
Ocean Observations for an End-to-End Seasonal Forecasting System

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Overview

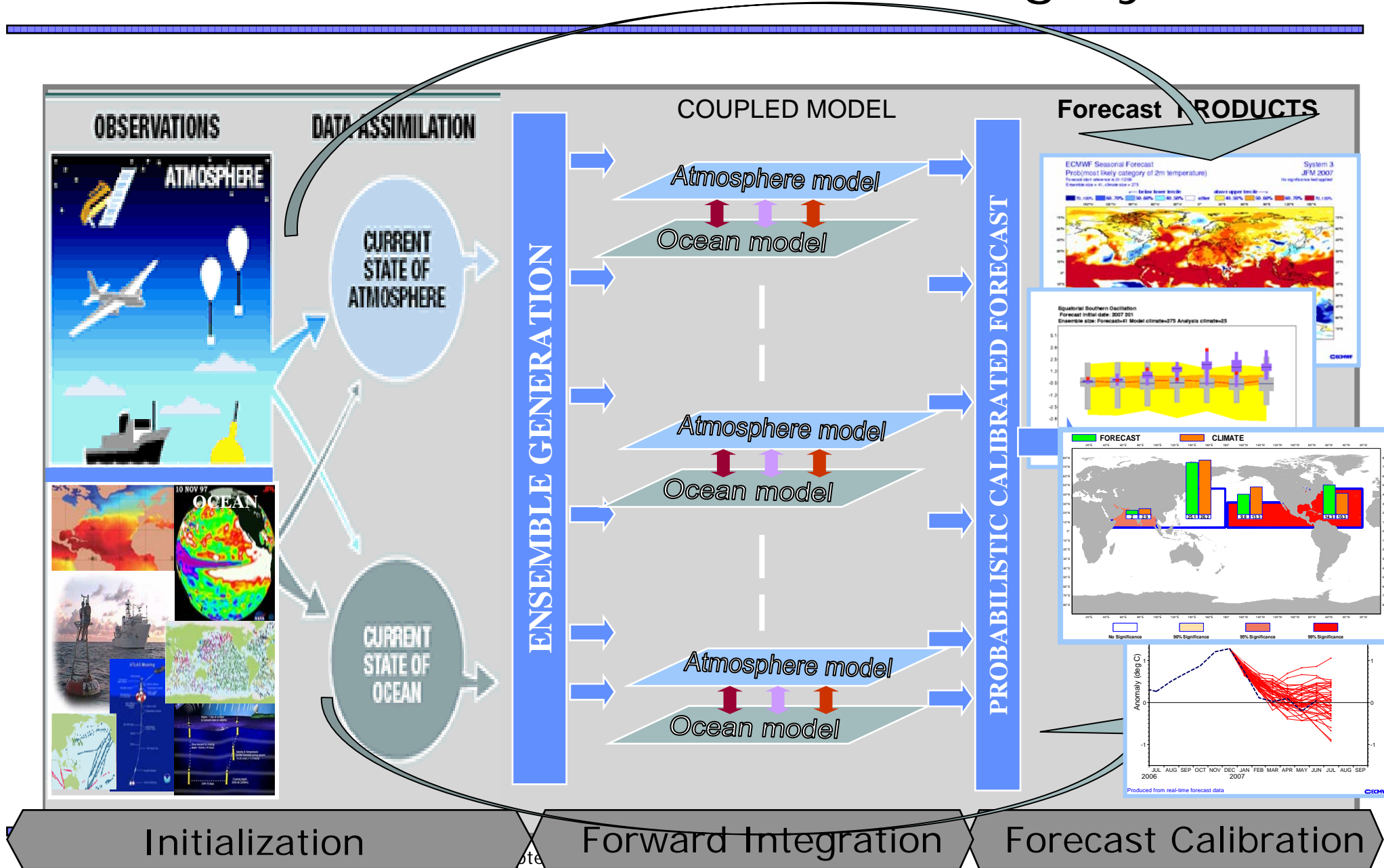
- Why do we want forecast at seasonal time scales?
 - Societal applications
- End To End Seasonal Forecasting Systems
 - Role of ocean observations.
- Initialization
 - Achievements and challenges
- Development of model and assimilation systems:
 - Process studies, multivariate relationships
- Calibration and skill assessment
 - providing meaningful forecasts from the numerical output.
- Recommendations

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- There is a clear demand for **reliable** seasonal forecasts:
 - Forecasts of anomalous rainfall and temperature at 3-6 months ahead
 - For a range of societal, governmental, economic applications:
 - Agriculture
 - Health (malaria, dengue,...)
 - Energy management
 - Markets, insurance
 - Water resource management,
 - Huge progress in the last decade:
 - Operational seasonal forecasts in several centres
 - Pilot/Research progress for demonstrating applicability (DEMETER, IRI, EUROBRISA,...)
 - Build-up of community infrastructure (at WMO level)

The basis for extended range forecasts

- Forcing by boundary conditions changes the atmospheric circulation, modifying the large scale patterns of temperature and rainfall, so that the probability of occurrence of certain events deviates significantly from climatology.
 - Important to bear in mind the probabilistic nature of climate forecasts
 - How long in advance?: from seasons to decades
 - The possibility of seasonal forecasting has clearly been demonstrated
 - Decadal forecasting activities are now starting.
- The boundary conditions have longer memory, thus contributing to the predictability. Important boundary forcing:
 - **SST: ENSO, Indian Ocean Dipole, Atlantic SST**
 - Land: snow depth, soil moisture
 - Atmospheric composition: green house gases, aerosols,...
 - Ice?

End-To-End Seasonal forecasting System



Importance of Initialization

- *Atmospheric point of view: Boundary condition problem*

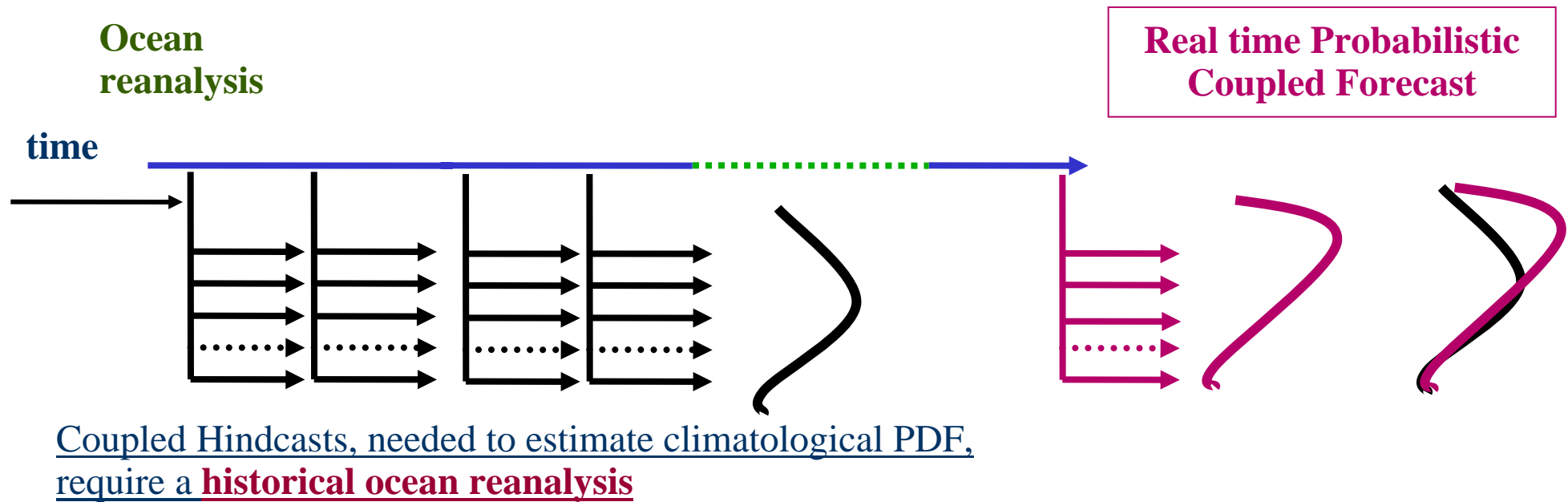
- Forcing by lower boundary conditions changes the PDF of the atmospheric attractor

