

## **MJO teleconnections in the S2S database**

*Frédéric Vitart*  
*ECMWF*

## Index

- Introduction: MJO teleconnections in observations and ECMWF model
- The WWRP/WCRP S2S database
- Representation of the MJO and its teleconnections in the S2S models



# Introduction

## Impact of the MJO on Extratropics



*Lin et al, MWR 2010*

See also

*Simmons et al JAS 1983*

*Ting and Sardeshmukh JAS 1993*



## Impact of the MJO on Extratropics

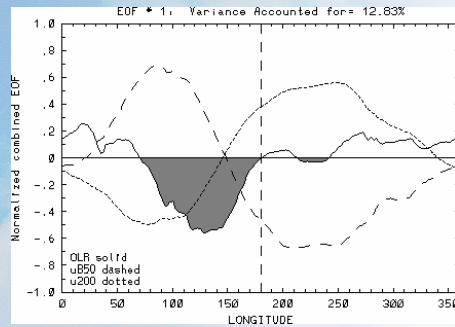
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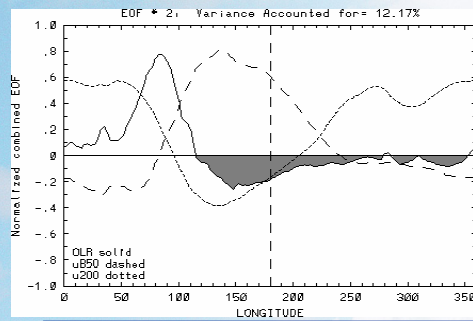
*Lin et al, MWR 2010*

## MJO Metrics: combined EOFs of U200,U850 and OLR

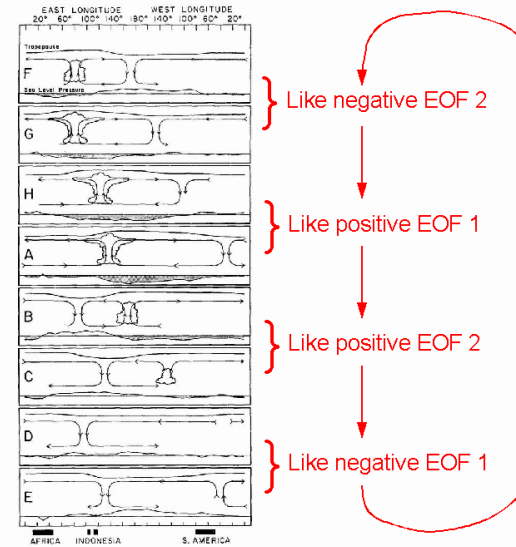
### Combined EOF1



### Combined EOF2

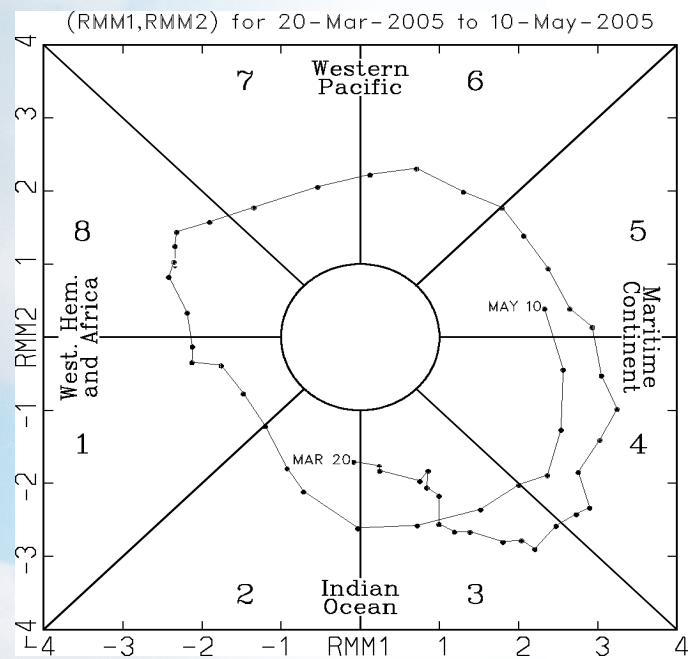


Madden and Julian's (1972) schematic

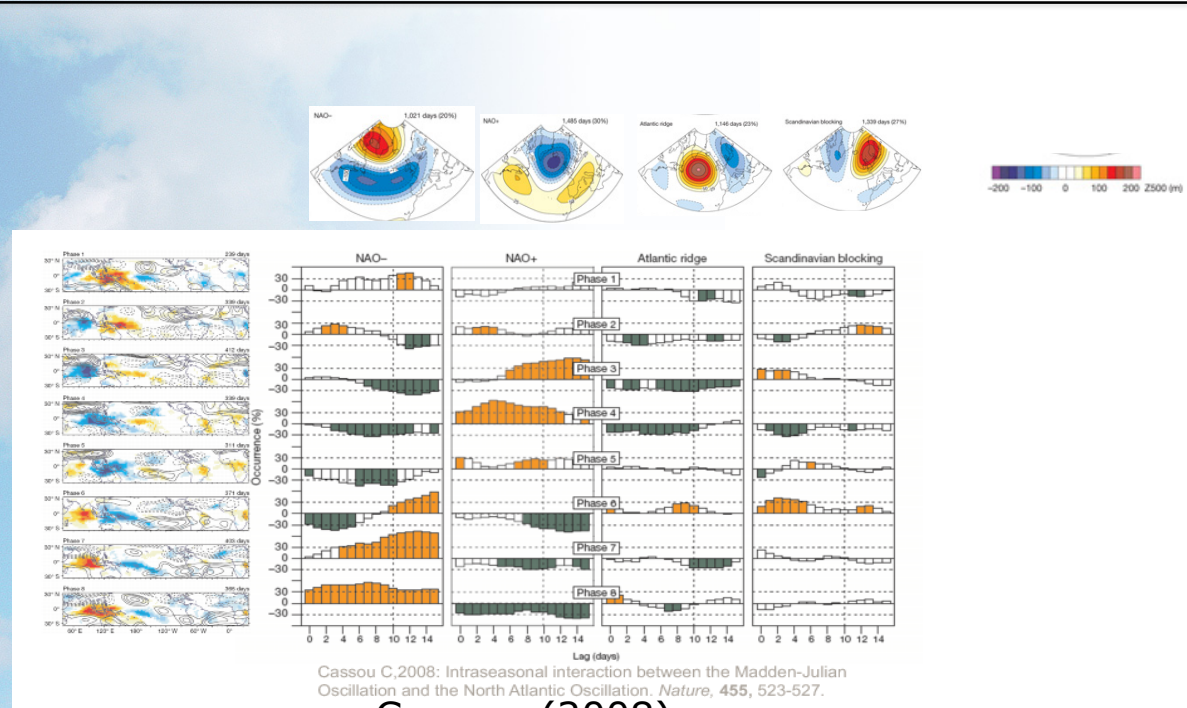


*Wheeler and Hendon, MWR 2004*

## MJO Metrics: combined EOFs of U200,U850 and OLR



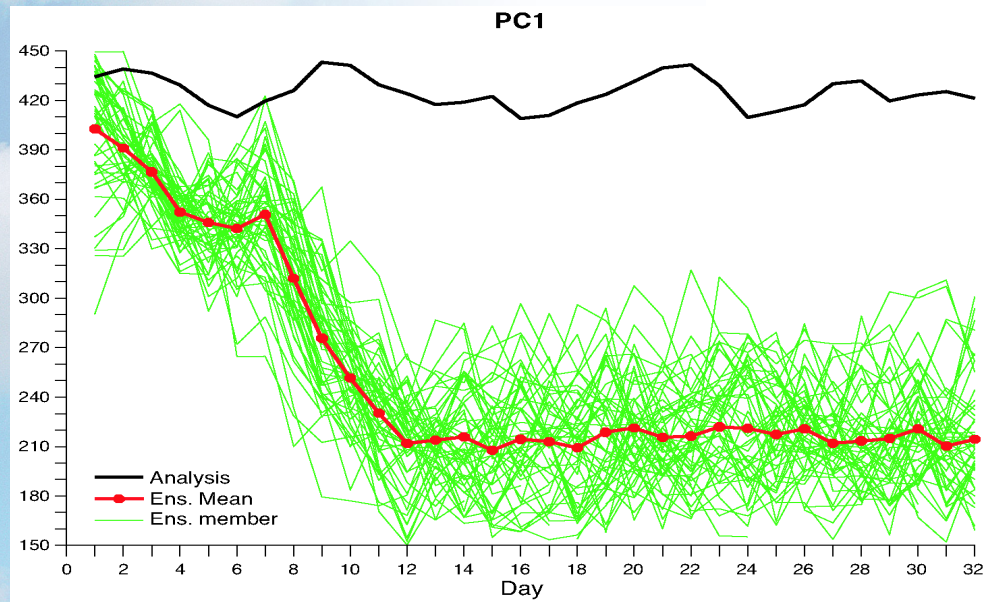
# 1. Impact of the MJO on weather regimes



Cassou C, 2008: Intraseasonal interaction between the Madden-Julian Oscillation and the North Atlantic Oscillation. *Nature*, 455, 523-527.

