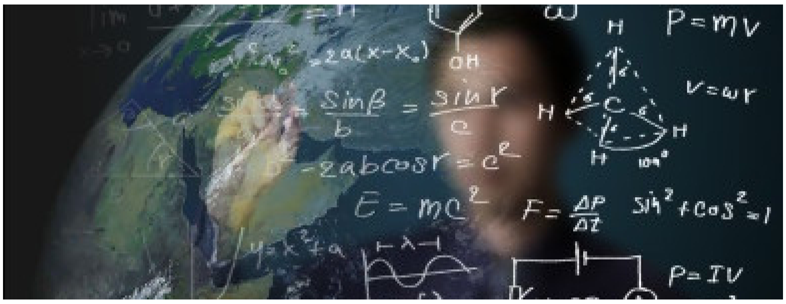
Climate Model Initialization and Data Assimilation



At sub-seasonal to interannual time scales, climate predictability is thought to arise significantly from the knowledge of initial conditions. Initializing climate models with observationally-based estimates is a very challenging task scientifically, but also technically.

Summary

Owing to their large thermal inertia, the world oceans are often cited as the main source of predictability of our climate at sub-seasonal to multi-decadal time scales. Recent studies (e.g., *Bellucci et al., 2015*) have revealed that other components of the climate system also bear memory for our climate system, up to a few years at least. Sea ice, land, soil moisture, stratosphere and aerosols are all examples of such drivers.

Accurate near-term predictions from climate models rely, among others, on a realistic specification of initial conditions. The problem is simple to state, but difficult to address for two reasons: (1) the observational coverage is sparse, (2) climate models "live" in their preferred state.

The observational coverage is sparse. The first issue is technical. Heat content of the oceans, sea ice thickness, moisture of the soil are all examples of quantities that are known to be important for climate predictability. They also share one common problem: it is impossible to estimate them accurately only from observations and on large scales. This is why it is often not possible to directly use observational information to initialize climate models: significant gaps are present and not all the variables that the model needs to restart can be observed.

Climate models live in their preferred state. The second issue is physical. Even if we could measure all climate variables and build the perfect set of initial conditions for our models, predictions would still "feel" the effect of the initialization. This is because climate models have systematic biases (see the Research Line on Bias Development Mechanisms): they will always tend to catch up with their own, preferred state even if we forced the model to be close to observations at initialization time.

Accordingly, the *Climate Model Initialization and Data Assimilation Research Line* of the Climate Prediction Group works on two fronts.

In the first front, several methods are explored to propagate observational information into the model. Some of our predictions are initialized from existing reanalyses (GLORYS, ORAS4/5, in-home sea ice reconstructions, ERA-Interim for the atmosphere and ERA-land for soil moisture). We literally "plug" these reanalyses into EC-Earth and let the model evolve afterwards. We also explore another method of intialization: EC-Earth is run and is nudged (i.e., restored) to some reference data during the simulation. The simulation is then stopped at the time of initialization, and the current state of the system is used to initialize our predictions. This second method is much more expensive to implement, but also believed to be much smoother and consistent physically. However, none of the methods was found to be superior at this stage.

The second front explores methods to account for model systematic biases during initialization. One common way to get rid of model biases is to assimilate observational *anomalies* rather than the raw values, so that the model is not forced to live in a state that is incompatible with its own climate. However, the so-called "anomaly-initialization" raises new challenges: there is evidence that mean state and anomalies are not entirely decoupled. In addition, the nonlinear relationships between state variables, as for example seawater temperature and salinity, are not preserved in this approach. Again, while "full-field" and "anomaly" initialization have their own advantages, it is difficult to determine which one is superior to the other.

Objectives

The objectives of this Research Line are to:

- Gather observational data (land, ocean, sea ice) from observations or reanalyses, in order to use them later on for the initialization of climate predictions
- Investigate the role of underlying observational data on climate forecast skill and bias
- Implement, test and compare different initialization methods