value of ecmwf forecasts for predicting spatially distributed soil moisture

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Deltares
Enabling Delta Life

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introduction

Rainfall is the most important input variable for hydrological models. The numerical weather prediction model (NWP) of ECMWF produces twice a day an ensemble of 50 realistions 6 hour accumulated forecasts of rainfall [1].

research questions:
- how accurate are the rainfall forecasts?
- does accuracy of rainfall forecasts depend on lead time?
- using the rainfall forecasts, how well is spatially variable soil moisture predicted?

study area

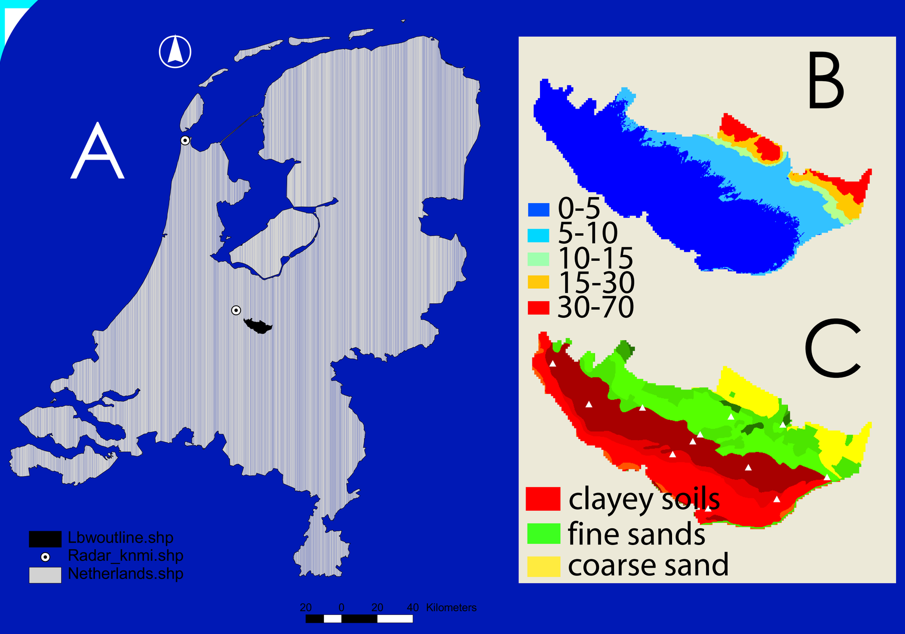

Fig 1: Location of study area within the Netherlands (A); surface elevation of study area (B) and soil types of study area with location of raingauges (C)

The study area 70 (km2) is in the middle of the Netherlands (Fig 1A).

The area lies on the transition of an ice-pushed ridge and a river plane. The elevation is between 0 - 70 meter +MSL (Fig 1B).

On the higher elevation coarse sand is found which changes to finer sand and clayley soils with lower elevation. Within the area we placed 15 raingauges (Fig 1C)

method

Rainfall accuracy:
We accumulated the ecmwf rainfall forecasts to daily values (06 UTC - 06 UTC), resulting in 9 forecasts of daily rainfall. We compared these with measured rainfall (08 UTC - 08 UTC). This means that the first lead time (lt 1) is 6 hours ahead, the last (lt 9) is 8 days and 6 hours.

Soil moisture accuracy:
Each member of the ensemble rainfall forecasts is used as input for the hydrological model. Per day we get 50 realisations of soil moisture up to lead time 9 (lt9).
For the next day initial values of the model were reset using the 'true' run (model forced with rainfall fields estimated with both radar and raingauges [2]) .
Results of forecasted soil moisture are compared to the 'true' run.

