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Progress Towards a Combined AMSR / SeaWinds Algorithm

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Preliminaries

- Response of SeaWinds sigma-0's to rain very similar to QuikSCAT on average.
  - Previously noted discrepancy the result of collocation dataset period and non-stationarity of means.

Purpose

- Gain understanding of rain effects
  - Drive algorithm development
  - Estimate confidence in corrected winds
- Complicating factors:
  - Beamfilling
  - Vertical profile
  - DSD
  - Rain roughening

Model

$$\sigma_{0,meas} = \tau_r^2 \left(\sigma_{0,wind} + \Delta\sigma_{rain} \right) + \sigma_{0,bscat}$$

surface signal

transmission

volumetric rain backscatter

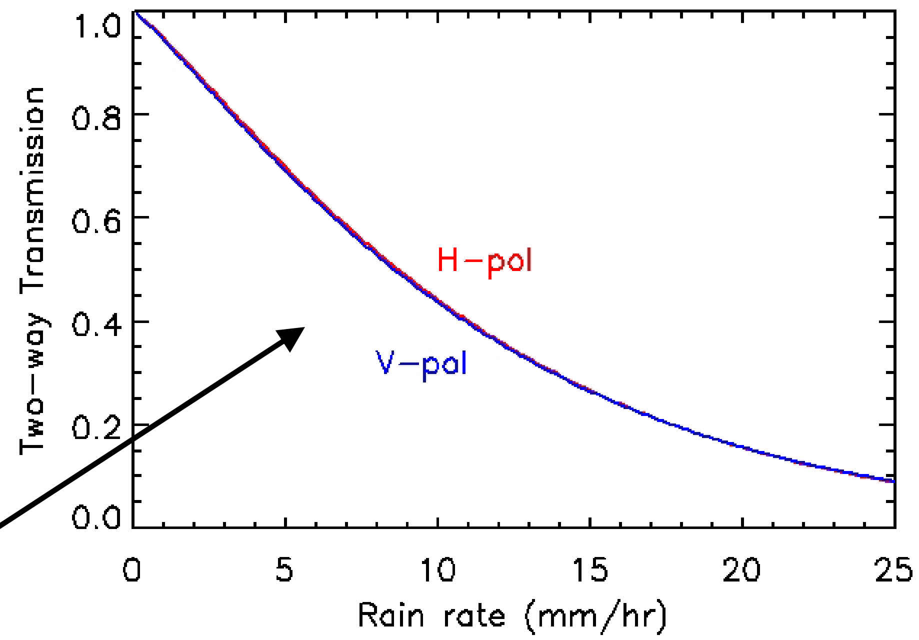
atmospheric signal

Transmission

$$\tau_r^2 = e^{-2\int_0^{H \sec\theta} k(l)\,dl}$$

$$= e^{-2H \sec\theta k}$$

ITU *k-R* relationships (*H*=3km).

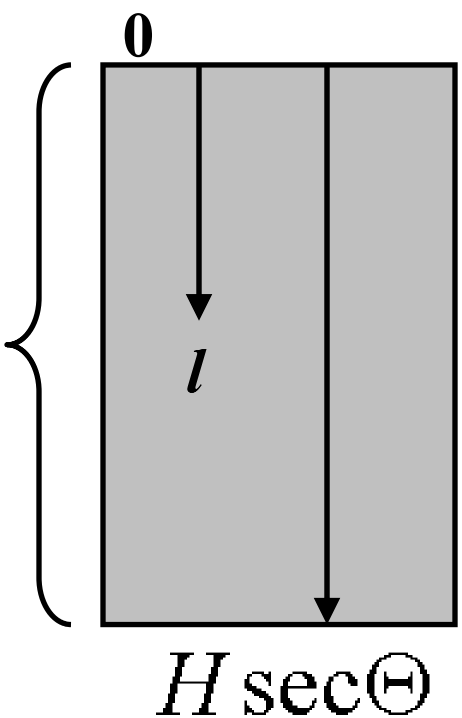


Volumetric Rain Backscatter

$$\sigma_{0,bscat} = \int_0^{H\sec\theta} e^{-2\int_0^l k\,dl}\,\eta\,dl$$

$$= \left(\frac{1-\tau_r^2}{2k}\right)\left(\frac{\pi^5 \left|K_w\right|^2}{\lambda^4}\right) z_{e,p}$$

