PERSPECTIVES ON THE USE OF FUTURE CLIMATE DATA

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1. **DATA AVAILABILITY:**

   Is there available future weather and climate data? Yes! Loads!
   - Ensembles of GCM future projections (CMIP6, PRIMAVERA)
   - Ensembles of RCM-downscaled future projections (CORDEX)
   - Even proof-of-concept energy variables datasets (ECEM)

2. **DATA SUITABILITY:**

   Is this data fit for purpose? The strengths and limitations strongly depend on the application!
   - Limitations by design: not a predictive tool!
   - Limitations of frequency and resolution
   - Need for bias adjustment
   - Sources of uncertainty

3. **USE EXAMPLES:**

   The good and the not so good …
   - Inconvenient uses …
   - Alternative approaches

DATA AVAILABILITY

1. **Ensembles of future projections from GCMs (General Circulation Models/Global Climate Models)**

- **CMIP6** : https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6
  - the main basis for IPCC Assessment Reports
  - standardized experiments, forcings and outputs
  - 33 global modelling centres, more than 70 models
  - global output, future: 2015-2100
- **PRIMAVERA** : https://www.primavera-h2020.eu/
  - next generation of high-resolution GCMs (up to 25km!)
  - enhanced representation of physical processes that condition weather (e.g., blocking, storms)
  - 7 European modelling centres, 15 models
  - global output, some at high frequency (1hr, 3hr, thanks to UREAD!), future: 2015-2050

2. **Ensembles of future projections from RCMs (Regional Climate Models)**

- **CORDEX** : https://cordex.org/
  - coordinated dynamical downscaling intercomparison
  - ensemble defined by multiple GCM-RCM combinations (forcing GCMs from CMIP#)
  - set of standard domains at 0.11° and 0.44° horizontal resolutions (e.g., EURO-CORDEX)
  - some high-frequency output

3. **Proof-of-concept datasets/climate services for energy applications**

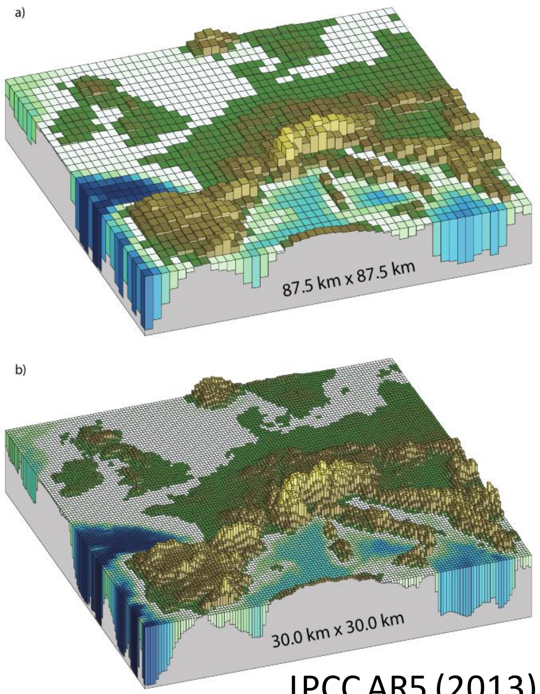
- **ECEM** (https://climate.copernicus.eu/european-climate-energy-mixes)
- **CLIM4ENERGY** (https://clim4energy.climate.copernicus.eu/, 11 EURO-CORDEX projections, 2 RCP scenarios)
- **CLIM2POWER** (https://clim2power.com/, to come)
- **Others?**

The extent to which future climate projections are fit for purpose depends strongly on the application. Important aspects to consider are :

1. EXPERIMENT DESIGN:

These are **projections** and **not predictions**, which means that they are ***subject to a specific scenario***

- CMIP projections: scenarios represent **changes in the external forcings**, mainly GHGs
- main goal --> how the climate system is **likely to respond to changes in these forcings**
- other research --> systematic model biases, roles of internal climate variability, predictability, and uncertainties



IPCC AR5 (2013)

