The Evolution and Outstanding Challenges for El Niño Modeling and Prediction

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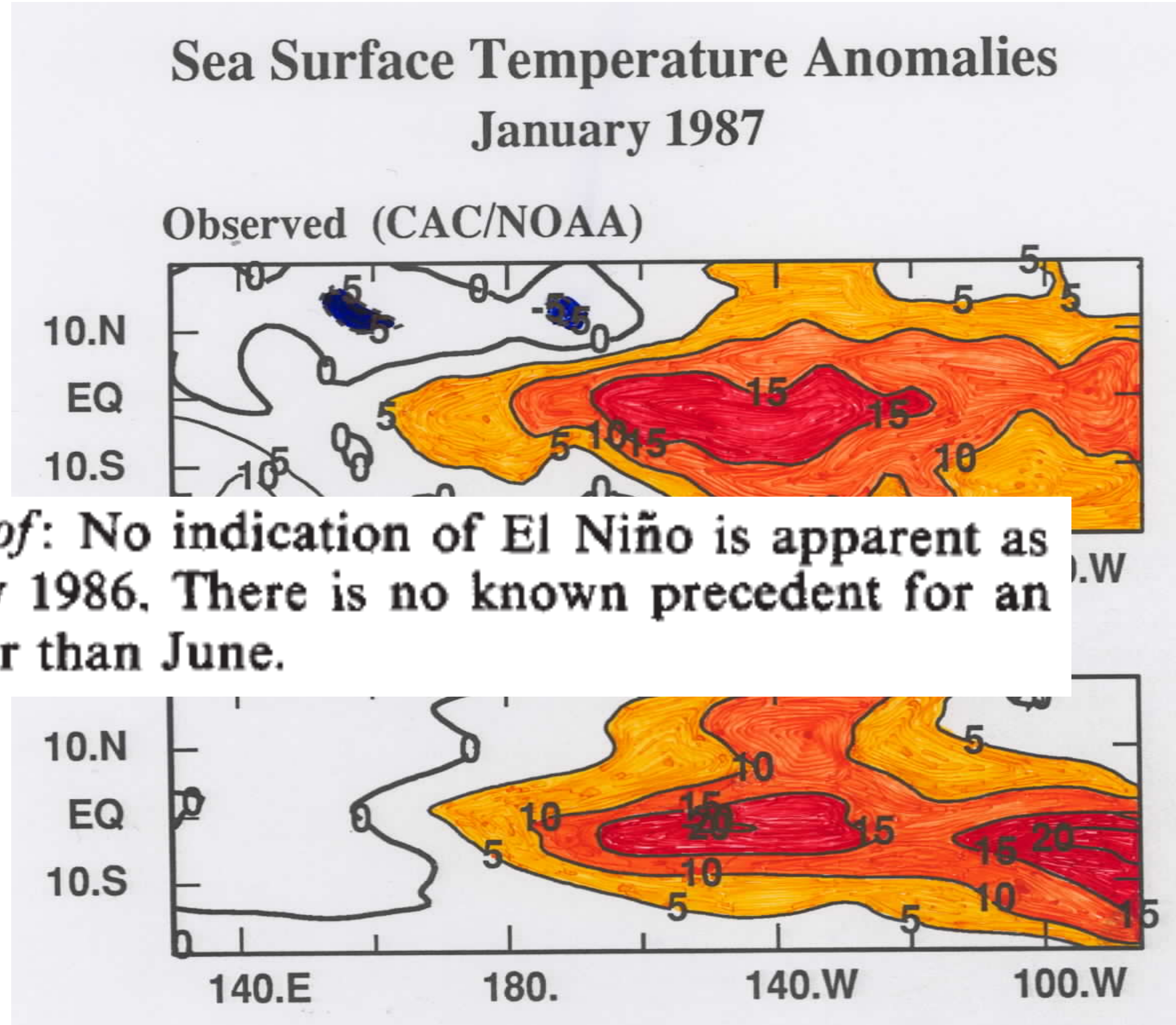
Thanks to *A. Wittenberg* (NOAA-GFDL); *T. Stockdale* (ECMWF); *B. Kirtman* (RSMAS); *D. DeWitt* (NOAA-CPC); *C. Deser, A. Karspec*, and *J. Richter* (NCAR)

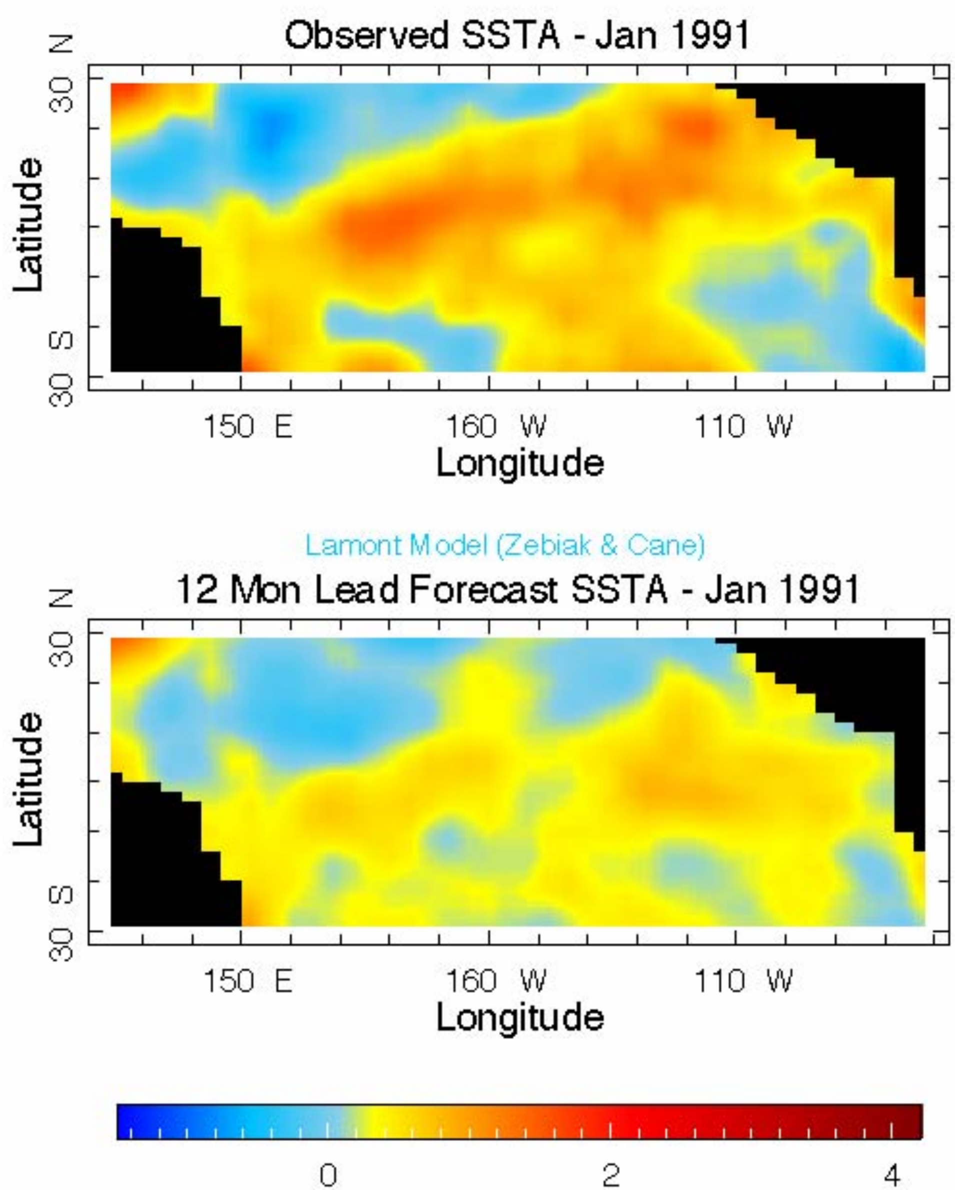
The FIRST ever El Niño forecast made 1 year before the peak



Note added in proof: No indication of El Niño is apparent as of the end of May 1986. There is no known precedent for an event to begin later than June.

