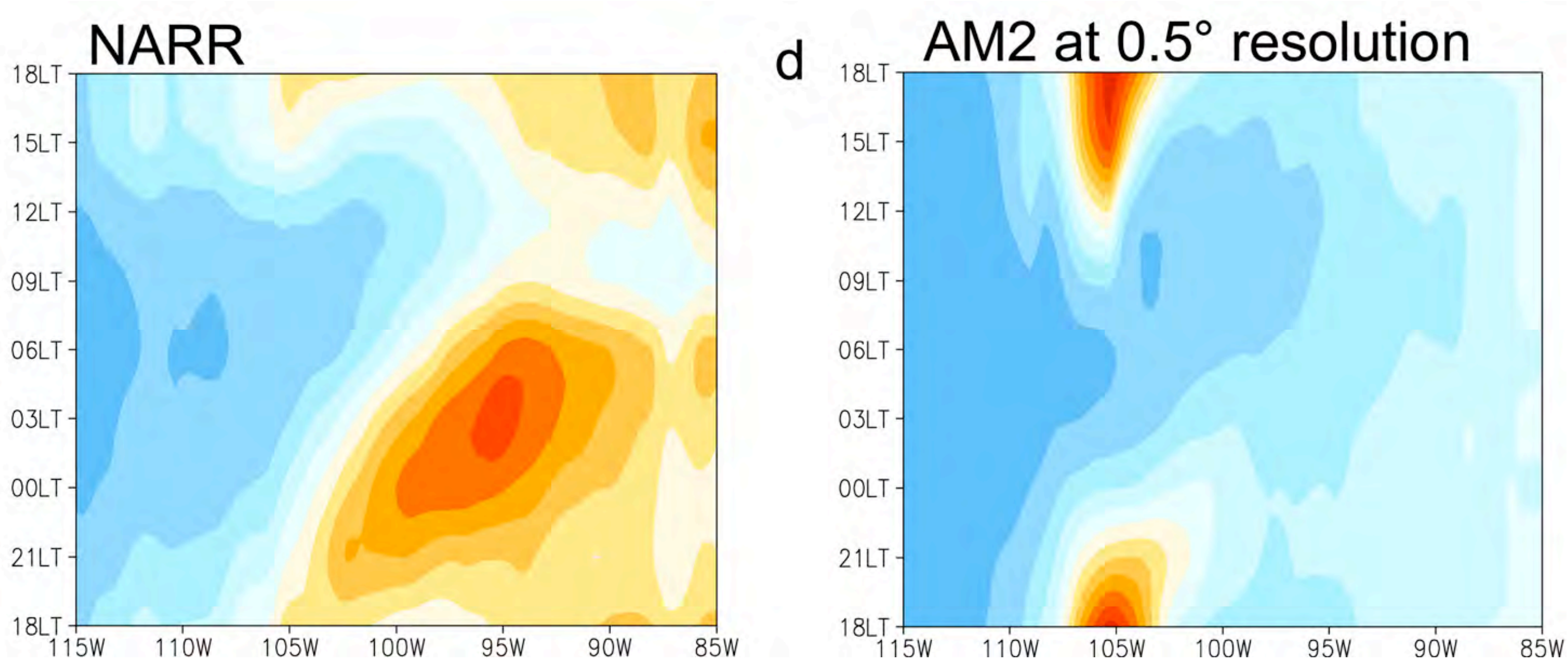


Relative frequency of occurrence and mean fall speed cirrus data at SGP (Deng and Mace 2008)




1.0*HD
2.5*HD
V_obs = 37 cm/s
V_mod = 46 cm/s
V_obs = 37 cm/s
V_mod = 103 cm/s
IWC_obs = 87 mg/m³
IWC_mod = 22 mg/m³
IWC_obs = 87 mg/m³
IWC_mod = 11 mg/m³
PDF [1e-4,0.01]
PDF [0.01,1]
PDF of w
V (cm/s)
PDF of IWC
IWC (g/m^3)

