Reading, 5 September 2019

Barcelona Supercomputing Center
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EXCELENCIA SEVERO OCHOA

Sub-seasonal and Seasonal Climate Forecast Applications

Francisco J. Doblas-Reyes

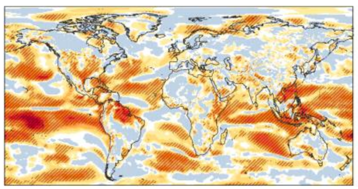
with contributions from Joaquín Bedia, Nicola Cortesi, Carlo Lacagnina, Llorenç Lledó, Jaume Ramón, Daniel San Martín, Marta Terrado, Verónica Torralba, Marco Turco, Ilaria Vigo and many more

S2S4E
Climate Services for Clean Energy

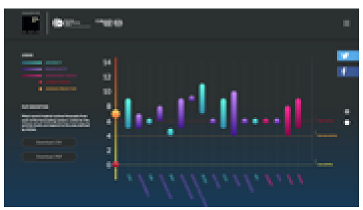
ICREA

Some definitions

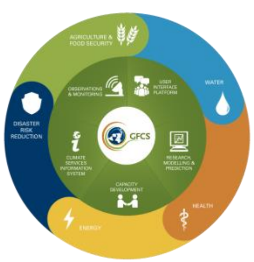
- Climate data: numerical values representing ECVs and associated magnitudes; includes metadata



- 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

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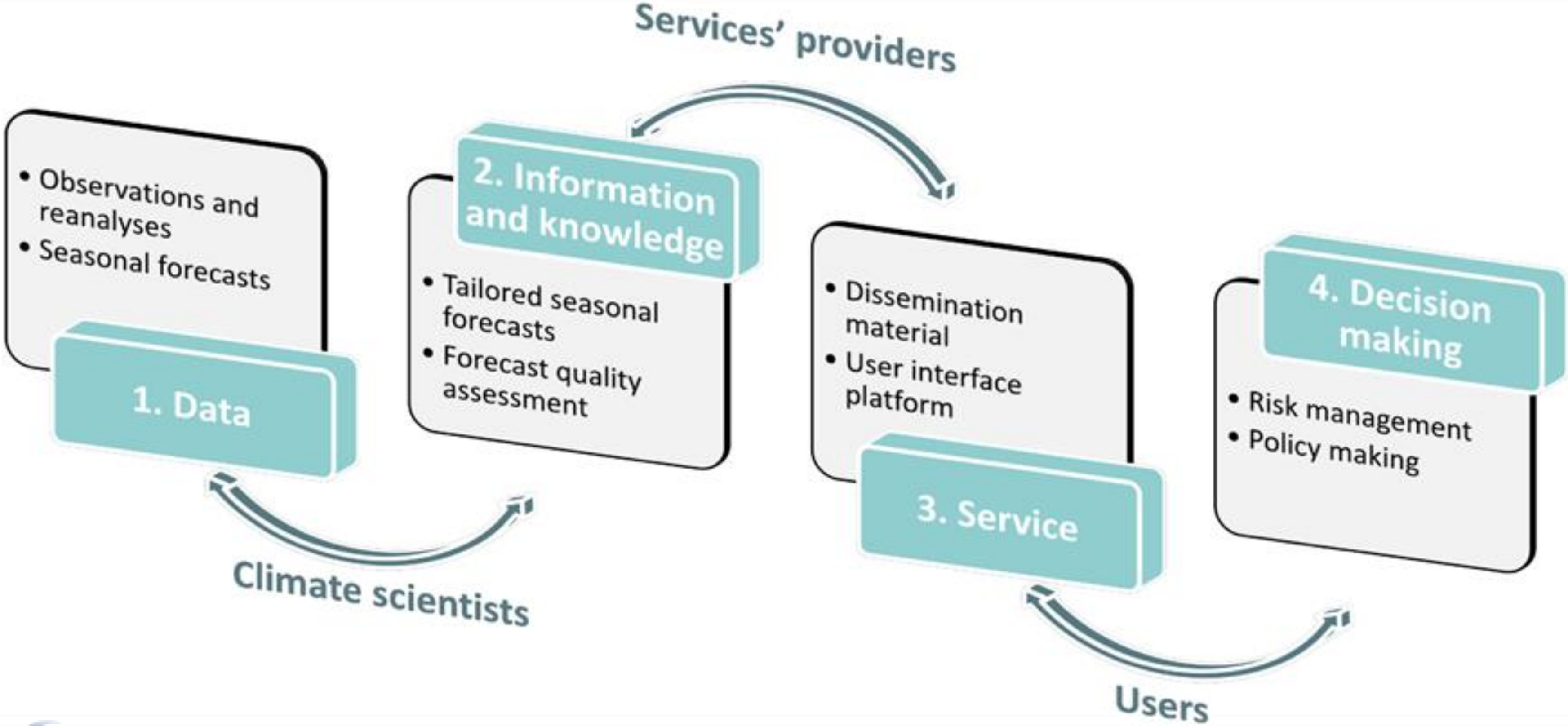
The research-provider-service paradigm

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 illustrate. This leaves a space for transdisciplinary research. This chain should not preclude basic research to take place though.



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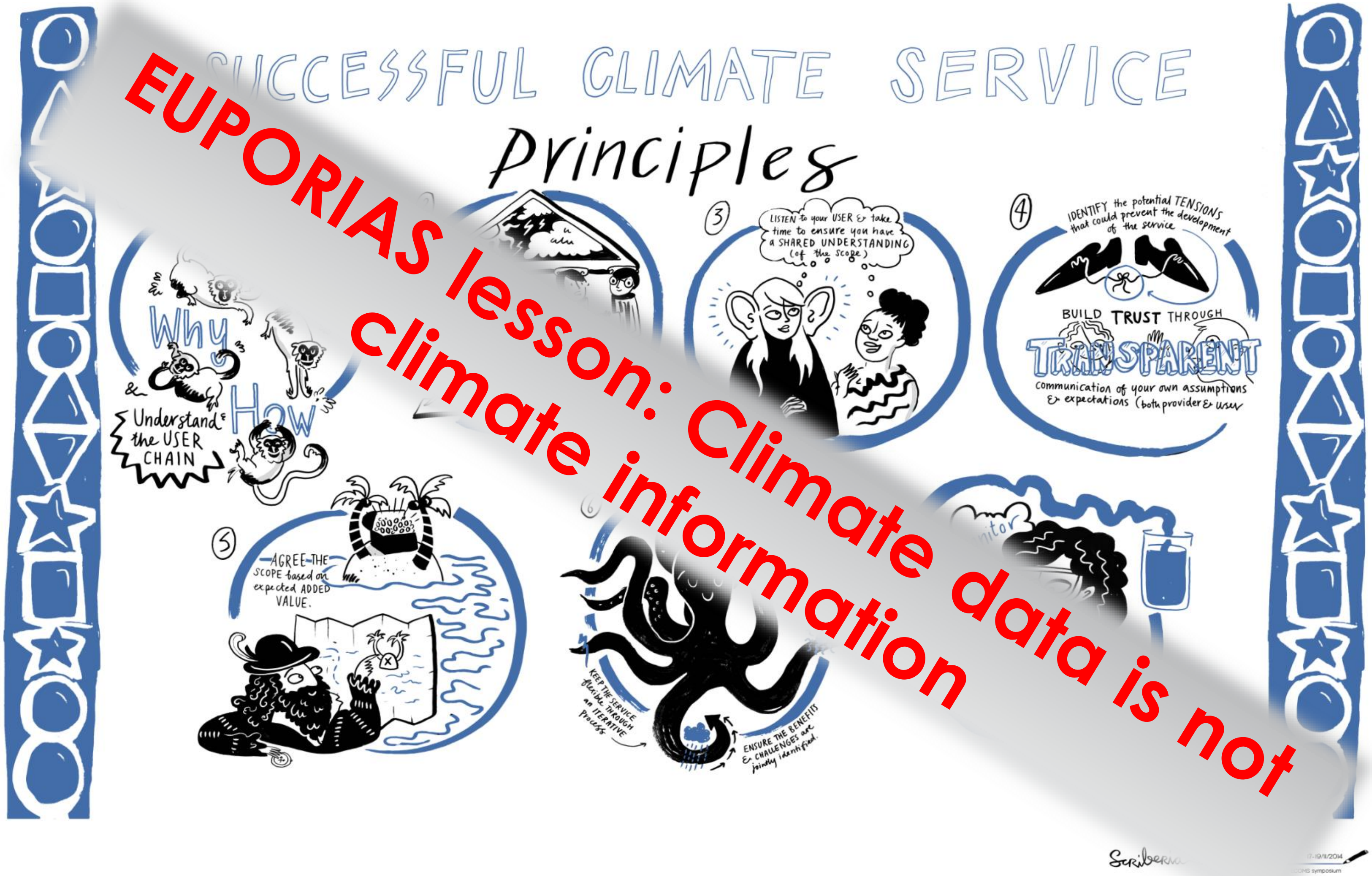
The research-provider-service paradigm



EUPORIAS lesson: Climate data is not climate information

Climate time scales

Subseasonal to seasonal forecasts (2 weeks-18 months)

Decadal forecasts (18 months-30 years)

Climate-change projections

Weather forecasts

Time

Initial-value driven

Boundary-condition driven

The user

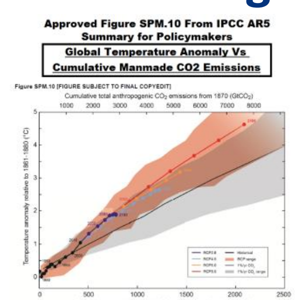
The data provider

WCRP CMIP6

World Climate Research Programme

The message producer

The message



e.g. IPCC SPM preparation

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Adapted from Meehl et al. (2009)

Barriers to use climate forecasts in applications

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

- Lack of awareness
- Difficult interpretation
- Lack of expert synthesis

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.

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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

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Dessai and Bruno-Soares (2013, SRI Paper 62)

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

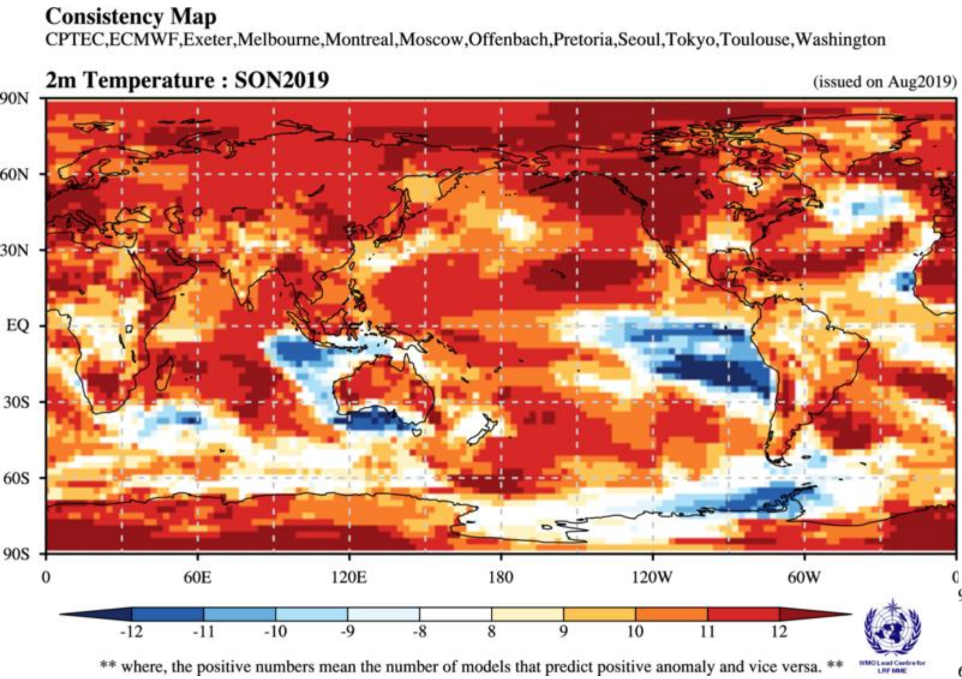
Mid-term planning

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

Energy traders: Anticipate energy prices.

