Seasonal Climate Prediction with IAP GCMs

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IAP ENSO Prediction with CGCM

Introduction

- Model Development in IAP

  AGCM: 2-L AGCM (Zeng *et al*, 1986)
  9-L AGCM (Zeng, Liang, Bi, 1993)
  OGCMs: Global OGCMs(Zhang et al, 1989, 199)
  Tropical Pacific OGCM (Zhang, 1992)
  Coupled GCM: Global (Zhang et al, 199)
  Tropical Pacific (Zhou, 1996)

- ExtraSeasonal Prediction of Precipitation by GCMs in IAP

  IAP AGCM: Zeng et al. 1990; Li,1992; Zeng, 1994;
  Zeng etal., 1997; Lin et al. 1998, 1999

- SST Forecast System

  IAP T-P CGCM: Zhou, etal. 1998; Zhou, et al. 1999

IAP ENSO Forecast System

- **Model:** IAP Coupled GCM for the Tropical Pacific
- **Initialization:** Climate Anomaly Forcing
- **Hindcast Experiments:** 1981~1997
- **Real Time Forecasts:** **1997~2000**

Model Description and Its Performance

- **IAP 2-Level Atmosphere General Circulation Model**

  Region: Global

  Resolution: 4^o x 5^o in Horizontal Direction

  2 Level in Vertical

- **Tropical Pacific Ocean General Circulation Model**

  Region: 120^oE - 70^oW, 30^oS - 30^oN

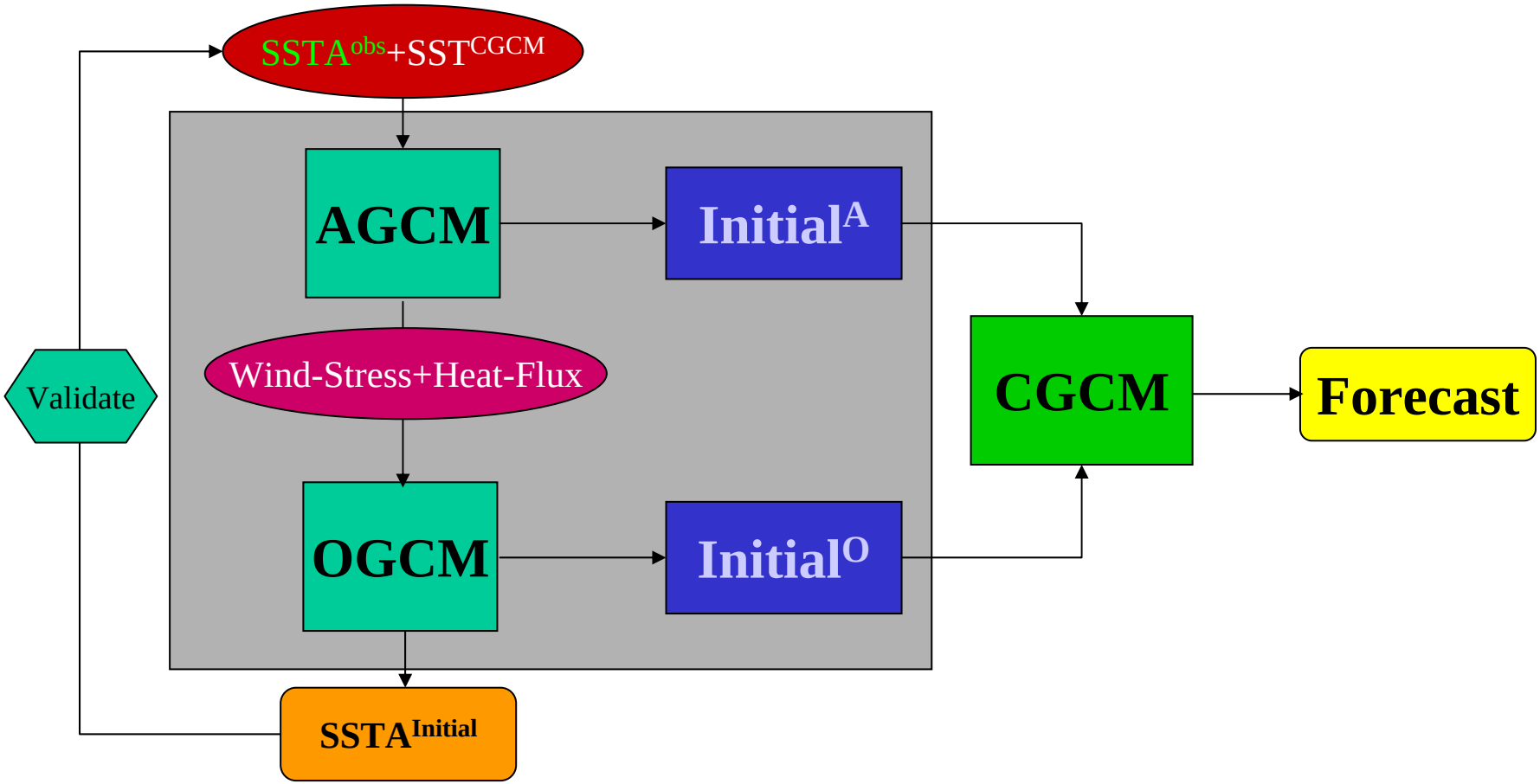
  Horizontal Resolution: 1^o x 2^o

  Vertical: Unequal 14 Layers from Surface to 4000m Depth

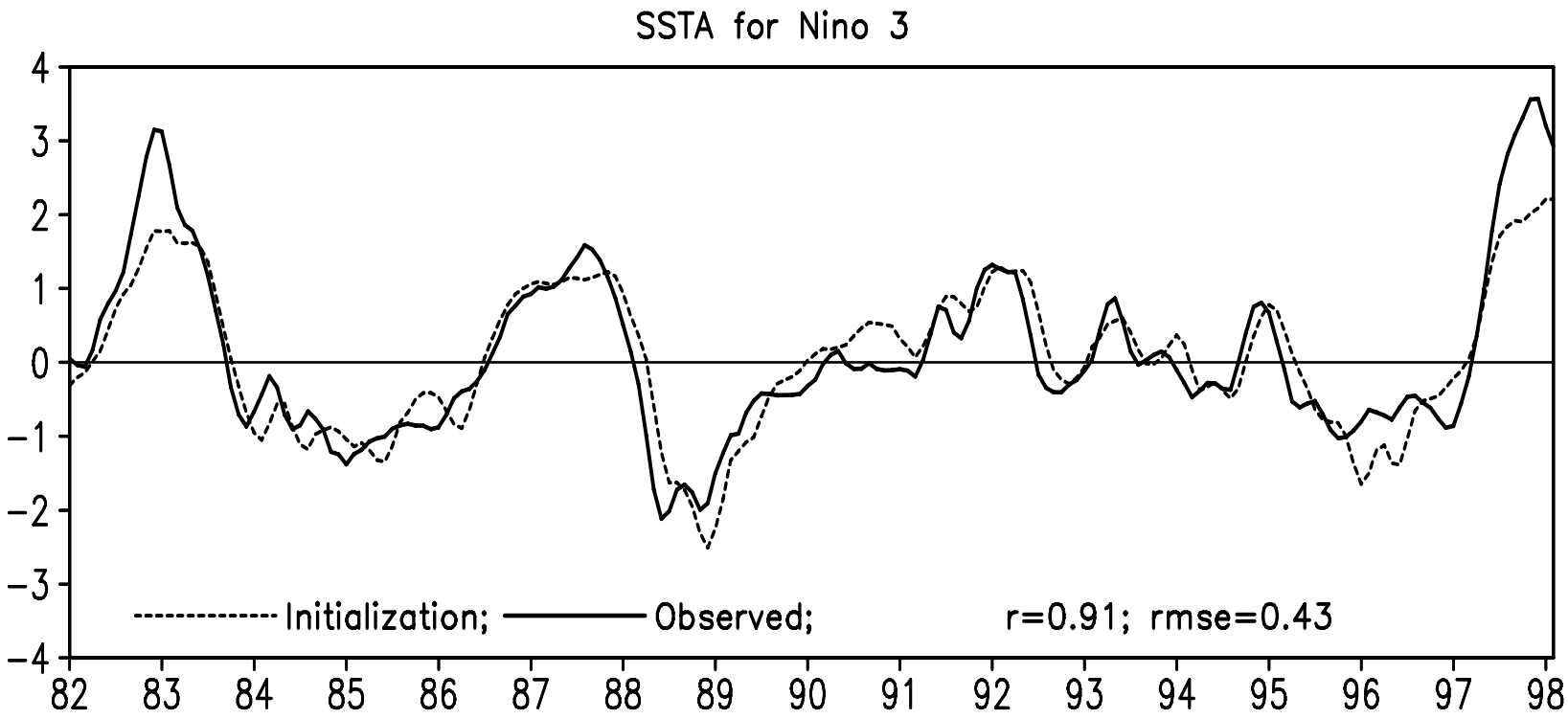
  9 Layers in the Upper 240m

Forecast Initialization

- Only SST Anomaly In the Tropical Pacific Is Used to Force Coupled Model to Get the Actual Inter-Annual Variability Phases.
- Consistency in the Initial Condition Between the Two Component Models is Considered



Schematic Picture of the Forecast Initialization Process. $SSTA^{obs}$ is observed SST anomaly, SST^{CGCM} is CGCM's Climatology, and $SSTA^{Initail}$ is simualated SST anomaly after 'Initialization Process'.

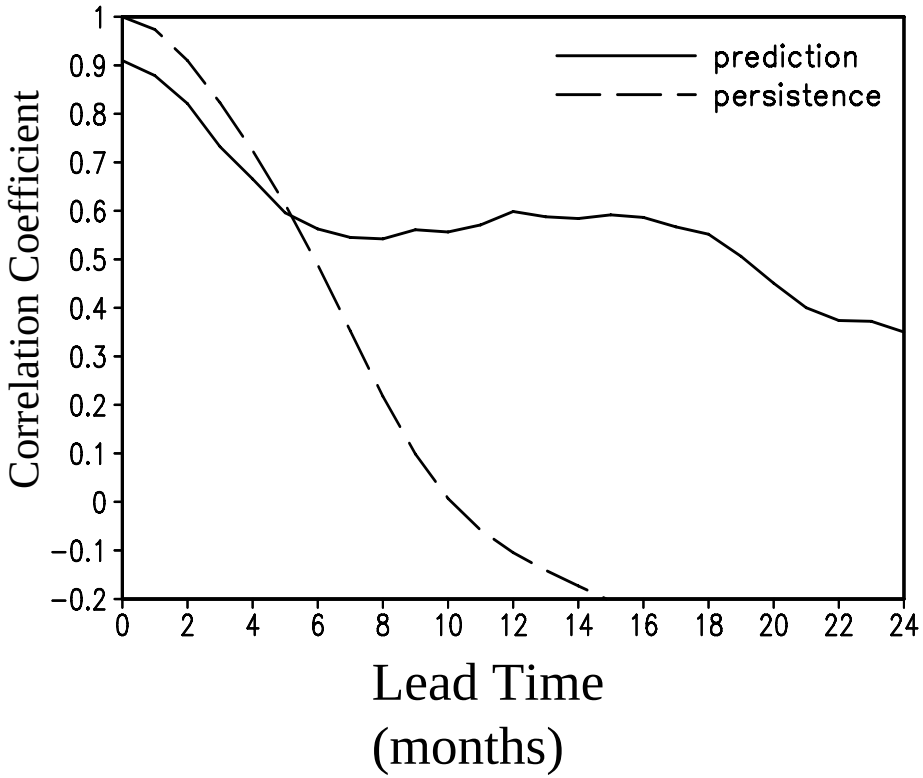


Comparison of the Initialized SSTA and Observed SSTA

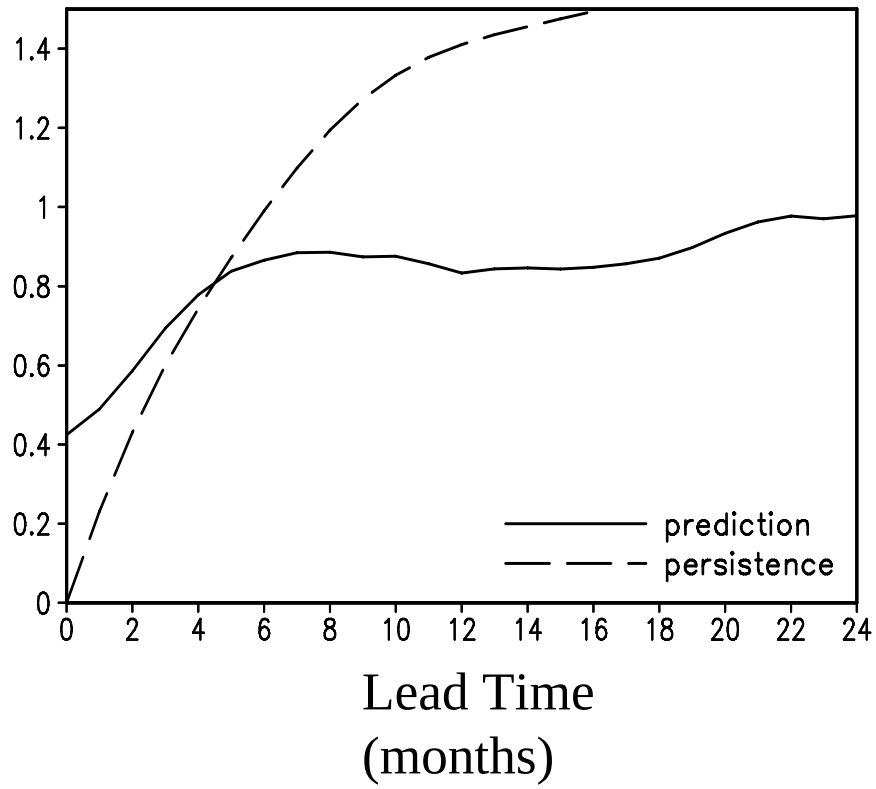
Hindcasts and Skill

• Totally About 200 Sets of Hindcasts up to 24 months in Advance from Nov. 1981 to Dec. 1997 to Evaluate the Model's Forecast Skill.

Forecast Skills in Nino 3



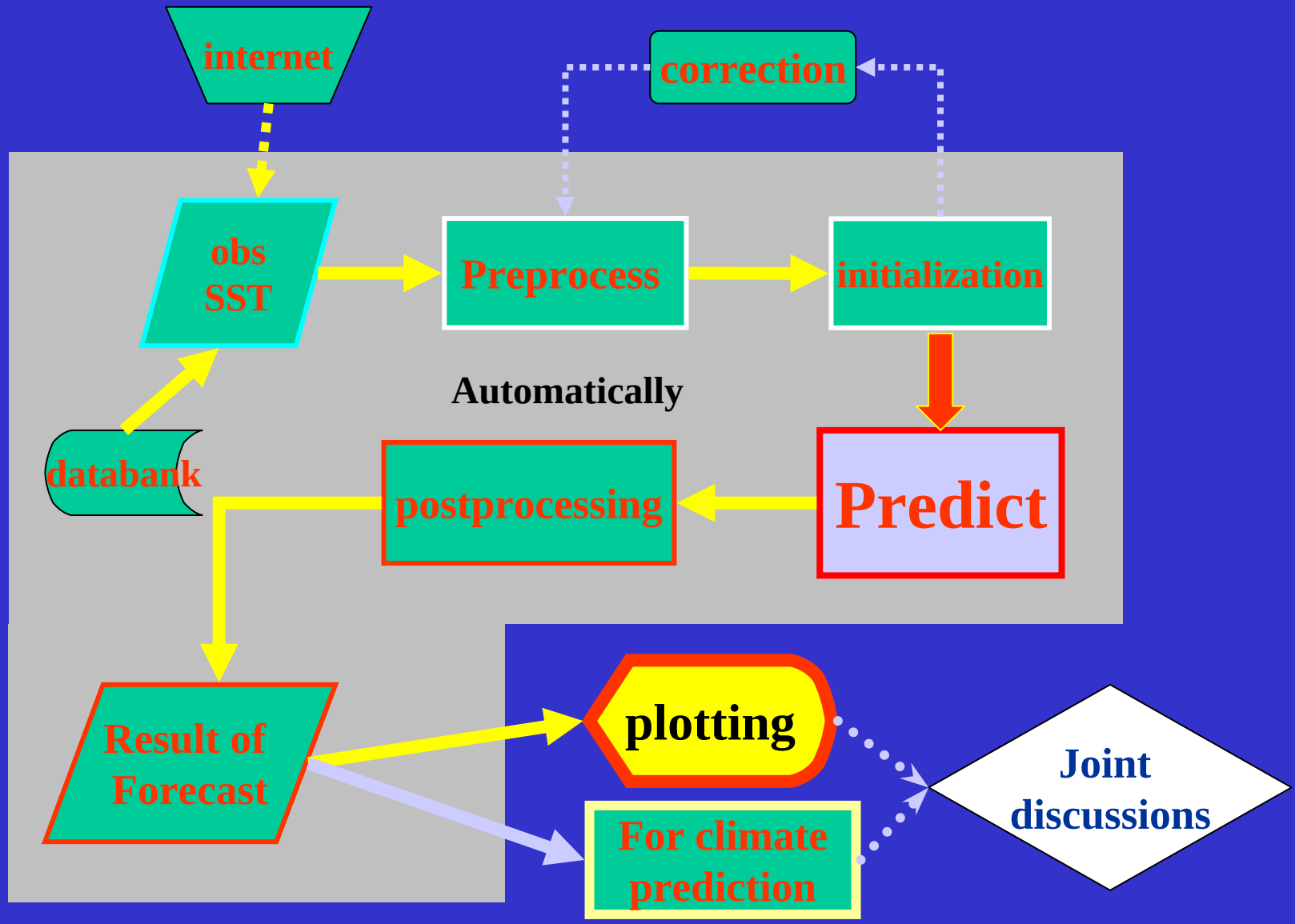
RMS Error (°C) in Nino 3



Corr. Coef. And RMS Errors Between Forecasts (Model and Persistence) and Observation in Nino3

