Historic meteorological datasets

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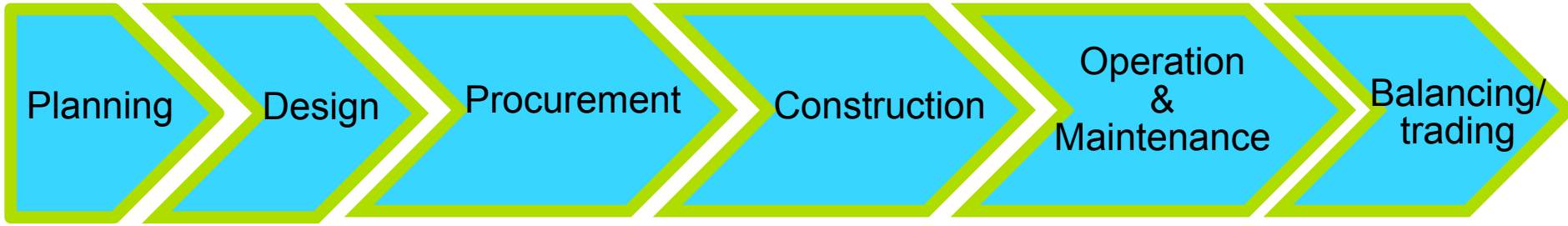
5th July

Contents

- Why does the energy industry care about the past?
- What is available?
  - Observations
  - Satellites
  - Modelled data
- Case studies
  - Site specific processing
  - Blending data sets to meet requirements
  - Taking account of variability and change

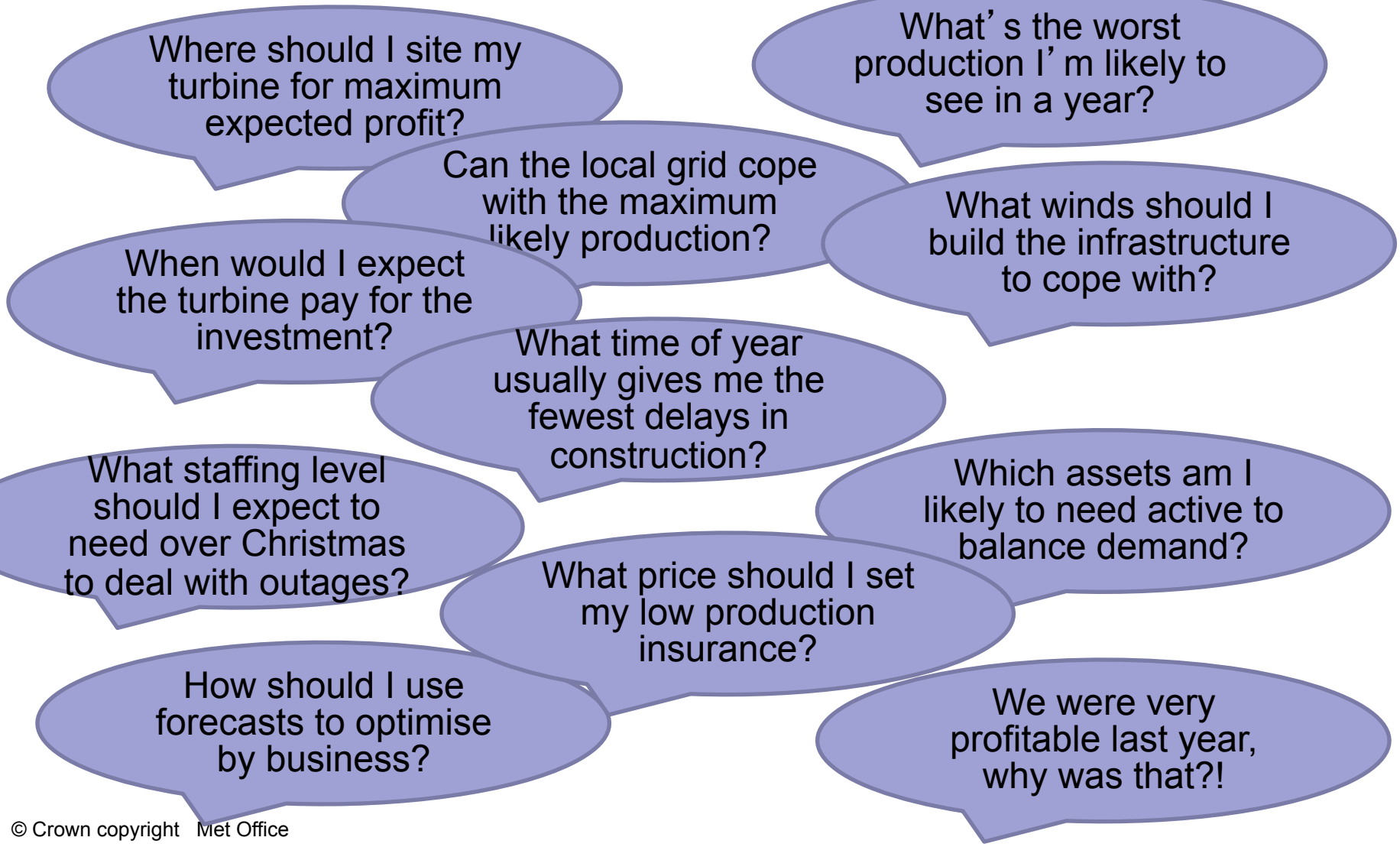
Introduction

Meteorological influences on the energy industry



- Choosing a location. Assessing feasibility
- Financing
- Planning maintenance
- Assessing extremes
- Weather windows
- What does normal look like?

What is being asked?



How can a climatology help?

Datasets are available which provide information back over 150 years, up to minute resolution, and very specific to the local area, for any meteorological parameter

- Allows *risk based* decision making based on what we can *expect* to happen

- Processing can be used to answer very specific industry questions

What’s available?

Observations

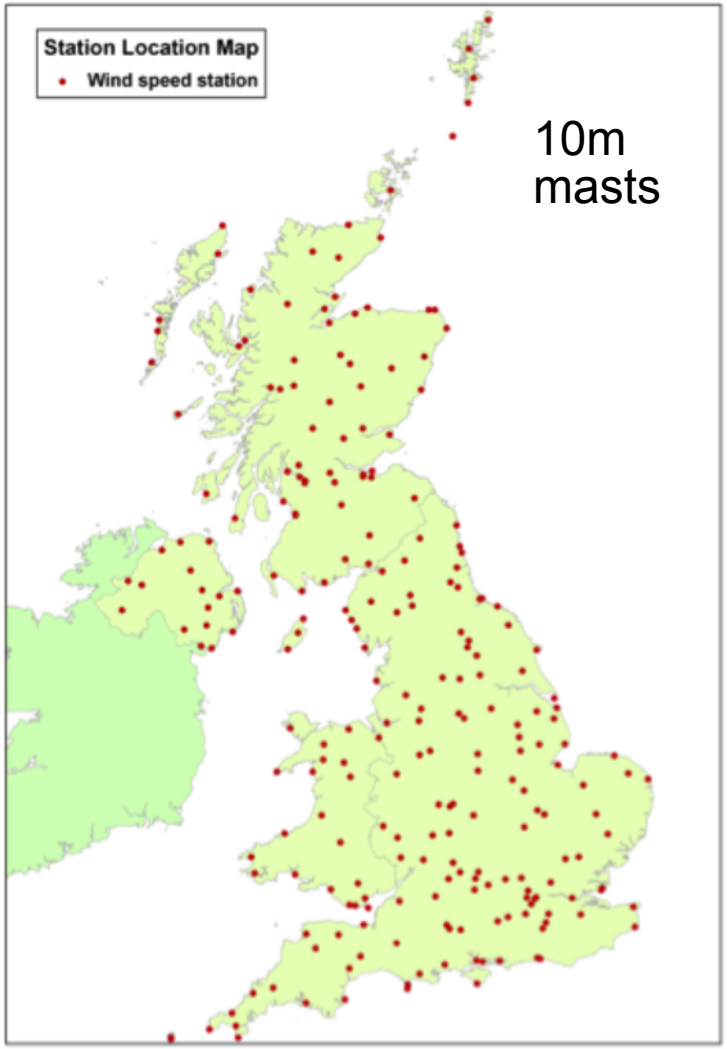
Availability: Create your own, or available through local met services

Advantages
- Best representation of very local area
- Easy to interpret
- Standardised globally
- Delay after capture usually short

Disadvantages
- Expensive to collect
- Sparse distribution, short records, often gaps
- Not representative of wider area (or other heights)
- Not necessarily consistent in time
- Errors are not uncommon

Example: Gridded observations

UK Wind Map



10m masts

Regression:

Location

Altitude

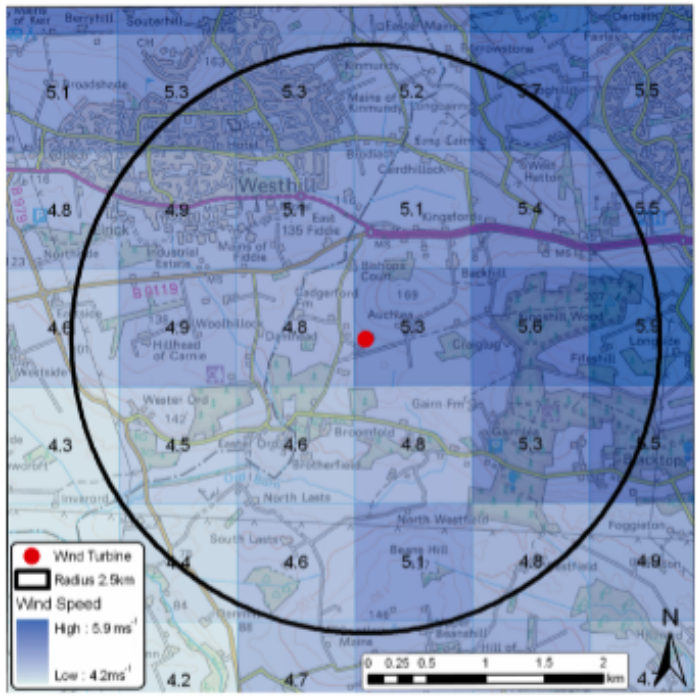
Local terrain

Coastal fraction

Interpolation

Annual average wind speed

Monthly average wind speed



10m, 15m, 20m, 25m, 35m and 45m

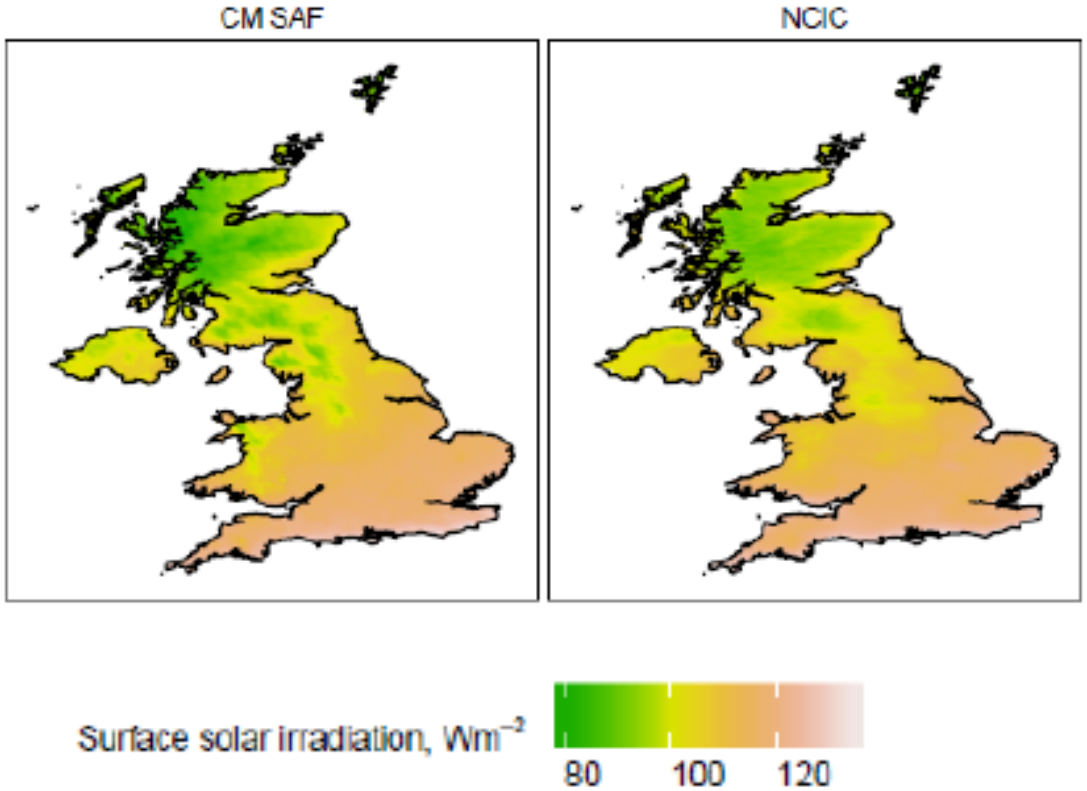
Satellite

Availability: Some freely available

Advantages
- Wide coverage
- Good accuracy for some parameters
- Some very fine resolution
- Delay after capture usually small

Disadvantages
- Coverage not global (geostationary always cover one area, geo-orbiting cover a moving swathe)
- Records start in ~1980s
- Interpretation not straight forward - some parameters have extensive post-processing

Understanding differences in PV power production



Mean surface solar radiation, Wm^{-2}, 1998-2013.

