Updating the ESA Earth System Model for Future Gravity Mission Simulation Studies: ESA ESM 3.0

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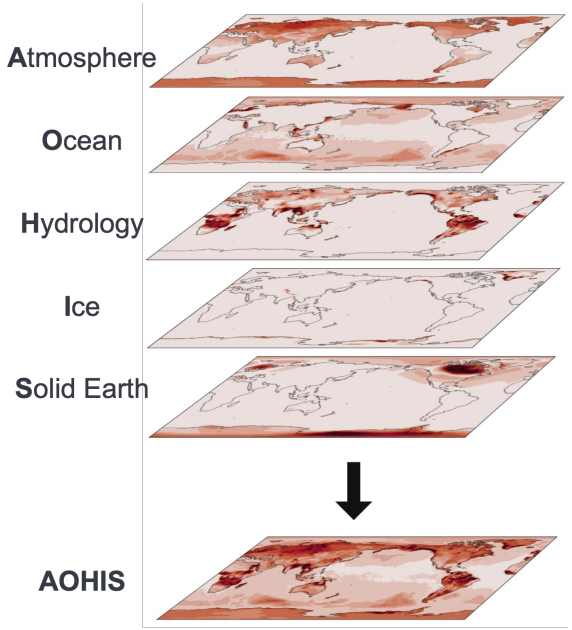
The ESA Earth System Model

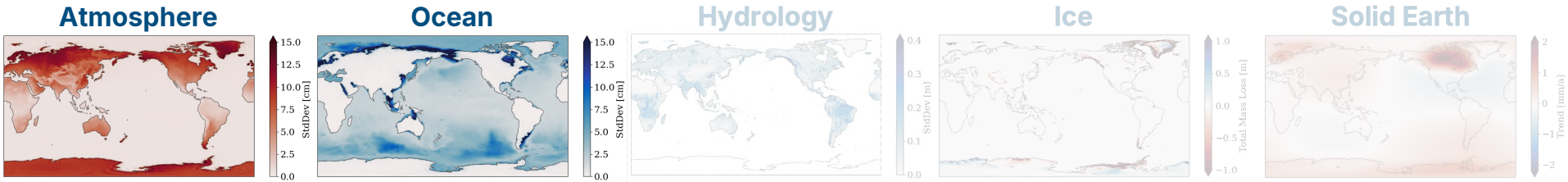
- Satellite simulations require reference model that captures mass redistribution across Earth's system

- Increased capabilities of future missions require ESM to include more comprehensive set of geophysical processes

→ Develop ESA ESM 3.0

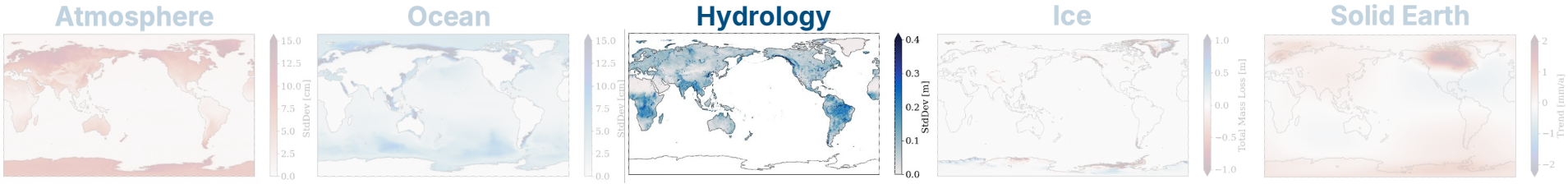


Updated Layers



- ECMWF ERA5 surface pressure anomalies & density anomalies in the upper atmospehre
- Ocean bottom pressure anomalies from MPIOM simulation
- Mass conservation for ocean layer

