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THE ASSESSMENT OF PREDICTABILITY OF NORTH PACIFIC SEA TEMPERATURE USIN G A CGCM

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Background and Motive

Importance of the North Pacific in regulating extratropical climate on a wide range of time scale
: Numerous studies dating back to Namias (1959) have found that SST and atmospheric circulation over the North Pacific have a strong influence on weather and climate of Northern Hemisphere

Contradictory insistences
1. North Pacific SST anomalies have minimal impacts on extratropical circulation.
2. North Pacific SSTA responses are very sensitive to the basic flow.
3. North Pacific SSTA is largely forced by the atmospheric forcing.

The role of the North Pacific on climate is still an open question.

Air-sea interaction over the North Pacific amplifying midlatitude climate variability.
The physical processes involved in extratropical air-sea interaction let the North Pacific be an important source of climate variability

This consideration provides a motivation for understanding and predicting the North Pacific under the framework of a coupled system.

In this study, the predictability of PNU/CME CGCM is assessed in terms of North Pacific sea surface temperature based on the analysis of 12-month lead hindcasts,

Example of Seasonal Forecast Using CGCM (DEMETER)

DEMETER: Development of European Multimodel Ensemble System for Seasonal to Interannual Prediction

	MPI (Germany)	METO (UK)	CNRM (France)	LODYC (France)	ING (Italy)	ECMWF	CERFACS (France)
atmosphere component	ECHAM-5	HadAM3	ARPEGE	IFS	ECHAM-4	IFS	ARPEGE
resolution	T42 19Levels	2.5°x3.75° 19 Levels	T63 31 Levels	T95 40 Levels	T42 19 Levels	T95 40 Levels	T63 31 Levels
atmosphere initial conditions	coupled run relaxed to observed SSTs	ERA-40	ERA-40	ERA-40	coupled AMIP-type experiment	ERA-40	ERA-40
reference	Roeeckner 1996	Pope et al. 2000	Deque 2001	Gregory et al.2000	Roeckner 1996	Gregory et al.2000	Deque 2001
ocean component	MPI-OM1	GloSea OGCM, based on HadCM3	OPA 8.0	OPA 8.2	OPA 8.1	HOPE-E	OPA 8.2
resolution	2.5°x1.5°-2.5° 23 Levels	1.25°x0.3°-1.25° 40 Levels	182GPx152GP 31 Levels	2.0°x2.0° 31 Levels	2.0°x 0.5°-1.5° 31 Levels	1,4°x 0.3°-1.4° 29 Levels	2.0°x2.0° 31 Levels
ocean initial conditions	coupled run relaxed to observed SSTs	ocean analyses forced by ERA-40	Ocean analyses forced by ERA-40	ocean analyses forced by ERA-40	ocean analyses forced by ERA-40	Ocean analyses forced by ERA-40	ocean analyses forced by ERA-40
reference	Marsland et al. 2002	Gordon et al. 2000	Madec et al. 1997	Delecluse and Madec 1999	Madec et al. 1998	Wolff et al. 1997	Delecluse and Madec 1999
ensemble generation	9 different atmospheric conditions from the coupled initialization run(lagged method)	windstress and SST perturbations	windstress and SST perturbations	windstress and SST perturbations	windstress and SST perturbations	windstress and SST perturbations	windstress and SST perturbations

Other Examples of Seasonal Forecast Using CGCM

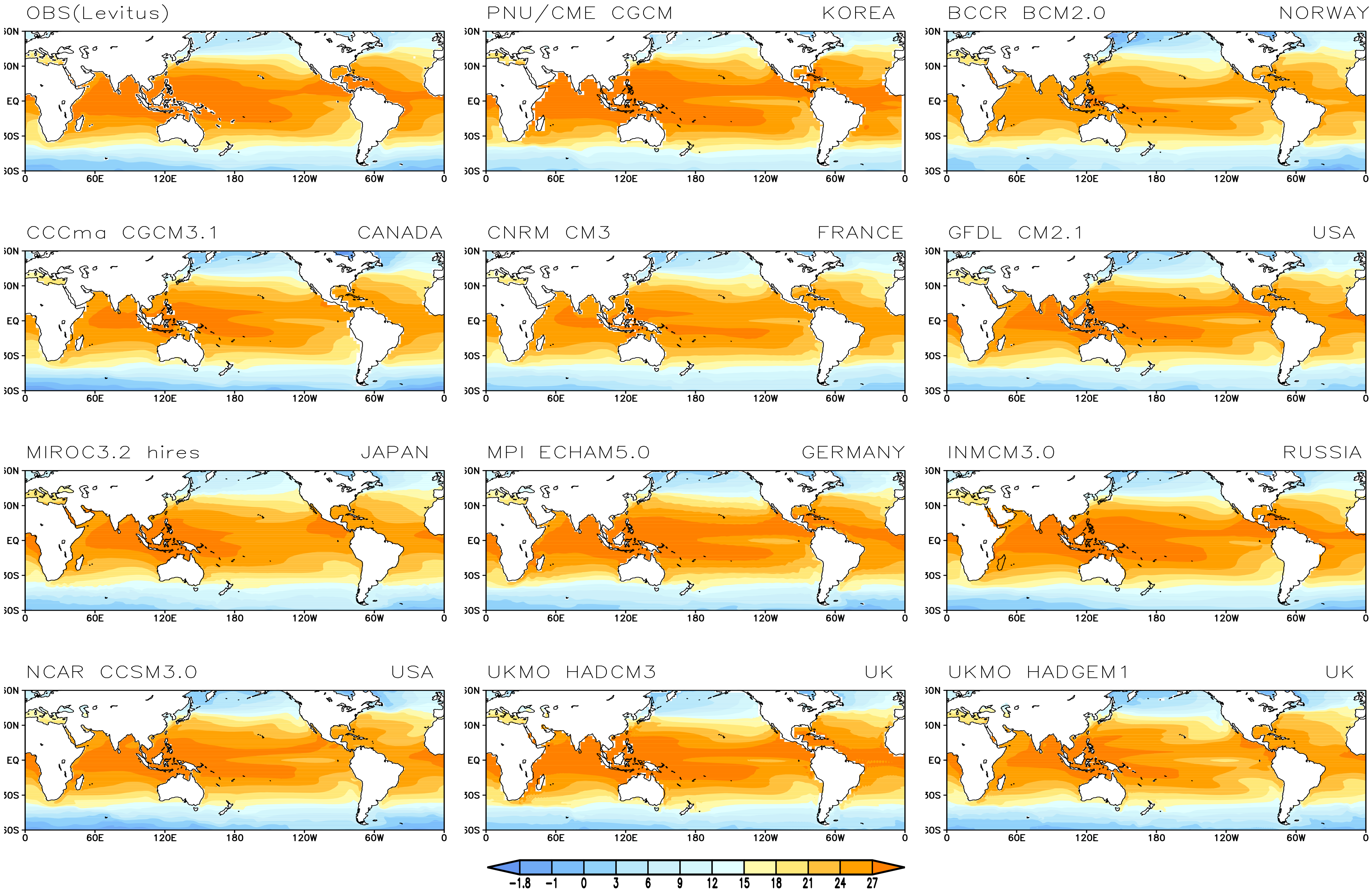
Model	CENTER (Nation)	AGCM	OGCM	SEA ICE	LSM	Flux Adjust (Coupler)
PNU/CME CGCM	PNU (S. Korea)	CCM3	MOM3	EVP dynamic sea-ice model	LSM, 1998	No flux adjustment
POAMA-1	(Australia)	BAM 3.0	ACOM2			(OASIS)
BCC-CM1	BCC (China)	BCC T63	IAP T63	thermodynamic sea-ice model	NCC/BATS/Su n snow	
NCC CGCM	CMA (China)	NMC/CMA AGCM 1.0	LASG OGCM 1.0	thermodynamic sea-ice model		(DFA, LAF method)
JMA CGCM	JMA (Japan)	The Barnett et al. type hybrid coupled model	2.5°x0.2°-2°, L20			with flux adjustments and with assimilated ocean I.C.
CFS03	NCEP/NOAA (U.S.A)	GFS03 ,T62 L64	GFDL MOM3 1/3° ~ 1°, L40			no flux adjustment
GFDL	GFDL (U.S.A)	AM2.1	MOM4			
UH	UH (U.S.A)	ECHAM4	UH Ocean			without heat flux correction
NSIPP CGCM V1	NASA (U.S.A)	NSIPP1	Poseidon V4	thermodynamic sea-ice model	Mosaic	
SNU	SNU (S. Korea)	SNU	MOM2.2			

Seasonal Prediction Verification (Temperature)