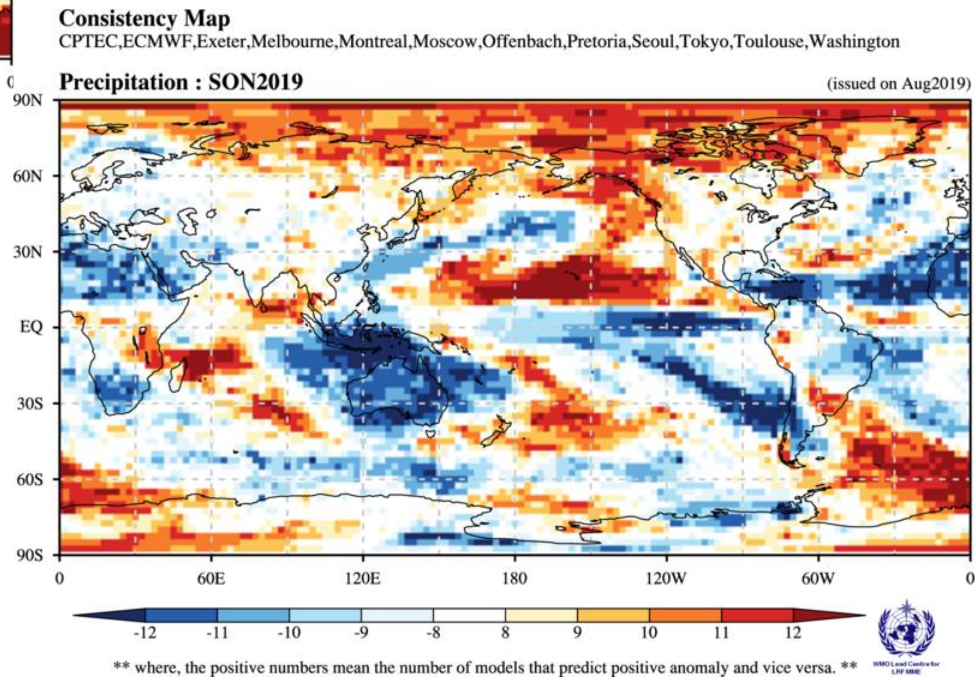
Sometimes, the user wants to understand

Other times, they look for climate forecasts



But some elements are missing:

- Quality assurance
- Traceability
- Interpretation



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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.

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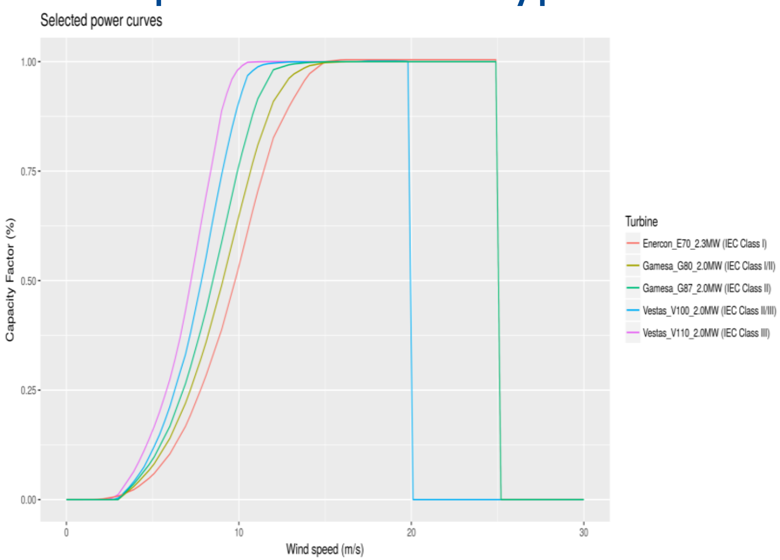
Some interactions are motivated by an event

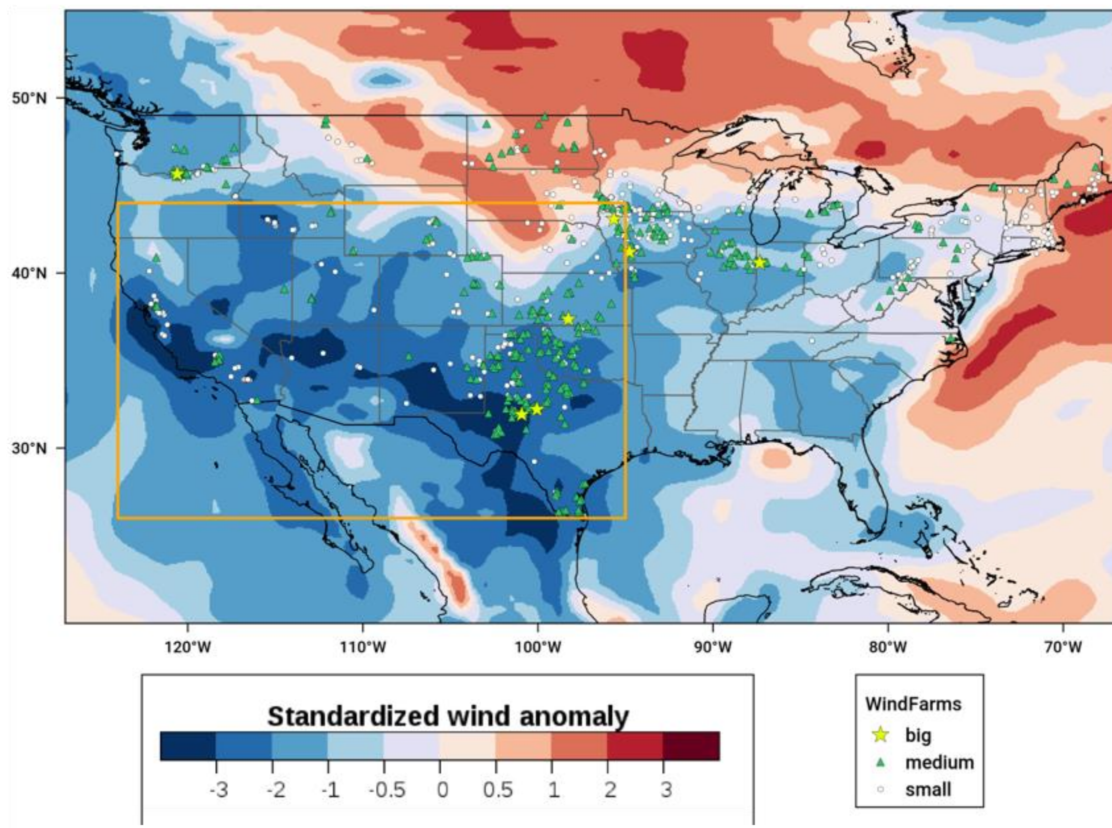
During the first quarter of 2015 the United States experienced a widespread and extended episode of low surface wind speeds. Some wind farms did not generate enough cash for their steady payments, decreasing the value of wind farm assets.

Aim to predict the capacity factor

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

for a specific turbine type.





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)

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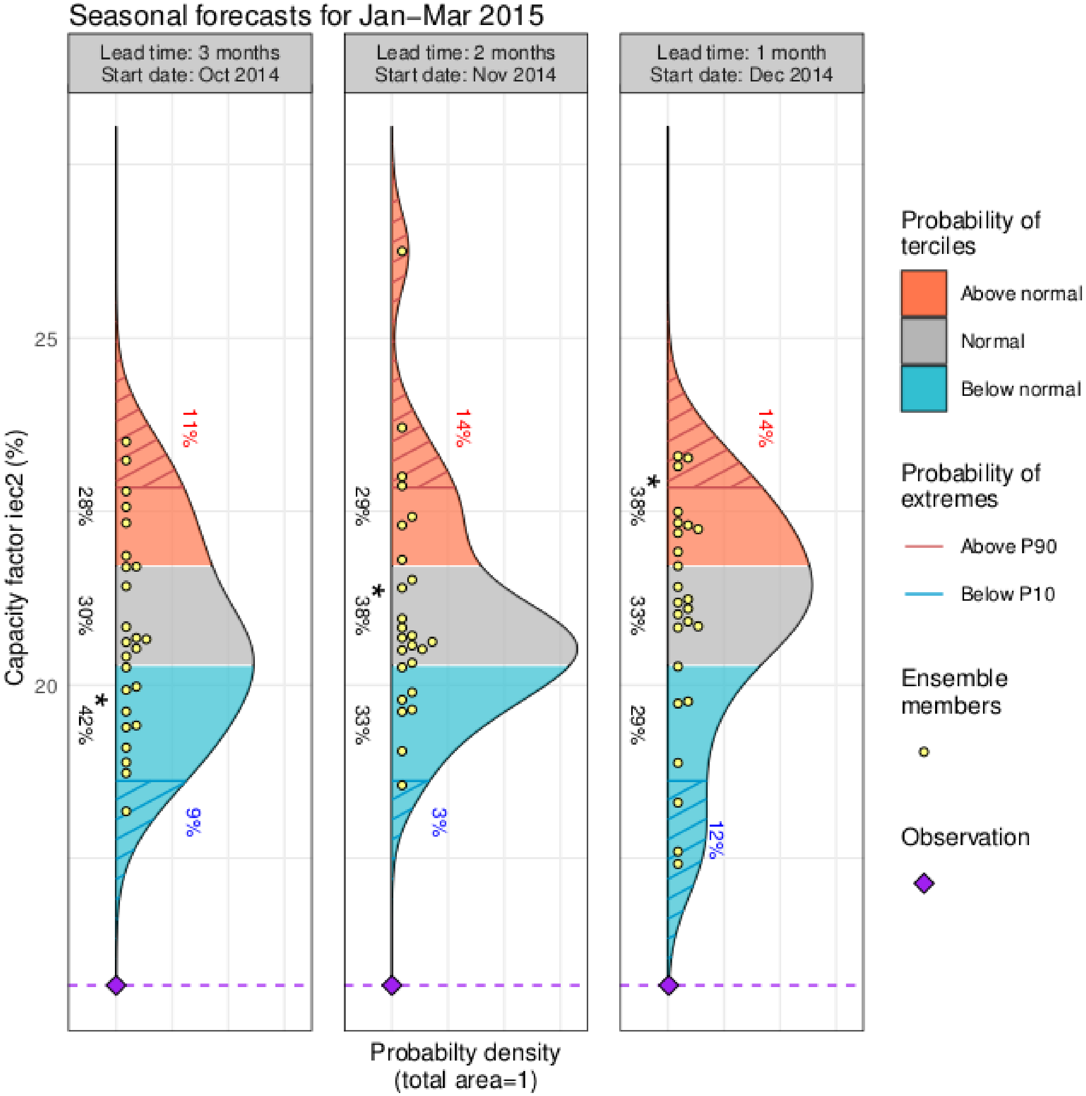
L. Lledó

Capacity factor forecasts



DJF capacity factor over North America (124-95ºW, 26-44ºN) 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
RPSS	0.23	0.25	0.24
BS P10	–0.18	–0.23	–0.16
BS P90	0.06	0	0.03
CRPSS	0.11	0.08	0.08
EnsCorr	0.5	0.45	0.42

