TCC Training Seminar on 30th January 2018

JMA's Ensemble Prediction Systems (EPSs) and their Products for Climate Forecast

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Contents

- Basic Knowledge
  - NWP Model and Predictability
  - Ensemble Prediction and Uncertainty
  - Hindcast
- JMA's NWP Models
  - JMA's Global Ensemble Prediction System
  - JMA's Seasonal Ensemble Prediction System
- TCC's NWP Model Products

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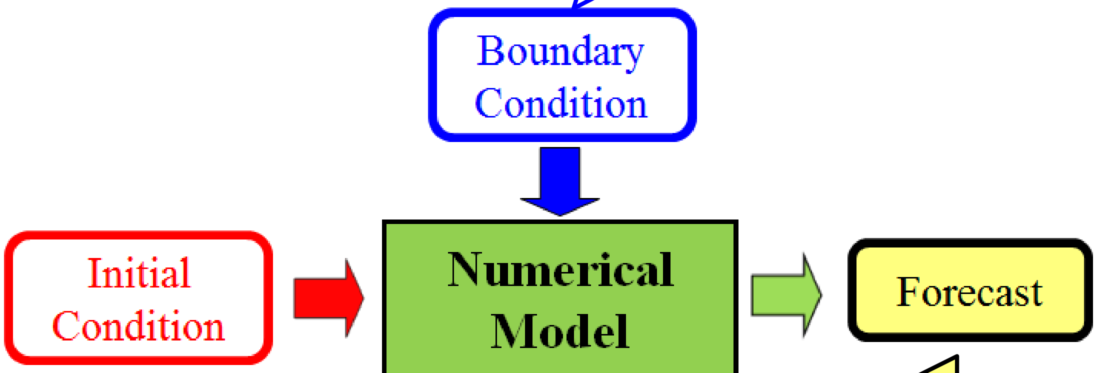
Numerical Weather Prediction

■ A Simplified Conceptual Chart of “Numerical Prediction”

In this case, boundary conditions mean many kinds of seasonal variable natural factors except atmosphere such as **sea surface temperatures (SSTs), sea ices and snow covers**. In general, **variations of boundary conditions are slower** than a variation of atmosphere.



A numerical model is made from many kinds of **physical laws** and **a large number of grids**.

If you input an initial atmospheric condition and boundary conditions into a numerical model, you can get to know a future atmospheric condition as an output.

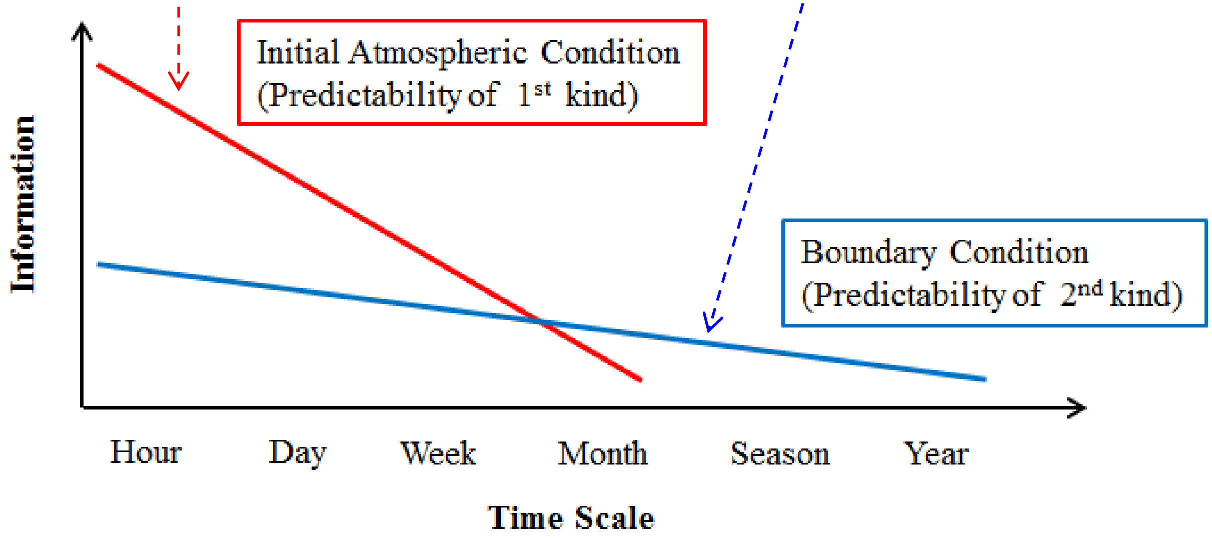
Predictability

■ A Simplified Conceptual Chart of "Predictability"

There are mainly 2 types of predictabilities.

■ **"Predictability of 1st kind"**
depends on an **initial atmospheric condition**. Because a variation of atmosphere is fast, information which an initial atmospheric condition has are lost rapidly.

■ **"Predictability of 2nd kind"**
depends on **boundary conditions** such as **sea surface temperatures (SSTs), sea ices and snow covers**. Because variations of boundary conditions are slow, they make a long-range forecast possible.

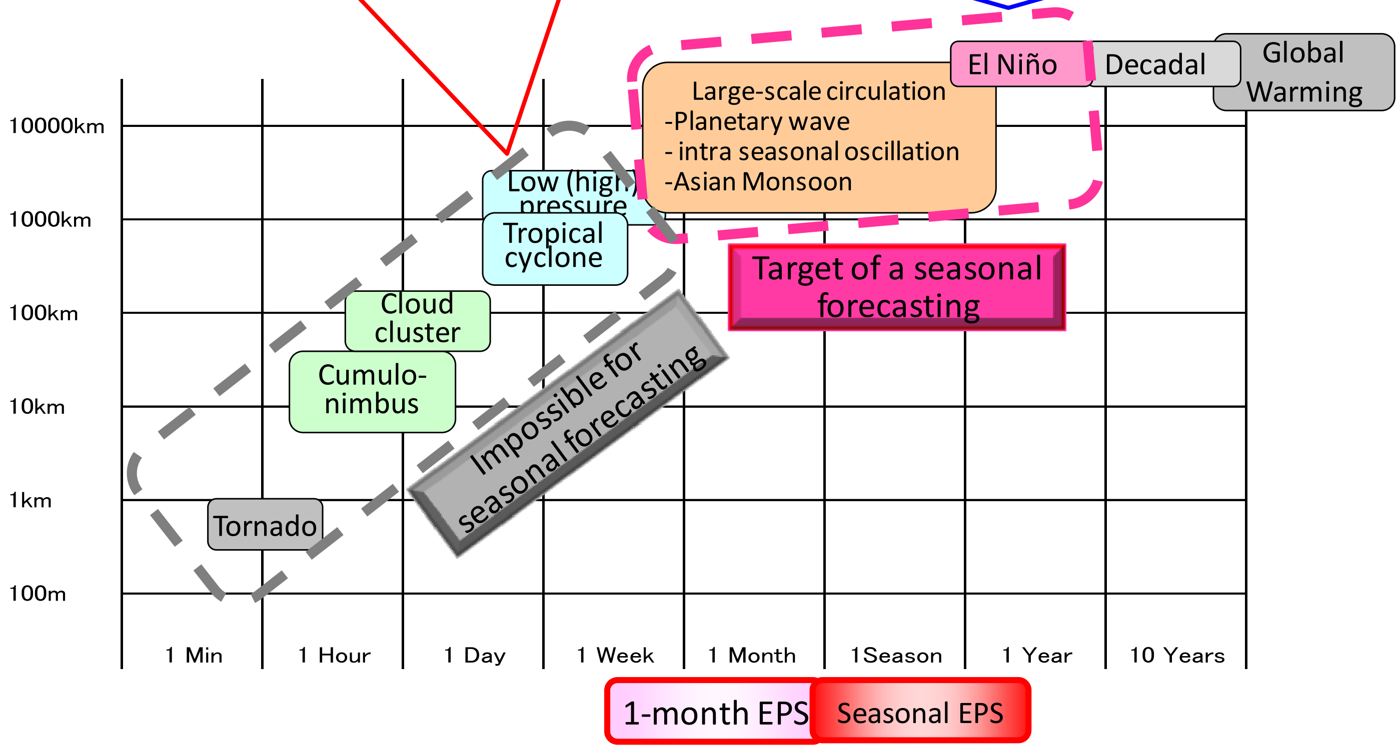


Predictability

■ Temporal and Spatial Scale of Atmospheric Phenomena

■ Short-life and Small-scale Phenomena
(e.g. Tornadoes, Cyclones)
Long-range forecast is impossible,
because they are sensitive to an initial atmospheric condition.

■ Long-life and Large-scale Phenomena
(e.g. Seasonal Oscillations, Monsoons)
Long-range forecast is possible,
because they are sensitive to boundary conditions rather than an initial atmospheric condition.



Predictability

■ Potential Predictability derived by SSTs

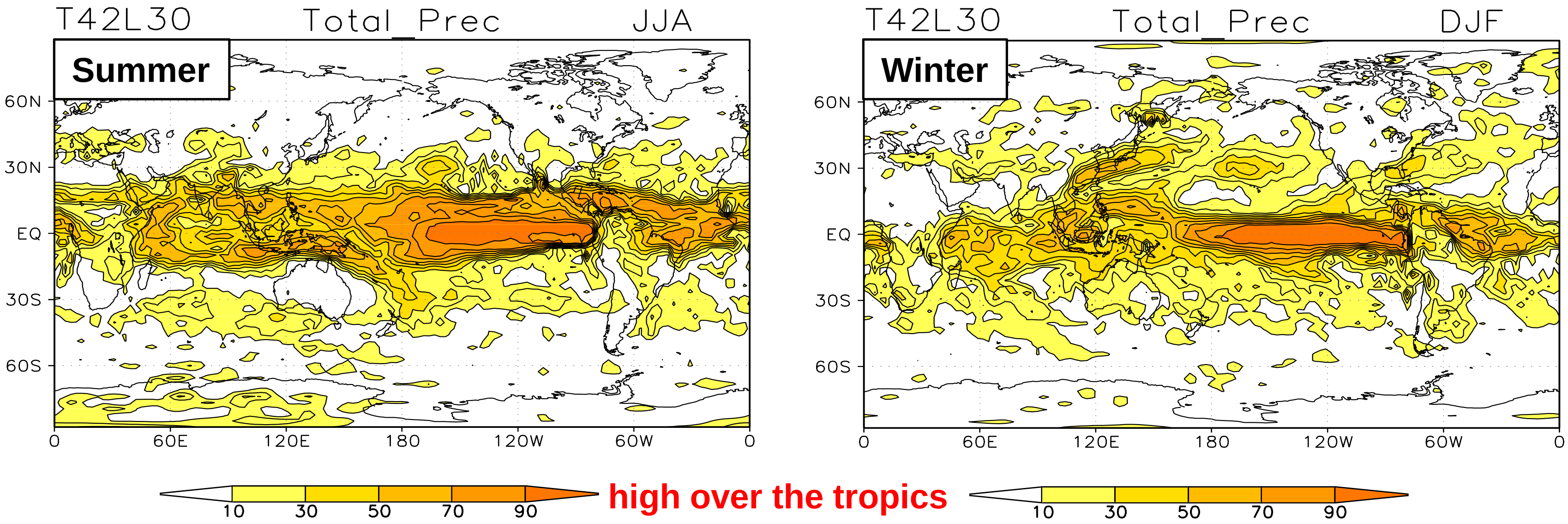
An experiment of giving same SSTs to all ensemble members (9 members, 1979-1993)

Signal: Anomaly of Ensemble Mean

Noise: Ensemble Spread

$$Potential\ Predictability = \frac{Signal}{Signal + Noise} \times 100\ (\%)$$

Potential Predictability for Seasonal Precipitation derived by SSTs



Sugi, M., R. Kawamura and N. Sato, 1997, J.Meteor.Soc.Japan, 75, 717-736.

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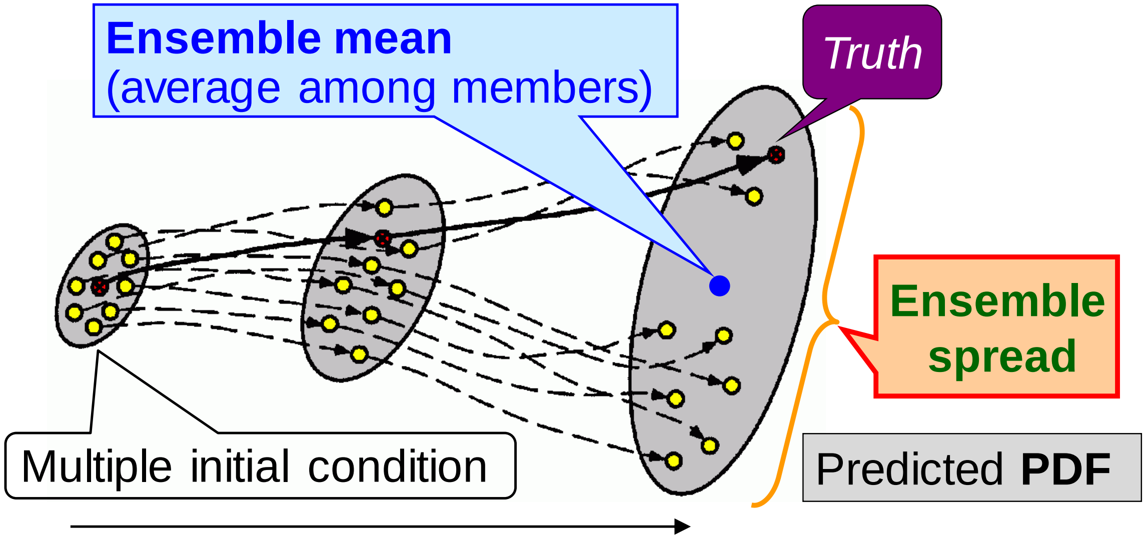
Uncertainty and Ensemble Prediction

■ A Simplified Conceptual Chart of Ensemble Prediction

Because atmosphere has chaotic nature, a small error in an initial condition grows rapidly. However, it is **impossible to know a perfect initial condition** even with the use of high accurate observations. Therefore, it is **essential to consider <u>uncertainty</u>** when forecasting. **Ensemble prediction makes it possible to estimate <u>uncertainty</u>** caused by initial condition errors with similar calculations from a little bit different multiple initial conditions.



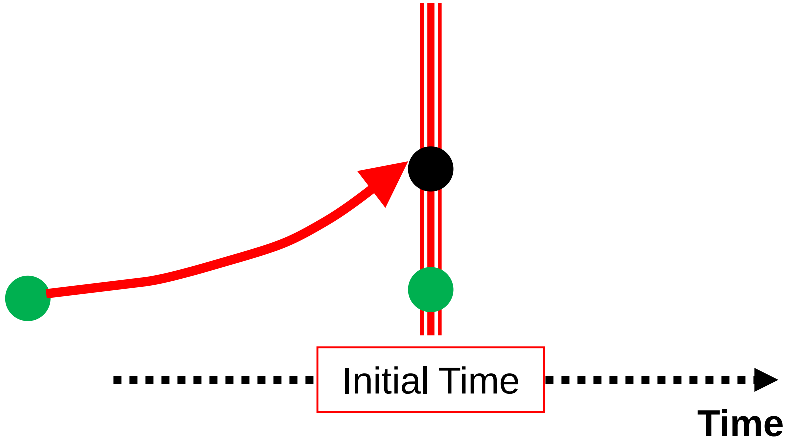
The individual calculation is called "**Ensemble member**" and the standard deviation among all members is called "**Ensemble spread**".

Initial Perturbation

In order to efficiently represent the initial observational error with initial perturbations (multiple initial conditions), the following methods are used.

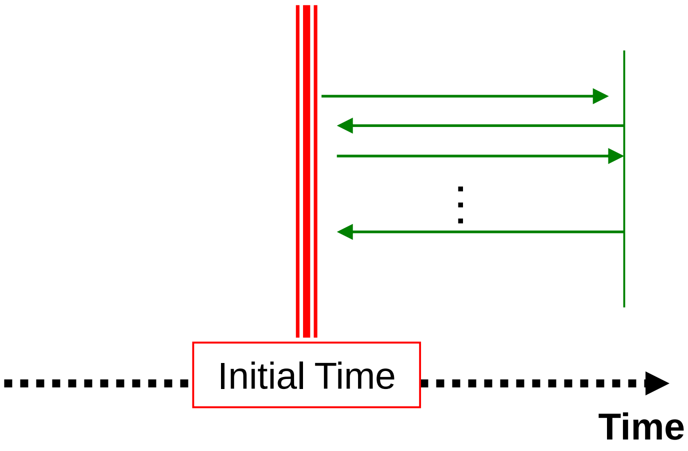
■Breeding of Growing Mode（BGM）

The BGM method **finds out the perturbation grew before the initial time** with a forecast and assimilation cycle.
This method is simple but **necessary to keep a forecast and assimilation cycle** even for the time except the initial time.



■Singular vector (SV)

The SV method **finds out the fastest growing perturbation after the initial time** with the use of a tangent linear model which is obtained by locally linearizing the original nonlinear NWP model and its adjoint model.
This method can find better perturbations, but **requires heavier resources for calculation and development.**



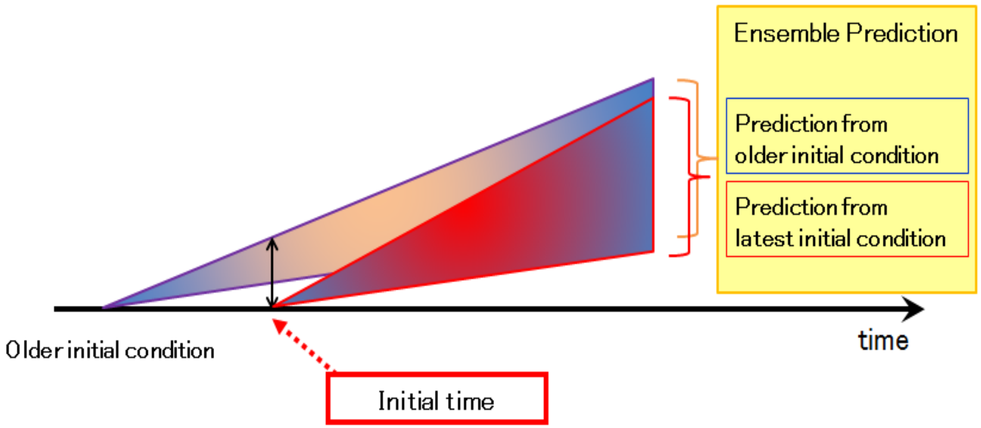
Ensemble Techniques

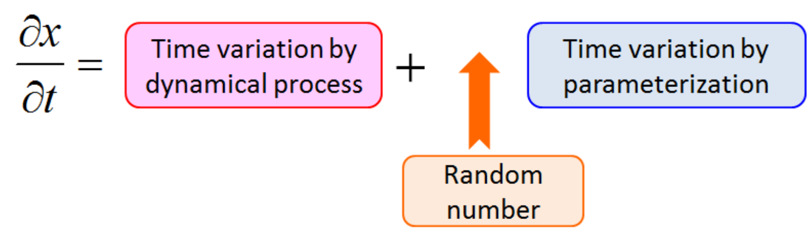
■LAF

Lagged Average Forecasting (LAF) is one of the ensemble prediction techniques.
Ensemble prediction is **calculated with the combination of predictions from not only latest initial condition but also older initial conditions**.
LAF is easy method for ensemble prediction and make it possible to share computer resources among several days.
However, the accuracy of prediction from older initial conditions is generally worse than that from latest initial conditions.

■Stochastic Physics Scheme

Uncertainty is caused by imperfection of not only initial conditions but also numerical prediction models. In order to consider uncertainty caused by imperfection of numerical prediction models, **multi-model ensemble (MME) system and stochastic physics scheme are often used**.
MME is an EPS using some different numerical ensemble prediction models.
Stochastic physics scheme is a calculation method which controls some physical calculations with random numbers.





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Hindcast

◆ **Hindcast** (= behind + forecast) ; coined term

Systematic forecast experiments for past cases performed with the use of the operational EPS.

- **Purpose of the hindcast**
  - to **understand prediction skill**
  - to **calculate the model statistics (bias, model climate)** for creating various products (e.g., forecast maps, numerical guidance)
- **Hindcast period** is required to be **more than 20 years**.
- **Difficulty**
  - In order to calculate a large number of past events, huge computer resources are required.

(Because of limited computer resources, ensemble size and calculation frequency are less than those for operational forecasts in JMA.)

Definition of Bias and Anomaly

Bias

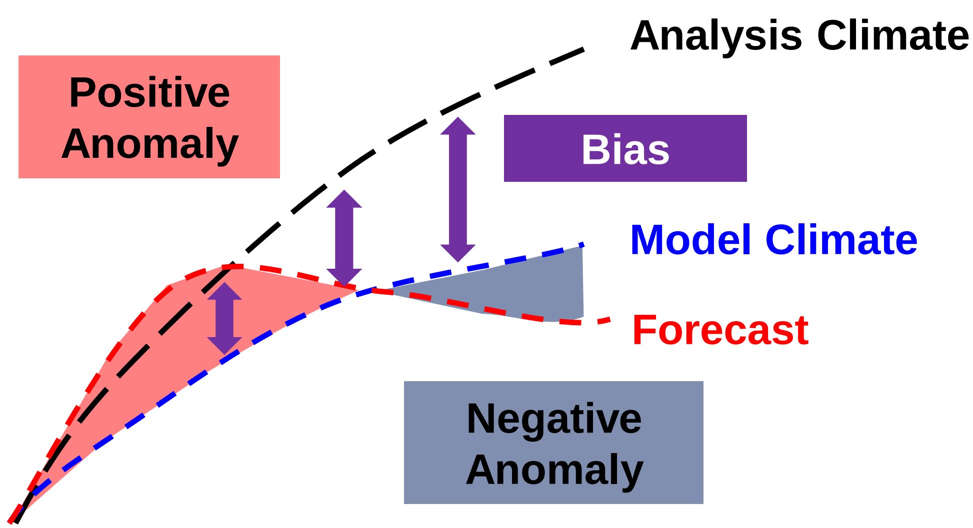
- Bias is systematic errors of the model, calculated as **the difference between <u>model climate</u> and <u>analysis climate</u>**.

