Causes of systematic errors in forecasts of near-surface weather parameters and prospects for reducing them

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& many ECMWF colleagues

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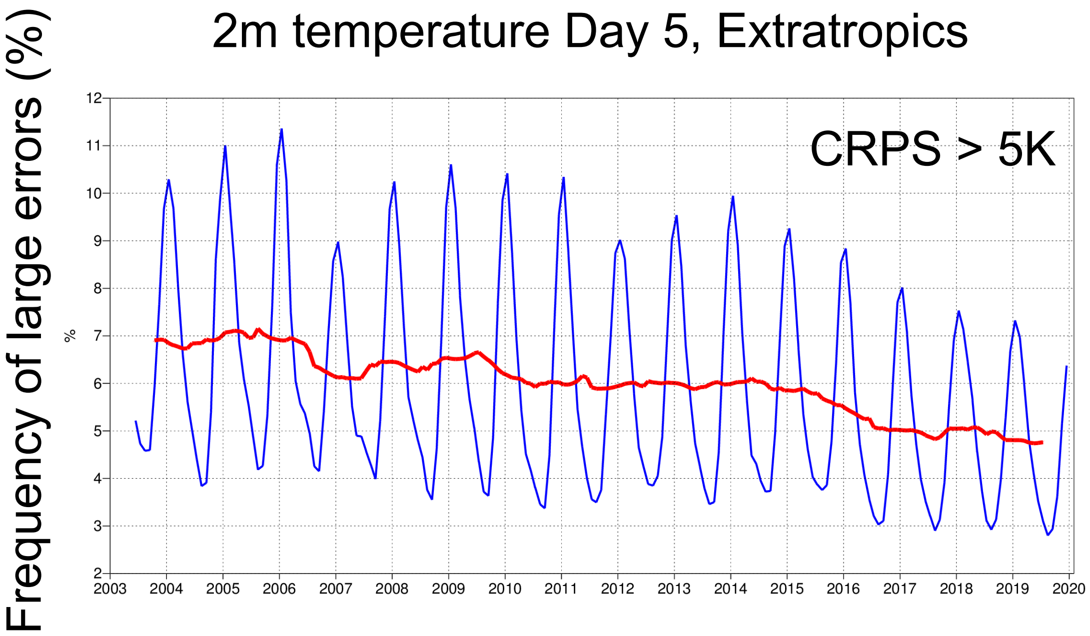
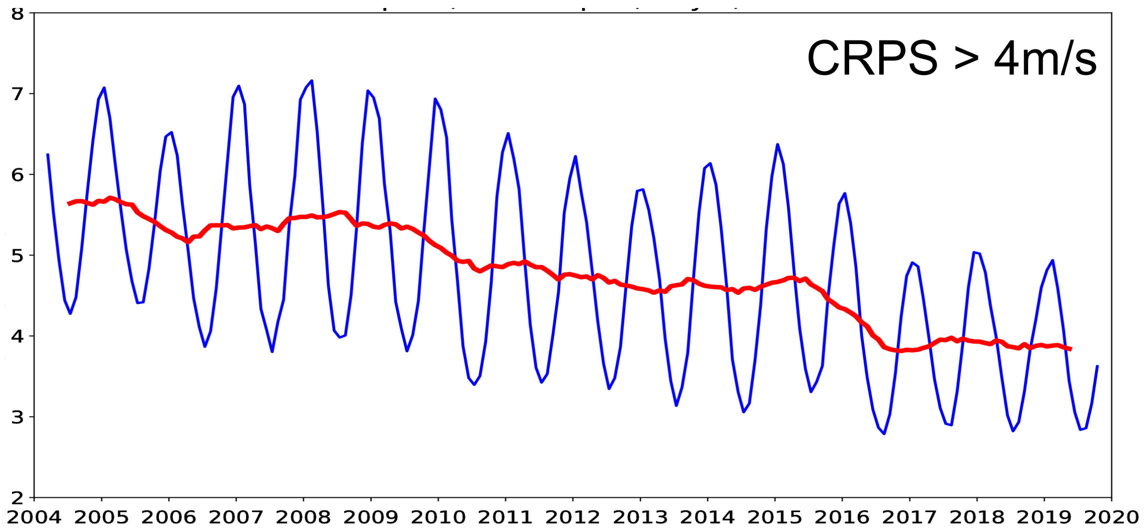
Systematic improvements of forecasts of near-surface weather parameters

2m temperature Day 5, Extratropics



10 wind speed Day 5, Extratropics



Forecasts of near-surface weather parameters (temperature, humidity, winds) are gradually improving, alongside upper-air forecasts due to improvements in NWP systems (see for e.g. Haiden et al. (2019))

