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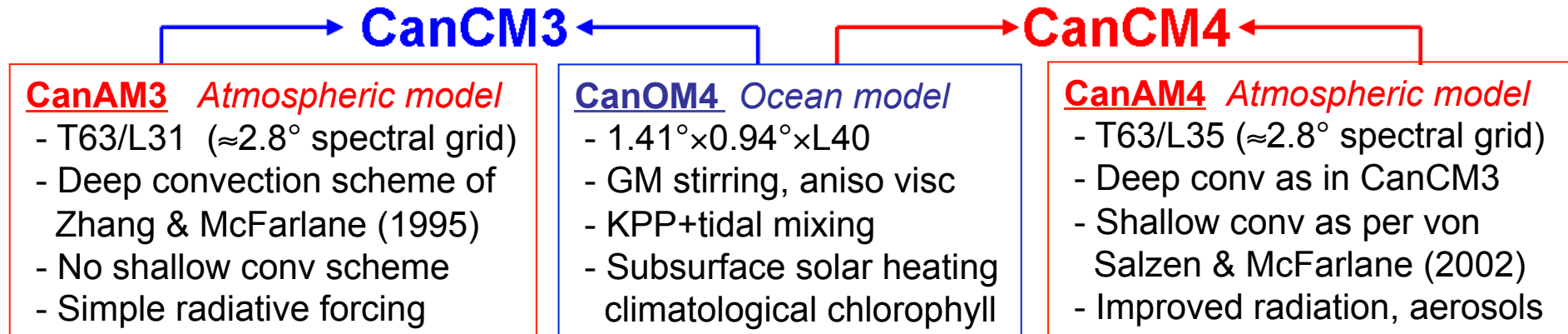
The Canadian Seasonal to Interannual Prediction System (CanSIPS)

**Bill Merryfield, Woo-Sung Lee, Slava Kharin, George Boer,
John Scinocca, Greg Flato**
Canadian Centre for Climate Modelling and Analysis (CCCma)

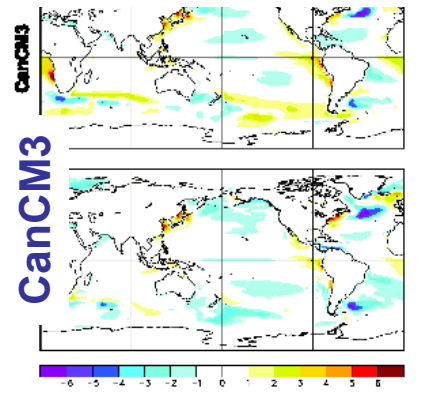
**Bertrand Denis, Juan-Sebastian Fontecilla, Jacques Hodgson,
Benoit Archambault**
Canadian Meteorological Centre (CMC)

WGSIP 25 Sep 2012

CanSIPS Models



SST bias vs OISST 1982-2009



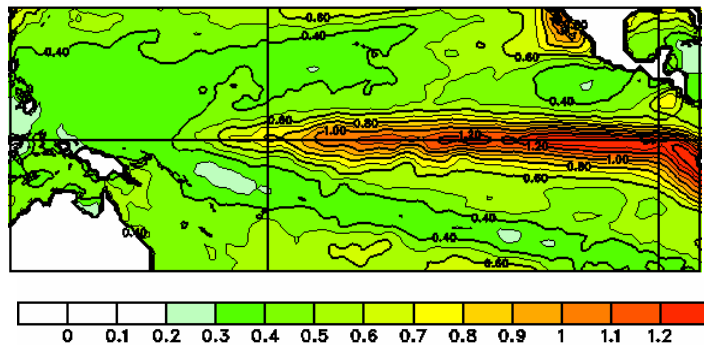
°C

°C

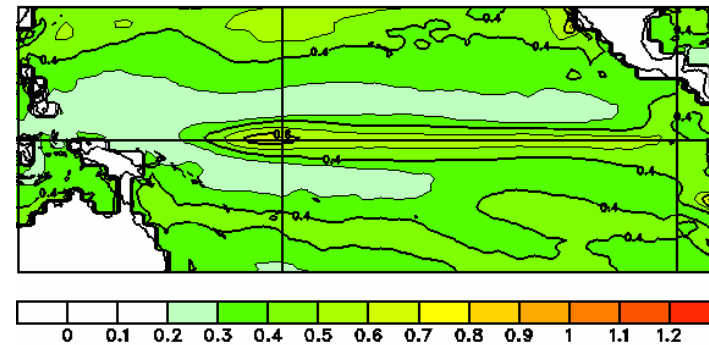
ENSO variability in models

Monthly SSTA standard deviation

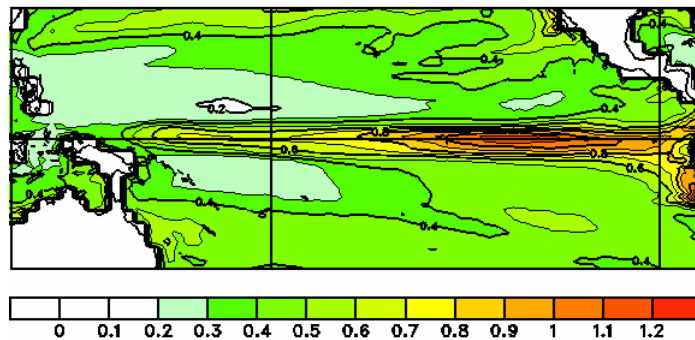
HadISST 1970-99



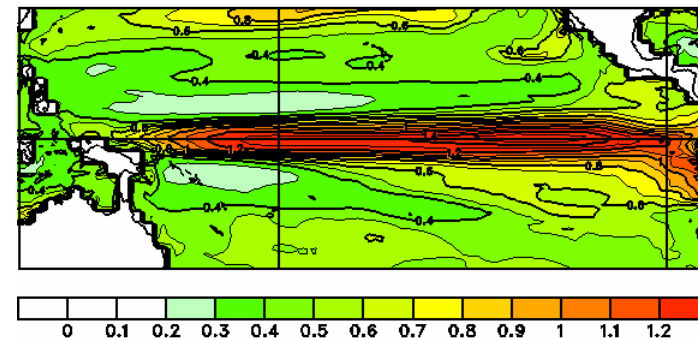
CGCM3.1 IPCC AR4, CHFP1



CanCM3 CanSIPS



CanCM4 CanSIPS



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CanSIPS timeline

GOAPP (Global Ocean-
Atmosphere Prediction and
Predictability) research
network funded

CHFP1 pilot project
(AR4 model, simple
initialization)

Initialization
development

CanCM3
development

CanCM3
hindcasts

CanCM4
development

CanCM4
hindcasts

Tech transfer
& implementation

2007

2008

2009

2010

2011

2012



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CanSIPS development & implementation



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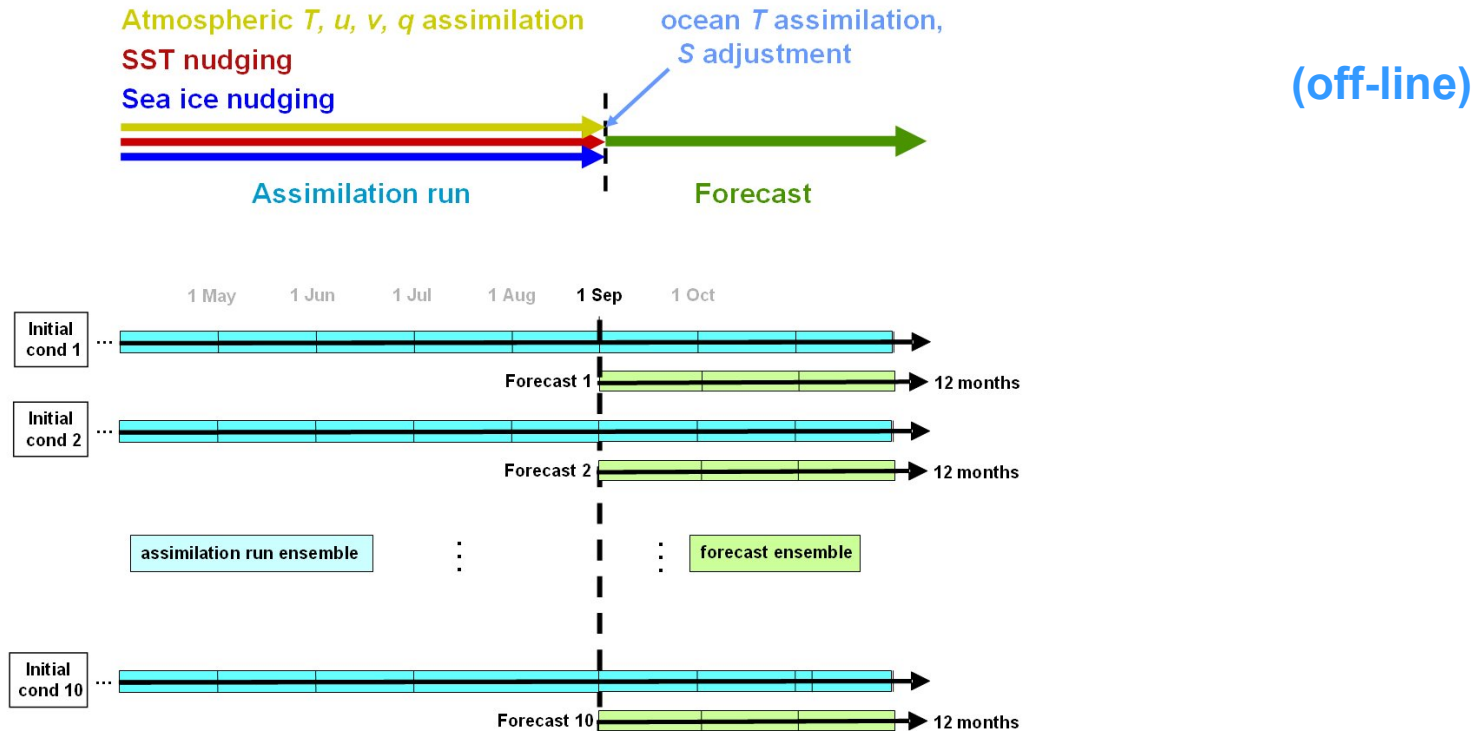
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WMO Global Producing Centres for Long-Range Forecasts

GPC	System/ Model	Type	Atmospheric Model Resolution	Hindcast Period	Implementation
→ Montreal, CMC	CanSIPS	Coupled	T63/L31, T63/L35	1981-2010	December 2011 ←
Melbourne, BoM	POAMA2	Coupled	T47/L17	1981-2010	Late 2011
ECMWF	System 4	Coupled	T255/L92	1981-2010	November 2011
Washington, NCEP	CFSv2	Coupled	T126/L64	1982-2010	March 2011
Tokyo, JMA	MRI-CGCM	Coupled	T95/L40	1979-2008	2010
Exeter, Met Office	GloSea4	Coupled	1.875x1.25/L38	1996-2009	2009
Toulouse, Météo-Fr	ARPEGE-Clim	Coupled	T63/L91	1997-2007	2008
Beijing, BCC	BCC-CGCM	Coupled	T63/L16	1983-2004	2005
→ Montreal, CMC	HFP2	2-tier	4 models	1969-2004	2007 ←
Seoul, KMA	GDAPS	2-tier	T106/L21	1979-2010	
Cachoeira Paulista, CPTEC	CPTEC AGCM	2-tier	T62/L28	1979-2001	2009
Moscow, HMC	SL-AV	2-tier	1.1x1.4/L28	1979-2003	2007
Pretoria, SAWS	ECHAM4.5	2-tier	T42	1982-2001	2007



CanSIPS initialization



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Atmospheric assimilation

Atmospheric (re)analysis T , winds, humidity assimilated every 6 hours using variant of incremental analysis update (IAU):

IAU:

$$\underbrace{\frac{d\mathbf{x}}{dt} = M(\mathbf{x})}_{\text{Model equations}} + \tau^{-1} \Delta \mathbf{x}_a$$

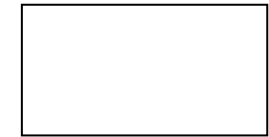
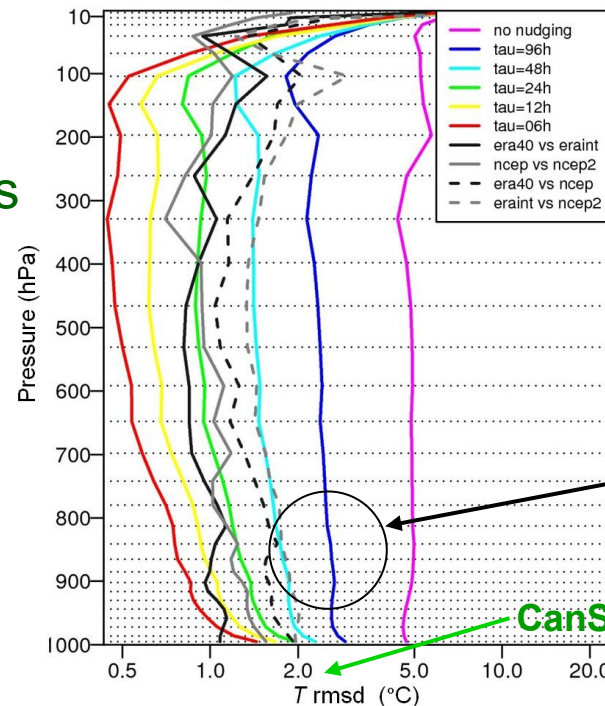
analysis increment

CanSIPS:

24h^{-1}

analysis increment
(T21 truncated)

→ weakening the assimilation increases ensemble spread to $O(\text{observational uncertainties})$



'uncertainty'

