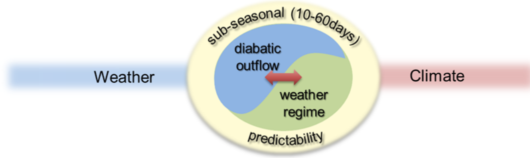

Stratospheric influences on European month-ahead wind power generation and its predictability on subseasonal time scales

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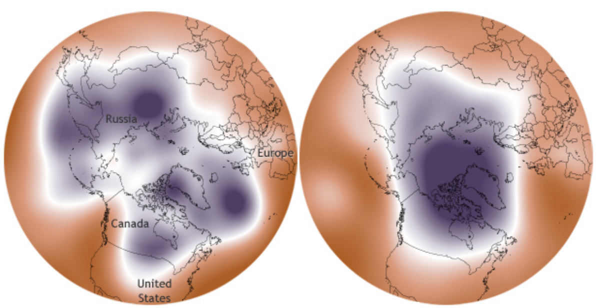


NOAA

EnergyWay

Motivation | Weather dependence of energy industry

Energy production

Wind, precipitation,
solar irradiance ...

Energy demand

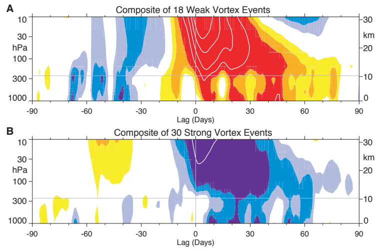
Temperature ...

Energy price

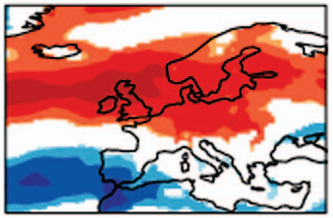
Current weather,
weather forecast

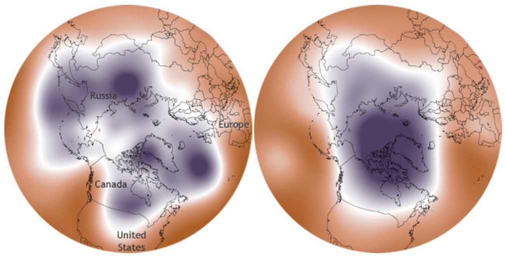
Motivation | **Polar vortex – weather regimes – wind power**

e.g. Baldwin & Dunkerton, 2001, SCI

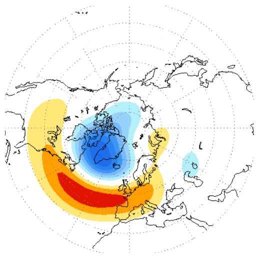


e.g. Clark et al., 2017, ERL,
Brayshaw et al., 2011, RE





NOAA



NOAA

EnergyWay

State of the **stratospheric polar vortex** (PV) as a direct **source of subseasonal predictability** for **European energy industry**?

Motivation | Research questions

Karlsruhe Institute of Technology

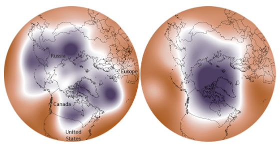
1. How does the **strength of the stratospheric polar vortex** affect **month-ahead wind power generation** in different European countries?

   → *Work from my colleague Remo Beerli (Beerli et al., 2017, QJRMS, https://doi.org/10.1002/qj.3158)*

2. How does this effect from the stratospheric polar vortex **influence the skill of subseasonal numerical weather models** in predicting energy-industry-relevant **surface wind, temperature, and precipitation** in different European countries?

