Ensemble prediction experiments with AMPT including soil perturbations

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Outline

1. AMPT including soil perturbations: approach
2. Experiments with EPS : set up and results

AMPT: **A**dditive **M**odel-error perturbations scaled by **P**hysical **T**endencies

The AMPT perturbations $\mathcal{P}(x, y, \mu, t)$ are spatio-temporal random fields scaled by the area averaged (in the horizontal) modulus of the physical tendency $P(x,y,\mu,t)$.

$$\mathcal{P}(x, y, \mu, t) = \sigma \cdot \overline{\{|P(x, y, \mu, t)|\}}\, \xi(x, y, \mu, t)$$

where σ determines the perturbation magnitude,
the overbar denotes the horizontal averaging operator,
$\xi(x, y, \mu, t)$ is the pseudo-random field generated by the Stochastic Pattern Generator SPG (Tsyrulnikov, Gayfulin, 2017),
μ is the vertical coordinate.

Now averaging can be over the **whole** domain (for Gaussian variables) or over a **sliding subdomain** (for non-Gaussian variables).

Application of AMPT to perturbation of soil characteristics

Which elements are perturbed?

Soil temperature T soil and soil water content W soil at all model levels are perturbed each model time step.

In addition, initial perturbations are introduced to T soil and soil moisture index (SMI). The perturbed SMI is then converted to W soil.

Does the perturbation pattern change from level to level ?

No, the same random field is used for all levels but perturbations have different magnitudes. The pseudo-random field ξ is 2D for soil.

Do the perturbations decay downward?

Yes, their magnitude is specified for the uppermost level k=1. At level k>1 (recall that levels in soil go downwards) the magnitude equals that at level k-1 divided by a number greater than one (from 1.5 to 3, subject for tuning).

Application of AMPT to perturbation of soil characteristics

Are the temperature and moisture perturbations related to each other?

No. But the temporal scales of W and T soil perturbations are the same (and significantly greater than in the atmosphere).

Are temperature and moisture perturbations introduced in the same manner?

Both T soil and W soil are perturbed using AMPT, but the averaging is different. We average over the whole domain for T soil and over a sliding spot around the point at which perturbation is calculated for W soil.

How often averaging is done?

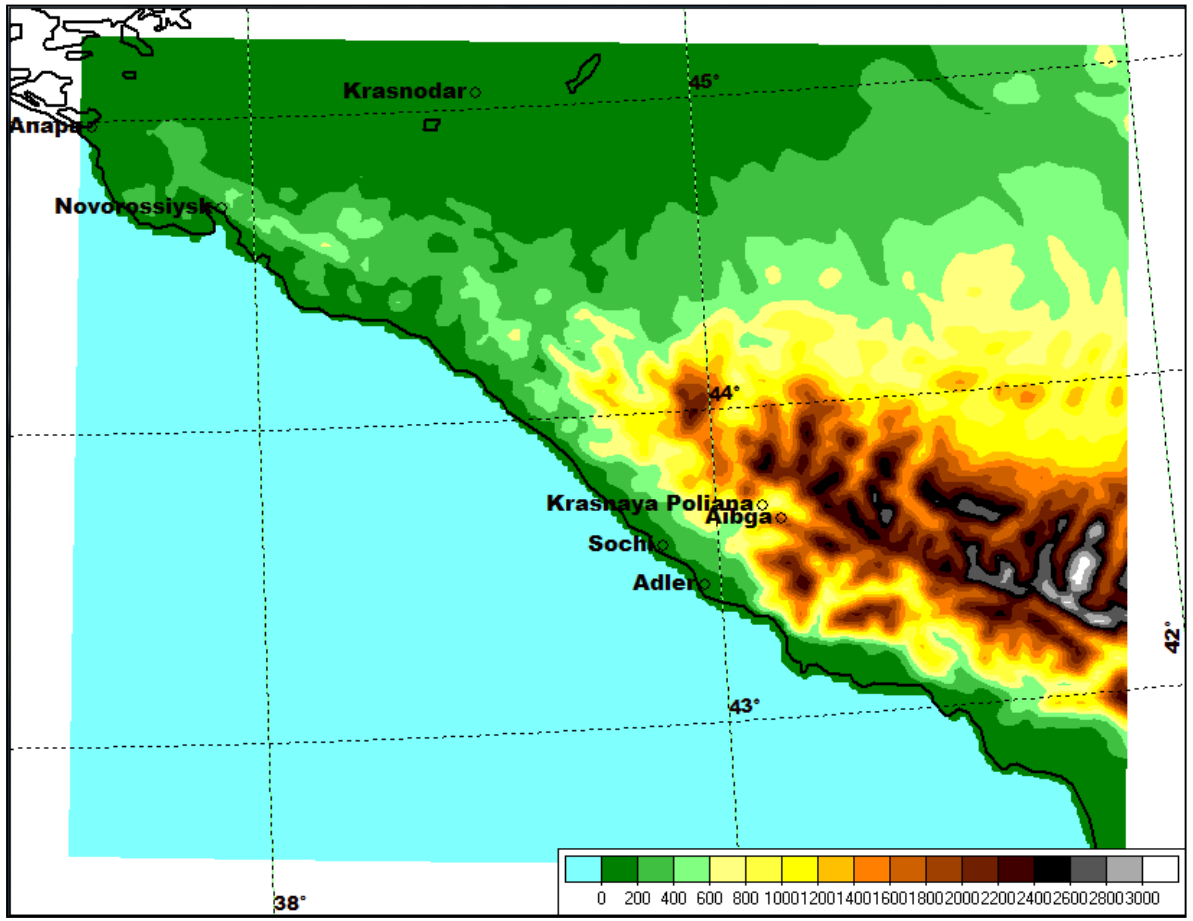
The averaging is done once per hour (less frequently than each 20 min for T, u, v)