IAU

τ dependence of T rmsd between pairs from assimilation run ensemble



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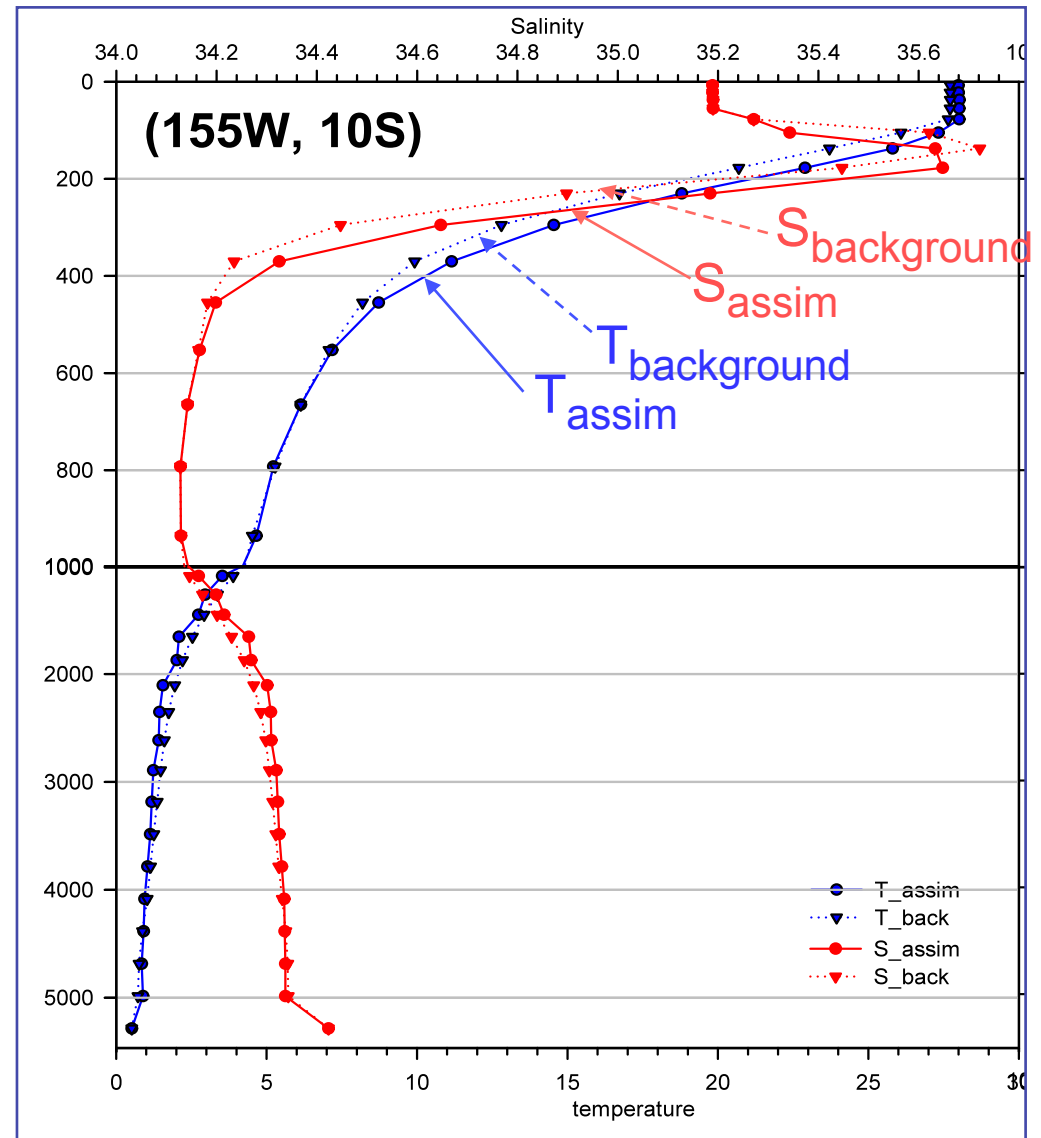
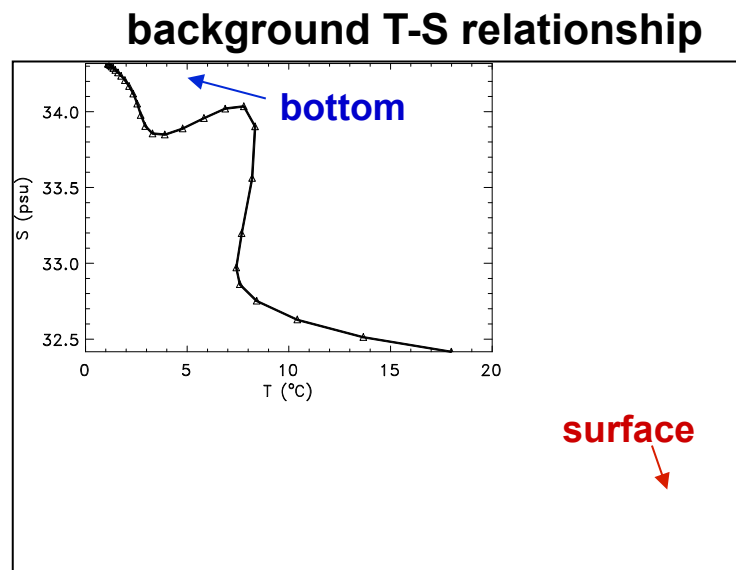
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Subsurface ocean assimilation

- Off-line variational assimilation of gridded T (Tang et al. *JGR* 2004; Derber & Rosati *JPO* 1989)
- S adjustment to preserve T-S relation, water column stability (Troccoli et al. *MWR* 2002)



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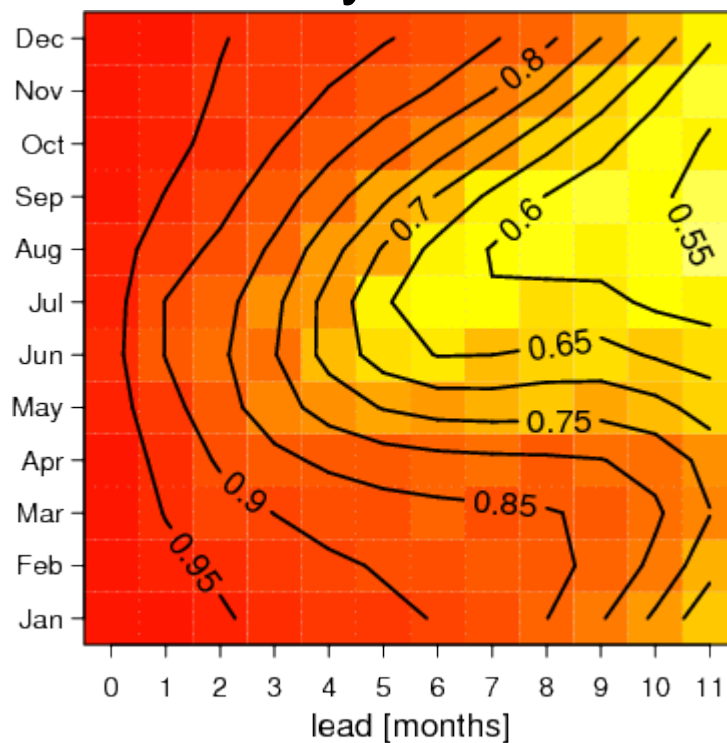
Data Sources: Hindcasts vs Operational

Field	Data Source during hindcast	Data Source during operations
3D atmospheric variables	ERA40; ERA interim	CMC
SST	monthly NCEP ERSST (1979-1981) weekly NCEP OISST (1981-present)	daily CMC
Sea ice concentration	monthly HadISST (1979-present)	daily CMC
3D ocean temperature	monthly NCEP GODAS ocean analysis	<u>daily NCEP GODAS</u> ocean analysis

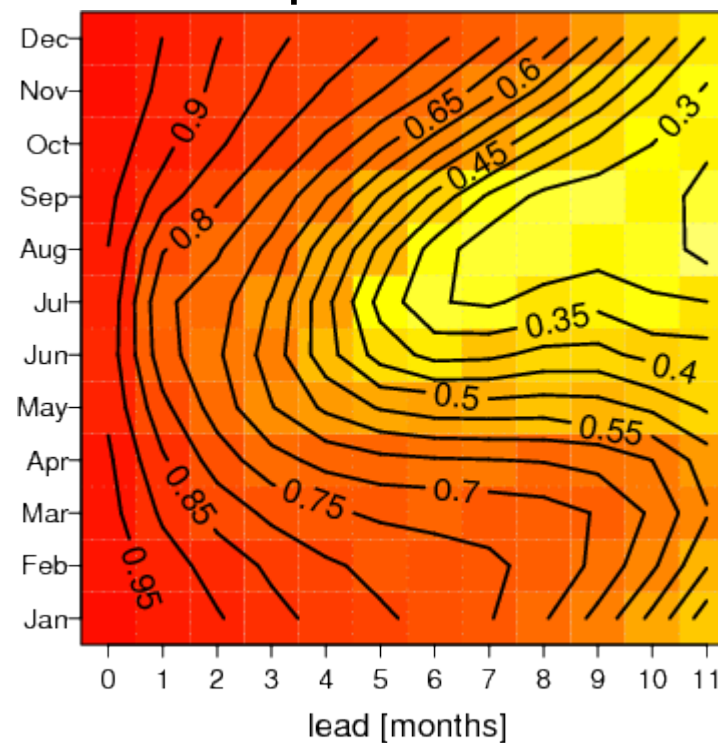


ENSO prediction skill (Nino3.4 index)

Anomaly correlation



Mean-square skill score



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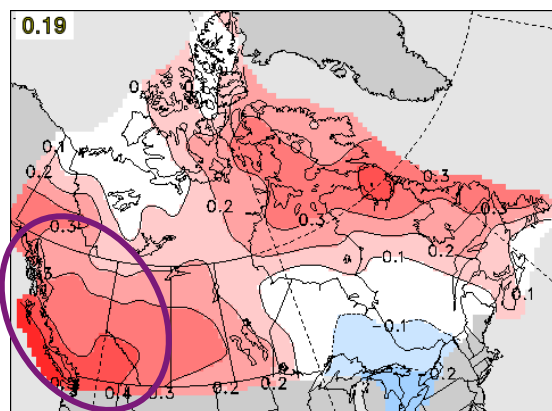
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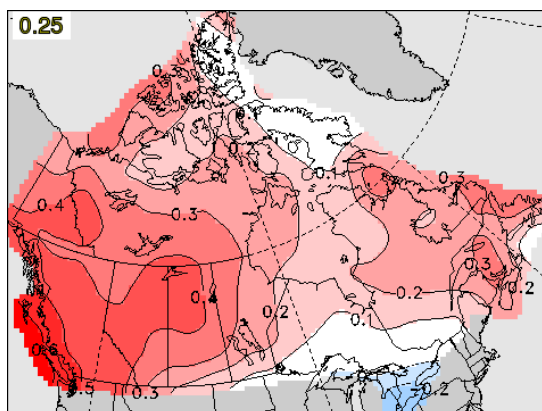
Is there value at longest lead times?

Long-lead skill for western Canada in winter/spring

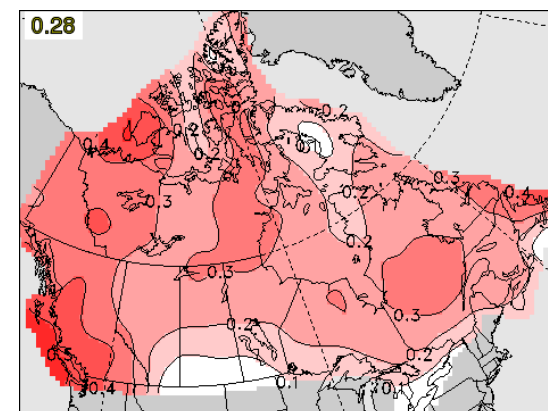
JFM



FMA

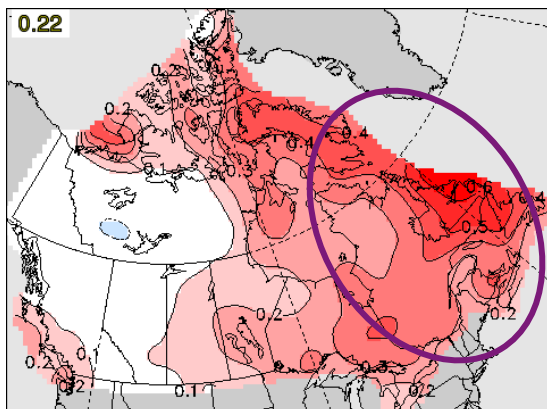


MAM

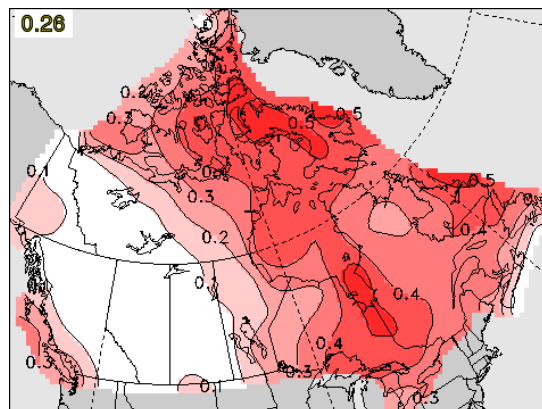


Long-lead skill for eastern Canada in summer/fall

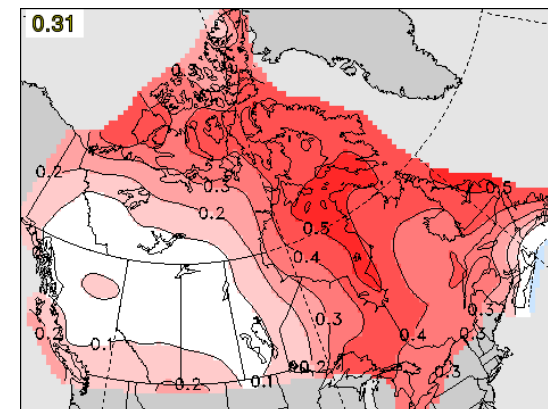
JAS



ASO



SON



Lead 9 month 2m temperature anomaly correlation



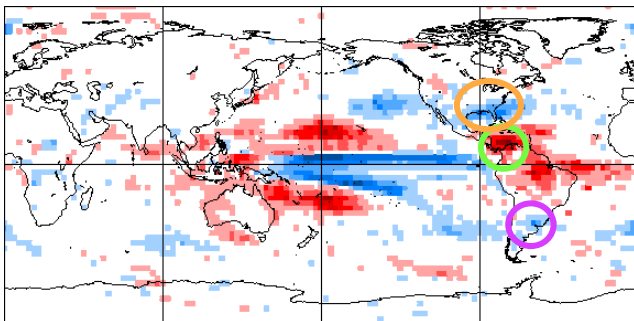
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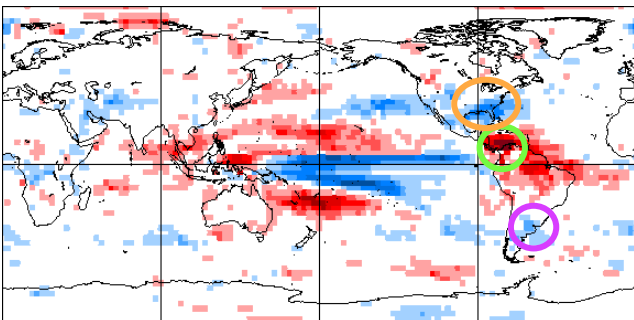
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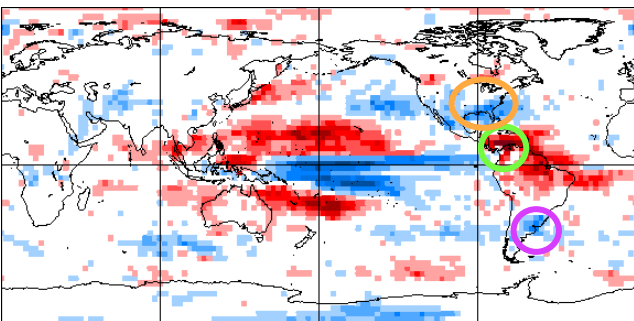
NDJ
2010-11
issued
1 Feb 2010



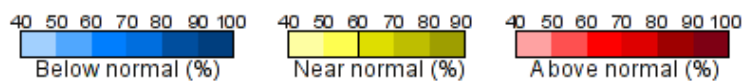
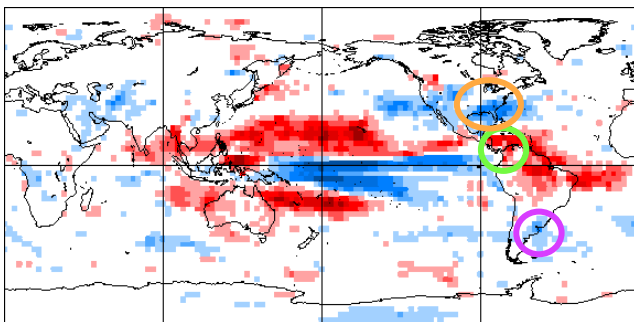
DJF
2010-11
issued
1 Mar 2010



