MJO teleconnections in the S2S database

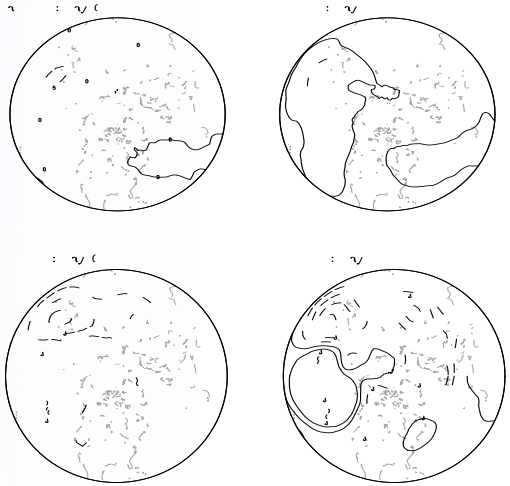
Frédéric Vitart
ECMWF

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



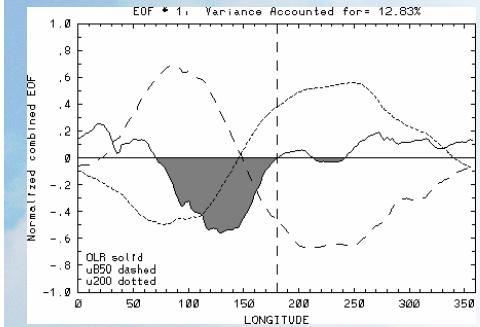
Lin et al, MWR 2010
See also
Simmons et al JAS 1983
Ting and Sardeshmukh JAS 1993

Impact of the MJO on Extratropics

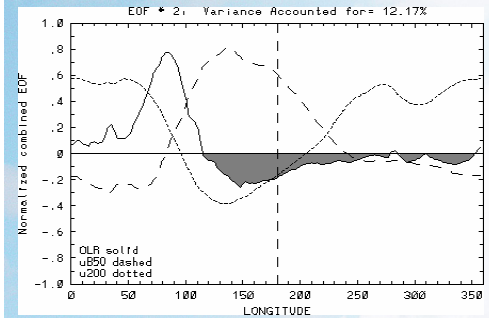
Lin et al, MWR 2010

MJO Metrics: combined EOFs of U200,U850 and OLR

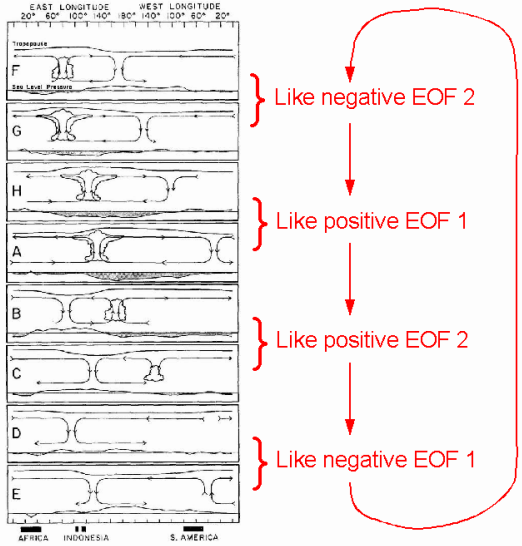
Combined EOF1



Combined EOF2

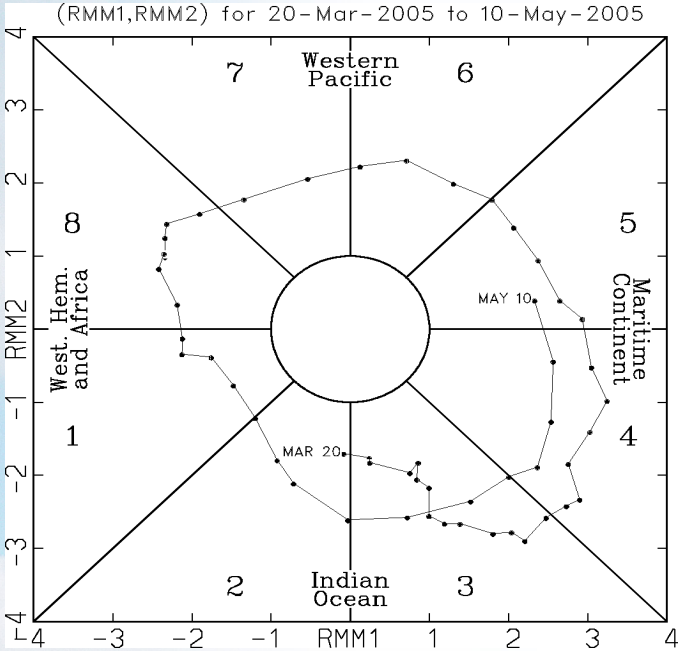


Madden and Julian's (1972) schematic

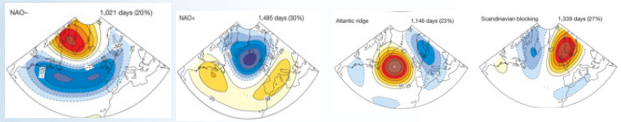


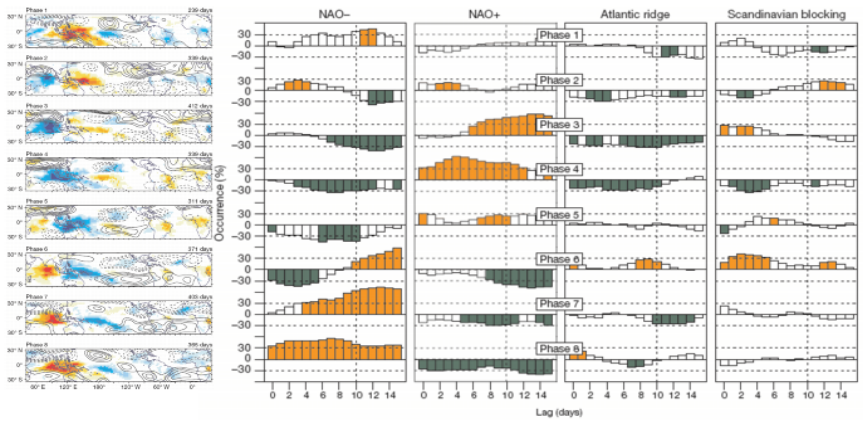
Wheeler and Hendon, MWR 2004

MJO Metrics: combined EOFs of U200,U850 and OLR



1. Impact of the MJO on weather regimes

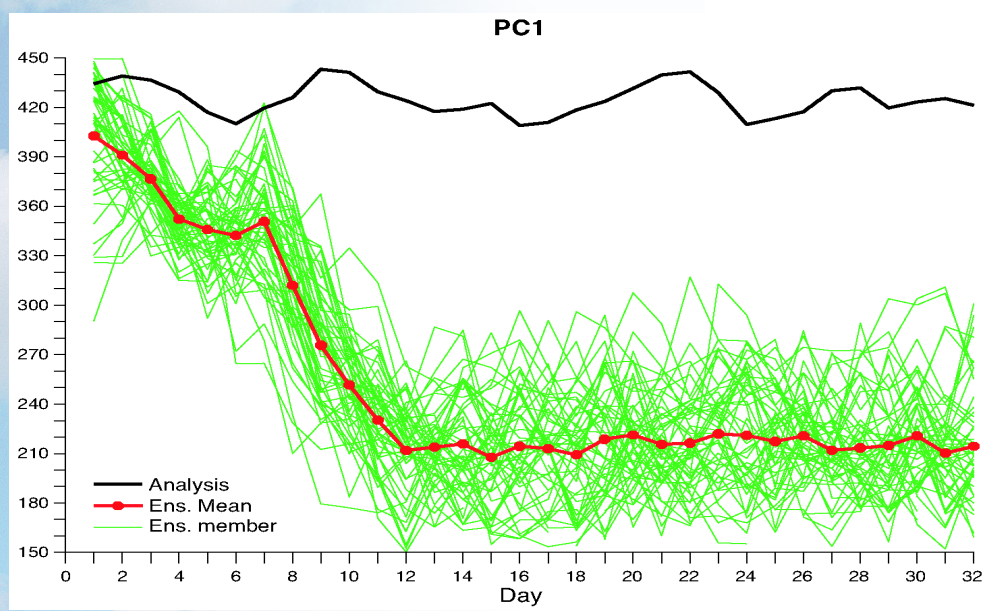




Cassou C,2008: Intraseasonal interaction between the Madden-Julian Oscillation and the North Atlantic Oscillation. *Nature*, **455**, 523-527.

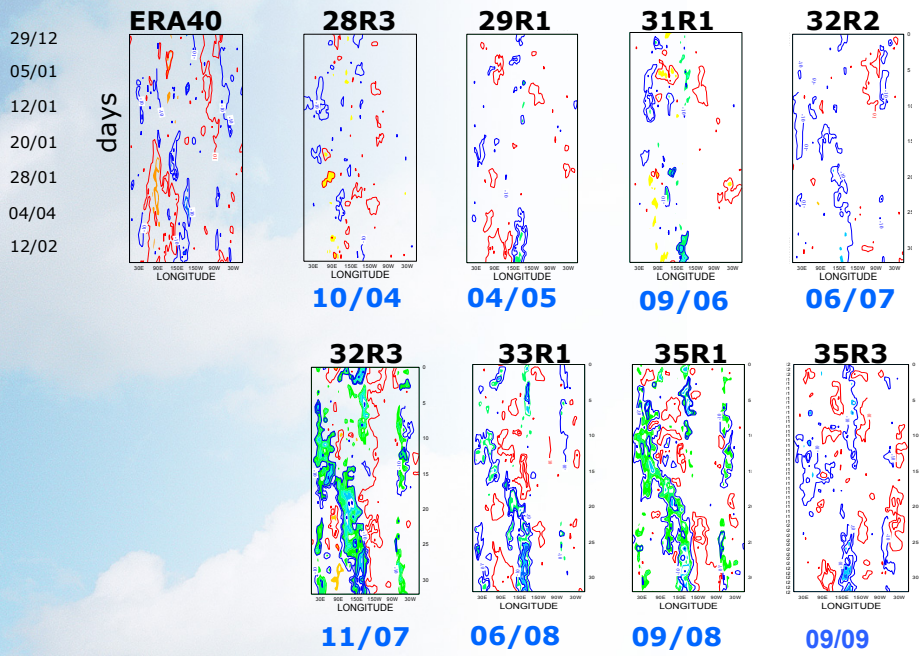
Cassou (2008)

Simulation of the MJO

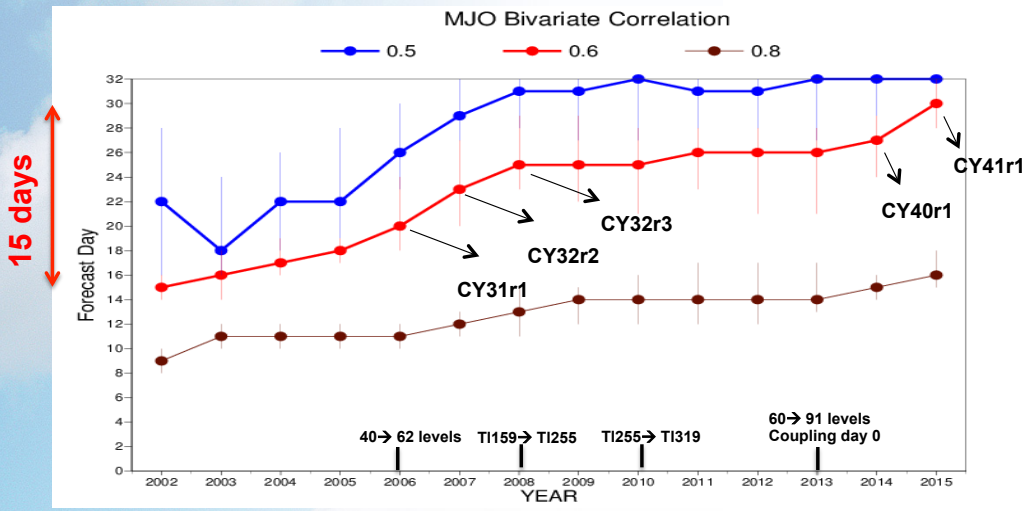


Vitart, 2003

OLR anomalies - Forecast range: day 15



Madden Julian Oscillation prediction at ECMWF



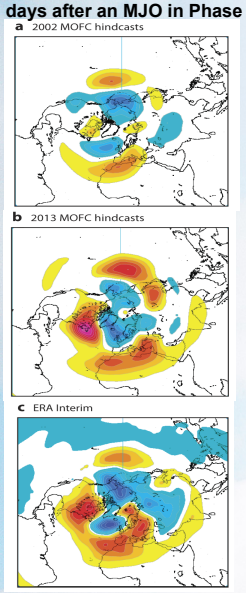
Wheeler and Hendon (2004) Index

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

Improvements in MJO Prediction mostly due to changes in convective parameterization

