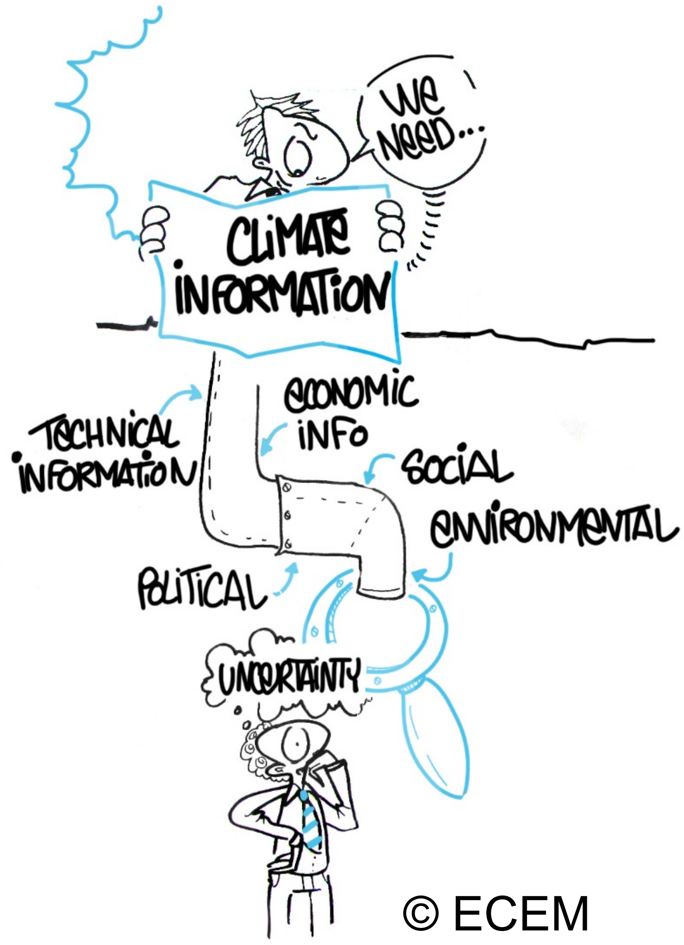
Understanding climate predictability and uncertainty (seasonal to decadal)



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University of East Anglia

WMO-WEMC-GFCS Summer Course on Climate & Energy

CRU

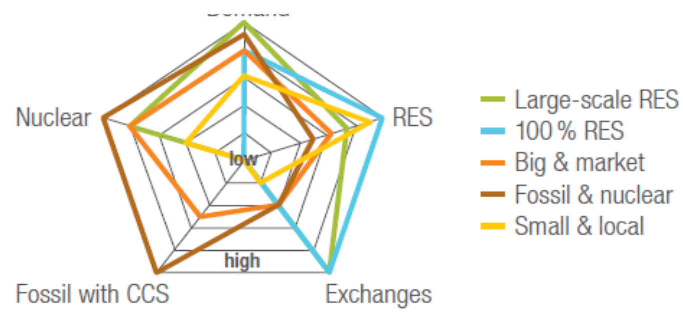
Some definitions

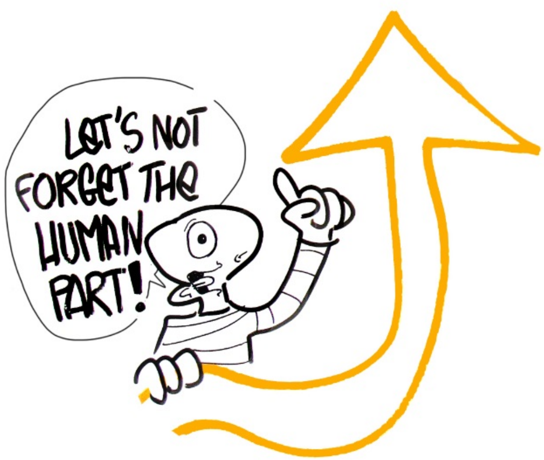
- **Predictability** The extent to which future states of a system may be predicted based on knowledge of current and past states of the system.

Projection A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized.

- **Uncertainty** A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour.

