



Modelling the vehicle bearing capacity for winter operations over frozen soil

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Climate and Land Surface Processes,
Lillehammer, 7-9 September

Why is the vehicle bearing capacity important for the armed forces?

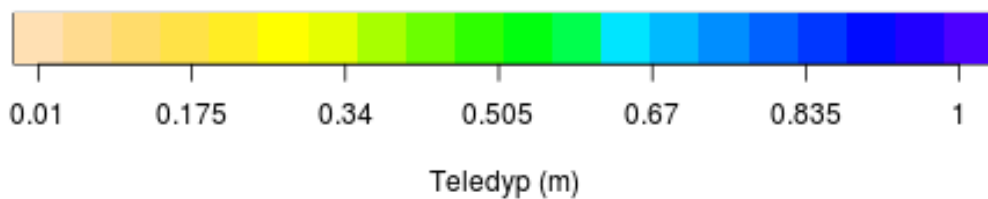
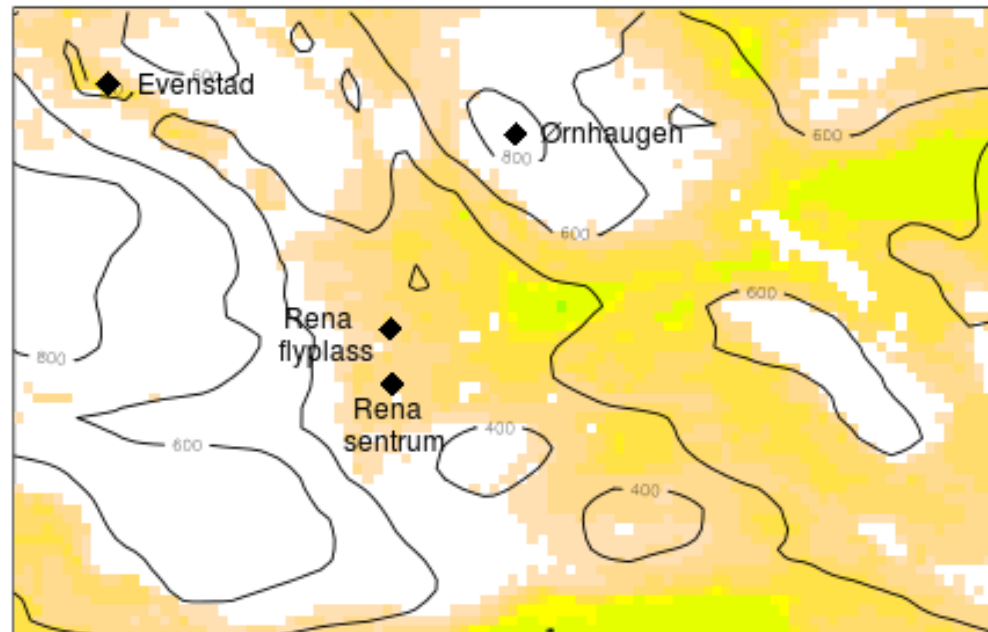
- Safety
- Damages to nature (cost)
- Operations/tactical maneuvers/optimal routes

Why is this challenging?

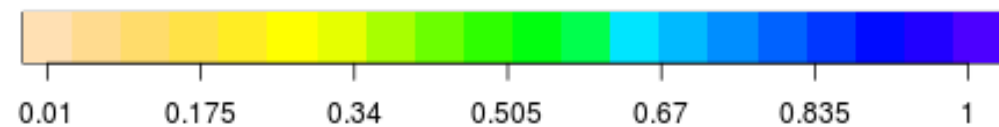
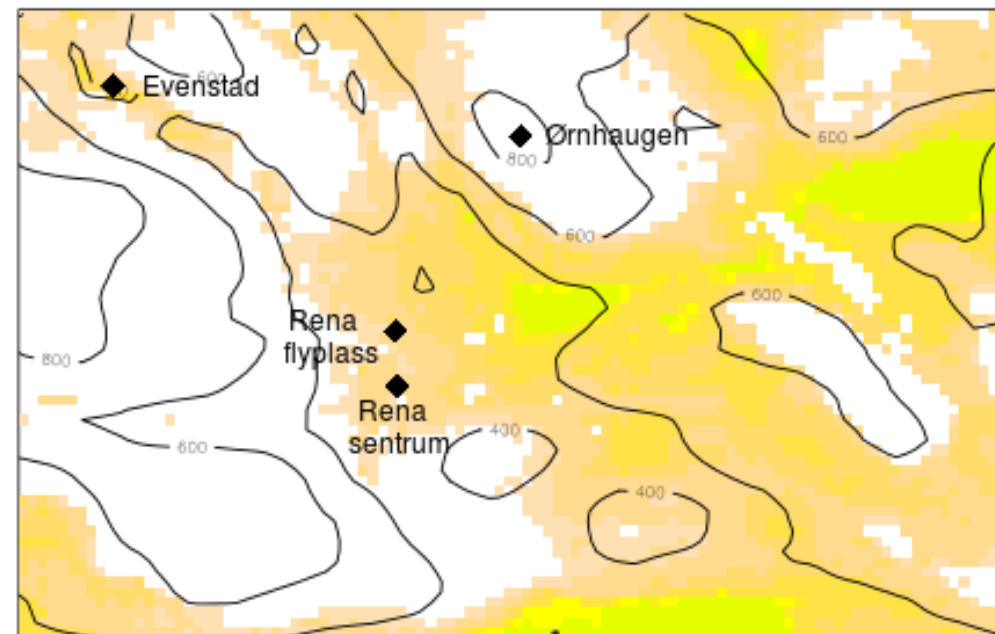
- Horizontal heterogeneities
- Vertical heterogeneities
- (Limited number of) local measurements
- Predictions versus current state
- Time consuming and need for dedicated resources

SURFEX forecast frost depth Rena

Rena 12. desember 18 UTC-01

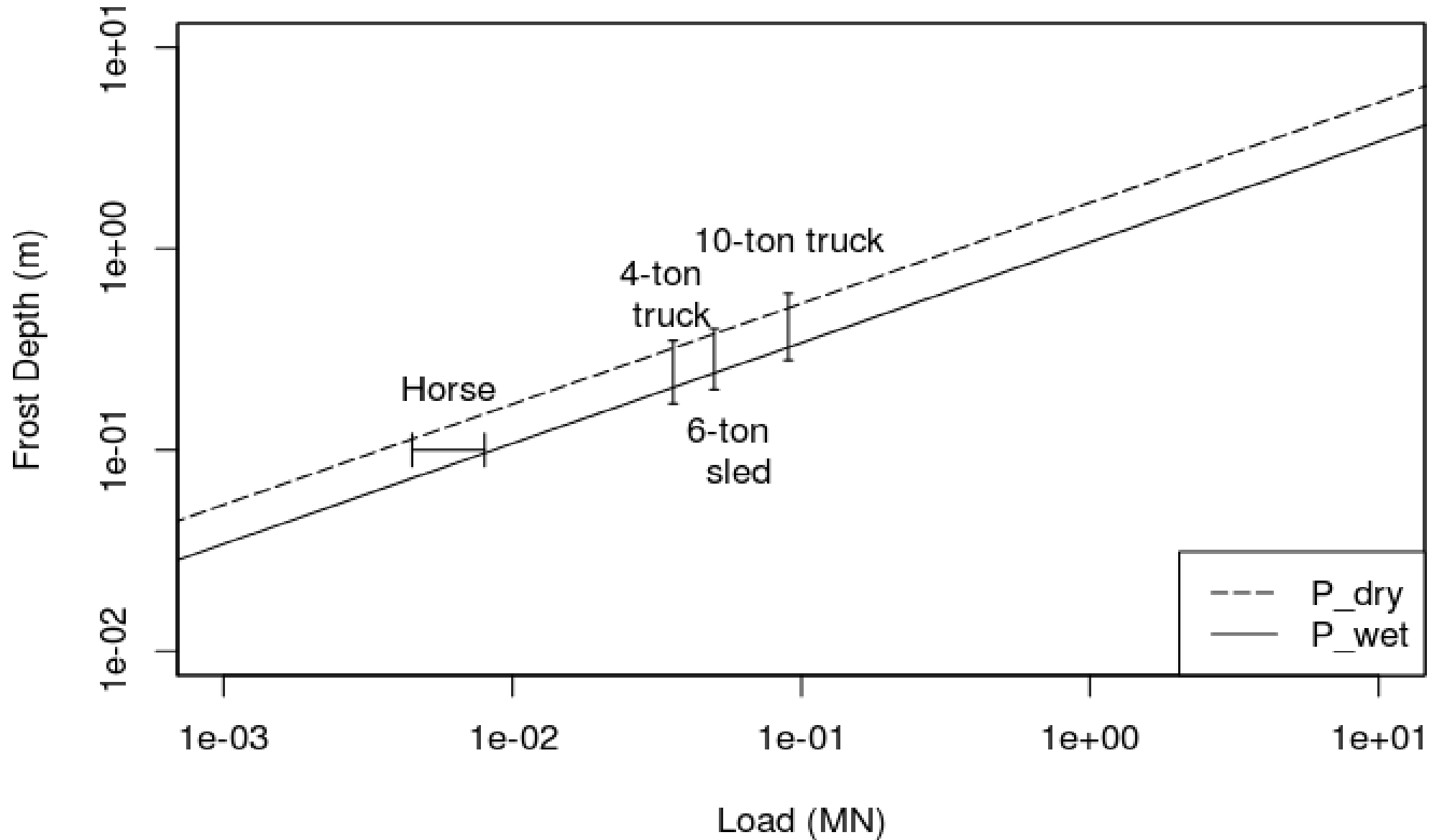


Rena 12. desember 18 UTC-30



Index of bearing capacity of frozen
ground

Proposed relationships for bearing capacity of frozen ground.



Bearing capacity $P=Cz^2$, where $C=0.35$ dry soil and 0.86 for wet soil, and z is the frost depth. Shoop (1995) Can. Geotech. J. Vol. 32, 1995.

