Global Ocean-Atmosphere Prediction and Predictability

Potential Seasonal Predictability of the Asian Summer Monsoon in a Coupled Model

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Outline

- NCEP coupled model and ensemble data
- Measures of potential predictability
- Results
- Conclusions

NCEP CFS

The NCEP Climate Forecast System (CFS)

1. fully coupled ocean-land-atmosphere model
2. T62L64 Global Forecast System (GFS)
3. 1°x 1/3°, 40 Layer Modular Ocean Model version 3 (MOM3)
4. No flux adjustment
5. 15 initial conditions per month, in clusters of 5
6. Retrospective 9-month forecasts for 28 years: 1981-2008

”For the first time in the history of U.S. operational seasonal prediction, a dynamical modeling system has demonstrated a level of skill in forecasting U.S. surface temperature and precipitation that is comparable to the skill of the statistical methods used by the NCEP Climate Prediction Center (CPC).” (Saha et al., 2006, J. Climate)

Ensemble runs and data

In this study, we just focus on the JJA summer mean climate of Asian-Australian monsoon region(40E-180,30S-50N). We define lead time as below:

-- LM0: initial conditions are from days May 9-13, May 19-23 and the last two days of May and days 1-3 of June .

-- LM1:initial conditions are from days April 9-13, April 19-23 and the last two days of April and days 1-3 of May .

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-- LM6:initial conditions are from days Nov 9-13, Nov 19-23 and the last two days of Nov and days 1-3 of Dec of the previous year.

There are totally 7 lead times from 0 to 6 months.

Measures of potential predictability

Predictability is a classical problem with comprehensive applications in the prediction of weather and climate.

Statistically predictability is recently considered as the difference between a prediction probability density function (PDF) and an appropriate climatological PDF.

Relative entropy (RE), a predictability measure from Information theory, quantifies the difference between the prediction and climatological PDFs.

The two PDFs and their derivatives are usually estimated in a ensemble prediction system.

Measures of potential predictability (Cont')

A climate variable is denoted as X. In practice, X can be grid variable, index or principle component of a EOF mode etc.

Its prediction PDF is denoted as p(x), and the climatological PDF is denoted as q(x).

$$RE = \int \frac{p(x)}{q(x)} dx$$

If X obeys Gaussian distribution, then

$$RE = \frac{1}{2}\left[-\ln\left(\frac{\sigma_p^2}{\sigma_q^2}\right) + \frac{\sigma_p^2}{\sigma_q^2} + \frac{(\mu_p - \mu_q)^2}{\sigma_q^2} - 1 \right]$$

In the above formula, $\frac{\sigma_p^2}{\sigma_q^2}$ and $\frac{(\mu_p - \mu_q)^2}{\sigma_q^2}$ can be understood as normalized ensemble variance (NEV) and normalized ensemble mean shift (NEMS) by climatological variance.

Average RE over initial conditions is mutual Information (MI), which measures average predictability. Under Gaussian assumption,

$$MI = -\frac{1}{2}\left\langle \ln\left(\frac{\sigma_p^2}{\sigma_q^2}\right) \right\rangle$$

Measures of potential predictability (cont')

Under Gaussian assumption, if further $\sigma_p^2 = const$ which approximately hold in seasonal mean climate (usually don't hold in weather prediction due to large day to day variability of flow-dependent instability) and model is perfect, then

$$AC = \sqrt{1-\exp(-2MI)}$$

$$MSESS = AC^2 = 1-\exp(-2MI)$$

Here, AC is anomaly correlation between ensemble means and observations ,and MSESS is MSE(mean squared error) skill score using ensemble mean as a prediction and climatology as a reference prediction. Their original metrics are

$$AC = \frac{\mathrm{cov}(f,o)}{std(f)std(o)}$$

$$MSESS = 1-\frac{MSE}{MSE_{c\lim}} = 1-\frac{\langle (f-o)^2 \rangle}{\mathrm{var}(o)}$$

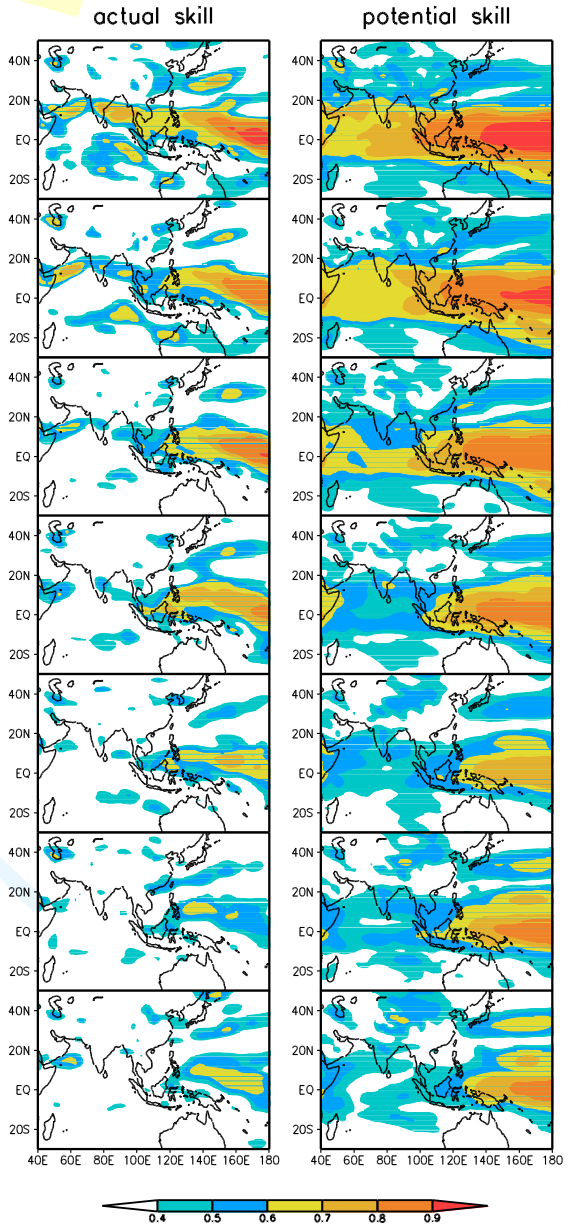
Additionally, we also use individual derivatives of the two metrics. That is,

$$C = \frac{1}{AC}\frac{\frac{1}{N}(f-\bar{f})(o-\bar{o})}{std(f)std(o)} \qquad MSESSIP = 1-\frac{(f-o)^2}{\mathrm{var}(o)}$$

