Microwave radiative transfer in support of cloud and precipitation assimilation

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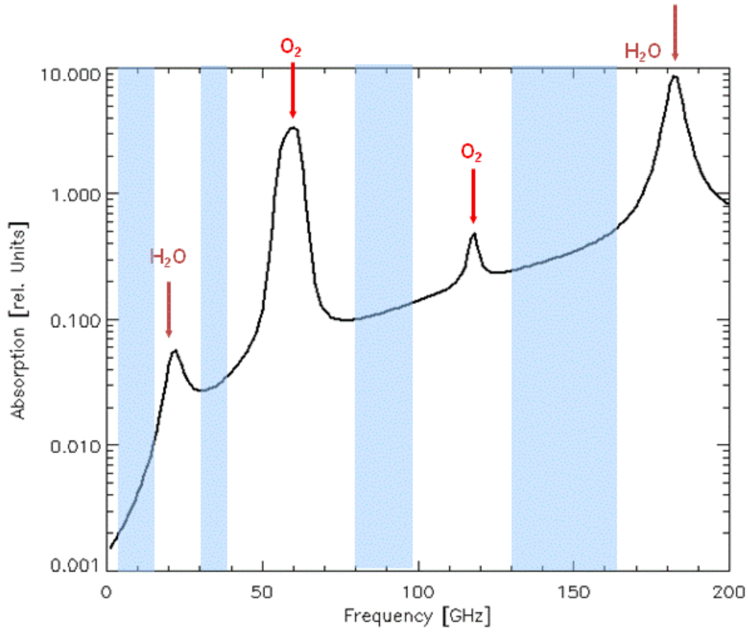
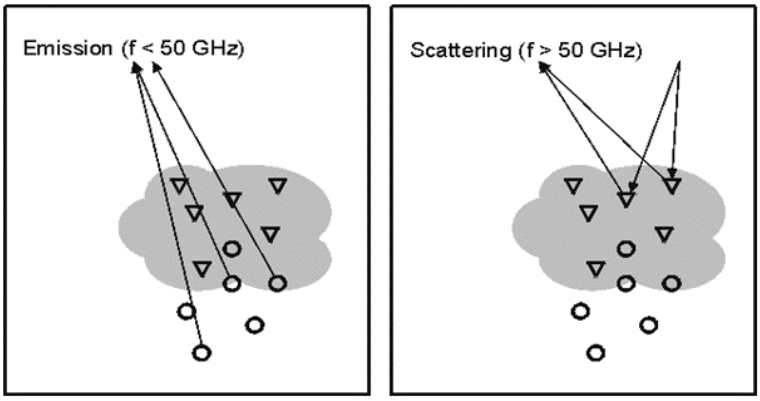
Outline

- Fundamentals
- Microwave RT for data assimilation
  - Microwave properties of clouds and precipitation
  - Radiative transfer solver
  - How important is scattering?
  - Integration with NWP models
- Status
- Recommendations

Fundamentals



Fundamentals



Fundamental observable: attenuation due to **liquid and rain column**

Precipitation ice scattering: Increasing effect at higher frequencies

Modeling Chain

NWP/Cloud physics model

↓

Optical properties model

↓

RT-solver

↓

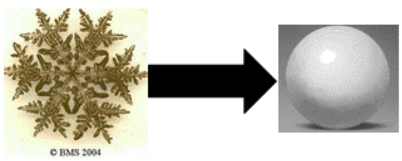
Integration with NWP (e.g. overlap)