Anomaly

- Anomaly is calculated as **the difference between <u>model climate</u> and <u>forecast</u>** to reduce the influence from bias.

Difficulty

- It is **impossible to adjust the systematic <u>positon errors</u>** of jet stream etc.
  Therefore, it is **essential to reduce model prediction bias**.



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WMO Forecast Classification

In line with "WMO's Manual on the Global Data-Processing and Forecasting System", forecasts are classified by their ranges. **Seasonal forecasting, which is the main topic of TCC seminar, corresponds to extended- and long- range forecasting.** Especially, this TCC seminar focuses on long-range forecasting.

	Forecasting target period
Nowcasting	Up to 2 hours
Very short-range weather forecasting	Up to 12 hours
Short-range forecasting	Beyond 12 hours and up to 72 hours
Medium-range weather forecasting	Beyond 72 hours and up to 240 hours
Extended-range weather forecasting	Beyond 10 days and up to 30 days
Long-range forecasting	Beyond 30 days up to two years
Climate forecasting	Beyond two years

https://www.wmo.int/pages/prog/www/DPS/Publications/WMO_485_Vol_I.pdf

JMA's Operational Global NWP Models

as of Jan.2018

	Main target	Horizontal resolution
Global Spectral Model (GSM)	•Short-range forecast	20km (TL959)
Global EPS	•Typhoon forecast	40km (TL479)
	•One-week forecast	
	•Early warnings for extreme events (Fortnight forecast)	
	•One-month forecast	55km (TL319)
Seasonal EPS	•3month forecast •Warm/Cold season forecast •El Niño outlook	110km (TL159)

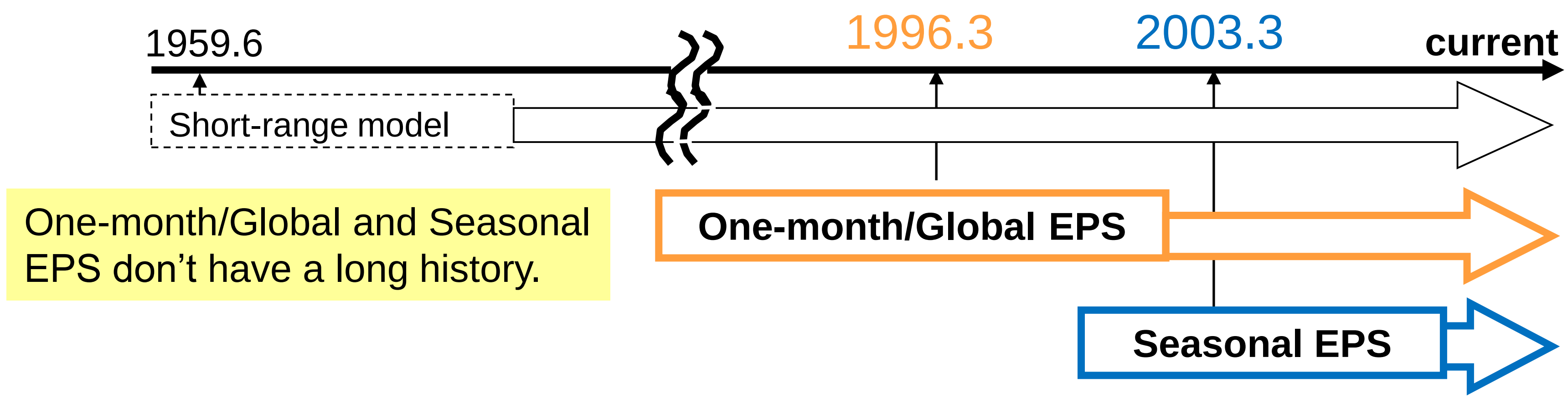
AGCM: Global Spectral Model (GSM), Global EPS

CGCM: Seasonal EPS

Numerical Prediction Division/JMA: Short-range forecast, Typhoon forecast, One-week forecast

TCC – Climate Prediction Division/JMA: Early warnings for extreme events (Fortnight forecast), One-month forecast, Seasonal EPS

History of EPSs



	Mar 1996	Mar 2001	Mar 2003	Mar 2006	Sep 2007	Mar 2008	Feb 2010	Mar 2014	Jun 2015	Mar 2017
One-month/ Global EPS	**T63 L30 M10**	**T106 L40 M26**		**TL159 L40 M50**		**TL159 L60 M50**		**TL319 L60 M50**		**TL479/319 L100 M50**
Seasonal EPS			**T63 L40 M31**	**TL95 L40 M31**	**TL95 L40 M51**		**TL95 L40 M51**		**TL159 L60 M51**	

Red: AGCM **Blue: CGCM**

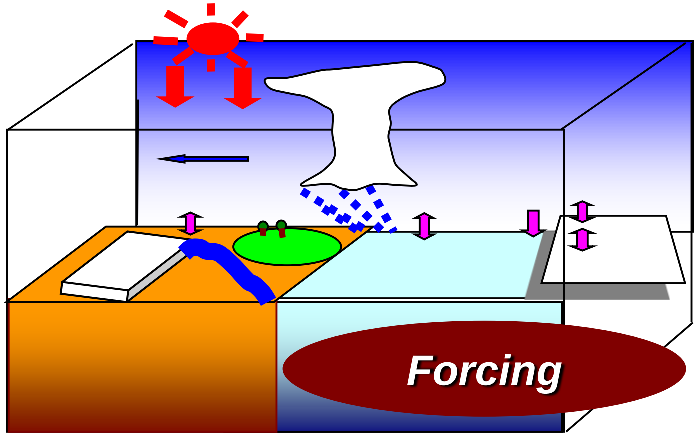
Difference between AGCM and CGCM

AGCM

Atmospheric **G**eneral **C**irculation **M**odel

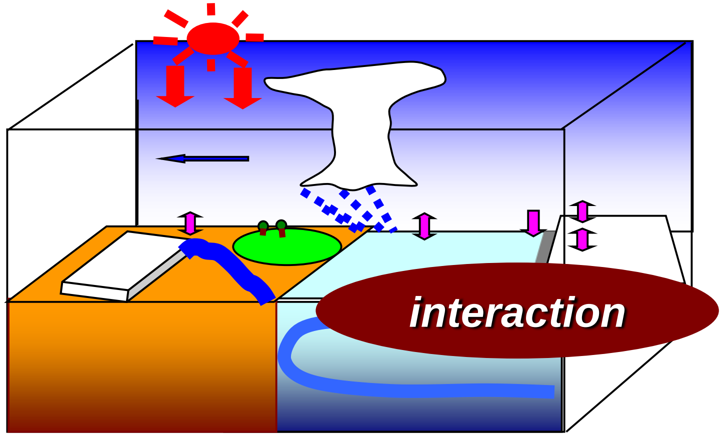
CGCM

Coupled Ocean-Atmospheric **G**eneral **C**irculation **M**odel



Oceanic conditions are given as a forcing. Prescribed anomalies are used for SST forcing.

Two-tiered method



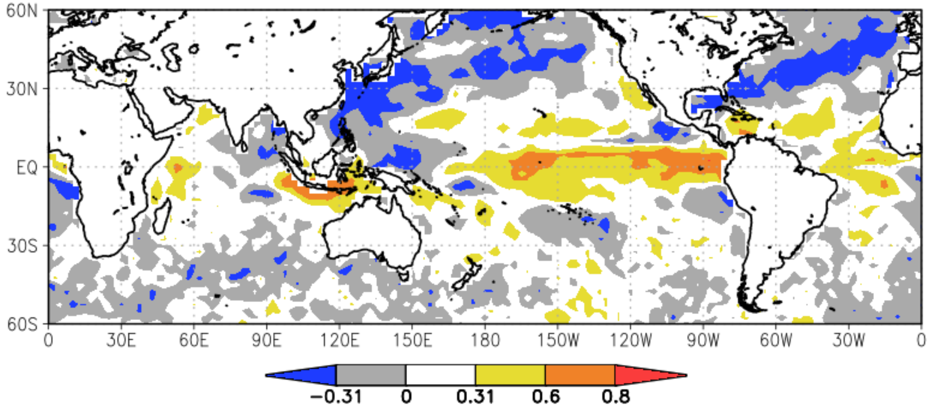
Ocean-atmosphere interaction is considered.

One-tiered method

Difference between AGCM and CGCM

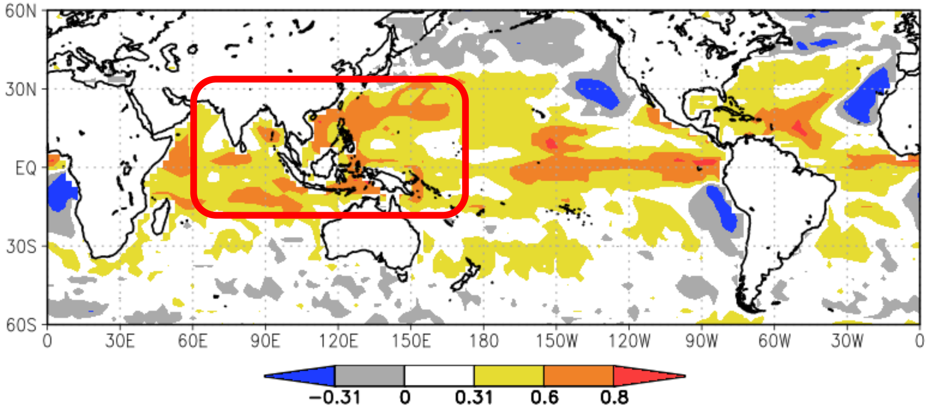
Correlation coefficient between SST and precipitation in July (Initial date: 30 June, 1979-2010)

Analysis

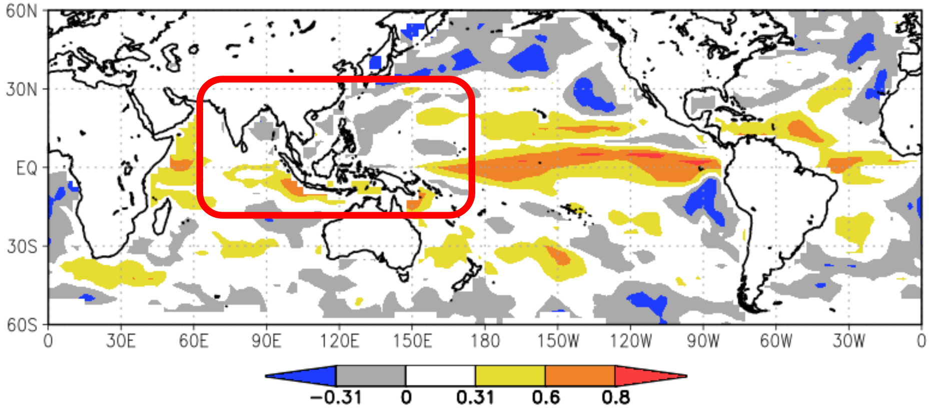


CGCM improves an excess positive correlation between SST and precipitation in tropics, especially over Asian monsoon. CGCM leads to improve prediction skills especially over the tropics, which are affected by tropical oceanic variations.

AGCM



CGCM



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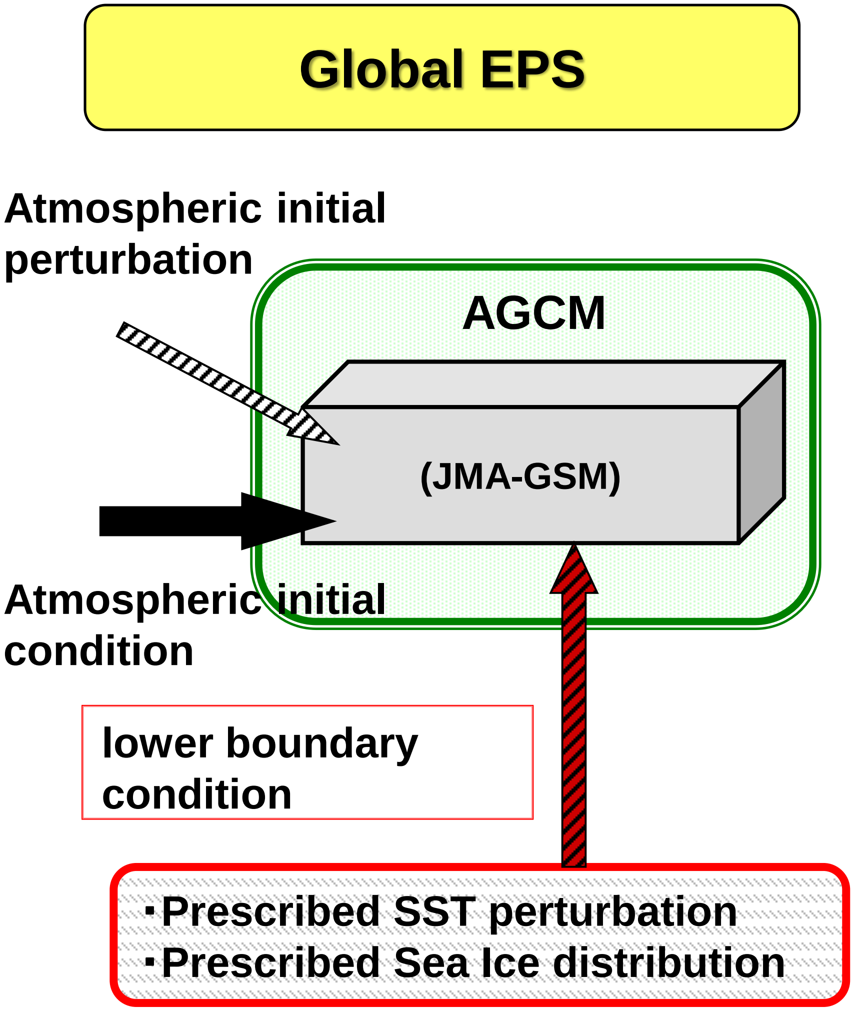
Specification of Global EPS

as of Jan.2018



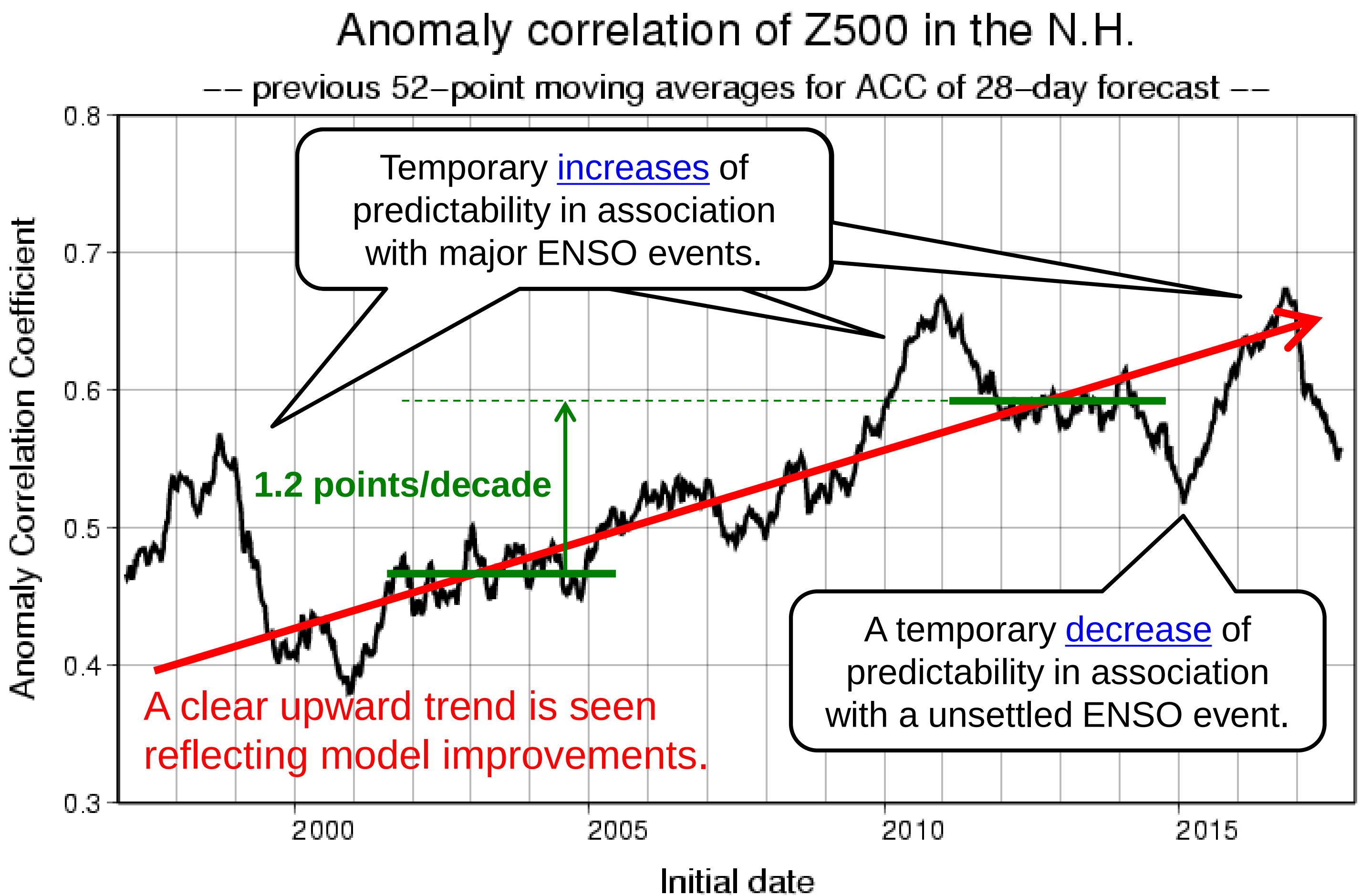
Upgrade	Last: March 2017 Frequently: Every few years
Model	AGCM
Horizontal Resolution	40km (TL479) up to 18 days 55km (TL319) after 18 days
Vertical Resolution	100 levels up to 0.01hPa
Forecast range	Up to 34 days
SST	Prescribed SST perturbation
Sea ice	Prescribed Sea Ice distribution (Sugimoto and Takaya, 2014)
Ensemble method	SV, LAF, LETKF (based on Hunt et al., 2007) Stochastic physics scheme
Ensemble size	50 (13-11 SVs x 4 initial LAFs at 12hour interval)
Freq. of operation	Every Tuesday and Wednesday
Freq. of model product creation	Once a week (Thursday)

Specification of Global EPS Hindcast

	Hindcast	Operational system
Initial Condition	JRA-55 Reanalysis	Global Analysis (Newer System than JRA-55)
Ensemble Size	5 (5 SVs, no using LAF)	50 (13-11 SVs x 4 initial LAFs with 12hour interval)
Forecast range	Initial date +40days	2,3,4,…,31,32days from the latest initial date (Wednesday)
Initial date	3 times per month (10th, 20th, end of month)	4 times per week (00 & 12 UTC on Tuesday and Wednesday)
Target period for hindcast	Available: 1981.1 - 2017.3 Verification: 1981.1 - 2010.12	---

Because of the limited computer resources, ensemble size and frequency of calculation for hindcasts are less than those for operational forecasts.
For the initial date on which no hindcast was performed, virtual hindcast data is created with a linear interpolation method using before and after initial dates on which hindcasts were performed.

Scores of Operational One-month Prediction

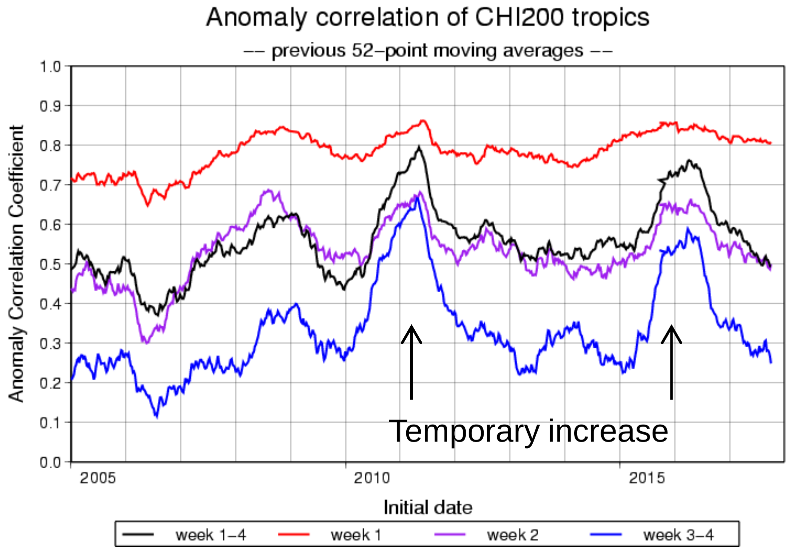


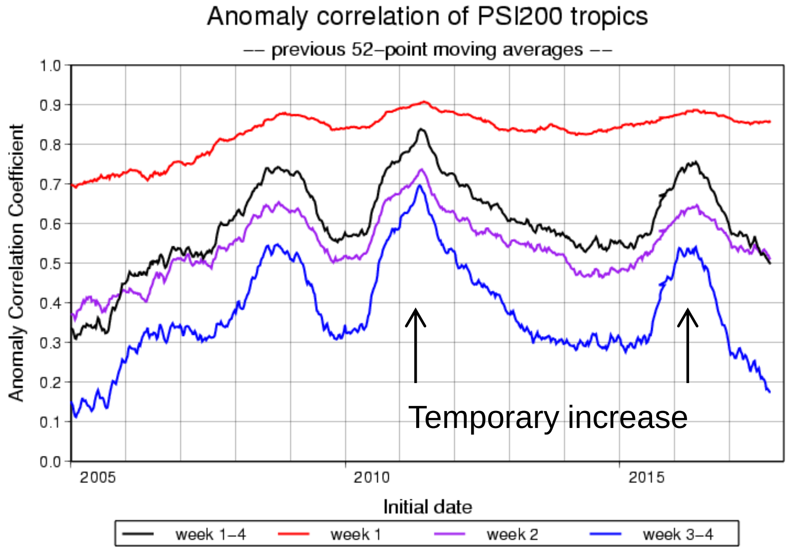
0.6 is the limit for deterministic forecast.

