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Can the assimilation of water isotopologue observation improve the quality of meteorological analyses fields?

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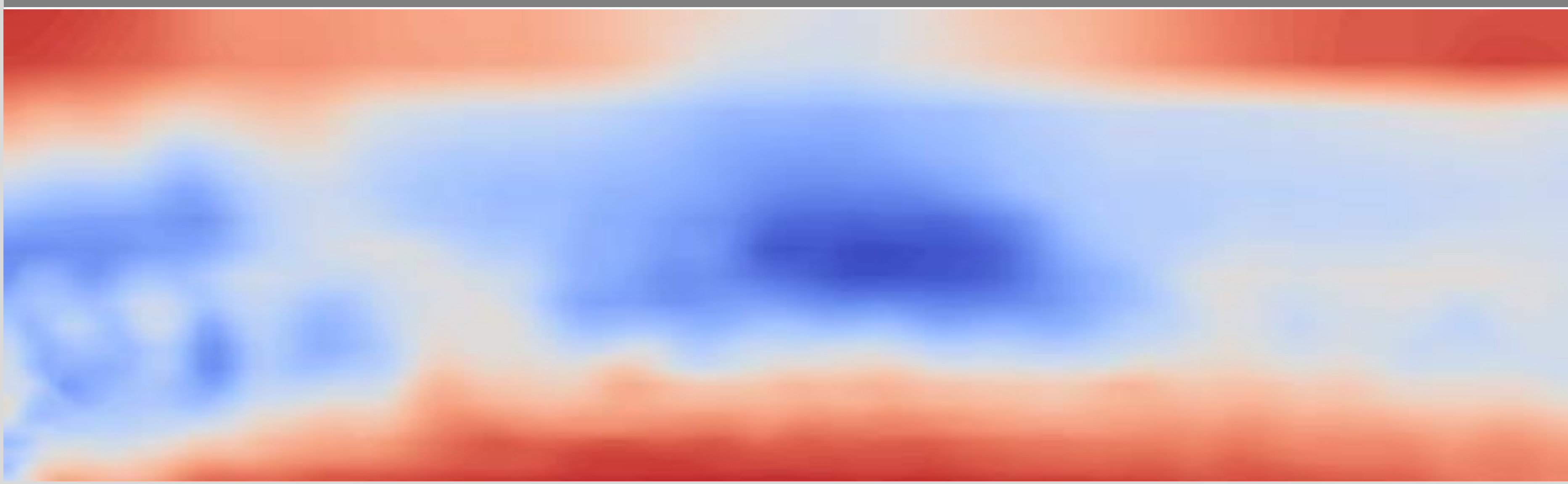
ATMOSPHERIC TRACE GASES AND REMOTE SENSING (ASF)
INSTITUTE OF METEOROLOGY AND CLIMATE RESEARCH (IMK)



Introduction

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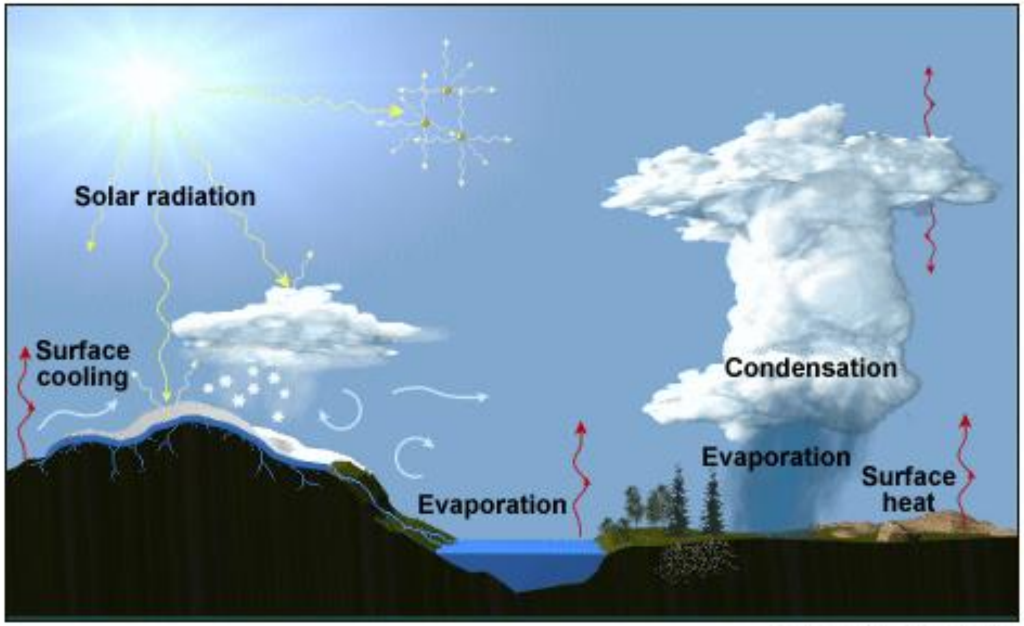

