How regional climate interacts with wind power generation

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& the EURO-CORDEX modelling consortium

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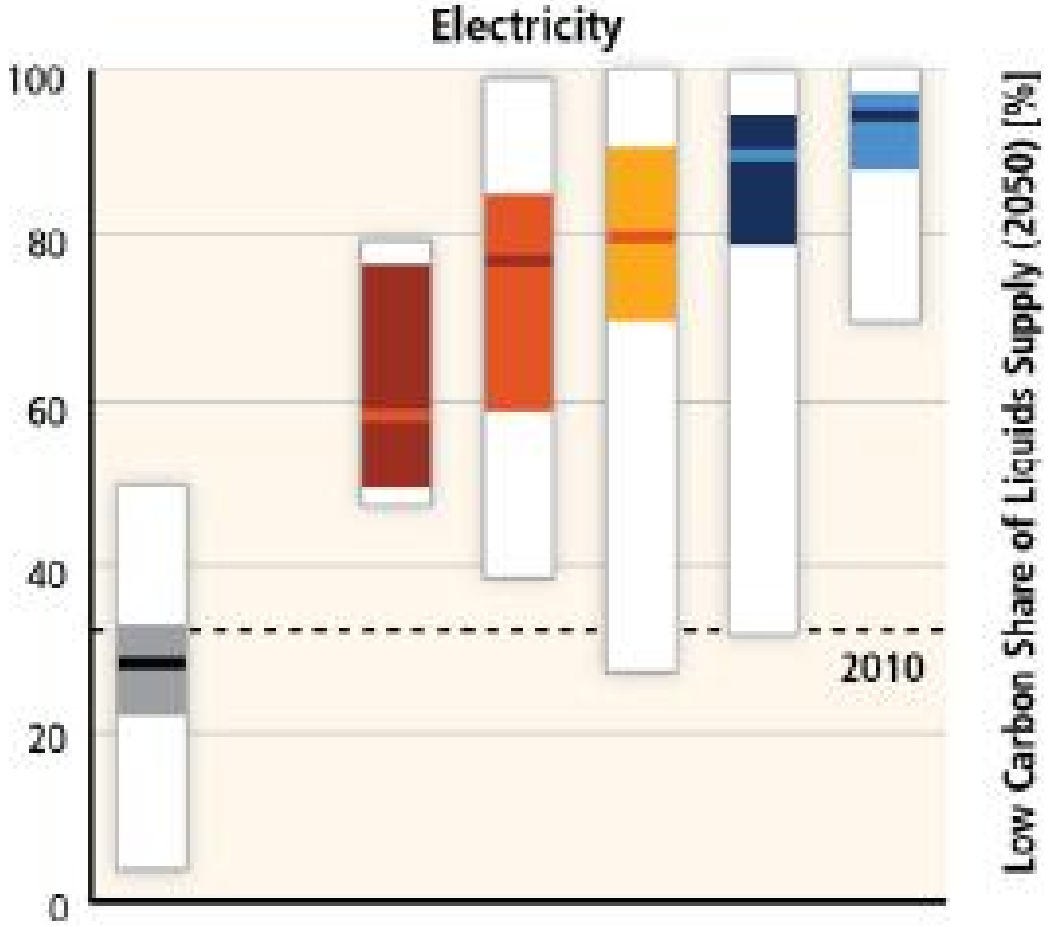
Electricity production to be decarbonized by 2050

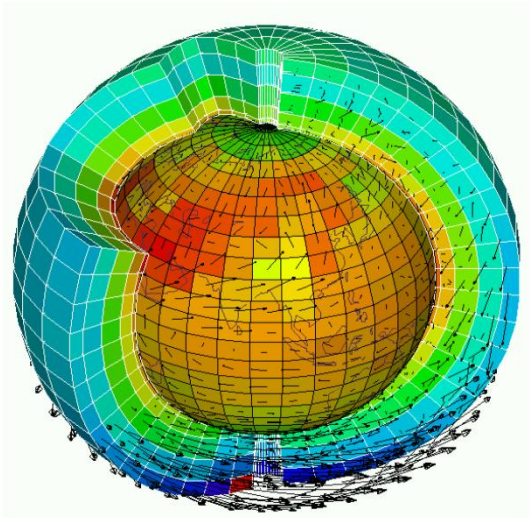


IPCC WG3 2014

Questions

- How does climate change impact wind power resources?
- Does wind power development have an impact on regional climate?
- Does wind power development have an impact on wind resource?

Global and regional modeling



Global model (eg IPSL-CM)

Zoom & Downscaling

Regional model EURO-CORDEX

Why?

- To provide higher-resolution climate projections for impact studies
- To better describe extreme events
- **To evaluate the effects of regional policies** (for some issues)

Uncertainty: use **ensembles** of simulations

Wind Power

Wind power computation

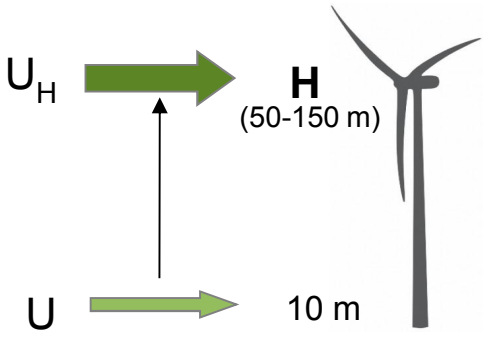
- Conversion ***10m wind speed*** *(uncorrected)* ⟶ ***Wind turbine power output***

