



**Barcelona
Supercomputing
Center**
Centro Nacional de Supercomputación



Sub-seasonal and Seasonal Climate Forecast Applications

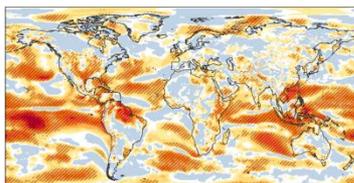
Francisco J. Doblas-Reyes

with contributions from Joaquín Bedia, Nicola Cortesi, Carlo Lacagnina, Llorenç Lledó, Jaume Ramón, Daniel San Martín, Marta Terrado, Verónica Torralba, Marco Turco, Ilaria Vigo and many more

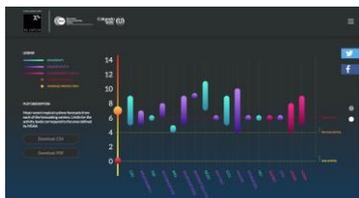
Some definitions



- **Climate data:** numerical values representing ECVs and associated magnitudes; includes metadata



- **Climate information:** the result of processing climate data according to the available climate knowledge



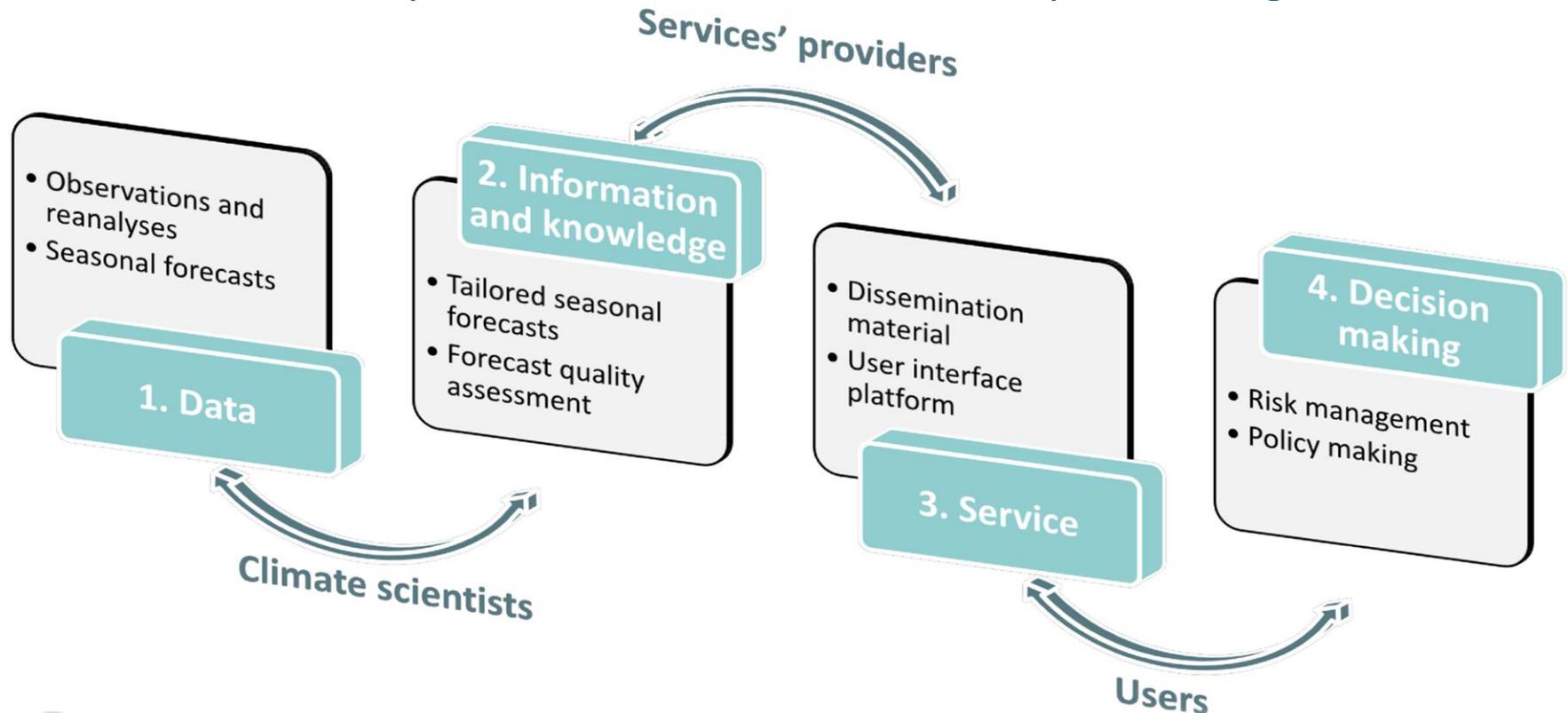
- **Climate message:** climate information put in context and generated in a co-production process



- **Climate service:** ensemble of processes through which a climate message is generated

The research-provider-service paradigm

A **service-oriented research agenda** requires the traditional chain “research development-operations-service provision” to move both ways so that not only information quality is demonstrated, but user requirements are adequately addressed and value illustrated. This leaves a space for **transdisciplinary research**. This chain should not preclude basic research to take place though.



The research-provider-service paradigm

SUCCESSFUL CLIMATE SERVICE

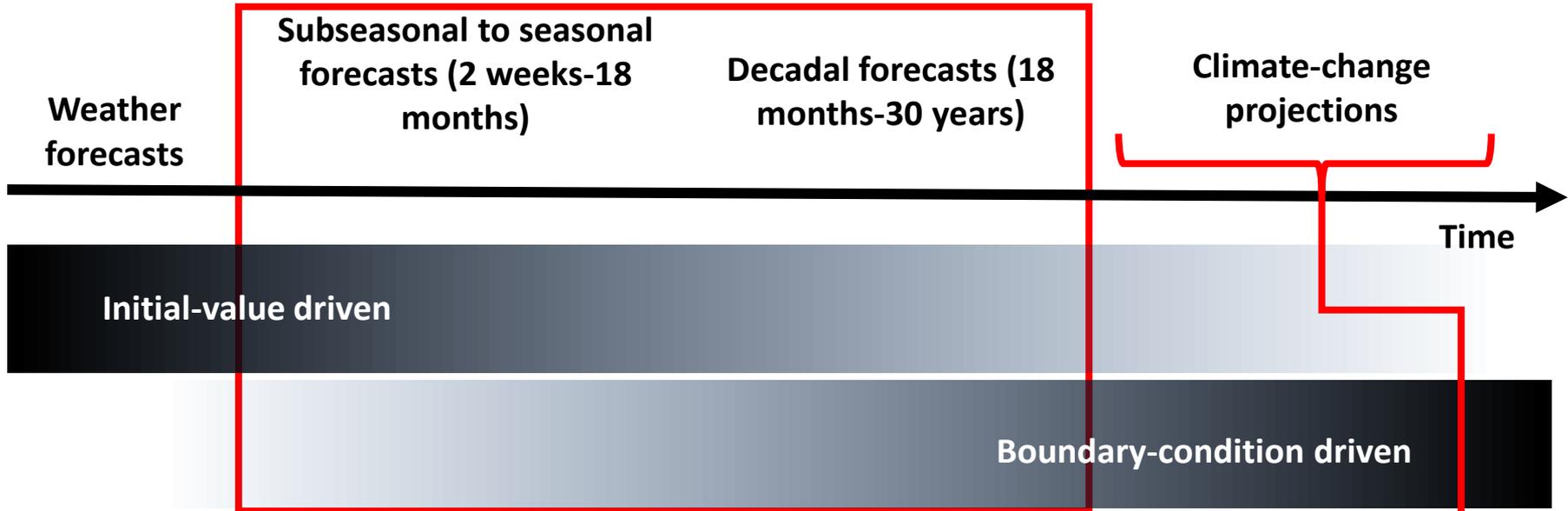
Principles



Scribbles

17/09/2014
Climate Symposium

Climate time scales



The user



The data provider

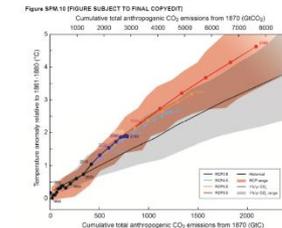


The message producer



The message

Approved Figure SPM.10 From IPCC AR5
Summary for Policymakers
Global Temperature Anomaly Vs.
Cumulative Manmade CO₂ Emissions



e.g. IPCC SPM preparation

Barriers to use climate forecasts in applications

Some limitations for the use of climate forecasts in different socio-economic sectors.



Possible solution: to adapt the climate forecasts into a message to be integrated in decision-making.



Climate services

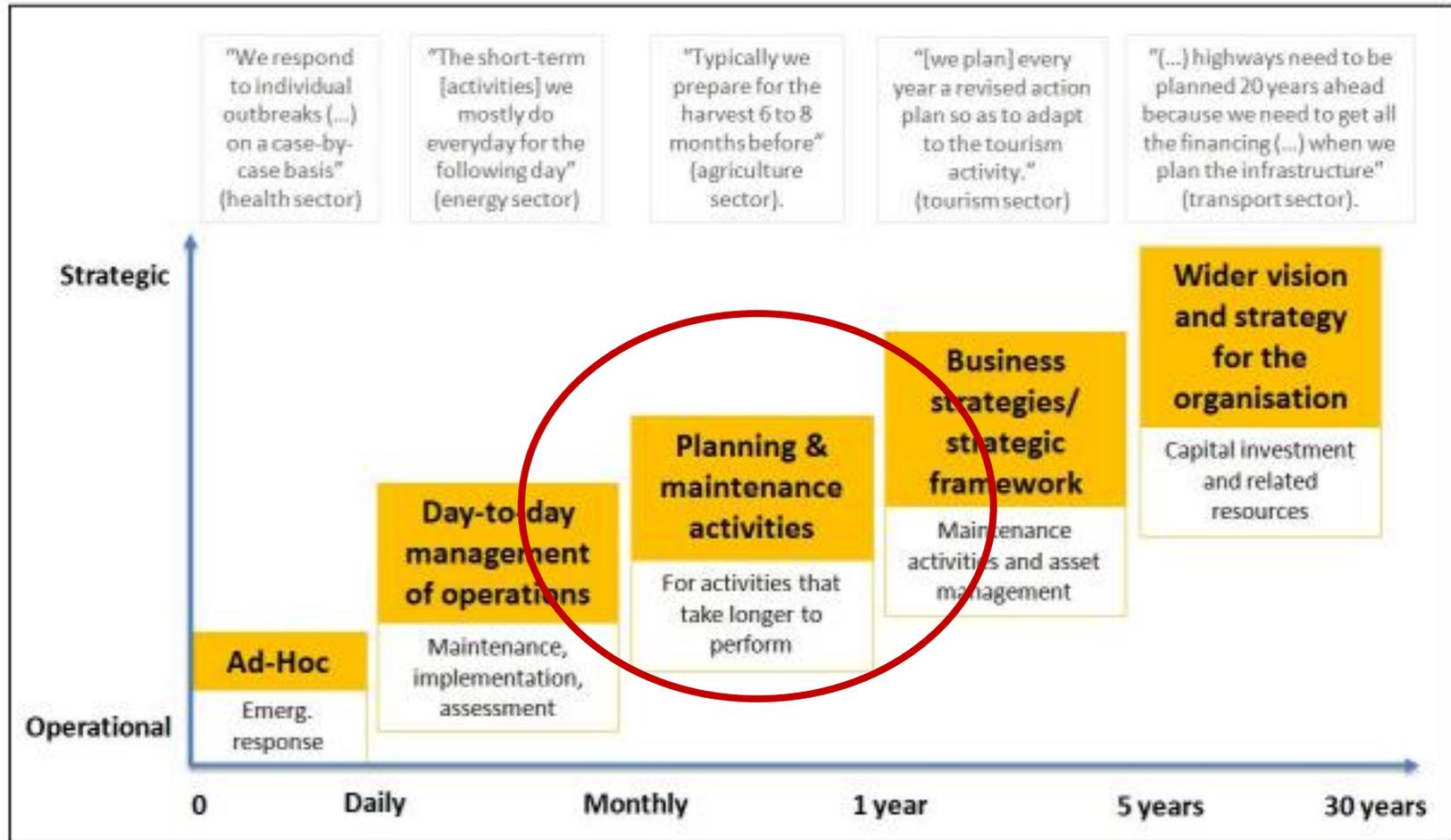
- **Goal:** the development and incorporation of climate messages based on forecasts for planning, policy-making and practice at the global, regional and national scale.
- **Implementation method:** co-production and co-design.

