Experiments with roughness length & ECOCLIMAP-SG (in Harmonie-Arome)

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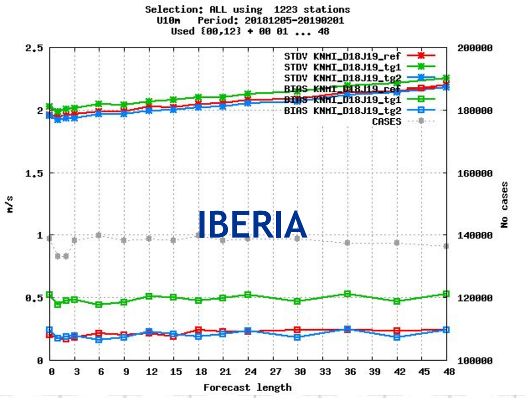
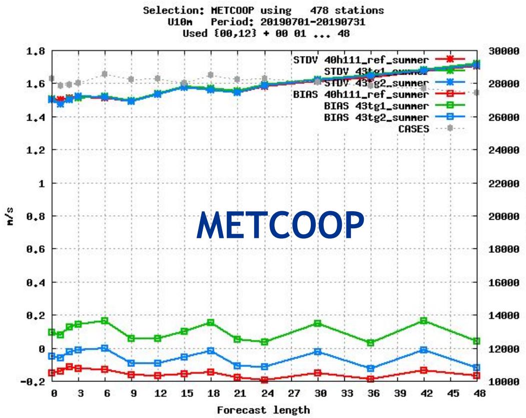
Outline

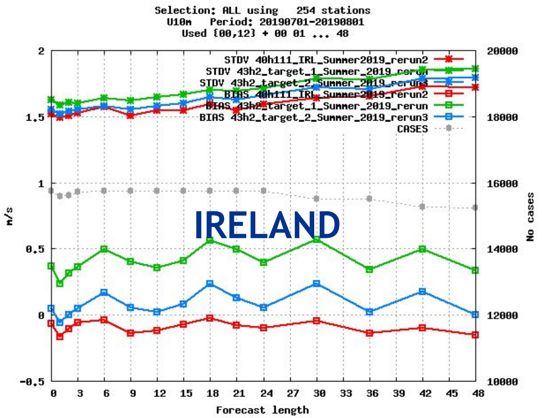
- Context: ECOCLIMAP-SG in cy43h2.1 validation tests
- Roughness length in SURFEX
- Impact of ECOCLIMAP-SG in roughness length
- Strategies to improve sfc wind speed in cy43h:
    - Tuning z_0 for crops & grasslands
    - Raupach's formulation (z_0 + displacement height)
- Conclusions & final remarks

Context: ECOCLIMAP-SG in cy43h2.1 validation tests:

- ECOCLIMAP-SG (**ECO-SG**) is the new land cover map and database of surface parameters for SURFEX: 33 land cover types, 330m resolution, three times finer than ECOCLIMAP2 (**ECO-II**) (*)
- It has been largely tested in cy43's "**target1**" experiments for cy43h2.1
- With the exception of surface wind speed, in general verification of **target1** is better than **target2** (which still uses **ECO-II**).
- For U10m, all domains show an increase in wind bias (wrt **ECO-II**).



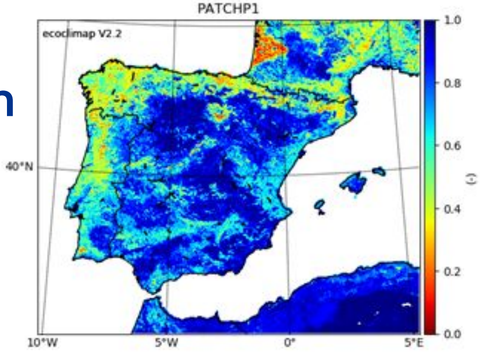


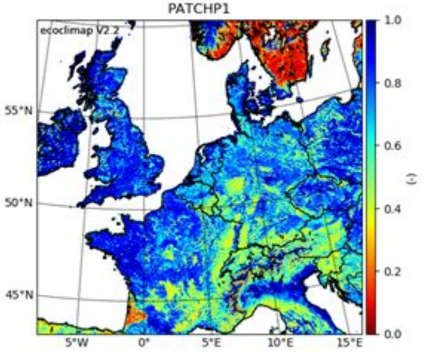


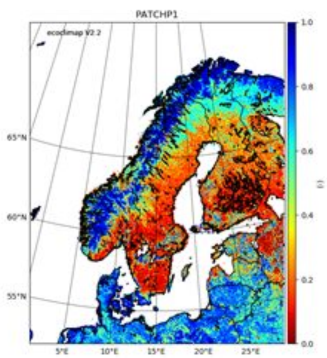
(*) More details in Aladin-Hirlam Newsletter Nº14:"HIRLAM experience with ECOCLIMAP Second Generation"

- Starting in cy40h1.1.1, SURFEX in Harmonie runs with **two patches** on the nature tile (grouping different veg. types, P1=open land, P2=forest).
- SFC fluxes are evaluated separately for each patch (different z_0, drag coeffs., etc); then averaged & used to force the atmospheric model.
- The fractions of open land / forest patches has changed a lot in ECO-SG:

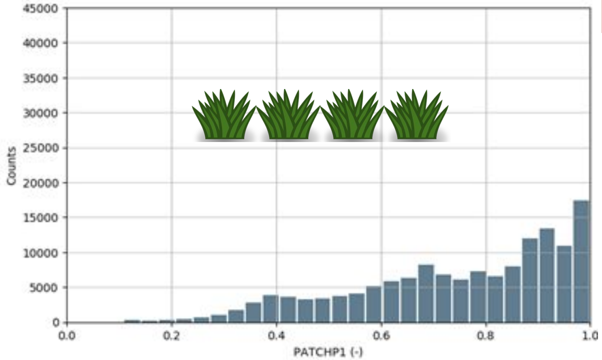
Fraction of PATCH1

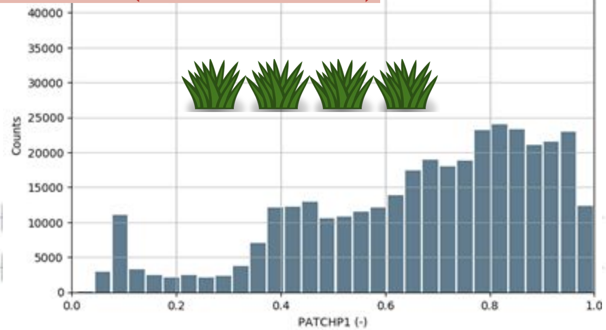


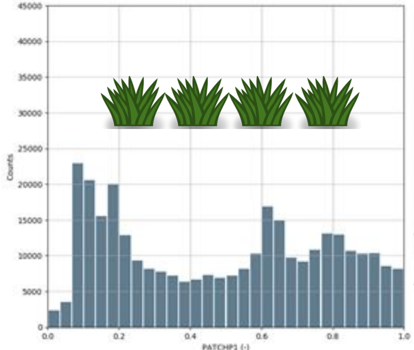




ECO-II (TARGET 2)







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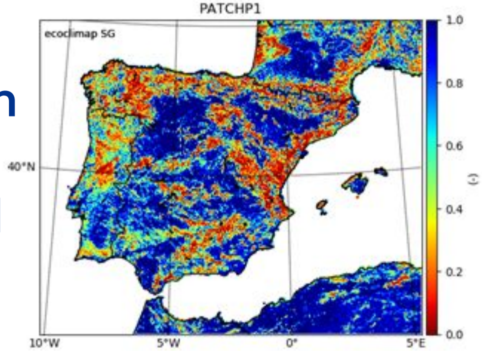
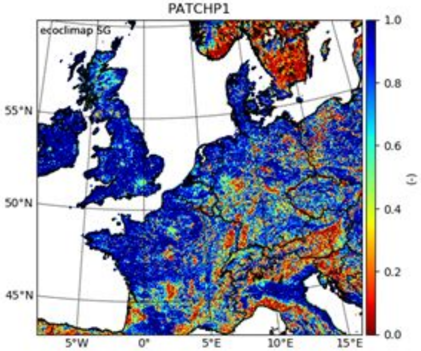
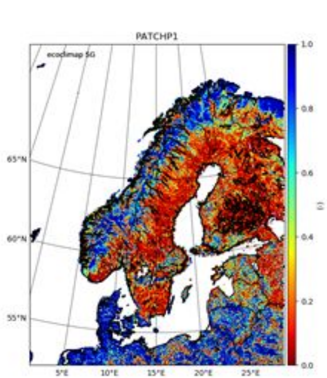
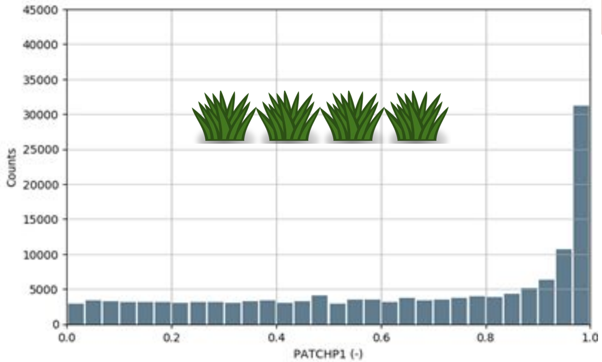
Fraction of PATCH1

