The Role of Argo in Seasonal Forecasts

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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
  - Temperature, Salinity and bias corrections
- Calibration and skill assessment
  - providing meaningful forecasts from the numerical output.
- Recommendations

- 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
  - Heath (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

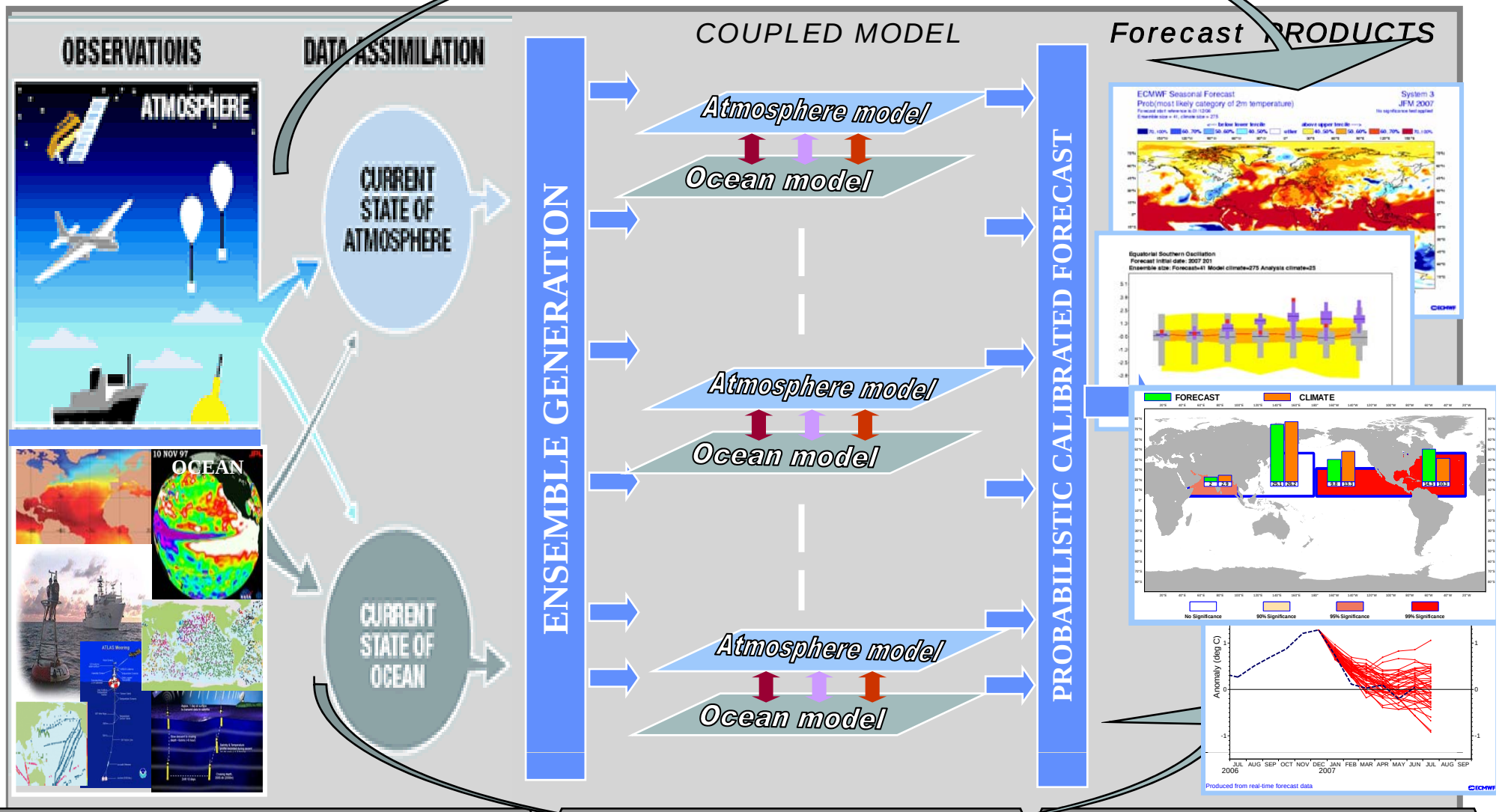
•Forcing by boundary conditions changes the atmospheric circulation, modifying the large scale patterns of temperature and rainfall, so that the probability of occurrence of certain events deviates significantly from climatology.

- 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



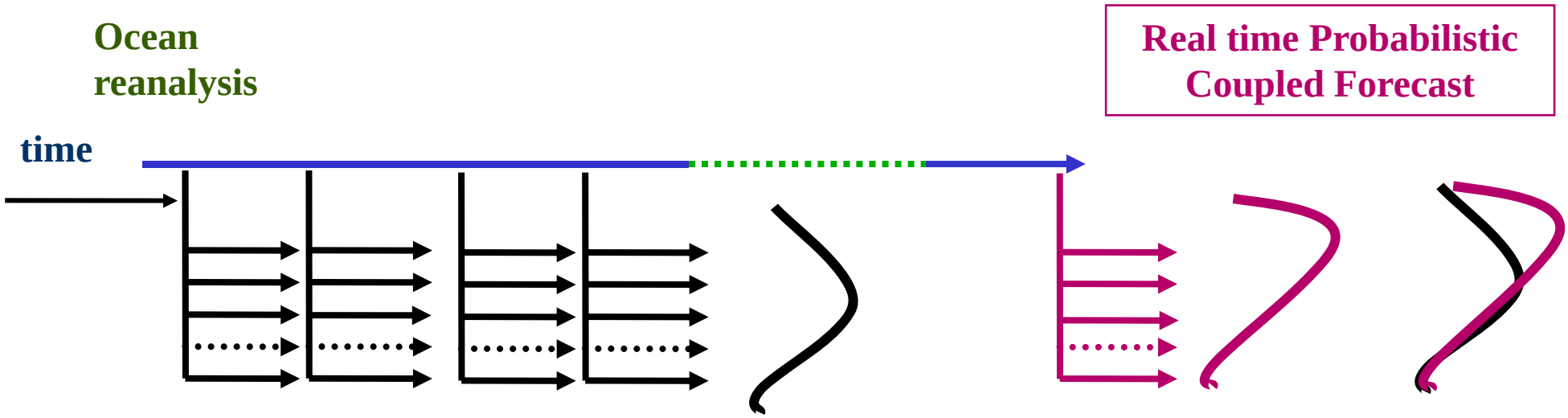
Importance of Initialization

- *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 <u>tropical</u> SST: need to initialize the ocean subsurface.*
    - *Emphasis on the thermal structure of the upper ocean*
    - *Predictability is due to higher heat capacity and predictable dynamics*
  - *A simple way: ocean model + surface fluxes.*
    - *But uncertainty in the fluxes is too large to constrain the solution.*
  - *Alternative : ocean model + surface fluxes + ocean observations*
    - *Using a data assimilation system.*
    - *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



Coupled Hindcasts, needed to estimate climatological PDF, require a **historical ocean reanalysis**