Some elements to produce climate messages

- **User engagement:** raise awareness, identification of requirements, indicators, roadmap for co-production, message format, funding model
- **Climate data:** observations, reanalyses, forecasts and hindcasts and measures of uncertainty for all of them
- **Forecast product:** unequivocal definition, adequate verification
- **Forecast quality:** verification (with uncertainty estimates), standards and data correctness, documentation, guidance, independent assessment
- **Traceability:** accessibility of the methodology, standards, provenance
- **Message synthesis:** elaboration of the message, consider difficulties for interpretation, including its periodicity, using multiple lines of evidence
- **Training:** gamification, workshops, case studies, webinars
- **The prediction has value if it can be used to build a climate message that helps the user to obtain some kind of benefit from the decisions she has to make. Let's leave it to them.**

User engagement: problem definition

Users of climate predictions are involved in more strategic decisions than those of weather forecasts



An example: Users in the energy sector

Long-term user engagement has allowed identifying a number of decisions that could benefit from climate predictions

Post-construction decisions

Energy producers: Resource management strategies

Energy traders: Resource effects on markets

Plant operators: Planning for maintenance works, especially offshore wind O&M

Plant investors: anticipate cash flow, optimize return on investment

Mid-term planning

Grid operators: Anticipate hotter/colder seasons to schedule power plants to reinforce supply.

Energy traders: Anticipate energy prices.

Sometimes, the user wants to understand

APPLICATE.eu
Advanced prediction in
polar regions and beyond

CASE STUDY 1

**ENERGY CASE
STUDY**

Effects of Arctic sea ice
on energy production in
mid-latitudes



CHAIN OF EVENTS

1. Historical low sea ice concentration in the Barents and Kara (BK) seas.

S2S4E
Climate Services
for Clean Energy

CASE STUDY #7

**COLD SPELL
IN EUROPE**
"Beast of the East"

Winter 2018



BASIC FACTS

- ▶ **Area:** Europe
- ▶ **Season:** winter
- ▶ **Year:** 2018
- ▶ **Forecast range:** sub-seasonal
- ▶ **Main interest:** electricity demand
- ▶ **Forecast variables:** temperature and electricity demand

WHAT happened

An unanticipated cold spell resulted in below average weekly temperatures and triggered an increase in power demand for heating.

WHERE it affected

The cold spell affected mostly eastern and central Europe.

WHEN it occurred

This case study analyses the extreme cold temperatures that occurred from February 27th to March 5th, 2018.

 This factsheet is based on S2S4E deliverable 4.1. To access the full report, please visit s2s4e.eu.

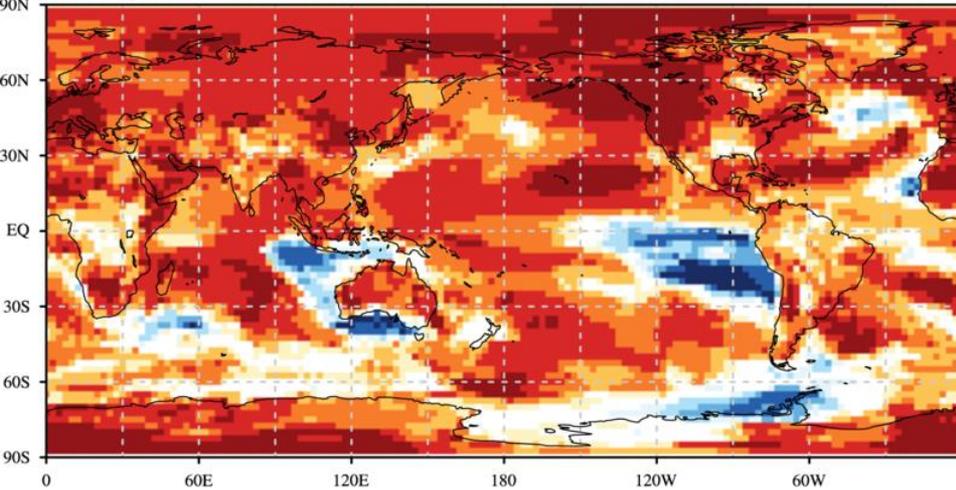
Other times, they look for climate forecasts

Consistency Map

CPTEC,ECMWF,Exeter,Melbourne,Montreal,Moscow,Offenbach,Pretoria,Seoul,Tokyo,Toulouse,Washington

2m Temperature : SON2019

(issued on Aug2019)



** where, the positive numbers mean the number of models that predict positive anomaly and vice versa. **

But some elements are missing:

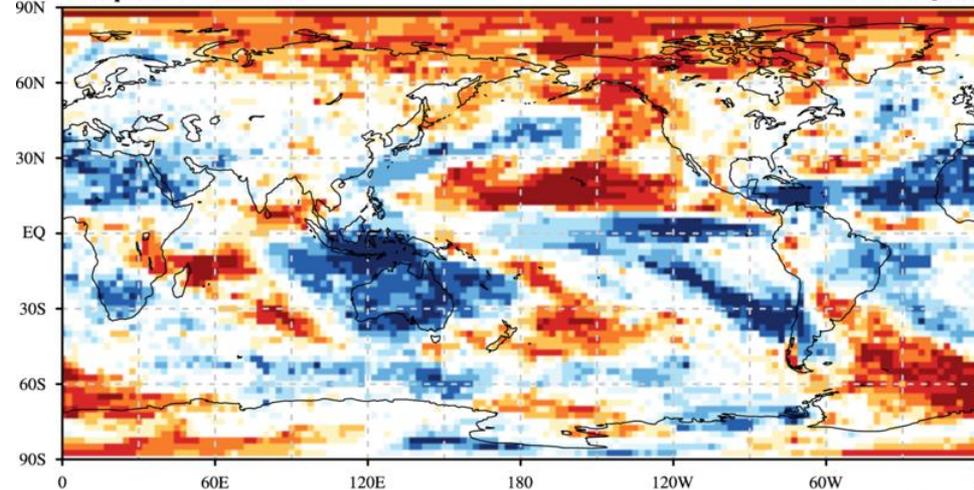
- Quality assurance
- Traceability
- Interpretation

Consistency Map

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** where, the positive numbers mean the number of models that predict positive anomaly and vice versa. **

Examples of dealing with missing elements

- **User indicators:** indicators do not have the same level of skill as the meteorological variables.
- **Observational uncertainty:** comparison between reanalyses in a forecast verification context.
- **Definition of standard procedures:** standards are less common than one would expect.
- **Traceability of data and products:** reproducibility is coming up in the research community, but its operational aspects are not solved yet.
- **Interpretation and training:** users are often not experts, and even when they are it is easy to misunderstand the existing information.
- **Synthesis and narratives:** how to deal with multiple lines of evidence in the message constructions.

Some interactions are motivated by an event

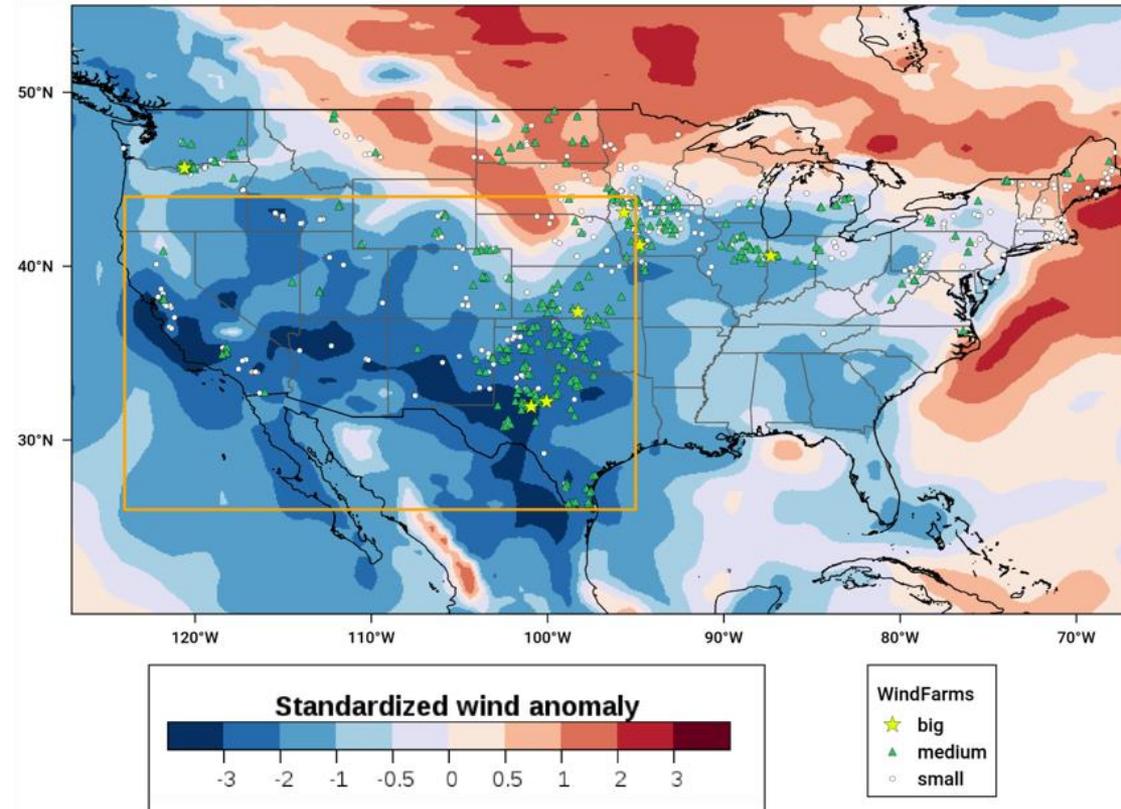
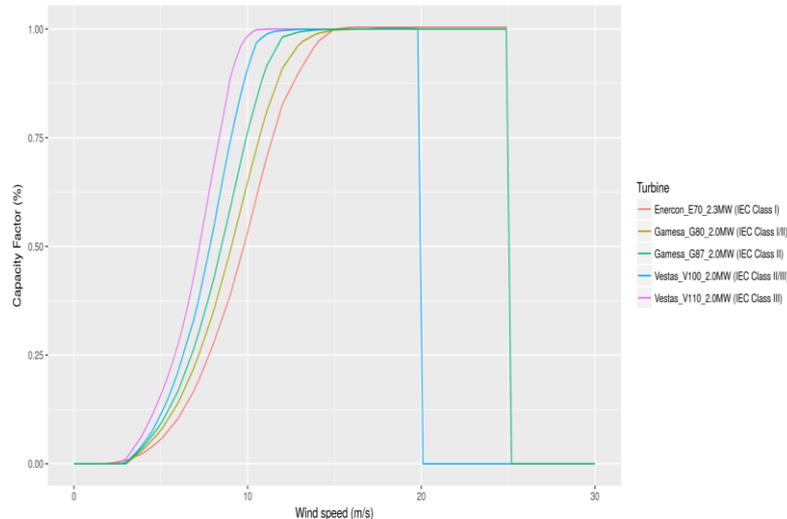
During the first quarter of 2015 the United States experienced a widespread and extended episode of low surface wind speeds. Some wind farms did not generate enough cash for their steady payments, decreasing the value of wind farm assets.

