Environment Canada Environnement Canada

Subseasonal-to-Seasonal S2S Prediction Project

Overview of Subseasonal Predictability

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Aknowledgements: H. Lin, J. Methven and F. Vitart

Introduction

- A decade ago, few operational centres produced sub-seasonal forecasts. Now most operational centres have forecasting systems targeting this time range;

- Increased interest in sub-seasonal prediction by operational centres triggered by:

  - Growing demand from applications (e.g. agriculture, health, hydrology,..);

  - Progress in medium-range forecasting (1 day of predictive skill per decade). Weeks 3 and 4 are seen as the new prediction frontier;

  - Progress in prediction of some key sources of predictability.

Bridging the gap between Weather and Climate predictions

Is it an atmospheric initial condition problem as medium-range forecasting or is it a boundary condition problem as seasonal forecasting?

Some sources of predictability with a ”boundary condition problem” flavour, but … :

- Sea surface temperatures
  - Impact of Gulf Stream on storm track (Arnaud Czaja)
- Land surface conditions
  - Land surface processes (Gianpaolo Balsamo)
  - Impact of snow (Emanuel Dutra)
- Sea ice cover (Matthieu Chevallier)
- Stratospheric variability (Mark Baldwin)
- Indian monsoon (R. Krishnan)
- The Madden Julian Oscillation (Steve Woolnough), but we have a two-way MJO-NAO interaction (Hai Lin).

Bridging the gap between Weather and Climate predictions

Predictability and dynamical processes:

Rossby wave propagations, weather regimes, teleconnections …

Charney and Devore's project (JAS, 1979)

We regard our preliminary findings as useful primarily for their heuristic character, not for their detailed explanations of specific phenomena. They suggest that a stochastic, dynamical system approach, in which the location of equilibrium points, attractor sets, stable and unstable limit cycles, etc., and the study of the stochastic forcing of the system by various instabilities, will become a useful tool for investigation of large-scale atmospheric phenomena. We believe that this approach can lead to a better understanding of large-scale variability, predictability, and climate. To know that a system is in the attractor basin of a stable or metastable equilibrium is to know that it will remain for a time. To know that the system is in a state of transition is to know that it will change more rapidly and be less predictable. Climate itself becomes a question of distributions among possible equilibrium states, and climate variation a matter of how boundary changes lead to altered distributions.

Wave Activity Variability on the NH 315K isentropic surface for 24 winters: an Empirical Normal Mode (ENM)analysis

- Discrete modes have finite contributions spanning the sub-seasonal variability and the continuous modes project on the baroclinic and transient wave activity, Brunet (1994, JAS);

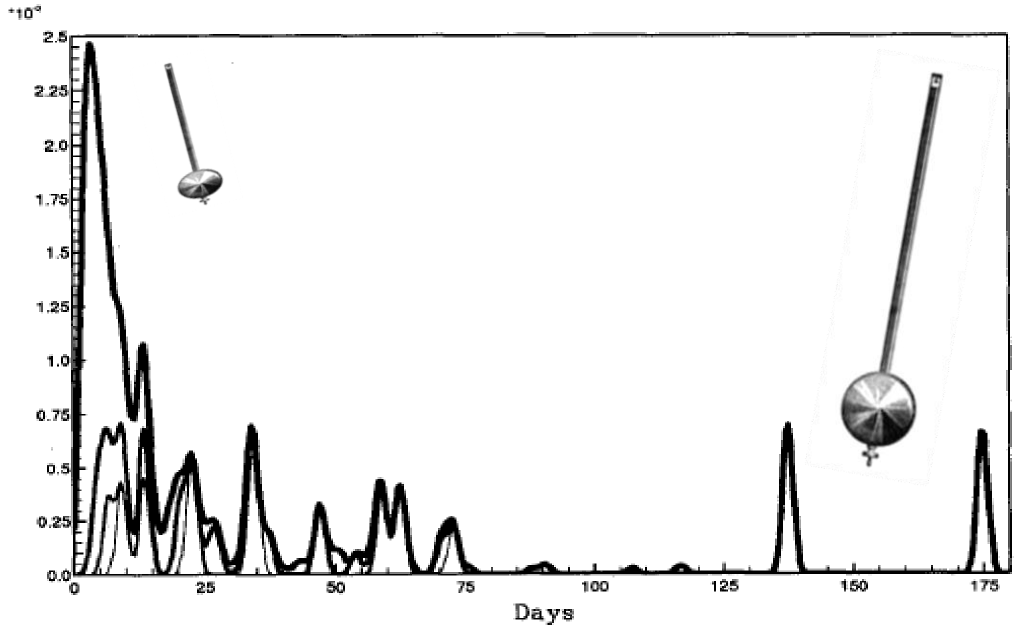


FIG. 4. Distribution of $R_{s,n}$ per day in function of the wave period for different truncations R_{min}. The solid curves correspond, from the thicker to the thinner, to R_{min} = .001, .004, .007, and .01, respectively.

Continuous spectrum (80%) **Discrete spectrum (dim. ~ 12, 20%)**

Cumulative wave activity in function of calculated intrinsic period of oscillation for each ENM

- The low frequency variability (AO, PNA, Atlantic ridge, Atlantic blockings, …) controls significantly the distribution of high-impact weather (like the Atlantic storm track).

Empirical Normal Modes (ENMs) for 24 winters

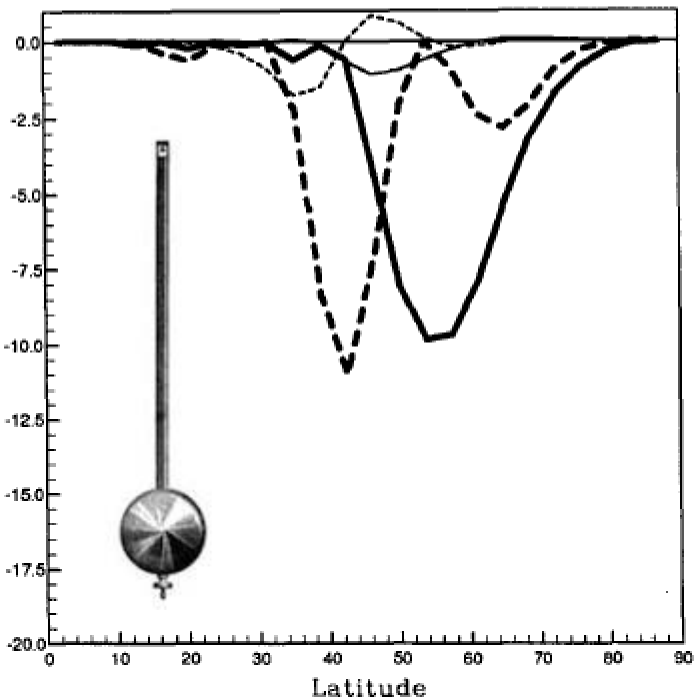


FIG. 8. Same as Fig. 5 except for $s = 2$.

