The Subseasonal to Seasonal Operational Forecast Systems Developed at CWB Taiwan

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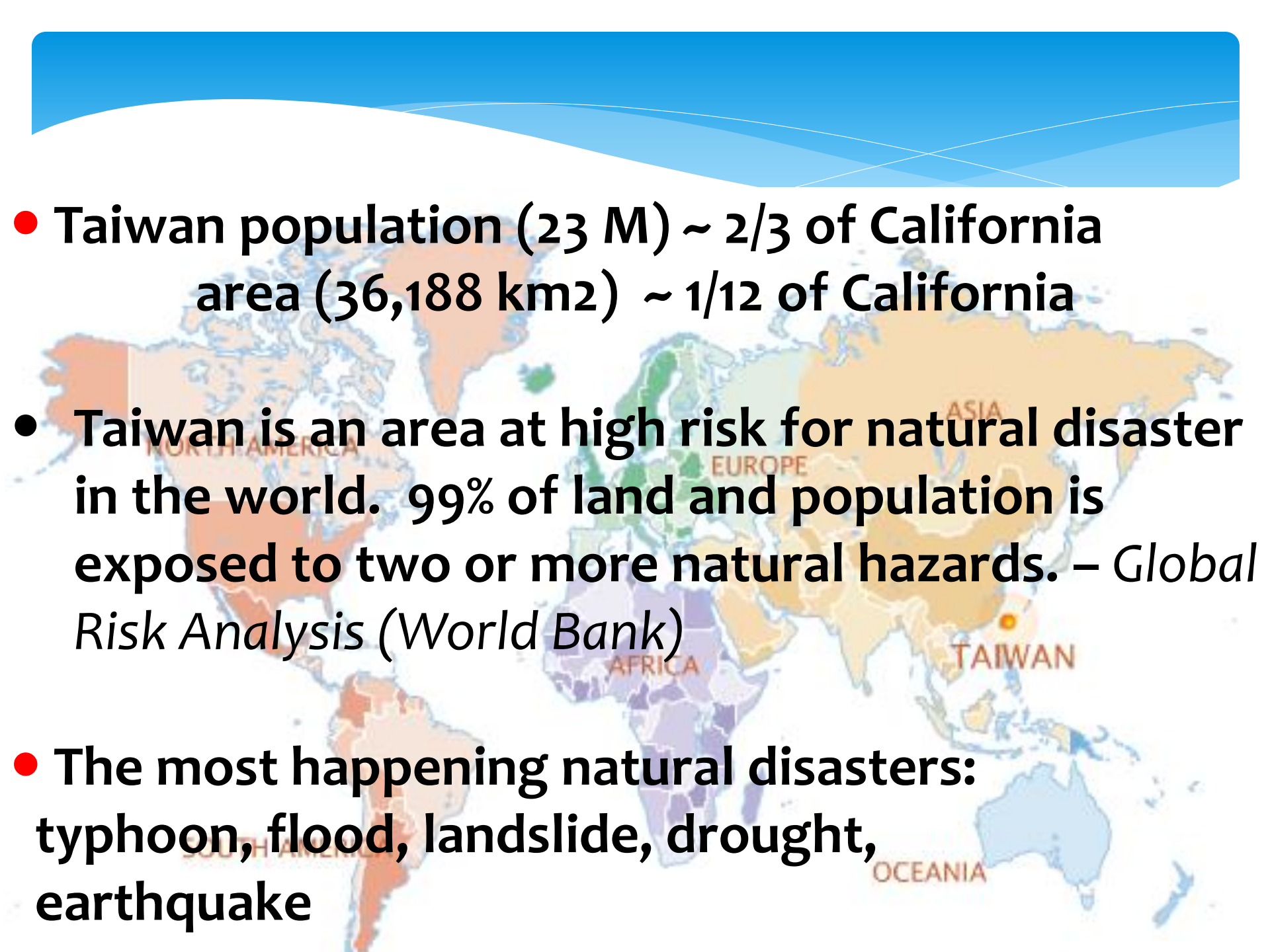
- **Taiwan population (23 M) ~ 2/3 of California**
  area (36,188 km2) ~ 1/12 of California

- **Taiwan is an area at high risk for natural disaster in the world. 99% of land and population is exposed to two or more natural hazards. –** *Global Risk Analysis (World Bank)*

- **The most happening natural disasters: typhoon, flood, landslide, drought, earthquake**



Seasonal Climate Forecast – development extended from NWP

1983 Beginning of the NWP era at CWB

1988 First generation GFS Grid-point&L9 operational <Gird-point 2.5 x 2.5>

1994 Second generation GFS T79L18 operational <Spectral T79 (~1.5°)>

1998 Second generation GFS T119L18 operational <T119 (~1°)>

2002 Second generation GFS T119L30 operational

Beginning of the development of multi-model multi-member ensemble Climate Forecast System at CWB <2-tier, T42L18, AGCM: ECHAM5&CWBGFS, SST: CWB-OPGSST&NCEP-CFSv1)>

2003 Second generation GFS T179L30 operational <T179 (<1°)>

2007 Second generation GFS T239L30 operational <T249 (~0.5°)>

2009 **First generation CWB 2-tier CFSv1 implemented** <40members, fcst:0-7mo>

2010 Third generation GFS T239L30 operational <GSI 3-D Var., NCEP-like model physics >

Developing the Second generation 2-tier CFS and First generation 1-tier CFS <2-tier, T119L40, AGCM: ECHAM5&CWBGFS&NCEP-CFSv2, SST: CWB-OPGSST&NCEP-CFSv2)>

2011 GFS T319L40 operational < ~42km, sigma, model top=1mb >

2015 Second generation 2-tier CFS operational, CWB 1-tier CFSv1 quasi-operational

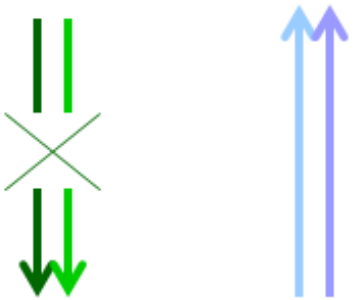
CWB *monthly and seasonal* Climate Forecast System

2-tiered approach

Atmospheric Model

TCWBGA T42L18

ECHAM5.2 T42L19



CWB Optimal Global SST forecast module (OPGSST)

-Statistical & Dynamical SST Forecast Models –

Dynamical Models: modified CZ intermediate air-sea coupled models (ICM2a, ICM2b)

Statistical Models: Persistence, NINOp6f7, Pslp3f1, TPOHC

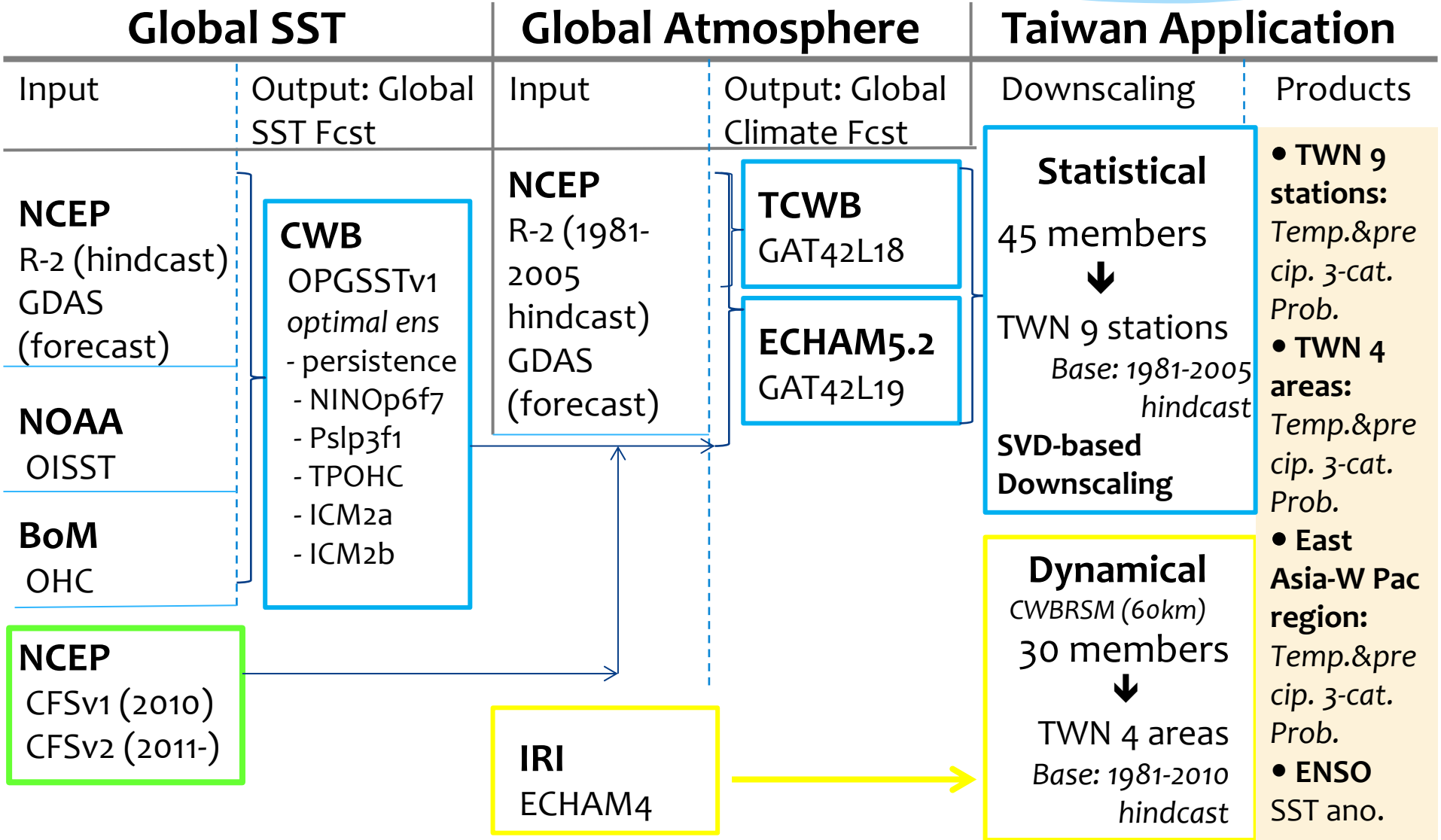
Prediction Integration Method: MLR MMSE scheme

NCEP CFS SST

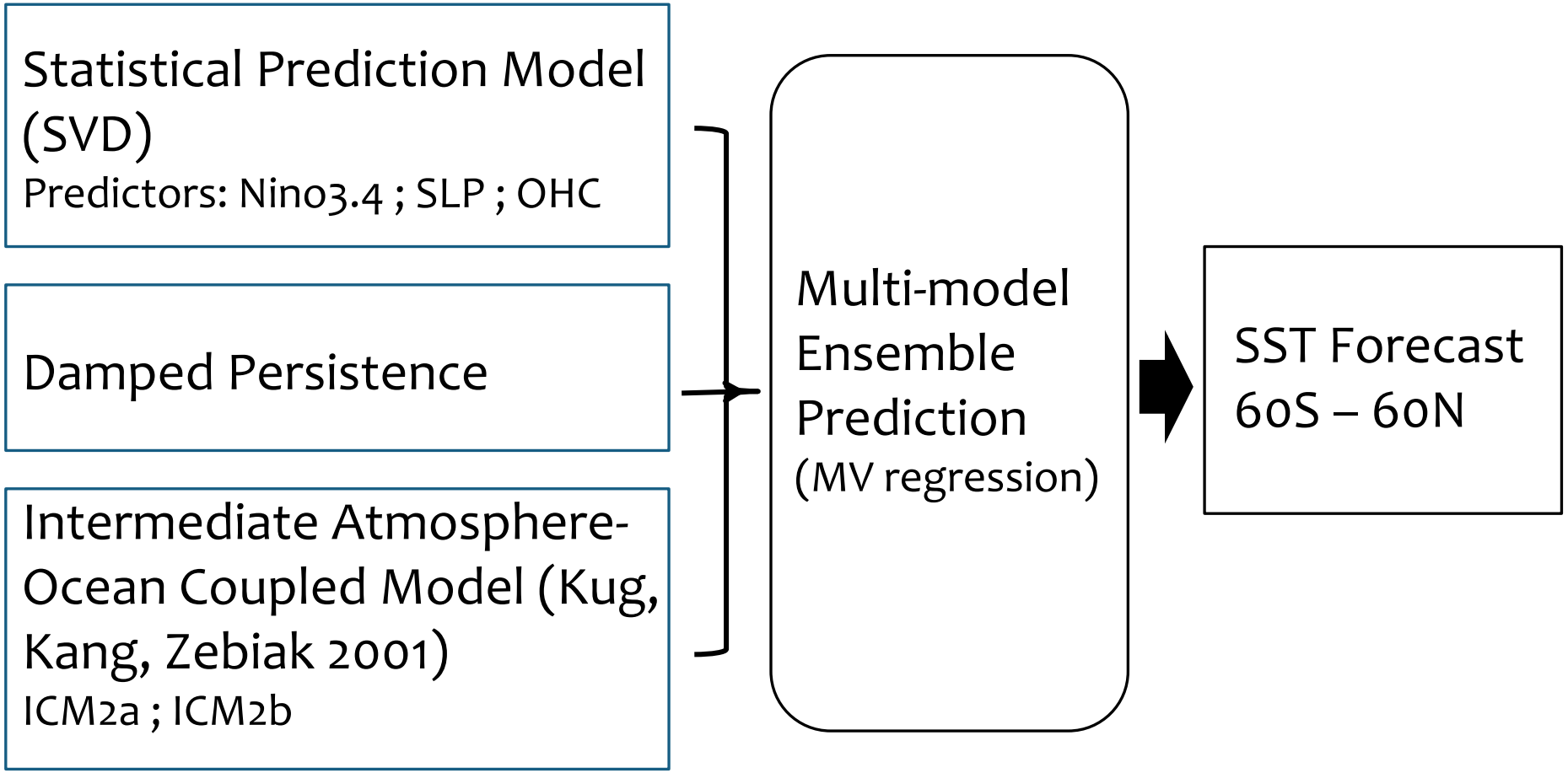
CWB *monthly and seasonal* Climate Forecast System v1