“Loaded dice”

- *Oceanic point of view: Initial value problem*

- *Prediction of tropical SST: need to initialize the ocean subsurface.*
 - o *Emphasis on the thermal structure of the upper ocean*
 - o *Predictability is due to higher heat capacity and predictable dynamics*
- *A simple way: ocean model + surface fluxes.*
 - o *But uncertainty in the fluxes is too large to constrain the solution.*
- *Alternative : ocean model + surface fluxes + ocean observations*
 - o *Using a data assimilation system.*
 - o *The challenge is to initialize the thermal structure*
 - *without disrupting the dynamical balances (wave propagation is important)*
 - *While preserving the water-mass characteristics*

Dealing with model error: Hindcasts



Impact of Data Assimilation

Forecast Skill

Ocean data assimilation
also improves the forecast
skill

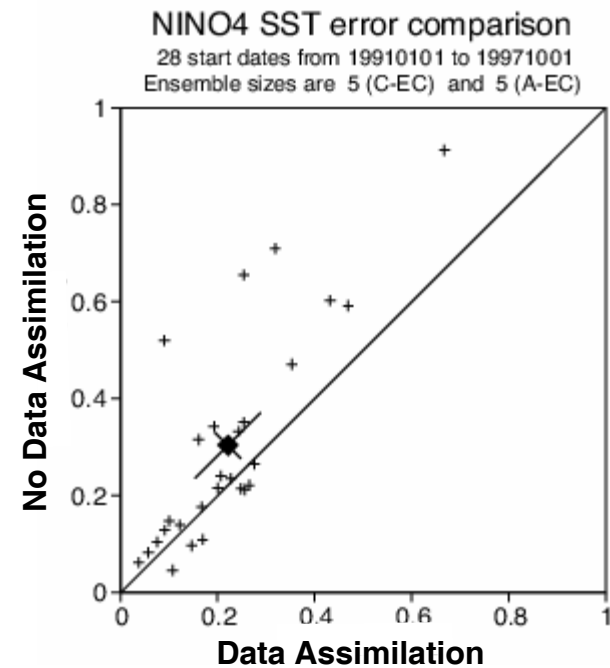
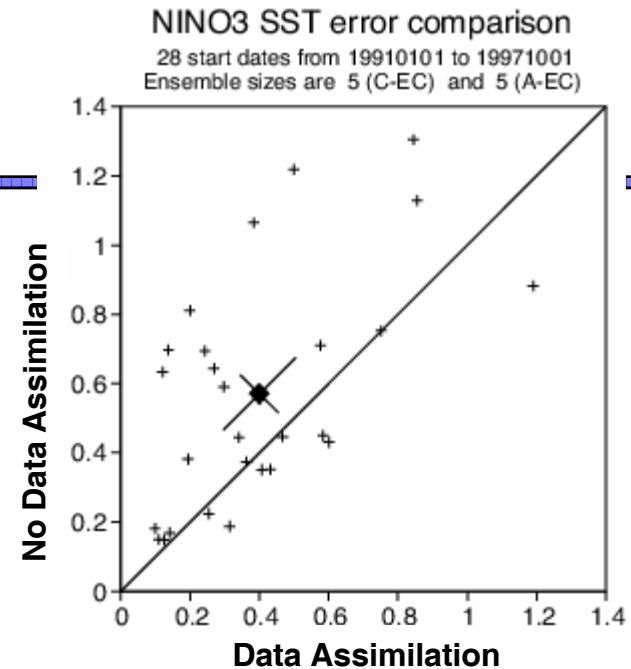
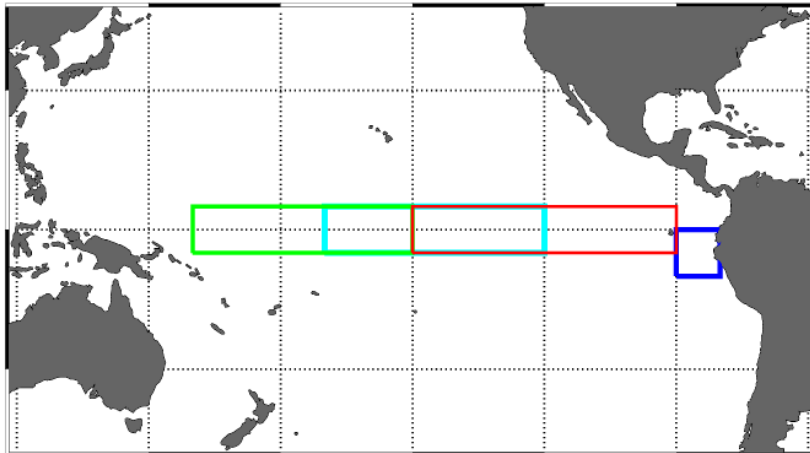
(Alves et al 2003)

Nino3.4, Lon = [-170, -120], Lat = [-5, 5]

