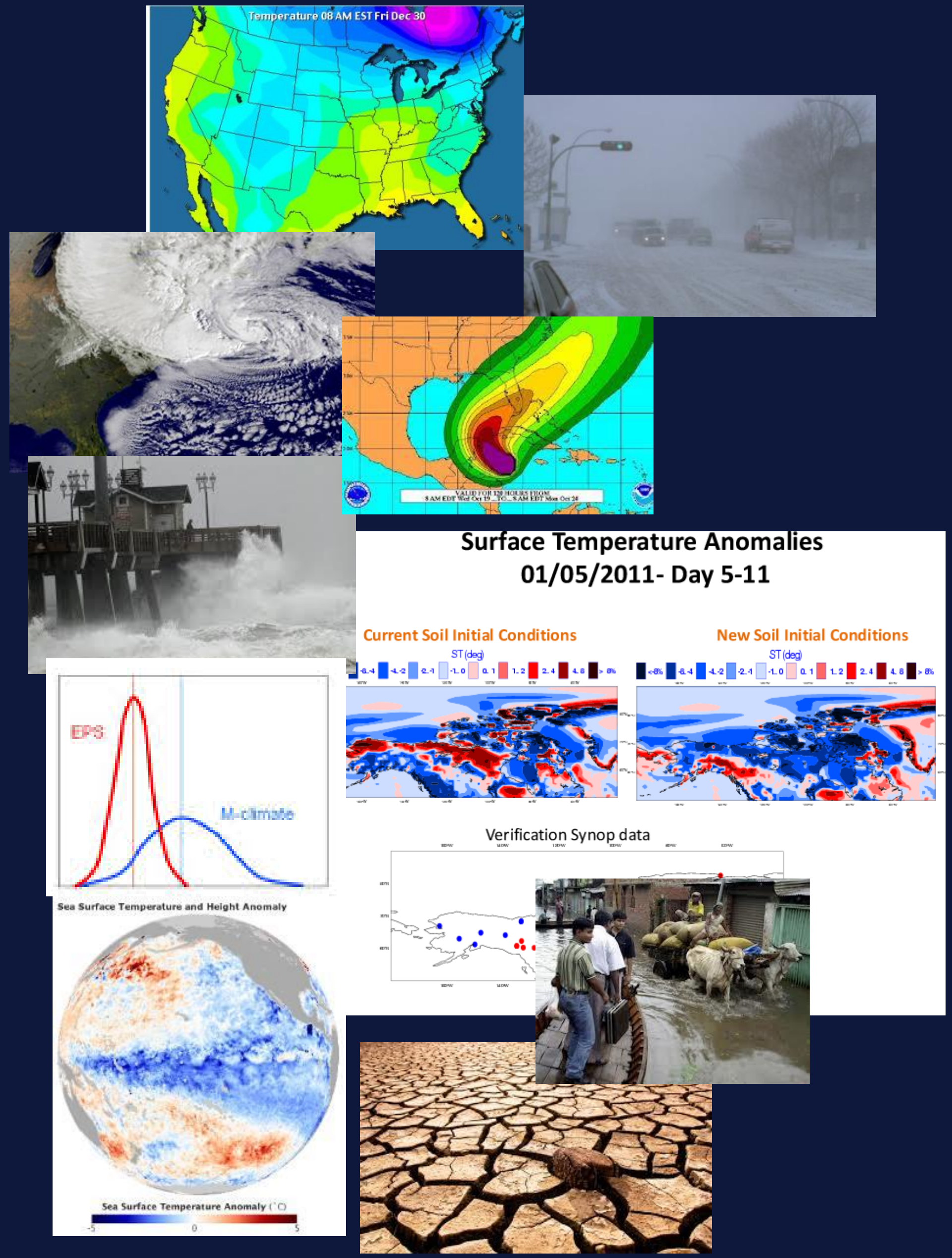
Probabilistic Forecasting System

Design Elements

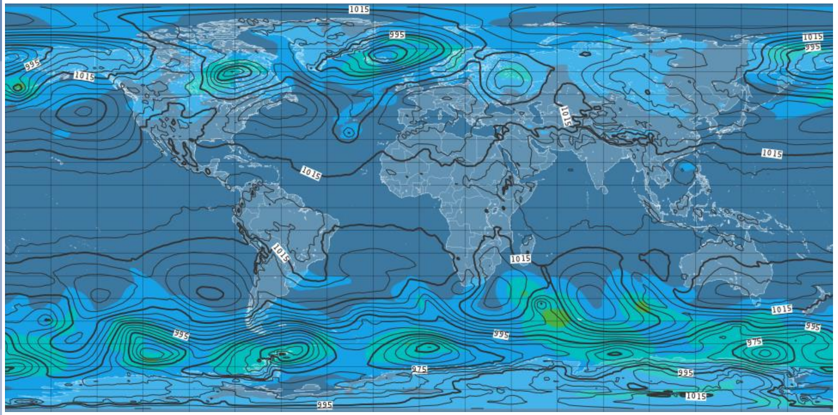
- The ECMWF FC system
- Error propagation and ensembles
- Time scales and model components
- Measuring performance
- Calibration, skill assessment and reanalyses



