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Evaluation of the land surface radiative transfer model CMEM for snow-covered regions

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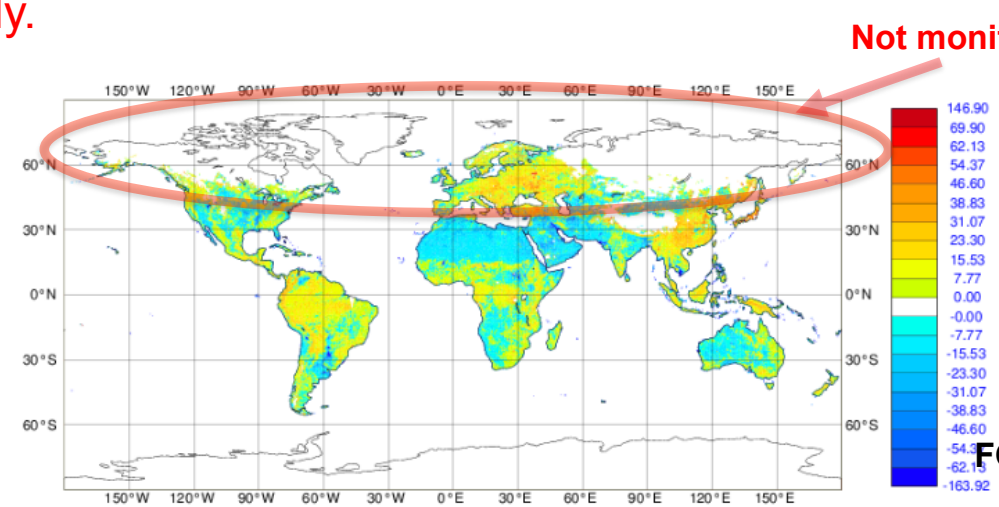
Outline

- Background for investigation
- Motivation for the study
- Experimental setup
- Results
- Conclusions

Background for investigation

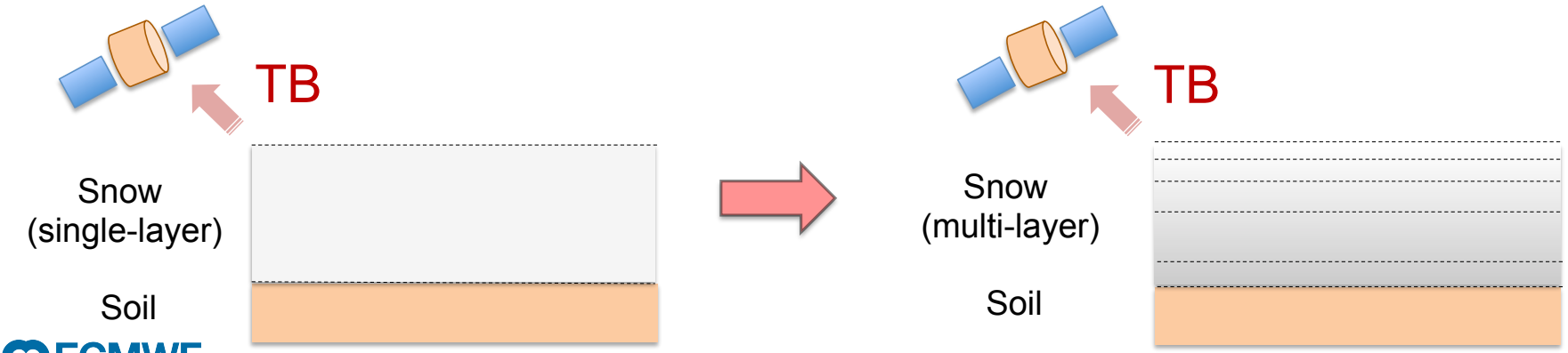
- CMEM (Community Microwave Emission Modelling platform) has been developed at ECMWF for low frequency (1-20GHz) microwave brightness temperature (TB) observations monitoring and data assimilation. (Apache Licence Version 2.0)
- CMEM is currently used at ECMWF as the SMOS forward operator to simulate L-band TB.
- However as SMOS is used for soil moisture purpose at ECMWF, CMEM has been used on snow free areas only.



SMOS Monitor
FG departure (1.4GHz: xx-pol)

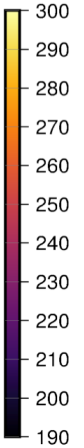
Motivation for the study

- Toward assimilation of surface-sensitive satellite data over land, uncertainties about the surface are critical.
- Especially, in snow-covered regions, emissivity varies dramatically with snow layer's properties.
- CMEM includes the HUT (Helsinki University of Technology) single layer snow emission model.
- To allow the simulation of vertically structured natural snowpack, we implemented the HUT multi-layer snow emission model (Lemmetyinen et al., 2010) in CMEM, in line with the on-going development of a multi-layer snow scheme for the ECMWF land surface model (HTESSEL).