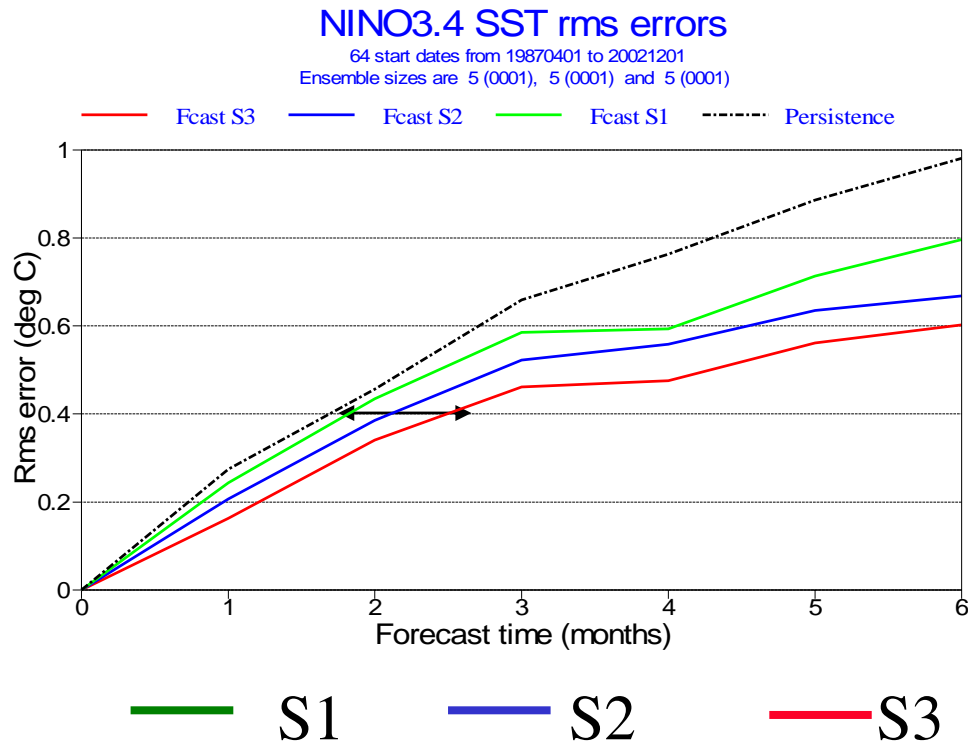
Nino12, Lon = [-90, -80], Lat = [-10, 0]

Nino4, Lon = [160, -150], Lat = [-5, 5]

Nino3, Lon = [-150, -90], Lat = [-5, 5]

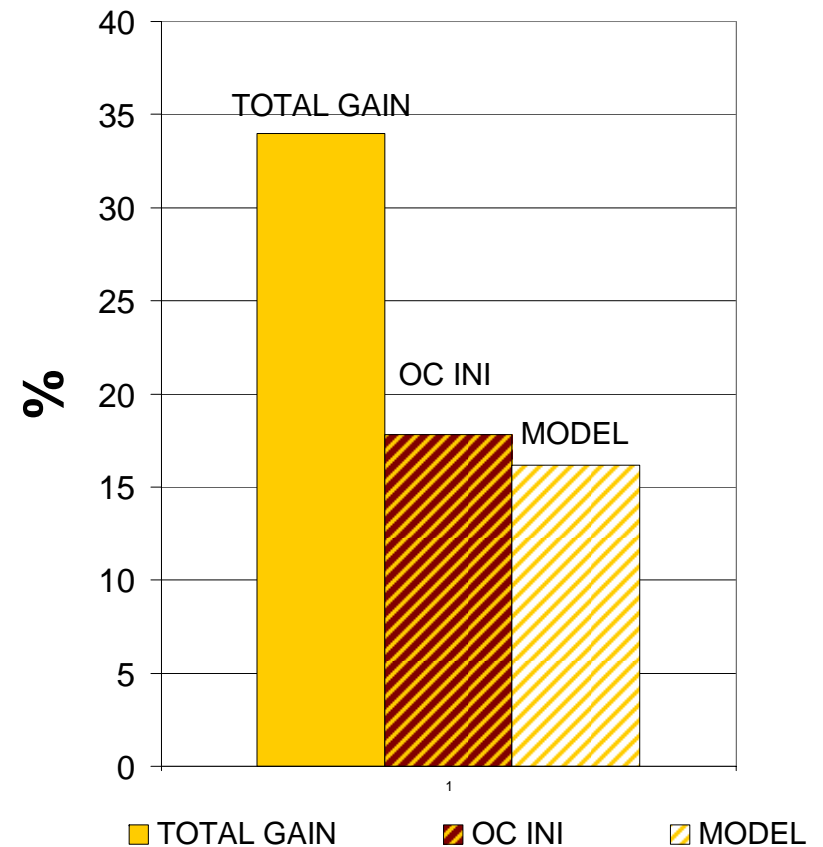


A decade of progress on ENSO prediction



- Steady progress: ~1 month/decade skill gain
- How much is due to the initialization, how much to model development?

Relative Reduction in SST Forecast Error ECMWF Seasonal Forecasting Systems



Half of the gain on forecast skill is due to improved ocean initialization

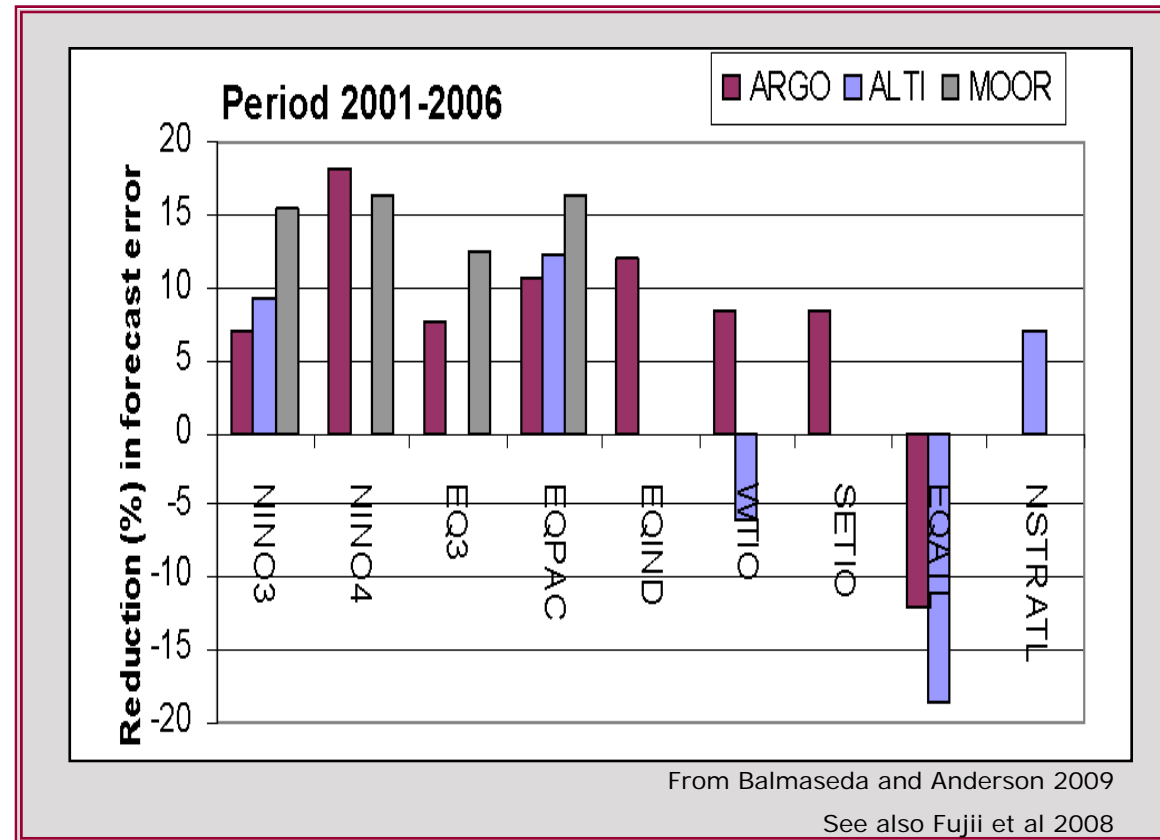
Assessing the Ocean Observing System

1. No observing system is redundant

- Example: the Pacific, where Argo, moorings and altimeter still complement.
- Lessons for other basins.
- Implications of the missing TAO data for the on-going El Nino

