Data Assimilation for Intra-Seasonal to Decadal Prediction

Issues for Discussion

Background

- **Typically, but not always, the analysis is performed separately for atmosphere, ocean, land and ice**
  - Some form “Coupled Data Assimilation” is Emerging
    - Best State Estimation vs. Initializing the Slow Manifold
- **Ocean: Resolution is typically 1 degree with finer resolution in the deep tropics and 10 meters in the upper ocean**
  - Quality Strongly depends on quality of surface fluxes
  - Surface fluxes typically come from operational weather forecast analyses
- **SST is a key parameter. Most systems use subsurface temperature and, some, salinity (mainly from Argo)**
- **Improvements in data and models improve forecast skill**

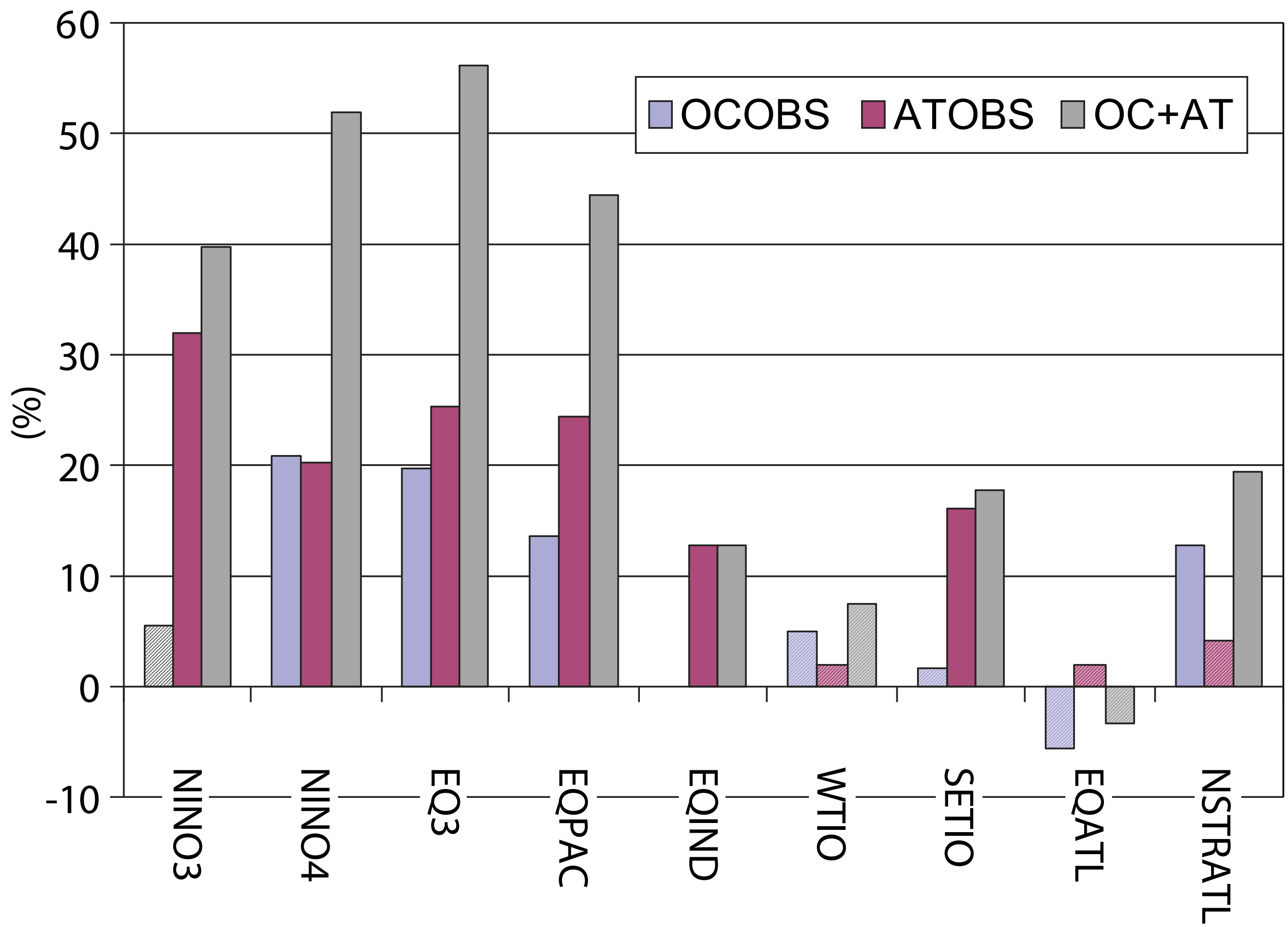


Figure 1. Impact of initialization on forecast skill for the different regions in Table 2, as measured by the reduction in mean absolute error for a one- to three-month forecast range. Solid bars indicate differences are above 80% significance level. Blue (OCOBS) indicates the impact of ocean observations, red (ATOBS) indicates the impact of atmospheric data, and grey (OC+AT) represents the combined impact of atmospheric and oceanic data.