effective radar reflectivity factor = $z_e\left(l\right) = \text{constant}$

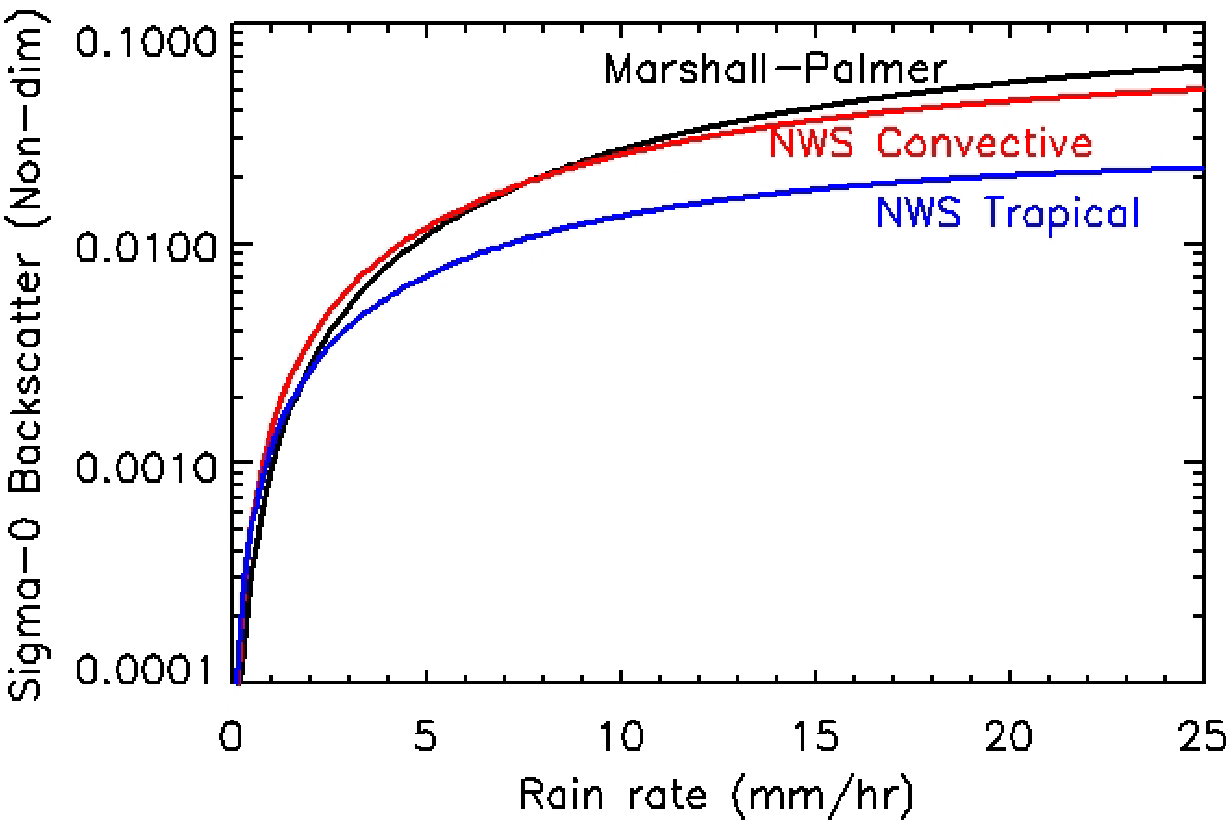


Polarization conversion:

$$R = c z_h^a z_v^b$$

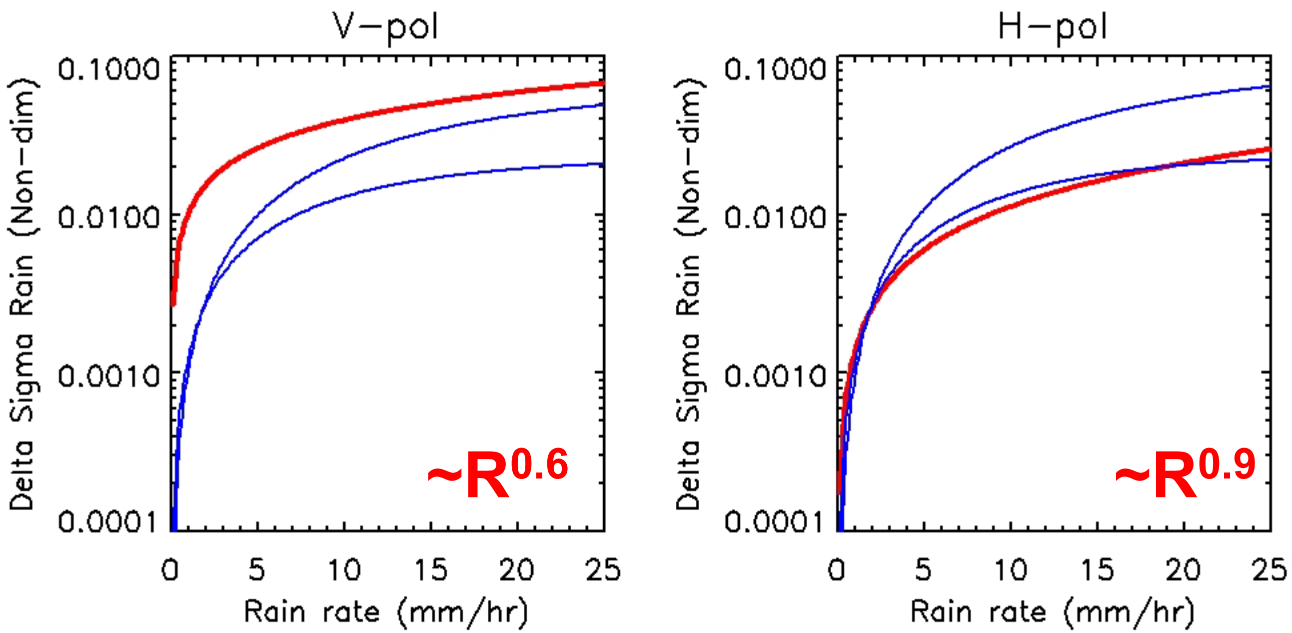
Polarimetric Doppler Weather Radar
Bringi and Chandrasekar (2001)

Volumetric Rain Backscatter



(H-pol, *H*=3 km)

Rain Roughening



Contreras et al., 2003 (JGR)
(all wind speeds, 51 deg incidence)

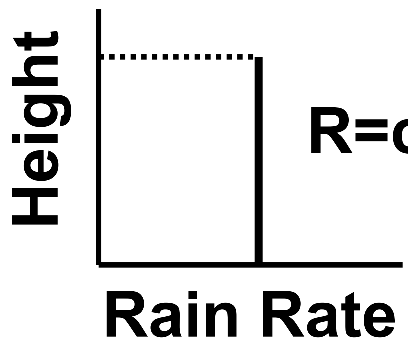
NWS Tropical and Marshall-Palmer (~$R^{1.2,1.6}$)

Beamfilling

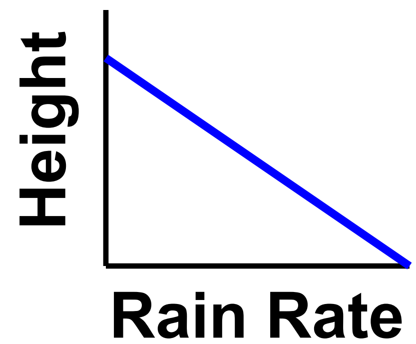
- Two assumptions
  - Constant vertical profile
  - Uniform horizontal distribution in footprint (Beamfilling)

Profiles

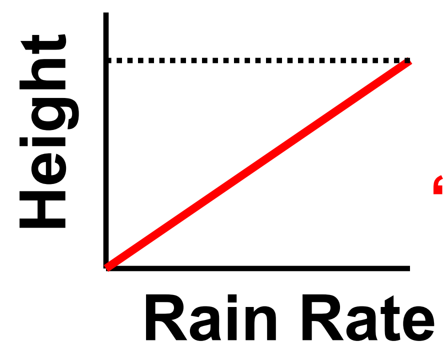
Zeroth Order Approx.



First Order Approx.



