Investigating spatial and temporal variability of Arctic water vapor from passive microwave radiometry and Arctic system reanalysis (ASR)

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Introduction

Water vapour (WV), as the most abounded GHG plays one of the key roles in understanding the climate changes. It absorbs 50% more downward longwave radiation (LW) than CO_2 and creates a positive feedback loop (Dessler and Sherwood[1]). Since temperature increase is most evident over Arctic region and is known as „Arctic amplification" we focus on the region above 60°N and investigate changes in temperature and integrated water vapor from passive microwave satellites and from Arctic System Reanalysis, respectively

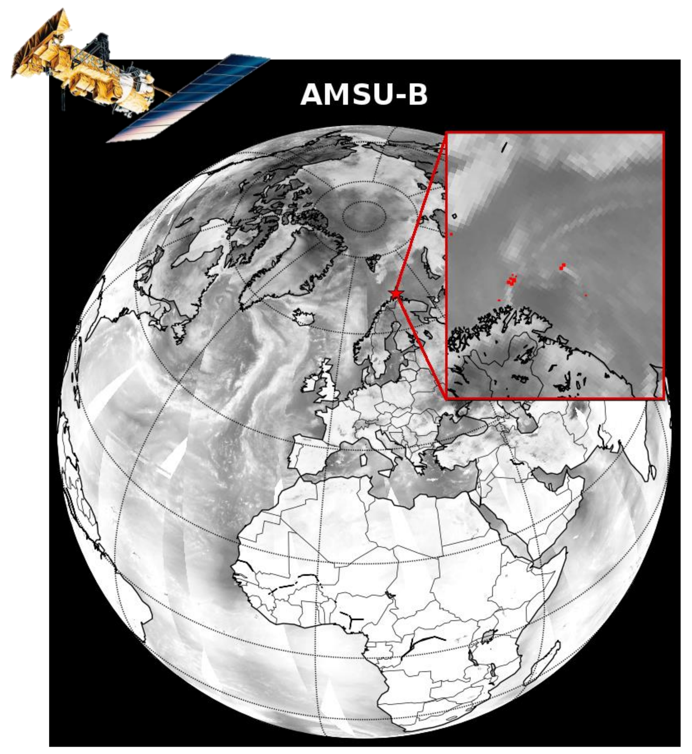

Fig.1: AMSU-B one day coverage (07 Jan, 2009) for 89GHz channel with polar low case at 09:00 UTC with red dots denoting convective cores(zoomed)

May is transitional period between cold winter environment and warmer spring, we focus our investigation on this month.

Data

Advanced Microwave Sounding Unite- B (AMSU-B) and Microwave Humidity Sounder (MHS)

- coverage over Arctic region (≈ 10 times/day)
- 5 channels: 2 (89 and 150 (157) GHz) window and 3 around strong water vapor line
- swath width ~ 2250 km (90 fields of view (FOV): 0° – 48° each side)
- Resolution ~ 15 km at nadir and around 48 km at the edges
- orbit time – 90 minutes

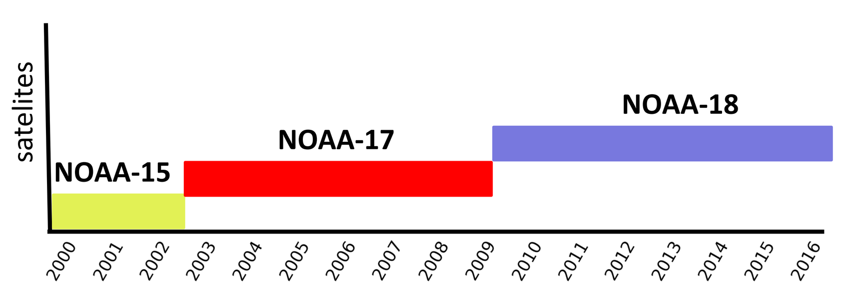

Figure 2: Time line of used data for the study

Table 1: AMSU-B and MHS chennels and altitude

AMSU-B (MHS)	
FREQUENCIES	ALTITUDE
89 GHz	surface
150 (157) GHz	~ 1.5 km
183.31 ± 7 (190) GHz	~ 3 km
183.31 ± 3 GHz	~ 7 km
183.31 ± 1 GHz	~ 10 km

Table 2: Basic ASR characteristics

ASRv2	
RESOULTION	
horizontal	~ 15 km
vertical	34 pressure levels
temporal	3 h
best estimate of atmospheric state including precipitation[2].	