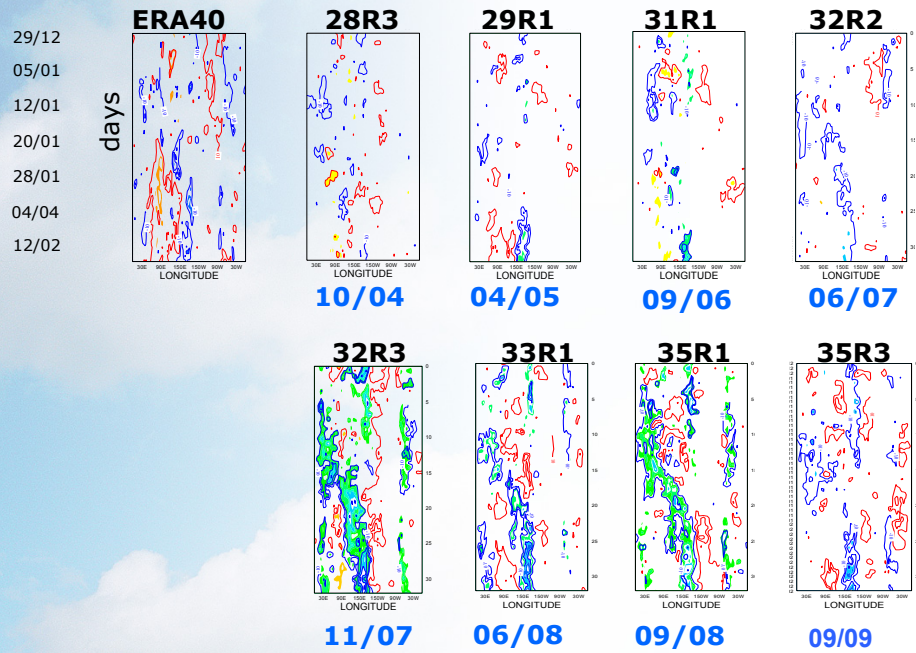
**Cassou (2008)**

## Simulation of the MJO



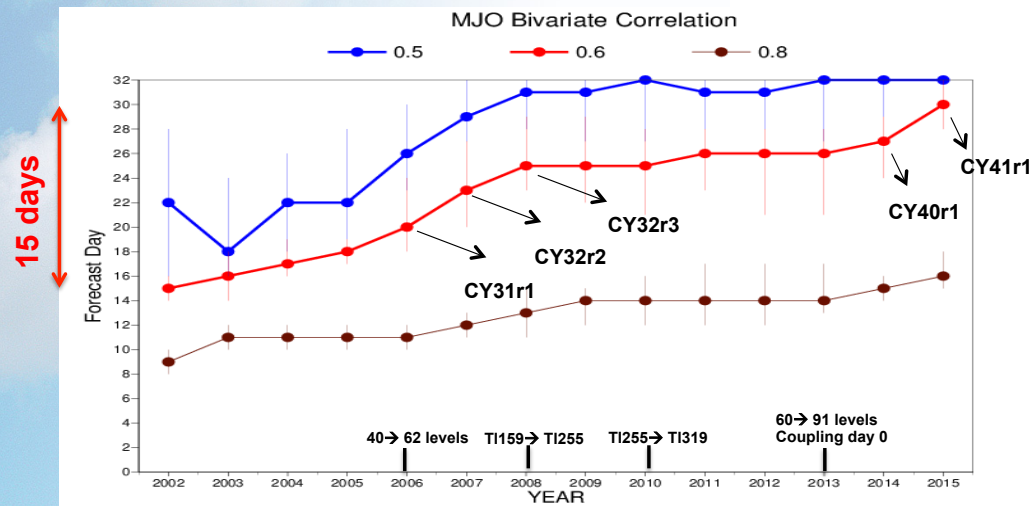
*Vitart, 2003*

## OLR anomalies - Forecast range: day 15





## Madden Julian Oscillation prediction at ECMWF



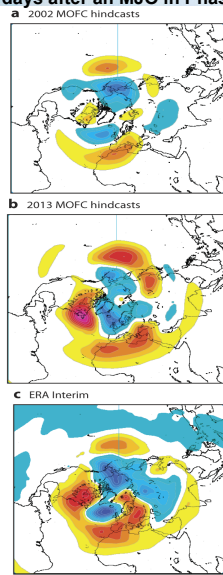
**CY31R1:** Parameterisation of ice supersaturation  
**CY32R2:** McRAD (radiation scheme)  
**CY32R3:** Changes in convective scheme (Bechtold et al. 2008)  
**CY40R1:** Improved diurnal cycle of precipitation  
**CY41R1:** revised organized convective detrainment and the revised convective momentum transport. ...

**Wheeler and Hendon (2004) Index**

**Improvements in MJO Prediction mostly due to changes in convective parameterization**

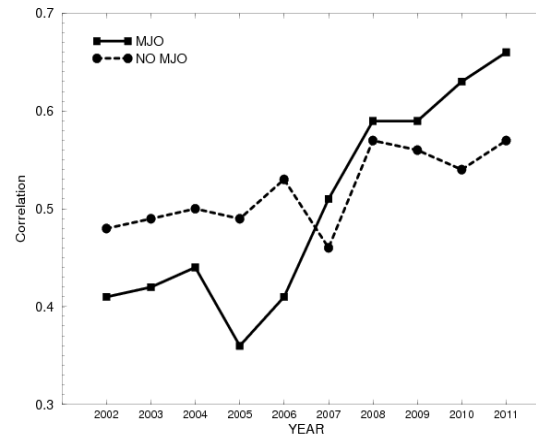
## MJO teleconnections

Z500 anomalies  
10 days after an MJO in Phase 3



## Evolution of NAO skill scores-Day 19-25

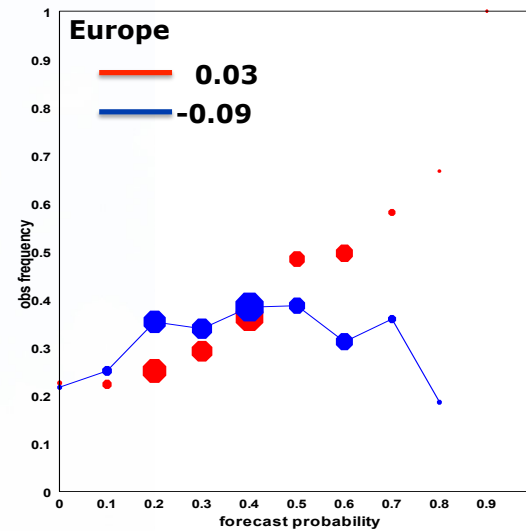
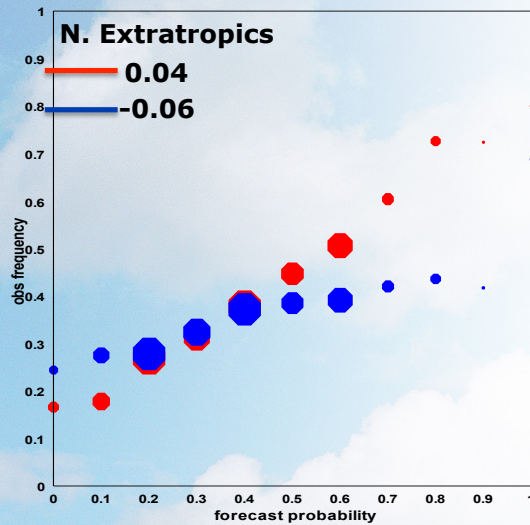
NAO Index: projection of Z500 on pre-computed EOF



Vitart, 2014

## Probabilistic skill scores – NDJFMA 1989-2008

### Reliability Diagram Probability of 2-m temperature in the upper tercile Day 19-25

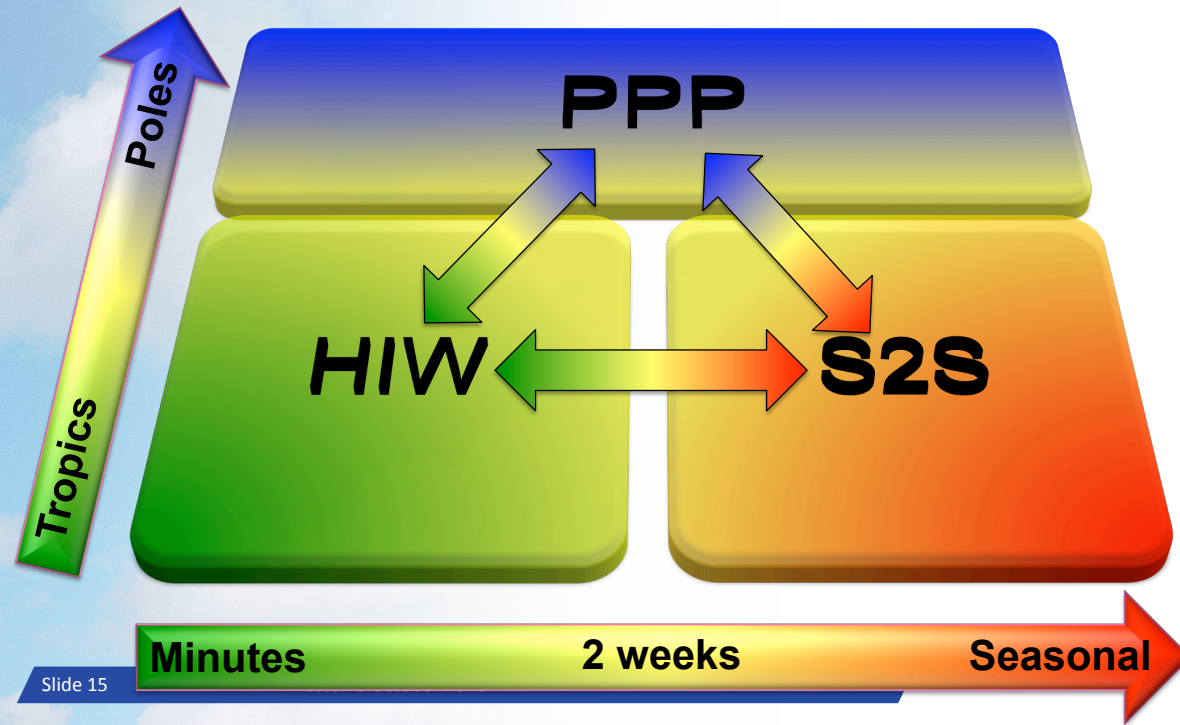


— MJO in IC      — NO MJO in IC



## **WWRP/WCRP S2S database**

# WMO/WWRP International Legacy Projects



## WWRP/WCRP S2S project Mission Statement

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- “To improve forecast skill and understanding on the sub-seasonal to seasonal timescale with special emphasis on high-impact weather events”
- “To promote the initiative’s uptake by operational centres and exploitation by the applications community”
- “To capitalize on the expertise of the weather and climate research communities to address issues of importance to the Global Framework for Climate Services”



## Sub-seasonal to Seasonal (S2S) Prediction Project

Sub-Projects

**Teleconnections** (*C. Stan and H. Lin*)

**Madden-Julian Oscillation** (*D. Waliser and S. Woolnough*)

**Monsoons** (*H. Hendon*)

**Africa** (*A. Robertson and R. Graham*)

**Extremes** (*F. Vitart*)

**Verification and Products** (*C. Coelho*)

### Research Issues

- Predictability
- Teleconnection
- O-A Coupling
- Scale interactions
- Physical processes

### Modelling Issues

- Initialisation
- Ensemble generation
- Resolution
- O-A Coupling
- Systematic errors
- Multi-model combination

### Needs & Applications

Liaison with SERA  
(Working Group on  
Societal and Economic  
Research Applications)

**S2S Database**

## Teleconnections Mid-latitudes-tropics (Cristiana Stan and Hai Lin)

### Major objectives:

- Better understand sub-seasonal tropical-extratropical interaction pathways.
- Identify periods and regions of increased predictability (“forecasts of opportunity”)
- Improve sub-seasonal to seasonal forecasts of weather and climate for applications.

### Issues to be addressed:

- Understand physical mechanisms of tropical-extratropical interaction
- Develop new comprehensive estimates of tropical diabatic heating
- Identify main errors associated with teleconnections.

Potential virtual field experiment: Year of Tropics-Midlatitude Interactions and Teleconnections (YTMIT) 2017-2019

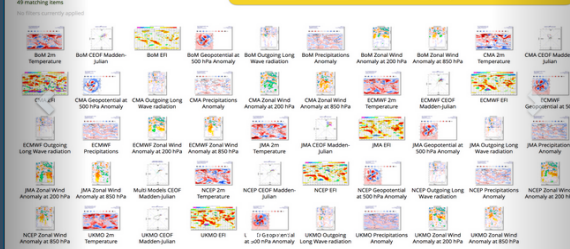
# www.s2sprediction.net



About S2S | News | Documents | Sub-projects | Database | Products | Meetings | People | Links

## Sub-seasonal to seasonal forecast

Please visit the S2S Product page in ECMWF at <http://www.ecmwf.int/en/research/projects/s2s/charts/s2s/>



## Upcoming Events

AGU 2016 Fall Session on Sub-seasonal to Seasonal Forecasting of High-impact Weather and Climate Events , 12-16 December 2016, San Francisco

5th S2S SG/LG meeting, 8-9 December 2016, IRI Lamont Campus

S2S Extremes Workshop 2016, 6-7 December 2016, Monell Building Columbia University at Lamont-Doherty

## S2S Database

ECMWF CMA

Charts of S2S Products/Indices are now available

Updated: 2016-09-22 08:41

S2S Database Paper will come soon on BAMS

Updated: 2016-08-29 01:25

Now 9 centres S2S data available!

Updated: 2016-01-14 06:16

S2S News

News Letter

FAQs

### New article on "Applications of S2S Forecasts: From Disaster Early Warning to Early Action"

The new article has been submitted, entitled "Applications of S2S Forecasts: From Disaster Early Warning to Early Action", by Sarah Bashford Lynagh, Andrew Robertson, and Roop Singh, Columbia University. You can read it by accessing at [http://s2sprediction.net/file/documents\\_reports/Blog%20for%20S2S\\_July28\\_ar2\\_eq\\_ff\\_ar\\_Sep30.pdf](http://s2sprediction.net/file/documents_reports/Blog%20for%20S2S_July28_ar2_eq_ff_ar_Sep30.pdf), or come to the report session in this webpage.