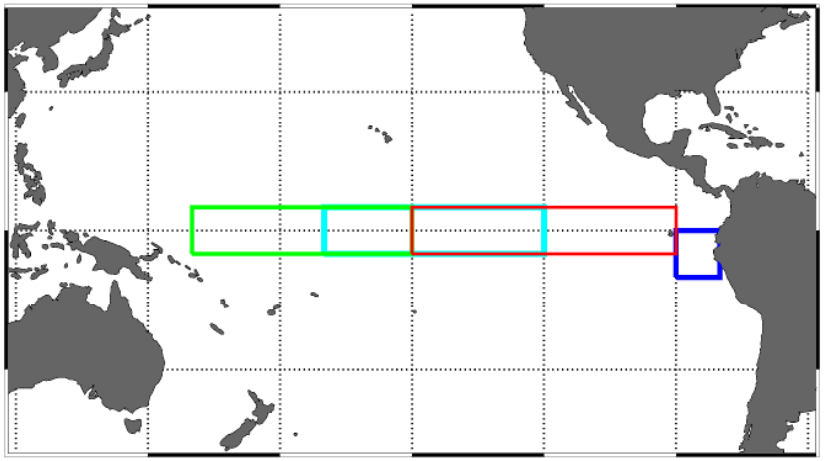
Impact of Data Assimilation

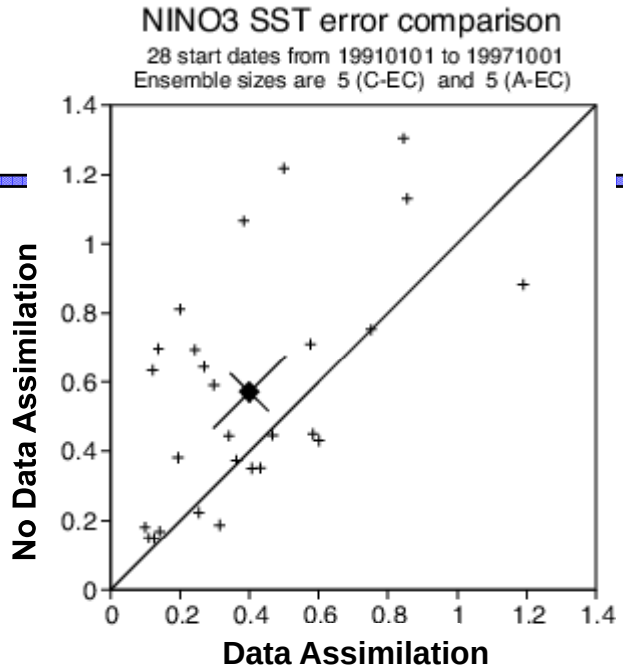
Forecast Skill

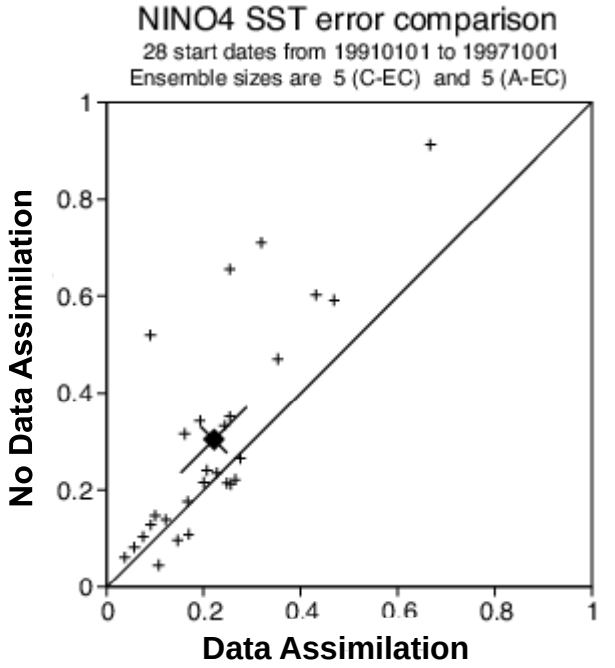
Ocean data assimilation also improves the forecast skill

(Alves et al 2003)

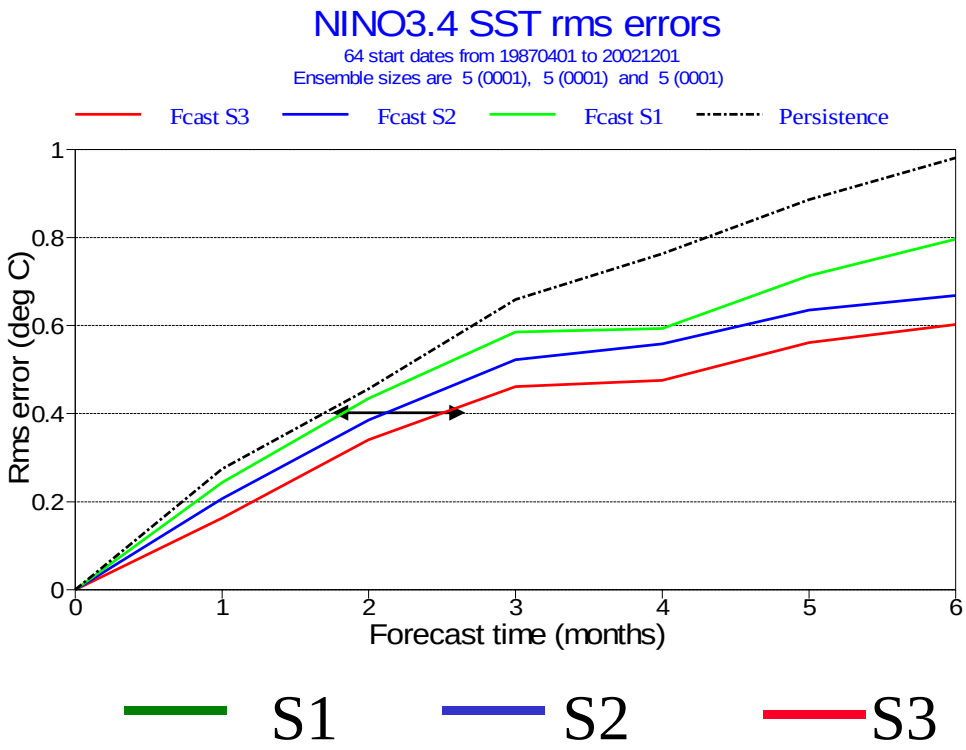
Nino3.4, Lon = [-170, -120], Lat = [-5, 5]
Nino12, Lon = [-90, -80], Lat = [-10, 0]
Nino4, Lon = [160, -150], Lat = [-5, 5]
Nino3, Lon = [-150, -90], Lat = [-5, 5]