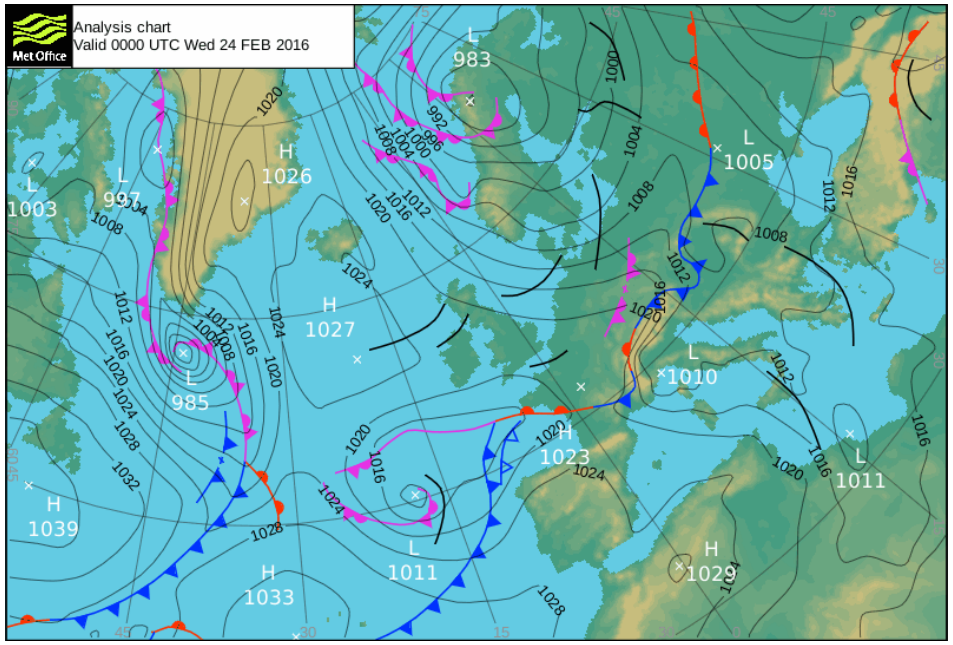
Using model data to assess the past

Possible modelled datasets: Using Numerical Weather Prediction (NWP)

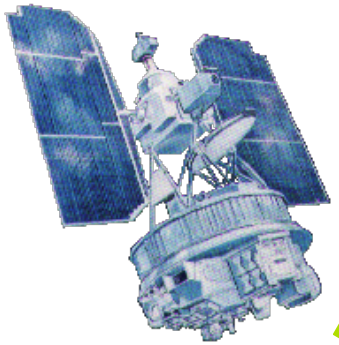
- Archived forecast data
- Reanalysis data
- *Downscaled model data*

What is an NWP data set?

Numerical weather prediction (NWP) is science based on reducing the atmosphere to a set of mathematical equations to project the atmosphere into the future



What is an NWP data set?



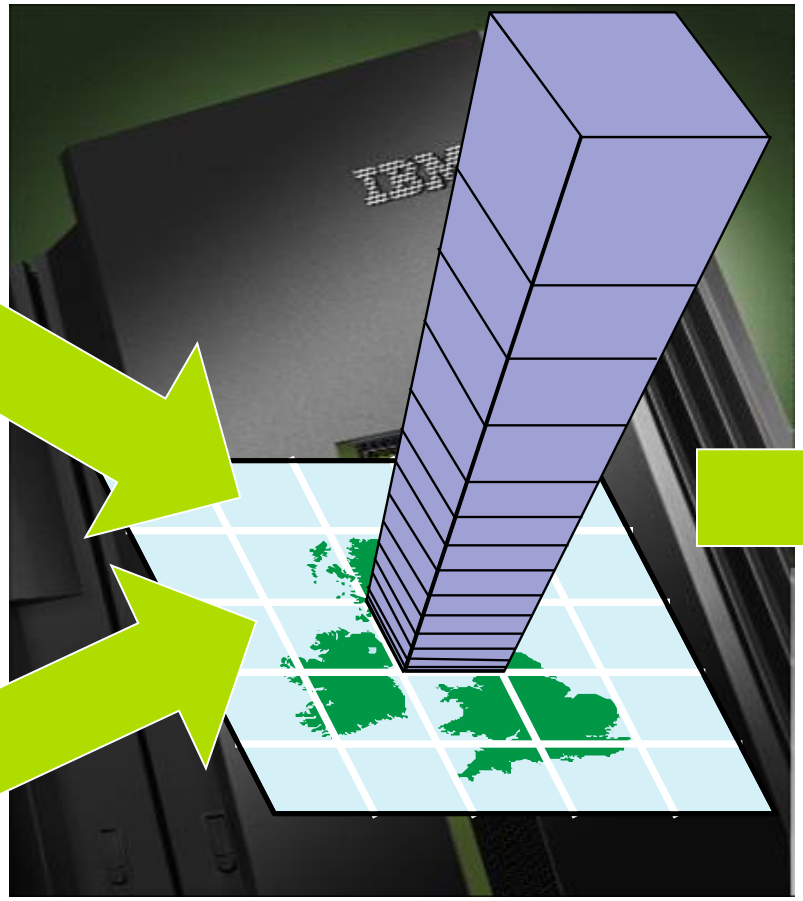
Observations

$$\frac{du}{dt} = \frac{\partial p}{\partial x} - fv$$

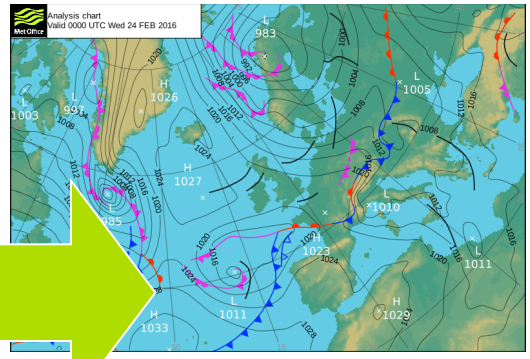
$$\frac{dv}{dt} = \frac{\partial p}{\partial y} + fu$$

$$p = RT\rho$$

Knowledge



Forecast Model



Weather
Forecasts & Data

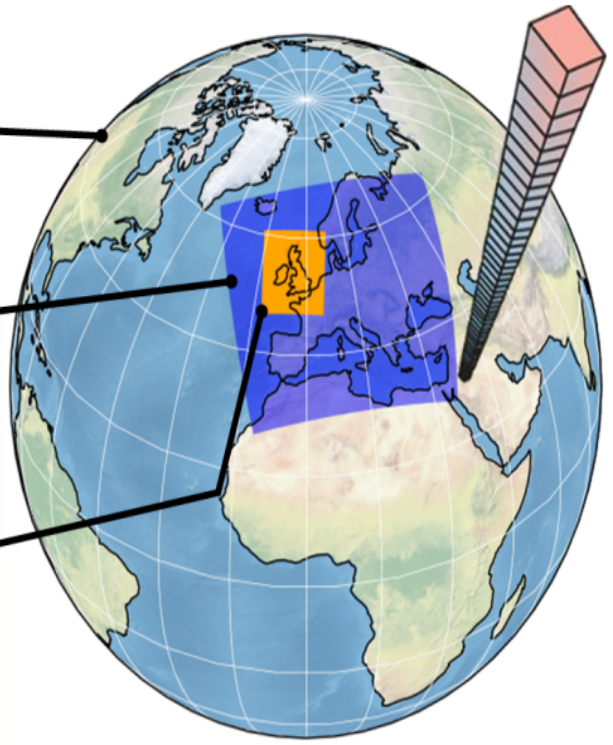
Forecast datasets

- Few centres run global models
- Grids that represent atmosphere limited in horizontal and vertical extent – processing constraints
  - ➢ Global model ~20-50km and 40-90 levels
  - ➢ Limits fine scale detail that can be included

Global
– 17km 70 Levels
– 48 hour forecast twice/day
– 6 day forecast twice/day

Euro4
– 4.4km 70 Levels
– 60 hour forecast twice/day
– 5 day forecast twice/day

UKV
– 1.5km 70 Levels
– 36 hour forecast eight times/day



- Improve resolution - smaller limited area models (LAM) domains used
- Models continually updated => lack of consistency, accuracy and errors not consistent over long periods

What is a reanalysis dataset?

- Originally created to support climate studies and produced by number of weather agencies
- Created using historical weather observations
- Drive global or regional NWP model
- Unlike weather forecasting models, which are frequently modified, reanalysis models are fixed for entire historical simulation

Archived forecast data

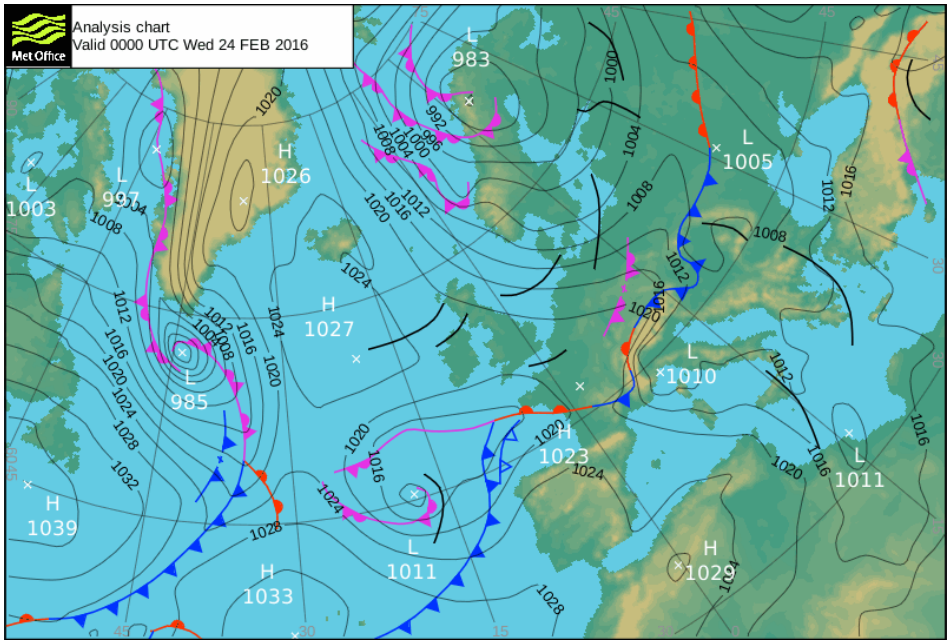
Availability: Data not commonly available, ask your local met service

