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SPACE
SPATIAL CALIBRATION IN HYDROLOGICAL MODELING

Evaluating the spatial performance of hydrological models using remote sensing data

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New opportunities in satellite and airborne remote sensing
Monday 11 December 2017

Geological Survey of Denmark and Greenland
Danish Ministry of Climate, Energy and Building

Outline of the presentation

- Introduction
- Methods
- Results
- Conclusions

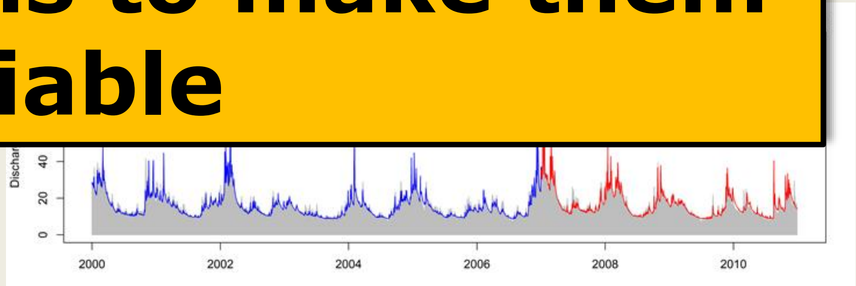
http://visibleearth.nasa.gov/view.php?id=71880

Evaluating the spatial performance of hydrological models using remote sensing data

Why is it important?

Hydrological model outputs are used by decision makers.

There is a need to evaluate the spatial patterns to make them reliable



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Traditional calibration techniques neglect the spatial component by being calibrated at discharge stations.

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Our main hypothesis

Evapotranspiration patterns obtained using both methods should be similar.

If not, can we make them more similar?

Methods

ET from DK-model

ET from Satellite

ET pattern evaluation

Modify DK model inputs

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What is the Dk-model?

Is the National water resources model of Denmark and is distributed, coupled Ground Water-Surface Water model. Includes unsaturated zone, ET, river routing modules and runs on MIKE-SHE at 500m.

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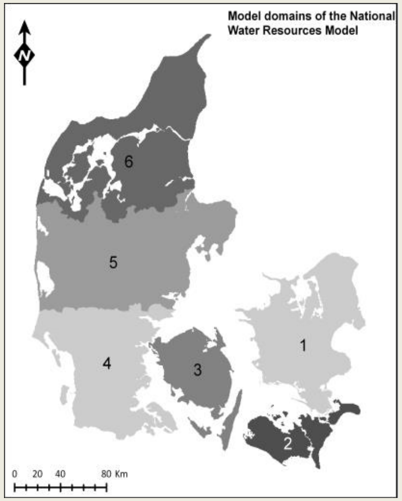
How is the model calibrated

Calibrated and validated against 191 discharge and around 17500 ground water head observations



(Taken from Stisen et al. 2012)

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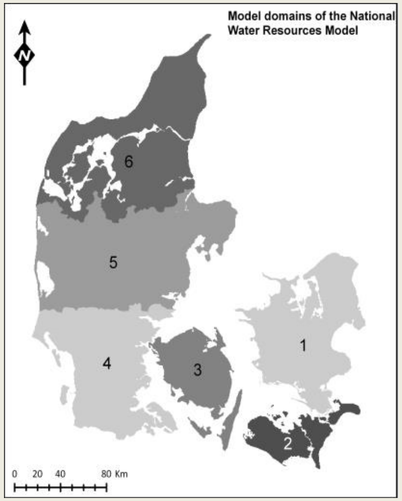
Why is the model important?

Different applications:

-Assessment of climatic change

- Water resources management within the EU Water framework directive

- Large scale nitrogen modeling



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Why satellite?

Remote sensing provides high spatial and temporal data of the earth surface. There are long time series of data records.

ET models have been developed and been validated

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The Two Source Energy Balance from Norman et al. 1995 was used to calculate the ET. (https://github.com/hectornieto/pyTSEB)

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Sensitivity analysis

A sensitivity analysis was conducted with PEST to evaluate the most sensitive parameters in the model.

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Results validations

Data from HOBE from 3 eddy covariance sites was used to ensure quality of the data.

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Map generation

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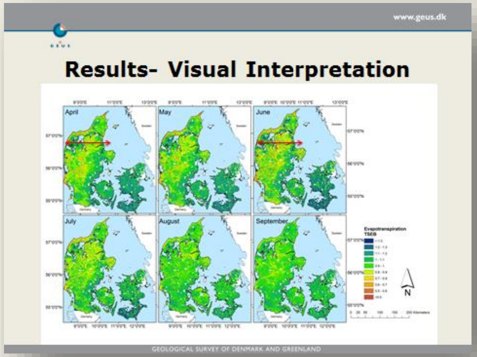
ET from Satellite

ET pattern evaluation

Modified DK model inputs

Map generation

Visual interpretation



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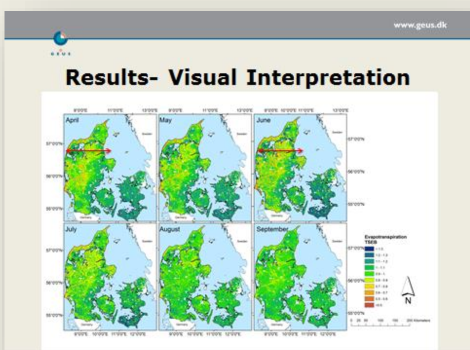
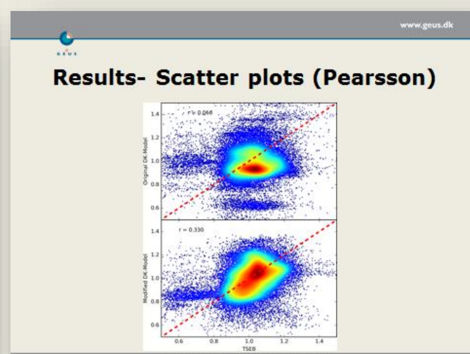
Scatterplots (r)





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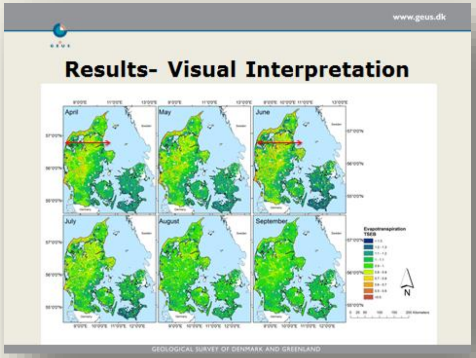
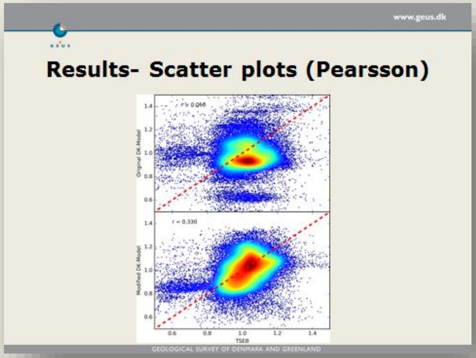
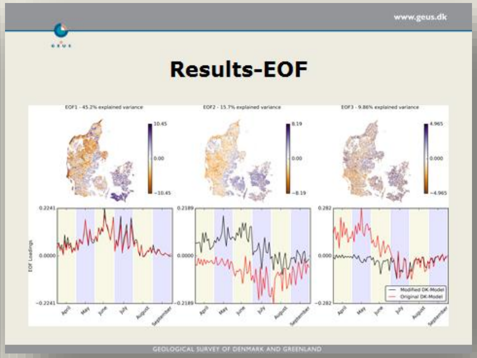
Empirical Orthogonal Functions (EOF)