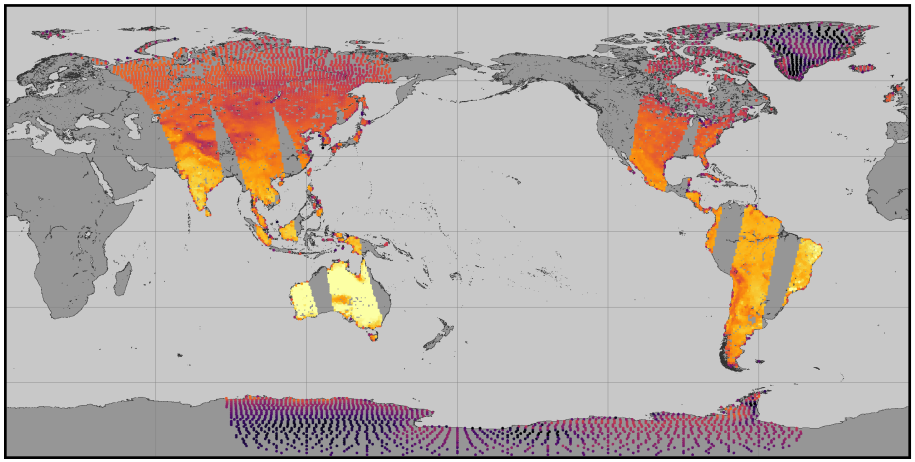


Experimental setup

- TB are simulated with CMEM(v5.1+α) for the in offline mode (over land)
  - Tco399 (octahedral cubic reduced Gaussian grid)
- Simulated TB are compared to
  - GCOM-W AMSR2 observations (6.925, 10.65, 18.7GHz)

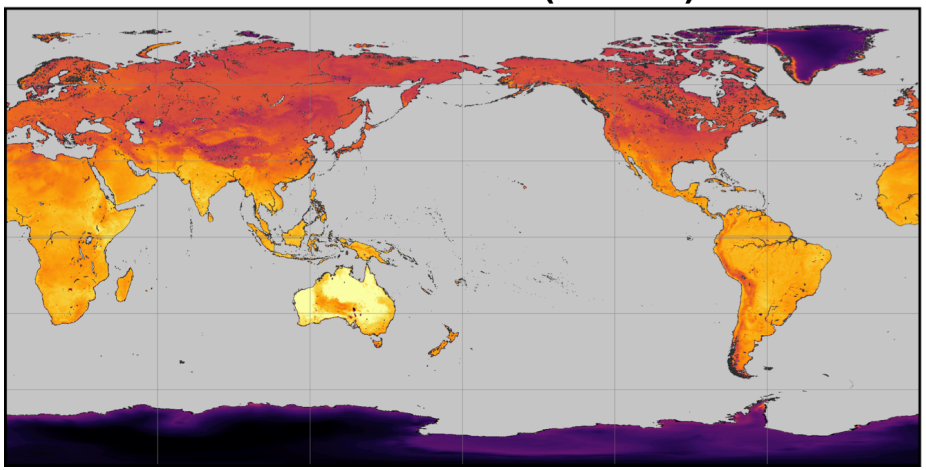


OBSERVATION



AMSR2 TB(V) 6.925GHz
2018-01-01 03UTC – 2018-01-01 09UTC

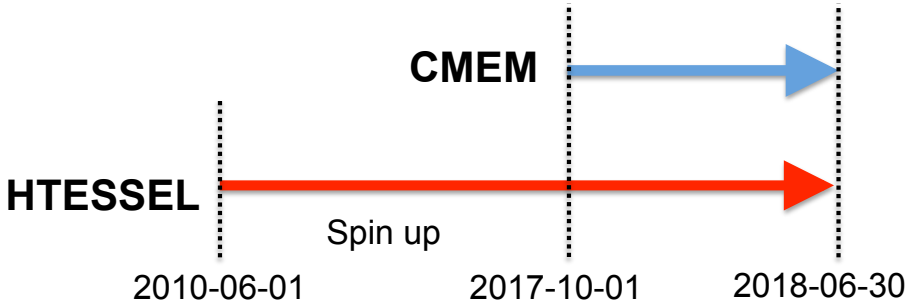
SIMULATION (CMEM)



AMSR2 TB(V) 6.925GHz
2018-01-01 06UTC

CMEM configuration (1)

- Span
  - 2017-10-01 – 2018-06-30 (every 6h)
- Input
  - Atmosphere
    - HRES operational ECMWF analysis
      - 2m temperature
  - Land, Snow
    - HTESSEL (offline) using ERA5 atmospheric forcing (Start date: 2010-06-01)
      - Soil moisture, Soil temperature, Tskin, Land cover, LAI, Soil texture
      - Snow temperature, Snow density, Snow water equivalent, Snow liquid water content
    - HTESSEL Snow scheme
      - SL1: Single layer snow scheme (as operational)
      - ML5: Multi-layer (5 layers) snow scheme (on-going development)



CMEM configuration (2)

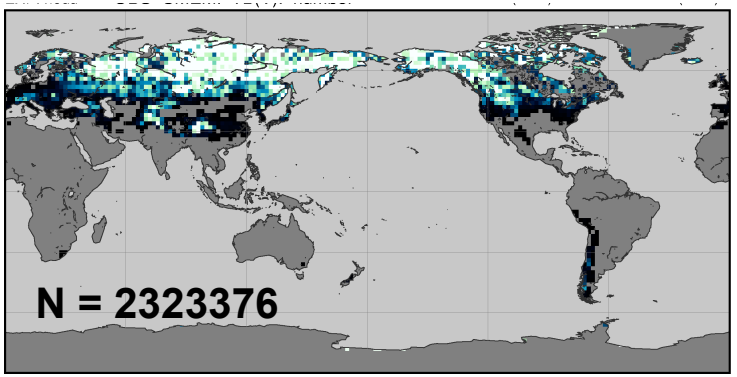
CMEM option	parameterization
Dielectric mixing model	Mironov et al., 2004
Effective temperature model	Choudhury et al., 1982
Smooth surface emissivity	Fresnel (Njoku and Kong, 1977)
Soil roughness model	Wegmüller and Mätzter, 1999
Vegetation optical depth model	Kirdyashev et al., 1979
Atmospheric emission model	Pellarin et al., 1999
Vegetation temperature	Tsurf
Vegetation cover input data	HTESSEL (Balsamo et al., 2009)
Snow emission model	HUT-S: HUT single-layer model (Pulliainen et al., 1999)
	HUT-M: HUT multi-layer model (Lemmetyinen et al., 2010) (extinction coefficient model: Hallikainen et al., 1987) (grain size option: dmax)