3-hr series

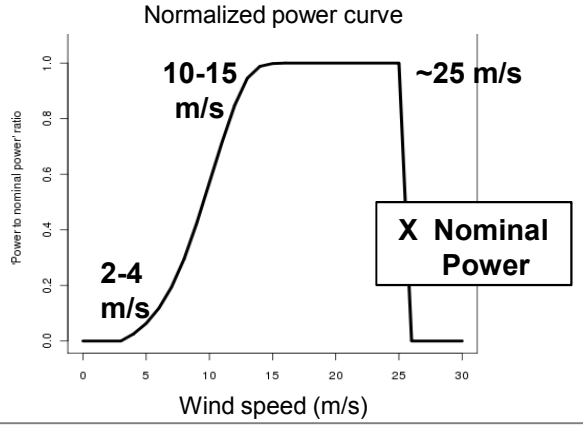
1- Wind vertical extrapolation

$$U_H = U.(\frac{H}{z})^{\frac{1}{7}}$$

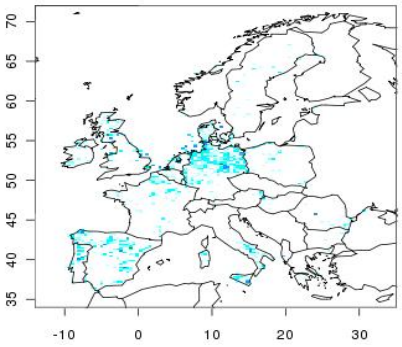
Elliott, 1979



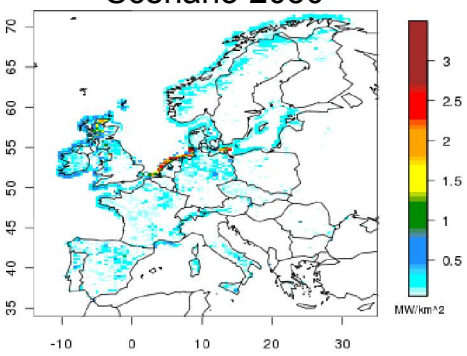
2- Turbine power output



Current wind farms fleet



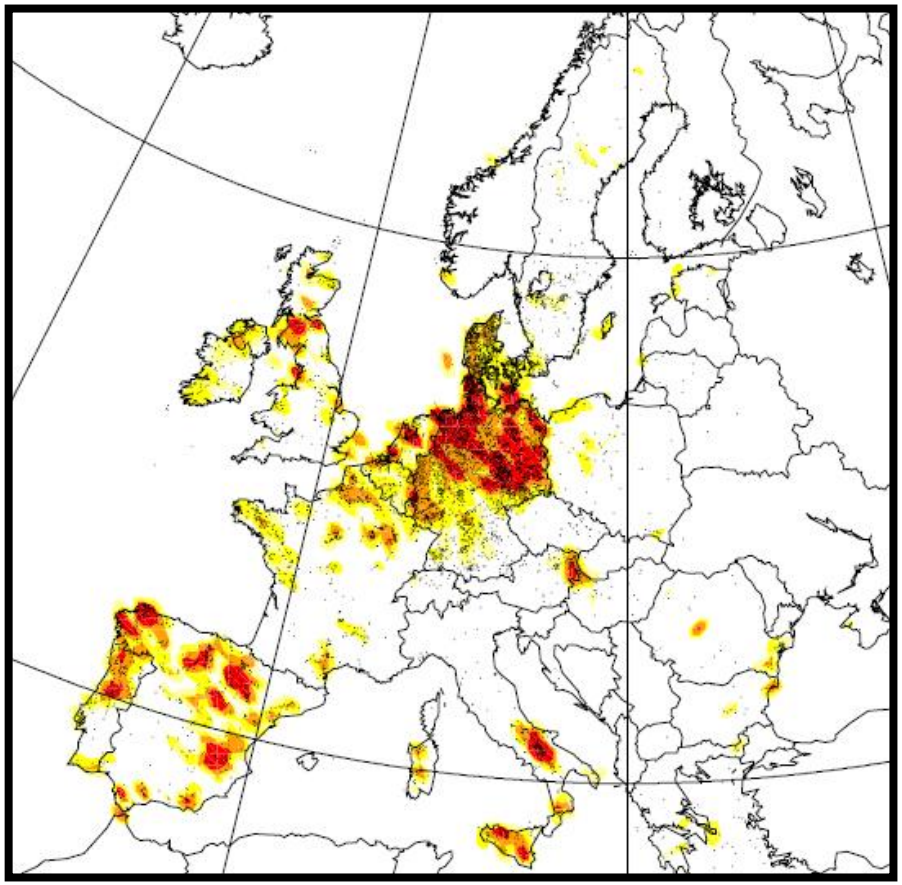
Scenario 2050



- Characteristics of current wind turbine fleets (location, installed power, hub height...)
(*www.thewindpower.net*)

- Spatialized scenarios for future wind turbine fleet
(the CLIMIX tool : *Jerez et al 2014*)

Wind turbines in Europe in 2012



Source http://www.thewindpower.net

2012: 100 Gwatts, 80000 windmills

2020: x2 (C&E package)

2035: x3 (IEA outlook)

2050: x3-5 (diverse scenarios)

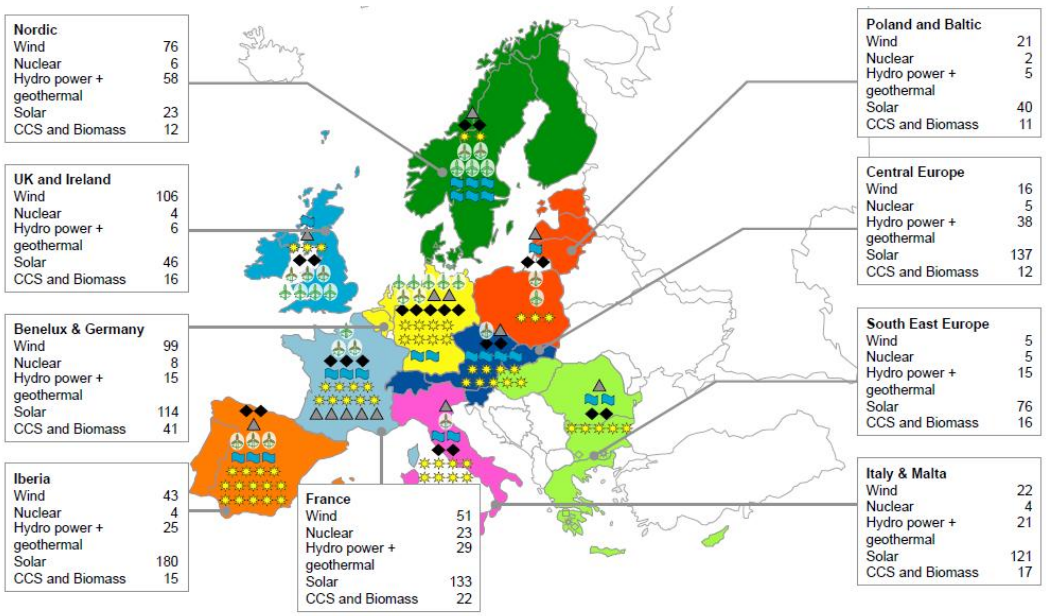
Scénarios for 2020 and 2050

2020: Climate & Energy Package

Wind energy	On shore		Off-shore	
MW	Operational end 2012	Planned 2020	Operational end 2012	Planned 2020
Austria	1314	2578	0	0
Belgium	842	2320	195	2000
Bulgaria	668	1115	0	0
Cyprus	0	300	0	0
Czech Republic	261	743	0	0
Denmark	3373	2621	1047	1339
Estonia	412	400	0	250
Finland	196	1600	32	900
France	7894	19000	6	6000
Germany	32118	35750	124	10000
Greece	1611	7200	38	300
Hungary	542	750	0	0
Ireland	1823	4094	25	555
Italy	8006	12000	0	680
Latvia	32	236	0	180
Lithuania	198	500	0	0
Luxembourg	44	131	0	0
Malta	0	14,45	0	0
Netherlands	2535	6000	247	5178
Poland	1867	5600	0	500
Portugal	4488	6800	4	75
Romania	1742	4000	0	0
SlovakRepublic	0	350	0	0
Slovenia	0	106	0	0
Spain	22131	35000	10	3000
Sweden	2702	4365	171	182
United Kingdom	5359	14890	2362	12990
EU 27	100158	168463	4261	44129

230 GWatts

2050: European Climate Foundation 80% renewables

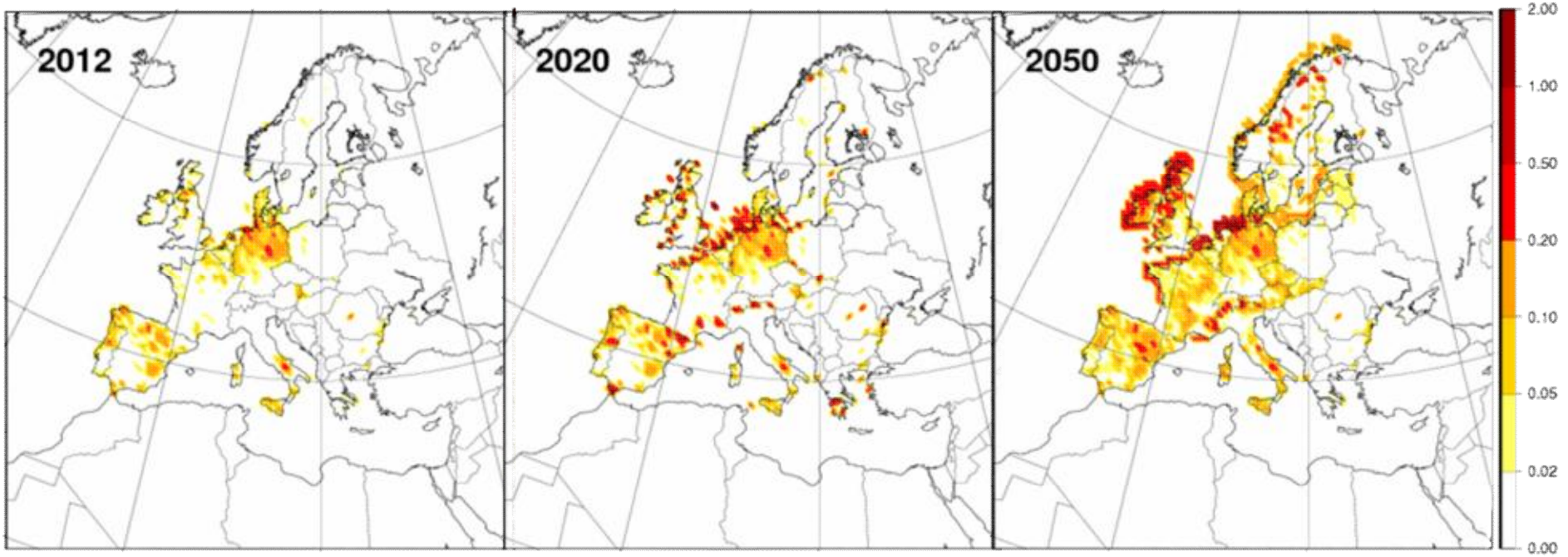


440 GWatts

Spatial distributions

Use of the CLIMIX approach for 2050 (Jerez et al., 2014, RSER), EMS2014-378 Talk by S Jerez