M.A. Balmaseda

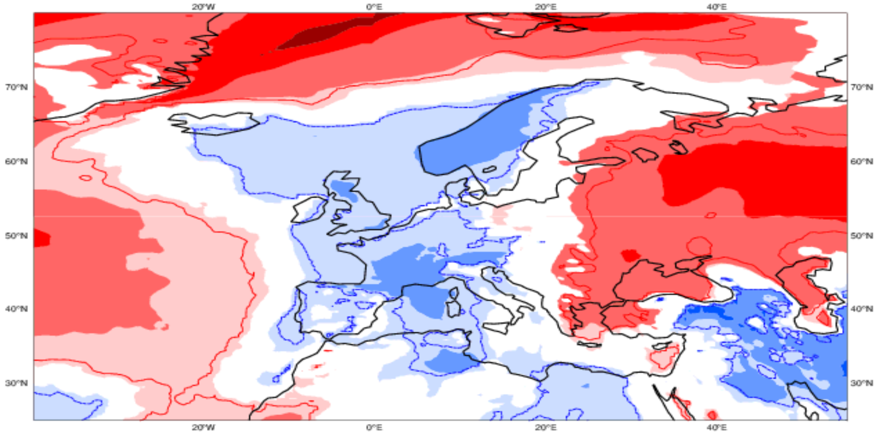
Deliverables: Global NWP from days to years

Medium range prediction



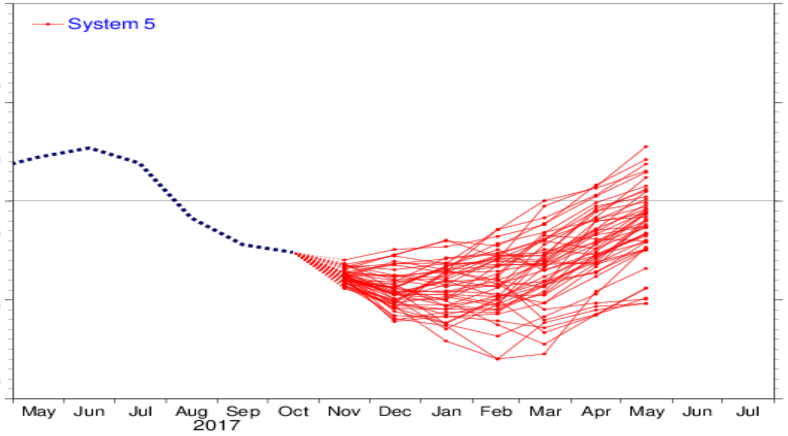
High resolution mean sea level pressure and ensemble spread
Forecast range: several days ahead