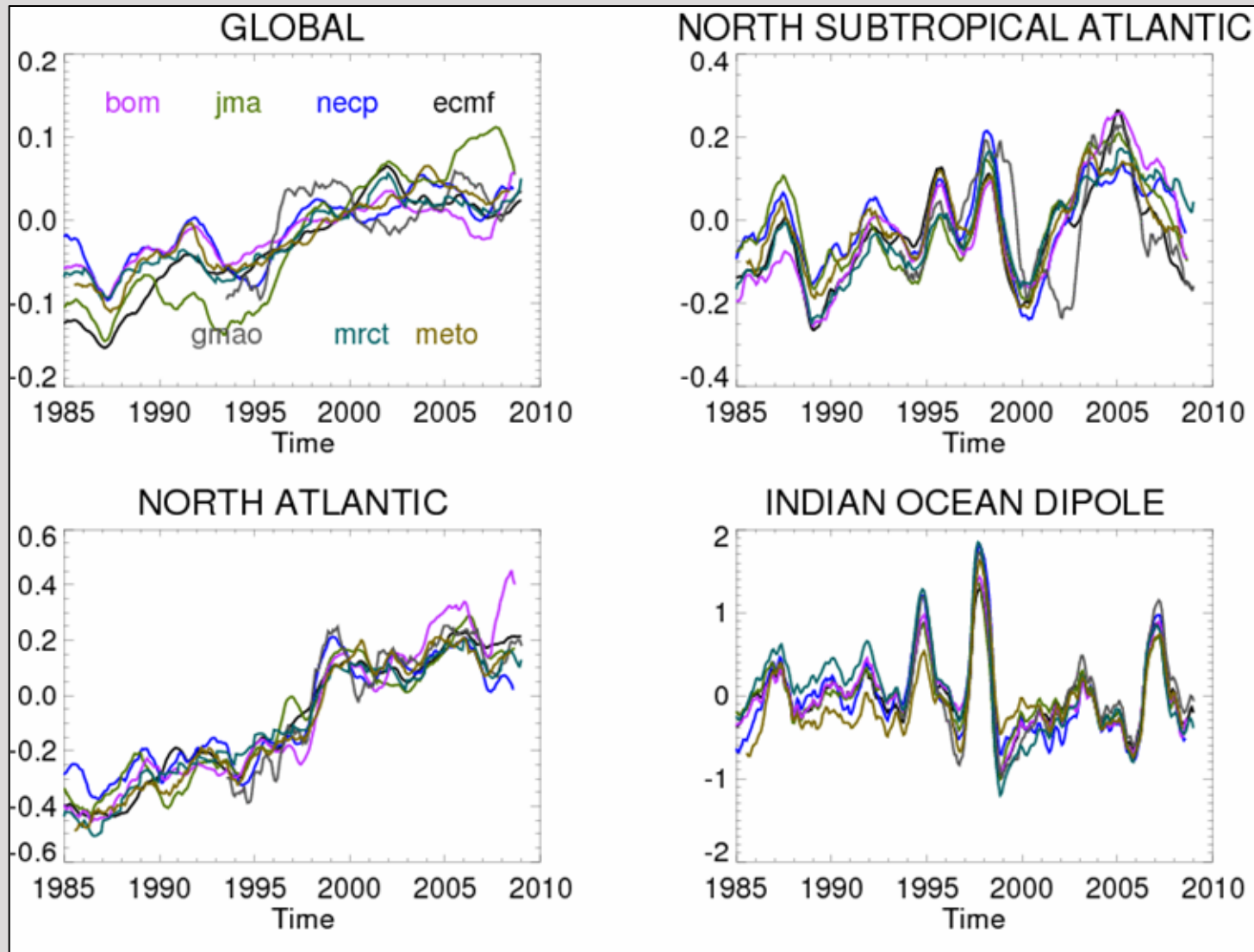
2. The altimeter is the only OS contributing to the North Subtropical Atlantic. Argo is the only OS contributing the skill on the Indian Ocean.

3. There are obvious problems in the Eq Atlantic: model error, assimilation, and possibly insufficient observing system



- The assessment depends on the quality of the coupled model
 - Sign of progress: a decade ago the OSES with Seasonal Forecasts were not considered a useful evaluation tool.
- Long records are needed for results to be significant:
 - Any observing system needs to stay in place for a long time before any assessment is possible.
- So far impact on forecasts of SST only. Impact on atmospheric variables next

Importance of Real Time Ocean ReAnalyses



From Xue et al CWP. Not operational yet

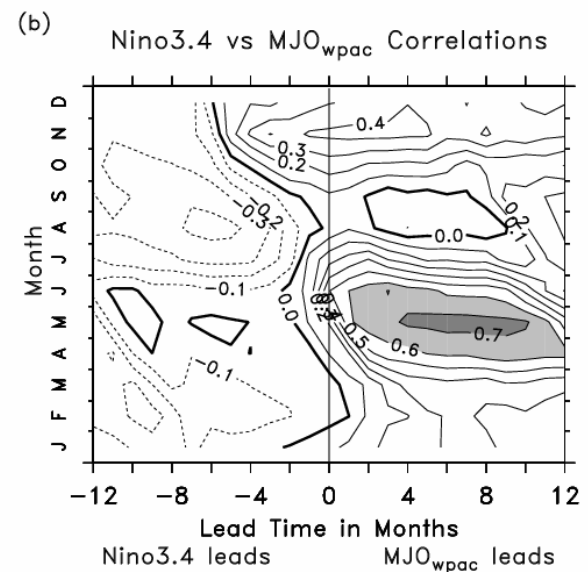
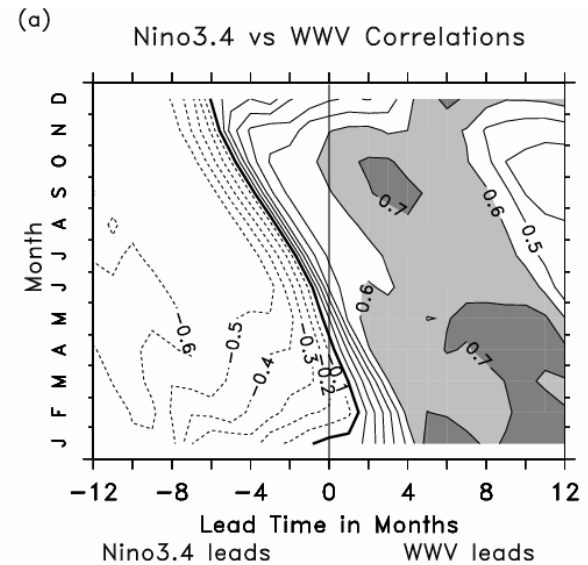
Ocean Observations & Model Development

Understanding and revealing important processes.

