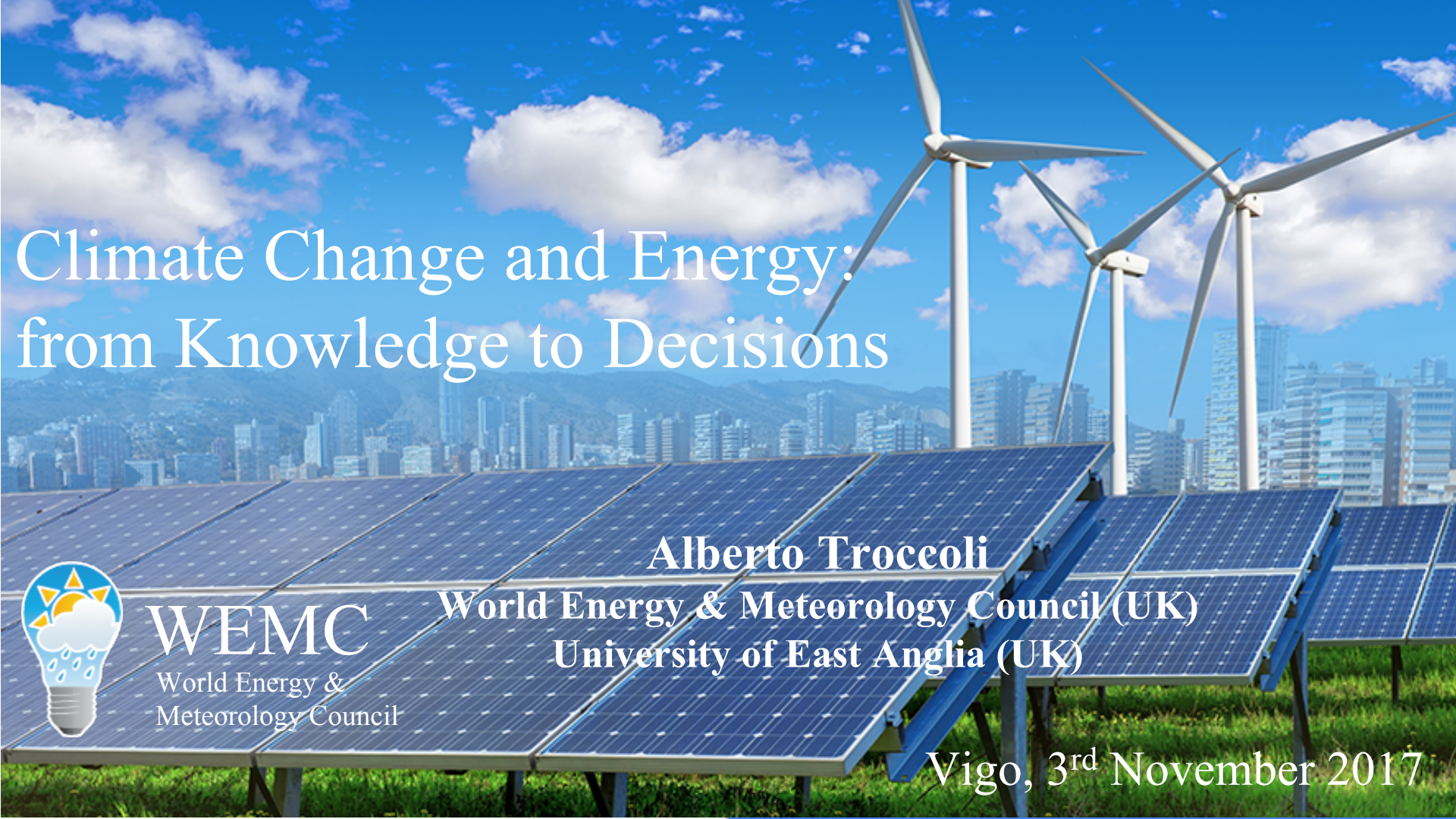

Climate Change and Energy: from Knowledge to Decisions

Alberto Troccoli
World Energy & Meteorology Council (UK)
University of East Anglia (UK)

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World Energy & Meteorology Council

Vigo, 3rd November 2017

Outline

- The evolving relationship between Energy and Climate
- How Weather/Climate impacts Energy
- A Copernicus Climate Change Service for Energy: ECEM
- Climate Services and decision making in Energy Sector

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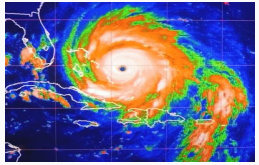
Energy and meteorology go hand in hand

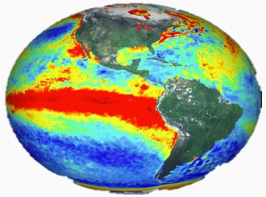
Passing clouds

Drop in solar power



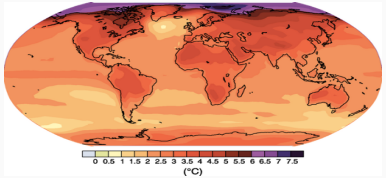
Hurricanes

Disruptions to oil rig operations



El-Niño

Changes in Demand Patterns



Long term changes

Renewable Resource Assessment

Seconds Minutes Days Months Seasons Years Decades

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World Energy & Meteorology Council (WEMC)

Our primary goal is to enable improved

Sustainable energy

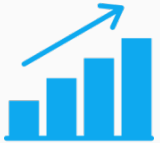
For a low carbon economy

Resilience

Of energy infrastructures

Efficiency

Of energy systems



Under ever changing weather and climate

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WEMC activities are:

1. The **dissemination of information** on products, practices, and experiences in Energy & Meteorology including the promotion of our members' work

2. The **coordination of Special Interest Groups** leading to the production of reports, analyses and syntheses on key topics in Energy & Meteorology

3. The development and maintenance of **climate and energy demonstration tools** for the energy industry and the education of the general public

4. The **organisation of events** such as the International Conference Energy & Meteorology (ICEM), professional workshops, seminars and webinars

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http://www.wemcouncil.org/

The energy industry has a multi-decadal experience in dealing with meteorological variables. So, what's the big deal?

The landscape, in both climate and energy spaces, is changing rapidly.

Energy industry is multi-faceted









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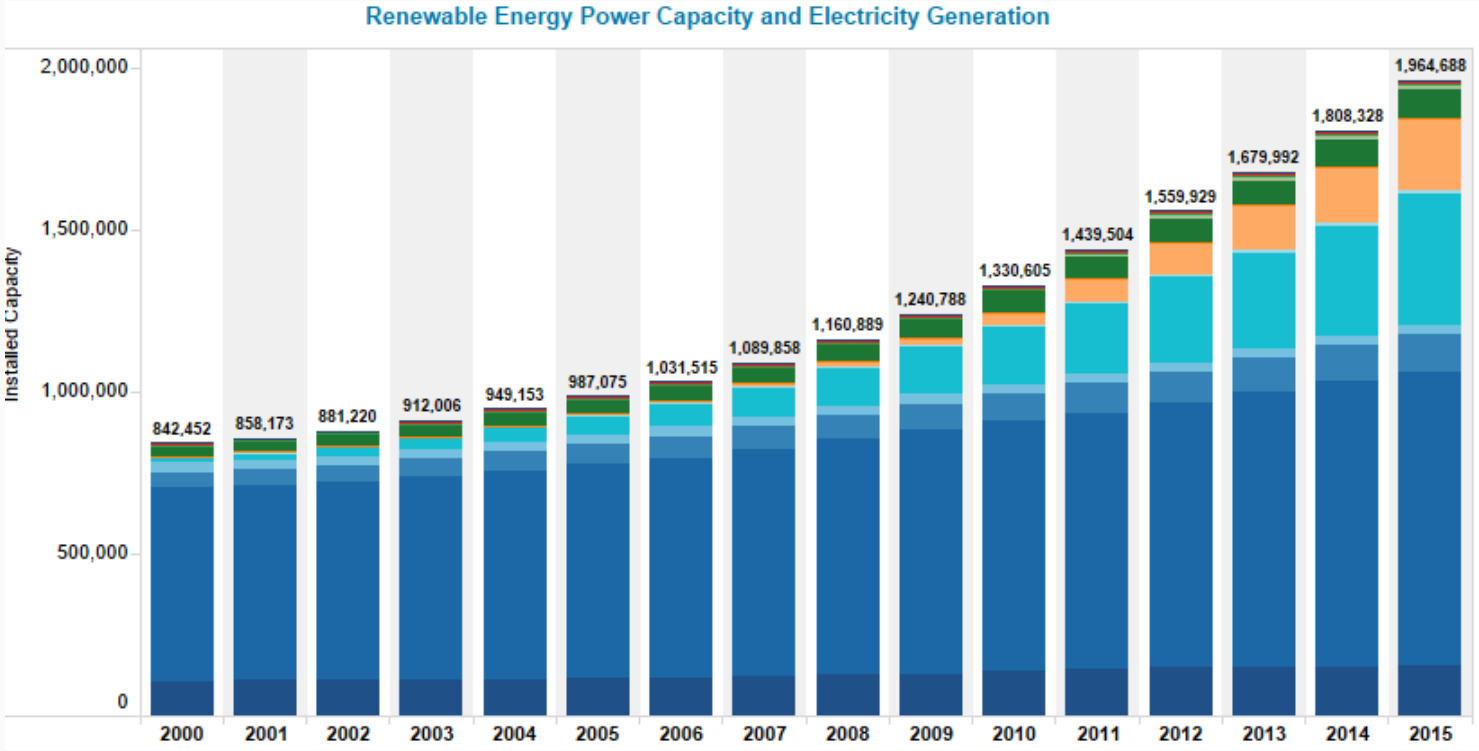
Strong growth in renewables



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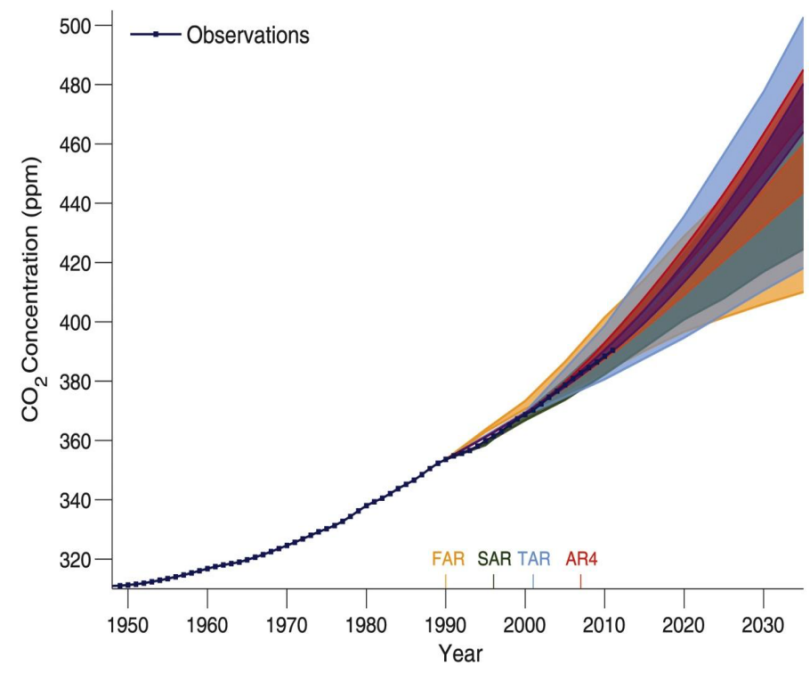
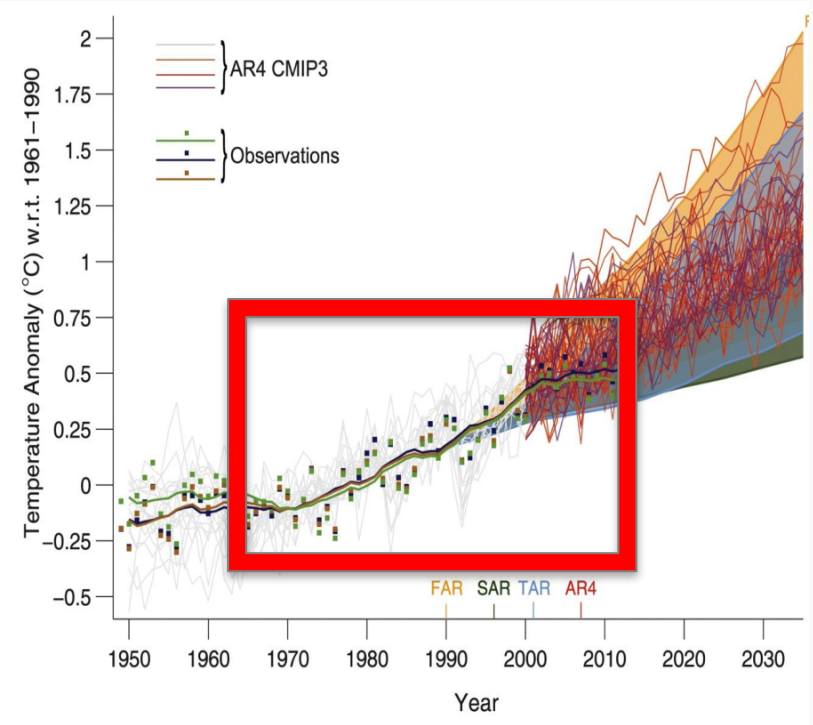
IRENA (2016)

C02 emissions and temperature





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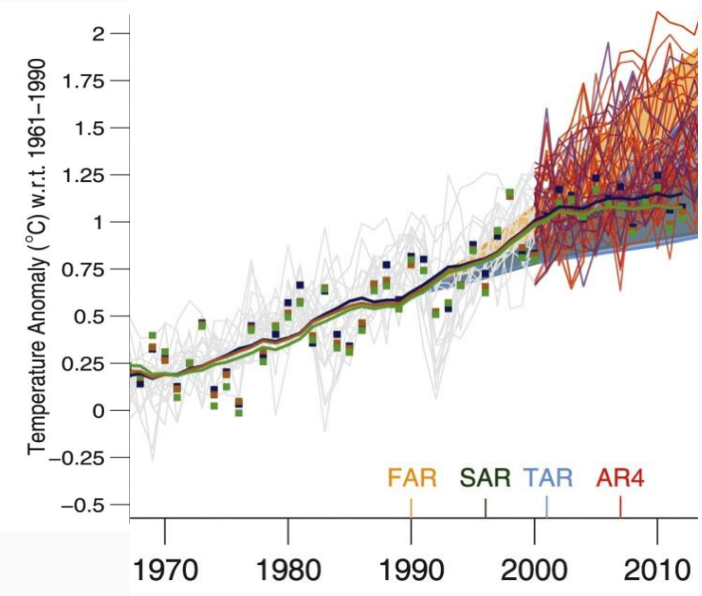
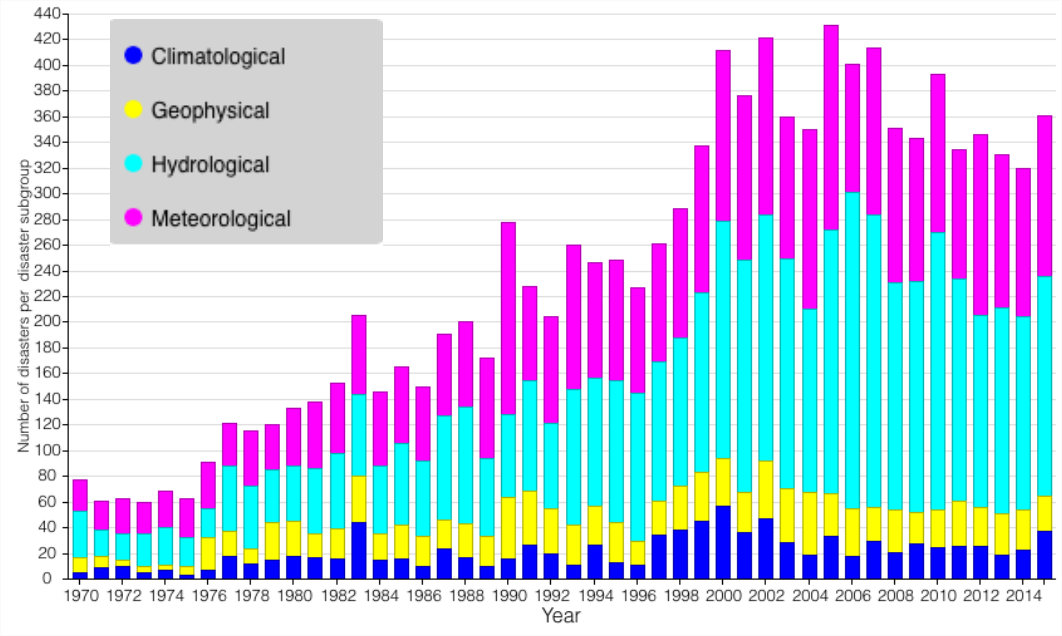
IPCC AR5 (2013)