2. SPATIAL AND TEMPORAL RESOLUTIONS OF THE DATA:

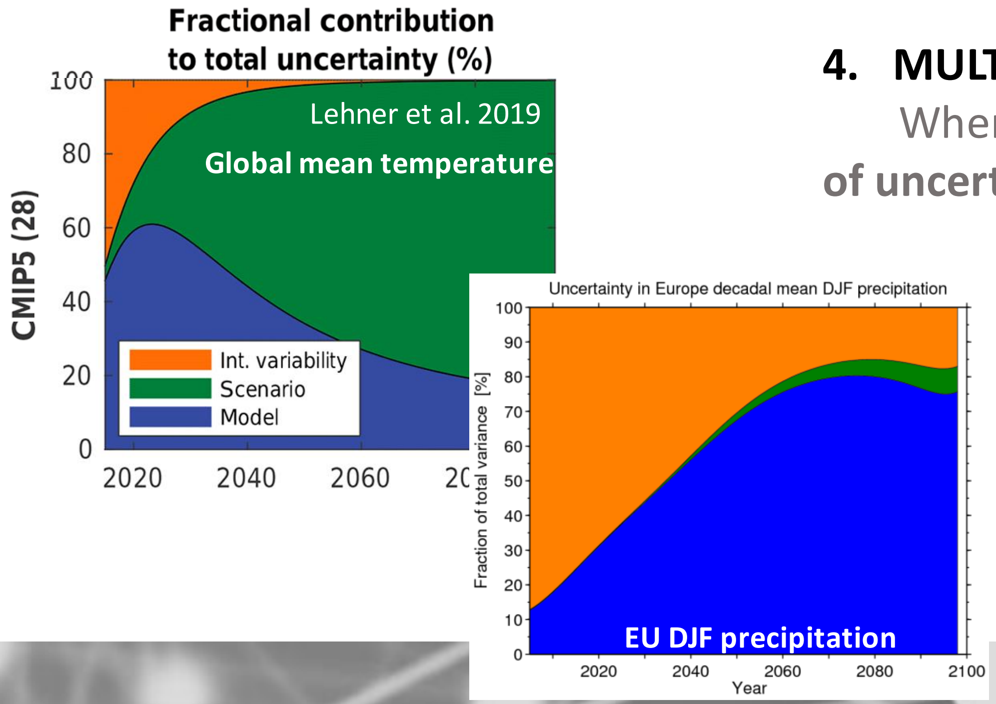
The resolutions and frequencies of the model outputs are **insufficient for very local applications**, such as a specific power plant or the topographic effects on a wind farm

- Last-generation GCMs: ~**100km resolutions** and ~ **6hr outputs**, now improving.
- Downscaling to fine resolutions --> **false sense of precision**
- Dynamical downscaling does **not guarantee the correct representation of weather at the gridpoint scale** (e.g., storm not present in forcing GCM, GCM errors + RCM errors)

3. NEED FOR BIAS ADJUSTMENT:

Even at their effective spatial and temporal resolutions, models aren't perfect …

- **historical simulations** --> model biases: 'correctable' (e.g. systematic model biases, such as a distribution shift) and 'uncorrectable' errors (e.g., frequency of occurrence event).
- A **multi-variate** correction might be needed to preserve consistency between parameters.
- **future projections** --> **additional assumptions** are necessary --> e.g., preservation of trends.
- General consensus --> bias correction needed **before any downstream modelling.** Weather-to-energy conversions --> **non-linear** --> excellent example for this need (e.g., wind power output very sensitive to shape of speed distribution --> simple mean correction might not suffice).



4. MULTIPLE SOURCES OF UNCERTAINTY:

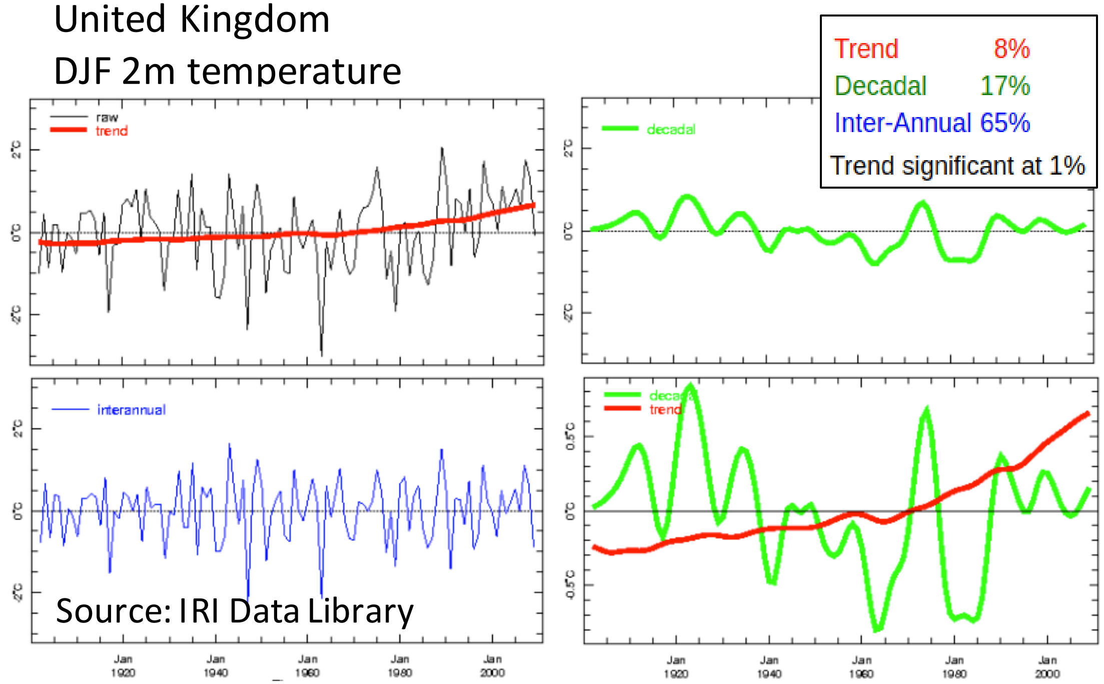
When using future projections, it is important to be aware of the **multiple sources of uncertainty**, their **relevance at different scales** and the **ability to quantify them**