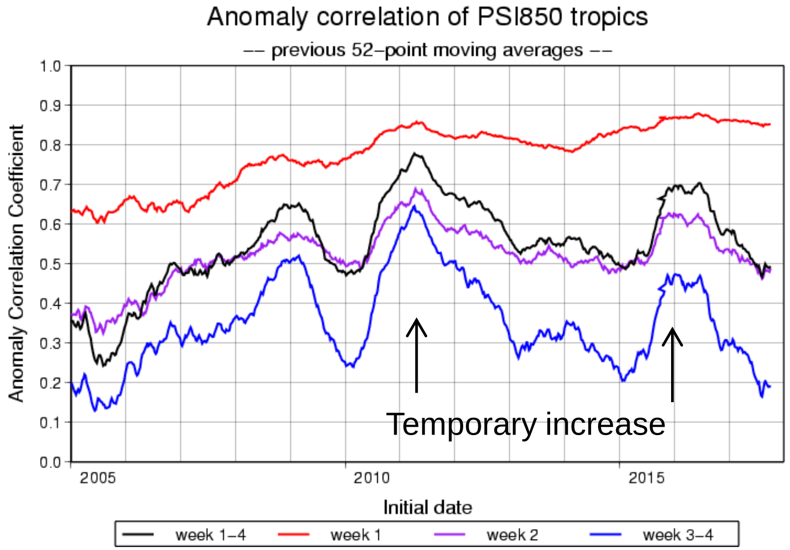
0.3 is the limit for probabilistic forecast.

http://ds.data.jma.go.jp/tcc/tcc/products/model/verif/1mE/Map_discussion/ACOR/vrfmap_acc_z500_nh_52wmean.e.html

Scores of Operational One-month Prediction





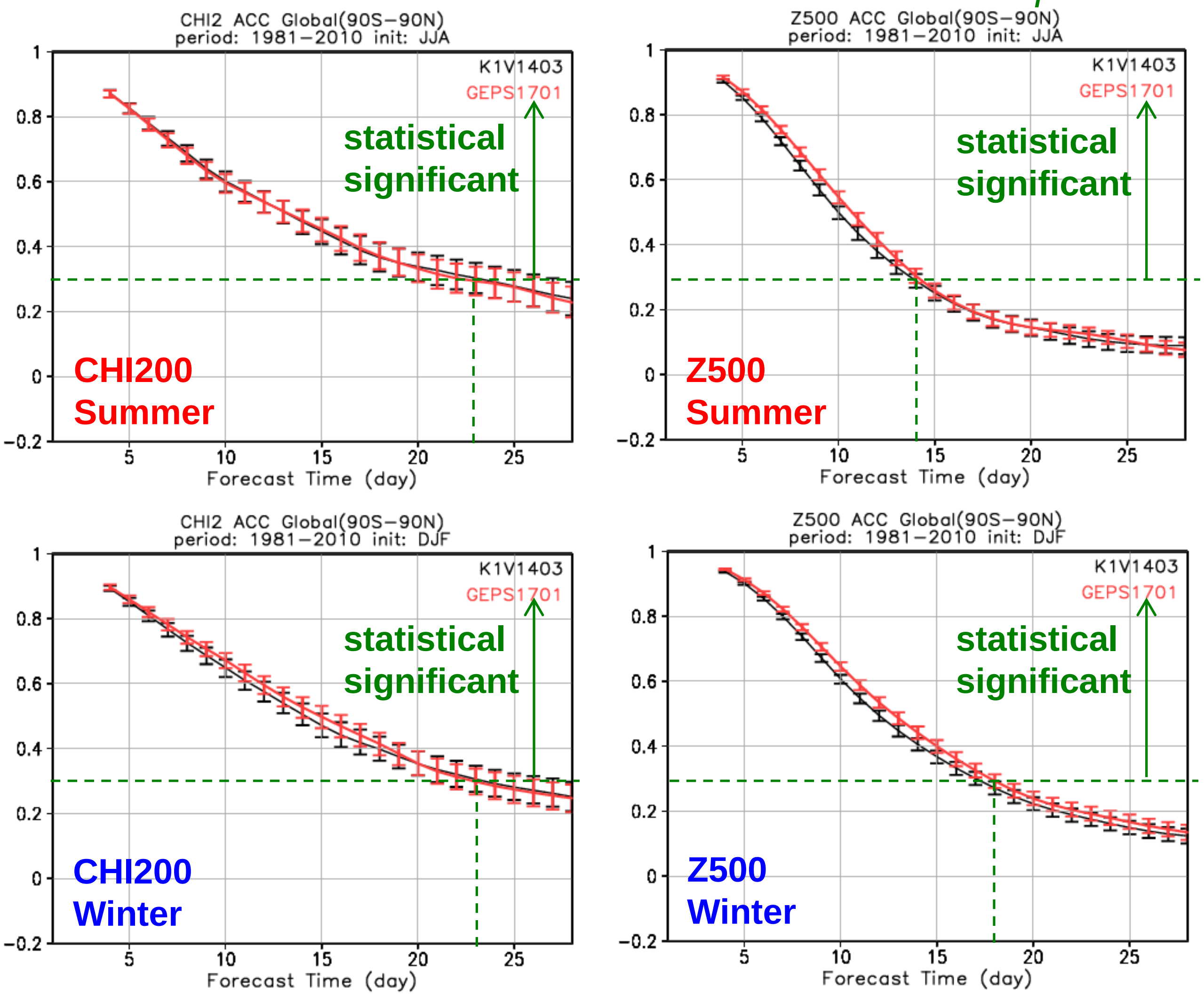


Scores for Tropics.
Clear upward trends are seen but scores longer than fortnight forecast are largely influenced by variations of predictabilities in association with ENSO events.

http://ds.data.jma.go.jp/tcc/tcc/products/model/verif/1mE/Map_discussion/ACOR/vrfmap_acc_tr_52wmean.e.html

Prediction Skill of One-month EPS

Hindcast experiments for 30 years (1981 – 2010)



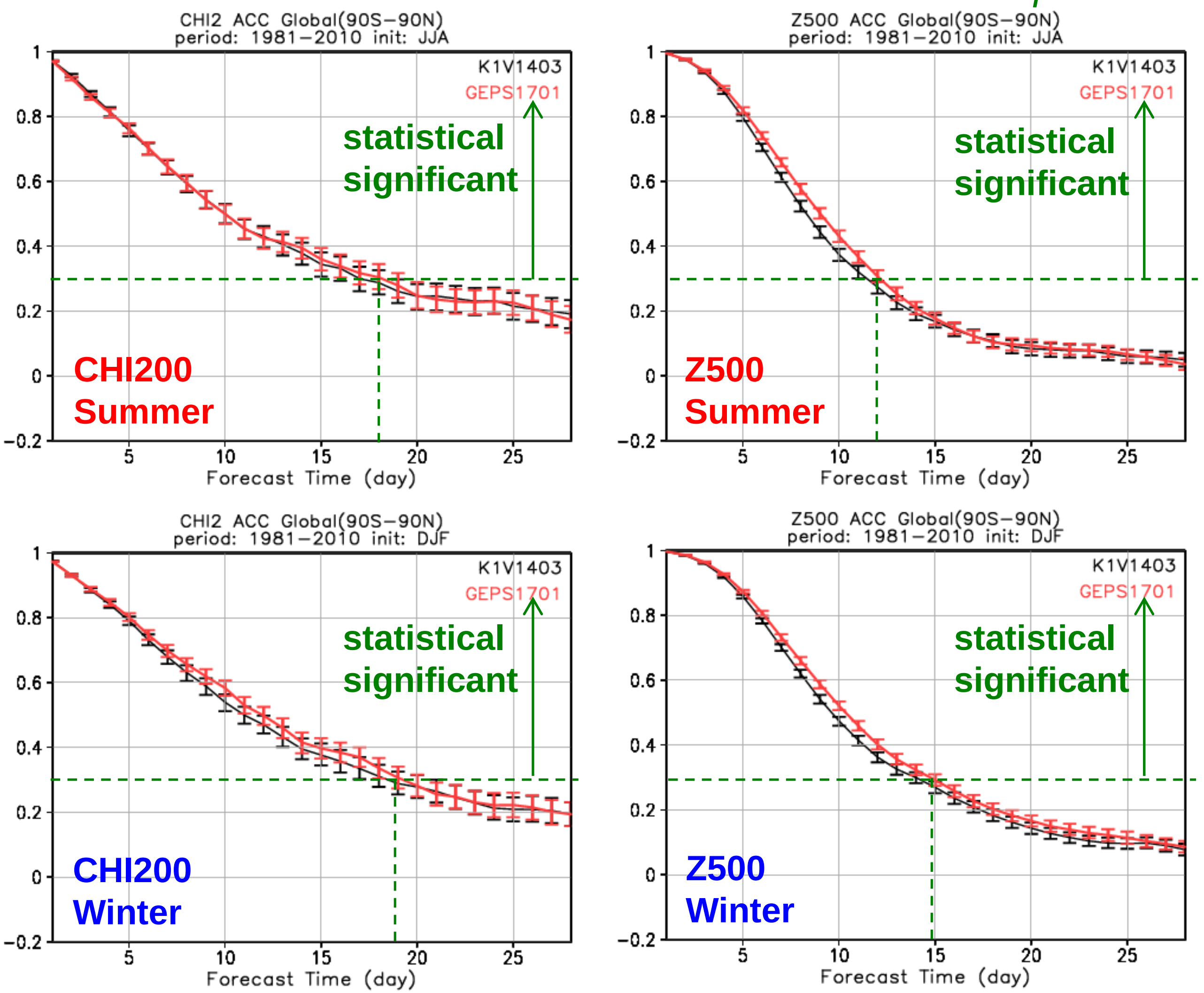
How many days are predictable for weekly mean forecast by 5-member ensemble?

- **CHI200** in the tropics is averagely predictable up to 21-25days with small seasonal dependency.
- **Z500** in the Northern Hemisphere is averagely predictable up to 14-18 days with large seasonal dependency.

The larger ensemble size is, the higher scores is.

Prediction Skill of One-month EPS

Hindcast experiments for 30 years (1981 – 2010)



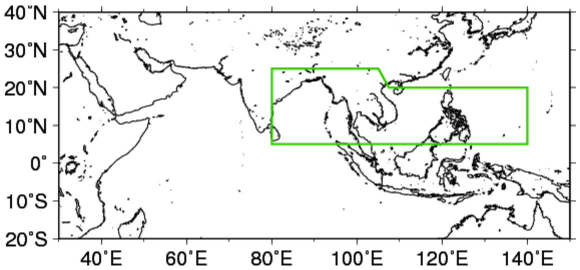
How many days are predictable for daily forecast by 5-member ensemble?

- **CHI200** in the tropics is averagely predictable **up to 16-20days** with small seasonal dependency.
- **Z500** in the Northern Hemisphere is averagely predictable **up to 12-15 days** with large seasonal dependency.

Predictable days for daily forecasts are a few days less than that for weekly mean forecasts.

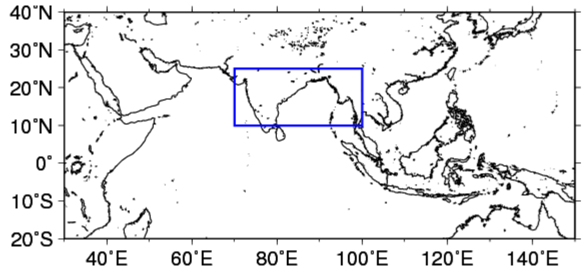
Prediction Skill of One-month EPS for Monsoon Rainfall

Hindcast experiments for 30 years (1981 – 2010)



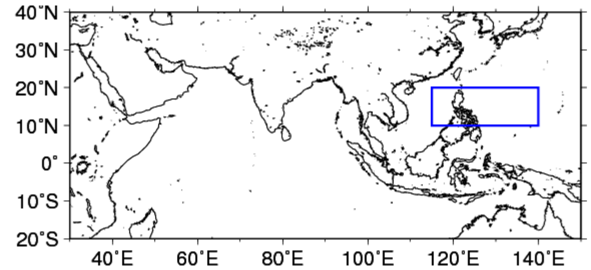
Initial month	<u>Daily</u> Rainfall Correlation (28day mean)
May	0.46
June	0.09
July	0.38
August	0.30

Skill for onset season is good but those for offset season and for mature season are not good.



Initial month	<u>Daily</u> Rainfall Correlation (28day mean)
May	0.48
June	0.05
July	0.31
August	0.14

Skill for onset season is good but those for offset season and for mature season are not good.



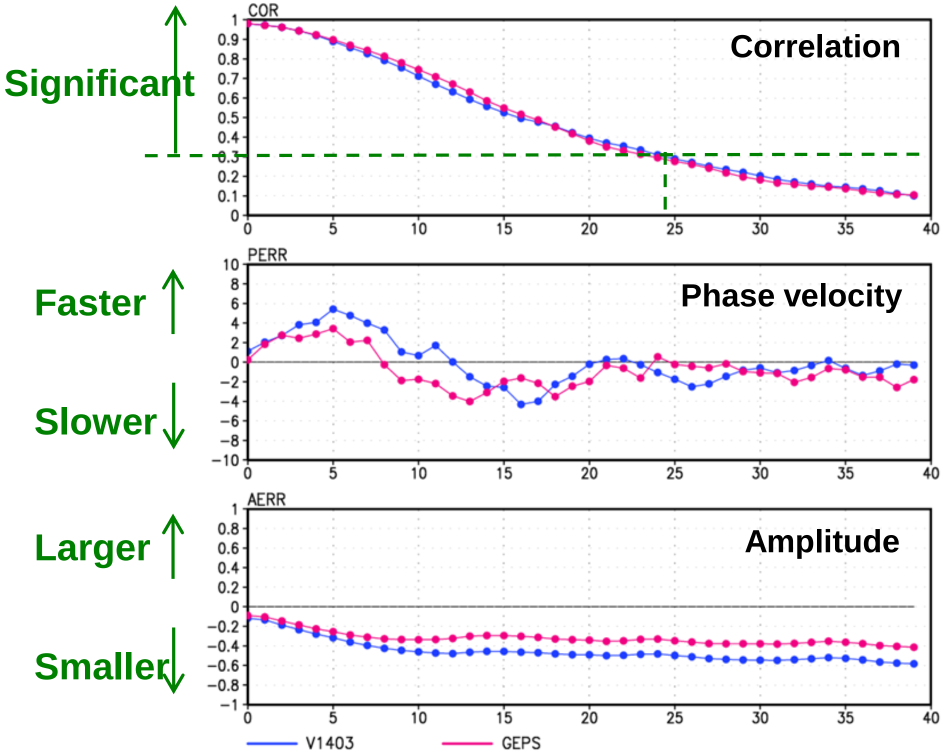
Initial month	<u>Daily</u> Rainfall Correlation (28day mean)
May	0.33
June	0.49
July	0.28
August	0.48

Skills are largely good through the whole season.

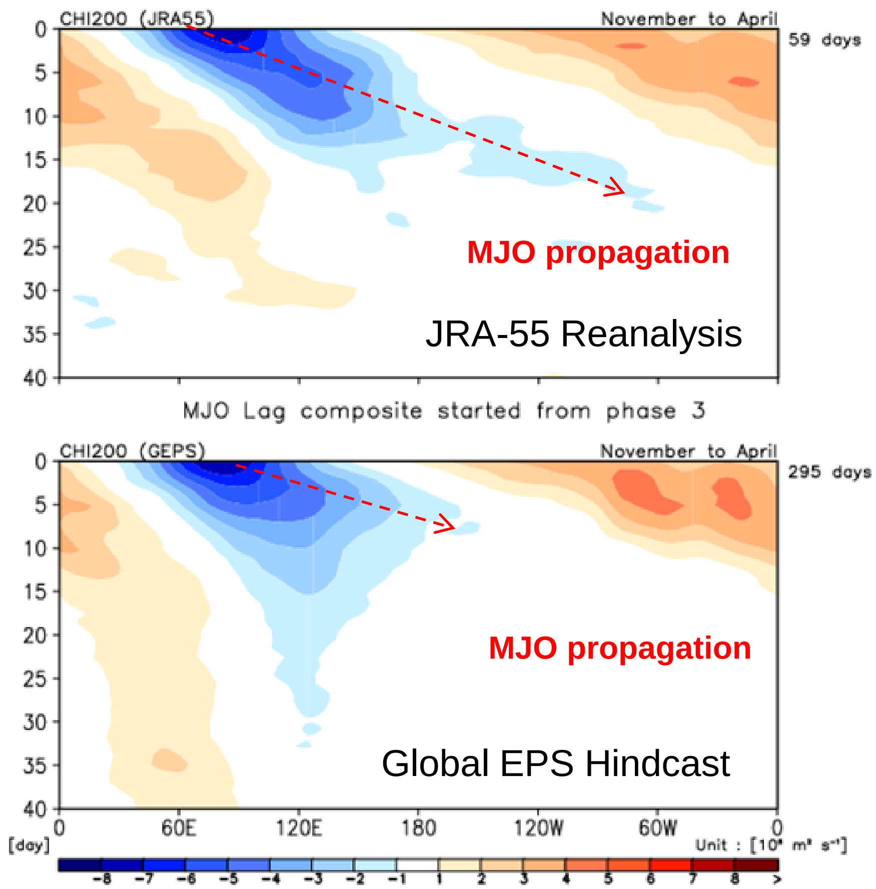
In case of weekly or monthly average rainfall, correlations are higher than daily rainfall.
Seasonal oscillations such as MJO and BSISO make a monsoon rainfall forecast difficult.

Verification of Global EPS for MJO

Hindcast experiments for 30 years (1981 – 2010)



Red: Global EPS, Blue: Previous EPS



CHI200 Hovemoller diagram from MJO phase 3

MJO is **predictable up to 25 days**. However, **faster phase velocity bias up to 8days**, **slower phase velocity bias after 8days** and **smaller amplitude bias** can be seen.

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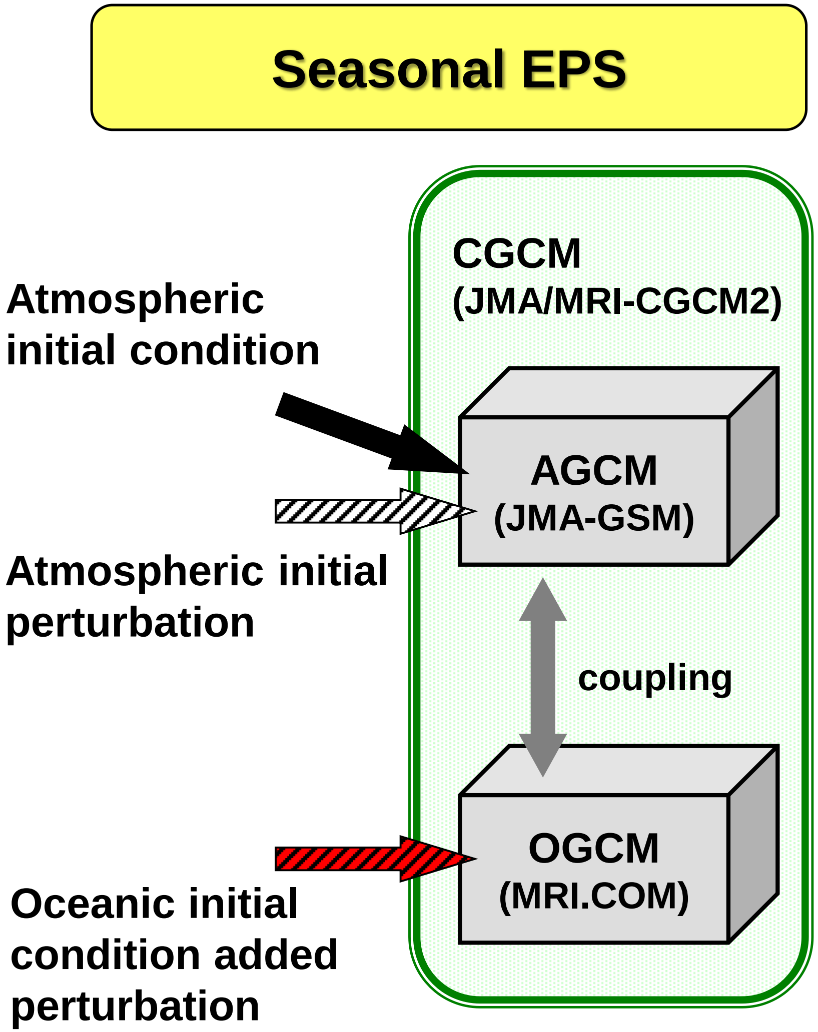
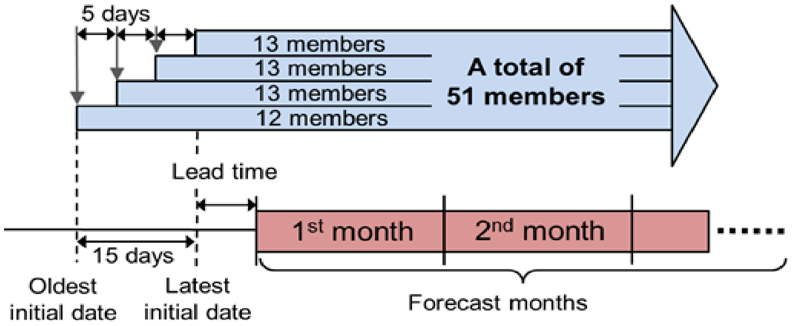
Specification of Seasonal EPS

