Assimilation of Clouds & Precipitation: Year 1 Progress Report

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Outline

- Introduction
- Towards ‘modeling chains’
- Errors and error covariances
- Towards assimilation studies
- Status and plans for year 2

Recommendations from IPWG Snowfall Workshop April 2008

Recommendation 1: Encourage the generation of **community CRM/NWP model profile databases** that represent natural variability. A parallel effort for databases from observations or combined model simulations and observations is also encouraged. **Modeling chains** (CRM/NWP -> optical properties -> radiative transfer) are highly valuable tools to evaluate model performance and to develop parameterizations for general use in cost-driven applications.

Recommendations from IPWG Snowfall Workshop April 2008

Recommendation 2: Further intensification of data assimilation studies for the inclusion of precipitation observations in NWP analysis systems (including aspects like short-range forecast errors inside precipitation, observation operator errors/linearity, control variables, model resolution). Investigation of assimilation schemes without linear model assumptions. Systematic studies to evaluate *error covariances* used for constructing retrieval databases; possibly error databases.

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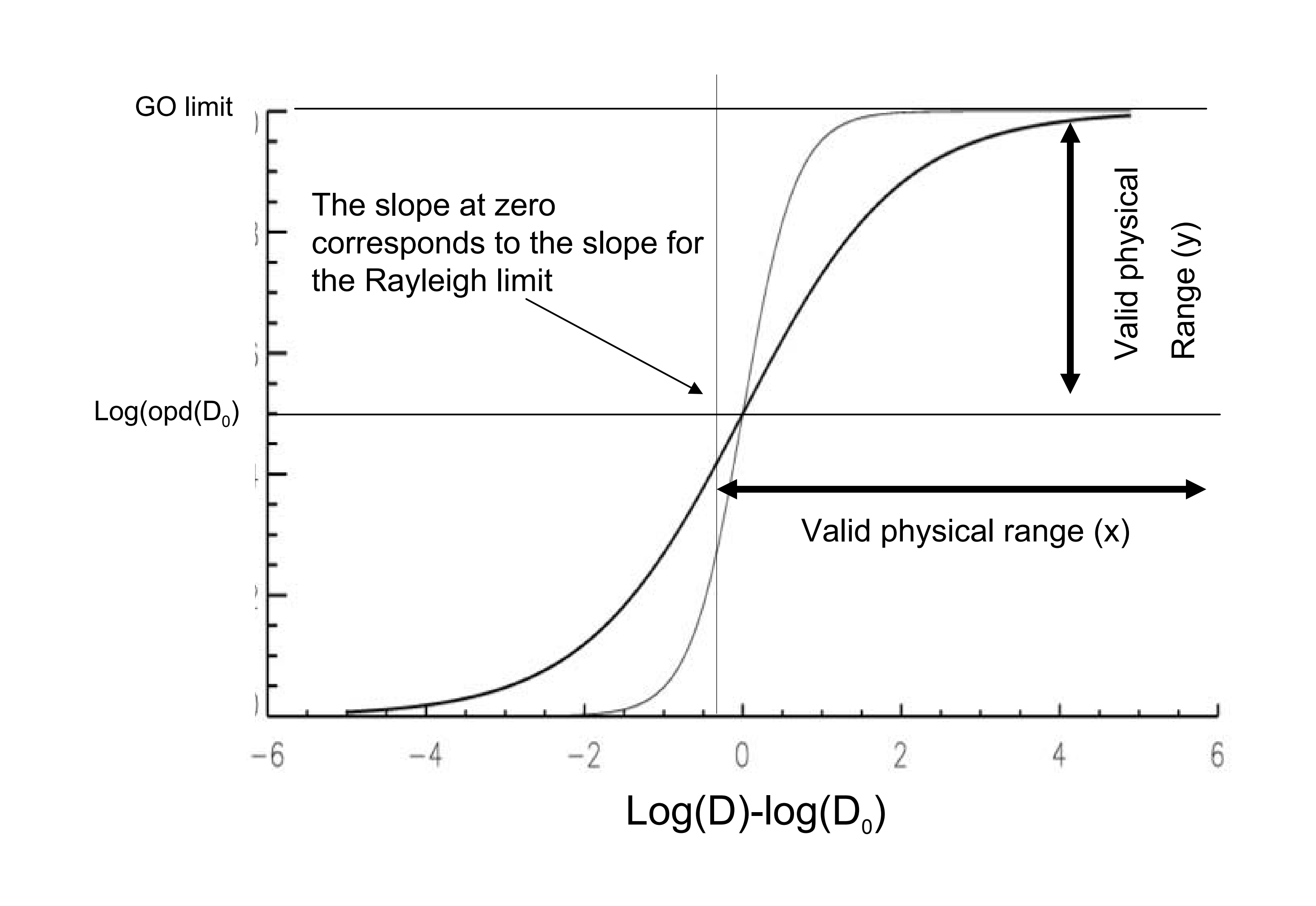
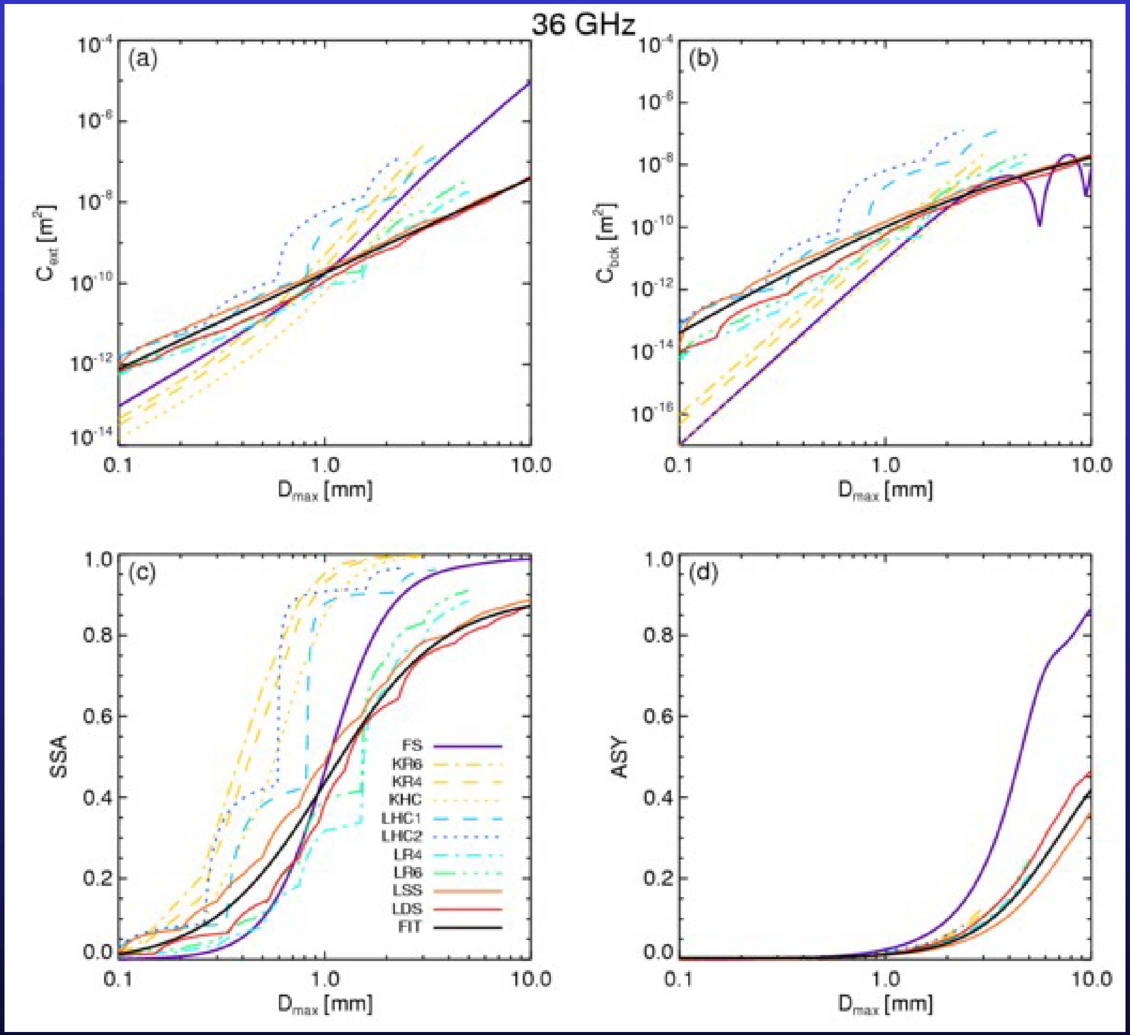
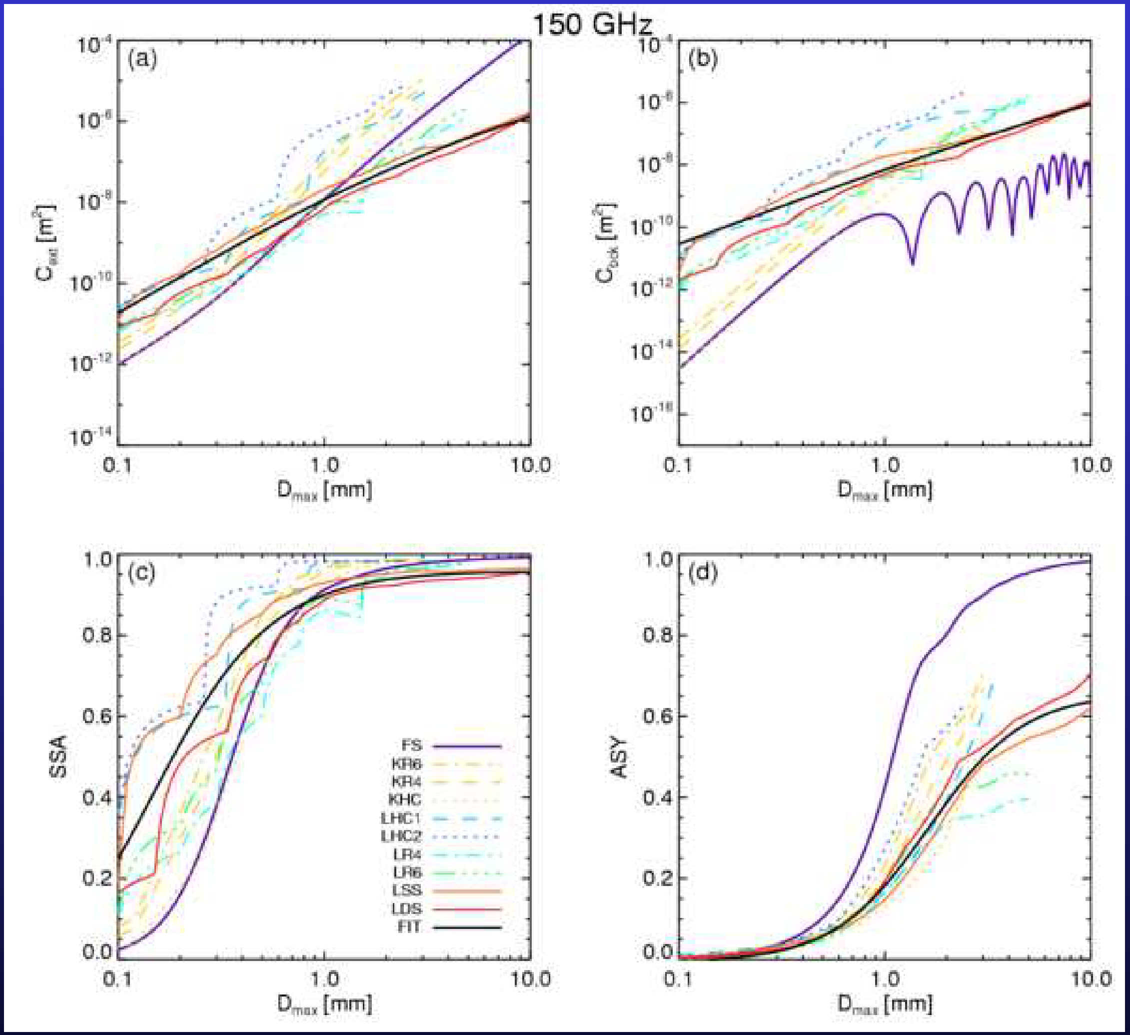
Sigmoid Snow/Rain Optical Properties Parameterization