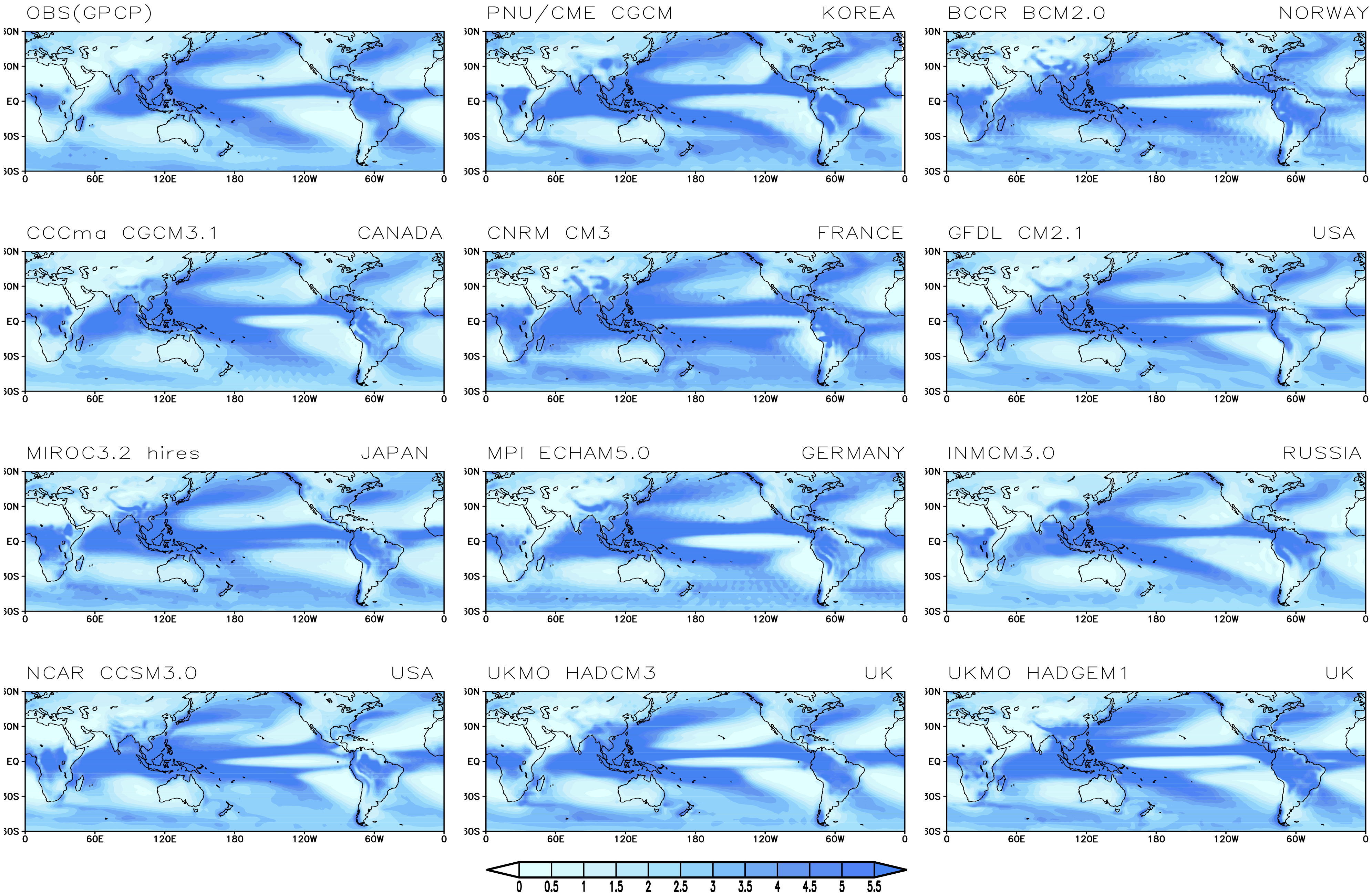
Courtesy of Korea Meteorology Administration

	Model	2006년 1	2	3	4	5	6	7	8	9	10	11	12	Hit No.	2007년 1	2	3	4	5	6	7	8	9	10	11	12	Hit No.	2008년 1	2	3	4	5	6	7	Hit No.	Hit sum	Hit (%)
STATISTIC	Periodic Method/KMA	O	O	×	×	O	O	×	O	×	×	O	×	6/12	×	O	O	×	×	O	×	O	O	O	O	O	8/12	O	×	O	O	×	×	×	3/7	17/31	54.8
	MLRM/KMA	O	O	×	×	O	O	×	×	×	×	×	×	4/12	O	O	×	O	×	×	×	×	×	×	O	×	4/12	O	×	×	×	O	×	×	2/7	10/31	32.3
	SNU	O	O	O	O	O	×	×	O	×	×	×	×	6/12	×	O	O	×	×	×	O	O	O	O	×	×	6/12	O	×	O	O	×	O	×	4/7	16/31	51.6
	KNU			O	×	O	O	×	×	×	×	×	×	3/10	×	O	O	×	×	O	O	×	×	O	O		6/11			O	O	O			3/3	12/24	50.0
DYNAMIC	GDAPS	×	×	O	×	O	O	×	×	×	O	×	O	5/12	O	×	×	O	×	O	×	×	×	×	O	×	4/12	×	×	O	O	×	×	×	2/7	11/31	35.5
	GCPS/SNU			O	×	O	O	×	×				×	3/7	O	O	×	O	×	O	×	O				×	5/9	O	×	O	O	O	×	×	4/7	12/23	52.2
	PNU	O	O				O	×	O	×	×	O	O	6/9	O	O	O	×	O	O	×	O	O	O	O	×	9/12	×	O	O	O	×	×	×	3/7	18/28	64.3
	PKNU						O	×	×	×	O	×	×	2/7	×	O	×	O	O	O	×	×	×	×	×	×	4/12	O	×	O	O	×	×	×	3/7	9/26	34.6
	CFS/NCEP	×	×							O	×	×	O	2/6	O	O	O	×	O	×	×	×	×	×	O	×	5/12	O	×	O	O	×	×	×	3/7	10/25	40.0
	IRI			O	×	O	O	O	O	×	O	O		7/9			×	O	×	×	O	×				O	3/7	O	×						1/2	11/18	61.1
	IRIF			O	×	O	×	×	×	×	O	O		4/9			×	×	×	×	×	×	O	×	O	O	3/10	×	×						0/2	7/21	33.3
	CWB	×	×	O	O	O	×	×	×	×	O	O	O	6/12	O	O	×	×	O	×	×	O	×	O	O	×	6/12	×	×	O	O	×	×	×	2/7	14/31	45.2
	HMC						O	O	×				O	3/4	O	O	O	×	O	×	O	×	×	×	×		5/11									8/15	53.3
	JMA	×	×				O	×	×				O	2/6	O	O	O	×	O	×	×	×					4/8									6/14	42.9
	nimr	×	O	×	×	×	O	×	×	×	×	×	O	3/12	O	O	O	×	×	O	×	×	×	×	O	O	6/12	O	×	×	×	O	×	×	2/7	11/31	35.5
	MGO	×	×	×	×	×	×	O	×	O	×	×	O	3/12	O	O	×	O	×	×	O	×	×	×	O		5/11			O	×	O	×	×	2/5	10/28	35.7
	NCEP	×	×	×	×	×	×	×	×	O	×	×	O	2/12	O	O	O	×	O	O	×	O	O	×	O	×	8/12	×	O	×	O	×	×	×	2/7	12/31	38.7
	COLA	O	O							O	×	×	O	4/6	O	O	×	×	×	×	×	×	×	×	×	O	3/12	×	O						1/2	8/20	40.0
	NASA	O	×										O	2/3	O	O	×	O	×	O	×	×					4/8									6/11	54.5
	NCC						O	O	×	×	×	O	×	3/7	×	O	×	O	×	O	×	×	O	×	×	×	4/12	×	×						0/2	7/21	33.3
	MSC	O	O	×	×	O				×	O	×	O	5/9	O	O	×	×	×	×	O	×	O	O	×		5/11						×	O	1/2	11/22	50.0
	POAMA	×	×							×	O	O	O	3/6	×	O	O	O	×	O	×	O					5/8									8/14	57.1
MME	SCM(1)	×	×	×	×	O	O	×	×	×	O	O	O	5/12	O	O	O	×	O	×	×	O	×	×	O	×	6/12	×	×	O	O	×	×	O	3/7	14/31	45.2
	MRG(2)	×	×	O	×	O	O	O	×	×	O	O	O	7/12	O	×	×	O	×	×	×	O	×	×	O	O	5/12	O	×	O	O	×	×	×	3/7	15/31	48.4
	SPM(3)	O	O	×	×	×	O	O	×	×	O	O	O	7/12	O	O	O	×	O	O	×	O	O	×	O	O	9/12	O	×	×	×	×	×	×	1/7	17/31	54.8
	SSE(4)	×	O	O	×	O	O	×	×	×	O	O	×	6/12	O	O	×	O	×	×	×	O	×	×	O	O	6/12	×	×	×	×	×	×	O	1/7	13/31	41.9
	composite	×	O	O	×	O	×	O	×	×	O	O	O	7/12	O	O	O	×	O	×	×	O	×	×	O	O	7/12	×	×						0/2	14/26	53.8

Sea Surface Temperature (Model Climate)



Precipitation (Model Climate)



PNU Dynamical Long-term Prediction System

AGCM Initialization

- Reproduction : 15th day of Jan, Apr, Jul and Oct.
- Initial Condition for CGCM: 16th day of Jan, Apr, Jul and Oct. of each year

LSM Initialization

- Reproduction : Sep. 01, 1978 ~ Jul. 31, 2008
- Initial Condition for CGCM: 16th day of Jan, Apr, Jul and Oct of each year.

