Developing a regionally refined high-resolution and mass-consistent atmosphere-hydrology de-aliasing data set for GRACE-FO and Next-Generation Gravity Missions

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Image: NASA "Worldview" (14 July 2021)

De-aliasing

Temporal aliasing – a limitation of improving accuracy and resolution of NGGMs

- Sub monthly non-tidal mass variations in ocean and atmosphere have to be removed from level-1 GRACE-/FO data
  - ➢ Atmosphere and Ocean De-Aliasing (AOD) products (latest release: RL07, Shihora et al. 2022)

The problem

- AOD data are inevitably imperfect → errors map into the GRACE/-FO level-2 data
- Essential task to improve background models of AOD products for future releases

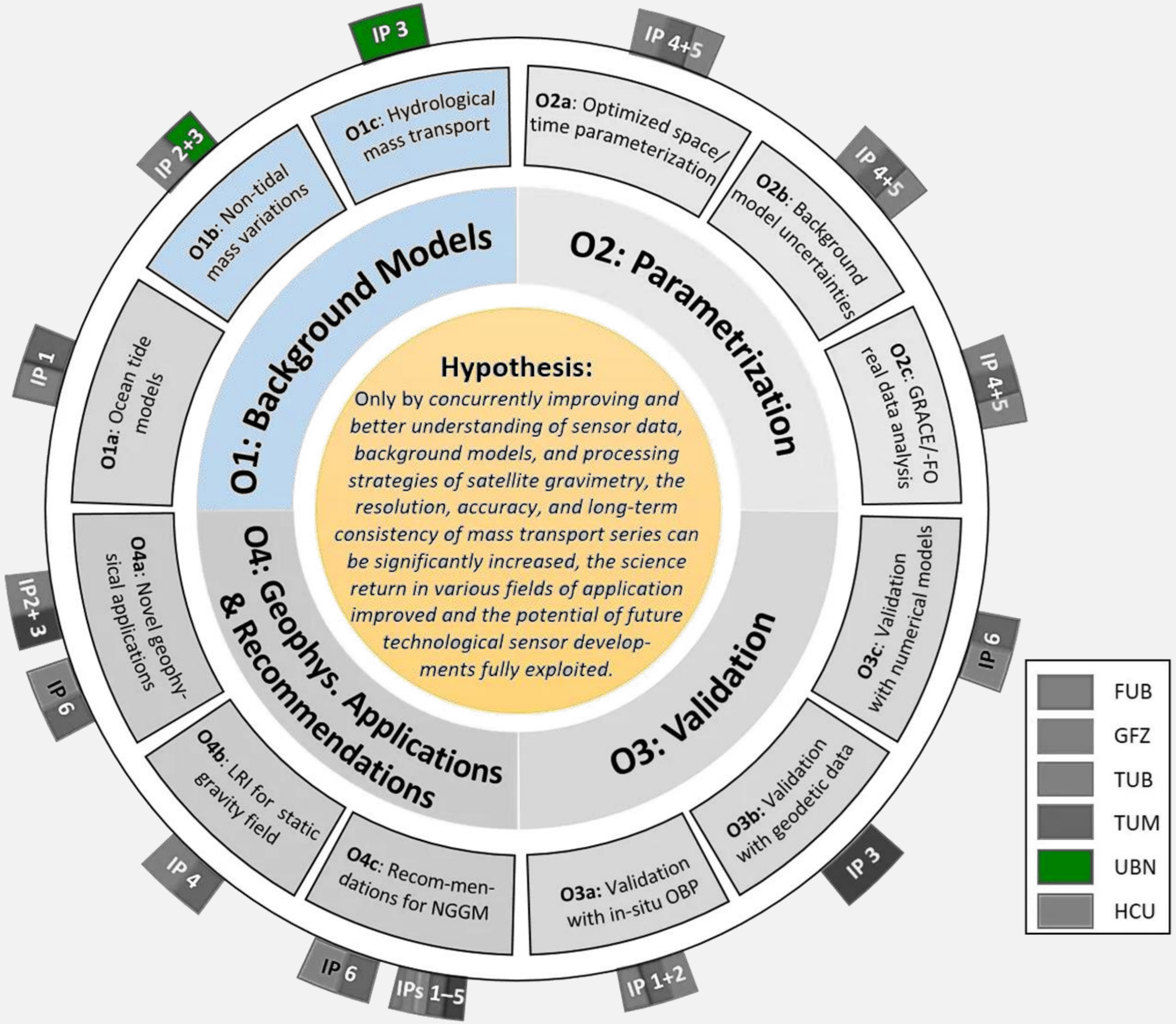
Room for improvements

- Temporal resolution (currently 3-hourly)
- Spatial resolution (currently d/o 180)

