JMA's New Seasonal Prediction System: JMA/MRI-CGCM2

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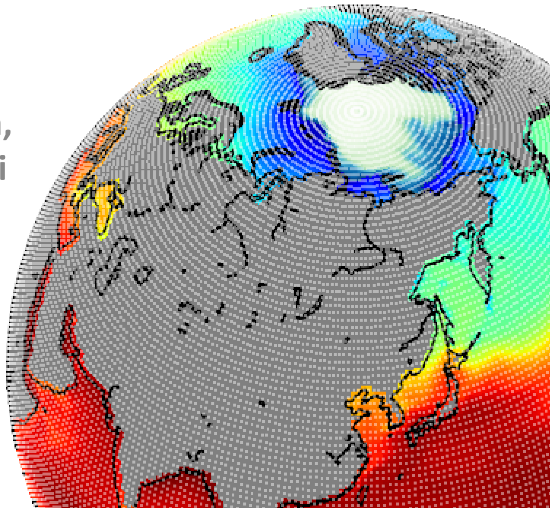


Outline

- History of Coupled Forecast System at JMA
- Configuration of JMA's Seasonal EPS
- New Sources of Predictability
- Evaluation of Performance for :
  - ENSO Prediction
  - 3-month Forecast
  - MJO Prediction
- Example of Retrospective Forecast

History of Coupled Forecast System at JMA

* CGCM for ENSO prediction

1999 **JMA-CGCM01 ***

Atmosphere: T42 (~250 km) L21 (~10hPa)

Ocean: 2.5x2-0.5(10N-10S) L20

2003 **JMA-CGCM02 ***

Atmosphere: T63 (~180 km, 1.875 deg.) L40 (~0.4hPa)

Ocean: 2.5x2-0.5(10N-10S) L20 (top: ~10 m)

2008 **JMA/MRI-CGCM *** ➔ **2010: for Seasonal Forecast**

Atmosphere: T_L95 (~180 km, 1.875 deg.) L40 (~0.4hPa)

Ocean: 1x1-0.3 (30N-30S) L51 (top: ~1m)

2015 **JMA/MRI-CGCM2**

Atmosphere: T_L159 (~110 km, 1.125 deg.) L60 (~0.1hPa)

Ocean: 1x0.5-0.3 L53

Configuration of JMA's Seasonal EPS

	JMA/MRI-CGCM (Current)	JMA/MRI-CGCM2 (Next)
Atmosphere (JMA-AGCM)	***TL95L40***, ~180km, Up to ***0.4hPa***	***TL159L60*** , ~110km, Up to ***0.1hPa*** ***Stochastic Tendency Perturbation*** ***GHG forcing*** from RCP4.5 scenario
Ocean (MRI.COM) (Tsujino et al 2010)	1.0° (lon) x ***0.3-1 °*** (lat) ***L51*** 75°S-75°N Ocean ***Sea-ice climatology***	1.0° (lon) x ***0.3-0.5 °*** (lat) ***L53*** ***Global Ocean with Tripolar Grid*** ***Sea-ice model***
Coupler (Scup) (Yoshimura and Yukimoto 2008)	1-hour coupling interval ***Momentum and heat flux adjustments***	1-hour coupling interval ***No flux adjustment***
Initial Condition	Atmosphere: ***JRA-25*** Land: ***Climatology with ERA-15 forcing*** Ocean: ***MOVE/MRI.COM-G*** T, S&SSH (Usui et al. 2006) ***Sea-ice climatology***	Atmosphere: ***JRA-55*** Land: ***JRA-55 land analysis*** Ocean: ***MOVE/MRI.COM-G2*** T, S & SSH ***Sea-ice model***
Ensemble Size	51 (***9*** BGMs, ***6*** days with 5-day LAF)	51 (***13*** BGMs, ***4*** days with 5-day LAF)

Specification of Hindcast

- Evaluation of the prediction skill of the EPS using the hindcast datasets

	Operational	Hindcast
Initial Condition	Atmosphere: JRA-55 Land: JRA-55 land analysis Ocean: MOVE/MRI.COM-G2 T, S & SSH Sea-ice model	**same as Operational**
Ensemble Size	51 (13 BGMs, 4 days with 5-day LAF)	**10** **(5 BGMs, 2 days with 5-day LAF)**
Initial date	Every 5 days	**twice a month** **(middle and end of month)**
Period	---	**30 years (1981-2010)**

New Sources of Predictability

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

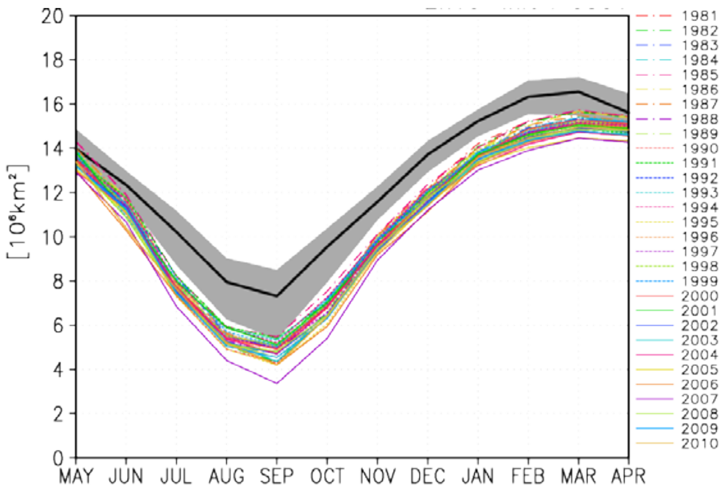
The new system is capable of incorporating a full range of potential sources of the predictability.

Sea-Ice Model and Initialization

- Model
  - Thermodynamic model (Sea-ice production / melting)
    - Mellor and Kantha (1989)
  - Dynamic model (Momentum equation)
    - Elastic-viscous-plastic rheology (EVP)
    - Hunke and Dukowicz (1997,2002)
- Initialization
  - JRA-55 forcing
  - T,S assimilation
  - Radiative flux adjustment

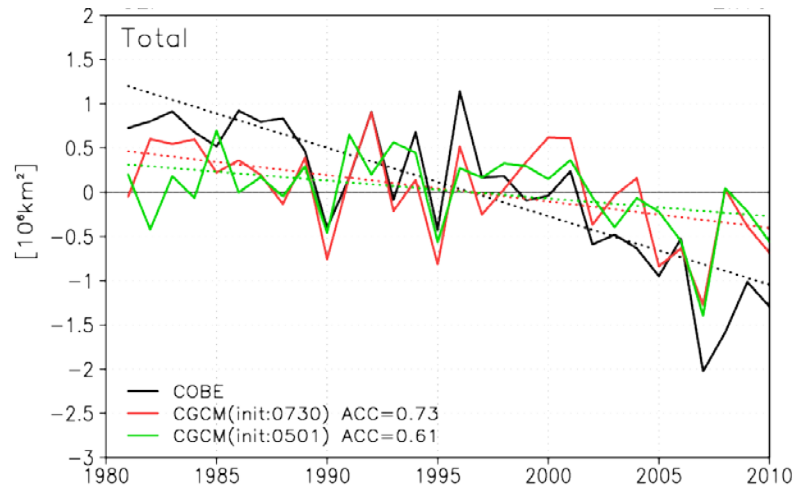
Arctic Sea-Ice Extent* Verification

Seasonal variation of Arctic sea-ice extent



Individual forecast started from 1st May 1981-2010 (**CGCM, color line**), climatology of analysis (**COBE, black line** ;Ishii et al. 2005), minimum and maximum of analysis (shaded area) of sea ice extent.