Disasters due to natural events





EM-DAT (2016)

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See also Diffenbaugh et el. (2017, PNAS)

Simplified Energy & Climate feedback

Emissions

Energy

Meteorology
Weather, Climate & Water

Impacts

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Climate impact on coal mines

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Love et al. (2014)

Climate impacts on hydro-power

Masinga Dam Water levels in different Years

From Christopher Oludhe (2015)

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Climate impact on nuclear power

The 2003 heatwave in France had serious consequences on the cooling of nuclear reactors. The overall cost of the heat wave for EDF was around €330 million

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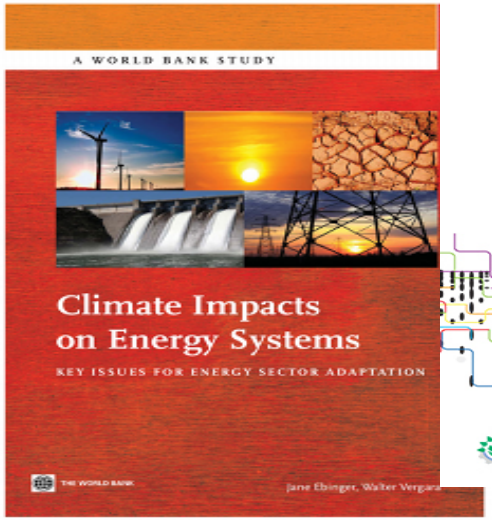
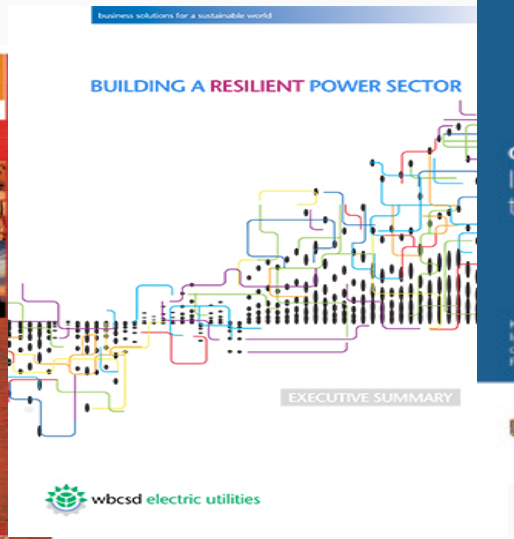
Dubus (2009)

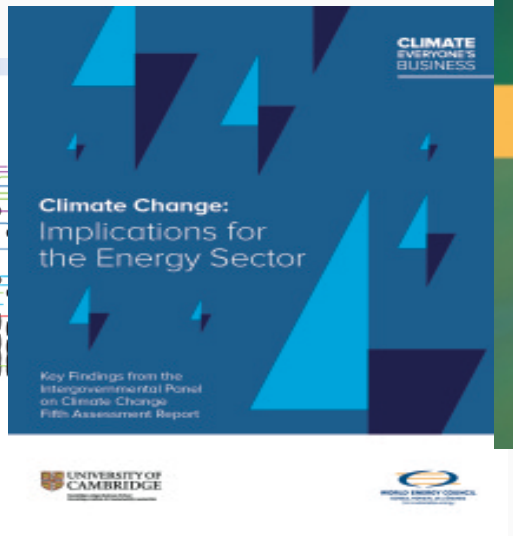
A selection of publications



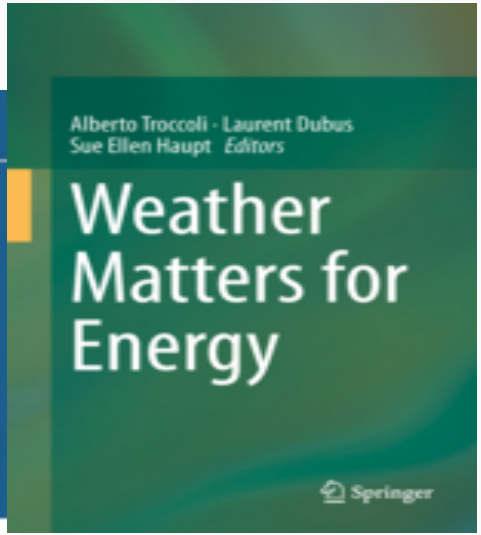
World Bank (2010)



WBCSD (2014)



WEC (2014)



ICEM (2014)

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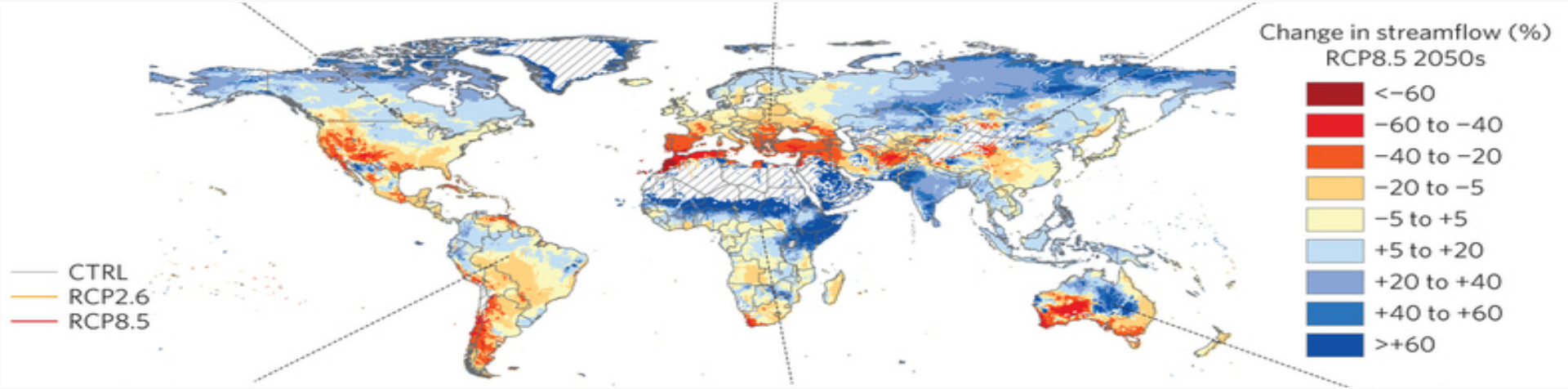
Global changes in streamflow projections



Change in streamflow for RCP8.5, 2040–2069 (2050s) vs1971–2000

Reductions in usable capacity for 61–74% of the hydropower plants

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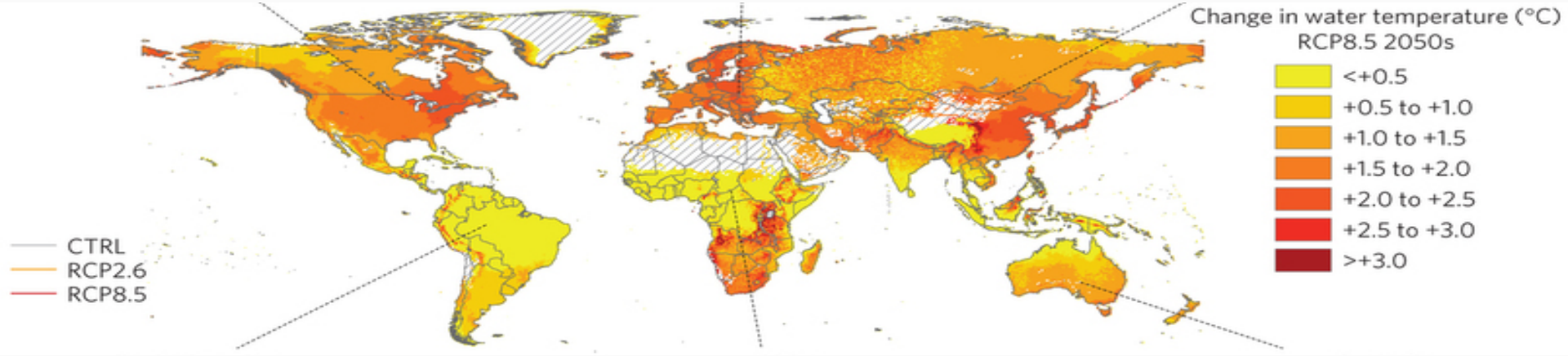
van Vliet et al. (2016)

Global changes in water temperature projections



Change in water temperature for RCP8.5, 2040–2069 (2050s) vs 1971–2000

Reductions in usable capacity for 81–86% of the thermoelectric power plants

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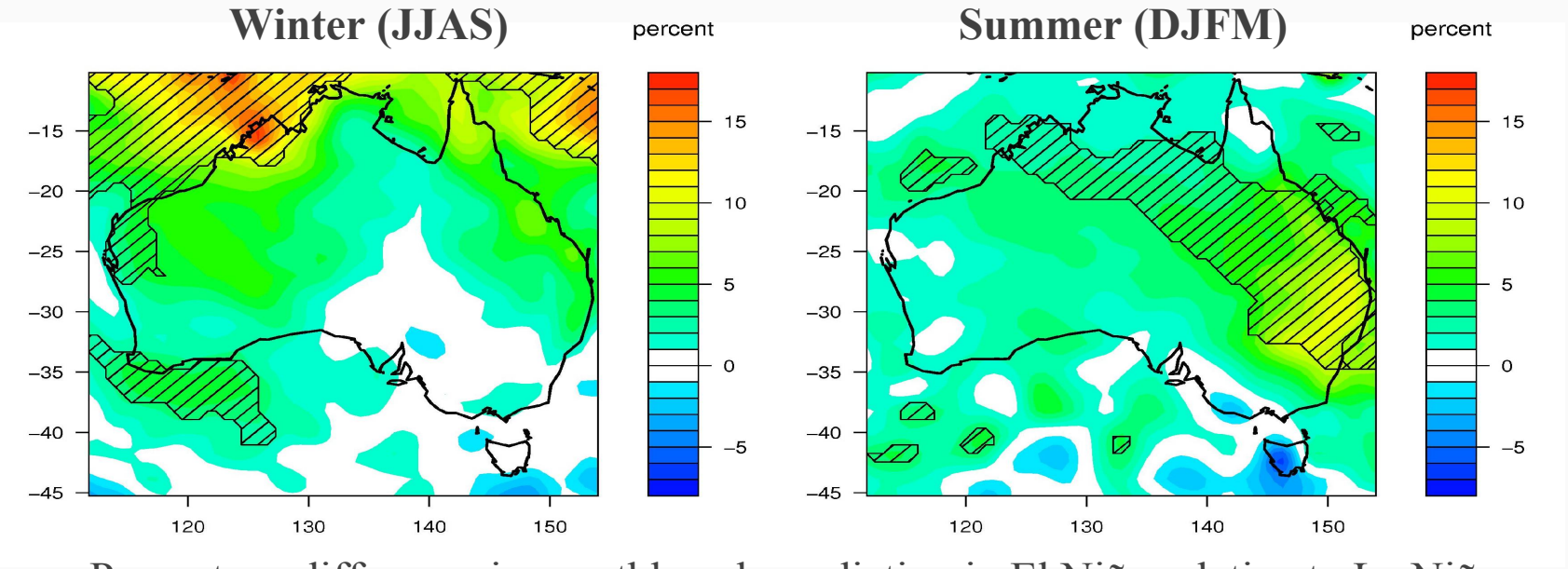
van Vliet et al. (2016)

Solar Radiation Inter-annual Variability



Percentage difference in monthly solar radiation in El Niño relative to La Niña

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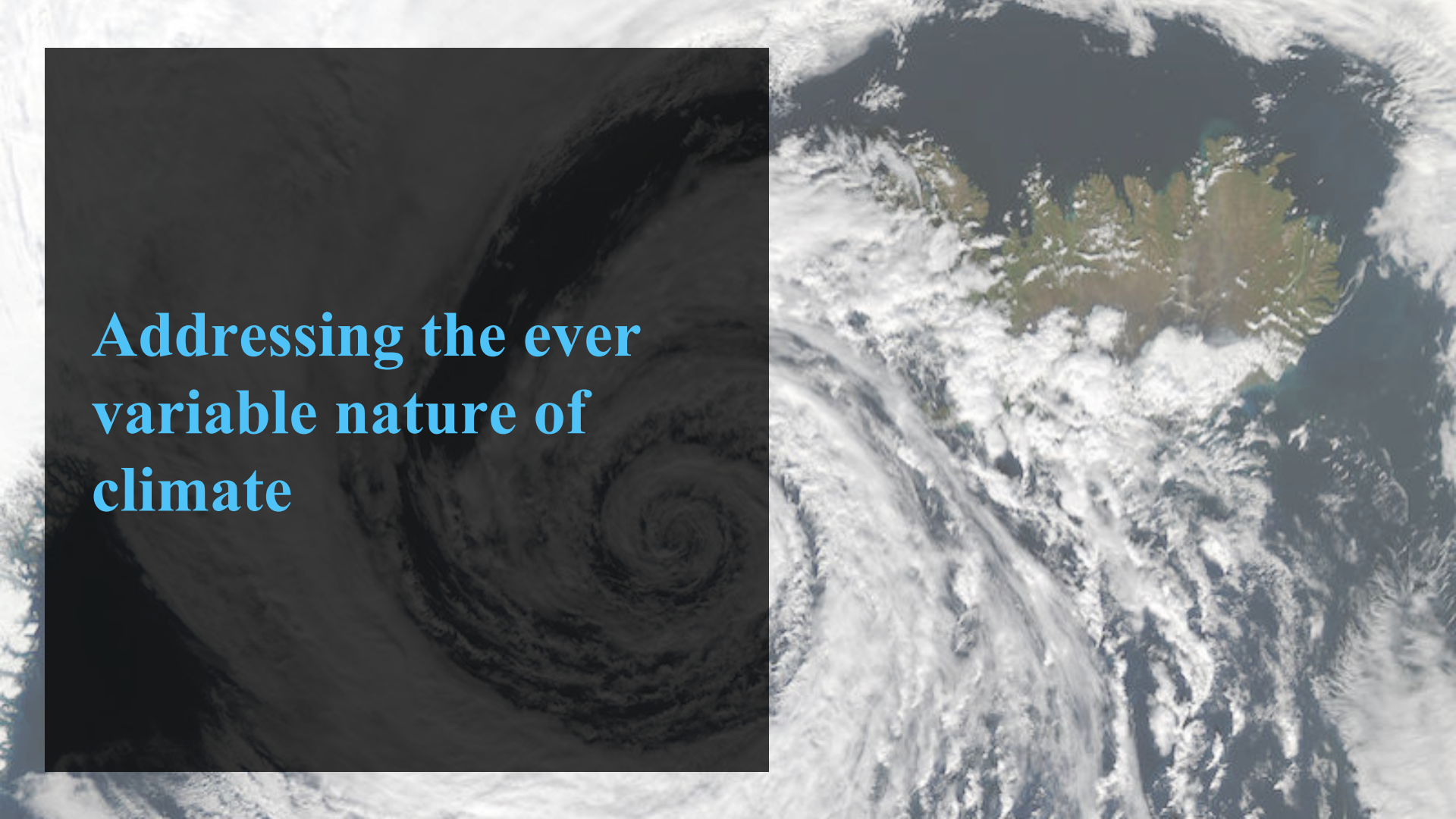
Davy and Troccoli (2012)

Addressing the ever variable nature of climate



Weather Services

- Very mature: 30+ years of experience
  - Also financial products since late 1990's
- Products well understood by many users
  - Relatively easy to identify needs
  - Users wish to be updated about latest developments in weather products but otherwise develop their own services
  - Regular (e.g. annual) users meetings and/or specific training normally offered by weather service providers

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Troccoli (2017)

Climate Services

- Relatively recent: ca. 10 years
  - First products from International Research Institute (IRI)
- Services still under developments
  - Large uncertainties in climate forecast/projections makes it more difficult for users to ascertain real value of climate information
  - Need to provide concrete examples of how to use climate information in practice

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Troccoli (2017)

But...