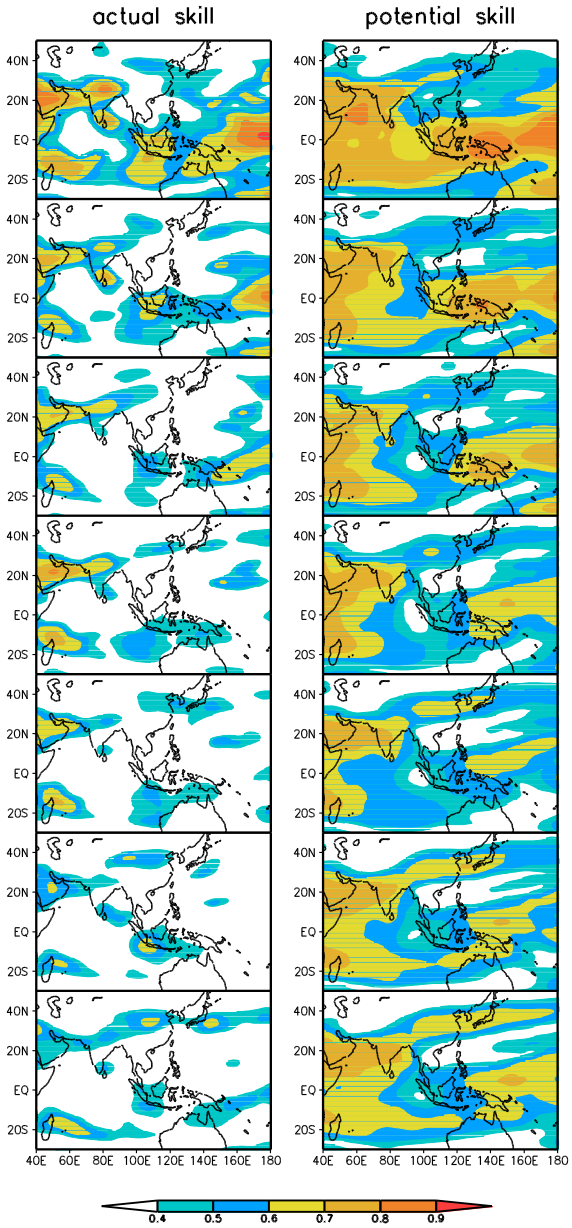
The former measure the contribution of individual prediction to the AC, and the latter is the individual MSE skill score.

Due to actual imperfection of model, AC and MSESS estimated from model MI are called ***potential skills***. Meanwhile, skill measures calculated using observations are called ***actual skills***.

AC

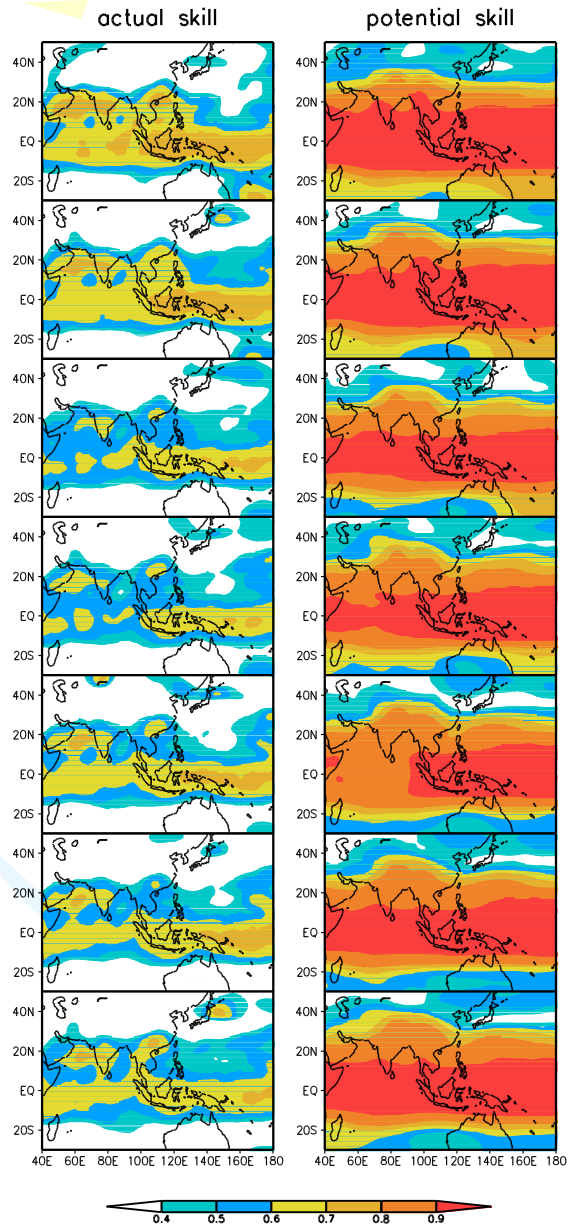


U850(LM0-LM6)