Advantages

- Continually upgraded to use best science
- No gaps during archive
- Provides data for difficult to measure parameters & locations
- Potentially very fast availability

Disadvantages

- Not a consistent record
- Time series often short

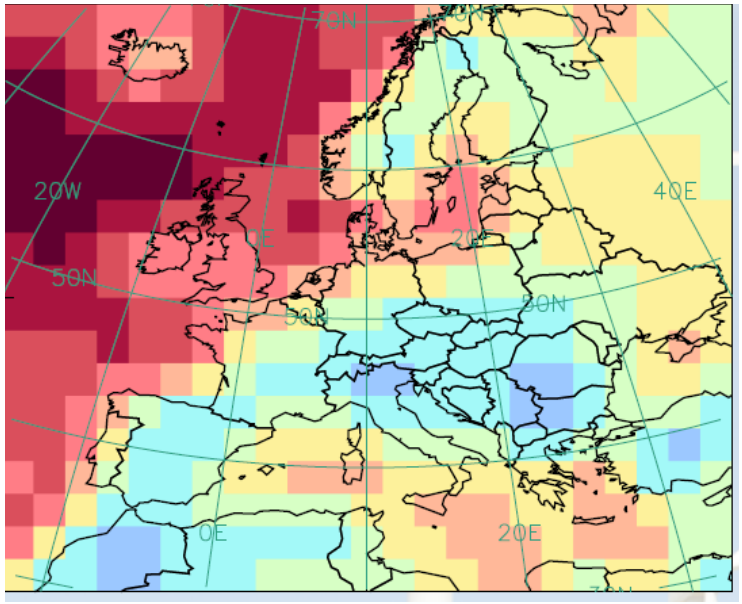


Reanalysis

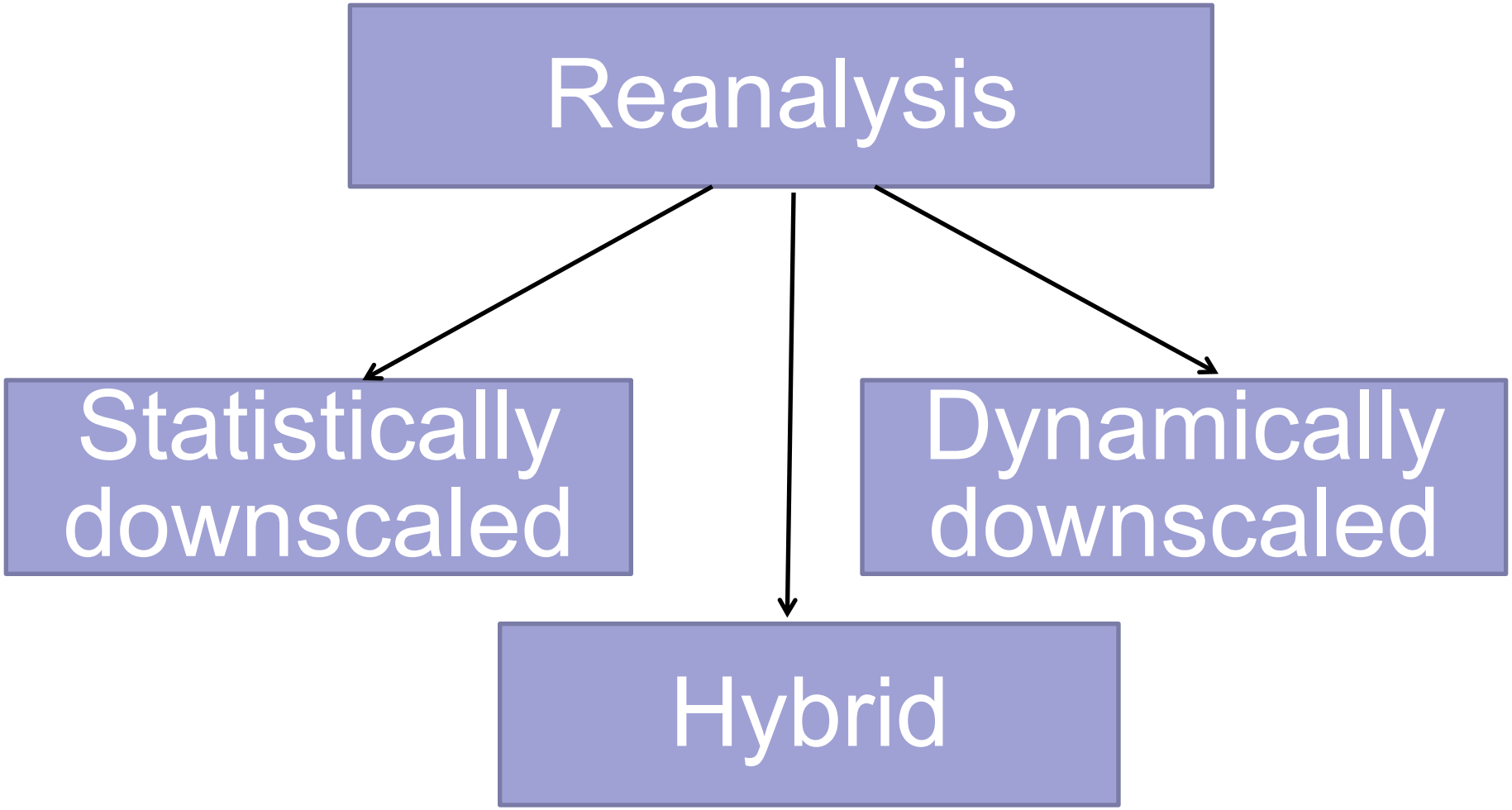
Availability: Several freely available (under licensing conditions), MERRA, ERA-Interim, 20th Century Reananlysis

Advantages
- Long, consistent time series
- Freely available
- No gaps
- Provides data for difficult to measure parameters & locations

Disadvantages
- Often coarse resolution
- Some parameters and locations known to have poor accuracy

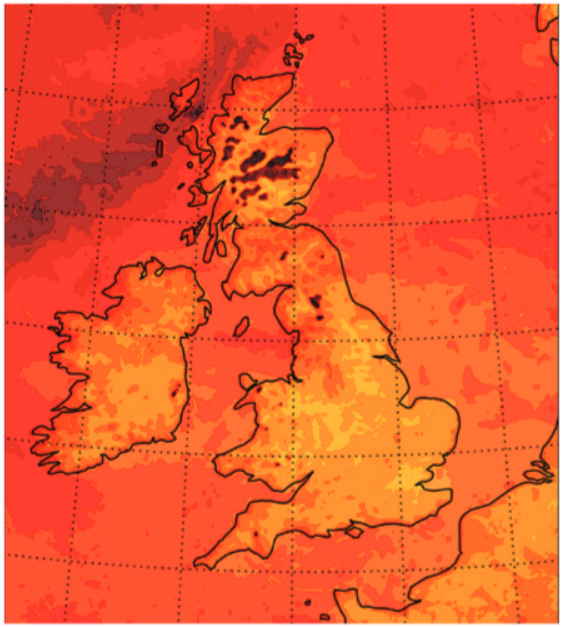


Downscaled reanalysis



Downscaled reanalysis

Availability: Usually commercial products (e.g. Euro4 hindcast)



Advantages
- Can be a long, consistent time series
- No gaps
- Provides access to hard to measure parameters
- Minimises use of rough and ready interpolation techniques

Disadvantages
- Expensive
- Fine resolution is not necessarily high accuracy!
- Quality is dependent on quality of large scale analysis
- Usually limited in geographic coverage
- Some parameters known to have poor accuracy

Climatology pitfalls

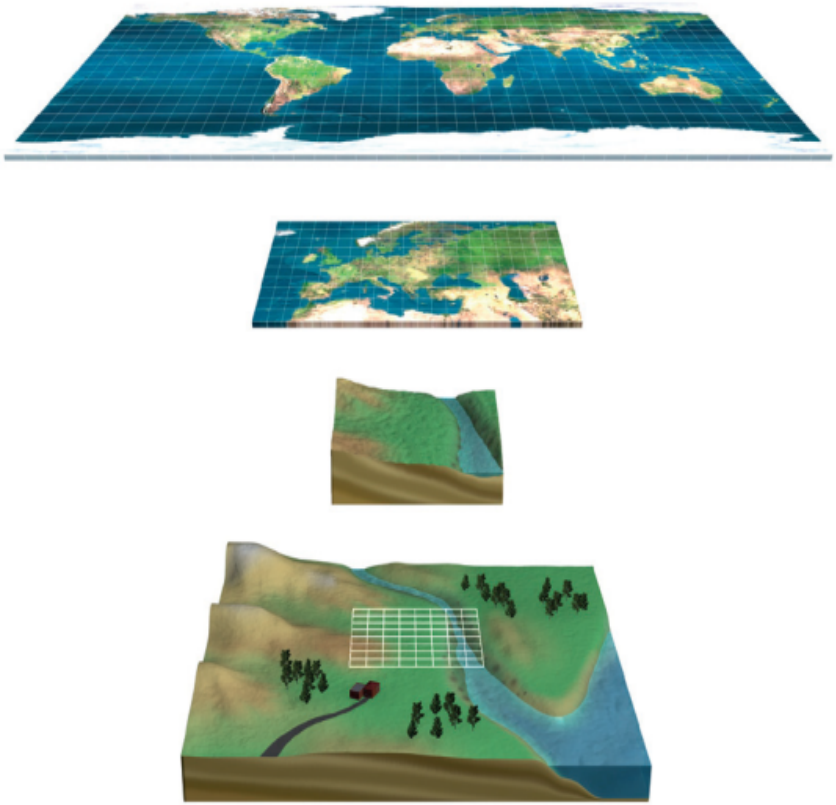
- Does the chosen dataset represent your local area?
- Does the chosen dataset give a good representation of climate variability?
- Is the chosen dataset relevant anymore?
- What accuracy do you need?
- How often will you need to update the dataset?
- Will the dataset be consistent in time and space?

Case studies: Using historical data

Site specific downscaling of reanalysis

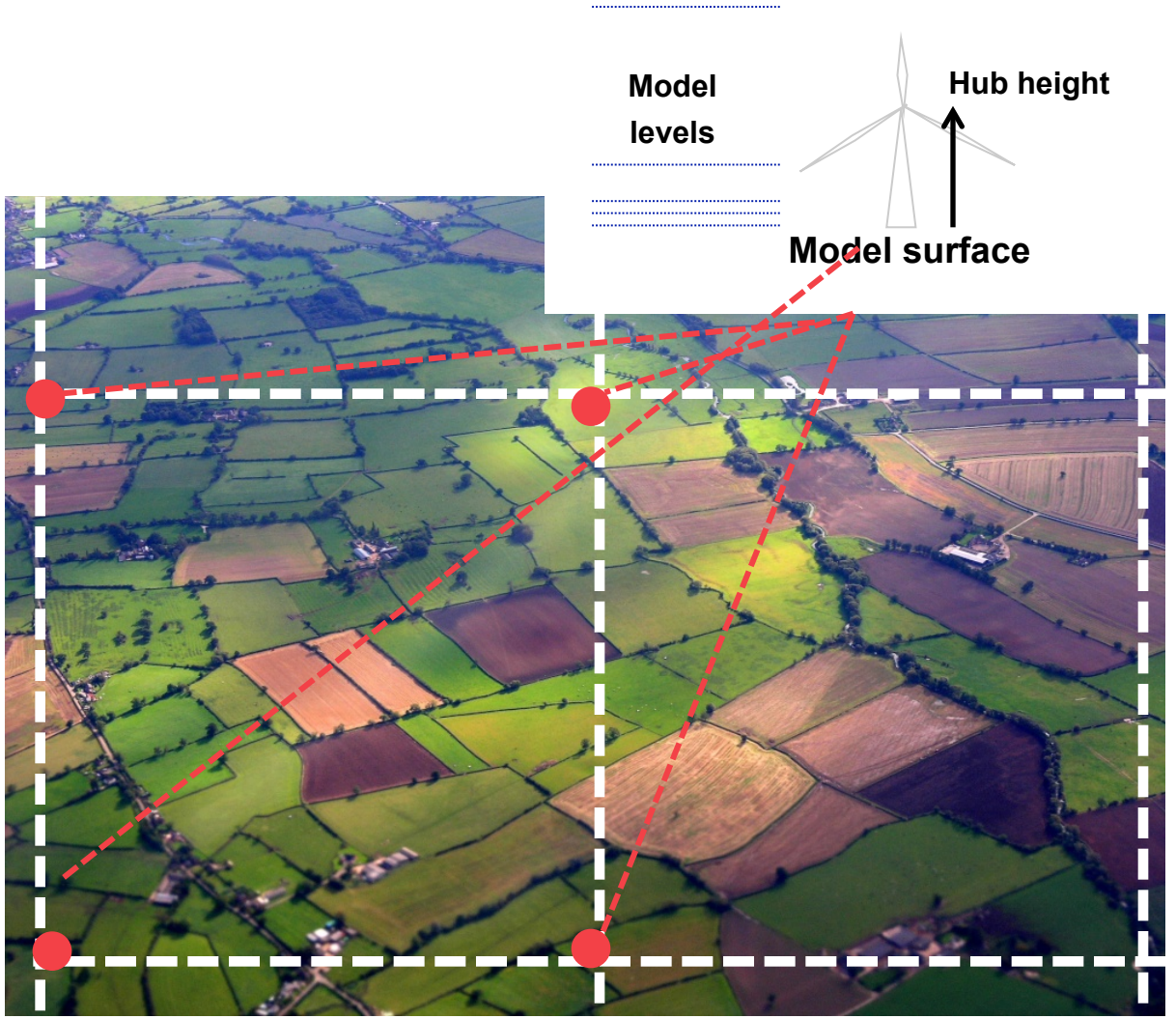
Accurate site specific time series: Virtual Met Mast