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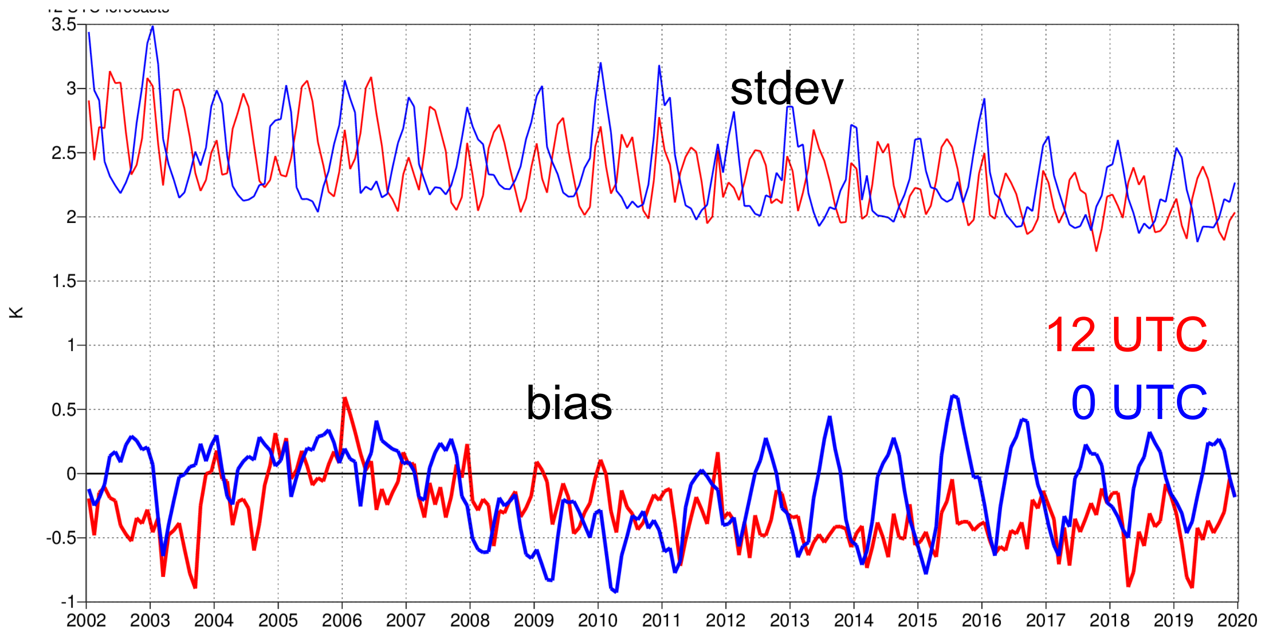
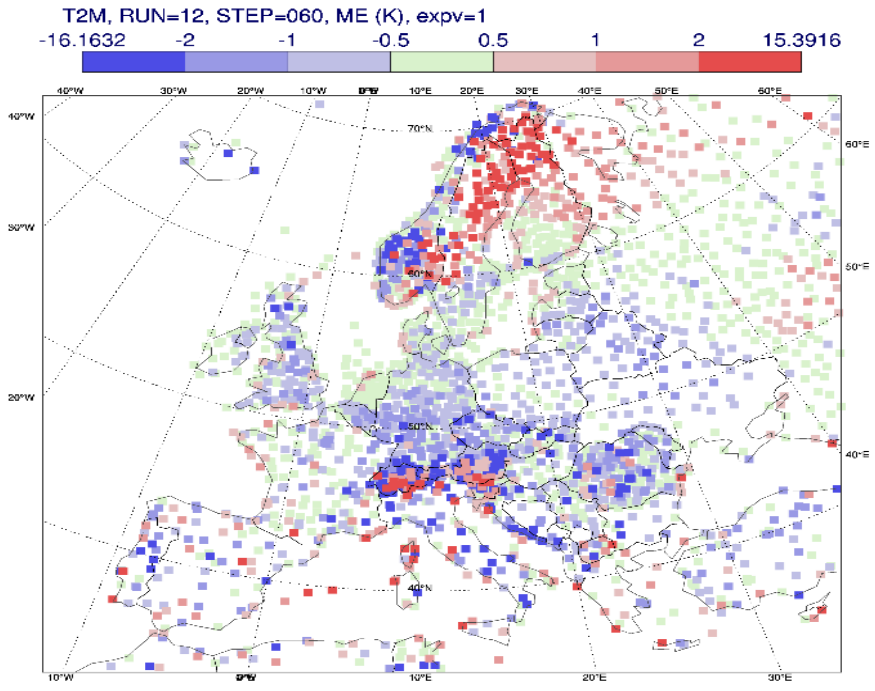
But systematic forecast biases remain for all modelling systems (see recent WGNE survey, Reynolds et al. 2019)

2m temperature bias and stdev, day 3, Europe



2m temperature bias, day 3, winter, 0 UTC Europe



… with complicated temporal (diurnal, seasonal) and geographical patterns

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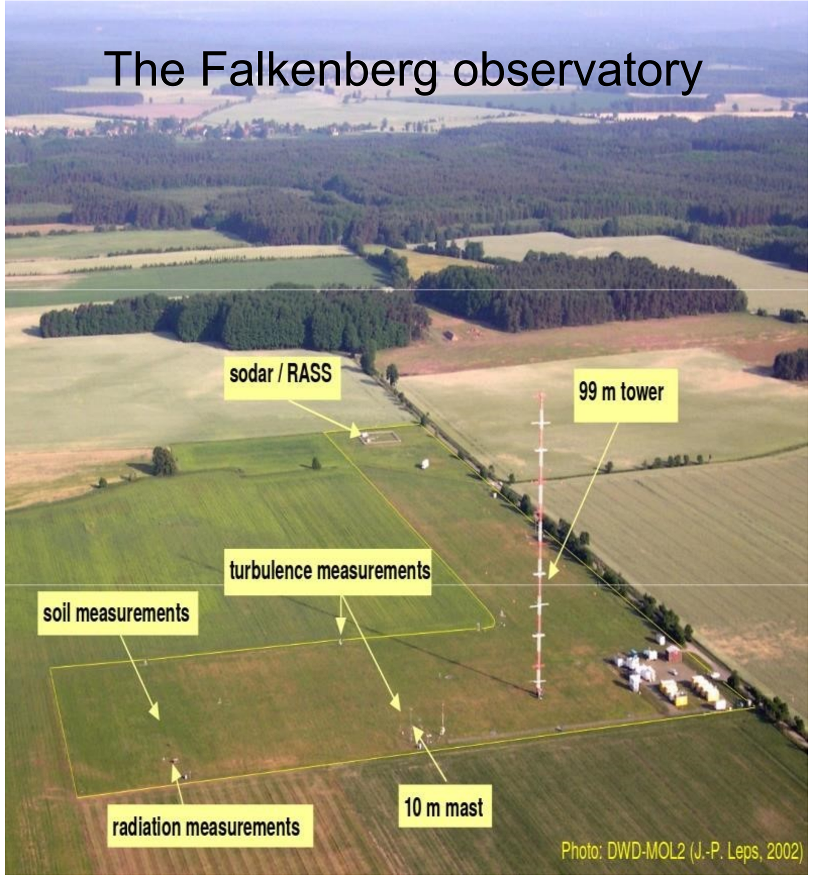
USURF – Understanding uncertainties in surface-atmosphere exchange

Cross-departmental ECMWF project (2017-2019) aiming at:

- disentangling the contribution of individual processes to systematic forecast errors in near-surface weather parameters by using a range of diagnostics for stratifying and attributing errors
- identify the necessary model developments to reduce systematic forecast errors in near-surface weather parameters

Guiding principles & methods

- start simple (focus on areas away from coasts, mountains)
- verify against routine (synop) observations
- develop routine verification versus super-site observations
- use conditional verification (stratify errors in various ways: cloudy/clear, by land surface characteristics, etc)
- use model sensitivity experiments (to disentangle role of atmospheric and land surface processes)