as of Jan.2018

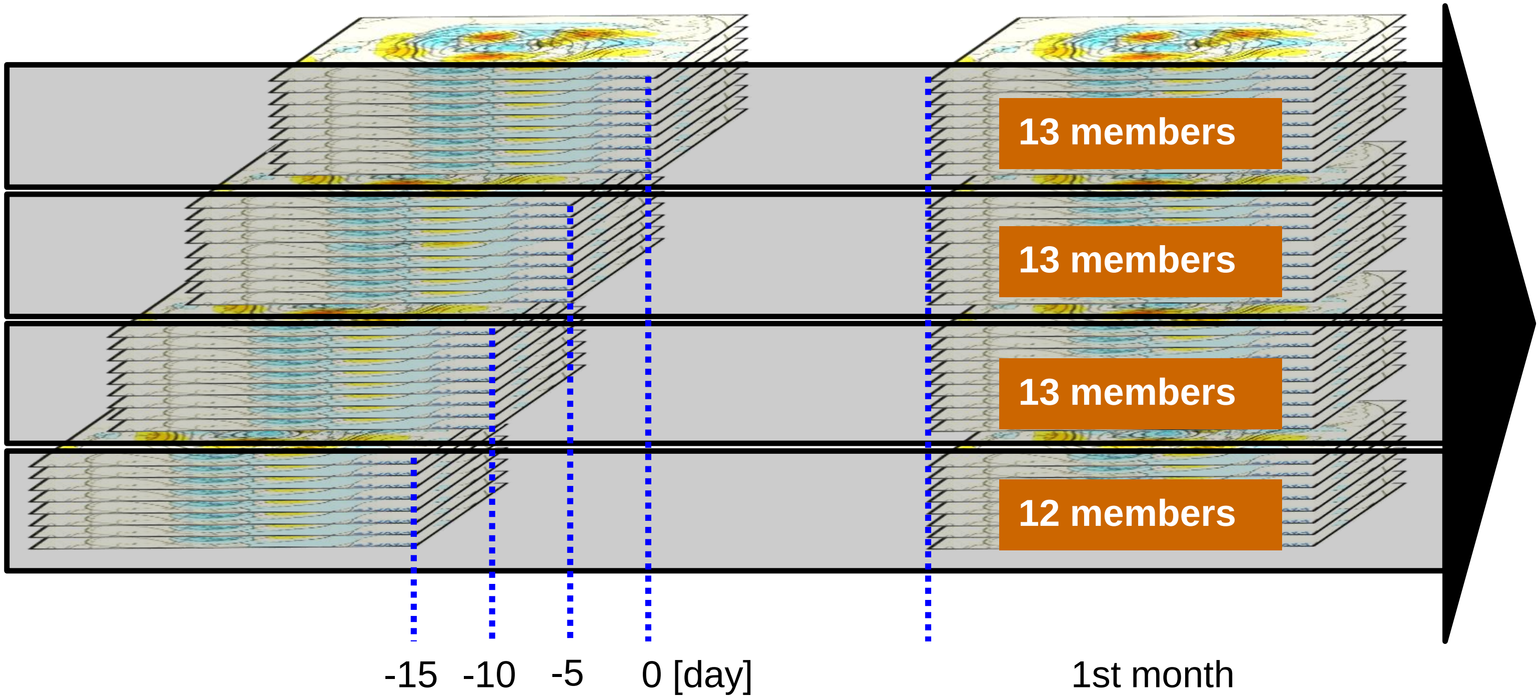


Upgrade	Last: June 2015 Frequently: Every Half Decade
Model	CGCM
Atmosphere Resolution	Horizontal: 110km (TL159) Vertical: 60 levels up to 0.1hPa
Ocean Resolution	Horizontal: 1.0 Lon x 0.3-0.5 Lat Vertical: 52 Levels + BBL With Tri-polar Grid
Forecast range	Up to 4 or 7 months
Initial Condition	Atmosphere: JRA-55 Land: JRA-55 Ocean: MOVE/MRI.COM-G2
Ensemble method	BGM, LAF, Stochastic Physics Scheme
Ensemble size	51 (13-12 BGMs x 4 days LAF at 5-day interval)
Freq. of model product creation	Once a month (Around 20th of every month)

Ensemble techniques for Seasonal EPS

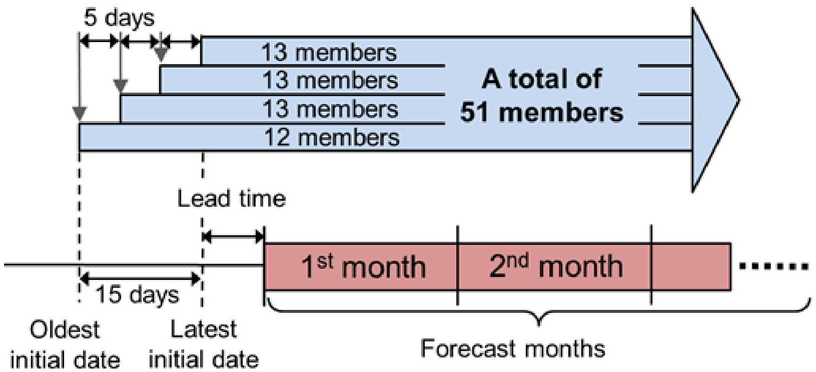


Initial perturbations are created with **the combination of BGM and LAF** method
- to disperse computing resources
- to get ensemble spread

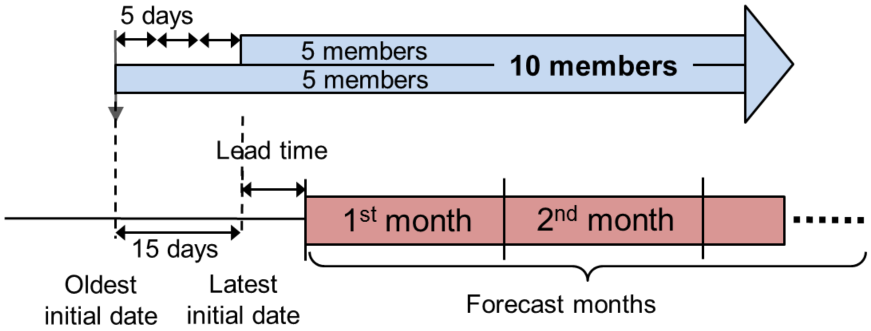


Hindcast for Seasonal EPS

Operational Forecast



Hindcast



Initial Month	Initial dates of the LAF ensemble
January	27 Dec., 12 Dec.
February	31 Jan., 16 Jan.
March	25 Feb., 10 Feb.
April	27 Mar., 12 Mar.
May	26 Apr., 11 Apr.
June	31 May, 16 May
July	30 Jun., 15 Jun.
August	30 Jul., 15 Jul.
September	29 Aug., 14 Aug.
October	28 Sep., 13 Sep.
November	28 Oct., 13 Oct.
December	27 Nov., 12 Nov.

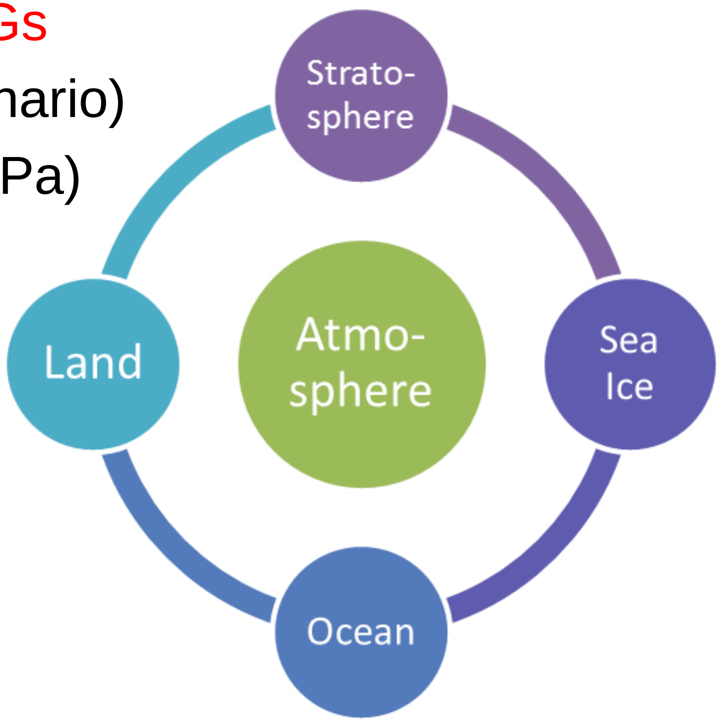
- Hindcast model must be equal to the operational forecast model in terms of initial conditions and sampling strategy except for ensemble size and initial date.
- Because of the limited computer resources, the number of ensemble size and initial dates are less than the operational forecast.
- The hindcast period is 36 years from 1979 to 2014.
- For the initial date on which no hindcast was performed, virtual hindcast data is created with a linear interpolation method using before and after initial dates on which hindcasts were performed.

New Sources of Predictability

New Predictability Sources since Last Update (June 2015)

1. Dynamical sea ice simulation
2. Land initialization with JRA-55
3. Global ocean domain
4. More sophisticated description of GHGs
   (6 gases prescribed with RCP4.5 scenario)
5. Fully covered stratosphere (Top: 0.1hPa)

Full natural origin potential sources of predictability except for chemical transport and ecosystem has been incorporated into the seasonal EPS since June 2015.

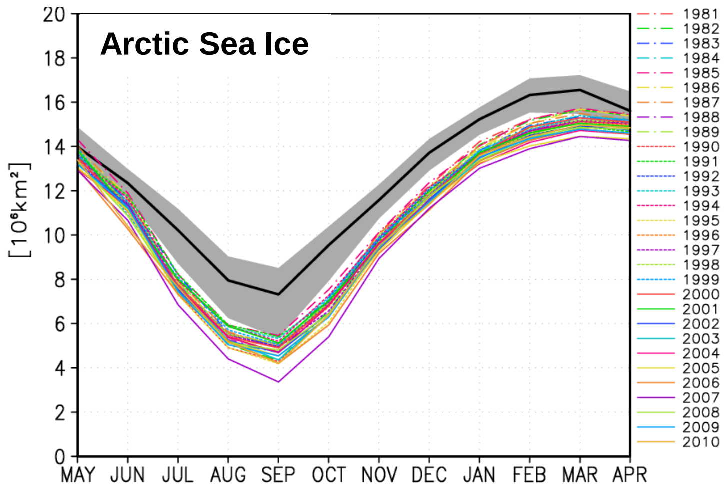


Dynamical Sea Ice Simulation

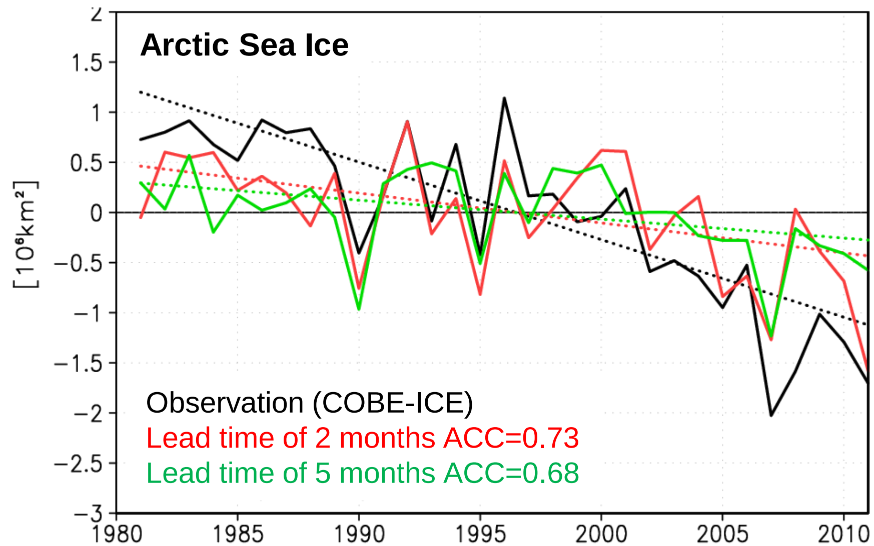
Interactive sea-ice model

Hindcast experiments for 30 years (1981 – 2010)

- Thermodynamic model (sea-ice production / melting)
- Dynamic model (momentum equation)



Color: Individual forecast
Black and Grey: Observed climatology (COBE-ICE)
(Grey) minimum and maximum



Annual variation is good but smaller bias can be seen.

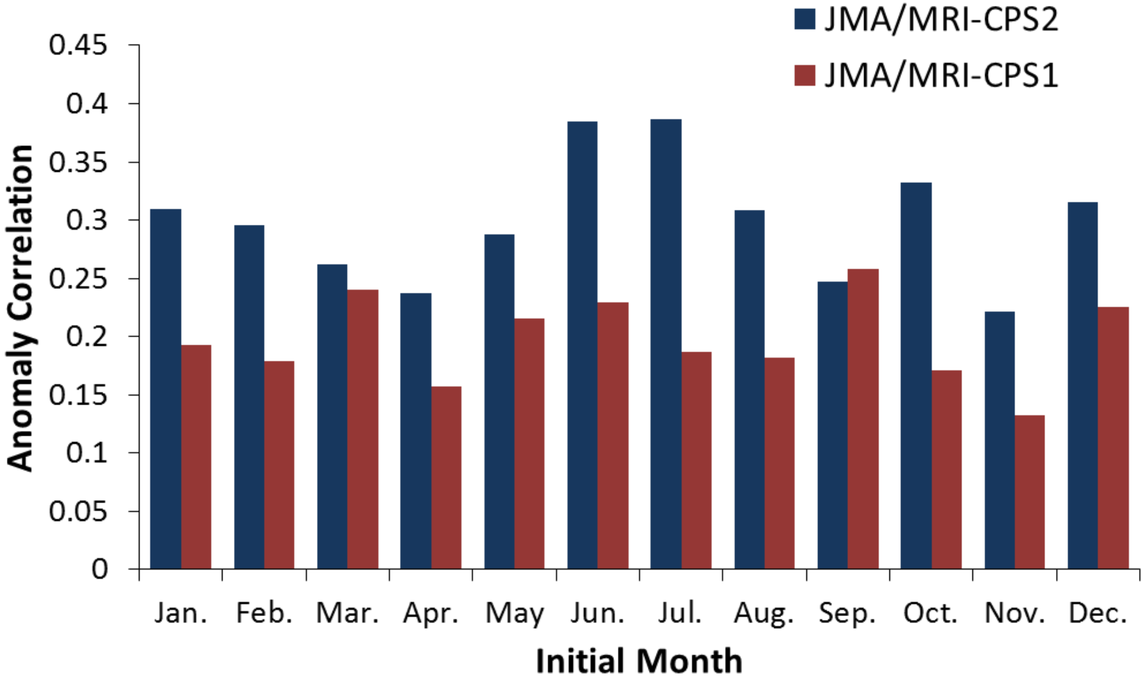
Sea ice melting trend is smaller than observation.

This sea ice model can represent
- Seasonal variation of sea ice extent
- Inter-annual variability and reduction trend of sea-ice extent

Dynamical Sea Ice Simulation

Hindcast experiments for 30 years (1981 – 2010)

Anomaly Correlation of 2-m Temperature over the Arctic region (60N-90N)

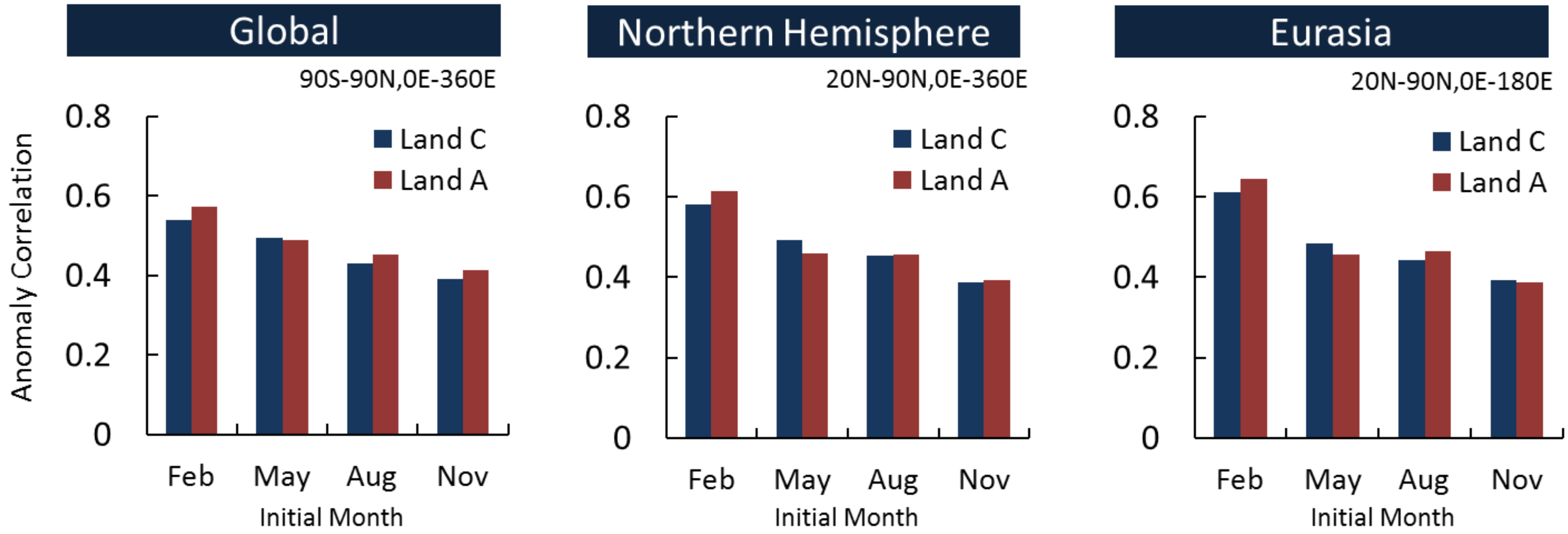


Prediction skill of 2-m temperature is much improved over the Arctic region for most of initial month, suggesting sea-ice model contribution to this improvement.

Land Initialization

Hindcast experiments for 30 years (1981 – 2010)

Comparison of Anomaly Correlation of 2-m Temperature
(Lead Time: 0 month)



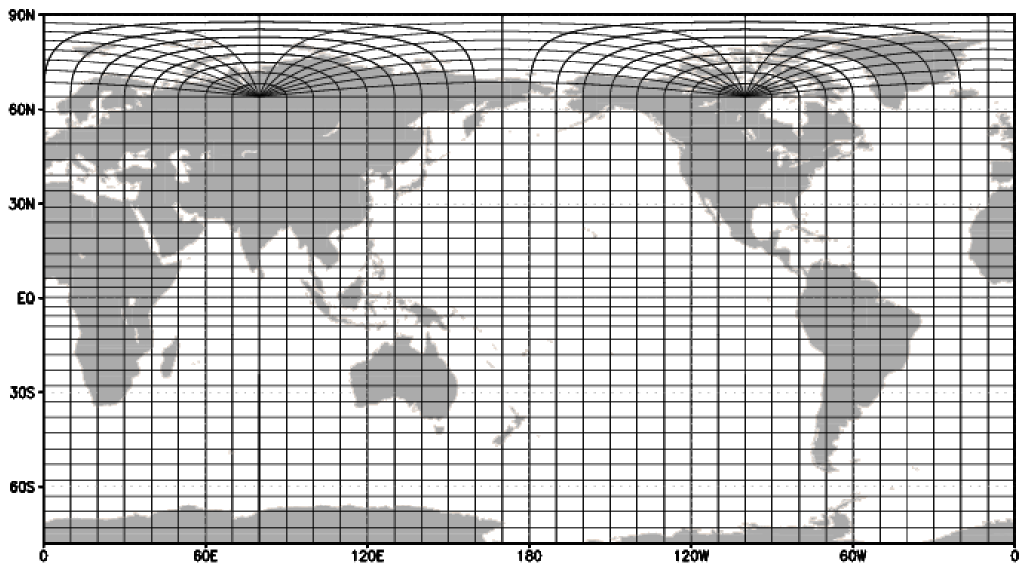
Land C ･･･ Land Initialization is Climatology
Land A ･･･ Land Initialization is Analysis with JRA-55

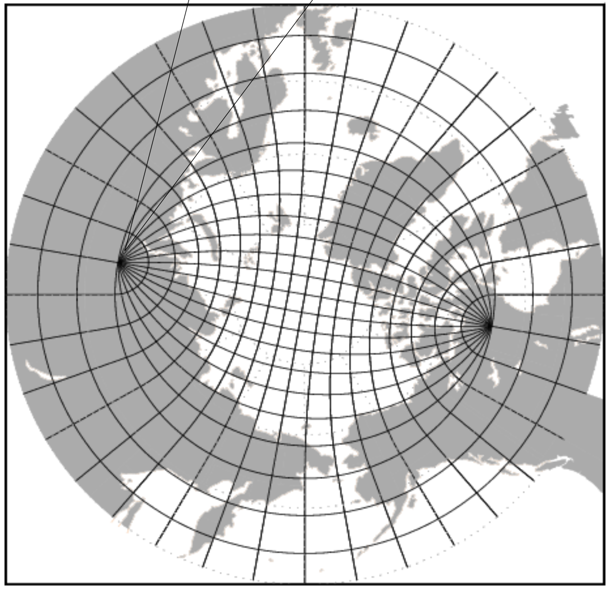
Land Initialization slightly improved prediction skill.
(except for May)

Global Ocean Domain

- Horizontal resolution
  - Longitude direction: 1° (approximately 100km)
  - Latitude direction: 0.3-0.5° (approximately 30-50km) with finer resolution near the equator
- Vertical level: 52 and BBL(bottom boundary layer)
- Global ocean with tri-polar grid