What is a Climate Service?

A set of actions/tools aimed at helping ‘people’ make the best use of climate information so as to improve their ‘business’

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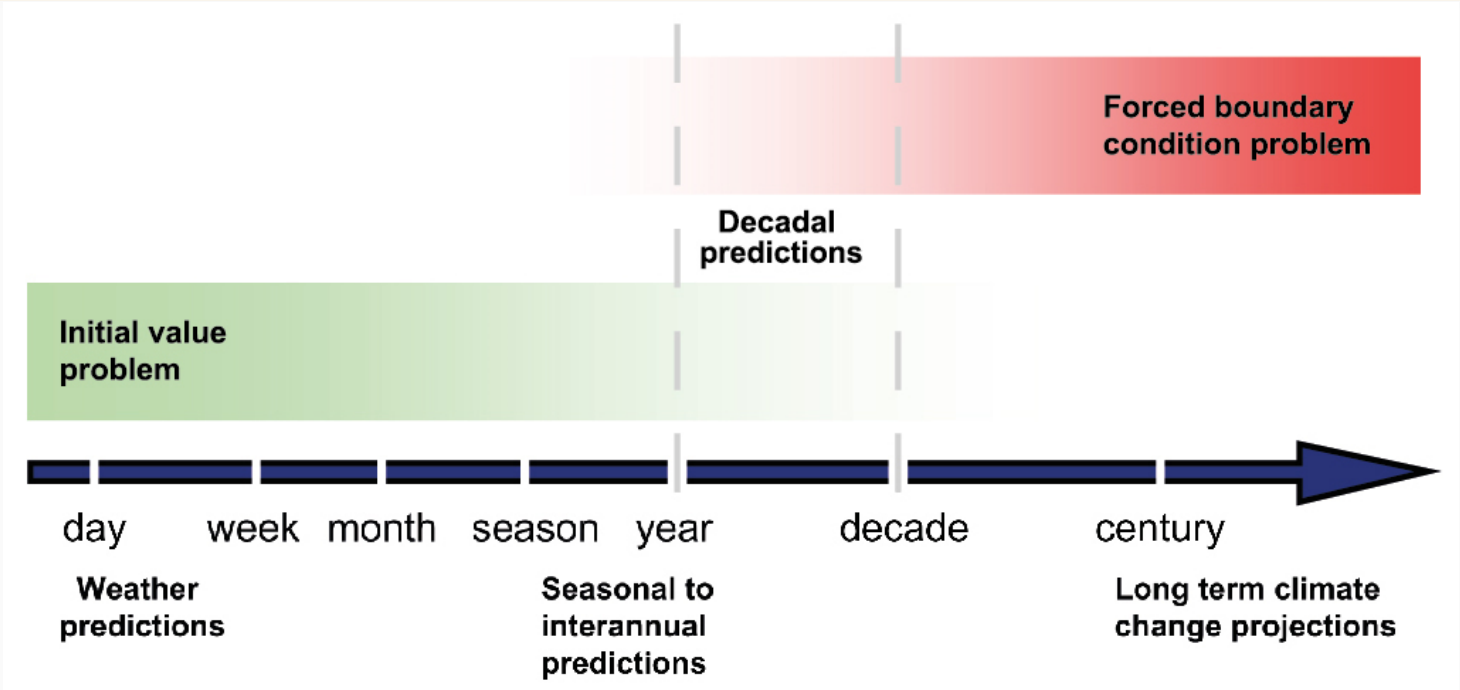
Troccoli (2017)

Meteorology forecasting issues at different time scales



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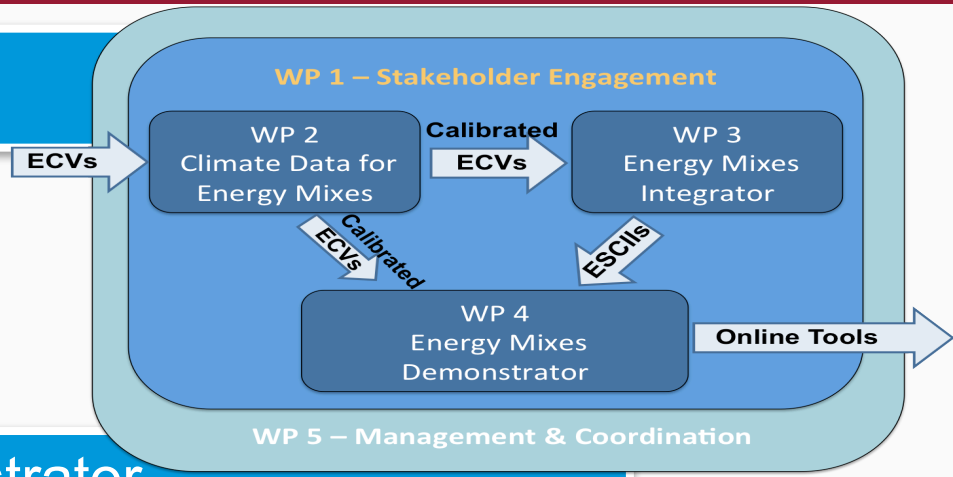
European Climatic Energy Mixes (ECEM)

Copernicus Europe's eyes on Earth

Climate Change Service
climate.copernicus.eu

C3S ECEM in brief

- Budget: €1.6 m
- Length: 27 mth (from Nov 2015)
- Six partners: UEA (lead) EDF, U Reading, Met Office, ARMINES and ENEA



Target: proof-of-concept or demonstrator

Stakeholder engagement central to ECEM

- Five stakeholder workshops, one every 6 months
- A tailored engagement plan

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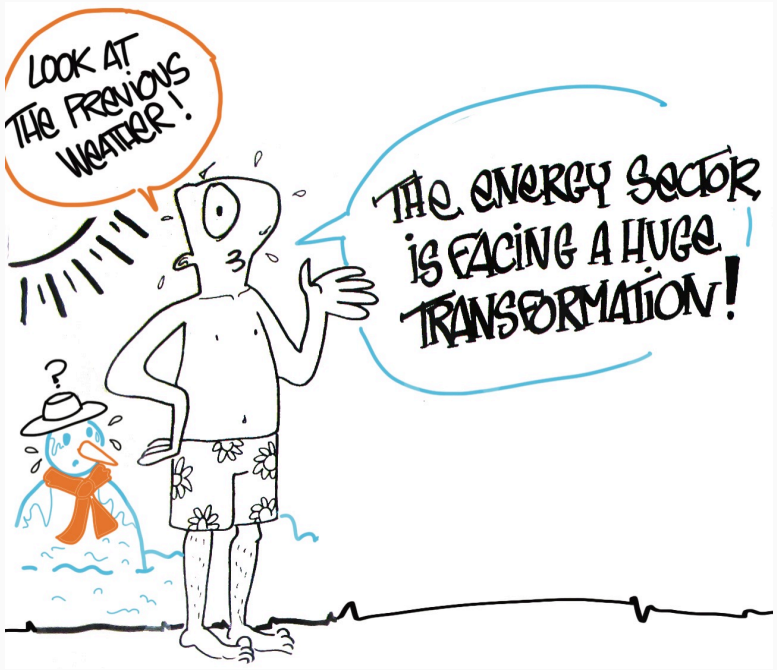
ECMWF · European Commission

European Climatic Energy Mixes (ECEM)



Increasing share of power supply from variable renewable energy (RE) sources. Demand variability is also increasing.
The transformation is taking place against a **variable and changing climate**.

European Climatic Energy Mixes (ECEM)

Integration of energy & climate information for energy mixes assessment

- ★ Is climate important for energy operations and planning?
- ★ What can climate R&D learn from interaction with energy sector and make output more easily adopted by the industry/policy makers?

European Climatic Energy Mixes (ECEM) is developing a demonstrator to assess how well **different energy supply mixes** in Europe will meet demand, over different time horizons, focusing on the role climate has on the mixes.

European Climatic Energy Mixes (ECEM)

Climate Change Service
climate.copernicus.eu

- **Energy Mix assessment for:**
  - **Present day**
  - **Seasonal Forecasts**
  - **Climate Projections**

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European Climatic Energy Mixes (ECEM)

Copernicus
Europe's eyes on Earth

Climate Change Service
climate.copernicus.eu

Calibrated Climate Variables

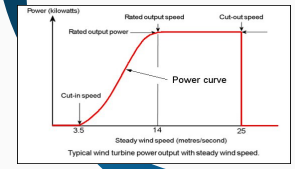
- Temperature
- Rainfall
- River Discharge
- Wind Speed
- Cloud Cover
- Solar Radiation
- Others ?

+Ancillary

- Skill & Reliability
- Assessment of Seasonal Forecasts of Energy Variables

+ Extreme Events Case Studies

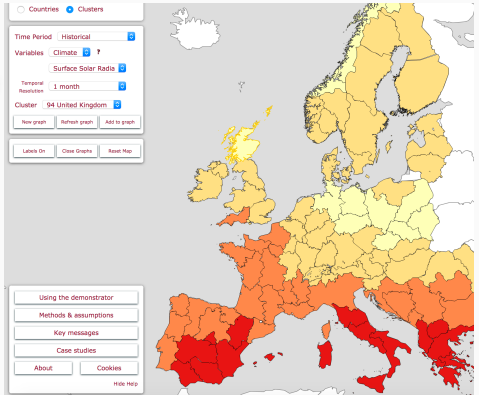
Define models & transfer functions
Select / Gather relevant datasets



Energy Variables

- Demand
- Hydro Power
- Wind Power
- Solar Power
- Thermal Power

- Sub-Country Scale
- Historical Period
- Seas. Fcst
- Clim. Proj.



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Multi-faceted Stakeholder Engagement

- ★ Workshops
- ★ Advisory Committee
- ★ Survey
- ★ Presentation at events
- ★ Webinars
- ★ Web site
- ★ Twitter

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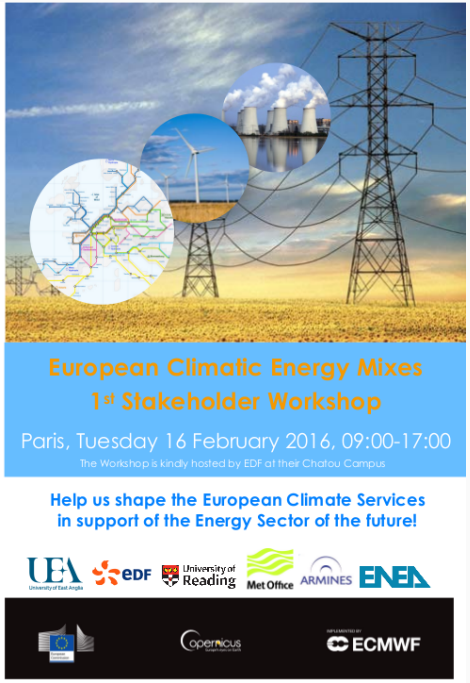
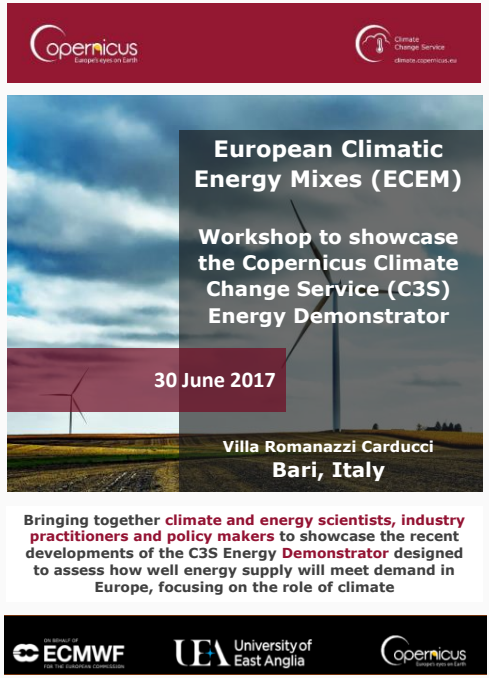
ECMWF · European Commission

Stakeholder Engagement: Workshops





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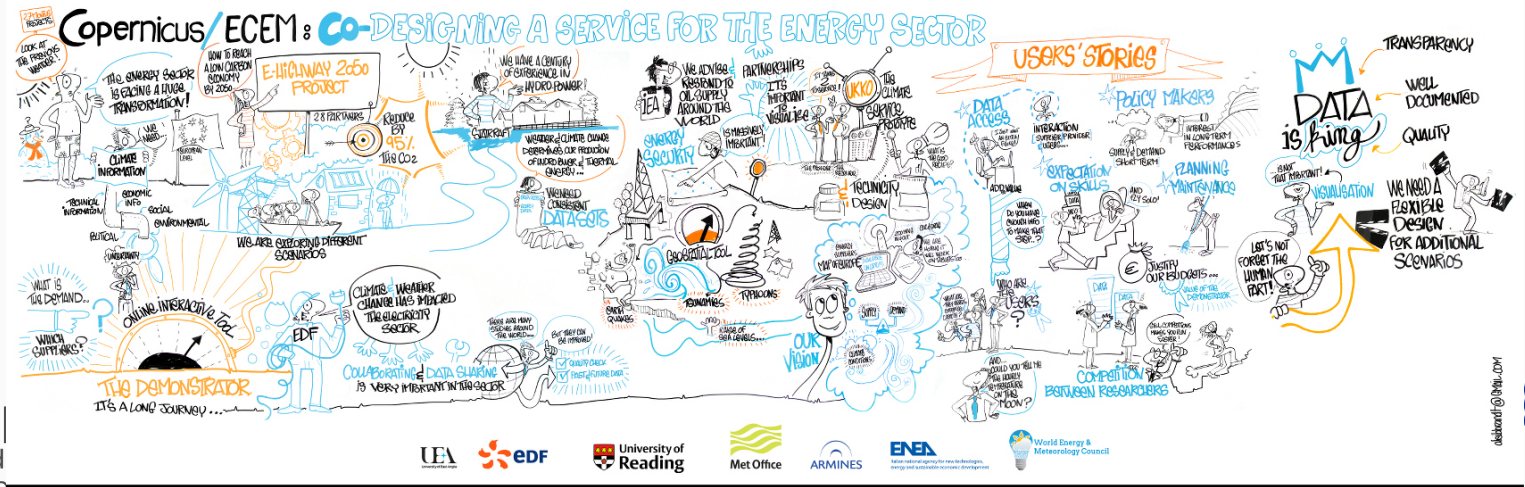
ECMWF · European Commission

Stakeholder Engagement: Workshops



Climate variables

- ★ Assessing ERA-Interim quality by comparison to gridded observed data (over land areas) for various variables
- ★ Emphasis here on Climate Variables of greatest relevance to Renewable Energy (radiation/sunshine and wind), but others (e.g. temperature, RH influence Demand, precipitation influences HEP) are also relevant
- ★ ERA-Interim despite possibly being the best Reanalysis is not perfect. We can assess how good it is (when and where) by comparisons with gridded observational datasets. Improving on it is termed bias adjustment

