Advancing Forecast Accuracy in NWP and Climate Models through Unified Geospatial Data Processing

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Importance of Geospatial Datasets

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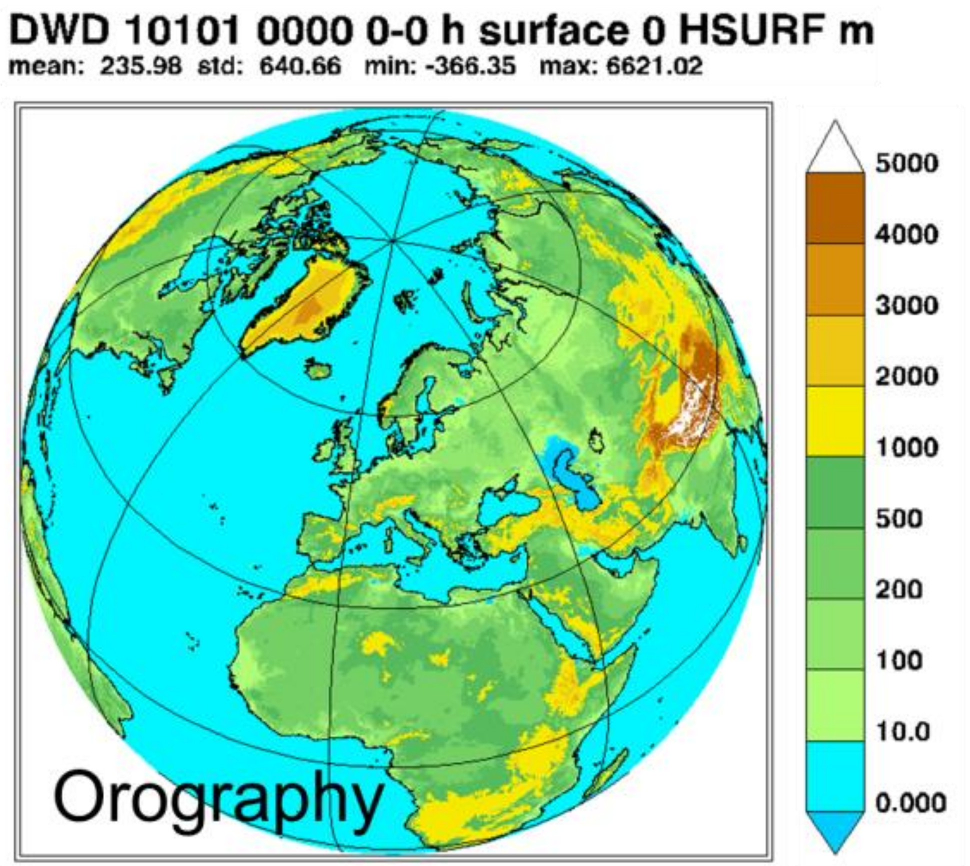
- Provide critical information on:
  - Orography
  - Land use
  - Soil properties
  - Vegetation
  - Radiative factors (e.g., aerosols)



Importance of Geospatial Datasets

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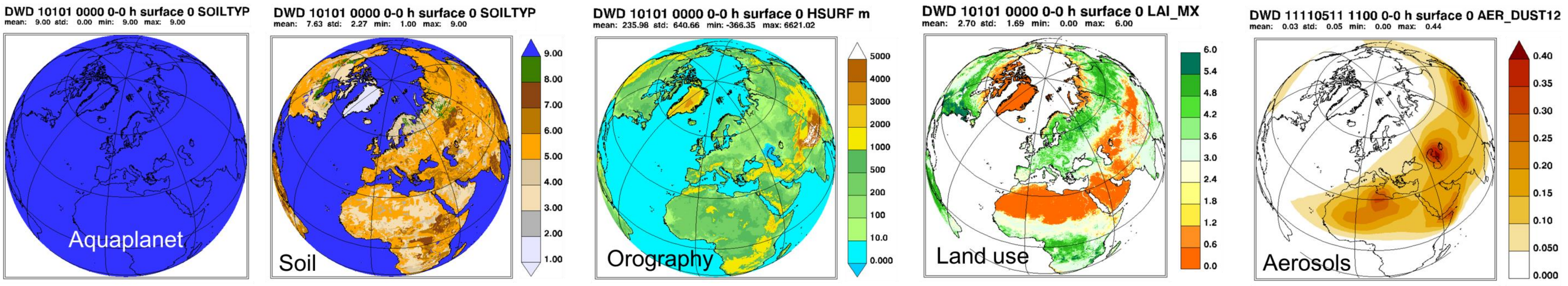


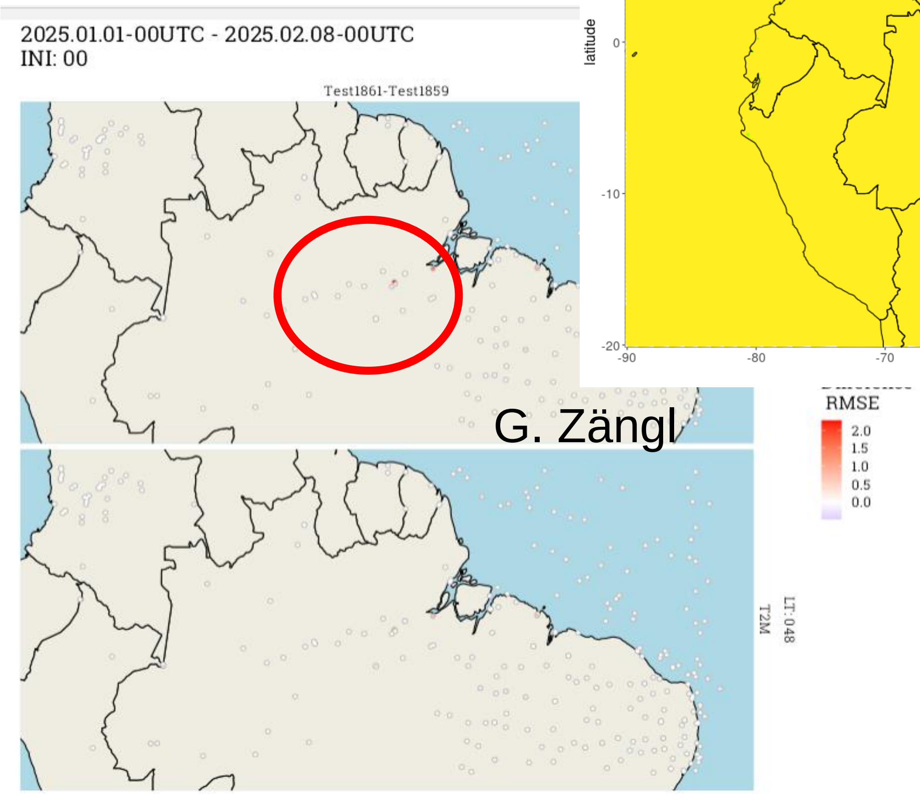
- Geospatial data are retrieved from high-resolution satellite information or land registers and are aggregated to the model’s global or limited-area grid.
- In a final processing step all available data are cross-checked for consistency (e.g., to exclude vegetation on glaciers).
- The required model parameters are very similar for NWP models, but the used data sources and the applied tools vary between different models – i.e. different mapping of geospatial information (Onvlee et al, 2014).

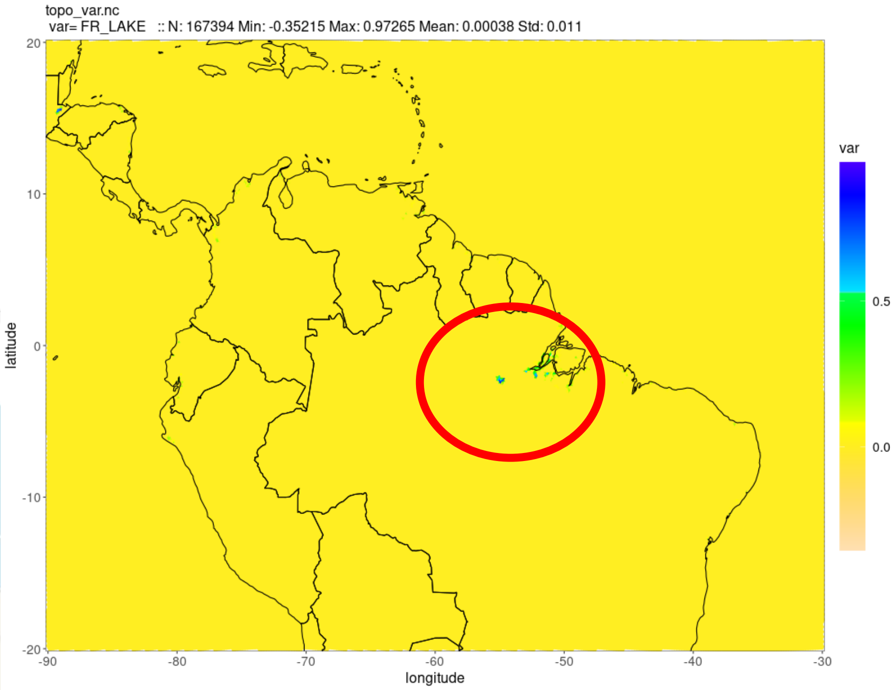
Geospatial data - Problems

Geospatial data are part of the NWP system.