OGCM/Sea ice Initialization

- Spin-up : 100 - year
- Reproduction : Jul. 16, 1980 ~ Jul. 31, 2008
- Initial Condition for CGCM: 16th day of Jan, Apr, Jul and Oct.of each year

AGCM

LSM

EVP Sea Ice

OGCM

PNU/CME CGCM (No Flux Adjustment)

Data Assimilation

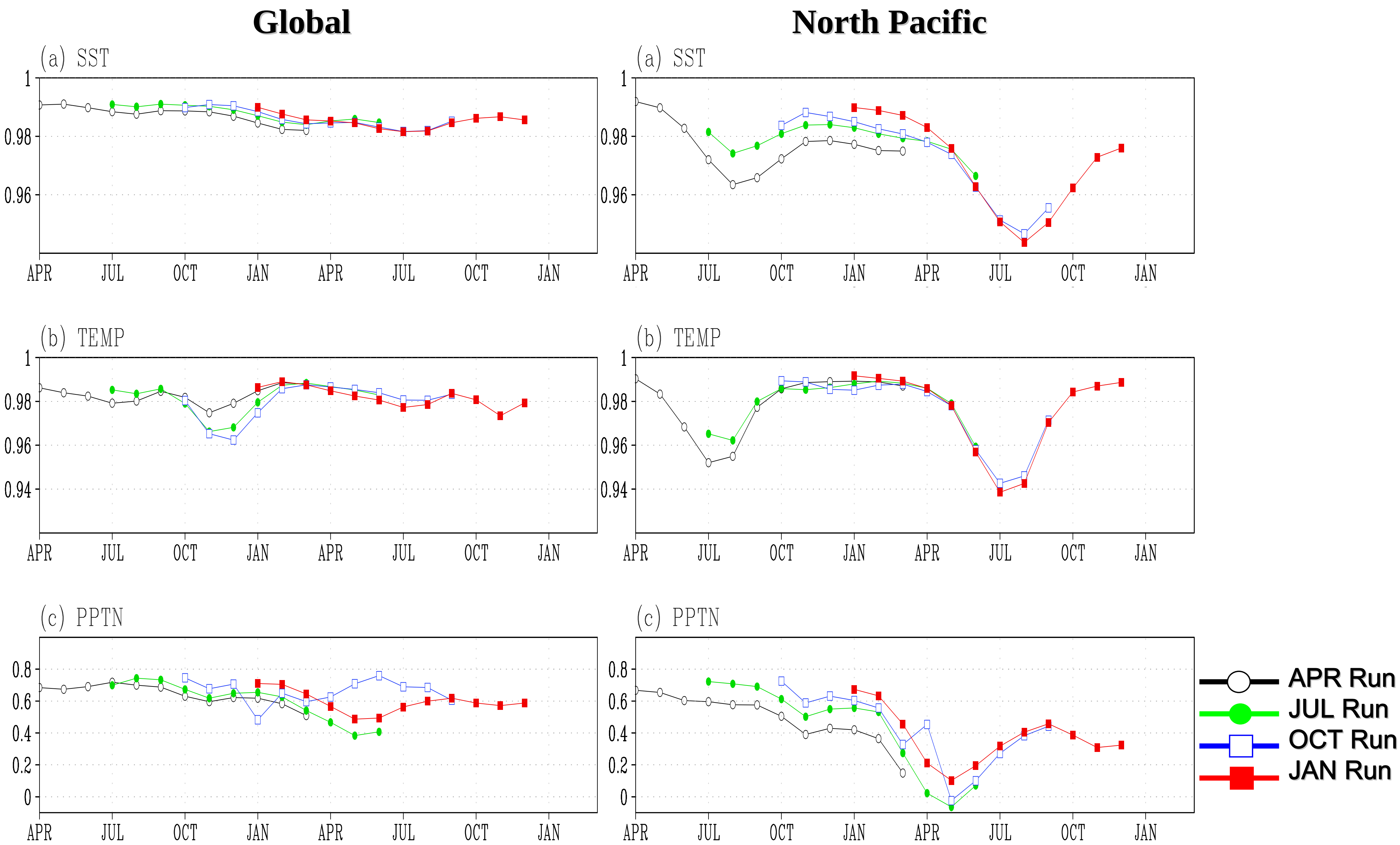
- 3-D VAR (VAF) for T and S
- Background field : Jul. 16,1980 ~Jul. 16,2008 OGCM reproduction
- OBS : GODAS pentad

CGCM Ensemble Hindcast

- 30-year (1979~2008) CGCM
- 12-Month Lead Hindcast
- Starting at 16th day of Jan, Apr, Jul and Oct. of each year
- 5-member ensemble

	Lead0	Lead1	Lead2	Lead3	Lead4	Lead5	Lead6	Lead7	Lead8	Lead9	Lead10	Lead11
JAN RUN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
APR RUN	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
JUL RUN	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
OCT RUN	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Nov

Pattern Correlation of Hindcasts



Verification (Potential Predictability)

Potential Variability (PP) : fraction of the total variance that is due to changes in the external forcing

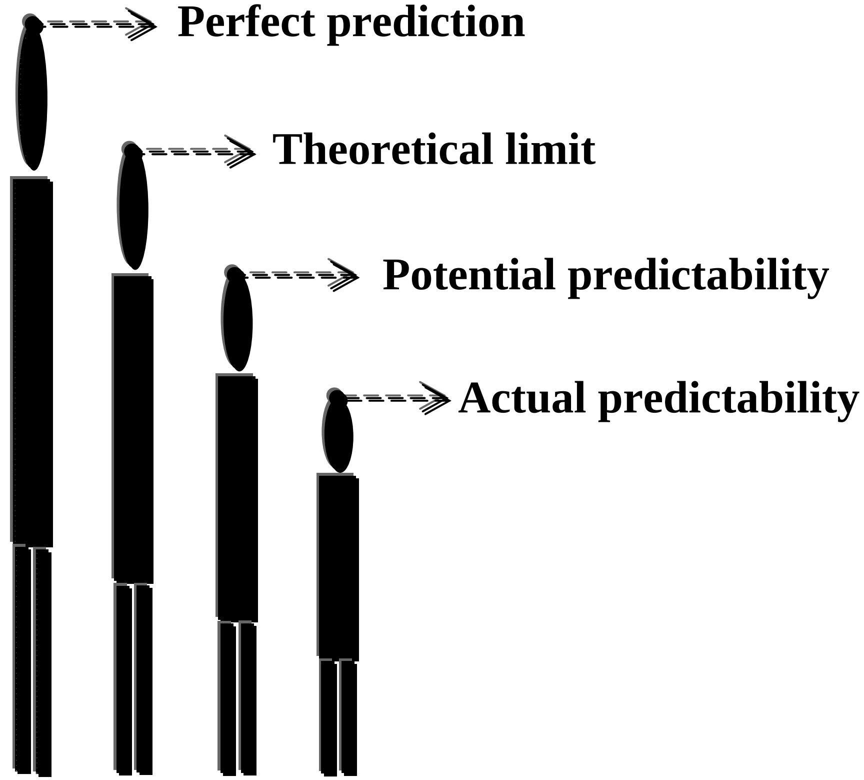
$$\mathrm{PP} = \frac{\sigma_{ext}}{\sigma_{T}}$$

$$\sigma_I^2 = \frac{1}{MN}\sum_{j=1}^{N}\sum_{i=1}^{M}\left|X_{ij} - \langle X\rangle_j\right|^2$$

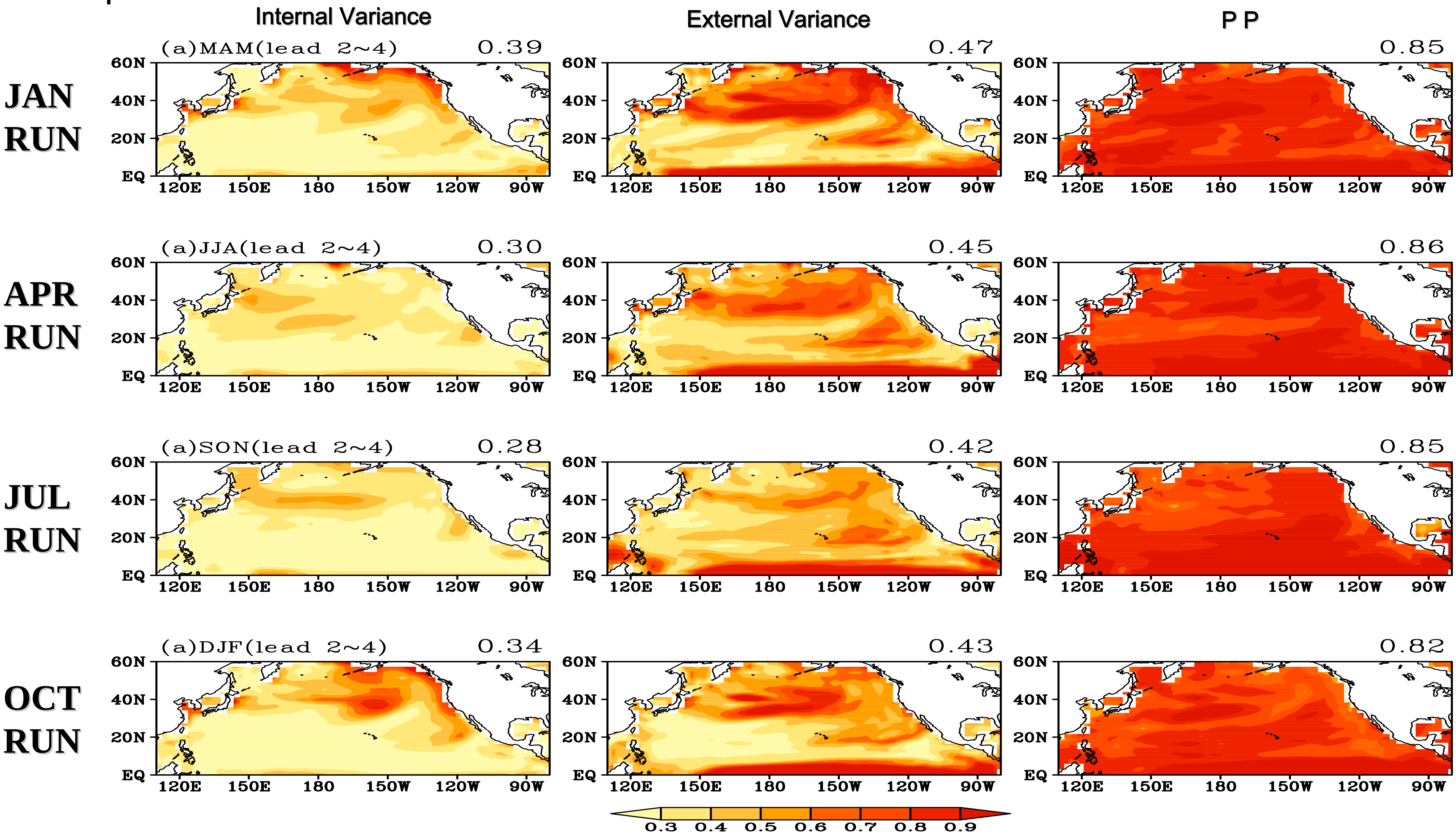
$$\sigma_{ext}^2 = \frac{1}{N}\sum_{j=1}^{N}\left|\langle X\rangle_j - \overline{X}\right|^2 \qquad \langle X\rangle_j = \frac{1}{M}\sum_{i=1}^{M} X_{ij}$$