Sigmoid Snow/Rain Optical Properties Parameterization



Sigmoid Snow/Rain Optical Properties Parameterization



Sigmoid Snow/Rain Optical Properties Parameterization

- Very accurate fits for all parameters
- Physically realistic behavior
- Sigmoid easy to differentiate ($dS/dx=S(1-S)$)
- Easy to implement TL and ADJ versions
- Uncertainties/errors can be specified via differences for different ice models

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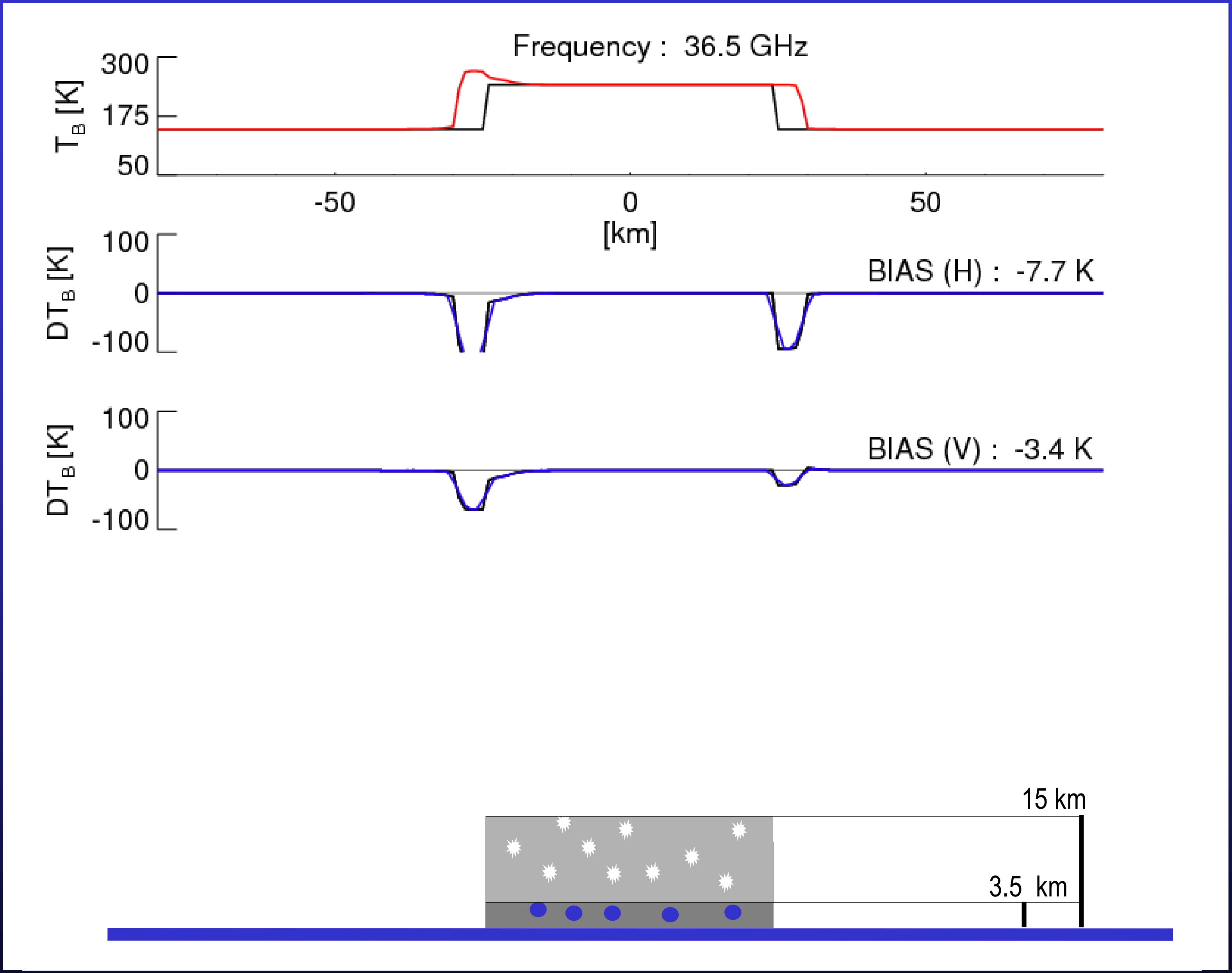
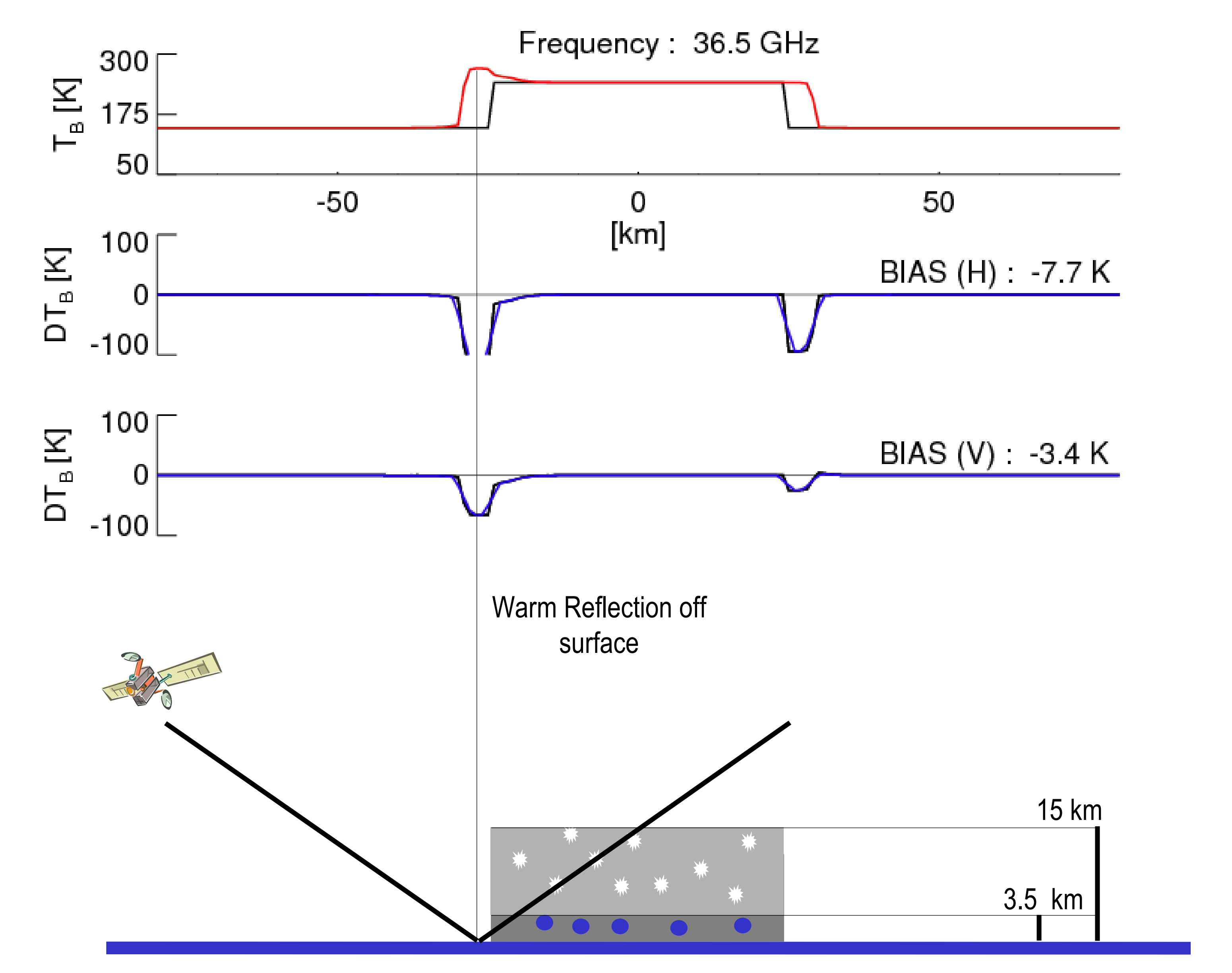
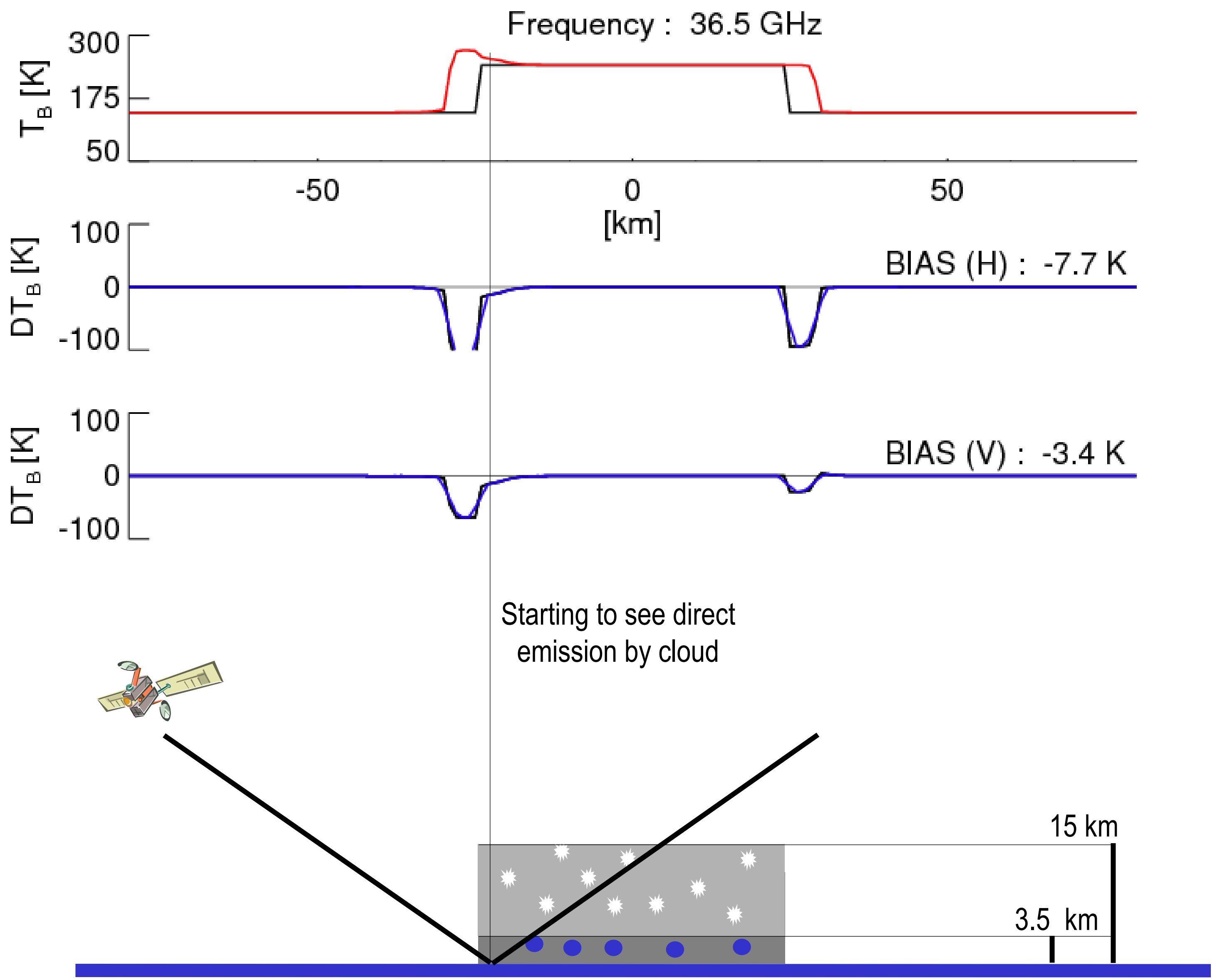
Slant Path Errors and Error Correlations