Experiments

Experiment setup

- Initial and lateral boundary conditions for ensemble members were taken from COSMO-LEPS adapted for a larger Sochi region (resolution 7 km) - made by the Italian colleagues

- 300*400 km area centered at Sochi (latitude 44N)
- Model resolution: 2.2 km, 50 levels
- Ensemble size: 10
- Time period: February - March 2014
- Verification against ~40 stations



Tuning AMPT parameters

1 forecast, initial time 1 Febr 2014/00

- **Magnitude of initial perturbations**

T soil : 0.3, **1**, 2, 3 K

W soil: **0.01** SMI

- **Decay of initial perturbations with depth**

(parameter decayPar: $\sigma(k+1)=\sigma(k)/decayPar$)

T soil : 1.5, **1.75**, 2, 4

W soil: 1., 1.5, **2.**

- **Time scale of perturbations in atmosphere**

~1h and ~1.5h

- **Time scale of perturbations in soil**

T05_soil_factor = temporal scale in soil/temporal scale in atmosphere

T05_soil_factor: 5, 10, **12,** 15, **20**

List of experiments

NOPERT No model perturbations

SPPTSW SPPT with MeteoSwiss settings

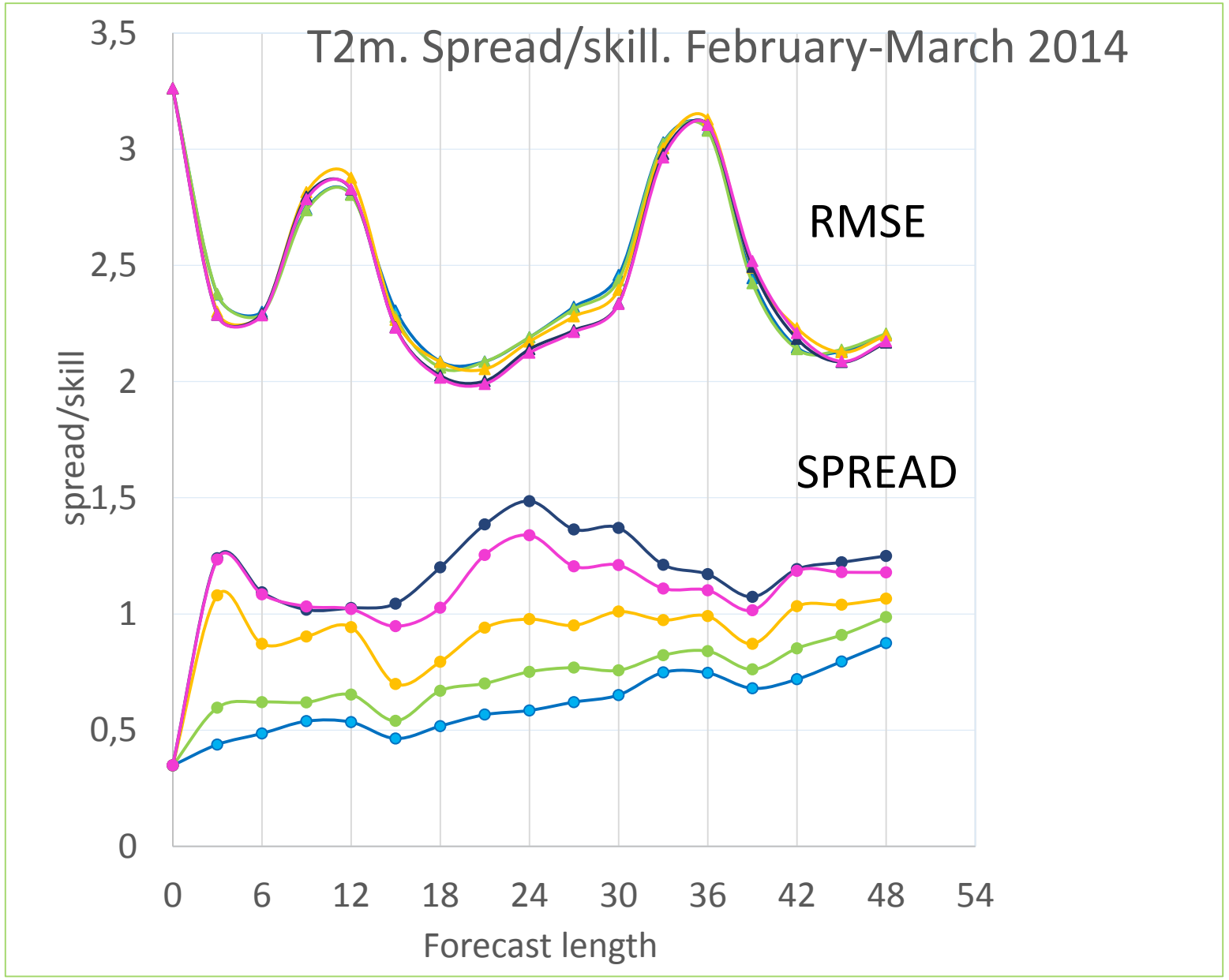
NOSOIL AMPT only in the atmosphere

SOIL_20 AMPT in the atmosphere and in the soil; T05_soil_factor = 20

T05_soil_factor = (temporal scale in soil)/(temporal scale in atmosphere)