Errors in this system due to these data can arise from:

1. not suitable processed geospatial data





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Processing errors e.g. in land-sea mask, land-use classes)

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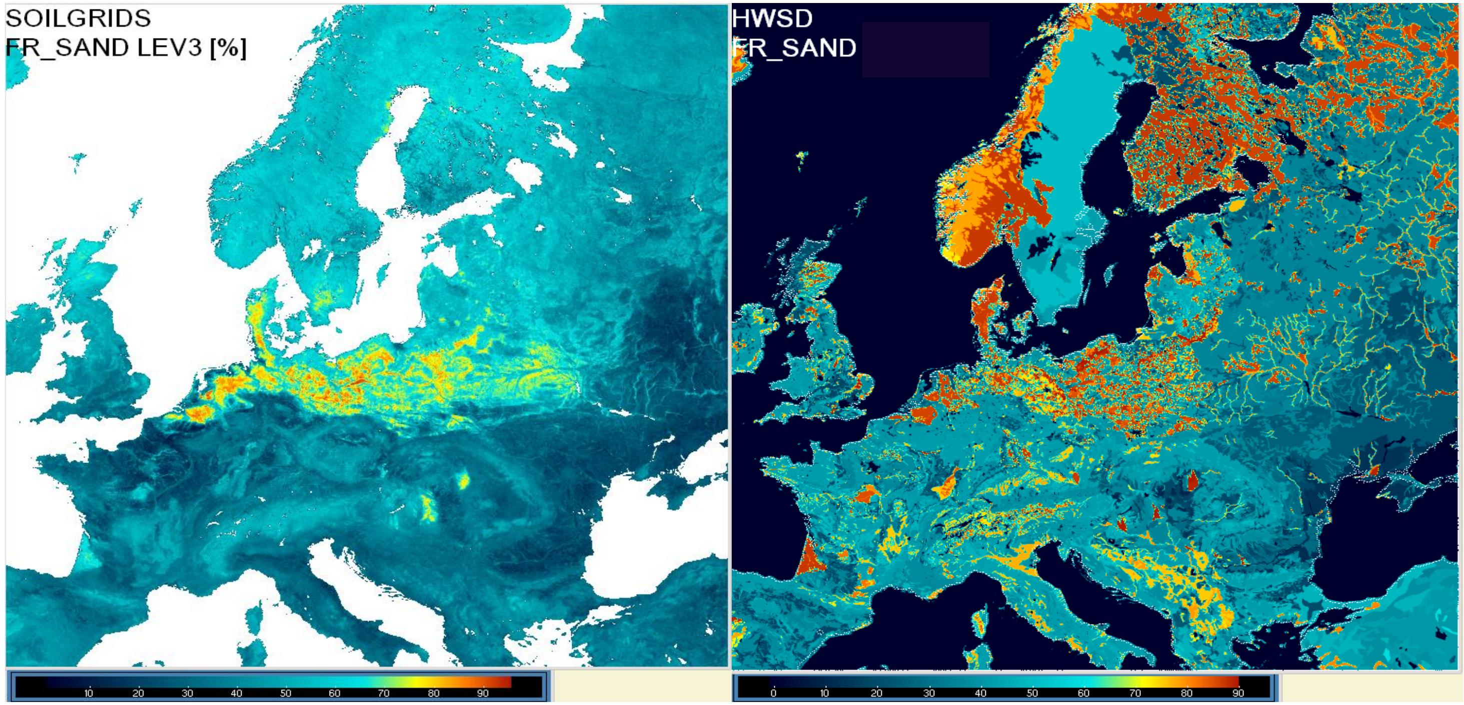

Fraction of sand in SoilGrids and HWSD

Geospatial data - Problems

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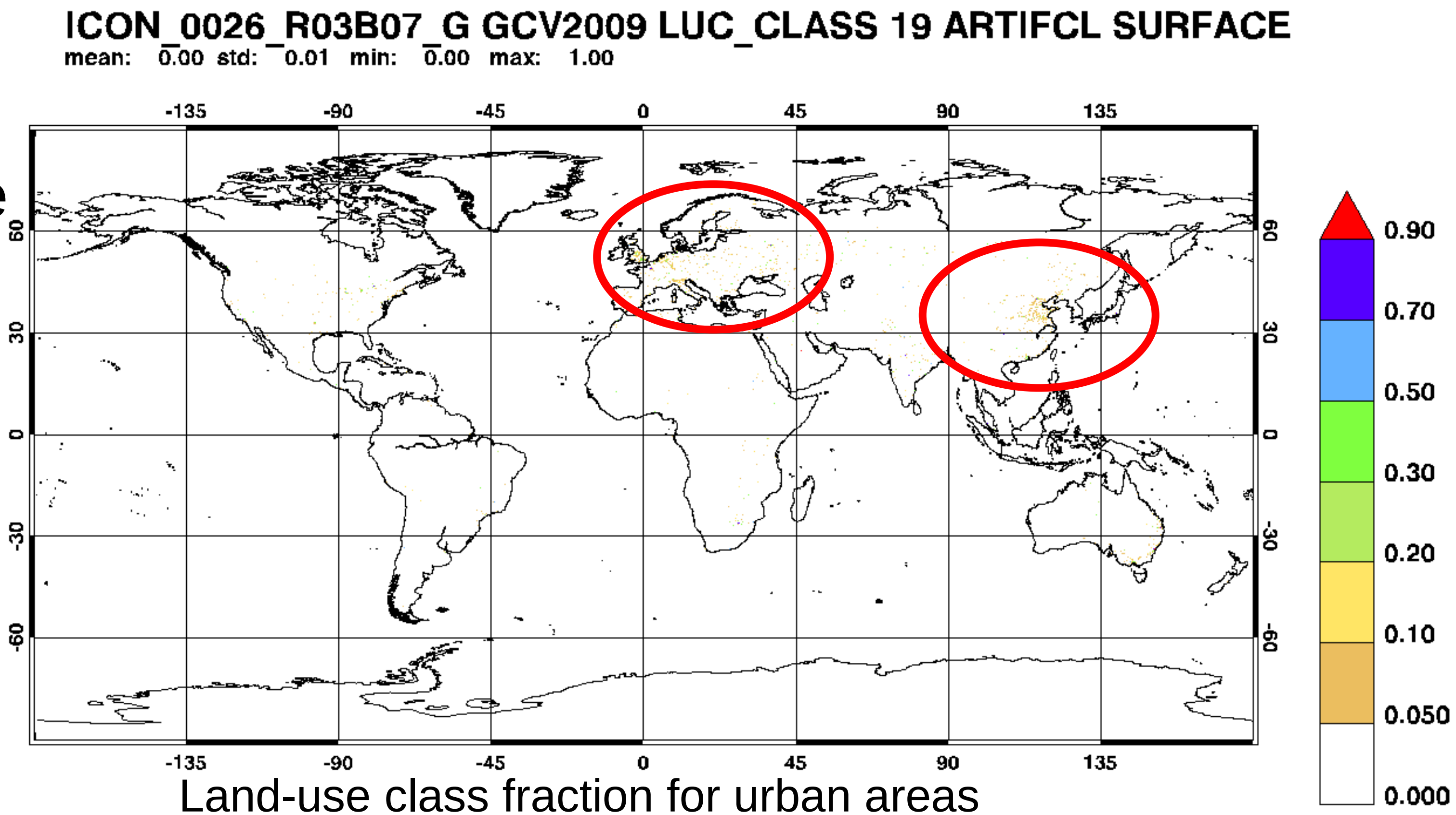
2. errors in geospatial data
3. changed geospatial data



Land-use class fraction for urban areas

Geospatial data - Problems

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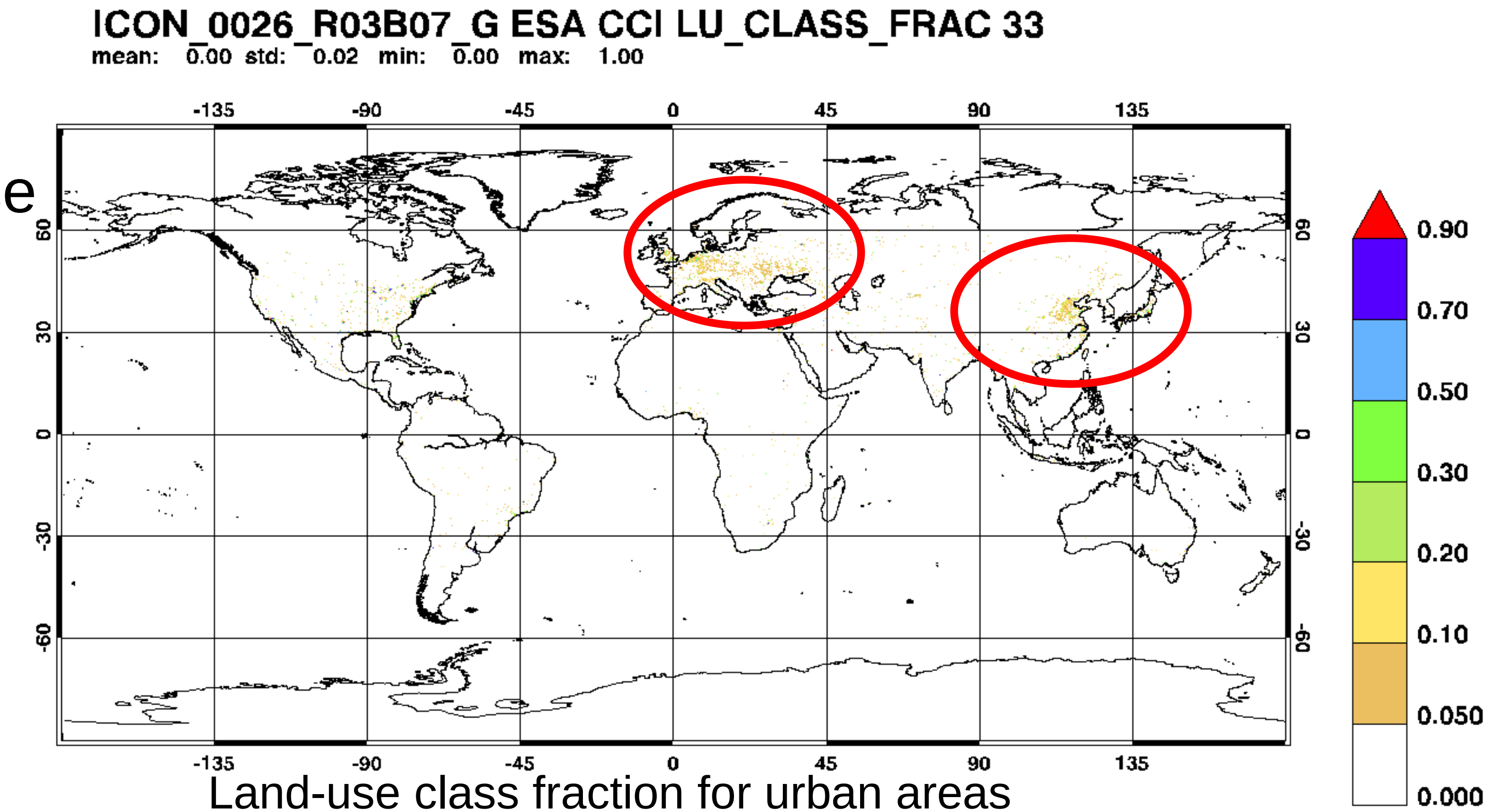

Land-use class fraction for urban areas

Geospatial data - Problems

Geospatial data are part of the NWP system.