Frost depth is a prognostic variable in SURFEX: FLT_ISBA

Observations

TYNSET
KOPPANG
EVENSTAD BY

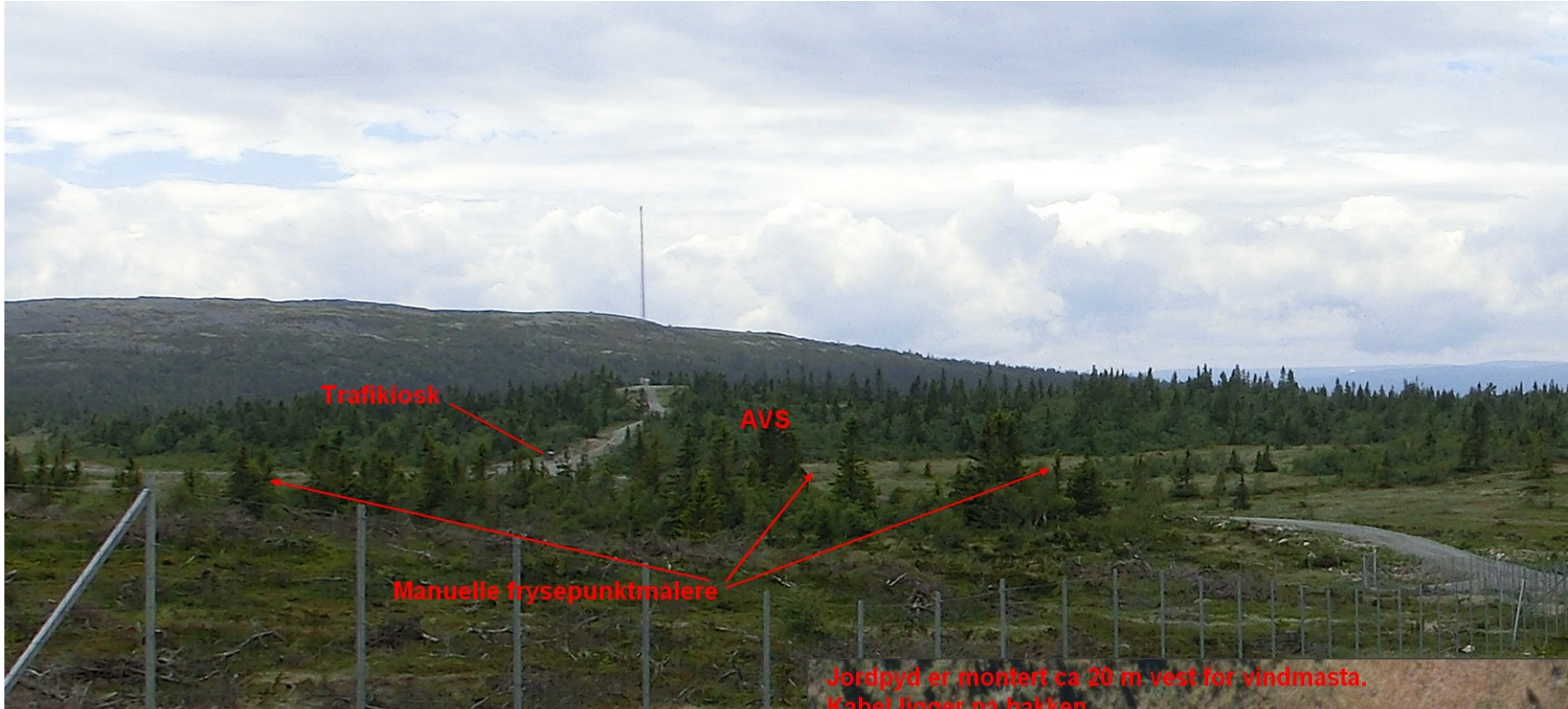


08140
EVENSTAD
257 moh

07420
RENA ØRN.
870 moh

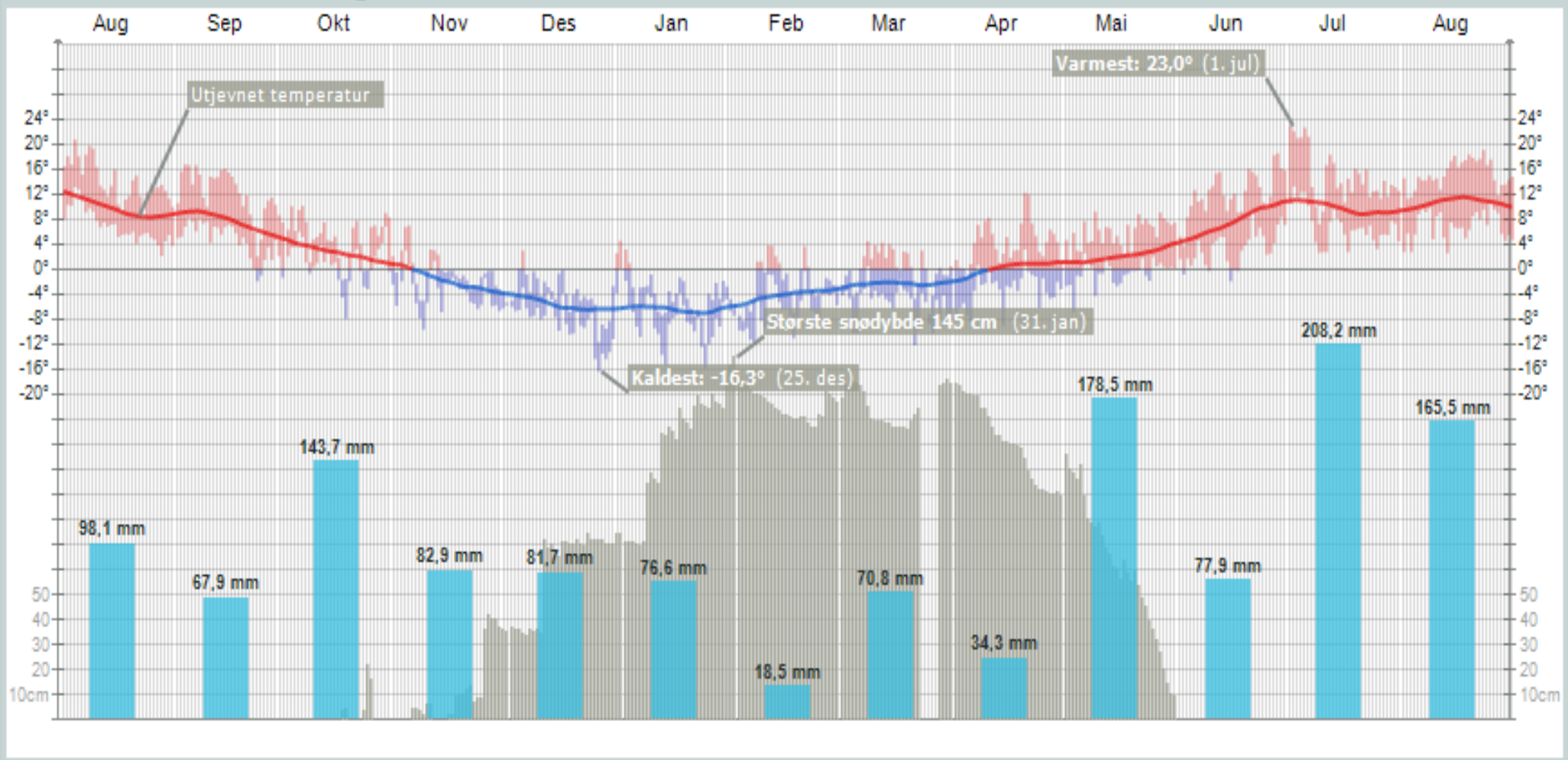
07950
RENA FLYR.
256 moh

RENA BY

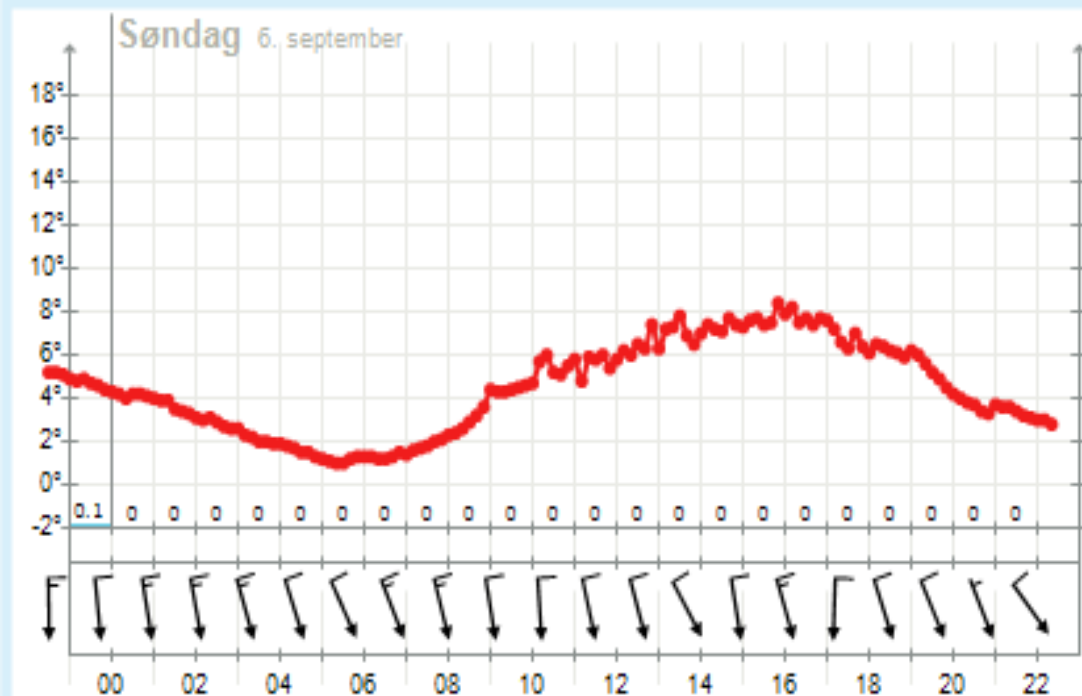


Rena-Ørnhaugen

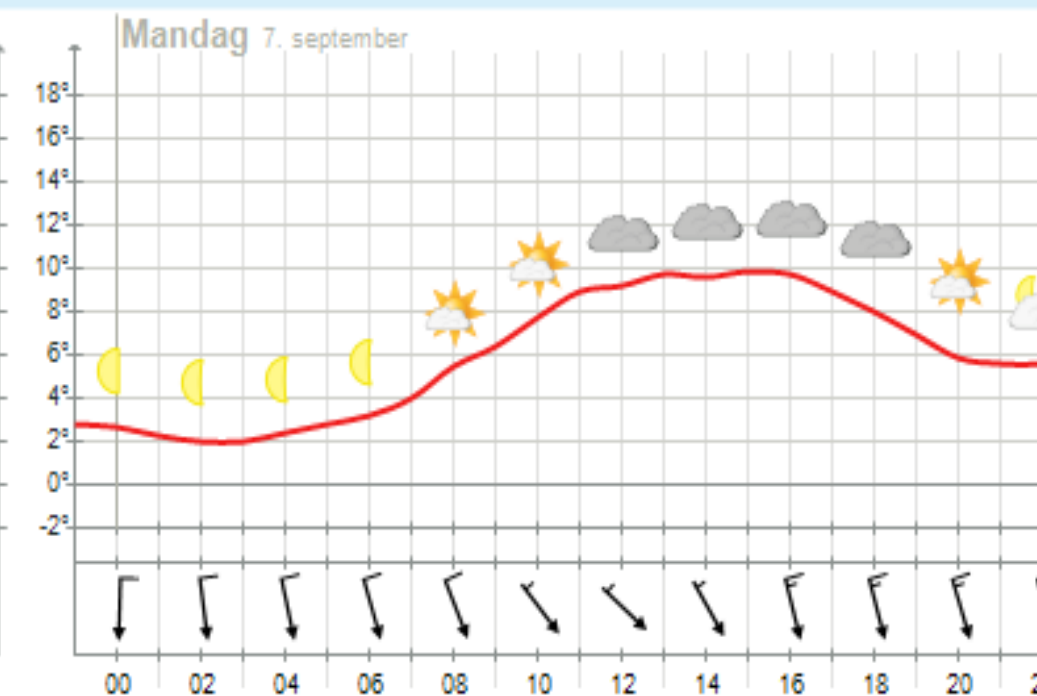
Værstatistikk for Rena øvingsfelt august 2014 – august 2015



Observasjoner fra Rena øvingsfelt målestasjon siste 24 timer **Meteogrammet for Rena øvingsfelt målestasjon, Åmot (**