hydrological model

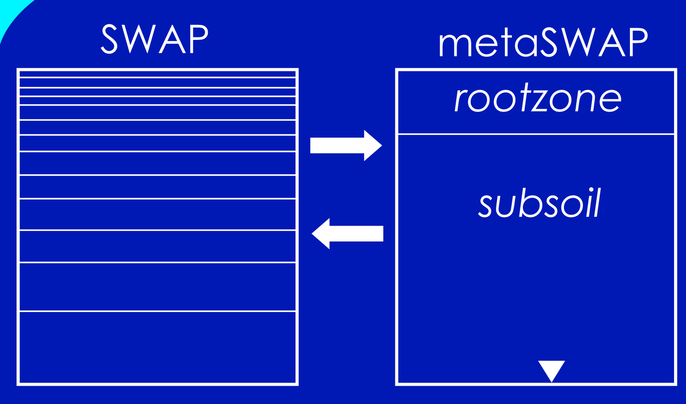

Fig 2: Schematic view of the unsaturated zone model metaSWAP; it uses a lookup table of almost 3 million stationary SWAP runs [3].

unsatured zone:
schematized with 2 layers, flow based on Richards' equation, using stationary runs of SWAP [Fig 2].

saturated zone:
metaSWAP is coupled with MODFLOW [5], which is schematized into 7 aquifers, seperated by aquitards.

Spatial resolution:
- 25 m x 25 m : unsaturated zone
- 100 m x 100 m : groundwater model

Simulation period: 1 March 2006 - 1 Nov 2006

Results

accuracy rainfall

measured time series | time series of forecasts

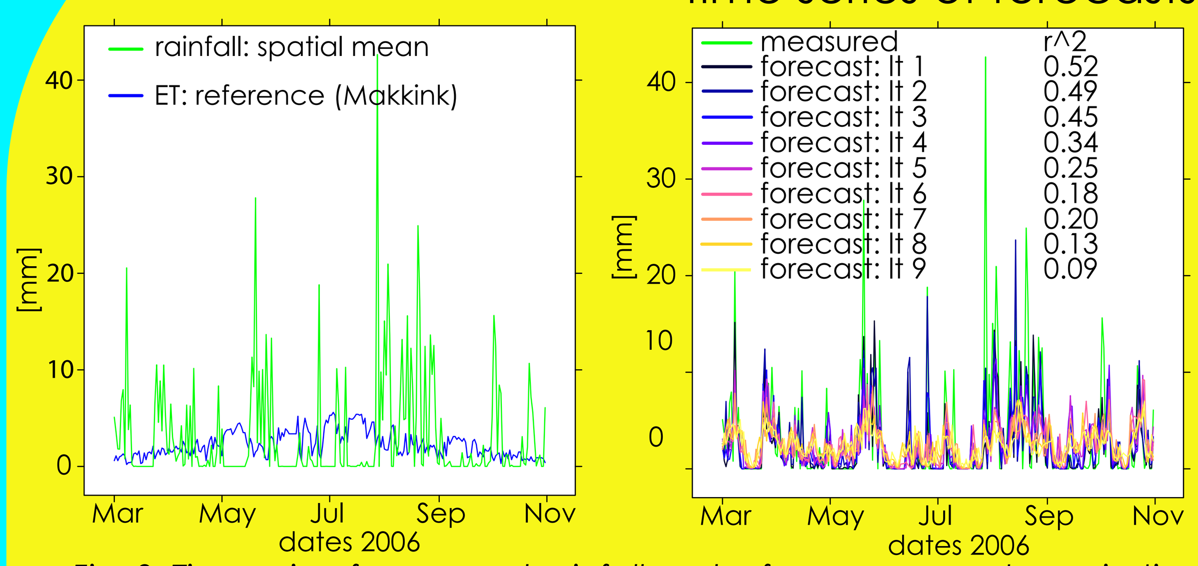

Fig. 3: Timeserie of measured rainfall and reference evapotranspiration (left) and timeserie of mean of ensemble forecasts for different lead times (right).