http://tornado.sfsu.edu/geosciences/classes/m201/buoyancy/SkewTMastery/mesoprim/skewt/stability_heat1.htm

Diabatic Heating

$$Q_{tot} = Q_{rad} + Q_{con} + Q_{sen}$$

Q_{rad} – radiative heating
Q_{con} – condensational heating
Q_{sen} – sensible heating

Diabatic processes drive atmospheric motion. The release of the latent heat of condensation has important local effects, potentially leading to deep convection. In addition, evaporation and melting effects have a significant impact on lapse rates locally in instances of heavy precipitation.

Introduction

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- Diabatic heating is the major driving force of atmospheric circulation on weather and climate time scales
- However, diabatic heating rates from current global reanalyses show significant inconsistencies
- This jeopardises the accuracy of:
  - Climate predictions
  - Numerical Weather predictions
- Major reason: diabatic heating rates cannot be directly observed

Introduction

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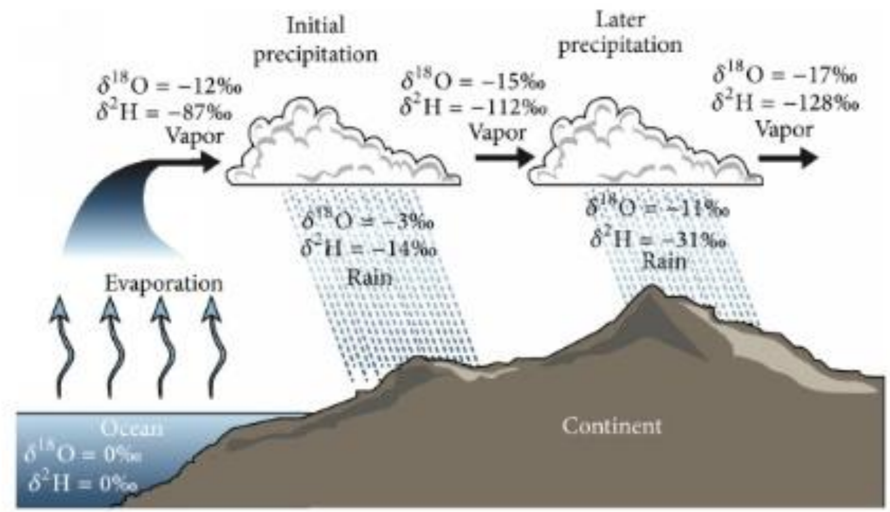
- Stable water isotopologues are sensitive to phase changes during atmospheric circulation
- Isotopes can be used for investigating atmospheric processes, such as large-scale transport, cloud-related processes and precipitation



From: Xi, International Journal of Atmospheric Sciences (2014)

