Climate change and wind energy; how can you estimate future yield?

Emilie C. Iversen

KJELLER VINDTEKNIKK
Part of Norconsult

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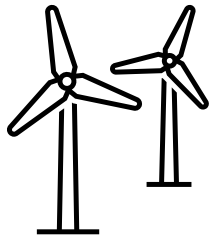
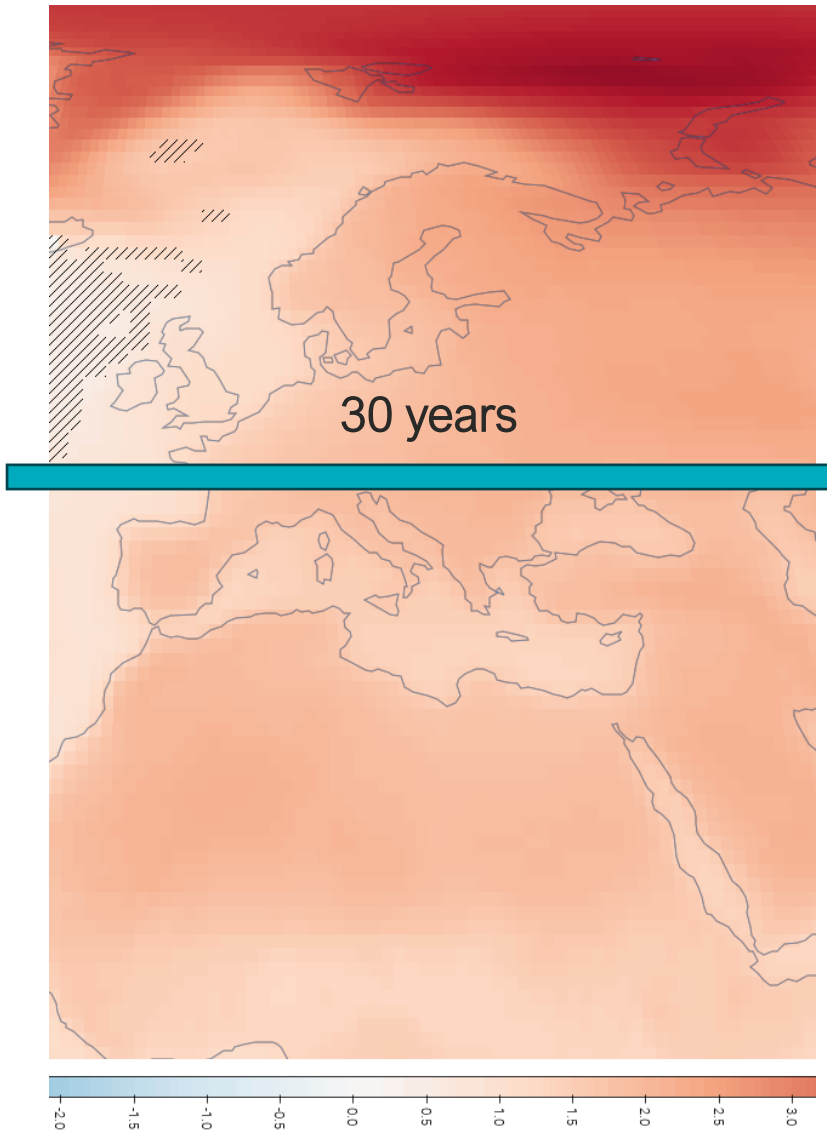
What will the future energy yield be?

Now

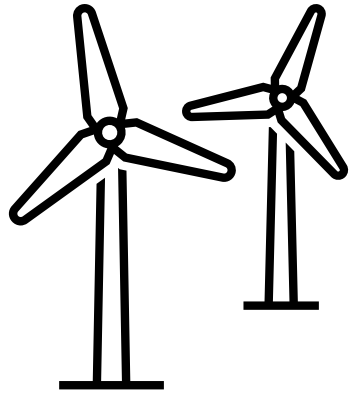
To invest, or not to invest?

Project X

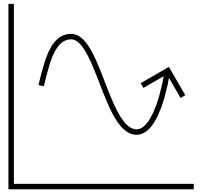




Future



?



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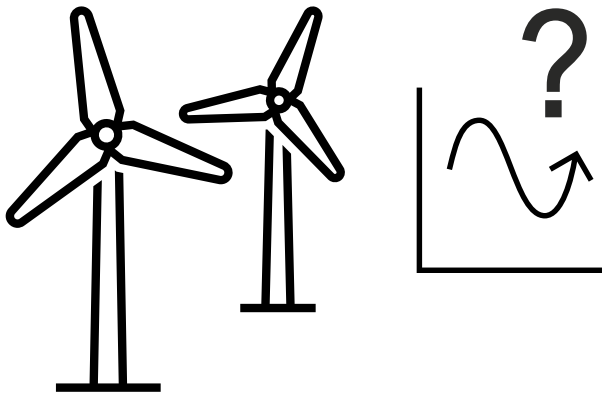
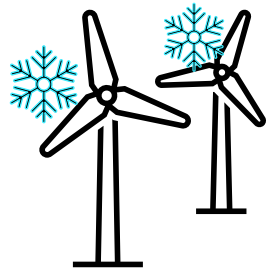
Future