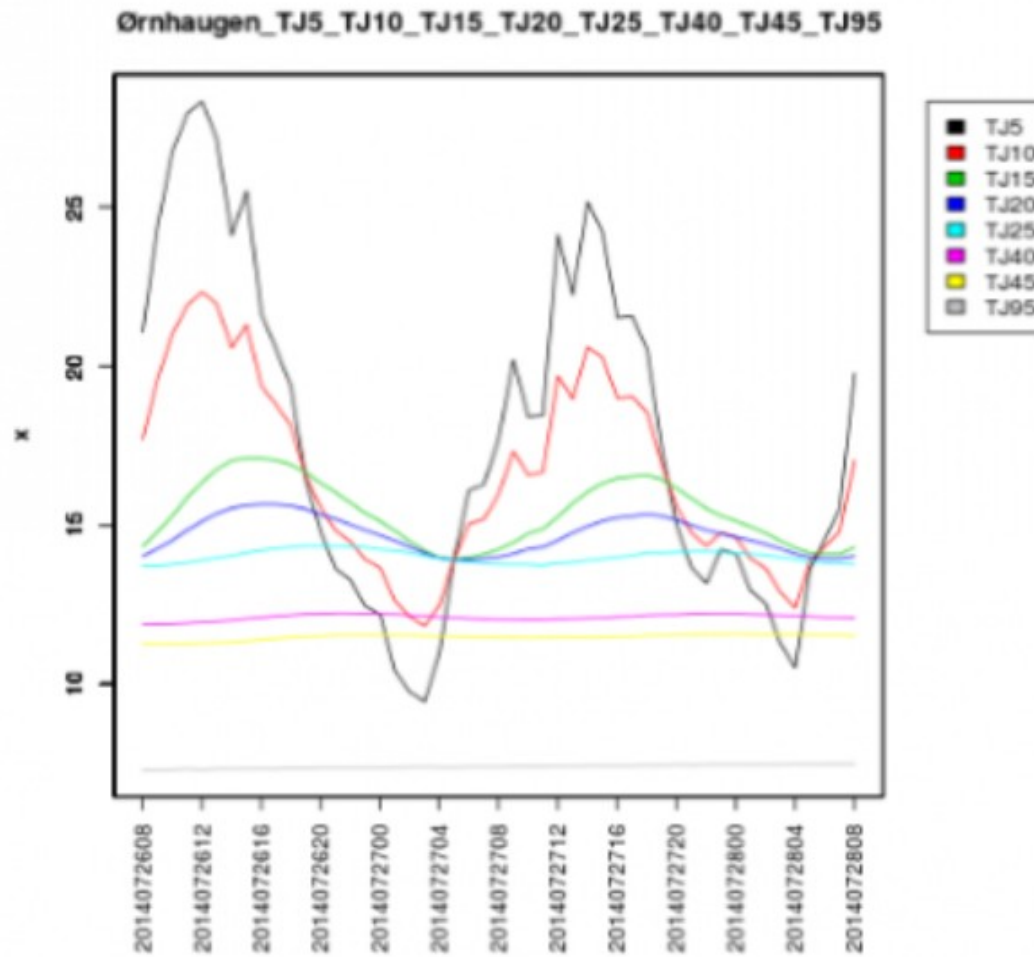


Observasjoner fra Rena øvingsfelt målestasjon, 0,0 km fra punktet Rena øvingsfelt målestasjon.



Værvarsel laget for Rena øvingsfelt målestasjon. Neste oppdatering av...
De blå nedbørssøylene viser maks- og min-verdier for ventet nedbør per t...
Når det er mange skraverte høye søyler er det usikkert nøyaktig når nedb...

Ex: Soil temperature July 2014



Fullstendig observasjonsprogram

Format	Fra	Til	Level	Sensor	Navn	Nr	Beskrivelse
506	2014-07-29	----	0	0	DD	61	Vindretning 10 minutt
506	2014-07-29	----	0	0	FF	81	Vindhastighet 10 minutt
506	2014-07-29	----	0	0	QSI_010	2072	Kortbølget stråling ovenfra, midlet over siste ti minutter
506	2014-07-29	----	0	0	RA	104	Nedbør, totalt bøtteinnhold
506	2014-07-29	----	0	0	RR_010	118	Nedbør, tilvekst siste 10 minutter
506	2014-07-29	----	0	0	RT_010	328	Nedbørtid siste ti minutter
506	2014-07-29	----	0	0	SA	112	Snødybde
506	2014-07-29	----	0	0	TA	211	Temperatur
506	2014-07-29	----	0	0	TSS	255	Flatetemperatur
501	2014-07-29	----	0	0	AA	1	Barografkurvens forløp
501	2014-01-28	----	0	0	DD	61	Vindretning 10 minutt
501	2014-02-18	----	0	0	DX_1	73	Vindretning maks. 10 minutt glidende middel siste time
501	2014-01-28	----	0	0	FF	81	Vindhastighet 10 minutt
501	2014-02-18	----	0	0	FG_1	90	Vindhastighet, maks. 3 sek. gust siste time
501	2014-02-18	----	0	0	FX_1	87	Vindhastighet, maks. 10 minutt middel siste time
501	2014-01-28	----	0	0	KLFG_1	1027	Tidsangivelse for FG_1
501	2014-01-28	----	0	0	KLFX_1	1028	Tidsangivelse for FX_1
501	2014-07-29	----	0	0	PO	173	Trykk QFE
501	2014-07-29	----	0	0	PP	177	Trykktendens
501	2014-07-29	----	0	0	PR	178	Trykk QFF
501	2014-01-28	----	0	0	QSI	2070	Kortbølget stråling ovenfra, midlet over siste time
501	2014-01-28	----	0	0	RA	104	Nedbør, totalt bøtteinnhold
501	2014-01-28	----	0	0	RR_1	106	Nedbør, tilvekst siste time
501	2014-07-29	----	0	0	RT_010	328	Nedbørtid siste ti minutter
501	2014-01-28	----	0	0	RT_1	123	Nedbørtid siste time
501	2014-01-28	----	0	0	SA	112	Snødybde
501	2014-01-28	----	0	0	STATSA	10289	Status snødybdesensor
501	2014-01-28	----	0	0	TA	211	Temperatur
501	2014-02-18	----	0	0	TAN	213	Temperatur minimum i timen
501	2014-01-28	----	0	0	TAX	215	Temperatur maksimum i timen
501	2014-02-19	----	1	0	TJ	226	Jordtemperatur
501	2014-01-28	----	5	0	TJ	226	Jordtemperatur
501	2014-01-28	----	15	0	TJ	226	Jordtemperatur
501	2014-01-28	----	25	0	TJ	226	Jordtemperatur
501	2014-01-28	----	45	0	TJ	226	Jordtemperatur
501	2014-01-28	----	95	0	TJ	226	Jordtemperatur
501	2014-01-28	----	0	0	TSS	255	Flatetemperatur
501	2014-01-28	----	0	0	UU	262	Relativ luftfuktighet

Observations

FF

FX_1

FG_1

DD

SA

TA

TSS

TJ(6) – 1, 5, 15, 25, 45 and 95 cm

QSI

RA

RR_1

UU

PR

Freezing depth

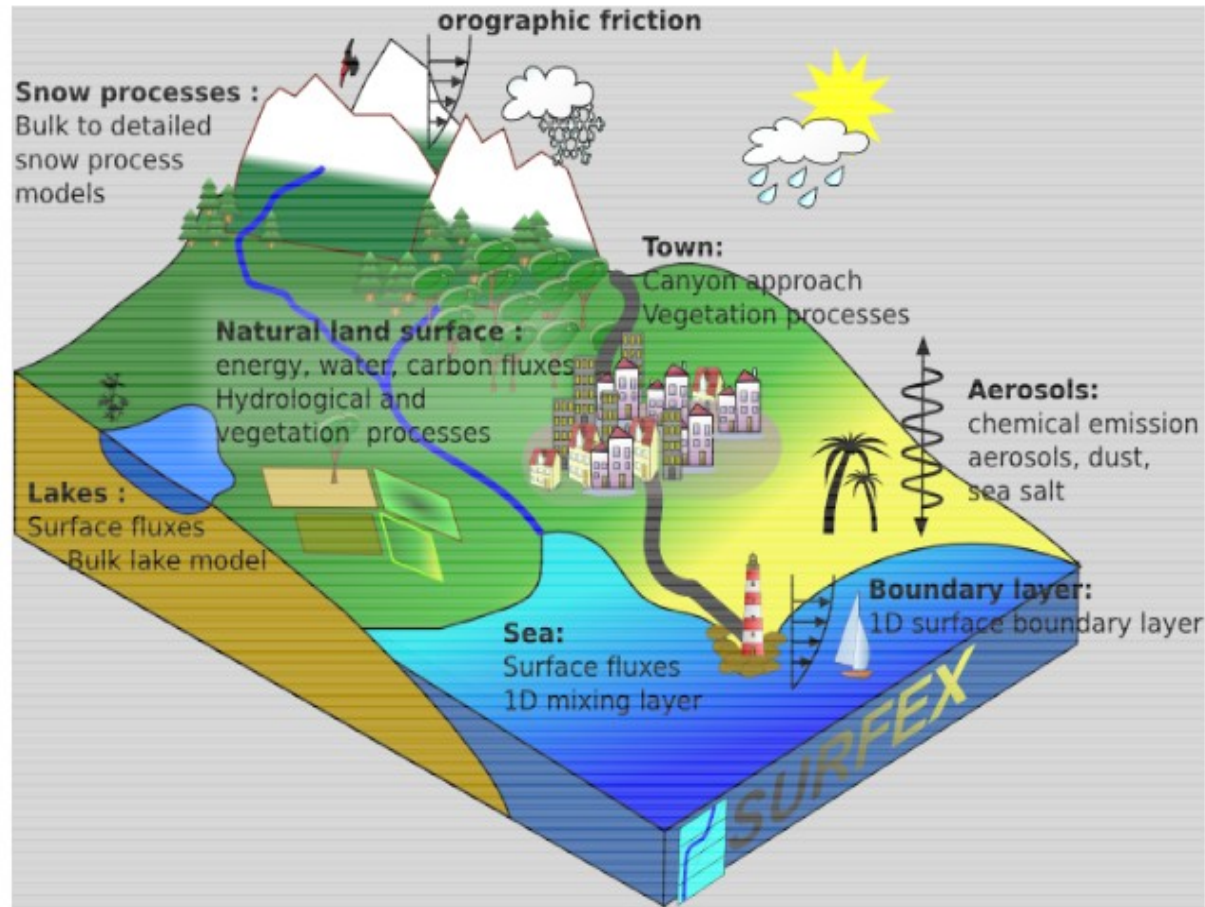
Future work

- Soil moisture observations
- Level the surface around the station
- Stabilize the measurements
- Measure the soil texture (and compare to model values)