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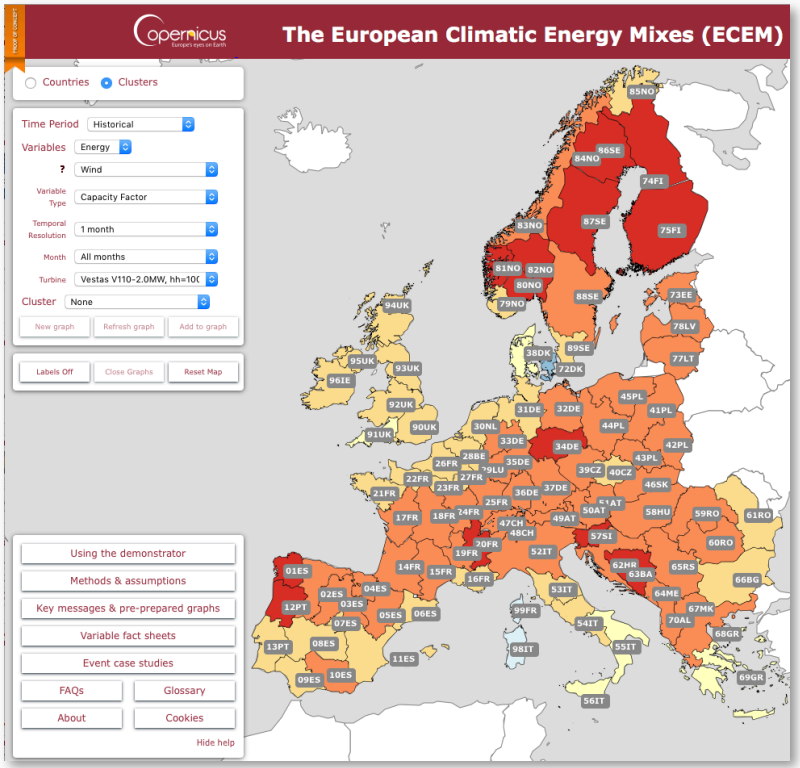
The ECEM Domain



- ERA-Interim regridded to a 0.5°x0.5° grid
- ERA-Interim available every 6-hours. Some variables are from the analysis, some from the forecasts
- Many gridded climate datasets available for assessment on the 0.5° by 0.5° grid
- Gridded climate datasets produced by interpolation of station observations accounting for elevation
- Energy Variables available at country (33) and eHighWay2050 cluster (96) level (+ gridpoint)

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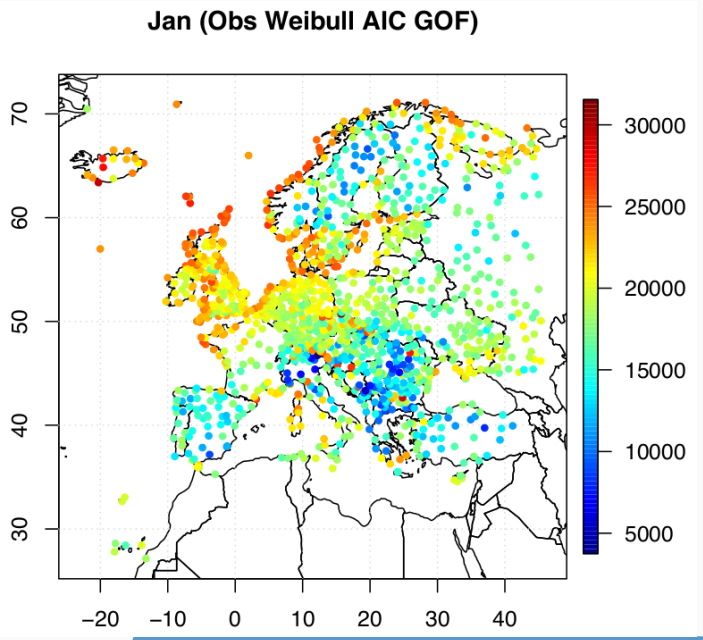
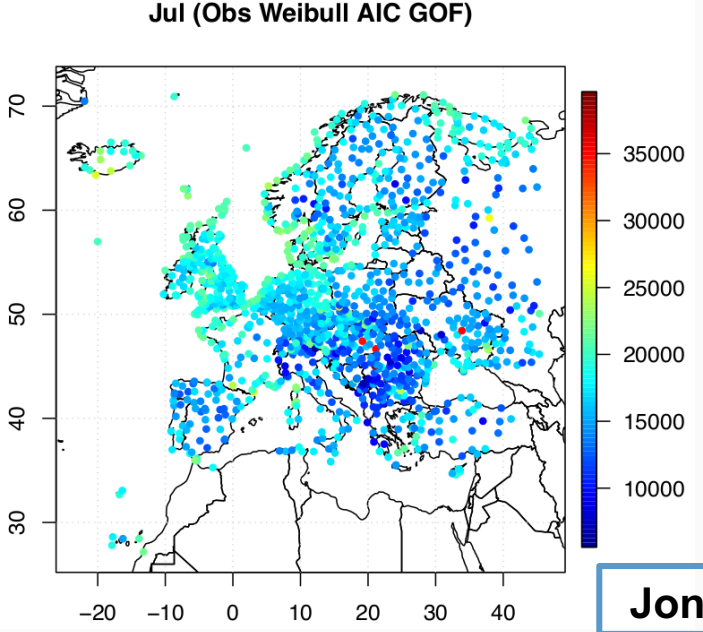
Ensuring Climate variables are fit-for-purpose

Fit of 10 m observations to Weibull distribution





Jones et al (2017)

Low number (blue) good fit; high number (red) poor fit

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Seasonal forecast information in the ECEM Demonstrator

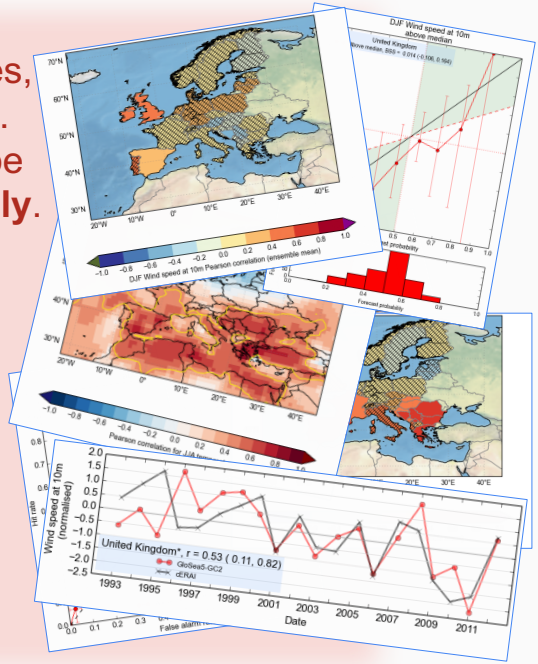
What seasonal statistics can be provided to the energy sector, to help with energy system balancing?

Main points:

1. How skilful are current models in predicting relevant climate variables in European countries?
2. Where there *is* skill, can it be translated into skilful forecasts of energy indicators (supply/demand)
3. Demonstrate the use of seasonal forecast information through Case Studies and in the Demonstrator.

Skill is **varies** across countries, variables, seasons or models.
→ Seasonal forecasts must be used **carefully** and **selectively**.

How skillful do seasonal forecasts need to be, to help in decision-making?



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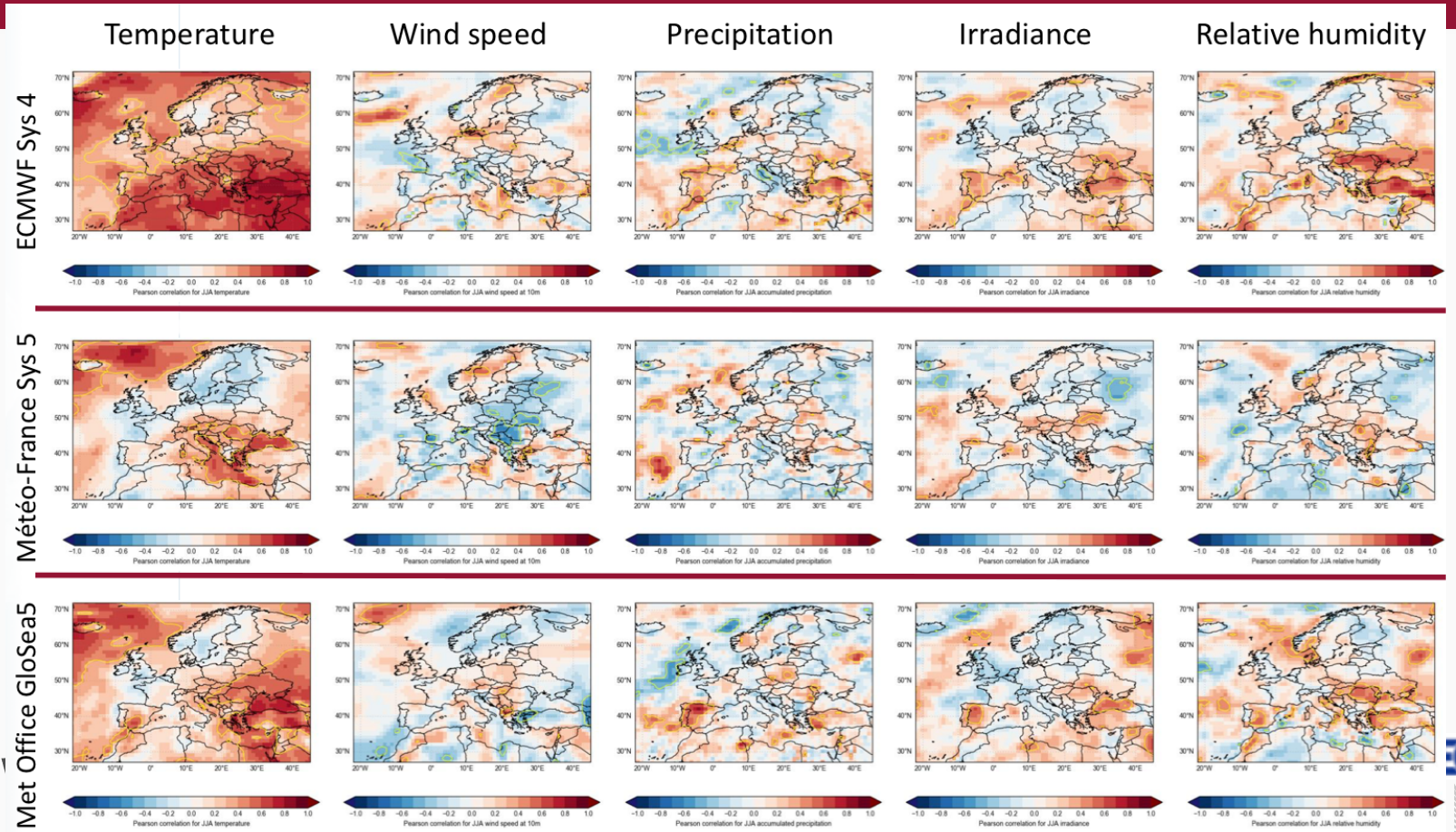
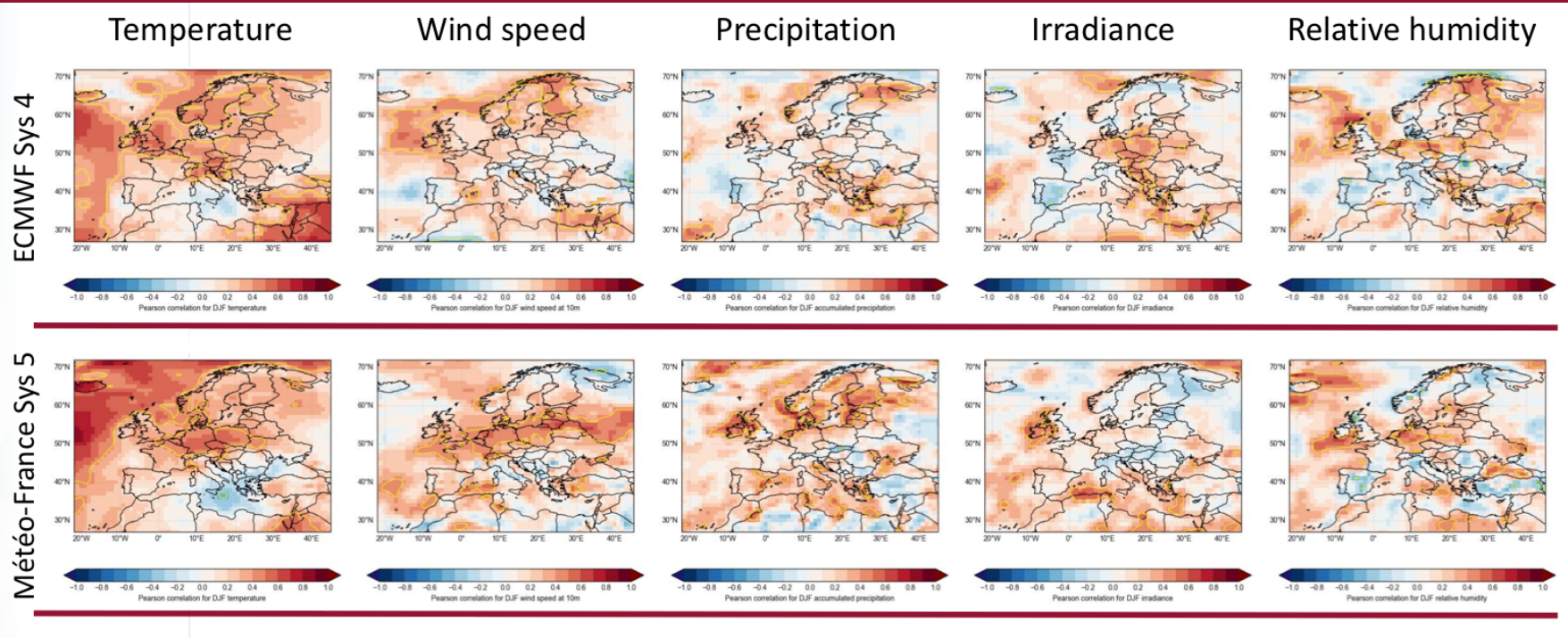
Seasonal forecasting skill: correlations for summer



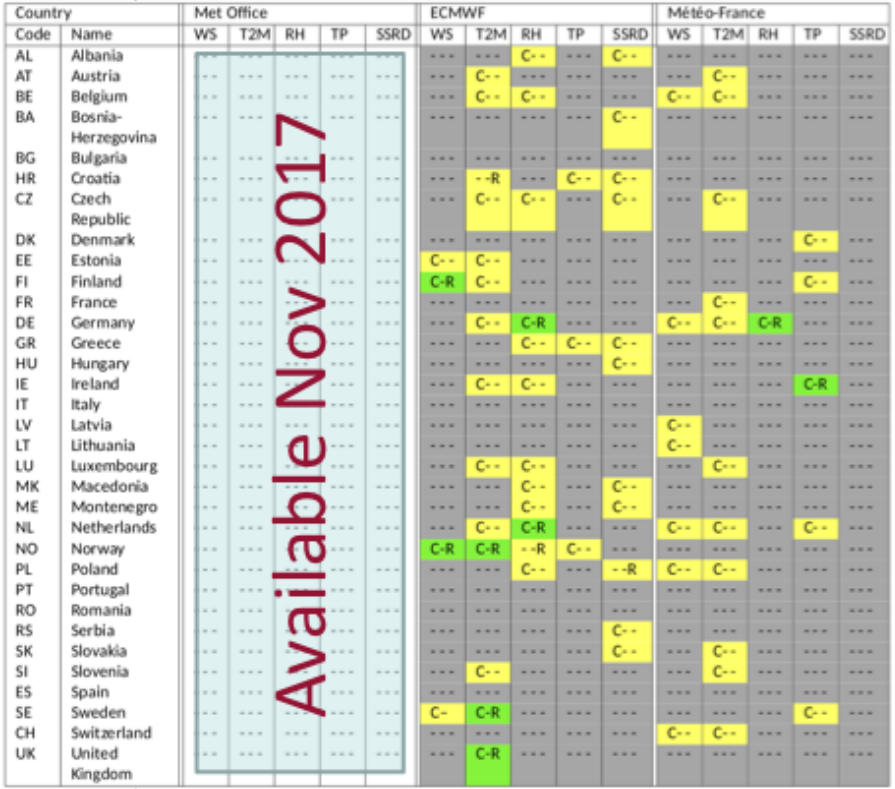
ECMWF

European Commission

Seasonal forecasting skill: correlations for winter



Seasonal forecast: summary table of skill for winter



Country		Met Office					ECMWF					Météo-France				
Code	Name	WS	T2M	RH	TP	SSRD	WS	T2M	RH	TP	SSRD	WS	T2M	RH	TP	SSRD
AL	Albania								C- -		C- -					
AT	Austria							C- -					C- -			
BE	Belgium							C- -	C- -			C- -	C- -			
BA	Bosnia-Herzegovina										C- -					
BG	Bulgaria															
HR	Croatia							- -R		C- -	C- -					
CZ	Czech Republic							C- -	C- -		C- -		C- -			
DK	Denmark														C- -	
EE	Estonia						C- -	C- -								
FI	Finland						C-R	C- -							C- -	
FR	France												C- -			
DE	Germany							C- -	C-R			C- -	C- -	C-R		
GR	Greece								C- -	C- -	C- -					
HU	Hungary										C- -					
IE	Ireland							C- -	C- -						C-R	
IT	Italy															
LV	Latvia											C- -				
LT	Lithuania											C- -				
LU	Luxembourg							C- -	C- -				C- -			
MK	Macedonia								C- -		C- -					
ME	Montenegro								C- -		C- -					
NL	Netherlands							C- -	C-R			C- -	C- -		C- -	
NO	Norway						C-R	C-R	- -R	C- -						
PL	Poland								C- -		- -R	C- -	C- -			
PT	Portugal															
RO	Romania															
RS	Serbia										C- -					
SK	Slovakia										C- -		C- -			
SI	Slovenia							C- -					C- -			
ES	Spain															
SE	Sweden						C-	C-R							C- -	
CH	Switzerland											C- -	C- -			
UK	United Kingdom							C-R								

DJF skill:

Where a skill score is significantly greater than zero, it is marked with a **C** (correlation), **B** (Brier skill score) or **R** (ROC skill score).