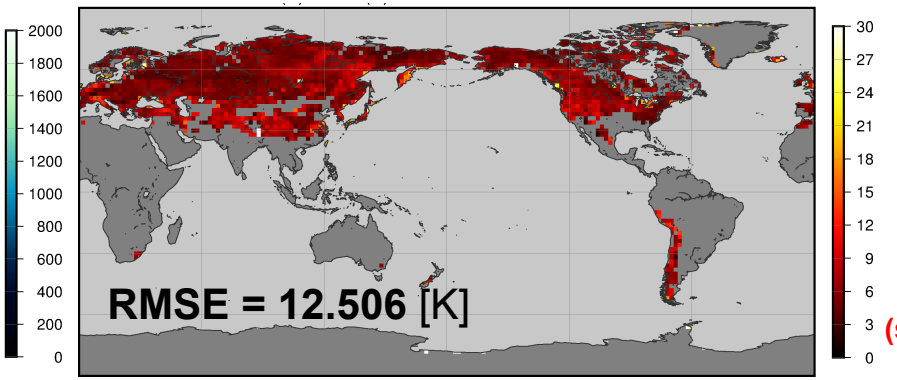
NEW !

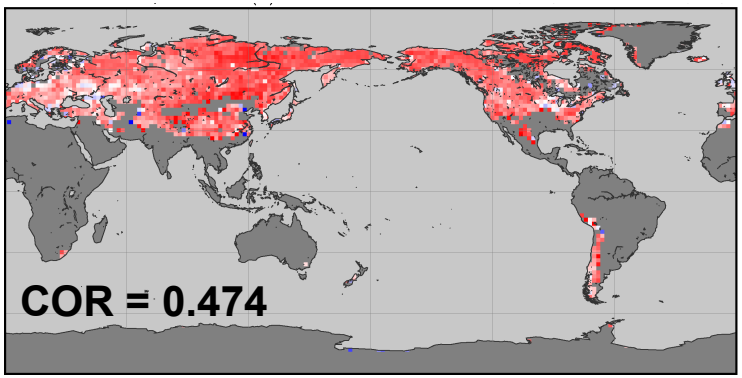
Results: CMEM TB compared to OBS

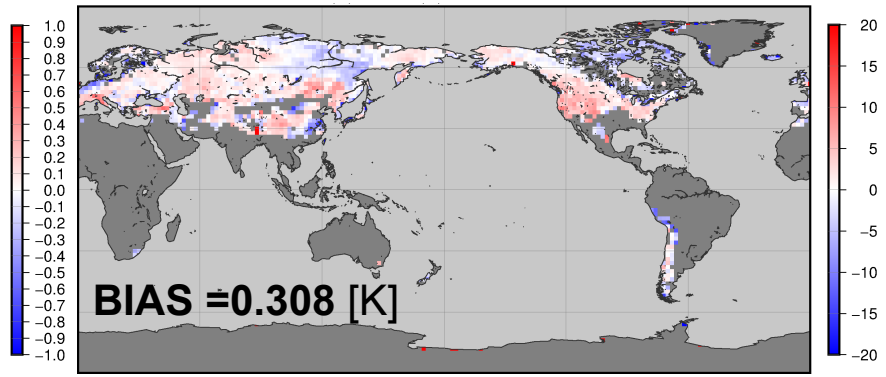
(a) HTESSEL:SL1, HUT-S

AMSR2 TB(V) 10.65GHz (2017-10-01 – 2018-06-30)









