

Progress and plans with SURFEX physics (DIF, 3-L, MEB) and data assimilation (EKF) for NWP in HIRLAM

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General surface comments

Cy40h1.1.1 is our latest official release of the ALADIN-HIRLAM NWP system with the HARMONIE-AROME model configuration.

cy43h2.1 represents the next meteorological release of cy43h (includes SURFEX8.1).

cy43h2.2 represents the big surface step towards new physics and new data assimilation.

Release SURFEX	cy40h1.1.1 v7.3	cy43h2.1 (2019) v8.1	cy43h2.2 (2020) v8.1
ISBA			
Patches	1 or 2 (no SBL model)	2	2 (-4)
Soil/veg	Force-restore	Force-restore	Diffusion (14 layers) + MEB
Snow	D95	D95	Explicit snow (12 layers)
Glacier	"Pile of snow"	"Pile of snow"	Explicit snow as glacier?
Assimilation	CANARI-OI	CANARI-OI	SEKF/EKF & TITAN/gridPP
Sea	SICE	SICE	SICE
Assim of ice	no	no	ice temperature EKF?
Waves	no	no	WW3?
Lake	FLake (optional)	FLake	FLake
Assimilation	no	no	EKF?
Town	TEB	TEB	TEB (more options?)
Assimilation	yes	no	??
Physiog.	ECOCLIMAP (modified)	ECOCLIMAP-SG(?)	Utilize high res. data

Surface options for potential activation in upcoming cy43h2.1 meteorological release

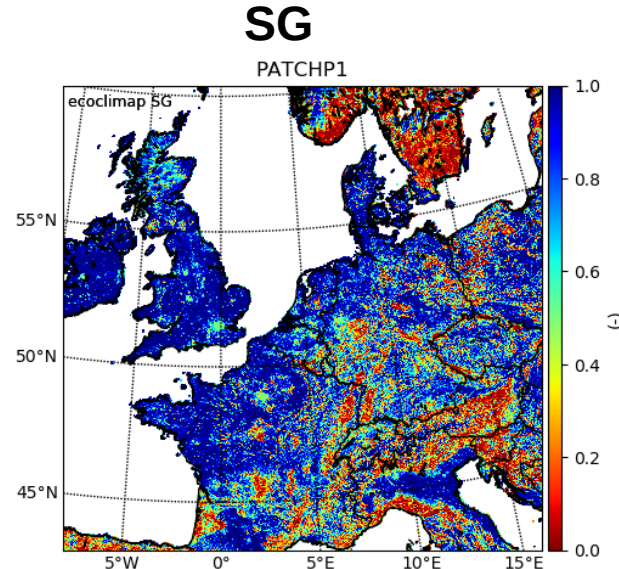
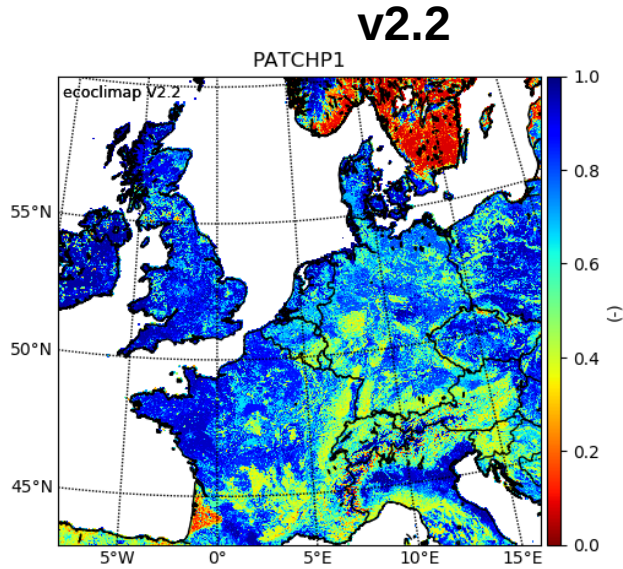
- **ECOCLIMAP-SG, Second Generation**
- **ECUME6 scheme for the water fraction of the sea tile**
- **Orography - turbulence (OROTUR)**
- **Modified values of minimum stomatal resistance R_{smin}**
- **Assimilation of satellite product of snow extent**
- **SOILGRIDS - New clay and sand database**
- **Test of soil-ice bug reported by Météo-France**

These options, and more, are described in detail on this HIRLAM wiki:

https://hirlam.org/trac/wiki/Surface_physics_assimilation/First_cy43h_setup

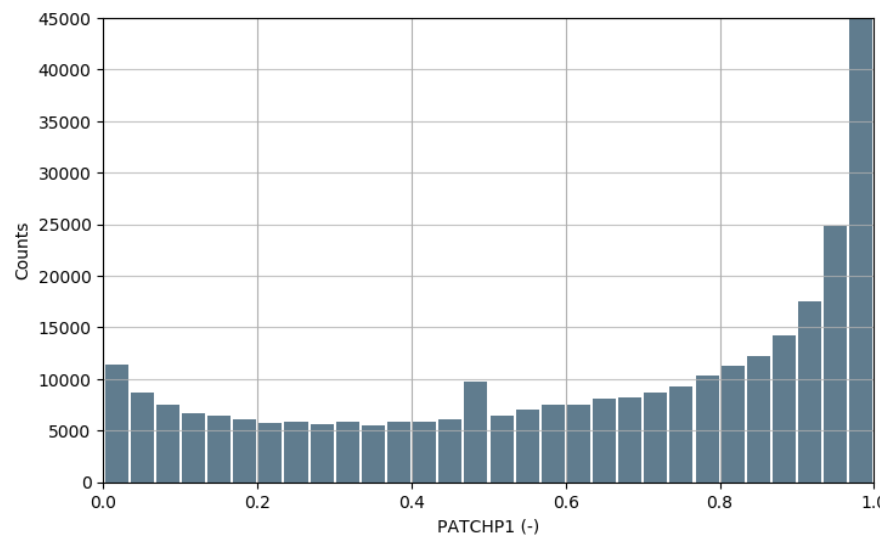
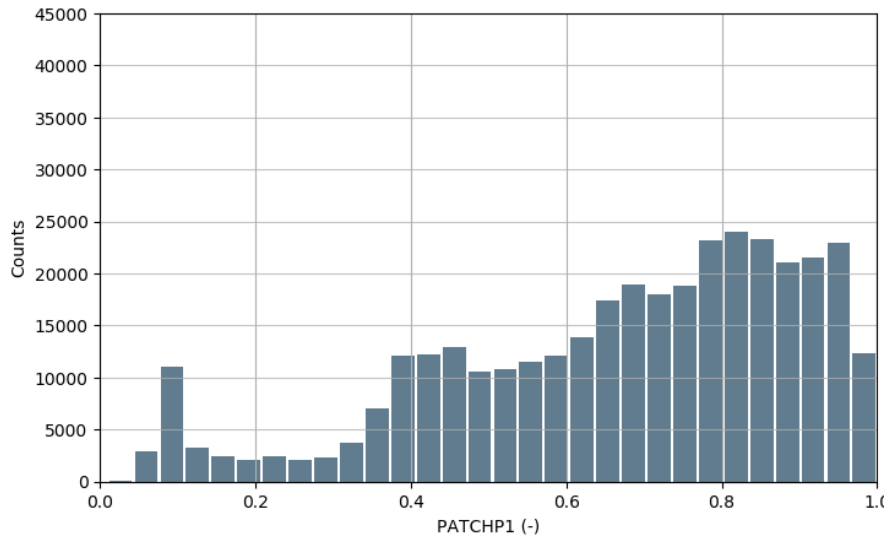
ECOCLIMAP Second Generation