Errors in this system due to these data can arise from:

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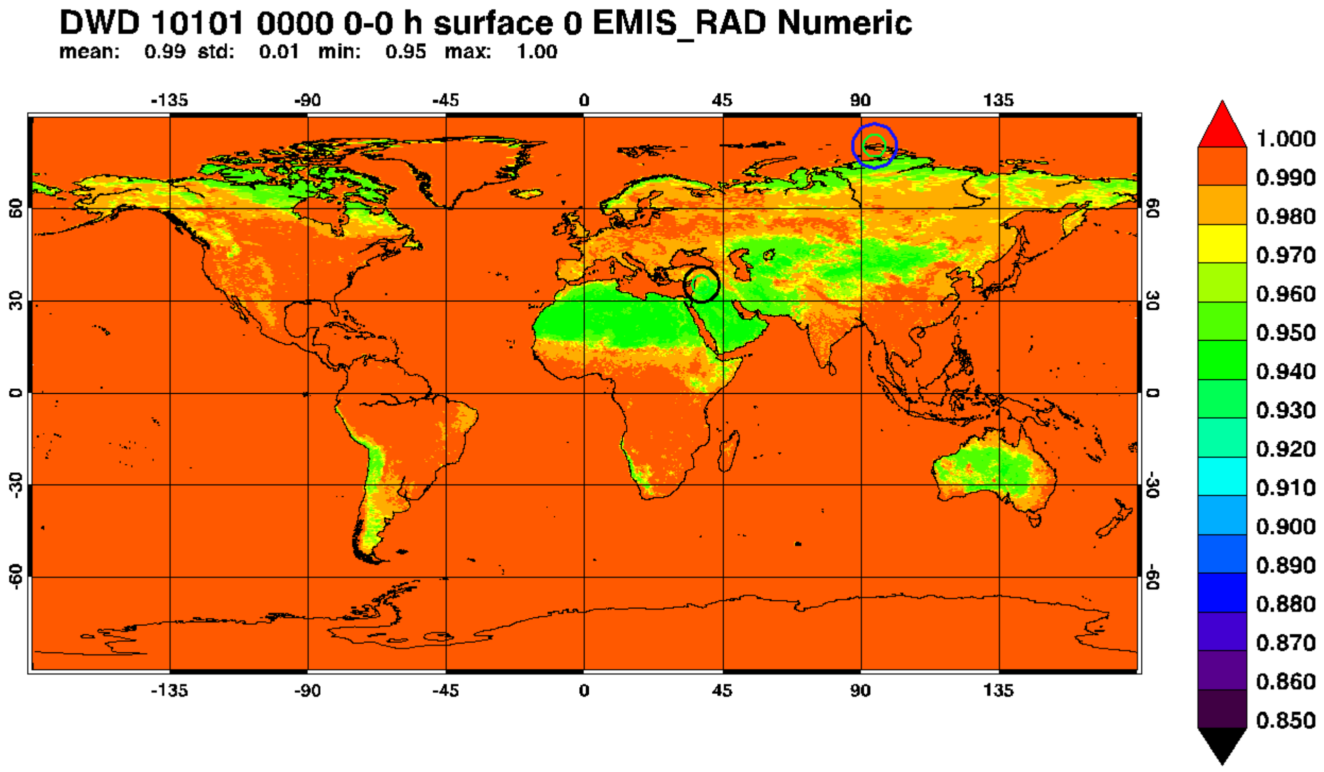
2. errors in geospatial data
3. changed geospatial data
4. missing geospatial data



Emissivity (based on look-up table for land-use classes)

Geospatial data - Problems

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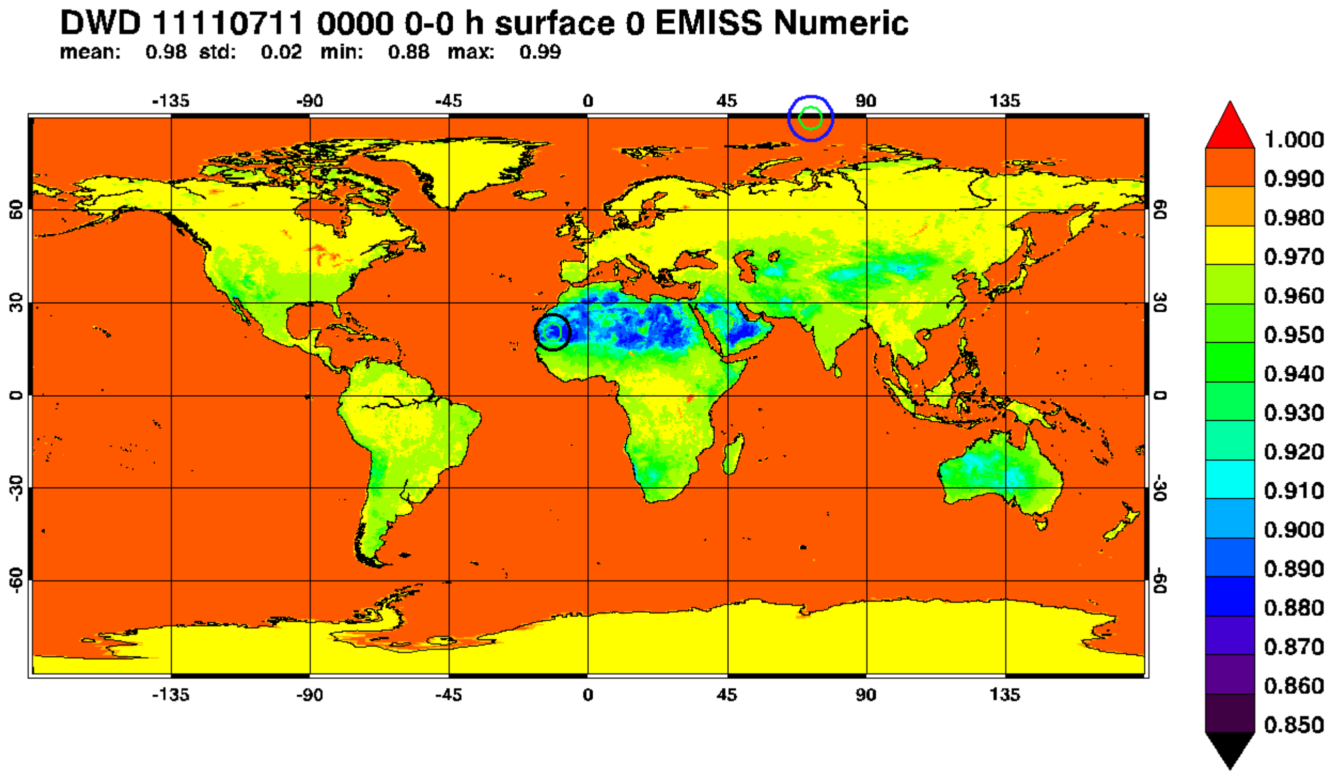


Combined ASTER and MODIS Emissivity database over Land (CAMEL) - B. Fay (DWD)

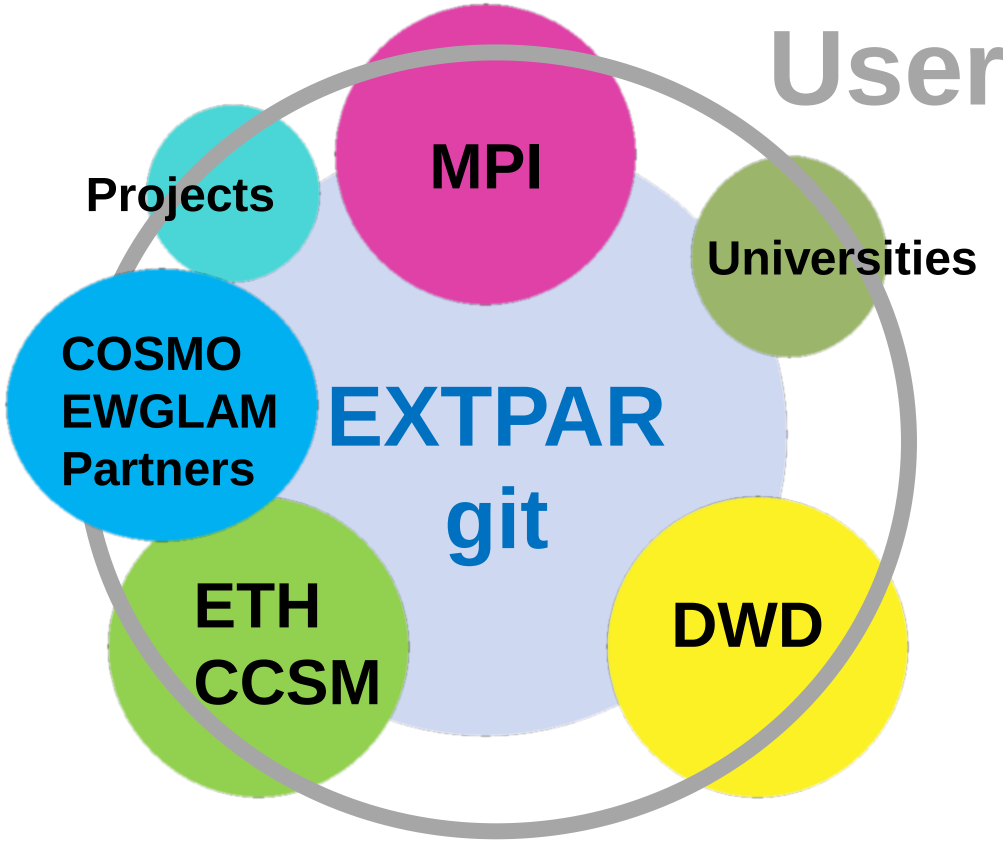
Geospatial data - Processing

- Demand for high-resolution remote sensing data to be used for: convection permitting global NWP or LES-type limited-area models.

- Increasing number of users for aggregated data on model’s grid

    - Increase in storage and I/O costs
    - Demand for improved approaches for data aggregation (e.g. soil)
    - Need for preprocessing of data (Python, cdo, NetCDF tools)
    - Need for parallelization (Open-MP, MPI)
    - Need for user-friendly, low maintainance front ends

EXTPAR: Geospatial Data Preprocessor



- Unified code of EXTPAR available for project partners
- Possible to run EXTPAR on different platforms (compilers)
- Use a modern development platform (git)
- Allow automatic tests of modified code (compilers and output)
- Benefit from developments in CLM/DWD/MPI
- Reduce maintanance overhead for developers
- Common code platform for new developments (e.g., Copernicus DEM, SoilGrids, EDGAR)