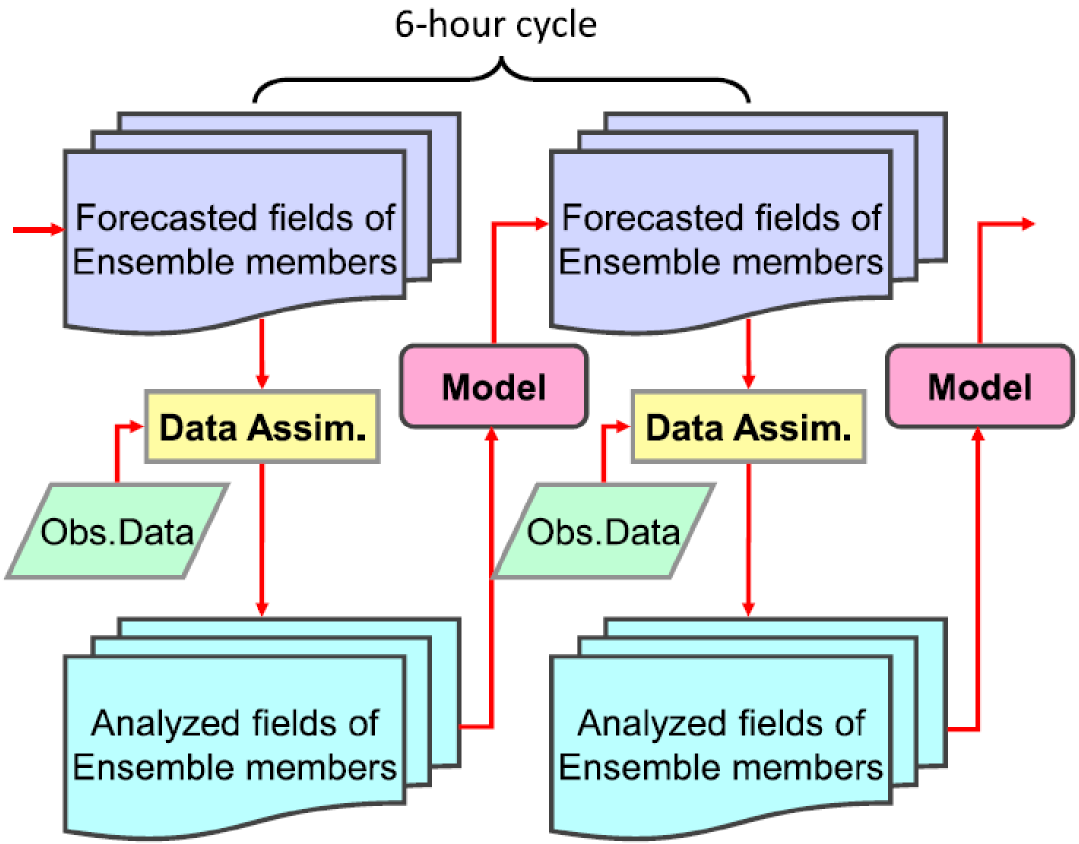
For isotopes the δ notation is used:

$\delta D = 1000 \times (R/R_s - 1)$ in ‰ with $R_s = 3.1152 \times 10^{-4}$

Method

- Assimilation of IASI data into an isotope enabled model (IsoGSM) to test if diabatic heating rates and thus atmospheric circulation can be improved
- Isotopologues observations from IASI (Infrared Atmospheric Sounding interferometer) onboard MetOp-A and MetOp-B (Schneider et al. 2015, 2016)
- OSSE- Observation System Simulation Experiment (Yoshimura et al. 2014)
- Impact assessment of the idealized assimilation experiment done by using the RMSD and Skill

Method



Model: IsoGSM (Yoshimura et al., 2008)
Data Assim.: LETKF (Miyoshi, 2011)
Obs.Data: Synthesized IASI data

Yoshimura et al. (2014)

Method

- Data Assimilation: Local Ensemble Transform Kalman Filter (LETKF)
- Model: Isotope-incorporated GCM IsoGSM
  - PREPBUFR: common assimilation
  - IASI: additionally IASI is assimilated (at 4.2 km)
- Ensemble simulations (size 96) with resolution T62L28 (1.875° x 2°)
- Initial conditions: 6-hourly 01.07.2017
- Evaluation with the Nature (“Truth“) for the period Jul-Aug 2016

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Results for the Idealized Assimilation Experiment (OSSE)

Experimental Set-up

- Two experiments performed with each two ensemble simulations

1. Experiment: PREPBUFR
   - PREPBUFR: common assimilation
   - PREPBUFR+IASI: common assimilation + IASI δD
2. Experiment: noDAvsDA
   - No DA: no data assimilation
   - DA IASI: assimilation of IASI δD