Fraction open land



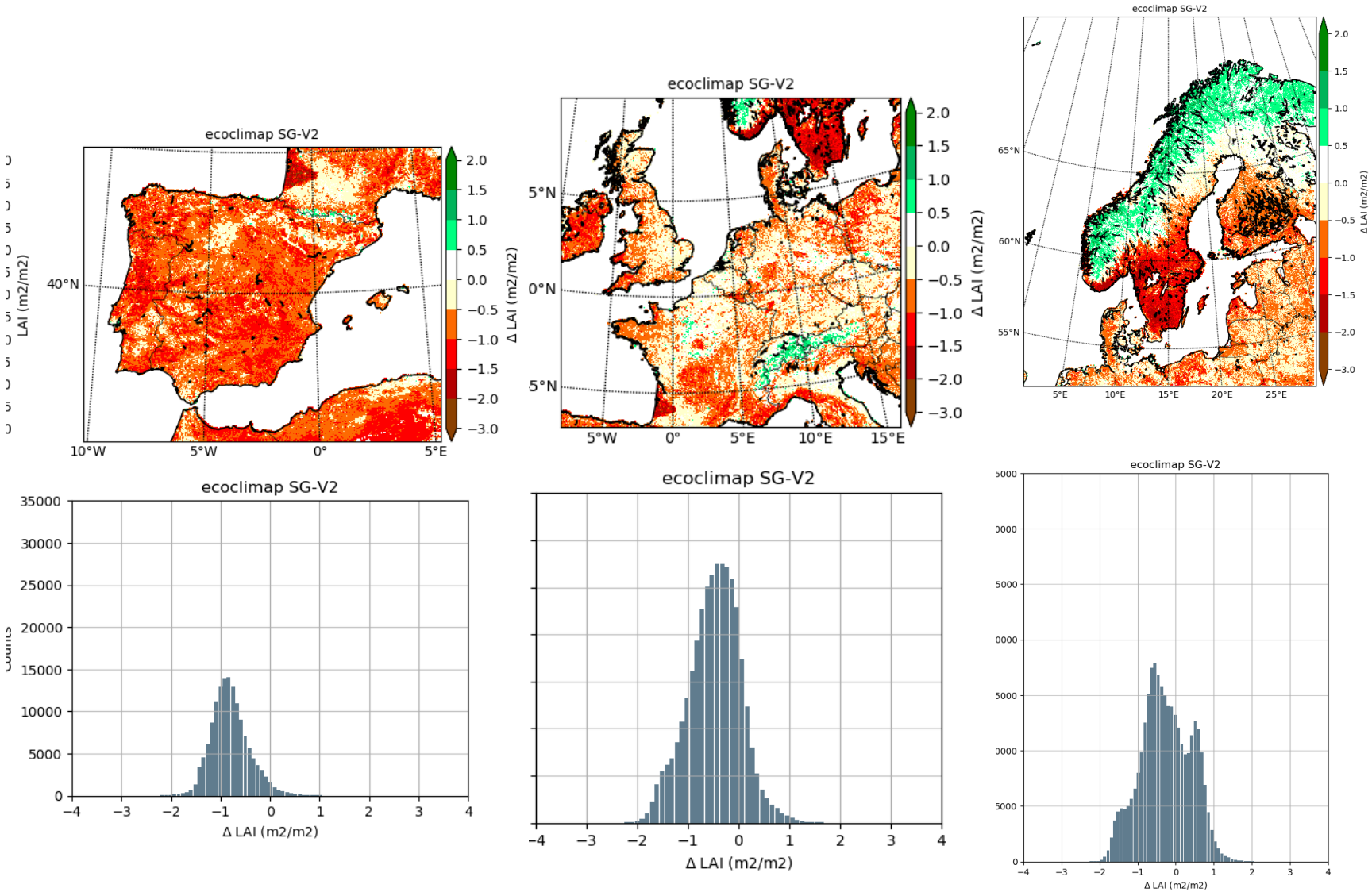
Quite some 50-50% areas in v2.2 (green) change to near 100% forest in SG (red).

Do we know if this is more realistic or not?



ECOCLIMAP Second Generation

LAI differences (SG – v2.2) at beginning of April



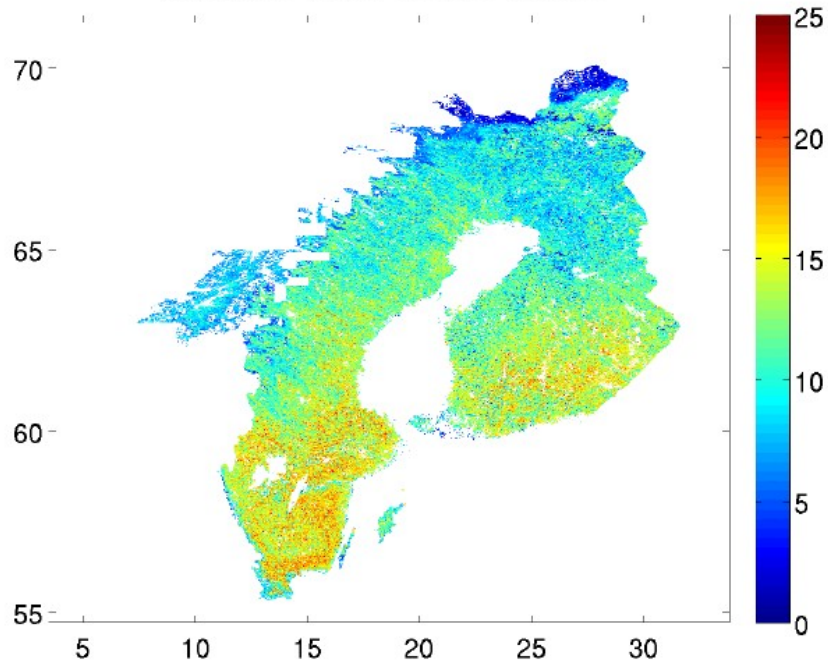
Spring LAI is in general smaller in SG than in v2.2.

This is considered to be more realistic since e.g. LAI in v2.2 show increasing LAI already in February-March, which is not realistic.

ECOCLIMAP – how to update?