Based on Cane, Zebiak and Dolan - Nature 1986.
Contours at 0.5°C

Winter 1990-91 Weak warming, but no El Niño



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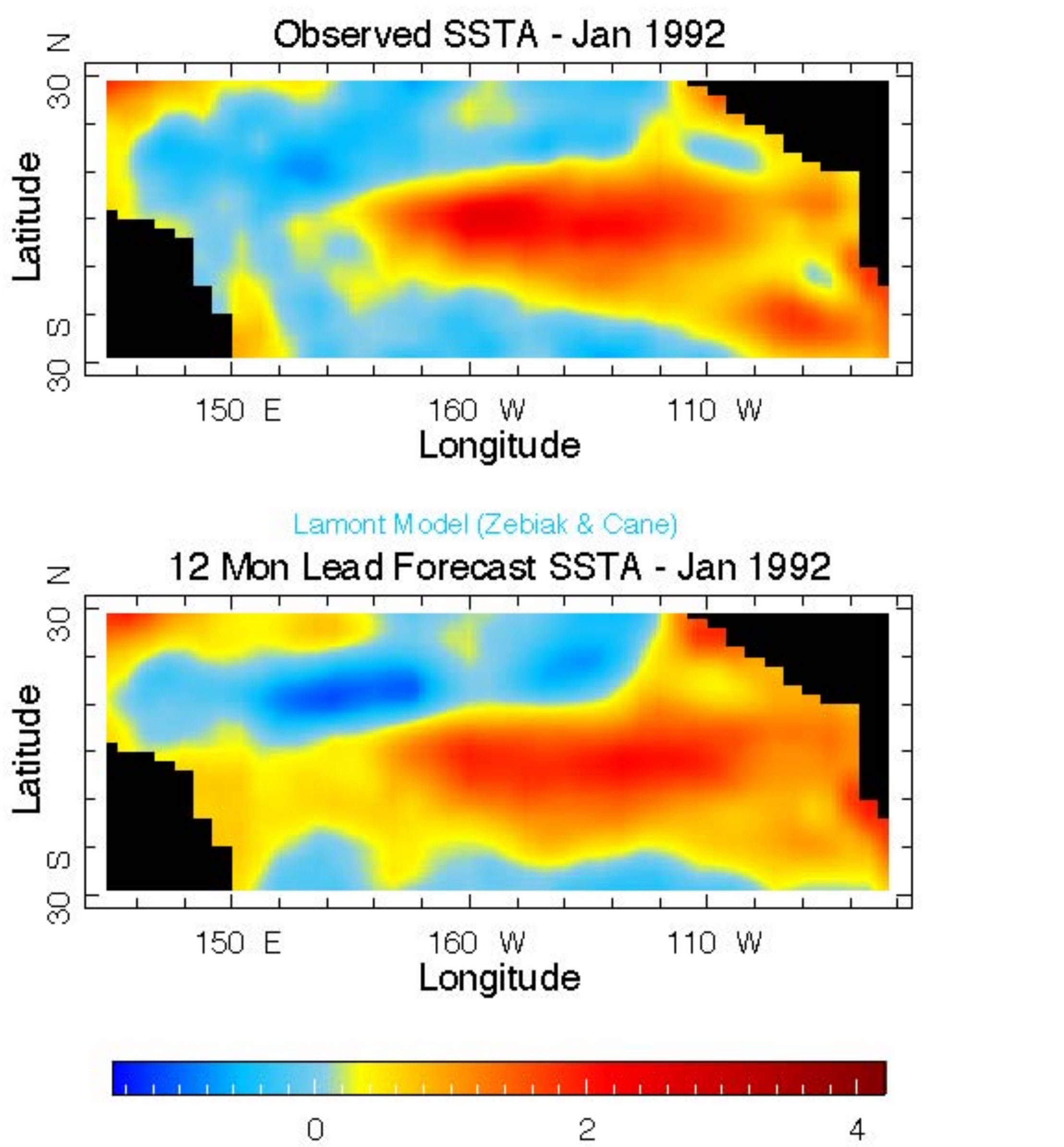
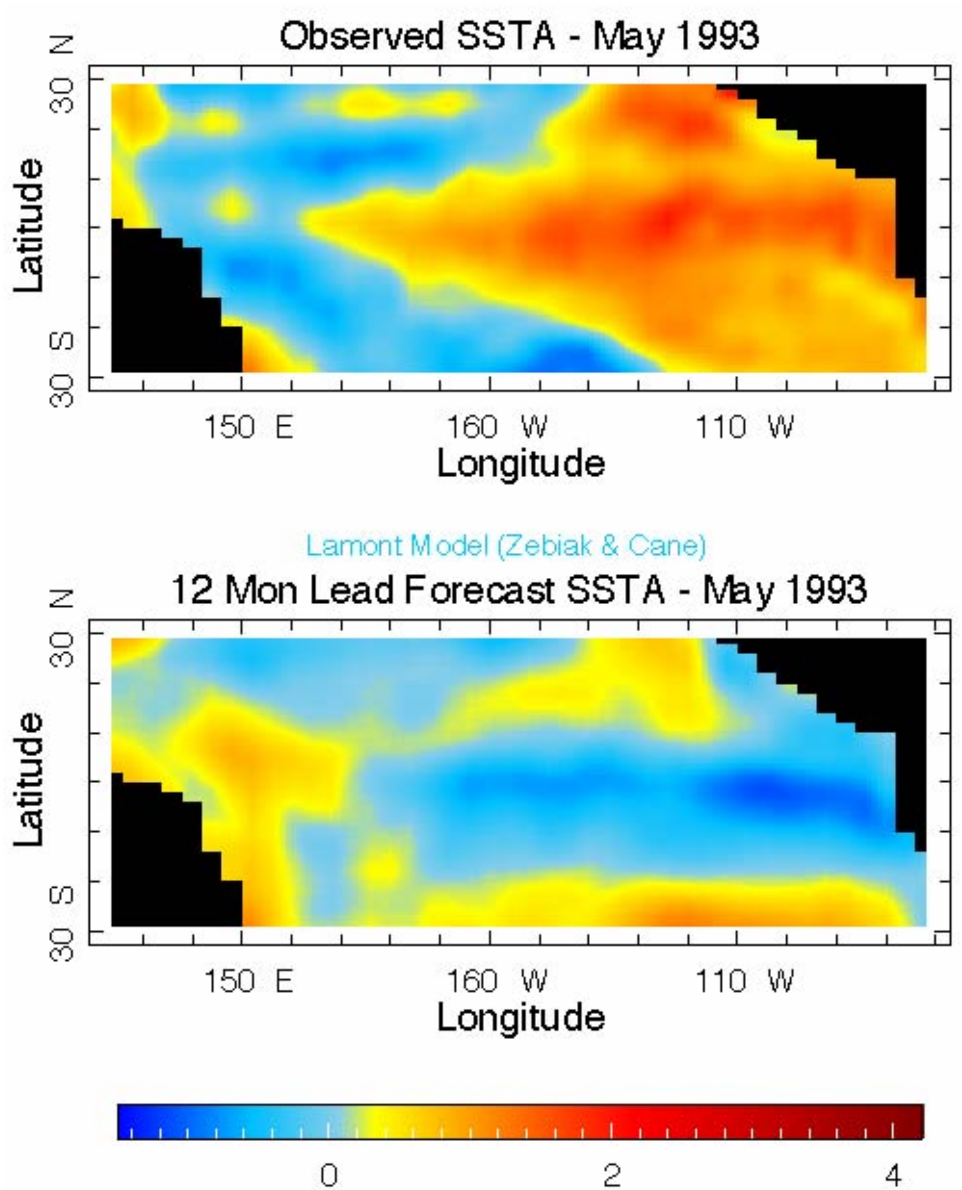
Winter 1991-92
Moderate El Niño



Spring 1993
Missed warming

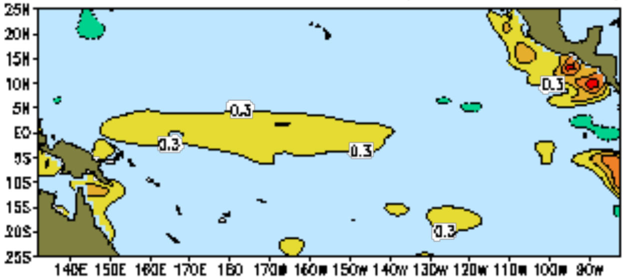


Forecasts of the 1997-98 El Niño

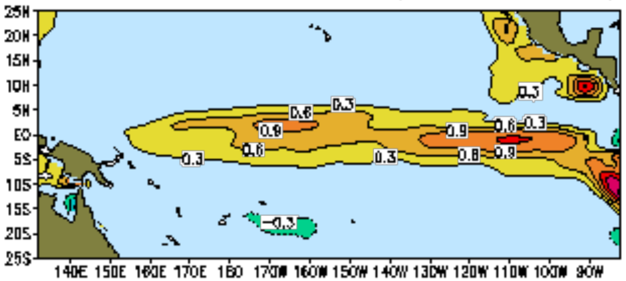
From the Experimental Long-Lead Forecast Bulletin (COLA)

Made March 1997

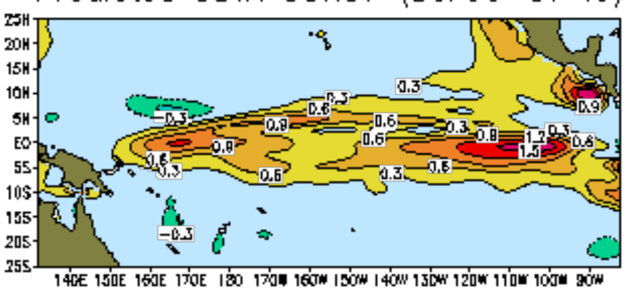
Predicted SSTA MAM97 (DJF96–97 IC)



Predicted SSTA JJA97 (DJF96–97 IC)

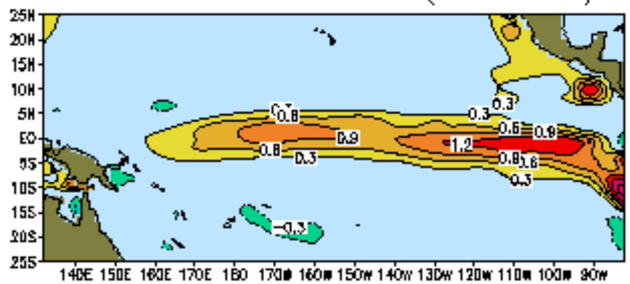


Predicted SSTA SON97 (DJF96–97 IC)



Made June 1997

Predicted SSTA JJA97 (MAM97 IC)



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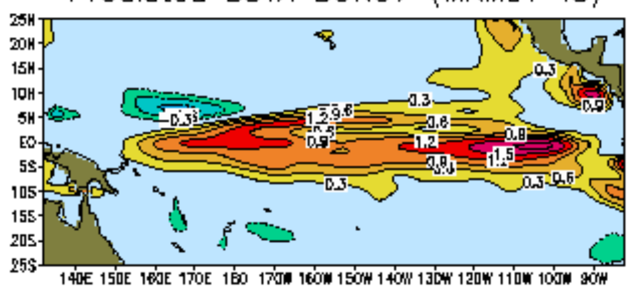
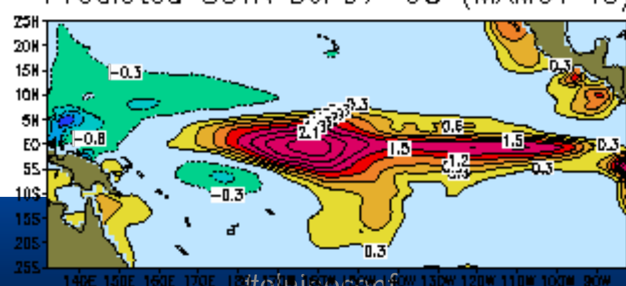
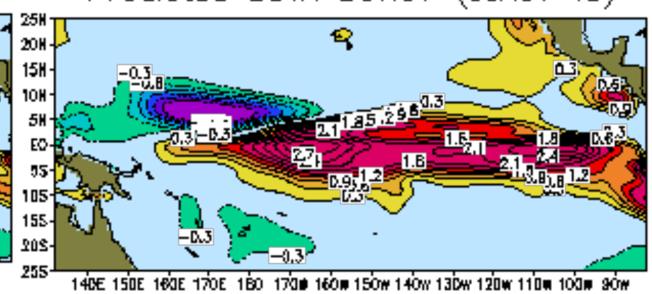


Predicted SSTA DJF97–98 (MAM97 IC)

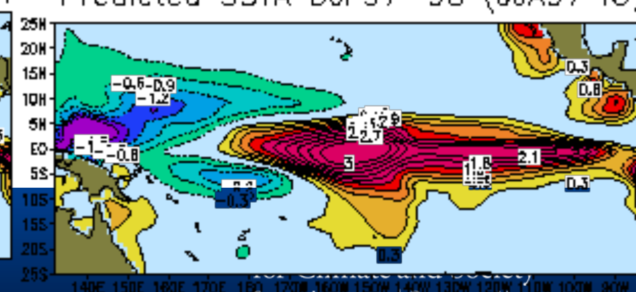


Made September 1997

Predicted SSTA SON97 (JJA97 IC)



Predicted SSTA DJF97–98 (JJA97 IC)



