Variability and trends of water vapour in the Arctic and related feedback processes

B05

Susanne Crewell, Annette Rinke, Georg Heygster, Christian Melsheimer, Lisa Dirks

TRANSREGIO TR 172 | LEIPZIG | BREMEN | KÖLN

UNIVERSITÄT LEIPZIG | Universität Bremen | University of Cologne | TROPOS | AWI

1 Summary

Combining long-term satellite data, regional climate model (RCM) simulations and high resolution field campaign data to address the central questions:

- How does the water vapour feedback influence the Arctic Amplification?
- What are the relative effects on radiation, clouds and temperature?
- How did the water vapour and related feedback processes change temporally and regionally over the last decades and how will they change in the future?

Hypothesis

Long–term, temporally and spatially different changes of water vapour influence Arctic Amplification via their effects on radiation, clouds, and temperature.

2 Research rationale

Motivation

- Water vapour (WV) is a crucial component in several feedback mechanisms leading to Arctic Amplification, e.g. sea-ice loss via enhanced longwave downward radiation (LWD), and cloud cover feedback
- Relative strength & future development of WV feedback are uncertain as observational basis and representation in models are limited
- Different reanalyses: large differences in precipitable WV (PWV) trends (Fig. 1)

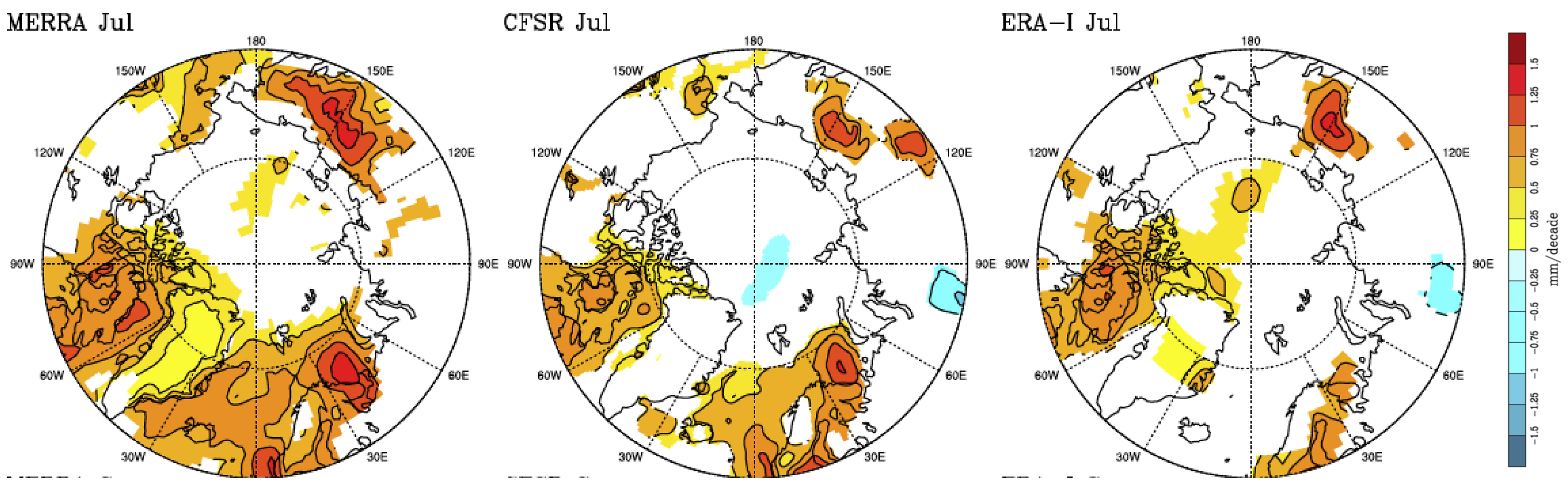


Fig. 1: Spatial pattern of linear trends in surface to 500 hPa PWV (mm/decade) in July for 1979-2010. Colours show statistically significant (> 90%) trends (Serreze et al., 2012).