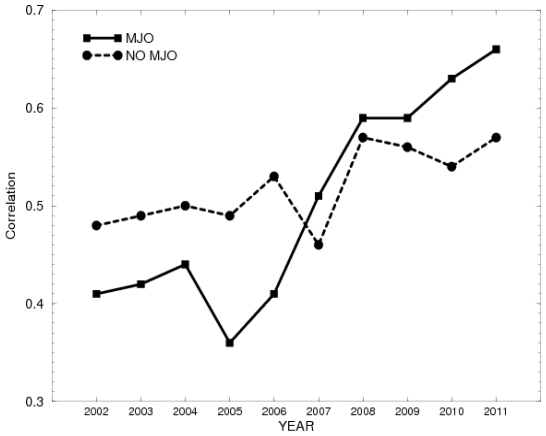
MJO teleconnections

Z500 anomalies
10 days after an MJO in Phase 3



Evolution of NAO skill scores-Day 19-25

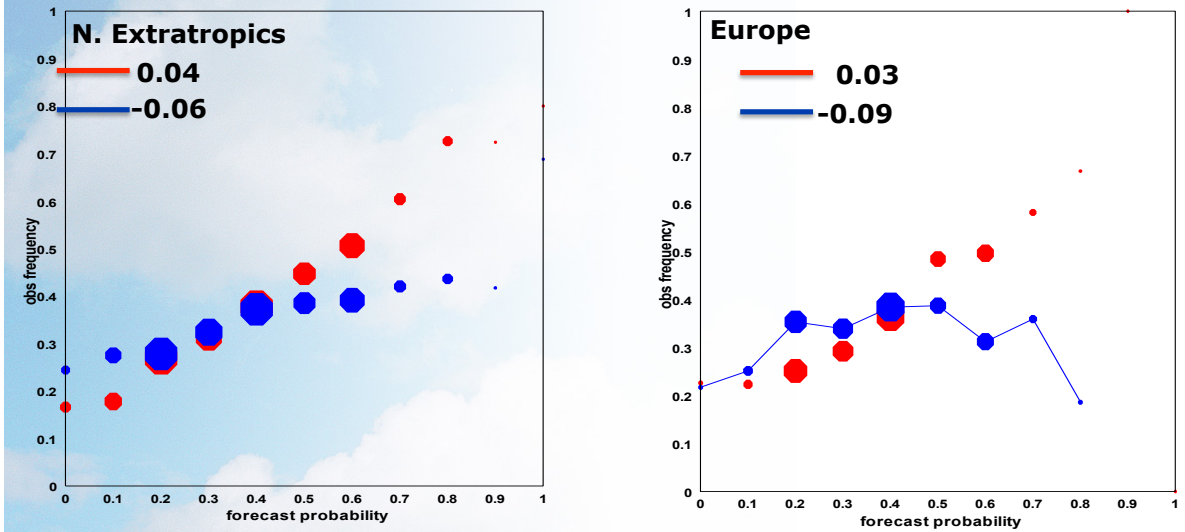
NAO Index: projection of Z500 on pre-computed EOF



Vitart, 2014

Probabilistic skill scores – NDJFMA 1989-2008

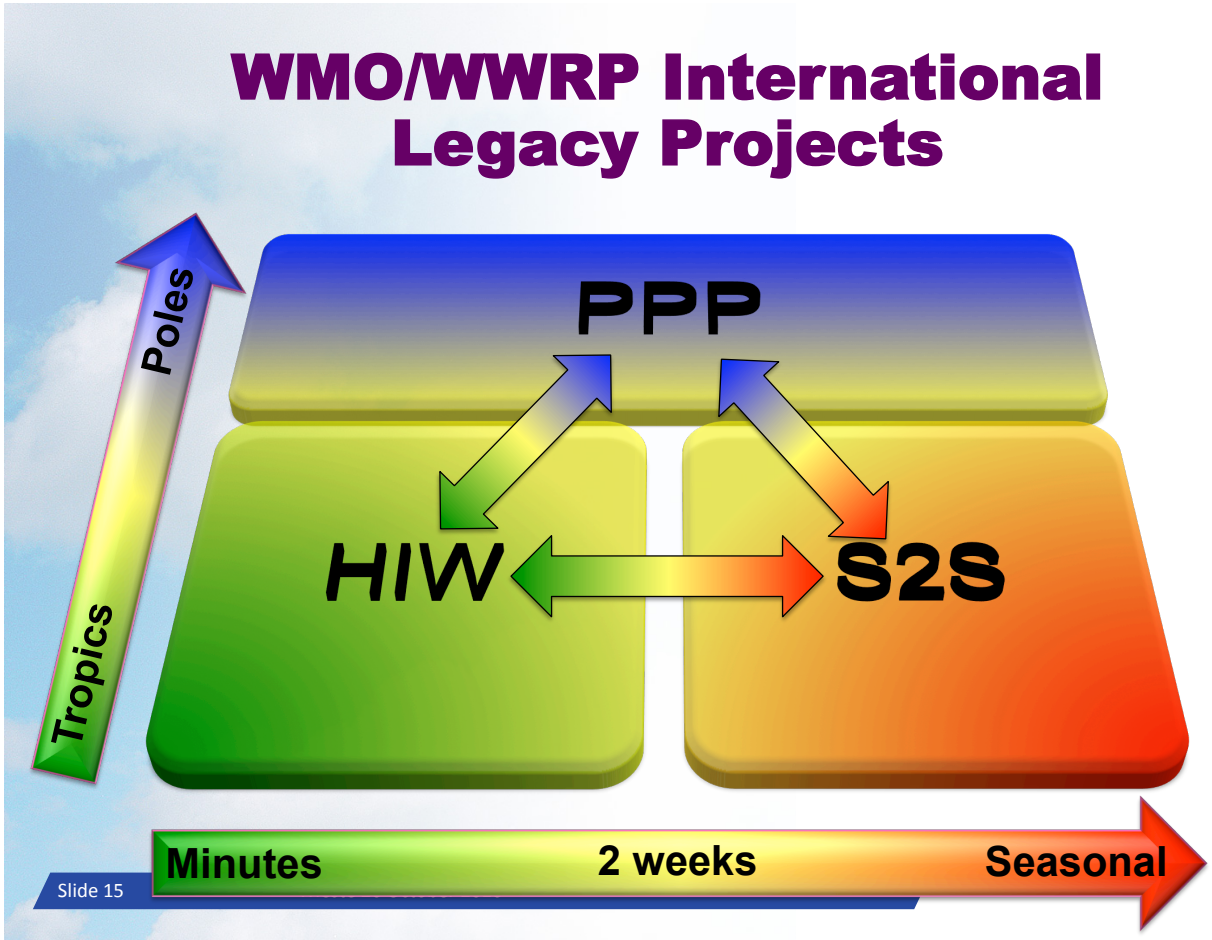
Reliability Diagram
Probability of 2-m temperature in the upper tercile
Day 19-25



MJO in IC **NO MJO in IC**

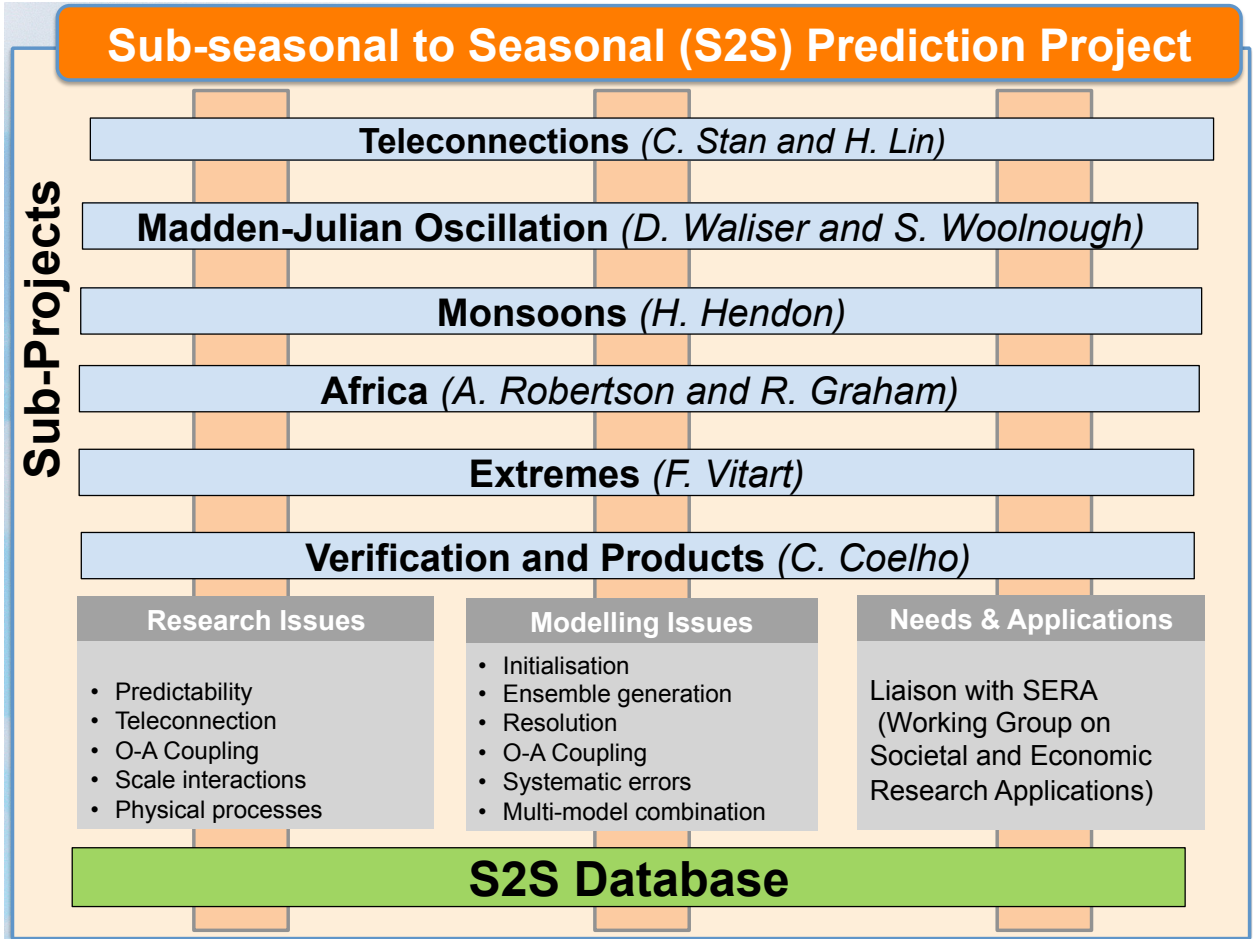
Vitart et al, 2010

WWRP/WCRP S2S database


WMO/WWRP International
Legacy Projects
PPP
HIW
S2S
Poles
Tropics
Minutes
2 weeks
Seasonal
Slide 15

