ENSO FORECASTS

with an intermediate coupled model

initialized and verified by historical climate datasets

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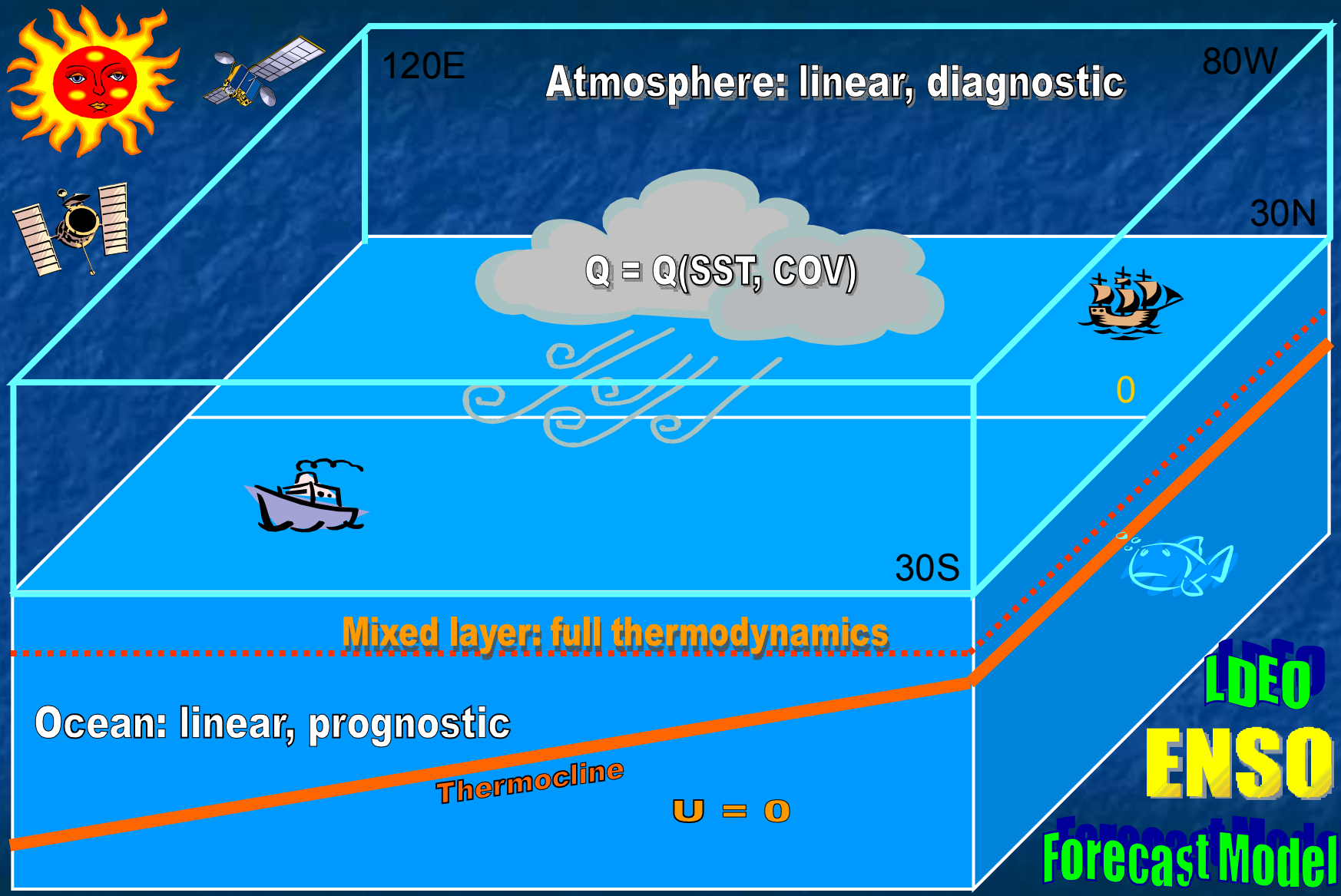
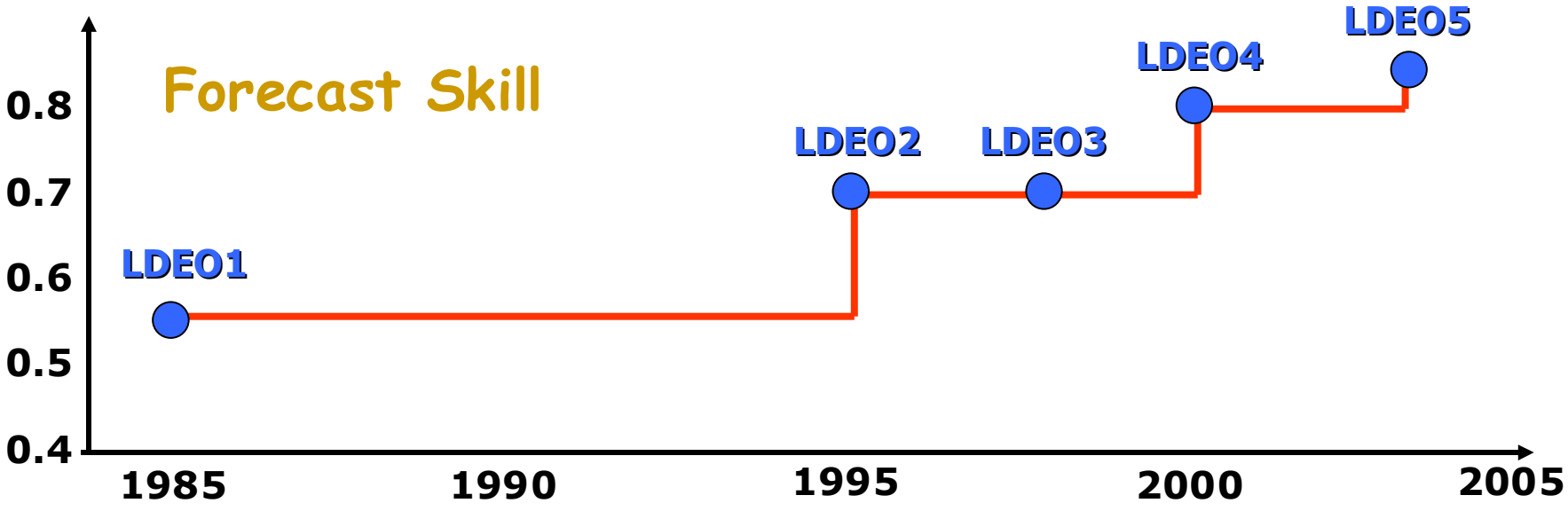
OUTLINE

