Coupled catchment-based meteorologic and hydrologic data reconstruction:

why, how and what for

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Outline

Conclusions/points for discussion

Problem

A little bit of theory

Foreseen progress

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Discussion

Conclusions/points for discussion

a CCH reanalysis is one of the few ways to achieve progress in hydrology by:

- making a single consistent data set available for a catchment, which is badly needed for developing measurement equations and testing new theories

- forcing meteorologists and hydrologists to use compatible models and data

- forcing to think about the models of choice and to actually choose a model

- forcing to start applying the available data assimilation technology

- starting to use the RS data that is, however imperfect for hydrological applications, massively available

Conclusions/points for discussion

Why a combined meteorologic & hydrologic modelling approach?

- To evenly distribute the observation errors – reduce the chance of drawing flase conclusions

- forcing meteorologists and hydrologists to use compatible models and data

Is it only applicable for huge areas, complex models and RS data?

- No, but these boundary conditions make the need more urgent.

The central problem in hydrological prediction is the fact that predictions are desired for:

1. processes that are non-linear
2. processes that are essentially unobservable (e.g. soil water movement, grid-scale soil moisture or evap. fluxes)
3. large domains (e.g. entire Rhine basin)
4. fine resolutions (e.g. 1 km^2)
5. boundary conditions (e.g. rainfall) and a medium (e.g. soil and land use) that are very heterogeneous (at a scale much smaller than 1 km^2)

The challange is to characterize the true state of the meteorol. & hydrologic system by combining information from measurements, models, and other sources (both quantitative and qualitative!) → data assimilation

If the information is combined properly, a description based on combined information will be much better than one obtained from either measurements or model alone. → So that is why!

Key Features of a reanalysis problem

Systems (like a rainfall-runoff system or a groundwater-flow system) are usually spatially distributed dynamic systems that are described in terms of state variables. For these systems models have been developed and calibrated. The models comprise often sets of non-linear partial differential equations.

Often multiple data sources are used. Parameters, inputs and outptus are often derived from various types of measurements (ground-based, remote sensing, etc.) measured over a range of time and space scales

The models used are inevitably imperfect approximations to reality, model inputs may be uncertain, and measurement errors may be important. All of these sources of uncertainty need to be considered.

State variables will fluctuate over a wide range of time and space scales -- Different scales may interact (e.g. small scale variability can have large-scale consequences)

The equations used to describe the system of interest are usually discretized over time and space -- Since discretization must capture a wide range of scales the resulting number of degrees of freedom (unknowns) can be very large.

Typical activities in hydrological reanalysis

In hydrologic problems one typically needs to:

- Downscale/disaggregate certain observations (such as discharge observations, or satellite measurements)
- Upscale/aggregate other observations (such as a point-observation of rainfall or ground water level).
- Assimilate (or incorporate) all measurements into the dynamic model (so that estimates derived from the model reflect measurements)
- Account for:
  - Subpixel variability
  - Model errors
  - Measurement errors

All of this needs to be done in a systematic framework!

foreseen progress:

New satellite missions/better sensors

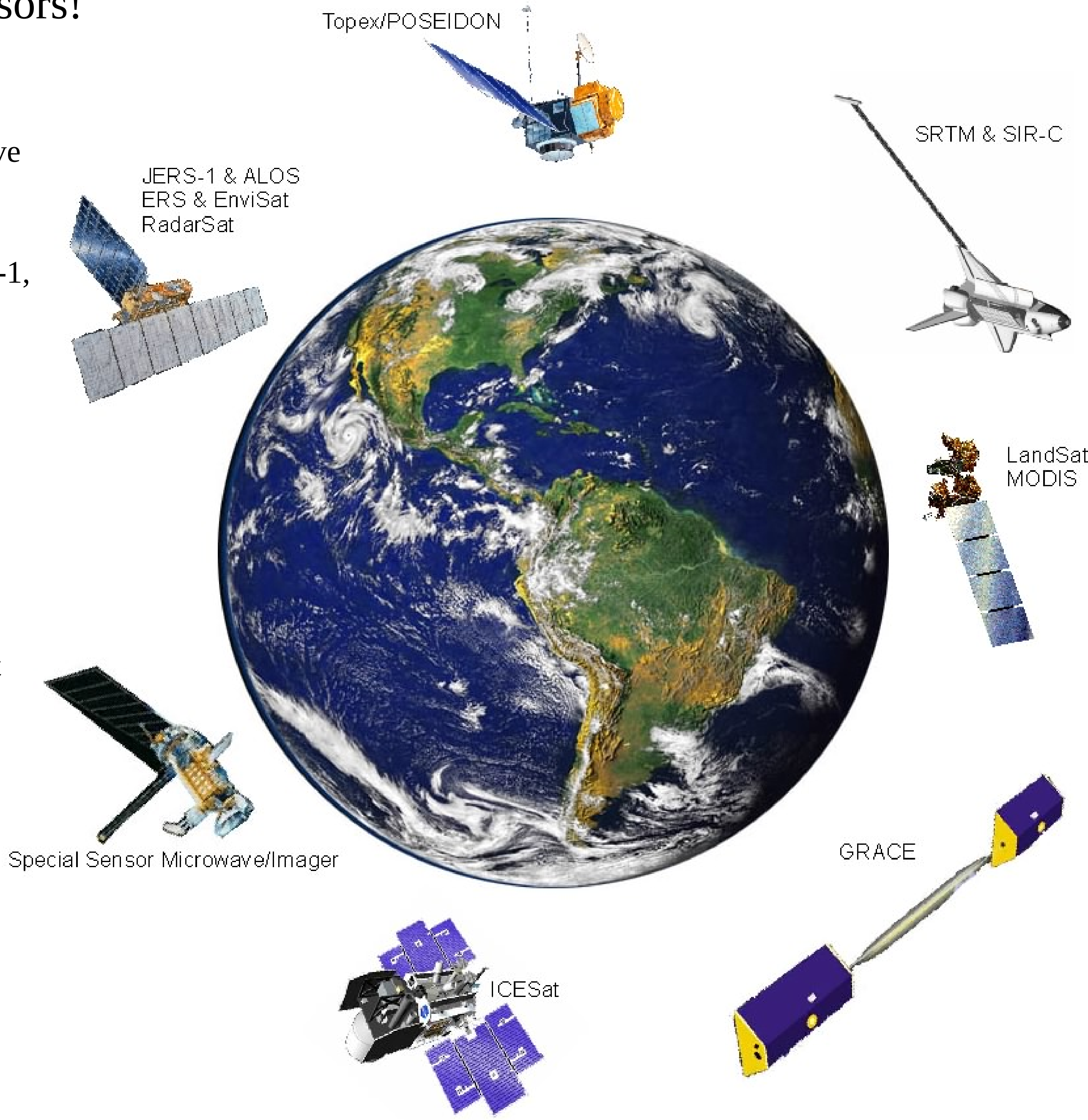
More integrated models (model coupling)

