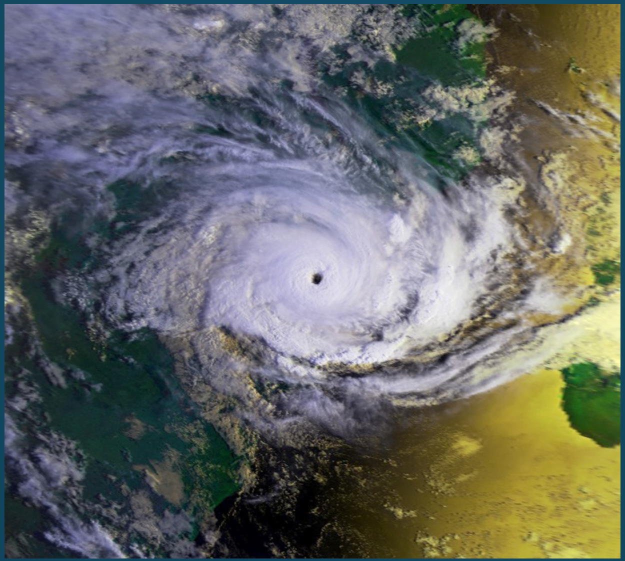
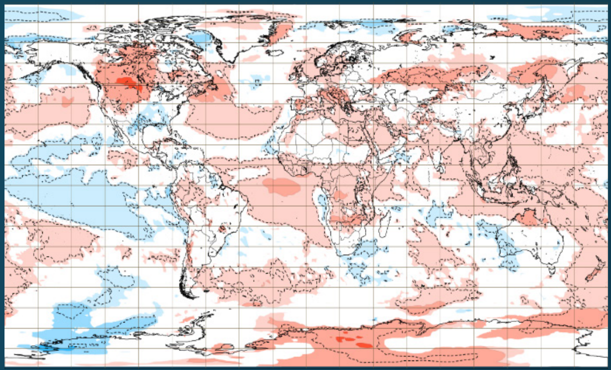




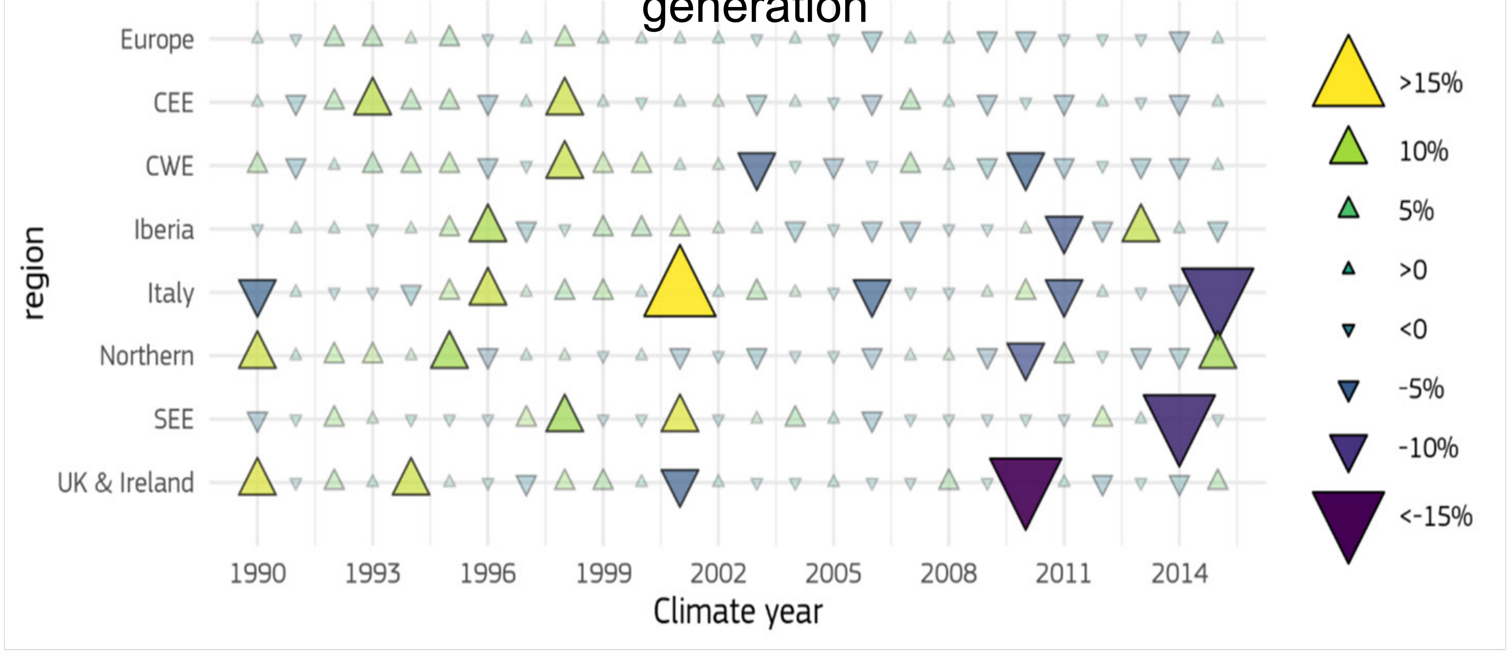
# Sub-seasonal to Seasonal Prediction for Energy

*Frédéric Vitart, ECMWF*
*Llorenc Lledo*

*EA State of the Art in Energy Forecasting Workshop, September 2022*

## With higher shares of renewables in the mix, the electricity system is more exposed to atmospheric variability risks

Yearly anomalies of wind power generation

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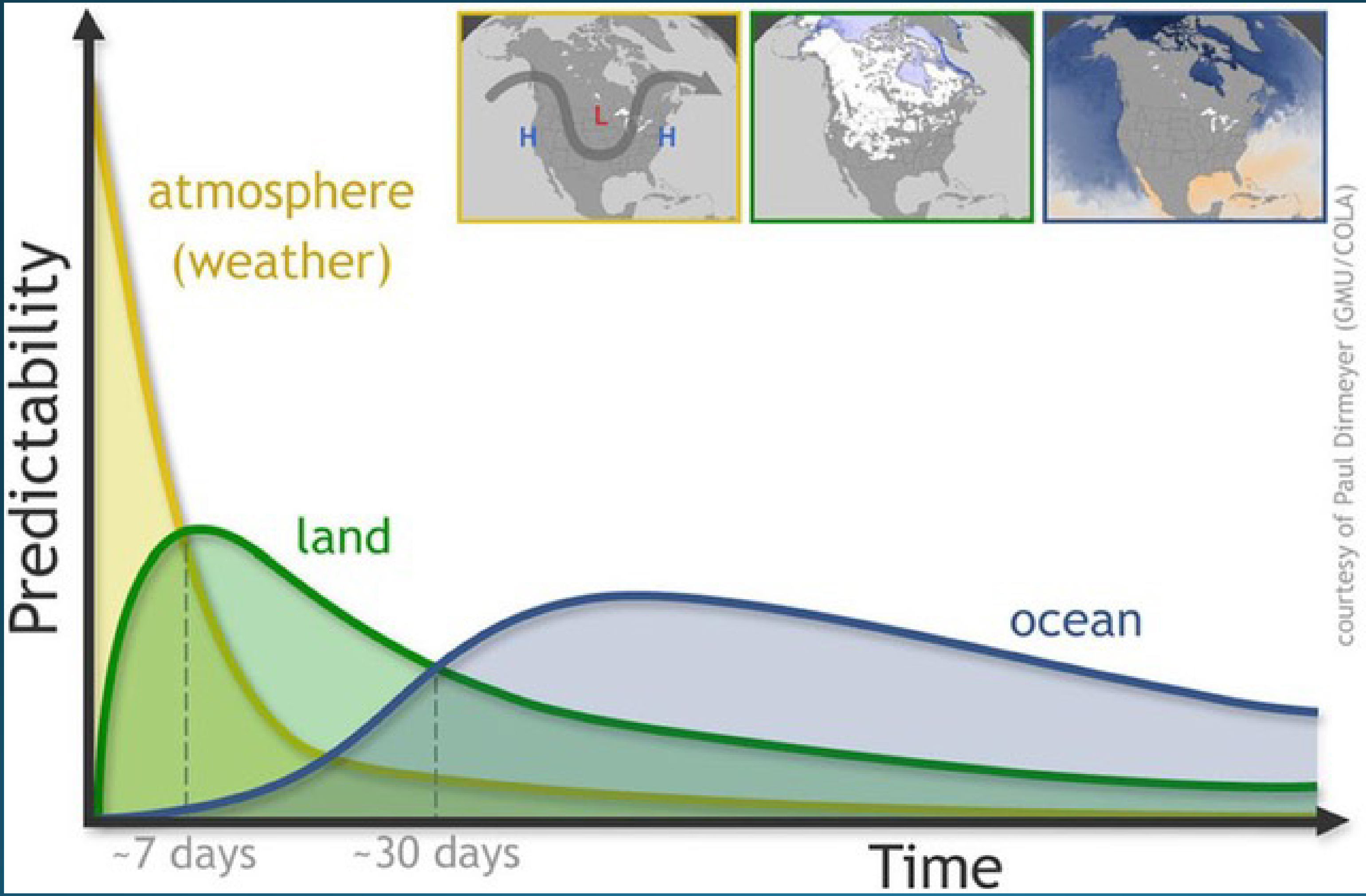
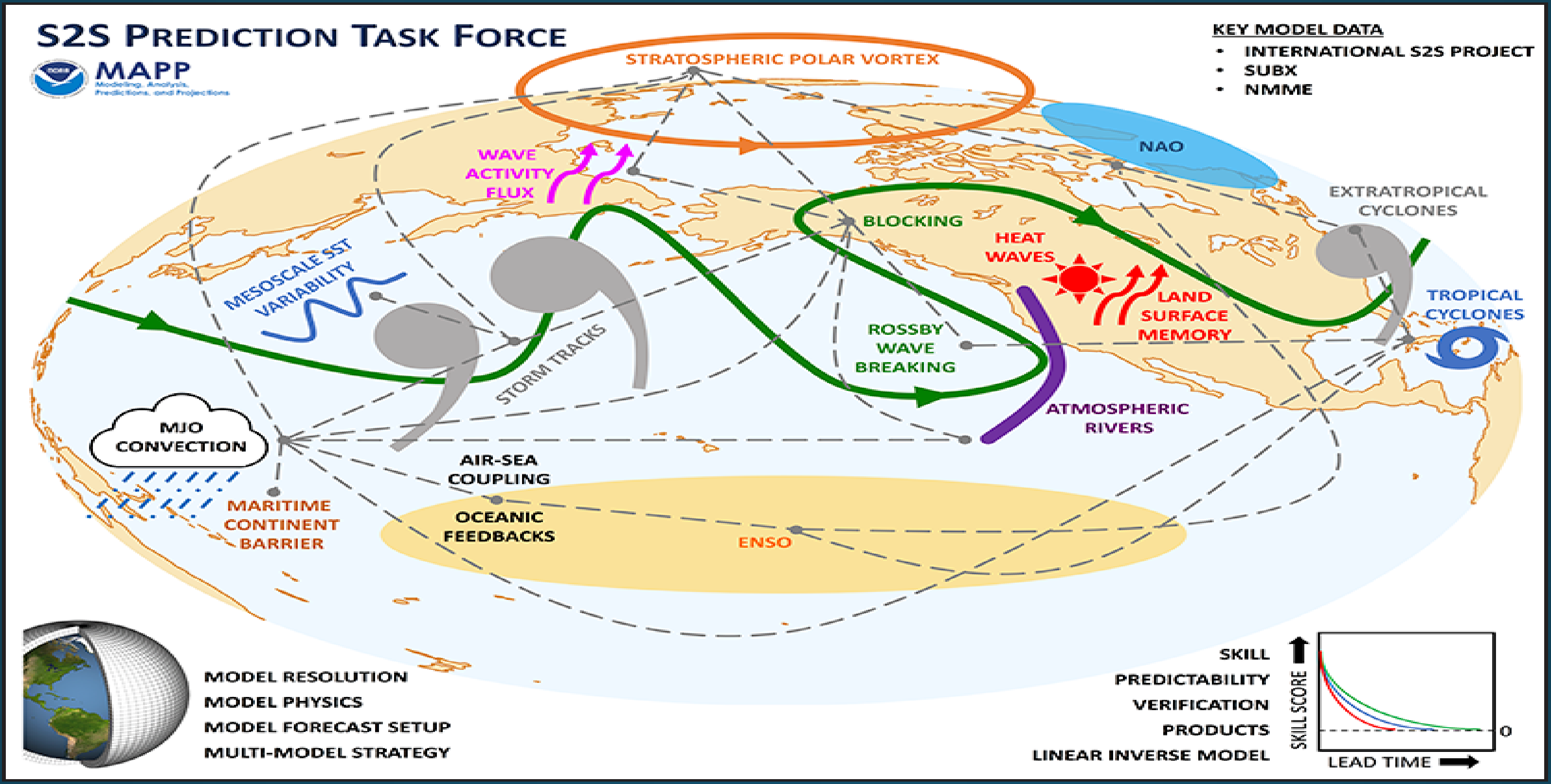
# Can we anticipate weekly, monthly and seasonal anomalies of wind speed, wind power generation or energy demand?