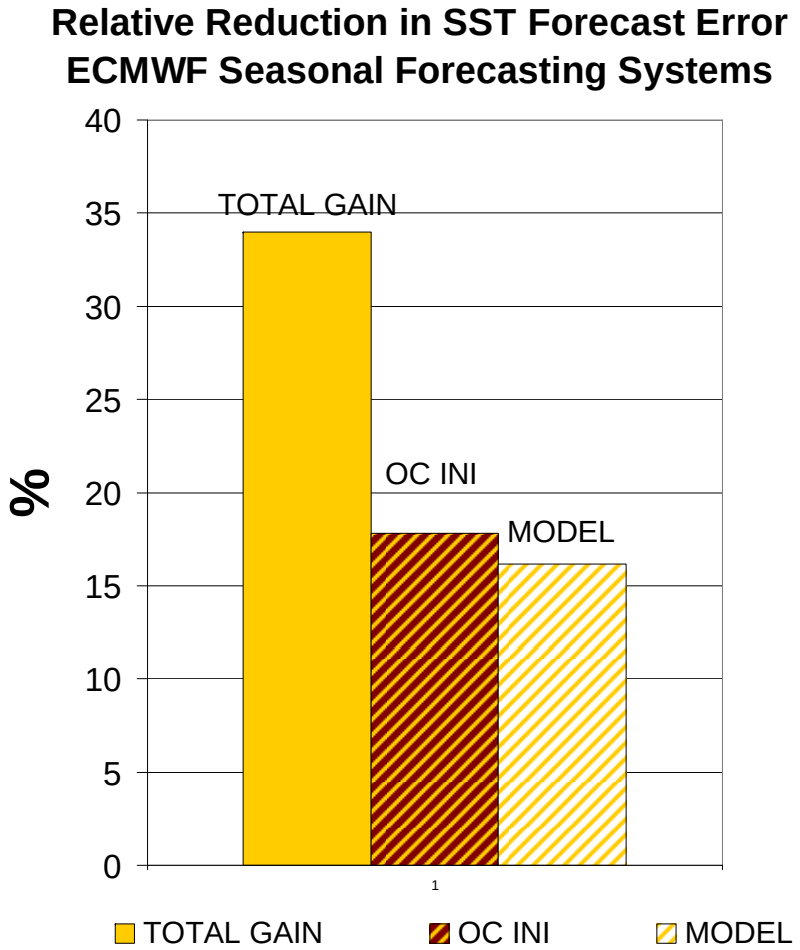






A decade of progress on ENSO prediction

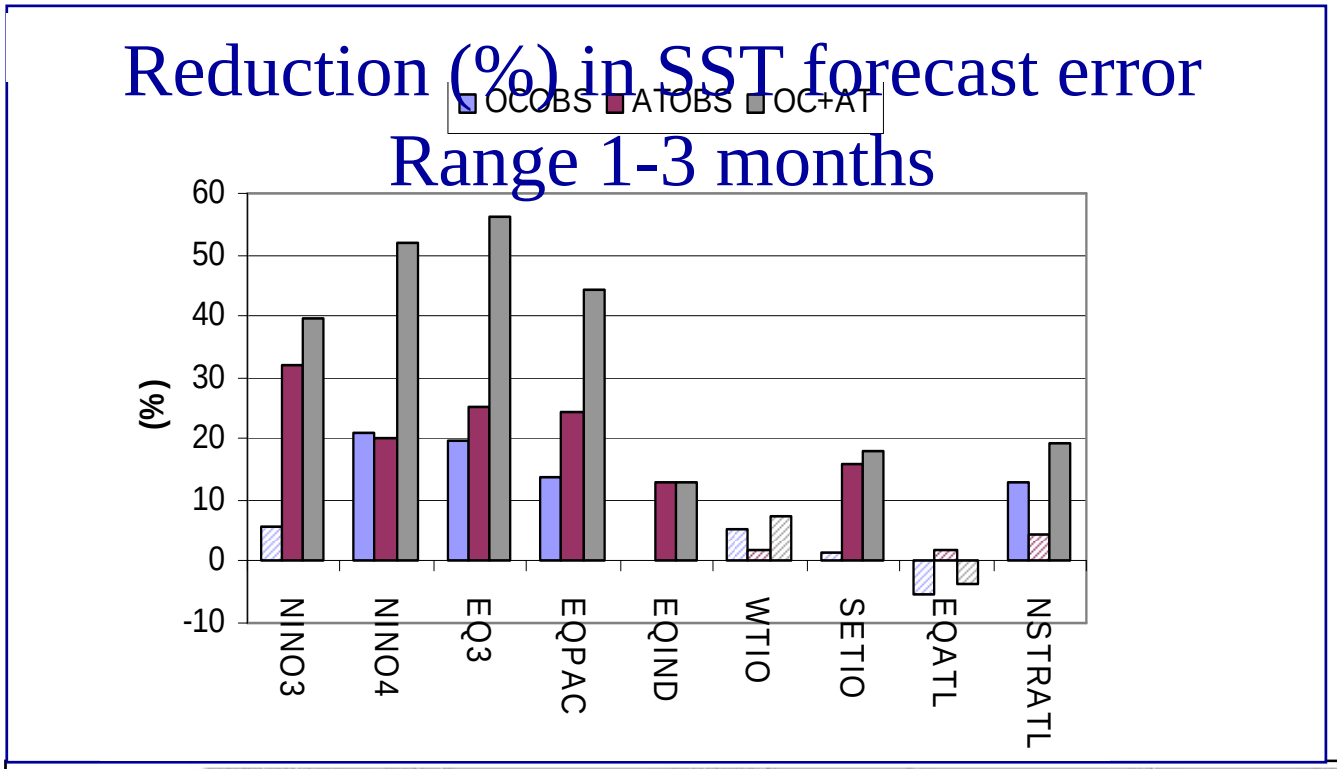


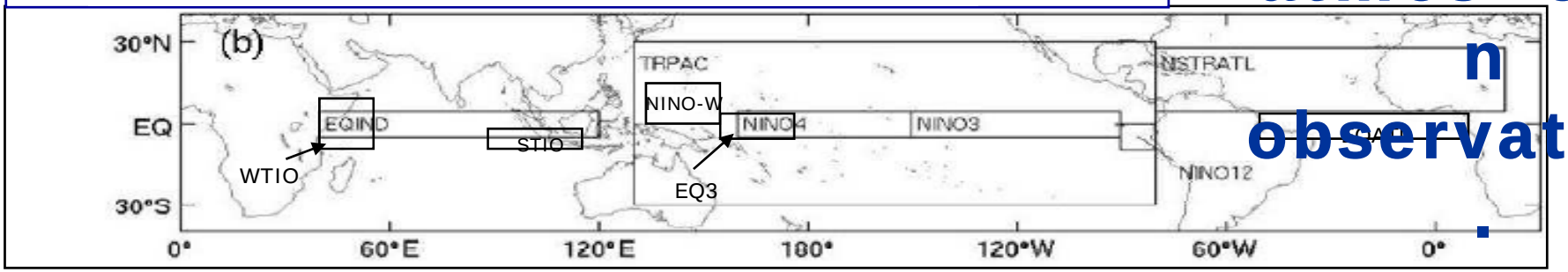


- Steady progress: ~1 month/decade skill gain
- How much is due to the initialization, how much to model development?

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

Impact on forecast skill (ECMWF-S3)





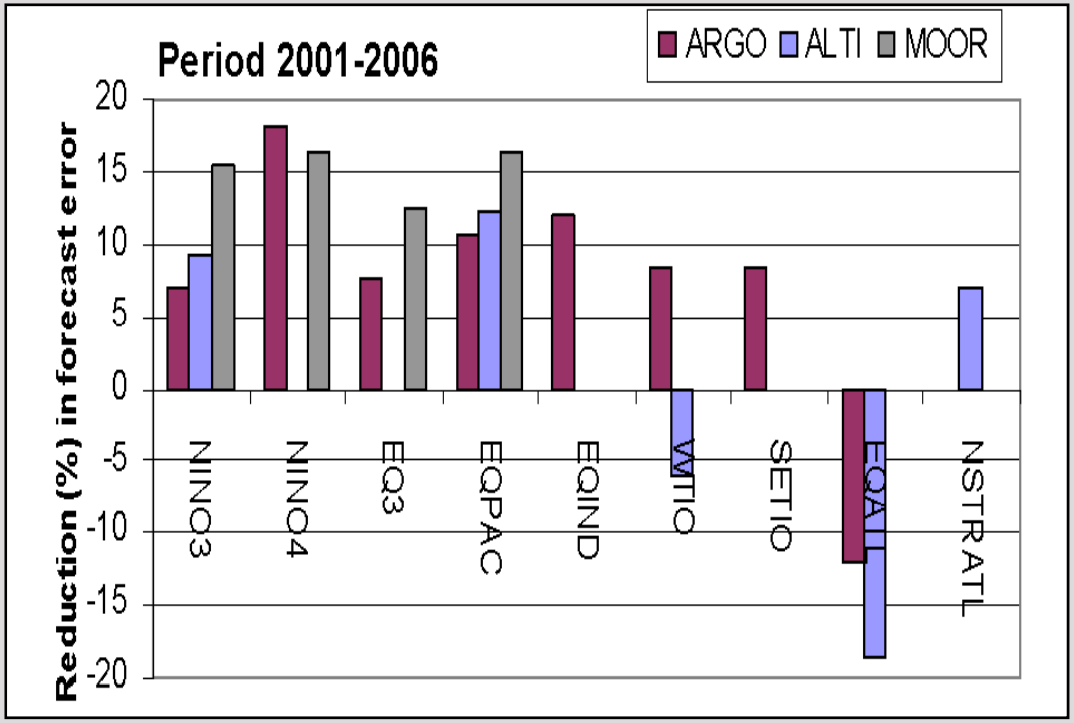
In Central/Western Pacific, up to 50% of forecast skill is due to atmos+ocean observations

Sinergy: ->

Balmaseda et al 2008

Assessing the Ocean Observing System

1. **No observing system is redundant**
   - Example: the Pacific, where Argo, moorings and altimeter still complement.
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

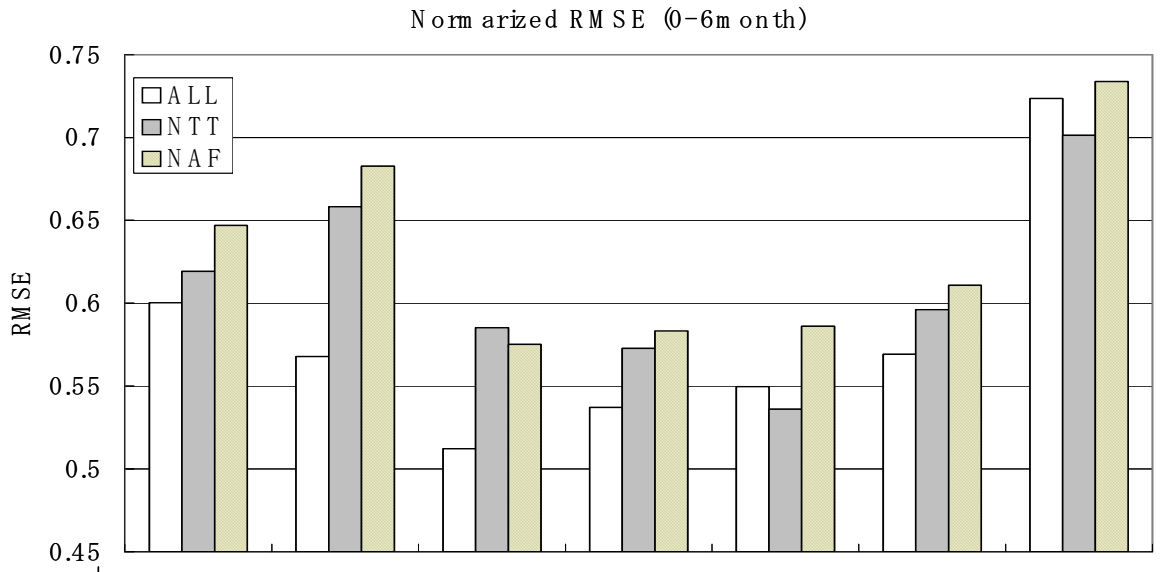


From Balmaseda and Anderson 2009

See also Fujii et al 2008

- 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

Impact of Different Ocean Observations JMA-MRI

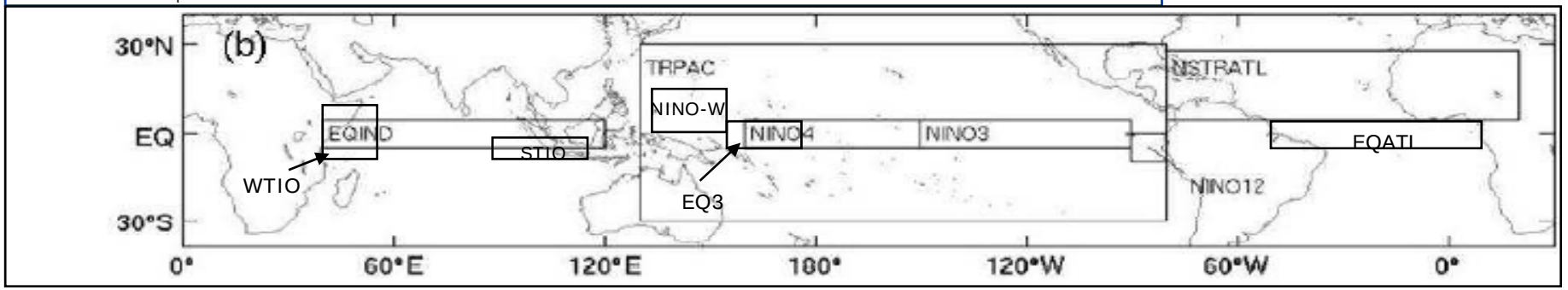


Significance	NINO12	NINO3	NINO34	NINO4	NINO-W	STIO	WTIO
NTT	61%	91%	89%	72%	41%	66%	39%
NAF	75%	95%	85%	77%	72%	74%	55%

OSEs in JM-MRI confirm the complementary nature of the observing systems (moorings and floats) on the skill of SF.