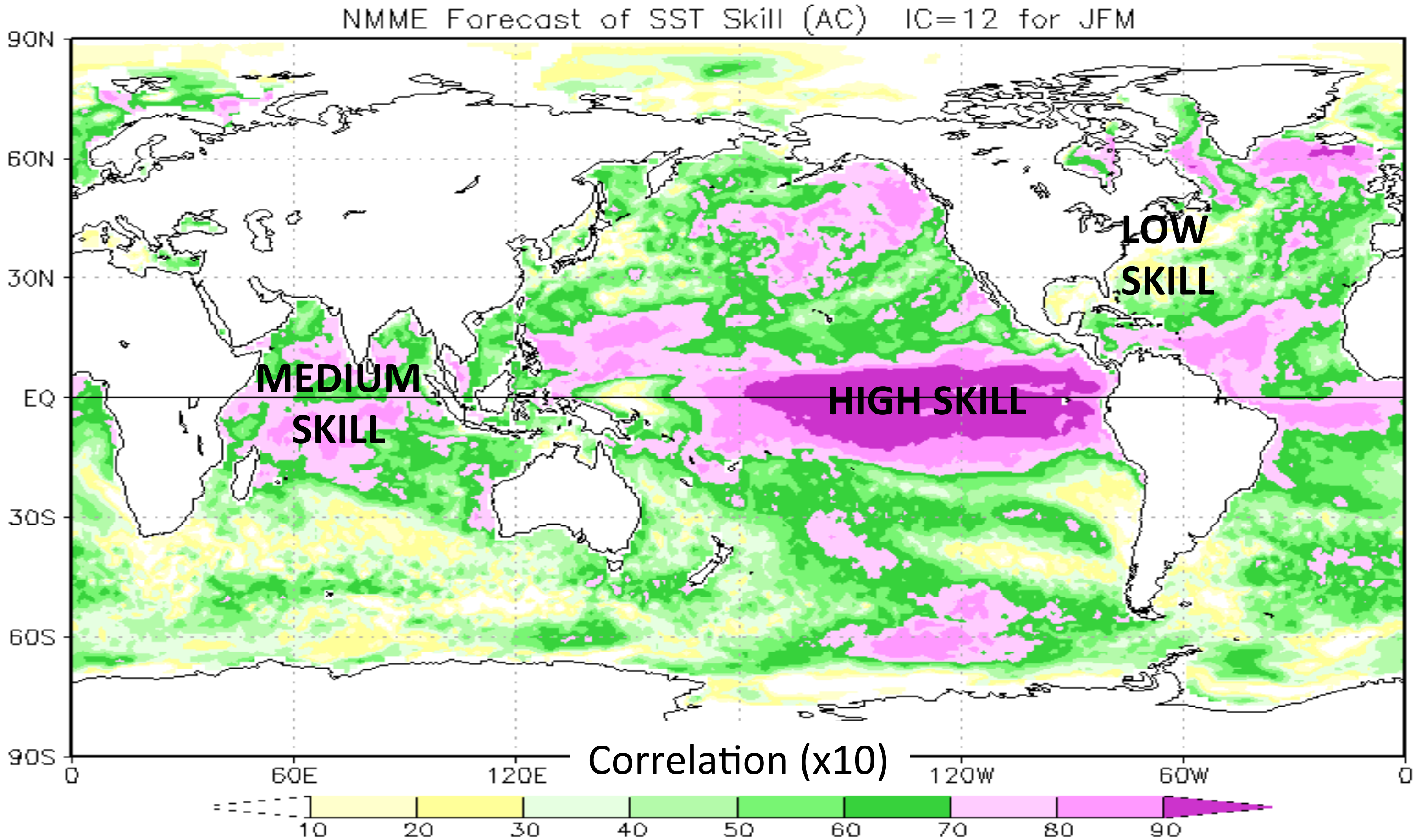
Structure of the Talk

Evolution and outstanding challenges for…

- Predicting El Niño events
- Forecasting the related climate impacts
- Doing something about it

Skill of SST Forecast for JFM

from North America Multi-Model Ensemble (NMME)



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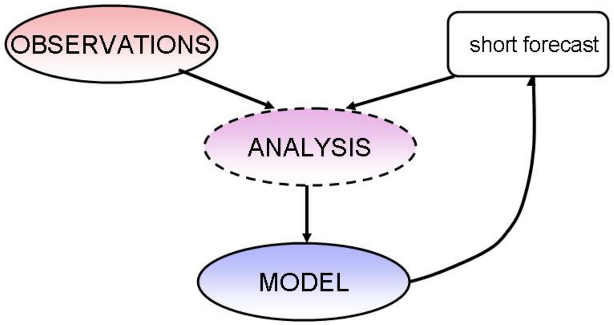
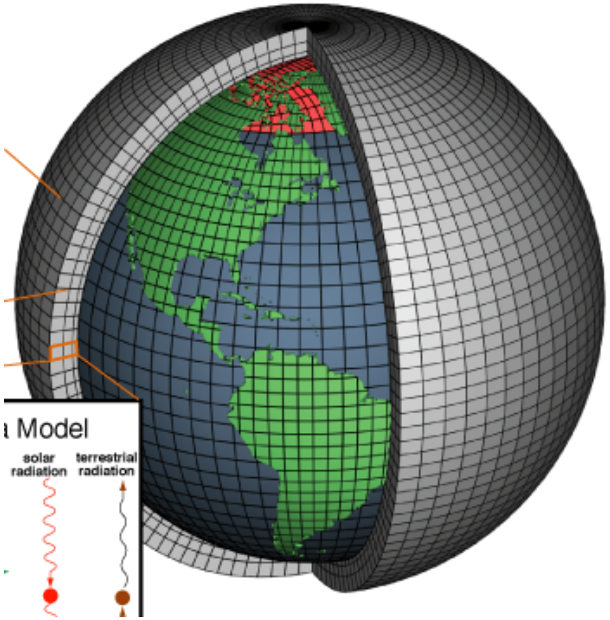
Building Blocks of Prediction Systems

Data Assimilation Systems



Models



Observational Networks

Modeling Challenges for El Niño

1) Model Biases:
   Double ITCZ (tropical rainfall biases)
   Equatorial cold bias
   ENSO variability too far west
   Poor structure of upper ocean thermal stratification

2) Biases and imbalances in ocean-atmosphere state estimation:
   Spurious currents
   Disagreement in regions of sparse observations

3) Representation of processes:
   Poor characterization of wind variability (e.g. MJO)

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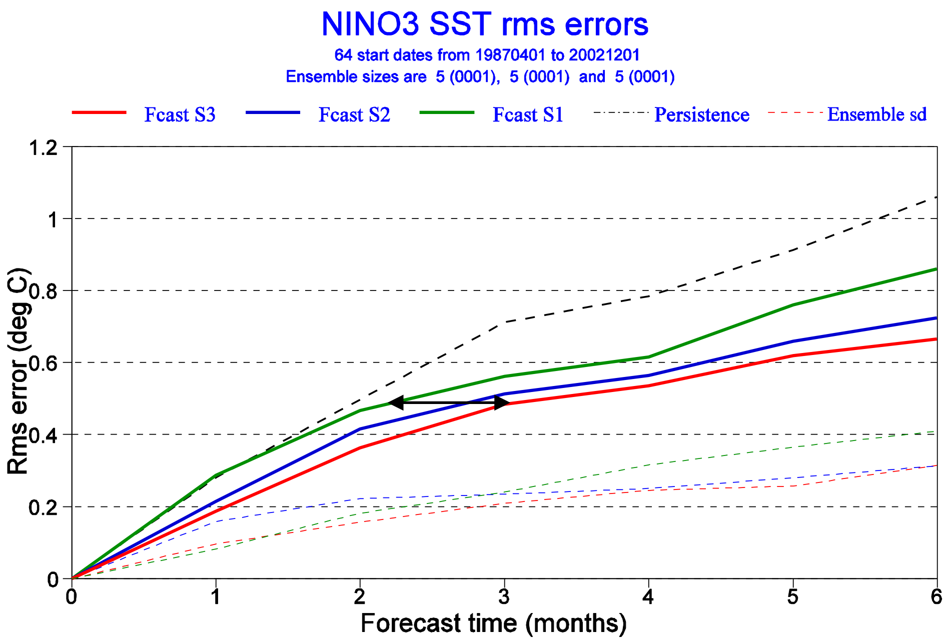
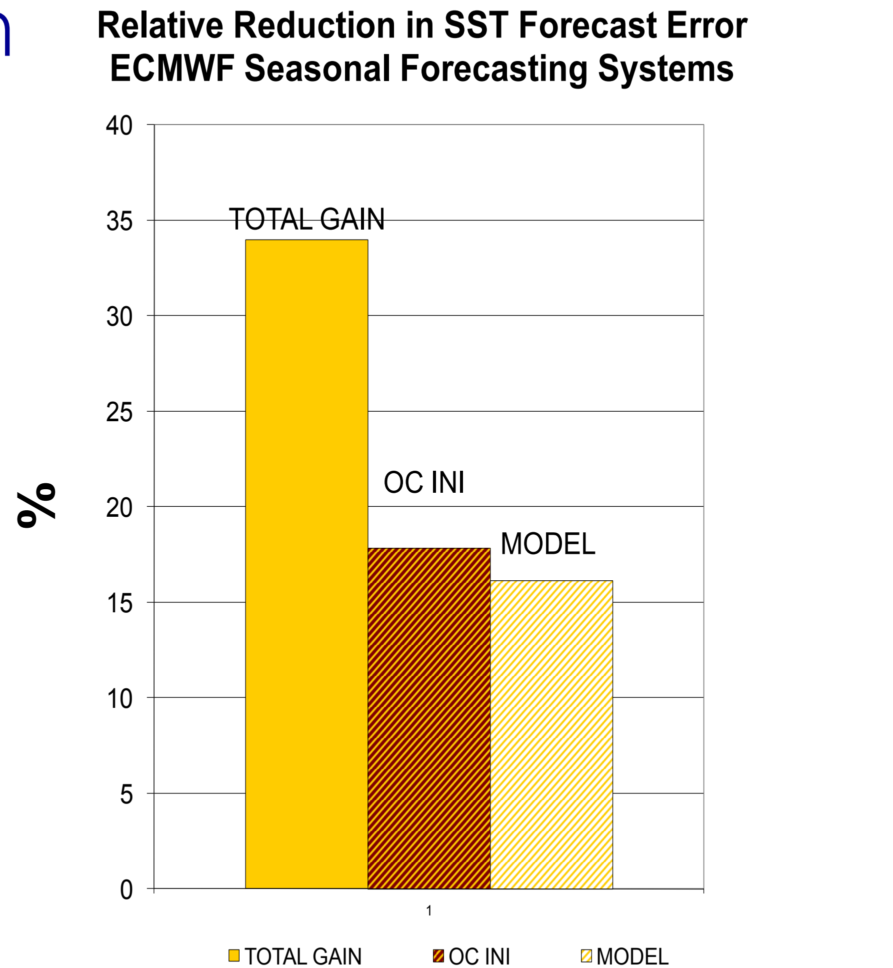
A decade of progress on ENSO prediction





S1 S2 S3

- 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

(Balmaseda et al 2010, OceanObs)