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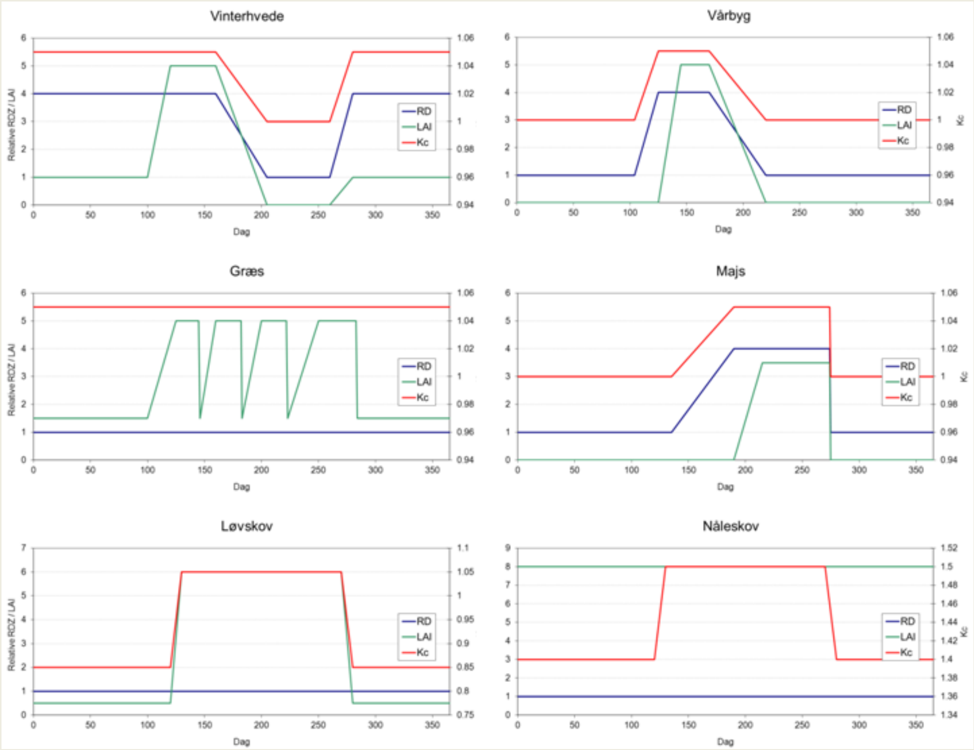
Original DK-model setup

Root depth, LAI and Kc changes in time and space based on the land cover type in the Dk-Model



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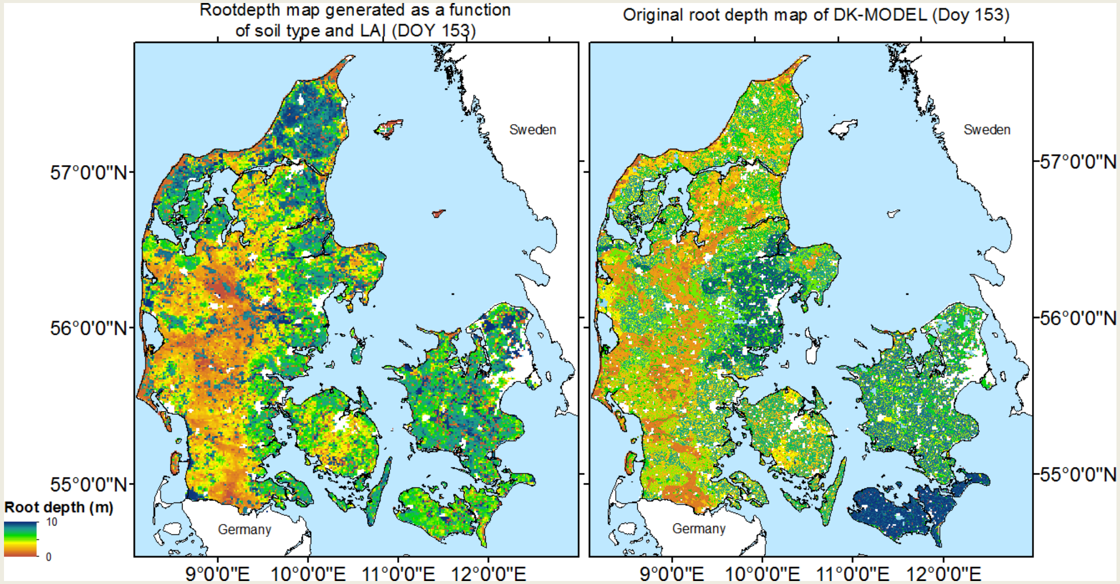
Root depth and Kc changes in time and space based on the land cover type in the Dk-Model

Root depth



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Root depth and Kc changes in time and space based on the land cover type in the Dk-Model

Root depth

New root depth maps based on NDVI and soil maps were created.

$\mathrm{RD_i}[m] = \mathrm{RD_{max}} \frac{\mathrm{NDVI_i}}{\mathrm{NDVI_{max}}}$ for forested areas,

and

$$\mathrm{RD_{(agri)i}}[m] = [(\alpha_{\mathrm{RD}} \cdot CF_i)+\beta_{\mathrm{RD}}] \cdot \frac{\mathrm{NDVI_i} - \mathrm{NDVI_{min}}}{\mathrm{NDVI_{max}} - \mathrm{NDVI_{min}}}$$