IPCC AR5 WG1 Glossary

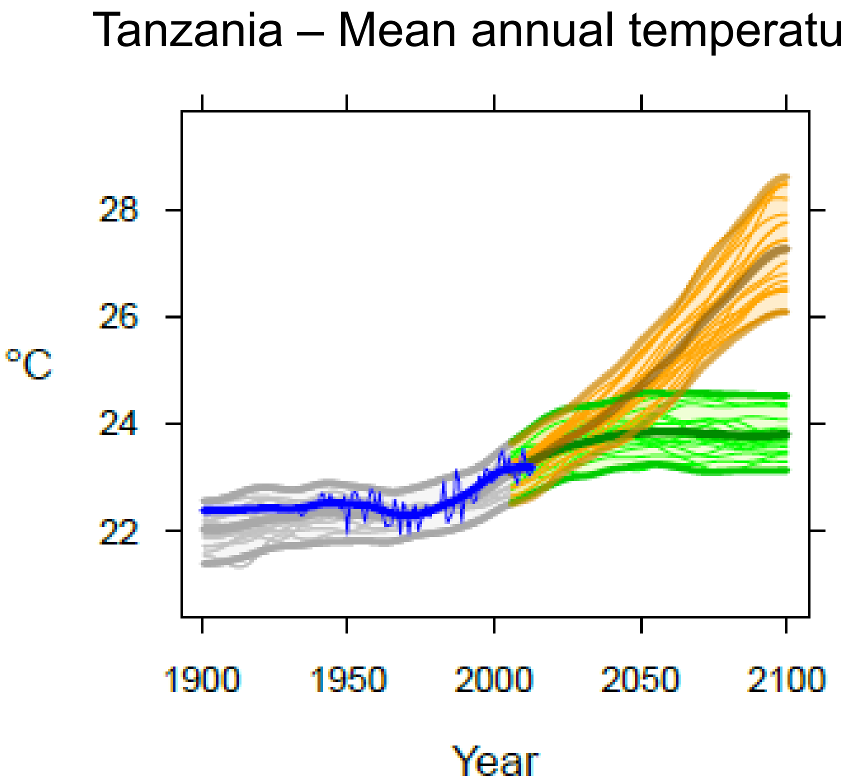


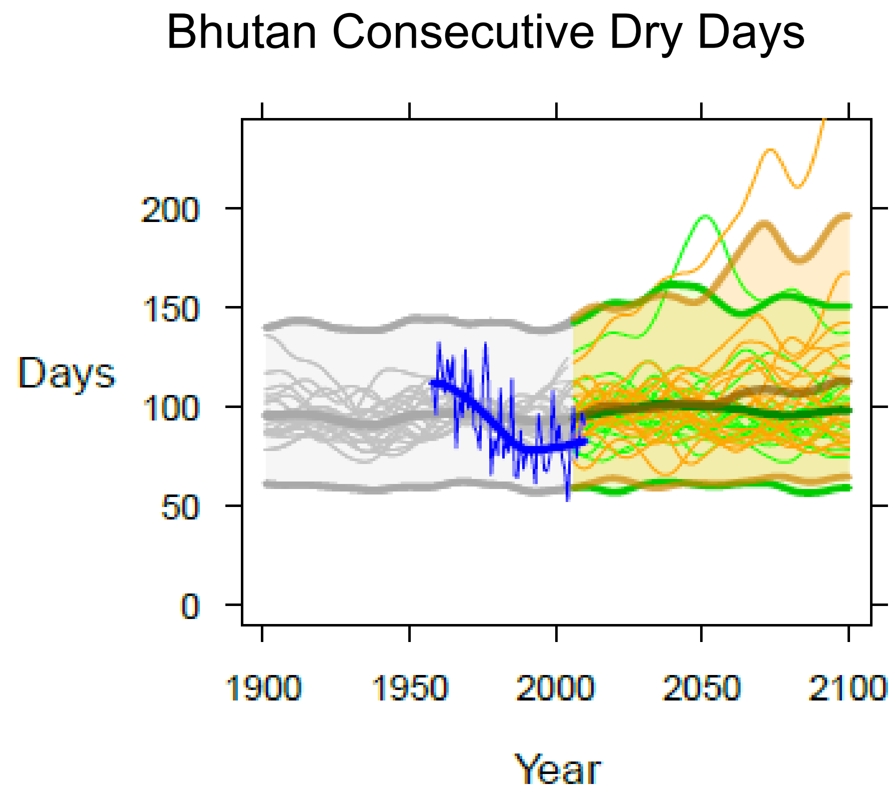


		SSP 1	SSP 2	SSP 3	SSP4	SSP5
	Reference	X	X	X	X	X
RCP Replication	8.5 Wm^{-2}					
	6.0 Wm^{-2}					
	4.5 Wm^{-2}					
	2.6 Wm^{-2}					

Representative Concentration Pathways (RCPs)
Shared Socioeconomic Pathways (SSPs)

What are you 'take away' messages from these examples?



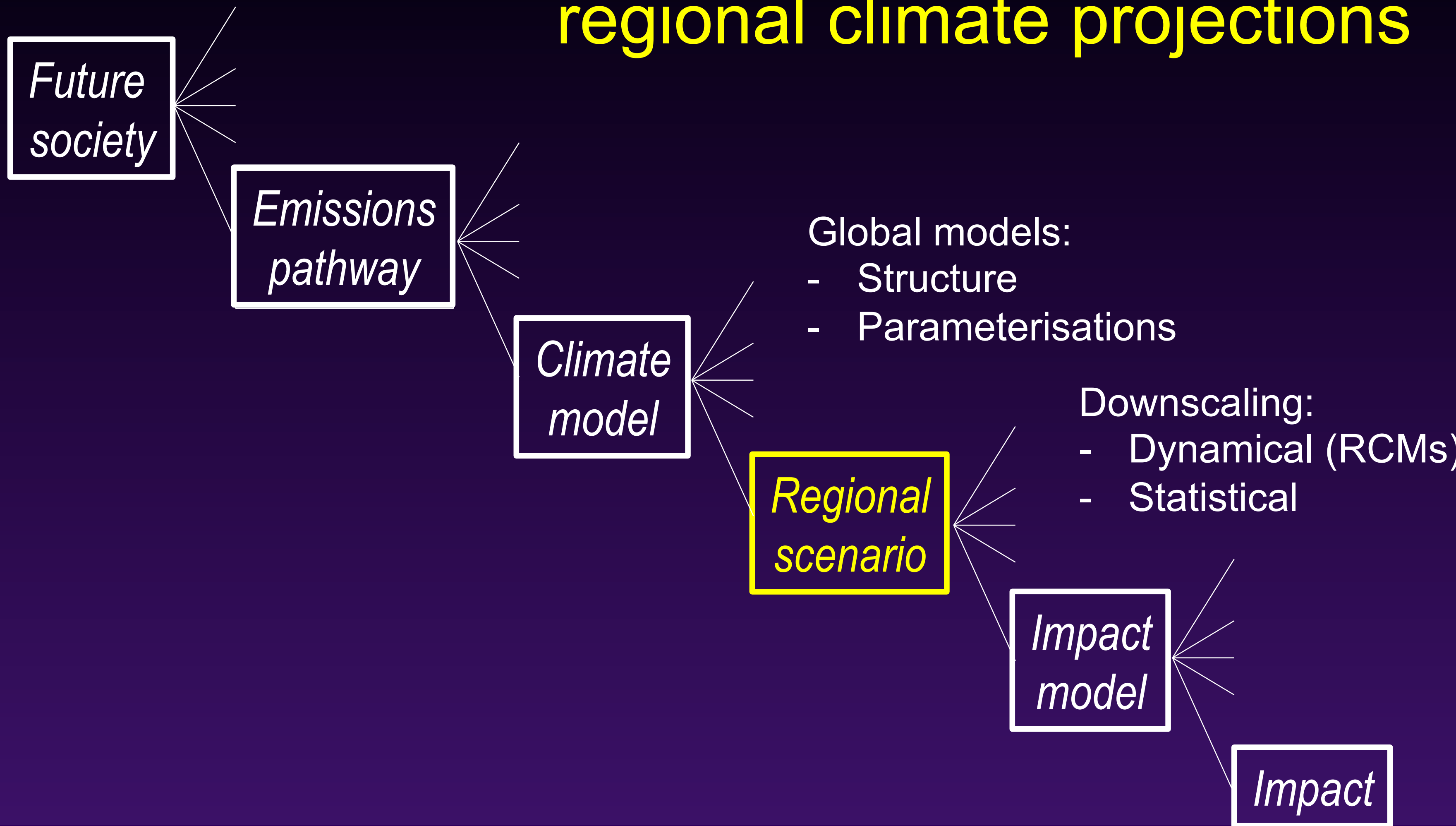


Based on about 20 CMIP5 GCMs: shading shows model spread (5th-95th percentile), thick line is the ensemble mean, thin lines are individual models. Orange: RCP8.5, Green: RCP2.6

Blue: HadEX2 observations.