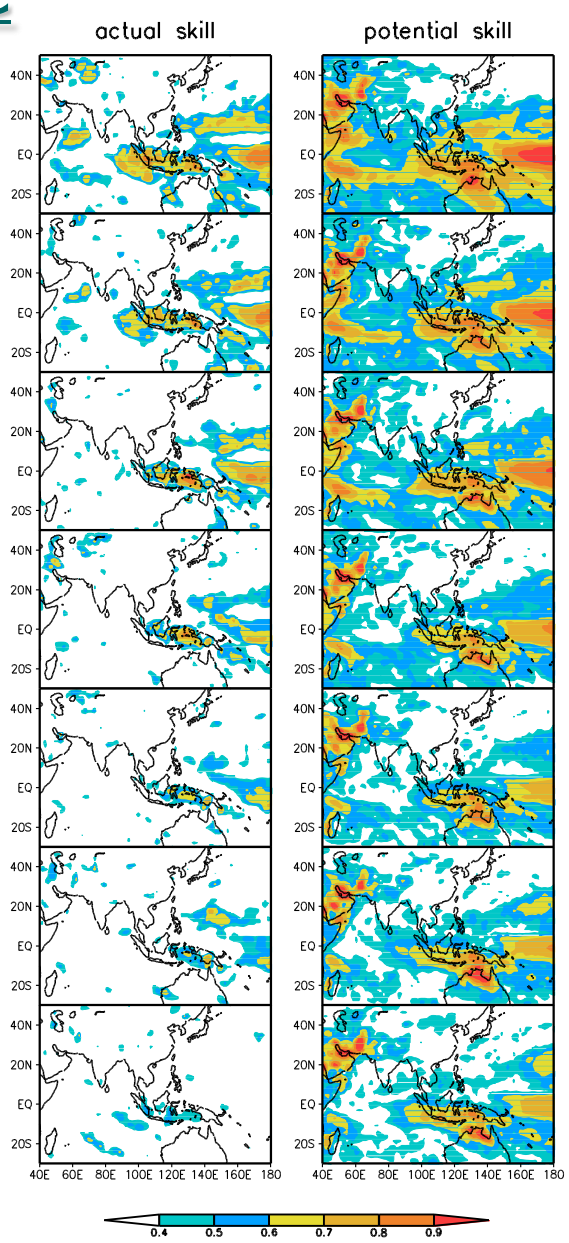


U200(LM0-LM6)

AC

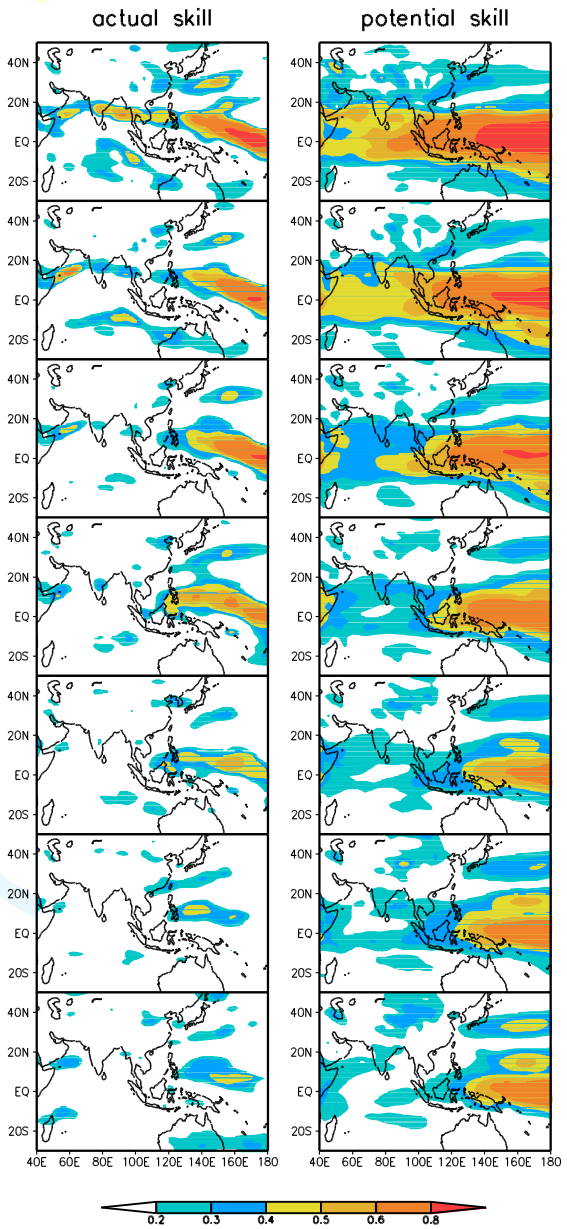


z500(LM0-LM6)

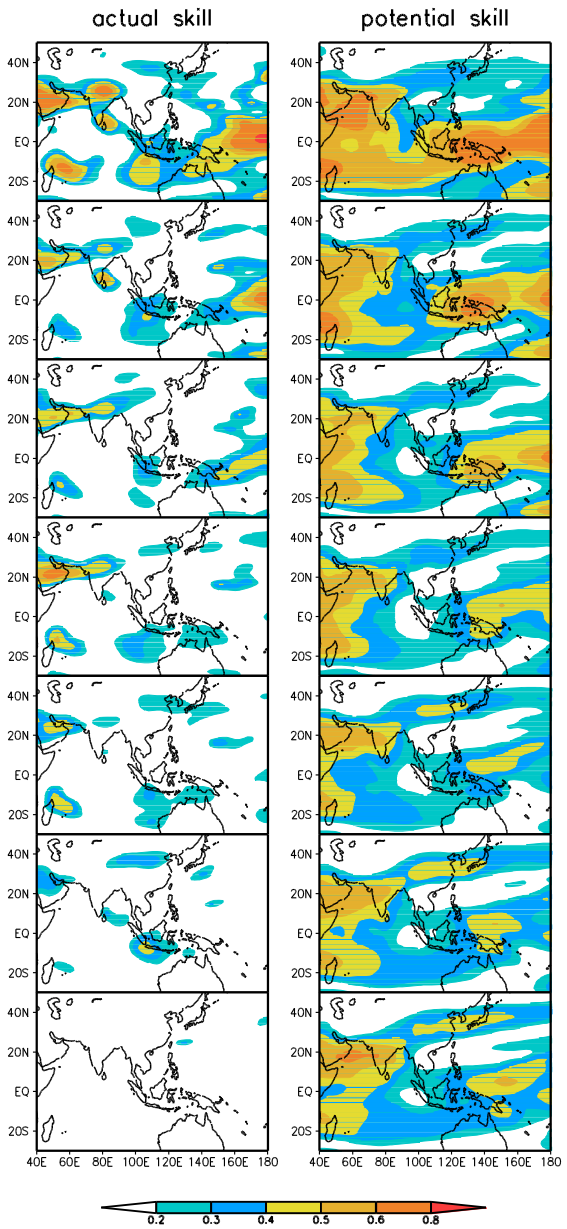


precip(LM0-LM6)