Aim to predict the **capacity factor**

$$CF (\%) = \frac{\text{Actual generation}}{\text{Installed capacity} * \text{hours}}$$

for a specific turbine type.

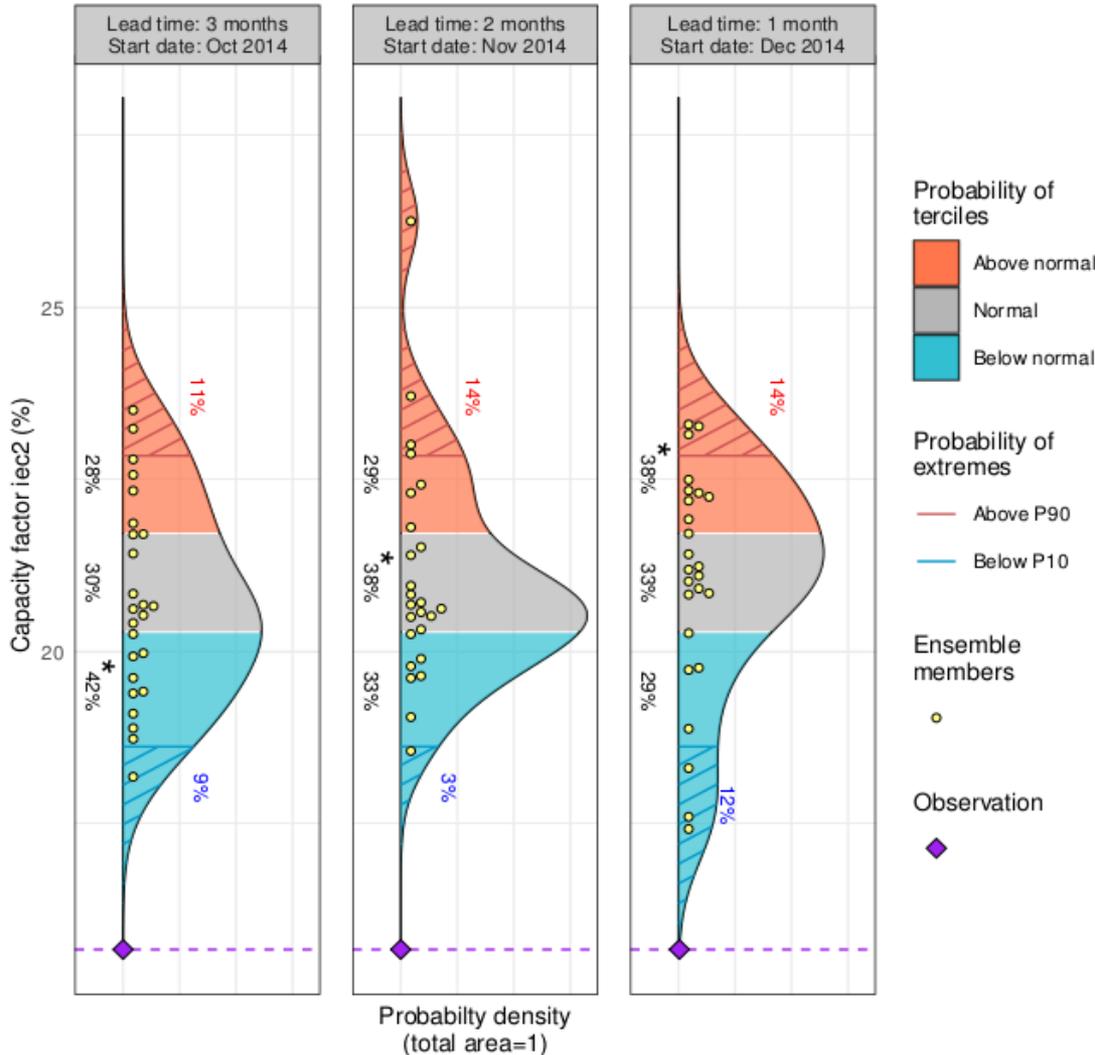
Selected power curves



Wind speed anomalies reflecting the wind drought over the United States for the first trimester of 2015, where the USA wind-farm fleet is also shown (Lledó et al., JGR 2018)

Capacity factor forecasts

Seasonal forecasts for Jan–Mar 2015

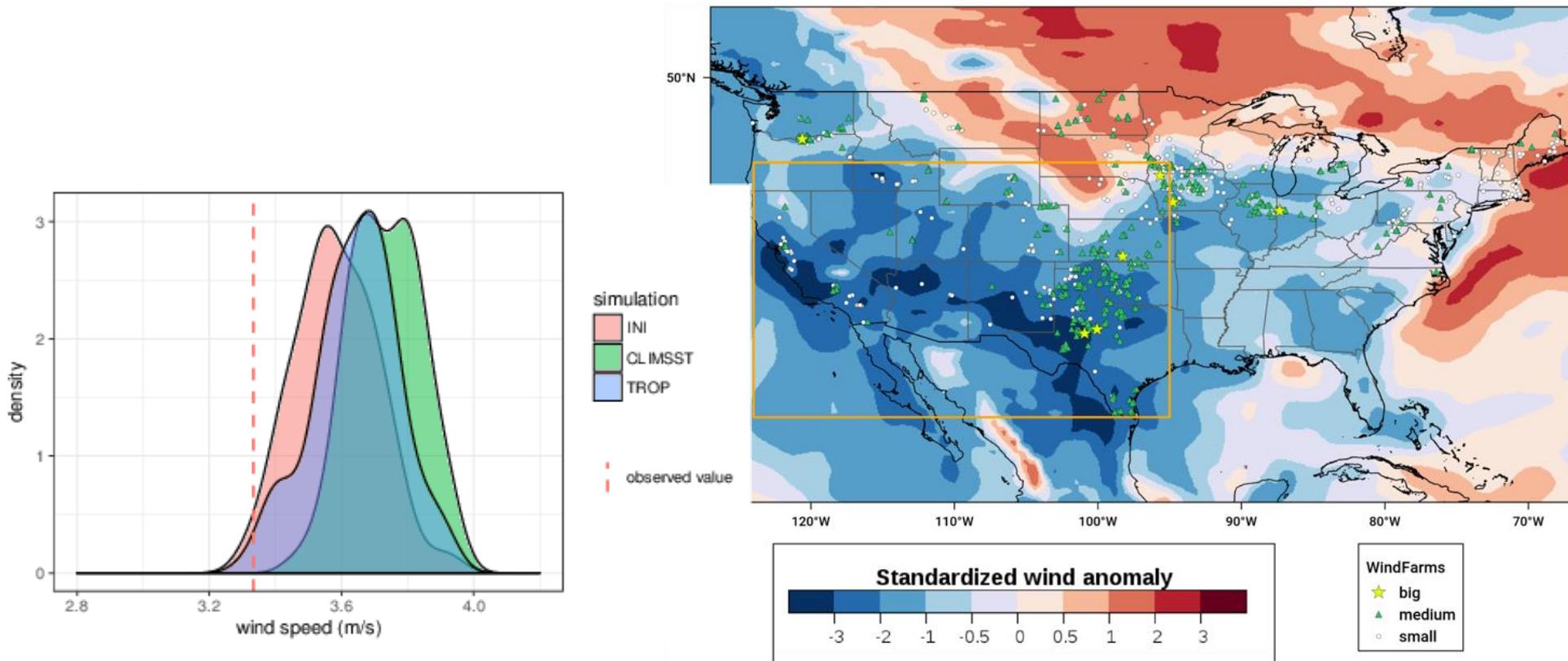


DJF capacity factor over North America (124-95°W, 26-44°N) predictions starting on the first of October, November and December for the first trimester of 2015, ECMWF SEAS5, reanalysis: ERA-Interim, hindcasts over 1993-2015.

	Oct	Nov	Dec
<i>RPSS</i>	0.23	0.25	0.24
<i>BS P10</i>	-0.18	-0.23	-0.16
<i>BS P90</i>	0.06	0	0.03
<i>CRPSS</i>	0.11	0.08	0.08
<i>EnsCorr</i>	0.5	0.45	0.42

Attribution as a service

During the first quarter of 2015 the United States experienced a widespread and extended episode of low surface wind speeds. Some wind farms did not generate enough cash for their steady payments, decreasing the value of wind farm assets.



