PAMTRA

Passive and Active Microwave TRAnfer model

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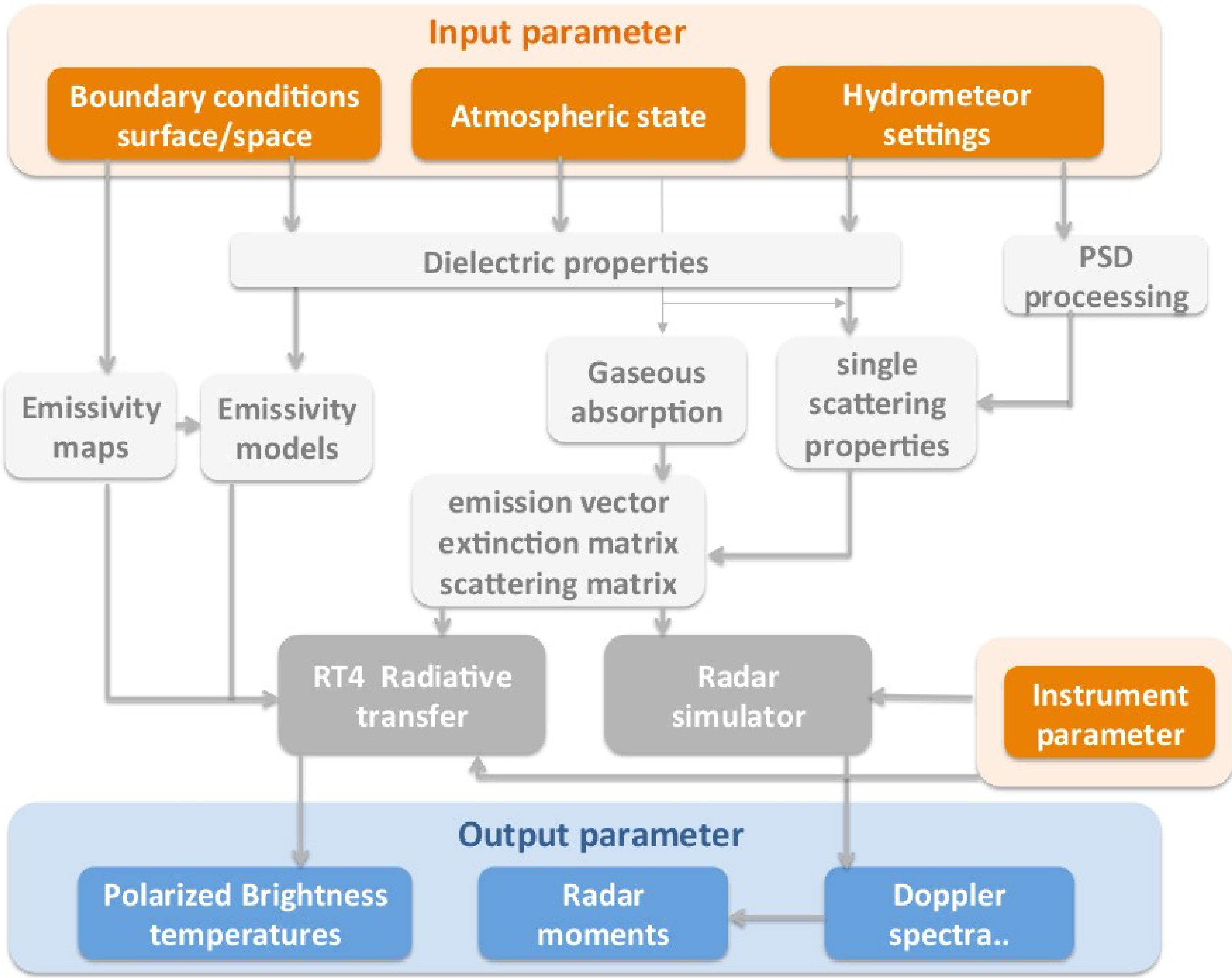
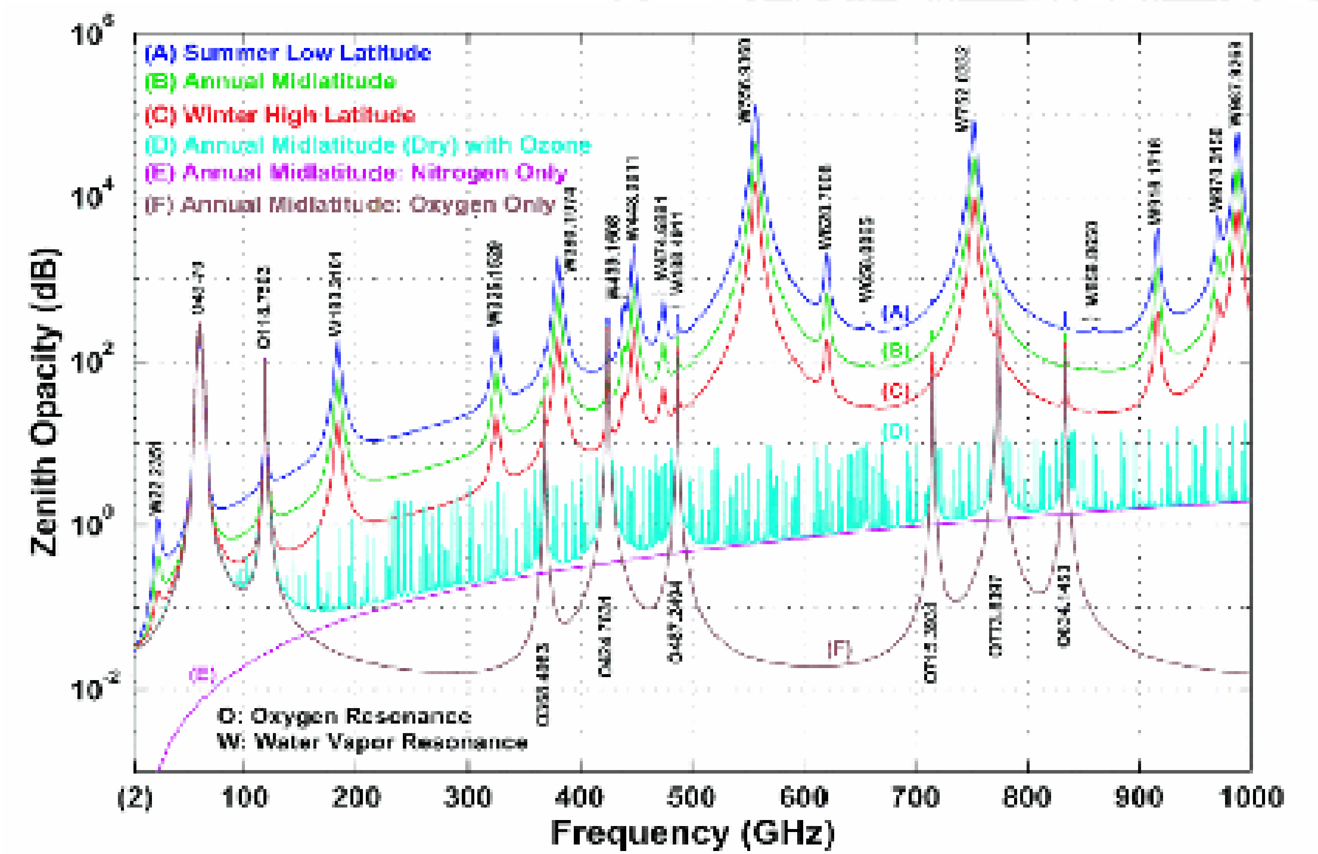