MSESS

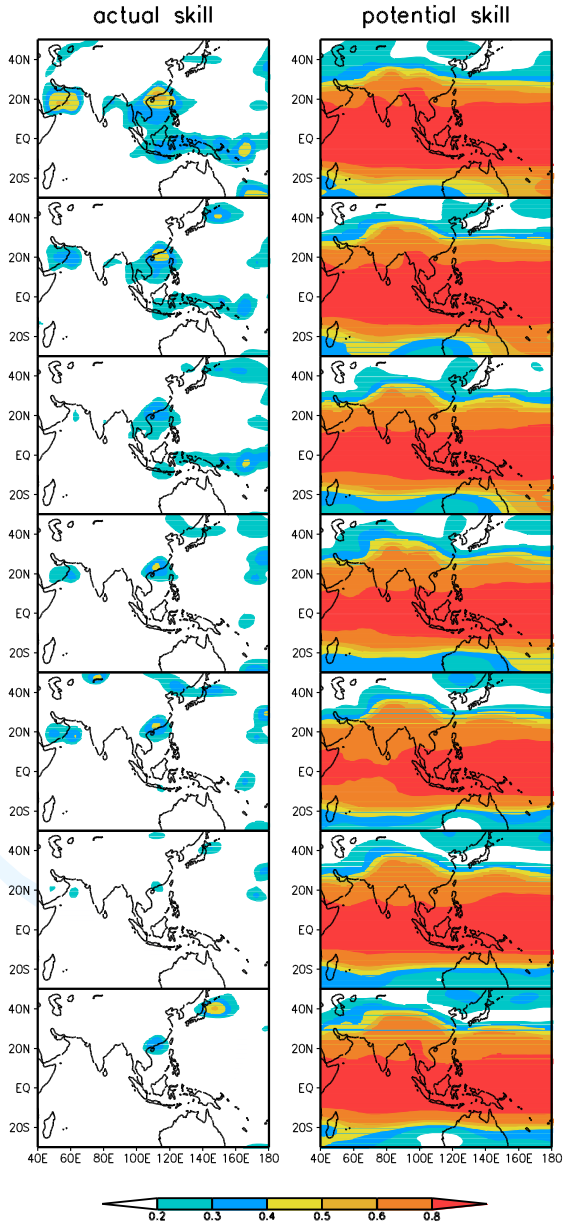


u850(LM0-LM6)

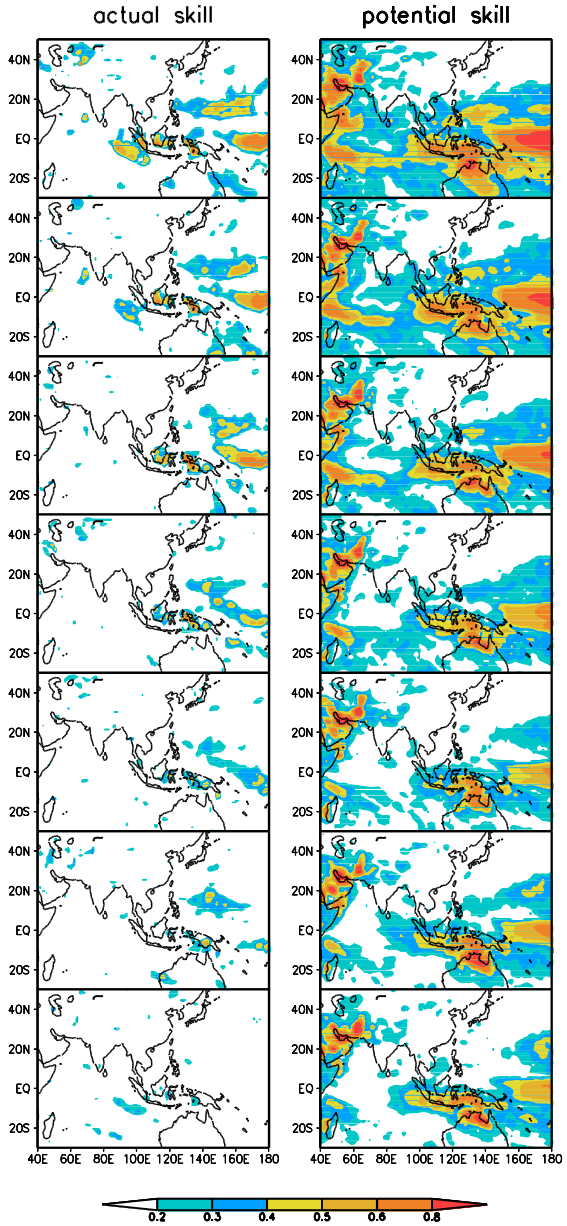


u200(LM0-LM6)

MSESS

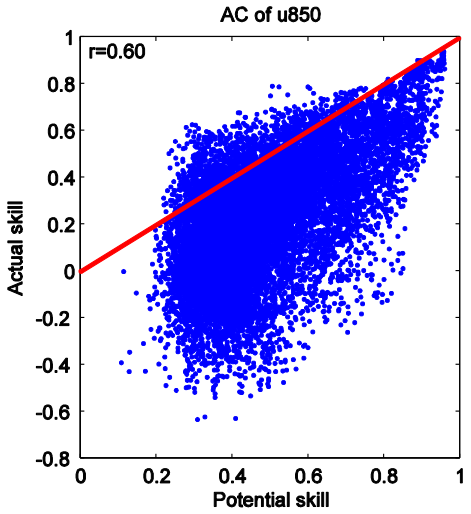


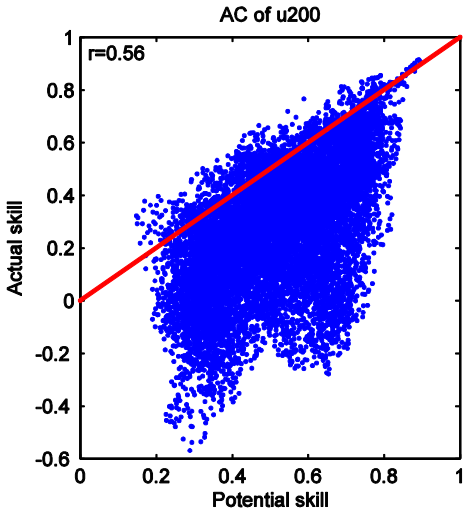
z500(LM0-LM6)