Wind power density:

$$WPD = \frac{1}{2}\rho v^2$$

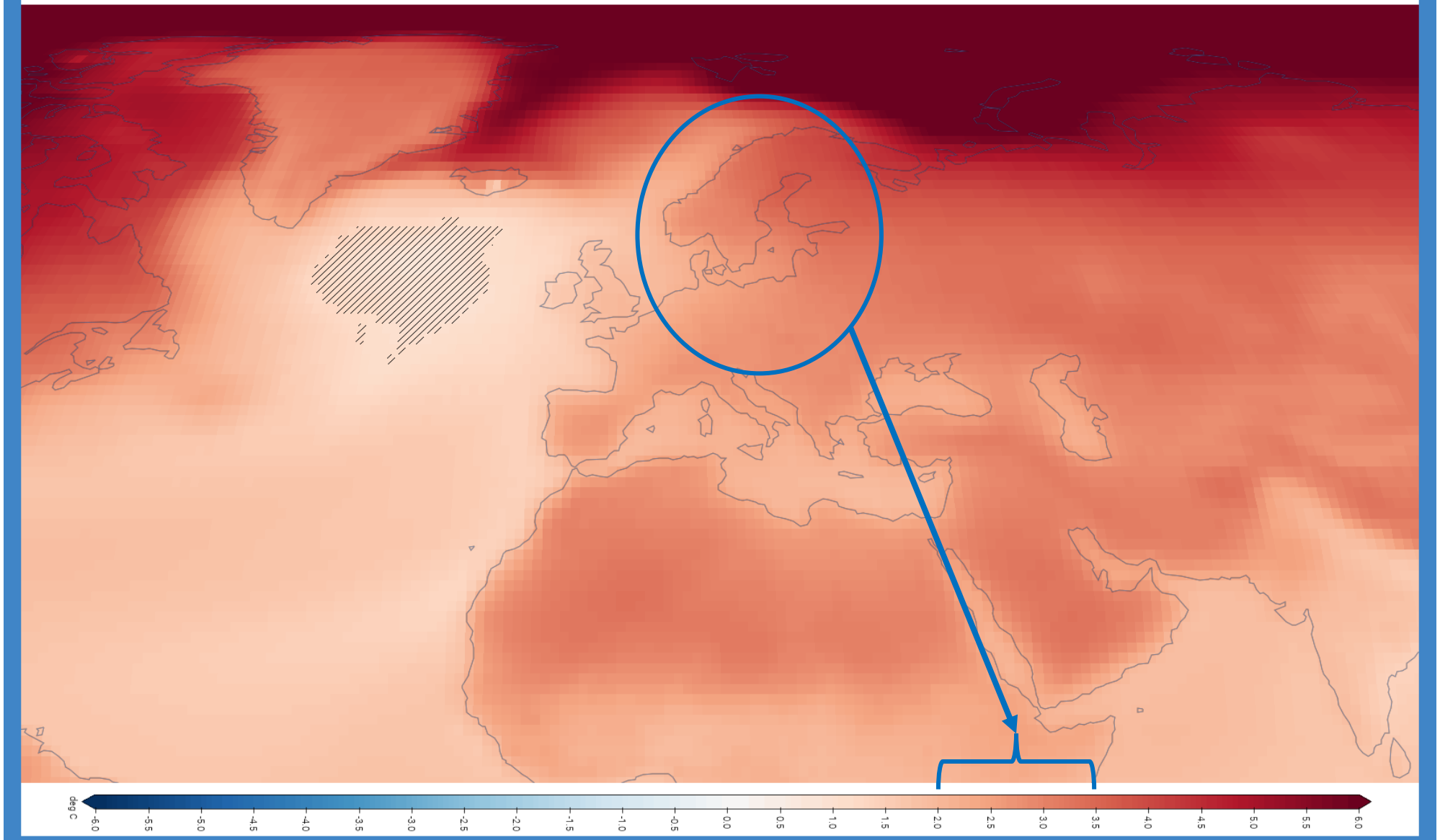
In cold climate, icing also affects power output:



$\Delta\rho$? Δv ? Δice ?

30 years

Temperature increase by 2041-2060 (SSP2-4.5)



Mean temperature (T) - Change (deg C)
Medium Term (2041-2060) (SSP2-4.5) (rel. to 1850-1900)
CMIP6 - Annual (34 models)

High agreement
Low agreement

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INTERGOVERNMENTAL PANEL ON climate change

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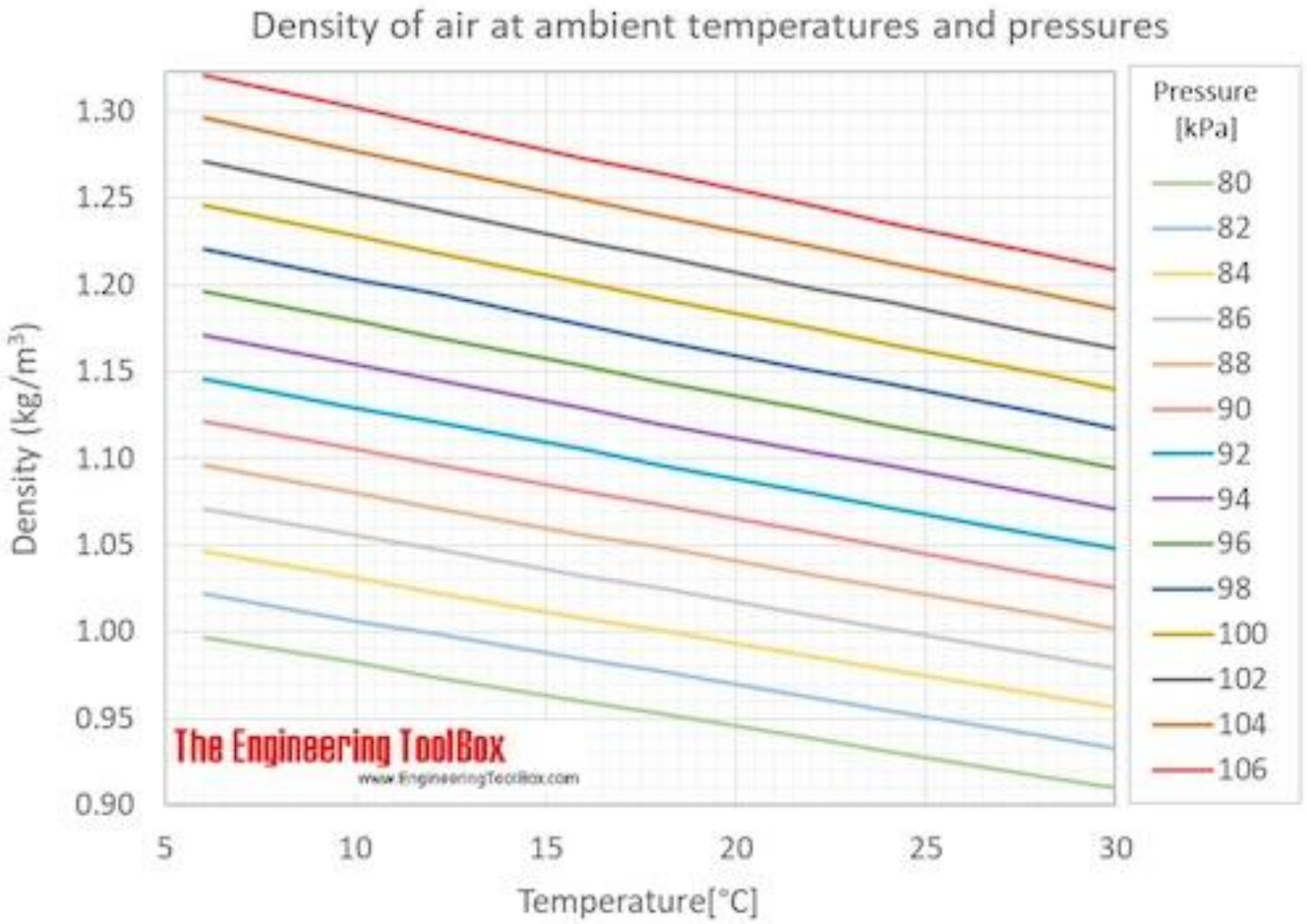
Air density decrease as temperature increase