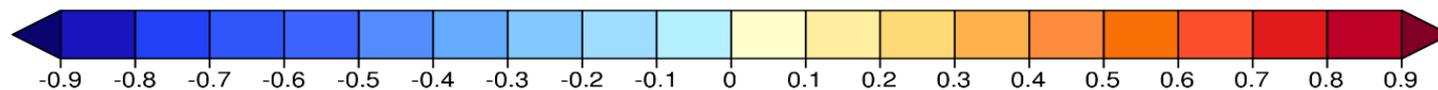
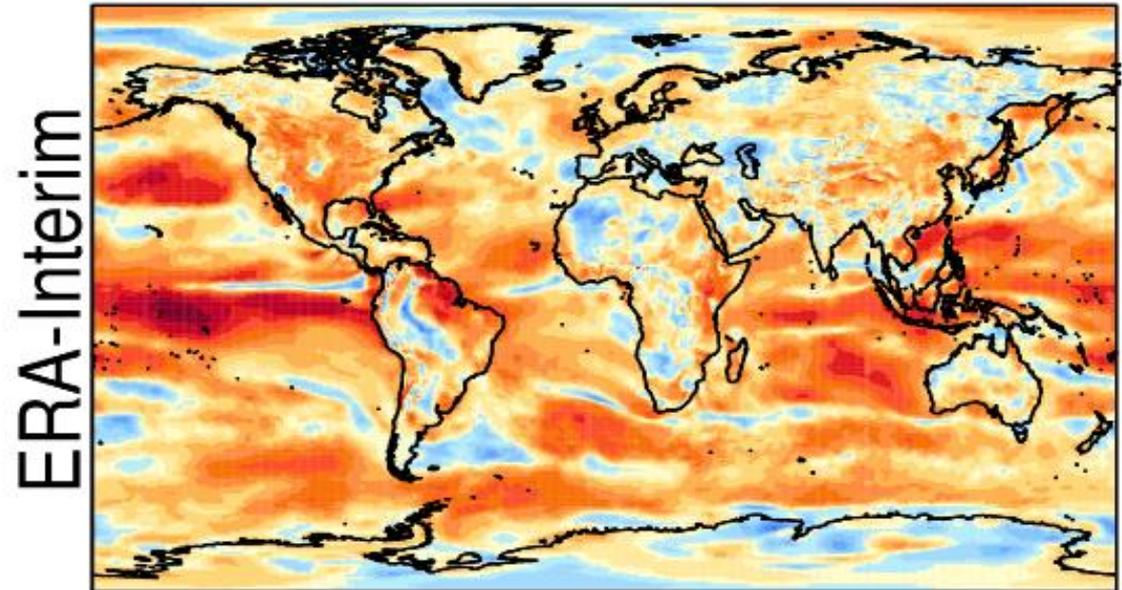
Wind speed anomalies reflecting the wind drought over the United States for the first trimester of 2015, where the USA wind-farm fleet is also shown (Lledó et al., JGR 2018) **Lledó et al. (2017, JGR)**

Observational uncertainty in verification

ECMWF System4
Period: 1981-2016
Season: DJF
Start date: 1st Nov
10-m wind speed

The election of a specific dataset as a reference for the forecast verification can lead to different results.

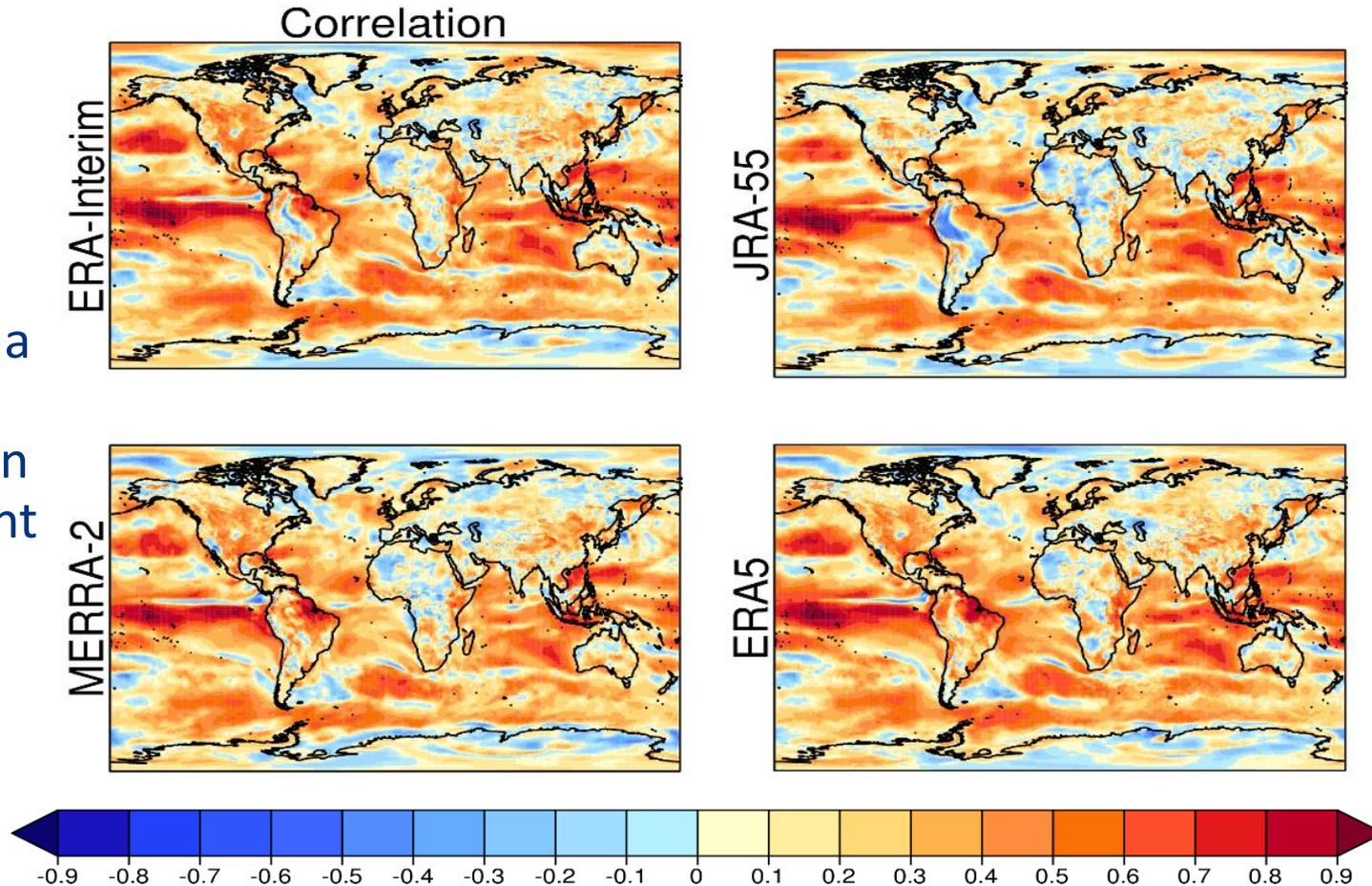
Correlation



Observational uncertainty in verification

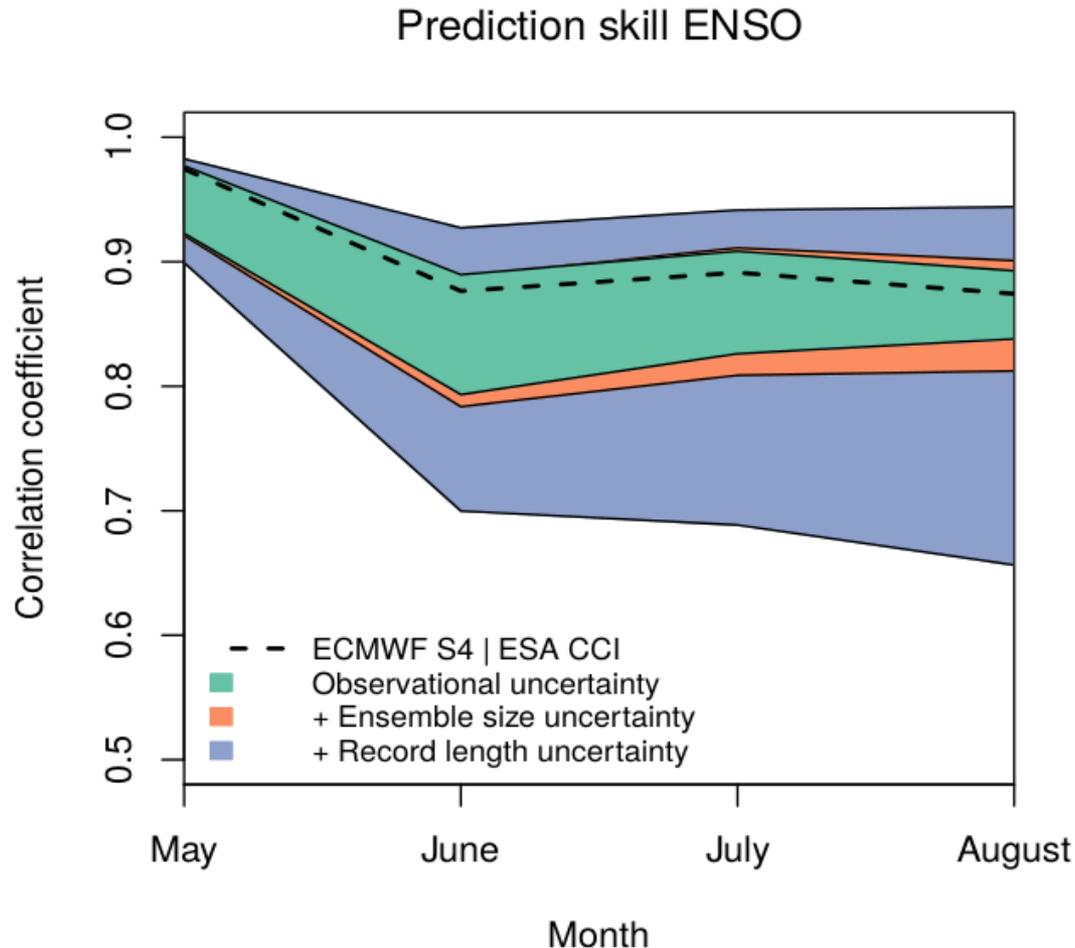
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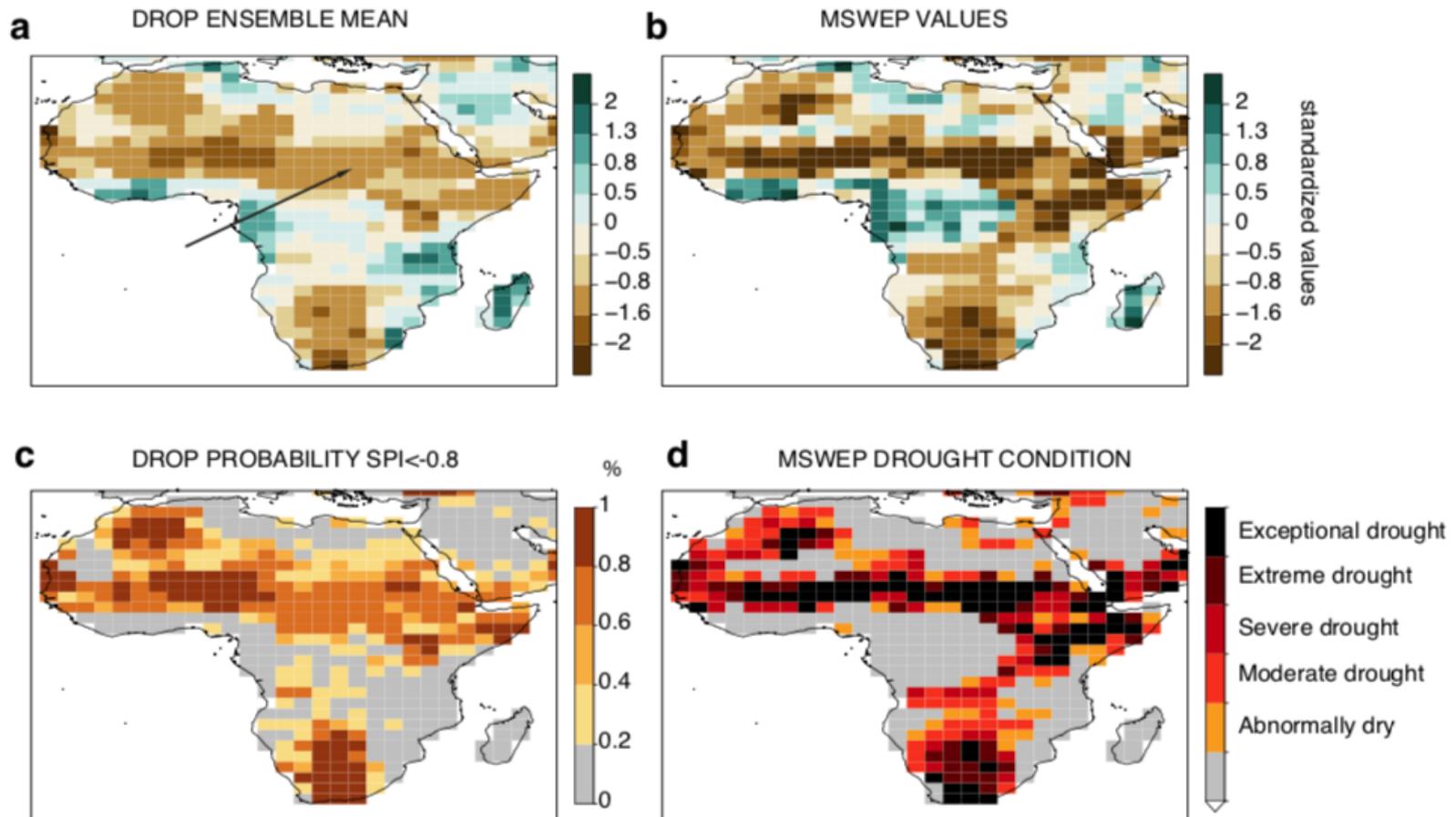
Sources of uncertainty of forecast quality