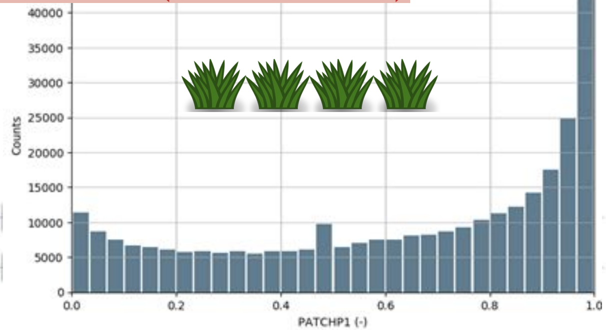


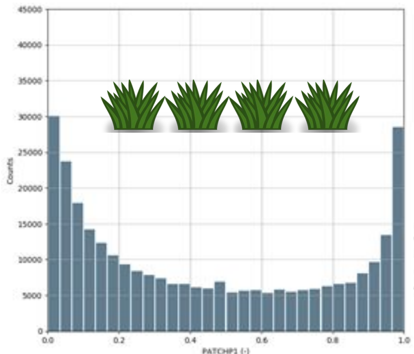




ECO-SG (TARGET 1)







U10m bias in target 1 is larger where PATCH1 (low veg.) is dominant

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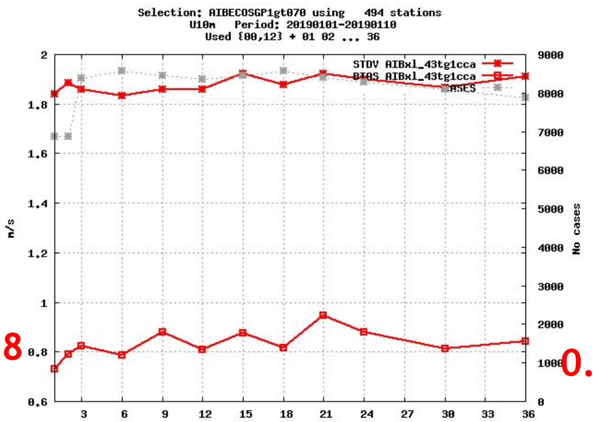
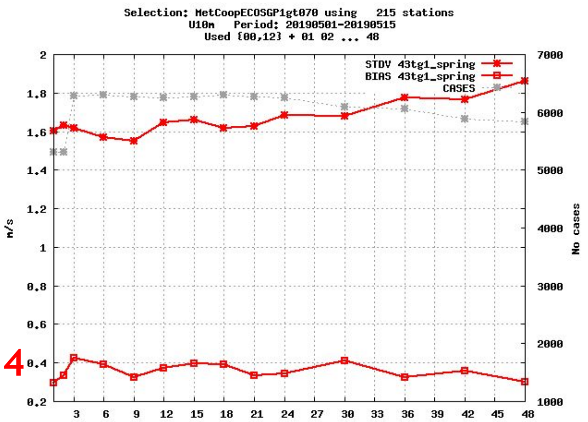
PATCH1>0.7

0.8

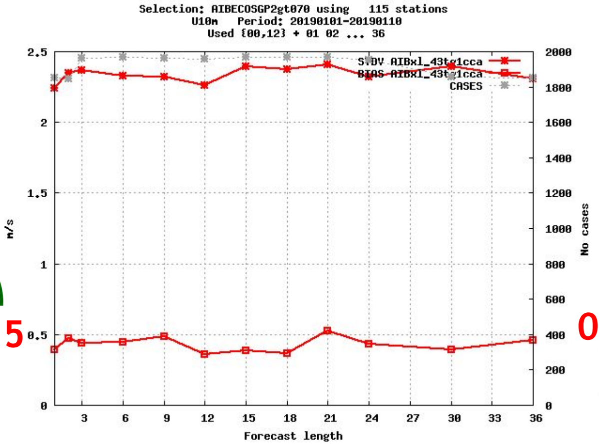


0.4

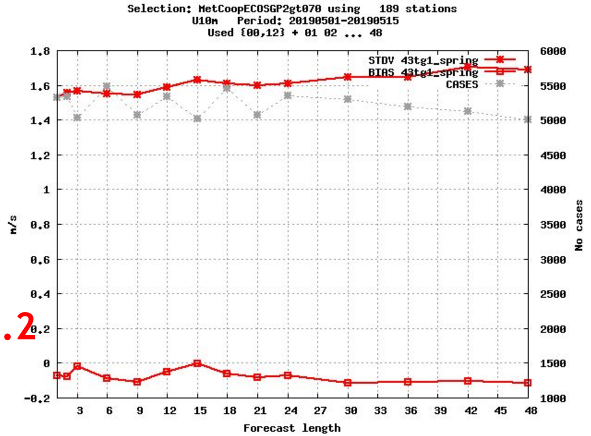


PATCH2>0.7

0.5



0.2



Roughness length in SURFEX/cy43h:

$z_0 = 0.13 * h$

Patch 1: 
h

Patch2: 
h

Grasslands

$z_0 = 0.13 * LAI/6$

Crops

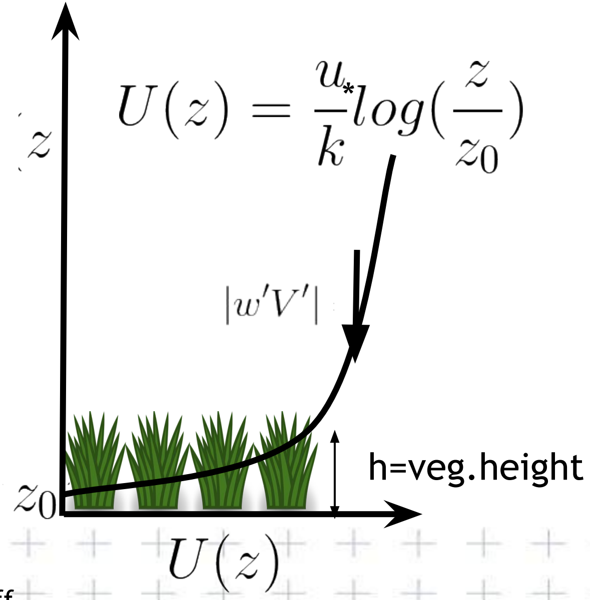
$z_0 = 0.13 * \min(1.0, \exp([LAI-3.5]/1.3)$

$z_0 = \min(0.13 * Tree\_height, 1.6m)$

$z_{0P1} \sim 0.1m$

$z_{0P2} \sim 1m$

$$|w'V'| = C_D |V_a|^2 = \frac{k^2}{[ln(z/z_0)]^2} |V_a|^2$$



Effective roughness length: Logarithmic areal averaging

$$\frac{1}{[ln(10/z_{0_{eff}})]^2} = \frac{P1}{[ln(10/z_{0_{P1}})]^2} + \frac{P2}{[ln(10/z_{0_{P2}})]^2}$$

$z_{0P2} \sim 10 * z_{0P1}$ ⇒ Changes in z_{0P1} have more impact in z_{0eff}

Roughness length in SURFEX/cy43h:

$z_0=0.13*h$

Patch 1: (h)

Grasslands

$z_0=0.13*LAI/6$

Crops

$z_0=0.13*\min(1.0, \exp([LAI-3.5]/1.3)$

Patch2: (h)

$z_0=\min(0.13*Tree\_height,1.6m)$

z_{0P1} ~ 0.1m

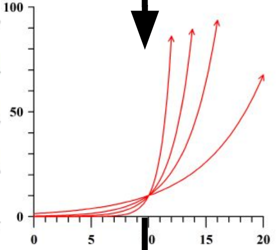
z_{0P2} ~ 1m

z_{0eff}

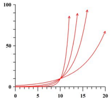
$$|w'V'|_{P1} = C_{D_{P1}}|V_a|^2 = \frac{k^2}{[ln(z/z_{0_{P1}})]^2}|V_a|^2 = u_*^2$$