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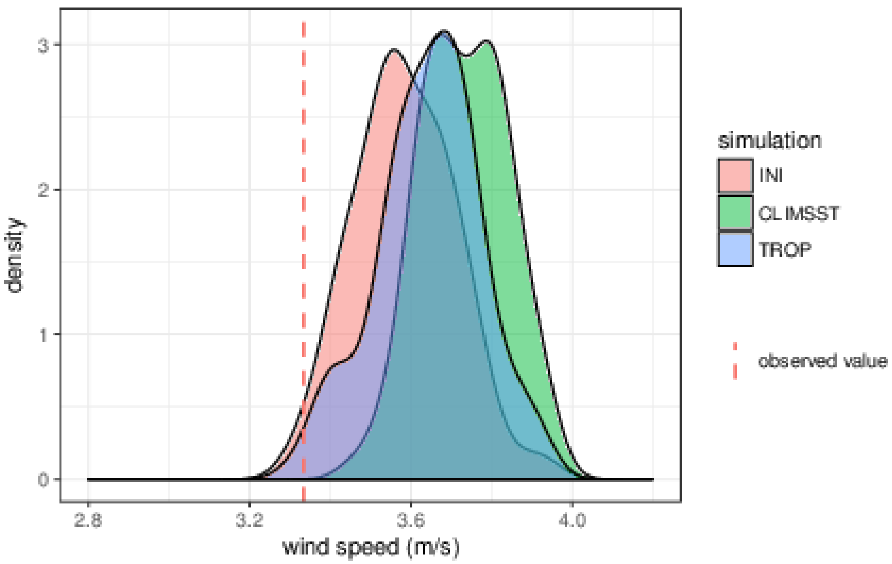
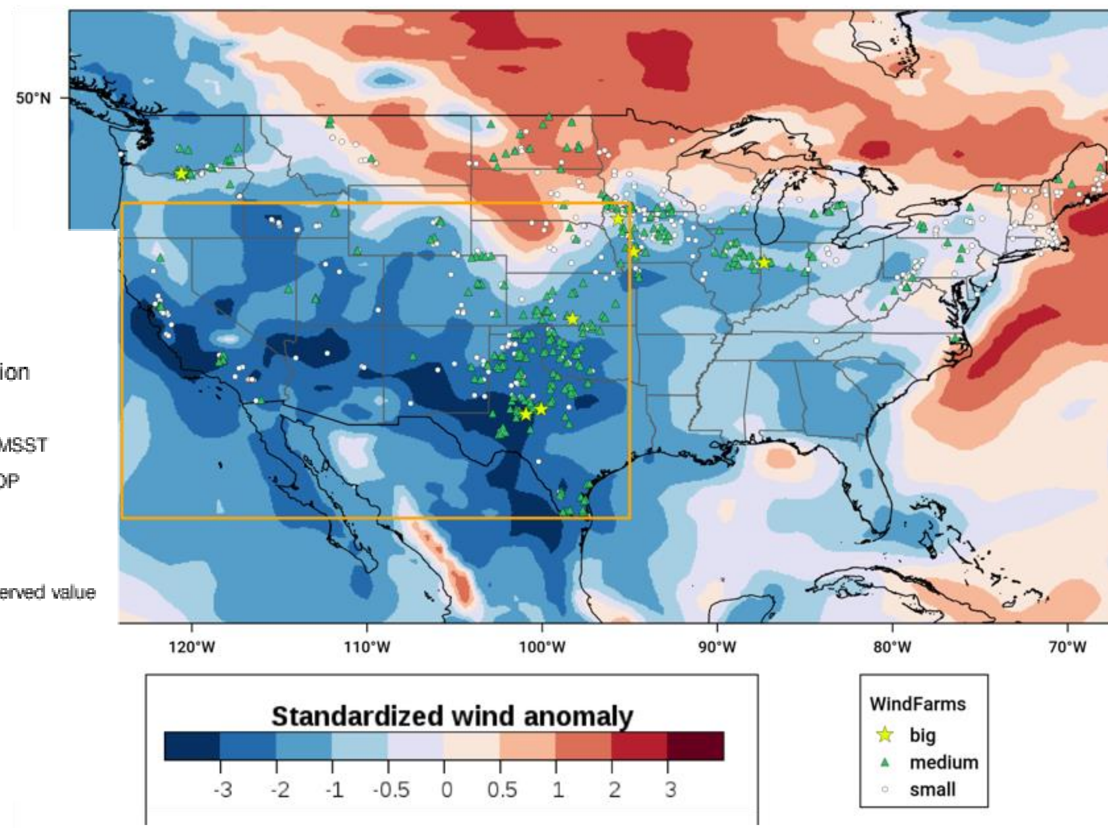
L. Lledó

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)

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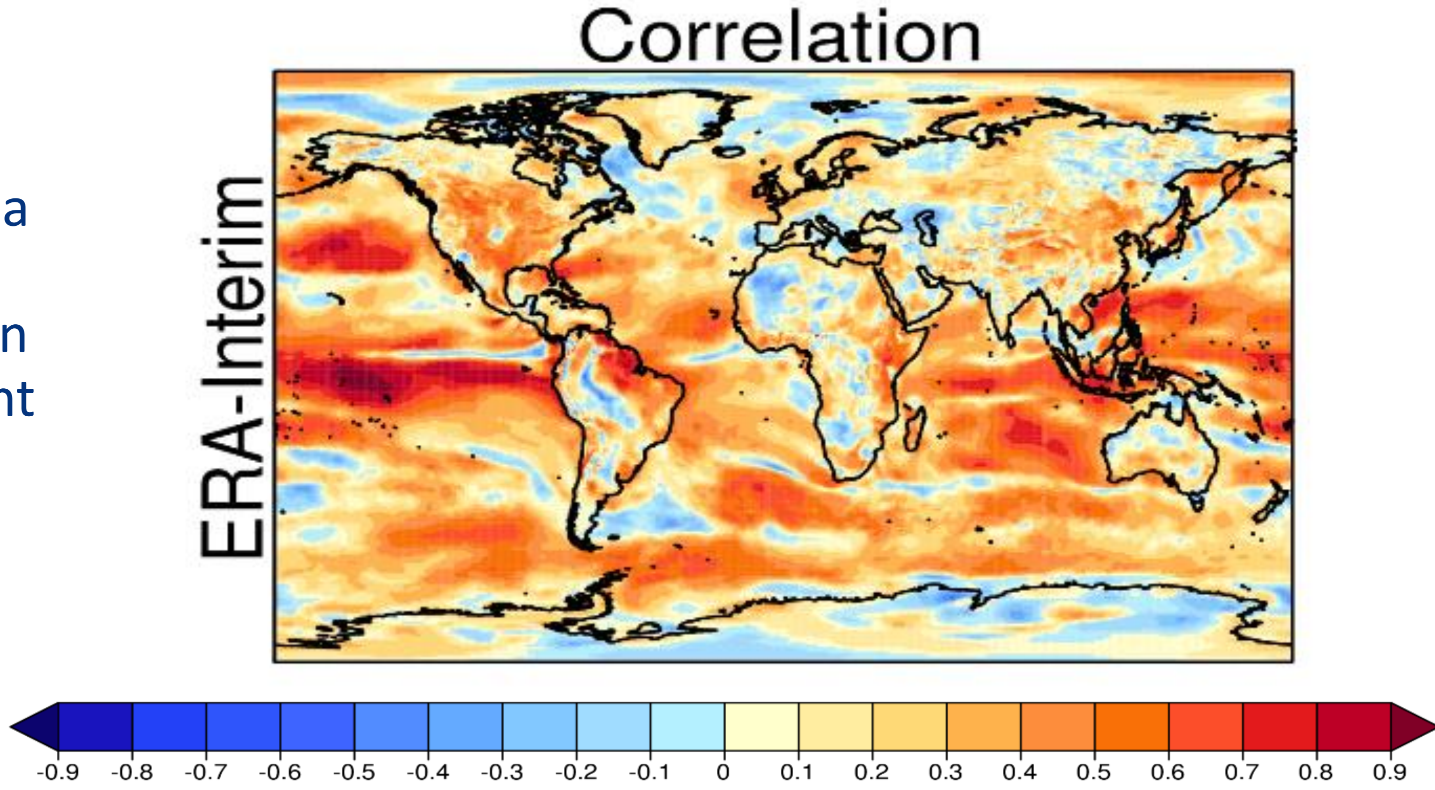
Lledó et al. (2017, JGR)

Observational uncertainty in verification

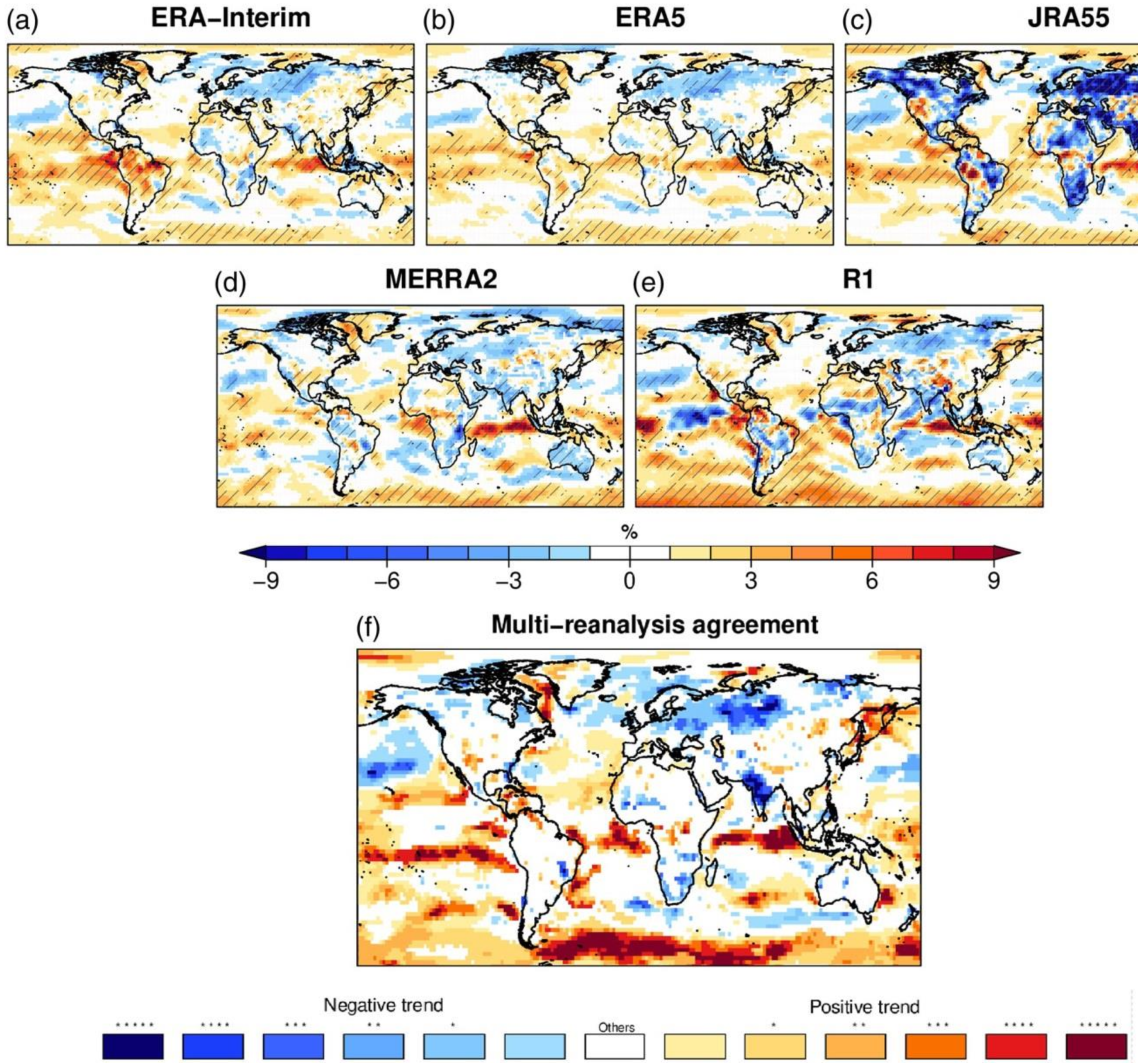
ECMWF System4
Period: 1981-2016
Season: DJF
Start date: 1st Nov
10-m wind speed

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



Observational uncertainty relevant to users

10-m wind speed variability (in percentage of the mean wind) for the multi-reanalysis (MR) and five reanalyses in DJF over 1981-2017.