Challenges

- High spatiotemporal WV variability over different sfc types hinders obs. evaluation
- Different PWV data sets (GEWEX water vapour assessment; GVAP) show largest relative standard deviations in the Arctic
- Humidity inversions: important for cloud-rad. processes but difficult to capture

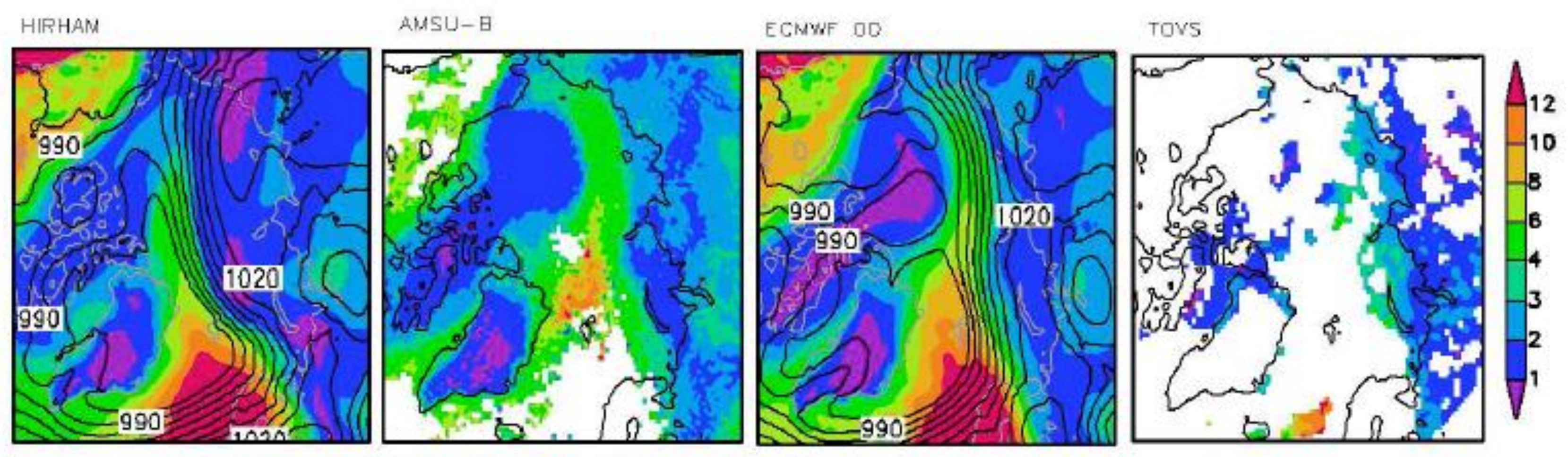
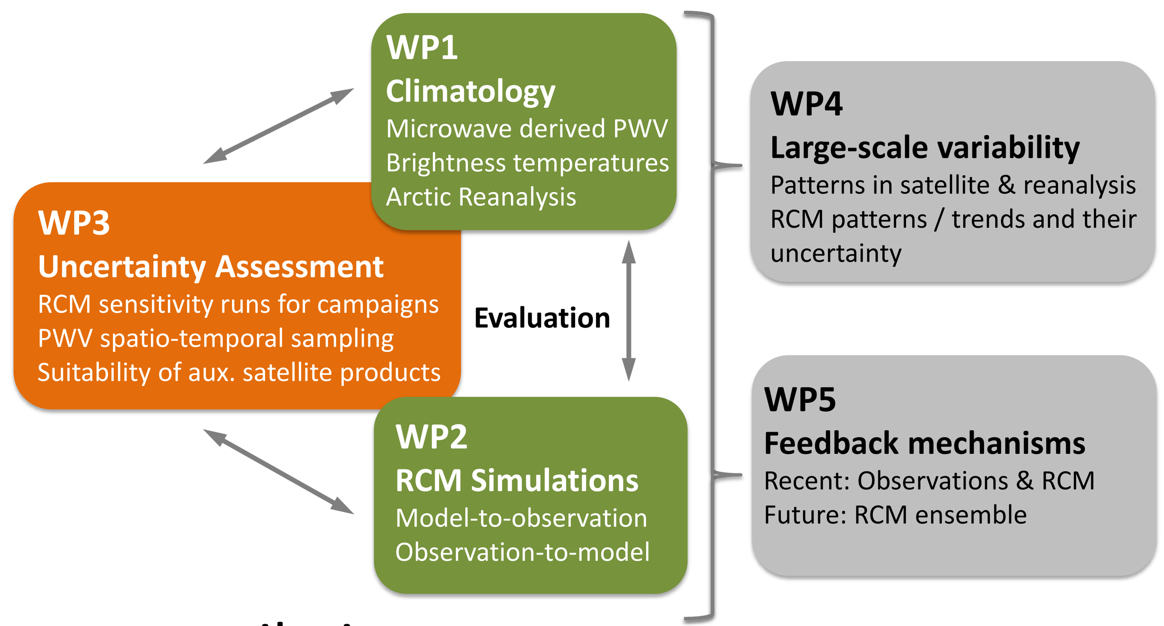