Niño 3.4 SST correlation of the ensemble mean for EC-Earth3.1 (T511/ORCA025) predictions with ERAInt and GLORYS2v1 ics, and BSC sea-ice reconstruction started every May over 1993-2009.

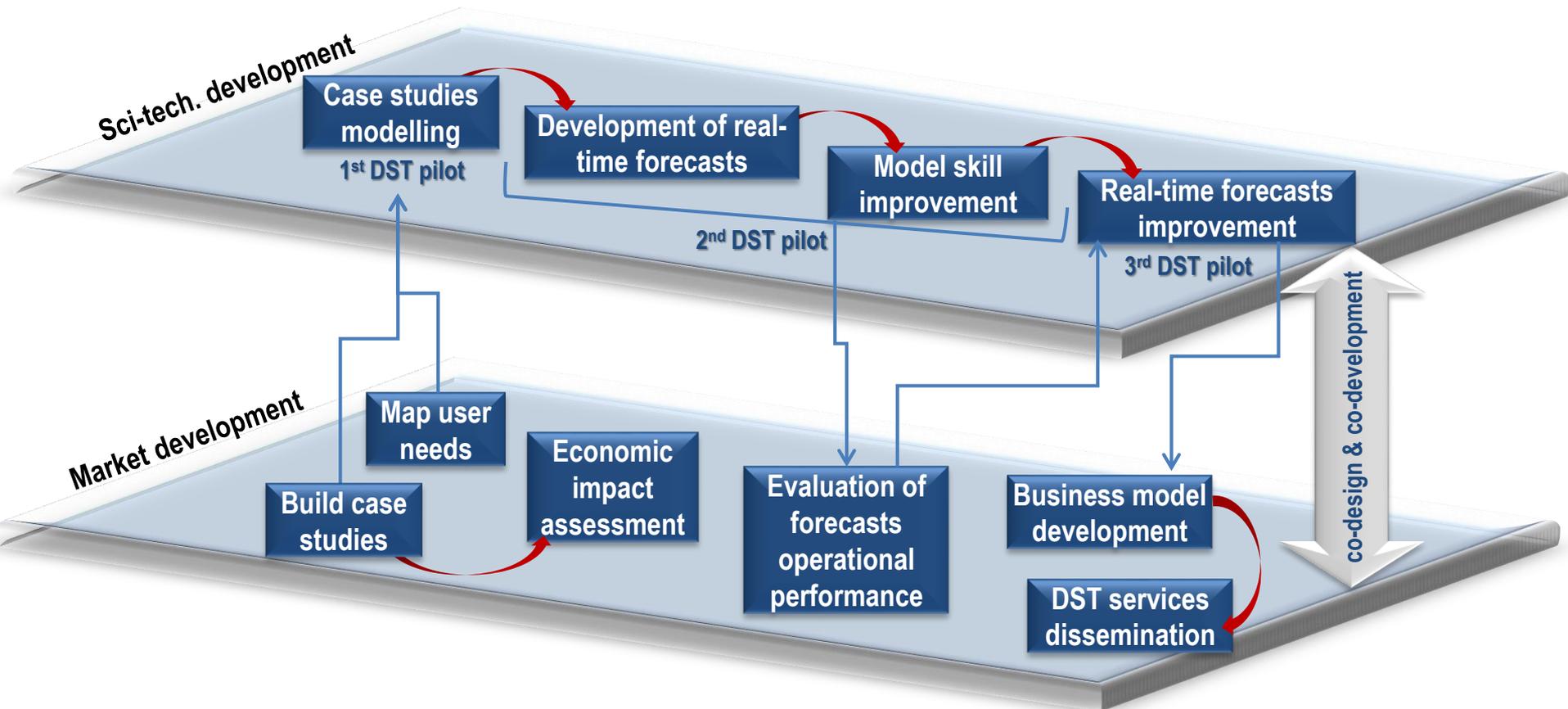


Observational uncertainty for monitoring

Multisource observational estimates of drought using SPEI12 for 1984. Note the probabilistic observational estimates of drought.

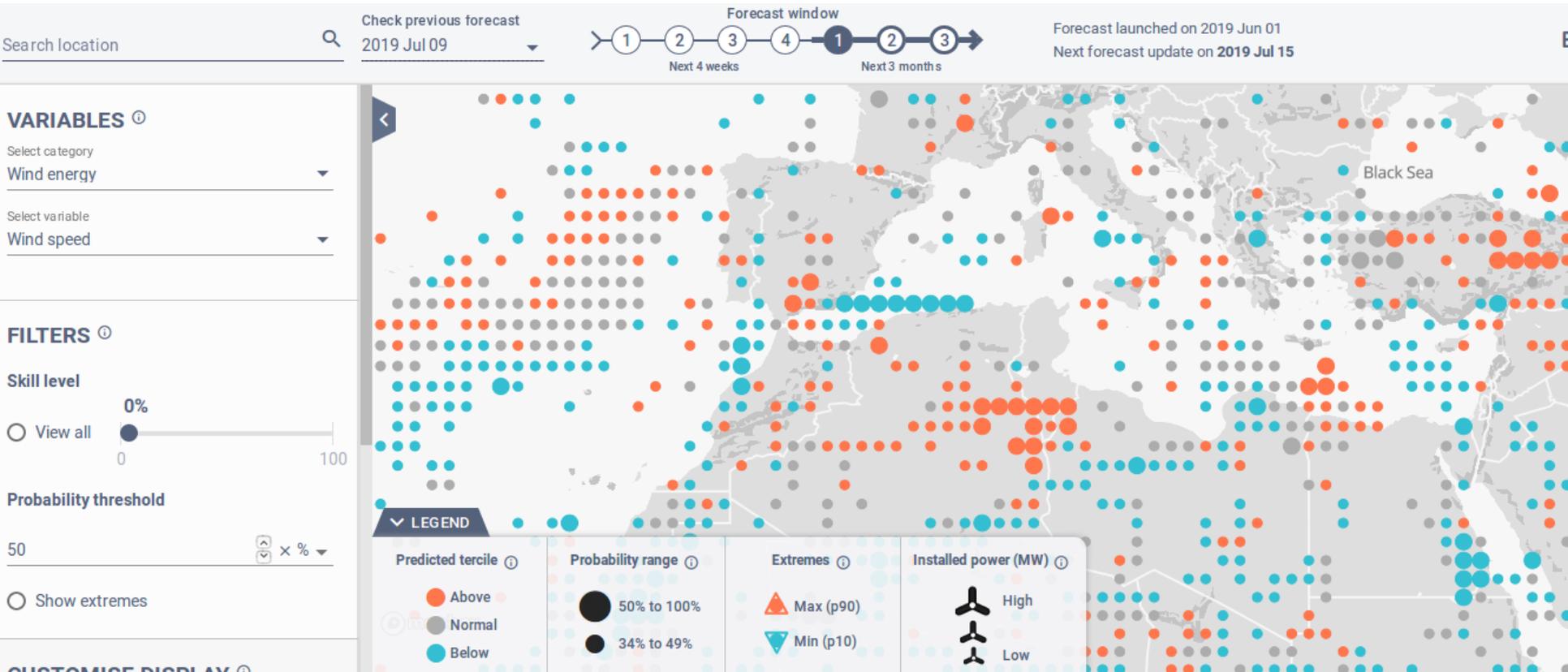


The message in a transdisciplinary environment



Prototypical climate services for energy

S2S4E is developing a [decision support tool](#) for the renewable energy sector based on [Copernicus climate forecasts](#) and NCEP operational predictions co-designed with the industry for periodic updates on the state of relevant climate variables.