Input parameter
Boundary conditions surface/space
Atmospheric state
Hydrometeor settings
Dielectric properties
PSD processing
Emissivity maps
Emissivity models
Gaseous absorption
single scattering properties
emission vector extinction matrix scattering matrix
RT4 Radiative transfer
Radar simulator
Instrument parameter
Output parameter
Polarized Brightness temperatures
Radar moments
Doppler spectra..

Gas absorption

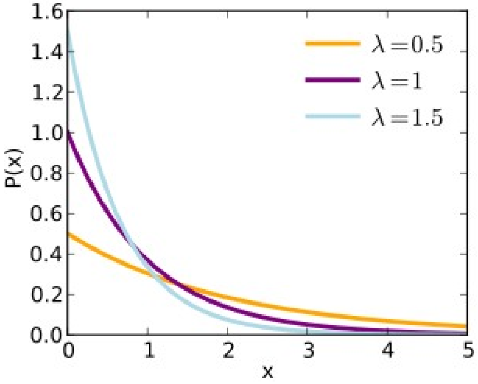
Absorption by lines and continuum (H_2O, O_2, O_3)

Models:

Liebe, Rosenkranz and corrections like Turner et al., 2009



Particle size distribution



Mono-disperse – 1 free parameter

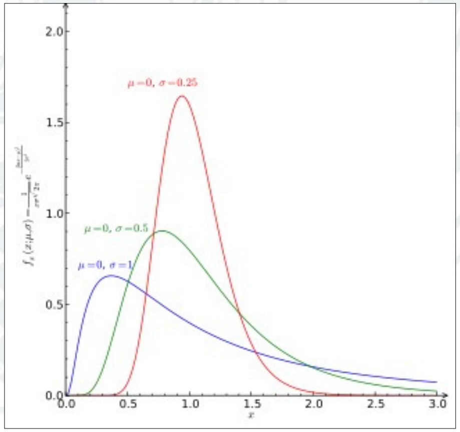
$$n(D_1) = N_0$$

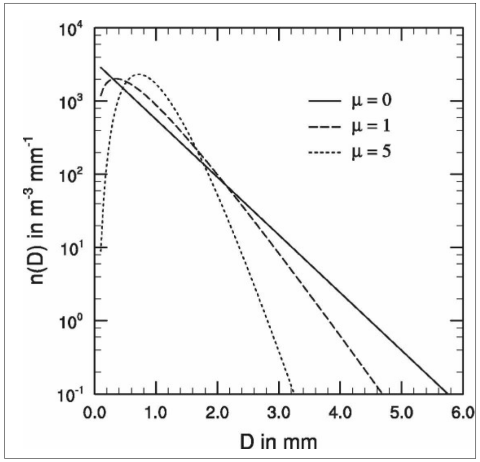
Exponential – 2 free parameters

$$n(D) = N_0 \times \exp(-\Lambda D)$$

Log-normal – 3 free parameters

$$n(D) = \frac{N_{tot}}{\sigma\sqrt{2\pi}D} \times \exp\left(-\frac{(\ln D - \mu)^2}{2\sigma^2}\right)$$