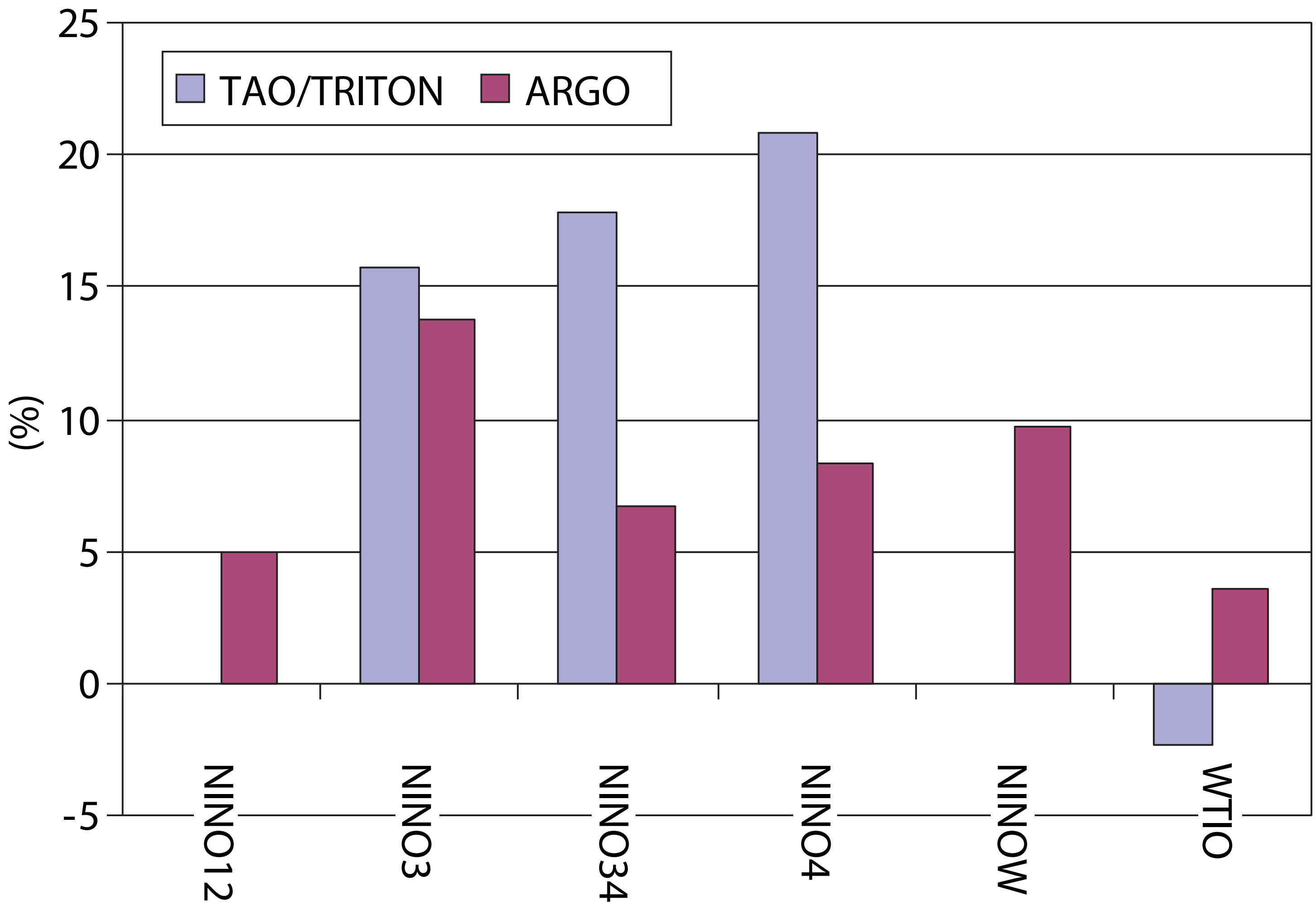
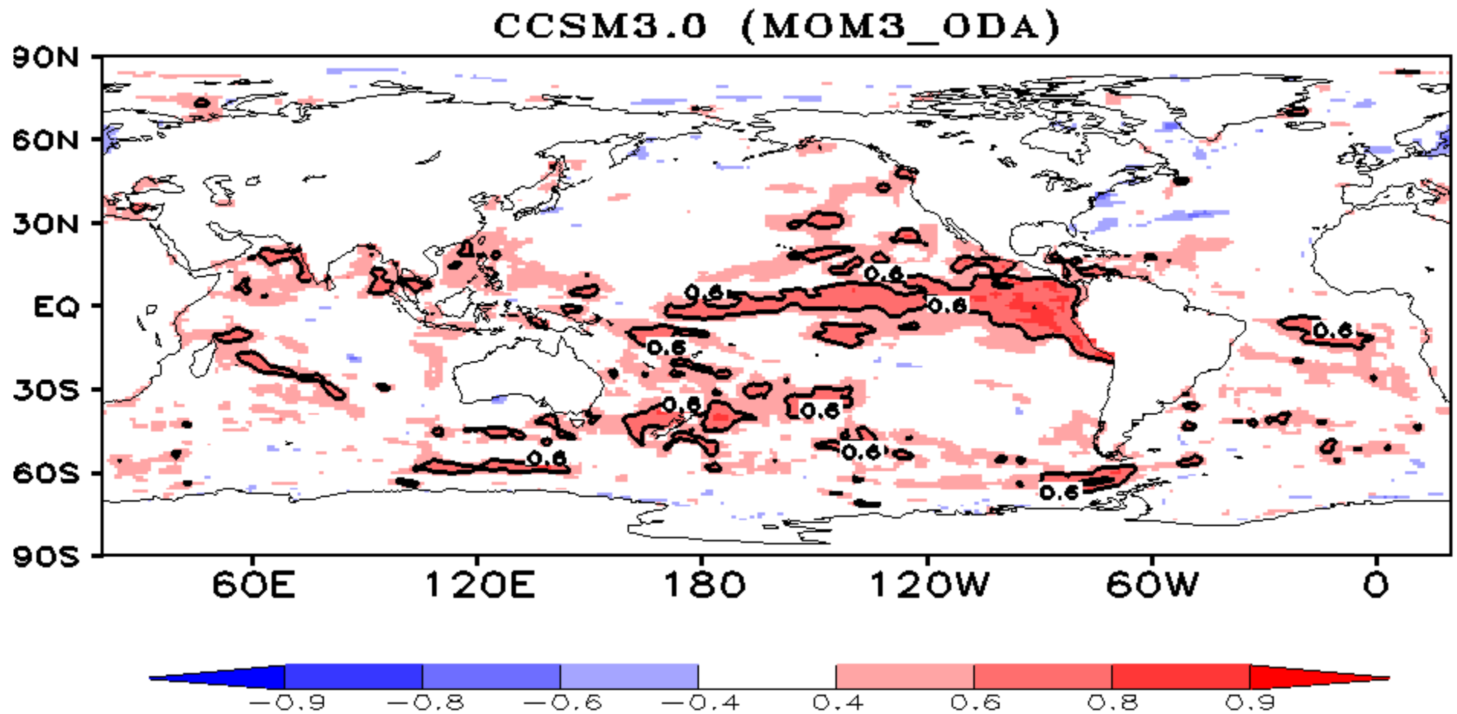
