Application Laboratory
Innovations from Earth Science

SINTEX-F seasonal prediction system
-its success & future -

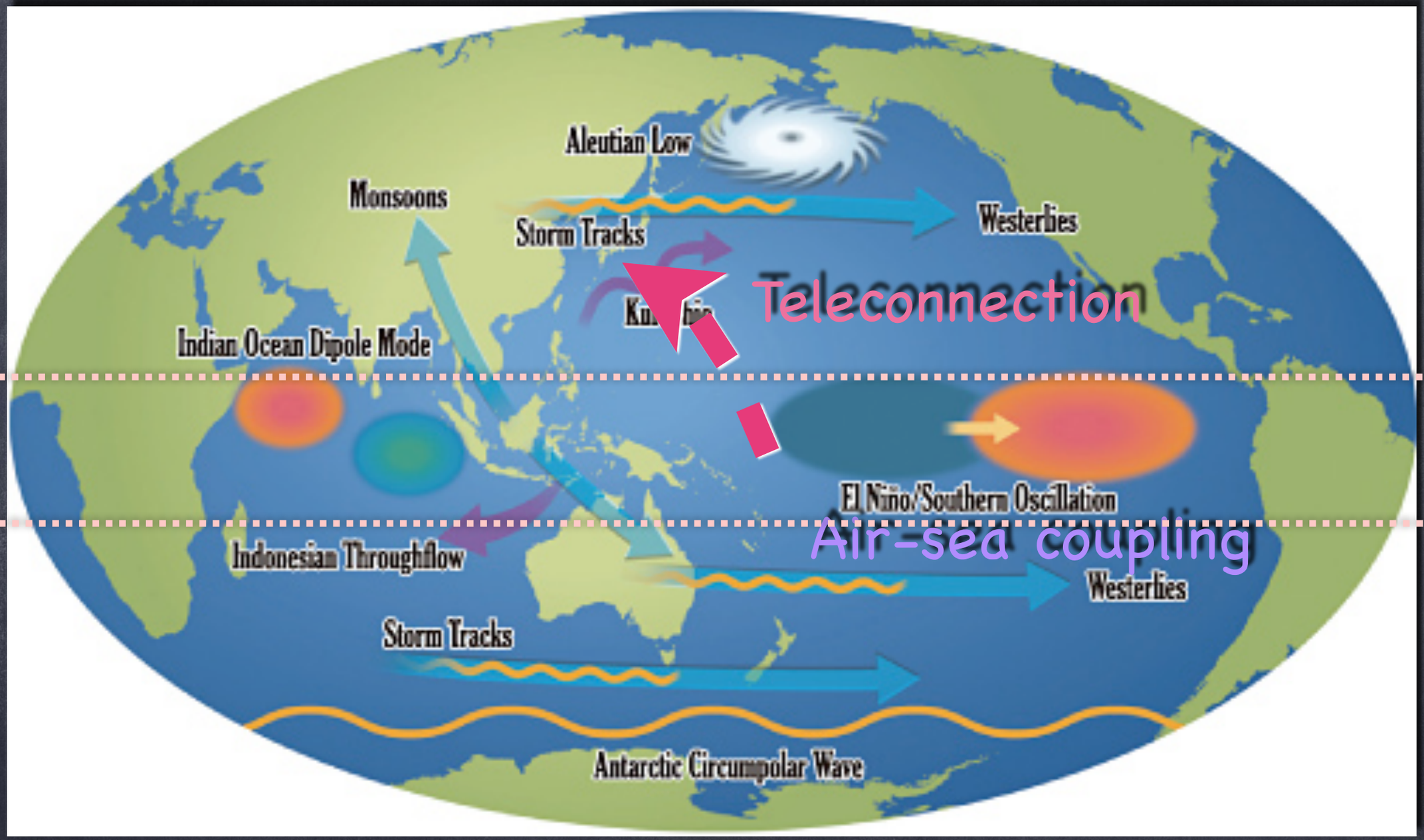
Takeshi Doi (APL/JAMSTEC),
Y. Morioka, S. Behera, and T. Yamagata

Acknowledgements:
The SINTEX-F1/F2 climate prediction system was produced by the Earth Simulator at JAMSTEC. We are grateful to Drs. Jing-Jia Luo, Sebastien Masson, W. Sasaki, and our European colleagues of INGV/CMCC and L'OCEAN for their contribution to the prediction system.

"seasonal prediction" v.s. weather prediction

climate: statistic of weather
(e.g. monthly ave., the number of a rainy day, the number of typhoon.....)

Potential source of seasonal predictability is mainly due to ENSO prediction

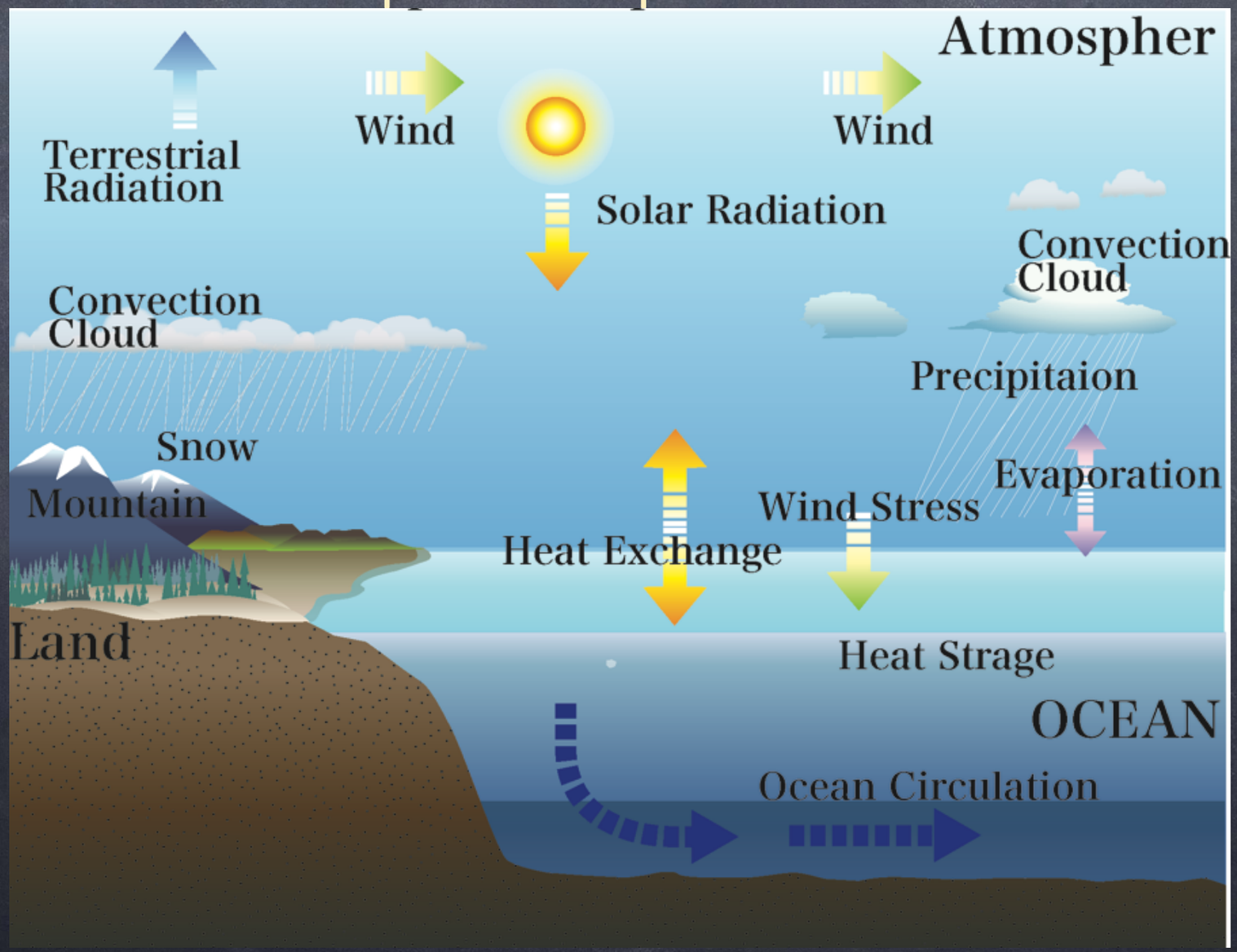


- Ocean's slow variability and large heat content relative to atmosphere
- Air-sea coupled phenomena in the tropical Pacific (Bjerknes 1964)
- Teleconnection from the tropics to the mid-latitude (Bjerknes 1969)

Numerical seasonal prediction system should be based on an ocean-atmosphere coupled model

The numerical weather prediction mostly employ stand-alone atmospheric models on the assumption that the oceans do not change in the relatively short prediction period (~1 week).

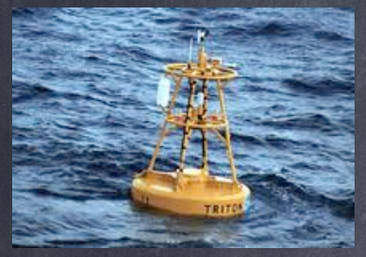
However, for predictions of ENSO and its induced seasonal anomaly, we needs application of an ocean-atmosphere coupled model

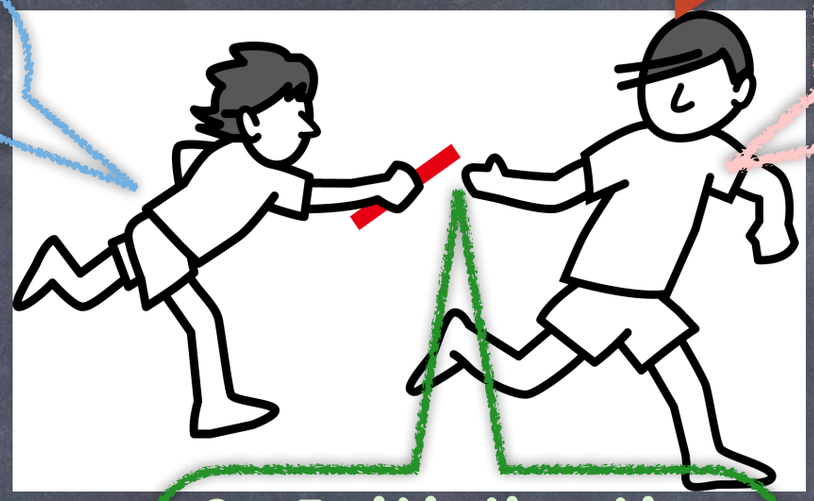


Schematic of numerical seasonal prediction

Time

1. "Observation" for the current state





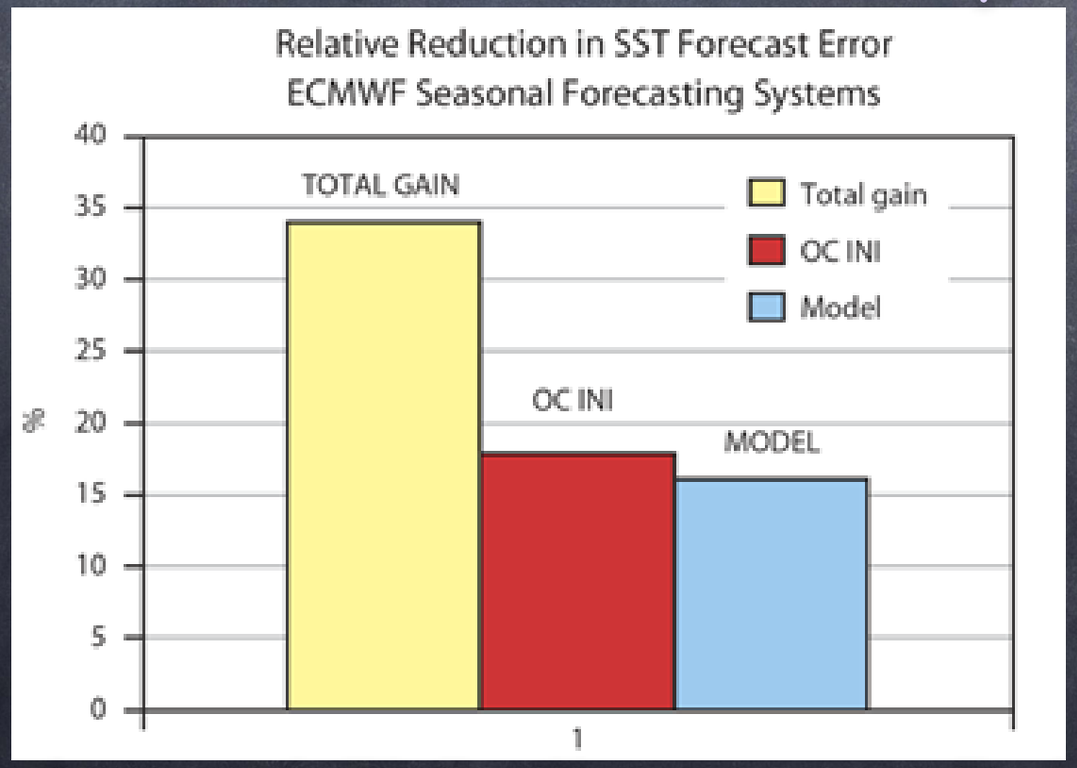
2. Initialization (assimilation)

3. Numerical integration by a coupled GCM

$$X(t_0 + \Delta t) = x(t_0) + \Delta t \times M$$

"The Earth Simulator"

Which step is the most critical for the prediction skill?



[Balmaseda et al. 2015]

Model development and ocean initialization are equally important for improving seasonal prediction skill.

The SINTEX-F1 ocean-atmosphere coupled model (Luo et al. 2005)
(developed at JAMSTEC under the EU-Japan collaboration)

AGCM:
ECHAM4.6
T106L19

OGCM:
OPA8.2
2×(0.5-2) L31

Coupler:
OASIS2.4
Every 2 hour
No flux correction
No sea ice model

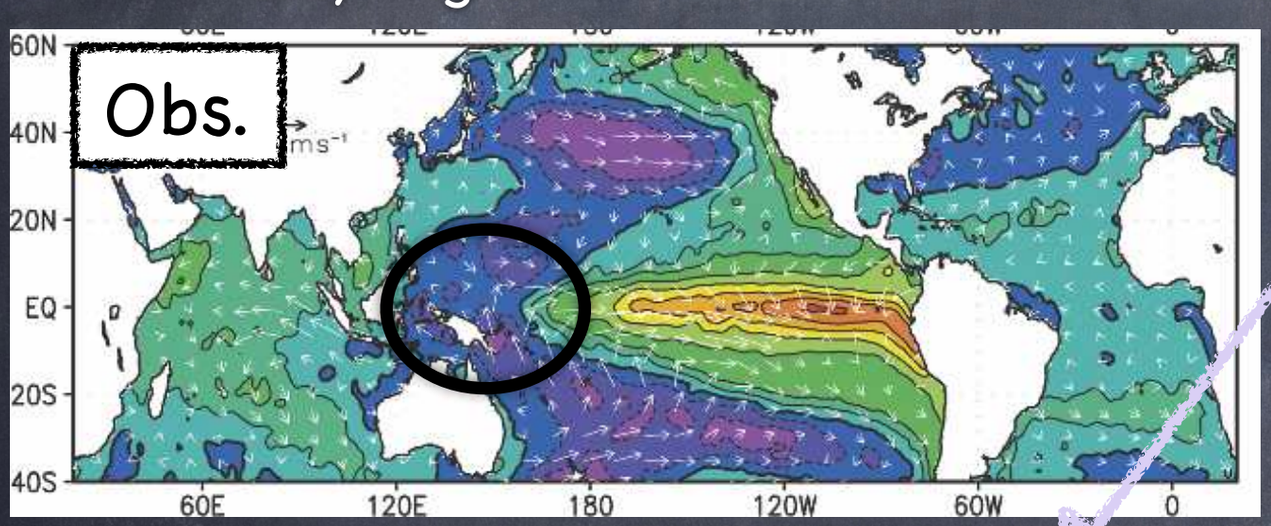
Q. How have we been developing the SINTEX-F model and its initialization?

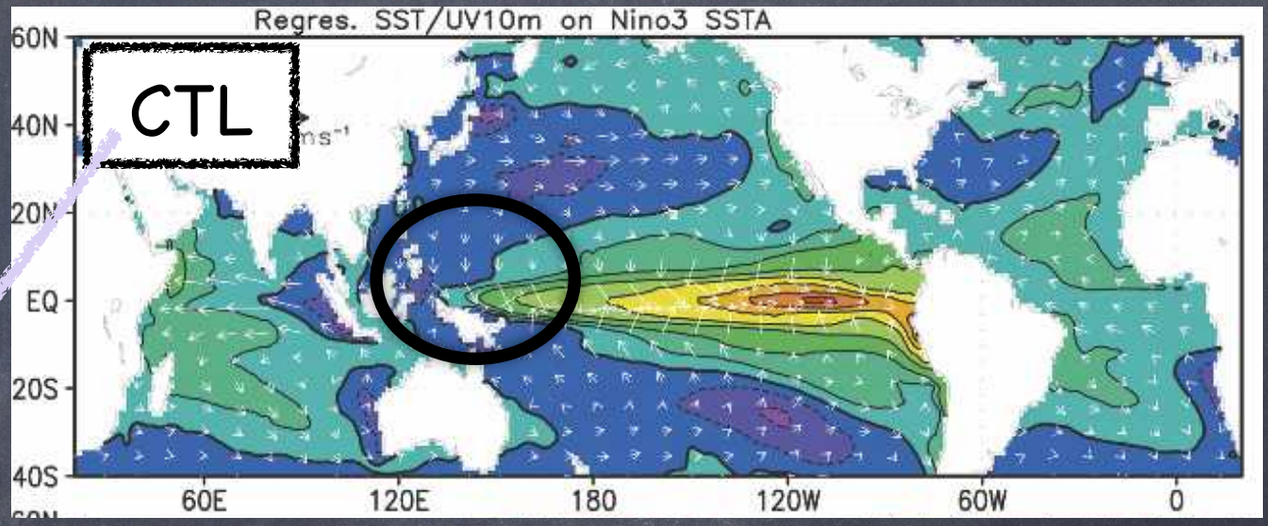
A1. SINTEX-F model development

In contrast to the classical method of tuning individual uncoupled GCMs separately, SINTEX-F1 model has been tuned directly by improving the air-sea coupling physics

"the potential effect of the strong ocean surface current on wind stress", (important to both the climatology and ENSO variability)

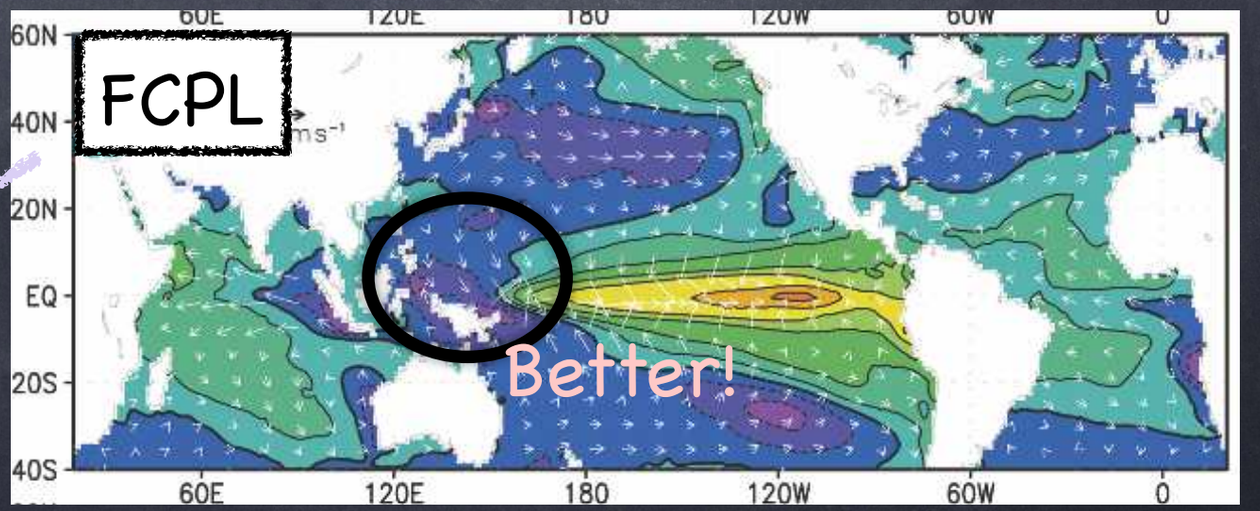
Linearly regressed SST and surface winds anomalies on the Niño-3 SST index





CTL: The effects of ocean surface current on wind stress are neglected

FCPL: The surface wind stress is calculated by $\rho_a C_D |\mathbf{v}_a - \mathbf{v}_o|(\mathbf{v}_a - \mathbf{v}_o)$



[Luo et al. 2005, JC]

A2. Initialization
SST-nudging scheme

The OGCM SST is strongly nudged toward the observed SST in a coupled mode. (The AGCM forced by such generated OGCM SSTs. Then, the OGCM forced by the AGCM simulated fluxes with nudging to observed SST.)