Downward
Increasing
"Typical"

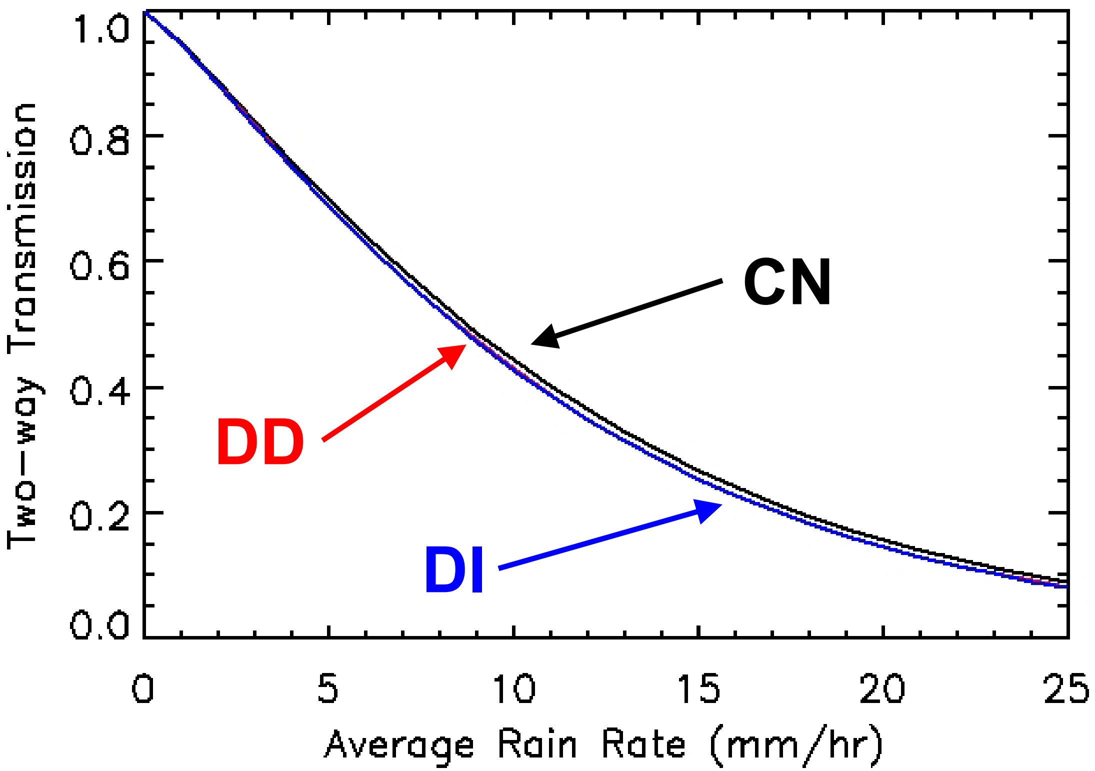


Downward
Decreasing
"Bright Band"

Note: All profiles have same

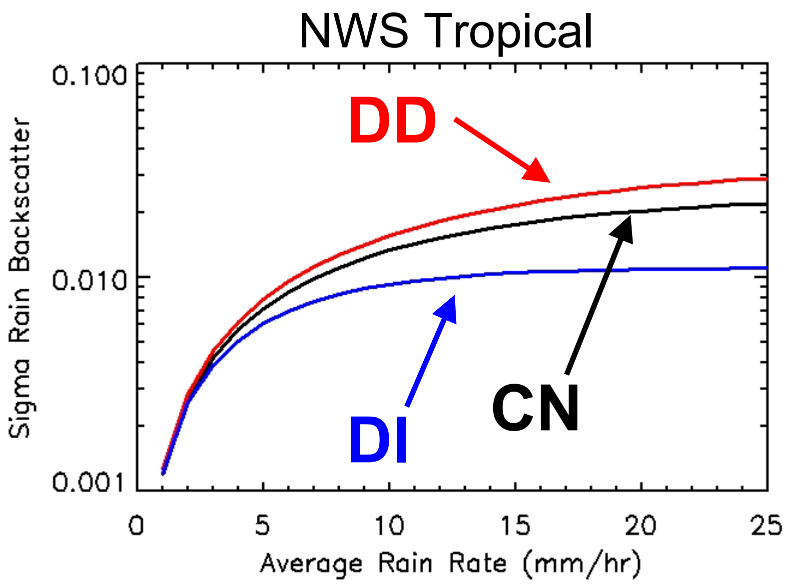
- **Average Rain Rate**
- **Rain Column Height**

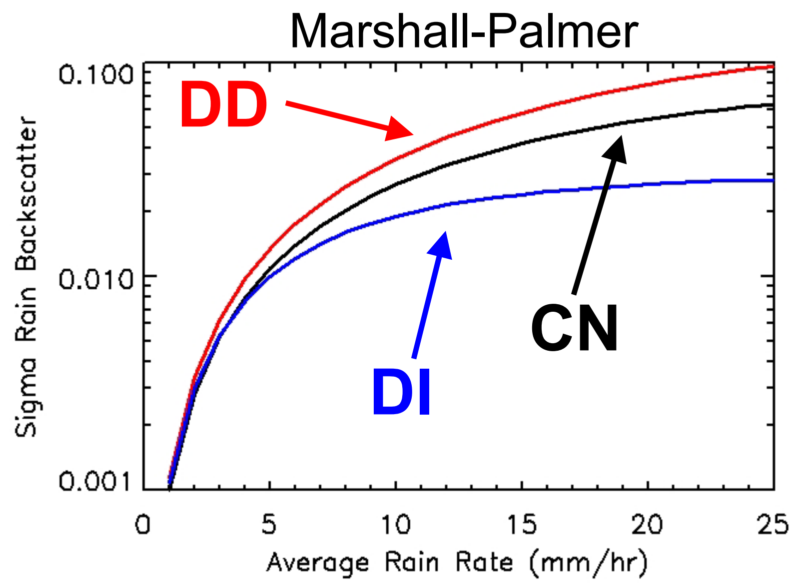
Profiles (Transmission)



Thus, it is the total rain water content, and not the profile, that is important for attenuation.

Profiles (Volumetric Backscatter)





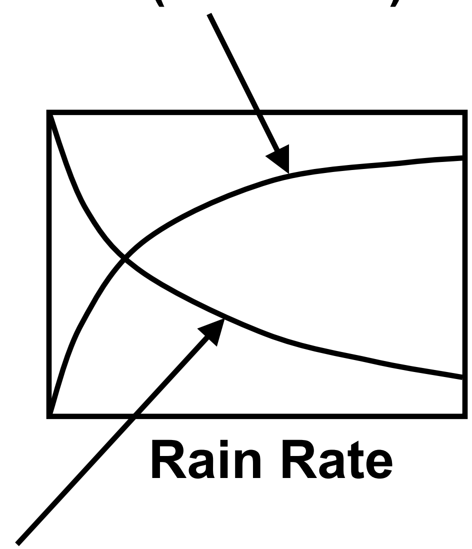
Thus, the profile shape is as important as the DSD!
. . . But the profile is only important for R > 3 mm/hr.

