# ISDA-Online
**June 04, 2021 07 – 09 UTC**

## “Earth Systems Components and Further Applications of Data Assimilation”

*Organizers:* *Nora Schenk (DWD, Germany)*
*Jana de Wiljes (University of Potsdam, Germany)*
*Harrie-Jan Hendricks-Franssen (Forschungszentrum Jülich, Germany)*

**Program:**

**07:00 – 07:10** **Welcome**

**07:10 – 07:30** **The Seamless Sea Ice Prediction System Based on AWI-CM**
Longjiang Mu, Lars Nerger, Qi Tang, Helge Goessling

**07:30 – 07:50** **Reconstructing the Dynamics of the Outer Electron Radiation Belt by Means of the Standard and Ensemble Kalman Filter with the VERB-3D Code**
Angelica M. Castillo, Jana de Wiljes, Yuri Y. Shprits, Nikita A. Aseev

**07:50 – 08:10** **Socio-Hydrological Data Assimilation: Analyzing Human-Flood Interactions by Model-Data Integration**
Yohei Sawada, Risa Hanazaki

**08:10 – 08:30** **Estimating Thermophysical Properties of Asteroid (162173) Ryugu Using Data Assimilation**
Maximilian Hamm, Matthias Grott, Jana de Wiljes, Hiroki Senshu, Frank Scholten, Jörg Knollenberg, Klaus-Dieter Matz, Yuri Shimaki, Alessandro Maturilli, N. Sakanti, Tatsuaki Okada, Frank Preusker, Stephan Elgner, Seiji Sugita, Ralf Jaumann, Satoshi Tanaka

**08:30 – 08:50** **Inferring Mantle Viscosity Through Data Assimilation of Relative Sea-Level Observations in a Glacial Isostatic Adjustment Model**
Reyko Schachtschneider, Jan Saynisch-Wagner, Volker Klemann, Meike Bagge, Maik Thomas

**08:50 – 09:00** **Closing: Information on upcoming sessions**

Please note:

- When you login to the session before 07:00 UTC, and everything is quiet, this is most likely because we muted the microphones.
- The times in UTC are approximate. In case of technical problems, we might have to change the order of the presentations.
- **Time Zones**: 07 – 09 UTC
  08 – 10 am BST (London) | 09 – 11 am CEST (Berlin)
  03 – 05 pm CST (Shanghai) | 04 – 06 pm JST (Tokyo) | 05 – 07 pm AEDT (Sydney)
  00 – 02 am PDT (San Fran.) | 01 – 03 am MDT (Denver) | 03 – 05 am EDT (New York)

# The Seamless Sea Ice Prediction System Based on AWI-CM

Longjiang Mu[1,2], Lars Nerger[2], Qi Tang[2,3], Helge Goessling[2]

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AWI-CM is a fully-coupled climate model developed at Alfred Wegener Institute. It has an ocean/ice component with unstructured-mesh discretization and smoothly varying spatial resolution, which aims for seamless sea ice prediction across a wide range of space and time scales. The atmospheric component is ECHAM for version 1.0 and 2.0 and OpenIFS for version 3.0. We first implement multivariate data assimilation in the sea ice and ocean component in AWI-CM v1.0 using a Local Error Subspace Transform Kalman Filter coded in the Parallel Data Assimilation Framework. Perfect-model experiments configured to assimilate synthetic observations validate the robustness of the assimilation system. Real observations from sea ice concentration, thickness, drift, and sea surface temperature are further assimilated in the system. The analysis results are evaluated against independent in-situ observations and reanalysis data. Further experiments that assimilate different combinations of variables are conducted to understand their individual impacts on the analysis step. Particularly we find that assimilating sea ice drift improves the sea ice thickness estimate in the Antarctic, and assimilating sea surface temperature is able to avert a circulation bias of the free-running model in the Arctic Ocean at mid-depth.

We further implement the same system with more observations like sea level anomaly, sea surface salinity, and T/S profiles into the recently developed AWI-CM 3.0, which has 2.5 times ensemble members than its ancestor, however, with the same computation resources benefiting from the speed-up from the finite volume discretization in the new ocean component and the semi-Lagrangian advection scheme used in the OpenIFS. To also constrain the atmospheric component, the strongly coupled data assimilation and nudging in the atmospheric model is under research.

**Reconstructing the Dynamics of the Outer Electron Radiation Belt by Means of the Standard and Ensemble Kalman Filter with the VERB-3D Code**

Angelica M. Castillo[1], Jana de Wiljes[2], Yuri Y. Shprits[1,2,3],
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Reconstruction and prediction of the state of the near-Earth space environment is important for anomaly analysis, development of empirical models and understanding of physical processes. Accurate reanalysis or predictions that account for uncertainties in the associated model and the observations, can be obtained by means of data assimilation. The ensemble Kalman filter (EnKF) is one of the most promising filtering tools for non-linear and high dimensional systems in the context of terrestrial weather prediction. In this study, we adapt traditional ensemble based filtering methods to perform data assimilation in the radiation belts. We use a one-dimensional radial diffusion model with a standard Kalman filter (KF) to assess the convergence of the EnKF. Furthermore, with the split-operator technique, we develop two new three-dimensional EnKF approaches for electron phase space density that account for radial and local processes, and allow for reconstruction of the full 3D radiation belt space. The capabilities and properties of the proposed filter approximations are verified using Van Allen Probe and GOES data. Additionally, we validate the two 3D split-operator Ensemble Kalman filters against the 3D split-operator KF. We show how the use of the split-operator technique allows us to include more physical processes in our simulations and offers computationally efficient data assimilation tools that deliver accurate approximations to the optimal solution of the KF and are suitable for real-time forecasting. Future applications of the EnKF to direct assimilation of fluxes and non-linear estimation of electron lifetimes are discussed.