Goodess et al., 2016: *Nature Scientific Data*, in preparation

A classical ‘top down’ view of the cascade of uncertainties in regional climate projections

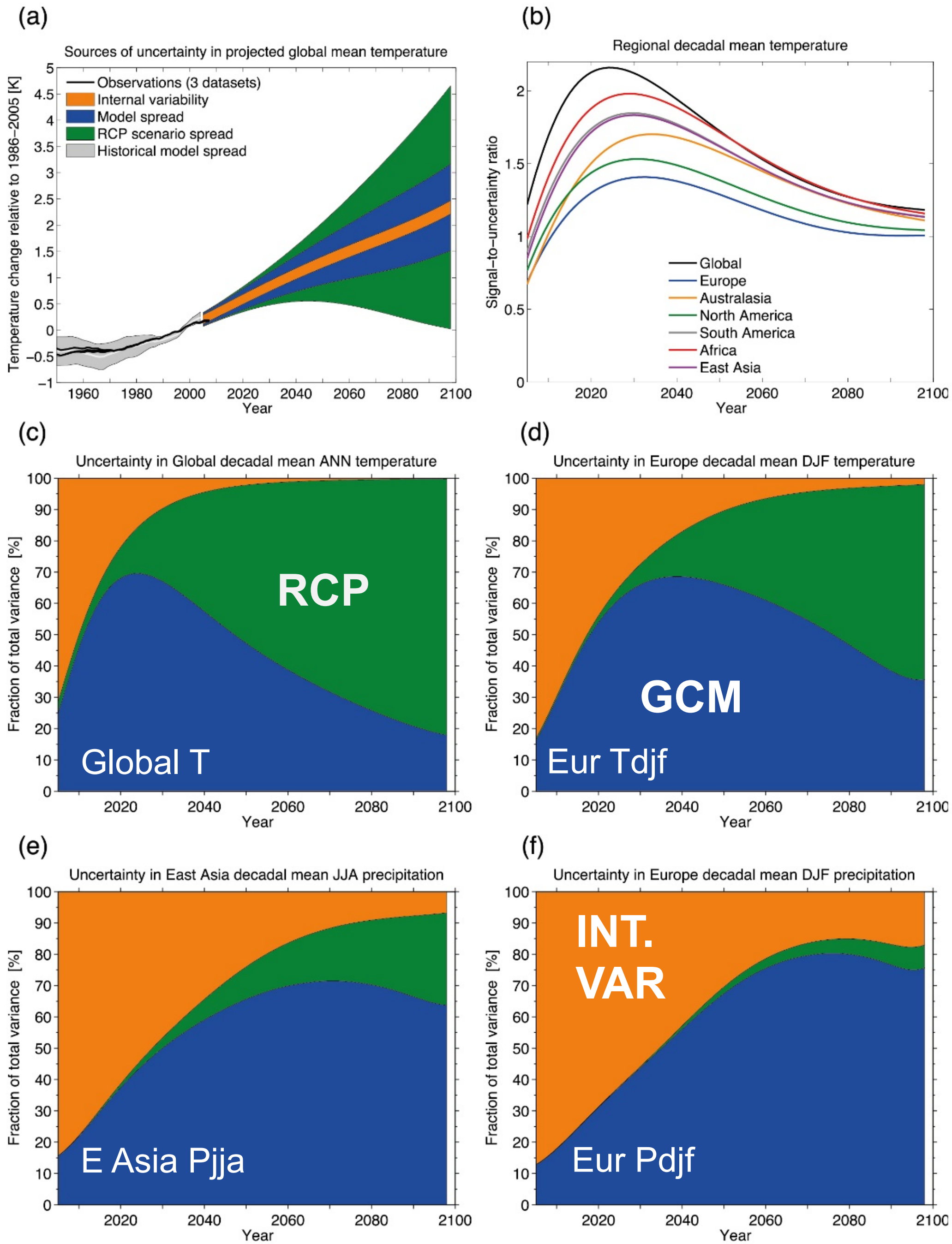


Rob Wilby
Loughborough University

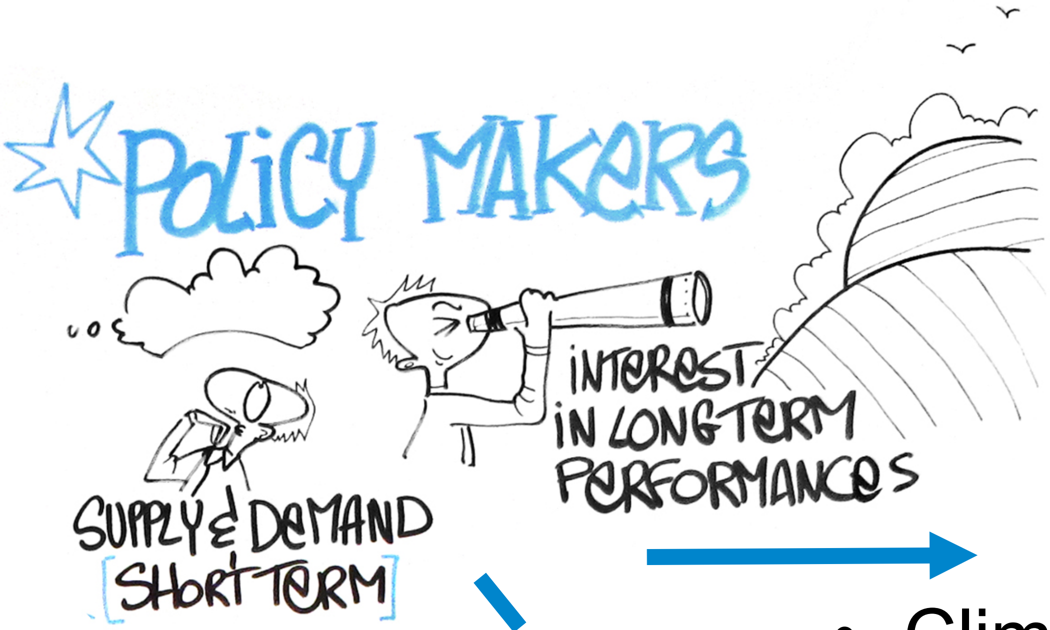
Some attempts have been made to ‘partition’ or quantify these different sources of uncertainty –

depends on variable, season, timeframe, location.