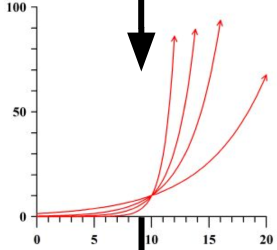
$$|w'V'|_{P2} = C_{D_{P2}}|V_a|^2 = \frac{k^2}{[ln(z/z_{0_{P2}})]^2}|V_a|^2 = u_*^2$$

$$|w'V'|_{ISBA} = C_{D_{ISBA}}|V_a|^2$$



Atmos. coupling: V_a





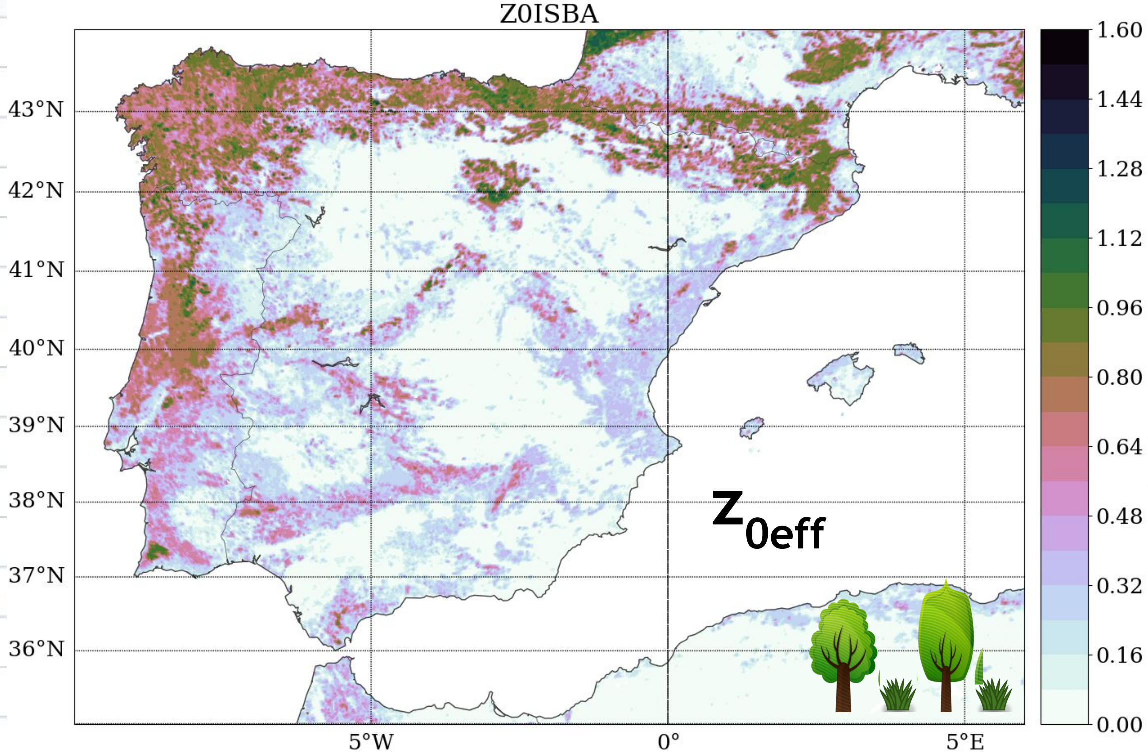
Geleyn diagnostics: V_{10m}

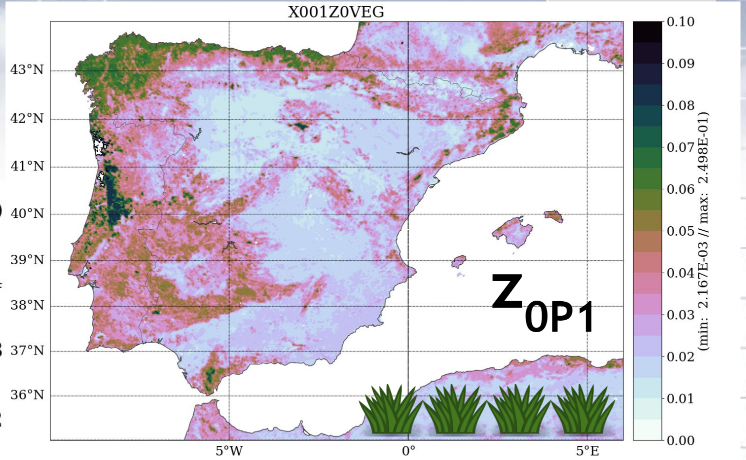
Geleyn diagnostics: $V_{10m\ -P1}$

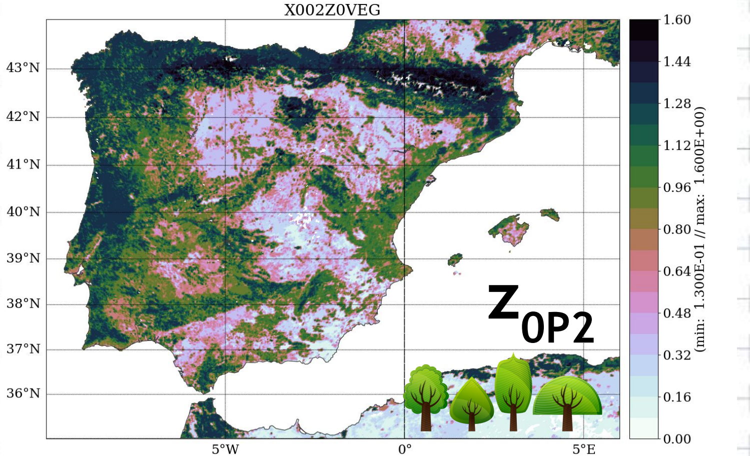
Geleyn diagnostics: $V_{10m\ -P2}$

Impact of ECOCLIMAP-SG in roughness length

ECO-II (TARGET 2)

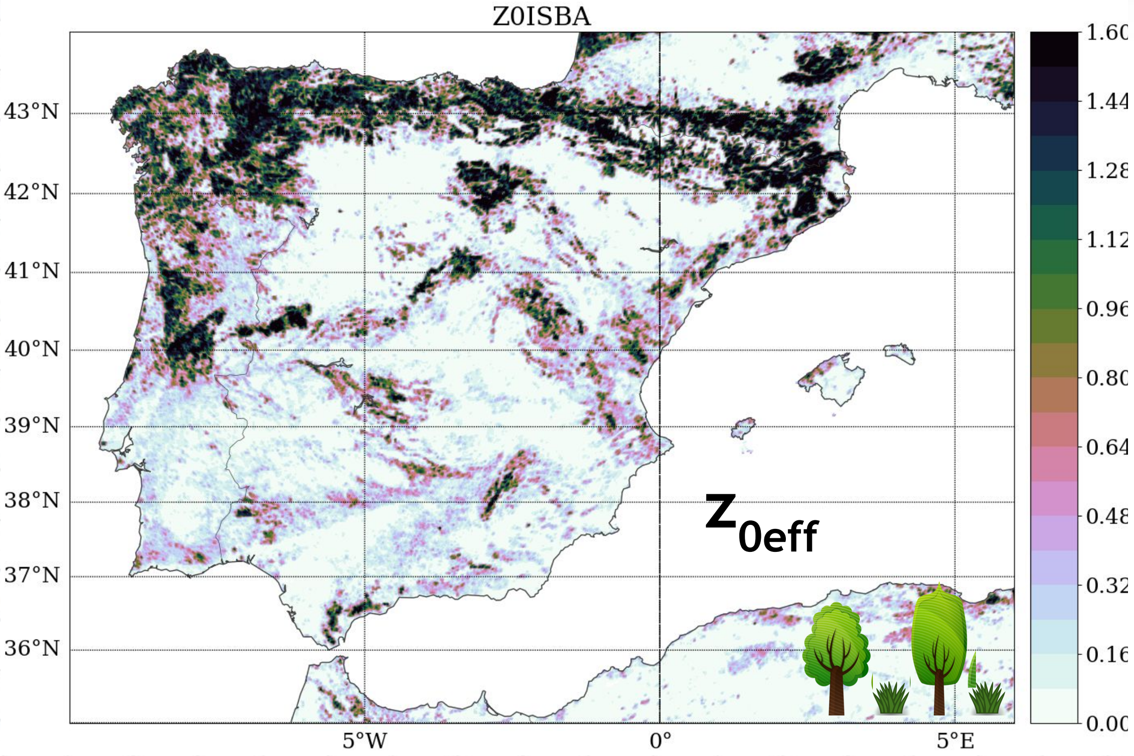


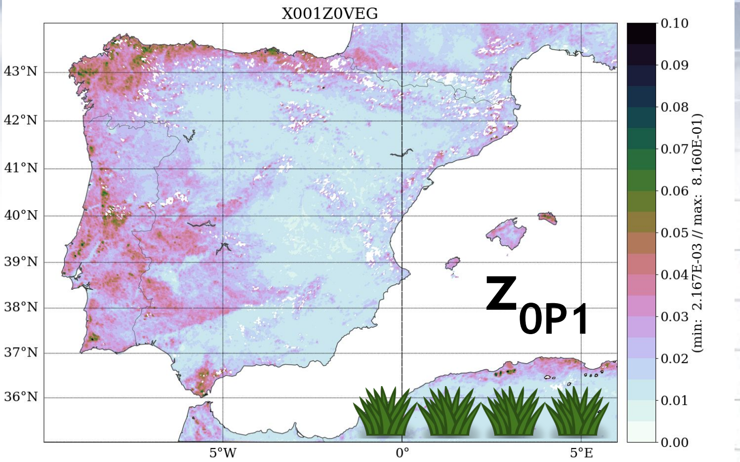


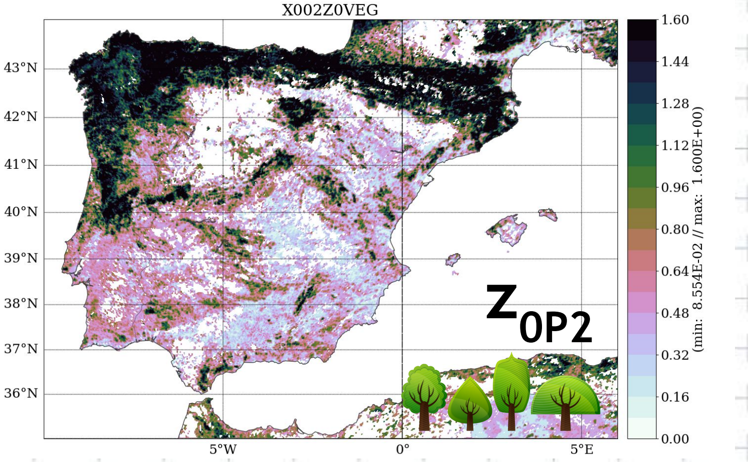


Impact of ECOCLIMAP-SG in roughness length

ECO-SG (TARGET 1)







z_0: difference between ECO-SG & ECO-II (in % wrt ECO-II)