Colours: 1 score, 2 scores, 3 scores

Skill is diverse across models, variables and seasons.

Having more significant skill scores can add confidence, but the behaviour of the models should be examined in detail for each use case.

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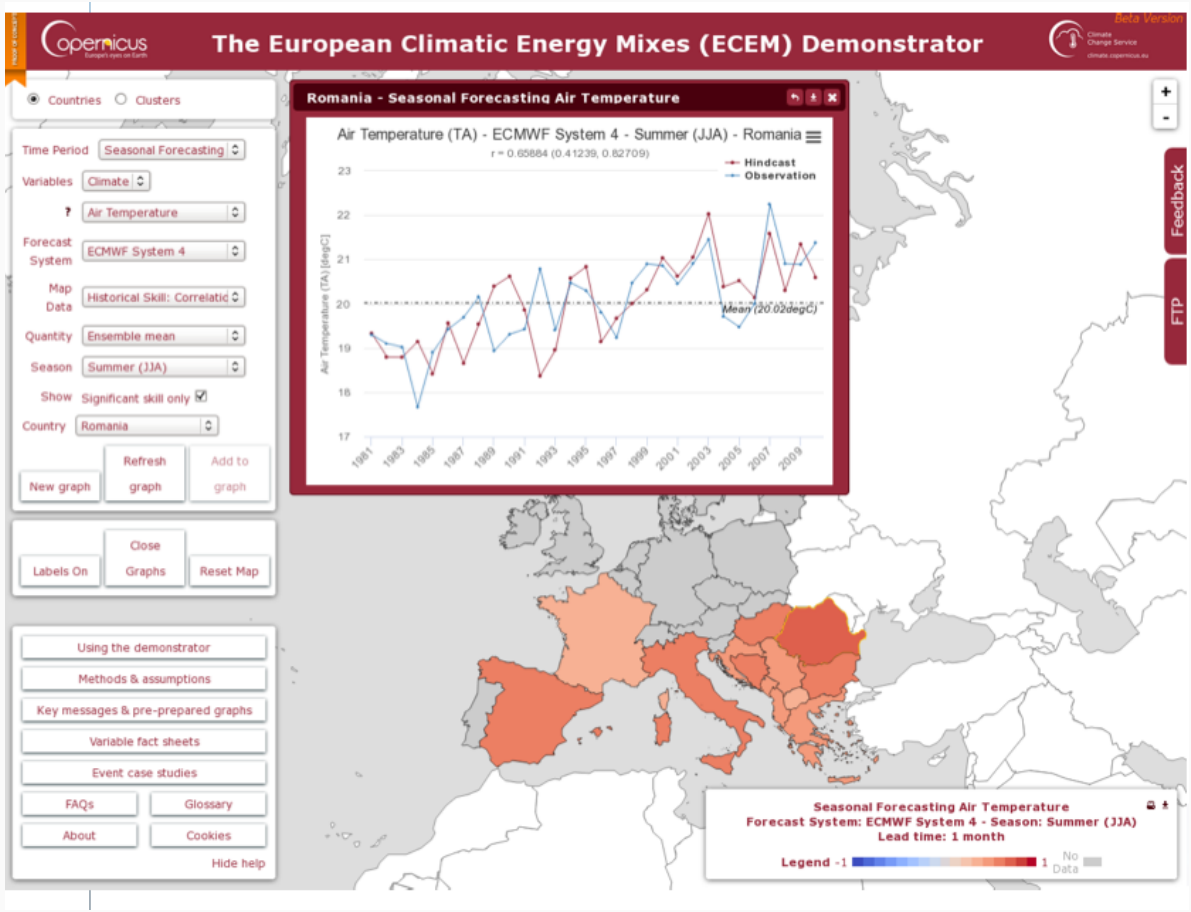
Seasonal forecasting for Summer Temperatures



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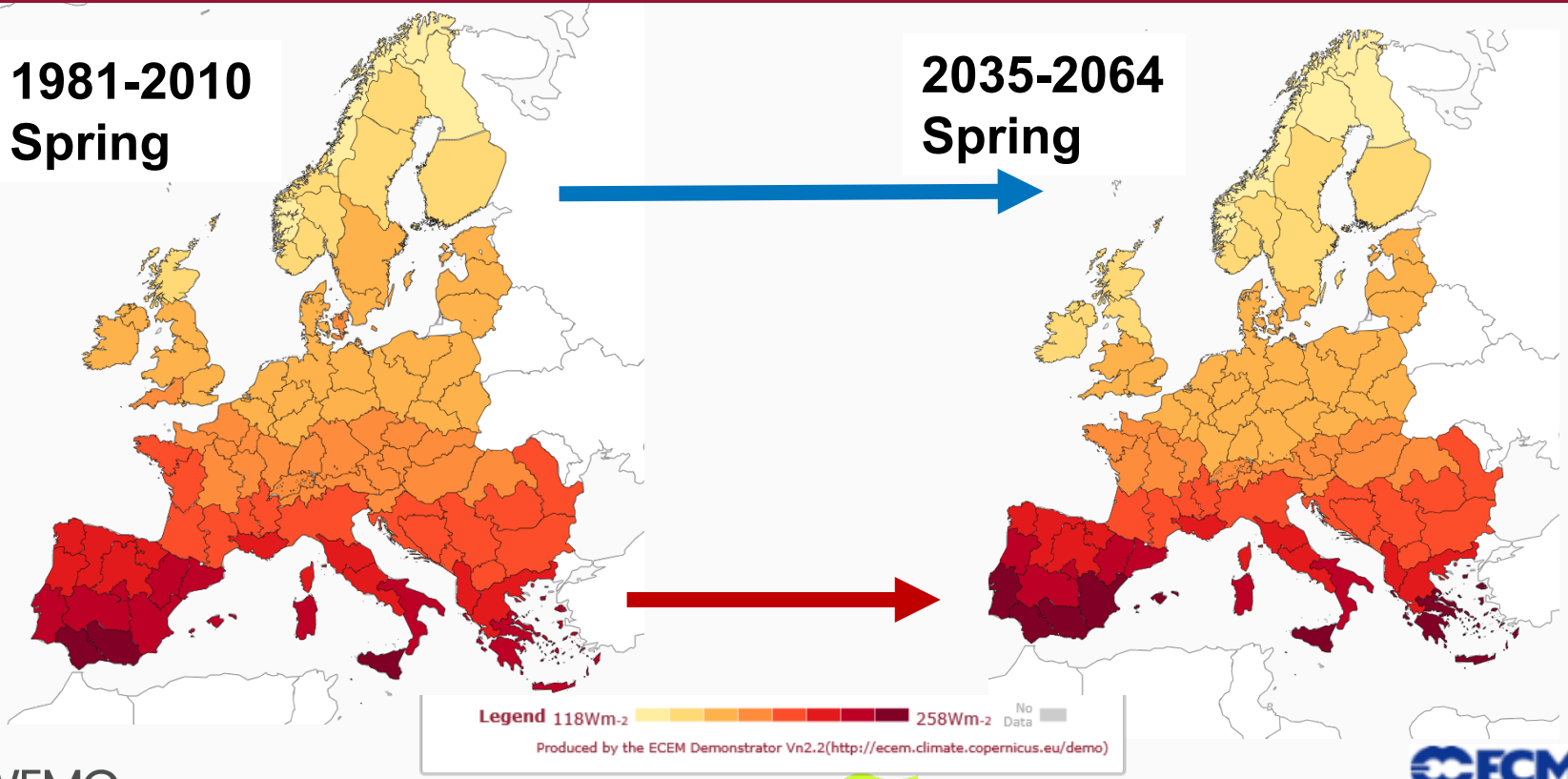
European Commission

Climate Projection (RCP 8.5) Radiation



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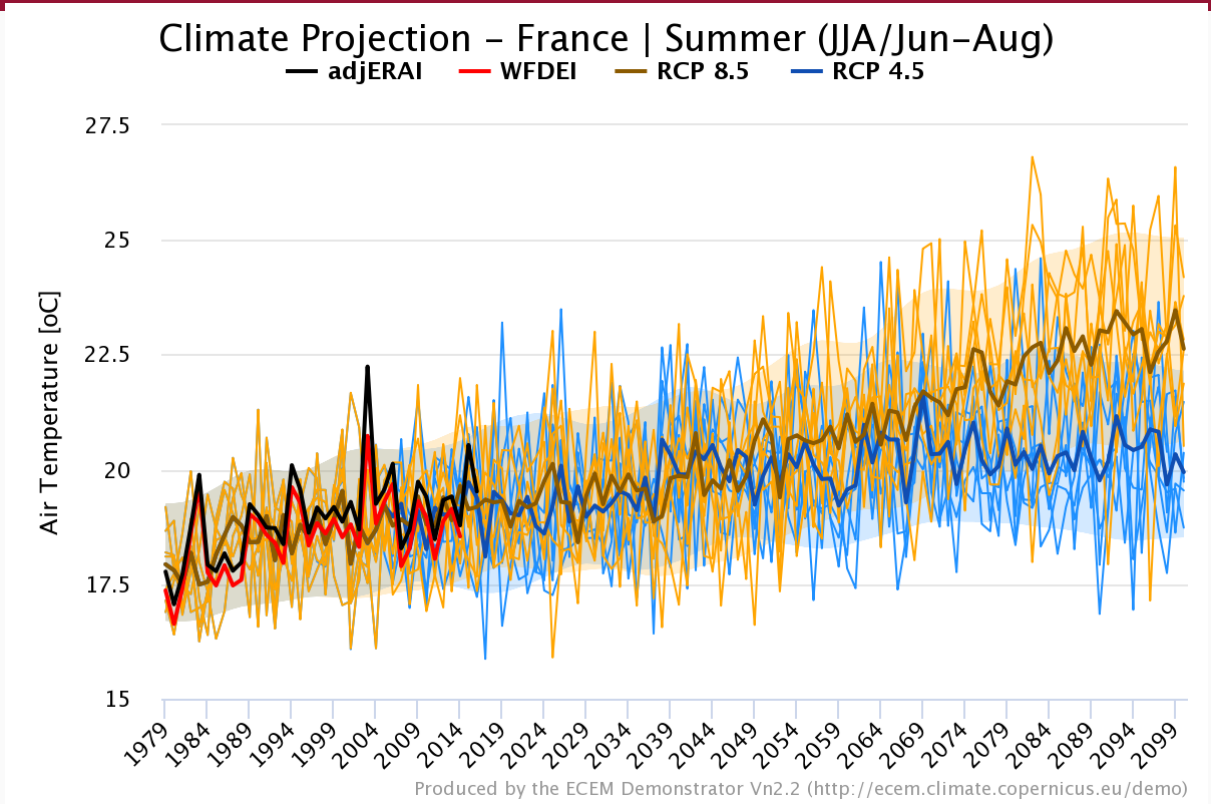
European Commission

Climate Projection time series – Temperature



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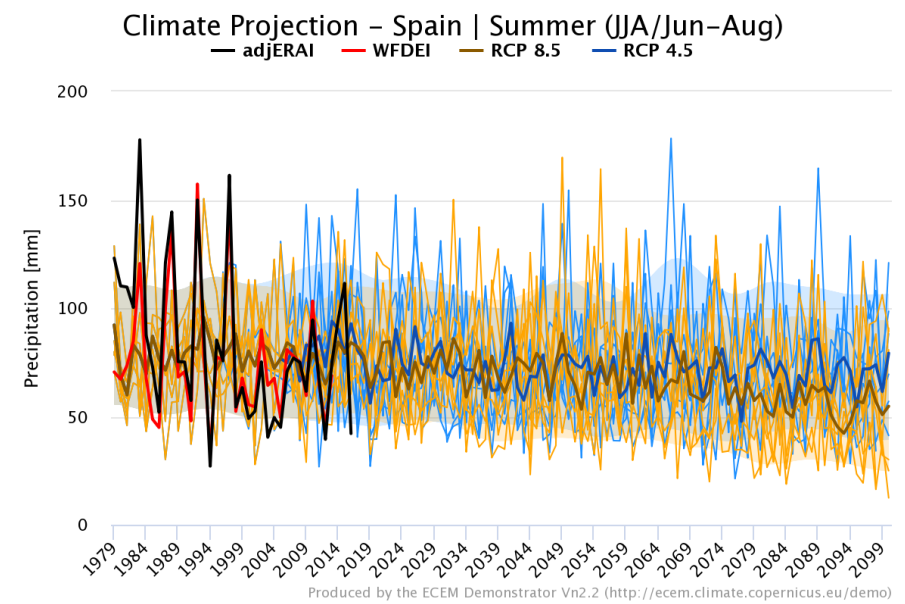
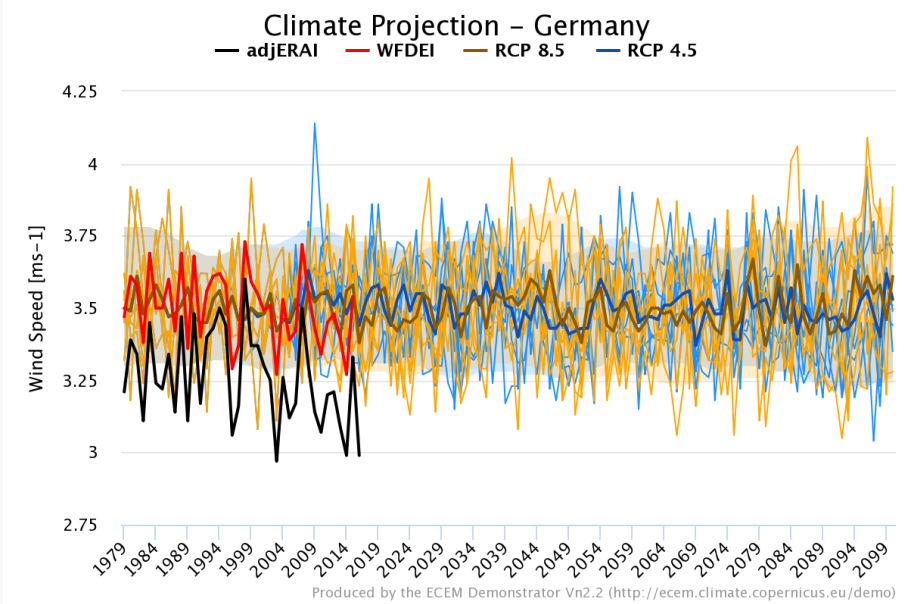
Climate Projection time series – Precip and Wind