2.0 x 2.0 deg

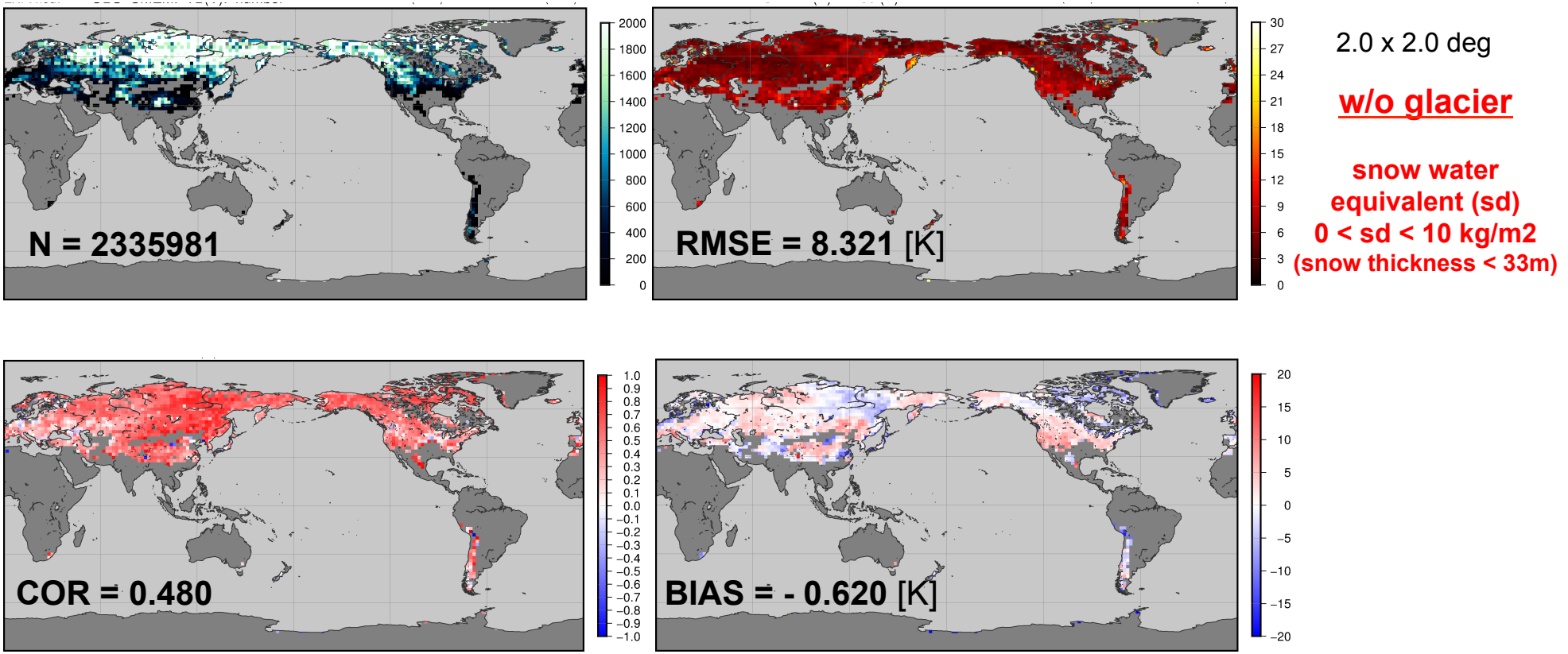
w/o glacier

snow water equivalent (sd)
0 < sd < 10 kg/m2
(snow thickness < 33m)

Results: CMEM TB compared to OBS

(b) HTESSEL:ML5, HUT-M

AMSR2 TB(V) 10.65GHz (2017-10-01 – 2018-06-30)



2.0 x 2.0 deg

w/o glacier

snow water equivalent (sd)
0 < sd < 10 kg/m2
(snow thickness < 33m)

AMSR2

Results: CMEM TB compared to OBS

Timeseries (2017-10-01 – 2018-06-30)

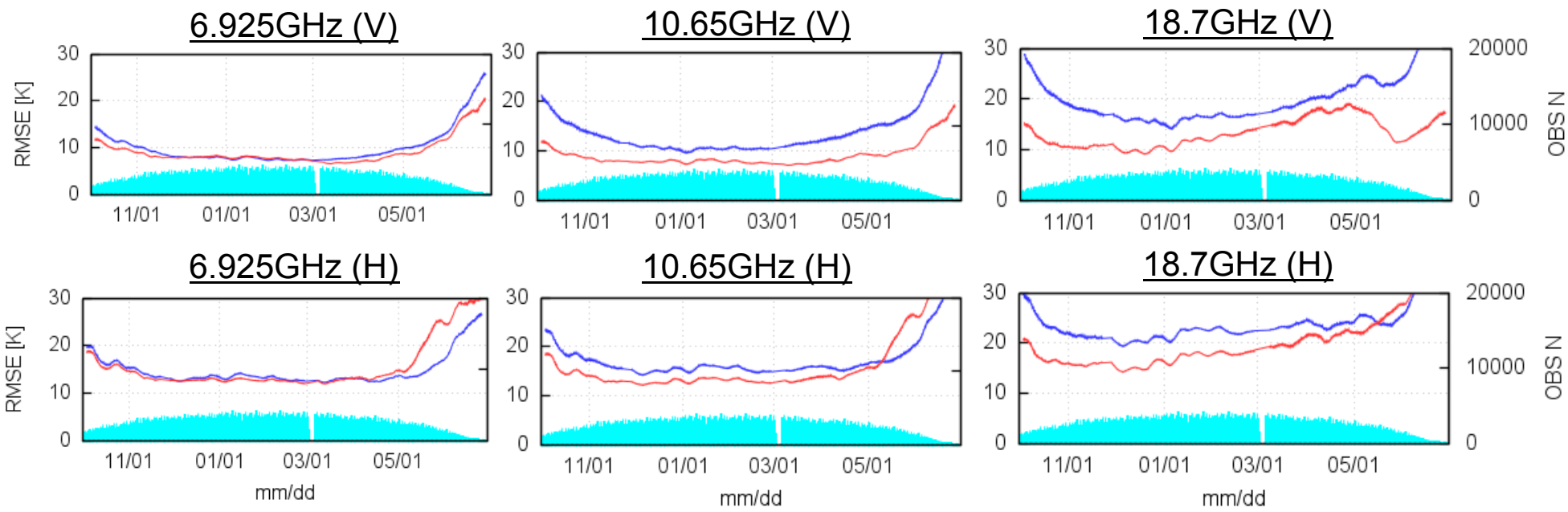
RMSE (5days moving averaged)

snow-covered area
[Global] (w/o glacier)

(a) HTESSEL:SL1, HUT-S

(b) HTESSEL:ML5, HUT-M

OBS Number



- RMSE: multi-layer < single-layer
- Difference: 6.9GHZ < 10.7GHZ < 18.7GHz
- Large error in Spring