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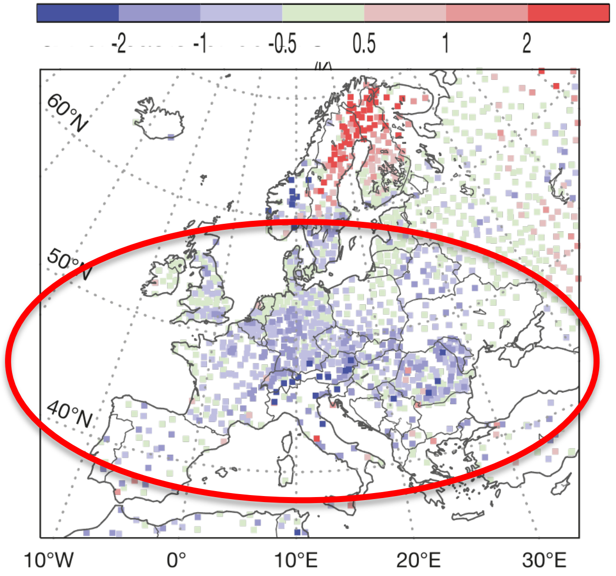
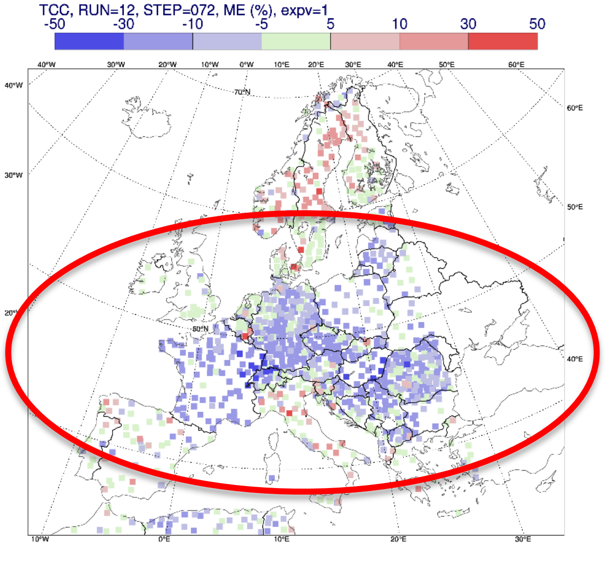
1. Causes of near-surface wintertime temperature biases

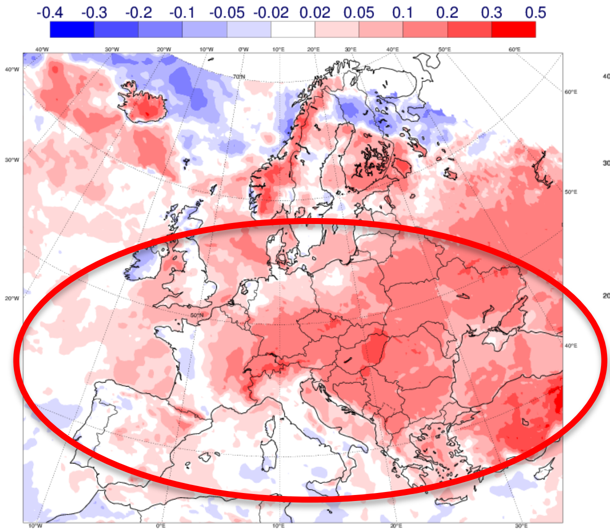
2m temperature bias (synops)



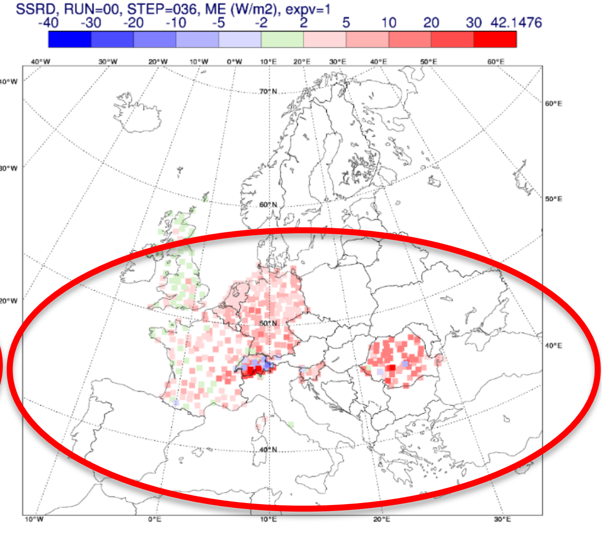
Cloud cover bias (synops)



Shortwave radiation downwelling (CM SAF)



Shortwave radiation downwelling (synops)



Cold bias over southern Europe partly related to cloud errors (approx. 5% underestimation of cloud cover)

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Haiden et al, ECMWF newsletter, 157