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Ramon et al. (2019, QJRMS)

Observational uncertainty in verification

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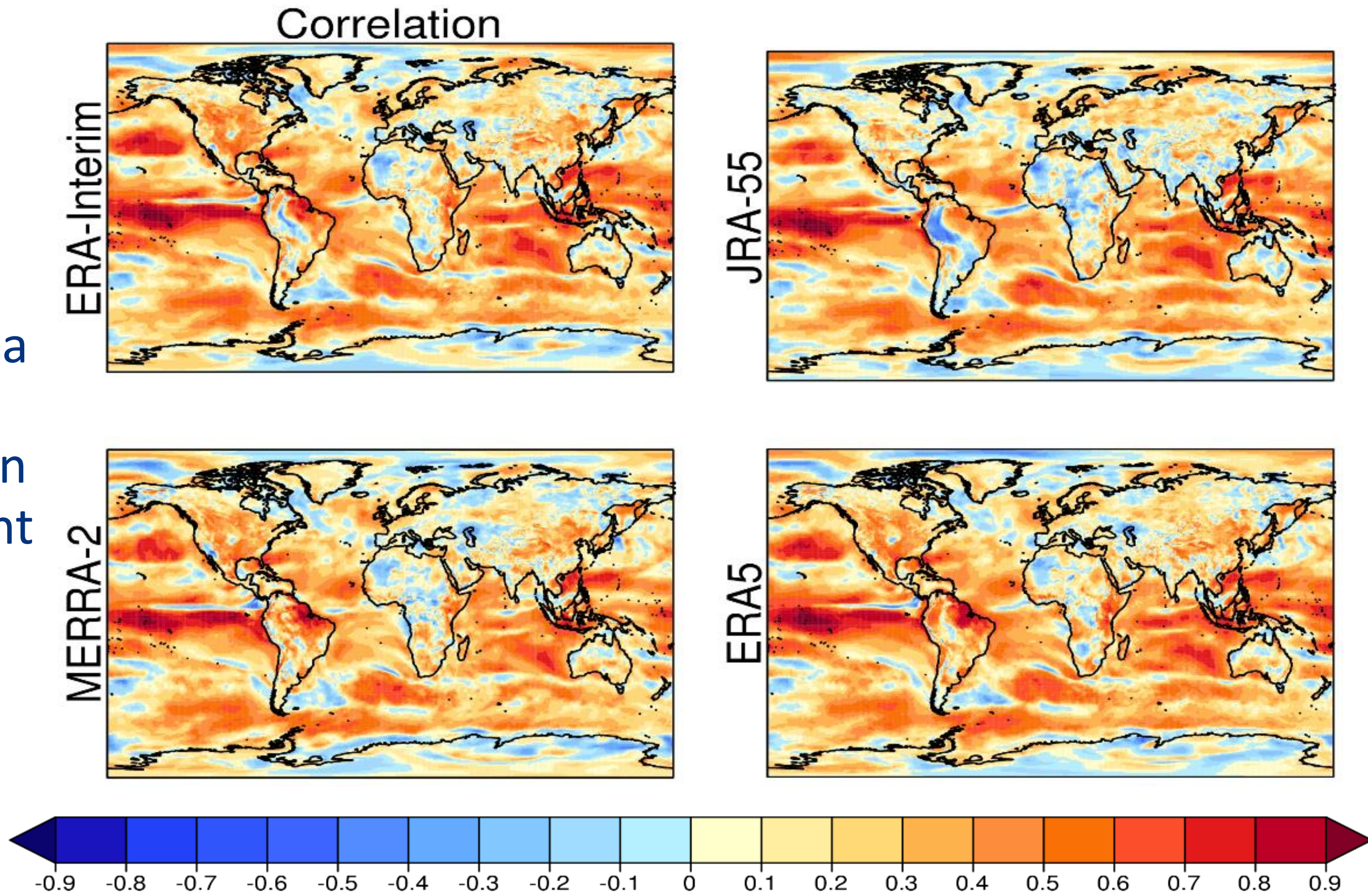

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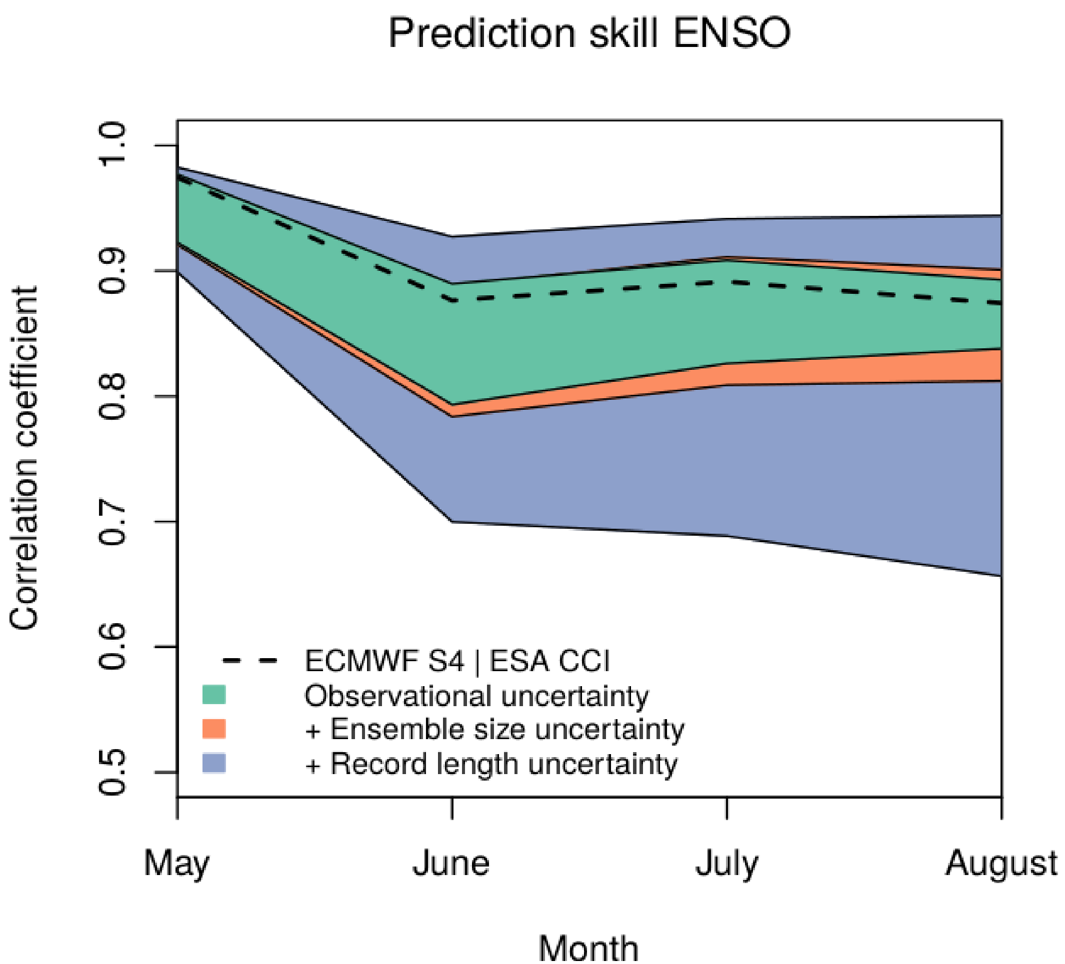
V. Torralba

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.



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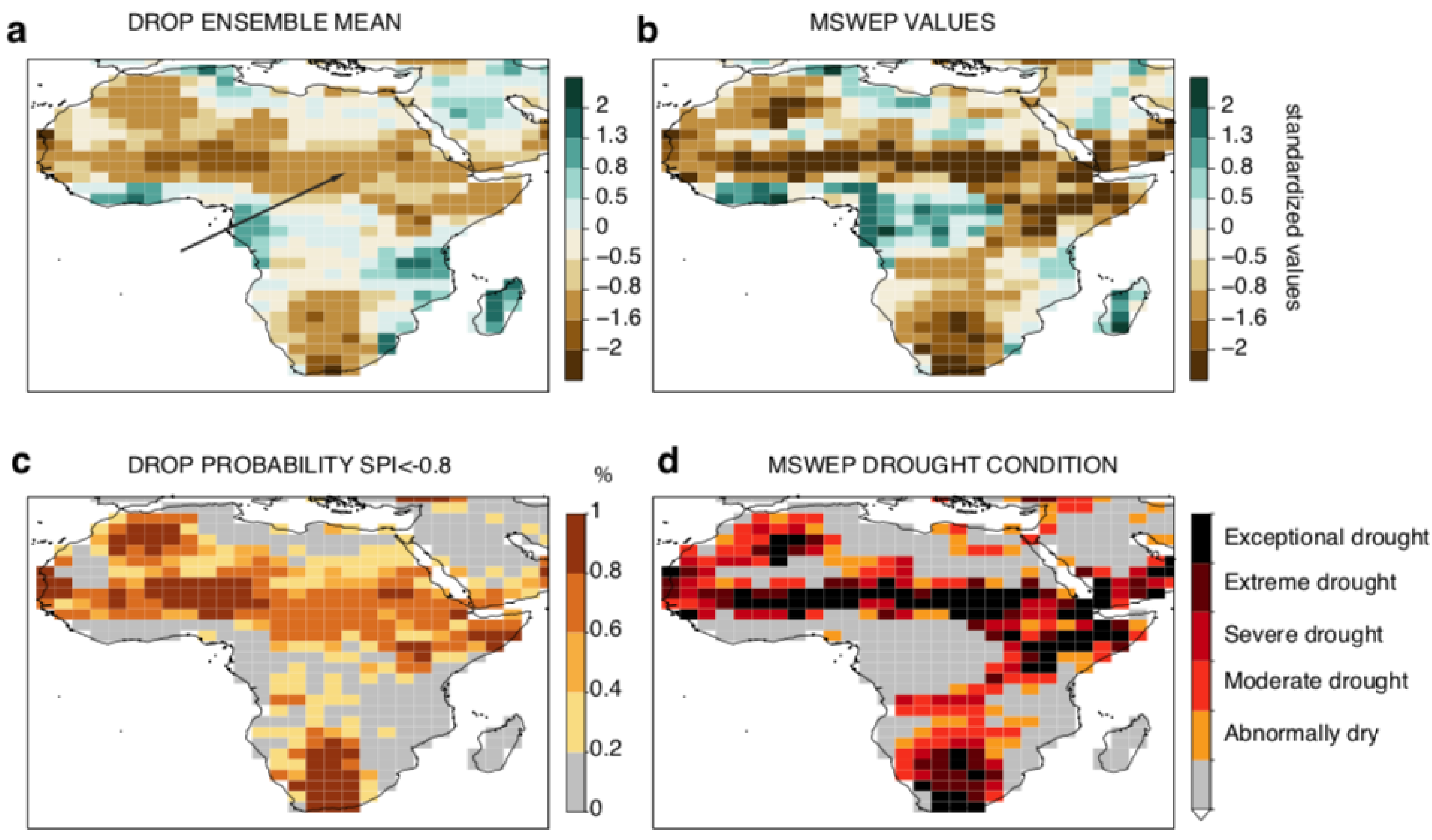
Bellprat et al. (2017, Rem. Sens. Env.)