# Extended-range predictability




S2S time range

# Sources of sub-seasonal and seasonal predictability

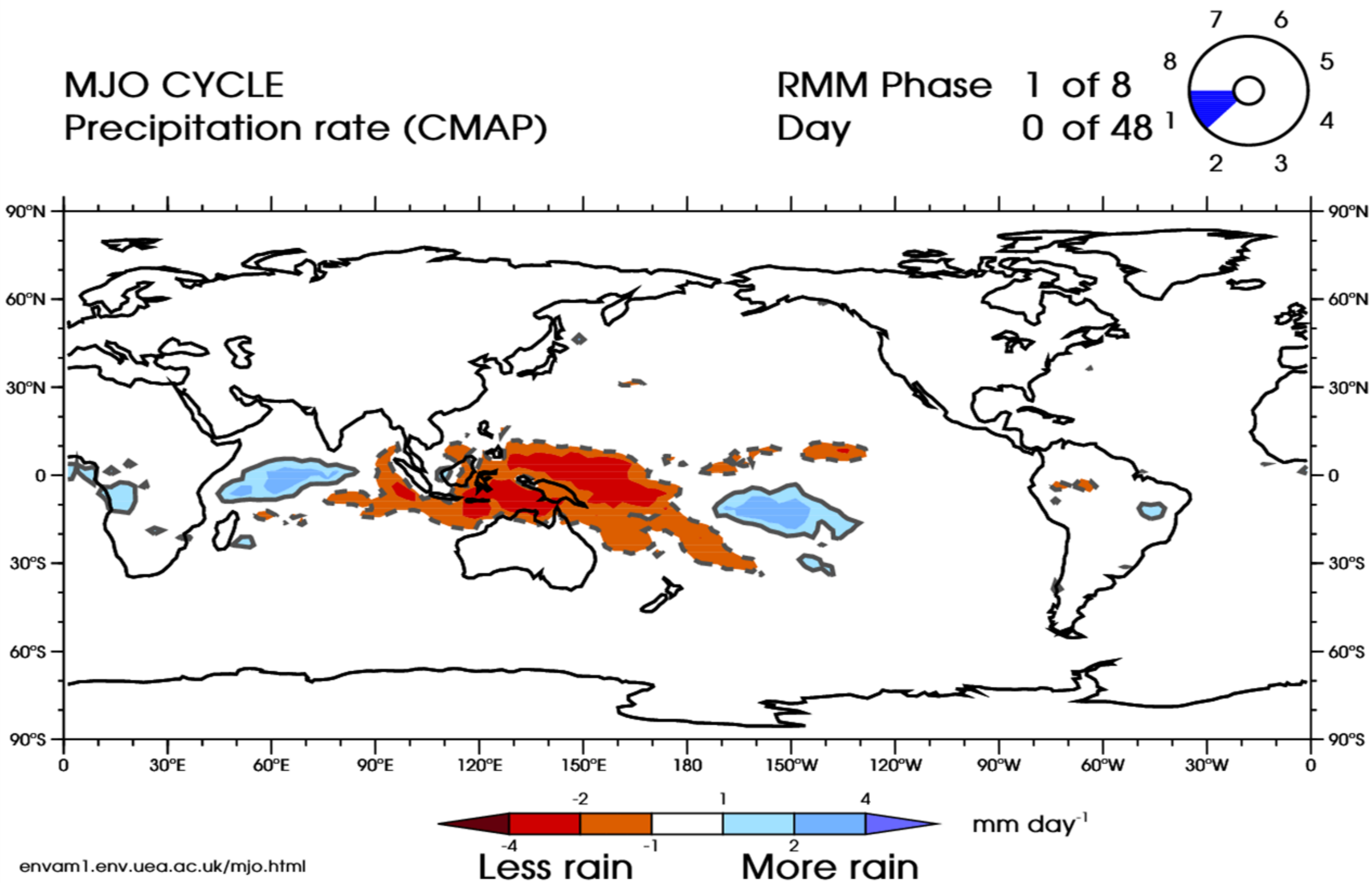



Main sources of predictability include:

- ENSO
- Madden Julian Oscillation
- Soil Moisture
- Stratospheric Initial conditions
- Rossby waves
- SSTs/Sea-ice
- Aerosols
- Others? …

Mariotti et al., 2019

# The Madden-Julian Oscillation is the main source of sub-seasonal variability in the tropics

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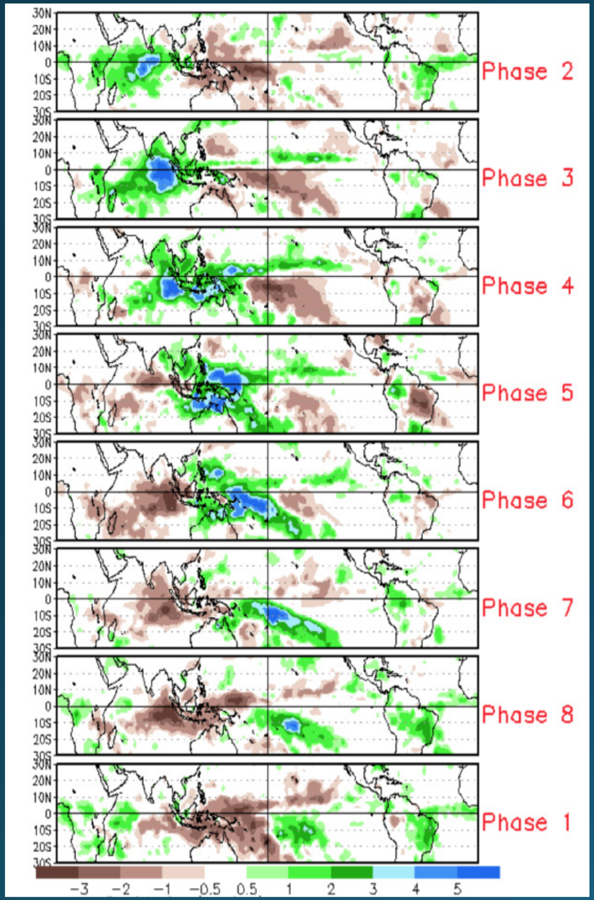
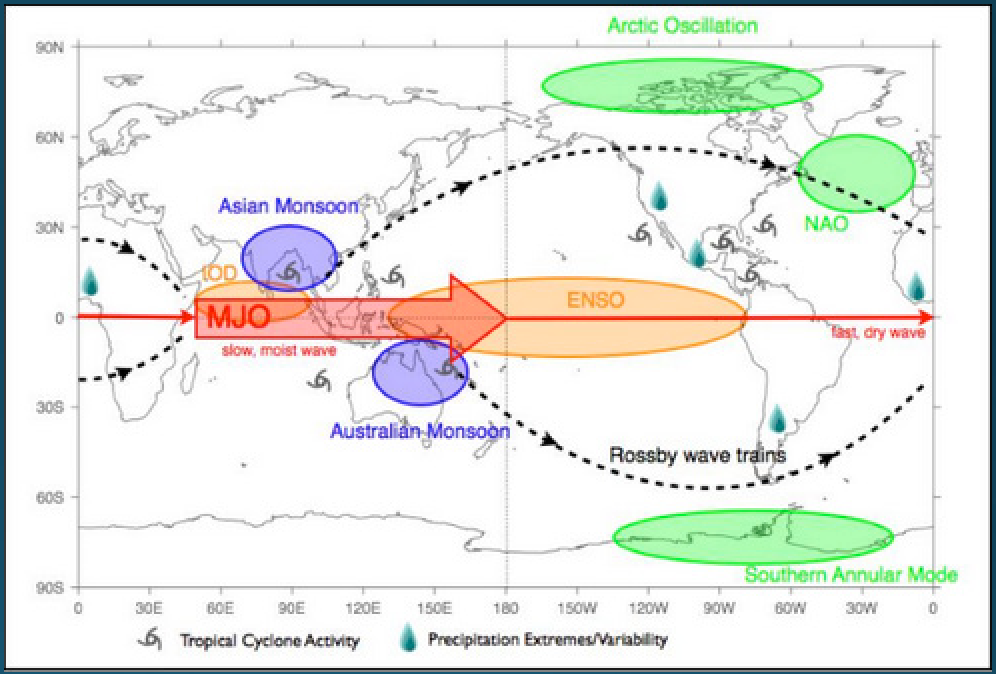
# The Madden Julian Oscillation