The (service) devil is in the detail

ECMWF 2016 System
 Period: 1996-2015
 Month: April
 Reference: ERA Int
 2-m temperature

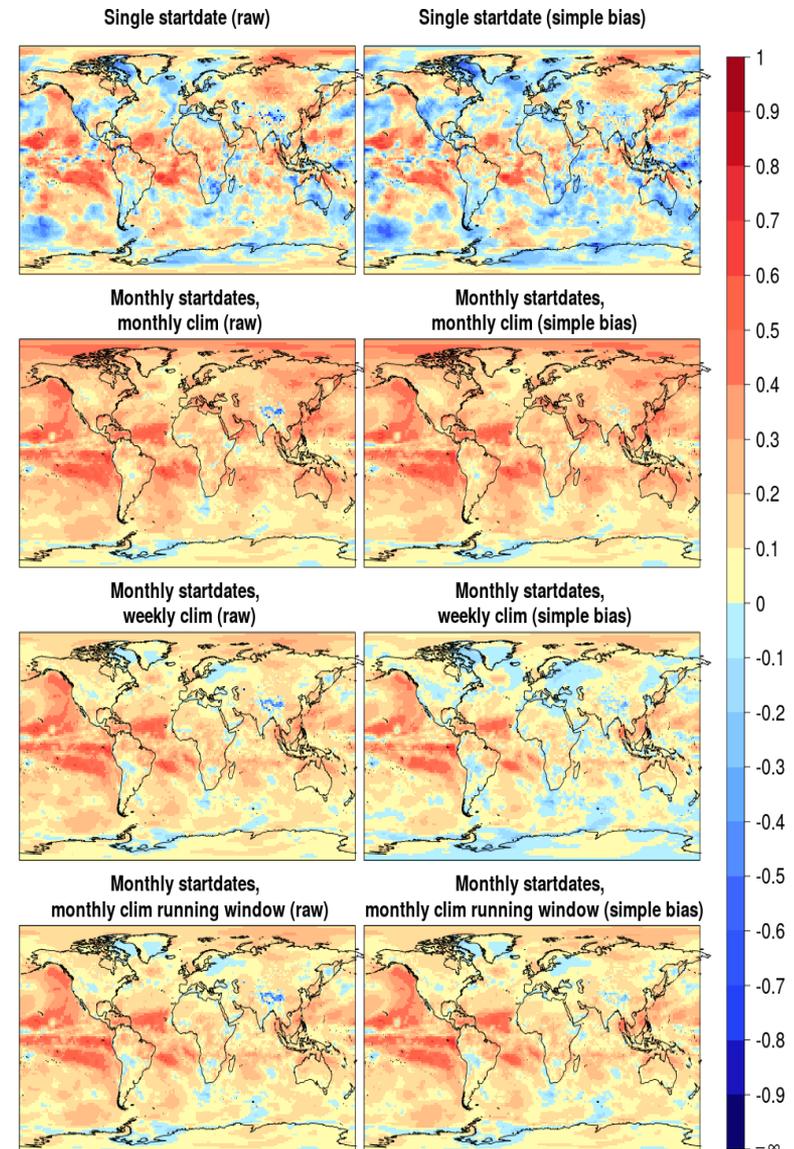
Weekly: too noisy

Monthly: good skill, but ...

Monthly running window,
 but weekly for the bias
 adjustment: lower skill , and
 too noisy for the adjustment

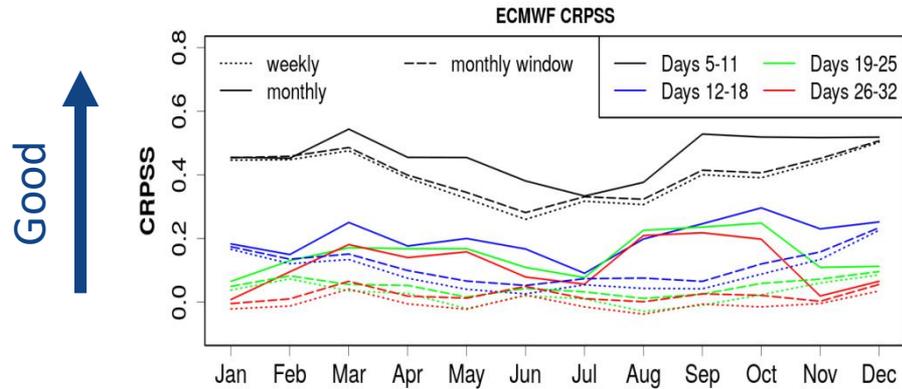
Monthly running window:
 more credible estimates

april Fair CRPSS - Fcst time: Days 12-18



The (service) devil is in the detail

ECMWF 2016 System
 Period: 1996-2015
 Month: All
 Region: North America
 Reference: ERA Int
 2-m temperature



Evaluation and quality control

C3S is developing the evaluation and quality control (EQC) function of the climate data store to:

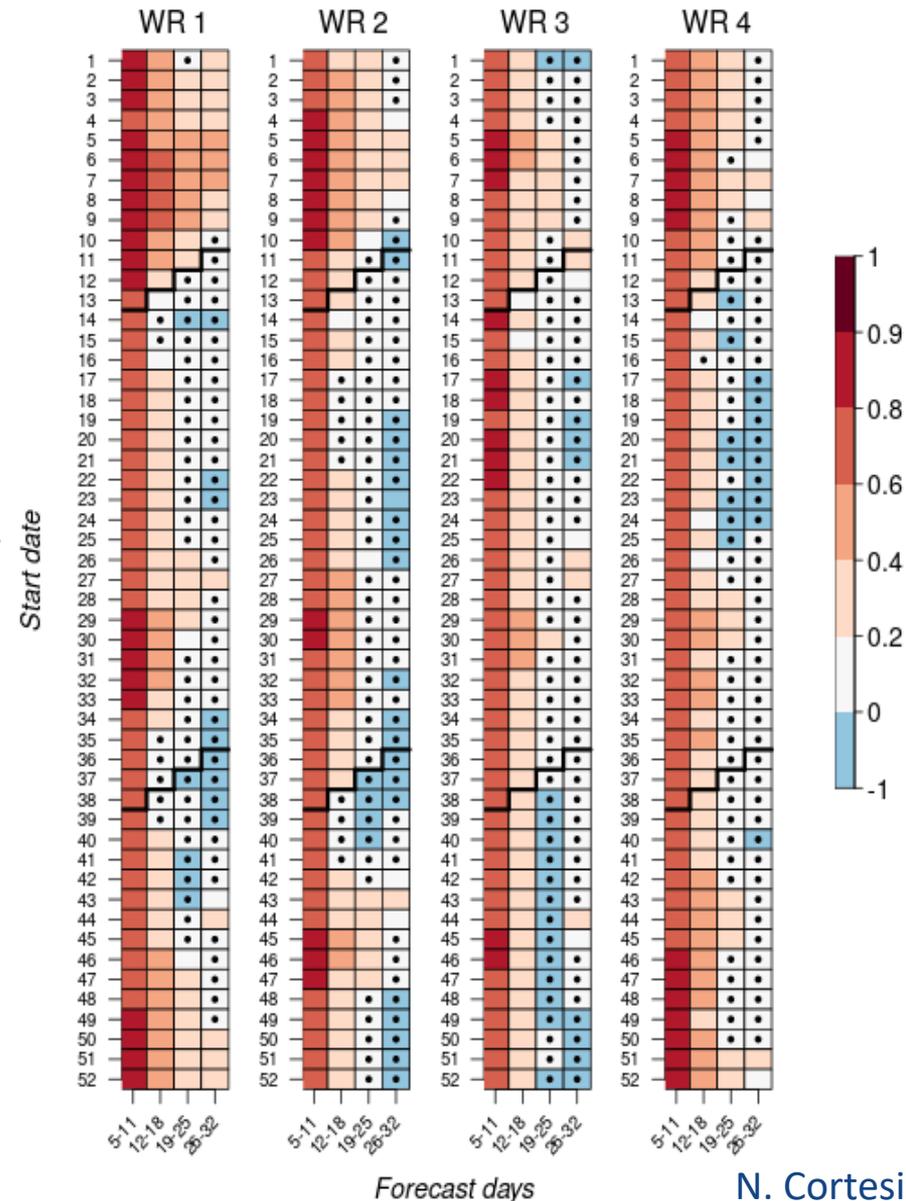
- Provide a user-led overarching EQC service for the whole CDS
- Provide an independent quality assessment



A user view of the WRs

ECMWF 2018 System
 Period: 1998-2017
 Month: All
 Region: North Atlantic
 Reference: ERA Int
 MSLP

Correlation between observed and predicted regime frequencies as a function of the forecast week (x-axis) and for each of the 52 weeks of the year (y-axis). Black points for non-significant correlations using a paired t-test at 0.01 level.



A user view of the WRs

The influence of each regime on the wind speed conditions can be explored in terms of composite maps.

How to quantify the combined effect of the four weather regimes?

RECONSTRUCTION

Total number of regimes ($R = 4$ in this example)

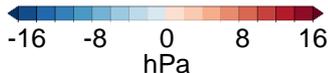
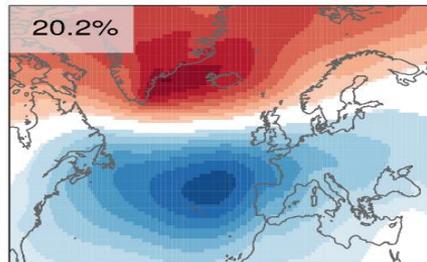
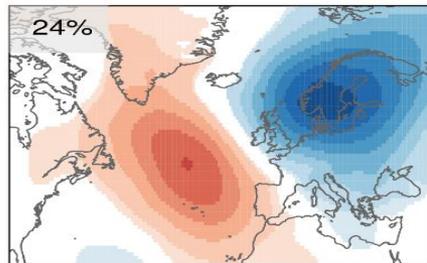
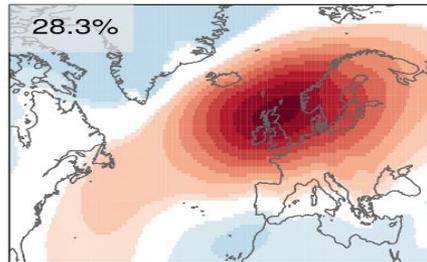
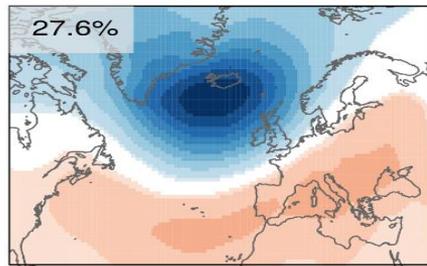
$$varRecon_{mon,yr}(lat, lon)$$

Variable to be reconstructed (wind speed or temperature) in a particular year (yr) and month (mon)

$$= \sum_{r=1}^R CM_{r,mon}(lat, lon) \cdot freq_{r,mon,yr}$$

Composite map of the variable for a specific regime (r) in the same month and in the full period (cross-validation)

