ETH Zürich, Institute for Atmospheric and Climate Science
KIT, Institute of Meteorology and Climate Research, Department Troposphere Research

# Verifying ECMWF‘s extended-range (re)forecasts: from large-scale weather to local extremes

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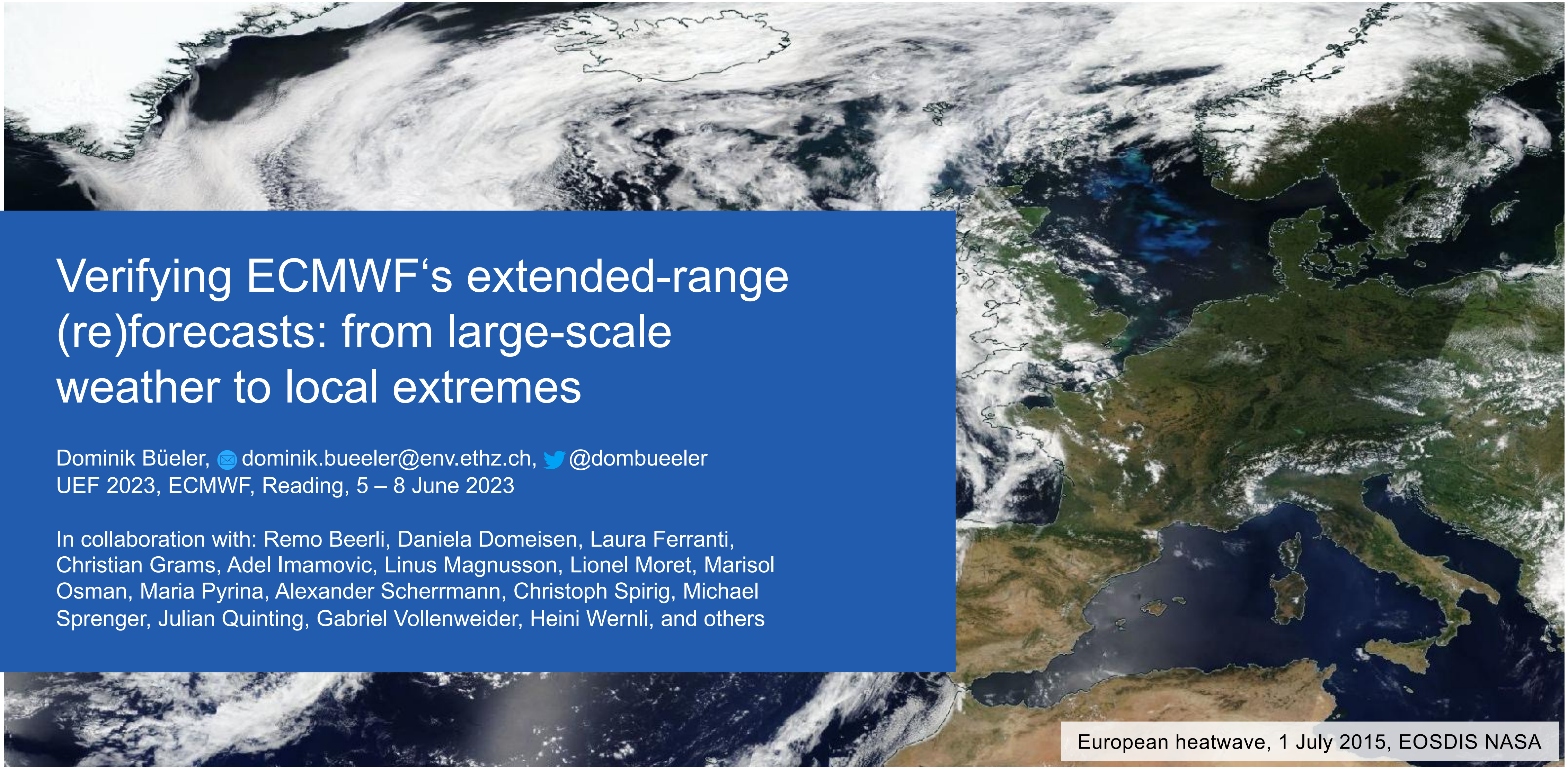
In collaboration with: Remo Beerli, Daniela Domeisen, Laura Ferranti, Christian Grams, Adel Imamovic, Linus Magnusson, Lionel Moret, Marisol Osman, Maria Pyrina, Alexander Scherrmann, Christoph Spirig, Michael Sprenger, Julian Quinting, Gabriel Vollenweider, Heini Wernli, and others