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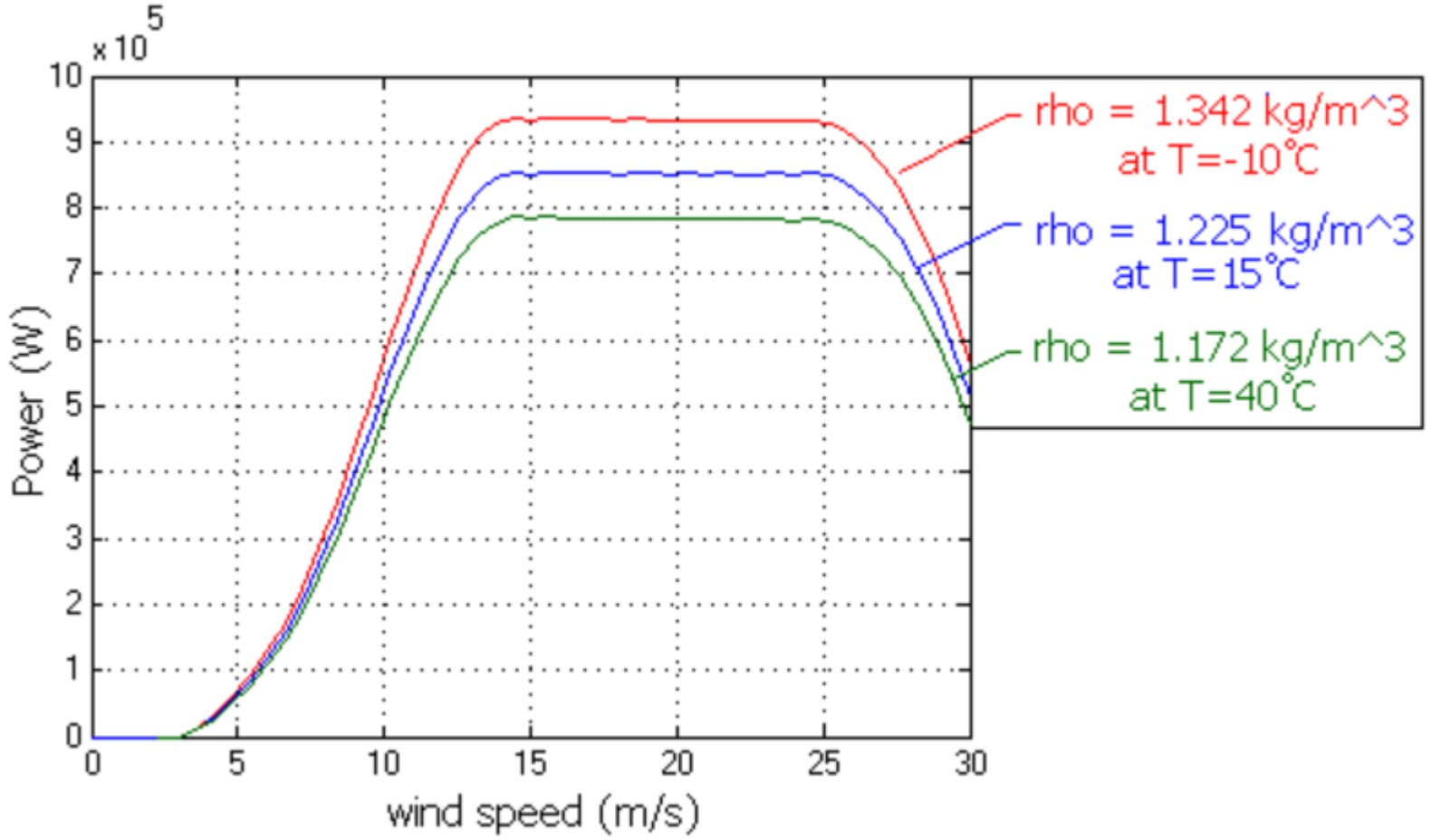
Decreased air density negatively affects power production



$$WPD = \frac{1}{2}\rho v^2$$

Badran et al. (1992)