- Optimize resource, avoid unsuitable lands, offshore near coast, no optimization yet

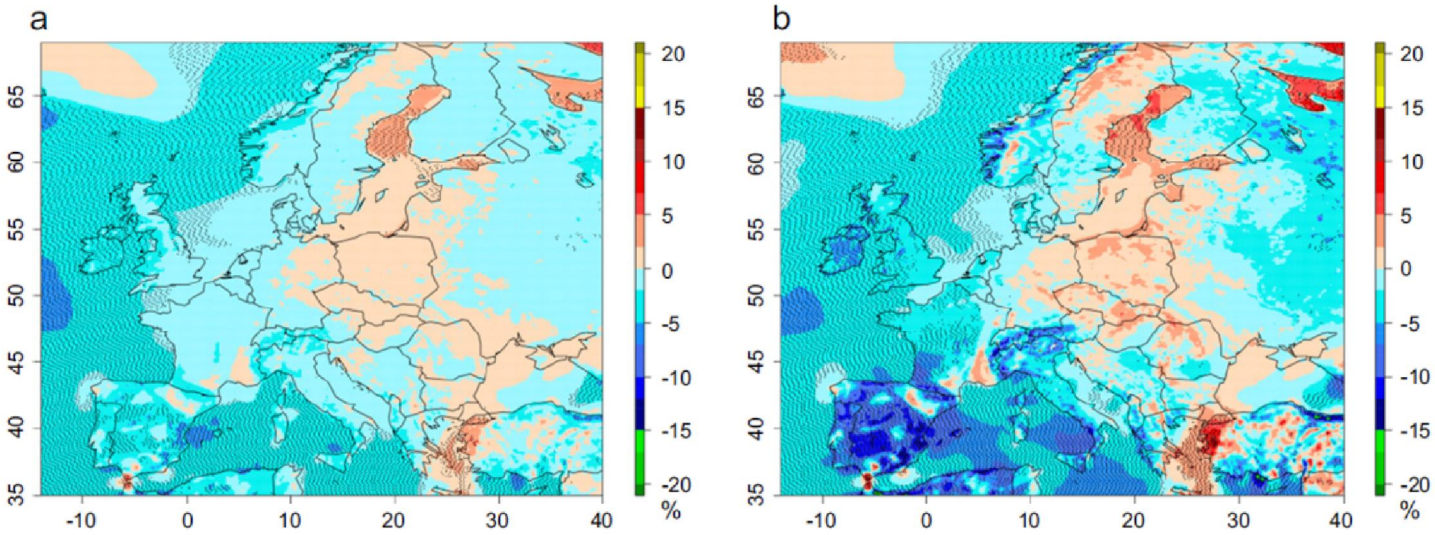


Impact in RCP8.5

Changes in 10m wind speed

Changes in wind power potential production

Dots :
At least 80% of models agree on sign + significance at the 95 % level over the model ensemble



- Changes in wind power potential within ± 5 %
- Robust increases over Baltic Sea, Aegan Sea, Bosporus, Gilbraltar Strait, Western Turkish coast
- Robust decreases over Atlantic Sea, Iberian Peninsula, Mediterranean Sea

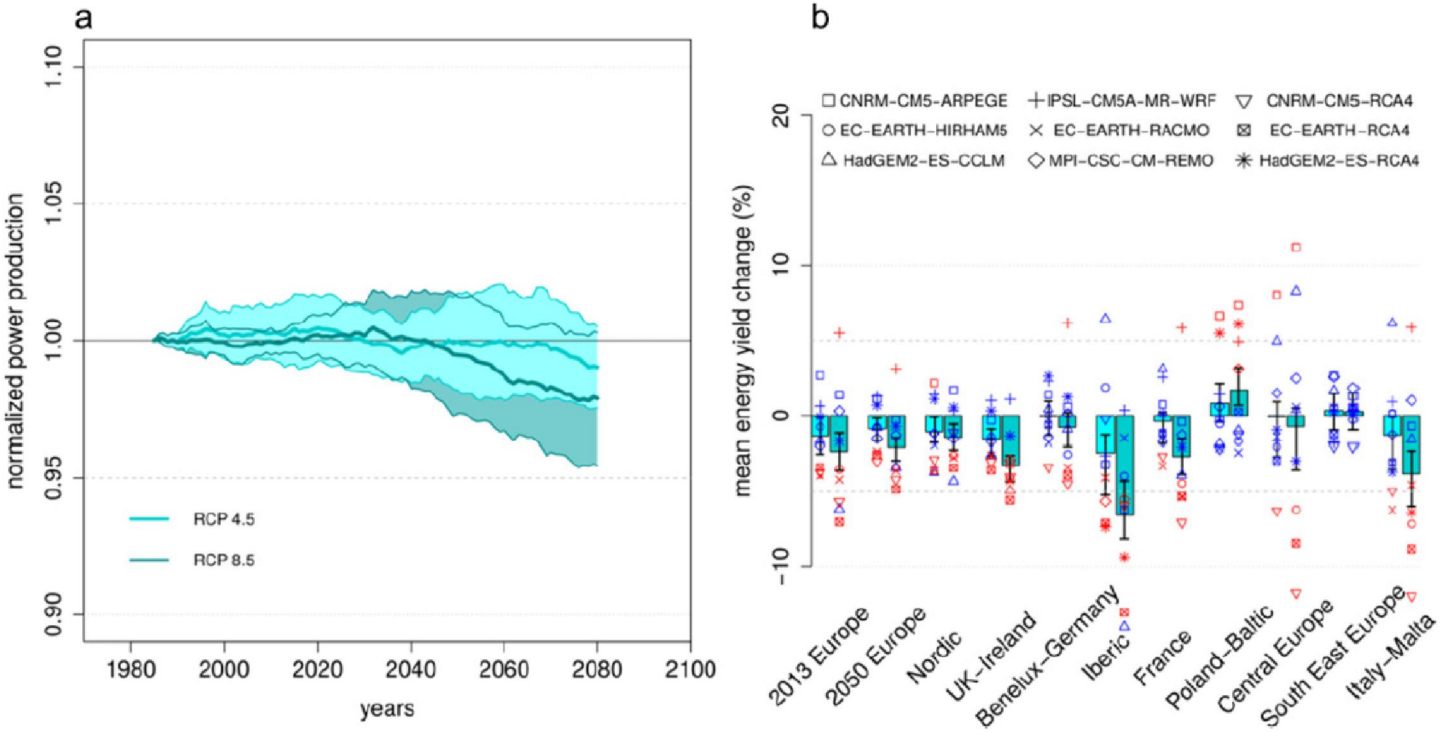
WP6 Task 2 : Impact of +2°C global warming on energy supply