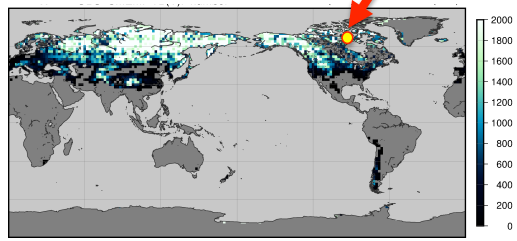
Results: CMEM TB compared to OBS

AMSR2 TB(V) 10.65GHz

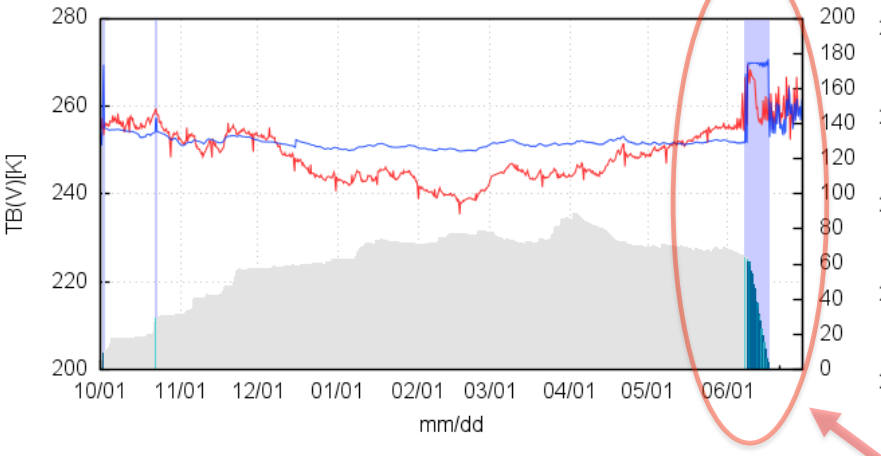
Timeseries (2017-10-01 – 2018-06-30)
lon = -94.0 lat = 66.0

TB(obs)
TB(cmem)
wet

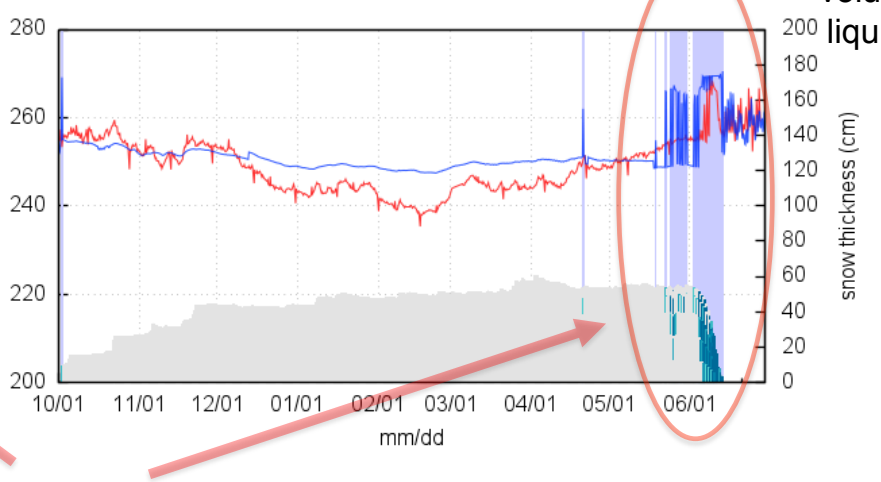
here



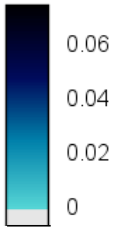
(a) HTESSEL:SL1, HUT-S



(b) HTESSEL:ML5, HUT-M



volume fraction of liquid water (0-1)



- TB(CMEM) is sensitive to volume fraction of liquid water. (dry snow or wet snow)

AMSR2

Results: CMEM TB compared to OBS

Timeseries (2017-10-01 – 2018-06-30)

RMSE (5days moving averaged)

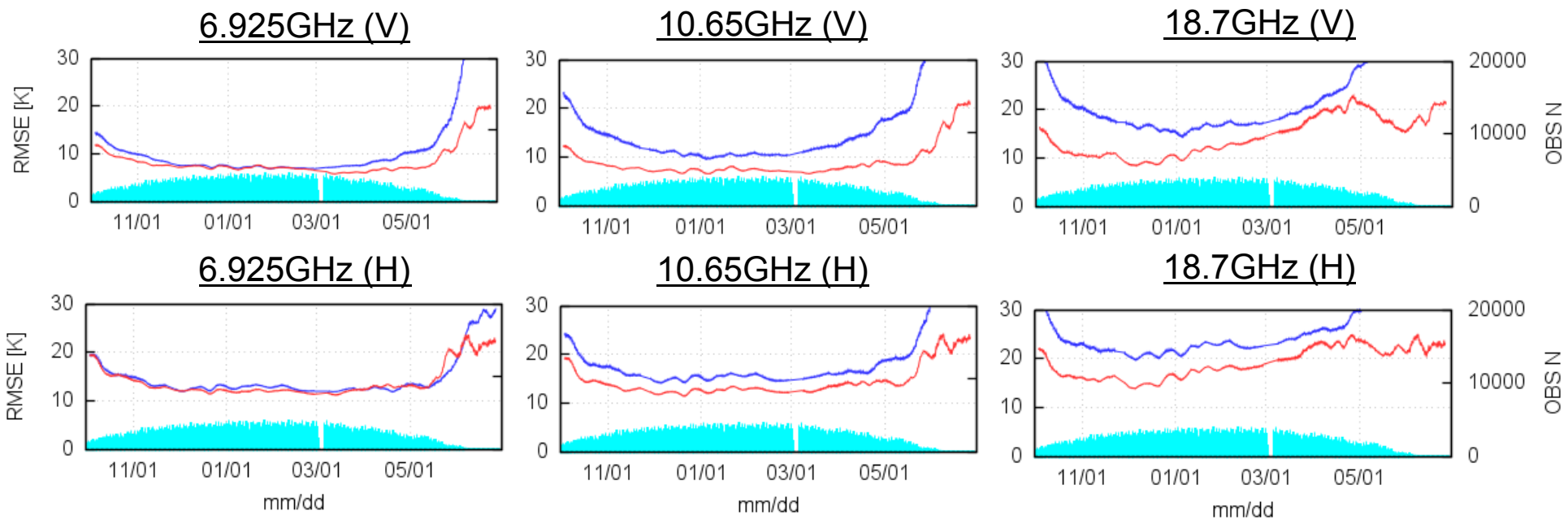
snow-covered area [Global] (w/o glacier)