Interannual variability and reduction trend of Arctic sea-ice extent in September



Analyzed (black) and forecasted anomalies of sea ice extent (solid line) in September at lead times of 2 (red) and 5 months (green) and its trends (left, dash line).

Introduced sea-ice model represents:

- Seasonal variation of Arctic sea ice.
- Interannual variability and reduction trend of Arctic sea-ice extent.

* Sea-Ice Extent: total area where the sea-ice concentration is higher than 15%.

Land Initialization

- **JMA/MRI-CGCM (Operational)**
  - Initial: Land Climatology with ERA-15 forcing

Koster et al. (2010) indicates that:
Land initialization improves predictability for 0 - 1month.

- **JMA/MRI-CGCM2 (Next)**
  - Initial: JRA-55 Land Analysis

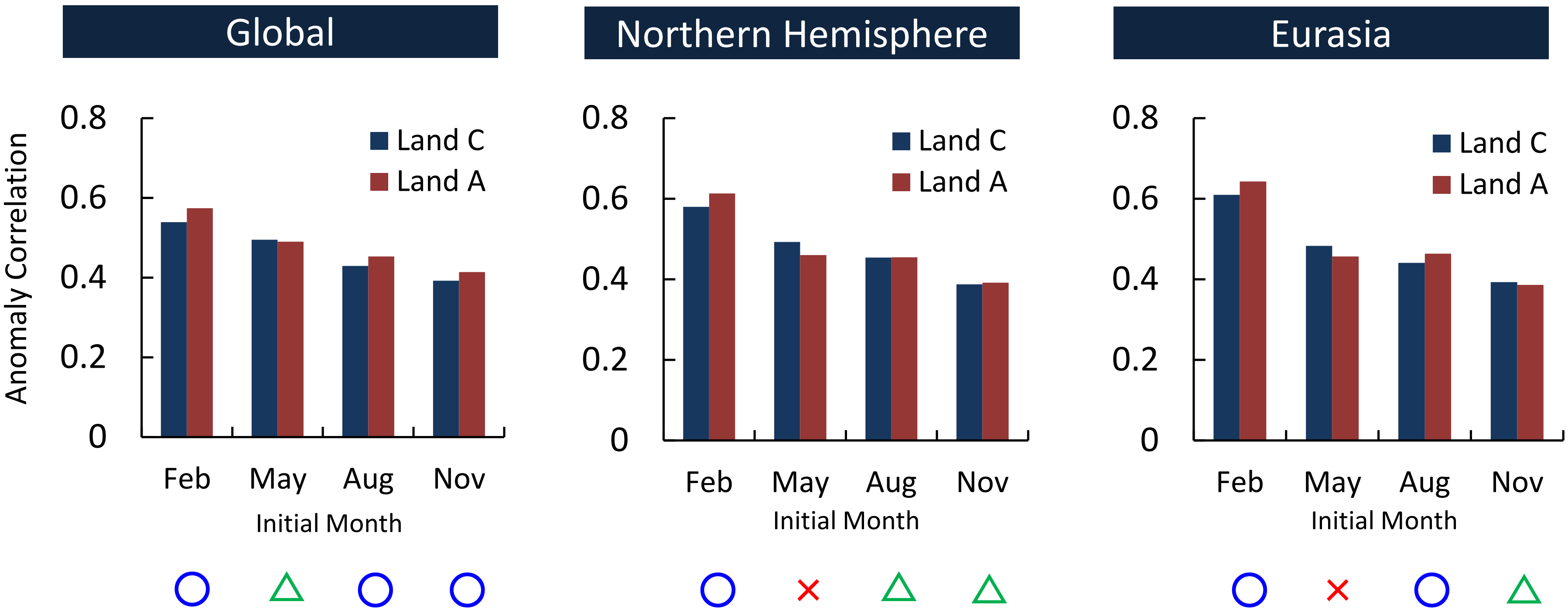
➡ Additional: Land C experiment

- Land A I.C. : JRA-55 Land Analysis (same as hindcast)
- Land C I.C. : Climatology (1981-2010) of JRA-55 Land Analysis

➔ Investigation of influence of land initialization

Improvement with Land Initialization

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



Global: 90S-90N,0E-360E
NH: 20N-90N,0E-360E
Eurasia: 20N-90N,0E-180E

Land initialization with JRA-55 land analysis results in slightly better predictions than that with climatology in shorter lead time.

Greenhouse Gases

- **JMA/MRI-CGCM (Operational)**
  - CO_2 Trend

    1979-2007 : GISS observation (Hansen and Sato 2004)

    2008- : 2007 CO_2 + WDCGG 1997-2007 trend
- **JMA/MRI-CGCM2 (Next)**
  - CO_2, CH_4, N_2O, CFC-11, CFC-12, HCFC-22
  - CMIP5: RCP 4.5 scenario