Better algorithms

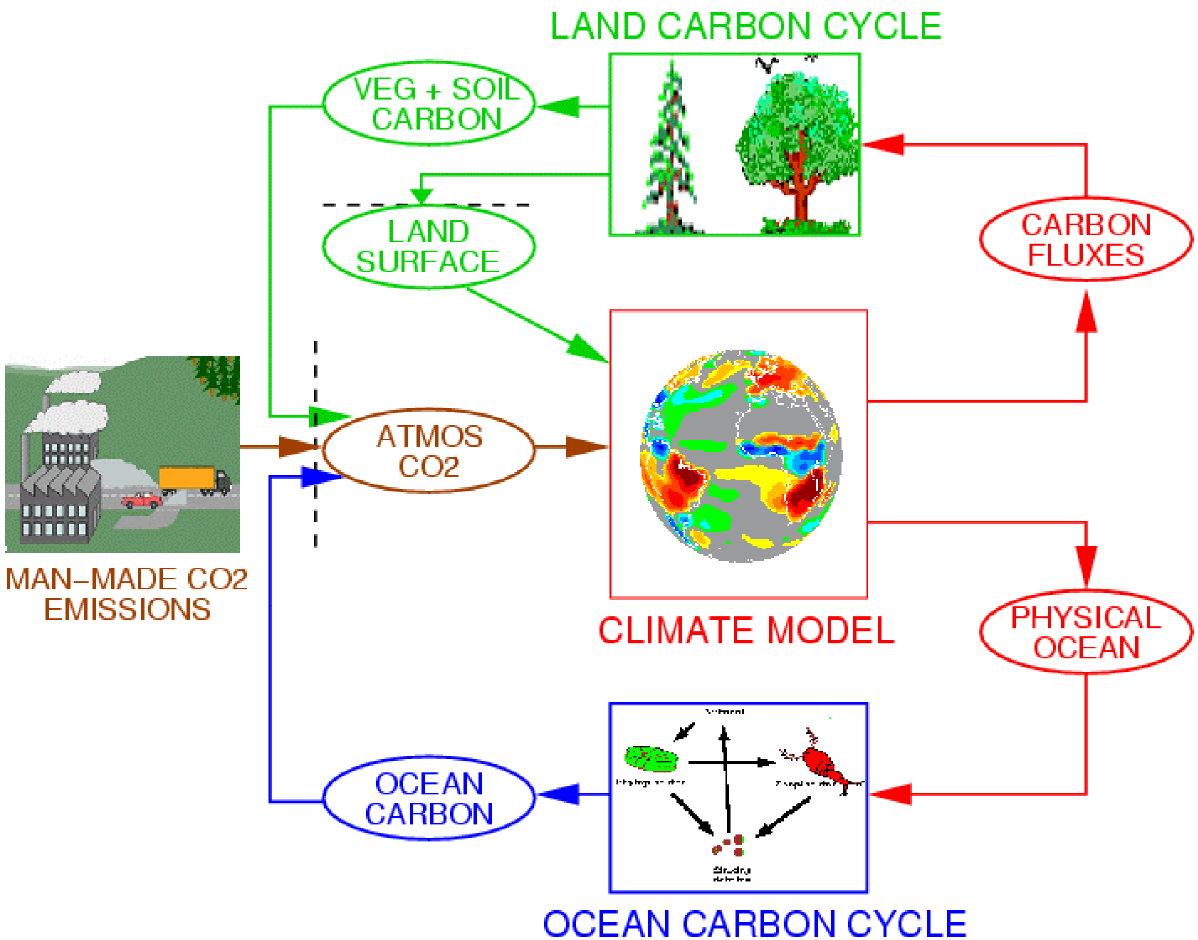
Model ensembles

Many useful RS sensors!

- **Water Surface Area:**
  - Low Spatial/High Temporal: Passive Microwave (SSM/I, SMMR), MODIS
  - High Spatial/Low Temporal: JERS-1, ERS 1/2 & EnviSat, RadarSat, LandSat
- **Water Surface Heights:**
  - Low Vertical & Spatial, High Temporal (> 10 cm accuracy, 200+ km track spacing): Topex/POSEIDON
  - High Vertical & Spatial, Low Temporal (180-day repeat): ICESat
- **Water Volumes:**
  - Very Low Spatial, Low Temporal: GRACE
  - High Spatial, Low Temporal: Interferometric SAR (JERS-1, ALOS, *SIR-C*)
- **Topography:**
  - SRTM (also provides some information on water slopes)