1. Causes of near-surface wintertime temperature biases

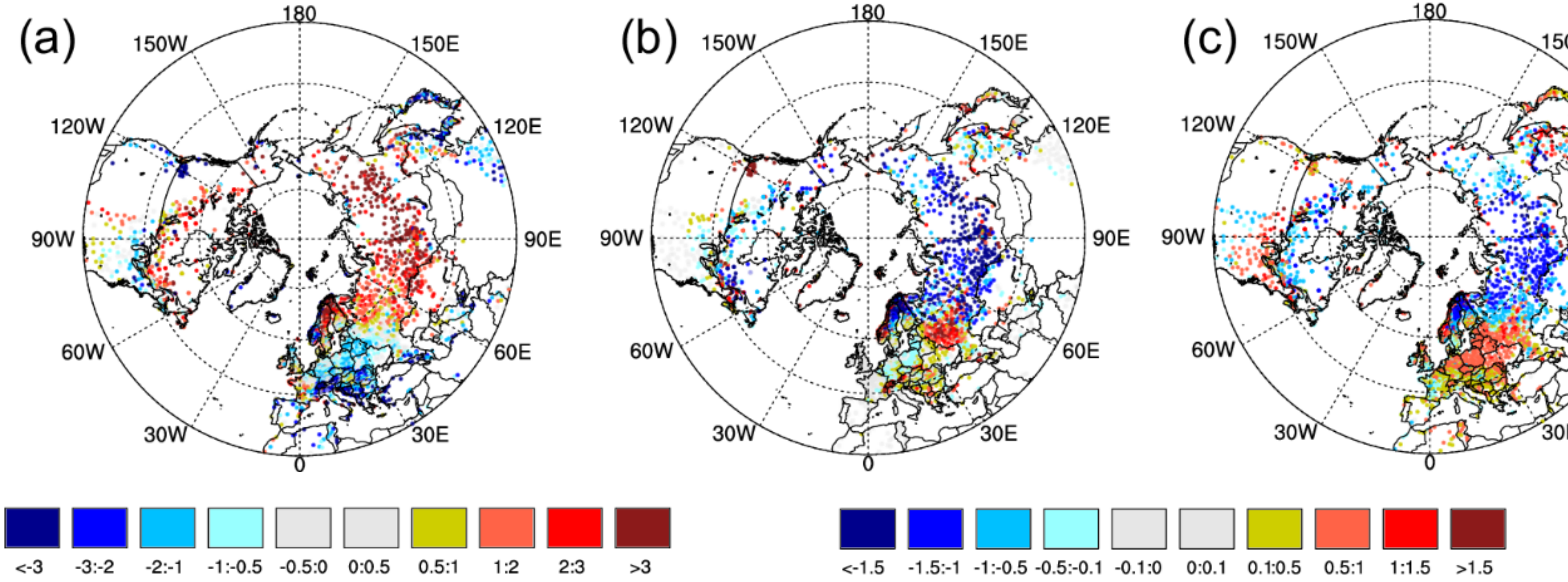
APPLICATE.eu
Advanced prediction in polar regions and beyond

Tmin bias

Change in absolute Tmin bias

Multi-layer vs single-layer snow

low vs high turbulent diffusion in stable conditions



Warm bias at high latitudes warm bias partly related to snow and turbulent diffusion representation

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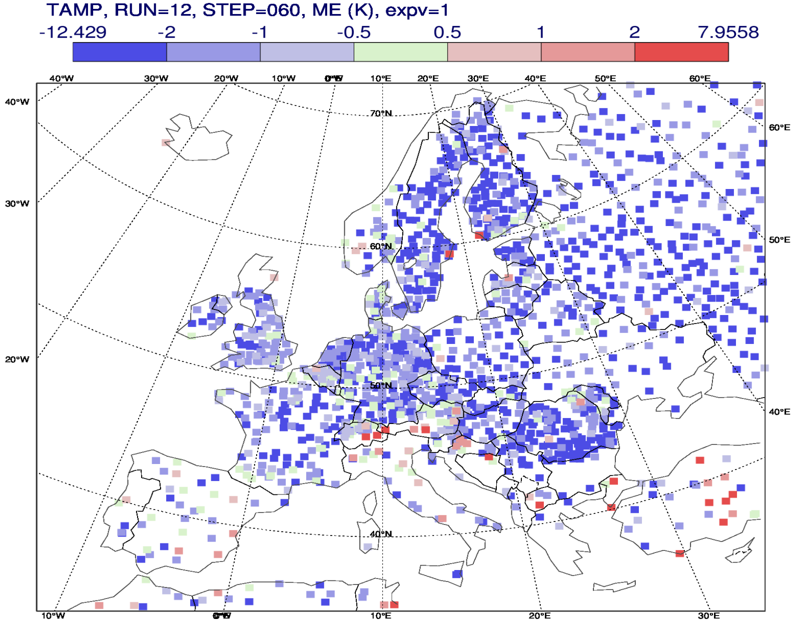
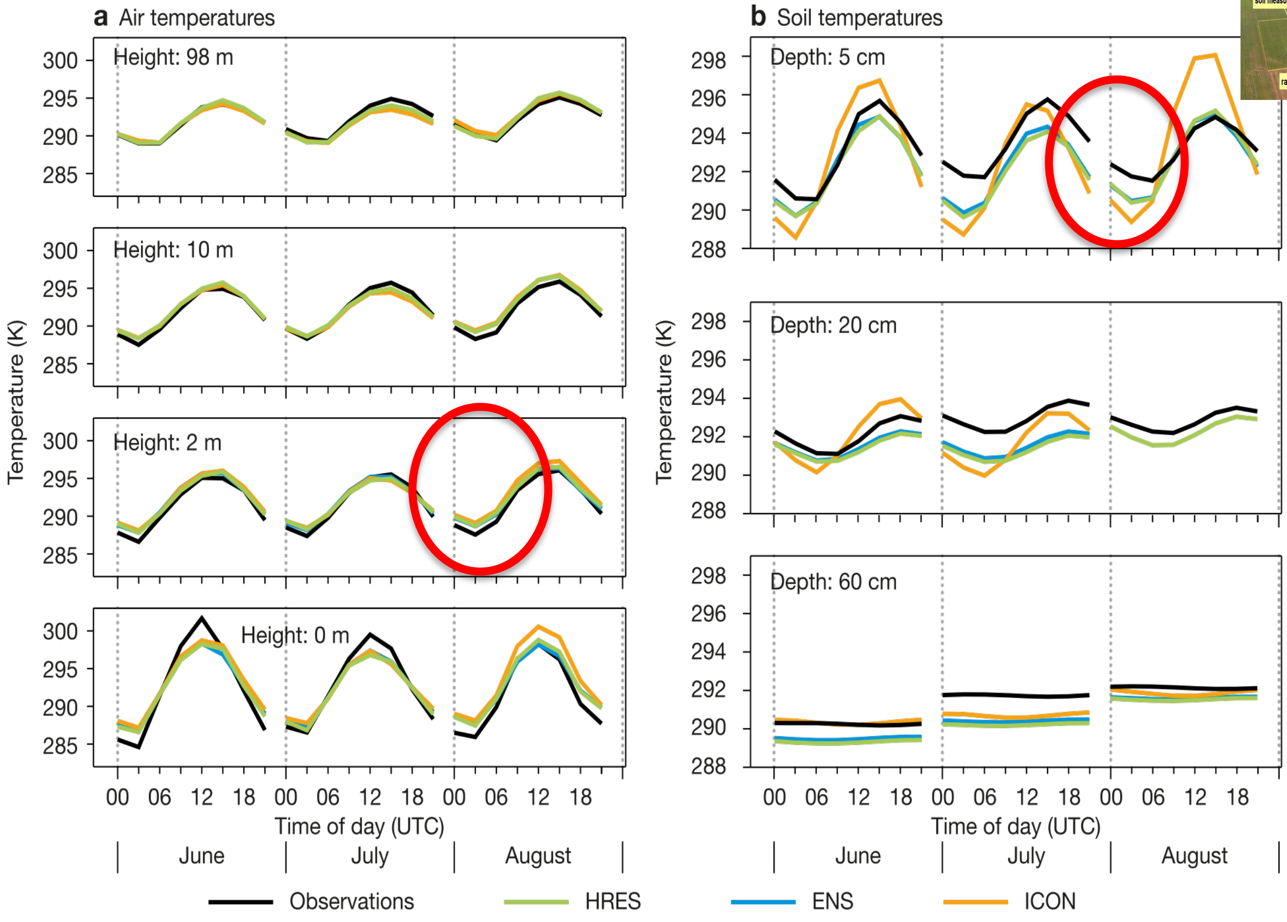
Arduini et al., JAMES, 2019, Day et al., JAMES, 2020