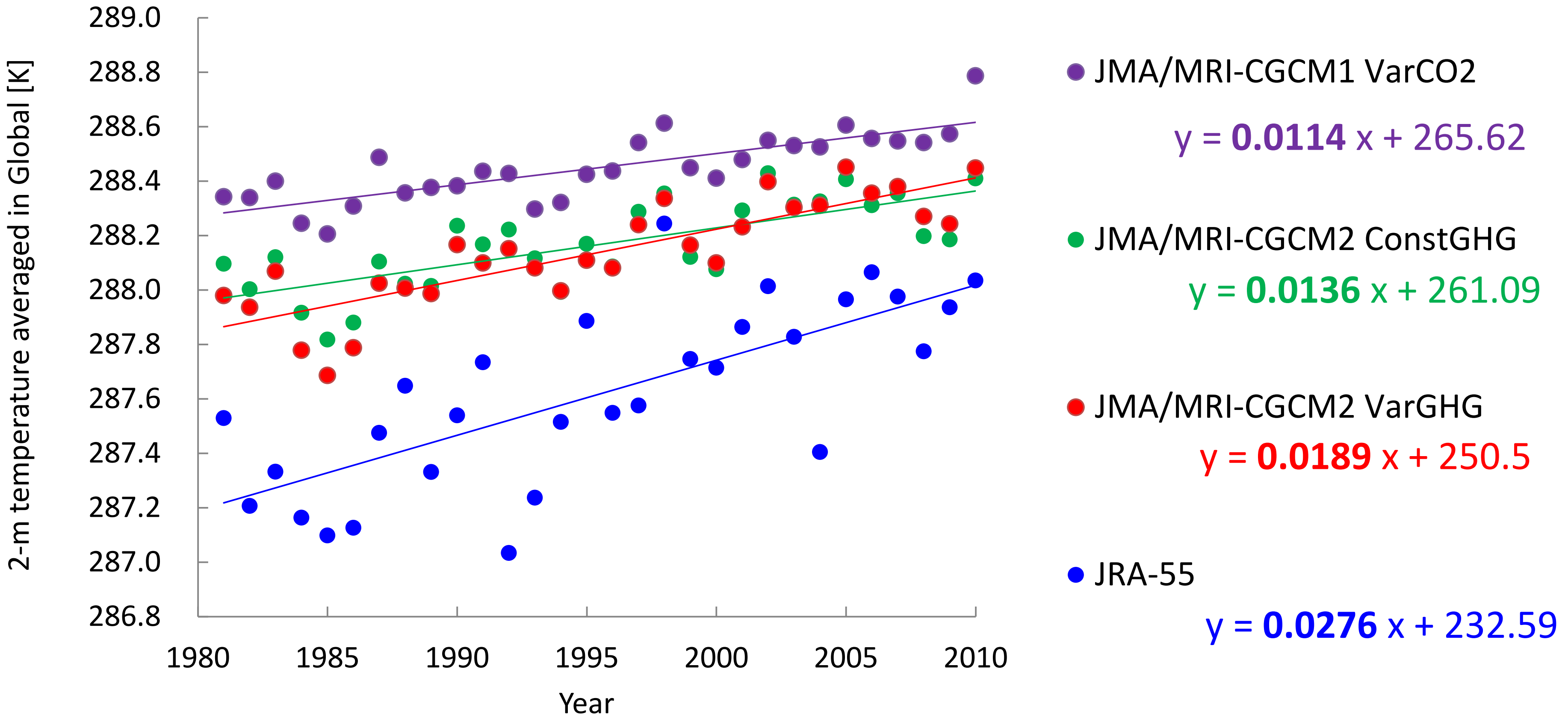
➡ Additional: ConstGHG experiment

- VarGHG : 6 types of GHG is RCP 4.5 scenario (same as hindcast)
- ConstGHG : 6 types of GHG is Constant

➔ Investigation of the effect of 6 types of GHG

2-m Temperature Trend over Land (JJA)

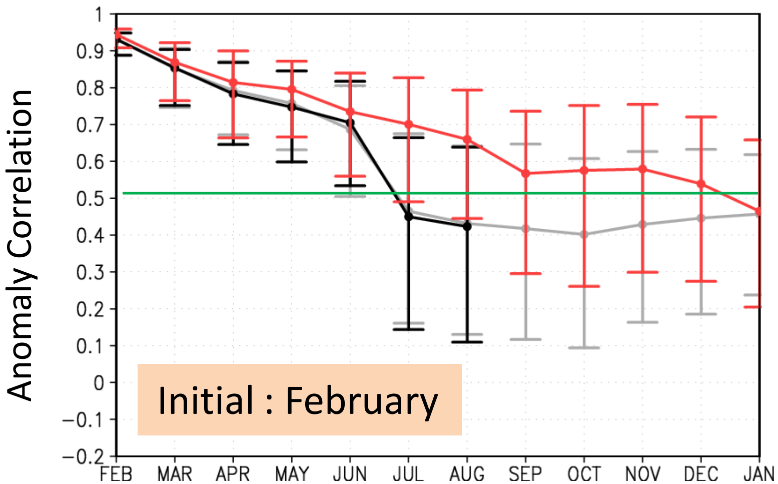
Ensemble Member: 10 Period: 30 years (1981-2010) Initial: May

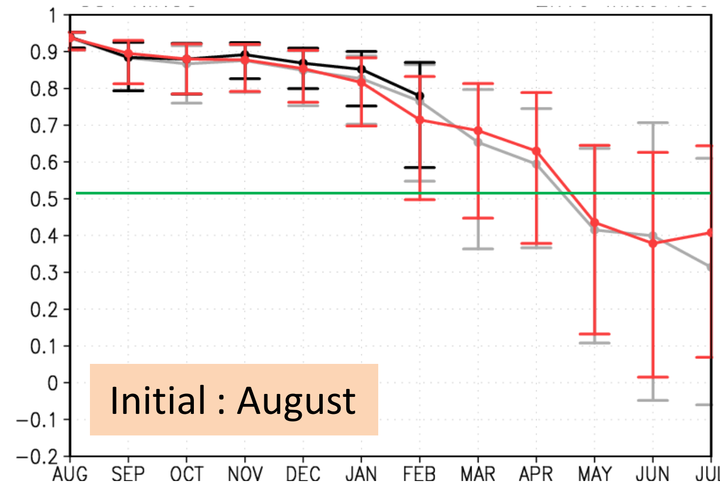


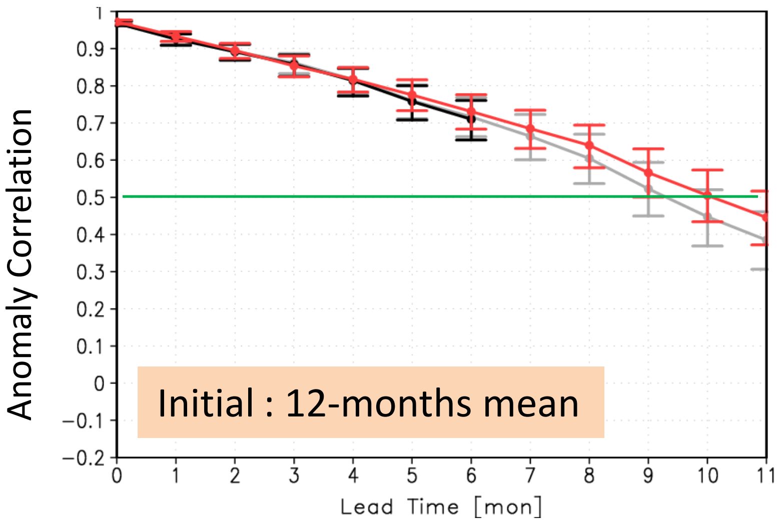
Linear trend of 2-m temperature: JMA/MRI-CGCM < ConstGHG < VarGHG < JRA-55

