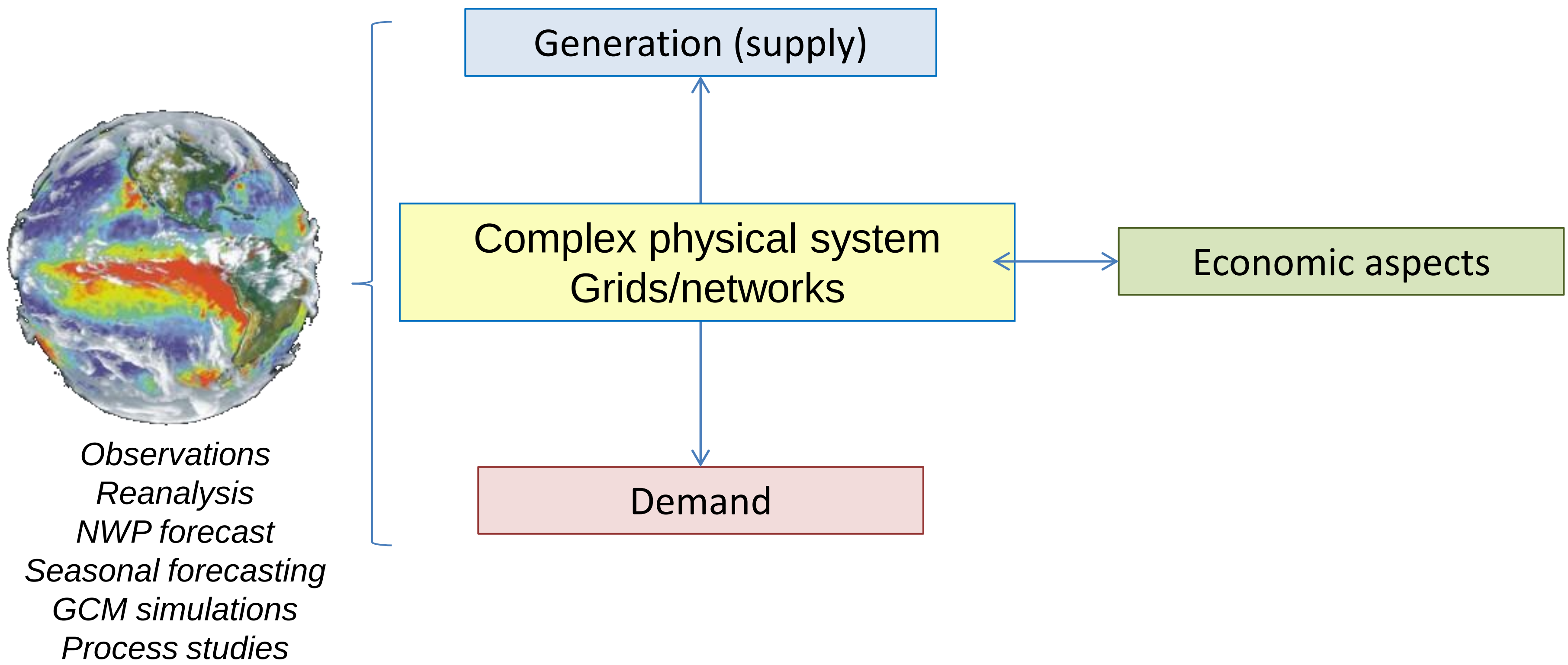
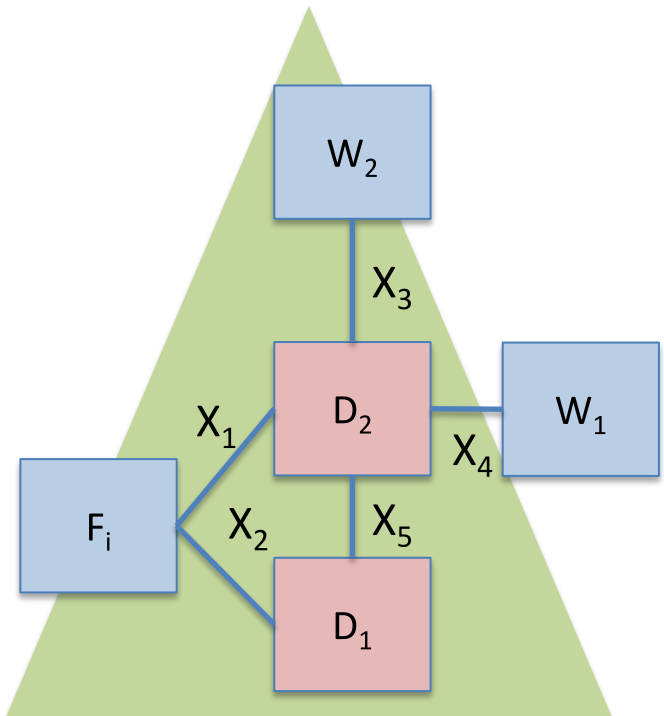
Climate impacts in complex impacted systems