Beamfilling

- **Jensen's Inequality gives**

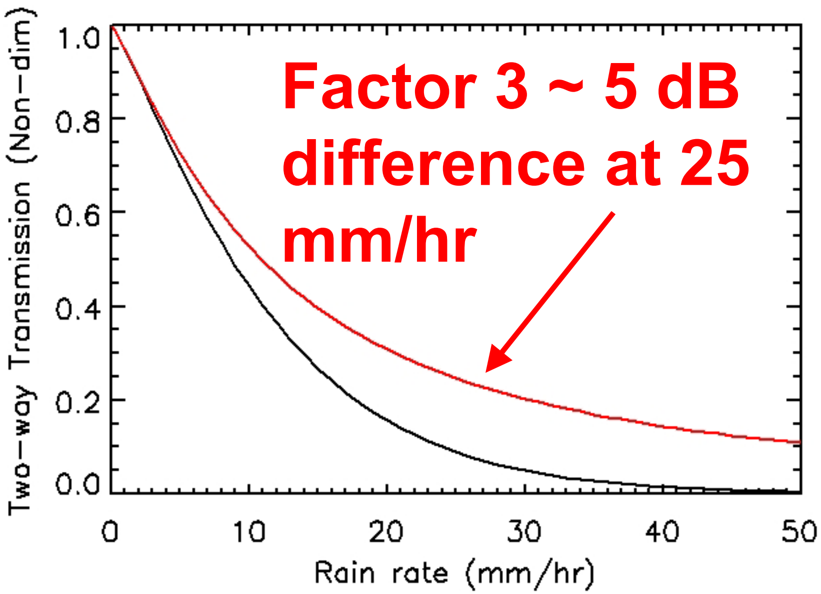
$$E\left[\tau_r^2(R)\right] > \tau_r^2\left(E[R]\right)$$

$$E\left[\sigma_{0,bscat}(R)\right] < \sigma_{0,bscat}\left(E[R]\right)$$



Beamfilling (Transmission)

$$E\left(\tau_r^2\right)=E\left(e^{tA}\right)=M_A\left(t\right)=\frac{1}{\left(1-\left(A_L\beta^2\right)t\right)^{\beta^{-2}}}$$



$$t=-2\sec\theta, A=kH$$

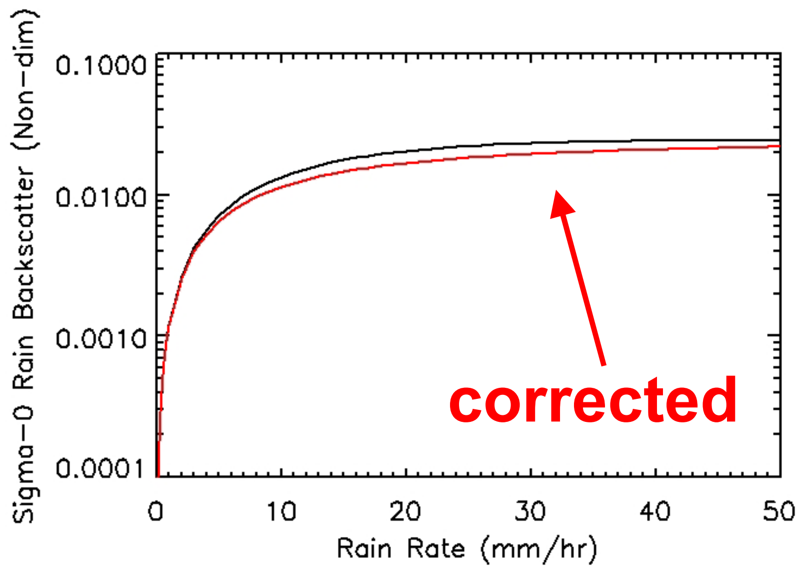
$$\beta=\frac{\Delta A_L}{A_L}=\frac{\mathrm{var}^{1/2}}{\mathrm{mean}}$$

= 0.85, typically

Beamfilling (Volumetric Backscatter)

$$\sigma_{0,bscat} = \int_0^{H\sec\theta} \left[\int_0^{\infty} e^{-2kl} c a k^b P(k)\, dk \right] dl$$

$$= \left[\frac{\Gamma\left(\beta^{-2}+b\right) ca}{\Gamma\left(\beta^{-2}\right)\left(A_L \beta^2\right)^{\beta^{-2}}} \right] \cdot \frac{\left(2H\sec\Theta + \frac{1}{A_L\beta^2}\right)^{\beta^{-2}+b+1} - \left(\frac{1}{A_L\beta^2}\right)^{\beta^{-2}+b+1}}{2\left(\beta^{-2}+b+1\right)}$$