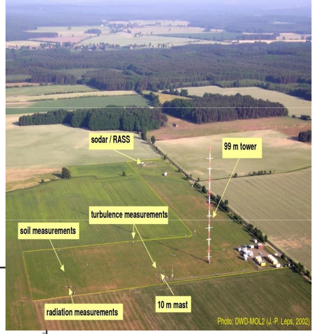
2. Causes of underestimation of diurnal cycle amplitude in summer

underestimation of diurnal cycle amplitude for 2m temperature



Falkenberg evaluation for temperature





OBS
HRES
ENS
ICON

Partially due to too strong land-atmosphere coupling, but representation of vegetation, surface characteristics, etc, can also play a role

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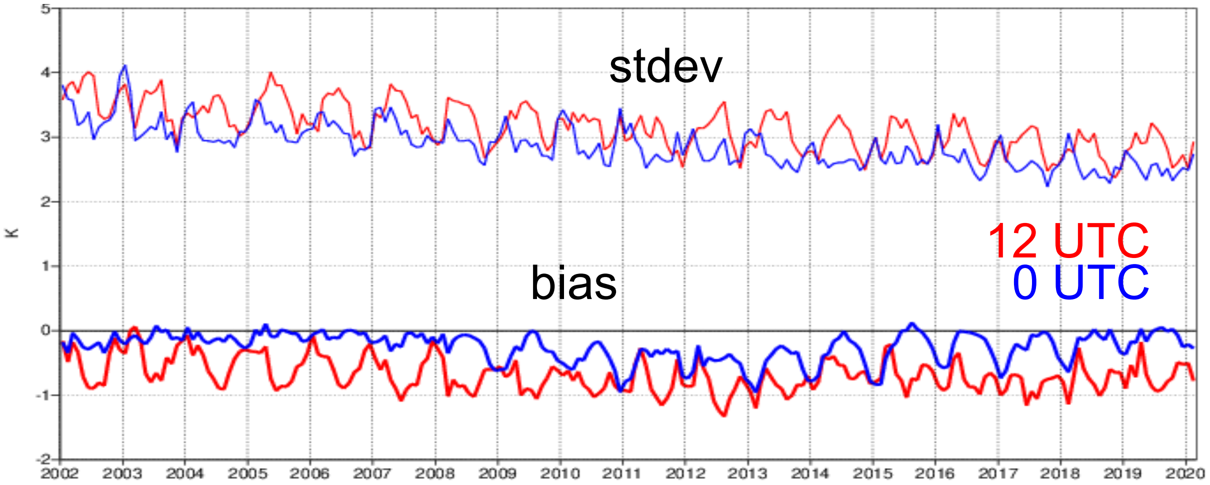
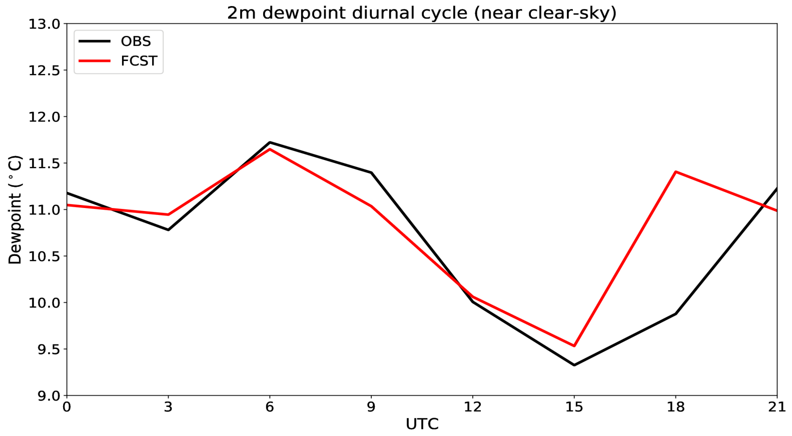
Schmederer et al, ECMWF newsletter, 161

3. Causes of dry summer daytime bias

2m dew point bias and stdev, day 3, Europe

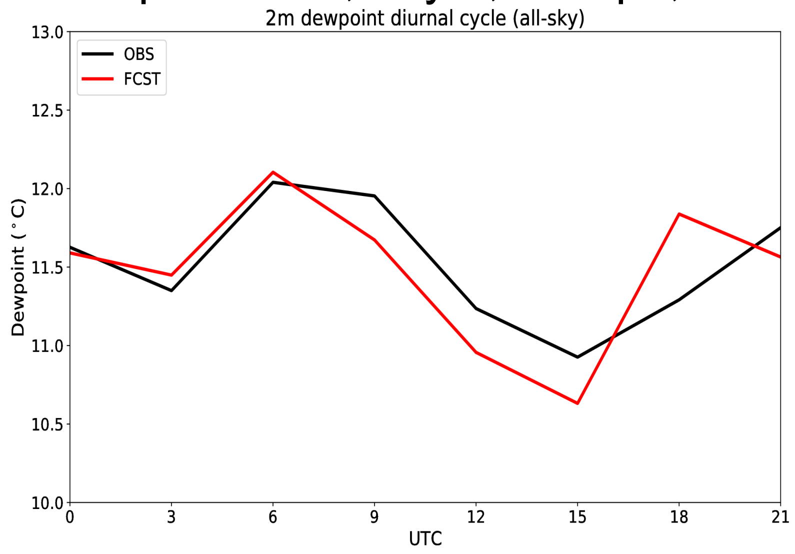


2m dew point bias, day 3, Europe, clear sky



OBS
HRES

2m dew point bias, day 3, Europe, all sky



Partially related to mixing in cloudy (convective) boundary layers

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4. Important to take into account observation representativness