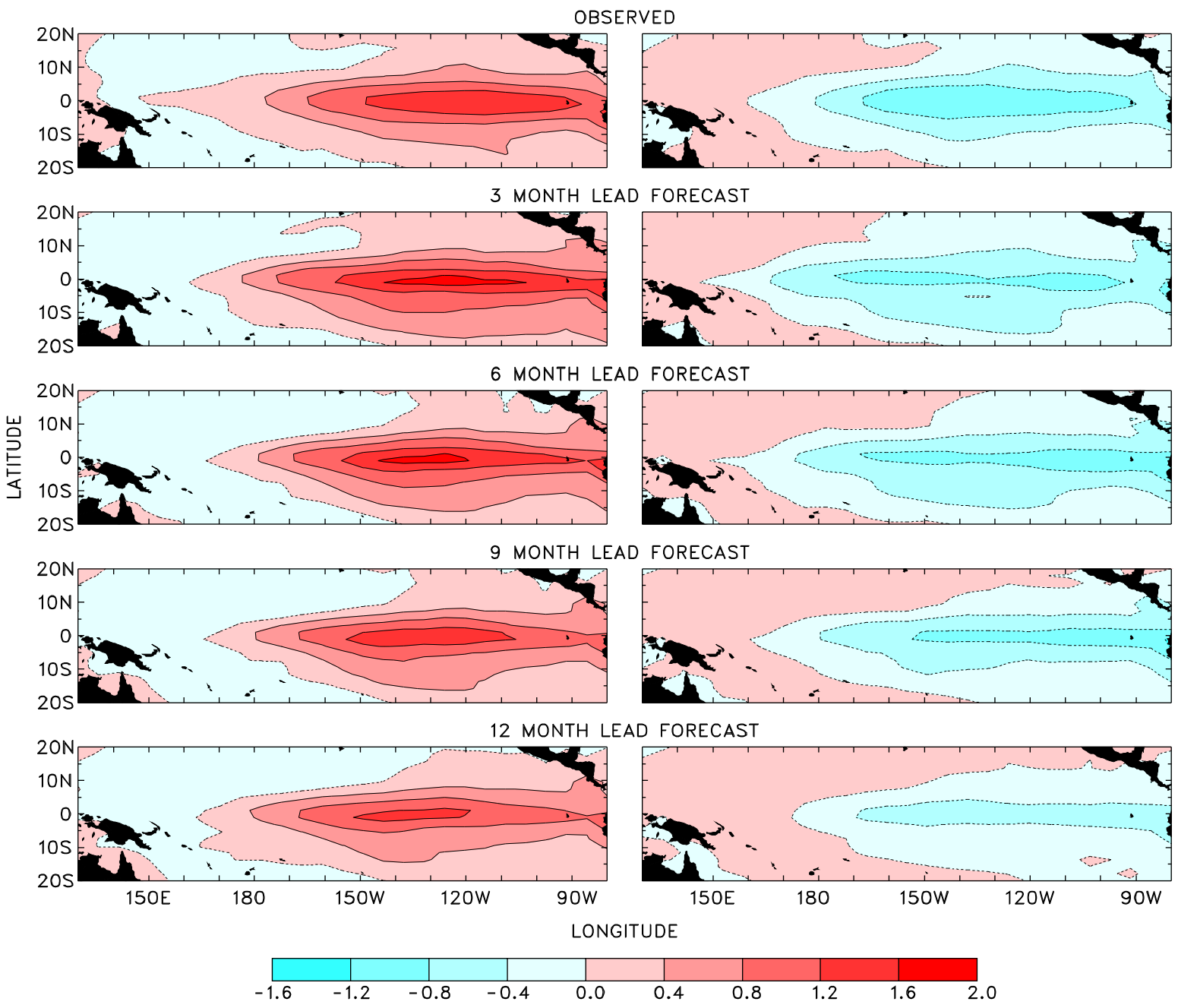
- LDEO ENSO forecast system
- ENSO prediction and predictability
- Potential areas for improvement
- Summary and conclusion

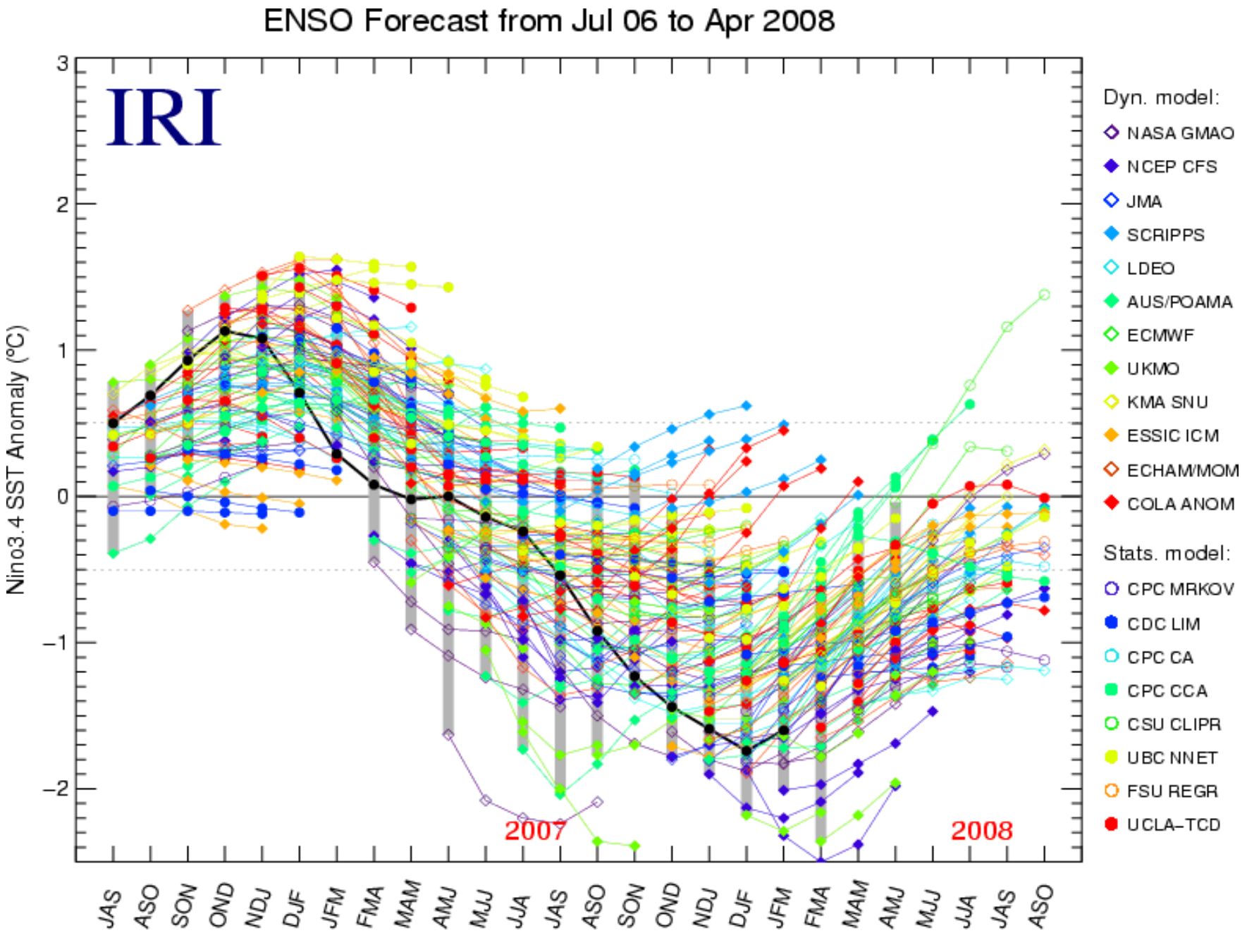

120E
Atmosphere: linear, diagnostic
80W
30N
Q = Q(SST, COV)
0
30S
Mixed layer: full thermodynamics
Ocean: linear, prognostic
Thermocline
U = 0
LDEO
ENSO
Forecast Model

A Brief History of LDEO Model

- LDEO1: Original Cane and Zebiak model (Cane et al., *Nature,* 1986)
- LDEO2: LDEO1 plus coupled initialization (Chen et al., *Science,* 1995)
- LDEO3: LDEO2 plus sea level data assimilation (Chen et al., *GRL*,1998)
- LDEO4: LDEO3 plus statistical bias correction (Chen et al., *GRL*, 2000)
- LDEO5: LDEO4 plus additional correction on SST (Chen et al., *Nature*, 2004)