MJO phases

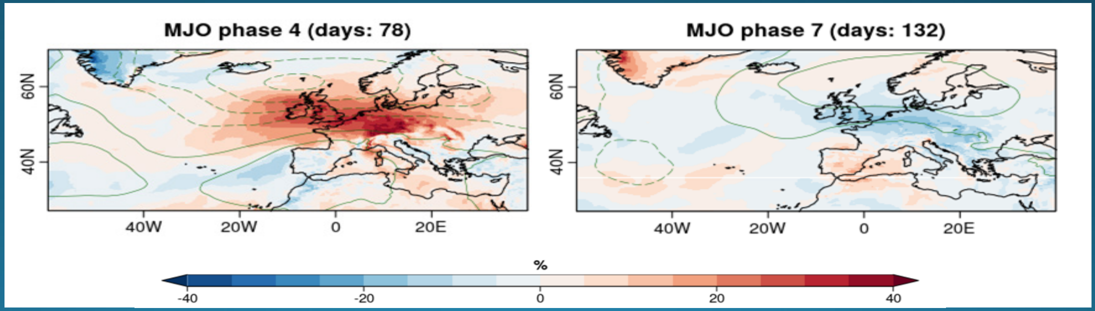



Gottschalk, 2014

MJO Impacts

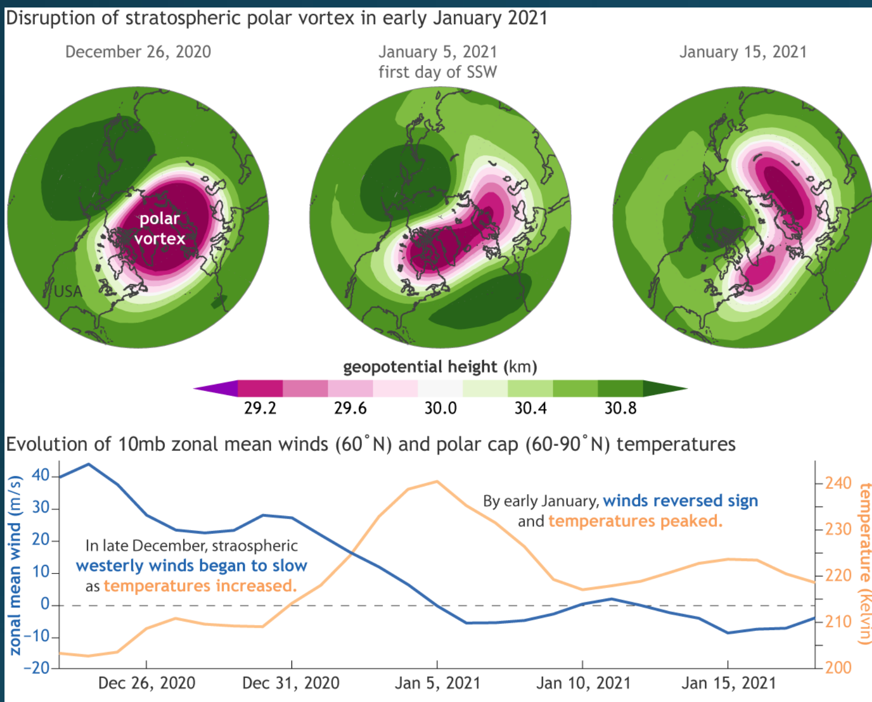



JFM surface wind anomalies in Europe

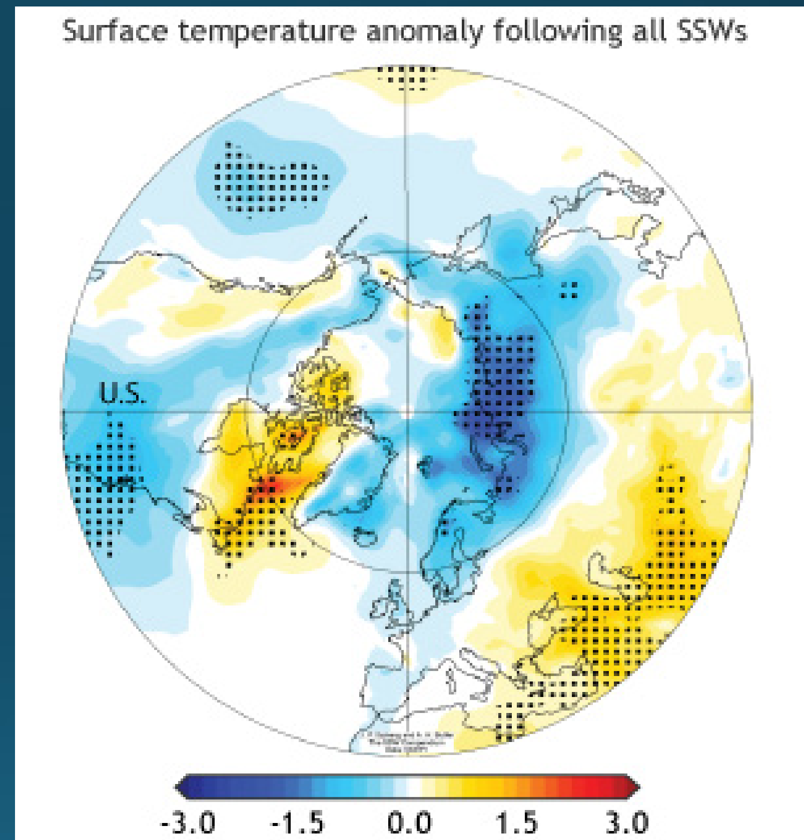


# Stratosphere: Weak vortex events

Jan 2021 weak vortex event




L'Heureux 2021



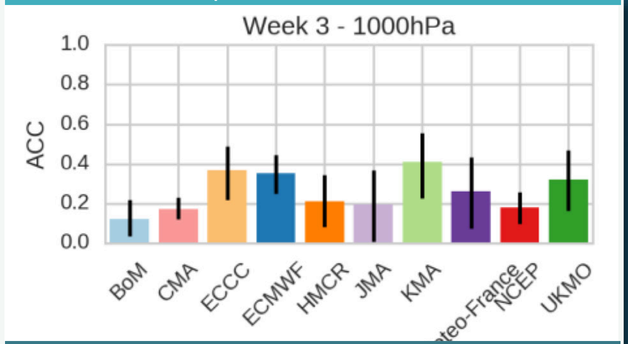

Surface temperature anomalies in degrees Celsius for (left) the 30 days following all identified SSWs in the NCEP-NCAR reanalysis record from 1958-2013. From Butler et al. 2017

# S2S prediction is challenging

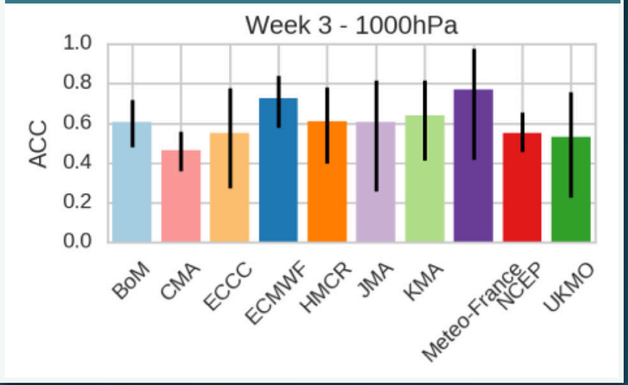
Forecast skill is not constant in time. It depends strongly on the occurrence of sources of predictability: "**windows of opportunity for forecast skill**" (e.g. strong MJO, weak vortex event…)

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

Neutral Stratospheric Vortex




Weak Stratospheric Vortex

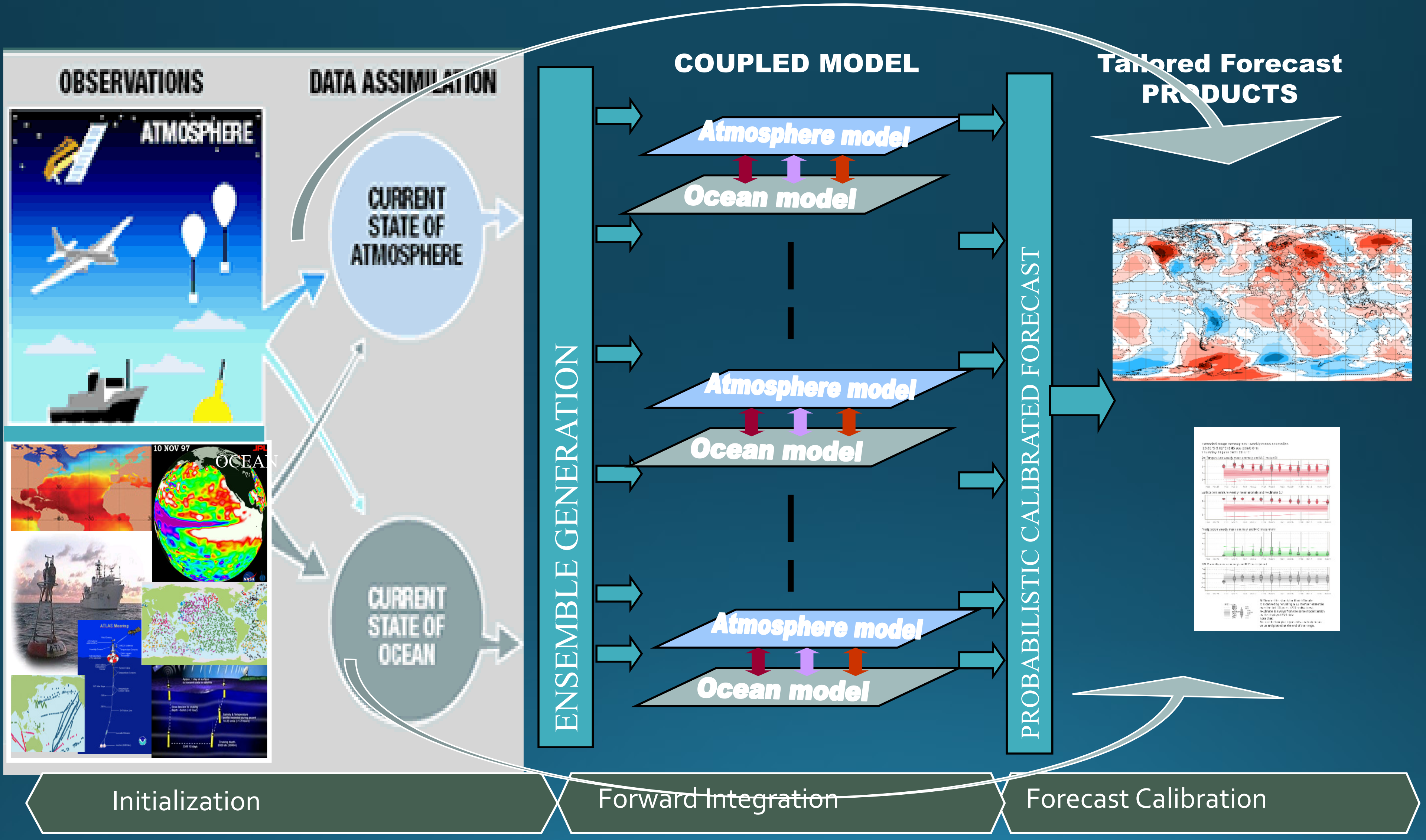



- For most models, skill is higher following weak vortex conditions.
- Similar results are found following strong vortex conditions.