→ take advantage of high-resolution regional models (<1-hourly, 6km)

- Modelling → more realistic shape of the Earth (e.g. following Forootan et al. 2013)
  → benefit from high-resolution global non-hydrostatic atmospheric models?
- Including short-time hydrological mass variation (suggested by e.g. Zenner et al. 2012, Eicker & Springer 2016)

NEROGRAV research objectives



IP3: HIRABAM

Address systematic and random errors in atmospheric background models, including small-scale processes

- ➢ Improved modelling of atmospheric mass
- ➢ Regional refinement
- ➢ Addition of hydrological data → AOHD
- ➢ Generating AOHD ensembles for error estimation

For more information on DFG RU NEROGRAV visit https://www.asg.ed.tum.de/iapg/nerograv/

Atmospheric mass modelling

More realistic shape of the Earth

– Vertical integration of atmospheric mass, using ITG-inner integral by Forootan et al. (2013) for a more realistic shape of the Earth:

$$I_n(\theta,\lambda) = \int_0^{P_s} \left(\frac{r_e(\theta)+\xi(\theta,\lambda)+h(\theta,\lambda)+z_{k+1/2}}{a}\right)^{n+2} \frac{dP_{k+1/2}(\theta,\lambda)}{g(\theta,z_{k+1/2})}$$

with Latitude (θ) dependent Earth's radius $r_e(\theta)$ and acceleration $g(\theta, z_{k+1/2})$

Wet atmosphere density (ρ_{wet})

– Standard approach: only use specific humidity (q)

– Add all mass-related model fields: specific rain water (q_r), cloud water (q_c), cloud ice (q_i), and snow (q_s) content:

$$\rho_{wet} = \rho_{dry} \frac{1}{1-(q+q_r+q_c+q_i+q_s)}$$

– May become interesting when highly localized

➢ e.g. hydrometeorological extremes

Atmospheric liquid and frozen water. Sum over 14.-15.07.21 (Ahr region flooding)

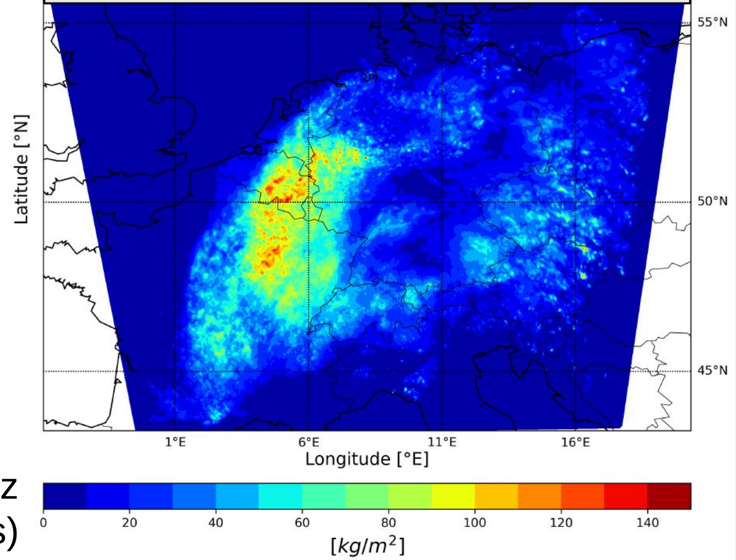
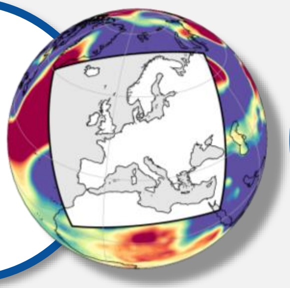


Figure: Magdalena Kracheletz (Bachelor thesis)

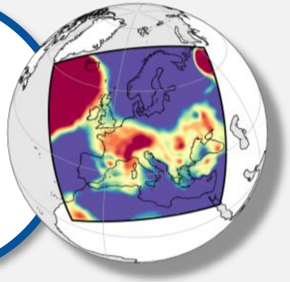
Regional Refinement

Input

Global data at arbitrary spatial and temporal resolution
- e.g. ERA-I (0.5°, 6-hourly)



