Environment Canada Environnement Canada

Canada

The intraseasonal forecast project

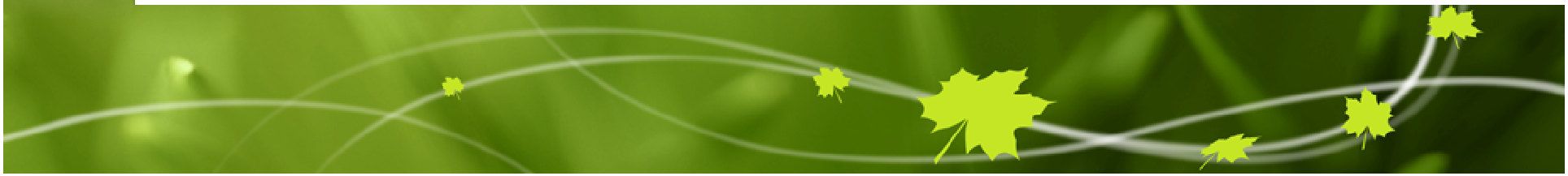
Hai Lin

Collaborators: G. Brunet, B. Dugas, J.-S. Fontecilla

Thanks to: M. Charron, P. Houtekamer, N. Gagnon, K. Winger, X. Deng, B. Brasnett, A. Methot, B. Denis, and more

RPN seminar

December 4, 2009



Outlines

- MJO influence

- Intraseasonal forecast project

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- MJO influence
  - on Canadian surface air temperature
  - on Canadian precipitation

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- MJO influence
  - on Canadian surface air temperature
  - on Canadian precipitation

- Intraseasonal forecast project
  - Monthly forecasts --- based on EPS
  - 24-year hindcast --- with GEMclim

Difficulty in extended-range forecasting

- Target range: 7-30 days
- Growth of initial error
- Time scale too long to have memory of initial condition, and too short for a boundary anomaly to take effect
- Lack of understanding of the dynamics

The Madden-Julian Oscillation (MJO)

- Discovered by Madden and Julian (1971). Spectrum analysis of 10 year record of SLP at Canton, and upper level zonal wind at Singapore. Peak at 40-50 days.
- Dominant tropical wave on intraseasonal time scale
- 30-60 day period, wavenumber 1~3
- propagates eastward along the equator (~5 m/s in eastern Hemisphere, and ~10 m/s in western Hemisphere)
- Organizes convection and precipitation

Vertical cross section

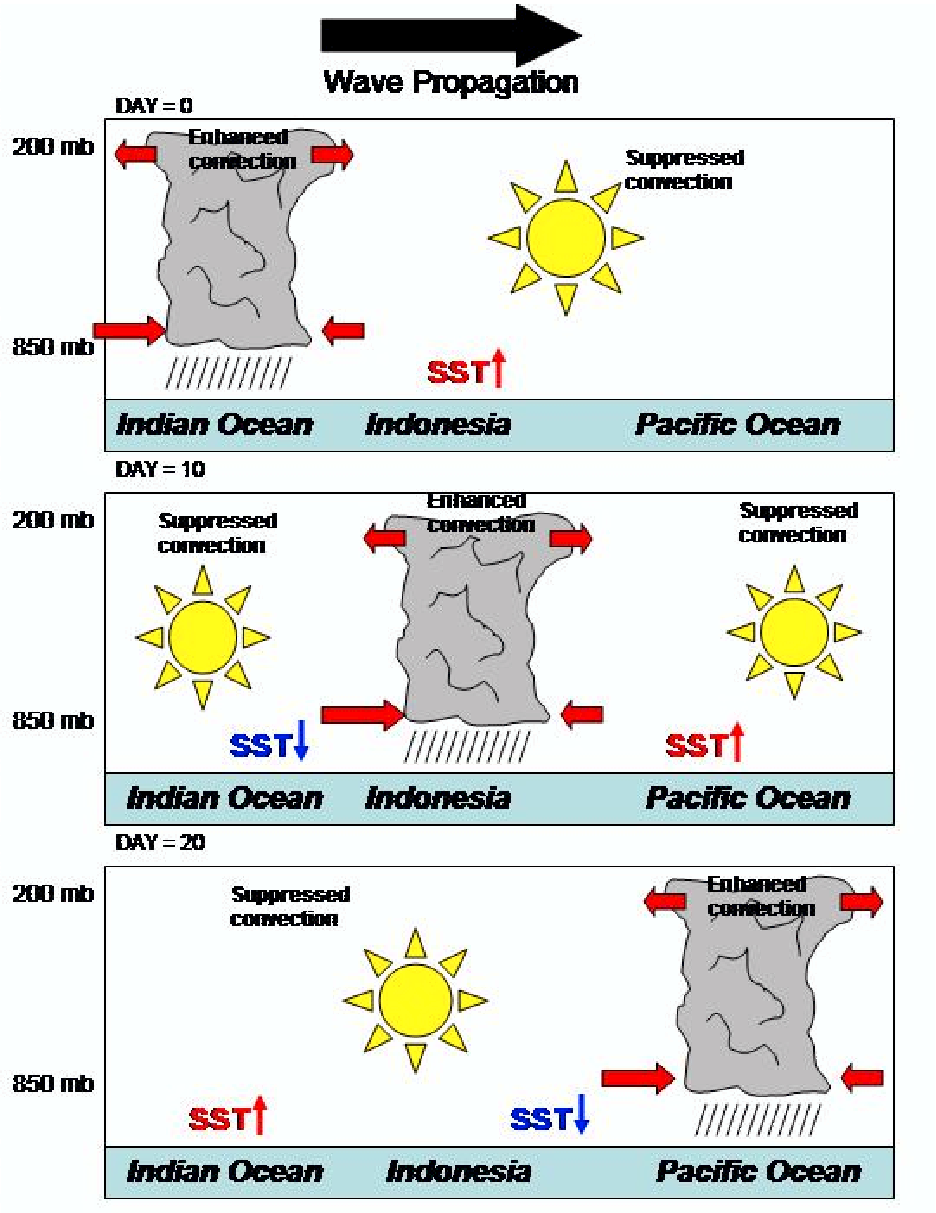
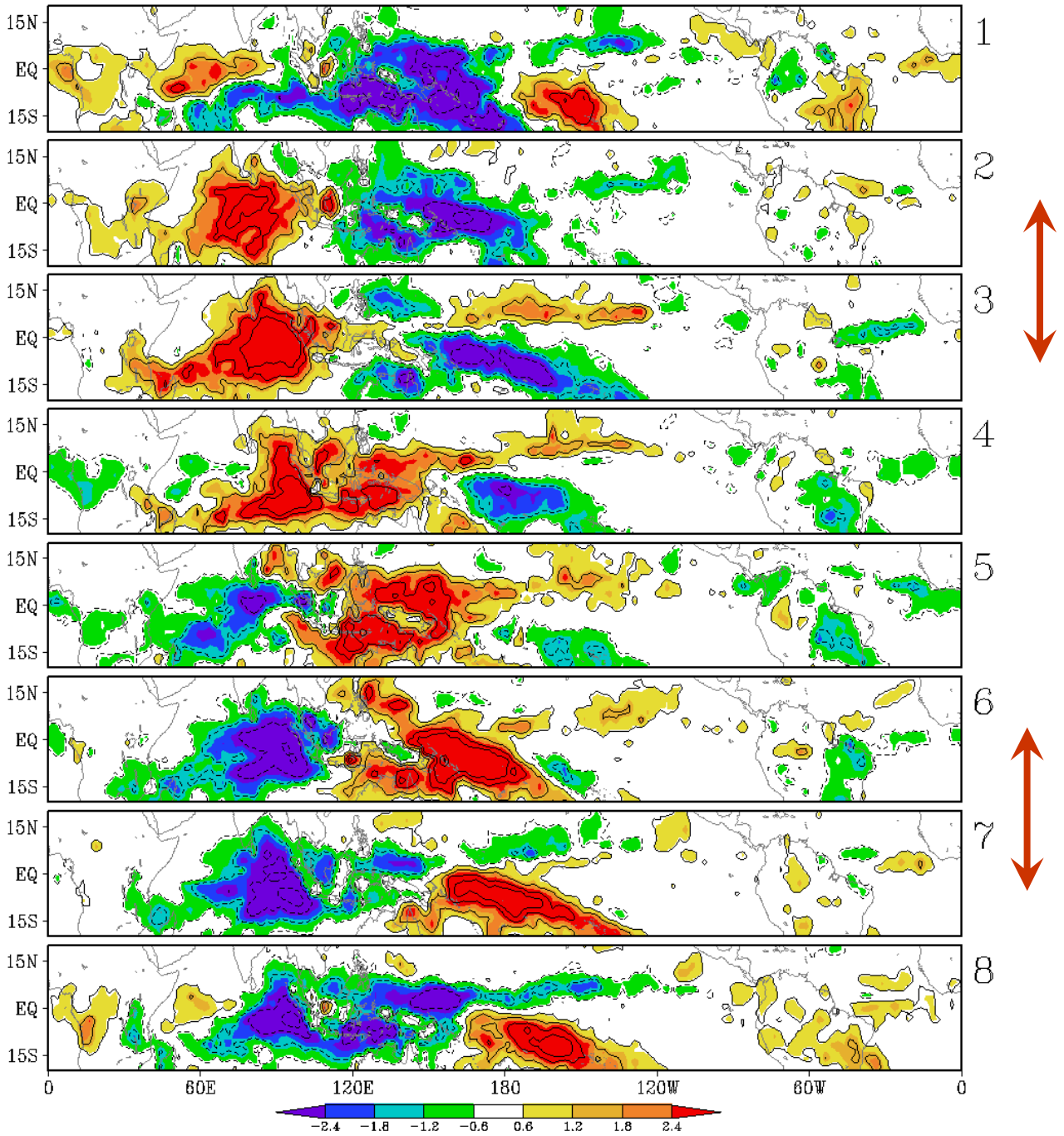


Figure 1: Equatorial vertical cross section of the MJO as it propagates from the Indian Ocean to the western Pacific. Red arrows indicate direction of wind and red (blue) SST labels indicate positive (negative) SST anomalies respectively. Figure adapted from Madden and Julian, 1971; 1972.

Composites of tropical

Precipitation rate for 8 MJO phases.

Xie and Arkin pentad data, 1979-2003



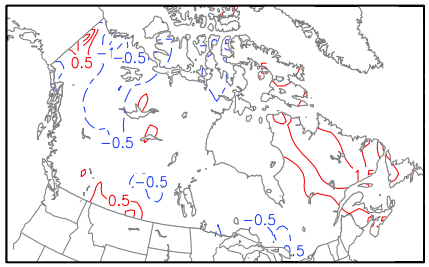
MJO influence on Canadian surface air temperature (SAT)

- Homogenized Canadian historical daily surface air temperature (SAT) --- 210 relatively evenly distributed stations across Canada (Vincent et al. 2002, JCLIM)
- 26 winters (DJF) 1978/80 to 2004/25
- All data grouped into pentads

Lagged composite of SAT for each MJO phase

(lag in pentad)

a) PHASE 1 lag=0



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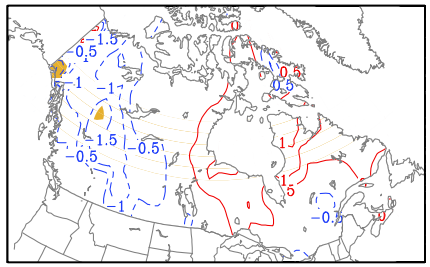

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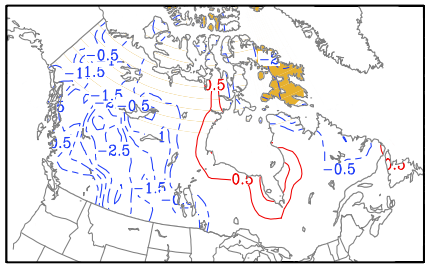

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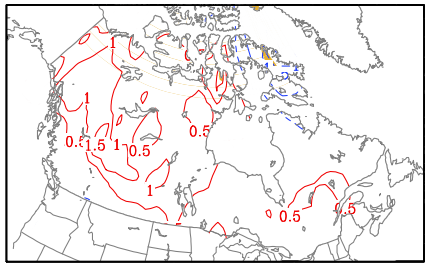

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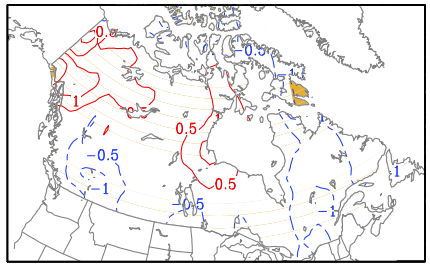