Geospatial data community

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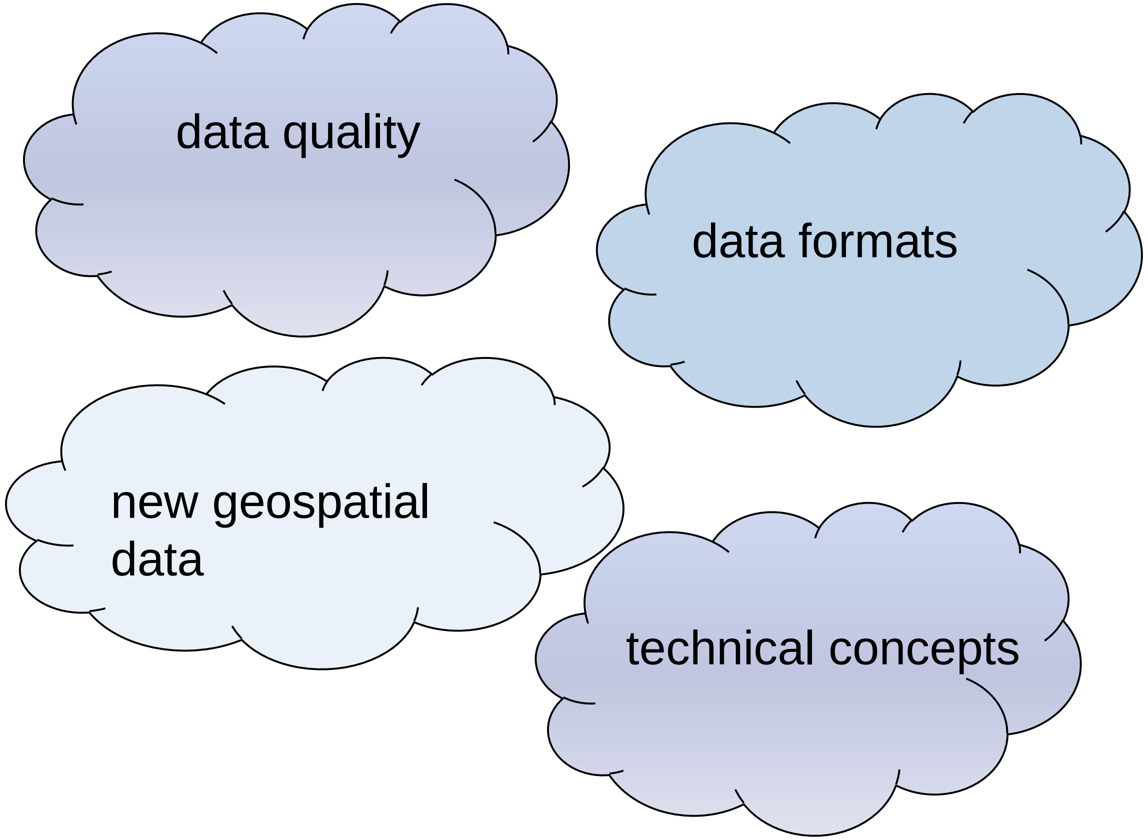
ALADIN	COSMO	HIRLAM	MetOffice	LACE	SEECOP	ECMWF



Common interests in:

- geospatial data retrieved from high-resolution satellite information or land registers and are aggregated to the model's global or limited-area grid.
- exploration of new geospatial data
- common standards for data formats
- collection of reports on data quality issues (e.g. HWSD)
- report on measures to address technical challenges (data in cloud, artificial intelligence?, user access, …)

Application of geospatial data processing

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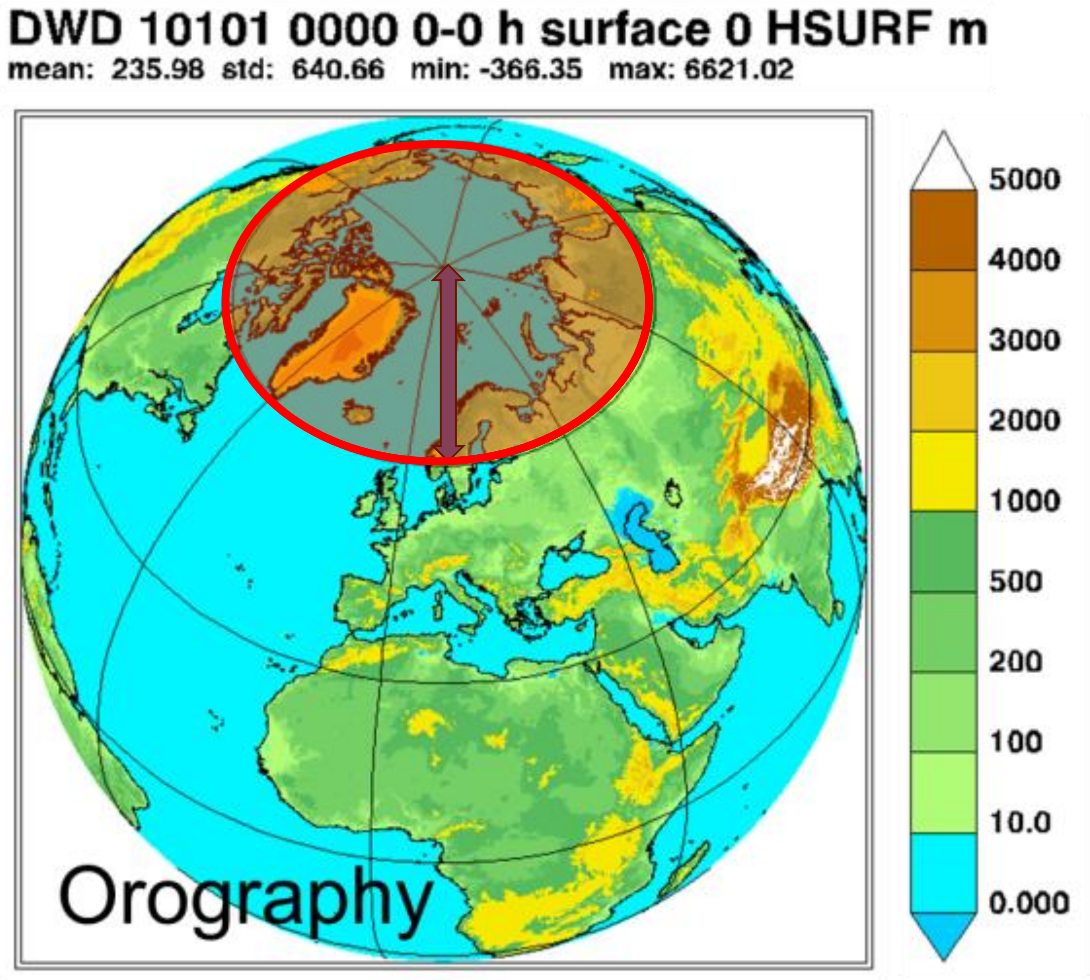
DWD



GLOBE-DEM (1km) global
ASTER-DEM (30m) +/- 60° lat
(available for DWD)

IGLO,ICON-EU: GLOBE
ICON-D2: ASTER

Automatic switch
for grid size < 3km to allow ICON-D2

SSO parameters adapted

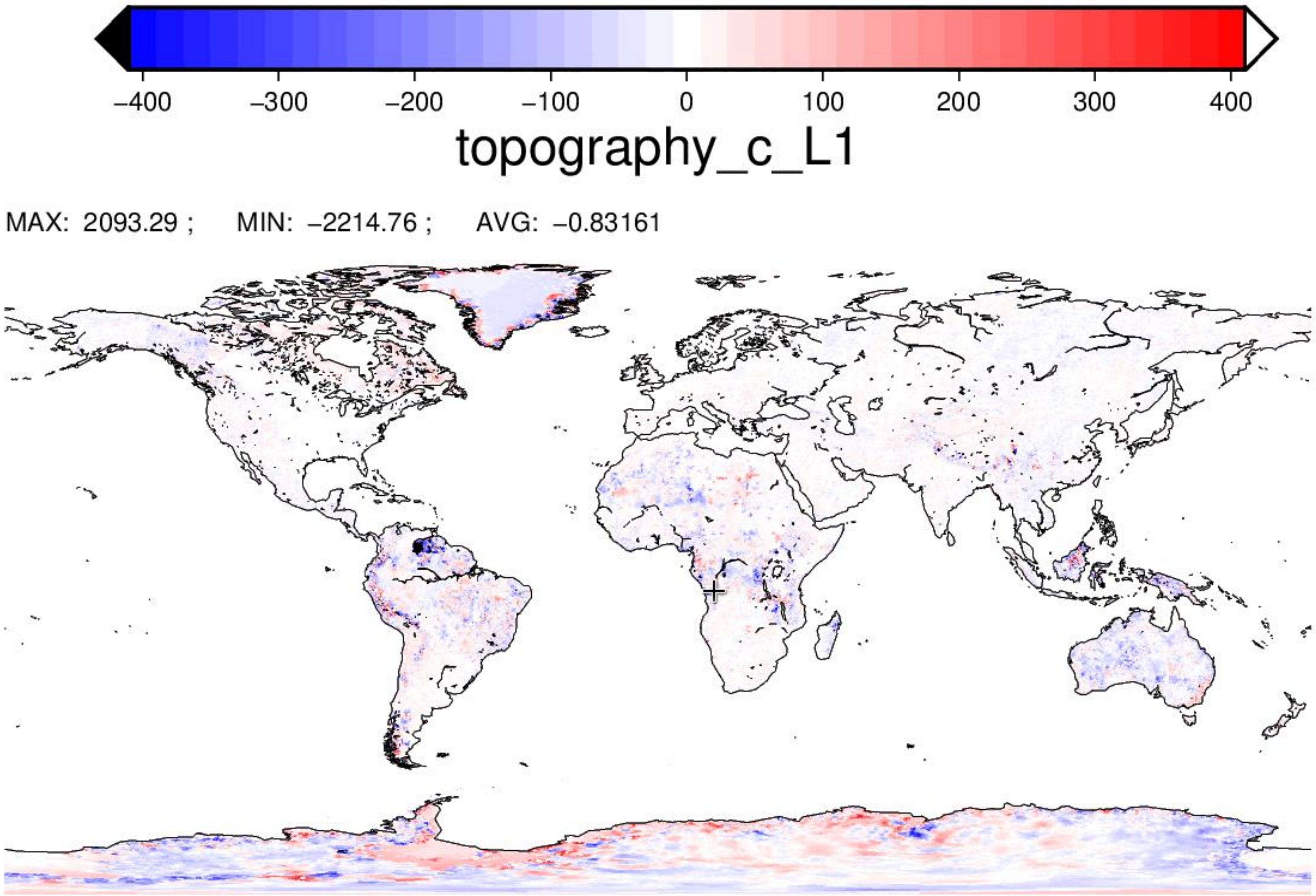
HiRes global orography needed

Application of geospatial data processing

- The GLOBE data set currently used for the global system has a rather coarse resolution (30´´) and known errors
- The high-resolution ASTER data set (1´) used for ICON-D2 is limited to 60°N-60°S
- Finding a global high-res data set without obvious quality issues turns out to be difficult; we thus decided to use a merge of MERIT (90°N-60°S) and REMA (62°S-90°S) data as an intermediate solution

- Most importantly, the higher raw data resolution allows a more accurate calculation of SSO parameters, which are highly relevant for the forecast quality in NH winter

Difference (MERIT/REMA – GLOBE) between ICON orographies for R3B7



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Additional processing steps

- The scaling parameters for SSO blocking and wave drag needed to be adjusted to the higher raw-data resolution
- It turned out to be beneficial to use SSO information even for marginal SSO standard deviations (cut in extpar reduced from 10 m to 1 m)