In most areas, errors are larger if Argo Floats (NAF) are removed.

Fujii etal 2008



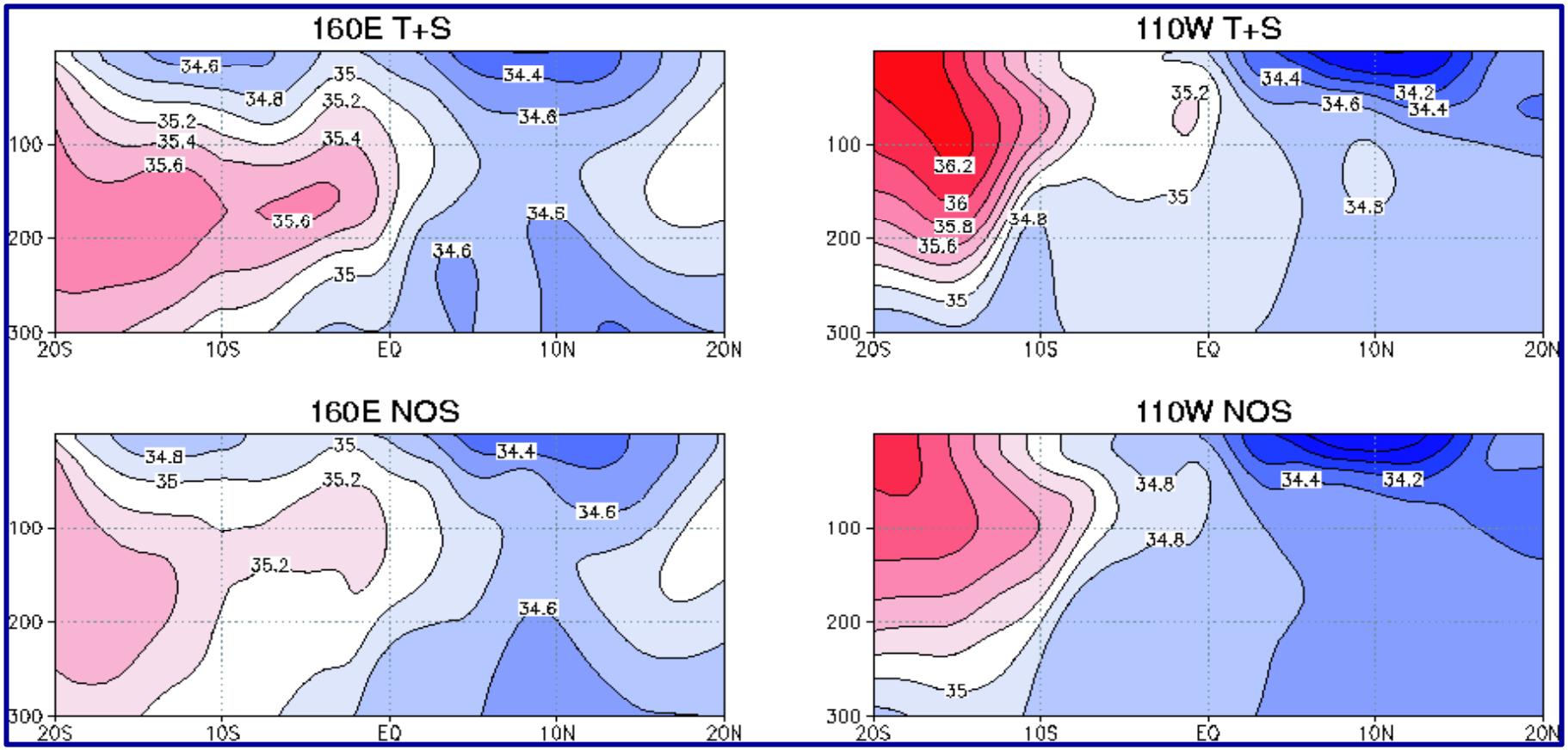
Influence of the observational data

- Direct correction of temperature profiles, correcting the model mean state and variability

- Salinity data:
  - To represent the water mass properties (stability and pressure gradients)
  - Barrier layer (see next examples, from Fujii et al 2008)

- Data can be also used retrospectively to estimate bias correction terms
  - To mitigate the detrimental effect of changes in the observing system
  - Example: the next ECMWF system will use Argo information to correct model bias prior to Argo.

Importance of Salinity



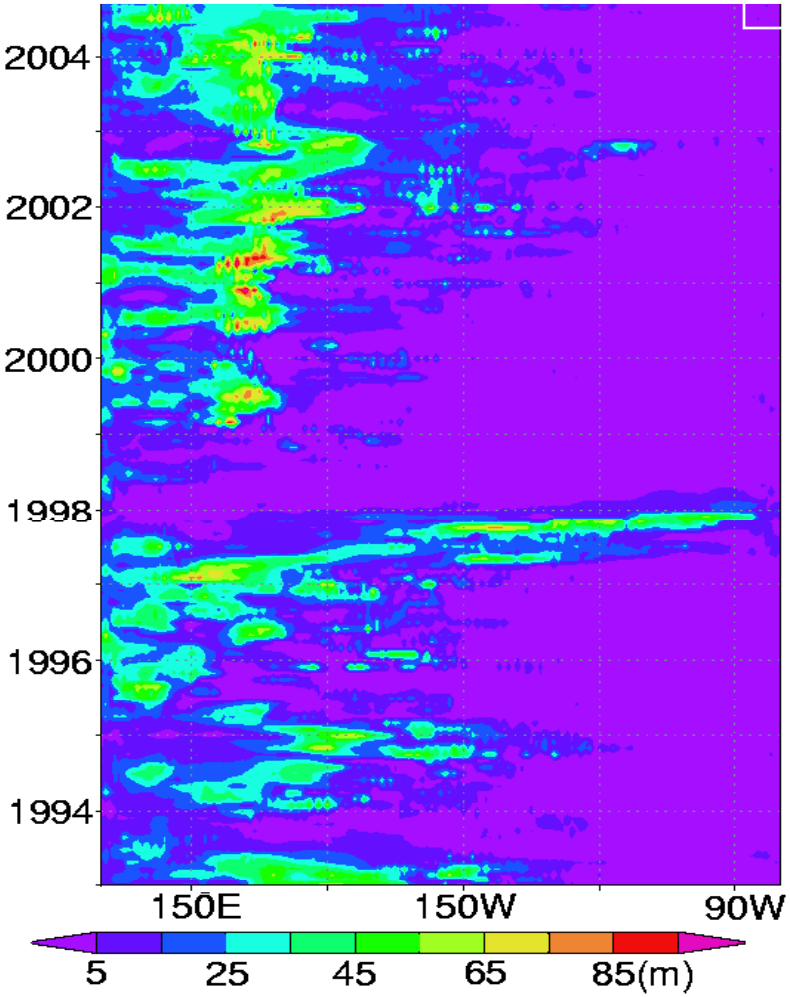
T+S: both temperature and salinity corrections