Modelling

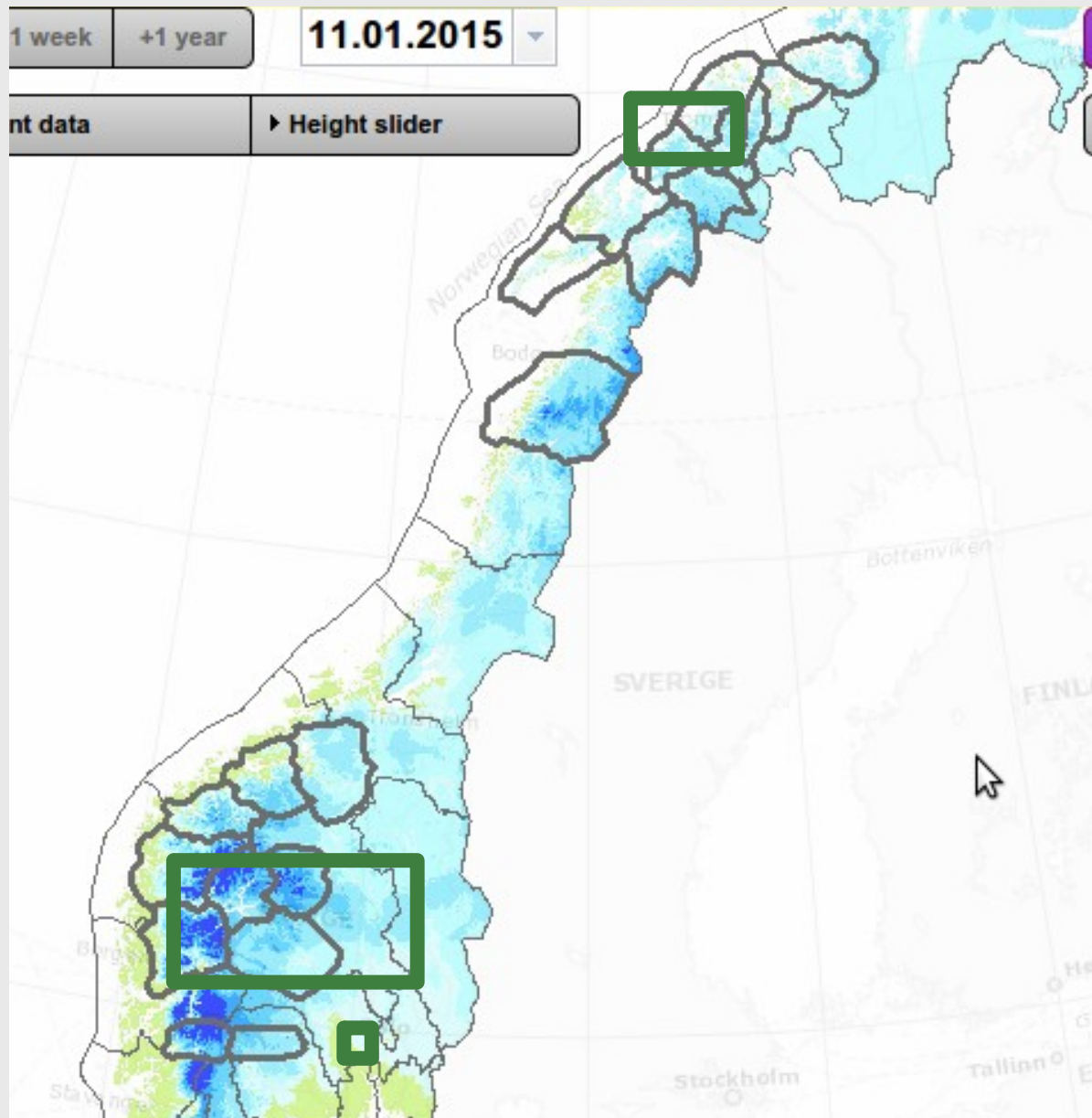
SURFEX - offline & inline*

*AROME's surface model



Citation: Masson, V., Le Moigne, P., Martin, E., Faroux, S., Alias, A., Alkama, R., Belamari, S., Barbu, A., Boone, A., Bouyssel, F., Brousseau, P., Brun, E., Calvet, J.-C., Carrer, D., Decharme, B., Delire, C., Donier, S., Essaouini, K., Gibelin, A.-L., Giordani, H., Habets, F., Jidane, M., Kerdraon, G., Kourzeneva, E., Lafaysse, M., Lafont, S., Lebeaupin Brossier, C., Lemonsu, A., Mahfouf, J.-F., Marguinaud, P., Mokhtari, M., Morin, S., Pigeon, G., Salgado, R., Seity, Y., Taillefer, F., Tanguy, G., Tulet, P., Vincendon, B., Vionnet, V., and Voldoire, A.: The SURFEXv7.2 land and ocean surface platform for coupled or offline simulation of earth surface variables and fluxes, *Geosci. Model Dev.*, 6, 929-960, doi:10.5194/gmd-6-929-2013, 2013.

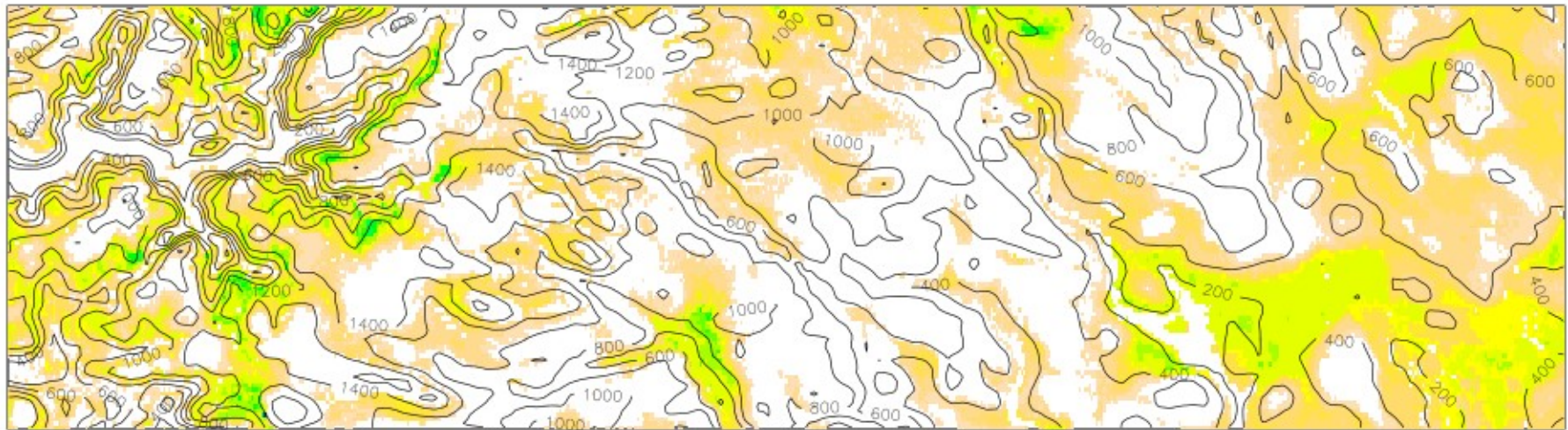
New in 2015: 2D simulations



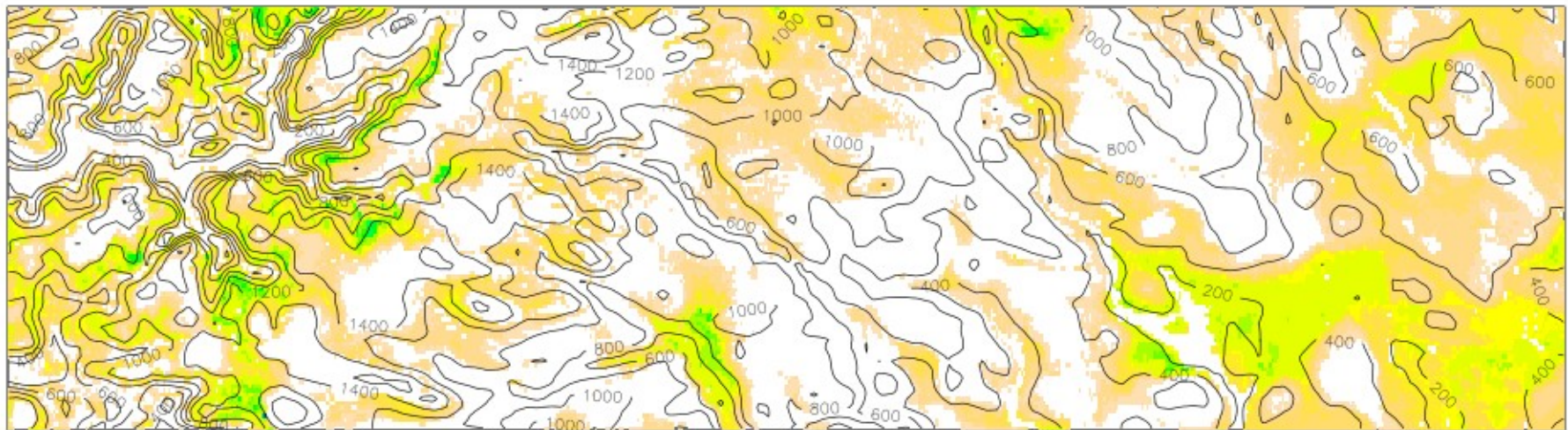
- Offline SURFEX model runs for regions (1 km*1km):
 - Tromsø
 - South Norway
 - Drammen

SURFEX-RENSK

RENSK 12. desember 18 UTC-01



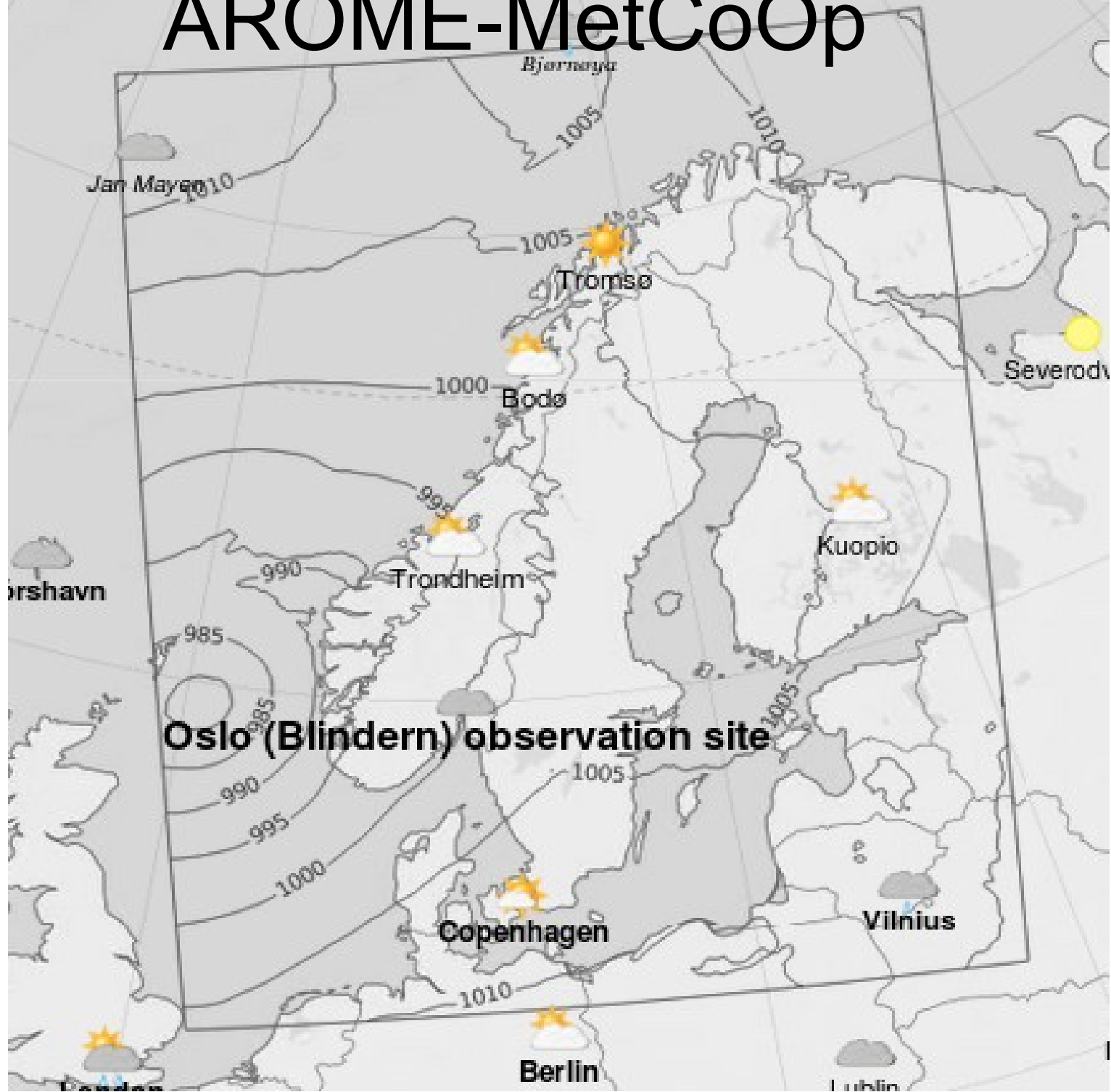
RENSK 12. desember 18 UTC-30



Teledyp (m)

