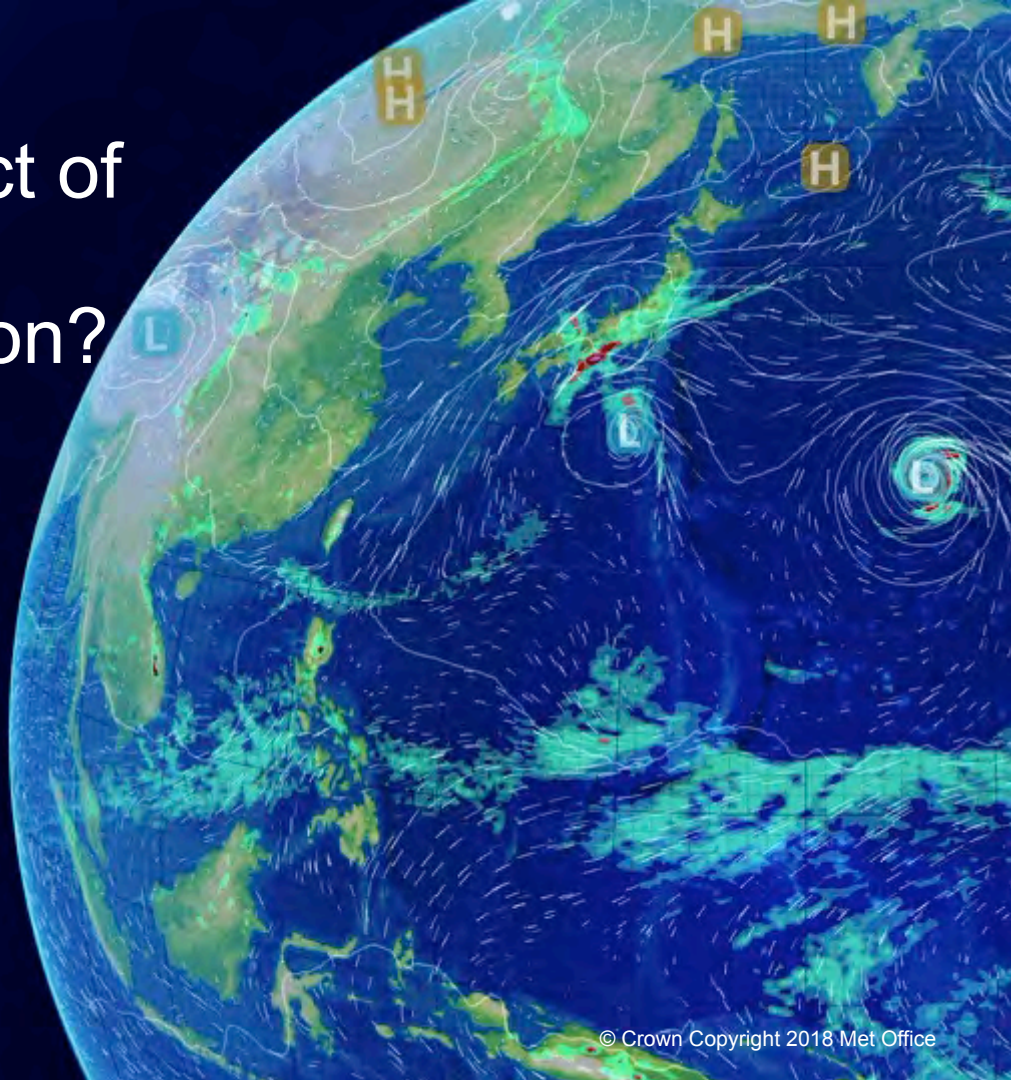
What could be the impact of neglecting surface momentum flux evaluation?



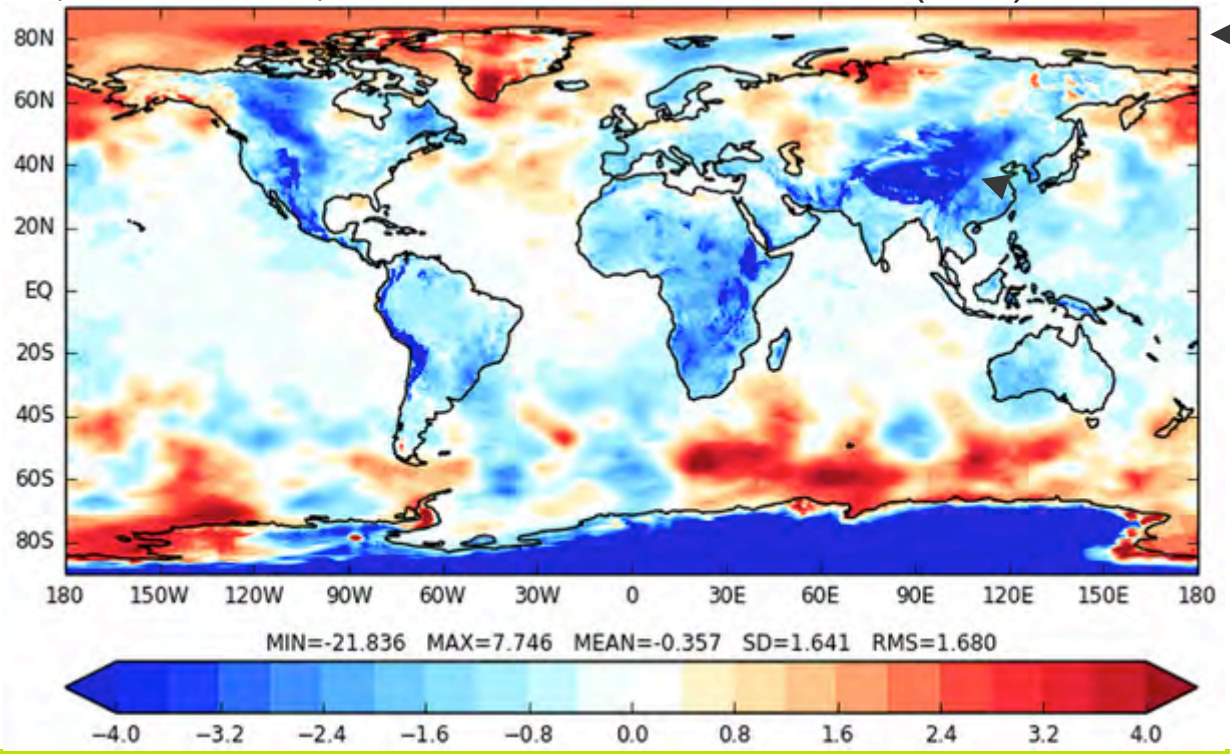
Graham Weedon*, Martin Best, Heather Rumbold, Ruth Lewis & Adrian Lock

* graham.Weedon@metoffice.gov.uk

Bias in Unified Model GCM surface pressure (MSLP)

Surface Pressure (MSLP) : Model minus Observations

(GA7.0, T+120h) (hPa)



- *North polar positive bias.*
- *Land generally negative bias (size approximating topography apart from Greenland).*

Why are we worried about drag?

- The Met Office Global model ("Unified Model", UM) has a high pressure bias in the North polar region (esp. North Atlantic).
- Decreasing the drag in the UM would reduce this pressure bias, but this would also increase the positive bias in 10 m wind speed.
- Surface observations suggest that vegetation canopy heights (H_c) should be lower as used in the UM - which would reduce drag.
- However, drag is related to roughness length (z_0) which only partly depends on canopy height:

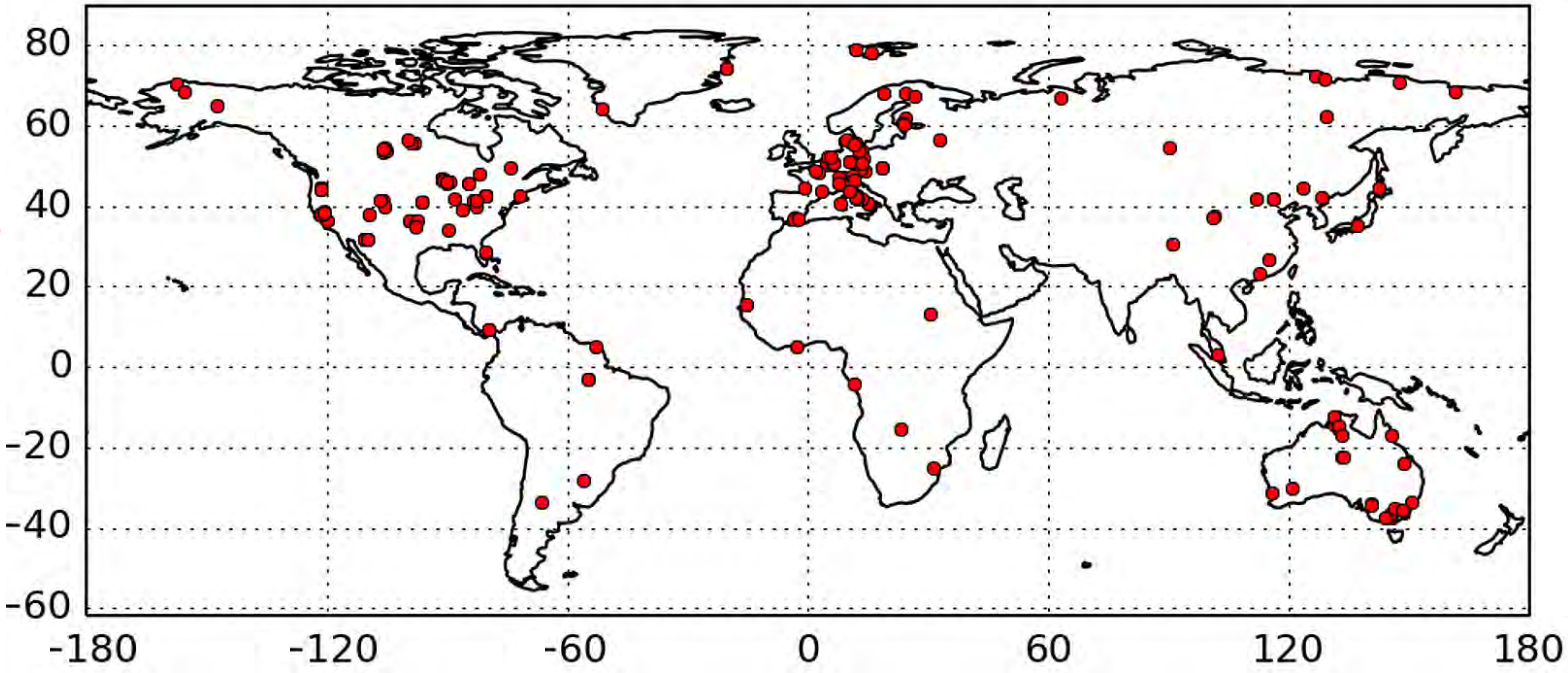
$$z_0 = H_C \left(\frac{\partial z_0}{\partial H_C} \right)$$

- What about the other parameter?
- **Should roughness lengths be increased, decreased or left unchanged?**

FLUXNET2015 observed fluxes: Momentum flux, sensible heat & latent heat

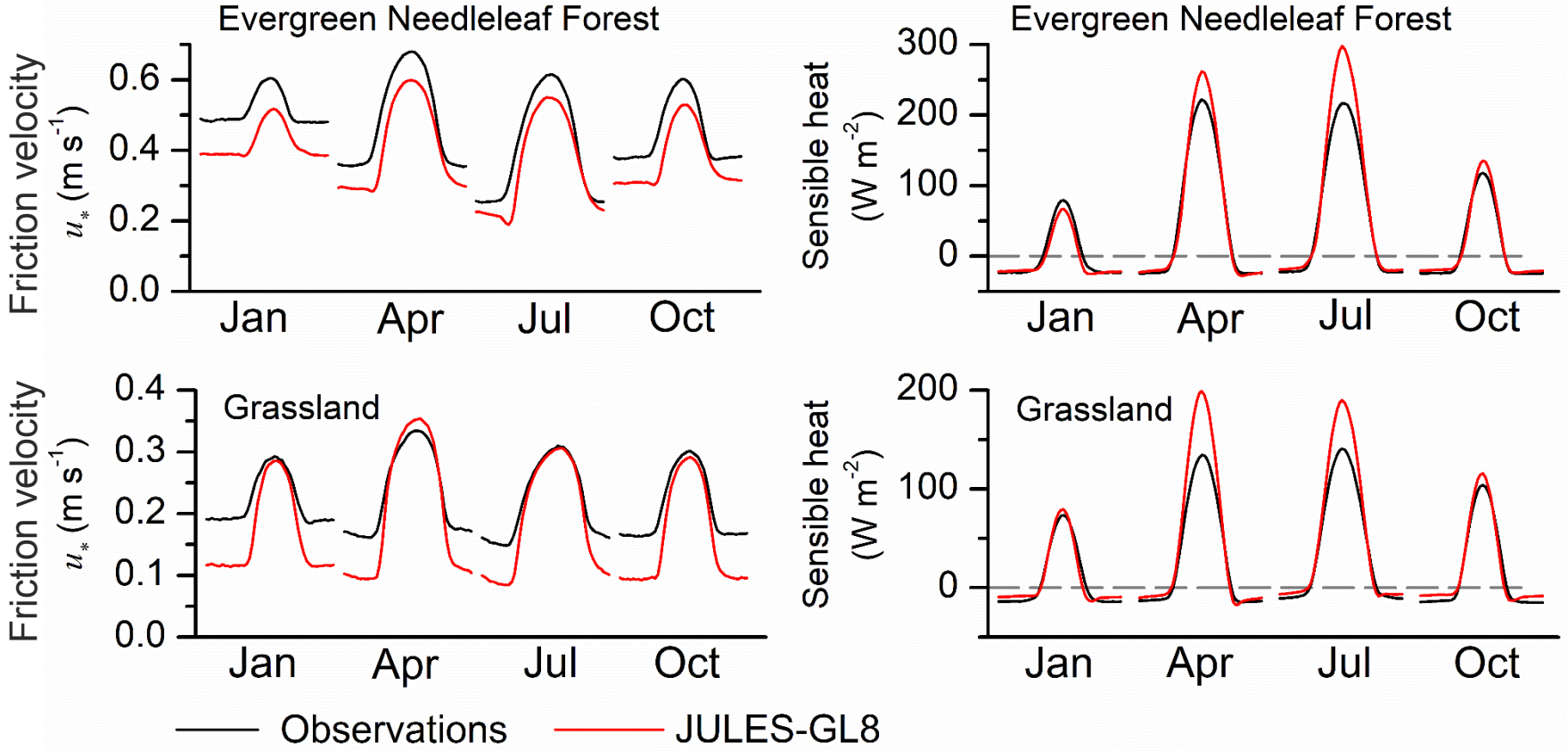
JULES (Met Office land surface model) offline runs using FN2015 meteorological forcing with 100% site's IGBP land cover type. Evaluated JULES friction velocity (u_*) against FLUXNET2015 observations of momentum flux (converted to u_*).

FLUXNET2015 sites
(*n* = 213)



JULES-GL8 Friction velocity & Sensible heat v FLUXNET2015

Average diurnal cycles in u_* and Qh across Northern hemisphere sites



Diagnosing Roughness length (z_0) from observations

Friction velocity (u_*):

$$u_* = \frac{\kappa U}{\ln\left(\frac{z_h}{z_0}\right) - \varphi\left(\frac{z_h}{L}\right)}$$

Obukhov length (L):

$$L = \frac{\rho c_p T u_*^3}{\kappa g Q_H}$$

Pastorello *et al.* (2017) A new dataset to keep a sharper eye on land-air exchanges, *EOS*, 98, doi:10.1029/2017EOS071597

Required values:

z_0 = Roughness length

z_h = Reference height for observations

Observations from FLUXNET2015 (Pastorello et al., 2017):

U = Wind speed at 10 m

Q_H = Sensible heat flux

T = Air temperature at z_h

ρ = Air density

u_* = Friction velocity (Nb FN2015 provides Momentum flux or τ_R, and $u_* = (\tau_R/\rho)^{1/2}$)

Constants and Corrections:

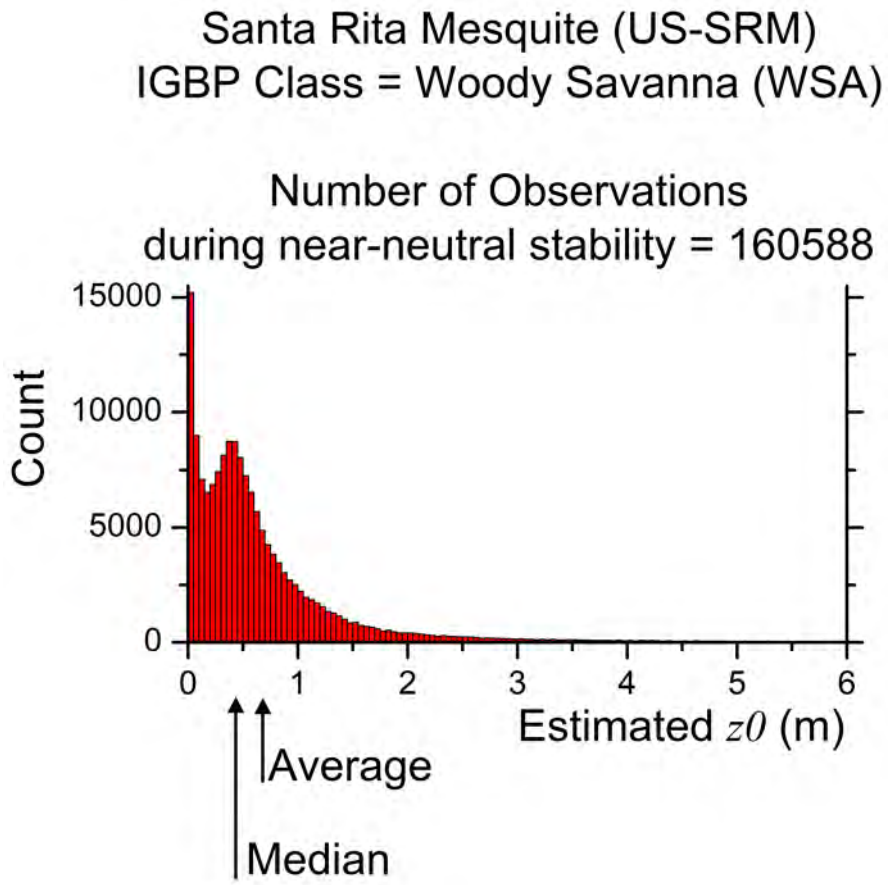
κ = Von Karman constant

φ = Stability function (correction to u_* according to stability)