Summer dryness over the Great Plains

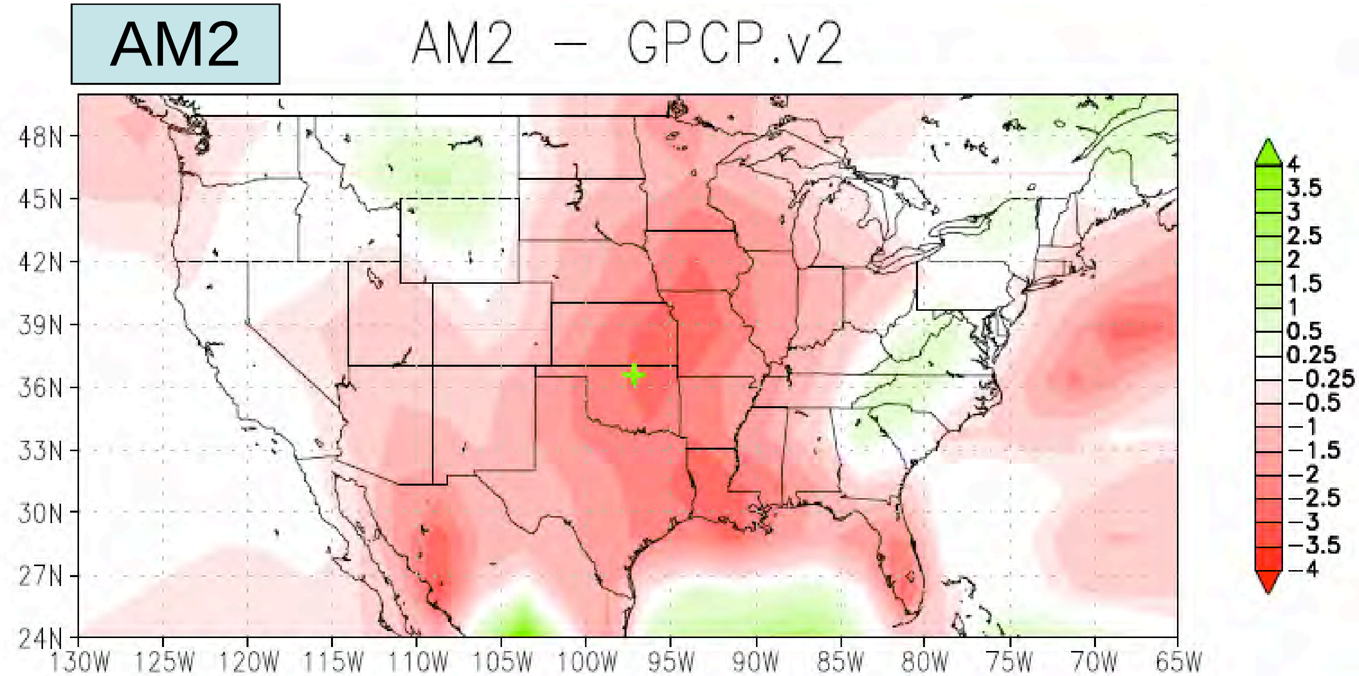


Klein et al. 2006 (GRL), AM2

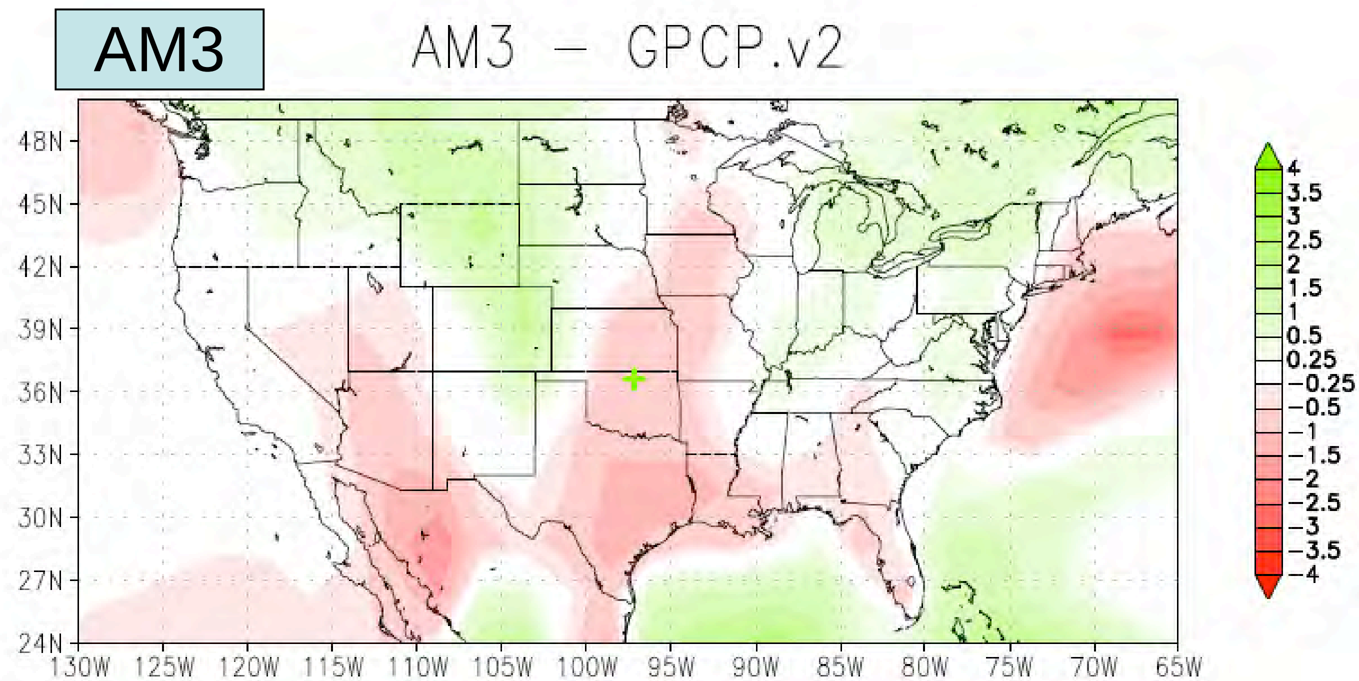
JJA precipitation

mm/day

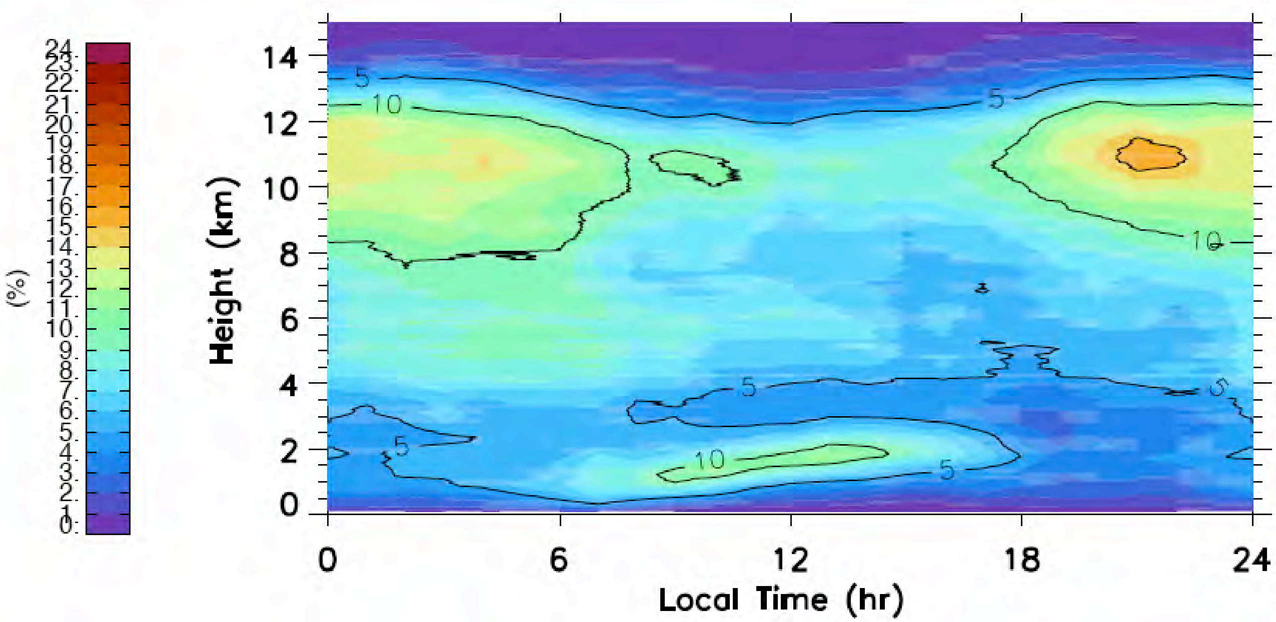
AM2



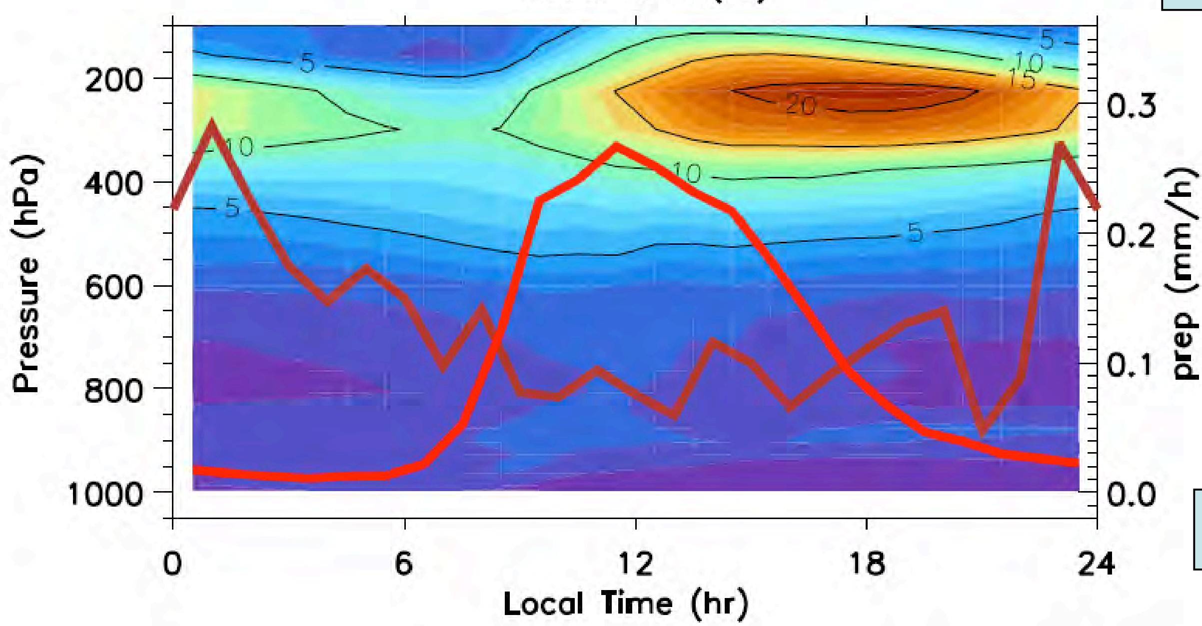
AM3



Diurnal variation of cloud amount

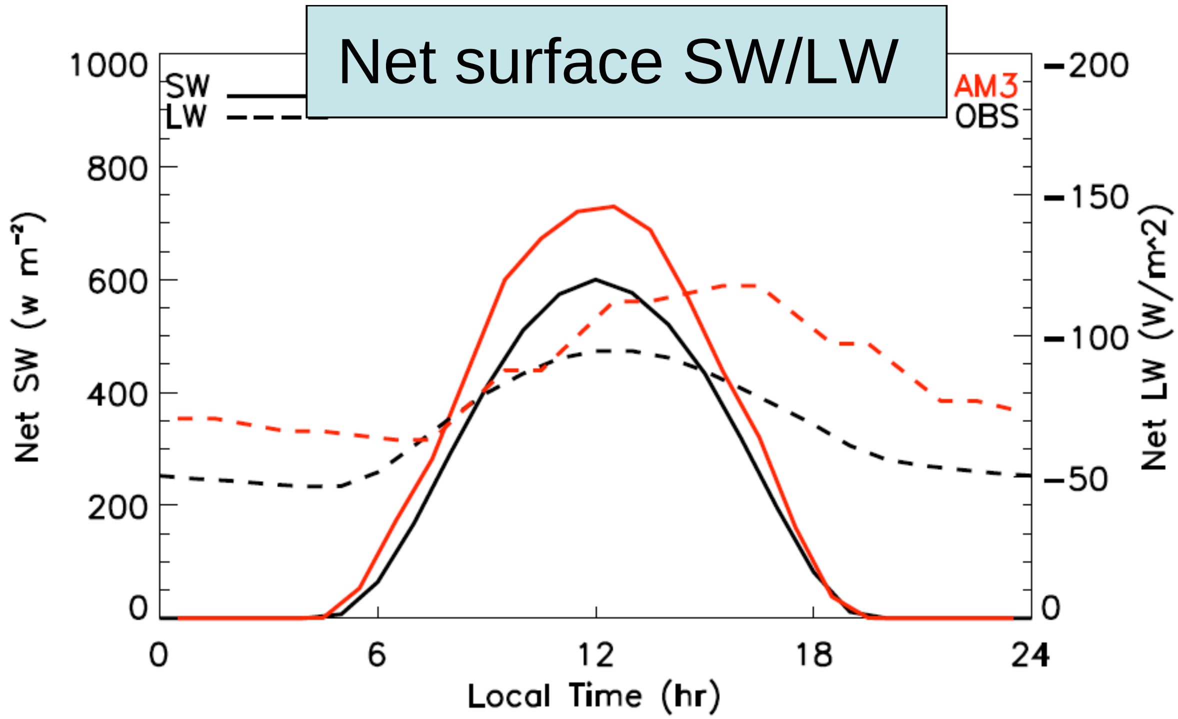


ARM CMBE

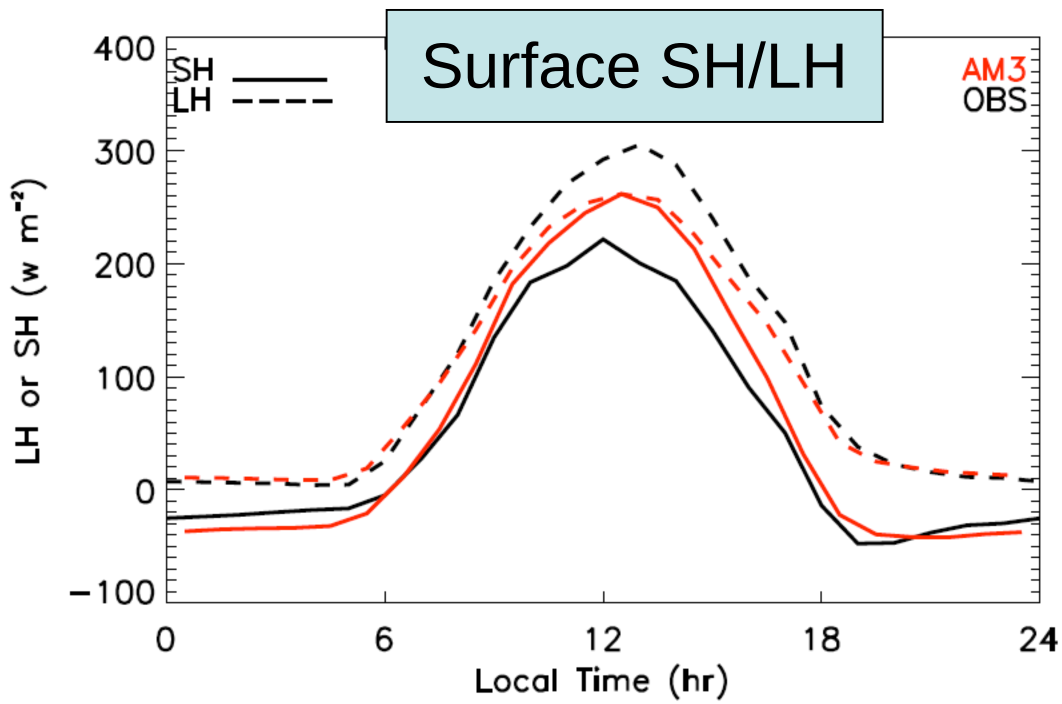


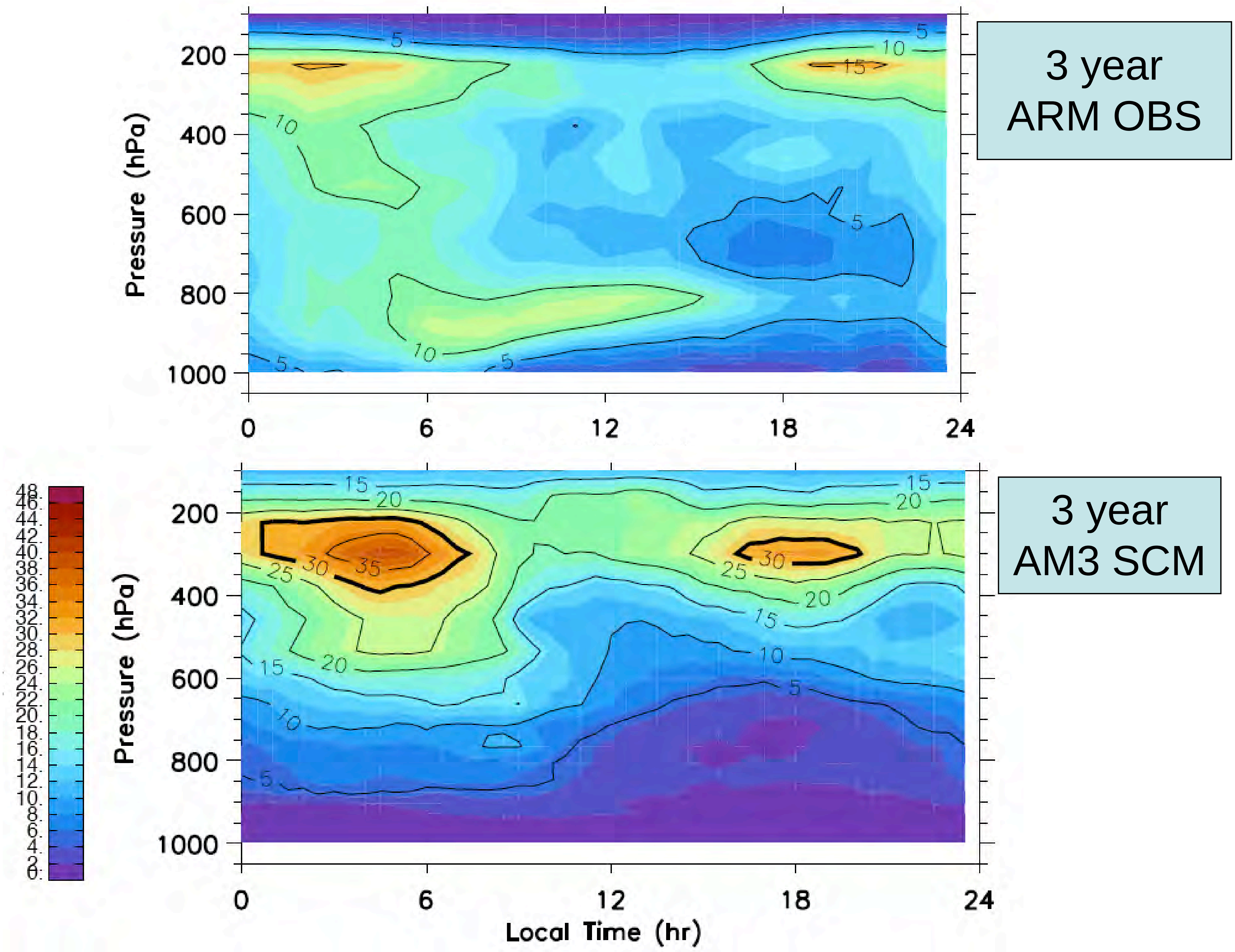
AM3 AMIP