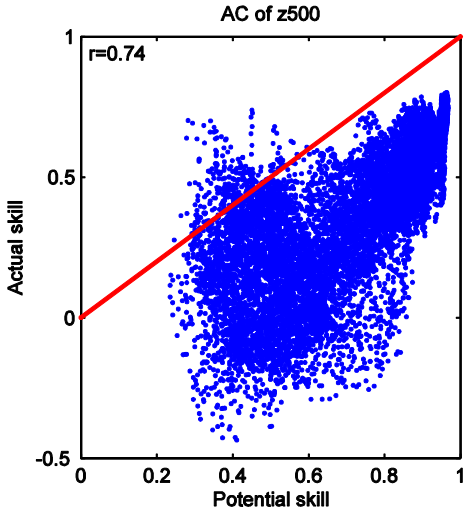


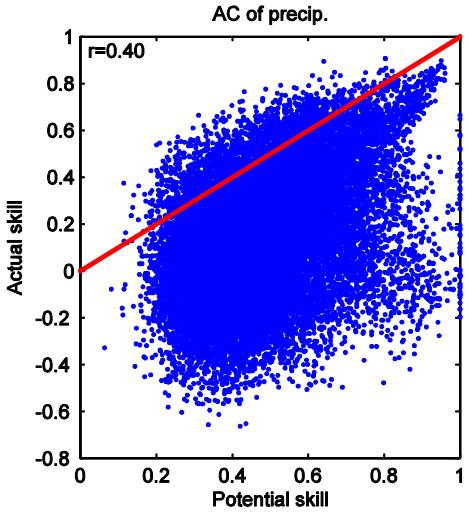
precip(LM0-LM6)