Spatial and temporal agreement of satellite BT and reanalysis IWV

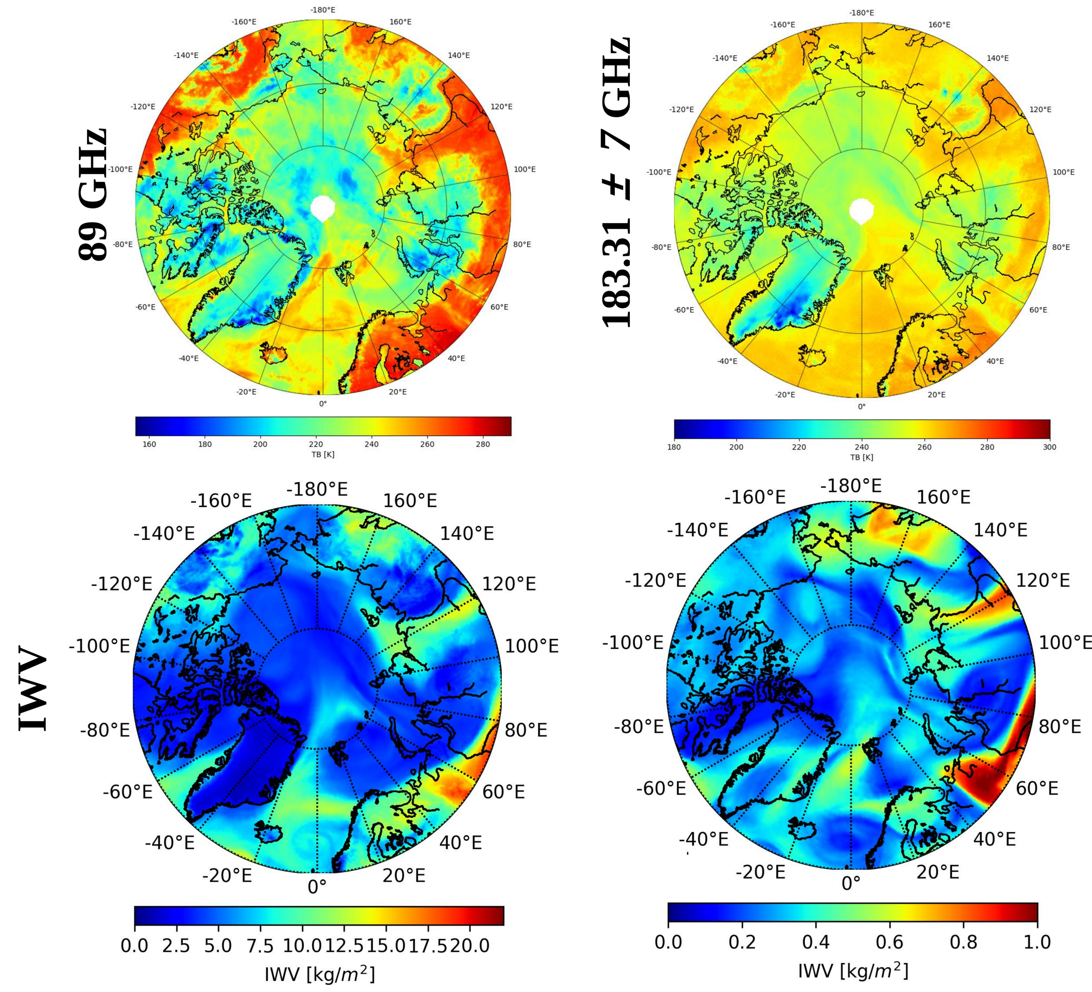

Fig. 5:AMSU-B BTs at 89 GHz (top left) and 183.31 ± 7 GHz (top right and IWV for the whole atmospheric column (bottom left) and for the column above 500 hPa (bottom right).. Data are shown for the 11th of May 2007.(top) and IWV (bottom) .