WWRP/WCRP S2S project Mission Statement

- "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

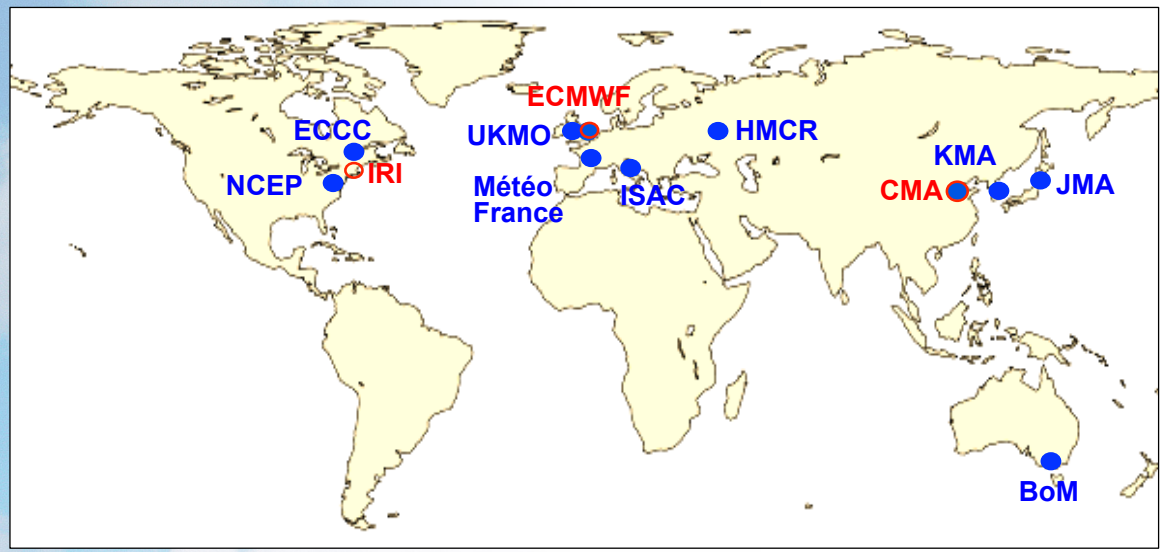
www.s2sprediction.net

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) O Archiving centre (3)



S2S Models

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

S2S Database current status

- 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.

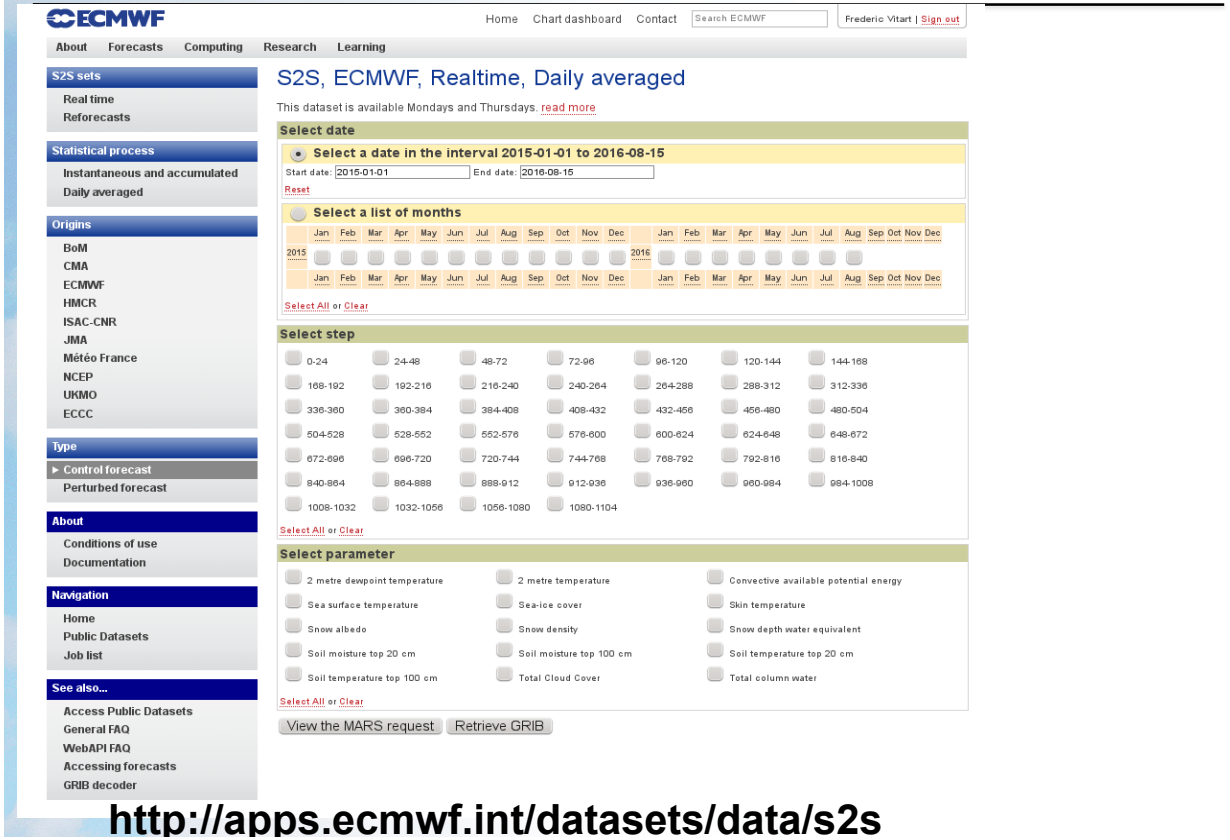
- Total size of the database so far: 43 Tbytes

  - 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
CMA website: s2s.cma.cn

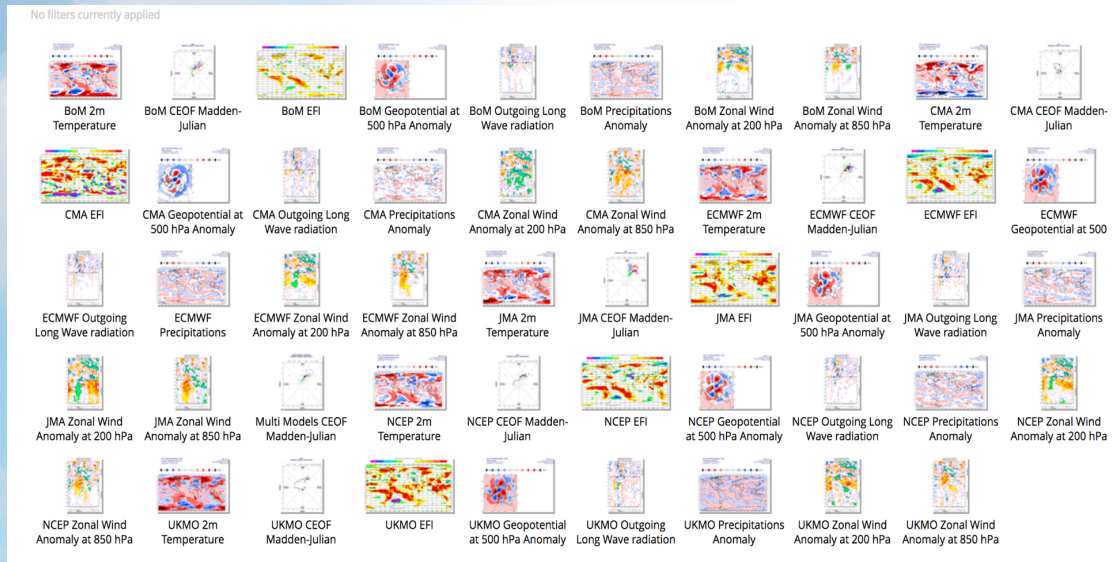


http://apps.ecmwf.int/datasets/data/s2s

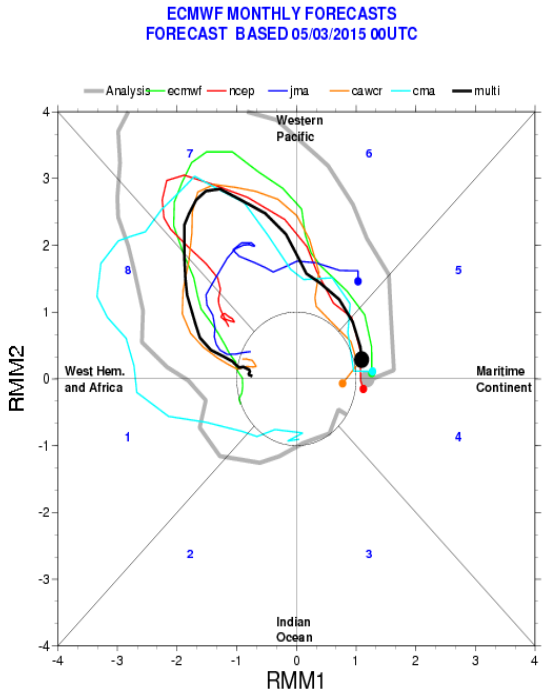
S2S product website at ECMWF

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

Contains near real-time products (anomaly maps, MJO forecasts, EFI…) from S2S models from 1st January 2016