NINO3 SST Prediction Score

Ensemble Member: 10 Period: 30 years (1981-2010) Analysis: COBE-SST







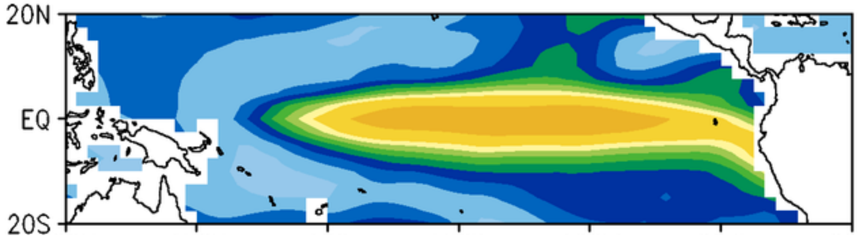
- JMA/MRI CGCM2
- JMA/MRI CGCM
- JMA/MRI CGCM (elongated hindcast re-run)

ENSO prediction of next system includes:

- improvement of ACC over the spring barrier
- improvement of ACC in longer lead time

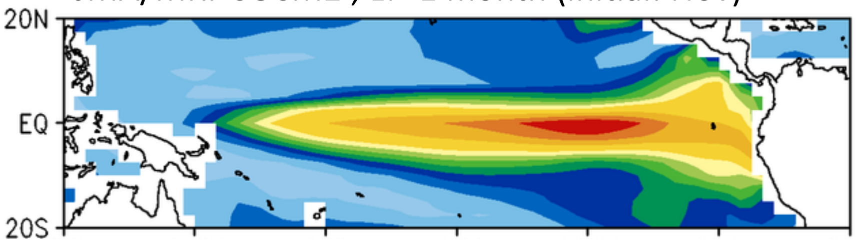
SST Standard Deviation (DJF)

COBE-SST

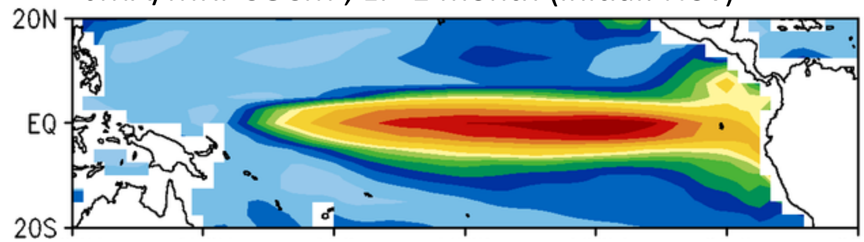


- Too large amplitude of SST interannual variability will be improved.
- The larger amplitude than analysis remains even in the next system.

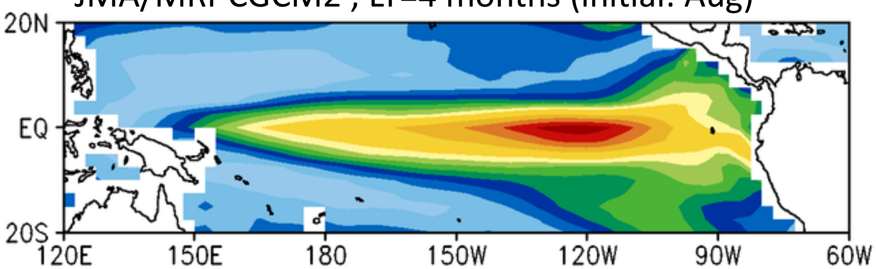
JMA/MRI-CGCM2 ; LT=1 month (initial: Nov)



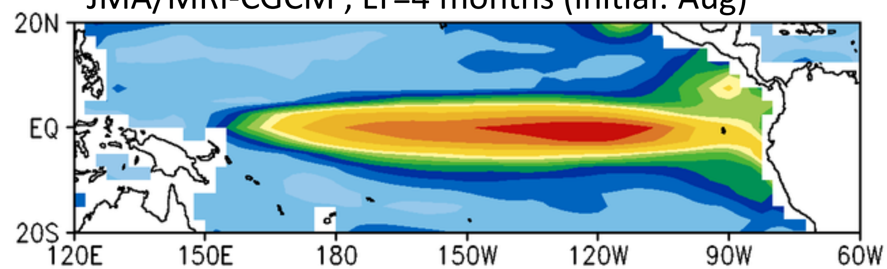
JMA/MRI-CGCM ; LT=1 month (initial: Nov)

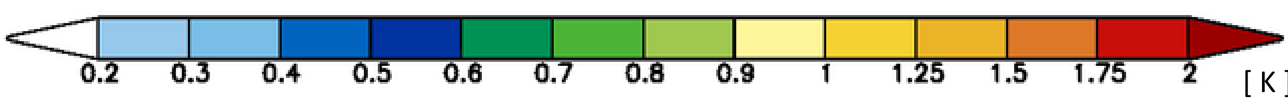


JMA/MRI-CGCM2 ; LT=4 months (initial: Aug)