- model misses the low level clouds in the day time
- Precipitation is out of phase



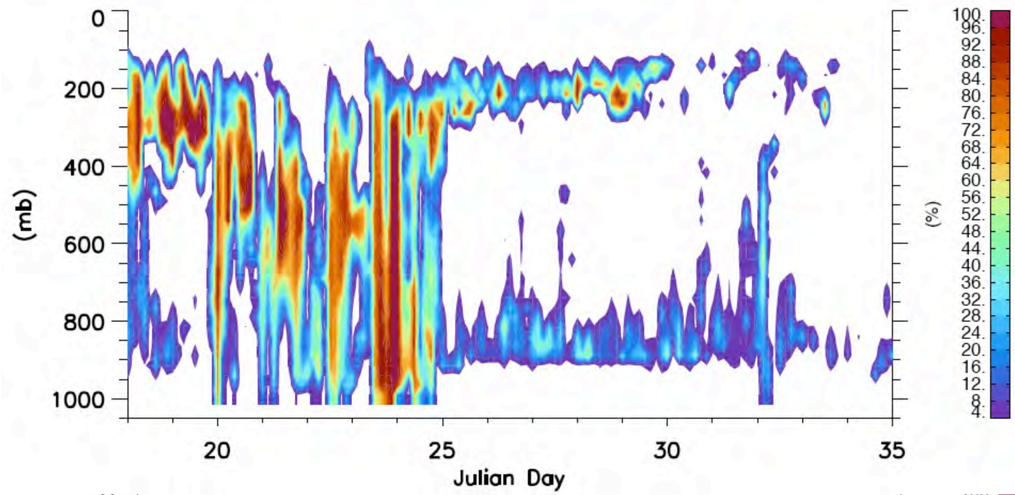
Net surface energy budget:
model 3.5 w/m^2 larger



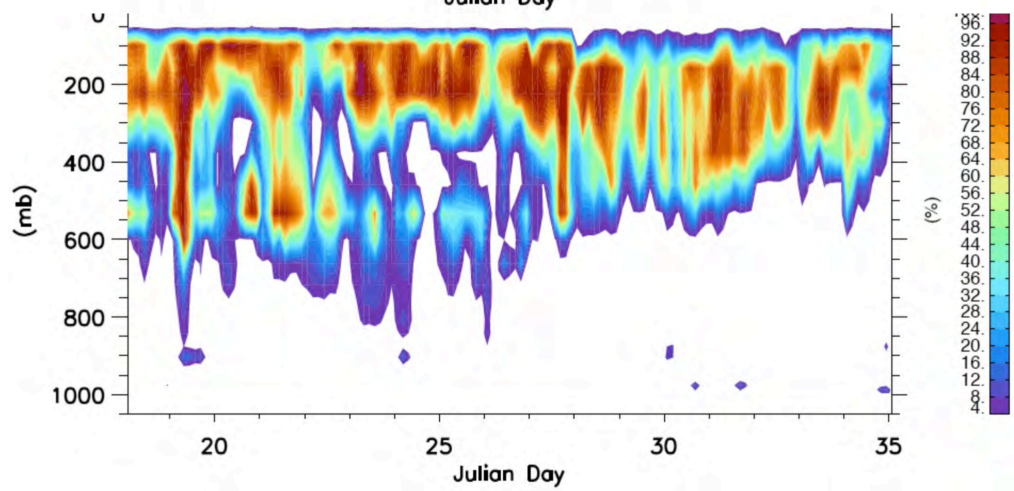

3 year
ARM OBS
3 year
AM3 SCM
Pressure (hPa)
Local Time (hr)

TWP-ICE NWP Simulations

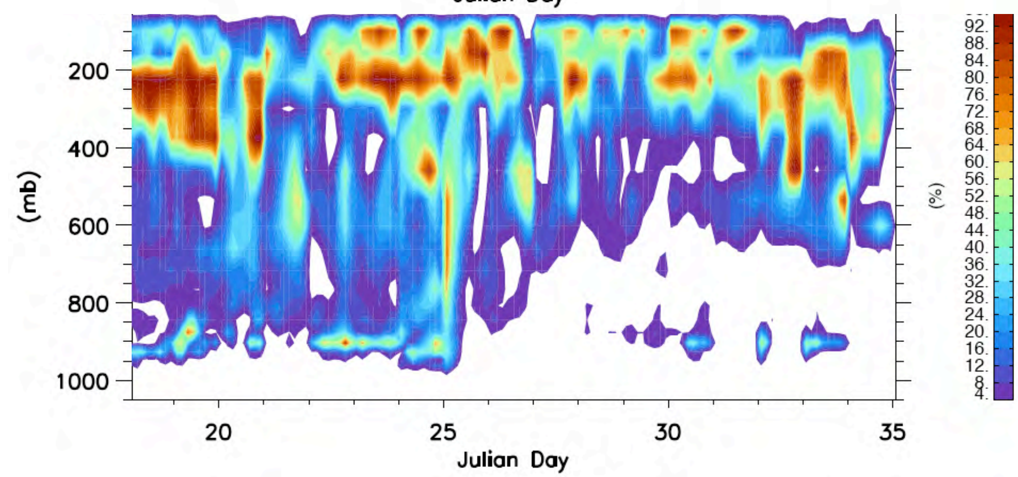
OBS cloud fraction



GFDL AM3



GFDL AM2



Preliminary results

- ARM data is valuable for both GCM evaluation and model scheme development.
- GCM simulations are sensitive to ice fall speed parameterization. A new ice fall speed formula considering riming improves precipitation simulation.
- Preliminary comparison indicates AM3 might underpredict IWC, which is compensated by overpredicted upper level cloud fraction.
- GFDL AM3 improves the summer dryness over the Great Plains, but its precipitation is out of phase and it underestimates the shallow cumulus.