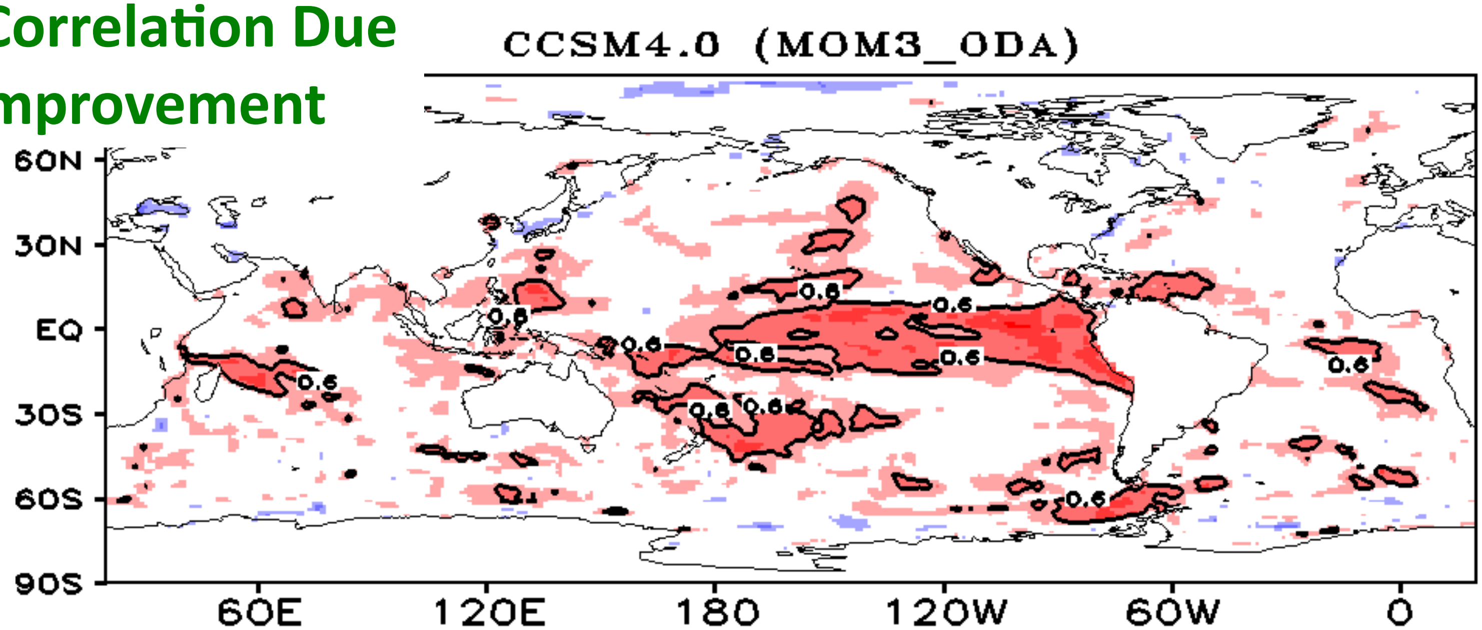