c_p = Heat capacity of air

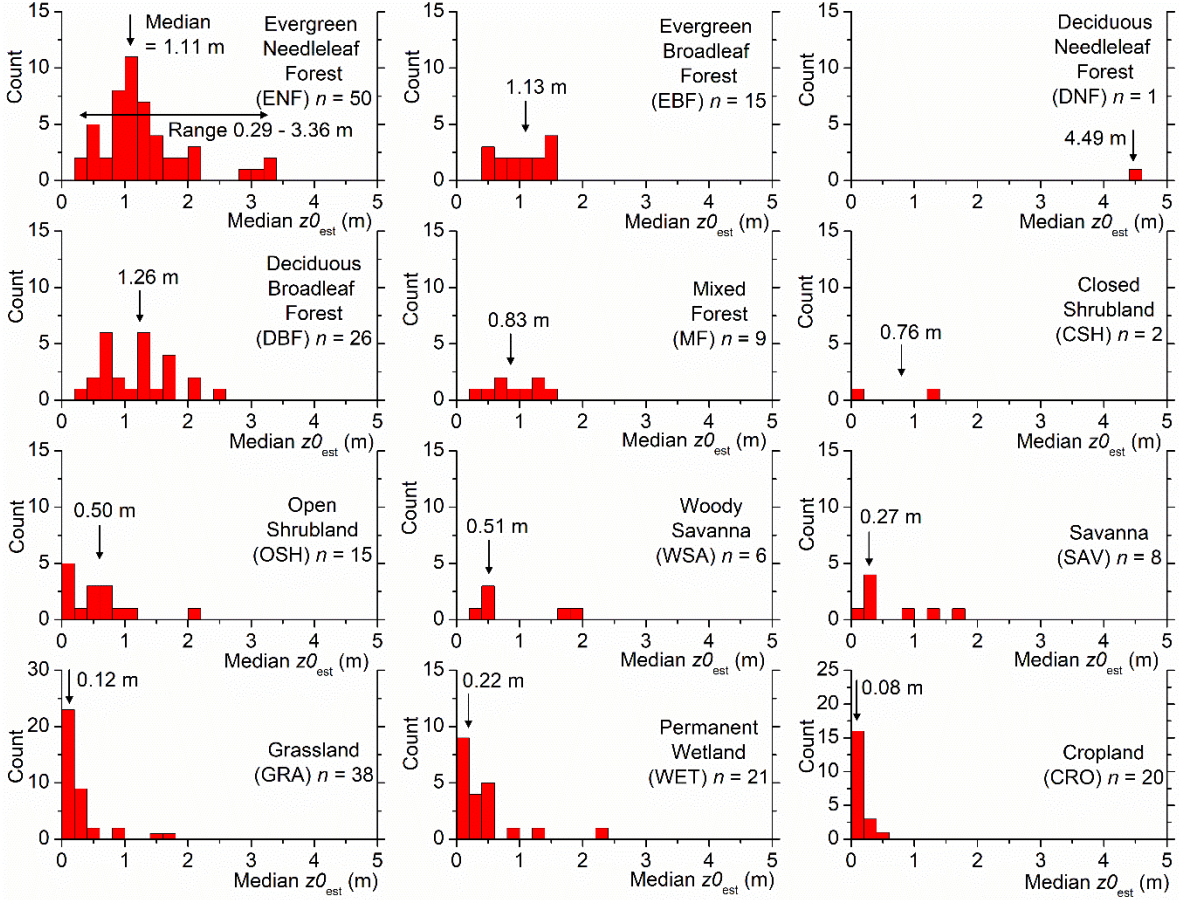
g = Acceleration due to gravity

Diagnosing Roughness length (z_0) from observations

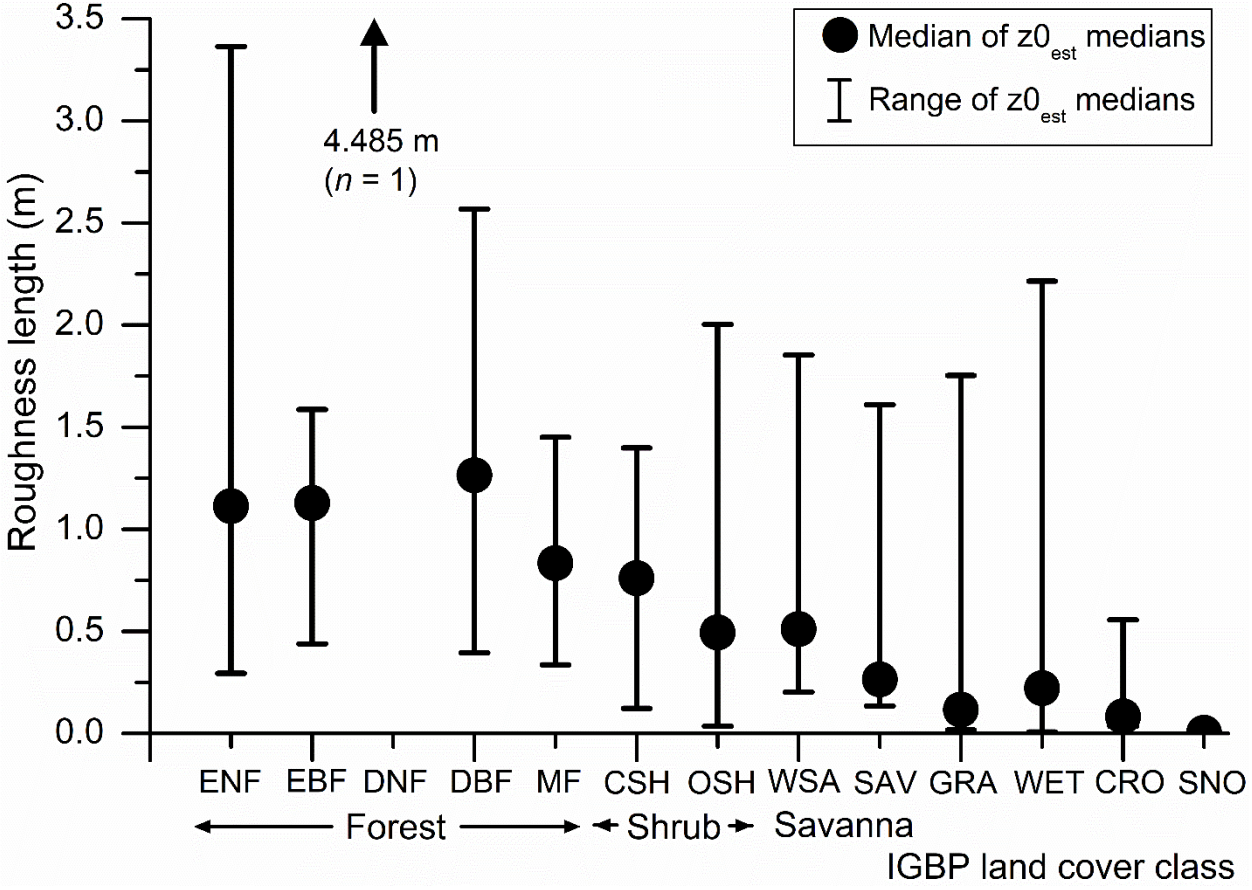


Diagnosing Roughness length (z_0) from observations

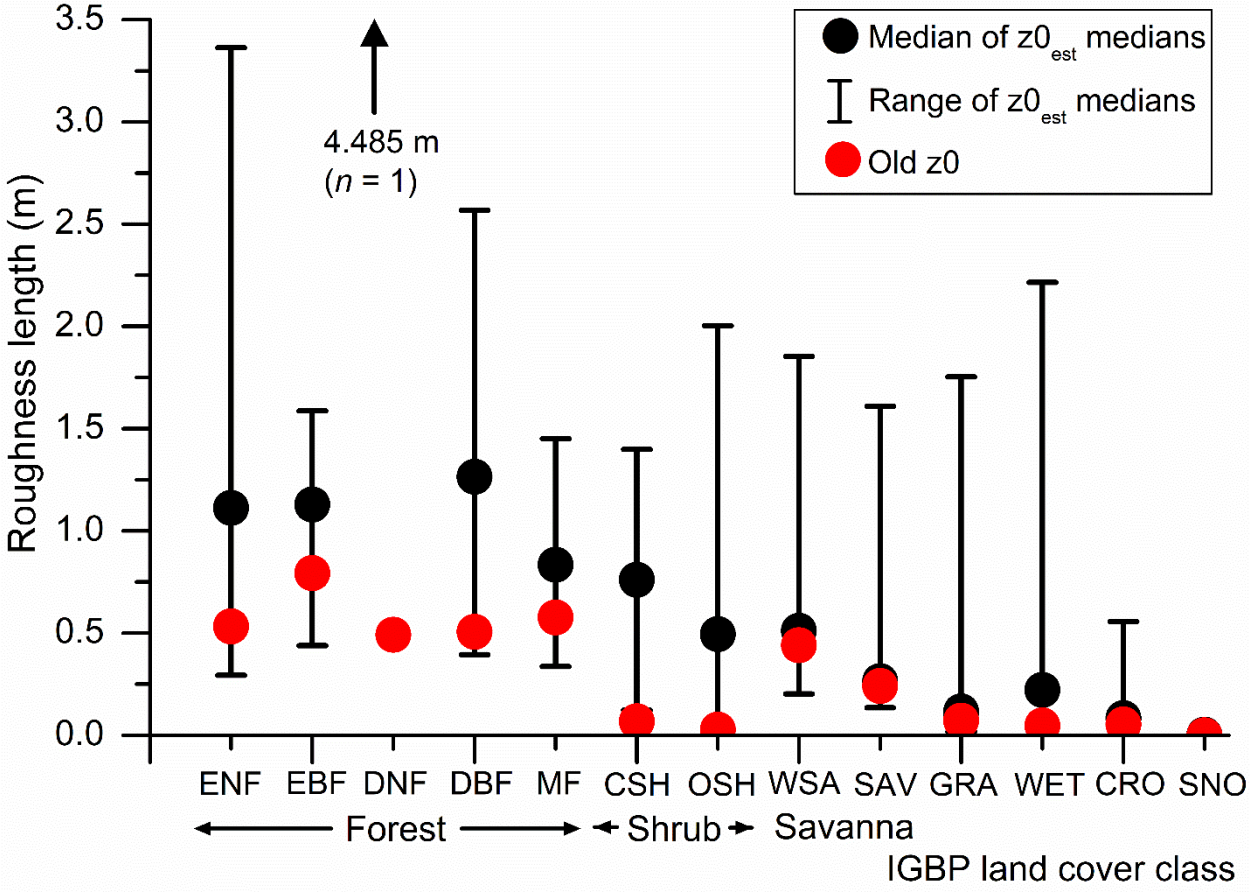
Histograms of FLUXNET2015 site median z_{0est} according to IGBP land cover class



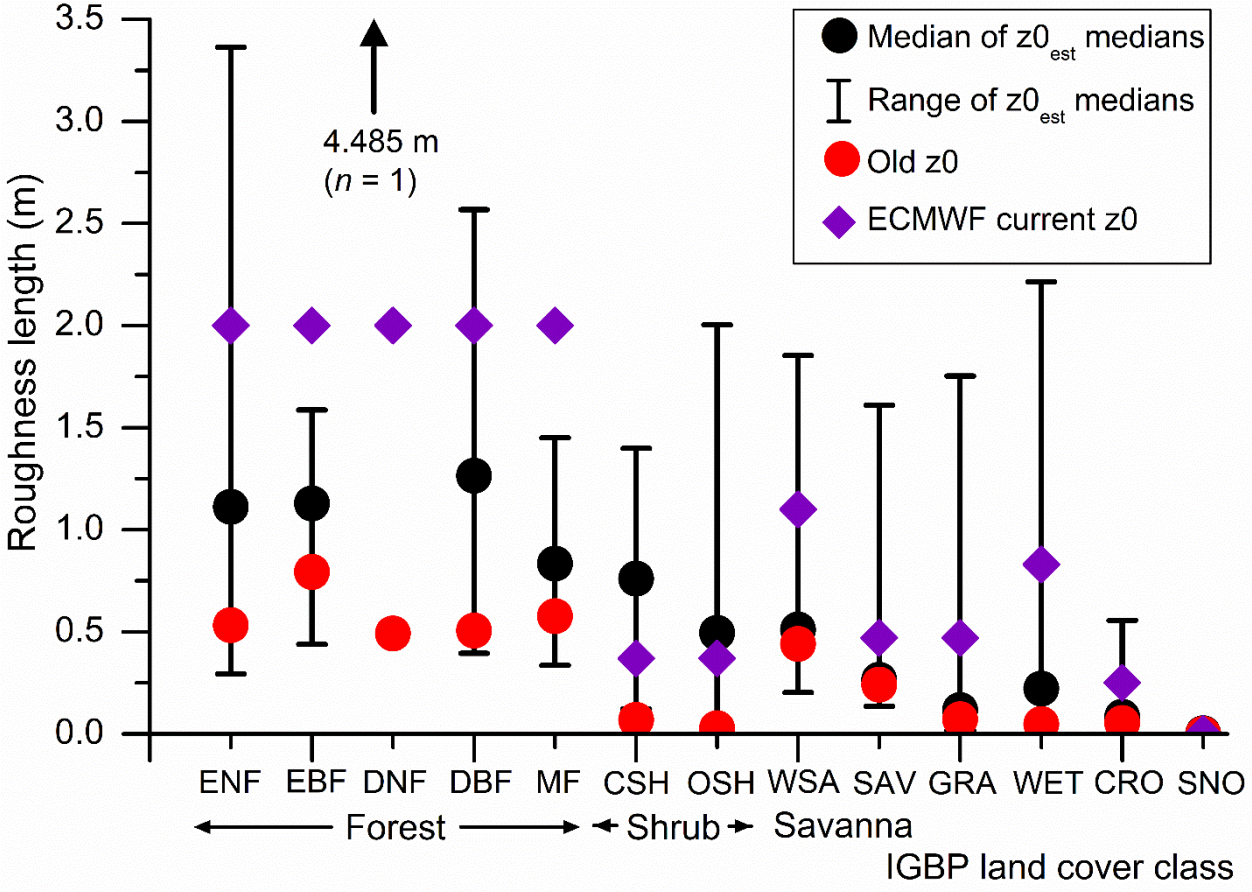
Diagnosing Roughness lengths (z_0) from observations