Updated: 2016-10-01 07:52

### S2S Extremes Workshop 2016

## Tweets by @s2sprediction

s2sprediction Retweeted

Reporting Climate @Reportingclimat

Climate scientist @ed\_hawkins tells us why climate model "zoos" make regional forecasting hard [reportingclimatescience.com/news-stories/a...](http://reportingclimatescience.com/news-stories/a...)

Embed

View on Twitter



## Mission

The main goal of the proposed WWRP/THORPEX/ WCRP joint research project is to improve forecast skill and understanding on the subseasonal to seasonal timescale, and promote its uptake by operational centres and exploitation by the applications community. Specific attention will be paid to the risk of extreme weather, including tropical cyclones, droughts, floods, heat waves and the waxing and waning of monsoon precipitation. Work will be guided by a steering committee.



## Reports & Publications

- Applications of S2S Forecasts: From Disaster Early Warning to Early Action
- Report on subseasonal MME in LC-LRFMME
- Subseasonal to Seasonal Prediction Research Implementation Plan
- (Early Release) The Sub-seasonal to Seasonal Prediction

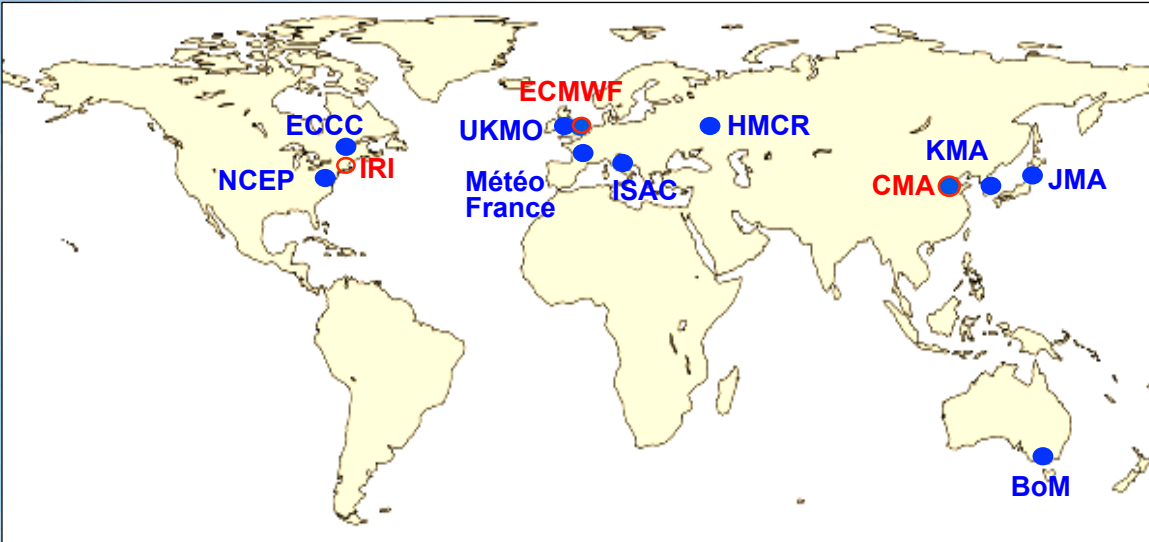
## S2S database

- **3-week behind real-time forecasts + re-forecasts (up to day 60)**
- **Common grid (1.5x1.5 degree)**
- **Data archived with a daily frequency (sub-daily for total precip/max and min 2mtm) in GRIB2**
- **About 80 parameters, including:**
  - 3D fields (u/v/w/z/t/q) on 10 pressure levels (up to 10 hPa)
  - Surface fluxes
  - Sea Surface temperature
  - Sea-ice cover (fraction)
  - Snow depth/density/snow fall/snow albedo

# Contributing Centres to S2S database

● Data provider (11)

○ Archiving centre (3)



## S2S Models

	Time-range	Resol.	Ens. Size	Freq.	Hcsts	Hcst length	Hcst Freq	Hcst Size
<b>ECMWF</b>	D 0-46	T639/319L91	51	2/week	On the fly	Past 20y	2/weekly	11
<b>UKMO</b>	D 0-60	N216L85	4	daily	On the fly	1993-2015	4/month	3
<b>NCEP</b>	D 0-44	N126L64	4	4/daily	Fix	1999-2010	4/daily	1
<b>ECCC</b>	D 0-32	0.45x0.45 L40	21	weekly	On the fly	1995-2014	weekly	4
<b>BoM</b>	D 0-60	T47L17	33	weekly	Fix	1981-2013	6/month	33
<b>JMA</b>	D 0-34	T319L60	25	2/weekly	Fix	1981-2010	3/month	5
<b>KMA</b>	D 0-60	N216L85	4	daily	On the fly	1996-2009	4/month	3
<b>CMA</b>	D 0-45	T106L40	4	daily	Fix	1886-2014	daily	4
<b>CNRM</b>	D 0-32	T255L91	51	weekly	Fix	1993-2014	2/monthly	15
<b>CNR-ISAC</b>	D 0-32	0.75x0.56 L54	40	weekly	Fix	1981-2010	6/month	1
<b>HMCR</b>	D 0-63	1.1x1.4 L28	20	weekly	Fix	1981-2010	weekly	10



## S2S Database current status

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- Open access to researchers since May 2015 from ECMWF and Nov. 2015 from CMA. Subset of the database also available in netcdf from IRI data library.
- Currently, data from all centres except KMA (will become available soon) are available.
- Total size of the database so far: 43 Tbytes
  - real-time: 7 Tbytes
  - re-forecasts: 36 Tbytes
- Plans
  - End of 2016: all 11 Data Providers
  - Add new ocean sub-surface and sea-ice variables
  - Compute and archive indices such as MJO RMMs, SSW index, Weather regimes, Tropical storm tracks, Monsoon indices to be available for the research community from ECMWF and IRI servers.

# ECMWF S2S website: [s2s.ecmwf.int](http://s2s.ecmwf.int) CMA website: [s2s.cma.cn](http://s2s.cma.cn)

The screenshot displays the ECMWF S2S website interface. At the top, there is a navigation bar with links for Home, Chart dashboard, Contact, and a search box for ECMWF. The user is identified as Frederic Vitart with a sign-out option. The main content area is titled "S2S, ECMWF, Realtime, Daily averaged" and includes a note that the dataset is available on Mondays and Thursdays. Below this, there are several selection sections: "Select date" with a date range from 2015-01-01 to 2016-08-15; "Select a list of months" with a calendar view for 2015 and 2016; "Select step" with a grid of step ranges from 0-24 to 1008-1104; and "Select parameter" with a grid of parameter options such as 2 metre dewpoint temperature, sea surface temperature, and soil moisture. A left sidebar contains navigation links for S2S sets, Statistical process, Origins, Type, About, Navigation, and See also... At the bottom, there are buttons for "View the MARS request" and "Retrieve GRIB".

**ECMWF** Home Chart dashboard Contact Search ECMWF Frederic Vitart | [Sign out](#)

About Forecasts Computing Research Learning

### S2S sets

- Real time
- Reforecasts

### Statistical process

- Instantaneous and accumulated
- Daily averaged

### Origins

- BoM
- CMA
- ECMWF
- HMCR
- ISAC-CNR
- JMA
- Météo France
- NCEP
- UKMO
- ECCC

### Type

- Control forecast
- Perturbed forecast

### About

- Conditions of use
- Documentation

### Navigation

- Home
- Public Datasets
- Job list

### See also...

- Access Public Datasets
- General FAQ
- WebAPI FAQ
- Accessing forecasts
- GRIB decoder

## S2S, ECMWF, Realtime, Daily averaged

This dataset is available Mondays and Thursdays. [read more](#)

#### Select date

Select a date in the interval 2015-01-01 to 2016-08-15

Start date:  End date:

[Reset](#)

#### Select a list of months

2015: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

2016: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

[Select All](#) or [Clear](#)

#### Select step

<input type="checkbox"/> 0-24	<input type="checkbox"/> 24-48	<input type="checkbox"/> 48-72	<input type="checkbox"/> 72-96	<input type="checkbox"/> 96-120	<input type="checkbox"/> 120-144	<input type="checkbox"/> 144-168
<input type="checkbox"/> 168-192	<input type="checkbox"/> 192-216	<input type="checkbox"/> 216-240	<input type="checkbox"/> 240-264	<input type="checkbox"/> 264-288	<input type="checkbox"/> 288-312	<input type="checkbox"/> 312-336
<input type="checkbox"/> 336-360	<input type="checkbox"/> 360-384	<input type="checkbox"/> 384-408	<input type="checkbox"/> 408-432	<input type="checkbox"/> 432-456	<input type="checkbox"/> 456-480	<input type="checkbox"/> 480-504
<input type="checkbox"/> 504-528	<input type="checkbox"/> 528-552	<input type="checkbox"/> 552-576	<input type="checkbox"/> 576-600	<input type="checkbox"/> 600-624	<input type="checkbox"/> 624-648	<input type="checkbox"/> 648-672
<input type="checkbox"/> 672-696	<input type="checkbox"/> 696-720	<input type="checkbox"/> 720-744	<input type="checkbox"/> 744-768	<input type="checkbox"/> 768-792	<input type="checkbox"/> 792-816	<input type="checkbox"/> 816-840
<input type="checkbox"/> 840-864	<input type="checkbox"/> 864-888	<input type="checkbox"/> 888-912	<input type="checkbox"/> 912-936	<input type="checkbox"/> 936-960	<input type="checkbox"/> 960-984	<input type="checkbox"/> 984-1008
<input type="checkbox"/> 1008-1032	<input type="checkbox"/> 1032-1056	<input type="checkbox"/> 1056-1080	<input type="checkbox"/> 1080-1104			

[Select All](#) or [Clear](#)

#### Select parameter

<input type="checkbox"/> 2 metre dewpoint temperature	<input type="checkbox"/> 2 metre temperature	<input type="checkbox"/> Convective available potential energy
<input type="checkbox"/> Sea surface temperature	<input type="checkbox"/> Sea-ice cover	<input type="checkbox"/> Skin temperature
<input type="checkbox"/> Snow albedo	<input type="checkbox"/> Snow density	<input type="checkbox"/> Snow depth water equivalent
<input type="checkbox"/> Soil moisture top 20 cm	<input type="checkbox"/> Soil moisture top 100 cm	<input type="checkbox"/> Soil temperature top 20 cm
<input type="checkbox"/> Soil temperature top 100 cm	<input type="checkbox"/> Total Cloud Cover	<input type="checkbox"/> Total column water

[Select All](#) or [Clear](#)

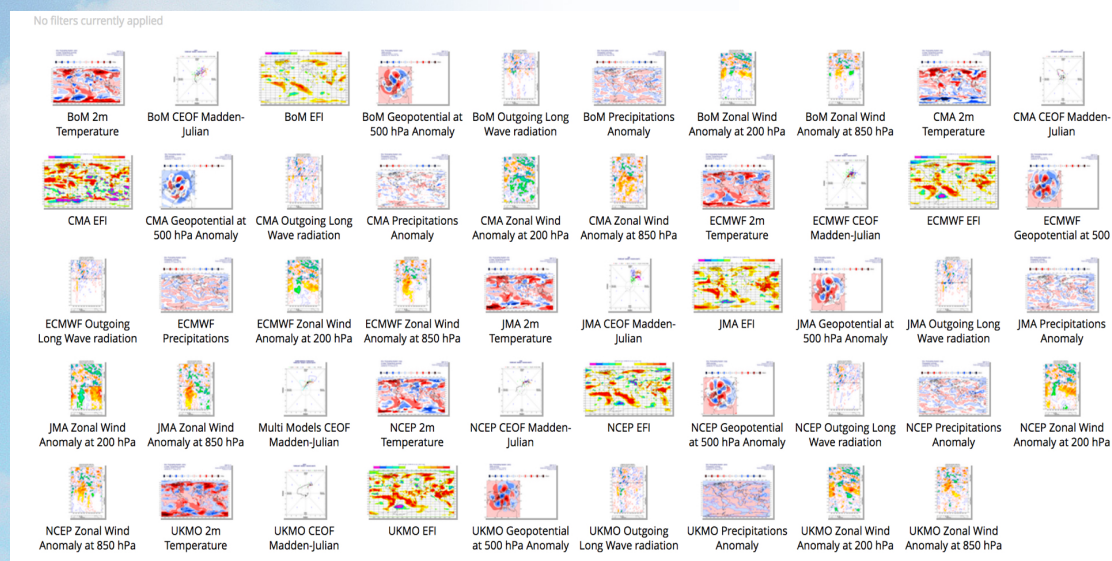
[View the MARS request](#) [Retrieve GRIB](#)