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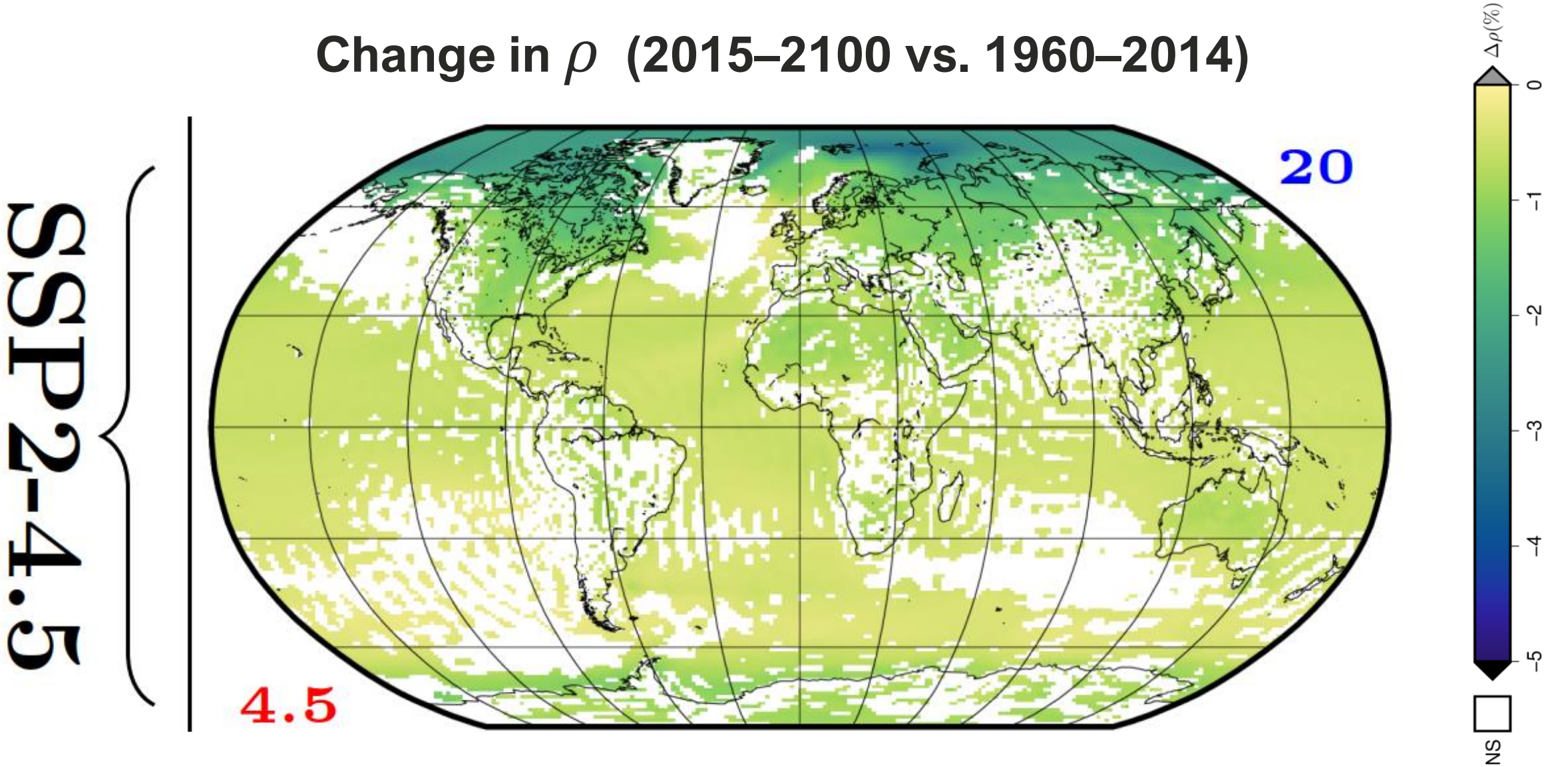
Change in ρ (2015–2100 vs. 1960–2014)



Esnaola et al. (2024),
25 CMIP6 simulations

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Change in wind speed ($\mathcal{V}$)

General consensus (Pryor et al. 2020, Nature reviews):

- Natural variability in wind speed appears to dominate over global-warming-induced change over most areas with large wind energy installations or potential.
- However, wind resources in Northern Europe may show small magnitude increases over the current century.
- Increases are generally larger in winter.

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Review Article | Published: 20 October 2020

Climate change impacts on wind power generation

Sara C. Pryor, Rebecca J. Barthelmie, Melissa S. Bukovsky, L. Ruby Leung & Koichi Sakaguchi