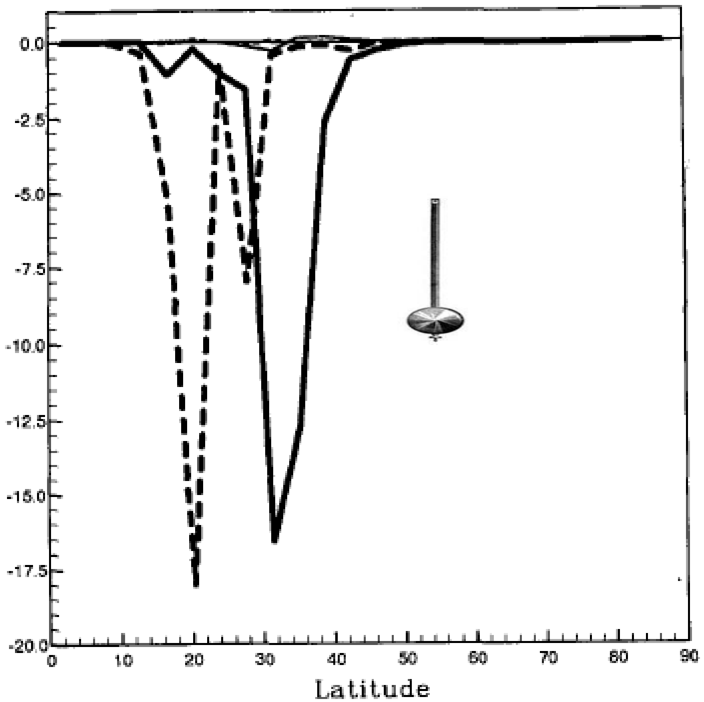


FIG. 9. Same as Fig. 5 except for $s = 15$.

Low-frequency ENMs project on NAO, Atlantic blockings and other weather regimes

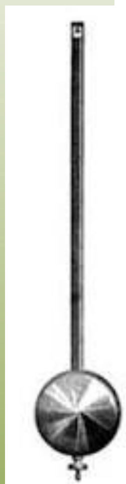
High-frequency ENMs project on transient storms and teleconnections

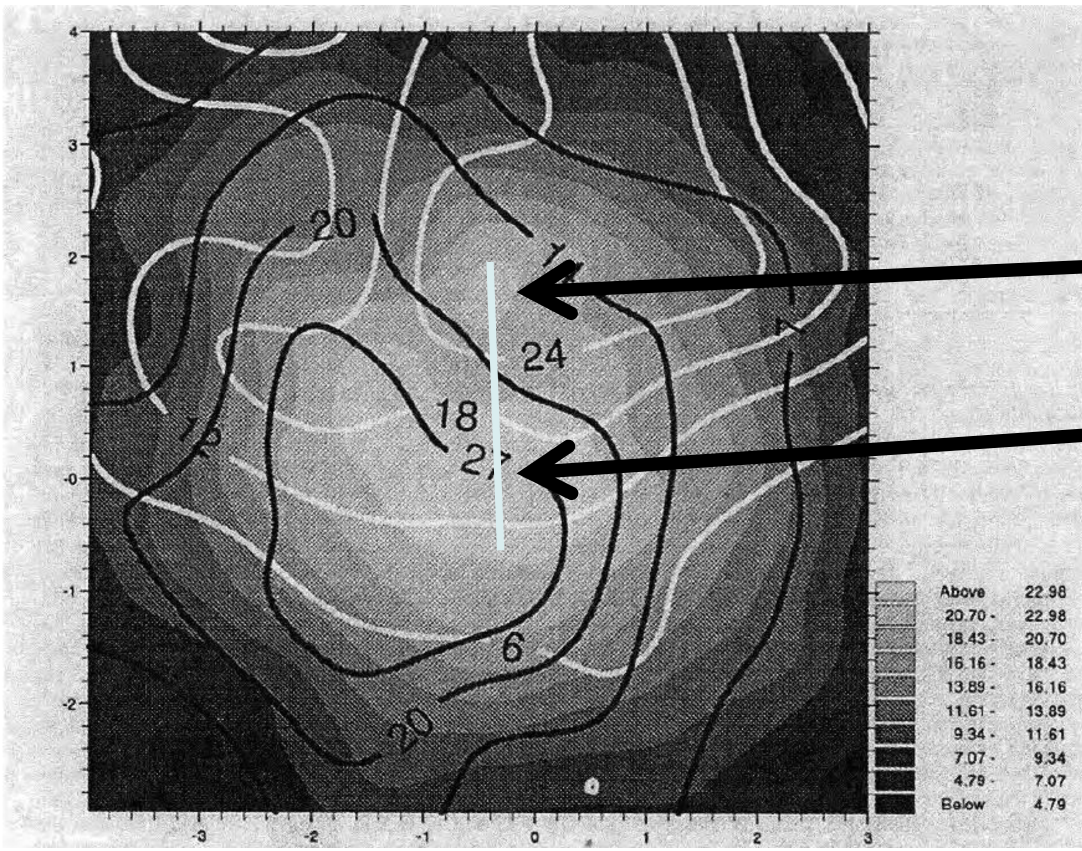
• Brunet, G. 1994 Empirical normal mode analysis of atmospheric data. J. Atmos. Sci., **51**, 932-952.

Blockings and resonances

TABLE 3. The ratio $r_{s,n}$ (BL) defined at (56) and the phase jump $PH_{s,n}$ (BL) between density maximum of the ZO and BL events for the ENMs with s = 1, 2, 3, 4 and n = 1, 2.

s	n	$r_{s,n}$ (BL)	$PH_{s,n}$ (BL)
1	1	0.6	0°
1	2	0.6	170°
2	1	0.0	0°
2	2	4.8	150°
3	1	0.8	10°
3	2	2.3	150°
4	1	0.0	30°
4	2	1.2	20°





- Vautard (MWR, 1990)
- Altlantic blockings (white contours)
- Zonal regimes (black contours)