<http://apps.ecmwf.int/datasets/data/s2s>

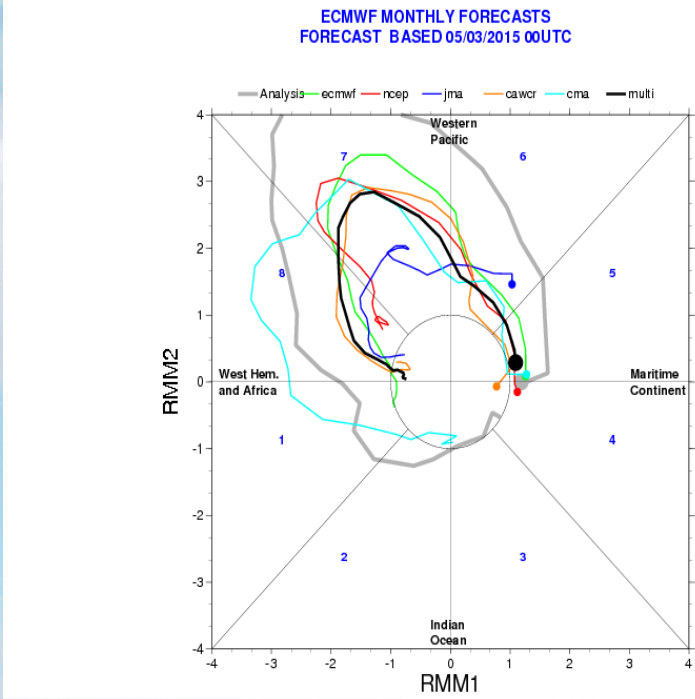
## S2S product website at ECMWF

<http://www.ecmwf.int/en/research/projects/s2s/charts/s2s/>

Contains near real-time products (anomaly maps, MJO forecasts, EFI...) from S2S models from 1<sup>st</sup> January 2016

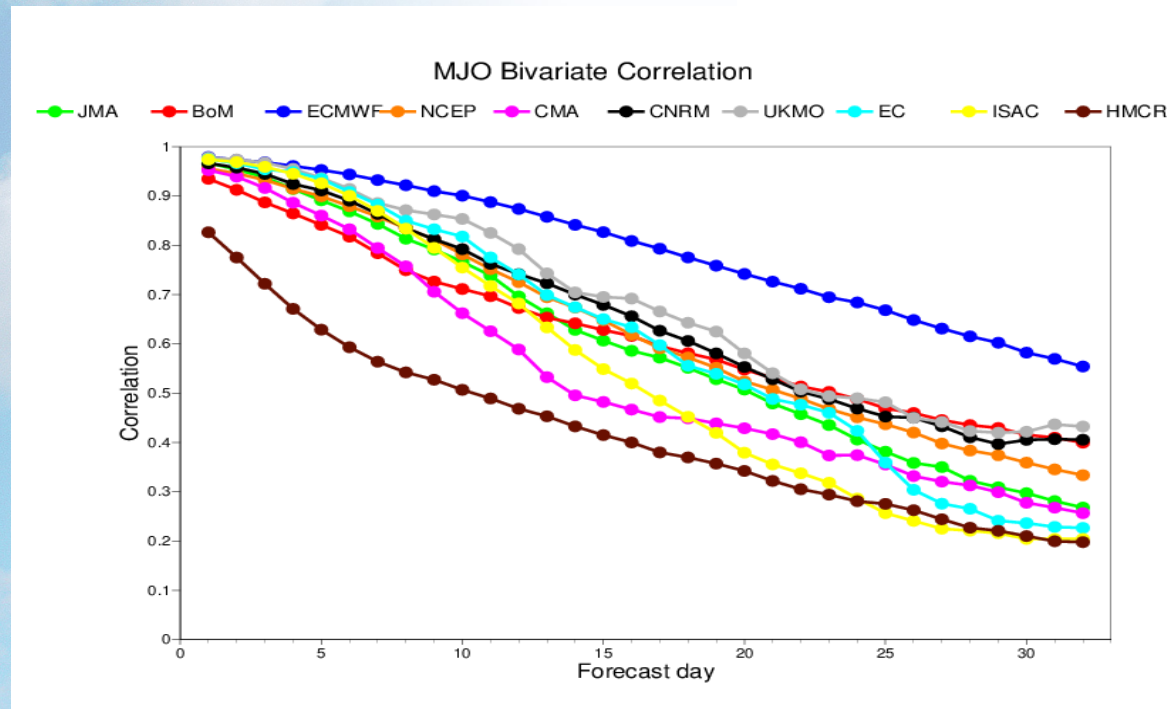


# MJO prediction in S2S database

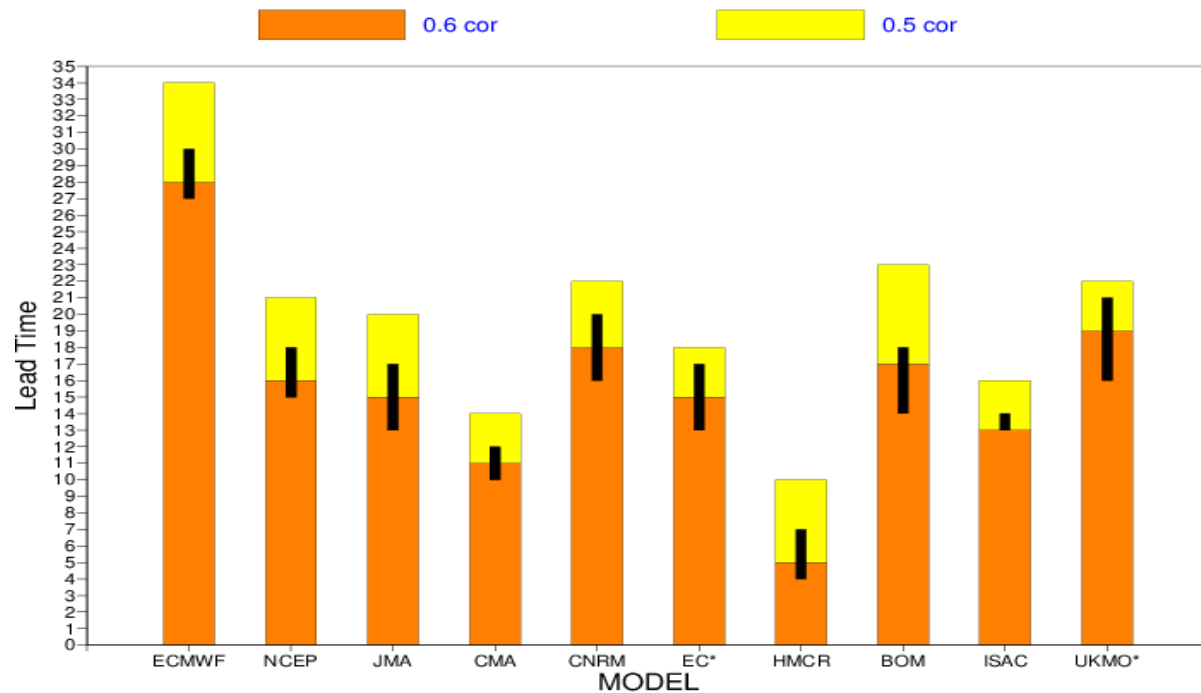


## Bivariate Correlation with ERA Interim – Ensemble Mean

### 1999-2010 re-forecasts - ALL YEAR

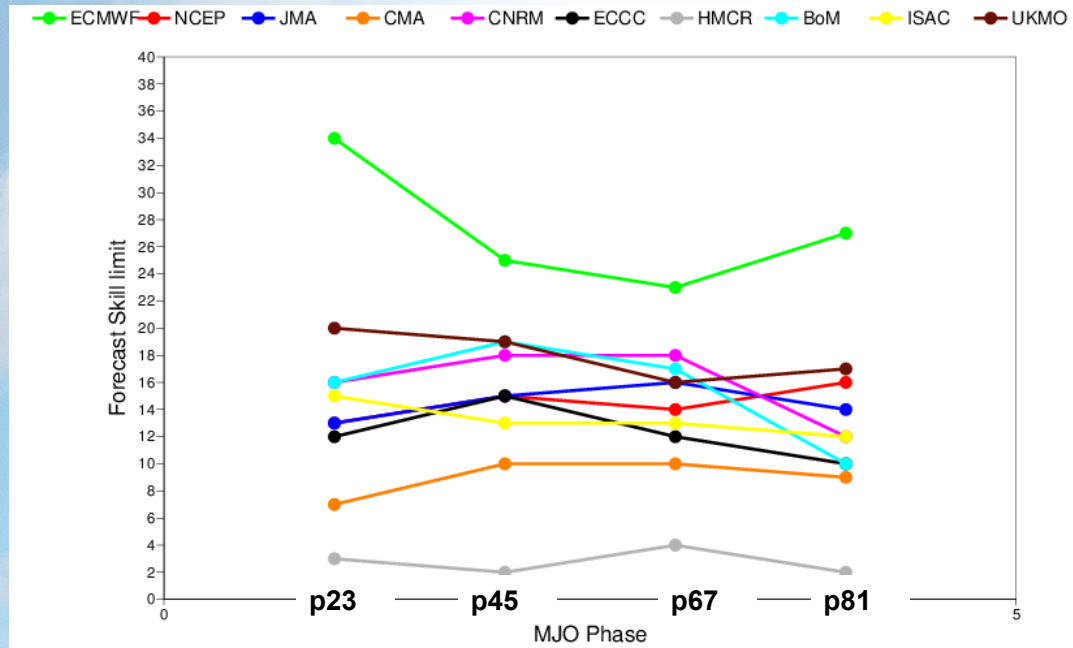


### MJO Bivariate Correlation S2S REFORECASTS 1999-2010





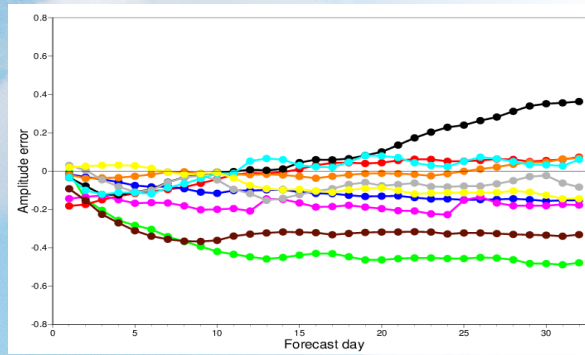
## MJO forecast skill as a function of MJO Phase



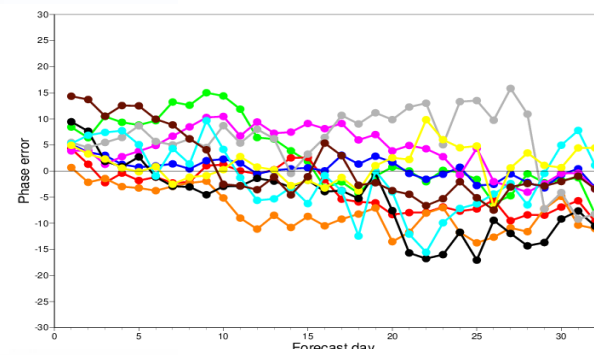
## MJO - 1999-2010 re-forecasts

Legend: JMA (green), BoM (red), ECMWF (blue), NCEP (orange), CMA (magenta), CNRM (black), UKMO (grey), EC (cyan), ISAC (yellow), HMCR (brown)