Modified gamma – 4 free parameters

$$n(D) = N_0 \times D^{\mu} \times \exp(-\Lambda D^{\gamma})$$

Spectral bin models (PyPamtra)

Moments of the drop-size distribution

$$M_k = \int_0^\infty D^k \times n(D)\, dD$$

$$N_{tot} = M_0 \left(= \frac{N_0}{\Lambda} \right)_{exponential}$$

Constrain the free parameters of the drop-size distribution

$$R_{eff} = \frac{M_3}{M_2}$$

$$Q_h = \int_0^\infty a \times D^b \times n(D)\, dD = a \times M_b$$

Moments:

- can be kept **fixed** when specified in the hydrometeors descriptor file
- **one** or **two** moments can be provided as profiles the input file:

  $Q_h(z)$, $N_{tot}(\ldots)$, $R_{eff}(\ldots)$
- computed using (some) published relations

ex: Field05 $N_0 = N_0(t, lwc)$

- ….implement new formulations if needed….

What can we do with this?

- Prescribe R_{eff} in RTM simulation
- Calculate Jacobians for R_{eff} (RADAR and high frequency MWR)
  - retrieve R_{eff} in Integrated Profiling Technique

- Test the sensitivity of RT simulations to:
  - drop-size distributions
  - mass-size relations
  - scattering models
  - liquid water refractive index models

- Evaluate CRM micro-physics consistently

Single scattering properties and models

Calculation of the single scattering properties for a set of in- and output scattering angles in dependence of: size (parameter), shape, orientation distribution, wavelength/frequency, refractive index (dielectric properties)

