Training database and NN retrieval

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Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

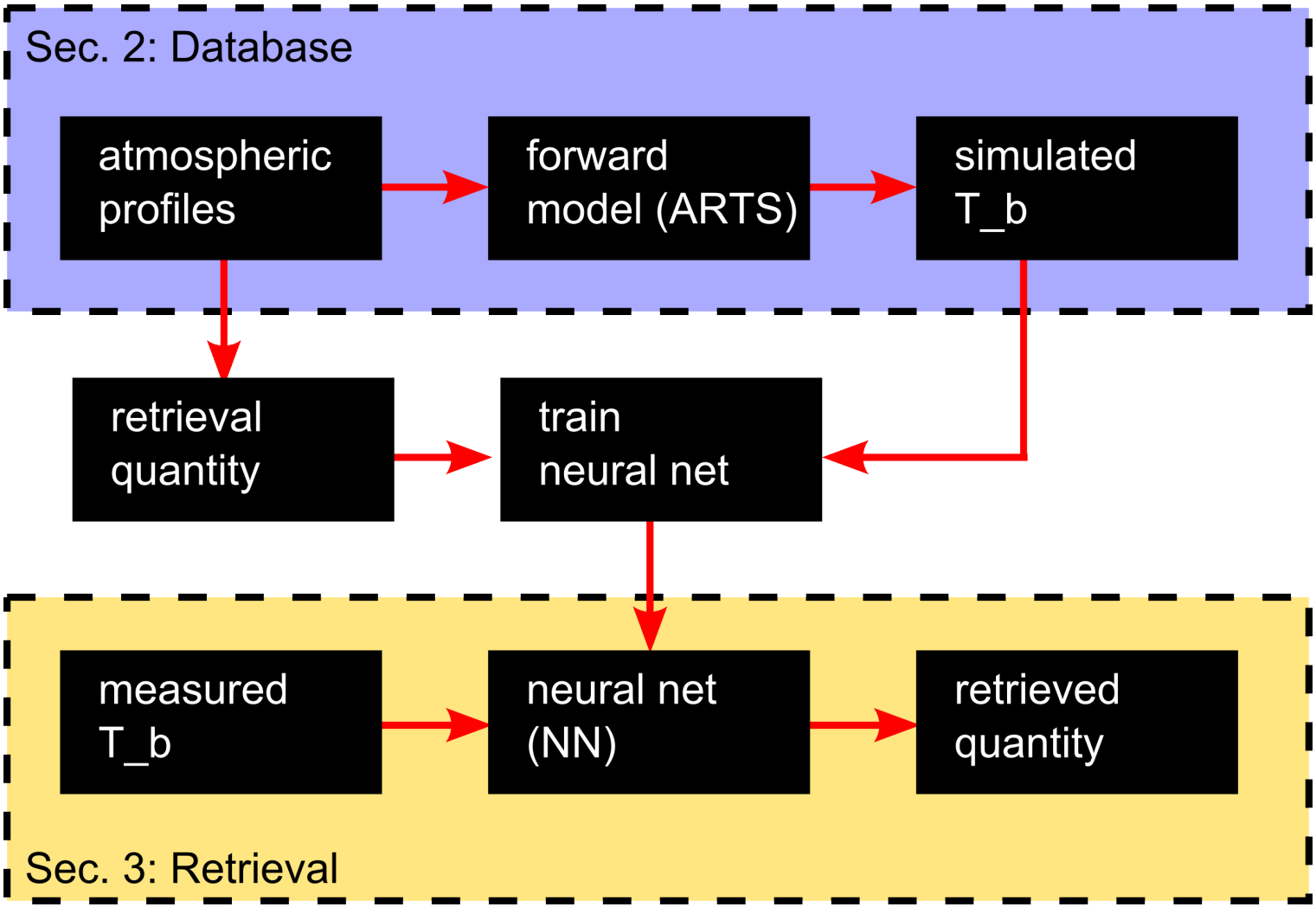
Introduction

Purpose

Retrieval of the hydrometeor paths (HMP)

- Liquid water path (LWP)
- *Ice water path (IWP)*
- Rain water path (RWP)
- *Snow water path (SWP)*

Main idea of the retrieval



Database

Atmospheric data

Chevallier data set (Chevallier *et al.*, 2006)

- 25.000 atmospheric profiles, 5.000 randomly chosen profiles are used for training of the neural nets and the other 20.000 are used for validation and analysis (Sec. 3: Retrieval).

- 91 pressure levels between 0.02 hPa and the surface pressure. From the data set following profiles on the 91 level grid were used:
  - atmospheric temperature [K]
  - atmospheric humidity, converted to volume mixing ratio (vmr)
  - atmospheric ozone, converted to volume mixing ratio (vmr)
  - cloud liquid water, converted to mass concentration $\left[\mathrm{kg/m^3}\right]$
  - cloud ice water, converted to mass concentration $\left[\mathrm{kg/m^3}\right]$
  - rain, as mass flux $\left[\mathrm{kg/(m^2 s)}\right]$
  - snow, converted to mass concentration $\left[\mathrm{kg/m^3}\right]$

Forward model

Atmospheric Radiative Transfer Simulator (ARTS)

- line by line radiative transfer model
- includes absorbtion and scattering
- scattering calculation using DOIT
- main developers: Chalmers University, Lulea University of Technology and University of Hamburg
- `http://www.radiativetransfer.org/`

Forward model

Main assumptions for the simulations

- following the setup from Geer & Baordo (2014):

Hydrometeor	Shape	PSD
cloud liquid water	solid sphere	modified gamma
cloud ice	slightly soft sphere	modified gamma
rain	solid sphere	Marshall & Palmer (1948)
snow	Liu (2008)-sector-like snowflake Hong *et al.* (2009)aggregates	Field *et al.* (2007), tropic

- randomly oriented particles
- 1D-Atmosphere
- full stokes vector (right now, only first component is used for retrieval)
- blackbody surface
- simulation of the complete radiation field between surface and about 20 km