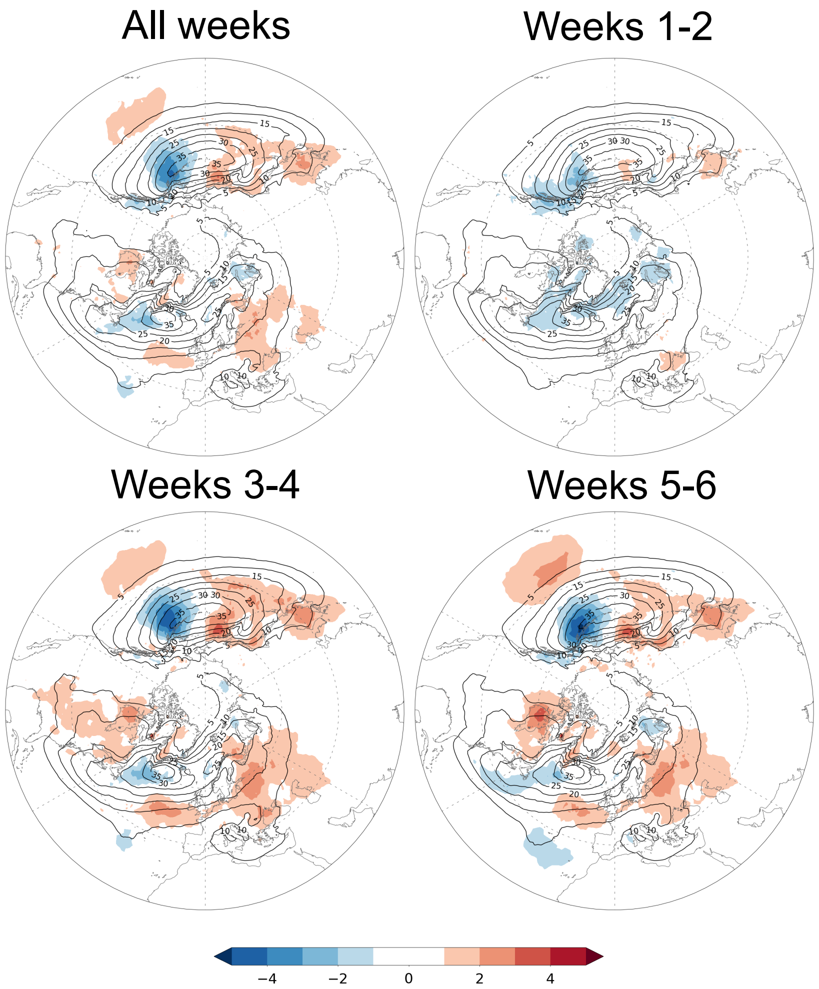
European heatwave, 1 July 2015, EOSDIS NASA

# Outline

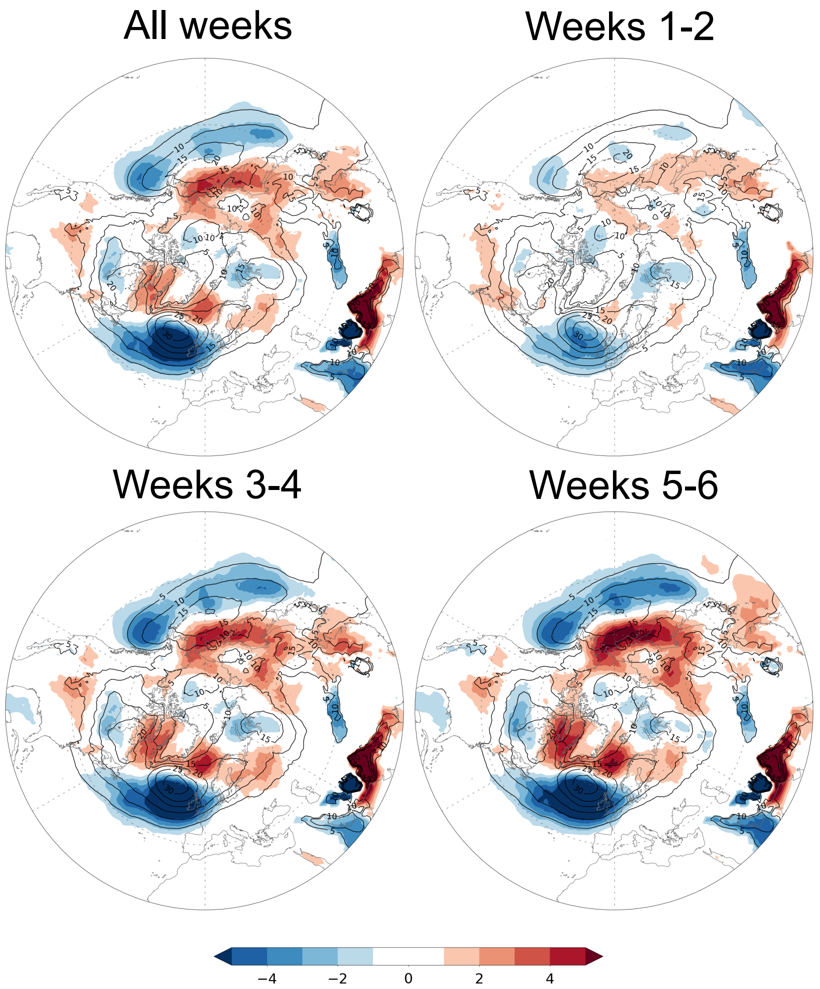
- **Biases** in sub-seasonal (re)forecasts
- Medium-range / sub-seasonal (re)forecast **skill evaluation**
- **Learnings and challenges** from our work with ECMWF's reforecasts – and what the update to cycles 48r1 and 49r1 might bring

# Sub-seasonal (re)forecast biases in Northern Hemisphere extratropical cyclone activity (Büeler, Sprenger, and Wernli, under review in QJRMS)