- Subsequent slides: result from an experiment with full data assimilation over 2.5 months (autumn/winter; difference would be smaller in NH summer)

Application of geospatial data processing

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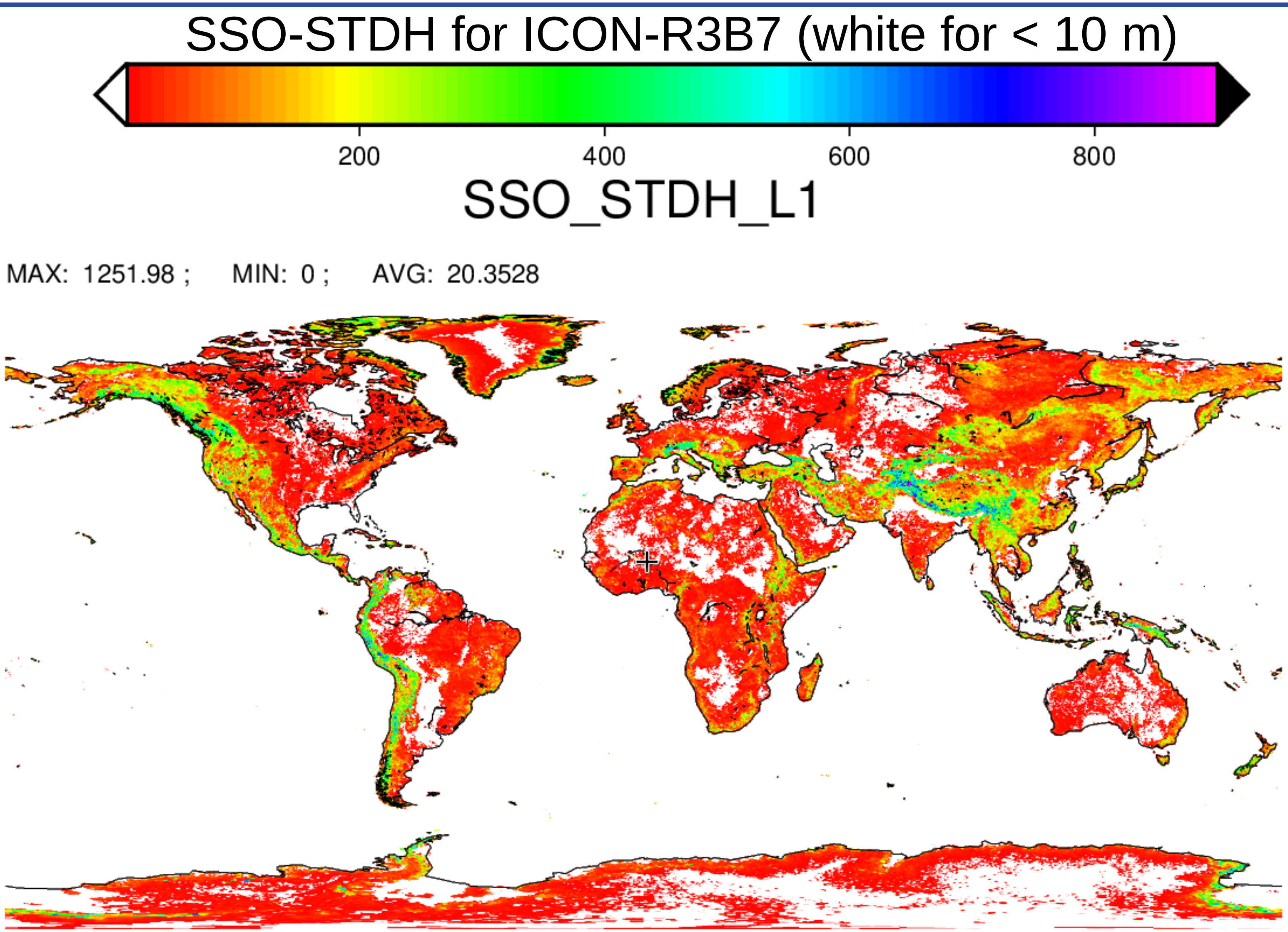

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Zoom at NW-Siberia: effect of reducing the ‚SSO cutoff‘ from 10 m to 1 m

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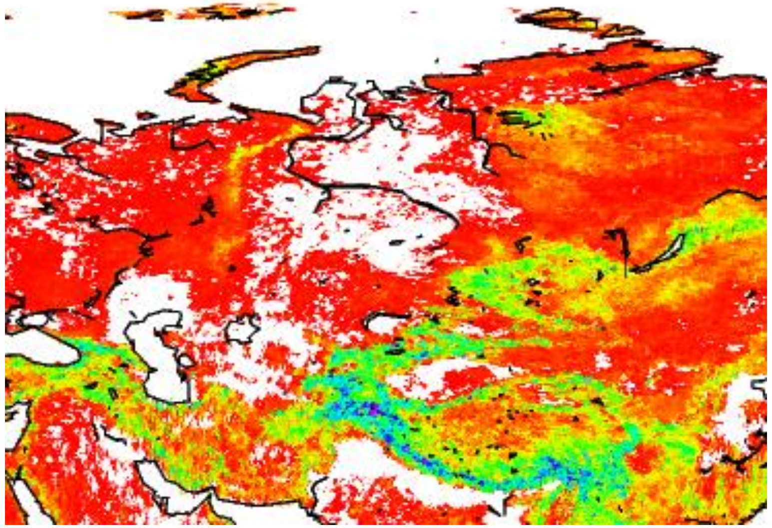
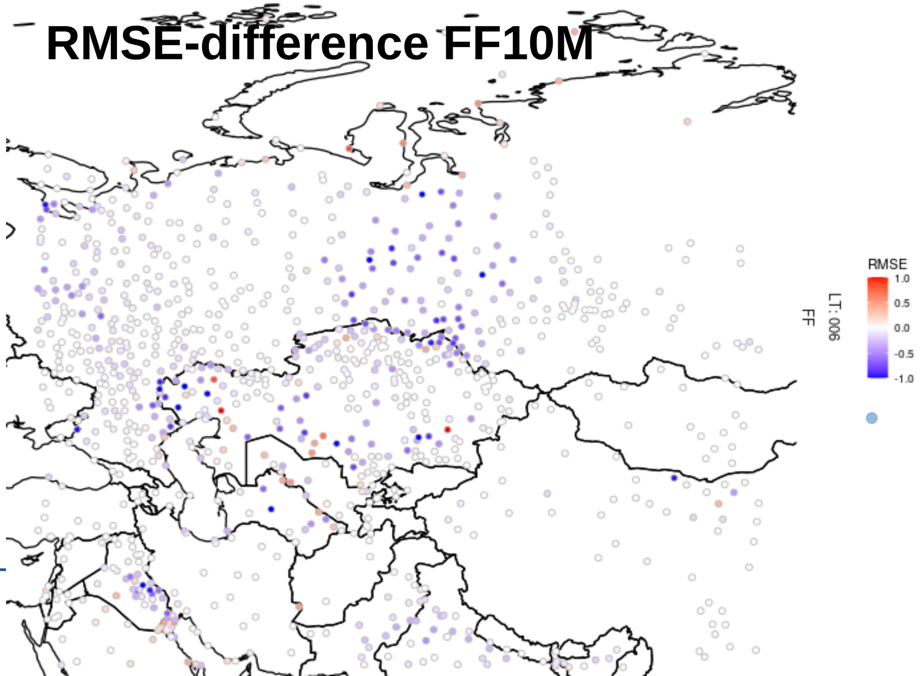
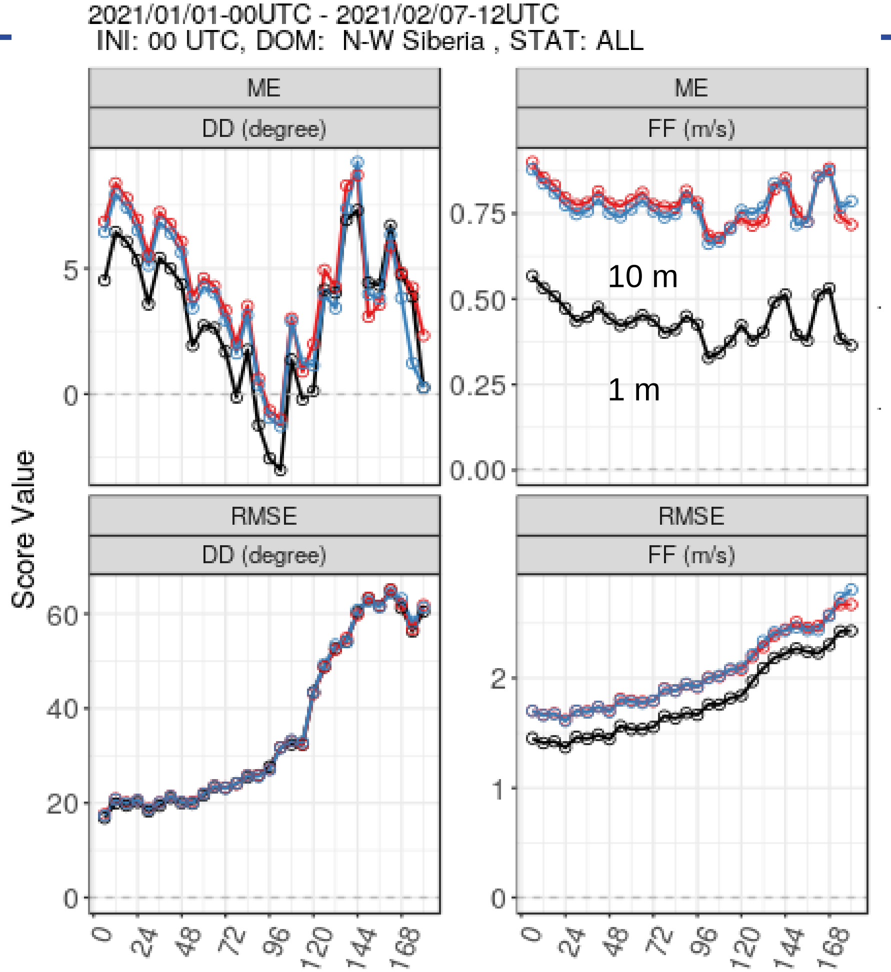


RMSE-difference FF10M





- Results from experiment with full data assimilation over 2.5 months (autumn/winter; difference would be smaller in NH summer)

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Scorecard DET SYNOP verification

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Key Takeaways - Geospatial Data in NWP and Climate Models

