Scientific advancements in sub-seasonal to seasonal prediction

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Sub-seasonal to Seasonal prediction (S2S)

WEATHER EVENTS
Individual storm events: blizzards, rainstorms, hurricanes

S2S EXTREMES
Tropical cyclone activity, heat waves, storm tracks, severe weather threats

SEASONAL OUTLOOKS
El Niño-Southern Oscillation, temperature and precipitation anomalies

S2S: The "gap" Between weather and Climate forecasts

?

Predictability Desert?

Prediction skill — Higher / Lower

Prediction lead time — hours, 2 weeks, 1 month, 3 months, 12 months

Adapted from: iri.columbia.edu/news/qa-subseasonal-prediction-project

S2S sources of predictability
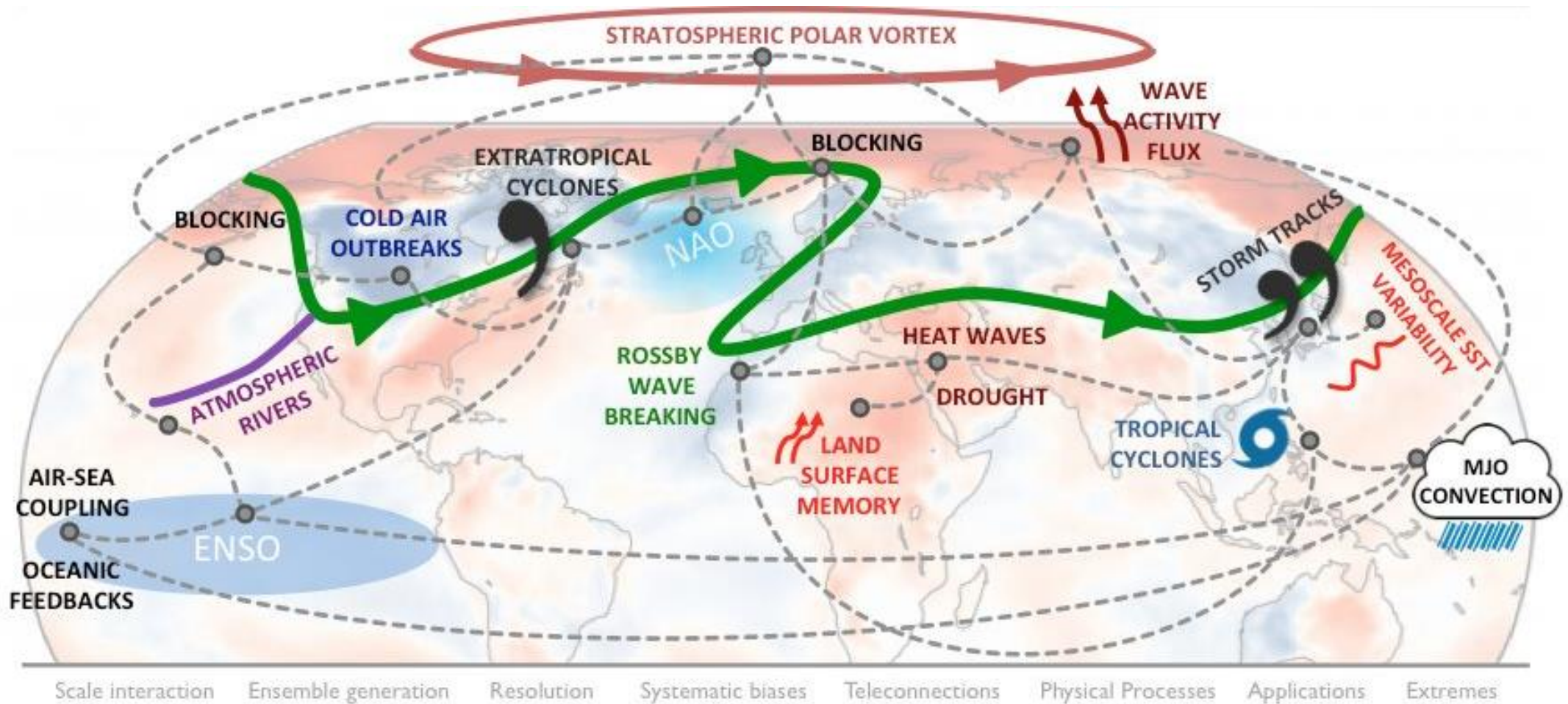
S2S prediction is challenging

- Forecast skill is not constant in time. It depends strongly on the occurrence of sources of predictability, as well as their interactions: "**windows of opportunity for forecast skill**" (e.g. strong MJO)

- Production of S2S forecasts needs frequent updates (at least weekly) and short delay of production (less than a day).