**Cyclone frequency biases in winter (DJF)**




**Cyclone frequency biases in summer (JJA)**




**Largest in summer, smallest in winter** → role for **predictability of heat and precipitation** in summer?

**Patterns appear at medium-range**, but **magnitudes saturate at sub-seasonal lead times** → understanding model drift also **requires identifying bias sources at early lead times**

Further findings (not shown here): **cyclones are too deep** during most seasons

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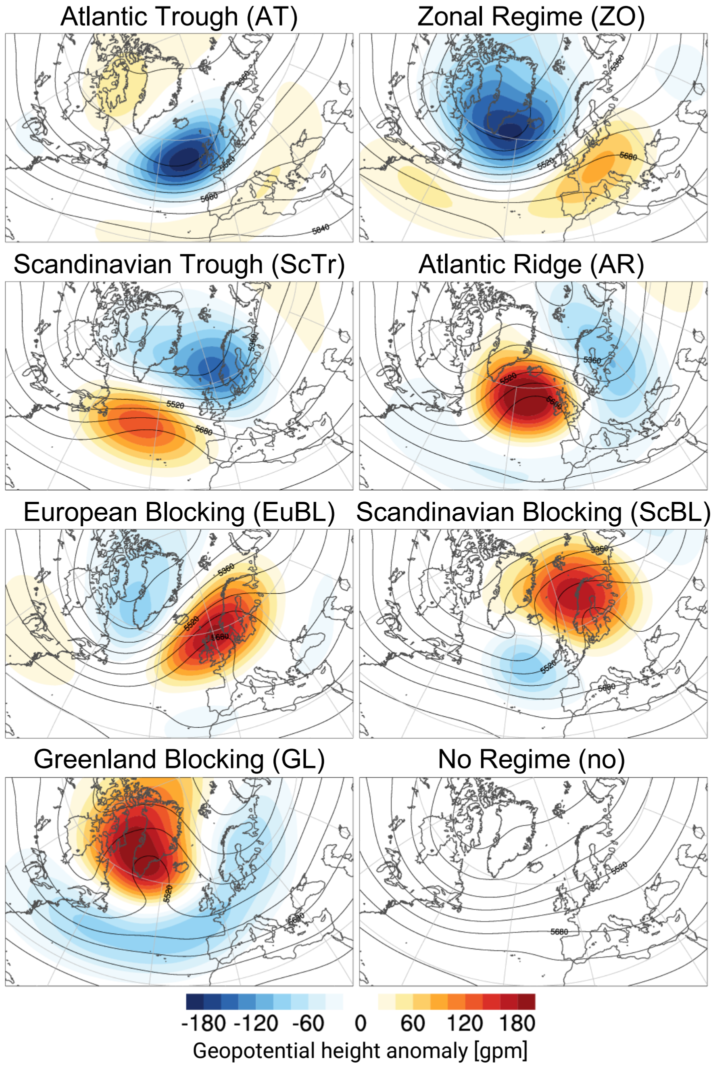
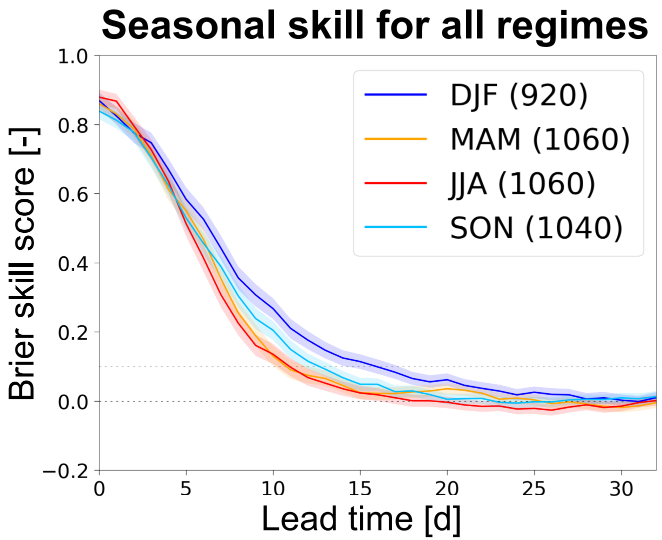
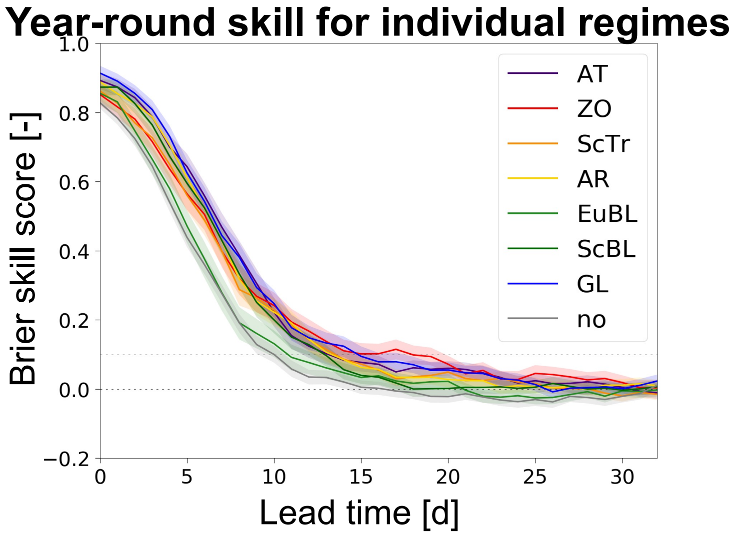
# Year-round sub-seasonal (re)forecast skill for Atlantic-European weather regimes (Büeler, Ferranti, Magnusson, Quinting and Grams, 2021, QJRMS; Osman et al., under review in QJRMS; Grams et al., 2017, NATCLIM)