LSCE

Sciences de l'environnement Pierre Simon Laplace

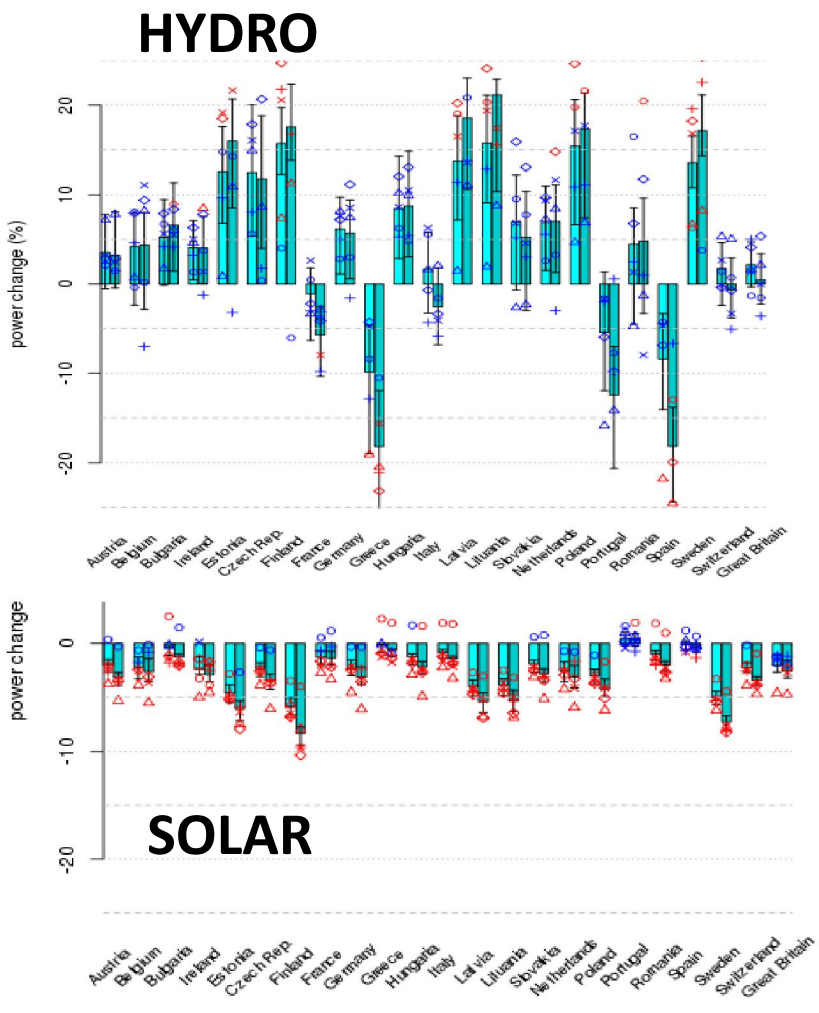
Results based on mandatory EUROCORDEX simulations RCP4.5 *merged with* RCP8.5 (9 simulations)

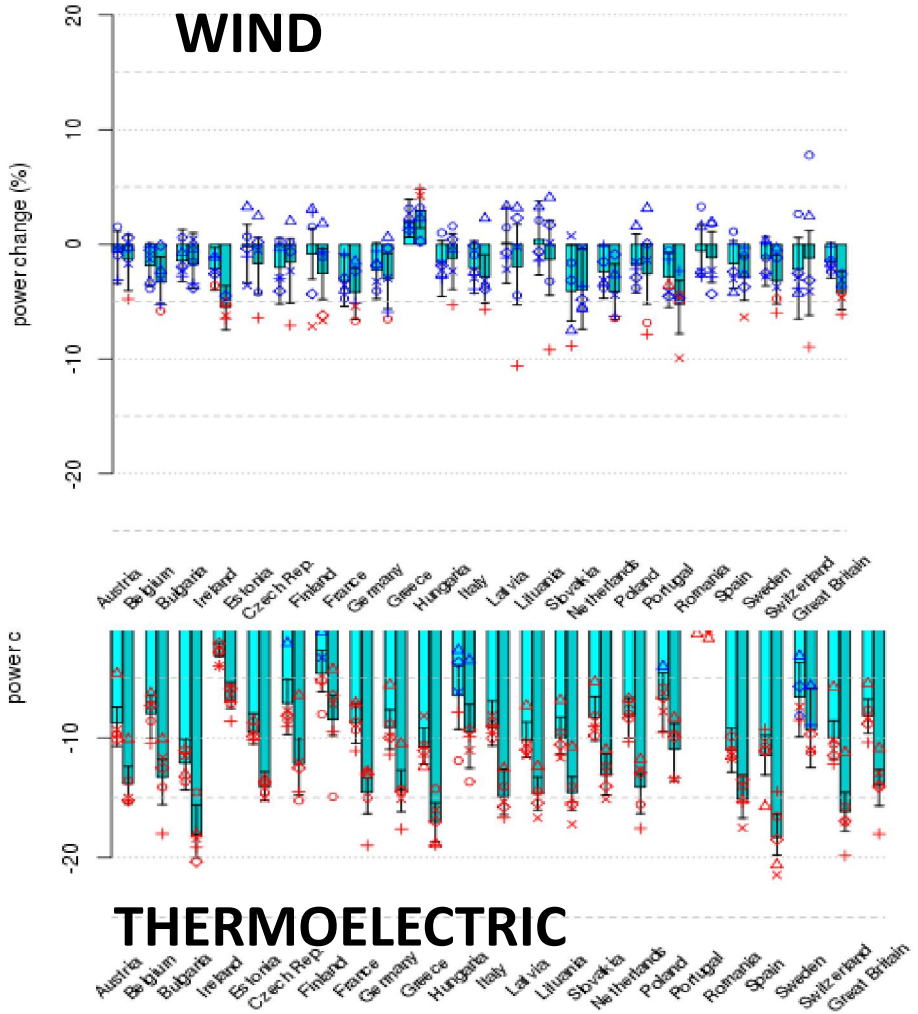
2050 Fleet and End-of-Century effect



- Changes in wind power production are within +-15 % for all national fleets for all models

Energy production per technology (+2°C and +3°C)





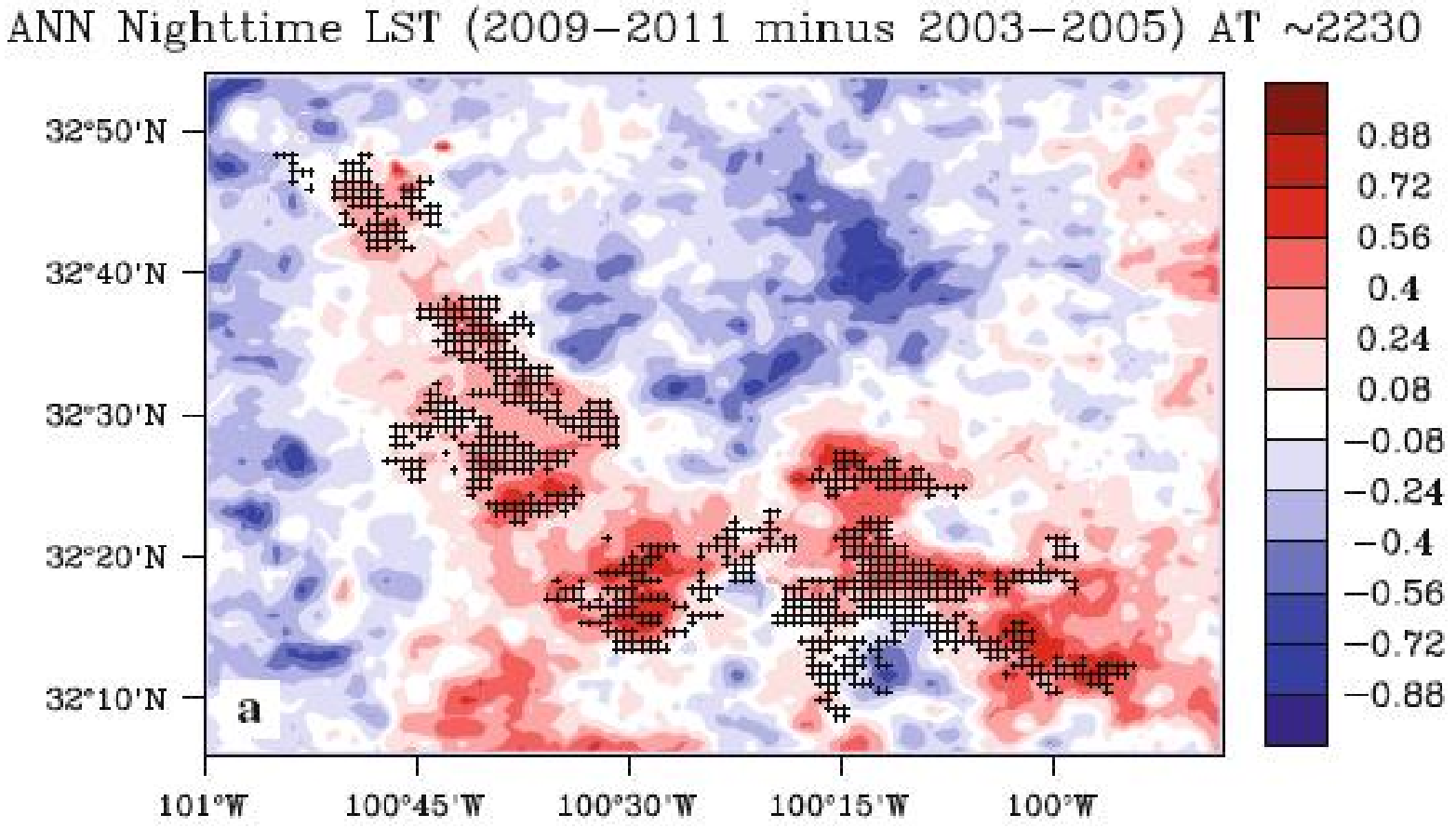
IMPACT2C results

Impacts of WP on climate?