summer day 4

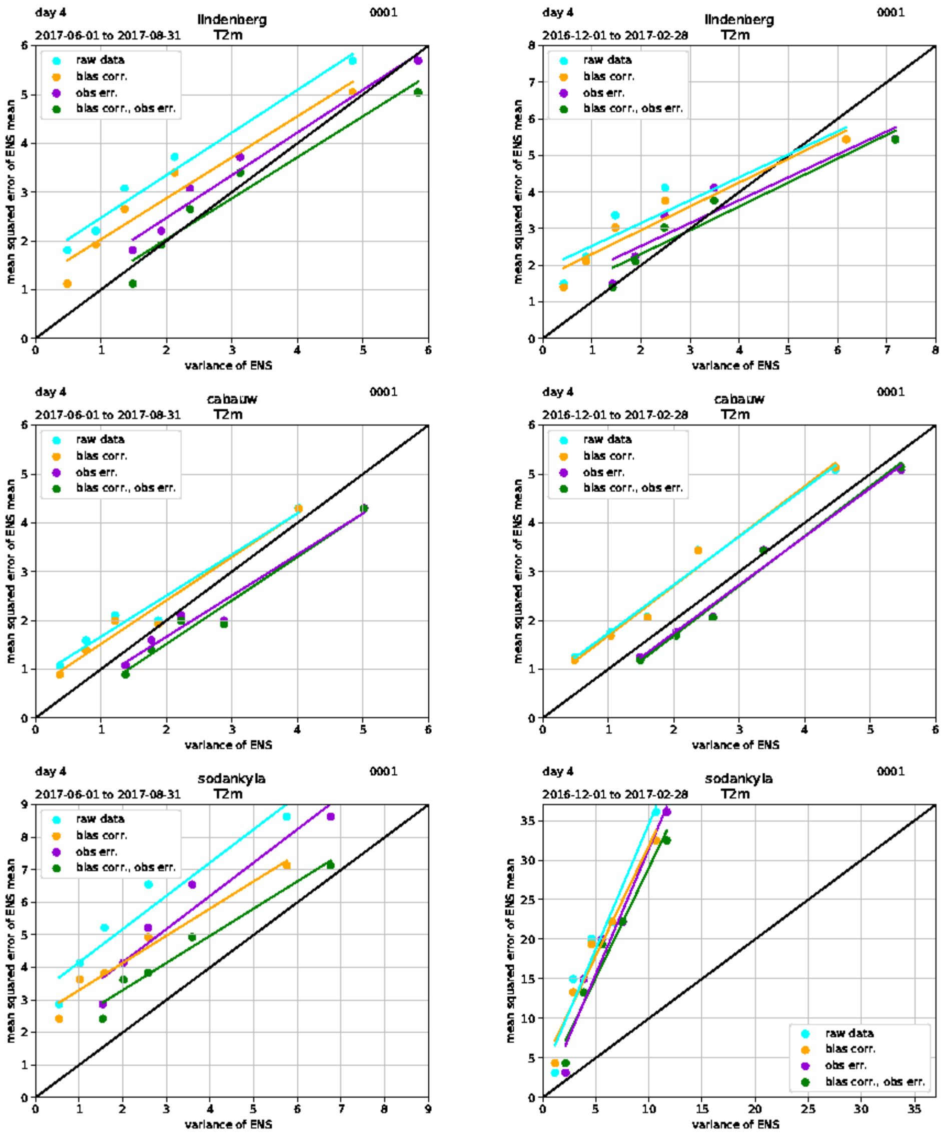
winter day 4

Falkenberg

Cabauw

Sodankyla

Mean squared error of ENS mean



Variance of ENS

Raw data
Bias corr.
Obs. Err
Bias corr + obs err

Schmederer et al, ECMWF newsletter, 161
Boullegue et al, 2020

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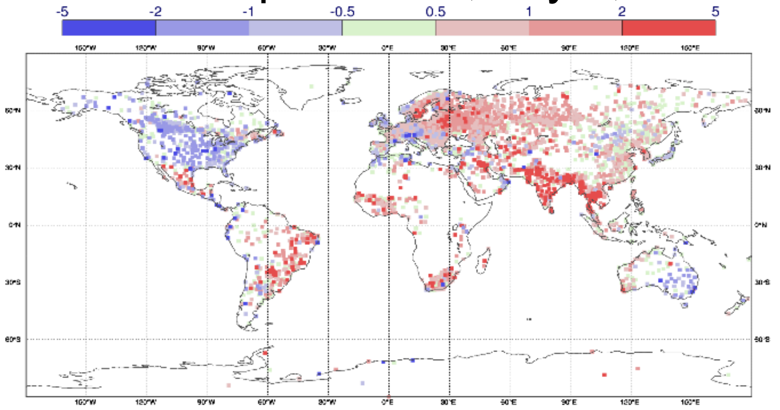
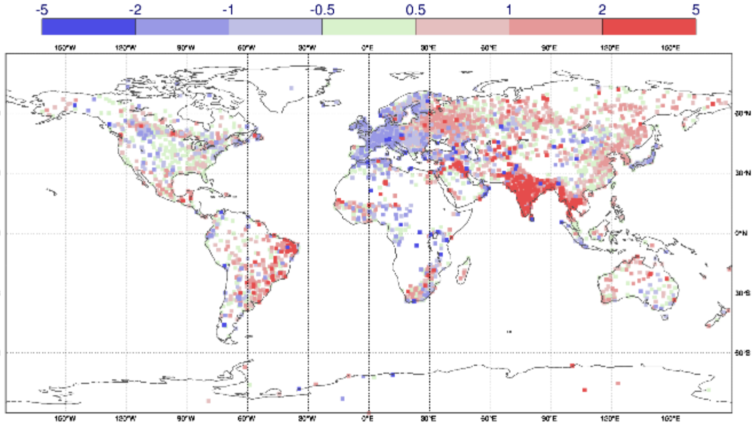
5. Wind errors (summertime)