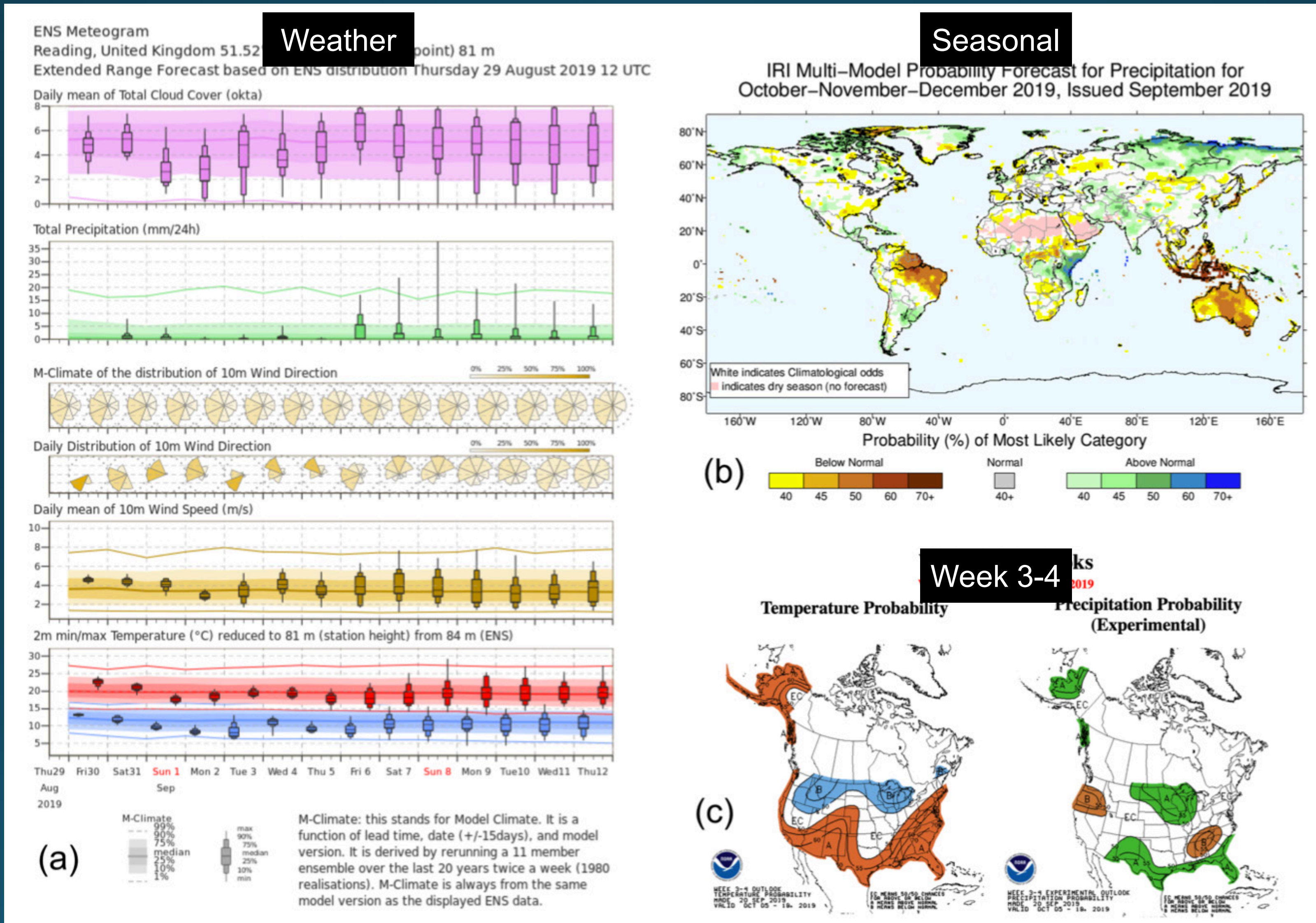
Domeisen et al. (2019)

# How are S2S forecasts produced?

## End-To-End forecasting System



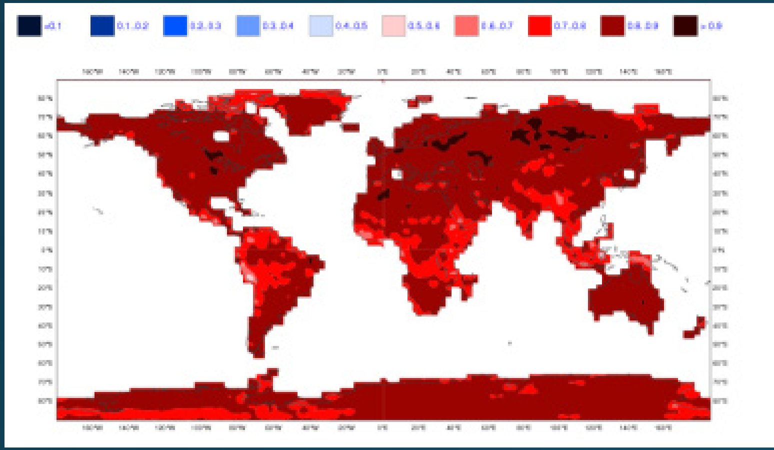
# What is the appropriate forecast format?



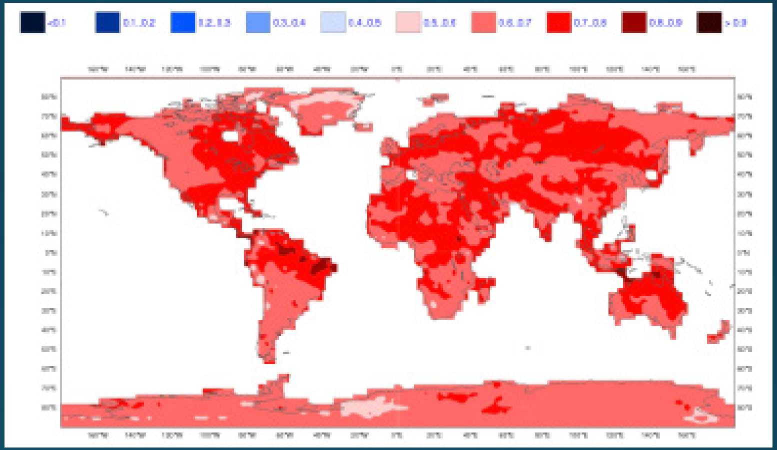
# What is the skill of 2-metre temperature?