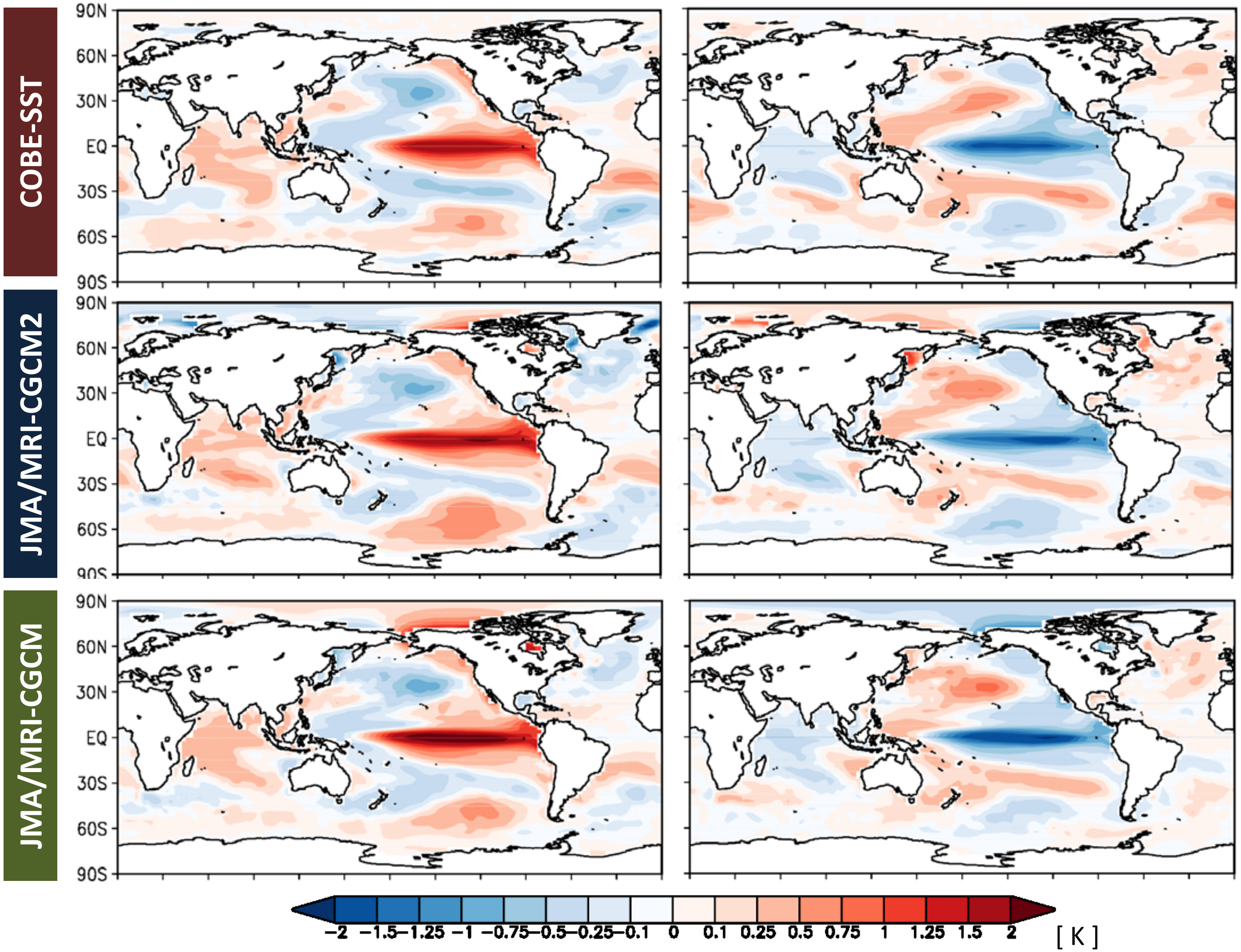


JMA/MRI-CGCM ; LT=4 months (initial: Aug)





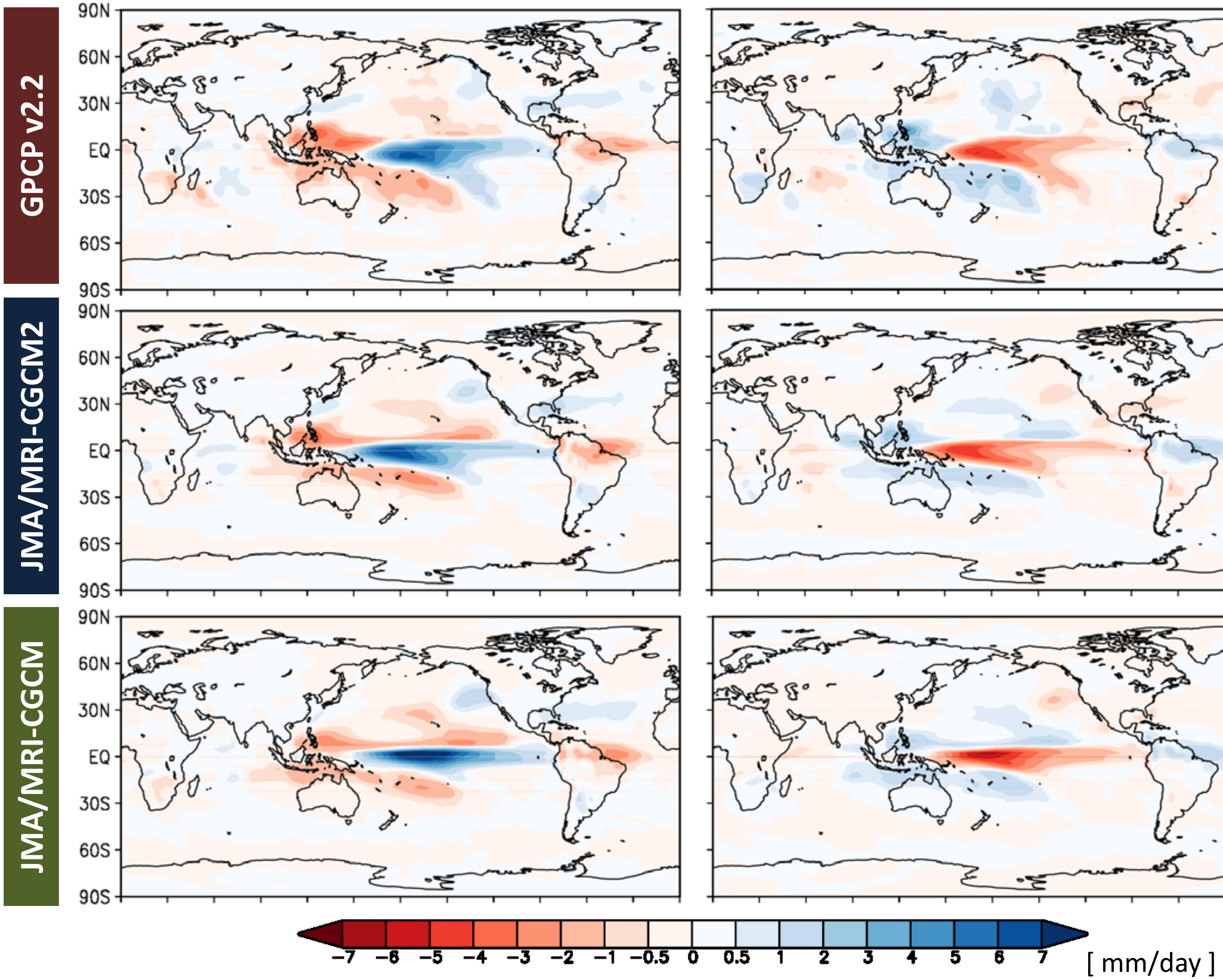
El Niño / La Niña SST Composite (DJF)



Ensemble Member: 10
Initial: Nov
Valid: DJF

Left) El Niño composite
Right) La Niña composite

El Niño / La Niña Precipitation Composite (DJF)