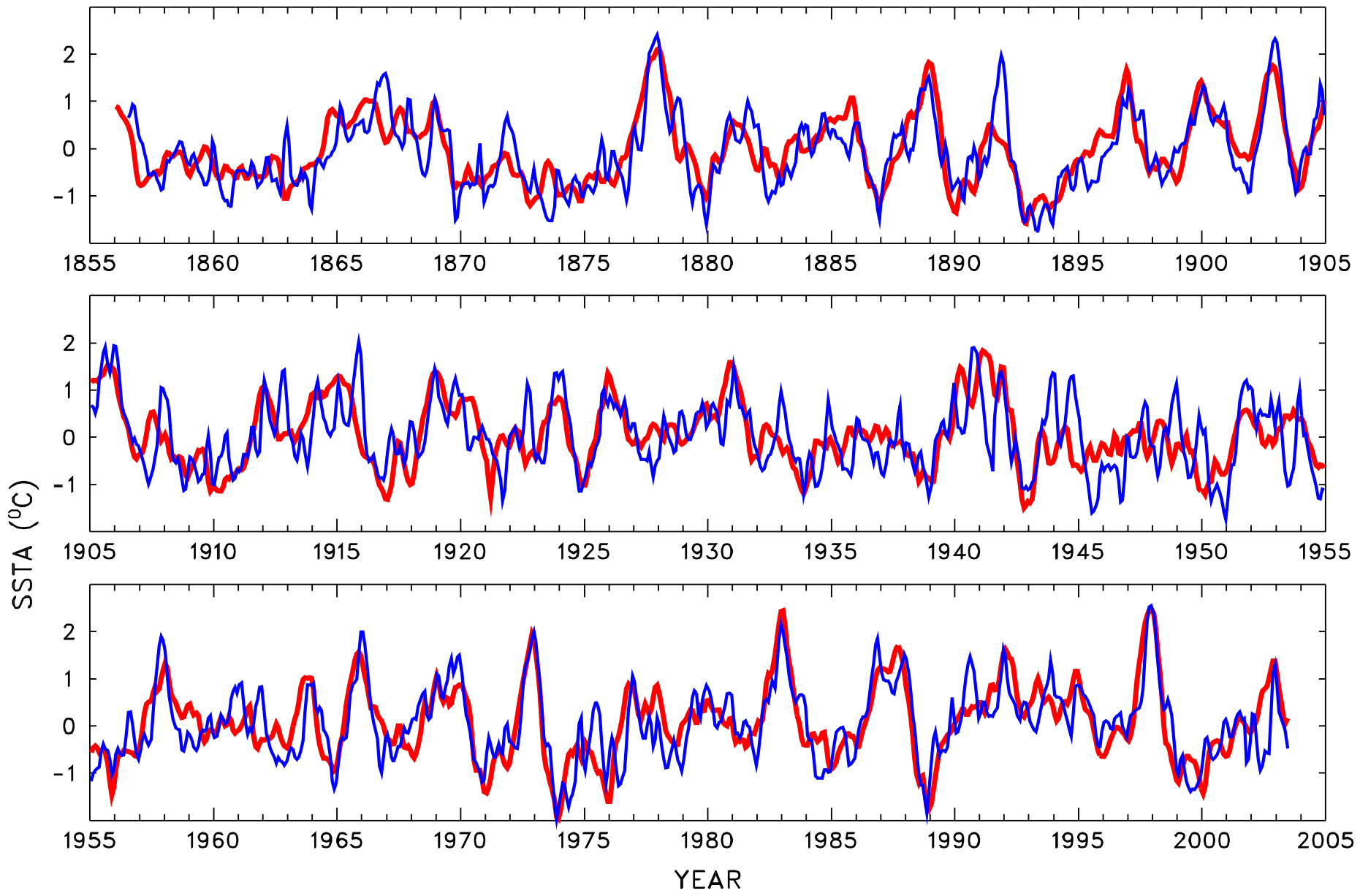

COMPOSITE EL NINO
COMPOSITE LA NINA
OBSERVED
3 MONTH LEAD FORECAST
6 MONTH LEAD FORECAST
9 MONTH LEAD FORECAST
12 MONTH LEAD FORECAST
LATITUDE
20N
10N
0
10S
20S
150E
180
150W
120W
90W
LONGITUDE
-1.6
-1.2
-0.8
-0.4
0.0
0.4
0.8
1.2
1.6
2.0

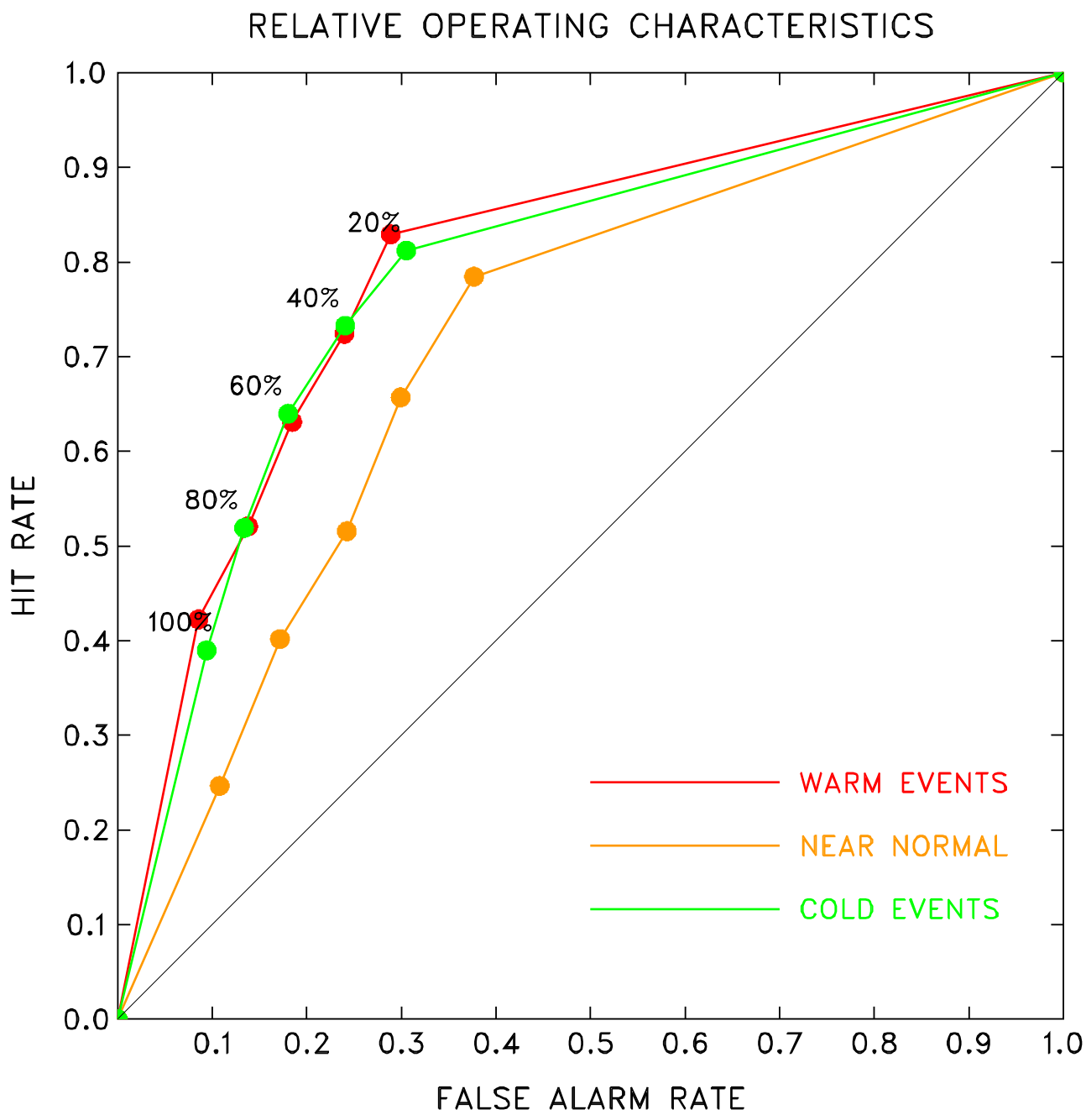

ENSO Forecast from Jul 06 to Apr 2008
IRI
Nino3.4 SST Anomaly (°C)
3
2
1
0
−1
−2
2007
2008
JAS
ASO
SON
OND
NDJ
DJF
JFM
FMA
MAM
AMJ
MJJ
JJA
JAS
ASO
SON
OND
NDJ
DJF
JFM
FMA
MAM
AMJ
MJJ
JJA
JAS
ASO
Dyn. model:
NASA GMAO
NCEP CFS
JMA
SCRIPPS
LDEO
AUS/POAMA
ECMWF
UKMO
KMA SNU
ESSIC ICM
ECHAM/MOM
COLA ANOM
Stats. model:
CPC MRKOV
CDC LIM
CPC CA
CPC CCA
CSU CLIPR
UBC NNET
FSU REGR
UCLA−TCD