DRY-SNOW only

(a) HTESSEL:SL1, HUT-S

(b) HTESSEL:ML5, HUT-M

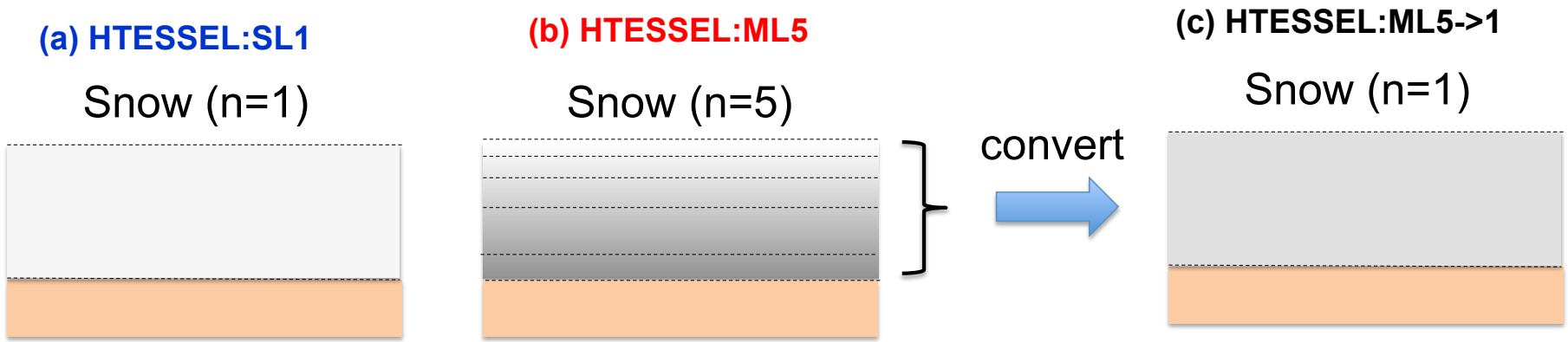
OBS Number



- Large change in Spring
- RMSE: multi-layer < single-layer

Results: CMEM TB compared to OBS

- Confirm the reason of TB difference between single-layer and multi-layer
  - How much the effect of multi-layer snow HTESSEL ?
  - How much the effect of multi-layer HUT ?
- Use single-layer snowpack converted from multi-layer snow HTESSEL
  - with single-layer HUT



AMSR2

Results: CMEM TB compared to OBS

Timeseries (2017-10-01 – 2018-06-30)

RMSE (5days moving averaged)

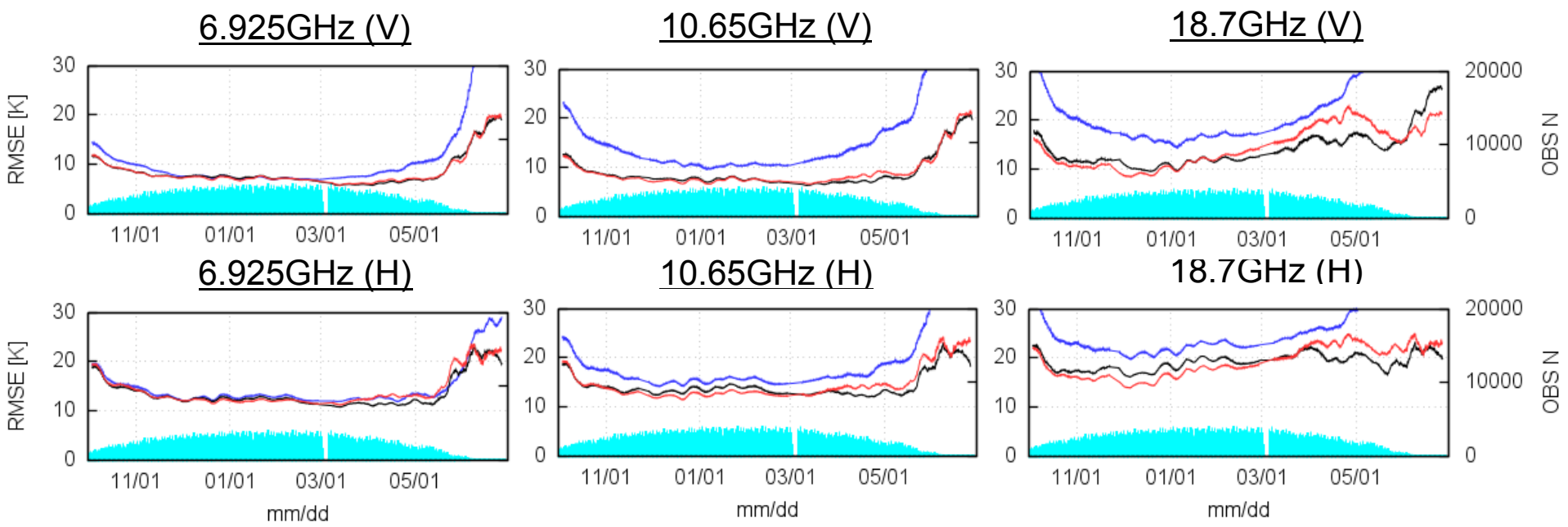
snow-covered area [Global] (w/o glacier)