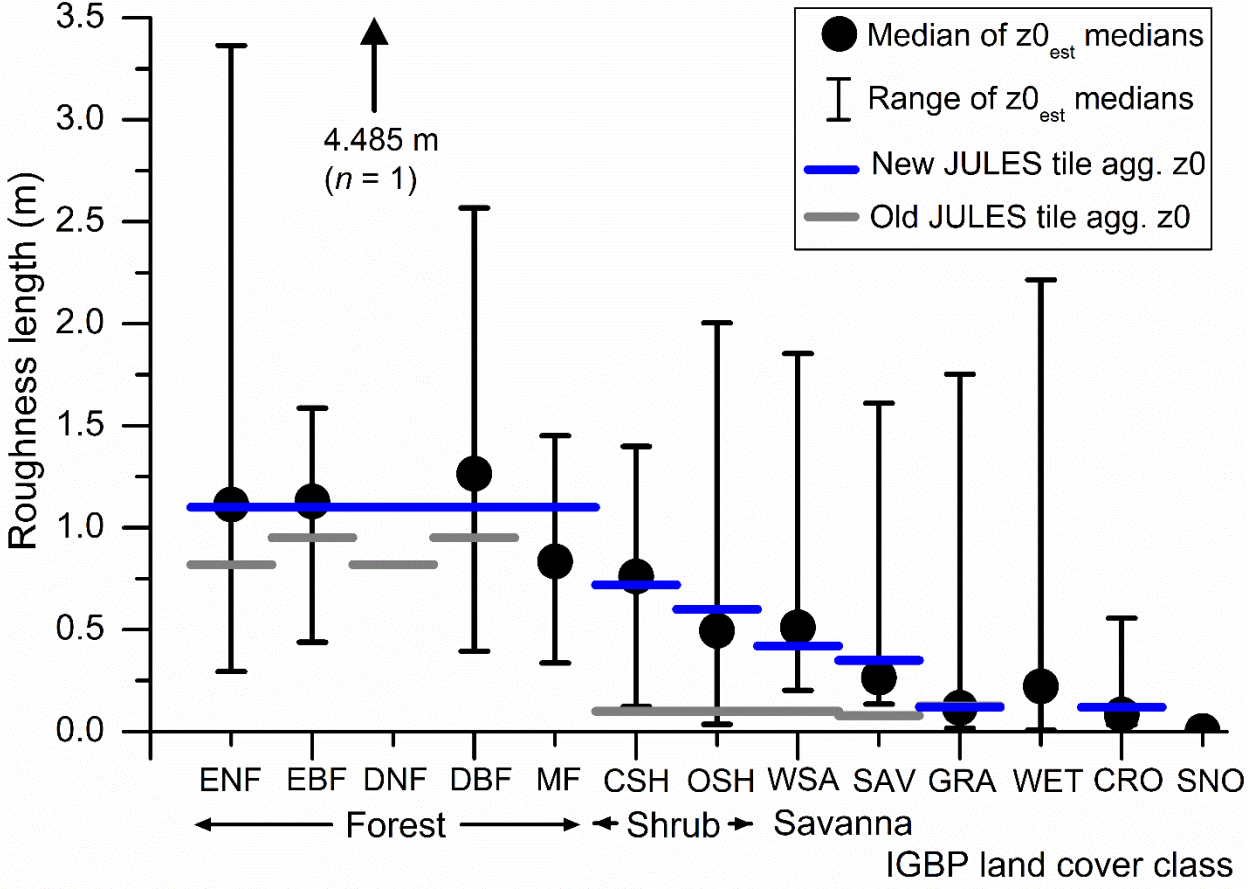
Old roughness lengths versus z_0 from observations



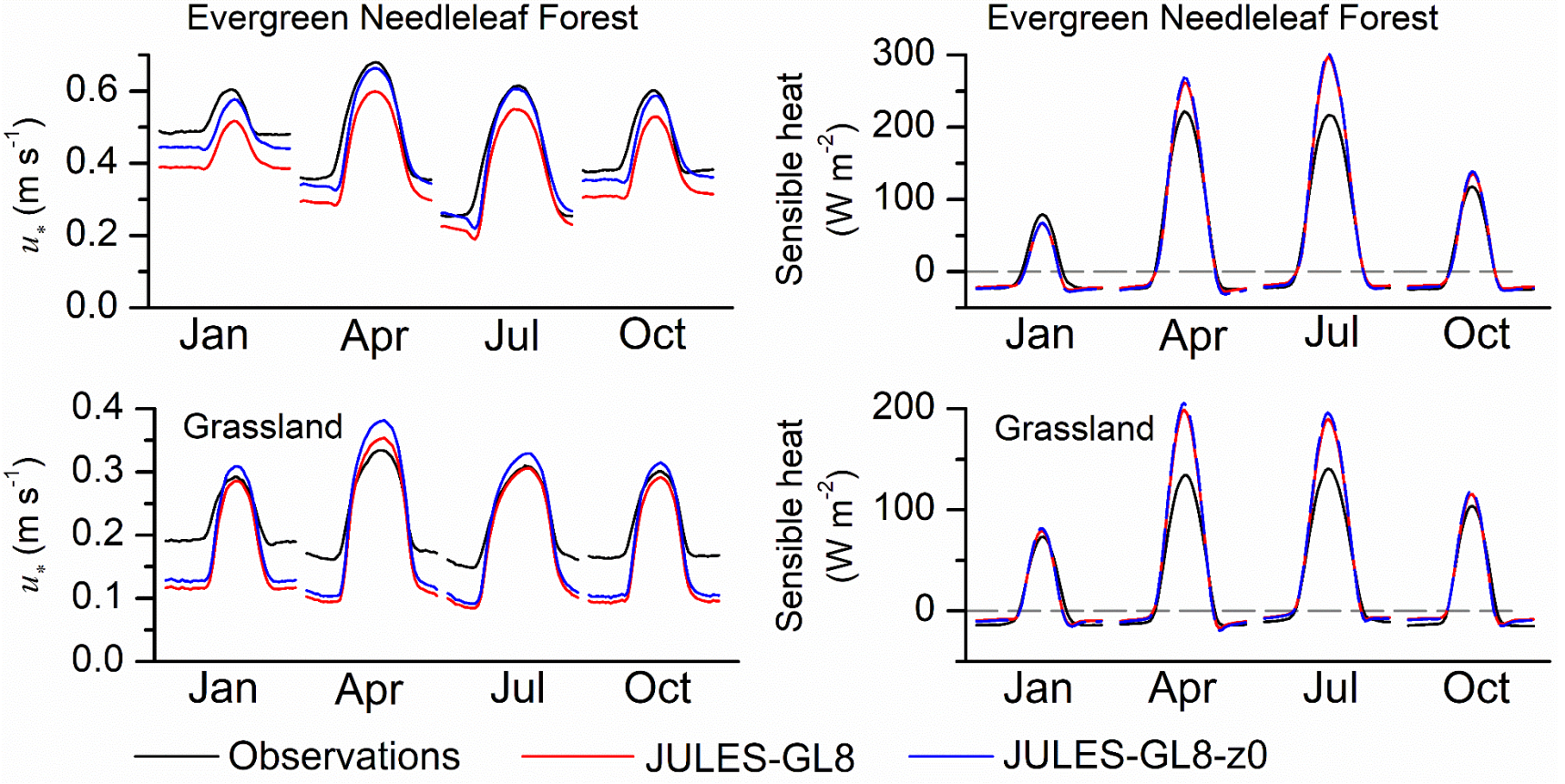
Old roughness lengths versus z_0 from observations



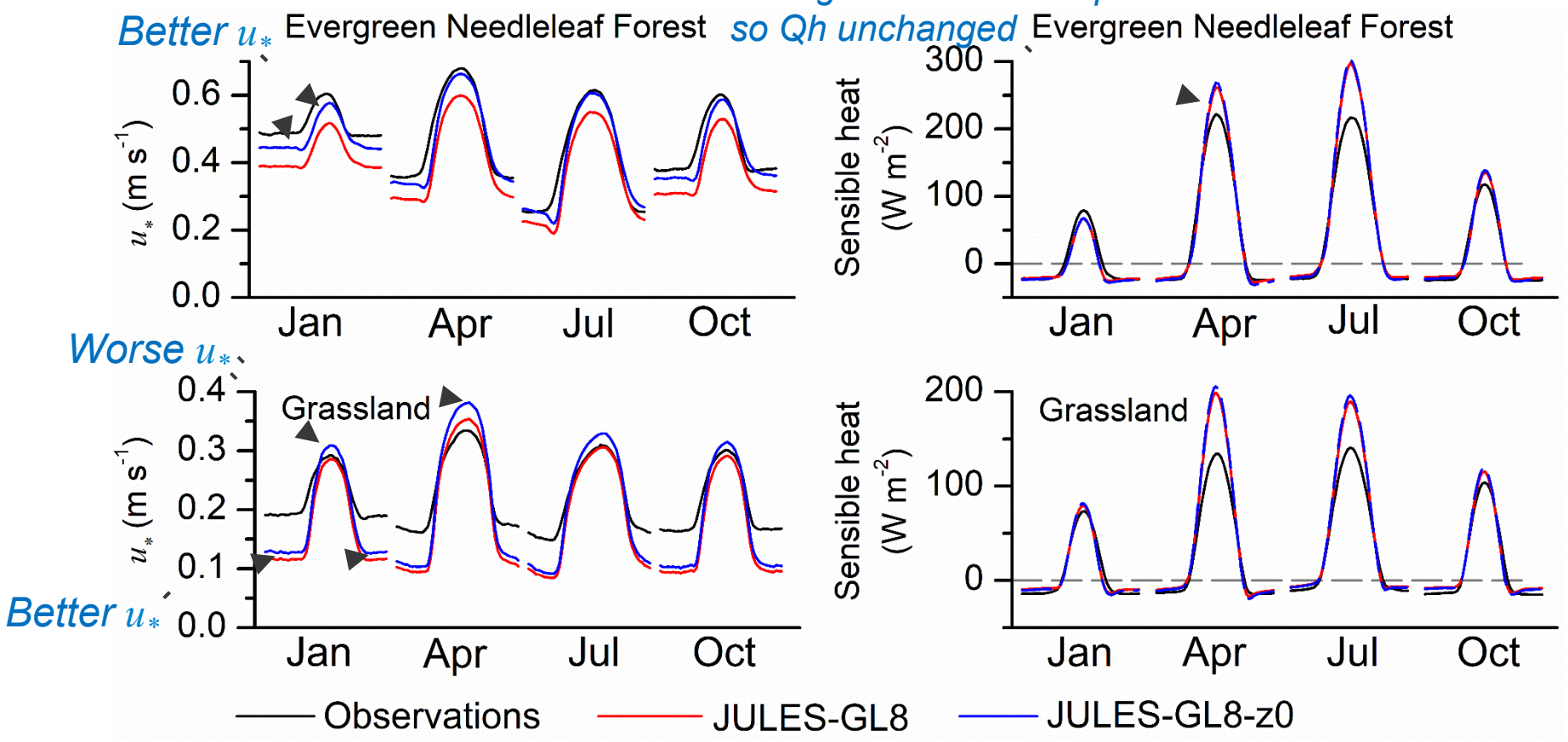
Old roughness lengths versus z_0 from observations



