The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

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Targeted Training Activity: Seasonal Predictability in Tropical Regions to be followed by Workshop on Multi-scale Predictions of the Asian and African Summer Monsoon

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Introduction to ENSO
(Part 3)

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III. PREDICTING PHASES OF ENSO & ITS EFFECTS AND USING THE PREDICTIONS

a. Three Types of Prediction

b. Why is ENSO predictable?

c. The current state of the art

d. How predictable is it?

The relationship between mechanism and predictability

e. Using the predictions

Who are the Users? What do they want?

General Principles of End-to-End Forecasting

f. Institutions for Seasonal-to-Interannual Prediction

The IRI

Towards a National Climate Service

a. Three Types of Prediction

1. Weather Prediction

What: Predicts the actual state of the atmosphere a few days in advance

How:

- ►Measure the state of the atmosphere over a six hour window
- ►Assimilate the data into a model and use the previous forecast to get a dynamically consistent state of the atmosphere at time zero
- ►Initialize the state of the atmosphere
- ►Run the atmospheric model for time T
- ►Evaluate the prediction at time T by comparing with the initialized state at time T
- ►Repeat forever

Why it works: The chaos of the system allows errors in the initial condition to grow on doubling times of about two days allowing a dynamical prediction of no more than ~two weeks.

2. ENSO Prediction

What: Predict the statistics of the atmosphere a season or so in advance by predicting the slowly varying lower boundary condition (soil, ice, vegetation, SST)

How and Why it Works: (Below in Secs. b, c)

3. Predicting Global Warming

What: Predict the statistics of the climate system 50 years in advance.

How:

- **Initialize the state of the ocean**
- **Predict the future emissions of the radiative active species (how?)**
- **Run coupled models of atmosphere-ocean-land-chemistry models to calculate the future concentration of the radiatively active species and the climate that is forced by it**

Why it works: Response to "externally" imposed forcing by anthropogenically added constituents and natural forcing.

b. Why is ENSO Predictable?

"… the time averages (monthly and seasonal means) for the tropics have more predictability. This is because they are largely determined by fluctuations of the seasonally varying boundary conditions of sea surface temperature and soil moisture. Under favorable conditions, they can contribute to the predictability of middle latitudes also." Shukla, 1981

- ►**Atmospheric weather is IN PRINCIPLE not predictable more than 2 weeks or so;**
- ►**Over the tropical oceans, the STATISTICS of atmospheric weather depends on the sea surface temperature (e.g. Rains over warm water);**
- ►**Sea surface temperature CAN be predicted by a coupled atmosphere-ocean model if the internal state of the upper tropical ocean in known;**
- ►**Skill is likely to be much less in mid-latitudes because the SST determines the statistics in the presence or much variability.**

c. The current state of the art

The prediction process:

- ►**Data: Collect data defining the state of the tropical Pacific by the TAO/TRITON Array and other sources;**
- ►**Assimilate the data into an ocean model to get an estimate of the current state of the ocean (or the tropical ocean for two-tiered forecasting)**
- ►**Use the current initial state of the atmosphere obtained in the weather prediction process**

  [The ocean is initialized once a month, the atmosphere several times a day--the predictions are made with many atmospheric initializations]