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Ensuring we use the most accurate Energy data

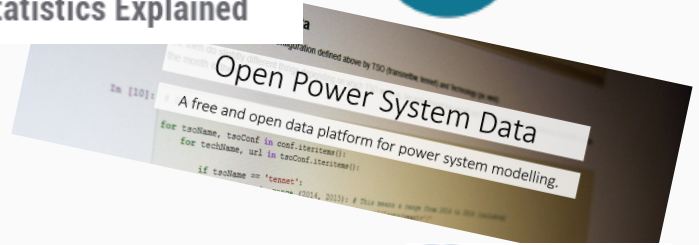
The Energy data challenge:

- ★ There is no single reference database for energy
- ★ Many data sources, inconsistencies between them, incompleteness, access rights (minimal open/free access data) …

- ➔ Need strong support to collect & organise the huge amount of energy data required for a useful service
- ➔ **ECEM is demonstrating that good data allows a good service!**

Rte open data

Enerdata intelligence + consulting



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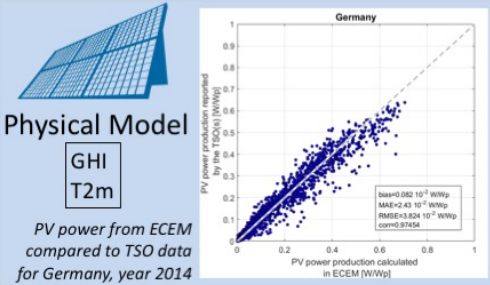
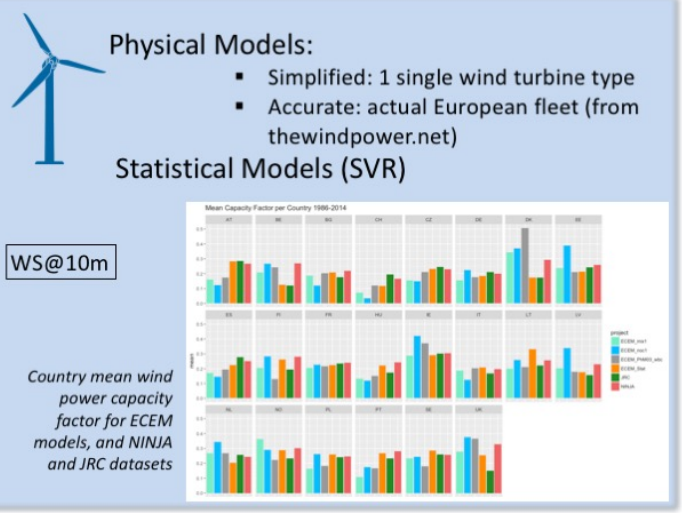
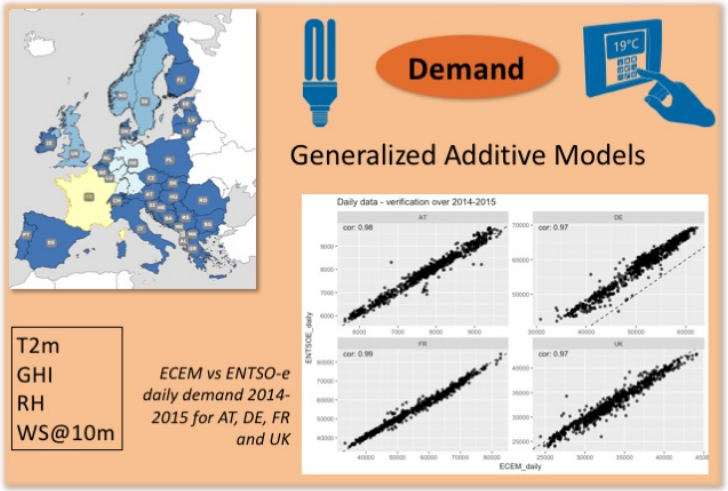
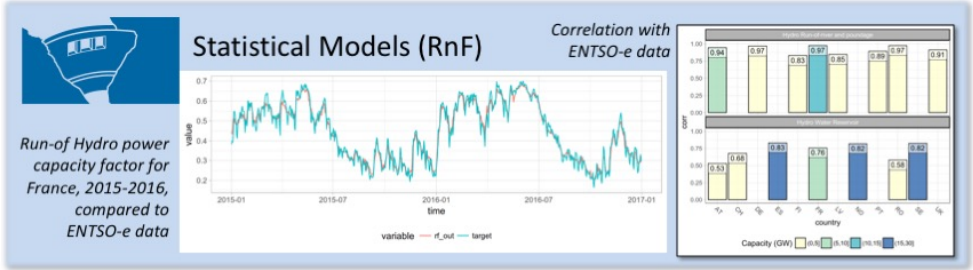
Energy variables: A summary

A mix of **physical** & **statistical** models, based on energy data availability



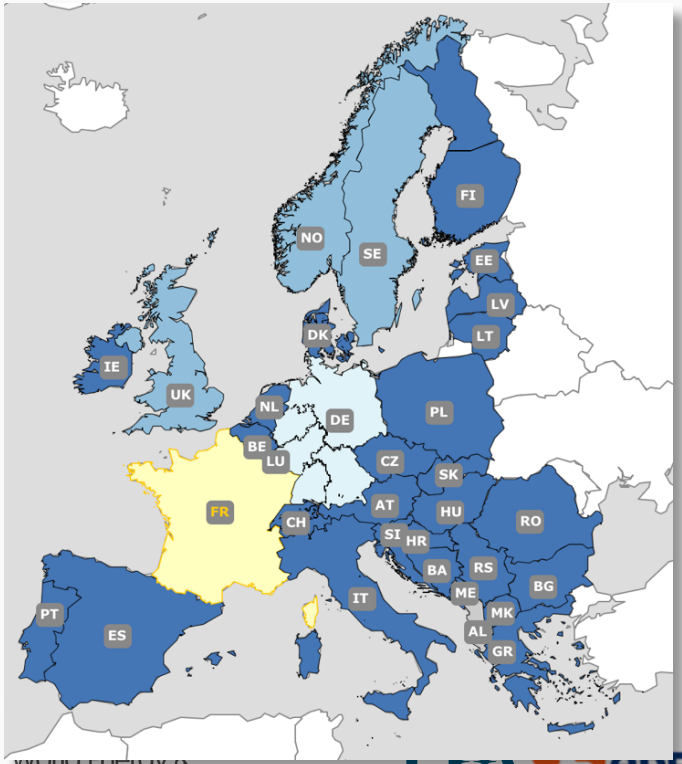






Demand modelling – Historical

Challenge: identify role of climatic factors

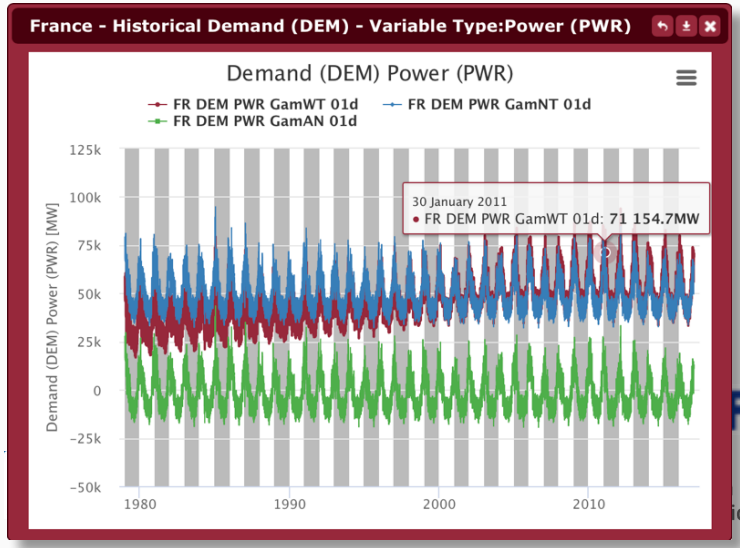


All countries but Albania

- **With long-term trend**
- **Without long-term trend**
- **Anomaly**

France

	Training	Assessment
RMSE	36761 MWh	40194 MWh
MAPE	2.1%	2.2%



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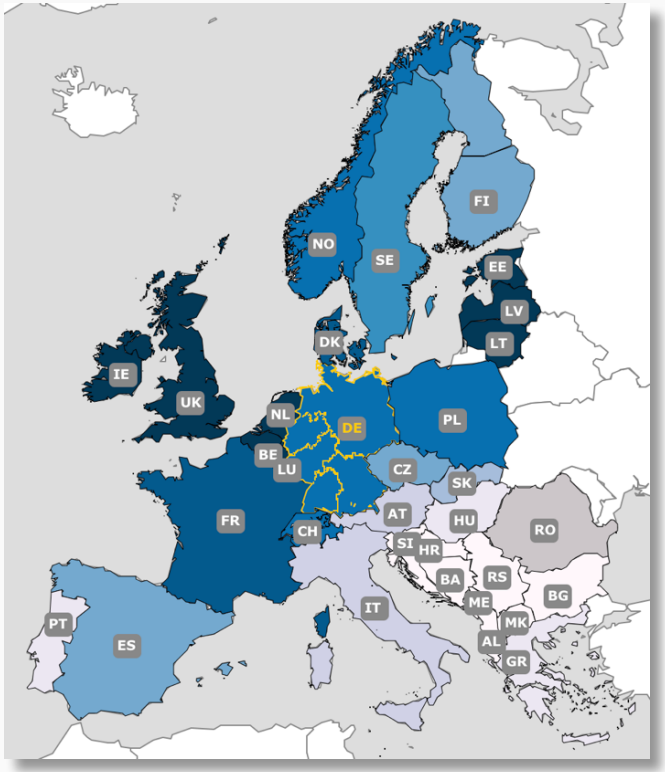
Wind Power – Historical



All countries
- **Capacity factor**
- Power (MW)
- Energy (MWh)

Statistical Model:
- **SVR**
- RnF

Training: 2015-2016
Simulation: 1979-2016

Physical Models:
- **Capacity factor**
- Power (MW)
- Energy (MWh)

➢ **Simplified:**
- **Enercon E70-2.3MW**
- **Gamesa G87-2.0MW**
- **Vestas V110-2.0MW**

➢ **More Accurate:**
- **Actual Fleet**

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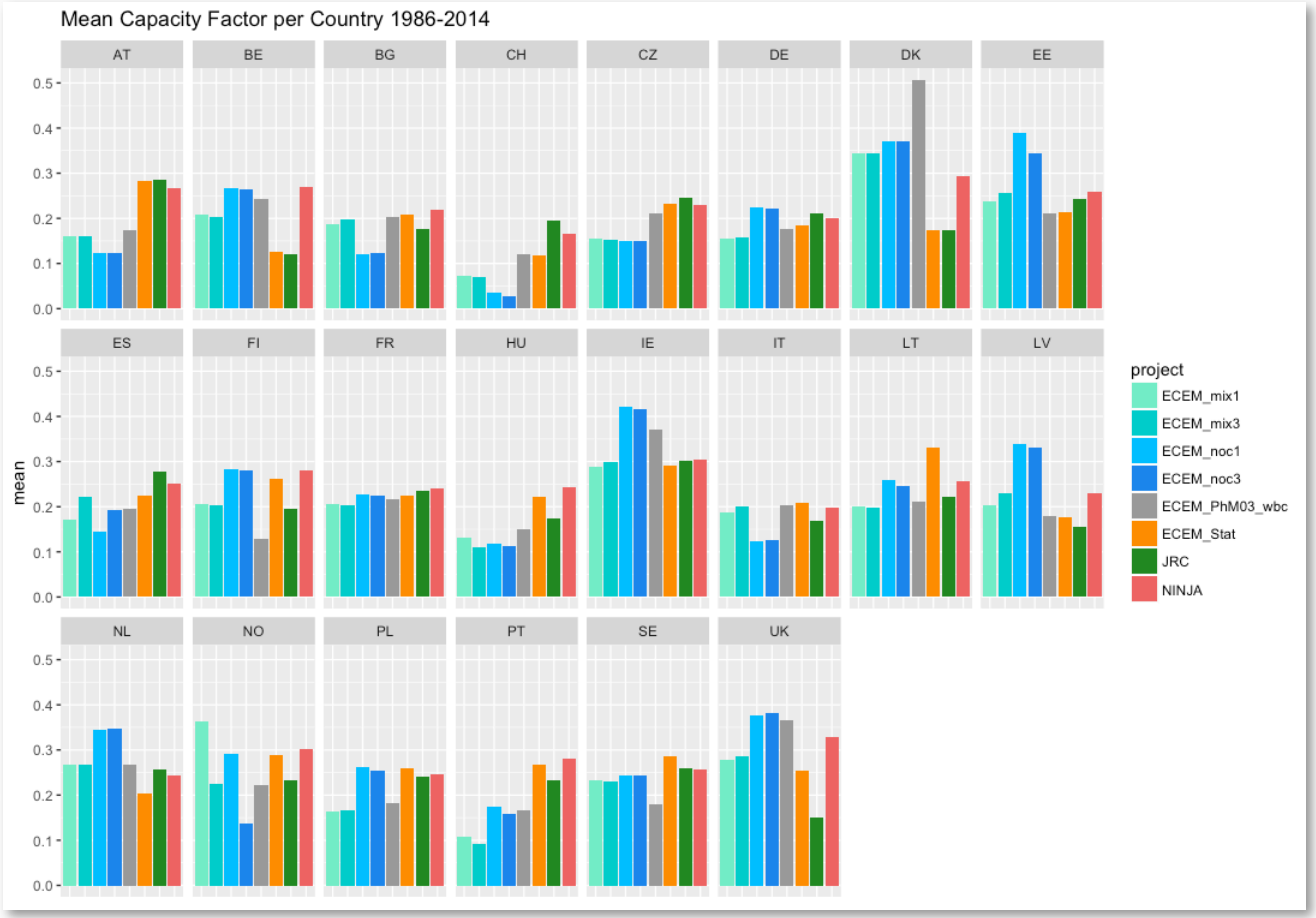
Wind Power – Country Mean Capacity Factor