In the early 2000, only 2 operational centres were producing S2S forecasts. Now about 20 centres are producing routinely extended range forecasts every day or week.

This is due to an increased demand for forecasts at this time range, but also because of a better understanding on S2S sources of predictability and **progress in S2S prediction skill**,

MJO Bivariate Correlation

— 0.5 — 0.6 — 0.8
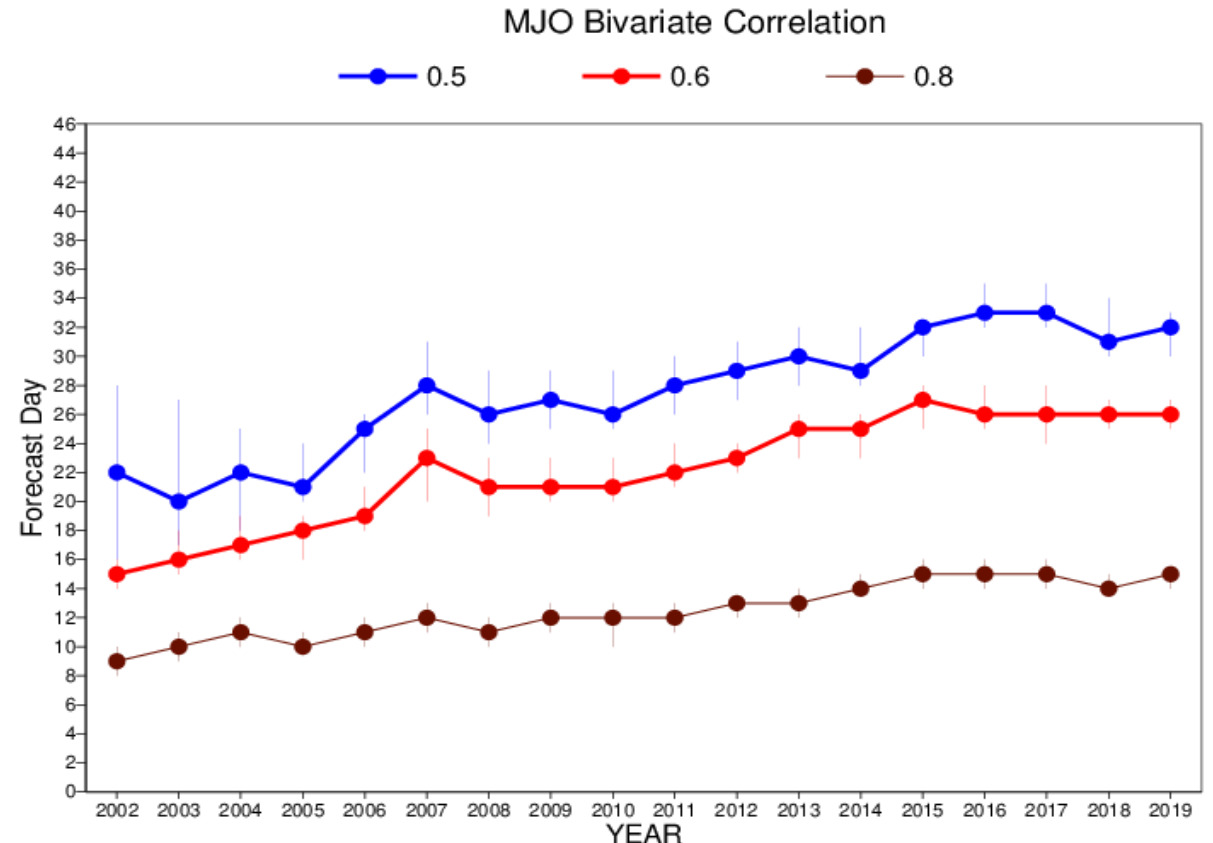
The WWRP/WCRP S2S Database

- Daily *3-week behind real-time* forecasts since January 2015 + re-forecasts

- 11 models currently available (3 new models soon: IMD/NASA/CAS)

- Same grid (1.5 degree) / GRIB2 format (netcdf converter available)

- About 80 variables available, including 3D variables on 10 pressure levels and a few ocean sub-surface variables have been recently added.