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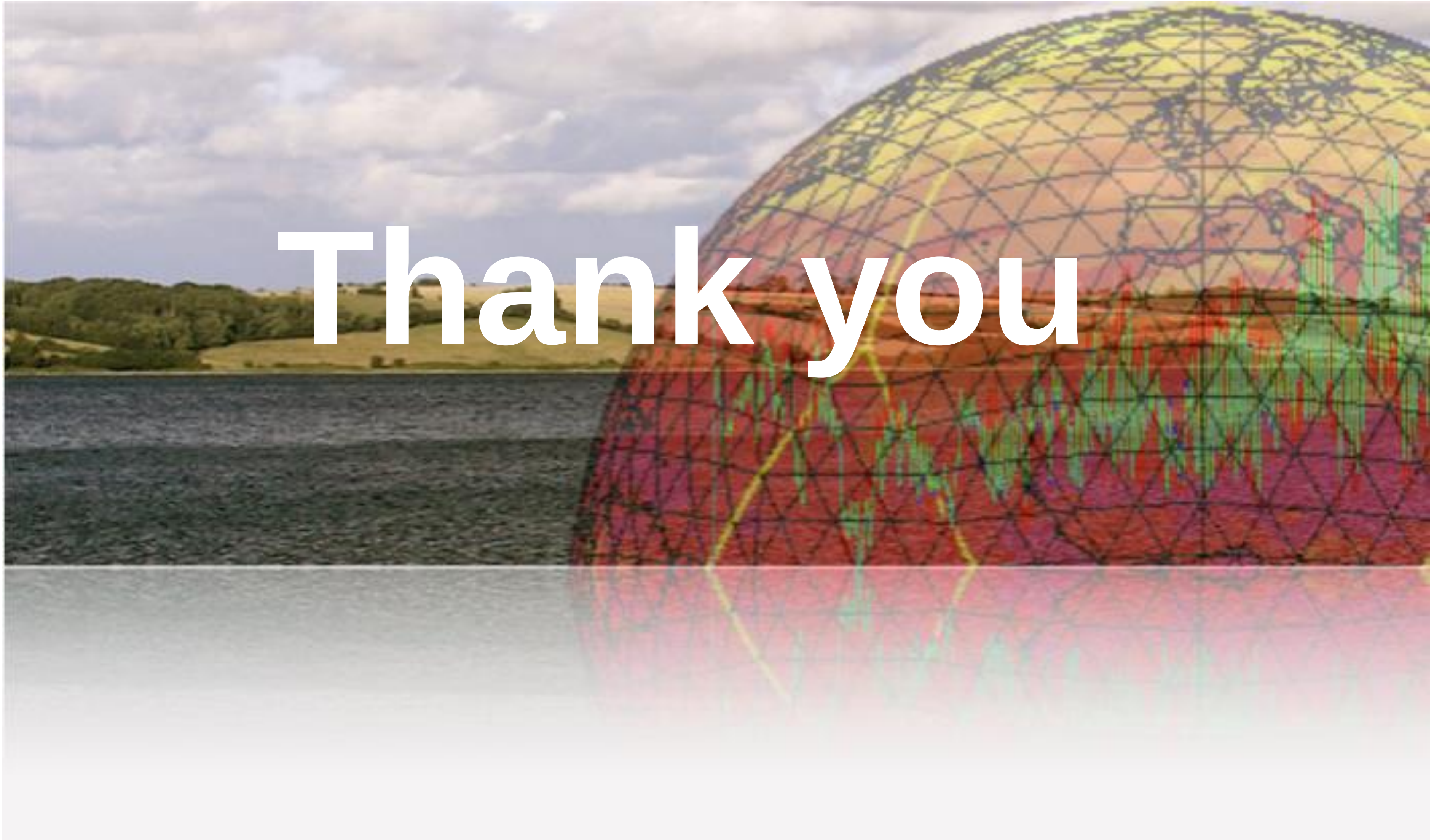
- **Role of Geospatial Data**: Critical for NWP and climate models (orography, land use, soil, vegetation, aerosols).
- **EXTPAR Integration**: Unified tool enhances data processing and quality assurance for ICON grids.
- **Impact**: Improved forecast accuracy through consistent data handling (e.g., MERIT/REMA orography).
- **Future Focus**: Expand dataset coverage (HiHydroSoil) and adapt to high-resolution modeling needs.



Thank you

Abstract

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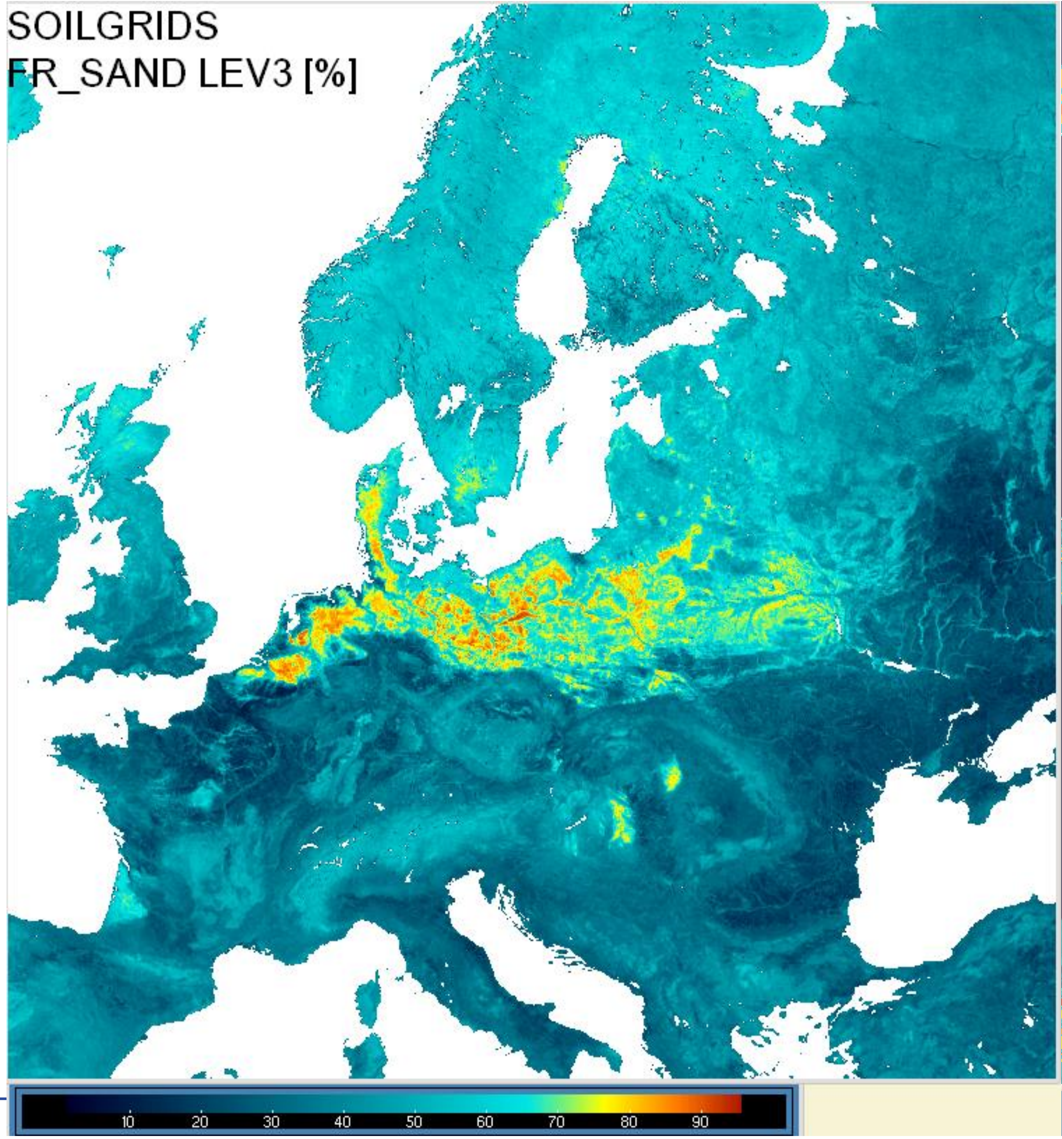
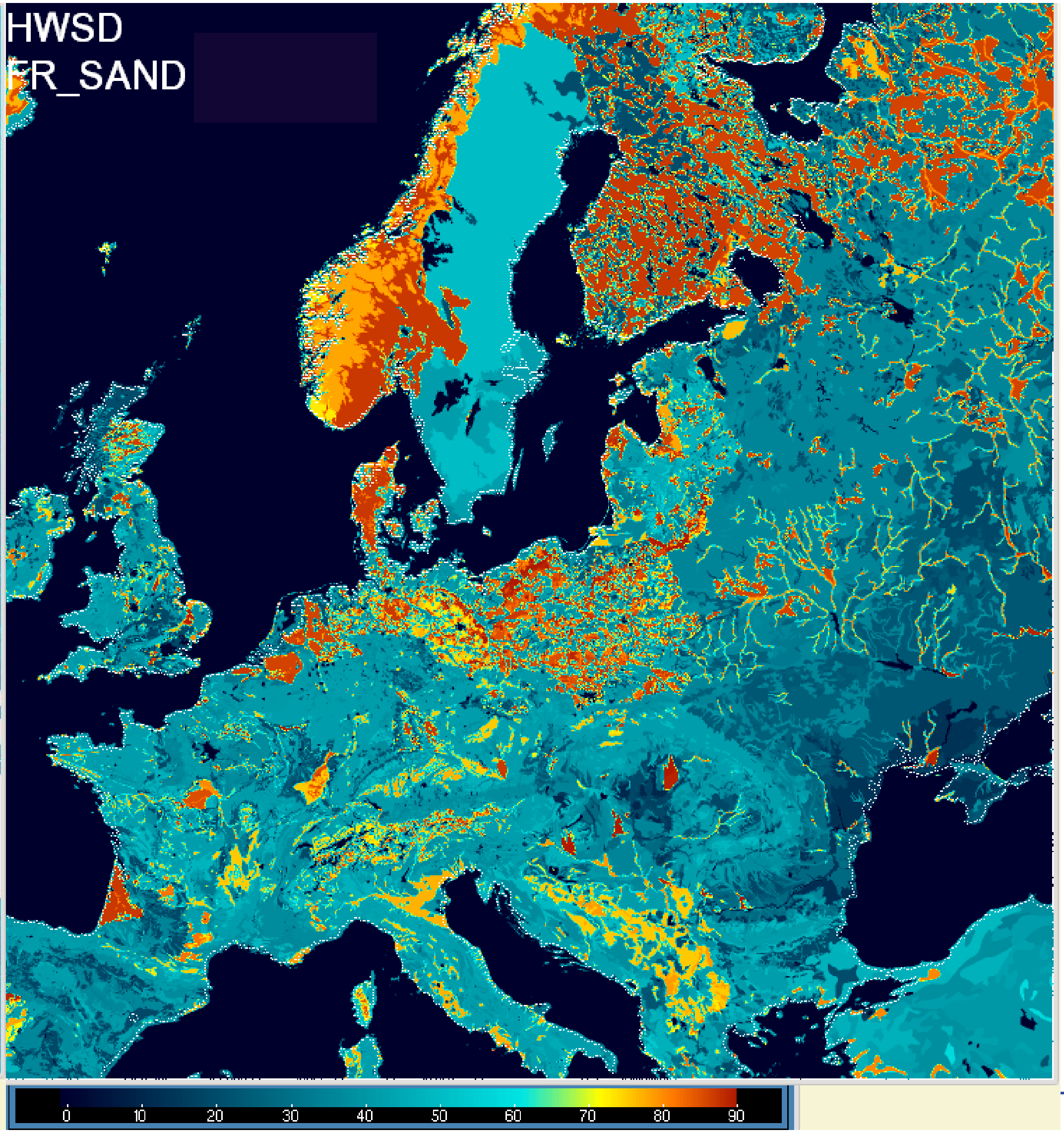
Geospatial datasets are pivotal for numerical weather prediction (NWP) and climate modeling, providing critical information on orography, land use, soil properties, vegetation, and radiative factors such as aerosols.
Rapid integration of new, high-resolution data sources into models is essential to keep pace with advancements in satellite technology and increasing model grid resolutions.
The geospatial data preprocessor EXTPAR has been unified and integrated as community software within the COSMO consortium. This robust and flexible tool supports the COSMO and ICON model grids in both NWP and climate applications, enabling streamlined processing and quality assurance of geospatial datasets.