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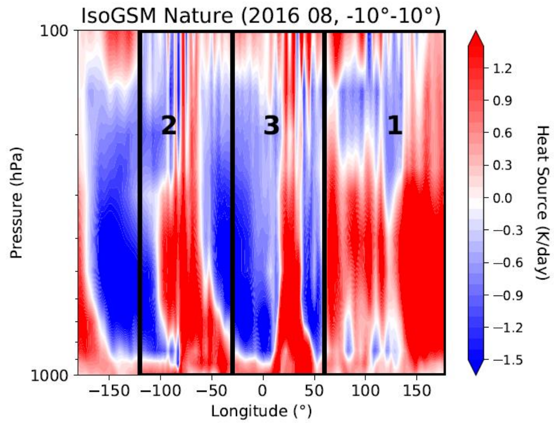
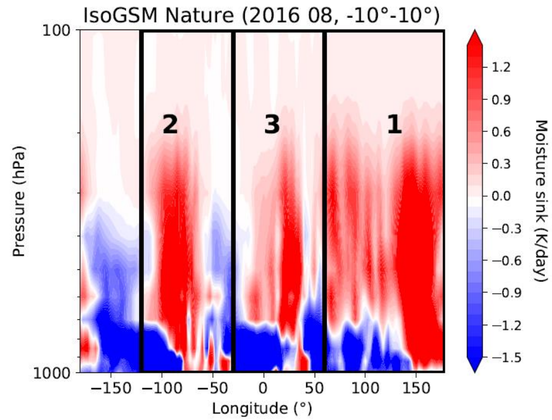
Vertical Cross Sections

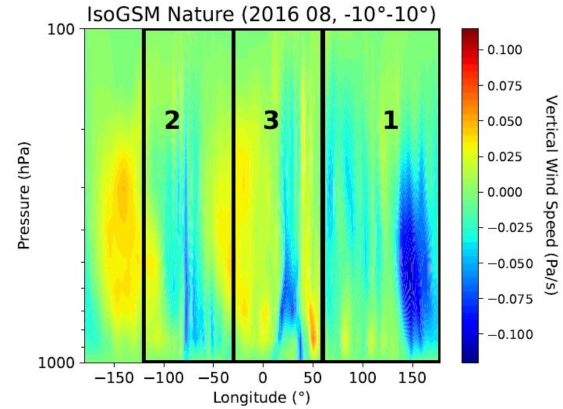
Heat Source



Moisture Sink



Vertical Wind



Considered Latitude Region -10° – 10° (Tropics)

Consideration of entire tropics and specific regions:

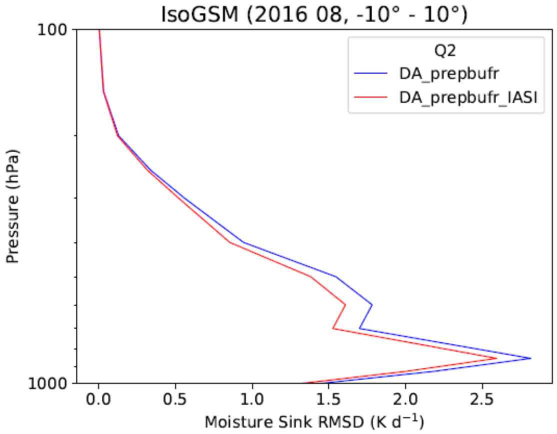
Lon 60° to 180° Asia (1)
-120° to 30° America (2)
-30° to 60° Africa (3)

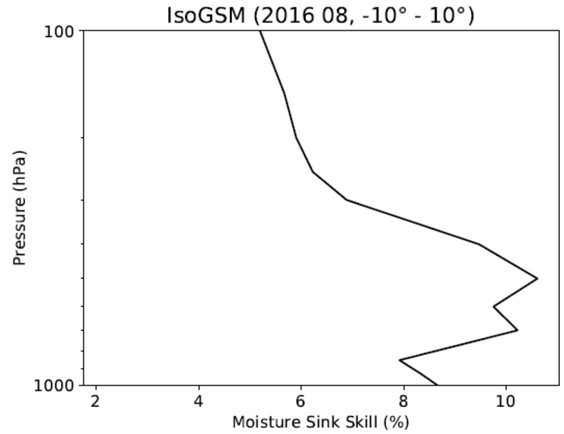
RMSD and Skill – Tropics (-10 to 10)