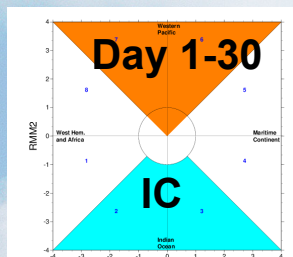
Amplitude error relative to ERA Interim



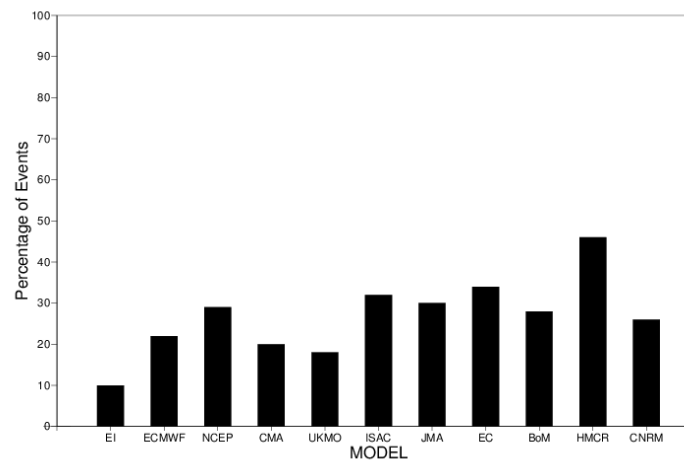
Phase error relative to ERA Interim



## Maritime Continent crossing

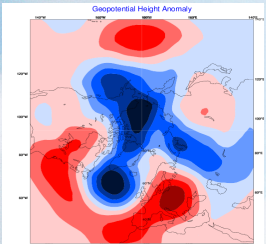


Percentage not crossing the MC  
S2S REFORECASTS DJFM 1999-2010

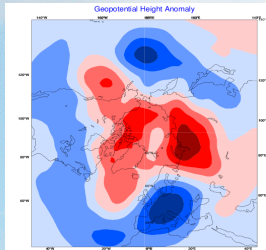


# MJO Teleconnections in ERA Interim

Phase 23 + 10 days –  
NAO= 0.32

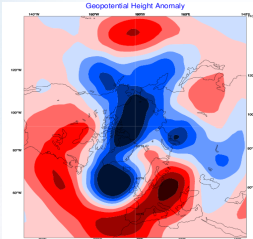


Phase 67 + 10 days –  
NAO= -0.27

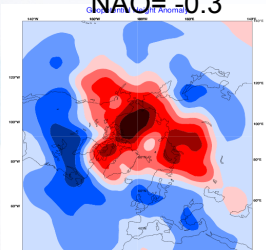


## ONDJFM

Phase 3 + 10 days –  
NAO= 0.42

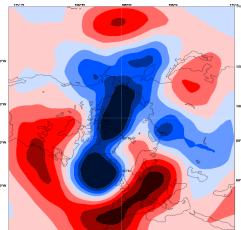


Phase 7 + 10 days –  
NAO= -0.3

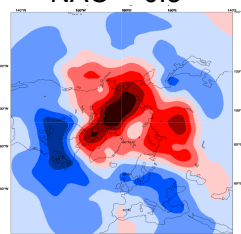


## NDJFM

Phase 3 + 10 days –  
NAO= 0.47



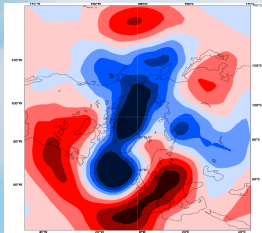
Phase 7 + 10 days –  
NAO= -0.3



## MJO Teleconnections in ERA Interim

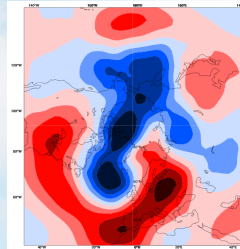
Phase 3 + 10 days  
NDJFM

**NAO = 0.472**



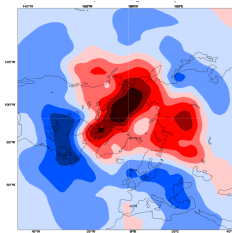
Phase 3 + 3 pentads  
NDJFM

**NAO = 0.48**



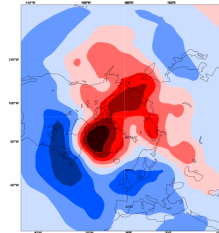
Phase 7 + 10 days  
NDJFM

**NAO = -0.299**



Phase 7 + 3 pentads:  
NDJFM

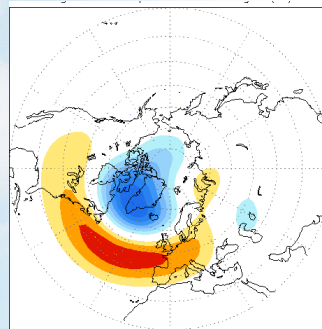
**NAO = -0.45**



## NAO Index

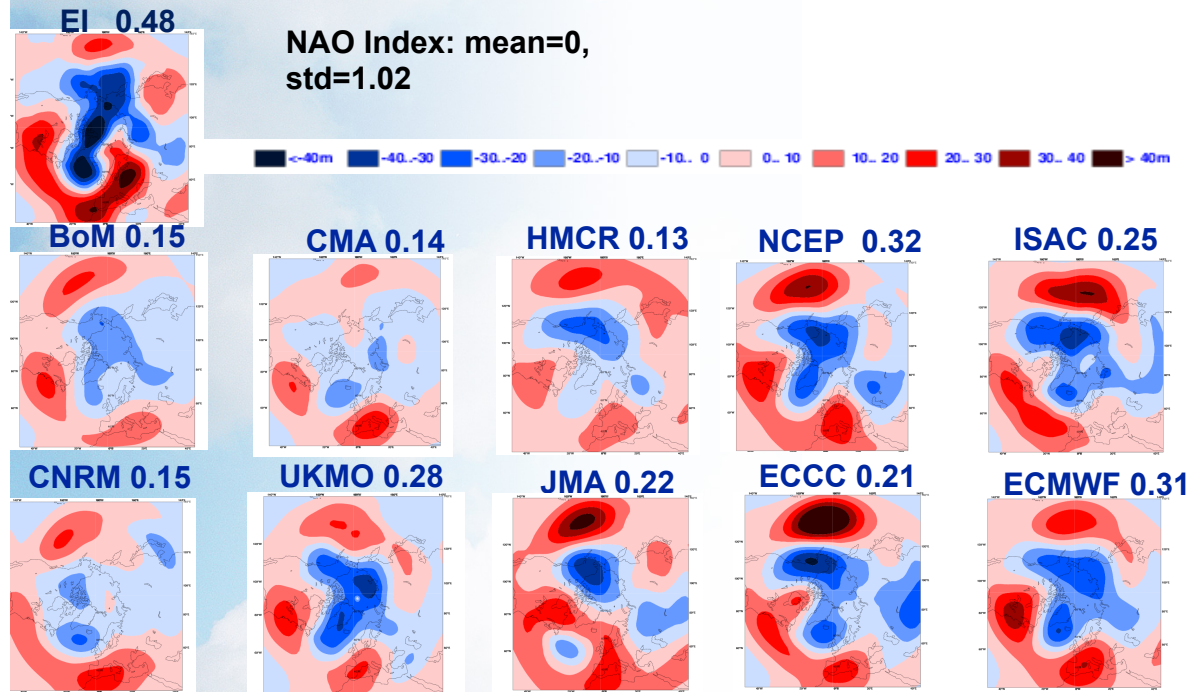
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**Projection of Z500 anomalies on NAO pattern computed from EOF analysis on NCEP reanalysis**



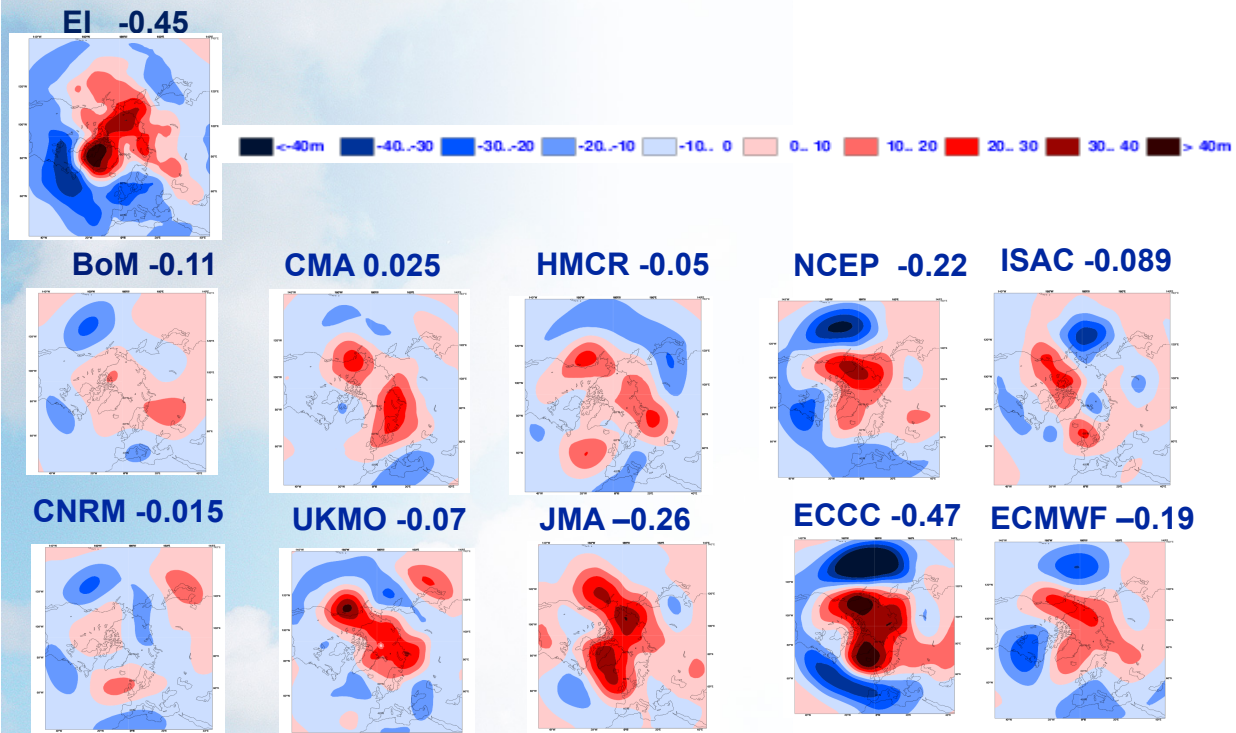
- Daily frequency: Mean=0 , standard deviation = 1.13
- Pentad average: mean=0, standard deviation = 1.02