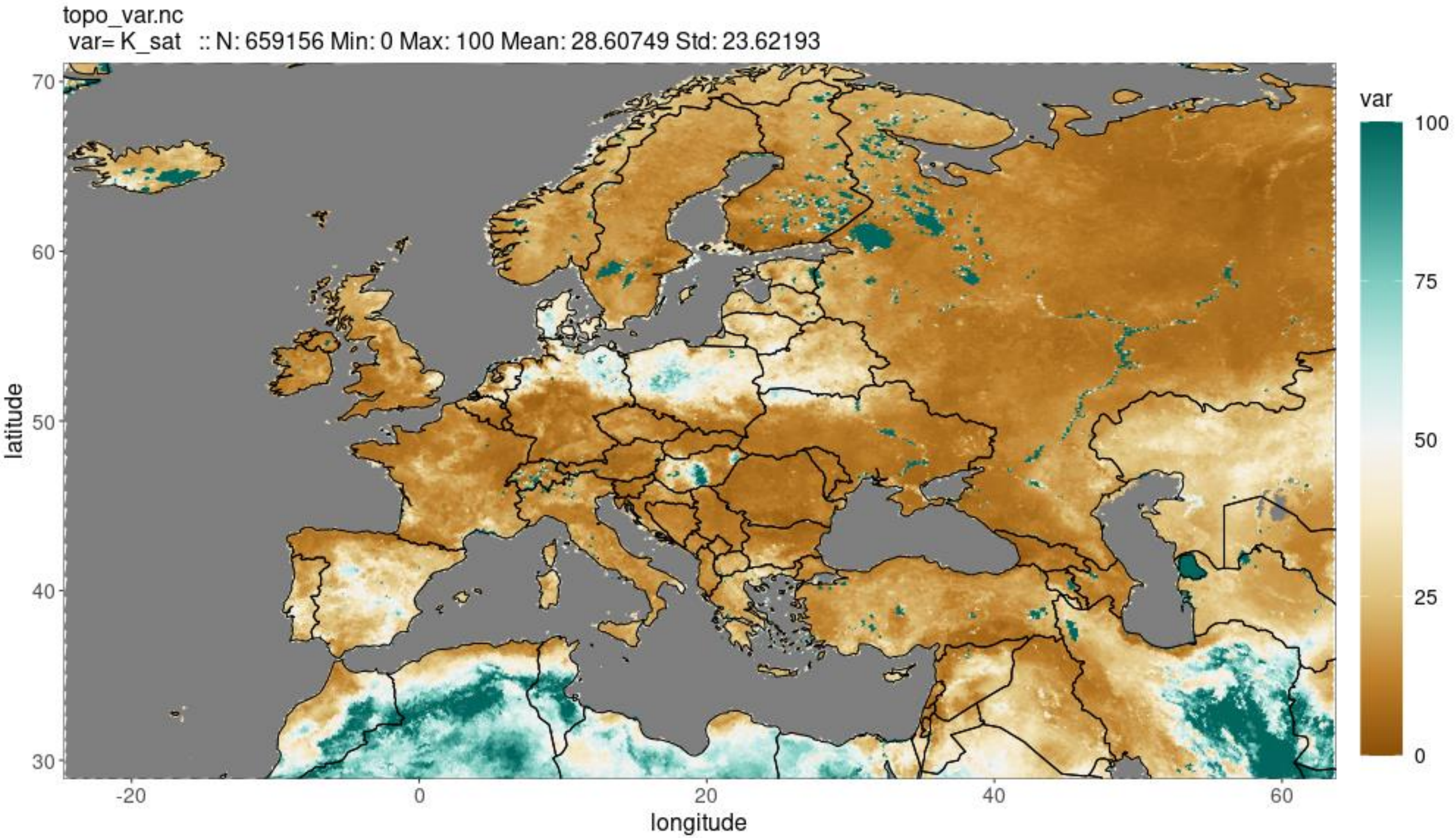
This presentation highlights the role of geospatial datasets in improving forecast accuracy in NWP and explores the outcomes of EXTPAR's integration as a shared resource. Specific examples will demonstrate how consistent and efficient geospatial data handling enhances model performance and facilitates the rapid adoption of new data sources. Future priorities include expanding dataset coverage and ensuring the tool remains adaptable to evolving scientific and operational needs.

Fraction of sand in soil data sets





HiHydroSoil v2.0 – hydraul. conductivity



ZKW [cm/d]

Simons et al., 2020: https://www.futurewater.nl/wp-content/uploads/2020/10/HiHydroSoil-v2.0-High-Resolution-Soil-Maps-of-Global-Hydraulic-Properties_v2.pdf

HiHydroSoil v2.0 – global physical parameters

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Table 5. Soil hydraulic properties included in the HiHydroSoil v2.0 database.

Name	Variable	Unit
ORMC	Organic Matter Content	%
STC	Soil Texture Class	O (Organic), VF (Very Fine), F (Fine), MF (Medium Fine), C (Coarse), M (Medium)
ALPHA	Alpha parameter for Mualem Van Genuchten Equation	1/cm
N	N parameter for Mualem Van Genuchten Equation	-
WCsat	Saturated Water Content	m^3/m^3
WCres	Residual Water Content	m^3/m^3
Ksat	Saturated Hydraulic Conductivity	cm/d
WCpF2	Water content at pF2 (field capacity)	m^3/m^3
WCpF3	Water content at pF3 (critical point)	m^3/m^3
WCpF4.2	Water content at pF4.2 (permanent wilting point)	m^3/m^3
WCavail	Available water content	m^3/m^3
SAT-FIELD	Water content between saturation point and field capacity (pF2)	m^3/m^3
FIELD-CRIT	Water content between field capacity (pF2) and critical point (pF3)	m^3/m^3
CRIT-WILT	Water content between critical point (pF3) and permanent wilting point (pF4.2)	m^3/m^3

- HiHydroSoil v2.0: Enhancing Global Soil Data
- Important input: ISRICS' **SoilGrids database**
- Addresses the limitations of global soil maps
- Data provided by HiHydroSoil v2.0:
  - Organic Matter Content
  - Soil Texture Class
  - Saturated Hydraulic Conductivity
  - Mualem van Genuchten parameters (Alfa and N)
  - Saturated Water Content
  - Residual Water Content
  - Water content at pF2, pF3, and pF4.2
  - Hydrologic Soil Group (USDA)

Simons et al., 2020: https://www.futurewater.nl/wp-content/uploads/2020/10/HiHydroSoil-v2.0-High-Resolution-Soil-Maps-of-Global-Hydraulic-Properties_v2.pdf

Soil hydraulic model

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Richards Equation: Flux

$$F = -\rho_w \left[-D(\theta) \frac{\partial \theta}{\partial z} + K(\theta) \right]$$

θ : volumetric soil moisture ([ ] = m^3 m^{-3})

Rijtema (1969):

$$K(\theta) = K_s \cdot \exp\left(kw_1 \frac{pv - \theta}{pv - adp} \right)$$

$$D(\theta) = D_s \cdot \exp\left(dw_1 \frac{pv - \theta}{pv - adp} \right)$$

Mualem (1976) – van Genuchten (1980):

$$\theta_f(\theta) = \frac{\theta - adp}{pv - adp}$$

$$K(\theta) = K_s \cdot \theta_f^{\frac{1}{2}} \cdot (1 - (1 - \theta_f^{\frac{1}{m}})^m)^2$$

$$D(\theta) = (1 - m) \frac{K_s}{m \cdot \alpha \cdot (zporv - zadp)} \cdot \theta_f^{(\frac{1}{2} - \frac{1}{m})} \cdot ((1 - \theta_f^{\frac{1}{m}})^{(-m)} + (1 - \theta_f^{\frac{1}{m}})^m - 2))$$

Retrieval of TERRA soil properties

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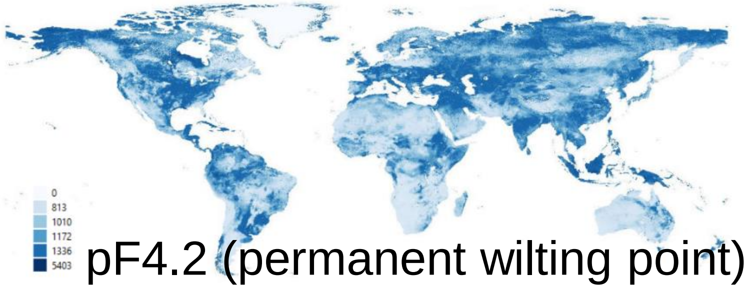
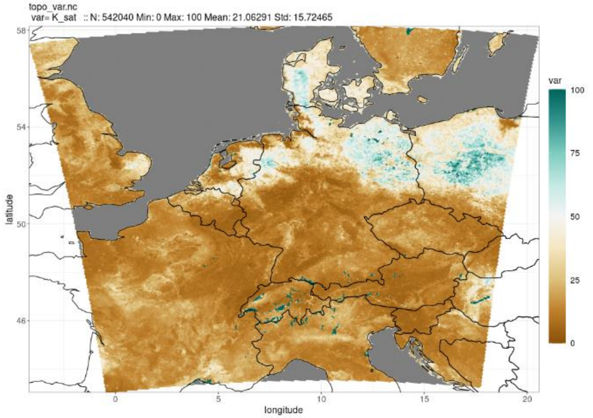
EXTPAR