Figure 2. Impact of Tropical Atmosphere Ocean/Triangle Trans-Ocean Buoy Network (TAO/TRITON) and Argo data on seasonal forecast skill. The bars show the relative increase in root mean square errors of one- to seven-month forecasts of monthly sea surface temperature resulting from withholding TAO/TRITON and Argo data from the initialization of seasonal forecasts. The regions are defined in Table 2. *From Fujii et al. (2008)*

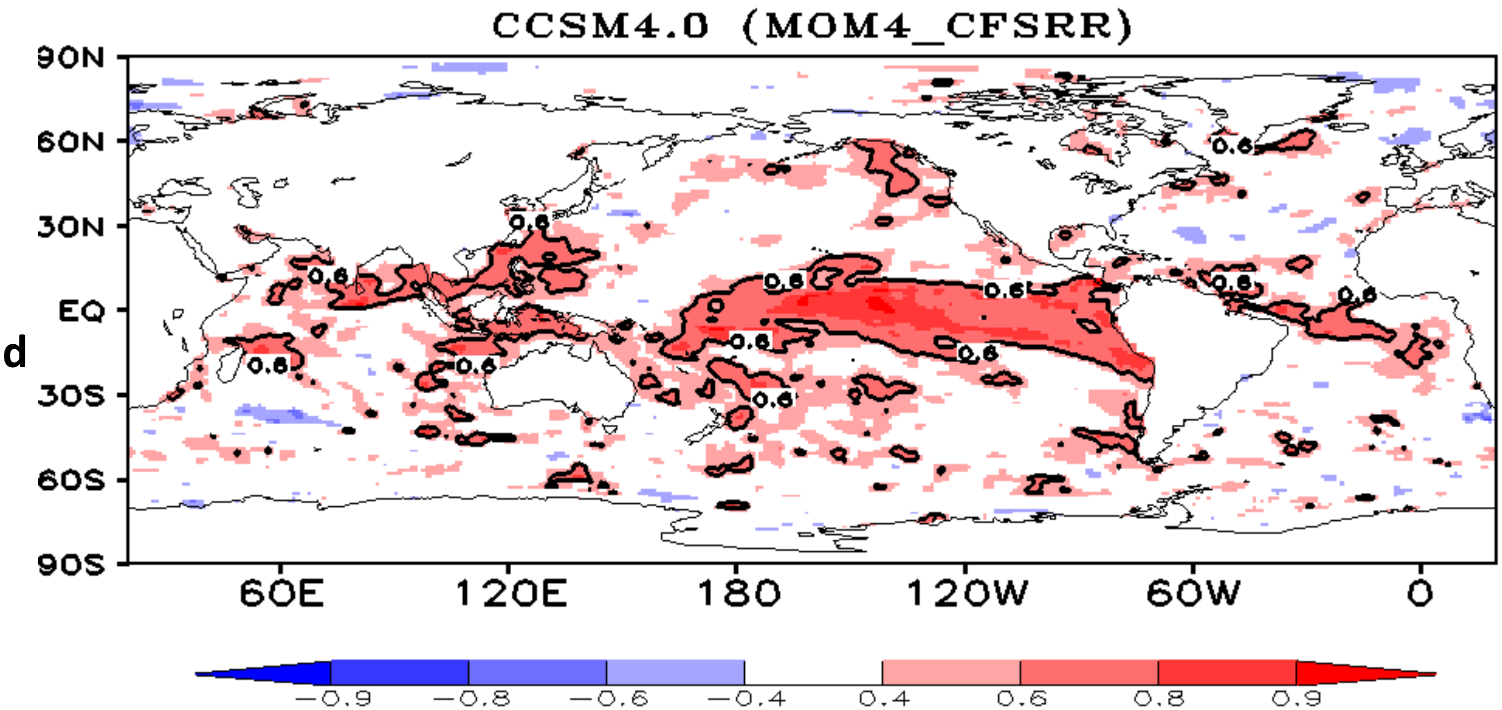
May Initial Conditions
3-Months Lead



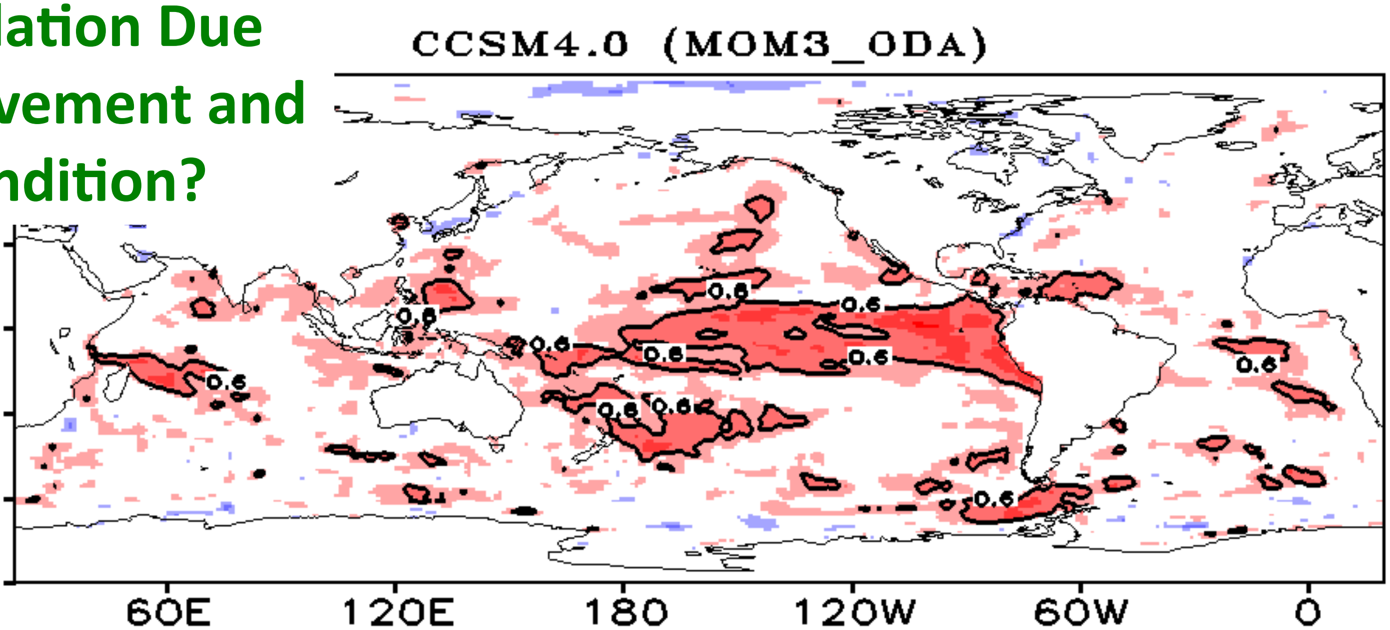
Improved Correlation Due to Model Improvement