Nature Reviews Earth & Environment **1**, 627–643 (2020) | Cite this article

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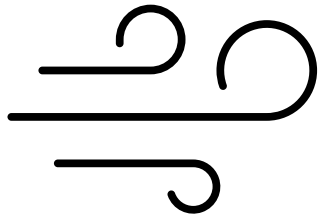
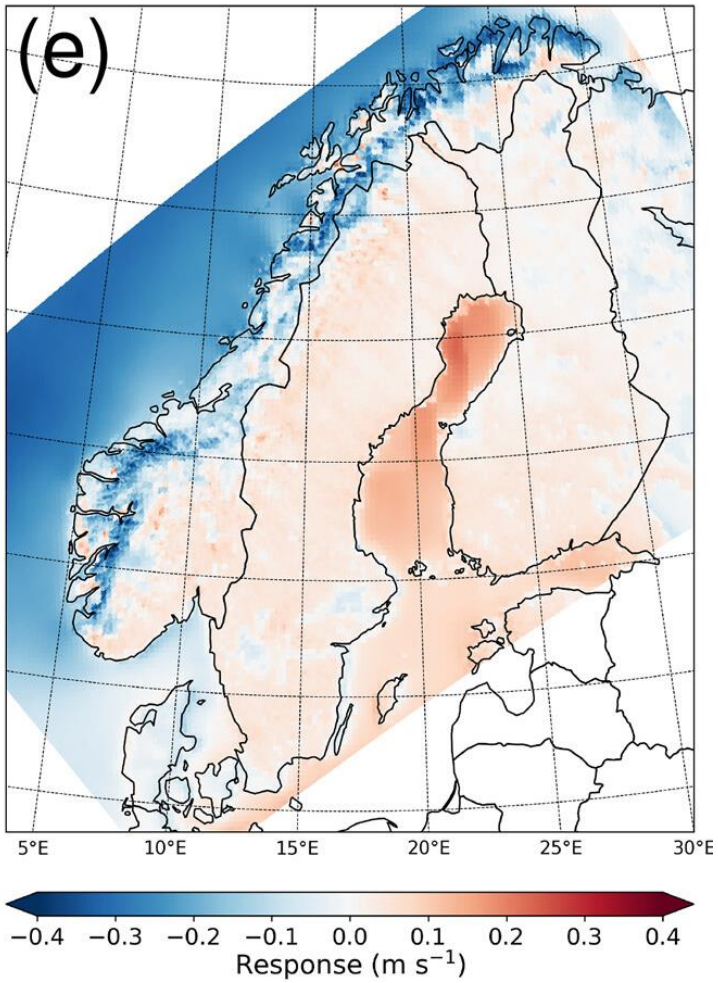
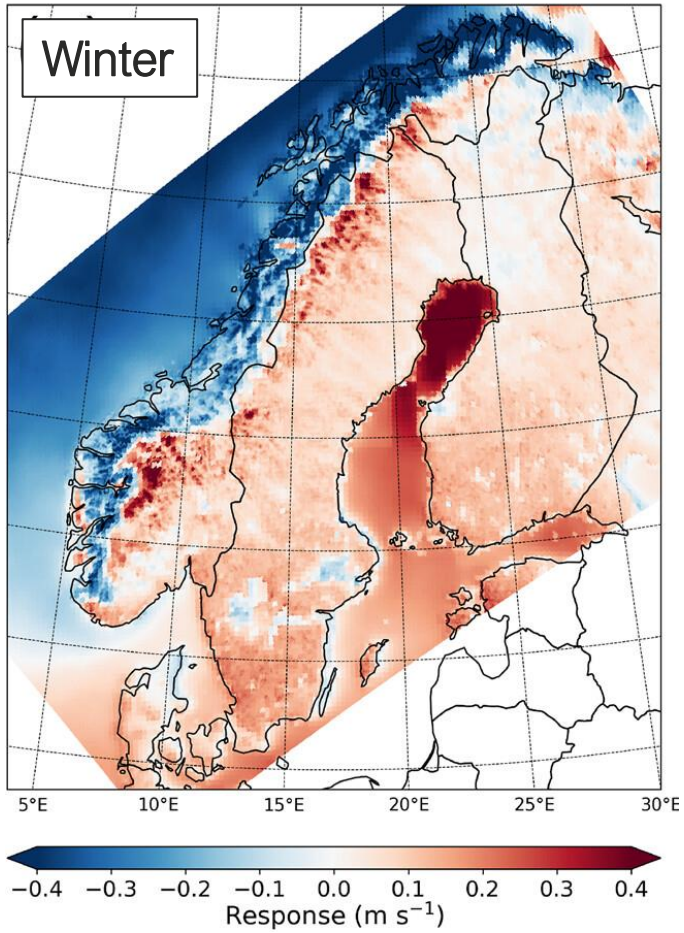
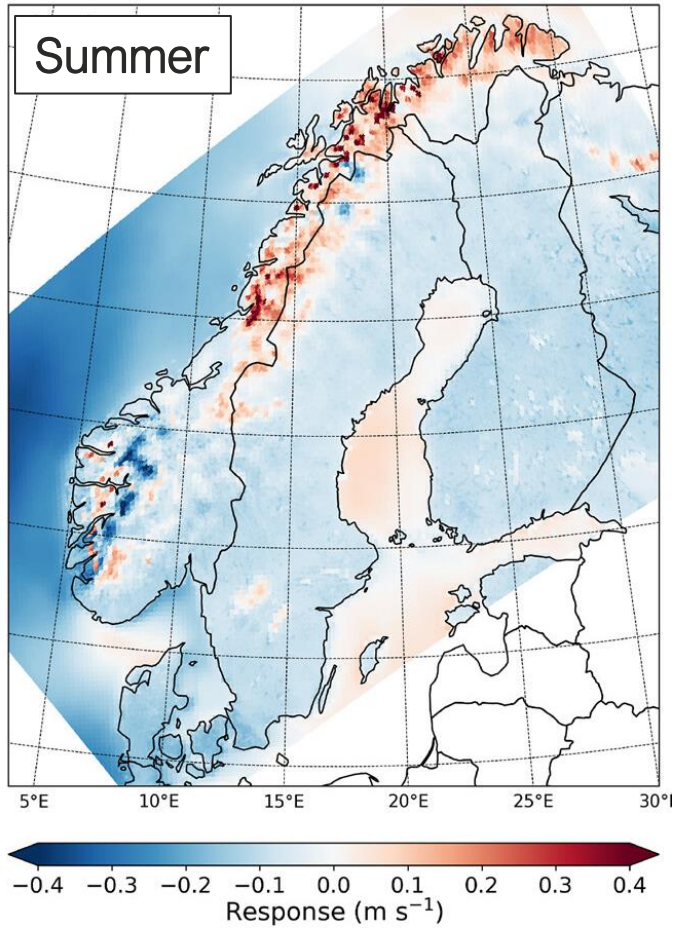


Change in (daily max. near surface) wind speed (v) (2071–2100 vs. 1985–2014)







Michel & Sorteberg (2023),
20 GCM-RCM combinations (EURO-CORDEX)