Global physical parameters

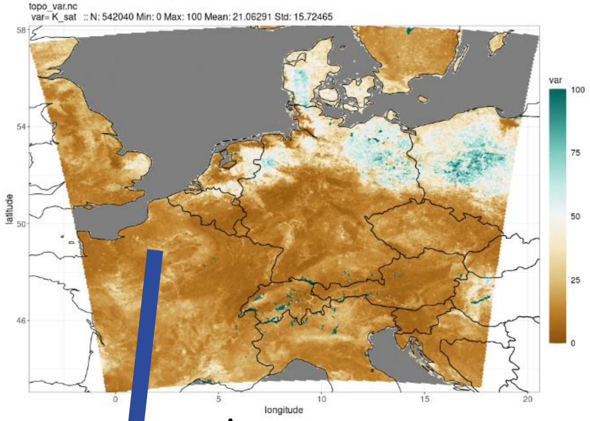


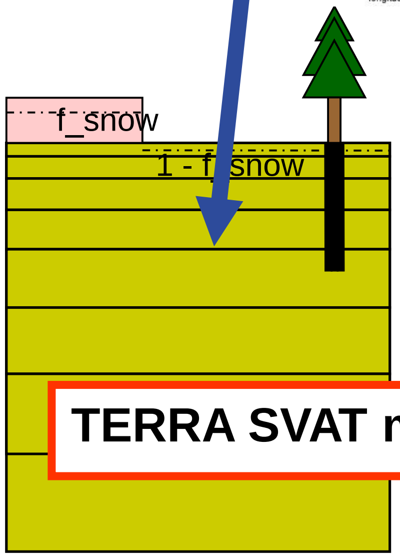
pF4.2 (permanent wilting point)

Mapping to ICON grid



ICON

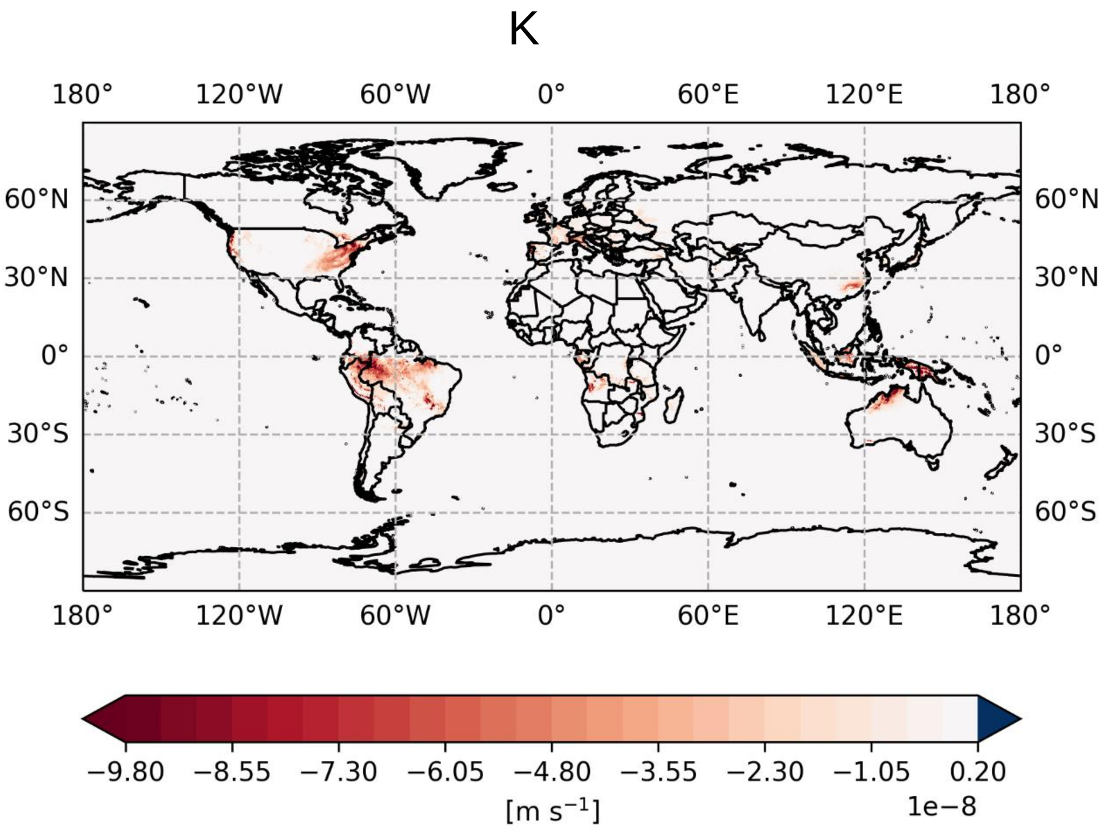


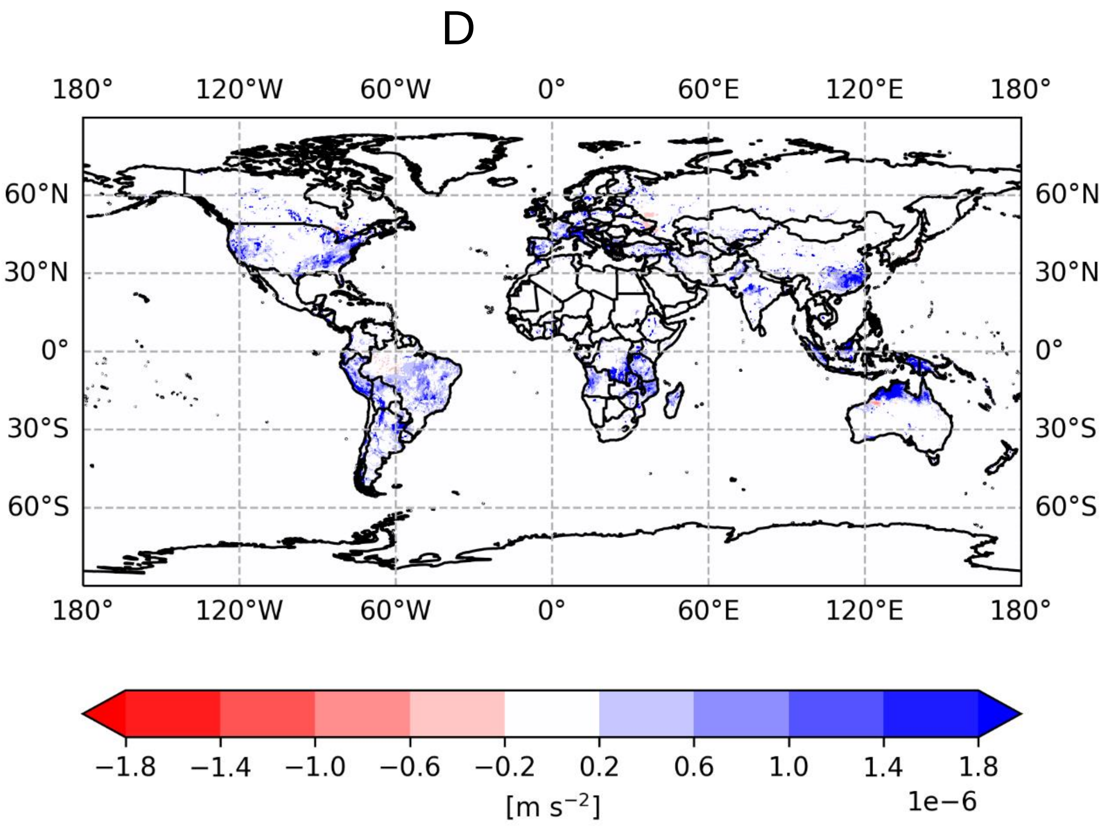


Direct usage of fields of physical parameters without look-up table

TERRA SVAT model

K and D
(difference HiHydroSoil+vanGenuchten – FAO+Rijtema)





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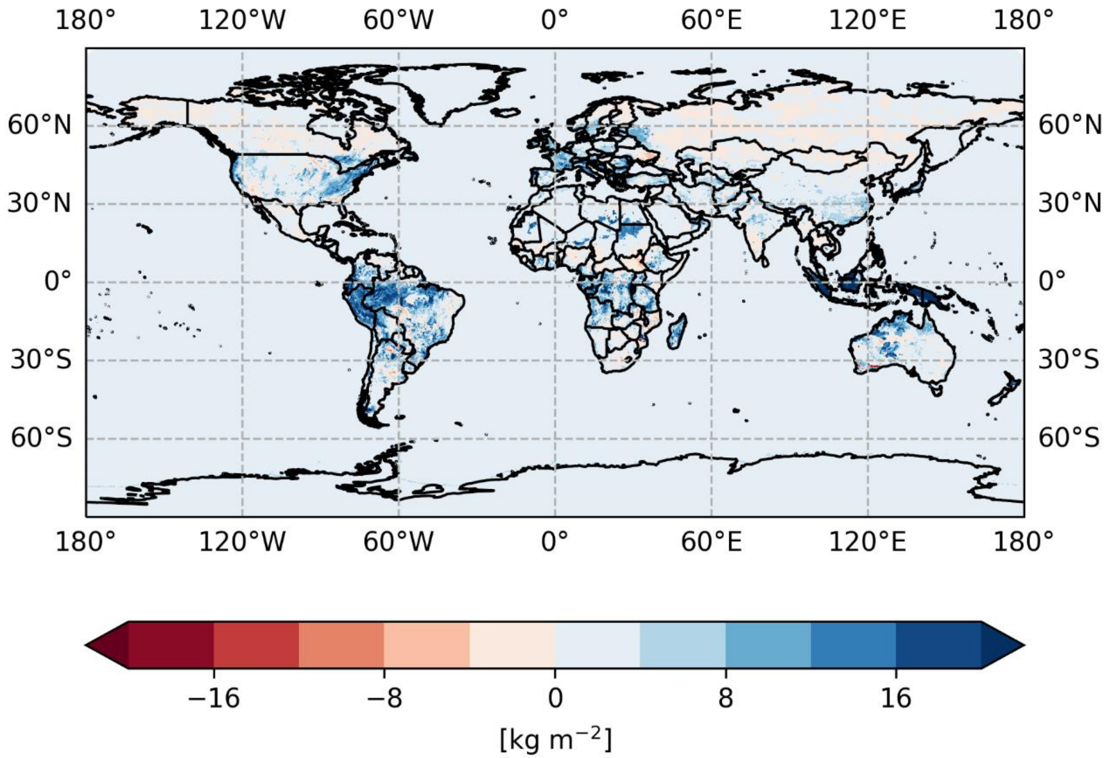
W_SO and T_SO (difference HiHydroSoil+vanGenuchten – FAO+Rijtema)

W_SO



T_SO