RMSD

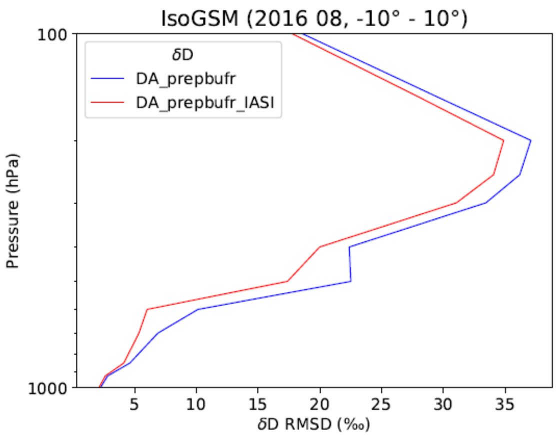
Skill

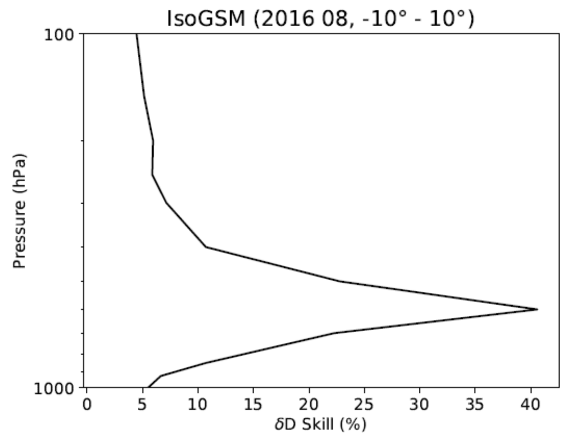
Moisture Sink





δD





RMSD for assimilation with IASI decreased

Highest improvement ín skill at 500 hPa, the altitude where IASI δD has the highest sensitivity

Skill in the Tropics/Regions (Troposphere)

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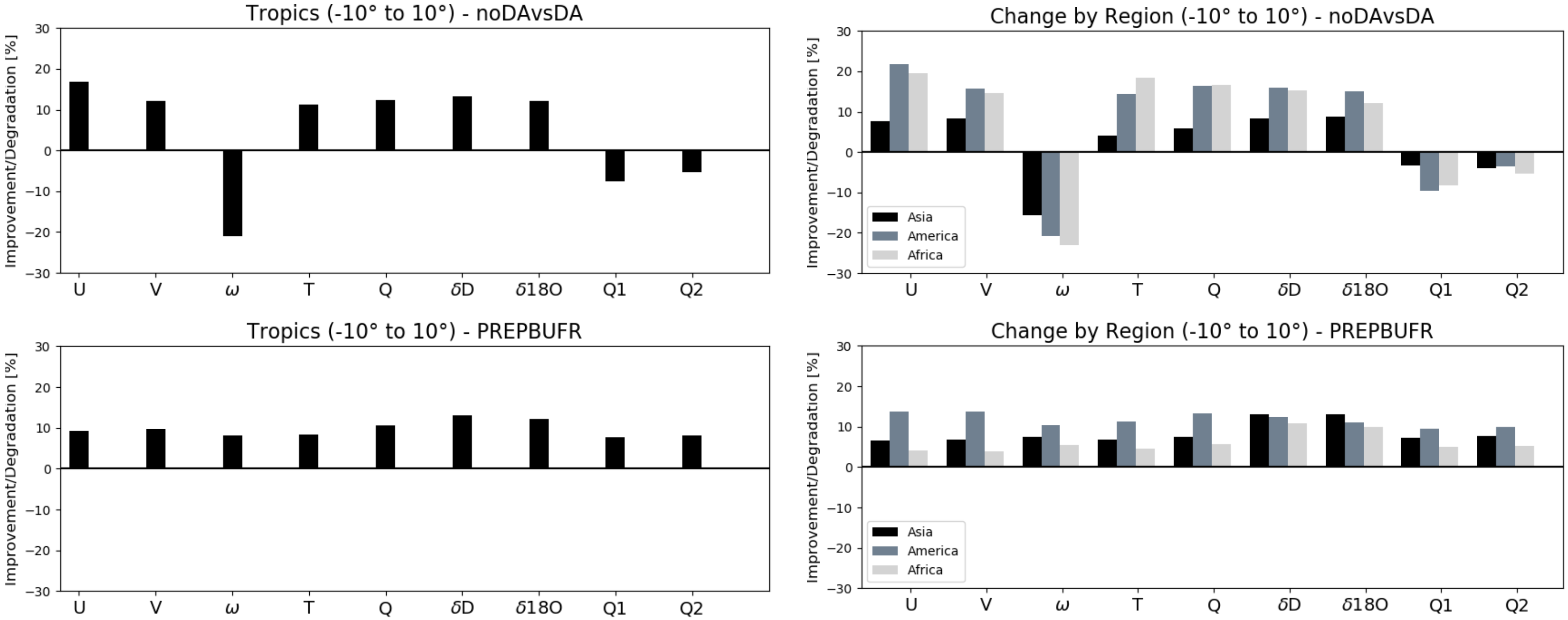