DRY-SNOW only

(a) HTESSEL:SL1, HUT-S

(b) HTESSEL:ML5, HUT-M

(c) HTESSEL:ML5->1, HUT-S



- RMSE: almost same between (b) and (c)
- Difference between (b) and (c): 6.9GHZ < 10.7GHZ < 18.7GHz

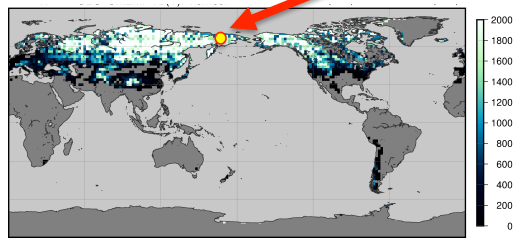
Results: CMEM TB compared to OBS

AMSR2 TB(H) 10.65GHz

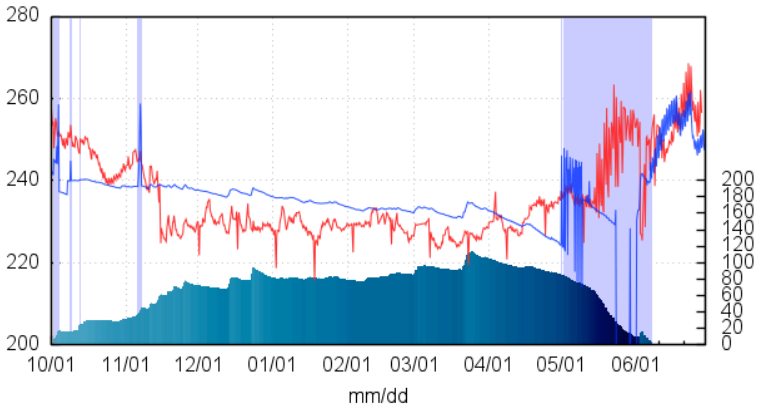
Timeseries (2017-10-01 – 2018-06-30)
lon = 170.0 lat = 67.0

TB(obs)
TB(cmem)
wet

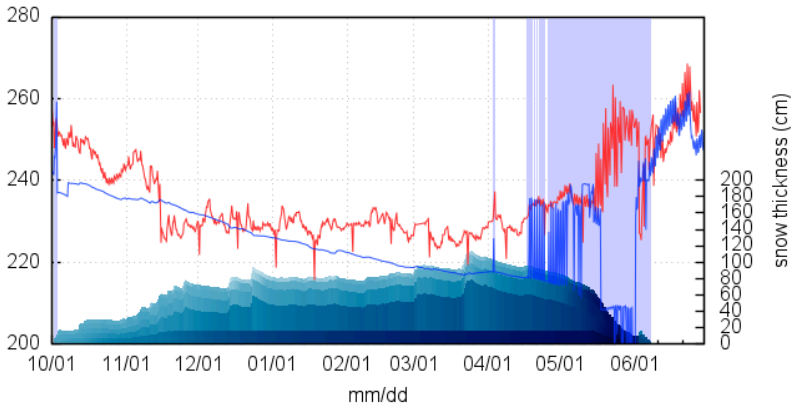
here



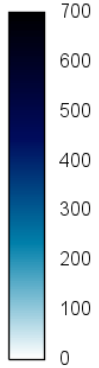
(c) HTESSEL:ML5->1, HUT-S



(b) HTESSEL:ML5, HUT-M



Snow density [kg/m3]



- Snow density

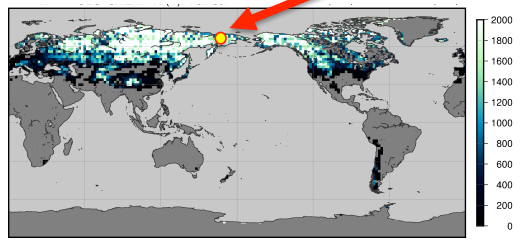
Results: CMEM TB compared to OBS

AMSR2 TB(H) 10.65GHz

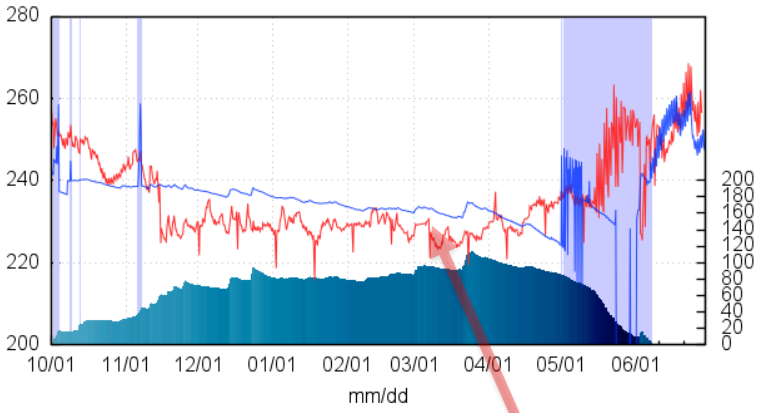
Timeseries (2017-10-01 – 2018-06-30)
lon = 170.0 lat = 67.0