- No clear answer as yet
  - Experiments with different models with different parameterizations

- First study : Keith et al. (2004), using roughness changes and idealized wind farms distribution in a AGCM, shows regional differences

Temperature effects in wind warm areas

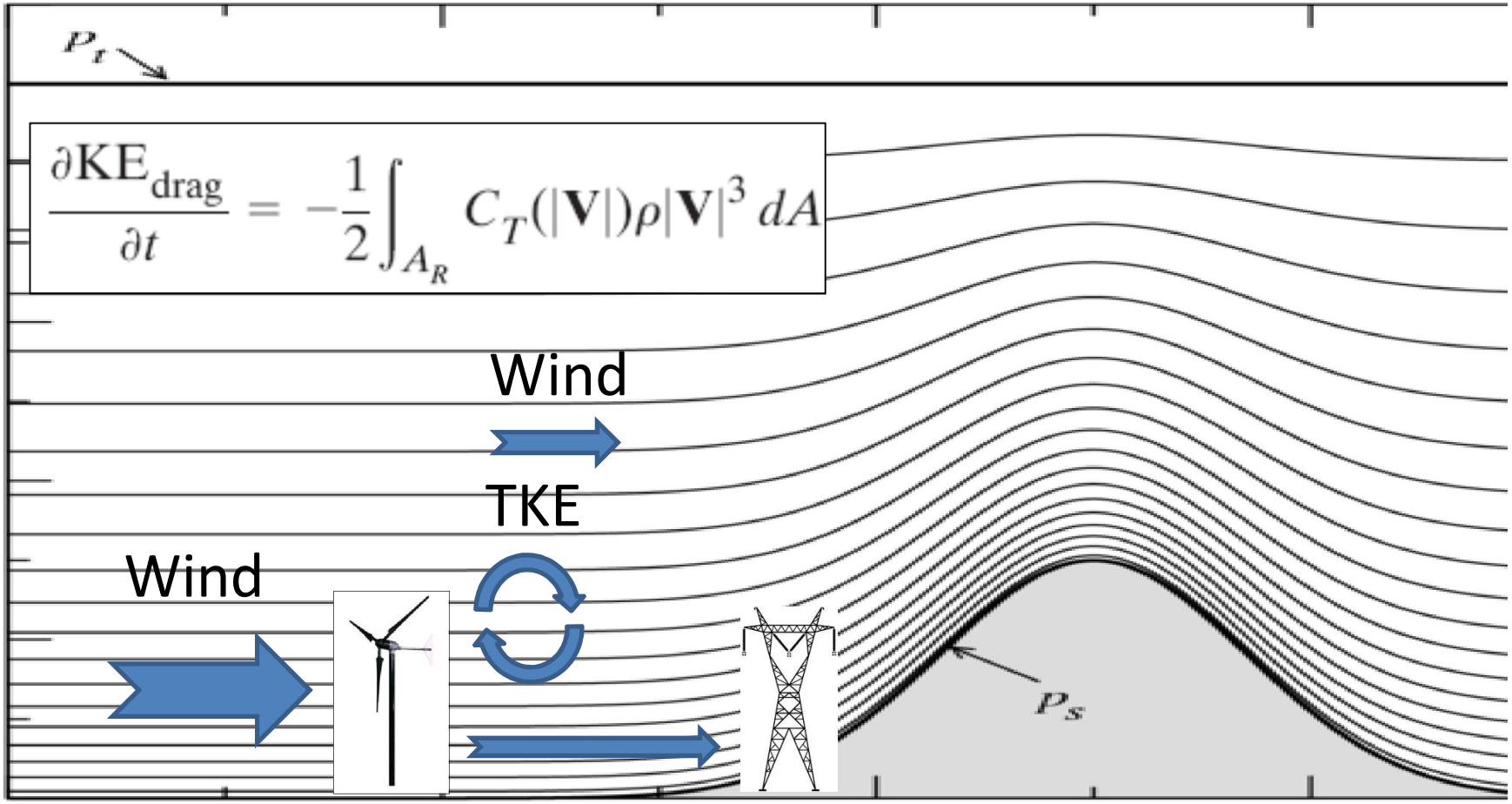


Zhou et al., 2013

Experiments with the WRF-Turbine model

Fitch et al., 2012
Adams and Keith, 2013

Online power generation & atmosphere interactions

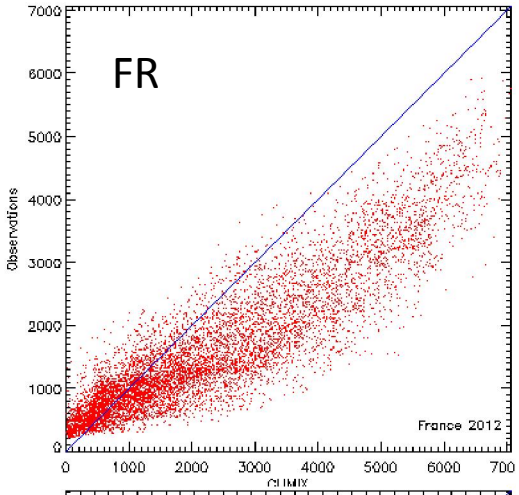


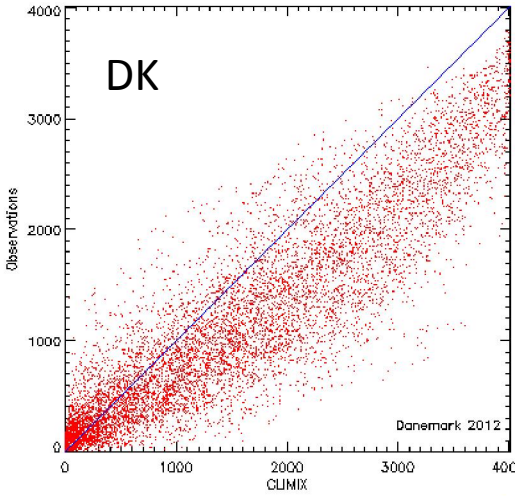
Power

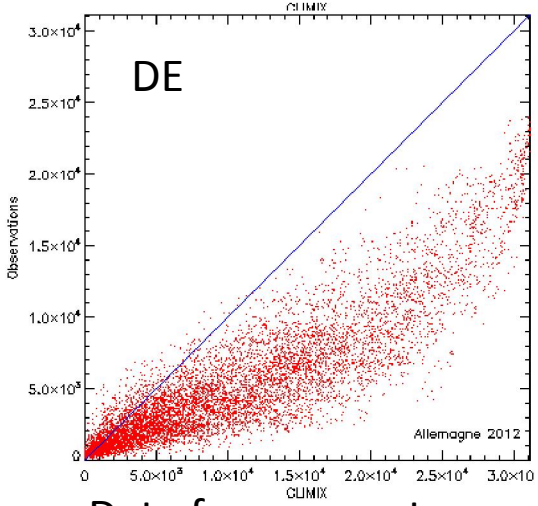
Experiments

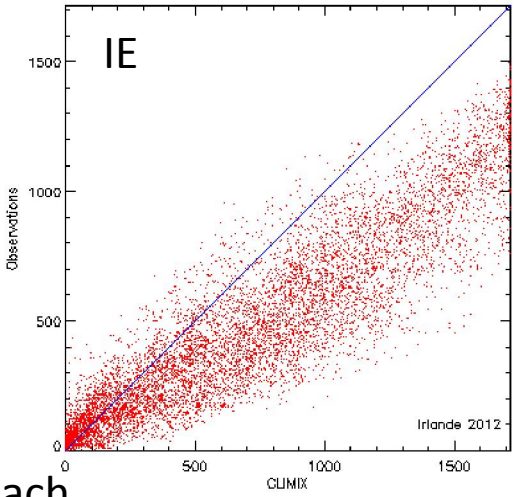
- 4 experiments:
- No wind farms, 2012, 2020 fleets
- WRF simulations forced by ERA-Interim 1980-2012 (33 years)
- 50 km resolution over the EURO-CORDEX domain
- Validation (2011-2012)
- Comparisons for scenarios