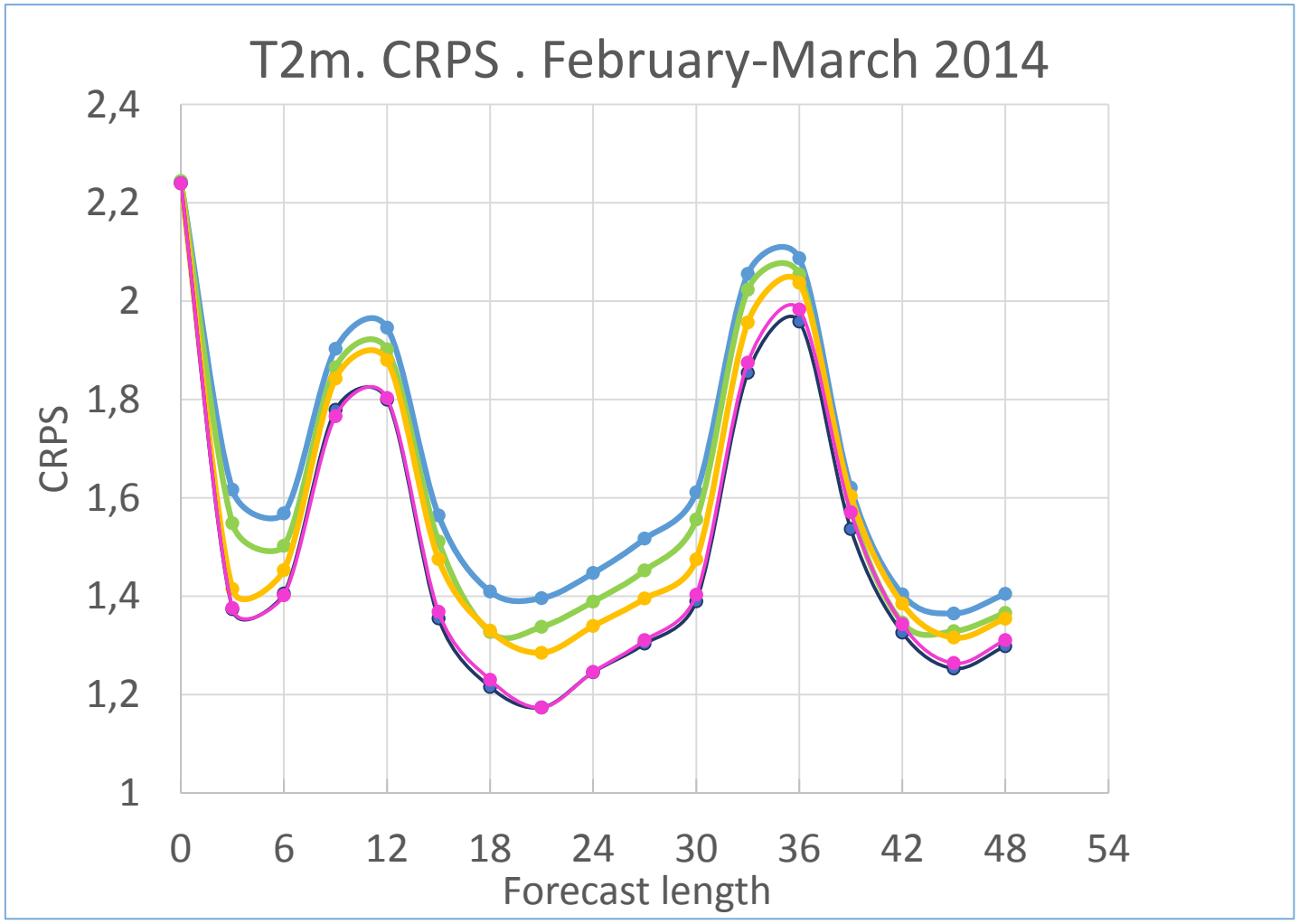
SOIL_12 AMPT in the atmosphere and in the soil; T05_soil_factor = 12

In all AMPT experiments: *no tapering near the surface, no tapering in the stratosphere*
Magnitude of initial perturbations is 1K for T soil, 0.01 SMI.
Model-error perturbation magnitude σ=0.75 (both for soil and atmosphere).
The random field in the atmosphere is characterized by a spatial scale of 50 km and a temporal scale of ~1h.



NOPERT
SPPTSW
NOSOIL
SOIL_20
SOIL_12

Spread is sensitive to the variations of the temporal scale of soil perturbations but rmse is not!