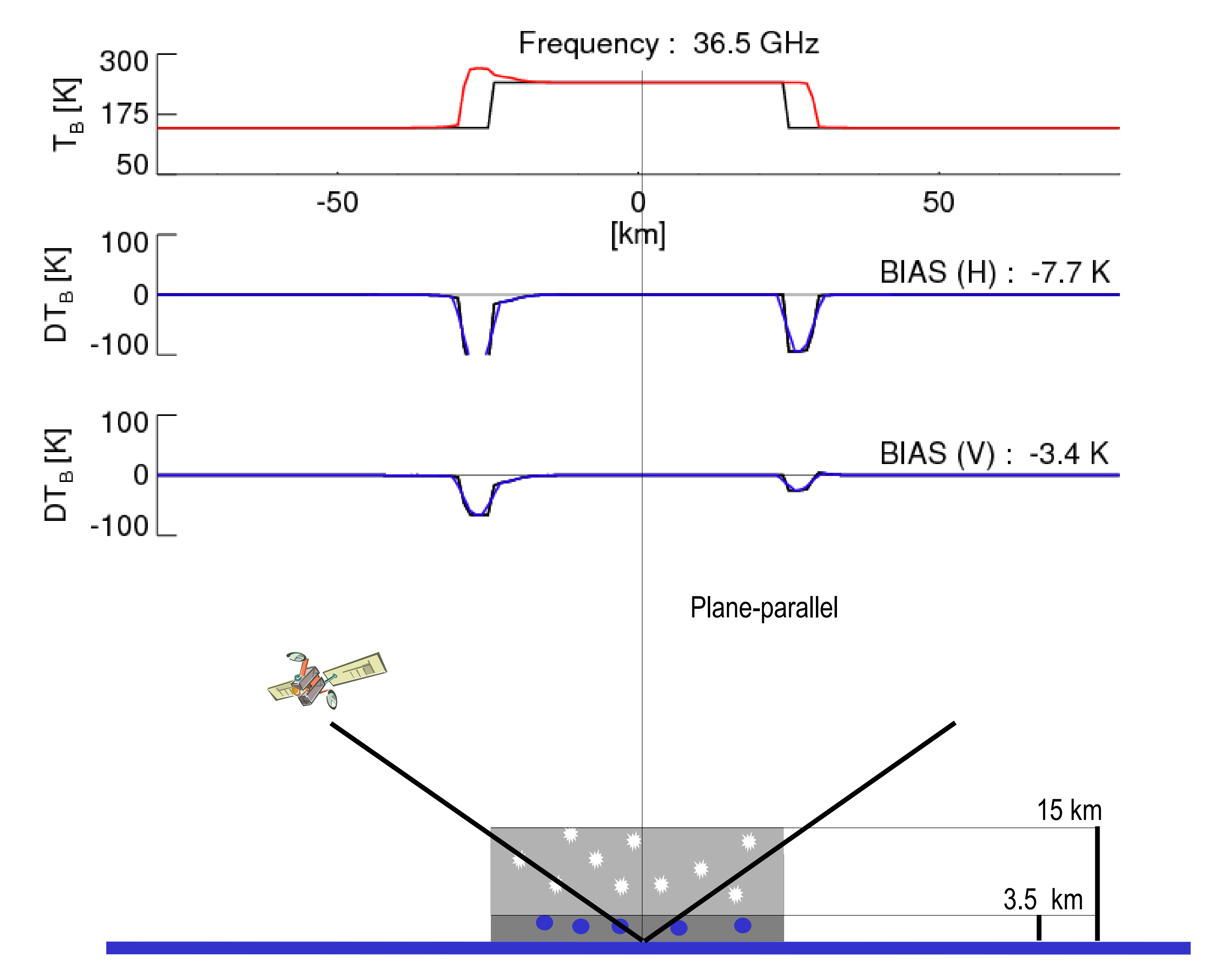
Frequency : 36.5 GHz
300
175
50
T_B [K]
-50
0
50
[km]
100
0
-100
DT_B [K]
BIAS (H) : -7.7 K
100
0
-100
DT_B [K]
BIAS (V) : -3.4 K
15 km
3.5 km



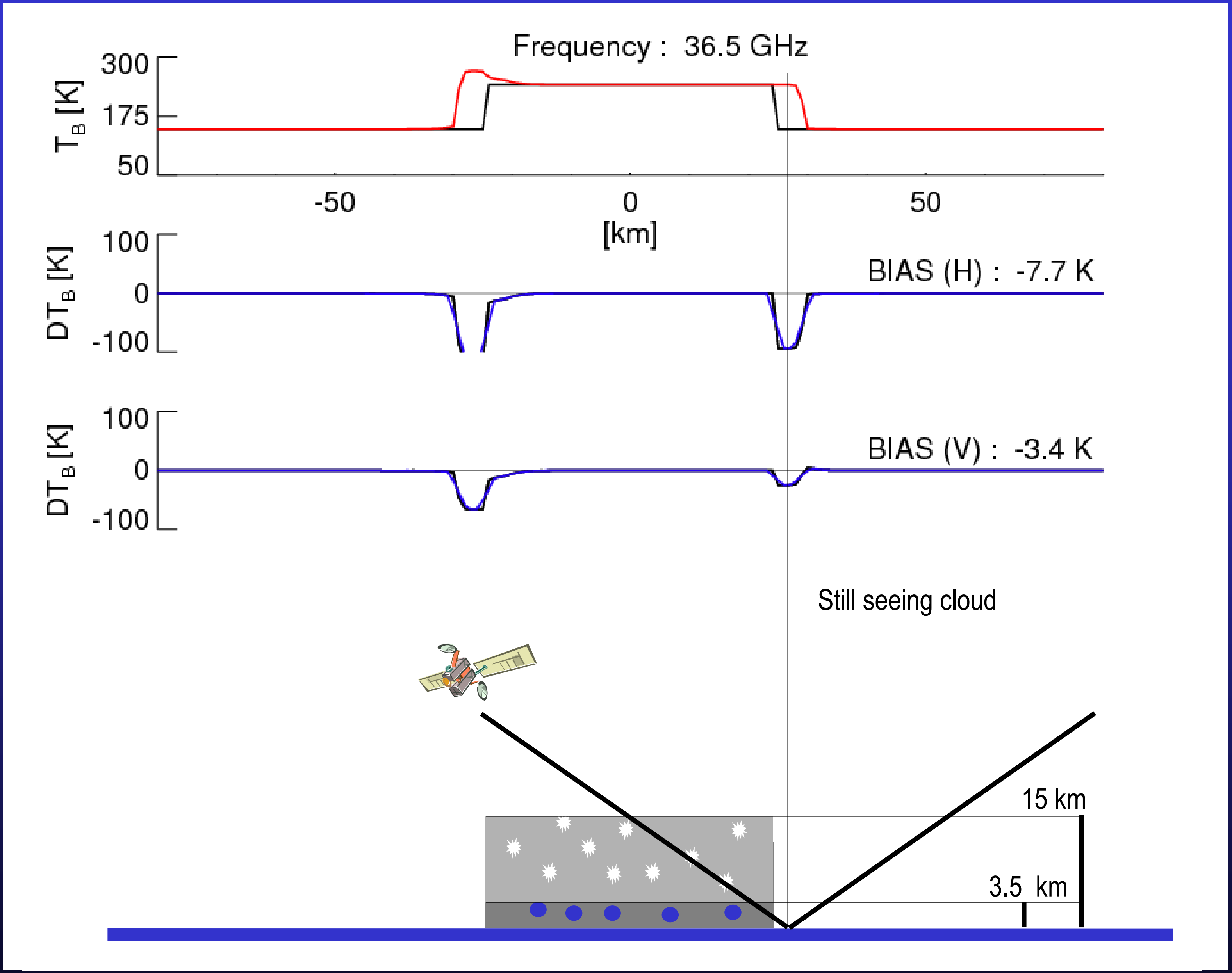
Frequency : 36.5 GHz
T_B [K]
300
175
50
-50
0
50
[km]
DT_B [K]
100
0
-100
BIAS (H) : -7.7 K
DT_B [K]
100
0
-100
BIAS (V) : -3.4 K
Warm Reflection off surface
15 km
3.5 km