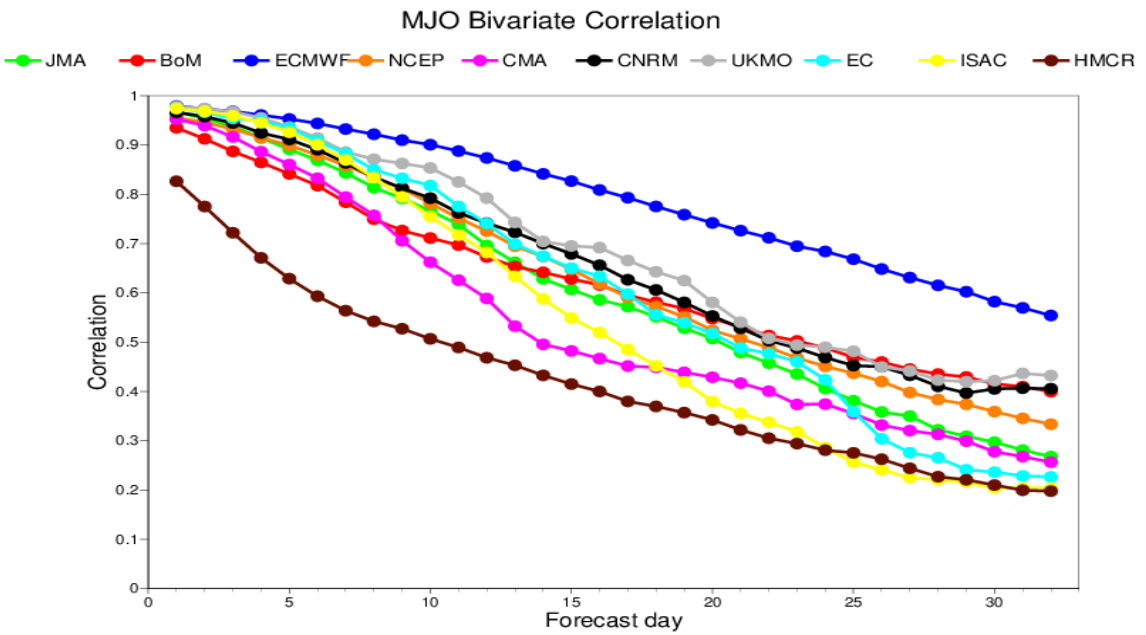


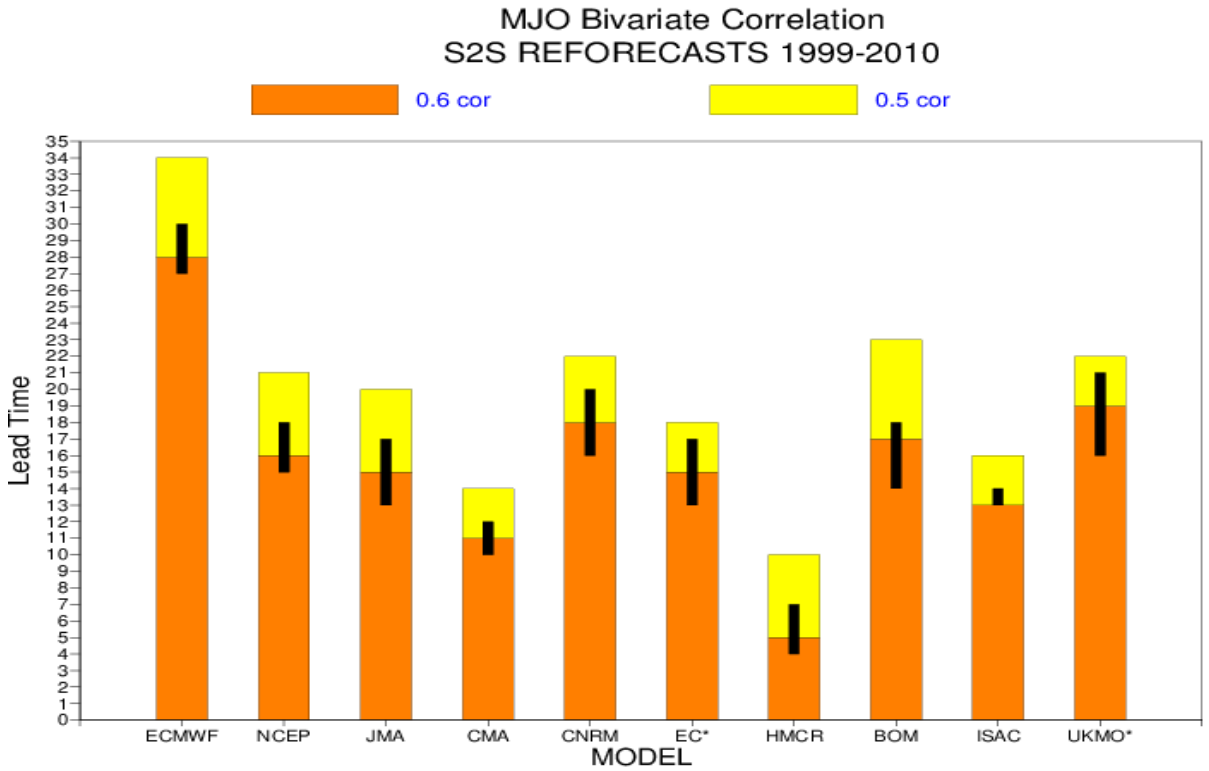
MJO prediction in S2S database



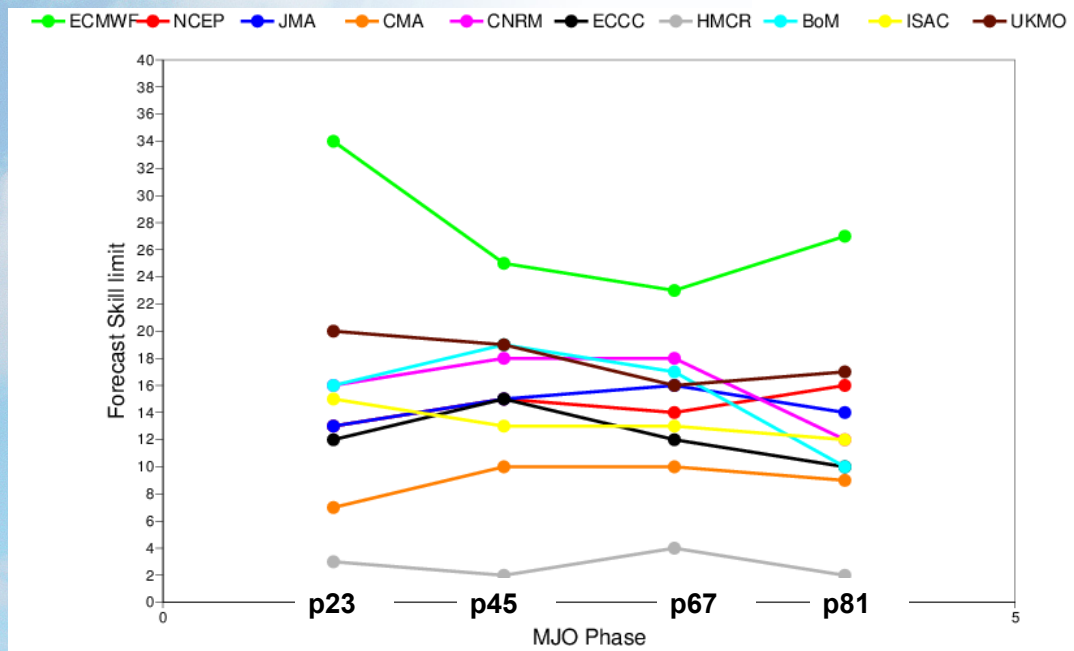
Bivariate Correlation with ERA Interim – Ensemble Mean

1999-2010 re-forecasts - ALL YEAR




MJO Bivariate Correlation
S2S REFORECASTS 1999-2010
0.6 cor
0.5 cor
Lead Time
MODEL
ECMWF
NCEP
JMA
CMA
CNRM
EC*
HMCR
BOM
ISAC
UKMO*

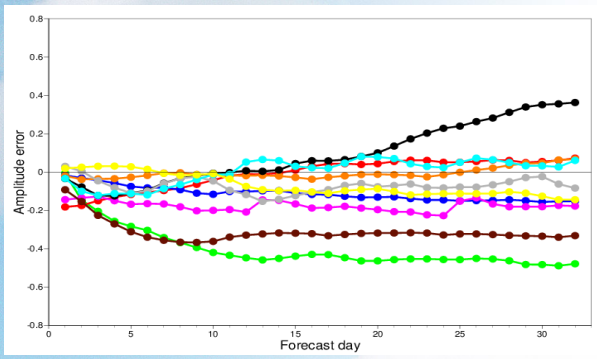
MJO forecast skill as a fonction of MJO Phase