$$\sigma_T^2 = \frac{1}{MN}\sum_{j=1}^{N}\sum_{i=1}^{M}\left|X_{ij} - \overline{X}\right|^2 \qquad \overline{X} = \frac{1}{MN}\sum_{j=1}^{N}\sum_{i=1}^{M} X_{ij}$$

Here: i : individual ensemble member for each RUN,
M : ensemble size of each RUN
j : individual RUN for each lead
N : number of total RUN for each lead
$\langle X\rangle_j$: Ensemble mean for individual RUN
$\overline{X}$: Sum of X_{ij}



Potential Predictability (Lead 2~4)



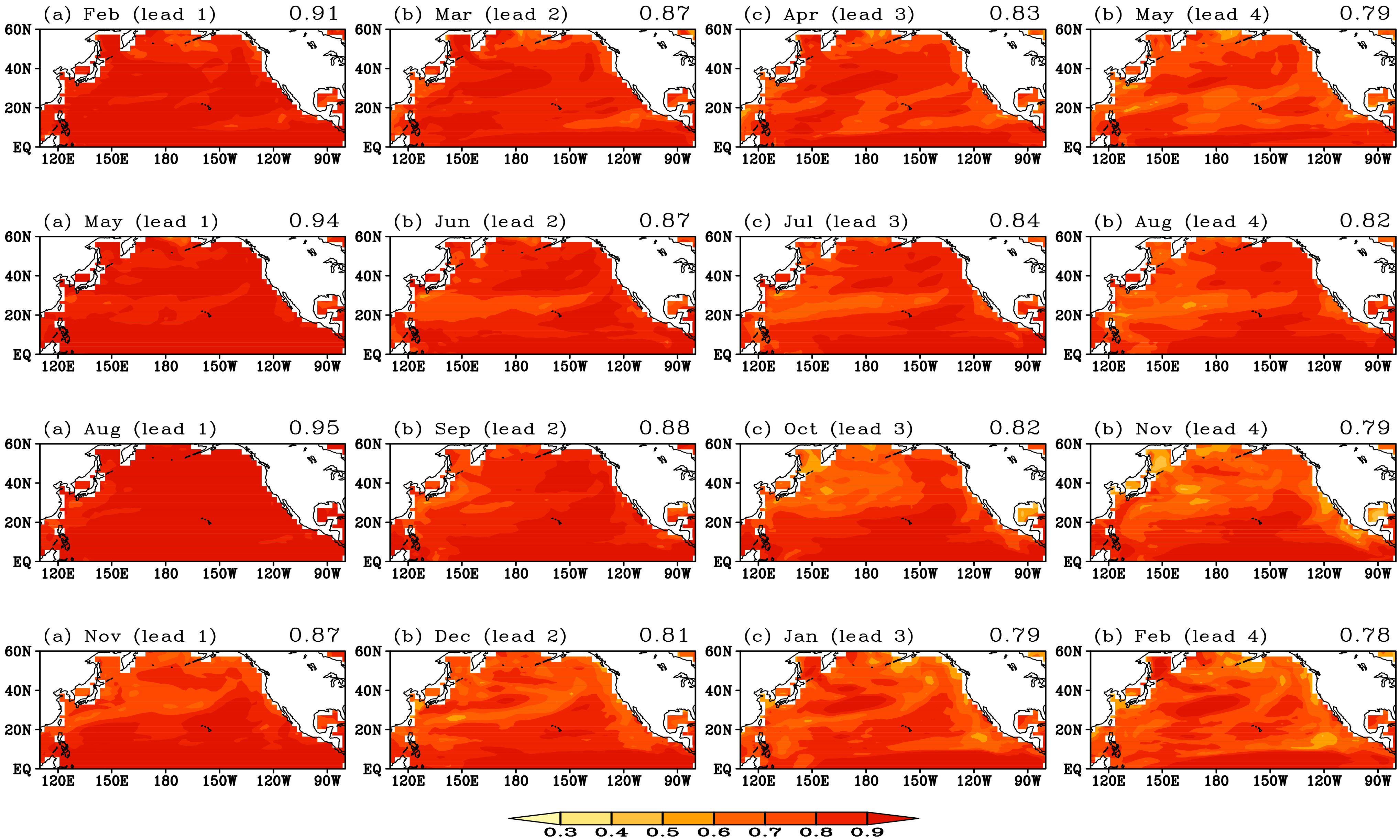
Potential Predictability (SST)

JAN RUN

APR RUN

JUL RUN

OCT RUN



Verification (Skill Scores)

- **Hit rate** = $\dfrac{A+F+K}{P}$
- **False alarm rate** = $\dfrac{(E+I)+(B+J)+(C+G)}{(P-D)+(P-H)+(P-L)}$
- **Heidke Score** = $\dfrac{(A+F+K)-C1}{P-C1}$

Obs \ Fcst	+	0	-	Total
+	A	B	C	D
0	E	F	G	H
-	I	J	K	L
Total	M	N	O	P

C1 = 0.3*(M+O) + 0.4*N

- **Brier Score(BS)**

$$= \frac{M}{P}\left(\frac{A}{M}-\frac{A}{D}\right)^2 + \frac{N}{P}\left(\frac{F}{N}-\frac{F}{H}\right)^2 + \frac{O}{P}\left(\frac{K}{O}-\frac{K}{L}\right)^2 + \frac{M}{P}\left(\frac{A}{D}-\frac{(A+F+K)}{P}\right)^2$$

$$+ \frac{N}{P}\left(\frac{F}{H}-\frac{(A+F+K)}{P}\right)^2 + \frac{O}{P}\left(\frac{K}{L}-\frac{(A+F+K)}{P}\right)^2 + \frac{(A+F+K)}{P}\left(1-\frac{(A+F+K)}{P}\right)$$

	Below Normal	Normal	Above Normal
Temperature	SSTA ≤ -σ	-σ < SSTA < +σ	SSTA ≥ +σ

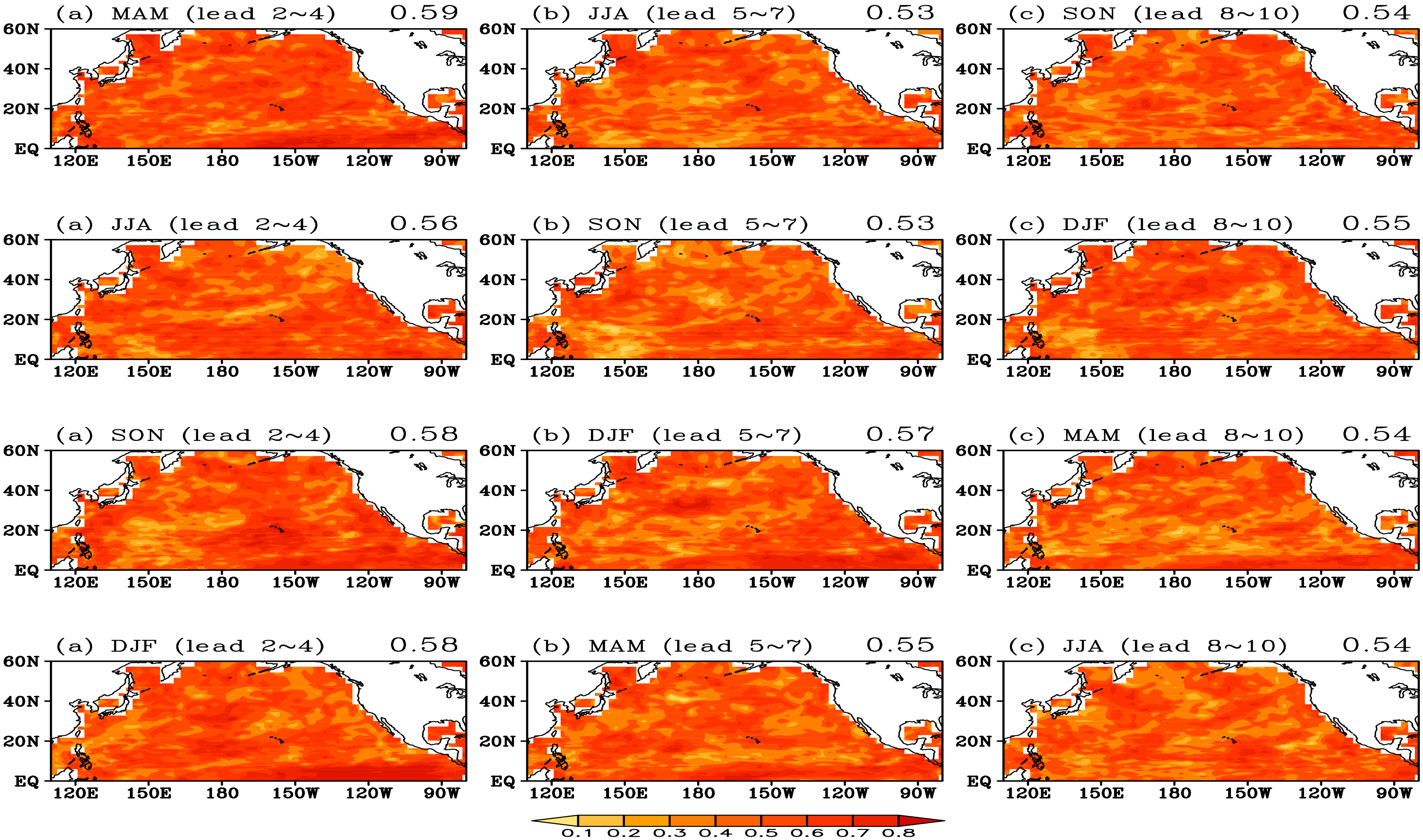
Hit Rate (SST)