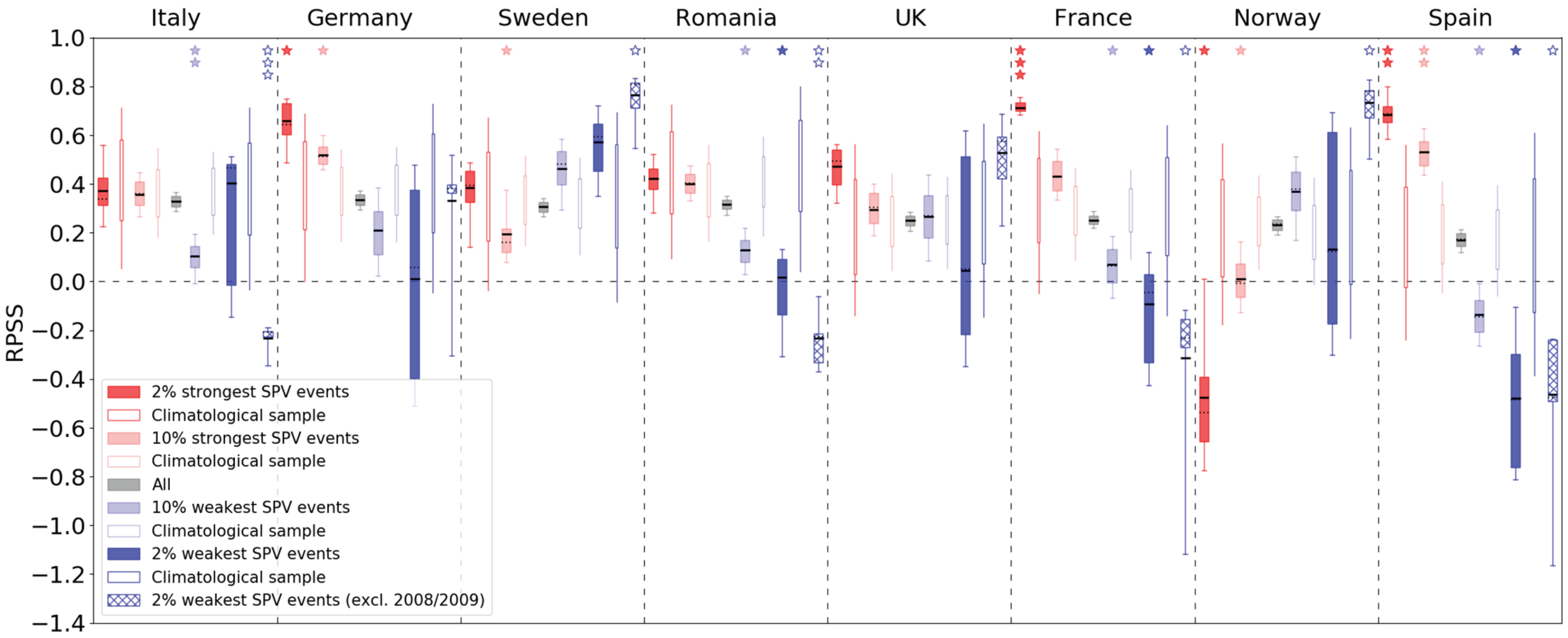

Skill horizon **longest in winter, shortest in summer**

**Strong differences in skill** for individual regimes → skill horizon longest for “ZO” and “GL”, shortest for “no regime” and “EuBL”

Despite better skill for regimes than “no regime”, **useful average regime skill still limited to medium-range** → crucial to **extract / better understand “windows of opportunity” for useful sub-seasonal skill** (e.g., stratosphere, MJO; cf. Büeler et al., 2021, QJRMS)

# Sub-seasonal (re)forecast skill for 2m-temperature in Europe following extreme stratospheric polar vortex states (Büeler, Beerli, Wernli, and Grams, 2020, QJRMS)

**Country-aggregated month-ahead forecast skill for 2m-temperature terciles following strong and weak stratospheric polar vortex (SPV) states during winter (DJF)**