JFM
2011
issued
1 Apr 2010

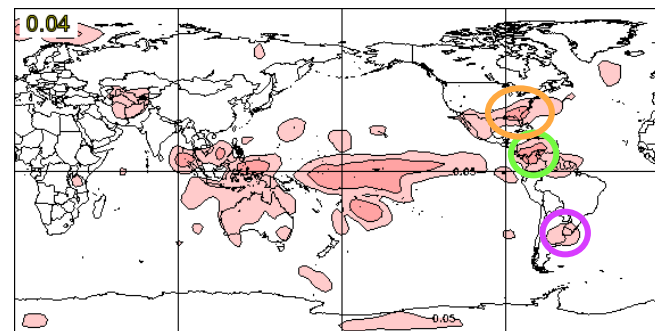


FMA
2011
issued
1 May 2010

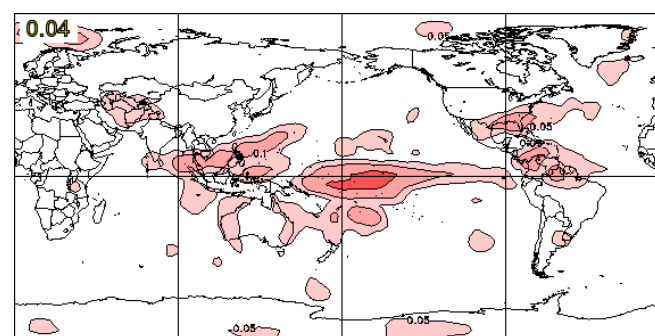


Lead 9 months

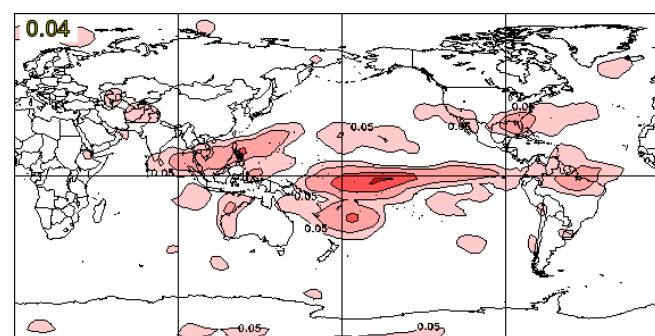
NDJ
skill



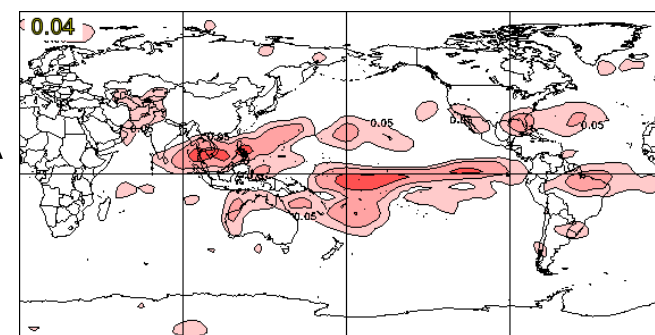
DJF
skill



JFM
skill



FMA
skill



Continuous Rank Probability Skill Score

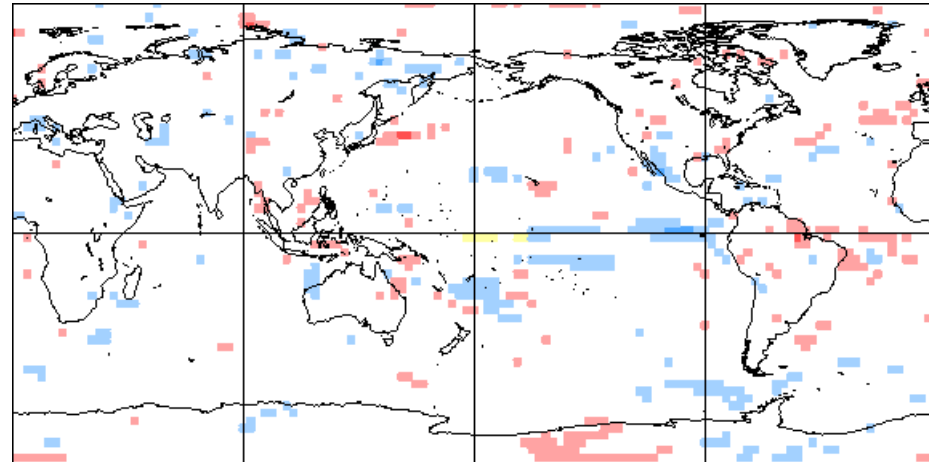
Is there value at longest lead times?

Seasonal precipitation forecasts at *lead 9 months*

MJJ 2006

Issued 1 Aug 2005

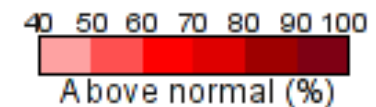
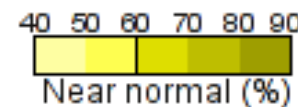
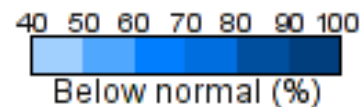
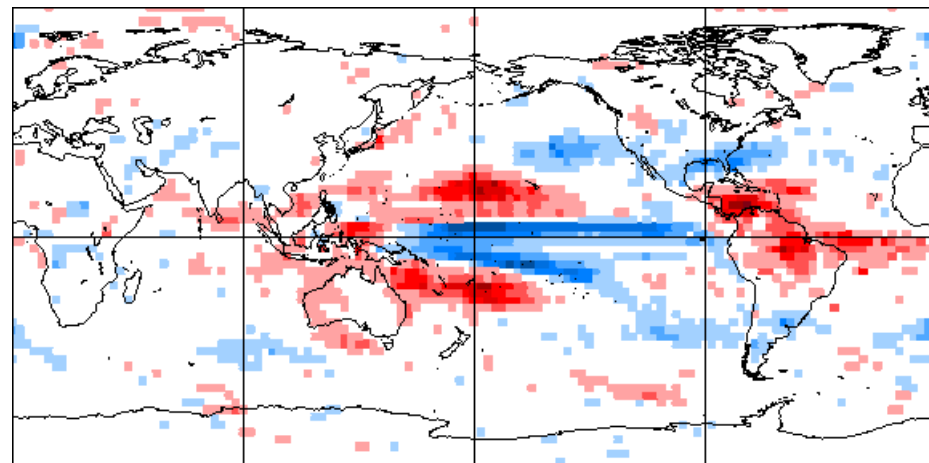
***ENSO neutral conditions
predicted***



NDJ 2010-11

Issued 1 Feb 2010

La Niña predicted



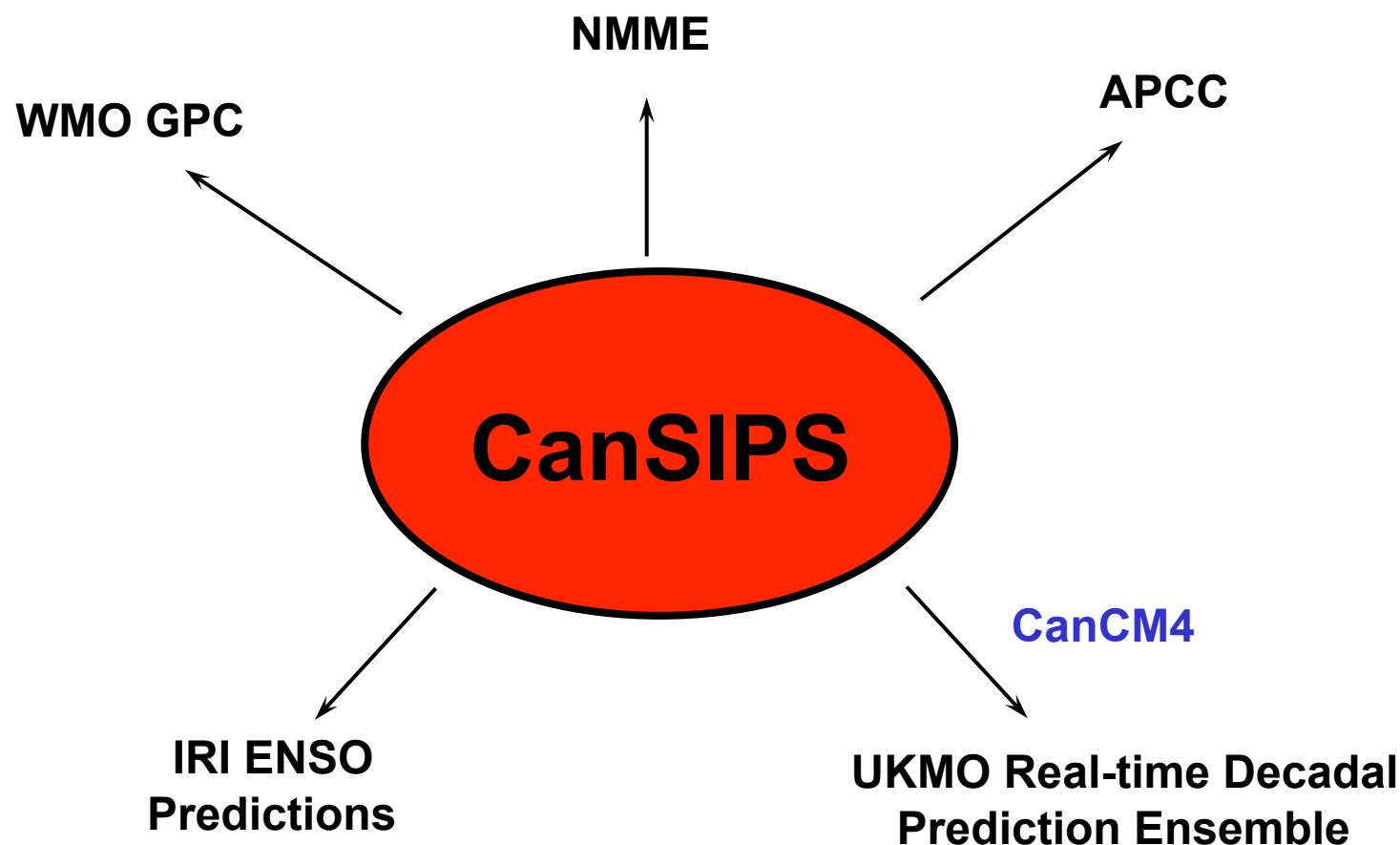
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Contributions to forecast compendia



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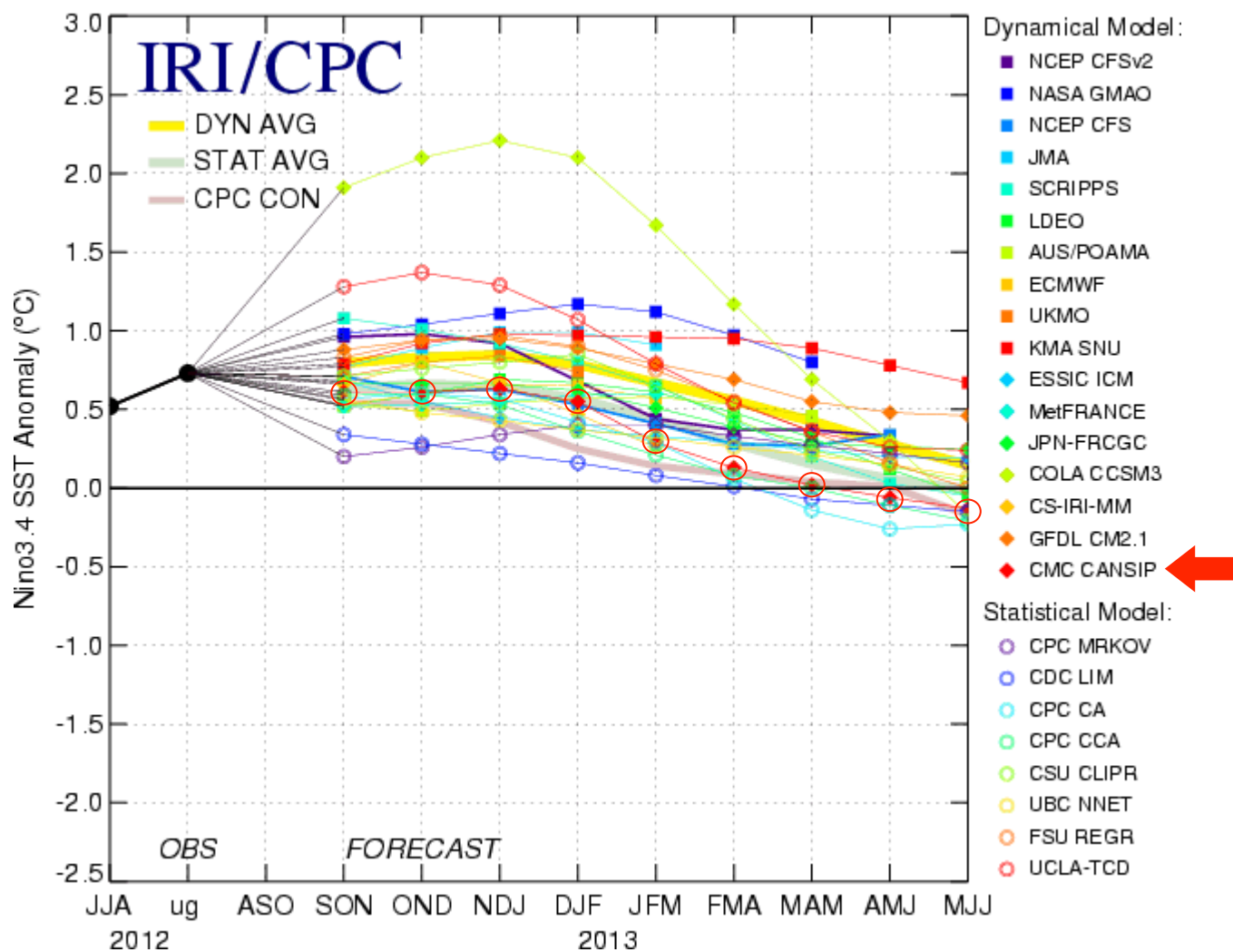
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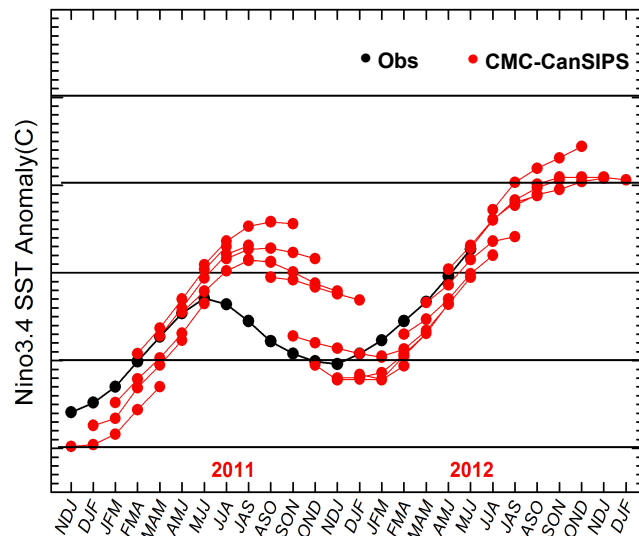
IRI ENSO Prediction plume