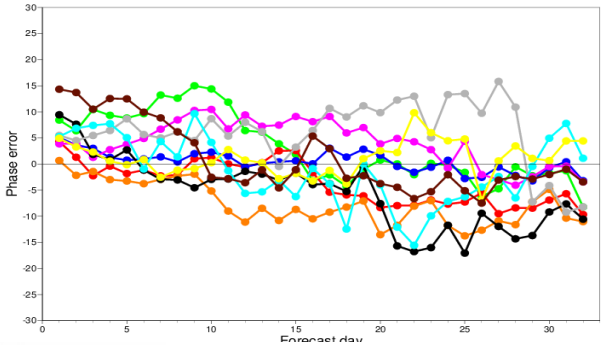
MJO - 1999-2010 re-forecasts

JMA BoM ECMWF NCEP CMA CNRM UKMO EC ISAC HMCR

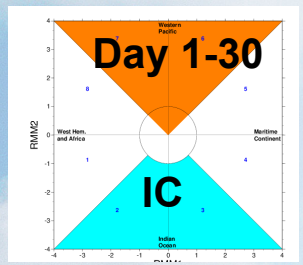
Amplitude error relative to ERA Interim

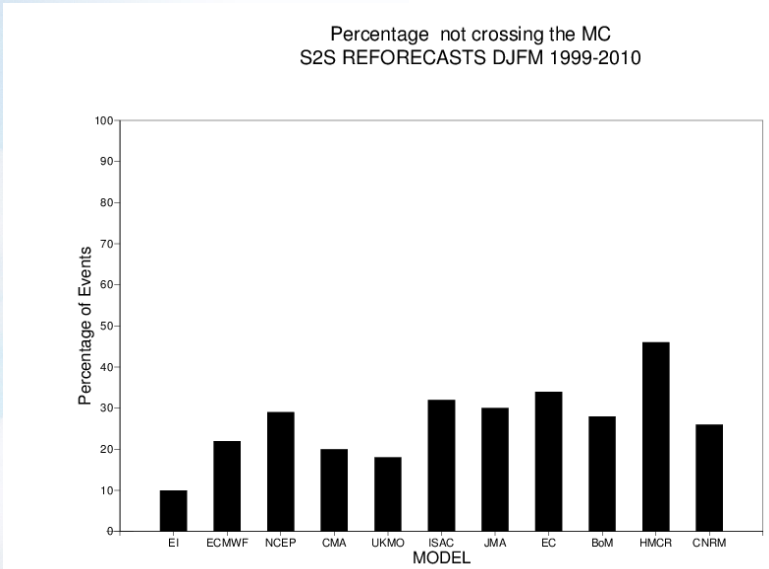


Phase error relative to ERA Interim



Maritime Continent crossing

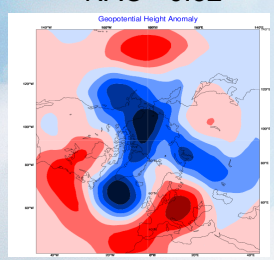




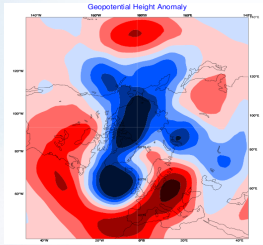
MJO Teleconnections in ERA Interim

ONDJFM

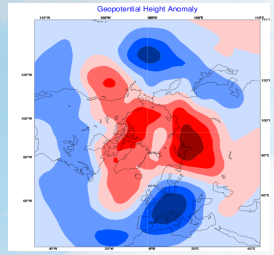
Phase 23 + 10 days –
NAO= 0.32



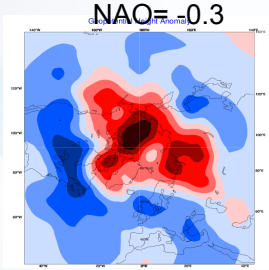
Phase 3 + 10 days –
NAO= 0.42



Phase 67 + 10 days –
NAO= -0.27

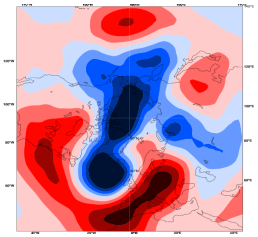


Phase 7 + 10 days –
NAO= -0.3

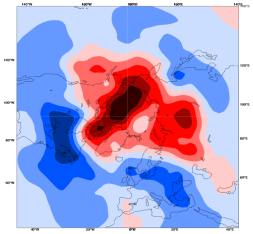


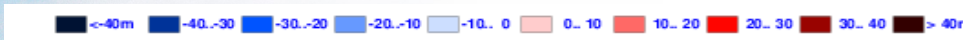
NDJFM

Phase 3 + 10 days –
NAO= 0.47



Phase 7 + 10 days –
NAO= -0.3

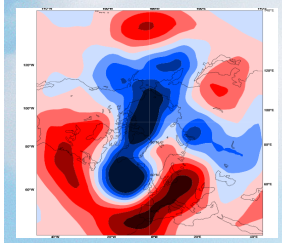




MJO Teleconnections in ERA Interim

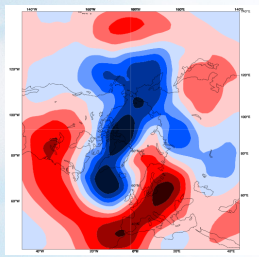
Phase 3 + 10 days
NDJFM

NAO = 0.472



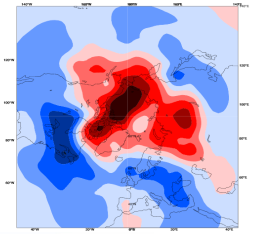
Phase 3 + 3 pentads
NDJFM

NAO = 0.48



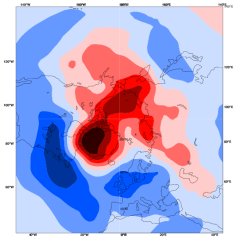
Phase 7 + 10 days
NDJFM

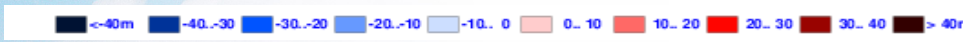
NAO = -0.299



Phase 7 + 3 pentads
NDJFM

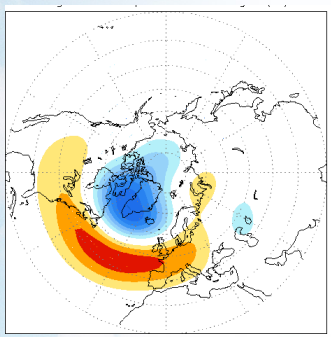
NAO = -0.45





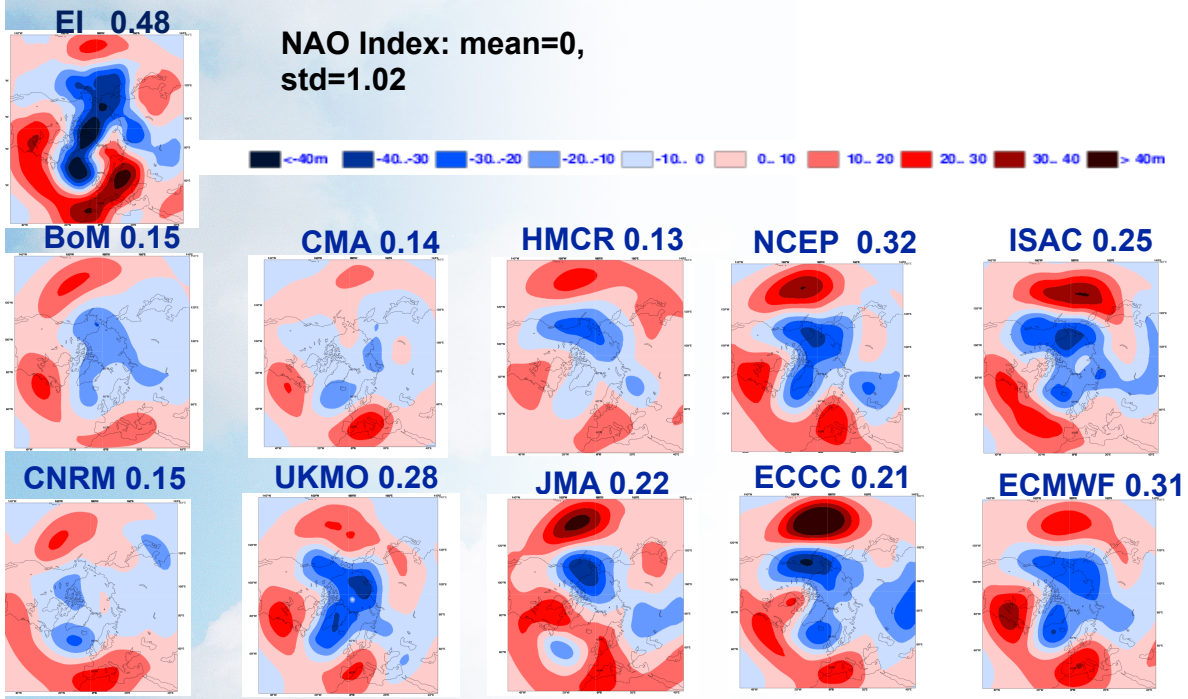
NAO Index

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



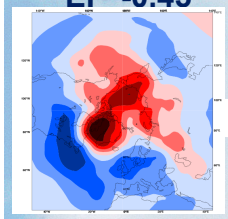
- Daily frequency: Mean=0 , standard deviation = 1.13
- Pentad average: mean=0, standard deviation = 1.02