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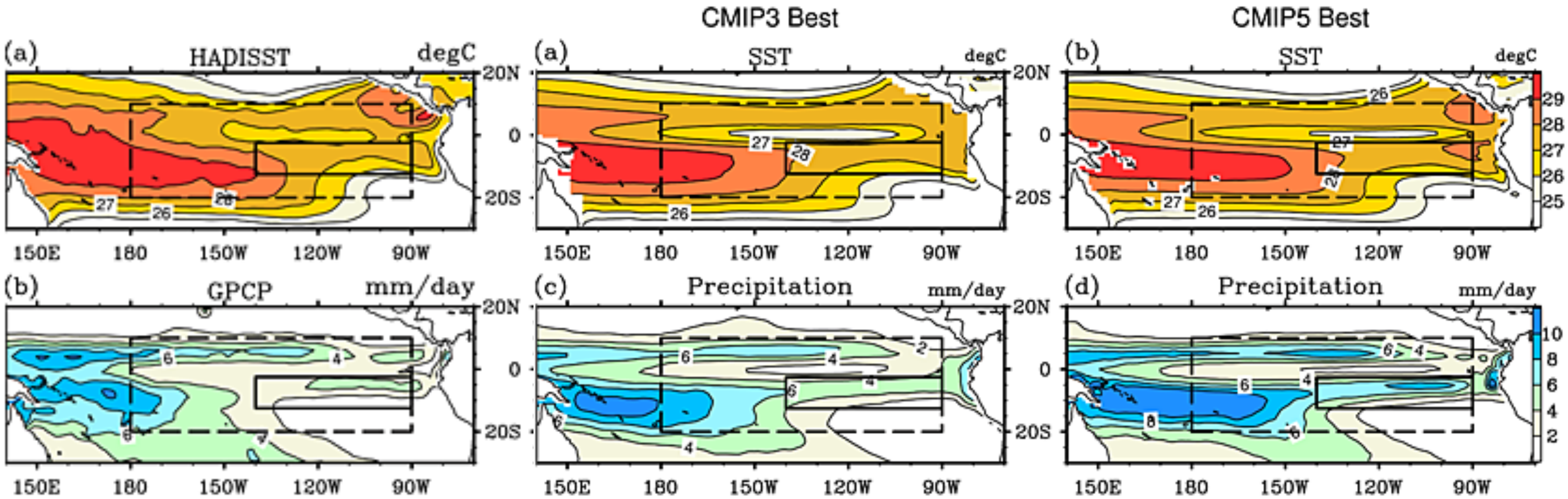
Double ITCZ in Coupled Ocean-Atmosphere Models



(Zhang et al. 2015, GRL)

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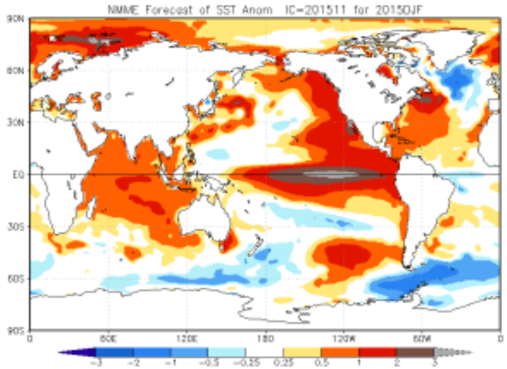
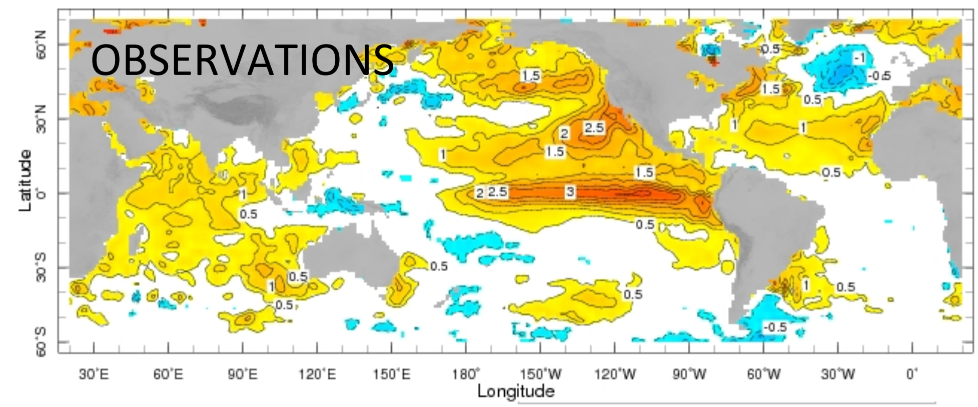
SSTA Forecast DJF 2015-16

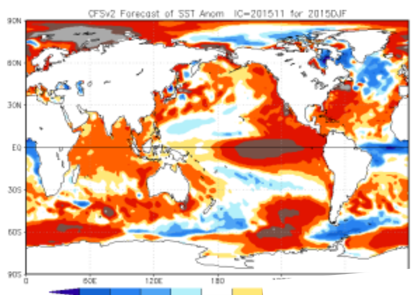
NMME



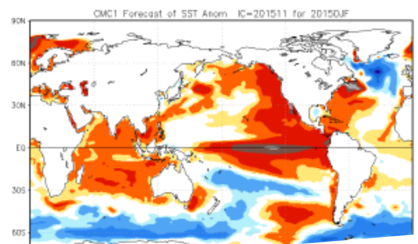
Aug-Oct 2015



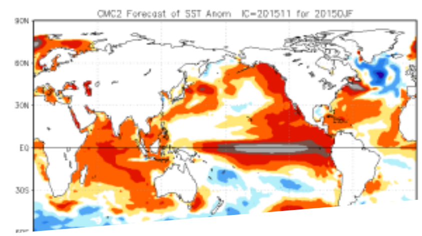
NCEP_CFSv2



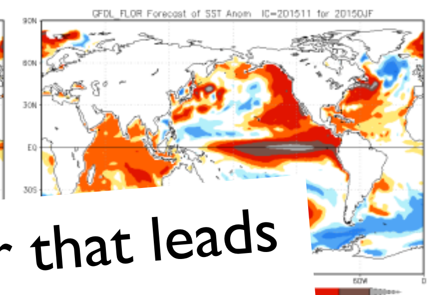
CMC1_CanCM3



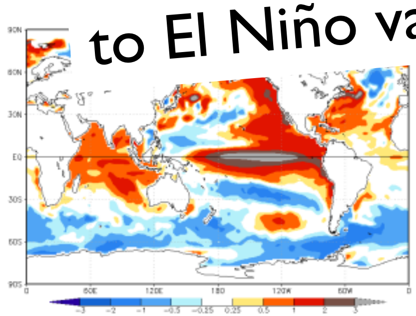
CMC2_CanCM4

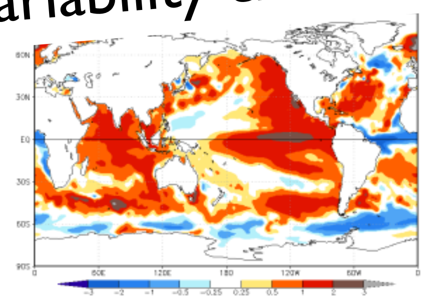


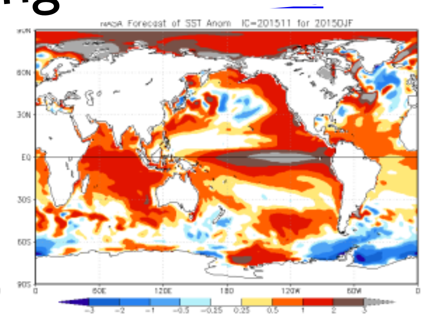
GFDL_FLOR



Double ITCZ bias is one model error that leads to El Niño variability extending too far west