May Initial
Conditions
3-Months Lead

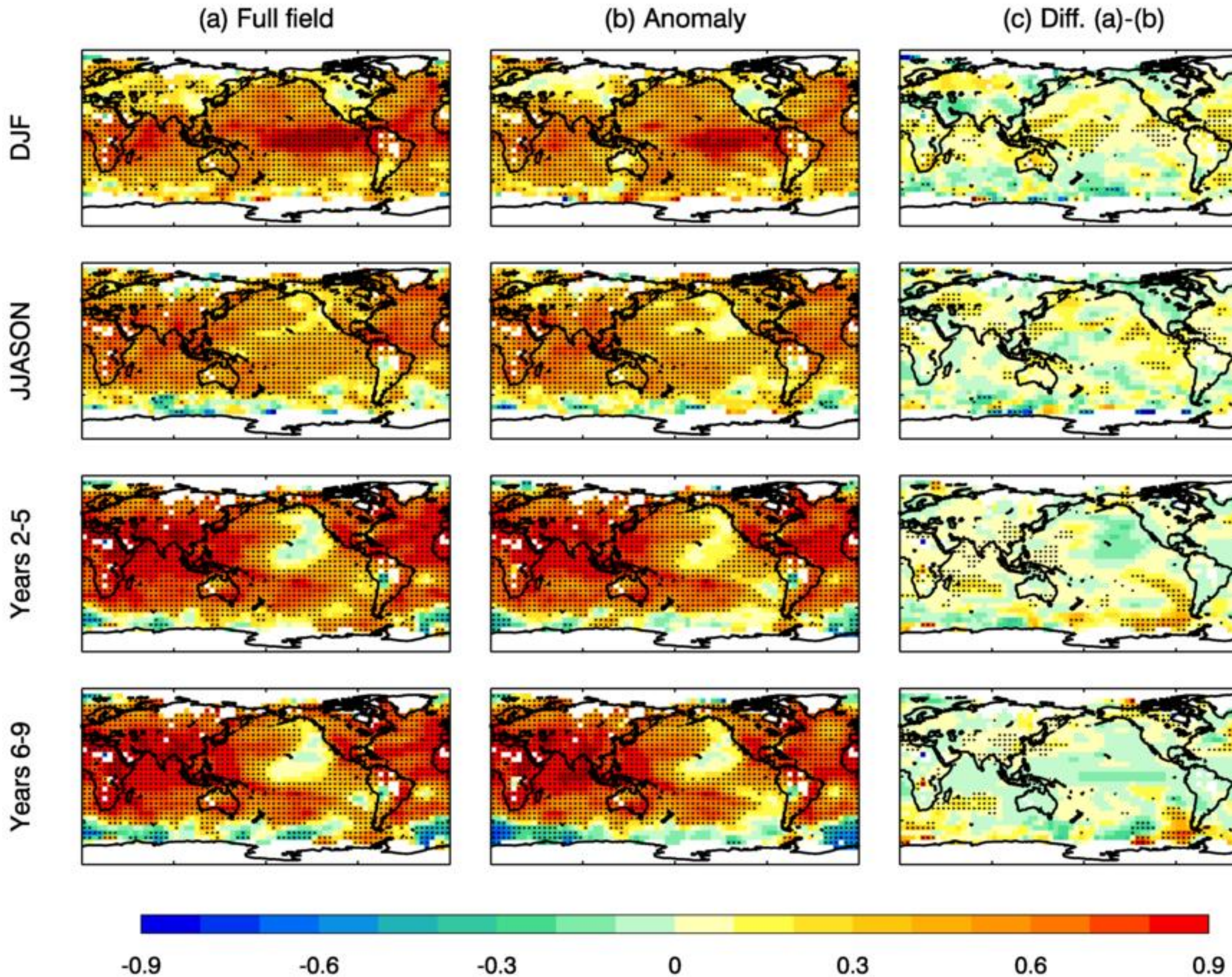


Improved Correlation Due to Model Improvement and Better Initial Condition?



Initialization

- **Not necessarily the same thing as assimilation**
  - Shock and/or Coupled Model Biases
- **Anomaly Initialization vs. Full Initialization**
- **Coupled Data Assimilation**
  - Slow Manifold vs. Best State Estimations


(a) Full field
(b) Anomaly
(c) Diff. (a)-(b)
DJF
JJASON
Years 2-5
Years 6-9
-0.9
-0.6
-0.3
0
0.3
0.6
0.9

What do we mean by "coupled data assimilation"?

- Assimilation into a coupled model where observations in one medium are used to generate analysis increments in the other [minimization of a joint cost function with controls in both media].