**Very strong SPV | Strong SPV | All forecasts | Weak SPV | Very weak SPV**

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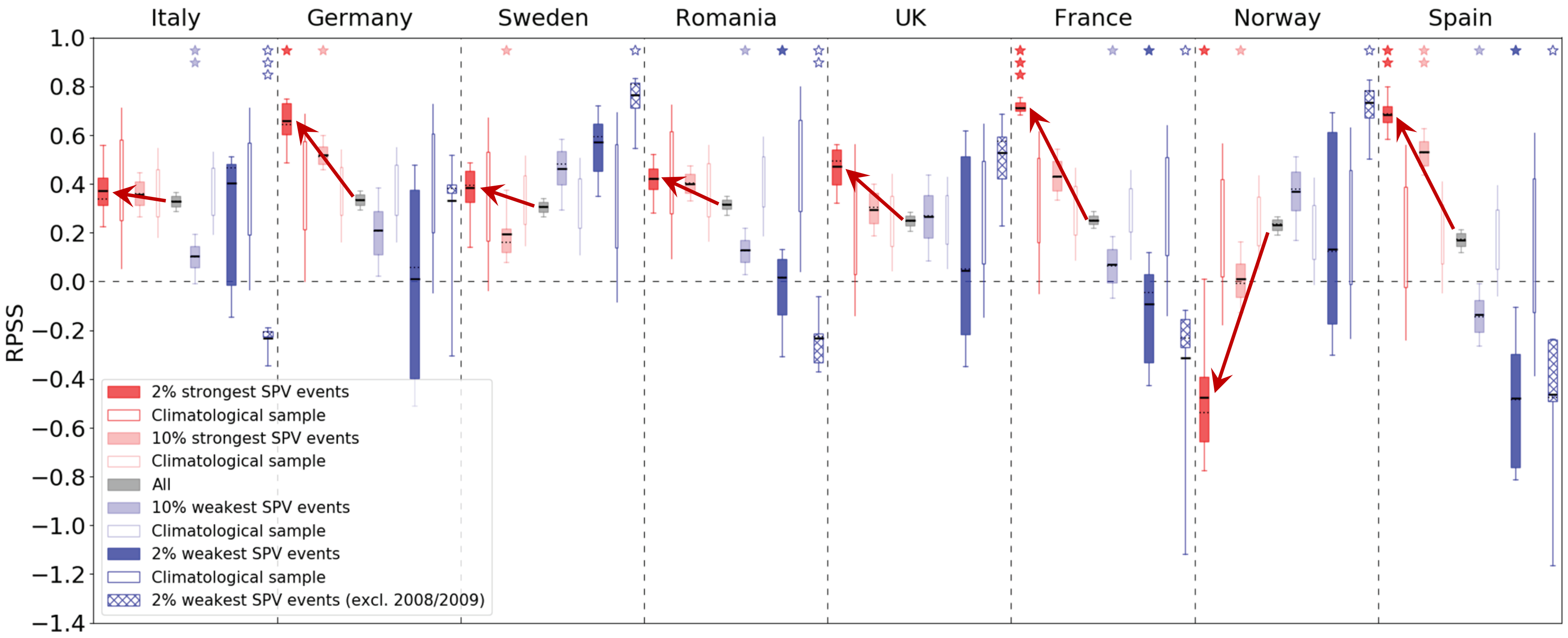


**Very strong SPV** | **Strong SPV** | **All forecasts** | **Weak SPV** | **Very weak SPV**

**Strong SPV states:** enhanced skill for most of Europe except for some Scandinavian countries

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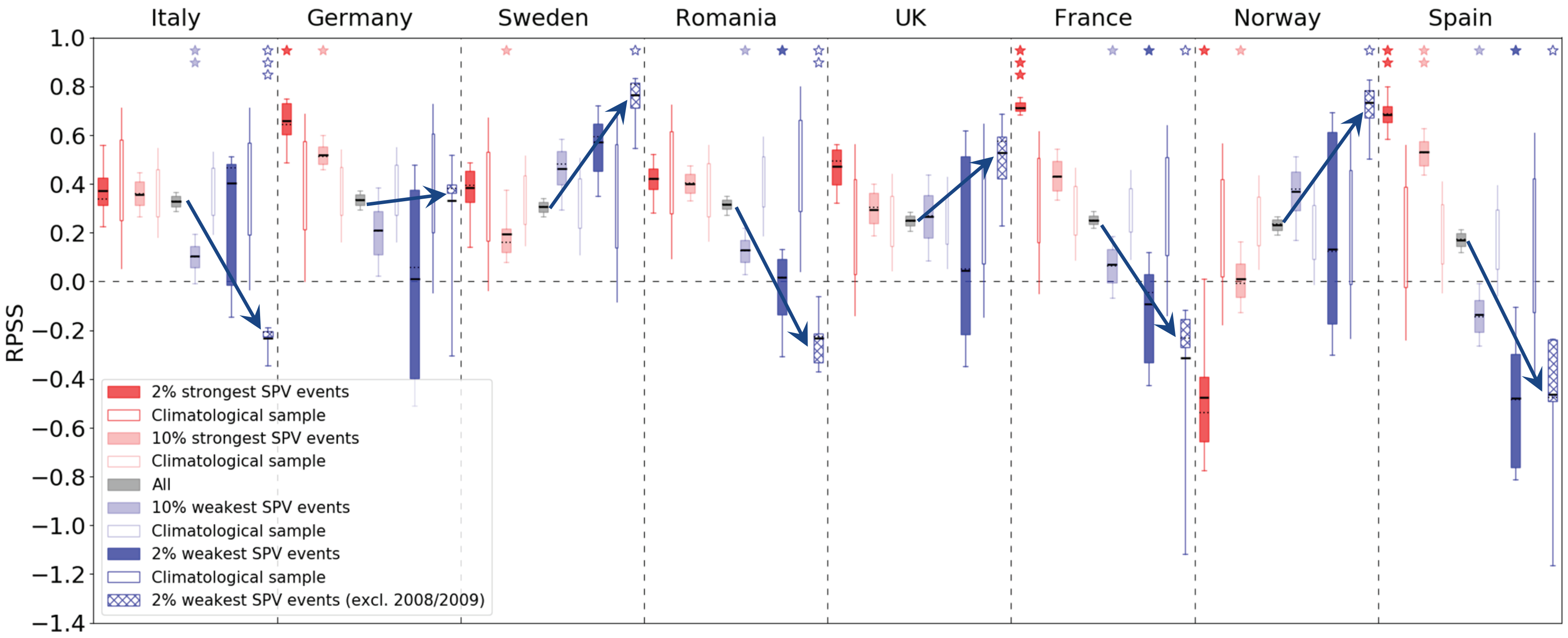