↓

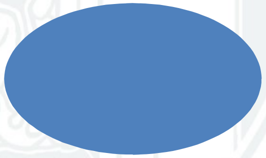
scatt. amplitude / phase matrix

extinction matrix

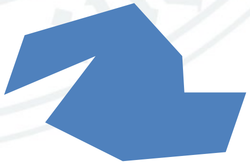
emission vector

Mie

T-Matrix

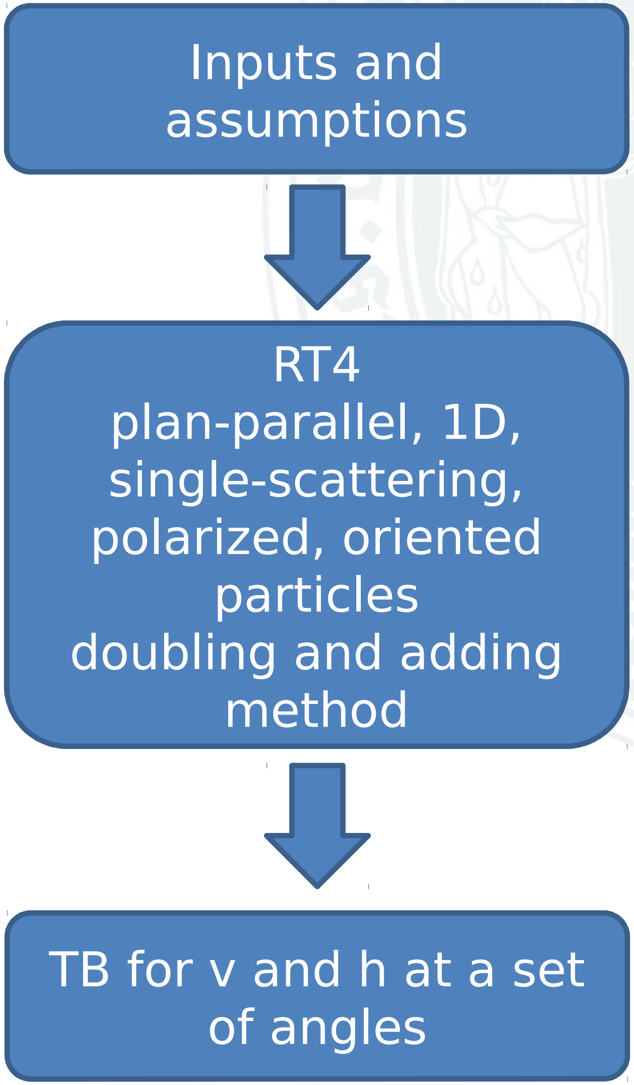


DDA - DBs



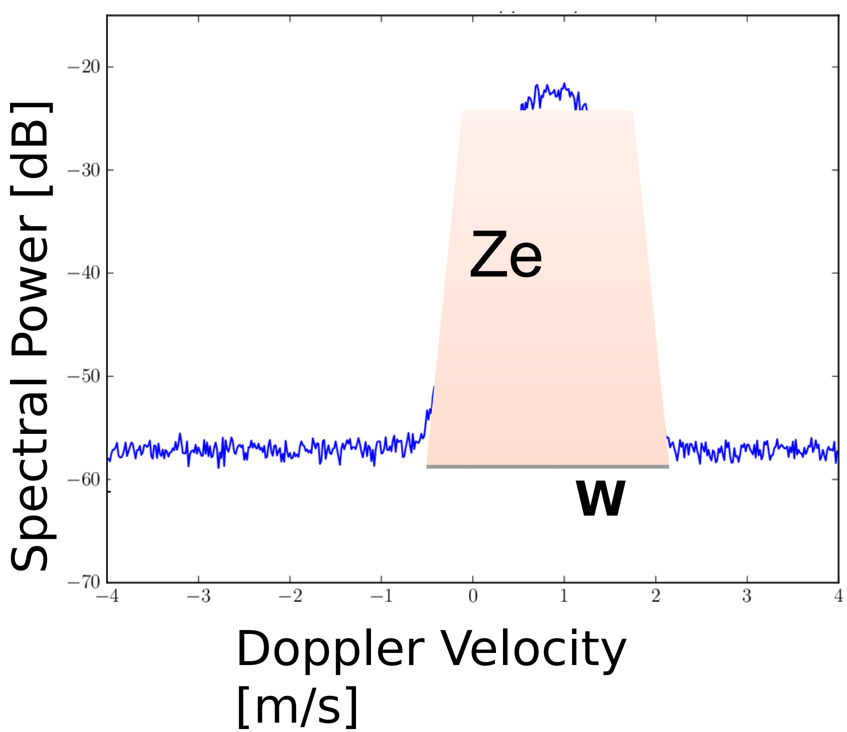
Rayleigh-Gans Approximation (radar only)

Input – RT4 – output



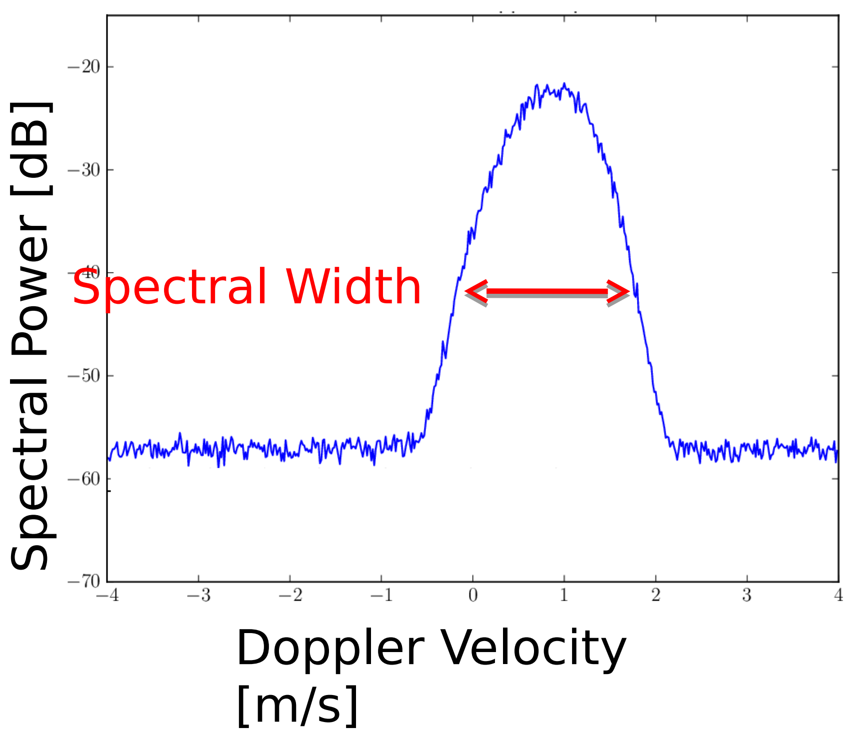
What does a vertically pointing radar actually measure?

Radar Doppler Spectrum



- Reflectivity Ze is sensitive to radar calibration
- Doppler Velocity W is sensitive to vertical air motion