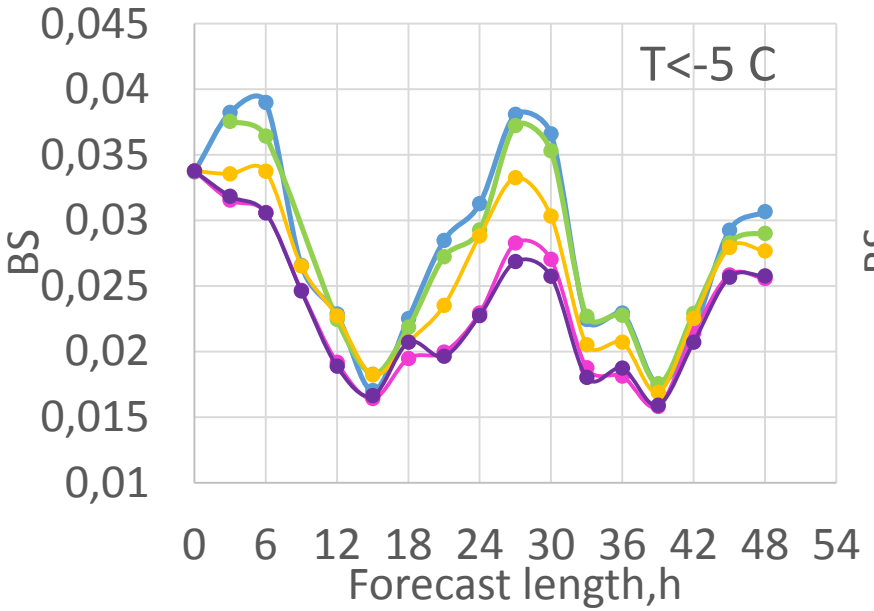
NOPERT SPPTSW
NOSOIL SOIL_20 SOIL_12

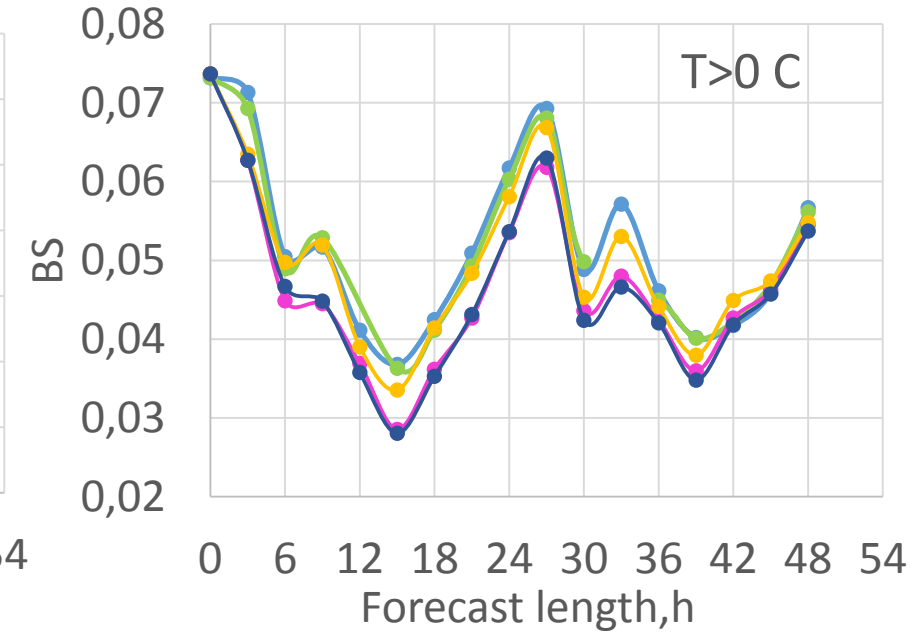
Continuous Ranked Probability Score (CRPS)