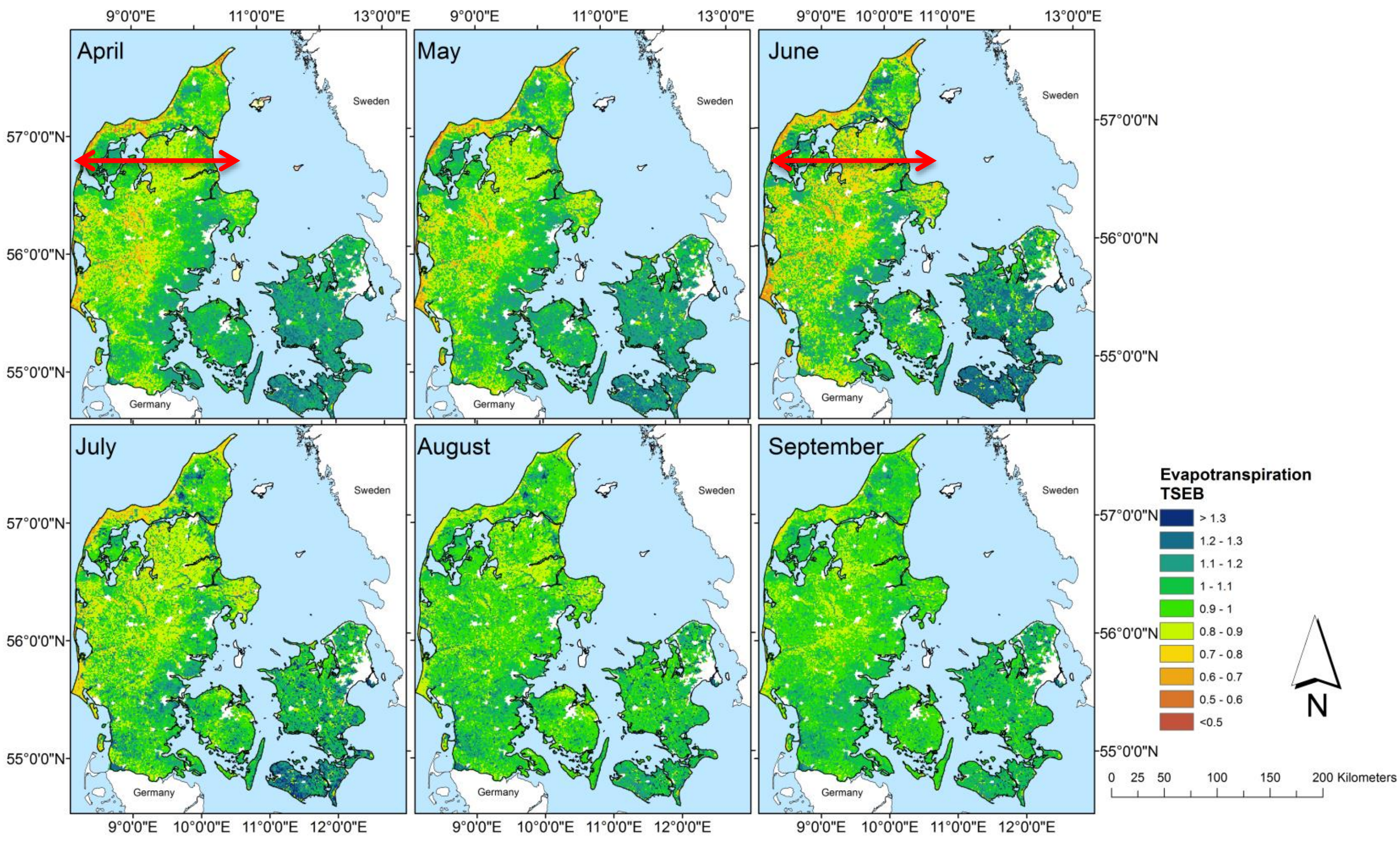
Crop Coefficient (Kc)

Kc is derived from remotely sensed LAI using:

$$\mathrm{Kc}[-] = \mathrm{Kc}_{c,min} + \left(\mathrm{Kc}_{c,max} - \mathrm{Kc}_{c,min}\right) \cdot \left(1 - \mathrm{e}^{(-0.7\cdot\mathrm{LAI})}\right) = 0.95 + 0.2 * (1 - \mathrm{e}^{(-0.7*\mathrm{LAI})})$$

Where the Kc_{min} and Kc_{max} are set to 0.95 and 1.15 respectively.