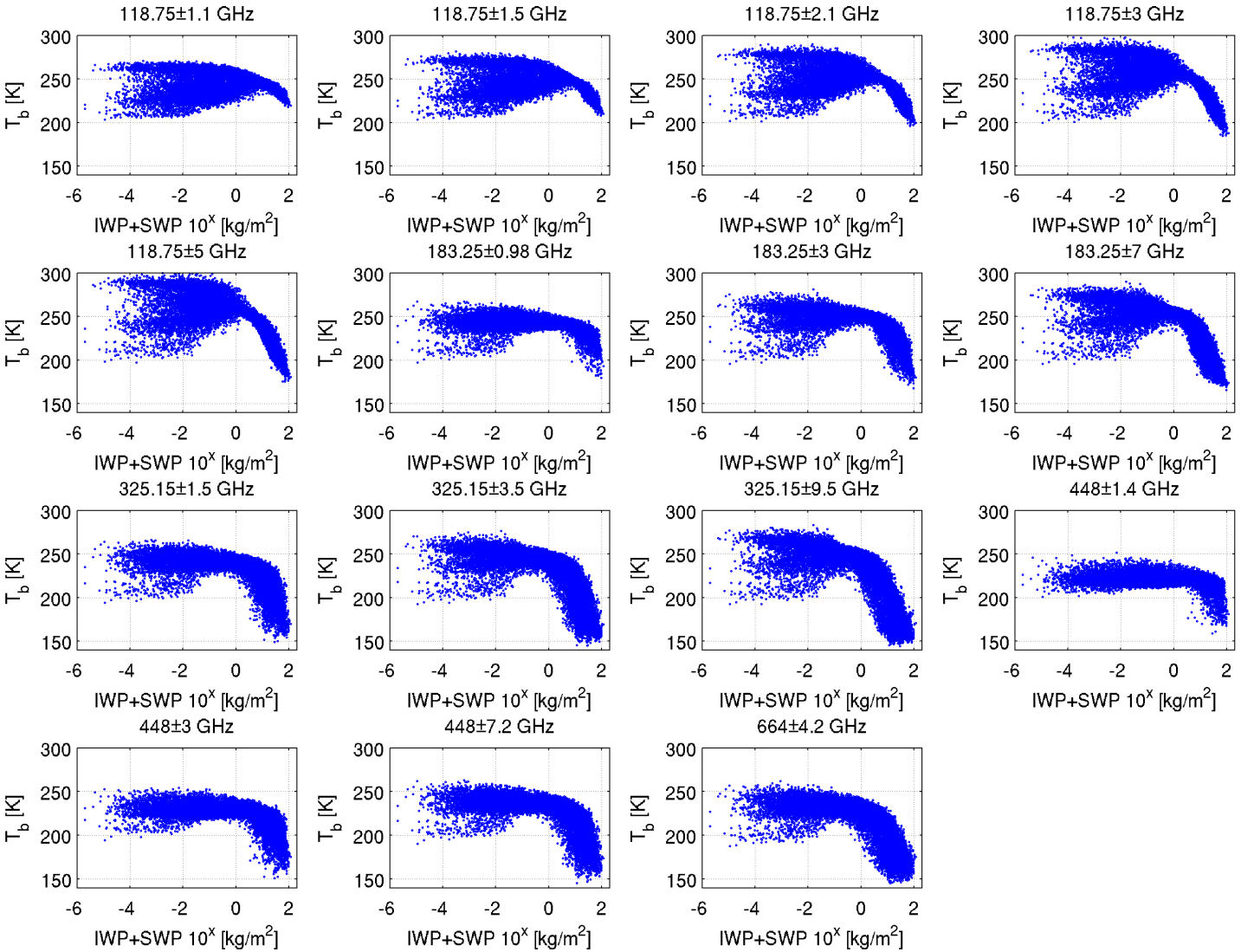
Forward model

simulated channels

channel_no	f [GHz]	Δf [GHz]	Instrument	Feature	channel_no	f [GHz]	Δf [GHz]	Instrument	Feature
1	23.8	$\pm$0.07	Deimos	H_2O	13	243.20	$\pm$2.5	ISMAR	window
2	50.1	$\pm$0.08	Deimos	O_2 wing	14	325.15	$\pm$1.5	ISMAR	H_2O
3	89.0	$\pm$1.1	MARSS	window	15	325.15	$\pm$3.5	ISMAR	H_2O
4	118.75	$\pm$1.1	ISMAR	O_2	16	325.15	$\pm$9.5	ISMAR	H_2O
5	118.75	$\pm$1.5	ISMAR	O_2	17	424.70	$\pm$1.0	ISMAR	O_2
6	118.75	$\pm$2.1	ISMAR	O_2	18	424.70	$\pm$1.5	ISMAR	O_2
7	118.75	$\pm$3.0	ISMAR	O_2	19	424.70	$\pm$4.0	ISMAR	O_2
8	118.75	$\pm$5.0	ISMAR	O_2	20	448.0	$\pm$1.4	ISMAR	H_2O
9	157.05	$\pm$2.6	MARSS	window	21	448.0	$\pm$3.0	ISMAR	H_2O
10	183.31	$\pm$1.0	MARSS	H_2O	22	448.0	$\pm$7.2	ISMAR	H_2O
11	183.31	$\pm$3.0	MARSS	H_2O	23	664.0	$\pm$4.2	ISMAR	window
12	183.31	$\pm$7.0	MARSS	H_2O	24	874.4	$\pm$6.0	ISMAR	wndow

Channel description, taken from: http://www.sat.ltu.se/workshops/ismar/material/20140611_11_rule_ismar_overview.pdf