- ERA interim reanalysis & Global Model
- 12 km nested domain
- 4km European model
- VMM technique



VMM: How does it work?

- **Statistical downscaling**
  - Vertical interpolation to hub height
- Applying **scaled roughness correction**
- Adjusting for local **height** differences
- Applying **empirical error correction**



Slide courtesy Karen Walter

VMM: How does it work?

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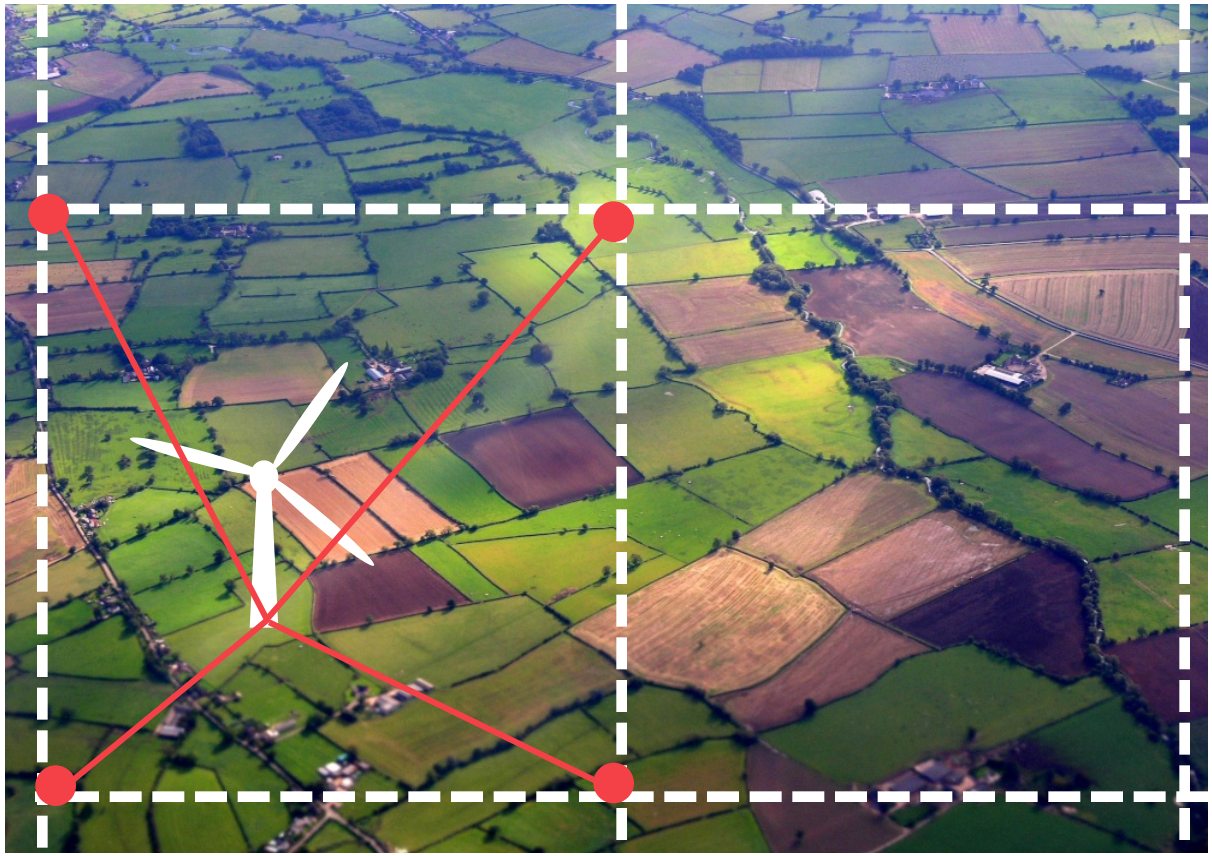

Slide courtesy Karen Walter

VMM: How does it work?

- **Statistical downscaling**
  - Horizontal and vertical interpolation to site location and hub height
- Applying **scaled roughness correction**
  - Over areas with significant orography
- Adjusting for local **height** differences
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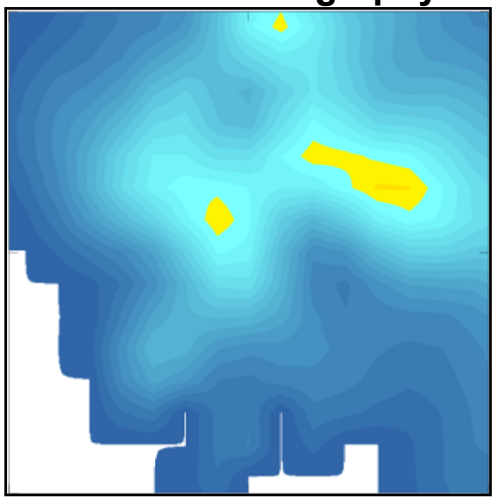
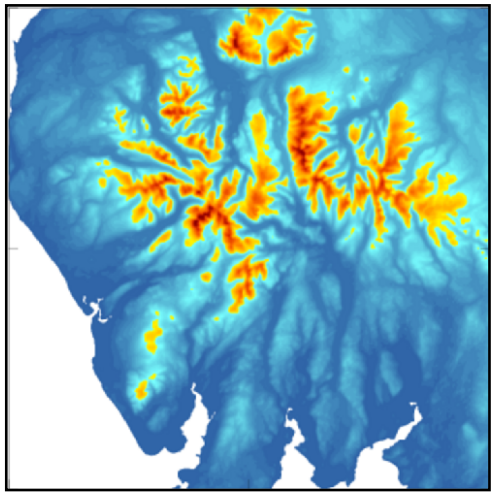
4 km model orography



Terrain at 100 m resolution



Height in Metres

Slide courtesy Karen Walter

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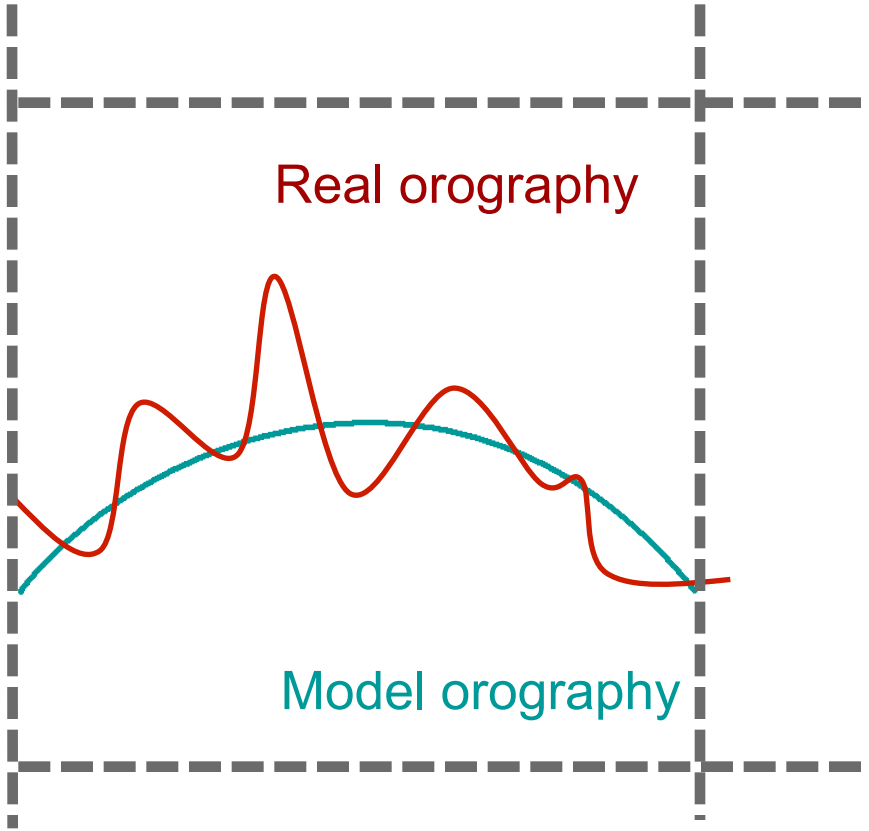

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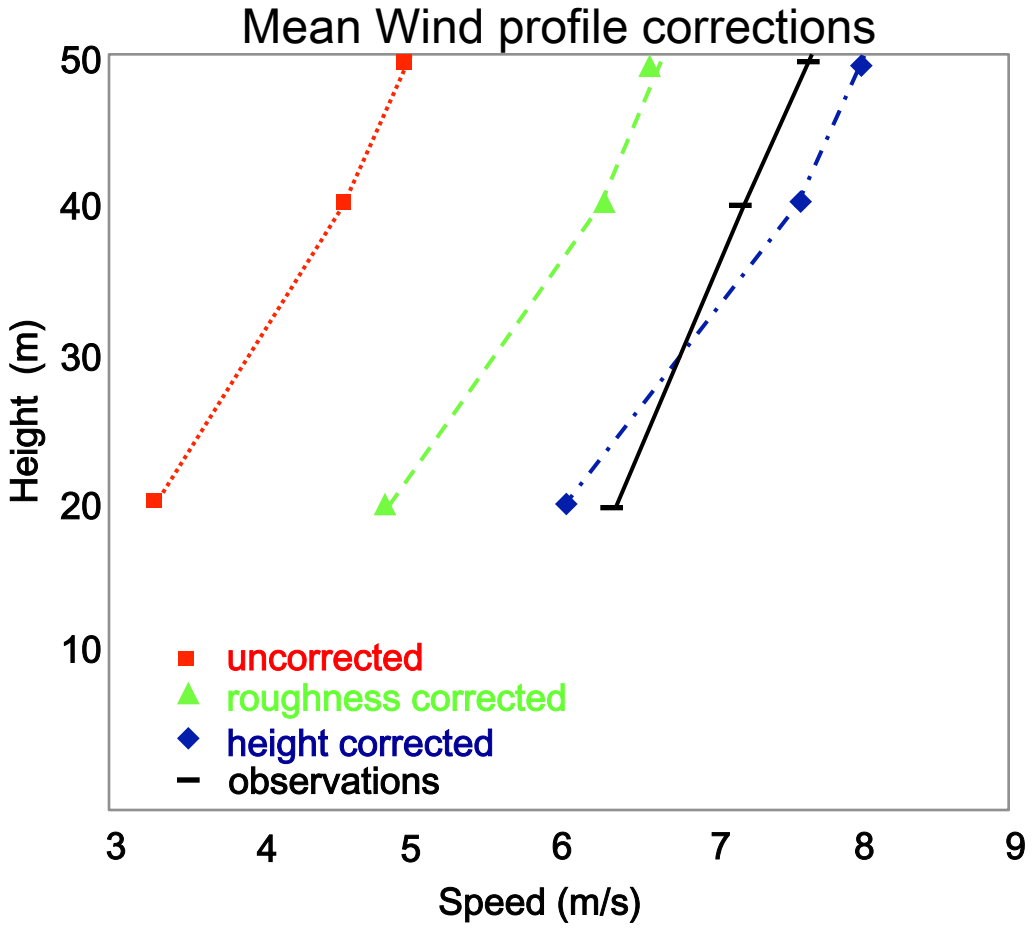