Thank you!

Implementation

M(D):mass dimension

Equivalent density

$$M = a_m D^{b_m}$$

Fractal dimension

$$a_m = c_0 + c_1 T + c_2 Ri^2$$

$$b_m = d_0 + d_1 T + d_2 Ri$$

Varying habit from Heymsfield et al. 2007 and Baker and Lawson 2006

A(D): area dimension

$$A = a_a D^{b_a}$$

$$a_a = C_0 + C_1 T + C_2 Ri$$

$$b_a = D_0 + D_1 T + D_2 Ri$$

Riming effect

Capacitance(b_m)

$$V = AD^B$$

V(D): velocity dimension

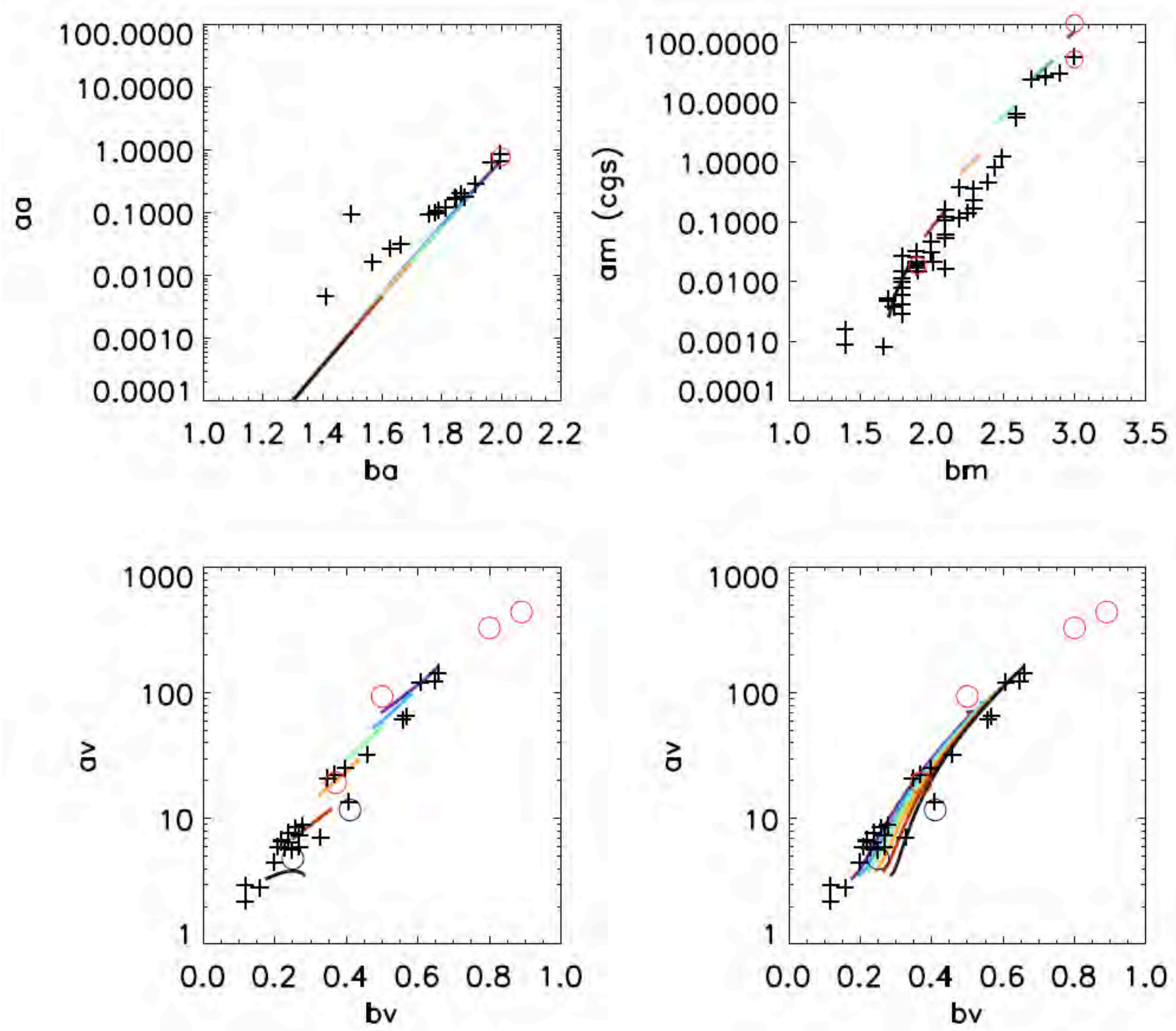
$$A = a\mu\left(\frac{2ga_m}{\rho_a \mu^2 a_a}\right)^b$$