- **Model uncertainty**: need for **multiple models** to capture it, but still deficient approach due to model's interdependence. More relevant in near-term projections and at regional scale. **Reducible** but models evolve slowly.
- **Scenario uncertainty**: due to unknown evolution of GHGs, **irreducible**, **several scenarios** needed
- **Internal variability**: due to chaotic nature of climate system, inherently **irreducible** after initial condition information is lost. Represented by **large ensemble**

1) Sampling climate data

In some regions, **decadal variability** explains a portion of the variance equal or **larger than the trend** --> **single years or time-slices can be very problematic**

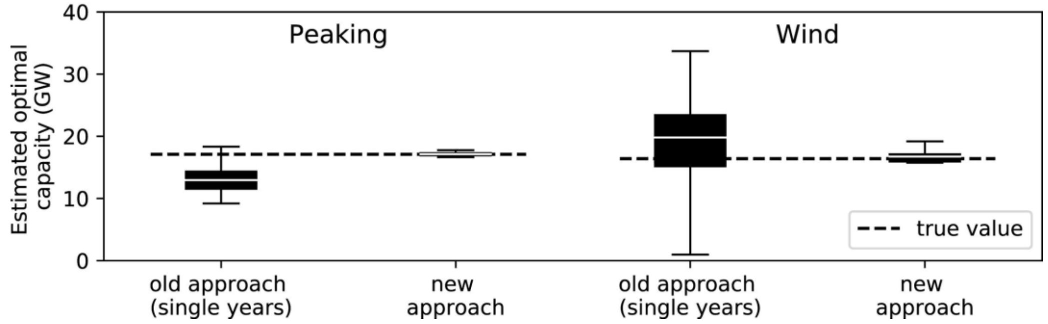
United Kingdom
DJF 2m temperature



But...there are **computational constraints** to using long climate time-series in power system modeling

From Hilbers et al. (2019): Year-to-year climate variability is important for planning and new techniques are being developed to tackle data size for computationally expensive PSMs.

Use of novel *importance subsampling* approach greatly reduces error and uncertainty in estimates of optimal generation capacities



Standard sub-sampling can lead to sub-optimal systems. **'importance subsampling'** --> more robust future power systems (e.g., less uncertain capacity factors, reduced unmet demand)