Results- TSEB ET



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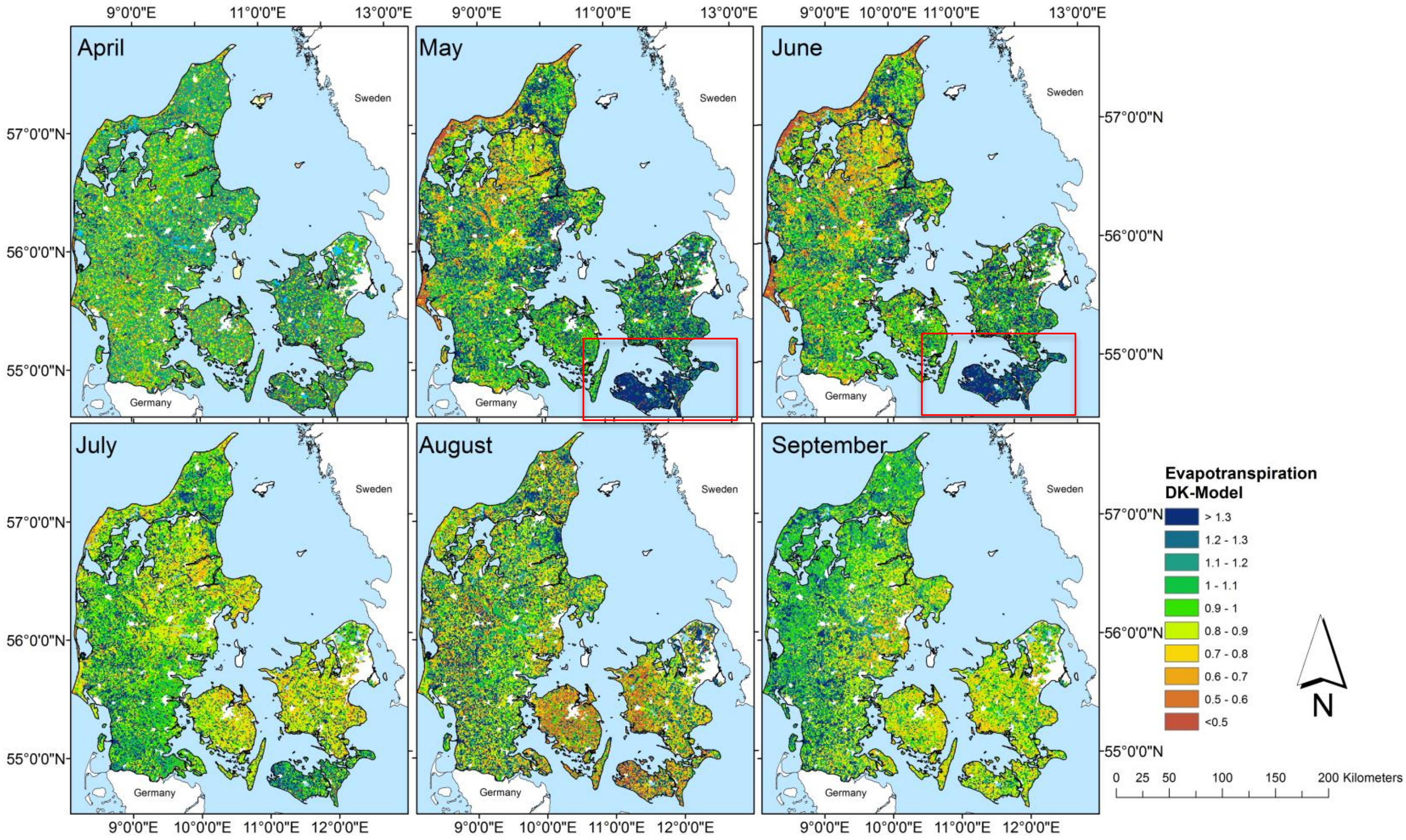