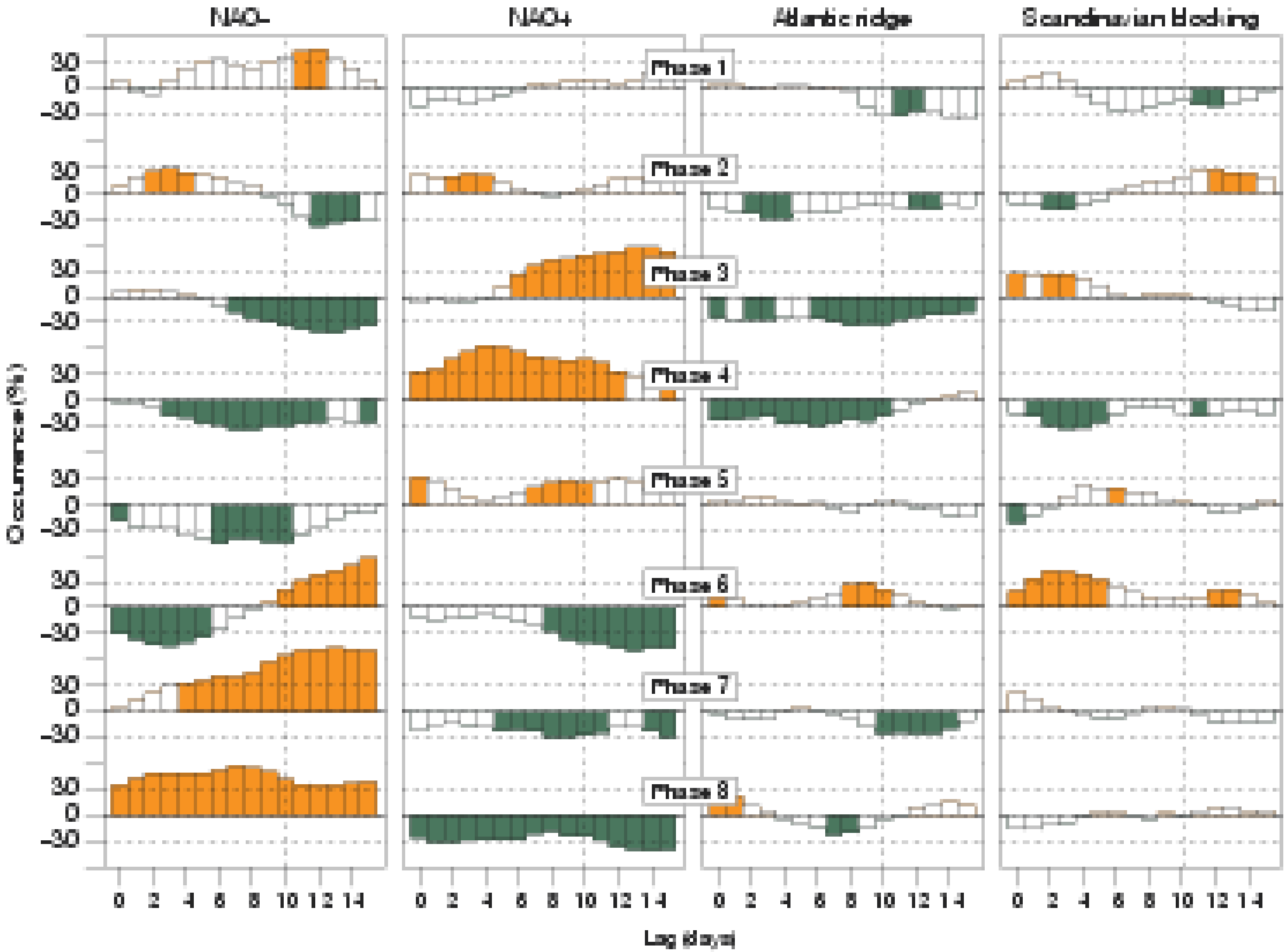
Charney&Devore (JAS, 1979) proposed orographic induced linear and nonlinear resonance mechanisms to explain phase locking of weather regimes.

Characteristics of the low frequency variability (subseasonal to seasonal)

- The dimension of the low frequency variability is of the order of 10-20;
- To contrast with seasonal variability where we have essentially only PNA and NAO in the Northern hemisphere;
- Variability explained by internal interactions (e.g. teleconnections) and external forcing (e.g. SST) and sub-weekly stochastic forcing;

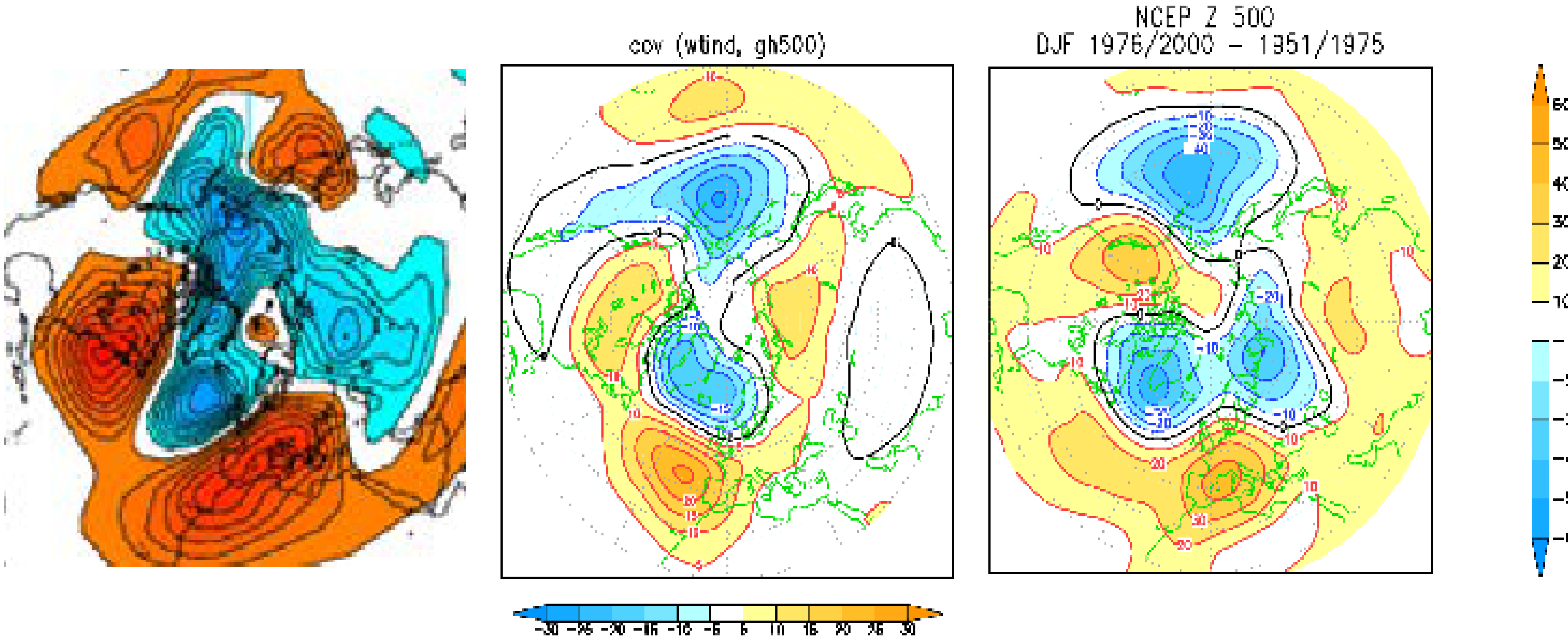
- Phase locking and resonance seem to characterize many modes of variability consistent with results by Molteni (2014) and Cassou (2008).

Subseasonal variability internal interaction: Impact of MJO on Euro-Atlantic weather regimes



Cassou (2008)

A planetary-wave signal common to different time scales?



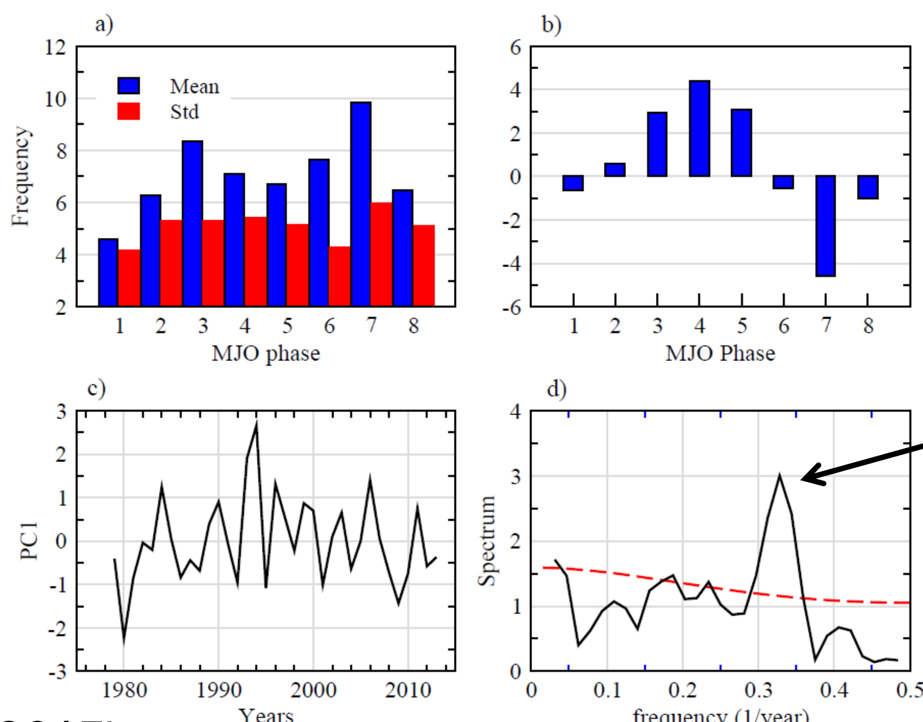
Z 500hPa anomaly

MJO phase3 + 10d | DJF W. Indian Oc. Rain | 20th C. decadal variability

Molteni et al. (2014)

Interannual variability of MJO occurrence modulating extra-tropical seasonal variability of NAO

- A year-to-year changes in the occurrence frequency of individual significant MJO phases is calculated for 34 winters;
- EOF analysis of occurrence frequency of MJO phases shows an out-of-phase relationship between MJO phase 7 and phases 3-5.