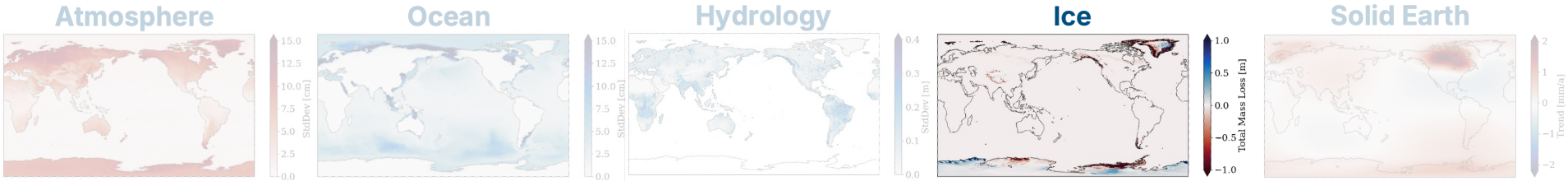
Updated Layers



- TWS from high-resolution OS LISFLOOD simulation
- Forced using ERA5
- Daily output
- Comparison to previous LSD model and details in:

Jensen et al. (2025), Global 0.05° water storage simulations with the OS LISFLOOD hydrological model for geodetic applications, GJI, 10.1093/gji/ggaf129

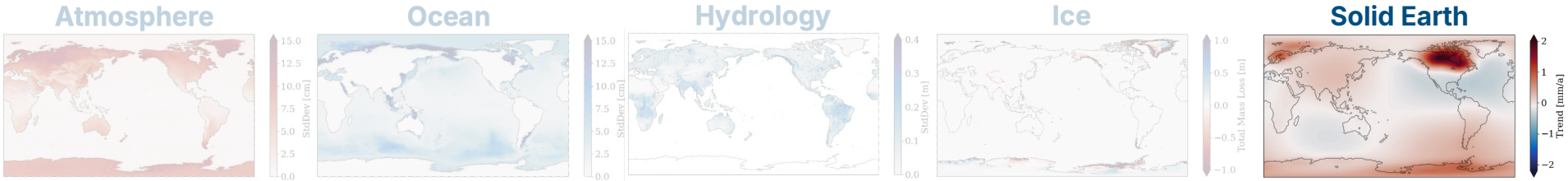
Updated Layers



- Developed in collaboration with I. Sasgen (AWI) & B. Wouters (TU Delft)

- Greenland & Antarctica: daily surface-mass balance + ice dynamics (trend + acc.)
- Glaciers:
  - Daily surface-mass balance or
  - High-resolution elevation change trends
- Arctic Permafrost based on latent heat change trend

Updated Layers

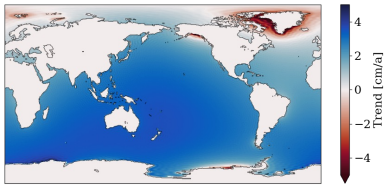


- Long-term trend from GIA
- Simulated with viscoelastic lithosphere and mantle model VILMA
- Include signals from low-viscosity zones and ice mass loading from little ice-age
- No earthquakes

- Include time-variable gravity model of the Earth's core in collaboration with H. Lecomte (Finnish Geospatial Research Institute)

New Layers

Sea Level



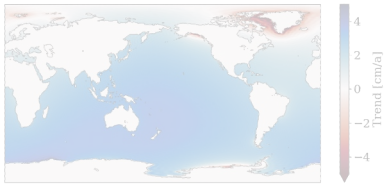
Earthquakes

AMOC / Sedimentation

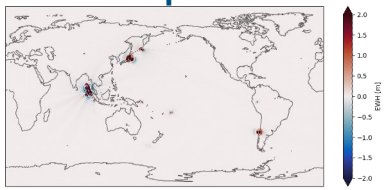
- Global mass conservation as separate layer
- Sea-level fingerprints as solution to elastic GRD
- Based on mass variations in A, H & I layers

New Layers

Sea Level



Earthquakes



AMOC / Sedimentation

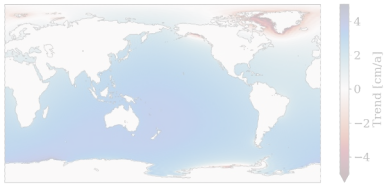
- Developed in collaboration with S.-C. Han (Ohio State), J. Sauber (GSFC), Y. Tanaka (U. Tokyo), C. Braitenberg (U. Trieste)