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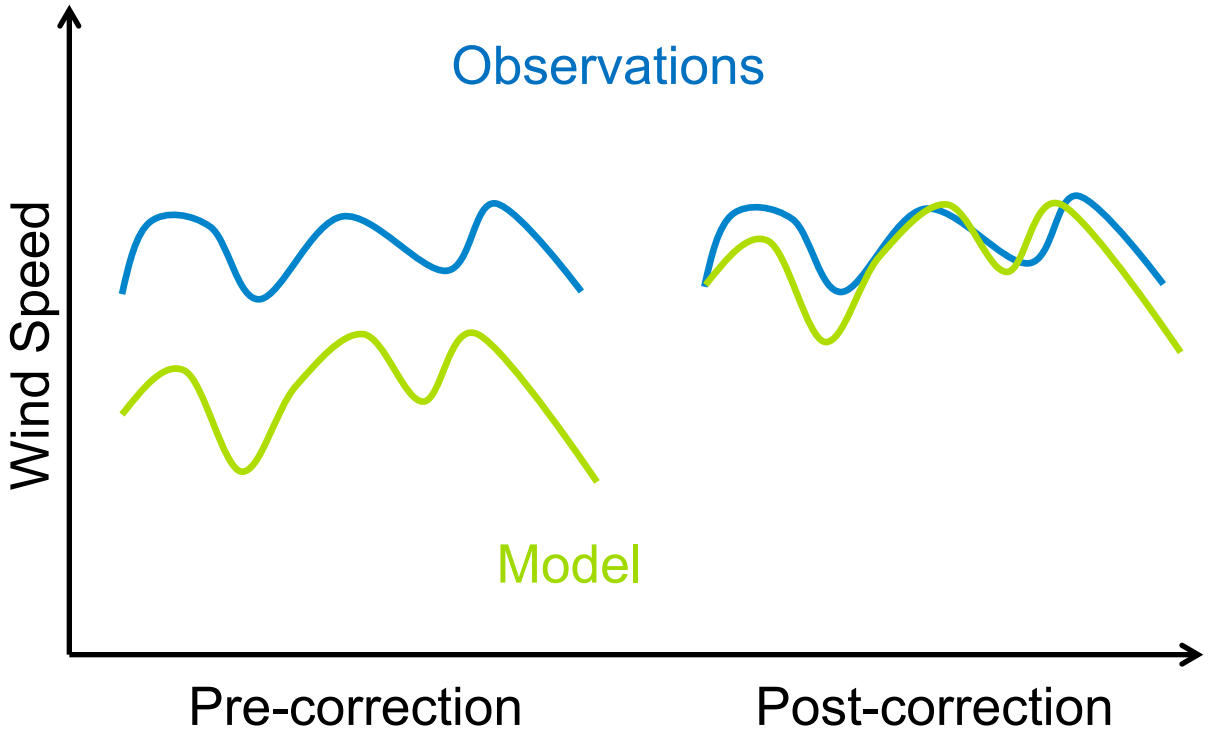


Slide courtesy Karen Walter

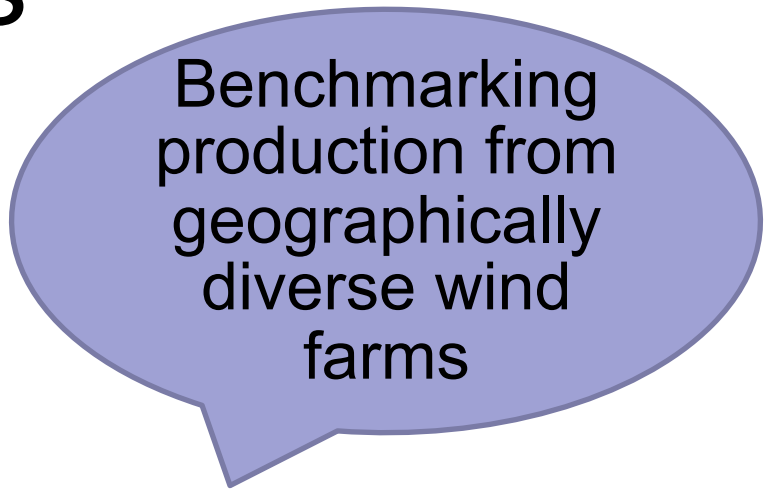
VMM Example

- **Max gust**– highest 3 second gust calculated over the period of hourly time series produced by VMM
- **1 in 50 years max wind speed** – 10 min average wind speed to be expected once in every 50 years.
- **1 in 50 years max gust**– 3 second gust speed to be expected once in every 50 years
- **Mean Turbulence Intensity at 15m/s** – mean of all the values of TI when the mean wind speed is between 14.5 and 15.5 m/s as predicted by VMM model
- **Mean wind shear exponent** – difference in wind speeds between tip of the turbines at the top and bottom of their sweep

Blending datasets to meet requirements

Blending datasets to meet requirements

- Accuracy?
- **Spatial consistency?**
- Temporal consistency?
- **Resolution?**
- Transparency?
- **Timeliness?**



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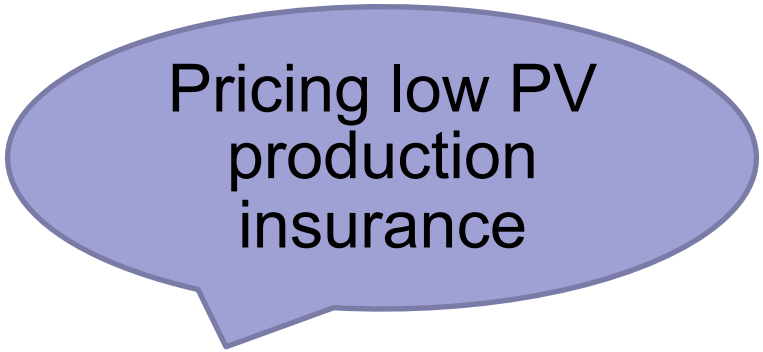


Solar radiation climatology

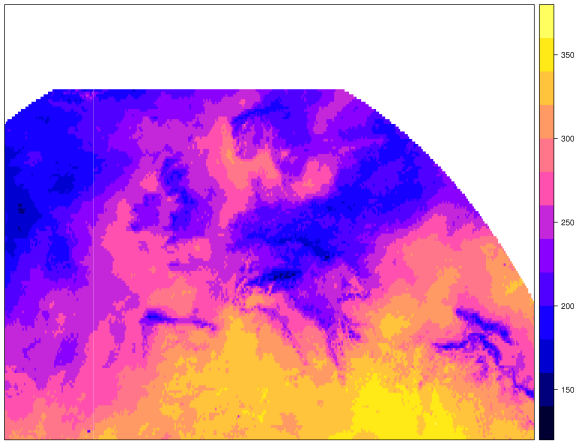
Several climatology datasets available

- Reanalyses
  - ERA-Interim (ECMWF)
  - MERRA (NASA)
  - Watch Forcing Data from ERA-Interim (WFDEI)
- Satellite
  - Geostationary
  - Polar orbiting

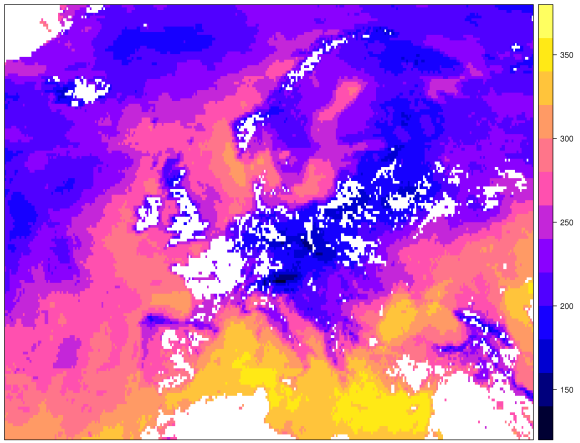
Each have their own strengths and weaknesses