NOS: No Salinity corrections, only temperature

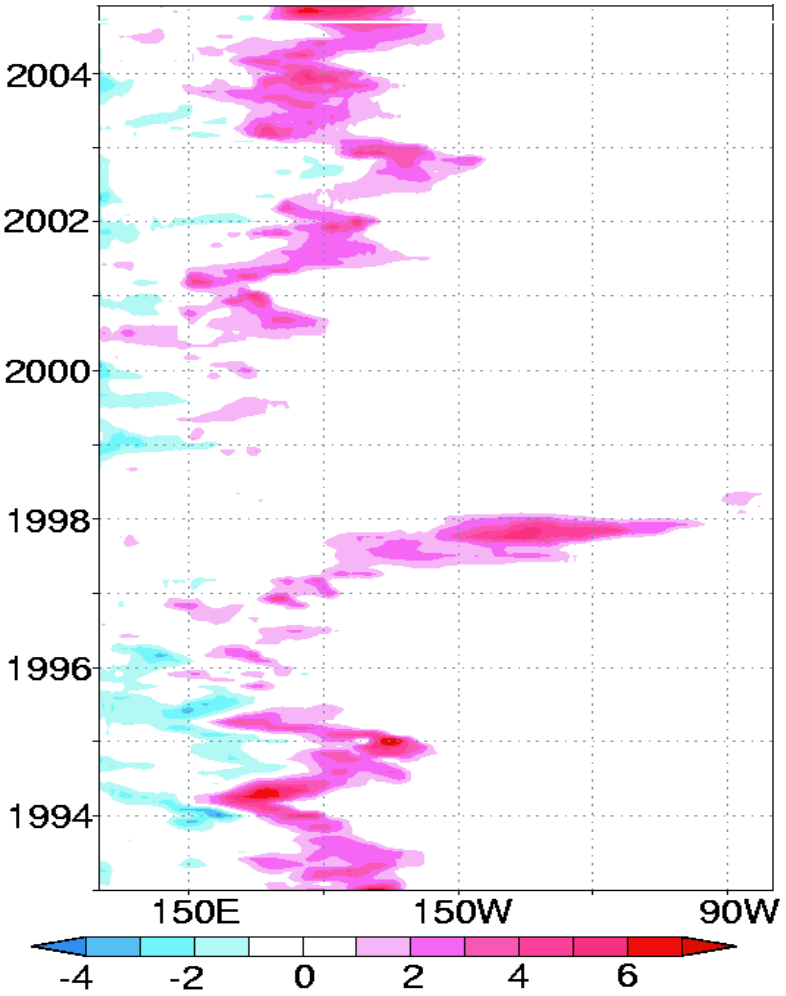
Results from MRI
Fujii et al 2008

barrier layer and warm water content

Barrier layer thickness T+S



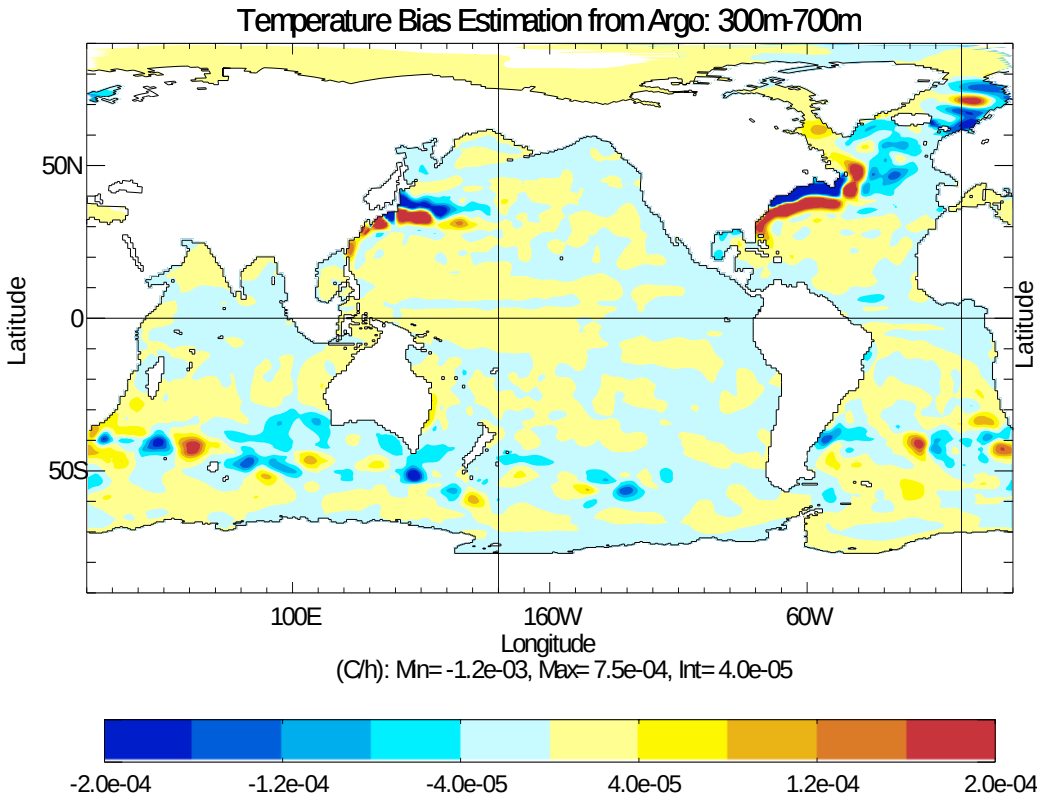
WWC: T+S -NOS

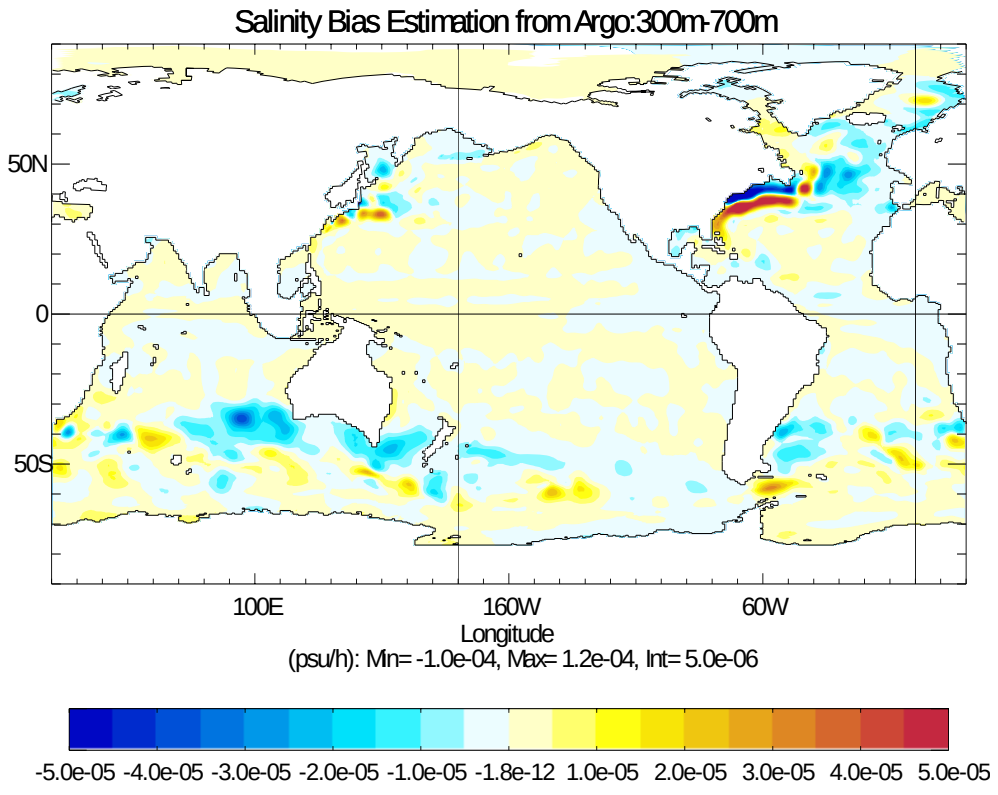


The WWC, function of the barrier layer thickness, plays an important role on ENSO