- Climate impacts should not be viewed as a mapping: climate => weather => impact
- Better incorporate climate science (models, knowledge, data) into *simulations* of system behaviour (power, economy, finance, insurance, water resources, …)
- Power/energy sector as an example



The power system as an example

Great Britain power system



Generation:

- $F_{1,2,\ldots N}$: Controllable power stations
  - "inflexible" nuclear plant
  - "cheap slow" coal plant
  - "expensive fast" gas plant
- W_1, W_2: Wind power, $W(u, \rho)$

Demand:

- D_1, D_2: Demand, $D(T, u)$

Transmission:

- X_1, …, X_N: Limited maximum power transmission, L_i

"Impact" questions:

- What is wholesale price, *P*, of electricity at time *t*?
- How much of each type of *F* do I need to ensure supply can always meet demand?
- If more wind power capacity is installed, to what extent does my transmission capacity L_i need to be uprated?

Power system modelling

Generation:
- $F_{1,2,\ldots N}$: Controllable power stations

Challenge:
- W_1, W_2, D_1, D_2 all depend non-linearly on weather
- For every time, t, require:
  - Balance constraint: $\Sigma F(t) = D_1(t) + D_2(t) - W_1(t) - W_2(t)$
  - Ramping constraint: For each F_i require $|F_i(t+1) - F_i(t)| < R_i$
  - Transmission constraint: For each X_i, require $X_i < L_i$
- Such that the cheapest F_i are used

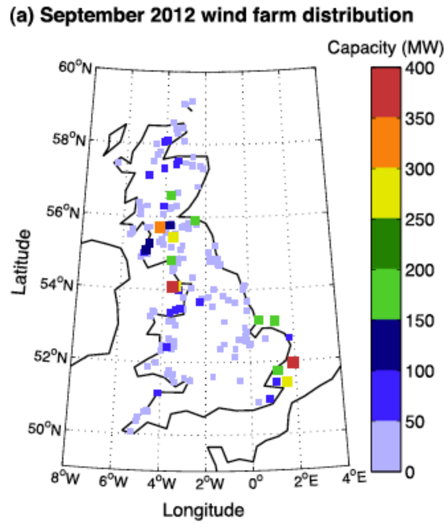
Answers:
- *P* set by the most expensive F_i in use at time *t*
- $Max(\Sigma_i F_i)$ set by spatio-temporal covariability of D and W given constraints *R* and *L*
- Required *L* depends on required power flows between nodes