Example: monthly mean GHI, June 2009

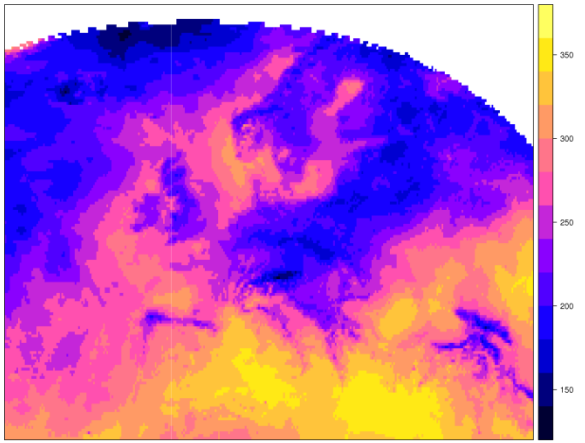
CMSAF Climate (GS), 0.05°



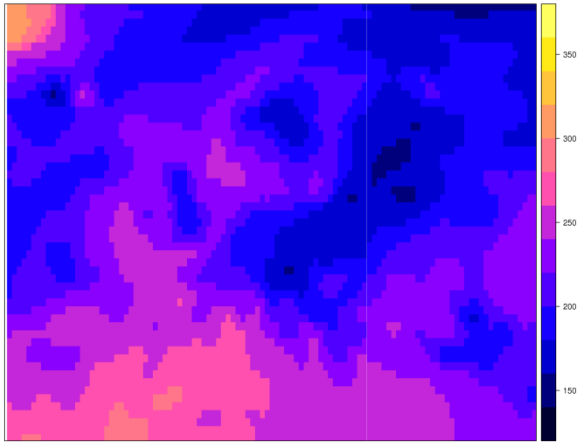
CMSAF Climate (PO), 0.25°



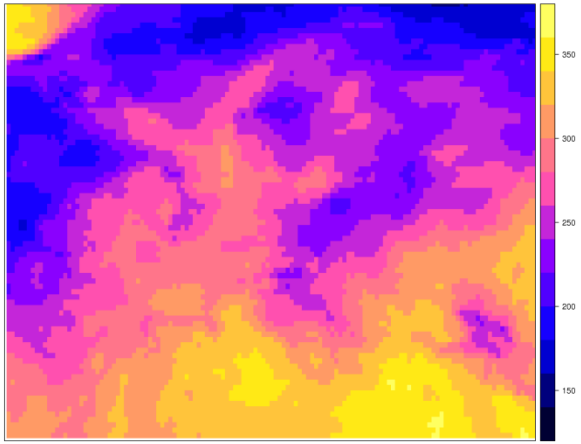
CMSAF Operational (GS), 15km



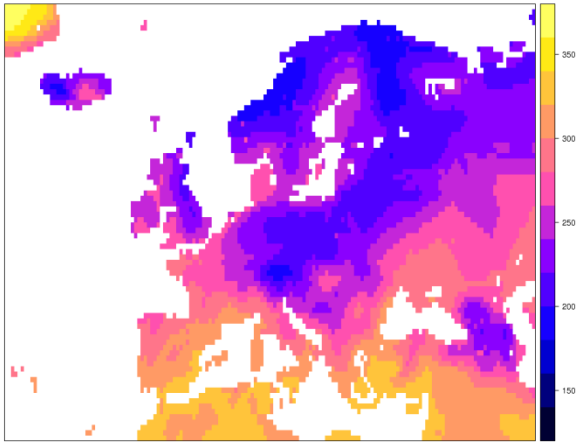
ERA-Interim, 0.75°



MERRA, 0.625°x 0.5°

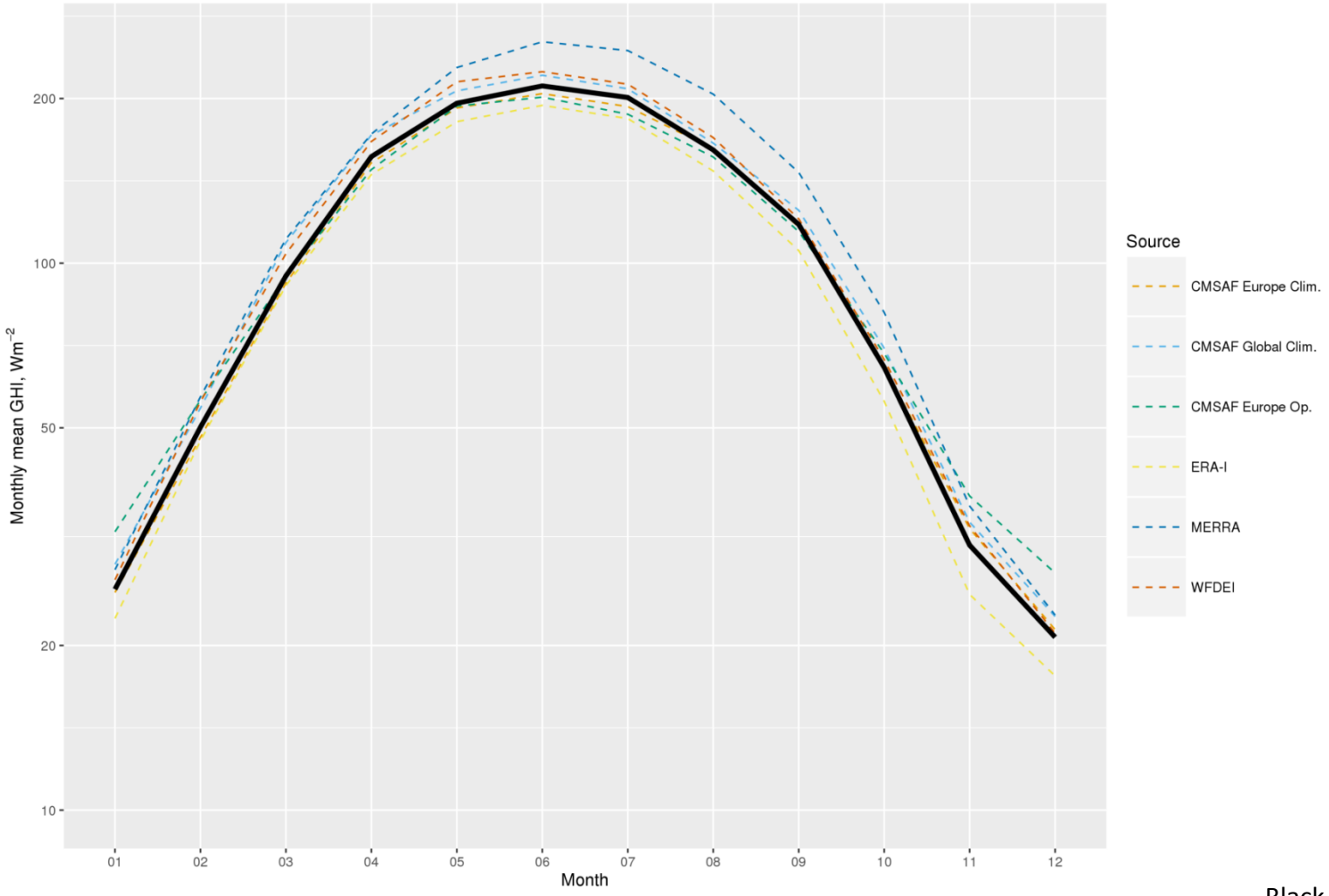


WFDEI, 0.5°



Slide courtesy Paul Newell

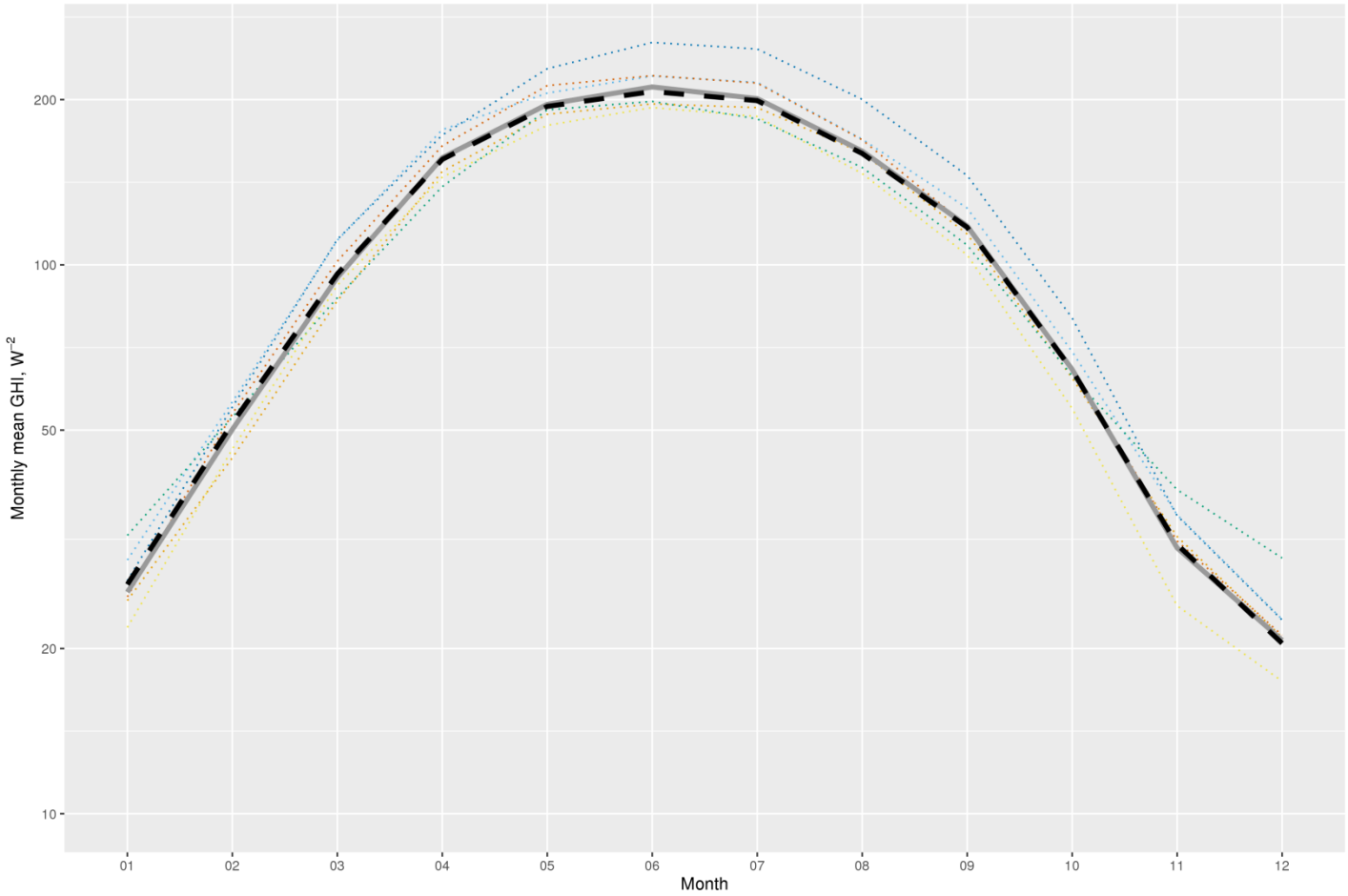
Monthly mean GHI



Black = observations

Slide courtesy Paul Newell

Bias-corrected GHI



Solid grey = observations; Dashed black = bias-corrected `blend`

Slide courtesy Paul Newell

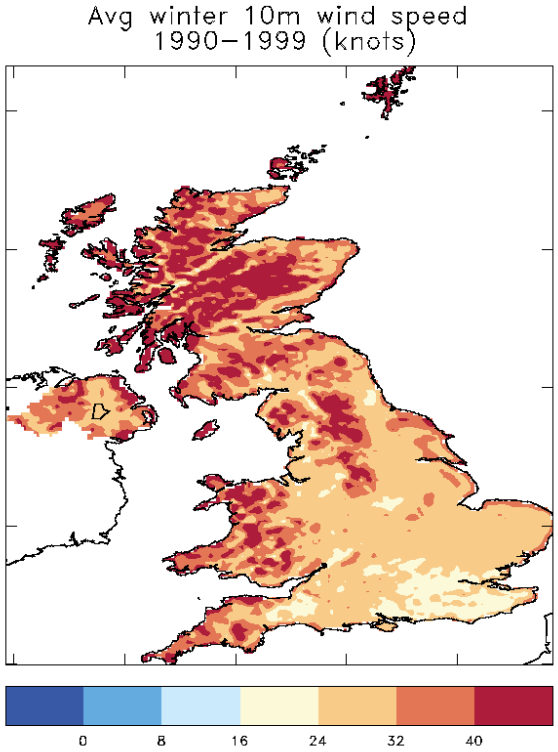
Blending datasets to meet requirements

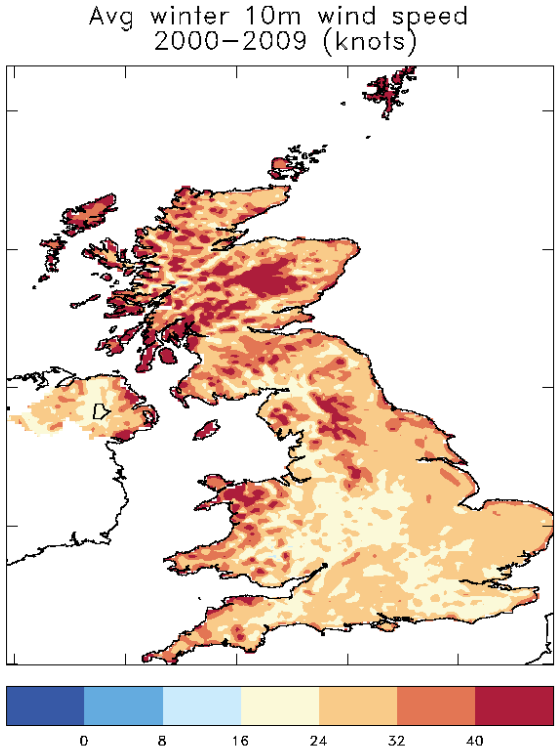
- **Accuracy**?
- Spatial consistency?
- **Temporal consistency?**
- **Resolution?**
- **Transparency?**
- **Timeliness?**

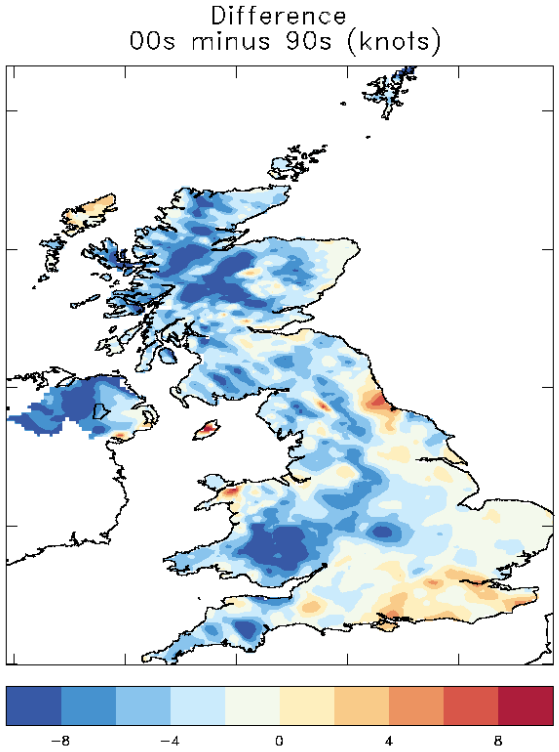
Pricing and **settling** low PV production insurance

Why is production not as expected?