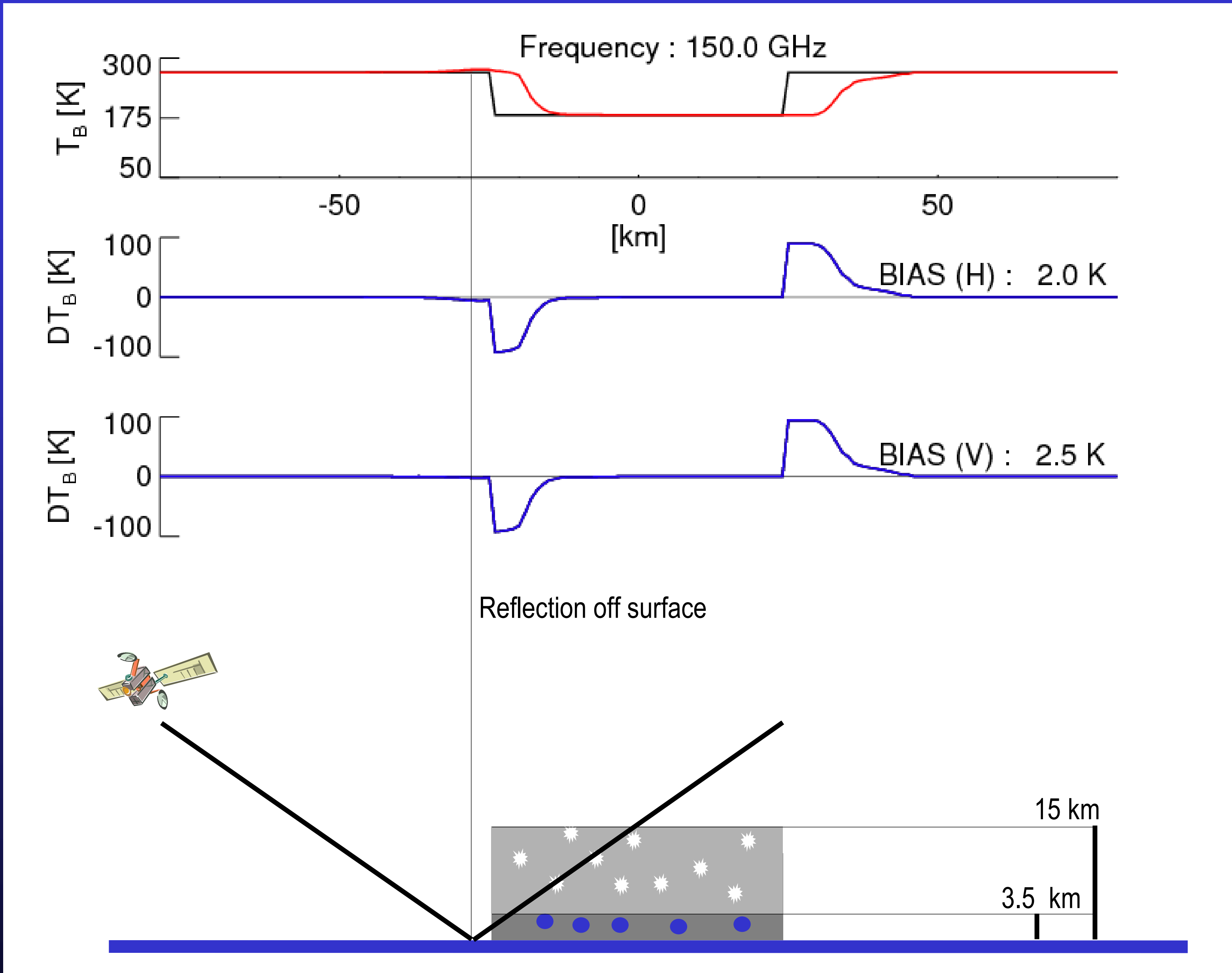


Frequency : 36.5 GHz
T_B [K]
300
175
50
-50
0
50
[km]
100
0
-100
DT_B [K]
BIAS (H) : -7.7 K
100
0
-100
DT_B [K]
BIAS (V) : -3.4 K
Starting to see direct
emission by cloud
15 km
3.5 km

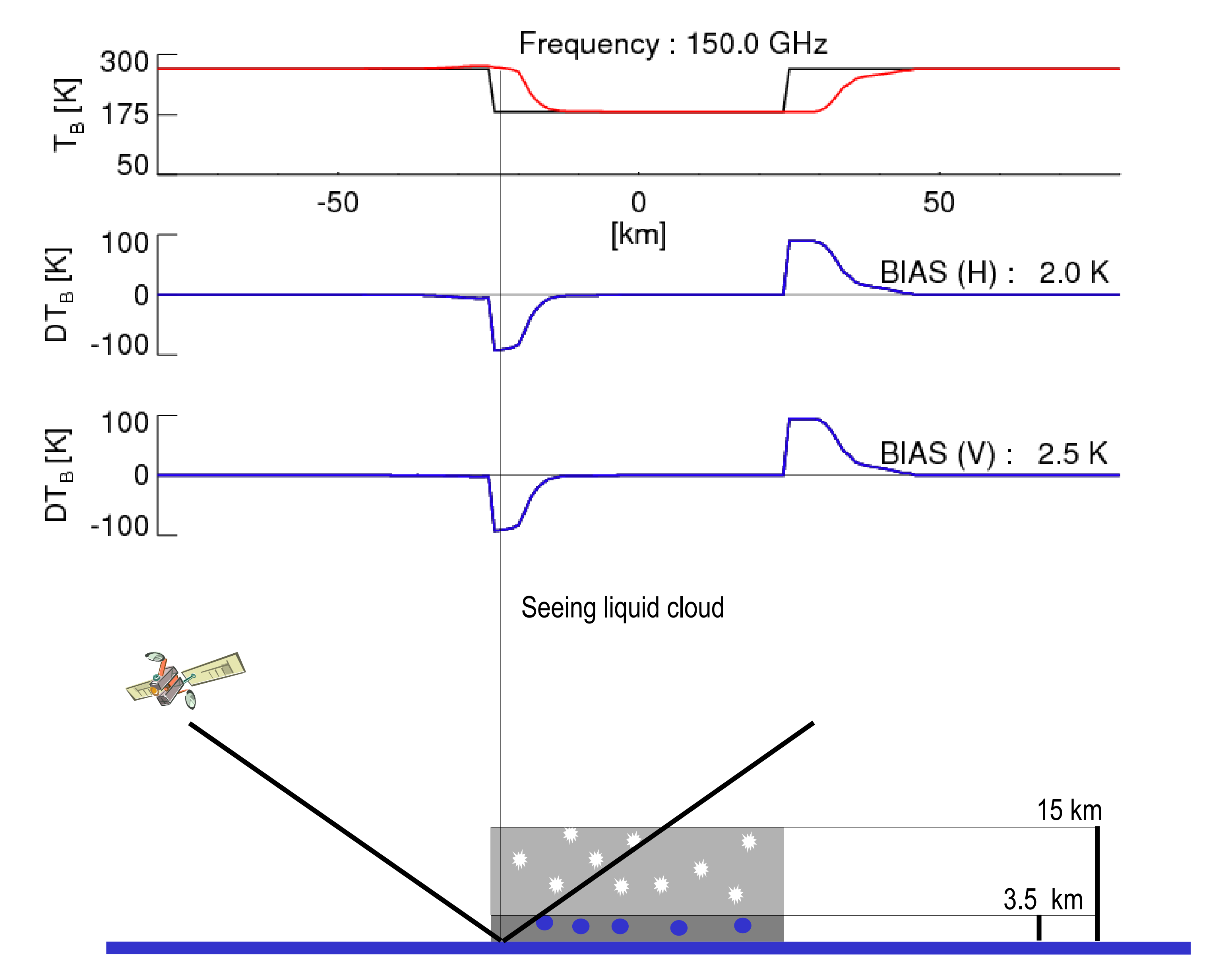


Frequency : 36.5 GHz
T_B [K]
300
175
50
-50
0
50
[km]
BIAS (H) : -7.7 K
DT_B [K]
100
0
-100
BIAS (V) : -3.4 K
DT_B [K]
100
0
-100
Plane-parallel
15 km
3.5 km

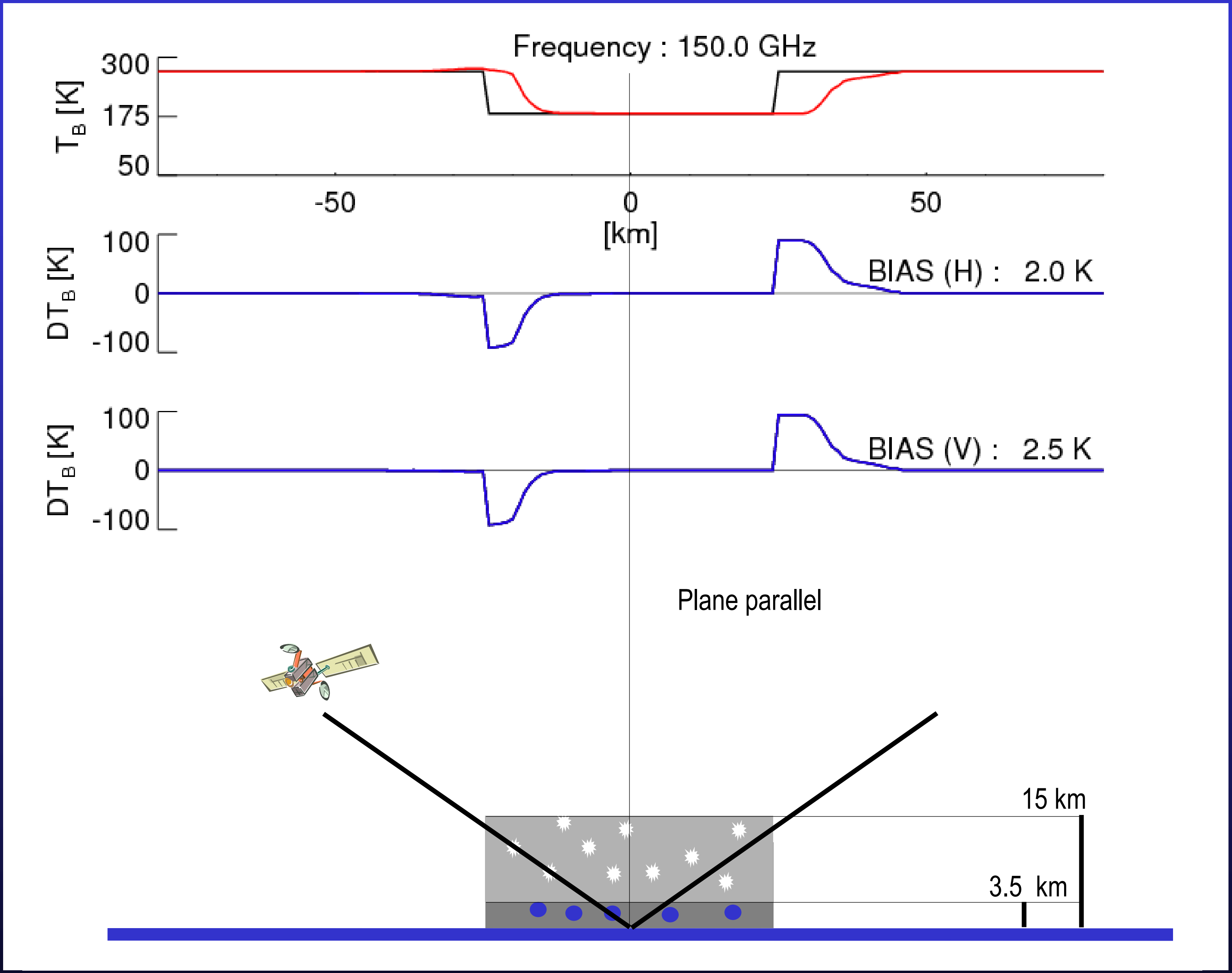

Frequency : 36.5 GHz
T_B [K]
300
175
50
-50
0
50
[km]
DT_B [K]
100
0
-100
BIAS (H) : -7.7 K
DT_B [K]
100
0
-100
BIAS (V) : -3.4 K
Still seeing cloud
15 km
3.5 km