Geographically limited data bases,
e.g. laser scanned tree height

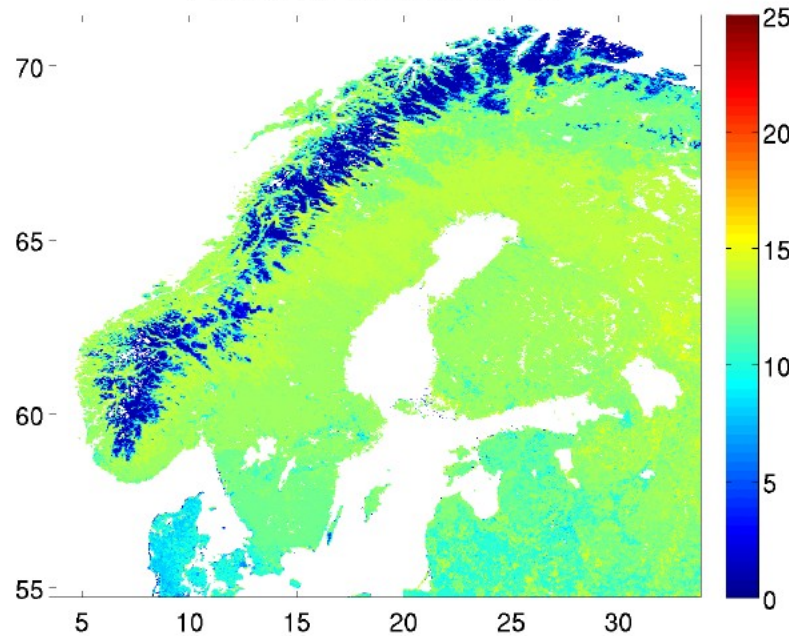
Nordic tree height: 0.12032 - 34.4928



+

ECOCLIMAPv2.2 tree height

ECOCLIMAP tree height: 1 - 15



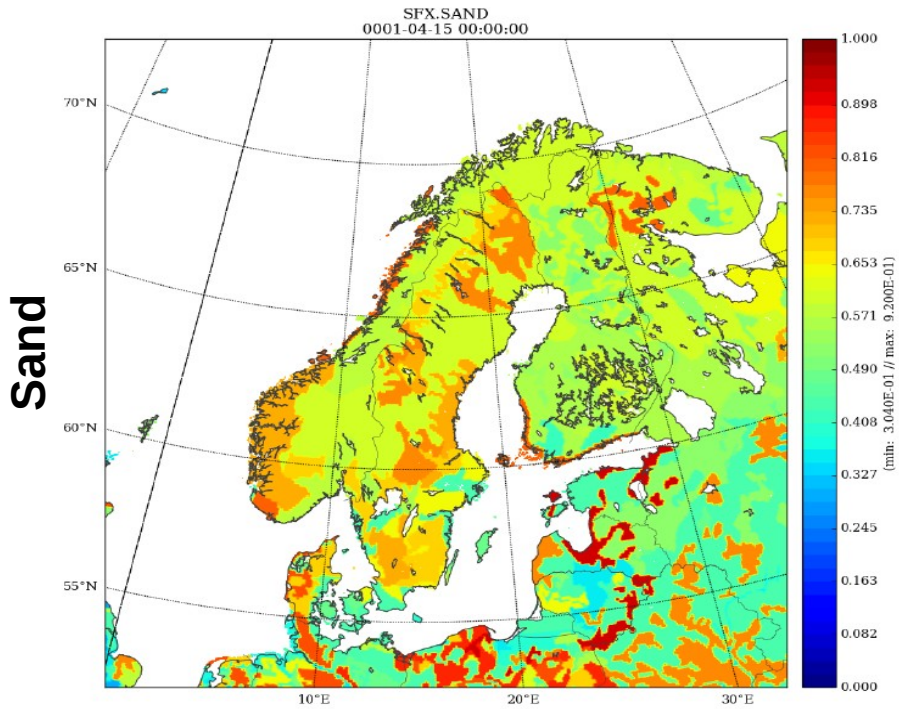
= ?

How to treat combination with global data to avoid artificial boundaries?

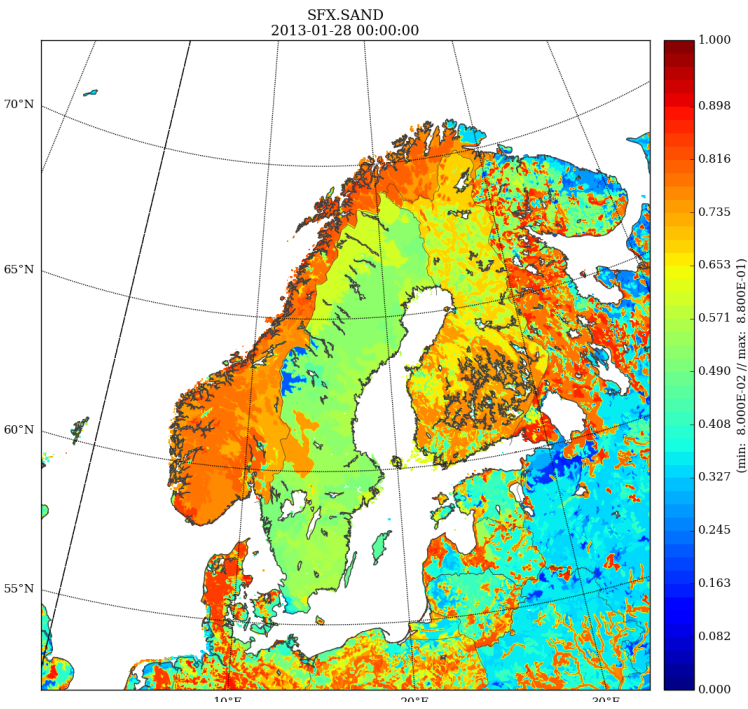
How to combine contributions from different partners into a common update?

New clay and sand database - SOILGRIDS

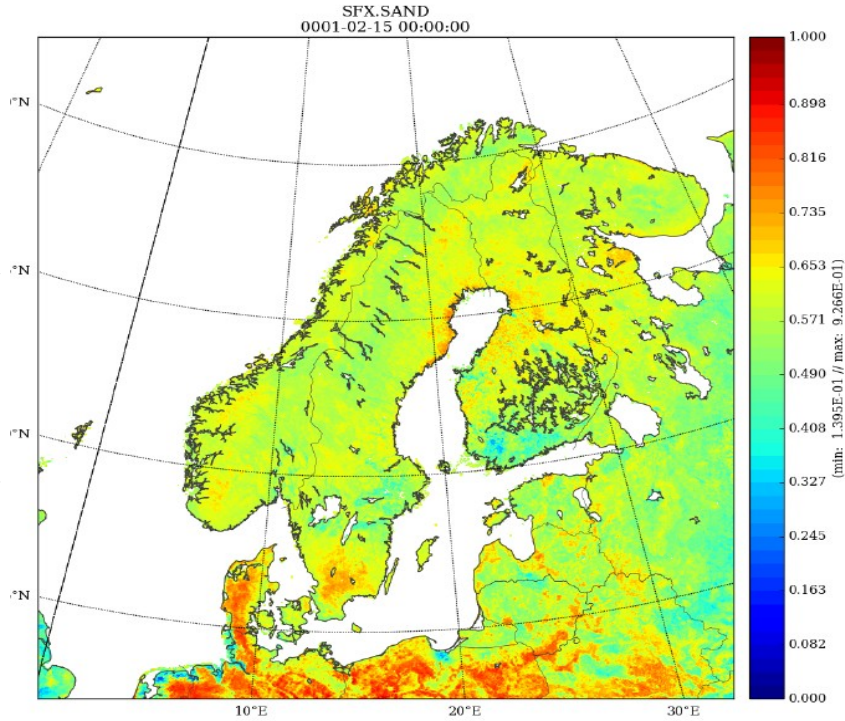
FAO - 10km



HSWD - 1km



SOILGRIDS - 300m



HSWD looks strange for Scandinavia. Thus, until recently we have used FAO but now we will move to SOILGRIDS.

Tests of meteorological impact when moving from FAO to SOILGRIDS shows

- Small impact on meteorology in general.
- Where differences appear the new sand and clay data gives in general an improvement compared to FAO.

Modified values of minimum stomatal resistance R_{smin} ...?