- Ensemble of 15 events
- Filtering to minimise Gibbs effects
- Additionally include Tsunami simulation for Tohoku & Sumatra-Andaman

Earthquake	Date	Magnitude
Amorgos	1956	M_w 7.7
Portugal	1969	M_w 7.8
Macquarie Island	2004	M_w 8.1
Sumatra-Andaman	2004	M_w 9.2
Nias-Simeulue	2005	M_w 8.6
Kuril Islands	2006/7	M_w 8.3
Bengkulu	2007	M_w 8.5
Samoa	2009	M_w 8.1
Maule	2010	M_w 8.8
Tohoku	2011	M_w 9.1
Indian Ocean	2012	M_w 8.6
Sea of Okhotsk	2013	M_w 8.3
Papua New Guinea	2016/17	M_w 8.1
Peru	2019	M_w 7.9
Kahramanmaras	2023	M_w 7.8

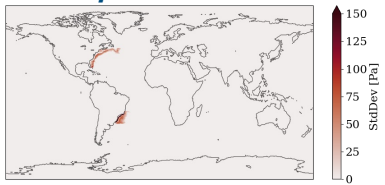
New Layers

Sea Level



Earthquakes

AMOC / Sedimentation



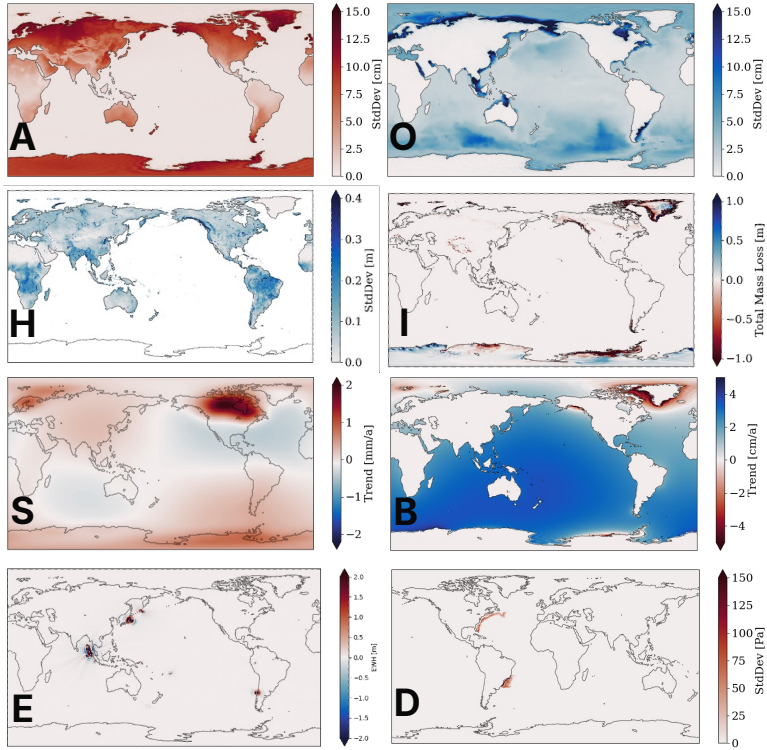
- OBP signals representing changes in meridional mass transports (AMOC)
- Based on VIKING20X high-resolution OGCM simulation in collaboration with GEOMAR
- Detailed assessment in:

  Shihora et al. (2025), Relating Atlantic meridional deep-water transport to ocean bottom pressure variations as a target for satellite gravimetry missions, Ocean Sci., 10.5194/os-21-1533-2025

- Include trends from erosion and marine deposition

Outlook

- ESA ESM 3.0 to cover 2007 – 2020
- Can be combined with ESA ESM 2.0 for longer time-series
- Resolution: 6h at d/o 180
- Identical file format as ESM 2.0
- Available end of 2025



The work presented here was performed as part of the project ‚NGGM and MAGIC Science and Applications Impact Study', ESA Contract No. 4000145265/24/NL/SC, funded by the European Space Agency

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