operational since 2010

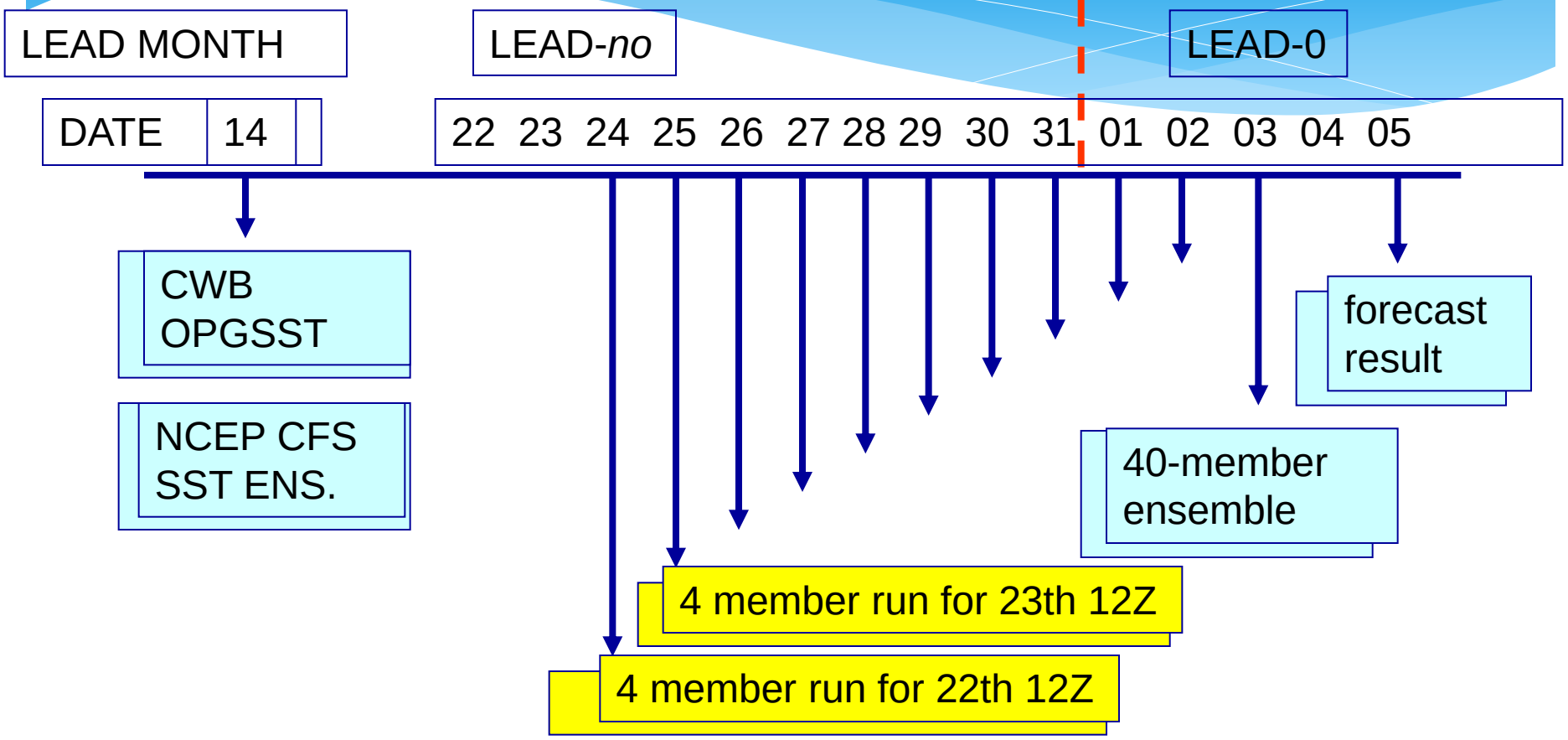
(no data assimilation, not for subseasonal prediction)



CWB OPtimal Global SST (OPGSST) Forecast

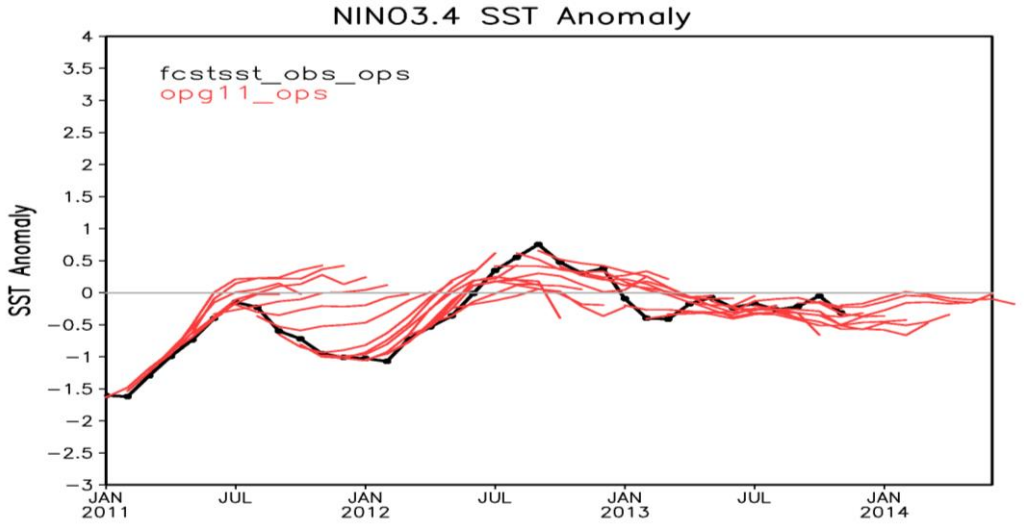


Operational Forecast Schedule

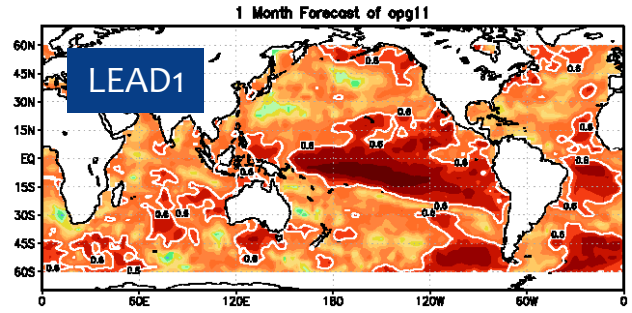


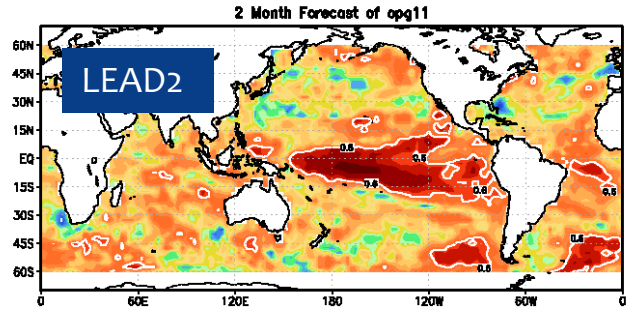
- IC: last 10 days of lead-no month from NCEP/GDAS.
- 4 members run in all IC+2 days (TCWBGA/OPGSST, TCWBGA/NCEPCFS, ECHAM/OPGSST, ECHAM/NCEPCFS) with 7 months forecasting.
- Each member need about 40 minutes for model running and another 30 minutes for post process.

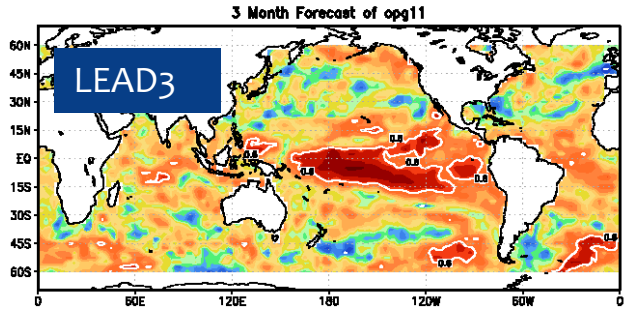
ENSO Prediction Skill

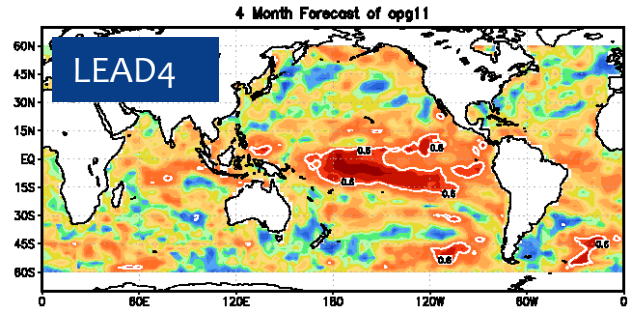


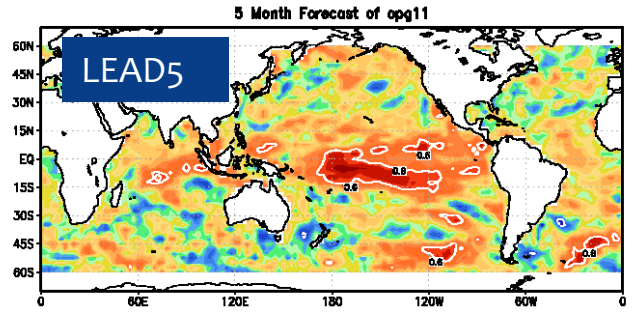
SST Temporal Anomaly Correlation Jan2011 ~ Nov2011

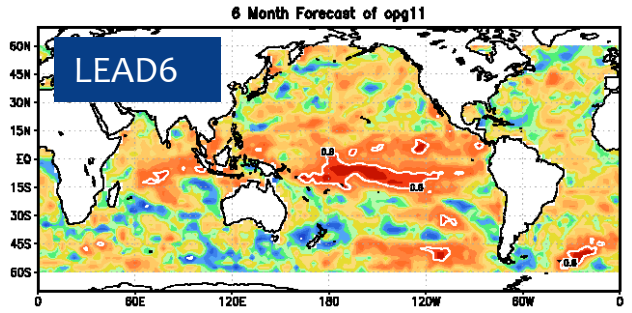










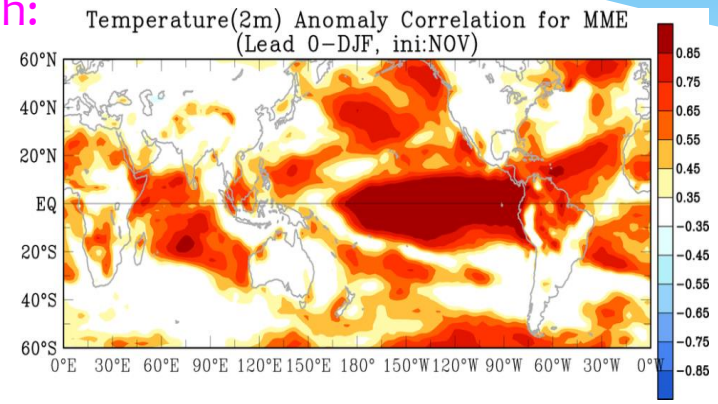


Temperature (T2m) Prediction Evaluation

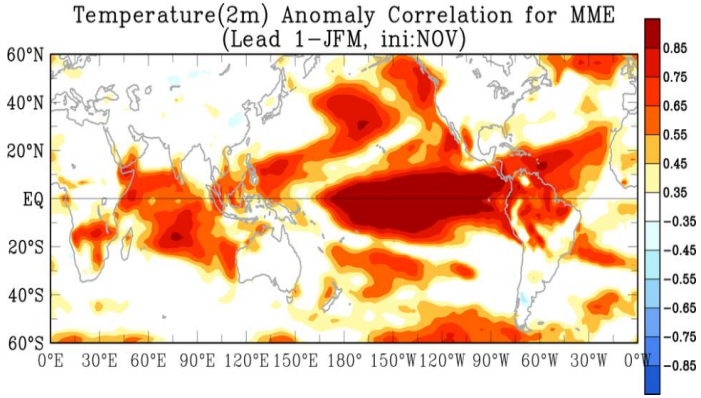
Ensemble Mean **Anomaly Correlation,** 1982-2011