- Hosted at ECMWF, CMA and IRI

- "Usage is increasing. The database has served so far more than 1500 users from 92 countries. More than 160 articles have been published.

Links to data portals available at www.s2sprediction.net

Contributing Centres to S2S database

● Data provider (11)   O Archiving centre (3)
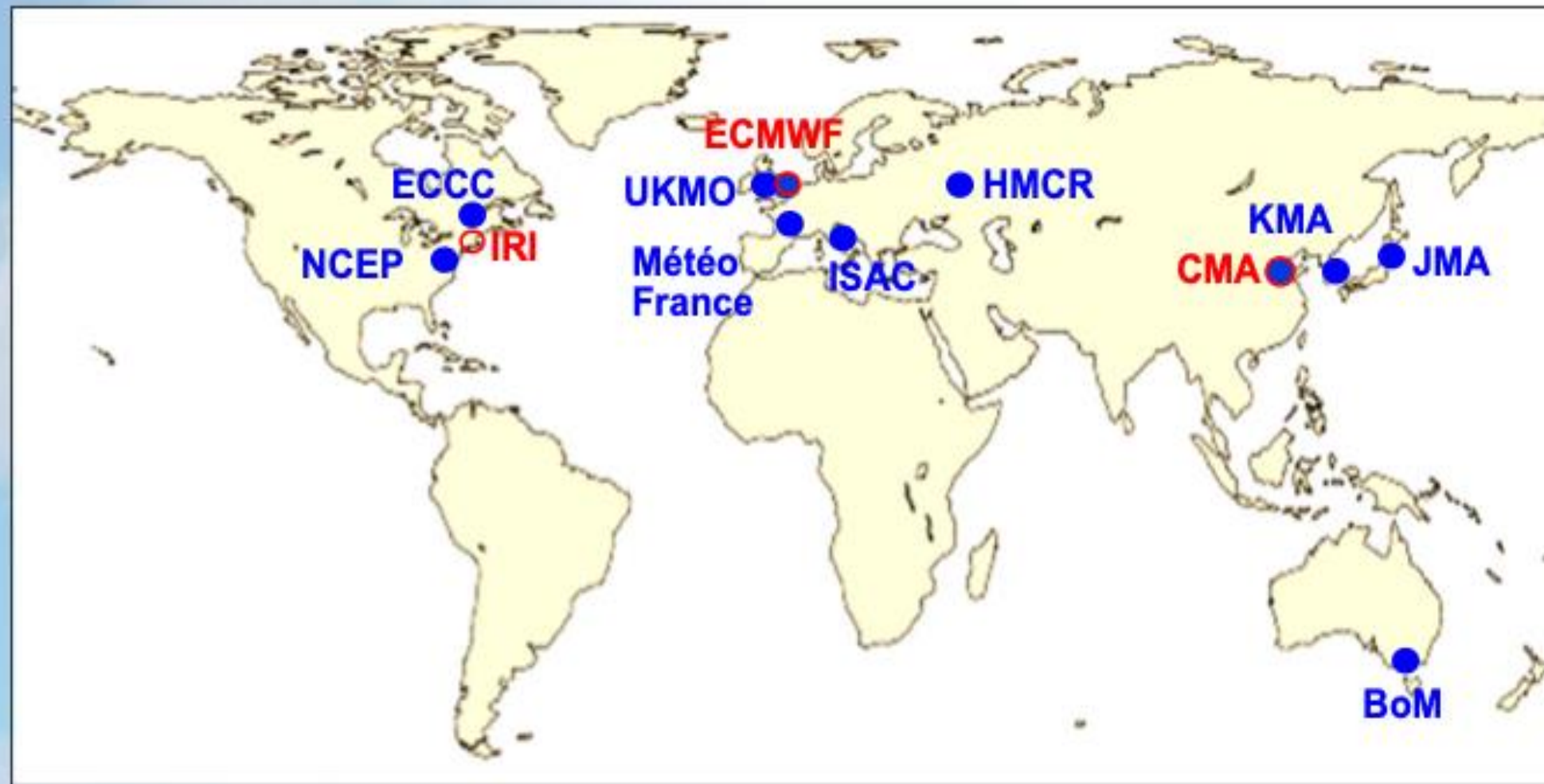
S2S database 3-week behind real-time products