Controversy on ENSO predictability

- *Classic theories consider ENSO as a self-sustaining interannual fluctuation in the tropical Pacific, being chaotic yet deterministic. Thus its predictability is largely limited by the growth of initial errors, and the potential forecast lead time has been suggested to be on the order of years.*

- *Some other studies emphasize the importance of atmospheric noise, particularly the westerly wind bursts in the western equatorial Pacific. In such a scenario, ENSO is a damped oscillation sustained by stochastic forcing. This implies that El Niños are essentially unpredictable at long lead times.*


OBSEREVD AND PREDICTED NINO3.4 SSTA
SSTA (°C)
YEAR
2
1
0
-1
1855
1860
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005


RELATIVE OPERATING CHARACTERISTICS
HIT RATE
FALSE ALARM RATE
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
20%
40%
60%
80%
100%
WARM EVENTS
NEAR NORMAL
COLD EVENTS

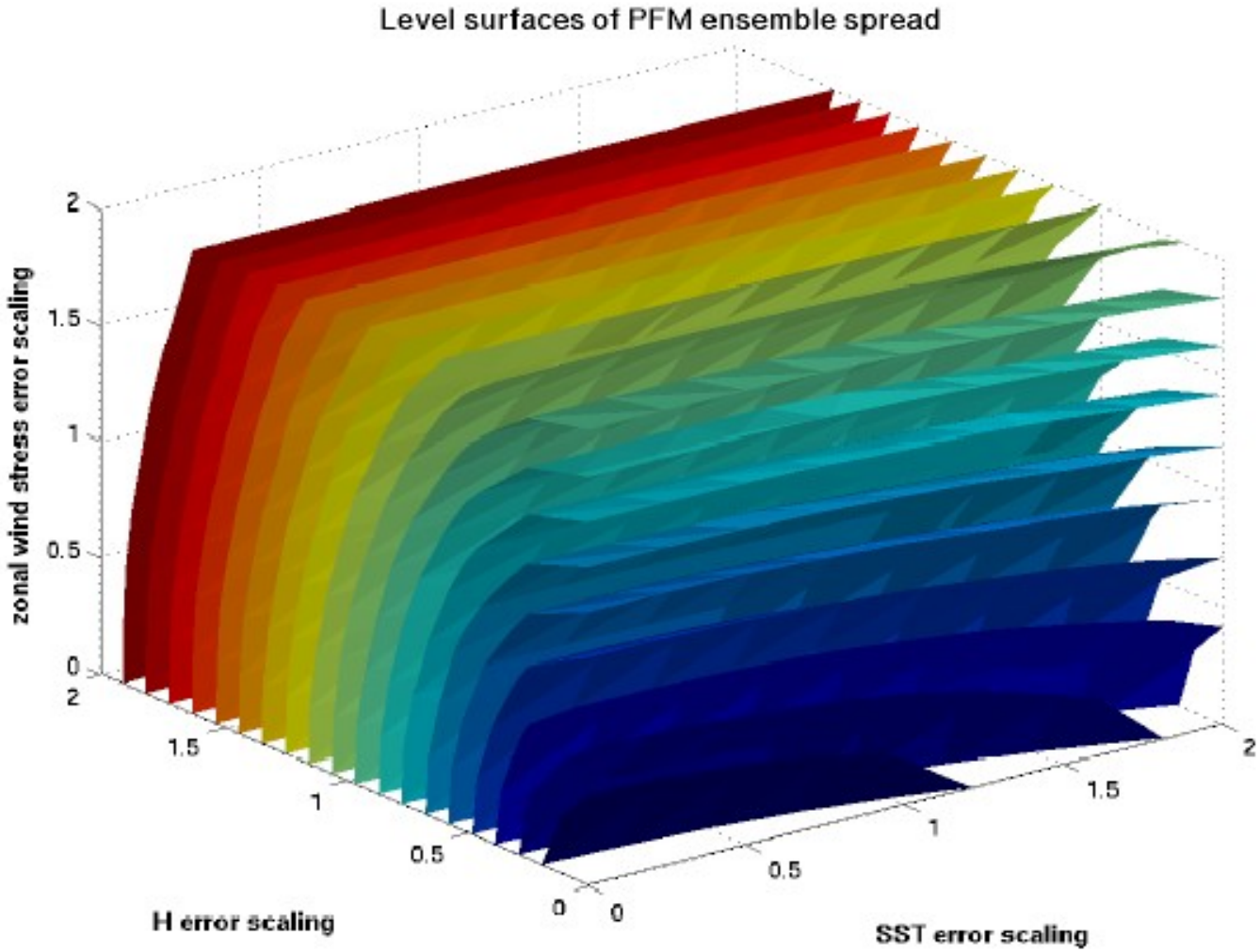
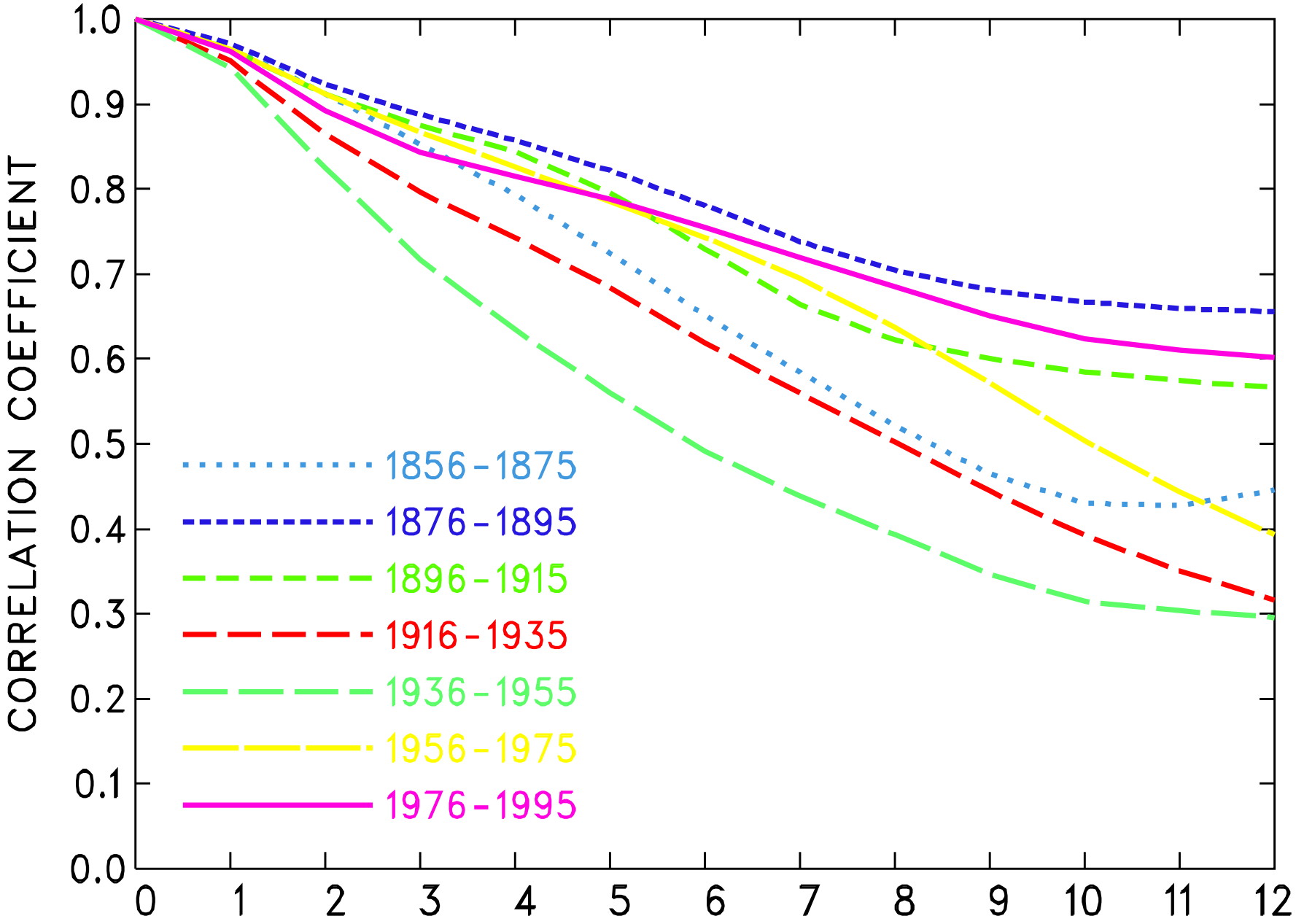