JAN RUN

APR RUN

JUL RUN

OCT RUN



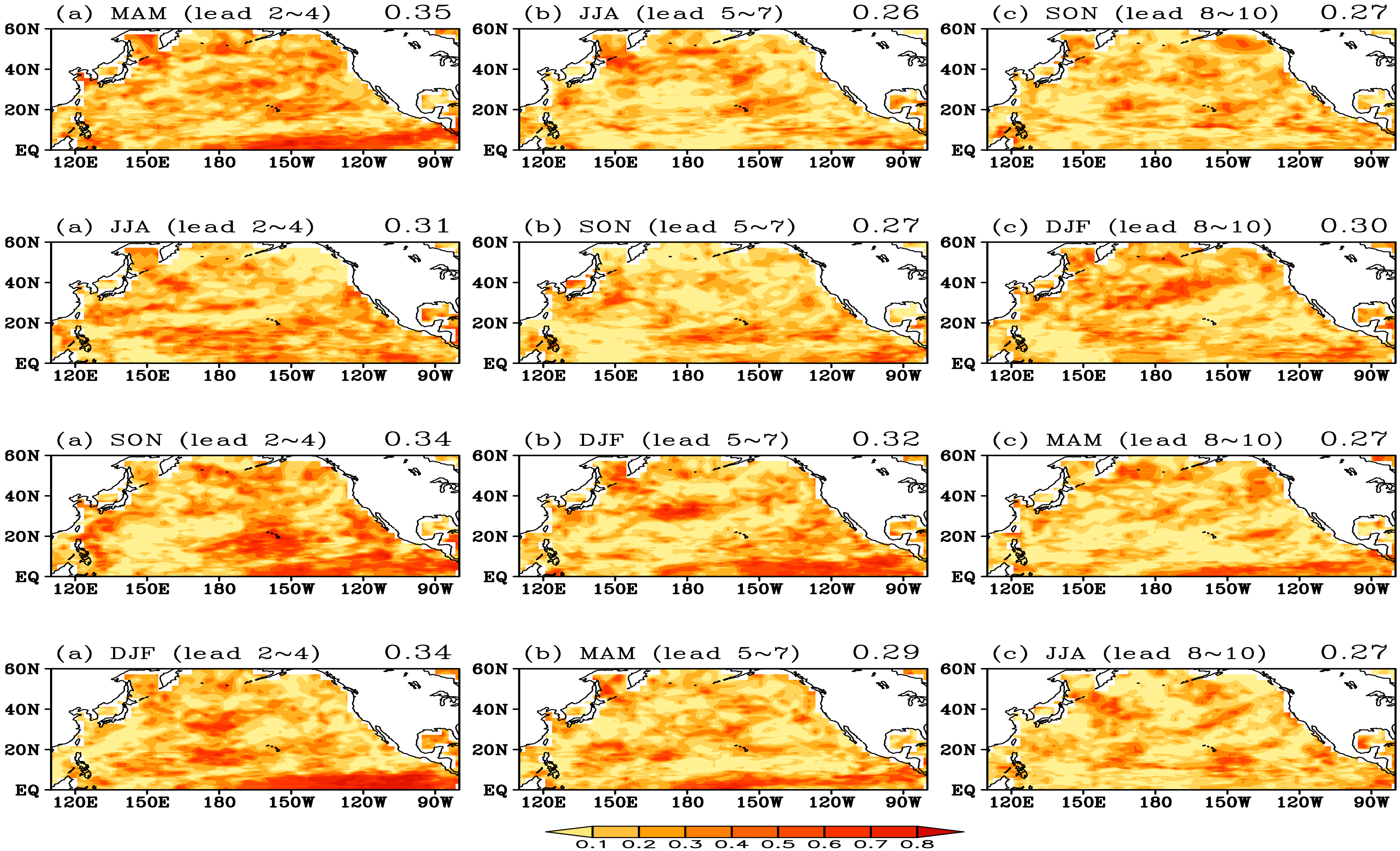
Heidke Score (SST)