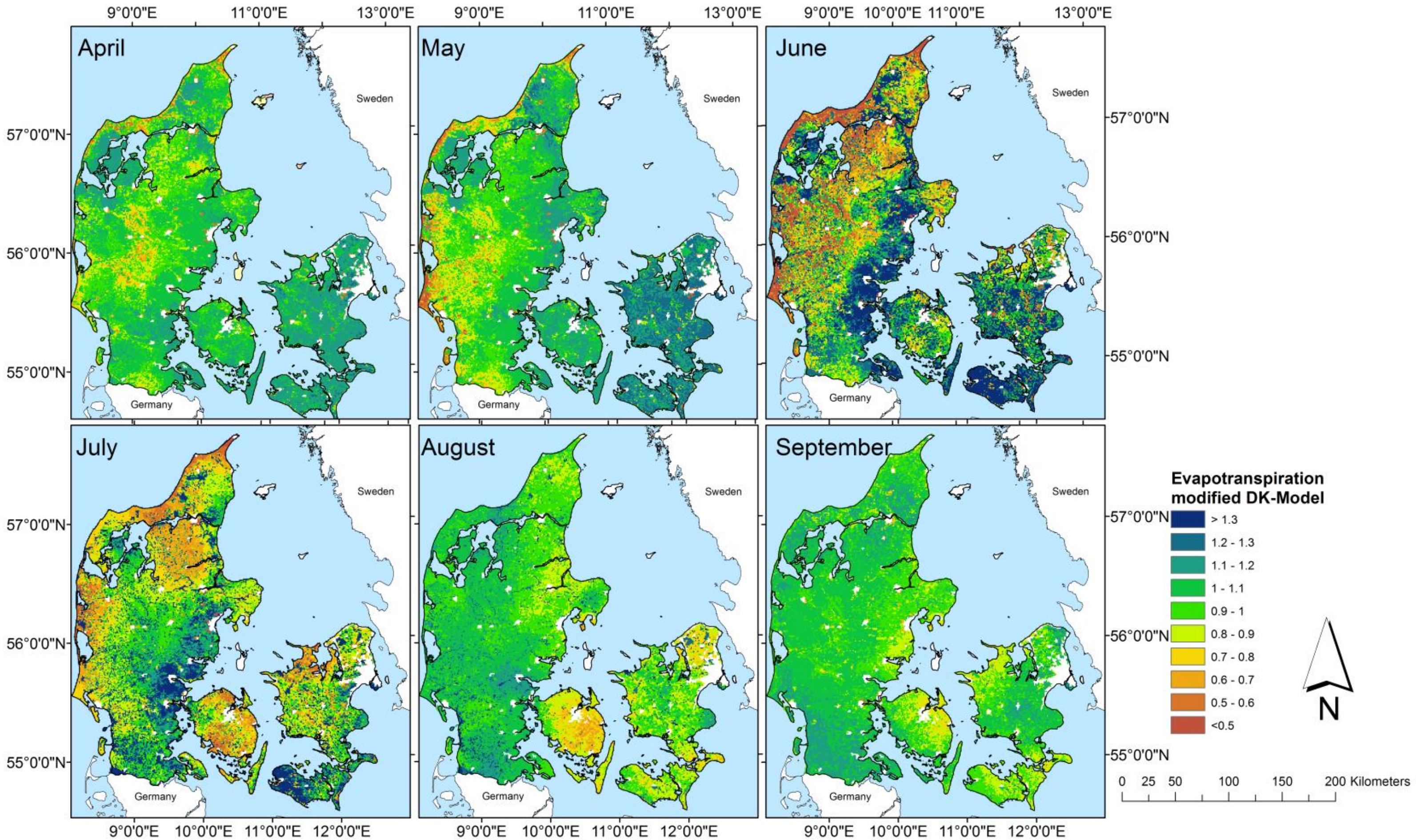
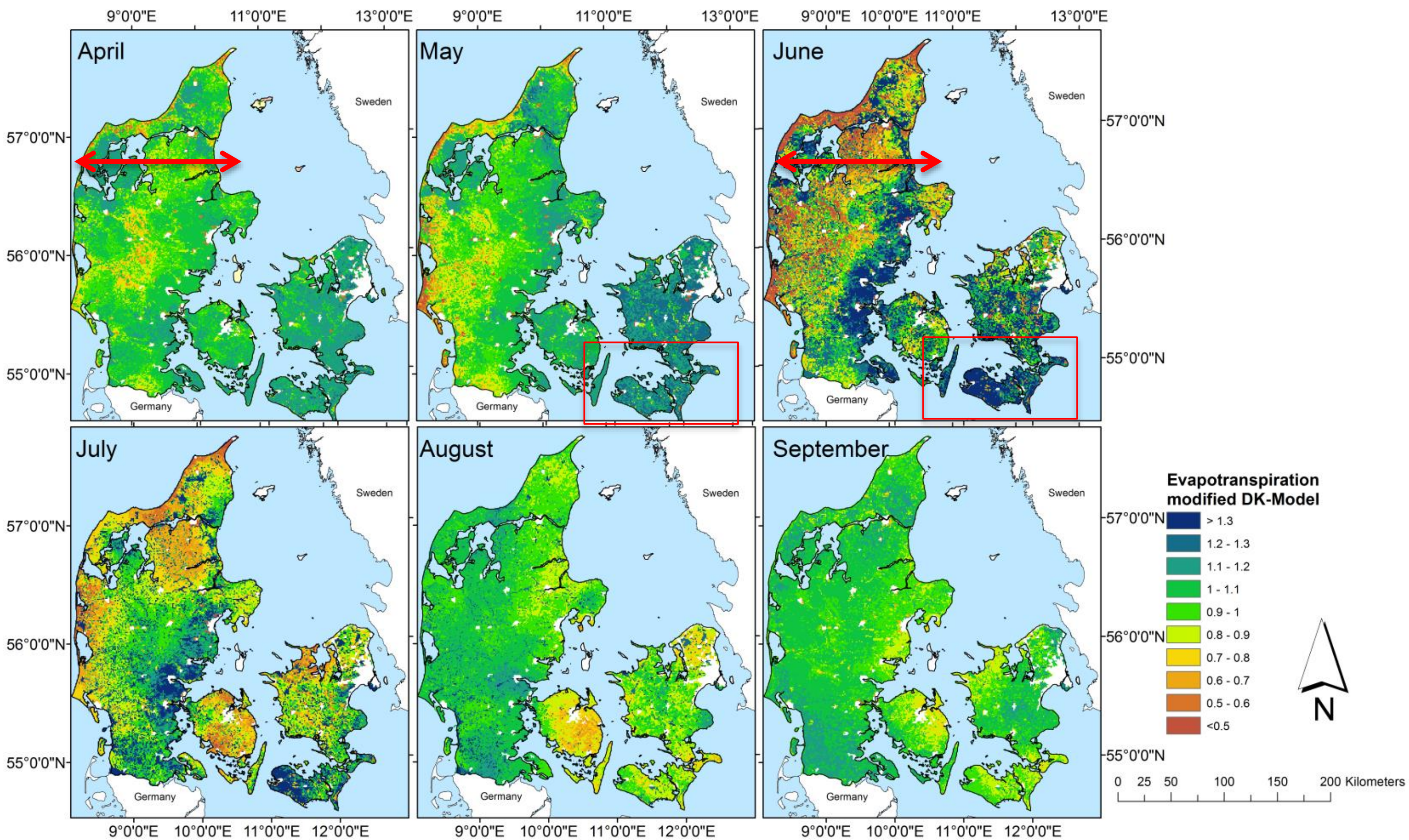
Results- DK model ET