Initial Month: **November**

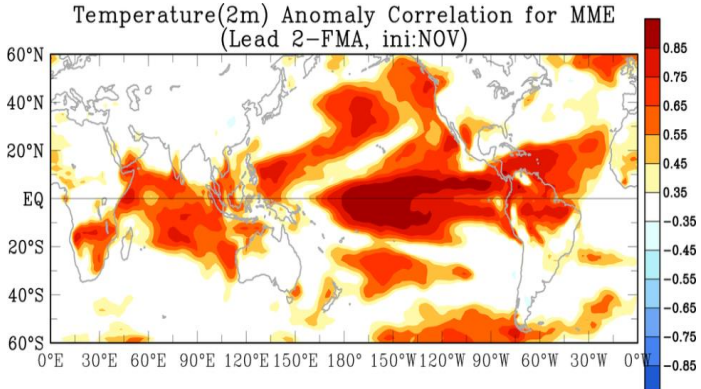
Lead 0-month fcst: DJF



Lead 1-month fcst: JFM

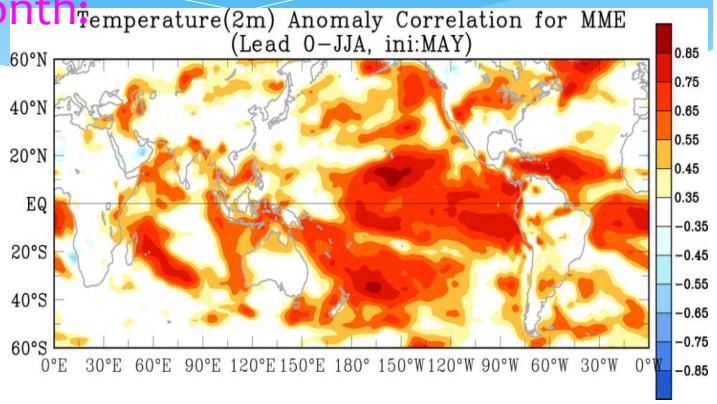


Lead 2-month fcst: FMA

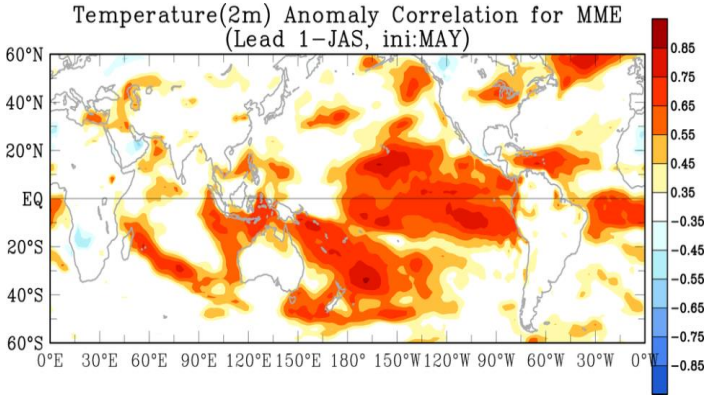


Initial Month: **May**

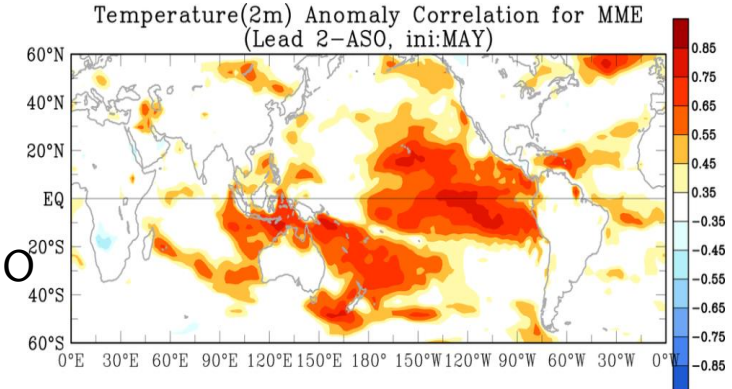
fcst: JJA



fcst: JAS



fcst: ASO

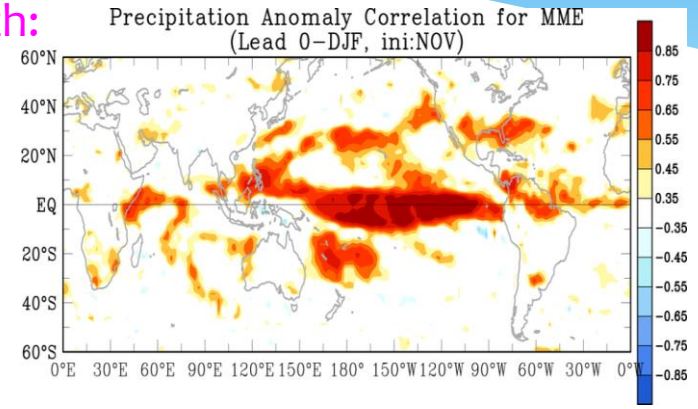


Precipitation Prediction Evaluation

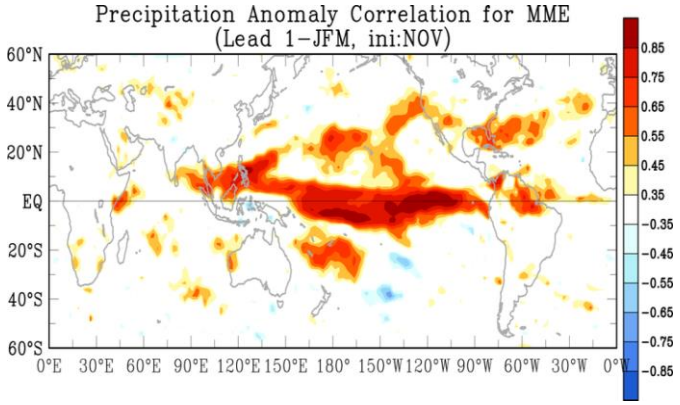
Ensemble Mean **Anomaly Correlation,** 1982-2011

Initial Month: **November**

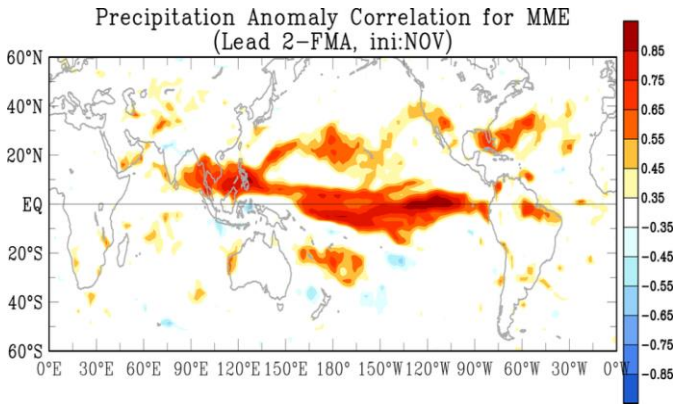
Lead 0-month fcst: DJF



Lead 1-month fcst: JFM

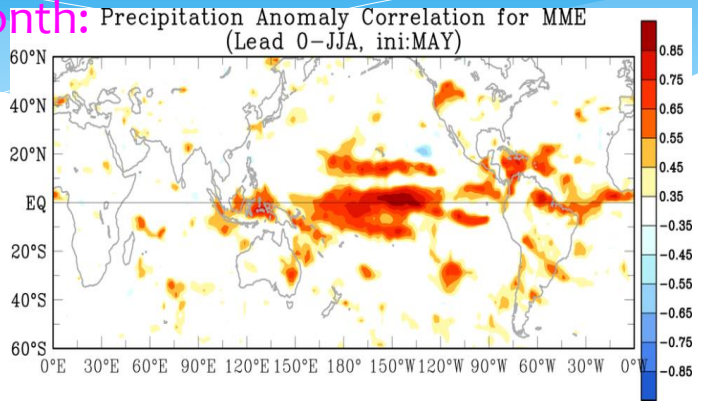


Lead 2-month fcst: FMA



Initial Month: **May**

fcst: JJA



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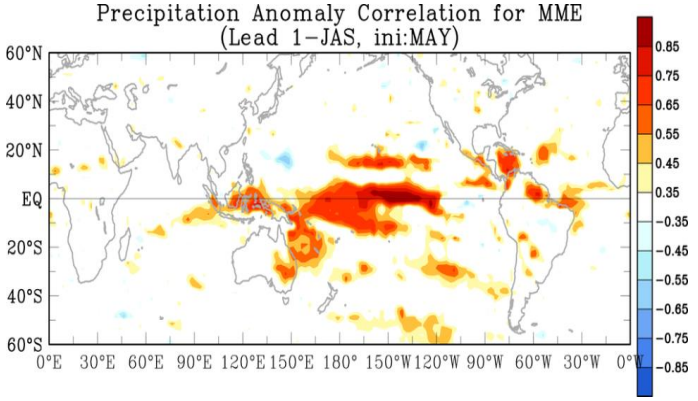

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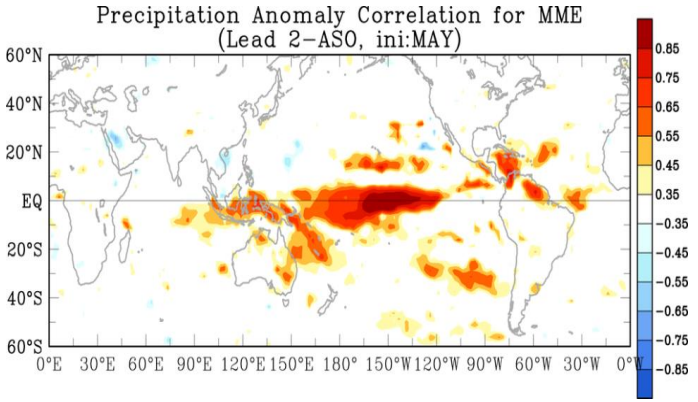
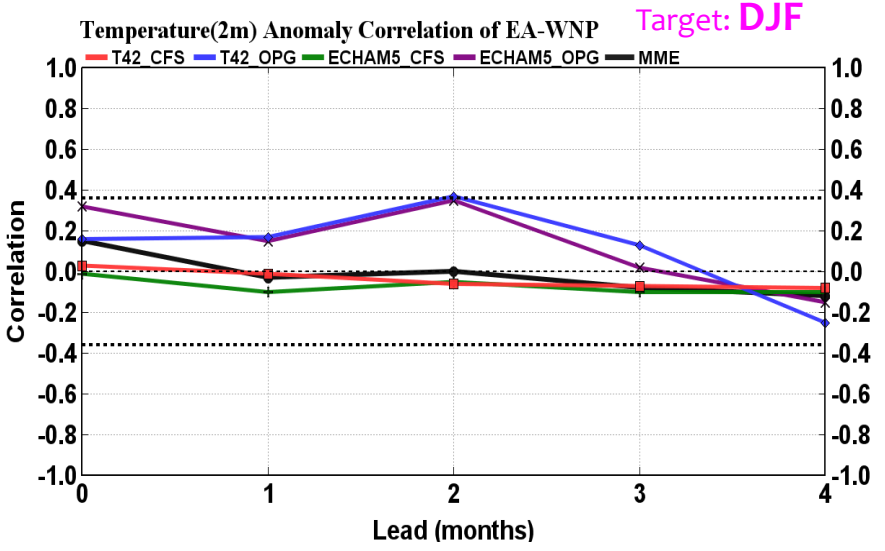