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

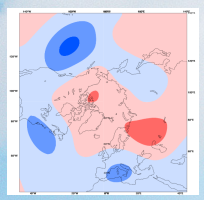


Composites of Z500 3 pentads after an MJO in Phase 7 NDJFM

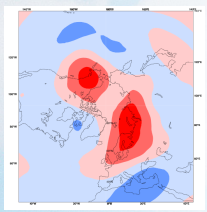
EI -0.45



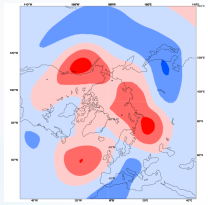
BoM -0.11



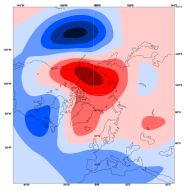
CMA 0.025



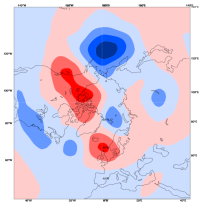
HMCR -0.05



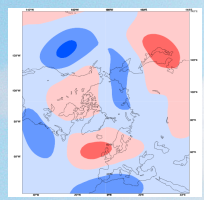
NCEP -0.22



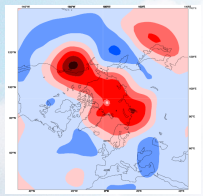
ISAC -0.089



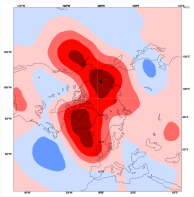
CNRM -0.015



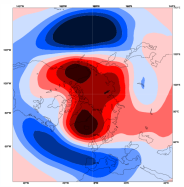
UKMO -0.07



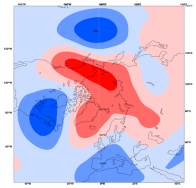
JMA –0.26

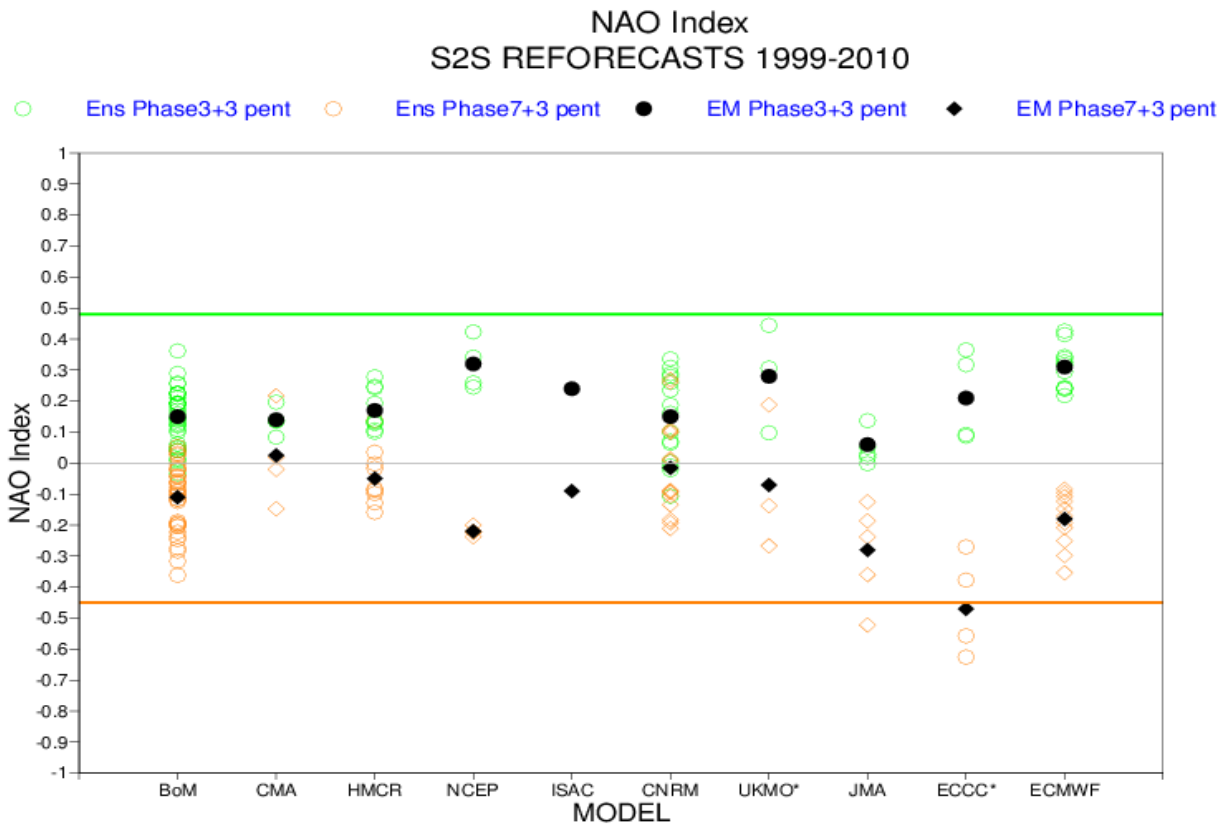


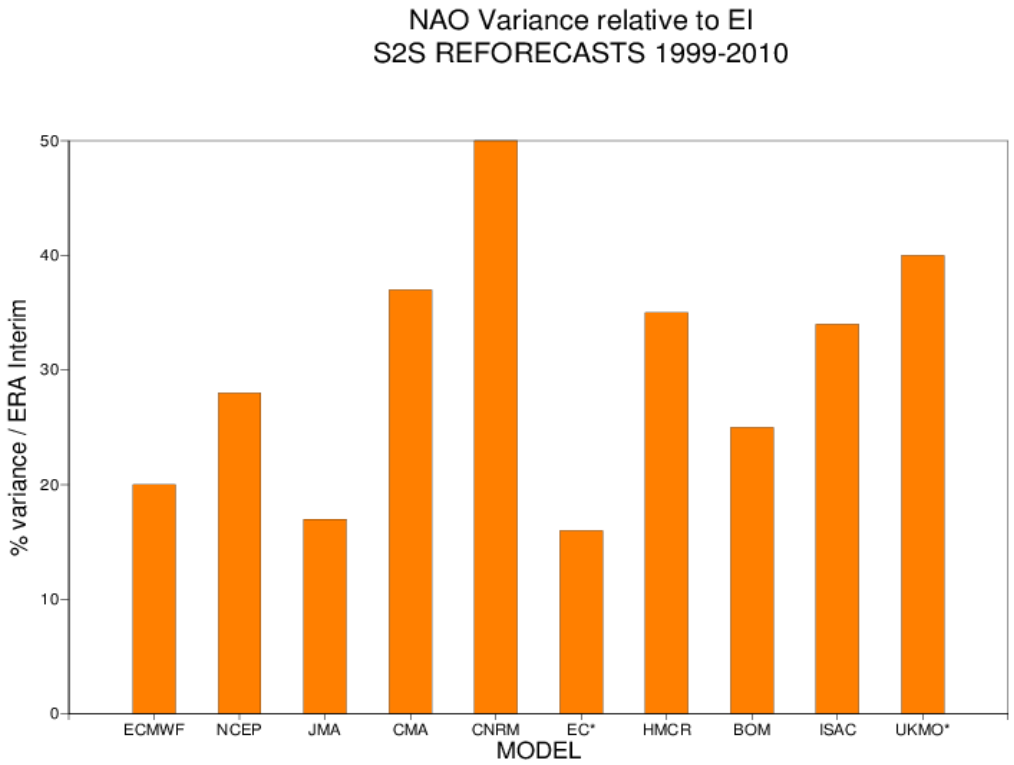
ECCC -0.47



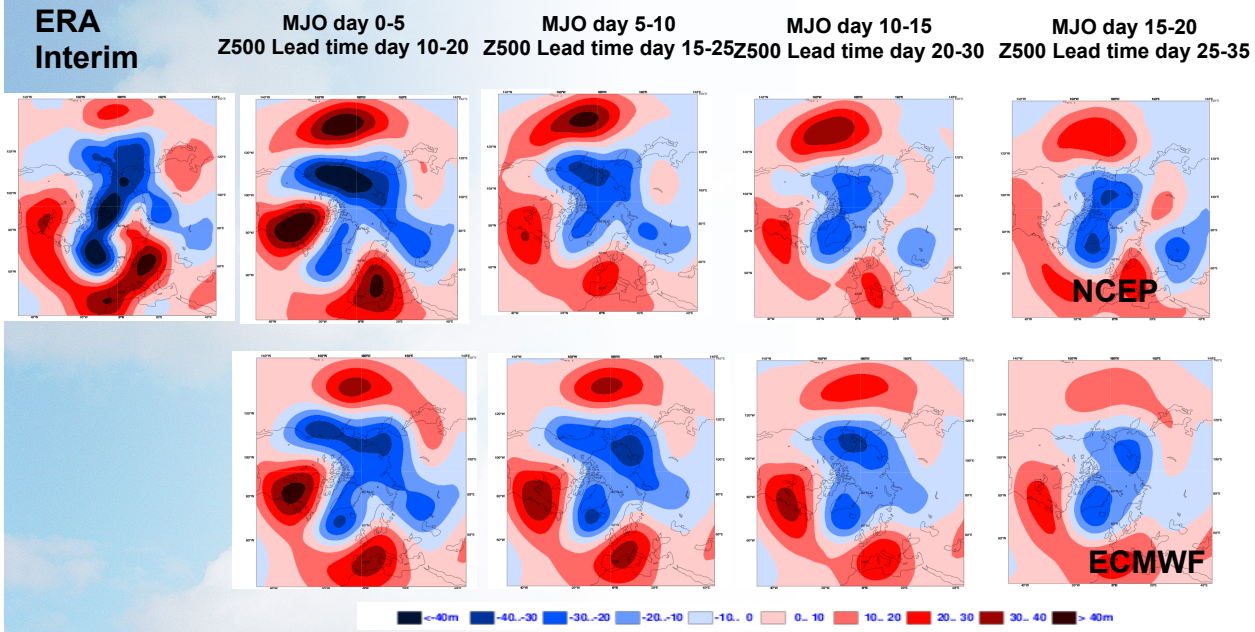
ECMWF –0.19




NAO Index
S2S REFORECASTS 1999-2010
Ens Phase3+3 pent
Ens Phase7+3 pent
EM Phase3+3 pent
EM Phase7+3 pent
NAO Index
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
BoM
CMA
HMCR
NCEP
ISAC
CNRM
UKMO*
JMA
ECCC*
ECMWF
MODEL

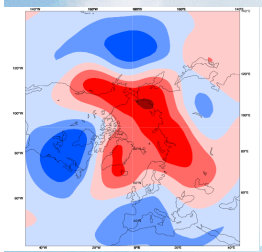

NAO Variance relative to EI
S2S REFORECASTS 1999-2010
% variance / ERA Interim
0
10
20
30
40
50
ECMWF
NCEP
JMA
CMA
CNRM
EC*
HMCR
BOM
ISAC
UKMO*
MODEL

Evolution of Teleconnection with lead time –MJO Phase 3

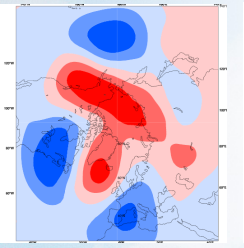


Evolution of Teleconnection with lead time – ECMWF - MJO Phase 7

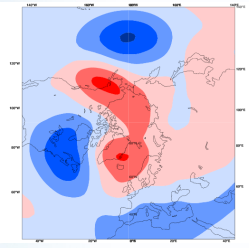
MJO day 0-5
Z500 Lead time day 10-20
-0.21



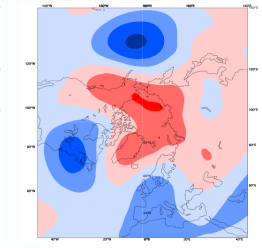
MJO day 5-10
Z500 Lead time day 15-25
-0.21



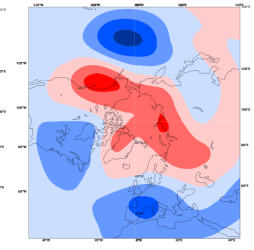
MJO day 10-15
Z500 Lead time day 20-30
-0.14



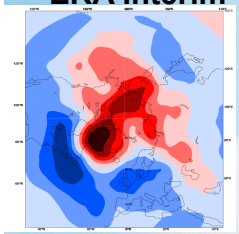
MJO day 15-20
Z500 Lead time day 25-35
-0.14



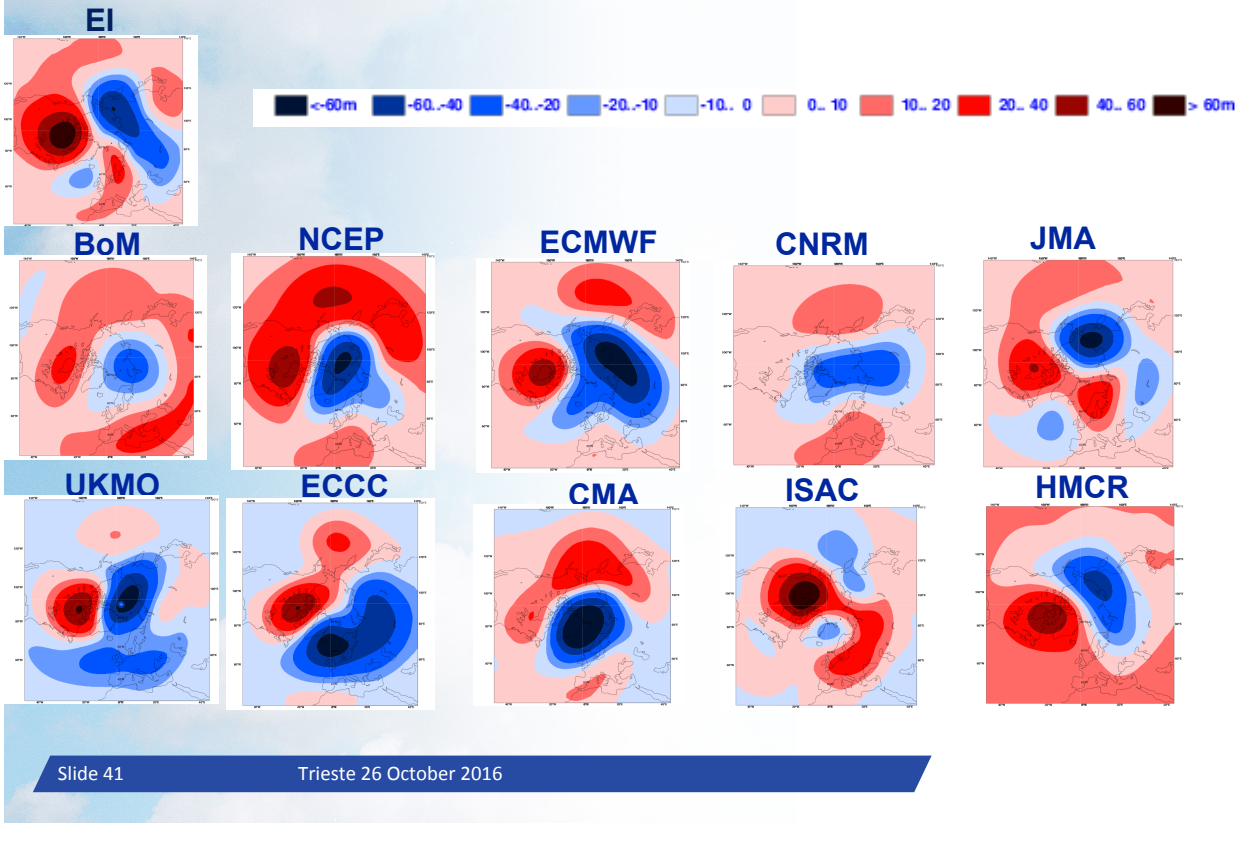
MJO day 20-25
Z500 Lead time day 30-40
-0.13



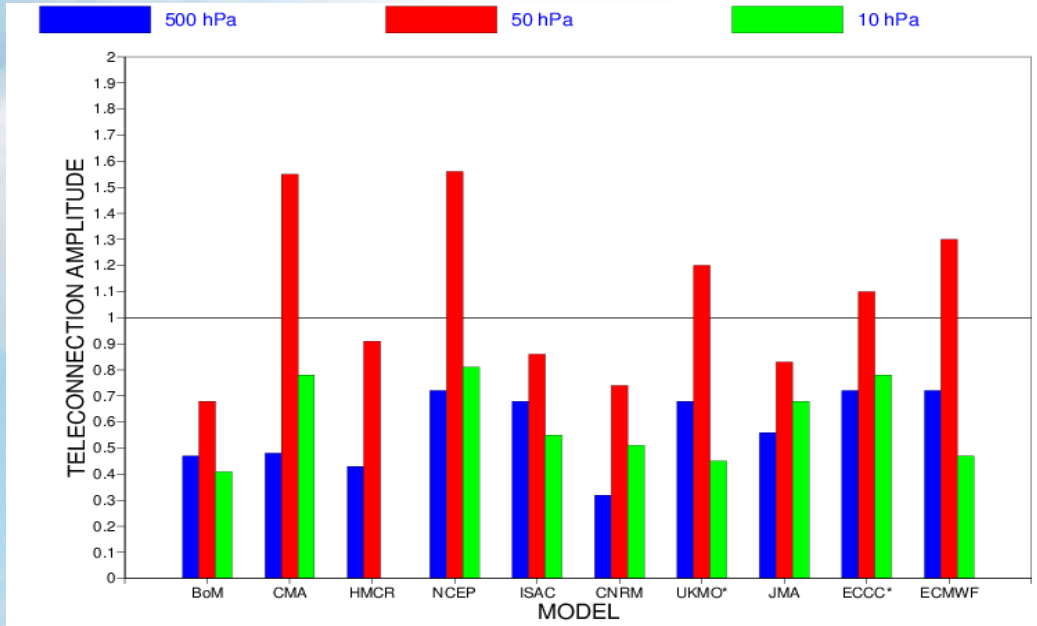
ERA Interim



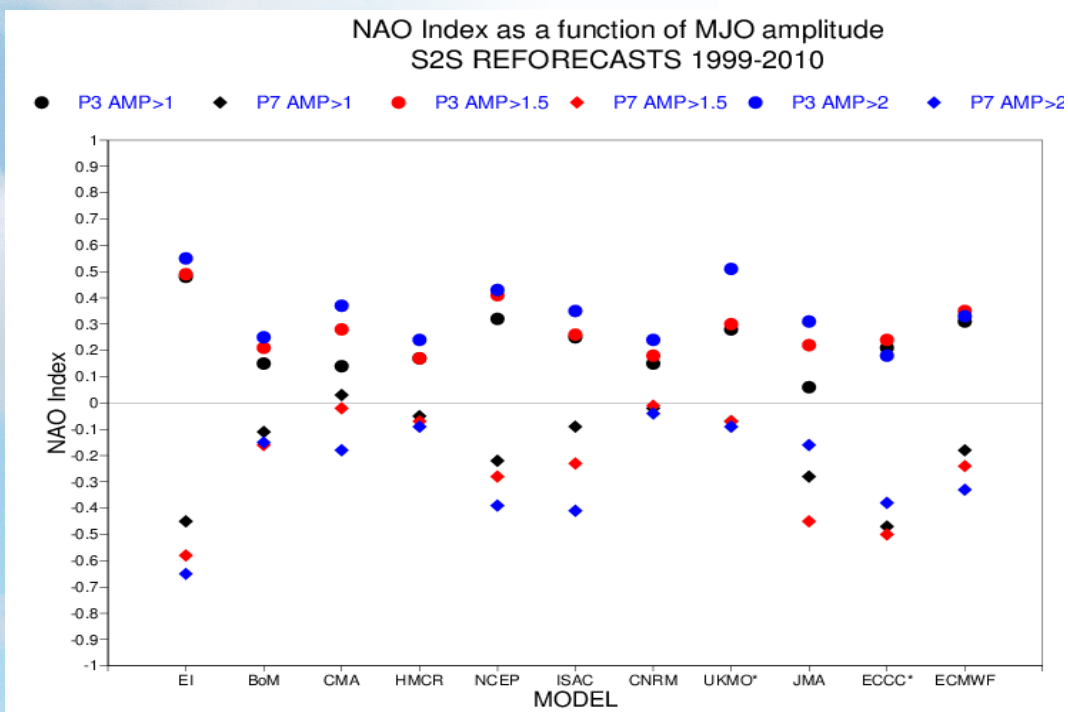
Composites of Z50 3 pentads after an MJO in Phase 3 NDJFM