Monthly forecast plumes



Weekly anomaly – 2m temperature over Europe
Forecast range weeks 3-4

Long range prediction

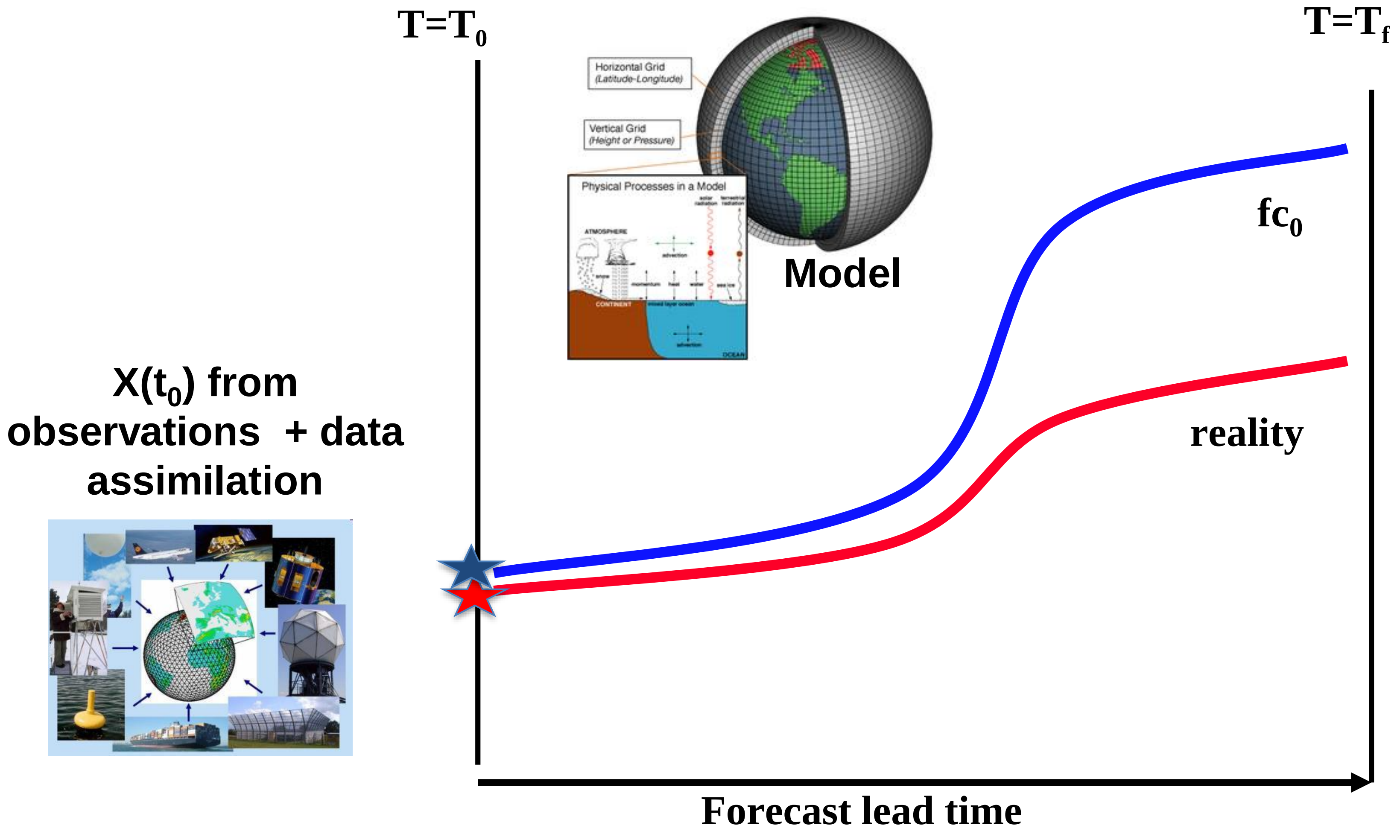


El Nino 3.4 SST anomaly plume – 1 November 2017

Up to 6-12 months

1. Weather forecast as an initial value problem

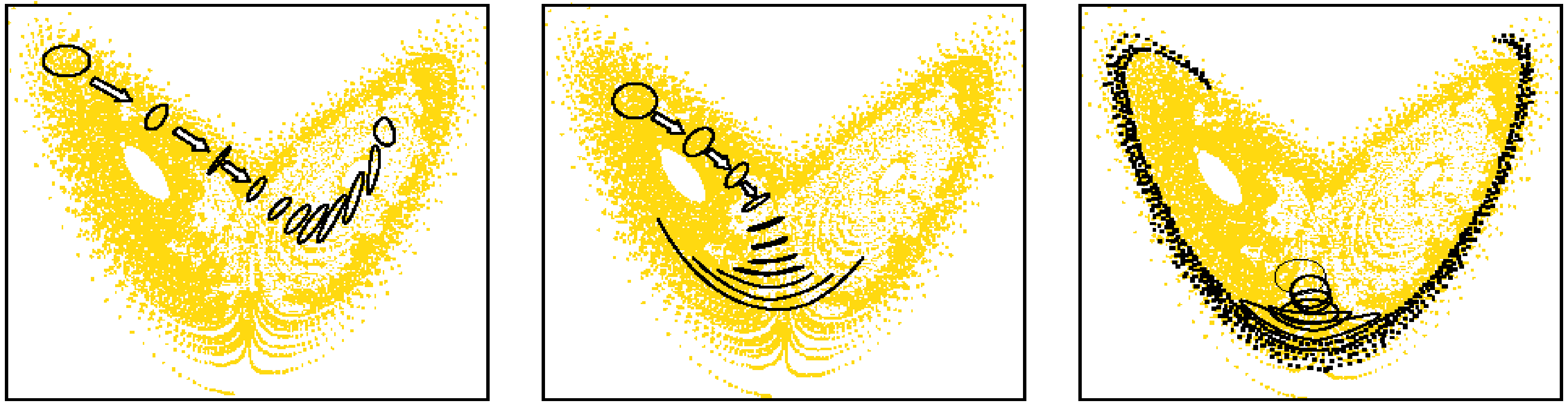
$$X(t_f) = M[X(t_0)]$$



2. What is the quality of the forecast?

- Weather is intrinsically unpredictable in the deterministic sense: The atmosphere as a chaotic system