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

- "S2S Museum" at University of Tsukuba, Japan (Mio Matsueda)
  http://gpvjma.ccs.hpcc.jp/S2S/S2S_SICmap.html

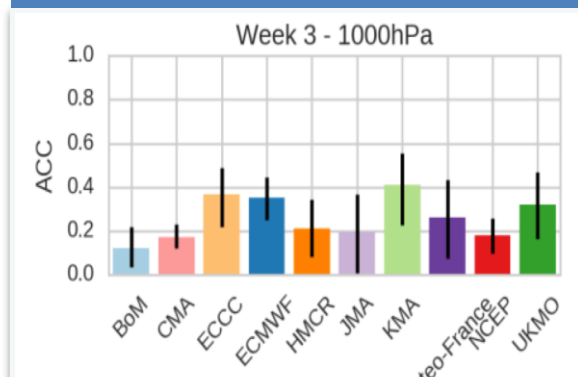**NAO Index – 8 Feb 2018 start date**
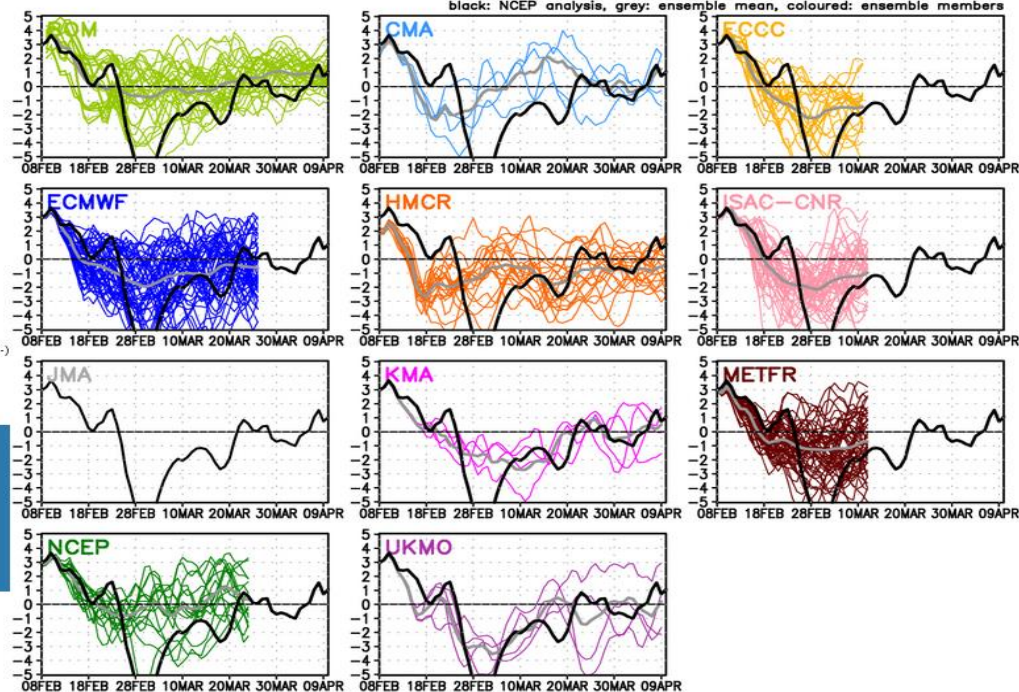
Some Results from the S2S database

Identifying windows of opportunity for S2S skill
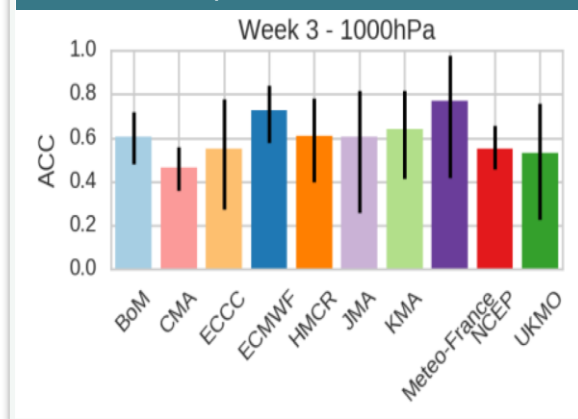
Stratosphere polar Vortex Events

Prediction skill of the 1000 hPa Northern Annular Mode for week 3 in the S2S models