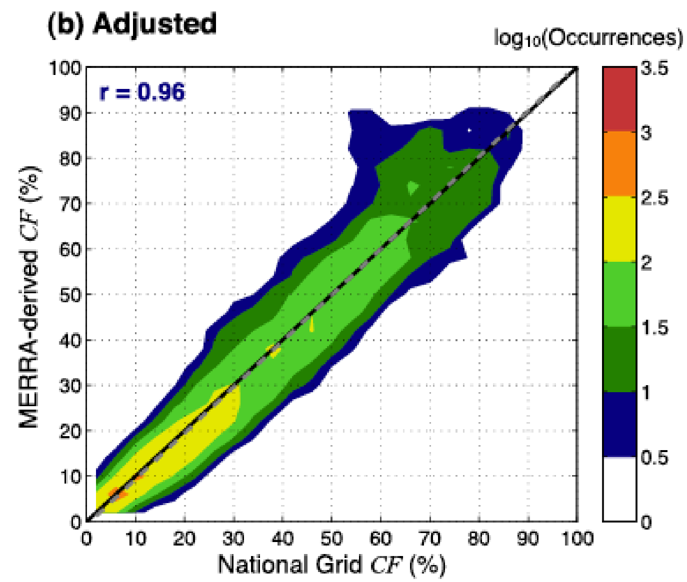
can

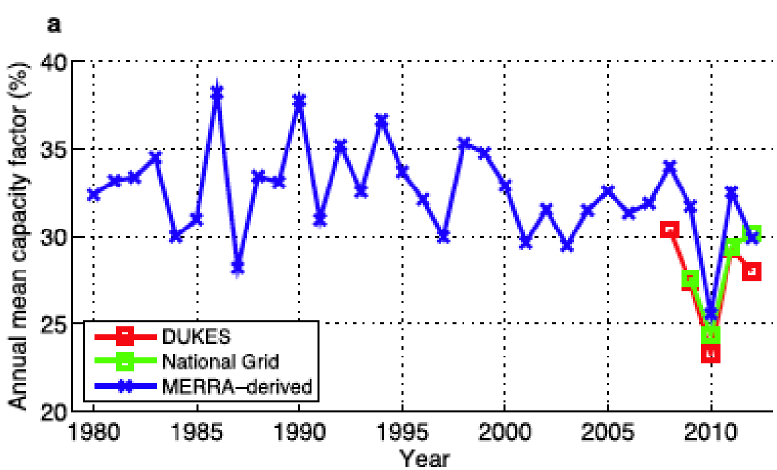
Corollaries:
- Impacted systems can be very complex ("impact functions" helpful but limited)
- To estimate the climate *impact* you need to be able to *simulate* climate response in the target system

does

Example questions for PRIMAVERA







GB wind power

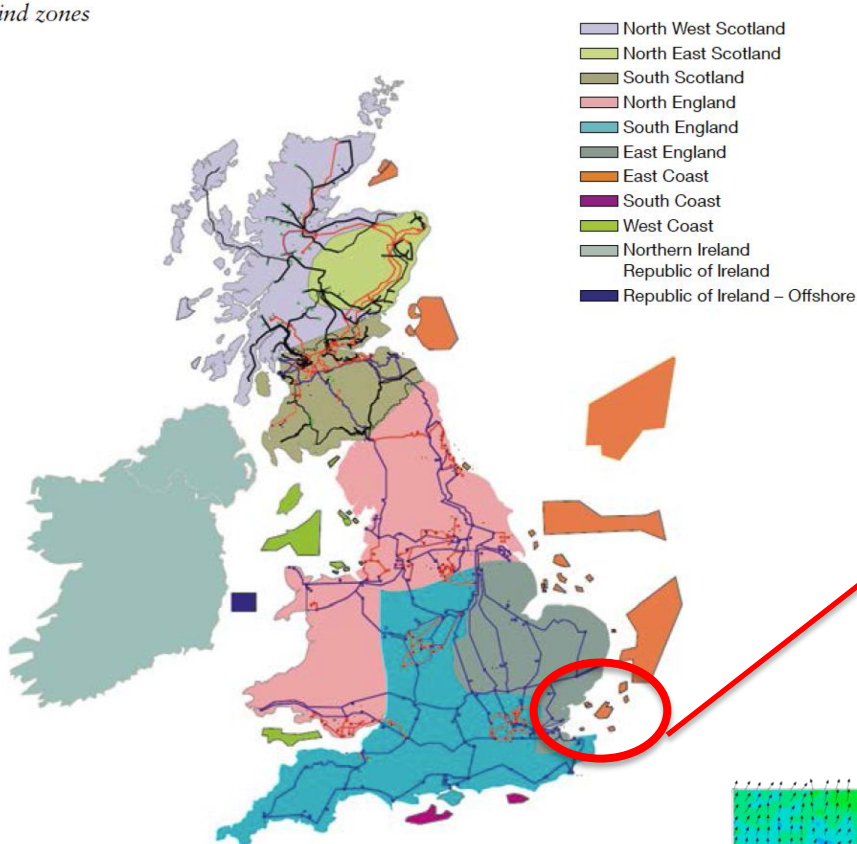
Reanalysis data used to massively extend record

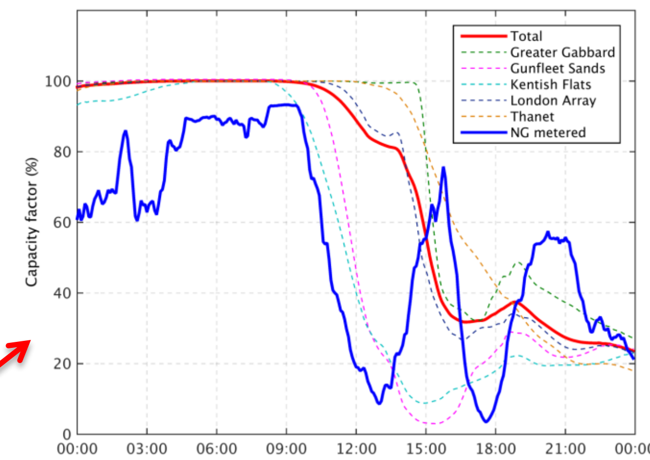
- Useful for understanding extremes in output an **rapid changes in output**
- Limited to 30y – GCM to extend?