**Very strong SPV** | **Strong SPV** | **All forecasts** | **Weak SPV** | **Very weak SPV**

**Strong SPV states:** enhanced skill for most of Europe except for some Scandinavian countries

**Weak SPV states:** enhanced skill for Scandinavian countries but reduced skill for many Central/Southern European and Balkan countries → **problems in predicting varying extent of cold air masses into Central/Southern Europe**

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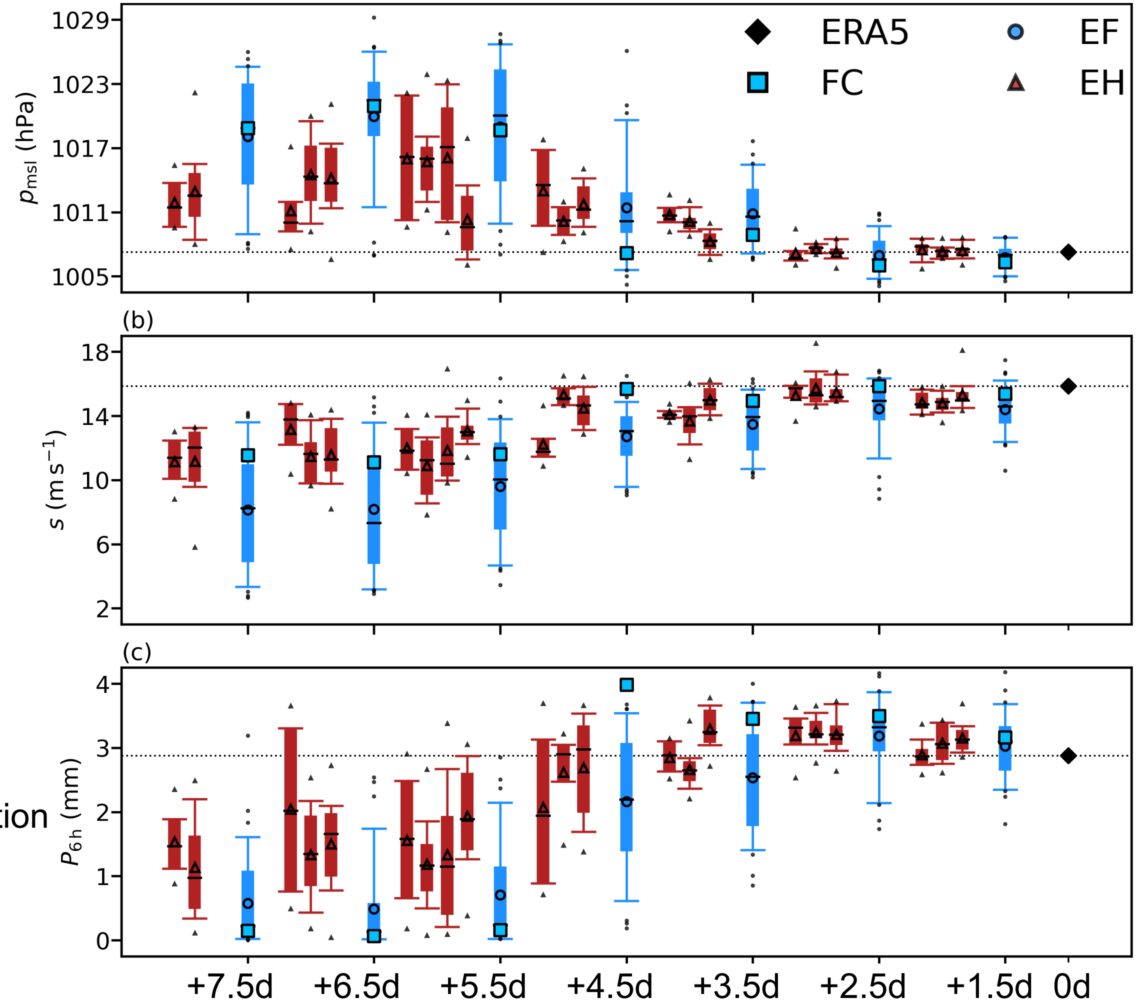
# How well would extreme Mediterranean cyclones in history have been predicted with today's ECMWF forecast system? - Algiers flooding 2001 case study (Gabriel Vollenweider, 2023, MSc thesis ETH Zürich)