Mid-Sep 2012 Plume of Model ENSO Predictions

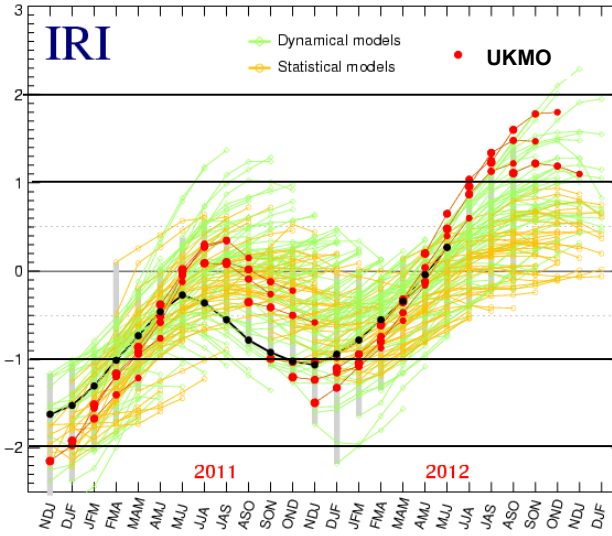


IRI Nino3.4 forecasts from CanSIPS & other WMO GPCs

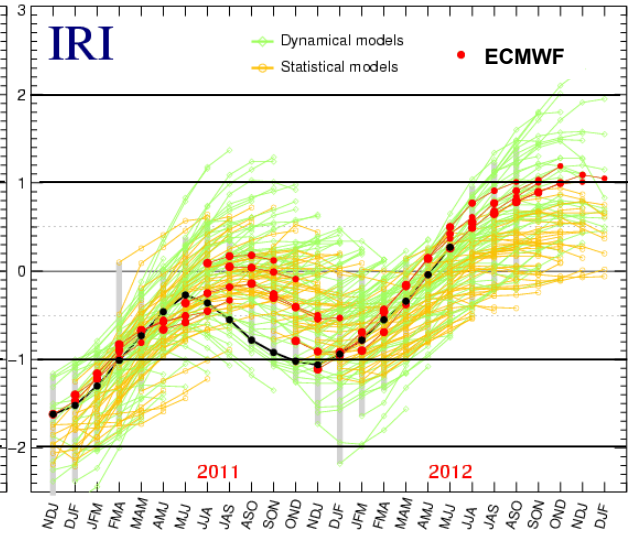
ENSO Predictions from Nov 2010 to Aug 2012



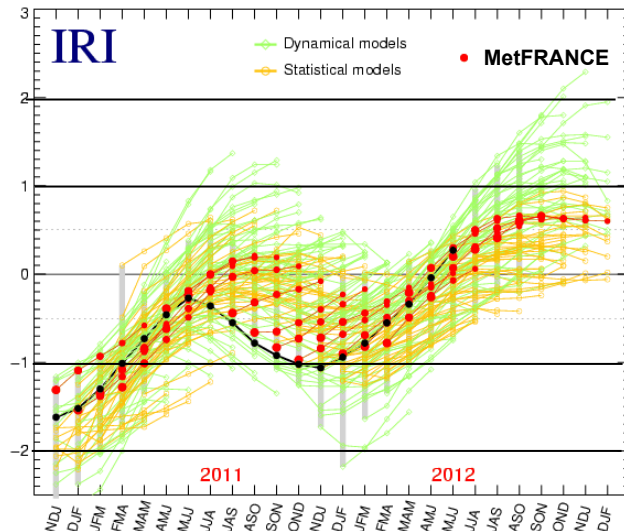
ENSO Predictions from Nov 2010 to Aug 2012



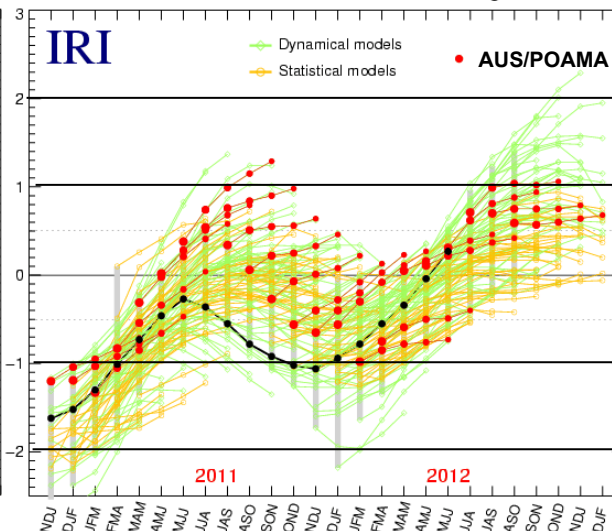
ENSO Predictions from Nov 2010 to Aug 2012



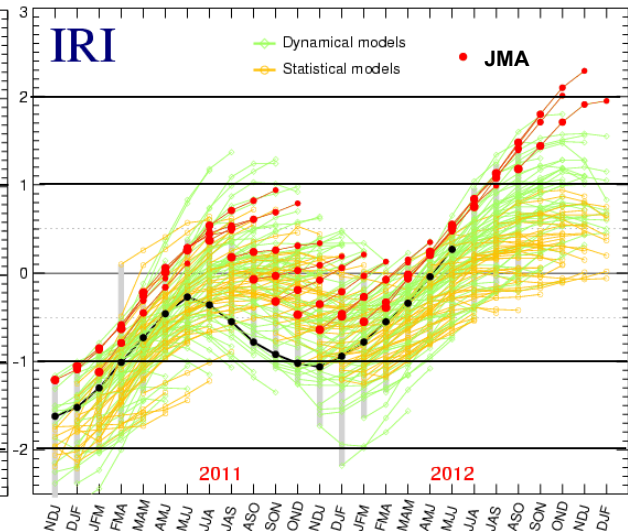
ENSO Predictions from Nov 2010 to Aug 2012



ENSO Predictions from Nov 2010 to Aug 2012

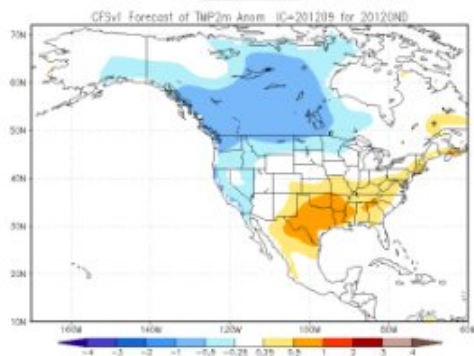


ENSO Predictions from Nov 2010 to Aug 2012

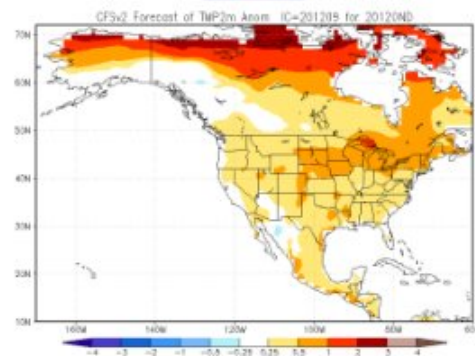


US National Multi-Model Ensemble (NMME)

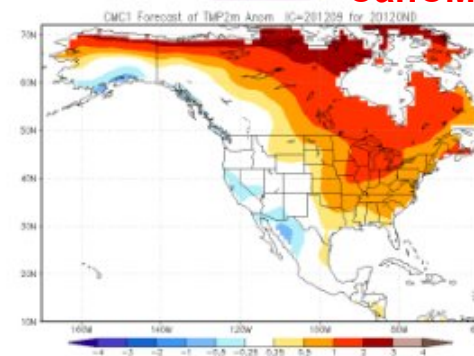
CFSv1



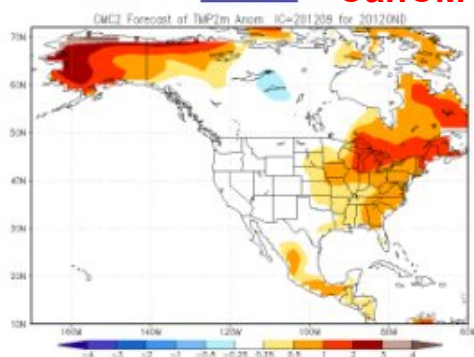
CFSv2



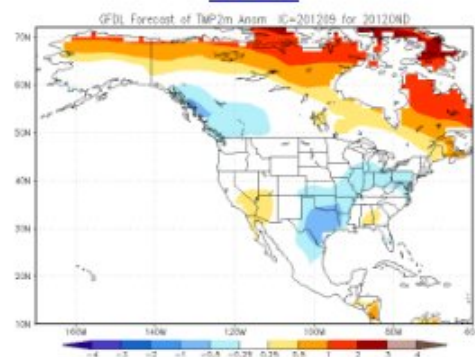
CMC1 = CanCM3



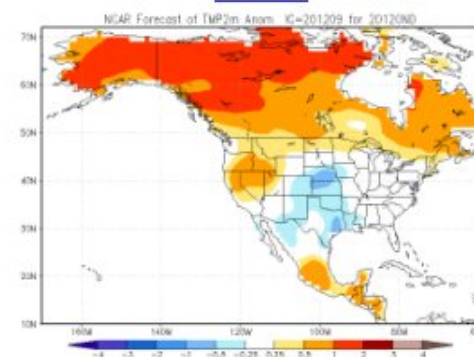
CMC2 = CanCM4



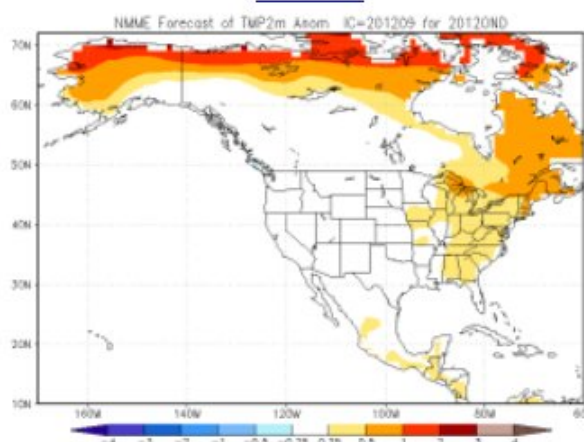
GFDL



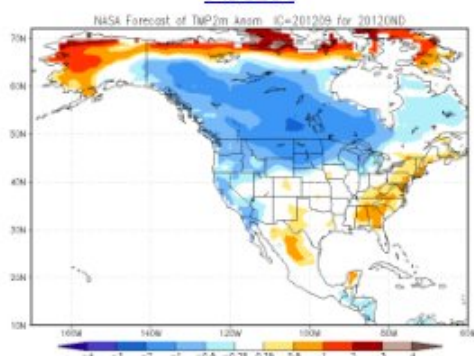
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NMME



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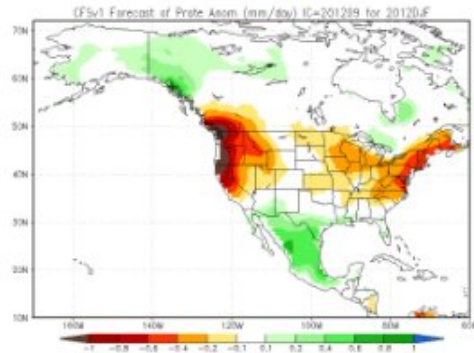


**NMME models +
ensemble mean**

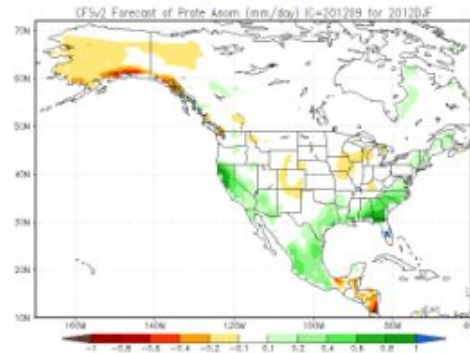
**T2m OND 2012
(from Sep 2012)**

US National Multi-Model Ensemble (NMME)

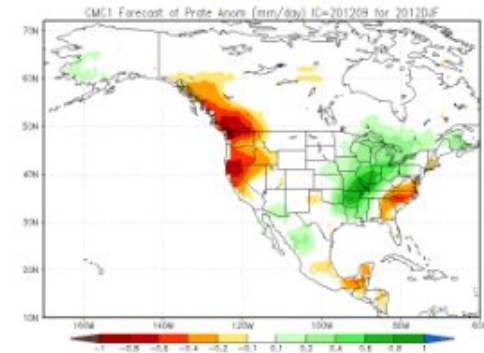
CFSv1



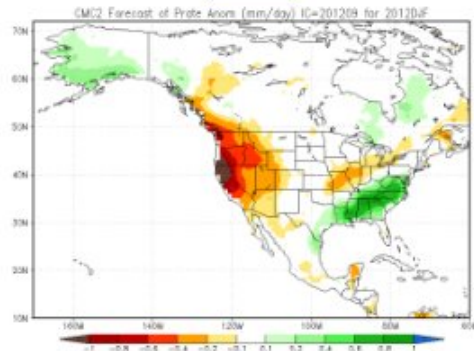
CFSv2



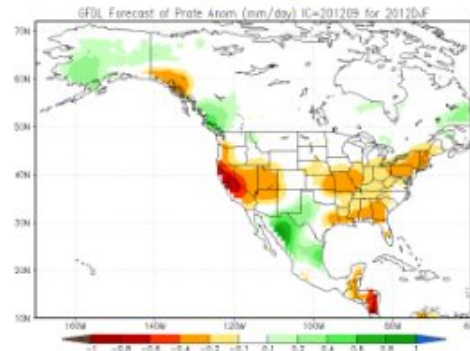
CMC1 = CanCM3



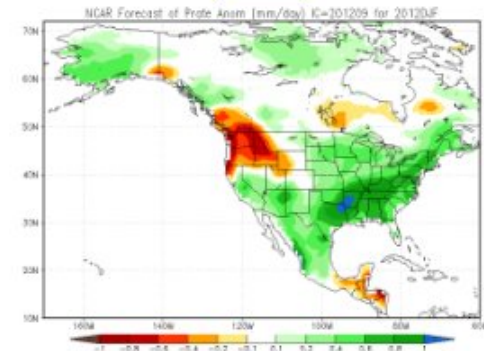
CMC2 = CanCM4



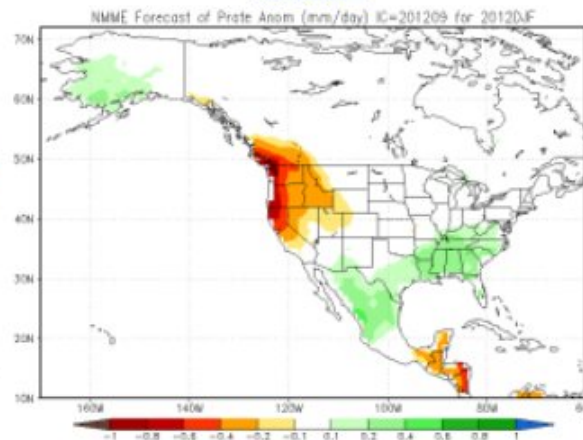
GFDL



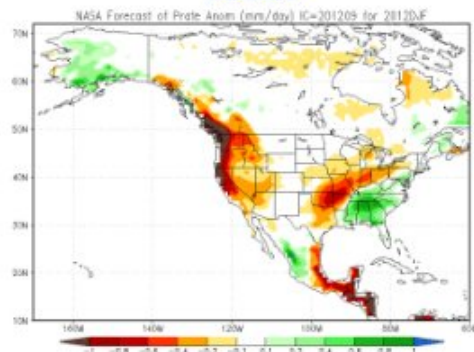
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NMME