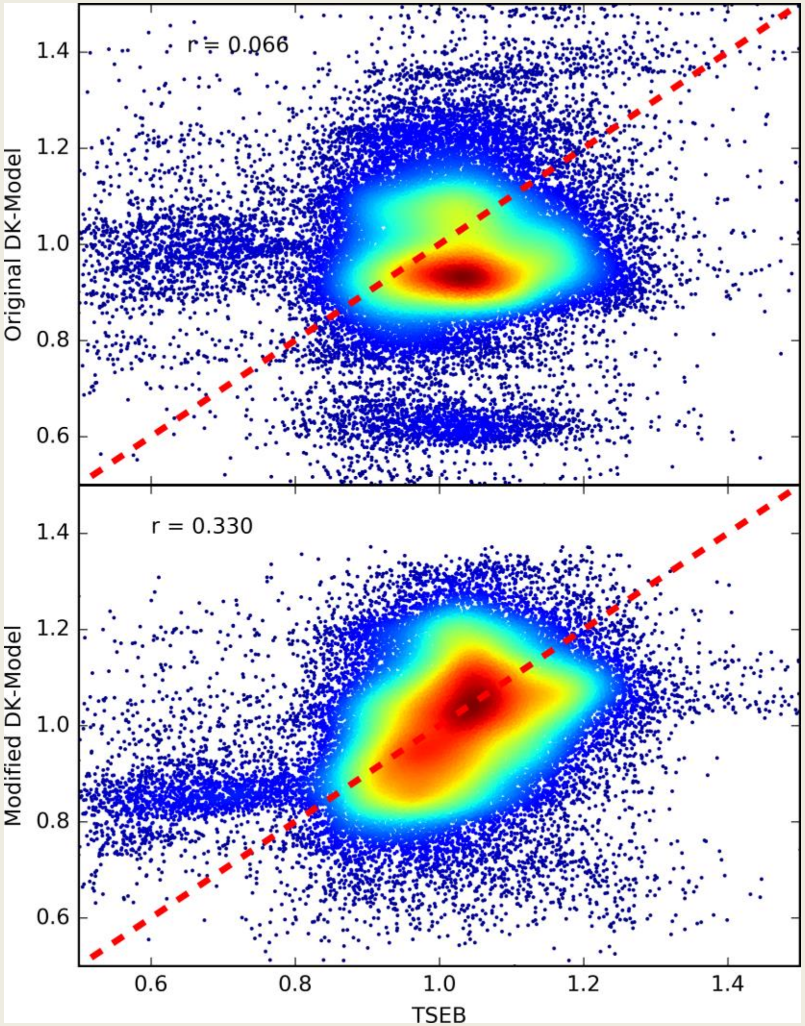
Results- Modified DK model ET



Results- Modified DK model ET



Results


r = 0.066
r = 0.330
Original DK-Model
Modified DK-Model
TSEB
0.6
0.8
1.0
1.2
1.4

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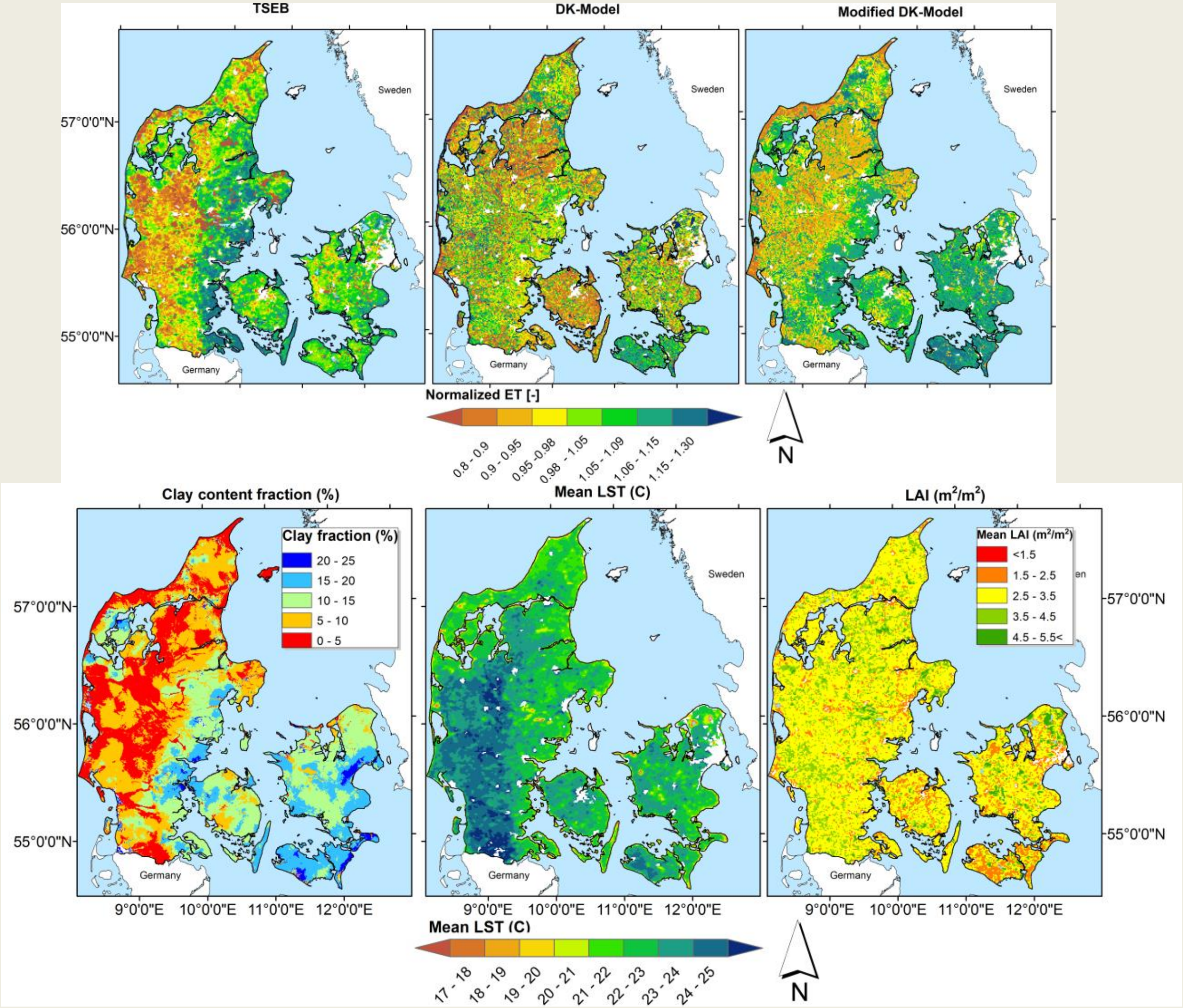
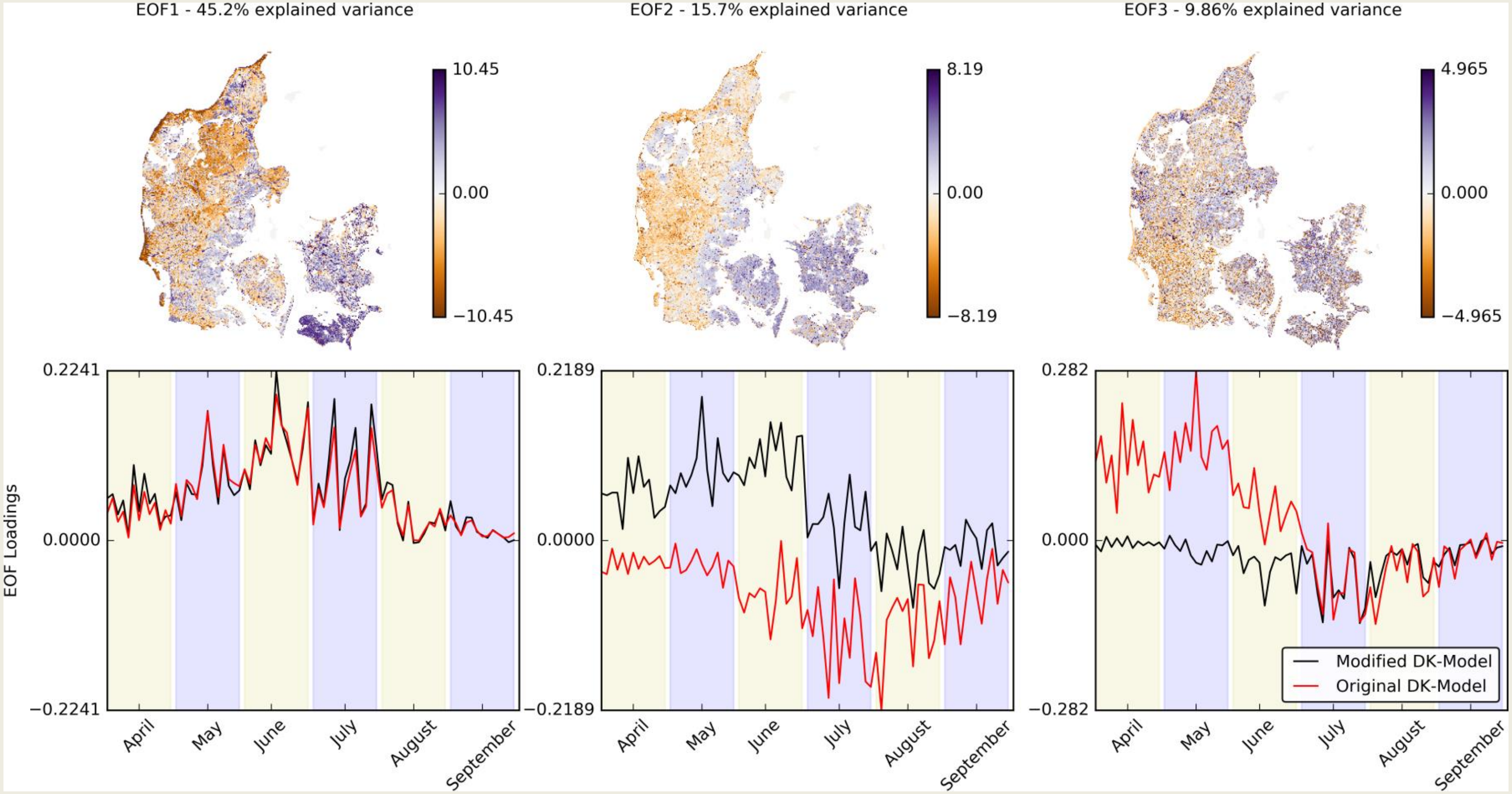
Results



Results-EOF


EOF1 - 45.2% explained variance
EOF2 - 15.7% explained variance
EOF3 - 9.86% explained variance
10.45
0.00
−10.45
8.19
0.00
−8.19
4.965
0.000
−4.965
0.2241
0.0000
−0.2241
0.2189
0.0000
−0.2189
0.282
0.000
−0.282
EOF Loadings
April
May
June
July
August
September
Modified DK-Model
Original DK-Model