Figure 5-11: Level contours of the 6-month spread in Nino3 as calculated with the PFM approximations to LDEO4. Contours range from 0.1°C (blue) to 1°C (red) in intervals of 0.05°C. The scales represent the magnitude of each error field relative to our most realistic estimate.


CORRELATION COEFFICIENT
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
1856-1875
1876-1895
1896-1915
1916-1935
1936-1955
1956-1975
1976-1995

Prediction of Tropical Pacific Decadal Variability

	ZC Dynamical Forecasts			Naive Reference Forecasts ZC-Long distribution			AR(2)		
	correct	*weak*	*wrong*	*correct*	*weak*	*wrong*	*correct*	*weak*	*wrong*
warm shift	59%	23%	18%	44%	25%	31%	46%	17%	37%
neutral shift	21%	45%	34%	19%	40%	41%	13%	31%	56%
cold shift	41%	23%	36%	30%	22%	48%	34%	16%	50%

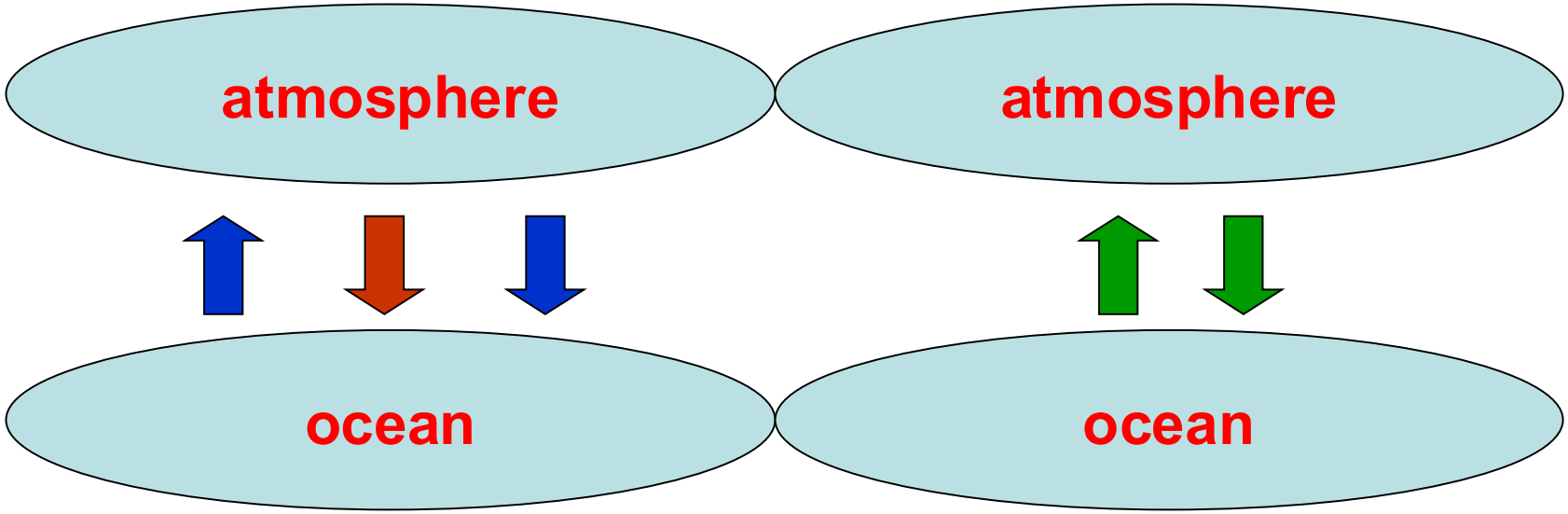
Table 1: Performance of the dynamical model and two naive forecasting strategies presented as a function of the sense of the shift (warm, neutral or cold). Results for the dynamical model are based on 100 member ensembles for each of the 72 analog series (24 each of warm, neutral and cold shifts). Ensembles of size 500,000 were used for the naive forecasts.

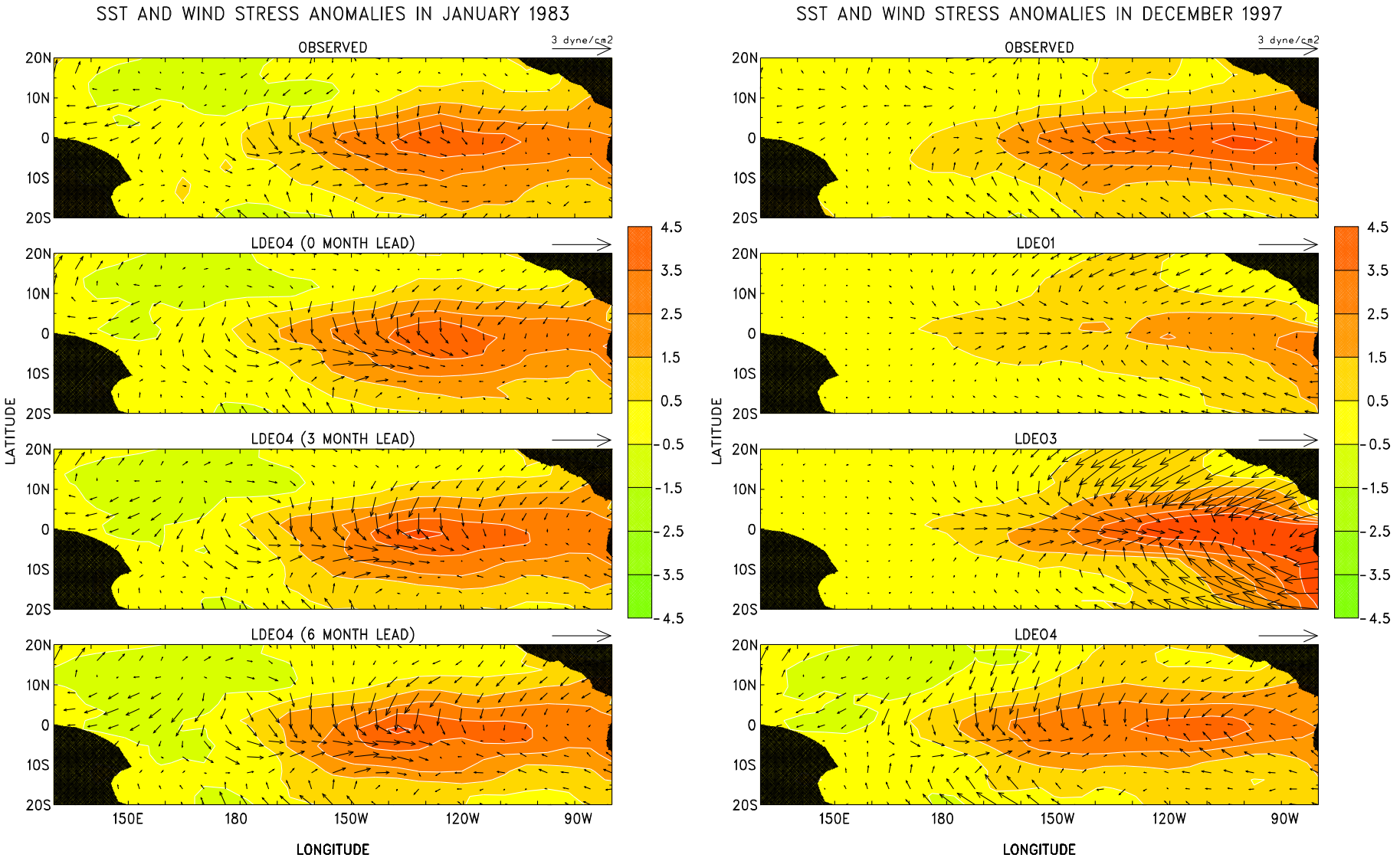
Factors Limiting Forecast Skill:

- **Model flaws**
  - ---- physics, forecast techniques, etc.
- **Flaws in the way the data are used**
  - ---- data assimilation and initialization
- **Gaps in the observing system**
  - ---- in situ and remote sensing
- **Inherent limits to predictability**
  - ---- noise or initial condition?

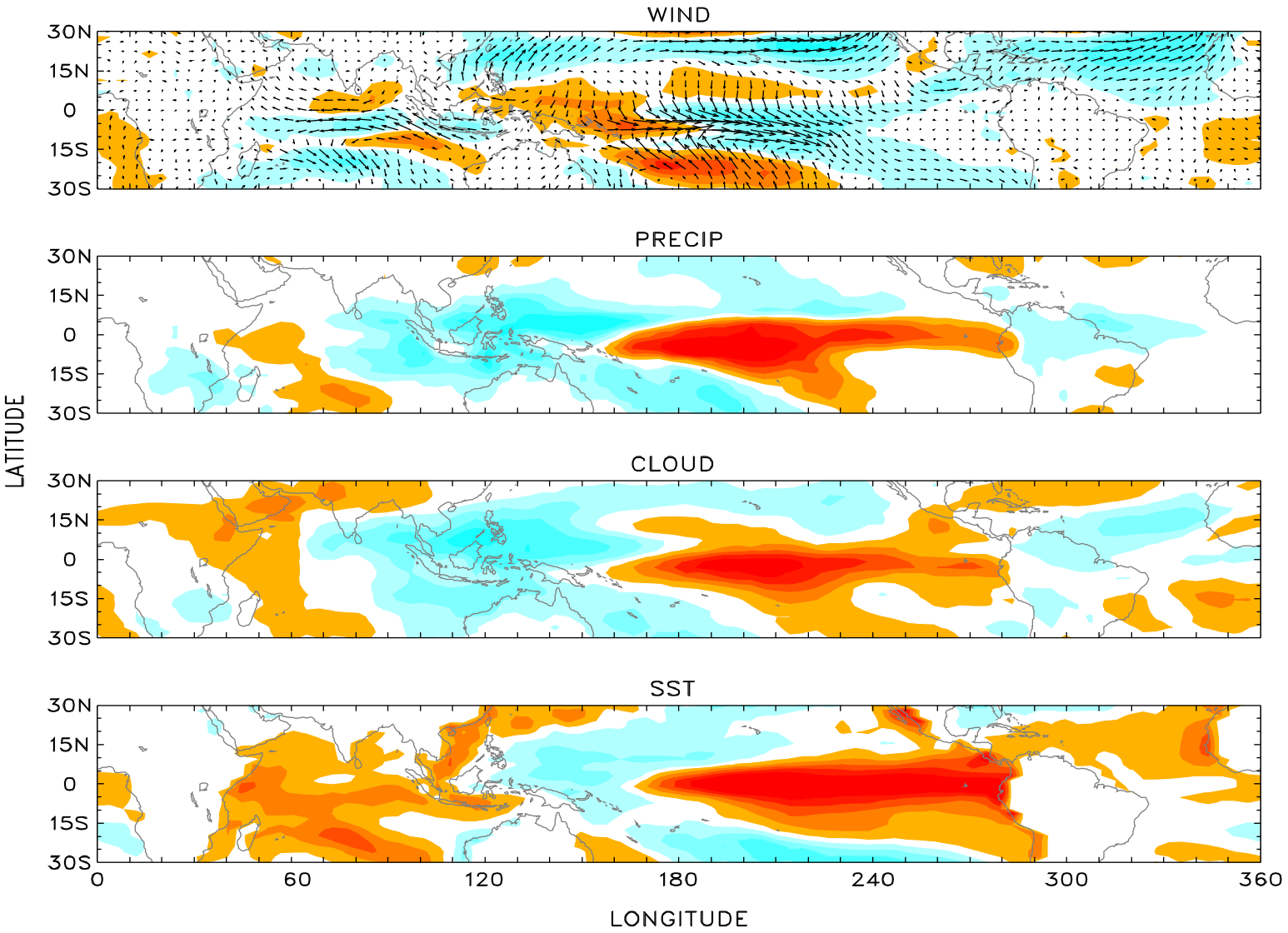
Potential area for improvement:
Coupled data assimilation and bias correction