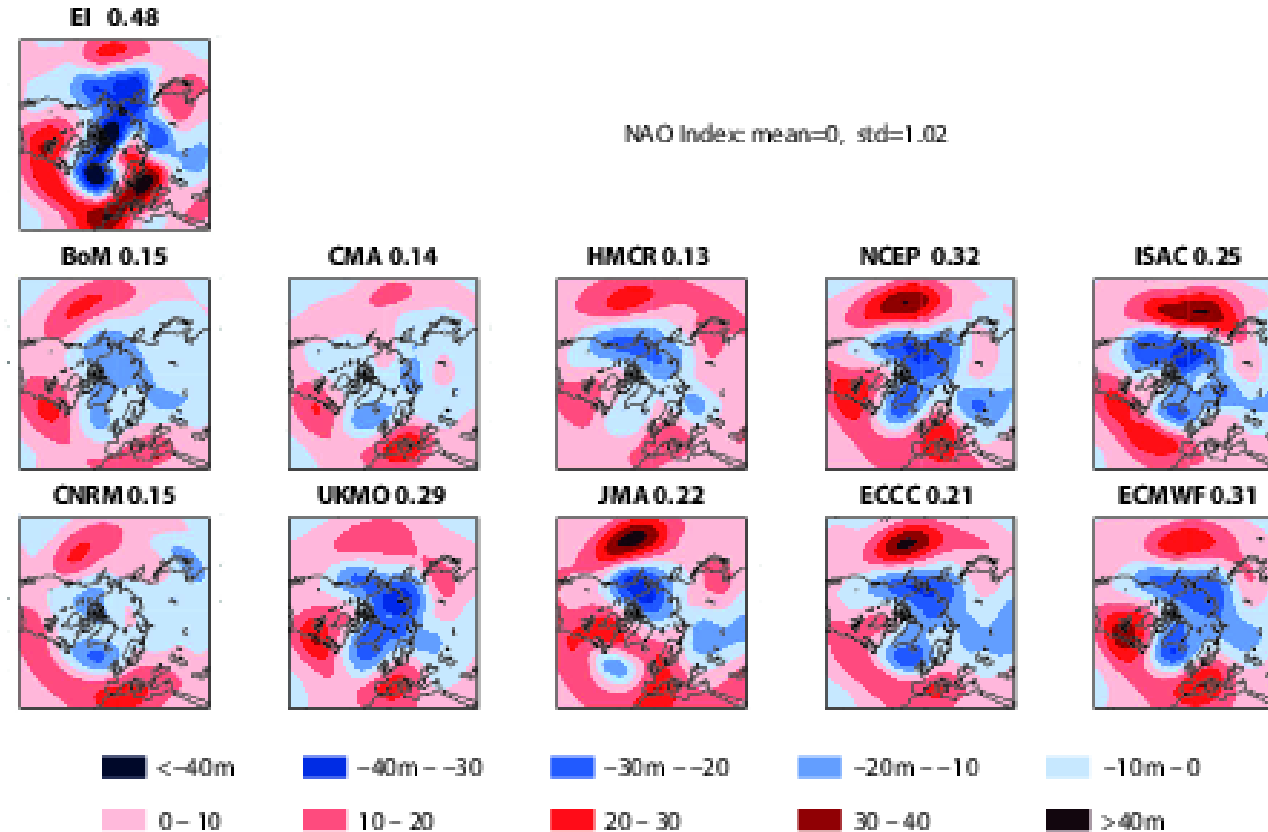Neutral Stratospheric Vortex

Weak Stratospheric Vortex

• For most models, skill is higher following weak vortex conditions.

• Similar results are found following strong vortex conditions.

Domeisen et al. (2019)

Some Results from the S2S database

Impact of the MJO on European weather is underestimated in S2S models

Z500 anomalies 10 days after an MJO in Phase 3

NAO Index mean=0, std=1.02

EI 0.48

BoM 0.15   CMA 0.14   HMCR 0.13   NCEP 0.32   ISAC 0.25

CNRM 0.15   UKMO 0.29   JMA 0.22   ECCC 0.21   ECMWF 0.31

■ <−40m	■ −40m − −30	■ −30m − −20	■ −20m − −10	■ −10m − 0
■ 0 − 10	■ 10 − 20	■ 20 − 30	■ 30 − 40	■ >40m

Vitart (2017)