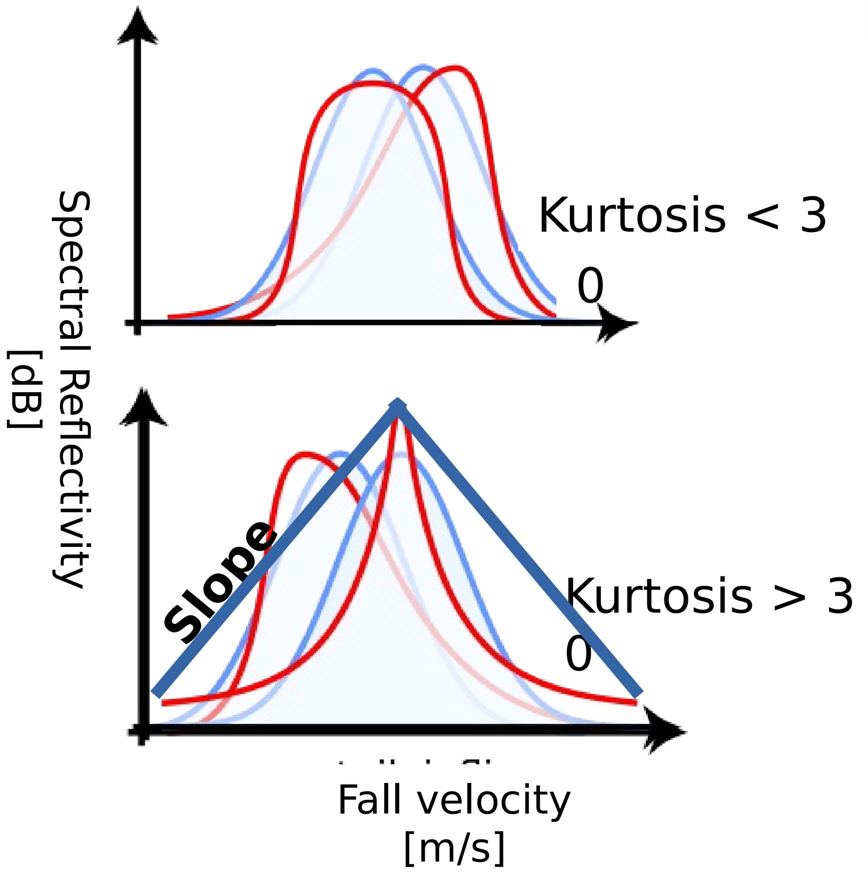
Idea: Exploit higher moments of the Doppler Spectrum



In addition to Ze and W, use also:

– Spectral Width
– Skewness
– Kurtosis
– Right and Left Slope

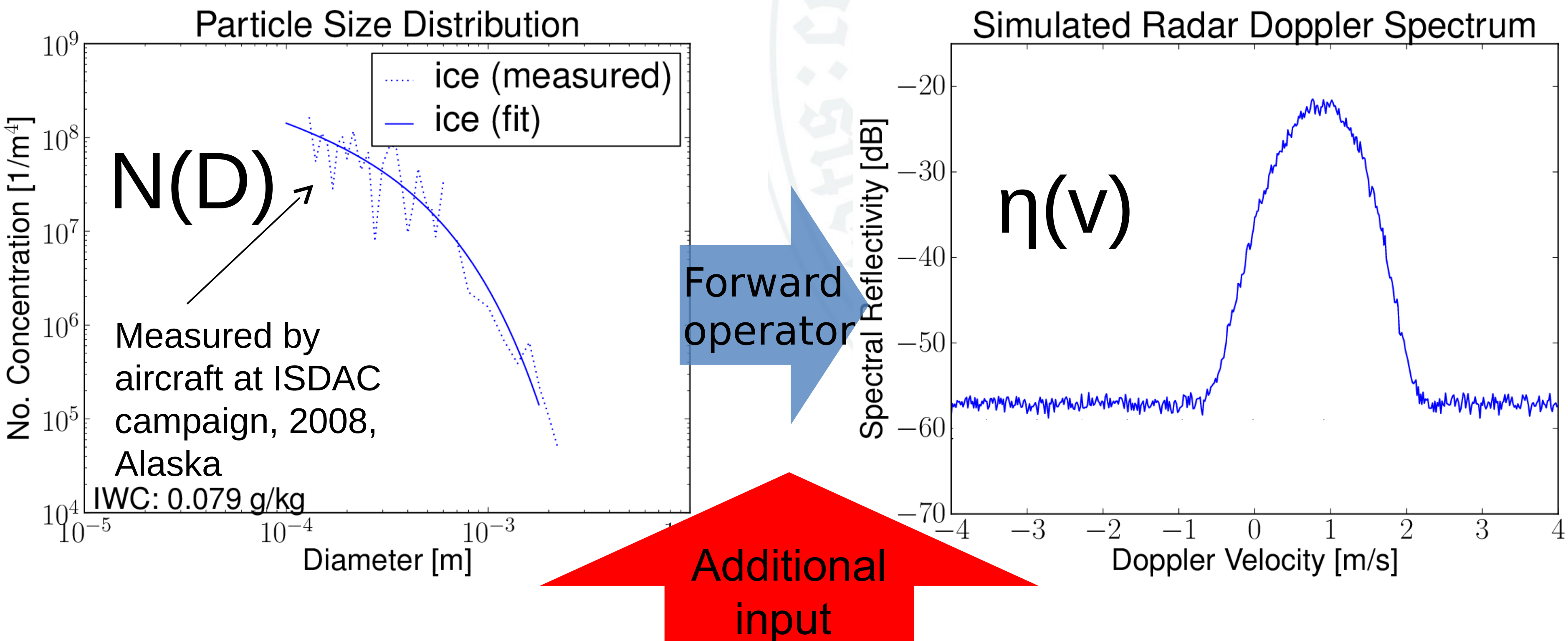
Idea: Exploit higher moments of the Doppler Spectrum



- In addition to Ze and W, use also:
  - Spectral Width
  - Skewness
  - Kurtosis
  - Right and Left Slope
- Strong influence by turbulence