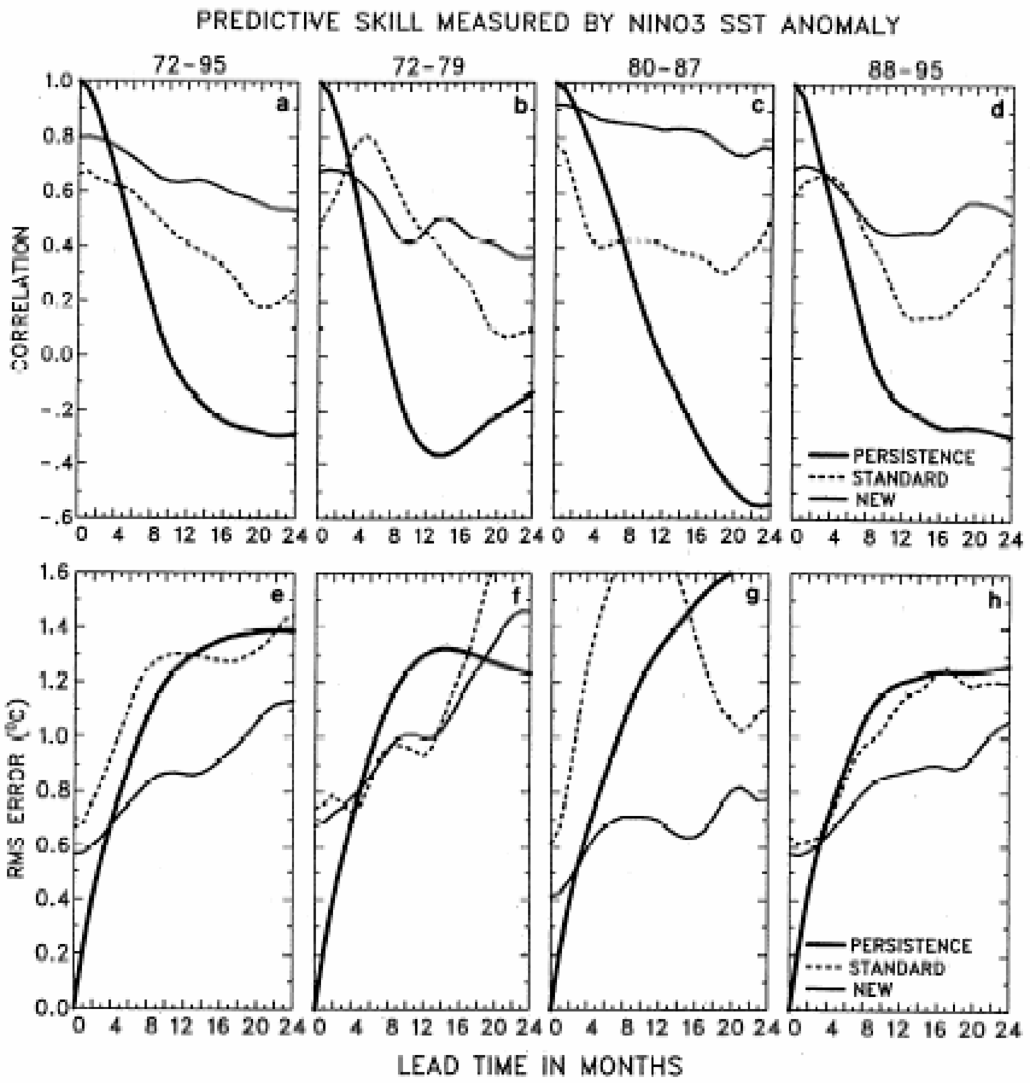
- ►**Initialize the coupled atmosphere-ocean system**

  [This is a work in progress]

- ► **Make the prediction**
  - **Two Tiered:**
    1. **SST Prediction in Tropics by Coupled GCMs**
    2. **Mid-Latitude Prediction by Atmospheric GCM**
  - **One Tiered:**
    - **Predict Atmosphere and Ocean all at Once Using CGCM**
- ► **Evaluate the results at prediction time t by comparing with the initialization at time t**
- ► **Downscale the results to the region of interest by either:**
  - **Statistical correlation with the large scale**
  - **Dynamical simulation of region driven by large scale conditions (usually at very high resolution to resolve topography and orography) given by the prediction**