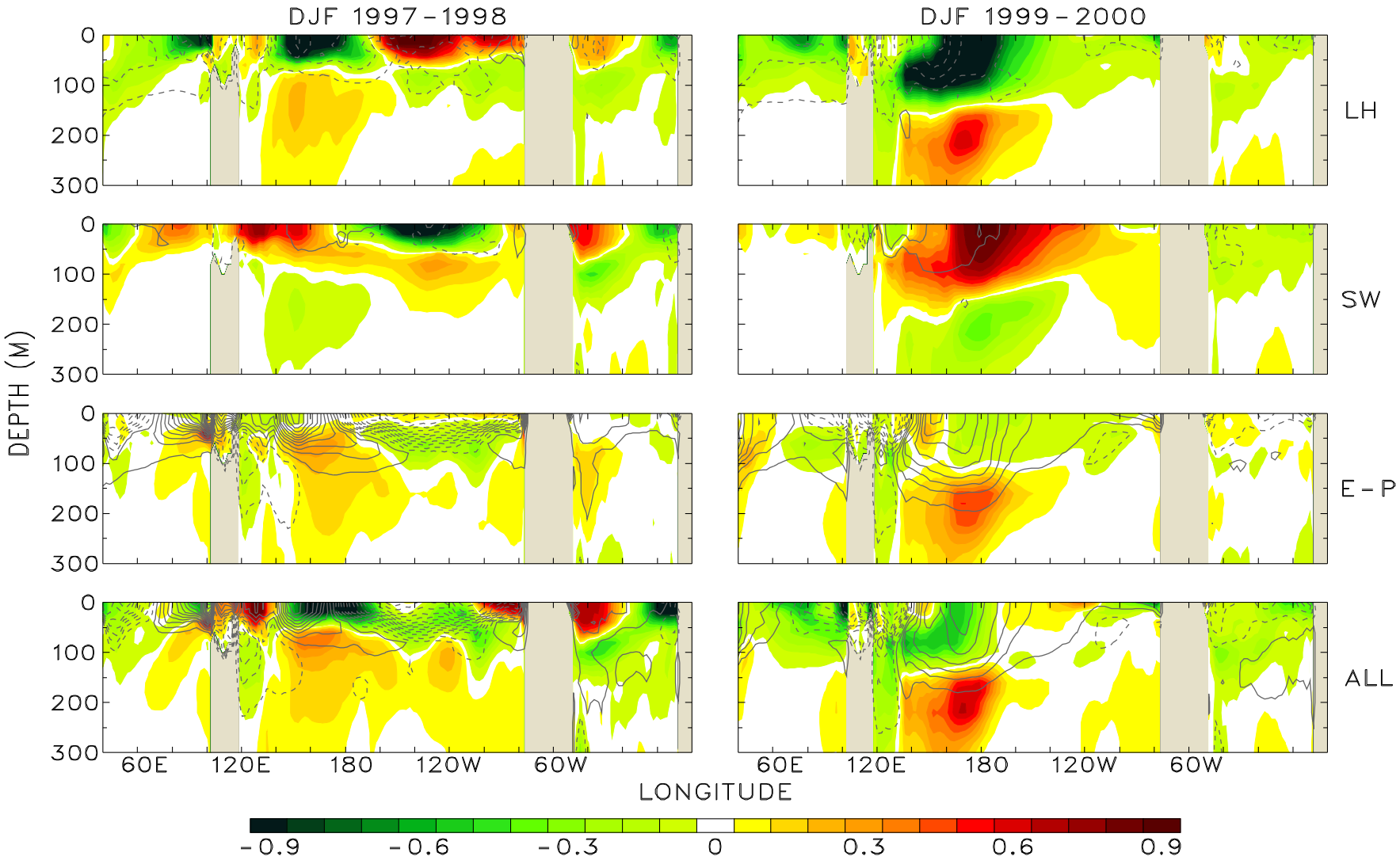
CDA vs. ODA




SST AND WIND STRESS ANOMALIES IN JANUARY 1983
OBSERVED
3 dyne/cm2
LDEO4 (0 MONTH LEAD)
LDEO4 (3 MONTH LEAD)
LDEO4 (6 MONTH LEAD)
20N
10N
0
10S
20S
LATITUDE
150E
180
150W
120W
90W
LONGITUDE
4.5
3.5
2.5
1.5
0.5
-0.5
-1.5
-2.5
-3.5
-4.5
SST AND WIND STRESS ANOMALIES IN DECEMBER 1997
OBSERVED
3 dyne/cm2
LDEO1
LDEO3
LDEO4
20N
10N
0
10S
20S
LATITUDE
150E
180
150W
120W
90W
LONGITUDE
4.5
3.5
2.5
1.5
0.5
-0.5
-1.5
-2.5
-3.5
-4.5

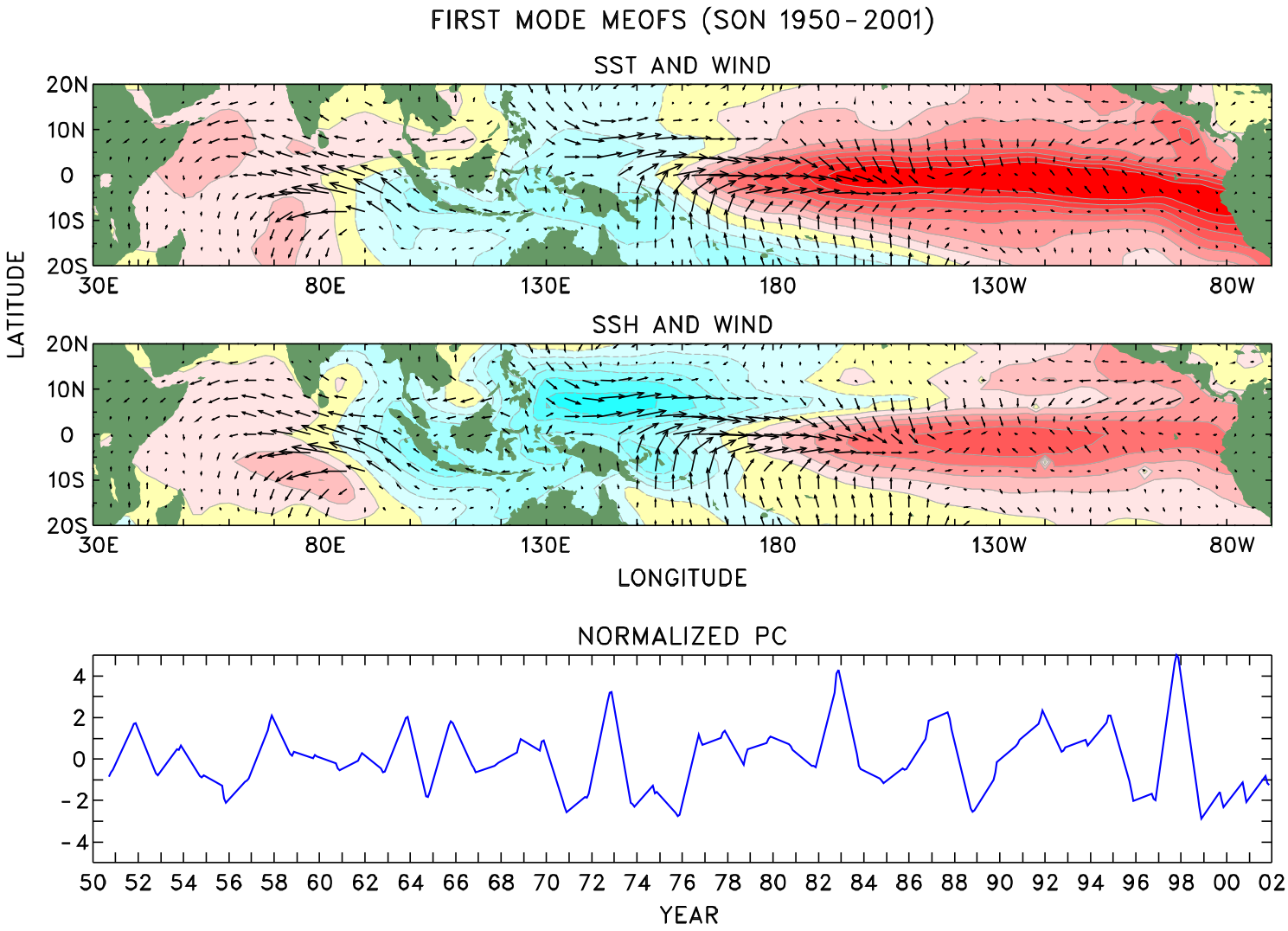
Potential area for improvement:
Surface heat and freshwater fluxes