$$\mathrm{Re} = aX^b$$

$$B = b(b_m - b_a + 2) - 1$$

Mitchell 1996

Justification of the approach

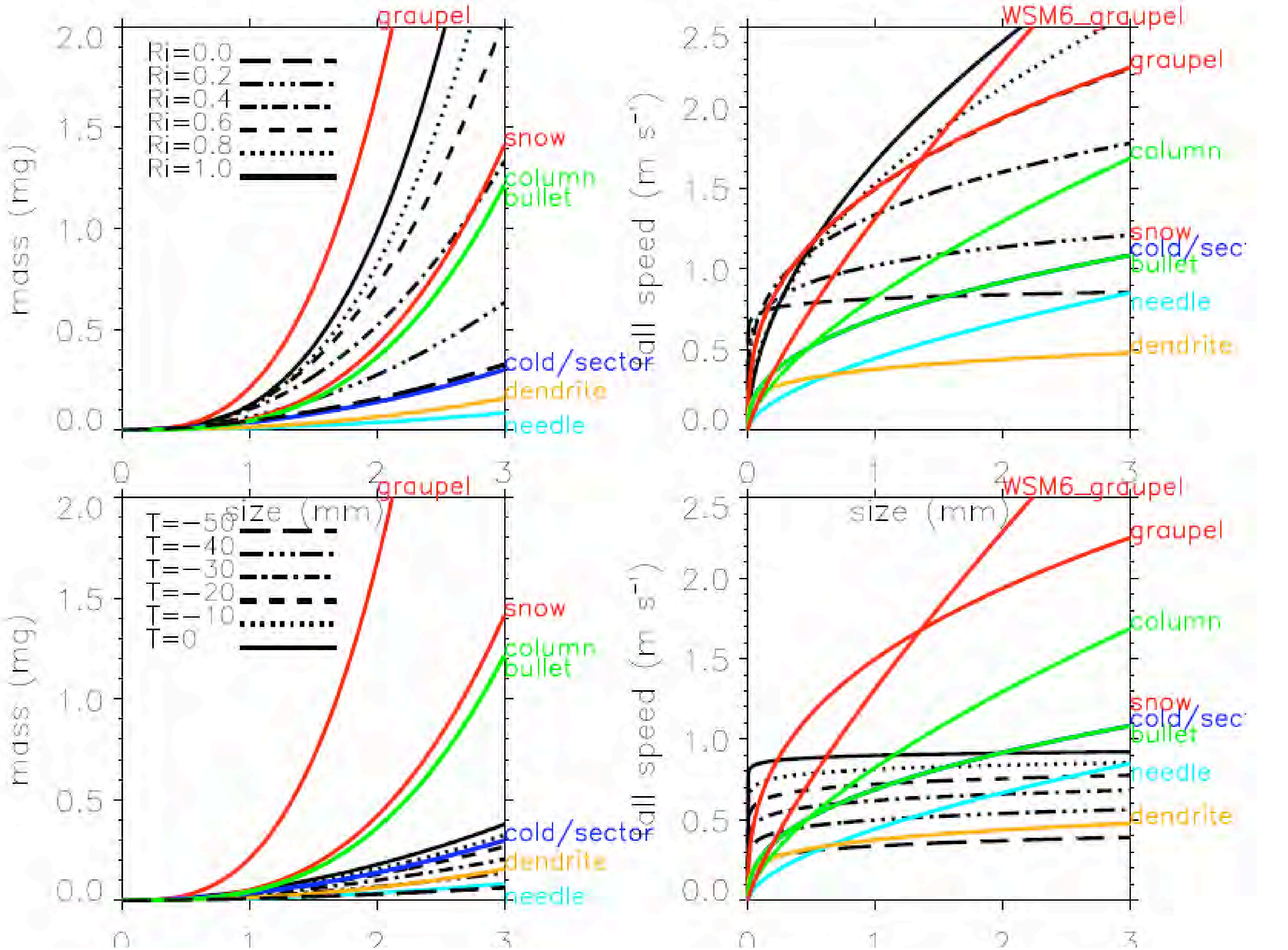


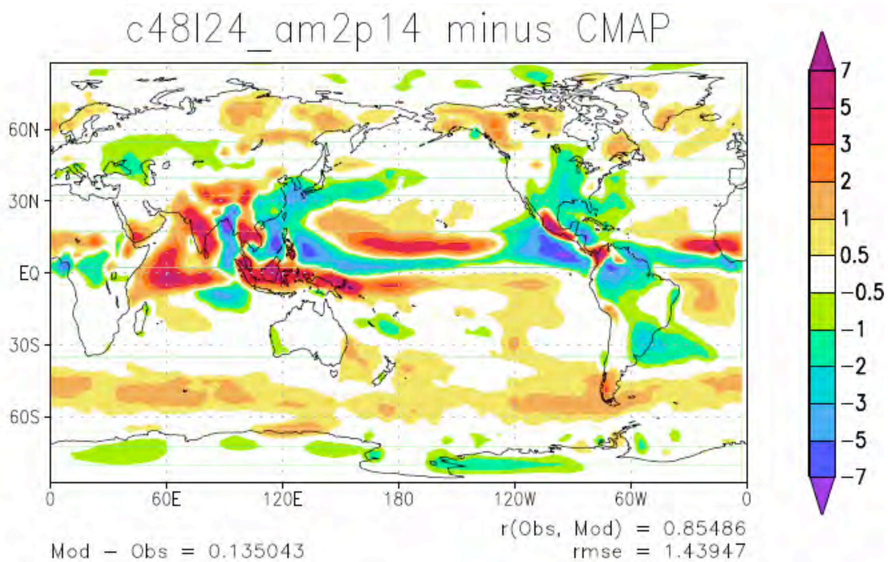
Crosses:
Empirical
coefficients
from observations

Circles:
WRF schemes

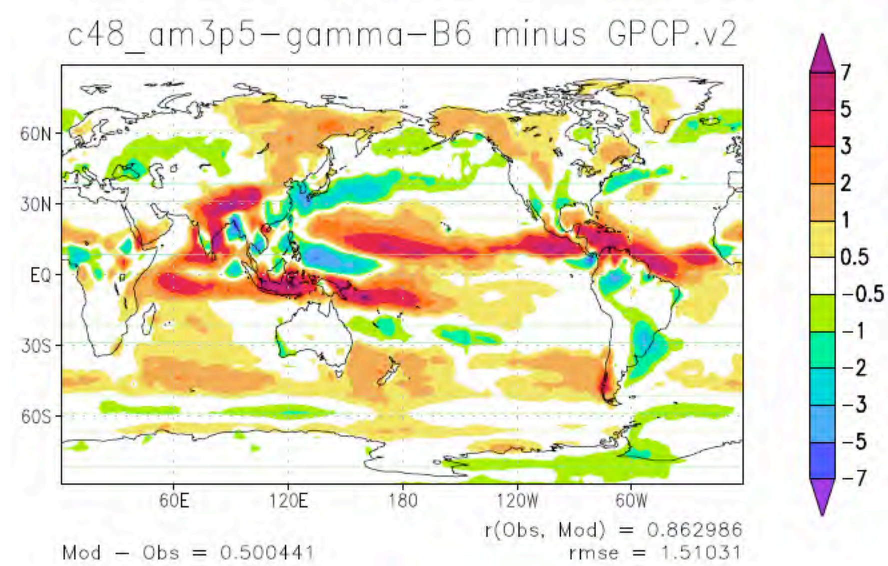
Lines:
new approach

Power law coefficients for A, M, and V

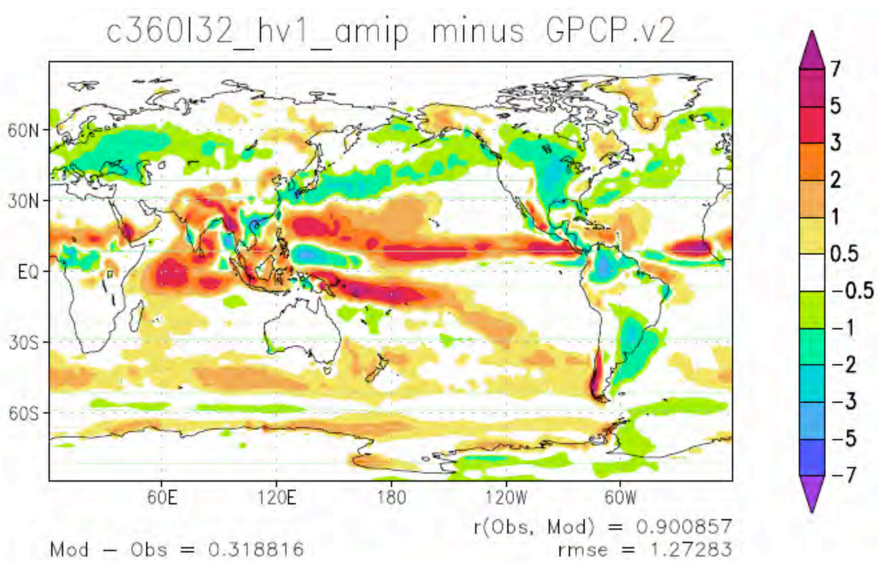

graupel
Ri=0.0
Ri=0.2
Ri=0.4
Ri=0.6
Ri=0.8
Ri=1.0
snow
column
bullet
cold/sector
dendrite
needle
mass (mg)
size (mm)
WSM6_graupel
fall speed (m s⁻¹)
T=−50
T=−40
T=−30
T=−20
T=−10
T=0