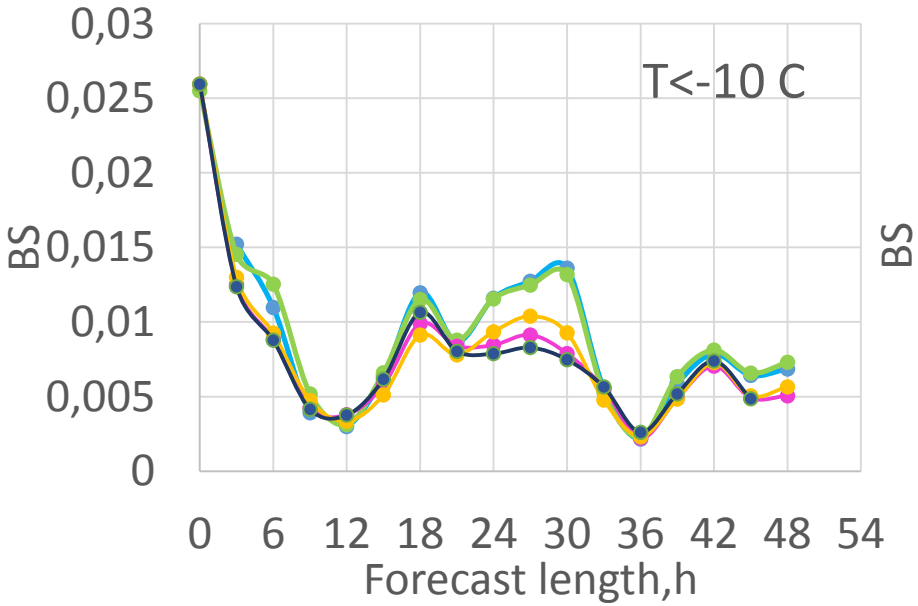
The lower the better

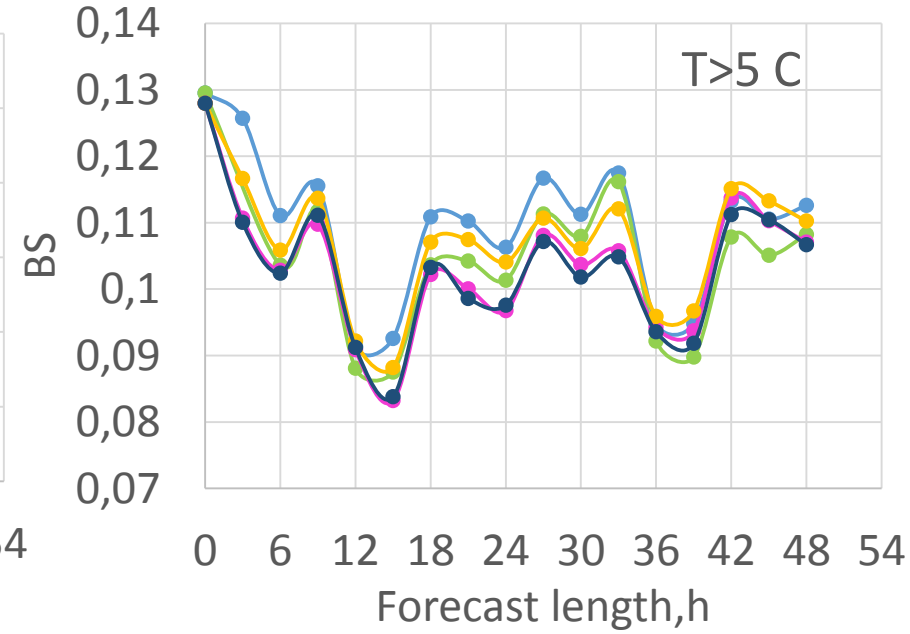
Measures the difference between the predicted and occurred cumulative distributions

Experiments SOIL_20 and SOIL_12 demonstrate the same CRPS









T2m. February-March2014.