## Composites of Z500 3 pentads after an MJO in Phase 3 NDJFM



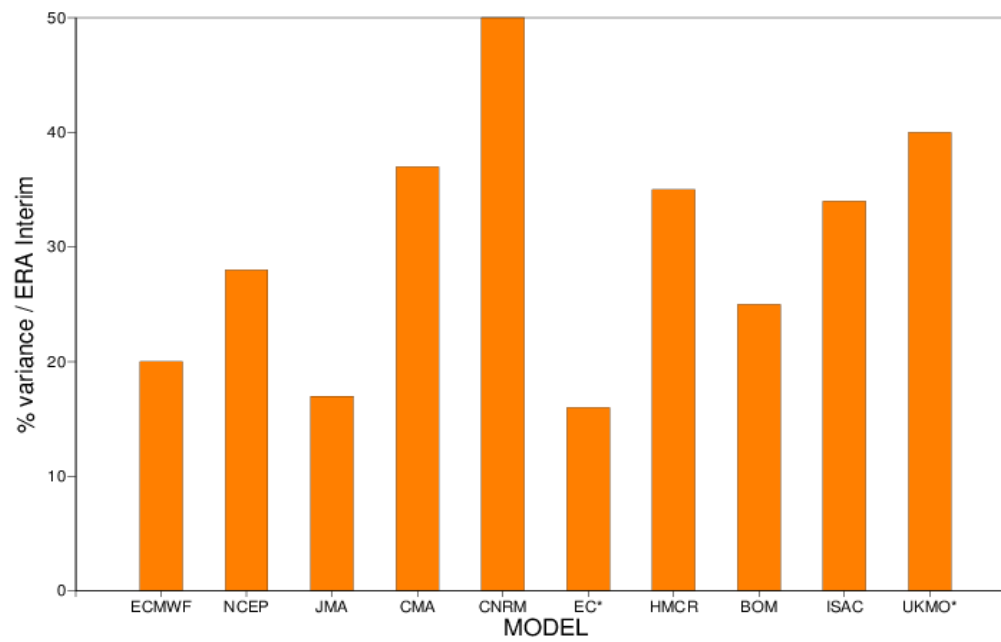


## Composites of Z500 3 pentads after an MJO in Phase 7 NDJFM





NAO Variance relative to EI  
S2S REFORECASTS 1999-2010



## Evolution of Teleconnection with lead time –MJO Phase 3

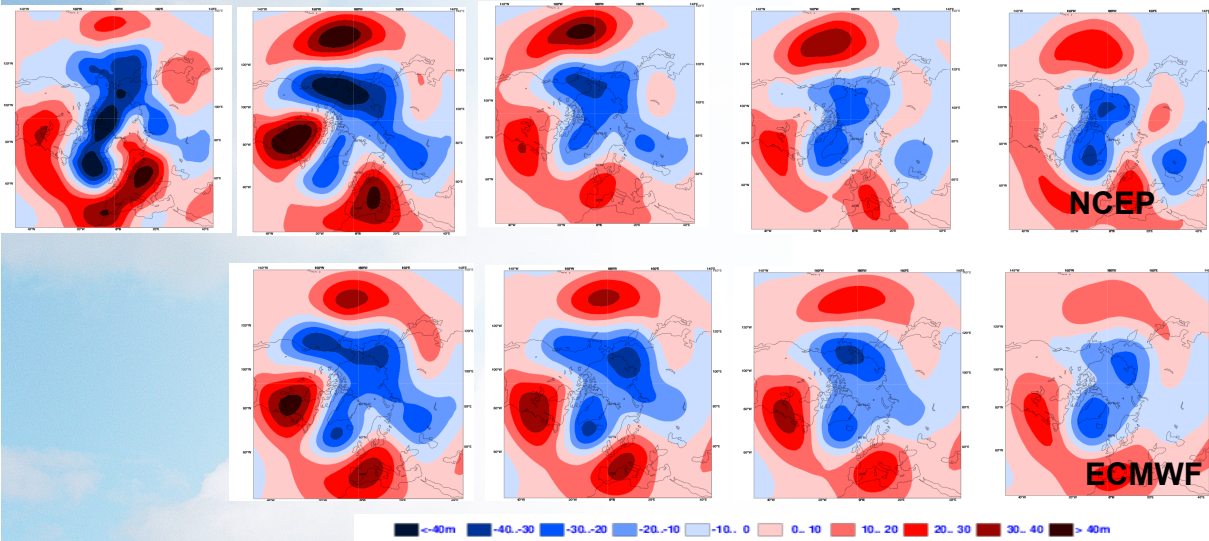
ERA  
Interim

MJO day 0-5  
Z500 Lead time day 10-20

MJO day 5-10  
Z500 Lead time day 15-25

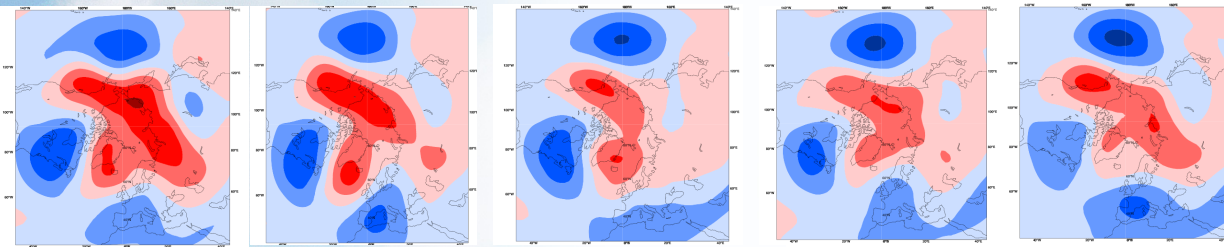
MJO day 10-15  
Z500 Lead time day 20-30

MJO day 15-20  
Z500 Lead time day 25-35

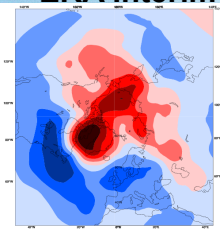


## Evolution of Teleconnection with lead time – ECMWF - MJO Phase 7

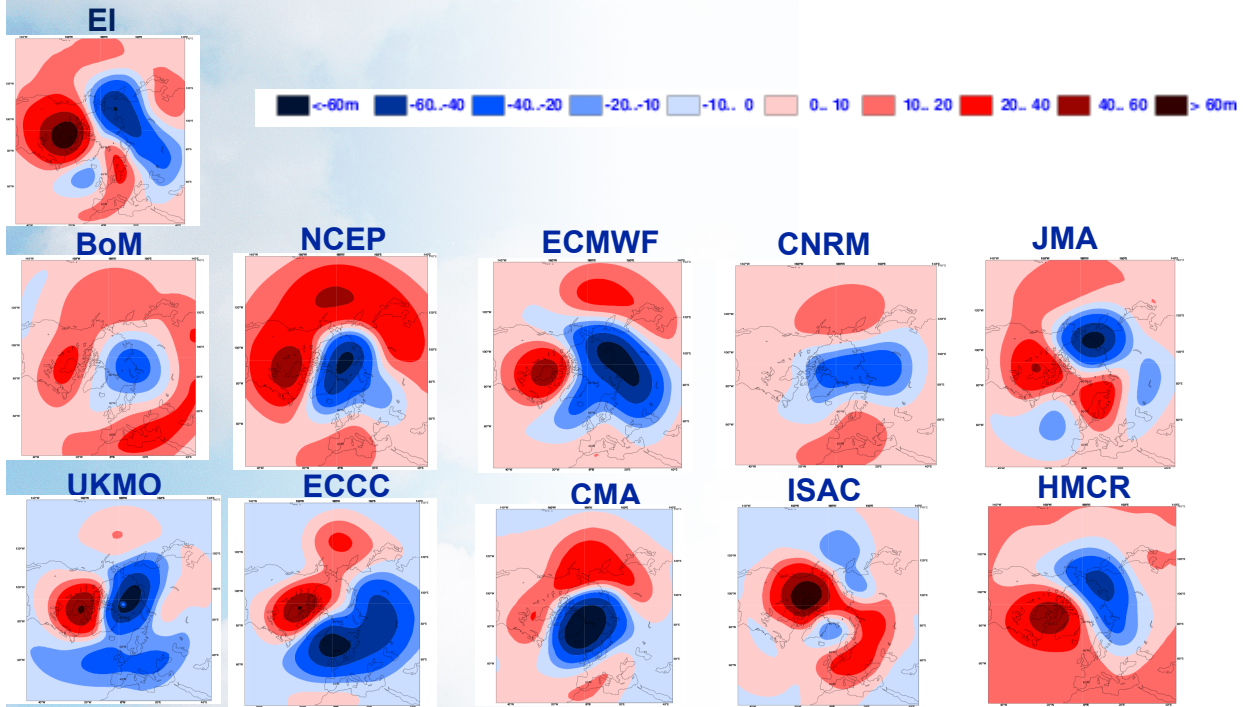
**MJO day 0-5**      **MJO day 5-10**      **MJO day 10-15**      **MJO day 15-20**      **MJO day 20-25**  
**Z500 Lead time day 10-20**    **Z500 Lead time day 15-25**    **Z500 Lead time day 20-30**    **Z500 Lead time day 25-30**    **Z500 Lead time day 30-40**  
**-0.21**                    **-0.21**                    **-0.14**                    **-0.14**                    **-0.13**