Regional data at arbitrary spatial and temporal resolution
- e.g. COSMO-REA6 (~0.1°, 1-hourly)

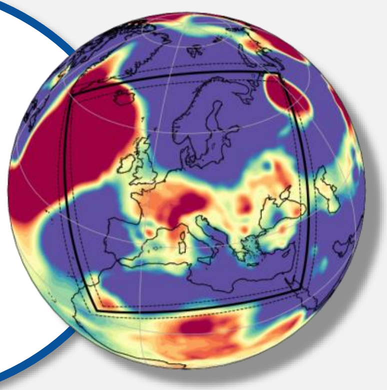


Nesting

Step 1: Temporal interpolation
Step 2: Spatial interpolation and nesting
Step 3: Filtering of transition area

Output

- **Nested data set** either on global input grid (e.g. ERA-I grid) or on global grid with user specific spatial and temporal resolution
- **Spherical harmonic coefficients** at user specific maximum degree and user specific temporal resolution



Regional Refinement

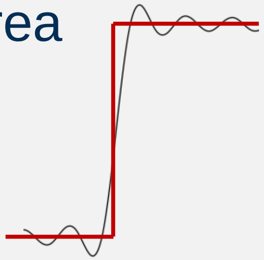
Filtering of transition area

- Of course, the global model will not fit the regional one at the edges!

➢ No smooth transition from the nested regional model to the global model

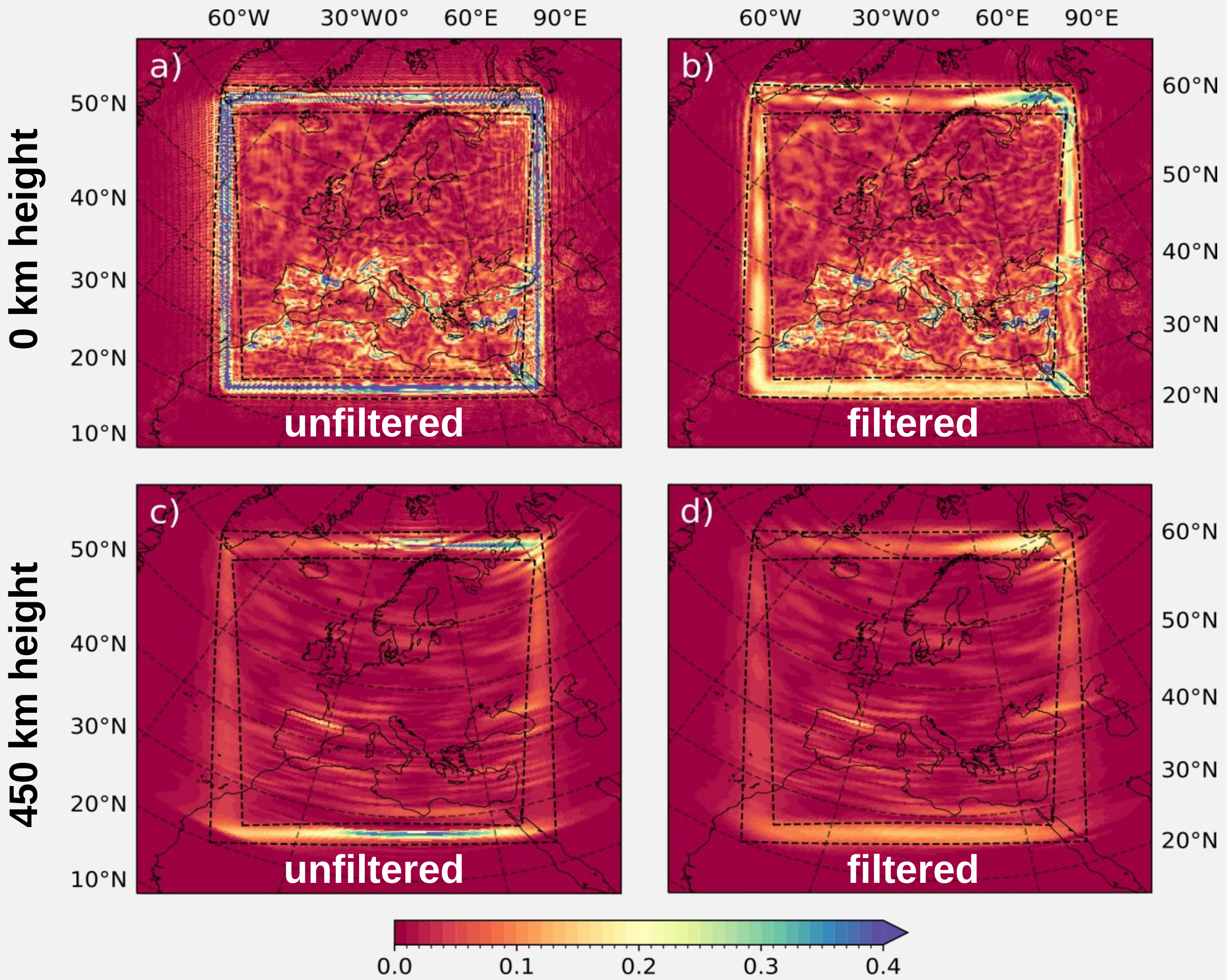
➢ We have to apply a spatial filter within the transition area