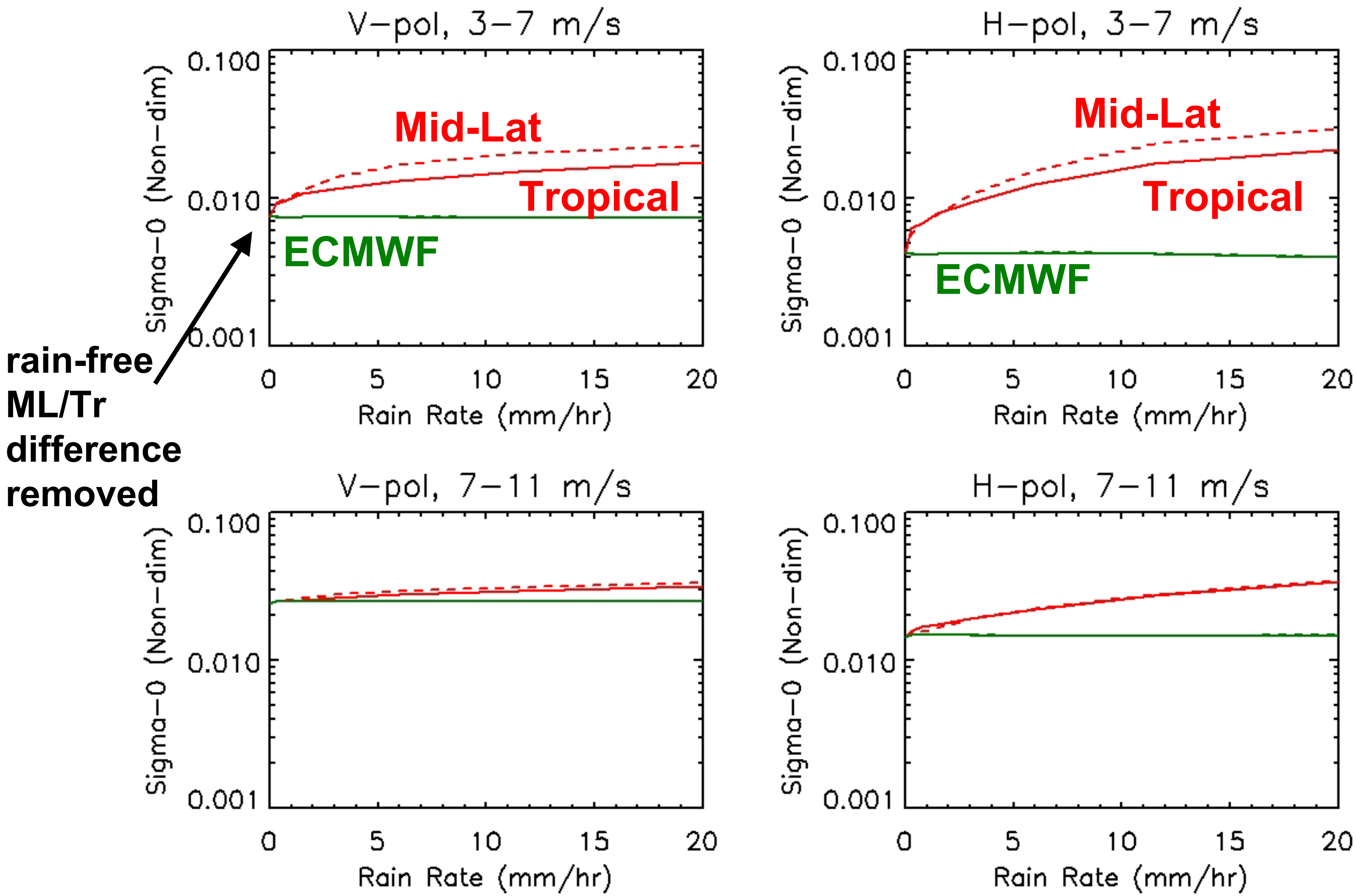


Data to Test Model

- **Used 15 minute collocated SeaWinds sigma-0's with SSM/I rain rates**
  - Upwind normalized
  - F15 usually
- **Used ECMWF tri-linearly interpolated wind speed and directions to get the wind sigma-0**
  - Linearly adjusted ECMWF sigma-0's to rain-free SeaWinds sigma-0's for each beam and wind speed