  Uncertainty: In a chaotic system, small uncertainty in the initial conditions leads to forecast uncertainty



- Forecasting system deficiencies leads to forecast **error**

  – The initial conditions are not accurate enough, e.g. due to poor coverage and/or observation errors, or errors in the assimilation.

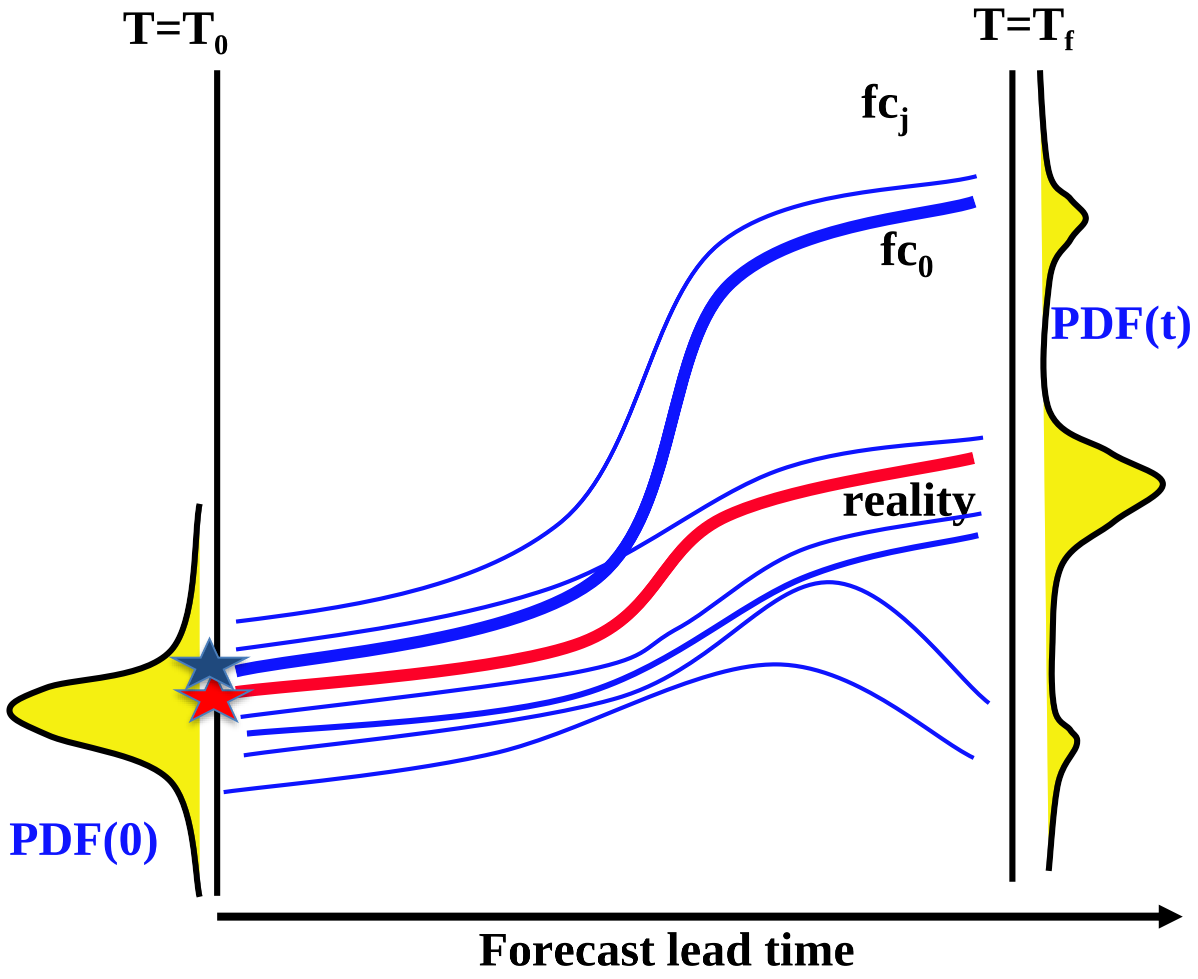
  – The model used to assimilate the data and to make the forecast describes only in an approximate way the true atmospheric phenomena (model error).