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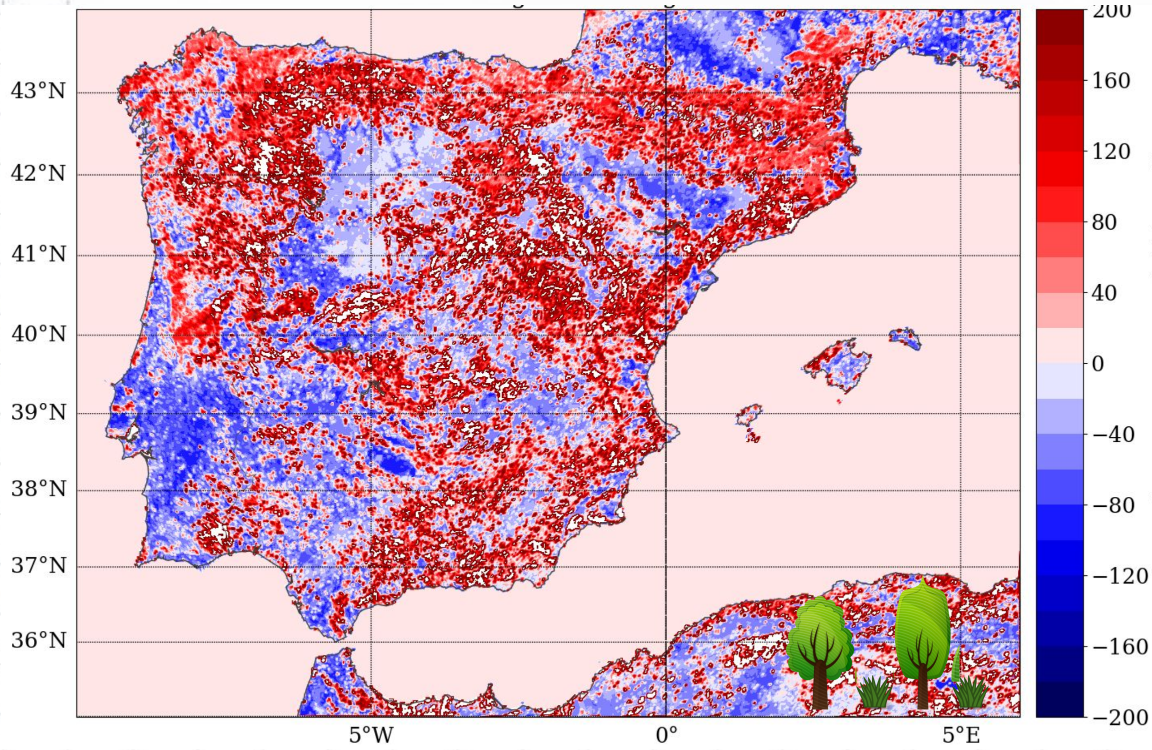
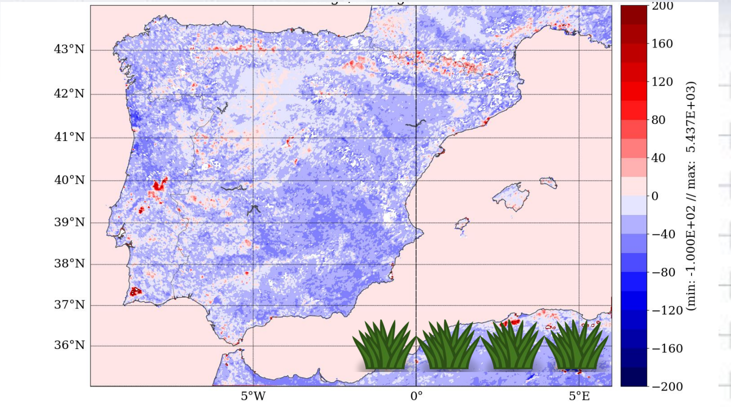
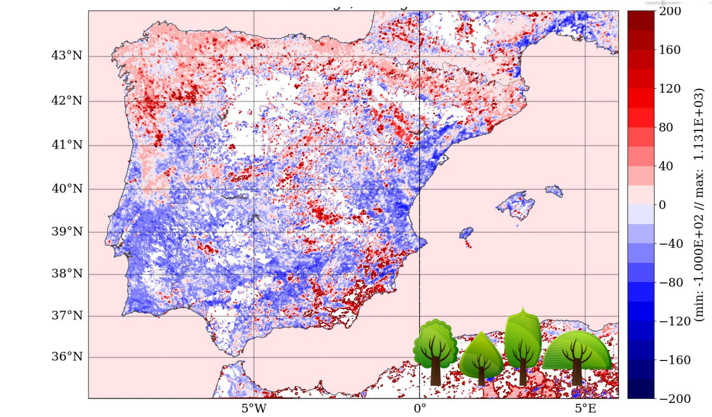
Change in z_{0ISBA} seems quite balanced (incr/decr)



Diff $z_{0\ PATCH1}$ (%)



Diff $z_{0\ PATCH2}$ (%)

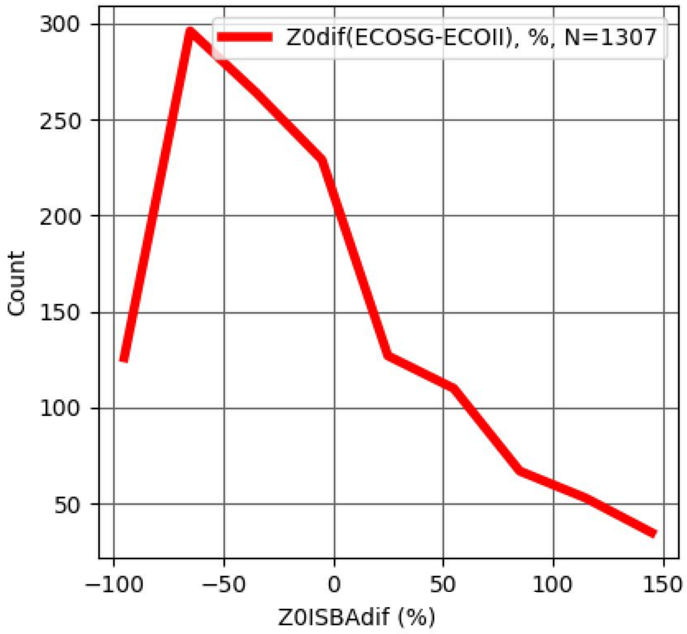


But then, why verification plots show more wind with ECO-SG? ...

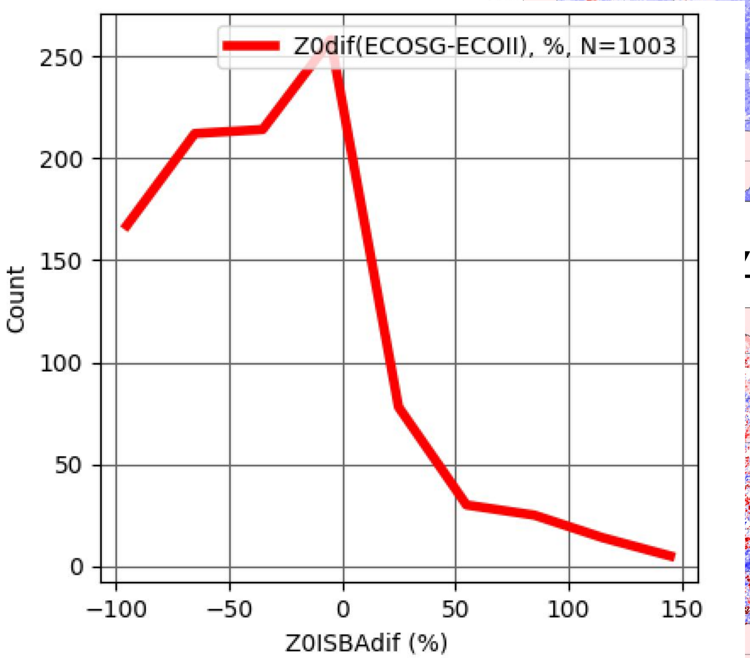
z_0: difference between ECO-SG & ECO-II (in % wrt ECO-II)