Examples are too many to mention.

Role of the MJO on ENSO

- It has changed the conceptual models for ENSO with implications for predictability
- It has triggered intense activities on **improving the model representation of tropical convection**

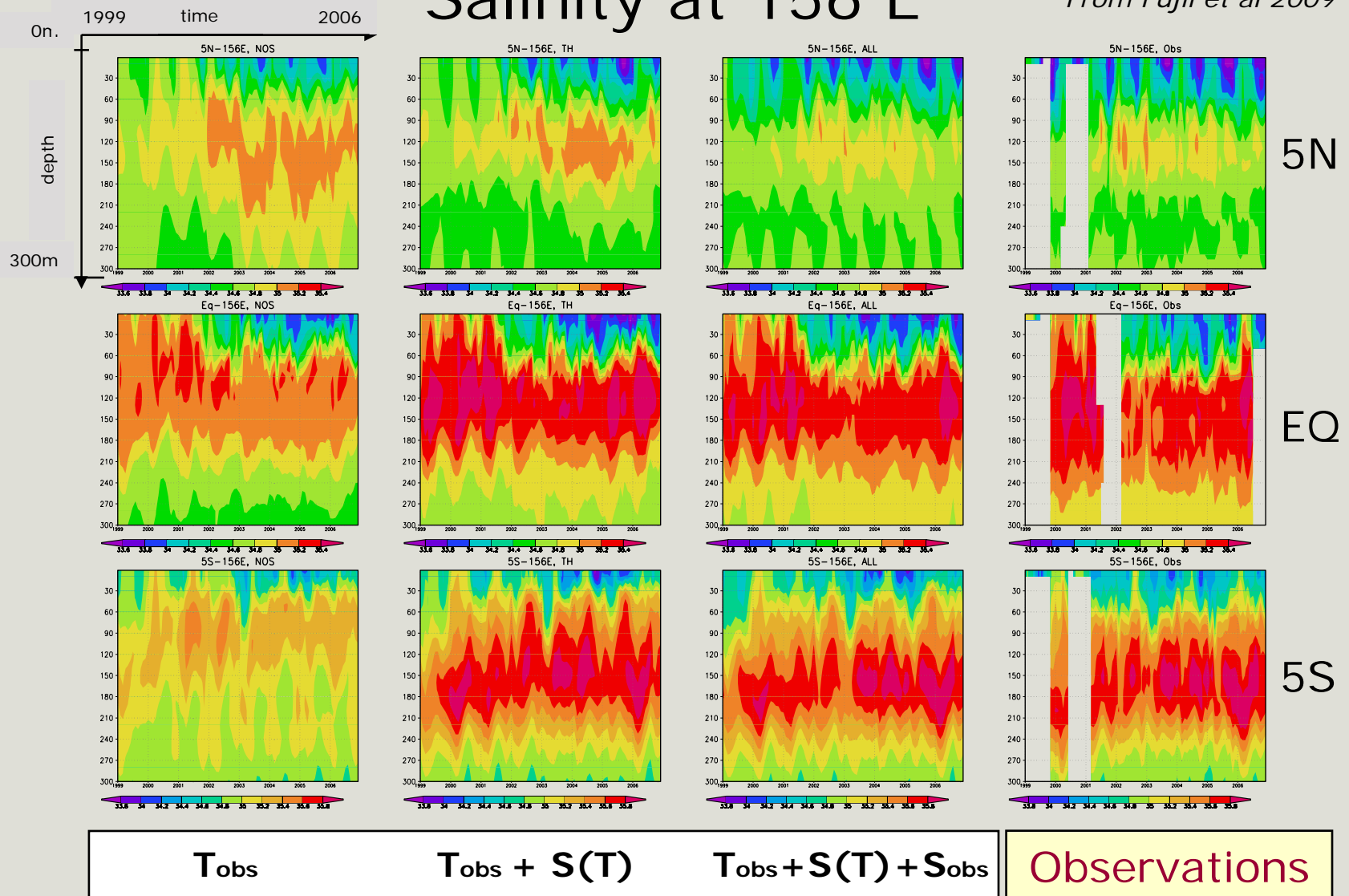


Ocean Observations & Assimilation Development

- [Importance of] Multivariate relationships. Example: (T & S)

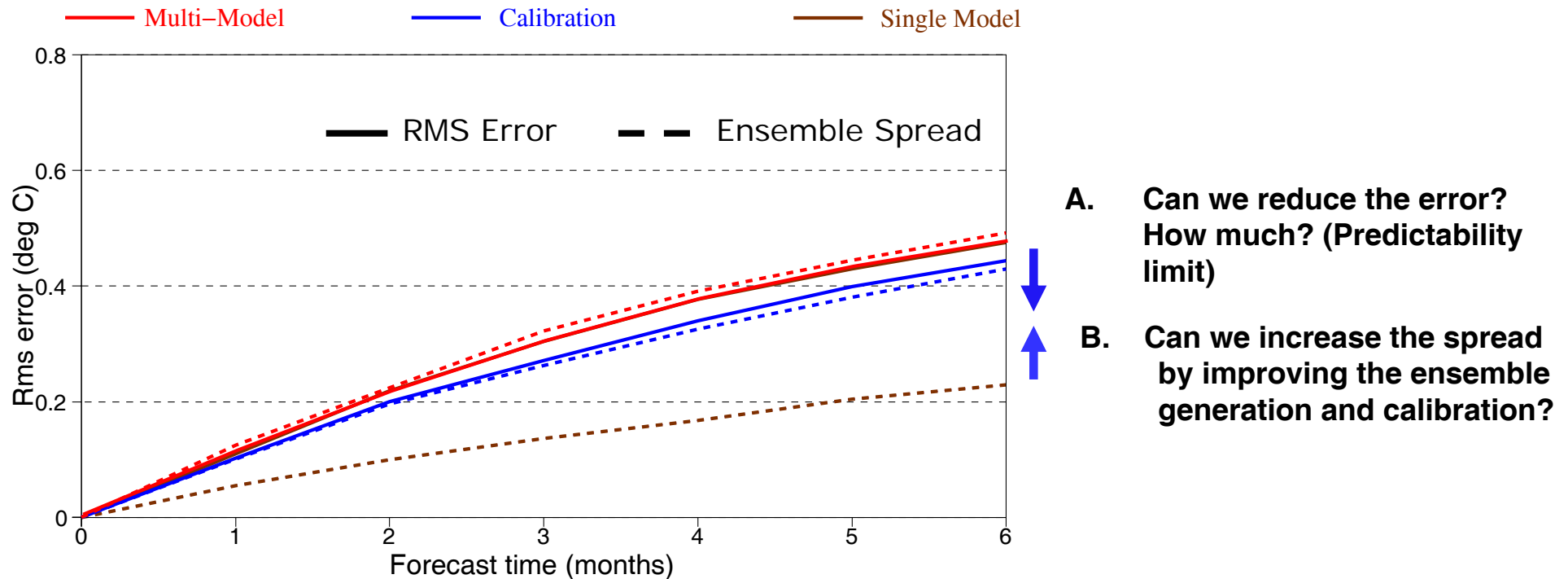
Salinity at 156 E

From Fujii et al 2009



Ocean Observation & Reliable forecast products

Forecast Systems are generally not reliable ($RMS > Spread$)