ECEM Phys BA WS mod1

ECEM Phys BA WS mod3

ECEM Phys noBA WS mod1

ECEM Phys noBA WS mod3

ECEM Phys single turbine

ECEM Stat

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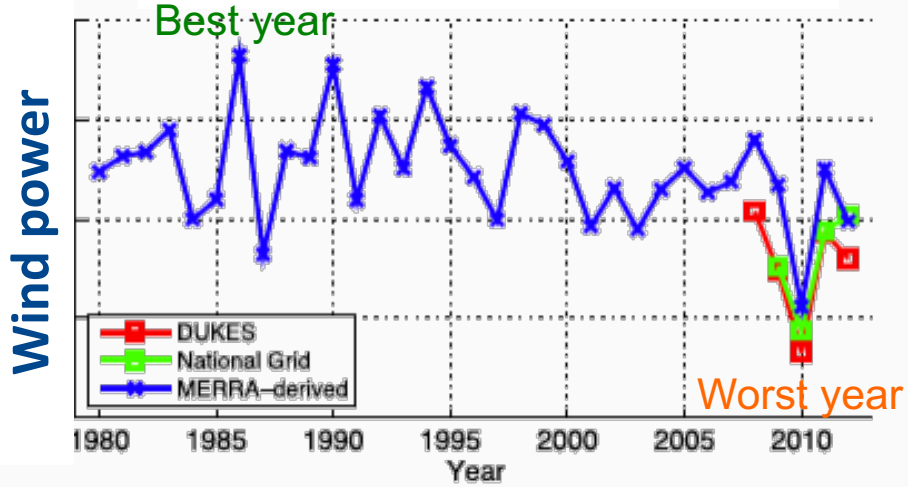
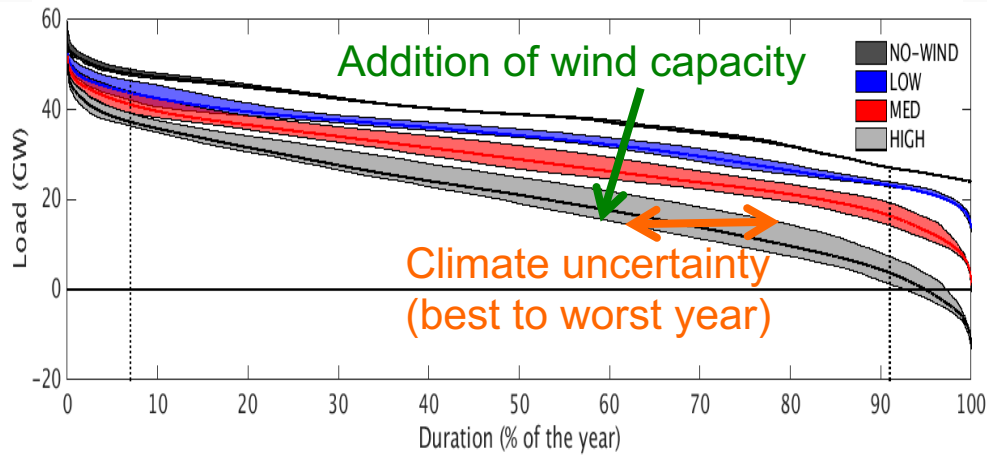
Risk climatologies - examples

★ Investor/owner/planner: Volumetric generation risk

Annual-total wind production



Load-duration



★ Ideas: p5-p95 of production volume for RE, p5-p95 of annual hours at a specified load level for conventional plant ,"best" and "worst" case years, Curtailment, Spatial correlations maps for neighbouring zones

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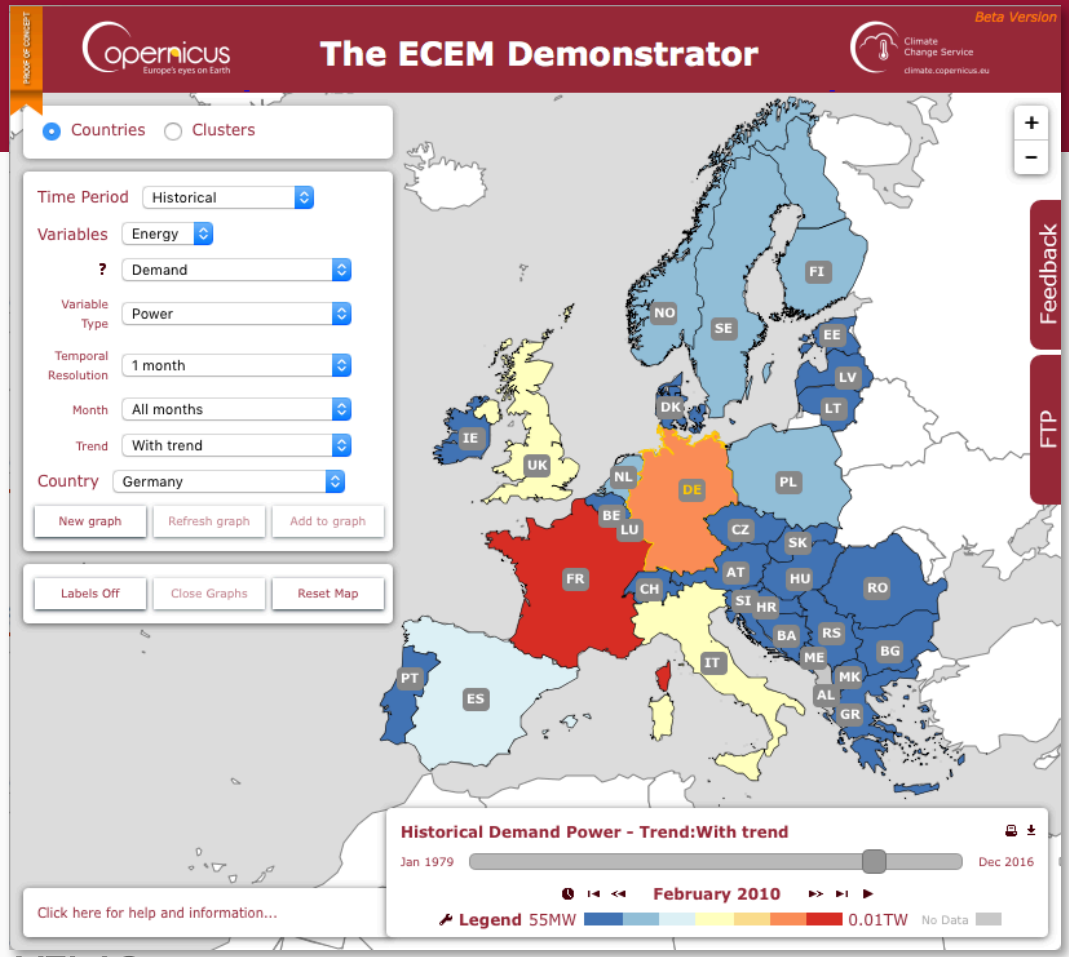
Cannon et al (2015, RE)
Bloomfield et al (2016)

An online interactive tool to test energy mixes



http://ecem.climate.copernicus.eu/demo

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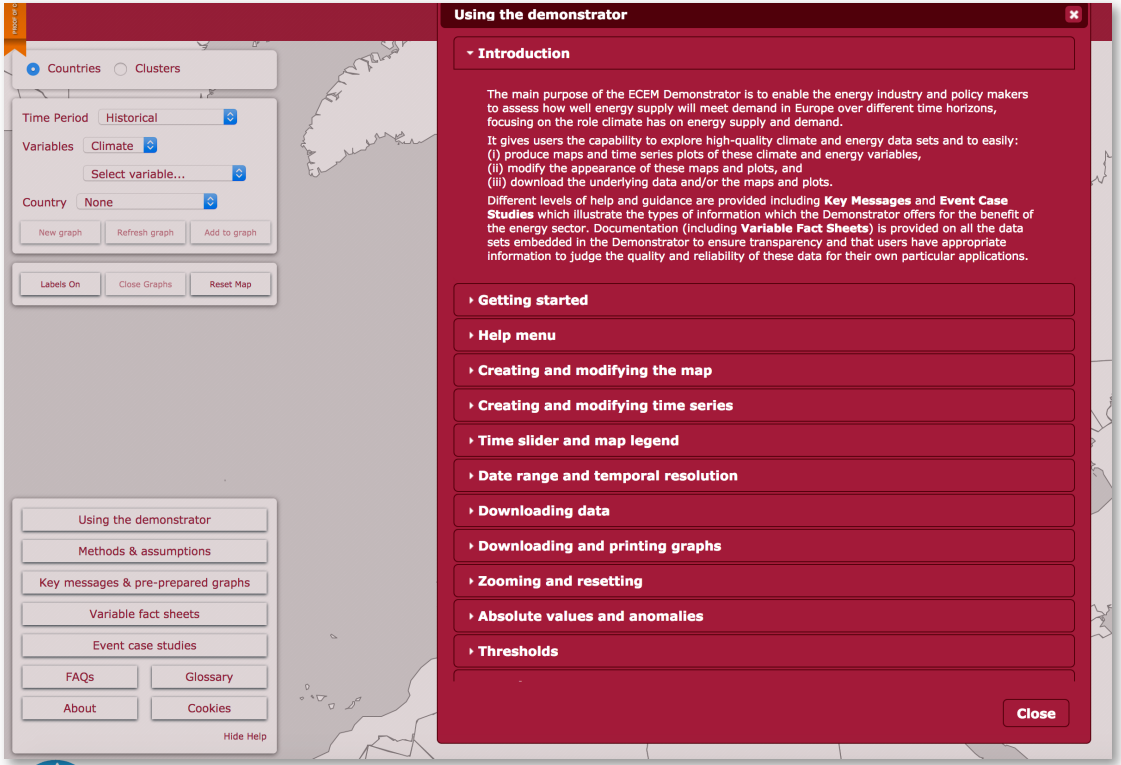
General Documentation and Key Messages



EUROPEAN CLIMATIC ENERGY MIXES (ECEM)

KEY MESSAGES

ECEM KM 01

A warming Europe

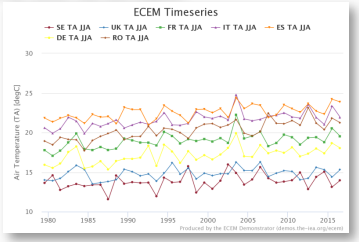
A series of Key Messages for the European energy sector based on the analysis of data in the ECEM Demonstrator.

Key messages: A warming Europe

- Temperatures have risen consistently across Europe over the last ~40 years
- In countries such as Germany the warming has been strongest in winter whereas in Spain, for example, it is strongest in summer
- At the same time, variability from year-to-year and day-to-day persists, and cold events have continued to occur in recent years
- Temperature is a major driver of the ECEM models for energy demand and of solar and hydro supply thus these trends and patterns of variability will impact estimates of these energy variables

How do we know Europe is warming?

Warming trends are evident in time-series plots of historic air temperature data (°C) for 1979-2016 including those for the seven countries shown here (Sweden, UK, France, Italy, Spain, Germany and Romania). The plot below shows the trends for summer (June, July and August).



For more information visit
www.ecem.climate.copernicus.eu
or contact the ECEM team at
support@ecem.climate.copernicus.eu

Date of publication: 25 June 2017

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Variables and Event Case Studies Fact Sheets

EUROPEAN CLIMATIC ENERGY MIXES (ECEM)

VARIABLE FACT SHEET
ECEM VFS E01

Energy demand

A series of fact sheets which provide metadata for the climate and energy variables produced by ECEM

1 General

1.1 Description
1.2 Units
1.3 Links
1.4 Data format
1.5 Keywords
1.6 Contact

2 Dataset coverage

2.1 Geographic area
2.2 Temporal resolution
2.3 Time period
2.4 Spatial resolution

3 Usage

3.1 License conditions
3.2 Citation(s)

4 Lineage statement

4.1 Original data source
4.2 Tools used in production of indicators

5 Data quality

For more information visit
http://ecem.climate.copernicus.eu
Date of publication: 12 June 2017

EUROPEAN CLIMATIC ENERGY MIXES (ECEM)

EVENT CASE STUDY
ECEM CS 001

Winter 2009-2010

A series of case studies based on extreme events which illustrate how the ECEM Demonstrator can be used by the energy sector to enhance understanding and support decision making.

Boosting Decision Making

1 Winter 2010 saw amongst the coldest seasonal temperatures and highest power demand in recent history across much of northern Europe, which can be seen in the ECEM demonstrator

2 The impact of a winter like 2010 would be greater today, given the increase of renewables in the energy mix. The ECEM reanalysis shows the UK would have seen a significant drop in wind power capacity factor if 2010 conditions occurred today

Scientific/Technical Advances

1 ECEM has brought together credible data from the climate and energy communities, processed in a consistent way over a range of time scales

2 The demonstrator tool has been valuable for gaining insight into the winter 2010 event and can be used to study other extreme events

3 Analysis of the ECEM datasets has revealed dependencies and risks across European countries and between energy and climate variables

Key Lessons

1 The ECEM reanalysis dataset provides the ability to:

- Investigate an event or type of event in the context of recent history
- Ask 'what if' questions based on todays energy mix and the climate drivers

2 The demonstrator tool could be useful for anticipating future risks through:

- Seasonal forecasts
- Climate projections

For more information visit
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Date of publication: 30 June 2017

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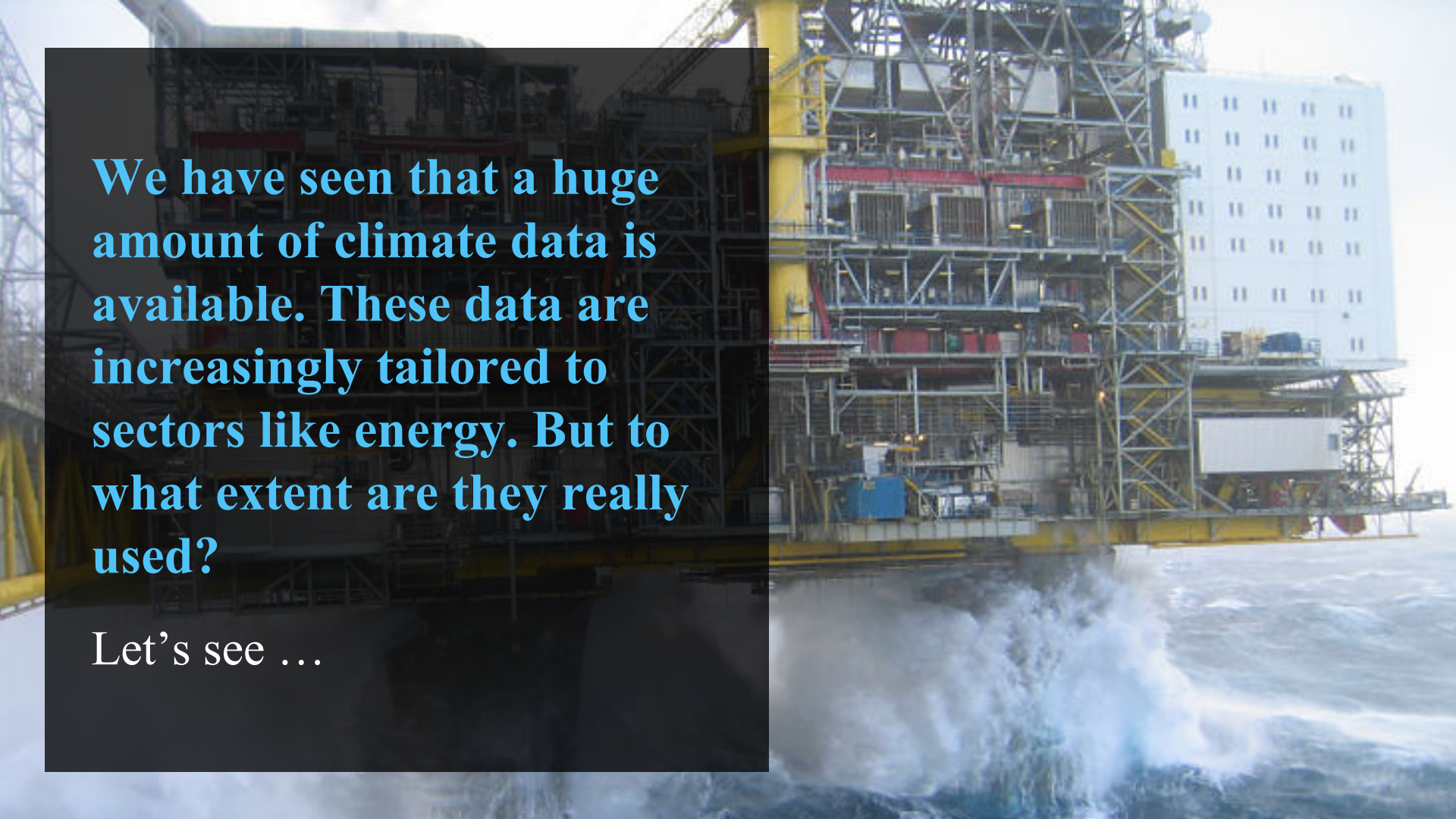
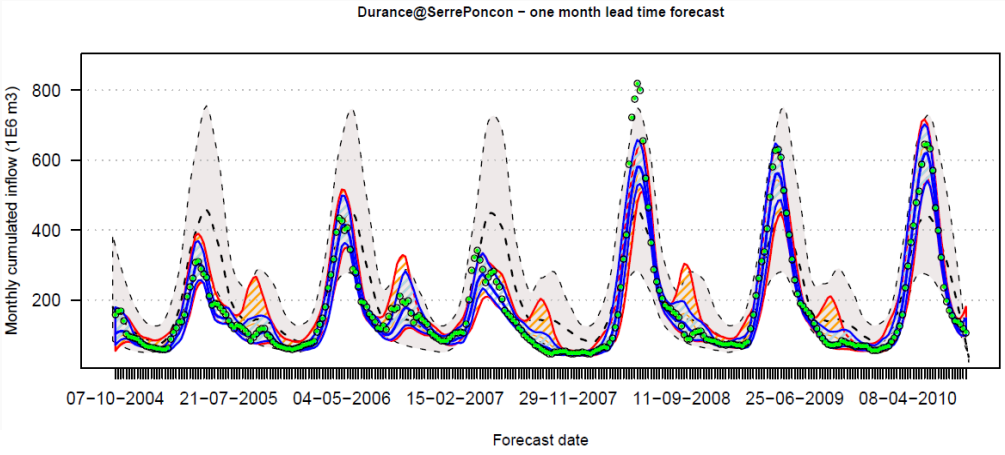


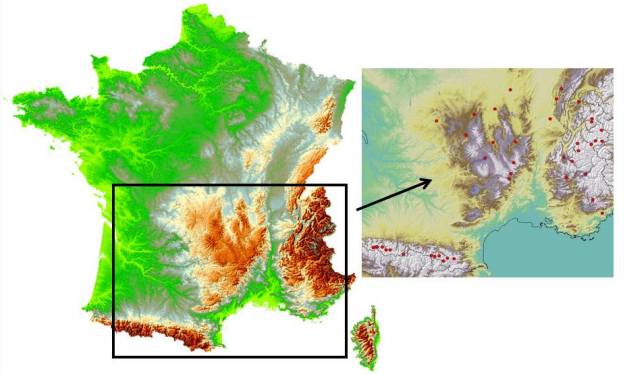
We have seen that a huge amount of climate data is available. These data are increasingly tailored to sectors like energy. But to what extent are they really used?