Will climate change cause low wind speeds?

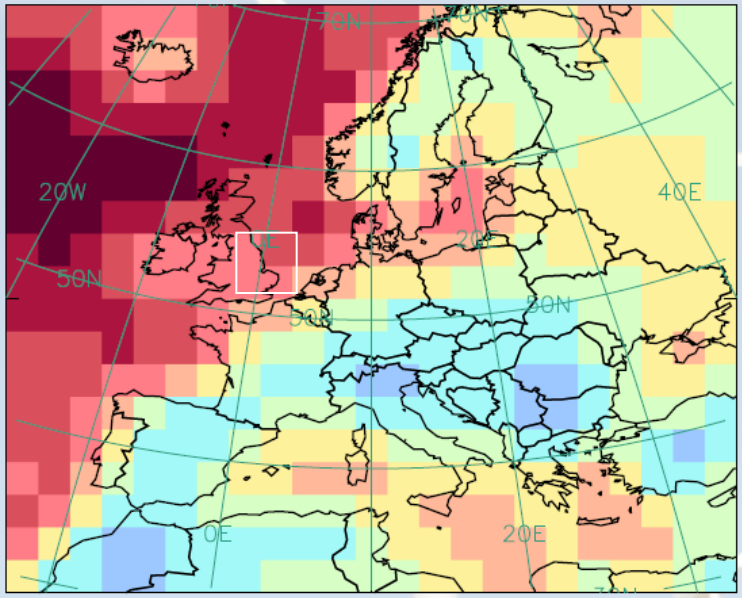






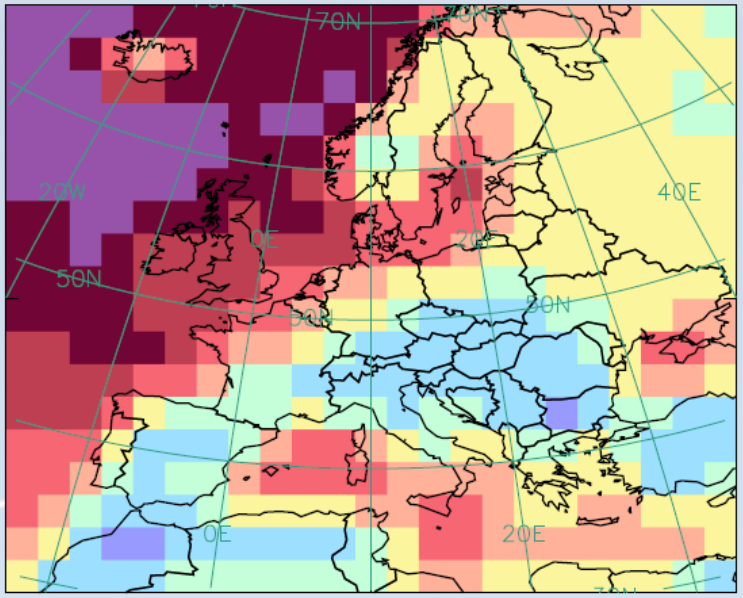
Use a very long climatology

Wind speed and variability



Mean daily wind speed 1871-2010 (m/s)

0 1 2 3 4 5 6 7 8 9 10 11 12

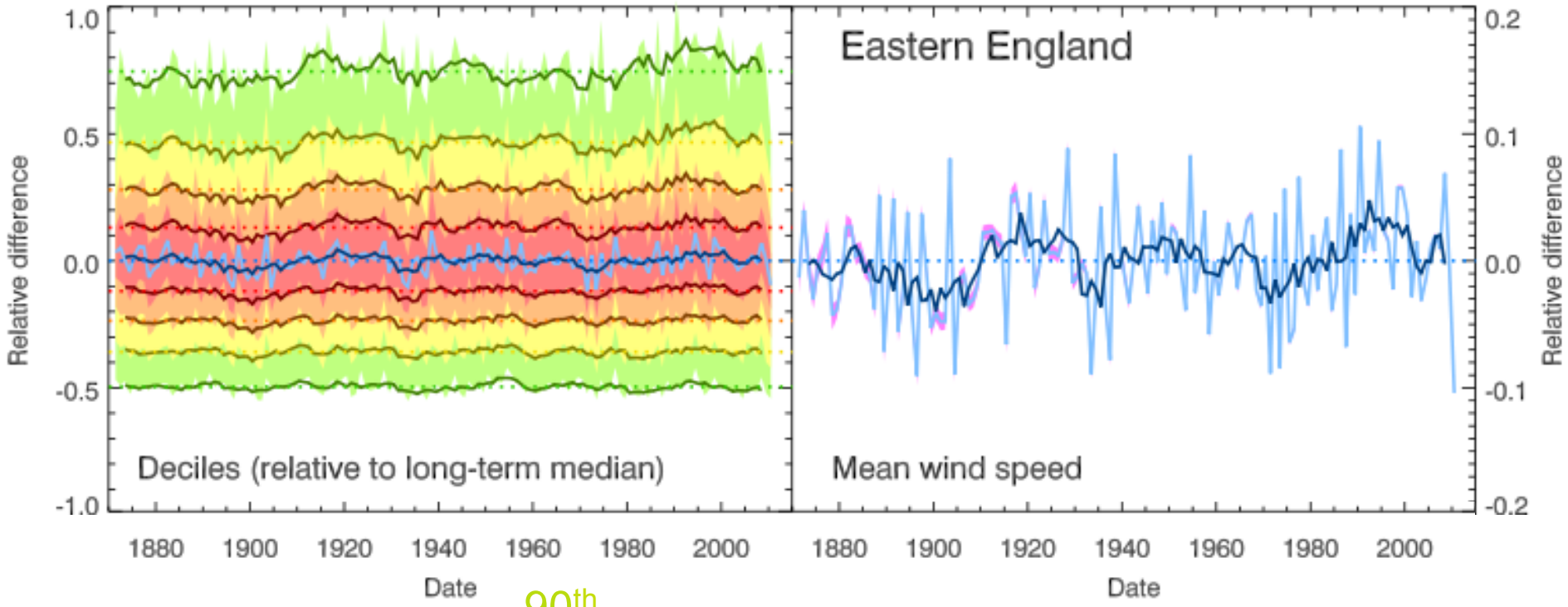


Standard deviation of daily wind speeds 1871-2010 (m/s)