Simulated brightness temperatures

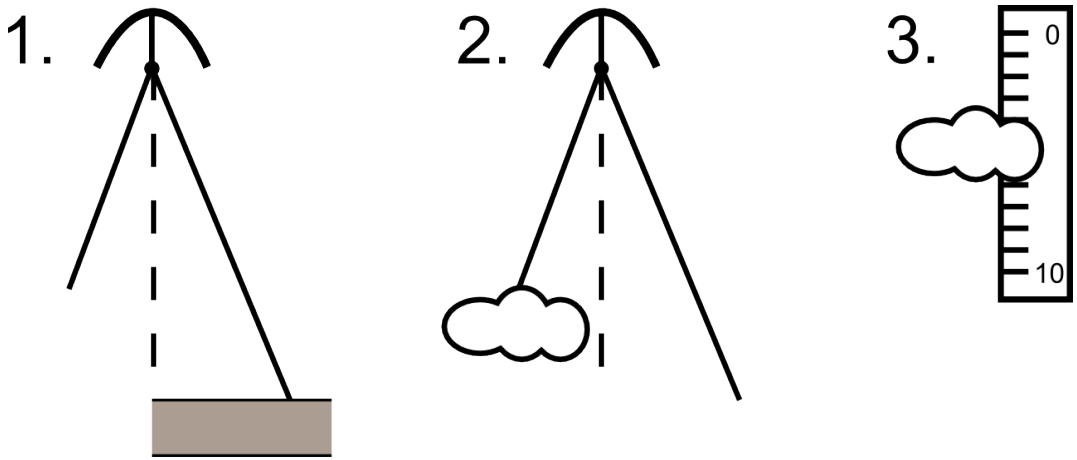


Database summary

- simulated brightness temperature of 24 channels for 25.000 atmospheric profiles
- 1D-Atmosphere
- full stokes vector (right now, only first component is used for retrieval)
- blackbody surface
- simulation of the complete radiation field

Retrieval

Retrieval steps



Retrieval steps

1. Filter the channels which are influenced by surface radiation (retrieval of integrated water vapor)
2. Classification of the measured brightness temperature as clear sky or cloudy
3. Retrieve for the cloudy cases the hydrometeor path

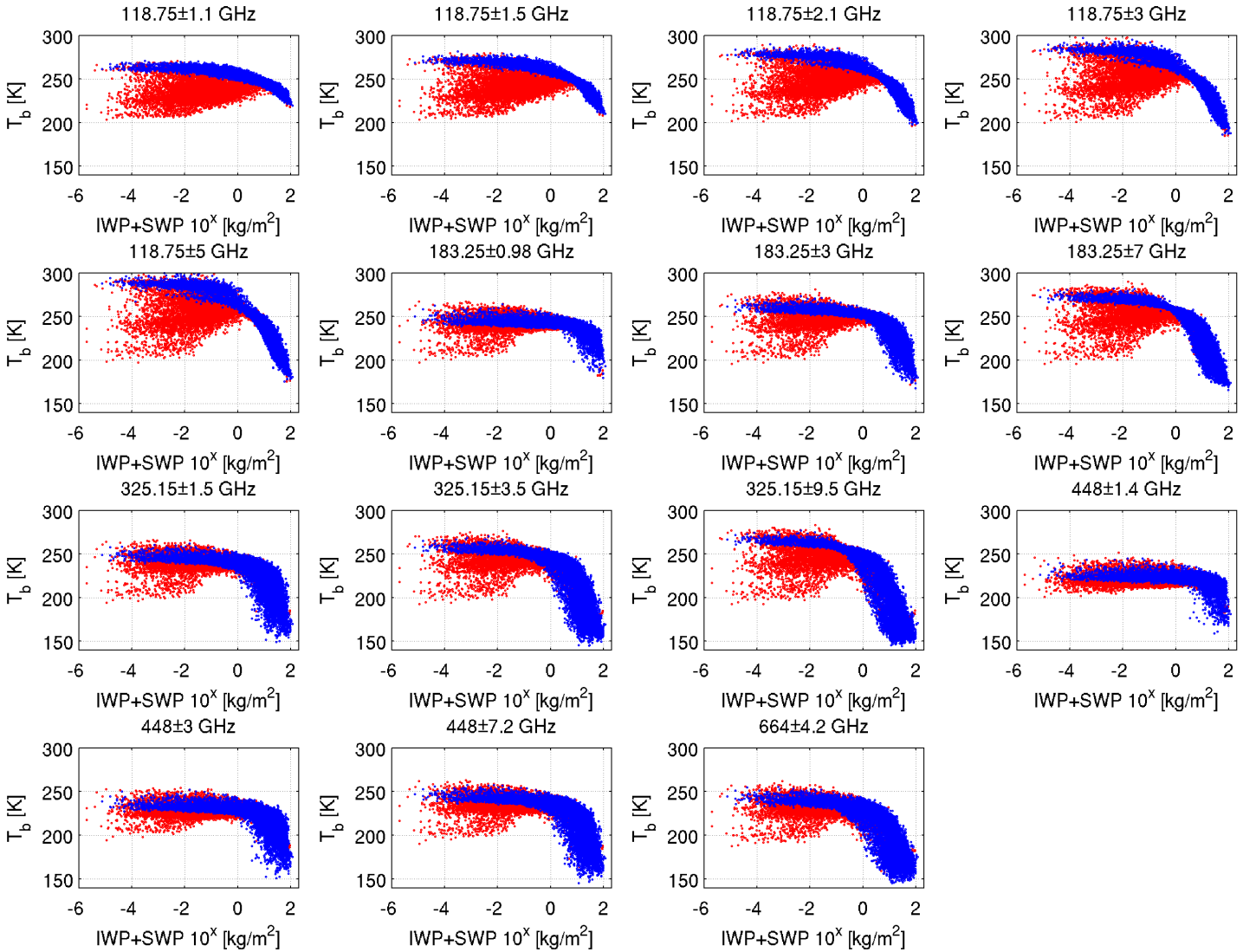
Neural nets

Neural nets

- Input: vector of the brightness temperature of the different channels.
- Output: integrated water vapor (step 1), classification (step 2), four HMPs (step 3)
- Feed forward network with one hiddenlayer (step 1 and 3) and two hiddenlayers (step 2) with 4 to 16 neurons within the hidden layers
- For every flight altitude, looking direction and channel combination a different neural net is trained.