JAN RUN

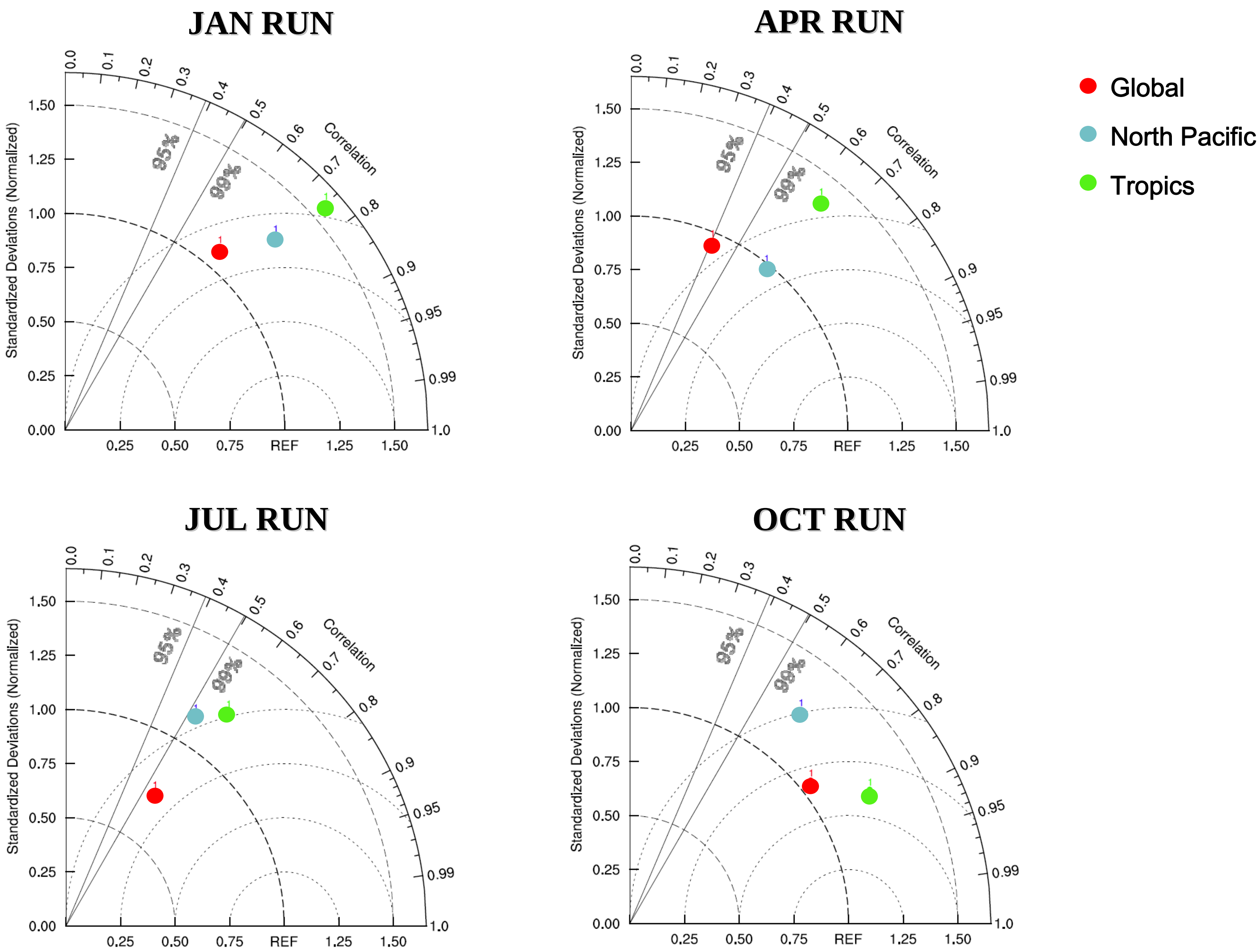
APR RUN

JUL RUN

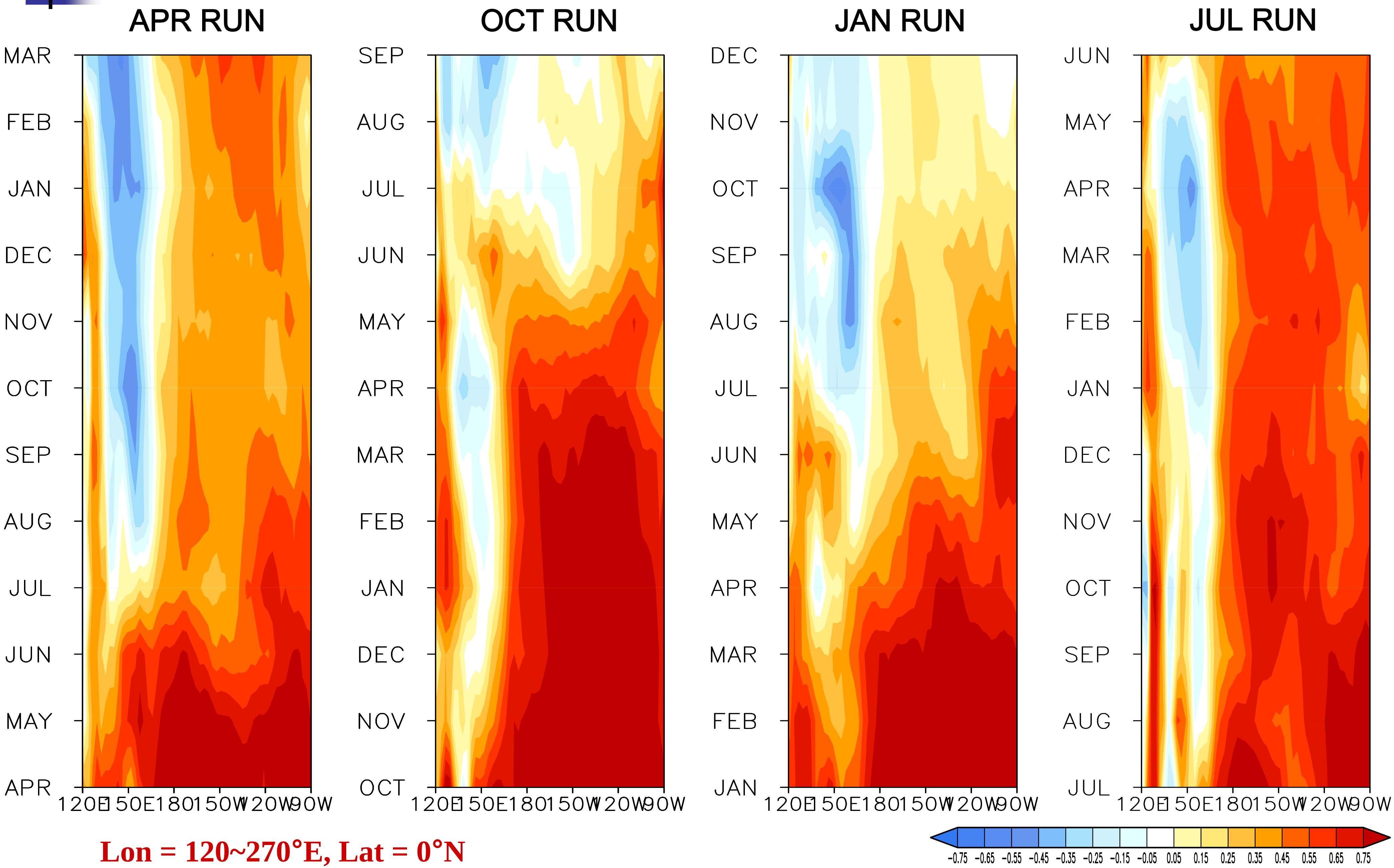
OCT RUN



Taylor Diagram of Predicted SST (Lead 2~4)



Temporal correlation of 12-month lead SSTA along the equator



Lon = 120~270°E, Lat = 0°N

Economic Impact Assessment for Deterministic Prediction

		Observation		
		above normal	normal	below normal
Forecast (action)	above normal	Hit (a) Cost	False Alarm (b) Cost	Miss + False Alarm (c) Loss + Cost
	normal	Miss (d) Loss	Correct rejection (e) 0	Miss (f) Loss
	below normal	Miss + False Alarm (g) Loss + Cost	False Alarm (h) Cost	Hit (i) Cost

- **Economic Value , EV**

$$EV = \frac{E_{clim} - E_{fcst}}{E_{clim} - E_{perf}}$$

E_{fcst} **: Expected expense of a forecast**

E_{perf} **: Expected expense of a perfect forecast**

E_{clim} **: Expected expense of climatological forecast**

EV = 1 : Perfect forecast

EV = 0 : Climatological forecast

- $E_{fcst} = \dfrac{(a+b+c+g+h+i)C + (c+d+f+g)L}{L}$
- $E_{perf} = \dfrac{C}{L}\,\overline{o}$

$\overline{o}$: relative frequency of cases in which climate event occurs

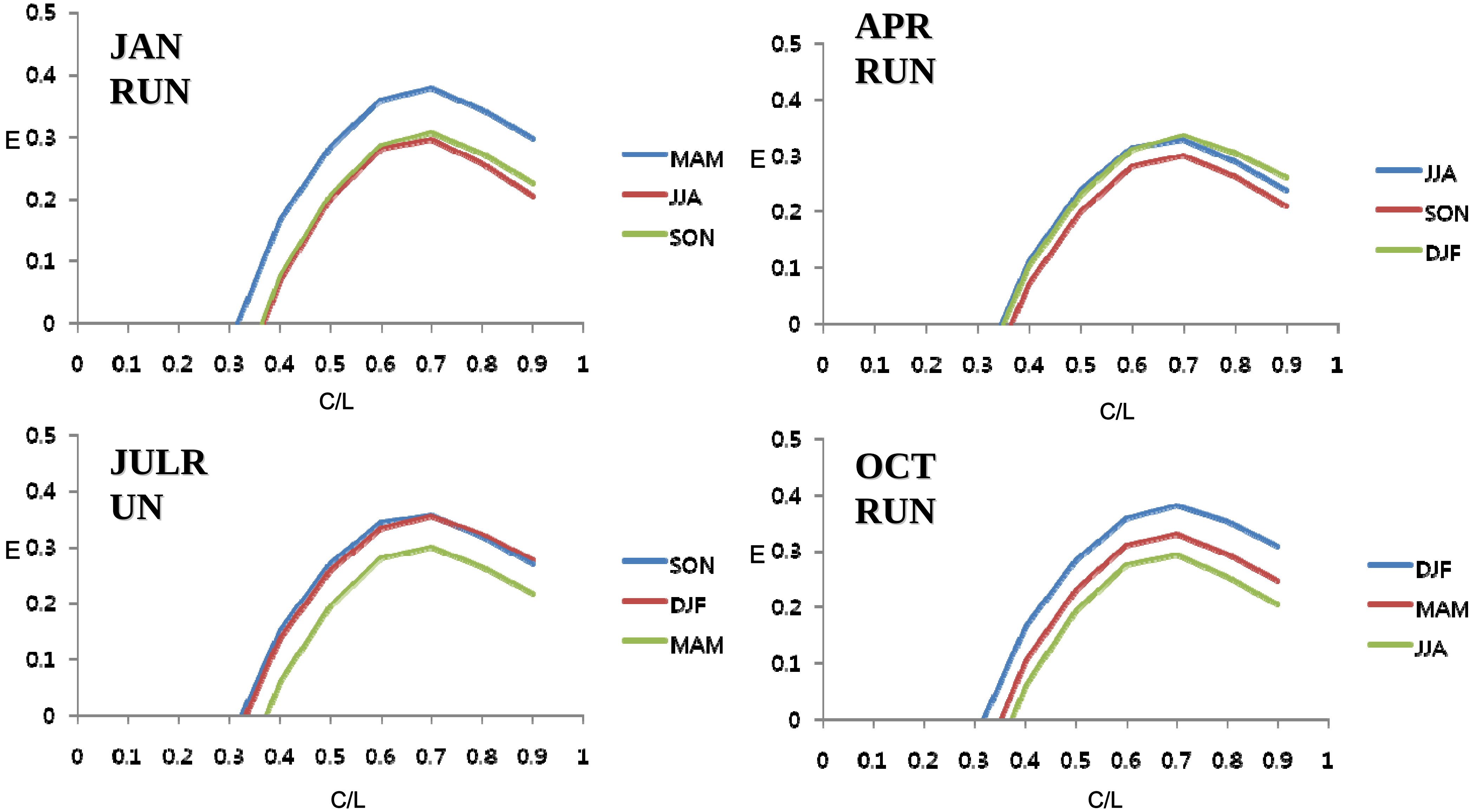
- $\overline{o} = \dfrac{a+i}{a+b+c+d+e+f+g+h+i}$