EOF 1

3 years (ENSO?)

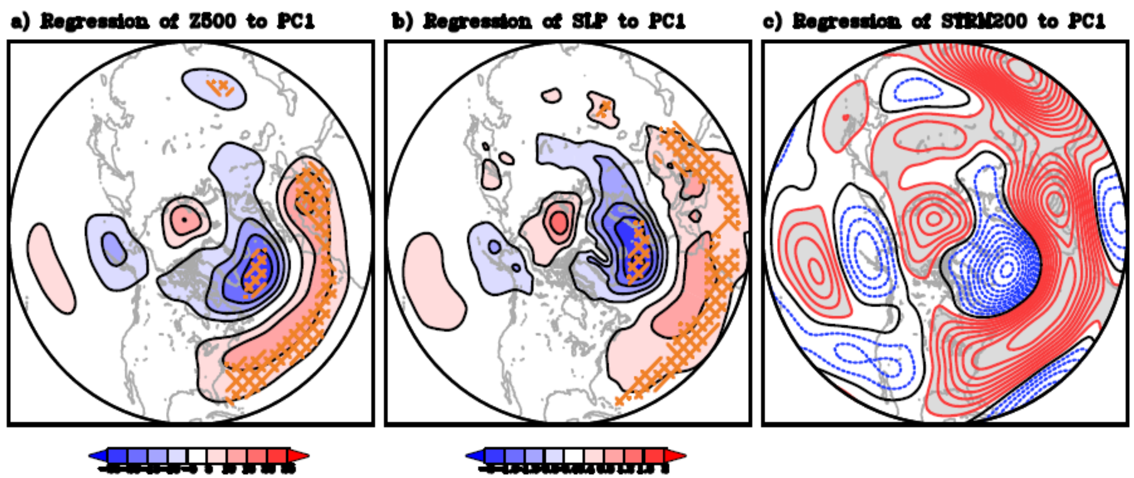
PC1 (29%)

Spectrum

Lin, Brunet and Yu (GRL, 2015)

Impact on NAO variability

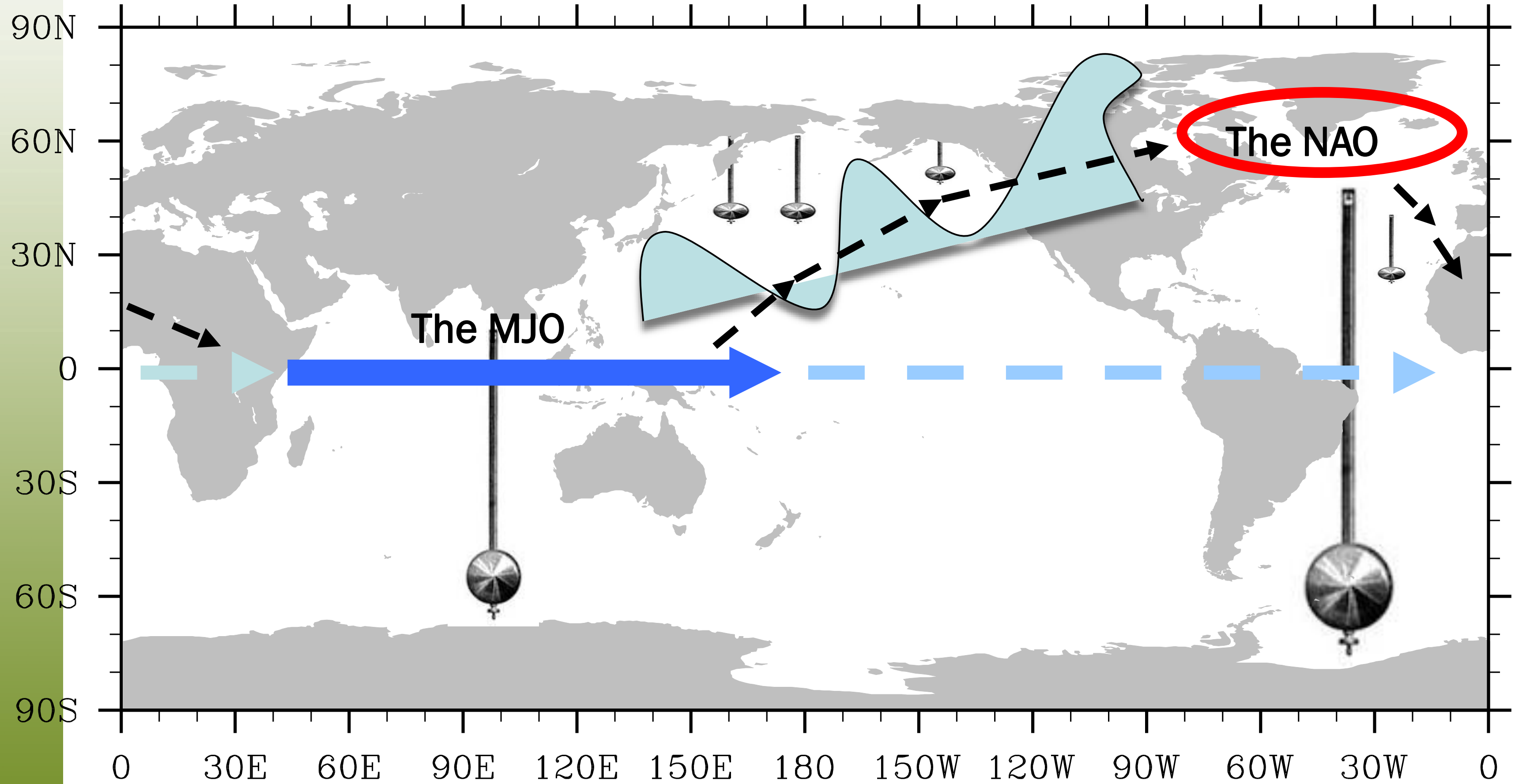
- An increased frequency of the MJO activity in the tropical Indian Ocean is associated with a positive DJF-mean NAO;



(5% confidence for hatched areas).