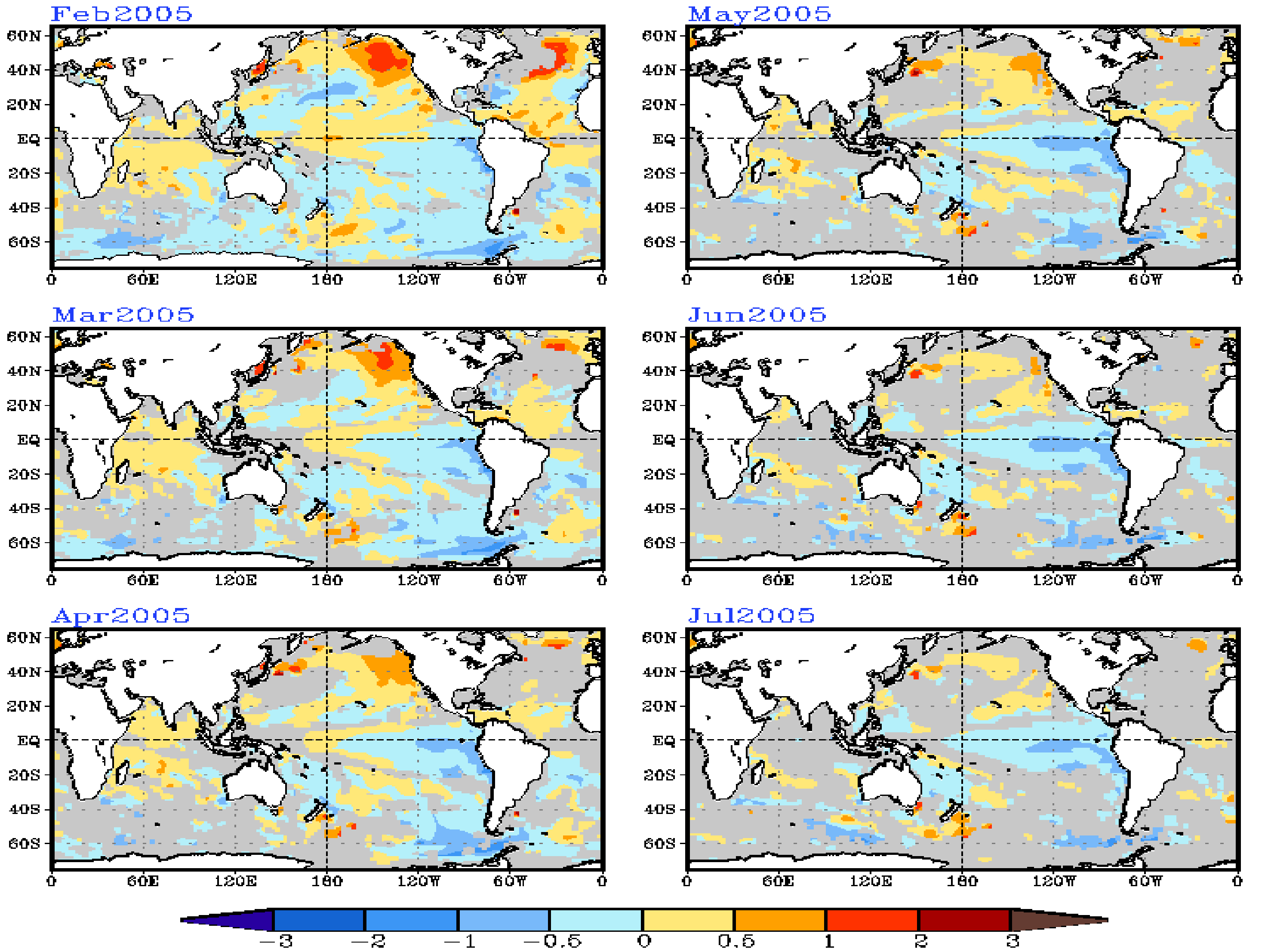
►**Evaluation is usually in terms of correlation and rms error of retrospective forecasts**