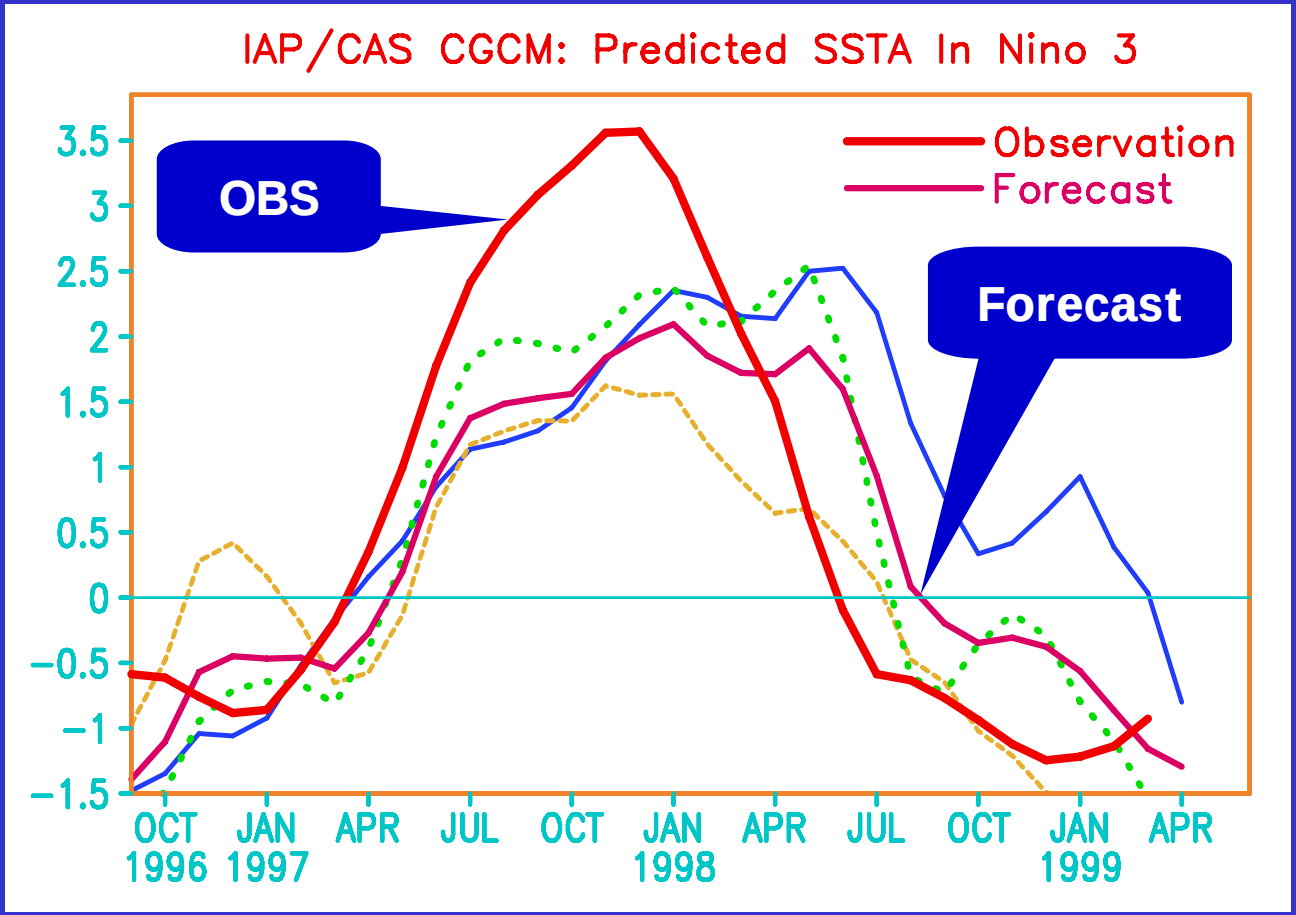
Near Real Time Forecasts

Flow Chart of IAP ENSO Forecast System

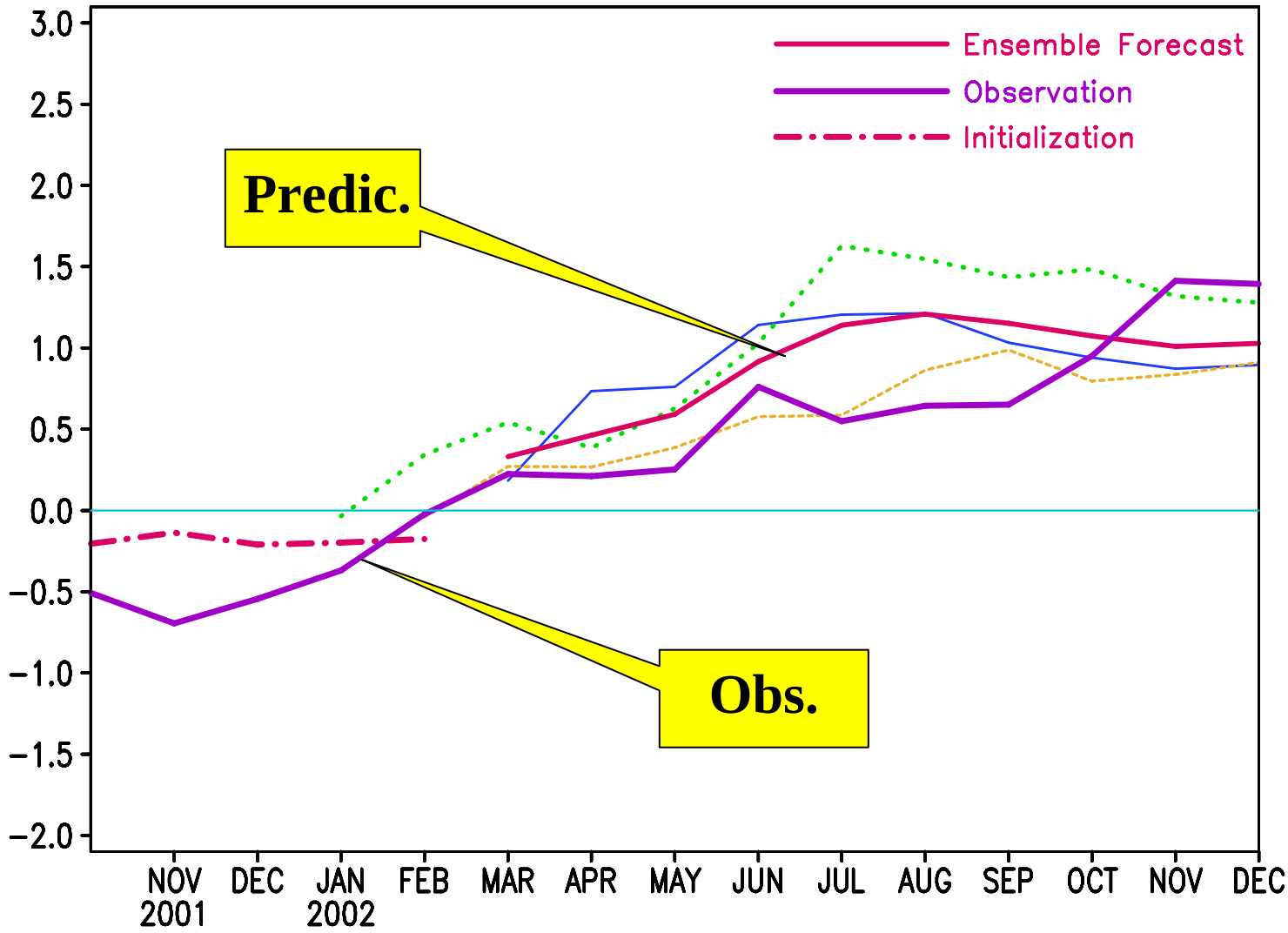


Real Time Forecasts

Some Samples

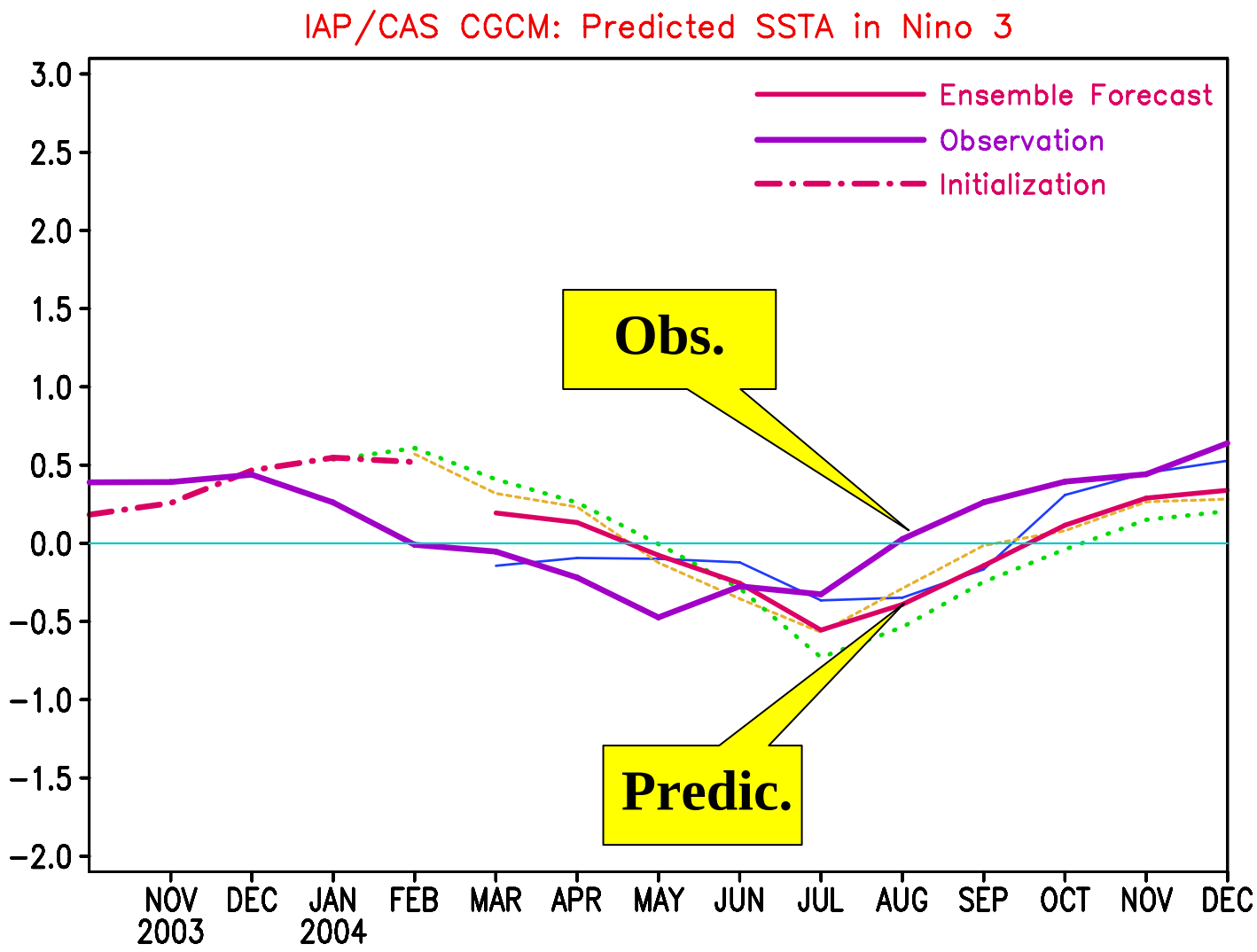


Forecast in the Spring, 2002

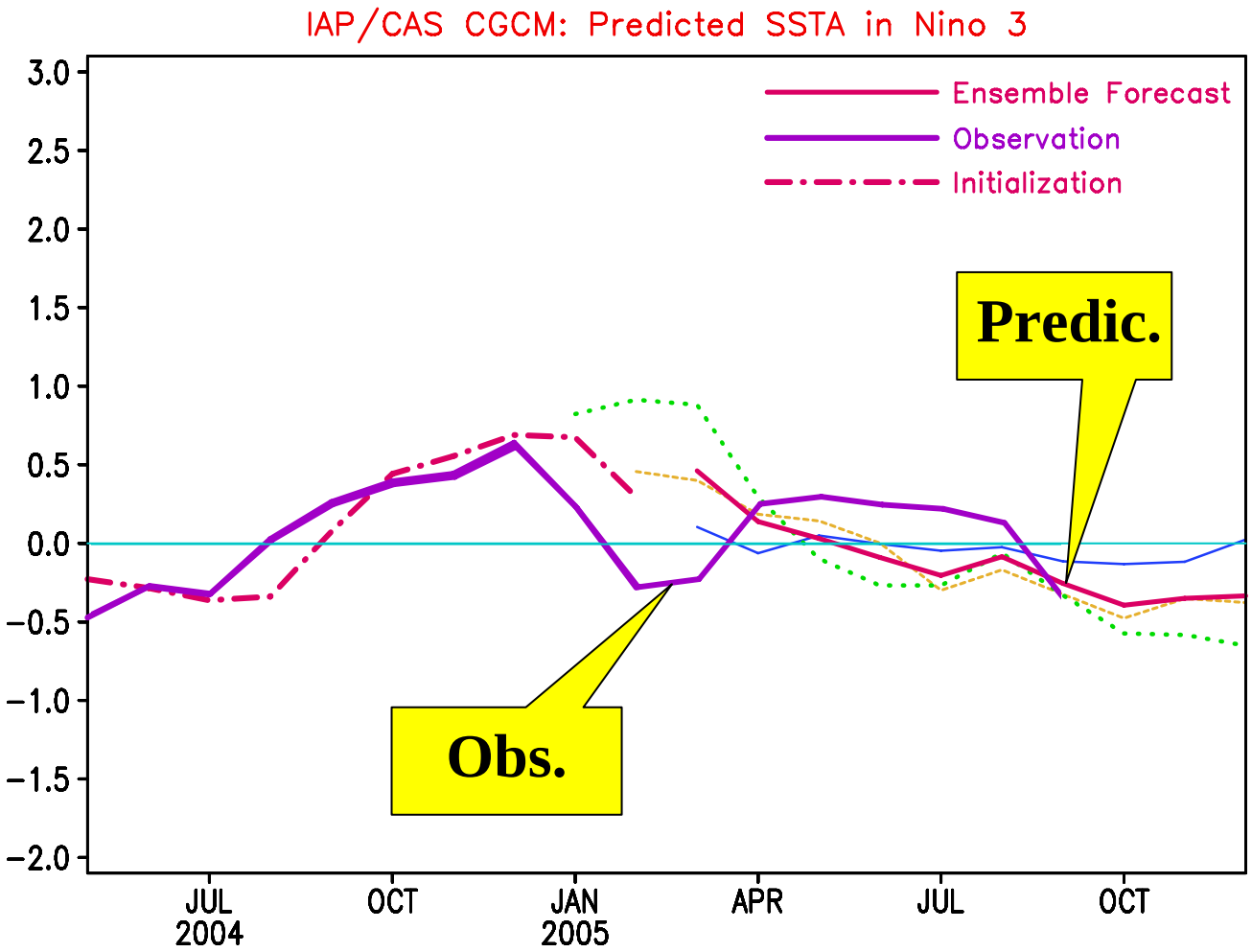


Forecasts Initialed from jan, feb, mar, 2002 and Their Ensemble Mean.

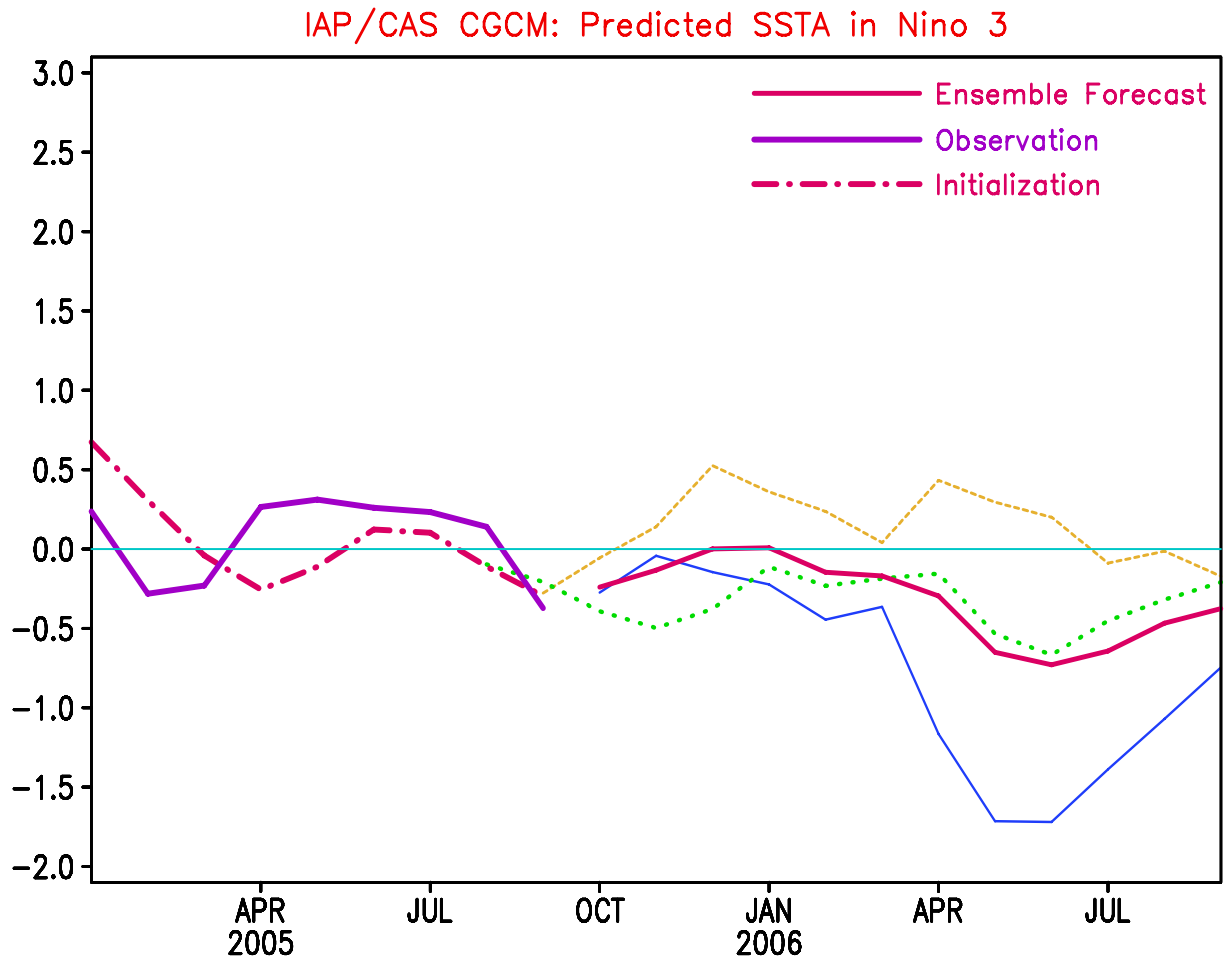
Forecast in the Spring, 2004



Forecast in the Spring, 2005



Forecast in the Fall, 2005



Near Neutral Condition in the following Months

Some New Progresses

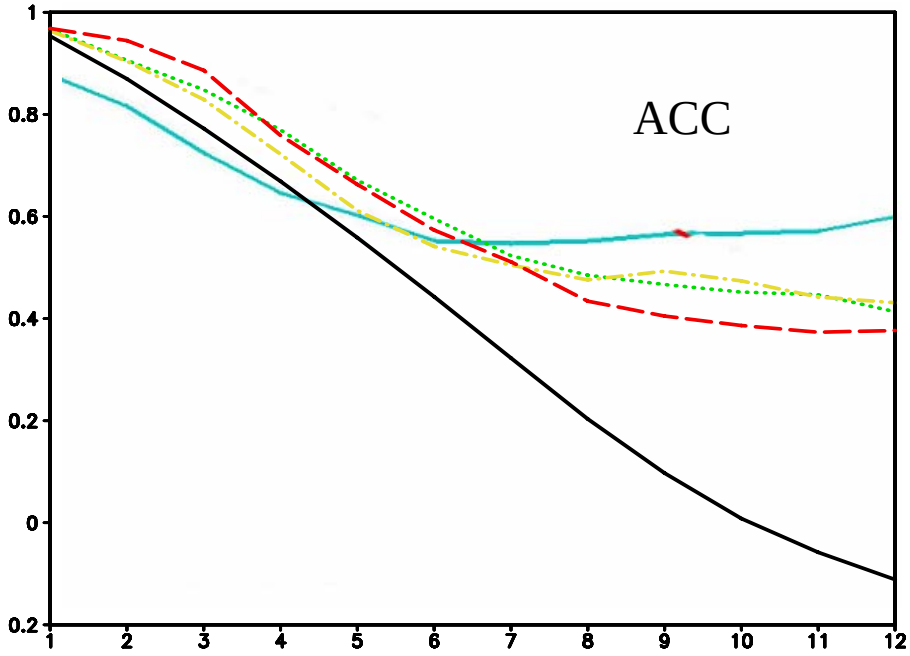
Impact of Ocean Data assimlation

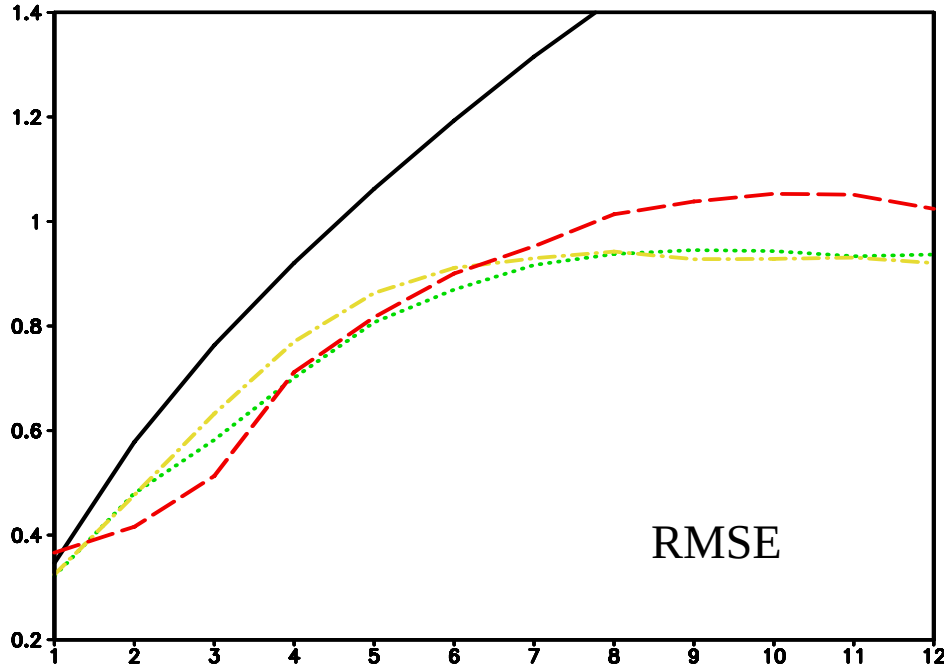
- **A 3DVar oceanic data assimilation system named OVALS (Oceanic Variational Data Analysis System) was developed in which the in situ temperature, salinity profiles and the satellite altimeter data can simultaneously be assimilated such as XBT, CDT, TAO, ARGO and T/P data et al.**

- **Three experiments were made to study the impact of data assimilation on forecasts:**

1. OGCM	Force AGCM and OCGCM respectively with OBS data + Assimilate temperature profiles
2. CGCM	Same as present system, but assimilate temperature profiles
3. CGCM_a	Same as 2, but assimilate temperature anomaly

Skill of Niño3 index for hindcasts from 1982-1999





OGCM CGCM CGCM_a Persistence

no data assimilation

Some New Progresses

A New Coupled Model with Higher Resolution

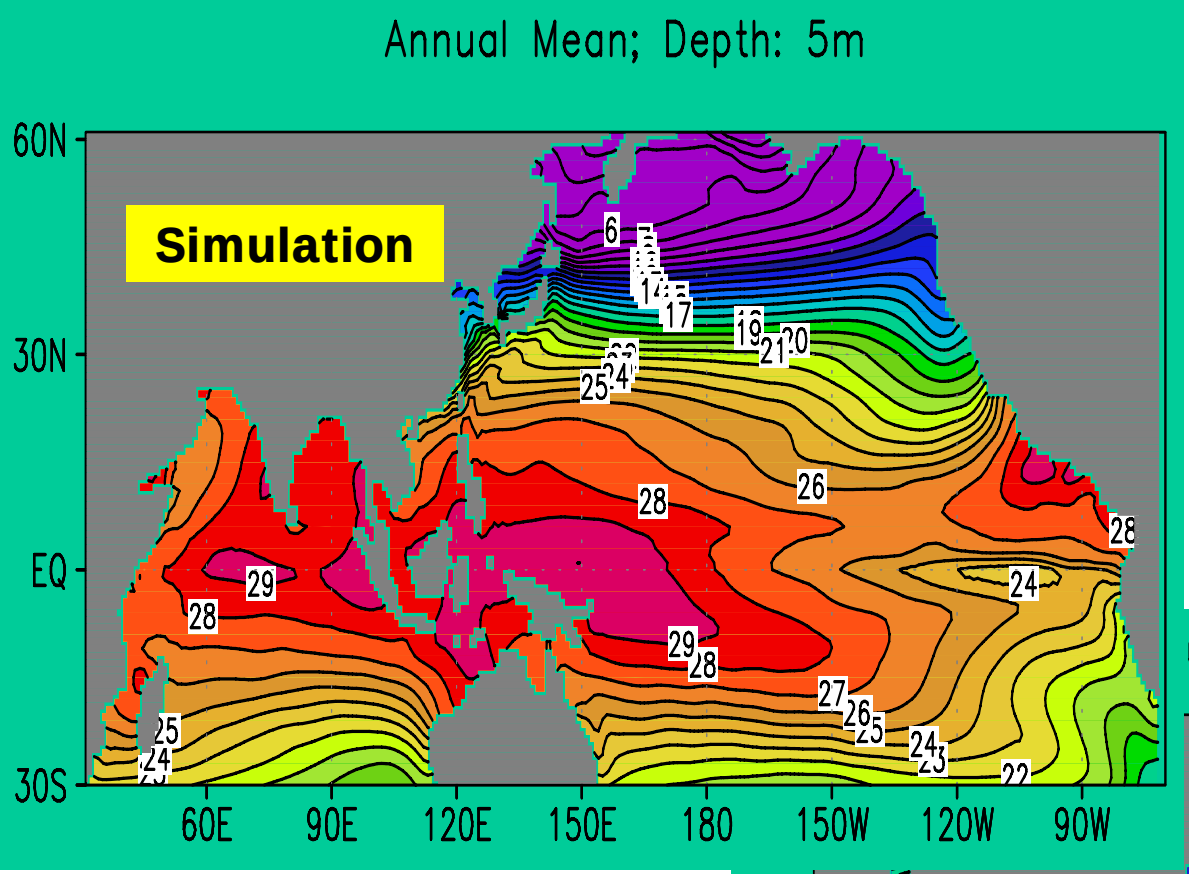
- Increased tropical OGCM's resolution from $1^{o}x2^{o}$ to $0.5^{o}x0.5^{o}$
- Coupled with A 9-L AGCM
- Showed some improvements in simulations