ROC score: 2-meter temperature in the upper tercile

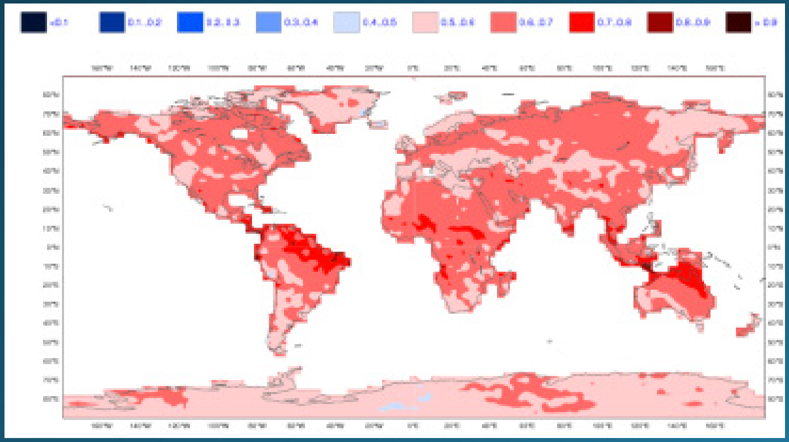
Day 5-11



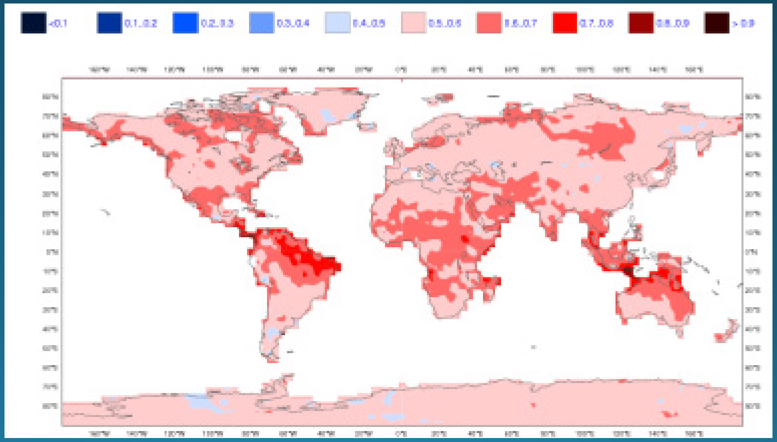
Day 12-18



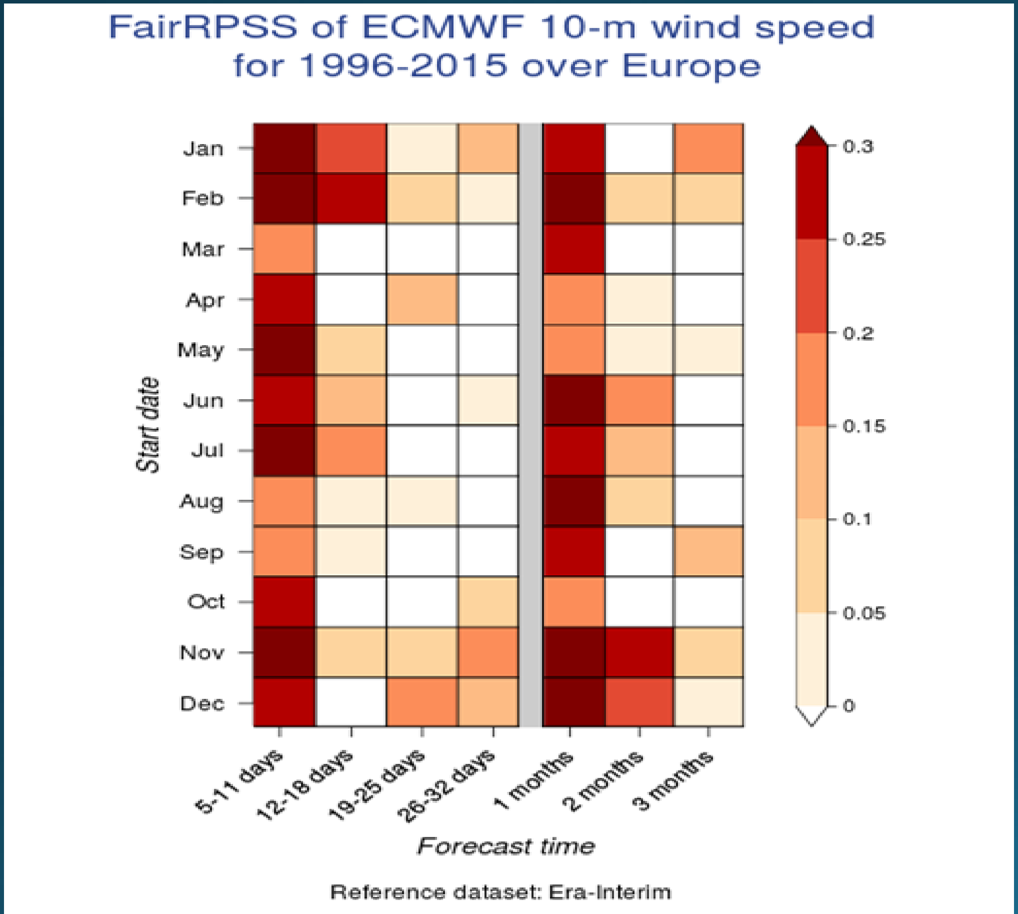
Day 19-25



Day 26-32



# S2S skill evolution over the year

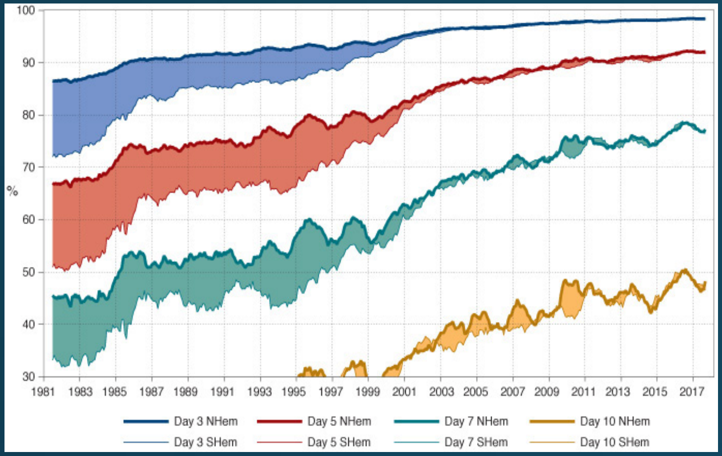




Forecast skill characterization in the Fino 1 area for different start dates (Y axis) and forecast window (X axis).

# Forecast skill. Are we filling the gap?

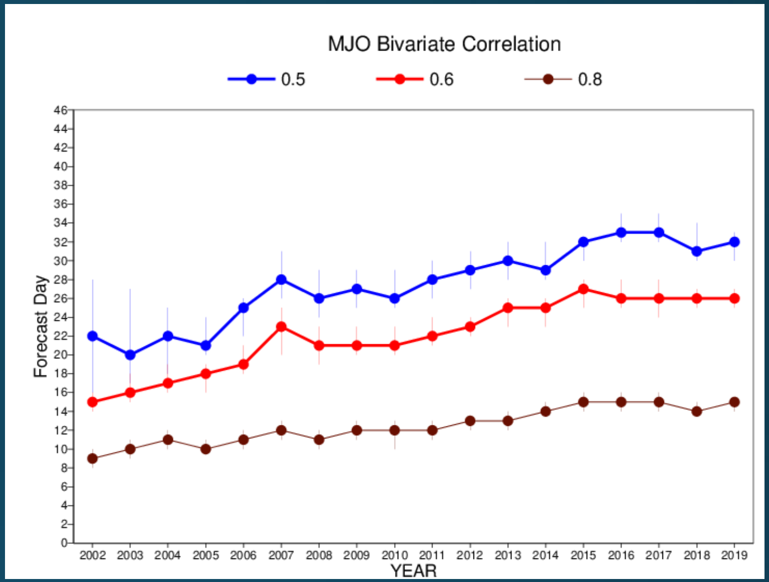
## Weather forecasting




Toth and Buizza, 2018

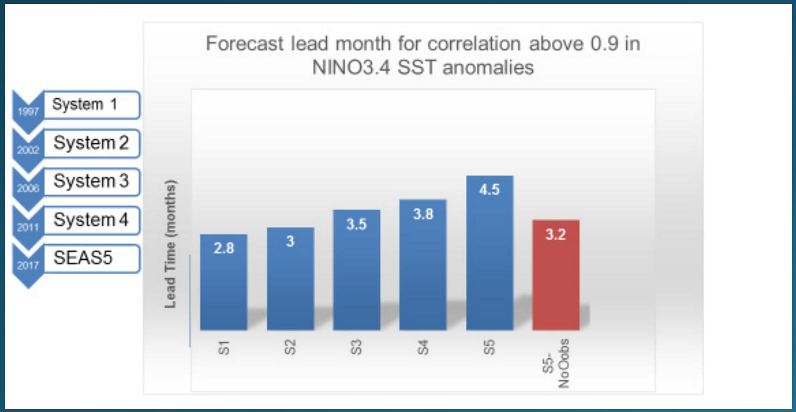
Incremental Improvement => "quite revolution"

## Extended-range forecasting

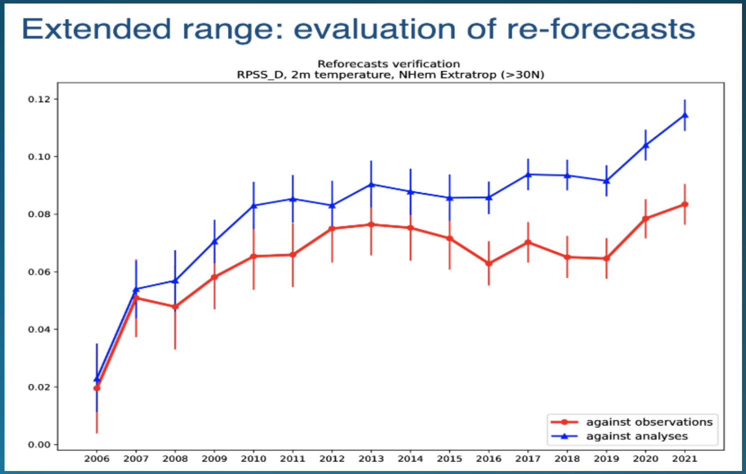



Week 3 2m temp over N. Extratropics

## Seasonal forecasting




Improved ENSO prediction over past 20 years



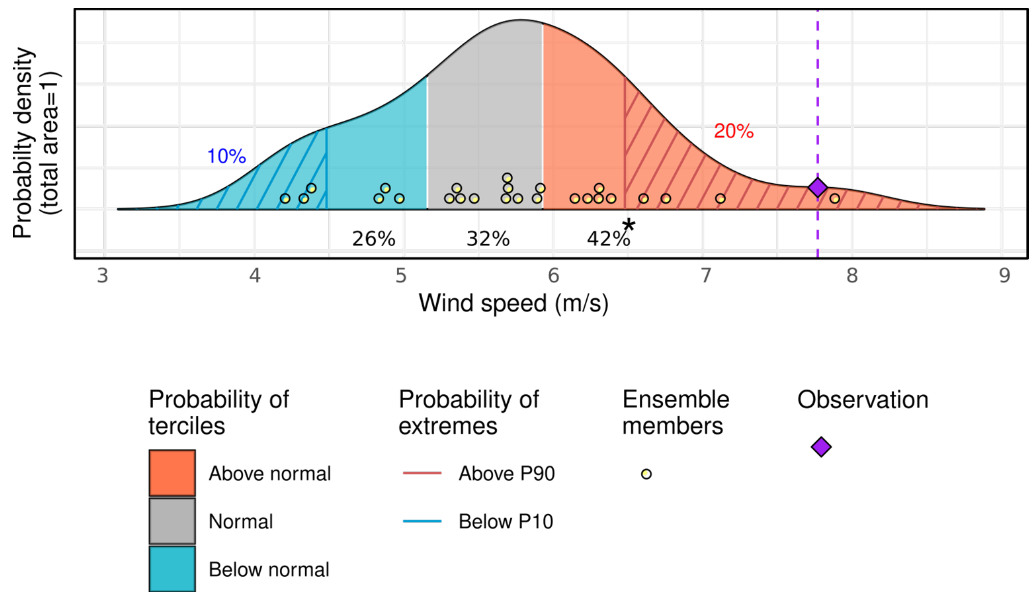

Rapid progress!

# CASE STUDIES

## from S2S4E

# A climate forcing can be detected in an ensemble of numerical simulations

- Coupled Earth System Model
  Forecast fast & slow evolution fields and its interactions
- Ensemble members
  Each member represents one possible system evolution
- Signal extraction
  Average whole period to filter noise and obtain forcing signal
- Probabilities
  Count members above/below threshold

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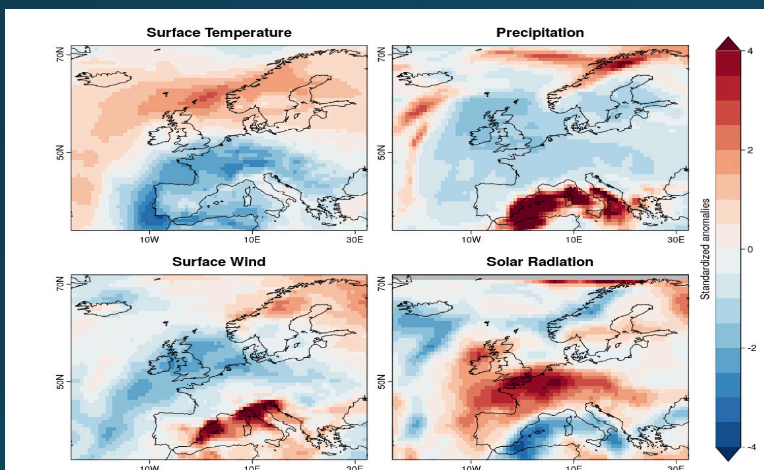
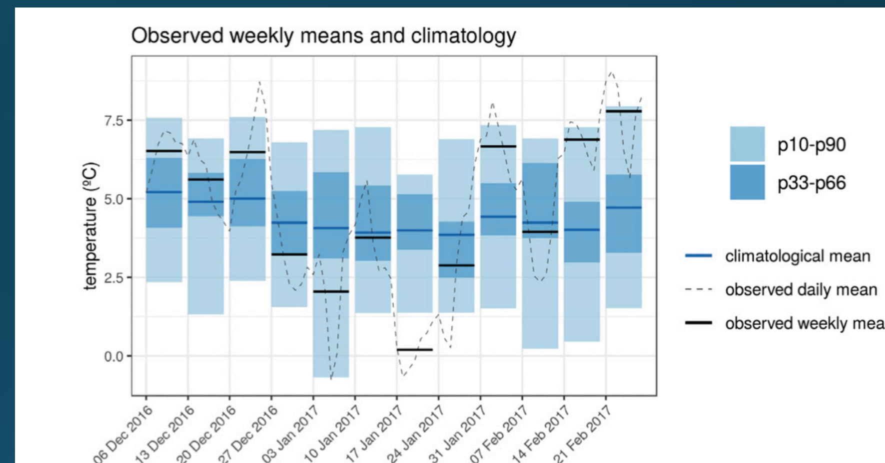
# Cold spell and wind drought in Europe January 2017