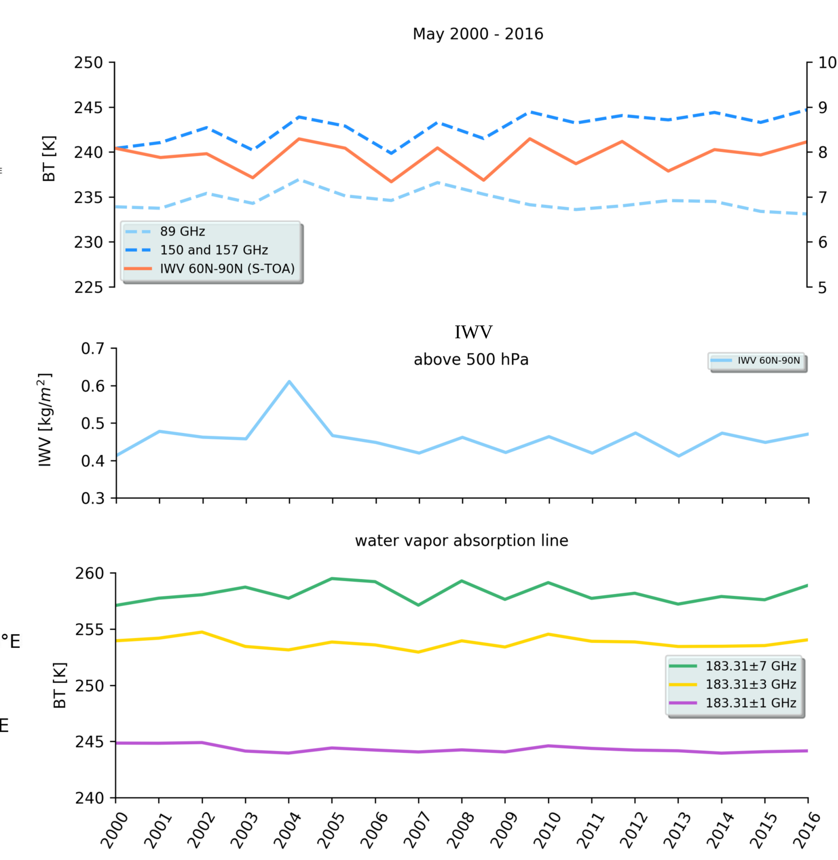

Fig. 6:BT from AMSU-B for the May between 2000-2016 period for all channels (89 GHz, 150 GHz (top), 183.31 ± 7 GHz, 183.31 ± 3 GHz and 183.31 ± 1 GHz (bottom) and IWV from ASRv2 for whole column and for above 500 hPa

- Daily IWV from ASR for the:
  - whole column matches well with the BTs from AMSU-B at channel 89 GHz
  - column above 500 hPa matches well with the BTs from AMSU-B at channel 183.31 ± 7 GHz (*Fig 5*)
- Monthly IWV time scale: pattern for the whole column matches better with the pattern in BT at the 183.31 ± 7 GHz (*Fig 7*)
- Possible reason for this could be high variability of WV on daily basis which is strongly affected by the surface and therefor BT pattern from channel at 89 GHz match better
- For the whole period, BT sensed by 89 GHz, 183.31 ± 3 and ± 7GHz channel show increase in May (*Fig 6*)
- IWV for both, whole column and column above 500 hPa shows increase over time