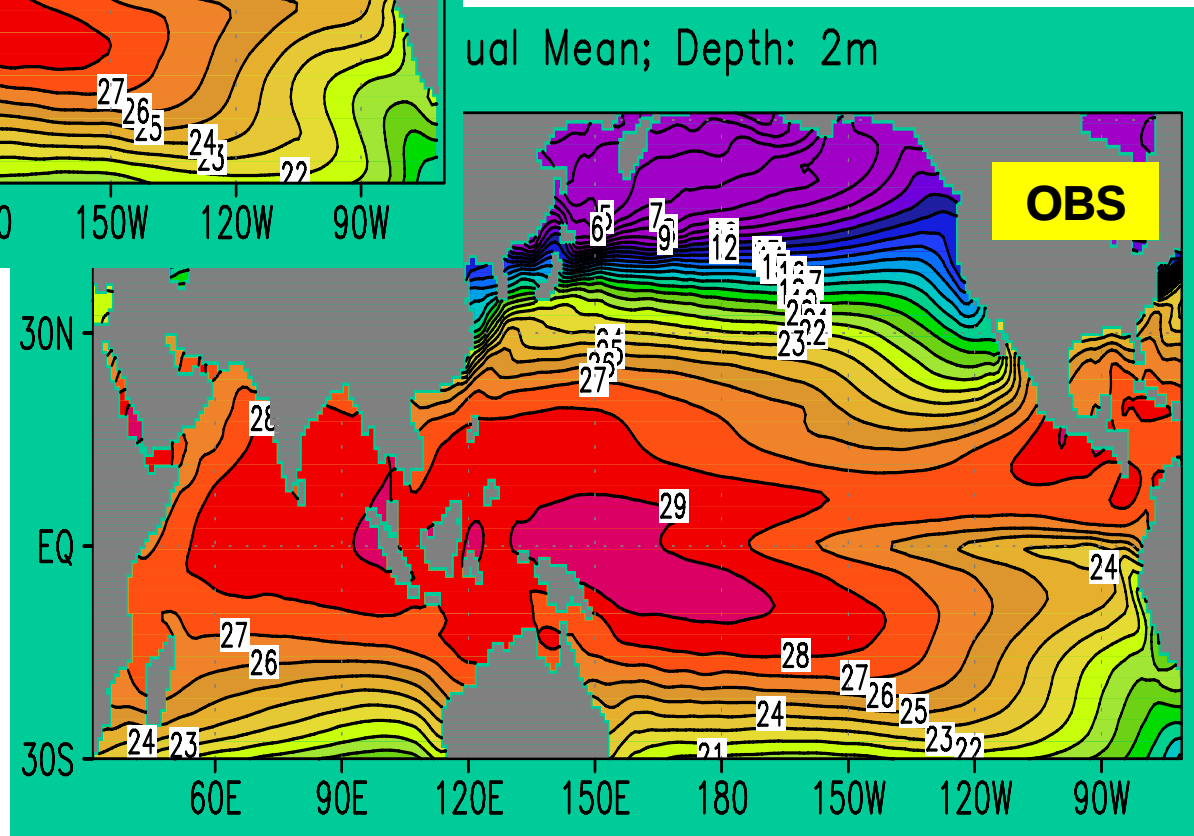
Some New Progresses

A New Pacific-Indian OGCM

- Model's Domain: 30°E-70°W, 30°S-62°N
- Model's resolution: 1°x1°, 26-layers
- Good simulations driven by ERA40 data.
- Next: Increase Model's resolution to 0.25°x0.25° in Equatorial Region
- Next: Couple with AGCM and Forecast

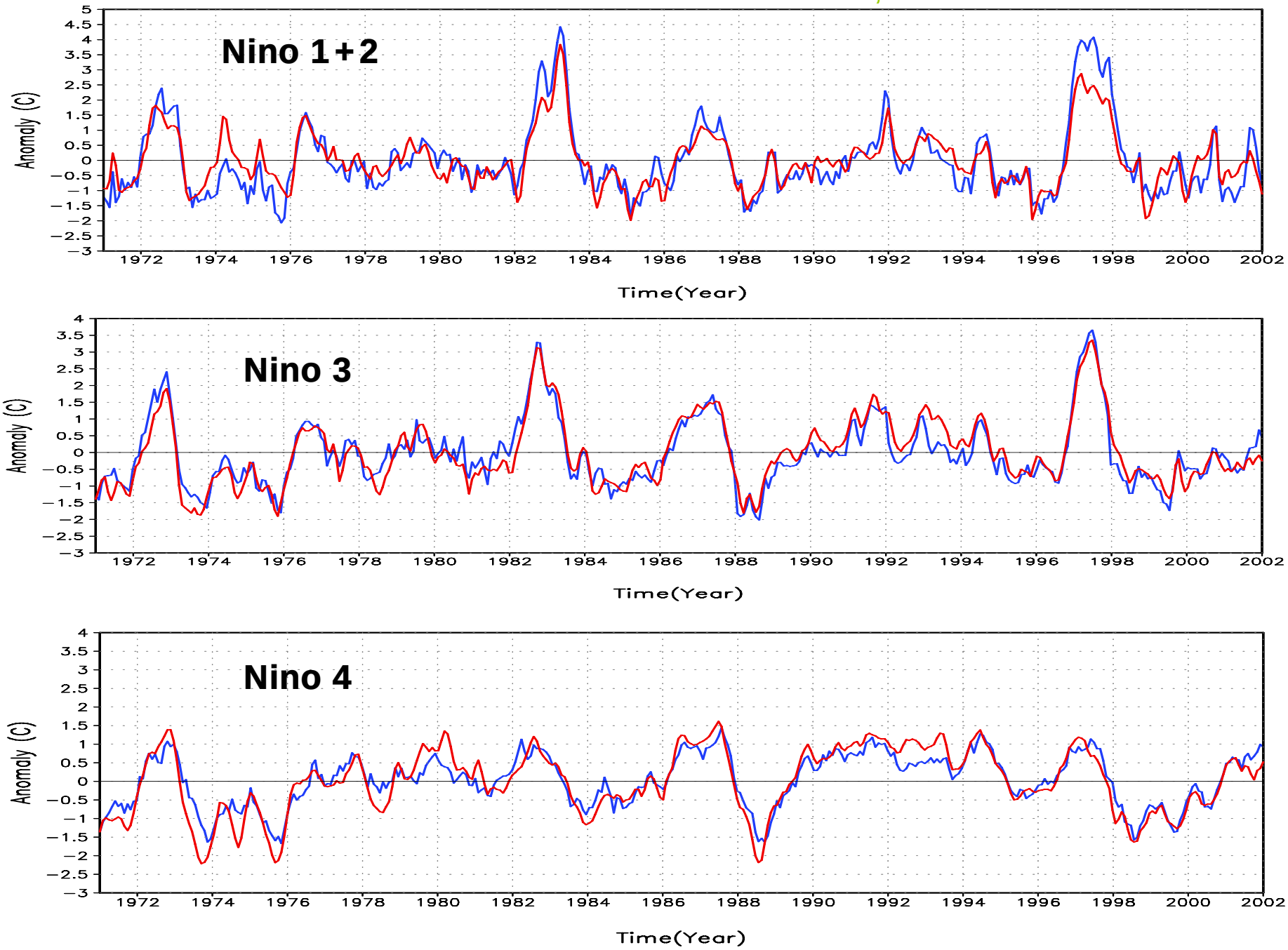
Annual mean SST





Pacific-Indian OGCM with 1x1

Pacific –Indian OGCM Simulation. Red : simulation; Blue: observation



Numerical Prediction by IAP9L-AGCM

Outline

- Introduction
- Model description and predictability assessment
- Real-time Prediction and Verification
- Summary

Dynamical Extraseasonal Climate Prediction Activities in IAP/CAS

- First Extraseasonal Prediction by Numerical Climate Models in 1988 (*Zeng et al., 1990*)

- The ensemble prediction is conducted in two-tiered fashion. Firstly, the tropical Pacific SST anomaly is predicted by IAP ENSO prediction system (*Zhou et al., 1998*). In the second step, an ensemble of AGCM integrations is performed with the predicted SSTs to obtain the final prediction product.

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IAP9L-AGCM

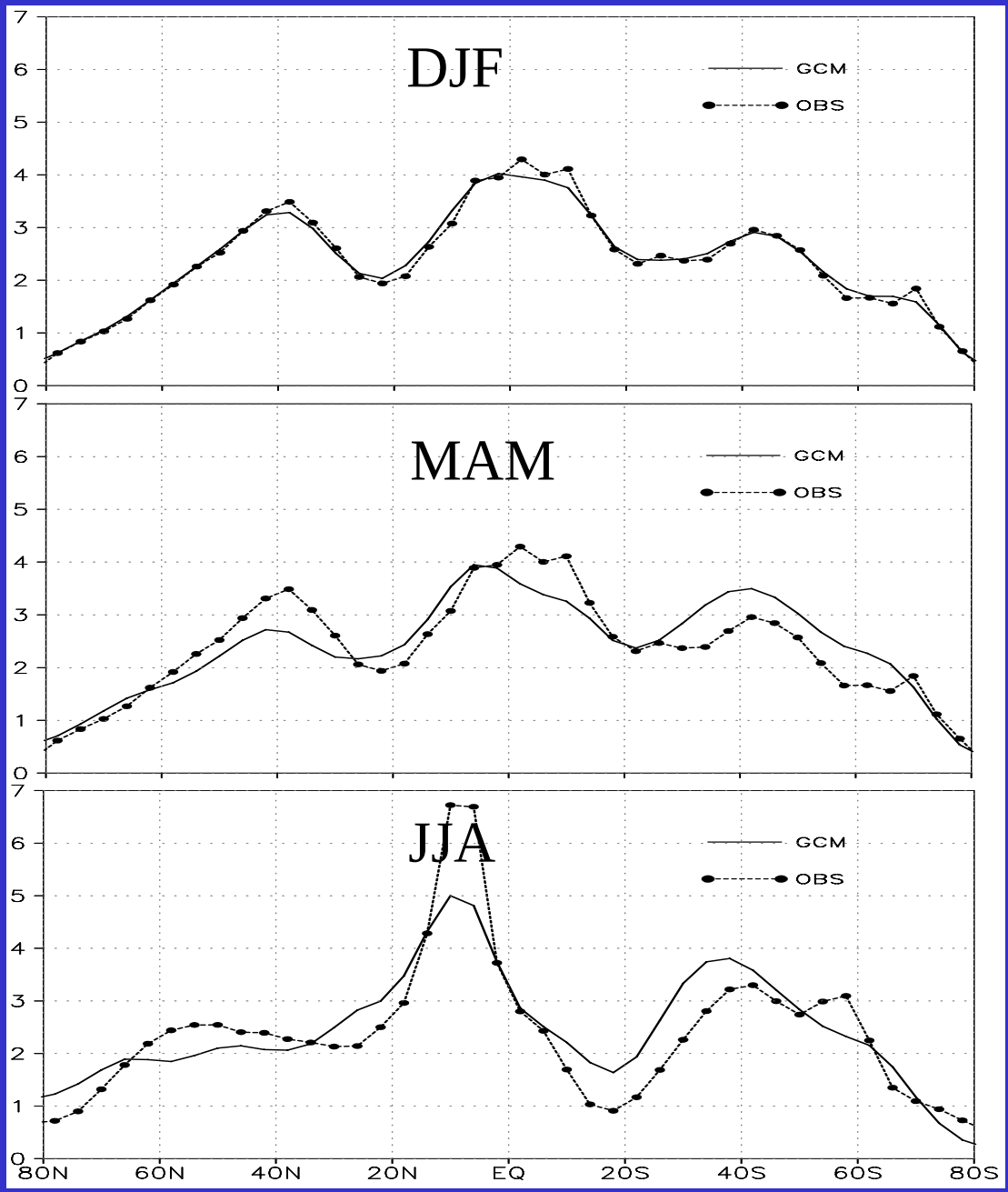
• **A global atmospheric general circulation model developed at the Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences (CAS) . (*Zeng, 1987; Zhang, 1990; Liang, 1996; Bi, 1993*)**

Horizontal Resolution: $4^o \times 5^o$;
Vertical Resolution: 9 levels, with a top at 10hPa.

Brief review of the earlier studies with IAP9L-AGCM

- ✓ Verification of the model's ability in simulating climatology, seasonal cycle, climatic classification, and regional climate. [*Bi, 1993*]
- ✓ Simulations of monsoon and climate change.
  [*Wang et al., 1996; Chineke et al., 1997; Li et al., 2000; Xue et al., 2001; Wang, 2001 ; Xue et al., 2003*]
- ✓ Researches on the interannual variation and predictability of the atmospheric general circulation. [*Wang et al., 1997*]
- ✓ Researches on paleoclimate simulation.
  [*Wang, 2002 ; Jiang et al., 2002; Wei et al., 2002; Jiang et al., 2003*]
- ✓ Assessments on the model's predictability of seasonal climate.
  [*Lang et al., 2003; 2004; 2005*]

Simulated versus observed zonally climatological precipitation



from IAP9L-AGCM

from observation

The potential predictability of the IAP9l-AGCM on Short-term Climate Prediction

dataset

The real-time initial atmospheric data (2.5°×2.5°), observed real- time global monthly mean SST ($1^o \times 1^o$ or $5^o \times 5^o$) and climatological ($1^o \times 1^o$) SST are from NCEP

Hindcast

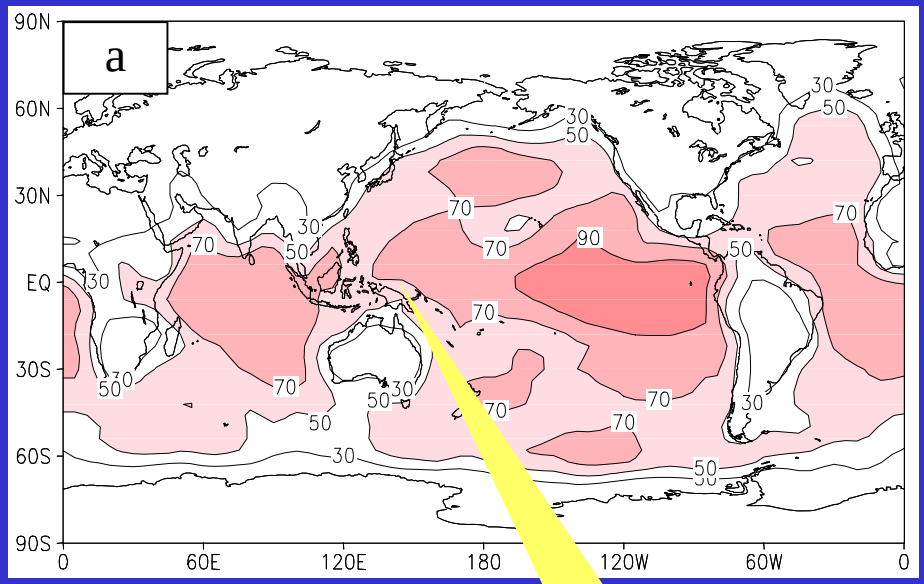
period: 30 years (1970-1999) ; DJF, MAM, and JJA for each year;
Intial time: 00GMT of November 24-30 for DJF, January 25-31 for MAM, and April 24-30 for JJA, respectively.

Statistical approach

Variance analysis (signal-noise ratio R)

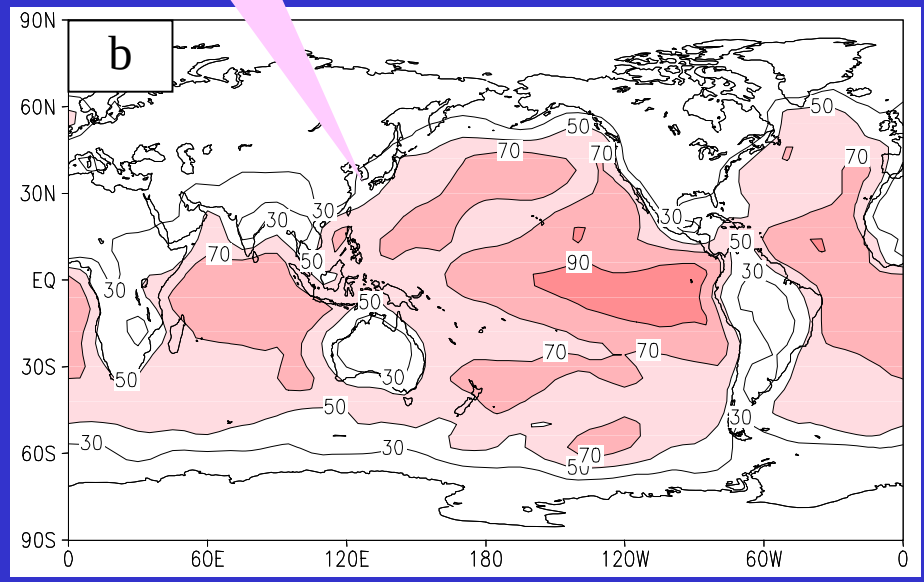
$$R = \hat{\sigma}^2_{TOT} = \frac{1}{N(n-1)} \sum_{i=1}^{N} \sum_{j=1}^{n} (x_{ij} - \bar{x}_i)^2 + \frac{1}{N-1} \sum_{i=1}^{N} (\bar{x}_i - \bar{\bar{x}})^2 - \frac{1}{n} \frac{1}{N(n-1)} \sum_{i=1}^{N} \sum_{j=1}^{n} (x_{ij} - \bar{x}_i)^2$$

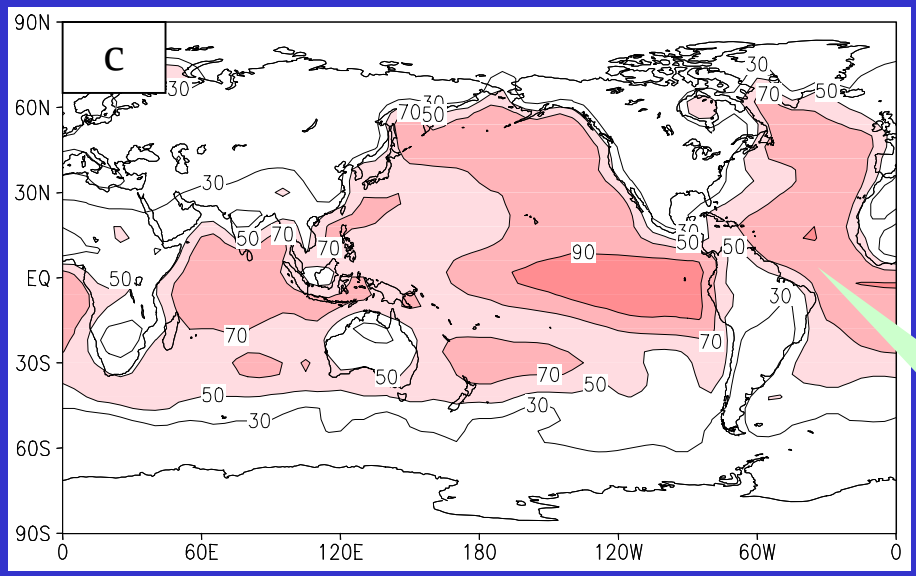
Distribution of R for surface air temperature