   → *My work*

Data | 1st research question



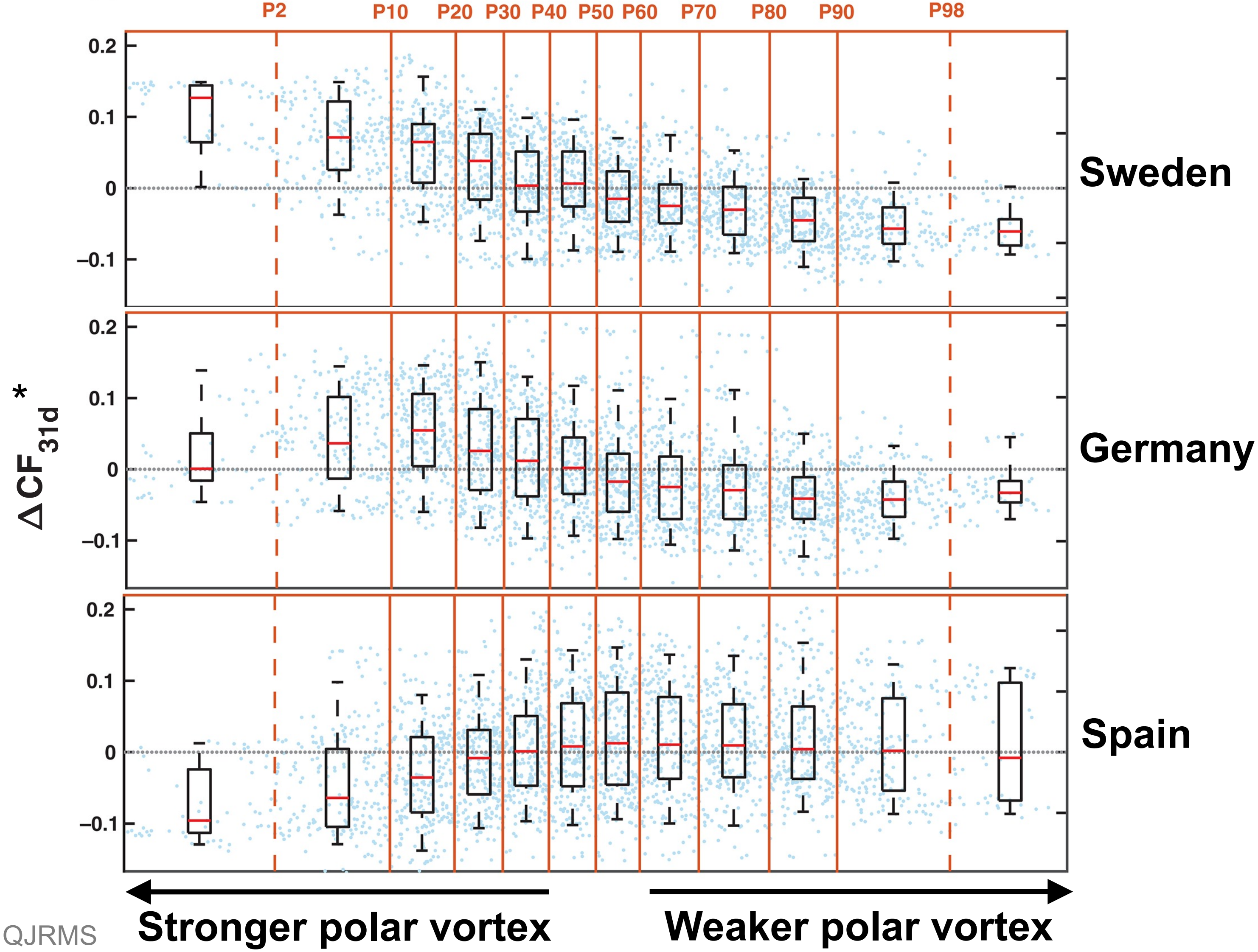
- **Strength of stratospheric polar vortex:**
  - Geopotential height anomalies from ERA-Interim reanalysis
  - Definition = $(\Delta Z \text{ @ } 150\text{hPa})_{60°\text{-}90°\text{N}}$
  - **Daily**, 1985 – 2014, DJF

- **Wind power generation:**
  - European country-aggregated hourly wind power generation dataset „Renewables.ninja“ (Staffel & Pfenninger, 2016, ENE / www.renewables.ninja)
  - Principle: Installed wind turbines of 2014 + wind from MERRA reanalysis dataset => „wind power generation reanalysis“
  - **Daily month-ahead average**, 1985 – 2014, DJF