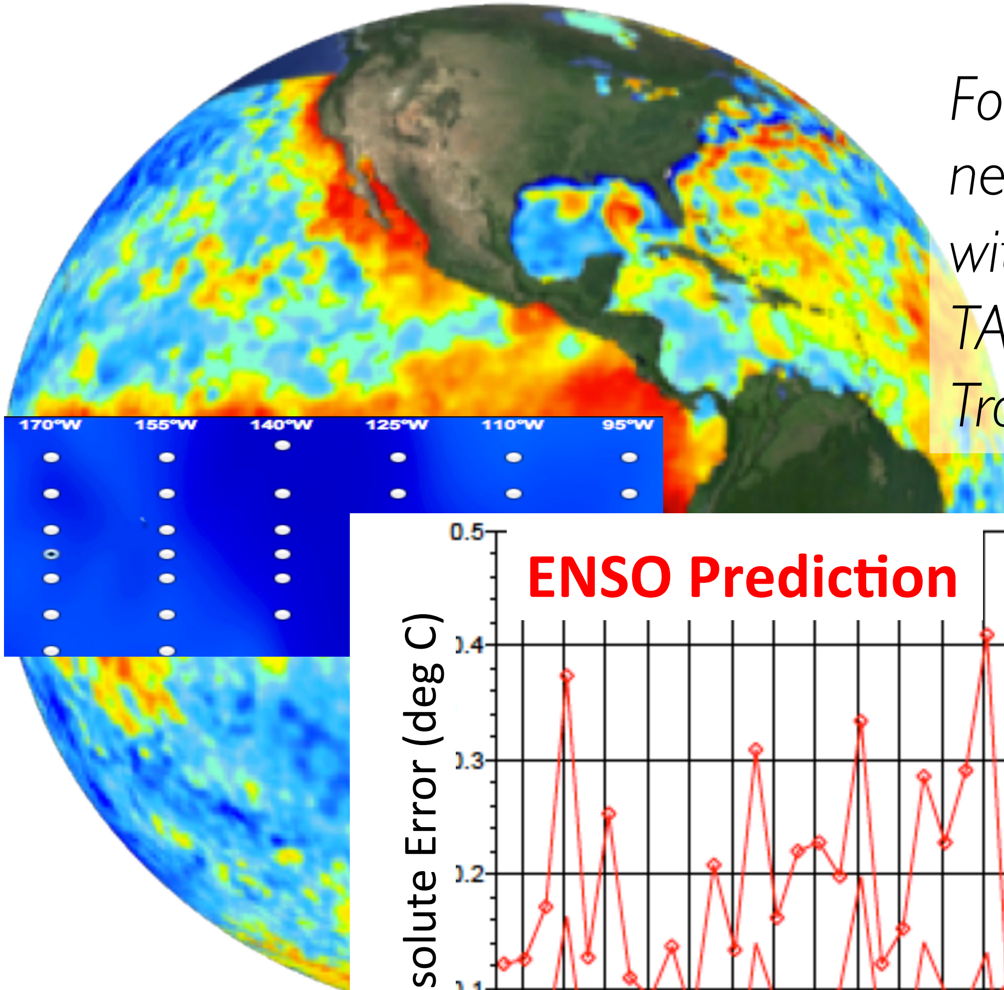


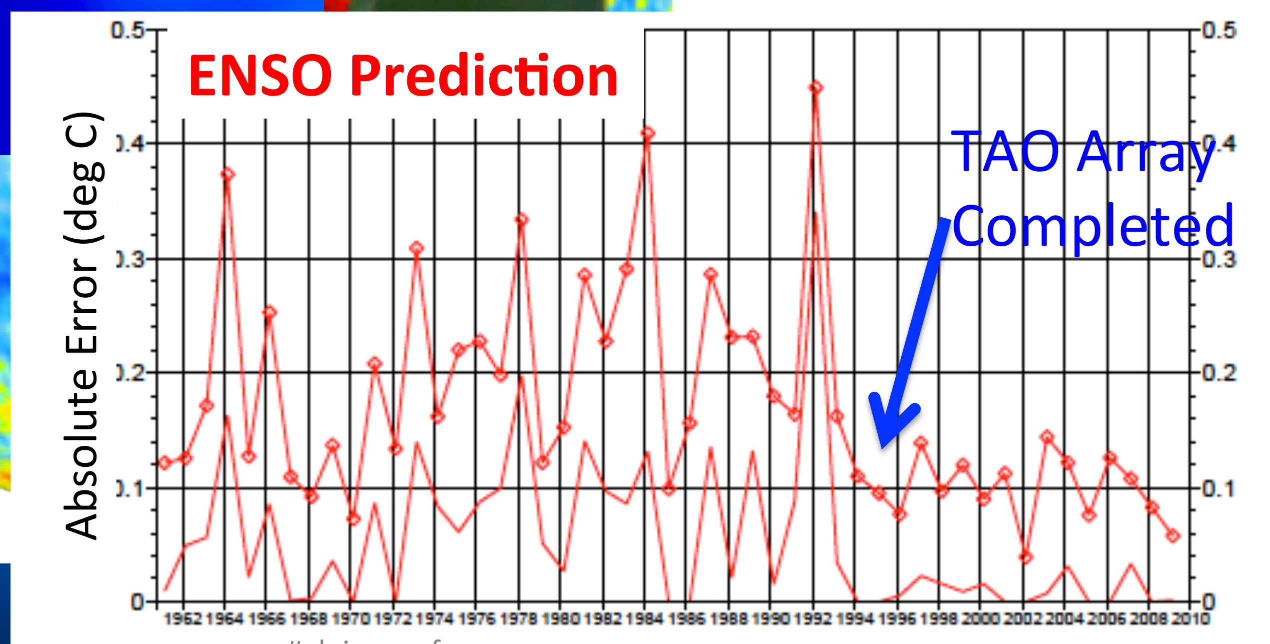




Observations are Critical

Forecast error drops to near-zero in European model with completion of TAO buoy array in the Tropical Pacific.



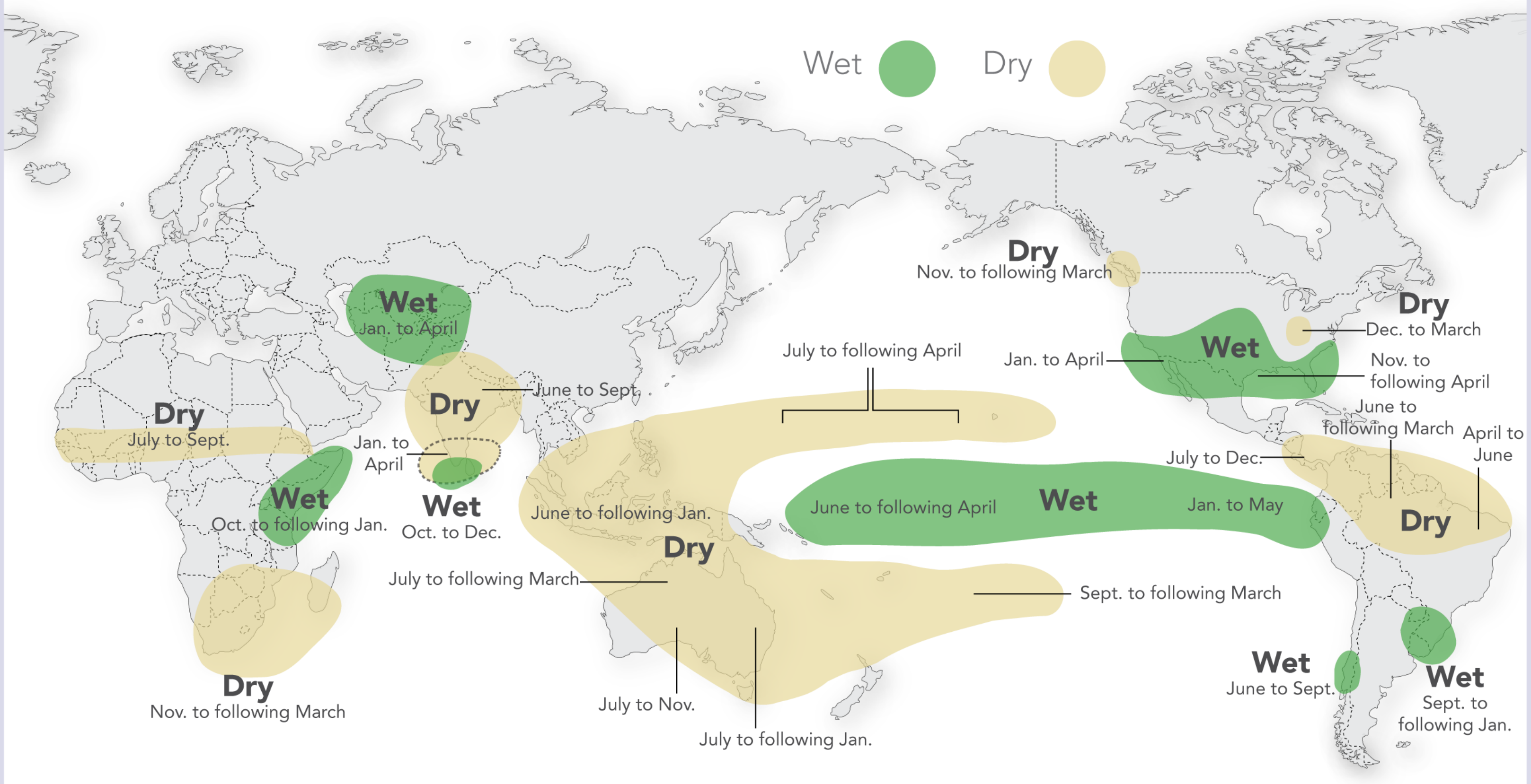


(Stockdale et al. 2010)

"Expected" Climate Impacts During El Niño

El Niño and Rainfall

El Niño conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. Although they vary somewhat from one El Niño to the next, the strongest shifts remain fairly consistent in the regions and seasons shown on the map below.



For more information on El Niño and La Niña, go to: http://iri.columbia.edu/enso/

Sources:
1. Ropelewski, C. F., and M. S. Halpert, 1987: Global and regional scale precipitation patterns associated with the El Nino Southern Oscillation. Mon. Wea. Rev., 115, 1606-1626;
2. Mason and Goddard, 2001. Probabilistic precipitation anomalies associated with ENSO. Bull. Am. Meteorol. Soc. 82, 619-638

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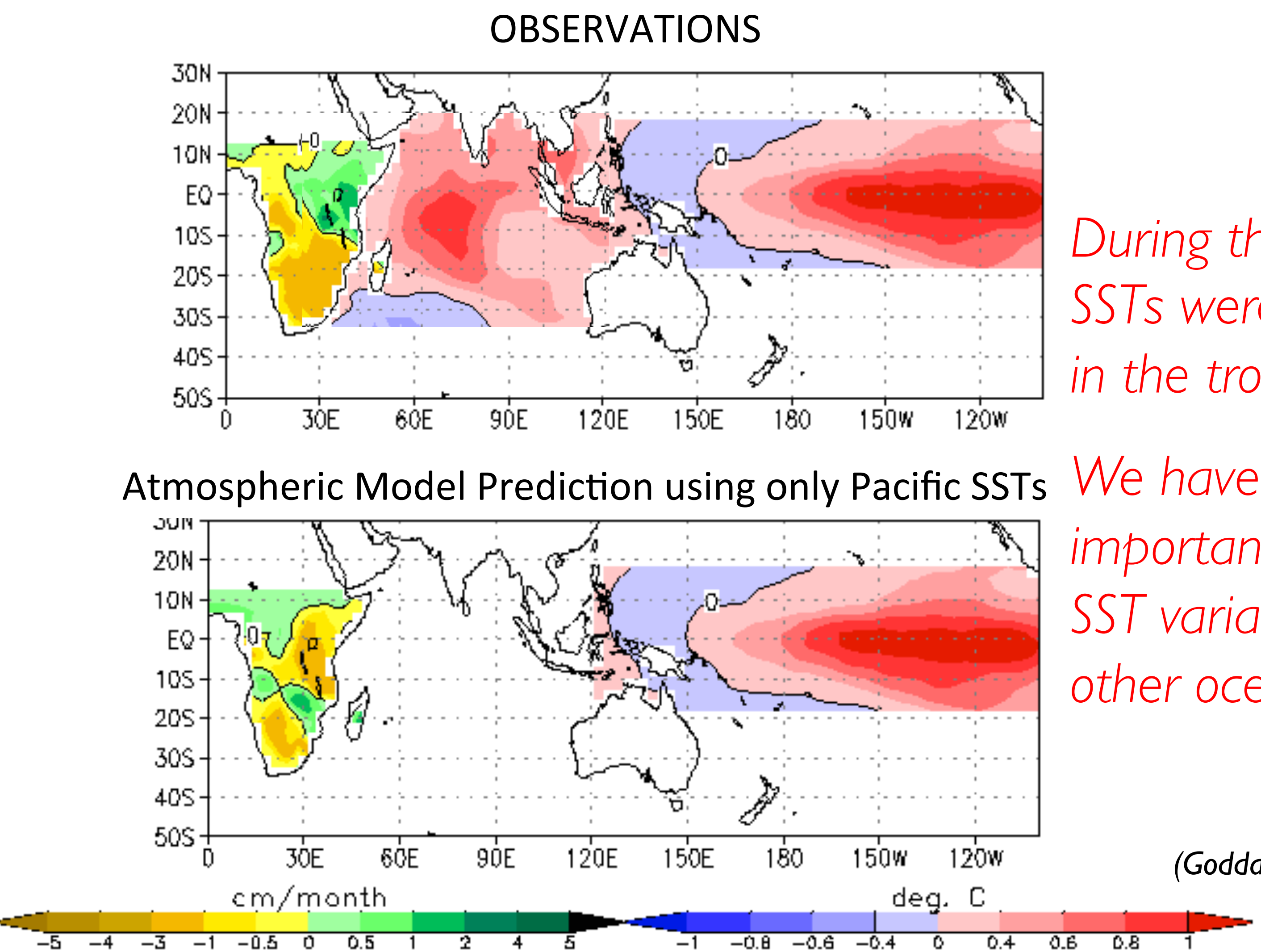
http://iridl.ldeo.columbia.edu/maproom/IFRC/ → "Past Conditions"