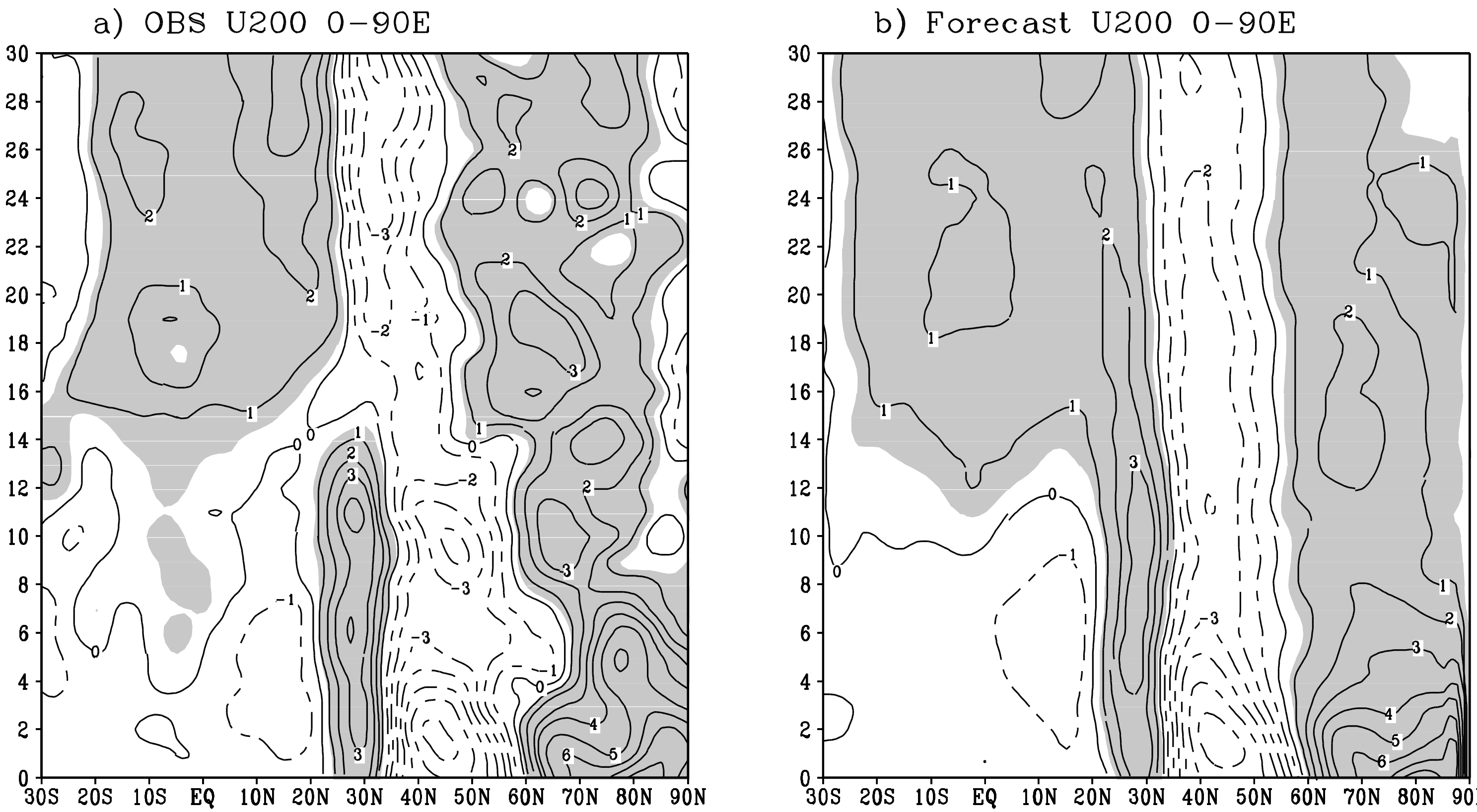
- In Branstator [2002], a circumglobal waveguide was identified that links distant regions in midlatitude for the atmospheric internal variability (including NAO);
- The Indian Ocean convection seasonal anomaly, due to the increase in MJO occurrences, seems to influence the NAO seasonal variability through this waveguide.

The multi-scale organisation of tropical convection and its two-way interaction with the global circulation.



How large scale oscillations interact?

Figure 4. (a) Observed and (b) forecast difference of U200 between positive and negative NAO composites averaged from 0° to 90°E, as a function of latitude and lead time. Contour interval is 1 m s−1. Shaded areas are those with a value greater 0.5 m s−1.



• **Lin, H., and G. Brunet, 2011: Impact of the North Atlantic Oscillation on the forecast skill of the Madden-Julian Oscillation. Geophys. Res. Lett., VOL. 38.**

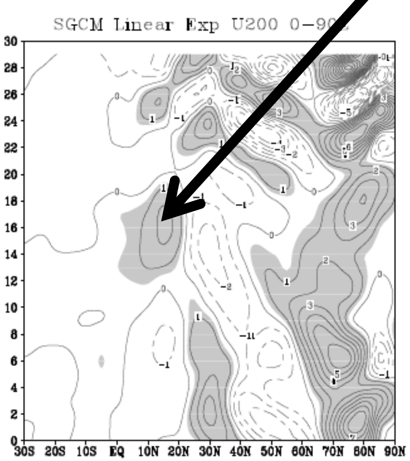
A Normal Mode Study in Preparation (Brunet, Lin and Grimshaw)

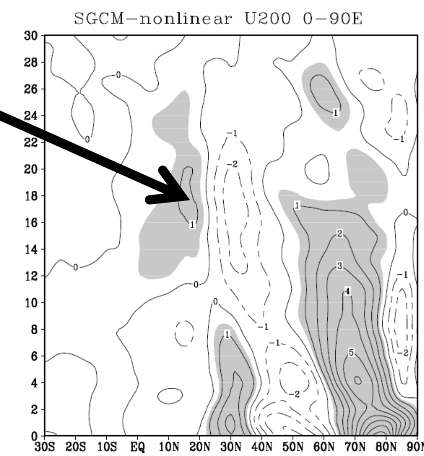
- A wave-mean flow barotropic linear interaction seems to explain this transient (i.e. continuous spectrum) westerly wind surge;
- A robust and predictable dynamical process.

$$u_0 = \frac{igkU_Y T}{f} h_1$$

$$v_1 = \frac{ikg}{f(f - U_Y)} \left(f - U_Y \left(\frac{R_D^2 k^2 U_Y^2 T^2 - \varepsilon^2}{R_D^2 k^2 U_Y^2 T^2 + \varepsilon^2} \right) \right) h_1 \qquad \text{(A.11)}$$

$$h_1 = \frac{A(y)}{1 + \varepsilon^{-2} R_D^2 k^2 U_Y^2 T^2}$$





where R_D is the Rossby radius of deformation for this problem

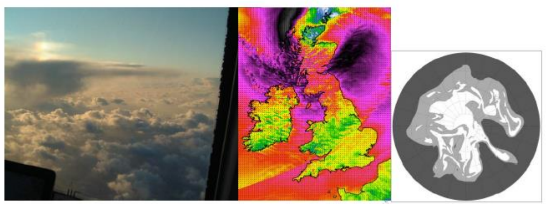
$$R_D = \sqrt{\frac{c_p}{R} \frac{g z_0}{f(f - U_Y)}}.$$

For relatively large Rossby radius of deformation the height disturbance is decaying quadratically in time [Brown&Stewartson, 1980], but for relatively small Rossby radius the asymptotic behavior is quite different. It is associated with a surge of zonal wind increasing to a maximum at time $t_{\max} = \dfrac{1}{kU_Y R_D}$

Charney and Devore's project: Ongoing effort to revisit the atmospheric variability phase space with Wave Activity and Empirical Normal Mode (ENM)