TB(obs)
TB(cmem)
wet

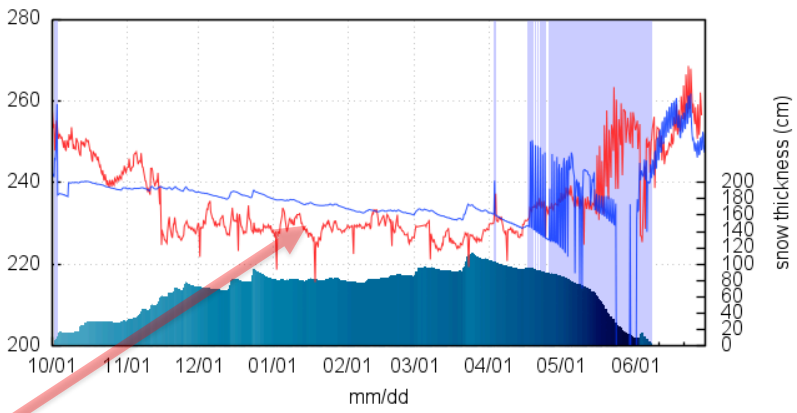
here



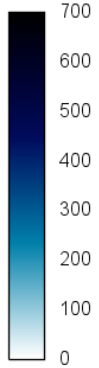
(c) HTESSEL:ML5->1, HUT-S



(d) HTESSEL:ML5
(only snow density n5 -> n1), HUT-M



Snow density [kg/m3]



- Snow density

- (d) Modification of only snow density affect to TB(CMEM)
- Almost same to (c) in dry snow season
  - On the other hand, modification of only snow temperature does not affect to TB(CMEM) (not shown)

AMSR2

Results: CMEM TB compared to OBS

Timeseries (2017-10-01 – 2018-06-30)

RMSE (5days moving averaged)

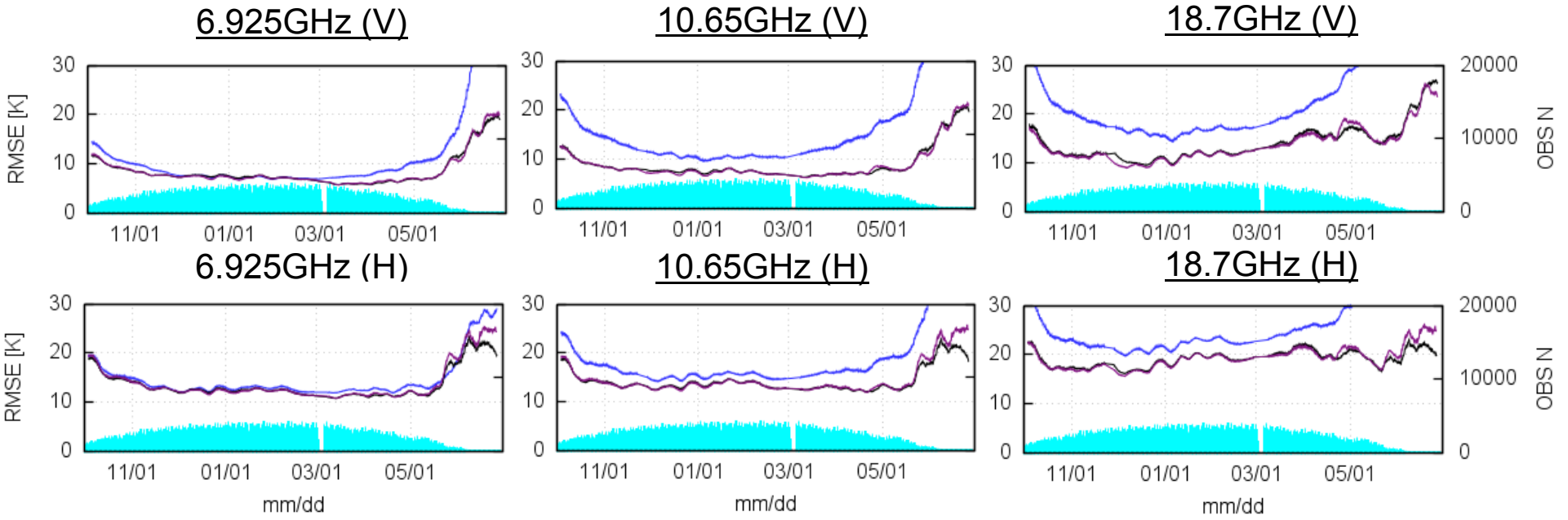
snow-covered area [Global] (w/o glacier)

DRY-SNOW only

(a) HTESSEL:SL1, HUT-S

(c) HTESSEL:ML5->1, HUT-S

(d) HTESSEL:ML5 (only snow density 5->1), HUT-M



- RMSE: (c) and (d) are almost same
- Impact of snow density is large for multi-layer HUT

Conclusions and perspectives

- We implemented the HUT multi-layer snow emission model in CMEM.
  - Results
    - HUT is sensitive to volume fraction of liquid water in snowpack.
    - Multi-layer snow HTESSEL and Multi-layer HUT improve simulated TB.
      - Mainly from Multi-layer snow HTESSEL.
      - In dry-snow area, snow density is important for multi-layer HUT at low frequency MW (1-20GHz).
- Perspective
    - The impact of CMEM land surface emissivity for low frequencies microwave monitoring and assimilation over snow covered surfaces will be evaluated.
    - Longer term perspectives will address initialization of multi-layer sow conditions from satellite radiances assimilation, taking advantage of opportunities arising from enhanced land atmosphere coupled data assimilation and from the future generation of polar orbiting satellites.
- CMEM update
  - New version (v6.0) will be available soon. (Sep. 2019 ?)
    - CMEM information -> https://confluence.ecmwf.int/display/LDAS/CMEM