winter

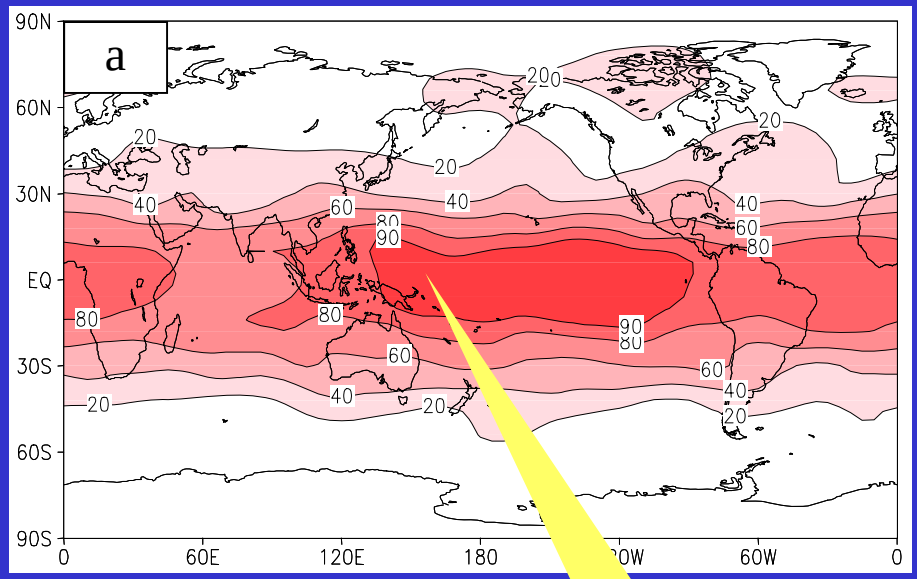
spring





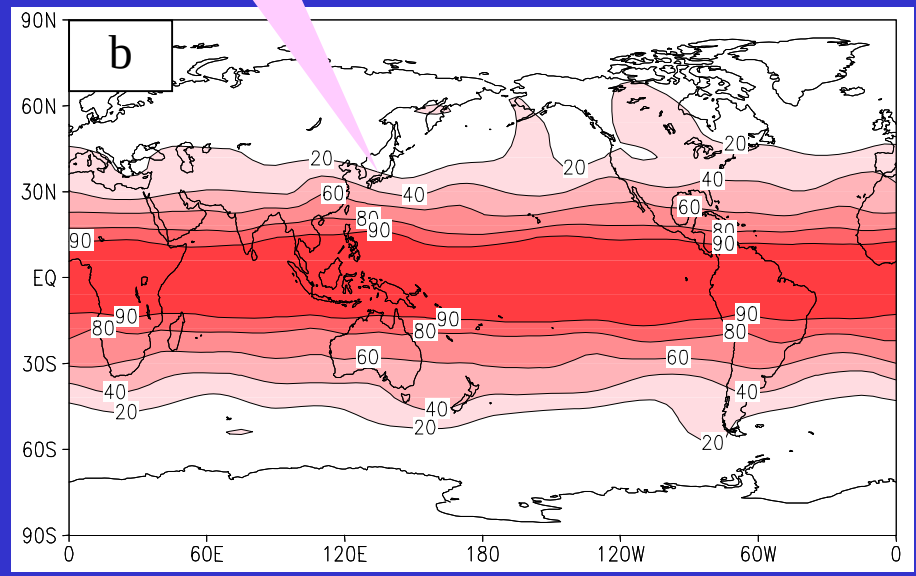
summer

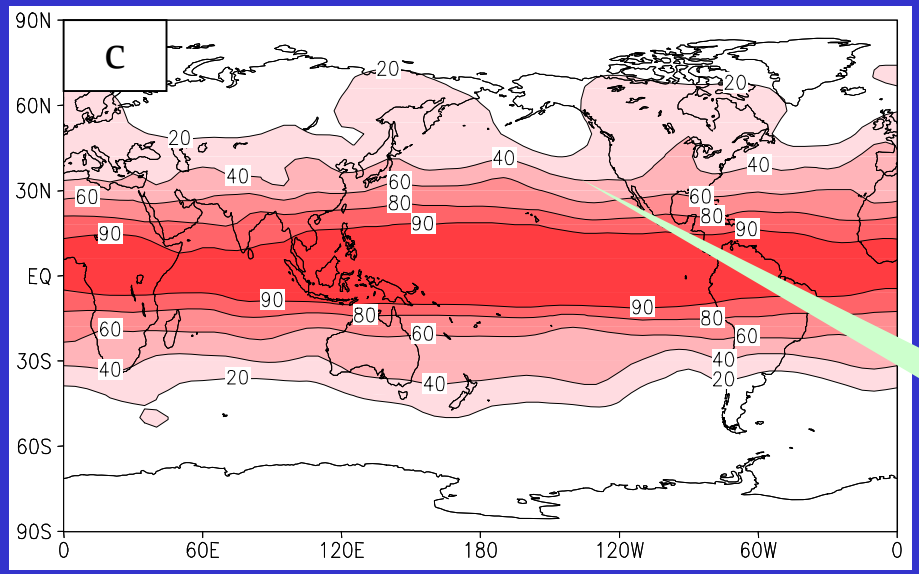
Distribution of R for geopotential height at 500 hPa



winter

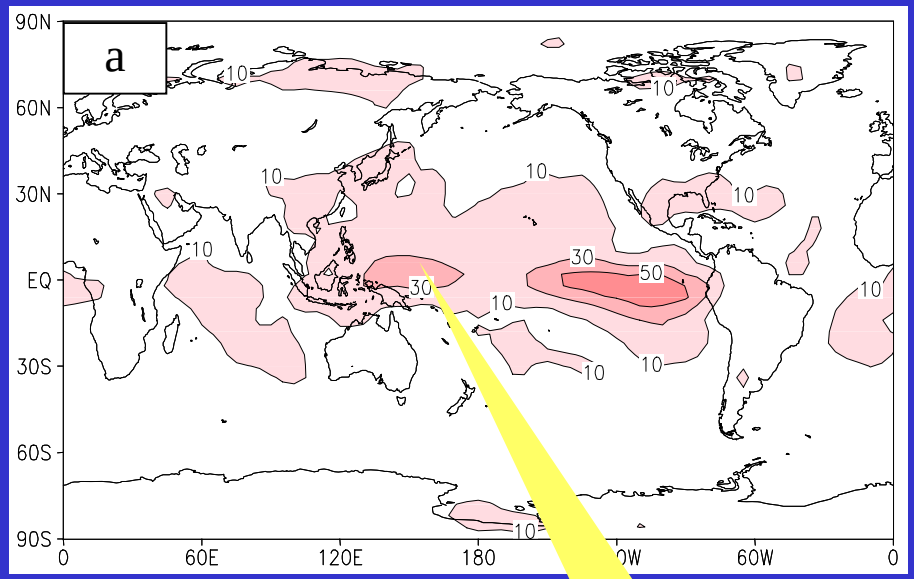
spring



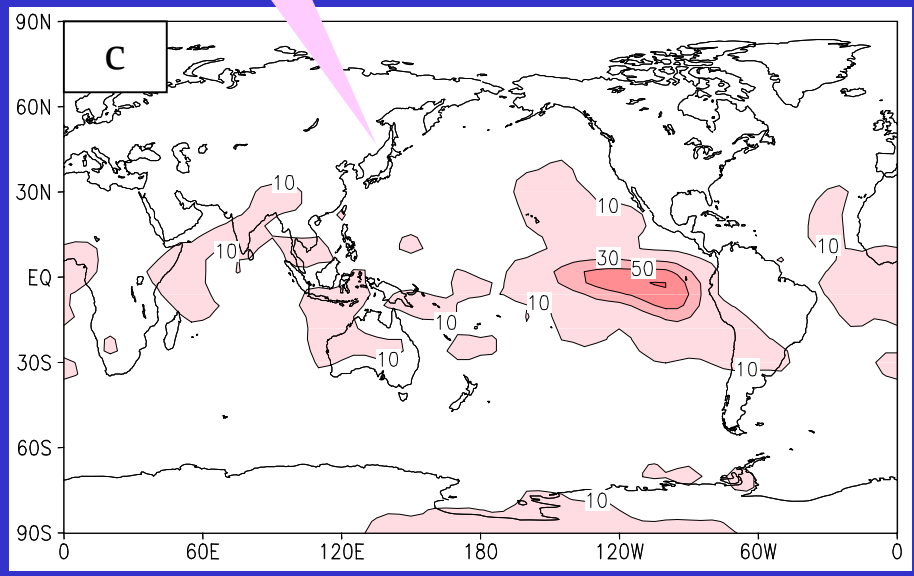


summer

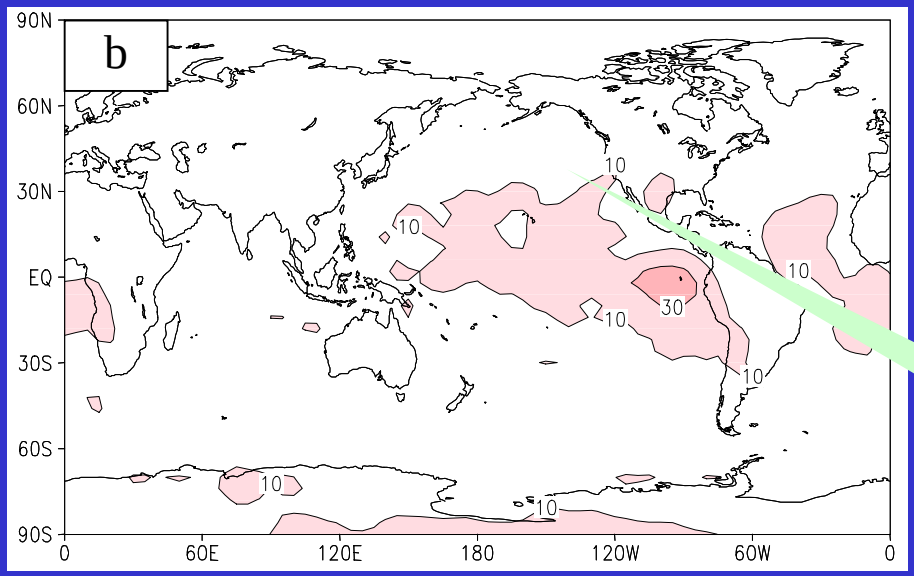
Distribution of R for precipitation



winter

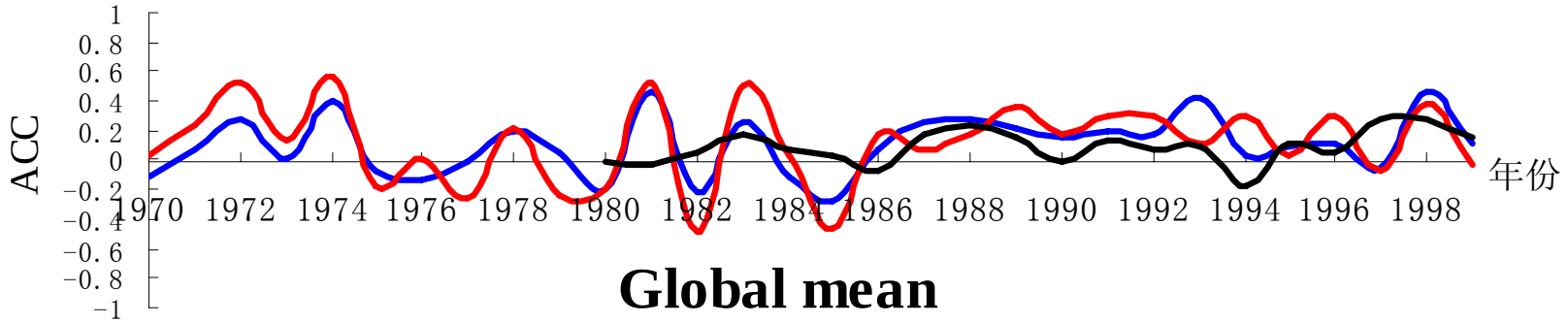


spring

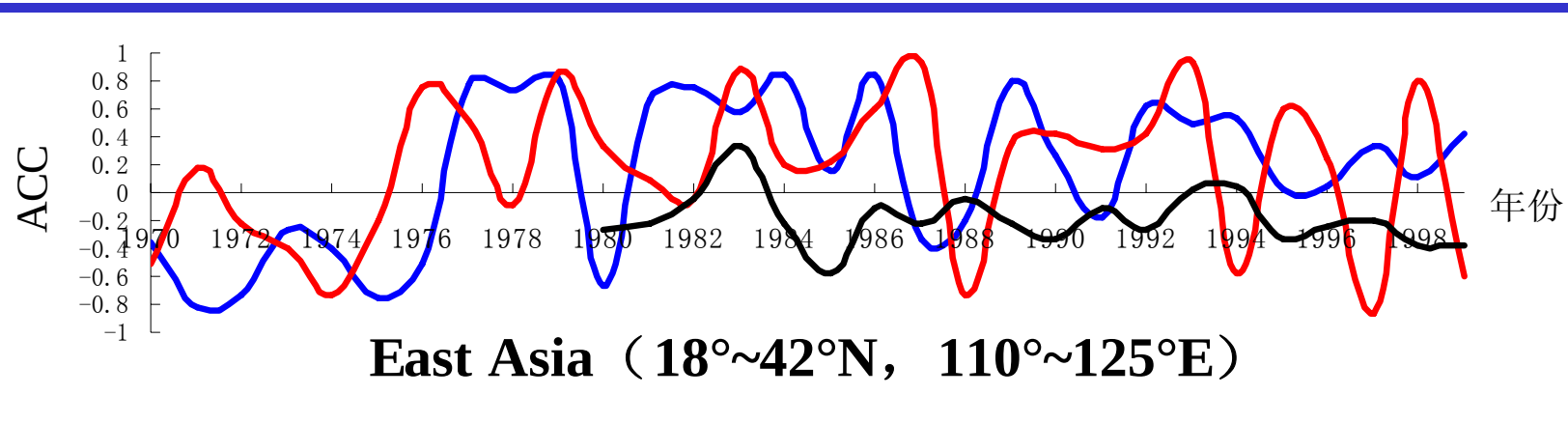


summer

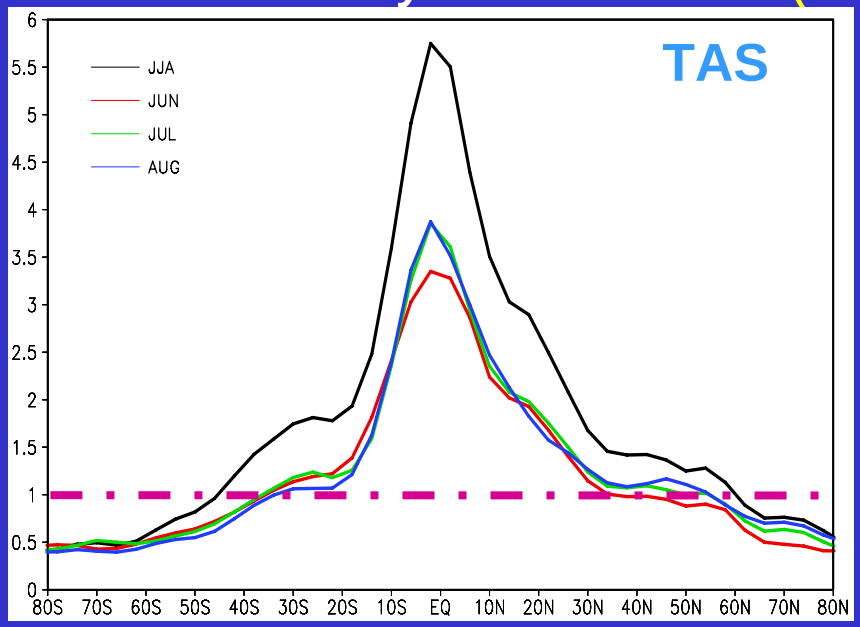
Interannual variation of spatial anomaly correlations, computed for the period 1970-1999

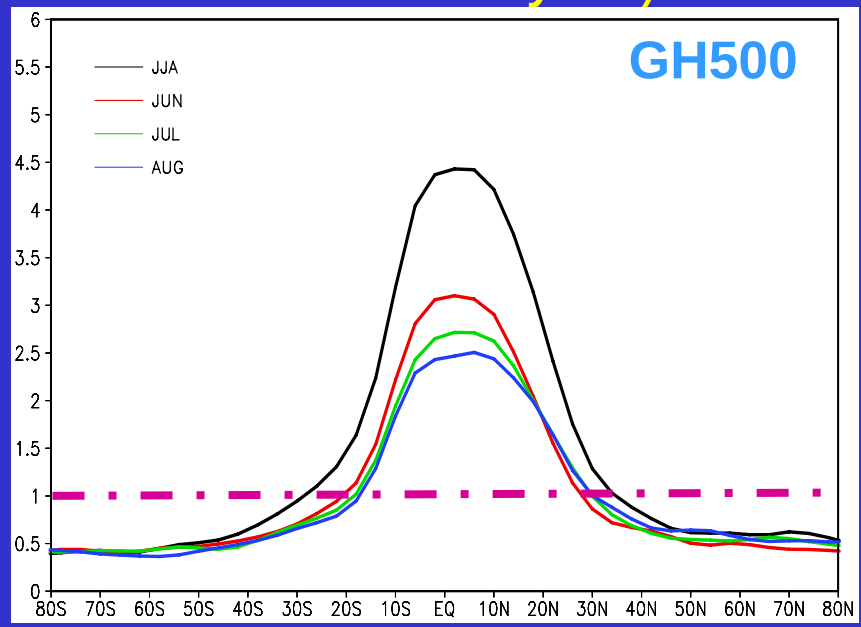


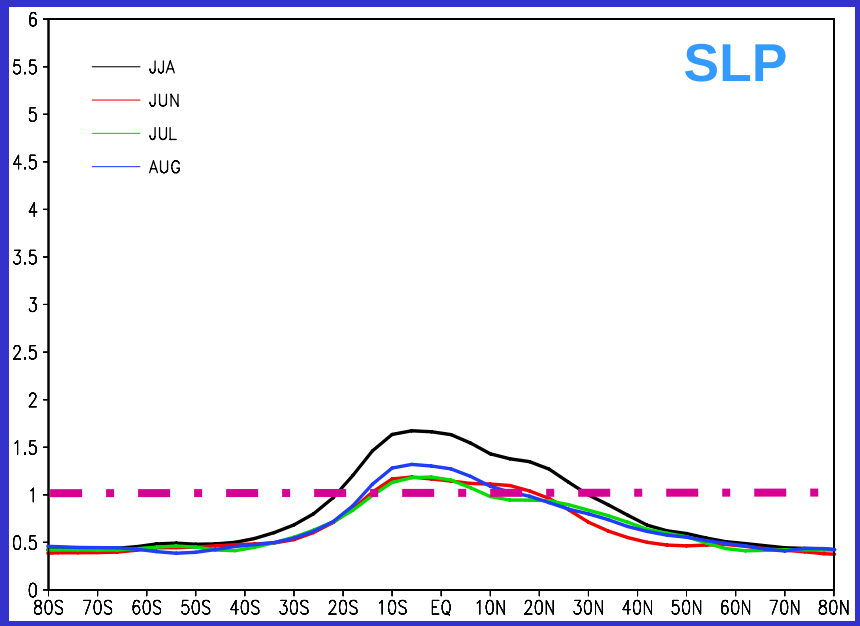
sea-level pressure — geopotential height at 500hPa — precipitation

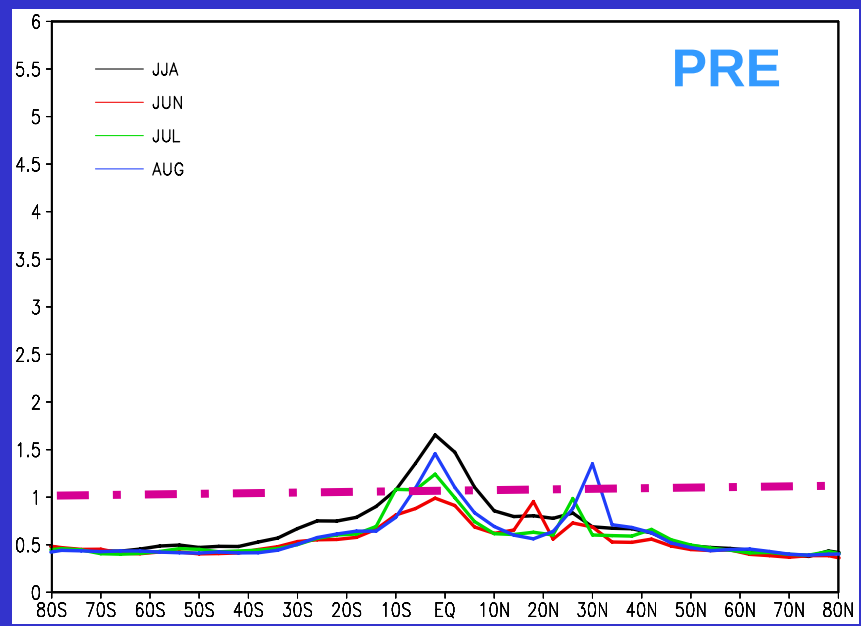


Zonal–mean distribution of the predictability of the seasonal and monthly mean climate (Standard deviation analysis)









Correlation coefficient difference between typical years and normal ones (Values greater than 0.1 are red)

Variables / Regions	H500	U200	TMP	SLP	PRE
Northwest China	0.195	-0.033	-0.014	-0.128	0.247
Northeast China	0.097	0.014	0.137	0.090	-0.062
Middle of North China	0.052	0.033	-0.275	0.126	-0.007
Middle of South China	0.185	-0.633	0.530	0.102	0.078
Southwest China	0.136	0.046	0.221	0.120	0.211
Jianghuai valley	-0.089	0.029	-0.249	-0.047	0.268
East Asia	0.010	-0.311	0.0023	0.195	0.148
Chosen years:1982, 1986, 1987, 1991, 1994, 1997					

El Niño events

Variables / Regions	H500	U200	TMP	SLP	PRE
Northwest China	0.404	0.521	0.070	0.573	-0.060
Northeast China	0.581	0.605	0.321	0.125	0.109
Middle of North China	0.353	0.252	0.064	-0.066	-0.336
Middle of South China	0.365	0.741	0.226	0.412	-0.026
Southwest China	0.097	0.539	-0.074	0.079	-0.141
Jianghuai valley	0.427	0.198	0.212	0.550	-0.184
East Asia	0.491	0.426	0.515	0.523	-0.060
Chosen years:1984, 1985, 1988, 1996, 1998					

La Niña events

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The initial atmospheric data and observed SSTA are from NCEP. The ensemble consists of seven integrations starting form last seven consecutive days in Feb or Oct., respectively.