↓

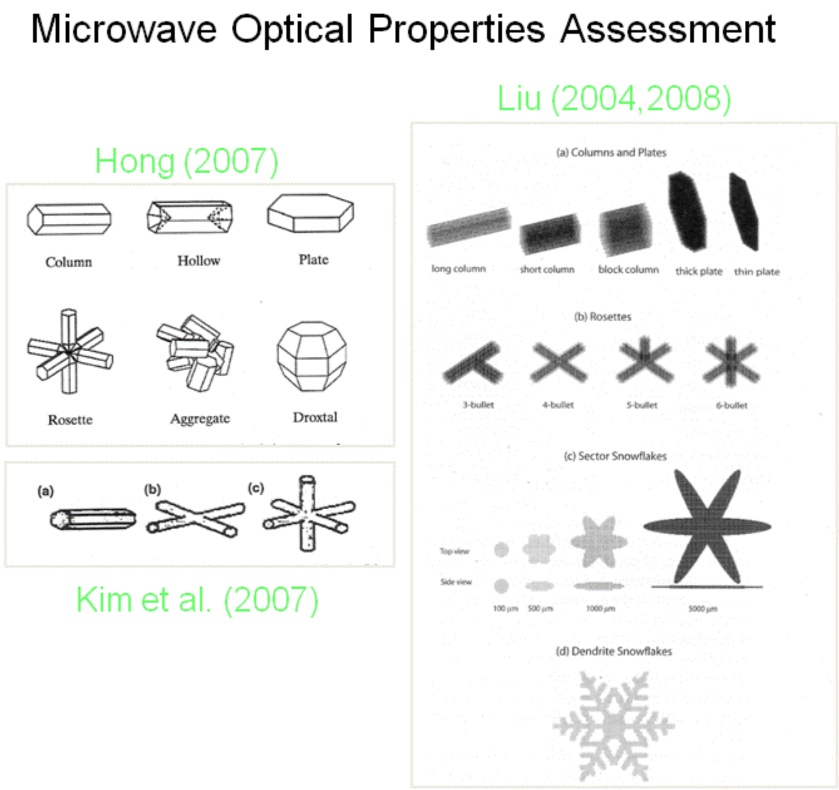
Simulated Tb

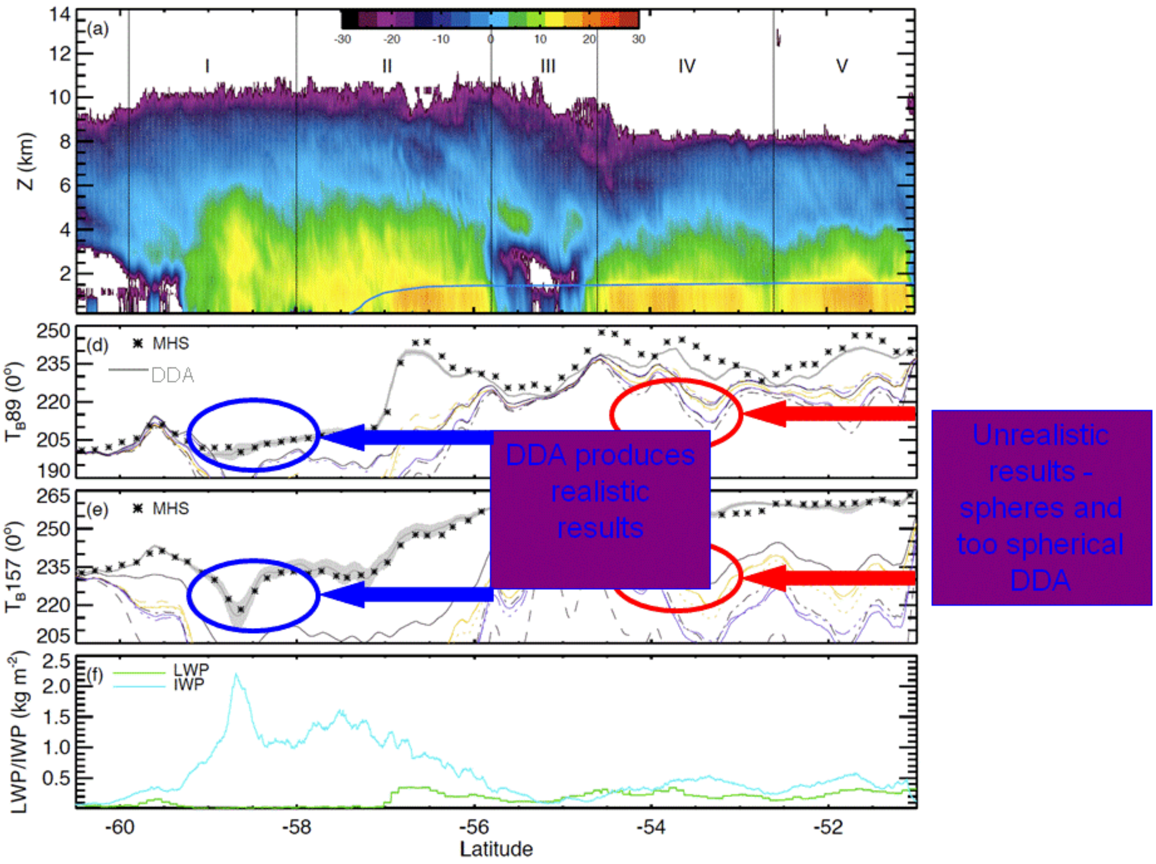
Microwave Optical Properties Assessment

- Spheres (Mie theory)
  - ✓ JCSDA (snow, graupel, hail)
  - ✓ Surussavadee and Staelin (2006)
  - ✓ Dielectric mixing rules



- Non-spherical (Discrete Dipole Approximation - DDA)
  - ✓ Liu (2004,2008)
  - ✓ Kim et al. (2007)
  - ✓ Hong (2007)

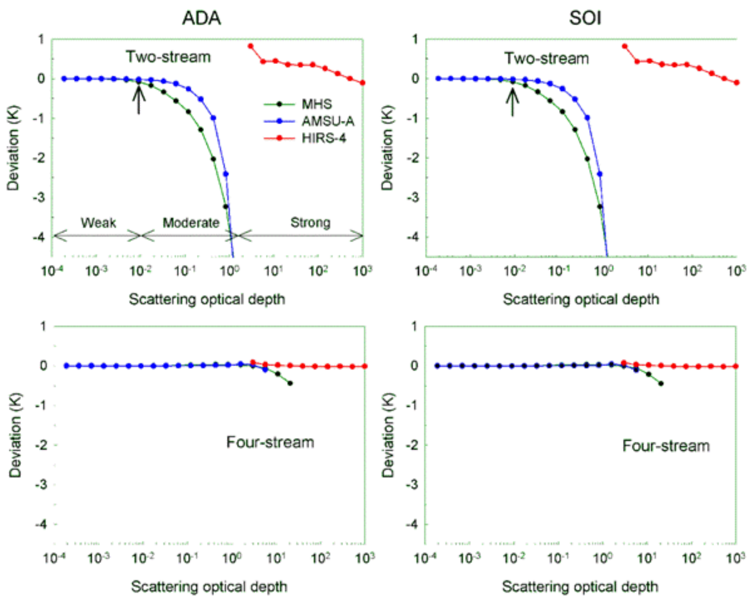

Microwave Optical Properties Assessment
Hong (2007)
Column
Hollow
Plate
Rosette
Aggregate
Droxtal
(a)
(b)
(c)
Kim et al. (2007)
Liu (2004,2008)
(a) Columns and Plates
long column
short column
block column
thick plate
thin plate
(b) Rosettes
3-bullet
4-bullet
5-bullet
6-bullet
(c) Sector Snowflakes
Top view
Side view
(d) Dendrite Snowflakes


(a)
I
II
III
IV
V
Z (km)
(d)
MHS
DDA
T_B89 (0°)
(e)
MHS
T_B157 (0°)
DDA produces realistic results
Unrealistic results - spheres and too spherical DDA
(f)
LWP
IWP
LWP/IWP (kg m^{-2})
Latitude

RT Solvers:

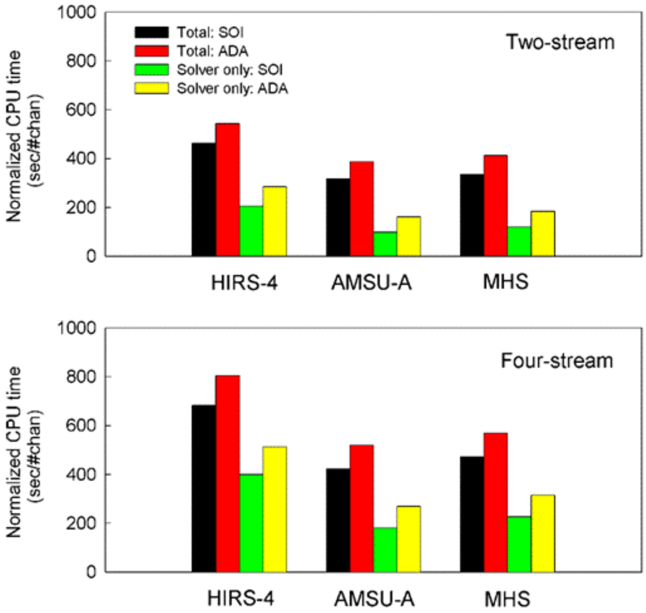
- Two community efforts:
  - RTTOV (Supported by EUMETSAT's NWP-SAF)
    - Non-scattering RT
    - Two-Stream Delta-Eddington
  - CRTM (Supported by JCSDA)
    - Non-scattering RT
    - ADA (Advanced Doubling and Adding)
    - SOI (Successive Order of Interaction)

RT solvers accuracy tests



Results from Greenwald

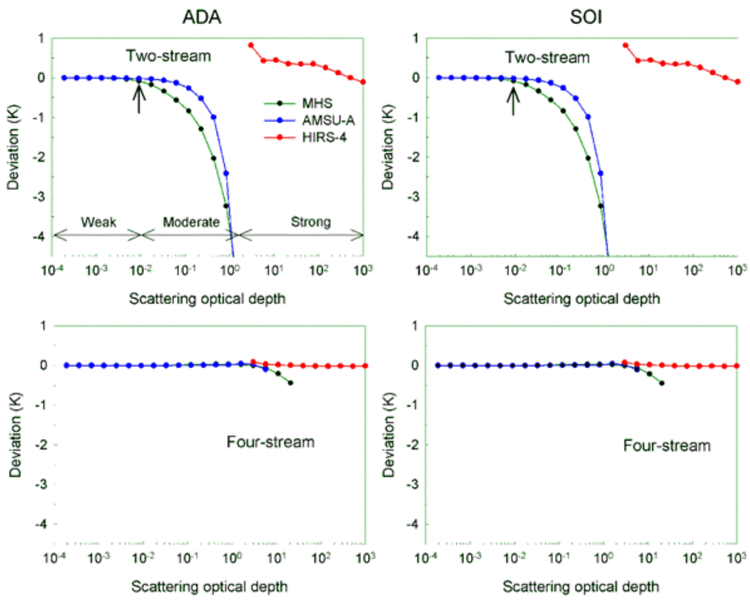
RT solvers speed tests



- ✓ Uses core CRTM routines
- ✓ About 10 - 20 % speed increase due to truncated doubling and iteration instead of adding

Results from Greenwald

RT solvers accuracy tests



Results from Greenwald

How important is scattering?