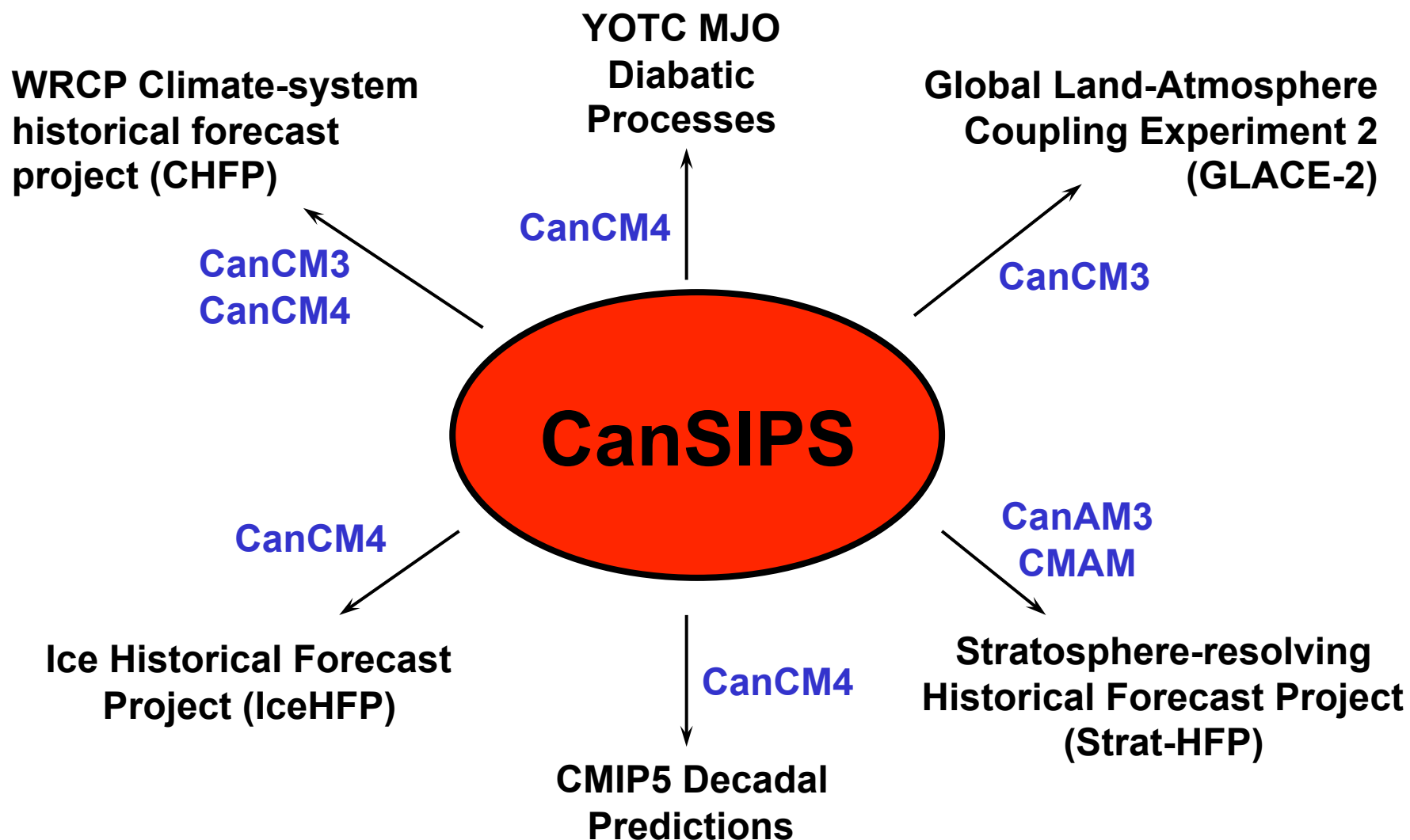
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**NMME models +
ensemble mean**

**precip DJF 2012
(from Sep 2012)**

CanSIPS 'HFPs'



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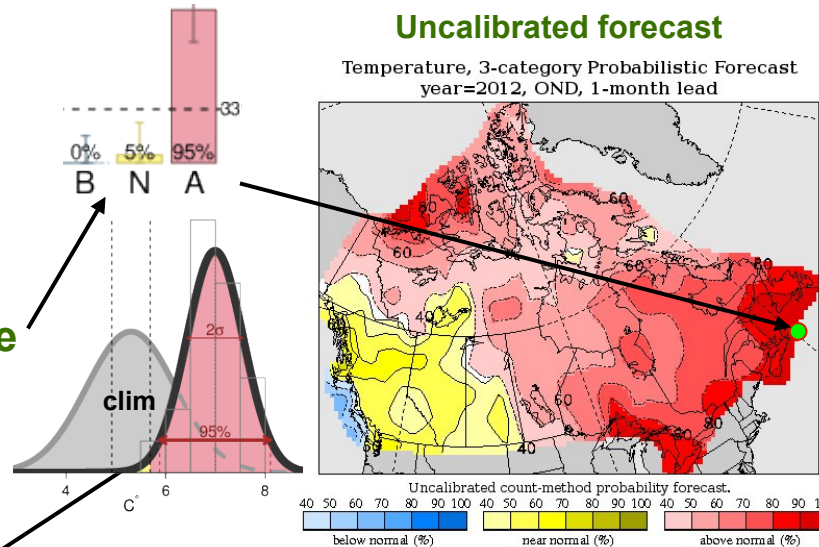
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Calibration of probability forecasts

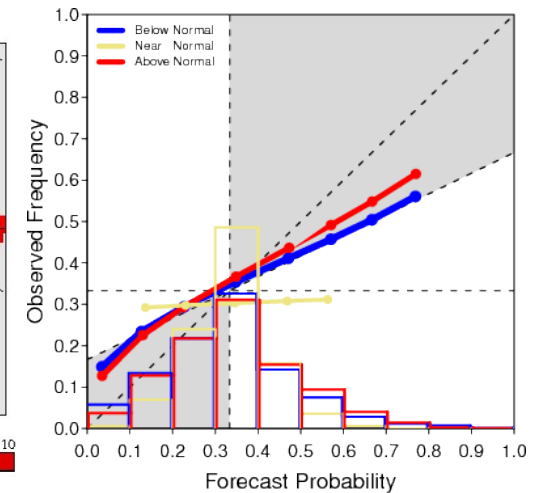
3-category probabilities: **Below** - **Near** - **Above** normal

Uncalibrated:

- Compute anomalies for each ensemble member
- Count # of ensemble members in each category

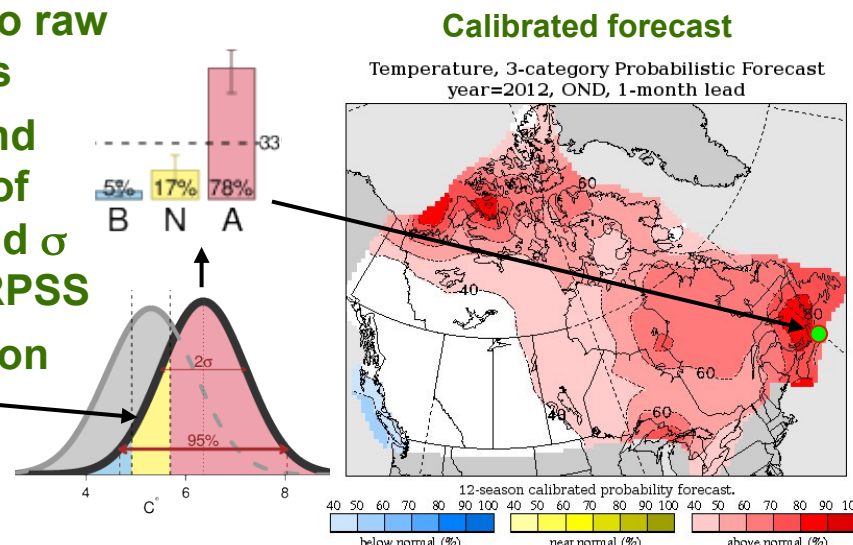


Skill

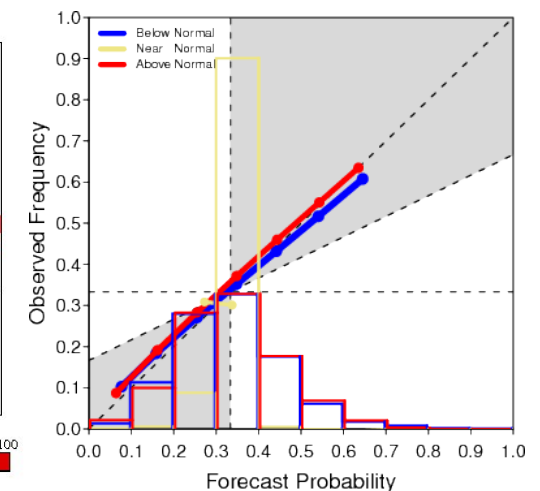


Calibrated:

- Fit Gaussian PDF to raw forecast anomalies
- From hindcasts, find optimal rescaling of Gaussian mean and σ that maximizes CRPSS
- Apply this calibration to forecast PDF



Skill



Reference:

Kharin & Zwiers *J. Clim* 2003

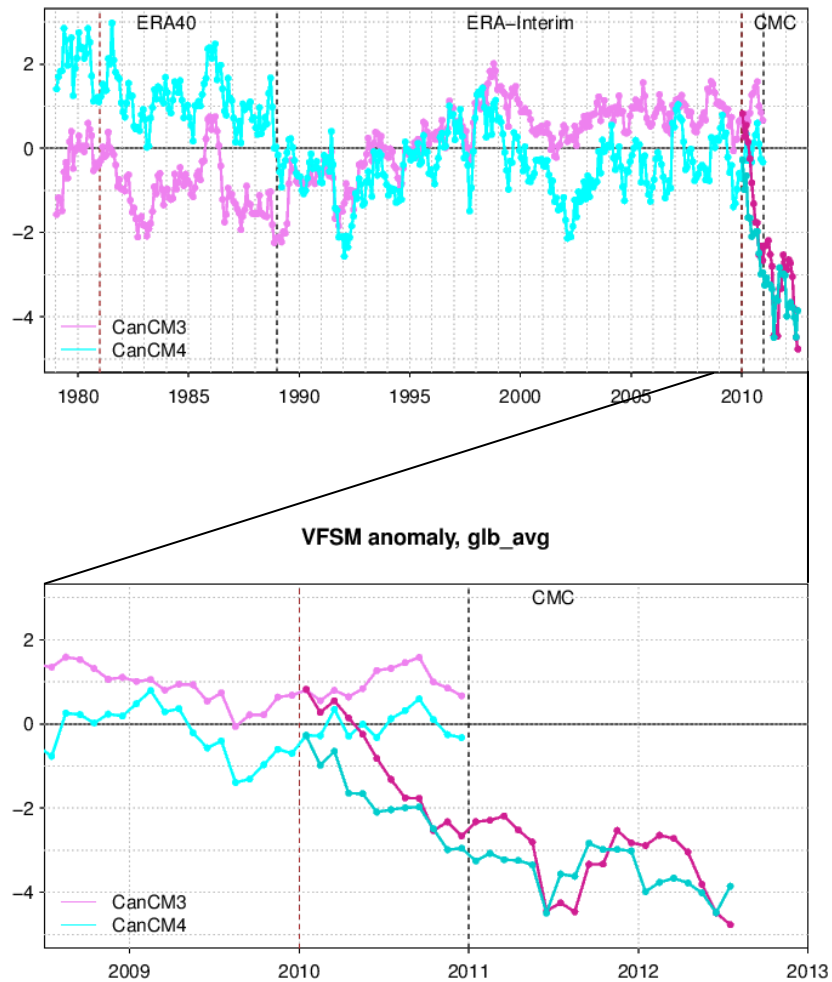
White: no category exceeds 40%

Soil moisture in first forecast month: ERA vs CMC

VFSM = volume fraction of soil moisture

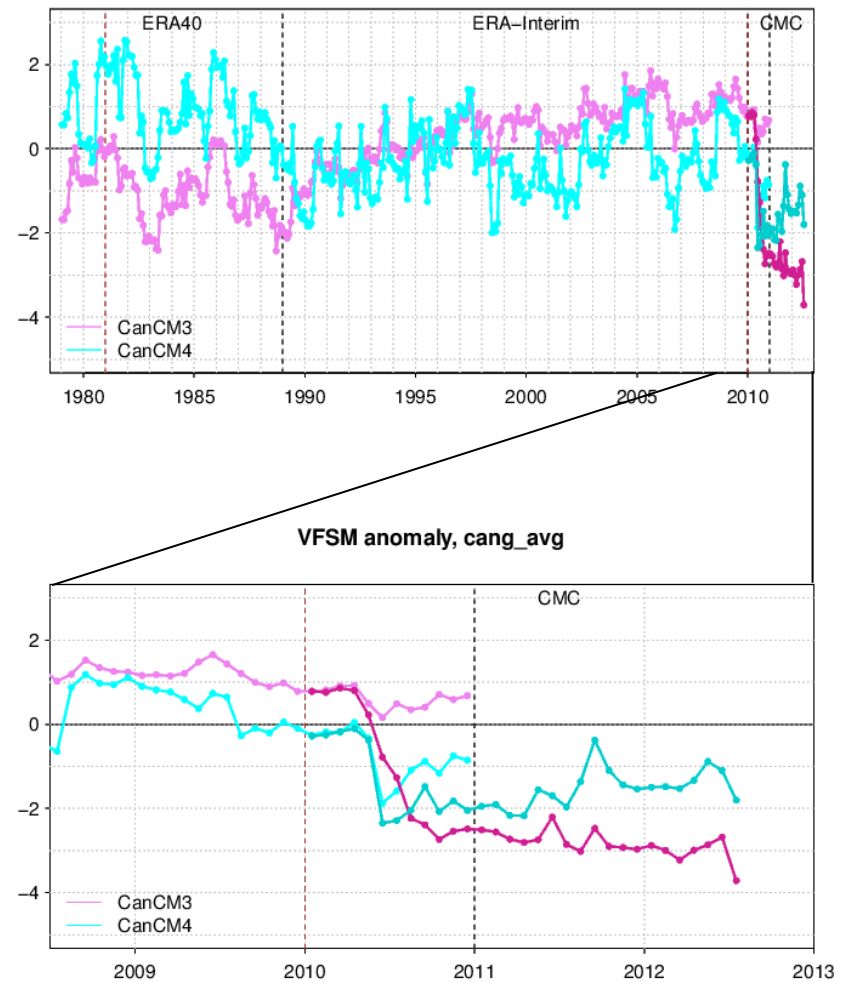
Global mean

VFSM anomaly, glb_avg



Canada mean

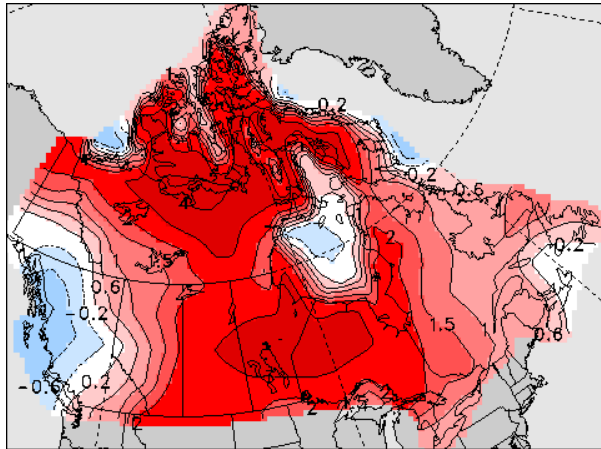
VFSM anomaly, cang_avg



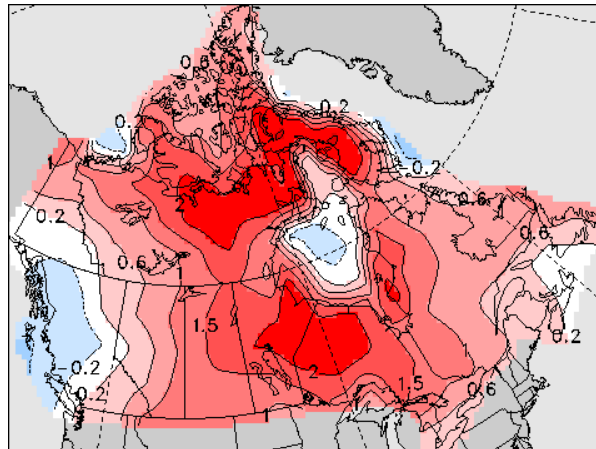
July lead 0 predicted temperature anomalies and verification