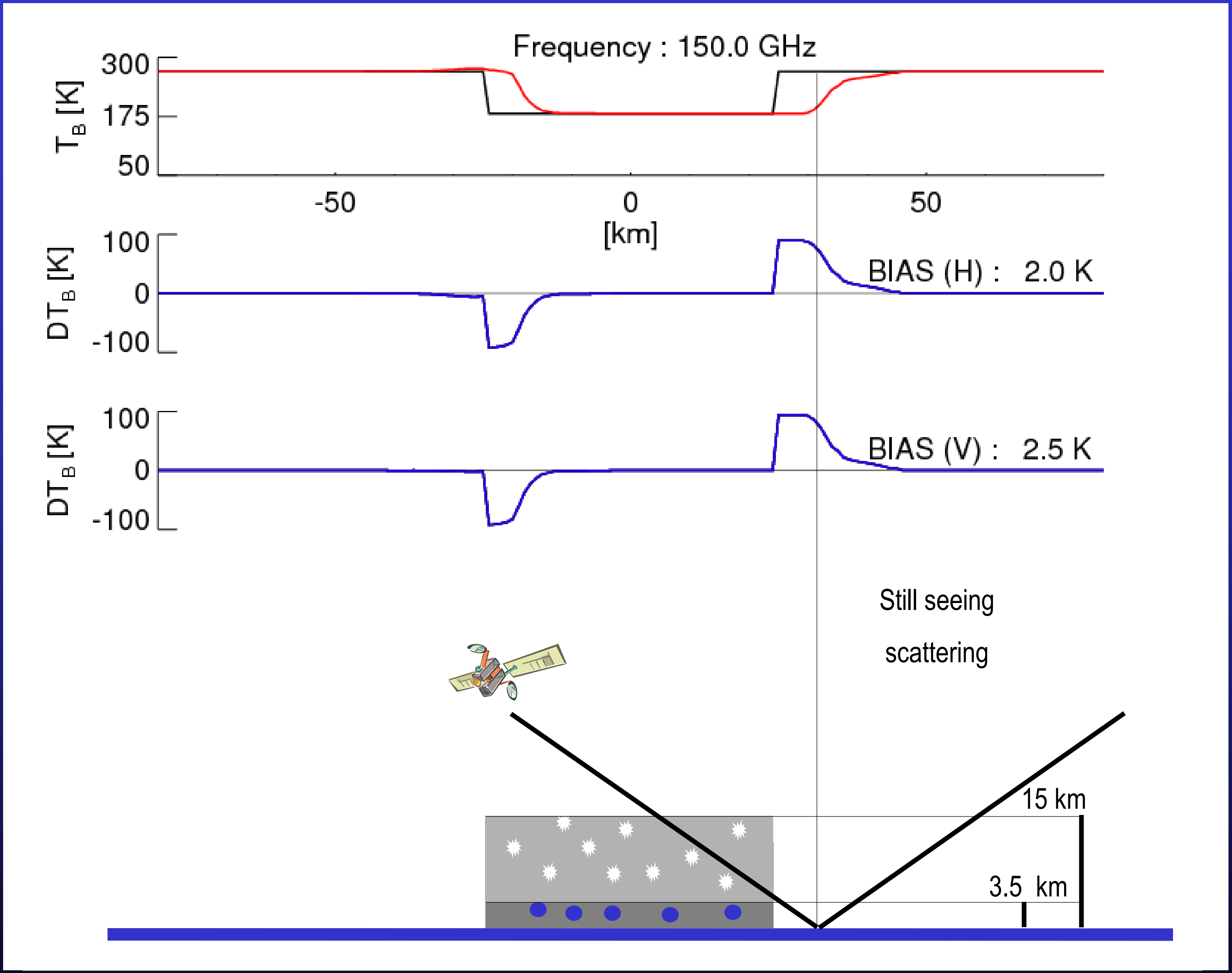
Frequency : 150.0 GHz
300
175
50
T_B [K]
-50
0
50
[km]
100
0
-100
DT_B [K]
BIAS (H) : 2.0 K
100
0
-100
DT_B [K]
BIAS (V) : 2.5 K
Reflection off surface
15 km
3.5 km



Frequency : 150.0 GHz
T_B [K]
300
175
50
-50
0
50
[km]
DT_B [K]
100
0
-100
BIAS (H) : 2.0 K
DT_B [K]
100
0
-100
BIAS (V) : 2.5 K
Seeing liquid cloud
15 km
3.5 km



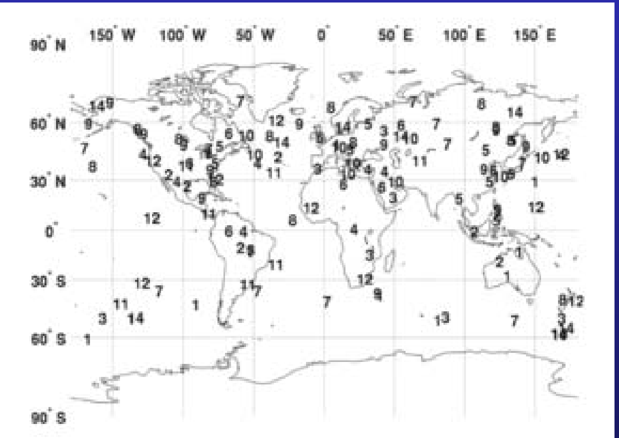
Frequency : 150.0 GHz
T_B [K]
300
175
50
-50
0
50
[km]
DT_B [K]
100
0
-100
BIAS (H) : 2.0 K
DT_B [K]
100
0
-100
BIAS (V) : 2.5 K
Plane parallel
15 km
3.5 km



Frequency : 150.0 GHz
T_B [K]
300
175
50
-50
0
50
[km]
DT_B [K]
100
0
-100
BIAS (H) : 2.0 K
DT_B [K]
100
0
-100
BIAS (V) : 2.5 K
Still seeing
scattering
15 km
3.5 km

Error Correlations
(with Staelin/Surussavadee)

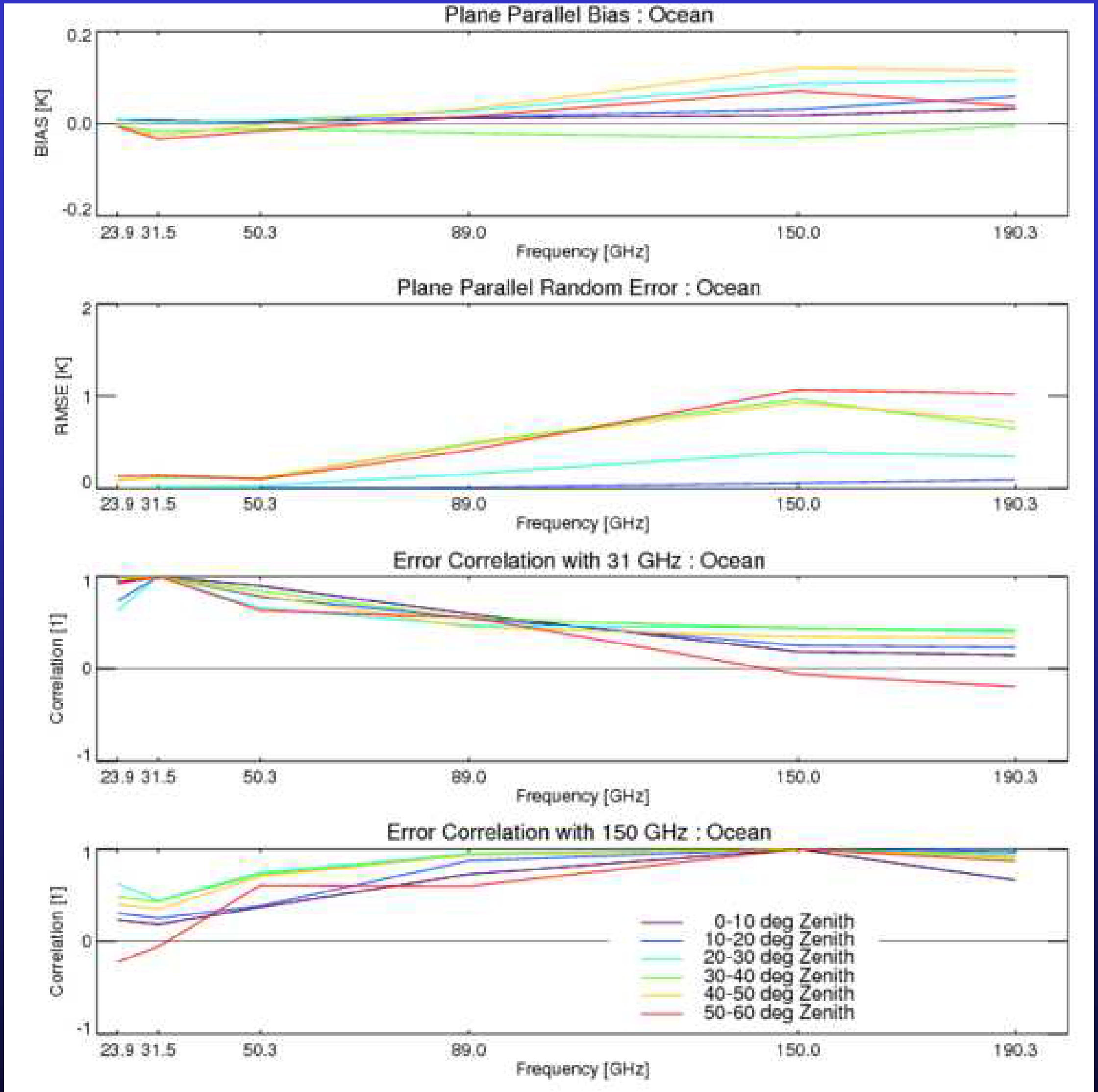
- 122 MM5 simulations of various global precipitation systems (each 190x190x41 with 5 km horizontal resolution, bulk microphysics)
- Ice scattering using Liu particles with Bennartz/Kulie approach
- Marshall-Palmer rain
- AMSU frequencies
- Coincident AMSU overpasses
- SOI Plane parallel versus SOI-SLANT



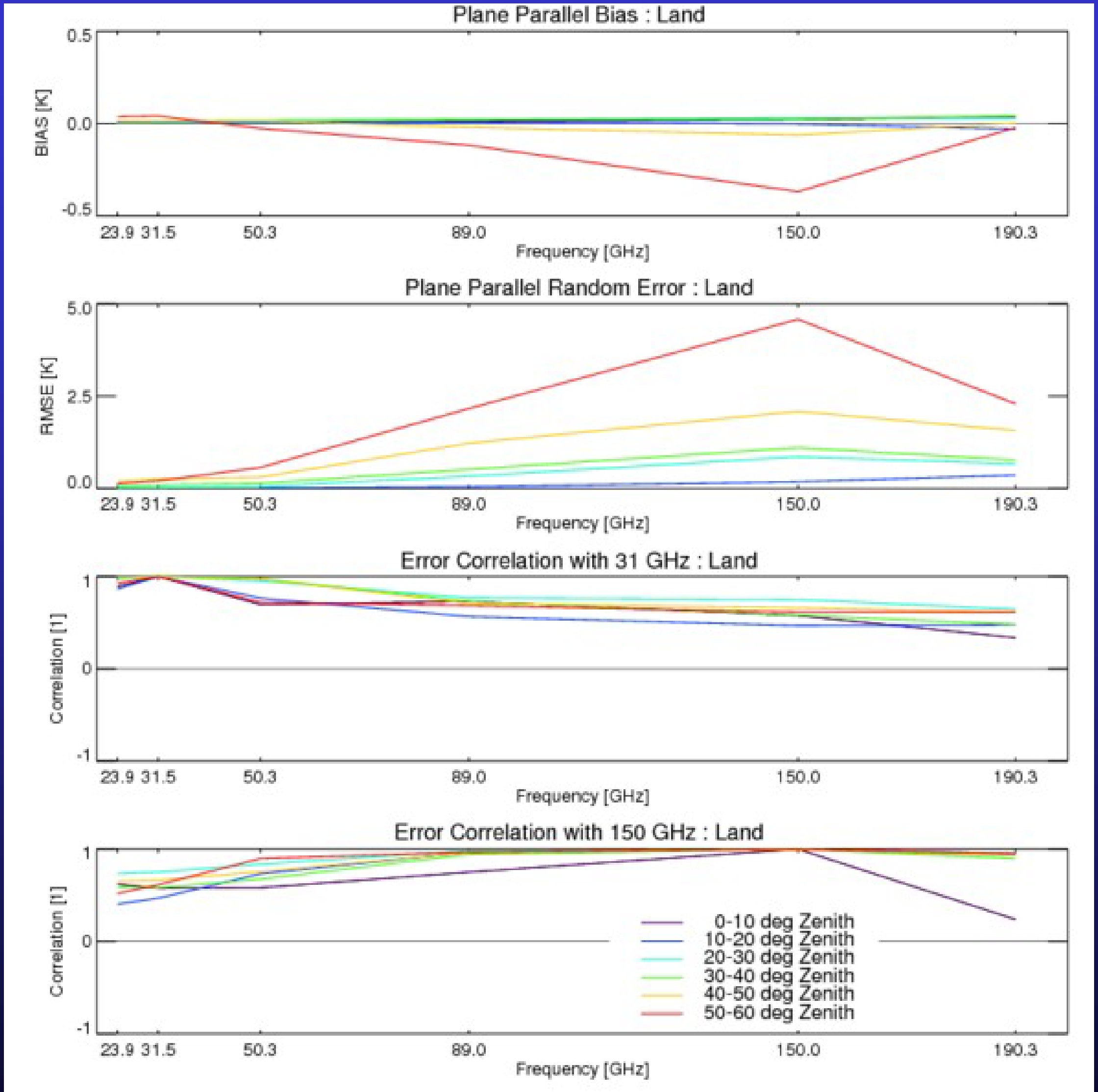
From Surussavadee and Staelin (2006)

Fig. 5. One hun... numbers 1–12 stand for January–December, and 14 indicates largely unglaciated cases.