Fujii et al 2008

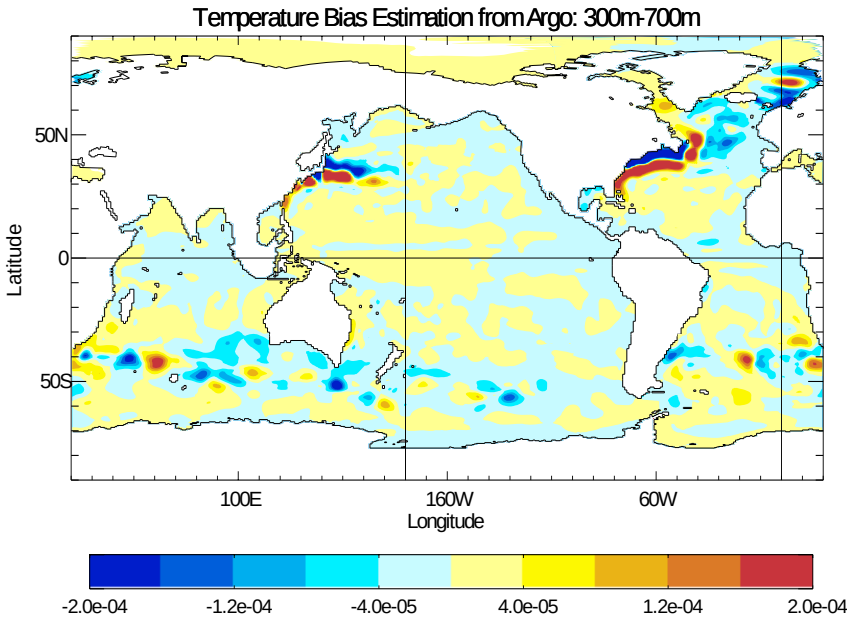
Estimating Bias Correction From Argo

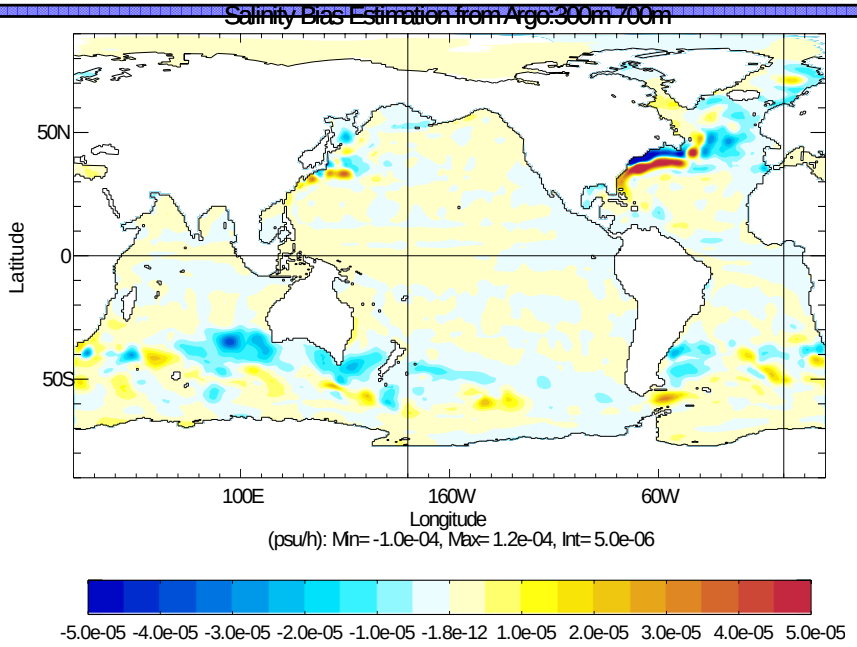


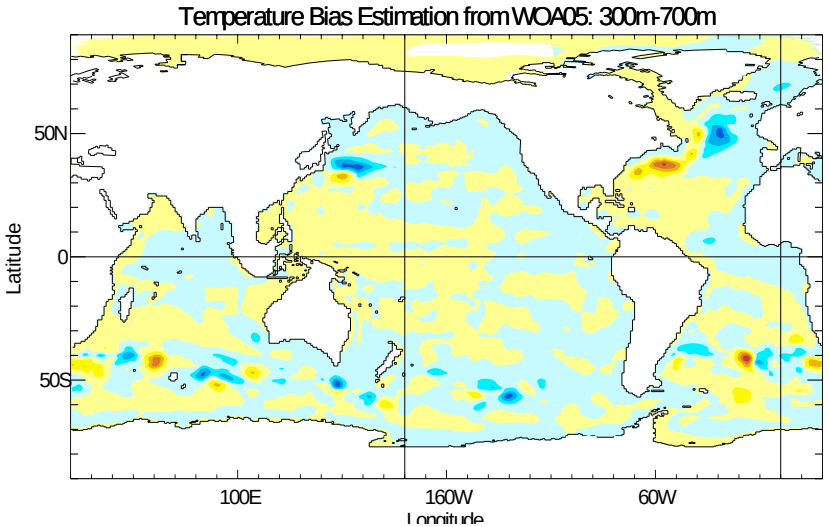


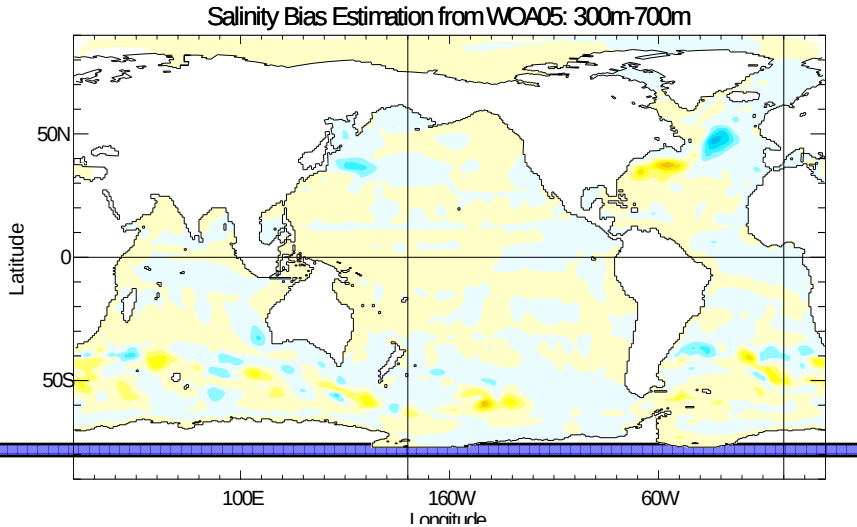
In the next ECMWF system, a seasonal dependent bias correction (from Argo) is applied during the data assimilation process in the production of long climate reanalysis (1957 to present)