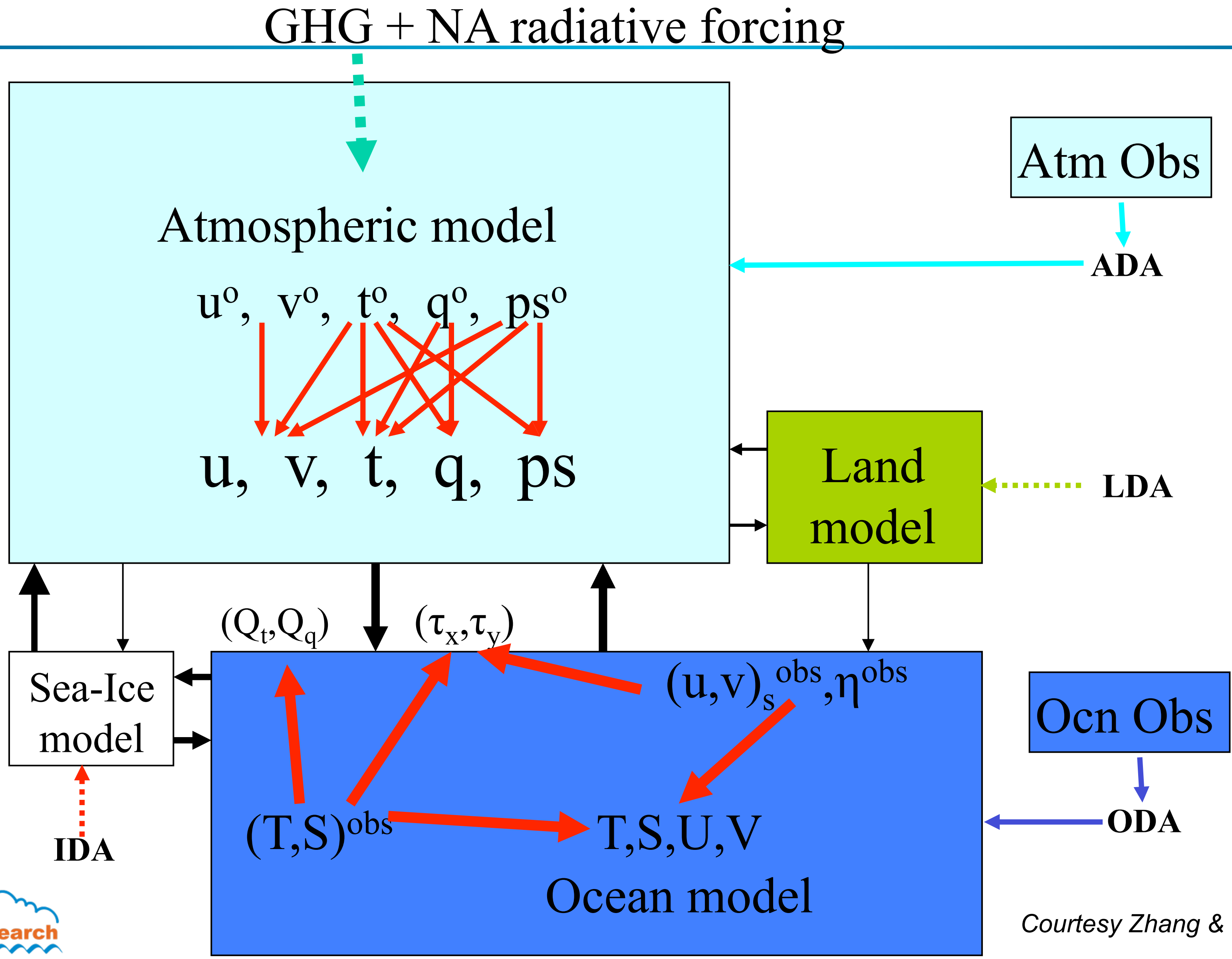
or

- Loosely (weakly) coupled: the first guess (background) for each medium is generated by a coupled integration.

or

- Reduced systems: atmosphere with corrections in ocean mixed layer model; ocean with correction of surface fluxes