Fig. 2: Example of daily patterns of PWV (mm) for 7 Jan 2002. The daily sea level pressure (hPa) patterns from HIRHAM and ECMWF are included as isolines (from Rinke et al., 2009).

Opportunities

- Comprehensive high frequency microwave (>150 GHz) satellite observations suitable for all weather, low PWV conditions, are available for nearly two decades
- Availability of new high resolution (15 km) Arctic system reanalysis (ASR) and multi–model ensemble of high–resolution Arctic RCM simulations
- Improved techniques for model evaluation and feedback attribution

3 Research plan



WP1 & 2: Data compilation

- Merged microwave (MW) satellite PWV climatology over ocean and land (UNI-B)
- RCM simulations with and without ocean coupling (AWI-P)
- Multi-frequency synthetic MW brightness temperatures (BT) from RCM and CM-SAF intercalibrated measurements (UNI-K)

WP3: Uncertainty assessment – focus on water vapour variability

- High resolution nudged RCM runs for (AC)³ intensive observation periods and sensitivity studies (horizontal & vertical resolution, boundary layer & cloud parameterizations, longwave downward radiation)
- Evaluate RCM, satellites and reanalysis with time series from atmospheric observatories, airborne and ship measurements and assess uncertainty
- Test information content with respect to WV vertical structure in BT space and explore potential of auxiliary data sets, e.g. IASI, GOME

WP4: Large–scale spatio–temporal variability of water vapour

- Monthly and seasonal regional PWV patterns and their interannual variability & trends
- Use WP1 & 2 climatologies and ATOVS climatology from CM–SAF to quantify uncertainty of WV patterns
- Characterize model PWV biases, influence of atm. stability, circulation, cyclone activity (Figs. 2, 3)