- $E_{clim} = \mathrm{Min}\left(\dfrac{C}{L}, \overline{o}_{cli}\right)$

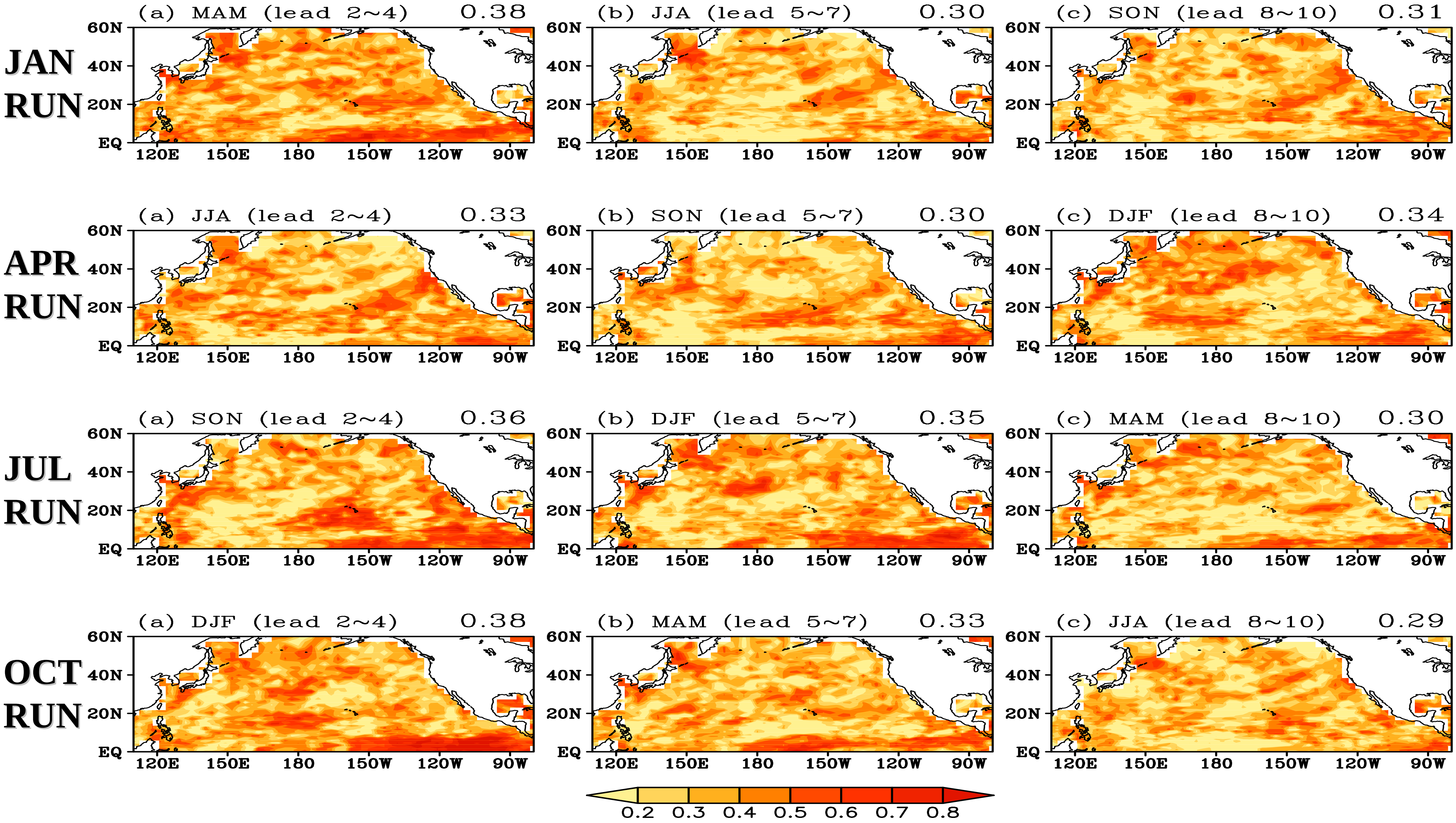
$\overline{o}_{cli}$: climatological frequency of the event

- $\overline{o}_{cli} = \dfrac{d+e+f}{a+b+c+d+e+f+g+h+i}$

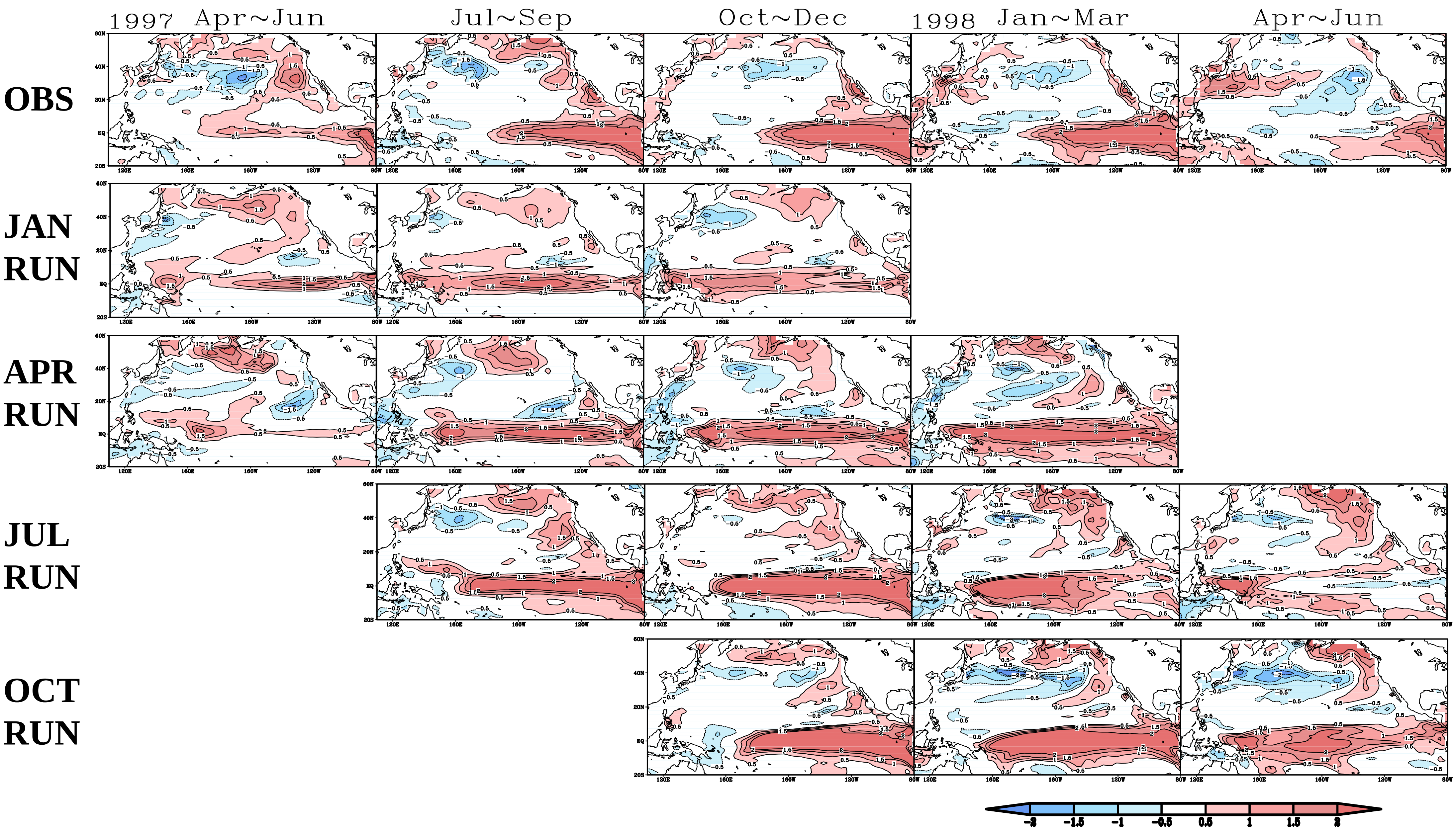
Economic Values for Seasonal Hindcast (Lead 2~4)



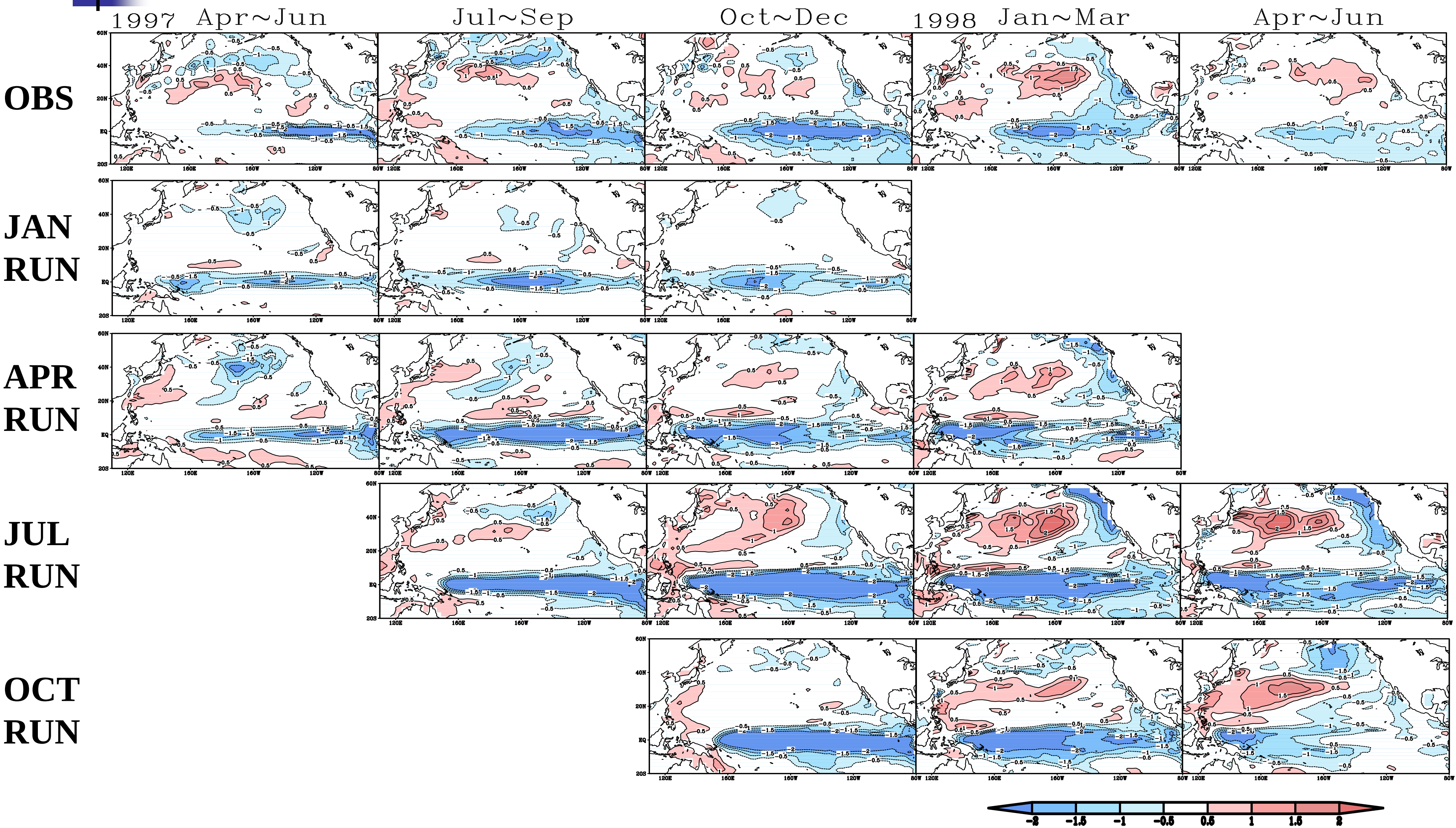
Economic Value (C/L = 0.7)