10m wind speed bias, day 3, 00 UTC



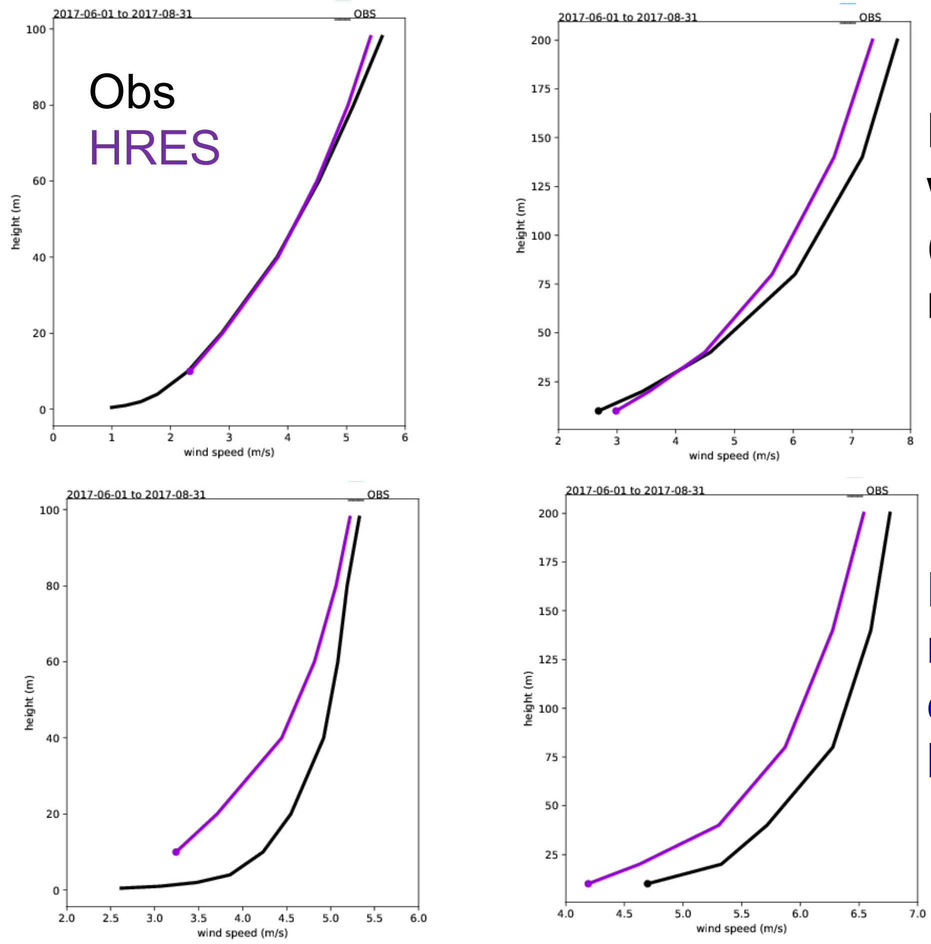
10 m wind speed bias, day 3, 12 UTC



10 m wind speed depends on the quality of the underlying vegetation maps

Falkenberg

Cabauw



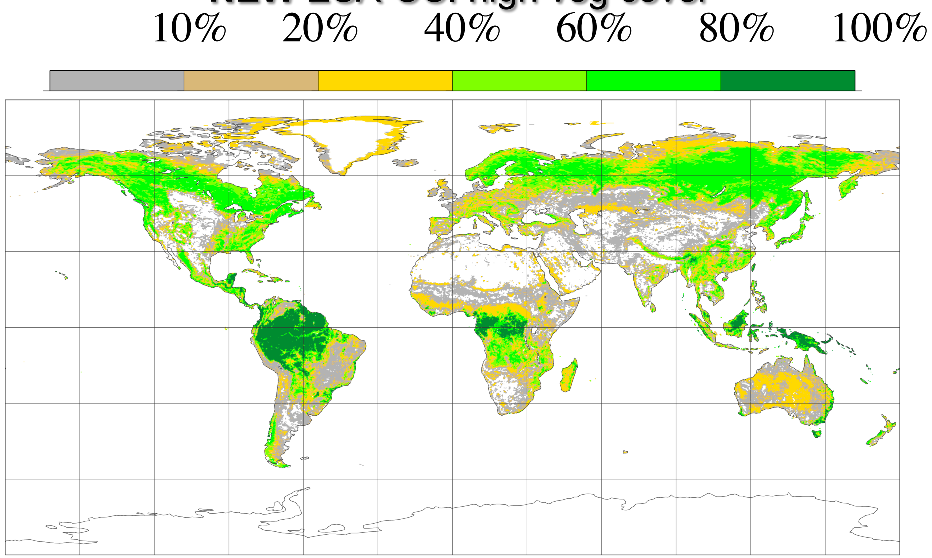
Nightime low-level winds have improved (Sandu et al, ECMWF newsletter, 138)

Daytime biases partially related to mixing in cloudy (convective) boundary layers

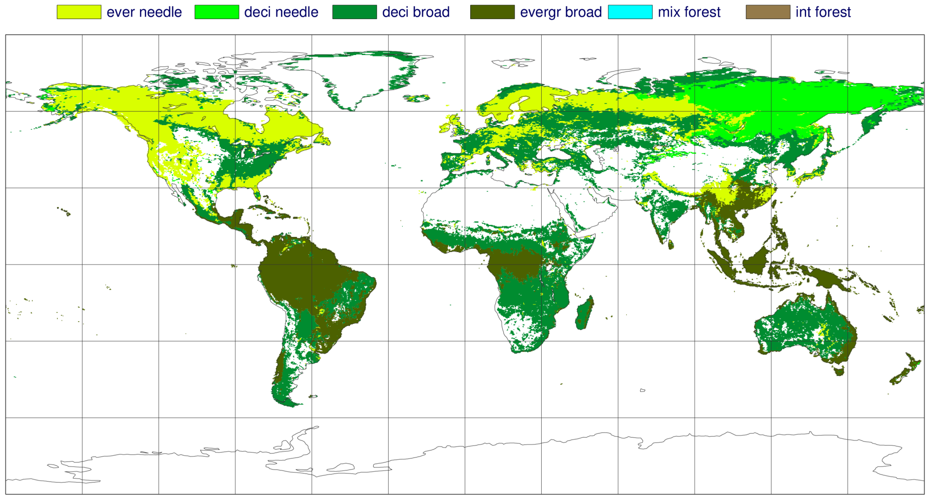
Perspectives of a new land-use for calibrating weather parameters