Estimating Bias Correction From Argo







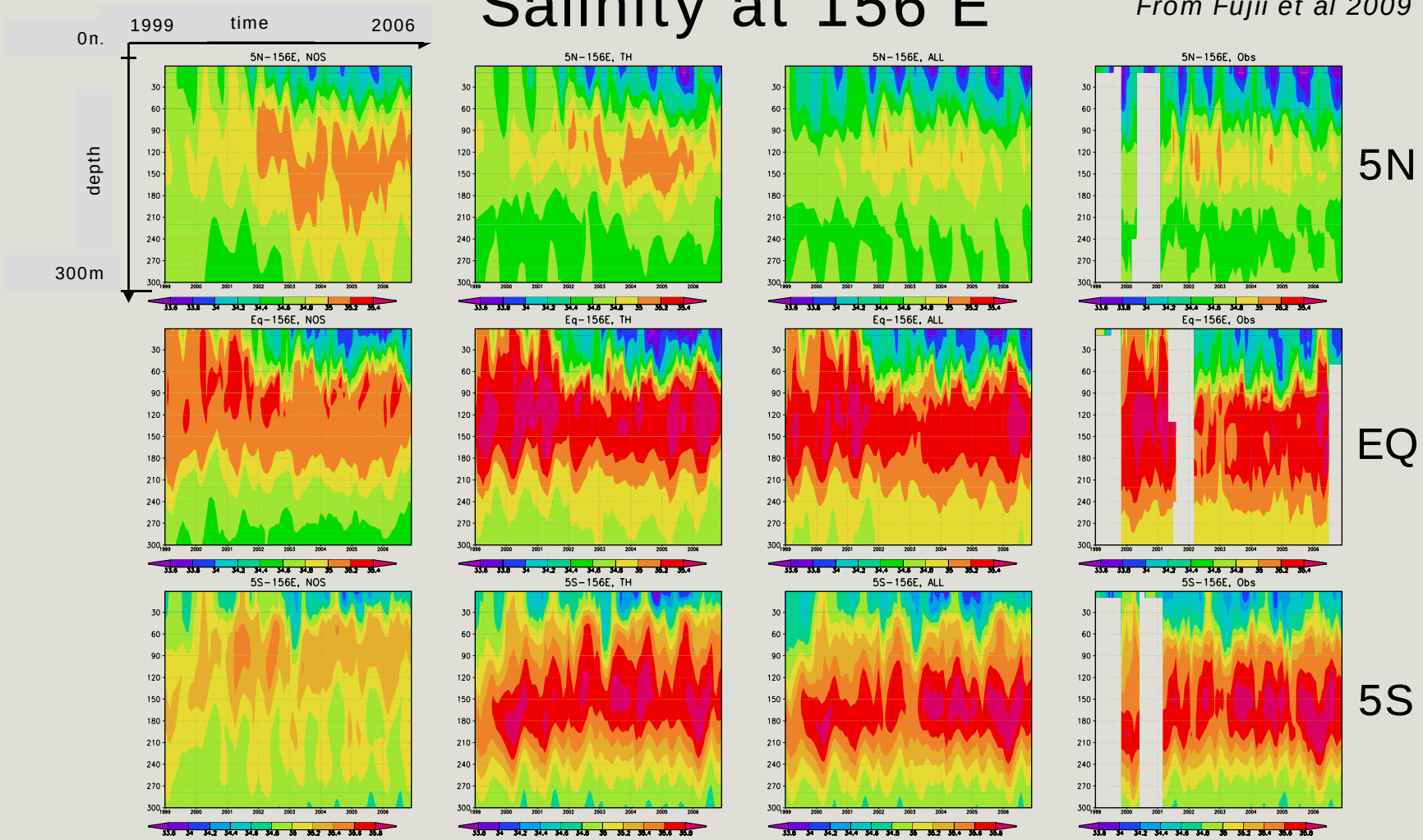


Ocean Observations & Assimilation Development

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

Salinity at 156 E

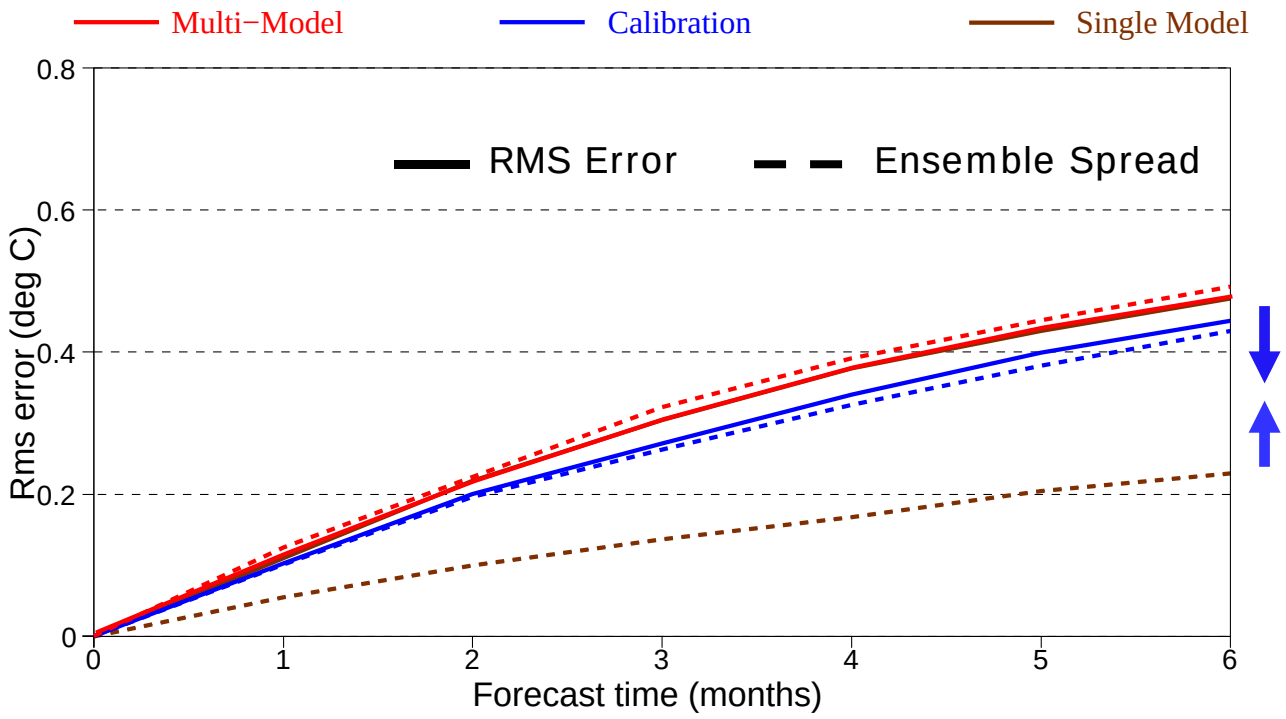
From Fujii et al 2009



T_{obs}	T_{obs} + S(T)	T_{obs} + S(T) + S_{obs}	Observations

Ocean Observation & Reliable forecast products

Forecast Systems are generally not reliable (RMS > Spread)



A. **Can we reduce the error? How much? (Predictability limit)**

B. **Can we increase the spread by improving the ensemble generation and calibration?**

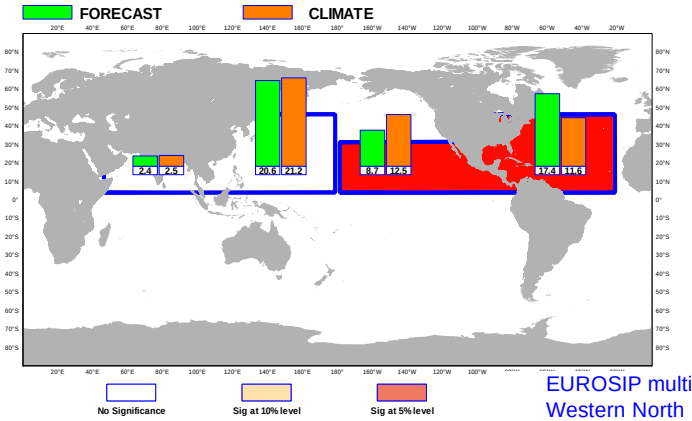
Calibration and multi-model can increase the skill and reliability of forecasts.

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

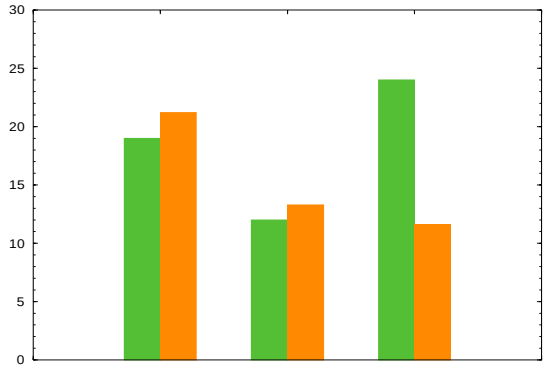
Long records are essential for robust calibration and downscaling

Multi-Model Seasonal forecasts of Tropical Cyclones

Multi-model Forecasts: 1st June 2005: JASON

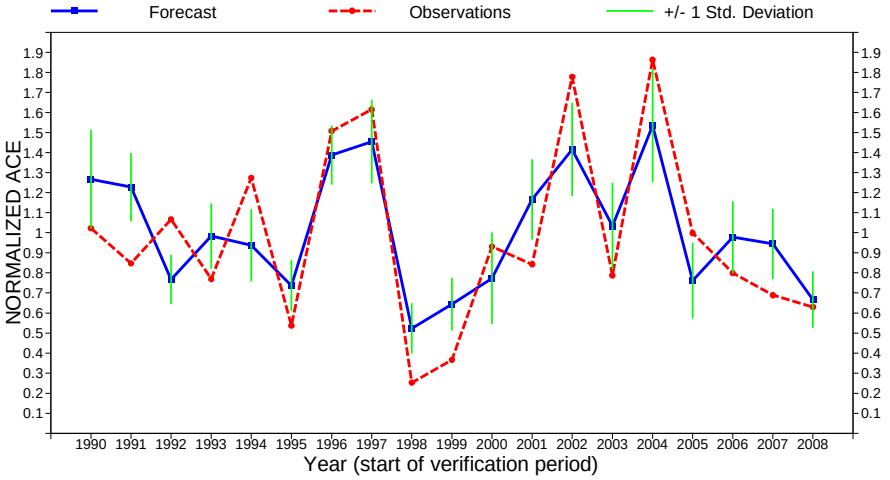


Obs July-November



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

Correlation= 0.83(1.00)
RMS Error= 0.26(0.43)



W-Pac E-Pac Atl

1987-2004

2005

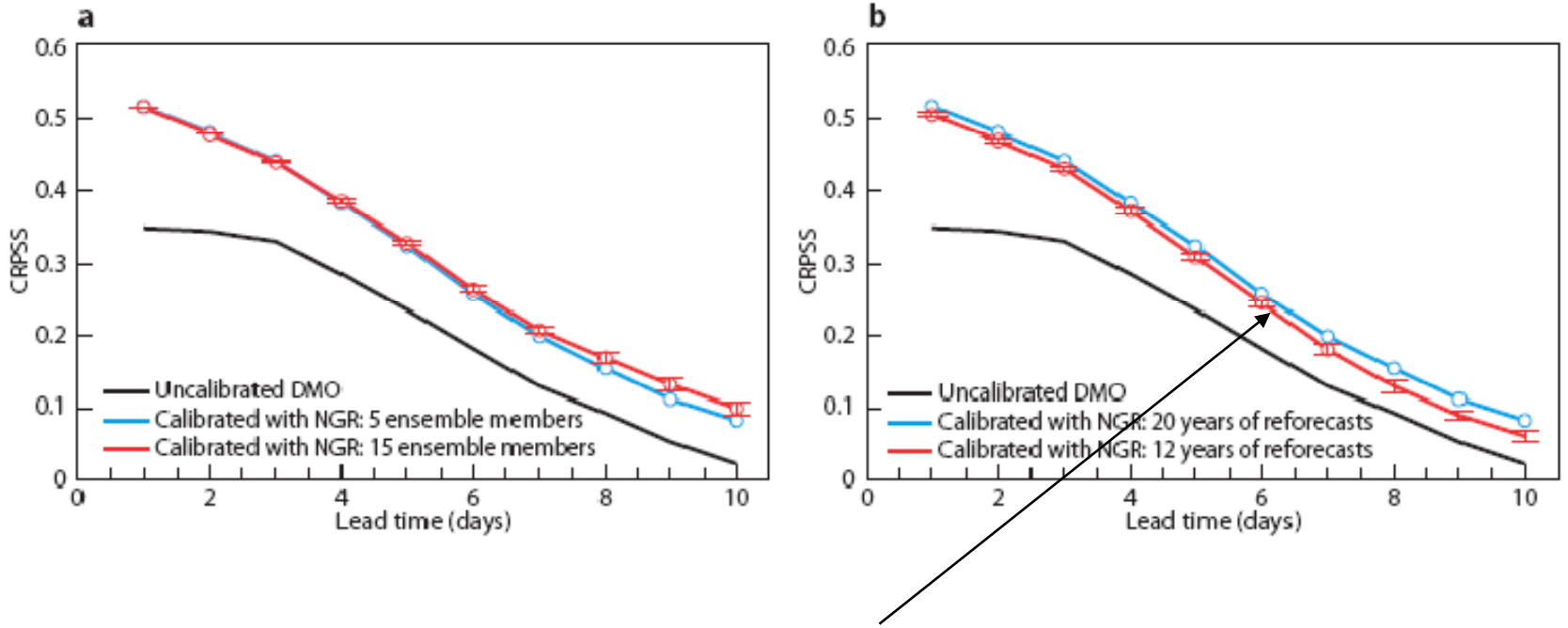
Vitart et al, GRL 2007

What is the value of a long historical record?