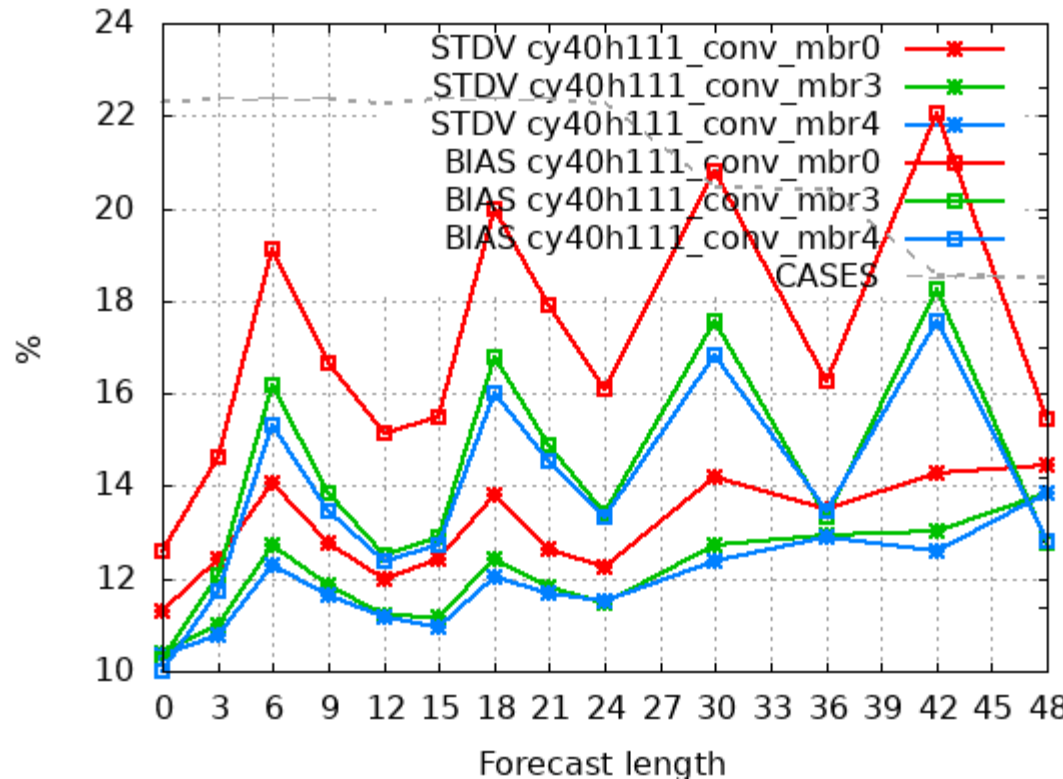
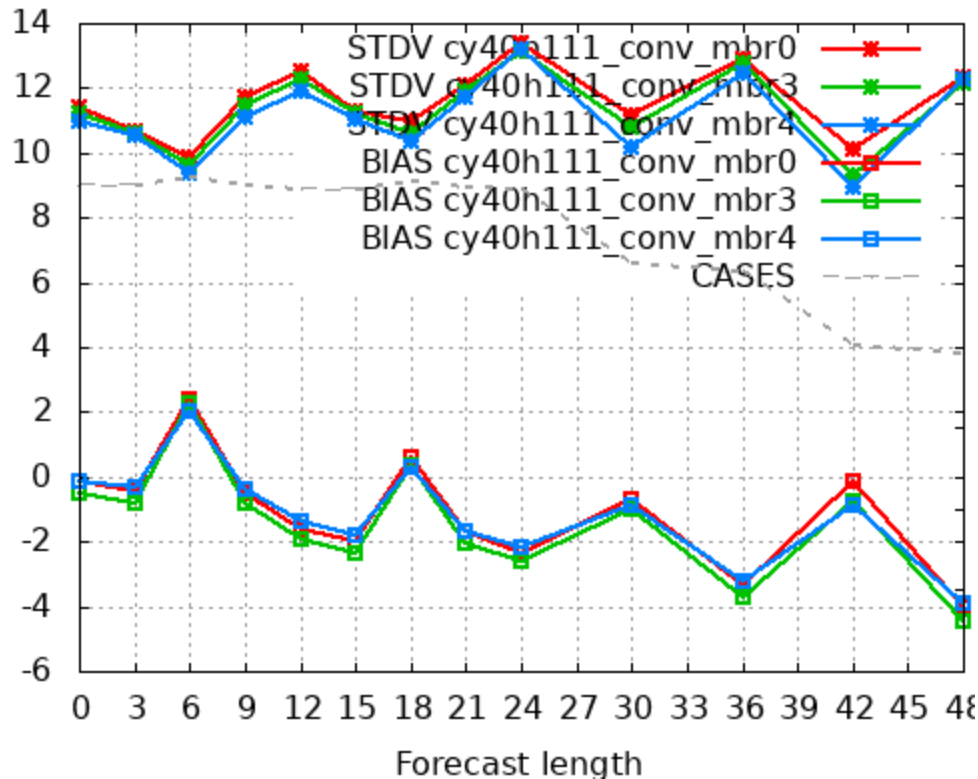
Connected to identified problems with convection initialisation in HARMONIE-AROME we have critically been studying the role of the surface (transpiration, assimilation, LAI, R_{smin} , ...). Following a study by Hoshika et al. (2018) it **suggests that R_{smin} values in SURFEX should be 1.5-3 times larger:**

Trees (4) = $150 * 1.5$, Coniferous (5) = $150 * 2.75$, C3 crops (7) = $40 * 3.0$, C4 crops (8) = $120 * 1.5$.