- MJO Teleconnections still show serious biases in all S2S models
- Higher resolution models tend to have better teleconnections
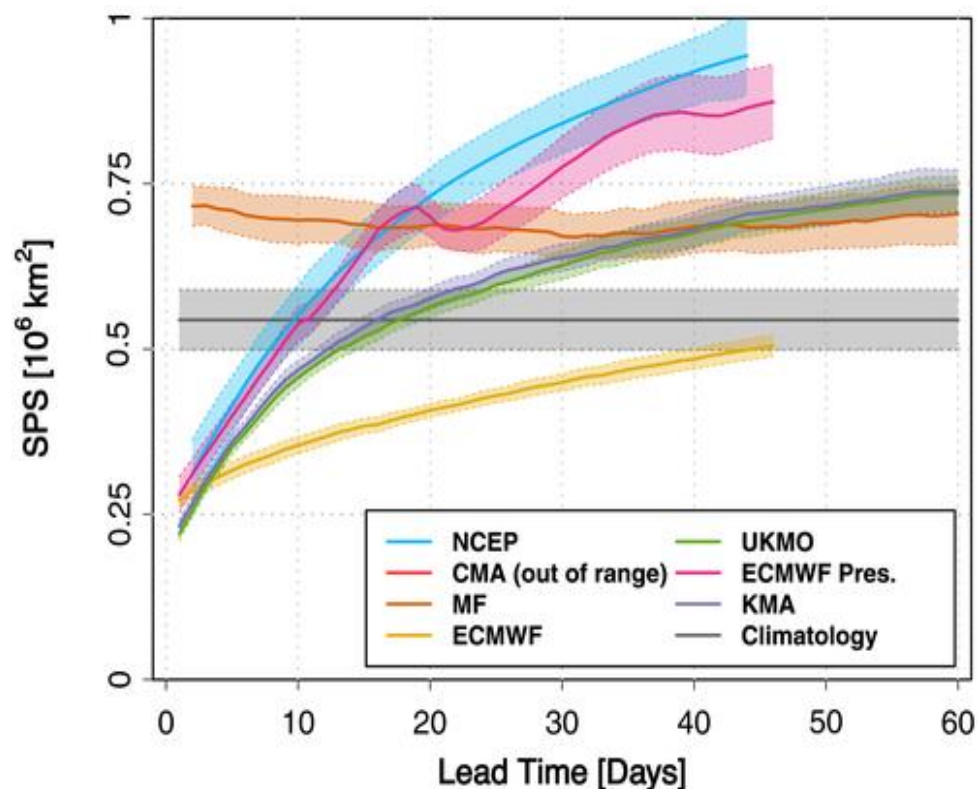- No link between good MJO skill and good teleconnections

Some results from the S2S database
Assessing the predictability in S2S models to identify potential use for applications