Error Correlations: Ocean



Error Correlations: Land



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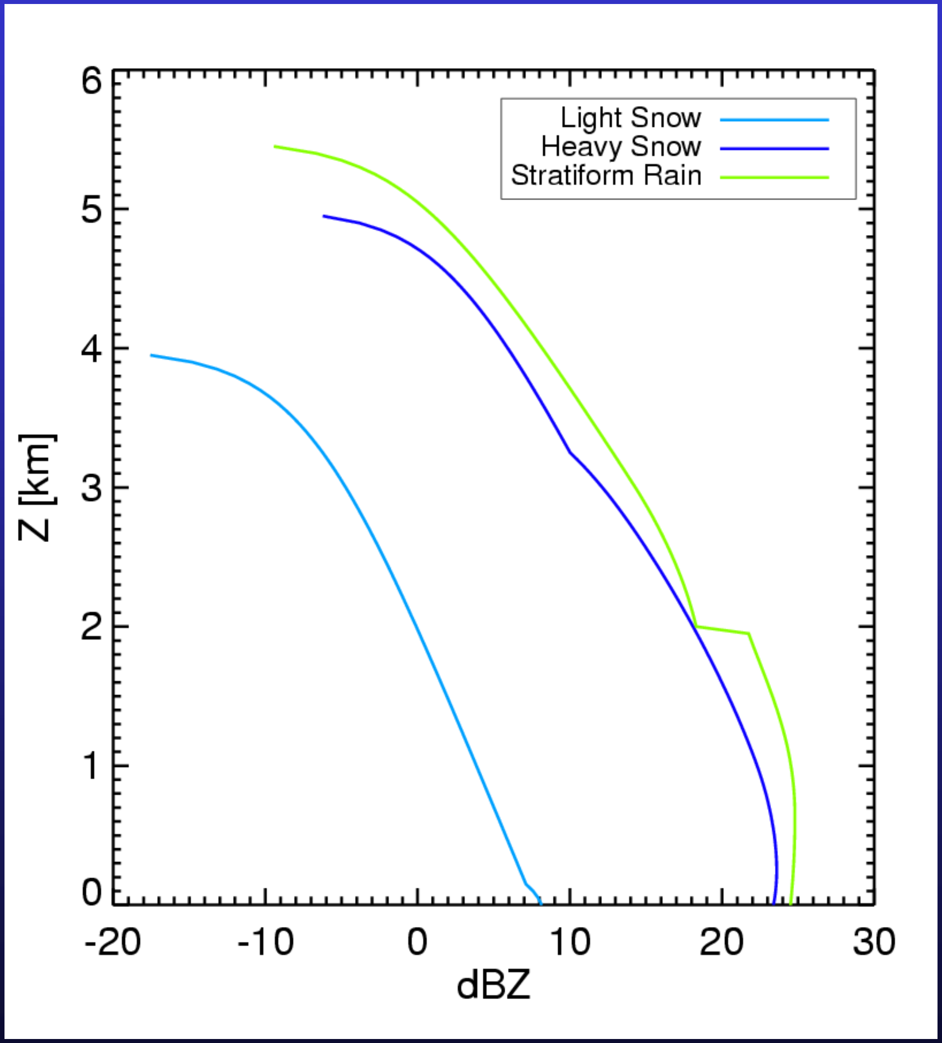
Towards assimilation studies

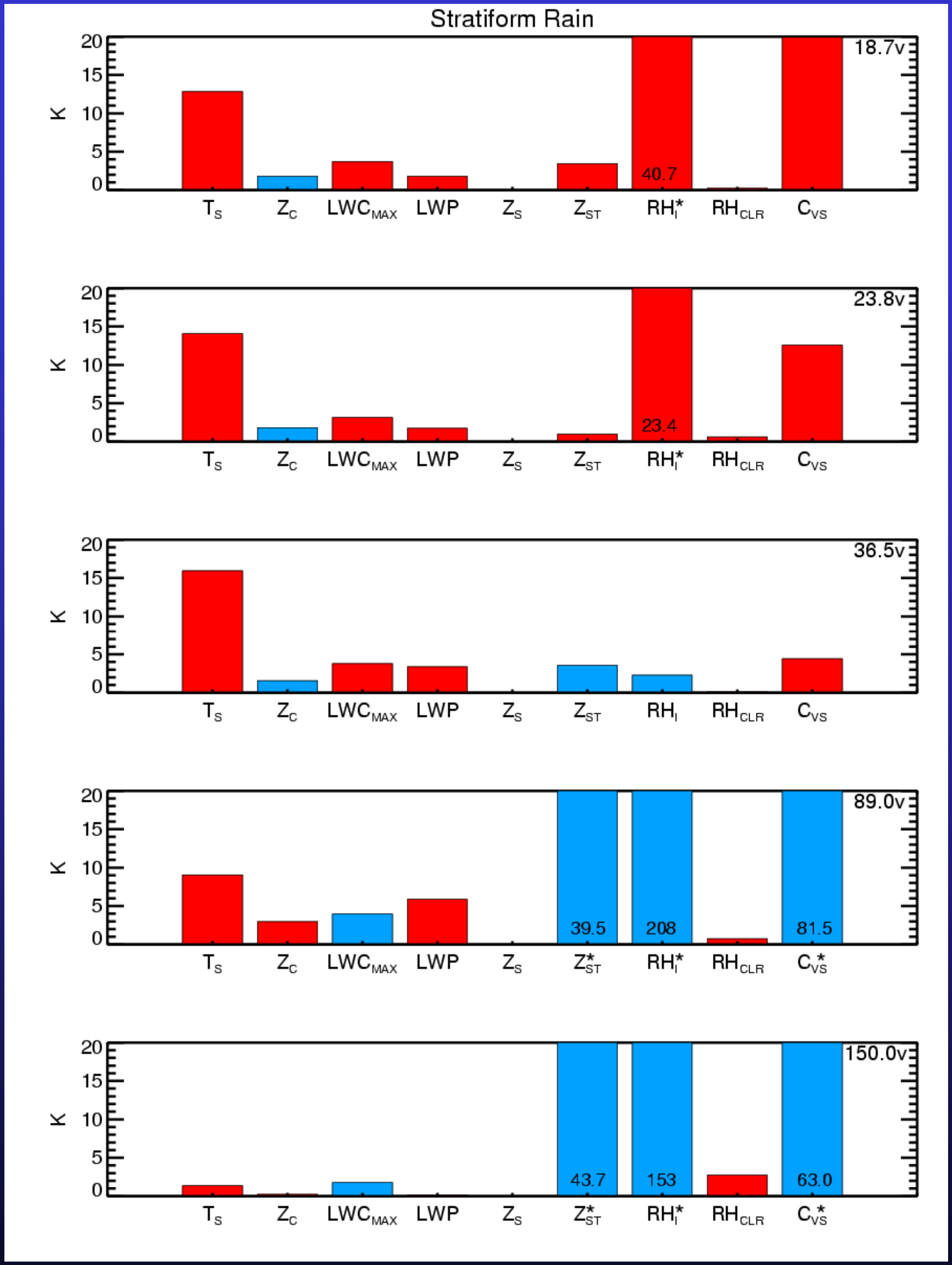
- Simple case: A one dimensional parametric rain model
  - Test impact of different error covariances
  - Fast and simple to use
  - General insight - information content analysis
  - Less complex - less realistic
- Full complexity: WRF mesoscale studies
  - Would yield actual forecast impacts - but hard to quantify
  - Computationally demanding
  - Highly complex - more realistic

One dimensional parametric rain model (modified from Petty (2001))

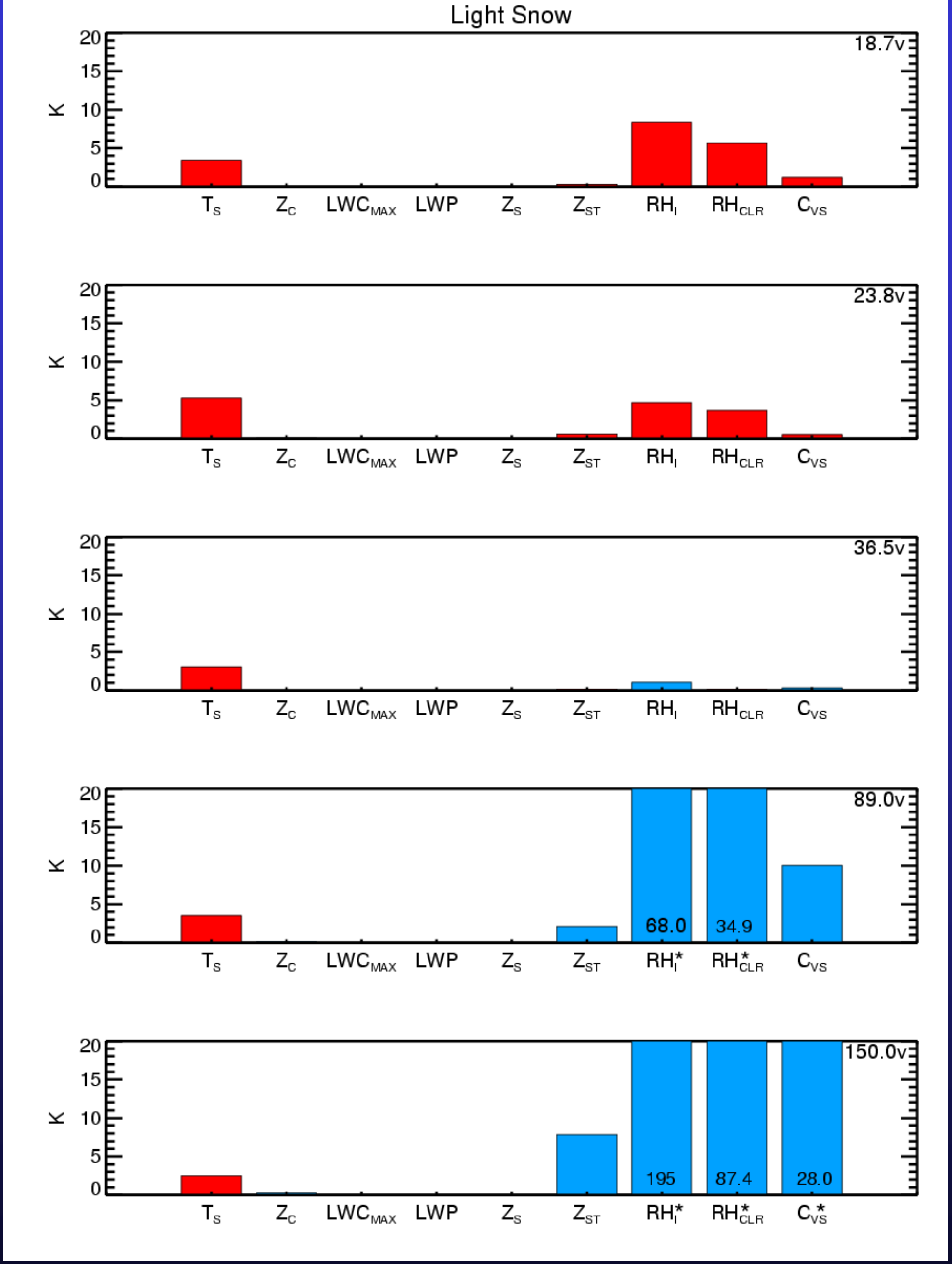
	Description	Units	Light Snow	Heavy Snow	Stratiform
T_s	2 m temperature	C	-3.0	-3.0	10.0
Z_c	Liquid cloud base	km	0.1	1.0	0.6
LWC_{MAX}	Cloud liquid water content maximum	$g\ m^{-3}$	0.1	0.1	0.15
LWP	Cloud liquid water path	$kg\ m^{-2}$	0.0005	0.15	0.2
Z_S	Bottom of snow layer	km	2.0	2.0	2.6
Z_{ST}	Top of snow layer	km	4.0	5.0	5.5
RH_I	RH with respect to ice in snow layer	-	1.01	1.06	1.05
RH_{CLR}	RH with respect to ice above cloud top and outside of snow layer	-	1.01	1.01	1.1
C_{VS}	Vapor to snow conversion rate	$mm\ h^{-1}\ km^{-1}\ Pa^{-1}$	0.01	0.05	0.015
R_{SFC}	Surface rain rate	$mm\ h^{-1}$	0.12	3.8	1.0
Z_F	Freezing level height	Km	-	-	2.0
dBZ_{MAX}	Maximum radar reflectivity	dBZ	8.1	23.6	24.8