Land Use: Vegetation cover & Vegetation types & Statistics

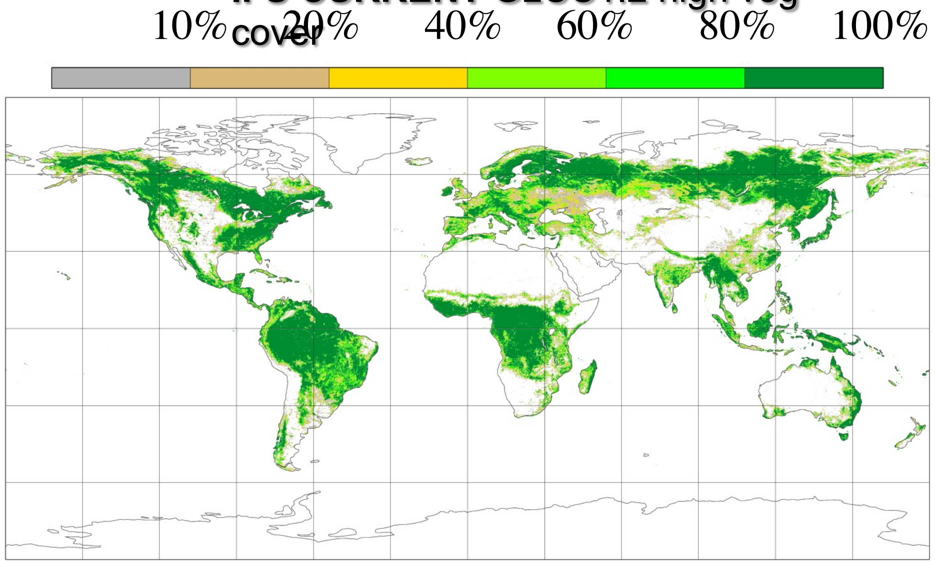
NEW ESA-CCI high veg cover



NEW ESA-CCI high veg type



IFS CURRENT GLCC1.2 high veg cover



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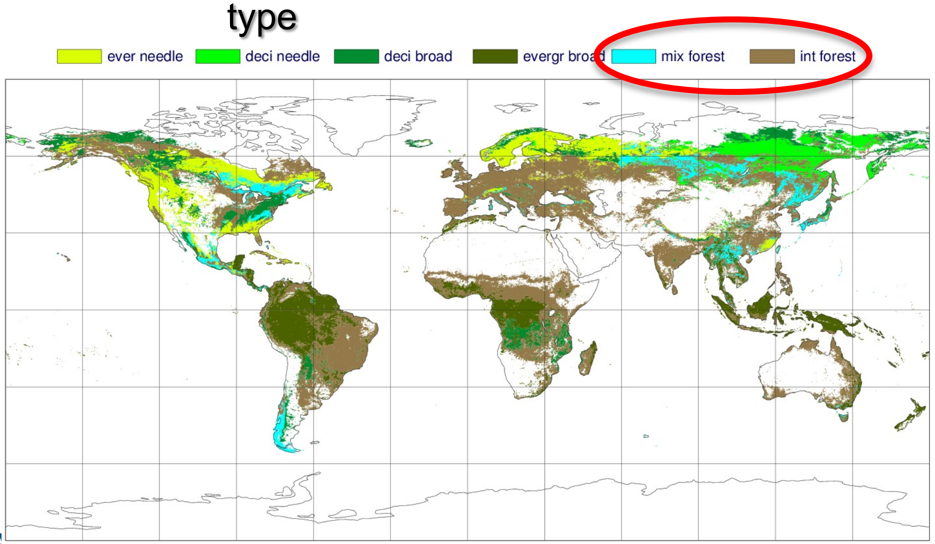

Index	Vegetation type	Percentage of land points	
		ESA-CCI	GLCC1.2
	Low vegetation		
1	crops	23.50%	18.00%
2	sh grass	38.70%	9.00%
7	ta grass	0.00%	12.80%
9	tundra	0.70%	6.00%
10	irr crops	1.90%	3.90%
11	semidesert	0.00%	11.60%
13	bog/marsh	0.00%	1.50%
16	ever shrub	5.10%	1.20%
17	deci shrub	4.70%	3.90%
	Remaining points	25.00%	31.40%
	High Vegetation		
3	ever needle	11.70%	5.40%
4	deci needle	4.70%	2.50%
5	deci broad	29.50%	5.60%
6	ever broad	18.20%	12.90%
18	mix forest	0.00%	3.00%
19	int forest	0.00%	24.70%
	Remaining points	35.60%	45.50%

Sandu et al. (2012) large reduction in wind speed error with land-use calibrated z_0 but Interrupted forest type was a clear limitation for calibration

Prospects for reducing systematic biases

These issues are relevant to other forecasting systems so a lot of work will be done in partnership with colleagues from our Member States

Taking observation (representativness) error into account is very important in particular for ensemble verification

These biases depend on a multitude of factors, so ‘package’ changes are needed, instead of individual changes

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Ongoing work and future plans:

- multi-layer snow scheme (developed in APPLICATE, planned for implementation in Bologna) – will reduce wintertime temperature and snow biases (Arduini et al, 2019, Day et al, 2020)
- Vegetation maps (with Meteo-France & IPMA) and vegetation seasonality – can help reduce summertime and transition seasons biases in near-surface temperature, dew point and winds – optimisation of uncertain parameters will be needed
- Revision of moist physics (planned for implementation in Bologna) – cleaner interaction between turbulence, cloud and convection schemes helps address cloud, precipitation, radiation and potentially dew point biases
- Partition of mixing between clear and cloudy updrafts (with TU Delft) - can help with wind and dew point biases in summer time
- Revision of post-processing of 2t/2d (grid-box average instead of low vegetation category)