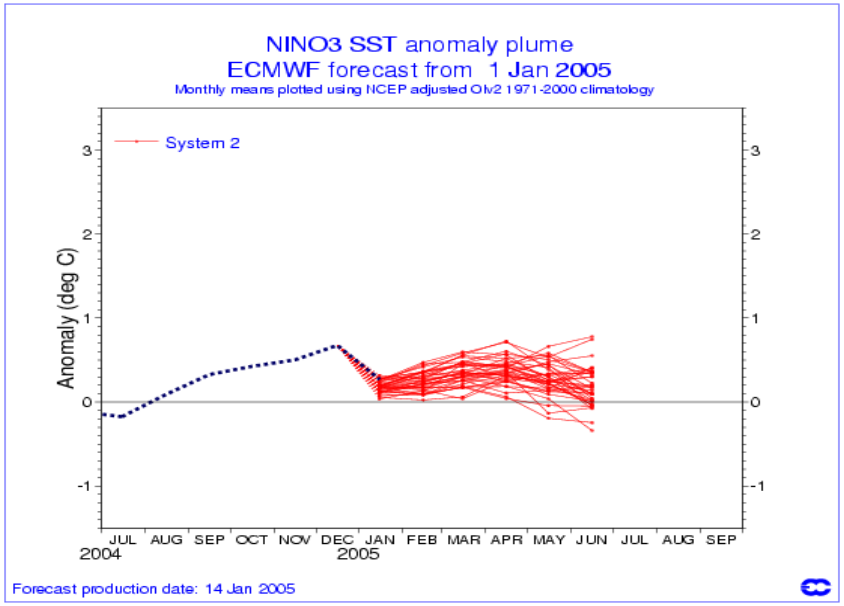
Chen et al, 97, using CZ model

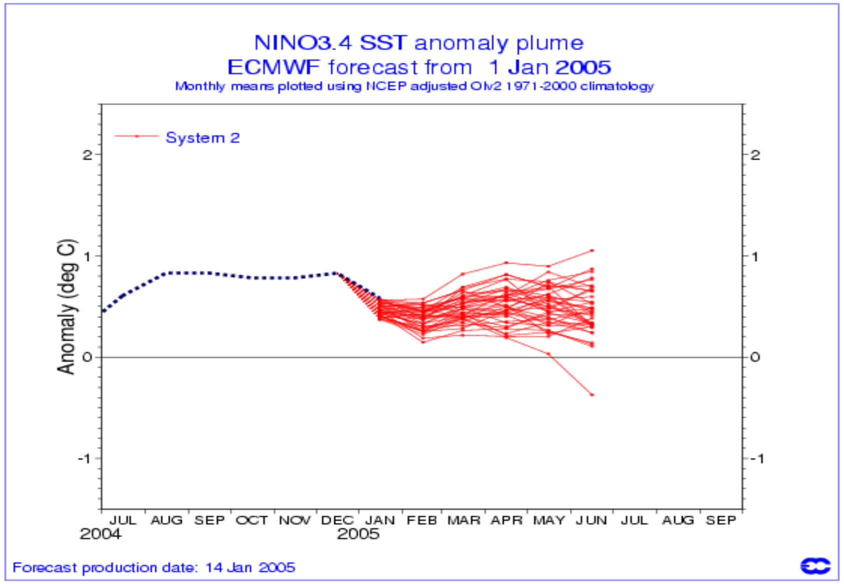