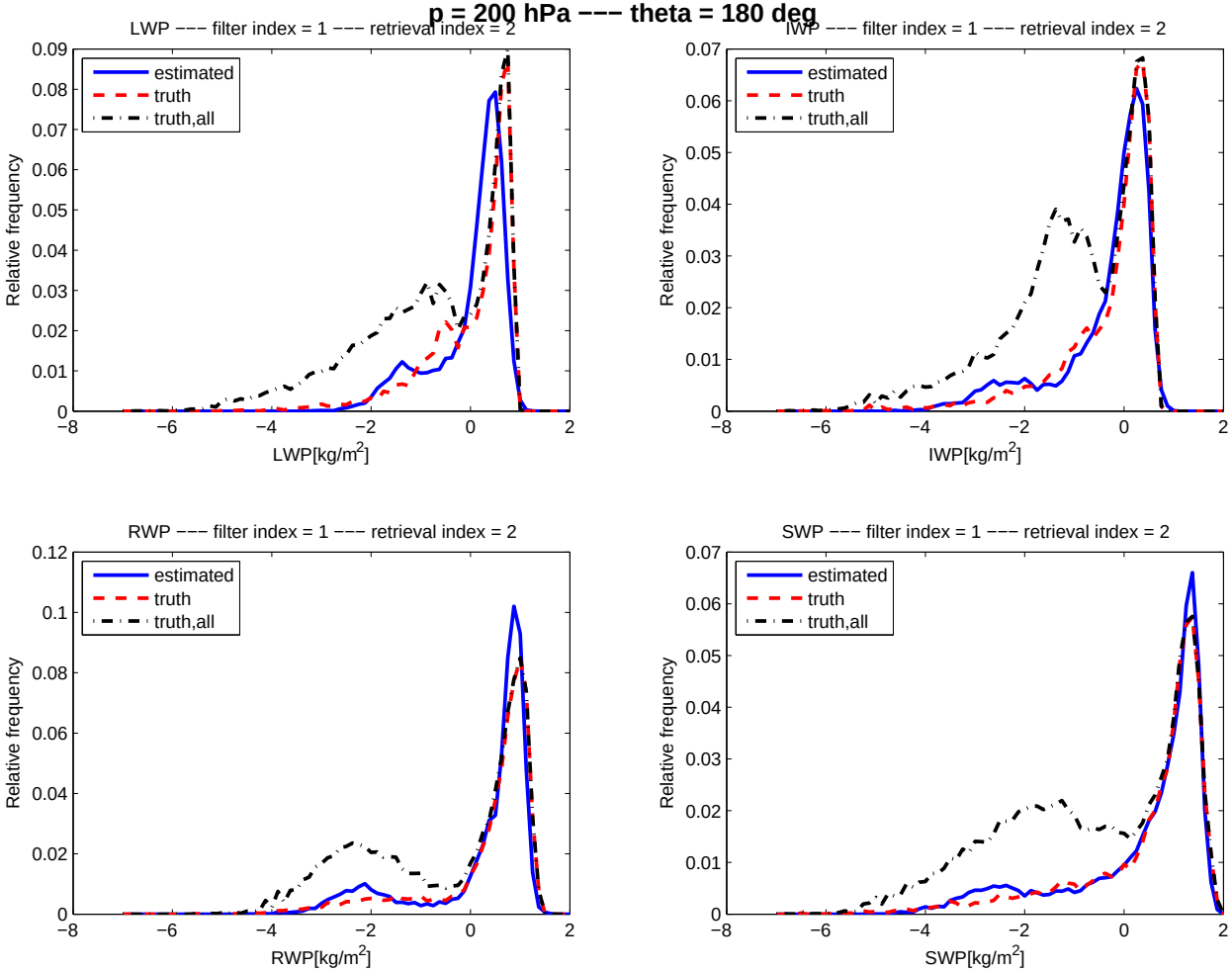
- Retrieval is trained for nadir direction and a flight altitude of 200 hPa and uses only the I-component of the Stokes vector, but it can easily adapted to other looking directions and the usage of polarization.