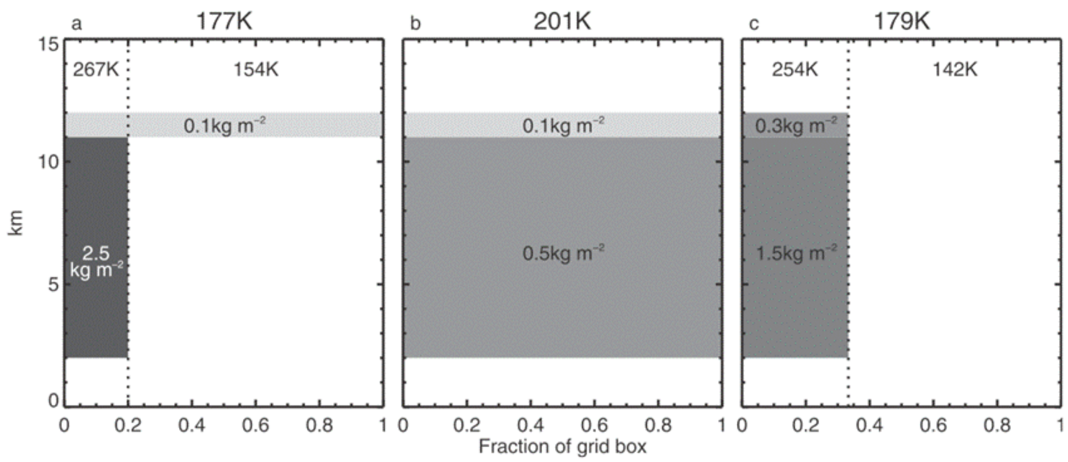
$$\delta_S(z) = \int_z^{TOA} k_S(z)dz$$

$$\delta_{S,Eff}(z) = \int_z^{TOA} k_S(z)e^{-\delta_A(z)}dz$$

Effective scattering optical depth gives an upper limit for the amount of scattering influencing the TOA radiance field

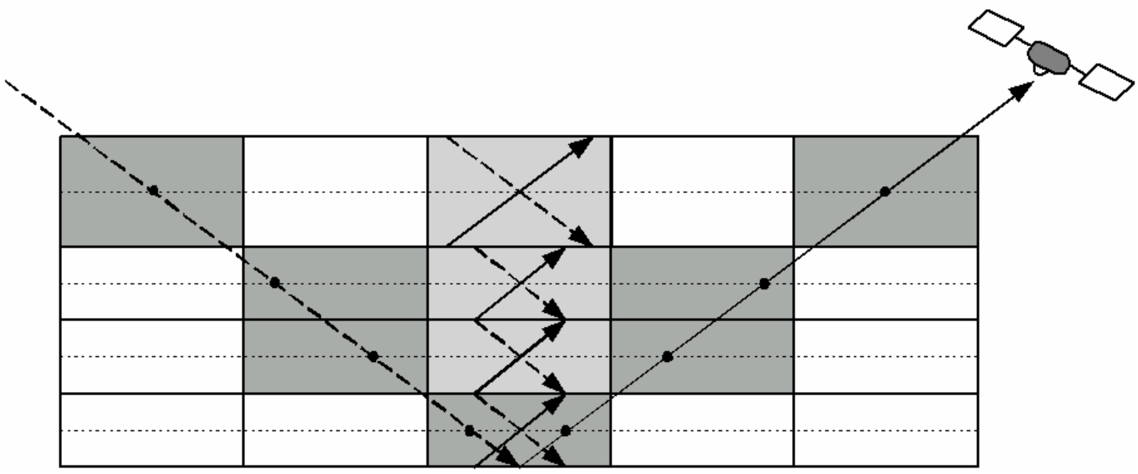
$$0 \leq \frac{\delta_{S,eff}(z)}{\delta_S(z)} \leq 1$$