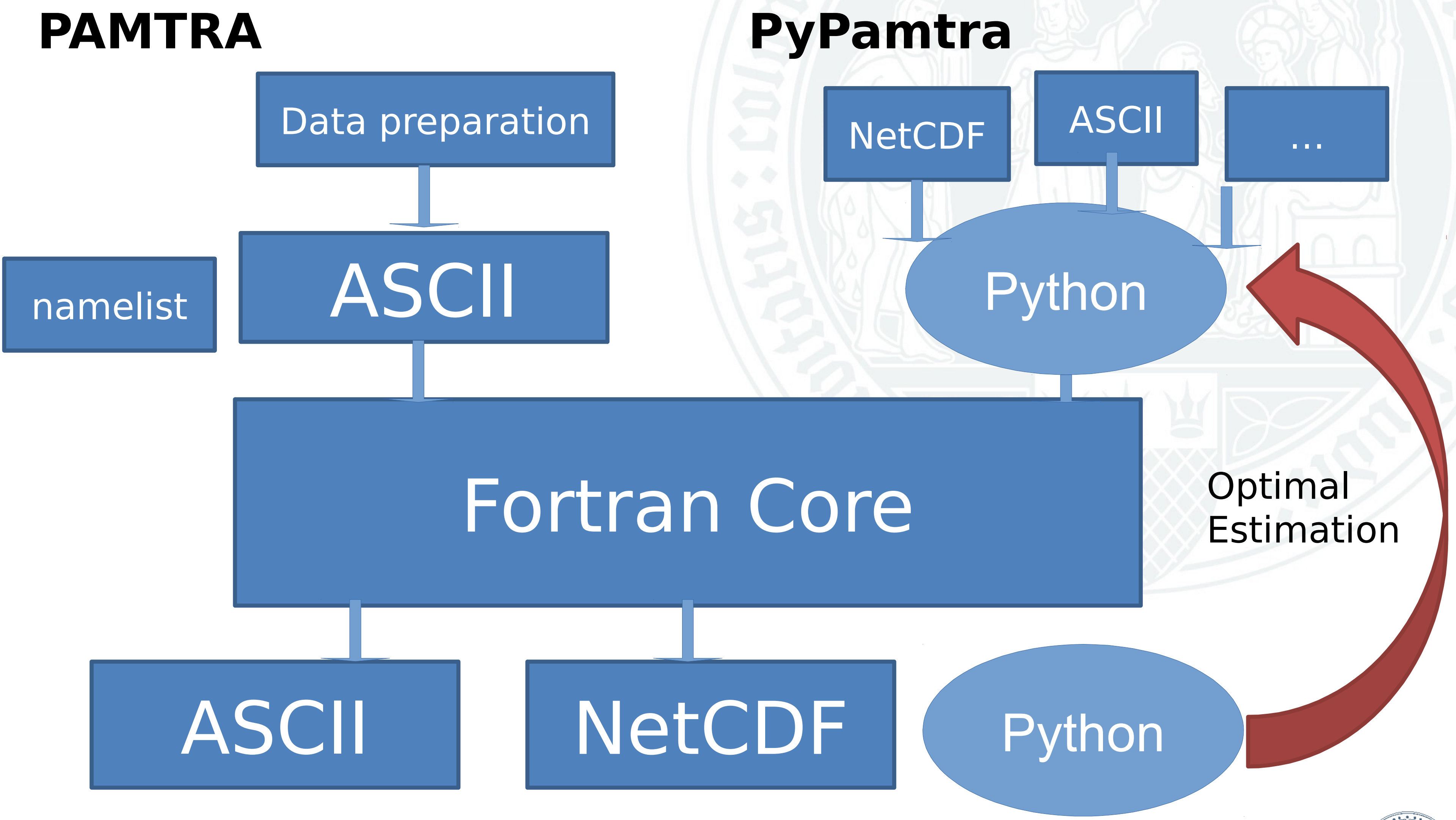
Higher Moments

What do we need for modelling?