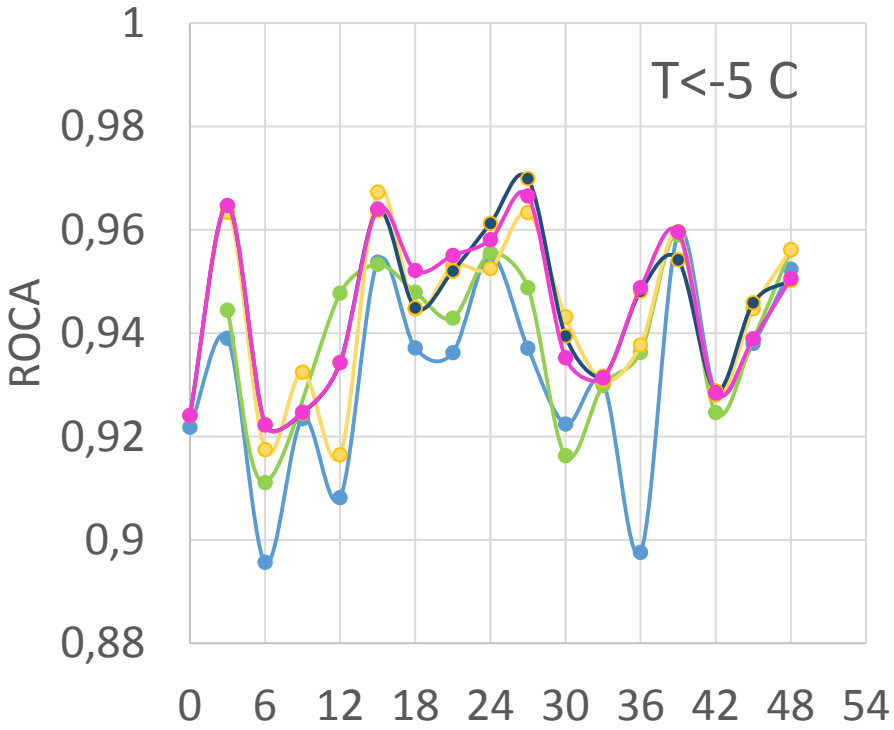
Brier score

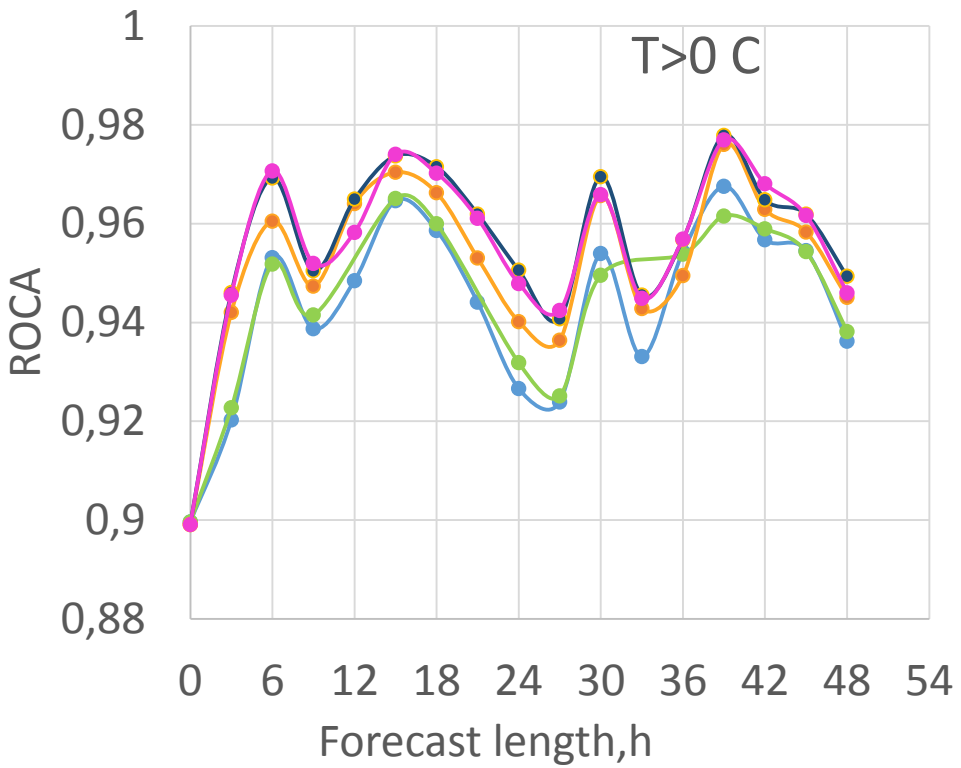
The smaller the better

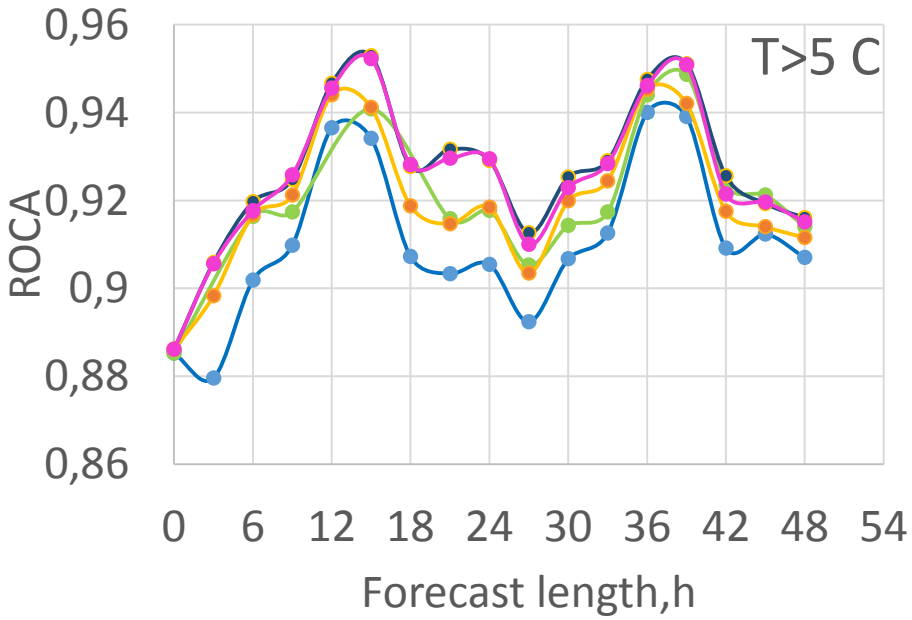
Characterizes the magnitude of the probability forecast errors

NOPERT
SPPTSW
NOSOIL
SOIL_20
SOIL_12

Experiments with AMPT soil perturbations show the best results







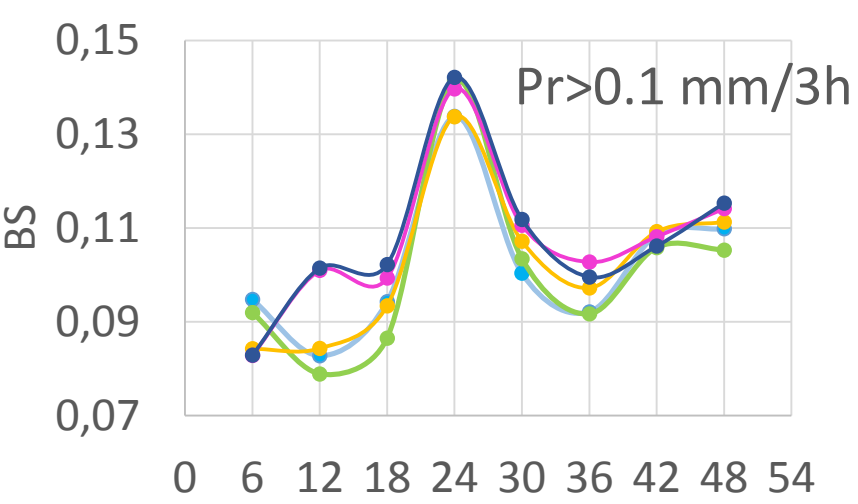
Area beneath the relative operating characteristics (ROCA)