July 2011

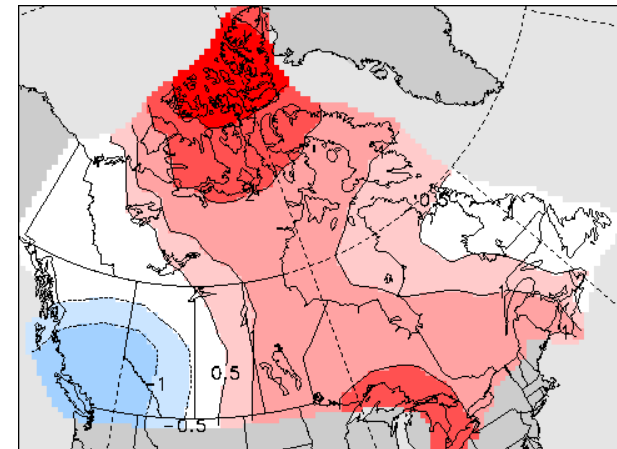
uncalibrated



calibrated

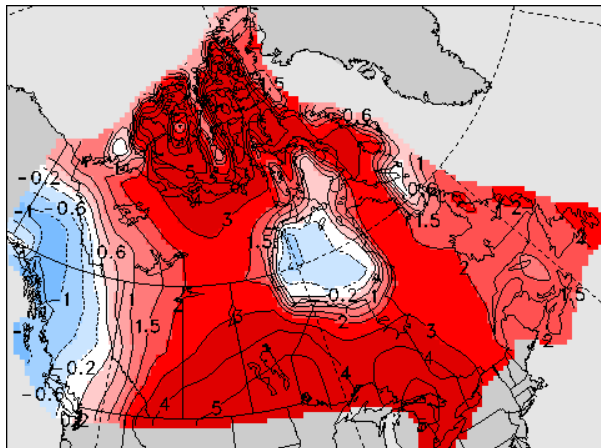


verification (GISS)

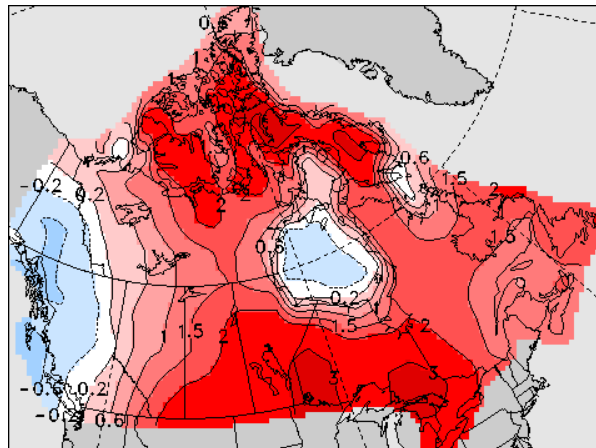


July 2012

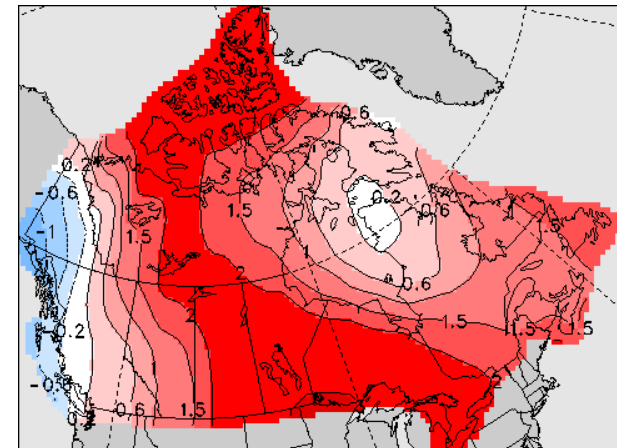
uncalibrated



calibrated



verification (GISS)



References

Journal publications

Merryfield, W. J., W.-S. Lee, G. J. Boer, V. V. Kharin, J. F. Scinocca, G. M. Flato, R. S. Ajayamohan, J. C. Fyfe, Y. Tang, and S. Polavarapu, 2012. The Canadian Seasonal to Interannual Prediction System. Part I: Models and Initialization, *Mon. Wea. Rev.*, submitted.

----- The Canadian Seasonal to Interannual Prediction System. Part II: Hindcast performance, *in preparation*.

Technical report

The Canadian Seasonal to Interannual Prediction System (CanSIPS): An overview of its design and operational implementation. CMC technical note (web search [CanSIPS CMC note](#)):

http://collaboration.cmc.ec.gc.ca/cmc/cmoe/product_guide/docs/lib/op_system/doc_opchanges/technote_cansips_20111124_e.pdf

Verification interface:

username: cccmasf

password: seasforum

http://www.cccma.ec.gc.ca/cgi-bin/data/seasonal_forecast/sf2



Environnement
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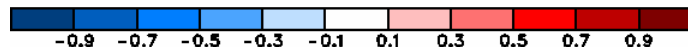
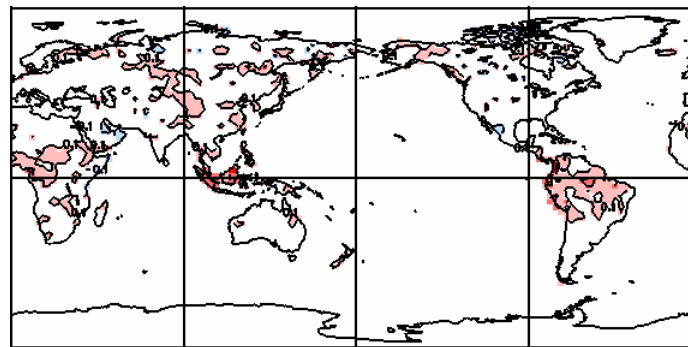
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Benefits of coupled atmospheric assimilation: Improved land initialization

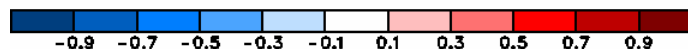
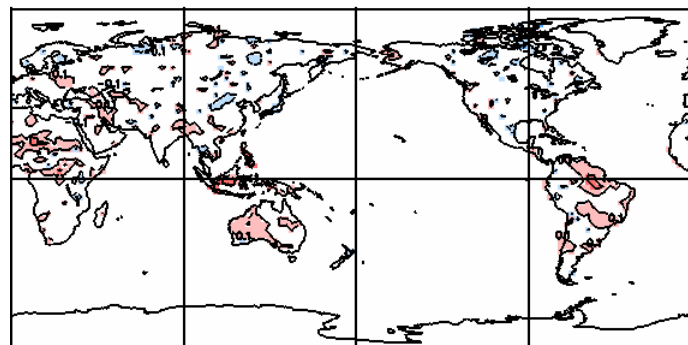
Correlation of assimilation run vs offline analysis

Soil temperature
(top layer)

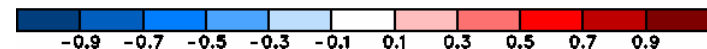
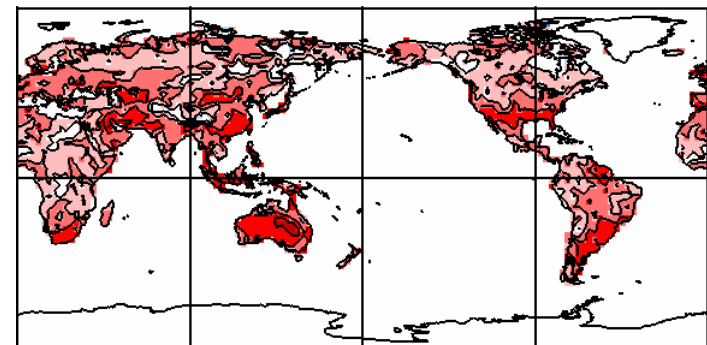
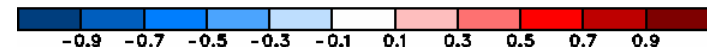
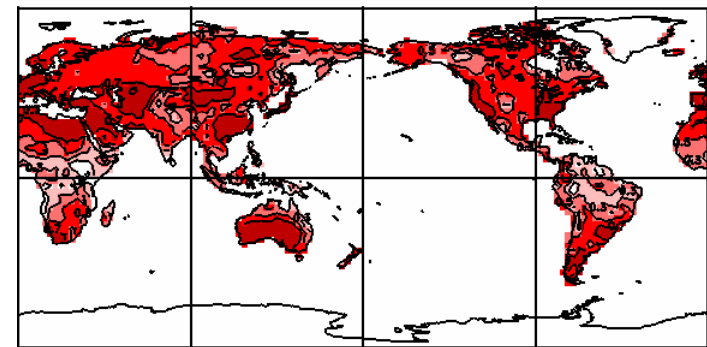
SST nudging only



Soil moisture
(top layer)



SST nudging + atmospheric assim



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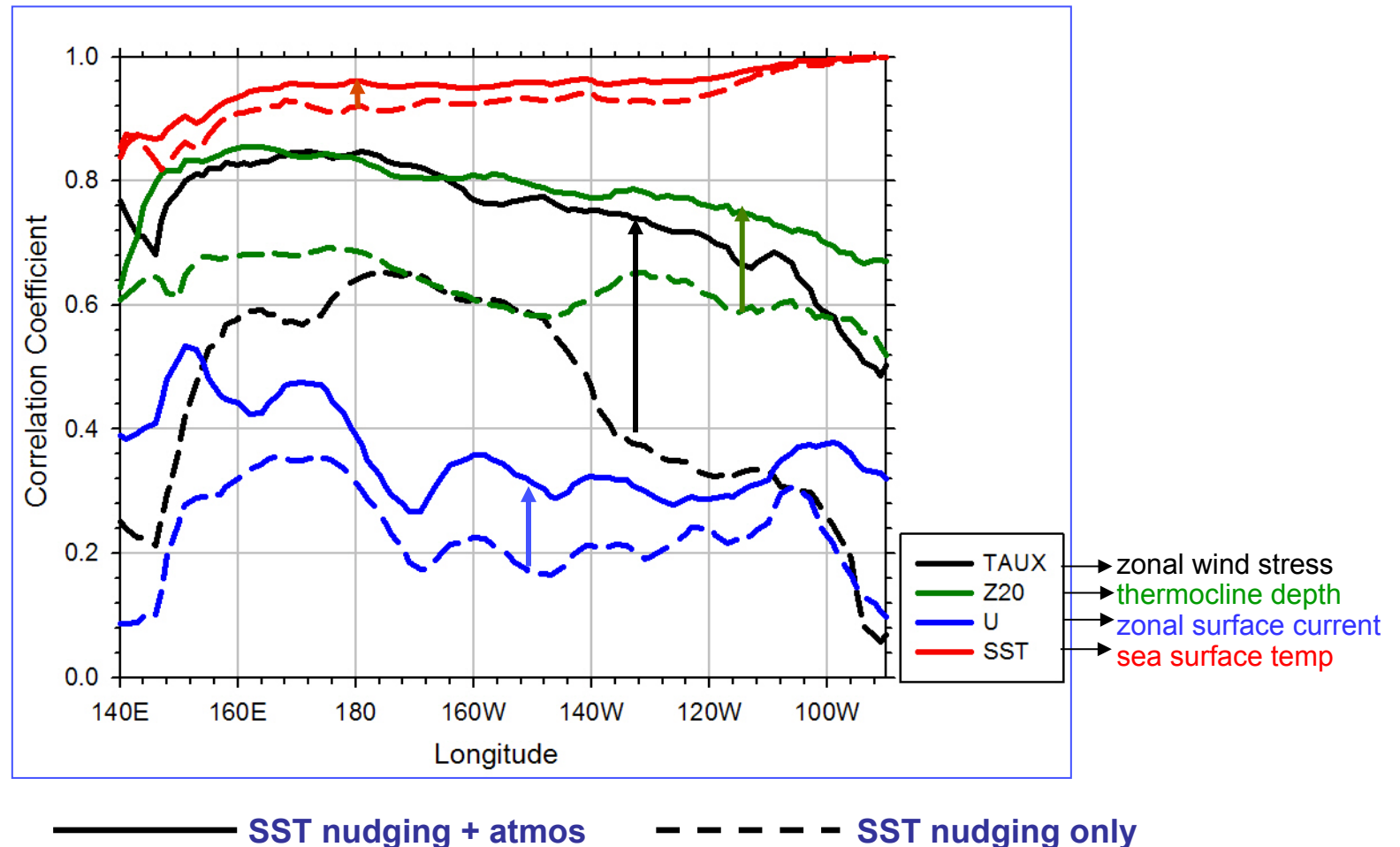
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Benefits of coupled atmospheric assimilation: Improved ocean initialization

Correlations vs obs in equatorial Pacific (5S→5N)