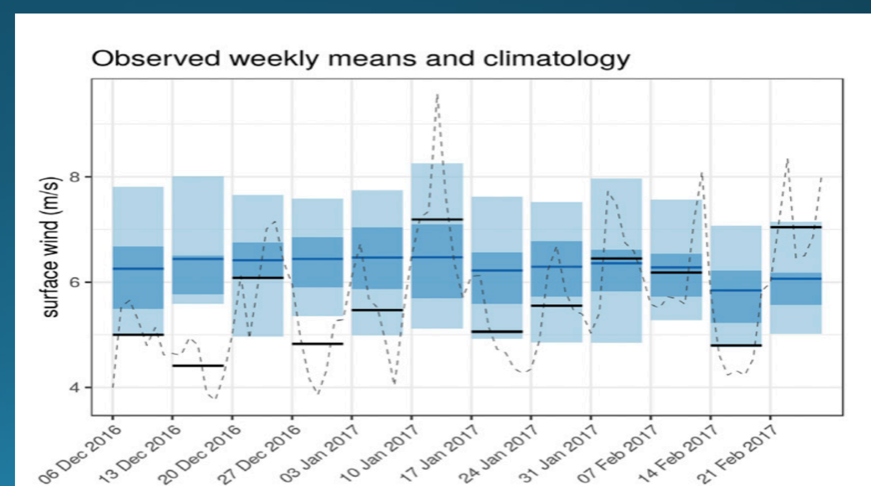
Standardized anomalies - Dec 2016-Feb 2017- ERA-Interim




Surface temperature




Wind Speed

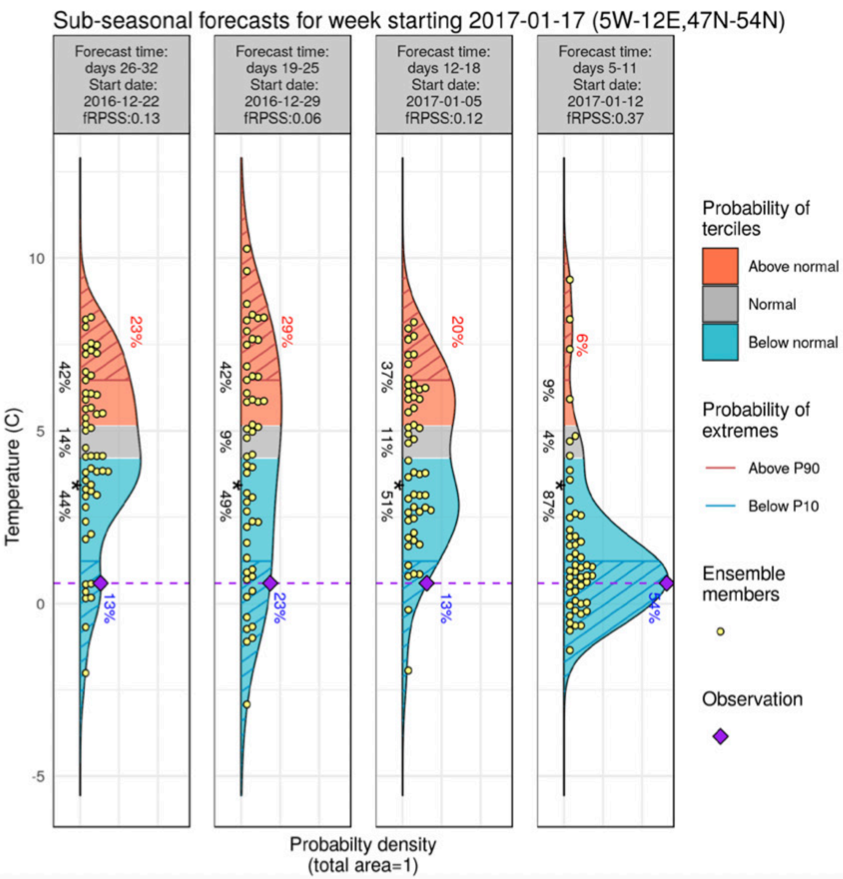


# Cold spell and wind drought in Europe January 2017

17 January 2017

## Surface temperature forecast in Europe

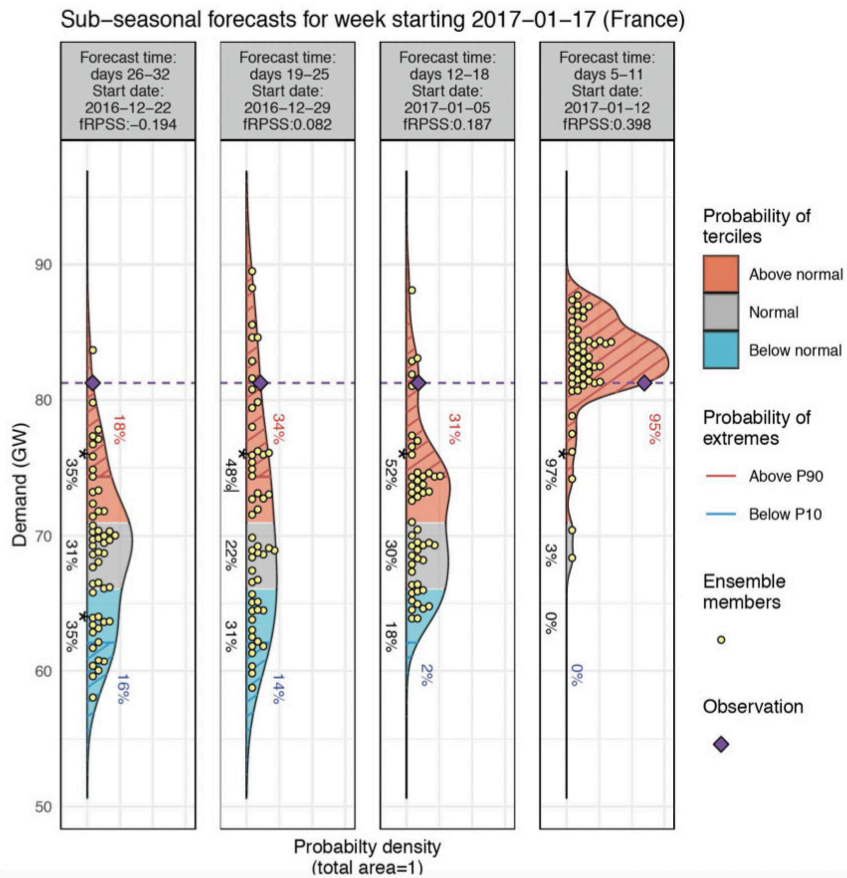
| Skill (Temperature) | Forecast lead time Days 26-32 | Days 19-25 | Days 12-18 | Days 5-11 |
|---|---|---|---|---|
| **RPSS** | 0.13 | 0.06 | 0.12 | 0.37 |




## Electricity demand forecast in France

(see Bloomfield et al, 2021)

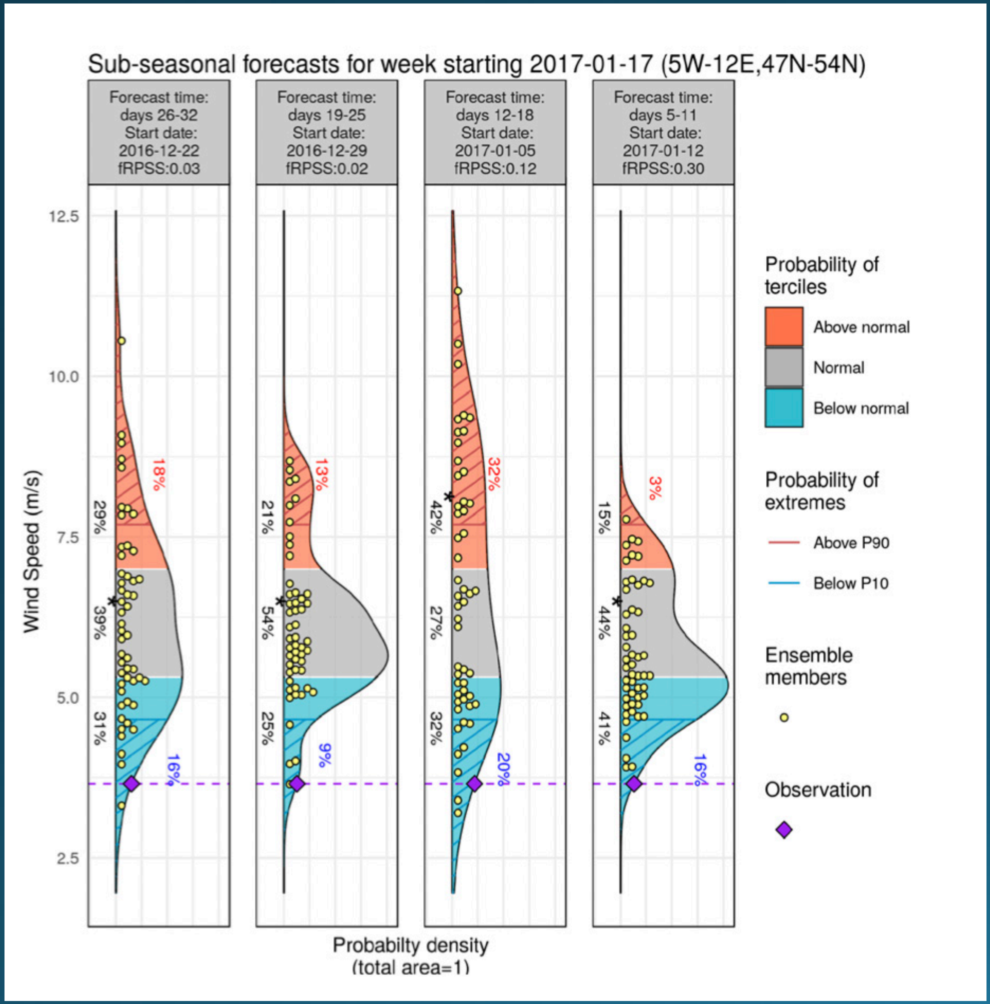
| Skill (Electricity demand) | Forecast lead time Days 26-32 | Days 19-25 | Days 12-18 | Days 5-11 |
|---|---|---|---|---|
| **RPSS** | -0.19 | 0.08 | 0.19 | 0.40 |