PANDOWAE Final Symposium, May 2015

University of Reading



Propagation and interaction of large amplitude Rossby waves

John Methven

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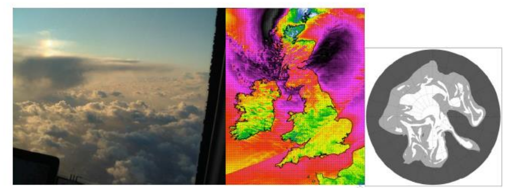
Gilbert Brunet, Environment Canada

 www.reading.ac.uk

SPARC/WCRP storm tracks workshop, Grindelwald, August 2015

University of Reading



Atmospheric background state and modes of variability

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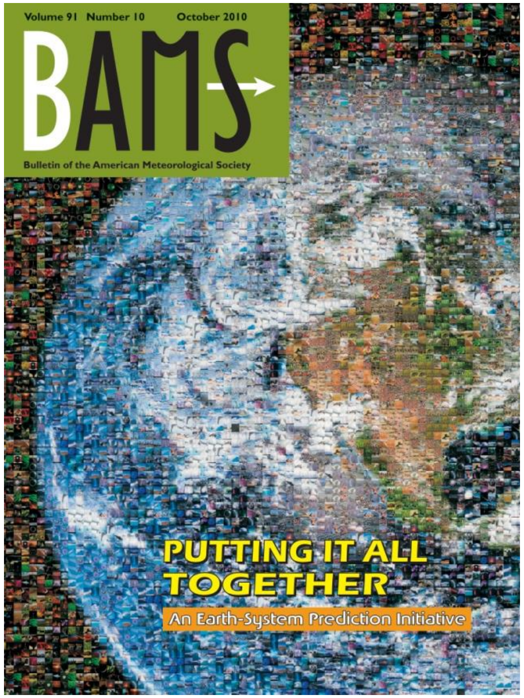
Putting it All Together (BAMS 2010)

World Meteorological Organization (WMO), World Weather Research Programme (WWRP), World Climate Research Programme (WCRP), International Geosphere-Biosphere Programme (IGBP), Global Climate Observing System (GCOS), and natural-hazards and socioeconomic communities.

- An Earth-System Prediction Initiative for the Twenty-First Century (Shapiro et al.,)
- Addressing the Complexity of the Earth System (Nobre et al.)
- Toward a New Generation of World Climate Research and Computing Facilities (Shukla et al.)
- Collaboration of the Weather and Climate Communities to Advance Subseasonal-to-Seasonal Prediction (Brunet et al.)

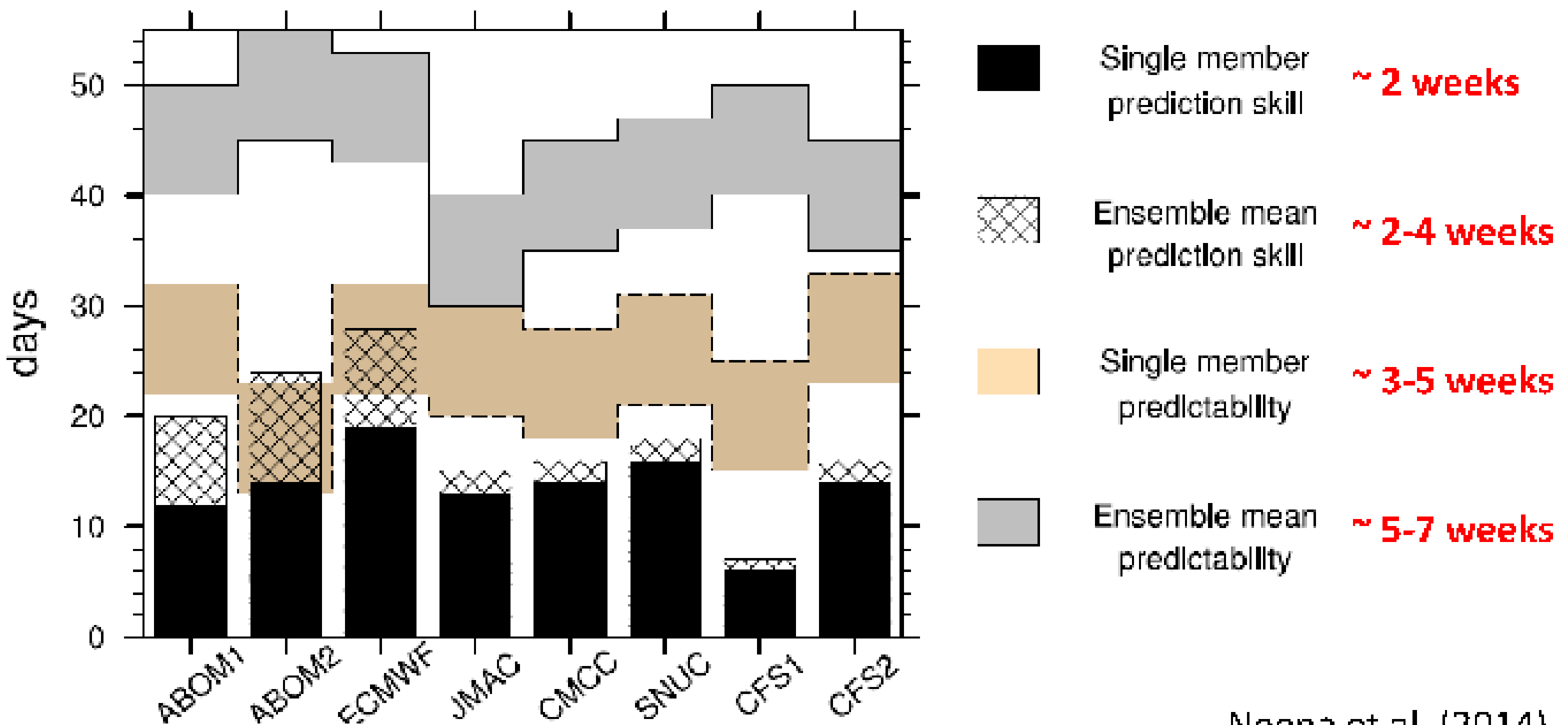


Subseasonal-to-Seasonal S2S Prediction Project

Putting it All Altogether: some predictability related recommendations

- Weather and climate prediction systems need to have good climatology: teleconnections depend crucially on it;
- GCM systems should represent properly statistics of high-impact weather;
- NWP systems needs to have atmosphere-sea-ice coupling and improve stratosphere to obtain better subseasonal and seasonal variability;
- Ensemble Prediction Systems (EPSs) are needed to obtain prediction of likelihood of high-impact weather events;
- Hindcast experiment are needed for identifying bias and model deficiencies.