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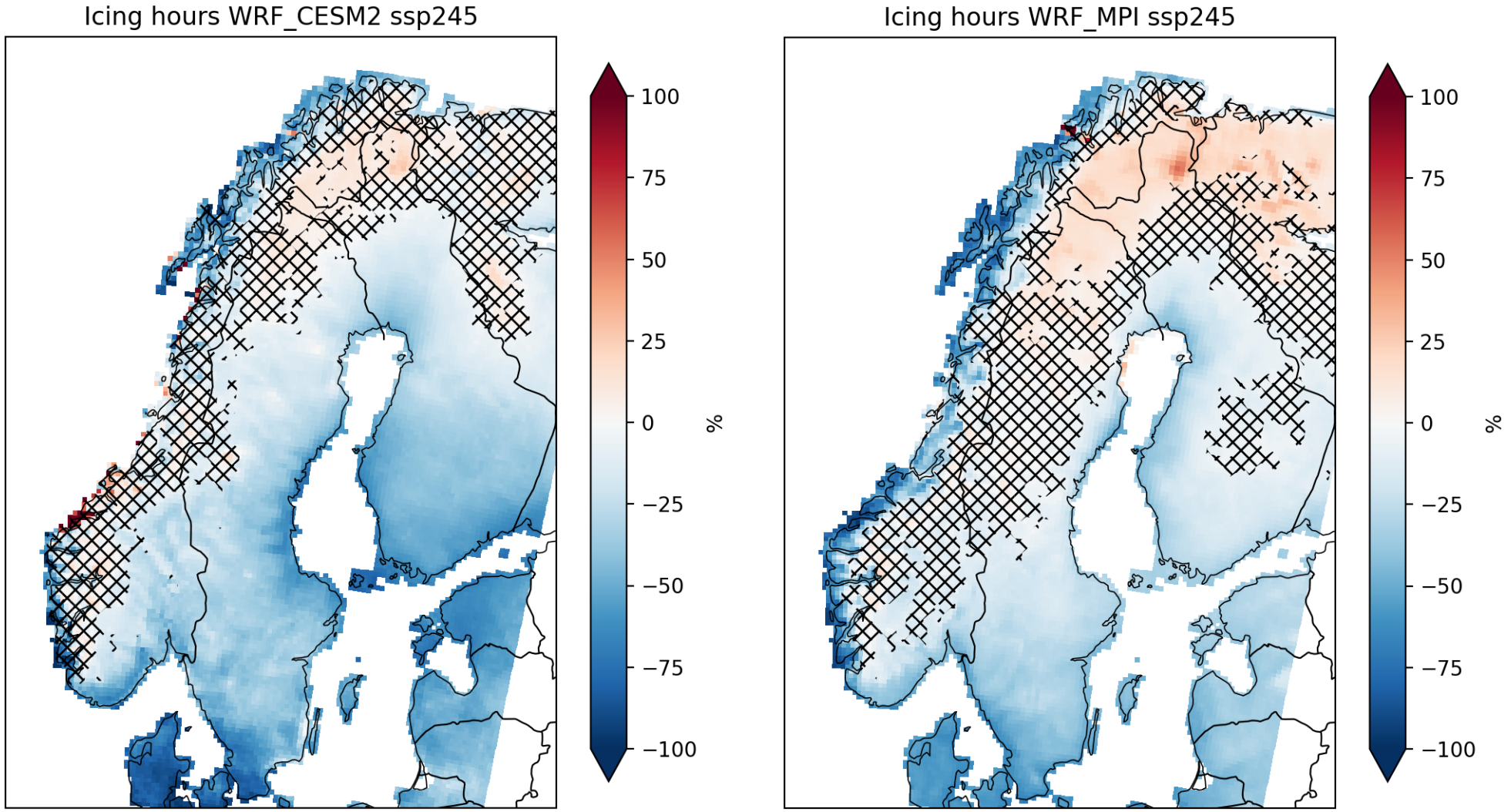
Change in icing hours (2040-2065 vs. 1990-2015)



Iversen et al. (2023)

Icing hours = dM/dt > 10 g/t

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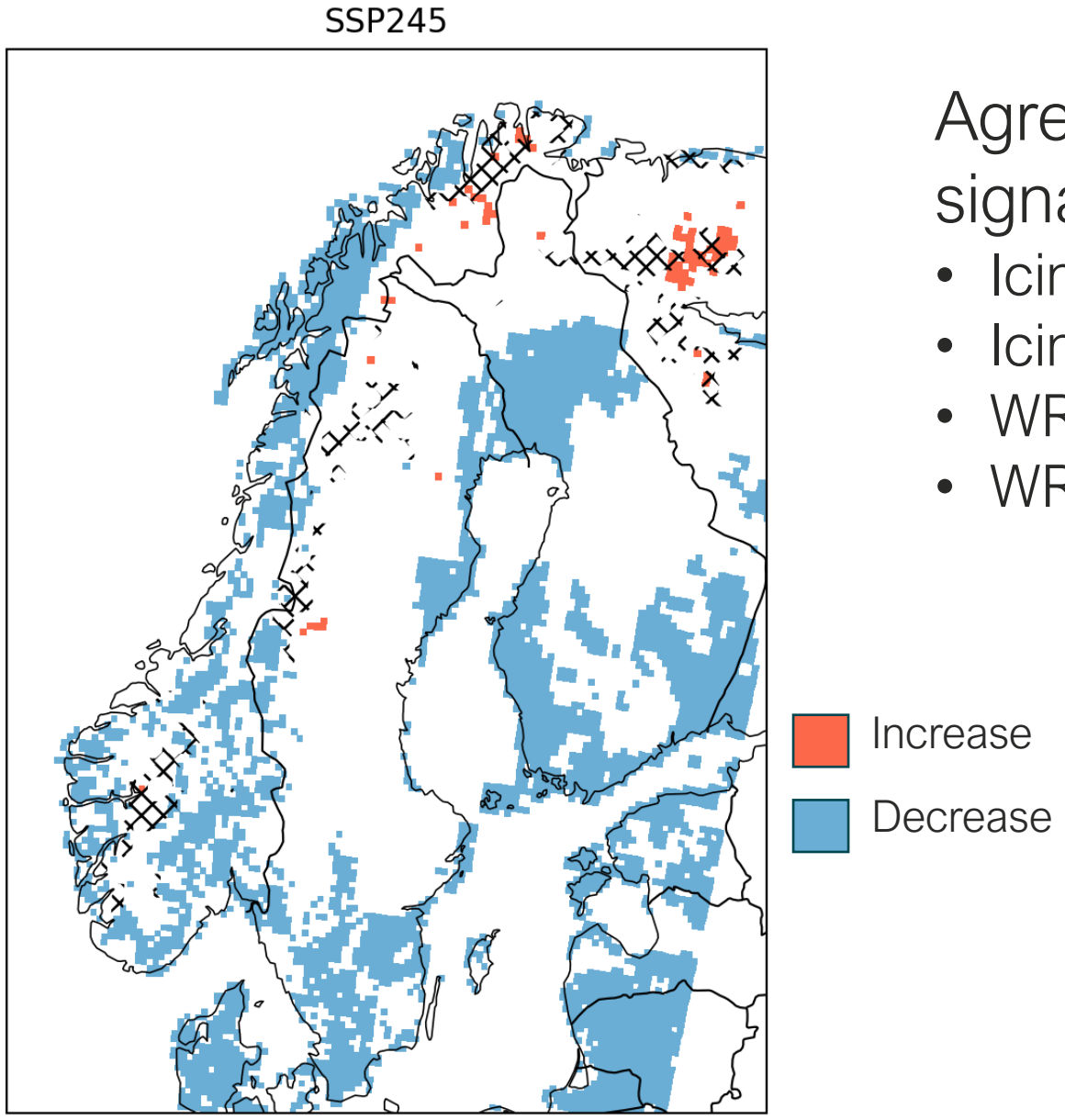
Agreement in icing condition changes