...because there are more stations where z_0 decreases:

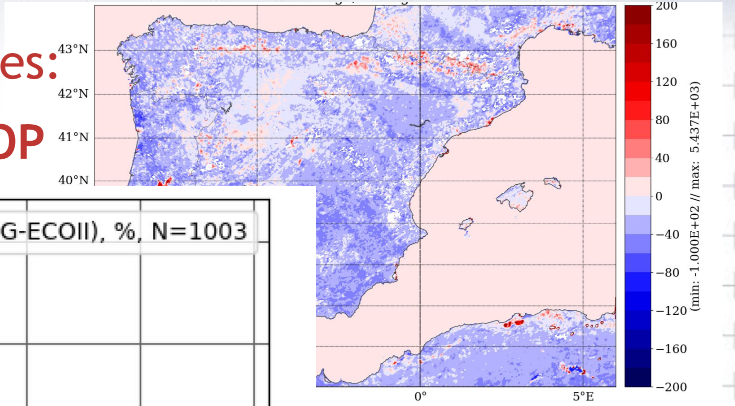
IBERIA



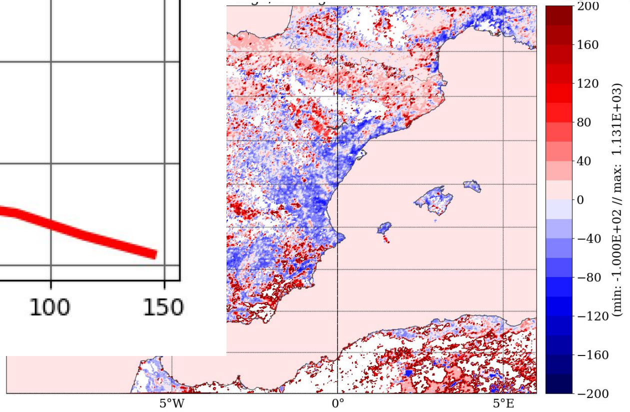
METCOOP



Diff $z_{0\ PATCH1}$ (%)



[illegible] $z_{0\ PATCH2}$ (%)



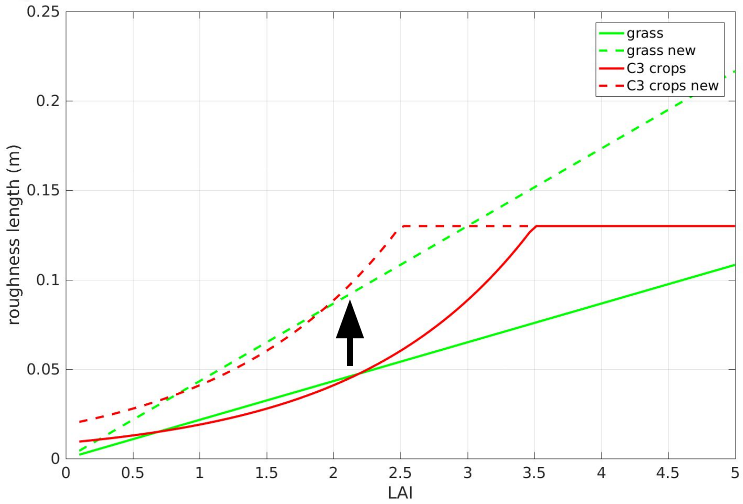
Strategies to improve sfc wind speed in cy43h:

- Increase roughness length in PATCH1 (to compensate for the increase in fraction of PATCH1 and the reduced Leaf Area Index (LAI) in ECO-SG)

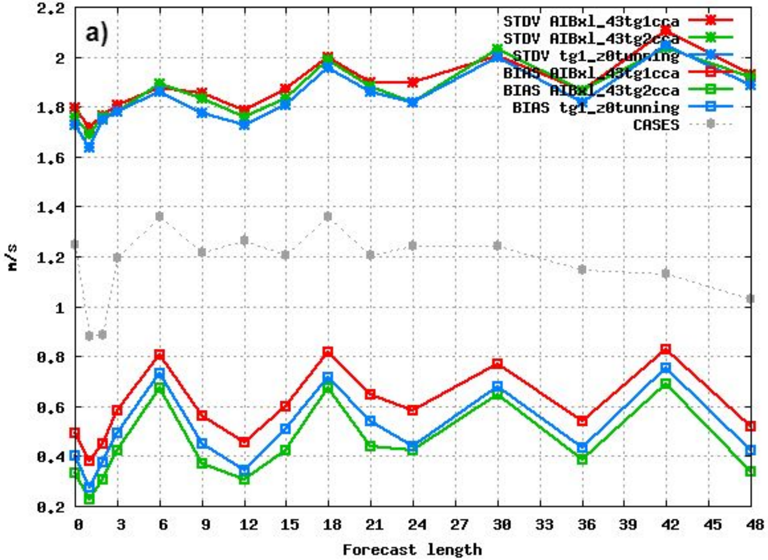
Patch 1 (open land)

Grasslands
$z_0 = 0.13*LAI/3$

Crops
$z_0 = 0.13*\min(1.0, \exp([LAI-2.5]/1.3))$

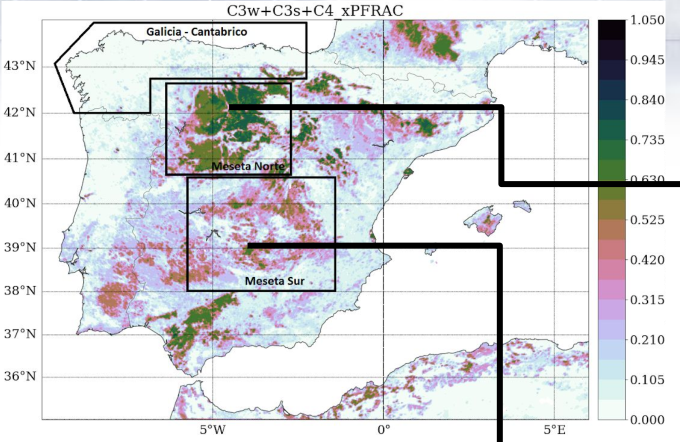


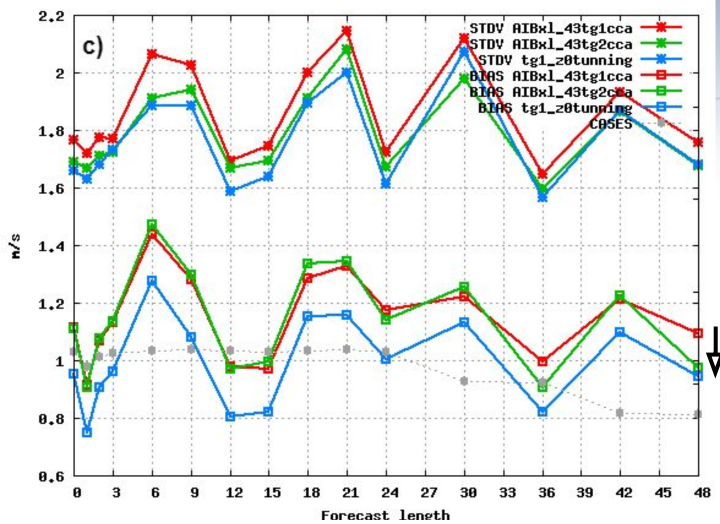
target1+z_0 tuning vs target 1 & target 2 over IBERIA, 1-10 August 2018



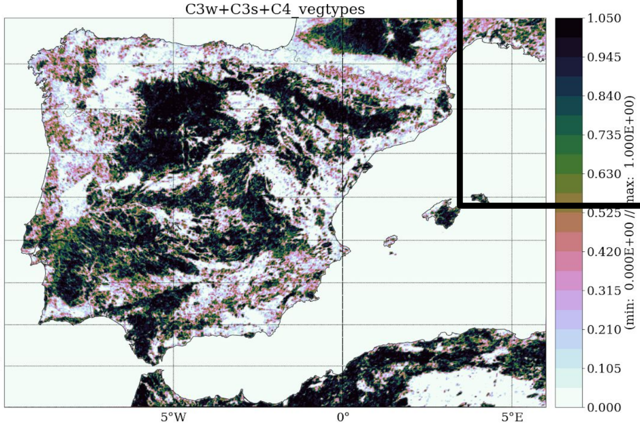
Total fraction of crops+ grassland x gridpoint:

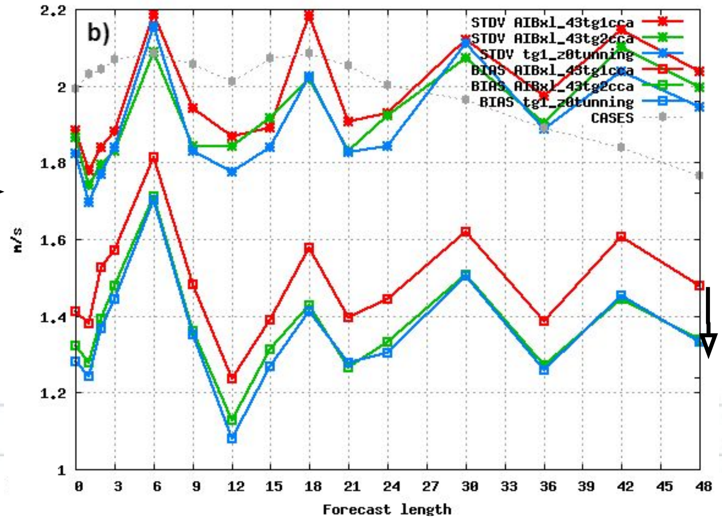
ECOCLIMAP II





ECOCLIMAP SG





(*) More details in Aladin-Hirlam Newsletter Nº14

Strategies to improve sfc wind speed in cy43h:

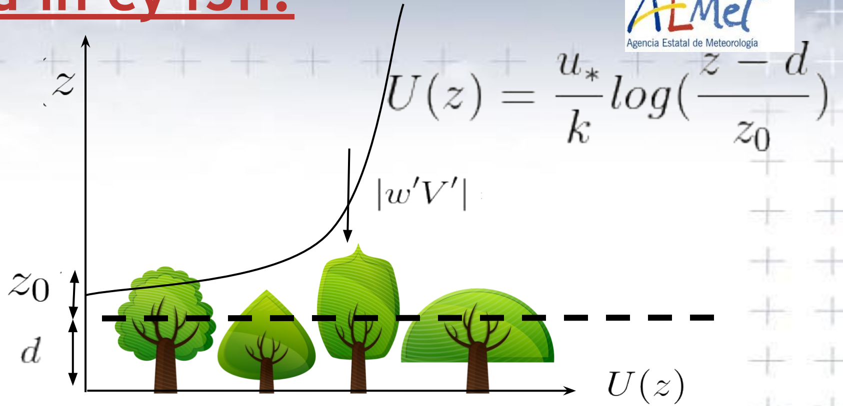
- **Improve roughness length for PATCH2 :**

Raupach (1994) formulation for z_0 and zero-plane displacement height:

$$Z_0 = (1 - \frac{d}{h_{veg}})exp(\frac{-k}{u_*/U_h} - \Psi_h)$$

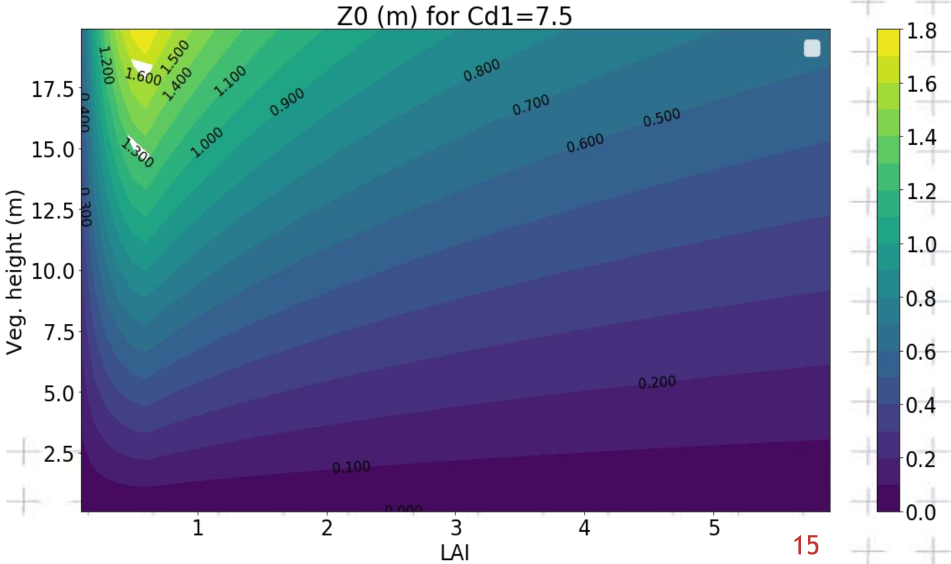
$$\frac{d}{h_{veg}} = 1 - \frac{1 - exp(\sqrt{C_{d1}LAI})}{\sqrt{C_{d1}LAI}}$$

$$C_D = \frac{k^2}{[ln((z-d)/z_0)]^2}$$



- Raupach's $z_0 < 0.13*h$. It evolves more realistically as vegetation becomes less sparse, increasing (decreasing) with LAI for small (large) LAI.

- Free parameter C_{d1} can be used for tuning.
  - Values tested: C_{d1}=7.5 (recommended)
    C_{d1}=3.5



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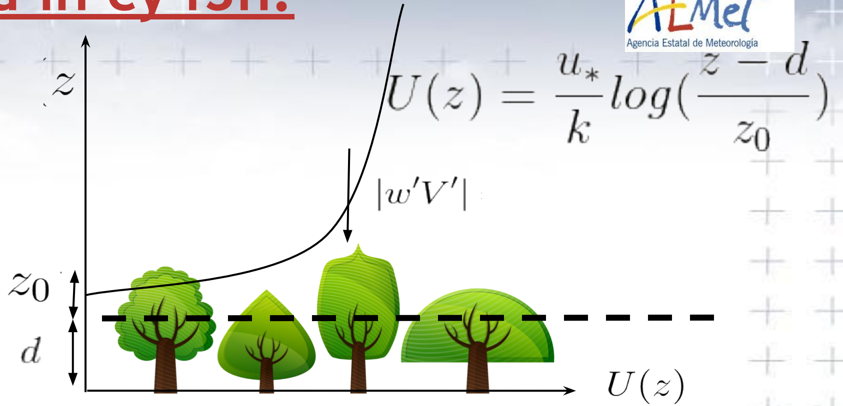

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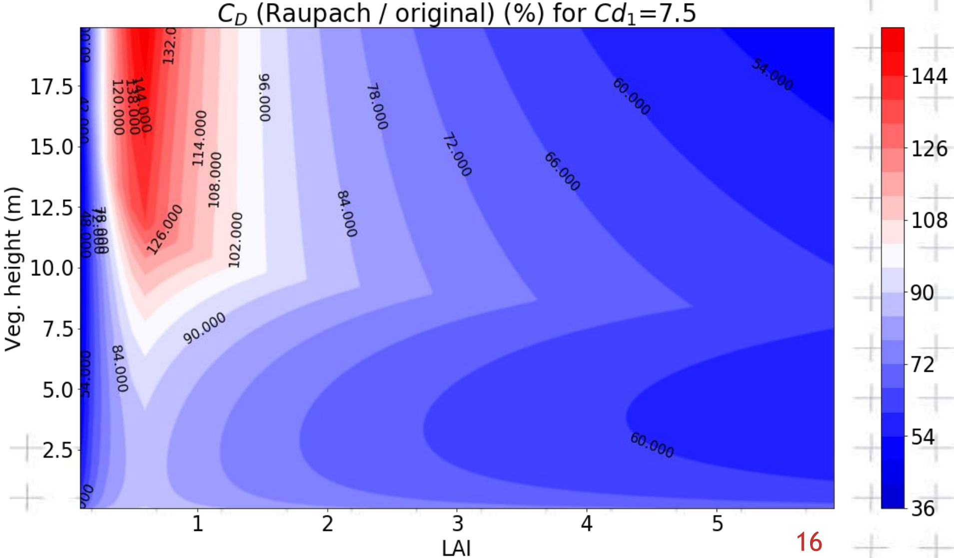
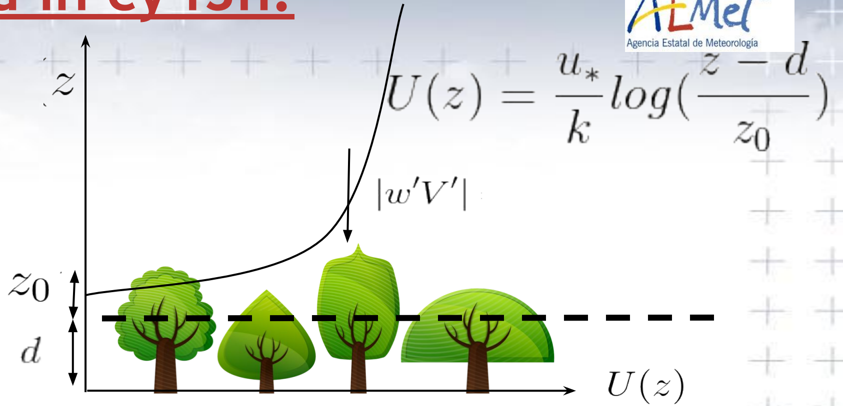


Strategies to improve sfc wind speed in cy43h:

- **Improve roughness length for PATCH2 :**



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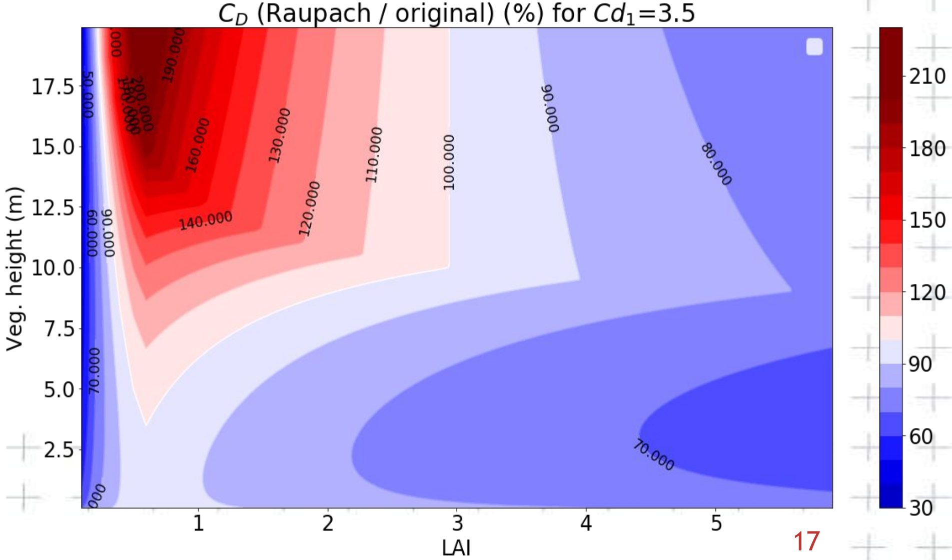
$$\frac{d}{h_{veg}} = 1 - \frac{1 - exp(\sqrt{C_{d1} LAI})}{\sqrt{C_{d1} LAI}}$$

$$C_D = \frac{k^2}{[ln((z-d)/z_0)]^2}$$

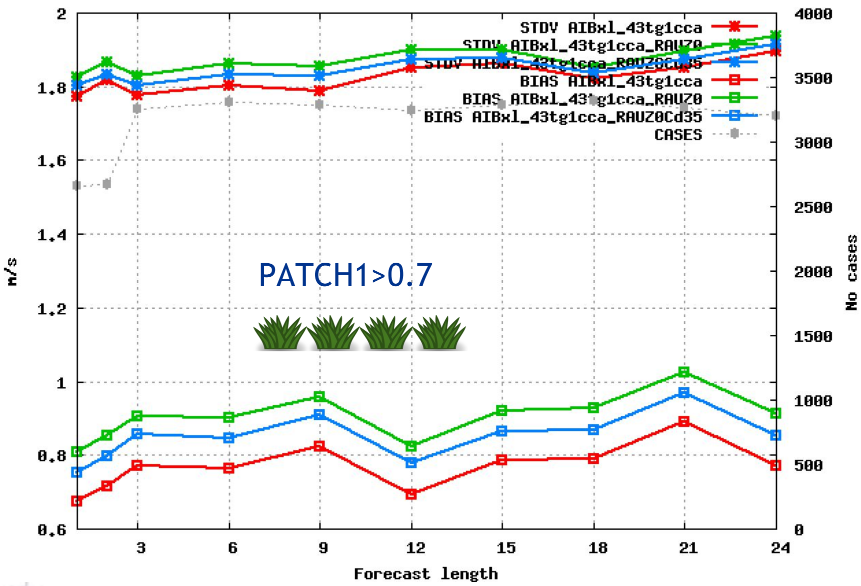
- Raupach's z_0 < 0.13*h. It evolves more realistically as vegetation becomes less sparse, increasing (decreasing) with LAI for small (large) LAI.

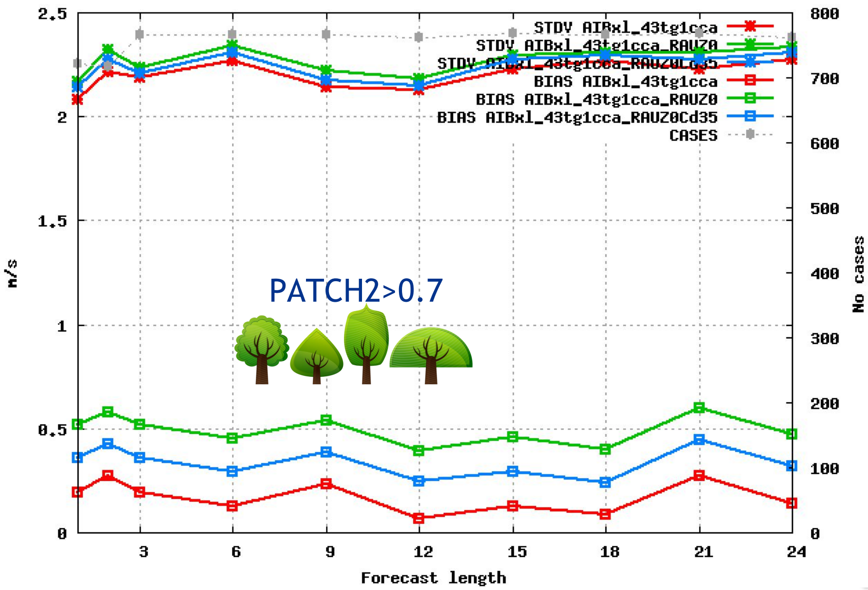
- Free parameter Cd1 can be used for tuning.
    - Values tested: Cd1=7.5 (recommended)
      Cd1=3.5



Options considered for a roughness length “a la Raupach”

- **Use Raupach’s z_0 but keep drag coefficients unchanged:** $\frac{k^2}{[ln(z/z_{0_{P2}})]^2}$
  - $C_{d1}=7.5$, $C_{d1}=3.5$ —— target1 (reference)



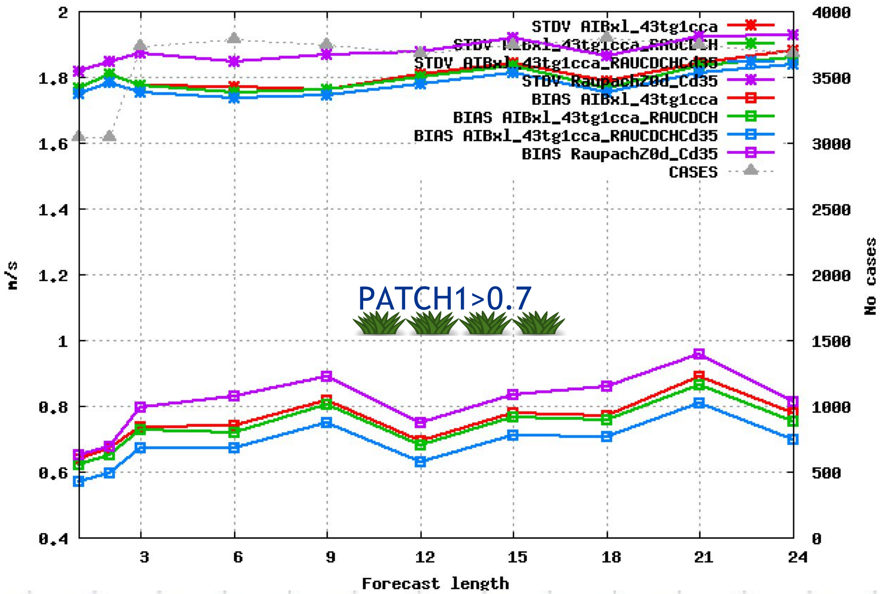


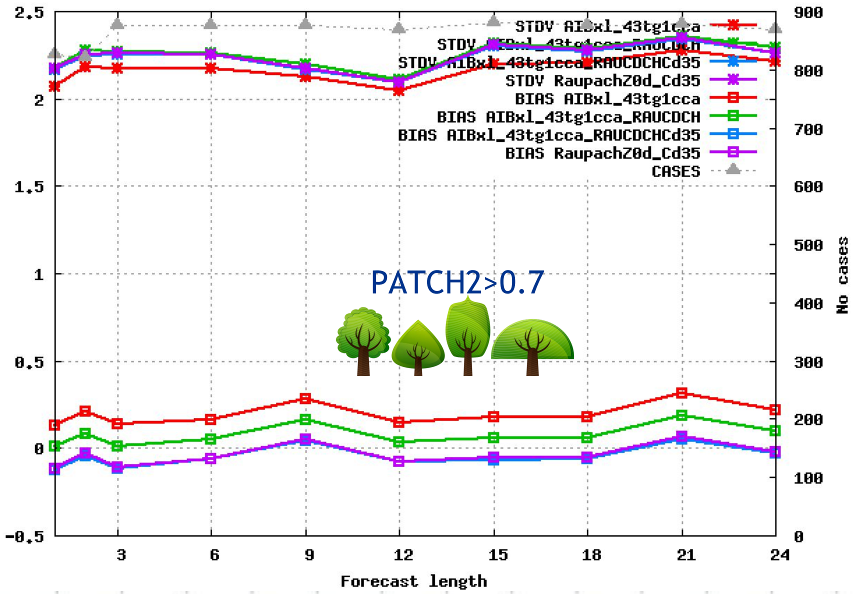
➔ z_0 & drag decreases, wind bias increases (more in Patch2: less wind bias difference between patches). Other sfc variables strongly affected (T2m etc).