AC

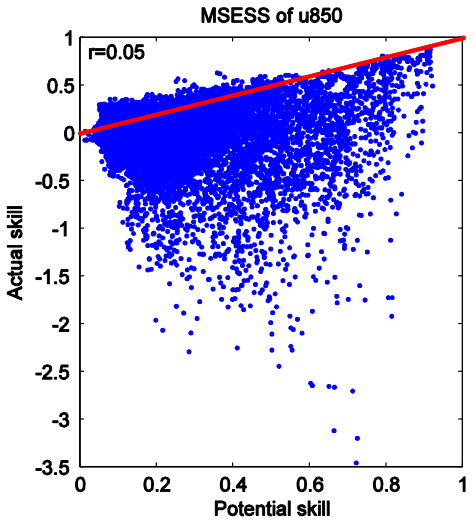

AC of u850
r=0.60
Actual skill
Potential skill

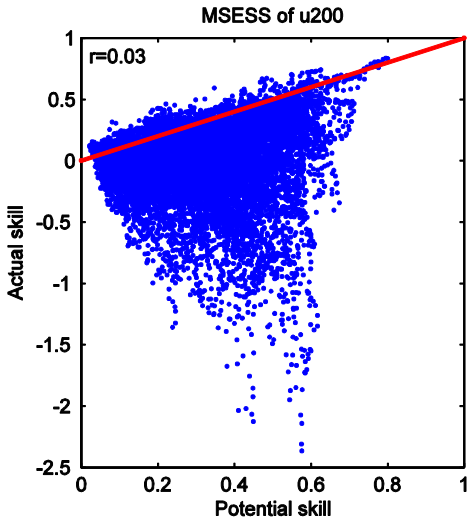

AC of u200
r=0.56
Actual skill
Potential skill

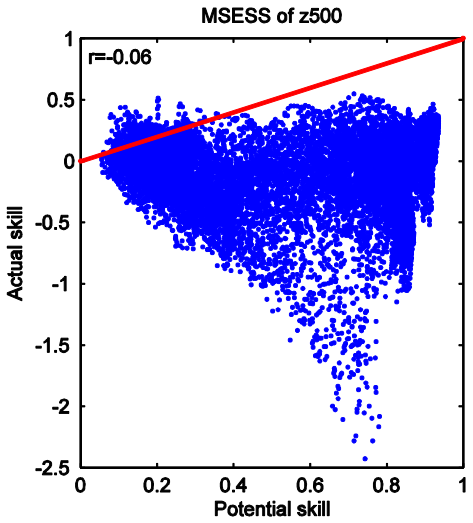

AC of z500
r=0.74
Actual skill
Potential skill

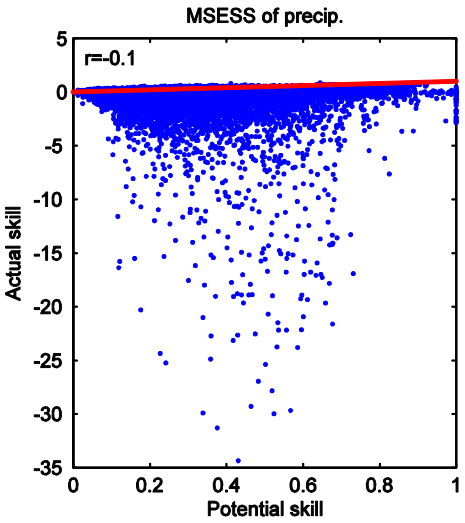

AC of precip.
r=0.40
Actual skill
Potential skill

MSESS


MSESS of u850
r=0.05
Actual skill
Potential skill


MSESS of u200
r=0.03
Actual skill
Potential skill


MSESS of z500
r=-0.06
Actual skill
Potential skill


MSESS of precip.
r=-0.1
Actual skill
Potential skill

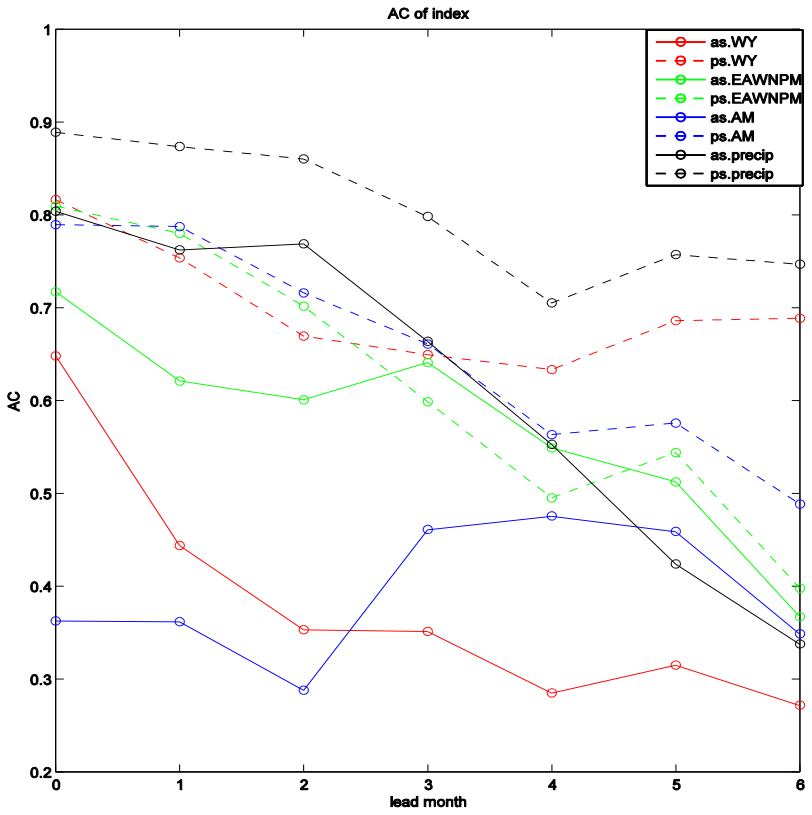
Index

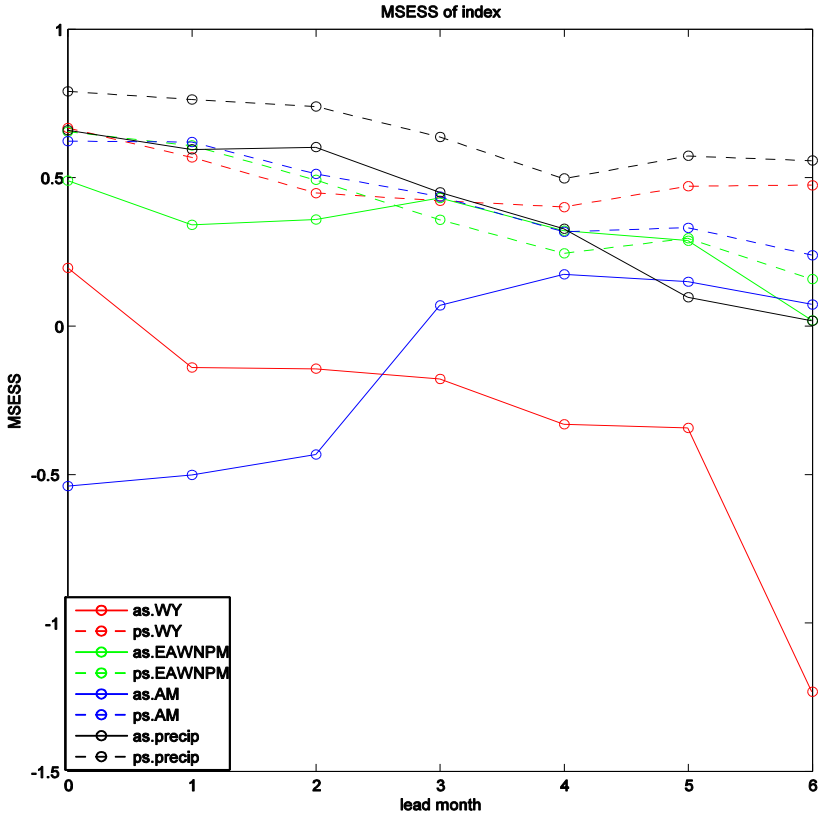
(1)WY: Webster-Yang monsoon index (U850-U200 averaged over 0-20ºN, 40ºE-110ºE)

(2)EAWNPM: East Asia - Western North Pacific monsoon index(U850 (5ºN -15ºN, 90ºE-130ºE) – U850 (22.5ºN -32.5ºN, 110ºE-140ºE)

