ISDA-Online

Thursday, February 13, 2025 from 15 – 17h UTC

“Coupled Data Assimilation”

Organizers: *Clara Draper (NOAA, US)*
Philip Browne (ECMWF, UK)
Qi Tang (University of Neuchâtel/University of Basel, Switzerland)
Philipp Griewank (University of Vienna, Austria)
Nora Schenk (DWD, Germany)

Coupled data assimilation, spanning weakly and strongly coupled methods, is critical for improving predictions across interconnected Earth system components. We invite contributions on theoretical and applied aspects of coupled data assimilation in systems integrating model components such as atmosphere, ocean, sea ice, land, and hydrology, with a focus on how coupling improves model accuracy and captures system interactions in global, regional, and idealized contexts.

Program:

15:00 – 15:10 **Welcome**

(30min invited talk + 5min Q&A)

15:10 – 15:45 **Treating different timescales in weakly-coupled variational data assimilation**
Amos S. Lawless, Nancy K. Nichols

(17min contributed talks + 3min Q&A each)

15:45 – 16:05 **Estimating background errors crossed covariances for an ocean-atmosphere coupled EDA**
Argan Purcell, Pierre Brousseau, Loïk Berre, Sylvie Malardel

16:05 – 16:25 **Pre-operational performance of NCMRWF Coupled NWP system**
Sumit Kumar, Imranali M. Momin, K. Niranjan Kumar, Sukhwinder Kaur, Sushant Kumar, John P. George, V. S. Prasad

16:25 – 16:45 **Outer loop coupled data assimilation for the land surface**
Christoph Herbert, Peter Weston, Patricia de Rosnay, Sébastien Massart

16:45 – 17:00 **Closing / Outlook**

<u>Please note:</u>

- When you login to the session before 15:00 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**: 15 – 17 UTC
  03 – 05 pm GMT (London) | 04 – 06 pm CET (Berlin)
  11 – 01 am CST (Shanghai) | 00 – 02 am JST (Tokyo) | 02 – 04 am AEDT (Sydney)
  07 – 09 am PST (San Fran.) | 08 – 10 am MST (Denver) | 10 – 12 am EST (New York)

Treating different timescales in weakly-coupled variational data assimilation

Amos S. Lawless[1,2], Nancy K. Nichols[1,2]

[1]University of Reading, UK
[2]National Centre for Earth Observation, UK

The length of the assimilation window in variational data assimilation is usually chosen according to the error growth rate of the underlying physical system. For atmospheric data assimilation the window is usually 6-12 hours at synoptic scales, with much smaller windows at convective scales. For ocean data assimilation windows of a few days can be chosen, reflecting the slower timescales of the ocean. When implementing variational data assimilation systems for coupled atmosphere-ocean models, many operational forecasting centres have initially opted to implement weakly-coupled assimilation, in which the coupled model is used to provide the background forecast and calculate the innovations, while the analysis increments are calculated separately for the atmosphere and ocean. In this case the assimilation window length must be the same for both the atmosphere and ocean, and is chosen according to the faster error growth timescales of the atmosphere. This leads to a sub-optimal use of the sparser and less frequent ocean observations.

In previous presentations we have demonstrated a method for treating the different timescales that applies a long-window smoother step in the ocean after the usual cycled, weakly-coupled assimilation steps. Here we introduce a new, alternative method for treating the different timescales in the problem. We propose to perform the data assimilation over a long window determined by the ocean timescales, but to treat the atmospheric model as a weak-constraint over this window. The long window is divided into sub-windows whose length are determined by the atmospheric timescales, and the atmospheric model is only assumed to be perfect over each sub-window. We will present both algorithms and compare them numerically with the standard weakly-coupled assimilation using a 5-variable idealised model. We will then show some further results for the smoother method with a new coupled model based on the Lorenz-96 equations.

Estimating background errors crossed covariances for an ocean-atmosphere coupled EDA

Argan Purcell[1], Pierre Brousseau[1], Loïk Berre[1], Sylvie Malardel[1]