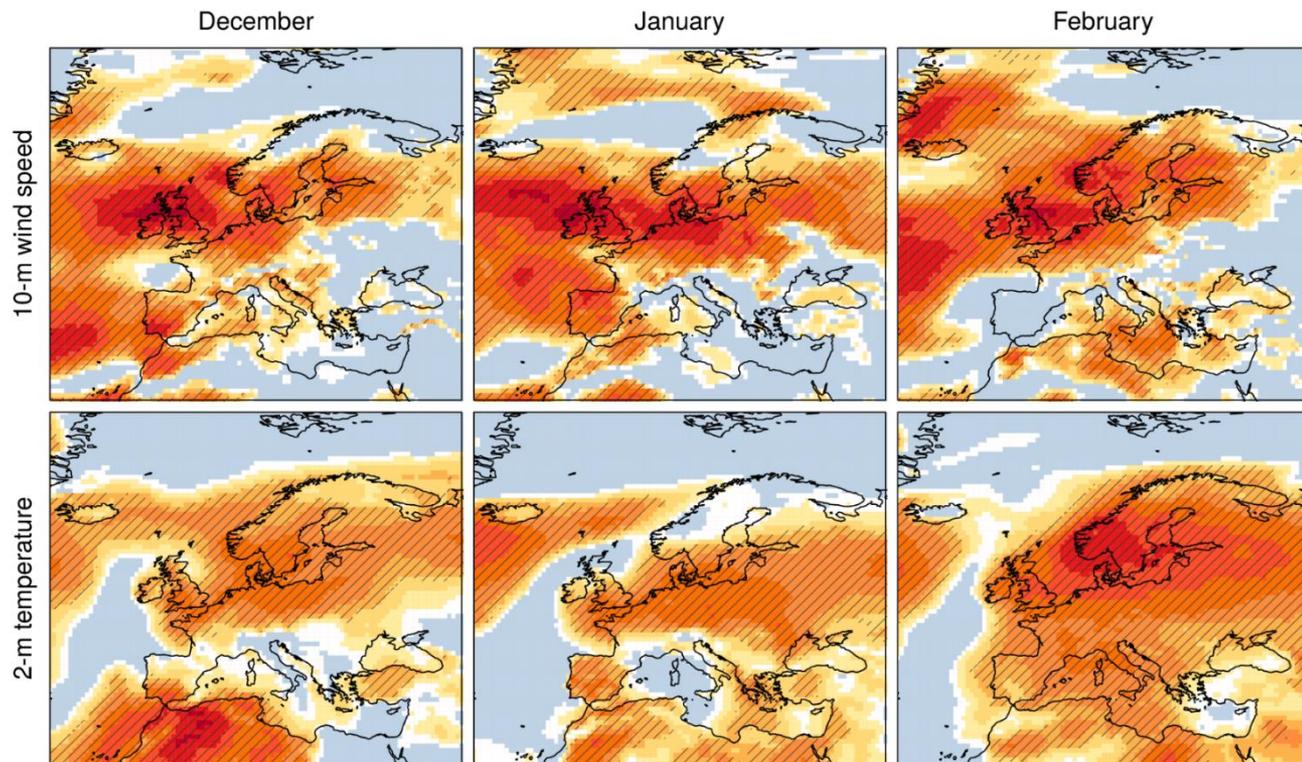
Percentage of days that particular month, year and regime



A user view of the WRs

Period: 1982-2016
Hatching: significant at
95% level (t-test)

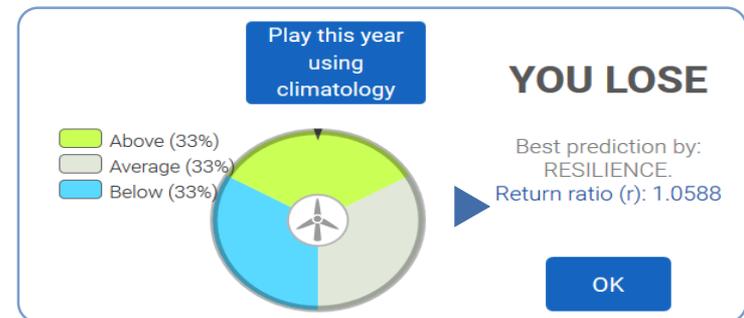
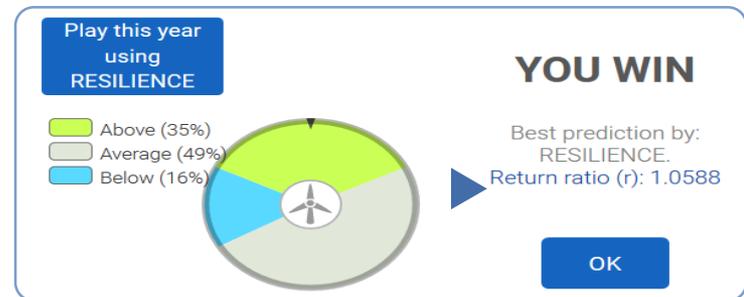
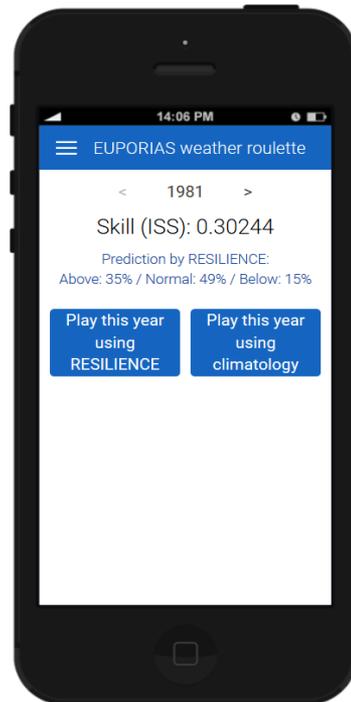
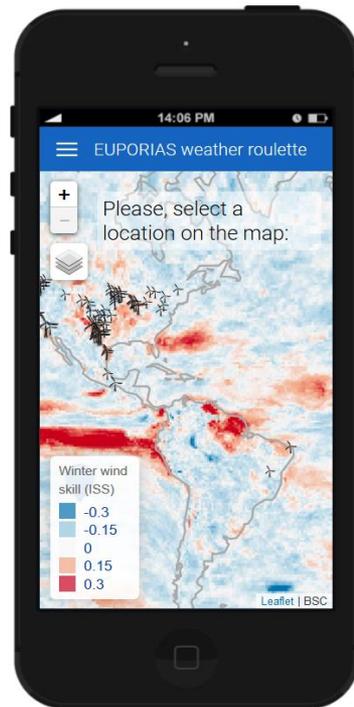
Correlation coefficient between the variables reconstructed with WRs and the original ones in ERA-Interim



The communication challenge

Gamification is useful to illustrate the challenges of using and the value of seasonal climate predictions addressed to the wind energy sector:

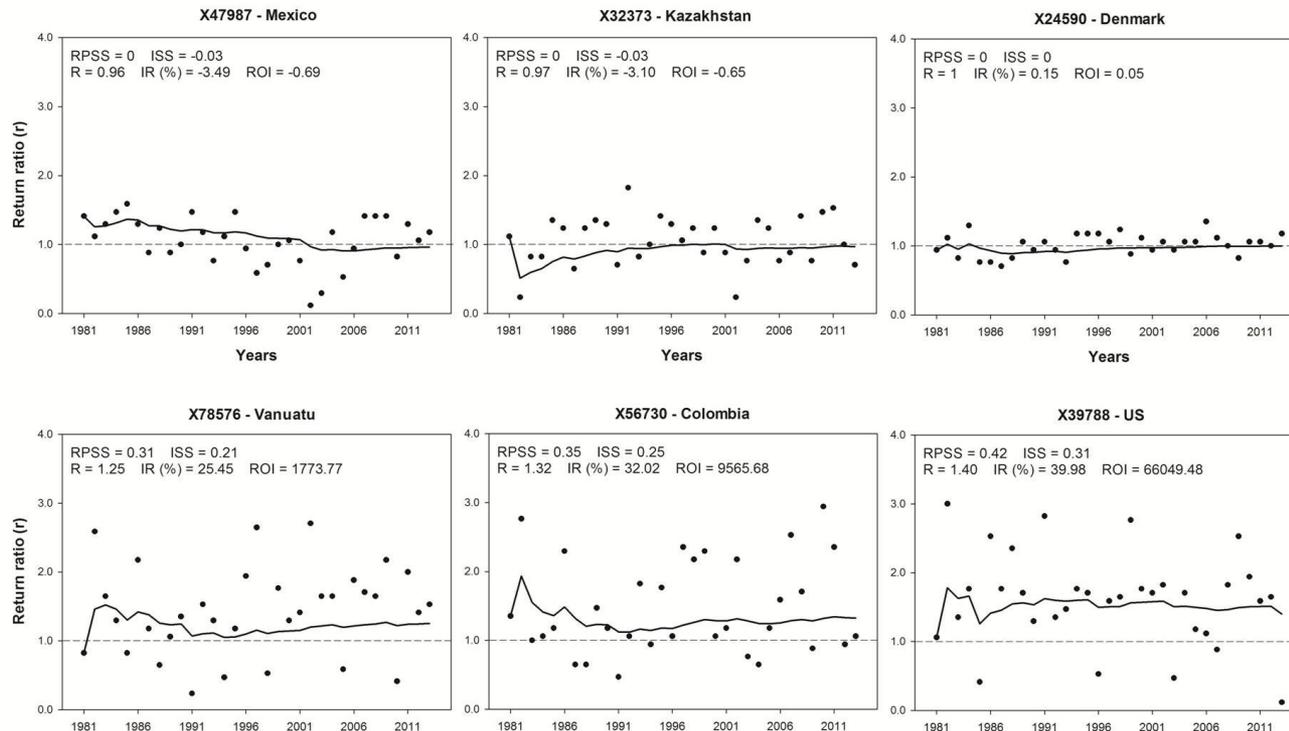
- Play against a reference taken from climatological frequencies.
- The bets are proportional to the predicted probabilities.
- The amount invested in the observed category is multiplied by 3.



Illustrating prediction value

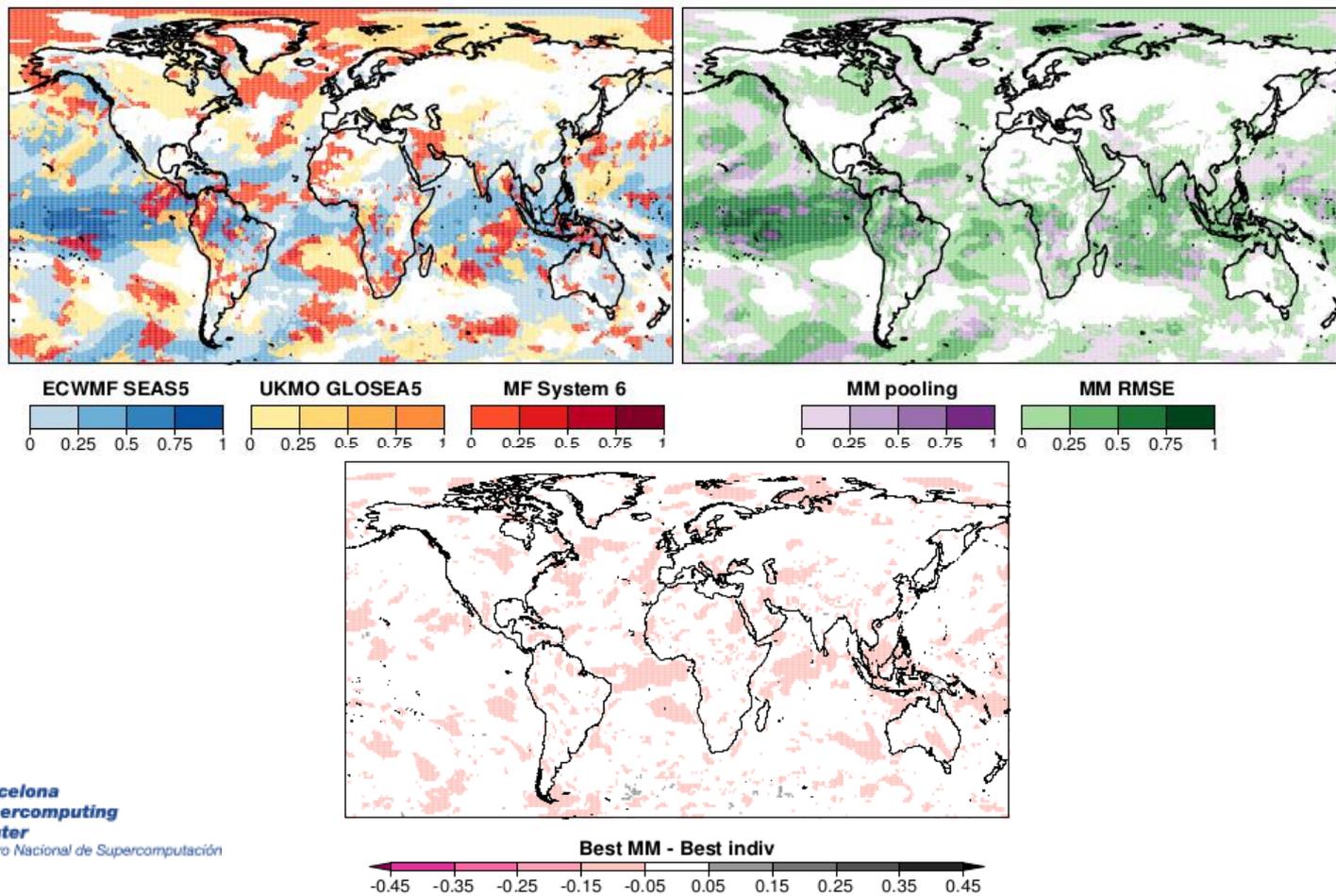
Examples of return ratio for 33 betting runs for different points where wind power plants are installed:

- Top row cases with $RPSS=0$, but ignorance skill score negative or zero.
- Bottom row cases with $RPSS>0$.
- Line for the geometric average of return ratios (interest rate).



Multi-model forecasts

CRPSS of DJF two-metre temperature for C3S forecasts initialized in November, all systems bias adjusted (MVA) compared to a simple and weighted multi-model (as inverse function of RMSE). Bottom gain of the best multi-model with respect to the best single system. Verified against ERA Interim for 1993-2015.



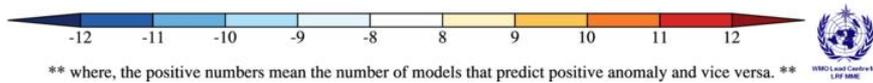
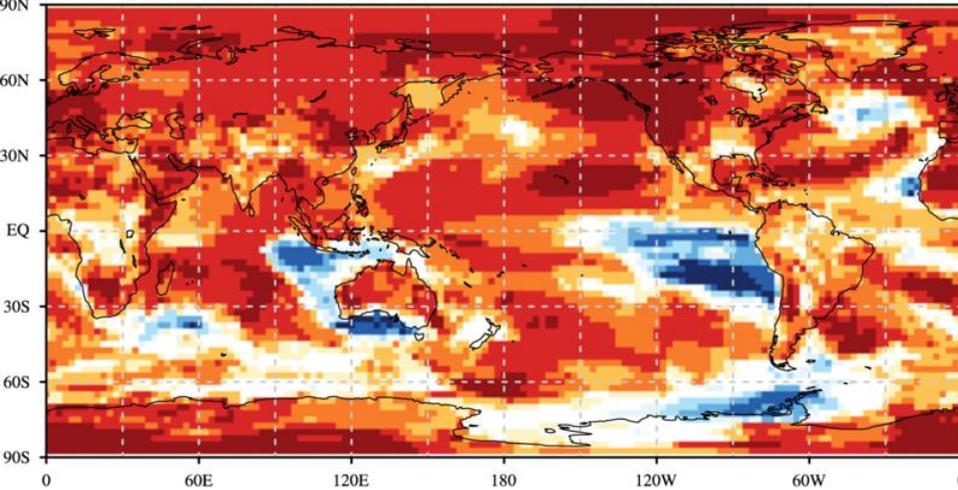
Other approaches for the synthesis

Consistency Map

CPTEC,ECMWF,Exeter,Melbourne,Montreal,Moscow,Offenbach,Pretoria,Seoul,Tokyo,Toulouse,Washington

2m Temperature : SON2019

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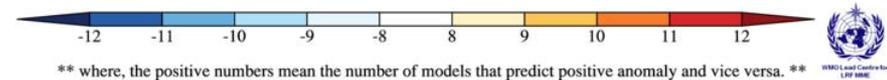
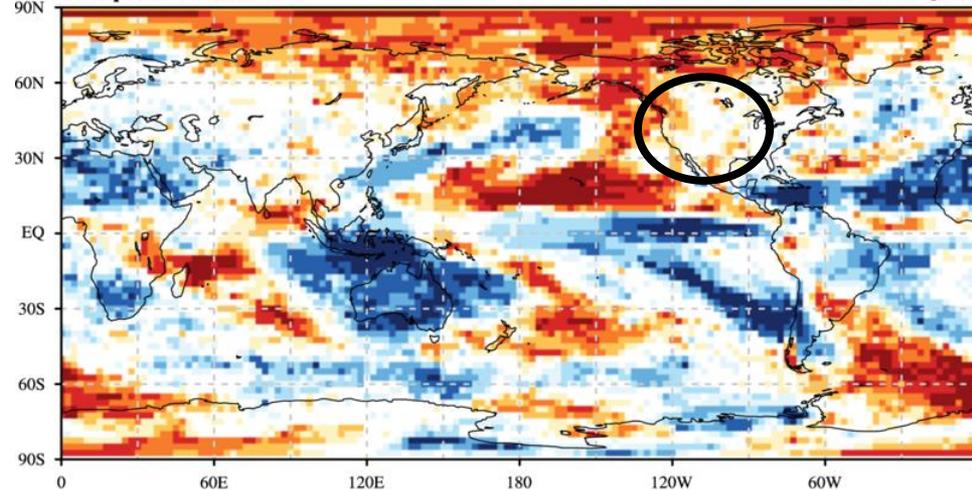
Storylines built on process-based narratives are a useful tool to communicate uncertainty when the signal is weak, the forecast is not Gaussian or windows of opportunity appear.

Consistency Map

CPTEC,ECMWF,Exeter,Melbourne,Montreal,Moscow,Offenbach,Pretoria,Seoul,Tokyo,Toulouse,Washington

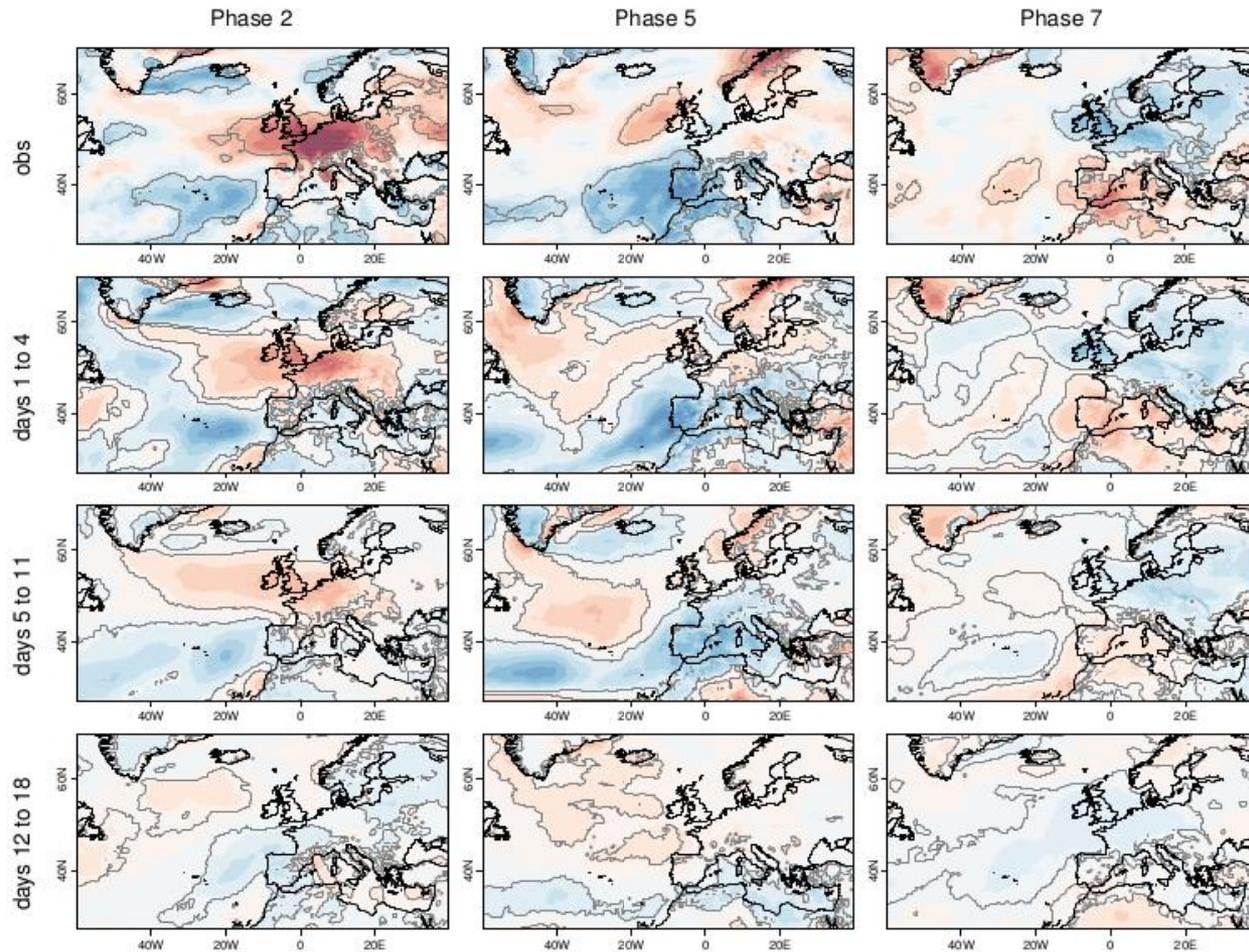
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Other approaches for the synthesis

10-metre wind speed anomalies (percentage wrt to the mean) associated with three phases of the MJO (S2S definition) in ERA Interim and ECMWF 2016.



Summary

- Requests for contextual climate information based on climate forecasts come from a **broadening range of users** and needs to be addressed from an operational climate services perspective. Addressing this requirement require a **new paradigm for climate research**.
- Applications struggle with the current **compartmental provision** of climate data and information.
- Entry-level **documentation** and **training**, formulation of **standards**, as well as **communication**, among many others, have become fundamental.
- None of this will materialise without appropriate **investment in observational networks**, **increased collaboration** and **research for the reduction of all aspects of model error**, among many other critical aspects.