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5

Bett, Thornton, Clark, (2013), Adv. Sci. Res., 10, 51-58

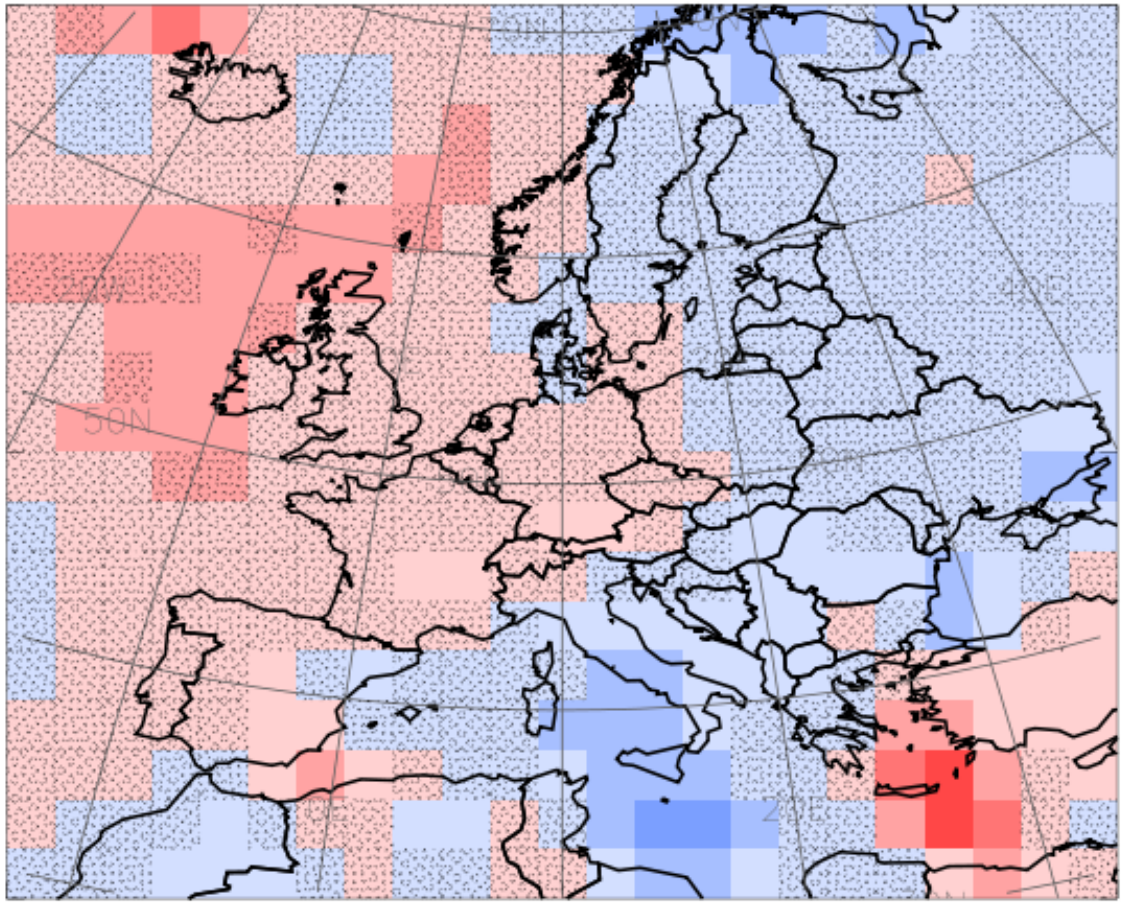
Long-term variability in wind speed



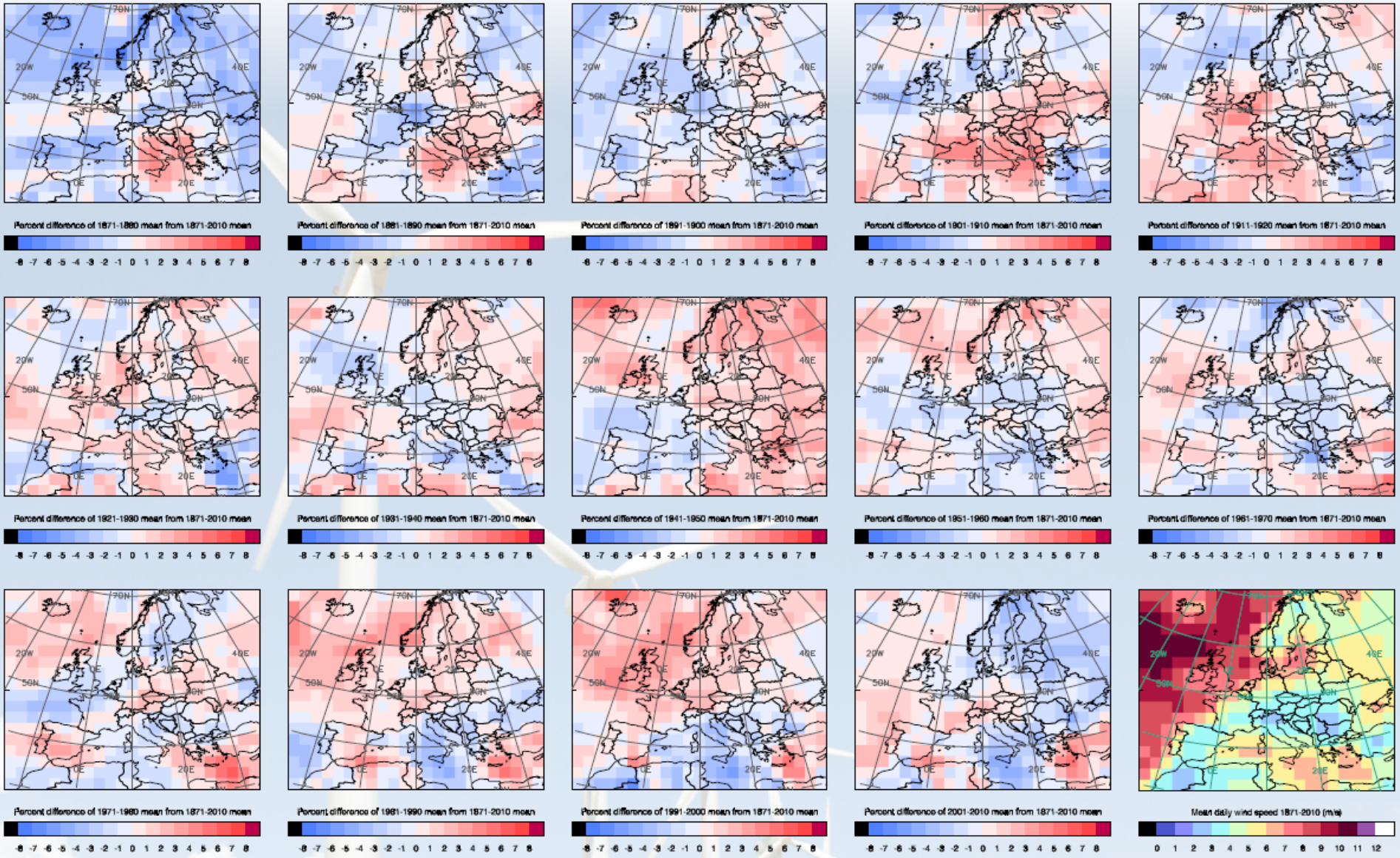
Percentiles

90th
80th
70th
60th
Median
40th
30th
20th
10th

Almost no linear trend



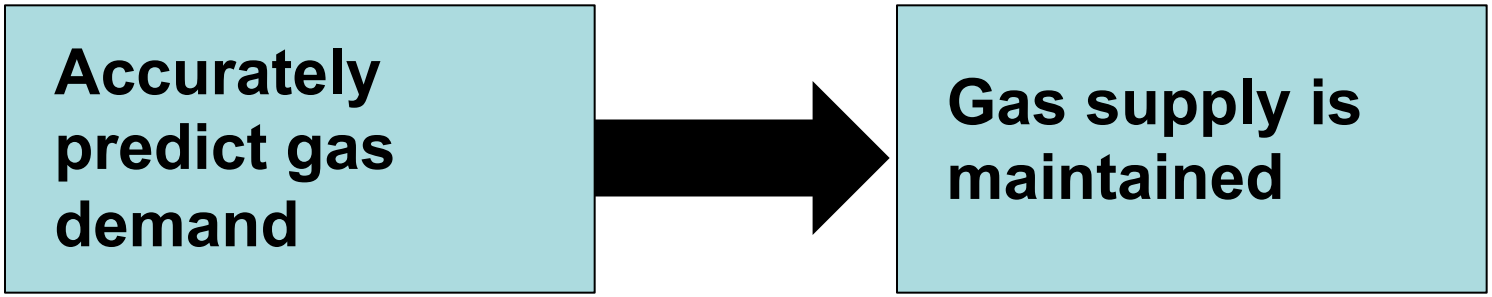
Comparing Decades:
% difference from long-term mean



Taking variability into account

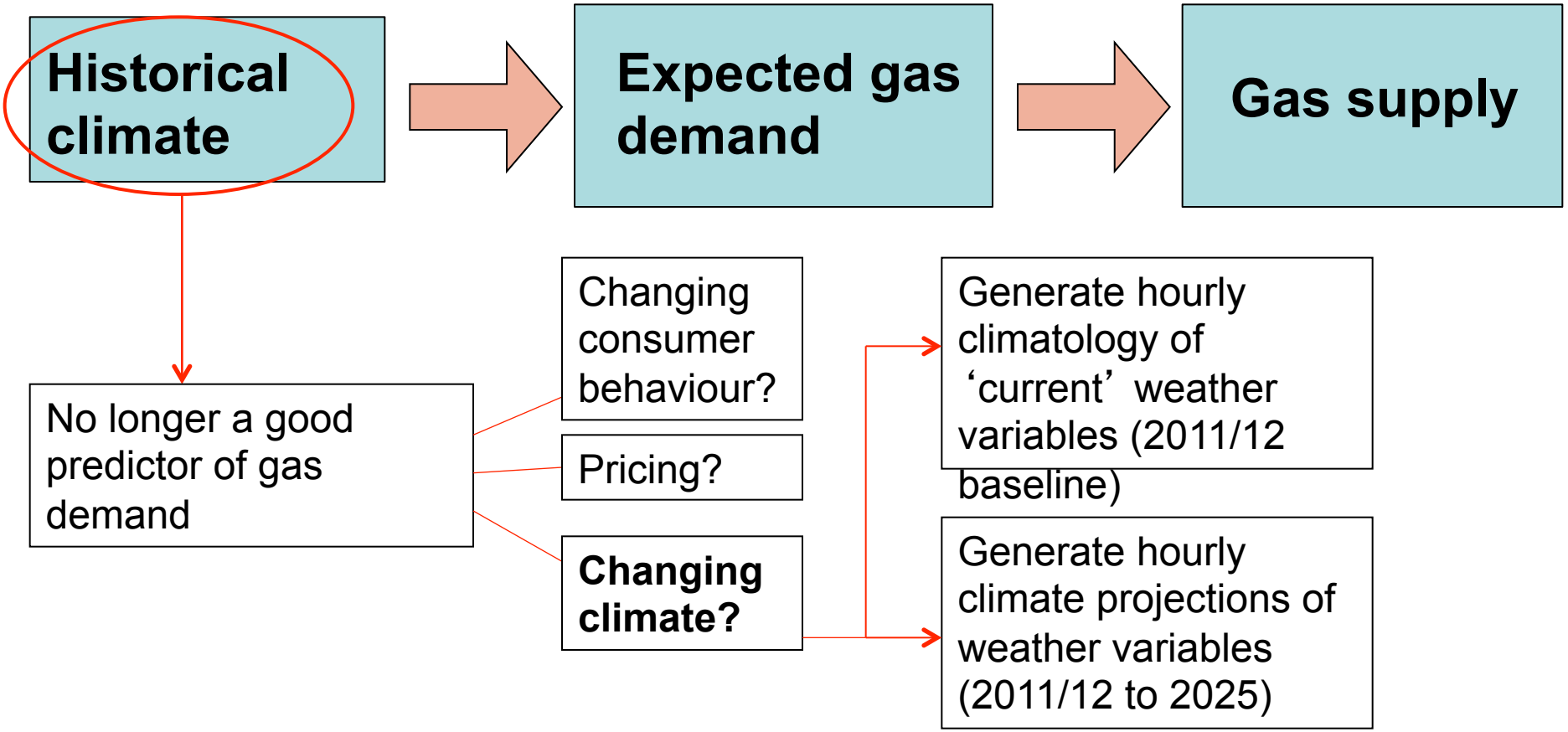
Matching demand and supply for gas

From a gas distributor's perspective



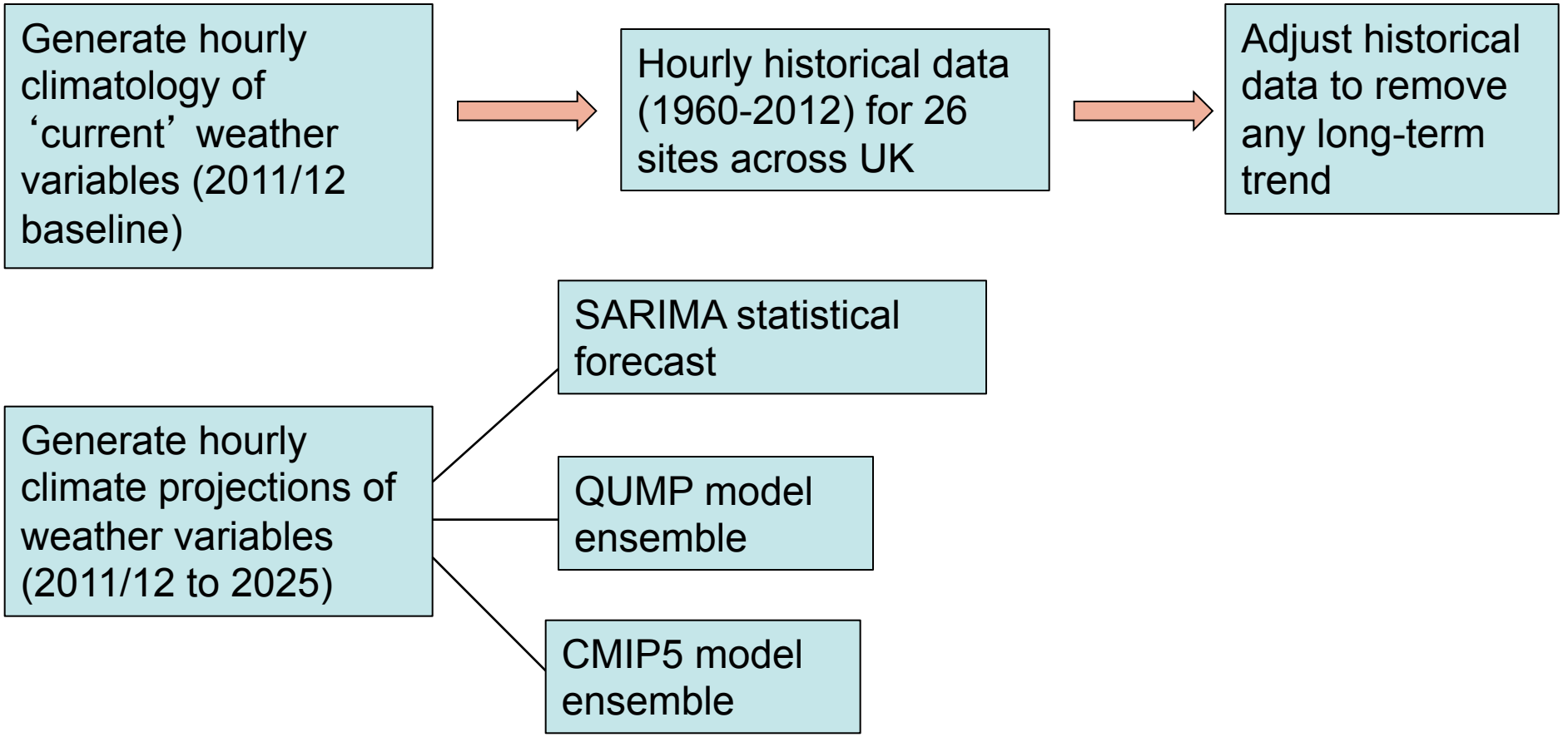
Slide courtesy Justin Krijnen

Proposed approach



Slide courtesy Justin Krijnen

Data sources/methods



Slide courtesy Justin Krijnen

Summary of project

- The UK gas industry requires information about weather and climate in order to plan for gas demand now and in future
- We adjusted historical data so take account of climate variability and change

Summary

Summary

- There are numerous sources of historical data
- Each has its own advantages and disadvantages

Top tips for using climatologies:

- Understand your requirements
- Blending several sources may give you the best solution
- Understand the process: finer resolution isn't necessarily greater accuracy
- Have you taken adequate account of factors that might mean the climatology is irrelevant to your business:
  - Local surface features?
  - Climate variability?
  - Climate change?

Questions