Forcing data

AROME-MetCoOp



Data distribution





Catalog <http://thredds.met.no/thredds/metno.html>

Dataset


 Proff 4km (Testing)


 [Proff Default 4km/](#)

 Oilspill

 [Oilspill Oscar/](#)


 MET Arome MetCoOp


 [Arome 2.5 files/](#)

 [Arome 0.5 files/](#)

 MET Arome Arctic (Testing)

 [Arome Arctic files/](#)

 MET Arome MetCoOp Forecast Archive

 [Arome MetCoOp Forecast Archive files/](#)

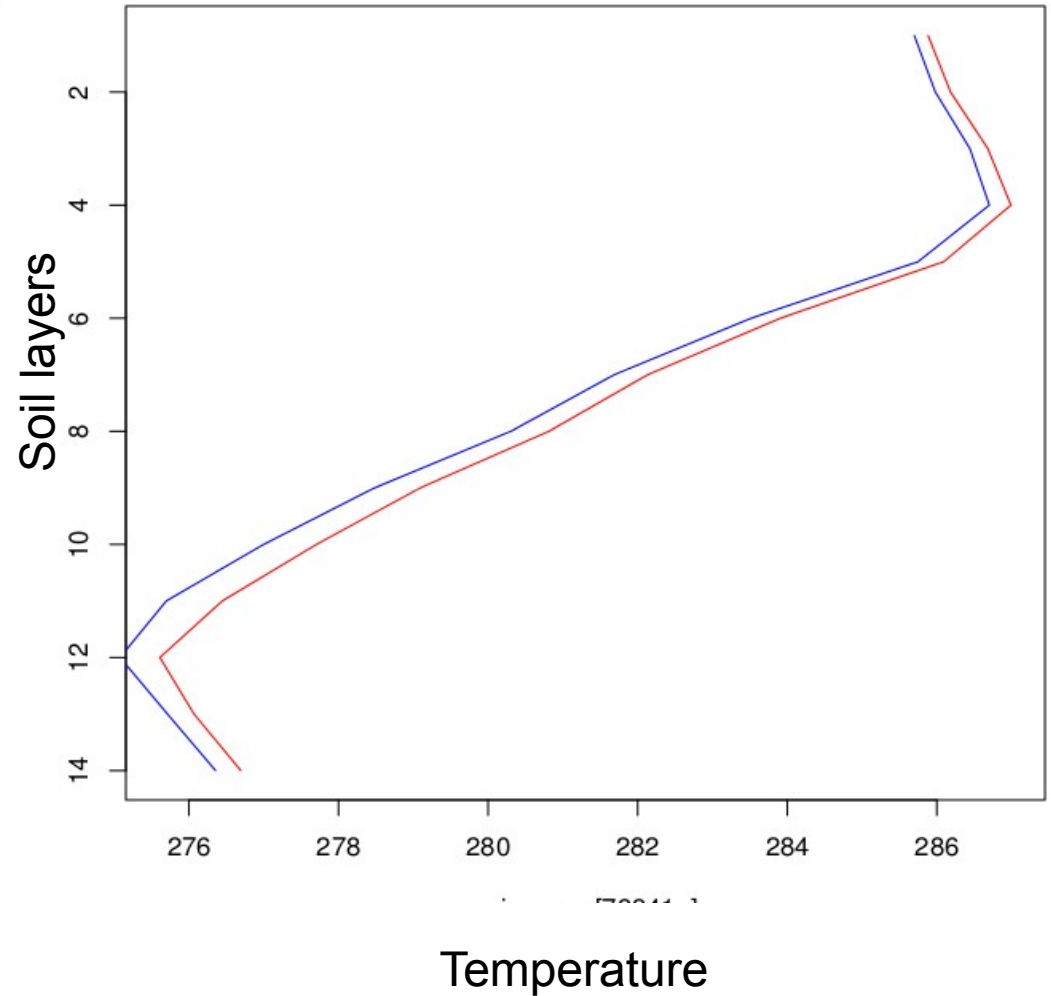
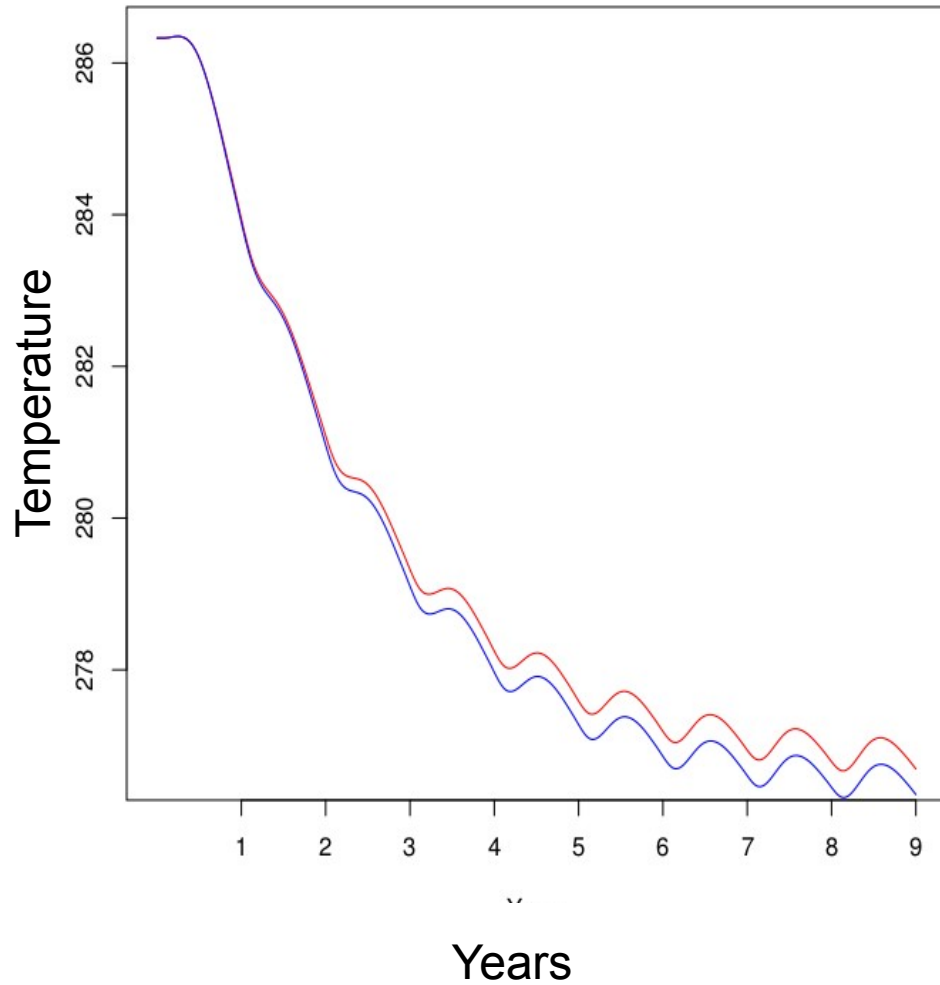
Results

1D simulations at Ørnhaugen

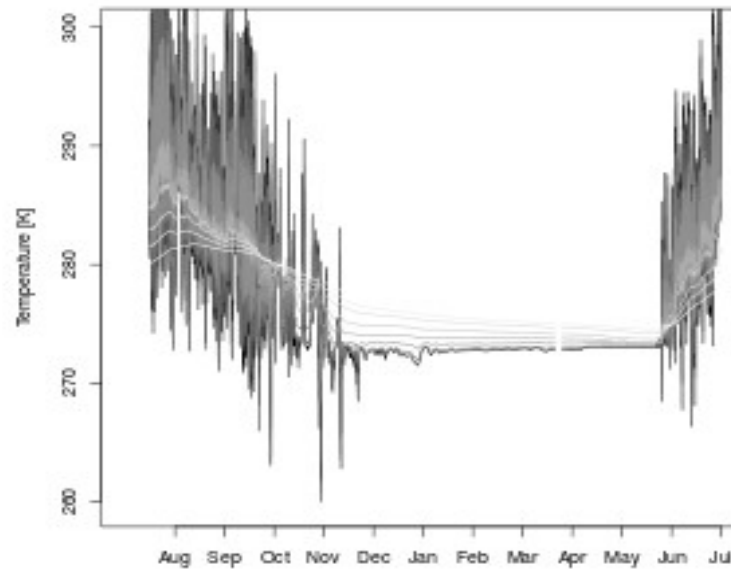
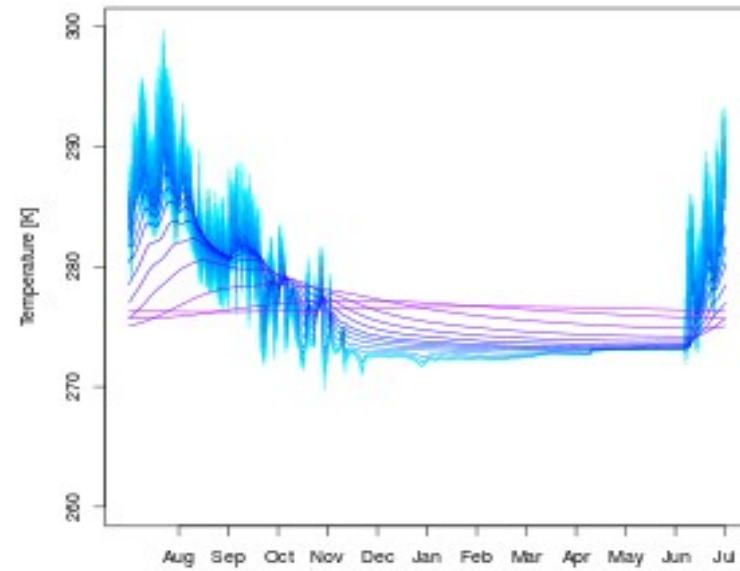
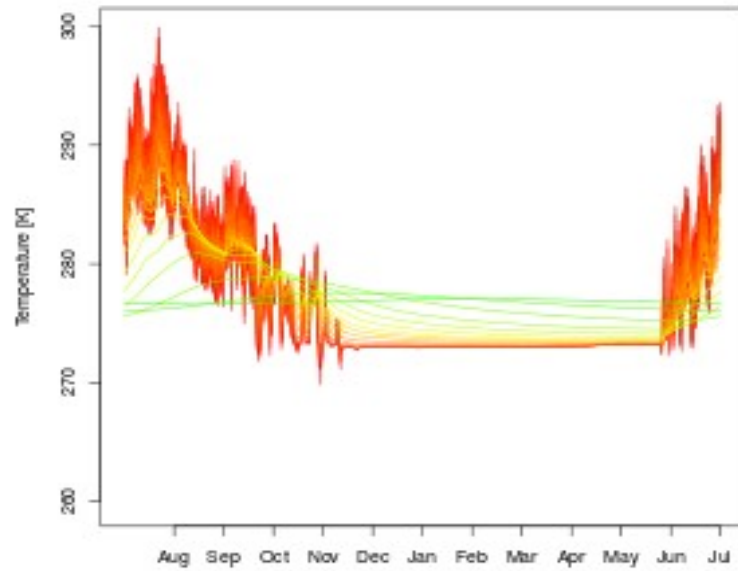
Configured as Rensik but also 3-L snow