**Predictions for different forecast initial times before event**

SLP

Wind

Precipitation




**Ensemble hindcasts (EH**; i.e., based on more recent model versions) **outperform ensemble (EF) and deterministic forecast (FC) operational back then** → improved ensemble mean and spread, extended skill horizon

**Improvements less obvious for other cases** → model improvements **translate very differently into predictability gains for individual extreme events**

Thesis was insightful, but **reached limits of what is possible with data availability in ECMWF's public reforecast archive**

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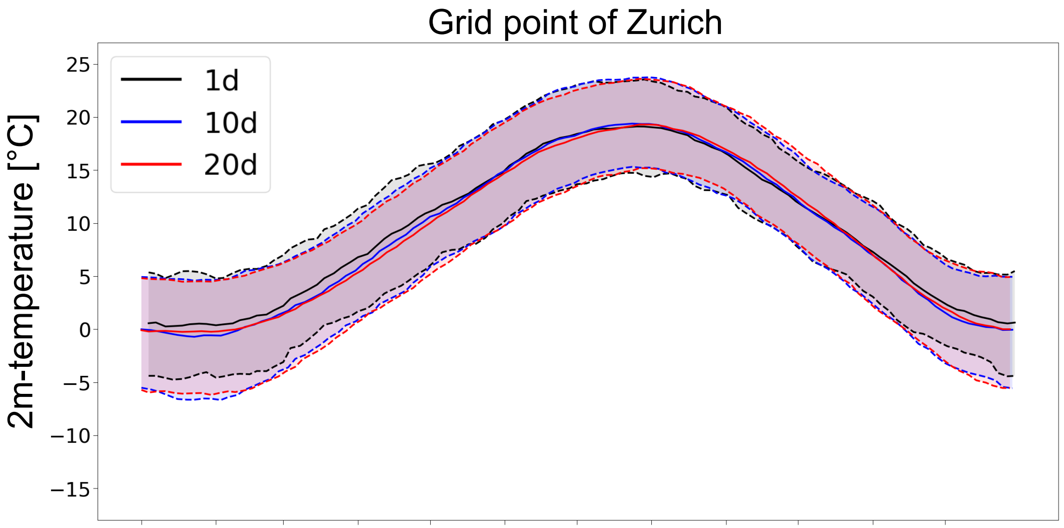
# Ongoing work: how to define climatological reforecast distribution to identify extreme temperature in individual ensemble members

(new project on sub-seasonal heatwave/drought prediction with M. Pyrina and D. Domeisen in collaboration with MeteoSwiss)

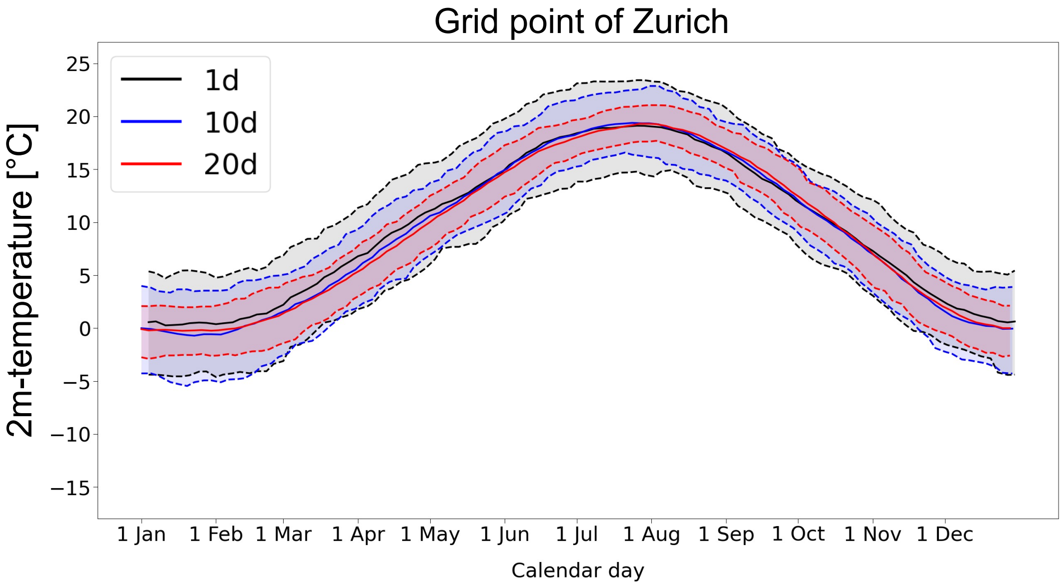
30d running clim. T2M reforecast distribution **based on individual ensemble members**

(20 years x 9 initializations x 11 members = 1980 fields)




30d running clim. T2M reforecast distribution **based on ensemble means**

(20 years x 9 initializations x 1 ensemble mean = 180 fields)




Climatological **forecast distribution becomes narrower with lead time** when defined **based on ensemble means** → effect on **identification of heatwave events** (i.e., T2M above certain percentile)

Which way to go? How does ECMWF do this for EFI?