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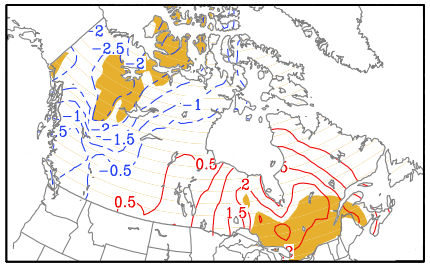

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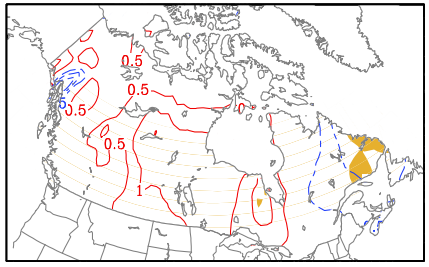

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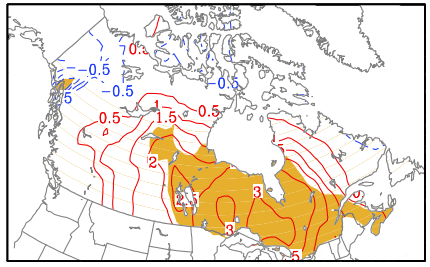

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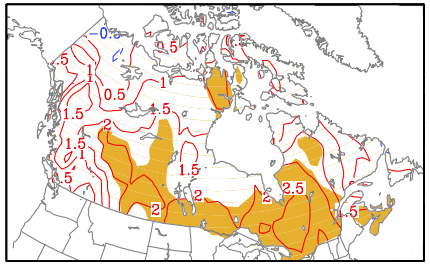

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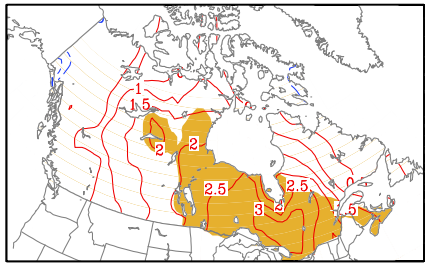

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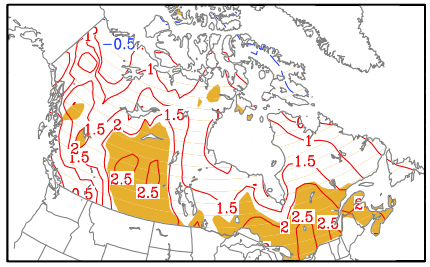

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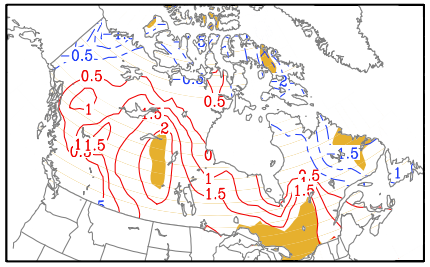

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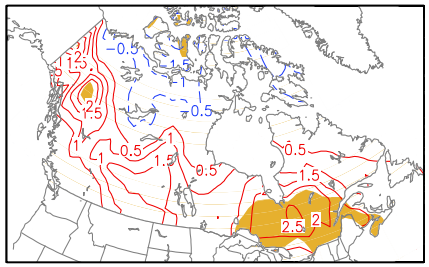

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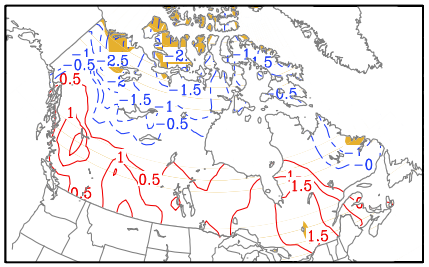

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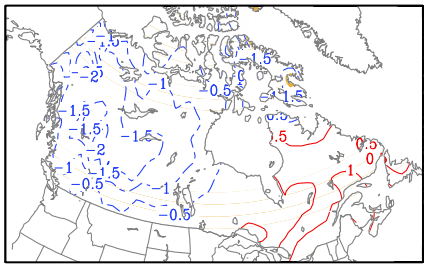

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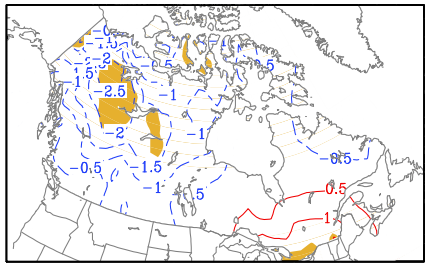

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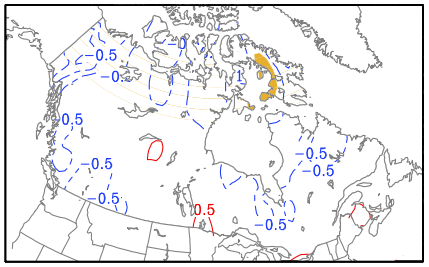

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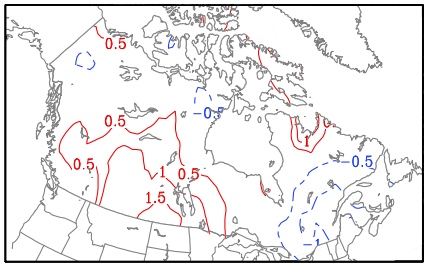

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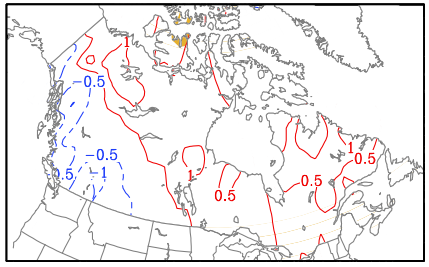

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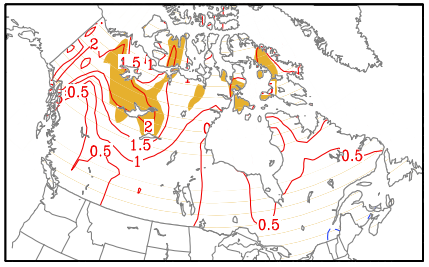

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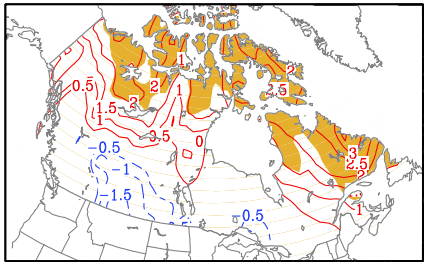

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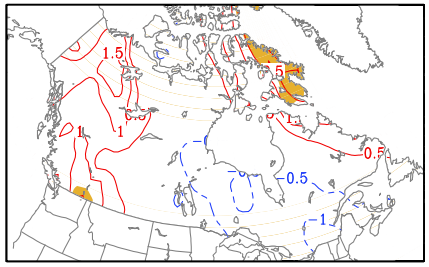

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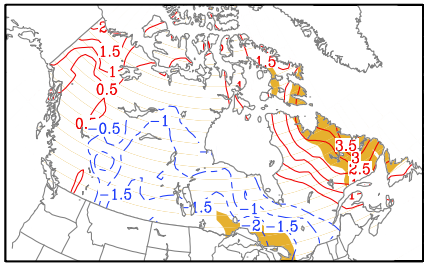

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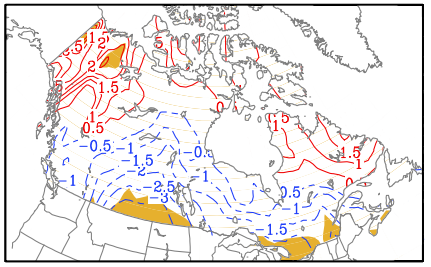
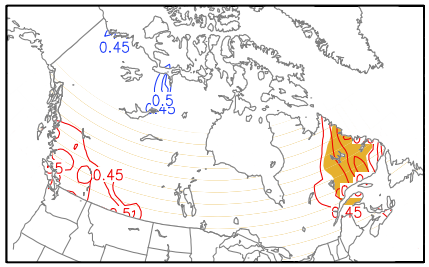


Lagged probability composite for each MJO phase

- Three categories: above normal, near normal and below normal
- Each category has 33% average probability

a) PHASE 1 lag=0



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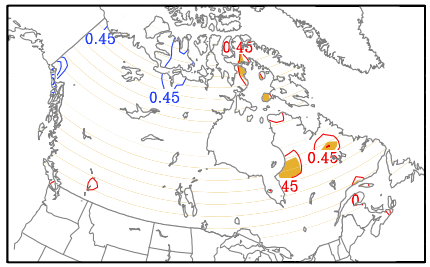

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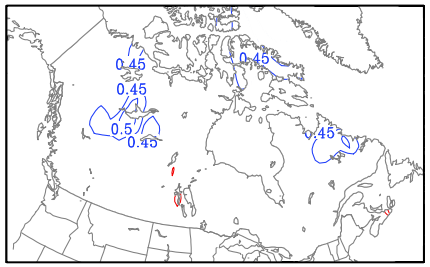

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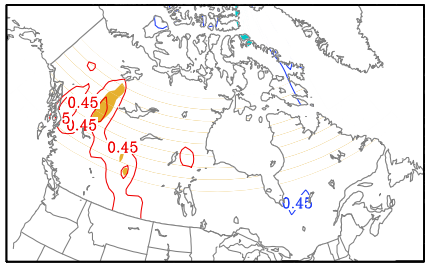

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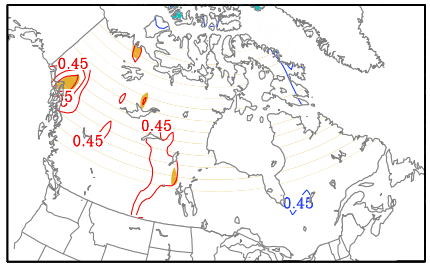
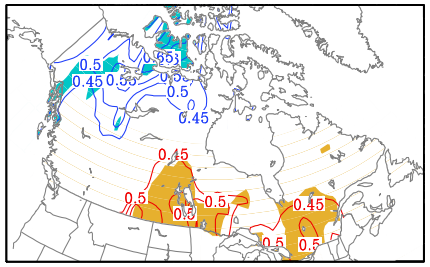


f) PHASE 2 lag=2



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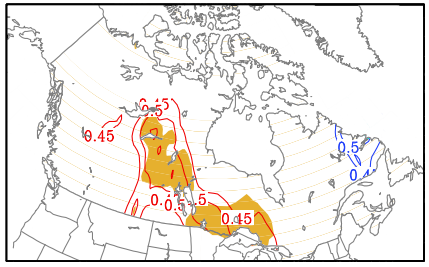

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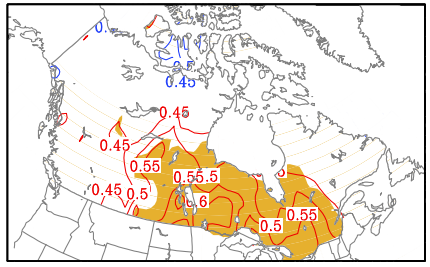

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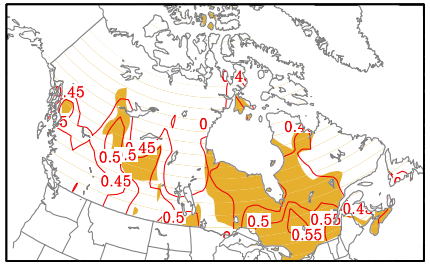

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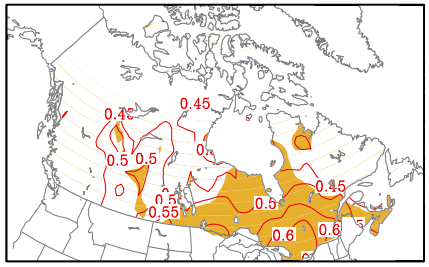

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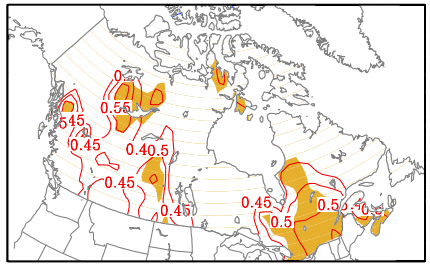