Regional Temperature (T2m) Prediction Skill

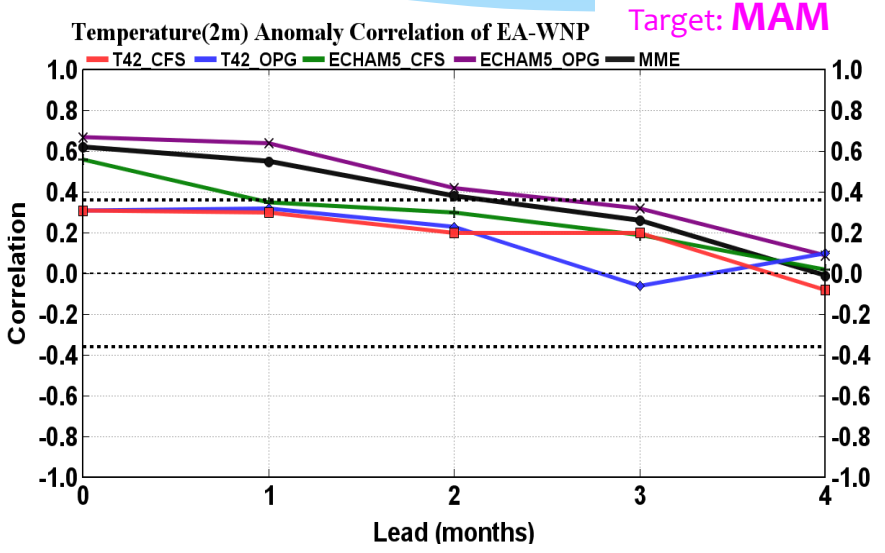
East Asia–west North Pacific (EAWNP) 5-45°N, 100-140°E

Ensemble Mean **Anomaly Correlation**, 1982-2011

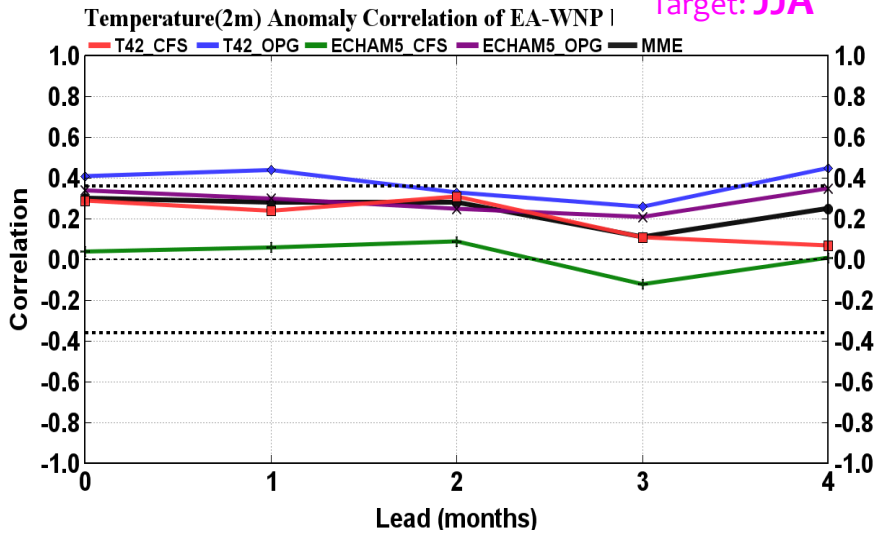
Target: **DJF**



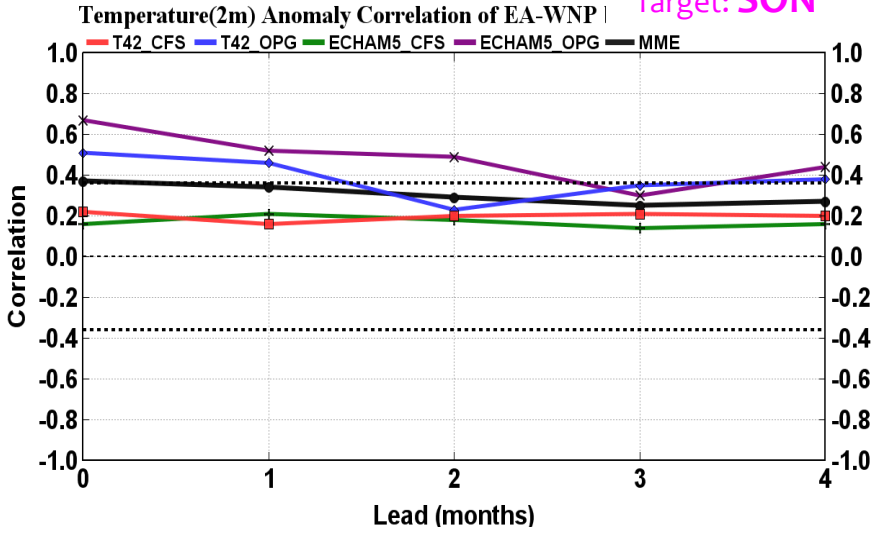
Target: **MAM**



Target: **JJA**



Target: **SON**

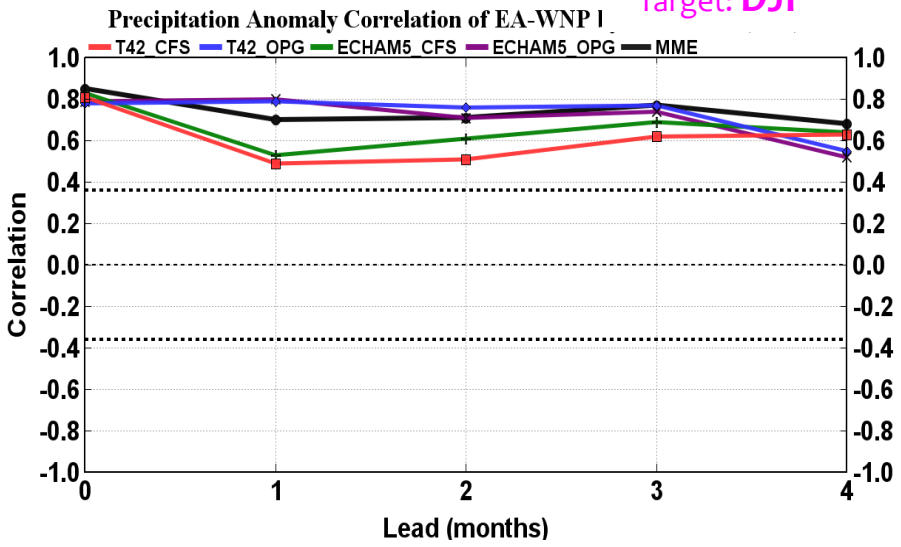


Regional Precipitation Prediction Skill

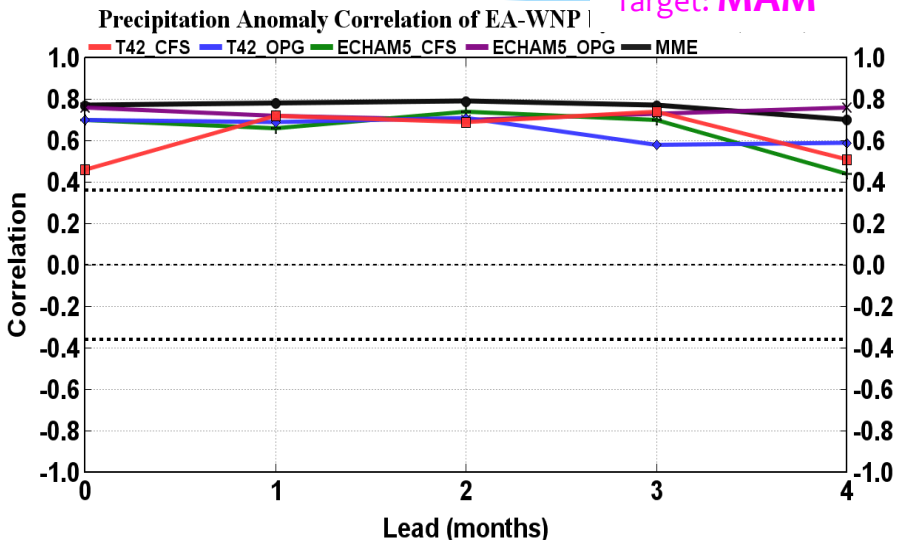
East Asia–west North Pacific (EAWNP) 5-45°N, 100-140°E