Spin-up of soil temperature

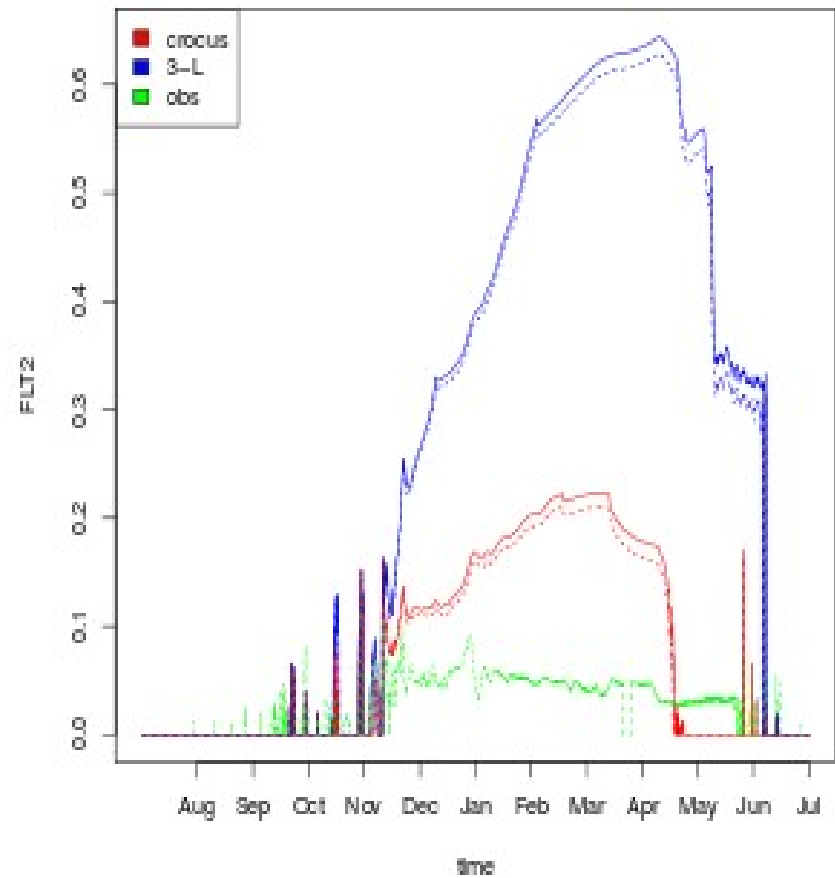
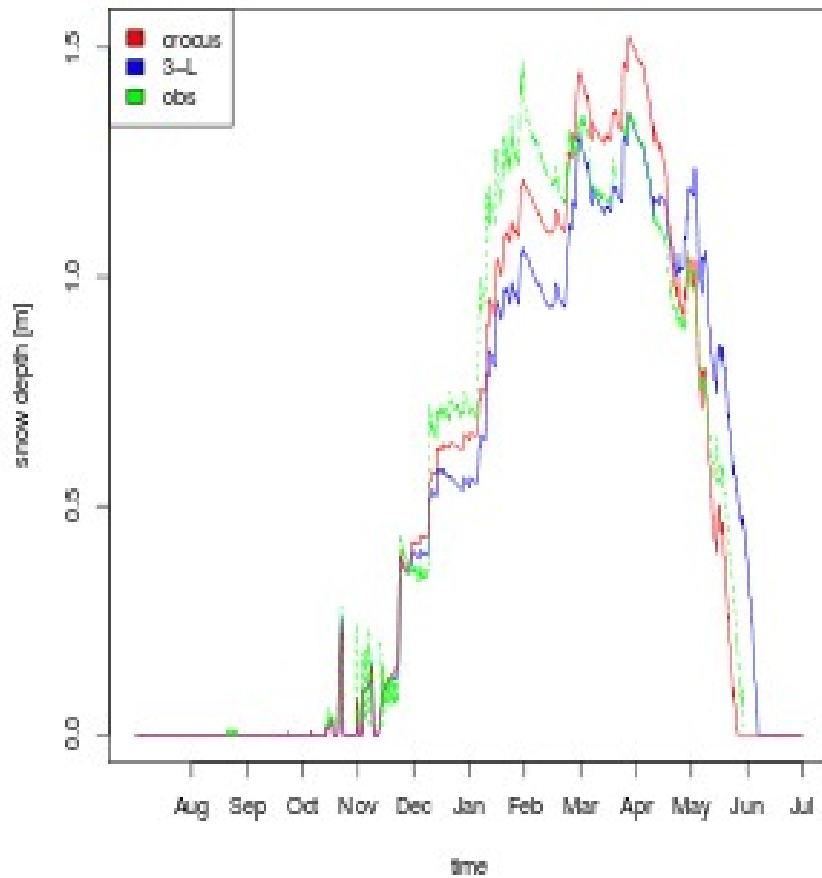
Crocus – red; 3-L - blue