AM2

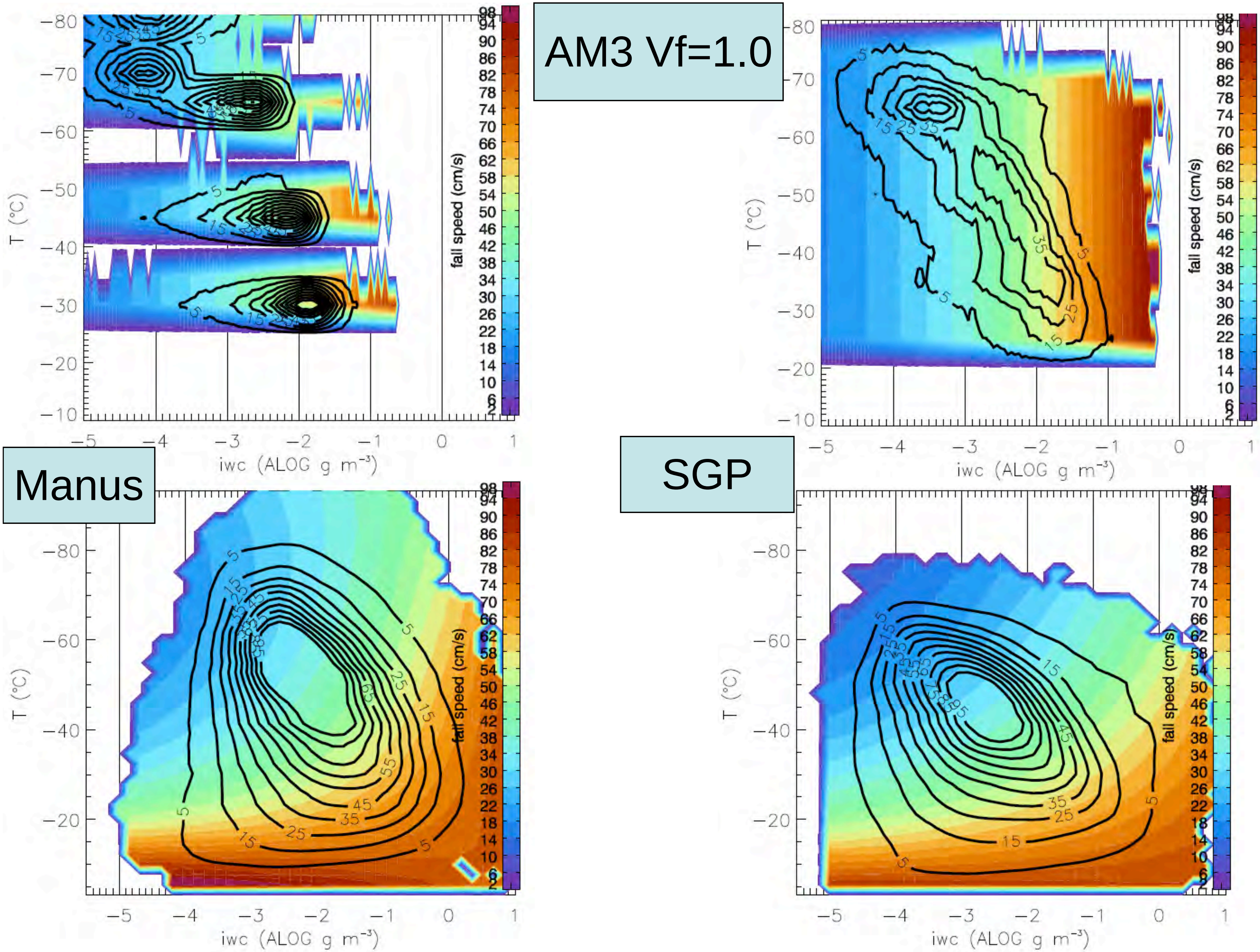


AM3P5

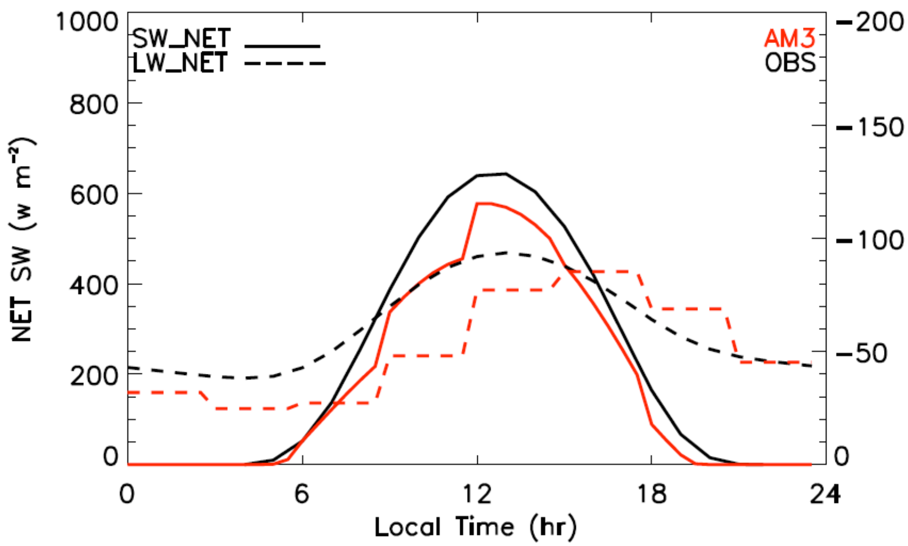


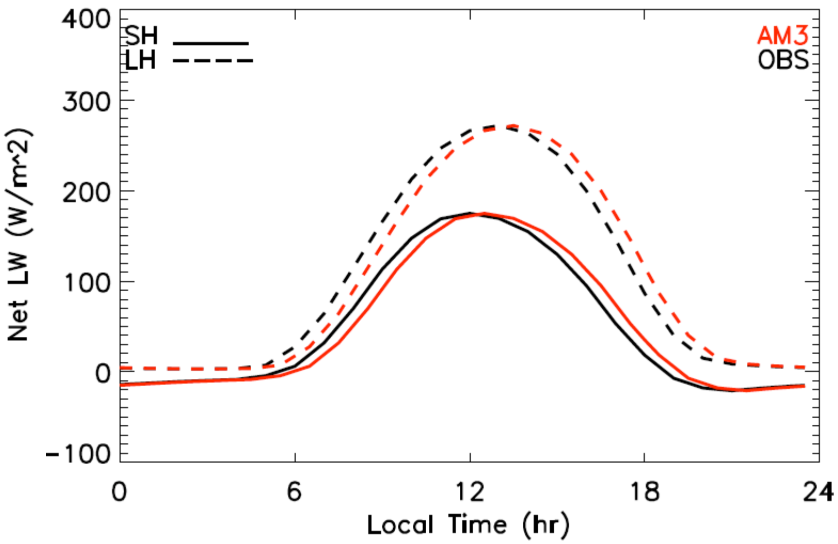
HIRAM,~25km

Klein et al. 2006, AM2

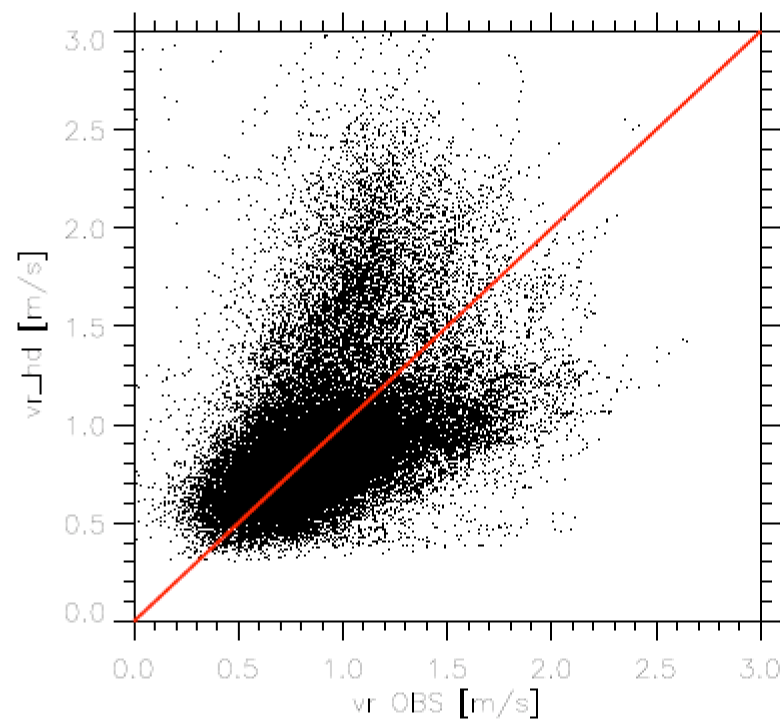


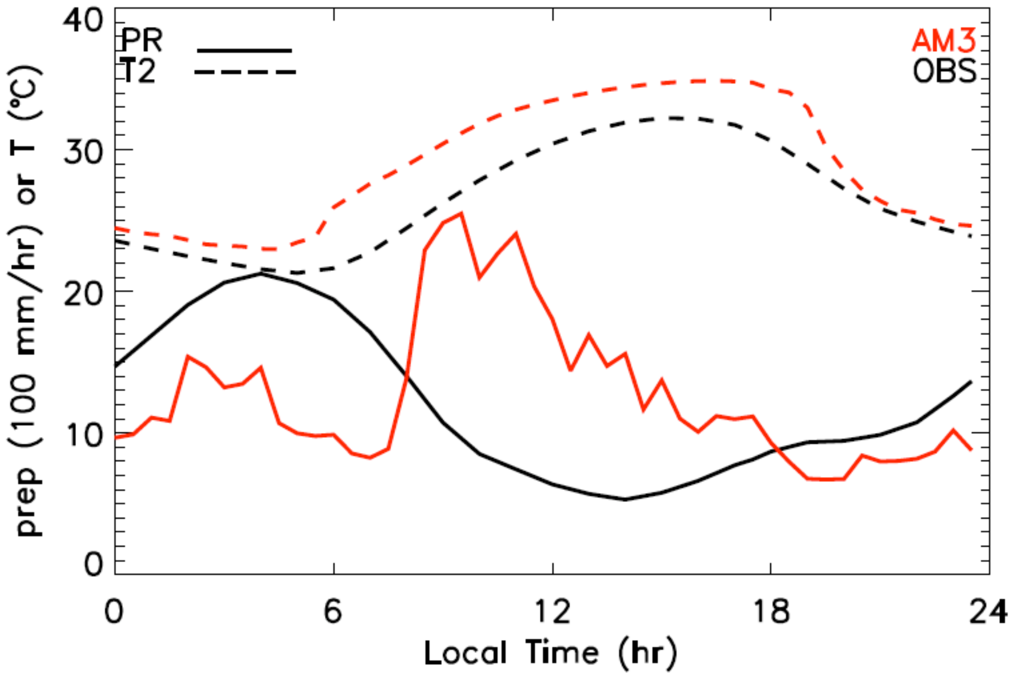