Agreement in change signal of:

- Icing hour
- Icing intensity
- WRF-CESM2
- WRF-MPI

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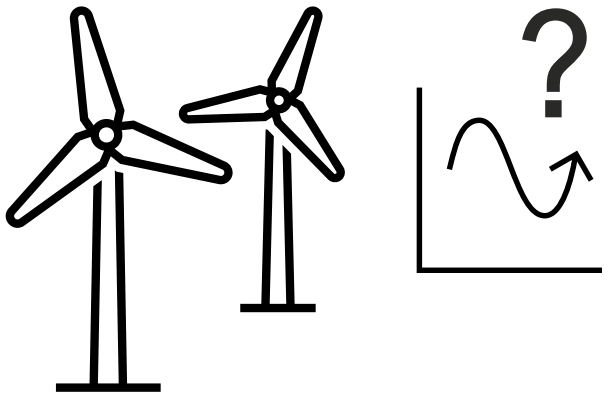
Future



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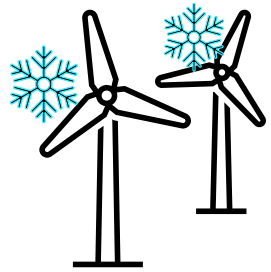

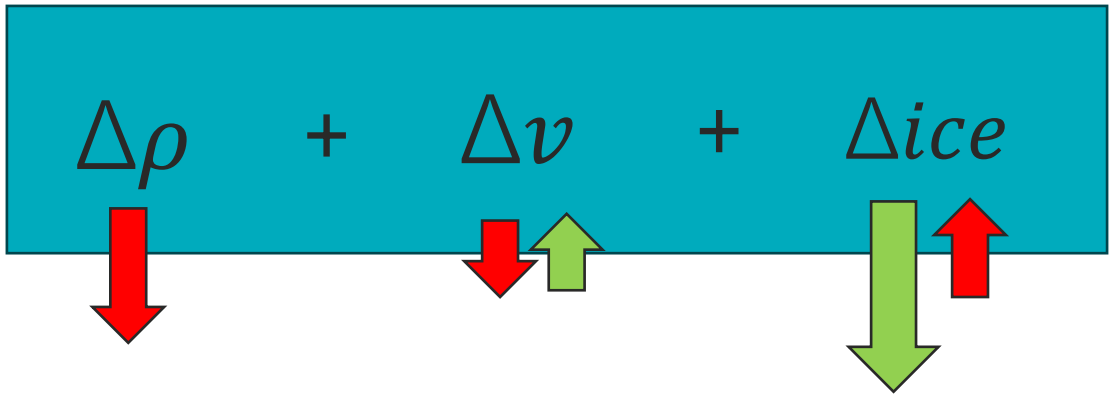

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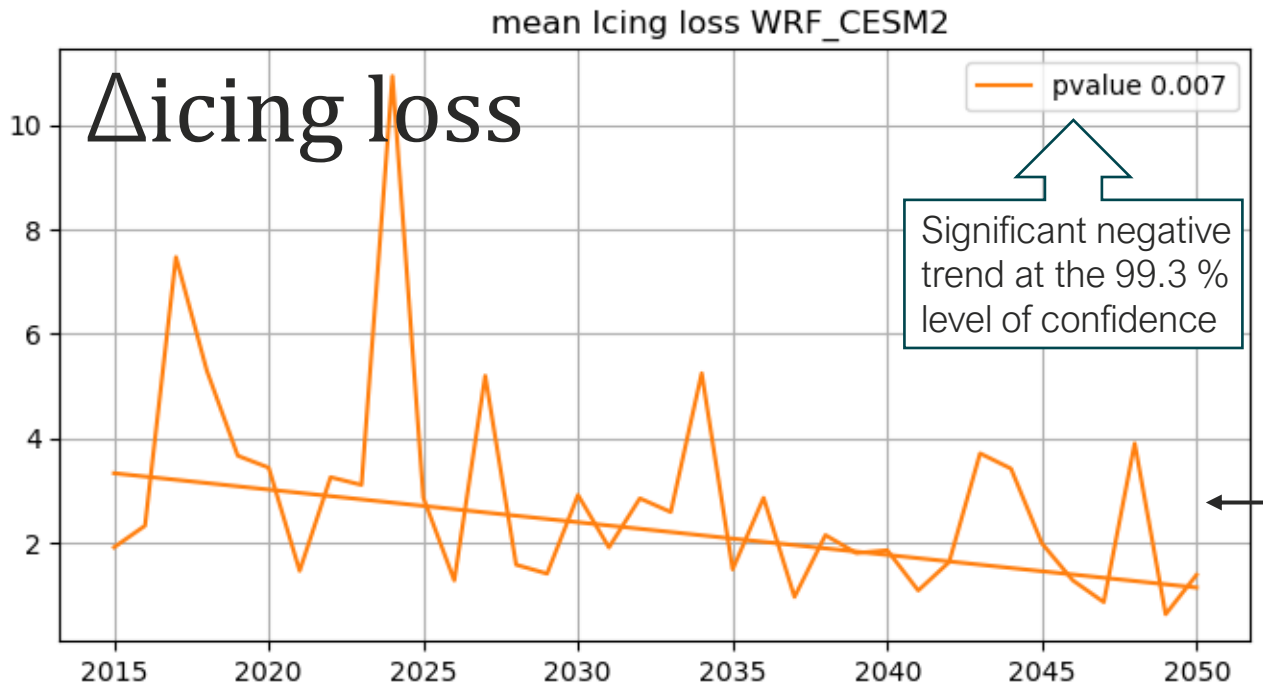
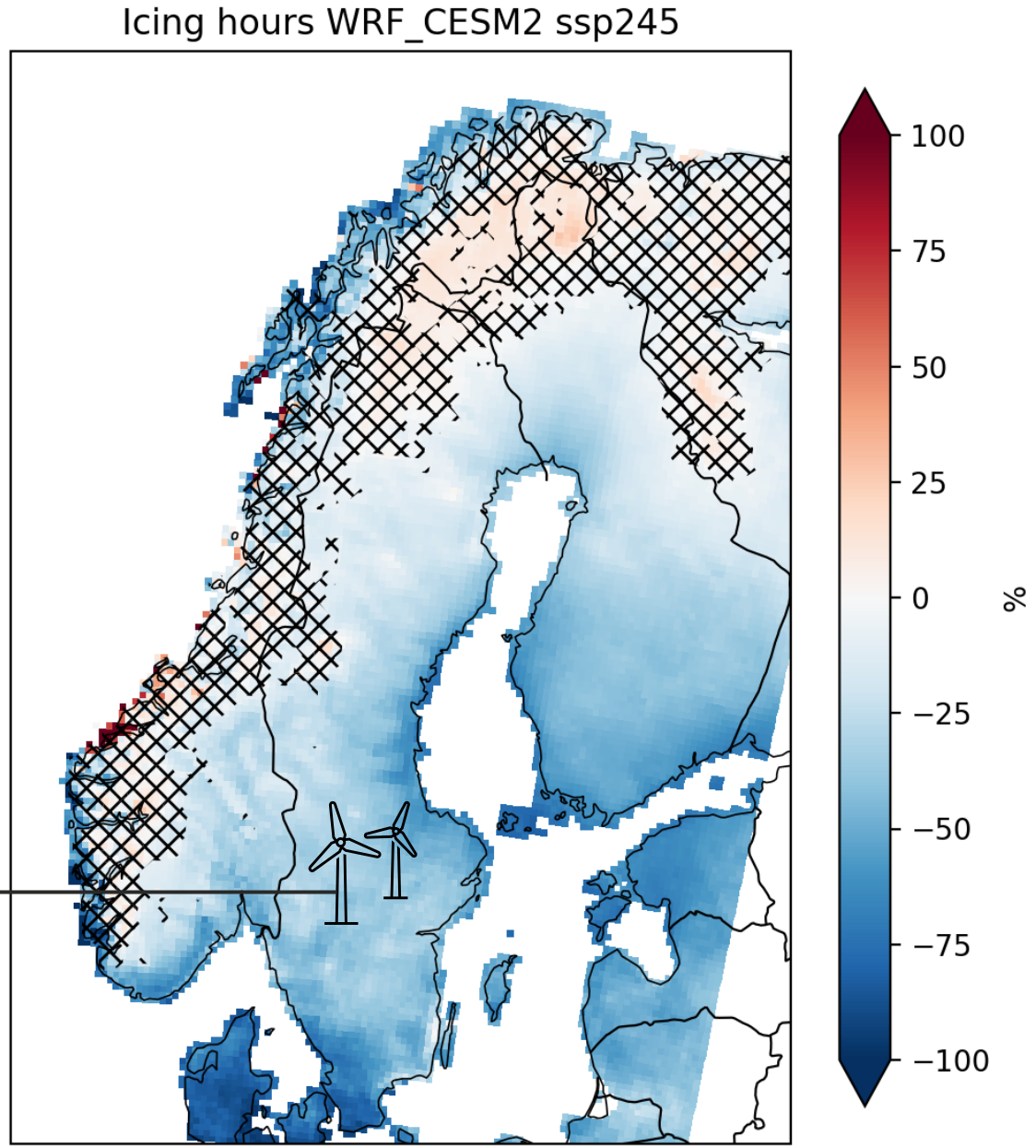
We need to perform site specific analysis of change in future yield

$$\Delta\rho \approx -2\%$$