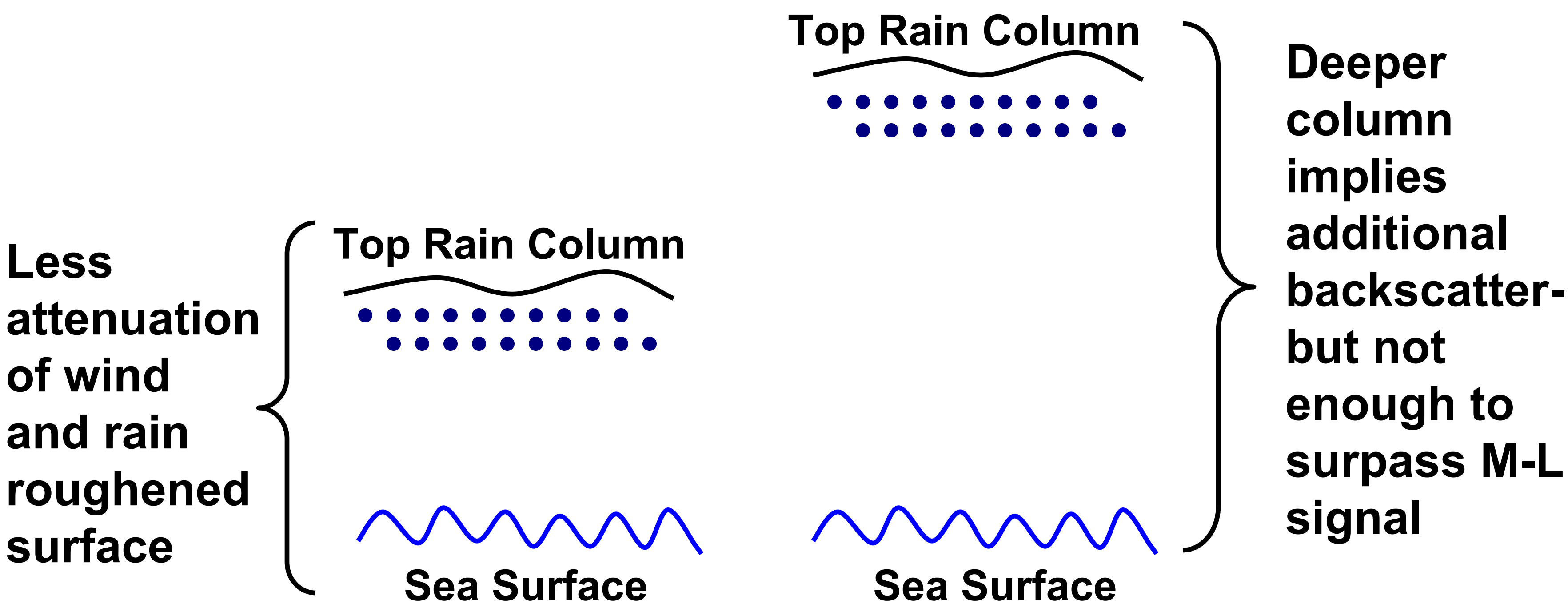
dash: ML
solid: Tr

SeaWinds Data



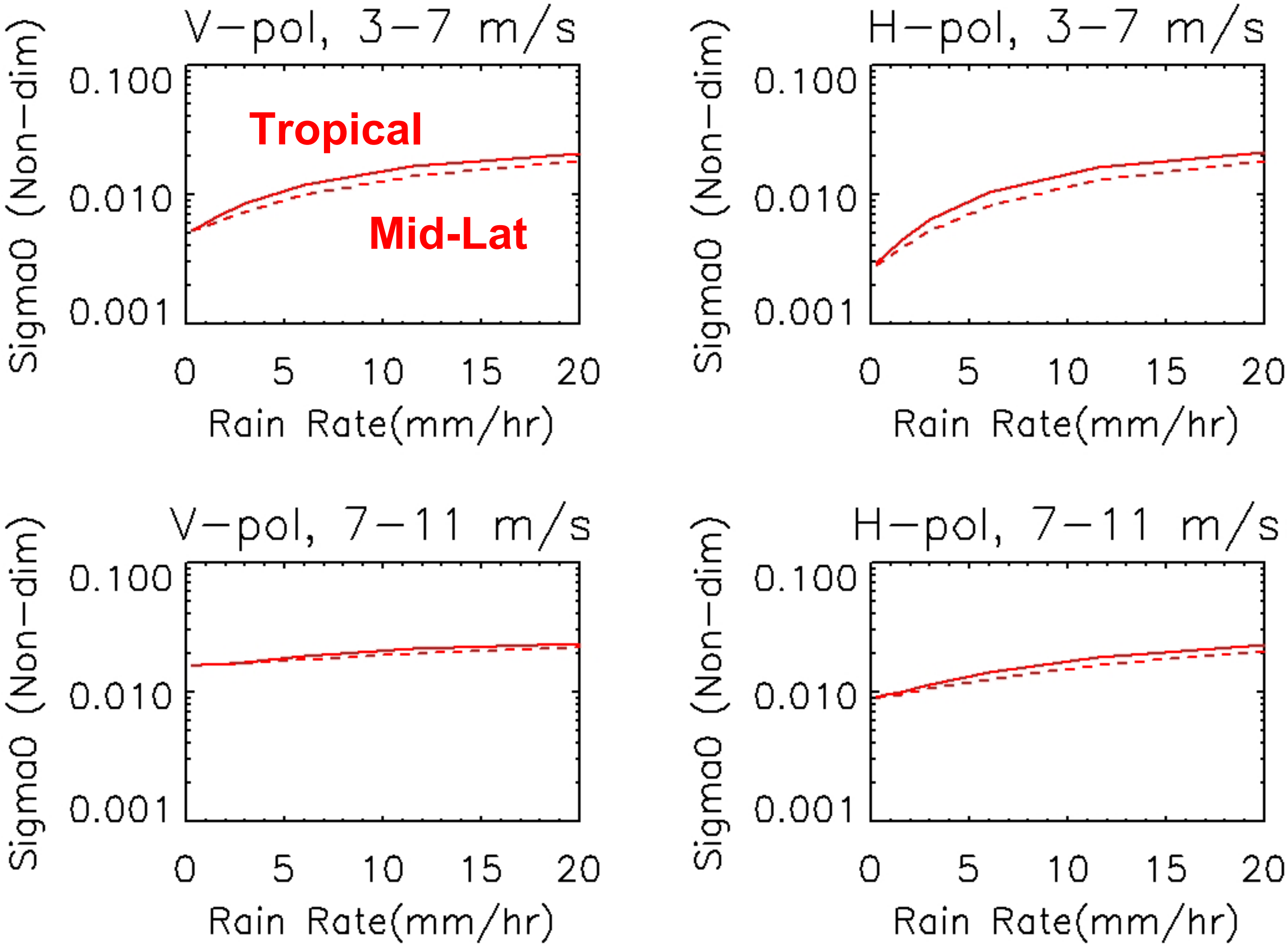
Conceptual Model

Mid-Latitude **Tropics**



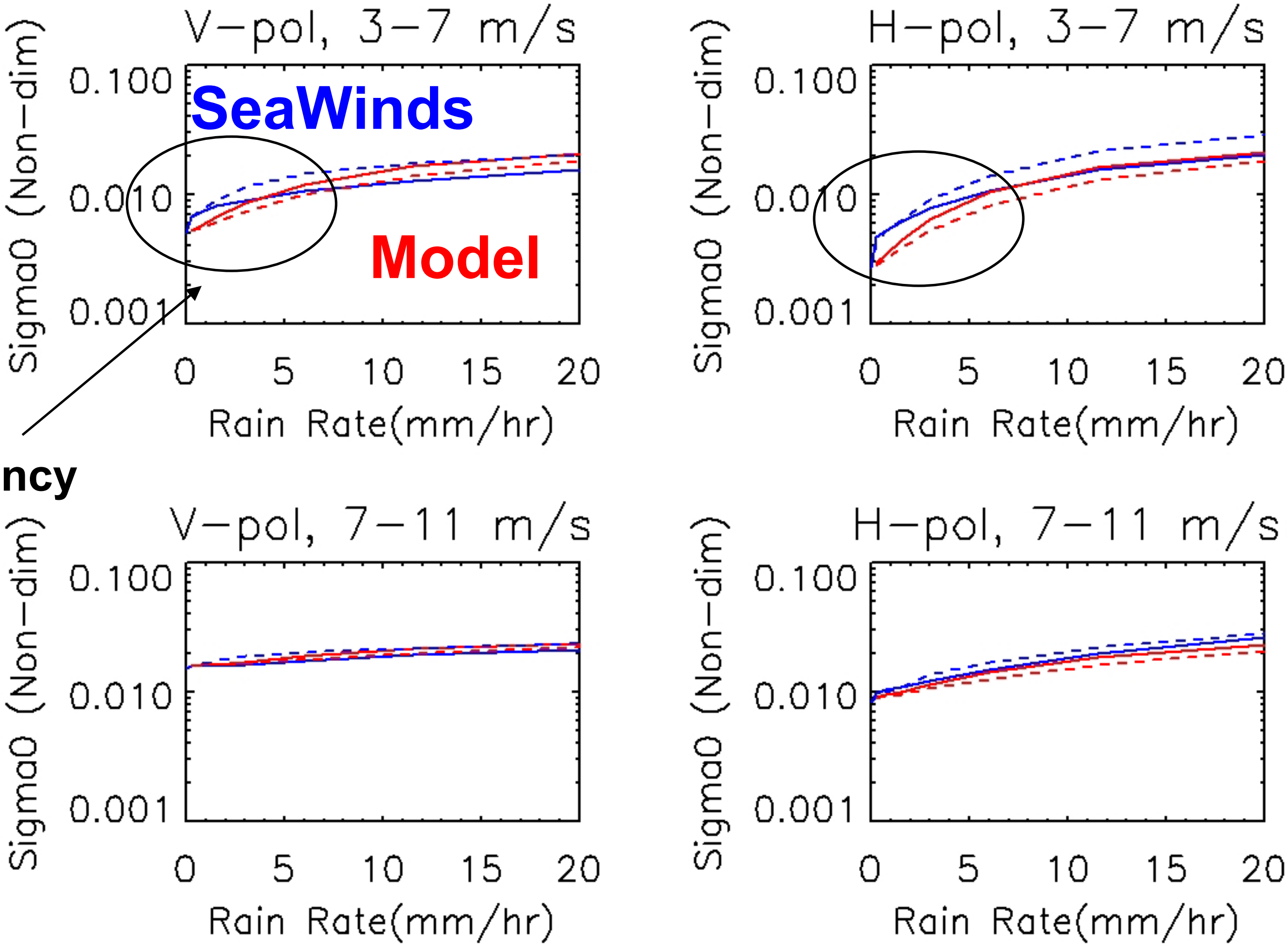
dash: ML
solid: Tr

No Rain Roughening