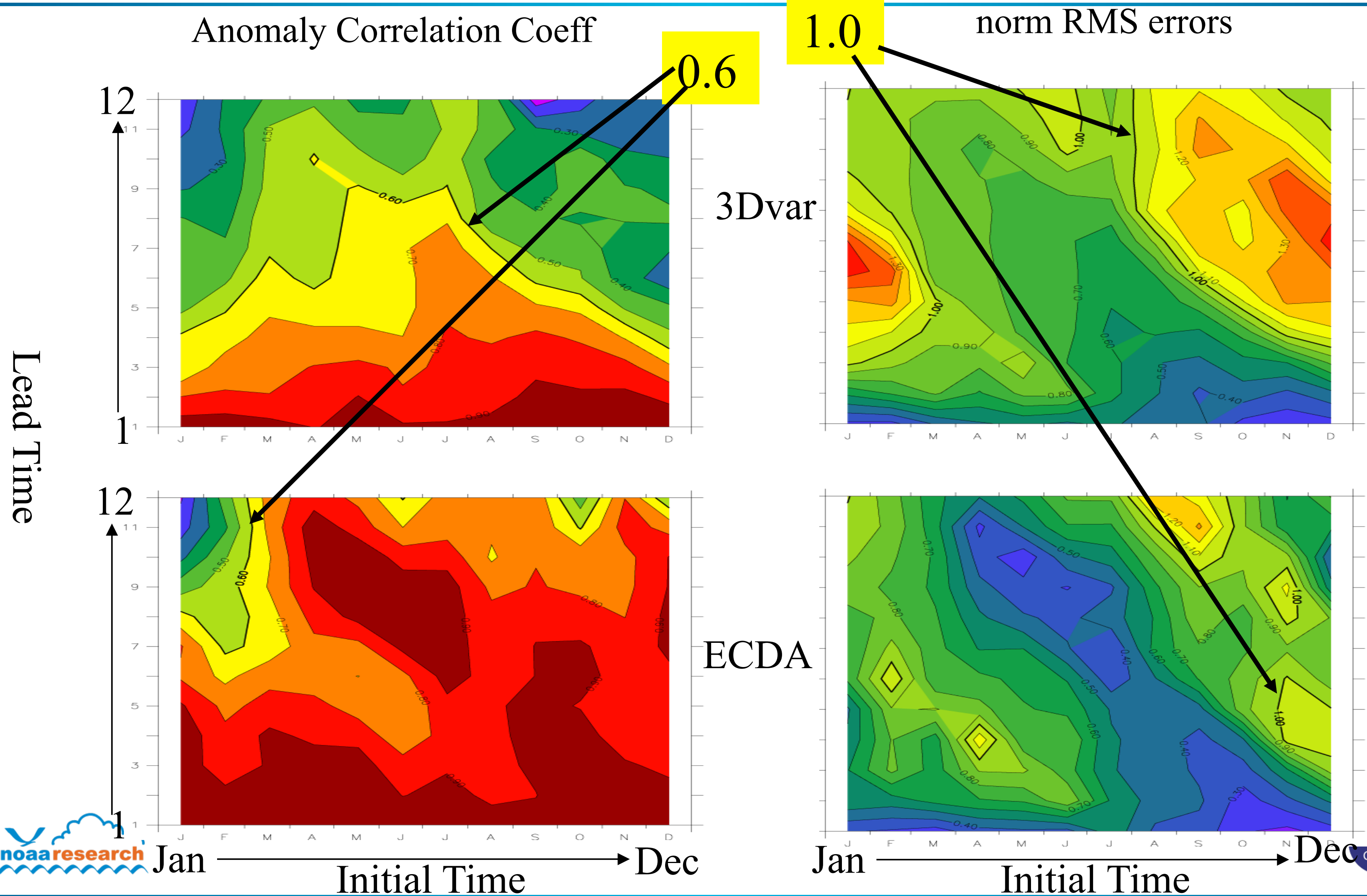
ECDA - Fully-coupled data assimilation system