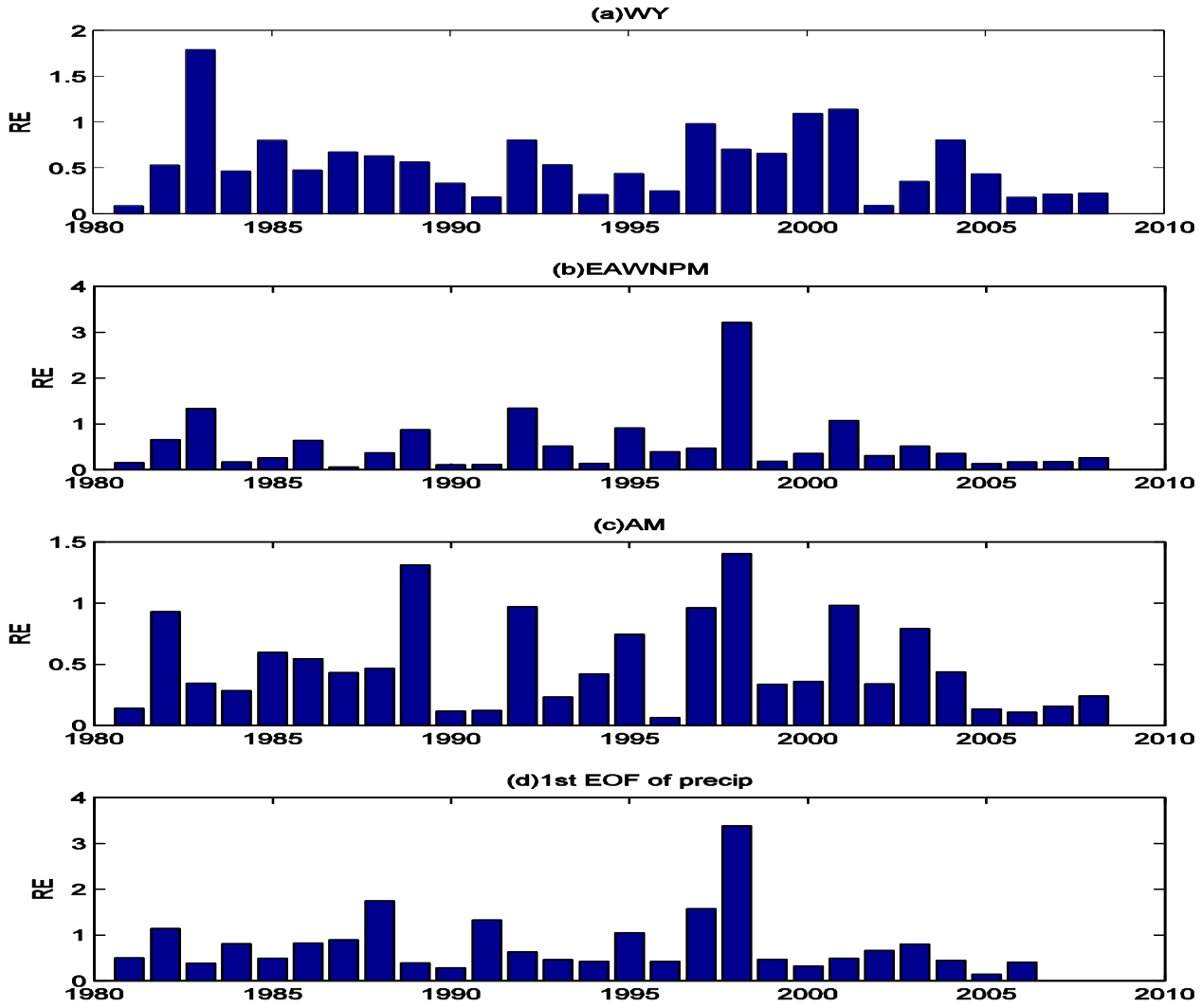
(3)AM: Australian monsoon index (U850 averaged over 2.5ºS-15ºS, 110ºE-150ºE)