Rh2m for May 7-10, 2018, for

Southern Sweden (Gotaland)
No snow

Northern Sweden (Norrland)
2/3 still snow covered



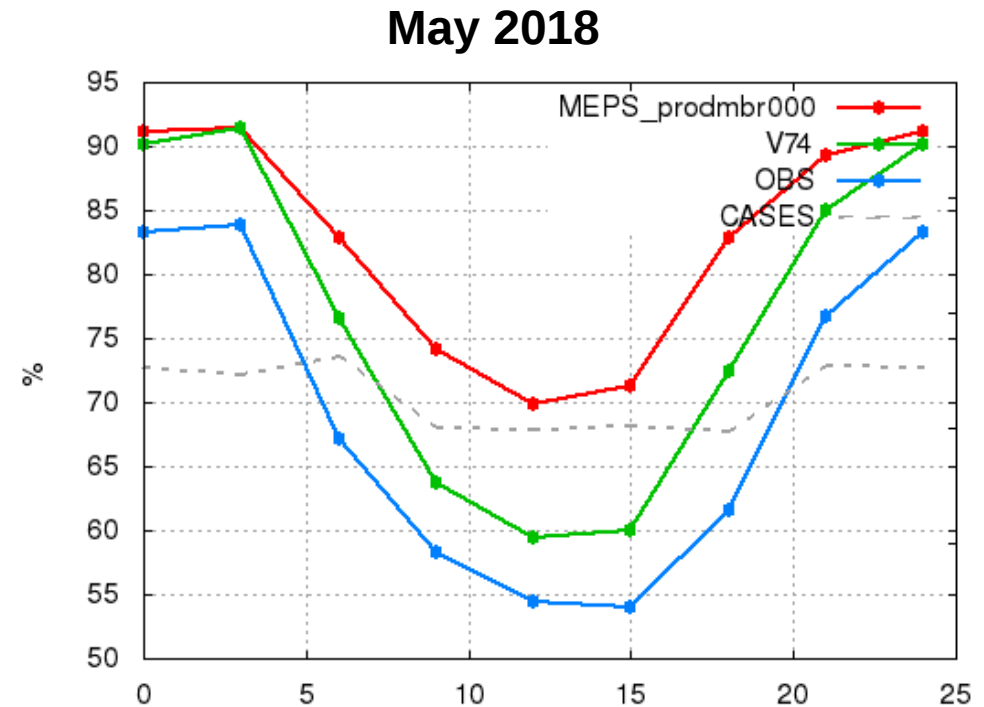
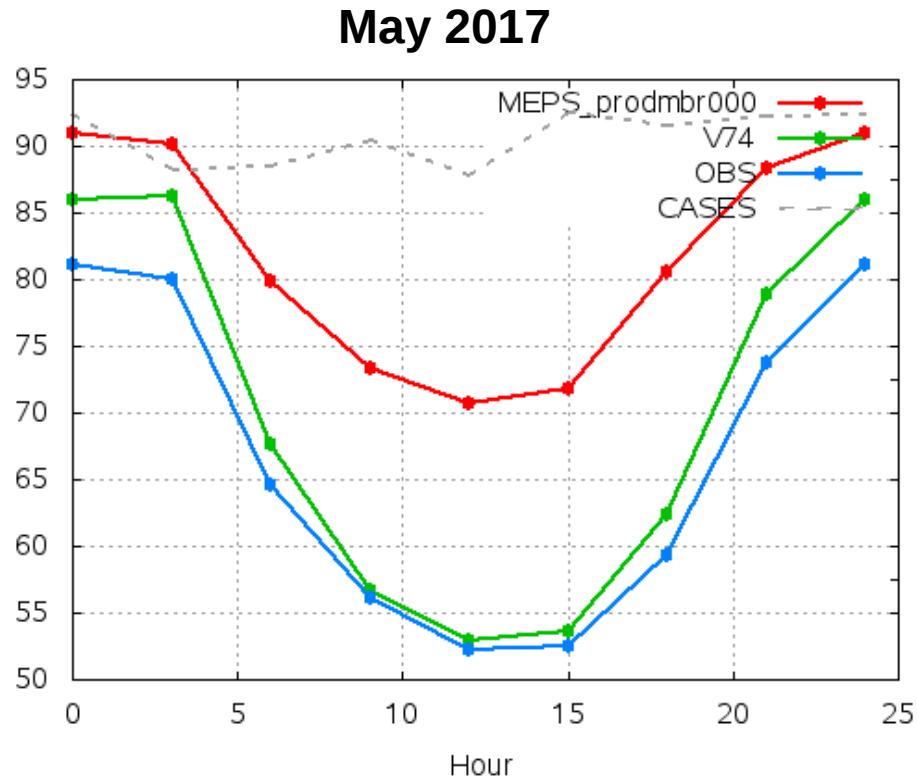
0: default
3: LAI/2
4: $R_{smin} * (1.5-3)$

Conclusion:
Worth testing
higher R_{smin}

ECO-SG
also suggests
lower LAI...

An example to motivate why we need better physics

Diurnal cycle of Rh2m over Finland for **observations**, operational **HARMONIE-AROME** and operational **HIRLAMv7.4**:

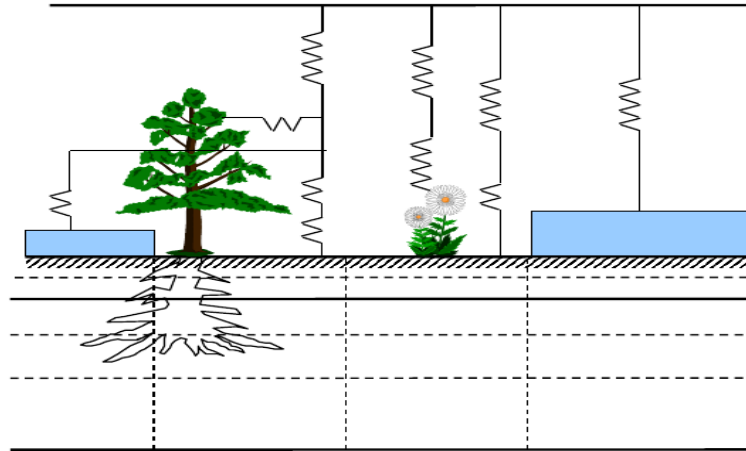


It is believed that the positive daytime bias in HARMONIE-AROME is partly due to too warm soil (due to shallow soil and short memory) which makes soil water available for transpiration. While HIRLAM still has cooler soil (longer memory) which prevents vegetation to become active.