Ensemble Mean **Anomaly Correlation**, 1982-2011

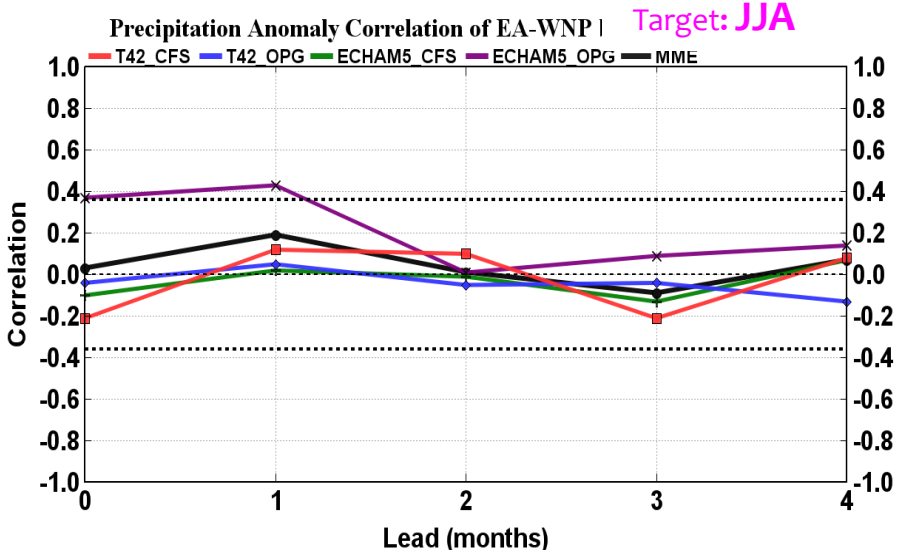
Target: **DJF**



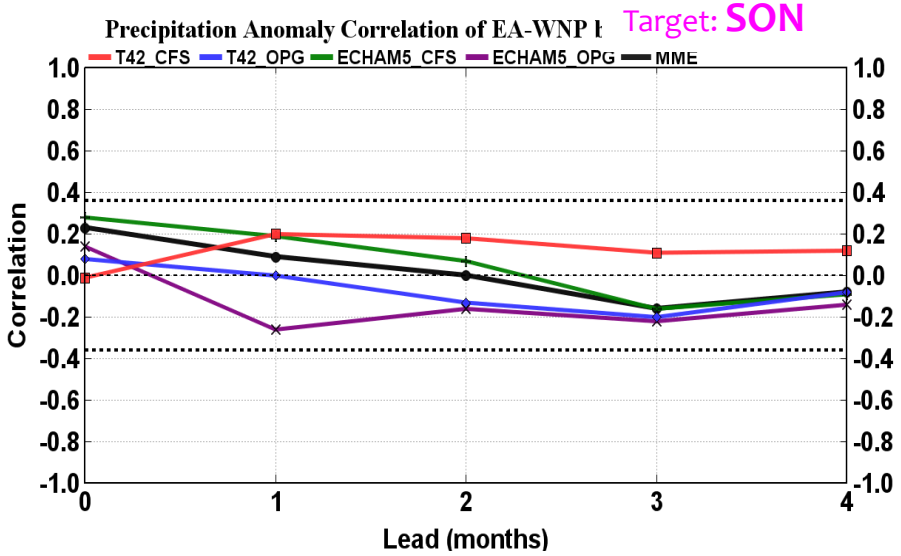
Target: **MAM**



Target: **JJA**



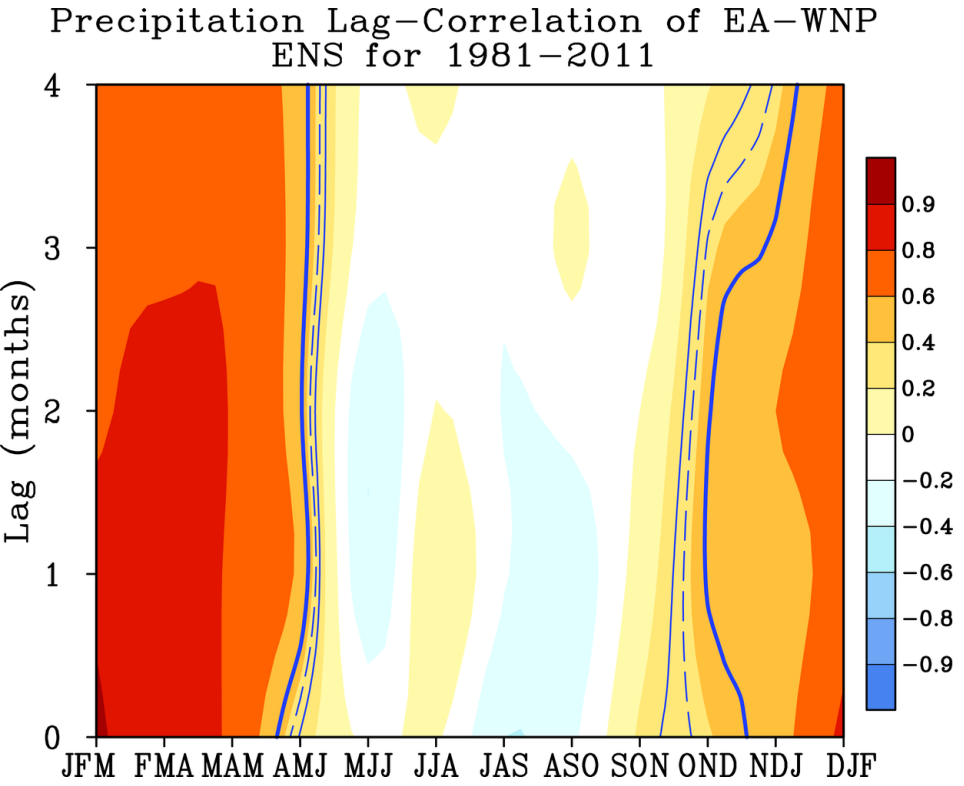
Target: **SON**

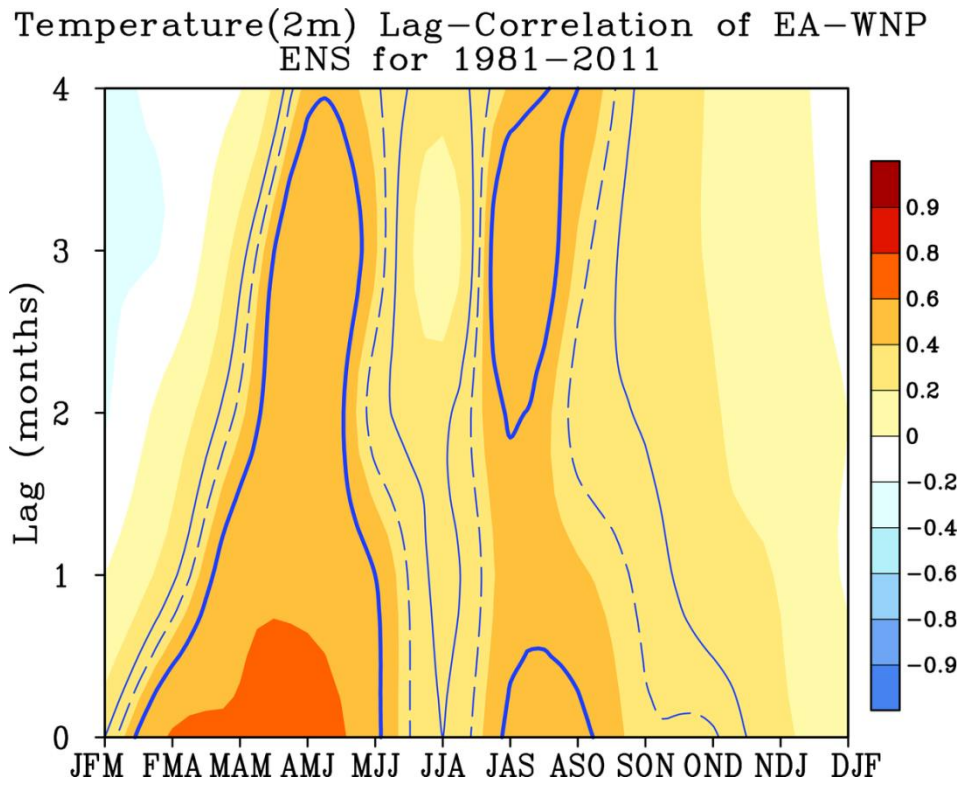


Regional Prediction Skill Evaluation

East Asia–west North Pacific (EAWNP) 5-45°N, 100-140°E

Ensemble Mean **Anomaly Correlation**, 1982-2011





Example Operational Forecast Product

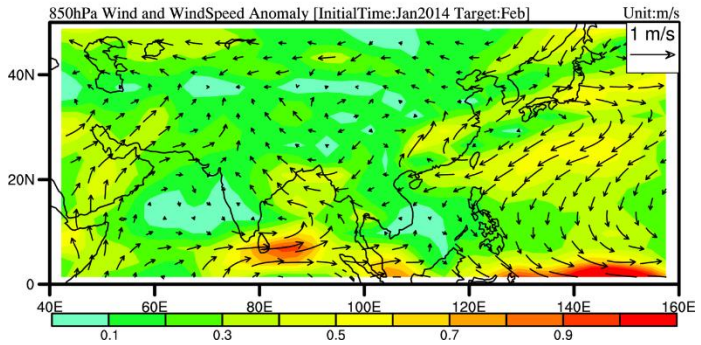
E Asian Winter to Summer Monsoon Transition

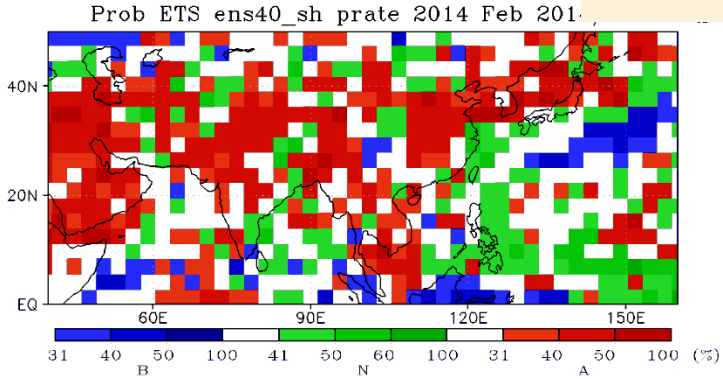
850hPa Wind Ano

Initial Data: **Dec 2013**

Rain Prob.

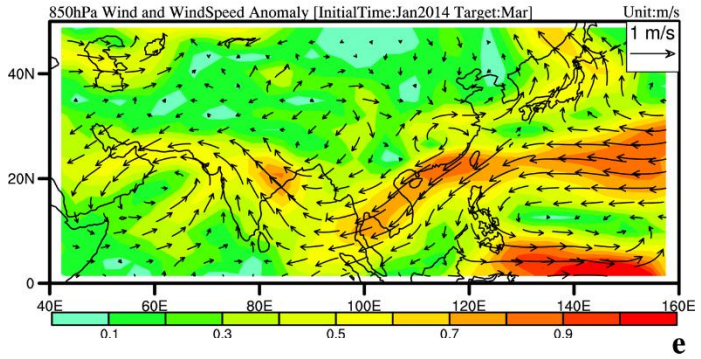
Lead 1-month

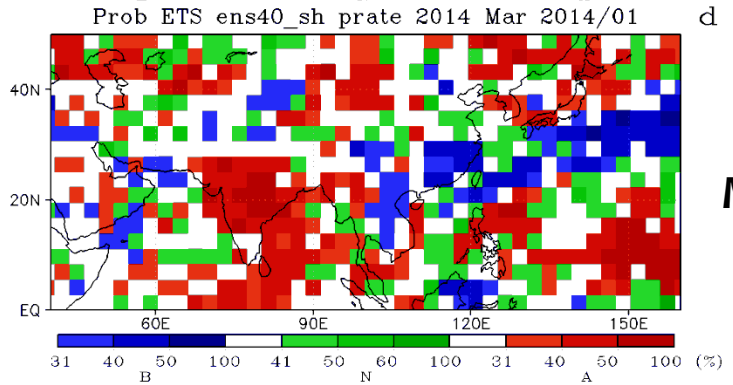




Feb 2014

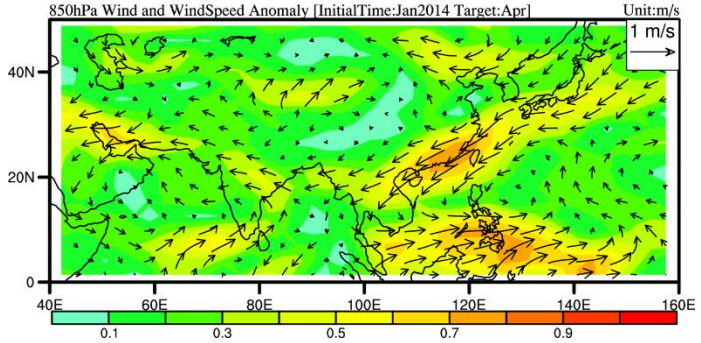
Lead 2-month

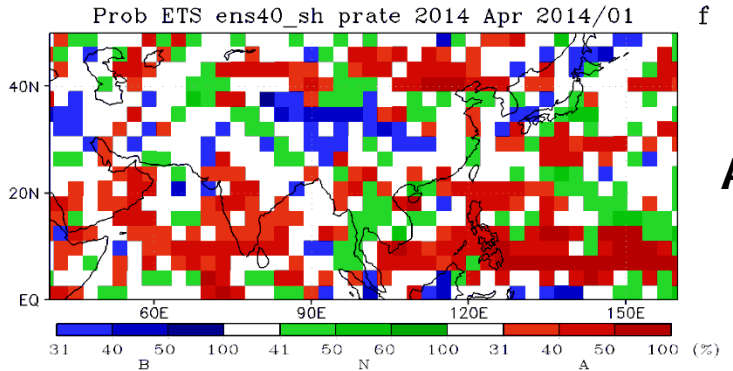




Mar 2014

Lead 3-month





Apr 2014

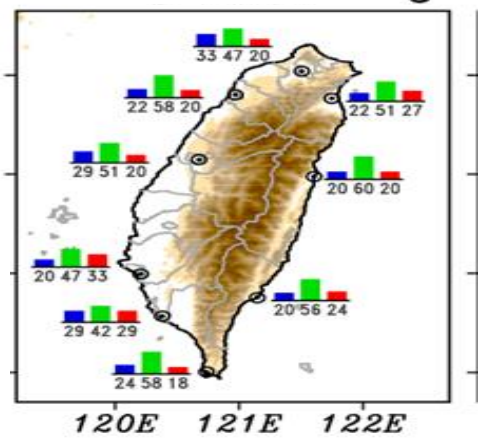
Example Operational Forecast Product

Taiwan Spring Climate Outlook from Statistical Downscaling

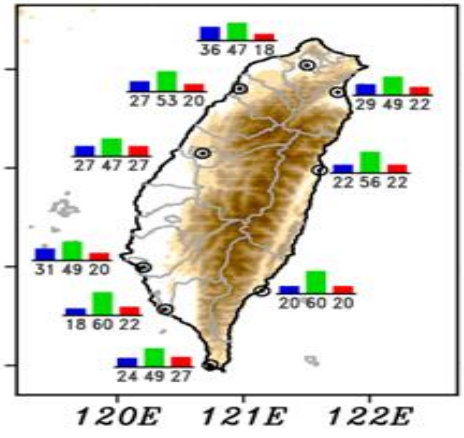
Temperature

Precipitation

Feb. 2014



Feb. 2014



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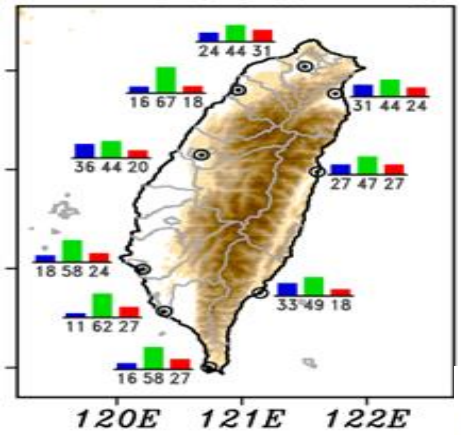