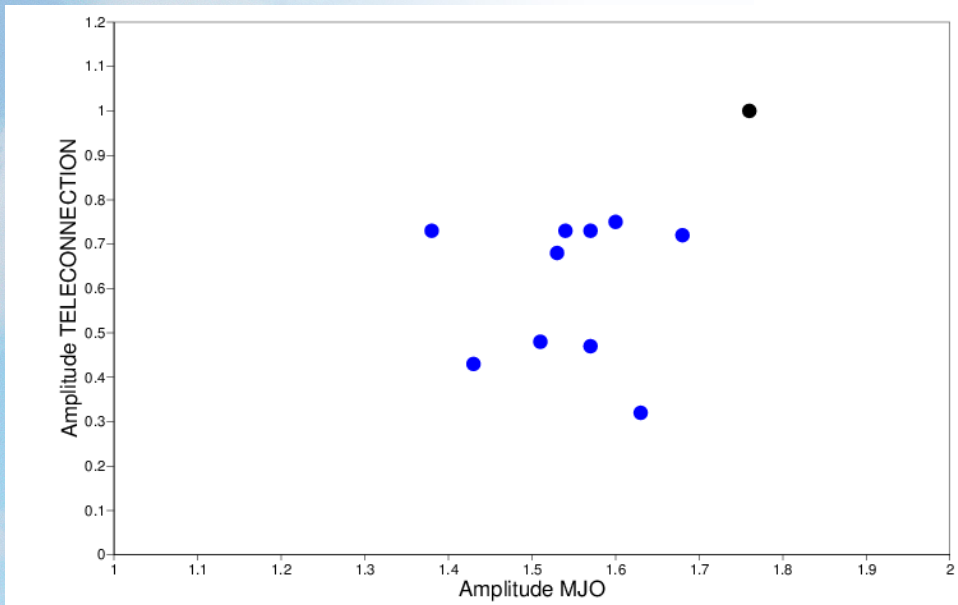
Amplitude MJO Teleconnections 3rd pentad after an MJO in Phase 3



Impact of MJO Intensity on NAO Index



Impact of MJO Amplitude in Phase 3



S2S model

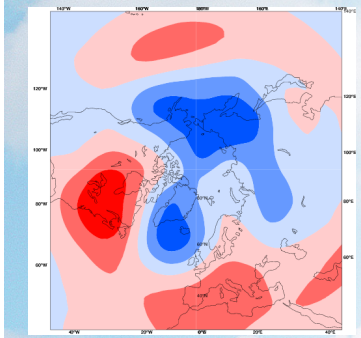
ERA Interim

Tropical relaxation experiment

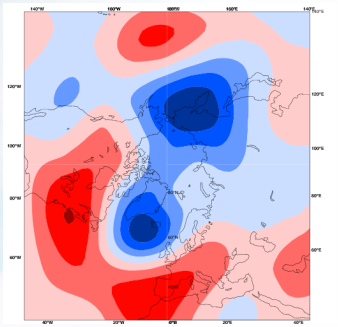
15 member ensembles running on 1st NDJFM 1989-2015 for 46 days

Control: IFS CY43R1
Relaxation: Tropical band 20N-20S relaxed towards ERA Interim

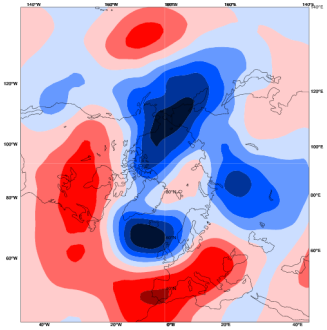
Control



Relaxation

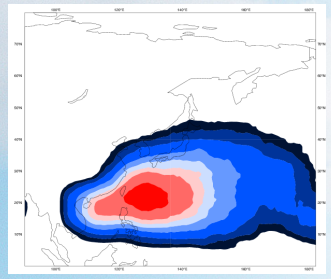


ERA Interim

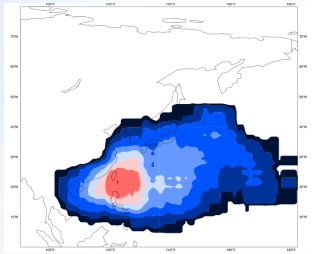


TC Density - OBSERVATIONS

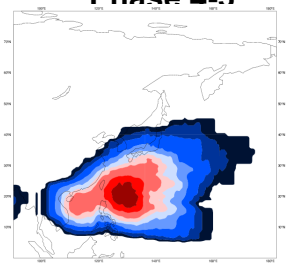
ALL



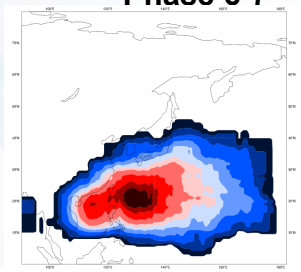
Phase 2-3



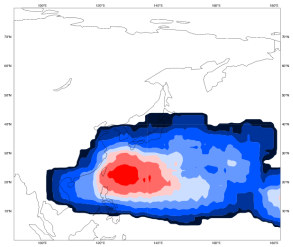
Phase 4-5



Phase 6-7



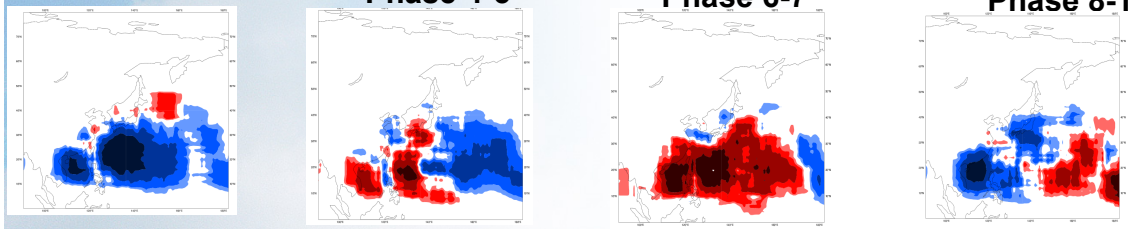
Phase 8-1



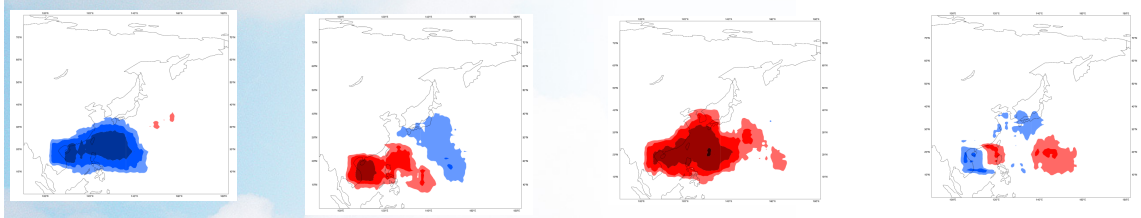
TC Density anomalies

Observations

Phase 2-3 | Phase 4-5 | Phase 6-7 | Phase 8-1



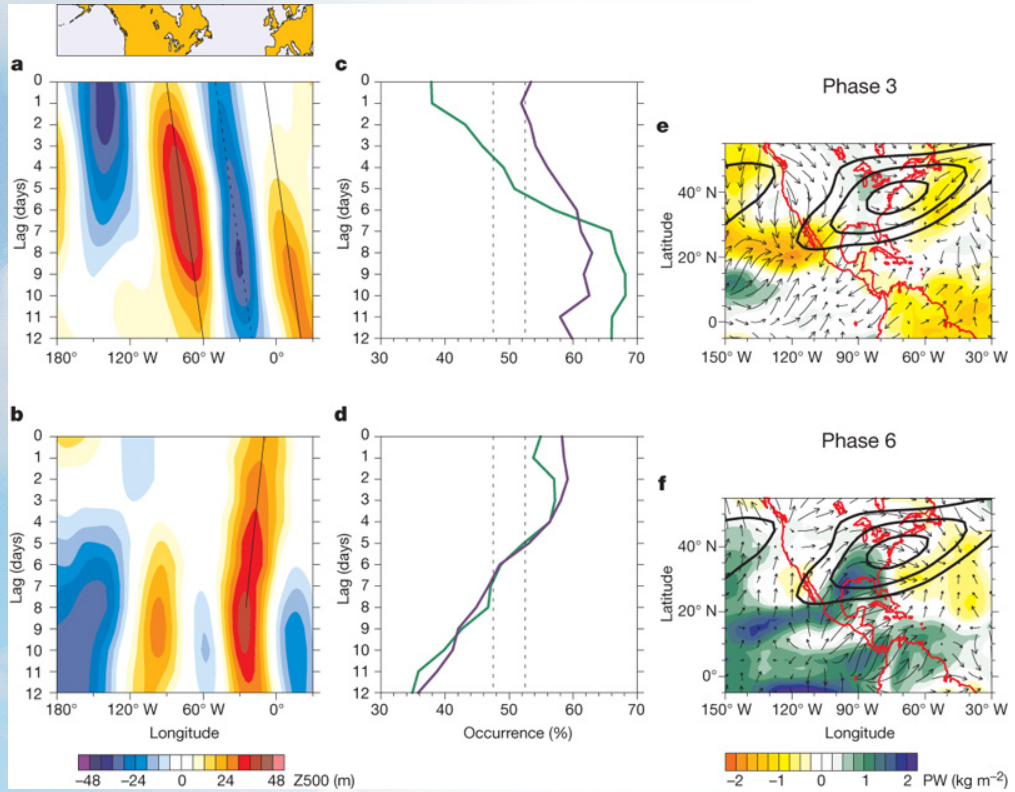
ECMWF



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

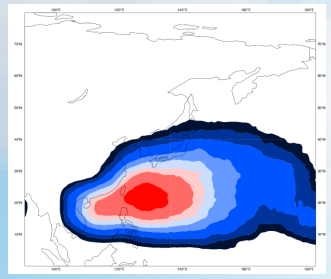
Asymmetrical tropical–extratropical connection between two specific phases of the MJO leading to NAO+ and NAO- events.