HIRLAM - cy40 SURFEXv7.3 - cy43 SURFEXv8.1

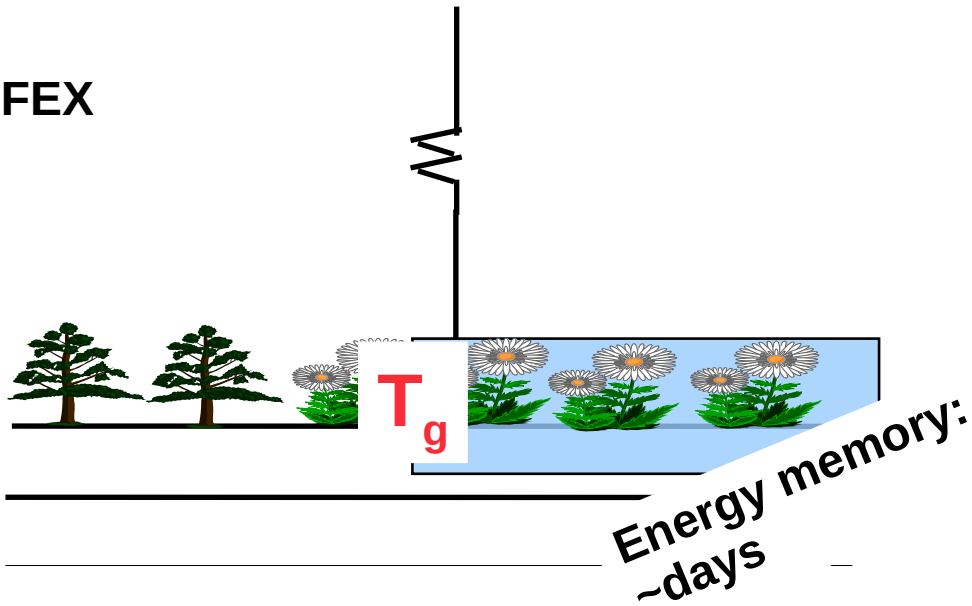
HIRLAM

Multi level/energy with OI

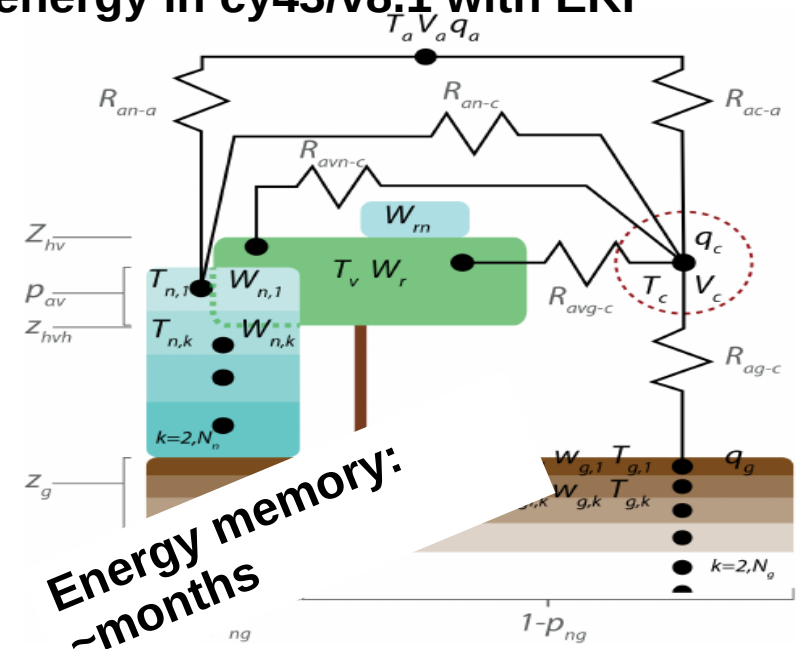


Force-restore in cy40/v7.3 with OI

SURFEX



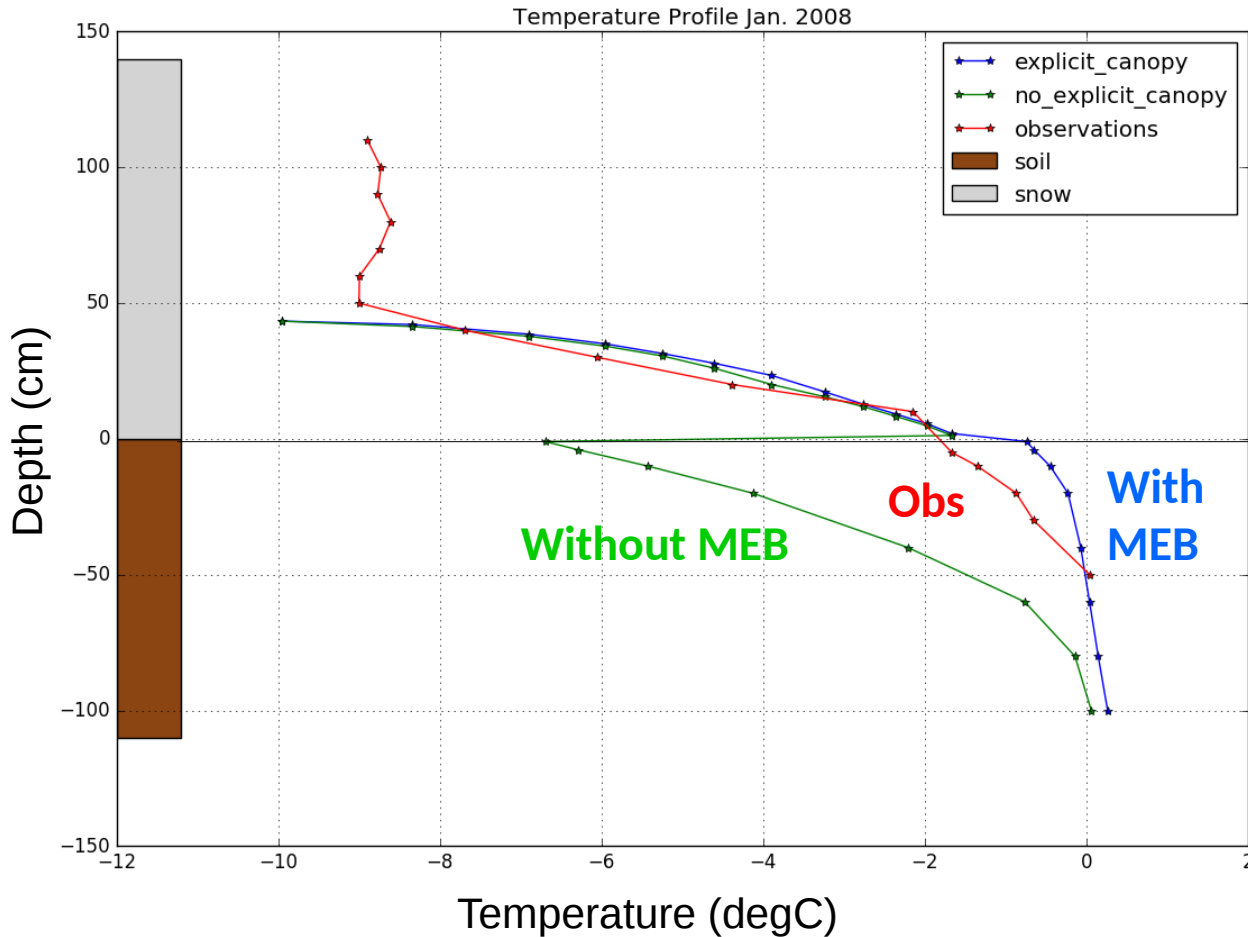
Multi level/energy in cy43/v8.1 with EKF



Why an explicit canopy (MEB) is important (in combination with snow/soil)

Simulated (offline open loop) versus observed soil-temperature profile in Sodankylä, northern Finland.
Mean temperature profile in January 2008

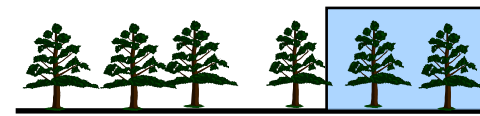
Station MET0002



Observed temperature profile

Without MEB (no_explicit)

With MEB (explicit)



<25% snow cover



>95% snow cover

When the soil is exposed during winter (without MEB) the soil column cools unrealistically. In principle data assimilation can help (although it is not the purpose of DA to cure bad physics) but it will lead to problems anyway during spring time since the soil memory is long $O(\text{months})$.

Note, same soil column below snow and for bare soil

cy43h is now tested in climate mode using DIF, Explicit, snow,...

Results shown are based on a 4-year (2014-2017) climate simulation by Samuel Viana over the Iberia domain. First year is used as spinup. Thus analysis concerns 2015-2017.

Model configuration is HARMONIE-AROME at 2.5 km resolution where upper atmosphere spectral nudging is used to constrain the large scales.

The SURFEXv8.1 settings include e.g.

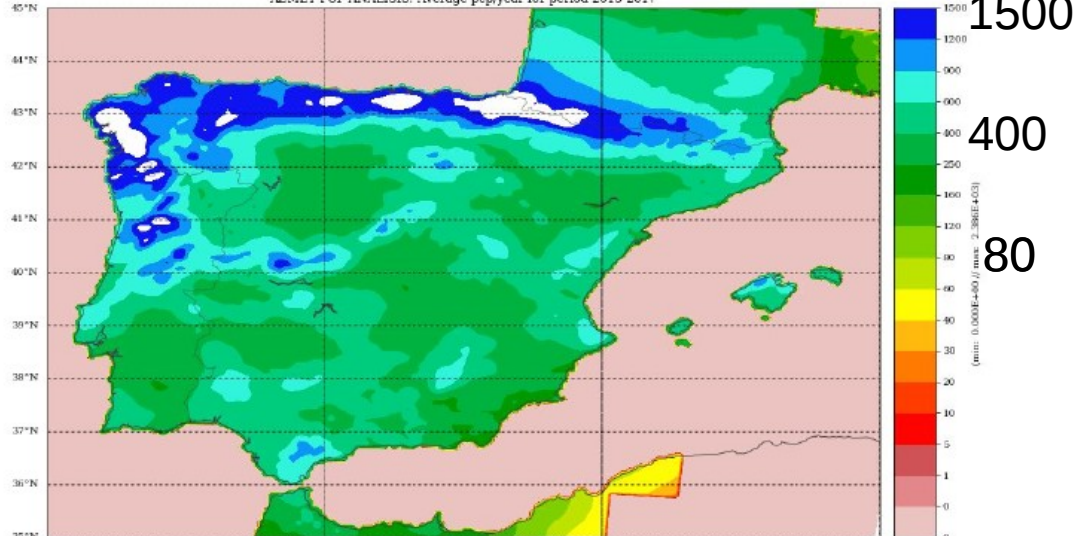
- diffusion soil scheme
- explicit snow scheme
- soil-organic carbon
- 2 patches (forest and open land)
- CM13-albedo
- Dumenill and Todini subgrid runoff
- Unfortunately no MEB yet...

cy43h is now tested in climate mode using DIF, Explicit, snow,...