- One of the simplest approaches, but can provide "compatible initial conditions between the atmosphere and ocean" can reduce the initial shock during forecasts

- Realistic subsurface ocean structures in the tropical Pacific (Luo et al. 2005; Kumar et al. 2013)

- The success depends on the performance of both AGCMs and OGCMs.

D20A along the equatorial Pacific

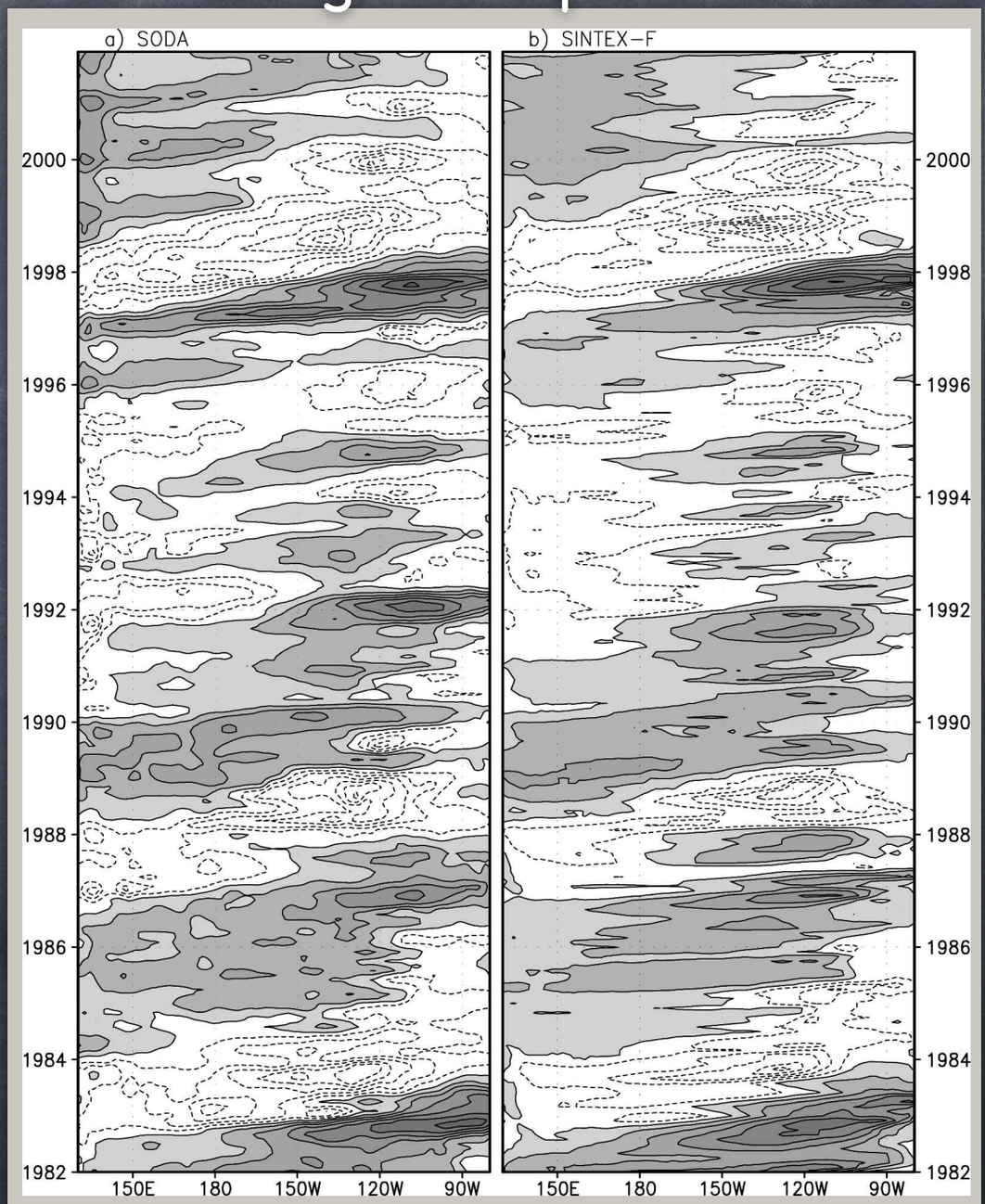
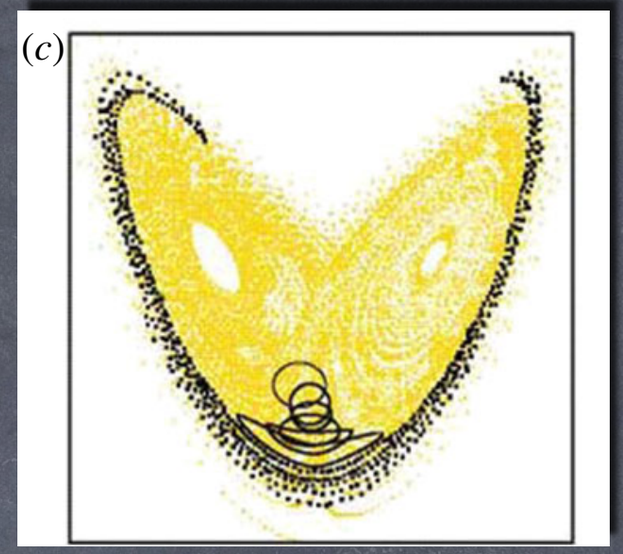


FIG. 1. The 20°C isotherm depth anomalies (contour: 10 m) along the equatorial Pacific (2°S–2°N) from (a) SODA and (b) model results based on the SST-nudging scheme. Regions with positive values are shaded.

[Luo et al. 2005, JC]

How do we generate ensemble members?

Since atmosphere-ocean coupled system involves the strong nonlinearity,
variations in initial conditions and physical schemes lead to diverse solutions.
—>"need ensemble prediction" to reduce the prediction uncertainties



Butterfly effect

Therefore, we generate ensemble members associated with different initial conditions and physical schemes.
-3 strength of SST-nudging
-3 coupling physics for effect of the ocean surface current on wind stress

Total 9 ensemble members are employed for our seasonal climate predictions initiated every month in 1982-present.

The SINTEX-F1 seasonal prediction system (Luo et al. 2005)
(developed at JAMSTEC under the EU-Japan collaboration)

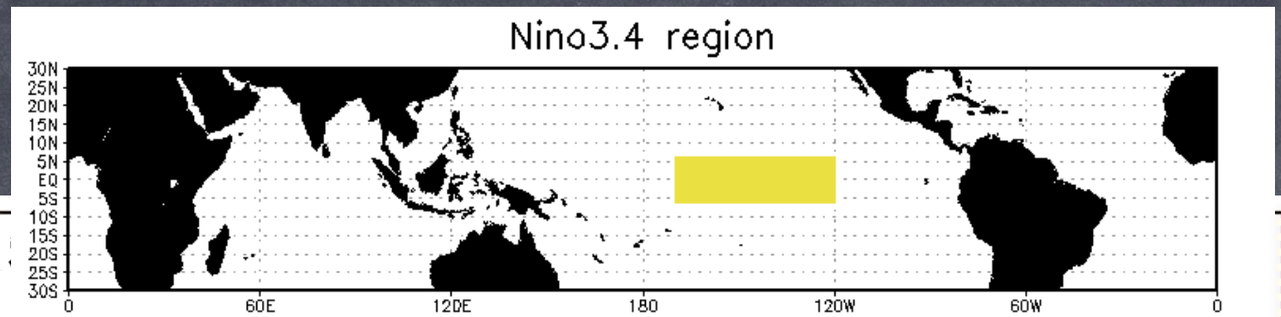
	AGCM	OGCM	Coupling	Sea Ice
SINTEX-F1	ECHAM4.6 T106L19	OPA8.2 2×(0.5~2) L31	Every 2 hour No flux correction	No

- ☑ Initialization: SST-nudging system
- ☑ 9 ensemble members (3 nudging strength × 3 coupling physics)
- ☑ Hindcast experiments (every month initialization in 1982—present, 2yr-lead time)
- ☑ Real-time seasonal forecast & outlook

(e.g. Hindmost experiment of Aug. 2015 from the May. 1st 2015 ini.)

Q. How skillful is the SINTEX-F system for ENSO prediction?

Time series of Nino3.4



Obs.

Strongest El Niño
(The WMO estimate 34billion US$ loss)

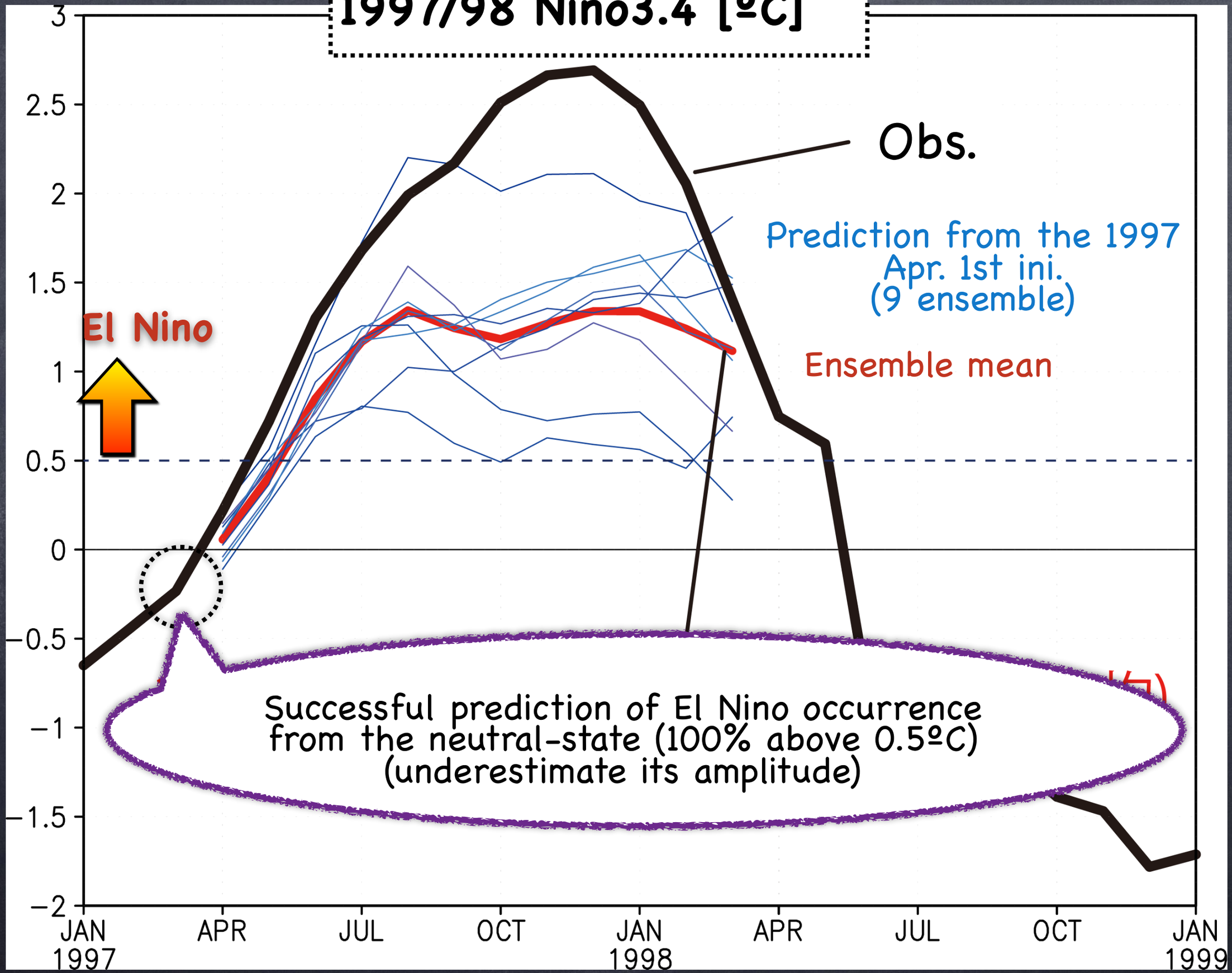
3 2.5 2 1.5 1 0.5 0 −0.5 −1 −1.5 −2 −2.5 −3

1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999

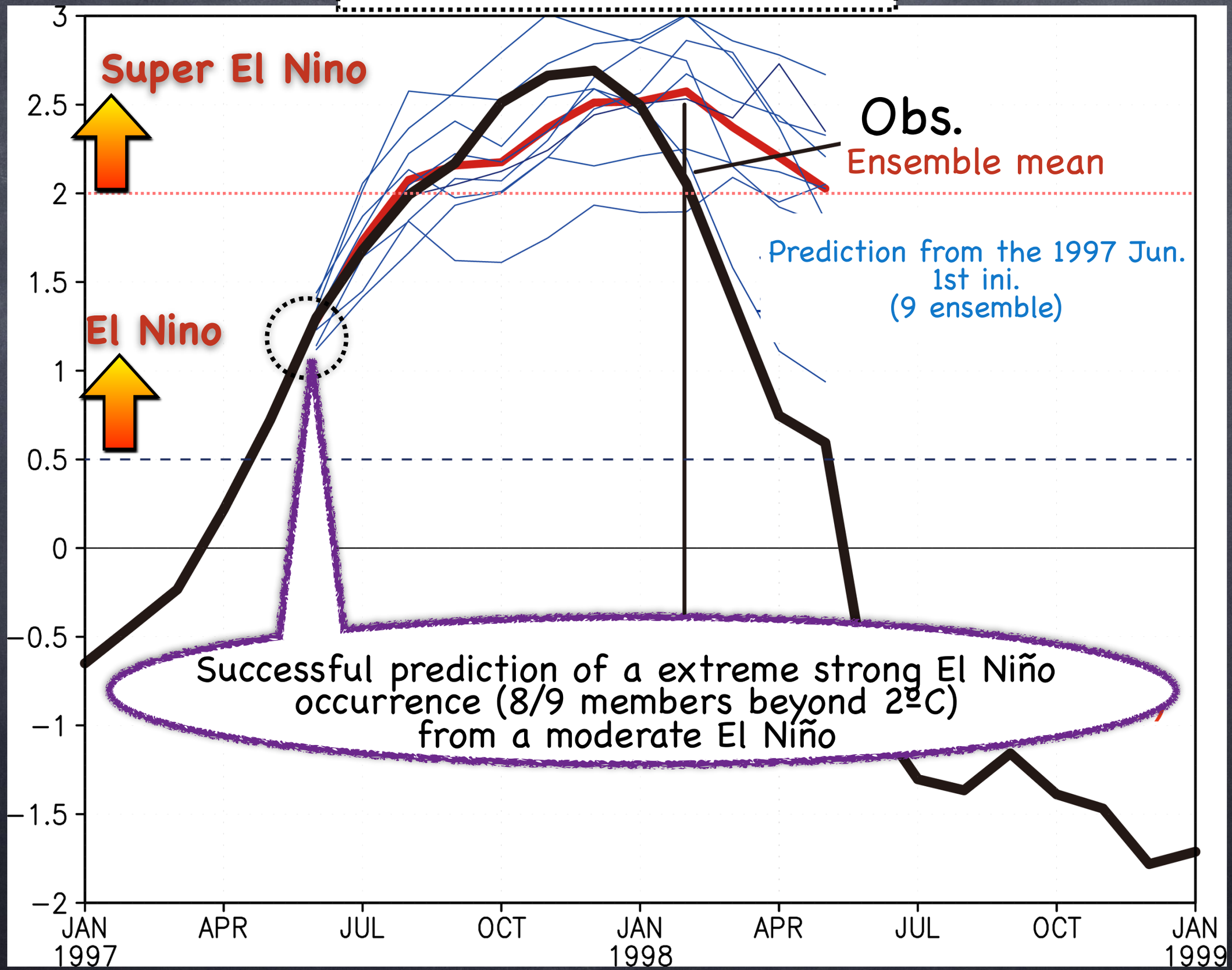
3 2.5 2 1.5 1 0.5 0 −0.5 −1 −1.5 −2 −2.5 −3

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

1997/98 Nino3.4 [ºC]

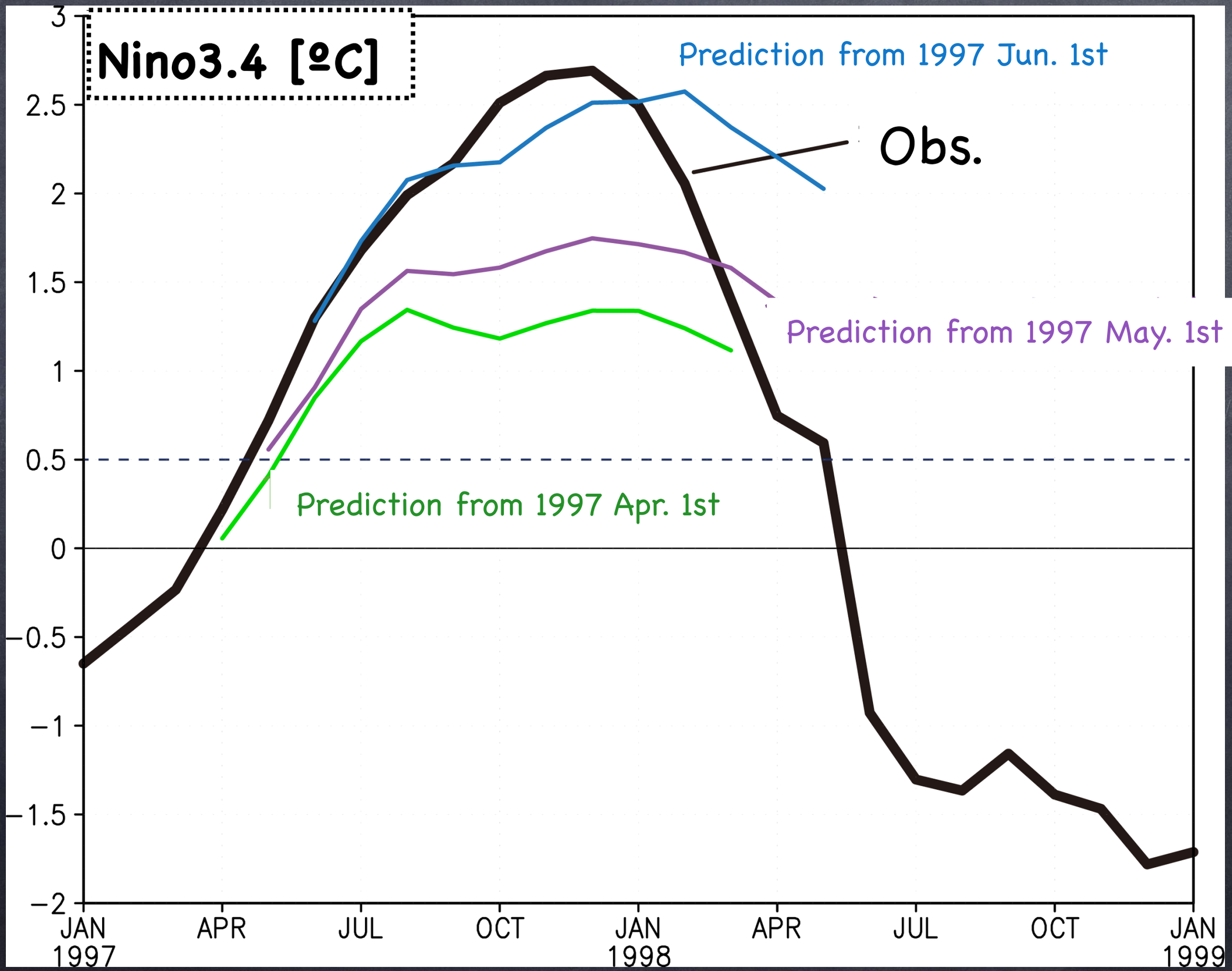


1997/98 Nino3.4 [ºC]