Same goes for uncertainty related to downscaling. e.g., Dequé et al., 2011, *Climate Dynamics*

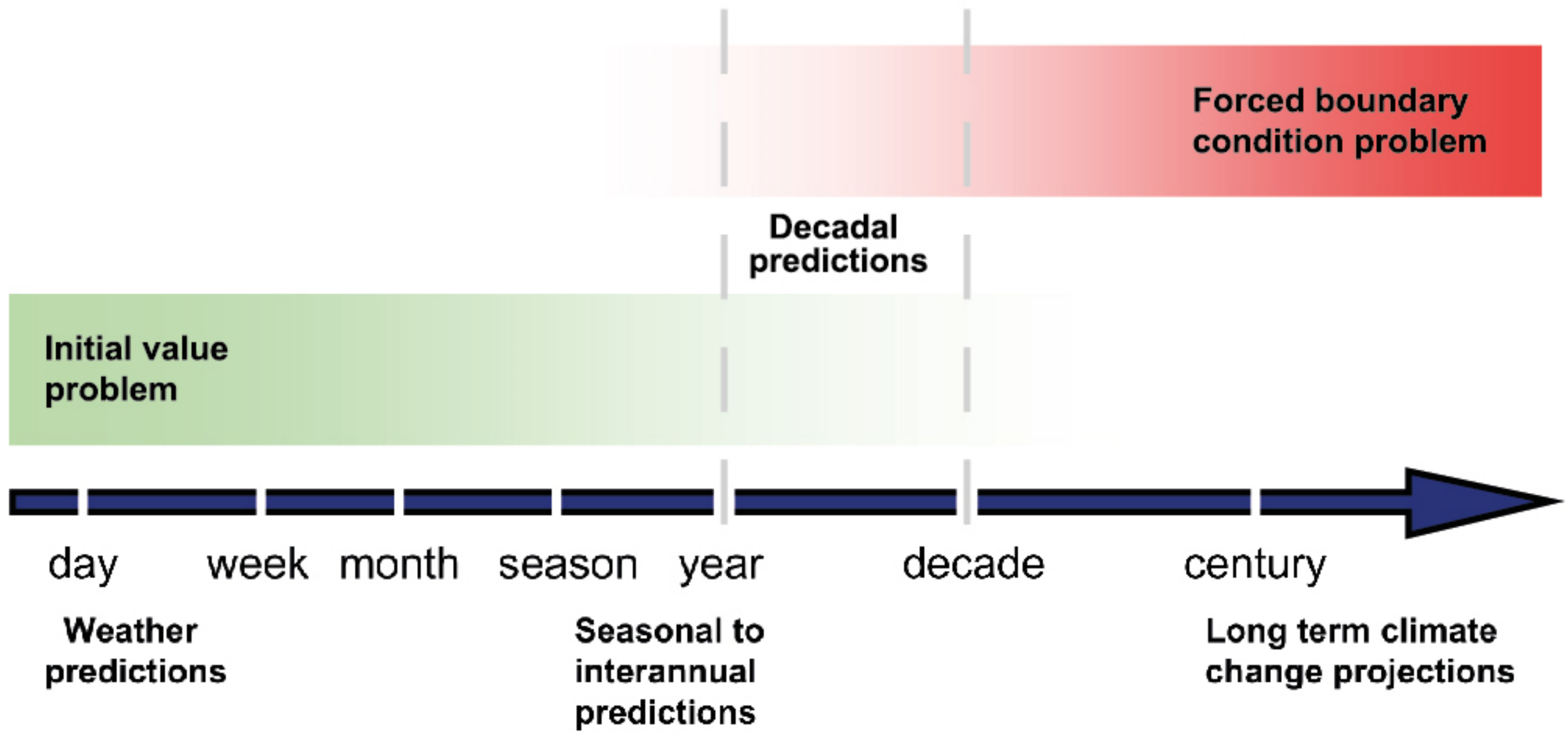


IPCC AR5 WG1
Fig. 11.08



- Climate change projections
- Decadal predictions
- Seasonal forecasts

IPCC AR5 WG1 Chpt 11, Box 11.1



So can we take a seamless approach, given the different nature of the modelling problem and the associated uncertainties?

But whatever the timescale, need to verify/validate against observations

Seasonal climate predictability and forecasting: status and prospects
Doblas-Reyes et al., *WIREs Climate Change* 2013

Provides a very accessible review of the issues:

- Initial condition uncertainty
- Model inadequacy
- Lack of appropriate computational resources

And the sources of predictability:

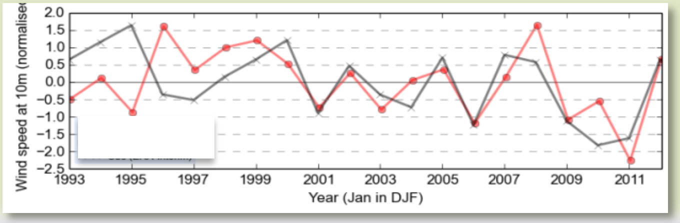
- ENSO, NAO, SST etc
- Tropospheric/stratospheric interactions etc

“Dealing with uncertainty helps decision makers with better decisions on whether or not to take any action given the probability forecast of an event”

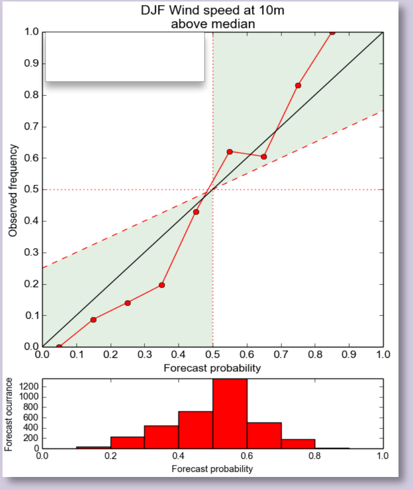
“Forecast quality is fundamental to the prediction problem because a prediction has no value without an estimate of its quality based on past performance” So crucial for climate services!

Skill & reliability of seasonal forecasts (hindcasts)

Correlations, reliability diagrams, ROC diagrams

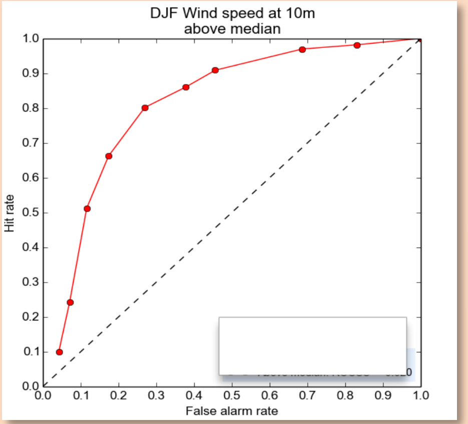


Time series plot
Correlation: basic co-variability between standardised time series (using ensemble mean)



Reliability diagrams: do forecast probabilities agree with historical observed frequencies?

Brier Skill Score = how much better is the forecast system, compared to climatology?



ROC diagrams: how well the forecast system can distinguish between events occurring and not occurring

ROC Skill Score (area under ROC curve) = potential usefulness (no info on bias or reliability)

With thanks to Philip Betts, UKMO

Met Office Hadley Centre

Reliability: do forecast probabilities match observed frequencies?

Brier skill score: How much better, compared to climatology?