- Vertically averaged from mean profiles, up to 100 hPa (Troposphere)
- Average improvement 10% for PREPBUFR, a bit higher for noDAvsDA
- Improvement for all parameters (PREPBUFR), except ω, Q1, Q2 (noDAvsDA)
- Highest improvement for America, lowest for Asia (noDAvsDA) and Africa (PREPBUFR)

Skill in the Tropics/Regions (at 500 hPa)

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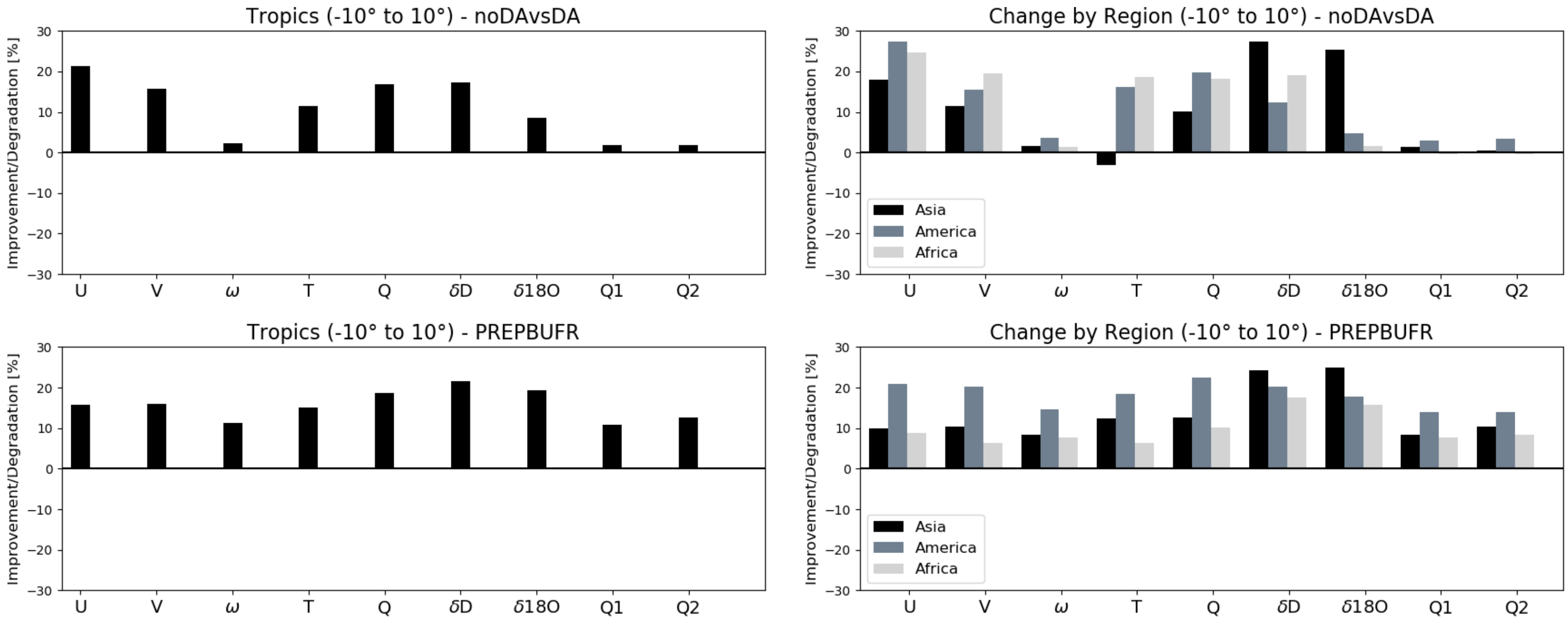

- Mean skill at 500 hPa, averaged over 1 month (Aug 2016); as from the vertically averaged skill the improvement is lowest for Asia except for isotopes (noDAvsDA) and lowest for Africa (PREPBUFR)
- Improvement 10-20% for both experiments, but lower for ω, Q_1, Q_2 (noDAvsDA)
- PREPBUFR and noDAvsDA: highest improvement for America

Conclusions

- Idealized assimilation experiment with mocking IASI data into OSSE shows that the RMSD can be decreased and the Skill improved
- Highest improvement in skill at ~500 hPa, the altitude where IASI has the highest sensitivity
- Improvement about 10-20% dependent on parameter and region considered
- This shows that the assimilation of IASI data has the potential to improve meteorological analyses and thus also weather forecasts and climate predictions