  – Otherwise: strong Gibbs phenomenon



- Width of transition area 7.5°

Significant improvement that comes with the filtering!



Between 0 and 1 normalized gradient[1] of RMS(ERA-I minus CSOMO-REA6)

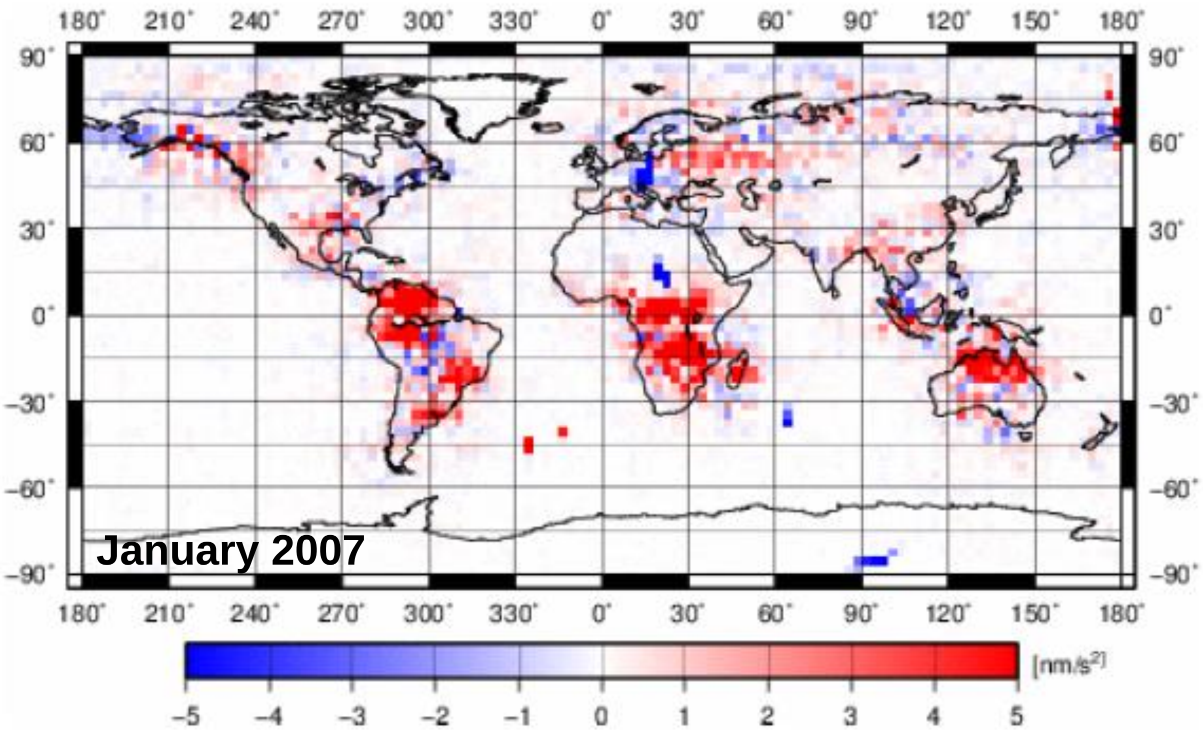
[1]in x- and y-direction combined gradients

Short-time hydrological mass variation

- Hydrology (HYDOL)
  - CLM3.5 (forced with COSMO-REA6) nested into WGHM standard model
- Impact of sub-monthly hydrological signals of K-band range-acceleration pre-fit residuals
  - **AOHD**: AOD1B RL06 + HYDOL

Improvement in regions with high sub-monthly hydrological signals!