Lower boundary conditions: Over the tropical Pacific region, the SSTA used in IAP9L-AGCM is the linear combination of observed SSTA in initial month and SSTA forecasted by IAP ENSO prediction system：

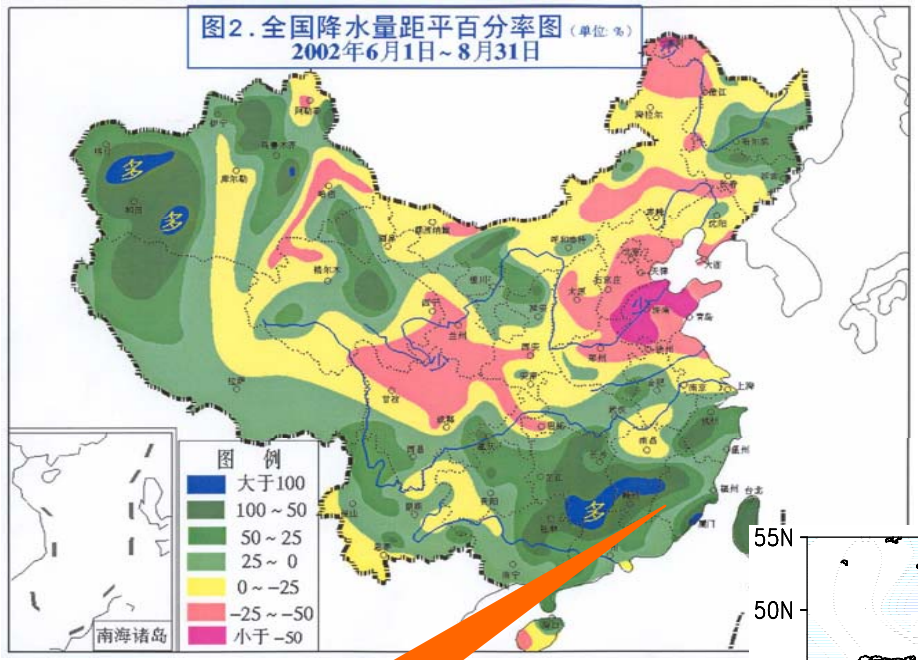
$$(SSTA)^t=\alpha(t)\,[(SSTA)_{to}]_{Obs}+[1-\alpha(t)][\,(SSTA)_{Fcst}]^t$$

Here, $\alpha(t)$ varies from 1.0 to 0.0 during the integration time

Over other regions, SSTA is kept as the observed SSTA in initial month.

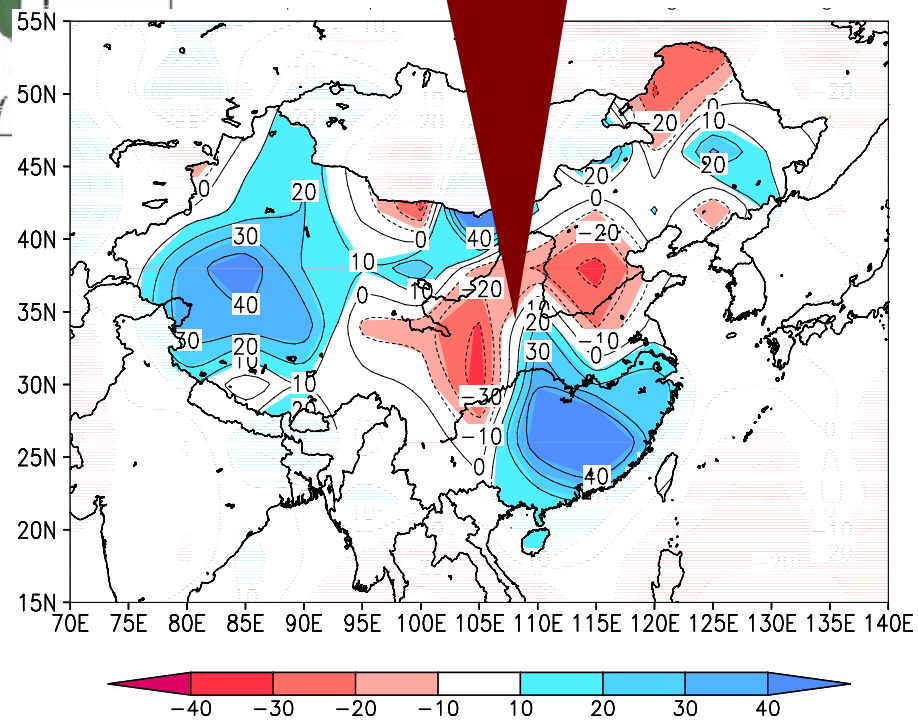
Real-time prediction for summer climate

Percentage Summer Rainfall Anomaly for 2002

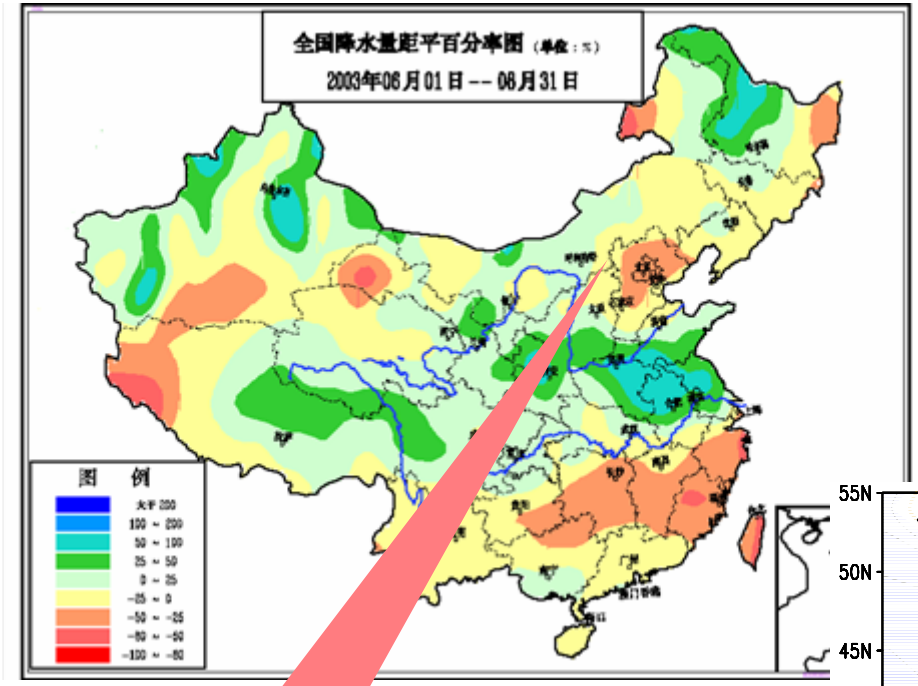


obserbvation

Prediction (corrected)

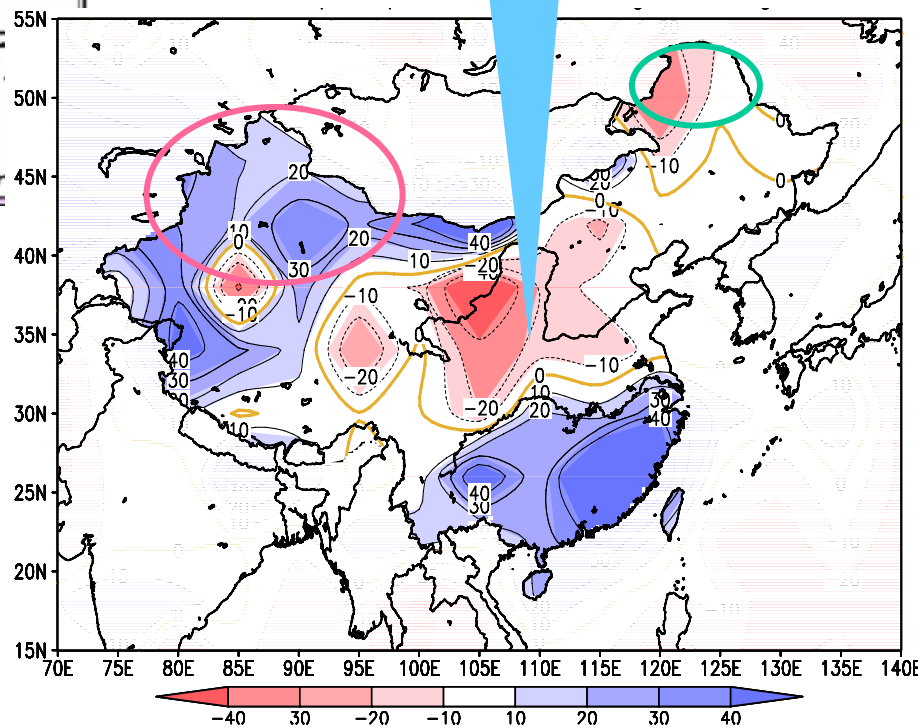


Percentage Summer Rainfall Anomaly for 2003

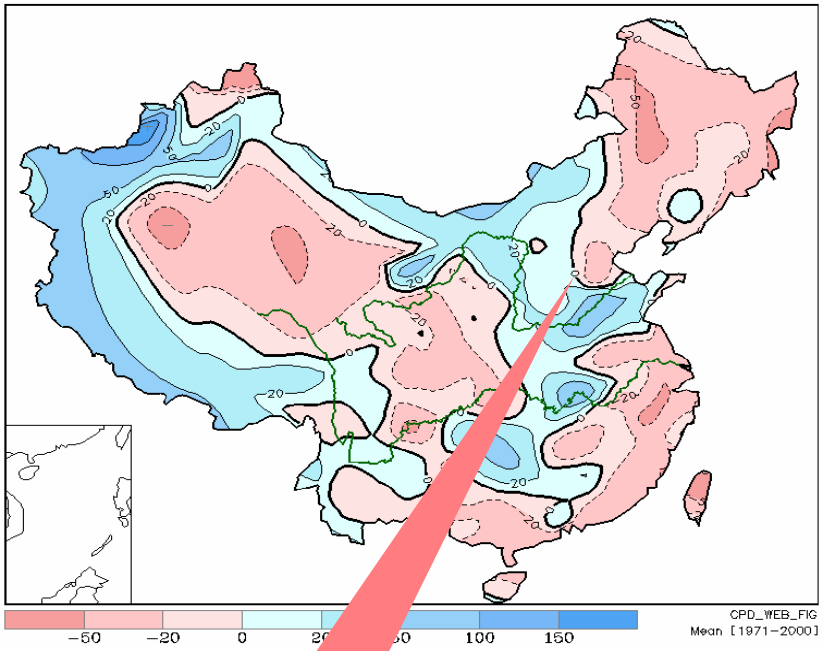


observation

prediction

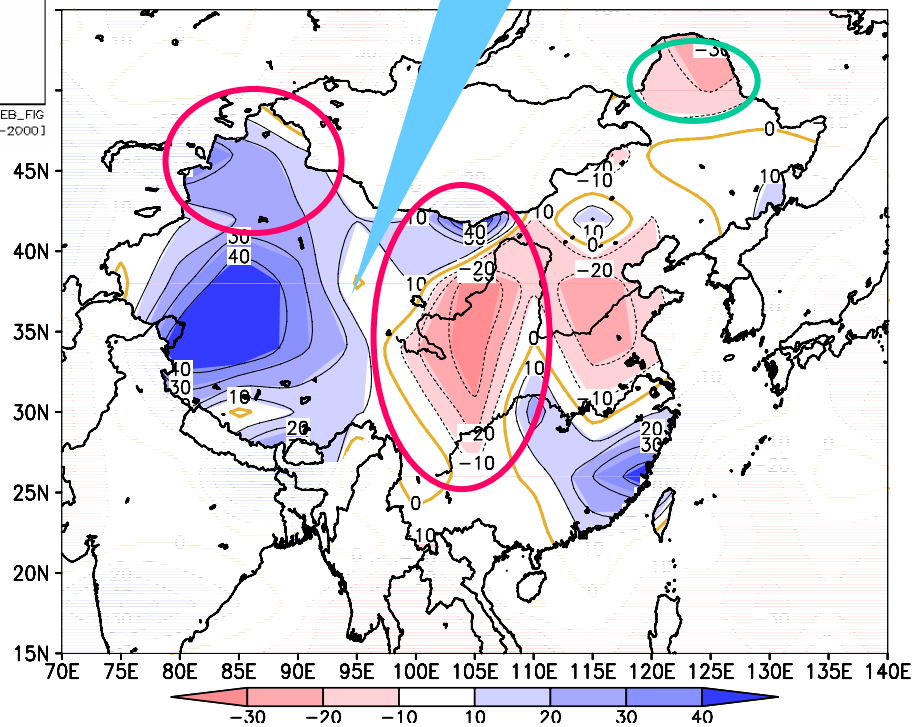


Percentage Summer Rainfall Anomaly for 2004

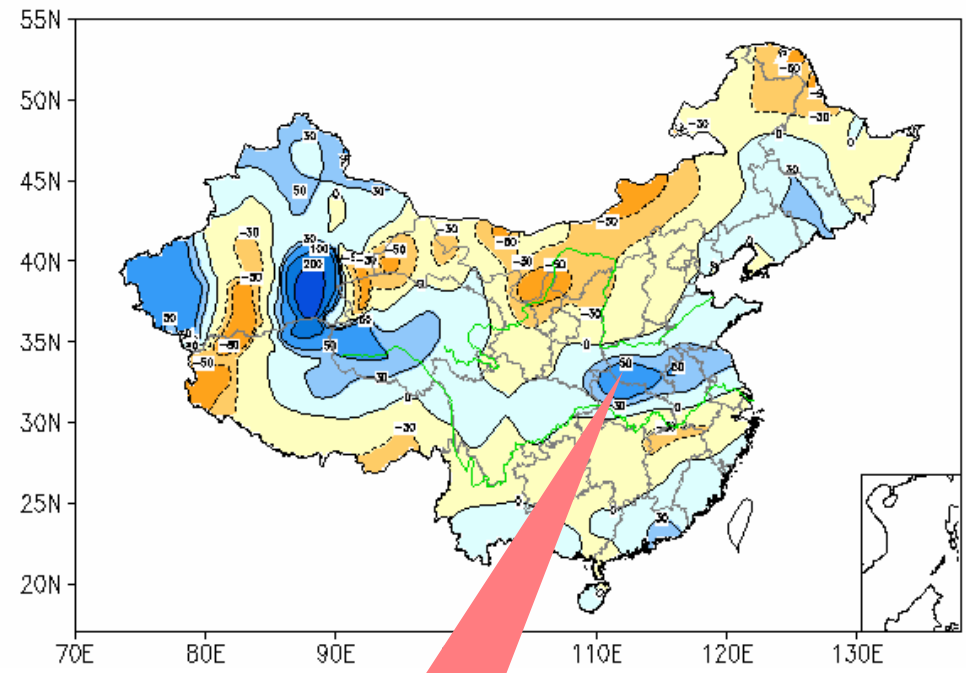


observation

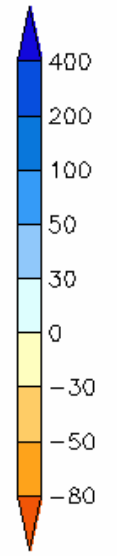
prediction



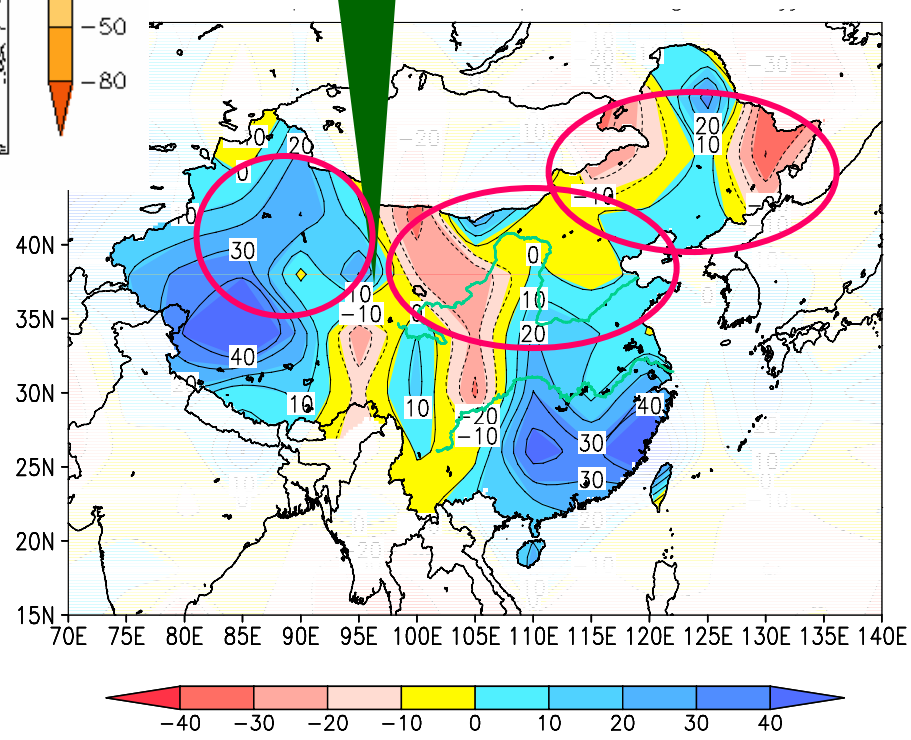
Percentage Summer Rainfall Anomaly for 2005



observation



prediction



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Summary

- The predictability of winter climate over China and even East Asia enhances obviously during ENSO cycle, especially during La Niña phase;

- The impact of initial anomalies play an very important role in short-term climate prediction over both China and Europe, and it is much more significant in the typical years , especially over northern mid- and high latitudes;

Summary

- Summer rainfall anomalies over China can be well captured by IAP9L-AGCM during some years, especially for 2002. Generally, the model's skill is comparatively high over Northern part of China and upper reach of Yellow River;

- Detailed pattern of the rainfall anomalies can't be predicted.
  ----- Coarse resolution, parameterization, physical process depiction ….;
- Magnitude of the prediction is relative weak compared with the observation.
  ----- Initial anomalies, ensemble method ….

Thank you!

利用IAP9L-AGCM对2005年冬季至2006年夏气候异常的数值预测

报告内容

- 模式简介
- 资料及预测方案
- **2005/06**年冬季气候异常形势
- **2006**年春季沙尘气候异常
- **2006**年夏季气候异常形势

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IAP9L-AGCM

中科院大气物理研究所发展的全球格点大气模式. (*Zeng, 1987; Zhang, 1990; Liang, 1996; Bi, 1993*)

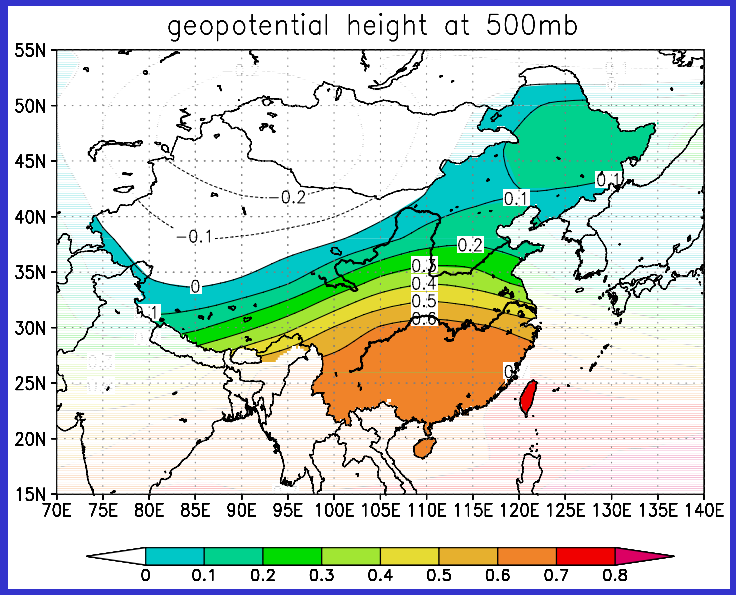
水平分辨率: $4^o \times 5^o$;
垂直分辨率: 9 层, 模式层顶 10hPa.