Example from the Medium Range Weather Forecasts (TIGGI)

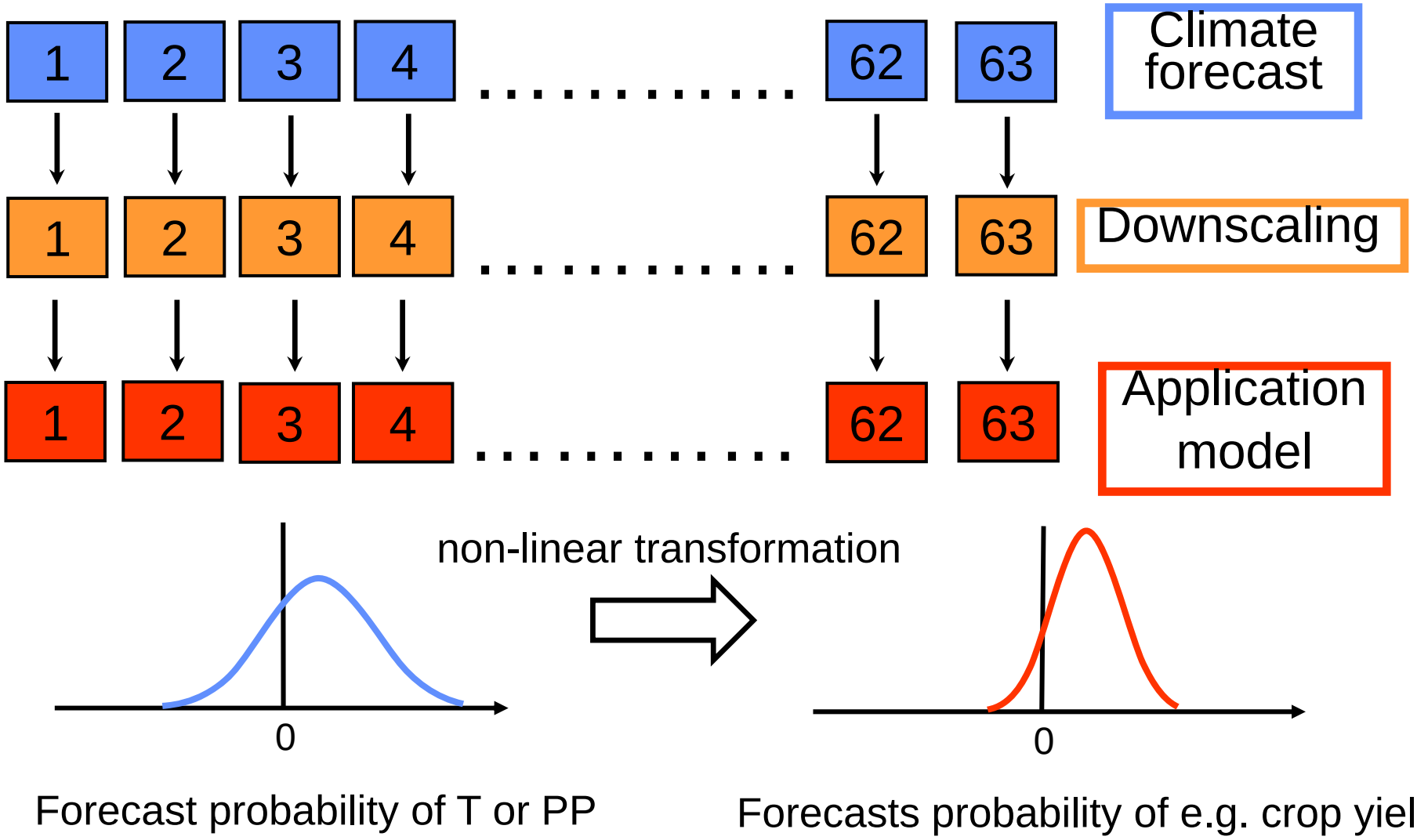
Impact of Increased ensemble size versus longer calibration period

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



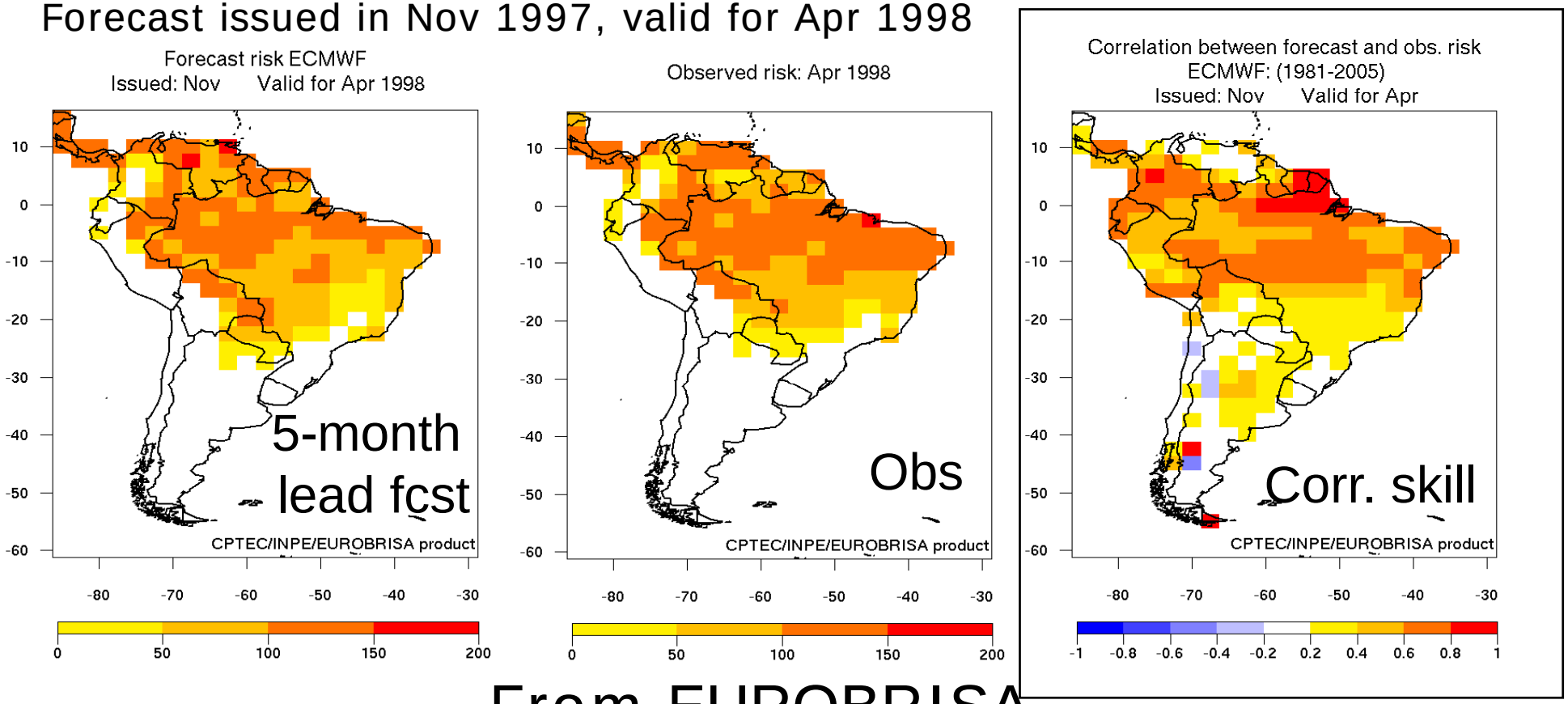
A longer calibration period has larger impact than increasing the ensemble size. From Hagerdorn 2008

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

Summary

- **The positive contribution of Argo to the skill of seasonal forecasts has been clearly demonstrated.**

- **The full potential of Argo data has not been fully exploited yet**
  - **Better models and better data assimilation methods.**
  - **More work on the impact of Argo on atmospheric variables is needed**
  - **The record is not long enough yet**

- **Long and consistent observational records are needed for calibration of forecast products useful for society. The longer the record, the better the calibration.**

Sustainability of the current observing systems is paramount to continue progress on seasonal prediction

THE END