Distinguishing between forecast error and intrinsic predictability is not easy.

A few rules of the forecast game

- We should ideally distinguish between
  - **Errors** - which we should aim at correcting
  - **Uncertainty** - we should aim at representing
- Any prior knowledge of uncertainty should be included in the forecast process (**model** and **initial condition** uncertainties are sampled in the ensemble)
- Errors can be reduced by improving models, data assimilation, more/better observations.
- Representation of uncertainty should also be continuously improved.
- Errors can also be accounted for in the forecasting system in order to provide reliable forecast products. (flux corrections?, tuning of model/IC errors , a-posteriori calibration),

3. Ensemble Prediction: A pragmatic approach for propagation of uncertainty



4. Predictability limits and drivers
Multiple time scales of earth system components

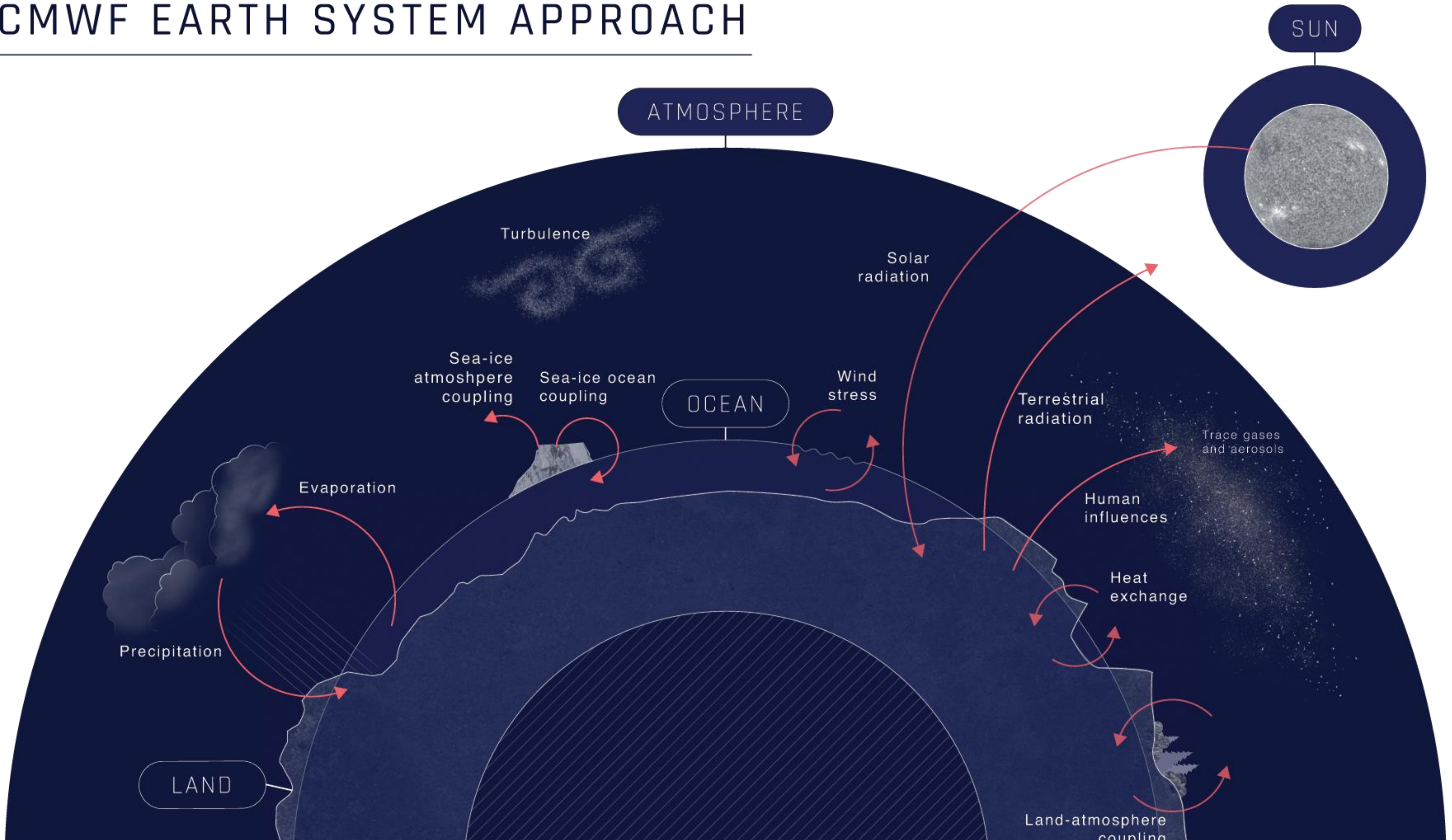
- Fast time scales limit predictability, since error grows rapidly: **predictability of the first kind.**
  - Short range: atmospheric convection; medium range: baroclinic instability