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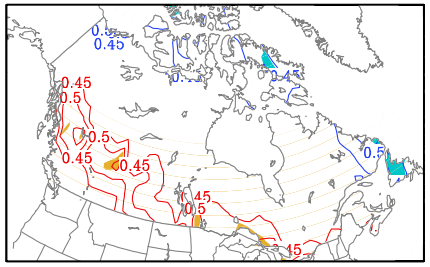

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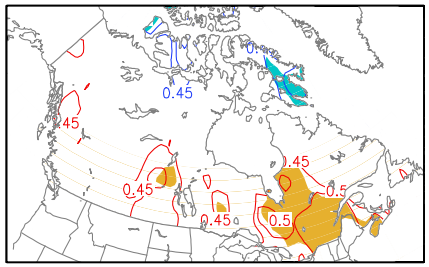

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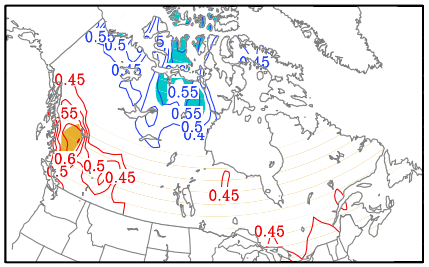

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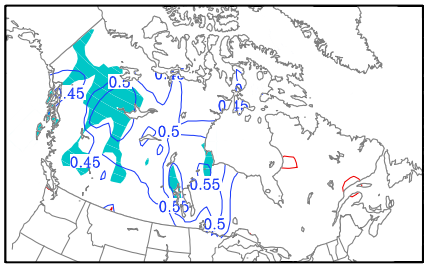

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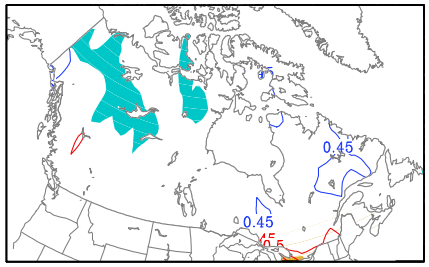

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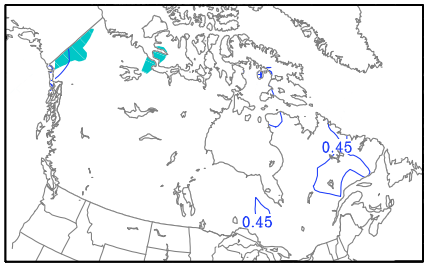

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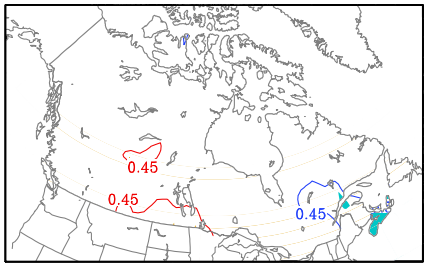

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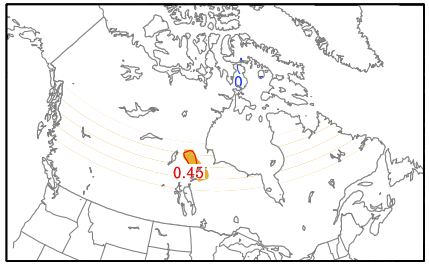

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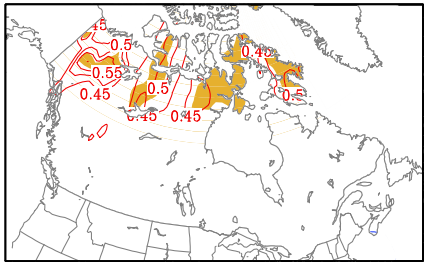

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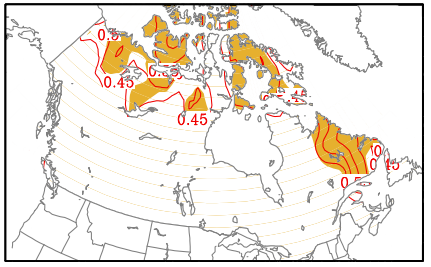
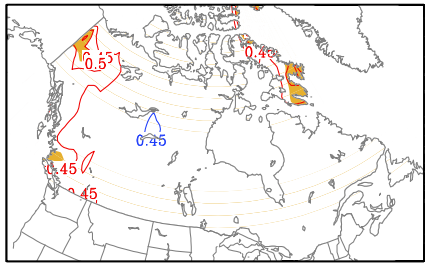


v) PHASE 8 lag=0



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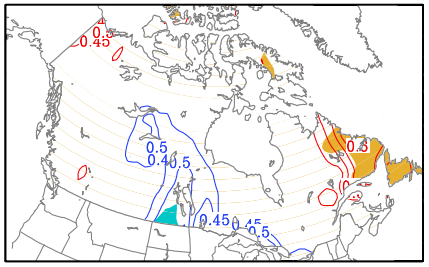

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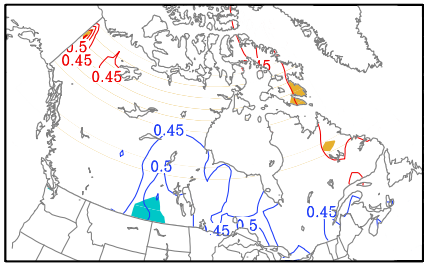
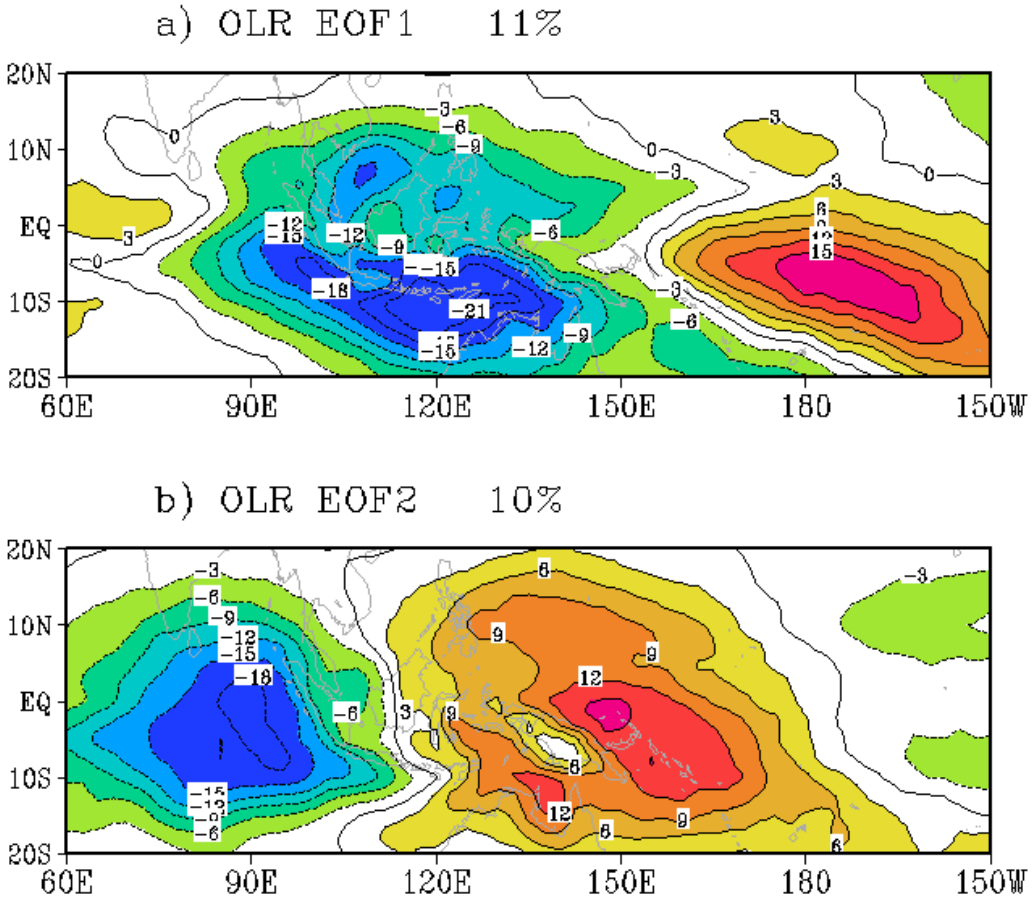


MJO influence on SAT

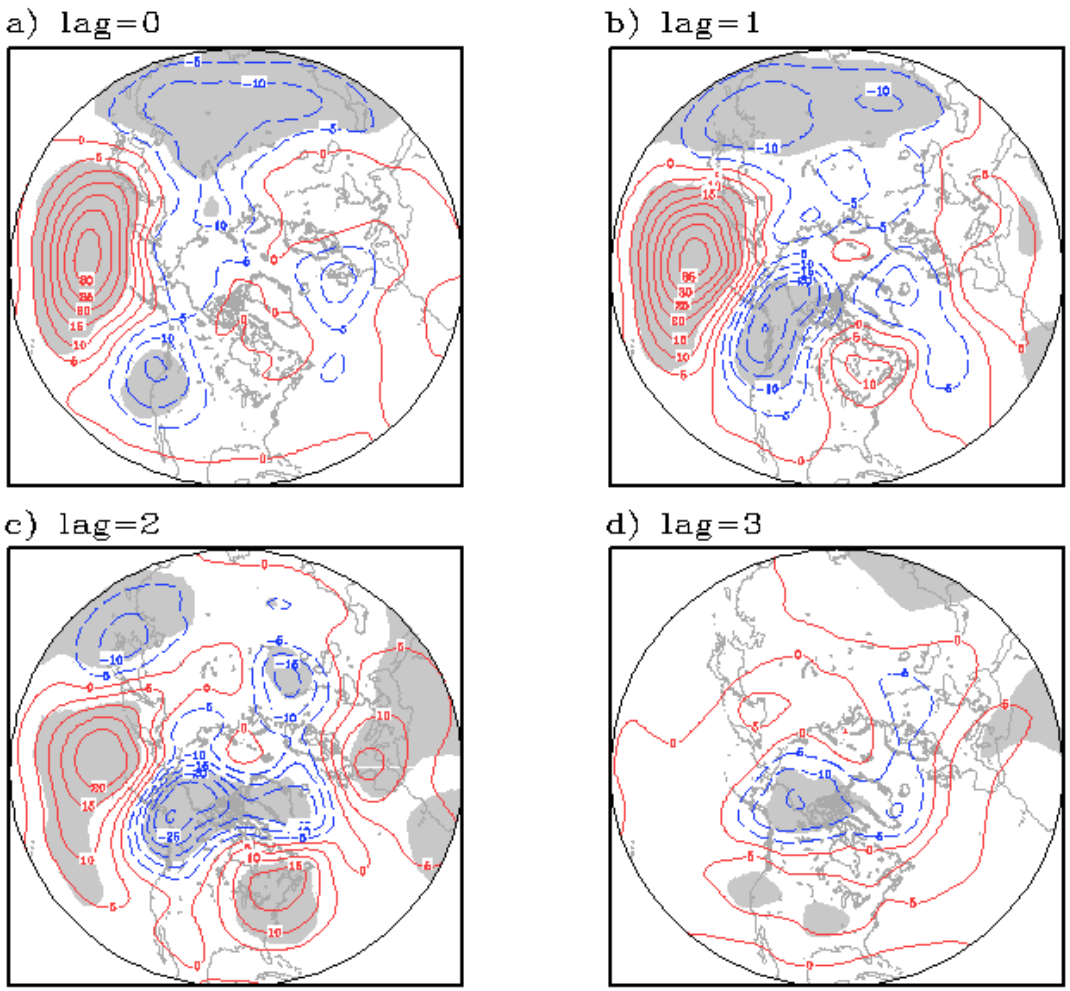
- Significant positive SAT and high probability of above normal events in central and eastern Canada 5-15 days following MJO phase 3
- A positive SAT anomaly appears over a large part of northern and northeast Canada 5-15 days after MJO phase 7
- MJO phase could be a useful predictor for Canadian SAT extended-range forecasts

Extended-range SAT forecast

- In addition to the phase, take into account the amplitude information of MJO
- An alternative definition of MJO index
- EOF of OLR pentad data in winter