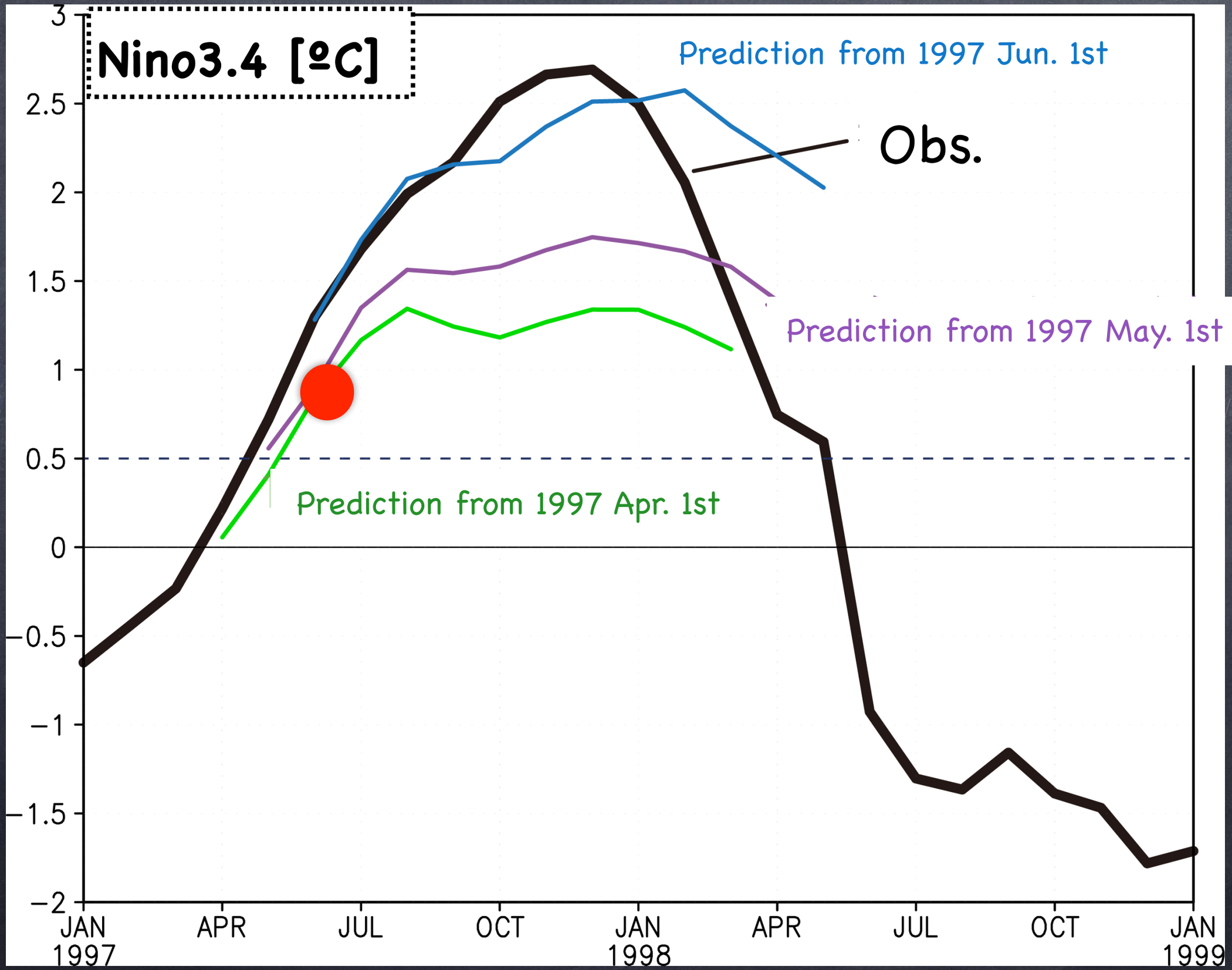
Q. How skillful is it for other ENSO events?

What is a line "3-month lead prediction" in the next figure?



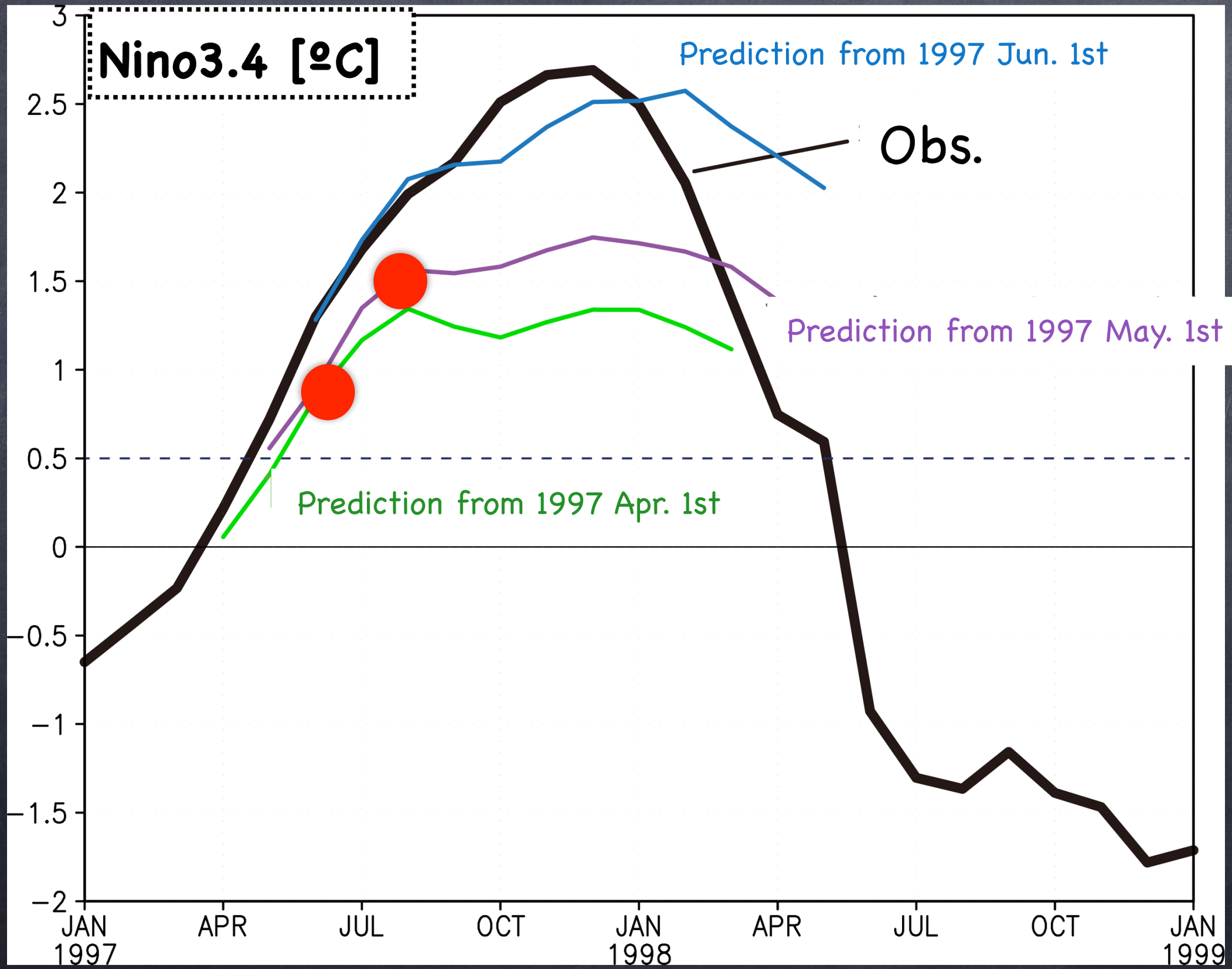
Q. How skillful is it for other ENSO events?

What is a line "3-month lead prediction" in the next figure?



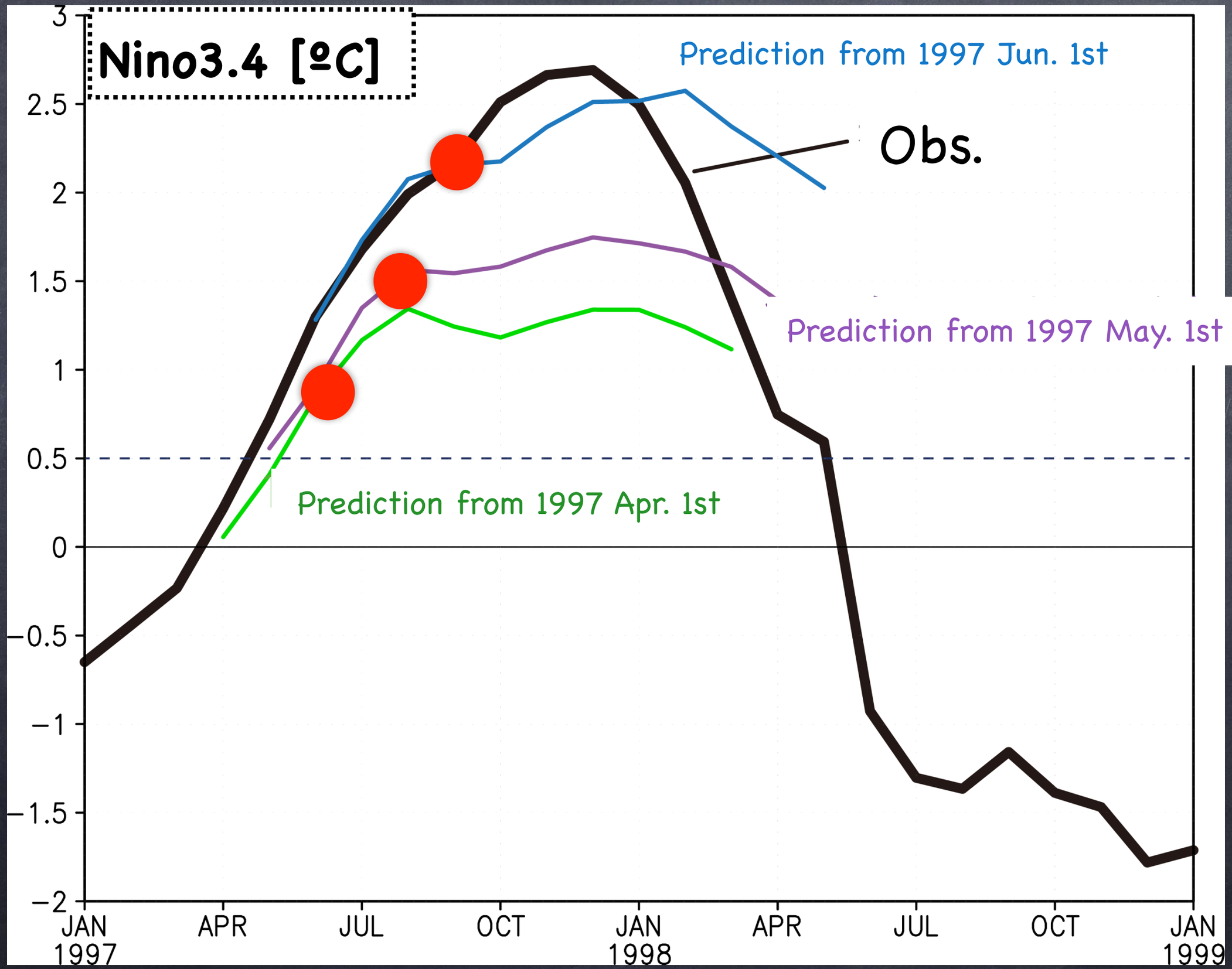
Q. How skillful is it for other ENSO events?

What is a line "3-month lead prediction" in the next figure?



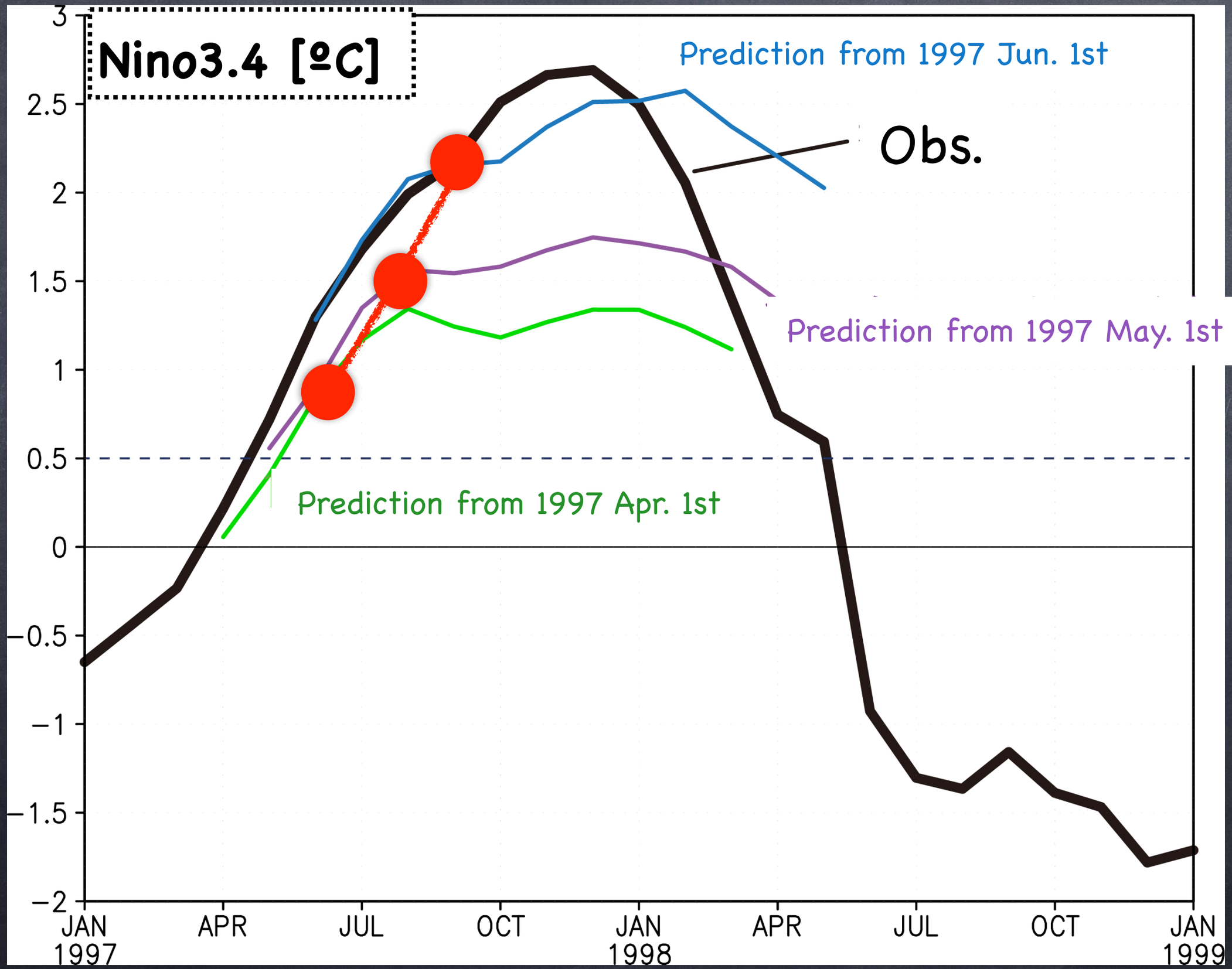
Q. How skillful is it for other ENSO events?

What is a line "3-month lead prediction" in the next figure?



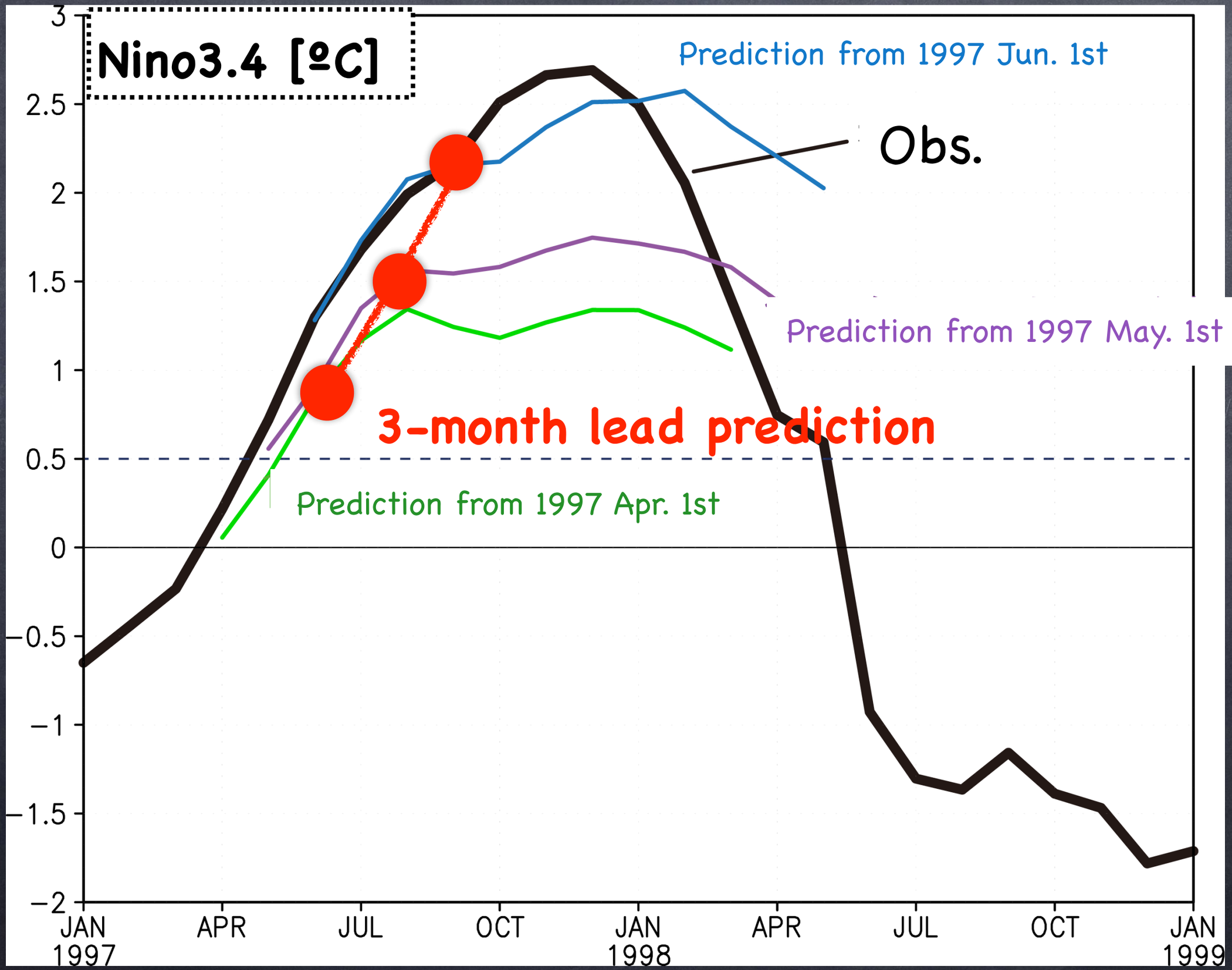
Q. How skillful is it for other ENSO events?