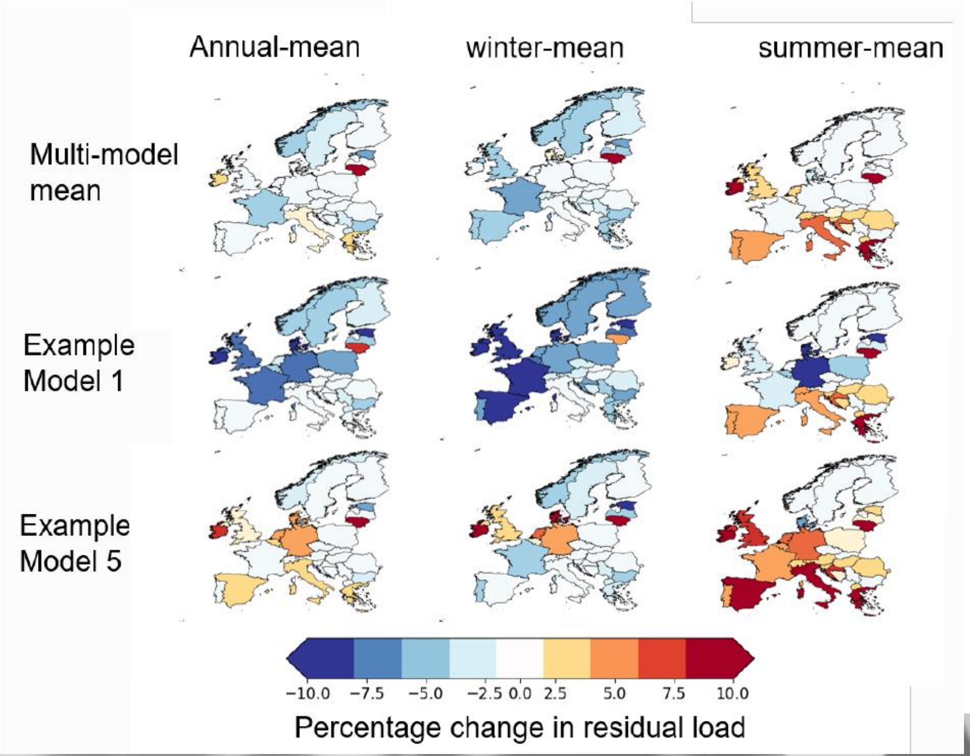
2) Presenting future results …

When dealing with **large multi-model ensembles**, the standard approach is to work with the ensemble mean, but this has several pitfalls:

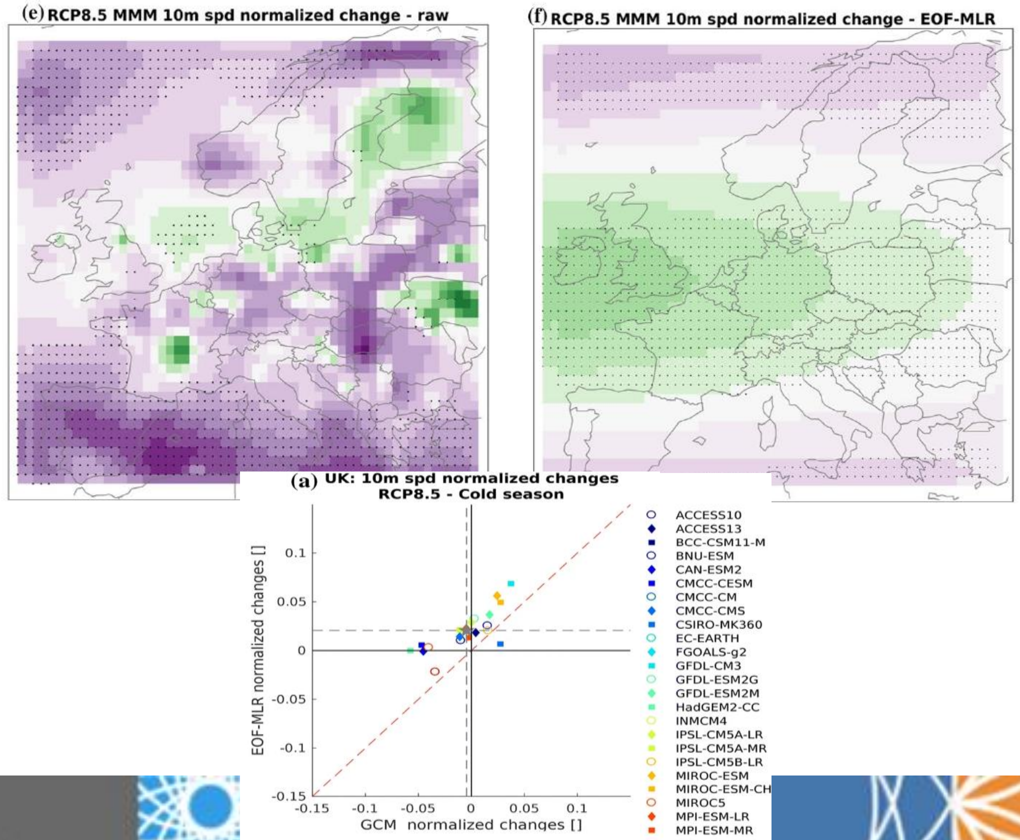
- the most likely outcome is not necessarily the most impactful one;
- if the **full spread** is considered --> extremely **large uncertainties** --> **useless for decision-making**;
- **not all uncertainty is of aleatoric nature -->** inaccurately represented by standard methods (e.g., confidence intervals).

As an alternative, a **'storylines'** approach implies developing a **set of physically plausible future evolutions** (scenarios/pathways)

From Bloomfield et al. (under review): future projections of demand-net-renewables from individual models (each is physically plausible)



From Gonzalez et al. (2019): future projections of winter wind speed constrained by the evolution of the North Atlantic jet



THANKS!

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