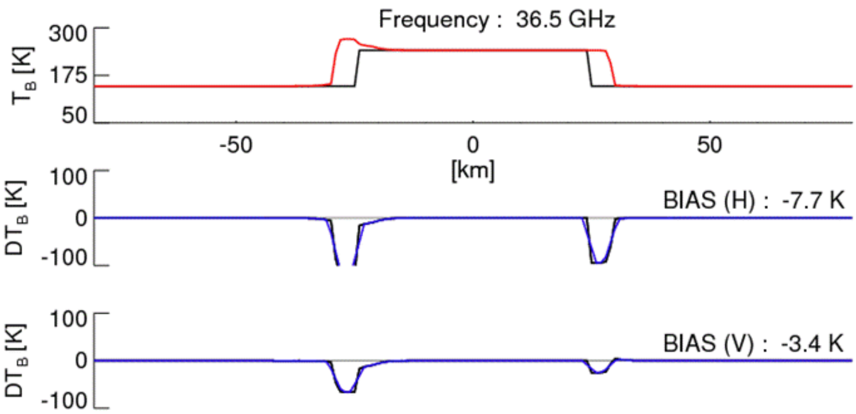
Integration with NWP models: Overlap

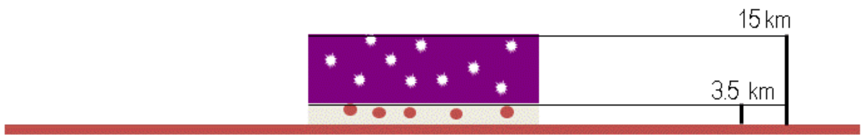


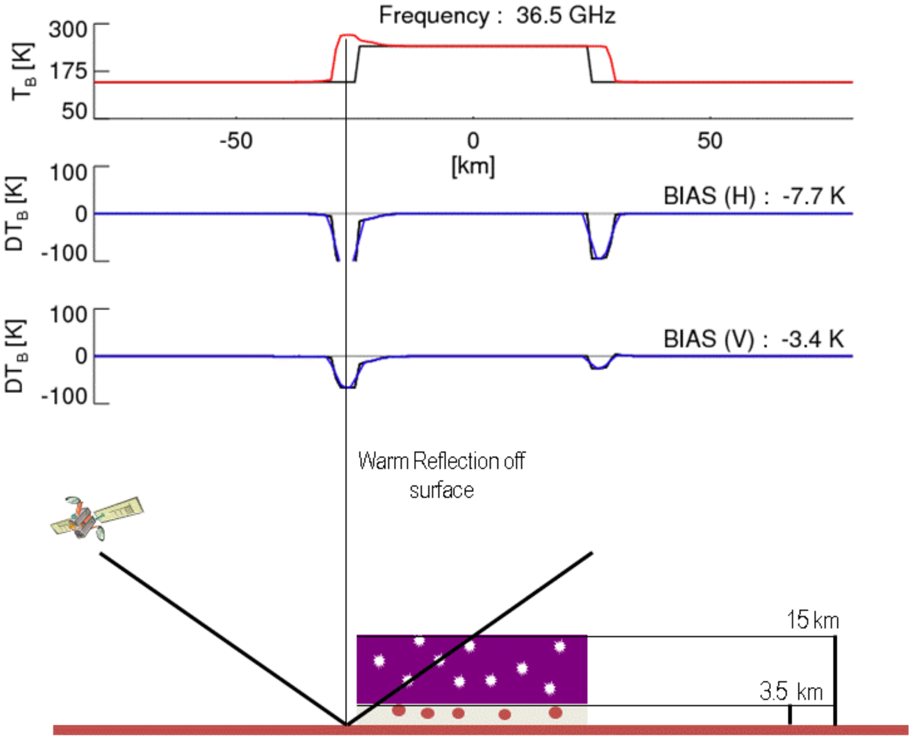
From Geer et al. (2009)