Singular grids are located on land for tri-polar grid

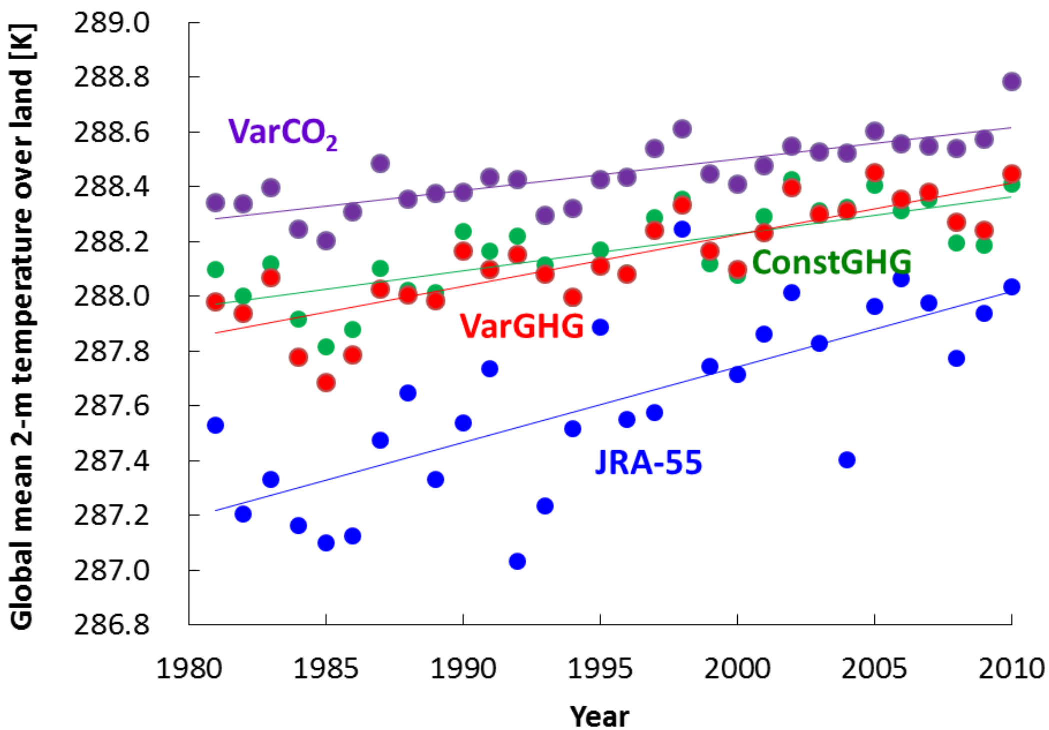




Green House Gases Forcing

Hindcast experiments for 30 years (1981 – 2010)

2-m temperature Trend over Land (JJA)   (Initial: May)



VarCO$_2$
- JMA/MRI-CPS1
- CO_2 Trend

VarGHG
- **JMA/MRI-CPS2:**
- CO_2, CH_4, N_2O, CHC-11, CHF-12, HCFC-22 (GHGs) Trend (Based on RCP 4.5 scenario)

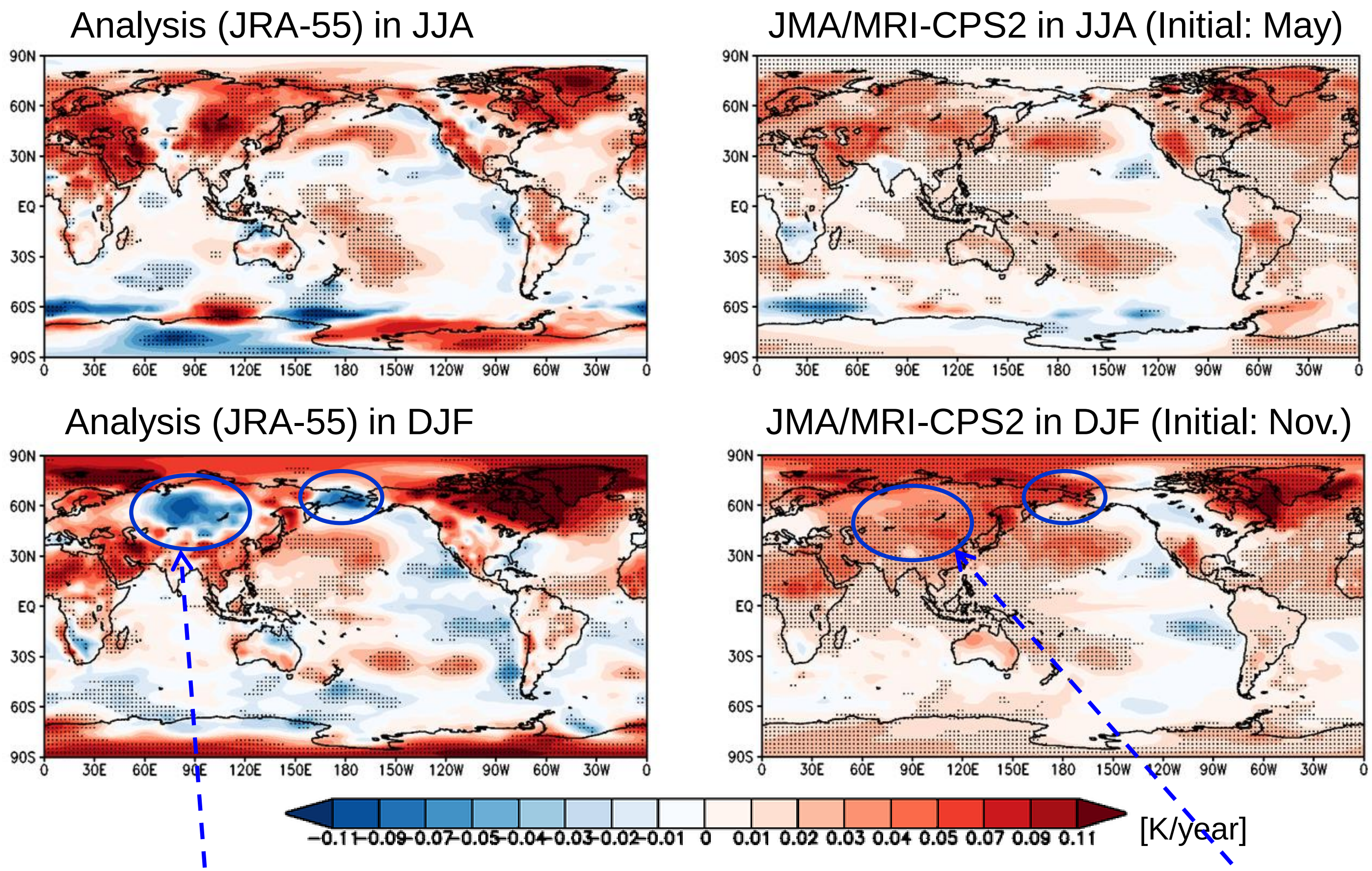
ConstGHG
(Additional experiment)
- JMA/MRI-CPS2
- Constant GHGs

linear trend of 2-m temperature over land
ConstGHG ≒ VarCO$_2$ < VarGHG < JRA-55(Analysis)

Global Warming Trend

Hindcast experiments for 30 years (1981 – 2010)

2-m temperature linear trend

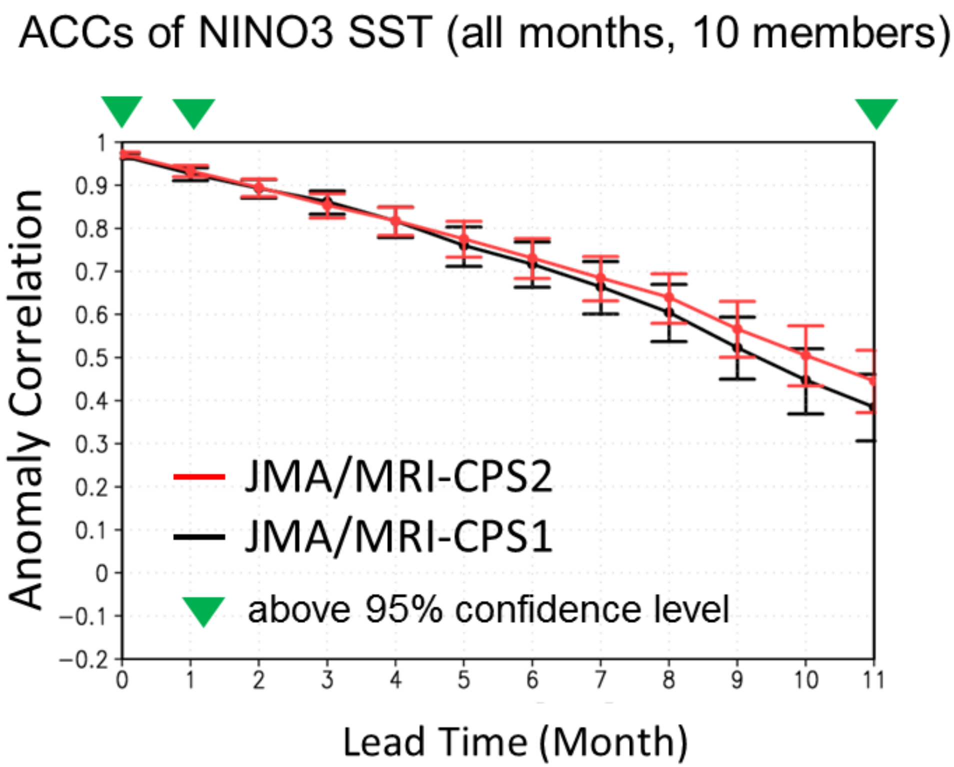


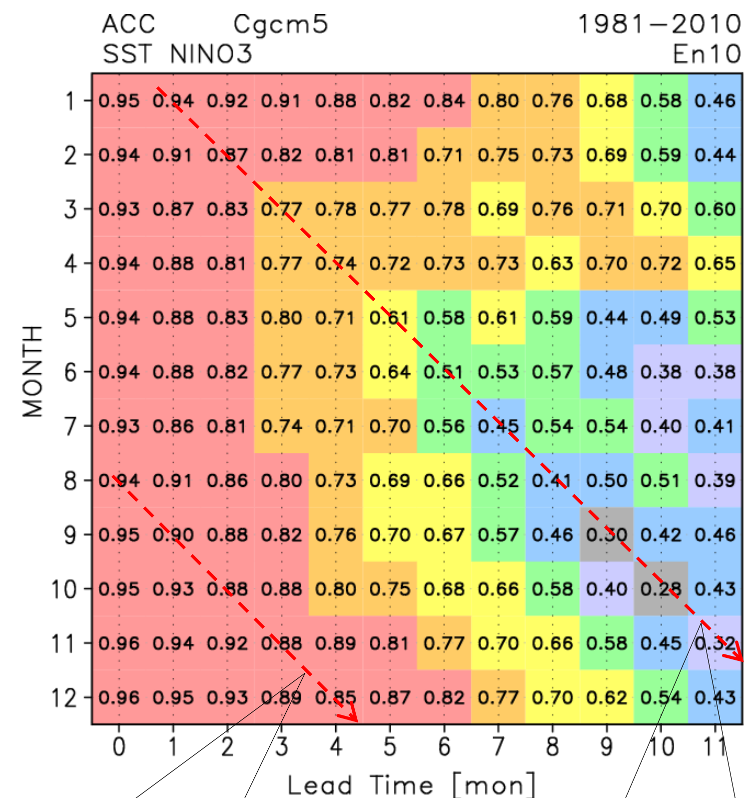
Cooling trend is visible in winter.

Cooling trend is invisible in winter.

Prediction Skill for El Niño/La Niña forecast

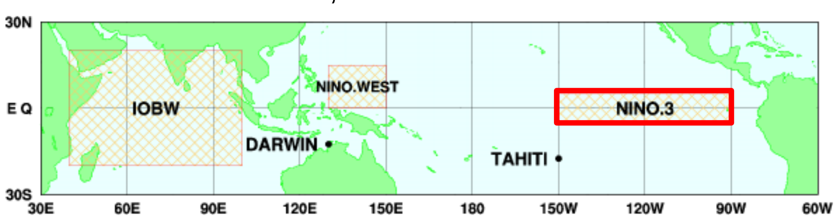
Hindcast experiments for 30 years (1981 – 2010)





MONTH	0	1	2	3	4	5	6	7	8	9	10	11
1	0.95	0.94	0.92	0.91	0.88	0.82	0.84	0.80	0.76	0.68	0.58	0.46
2	0.94	0.91	0.87	0.82	0.81	0.81	0.71	0.75	0.73	0.69	0.59	0.44
3	0.93	0.87	0.83	0.77	0.78	0.77	0.78	0.69	0.76	0.71	0.70	0.60
4	0.94	0.88	0.81	0.77	0.74	0.72	0.73	0.73	0.63	0.70	0.72	0.65
5	0.94	0.88	0.83	0.80	0.71	0.61	0.58	0.61	0.59	0.44	0.49	0.53
6	0.94	0.88	0.82	0.77	0.73	0.64	0.51	0.53	0.57	0.48	0.38	0.38
7	0.93	0.86	0.81	0.74	0.71	0.70	0.56	0.45	0.54	0.54	0.40	0.41
8	0.94	0.91	0.86	0.80	0.73	0.69	0.66	0.52	0.41	0.50	0.51	0.39
9	0.95	0.90	0.88	0.82	0.76	0.70	0.67	0.57	0.46	0.30	0.42	0.46
10	0.95	0.93	0.88	0.88	0.80	0.75	0.68	0.66	0.58	0.40	0.28	0.43
11	0.96	0.94	0.92	0.88	0.89	0.81	0.77	0.70	0.66	0.58	0.45	0.32
12	0.96	0.95	0.93	0.89	0.85	0.87	0.82	0.77	0.70	0.62	0.54	0.43

NINO.3 150W-90W, 5S-5N



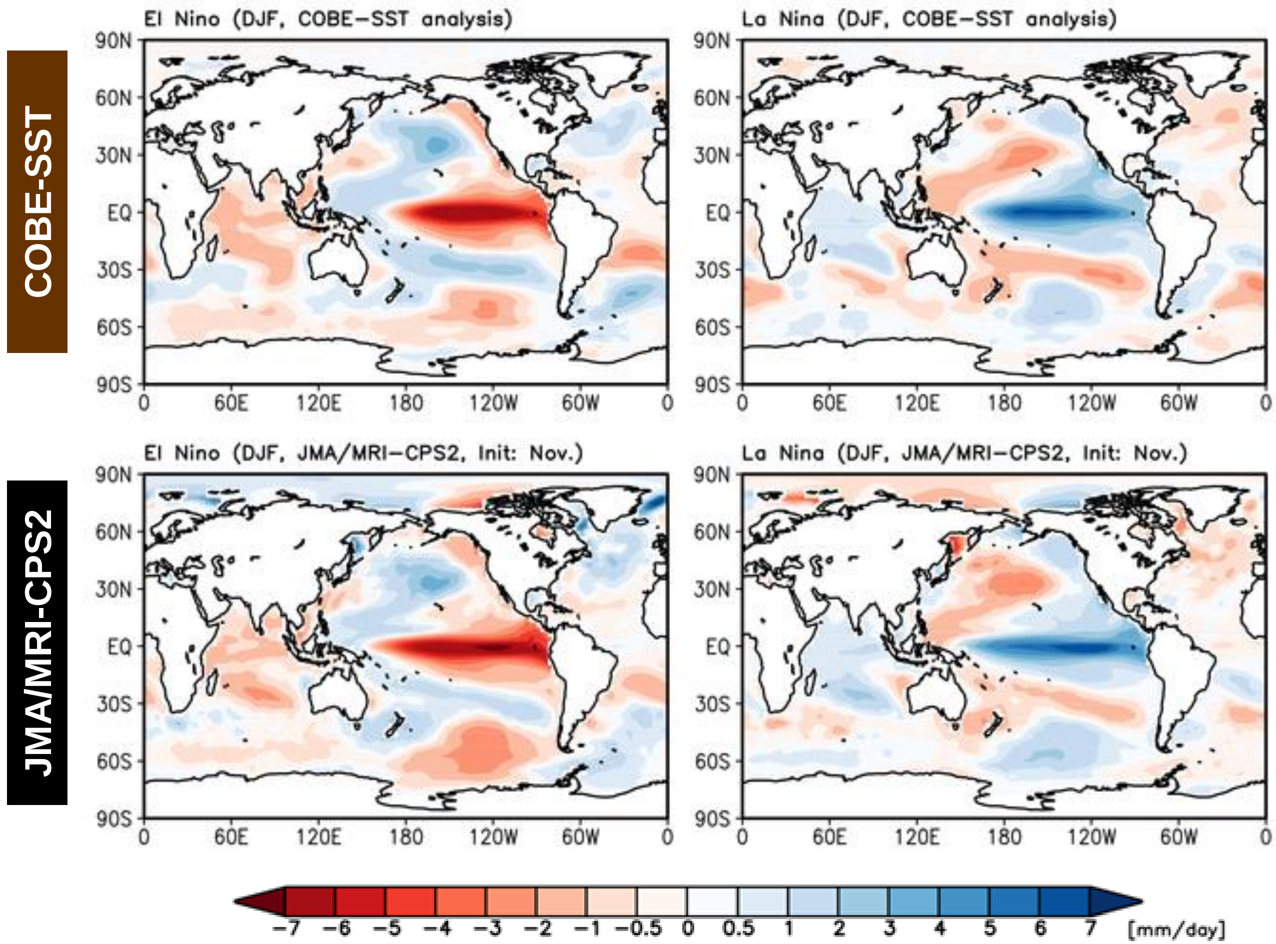
Forecasts through autumn and winter are **high skill**.

Spring Barrier
Forecasts through spring season are **low skill**.

Prediction Skill for El Niño/La Niña forecast

Hindcast experiments for 30 years (1981 – 2010)

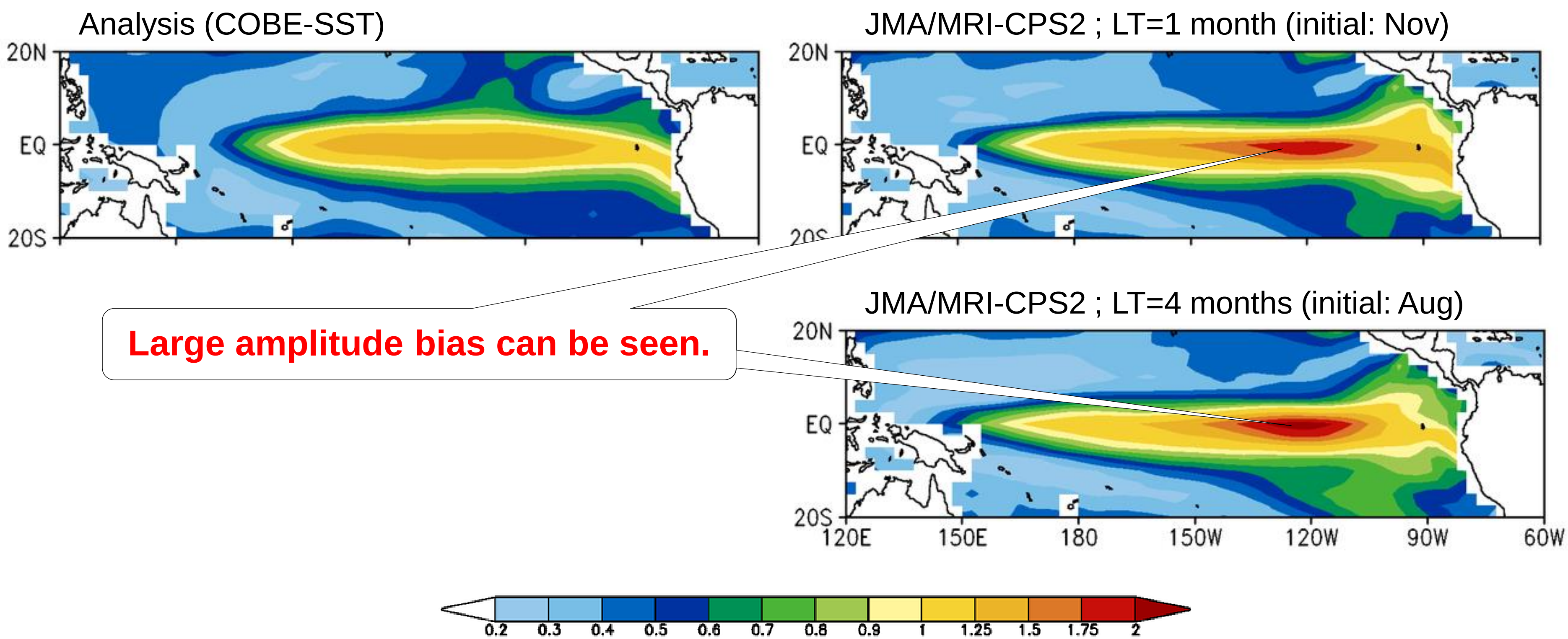
El Niño / La Niña SST Composite



Prediction Skill for El Niño/La Niña forecast

Hindcast experiments for 30 years (1981 – 2010)

SST Standard Deviation for DJF



Prediction Skill for Niño.WEST and IOBW

Only autumn season is predictable.