Soil temperature



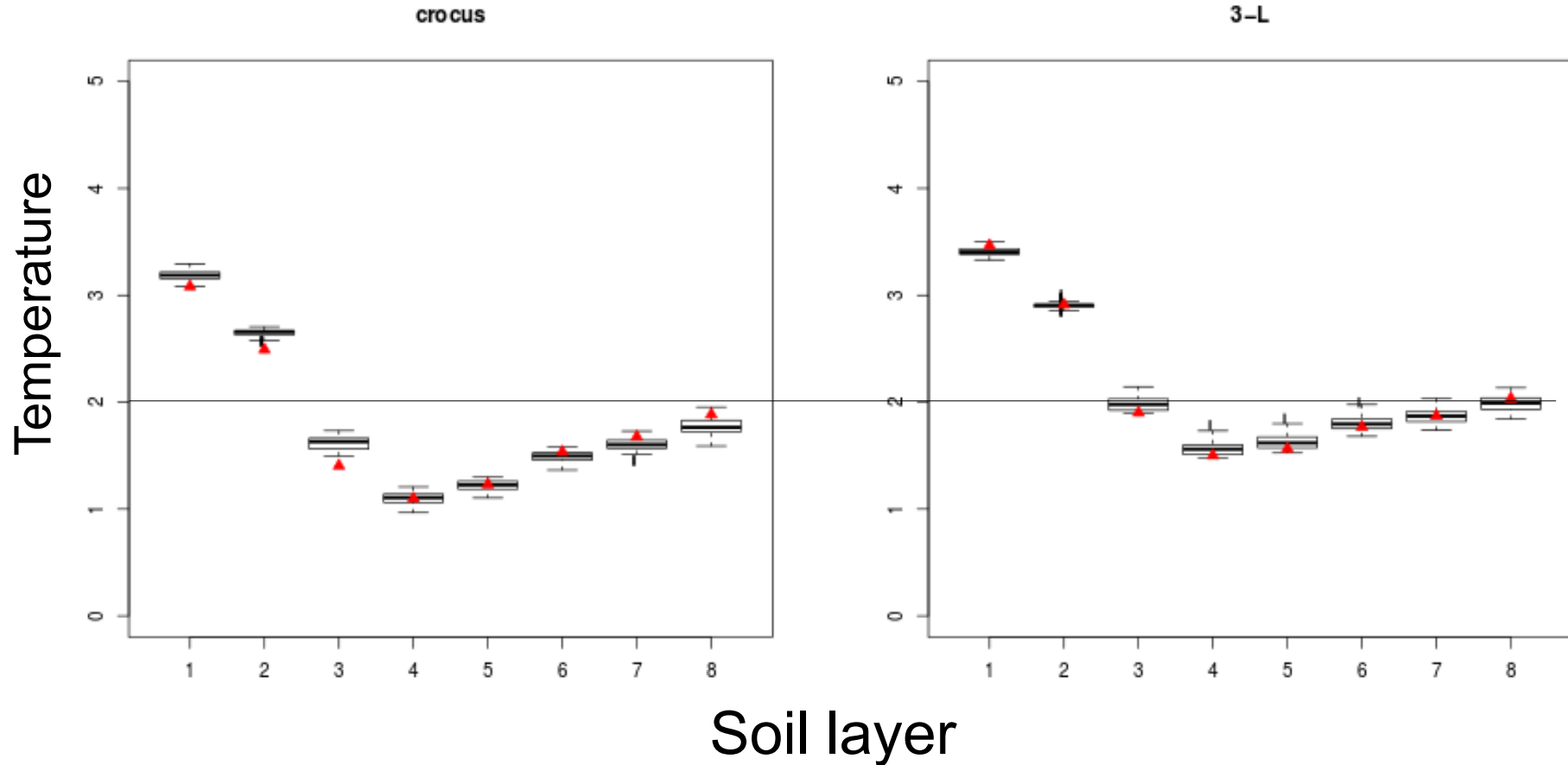
Snow depth & Frost depth



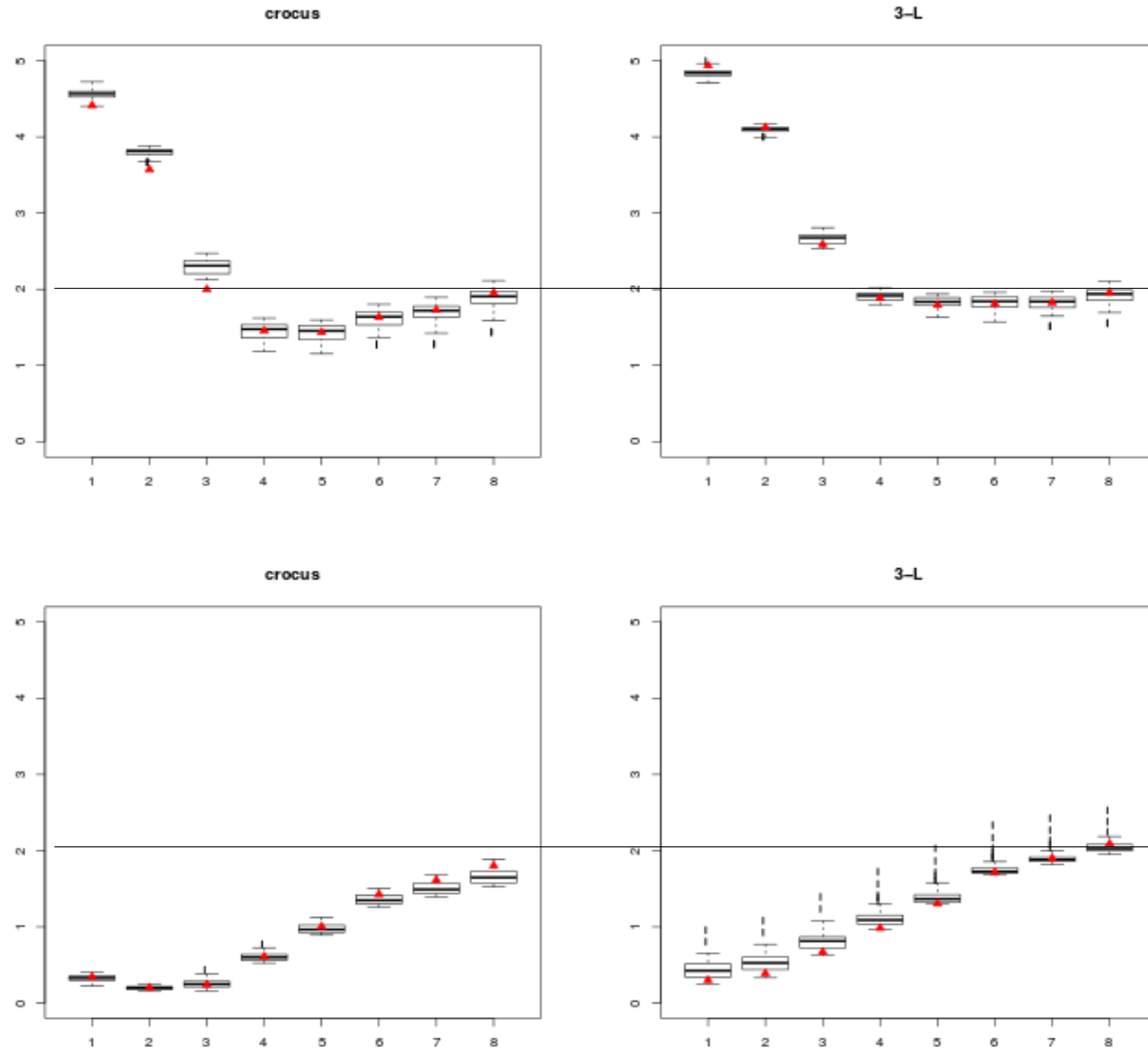
Sensitivity to soil texture and snow scheme—
“optimizing” SURFEX at Ørnhaugen

RMSE soil temperature

as a function of clay and sand fractions
-red is default



With (top) and without (bottom) ground snow



Lowest RMSE for each soil layer

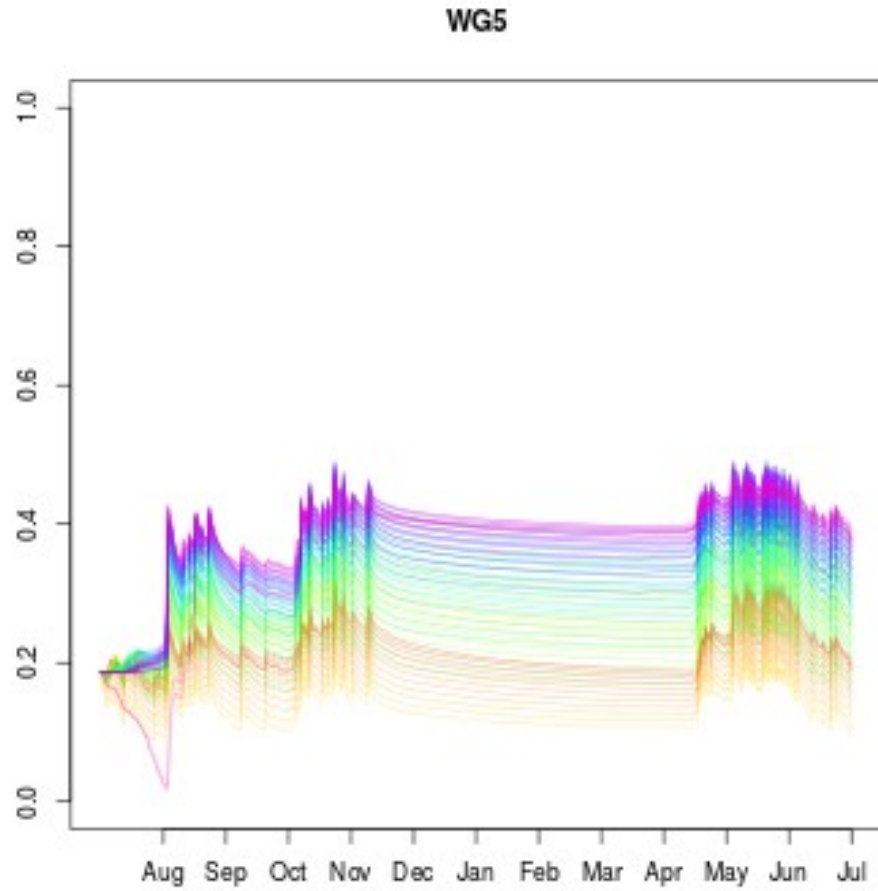
Crocus

3-L

Lag	leire %	sand %	rmse	Lag	leire %	sand %	rmse
TG1	00	20	3.084	TG1	00	20	4.711
TG2	00	30	2.556	TG2	00	20	3.994
TG3	00	60	1.498	TG3	00	60	2.533
TG4	00	30	0.966	TG4	00	30	1.799
TG5	00	20	1.104	TG5	100	00	1.635
TG6	90	00	1.364	TG6	100	00	1.574
TG7	90	00	1.443	TG7	100	00	1.507
TG8	90	00	1.590	TG8	90	00	1.547

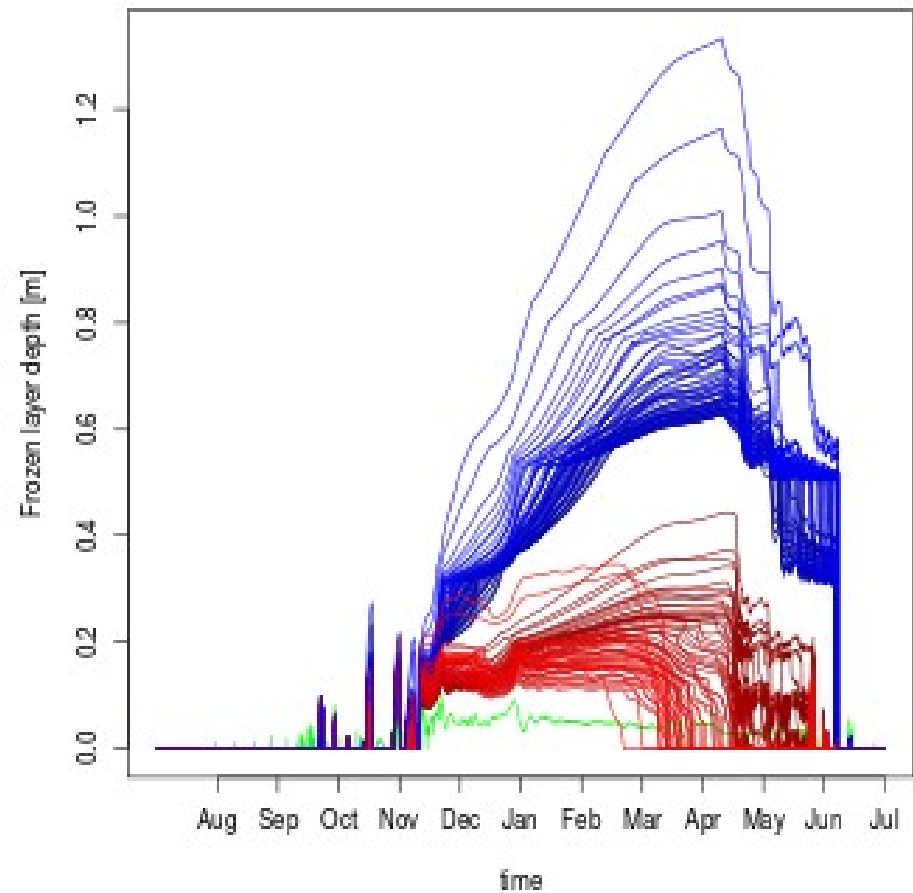
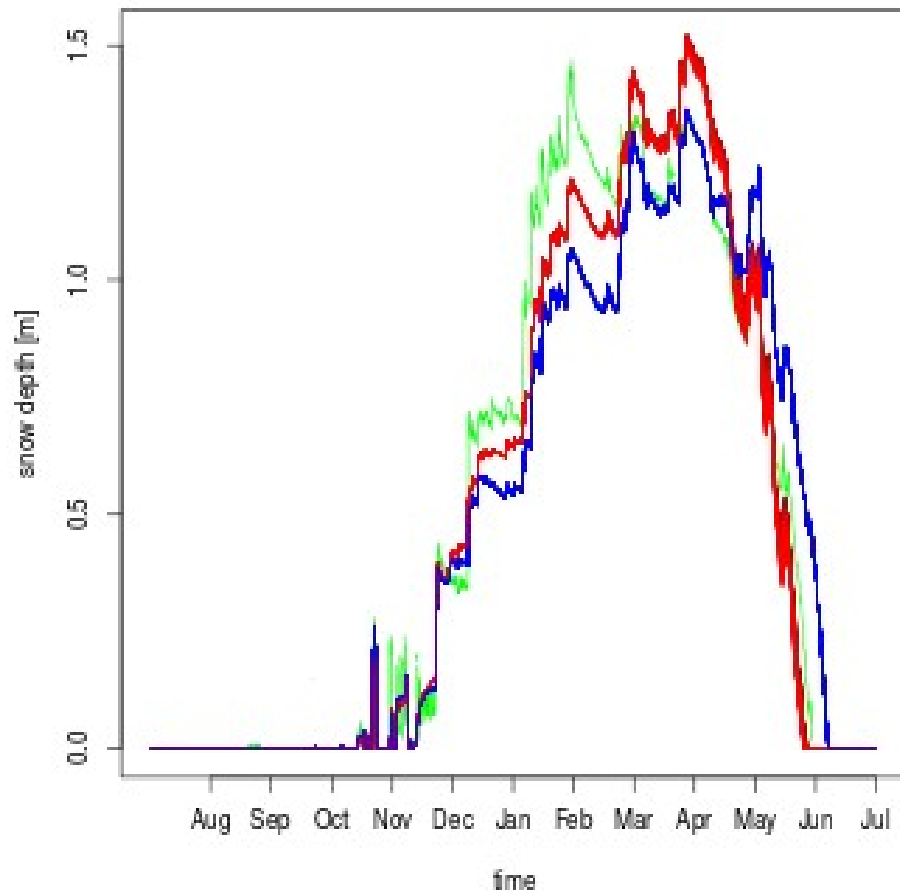
RENSK: 11% clay; 70% sand