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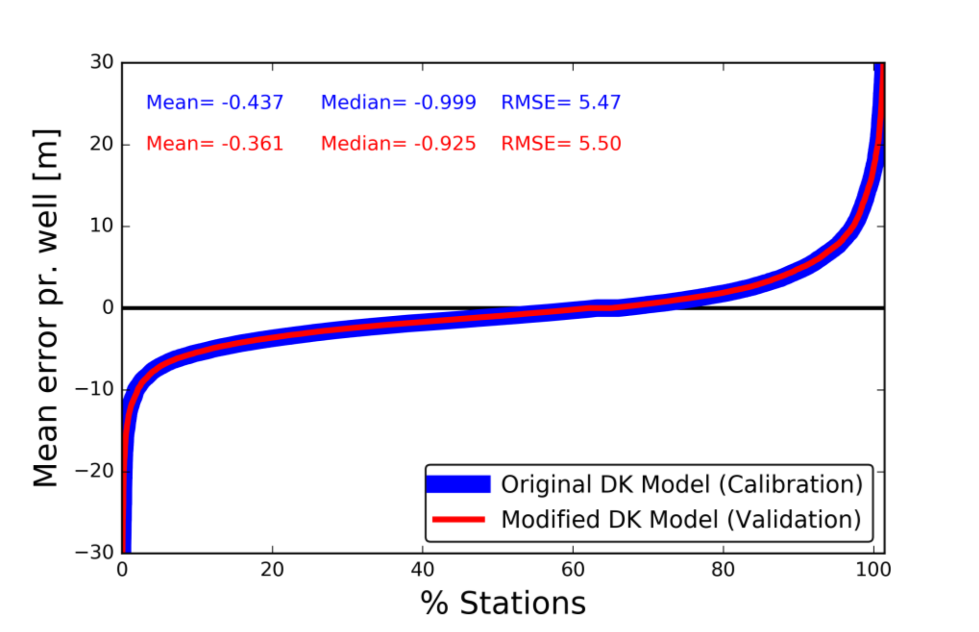
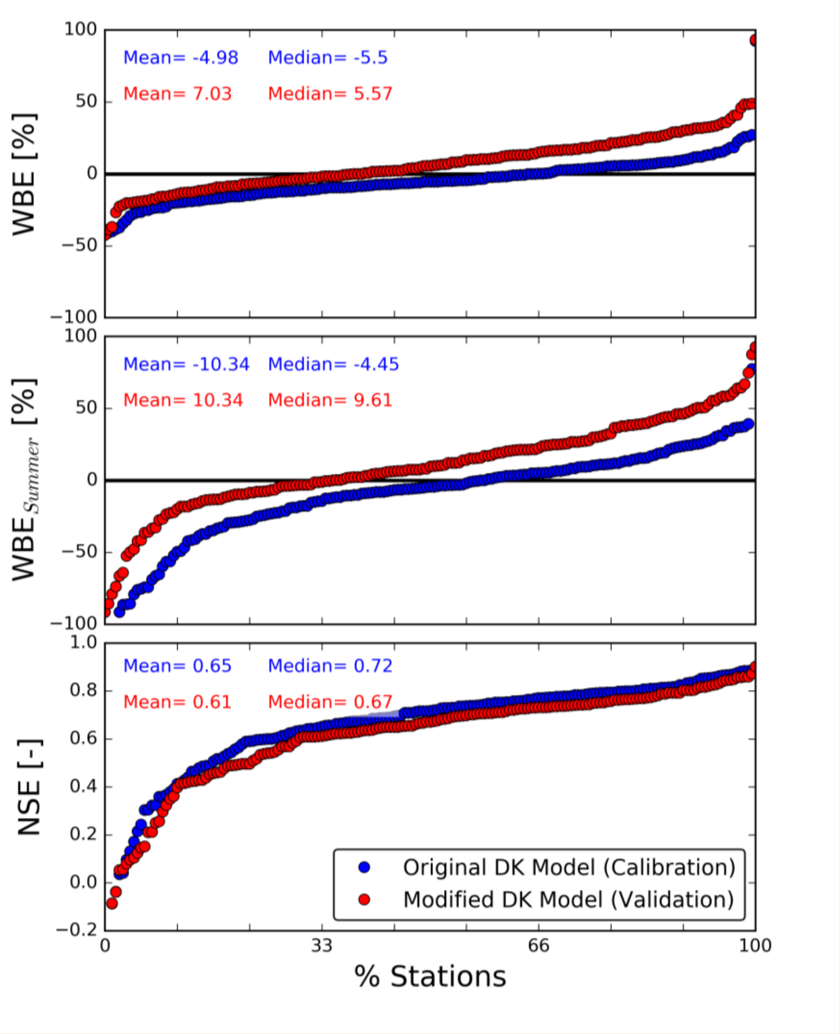
Results- Ground water heads and discharge





Can a hydrological model be calibrated spatially?

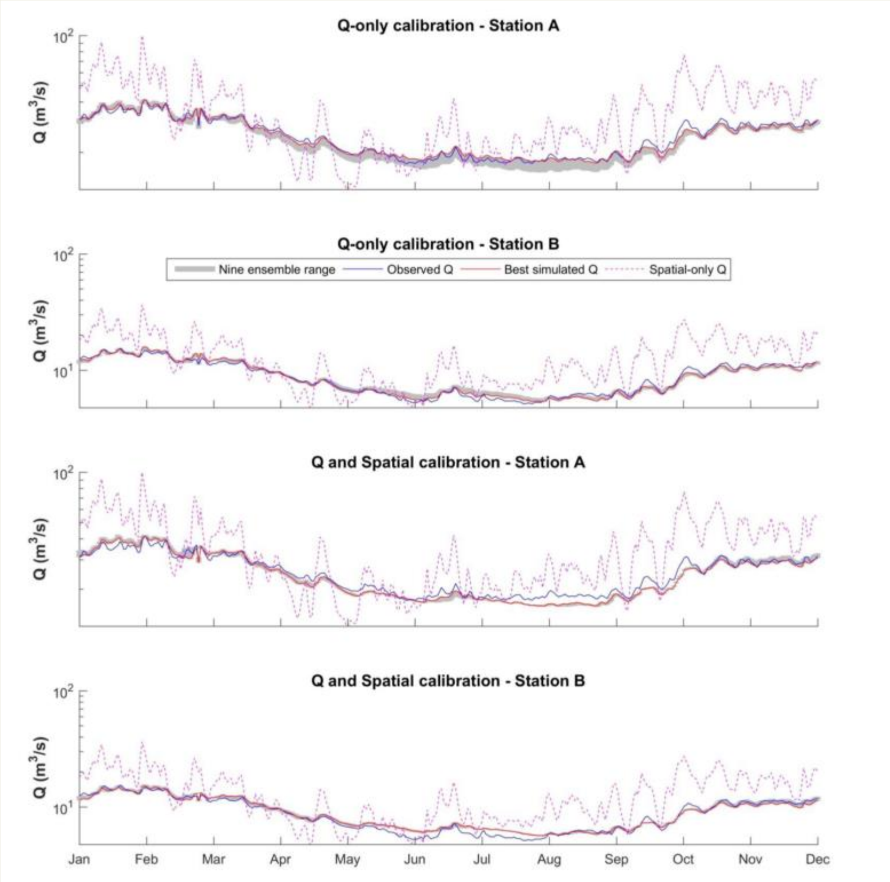
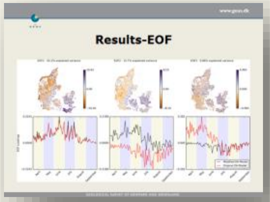


Figure 3. Average hydrograph of all years in the calibration period (2001-2008) to illustrate the ensemble of nine model calibrations with different seed numbers.

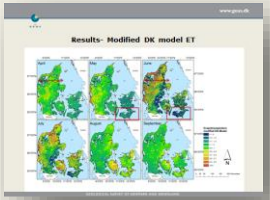
Demirel, M. C., Mai, J., Mendiguren, G., Koch, J., Samaniego, L., & Stisen, S. (2017). Combining satellite data and appropriate objective functions for improved spatial pattern performance of a distributed hydrologic model. *Hydrology and Earth System Sciences Discussions*, (October), 1–22. http://doi.org/10.5194/hess-2017-570

Conclusions and future perspectives

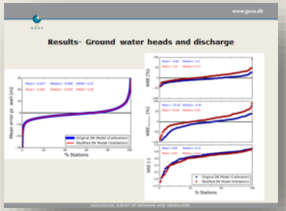
- The potential of remote sensing to evaluate the spatial patterns of hydrological models has been shown.



- Remote sensing derived variables added spatial information to the model and made the spatial patterns of both models more similar.



- The Dk-model was not recalibrated. We expect the validation with the discharge stations and ground water heads to improve when done.