What is a line "3-month lead prediction" in the next figure?



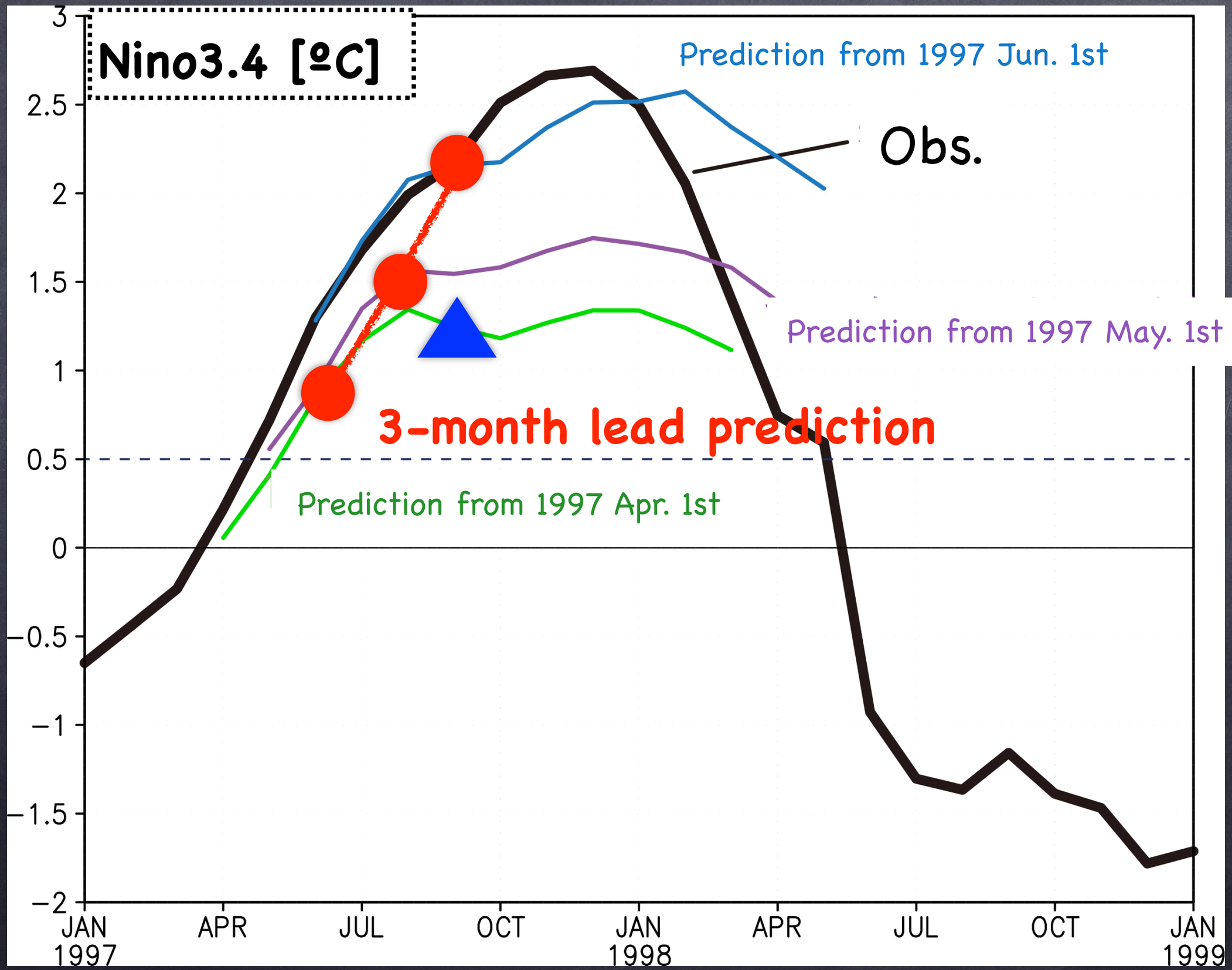
Q. How skillful is it for other ENSO events?

What is a line "3-month lead prediction" in the next figure?



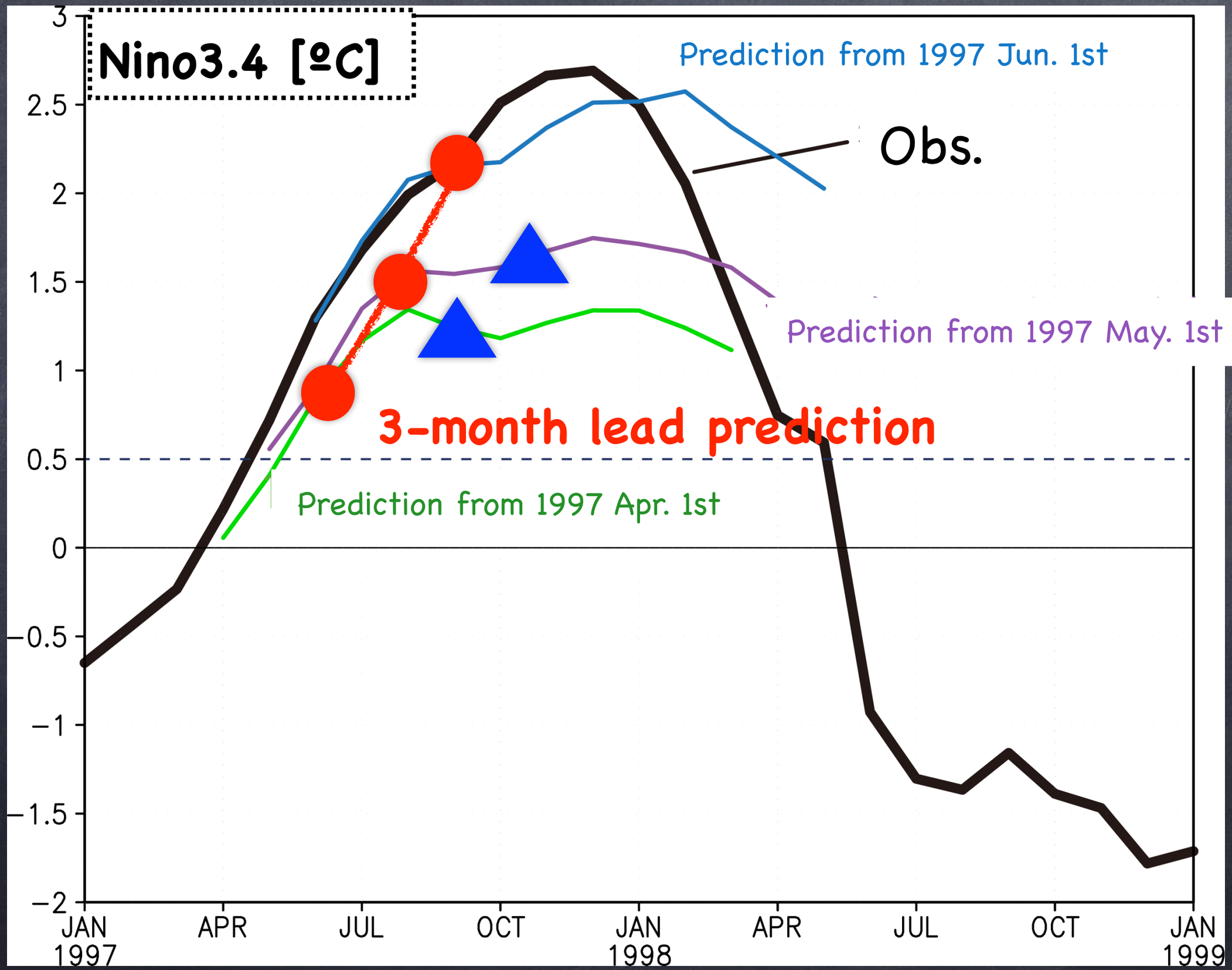
Q. How skillful is it for other ENSO events?

What is a line "3-month lead prediction" in the next figure?



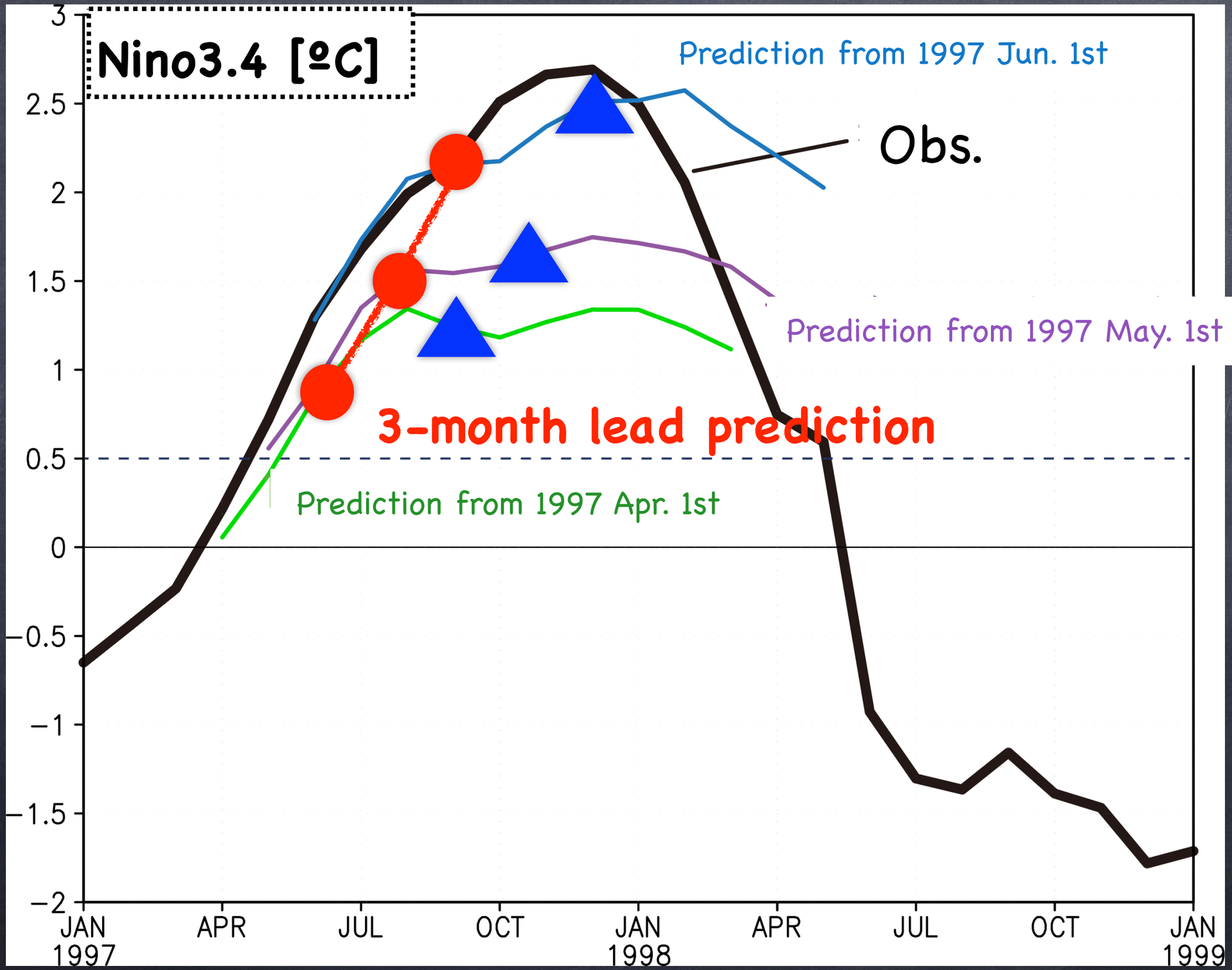
Q. How skillful is it for other ENSO events?

What is a line "3-month lead prediction" in the next figure?



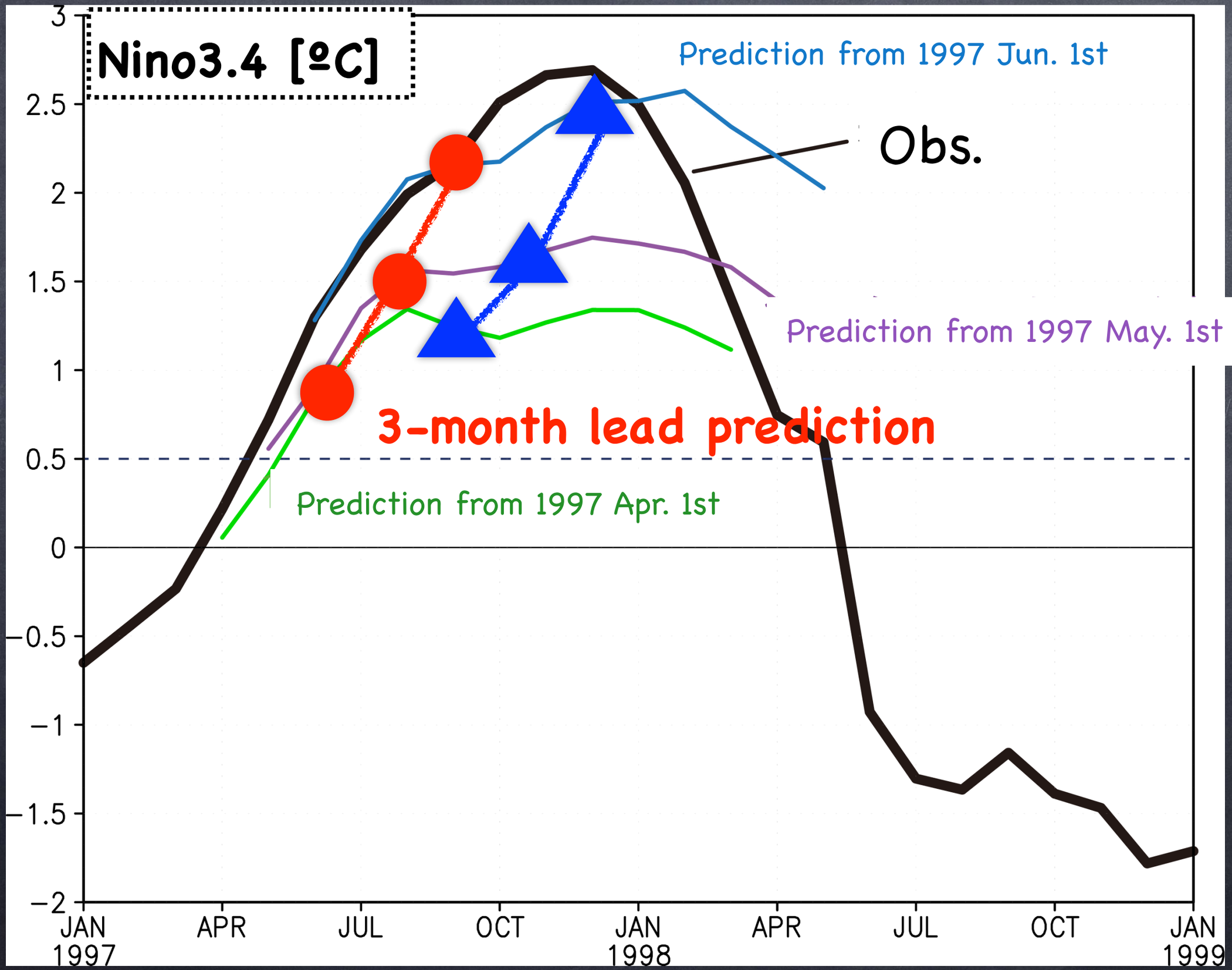
Q. How skillful is it for other ENSO events?

What is a line "3-month lead prediction" in the next figure?



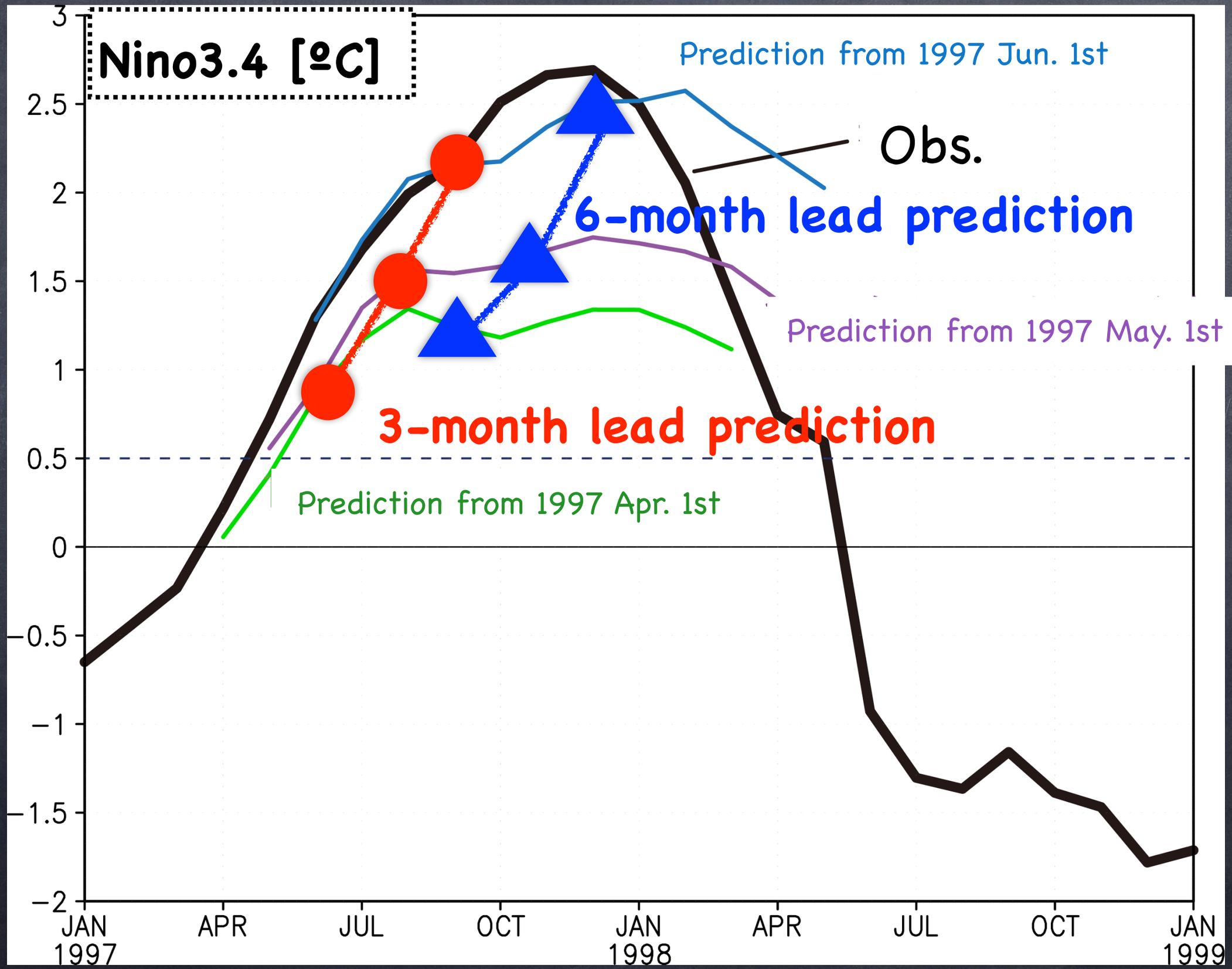
Q. How skillful is it for other ENSO events?