# Socio-Hydrological Data Assimilation: Analyzing Human-Flood Interactions by Model-Data Integration

Yohei Sawada[1], Risa Hanazaki[1]

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In socio-hydrology, human–water interactions are simulated by mathematical models. Although the integration of these socio-hydrological models and observation data is necessary for improving the understanding of human–water interactions, the methodological development of the model–data integration in socio-hydrology is in its infancy. Here we propose applying sequential data assimilation, which has been widely used in geoscience, to a socio-hydrological model. We developed particle filtering for a widely adopted flood risk model and performed an idealized observation system simulation experiment and a real data experiment to demonstrate the potential of the sequential data assimilation in socio-hydrology. In these experiments, the flood risk model's parameters, the input forcing data, and empirical social data were assumed to be somewhat imperfect. We tested if data assimilation can contribute to accurately reconstructing the historical human–flood interactions by integrating these imperfect models and imperfect and sparsely distributed data. Our results highlight that it is important to sequentially constrain both state variables and parameters when the input forcing is uncertain. Our proposed method can accurately estimate the model's unknown parameters – even if the true model parameter temporally varies. The small amount of empirical data can significantly improve the simulation skill of the flood risk model. Therefore, sequential data assimilation is useful for reconstructing historical socio-hydrological processes by the synergistic effect of models and data.

Reference

Sawada, Y. and Hanazaki, R.: Socio-hydrological data assimilation: analyzing human–flood interactions by model–data integration, Hydrol. Earth Syst. Sci., 24, 4777–4791, https://doi.org/10.5194/hess-24-4777-2020, 2020.

**Estimating Thermophysical Properties of Asteroid (162173) Ryugu using Data Assimilation**

Maximilian Hamm[1,2], Matthias Grott[2], Jana de Wiljes[1], Hiroki Senshu[3], Frank Scholten[2], Jörg Knollenberg[2], Klaus-Dieter Matz[2], Yuri Shimaki[4], Alessandro Maturilli[2], N. Sakanti[5], Tatsuaki Okada[4], Frank Preusker[2], Stephan Elgner[2], Seiji Sugita[6], Ralf Jaumann[7], Satoshi Tanaka[3]

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The Japanese Hayabusa2 sample return mission brought the MASCOT lander to the surface of asteroid (162173) Ryugu. Part of the payload of MASCOT was a radiometer (MARA) that observed the surface temperature of a single boulder in front of it for an entire asteroid rotation. MARA features six sensors observing the surface through different mid-infrared filters, i.e. two broad-band filters and four narrow-band filters. Using a thermophysical model we calculate the diurnal temperature variation on a multi-scale digital terrain model incorporating a detailed 3D shape model of the observed boulder into the terrain model of the landing site. The estimation of thermophysical properties is usually done by fitting temperature variations calculated by thermophysical models to infrared observations. For multiple free model parameters, traditional methods such as least-squares fitting or Markov chain Monte Carlo methods become computationally too expensive. Consequently, the simultaneous estimation of several thermophysical parameters, together with their corresponding uncertainties and correlations, is often not computationally feasible and the analysis is usually reduced to fitting one or two parameters. Data assimilation (DA) methods have been shown to be robust while sufficiently accurate and computationally affordable even for a large number of parameters. In this work we retrieve six model parameters, i.e., thermal inertia and emissivity spectrum of the boulder from the MARA observation by applying an Ensemble Square Root Filter. Preliminary results indicate a low bulk thermal inertia, implying high porosity, while the emissivity appears to be similar to the most primitive carbonaceous chondrites.

**Inferring Mantle Viscosity Through Data Assimilation of Relative Sea-Level Observations in a Glacial Isostatic Adjustment Model**

Reyko Schachtschneider[1], Jan Saynisch-Wagner[1], Volker Klemann[1], Meike Bagge[1], Maik Thomas[1,2]

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We present a data assimilation algorithm for the time-domain spectral-finite element glacial isostatic adjustment code VILMA. With this data assimilation approach we show in a synthetic setting that we are able to constrain the mantle viscosity structure with the help of paleo sea level observations. We consider a 1D earth structure and a prescribed glaciation history ICE5G for the external mass load forcing. The Parallel Data Assimilation Framework (PDAF) is used to assimilate sea level observations into the model. For this purpose, we apply a particle filter with resampling and perturbation. The assimilation period starts shortly before the last glacial maximum and lasts until present day. At epochs when observations are available, each particle's performance is estimated and they are resampled based on their performance to form a new ensemble that better resembles the true viscosity distribution.

Using this algorithm we show the ability to recover mantle viscosities from relative sea-level observations obtained in a identical twin setup. We use various subsets of real observation locations as locations for synthetic observations and show that it is possible to obtain the target viscosity values in those cases. We also vary the time period in which observations are available to evolve the test cases towards a realistic scenario for the availability of relative sea-level observations. The viscosity estimation technique is applied to a three-layer model with a fixed elastic lithosphere and two mantle layers, and to a 1D-model with a viscosity profile in 152 mantle layers.