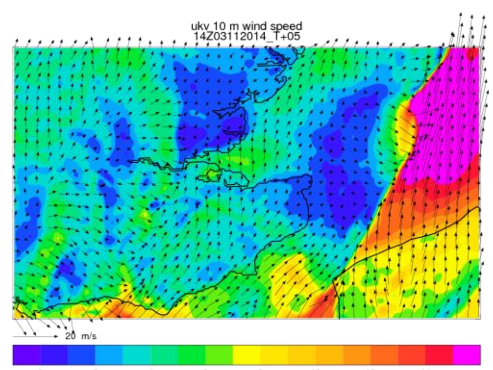
Figs: Cannon et al (2015).

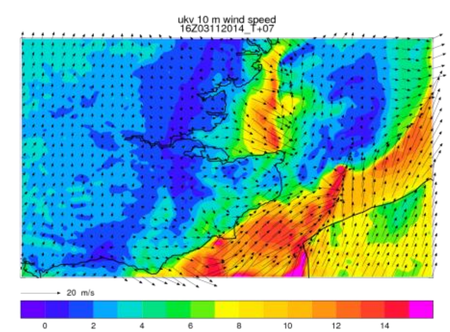
Example questions for PRIMAVERA

Figure 2.19
ELSI wind zones







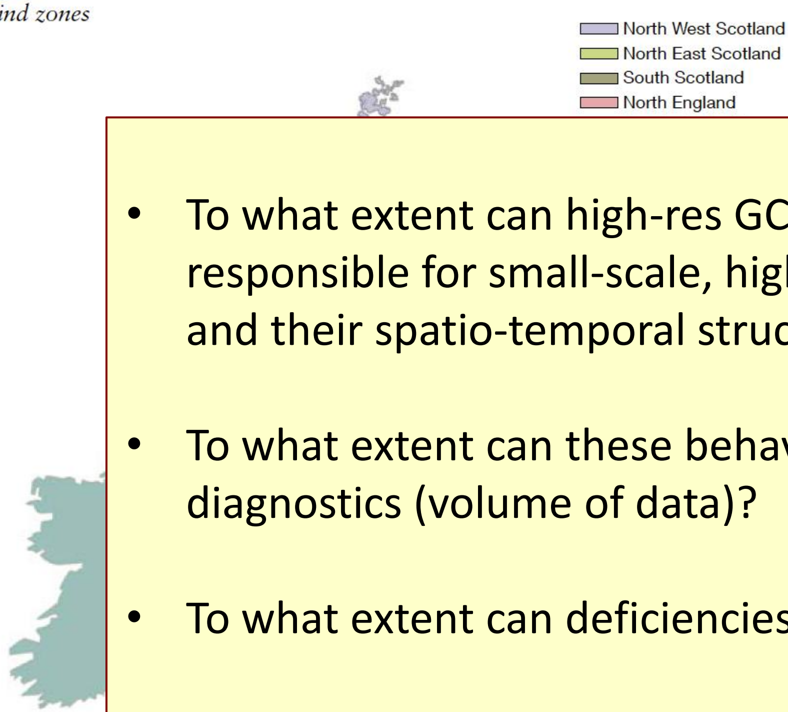


Regional wind power
- Fronts (resolution)
- Secondary structures

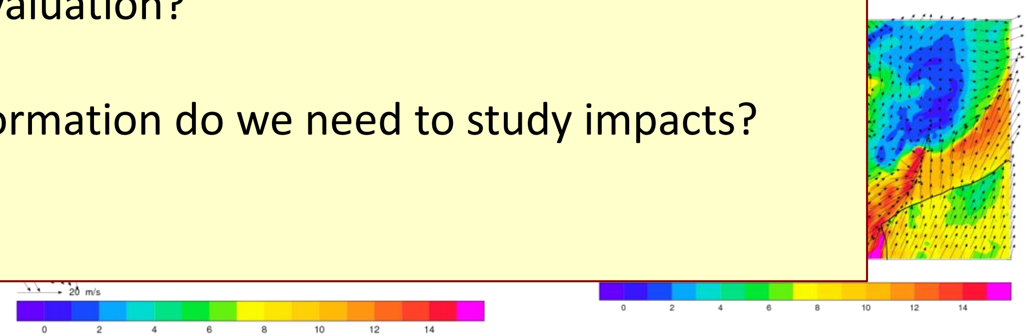
Figs: LHS – National Grid 10 year statement 2014. RHS – courtesy Dan Drew.