Effect of revised z_0 used in JULES-GL8



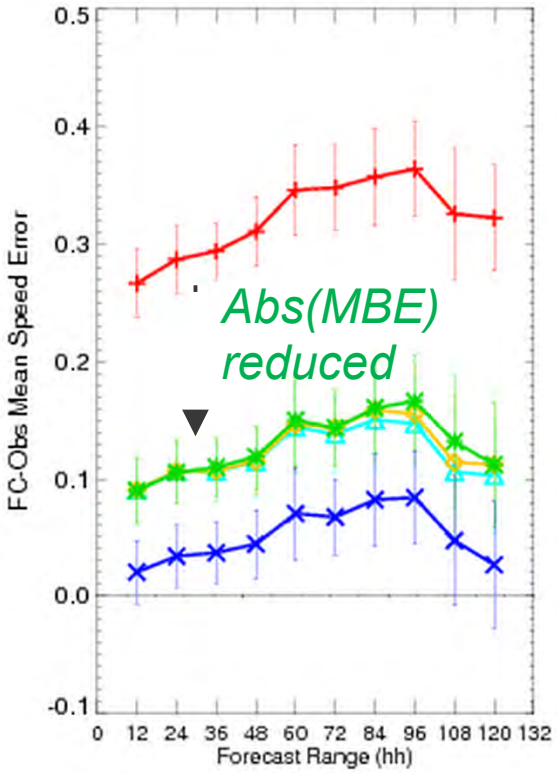
Effect of revised z_0 used in JULES-GL8



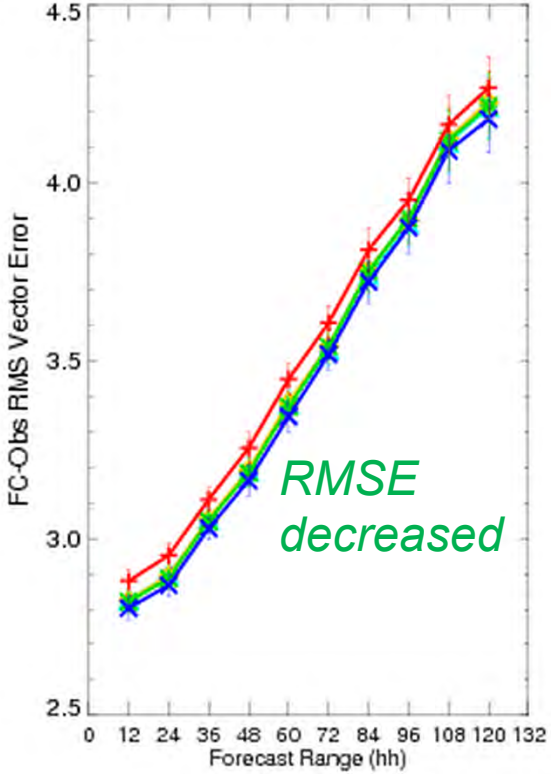
NWP assessment (20°N to 90°N, Obs June 2011 – April 2014): UM GA7.0 configuration + vegetation drag package

10 m Wind speed ($m\ s^{-1}$)

Mean bias error



Root mean square error

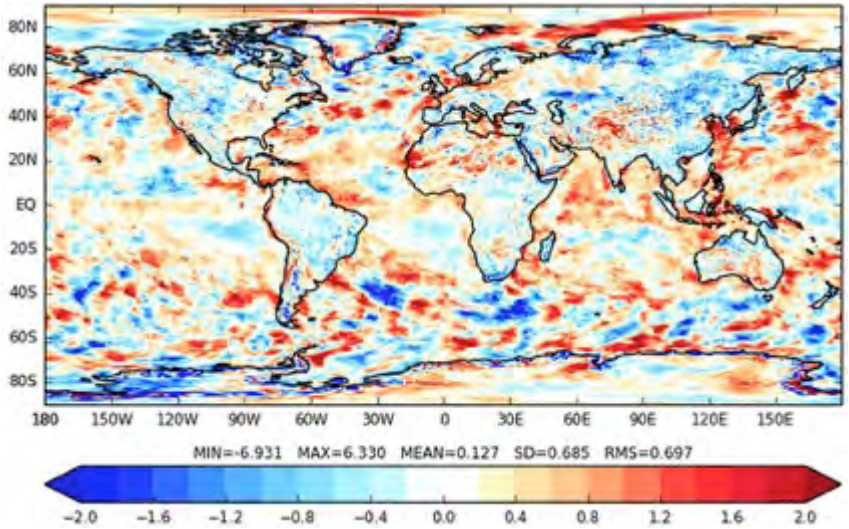


- GA7
- GA7 + veg. drag package

Wind speed MBE and RMSE improved with veg. drag package for all assessed forecast lengths.

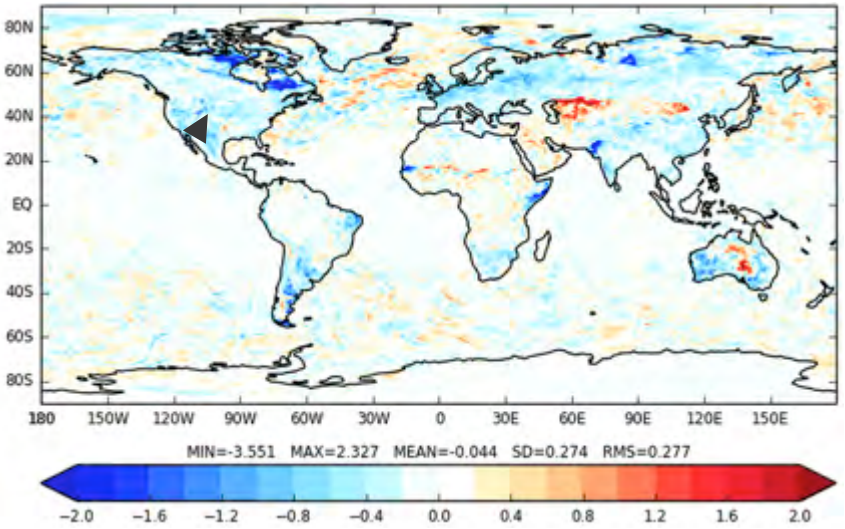
Unified Model errors using vegetation drag package

10m Wind speed:
Model minus Observations (m s^{-1})



Nb Forecasts at T+120h

Model with vegetation drag package:
Change in Model error (m s^{-1})



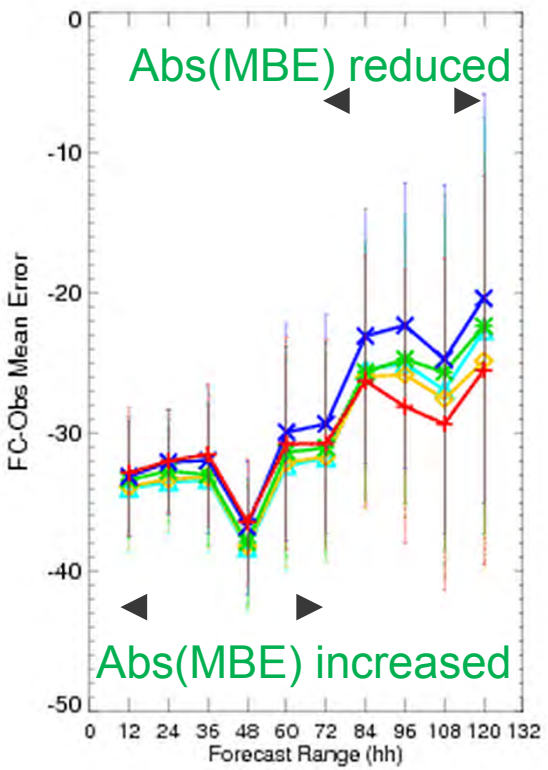
Global area-weighted MBE: 0.127 > 0.084 m s^{-1}
RMSE: 0.697 > 0.724 m s^{-1}

On land wind speed generally decreased (due to increased roughness lengths).