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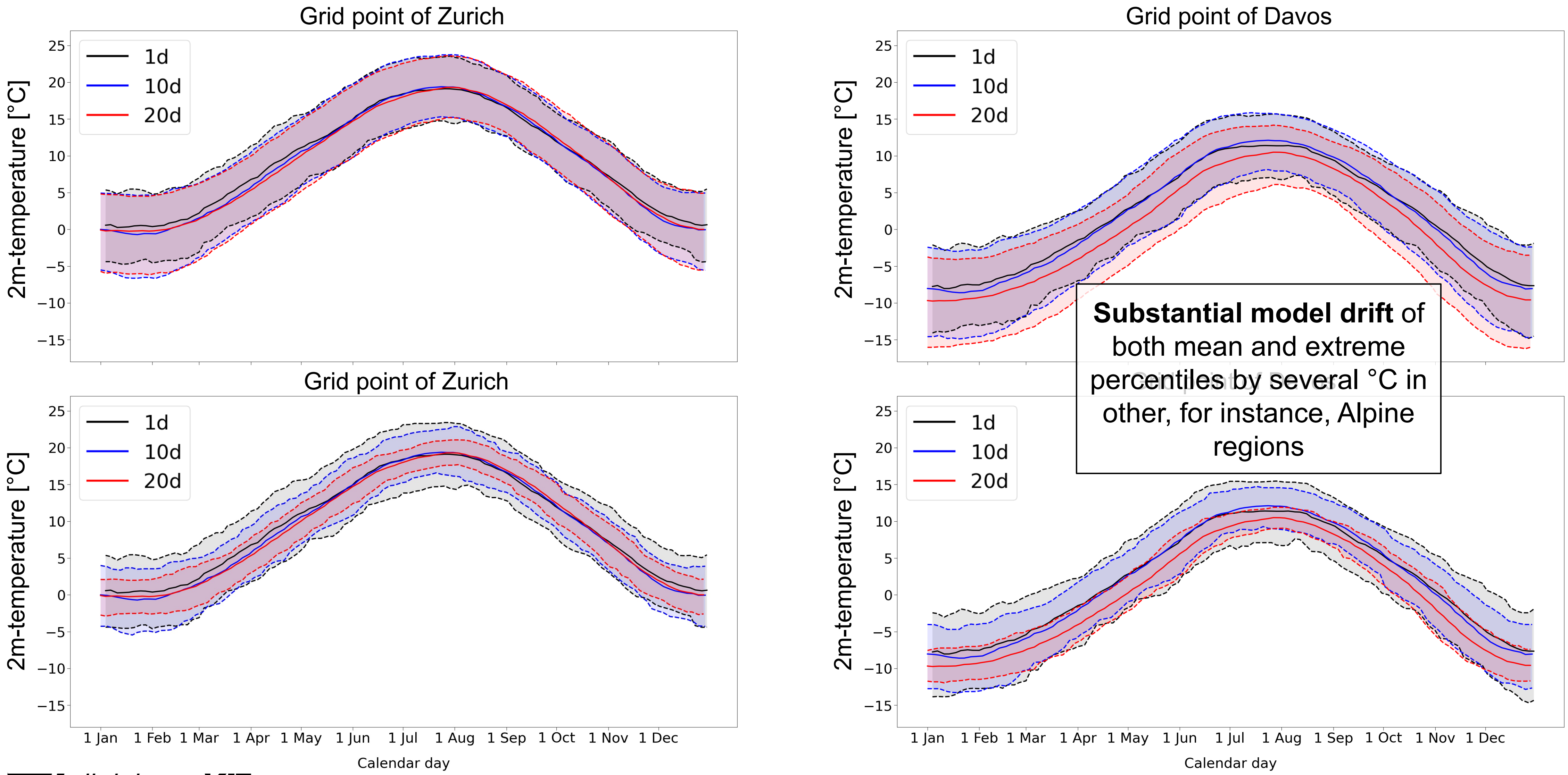


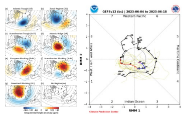

**Substantial model drift** of both mean and extreme percentiles by several °C in other, for instance, Alpine regions

# Learnings and challenges from our work with ECMWF's reforecasts – and what the update to cycles 48r1 and 49r1 might bring

**Great and easily accessible treasure** that should be used!

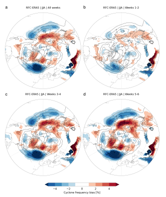
**Transferability** of insight gained **from reduced reforecast ensemble (11 members) to operational ensemble (51, soon 101, members)?**


**Irregular initialization frequency** makes things more **cumbersome**, particularly for extreme event studies and model intercomparison → **daily (?) initialization frequency** will help

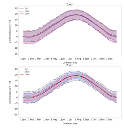


**Too small sample size** for **flow-dependent (re)forecast verification** (e.g., stratification for regimes *and* MJO states) → **daily (?) initialization frequency** will help, but only slightly → more **tailored simulations over longer periods** required for verification studies?

Sensitivity of verification to **mixing of model versions**?



**Understanding sub-seasonal model drift** also requires **identifying/understanding bias sources at early lead times** → **parallel medium-range and extended-range reforecasts in combination** will provide interesting new research dataset (→ e.g., role of spatial resolution for bias evolution at early lead times?)



**Different ways of calculating (re)forecast climatologies** (and distributions) to correct for biases → should ECMWF provide **official guidelines** or even **datasets?**

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