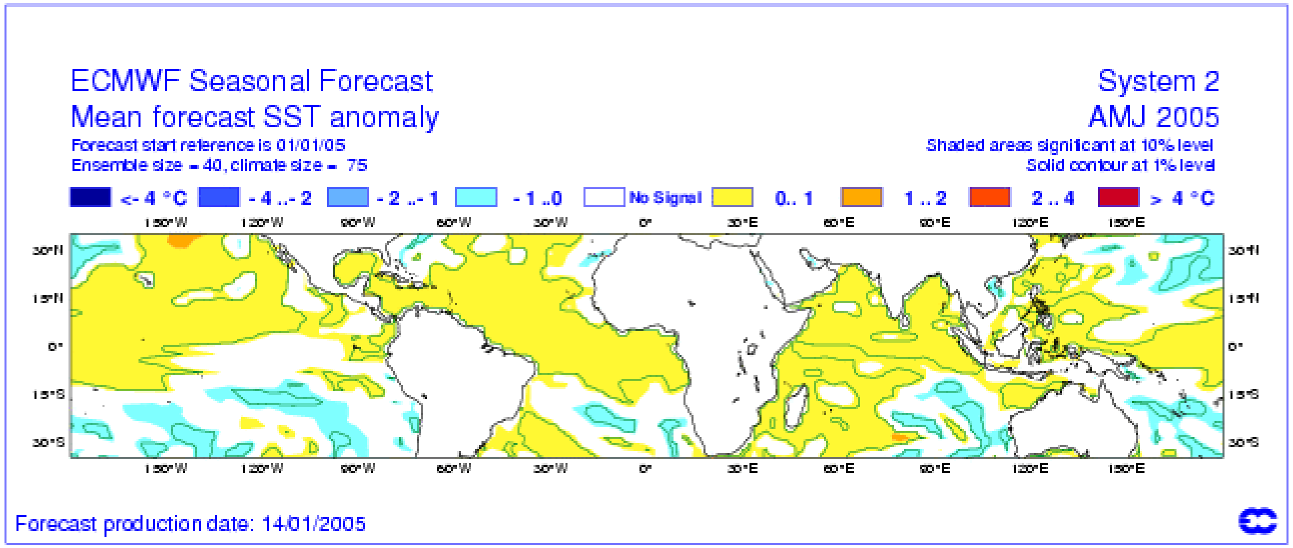
Initial conditions: 13Jan2005–01Feb2005

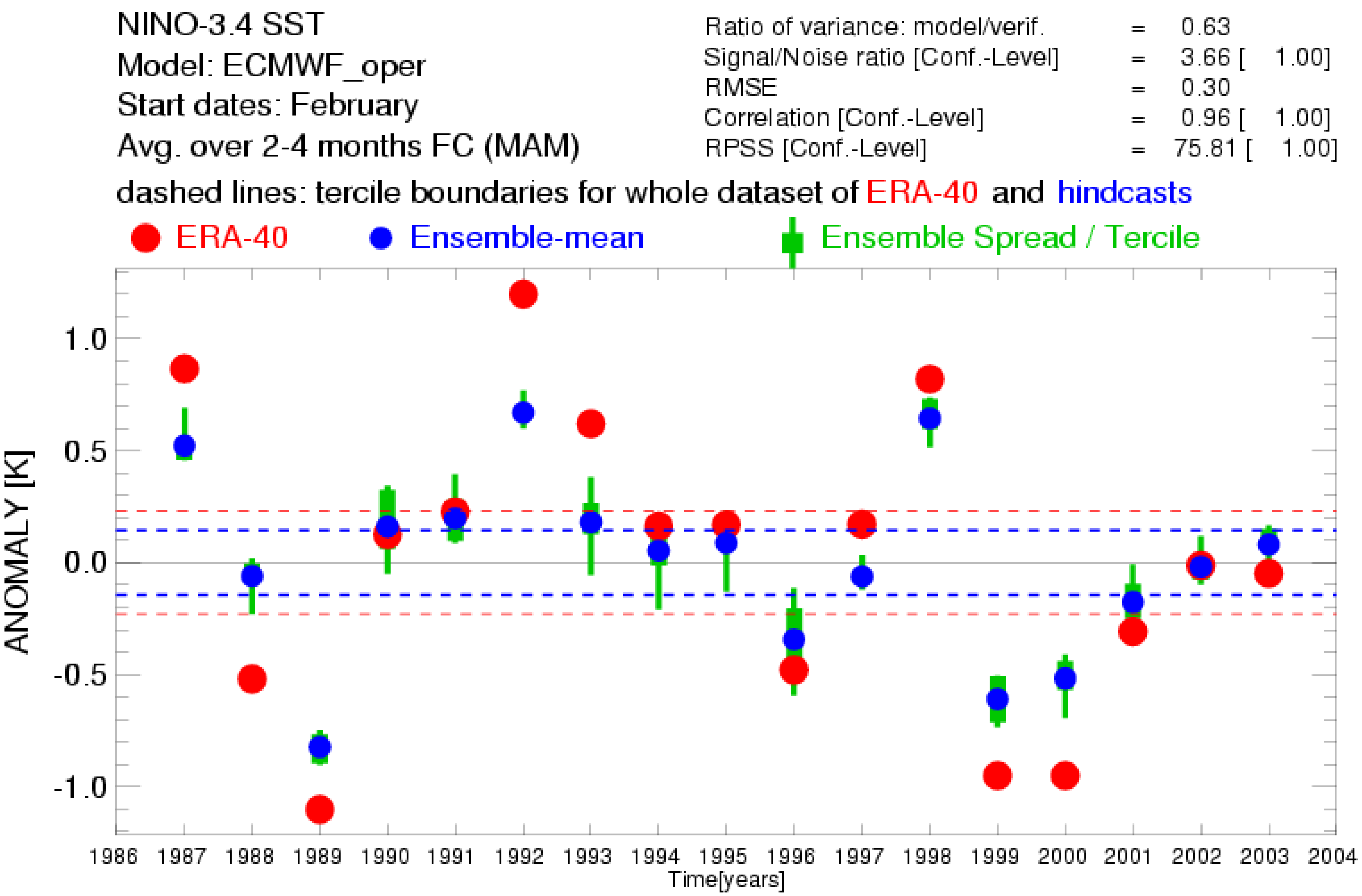
CFS seasonal SST forecast (K)