Pacific Ocean SSTa and rainfall over E. Africa

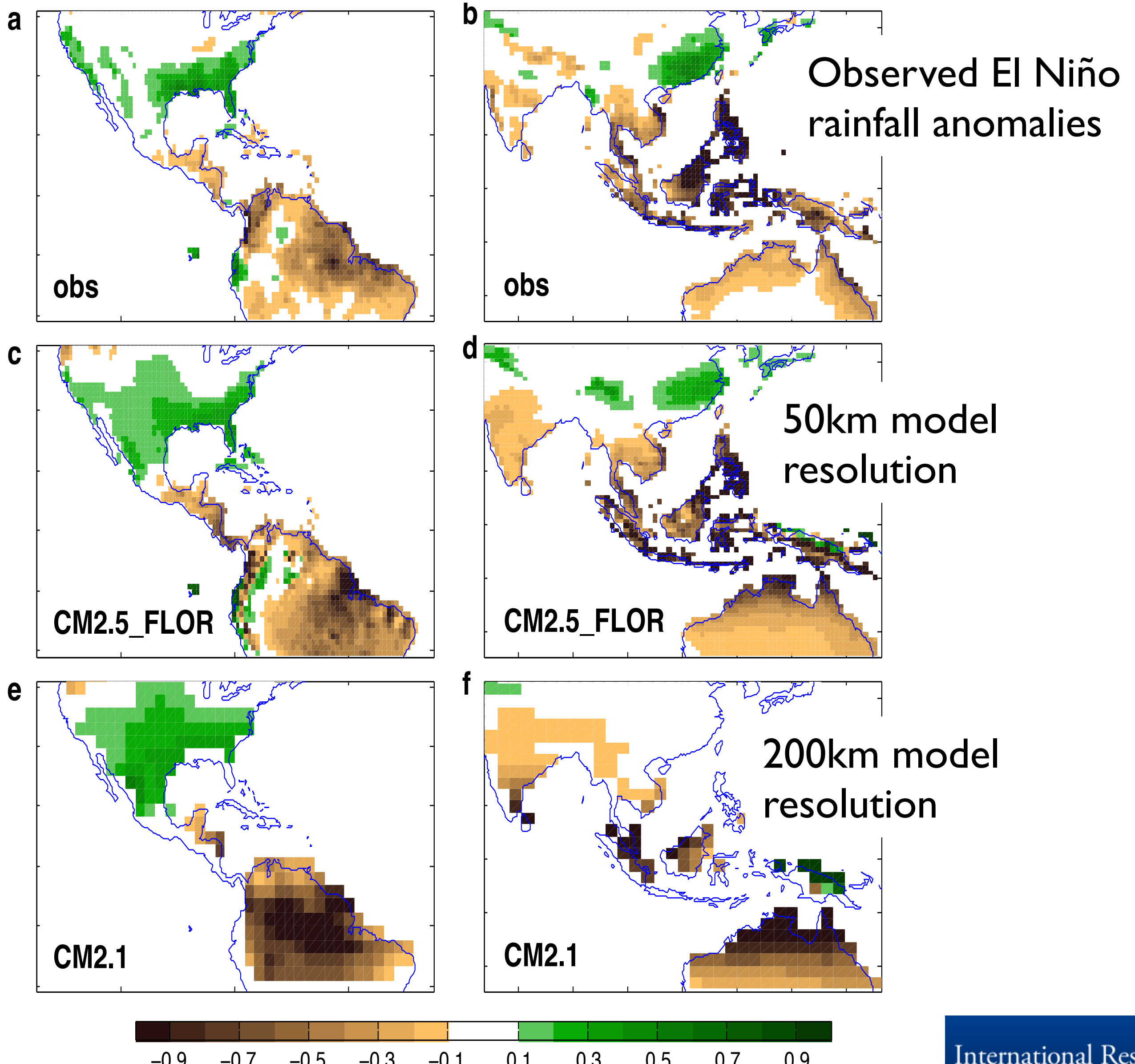


During the 1997-98 El Niño, SSTs were predicted only in the tropical Pacific.

We have since learned the importance of getting SST variability right in the other oceans.

(Goddard & Graham 1999, JGR-Atmos.)

Increasing Atmospheric Model Resolution



Higher-resolution atmosphere models can provide better teleconnections, including local-scale details.

(Jia et al. 2015, J. Climate)

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Meaningful climate information is only a start. We need to translate that into impacts (risk or likelihood) and translate *that* into meaningful action.

NOT something the climate community can (or should) do on their own.

Emergency appeal

International Federation
of Red Cross and Red Crescent Societies

West and Central Africa: Flood preparedness

Emergency appeal n° MDR61003
11 July 2008

This preliminary Emergency Appeal seeks CHF 750,000 (USD 731,134 or EUR 462,475) in cash, kind, or services to support the National Societies of West and Central Africa to assist 47,500 beneficiaries.

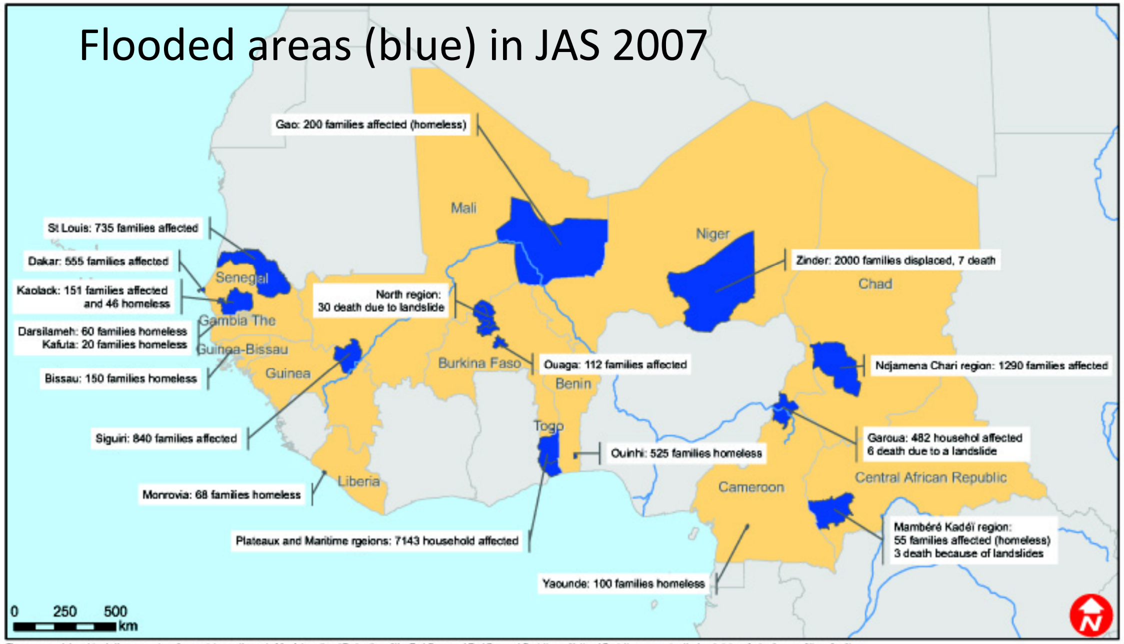
CHF 483,047 has been allocated from the Federation's Disaster Relief Emergency Fund (DREF) to start the planned activities. Discussions are currently taking place to reallocate approximately CHF 550,000 remaining from the 2007 West Africa floods appeal to support this appeal. While these discussions are underway, partners are encouraged to provide timely support to this appeal.

Red Cross Volunteer, Lomé, Togo, June, 2008

Early Action works:

- Faster response: 1-2 days rather than 40 in 2007
- Fewer victims (30 instead of hundreds)
- Lower cost per beneficiary (30%)

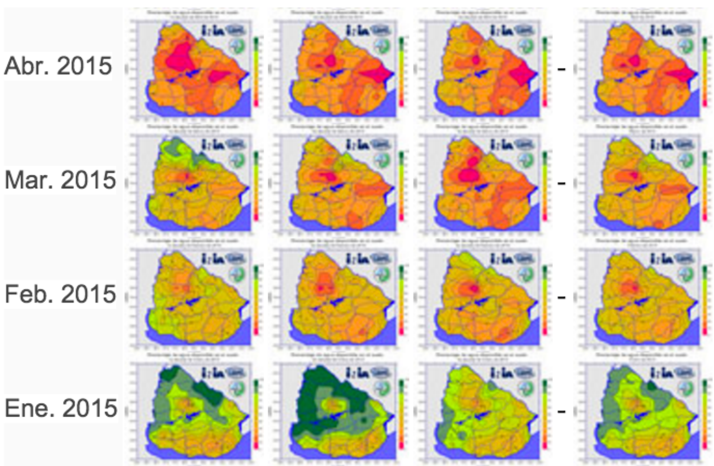
Example: Red Cross volunteers in Ghana saving lives by alerting Volta fishermen that the Bagre dam would be spilled.



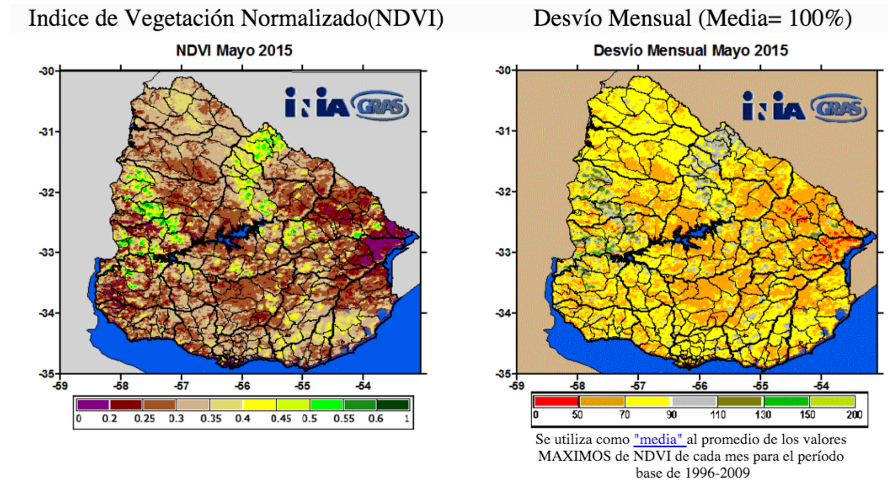
The maps used do not imply the expression of any opinion on the part of the International Federation of the Red Cross and Red Crescent Societies or National Societies concerning the legal status of a territory or of its authorities.
Map data sources: ESRI, DEVINFO, International Federation, floods2008.mxd