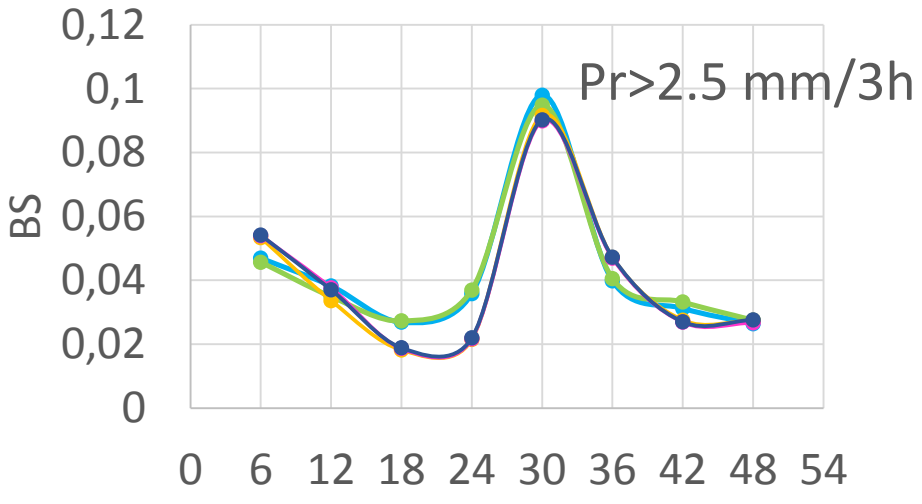
The higher the better

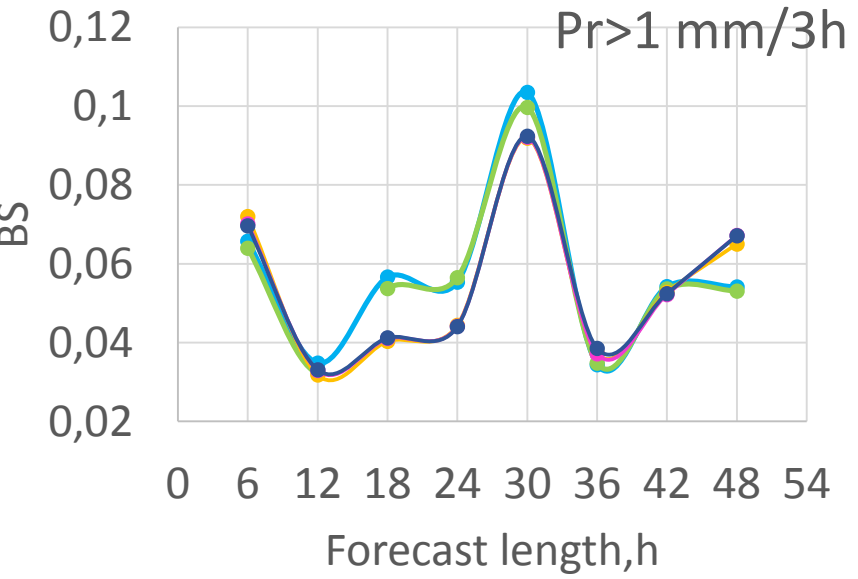
ROC measures resolution

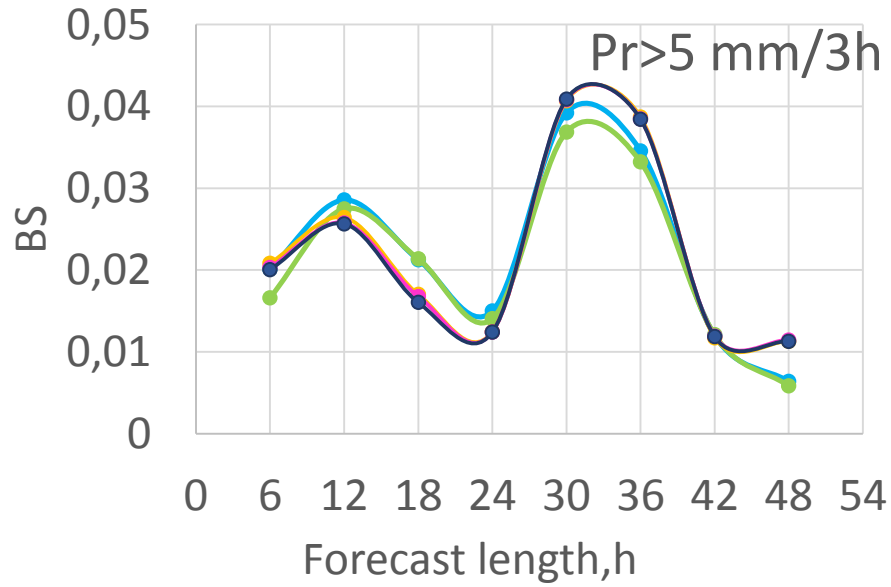
NOPERT **SPPTSW**
NOSOIL
SOIL_20 **SOIL_12**

ROCA is better for experiments with AMPT soil perturbations for most thresholds









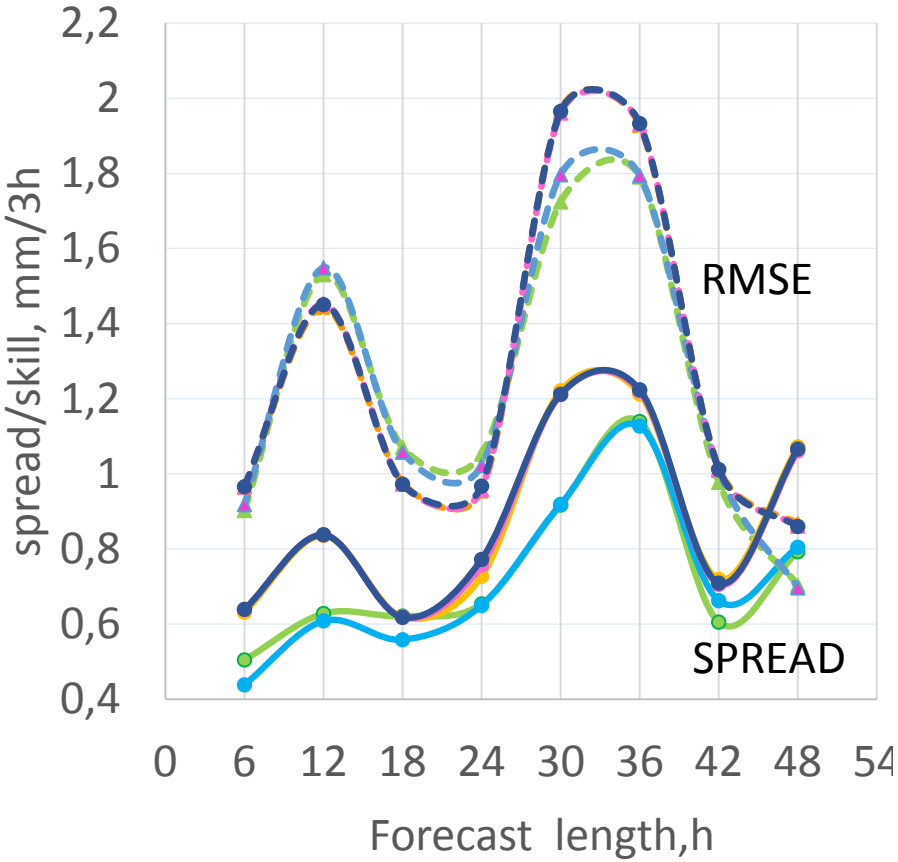
Precipitation.
February-March2014.