What is a line "3-month lead prediction" in the next figure?

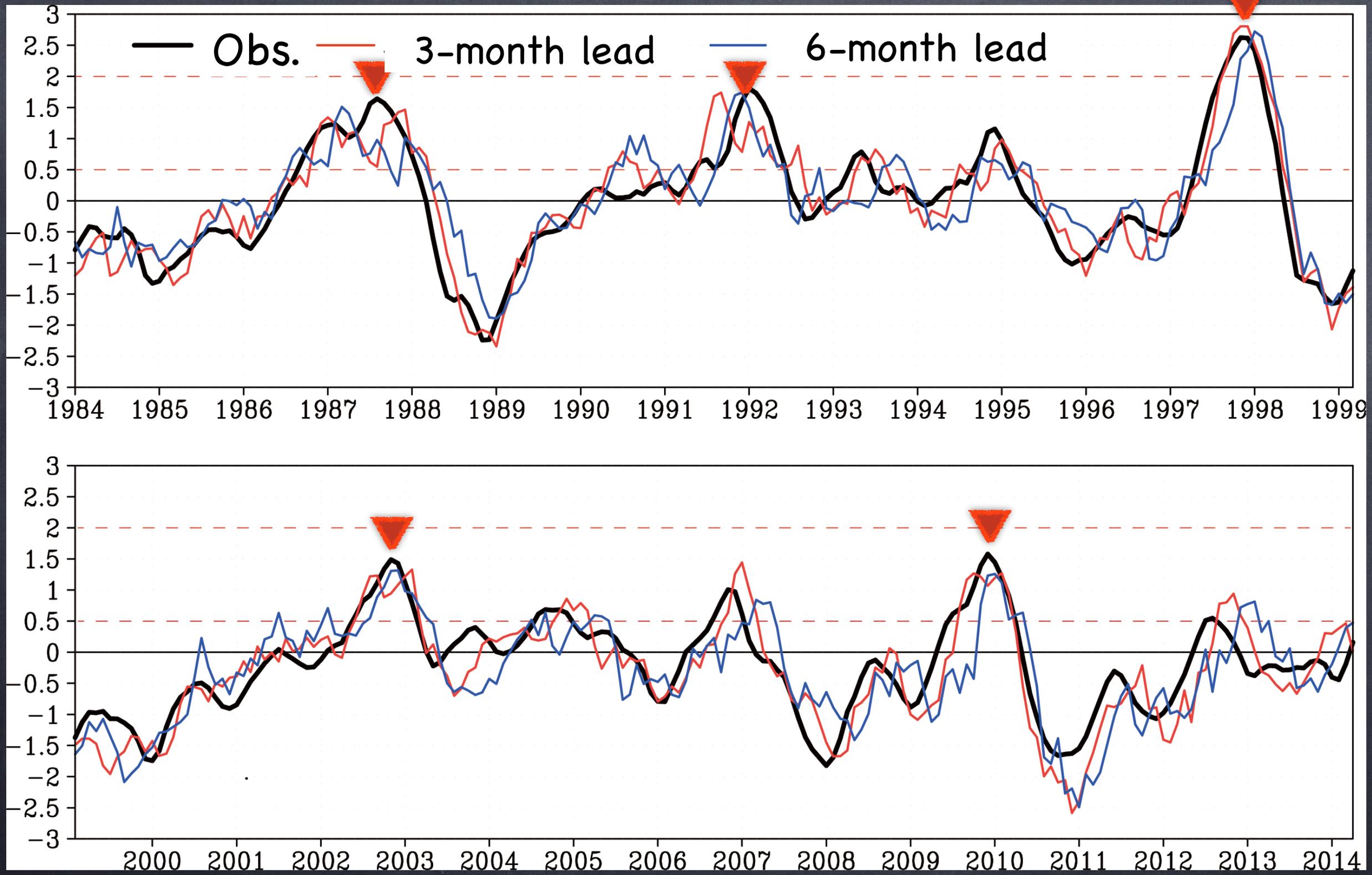


Q. How skillful is it for other ENSO events?

What is a line "3-month lead prediction" in the next figure?



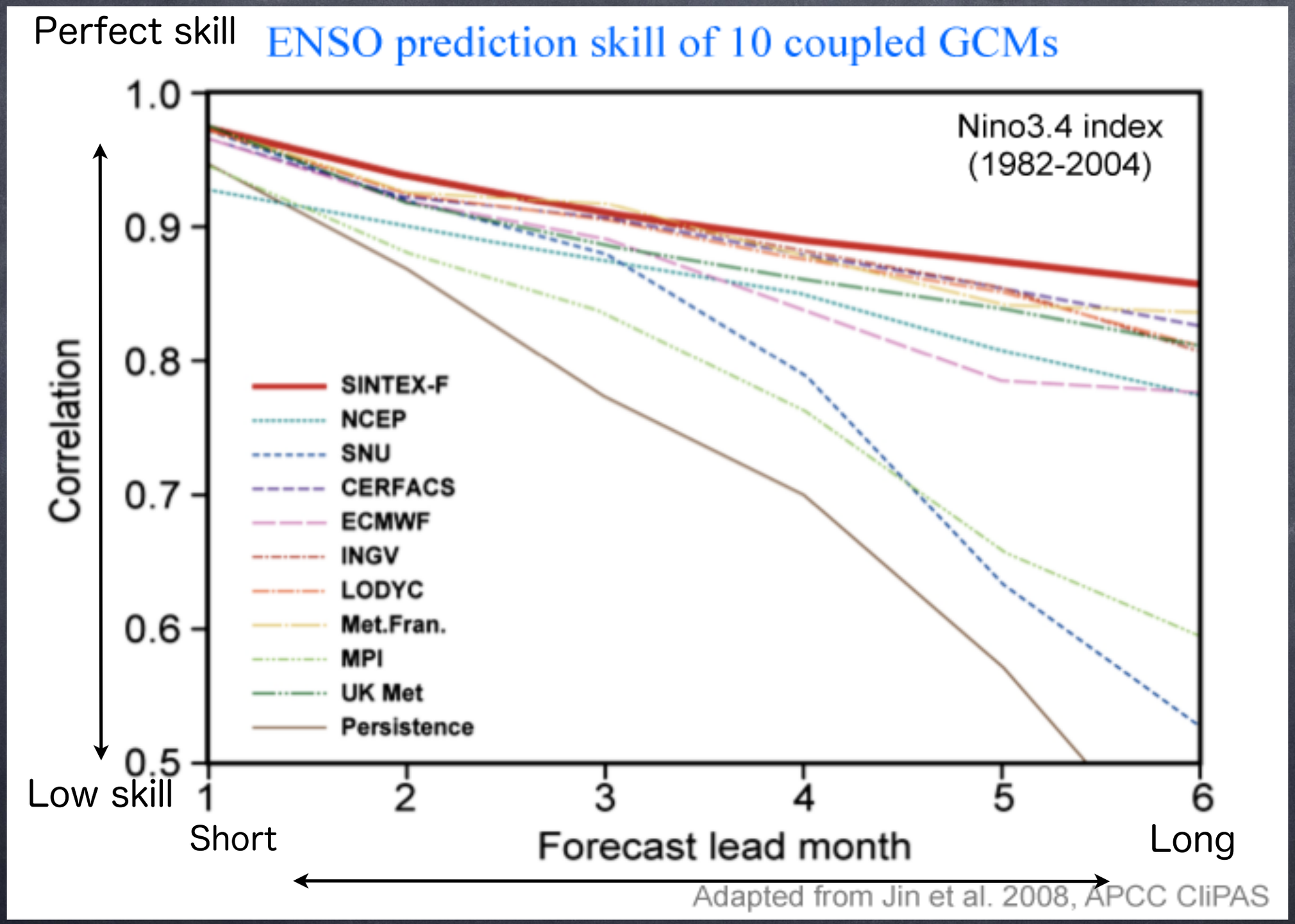
Q. How skillful is it for other ENSO events?



SINTEX-F1 is very skillful to predict ENSO (r > 0.85).
However, not good for the timing of initiation and termination

The SINTEX-F1 system is very skillful for the ENSO prediction relative to other models.

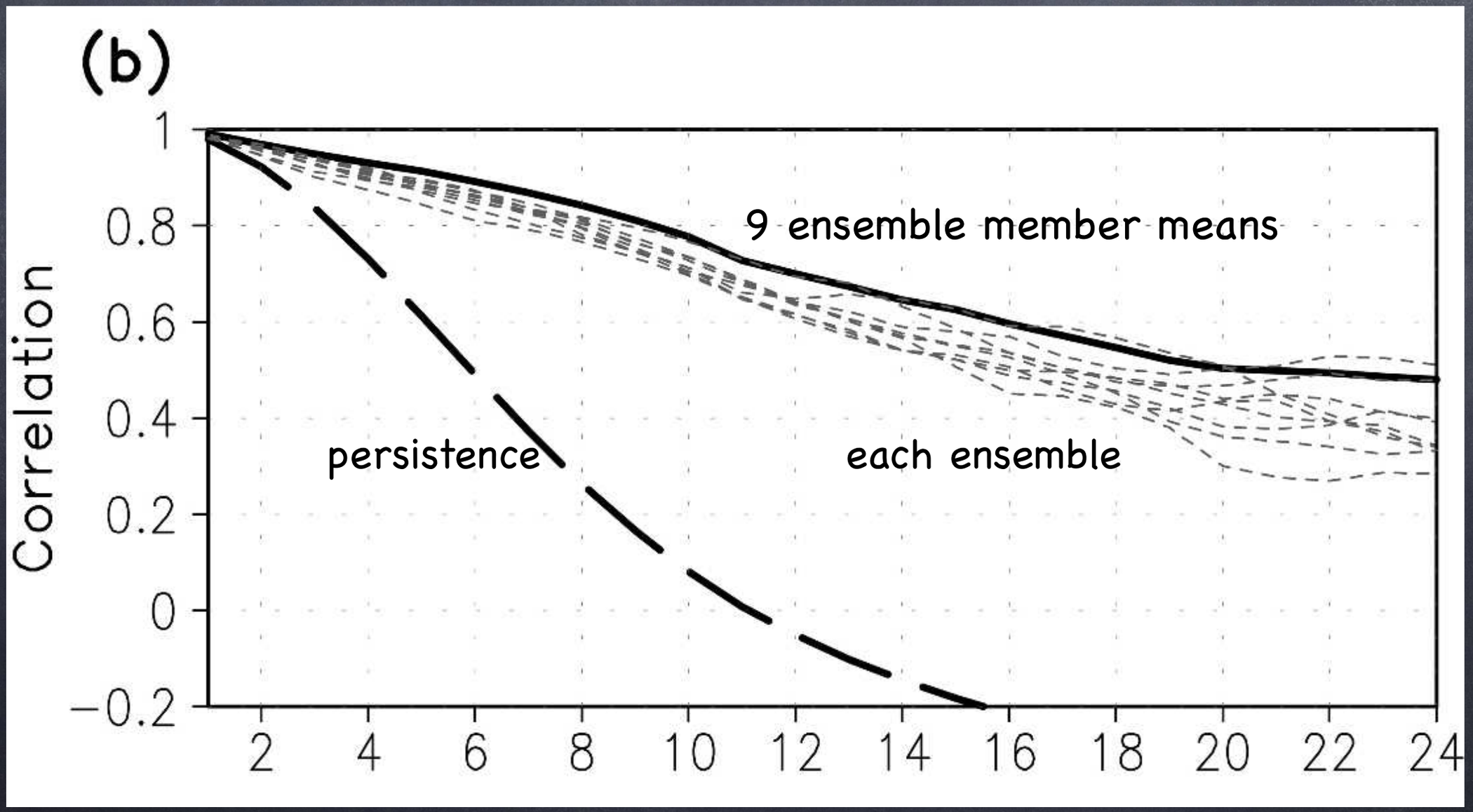
[Jin et al. 2008]



Q. How about prediction beyond 6-month lead?

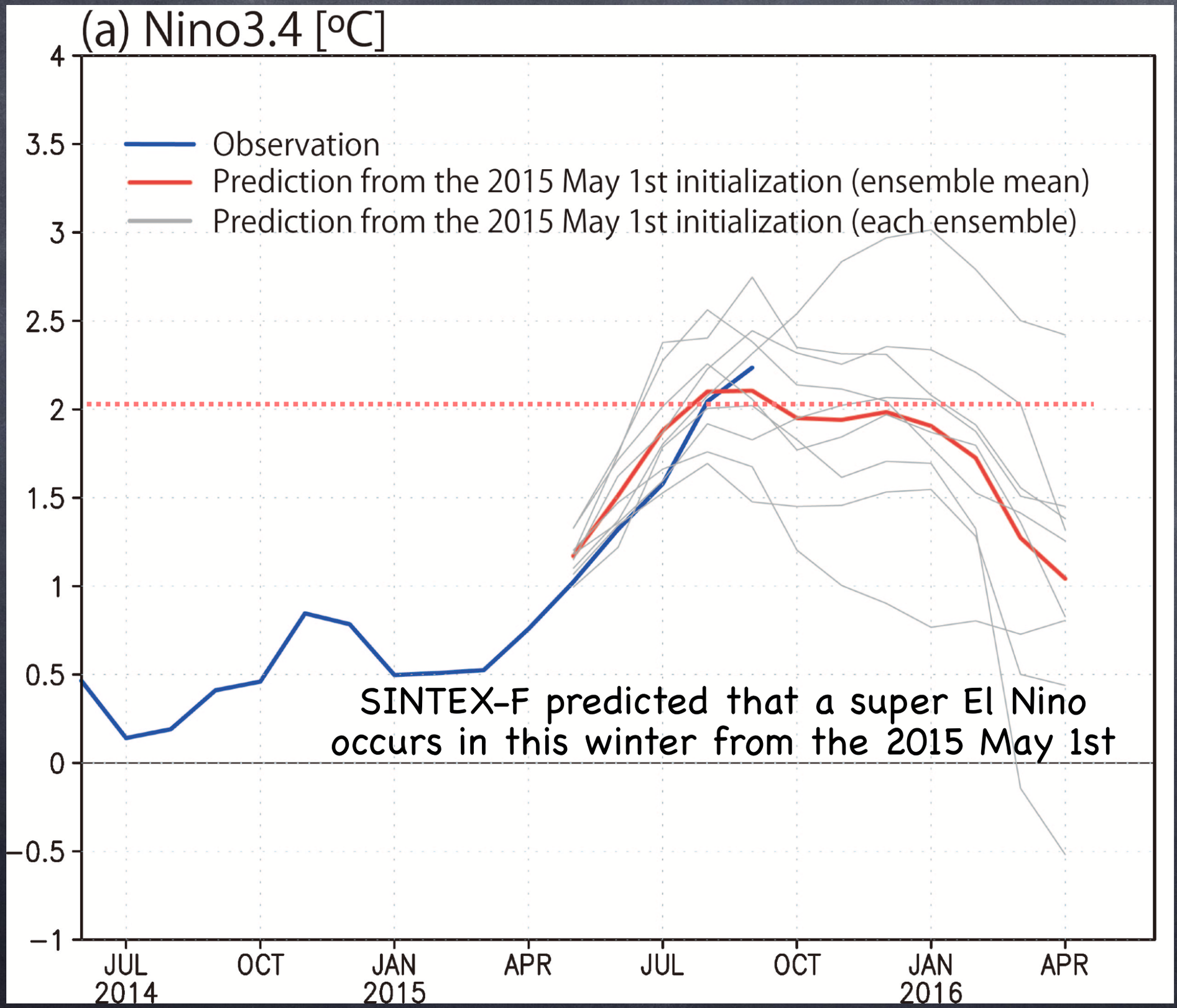
The SINTEX-F prediction system shows skillful for the 2-yr ENSO prediction (Luo et al. 2008)

Niño-3.4 SST anomaly correlations between the observations and 9 ensemble mean predictions up to a 24-month lead