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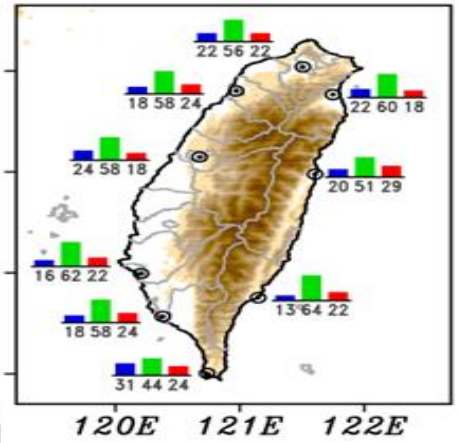
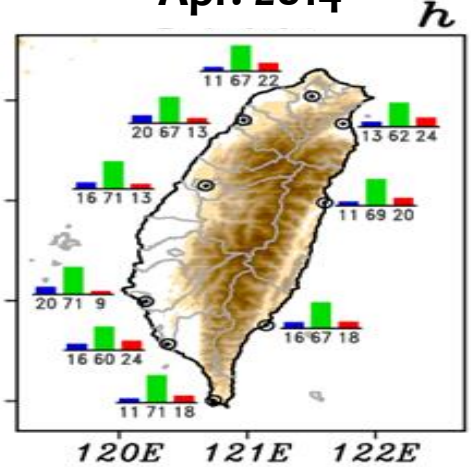
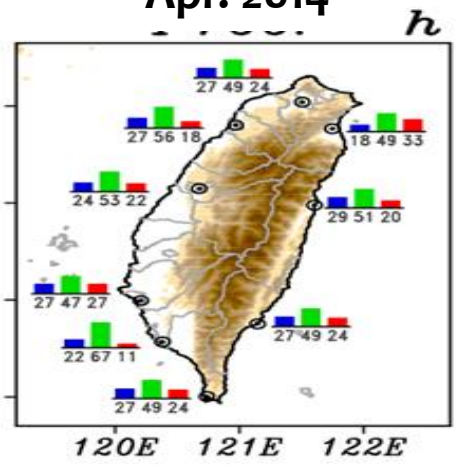


Blue-below, Green-normal, Red-above

Apr. 2014

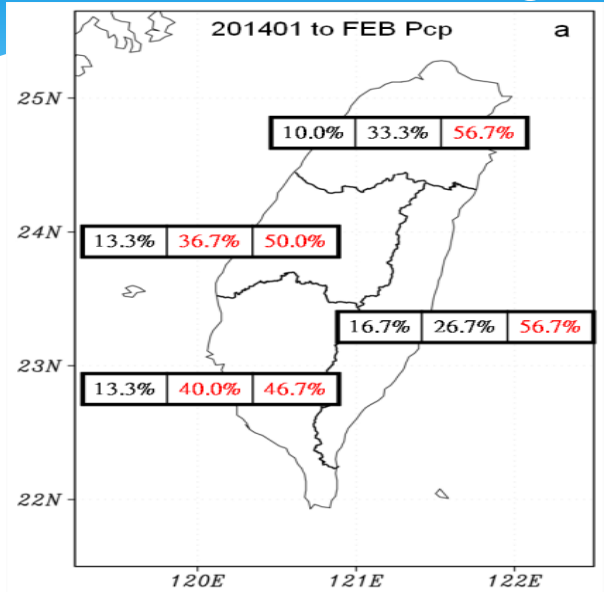


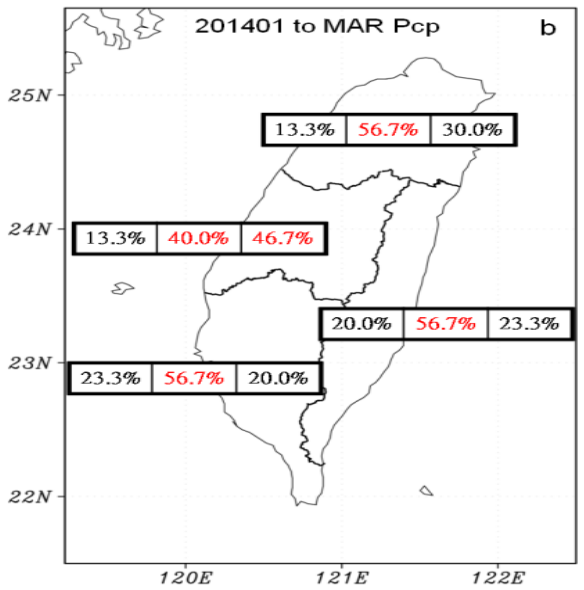
Apr. 2014

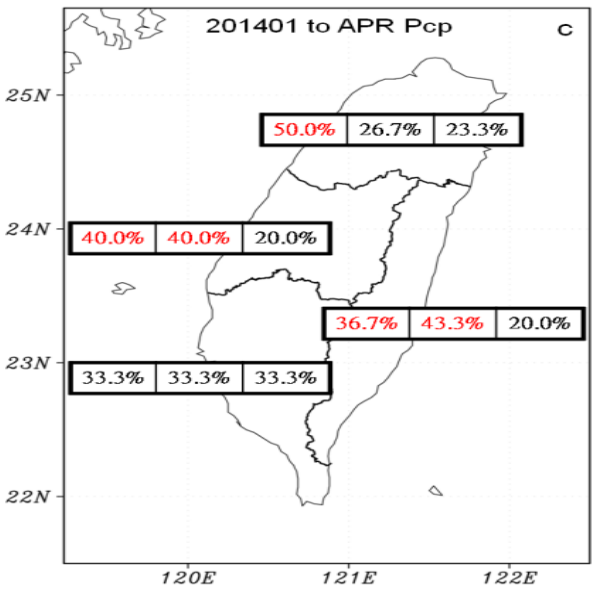


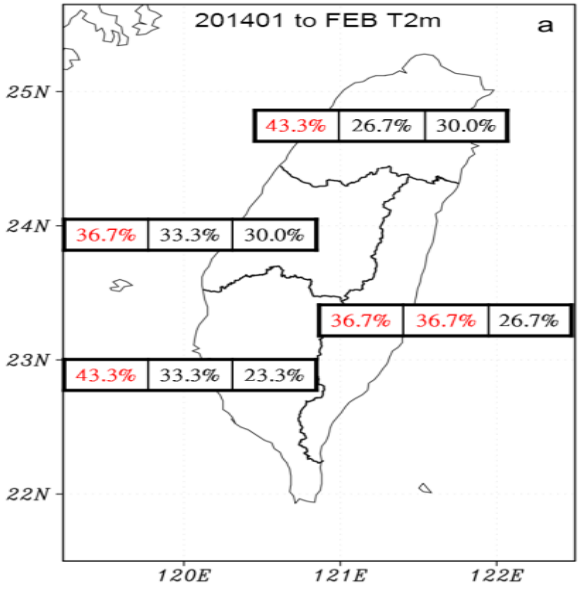
Example Operational Forecast Product

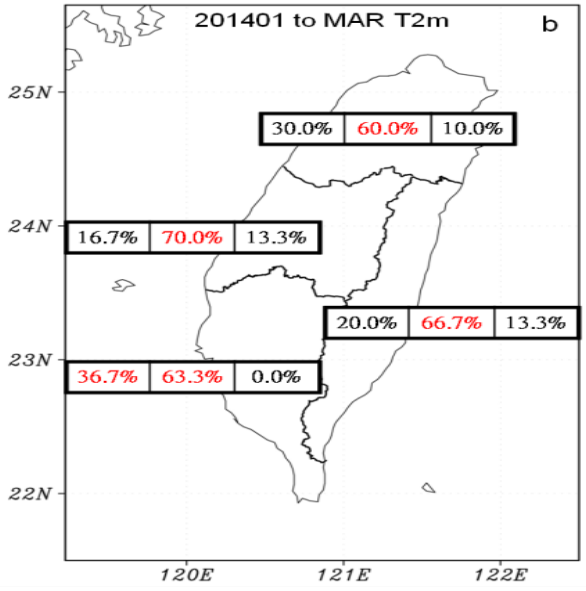
Taiwan Spring Climate Outlook from Dynamic Downscaling

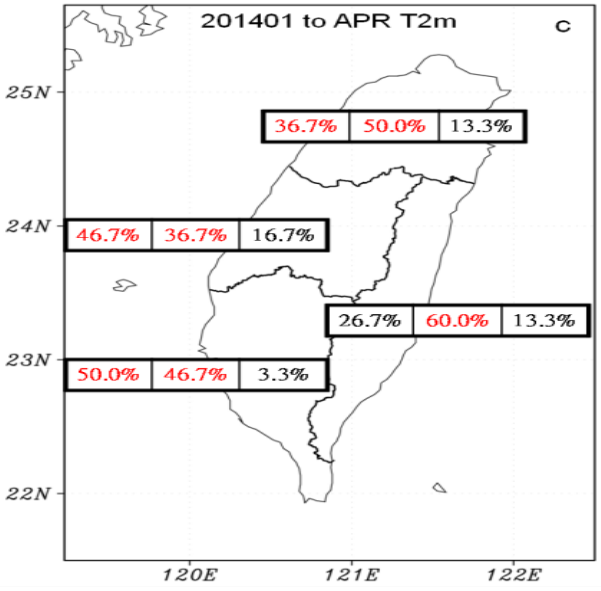












CWB Seasonal Climate Forecast System v2

to be operational 2016

*(no data assimilation, more flexibility for **subseasonal** prediction)*

- **Increase resolution - horizontal and vertical**
- **Improve model physics**
- **Change operational schedule to increase the forecast frequency**

Attribute	T119L40	T42L18
Radiation	Unified two-stream calculation with K-correlated method (Fu and Liou 1992, 1993; Fu et al. 1997)	Harshvardhan et al. (1987)
Cumulus Convection Parameterization	Simplified Arakawa-Schubert (Pan and Wu 1995)	Relax Arakawa-Schubert scheme (Moothi and Suarez 1992)
Grid-scale Precipitation	Predict could water scheme (Zhao and Frederick 1997)	Diagnostic method (RH value)
Shallow Cumulus Convection	Li and Young (1993)	Li (1994)
Boundary-layer Parameterization	First-order nonlocal scheme (Troen and Mahrt 1986)	TKE-ε scheme (Detering and Etling 1985)
Land Model	NOAH (Ek et. al. 2003)	Bucket method (Manebe 1969)
Surface-layer Parameterization	Similarity theory (Businger 1971)	Similarity theory (Businger 1971)
Gravity wave drag	Palmer et al. (1986)	Palmer et al. (1986)

CWB OPtimal Global SST Forecast v2 (OPGSST2.0)

Statistical Prediction Model (SVD)
Predictors: Nino3.4 ; ~~SLP~~ ; BoM/OHC

Damped Persistence
NOAA OISSTv2
~~*8 months*~~ → *4 months*

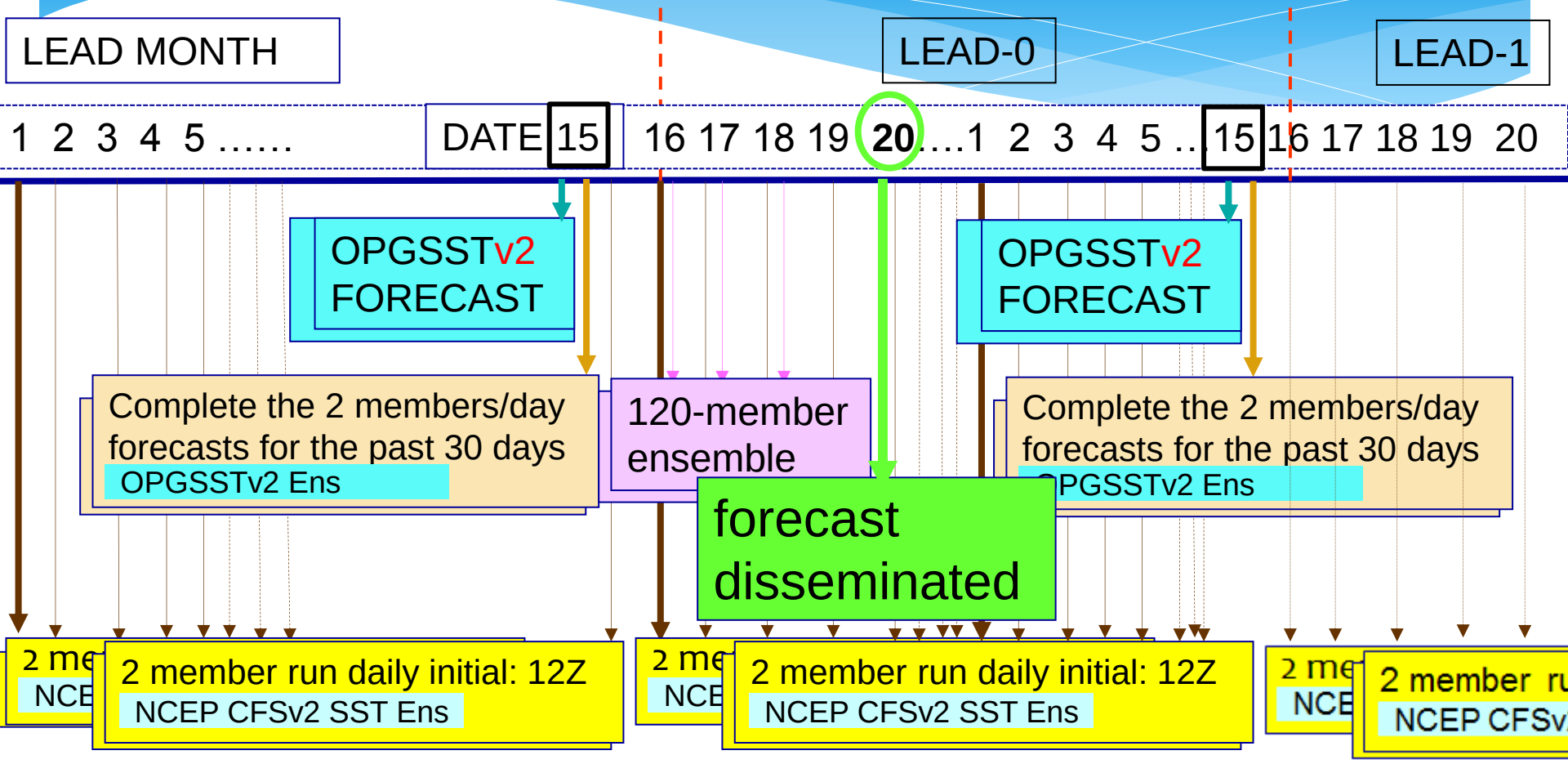
Intermediate Atmosphere-Ocean Coupled Model (Kug, Kang, Zebiak 2001)
ICM2a ; ICM2b
Input data (925hPa u,v) :
~~NCEP R2~~ → CFSR