Ensemble Member: 10
Initial: Nov
Valid: DJF

Left) El Niño composite
Right) La Niña composite

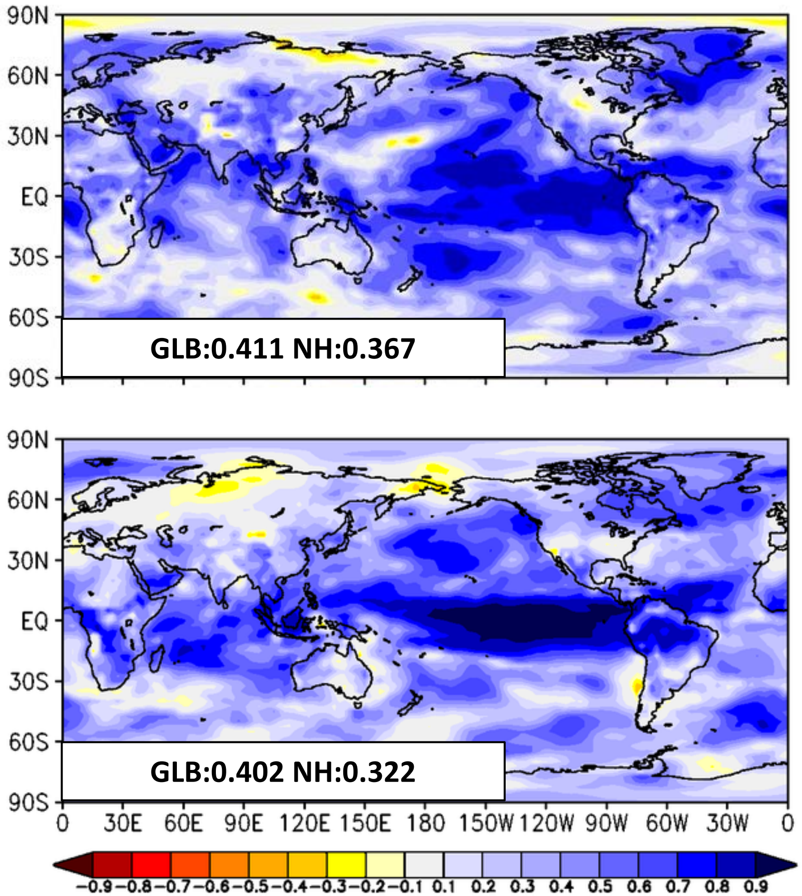
ACC of 2-m Temperature

Ensemble Member: 10 Period: 30 years (1981-2010) Analysis: JRA-55

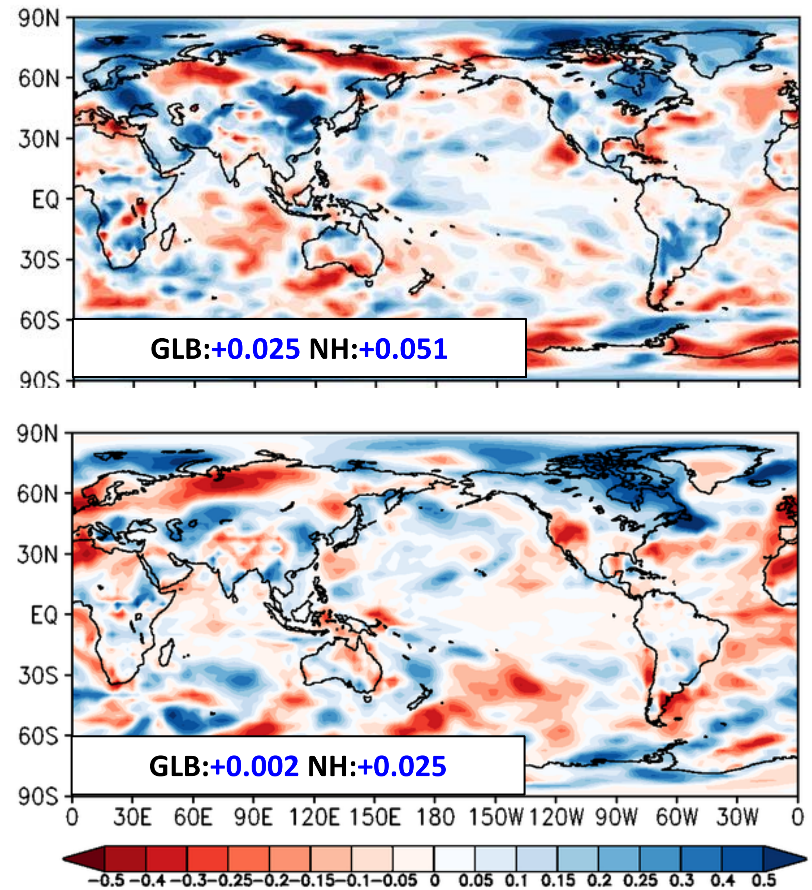
JMA/MRI-CGCM2 (Next)

JJA (Initial: May)

DJF (Initial: Nov)