Sea ice prediction

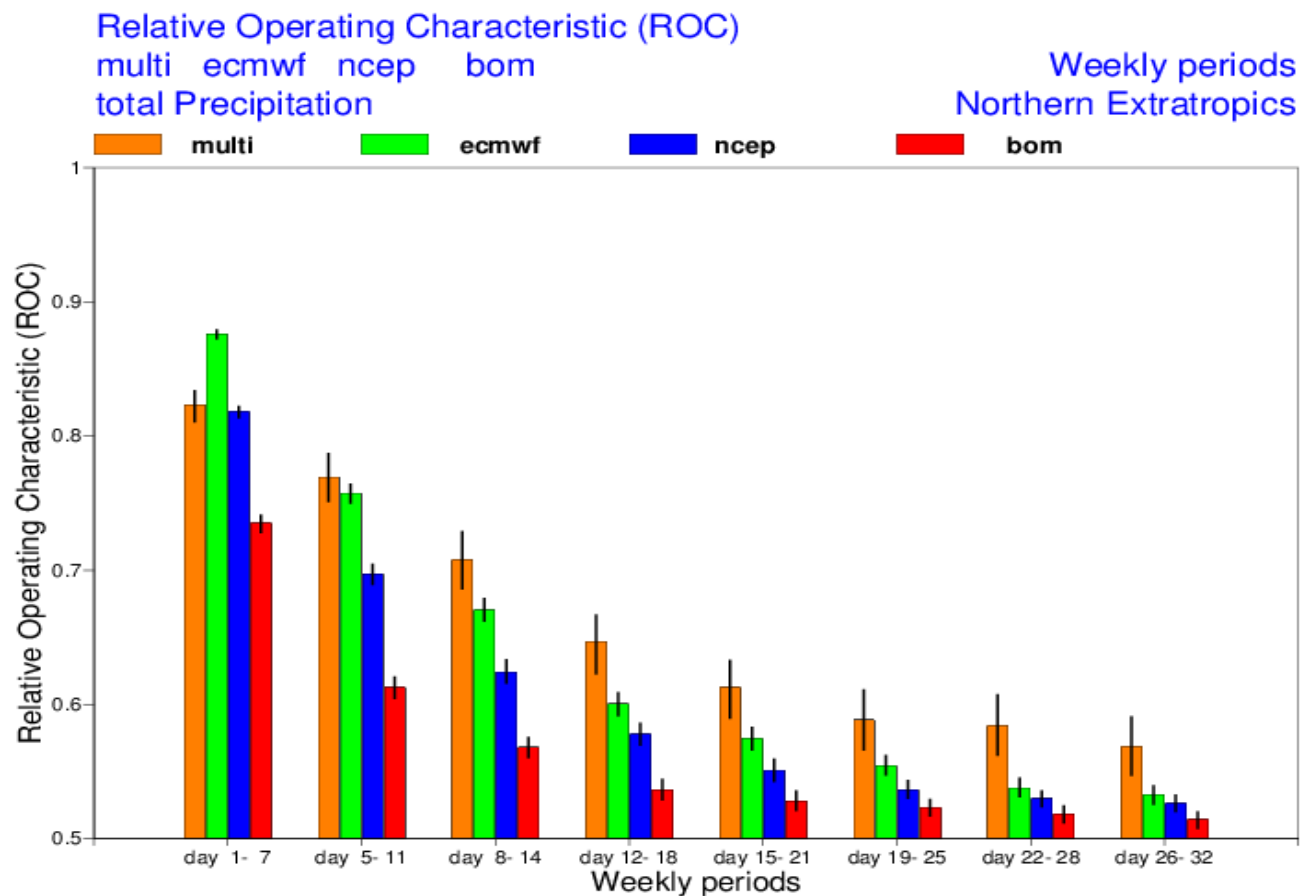Spatial probability score - Arctic Sea ice Edge

Zampieri et al. (2018)

- Arctic sea-ice edge prediction skill horizon can reach a month!
- Potentially useful sub-seasonal forecasts for ship routing
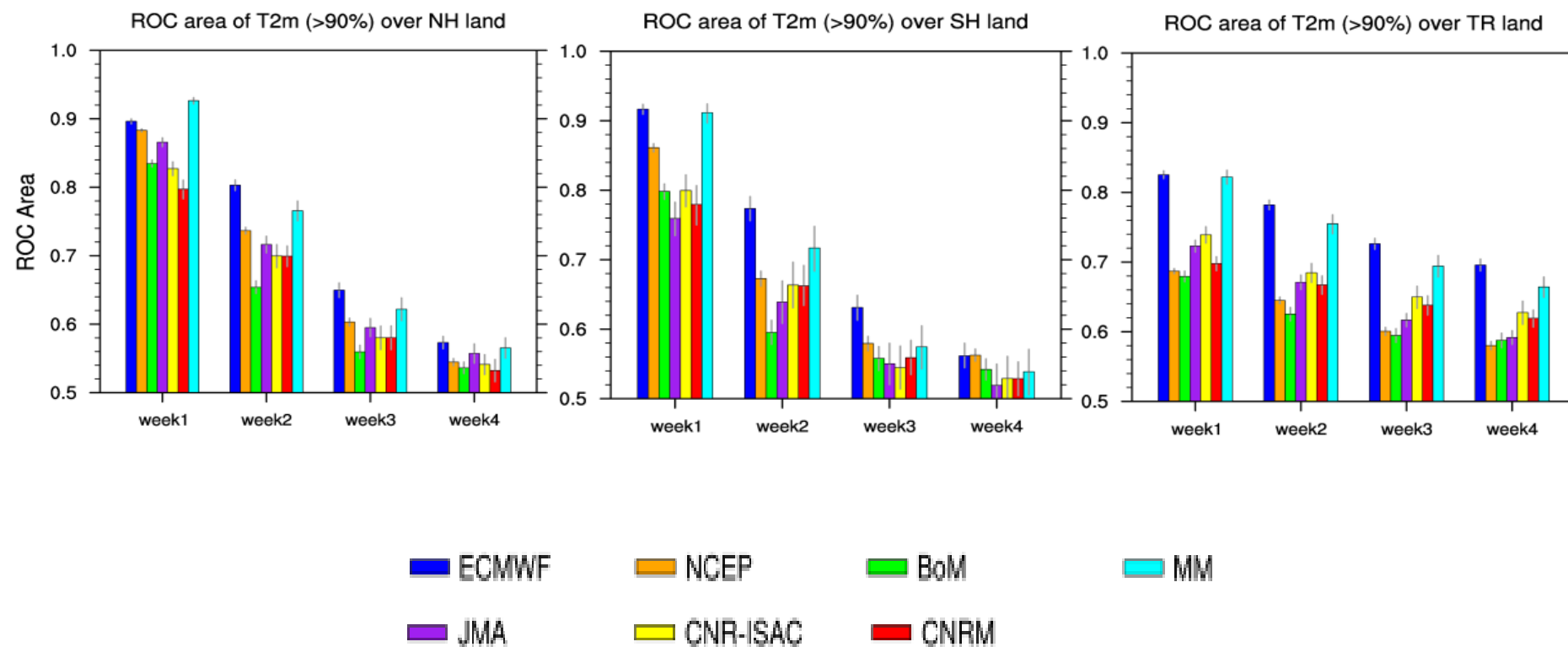
Some Results from the S2S database