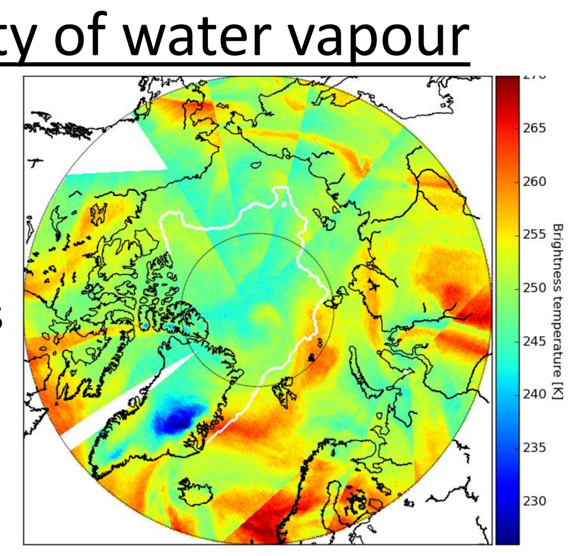
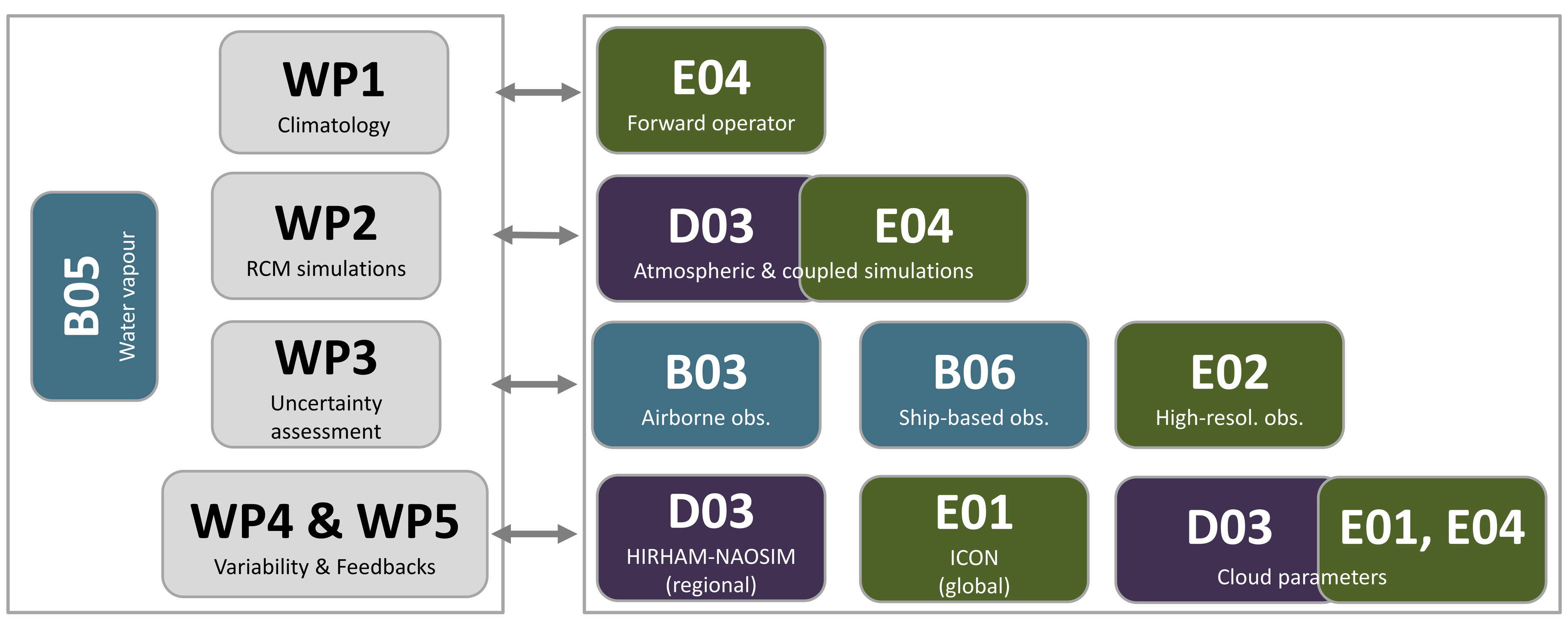


Fig. 3: BT at 183±3 GHz from various satellites during 0-6 UTC on 30 Sep 2011.

WP5: Related feedback processes

- PWV–LWD relationship & impact of vertical WV structure
- Identify spatial variability & strength of PWV-LWD relation
- Fingerprints due to interactive coupling with sea ice-ocean
- Potential impacts by clouds & changes in cyclone activity

4 Role within (AC)³ & perspectives



Collaboration within (AC)³

- Regional climate simulations, derivation of synthetic satellite observations, and feedback assessment (**D03**, **E01**, **E04**)
- Evaluation of high-resolution WV products at super sites (**B03, B06, E02**)

Perspectives

- Extend satellite time series to longer time spans (2002+) and enhanced products; use HALO and MOSAiC; assess vertical resolution
- Investigate interplay between the different WV-related feedback processes in particular with respect to clouds potentially using higher resolution non–hydrostatic RCM with interactive aerosol

printed at Universitätsrechenzentrum Leipzig