Example questions for PRIMAVERA

Figure 2.19
ELSI wind zones



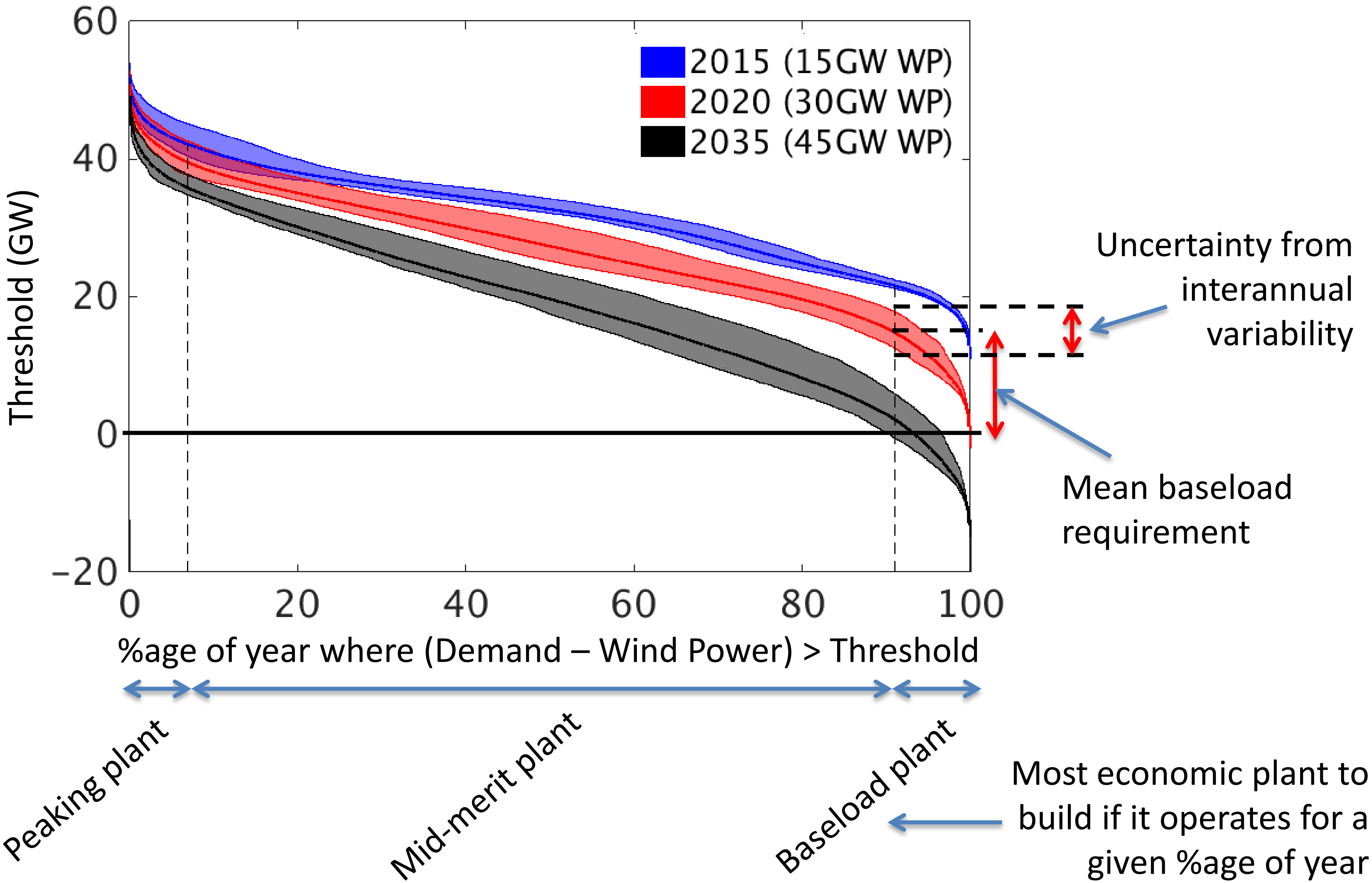
- To what extent can high-res GCMs represent the physical processes responsible for small-scale, high-frequency meteorological properties and their spatio-temporal structure?
- To what extent can these behaviours be captured efficiently in diagnostics (volume of data)?
- To what extent can deficiencies be corrected through post-processing?
- To what extent should/can this understanding feedback on model development and model evaluation?
- (Practically) What GCM information do we need to study impacts?