97/98 El Nino Prediction in Different Leads



98/99 La Nina Prediction in Different Leads



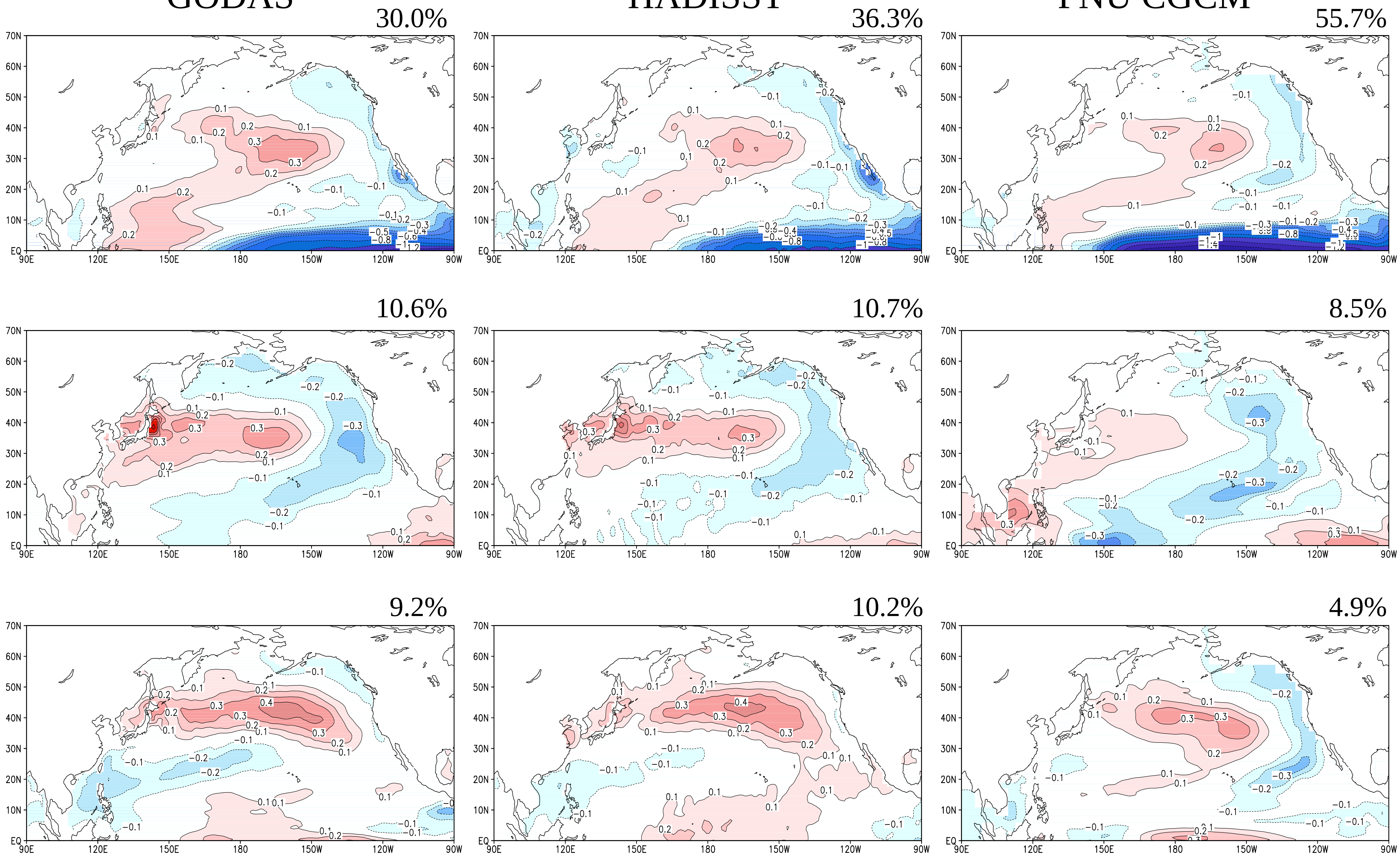
EOF Spatial Patterns for Observed and Predicted (Lead 2~4) SSTs

GODAS | HADISST | PNU CGCM

1st MODE

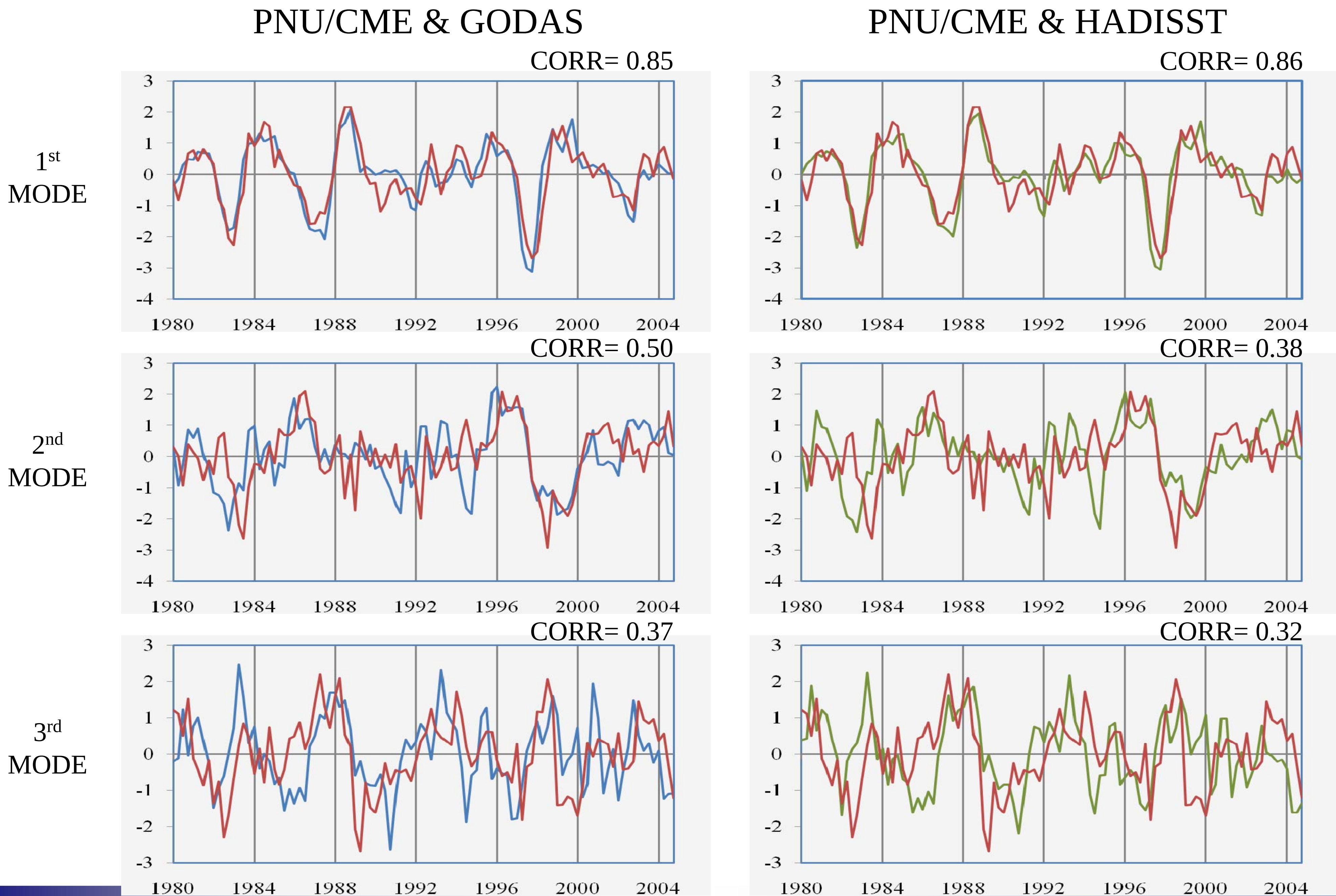
2nd MODE

3rd MODE



EOF Coefficients for Observed and Seasonally Predicted SST

※ 99% Significance level : 0.26



Summary

- The predictability of the PNU/CME CGCM is assessed by analyzing 29 cases of 12-month lead hindcasts.

- For the purpose, various skill scores and economic values are estimated in terms of mainly North Pacific sea temperature to access the performance of the CGCM predicting long-term climate.

- The CGCM has a good capability of predicting North Pacific climate 1- to 12-month ahead.

- The high predictability of the model is due to its capability of depicting the prominent modes existing over North Pacific.