DMI

MONTH \ Lead Time [mon]	0	1	2	3	4	5	6	7	8	9	10
1	0.43	0.35	0.22	0.32	0.12	0.22	0.40	0.35	0.01	0.21	−0.15
2	0.59	0.43	0.28	0.21	0.40	0.07	0.12	0.42	0.27	0.12	0.15
3	0.50	0.33	0.39	0.31	0.14	0.39	0.02	0.15	0.18	0.13	0.31
4	0.13	0.05	−0.05	0.21	0.19	0.08	0.25	0.01	0.17	−0.06	−0.04
5	0.33	0.06	0.00	0.00	−0.05	0.03	0.01	0.04	0.14	−0.03	−0.07
6	0.62	0.20	0.08	−0.01	−0.06	−0.20	−0.11	−0.06	−0.08	0.08	−0.18
7	0.80	0.54	0.24	0.19	0.10	−0.06	−0.21	−0.18	−0.11	−0.08	−0.03
8	0.83	0.81	0.56	0.32	0.29	0.22	−0.00	−0.05	−0.14	−0.10	0.07
9	0.85	0.84	0.83	0.64	0.45	0.41	0.34	0.15	0.18	0.00	0.05
10	0.73	0.75	0.82	0.82	0.67	0.51	0.44	0.39	0.25	0.24	0.11
11	0.66	0.40	0.43	0.58	0.61	0.69	0.58	0.48	0.41	0.34	0.32
12	0.57	0.48	0.25	0.17	0.36	0.38	0.45	0.32	0.27	0.08	−0.02

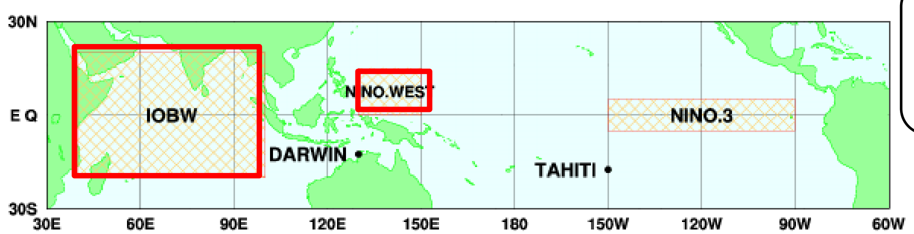
Forecast skills through **spring are high**.

IOBW

MONTH \ Lead Time [mon]	0	1	2	3	4	5	6	7	8	9	10	11
1	0.87	0.83	0.84	0.82	0.82	0.83	0.80	0.76	0.69	0.73	0.72	0.68
2	0.91	0.84	0.83	0.82	0.80	0.81	0.80	0.75	0.72	0.69	0.68	0.70
3	0.89	0.85	0.79	0.76	0.75	0.76	0.78	0.78	0.77	0.75	0.73	0.72
4	0.88	0.88	0.89	0.84	0.82	0.83	0.85	0.85	0.84	0.85	0.78	0.76
5	0.82	0.78	0.76	0.79	0.80	0.78	0.82	0.83	0.80	0.79	0.84	0.79
6	0.87	0.75	0.65	0.70	0.79	0.79	0.77	0.80	0.80	0.81	0.77	0.80
7	0.87	0.78	0.59	0.57	0.58	0.72	0.67	0.67	0.70	0.68	0.73	0.68
8	0.87	0.81	0.75	0.54	0.52	0.52	0.63	0.55	0.60	0.69	0.67	0.72
9	0.89	0.79	0.70	0.68	0.50	0.43	0.42	0.53	0.45	0.50	0.59	0.56
10	0.88	0.81	0.78	0.74	0.67	0.53	0.47	0.32	0.52	0.39	0.41	0.53
11	0.85	0.77	0.77	0.77	0.78	0.70	0.62	0.59	0.48	0.56	0.43	0.34
12	0.89	0.79	0.79	0.81	0.82	0.76	0.72	0.71	0.72	0.67	0.68	0.57

Niño.WEST

MONTH \ Lead Time [mon]	0	1	2	3	4	5	6	7	8	9	10	11
1	0.94	0.91	0.86	0.78	0.71	0.66	0.66	0.70	0.75	0.65	0.59	0.44
2	0.93	0.89	0.87	0.81	0.76	0.68	0.66	0.69	0.69	0.74	0.64	0.55
3	0.91	0.90	0.85	0.81	0.76	0.73	0.71	0.68	0.64	0.64	0.70	0.67
4	0.85	0.80	0.81	0.75	0.74	0.69	0.67	0.69	0.61	0.62	0.49	0.49
5	0.83	0.77	0.64	0.65	0.56	0.61	0.51	0.51	0.53	0.46	0.50	0.37
6	0.77	0.62	0.61	0.48	0.44	0.45	0.54	0.52	0.54	0.52	0.53	0.42
7	0.77	0.80	0.70	0.53	0.52	0.50	0.35	0.47	0.37	0.41	0.43	0.39
8	0.85	0.72	0.70	0.63	0.57	0.47	0.25	0.17	0.26	0.18	0.08	0.15
9	0.83	0.75	0.69	0.71	0.64	0.62	0.49	0.29	0.26	0.35	0.24	0.18
10	0.82	0.72	0.65	0.66	0.67	0.51	0.52	0.47	0.24	0.28	0.33	0.36
11	0.76	0.70	0.64	0.57	0.51	0.56	0.57	0.54	0.52	0.40	0.39	0.50
12	0.88	0.78	0.74	0.63	0.61	0.55	0.65	0.67	0.54	0.59	0.42	0.43



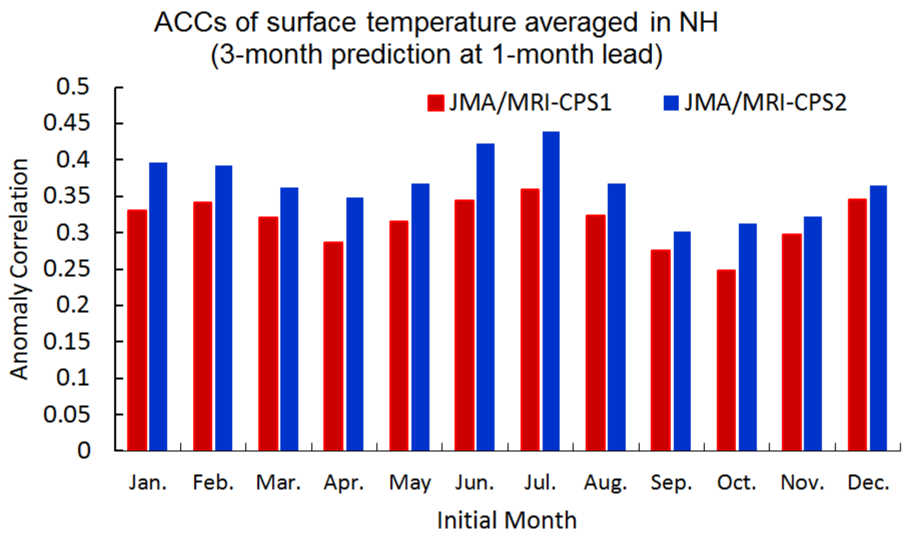
Forecast skills through **summer monsoon season are low**.

Forecast skills through **tropical cyclone season are low**.

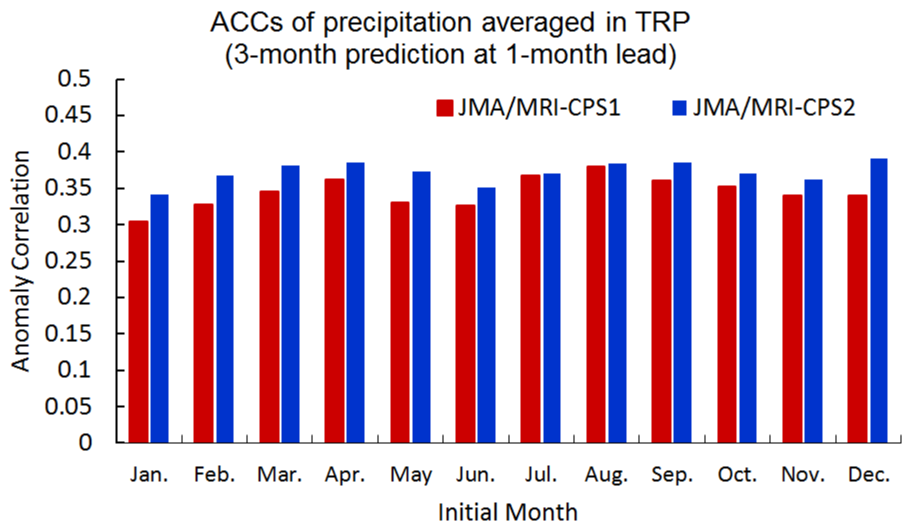
Prediction Skill for Seasonal forecast

Hindcast experiments for 30 years (1981 – 2010)

2m Temperature
(Northern Hemisphere)

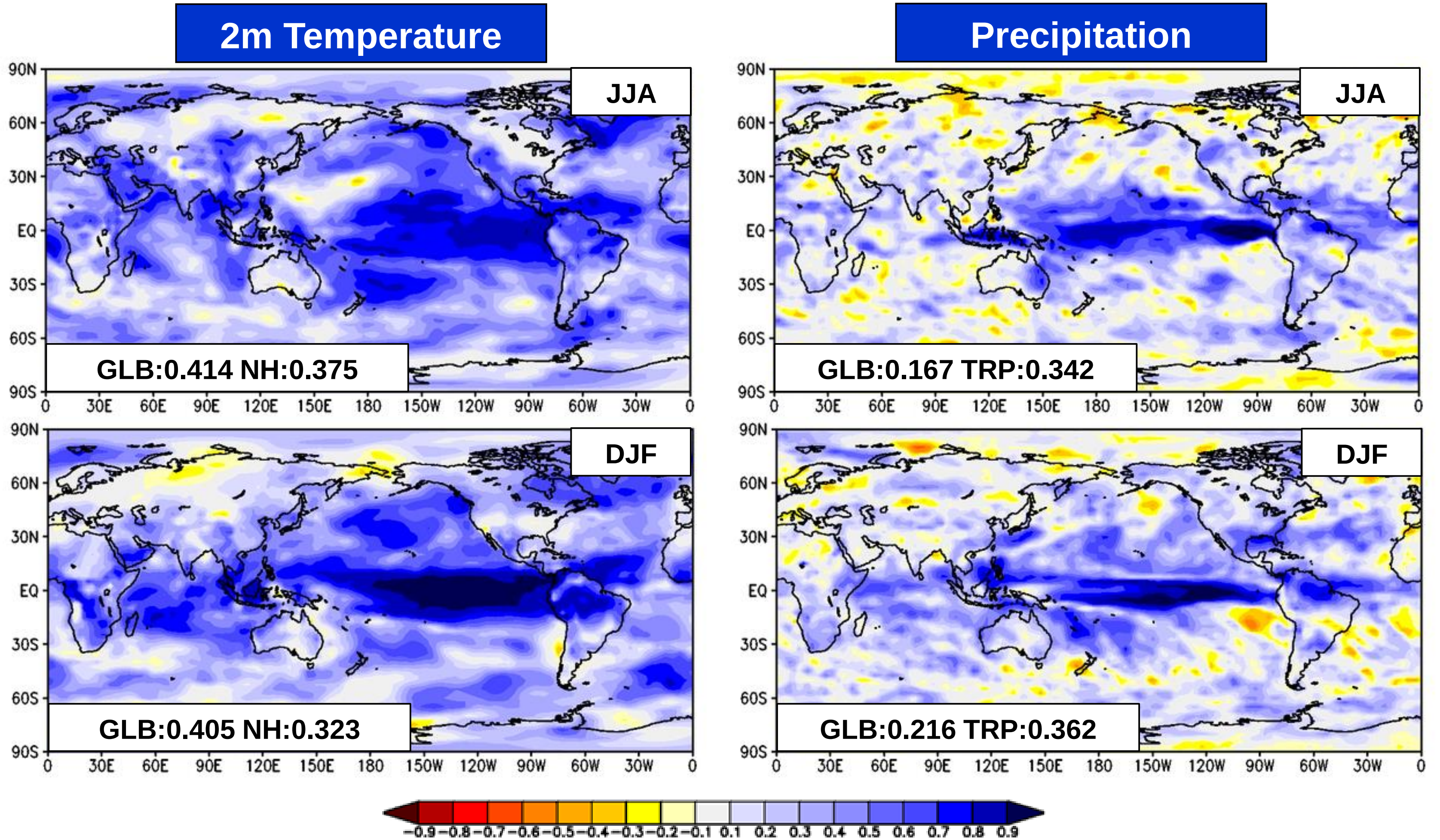


Precipitation
(Tropics)



Spatial Prediction Skill for Seasonal forecast

Hindcast experiments for 30 years (1981 – 2010)

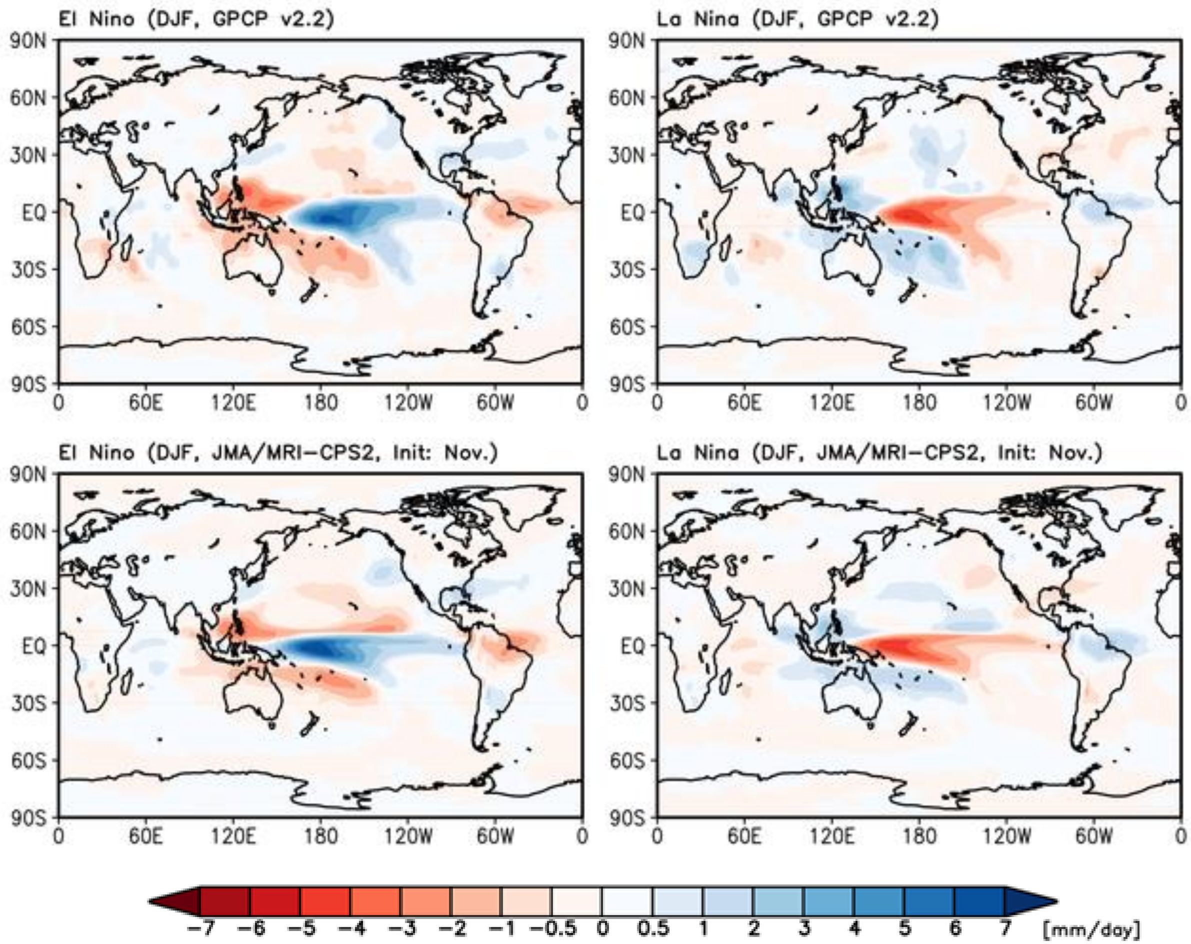


http://ds.data.jma.go.jp/tcc/tcc/products/model/hindcast/CPS2/index.html

El Niño / La Niña Composite

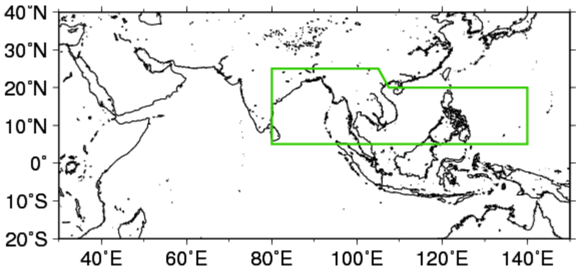
Hindcast experiments for 30 years (1981 – 2010)

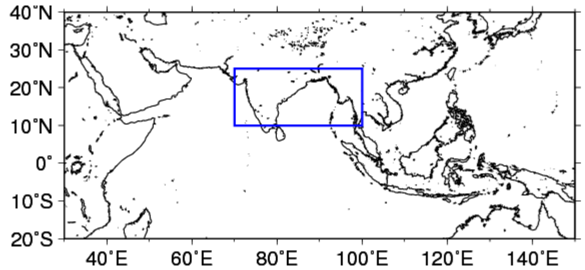
El Niño / La Niña Precipitation Composite

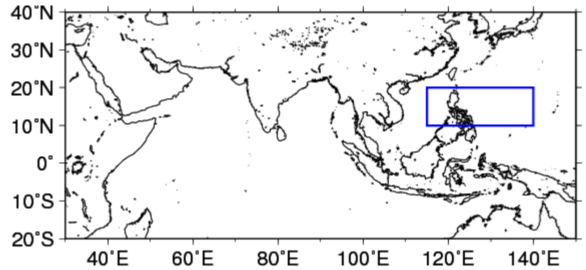


Prediction Skill of Seasonal EPS for Monsoon Rainfall

Hindcast experiments for 30 years (1981 – 2010)







Target Month	LAF period	
	11/26 April	16/31 May
June	0.20	0.63
July	0.08	0.21
August	0.05	-0.07
Sept.	0.45	0.30

Forecasts for onset and offset season is somehow possible. Mature season is unpredictable

Target Month	LAF period	
	11/26 April	16/31 May
June	0.45	0.58
July	-0.03	0.20
August	0.05	0.01
Sept.	0.34	0.21

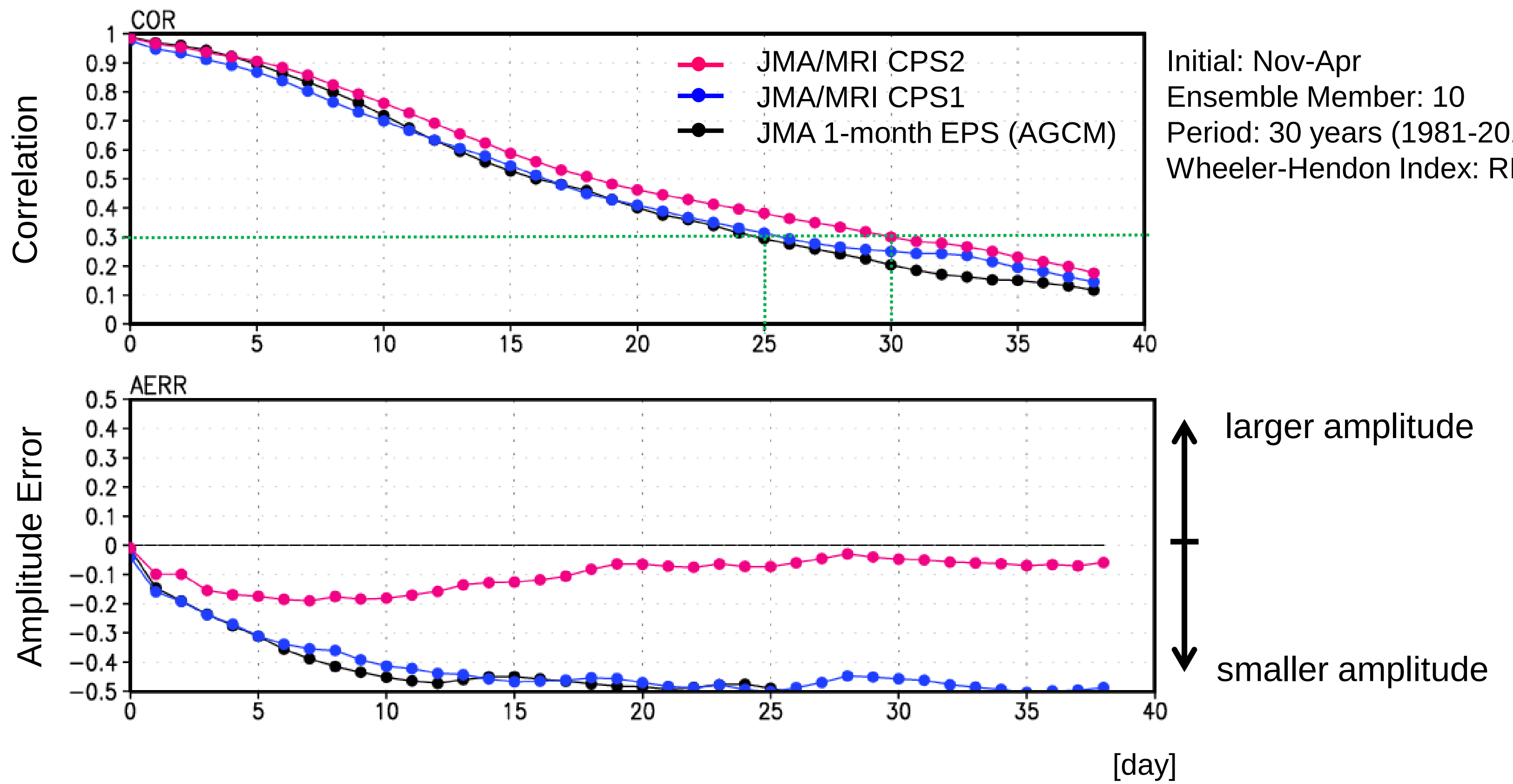
Forecasts for onset and offset season is somehow possible. Mature season is unpredictable.