Precipitation

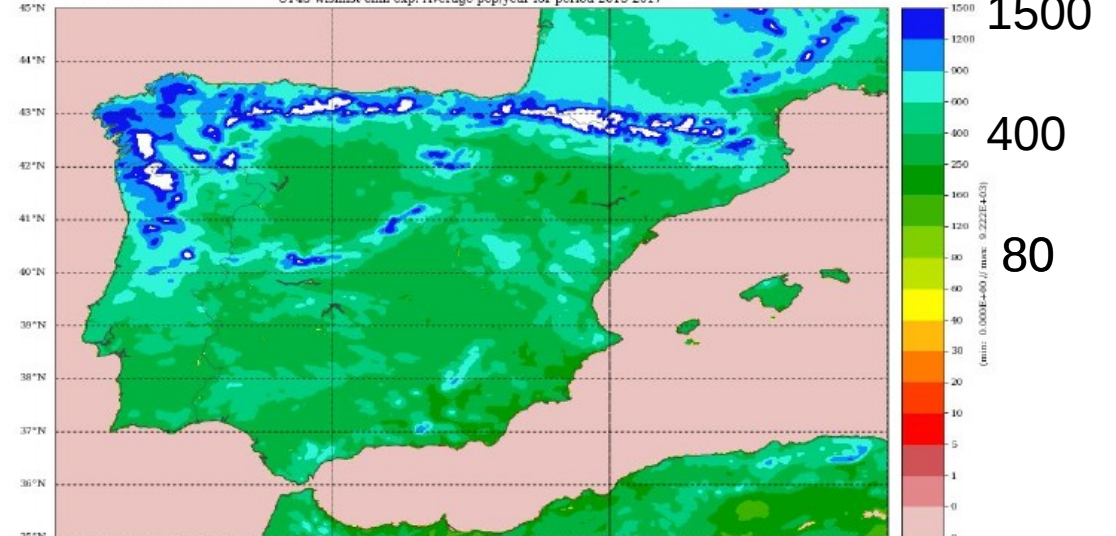
AEMET analysis

AEMET PCP ANALYSIS. Average pcp/year for period 2015-2017

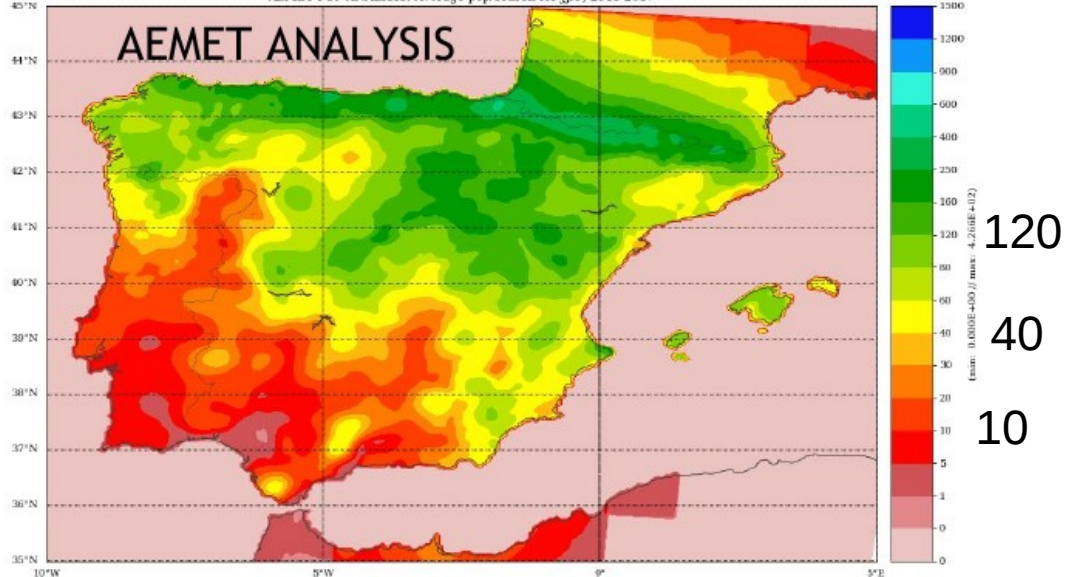


cy43h-climate

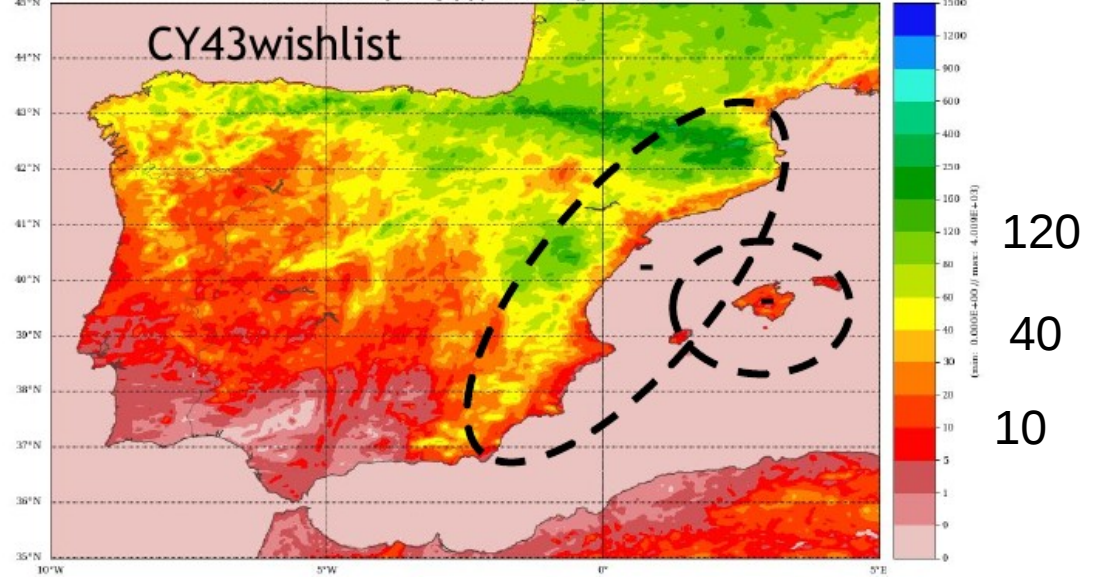
CY43 wishlist clim exp. Average pcp/year for period 2015-2017



AEMET PCP ANALYSIS. Average pcp/season for JJA, 2015-2017



CY43 wishlist clim exp. Average pcp/year for season JJA, 2015-2017



Annual mean (mm/year)

JJA (mm/3 months)

What to do with the forest column in EKF assimilation?