- Slower time scales can act as a source of predictability: **predictability of the second kind**
  The loaded dice paradigm

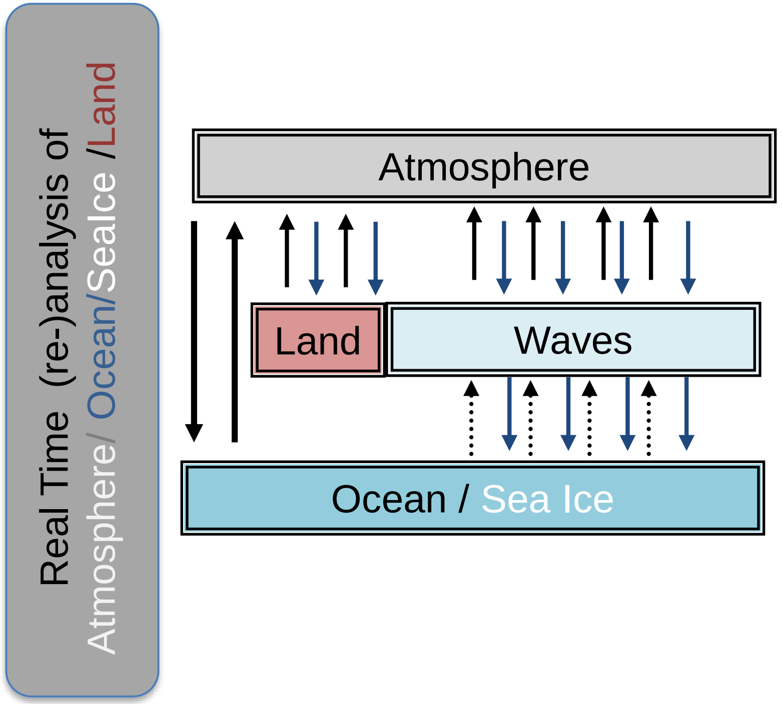
  - The atmospheric behaviour can be modulate by the state of slower neighbouring components, such as ocean, land, sea-ice, stratosphere

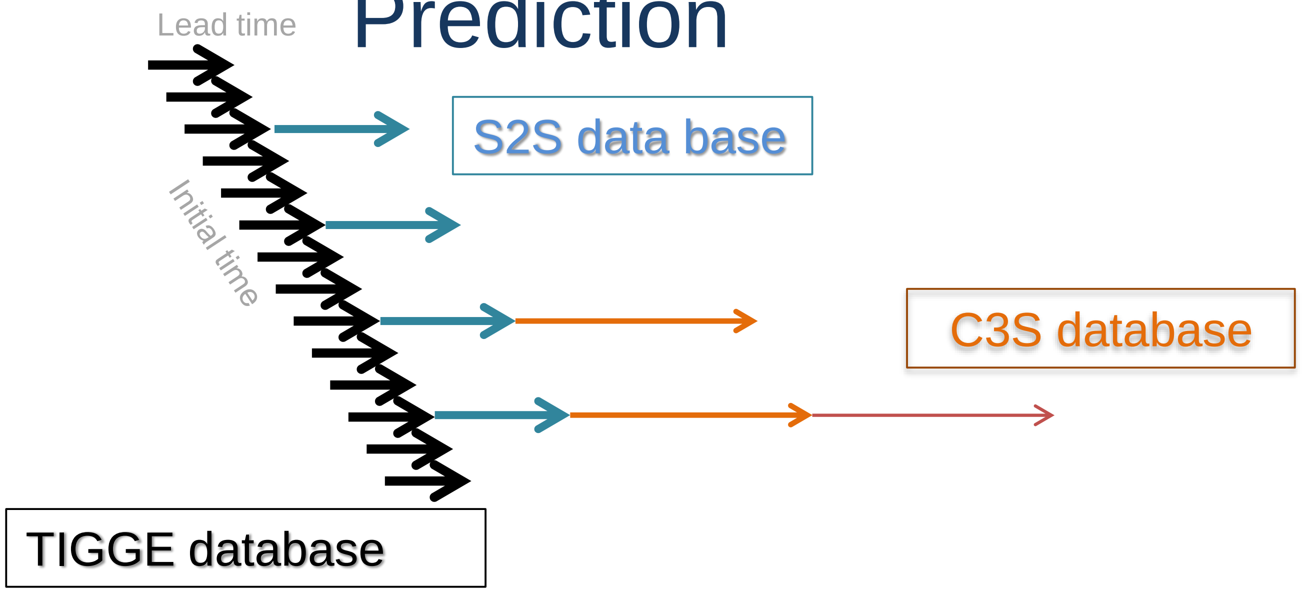
  - Including these slow components in the forecasting system allows extending the predictability horizon
    - Extended range: several weeks ahead
    - Seasonal forecast: several months ahead