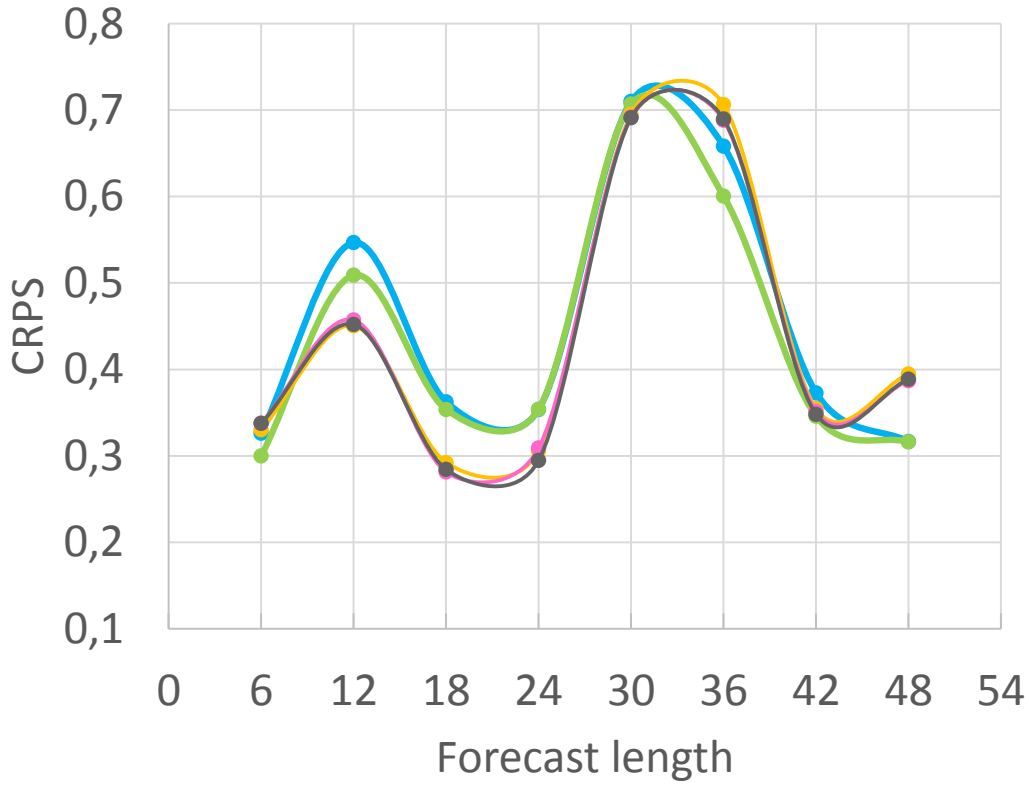
Brier score

The smaller the better

NOPERT
SPPTSW
NOSOIL
SOIL_20
SOIL_12

All AMPT experiments (NOSOIL, SOIL_20 and SOIL_12) demonstrate nearly the same BS for all thresholds except for 0.1. Probability of precipitation occurrence is worse predicted with AMPT, while probabilities of greater precipitation are predicted better





Precipitation. February-March2014.

NOPERT **SPPTSW** **NOSOIL** **SOIL_20** **SOIL_12**

Spread, rmse and CRPS for precipitation are not much affected by soil perturbations

Conclusions

- Application of AMPT soil perturbations improves ensemble forecast of 2m temperature. CRPS, Brier score, and ROCA for T2m are better than those without soil perturbations.
- The experiments with AMPT perturbations, both in the atmosphere alone and in the atmosphere and soil, demonstrate their superiority over experiments with no model perturbations or with SPPT perturbations
- The time scale of AMPT perturbations in atmosphere and in soil affects the ensemble spread substantially but has rather small influence on CRPS, BS, and ROCA
- Probabilistic scores of precipitation forecast are not much affected by AMPT soil perturbations. Maybe this is related to the fact that the examined period was rather dry.

Further plans

With COSMO model:

- Investigate in more detail the effect of the time scale of soil perturbations on probabilistic scores
- Examine AMPT perturbations for other seasons (but IC&BC perturbations are still missing)

With ICON model:

- Introduce AMPT to ICON model
- Continue experiments with ICON-based EPSs

Thank you for your attention !