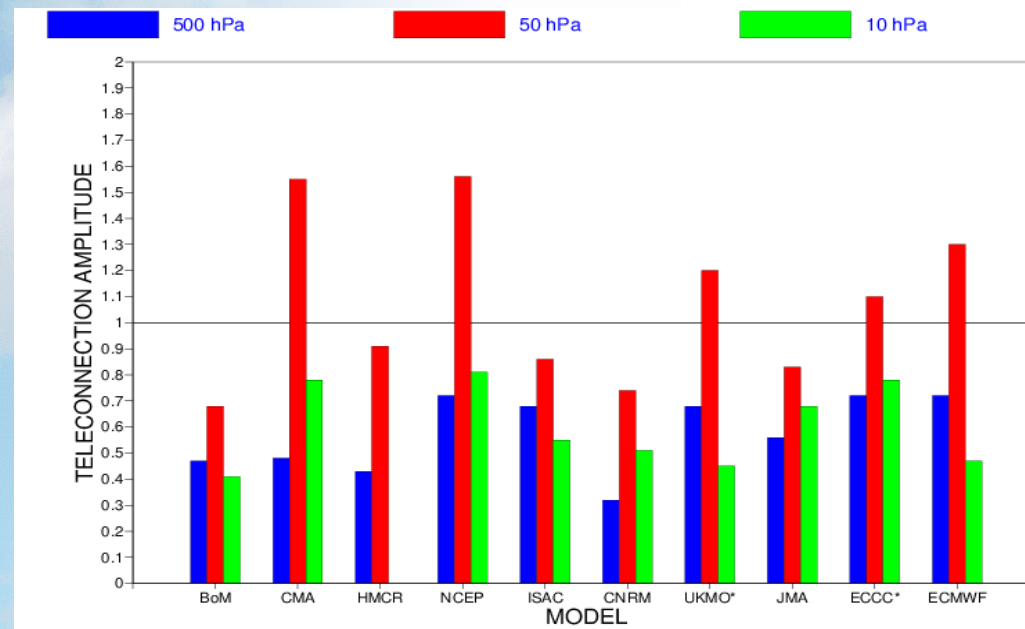
**ERA Interim**



## Composites of Z50 3 pentads after an MJO in Phase 3 NDJFM

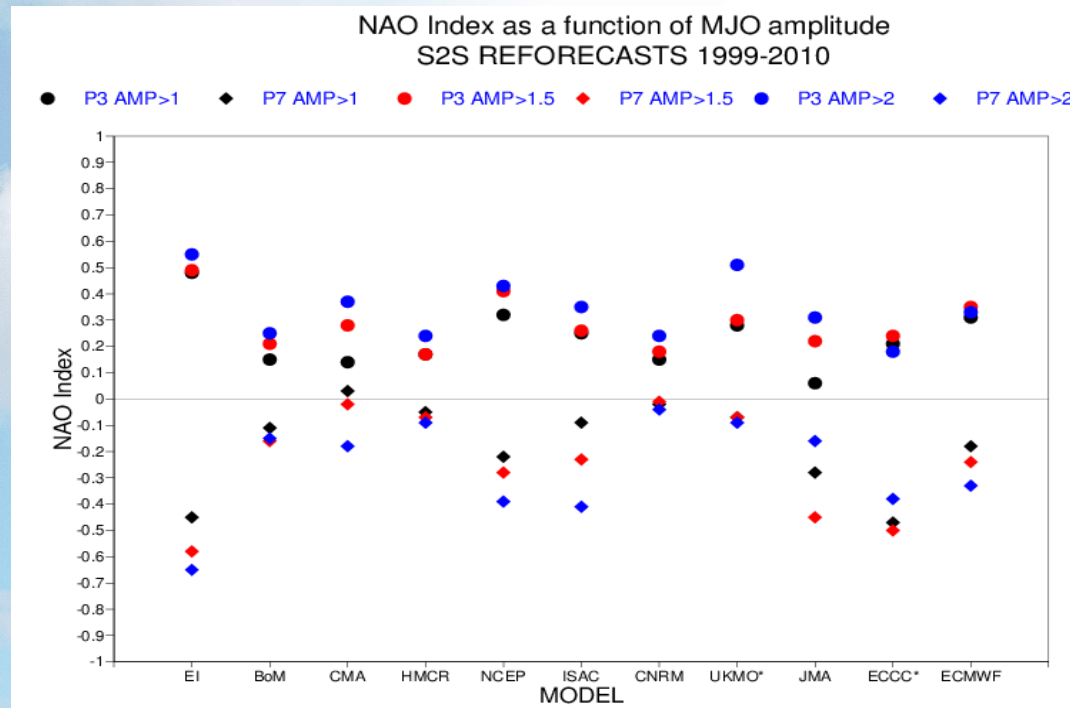


## Amplitude MJO Teleconnections 3<sup>rd</sup> pentad after an MJO in Phase 3

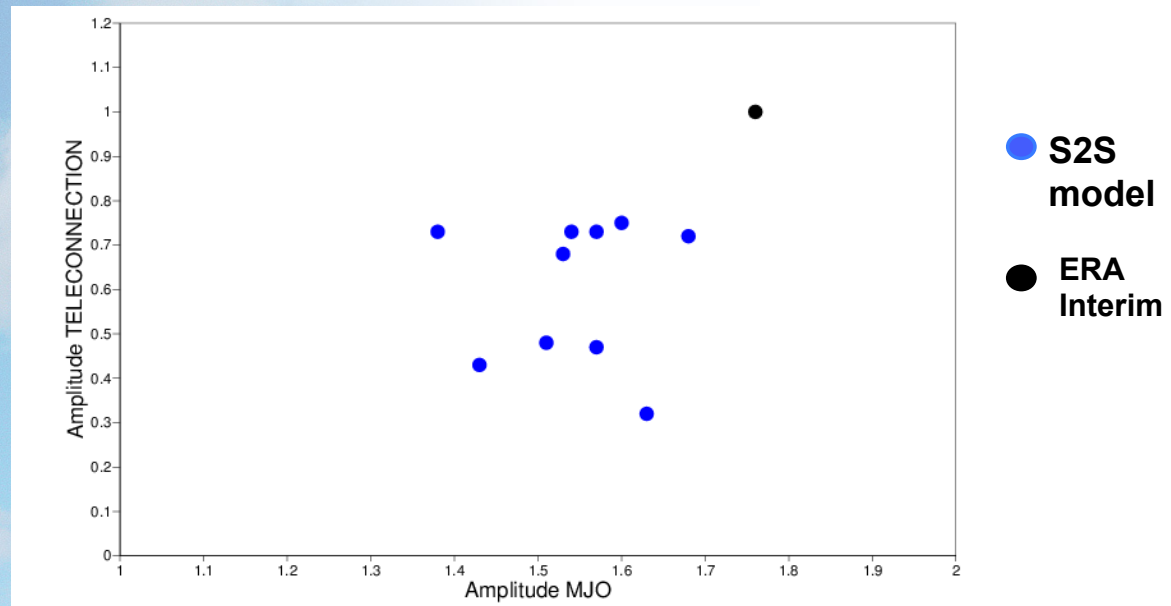




## Impact of MJO Intensity on NAO Index



## Impact of MJO Amplitude in Phase 3



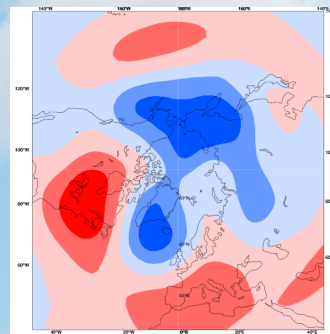
# Tropical relaxation experiment

15 member ensembles running on 1<sup>st</sup> NDJFM 1989-2015 for 46 days

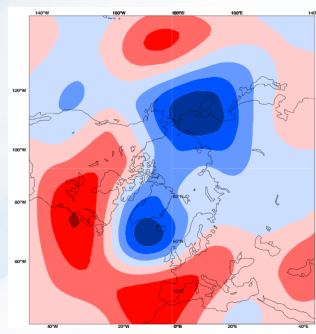
Control: IFS CY43R1

Relaxation: Tropical band 20N-20S relaxed towards ERA Interim

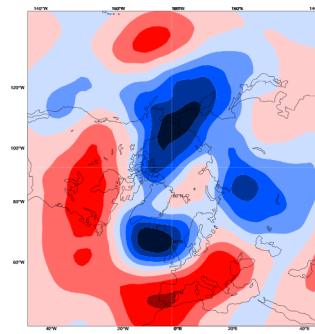
Control



Relaxation

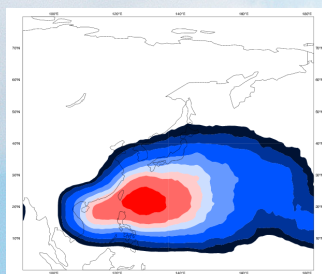


ERA Interim

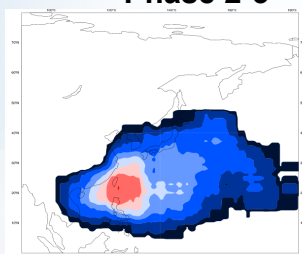


## TC Density - OBSERVATIONS

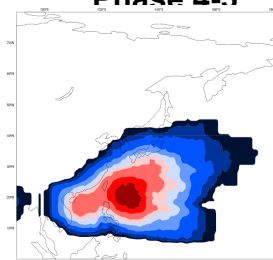
ALL



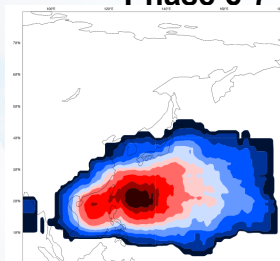
Phase 2-3



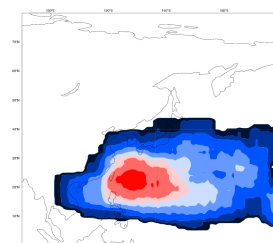
Phase 4-5



Phase 6-7



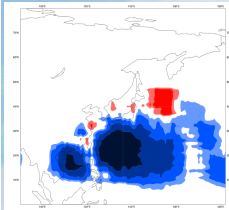
Phase 8-1



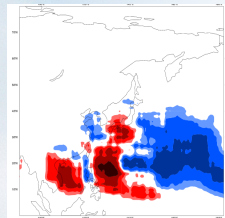
## TC Density anomalies

### Observations

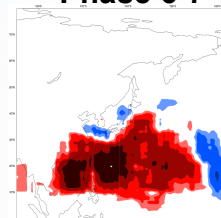
Phase 2-3



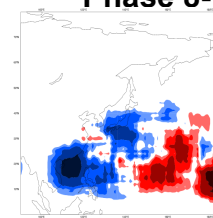
Phase 4-5



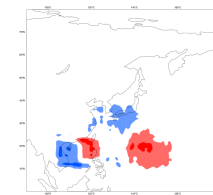
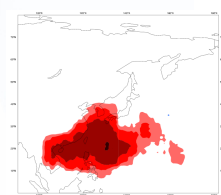
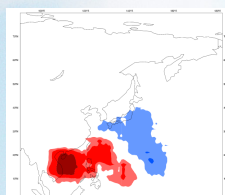
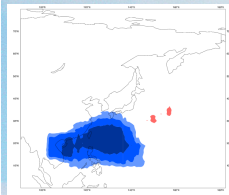
Phase 6-7



Phase 8-1



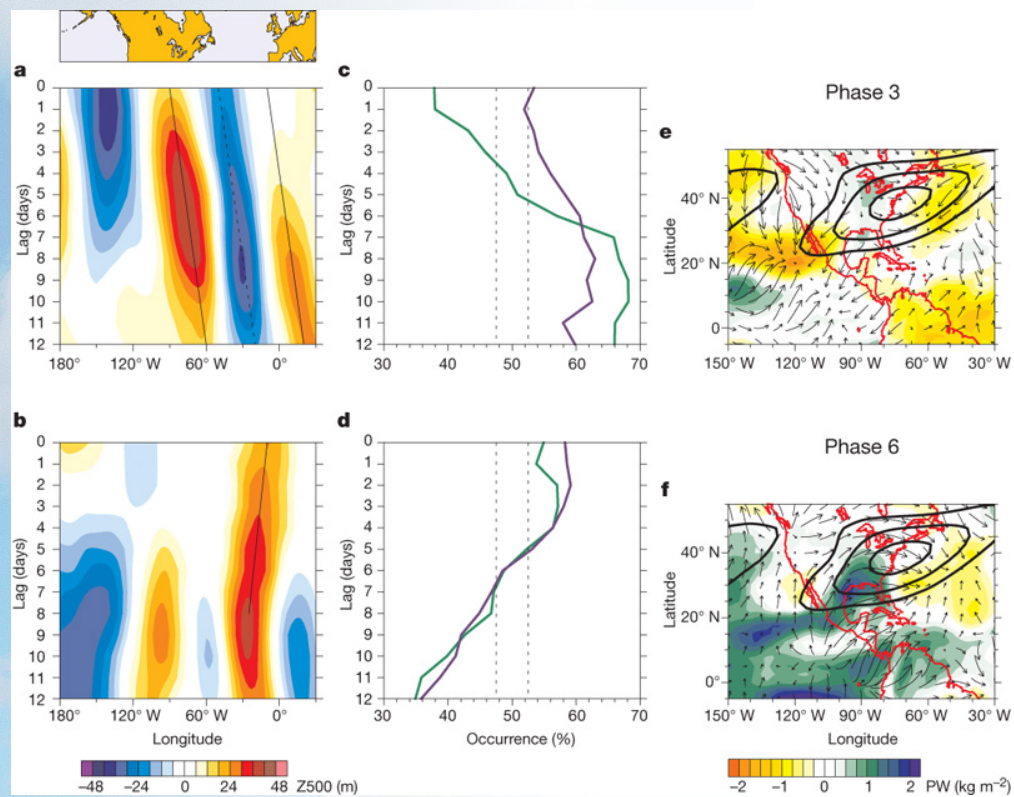
### ECMWF



## Conclusions

- Significant improvements in the representation and prediction of the Madden Julian Oscillation in S2S models over the past decade
- S2S models are able to represent the general patterns of MJO teleconnections in the Extratropics, but the amplitude in the Euro-Atlantic sector is too weak.
- The realism of teleconnections decreases quickly with lead time
- MJO teleconnections display more variability in models than in ERA-Interim.
- The MJO teleconnections are often too strong in the stratosphere

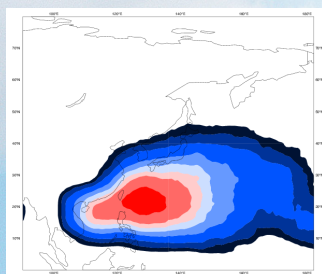
Asymmetrical tropical-extratropical connection between two specific phases of the MJO leading to NAO+ and NAO- events.