Comparaisons with electricity network observations



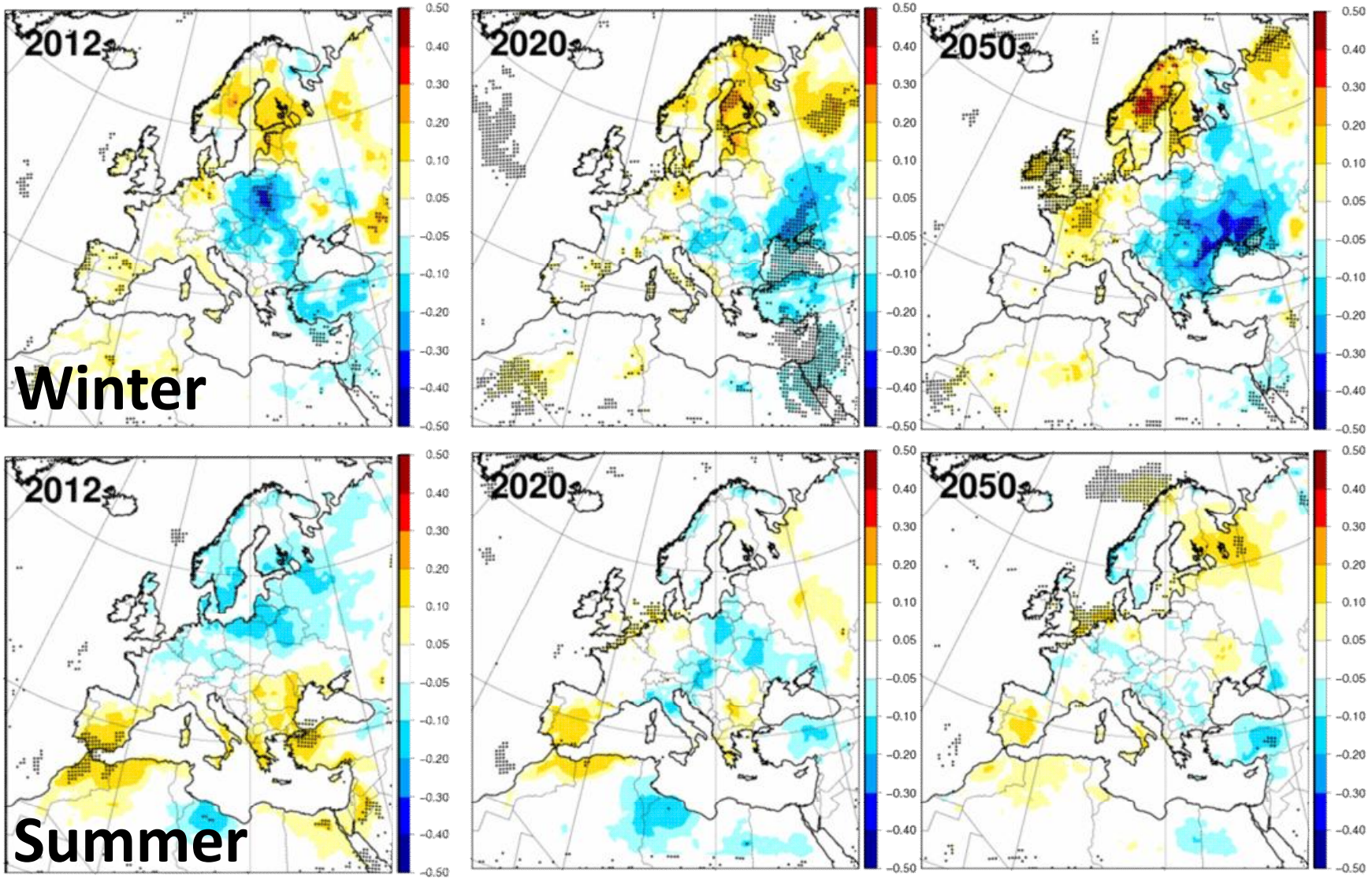






Data from operators, compiled from PF Bach

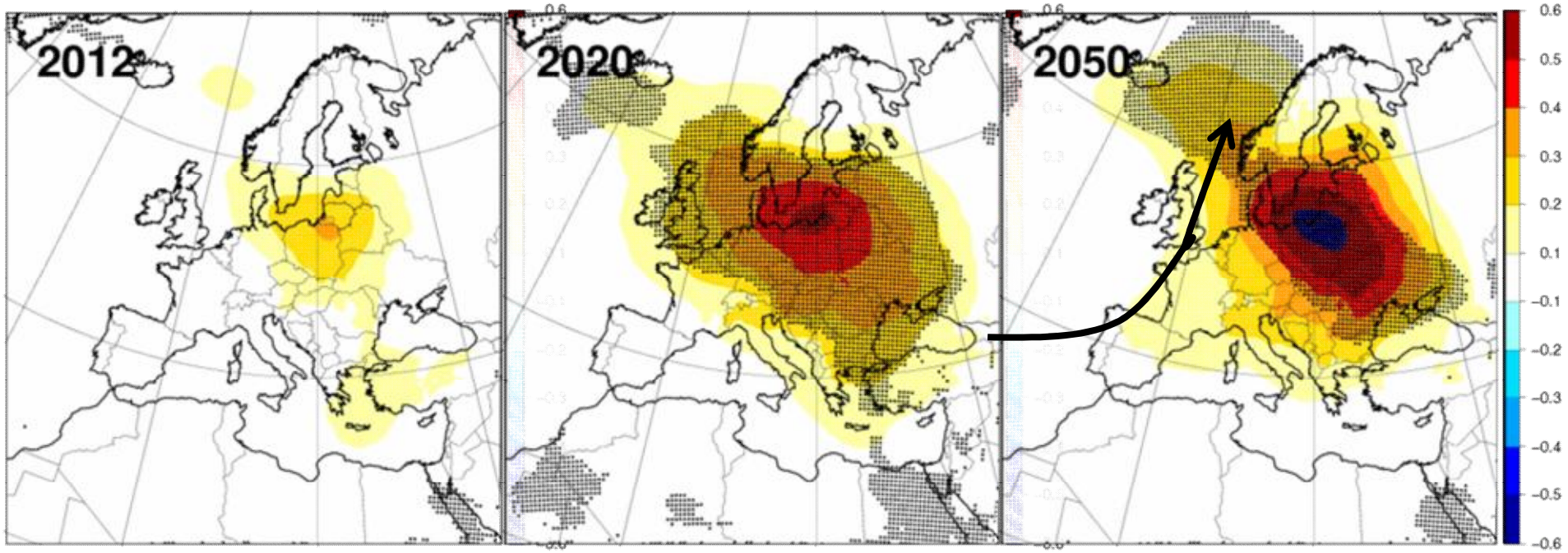
Impacts on temperature



Vautard et al., 2014, NCOMMS

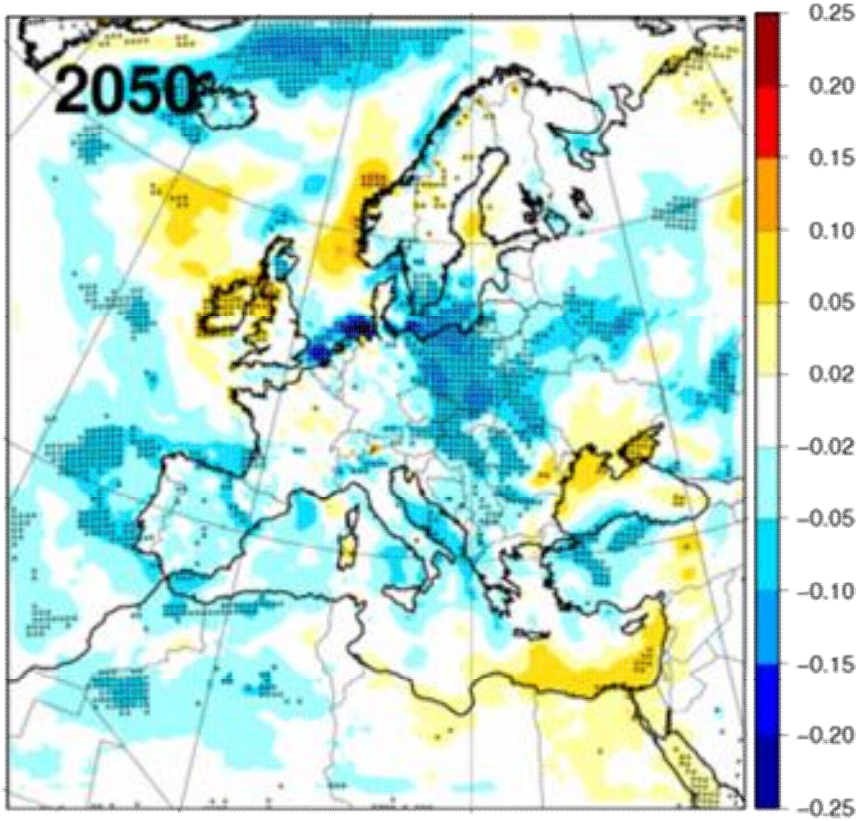