Timeseries of measured rainfall (spatial mean within study area) and reference evapotranspiration [Fig. 3, left]. Timeseries of mean of ensemble rain forecasts for each lead time and their correlation with the measured rainfall timeserie [Fig 3, right]

rainfall climatology

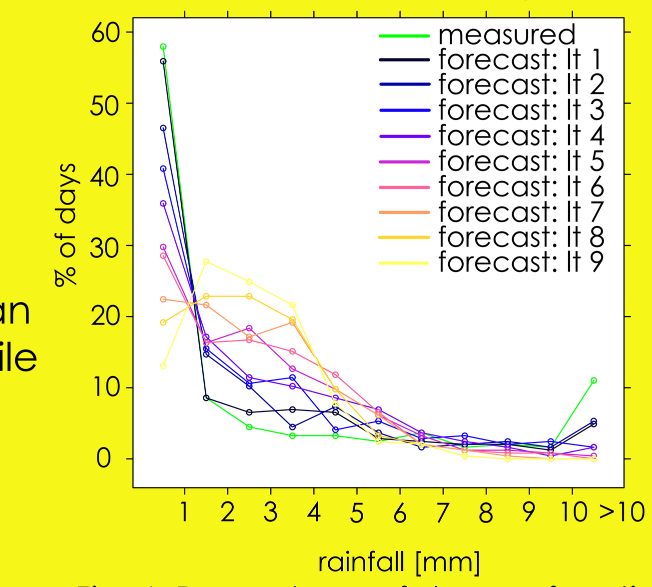

Fig. 4: Percentage of days as function of rainfall amount. Measured is the spatial mean of study area, forecasts are mean of the ensemble.

Measured rainfall shows a bimodal distribution; most of the days between 0-1 mm fell within the study area, followed by >10 mm. The number of these events is underestimated by the mean of the ensemble forecasts while the number of events with medium rainfall (1-7 mm) are overestimated [Fig. 4].

statistics medley

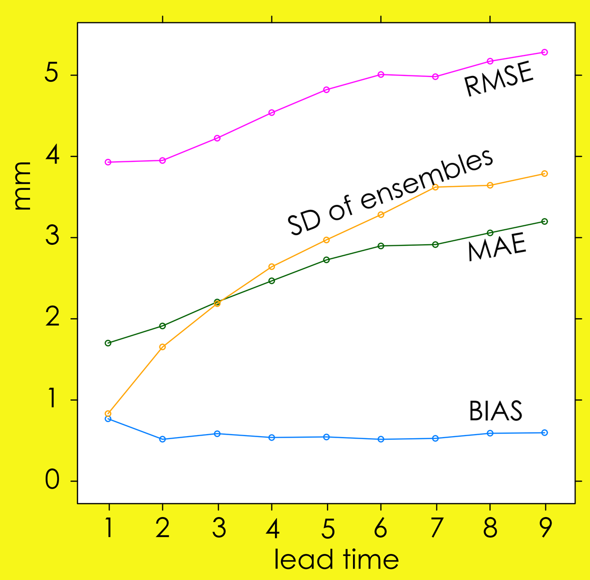

Fig. 5: error statistics and ensemble variation.

MAE and RMSE (mean of the ensemble forecasts against spatial mean of study area) increase with lead time. Bias is however ~constant with lead time. This means that in the bias under- and overestimations are compensated. The standard deviation (temporal mean) of the ensembles, which is a measure for the uncertainty, increases with lead time [Fig. 5]

accuracy soil moisture

statistics medley

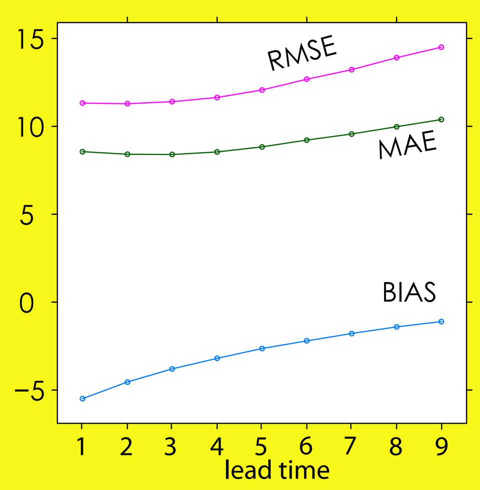

Fig. 6: Error statistics of spatial mean storage rootzone.