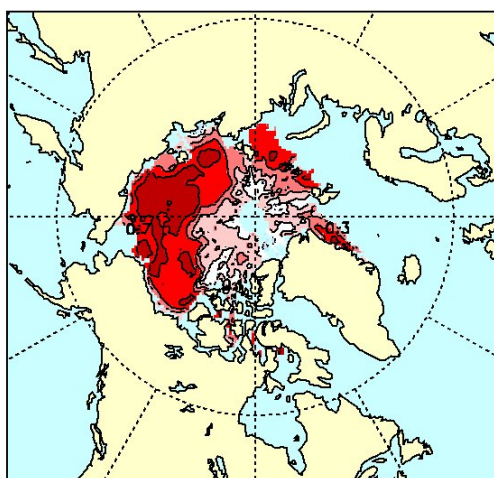


CanSIPS sea ice predictions

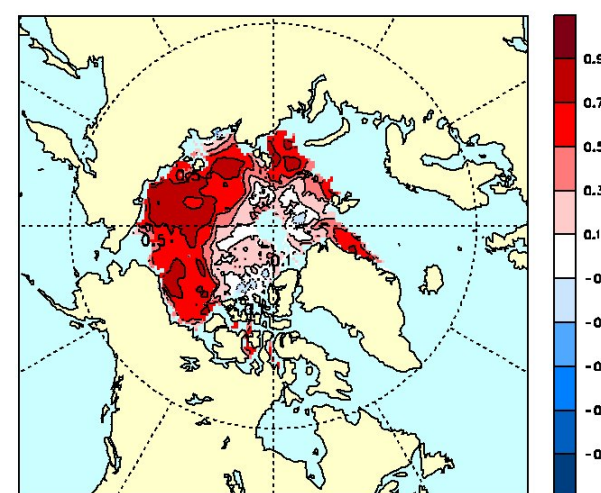
Anomaly correlation, Sep mean ice concentration

Forecasts initialized
End of July

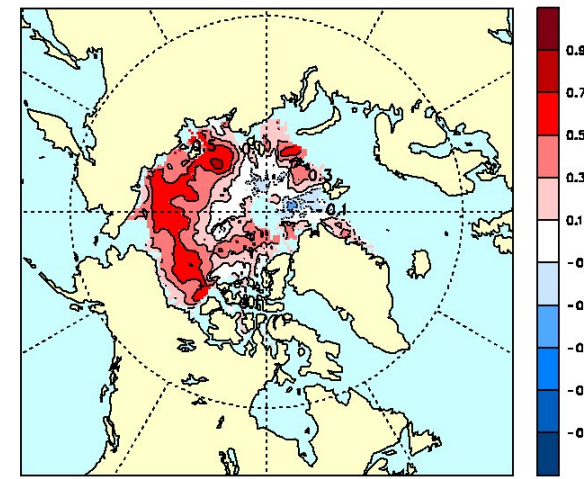
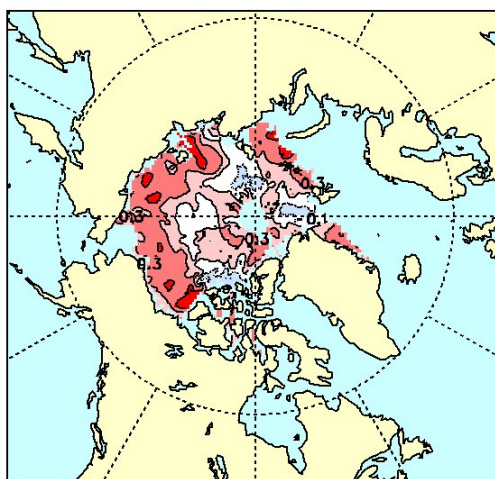
CanCM3



CanCM4



Forecasts initialized
End of June



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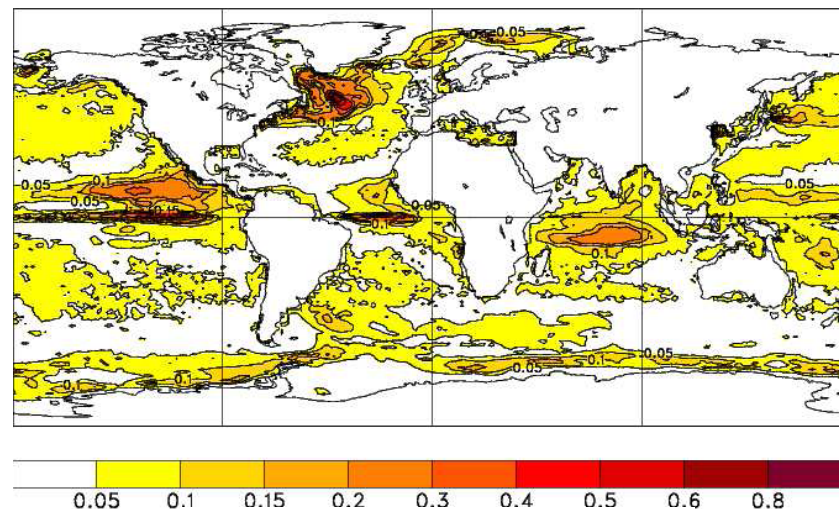
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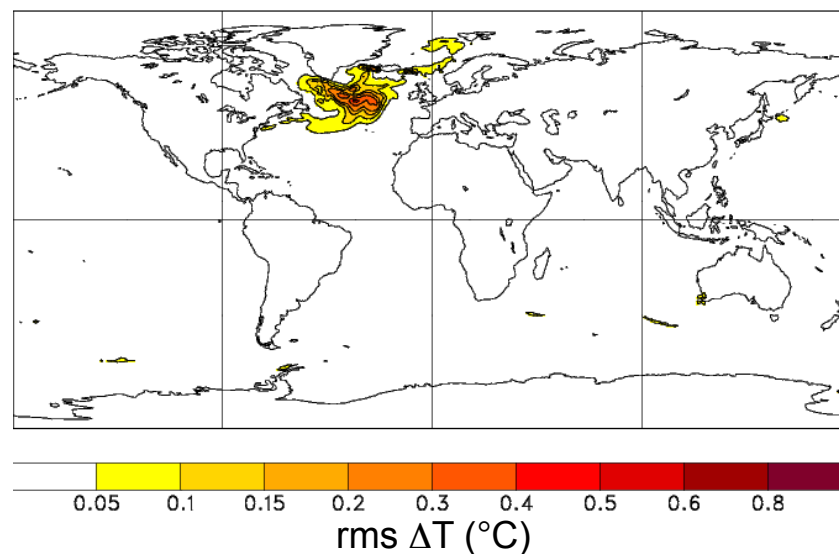
Assimilation runs: ocean ensemble spread

rms potential temperature
difference between two
members of assimilation
run ensemble

56 m depth



510 m depth



rms ΔT ($^{\circ}\text{C}$)



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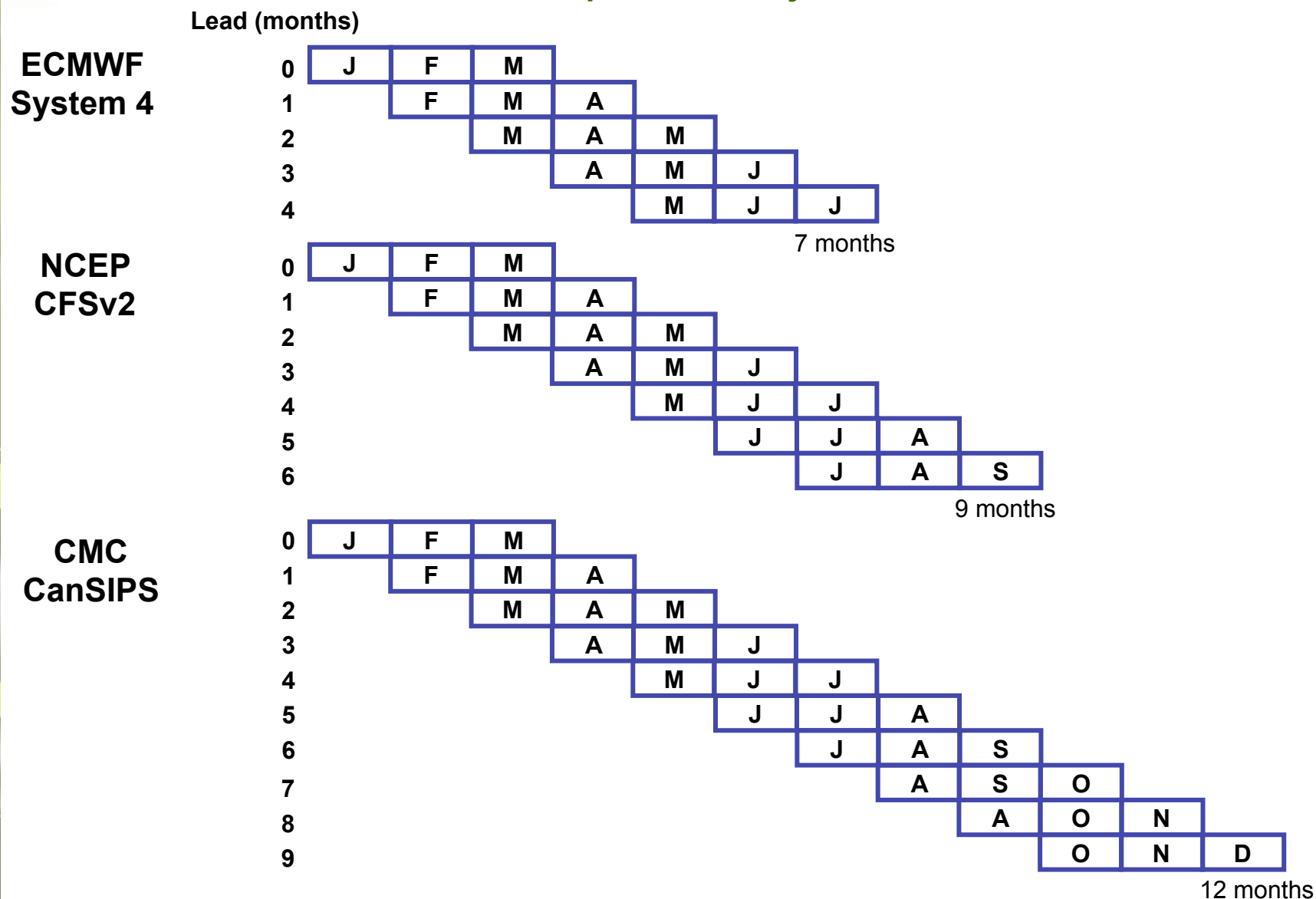
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Operational Multi-Seasonal Forecast Ranges

Example: 1 January start



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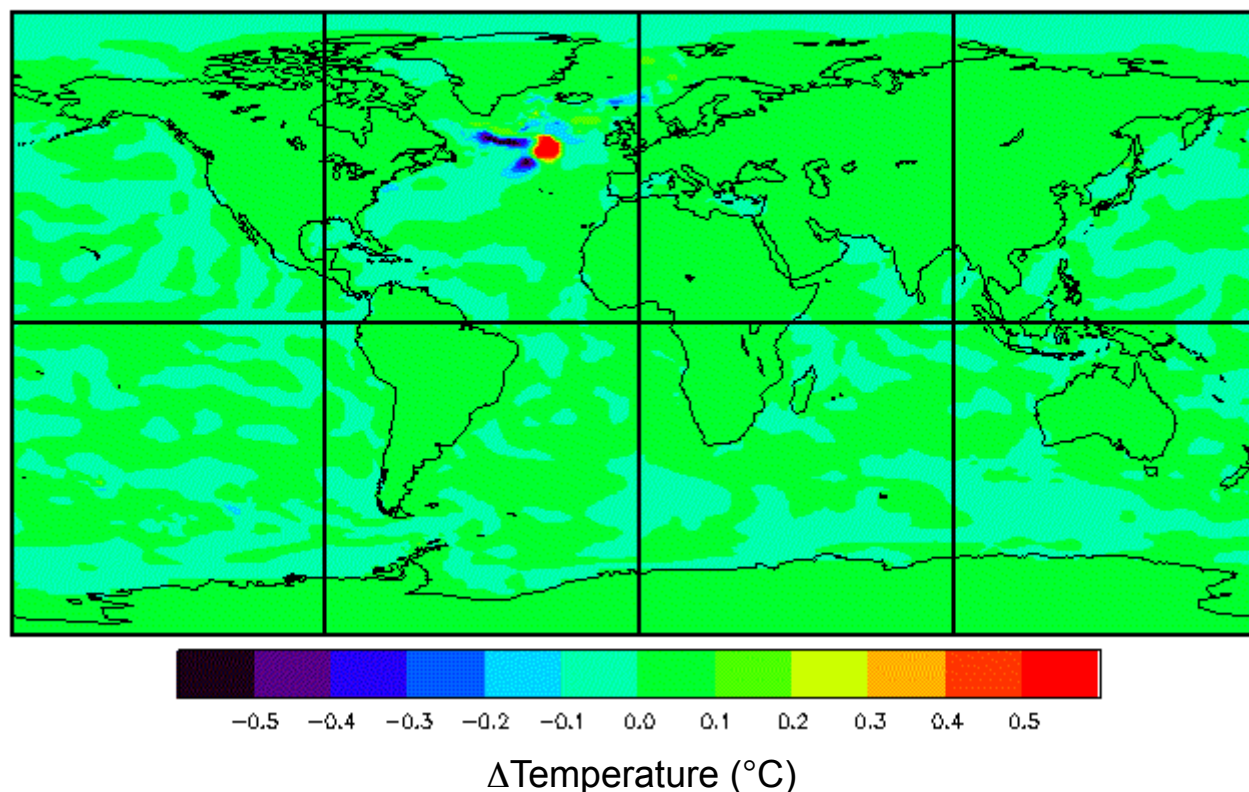
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Assimilation runs: ocean ensemble spread

Potential temperature difference at 510m depth between two members of assimilation run ensemble 1995-2003

e: sc_cg75_minus_cg74_1970_2003_gz_temp.001 Field: TEMP Time: 199501 Level: 51



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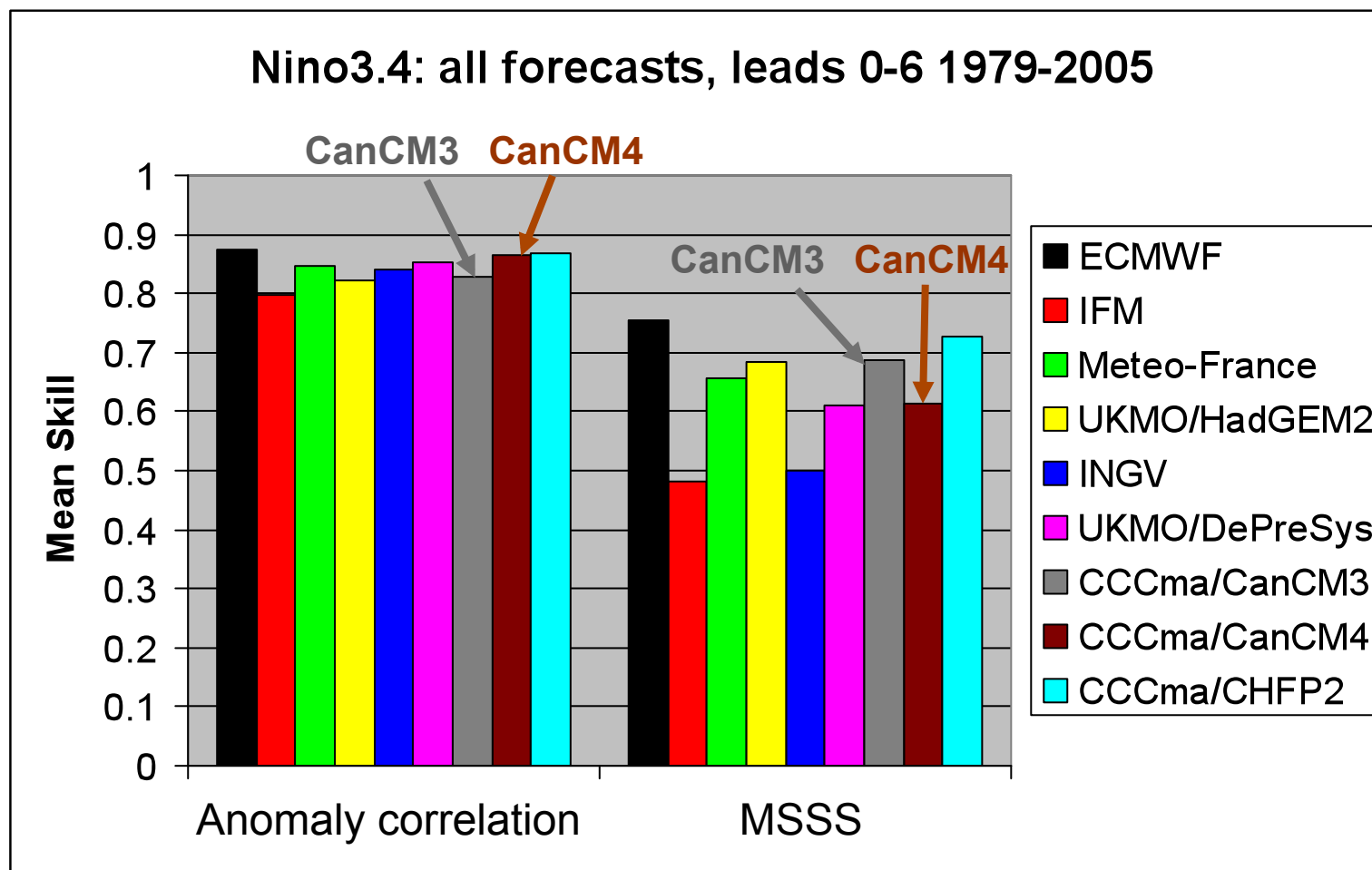
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ENSO prediction skill: model comparisons