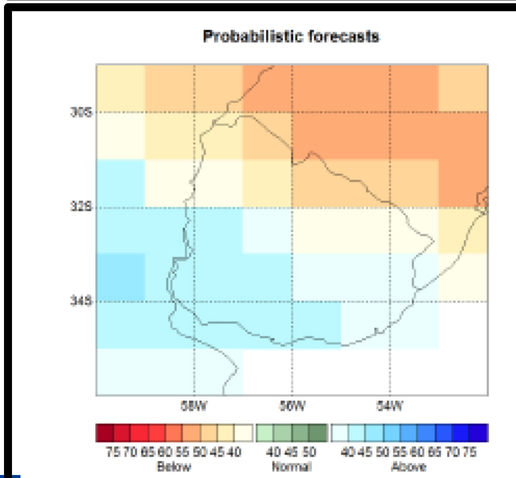
Climate Information for Agriculture - 2015

Soil Water Balance



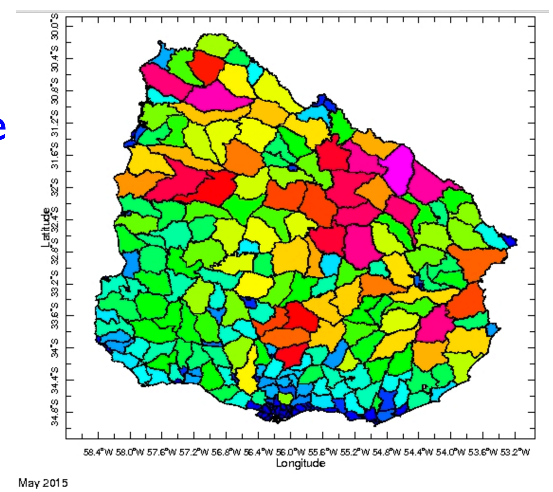
NDVI Actual and Relative to Normal





Rainfall Forecast for AMJ 2015

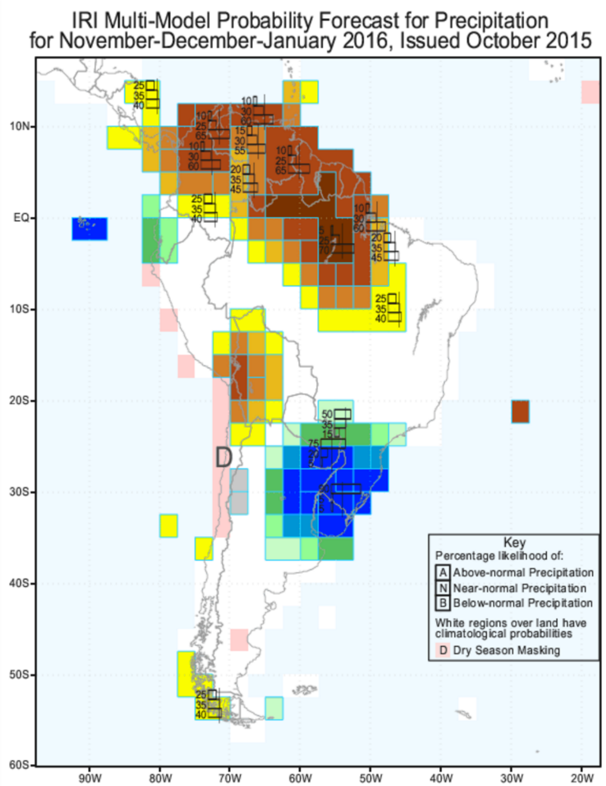
Stocking Rate Real time in Uruguay Data Library



Worst areas: low water, low vegetation, high stocking rate, “dry “forecast

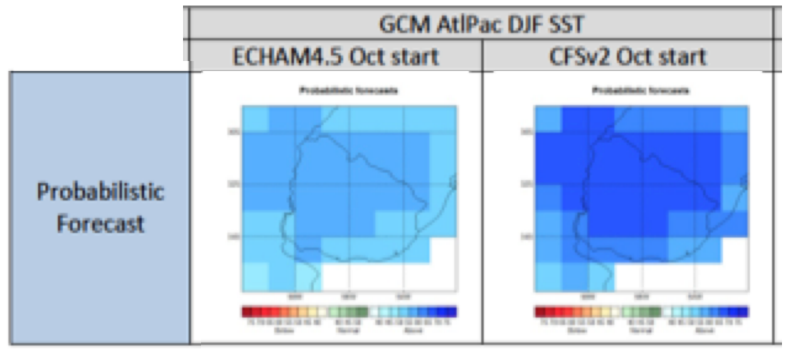
Climate Information for Agriculture - 2015

IRI Forecast DJF 2015/2016



Tailored Uruguay Forecast DJF 2015/16 from Nov 2015

(using IRI Climate Predictability Tool)



<u>Next steps:</u>

* Soil Water Balance Forecasts

* Stocking Rate Forecasts

* Weather-within-climate

- Forecasts of dry spell frequency
- Forecasts of frequency of storms

Conclusions

- Predicting El Niño events

El Niño events are predictable, but we could do better (timing, spatial pattern, diversity, uncertainty)

- Forecasting the related climate impacts

Good quality models are necessary for regional impacts.

Also needed are the analysis and tailoring to translate model uncertainty into forecast risk or likelihood.

- Doing something about it

Even with good climate information, need to translate that into socio-economic impacts, and translate that into meaningful action. This is not something the climate community can (or should) do alone.

Thank You

web: iri.columbia.edu

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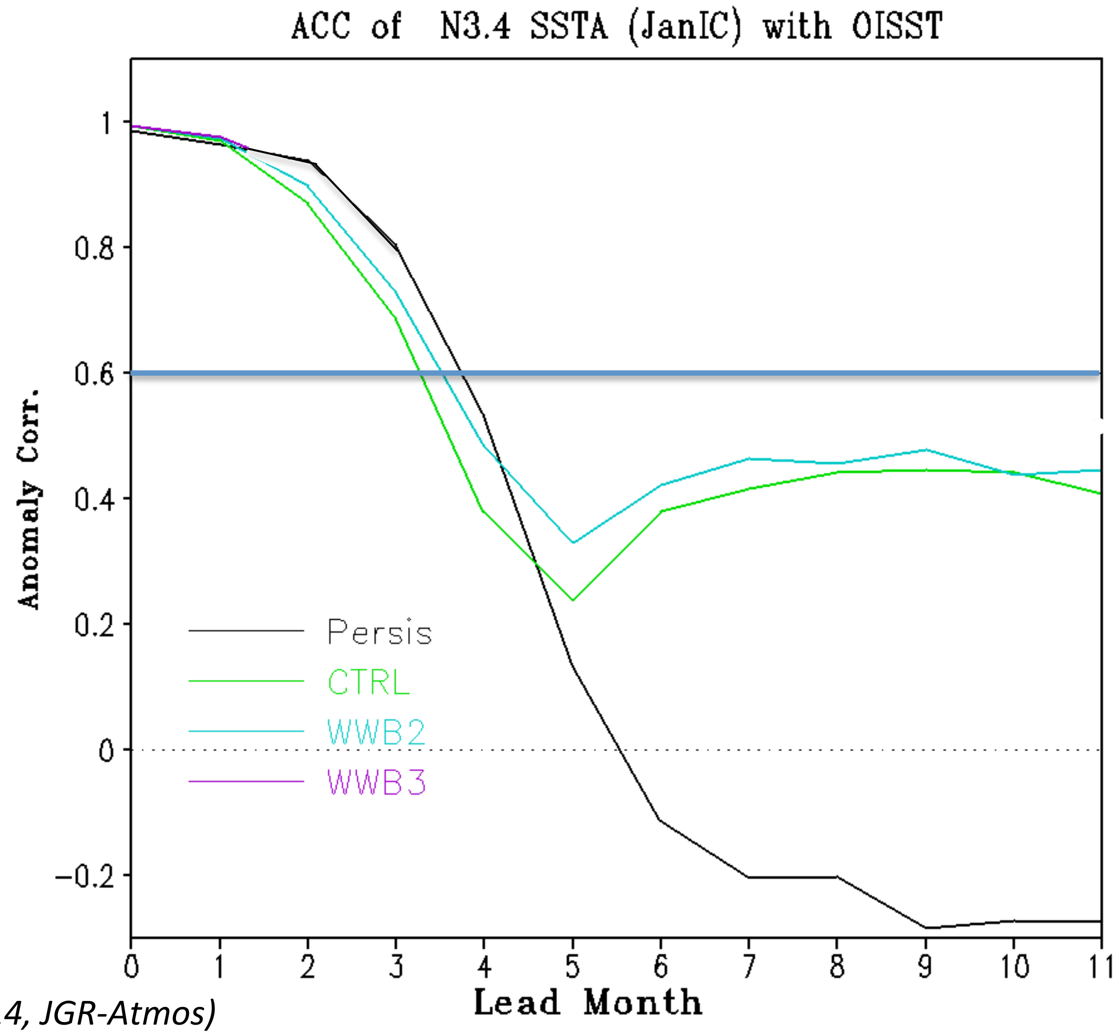
Fundamental Processes: Westerly Wind Bursts
Improving ENSO Prediction and Predictability



(Lopez and Kirtman 2014, JGR-Atmos)

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Fundamental Processes: Westerly Wind Bursts
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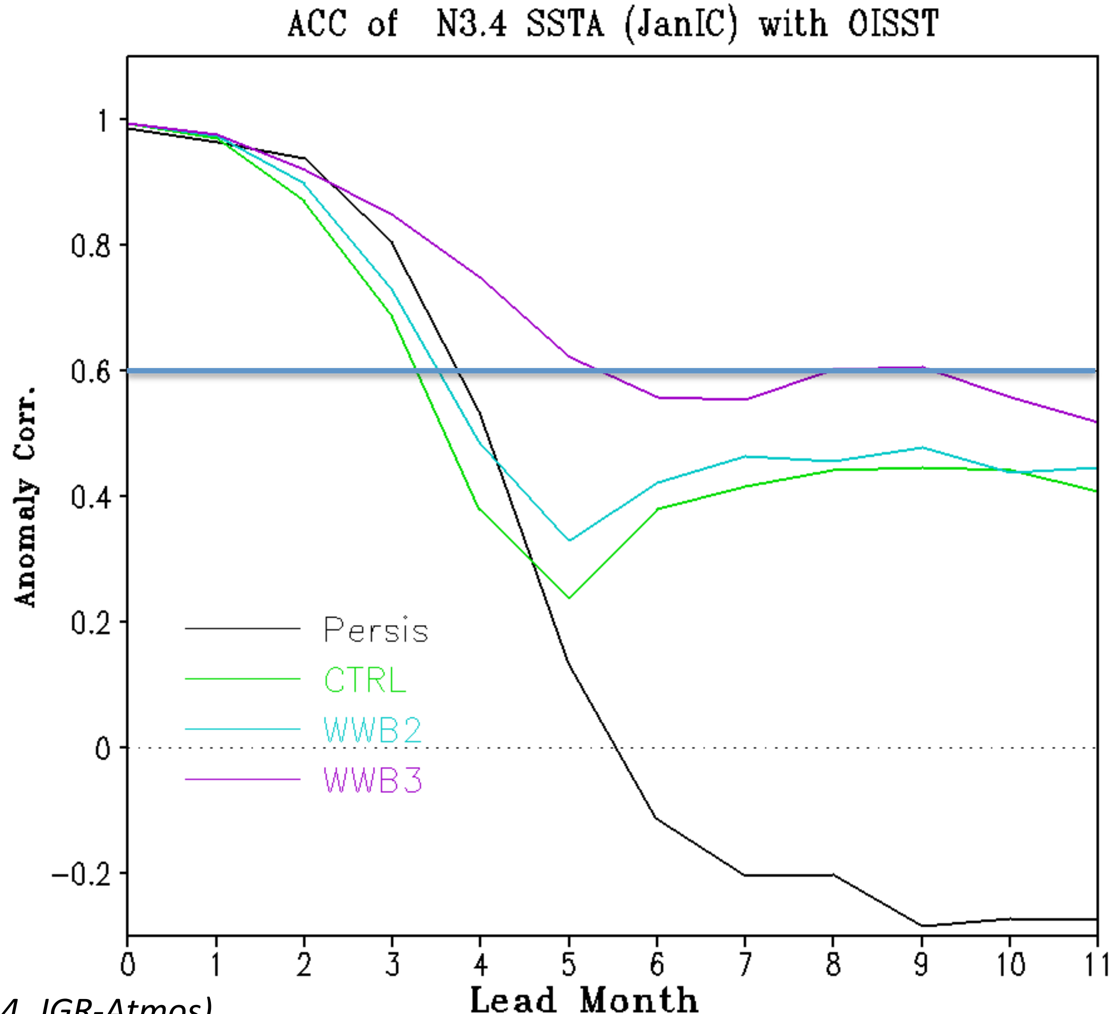