spatial bias of Sr

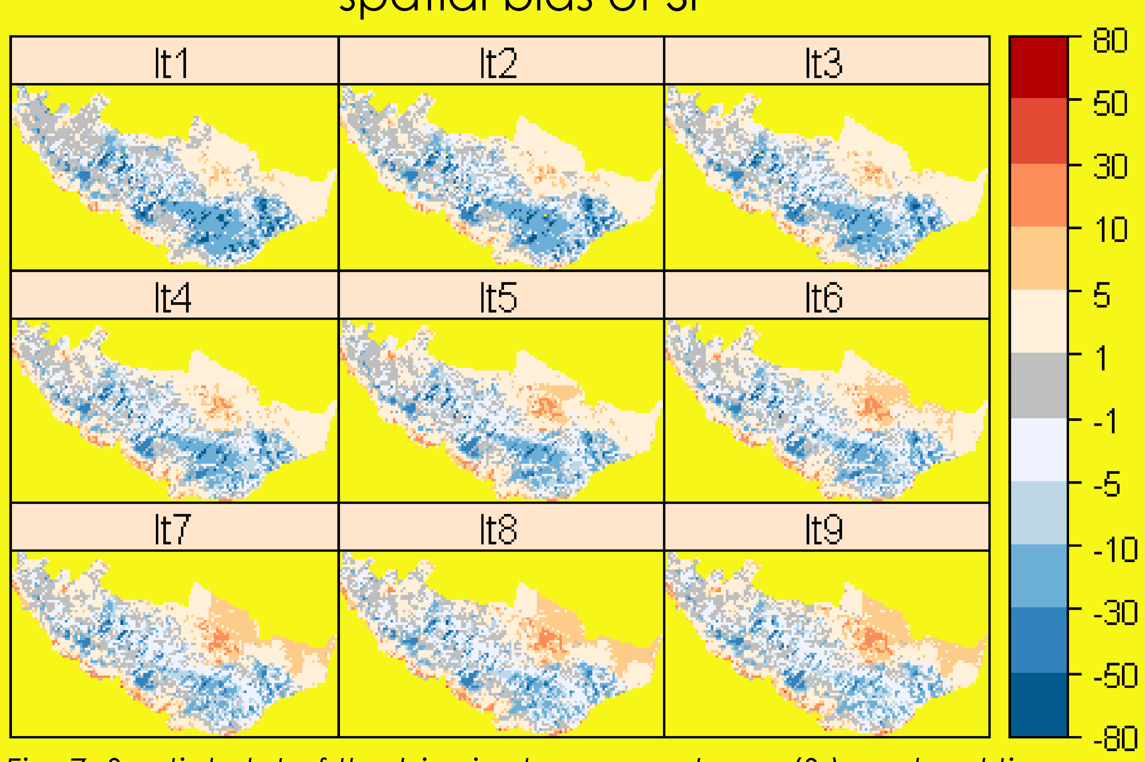

Fig. 7: Spatial plot of the bias in storage rootzone (Sr) per lead time.

Spatial mean bias in storage rootzone is negative (mean of the Sr ensembles against the 'true' run) and becomes less negative with increasing lead time (-5 - 0 mm).
Spatial mean of the mean absolute error (MAE) and root mean squared error (RMSE) increases with lead time (8 - 10 mm resp. 11 - 15 mm) [Fig. 6].