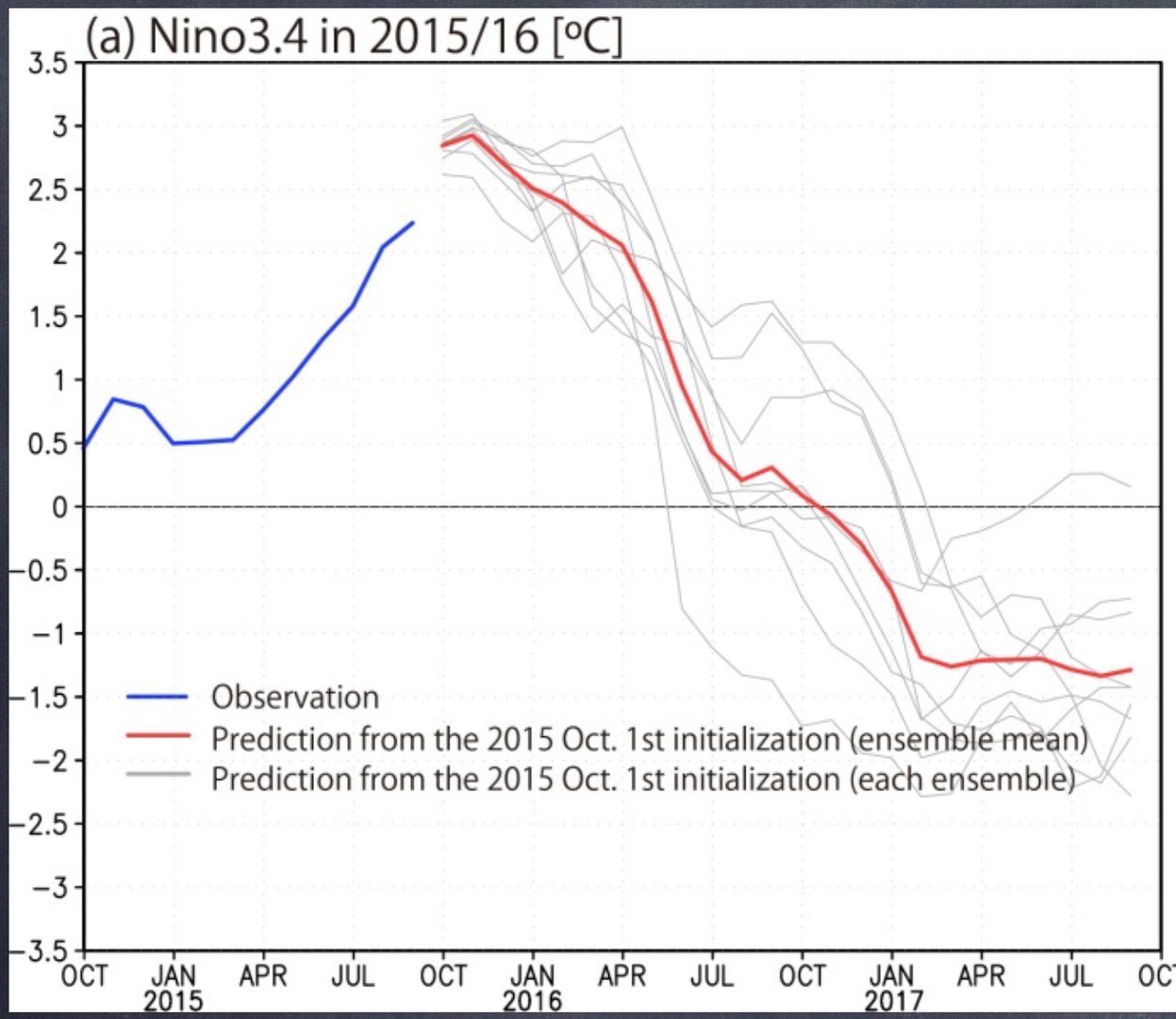


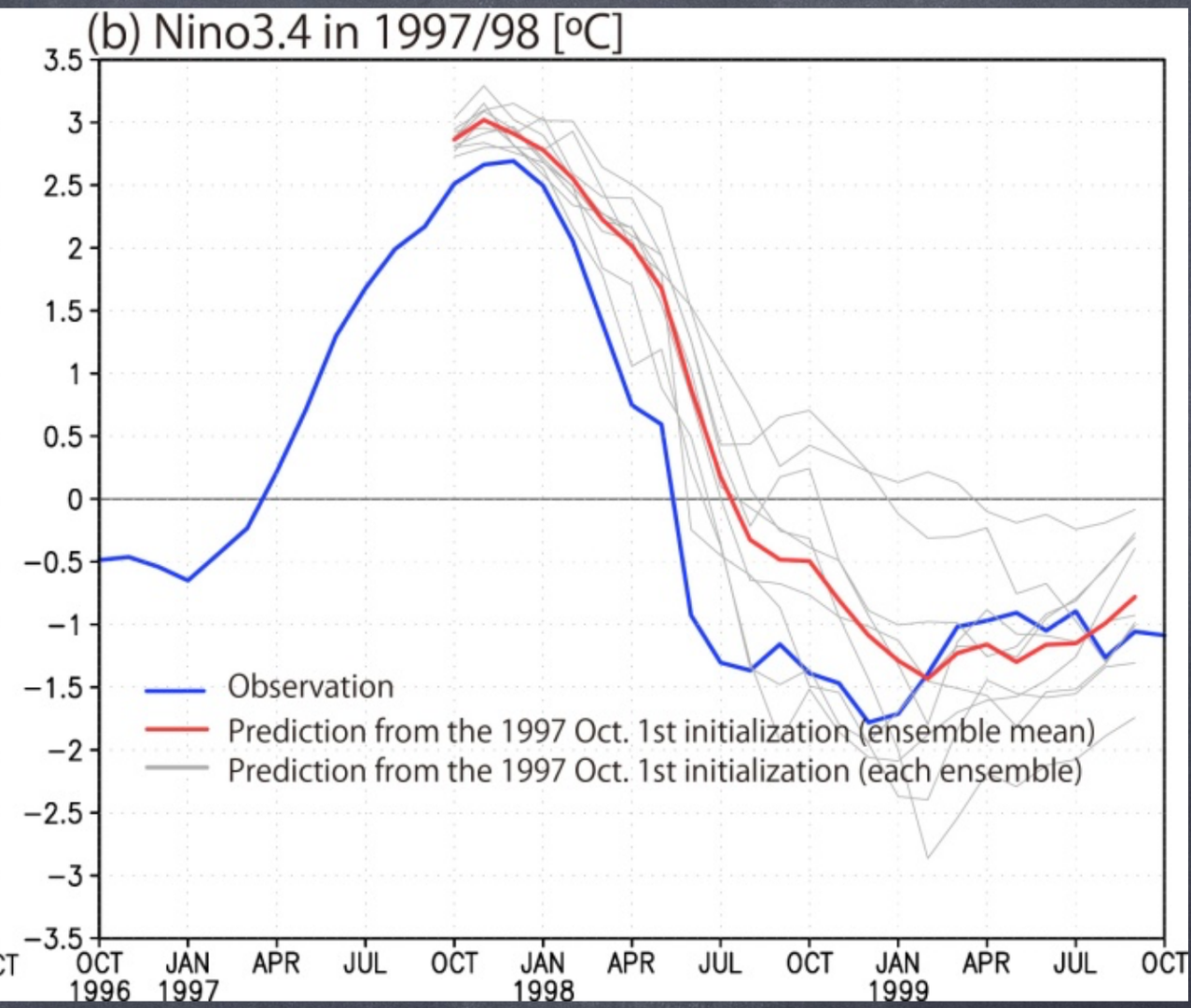
By the way…

How about this year's ENSO prediction?



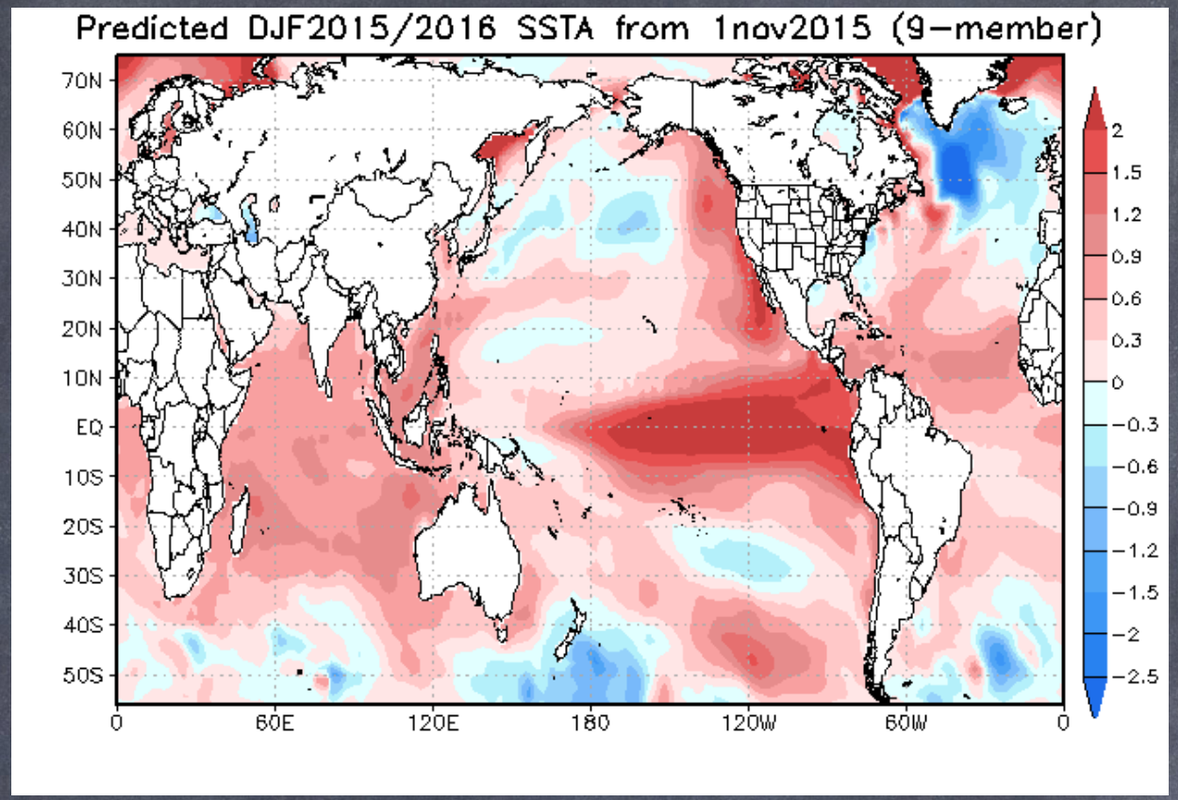
What will happen next 2 year?

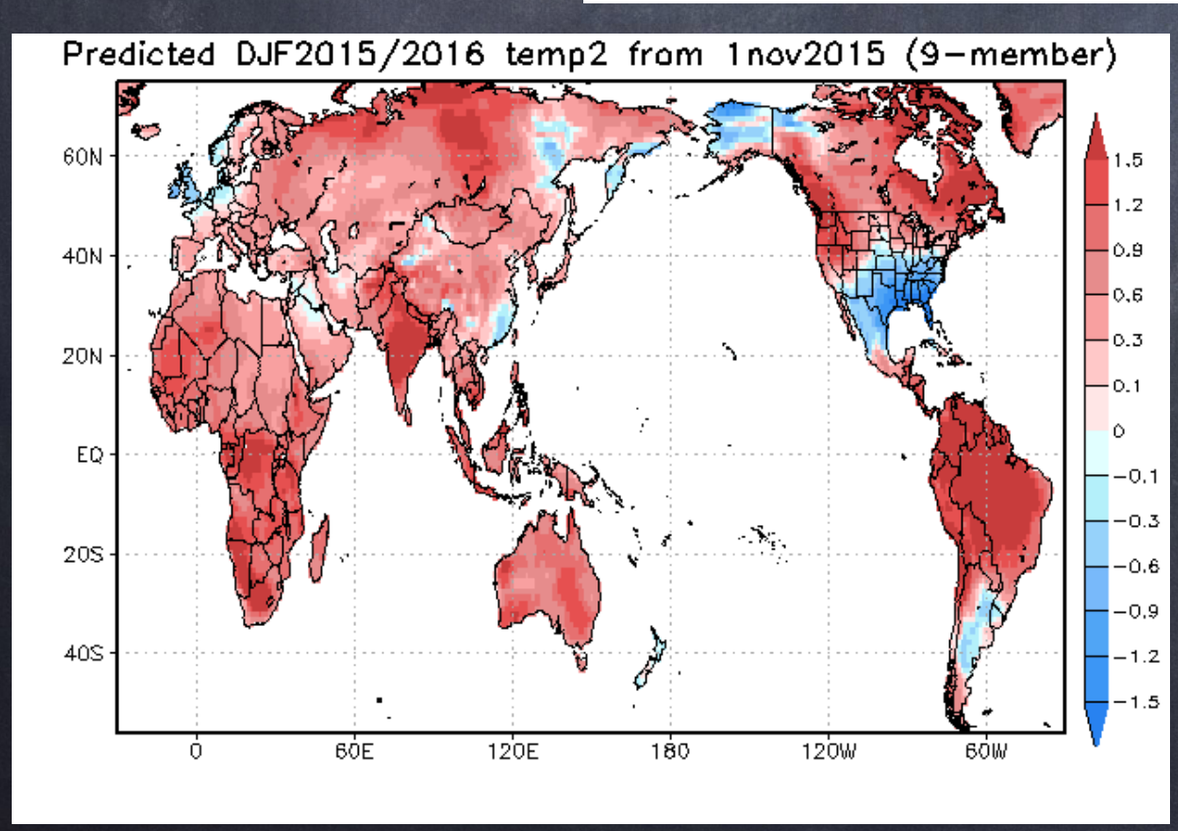


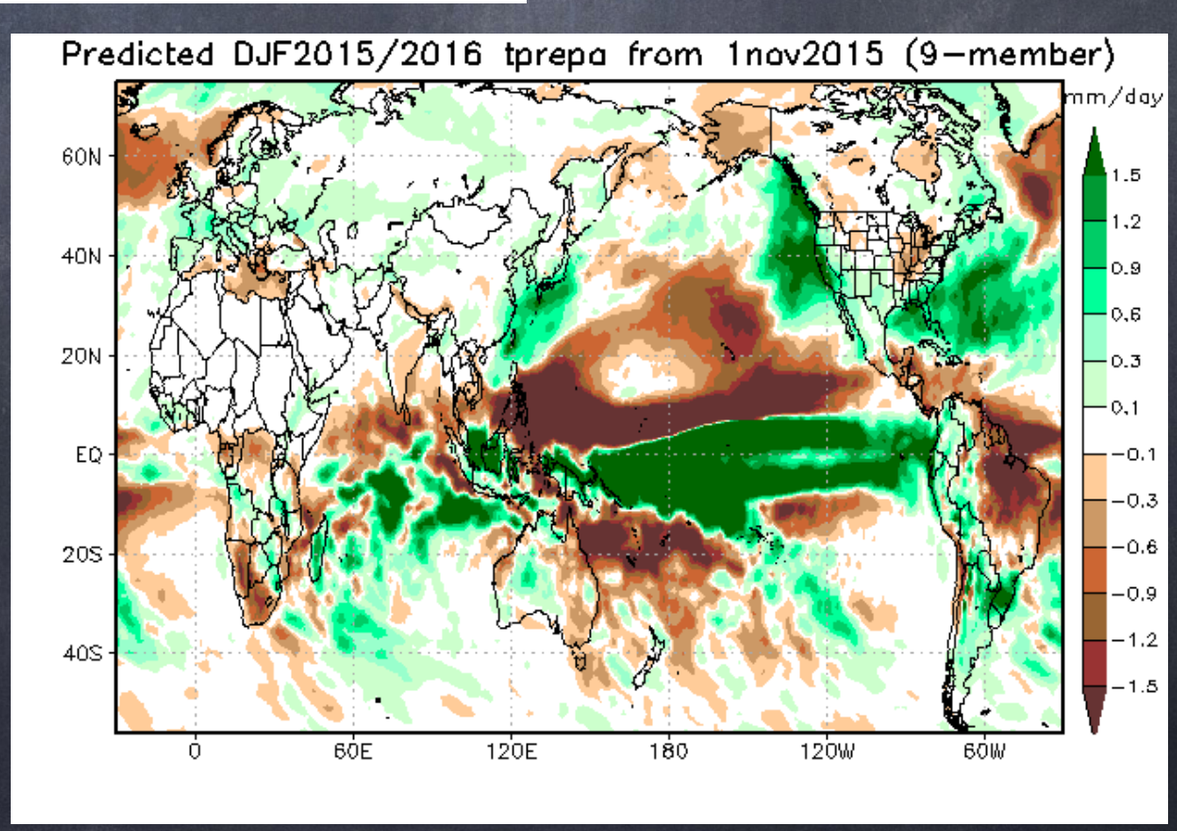


Strong El Nino may turn to a La Nina next year.
This year may be similar to the strongest El Nino in 1997/98

The coming winter prediction by SINTEX-F system







Summary

SINTEX-F1 is very skillful to predict ENSO. However, there is a room of improvement for the timing of initiation and termination.

How should we improve
the SINTEX-F prediction system ?

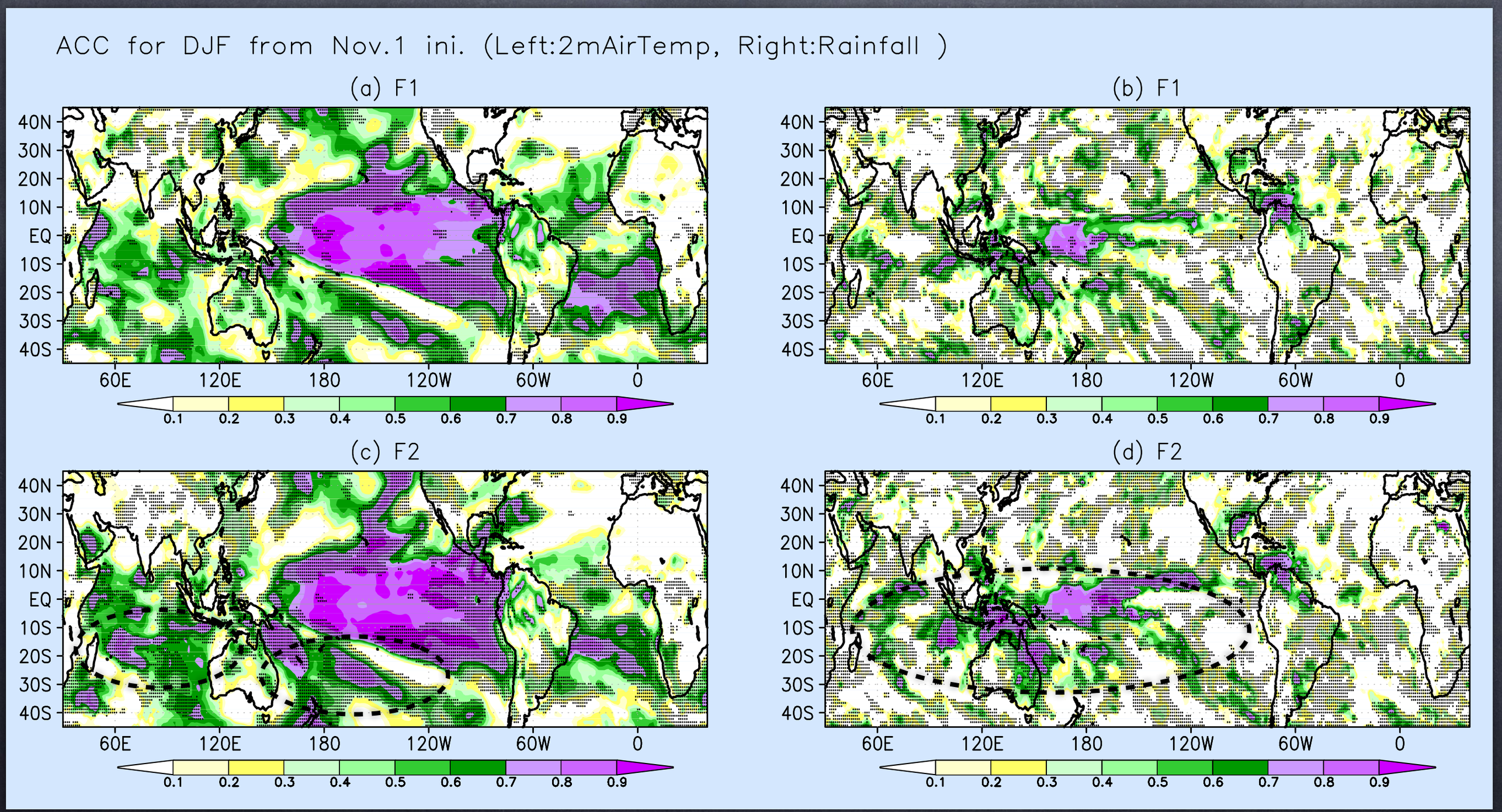
#1.Model development and #2. ocean initialization are equally important

Strategy 1: Model development

	AGCM	OGCM	Coupling	Sea Ice
SINTEX-F1	ECHAM4.6 T106L19	OPA8.2 2×(0.5-2) L31	Every 2 hour No flux correction	No
SINTEX-F2	ECHAM5 T106L31	NEMO(OPA9) 0.5×0.5 L31	Same as F1	Yes

The second version "SINTEX-F2 system" is coming soon !
(Doi et al. 2015, in preparation)