[1]Météo-France, CNRM, France

Coupled data assimilation is said to be strongly coupled when two different media are treated as one during the assimilation step, with observations affecting both media in the assimilation computation. In EnVar systems, background error covariances are not parameterized but rather estimated from an ensemble of predictions. Therefore, EnVar is an ideal framework to develop a strongly coupled DA : background error cross-covariances between both media are directly available from the ensemble, provided the required coupling is represented in the perturbed forecast step. At Météo-France the convective scale limited-area model AROME uses a 3DEnVar assimilation scheme operationally since the 15th of October 2024. Background perturbations come from an ensemble of data assimilation (EDA), whose aim is to simulate the propagation of errors throughout the cycled analysis and forecast steps. In addition to auto-covariances, this study aims to estimate ensemble background error statistics and ensemble ocean/atmosphere cross-covariances in particular, in order to assess if they could be used in a strongly coupled ocean-atmosphere EnVar scheme. To achieve this goal, an EDA has been built using a perturbed Mixing Ocean Layer model in the forecast steps. A version of this EDA over the AROME Indian Ocean domain has been cycled from the 31st of January 2022 to the 8th of February 2022 to study background error covariances during the Batsirai tropical cyclone. We will investigate to which extent the EDA represents uncertainties in the cyclone position and trajectory. Furthermore we will study whether the EDA is able to provide relevant background error statistics, and ocean-atmosphere cross-covariances in particular, as well as their potential flow-dependent variations.

Pre-operational performance of NCMRWF Coupled NWP system

Sumit Kumar[1], Imranali M. Momin[1], K. Niranjan Kumar[1],
Sukhwinder Kaur[1], Sushant Kumar[1], John P. George[1], V. S. Prasad[1]

[1]National Centre for Medium Range Weather Forecasting, India

National Centre for Medium Range Weather Forecasting (NCMRWF) operationally employed a global NWP system for weather forecasting, called NCUM, which is an adaptation of Unified Model (UM) seamless prediction system of “UM Partnership”. This NWP system is being continuously updated, such as adapting Hybrid-4D-Var system and Atmosphere-Land model, inclusion of variational bias correction scheme etc. to advance its forecast accuracy. In a quest to further improve the forecasting capability of NCUM, NCMRWF is planning to operationalize a coupled (Atmosphere-Land-Ocean-SeaIce) data assimilation cum NWP system (named C-NCUM) in the first quarter of 2025. This coupled system is comprised of weakly coupled data assimilation system, in which atmospheric assimilation is based on 4D-Var/Hybrid 4D-Var, whereas ocean and sea ices assimilation uses 3D-Var and land data assimilation is based on Extended Kalman Filter method. Various observations (land. atmosphere and ocean), both in-situ and remotely sensed are used in C-NCUM system, like the use of INSAT, ATOVS, IASI, AMSR2, JASON3, GPSRO, Radiosonde, SHIP, BUOY, Wind Profiler, etc. Coupled NWP system experiments were carried out, in parallel with operational uncoupled NWP system, to understand the impact of ocean and sea-ice coupling on monsoon as well as tropical cyclone forecasting during 2024 and 2023. The comparison of coupled and uncoupled NWP models highlights significant advantages of the coupled approach, particularly in forecasting extreme weather events. Preliminary results from the two experiments (coupled vs. uncoupled) indicate that the coupled NWP model demonstrates superior performance in terms of lead time and spatial location accuracy. This improvement is likely attributable to the integration of atmospheric, land and oceanic processes, enabling coupled models to dynamically simulate interactions between different components of the Earth system and thereby reduce spatial location errors.

Outer loop coupled data assimilation for the land surface

Christoph Herbert[1], Peter Weston[1], Patricia de Rosnay[1], Sébastien Massart[1]

[1]ECMWF, UK

The land-atmosphere coupling approach in current state-of-the-art NWP systems is based on weakly coupled data assimilation for individual Earth-system components, where atmospheric and land surface analyses are performed separately. This can lead to unbalanced initial conditions, and observations often cannot be fully harnessed if they are assimilated differently in one or both components within the same assimilation window. At ECMWF, a “quasi-strongly” coupled assimilation approach is being developed based on an "outer loop land-atmosphere coupling", exploiting the incremental formulation of the 4D-Var implementation for atmospheric analysis. Ongoing investigation includes activating the SEKF in multiple 4D-Var outer loops within the same assimilation window to initialise subsequent outer loops from updated land and atmospheric fields. The aim is to attain a configuration with an optimal degree of coupling that best balances the information between land and atmospheric variables. A new method using an eXtended Control Vector (XCV) had been developed where the 4D-Var control vector is extended by a selected number of surface-sensitive variables. The XCV approach is used for additional variables including skin and first-layer soil temperature, which are adjusted in the model space during the atmospheric analysis to achieve optimal accuracy. This work presents the results of numerical experimentation based on the latest outer loop coupling developments and the assessment of assimilating XCV first-layer soil temperature analysis fields as pseudo observations into the SEKF. The impact is evaluated in terms of atmospheric forecast skill and validation against observations such as the land surface temperature from the Spinning Enhanced Visible and Infrared Imager (SEVIRI). The infrastructure with increased coupling enables better exploitation of interface observations so that they can simultaneously influence the analysis of both the land and the atmosphere.