Beerli et al., 2017, QJRMS

Results | Polar vortex and wind power generation

*** Capacity factor**
= wind power generation / installed capacity

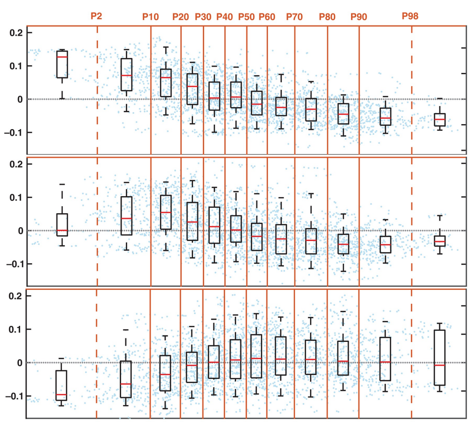


Beerli et al., 2017, QJRMS

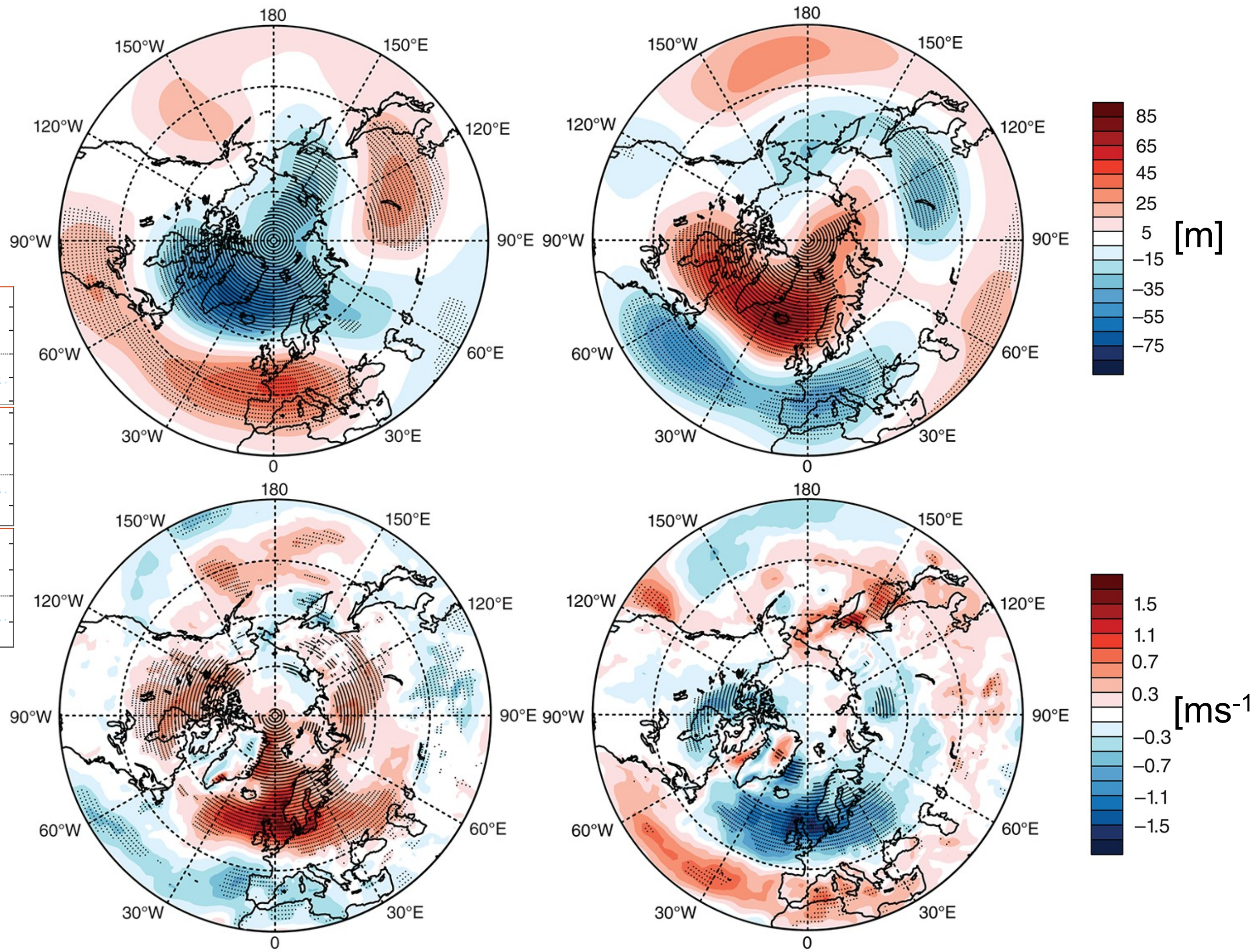
KIT Karlsruhe Institute of Technology

Strongest 10% PV events Weakest 10% PV events

(ΔZ @ 500hPa) $_{31d}$

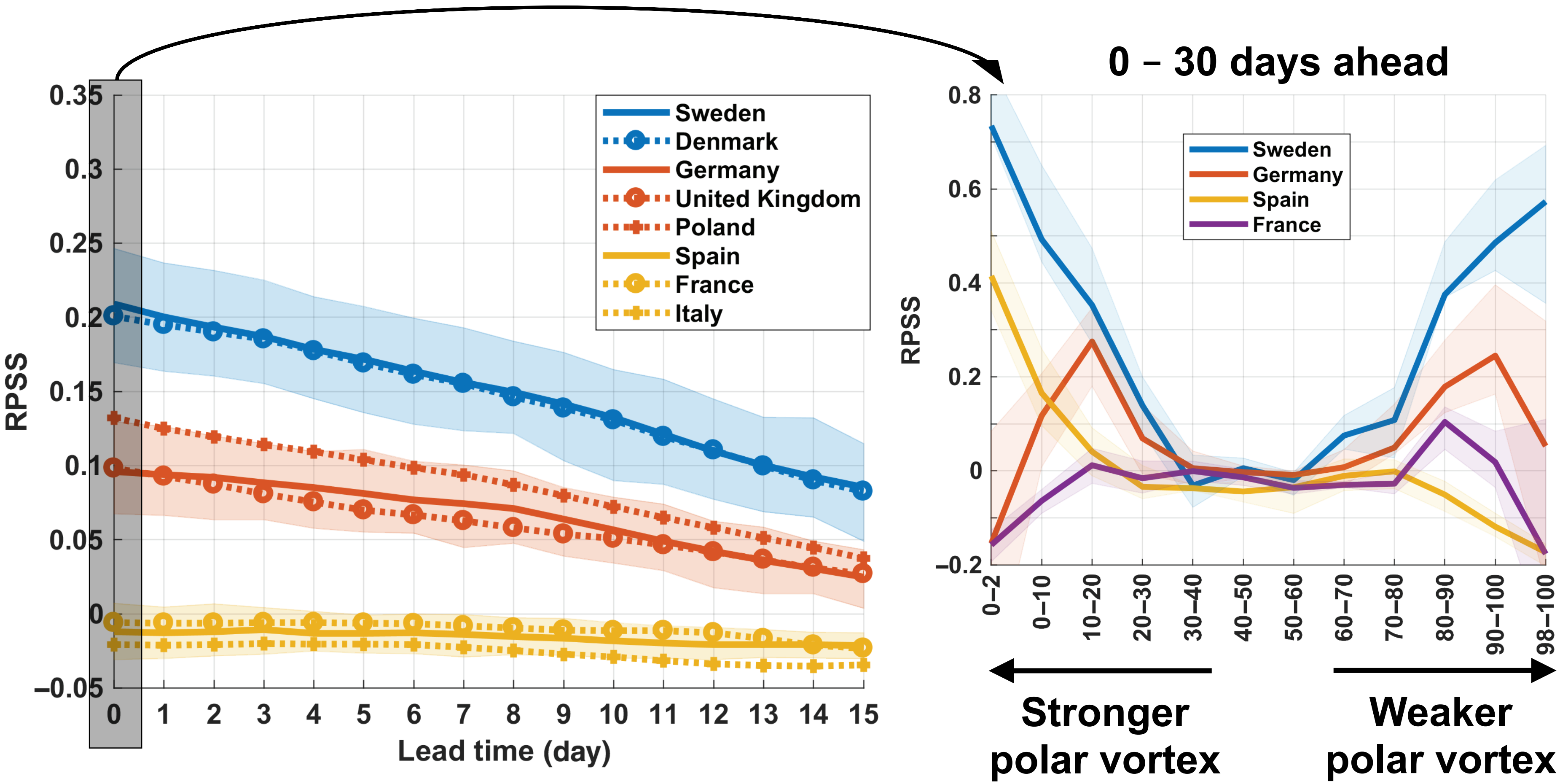


(ΔUV @ 100m) $_{31d}$



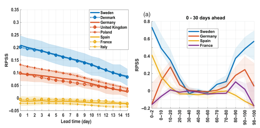
Beerli et al., 2017, QJRMS

Results | Simple 3-categorical statistical forecast



Beerli et al., 2017, QJRMS

Conclusions | Part I



- **Skill of simple statistical forecast** shows that **phases of anomalous stratospheric polar vortex strength** are **windows of enhanced predictability** for sub-seasonal wind power generation, but only for certain regions