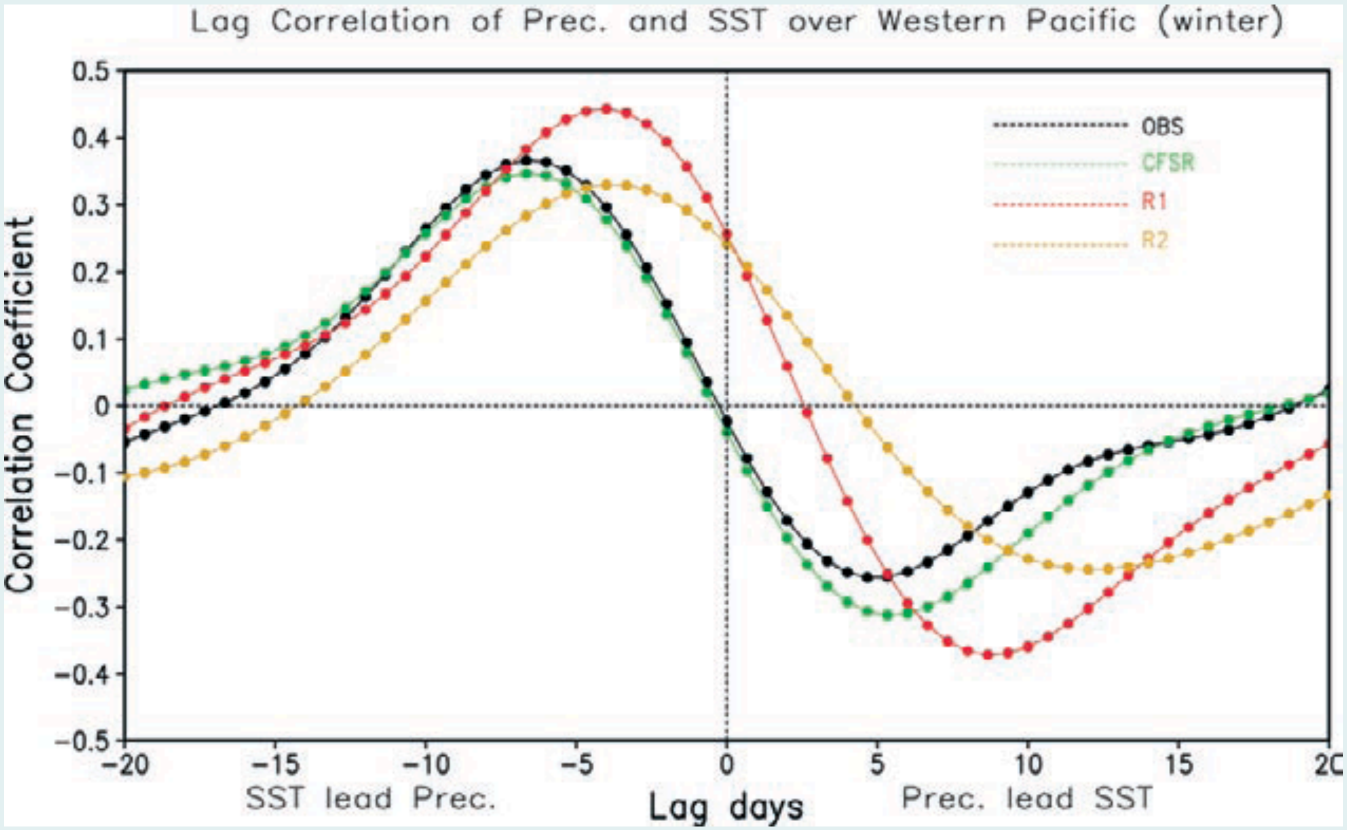
Courtesy Zhang & Rosati

Climate predictions – from SI to decadal time scales
ENSO forecast: NINO3 SSTA skills

Courtesy Zhang & Rosati

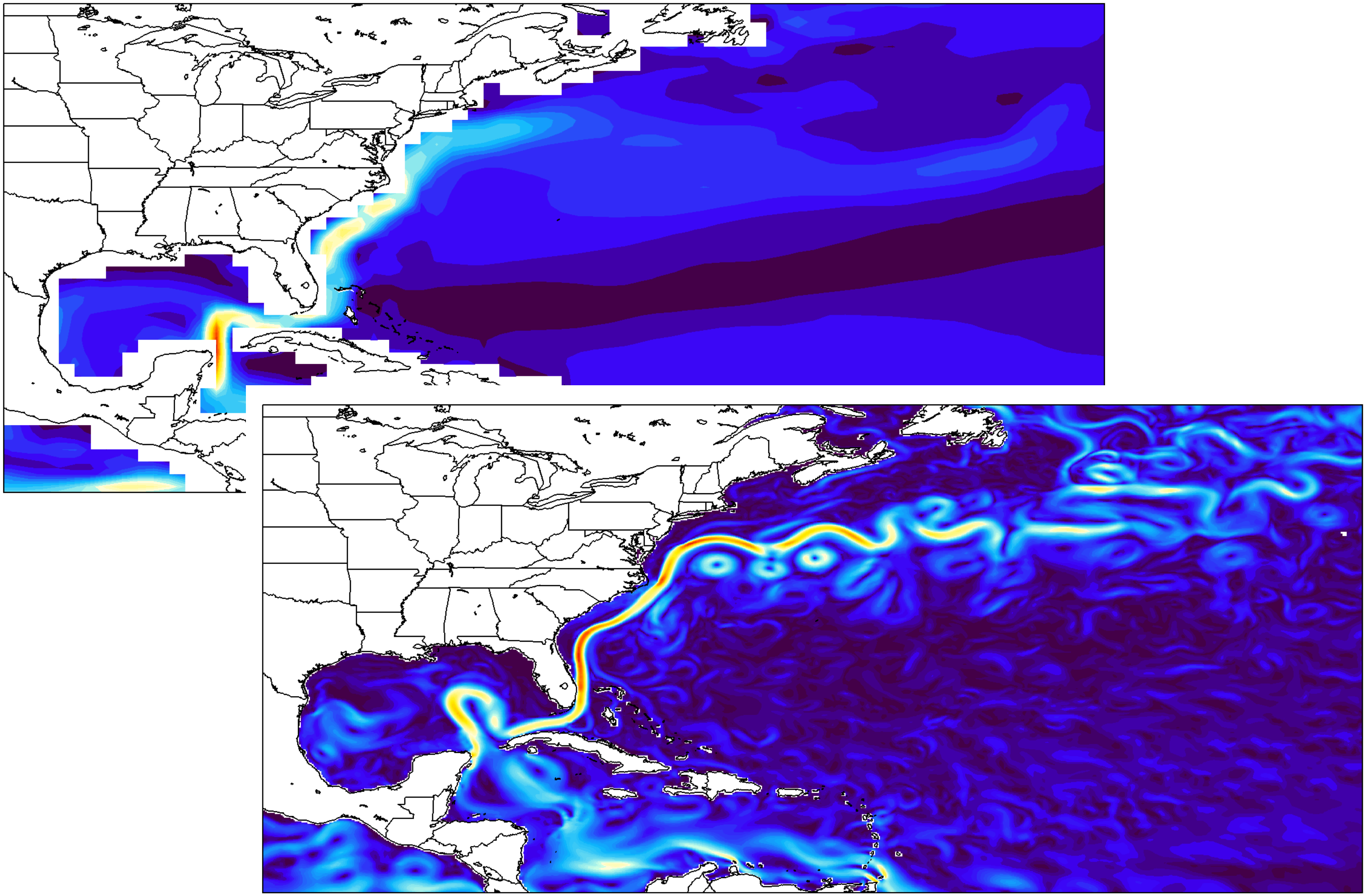


Precipitation – SST relation improved by coupled nature of CFSR
Tropical western Pacific – 10°S–10°N, 130°–150°E, Nov-Apr
Intraseasonal signal (20-100 days)



From Saha et al., BAMS 2010

Spatial Resolution



Perturbations

- **Standard Techniques**
  - Lagged Ensemble
  - Wind Perturbations
- **Ensemble Systems (e.g., EnKF, Perturbed Physics, Stochastic Physics) include perturbations**
- **Bred Vectors**
- **Stochastic Optimals**