Filter surface and apply classification



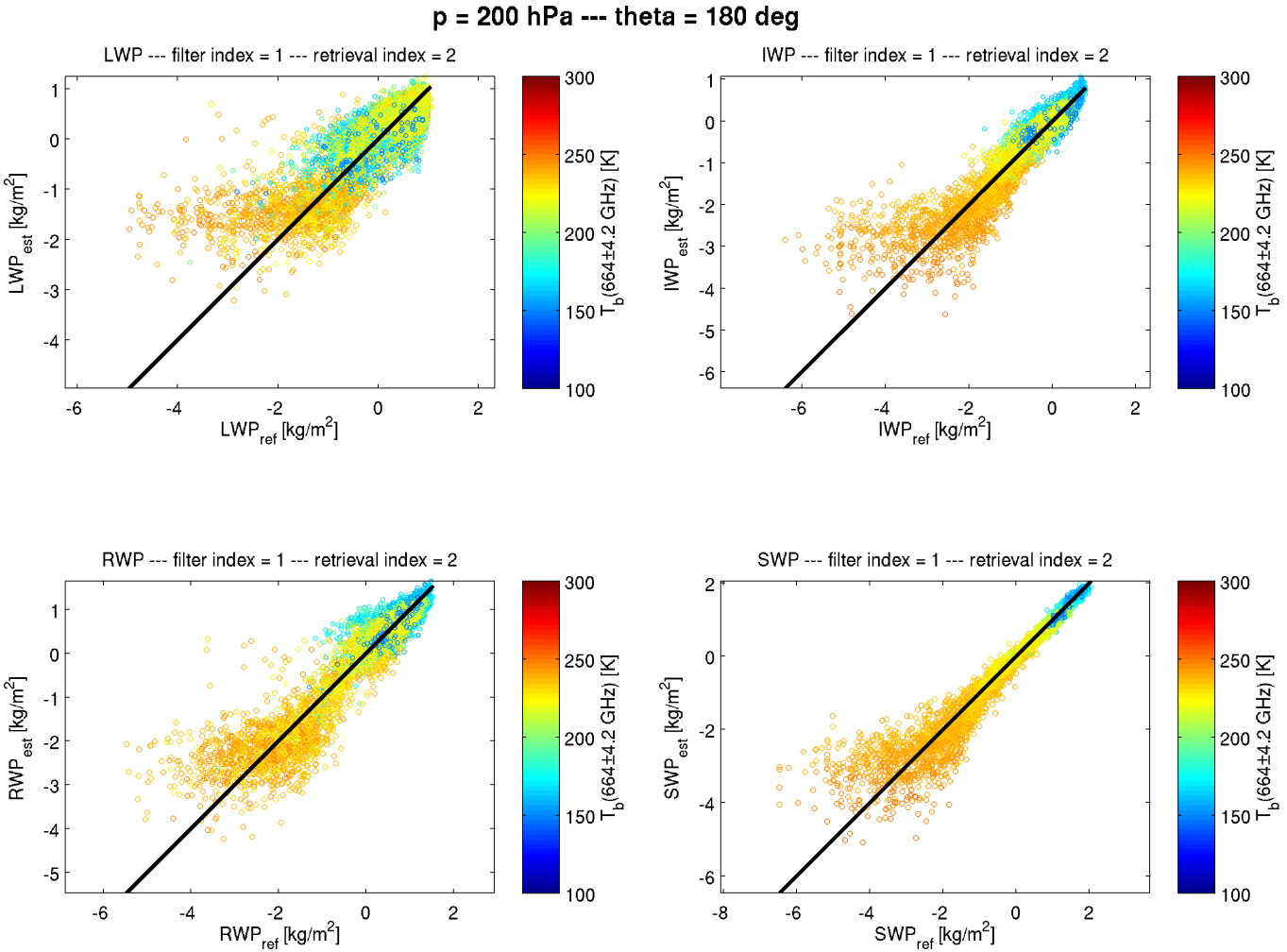
Histograms of the hydrometeor paths

caution: logarithmic units!