ROC skill score: potential usefulness, after calibration

www.metoffice.gov.uk

Validation of climate change projections, e.g., 50 km Africa CORDEX RCMs

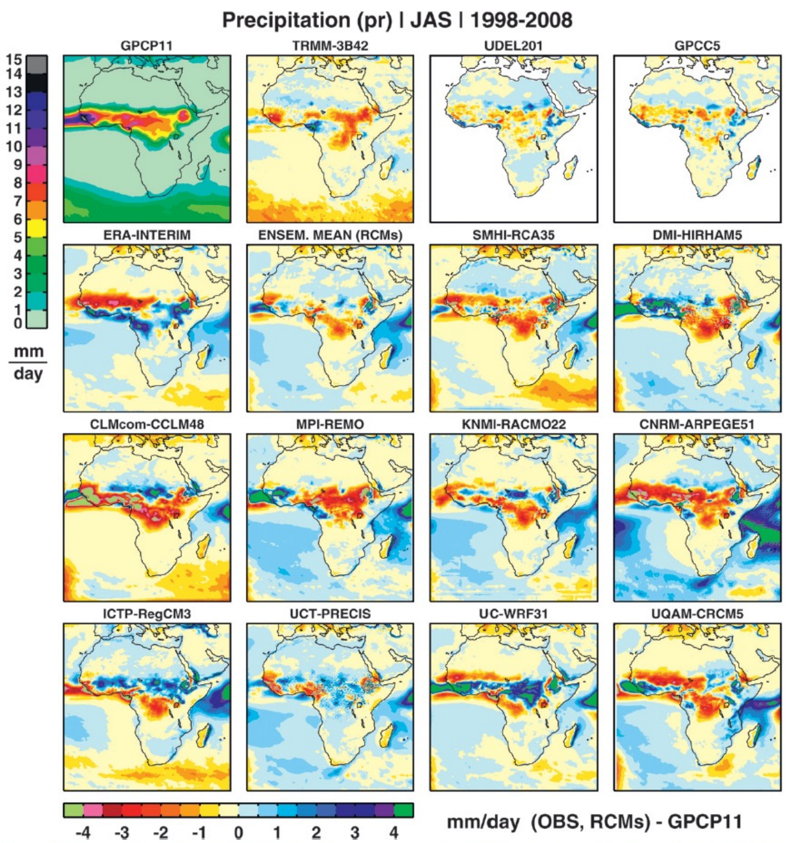
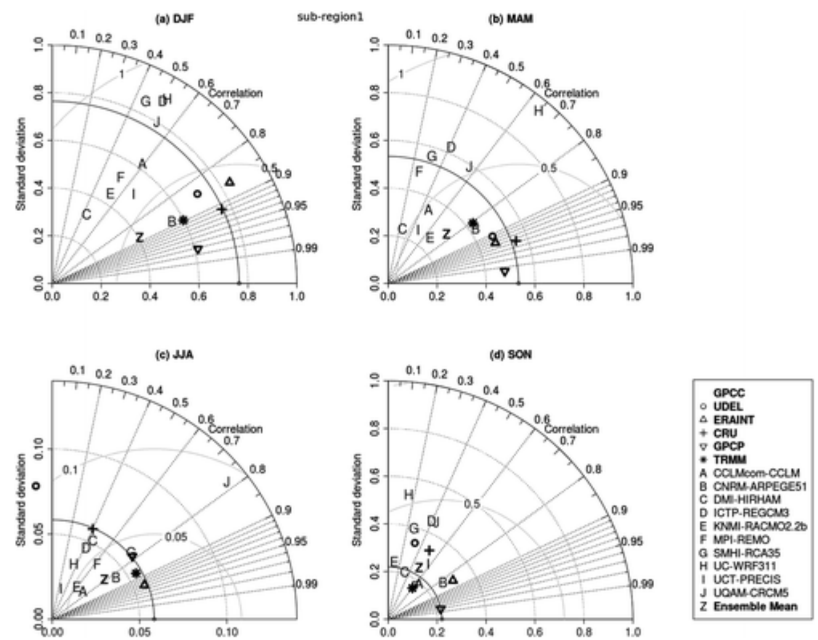


FIG. 4. GPCP mean JAS precipitation for 1998–2008 and differences compared to GPGP in the other gridded observations, the individual RCMs, and their ensemble average.

Taylor diagram – shows root mean square error, correlation coefficient and standard deviation



Top row: four different observational sets
12 GCM-forced CORDEX RCM runs

Nikulin et al 2012, *J Climate*,

Kalognomou et al., 2013, *J. Climate*
10 CORDEX RCMs, southern Africa
Seasonal rainfall vs GPCC

Some extreme views on downscaling!

Garbage in, garbage out – so what's the point of downscaling?

There's lots more detail – so it must be more accurate

It's like having a meteorological station every 9km, censored interpolates data collected from global meteorological stations and orbiting satellites, providing accurate data in detailed 9km grids.

The data available here are climate projections from GCMs that were statistically downscaled and calibrated … The spatial resolution is 30 arc seconds (~1 km2).

Added value of downscaling is a legitimate science question – particularly in the context of climate change projections which can't be verified – and is (to some extent) being addressed.

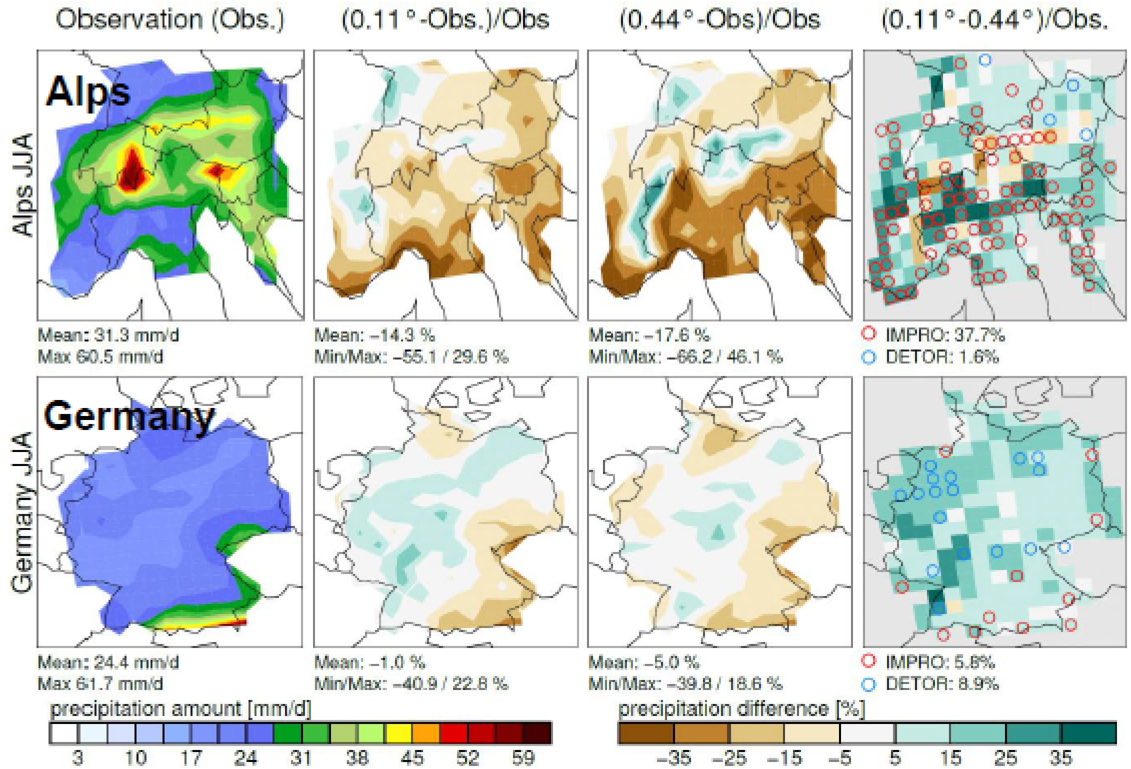
Gobiett et al: http://cordex2013.wcrp-climate.org/parallel_B1.shtml