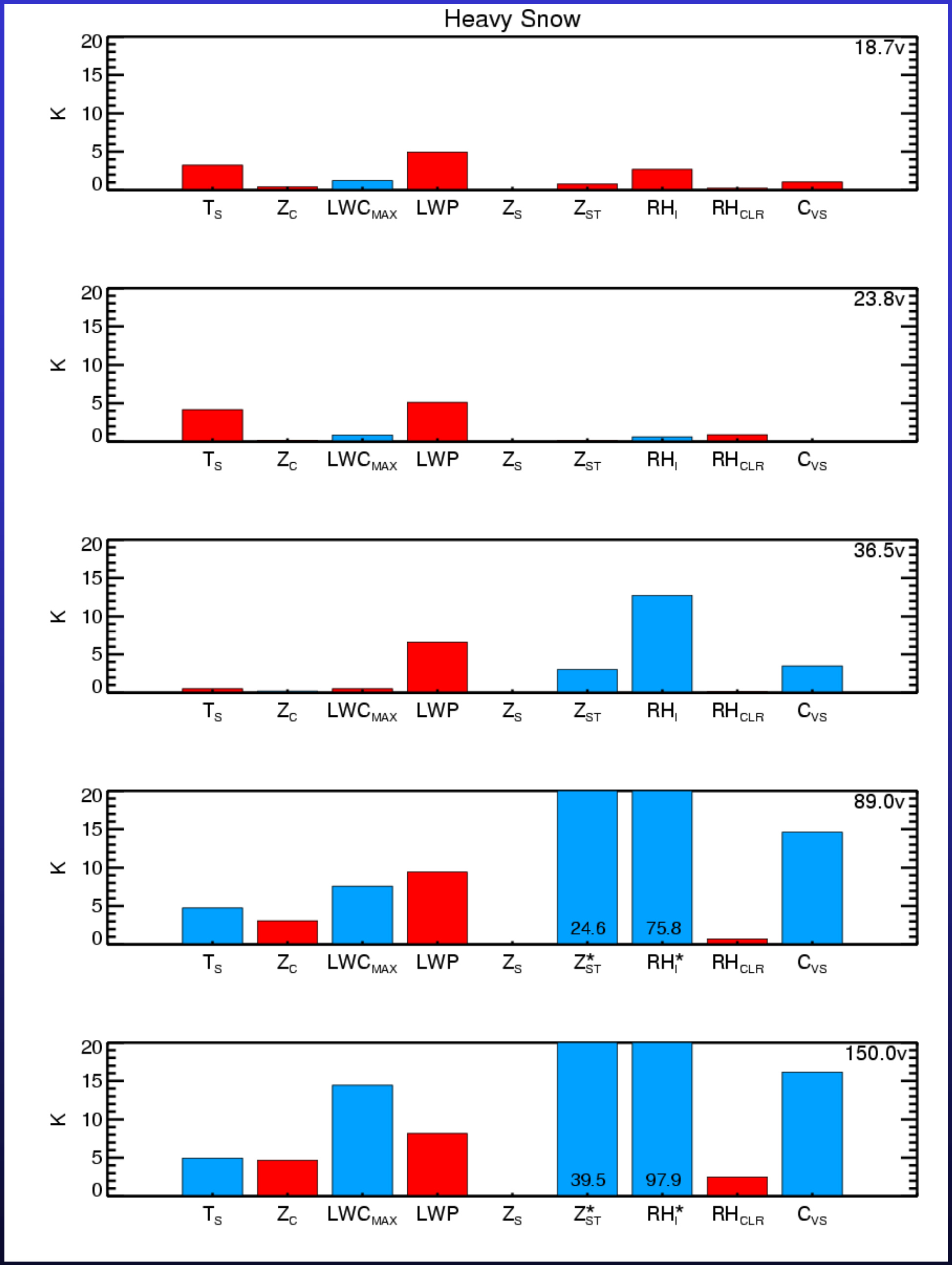
One dimensional parametric rain model (modified from Petty (2001))





Stratiform Rain
18.7v
23.8v
36.5v
89.0v
150.0v
K
40.7
23.4
39.5
208
81.5
43.7
153
63.0
T_S
Z_C
LWC_{MAX}
LWP
Z_S
Z_{ST}
RH_I^*
RH_{CLR}
C_{VS}


Light Snow
K
18.7v
23.8v
36.5v
89.0v
150.0v
20
15
10
5
0
T_S
Z_C
LWC_MAX
LWP
Z_S
Z_ST
RH_I
RH_CLR
C_VS
68.0
34.9
RH*_I
RH*_CLR
195
87.4
28.0
C*_VS

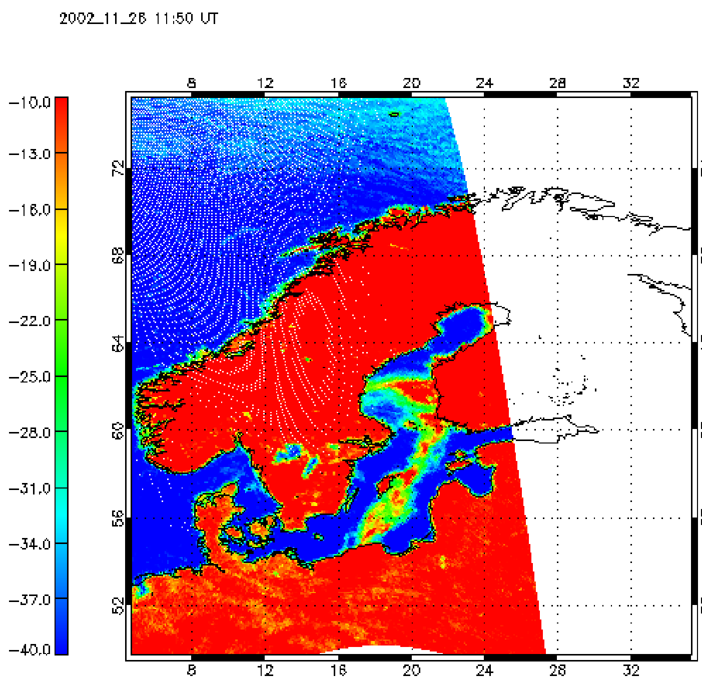

Heavy Snow
18.7v
23.8v
36.5v
89.0v
150.0v
K
24.6
75.8
39.5
97.9
T_S
Z_C
LWC_MAX
LWP
Z_S
Z_ST
RH_I
RH_CLR
C_VS
Z*_ST
RH*_I

WRF: Towards Assimilation Studies

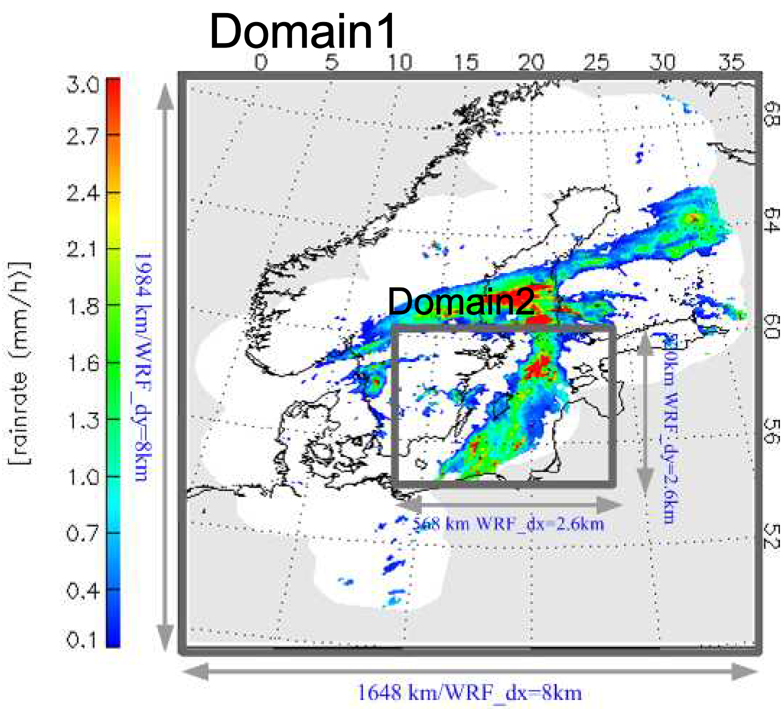
- WRF installed and running for several test cases
- Collocated AMSR (as well as ground radar data)
- Initial forward simulation studies

Case study : Frontal system

26 Nov. 2002 over Baltic sea (observed by BALTEX Radar)



AMSR DATA (36V−89V)