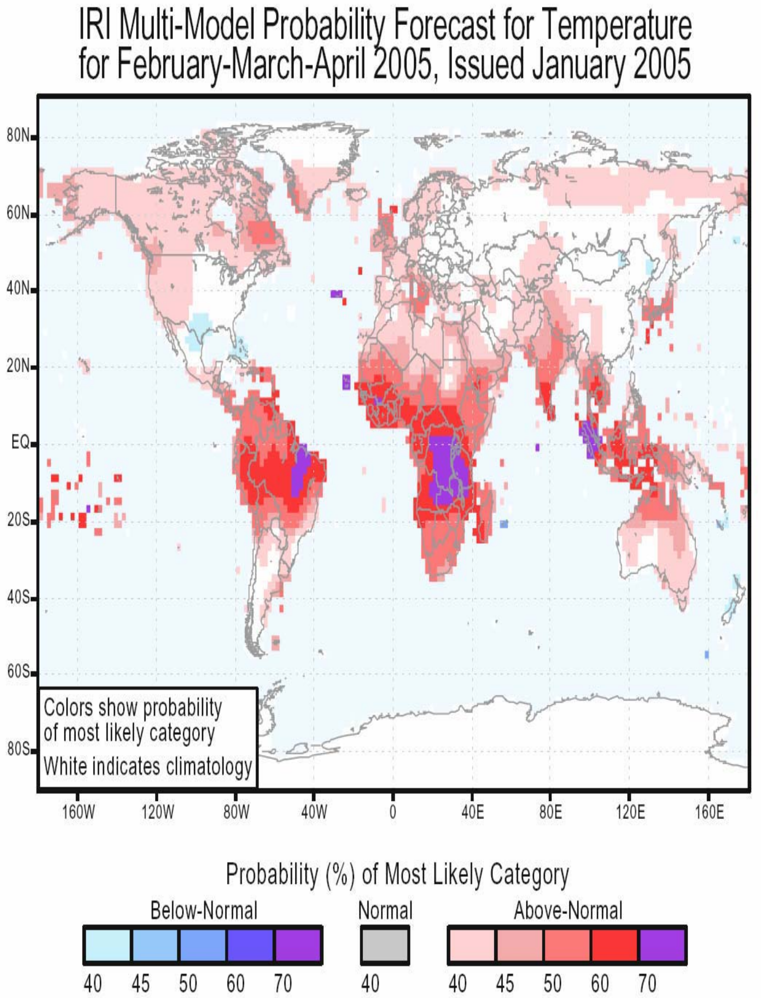


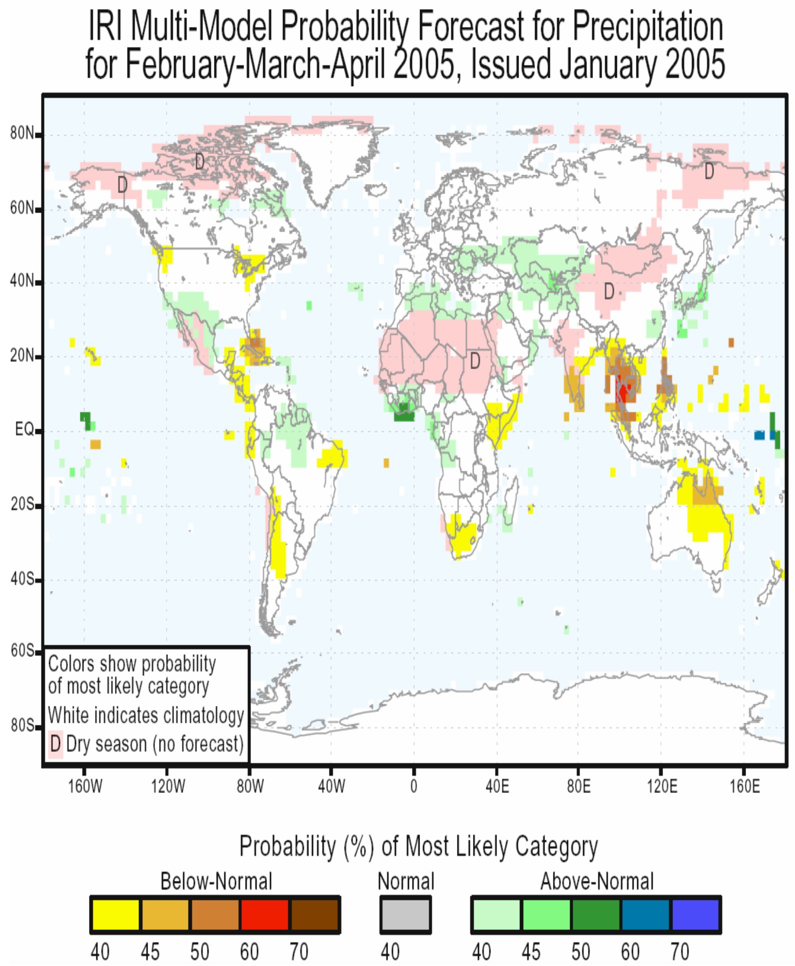

NINO3 SST anomaly plume
ECMWF forecast from 1 Jan 2005
Monthly means plotted using NCEP adjusted OIv2 1971-2000 climatology
System 2
Anomaly (deg C)
JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
2004
2005
Forecast production date: 14 Jan 2005


NINO3.4 SST anomaly plume
ECMWF forecast from 1 Jan 2005
Monthly means plotted using NCEP adjusted OIv2 1971-2000 climatology
System 2
Anomaly (deg C)
JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
2004
2005
Forecast production date: 14 Jan 2005