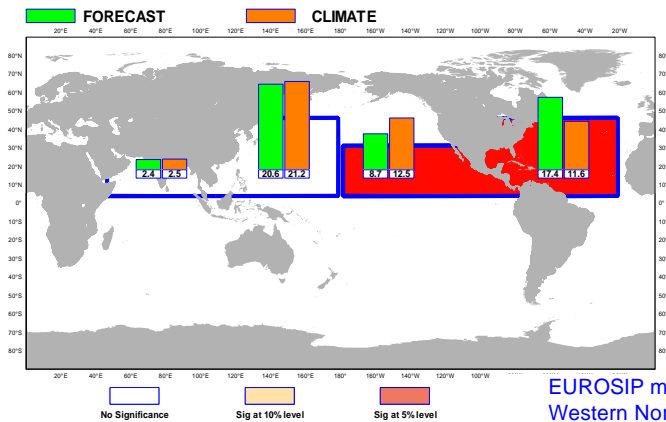
Calibration and multi-model can increase the skill and reliability of forecasts.

In a general case, even the multi-model needs calibration.

Long records are needed for robust calibration and downscaling

Multi-Model Seasonal forecasts of Tropical Cyclones

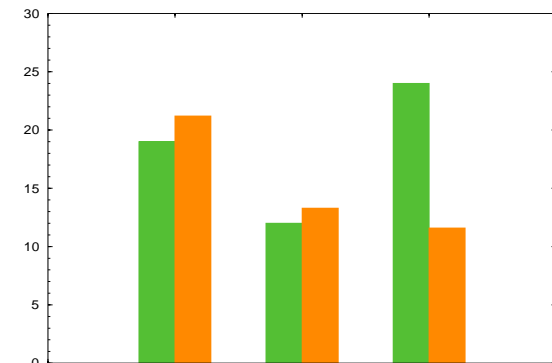
Multi-model Forecasts: 1st June 2005: JASON



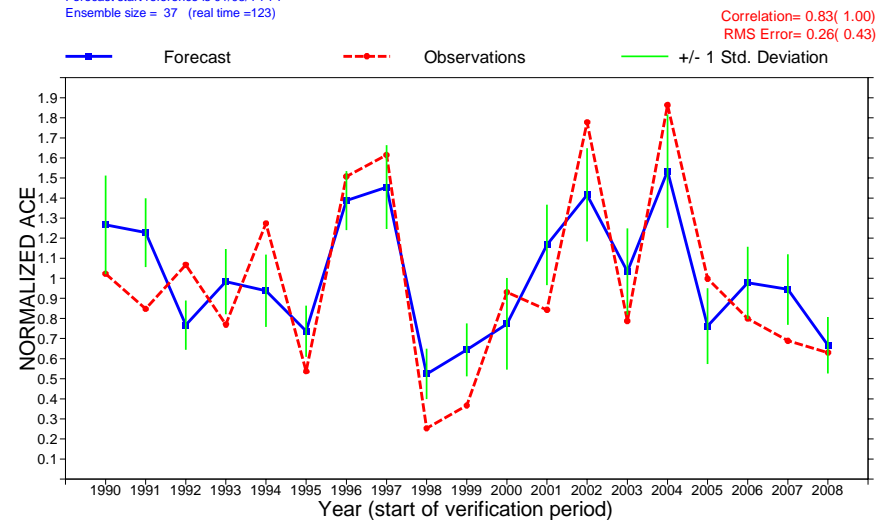
EUROSIP multi-model seasonal forecast
Western North Pacific Accumulated Cyclone Energy
Forecast start reference is 01/03/YYYY
Ensemble size = 37 (real time = 123)

ECMWF/Met Office/Météo-France
MJJA

Obs July-November



W-Pac E-Pac Atl
1987-2004
2005



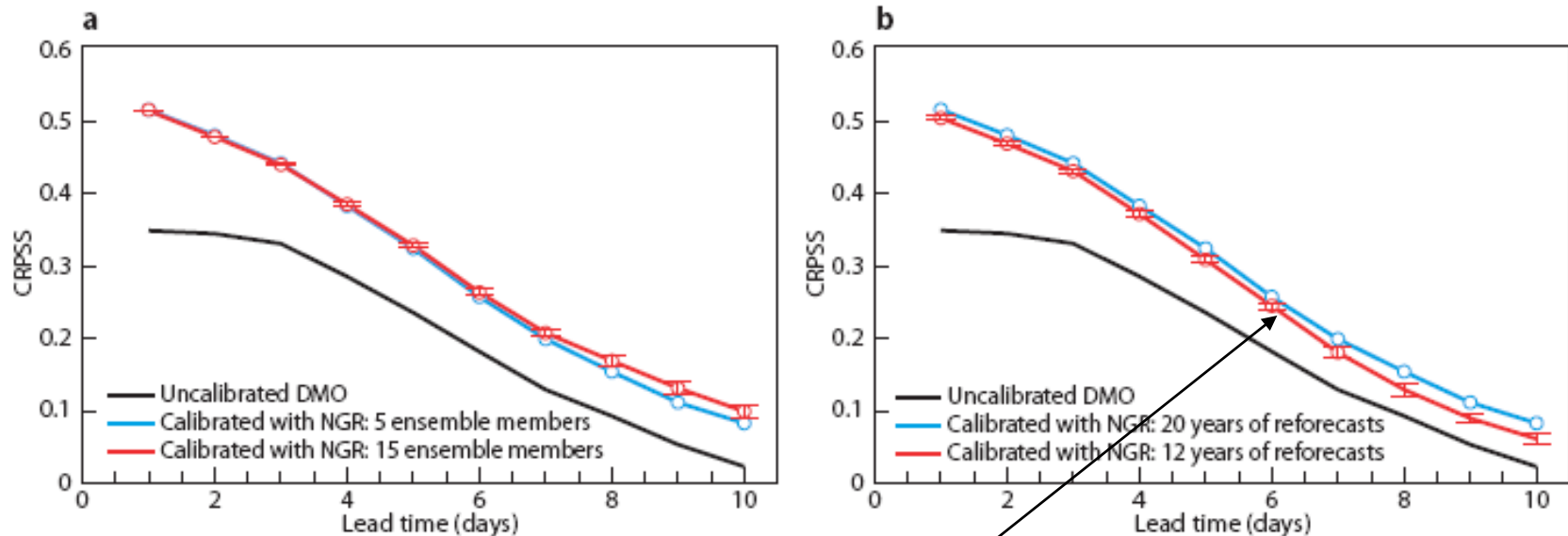
*Vitart et al, GRL
2007*

What is the value of a long historical record?