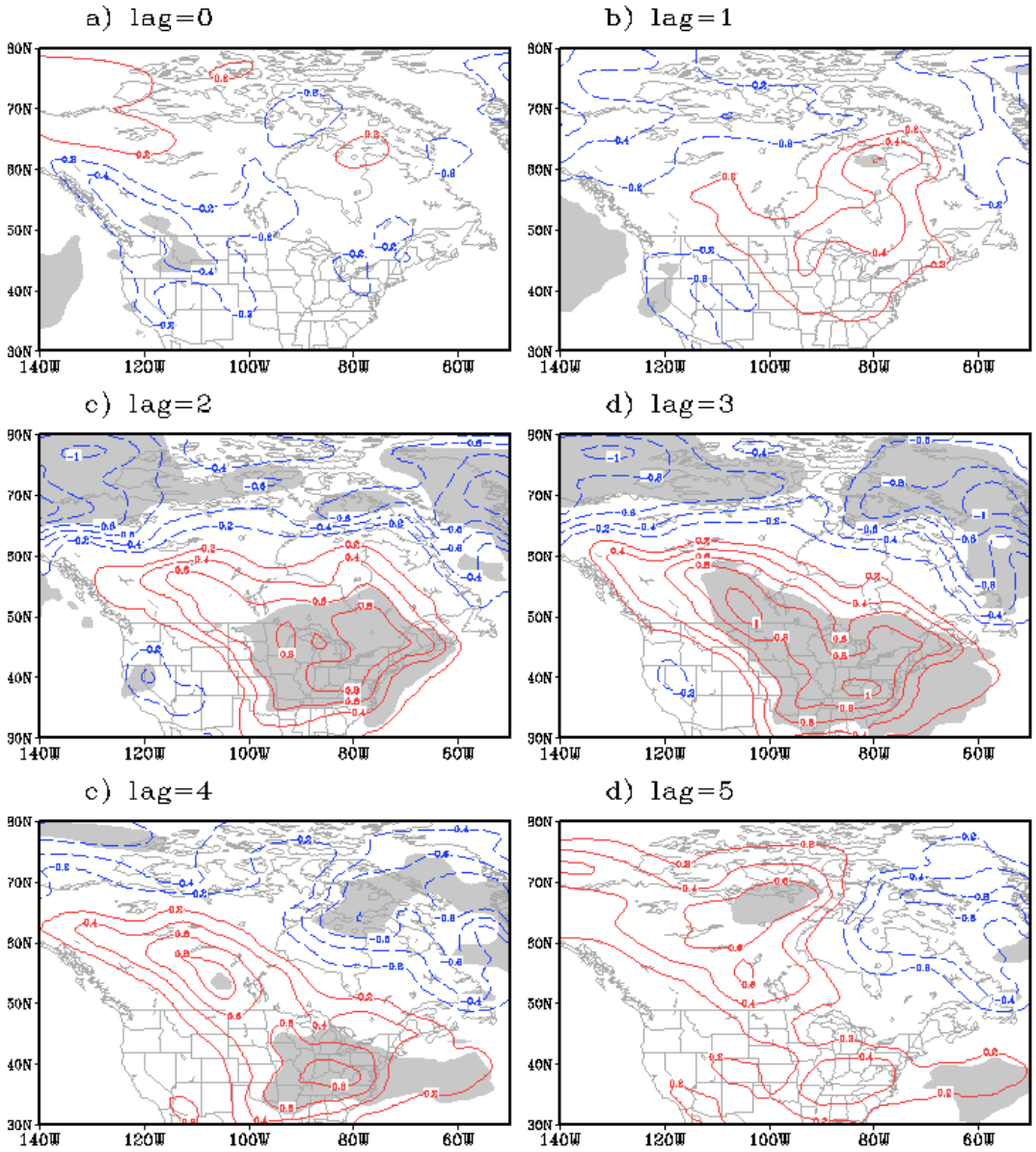


Correlation when PC2 leads PC1 by 2 pentads: 0.64



Z500 regression to PC2

T2m regression to PC2

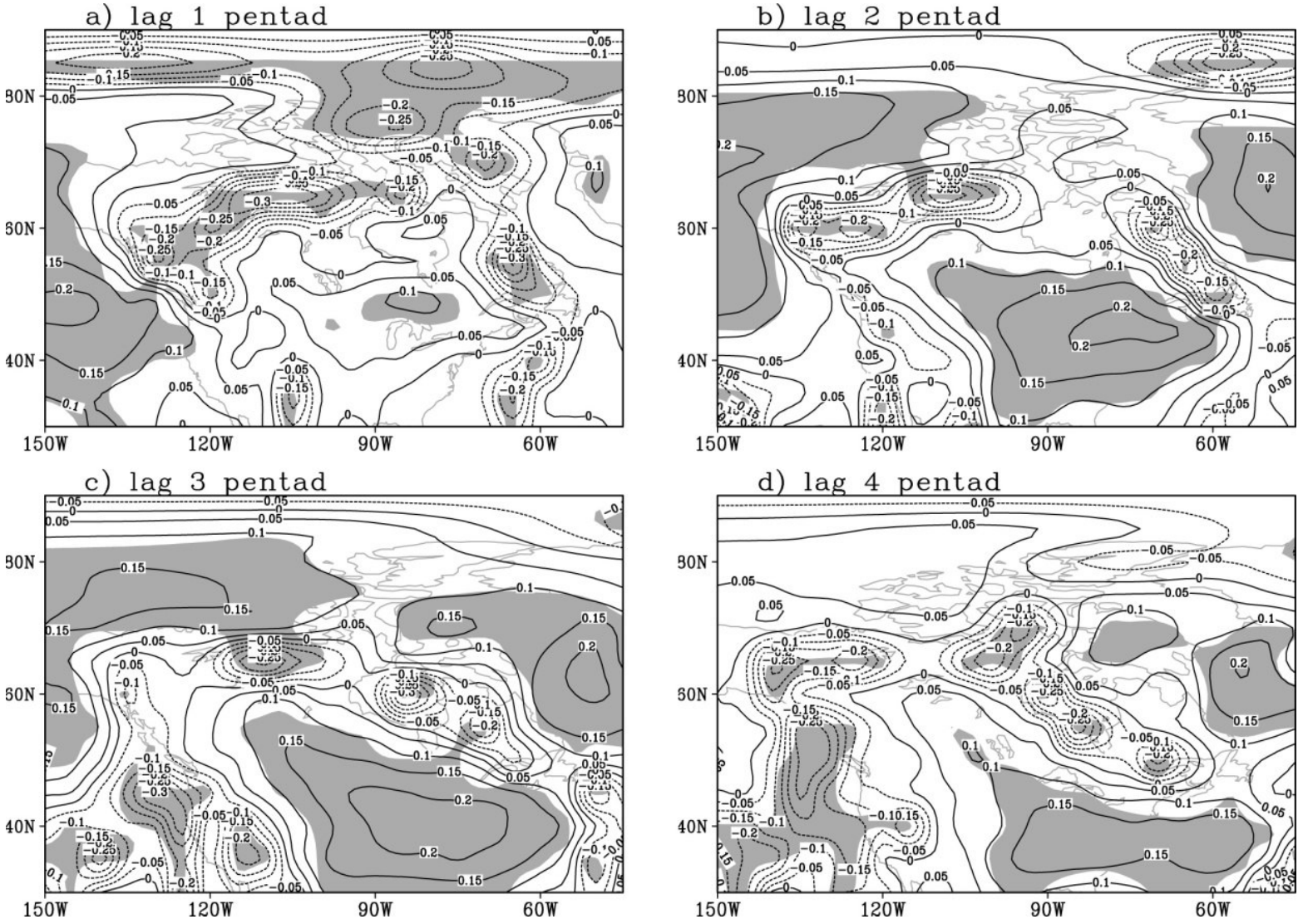


A very simple statistical model

- Linear regression with PC2 as the only predictor

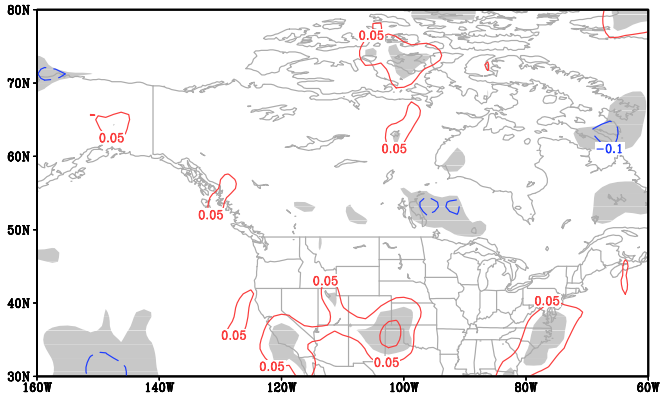
$$T = a\,PC2 + b$$

Forecast skill for SAT in North America winter

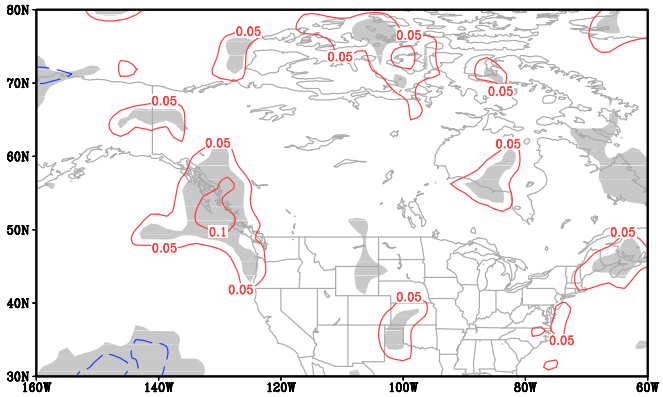


MJO influence on Canadian precipitation

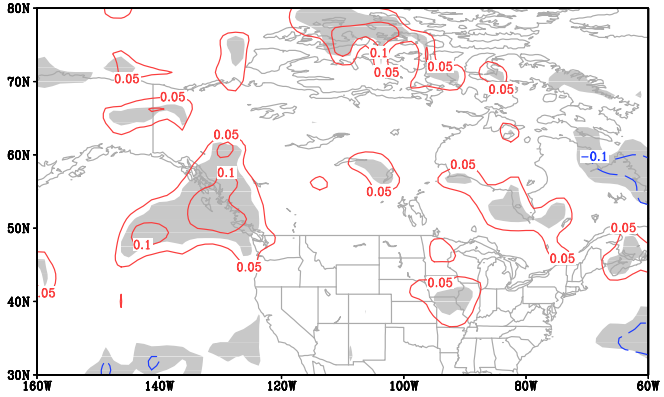
a) lag=0



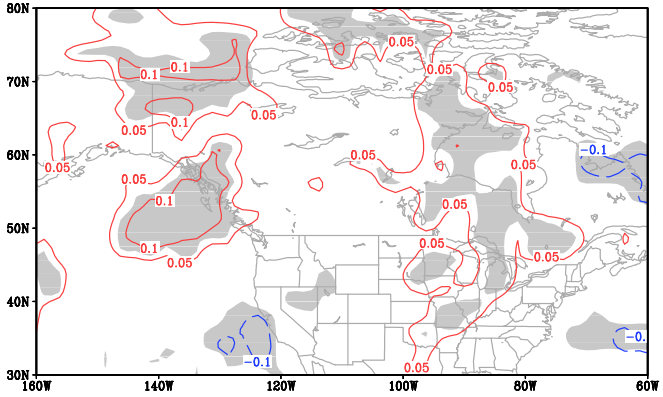
b) lag=1



c) lag=2



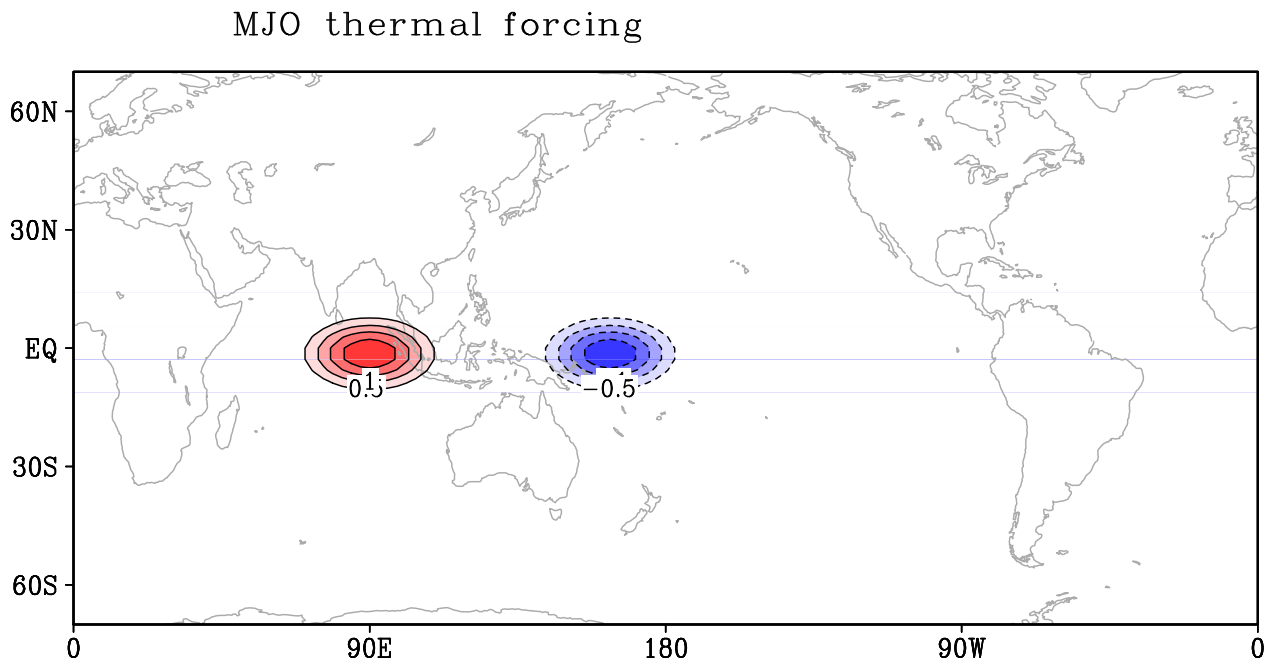
d) lag=3



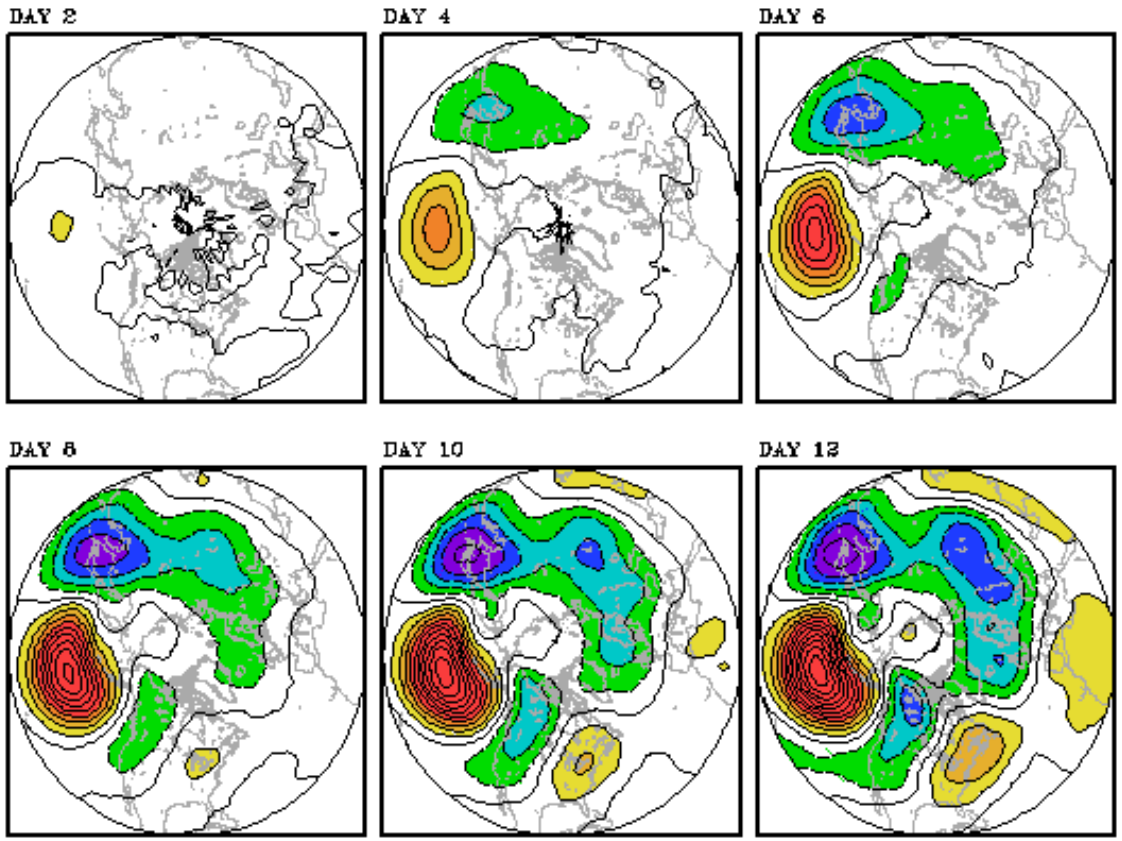
Normalized Precip Rate regression to PC2

Mechanism

- Primitive equation GCM