Spatial Temporal Projection Model (STPM)
Predictors: Indian Ocean 0、20、50、75、100、150m Subsurface Sea Water Temperature (BoM)
Predictand: 20°S-20°N Pacific SST

Multi-model Ensemble Prediction
~~MV regression~~ → *weighted average*

SST Forecast
60°S – 60°N

New Operational Forecast Schedule



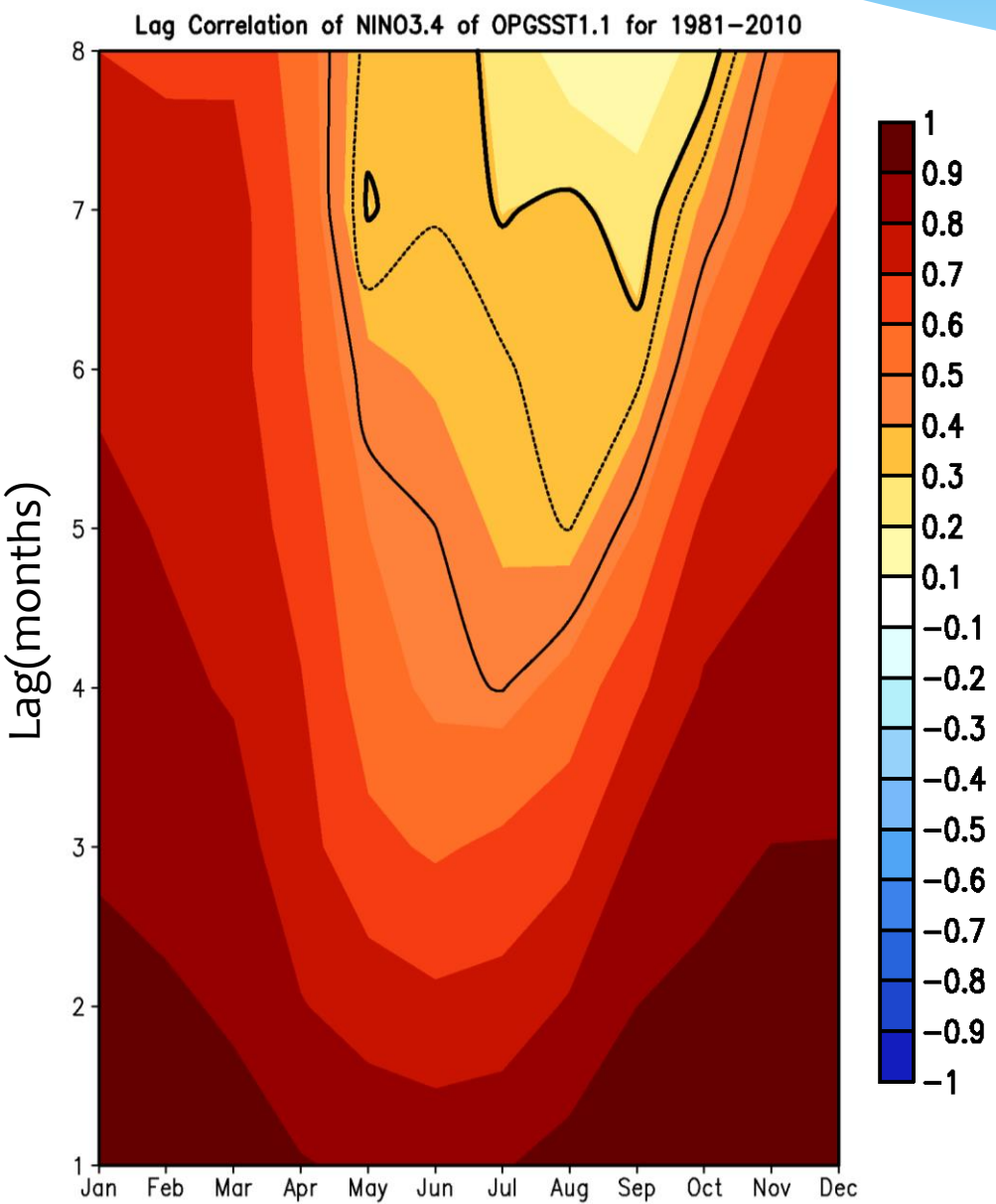
- IC: GAM- everyday12Z from NCEP/CDAS; OPGSST– 15th of each month from NOAA & BoM
- 2 members run in all IC+2 days (TCWBGA/OPGSST, TCWBGA/CFSSST, ECHAM/OPGSST, ECHAM/CFSSST) with 7 months forecasting.
- Each member need about 40 minutes for model running and another 30 minutes for post process.

The complete hindcast (1983-2012) performed in the same format as the operational forecast runs will be ready before Nov 2014.

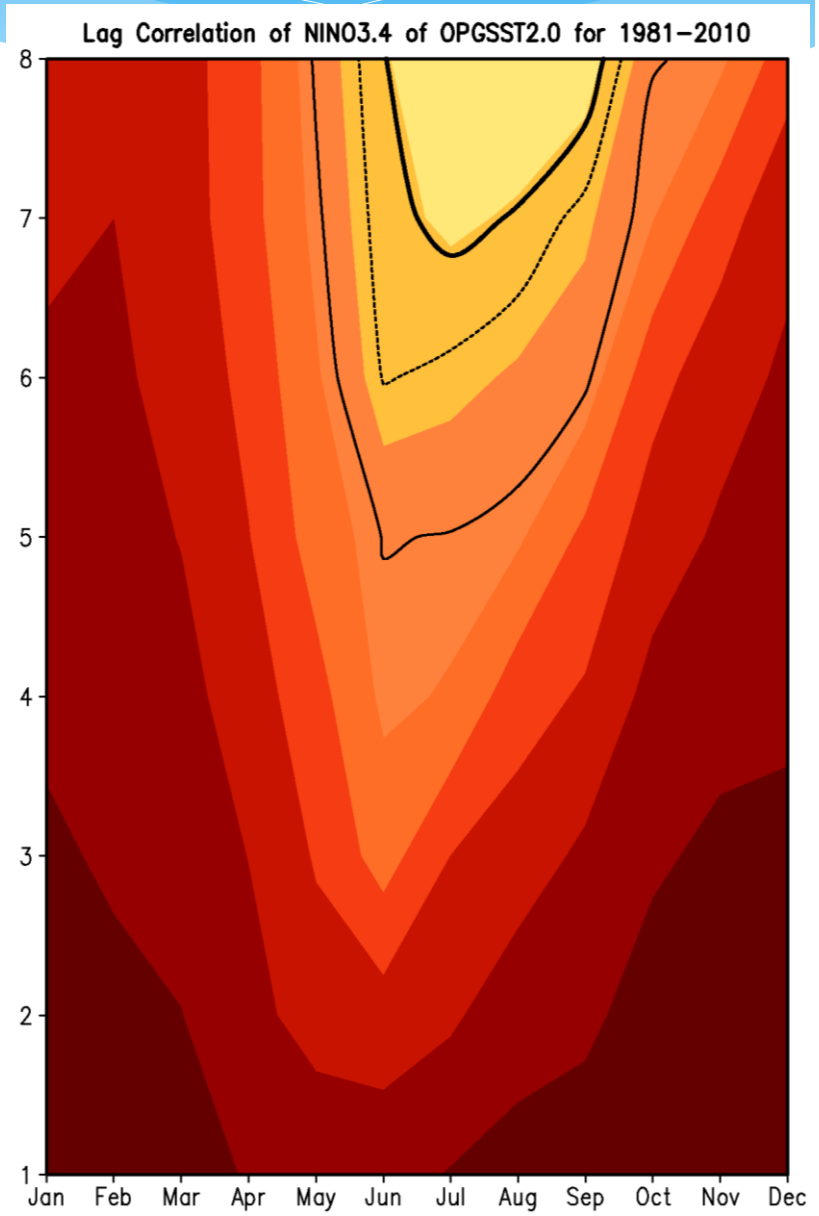
OPGSSTv2	Dec 2013
TCWBGM(T119L40)/CFS-SST	May 2014
TCWBGM(T119L40)/OPGSSTv2	Jun 2014
ECHAM5.2(T42L19)/CFS-SST	Oct 2014
ECHAM5.2(T42L19)/OPGSSTv2	Nov 2014

ENSO Prediction Skill

OPGSST1.1



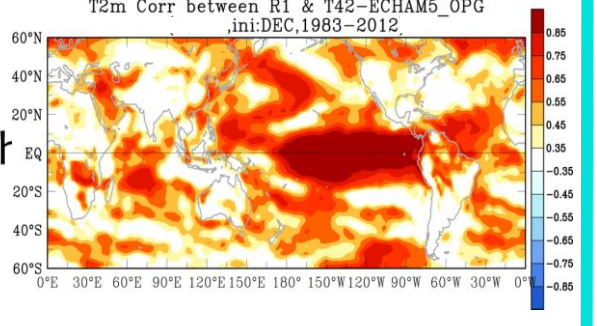
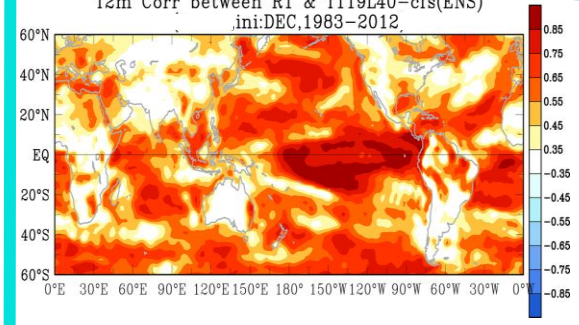
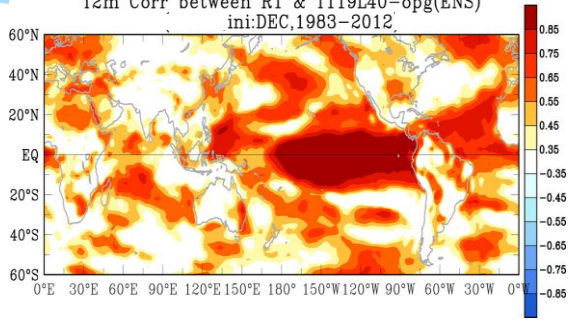
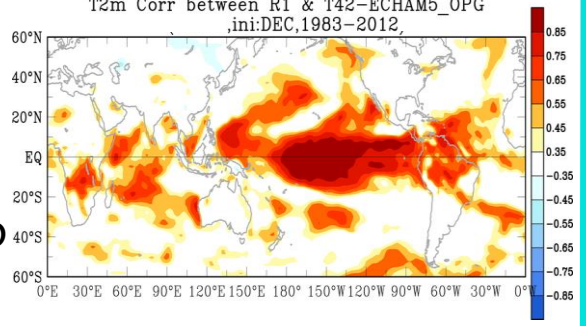
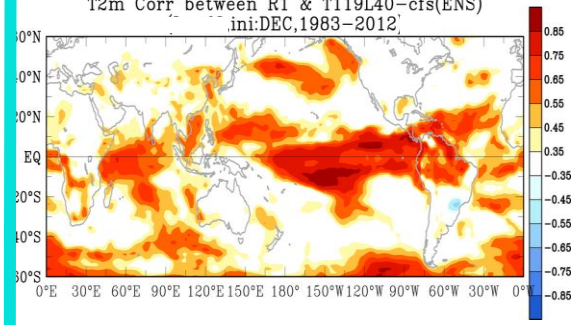
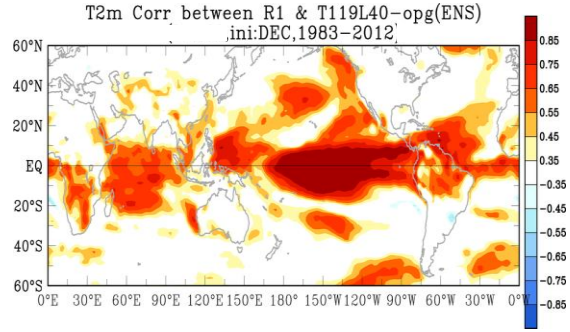
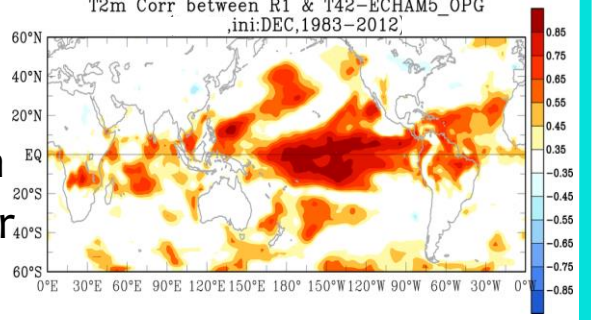
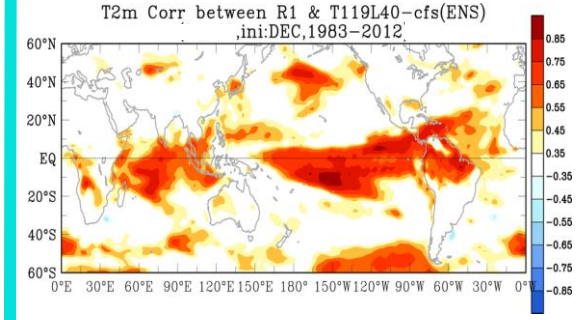
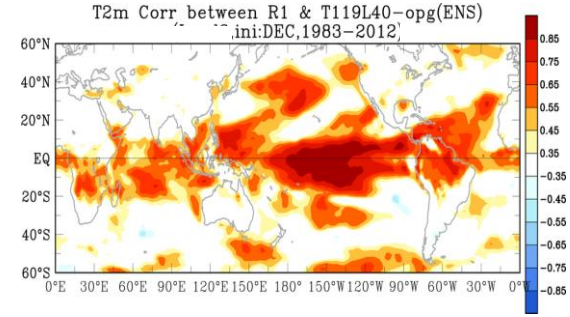
OPGSST2.0