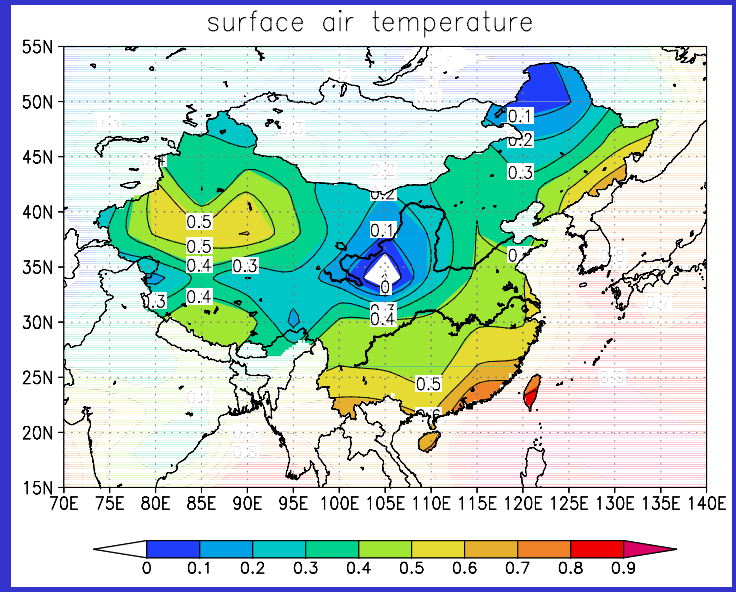
IAP ENSO 预报系统

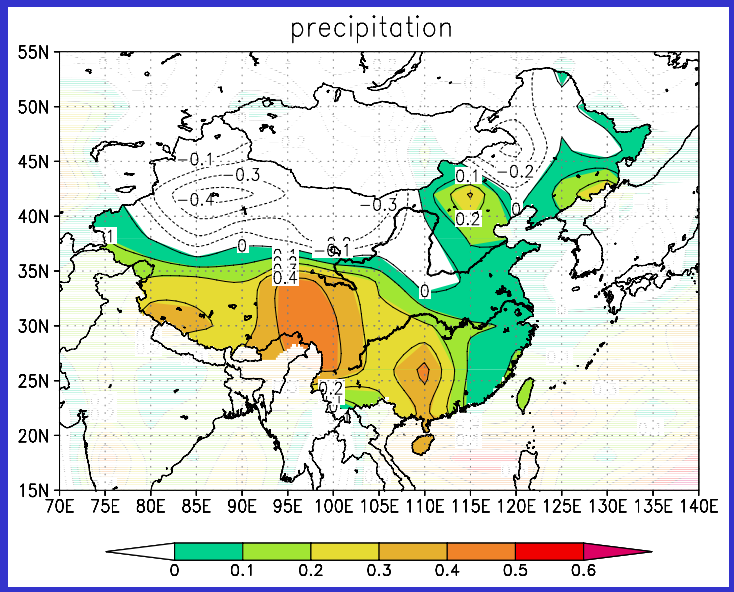
热带海洋和全球大气耦合模式. (*Zhou et al., 1998*)

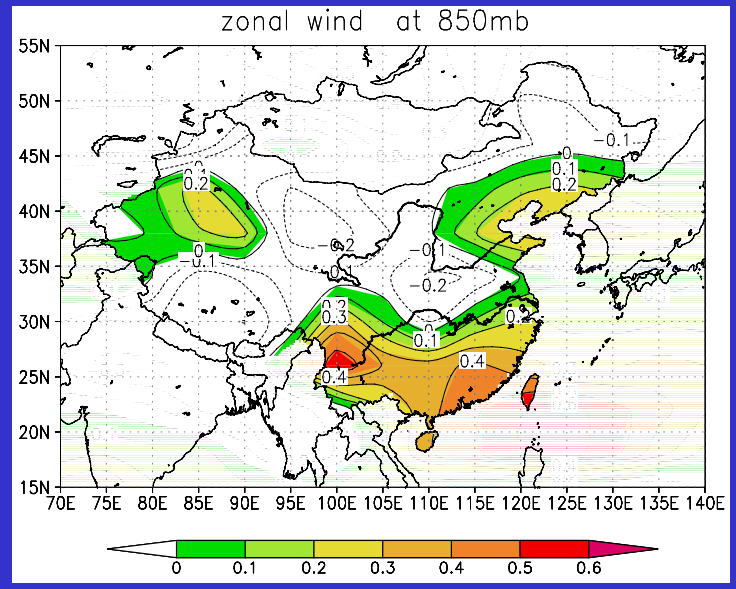
水平分辨率: $1^o \times 2^o$
垂直分辨率: 14 层

要素场冬季回报结果与实测间相关系数分布









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- **2006**年夏季气候异常形势

初始场：2005年10月16～23日00时NCEP实测大气，集合样本个数为8个

边界场：热带太平洋地区的SSTA为9月实测海温距平与IAP-ENSO预测系统预报结果的线性组合：

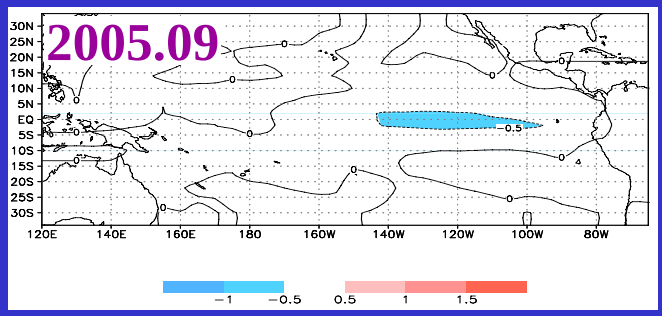
$$\alpha(t)SSTA_{obs}(t_0)+[1-\alpha(t)]SSTA_{mod}(t)$$

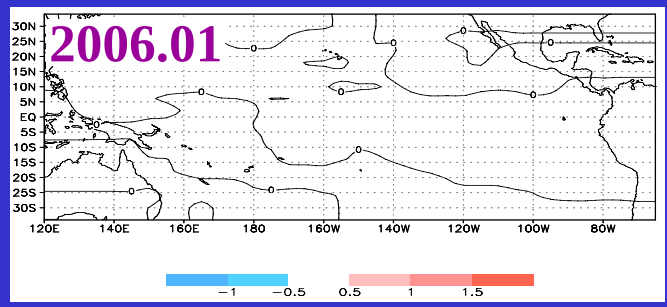
$\alpha(t) = 1.0, 0.8, 0.6, 0.4, 0.2, 0.1, 0.1$ 2005.09~2006.03

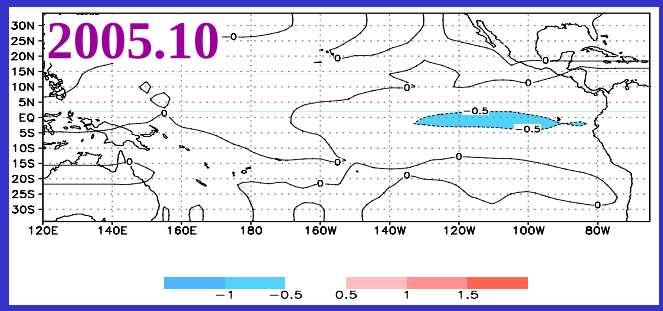
$\alpha(t) = 0.0$ 2006.04~2006.09

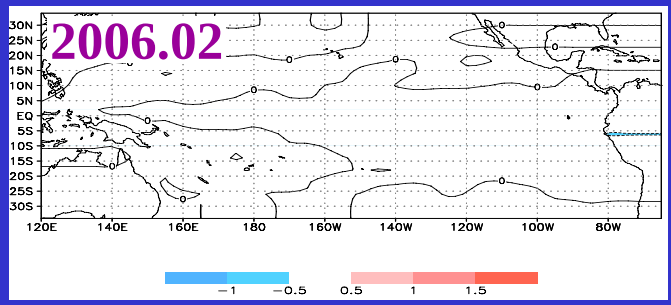
在热带太平洋以外地区保持9月份实测温距平不变

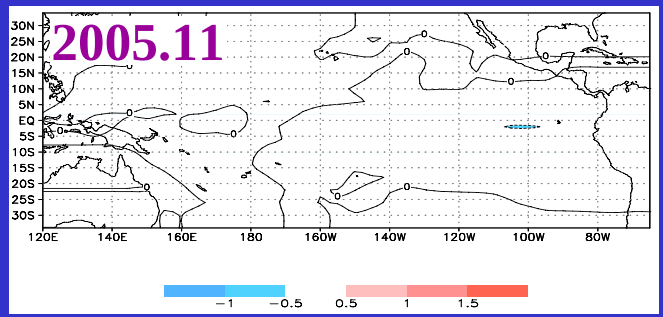
2005年9月至2006年4月海温演变的模式预报结果

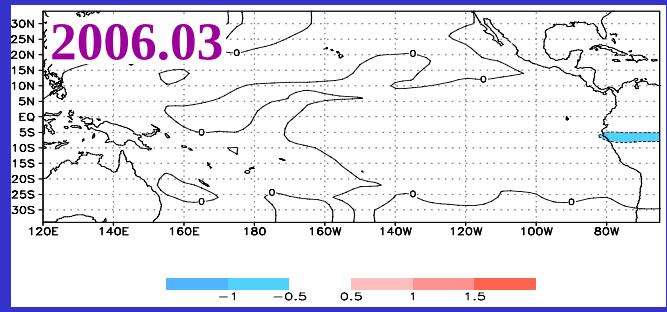


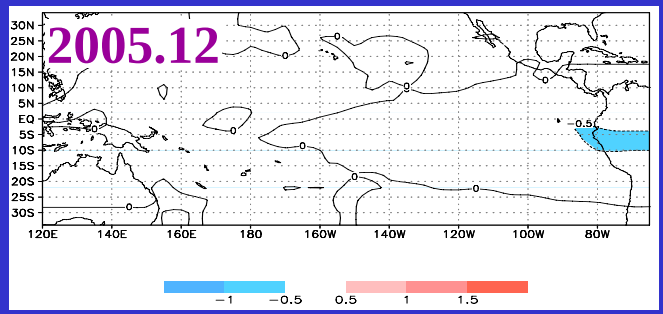


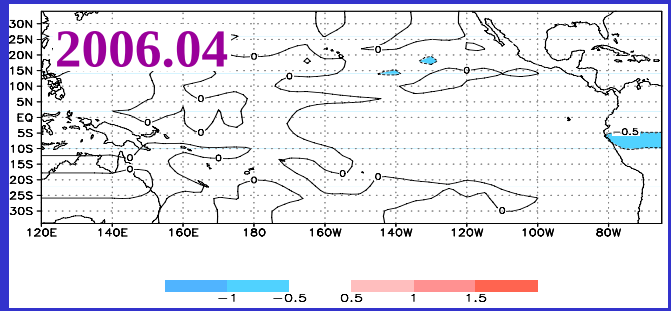












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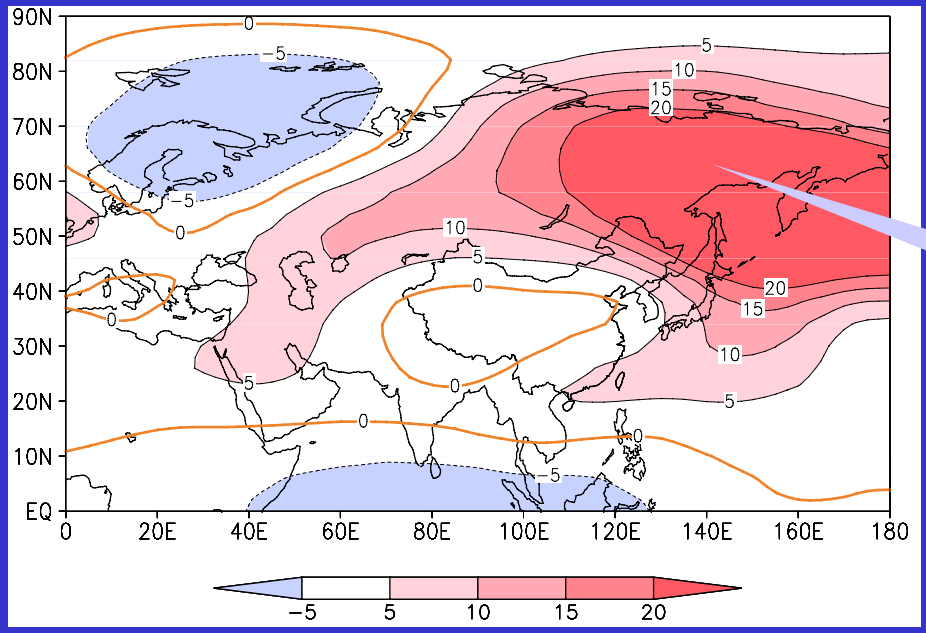
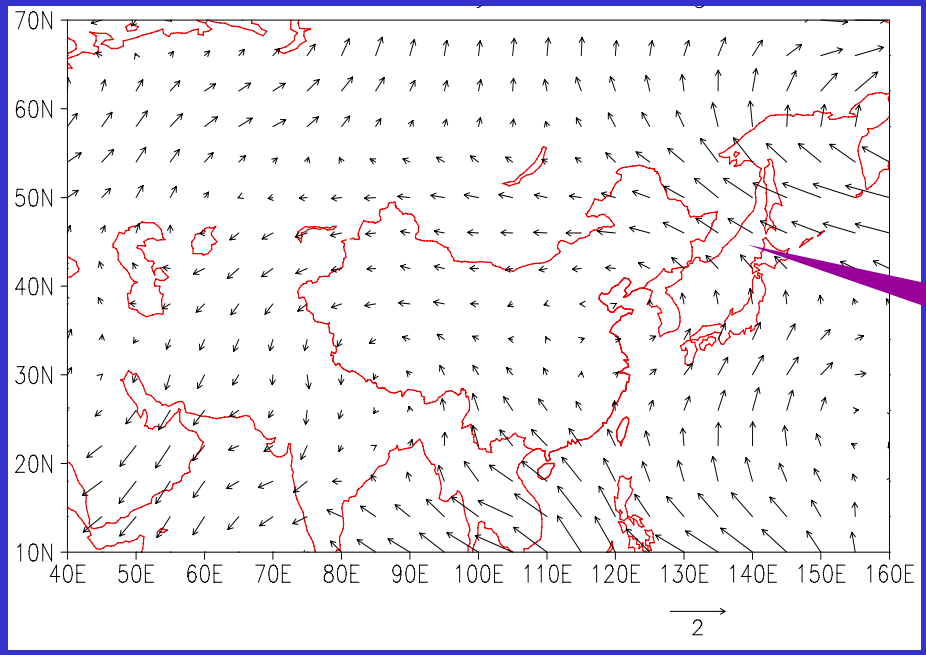
- **2006年夏季气候异常形势**

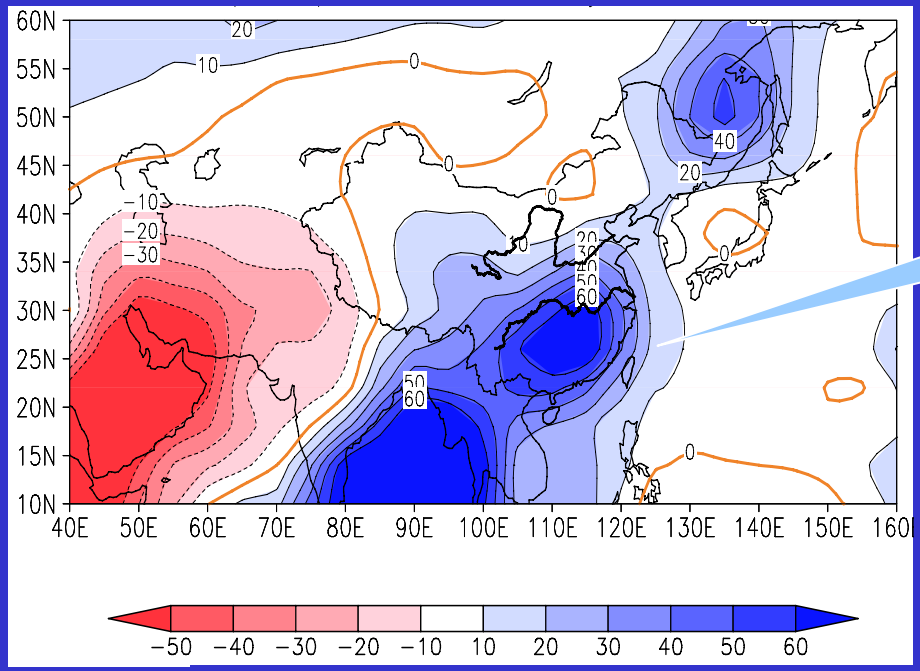


500 hPa位势高度场

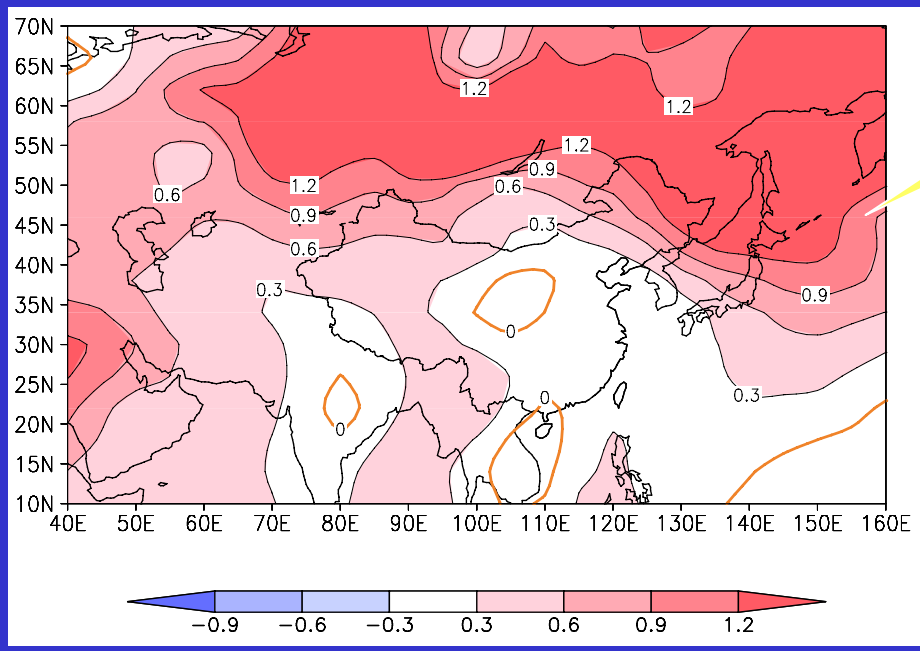


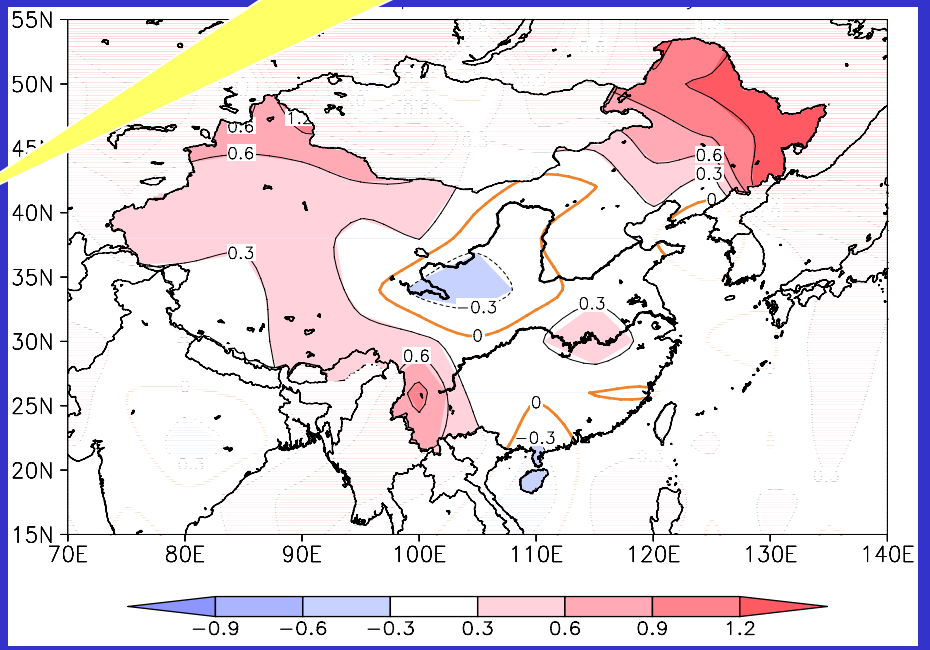
850 hPa风场

降水距平百分率



表面气温 距平





2005/2006年冬季气候预测意见

- 预计今冬影响我国的冷空气势力较弱，即冬季风偏弱. 东亚大槽将会减弱，不利于我国春季沙尘天气的发生.
- 我国南方大部分地区及东北东北部地区降水较常年偏多，降水中心位于长江以南。全国其它地区降水接近常年。
- 今冬我国大部分地区温度正常或略偏暖，主要的温度正距平区位于东北、西南及新疆北部；黄河上游地区温度较常年略偏低。此外，欧亚大陆北部出现温度正距平。

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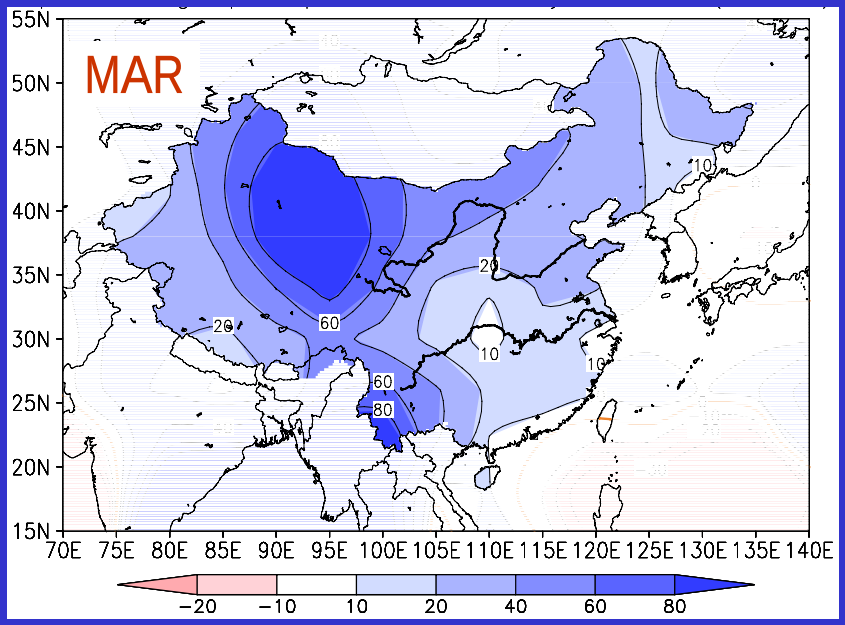
- **2006**年夏季气候异常形势