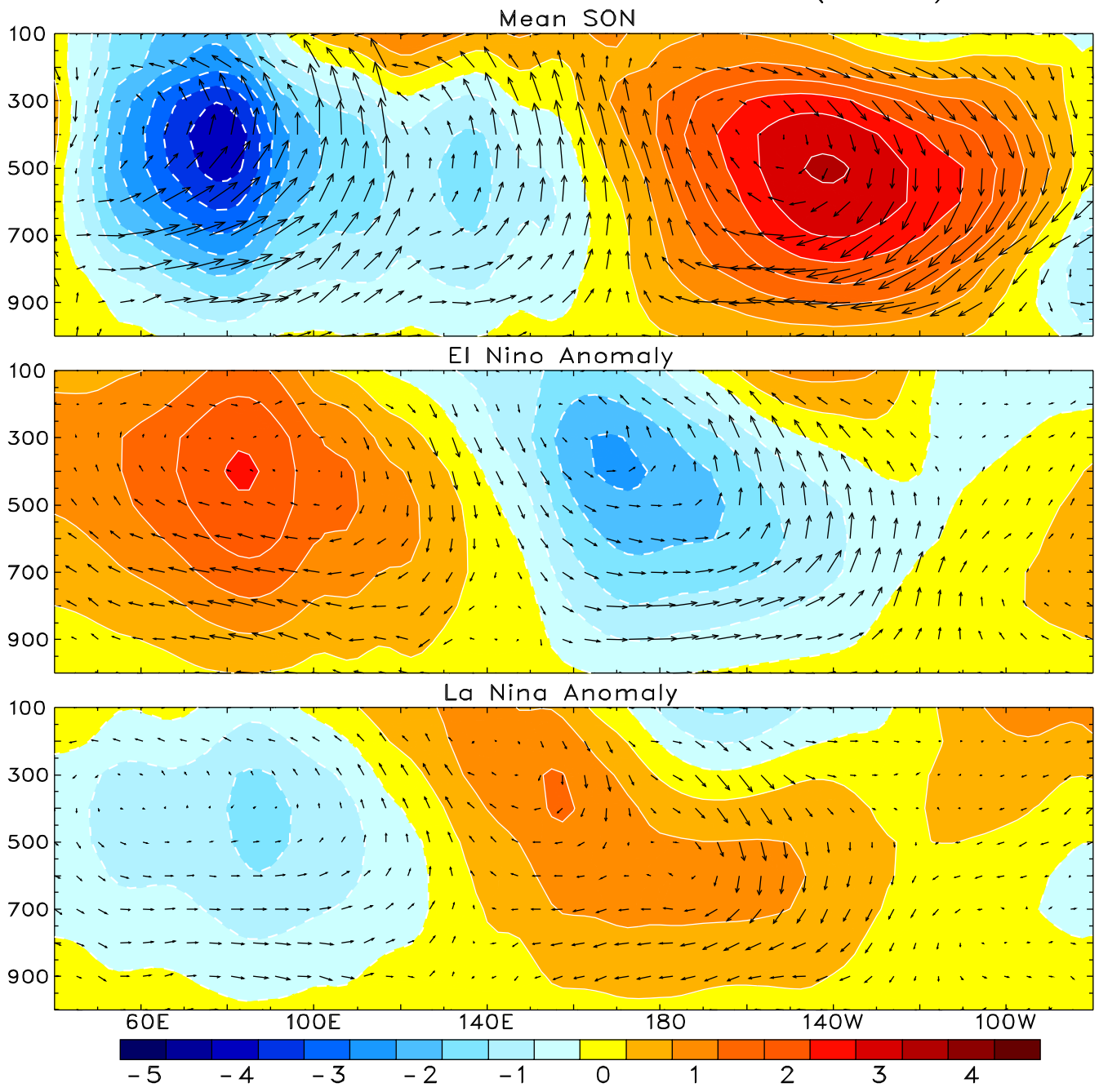


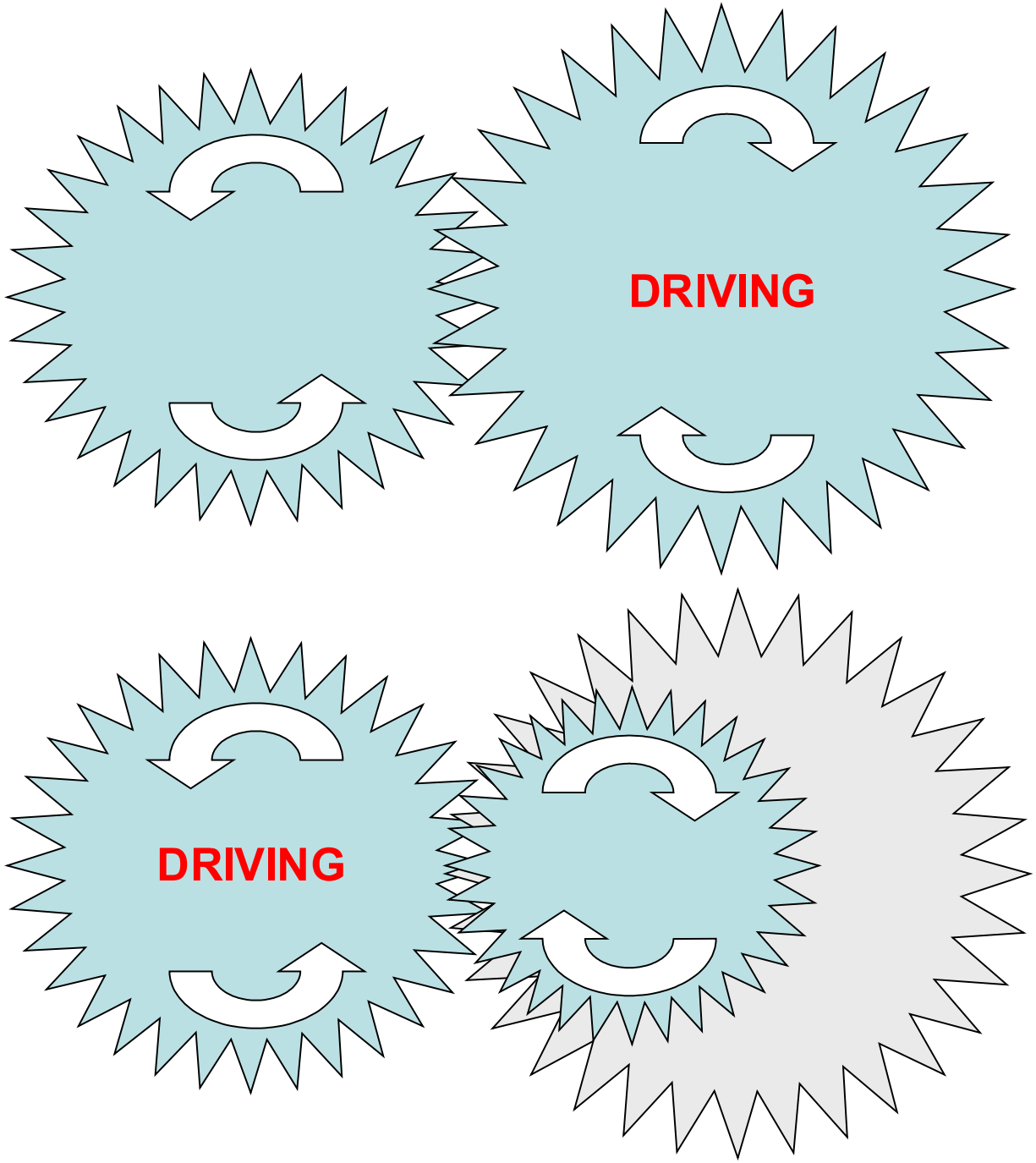
Colors: temperature; Contours: salinity

Potential areas for improvement:
Influences from outside of the tropical Pacific



Indo-Pacific Tripole


ZONAL MASS FLUX AND WIND VECTORS (5S-5N)
Mean SON
El Nino Anomaly
La Nina Anomaly
100
300
500
700
900
60E
100E
140E
180
140W
100W
-5
-4
-3
-2
-1
0
1
2
3
4


DRIVING
DRIVING

Summary and Conclusion

- When initialized with historical datasets, the LDEO model has successfully predicted all major ENSO events over the past 150 years, thus providing an optimistic view on the predictability of ENSO and possibly of the longer-term climate changes beyond.
- Mounting evidence suggests that there is still plenty of room for improvement. In particular, improved model initialization/data assimilation, surface heat and freshwater fluxes, and influences from outside of Pacific, could all lead to more skillful prediction.
- Very much needed are better and longer records of observational data, and better strategies to make optimal use of the available datasets.