Observational uncertainty for monitoring

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



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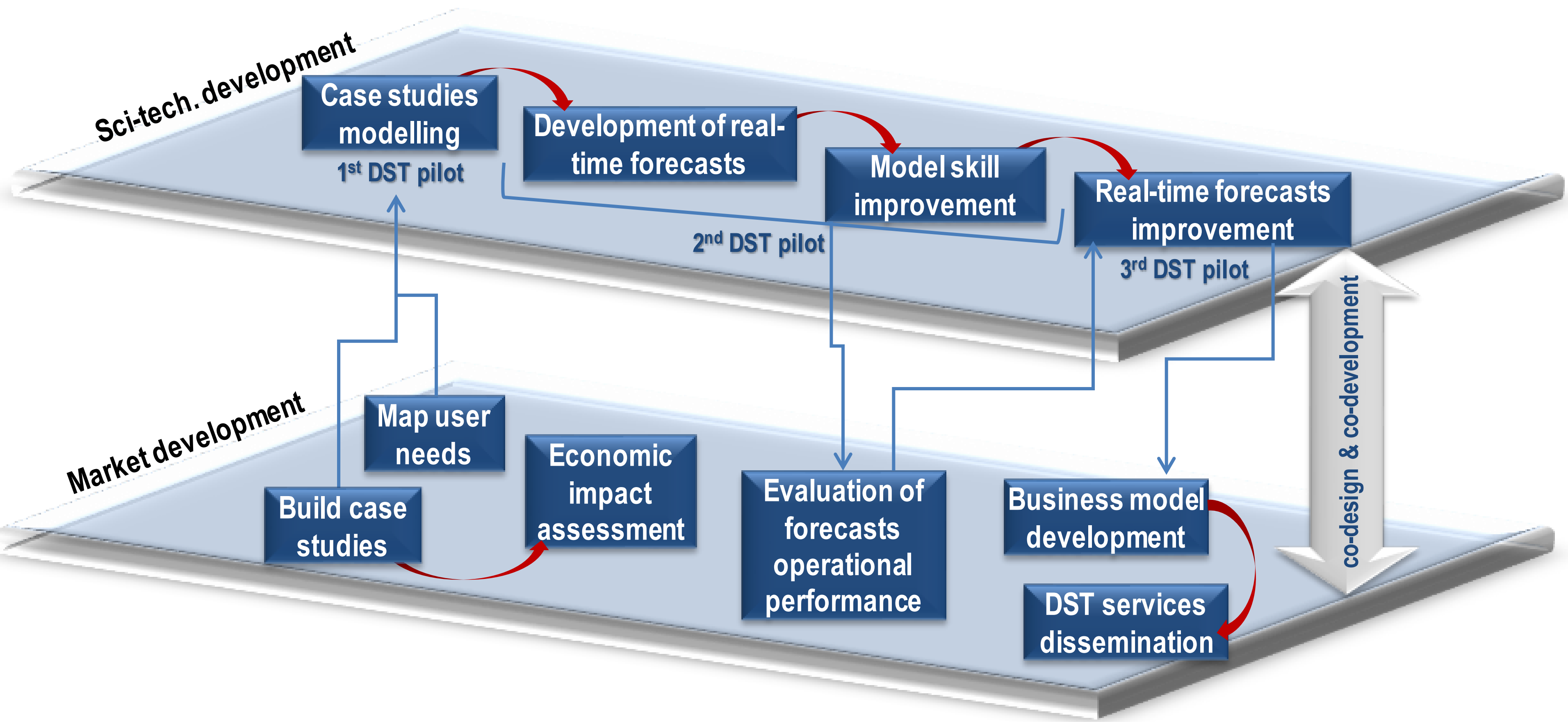
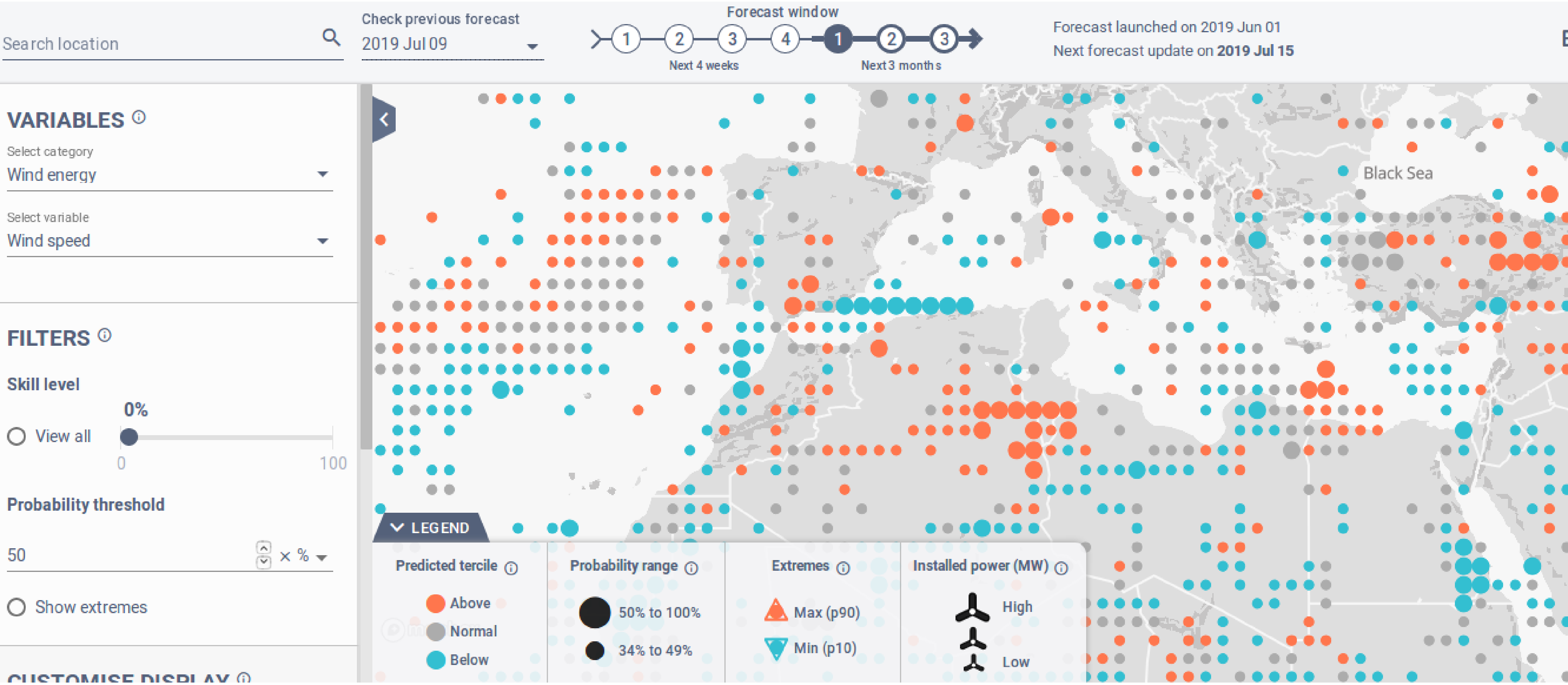
Turco et al. (2019, BAMS)

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.



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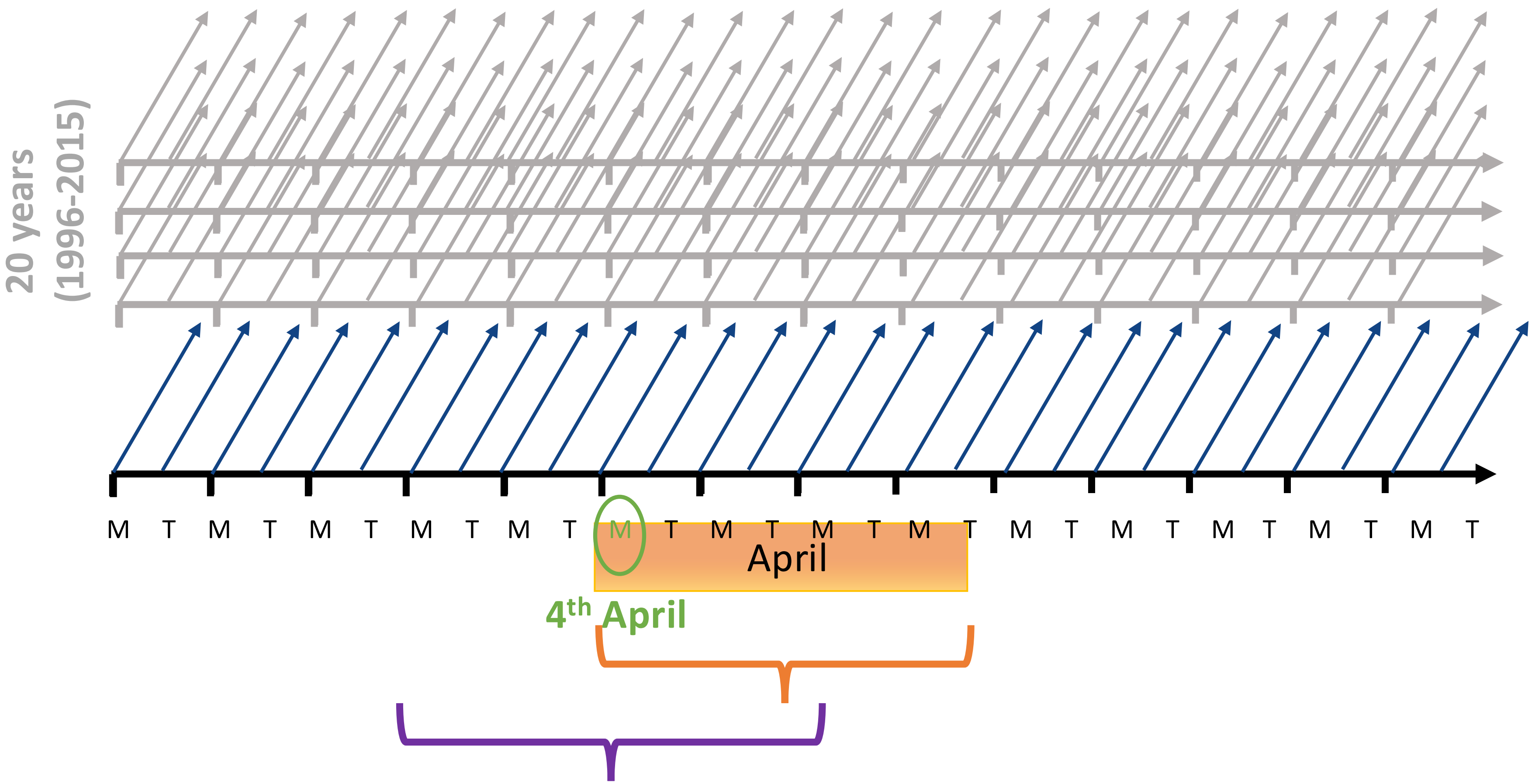
The (service) devil is in the detail



Weekly: 1 start date, 20 years

Monthly: All start dates in a calendar month, 8/9 start dates, 20 years

Monthly running window: Running window with 4 start dates before and after the target week, 9 start dates, 20 years

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A. Manrique

The (service) devil is in the detail

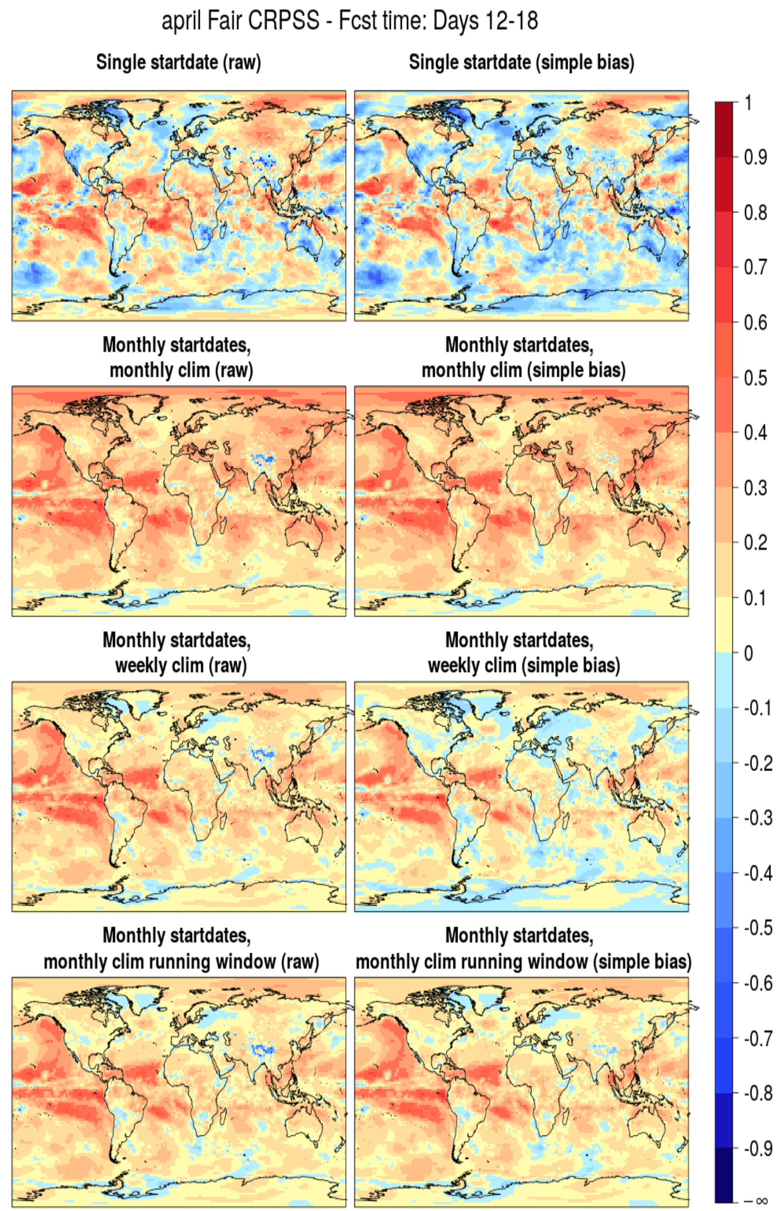
ECMWF 2016 System
Period: 1996-2015
Month: April
Reference: ERA Int
2-m temperature