Soil moisture



Snow depth & Frost depth

obs-green; crocus-red; 3-L-blue



Best fit Crocus

RMSE – 40% clay and 60% sand

Corr – 30% clay and 70% sand

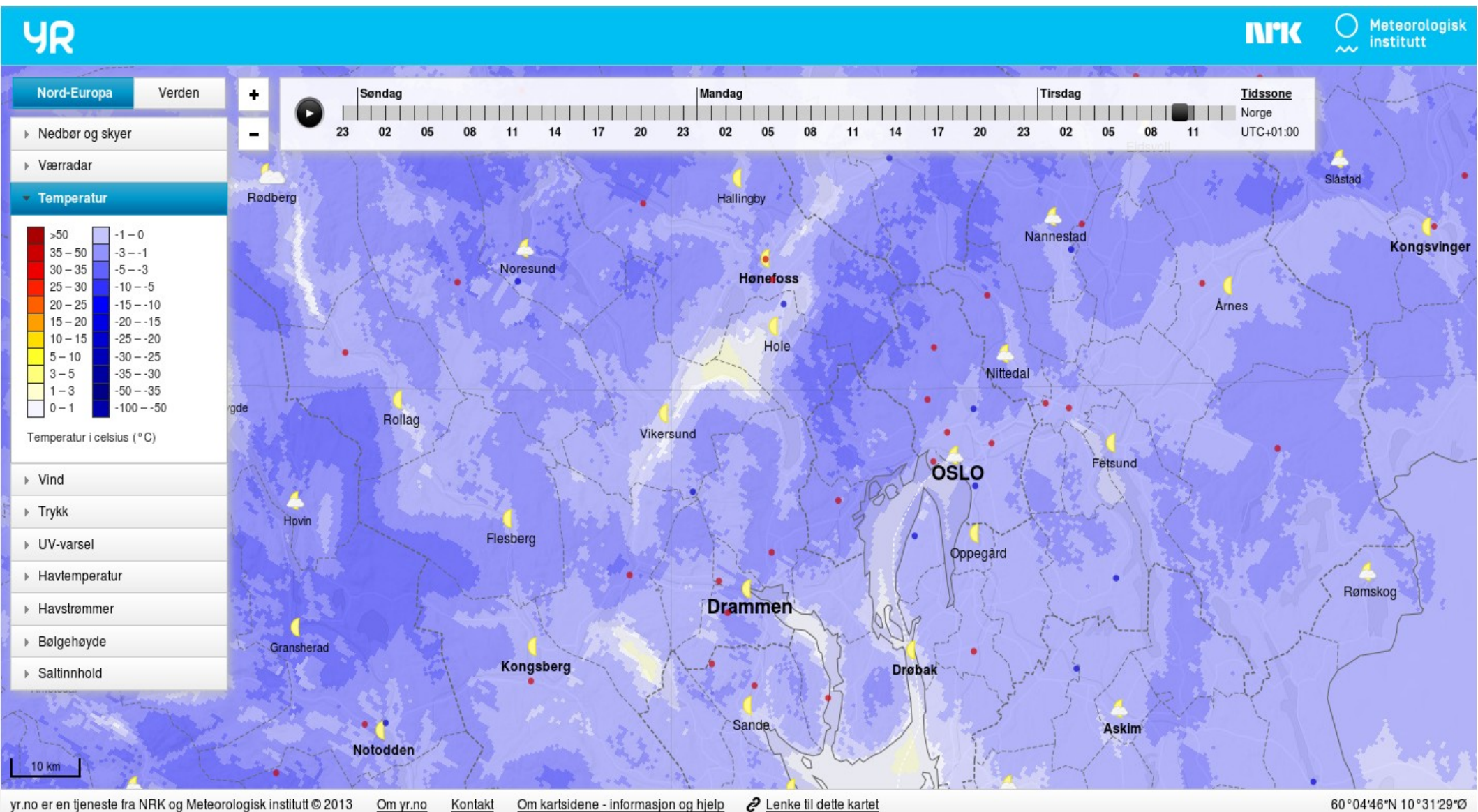
Binary (yes/no) – 0% clay and 50% sand

Future work

- Replace AROME-MetCoOp forcing with observations (shorter time period) – how large (relative) is the sensitivity to forcing?
- Sensitivity to physiography (e.g. local variability since SURFEX soil texture is constant over a large area)
- Test (some) soil texture configurations over a larger domain
- Suggest surface/soil perturbations for AROME-MetCoOp EPS
- Quantify uncertainty in estimates of bearing capacity

Lokale (statistiske) tilpasninger

Eks Temperatur

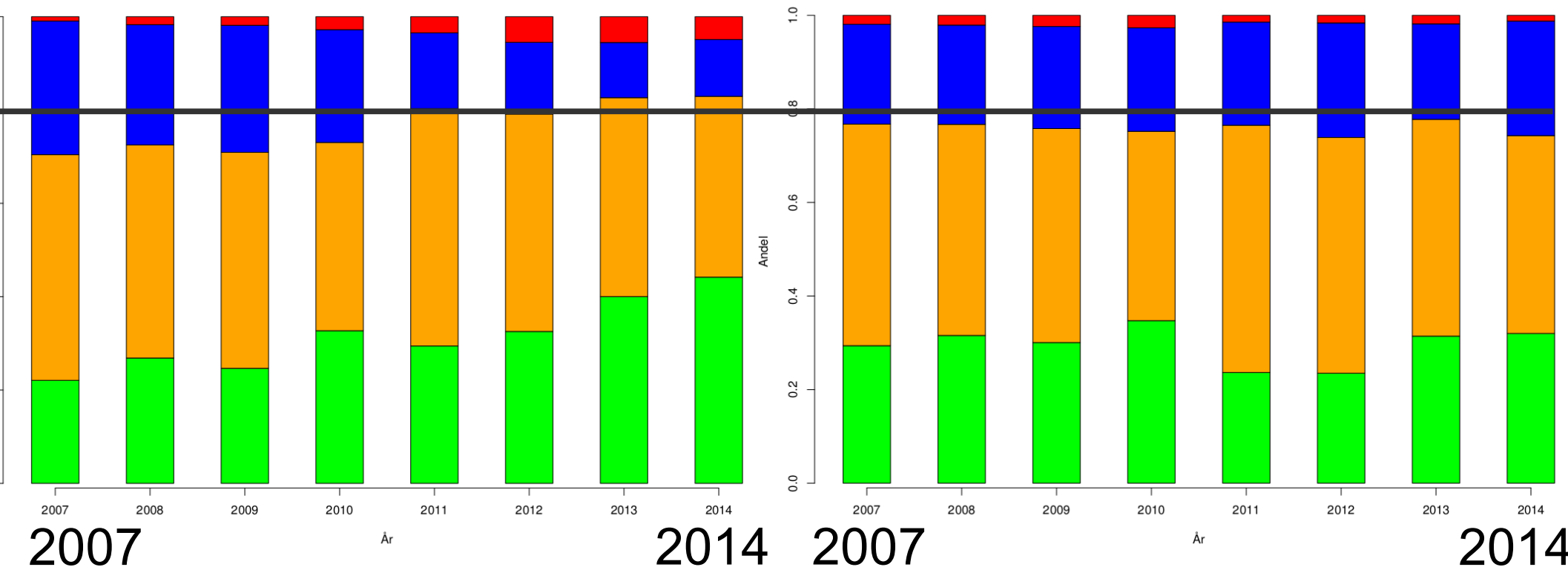


Yr (left) vs ECMWF HRES (right)

RR24 (event rain/no rain; threshold 0.2 mm/24h)

ke varslet, ikke observert d:varslet, observert c:varslet, ikke observert b:ikke varslet, observert a:ikke varslet, ikke observert d:varslet, observert c:varslet, ikke observert b:ikke varslet, observert

Kontingenstabell, andel a,b,c og d i perioden 2007060206–2014100106 Kontingenstabell, andel a,b,c og d i perioden 2007060206–2014102406

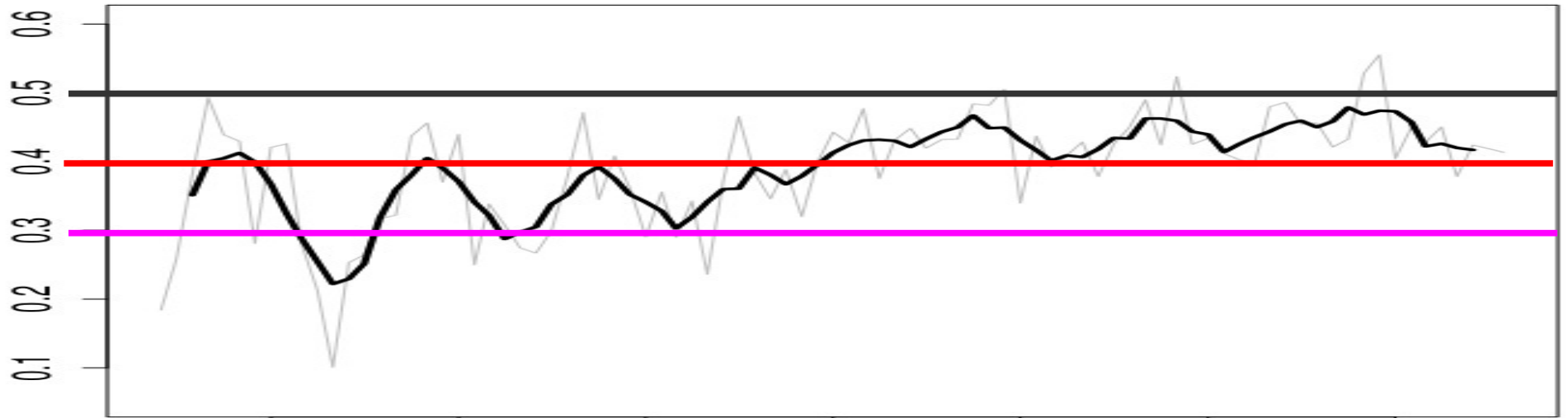


Orange + green = fraction of good forecasts

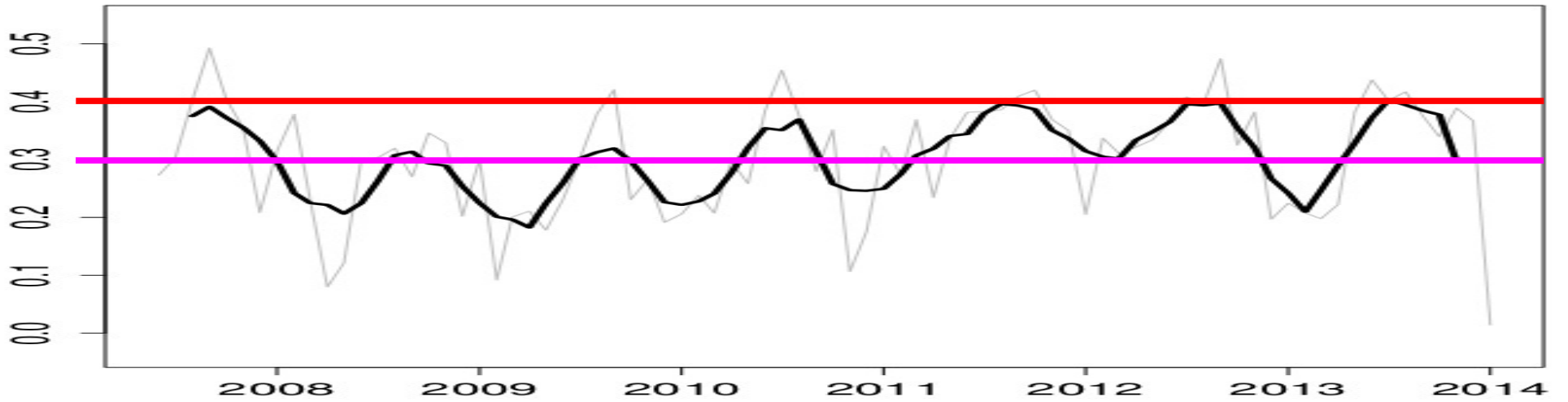
Yr (top) vs ECMWF HRES (bottom)

Screen Temperature

MAE Skill Score Temperature



MAE Skill Score Temperature



Hvilken værvarsling har du størst tiltro til?