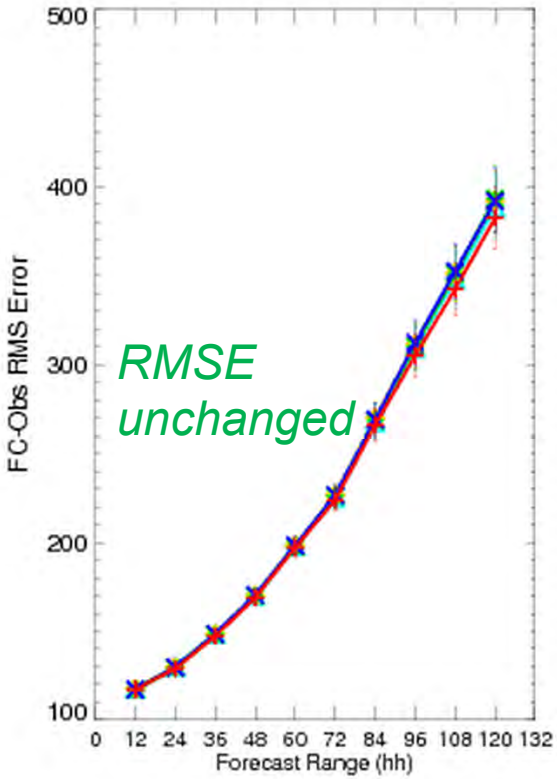
NWP assessment (20°N to 90°N, Obs June 2011 – April 2014): UM GA7.0 configuration + vegetation drag package

Surface pressure (hPa)

Mean bias error



Root mean square error

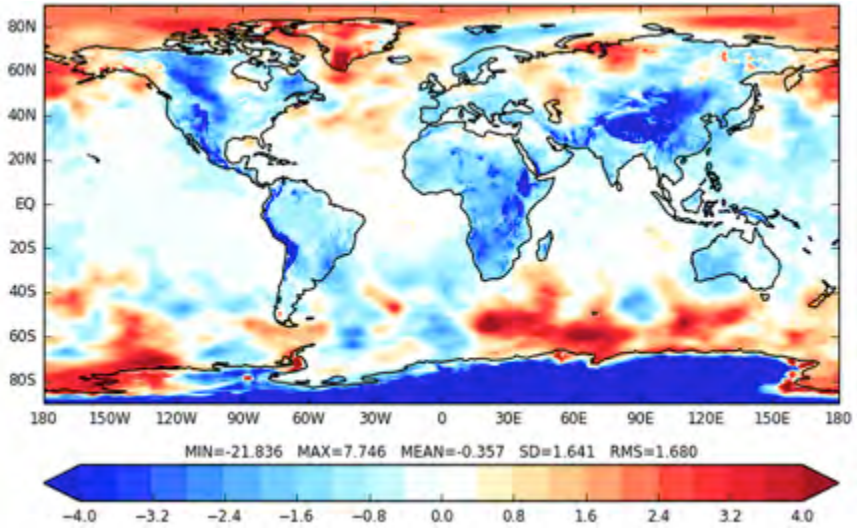


- GA7
- GA7 + veg. drag package

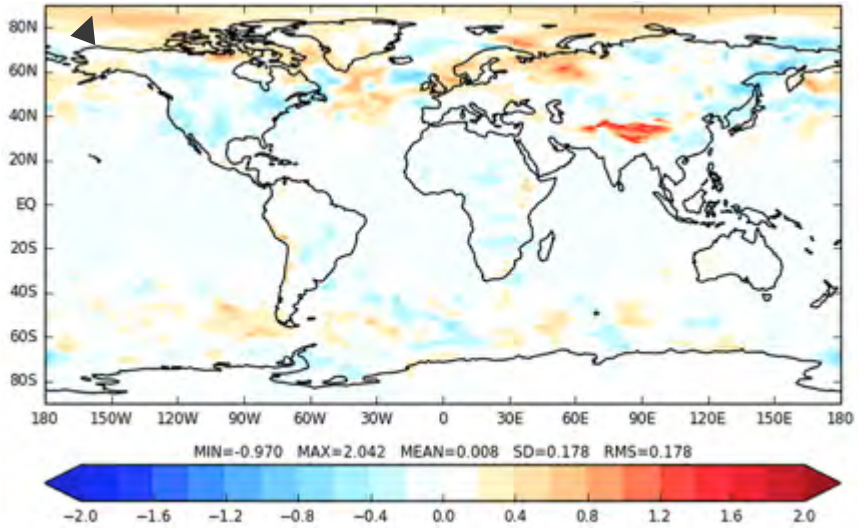
Surface pressure MBE slightly in worse short-, but better in long-forecasts. RMSE no significant change in short- & long-forecasts.

Unified Model errors using vegetation drag package

Surface pressure (MSLP):
Model minus Observations (hPa)



Model with vegetation drag package:
Change in Model error (hPa)



Nb Forecasts at T+120h

North polar bias is worse with vegetation drag package. However, re-parameterizing gravity wave & form drag might improve matters.

Global area-weighted MBE: -0.357 > -0.349 hPa
RMSE: 1.680 > 1.685 hPa

Conclusions

- At FLUXNET2015 sites JULES-GL8 under estimates friction velocity (hence momentum flux) particularly at sites with trees and shrubs.

- Estimating roughness length using FLUXNET2015, across sites with the same IGBP land cover class, produces higher median z0est where vegetation is tallest
  (i.e. $z0_{trees} > z0_{shrubs} > z0_{grassland}$).

- Using revised z0 in JULES-GL8 (offline) leads to much improved friction velocity estimates at the FLUXNET2015 sites with trees and shrubs.

- Using **increased z0** in JULES within the Unified Model (i.e. coupled to atmosphere, AMIP run with GL7 configuration) leads to much better diagnoses of 10m wind speed compared to observations (demonstrable improvements for forecasting in MBE and RMSE out to forecasts at T+120h).

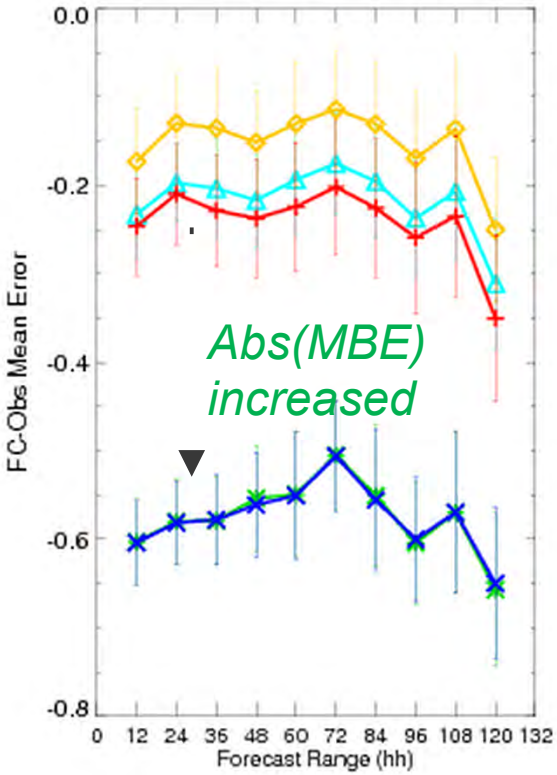
- Further work re-parameterizing the UM gravity wave drag and form/orographic drag is needed to improve the UM surface pressure bias.

- **Q:** What could be the impact of neglecting surface momentum evaluation?
- **A:** Missed opportunity to improve a coupled model when compensating errors in parameterization mask problems with drag.