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



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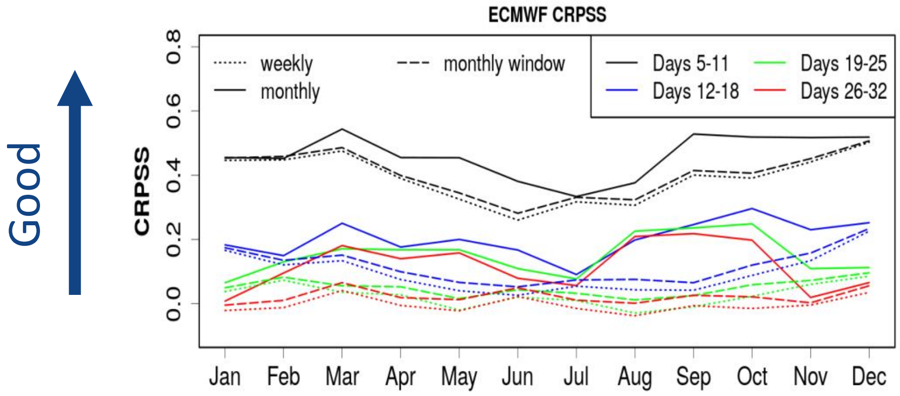
A. Manrique

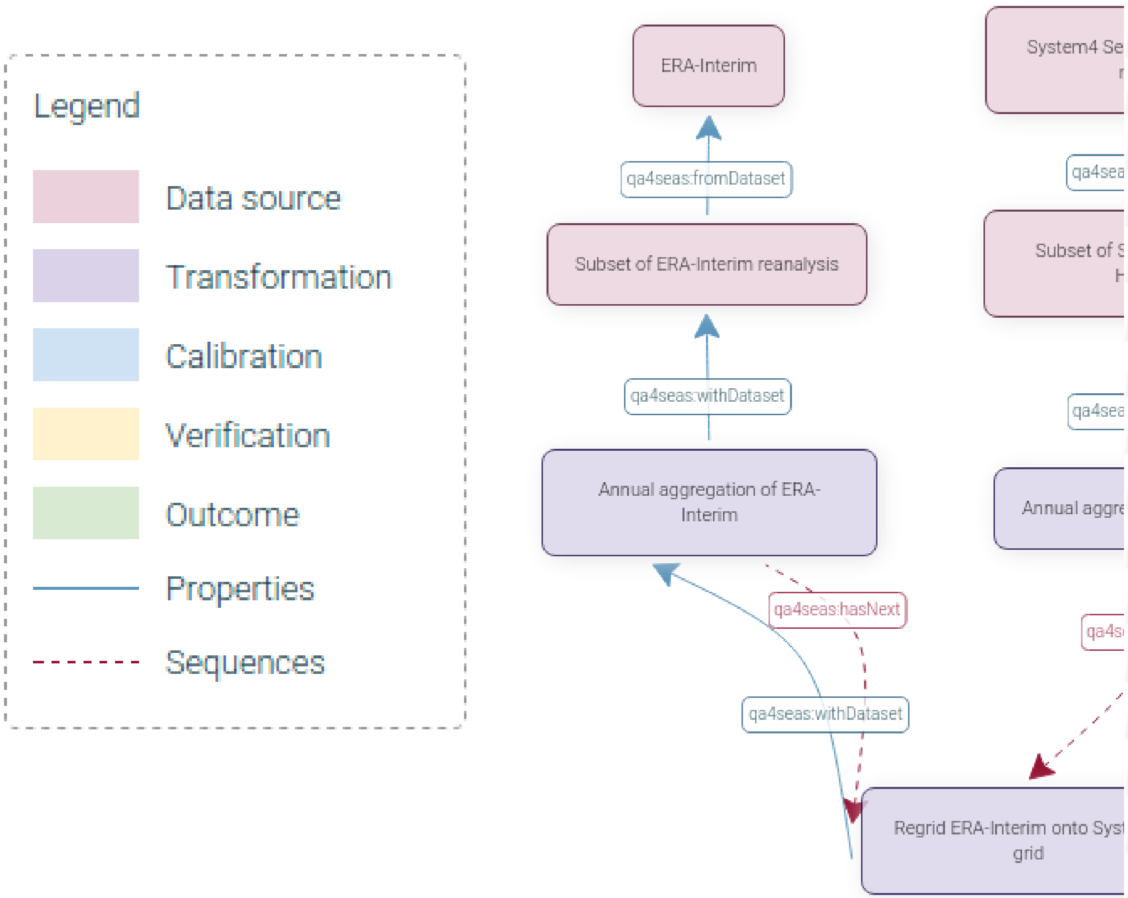
The (service) devil is in the detail

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



How traceable are the forecast products?

Generalised metadata provision and workflow provenance is required to ensure a minimum quality of the forecast-based climate information



Panadol

ActiFast
Soluble Tablets
Paracetamol

Please read right through this leaflet before you start using this medicine.
This medicine is available without prescription, but you still need to use Panadol ActiFast Soluble Tablets carefully to get the best results from them.
- Keep this leaflet, you may need to read it again.
- If you have any questions, or if there is anything you do not understand, ask your pharmacist.

In this leaflet:
1. What Panadol ActiFast Soluble Tablets do
2. Check before you take Panadol ActiFast Soluble Tablets
3. How to take Panadol ActiFast Soluble Tablets
4. Possible side effects
5. How to store Panadol ActiFast Soluble Tablets
6. Further information

1. What Panadol ActiFast Soluble Tablets do
Panadol ActiFast Soluble Tablets are used for the relief of headache, tension headache, migraine, backache, rheumatic and muscle pain, toothache and period pain. They also relieve sore throat and the fever, aches and pains of colds and flu.
The active ingredient is paracetamol which is a painkiller and also reduces your temperature when you have a fever.

2. Check before you take Panadol ActiFast Soluble Tablets

Do not take Panadol ActiFast Soluble Tablets:
- **if you have ever had an allergic reaction** to paracetamol or to any of the other ingredients (listed in Section 6)
- if you are **taking other medicines containing paracetamol.**

Ask your doctor before you take this medicine:
- if you have **liver** or **kidney disease**, including **alcoholic liver disease**
- if you have been told by your doctor that you have an **intolerance to some sugars**
- if you are on a **controlled sodium diet.** Each tablet contains **427 mg of sodium.**

If you are taking other medicines

Talk to your doctor or pharmacist before taking these tablets if you are taking any prescribed medicines; particularly **metoclopramide** or **domperidone** (for **nausea** [feeling sick] or **vomiting** [being sick]) or **colestyramine** (to lower **blood cholesterol**). If you take **blood thinning drugs (anticoagulants** e.g. **warfarin)** and you need to take a pain reliever on a daily basis, **talk to your doctor** because of the risk of bleeding. But you can still take **occasional** doses of Panadol ActiFast Soluble Tablets at the same time as anticoagulants.

Pregnancy and breast feeding

Talk to your doctor before taking Panadol ActiFast Soluble Tablets if you are **pregnant.** You can take this product whilst **breast feeding.**

31039448

3. How to take Panadol ActiFast Soluble Tablets

✓ Adults (including the elderly) and children aged 16 years and over: **Take 1-2 tablets dissolved in water every 4 to 6 hours as needed. Do not take more than 8 tablets in 24 hours.**

✓ **Children aged 10-15 years: Give 1 tablet dissolved in water every 4 to 6 hours as needed. Do not give more than 4 tablets in 24 hours. Do not give for more than 3 days at a time, unless your doctor tells you to.**

- **Do not take more frequently than every 4 hours.**
- **Do not take more than the recommended dose.**
- **Do not give to children under 10 years.**

If you take too many tablets
Immediate medical advice should be sought in the event of an overdose, even if you feel well, because of the risk of delayed, serious liver damage.
If your symptoms continue or your headache becomes persistent, **see your doctor.**

4. Possible side effects
Like all medicines, Panadol ActiFast Soluble Tablets can have side effects but not everybody gets them. A small number of people have had side effects.
Stop taking the medicine and **tell your doctor immediately** if you experience:
- **Allergic reactions** which may be severe such as skin rash and itching sometimes with swelling of the mouth or face or shortness of breath
- **Skin rash or peeling**, or **mouth ulcers**
- **Breathing problems.** These are more likely if you have experienced them before when taking other painkillers such as ibuprofen and aspirin
- Unexplained **bruising** or **bleeding**
- **Nausea**, sudden **weight loss**, **loss of appetite** and **yellowing of the eyes and skin.**

If you do get any side effects, even those not mentioned in this leaflet, tell your doctor or pharmacist.

5. How to store Panadol ActiFast Soluble Tablets
Keep out of the reach and sight of children.
Do not use this medicine after the 'EXP' date shown on the pack.
Store below 25°C.

6. Further information
Active ingredient: Each tablet contains Paracetamol 500 mg.
Other ingredients: Sorbitol powder (E 420), saccharin sodium, sodium bicarbonate, polyvidone, sodium lauryl sulphate, dimeticone, citric acid and sodium carbonate.

Packs of Panadol ActiFast Soluble Tablets contain 24 effervescent tablets.

The marketing authorisation holder is GlaxoSmithKline Consumer Healthcare (UK) Trading Limited, Brentford, TW8 9GS, U.K. and all enquiries should be sent to this address.

The manufacturer is GlaxoSmithKline Dungarvan Ltd., Co. Waterford, Ireland or Famar SA, Anthousis Av., 153 44, Pallini Attikis, Greece.

This leaflet was last revised in December 2016.
Panadol and **ActiFast** are registered trademarks owned by or licensed to the GSK group of companies.

GlaxoSmithKline

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J. Bedia (Predictia)

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

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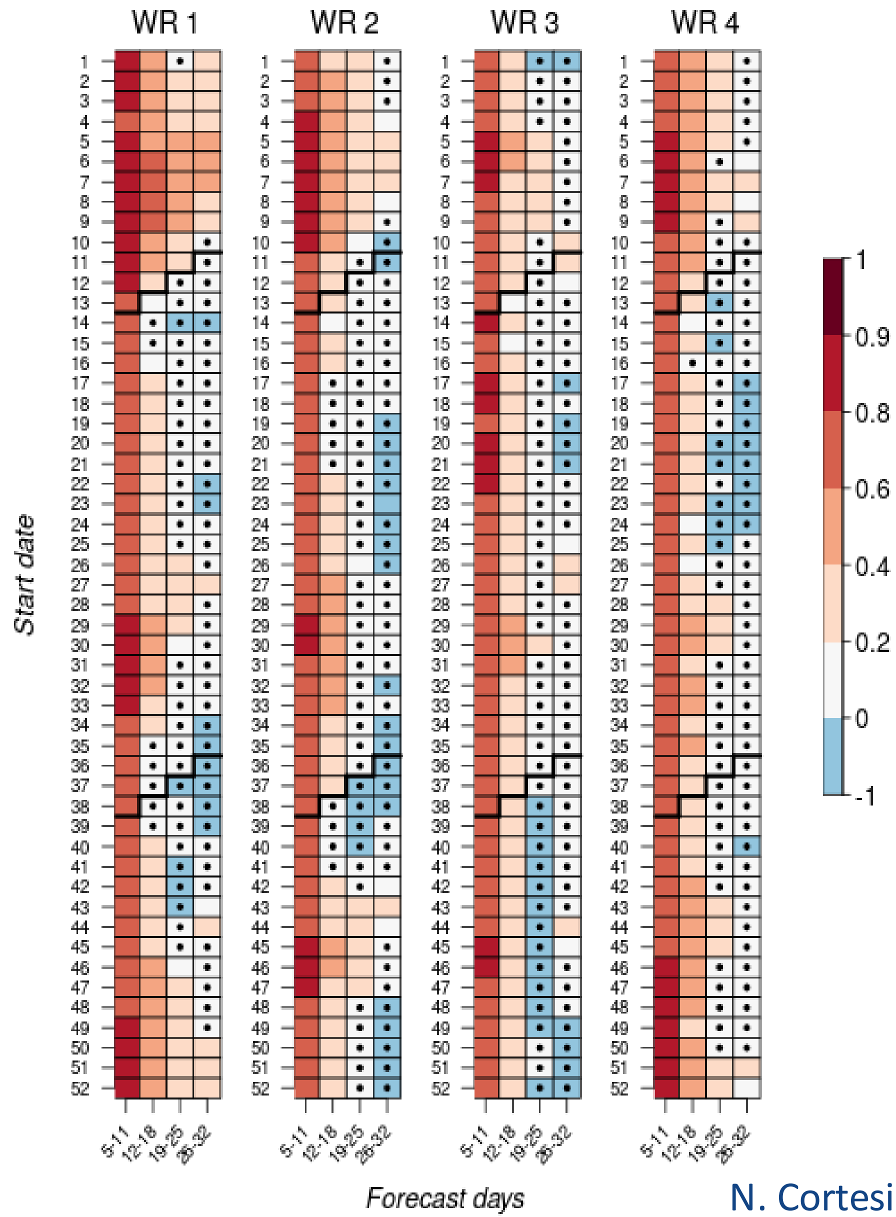
Copernicus
Europe's eyes on Earth

Climate Change Service

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.