Impact on the synoptic flow (sea level pressure, winter)

Units: hPa

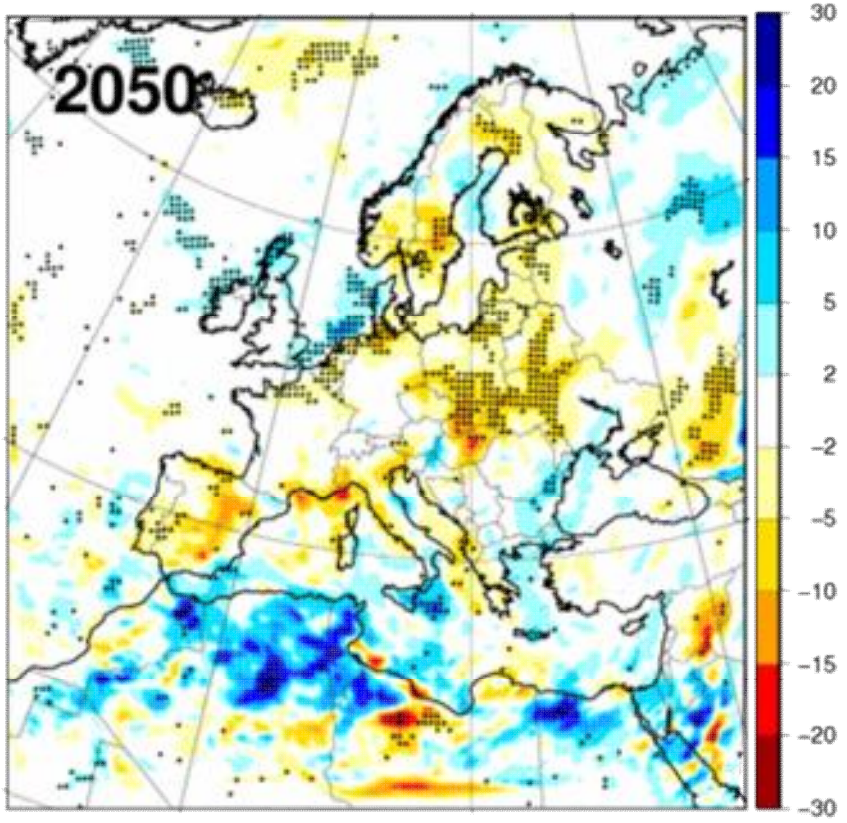


Precipitation, wind in winter

10m Wind (m/s)



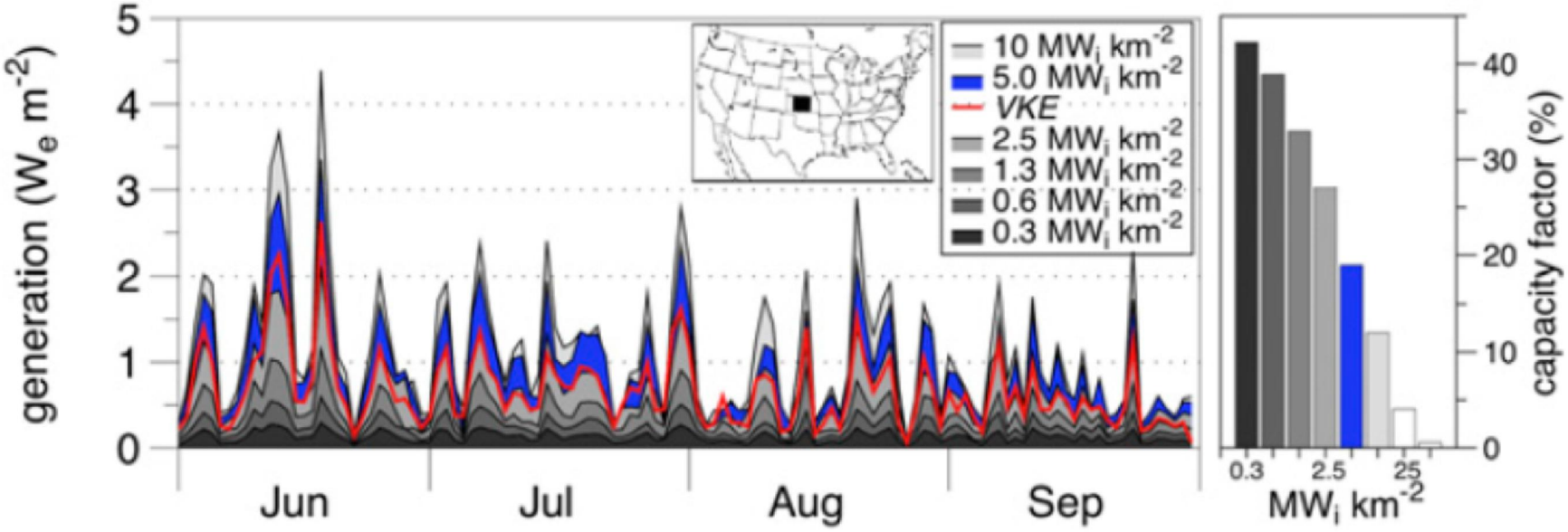
Precipitation (%)



Impact of regional WP development on resource: Study on Kansas (Miller et al., 2015)