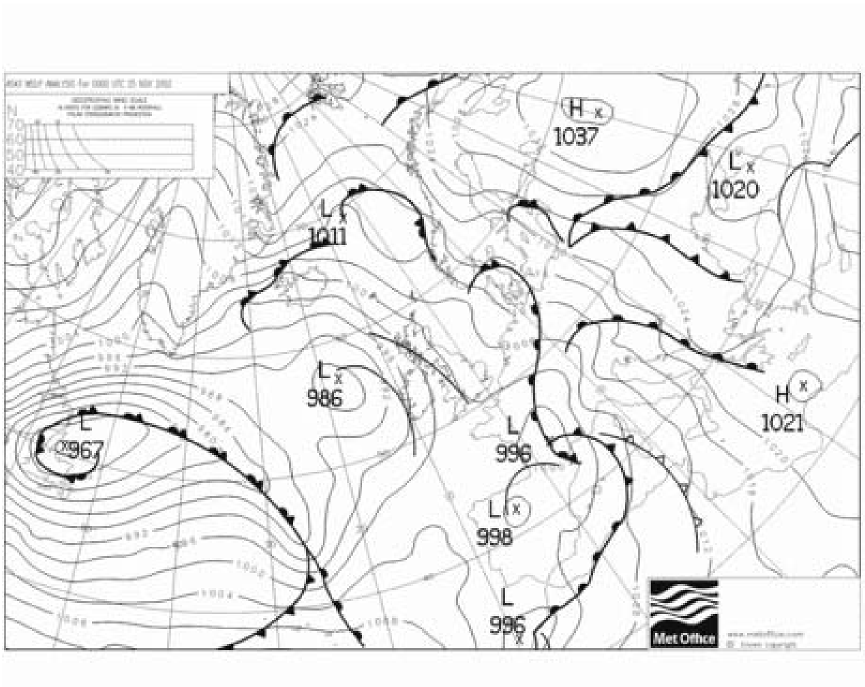


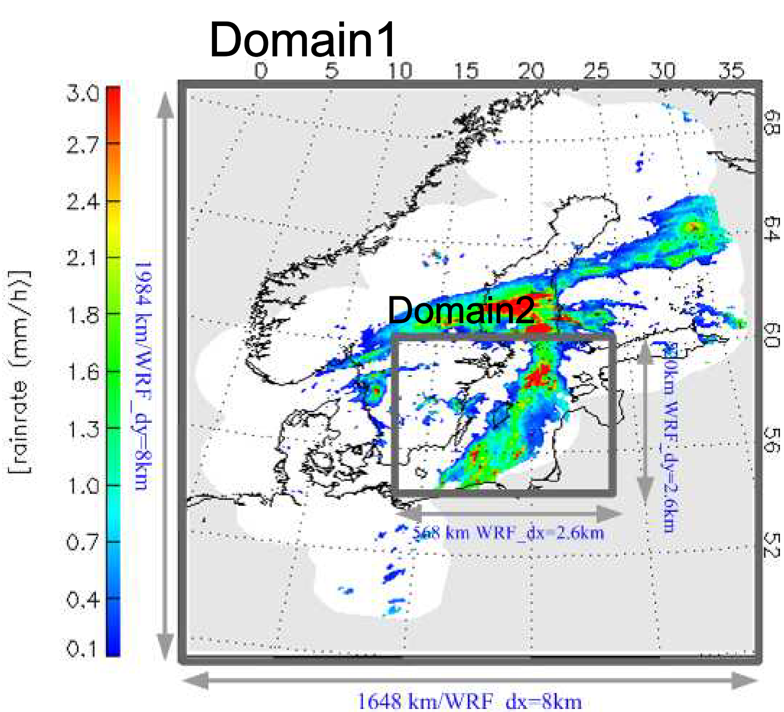
BALTRAD COMPOSITE RAINRATE IMAGE

Case study : Frontal system

26 Nov. 2002 over Baltic sea (observed by BALTEX Radar)

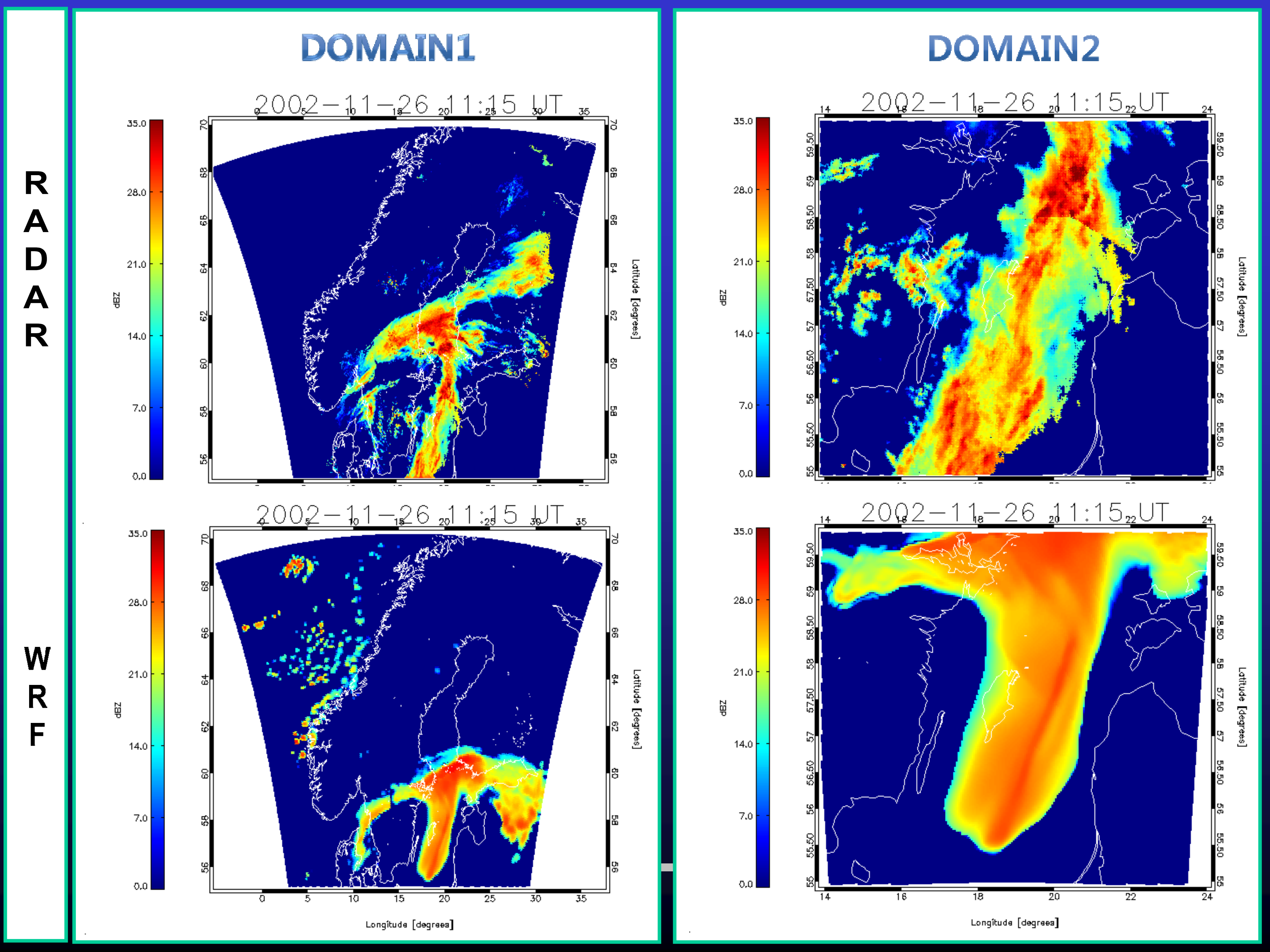
WRF domains

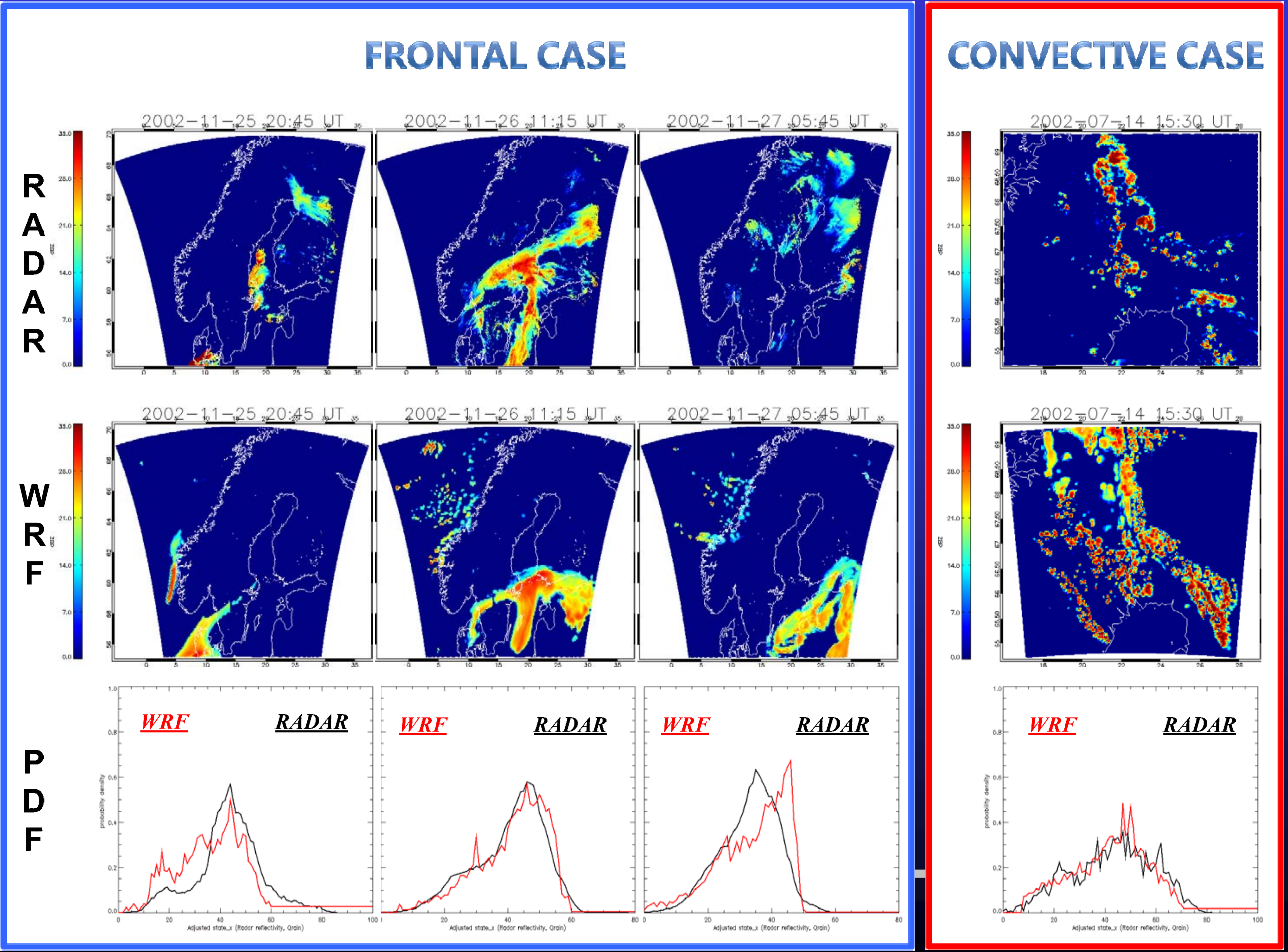




AMSR DATA (36V–89V)

BALTRAD COMPOSITE RAINRATE IMAGE


DOMAIN1
DOMAIN2
RADAR
WRF
2002-11-26 11:15 UT
2002-11-26 11:15 UT
2002-11-26 11:15 UT
2002-11-26 11:15 UT
dBZ
Latitude [degrees]
Longitude [degrees]



FRONTAL CASE
CONVECTIVE CASE
RADAR
WRF
PDF
2002-11-25 20:45 UT
2002-11-26 11:15 UT
2002-11-27 05:45 UT
2002-07-14 15:30 UT
dBZ
WRF
RADAR
probability density
Adjusted state_x (Radar reflectivity, Qrain)

Plans for Year 2

- Further test and integrate SOI with other models in CRTM
- Develop formulation for observation error including all modeling errors, RT solver, ice scattering, cloud overlap, 3 D effects etc.
- Further pursue simplified as well as full WRF assimilation studies

Assessing error characteristics: What are the challenges?

- Representativeness of forecast model
- Scale of forecast model
- Gas absorption models
- Representation of particle scattering
- Surface emissivity models
- Radiative transfer solver
- Instrument characteristics
- Various components need to go together