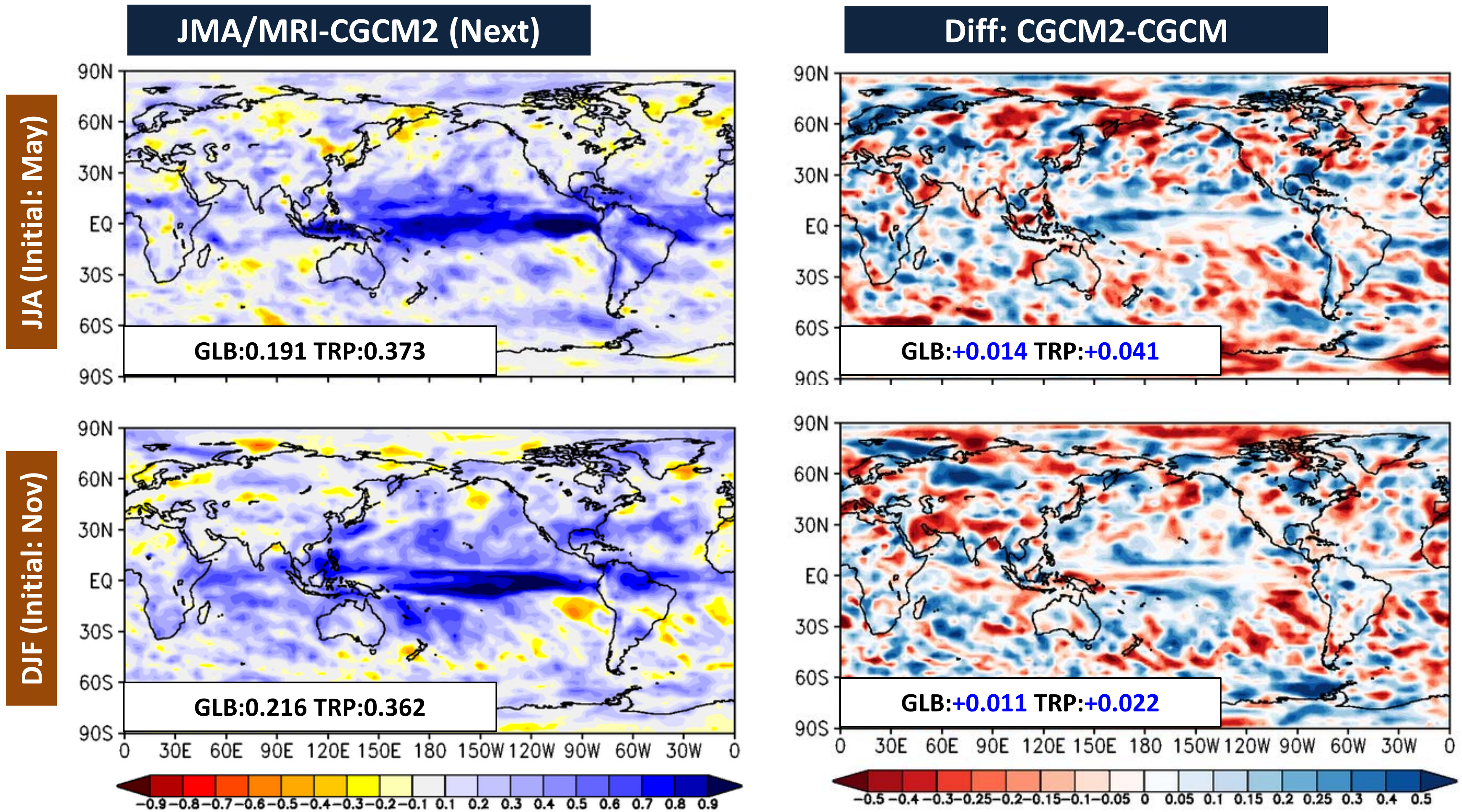
Diff: CGCM2-CGCM



Global: 90S-90N,0E-360E
NH: 20N-90N,0E-360E

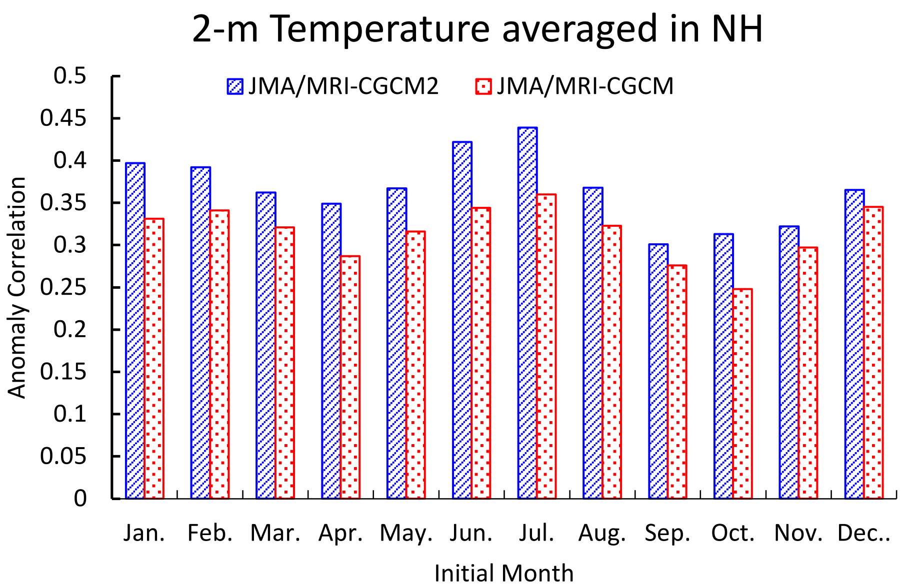
ACC of Precipitation

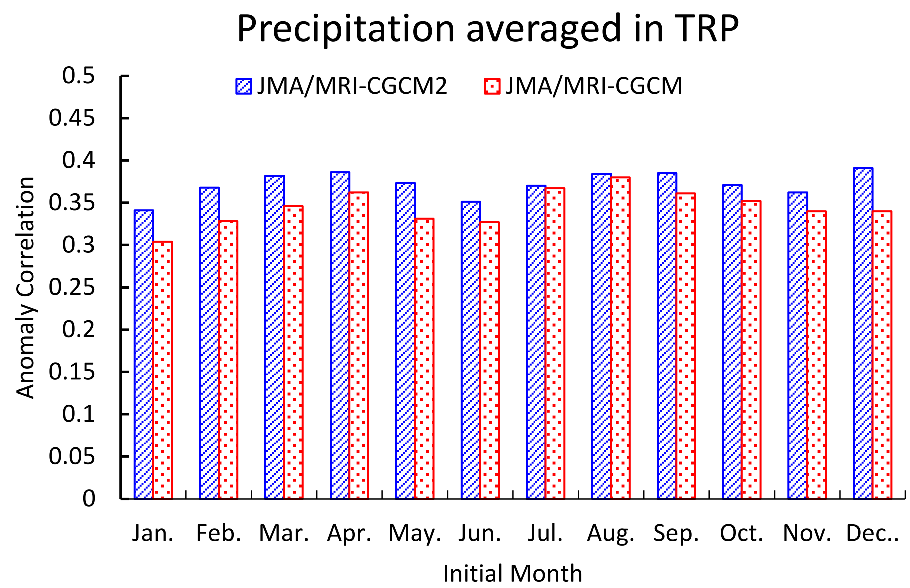
Ensemble Member: 10 Period: 30 years (1981-2010) Analysis: GPCP v2.2