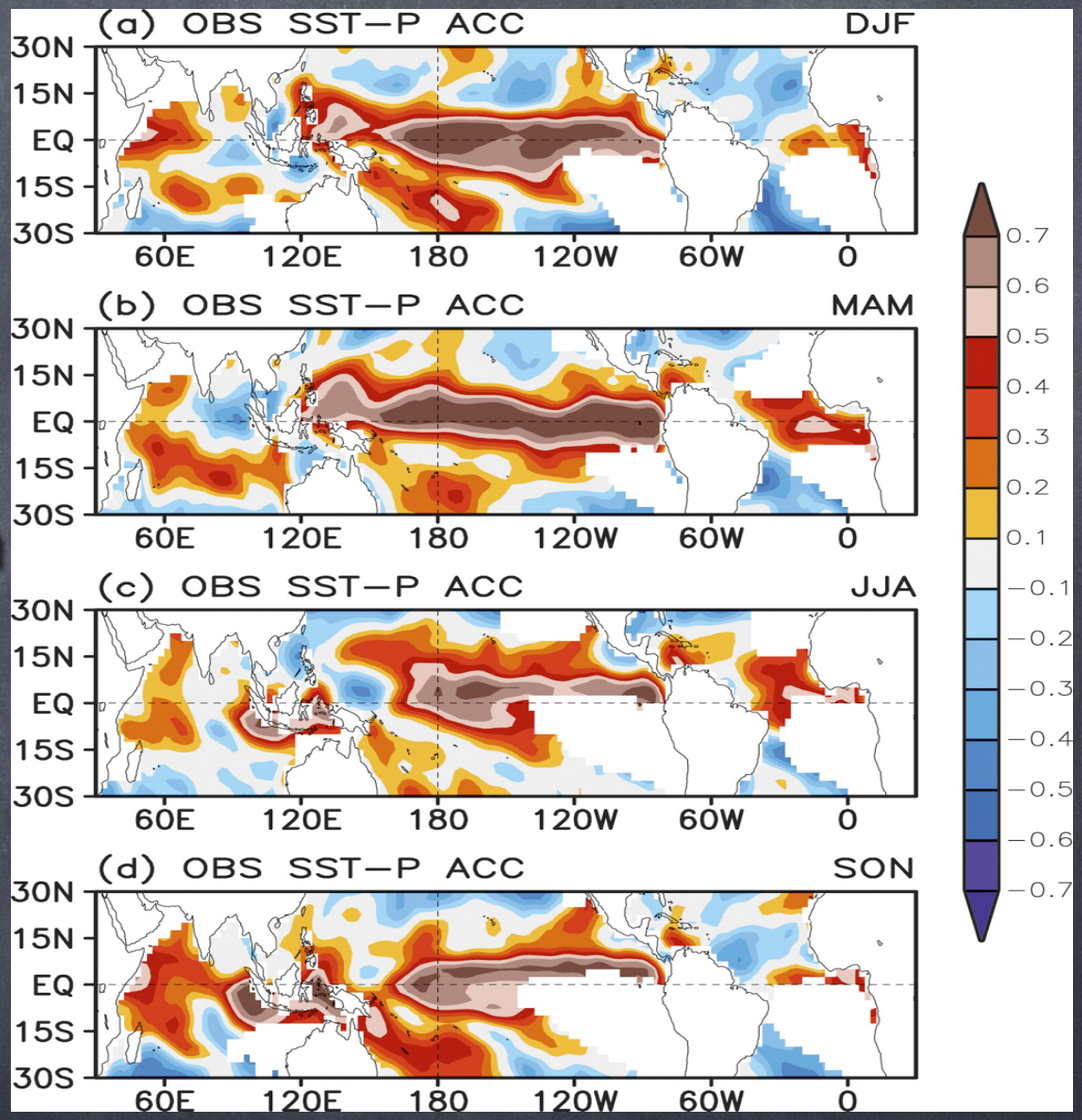
Anomaly Correlation coefficient for DJF between observation and the prediction from Nov. 1st ini. (Left: 2m air temp; Right: rainfall)



Strategy 2: Ocean Initialization

The success for the SST-nudging initialization scheme is that over regions where ocean variability is strongly constrained by coupled air-sea interaction (e.g. good for the equatorial tropical Pacific, but not for tropical Indian Ocean and tropical Atlantic)

Local simultaneous SST-P correlation from observations (Kumar et al. 2013)

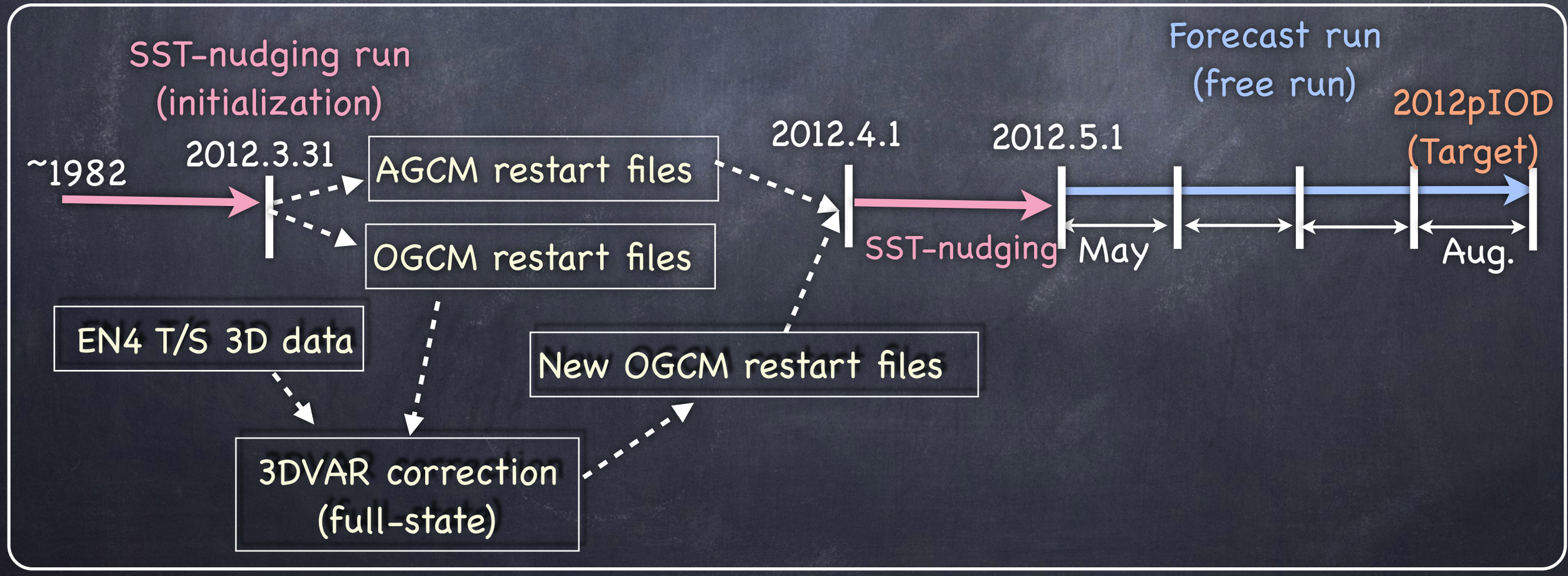


- The SST-nudging scheme cannot resolve high-frequency variability related to MJO, westerly wind bursts, etc. These events can have strong implications for the timing of initiation and termination of ENSO events (e.g., McPhaden 1999).

SST-nudging initialization scheme v.s. SST-nudging with 3DVAR correction (with Dr. Storto, CMCC)

Current system

Test with 3DVAR correction



Strategy 3: Discovery of new potential source of seasonal predictability

Traditional approach for seasonal prediction

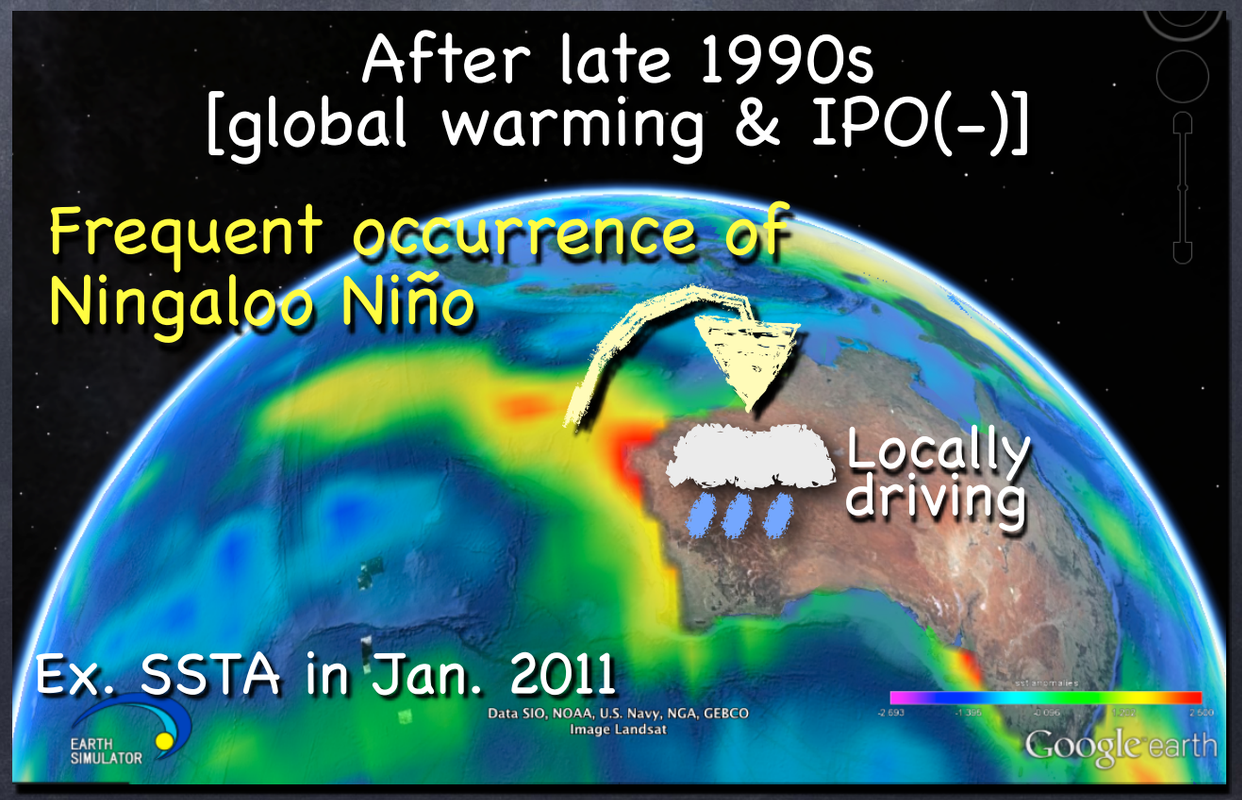
#1:Tropical climate variations (ENSO, IOD, Atlantic Niño, etc)

#2:Their teleconnection to the mid-latitude

Another possible way

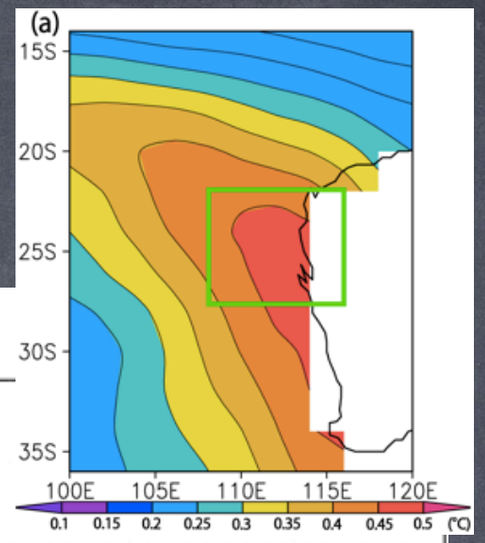
#3: Discovery of other potential source of predictability (regional air-sea coupled phenomena in mid-latitude, soil moisture, stratosphere, snow cover, sea-ice, etc…)

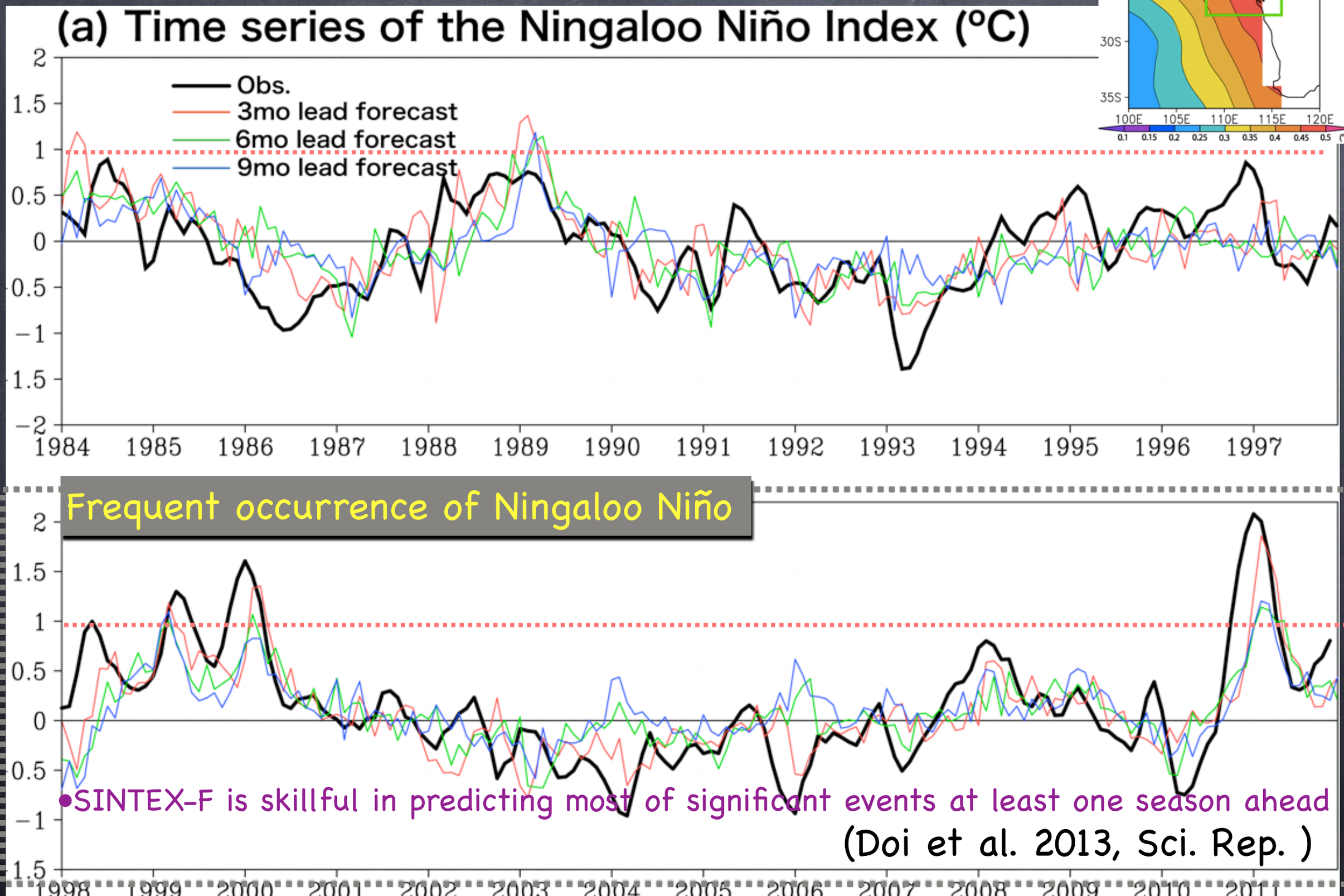
New potential source of seasonal prediction for West Australia: Ningaloo Niño (Doi et al. 2013; 2015,)



The Ningaloo Niño index (NNI)

(SSTA in 108º-116ºE, 28º-22ºS; Kataoka et al. 2013)

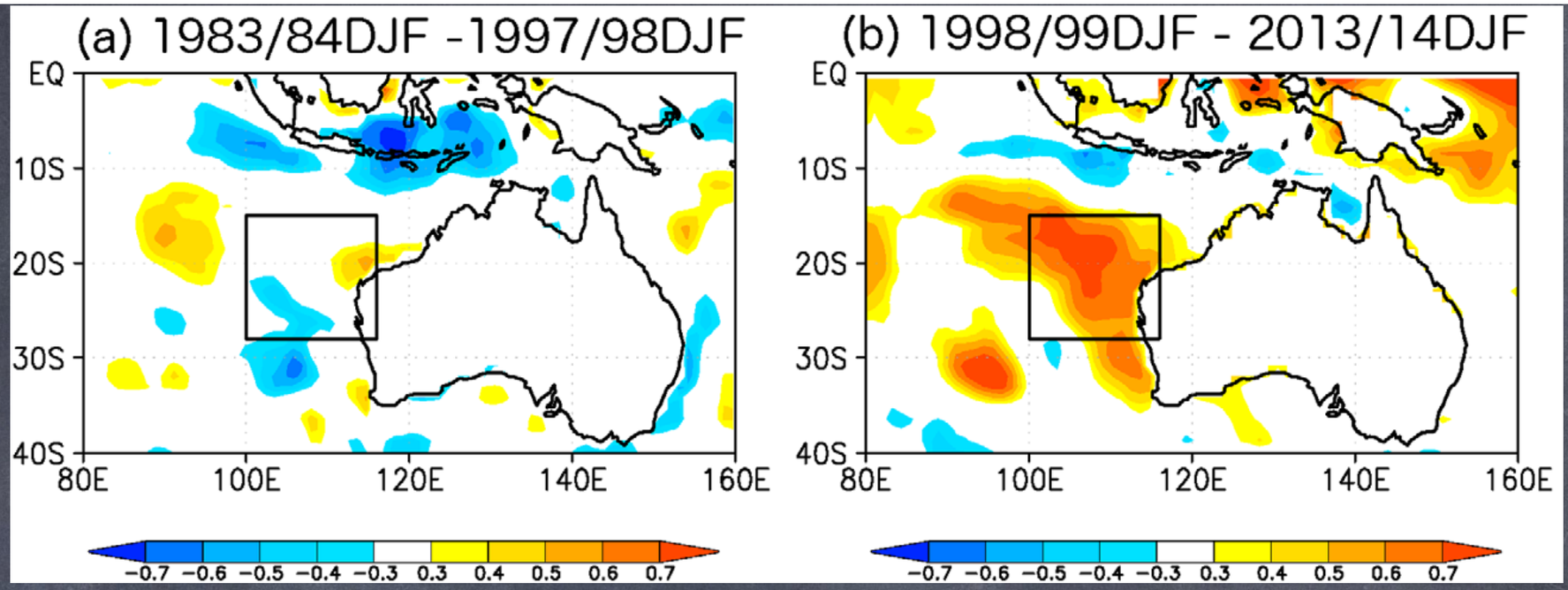


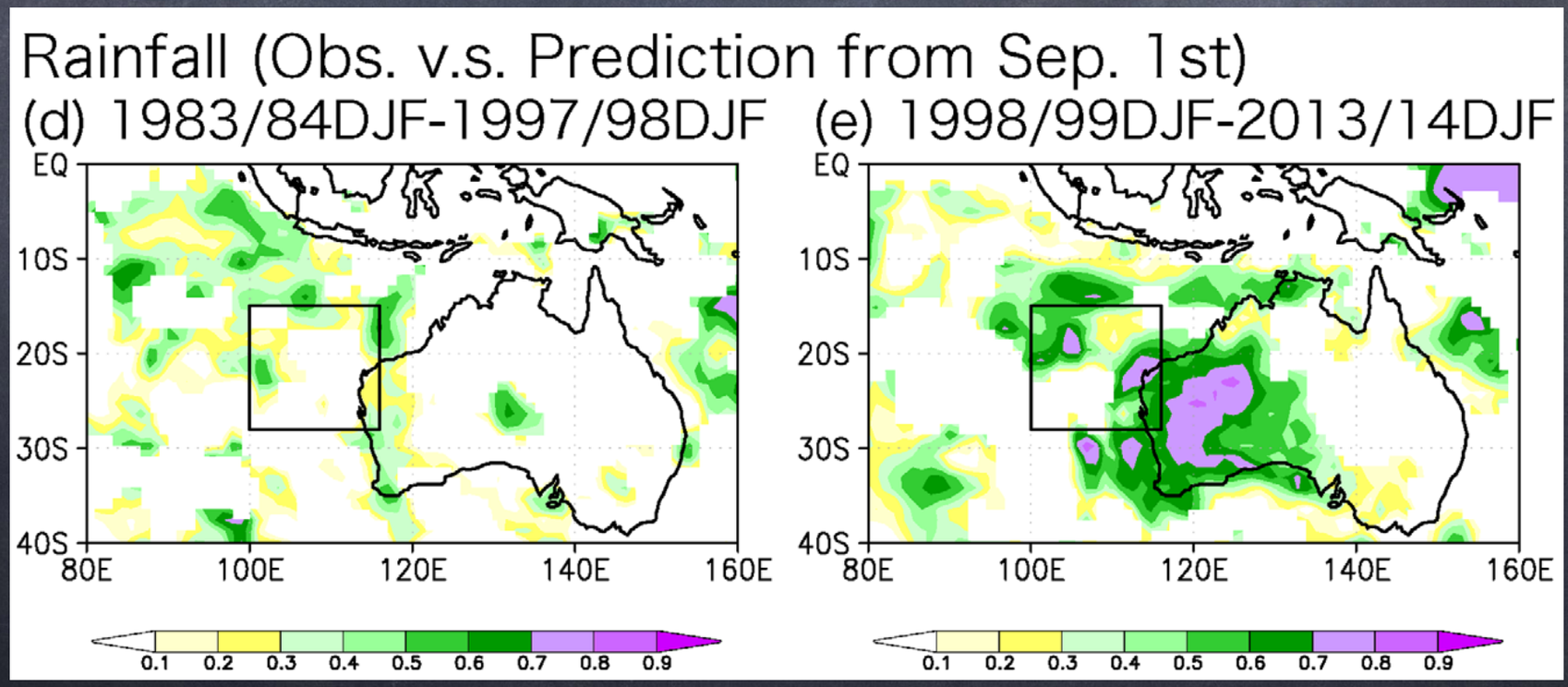


- SINTEX-F is skillful in predicting most of significant events at least one season ahead

(Doi et al. 2013, Sci. Rep.)