⇩

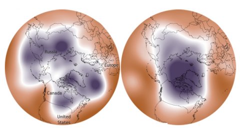
- How does this mechanism influence skill of subseasonal numerical weather models? → **2nd research question**

Beerli et al., 2017, QJRMS

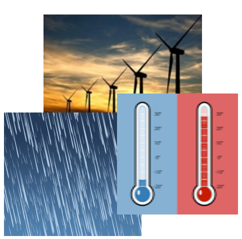
Data | 2nd research question

- **Subseasonal ECMWF model (S2S prediction project database):**
  - 2 reforecasts / week with lead time 46 d
  - 1995 – 2015 (20 years), DJF
  - Total: **994 reforecasts**
  - **11 ensemble members** (1 control, 10 perturbed forecasts)

- **Used fields** (both from the **model** and **ERA-Interim** for verification):

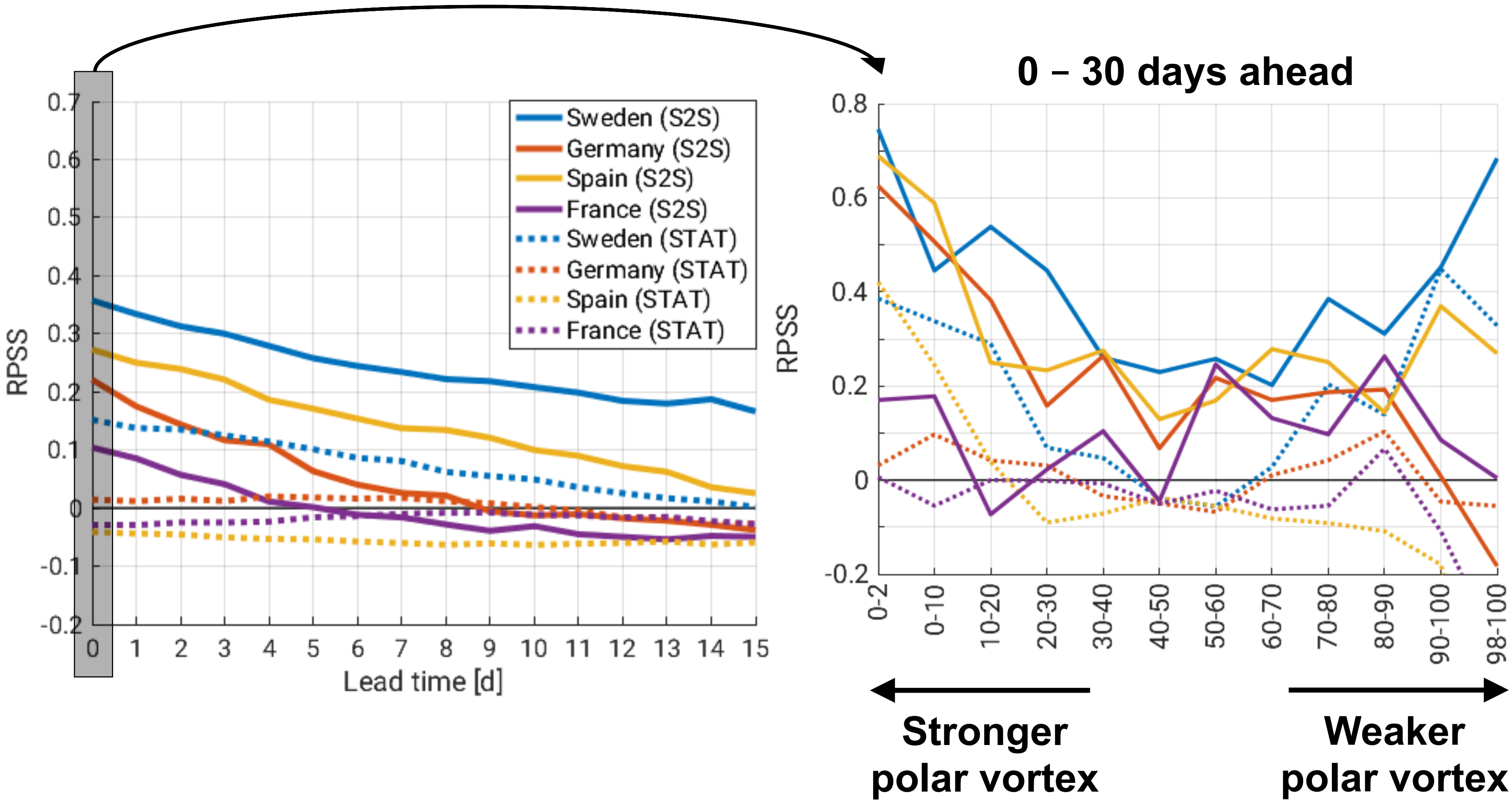


