Using soil moisture forecasts for sub-seasonal summer temperature predictions in Europe

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Introduction

Soil moisture is known for its integrative behavior and resulting memory characteristics.[1] Soil moisture anomalies can persist for weeks or even months into the future, allowing to predict soil moisture accurately on sub-seasonal time scales[2] and making initial soil moisture an important potential contributor to skill in weather forecasting.[3,4,5]

Especially through its impacts on the evapotranspiration of soils and plants, soil moisture may influence the land energy balance and hence surface temperature.[1]

This study investigates the potential of translating soil moisture forecasts into temperature forecasts. Using a simple water balance model[6] we show that considerable temperature forecast skill can be achieved. We also identify its main controls and discuss their negative relationship.

QUESTIONS

1. What is the spatial distribution of the temperature forecast skill?
2. How skillful are temperature forecasts derived from soil moisture in comparison with an established ECMWF product?
3. Which are the main controls of soil moisture-derived temperature forecast skill?

Water-balance model

Starting from the water balance equation:

$$w_{n+1} = w_n + P_n - E_n - Q_n$$

w_n ... Soil moisture at beginning of time period n
P_n ... Precipitation averaged over time period n
E_n ... Evapotranspiration averaged over time period n
Q_n ... Runoff averaged over time period n
R_n ... Net radiation averaged over time period n

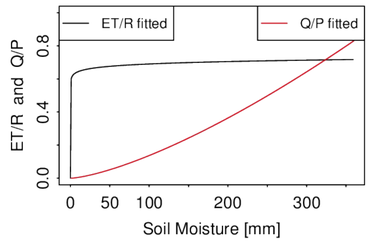
we assume:

$$\frac{E_n}{R_n} = \beta_0 \left(\frac{w_n}{c_s}\right)^{\gamma} \; with \; \gamma \leq 1 \; and \; \beta_0 \leq 1 \qquad \frac{Q_n}{P_n} = \left(\frac{w_n}{c_s}\right)^{\alpha} \; with \; \alpha \geq 1$$

c_s ... Water holding capacity of the soil
α ... Runoff ratio exponent
γ ... ET ratio exponent
β_0 ... Maximum ET ratio

Functions calibrated **using observed streamflow**;
Parameters α, γ, β_0 and c_s are chosen to yield highest correlation between modeled and observed streamflow.

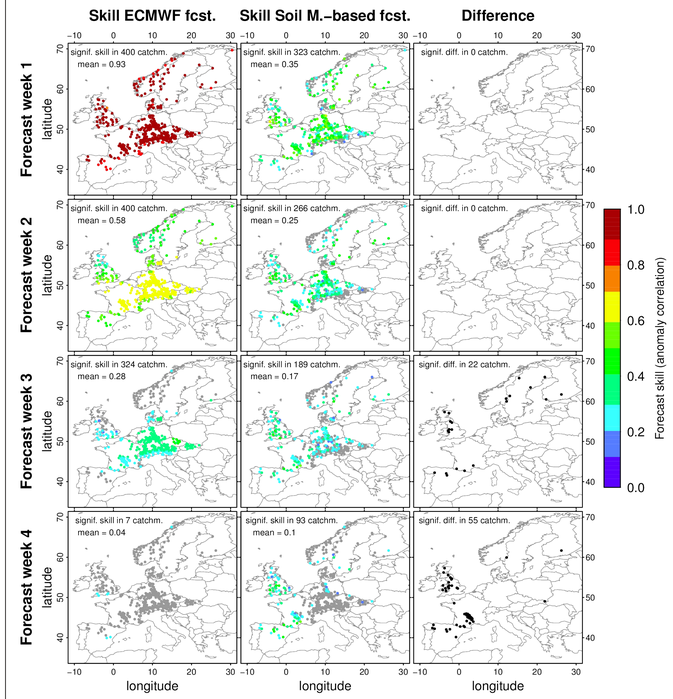
Resulting **catchment-specific functions** for site Oensingen:



Soil moisture (and all other water-balance components) **computed** with these functions **using precipitation and radiation only.**

Spatial patterns of skill

Temperature forecast skills of soil moisture-derived forecasts and VarEPS ECMWF reforecasts in 400 near-natural catchments.
Skills expressed as correlation of modeled vs. observed temperature anomalies. Gray dots denote no significant skill beyond climatology.