Spatial and temporal patterns matches well with pattern observed in BTs from AMSU-B and MHS

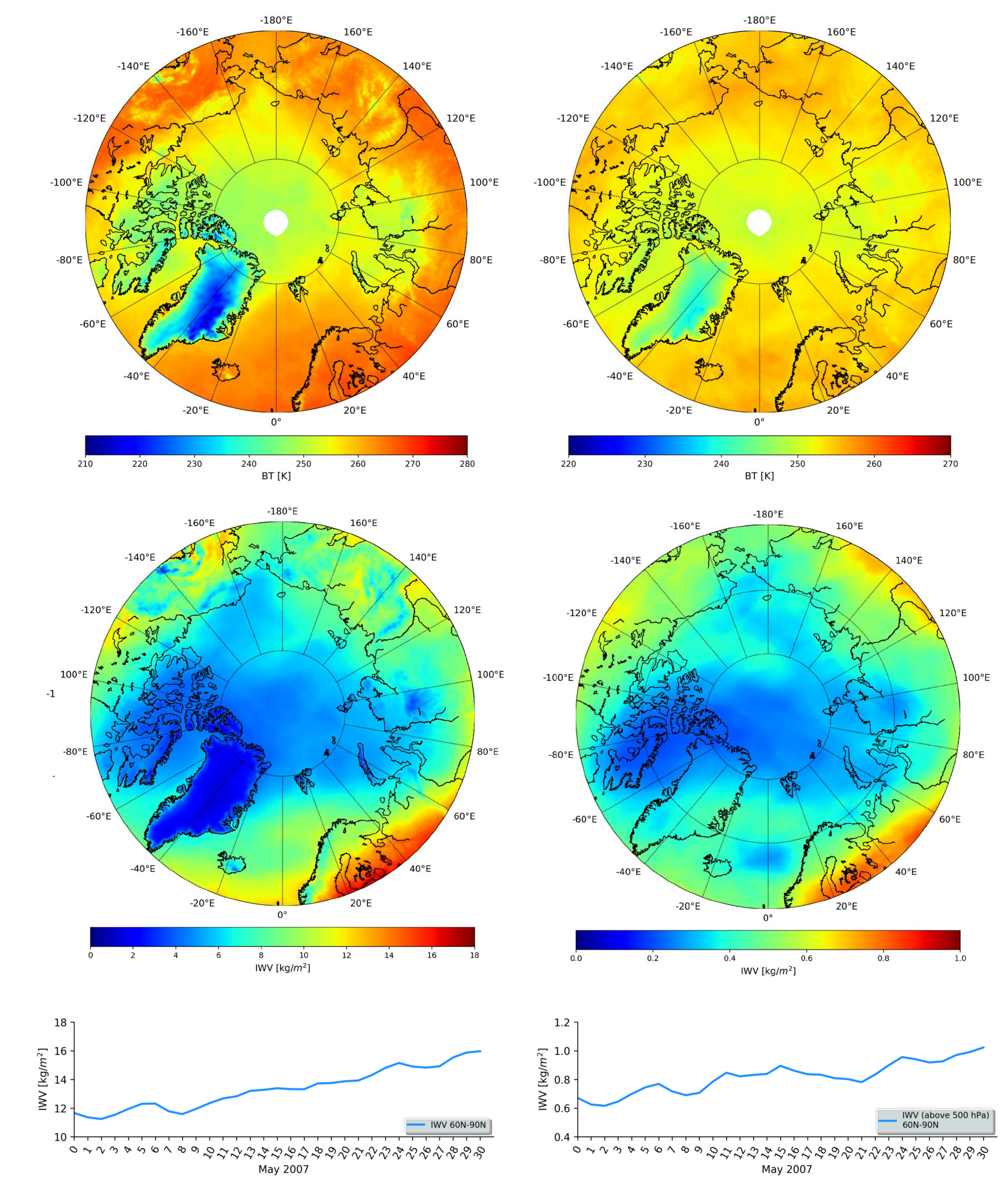

Fig. 7:BT from AMSU-B at 183.31 ± 7 GHz (left) and 183.31 ± 3 GHz (right) and IWV for the whole atmospheric column (left) and above 500 hPa (right). Data are represent for May 2007