  - Strength of stratospheric polar vortex = $(\Delta Z \text{ @ } 100\text{hPa})_{60^\circ\text{-}90^\circ\text{N}}$
  - **Daily**



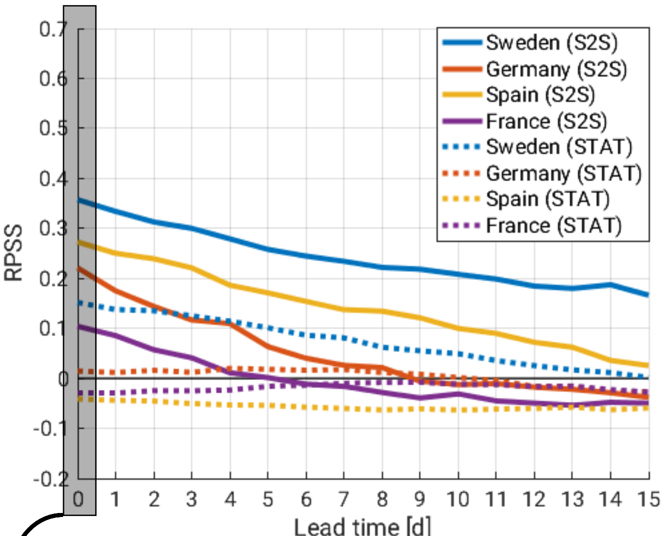
  - Surface wind = $(\Delta UV \text{ @ } 10\text{m})_{\text{European Countries}}$
  - Surface temperature = $(\Delta T \text{ @ } 2\text{m})_{\text{European Countries}}$
  - Precipitation = $(\Delta \text{TOT\_PREC})_{\text{European Countries}}$
  - **Daily month-ahead average**

Results | Statistical vs. model forecast (10m wind)

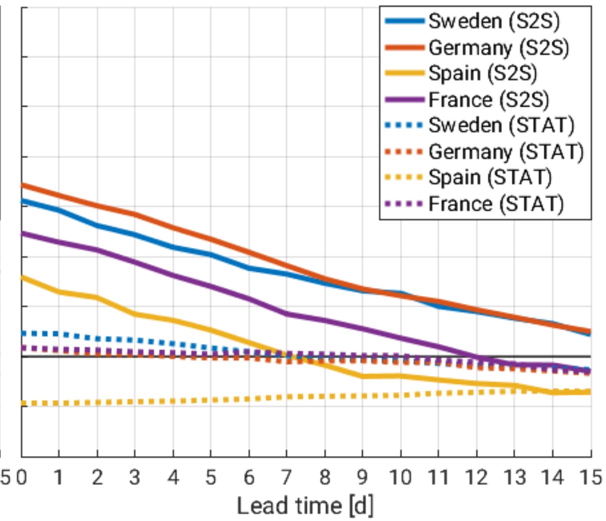


Results | Statistical vs. model forecast (all variables)