$$\vec{x}_a = \vec{x}_b + \mathbf{B}\mathbf{H}^T (\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1} (\vec{y} - \mathcal{H}(\vec{x}_b))$$

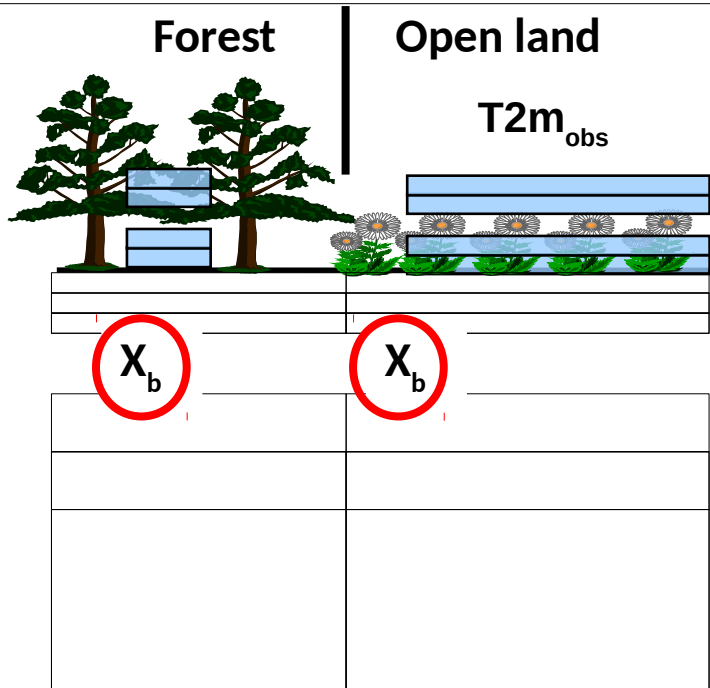
Patch dependent

T2m_{obs}
HU2m_{obs}

T2m_{grid}
HU2m_{grid}

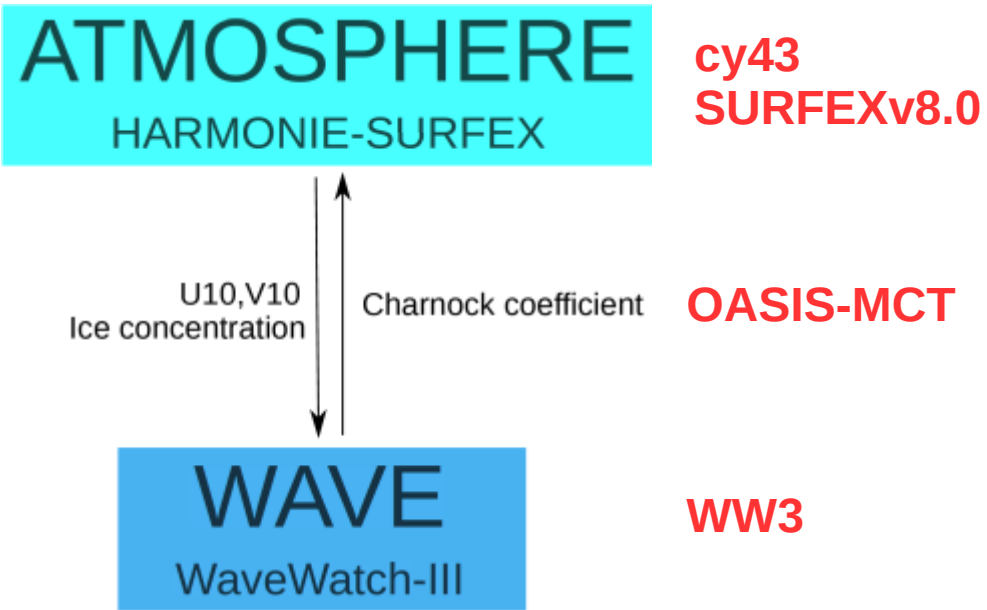
Currently patch independent.
But we have the patch info
available from SURFEX
(T2mopl)

Can the forest column drift away?
Should we nudge the forest column towards the open-land column?
Should we perform an offline surface spinup of deep variables using an analysis as forcing (MESAN)?
Use statistical correlations between open land and forest soil columns?



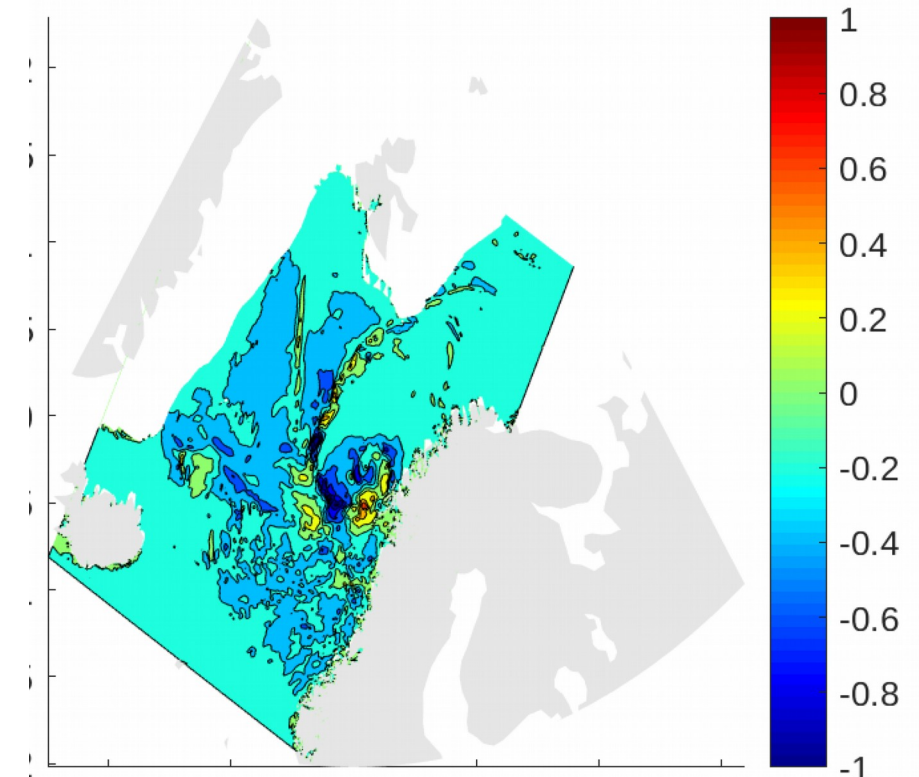
Prognostic variables	Time scale	Control variables
Tn1, SWE1, rho1	5m	Too fast
Tn6, SWE6, rho6	1M	Tn2, SWE(1-12)
Tn12, SWE12, rho12	5m	Tn4, SWE4
TG1, WG1	5m	Too fast
TG2, WG2	10m	TG2, WG2
TG4, WG4	4D	TG3, WG3
		TG4, WG4
TG8, WG8	6M	Too slow
TG14	5Y	Too slow

Sea wave modelling by Lichuan Wu, SMHI



- HARMONIE-AROME and WW3 has the same domain with same grid information. The boundary data for WW3 are from the WAM global run in ECMWF.
- HARMONIE-AROME and WW3 exchange information every 10 min through OASIS-MCT.

Test on a polar-low system between Norway and Iceland:
Difference in wave height (m), coupled – non-coupled, atmosphere-wave model



With support from Slovenia team, Météo-France team, Norwegian team



THANKS!