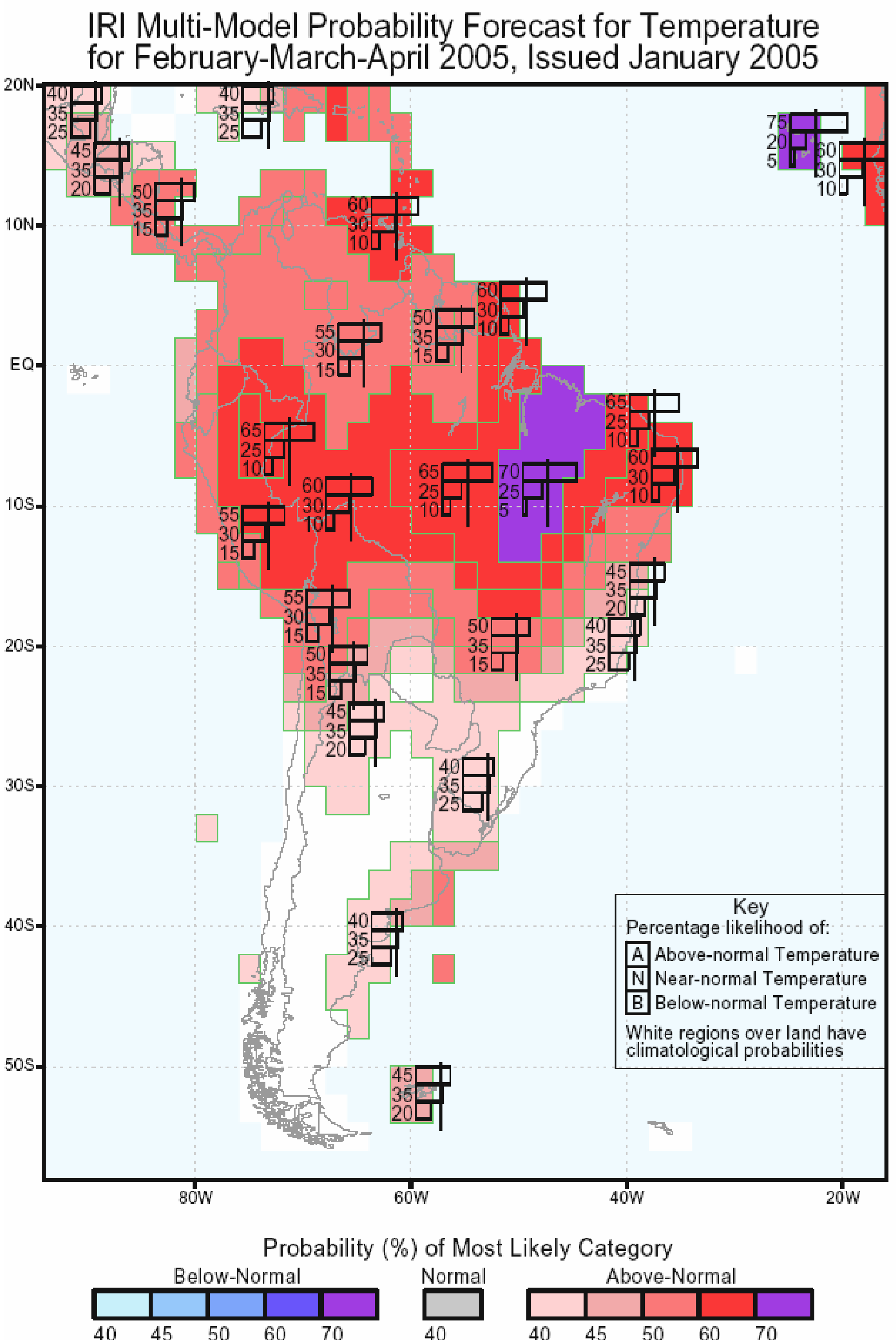

ECMWF Seasonal Forecast
Mean forecast SST anomaly
Forecast start reference is 01/01/05
Ensemble size = 40, climate size = 75
System 2
AMJ 2005
Shaded areas significant at 10% level
Solid contour at 1% level
<-4 °C
-4..-2
-2..-1
-1..0
No Signal
0..1
1..2
2..4
> 4 °C
Forecast production date: 14/01/2005


NINO-3.4 SST
Model: ECMWF_oper
Start dates: February
Avg. over 2-4 months FC (MAM)
Ratio of variance: model/verif. = 0.63
Signal/Noise ratio [Conf.-Level] = 3.66 [1.00]
RMSE = 0.30
Correlation [Conf.-Level] = 0.96 [1.00]
RPSS [Conf.-Level] = 75.81 [1.00]
dashed lines: tercile boundaries for whole dataset of ERA-40 and hindcasts
ERA-40
Ensemble-mean
Ensemble Spread / Tercile
ANOMALY [K]
1.0
0.5
0.0
-0.5
-1.0
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Time[years]





See http://www.atmos.washington.edu/tpop/pop.htm for papers & sites.