- T31, L10
- Linear integration, winter basic state
- Tropical thermal forcing similar to MJO phase 3 (or OLR EOF2)

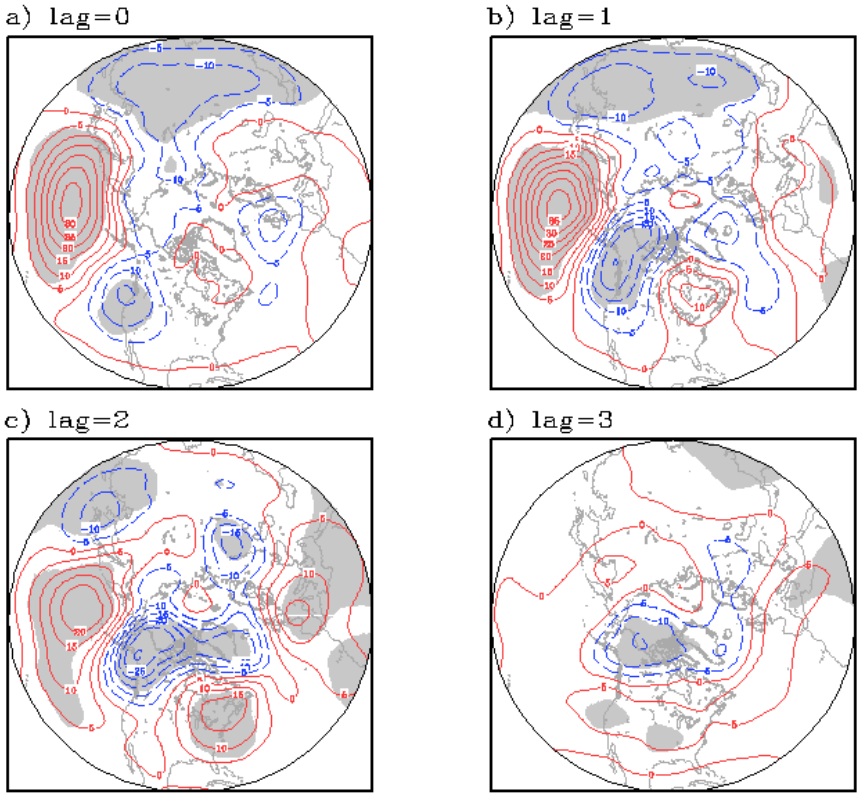

MJO thermal forcing
60N
30N
EQ
30S
60S
0
90E
180
90W
0
0.5
−0.5

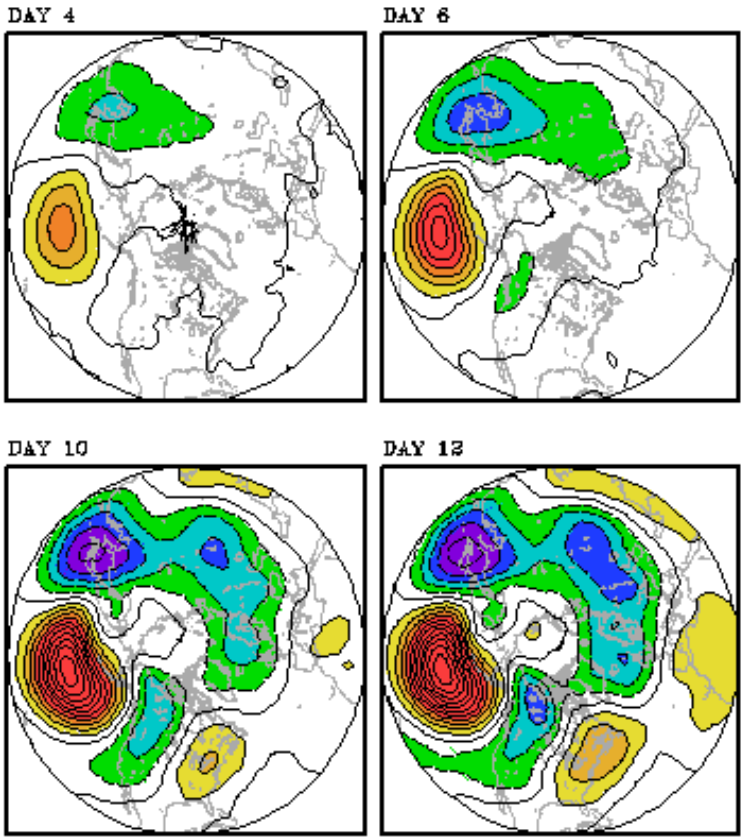
500 hPa geopotential height response



Interval: 10 m

500 hPa geopotential height response



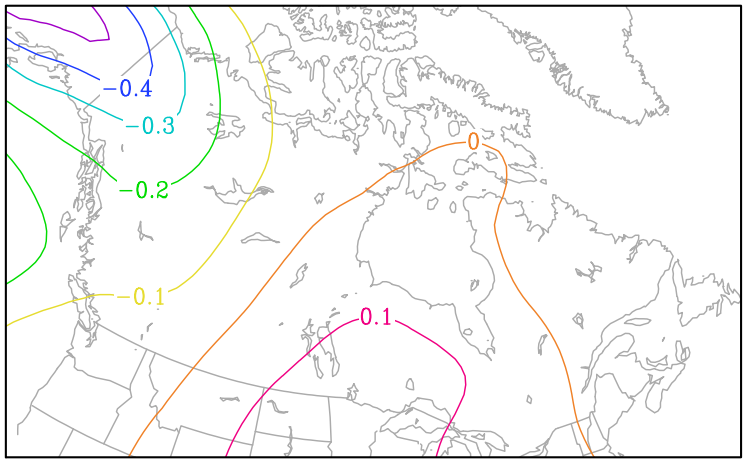


Observations

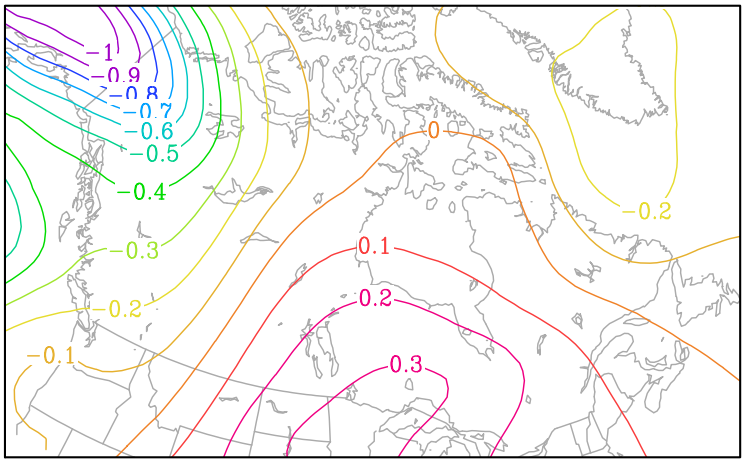
Model result

T950 response

a) Day10 T950 response



b) Day15 T950 response



Further dynamic problems

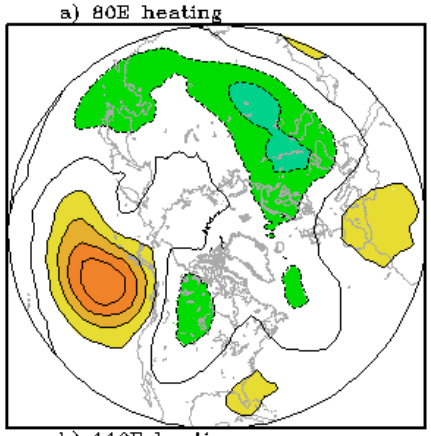
- Sensitivity to location of forcing --- why the response to a dipole heating is the strongest?

Why the response to a dipole heating is the strongest ?