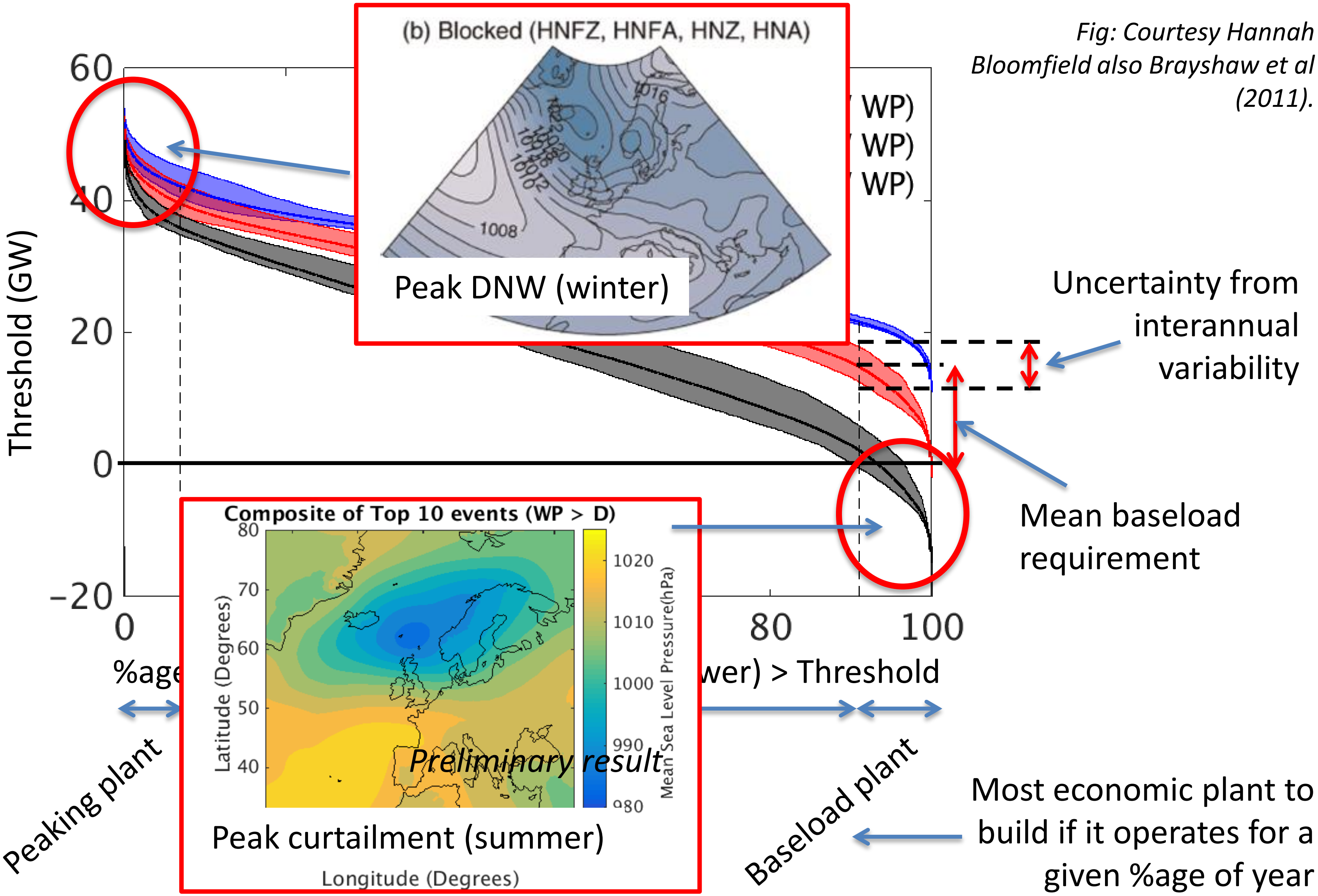
Figs: LHS – National Grid 10 year statement 2014. RHS – courtesy Dan Drew.