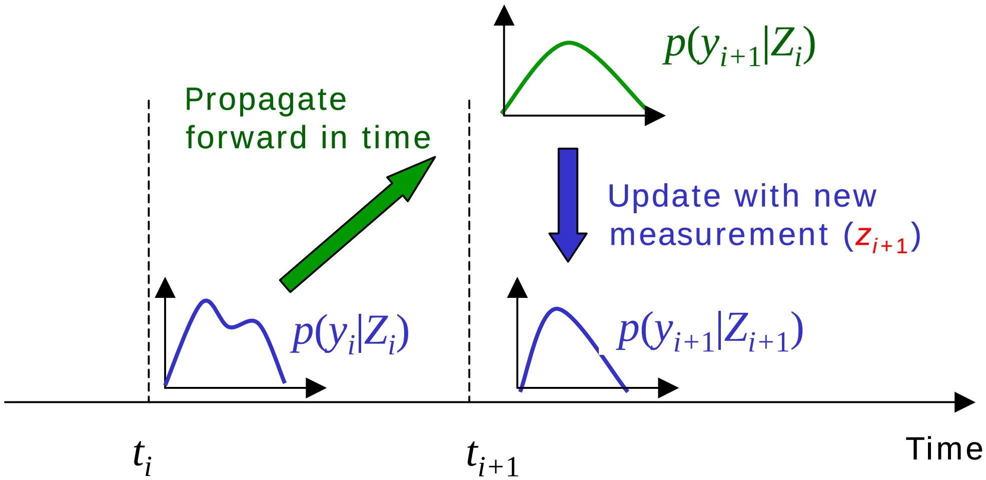


An example model: Coupled Climate-Carbon Cycle Model

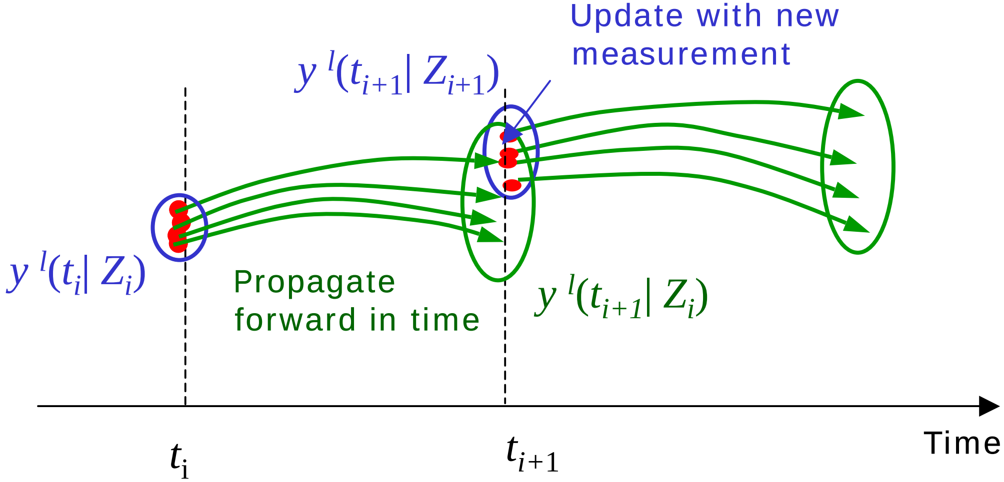


Ensemble filtering

Propagation of conditional probability density (formal Bayesian filtering):