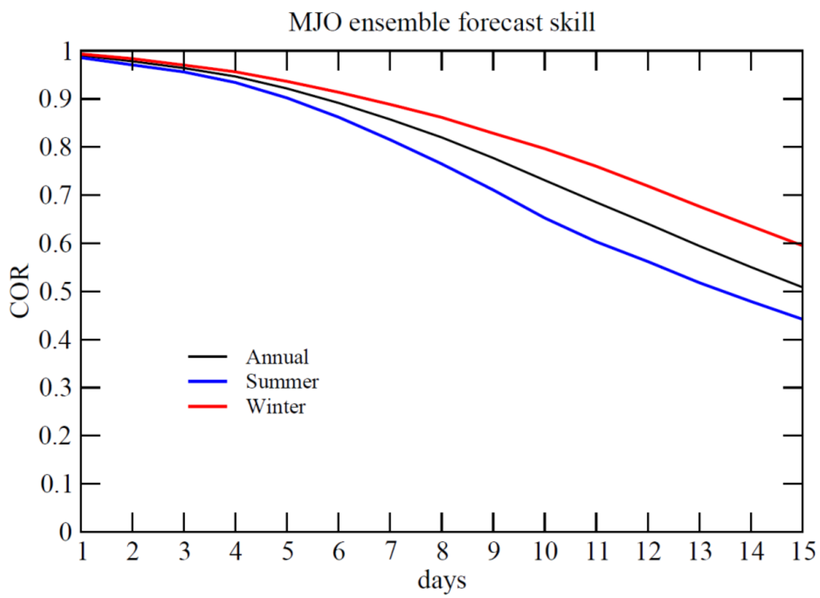
Capability of MJO forecast



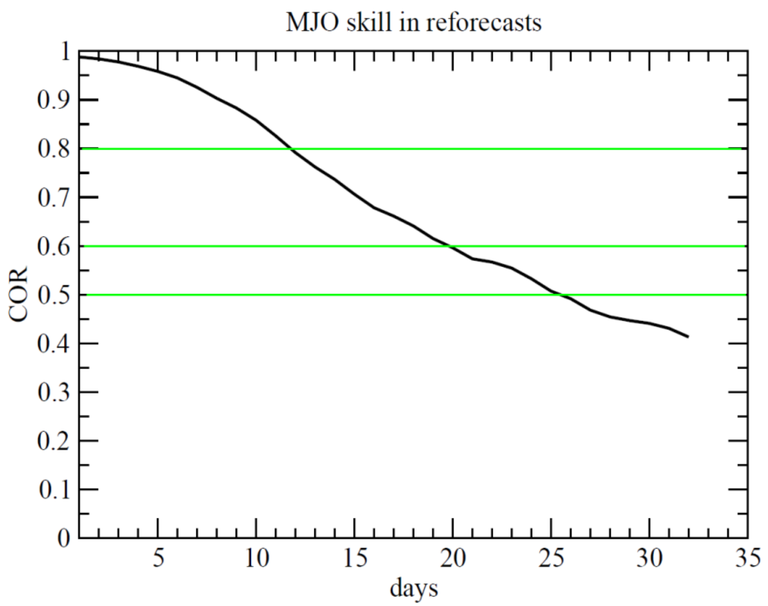
Neena et al. (2014)

* ISVHE (Intraseasonal Variability Hindcast Experiment)

Reforecast: Skill of MJO prediction with the Canadian GEM En-KF EPS (Anomaly correlation)