Example questions for PRIMAVERA

Fig: Courtesy Hannah Bloomfield.

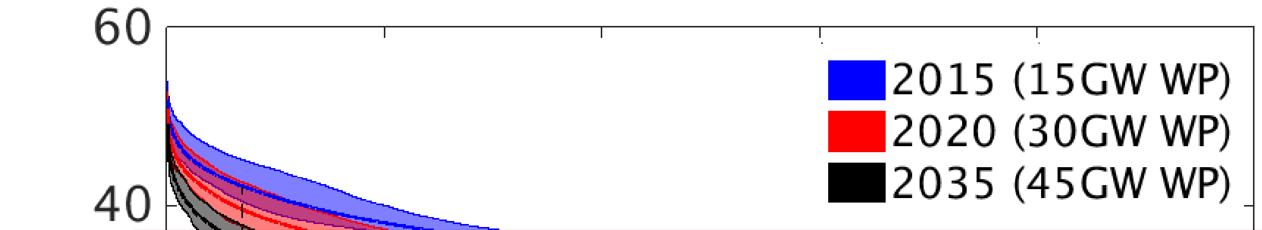


Example questions for PRIMAVERA



Example questions for PRIMAVERA

Fig: Courtesy Hannah Bloomfield.



- To what extent can high-res GCMs better represent the synoptic and low-frequency variability effecting the power systems?
- To what extent is there a robust relationship between large-scale LFV and small-scale surface properties (both synoptic and HFV) in high-res GCMs?
- To what extent can deficiencies be corrected through post-processing?
- To what extent should/can this understanding feedback on model development and model evaluation?

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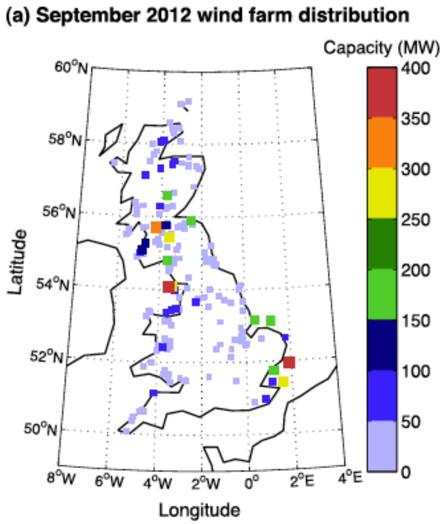
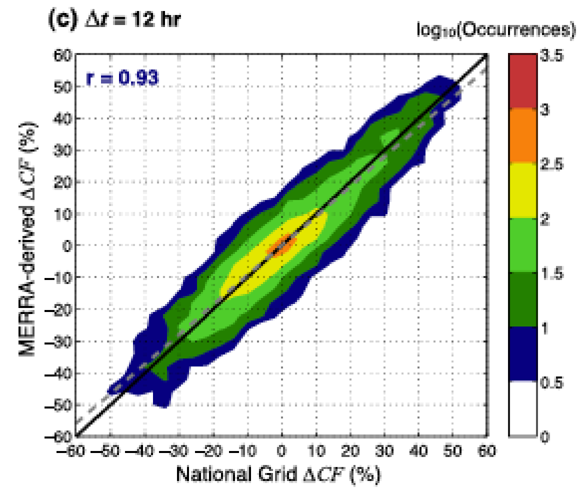
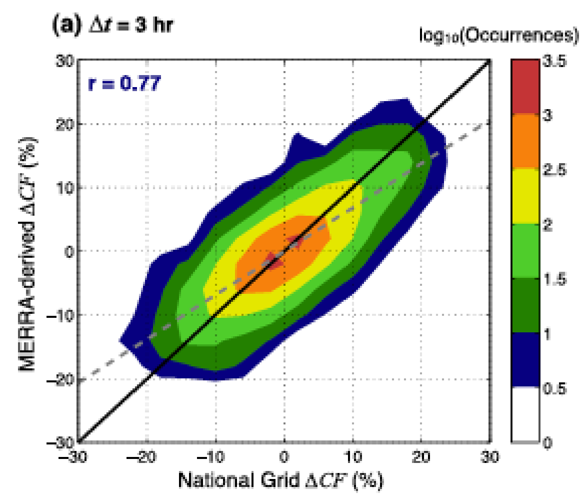
Example questions for PRIMAVERA