Let’s see …

Monthly forecasts for hydro power in France

Hydropower represents 20.6% of EDF's installed capacity in France and provides very attractive flexibility during peaks in demand. Forecasts of river flow and water stocks are therefore crucial for the managers of the system





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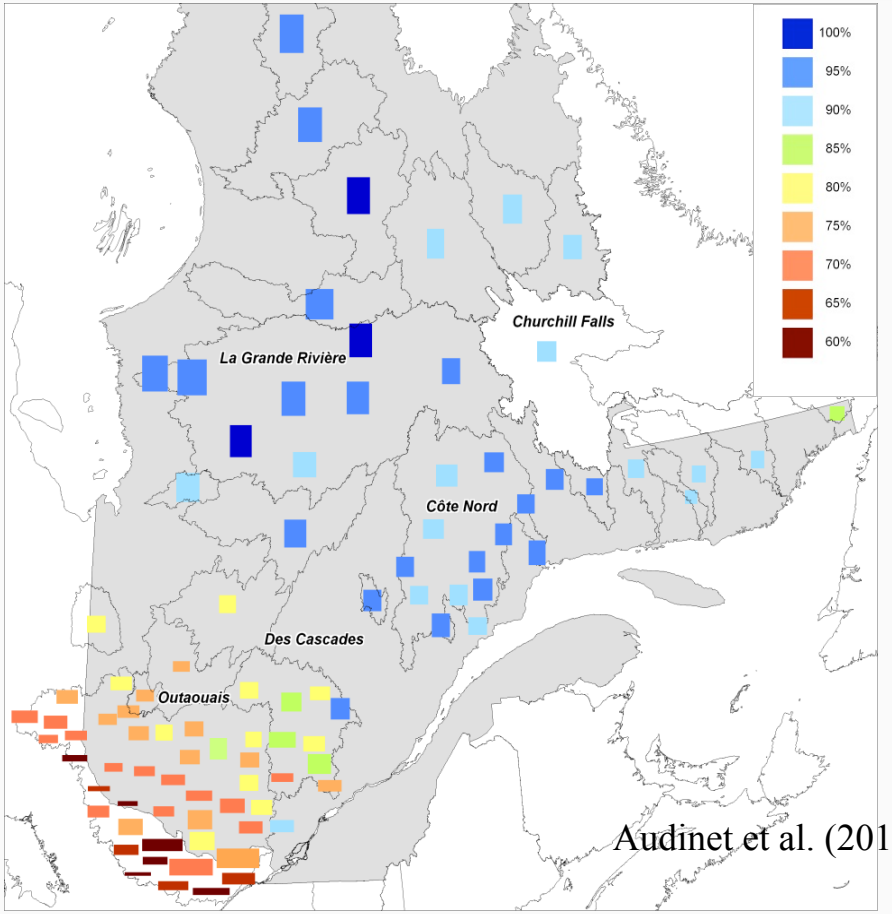
Dubus (2014)

Use of Climate Projections for HydroPower in Canada

In response to adverse weather impacts Hydro-Québec developed a research program to improve knowledge of climate change, business impacts and adaptation solution in the mid- to long-term. Runoff projections based on 90 hydro-climatic scenarios for 2040-2071 were developed.



Audinet et al. (2014)

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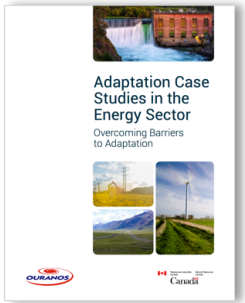
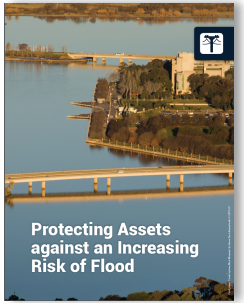
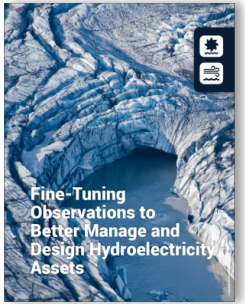
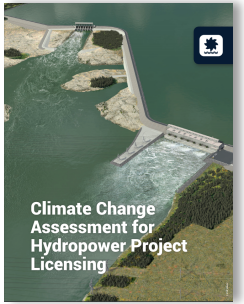
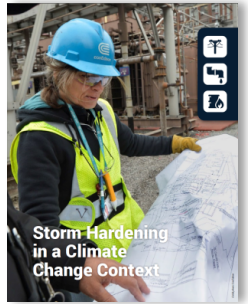
Case studies from Ouranos

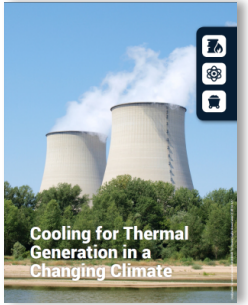


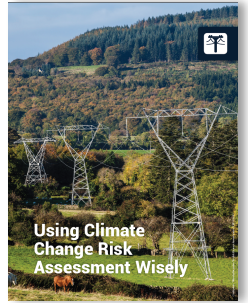












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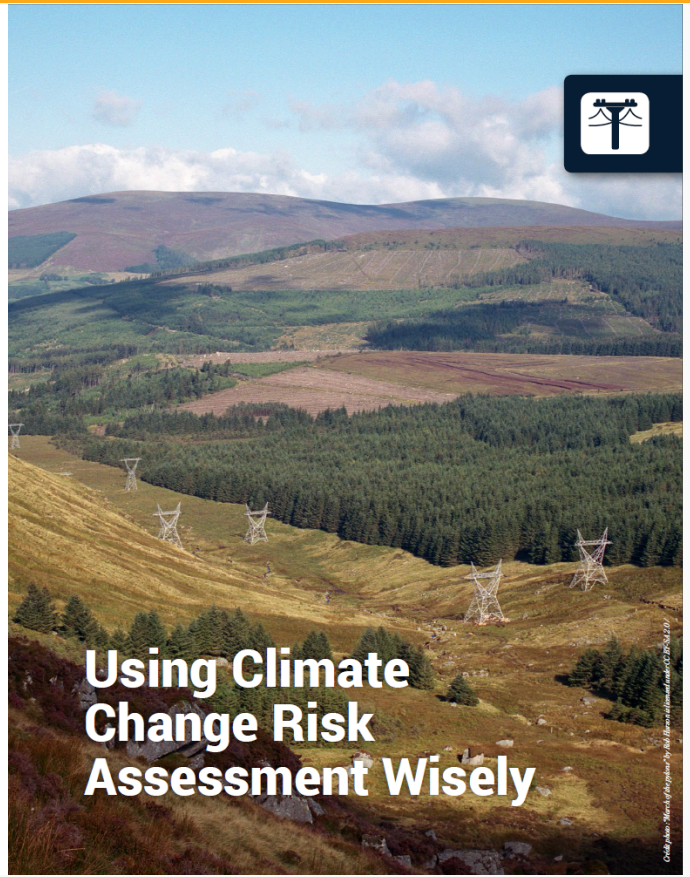
Available at: http://ouranos.ca/en/programs/energy-adaptation-case-studies/

OURANOS

Ouranos' Case study – Ireland Transmission Operator

CASE STUDY 11



Courtesy Braun

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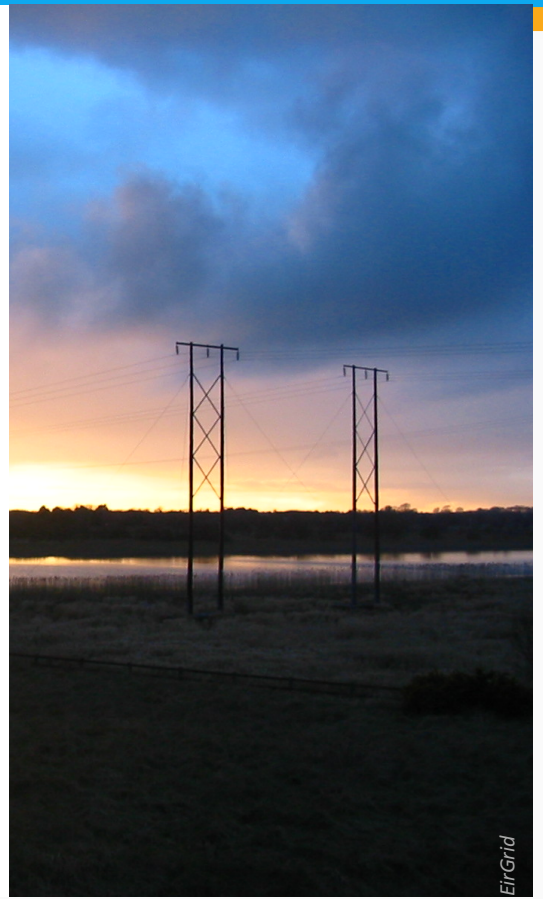
Ouranos' Case study – Ireland Transmission Operator

EirGrid
- System Operator
- Plan, develop, operate and maintain

ESBN
- System Owner
- Approve project
- Infrastructure Agreement

"To fulfil their mandate, EirGrid and ESBN must be aware of how climate change will impact Ireland, what risks it poses to the transmission system and what adaptation methods are available to reduce these risks."
John McGuckin, Engineer in Transmission Engineering & Maintenance, EirGrid

CASE STUDY 11 **Context**



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Ouranos' Case study – Ireland Transmission Operator

Increasing extreme precipitation

- Increase the risk of flood
- Damage to control building of substations
- Assess the need for flood management work

Five-year plan

- Budget for flood-alleviation measures
- Substations at highest levels of risk
- Implementation

The investigation of substation vulnerability

- Geographical Information Systems to provide guidance on the vulnerability of sites to flooding from rivers, lakes, estuaries and the sea.
- Questionnaires to record the knowledge and memory of operational staff regarding flood levels.

CASE STUDY 11 **The Climate Change Risk Assesment**

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Courtesy Braun

Summary

- Energy and Meteorology are closely connected
- Energy systems are already experiencing sizeable impacts, which are likely to become more severe
- Climate services are emerging as robust useful tools for Energy planning, and operations/maintenance
- Despite emerging use of climate in energy (and other) sectors, there is a strong need:
  - to improve knowledge of meteorological data and processes
  - to improve access to meteorological and energy data for improved products

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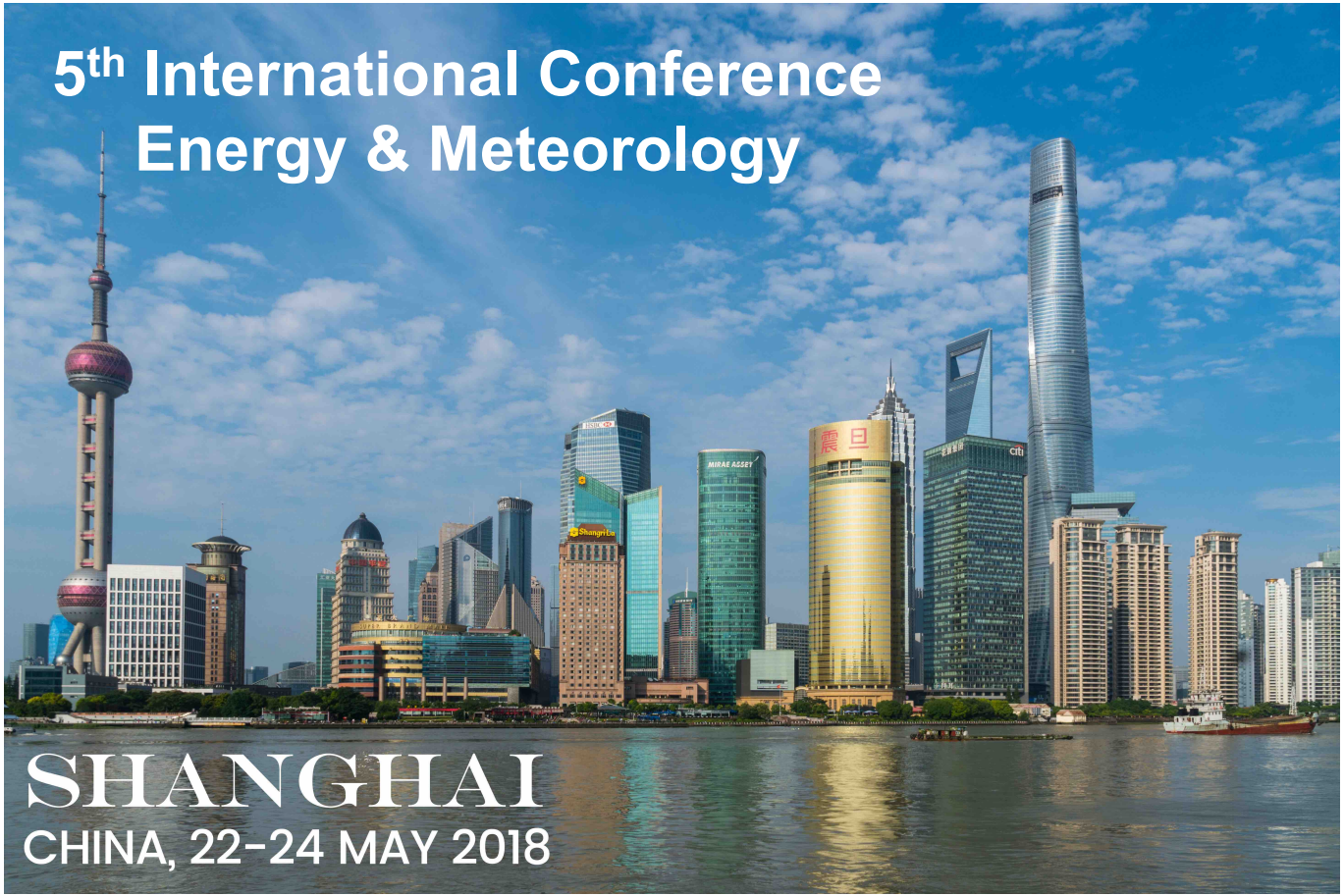

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Get in touch!

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