降水距平百分率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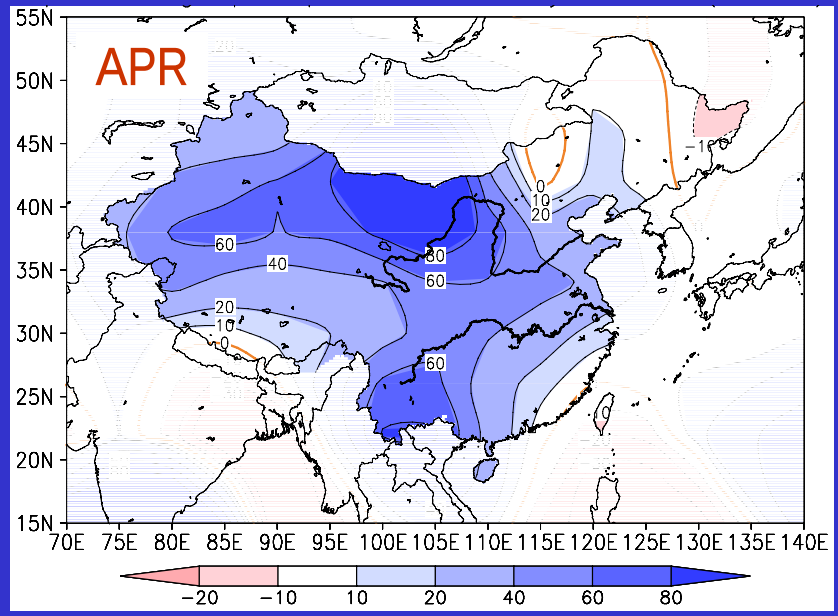
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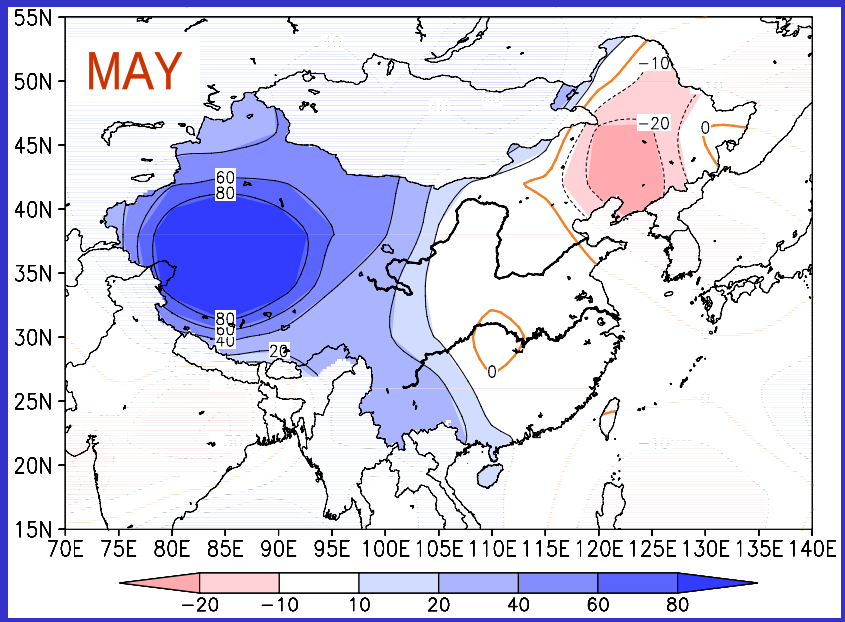
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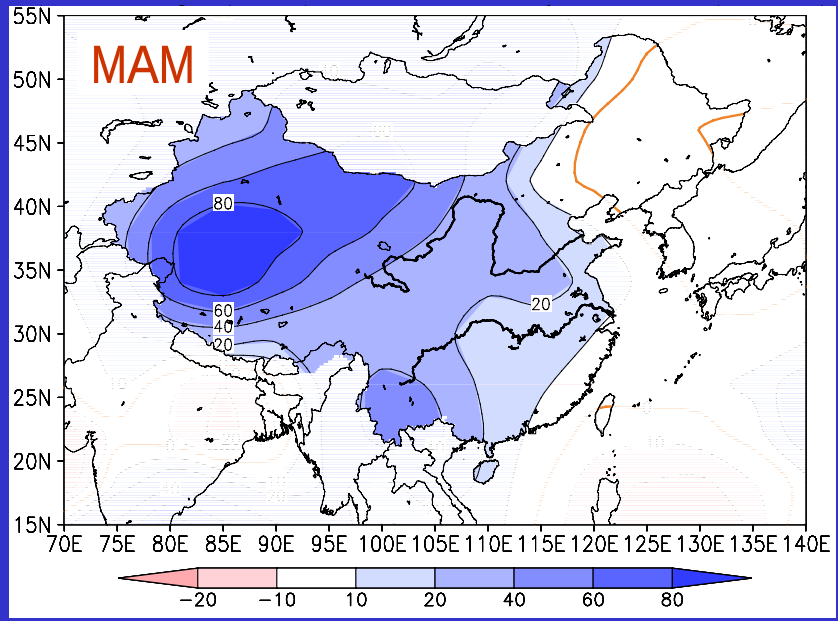
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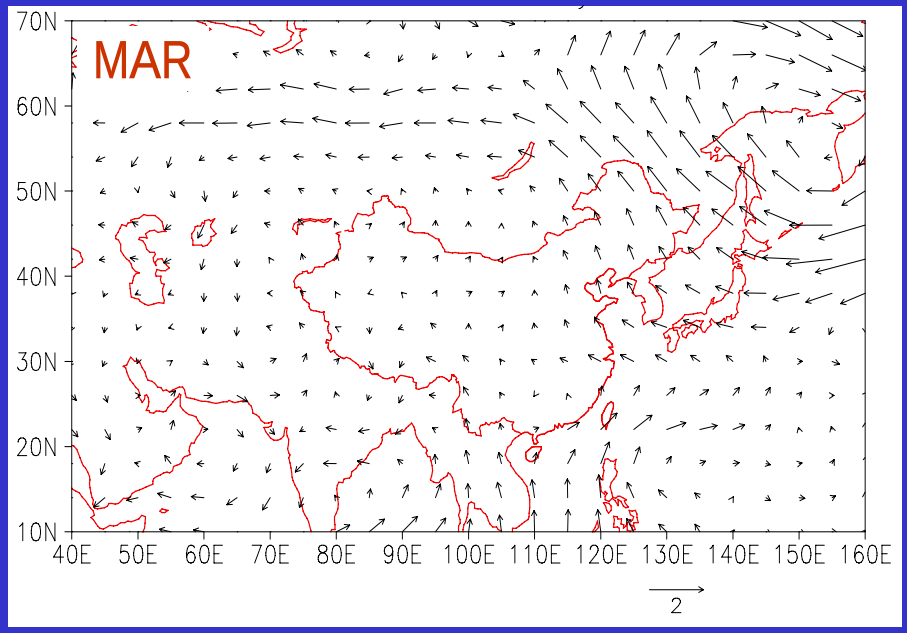
850hPa风场异常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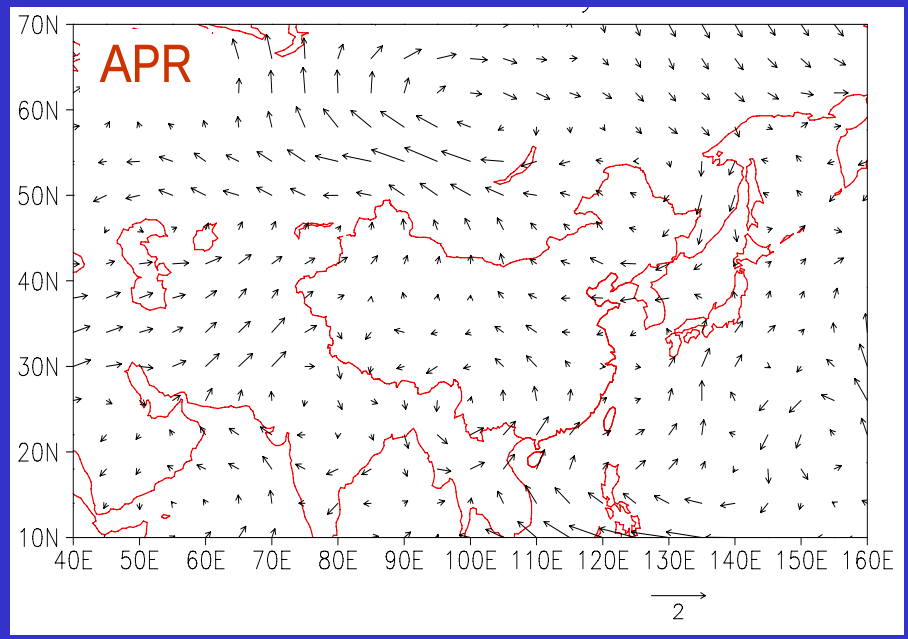
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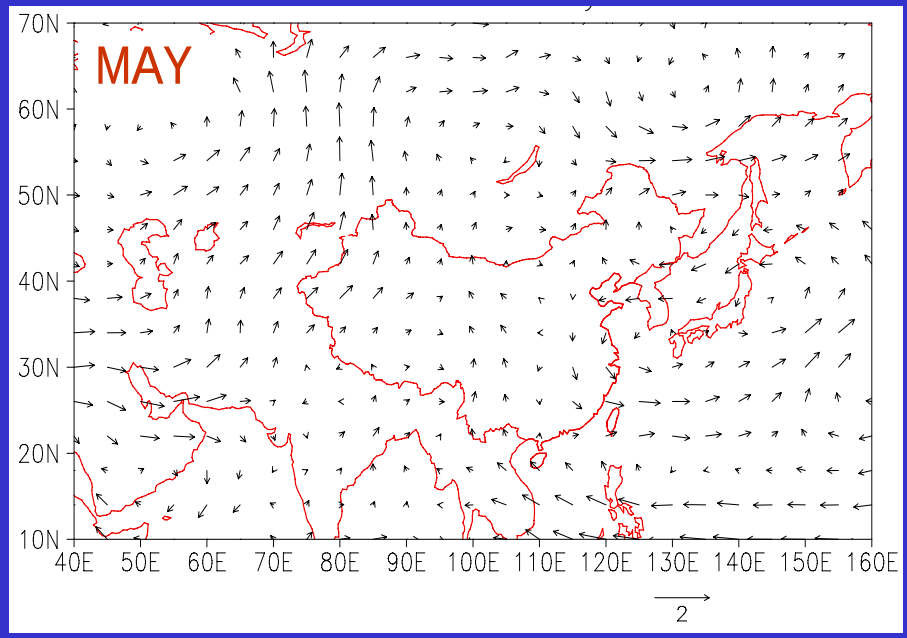
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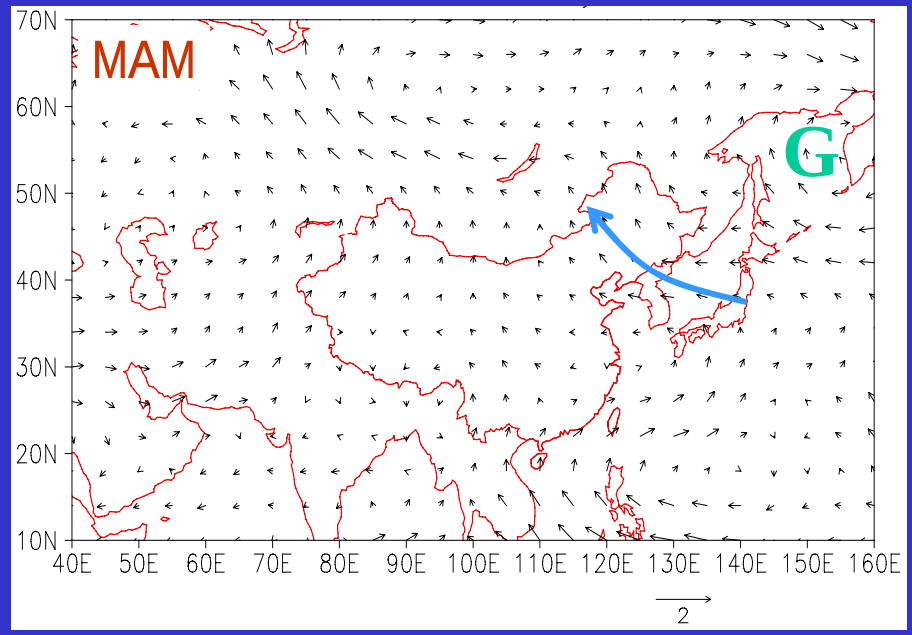
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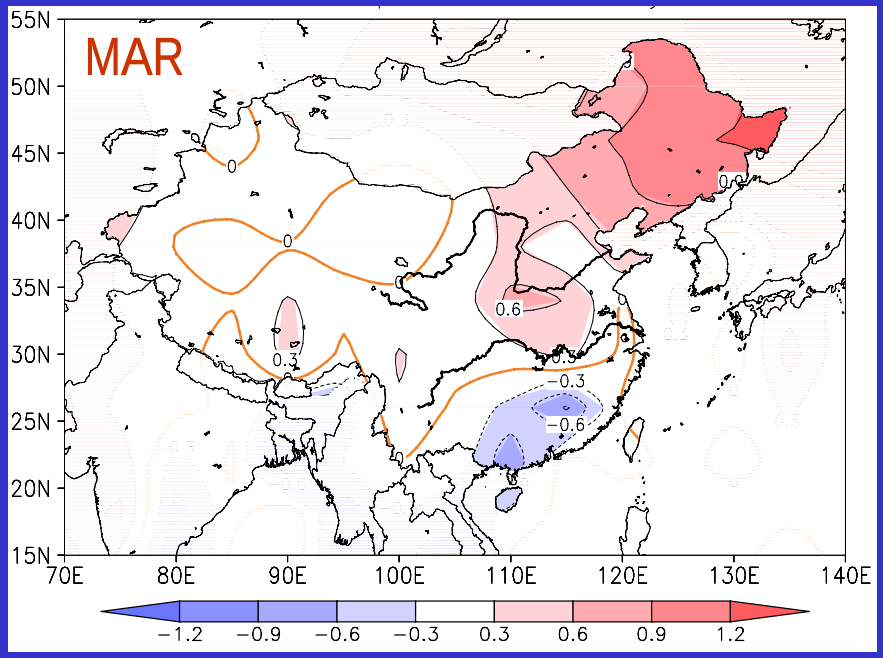
表面气温异常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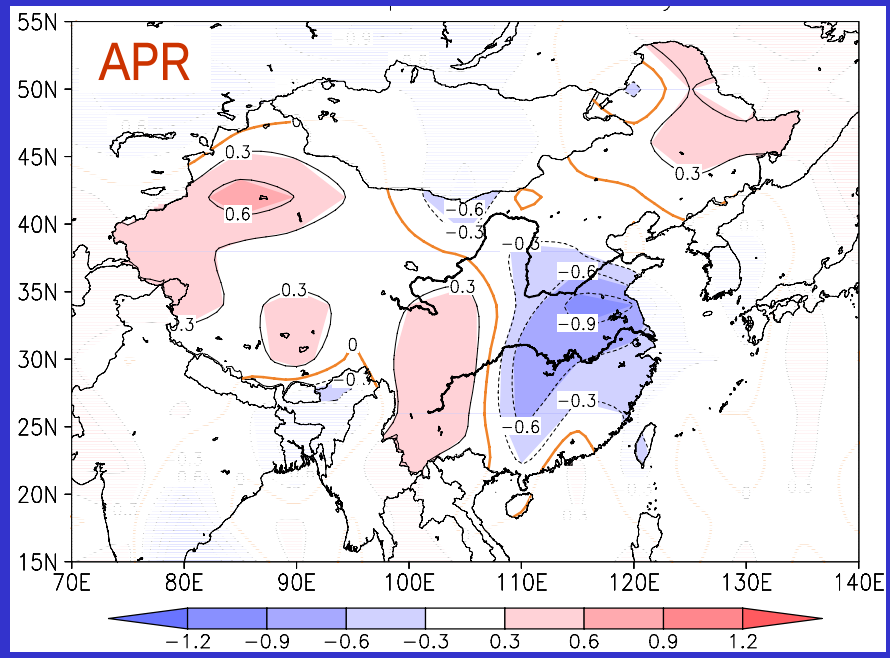
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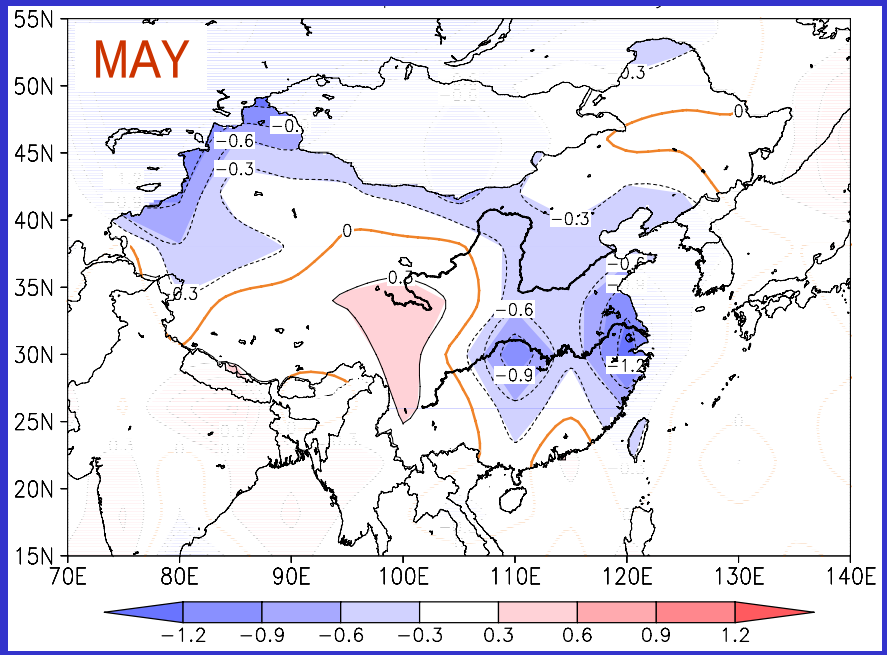
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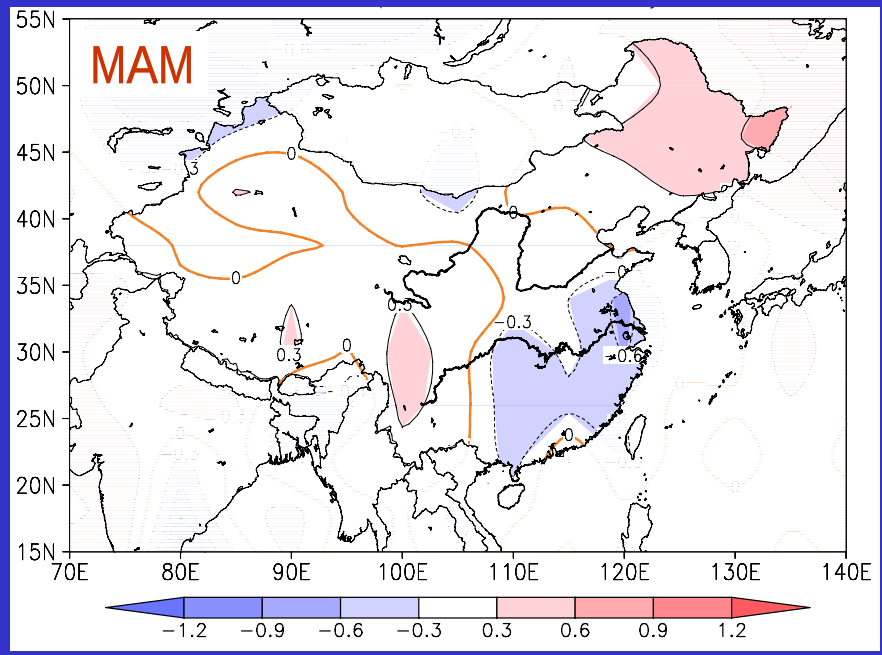
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2006年春季沙尘气候预测意见

- 预计明春我国西北及内蒙沙源地区的月平均及季节平均降水均较常年正常或略偏多，不利于沙尘天气的产生；
- 预测明春我国西北及内蒙地区无偏北风距平，这将不利于沙尘的产生和向我国输送，从而不利于我国沙尘天气的发生；
- 明春我国北方地区温度正常或较常年略低，西北北部以及内蒙地区月平均气温上升比较缓慢，致使地表解冻速度减缓，从而不利于春季我国沙尘天气的发生；
- 综合今冬、明春的预报结果，认为明春沙尘天气将正常略偏少.

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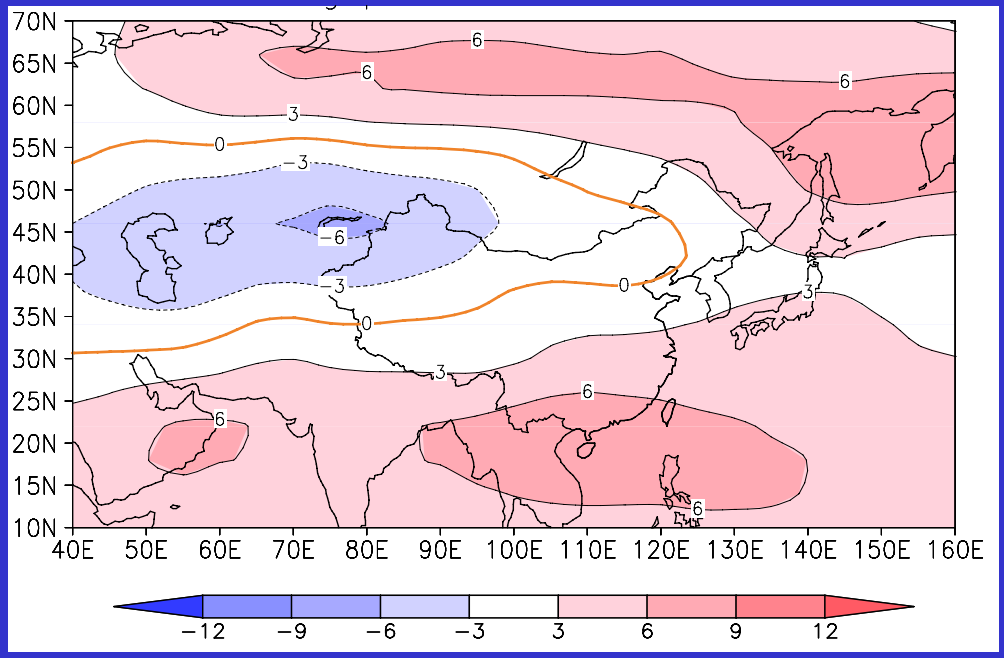
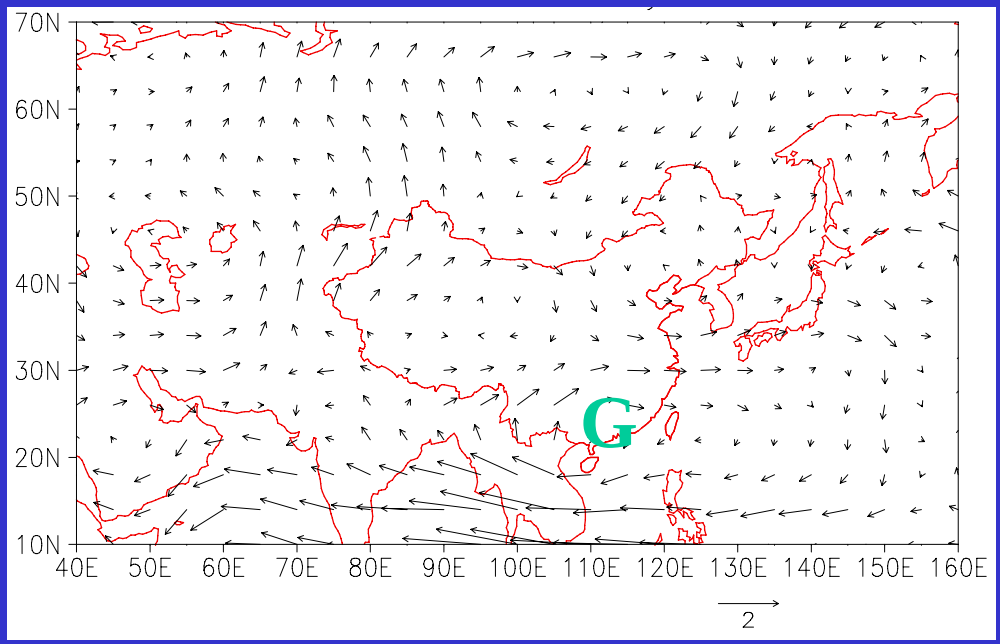
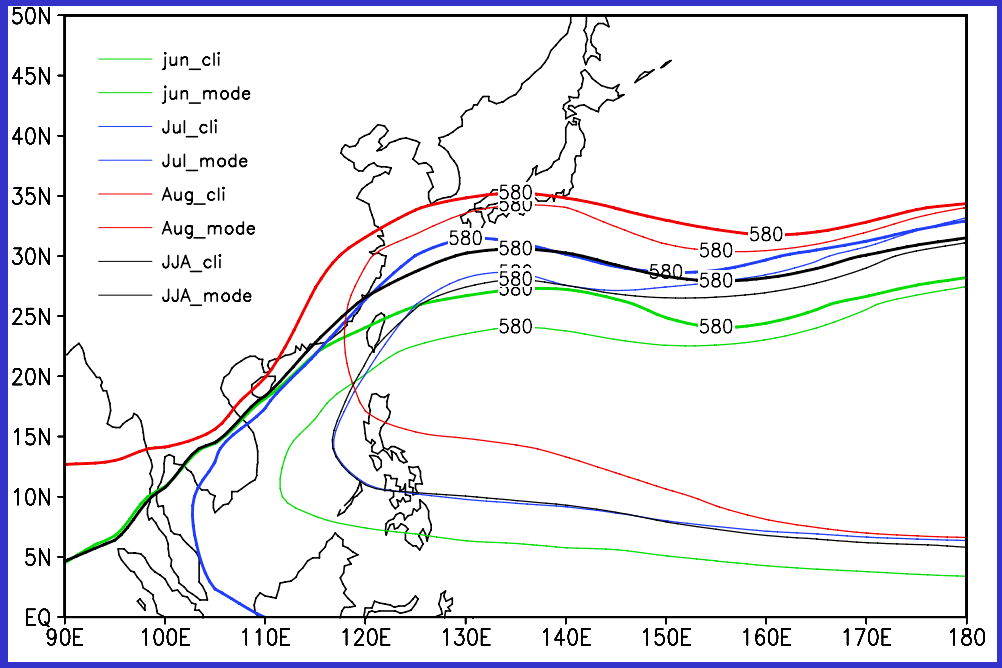