(Lopez and Kirtman 2014, JGR-Atmos)

Information to initialize the ocean

- Ocean model
- Plus:

  SST

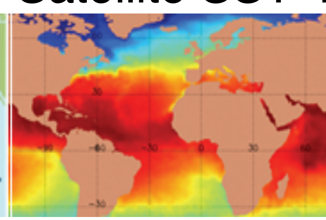
  Atmospheric fluxes from atmospheric reanalysis

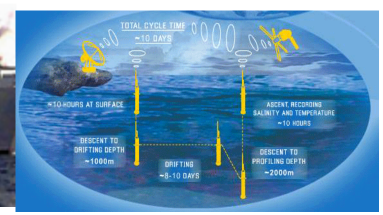
  Subsurface ocean information

Time evolution of the Ocean Observing System

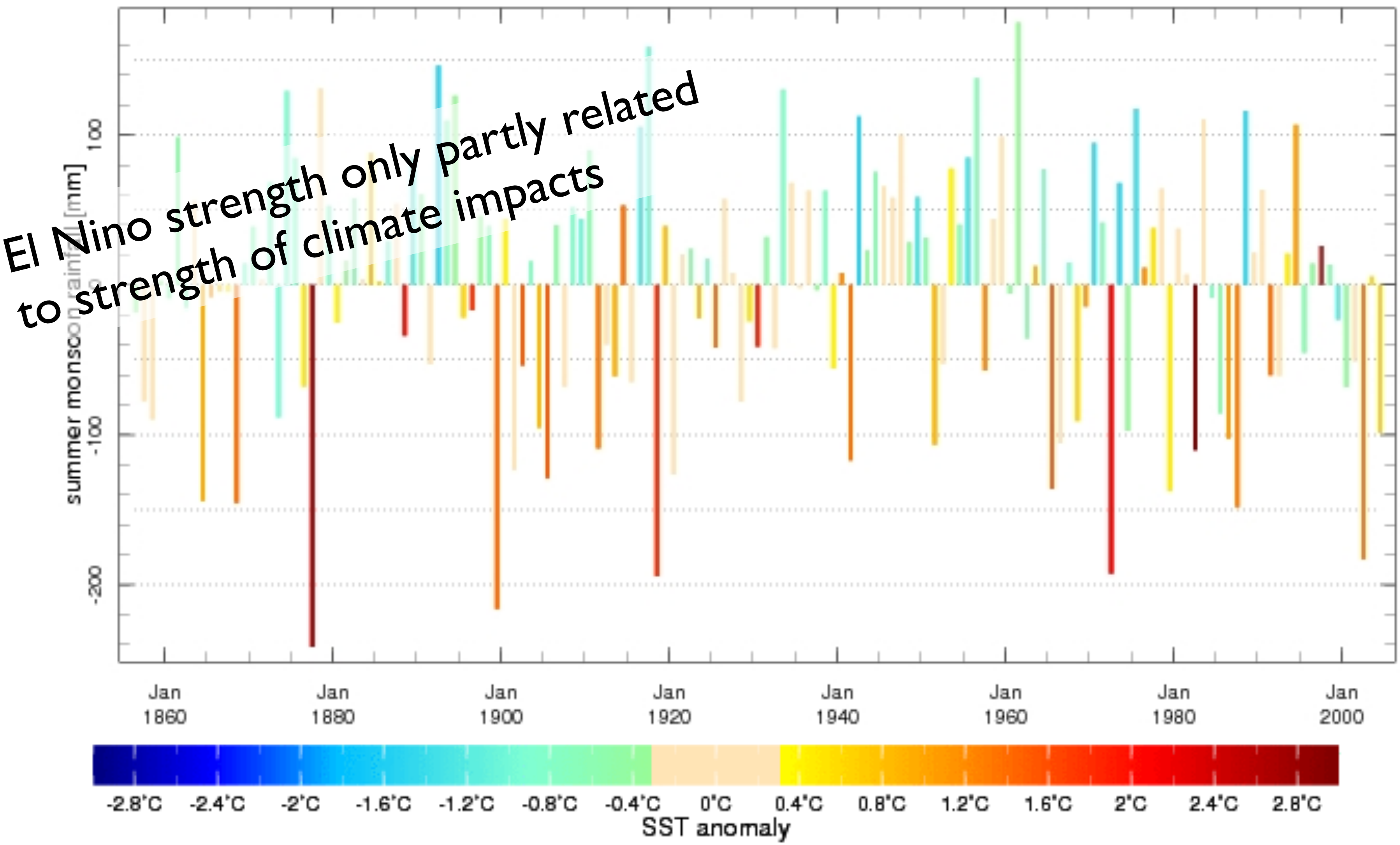
1982 1993 2001

XBT's 60's Satellite SST Moorings/Altimeter ARGO





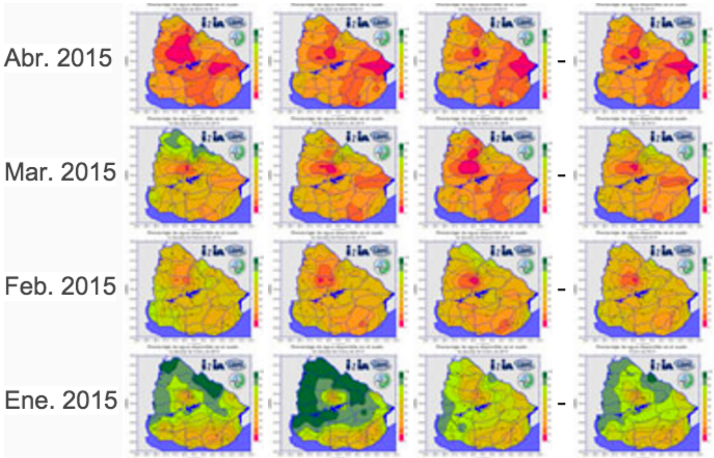
ENSO (color) and All-India Rainfall (bar)



http://iridl.ldeo.columbia.edu/maproom/ENSO/Impacts.html

April 2015: IRI – SNIA Provided this Information

Soil Water Balance



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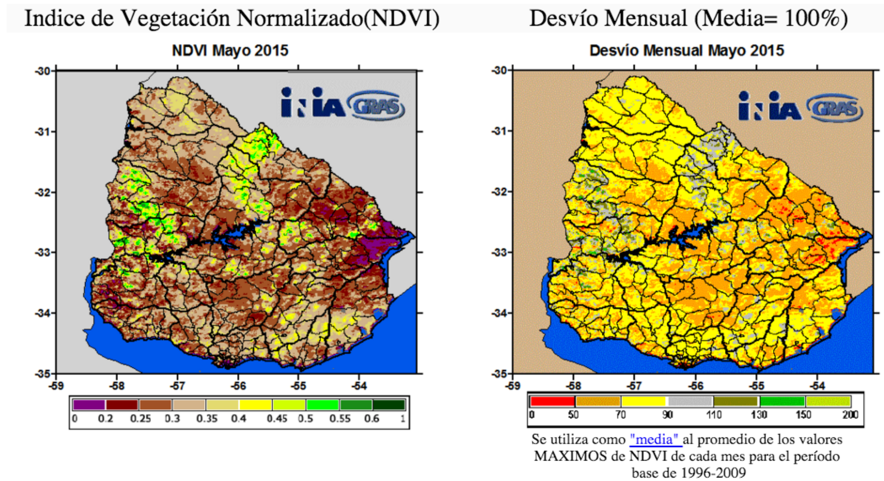
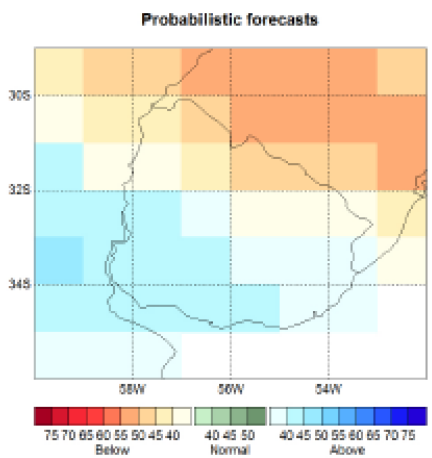
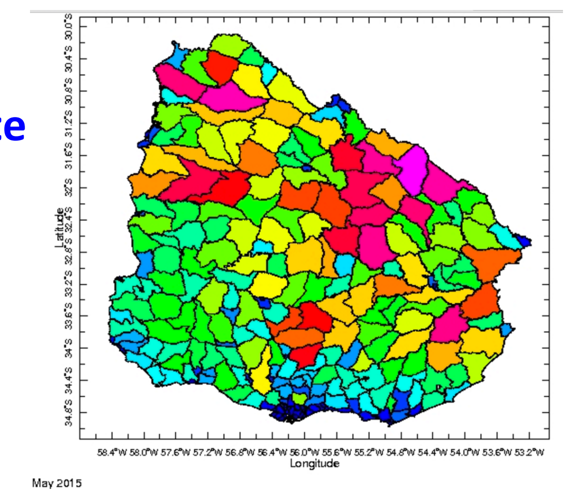




Precipitation Forecast for AMJ 2015

Stocking Rate Real time in Uruguay Data Library



Worse areas: low water, low vegetation, high stocking rate, "dry" forecast