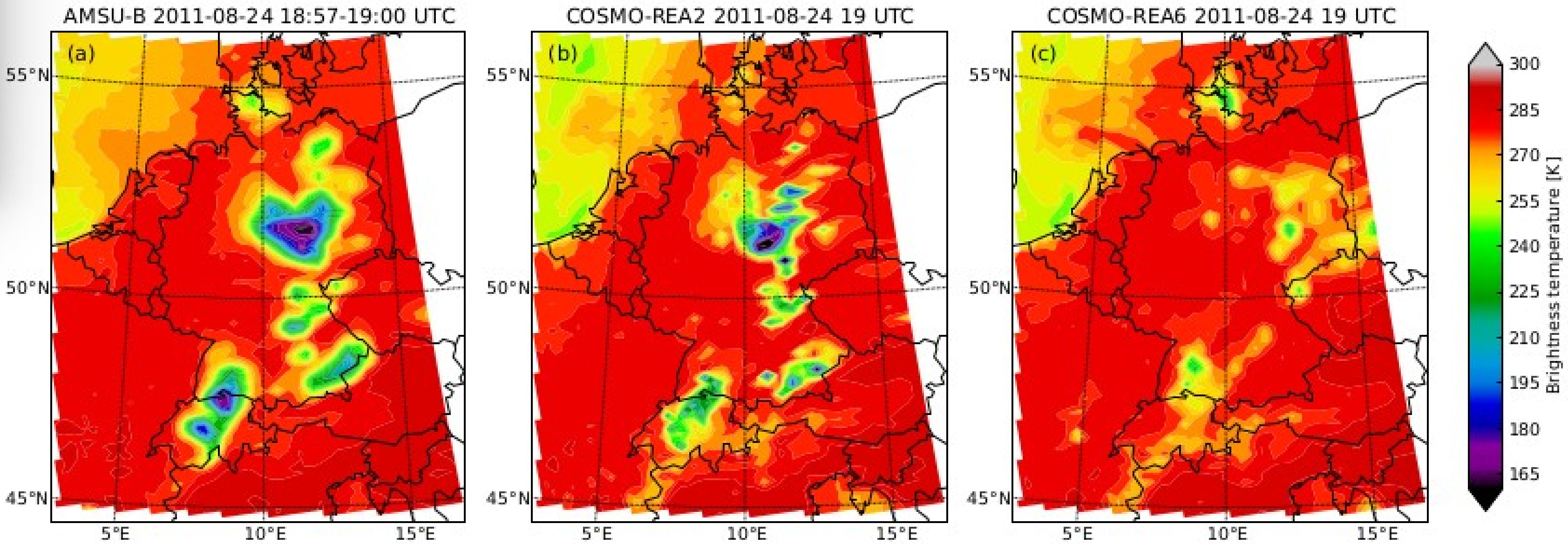


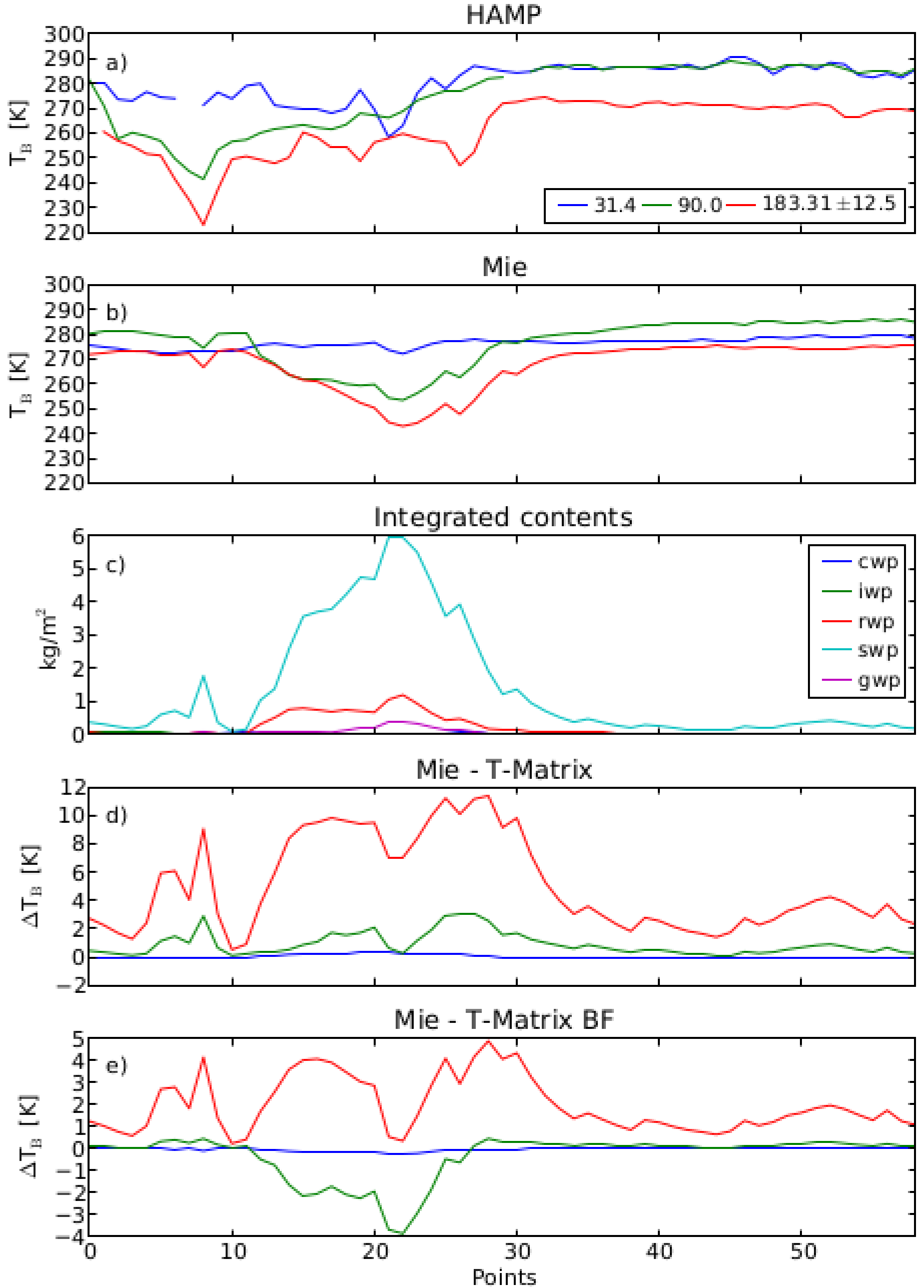
particle (distribution) properties, fall velocity, turbulence, instruments characteristics, spectral width, eddy disioation rate