- 16 linear experiments with a single center heating source
- Heating at different longitudes along the equator from 60E to 150W at a 10 degree interval

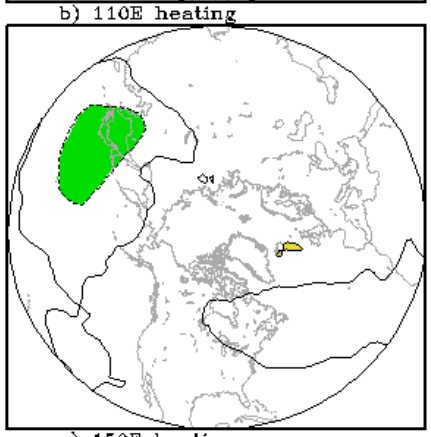
Day 10 Z500 linear response

80E

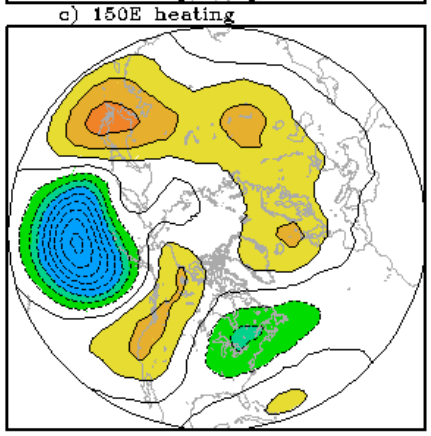


Similar pattern for heating 60-100E

110E



150E



Similar pattern for heating 120-150W

MJO influence

- Significant influence on Northern Hemisphere circulation by the MJO
- The influence in the strongest when the MJO forcing has a dipole structure
- The signal take 5-15 days to influence North America
- Rossby wave train mechanism
- Midlatitude response to MJO is sensitive to location of tropical heating and east Asian westerly jet structure
- MJO signal could be a useful predictor for extended-range forecasts

Intraseasonal forecast project

TARGET:

Range of 10-30 days, between medium-range and seasonal forecasts

PRODUCTS:

forecasts of monthly, 10-day,7-day and 5-day means (for surface air temperature, precipitation, 500 hPa height, etc)

Source of skill:

initial condition (e.g. state of MJO)
anomaly in boundary condition (e.g. SST)

Current monthly forecasting system

- Based on seasonal forecasting system
- 4 models (GEM, SEF, GCM2 and GCM3)
- persistent boundary anomaly (from last month)
- 10 members for each model
- 12-hour lagged initial conditions

Main shortcoming: initial conditions

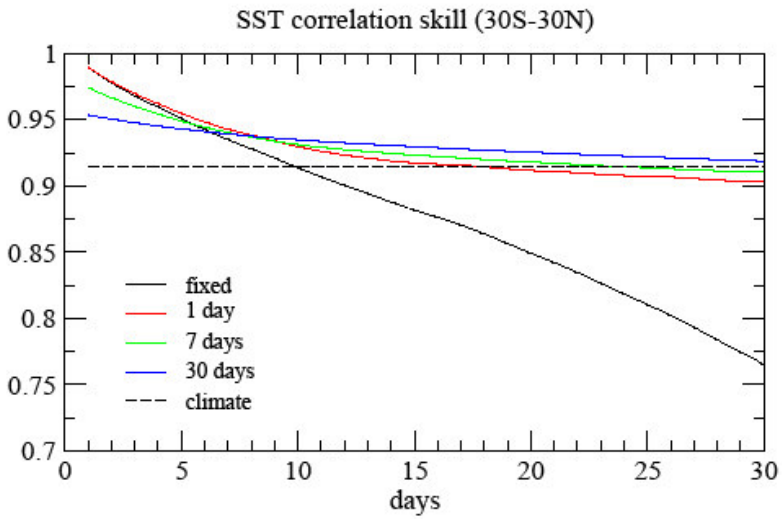
Current medium range forecasts (EPS)

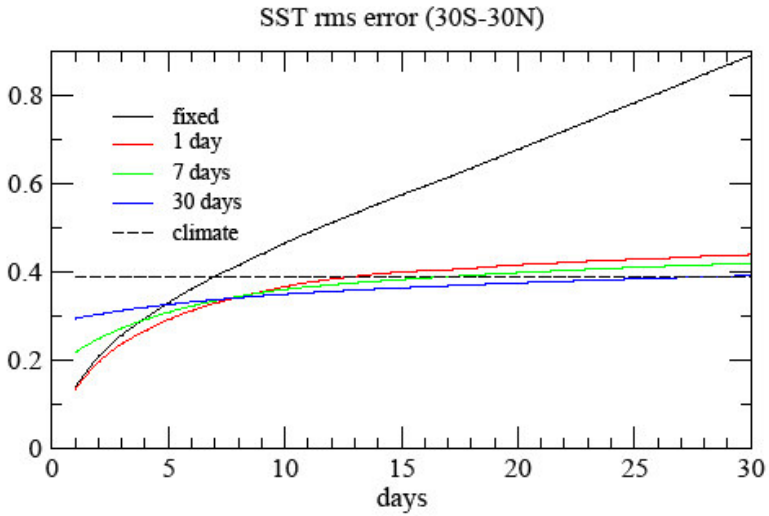
- GEM global
- 21 member, kalman filter
- fixed boundary
- 16 day integrations

Main shortcoming: boundary conditions

For forecasts beyond 16 days

SST skill with persistent anomaly





Proposed monthly forecasts

- EPS initial conditions → kalman filter generated
  21 members
- persistent SST anomaly (1-day to 30-day)
- 35 day integrations
- forecast frequency: 3 times a month (1^{st}, 11^{th}, 21^{st})
- GEM global, perturbed physics

Status:

- It is running in experimental mode since
  May 1, 2009

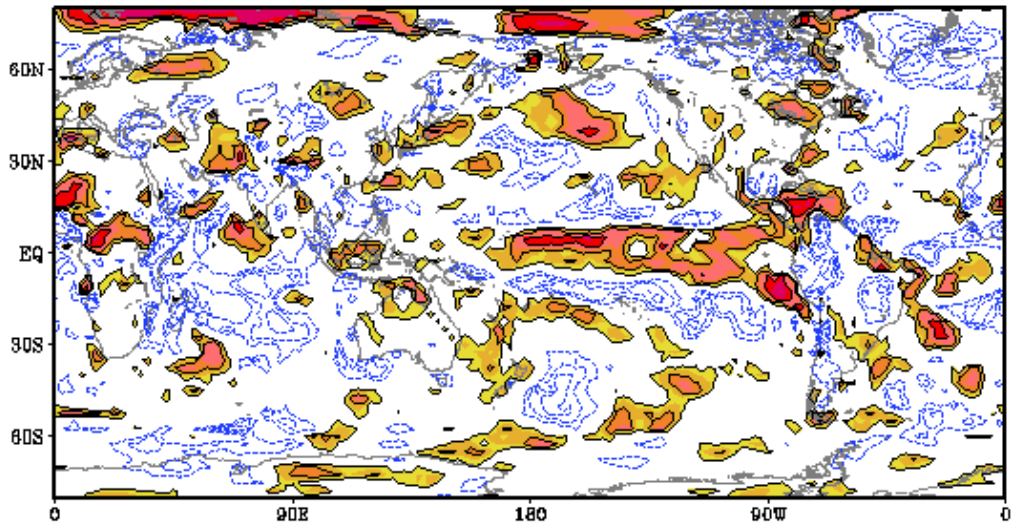
Verification for the recent 6 months,
with comparison to the current monthly forecasts

May-October 2009: 18 cases

Correlation skill for 30-day mean SAT forecast

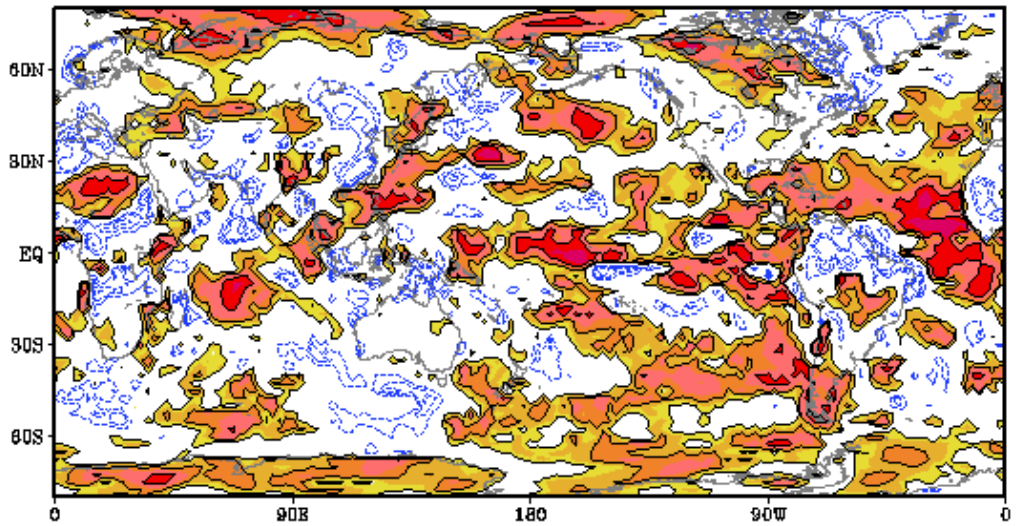
Operational

10-member GEMCLIM

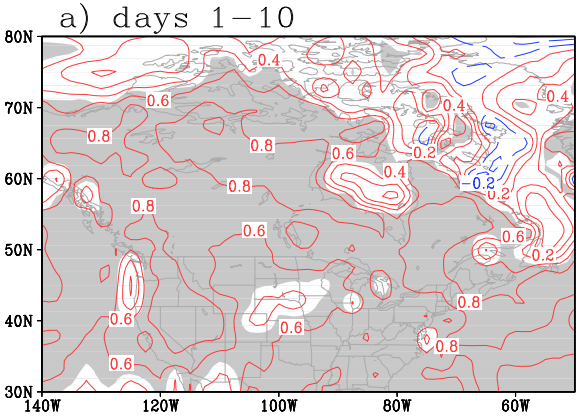


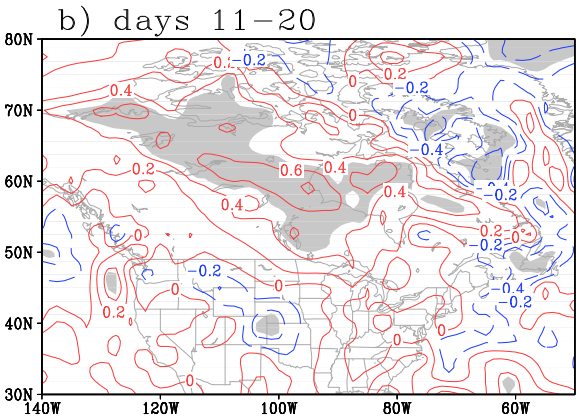
Proposed

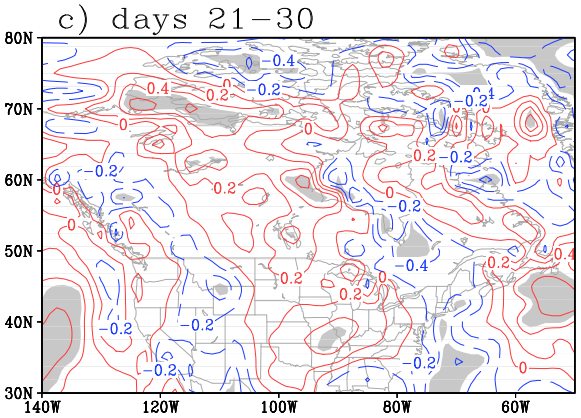
20-member



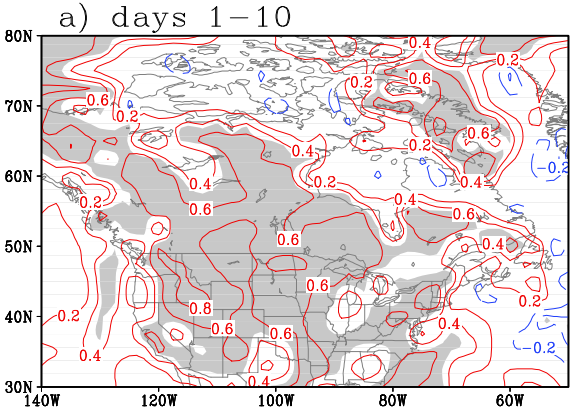
proposed

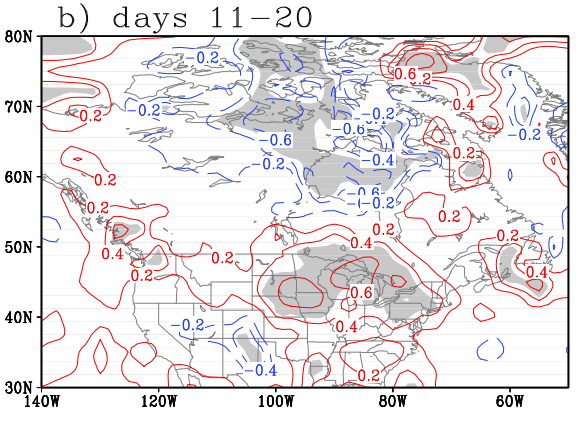


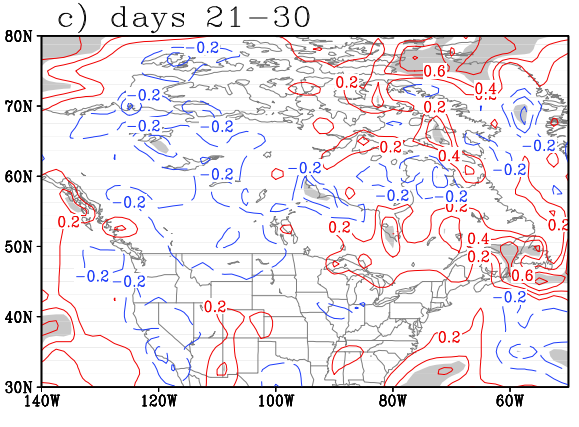




operational







Hindcast experiment for intraseasonal prediction

- Follow-up activity of the US CLIVAR MJO project (Bin Wang)
- Multi-Model ensemble (MME) approach
- 16 participating groups (ABOM, COLA, ECMWF, GFDL, IAP, JAMSTEC, NASA, NCEP, SNU, IPRC, UM, FSU, INGV, CMC, CWB, BCC)