Simultaneous correlation between sea surface temperature and rainfall in DJF





Ningaloo Niño can work as a new potential source of seasonal prediction for rainfall over West Australia (Doi et al. 2015, JGR-oceans)

Take home message

The SINTEX-F system is very skillful to predict ENSO. However, it is not good for the timing of initiation and termination.

How should we improve the seasonal prediction system ?

1. Model development and 2. ocean initialization are equally important for improving seasonal prediction skill.

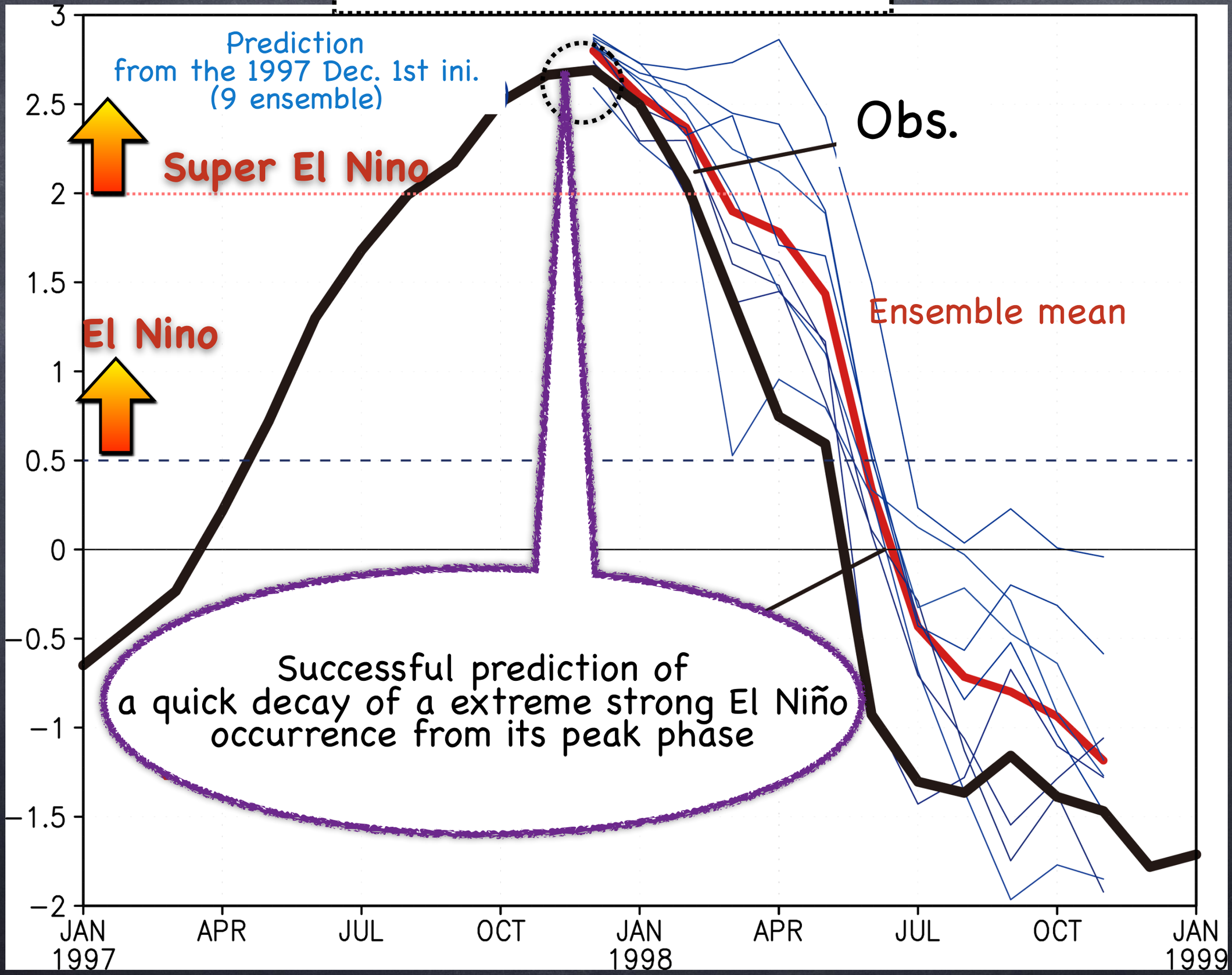
3: Discovery of new potential source of seasonal predictability

Supplementary Slides

For the initialization of ocean conditions,
a hierarchy of procedures with varying complexity have been used.

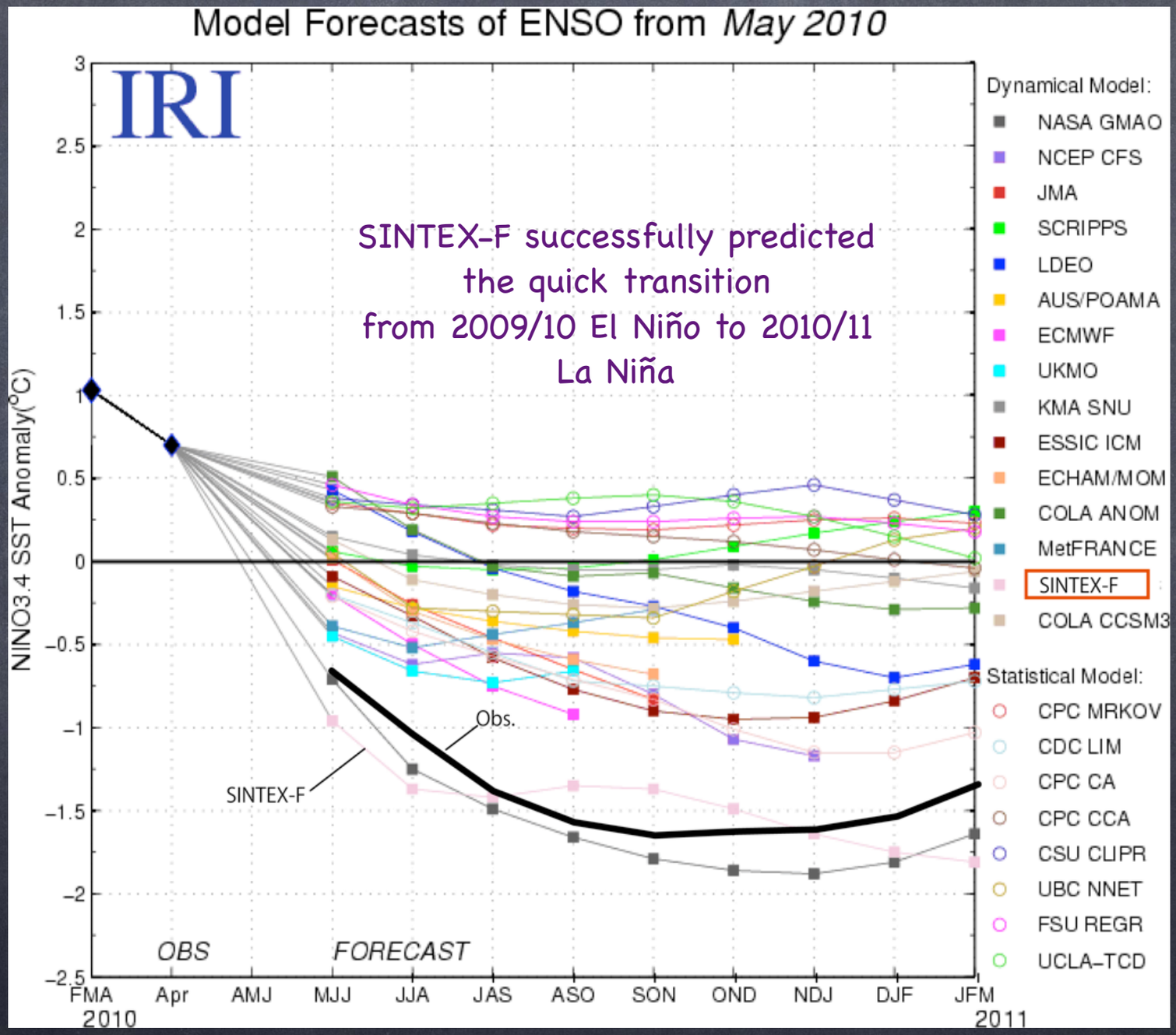
The initial conditions used for forecasts should be
not only realistic, but also compatible between the ocean and atmosphere

1997/98 Nino3.4 [ºC]



1. The SINTEX-F1 system is very skillful for the ENSO prediction.

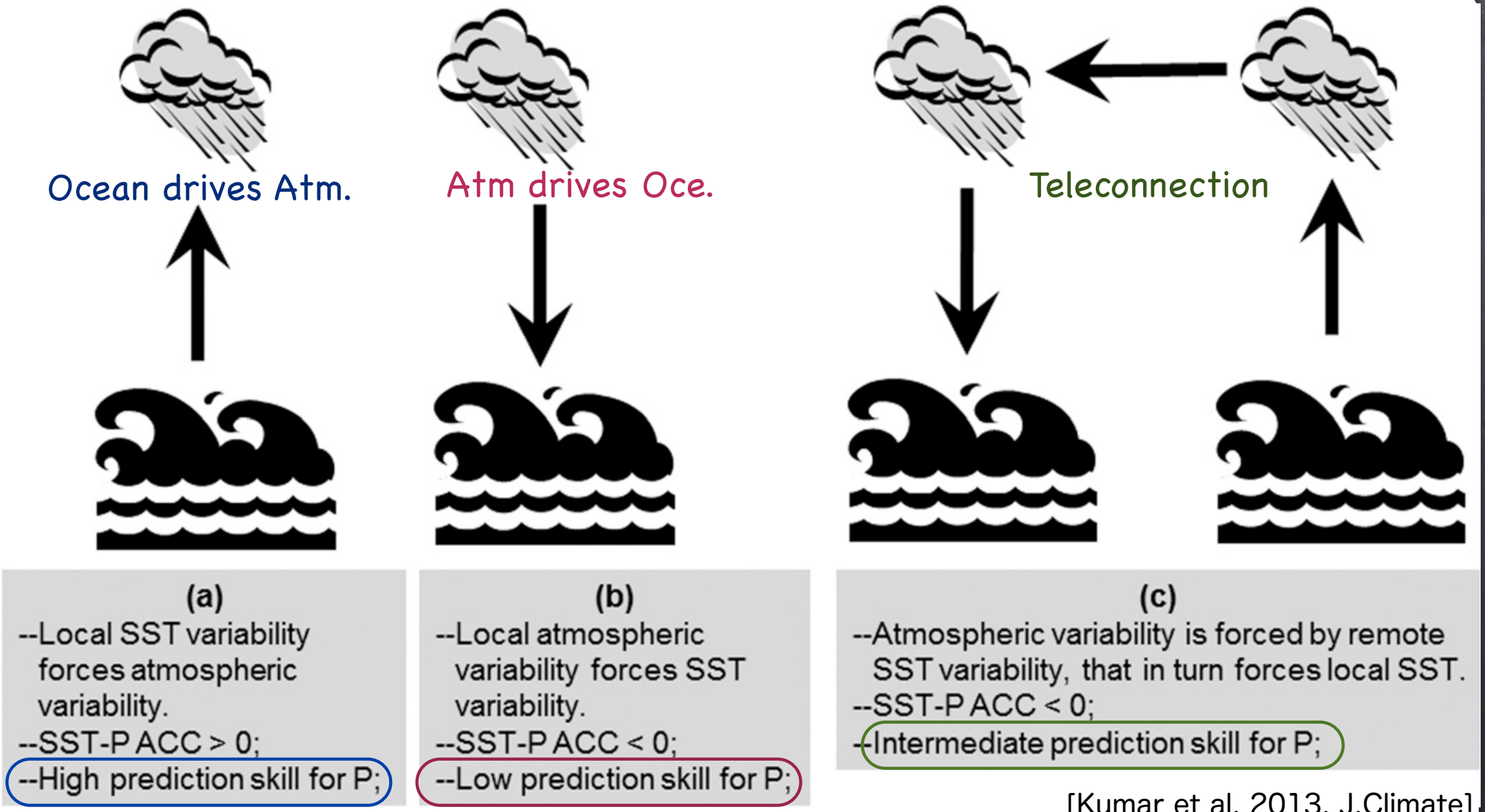
(Luo et al 2005a, 2007, 2008a, Jin et al 2008, Doi et al. 2013)



[Doi et al. 2013]

What is a potential source of seasonal predictability?

Generally, seasonal prediction skill of rainfall corresponds to the simultaneous correlation between SST and precip. (P) on a seasonal timescale



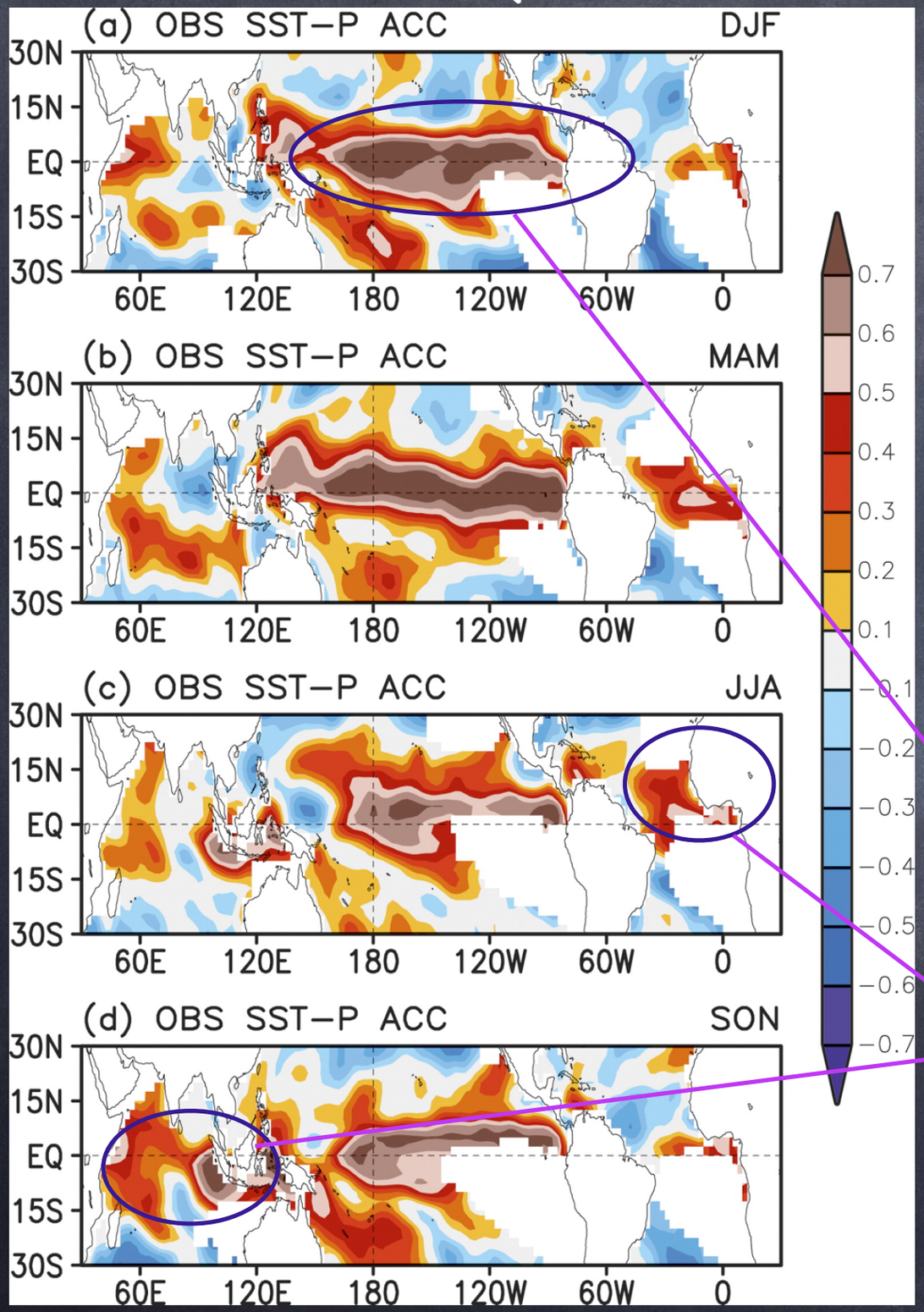
[Kumar et al. 2013, J.Climate]

FIG. 2. Schematic plot of conceptual connection between SST and precipitation variability.

(a): A potential source for seasonal predictability is slowly varying SST anomalies!
(b) is intrinsically unpredictable nature of atmospheric variability

Where is critical for seasonal prediction?

Local simultaneous SST–P correlation from observations (Kumar et al. 2013)



Potential source of seasonal predictability mainly from "tropical oceans", because the warm SST can drive global atmosphere.

Main drivers:

- ENSO (critical)
- Indian Ocean Dipole
- Tropical Atlantic Variability

* Regions with seasonal mean precipitation being less than 0.3 mm day−1 are not shaded.

- Seasonal predictability of the IOD is found (Luo et al. 2007)
- Successful prediction of 2006pIOD two season ahead (Luo et al 2008)

Flood

Drought