EURO-CORDEX Evaluation

Added Value of High Resolution (EUR-11) Simulations

Precipitation Extremes (Q97.5)

- 8 RCMs in 0.44 and 0.11 deg. resolution
- Analysis of various aspects of extreme precipitation.
- Analysis on 0.44 deg. grid



- Clearly added value (red circles) in orographically influenced areas.
- Less added value in flat regions

[Prein et al., 2013] *Clim. Dyn.*

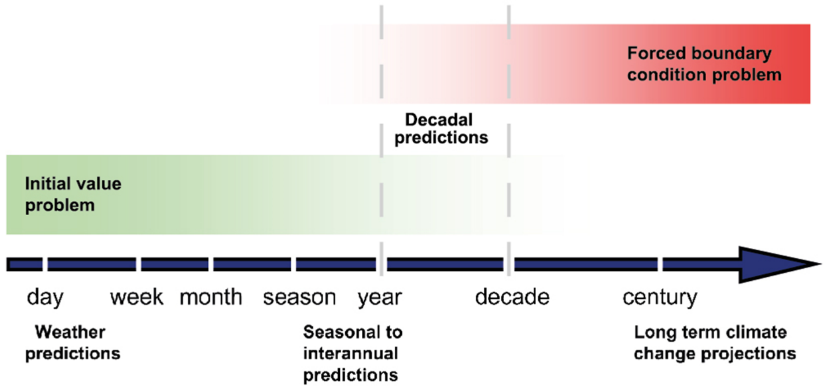
There is a huge literature on verification and validation and in any scientific conference you'll see hundreds of plots and maps showing comparisons with observations:

Two questions:

- How well are the underlying processes being simulated?
  (there is a need for more process-based evaluation)

- How to convey this information to the user?

On climate change timescales need to remember that good reproduction of observations is only a "necessary but not sufficient" guide to the reliability of future projections



Whatever timescale we’re interested in, an ensemble approach is appropriate for addressing modelling uncertainty:

- Multi-model ensembles
- Intra-model ensembles
- And a combination of the two

Motivation for:

- CMIP5 and CMIP6 (GCMs – climate change)
- CORDEX (RCMs – climate change)
- CMIP6 Decadal Climate Prediction Project (DCPP)
- EUROSIP (3 models, 12-51 hindcast members, 42/51 for seasonal forecasts)
- etc

But how to present ensemble information?