Temperature (T2m) Prediction Evaluation

Ensemble Mean **Anomaly Correlation**, 1983-2012

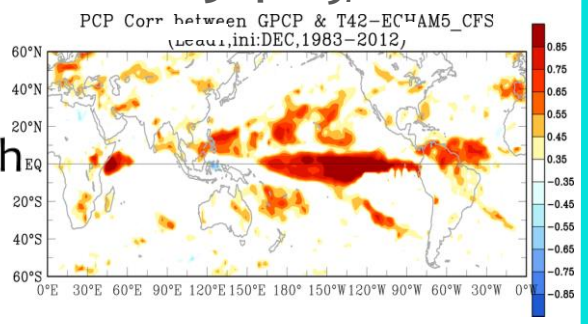
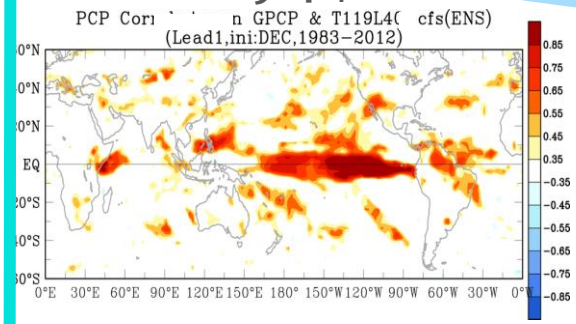
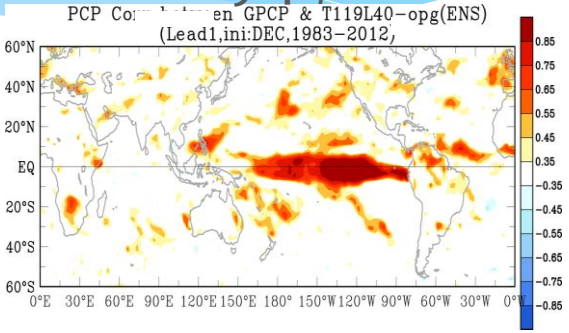
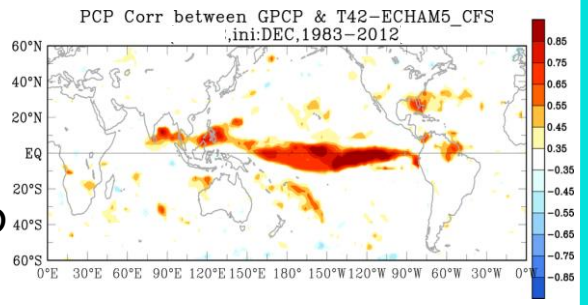
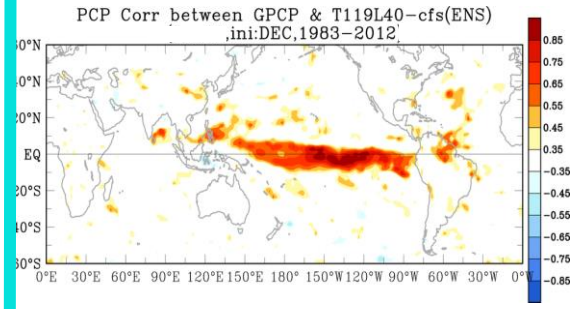
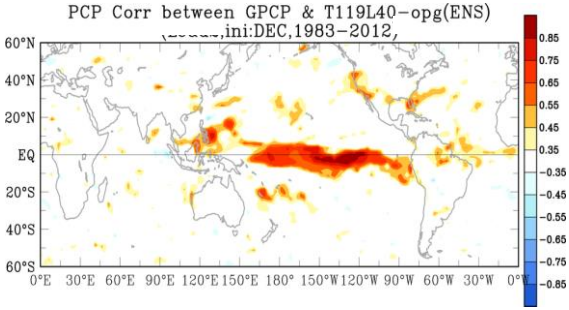
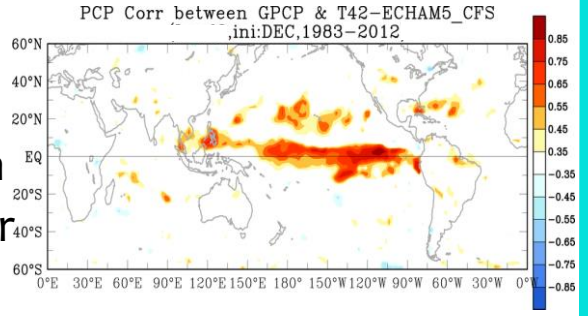
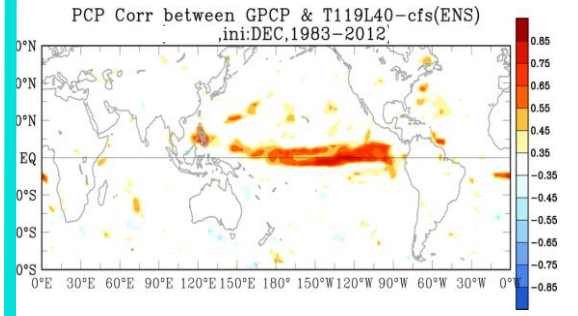
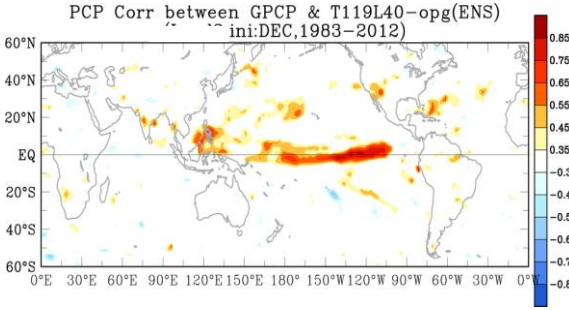
Initial Month: **December**

	ECHAM5T42L19/OPGSSTv1	TCWBGAT119L40/NCEPCFSv2	TCWBGAT119L40/OPGSSTv2
Lead 0-month fcst: Jan			
Lead 1-month fcst: Feb			
Lead 2-month fcst: Mar			

Precipitation Prediction Evaluation

Ensemble Mean **Anomaly Correlation,** 1983-2012

Initial Month: **December**

	ECHAM5T42L19/OPGSSTv1	TCWBGAT119L40/NCEPCFSv2	TCWBGAT119L40/OPGSSTv2
Lead 0-month fcst: Jan			
Lead 1-month fcst: Feb			
Lead 2-month fcst: Mar			

Subseasaonal to Seasonal Operational Forecast Processes at CWB, Taiwan

Atmosphere **Analysis:**
- **v1**: NCEP/DOE R-2; NCEP GDAS;
- **v2**: NCEP CFSRR ; NCEP CDAS

Ocean **Analysis:**
NOAA/OISSTv2
BoM/OHC &
Subsurface Sea Temperature

Ocean **Forecast:**
NCEP/CFS

Dynamical
Model Tools:
TWS2SPS,
CZ, … Others

Statistical
Taiwan T,P Model Tools

Statistical
Asia-WPac Monsoon & TC Model Tools

Statistical
Global SST Model Tools

Verification Tools:
http://www.bom.gov.au/wmo/lrfvs/users.shtml ;
http://ds.data.jma.go.jp/tcc/tcc/products/guidancetst/

Verification Tools

Predictability Assessment

Forecast Decision Support Tools

Consolidation with CPC, IRI ENSO Update/Forecast

Consolidation with WMO, ECMWF, NCEP, UKMO, JMA, APCC, IRI Seasonal Forecast

Consolidation with NCEP (NMME, NAEFS), JMA Forecast

OFFICIAL *ENSO* OUTLOOK

OFFICIAL *TAIWAN Temp*, *Precip*, *Typhoon* OUTLOOK

Statistical Forecast Models / Decision Support Tools

Monthly and Seasonal Forecast – *official outlook issued* ***once a month***

- Winter Monsoon, Siberia-Mongolian High (Chang+Lu, *J. Climate* 2013)
- Summer Monsoon, Western Pacific Sub-high (Wang+Xiang+Lee, *PNAS* 2013)
- Spring Rain, Taiwan (Hsu+Li+Lin+Lu+Lee, *J. Meteor. Soc. Japan* 2012)
- Mei-Yu Rain, Taiwan (Yim+Wang+Xing+Lu, submitted to *Clim. Dyn.* 2014)
- Typhoon JJASO counts, Taiwan (Lu+Chu+Lin, *Wea. Forecasting* 2010)
- Typhoon JJA ACE , Taiwan (Lu+Lee+Wang, *Int. J. Climatol.* 2012)
- Typhoon SON ACE, Taiwan (in preparation Lu+Lee+Wang 2014)
- Typhoon JJASO tracks, NW Pacific (Chu+Zhao+Ho+Kim+Lu, J. Climate 2010)
- ENSO influence, EAWNP (Wang+Wu+Fu J. Climate 2000; Wang+Wu+Li 2003)

Weekly Forecast – *official outlook issued* ***once a week***

- MJO (NOAA/CPC – http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml
  BoM/ - http://cawcr.gov.au/staff/mwheeler/maproom/RMM/)
  http://monitor.cicsnc.org/
- BSISO (U Hawaii/IPRC – http://iprc.soest.hawaii.edu/users/jylee/bsiso/definition.htm)
- Typhoon activity (CWB - http://tafislx2.cwb.gov.tw/NcepGefs/)

SUMMARY

- CWB has successfully developed a monthly and seasonal climate operational forecast system that can generate reasonably good local and global forecast information. The version 2 system will replace the version 1 in 2016. The new system runs 2 members of 8-month forecast everyday which makes a rich forecast data set for study.

- CWB's S2S prediction system in some sense can be viewed as an extension of NCEP/CFS because it relies on the historical and real-time analysis data generated by NCEP/CFS. The situation will remain the same in the next phase (2016-2020) of the development.

- CWB is aware of the importance of building close partnership with other operational centers in order to improve the forecast system and effectively deliver scientifically sound forecast information.

- The focus of CWB's next phase development of the S2S prediction is on developing high resolution (20km) global atmospheric model with improved physics good for the air-sea coupled forecast.