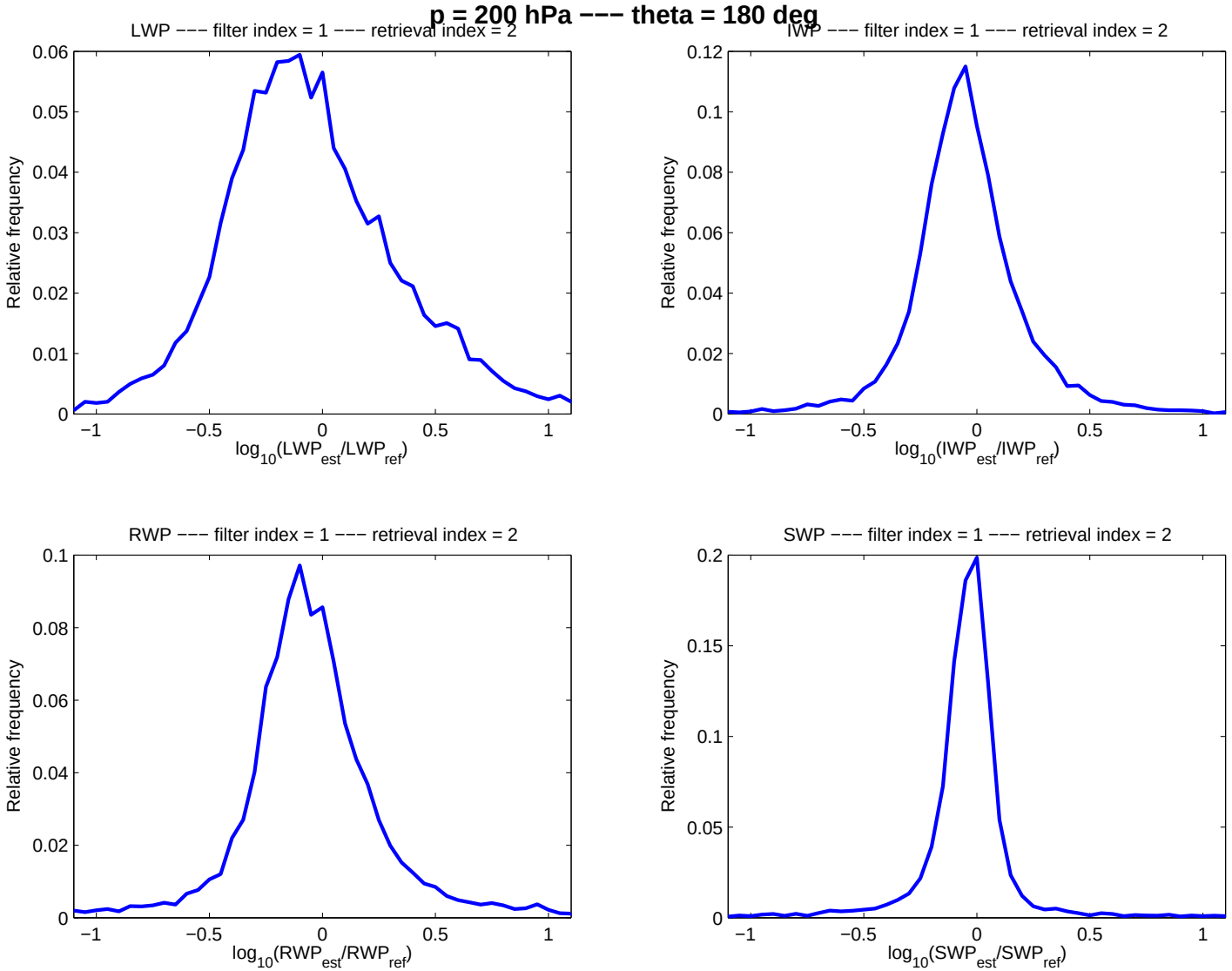


Estimated HMP vs. reference HMP

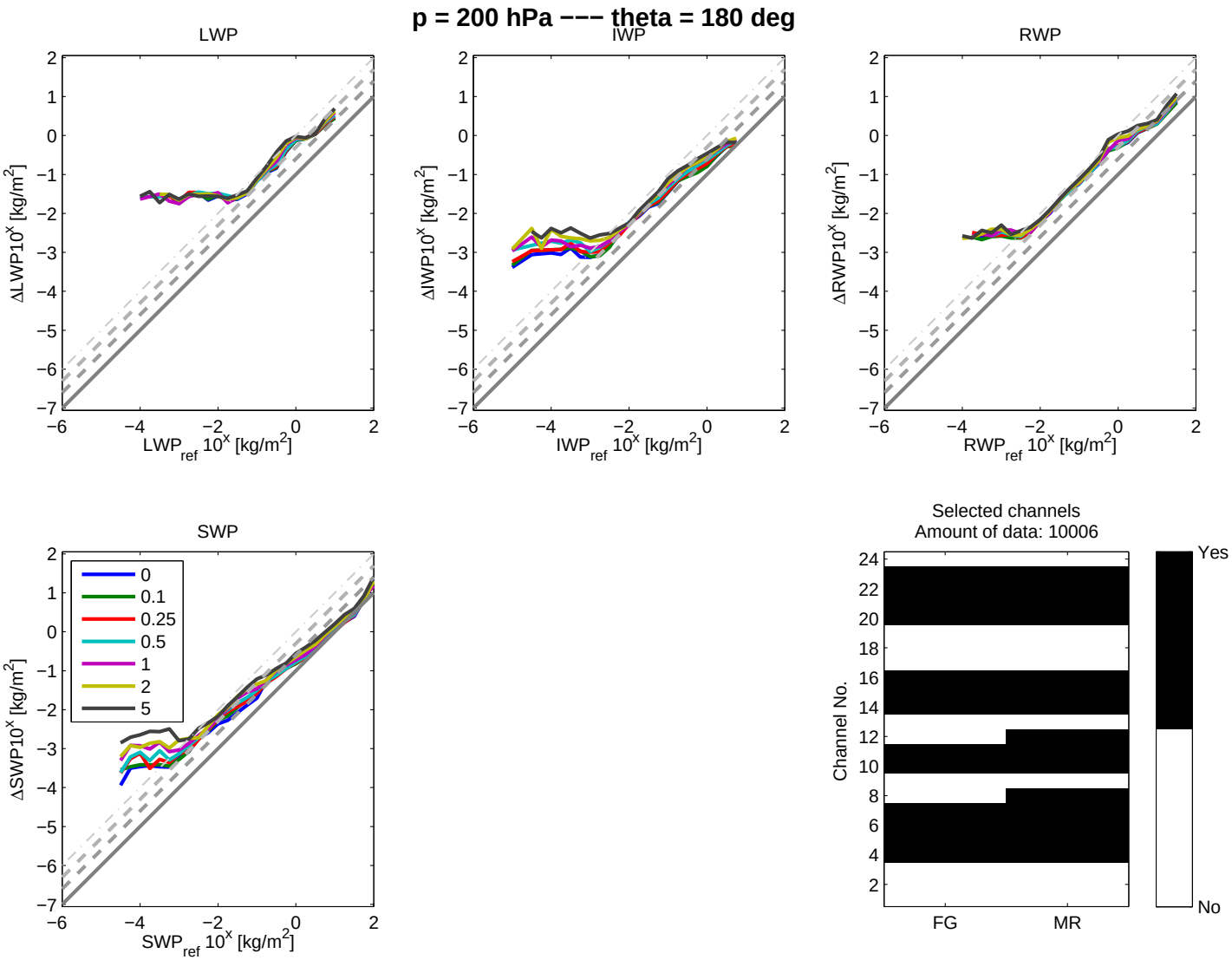
caution: logarithmic units!