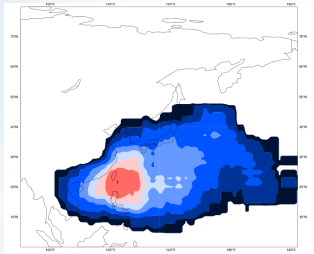
Cassou 2008

TC Density - OBSERVATIONS

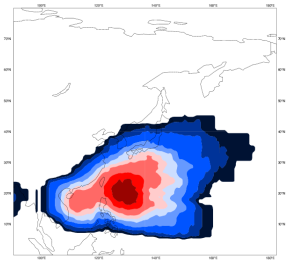
ALL



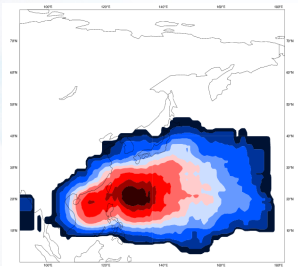
Phase 2-3



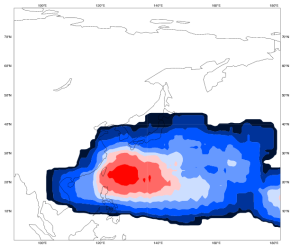
Phase 4-5



Phase 6-7

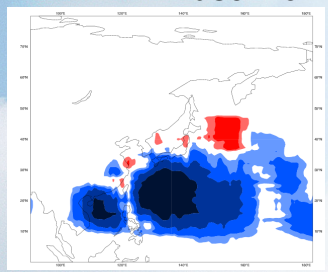


Phase 8-1

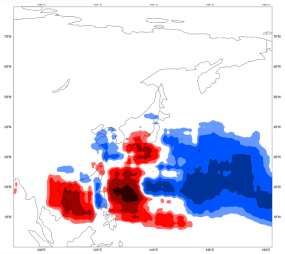


TC Density anomalies - OBSERVATIONS

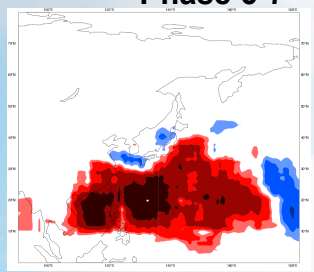
Phase 2-3



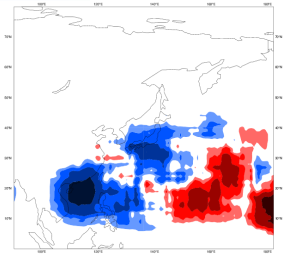
Phase 4-5



Phase 6-7

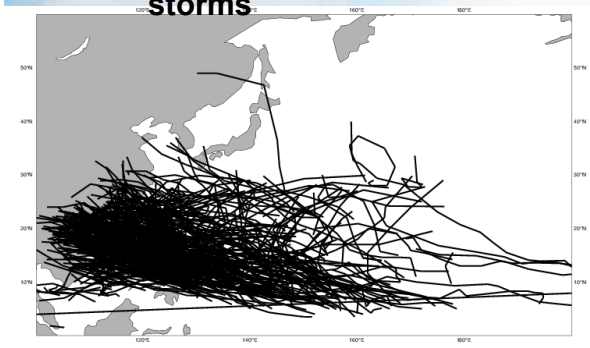


Phase 8-1

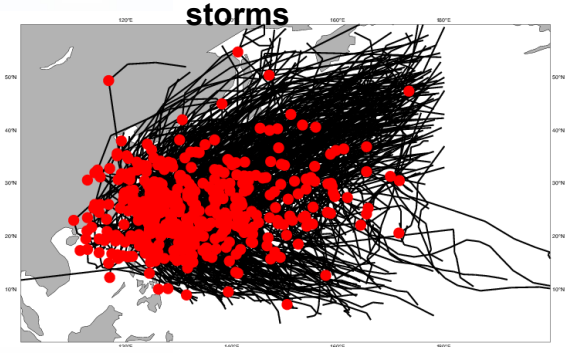


Detection of recurving tropical storms in Observations (IBTrACS)

Non-recurving tropical storms

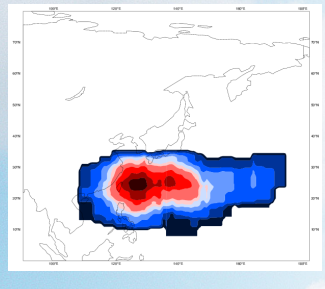


recurving tropical storms

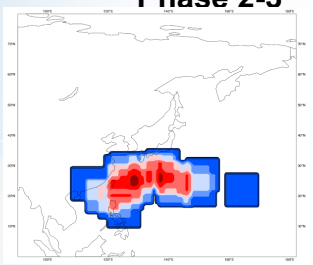


TC Recurvature point Density - OBSERVATIONS

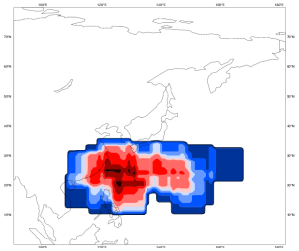
ALL



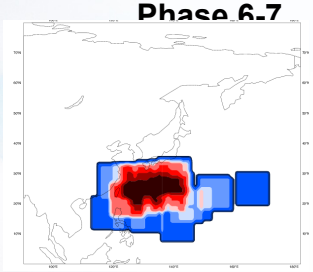
Phase 2-3



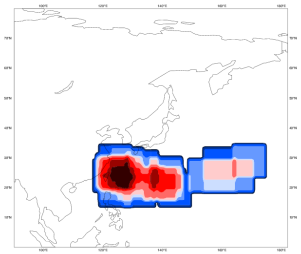
Phase 4-5



Phase 6-7



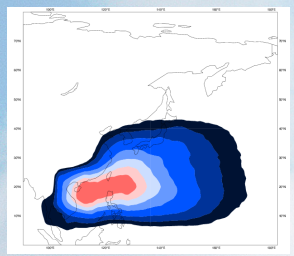
Phase 8-1



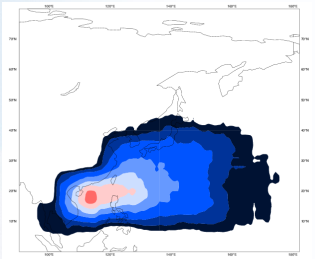
< 1 | 1.. 2 | 2.. 4 | 4.. 6 | 6.. 8 | 8..10 | 10.. 14 | 14.. 18 | 18..22 | > 22

TC Density - ECMWF

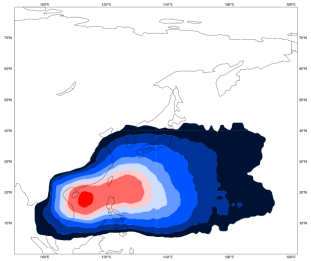
Model Climatology



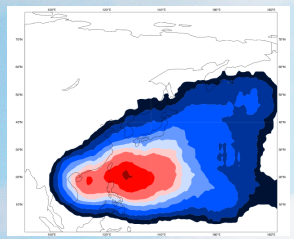
Phase 2-3



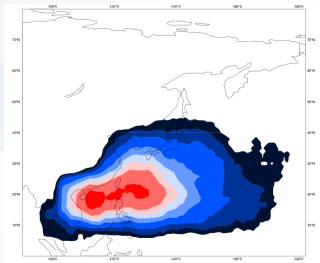
Phase 4-5



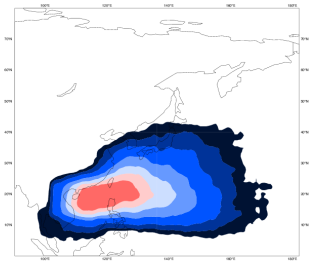
Observations



Phase 6-7



Phase 8-1

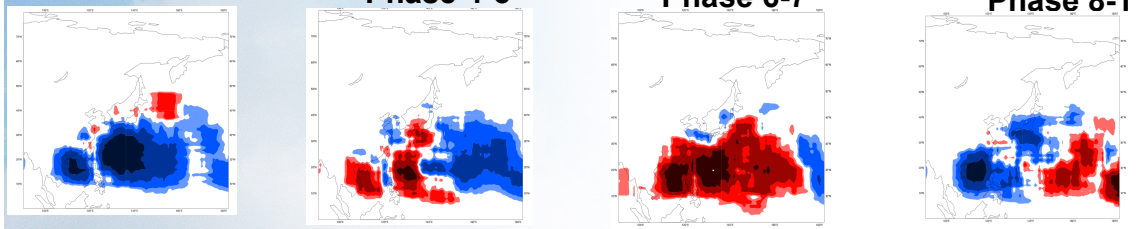


< 1 | 1.. 2 | 2.. 4 | 4.. 6 | 6.. 8 | 8..10 | 10.. 14 | 14.. 18 | 18..22 | > 22

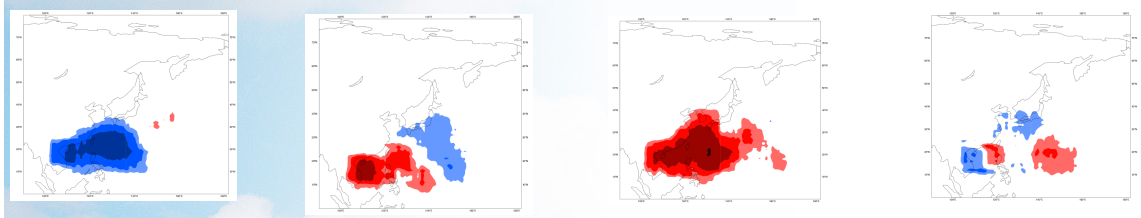
TC Density anomalies

Observations

Phase 2-3 | Phase 4-5 | Phase 6-7 | Phase 8-1



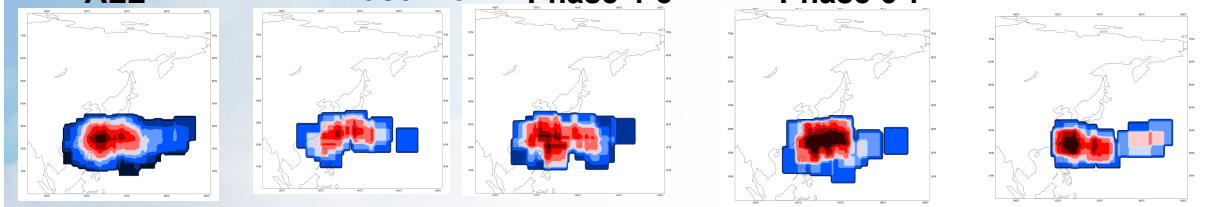
ECMWF



TC recurvature point Density

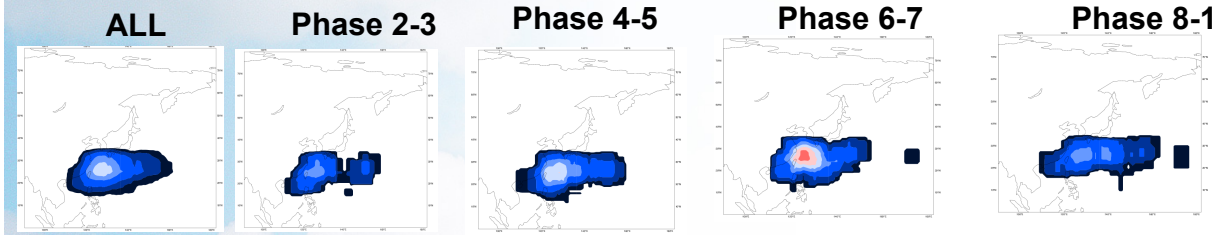
Observations

ALL | Phase 2-3 | Phase 4-5 | Phase 6-7 | Phase 8-1



ECMWF RE-FORECAST

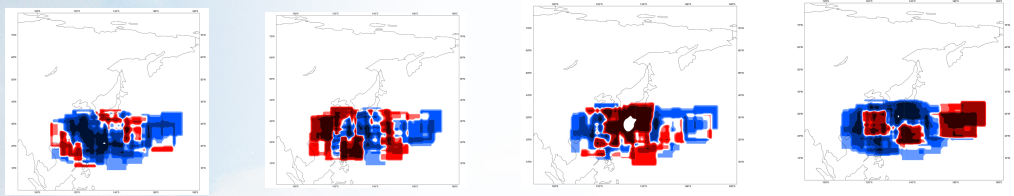
ALL | Phase 2-3 | Phase 4-5 | Phase 6-7 | Phase 8-1



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