dash: ML
solid: Tr

No Rain Roughening



note low rain rate discrepancy

dash: ML
solid: Tr

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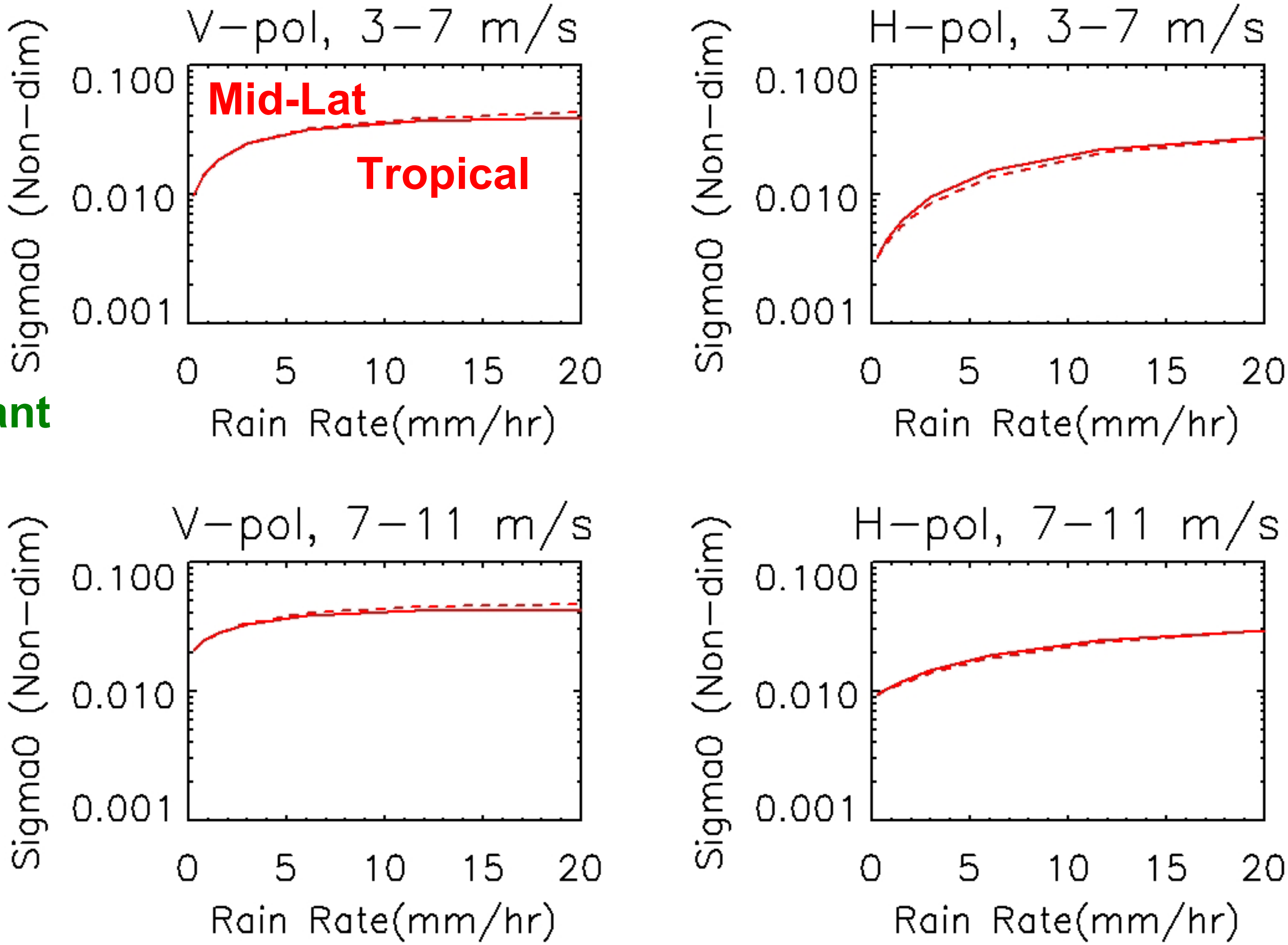
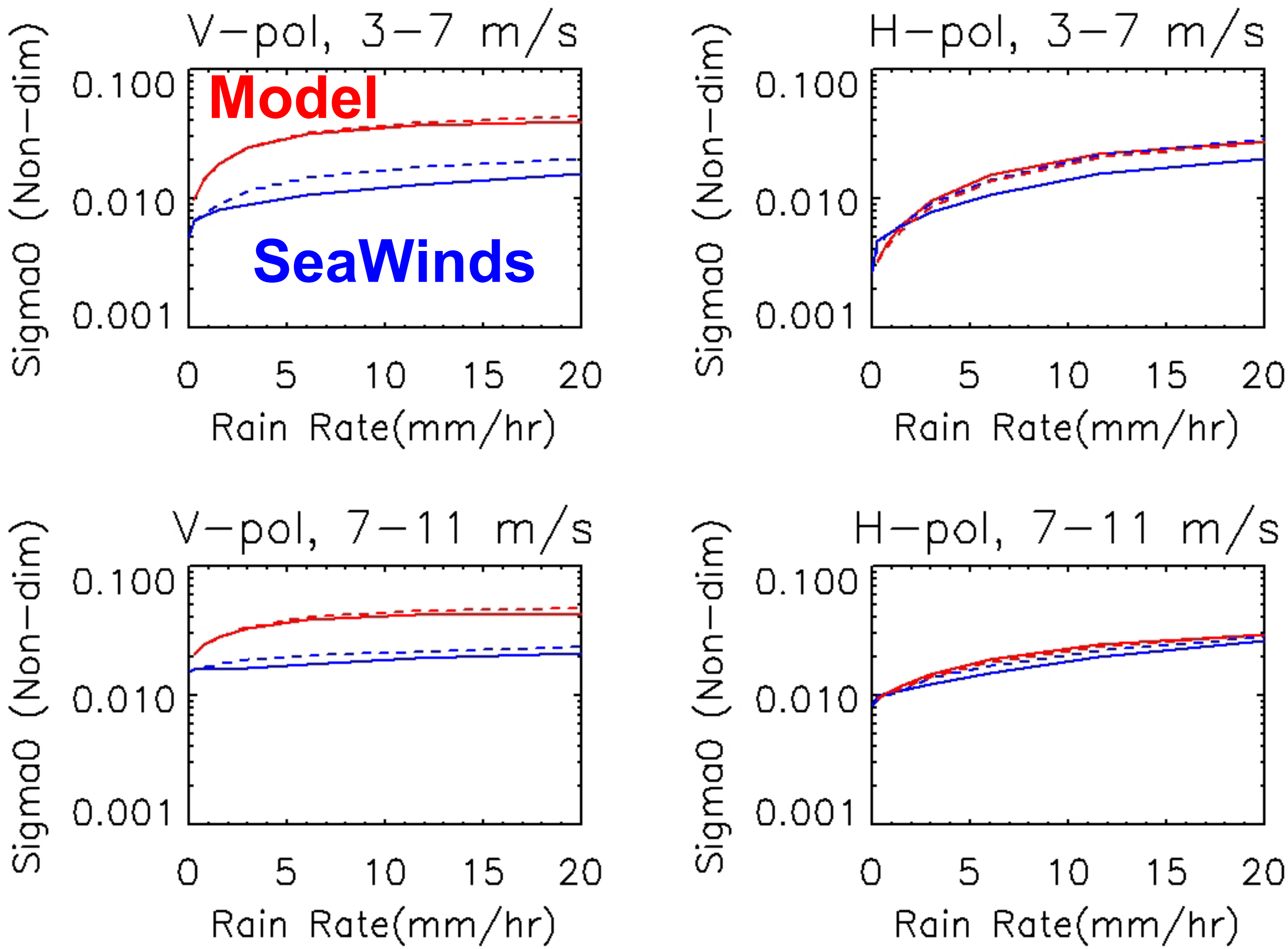
Rain Roughening