Tobin et al., 2015, *Climatic Change* – European wind power

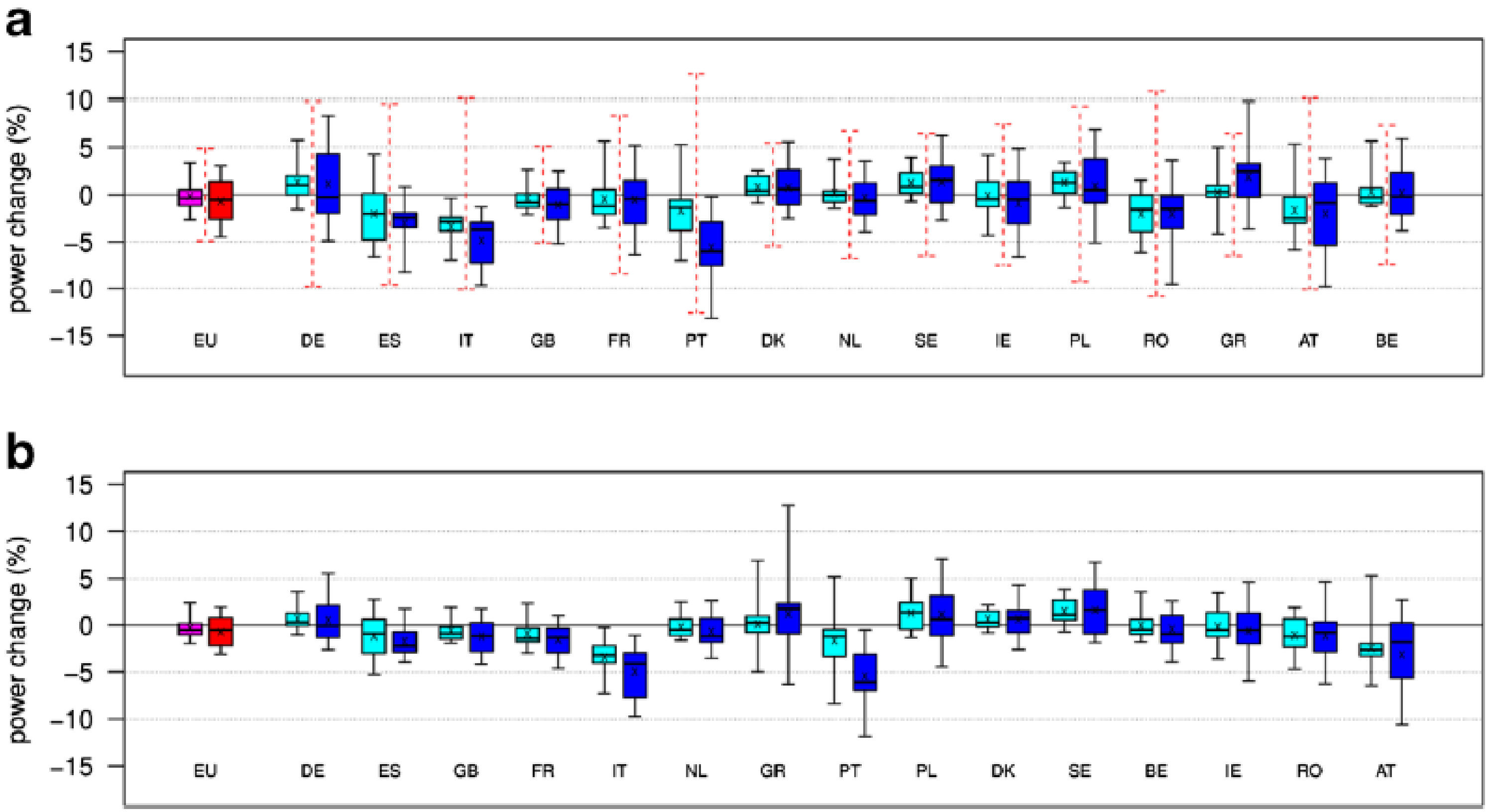


Fig. 3 **a** Future changes in annual wind power generated from the European and the 15 biggest national windmill fleets installed at the end of 2012, sorted by their installed power capacity (decreasing order). EU, DE, ES, IT, GB, FR, PT, DK, NL, SE, IE, PL, RO, GR, AT, BE refer to Europe, Germany, Spain, Italy, Great Britain, France, Portugal, Denmark, Netherlands, Sweden, Ireland, Poland, Romania, Greece, Austria and Belgium respectively. The changes are assessed with regards to the 1971–2000 period (in %). The cross within the boxes indicate the ensemble mean of changes, the line the median, the boxes the 25–75th percentile interval of the ensemble distribution and the whiskers the ensemble minimum and maximum changes. The left side bars correspond to the 2031–2060 period (*magenta/cyan*) and the right side bars to the 2071–2100 period (*red/blue*). Representing inter-annual variability, red bars indicate the standard deviation of the annual wind power production series for the period 1971–2000 (0±one standard deviation). **b** Same as **a** but for the European and the 15 biggest national fleets planned by 2020

Jerez et al., 2015, *Nature Communications* – European PV solar power

Authors include José María López-Romero!

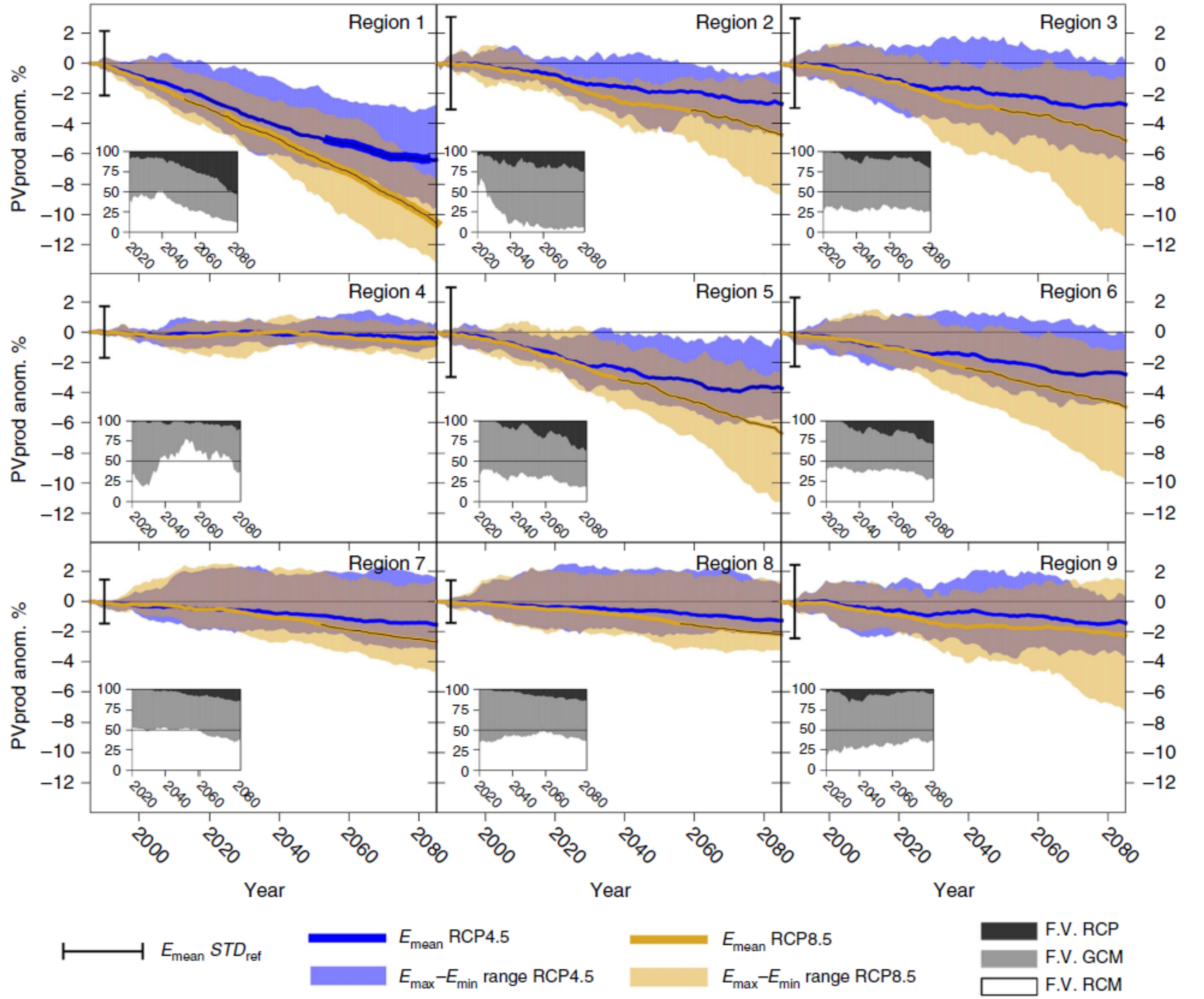
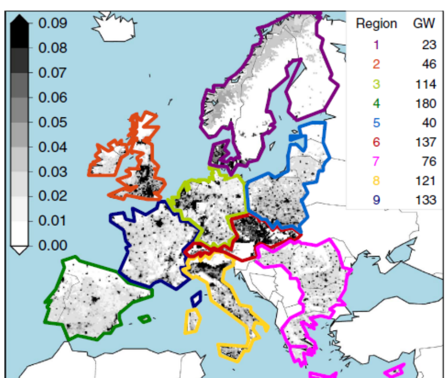


Figure 3 | Time series of PV power production along the 21st century under both RCP4.5 and RCP8.5. Thirty-year running mean time series of the estimated PV power production anomalies under both the RCP4.5 (blue) and the RCP8.5 (orange) in each region. Anomalies are computed with respect to the mean values in the reference period 1970–1999 and expressed in %. Solid lines depict the ensemble mean values, with the widest segments, appearing only in the first plot (region 1), indicating S2N > 1. Shadows show the ensemble spread. Vertical black bars depict 0 ± the ensemble mean value of the standard deviation of the annual series of PV power production anomalies in the reference period, as representative of the current natural variability. If the ensemble mean change exceeds such a quantity, a thin black line is superimposed on the ensemble mean series. Small subplots depict the fraction of variance (in %) explained by the change of RCP (dark-grey shadow), GCM driving run (light-grey shadow) or RCM (white shadow), as obtained from an analysis of variance applied to the whole set of 30-year running mean time series of PV power generation anomalies considering only the scenario period.