The spatial variability of the bias and MAE [Fig. 7 and 8] can probably explained by the heterogeneity in the area: the higher areas with coarse sand and forest are not sensitive to short term rainfall variability the low areas which are allready very wet are also not sensitive to rainfall variability as they will remain wet.

spatial MAE of Sr

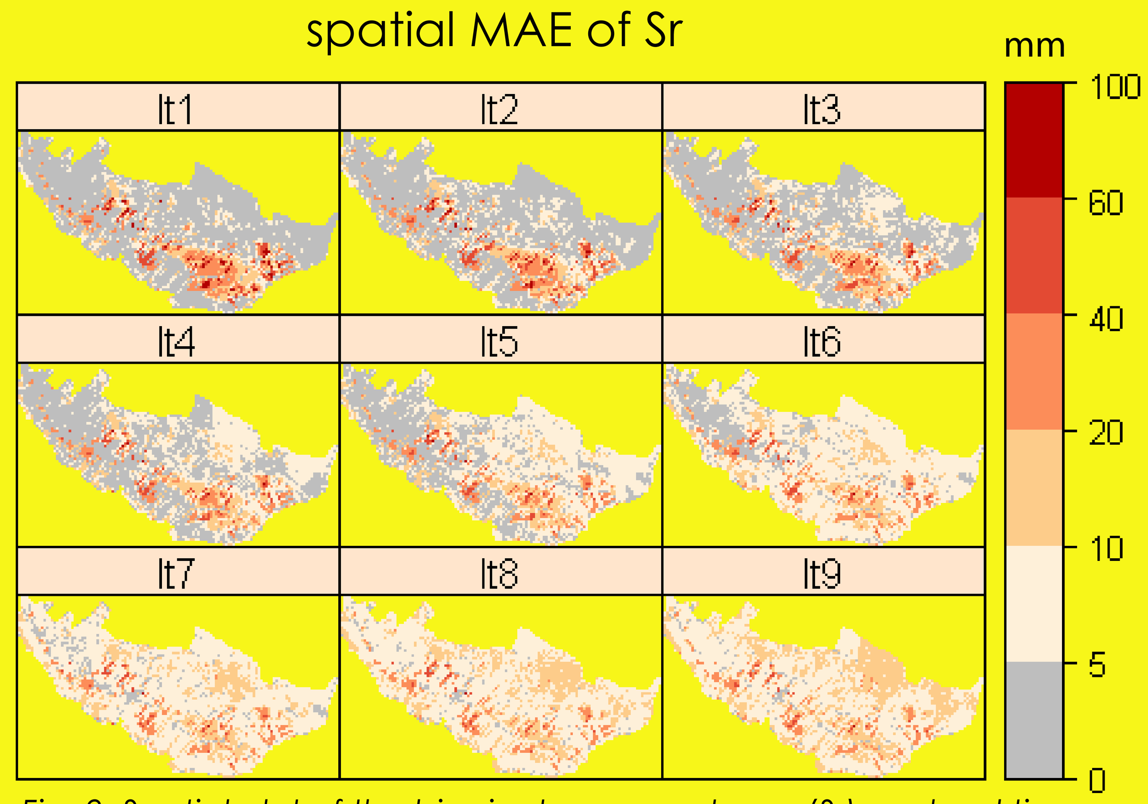

Fig. 8: Spatial plot of the bias in storage rootzone (Sr) per lead time.

Conclusions

- ★ Accuracy of rainfall forecasts decreases with lead time (r^2 from ~ 0.5 - 0.1)
- ★ Uncertainty of rainfall forecasts increases with lead time (~ 1 - 4 mm standard error)
- ★ Very low (0 - 1 mm) and very high (>10 mm) rainfall amounts are underestimated by the rainfall forecasts, while rainfall amounts between 1 - 7 mm are overestimated by the rainfall forecasts. This effect increases with lead time.
- ★ RMSE and MAE of rainfall forecasts increase with lead time, while bias remains constant
- ★ spatial mean RMSE and MAE of soil moisture increase with lead time the spatial mean bias becomes less negative.
- ★ The bias and MAE show clearly spatial variability within the study area caused by heterogeneity.

Literature

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Acknowledgements

The authors would like to thank the Royal Netherlands Meteorological Institute (KNMI), in particular Iwan Holleman, Kees Kok, Robert Mureau and Daan Vogelezang for their help and for providing us their data.