- However, it was also noted that channels 150 (157) GHz and 183.31 ± 1GHz show decrease in BT where this decrease is more pronounced for channel at 157 GHz
- Possible reason for this, for channel: 183.31 ± 1GHz could be due to high altitude at which this channel scans which in Arctic region is already stratosphere that showed noted decrease over decades (Solmon et al, 2010[3]).

Match satellite observations with the reanaysis IWV

AMSU-B & MHS data

- Resample AMSU-B and MHS brightness temperature (BT) fundamental climate data record (FCDR)[3] data from 2000 to 2016 on to the ASRv2 grid using nearest-neighbor method
- Excluding outer 9 angles of each scan line shows the best agreement with original data

ASRv2

- Calculate integrated water vapor (IWV) from2000 to 2016 for two different atmospheric column sizes:
  - whole atmosphric column (from surface to top of the atmosphere (TOA))
  - Atmospheric column obove 500 hPa

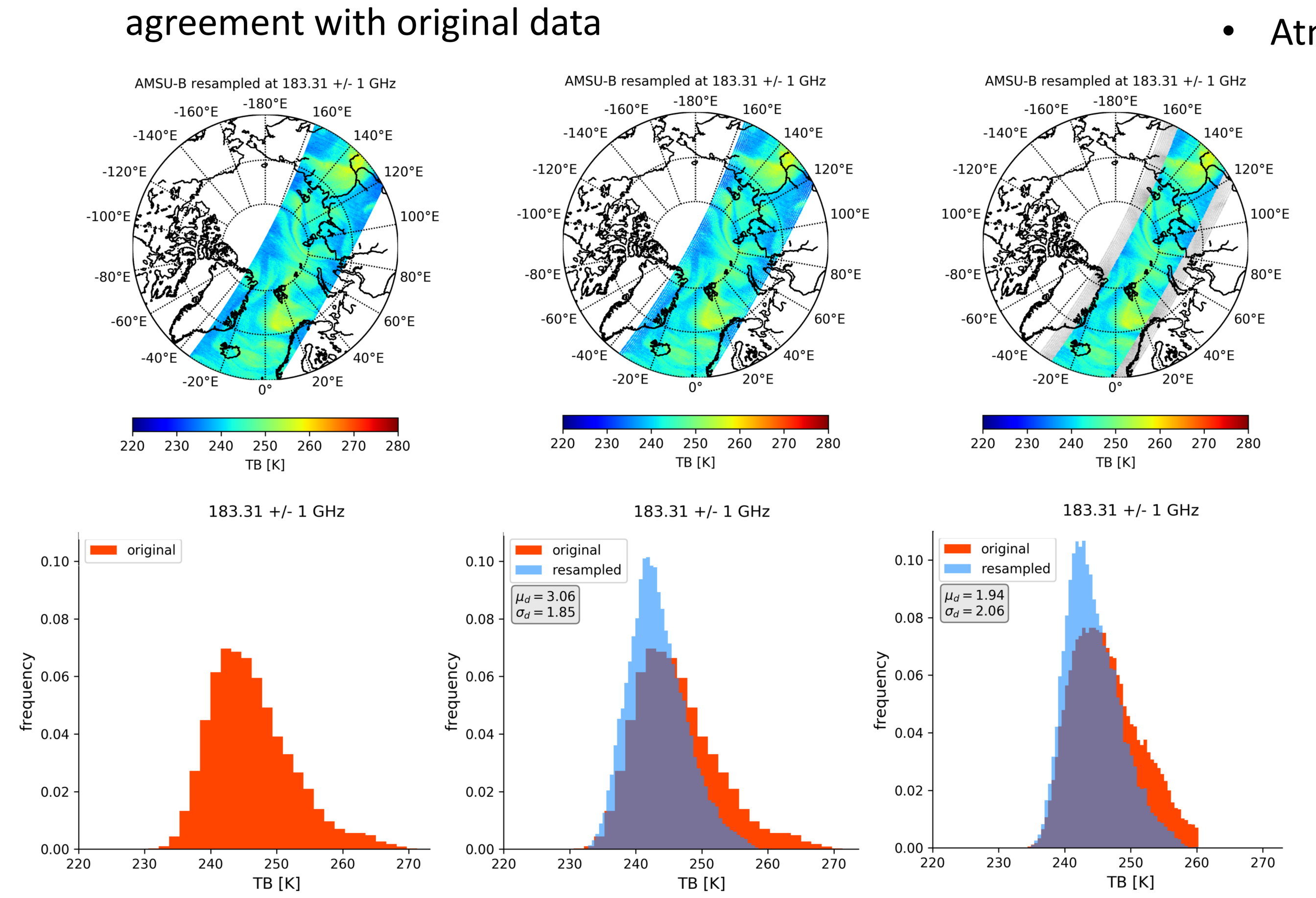

Fig. 3: AMSU-B BT hourly swath at 183.31 ± 1 GHz and histograms for original (top), resampled using all the scan angles (middle) and resampled excluding outer 9 angles of each side of each scan line for 11 May, 2007.

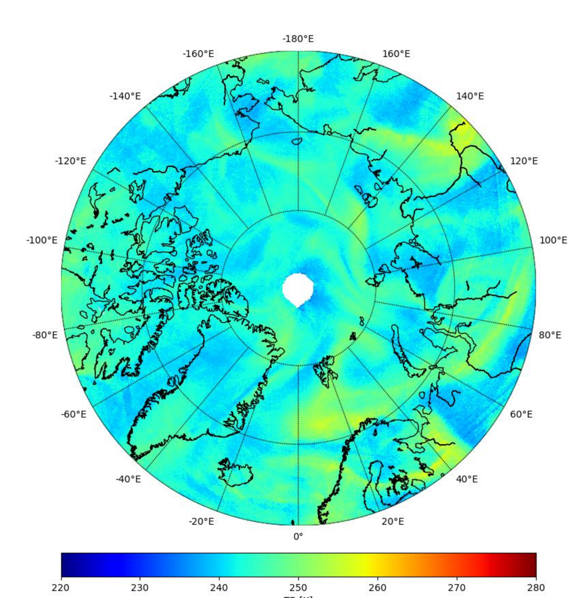