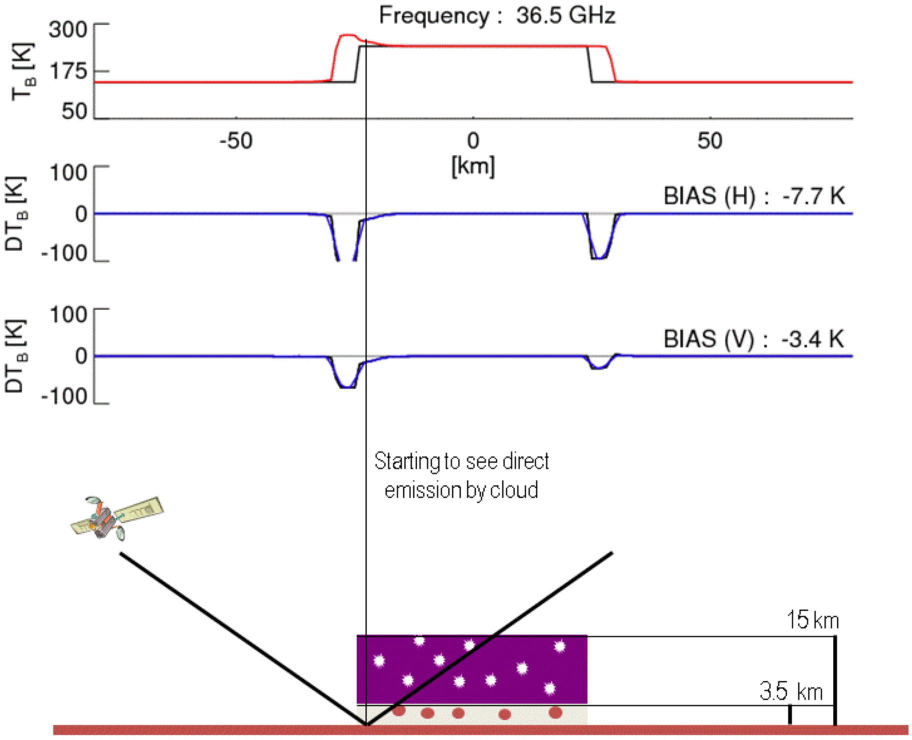
Going to higher spatial resolution

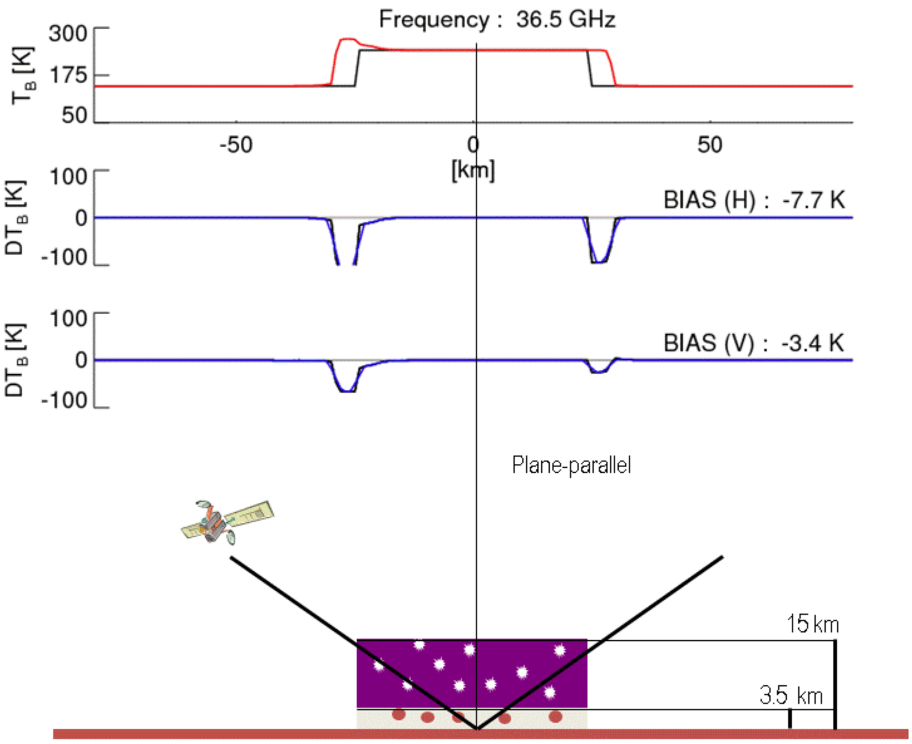


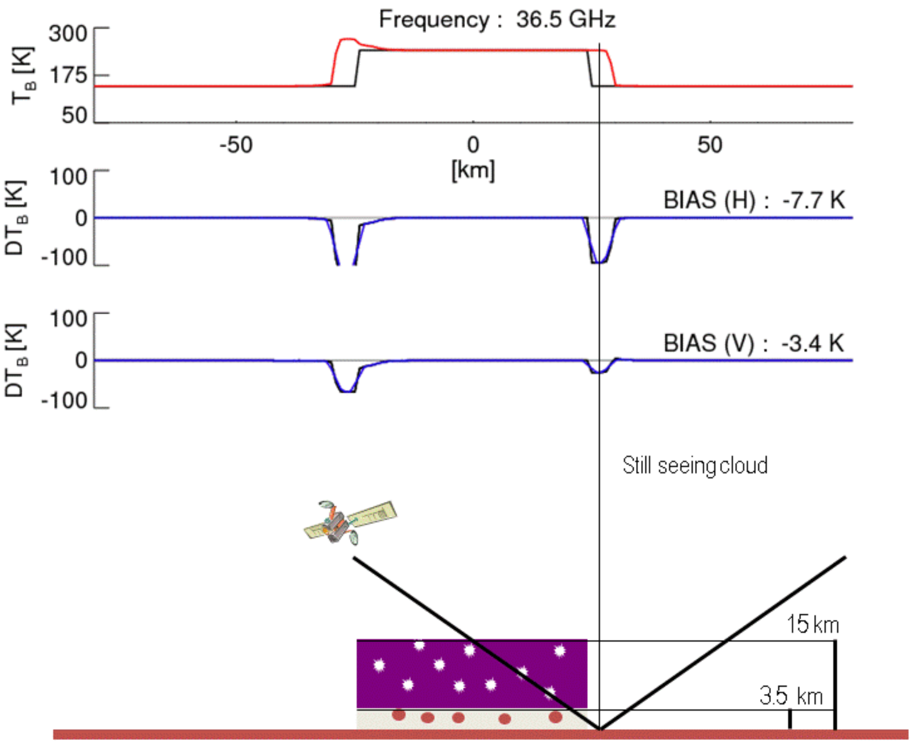





Frequency : 36.5 GHz
T_B [K]
300
175
50
-50
0
50
[km]
DT_B [K]
100
0
-100
BIAS (H) : -7.7 K
BIAS (V) : -3.4 K
Warm Reflection off surface
15 km
3.5 km


Frequency : 36.5 GHz
T_B [K]
300
175
50
-50
0
50
[km]
DT_B [K]
100
0
-100
BIAS (H) : -7.7 K
BIAS (V) : -3.4 K
Starting to see direct emission by cloud
15 km
3.5 km


Frequency : 36.5 GHz
T_B [K]
300
175
50
-50
0
50
[km]
DT_B [K]
100
0
-100
BIAS (H) : -7.7 K
DT_B [K]
100
0
-100
BIAS (V) : -3.4 K
Plane-parallel
15 km
3.5 km


Frequency : 36.5 GHz
T_B [K]
300
175
50
-50
0
50
[km]
DT_B [K]
100
0
-100
BIAS (H) : -7.7 K
DT_B [K]
100
0
-100
BIAS (V) : -3.4 K
Still seeing cloud
15 km
3.5 km

Status

- RT Solvers
  - ✓ Various available and integrated into CRTM/RTTOV
  - ✓ Work to be done to find good compromise accuracy vs. speed
- Optical properties
  - ✓ Active/passive evaluation of various optical property models ongoing
  - ✓ Allows realistic estimate of observation error
  - ✓ Inclusion into RT LUTs still outstanding
- Observation error characteristics
  - ✓ Realistic estimates of observation error
  - ✓ What to do when global NWP models reach resolution of passive MW sensors or for mesoscale models in general? Abandon overlap for slant models?

Recommendations

- Short term
  - ✓ Various smaller improvements (e.g. assessment of effective scattering optical depth for model selection, optical properties databases)
  - ✓ Pave way for models with higher spatial resolution.
- Longer-tem
  - ✓ Treatment of higher frequencies, full use of scattering information (Requires significant advances in interface to cloud physics)
  - ✓ Error covariances