OBJECTIVES OF ISO HINDCAST EXPERIMENT

- Predictability on intraseasonal time scale.
- Developing optimal strategies for multi-model ensemble (MME) ISO prediction system.
- Identifying model deficiencies in predicting ISO and finding ways to improve models' convective and other physical parameterizations relevant to the ISO through development of model process diagnostics.

Hindcast by GEM

- GEM clim (same configuration as HFP2) --

  GEMCLIM 3.2.2, 50 vertical levels and 2^{o} of horizontal resolution

- 1985-2008

- 3 times a month (1^{st}, 11^{th} and 21^{st})

- 10-member ensemble (balanced perturbation to NCEP reanalysis)

- NCEP SST, SMIP and CMC Sea ice, Snow cover: Dewey-Heim (Steve Lambert) and CMC

- 45-day integrations

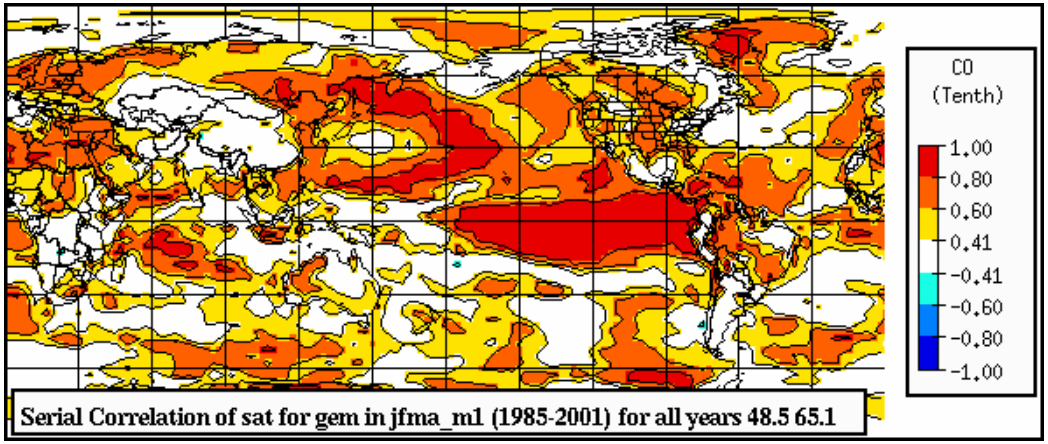
Use of GEM hindcast data

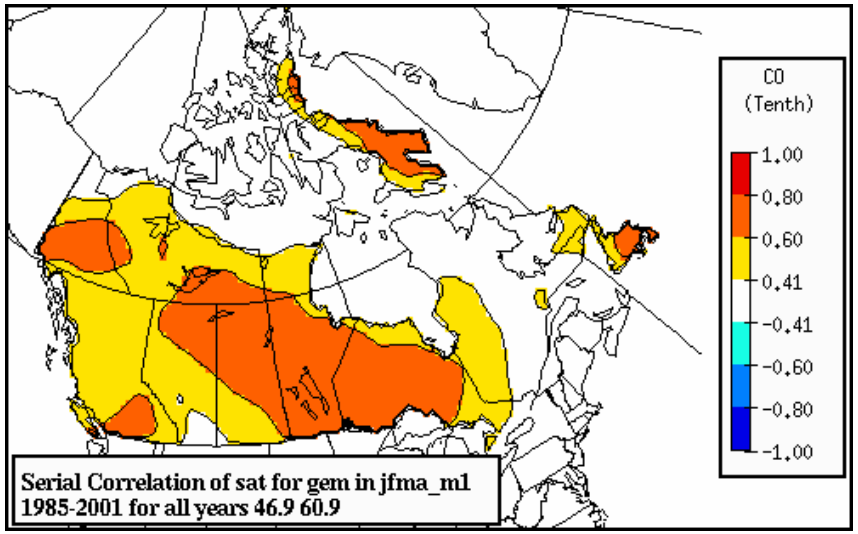
- Participation in the ISO hindcast project
- Bias correction for the newly proposed monthly forecasts