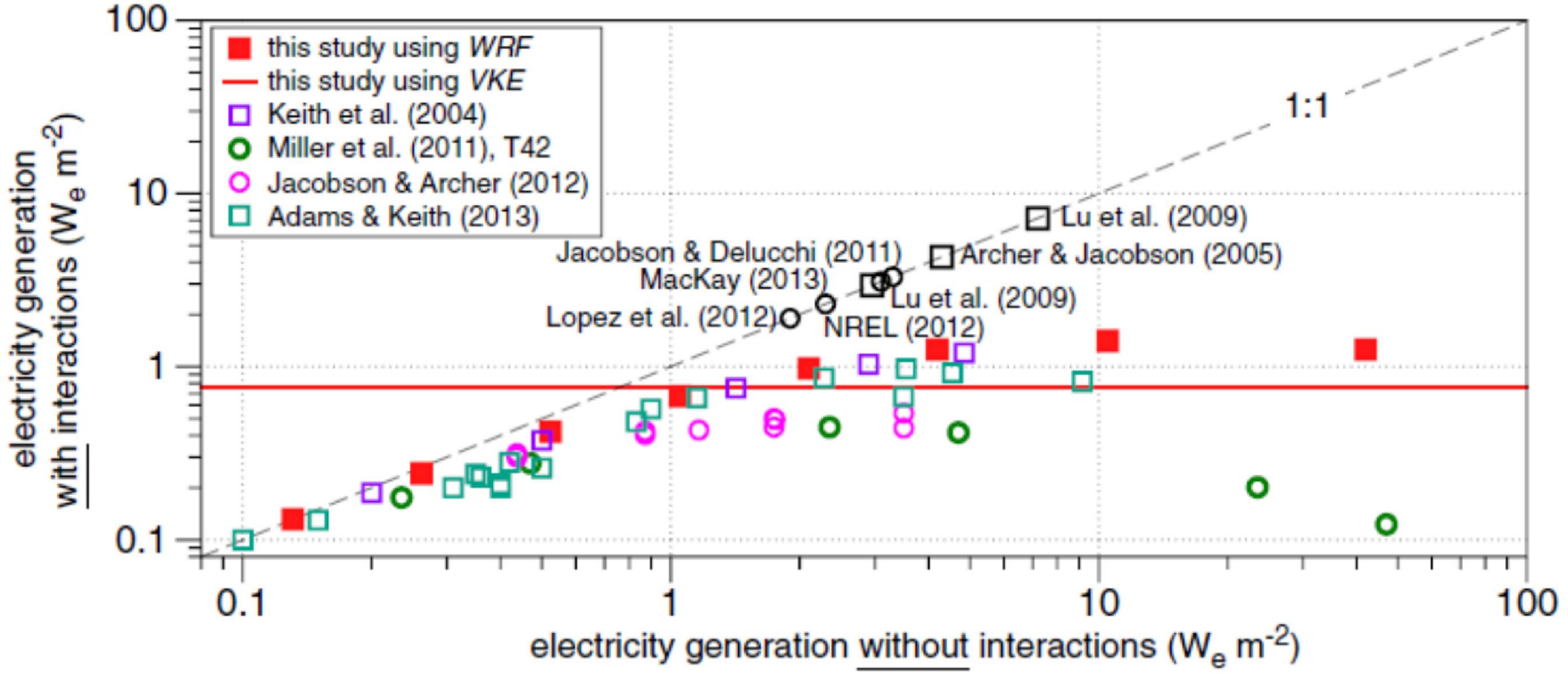
- WRF simulations June-Sep 2001 forced with reanalyses NARR, resolution 12 km
- Very large farm~330 km x 330 km
- Density of installed power: 0.3 W/m2 to 100 W/m2
- Comparison with a simplified method
- Turbine VESTAS V112 3 MW

Simulations



Miller et al., 2015 PNAS

Saturation around 1 W/m2



Comparaison avec autres études, méthodes

Miller et al., 2015 PNAS

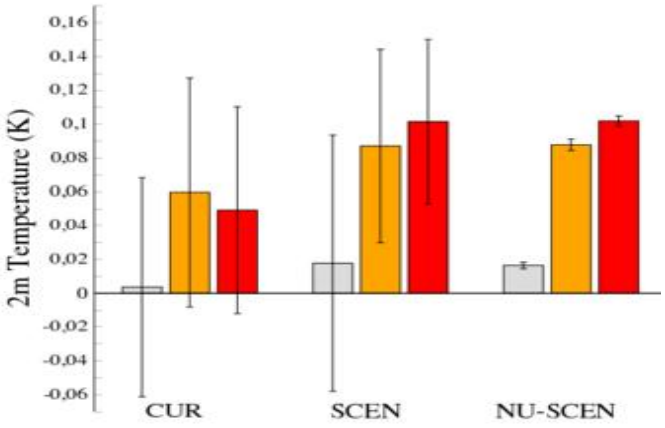
Conclusions

- Effects in general small but of large scale in both cases
- Impact of CC to reduce WP
- Limitations for the impact study: Rossby wave excited, may require global simulations
- Limitations of extractible wind power to 1 W/m2 for large-scale wind farms

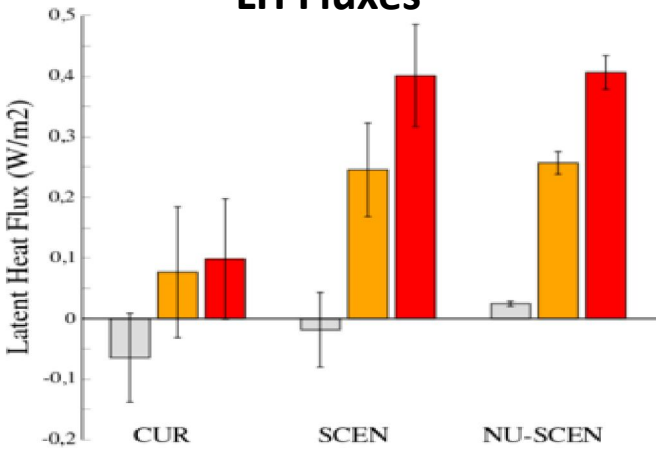
Local effects

(probably underestimated)

a) **Temperature**

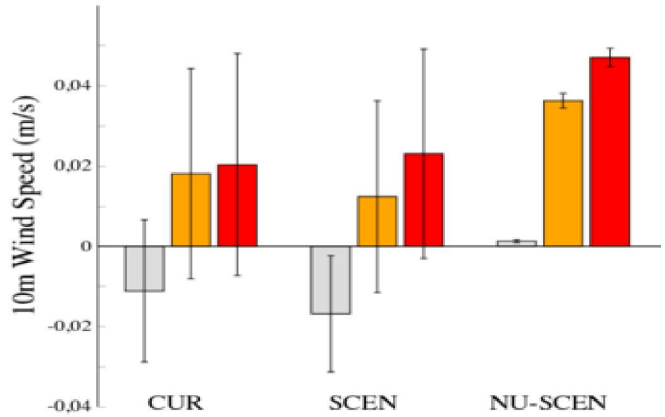


g) **LH Fluxes**

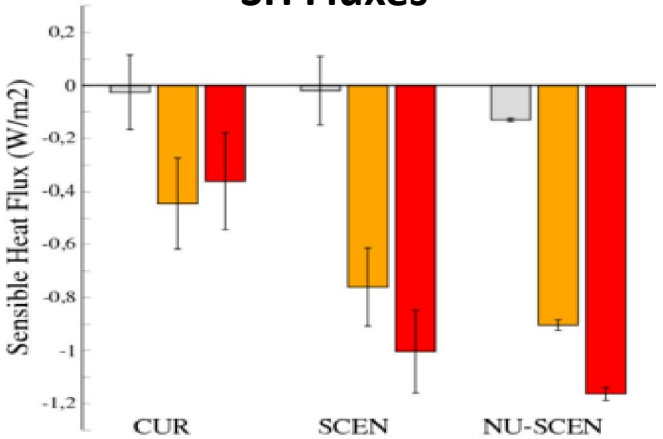


2012 **2020** **2020+Nudging**

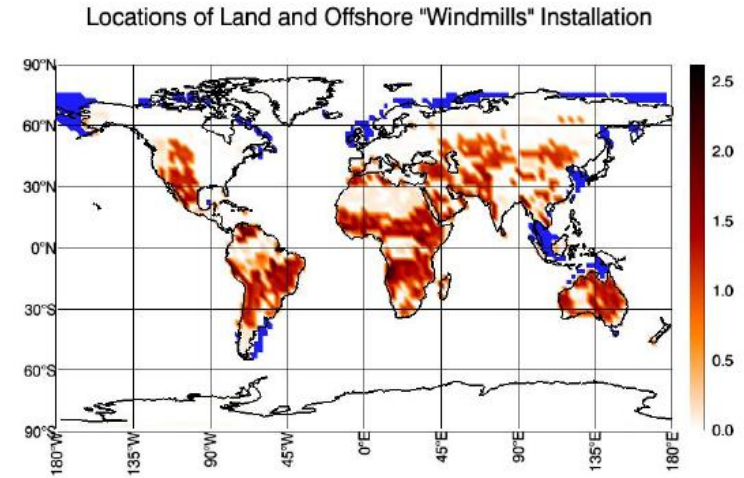
d) **10 m wind**



h) **SH Fluxes**



Echelle globale (Wang and Prinn, 2011)



Couverture des shrubland/grassland, zone côtière, approche couplée O/A
Changements pour satisfaire 10% de la demande mondiale en 2100