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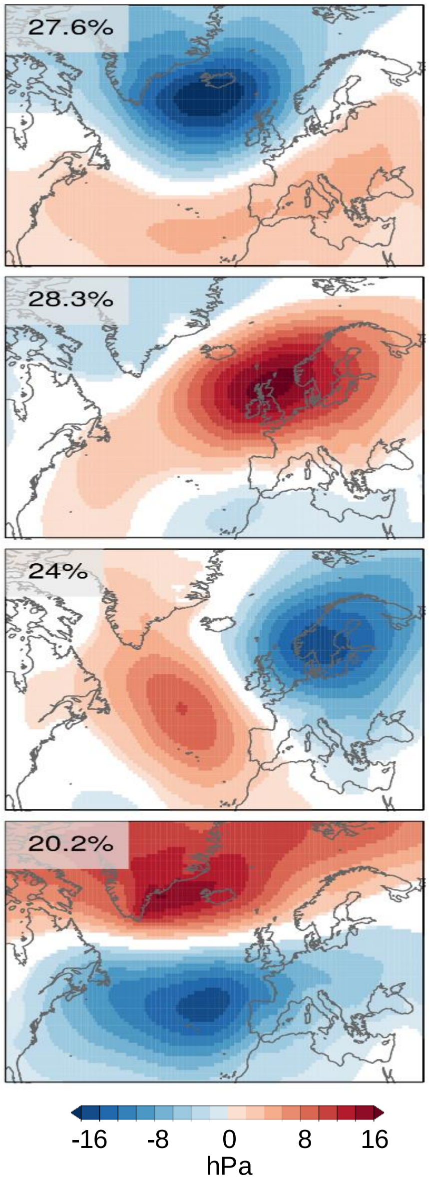
N. Cortesi

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)

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

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

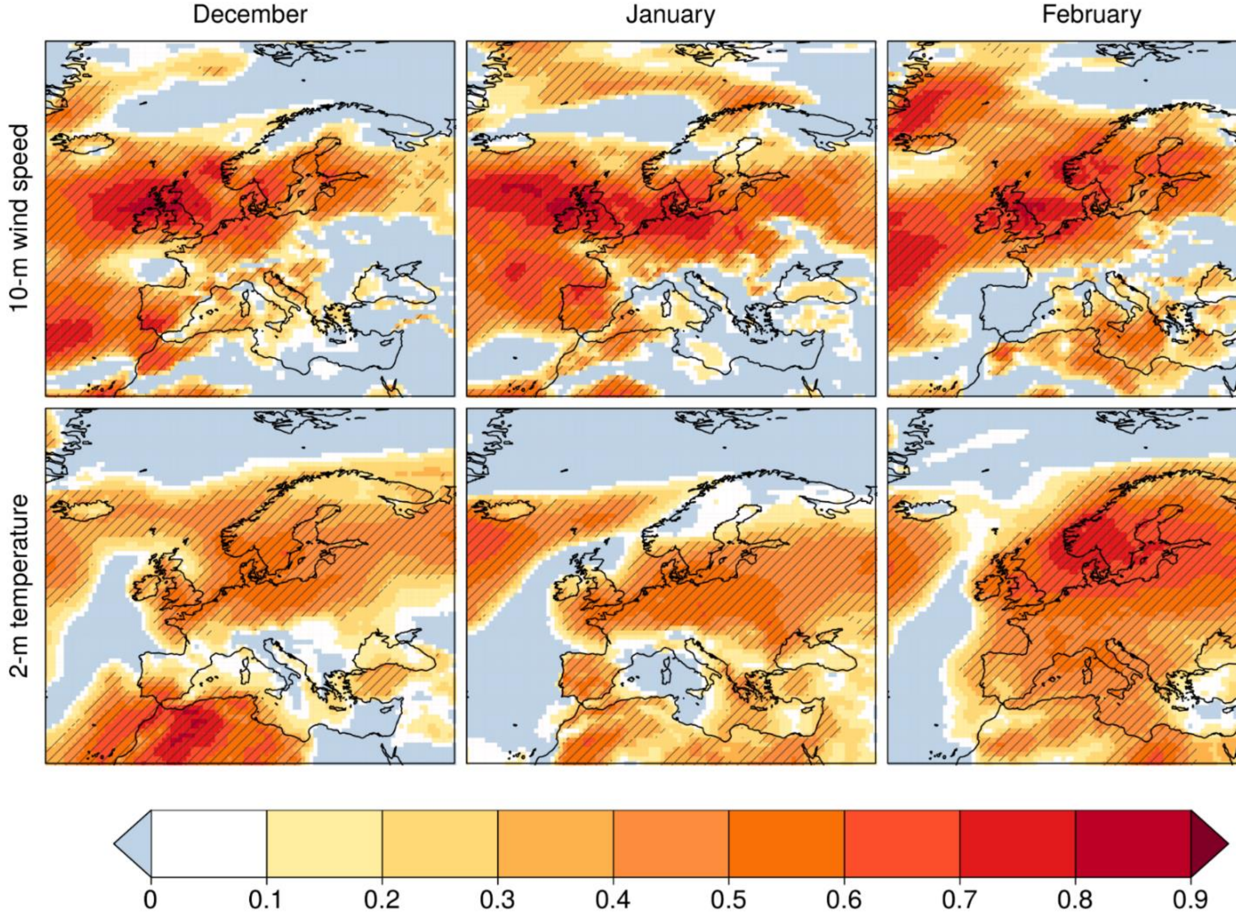
Composite map of the variable for a specific regime (r) in the same month and in the full period (cross-validation)

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



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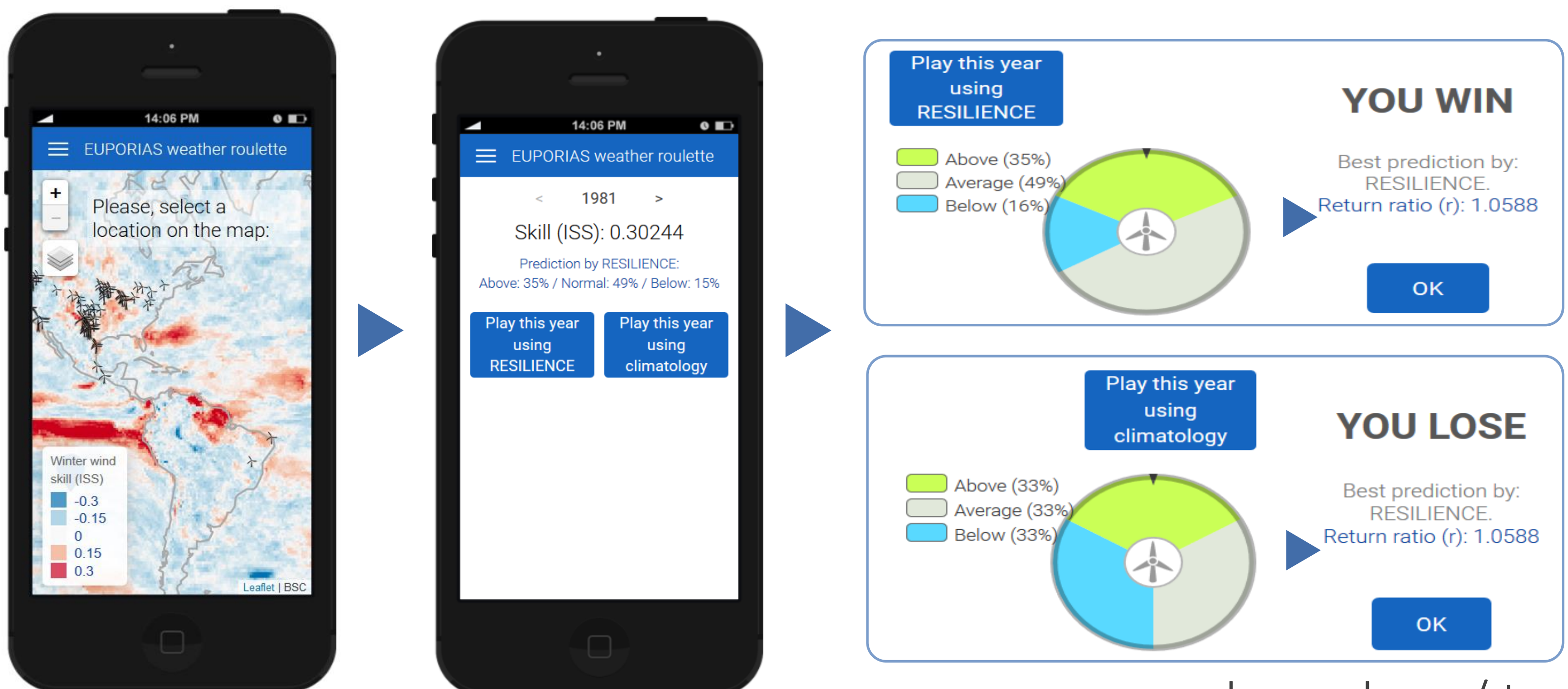
V. Torralba

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.



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EUPORIAS
European Provision Of Regional Impacts Assessments on Seasonal and Decadal Timescales

S2S4E
Climate Services for Clean Energy

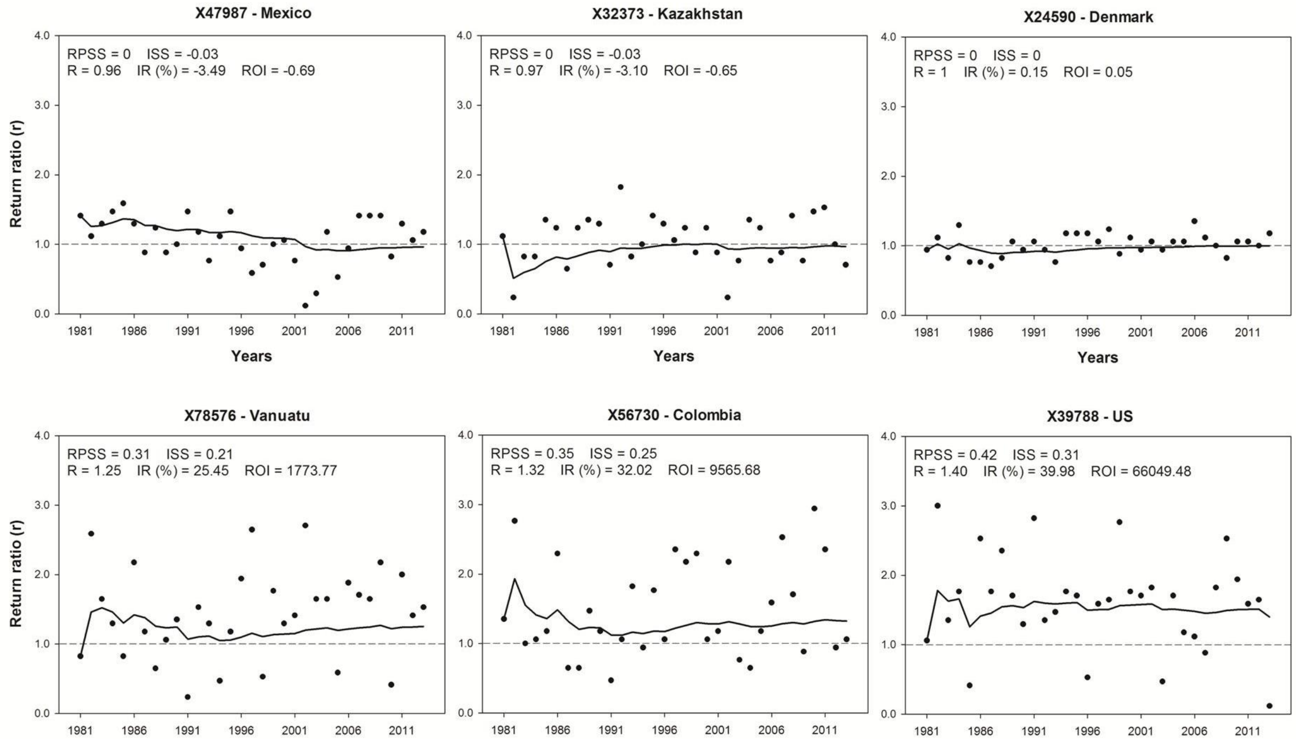
play.google.com/store/apps
demo.predictia.es/roulette-app/mobile.html

Terrado et al. (2019, BAMS)

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).