Assessing the benefit of multi-model S2S prediction

- Combining S2S forecasts of precipitation from different models provides more skilful forecast than individual models.

Some Results from the S2S database

T2m probability to be in upper decile

Multi-model is not more skilful than best model

Xiaoyun et al., 2019

Climate Services Development: The S2S Real Time Pilot Initiative

- Started November 2019. It will continue until end October 2021
- Goals:
  - Identify what is needed to make S2S forecasts usable & how this varies by sector/organisation/experience
  - Understand how projects engage with users & how this relates to pull-through/demand
  - Develop understanding of the S2S forecast value chain & the needs for end-to-end user applications
  - Development of best practice guidelines and/or recommendations to enhance pull-through & sustainability

- Approach
  - 16 co-development projects
  - 3 sets of questionnaires: April/May 2020, Winter 2020/2021, Autumn 2021

Sectors:
- Water
- Energy
- Health
- Agriculture/food security
- Disaster risk reduction

Countries/regions:
- Senegal
- Ethiopia
- Bangladesh
- Guatemala
- Columbia
- Ghana
- Kenya
- Nigeria
- Singapore
- USA
- Europe
- Asia & Pacific
- Global

Forecasting Meningitis Outbreaks in sub-Saharan Africa
African Swift

- Using S2S forecasts from S2S Real-time pilot to predict the location and scale of impeding meningitis outbreaks in sub-Saharan Africa.

- Early warning system with the aim of giving health agencies more time to activate emergency response plans

- Approach is pioneered by ACMAD, the African Centre of Meteorological Applications for Development, and the African SWIFT initiative, led by the University of Leeds and the National Centre for Atmospheric Science.

S2S AI/ML Competition

- The new WMO Research Board has identified Artificial Intelligence (AI) as a key research topic in weather and climate science for the upcoming years
- A competition will be held to encourage the use of AI tools to extract valuable information from the S2S database.

  - Can purely empirical forecasts beat S2S systems?

  - Can AI/ML methods improve S2S system forecasts by better calibration/muti-model ensembling methods?

- Hosted by Swiss Data Science Center at ETH Zürich, with ECMWF support through the new European Weather Cloud for data access and some CPU time
- Timeline: ~July-Dec
- All codes and forecasts will be made open source after the end of the competition to foster community learning on AI/ML methods for S2S
- Small monetary prizes from WMO

Conclusions

- S2S prediction is challenging: forecast skill is not uniform. Users need to be aware of windows of opportunity for forecast skill.

- Still much needs to be done to improve forecasts and make them usable.

- The S2S database represents an important resource to better understand the impact of various sources of predictability in state-of-the-art S2S models and identify potential benefits or limitations in the use of S2S forecasts.

- The recent S2S real-time pilot initiative will help to assess the potential value of S2S for a wide range of applications and geographical sectors.

WMO OMM