SAT Correlation skill, January

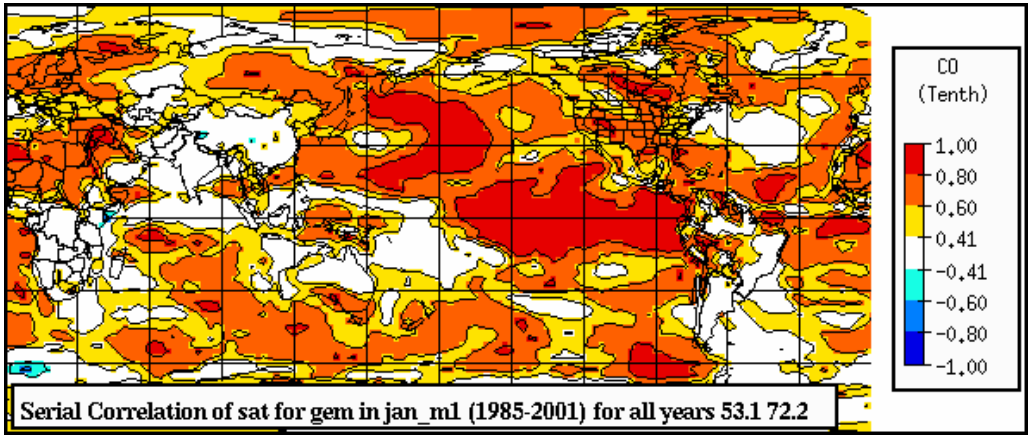
From: J. Fontecilla

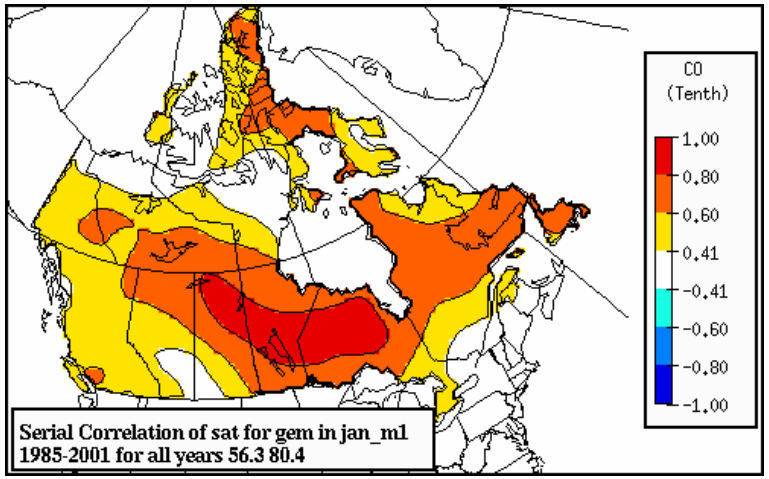
GEMCLIM HFP2





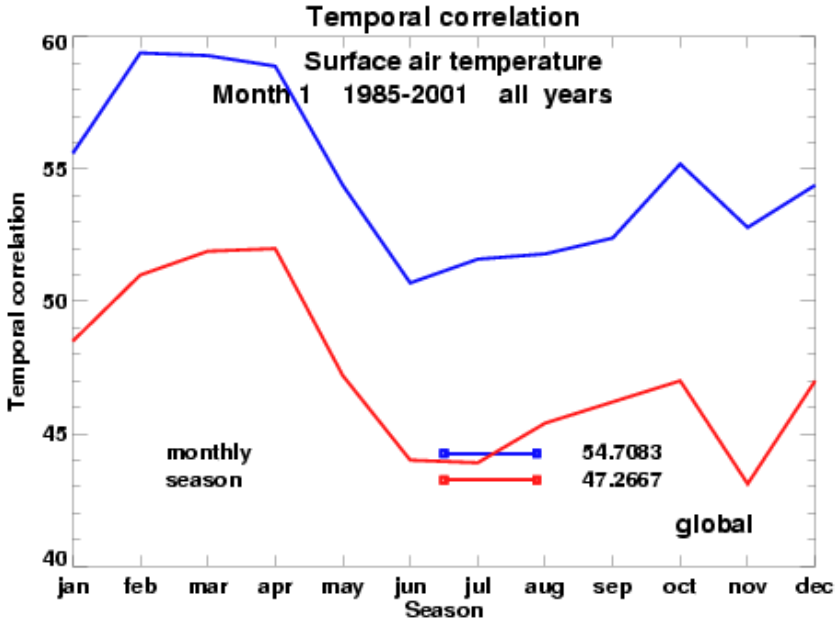
GEMCLIM monthly hindcast



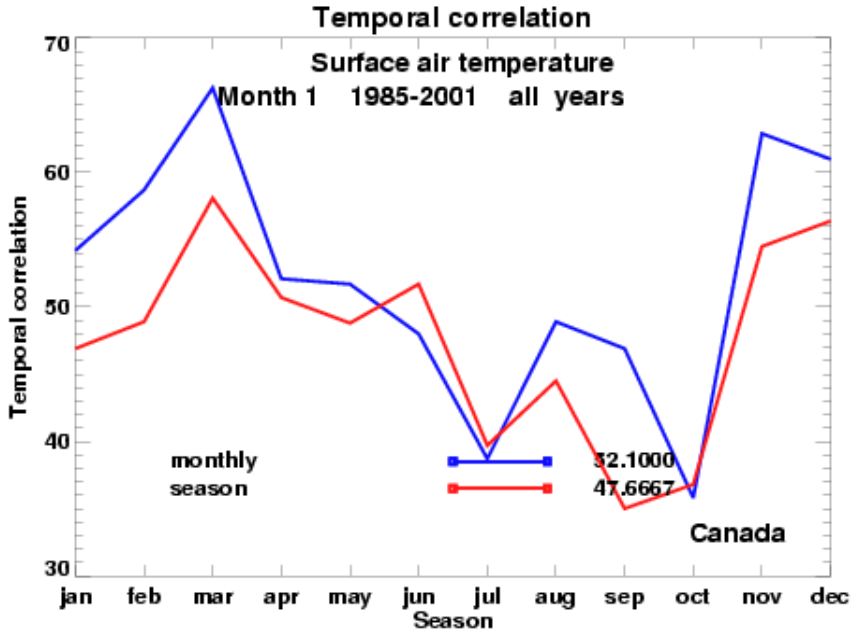


Surface air temperature

Global

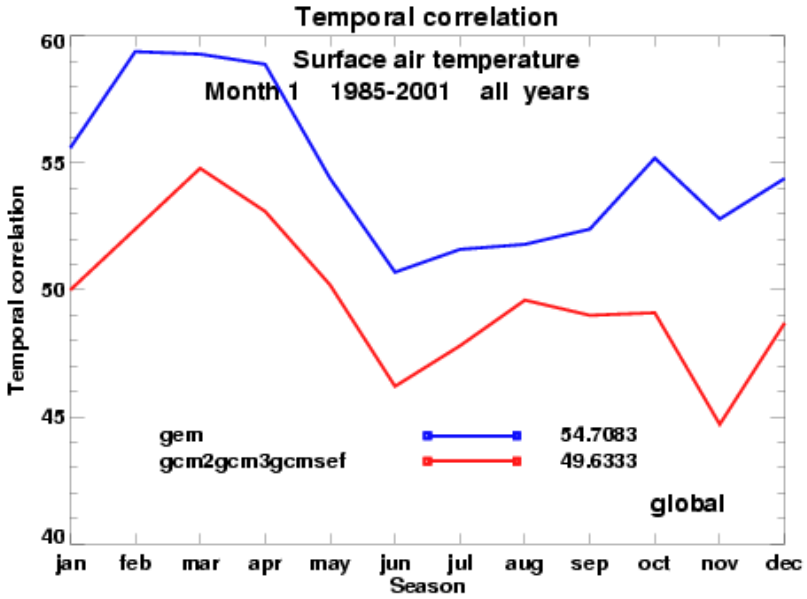


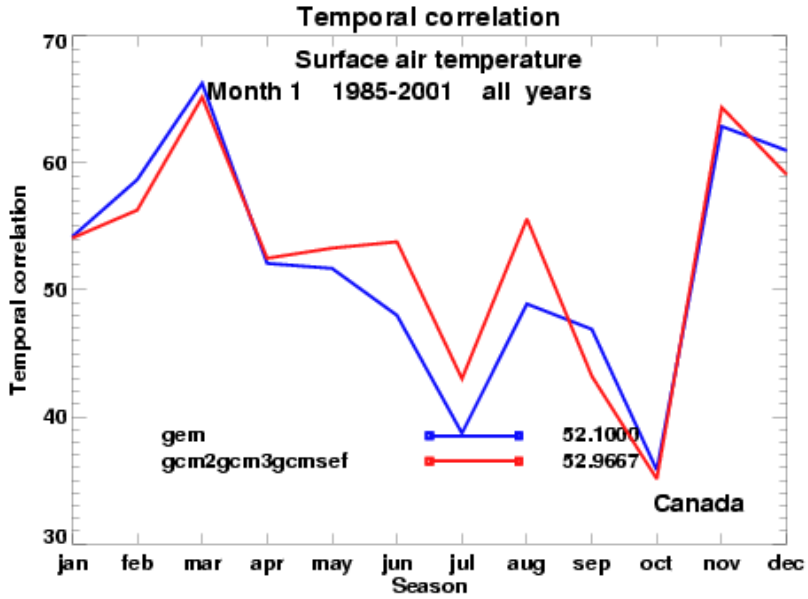
Canada



From: J. Fontecilla

New system vs. 4-models system





From: J. Fontecilla

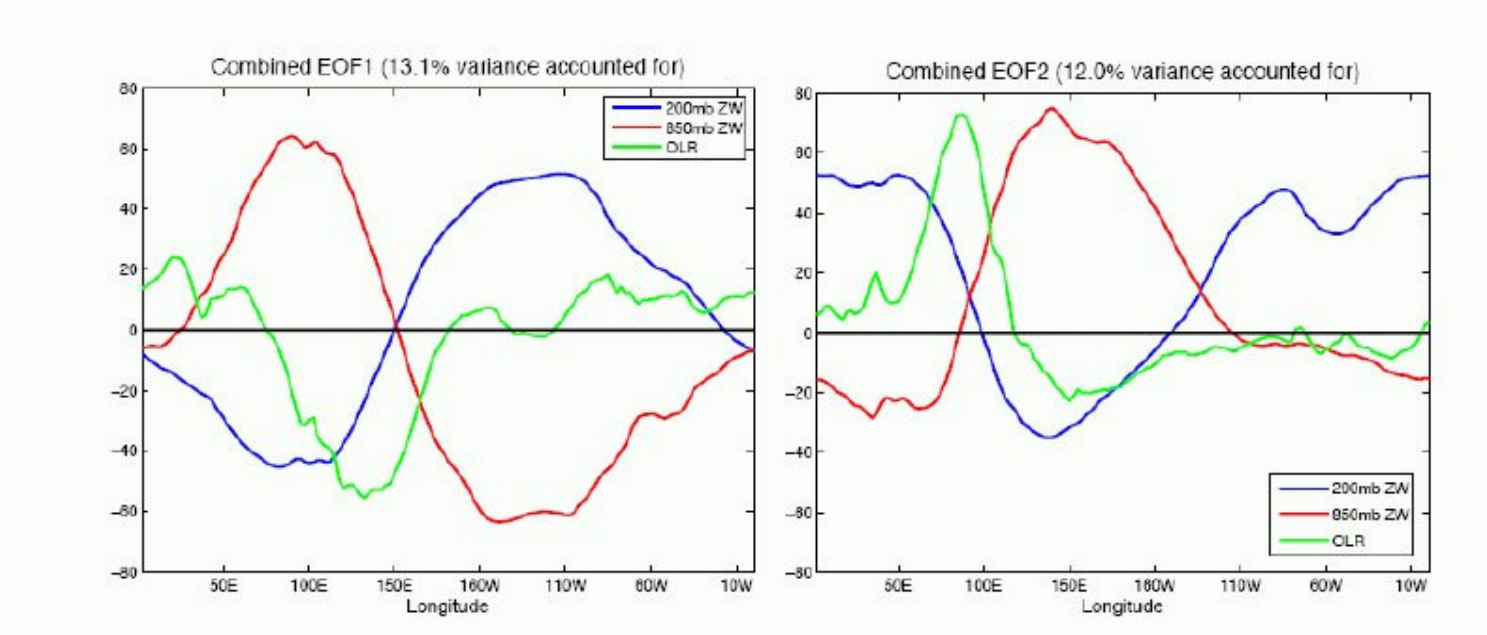
Conclusion

- A new monthly forecast system is proposed, which is running in an experimental mode
- Preliminary assessment shows much better skill than the current operational monthly forecast system
- ISO hindcast is completed
- The ISO hindcast has a skill higher than GEMCLIM of HFP over the globe and over Canada
- The ISO hindcast scores higher even than current 4-models system over the globe

Thank you!

Definition of MJO index

Combined EOF of OLR, u200 and u850 in the band of 15°S – 15°N (Wheeler and Hendon, 2004)



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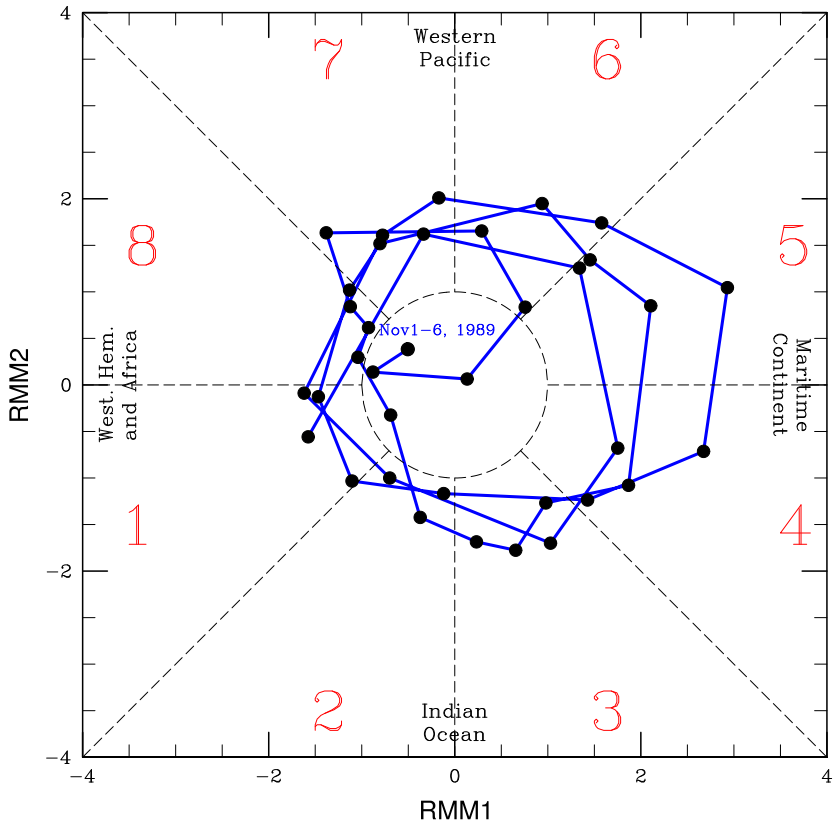


MJO index: RMM1 and RMM2

Period: 1979-2003

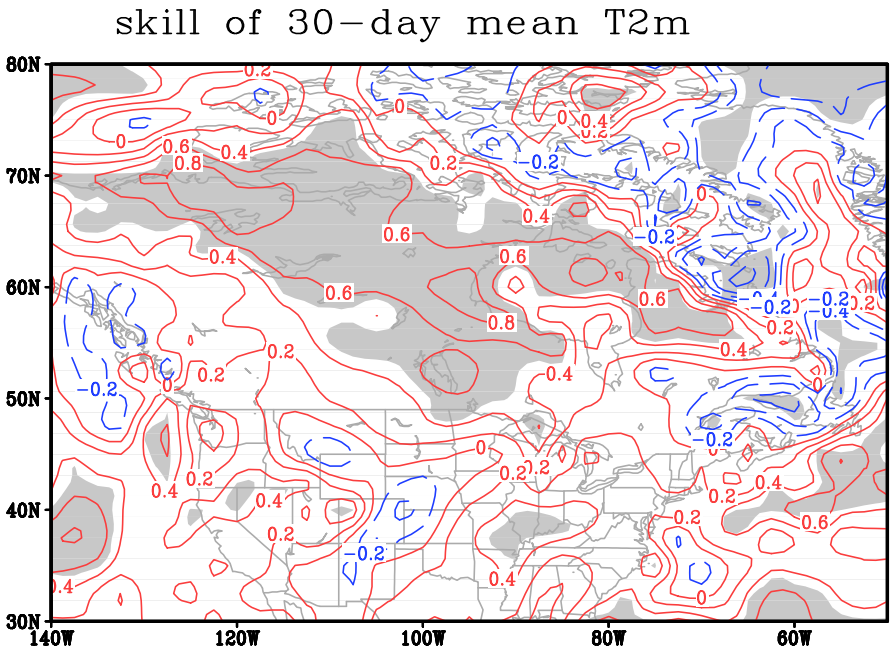
Extended winter, November to April (36 pentads)

Pentads in MJO phases

Extended winter from 1979 to 2004

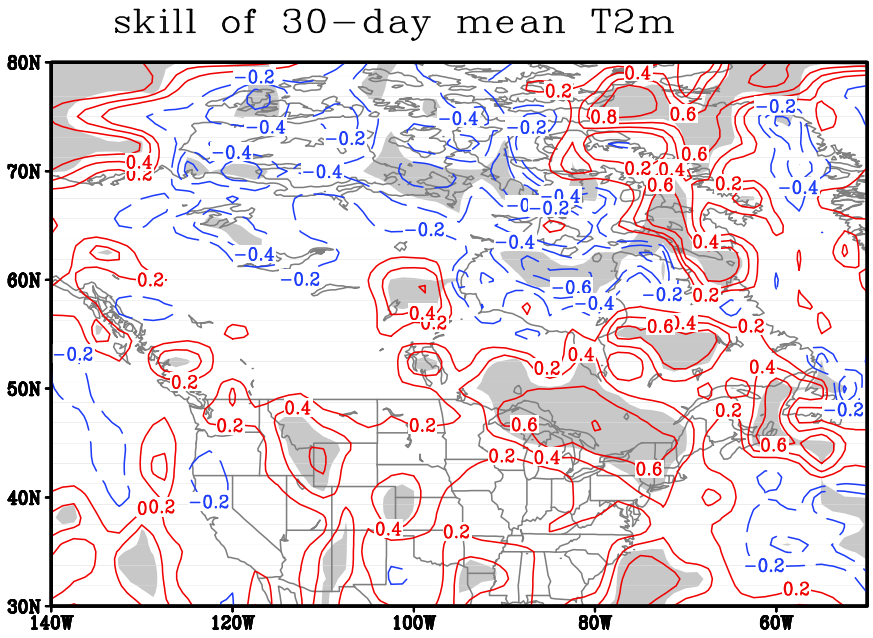
Phase	1	2	3	4	5	6	7	8
Number of pentads	55	79	78	78	63	71	87	66
Mean amplitude	1.67	1.66	1.81	1.78	1.66	1.70	1.62	1.75

SAT correlation skill



Proposed

20-member



Operational

10-member GEMCLIM