Options considered for a roughness length "a la Raupach"

- Use Raupach's z_0 and d for C_D, C_H …
  - Just for PATCH2, C_{d1}=7.5, C_{d1}=3.5
  - For PATCH2 & PATCH1, C_{d1}=3.5

$$C_D = \frac{k^2}{[ln((z-d)/z_0)]^2}$$



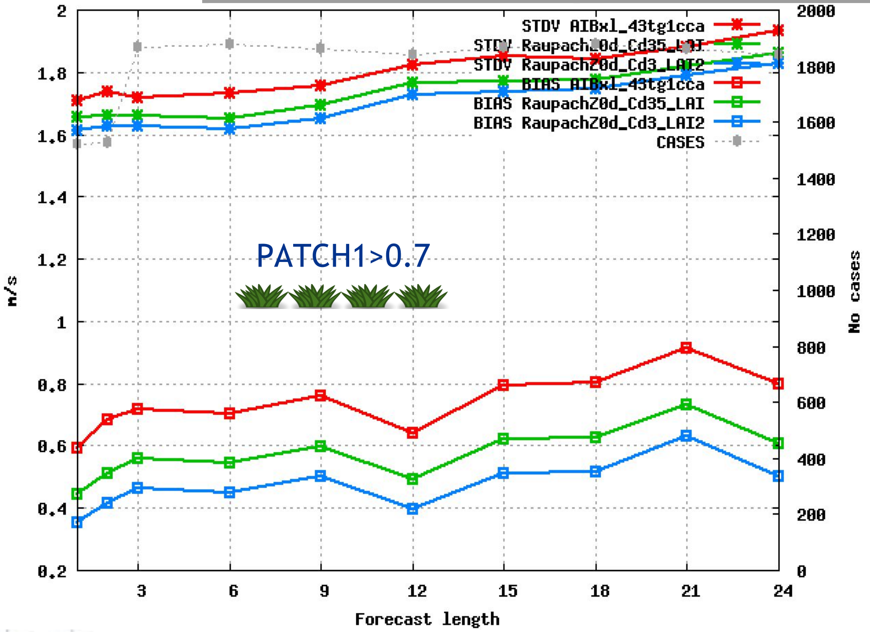


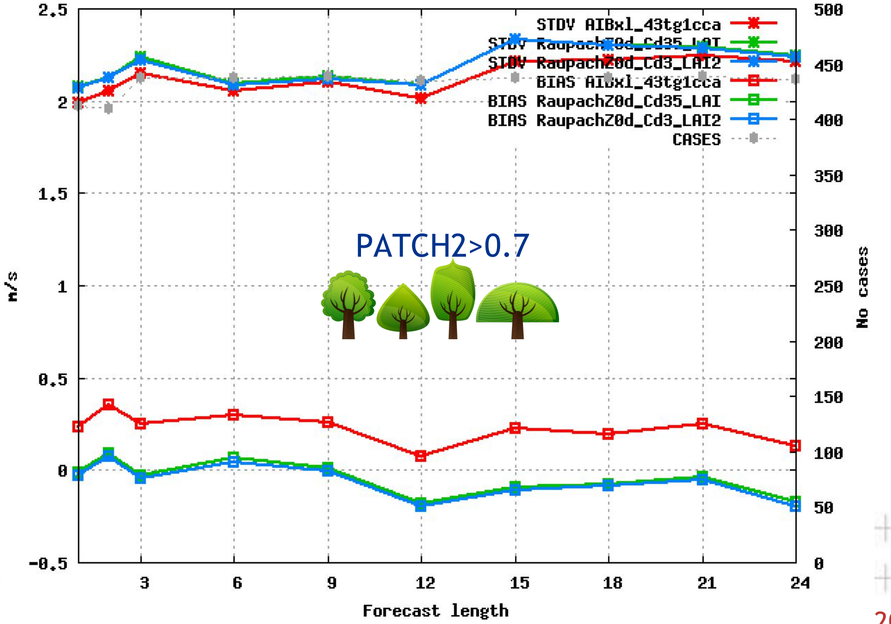
—— target1 (reference)

Options considered for a roughness length "a la Raupach"

- Combine Raupach's z_0 and d for PATCH2 and z_0(LAI) tunning for PATCH1

Grasslands	Crops	PATCH2
z_0=0.13*LAI/3	z_0=0.13*min(1.0, exp([LAI-2.5]/1.3)	C_{d1}=3.5
z_0=0.13*LAI/2	z_0=0.13*min(1.0, exp([LAI-1.5]/1.3)	C_{d1}=3.5





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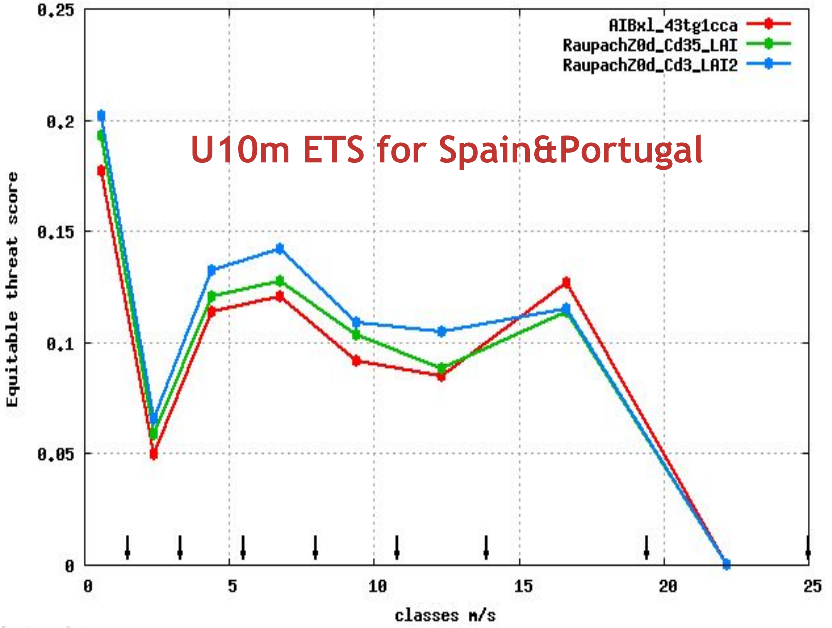

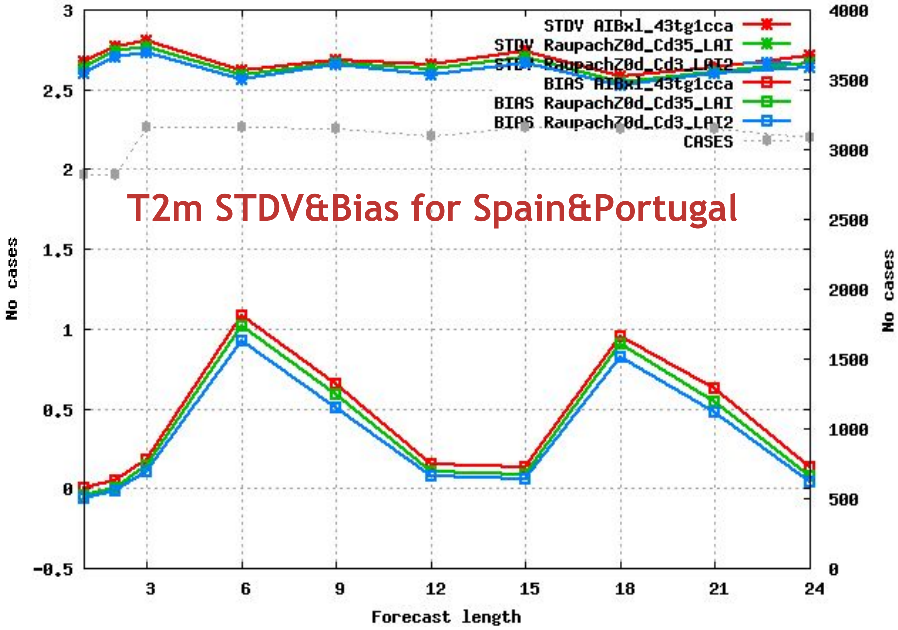

Conclusions & final remarks

- Wind is generally overestimated in Harmonie-cy43 but not uniformly:
  - More overestimation in areas where the open land is predominant
  - Differences in wind biases between domains are explained by different P1/P2 distribution.
- Changes in ECOCLIMAP-SG (distribution of low vegetation and forest, decreased LAI) have a strong impact in sfc wind.
- In order to improve the surface wind bias in Harmonie, the contribution by the different patches must be addressed separately, looking to decrease the difference in wind bias between patches.
- The combination of Raupach’s formulation for PATCH2 + tuning of Z_0 formulas for crops & grasslands give the best results over IBERIA. The impact in other sfc variables (T2m, Q2m… is small).

Conclusions & final remarks

- Some extra settings for cy43h2.1 can impact U10m (XRIMAX, OROTUR, etc). Tests with combined settings are needed to define optimum values for C_{d1},a,b.

- Possible extensions for this work:
    - Corrections to the traditional MO similarity functions for a surface layer over a tall canopy (Roughness sublayer theory, Harman & Finnigan, 2007,2008).

    - Introduction of a “blending height” well above the canopy. Currently, $d+z_0$ can be too close to the “forcing level” (~13m).

Thank you! (and stay safe)