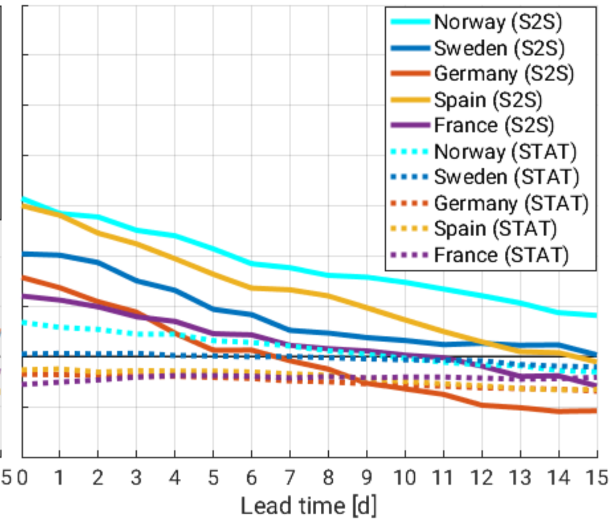
10m wind



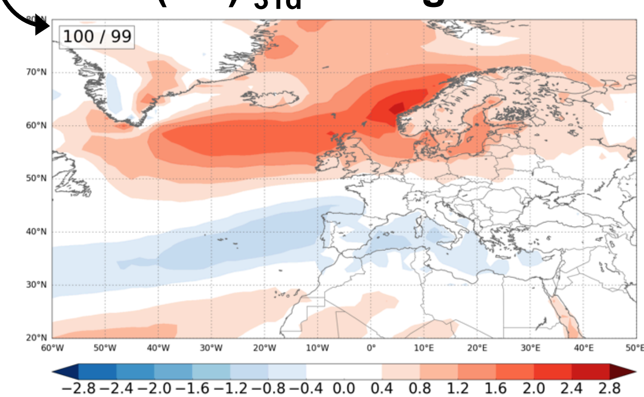
2m temperature



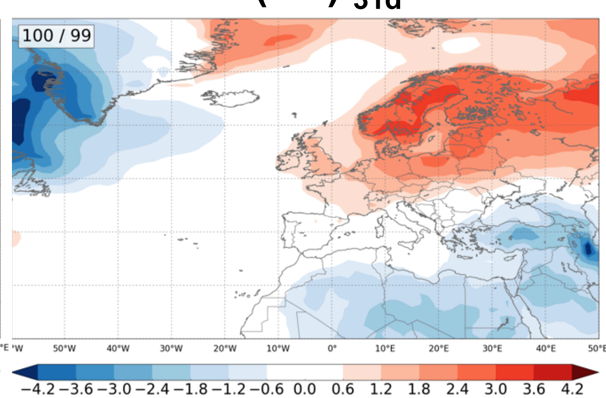
Precipitation



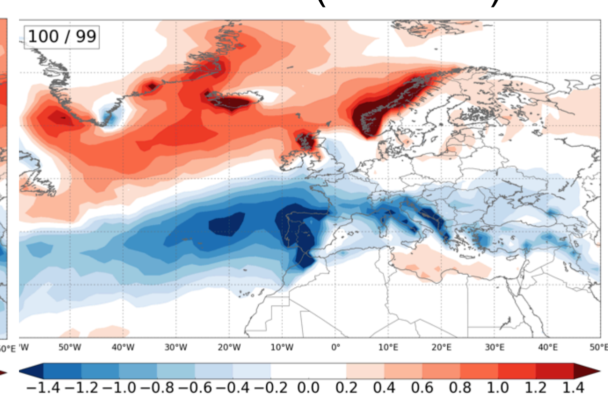
$(\Delta X)_{31d}$ strongest 10% PV events – $(\Delta X)_{31d}$ weakest 10% PV events (in model)



Δ 10m wind speed anomaly [m s^{-1}]

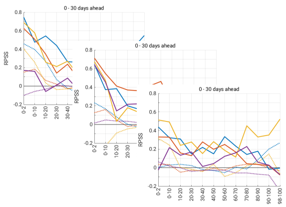


Δ 2m temperature anomaly [K]

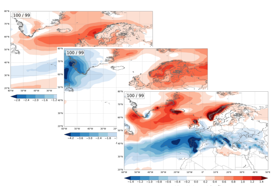


Δ daily precipitation anomaly [kg m^{-2}]

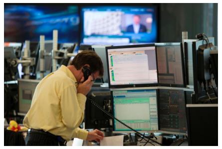
Conclusions | Part II



- **Increase of S2S model skill** through **anomalous strength of stratospheric polar vortex** depends on **variable** and **European region**



- Reason: **anomaly patterns** following anomalous polar vortex events have **different spatial characteristics for different surface variables**
→ a country is particularly **influenced if located in regions of strong anomalies**



- **Implication for energy meteorologists:** considering strength of stratospheric polar vortex and knowing about its representation in S2S models is beneficial

- **Implication for modeling community:** proper representation of stratosphere-troposphere coupling in S2S models is important