One model – two ways to use it



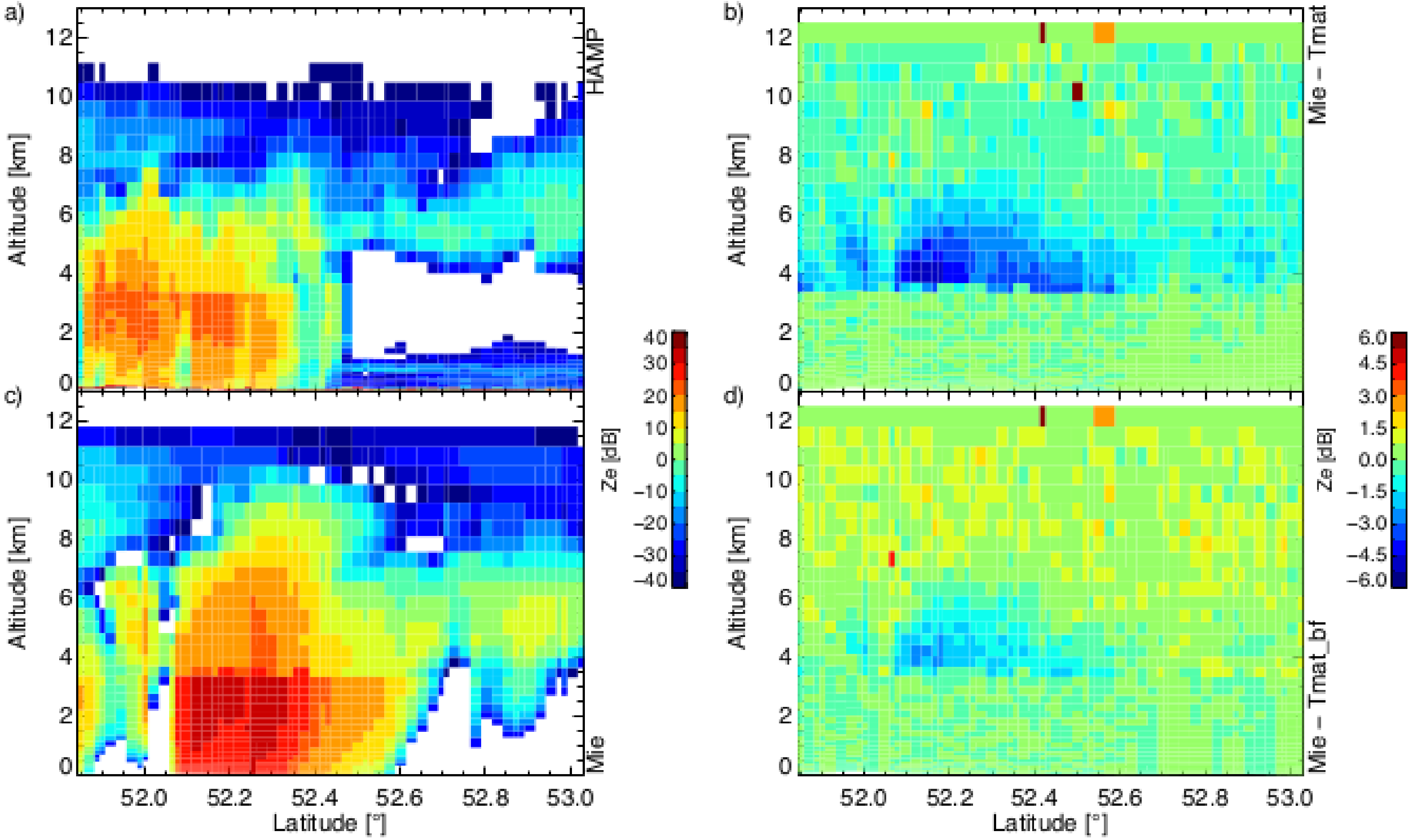
COSMO Reanalyses 2/6 – AMSU-B





HAMP
a)
T_B [K]
31.4
90.0
183.31±12.5
Mie
b)
Integrated contents
c)
kg/m²
cwp
iwp
rwp
swp
gwp
Mie - T-Matrix
d)
ΔT_B [K]
Mie - T-Matrix BF
e)
Points

HAMP Radar – PAMTRA sensitivity



Conclusions

PAMTRA as passive and active forward simulator for:

- Retrieval development for HAMP/MiRAC
- sensitivity to super cooled liquid water absorption model
- used in the IPT/optimal estimation (radar)
- satellite convolution -> model intercomparison
- exploration of information content in future satellite observation -> instrument development
- sensitivity studies for higher moments

Future development

- Surface emissivity: ocean, land, snow, and ice
- Scattering databases
- Publish the model (journal and github)
- Backend work (convolution to other satellites)
- ...