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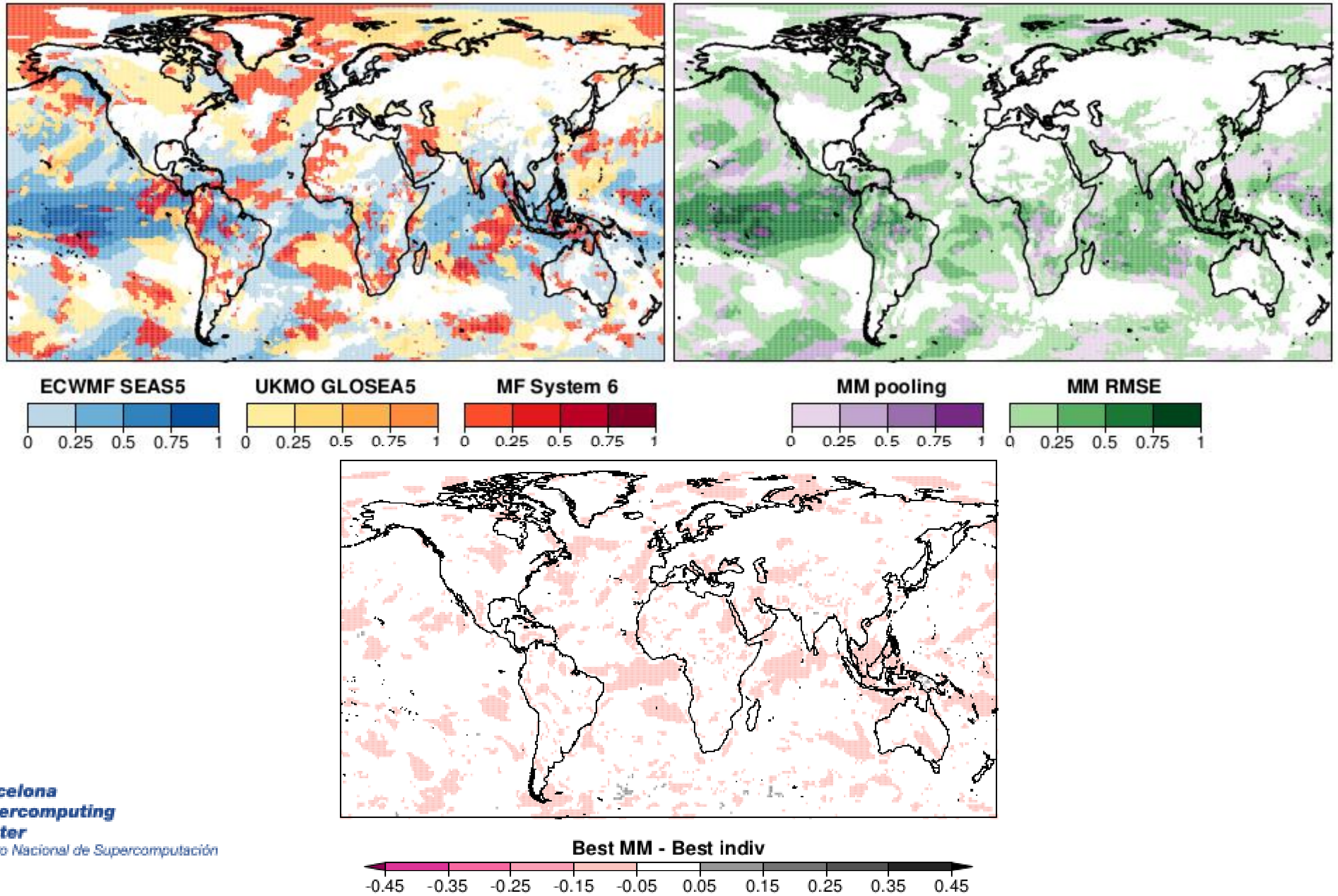
Terrado et al. (2019, BAMS)

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.



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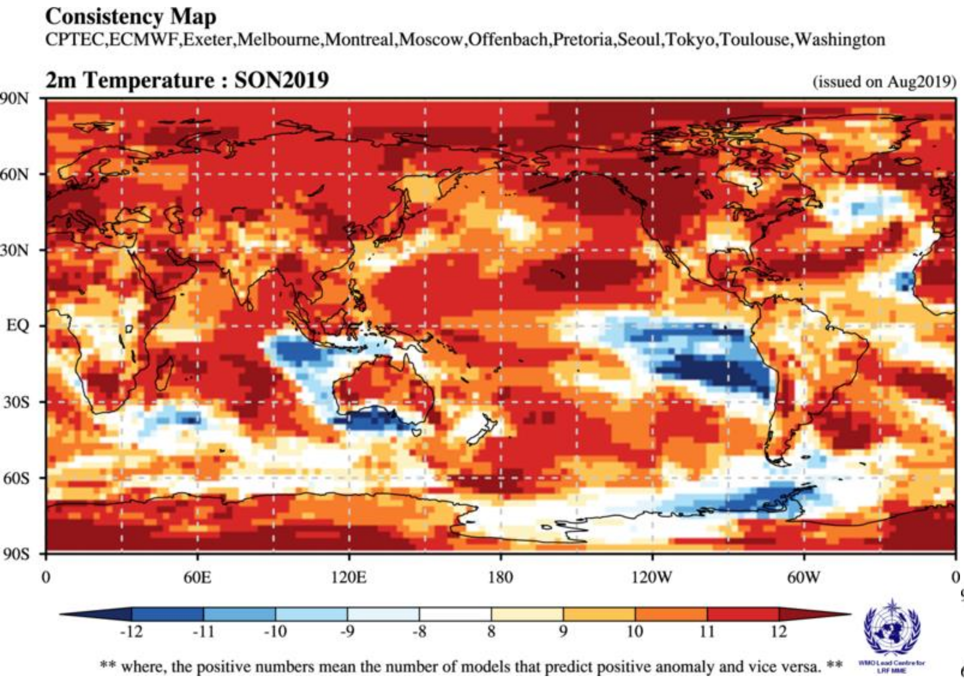
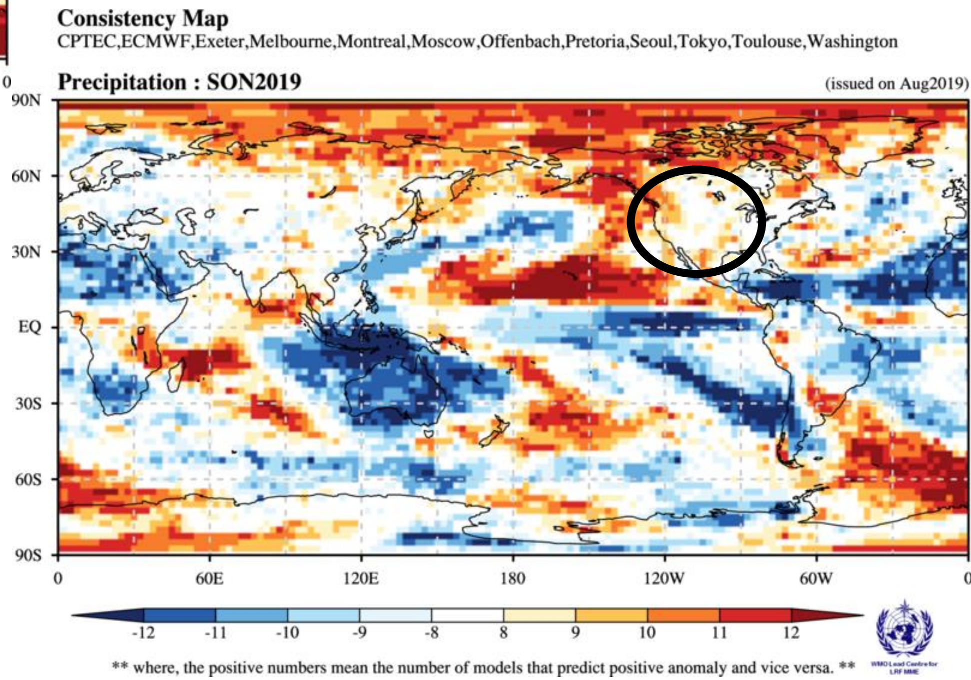
V. Torralba

Other approaches for the synthesis



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.



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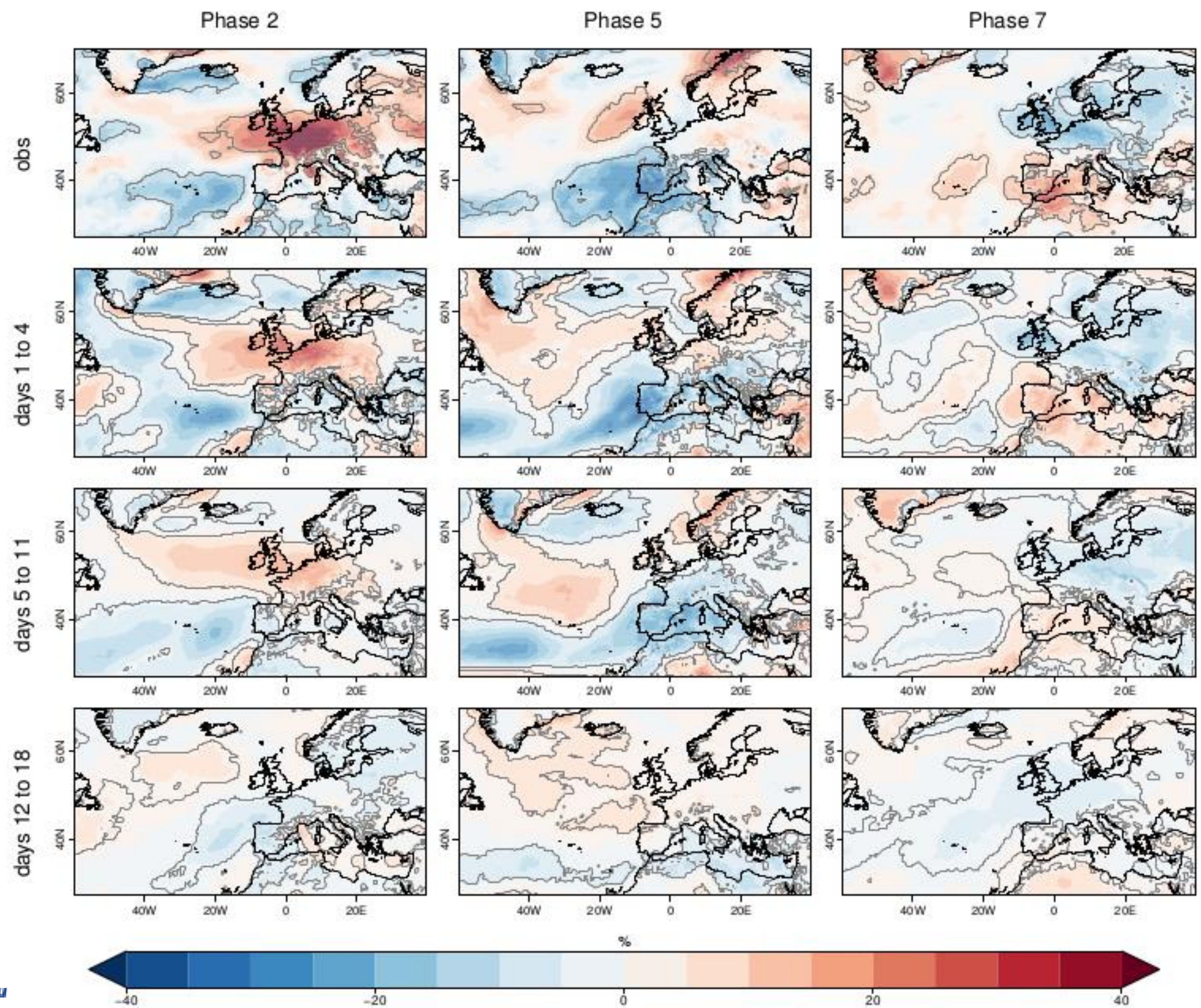
Other approaches for the synthesis

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.



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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.