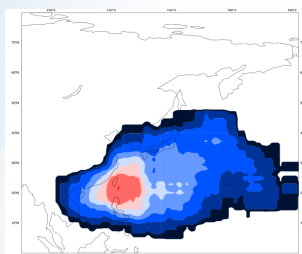


# TC Density - OBSERVATIONS

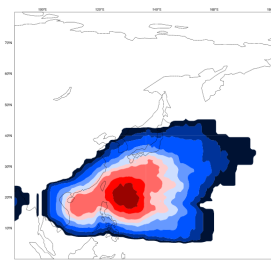
ALL



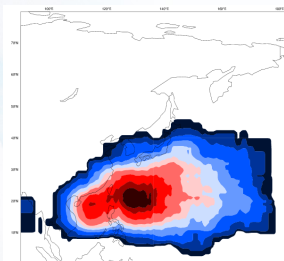
Phase 2-3



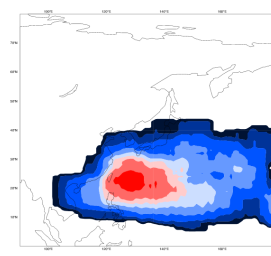
Phase 4-5



Phase 6-7

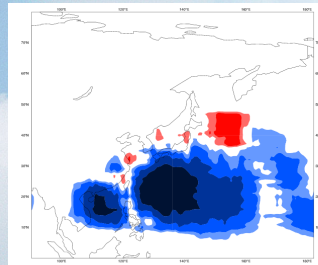


Phase 8-1

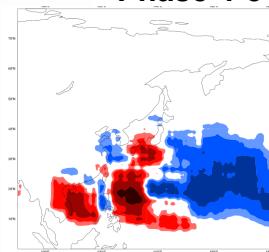


## TC Density anomalies - OBSERVATIONS

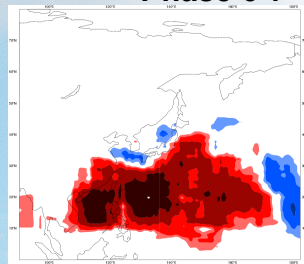
Phase 2-3



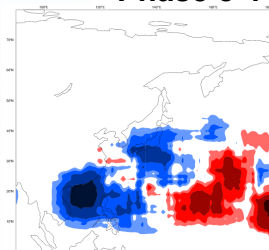
Phase 4-5



Phase 6-7



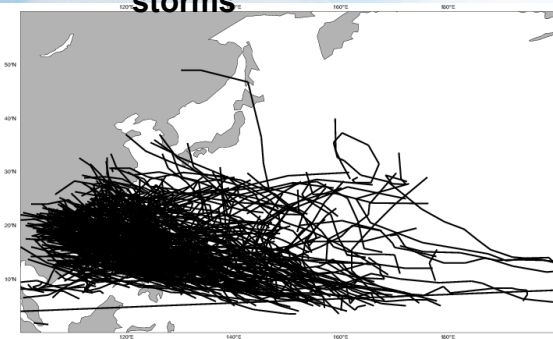
Phase 8-1



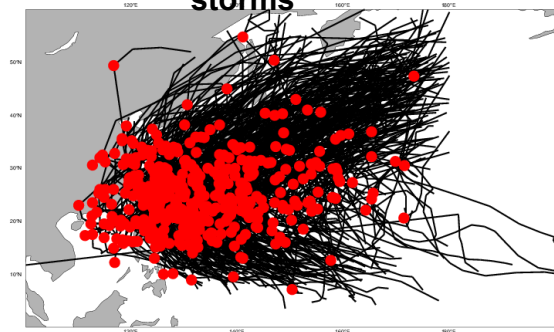
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## Detection of recurring tropical storms in Observations (IBTrACS)

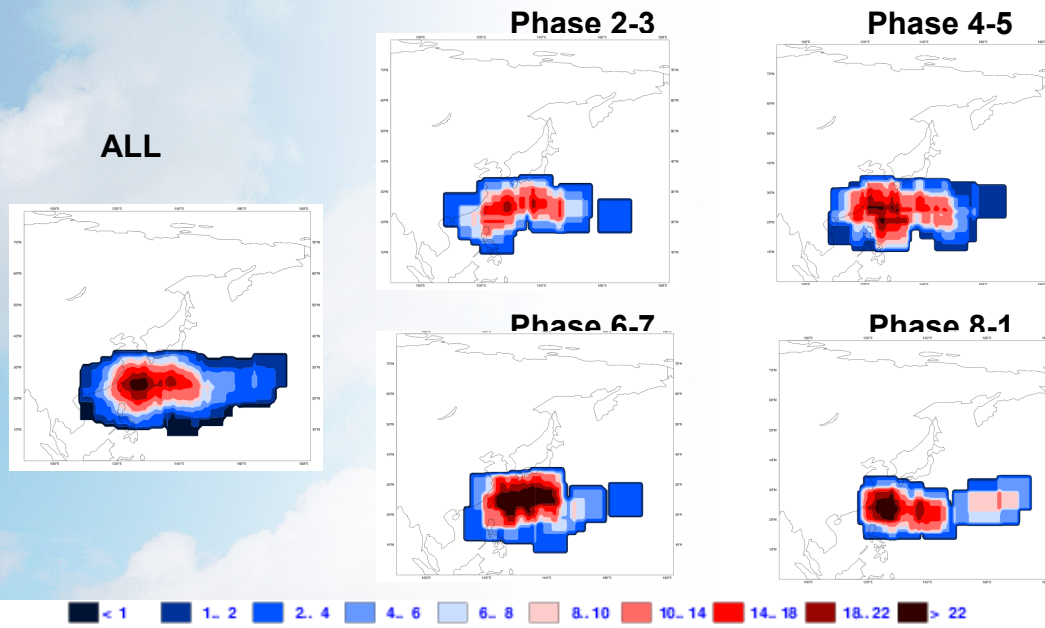
**Non-recurring tropical storms**



**recurring tropical storms**

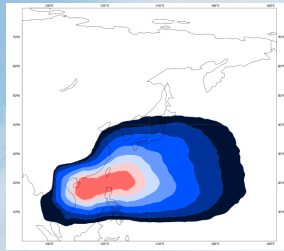


## TC Recurvature point Density - OBSERVATIONS

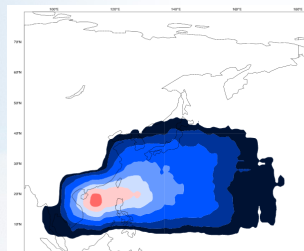


## TC Density - ECMWF

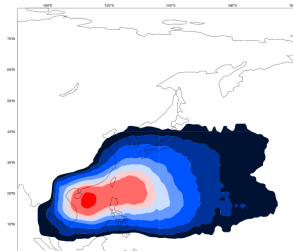
### Model Climatology



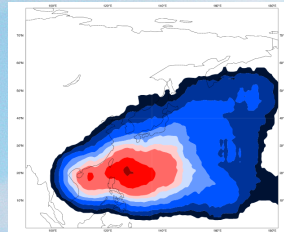
### Phase 2-3



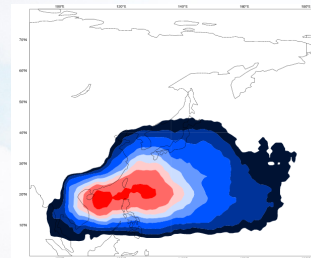
### Phase 4-5



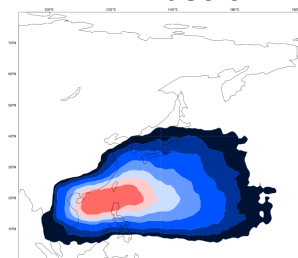
### Observations



### Phase 6-7



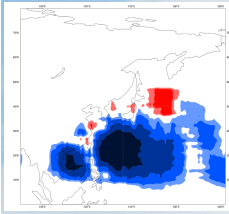
### Phase 8-1



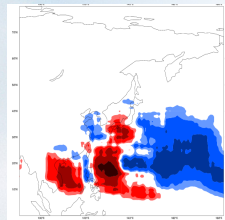
## TC Density anomalies

### Observations

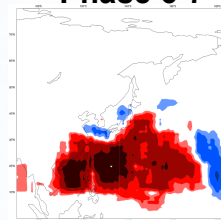
Phase 2-3



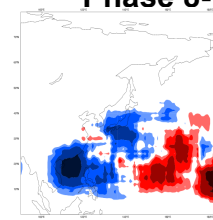
Phase 4-5



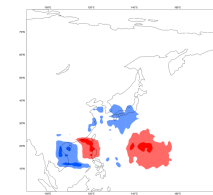
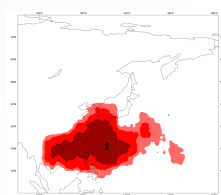
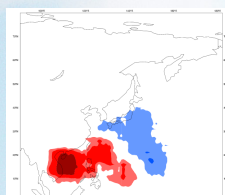
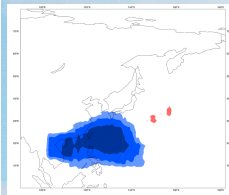
Phase 6-7



Phase 8-1



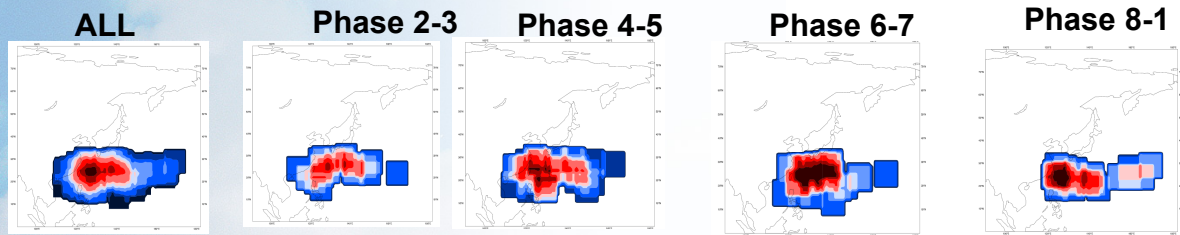
### ECMWF



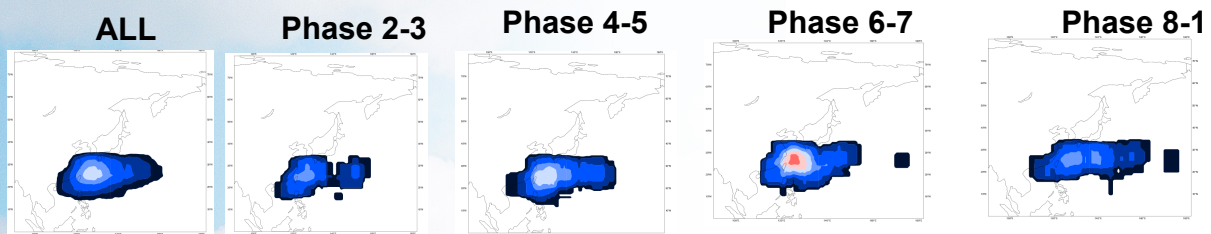


# TC recurvature point Density

## Observations



## ECMWF RE-FORECAST

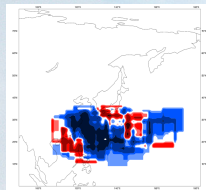




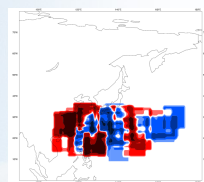
## TC recurvature Density Anomaly - OBSERVATIONS

### Observations

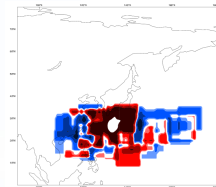
Phase 2-3



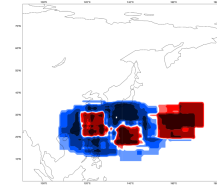
Phase 4-5



Phase 6-7

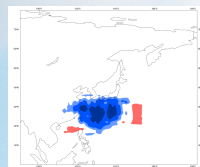


Phase 8-1

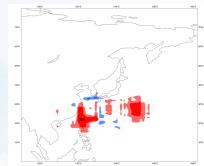


### ECMWF RE-FORECAST

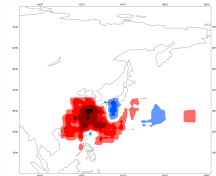
Phase 2-3



Phase 4-5



Phase 6-7



Phase 8-1