Relative errors of hydrometeor paths



ΔHMP as function of reference HMP

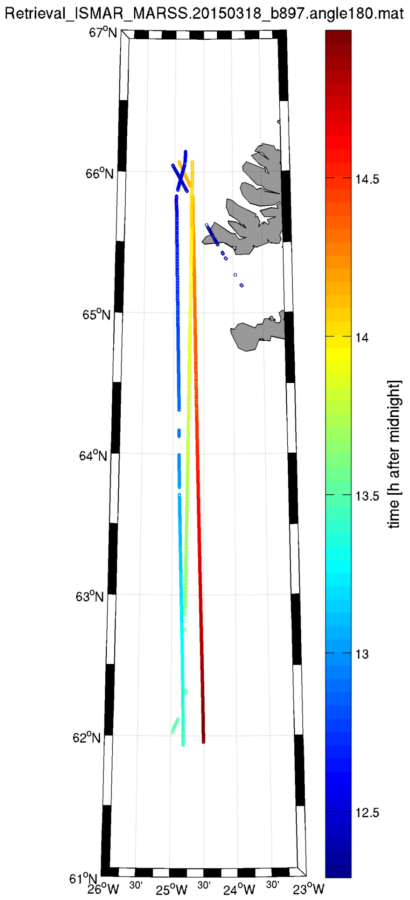


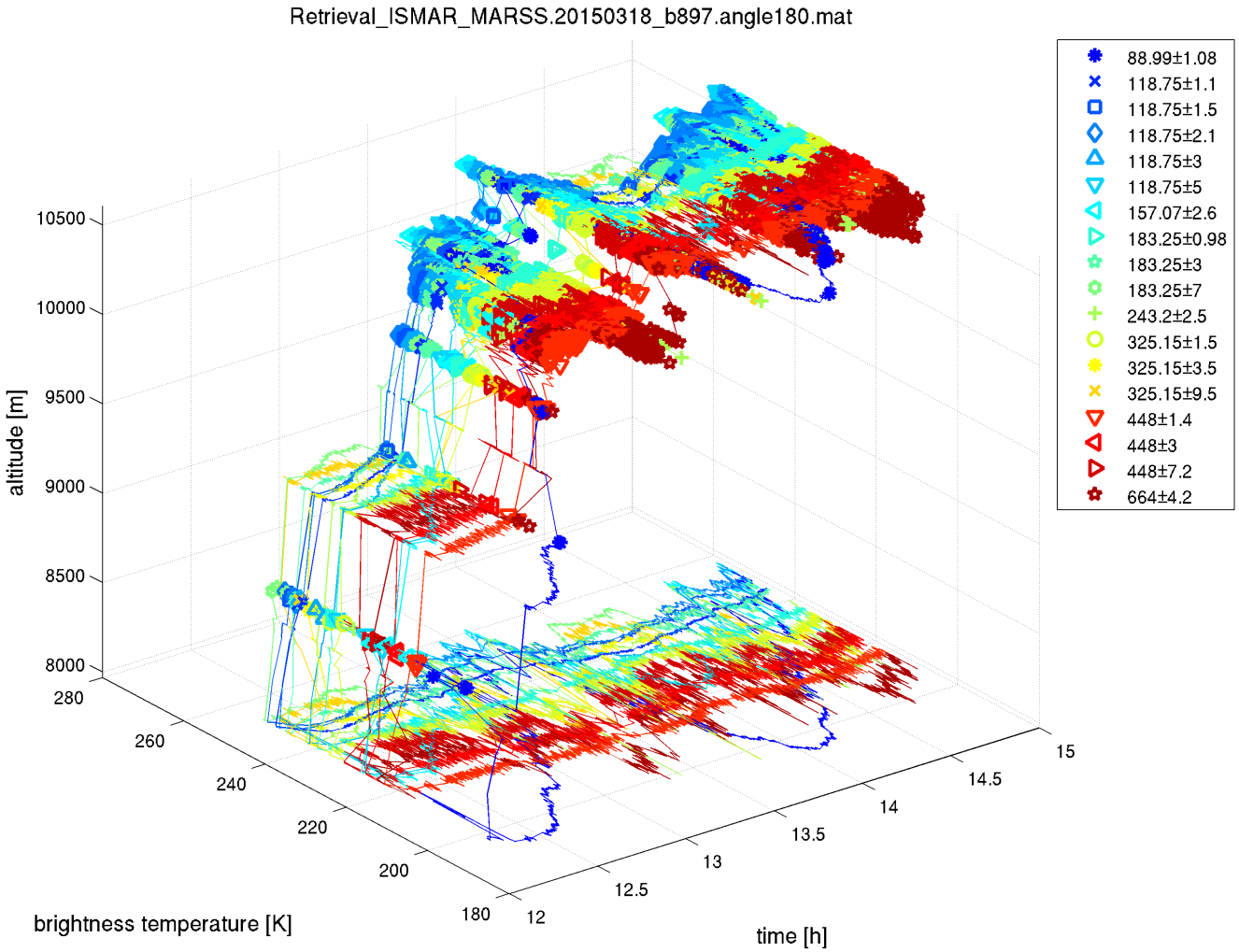
Retrieval summary

- Three step retrieval based on neural nets
- Retrieval of LWP, IWP, RWP and SWP for nadir direction and flight altitude of 200 hPa
- Retrieval of IWP and SWP works quite well, LWP and RWP have some issues.
- Only measured brightness temperature, flight altitude and looking direction is needed.
- Retrieval can easily adapted to other looking direction, other flight altitude and the use of polarization.