Fig. 4: Daily BT at 183.31 ± 1 GHz resampled on ASRv2 grid using nearest-neighbor method. Day show is 11th of May

Conclusions

- Resampled FCDR BTs match well with original after removal of 9 outer scan angles from each side of the scan
- BTs pattern for the 2000 to 2016 period is showing similar patter as the IWV from the ASRv2
- BTs spatial patterns at channels 183.31 ± 7 GHz and 183.31 ± 3 GHz for the whole month match well with the IWV for the whole column and above 500 hPa, respectively

References

[1] Dessler, A.E. and S. C. Sherwood, 2009, A matter of humidity, Science, vol. 323, 1020-1021
[2] ASR data, Polar Meteorology Group at ByrdPolar and Climate Research Center, the Ohio State University, available at https://rda.ucar.edu/datasets/ds631.1/
[3] DOC/NOAA/NESDIS/NCEI > National Centers for Environmental Information, NESDIS, NOAA, U.S. Department of Commerce
[4] Solmon et al., 2010, Contributions of Stratospheric Water Vapor to Decadal Changes in the Rate of Global Warming, Science, vol. 327, 1219--1223

Acknowledgemnts

This work was supported by Transregional Collaborative Research Center TR172 "ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms (AC)³" funded by the German Research Foundation (DFG).

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