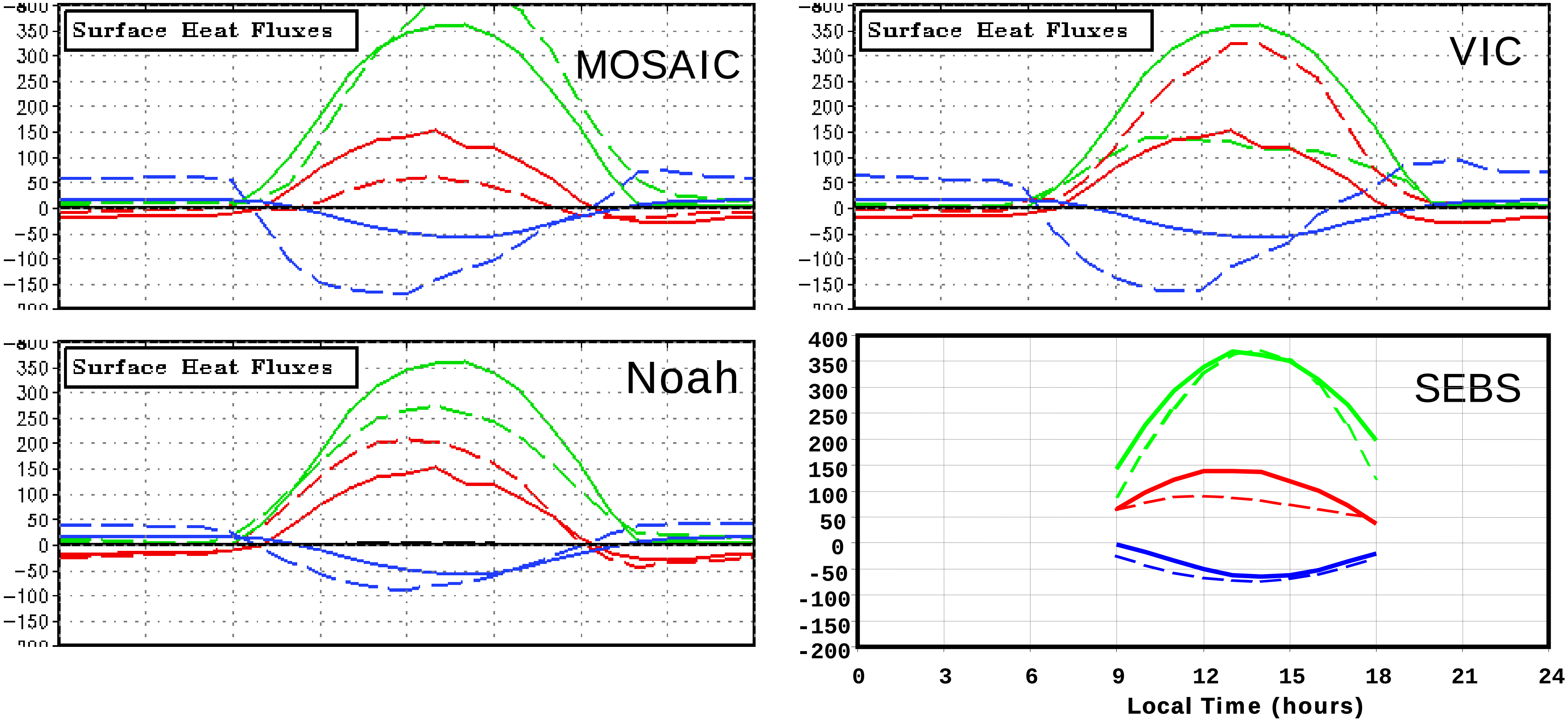


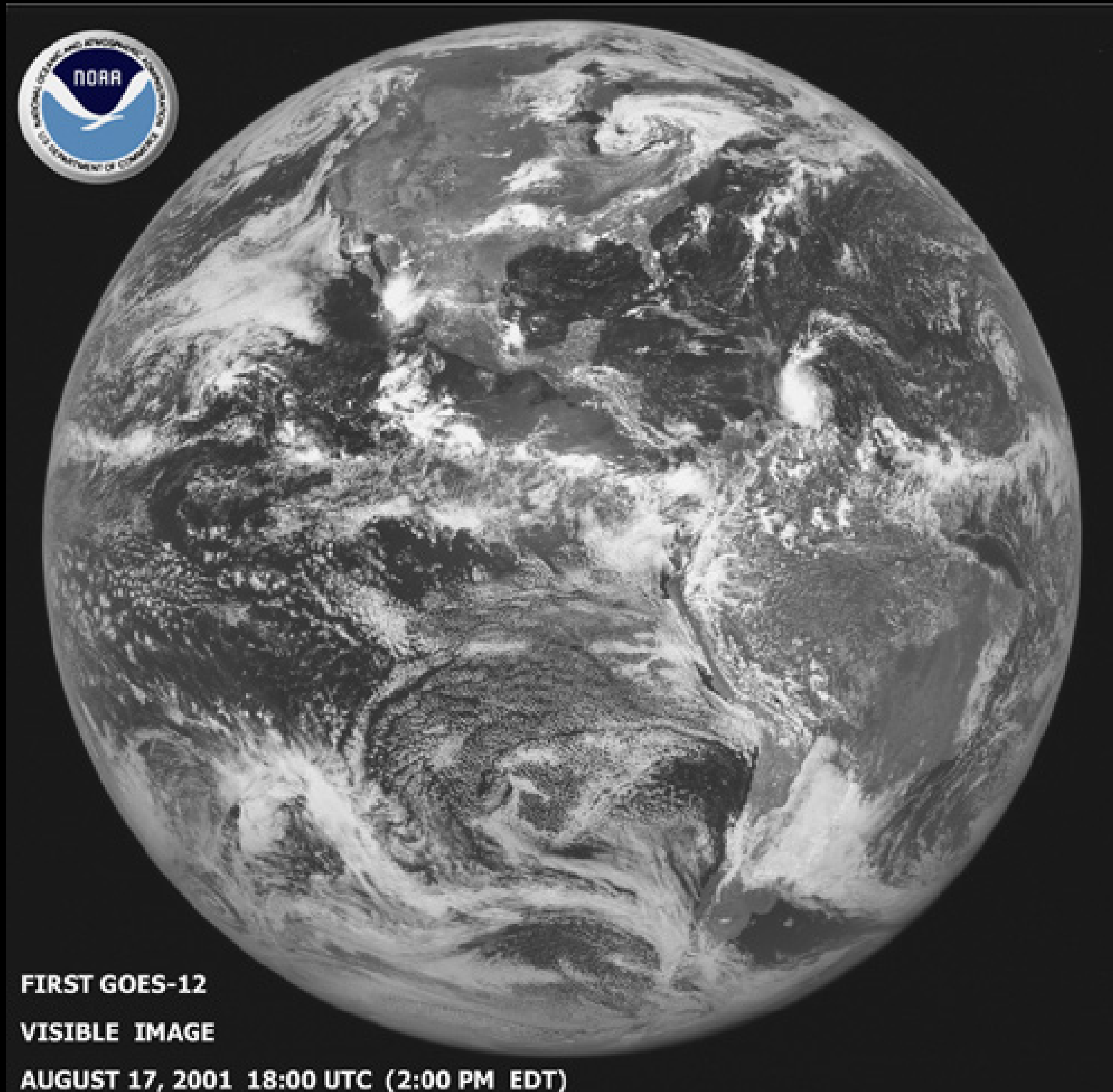
Evolution of random replicates in ensemble (Ensemble filtering):



Ensemble filtering propagates only replicates (no PDFs).

An example of a heterogeneous model ensemble (after Su et al., 2002):

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