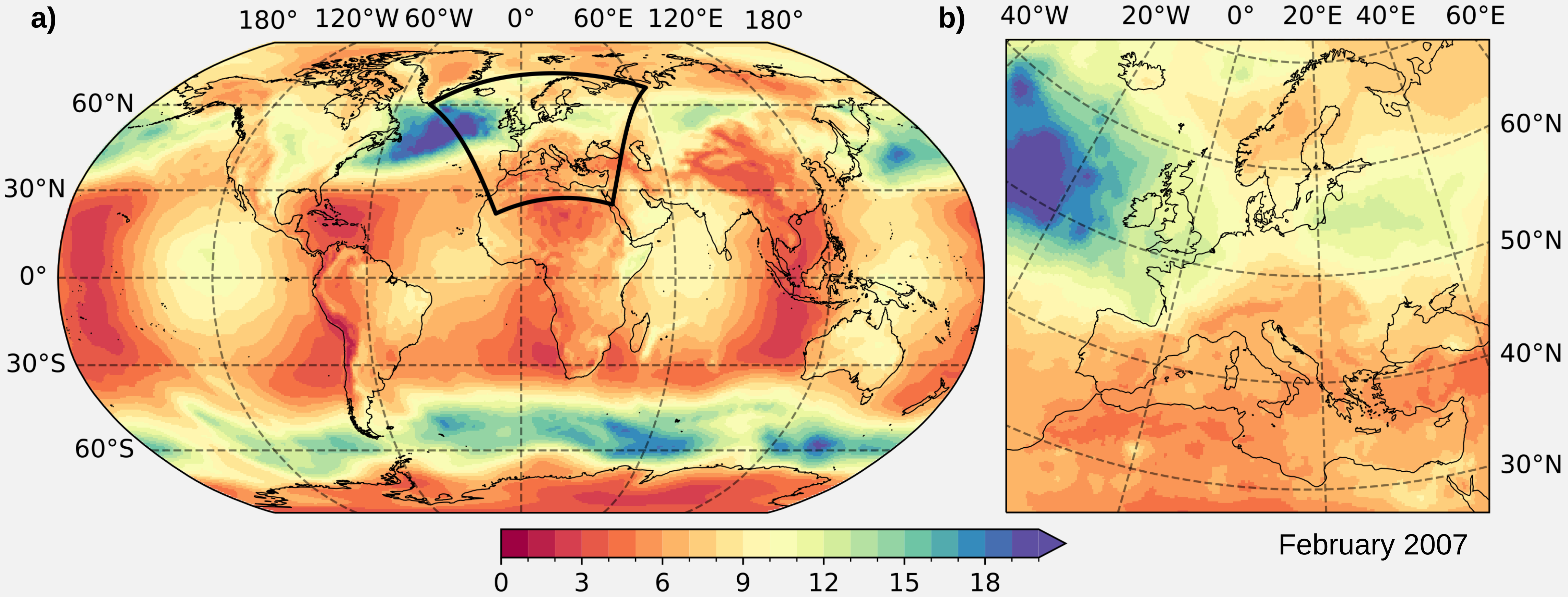
Which de-aliasing product explains GRACE observations better?