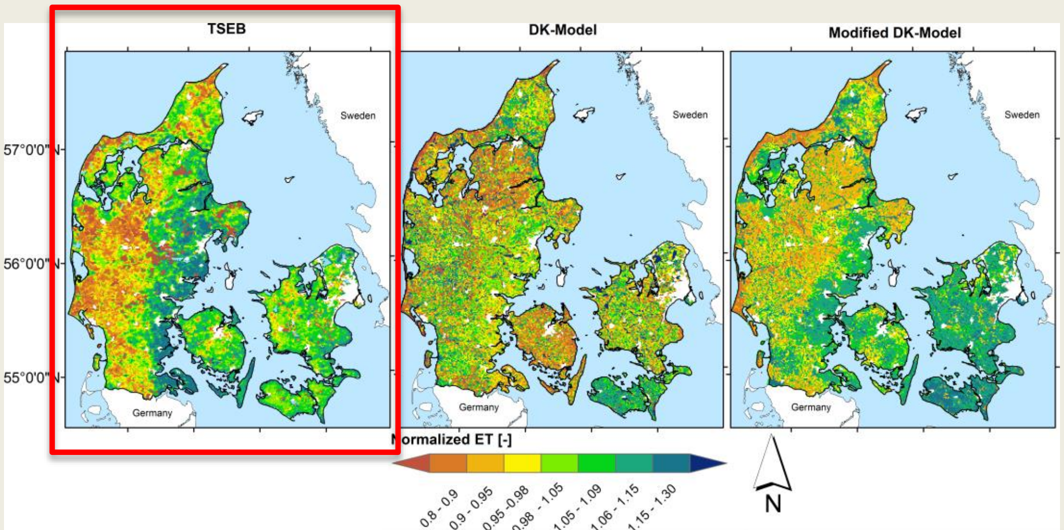


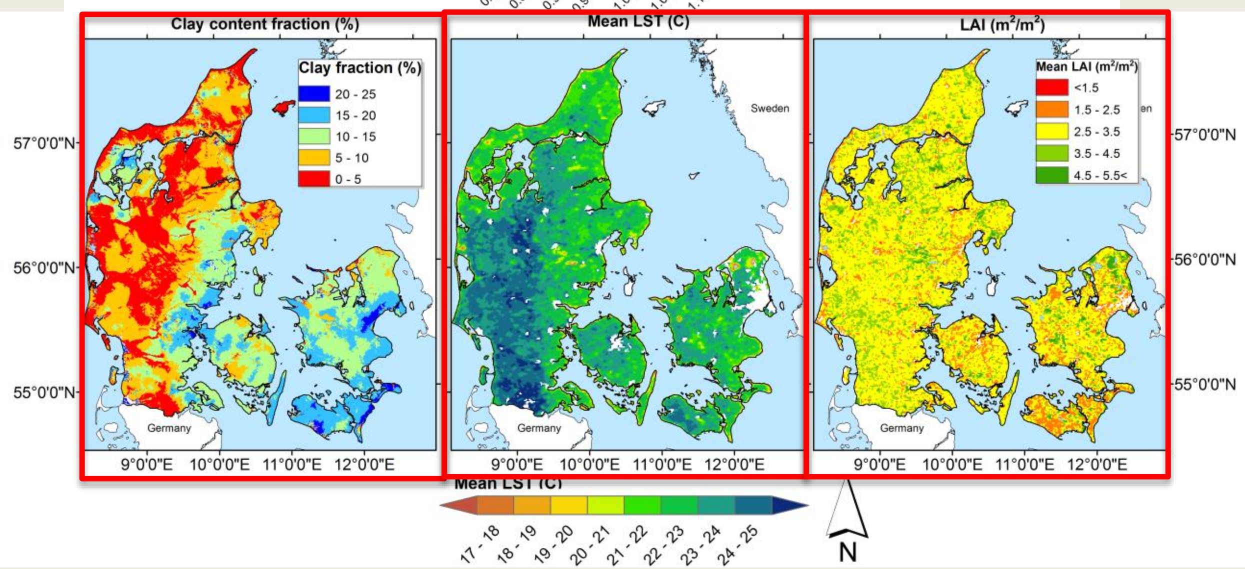
Thank you for your attention!

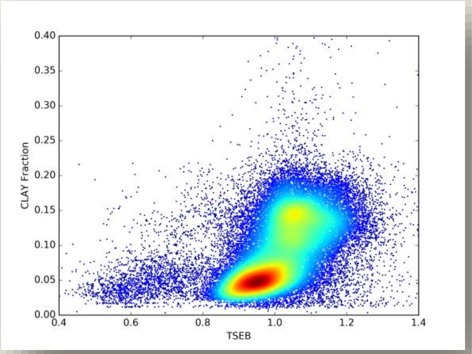
Questions?

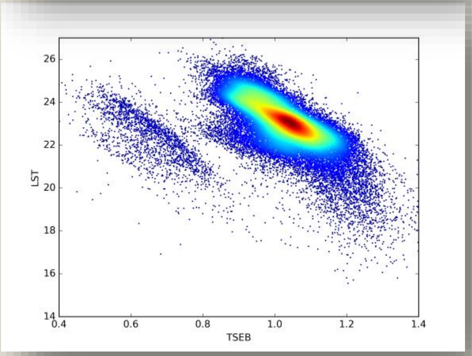
Mendiguren, G., Koch, J., & Stisen, S. (2017). Spatial pattern evaluation of a calibrated national hydrological model -- a remote-sensing-based diagnostic approach. *Hydrology and Earth System Sciences*, *21*(12), 5987–6005. http://doi.org/10.5194/hess-21-5987-2017

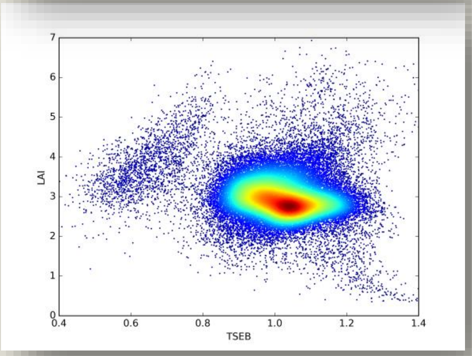
Results


TSEB
DK-Model
Modified DK-Model
57°0'0"N
56°0'0"N
55°0'0"N
Sweden
Germany
Normalized ET [-]
0.8 - 0.9
0.9 - 0.95
0.95 -0.98
0.98 - 1.05
1.05 - 1.09
1.06 - 1.15
1.15 - 1.30
N


Clay content fraction (%)
Clay fraction (%)
20 - 25
15 - 20
10 - 15
5 - 10
0 - 5
Mean LST (C)
LAI (m²/m²)
Mean LAI (m²/m²)
<1.5
1.5 - 2.5
2.5 - 3.5
3.5 - 4.5
4.5 - 5.5<
Sweden
Germany
57°0'0"N
56°0'0"N
55°0'0"N
9°0'0"E
10°0'0"E
11°0'0"E
12°0'0"E
Mean LST (C)
17 - 18
18 - 19
19 - 20
20 - 21
21 - 22
22 - 23
23 - 24
24 - 25
N


CLAY Fraction
TSEB


LST
TSEB


LAI
TSEB