$$\Delta v \approx 0.1\, m/s$$

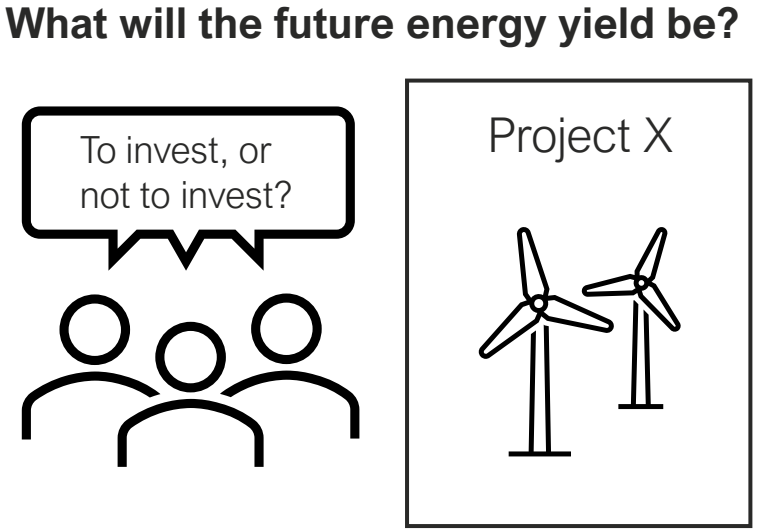
$$= \Delta WPD$$





Concluding remarks

- Although there are large uncertainties involved in climate projections, this is a better approach than not considering the future climate at all.
- If climate change is not considered, the uncertainties will be unknown.
- With this approach, the uncertainties will be explored and thereby constrained, which serves as a better foundation and a larger security for investment decisions.



Thank you!

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