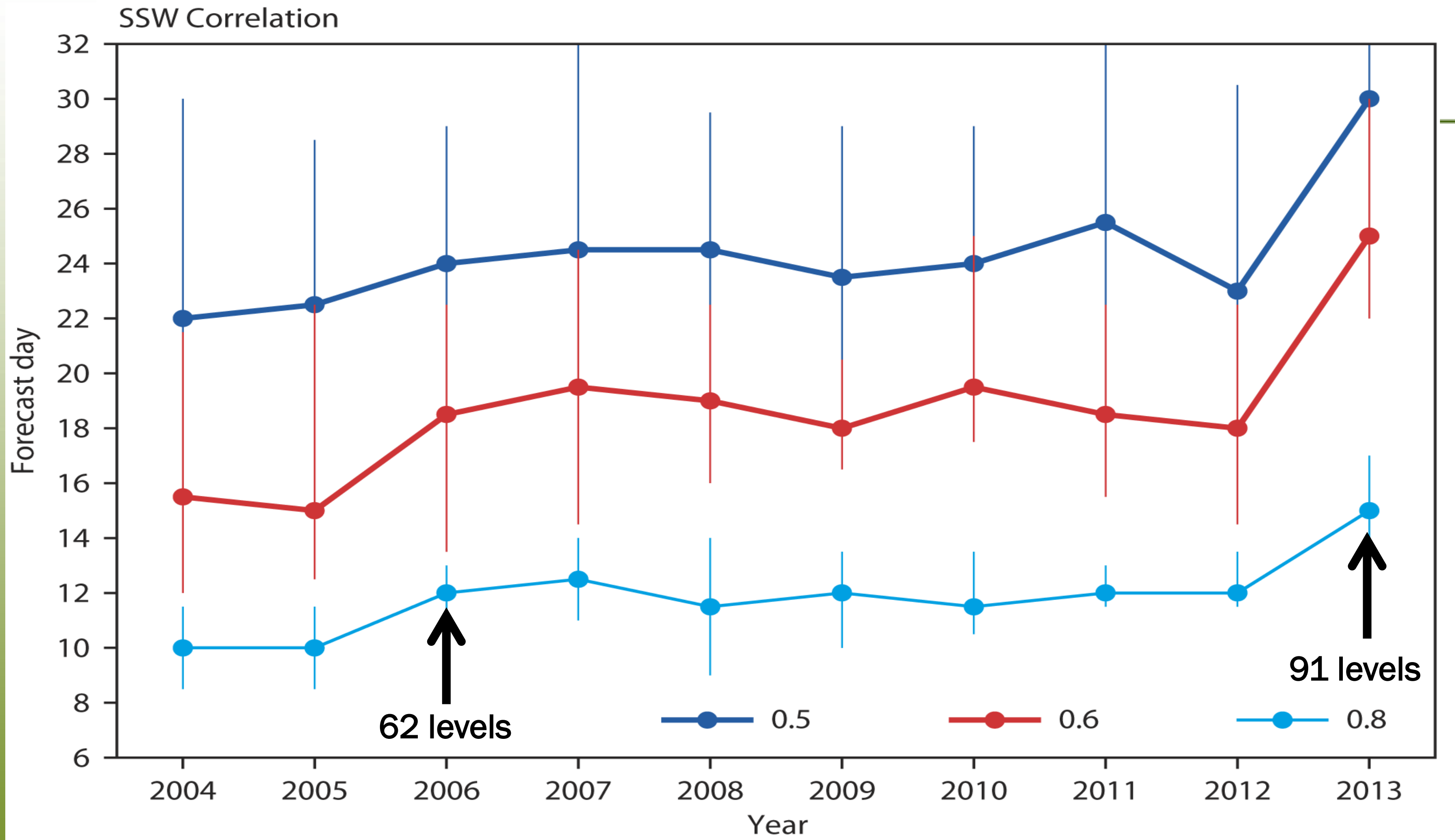
No reforecast



With reforecasts

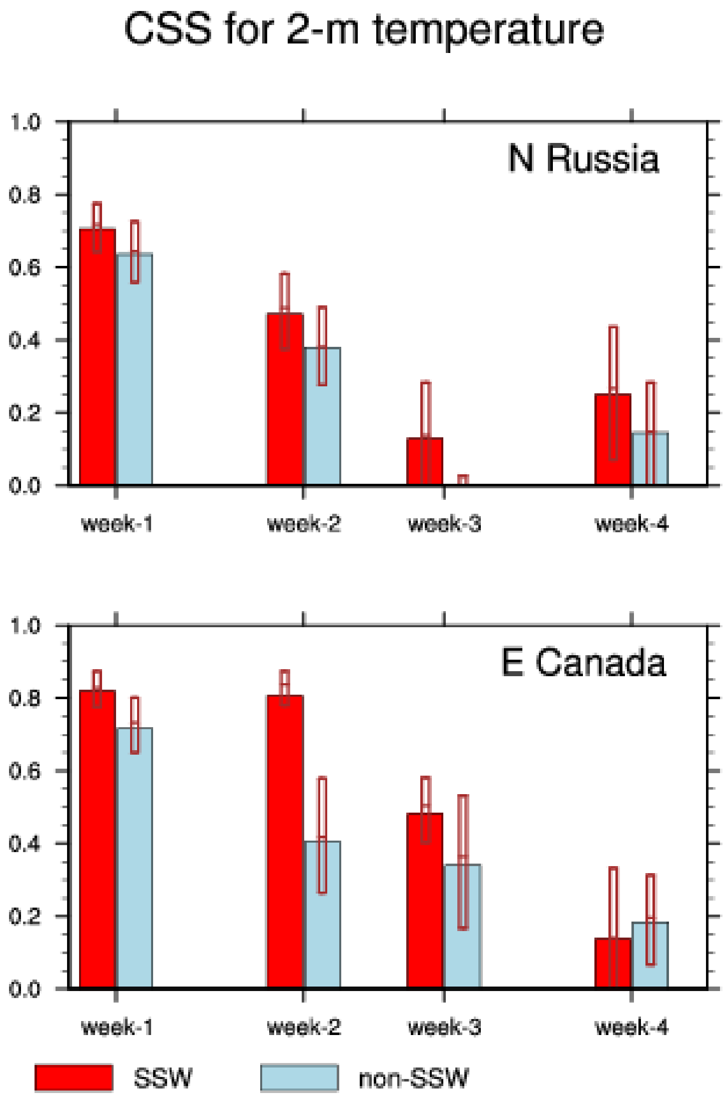
- EPS with no reforecast: got 0.5 up to 15 days, 0.6 at 13 days and .08 at 8 days;
- EPS reforecasts: got 0.5 up to 25 days, 0.6 at 20 days and 0.8 at 12 days;
- ECMWF: got 0.5 up to 30 days, 0.6 at 22 days and 0.8 at 12 days.

Sudden Stratospheric Warming



SSW index: Difference of temperature at 50hPa between 90N and 60N averaged over all the longitudes

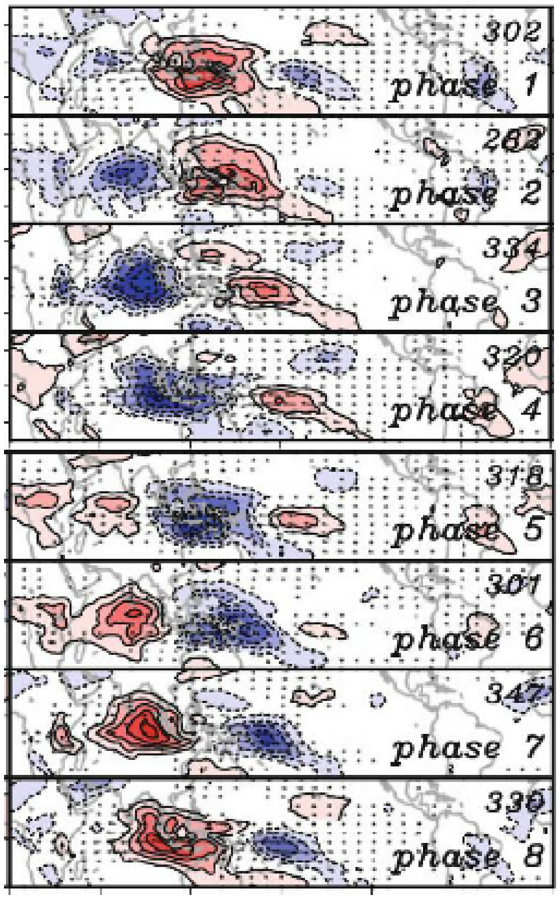
Impact of SSWs on forecast skill scores



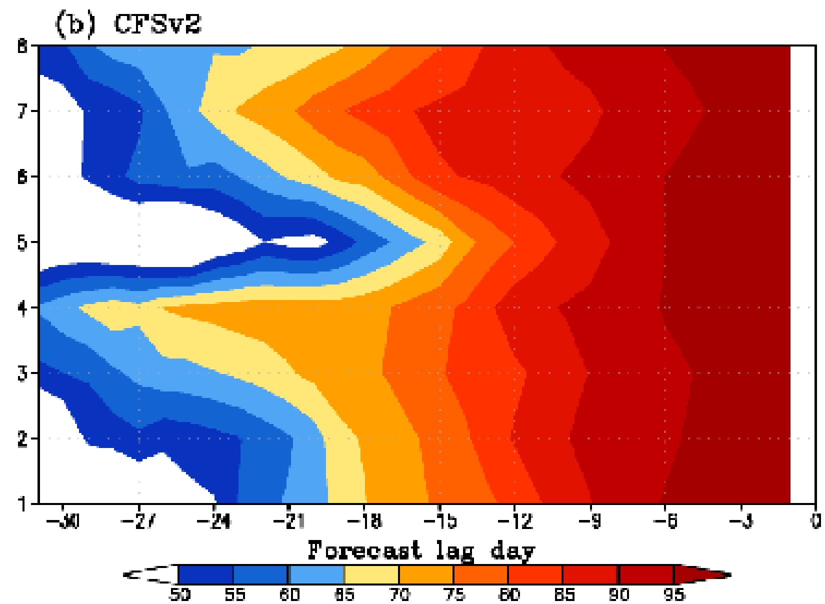
From Om Tripathi, 2015

MJO Maritime Continent Prediction barrier

MJO composite



MJO Prediction skill by target MJO phase



- CFSv2 shows sharp decrease in skill at phase 1 and 5

→ deficiency in predicting the enhanced (or suppressed) convective signal associated with the MJO over the Maritime Continent.

Kim et al. (2014)

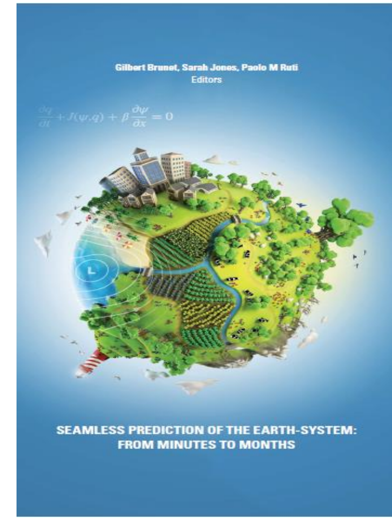
More results this week ...

Conclusion

- Increased interest for this time range – New frontier for prediction;
- Charney and Devore's project – Exploring the rich and complex low frequency variability landscape;
- Progress in the prediction of main sources of predictability over the past decade;
- Next challenge is the accurate simulation of their impact and better understand sub-seasonal interaction (e.g. MJO-AO);
- WWRP/WRCP S2S project to address some of these challenges;
- S2S prediction will benefit also of other advances in NWP (e.g. coupled data assimilation …).

World Weather Open Science Conference (Montreal, 2014)

- *Seamless Prediction of the Earth System: from minutes to months (*Editors: Brunet, Jones and Ruti)



  - Provide a reference of current state and future challenges of NWP Science in 25 chapters.
  - It is freely available on the WMO website

- *The quiet revolution of numerical weather prediction*

 Bauer, Thorpe and Brunet

 (Nature, September 3, 2015)

Thank you! Merci!