Van Vliet et al., 2016, *Nature Climate Change* – Hydropower and thermoelectric power

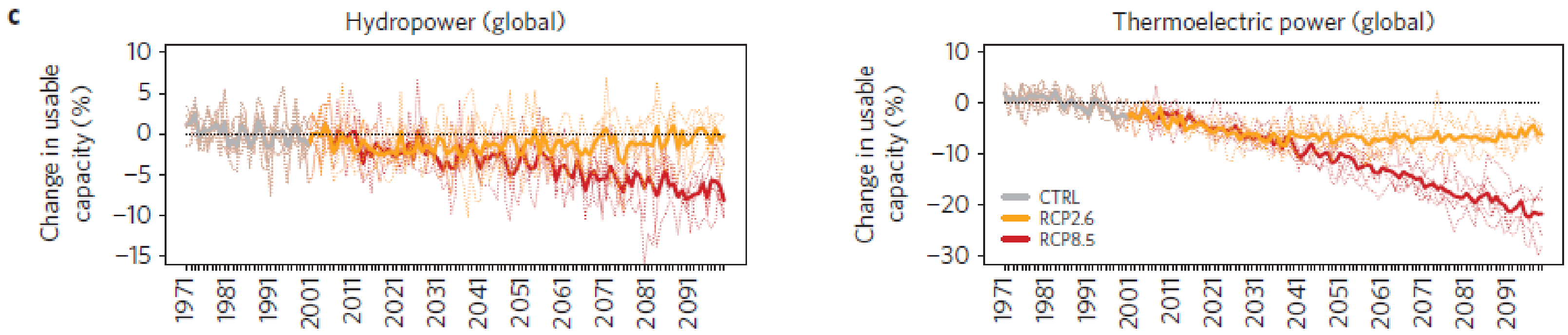
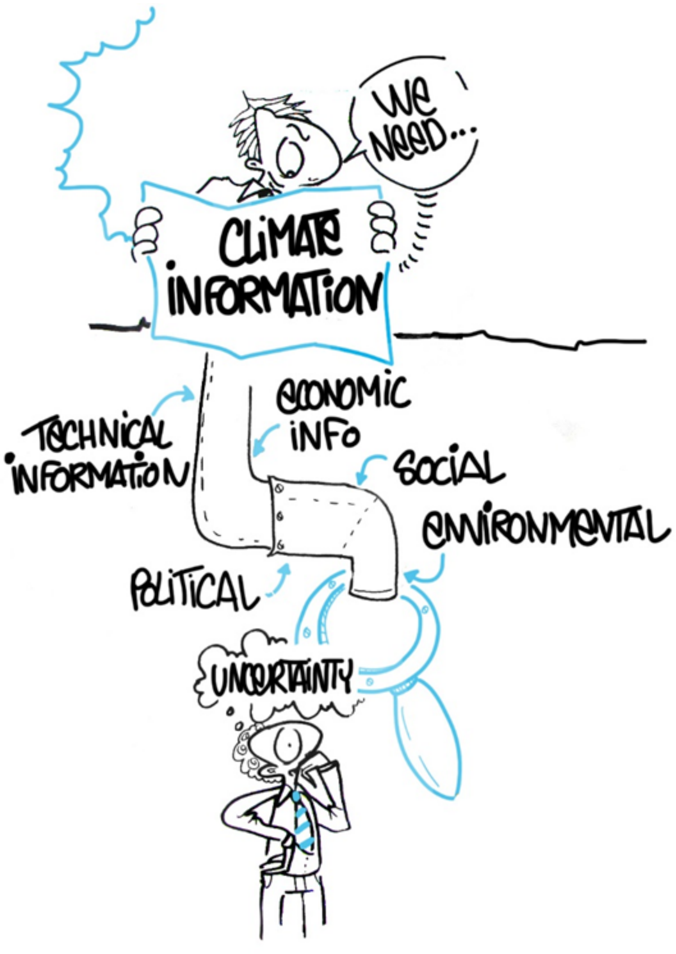


Figure 3 | Impacts of climate and water resources change on annual mean usable capacity of current hydropower and thermoelectric power plants.

In this example, when we look at the impacts of the projected climate changes, the picture looks a bit different – because the large and robust temperature changes dominate the more uncertain changes in streamflow.

So it's important to consider the impact on the system – not just the climate.

How to reduce/quantify/understand uncertainty:



- Better physical understanding of the climate system on different spatial and temporal scales
- More process-based evaluation
- Computing resources to produce larger ensembles and simulations at higher spatial resolutions (but need to use these resources intelligently)
- More/better observed data for assimilation, initialisation, verification, calibration, validation
- Better exploration of uncertainties associated with bias adjustment/correction
- More work on variables that are crucial for energy, e.g., wind, radiation, riverflow …….

But the real challenge for climate services is how to COMMUNICATE uncertainty

Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

Barriers to using climate information: Challenges in communicating probabilistic forecasts to decision makers

Melanie Davis[1], Rachel Lowe[1], Sophie Steffen[2], Francisco Doblas-Reyes[1,3], Xavier Rodó[1,3]

1.Institut Català de Ciències del Clima (IC3)

2. University of Barcelona

3. Institucio Catalana de Recerca i Estudis Avançats (ICREA)

SPECS Technical note 4

March 2015

Marta Bruno Soares and Suraje Dessai

Exploring the use of seasonal climate forecasts in Europe through expert elicitation.
Climate Risk Management, 2015

Identifies ‘communicating uncertainty’ as one of the barriers to uptake.

EUPORIAS

And finally, some questions to leave you with

- What is appropriate language to use in climate services?
  - Uncertainty, confidence, likelihood, probability, robustness……
- Should uncertainties be presented in quantitative/qualitative terms?
- How to visualise uncertainties?
- How do attitudes towards risk affect the interpretation of uncertainties?
- Does low skill/large uncertainties mean that information is not ‘useful’?
- What about ‘non-climate’ uncertainties?

- Are there additional or different types of uncertainty associated with forecasts/projections for (small) islands (e.g., PNG, Dominica)?