1 **Spatial patterns** of skill of soil moisture-derived forecasts **change with lead time**.
Highest skills found in Central Europe and Scandinavia (short lead times) and in south-western Europe (long lead times).

References

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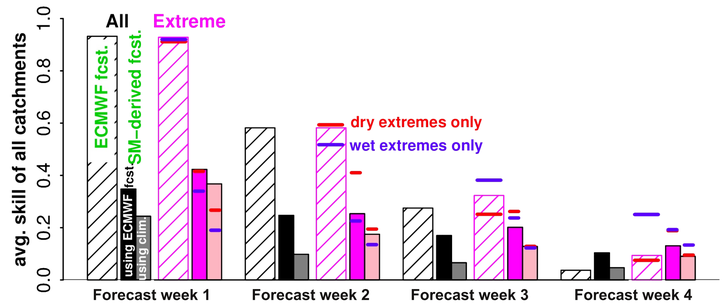
2) Orth, R., and S. I. Seneviratne, 2013: Predictability of soil moisture and streamflow on sub-seasonal timescales: A case study, J. Geophys. Res., 118(19), 10963-10979.
3) Koster, R.D. et al., 2010: Contribution of land surface initialization to subseasonal forecast skill: first results from a multi-model experiment. Geophys. Res. Lett., 37.
4) Koster, R.D. et al., 2011: The Second Phase of the Global Land-Atmosphere Coupling Experiment: Soil Moisture Contributions to Subseasonal Forecast Skill. J.Hydrometeor, 12, 805-822.
5) van den Hurk, B., F. Doblas-Reyes, G. Balsamo, R.D. Koster, S.I. Seneviratne, H. Camargo, 2012: Soil moisture effects on seasonal temperature and precipitation forecast scores in Europe. Climate Dynamics, 1-2, 349-362.
6) Orth, R., R. D. Koster, and S. I. Seneviratne, 2013: Inferring soil moisture memory from streamflow observations using a simple water balance model, J.Hydrometeorol., 14, 1773-1790.

Comparison with ECMWF product

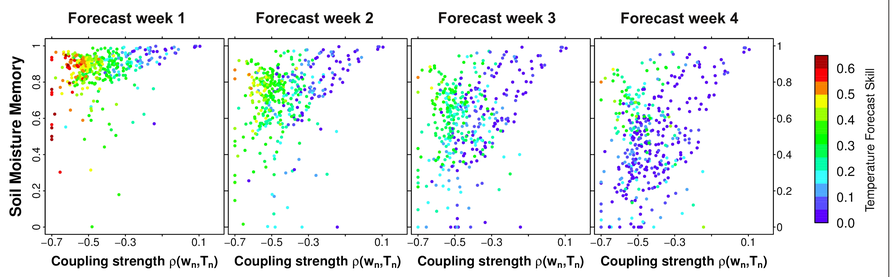
Comparison of simple soil moisture-based model with ECMWF forecasts; Figure shows mean skills of both temperature forecasts in all 400 European catchments. Results computed for wet, dry and all initial soil moisture conditions at forecast initialization.



2
> Much **better performance of ECMWF forecast skills at short and medium lead times** (several additional sources of predictability)
> **At long lead times, however, the soil moisture-only approach displays higher skill** in a significant number of catchments (potential for improvement of operational ECMWF forecasts)

Controls of skill

Skill of soil moisture-derived temperature forecasts depends on:
(i) soil moisture memory and (ii) soil moisture-temperature coupling.



3 Despite the **negative relationship between the two main controls** of skill there is a **middle ground** in some catchments that **promotes high forecast skills**.