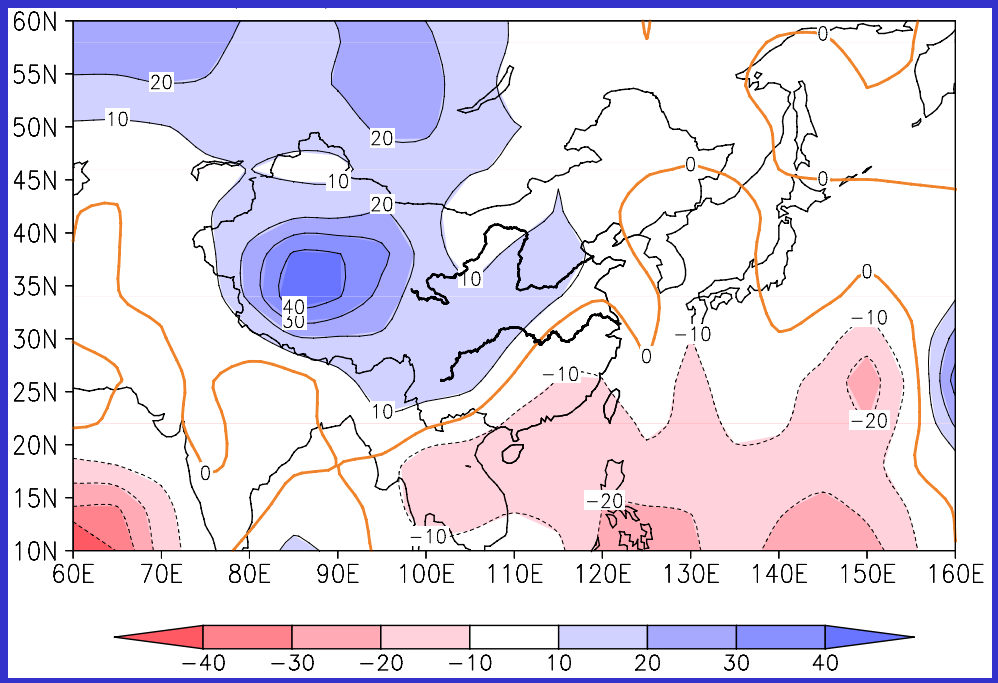
500hPa位势高度场距平



850 hPa 风场异常



副热带高压位置异常



降水距平百分率

2006年夏季气候预测意见

- 预计2006年夏季鄂藿次克海一带出现高度场正距平。夏季月平均及季节平均的副高位置均偏北；
- 除了我国东北东南部地区降水较常年略偏少以外，全国其他地区降水正常或略偏多，主要的降水正距平出现在新疆南部地区。

谢　谢!

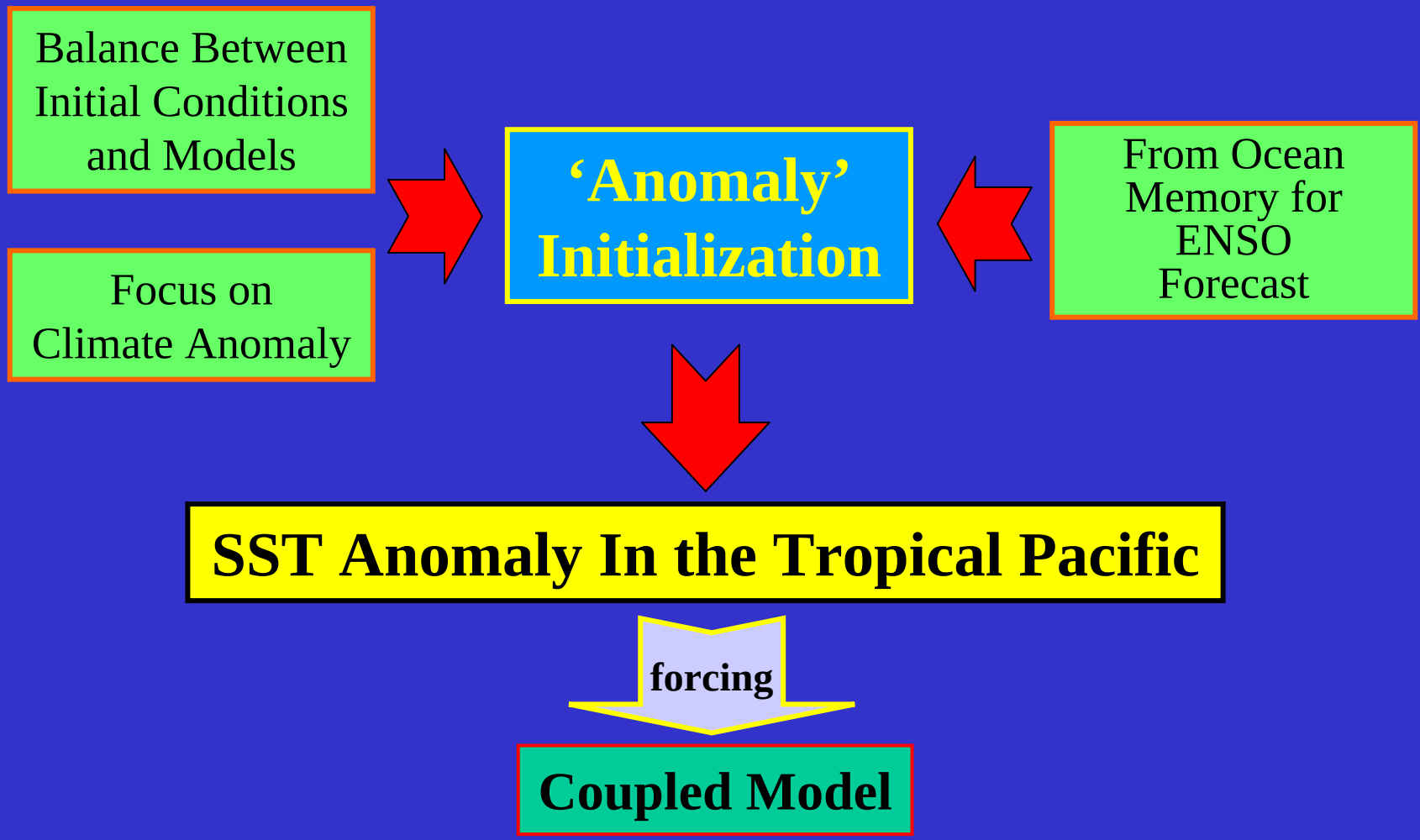
Summary

- Simulated climatological precipitation compares favorably to observational one in the both shape and magnitude of latitudinal profile, particularly in winter . In contrast, precipitation is somewhat underestimated by the IAP9L-AGCM near equator, which is more evident in summer ;

- The model's predictability is

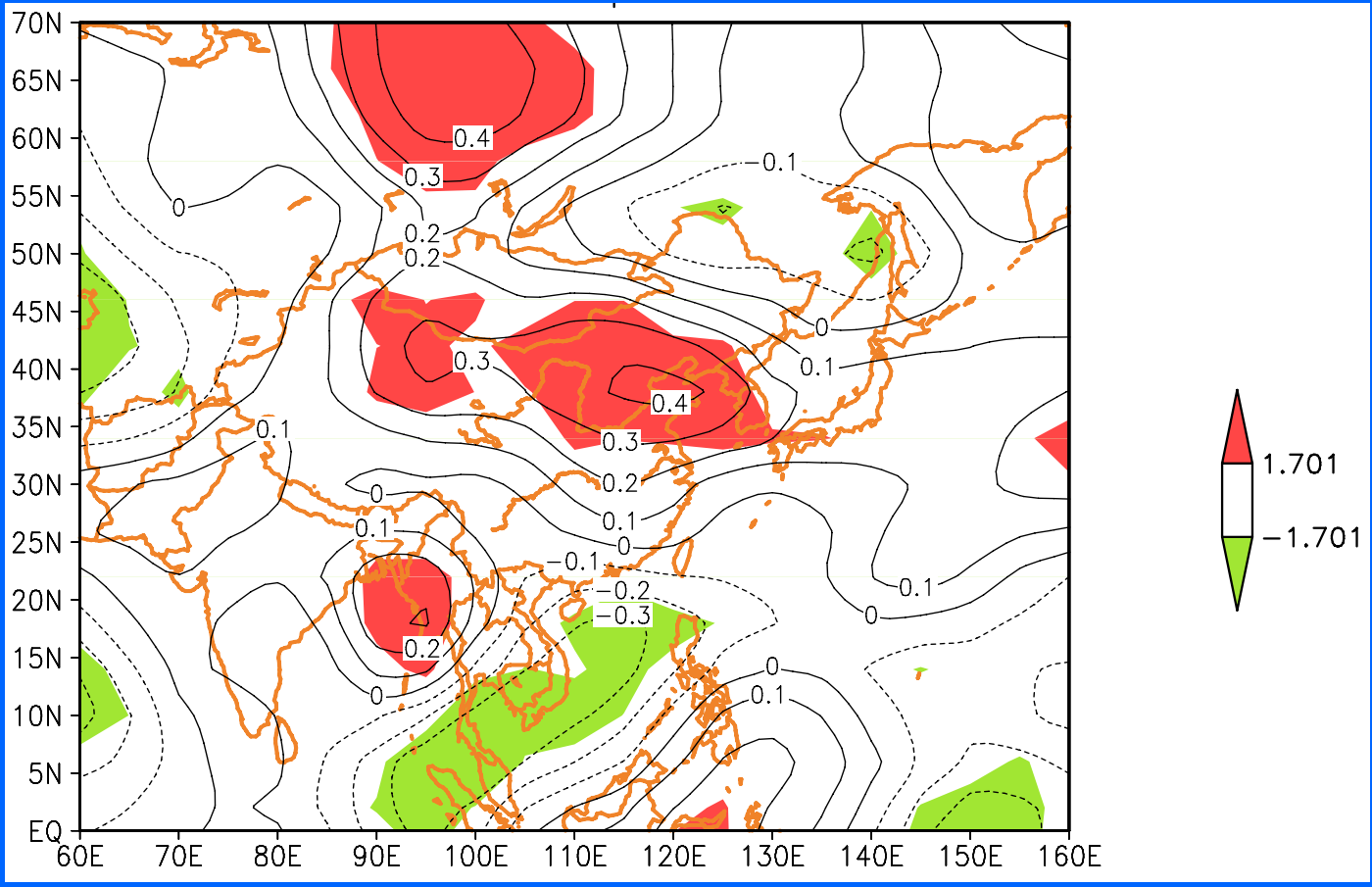
higher	lower
At low latitudes	At high latitudes
In ocean	Over land
In mid- and high	Lower one
Seasonal mean	Monthly mean

Forecast Initialization



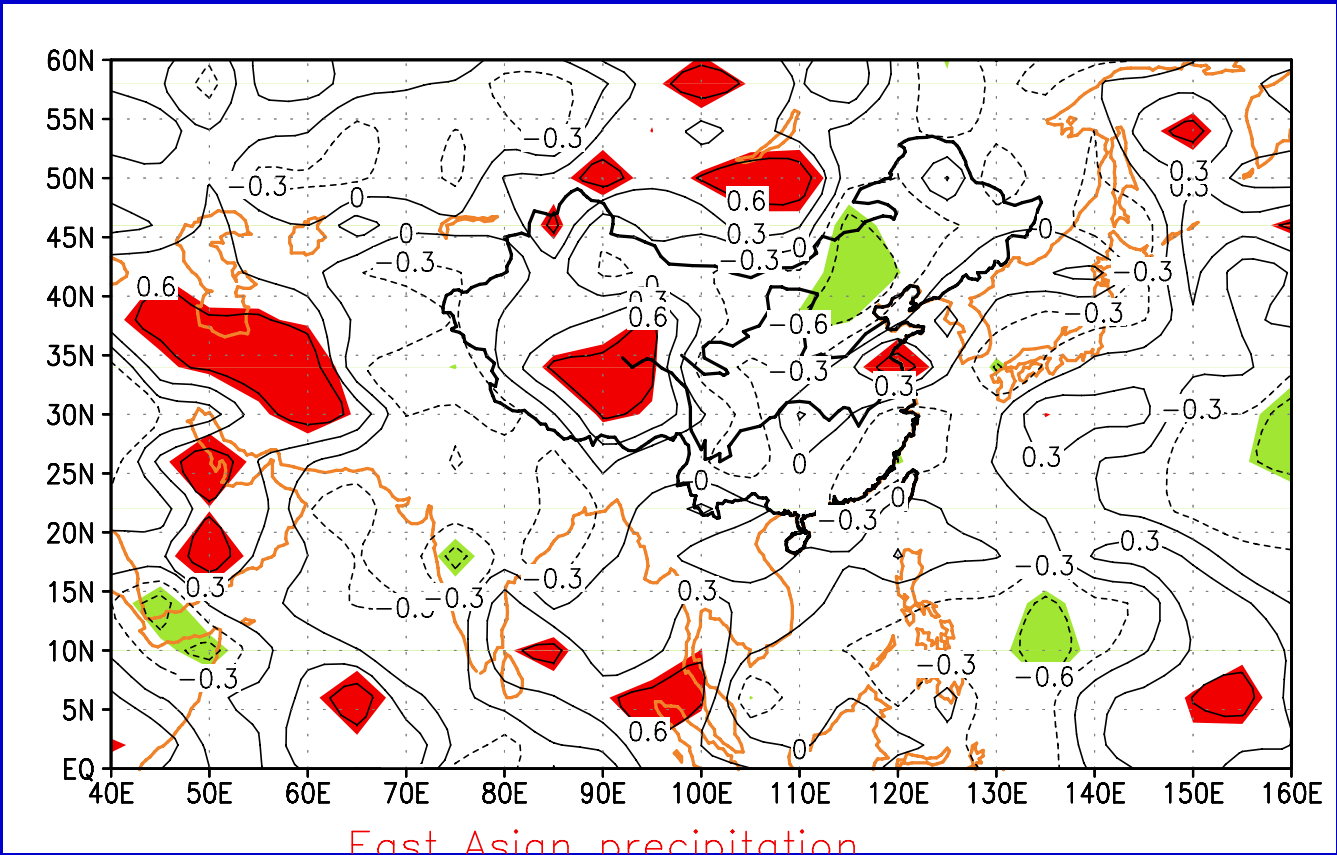
The Impact of Atmospheric Initial Anomalies on Extraseasonal Short-term Climate Prediction

Spatial maps of temporal anomaly correlations for hindcasted TAS, computed for the period 1970-1999



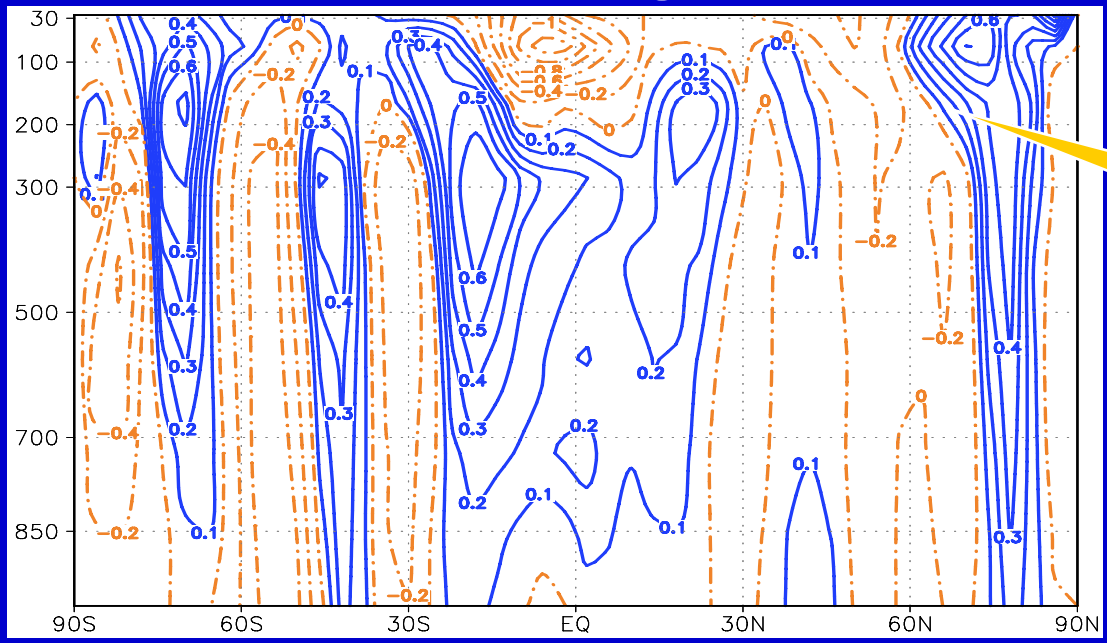
Areas within 95% confidence level are shaded

temporal anomaly correlations for hindcasted PRE in the typical years



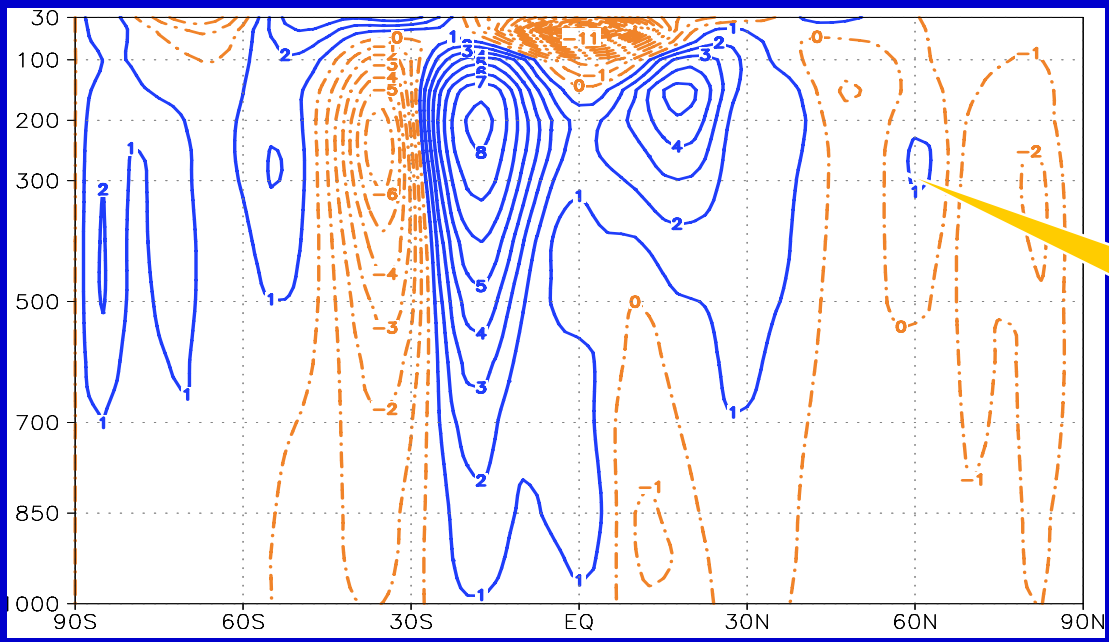
Chosen years: 1982/83, 1987/88, 1991, 1997/98, 1999

Zonal-altitude cross sections of hindcasted zonal wind gotten by subtracting 1988 from 1987 (unit: m/s).



hindcast production

Ordinate: altitude (hPa)
Abscissa: latitude



NCEP reanalysis

Importance of short-term climate prediction

- **Research on short-term climate is one of most important aims of the CLIVAR programme.**
- **Climatic variabilities are large and usually cause great impacts on the local social activities and the economy. So, it is of great importance for reducing and even avoiding disastrous climate events.**
- **It is urgent to use higher vertical resolution for real-time prediction, which is in favor of improvement of the prediction skill.**