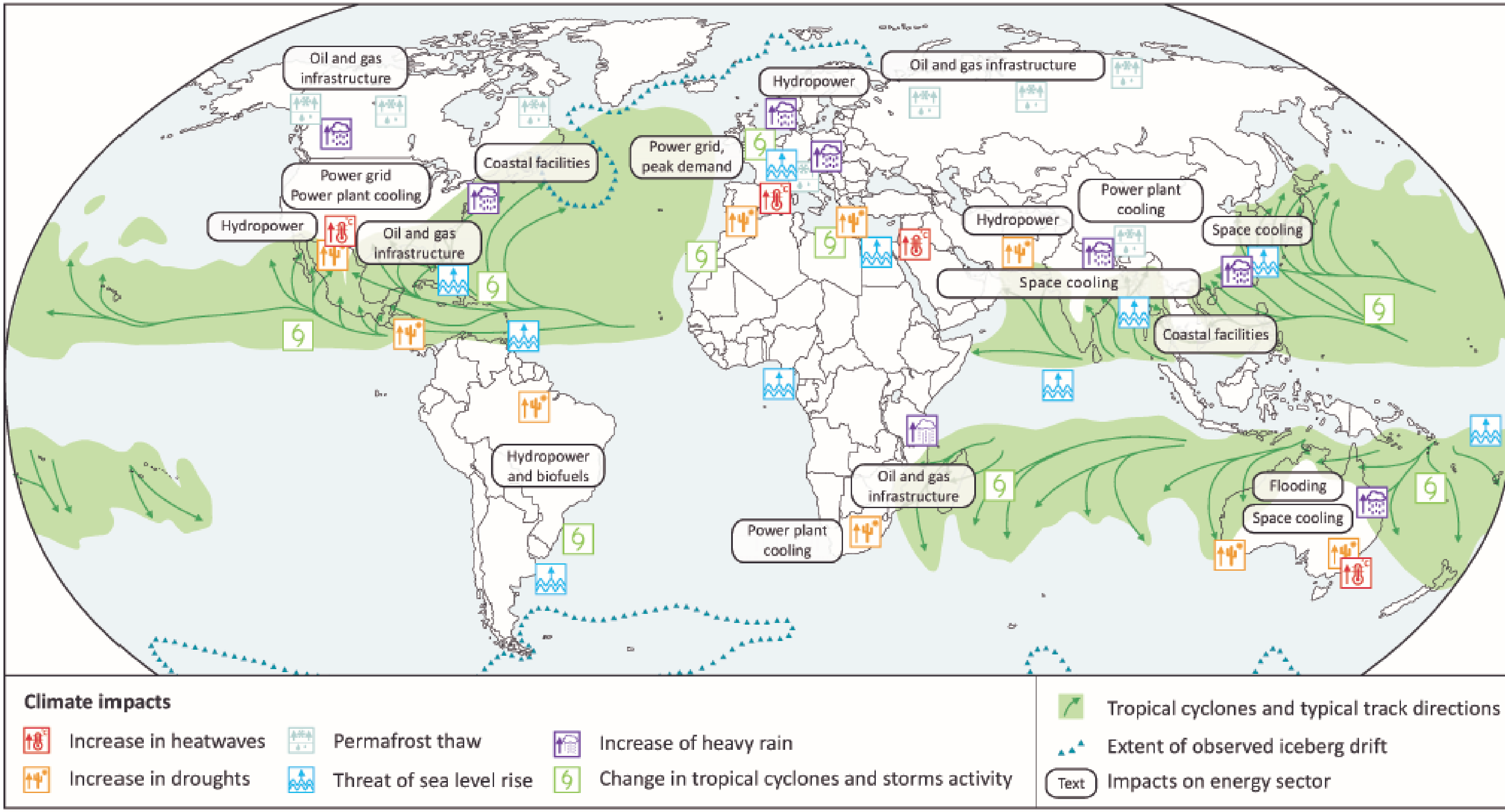
GB wind power

Reanalysis data used to massively extend record

- High frequency variability (<6h) underestimated
- To what extent will FCM experiments improve this?

Figs: Cannon et al (2015).

Globally interconnected



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Sources: Based on ©Munich RE (2011), with information from Acclimatise (2009), Foster and Brayshaw (2013), Schaeffer, *et al.* (2012) and IEA analysis.

Fig: IEA 2013 Redrawing the Energy Climate map