Target Month	LAF period	
	11/26 April	16/31 May
June	0.22	0.55
July	0.34	0.05
August	-0.02	0.37
Sept.	0.27	0.26

Skills are near border through monsoon season.

These scores are for monthly average rainfall, unlike previous slide for Global EPS.
Seasonal oscillations such as MJO and BSISO make a monsoon rainfall forecast difficult.

Verification of Seasonal EPS for MJO



Initial: Nov-Apr
Ensemble Member: 10
Period: 30 years (1981-2010)
Wheeler-Hendon Index: RMM1, RMM2

The MJO forecast skill of Seasonal EPS is better than that of one-month EPS.
Especially, the MJO amplitude error of Seasonal EPS is much smaller than that of one-month EPS.

Contents

- Basic Knowledge
  - NWP Model and Predictability
  - Ensemble Prediction and Uncertainty
  - Hindcast
- JMA's NWP Models
  - JMA's Global Ensemble Prediction System
  - JMA's Seasonal Ensemble Prediction System
- TCC's NWP Model Products

Introduction of TCC's NWP Model Products

Click "NWP Model Prediction" Tab or "GPC Tokyo" Icon on the top page of TCC website.

TCC website
http://ds.data.jma.go.jp/tcc/tcc/

Introduction of TCC's NWP Model Products

NWP products are available smoothly through the NWP Model Products page.

Main Products

One-month Prediction (Free accessible)

One-month Prediction

- One-month Prediction (30 Nov 2017)
- Z500, T850 & SLP (Northern Hemisphere) (30 Nov 2017)
- Stream Function, Velocity Potential & Surface Air Temperature (60N-60S) (30 Nov 2017)
- Verification (03 Dec 2017)
- Hindcast Verification NEW
- One-month Probabilistic Forecasts at station points

Monthly Discussion on Seasonal Climate Outlooks last updated : 24 Nov 2017

This product is intended to assist NMHSs in the Asia-Pacific region in interpreting GPC Tokyo's three-month prediction and warm/cold season prediction products.

Seasonal Prediction (Free accessible)

Three-month Prediction

- Three-month Prediction (12 Nov 2017)
- Z500, T850 & SLP (Northern Hemisphere) (12 Nov 2017)
- Stream Function, Velocity Potential & Surface Air Temperature (60N-60S) (12 Nov 2017)
- Verification (05 Dec 2017)
- Hindcast Verification (JMA/MRI-CPS2)
- Probabilistic Forecast and Verification (12 Nov 2017)
- SST Index Time-series Forecast (12 Nov 2017)

Warm/Cold Season Prediction

- Warm/Cold Season Prediction (18 Oct 2017)
- Z500, T850 & SLP (Northern Hemisphere) (18 Oct 2017)
- Stream Function, Velocity Potential & Surface Air Temperature (60N-60S) (18 Oct 2017)
- Verification (05 Sep 2017)
- Hindcast Verification (JMA/MRI-CPS2)
- Probabilistic Forecast and Verification (18 Oct 2017)

Extreme Weather Prediction (Authentication is required)

Forecast Products in Support of Early Warnings for Extreme Weather Events last updated : 29 Nov 2017

Early warning products for extreme weather events covering the period up to two weeks ahead. (Only registered NMHSs can access this page.)

- Application
- If you have any questions about ID and/or password, please e-mail to: tcc@met.kishou.go.jp

Gridded data (Authentication is required)

Download GPC Long-range Forecast (LRF) Products

- Download Gridded data File (Only registered NMHSs can access this page.)
- Application
- If you have any questions about ID and/or password, please e-mail to: tcc@met.kishou.go.jp

Model Descriptions

- Model Outlines NEW
- Operations for Extended-range Forecast Model NEW
- Operations for Long-range Forecast Model (JMA/MRI-CPS2)

NWP Charts for Seasonal Prediction

Some NWP charts for tropics are available on the Three-month and Warm/Cold season prediction menus.

Select a forecast period, an initial date, an area and a data type on these menu.

Three-month Prediction

- Three-month Prediction (12 Nov 2017)
- Z500, T850 & SLP (Northern Hemisphere) (12 Nov 2017)
- Stream Function, Velocity Potential & Surface Air Temperature (60N-60S) (12 Nov 2017)
- Verification (05 Nov 2017)
- Hindcast Verification (JMA/MRI-CPS2)
- Probabilistic Forecast and Verification (12 Nov 2017)
- SST Index Time-series Forecast (12 Nov 2017)

Three-month Prediction (Tropics and Asia)

This product is displayed for use by National Meteorological and Hydrological Services (NMHSs). It does not constitute an official forecast for any nation.

Forecast Maps

forecast period
3 months mean

initial date
2017.11.07.00Z

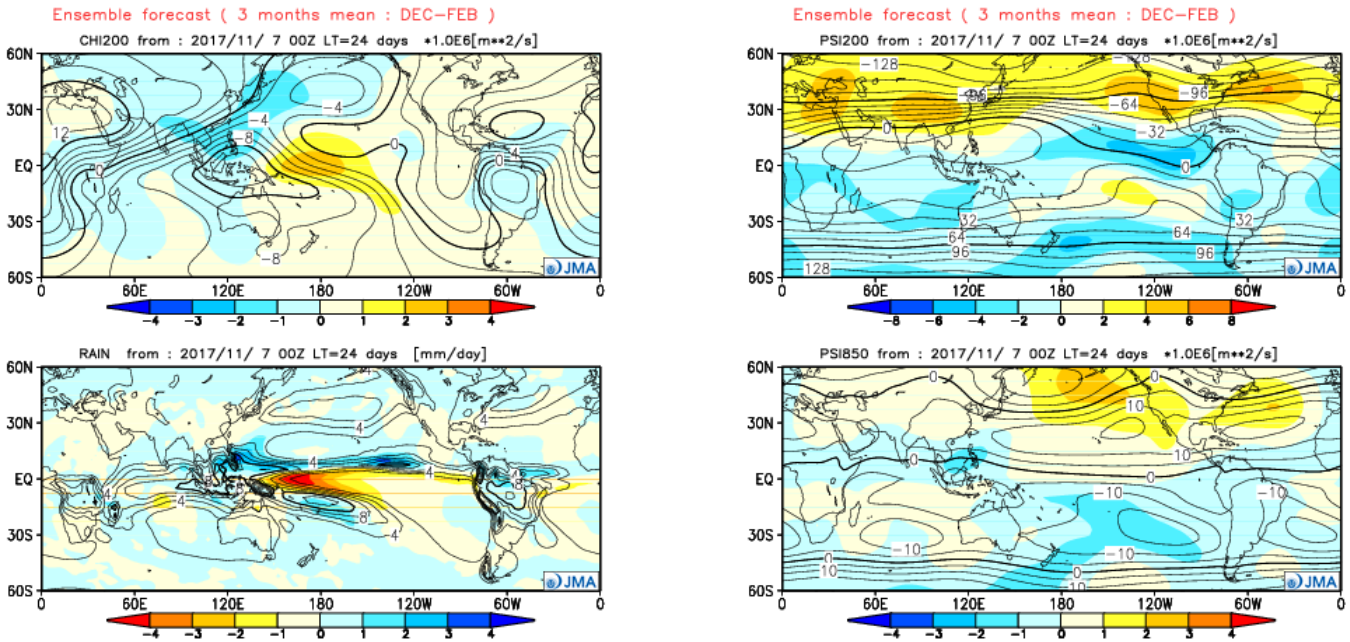
area
- (●) 60N-60S
- ( ) Asia

data
- (●) ensemble mean forecast
- ( ) ensemble mean forecast (mask [msss < 0] area)
msss : Mean Square Skill Score
- ( ) spread and anomaly

corresponding verification

LT : lead time(day)
kt : lead time(hour)

[forecast]
Contour show forecast, and



NWP Charts for Seasonal Prediction

Some NWP charts for the Northern Hemisphere are available on the Three-month and Warm/Cold season prediction menus.

Select a forecast period and an initial date on these menu.

Three-month Prediction

- Three-month Prediction (12 Nov 2017)
- Z500, T850 & SLP (Northern Hemisphere) (12 Nov 2017)
- Stream Function, Velocity Potential & Surface Air Temperature (60N-60S) (12 Nov 2017)
- Verification (05 Nov 2017)
- Hindcast Verification (JMA/MRI-CPS2)
- Probabilistic Forecast and Verification (12 Nov 2017)
- SST Index Time-series Forecast (12 Nov 2017)

Three-month Prediction (Northern Hemisphere)

This product is displayed for use by National Meteorological and Hydrological Services (NMHSs). It does not constitute an official forecast for any nation.

Forecast Maps

forecast period
3 months mean

initial date
2017.11.07.00Z

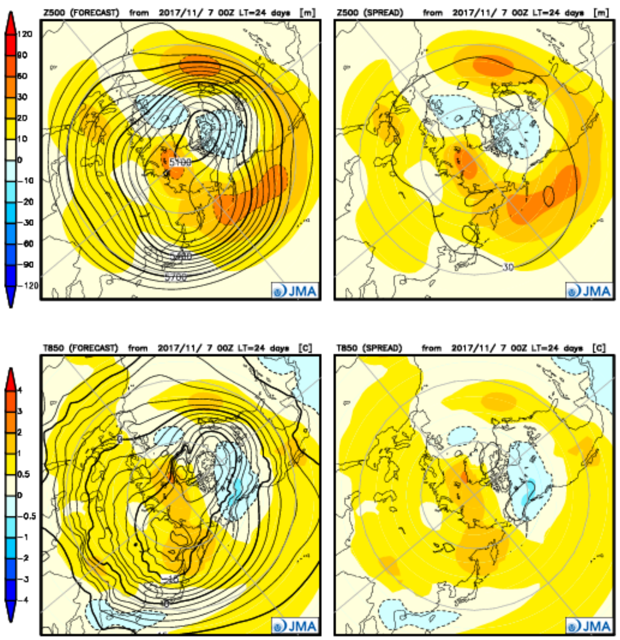
corresponding verification

LT : lead time(day)
kt : lead time(hour)

[FORECAST](left figures)
top : Contours show 500hPa height in an interval of 60m.
middle : Contours show 850hPa temperature in an interval of 3C.
bottom : Contours show sea level pressure in an interval of 4hPa.
(Shaded patterns show anomalies.)

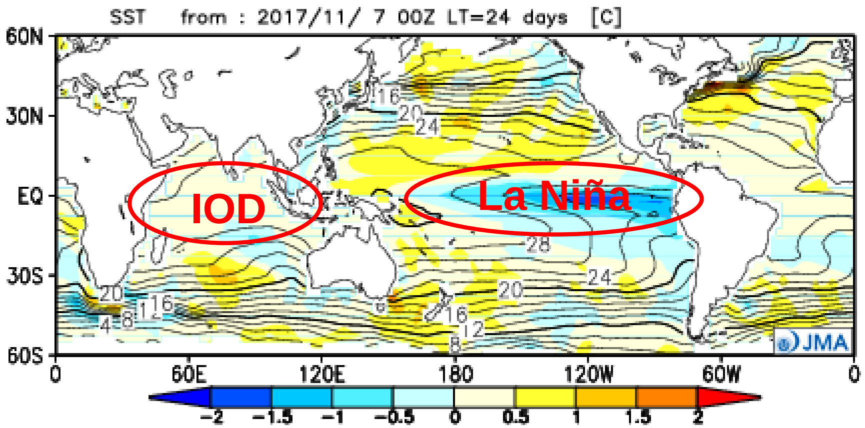
[SPREAD](right figures)
top : Contours show spread of 500hPa height in an interval of 30m.
middle : Contours show spread of 850hPa temperature in an interval of 2C.
bottom : Contours show spread of sea level pressure in an interval of 4hPa.
(Shaded patterns show anomalies.)

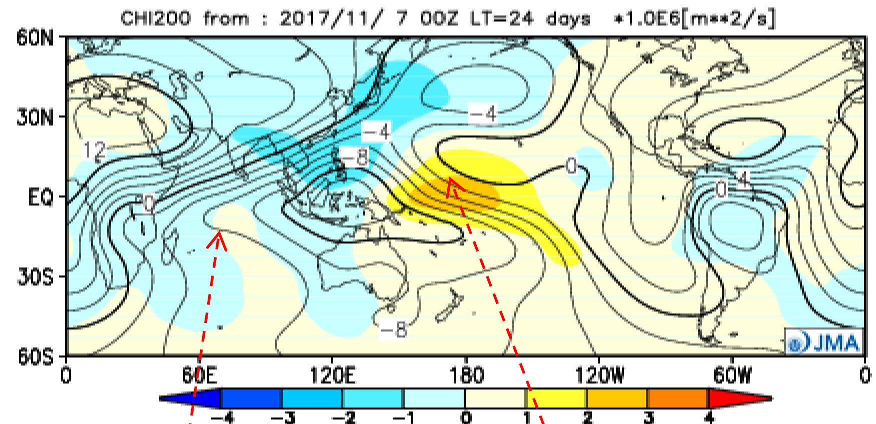
Ensemble forecast (3 months mean : DEC−FEB)

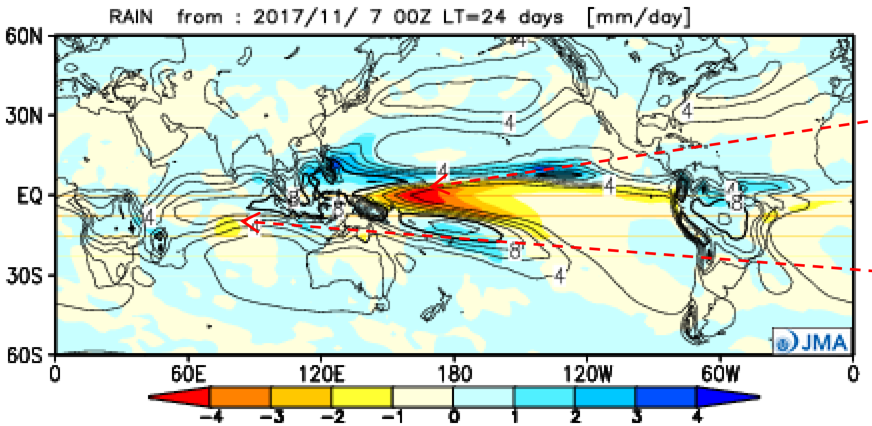


How to use NWP charts for Seasonal forecast

【Step 1】Let’s check predicted SST conditions and tropical convection fields.







In this case, a response associated with La Niña like SST conditions is clear.

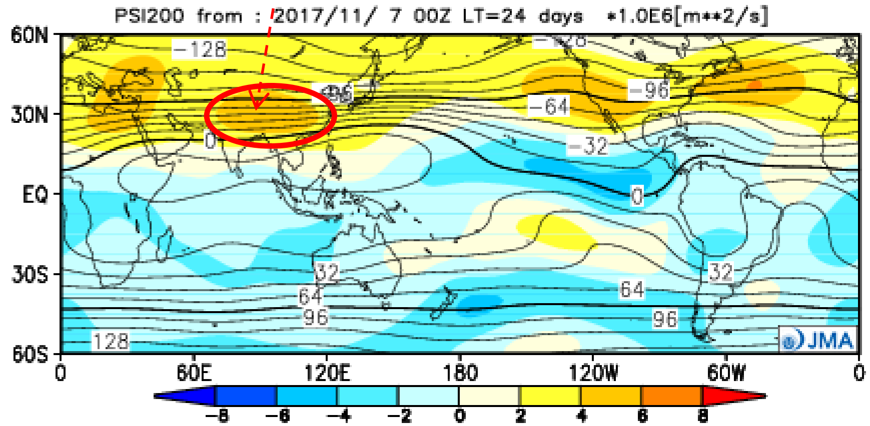
In this case, a response associated with positive IOD like SST conditions can be seen.

Contours indicate predicted values. Shading indicates anomaly.

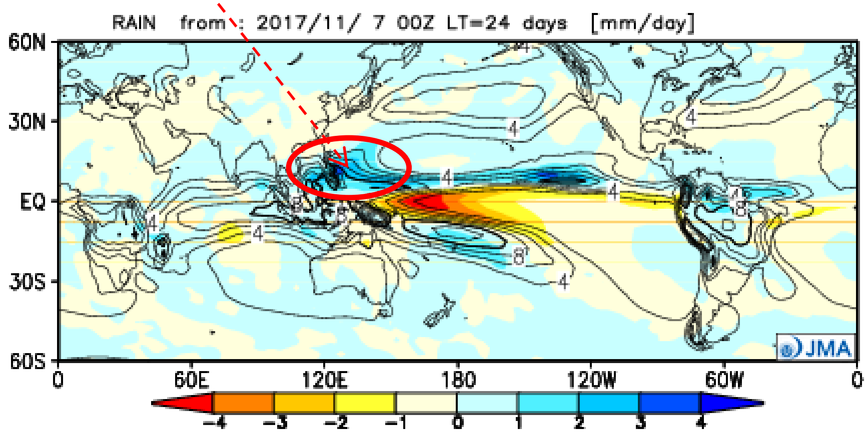
How to use NWP charts for Seasonal forecast

【Step 2】Let's check tropical convection response fields.

Anticyclonic Rossby Response (strengthened by a wave train)



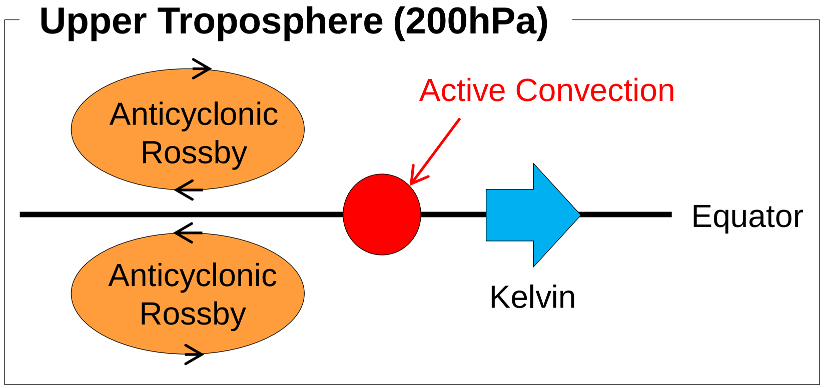
Active convection



Contours indicate predicted values. Shading indicates anomaly.

PSI200 (i.e. Stream function at 200hPa)

・Positive values indicate anticyclone in Northern Hemisphere and cyclone in Southern Hemisphere
・Negative values indicate cyclone in Northern Hemisphere and anticyclone in Southern Hemisphere
・Rossby waves associated with tropical convections has high reliability, because predictability of tropical convection is high in association with SST variabilities.

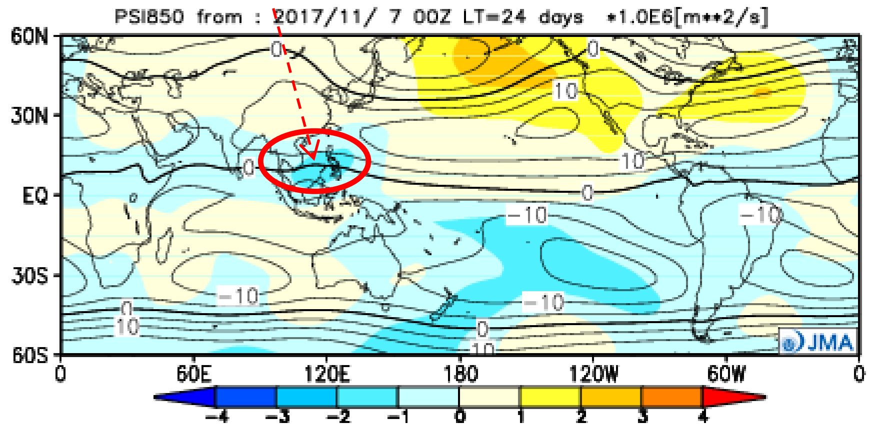


Typical Response Pattern
(The Matsuno-Gill Response)

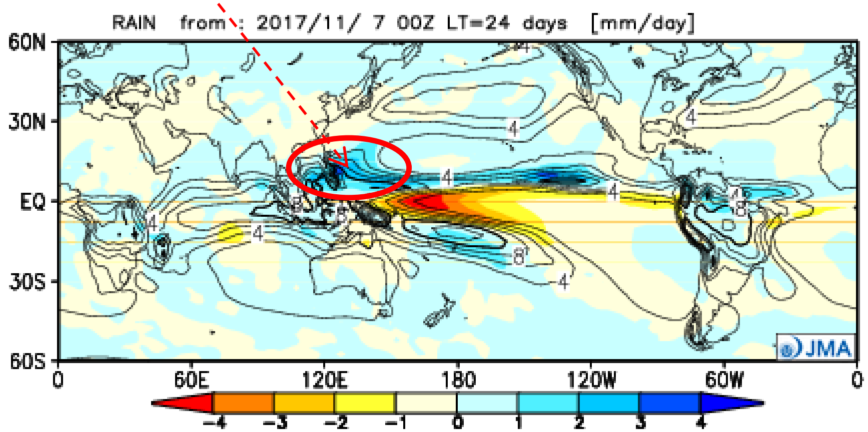
How to use NWP charts for Seasonal forecast

【Step 2】Let's check tropical convection response fields.

Cyclonic Rossby Response



Active convection



Contours indicate predicted values. Shading indicates anomaly.