AM3 Vf=1.0
Manus
SGP
T (°C)
iwc (ALOG g m⁻³)
fall speed (cm/s)





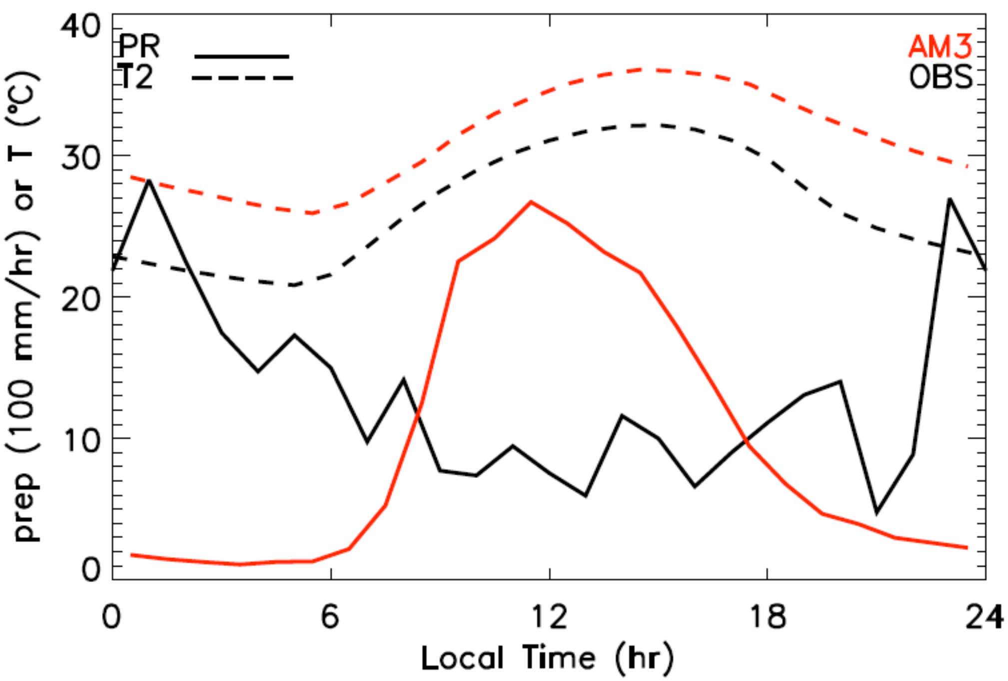
$$R_i = \frac{P_{rim}}{P_{rim} + P_{dep}} = \frac{1}{1 + \frac{F(T)}{LWC}\left(\frac{N0_s}{IWC}\right)^{\frac{0.5(b_v+1)}{b_m+1}}}$$





T2 and Prep

SCM



GCM