Example from the Medium Range Weather Forecasts (TIGGI)

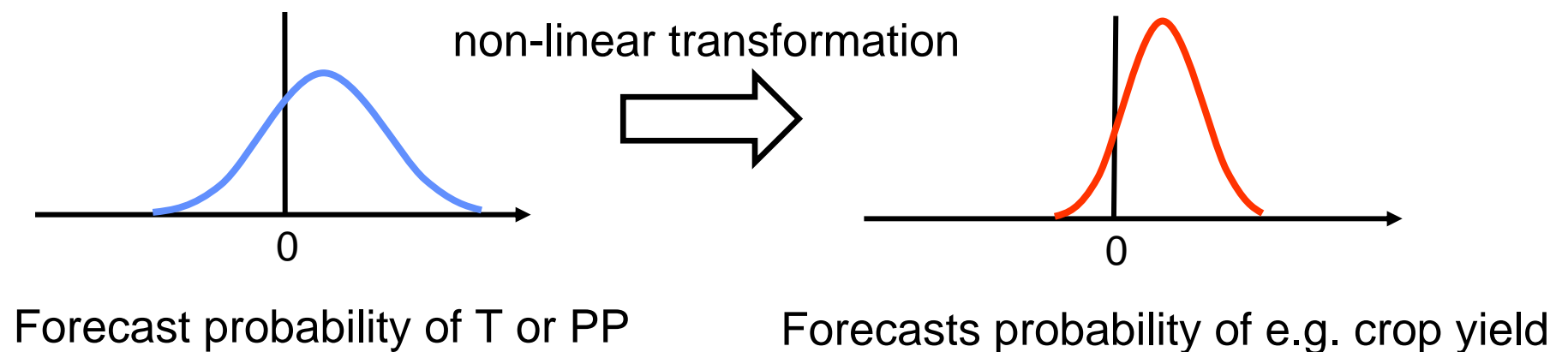
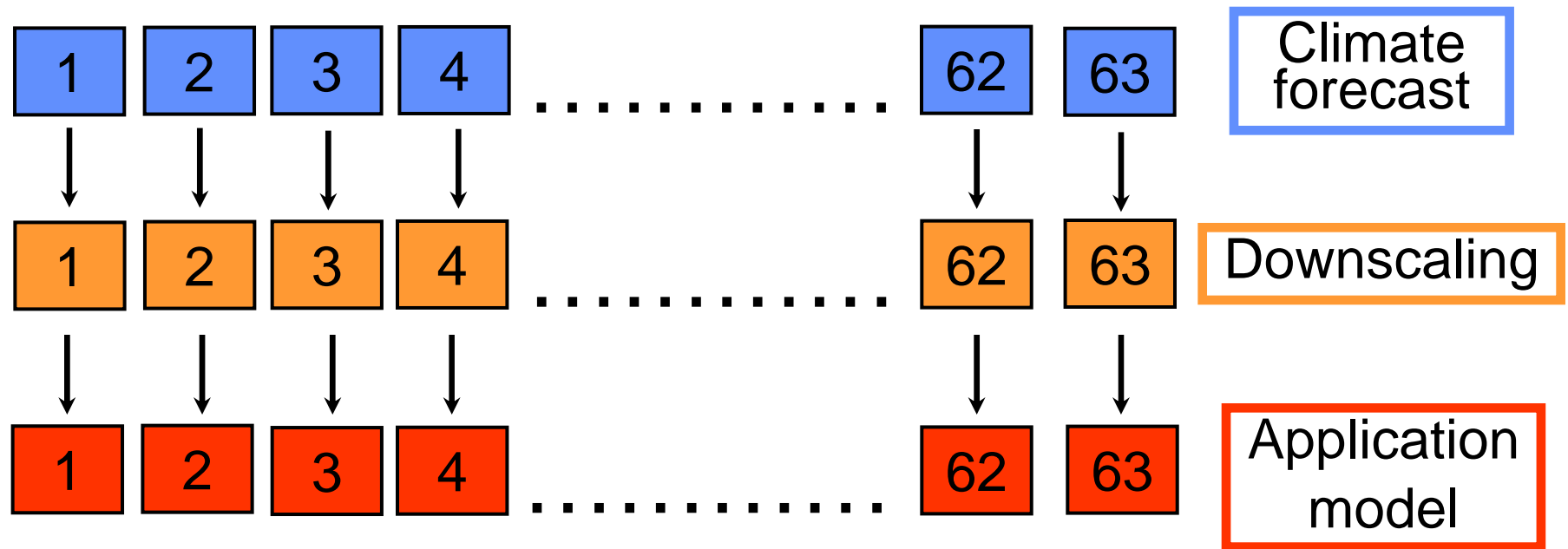
Impact of Increased ensemble size versus longer calibration period

(Continuous Rank Probability Skill Score, T-2m Europe)