original AOD1B RL06 better — AOHD better

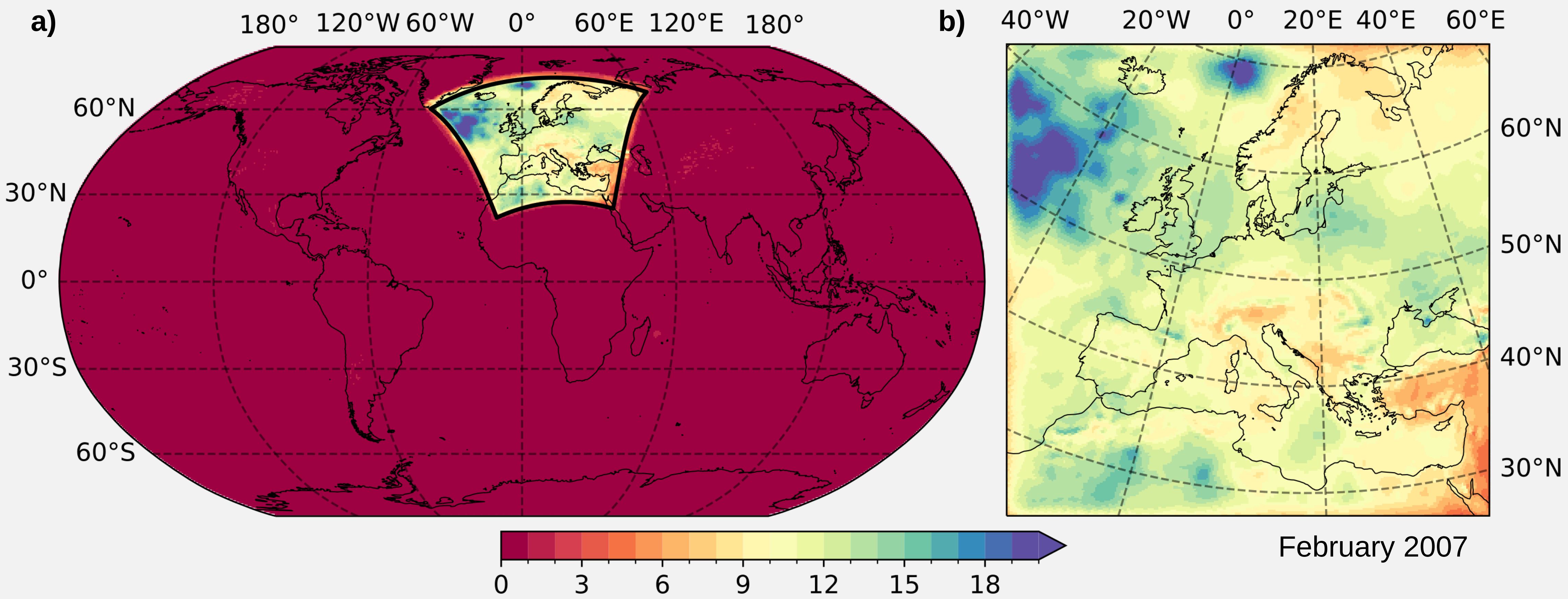
Credit: Christoph Dahle, GFZ

Impact of different temporal resolution



RMSD of 3-hourly and 6-hourly nested COSMO-REA6/ERA-I atmospheric mass [mm EWH]

Impact of different models (with different spatial resolution)



RMSD of nested COSMO-REA6/ERA-I and ERA-I atmospheric mass [mm EWH]

Data availability & Summary

Regionally refined high-resolution and mass-consistent AH+O de-aliasing coefficients for GRACE/-FO

Data access: https://doi.org/10.5880/nerograv.2023.002 (update by the mid of this year; paper in preparation)

- Atmosphere (**ATMOS**): COSMO-REA6 nested into ERA-I, *3-hourly, d/o180 & 360*
- Hydrology (**HYDOL**): CLM3.5 (forced with COSMO-REA6) nested into WGHM standard model, *3-hourly, d/o180 & 360*
- **HYDDA**: HYDOL, but with outputs of GRACE assimilation version (Springer, 2019)

In summary:

- We can provide high resolution ATMOS & HYDOL products that are approximately mass-consistent over the CORDEX-EU region
- AOD products may benefit by adding short-time hydrological mass variation → AOHD
- With better performing NGGMs, increasing the temporal and spatial resolution of AOD products will be an essential task

We are happy if you are interested in testing our data sets! ☺

References

Literature

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Data

- Mielke, C., Springer, A., Dixit, S., Friederichs, P., Kusche, J., Schindelegger, M., (2023): Regionally refined high-resolution and mass-consistent AH+O de-aliasing coefficients for GRACE/-FO. GFZ Data Services, doi.org/10.5880/nerograv.2023.002

Images

- NASA “Worldview” (14 July 2021), https://worldview.earthdata.nasa.gov/?v=-32.917176673896655,30.818209452282602,38.93318393684354,66.55627944356223&t=2021-07-14-T07%3A16%3A03Z (last access 21.04.2023)