Global:	90S-90N,0E-360E
TRP:	20S-20N,0E-360E

ACC for 3-month forecast



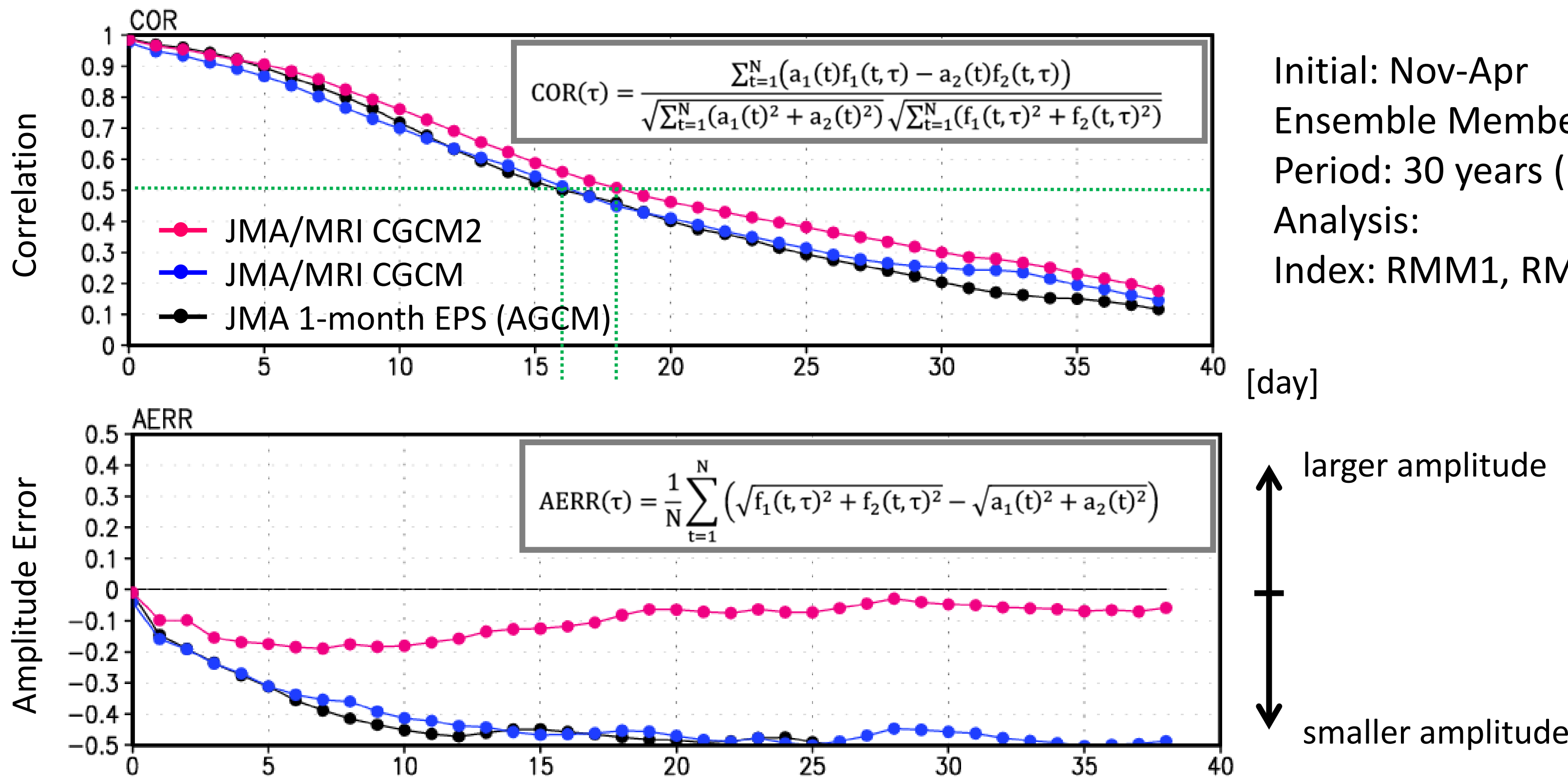


The performance of the next system is as follows:

- For 3-month forecast, anomaly correlation coefficients of 2-m temperature (NH) and precipitation (TRP) are greater than the current system in almost all initial months.
- Scores for other regions, lead times and variables are generally improved.
- As well as ACC, RMSE shows better prediction score.

NH: 20N-90N,0E-360E
TRP: 20S-20N,0E-360E

Improved Madden-Julian Oscillation



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

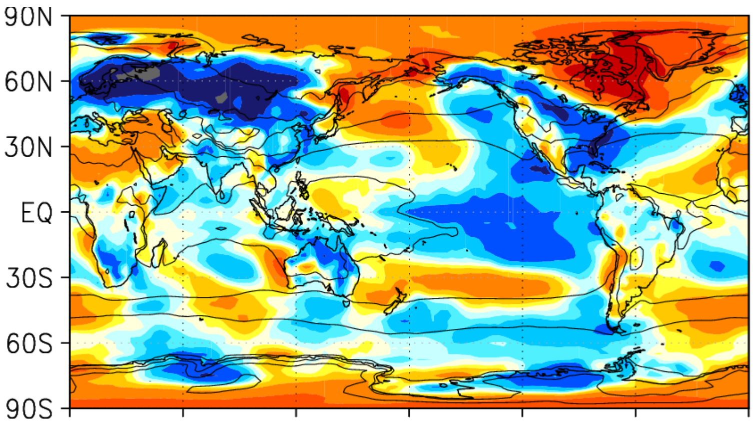
The verification of Wheeler-Hendon indices indicates that:

- the forecast time of 0.5 correlation extends roughly 2 days with model update.
- too small MJO amplitude is improved.

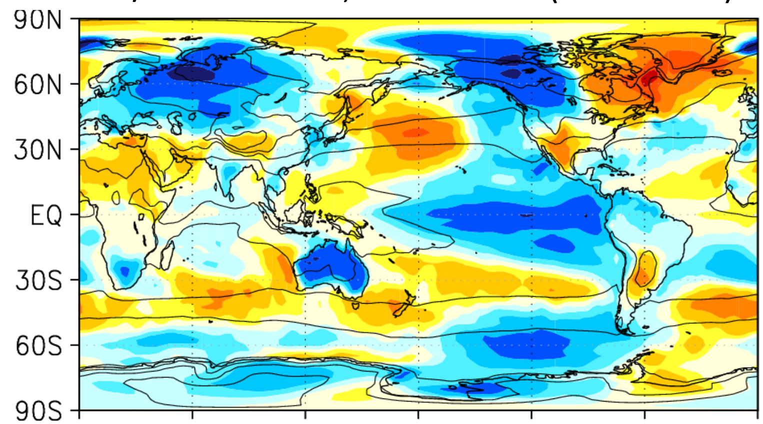
Example of Retrospective Forecast (Strong Winter Monsoon: 2010/2011 Dec-Feb)

Ensemble Member: 10 Period: 30 years (1981-2010)

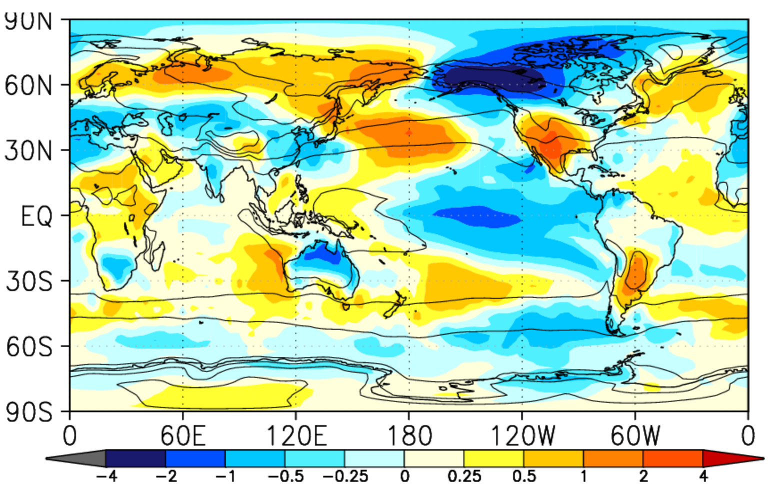
JRA-55



JMA/MRI-CGCM2 ; LT=1 month (initial: Nov)



JMA/MRI-CGCM ; LT=1 month (initial: Nov)



Contour: 2-m temperature
Shade: 2-m temperature anomaly [K] (climatology: 1981-2010)

- The 2010-2011 cold winter both in the East Asia and the Eurasia can be well predicted in the next system.

Summary

- The next system JMA/MRI-CGCM2 includes:
  - Enhanced horizontal / vertical resolution
  - New sources of predictability

    such as sea ice, stratosphere, global ocean, GHGs, …
  - New initial conditions for atmosphere, land surface, ocean

- The improvement in JMA/MRI-CGCM2 is as follows:
  - ENSO prediction score over the spring barrier
  - ENSO amplitude of interannual variability
  - 3-month forecast (2-m temperature, precipitation, …)
  - Sea-ice interannual variability and reduction trend
  - Warming trend of 2-m temperature over land
  - MJO amplitude

Thank you for your kind attention.