# Cold spell and wind drought in Europe January 2017

17 January 2017

Wind speed forecast

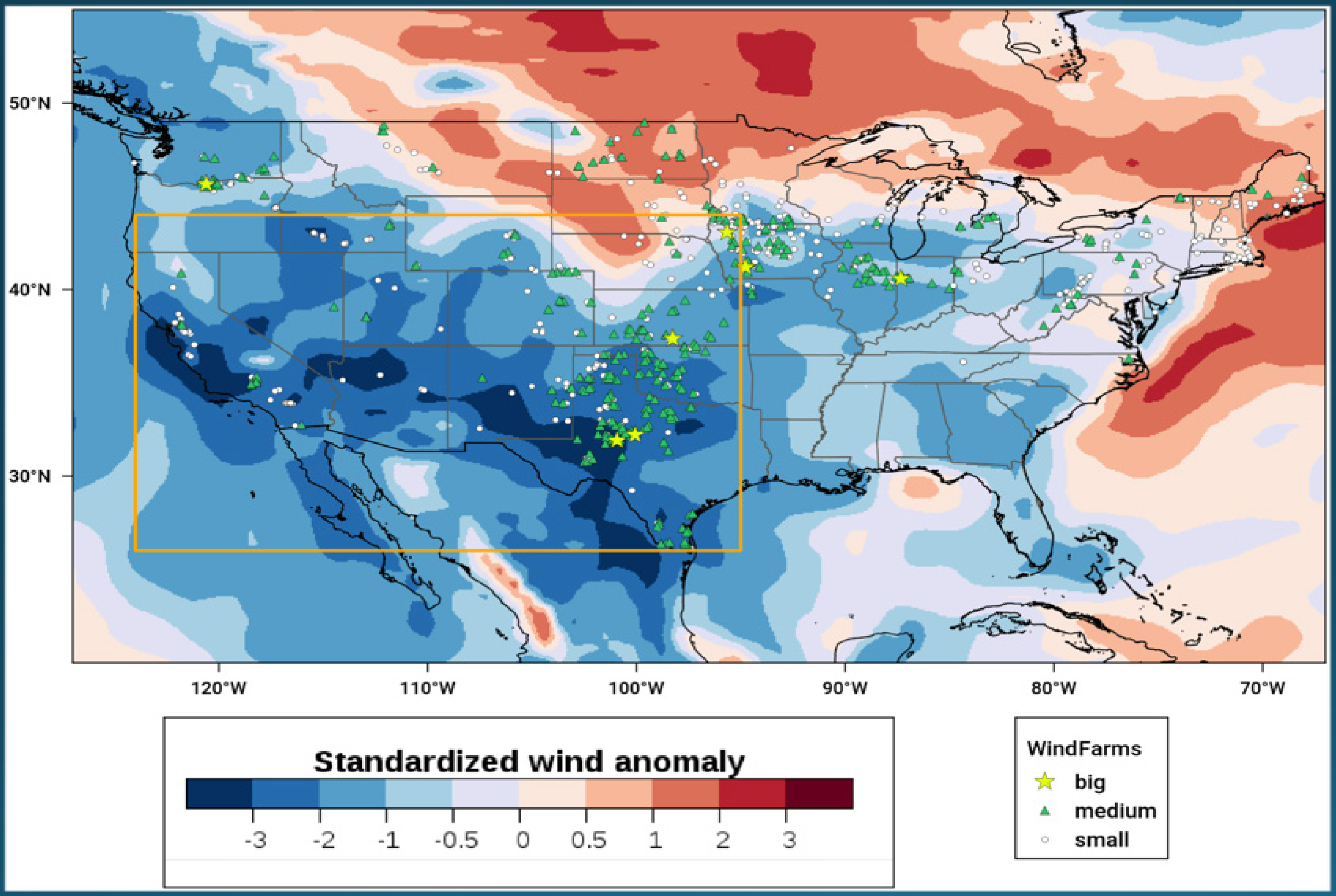



| Skill (Wind Speed) | Forecast lead time | | | |
|---|---|---|---|---|
| | Days 26-32 | Days 19-25 | Days 12-18 | Days 5-11 |
| **RPSS** | 0.03 | 0.02 | 0.12 | 0.30 |
| **BSS P10** | 0.07 | -0.02 | 0 | 0.21 |
| **BSS P90** | 0.02 | 0.01 | -0.01 | 0.19 |

# US wind drought

Q1 2015

# Wind anomaly Q1 2015




S2S4E
Climate Services for Clean Energy

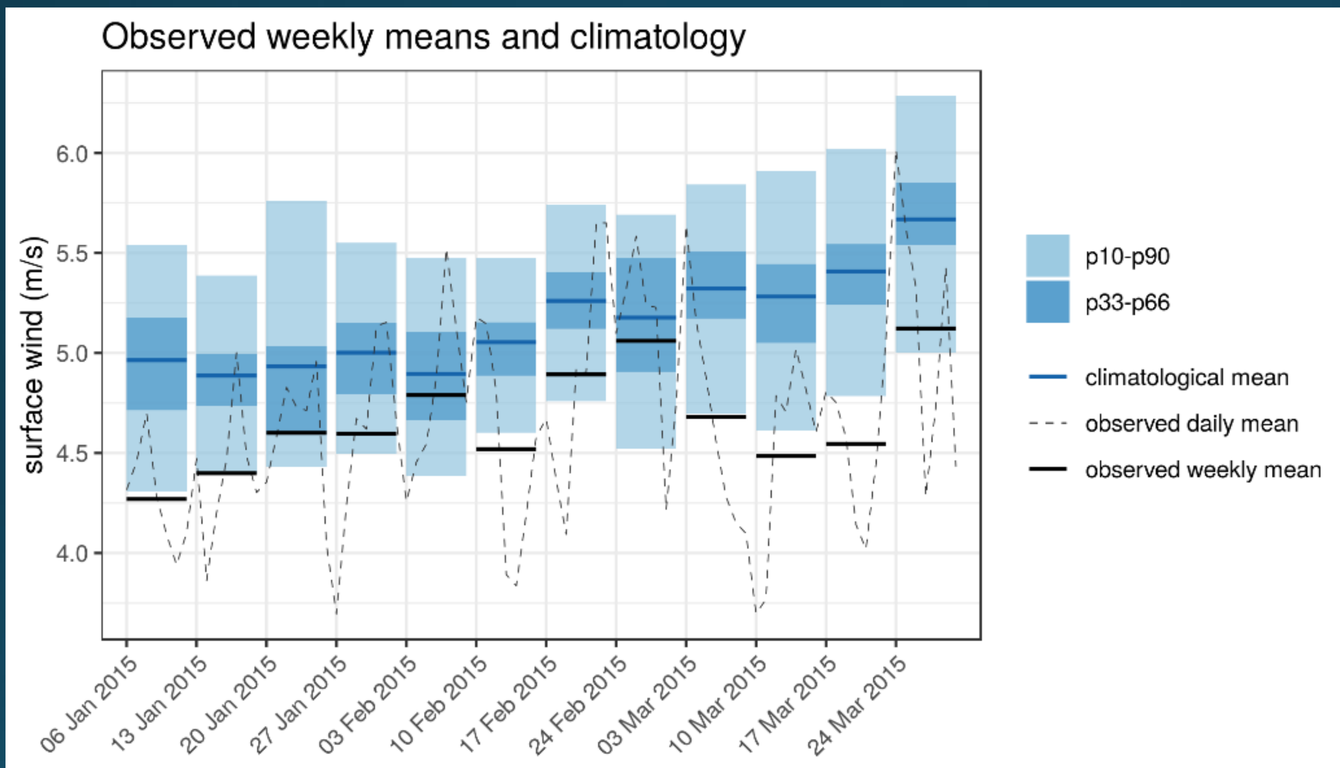
# Event impacts

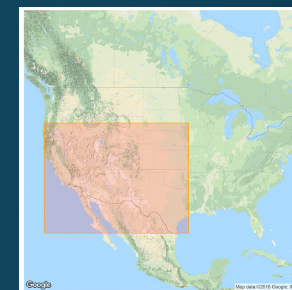
"US clean energy suffers from lack of wind"
*Financial Times, September 2015.*

"We never anticipated a drop-off in the wind resource as we have witnessed over the past six months"
*David Crane, RNG, September 2015.*

S2S4E
Climate Services for Clean Energy

# Widespread and extended in time



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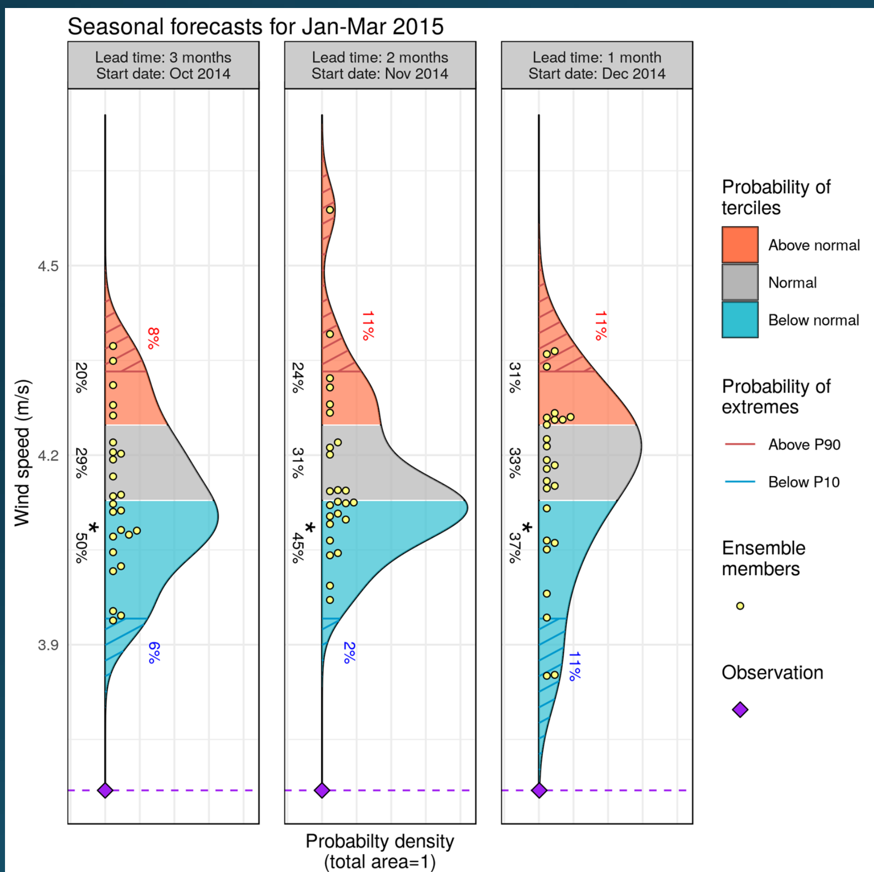
for Clean Energy

# Fcsts available 3 to 1 months ahead




System: ECMWF SEAS5
Reanalysis: ERA-Interim
Bias adjustment: calibration
Hindcast: 1993-2015