ECMWF EARTH SYSTEM APPROACH



5. **Seamless** Probabilistic Prediction

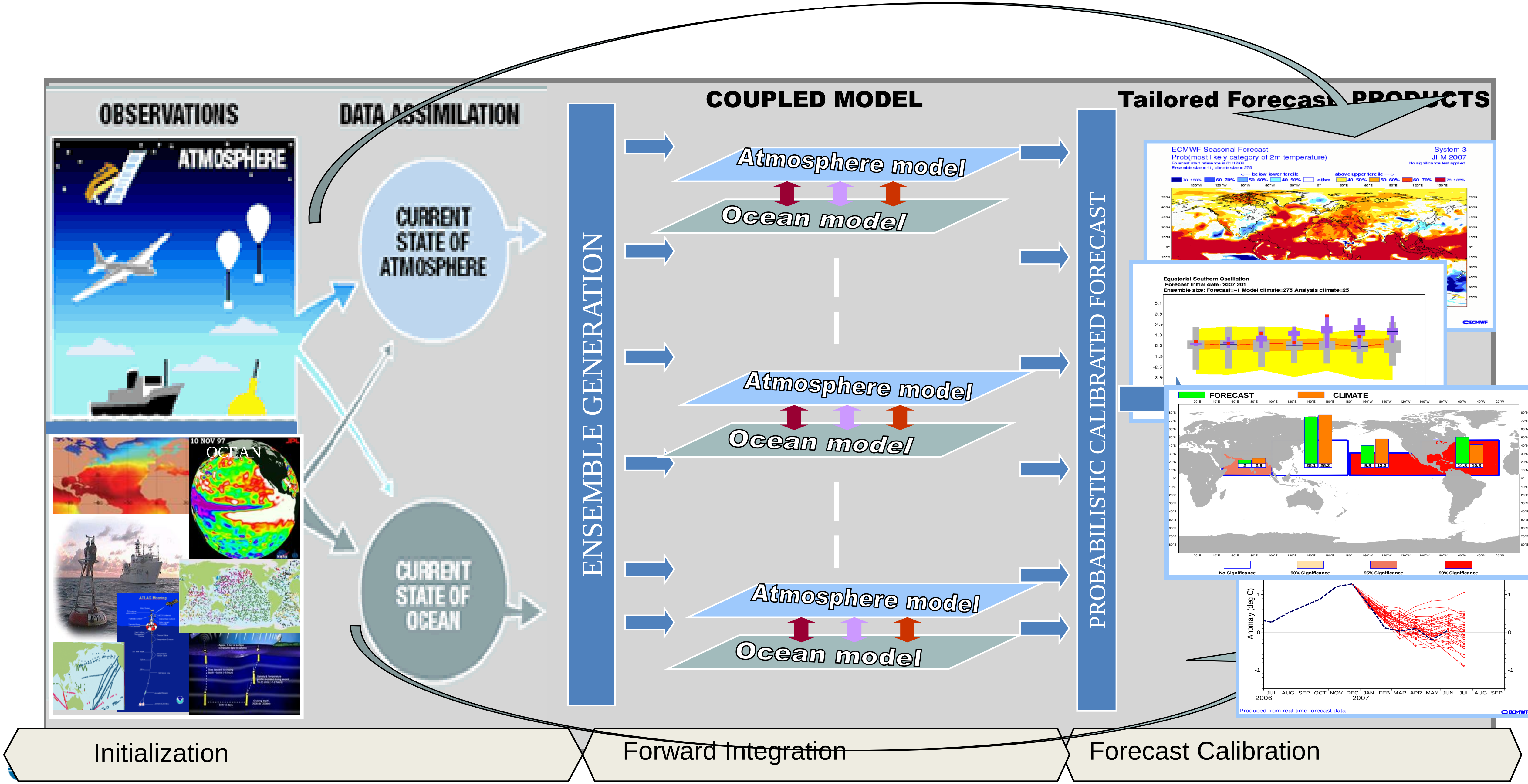




- Same model and initial conditions for different lead times.
- Resolution changes as a function of lead time.
- Main advantage: simplicity and cost
- Each prediction is an ensemble of N members (N~50)

System	Lead Time	Prod Frequency
Medium Range	15 days	twice daily
Monthly	46 days	twice weekly
Seasonal	7 months	monthly
Annual	12 months	quarterly

End-To-End forecasting System



6. Forecast Calibration and skill assessment

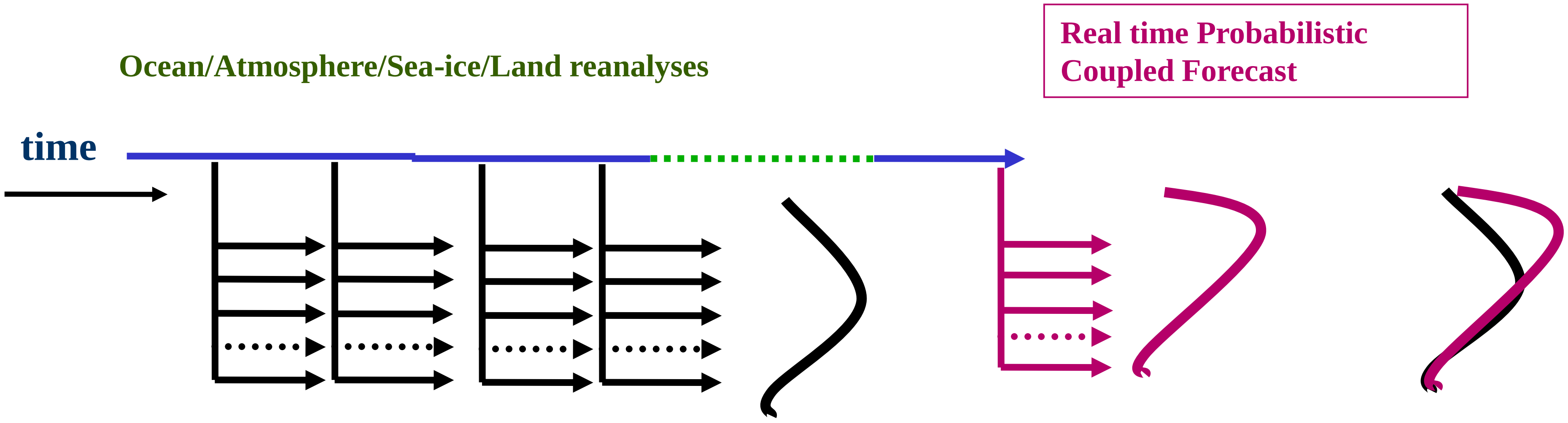
- The calibration needs and verification periods depend on the forecast lead time and products

  - **Medium range:**
    - Usually are not calibrated a posteriori (except for EFI-Extreme Forecast Index)
    - Skill can be estimated from a number of cases over a couple of seasons.

  - **Extended range:**
    - Forecast PDF needs a-posteriori calibration (around 20 years)
    - Strong conditional skill, several cases spanning different seasons and interannual variability

  - **Seasonal range:**
    - Forecast PDF needs a-posteriori calibration (30 years or more)
    - Skill and error depends on season. The calibration data set should cover several ENSO episodes, QBO phases…

Calibration and skill assessment:
Reanalyses as integral part of forecasting systems



Reforecasts require historical reanalyses for initialization, consistent with real-time initial conditions

Reforecasts are needed for

Calibration: dealing with model error

Detection of Extreme Events

Skill estimation

During this course you will learn about

- Atmospheric as a chaotic system
- Representing uncertainties in the atmosphere IC and model
- Interpreting probabilistic forecast, processing the ensemble, diagnosing error, detecting skill
- Slow Earth System components as predictability drivers
- Regimes and teleconnections
- Initializing slow system components and reforecasts.
- How to put together individual components to create a forecasting system