(constant profile used)



dash: ML
solid: Tr

Rain Roughening



dash: ML
solid: Tr

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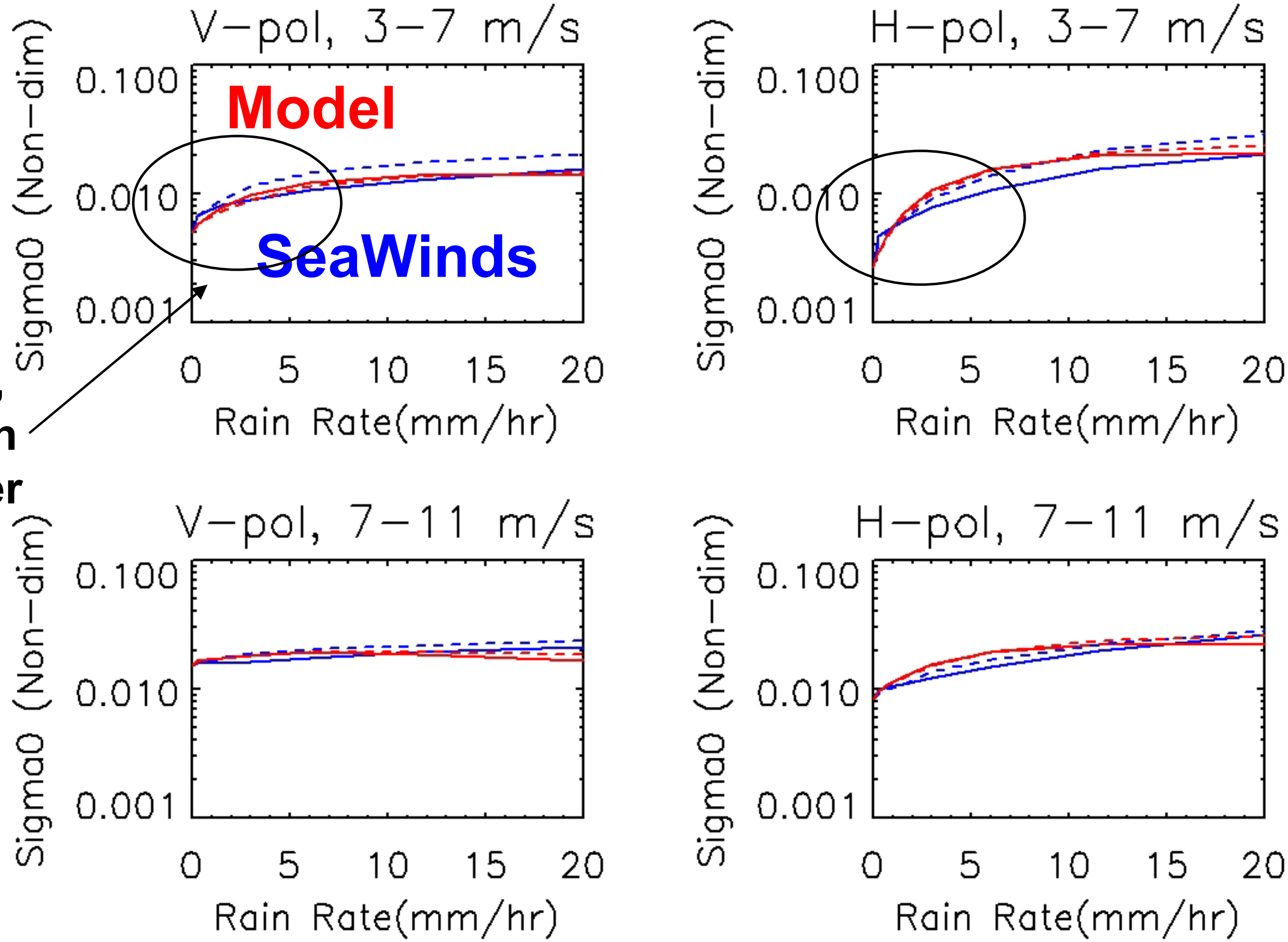
Rain Roughening (Scaled)



note, much better

Conclusions

- Regarding beamfilling, profiles, and DSDs
  - Beamfilling: Important for transmission, but not for backscattering
  - Profile: Important for backscattering, but not for transmission
  - Profile is as important as DSD
- Further refinement of model still necessary