(4) The first EOF mode of observed precipitation

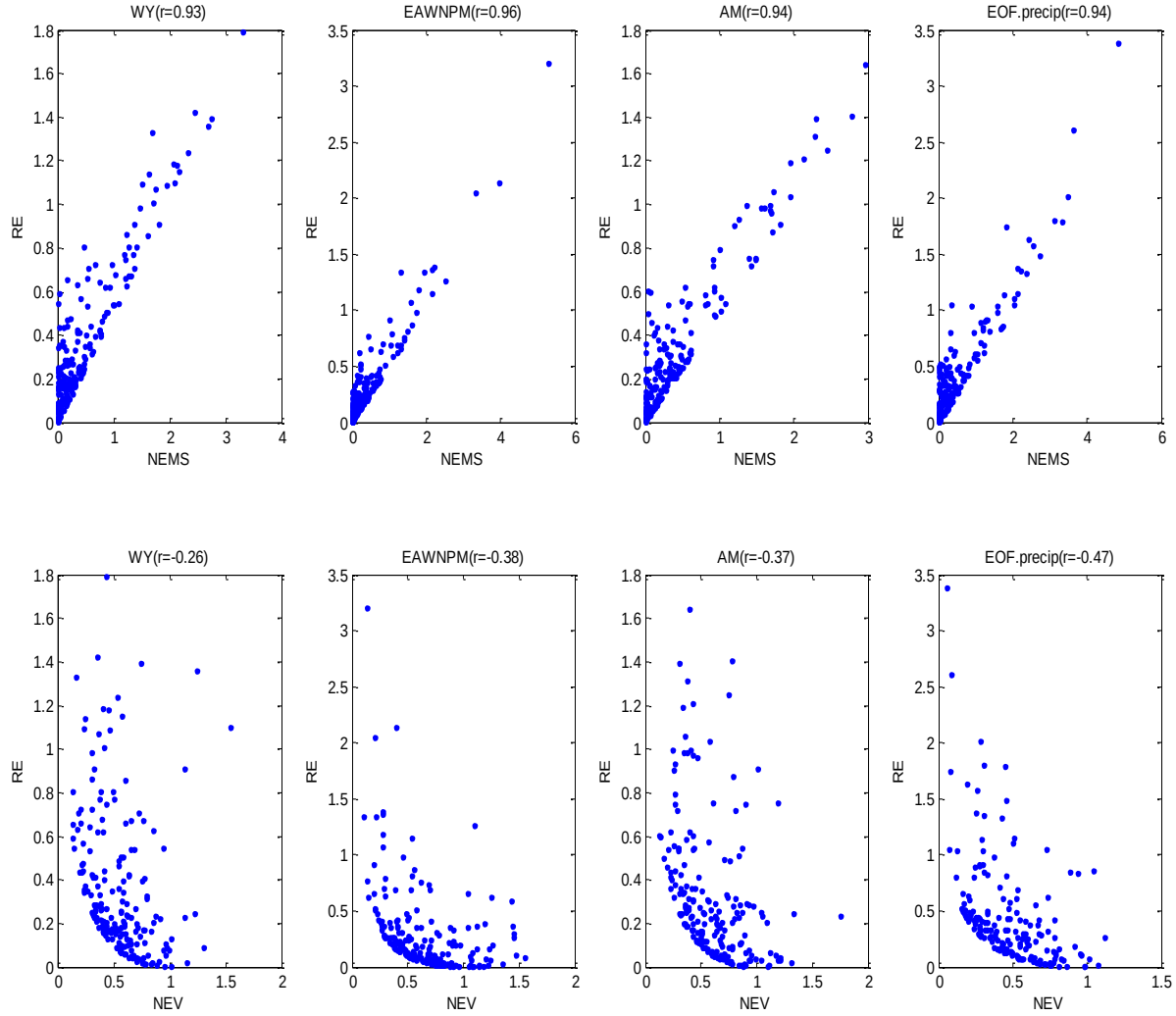




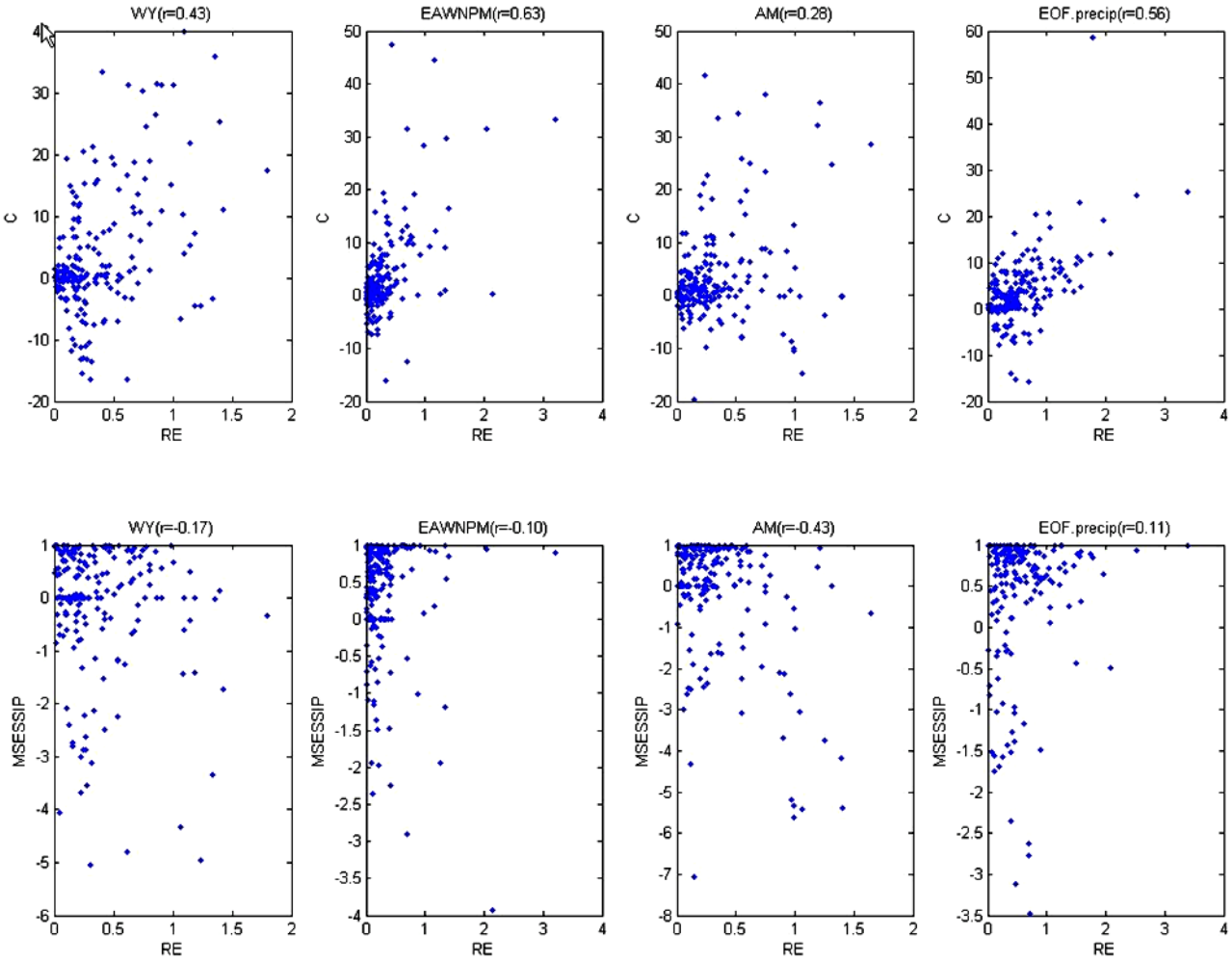
RE


(a)WY
RE
2
1.5
1
0.5
0
1980
1985
1990
1995
2000
2005
2010
(b)EAWNPM
RE
4
3
2
1
0
1980
1985
1990
1995
2000
2005
2010
(c)AM
RE
1.5
1
0.5
0
1980
1985
1990
1995
2000
2005
2010
(d)1st EOF of precip
RE
4
3
2
1
0
1980
1985
1990
1995
2000
2005
2010

RE,NEMS,NEV


WY(r=0.93)
EAWNPM(r=0.96)
AM(r=0.94)
EOF.precip(r=0.94)
WY(r=-0.26)
EAWNPM(r=-0.38)
AM(r=-0.37)
EOF.precip(r=-0.47)
RE
NEMS
NEV

RE,C,MSEIP


WY(r=0.43)
EAWNPM(r=0.63)
AM(r=0.28)
EOF.precip(r=0.56)
C
RE
WY(r=-0.17)
EAWNPM(r=-0.10)
AM(r=-0.43)
EOF.precip(r=0.11)
MSESSIP
RE

Conclusions

(1) Usually where actual skill is high, potential skill is high. However, where potential skill is high, actual skill is variable. Both actual and potential skill are larger in the tropical region than in the extratropical region, especially for 850hPa zonal wind, 500hPa geopotential height, and precipitation.

(2) Generally both actual and potential skill decrease as the lead time increases, and in most grid points, potential skill is larger than actual skill, indicating the possibility of skill improvement after model development.

(3) Regardless of the large direct distance between potential skill and actual skill, they have a good linear relationship for AC, implying AC potential skill play an important role on actual skill.

(4) RE has a large year to year variation, which is dominated by NEMS variation and it has a better relationship with C than with MSEIP.

acknowledgements

GOAPP

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