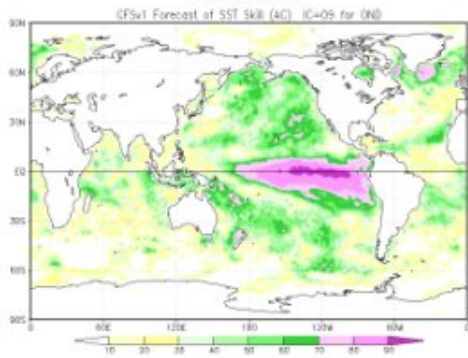
CanCM3, CanCM4 vs ENSEMBLES models



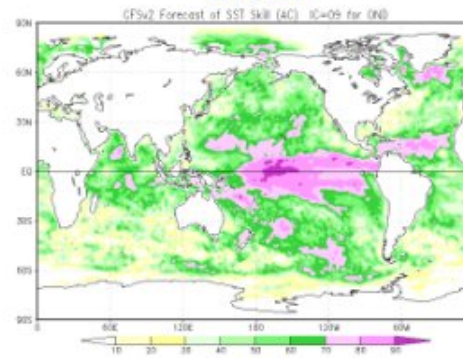
Comparison of **individual model forecasts** (ensemble size 9 for ENSEMBLES forecasts, ensemble size 10 for CanCM3 & CanCM4). CanSIPS skills are shown for comparison

US National Multi-Model Ensemble (NMME)

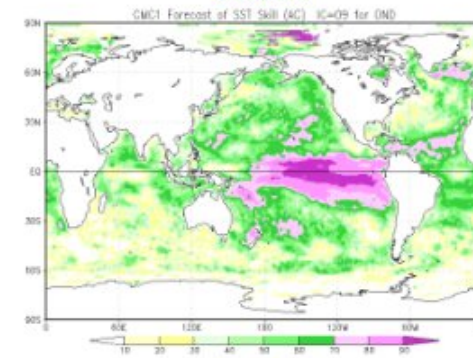
CFSv1



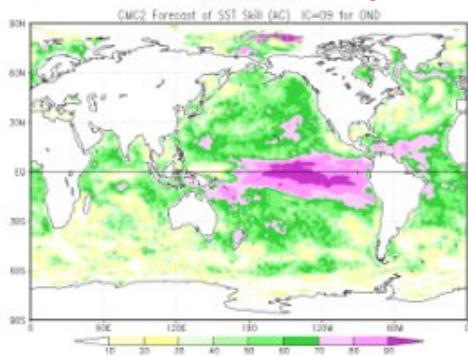
CFSv2



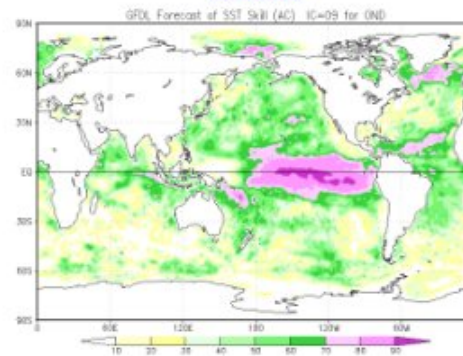
CMC1 = CanCM3



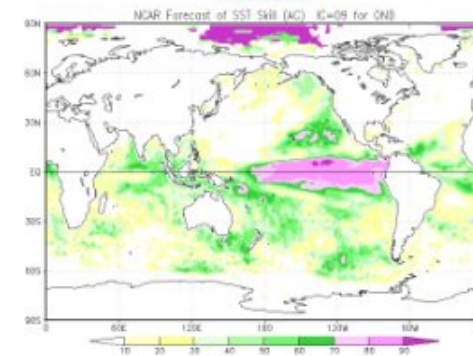
CMC2 = CanCM4



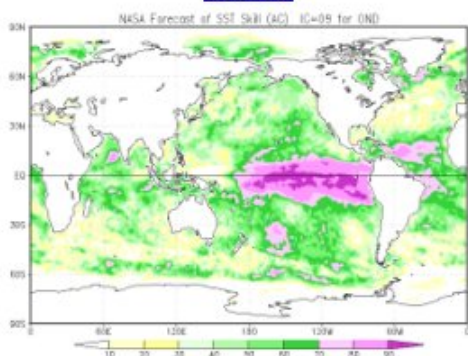
GFDL



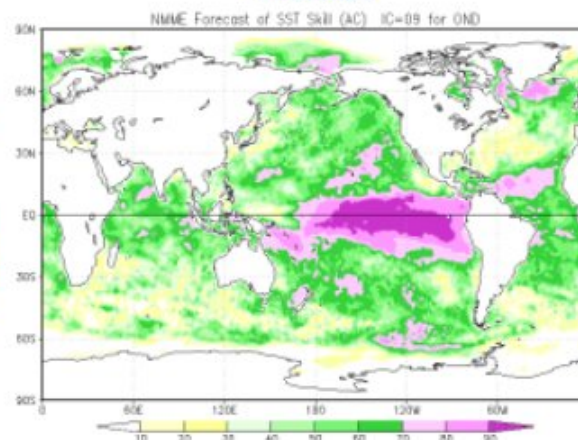
NCAR



NASA



NMME

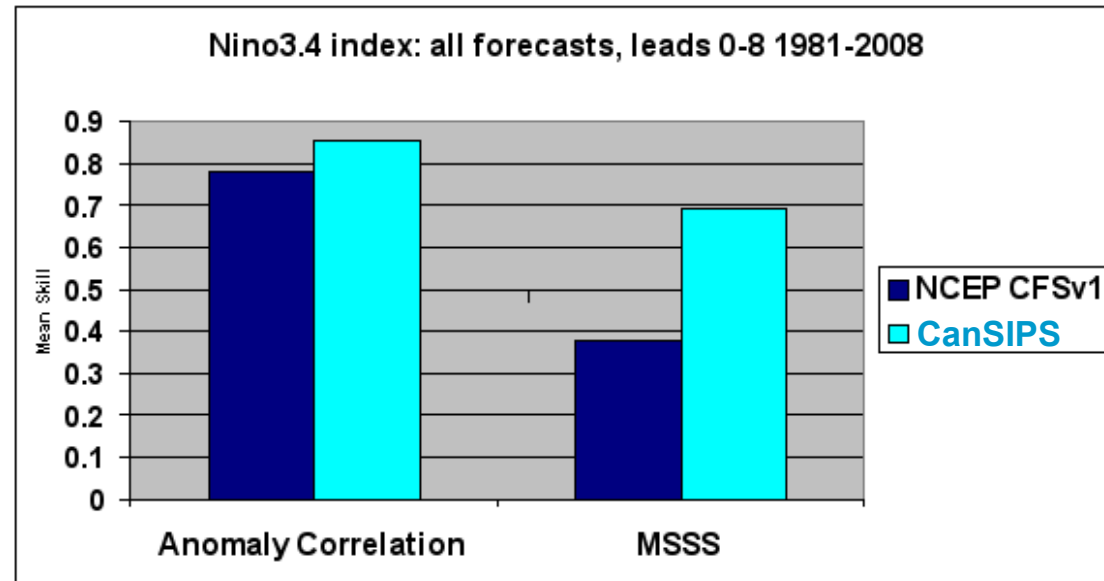


NMME models +
ensemble mean
anomaly correlation

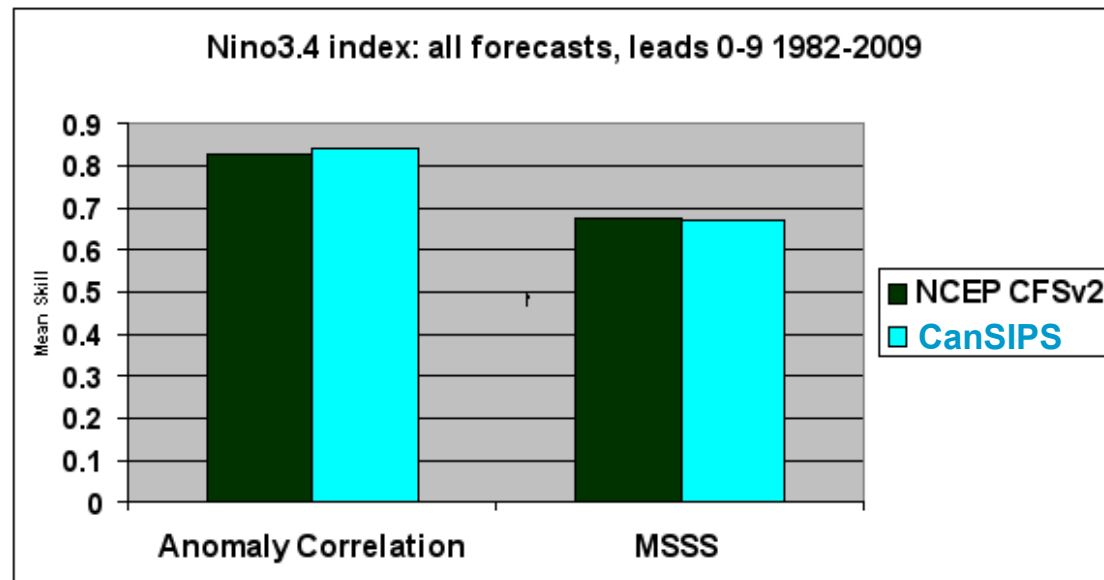
OND SST from
Sep initialization

ENSO prediction skill: system comparisons

CanSIPS
VS
CFSv1

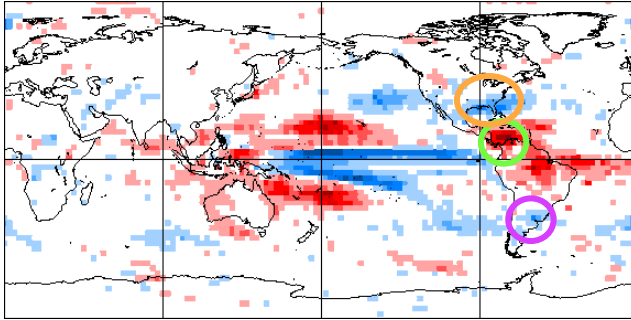


CanSIPS
VS
CFSv2*

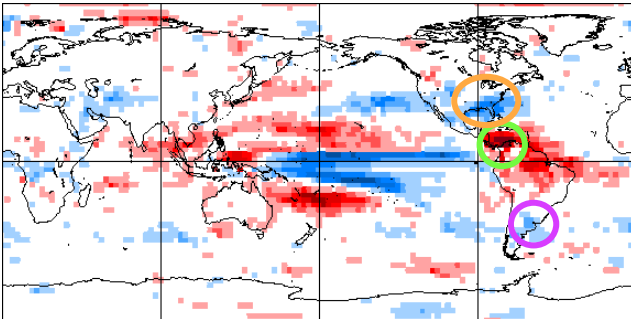


* with recommended adjustment to hindcast climatology

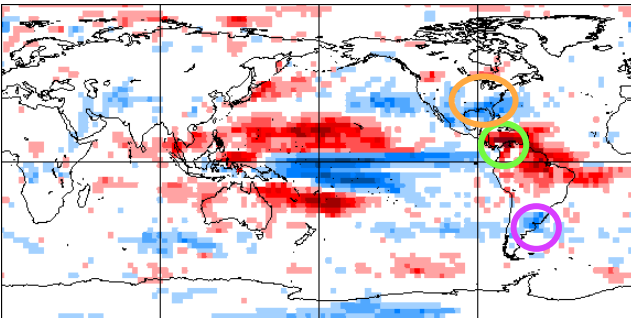
NDJ
2010-11
issued
1 Feb 2010



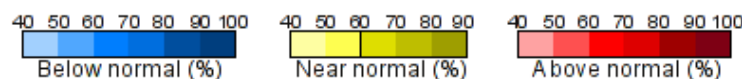
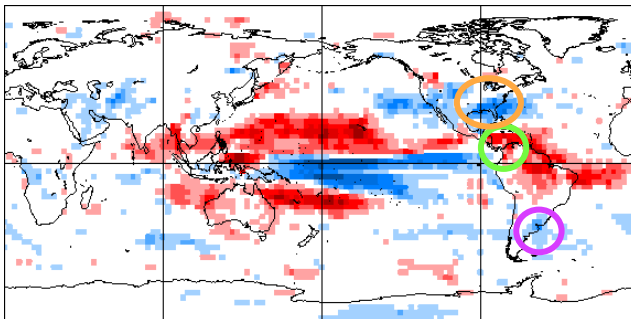
DJF
2010-11
issued
1 Mar 2010



JFM
2011
issued
1 Apr 2010



FMA
2011
issued
1 May 2010



Lead 9 months

Friday, December 24th 2010 - 08:06 UTC

24 December 2010

Uruguay under agriculture "state of emergency" because of lack of rains

The Uruguayan government declared Thursday an "agriculture state of emergency" because of the drought situation to the north of the country.

Bloomberg

20 January 2011

Argentina's Corn Crop Forecast Cut 4.9% on Drought

January 20, 2011, 2:11 PM EST

The Telegraph

19 April 2011

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Colombia floods are 'unprecedented tragedy'

Torrential rain unleashed by the La Nina weather system has flooded the country, killing hundreds and forcing millions from their homes.

What's next?

- Increased ensemble size 20 → 40
 - Increased horizontal resolution T63 → T127?
 - Assimilate CMC NEMOVAR ocean data
 - Assimilate land surface analysis
 - Sea ice thickness initialization
 - GEM - NEMO coupled model
- + New products: ocean, climate indices, sea ice,