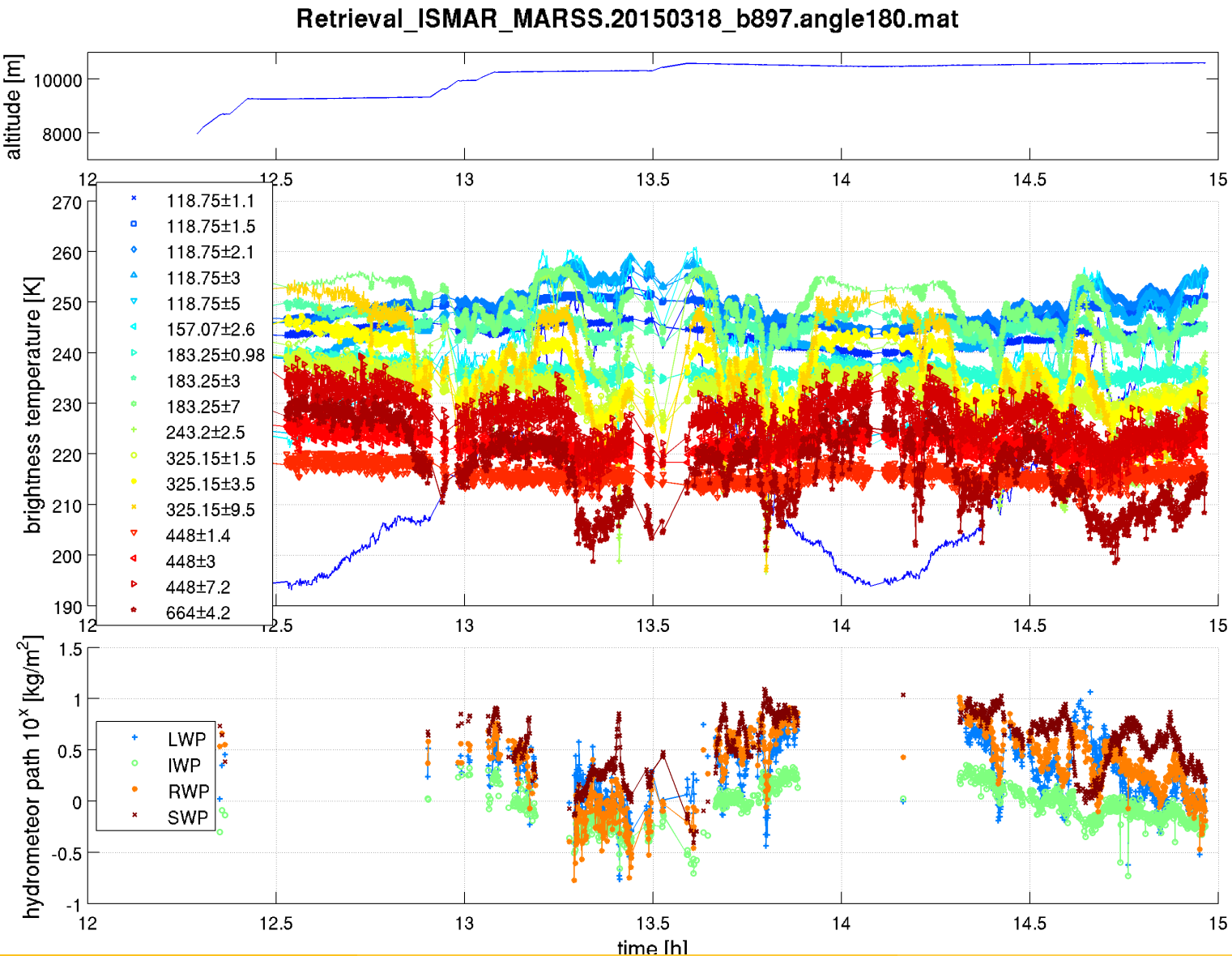
Retrieval: Flight 897

Overview

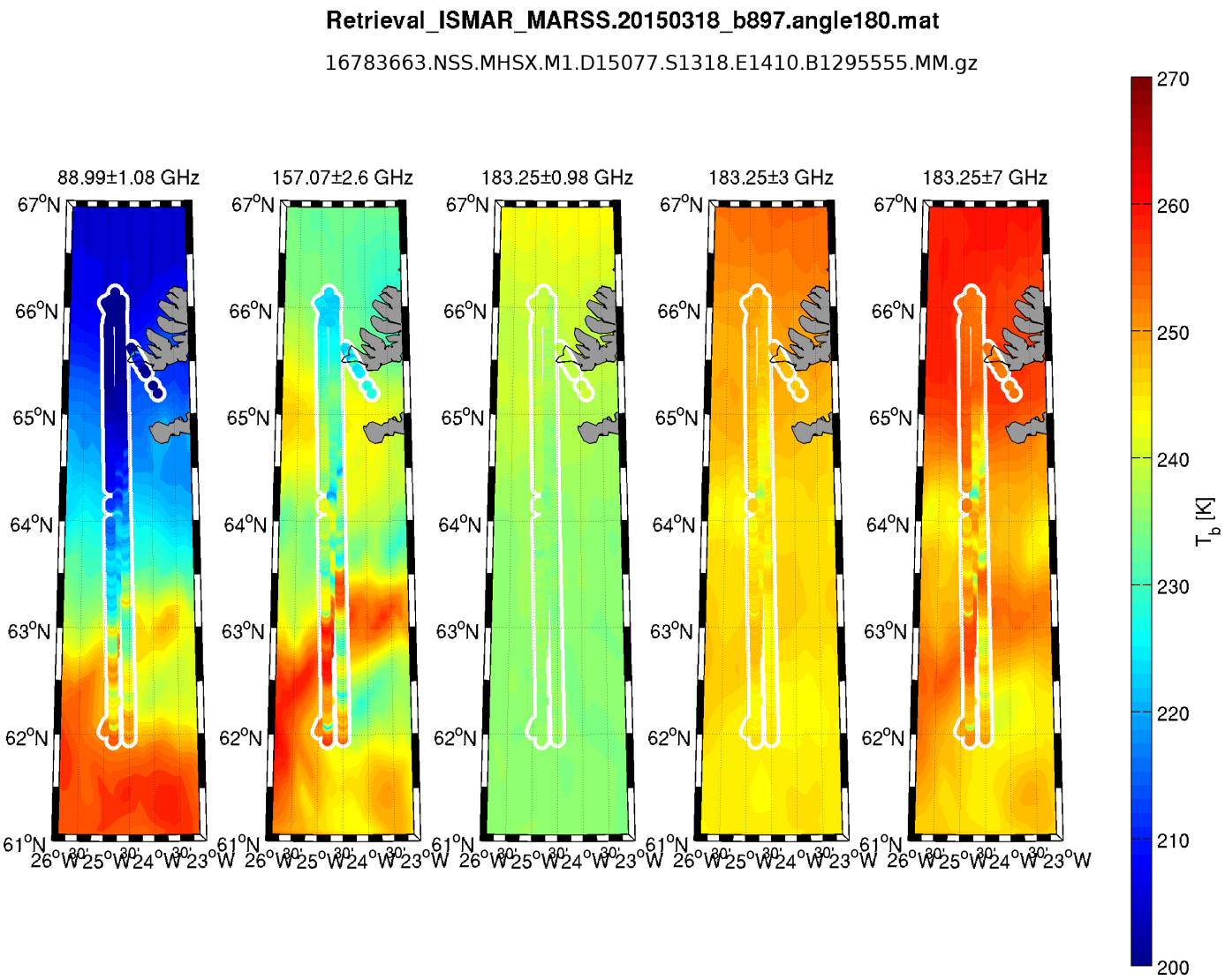

Retrieval_ISMAR_MARSS.20150318_b897.angle180.mat
67°N
66°N
65°N
64°N
63°N
62°N
61°N
26°W
30'
25°W
30'
24°W
30'
23°W
14.5
14
13.5
13
12.5
time [h after midnight]


Retrieval_ISMAR_MARSS.20150318_b897.angle180.mat
altitude [m]
10500
10000
9500
9000
8500
8000
280
260
240
220
200
180
brightness temperature [K]
12
12.5
13
13.5
14
14.5
15
time [h]
88.99±1.08
118.75±1.1
118.75±1.5
118.75±2.1
118.75±3
118.75±5
157.07±2.6
183.25±0.98
183.25±3
183.25±7
243.2±2.5
325.15±1.5
325.15±3.5
325.15±9.5
448±1.4
448±3
448±7.2
664±4.2

retrieved HMP



MHS and ISMAR



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