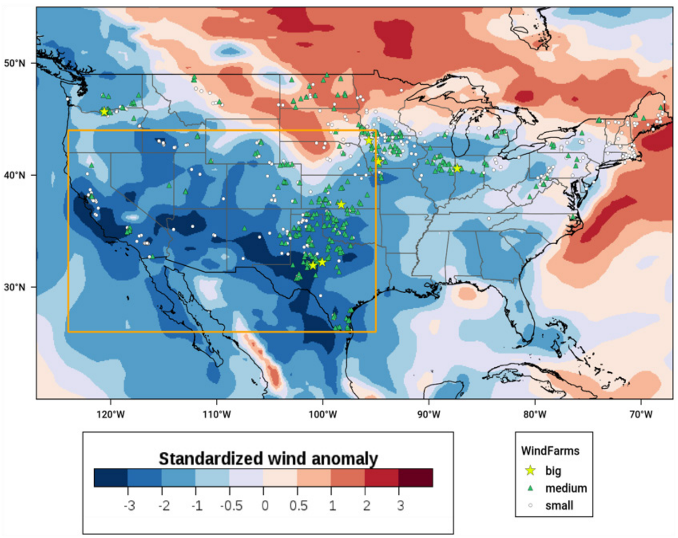
## ▶ Associated Skill Scores

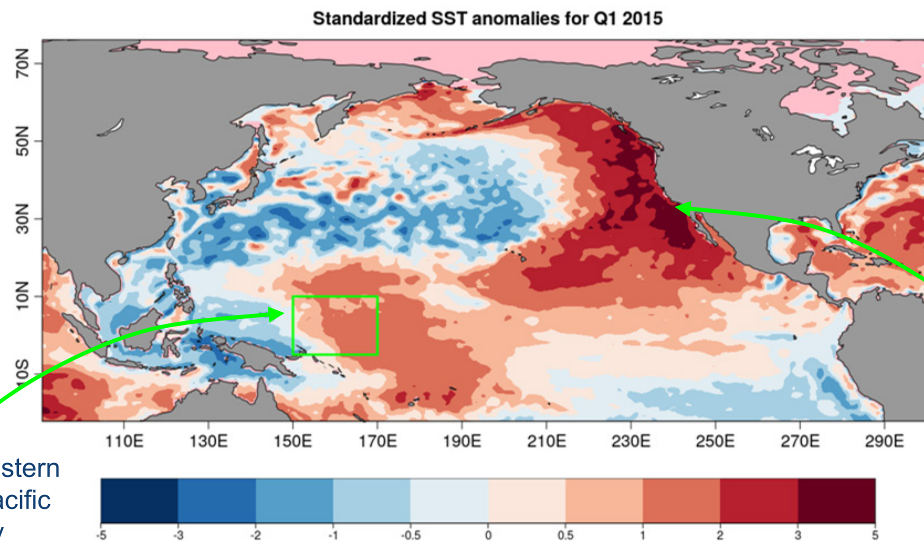
| | Start Date | | |
|---|---|---|---|
| | Oct | Nov | Dec |
| RPSS | 0.35 | 0.39 | 0.35 |
| BS P10 | −0.07 | −0.27 | −0.16 |
| BS P90 | 0.1 | 0.04 | 0.07 |
| CRPSS | 0.14 | 0.11 | 0.14 |
| EnsCorr | 0.55 | 0.54 | 0.51 |

Which decisions would you make in view of those forecasts?

S2S4E Climate Services for Clean Energy

# Why did it happen?




SSTs in Western Tropical Pacific are key

High SSTs in western coast partly due to an "atmospheric bridge" process

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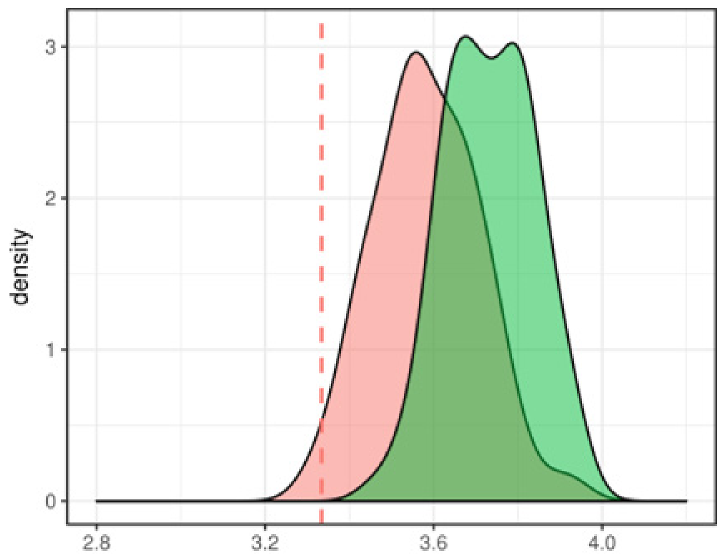
# Attribution experiment with EC-EARTH




2 experiments w 100 members
initialized 1st January 2015

**PDF(wind | normal SST)**

**PDF(wind | high SST)**

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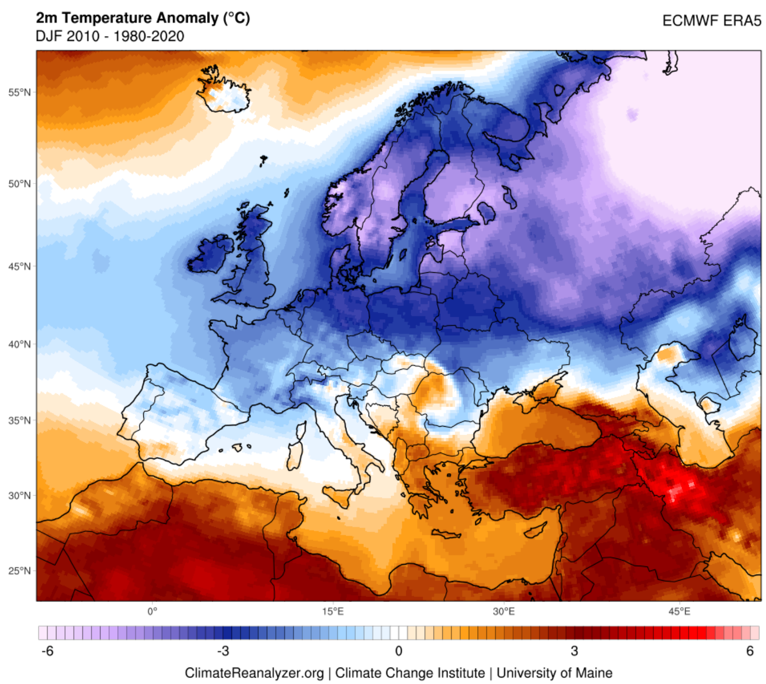
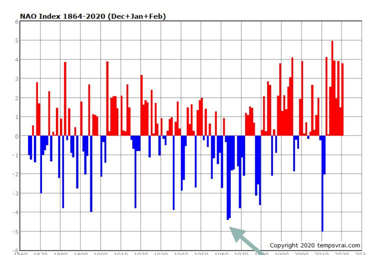
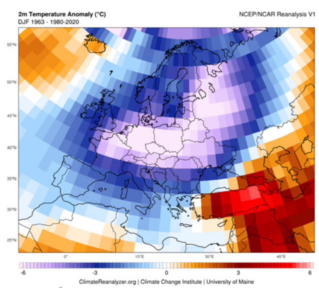
# A NAO⁻ as in 2009/10 winter would freeze Europe's most vulnerable homes

2009/2010 winter was cold and still: energy demand increased up to 20%




- Sea level pressure difference between Iceland and Açores very weak (NAO⁻ pattern)
- Easterly flow brings cold continental air
- 1962/63 is an analogue year based on NAO index

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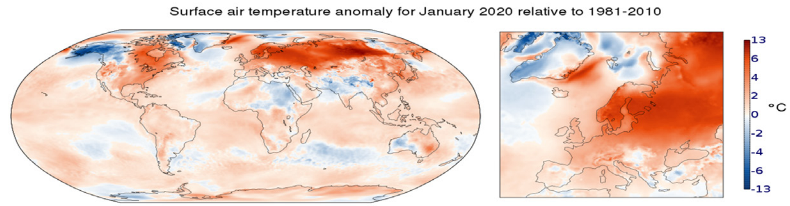
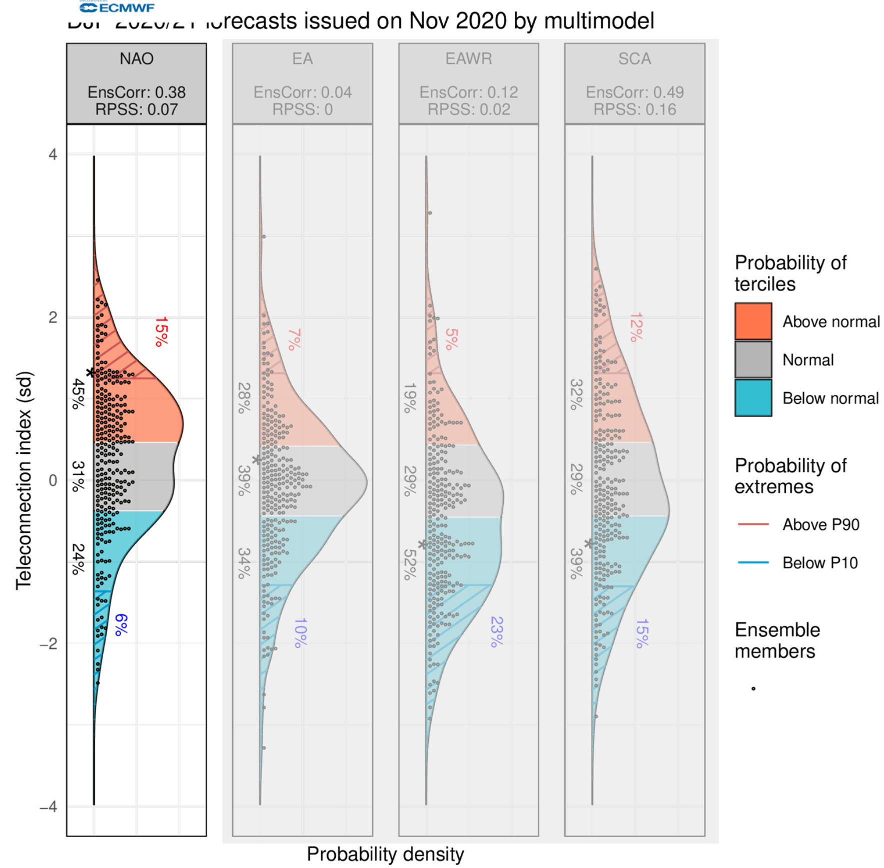
# January 2020: strong NAO+ pattern




- Multi-system predictions of 4 EATCs
- Combine info from several sources
- Skill almost as good a best system, and more robust.
- Extremes (PoE P10/P90) are better described with more members.
- Summary
  - Enhanced prob. of NAO+
  - Enhanced prob. of SCA-
  - High prob. of EAWR-

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# Conclusions

- S2S prediction is challenging. Skill at this time range depends strongly on the occurrence of sources of predictability
- S2S models are improving with better representation and prediction of sources of predictability such as the MJO and stratospheric processes
- There is room for improvement through the use of AI/ML methods to better calibrate model outputs.
- Case studies suggest that S2S forecasts can be useful for the prediction od energy demand. However, S2S prediction for wind production is more challenging.