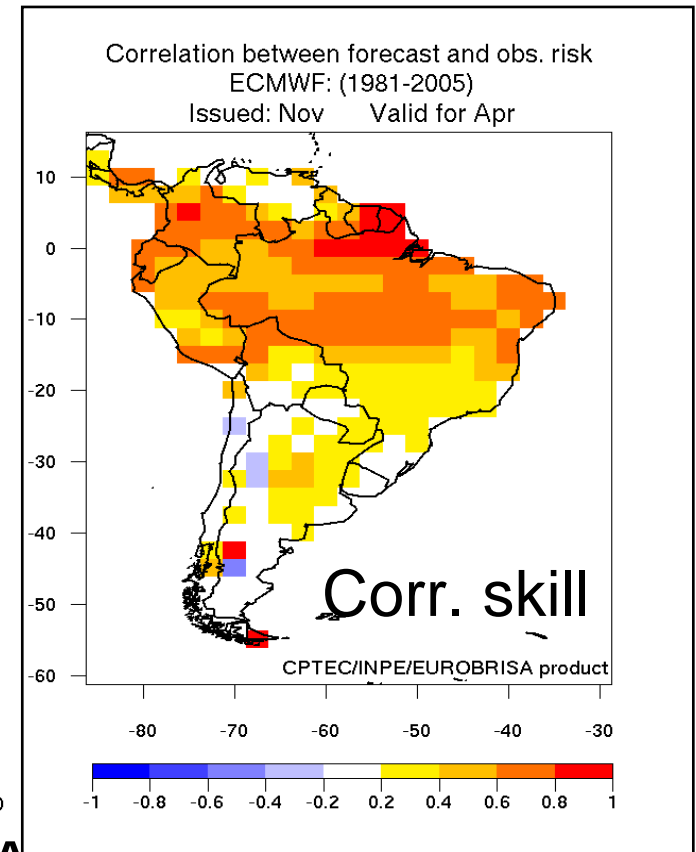
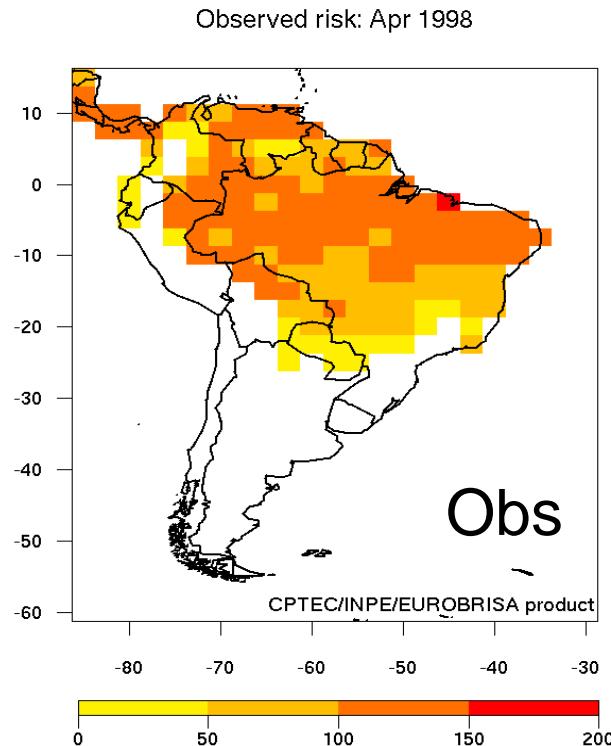
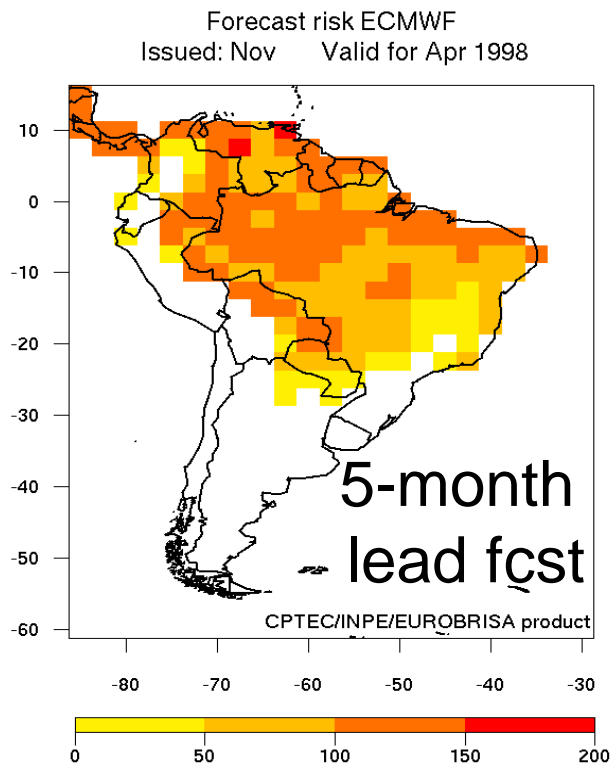
A longer calibration period has larger impact than increasing the ensemble size. From Hagerdorn 2008

Predicting for users: end-to-end



Prediction of Dengue Risk transmission: 5 month lead time

Forecast issued in Nov 1997, valid for Apr 1998



From EUROBRISA

<http://eurobrisa.cptec.inpe.br/>

Numerical Model+ Calibration + Dengue model

Recommendations for providers of observational data

1. Sustainability of the current observing systems and completion of impending missions.
2. **Complete implementation** of the RAMA array in the Indian Ocean. Add moorings in the S. Eq. Atlantic, where PIRATA sampling is very sparse.
3. **Collect observations of the ocean mixed layer** (likely to benefit medium-range, monthly and seasonal forecasts)
4. **Ensure availability of independent data** (ocean currents from current meters, sea-level gauges and transports), important for validation. Semi-independent data (OSCAR currents or Argo-derived velocities), are also valuable.
5. **Continue observations of sea-ice concentration and thickness**, important to for wide range of time scales, from weeks to decades.
6. **Enhance observations of surface salinity**, in order to reduce the large uncertainties in the fresh-water budget over the oceans.

Recommendations to the modeling and data assimilation communities

1. **Further develop models and assimilation methods to exploit existing observations.**
2. **The assimilation community should be ready for the timely use of imminent observing systems** (gravity missions, surface salinity and RAMA).
3. **Continue efforts on ocean re-analyses**, aiming at providing long, climate-quality records of the history of the ocean. This includes efforts on observation retrieval and quality control, as well as the improvement of assimilation methods.
4. **Improve forcing fluxes from atmospheric re-analyses**, ensuring that the products continue in near-real-time
5. **Closer interaction between the oceanic and atmospheric communities for the balanced initialization of coupled models**
6. **Work should continue on SST products and re-analyses.** (long records, high spatial and temporal resolution. Diurnal cycle)
7. **Work should continue on OSEs and OSSEs**

THE END

Recommendations for providers of observation data

1. It is essential to maintain the current observing system in the years to come and complete observing systems still under development.
2. Complete implementation of the RAMA mooring array in the Indian Ocean. Also add moorings in the south equatorial Atlantic in regions where PIRATA sampling is currently very sparse.
3. Collect observations of the ocean mixed layer, needed for better representation of processes related with the air-sea interaction at intraseasonal time scales, such as the MJO. This is likely to benefit medium-range, monthly and seasonal forecasts.
4. Ensure availability of independent data, such as ocean currents from current meters, sea-level gauges and transport, which are important to validate results from the assimilation systems. Semi-independent data, such as the OSCAR currents or Argo-derived velocities, are also very valuable, since they often involve an independent methodology.
5. *Continue observations of* sea-ice concentration and thickness, which are likely to be important to for wide range of time scales, from weeks to decades.
6. Enhance the in situ network of surface salinity observations, to complement impending satellite salinity missions, in order to reduce the large uncertainties in the fresh-water budget over the oceans.

Recommendations to the modeling and data assimilation

— communities

1. Further develop models and assimilation methods to exploit existing observations. Special attention should be paid to those areas where existing observations appear to have a negative effect on forecasts, such as the Equatorial Atlantic.
2. The assimilation community should be ready for the timely use of imminent observing systems, such as those coming from gravity missions, surface salinity and the newly developed Indian Ocean observing system.
3. Continue efforts on ocean re-analyses, aiming at providing long, climate-quality records of the history of the ocean. This includes efforts on observation retrieval and quality control, as well as the improvement of assimilation methods. In particular, it is important to develop methodology to extrapolate observational information into the past, as to mitigate the spurious variability induced by the ever evolving ocean observing system.
4. Improve forcing fluxes from atmospheric re-analyses, ensuring that the products continue in near-real-time as needed for the production of historically consistent records of ocean initial conditions.
5. Continue efforts in the oceanic and atmospheric community to develop more balanced initialization techniques that mitigate the undesirable initial adjustments by taking into account the air-sea interaction processes.
6. Work should continue on SST products and re-analyses. Ocean and atmosphere reanalysis would benefit from historical SST reconstruction resolving time scales shorter than one week as far into the past as possible. Future SST analysis resolving the diurnal cycle will be of interest for model development and shorter range forecasting.
7. Work should continue on OSEs and OSSEs so as to evaluate current and future ocean observing systems as well as current and future assimilation methods.