IRI Multi-Model Probability Forecast for Temperature
for February-March-April 2005, Issued January 2005
20N
10N
EQ
10S
20S
30S
40S
50S
80W
60W
40W
20W
Key
Percentage likelihood of:
A Above-normal Temperature
N Near-normal Temperature
B Below-normal Temperature
White regions over land have climatological probabilities
Probability (%) of Most Likely Category
Below-Normal
Normal
Above-Normal
40 45 50 60 70
40
40 45 50 60 70

d. How Predictable is ENSO?

►The ultimate limit of ENSO predictability is not known since it depends on the mechanism of ENSO

Unstable ENSO: Limit might be as much as a decade

Stable ENSO: Limit less than a year (may depend on properties of noise)

►At this time, all methods are giving useful skill for ENSO SST prediction of no more than 3 seasons. This does NOT mean that the mechanism is stable because:

We do not have a climate observing system

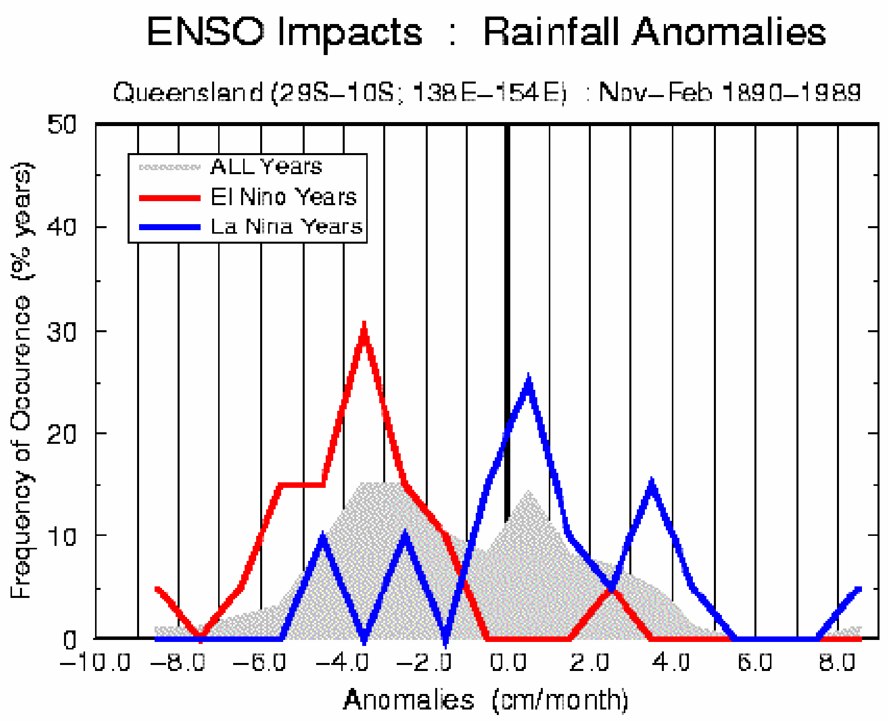
Operational prediction uses primitive assimilation methods

There is little effort being expended in prediction research

The predictions have not been demonstrated to be useful

e. Using the predictions

► **There must be some expression of ENSO variability in the region and sector**



►Predictions must be downscaled to the identified region and sector

►There must be some Action (Decision) that can be taken

Identify User, Understand How User Works

►There must be some way of convincing someone to take that action {Overcoming Barriers}

►The Action [Some Decision]

►There must be some way of evaluating the consequences of the action taken

[The Payoffs are cumulative--think of gambling with the odds shifted in your favor]

►The action is adjusted until optimal---this takes a very long time

Barriers to Using Prediction:

- ►Multiple Sources of Predictions--Lack of Authoritative Information
- ►Wrong or useless quantity forecast
- ►Blown Forecasts
- ►Accuracy both actual and perceived
- ►Lack of connection between climate prediction and resource predictions
- ►Lack of Diffusion of this new technology:

  Compatible, Observable, Demonstrable, Relative Advantage, Trialable

- ►Length of time it takes to become convinced

f. Institutions for Seasonal-to-Interannual Prediction

►There are needs for institutions to maintain the observing system, assimilate the data in models, and produce the predictions.

►But these are enormously expensive so why would the public support these expenses? Only if there is demonstrable evidence of useful and valuable information being produced.

►So the provision of climate information must include the provision and distribution of climate information for regional use

►Unlike the Weather Service, a Climate Service must have intermediate institutions to convert the weather information into detailed information that the user finds useful

Will we ever get a Climate Service?