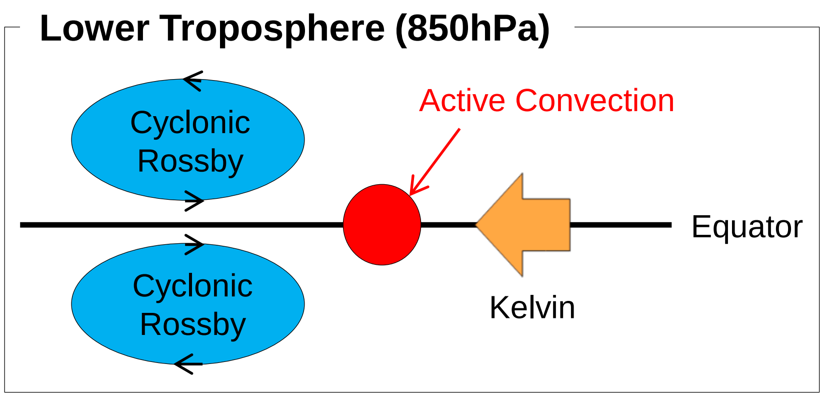
PSI850 (i.e. Stream function at 850hPa)

・Positive values indicate anticyclone in Northern Hemisphere and cyclone in Southern Hemisphere

・Negative values indicate cyclone in Northern Hemisphere and anticyclone in Southern Hemisphere

・Rossby waves associated with tropical convections has high reliability, because predictability of tropical convection is high in association with SST variabilities.

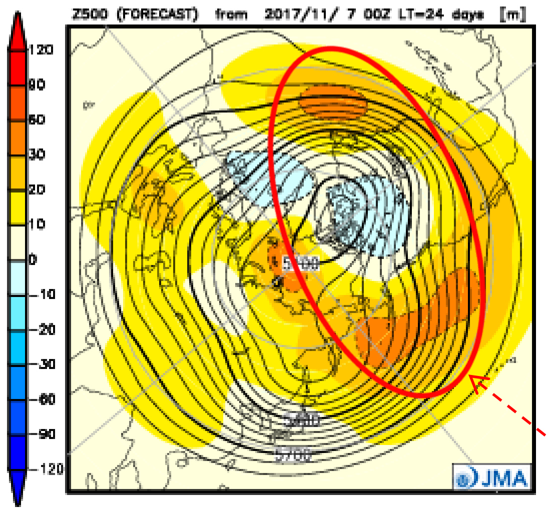
・Tropical cyclones are sometimes generated in strong cyclonic circulations.



Typical Response Pattern (The Matsuno-Gill Response)

How to use NWP charts for Seasonal forecast

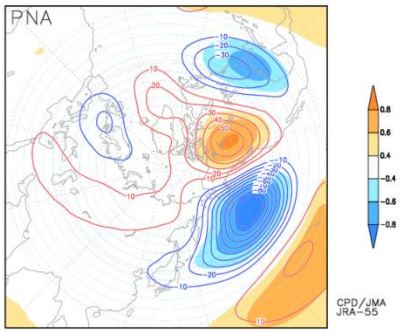
【Step 3】Let's check teleconnection patterns.

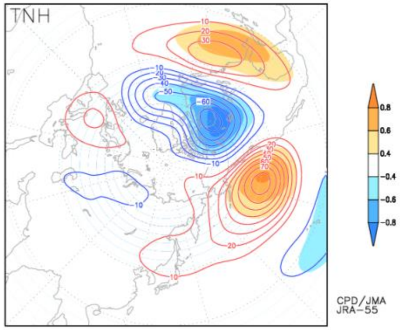


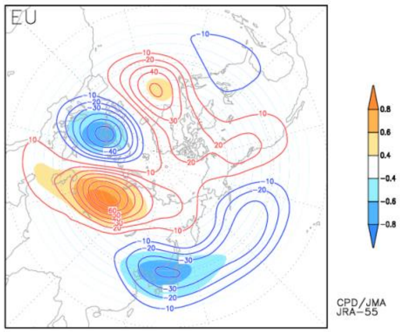
Z500 (i.e. Geopotential Height at 500hPa)

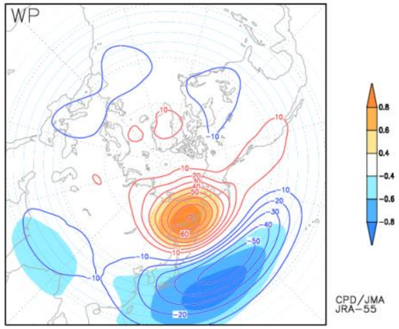
- In general, predictabilities over mid- and high- latitude are small, but teleconnection patterns associated with tropical convection patterns are relatively reliable.
- Positive/Negative Pacific-North America (PNA) pattern and Negative/Positive Tropical-Northern Hemisphere pattern are often seen with El niño/La niña.
- Eurasia(EU) pattern has strong correlation with PNA.
- Western Pacific (WP) pattern has strong correlation with tropical convection over NINO.WEST.

In this case, negative PNA and positive TNH are dominant.





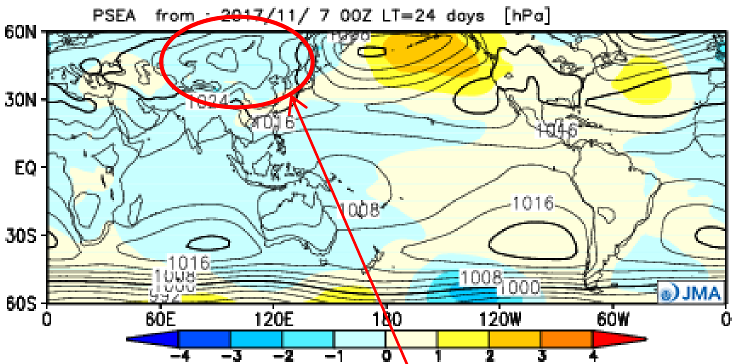


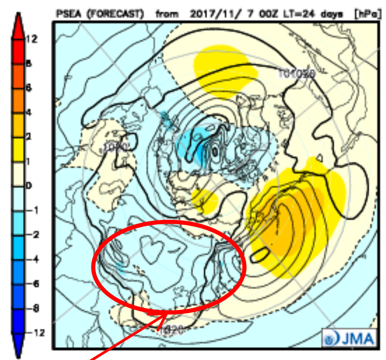


Contours indicate predicted values. Shading indicates anomaly.

How to use NWP charts for Seasonal forecast

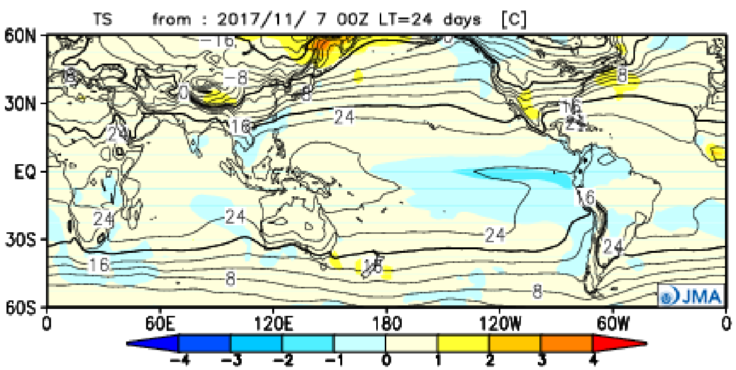
【Step 4】Let's check the other figures.

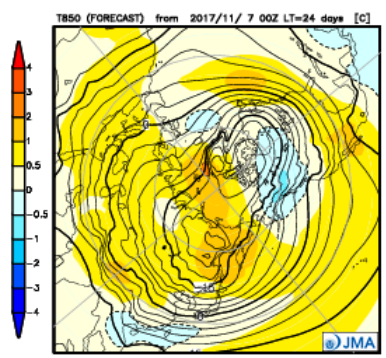




Weak Siberian High

PSEA（i.e. Sea Surface Pressure)
Sea Surface Pressure is useful to understand Arctic Oscillation (AO), North Atlantic Oscillation (NAO) and the strength of North Pacific High, Siberian High, Aleutian Low and so on.
Both tropical and northern hemisphere views are available.





Temperature
Model output temperature is necessary to check statistical guidance reliability.
If temperature in guidance is different from that in model, you should investigate the cause.
A tropical view of surface temperature and a northern hemisphere view of 850hPa temperature are available.

Contours indicate predicted values. Shading indicates anomaly.

How to use Verification charts for Seasonal forecast

Hindcast verification charts for seasonal forecast are available on the Three-month and Warm/Cold season prediction menus.

Three-month Prediction

- Three-month Prediction (12 Nov 2017)
- Z500, T850 & SLP (Northern Hemisphere) (12 Nov 2017)
- Stream Function, Velocity Potential & Surface Air Temperature (60N-60S) (12 Nov 2017)
- Verification (05 Nov 2017)
- Hindcast Verification (JMA/MRI-CPS2)
- Probabilistic Forecast and Verification (12 Nov 2017)
- SST Index Time-series Forecast (12 Nov 2017)

Hindcast Verification

- Deterministic score Maps
  - Variables to be Assessed: T2m, PSEA, SST, RAIN, Z100, Z200, Z300, Z500, Z850, T850, U200, U850, V200, V850, PSI200, PSI850, CHI200, CHI850
  - Diagonostic Measures:
    - Mean Square Skill Score(MSSS)
    - Anomaly Correation(ACOR)
    - Root Mean Squared Error(RMSE)
    - Ratio of Standard Deviation(SD)
    - Analysis Standard Deviation
    - Model Standard Deviation
    - Bias
    - Analysis Climatology
    - Model Climatology

- Probabilistic score Diagrams
  - Variables to be Assessed: T2m, PSEA, SST, RAIN, Z100, Z200, Z300, Z500, Z850, T850, U200, U850, V200, V850, PSI200, PSI850, CHI200, CHI850
  - Diagonostic Measures:
    - Reliability diagrams (Aggregated verification)
    - Relative Operating Characteristics(ROC) curve (Aggregated verification)
  - Event: Anomaly > 0, Below Normal, Near Normal, Above Normal, All

  The 3 categories(above-normal, near-normal, below-normal) are defined by standard deviations of the observed 30 years time series at each grid point.
- Probabilistic score Maps
  - Variables to be Assessed: T2m, PSEA, SST, RAIN, Z100, Z200, Z300, Z500, Z850, T850, U200, U850, V200, V850, PSI200, PSI850, CHI200, CHI850
  - Diagonostic Measures:
    - Relative Operating Characteristics(ROC) areas (Grid point verification)
  - Event: Anomaly > 0, Below Normal, Near Normal, Above Normal, All

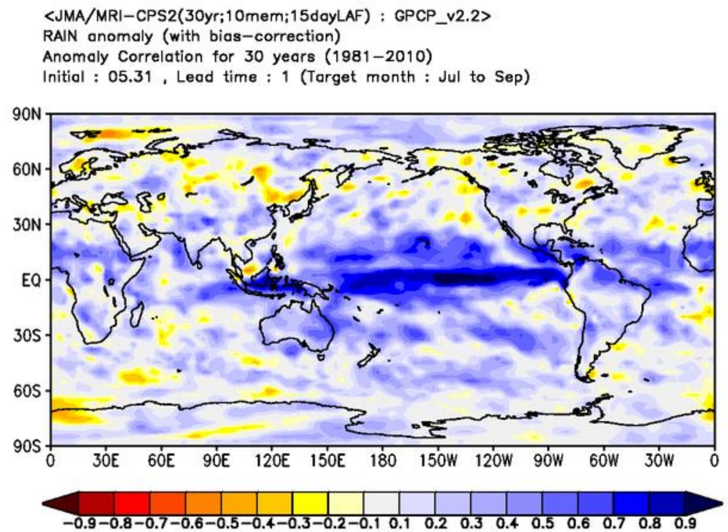
  The 3 categories(above-normal, near-normal, below-normal) are defined by standard deviations of the observed 30 years time series at each grid point.

- Time-series Circulation Index

- ENSO Index score
- ENSO Index time-series

http://ds.data.jma.go.jp/tcc/tcc/products/model/hindcast/CPS2/index.html

How to use Verification charts for Seasonal forecast



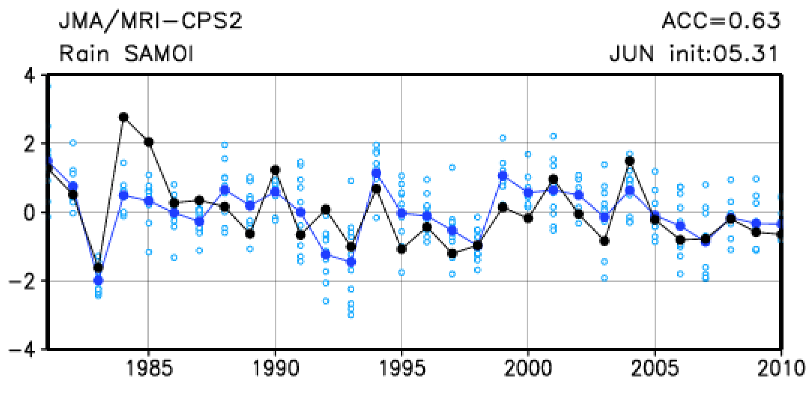
NH	TRP	SH	EU	PAC	JPN	N34	GLB
0.064	0.351	0.128	0.052	0.084	0.052	0.807	0.184
0.068	0.396	0.135	0.055	0.089	0.054	0.858	0.207

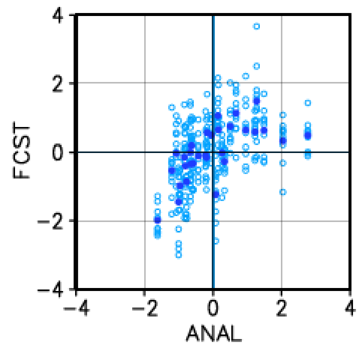
Deterministic and Probabilistic Score Maps

Hindcast score maps are useful to understand the spatial prediction skills. In the low prediction skill region, it is not recommended to use model output directly. Statistical relationships to the high skill region and calibration using past observation should be considered.

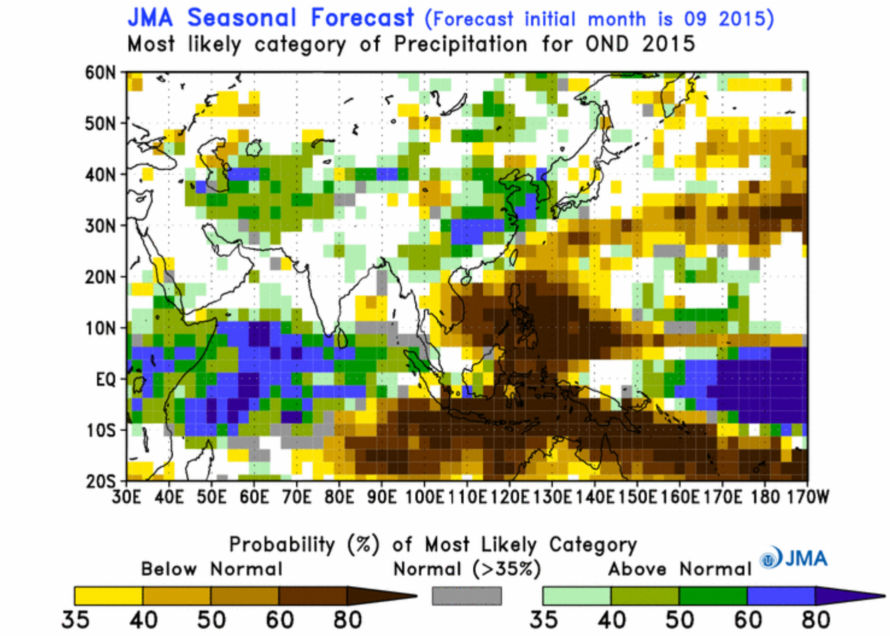
Time-series circulation Index

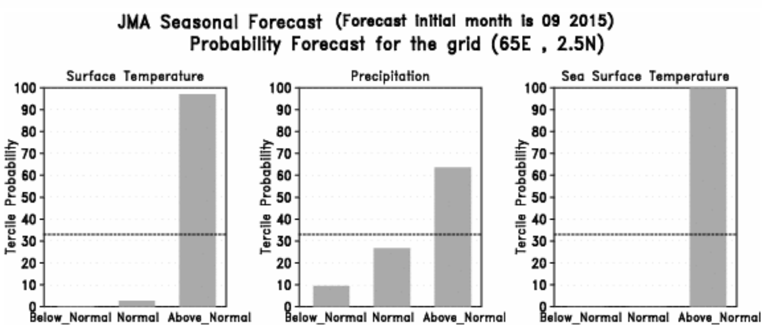
Time-series circulation indexes are useful to understand model predictabilities of various kinds of focal phenomena such as El Niño/La Niña, Indian Ocean Dipole (IOD), monsoon rainfalls and circulations. Higher skill phenomena should be used for explanation of forecast reasons.





Probabilistic Forecast for Seasonal Prediction



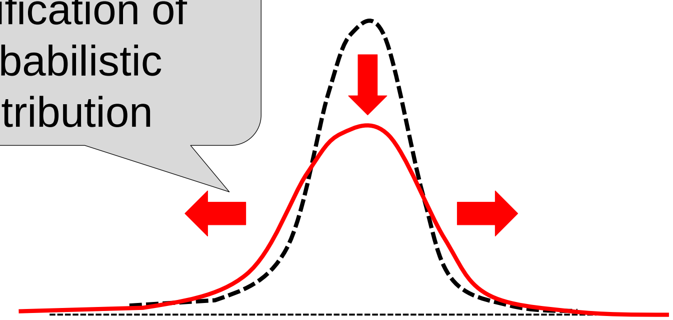


Probability distribution from the direct model output

Numerical guidance (Statistical technique based on hindcast)

Calibrated probabilistic forecast
(one of the statistical guidance)

Modification of probabilistic distribution

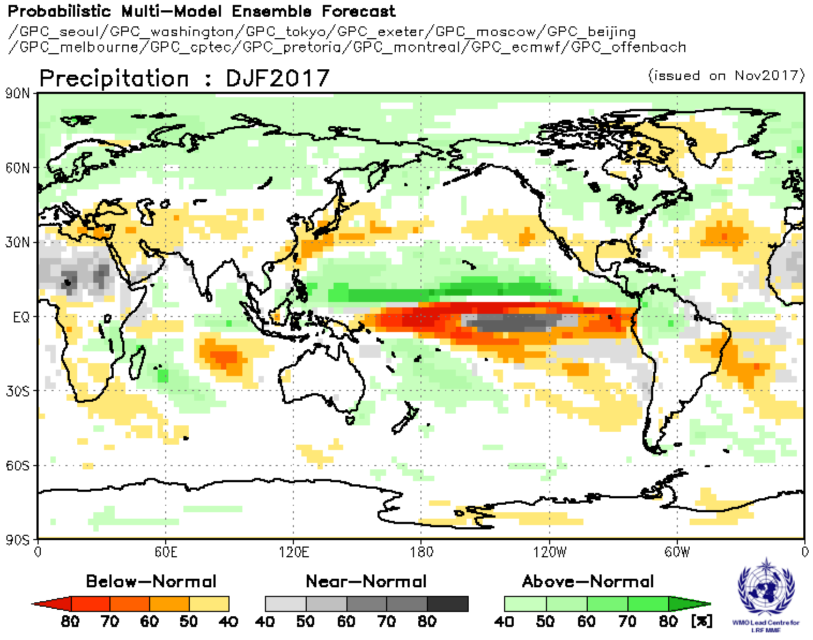


Example of calibration

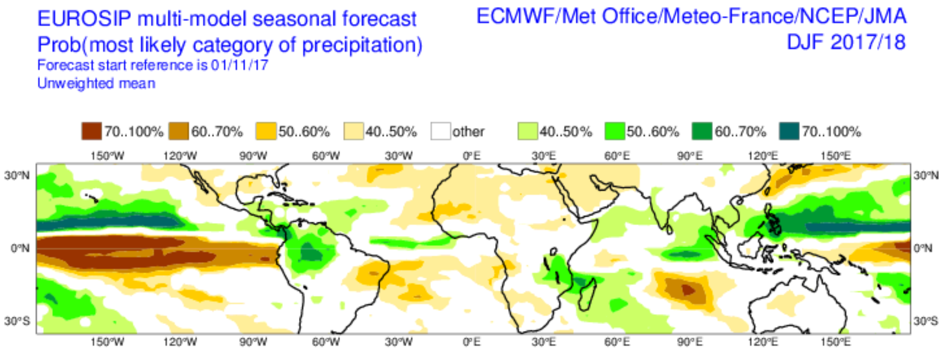
http://ds.data.jma.go.jp/tcc/tcc/products/model/probfcst/3-mon/index.html
http://ds.data.jma.go.jp/tcc/tcc/products/model/probfcst/warm_cold_season/index.html

WMO LC-LRFMME / EUROSIP

In order to reduce the uncertainty caused by model imperfections, multi-model ensemble forecasts are used in many nations. Multi-model ensemble forecasts including JMA are referenceable in WMO LC-LRFMME and EUROSIP websites.



https://www.wmolc.org/
(Authentication is required)



https://www.ecmwf.int/en/forecasts/documentation-and-support/long-range/seasonal-forecast-documentation/eurosip-user-guide/multi-model
(Authentication is required to refer forecasts for a mid- and high- latitudes.)

Summaries

Predictability

- There are 2 kinds of predictability.
  Predictability of 1st kind depends on an initial condition.
  Predictability of 2nd kind depends on boundary conditions.
- Temporal and spatial scales of forecast targets should be considered.

Uncertainty

- Because of chaotic nature, it is essential to consider uncertainty.
- Ensemble prediction system (EPS) make it possible to estimate uncertainty.

Hindcast

- Hindcast is essential to understand prediction skill and to make model climate.

Global EPS

- A high-resolution AGCM is used for extended range forecast (Predictability of 1st kind).
- Seasonal oscillations such as MJO and BSISO make a monsoon rainfall forecast difficult.
- MJO is predictable up to 25 days, but velocity and amplitude bias should be cared.

Seasonal EPS

- A CGCM is used for seasonal forecast (Predictability of 2nd kind).
- Not only an ocean model but also an interactive sea ice model were coupled.
- Tri-polar grid made it possible to cover full ocean.
- Representation of historical warming trend has been improved by consideration of 6 GHGs.
- Prediction skill for NINO3, NINO.WEST, IOBW and DMI depends on season.
- Prediction skill of Seasonal EPS for MJO is better than that of Global EPS.