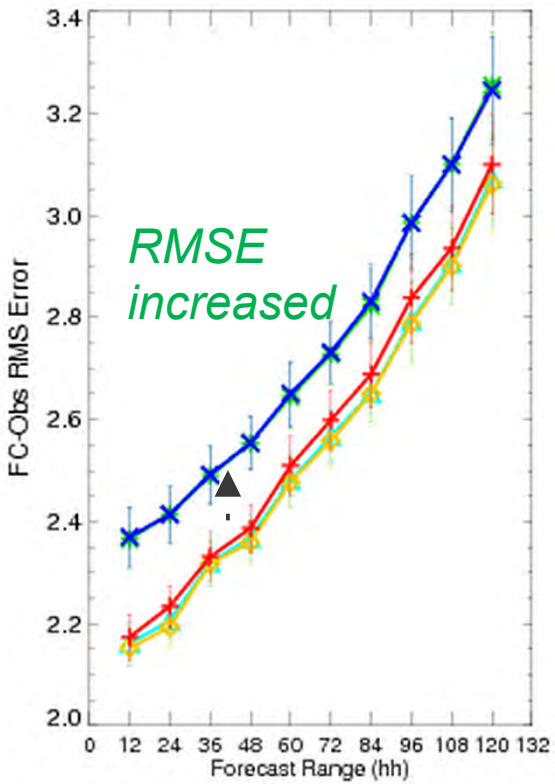
NWP assessment (20°N to 90°N, Obs June 2011 – April 2014): UM GA7.0 configuration + vegetation drag package

2 m Air temp. (K)

Mean bias error



Root mean square error



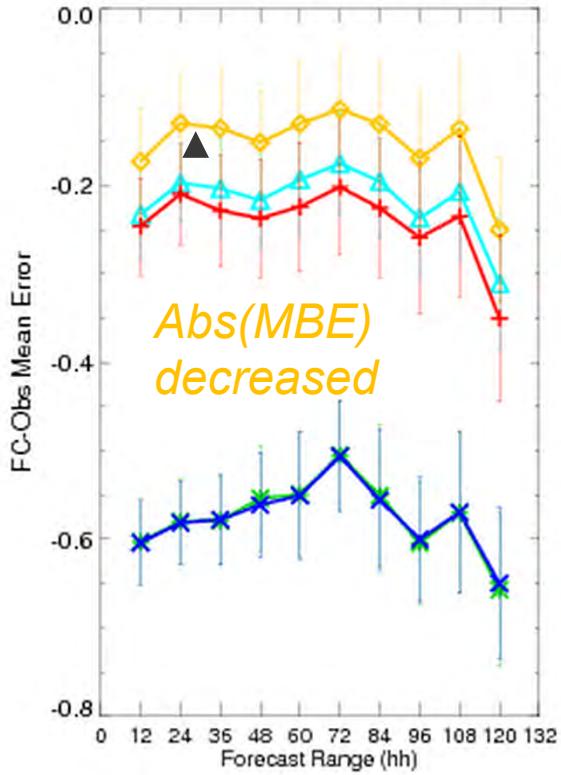
- GA7
- GA7 + veg. drag package

Tair MBE & RMSE worse at all forecast lengths.

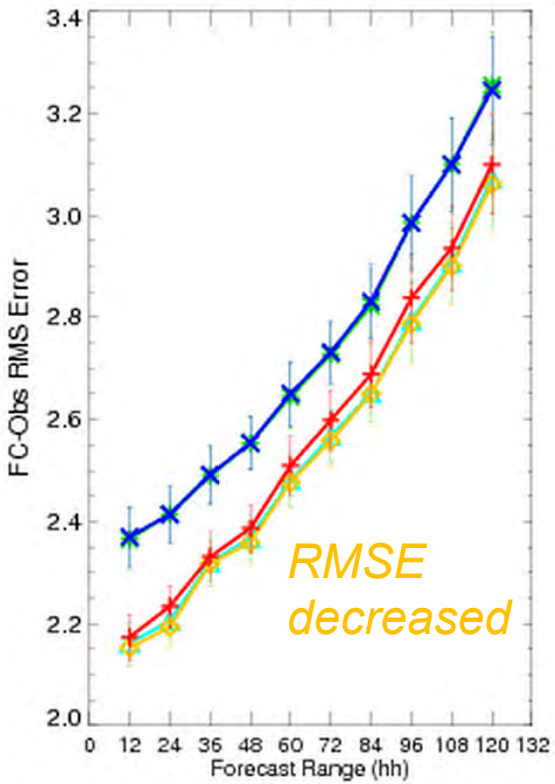
NWP assessment (20°N to 90°N, Obs June 2011 – April 2014): UM GA7.0 configuration + vegetation drag package

2 m Air temp. (K)

Mean bias error

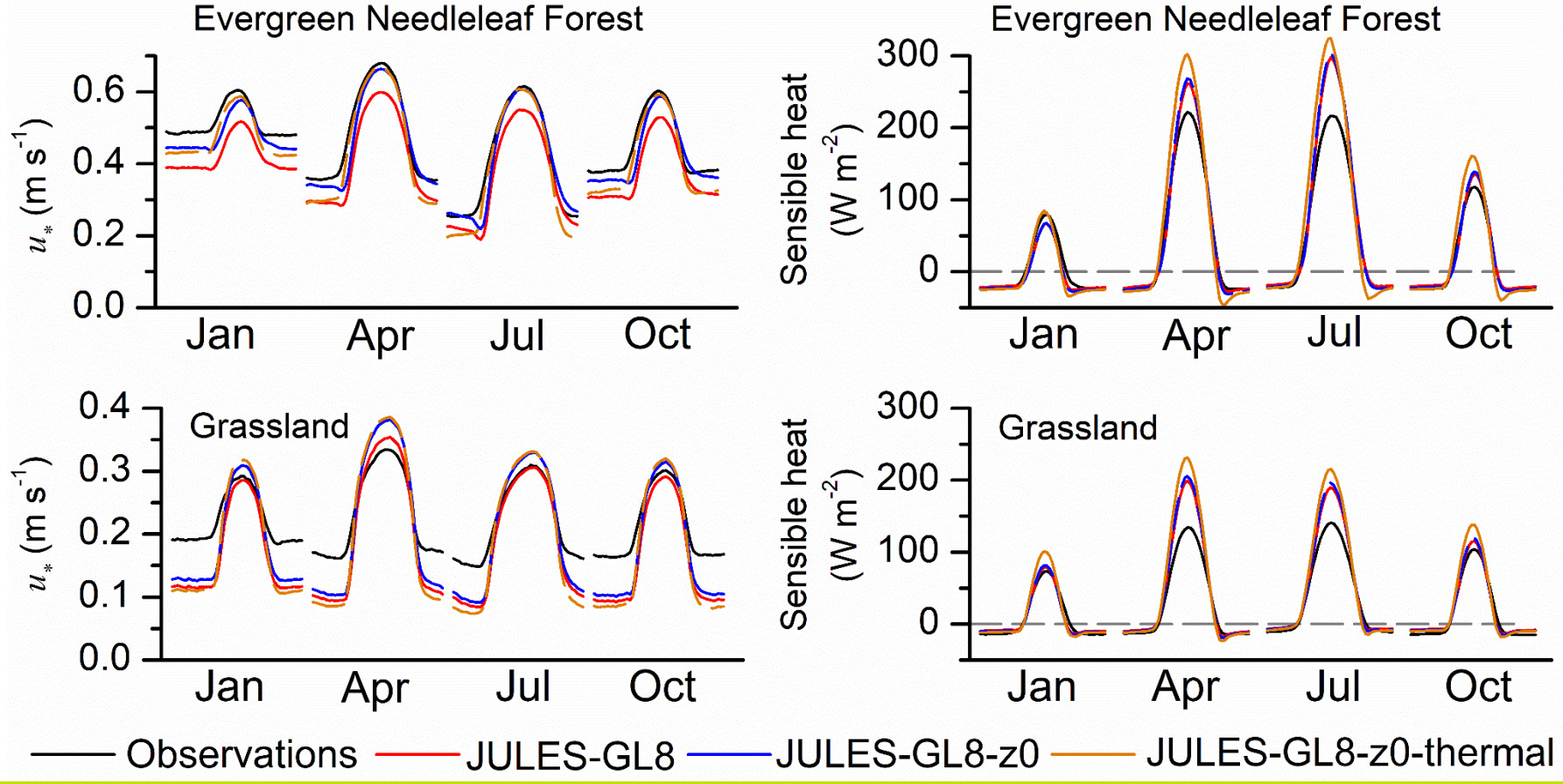


Root mean square error



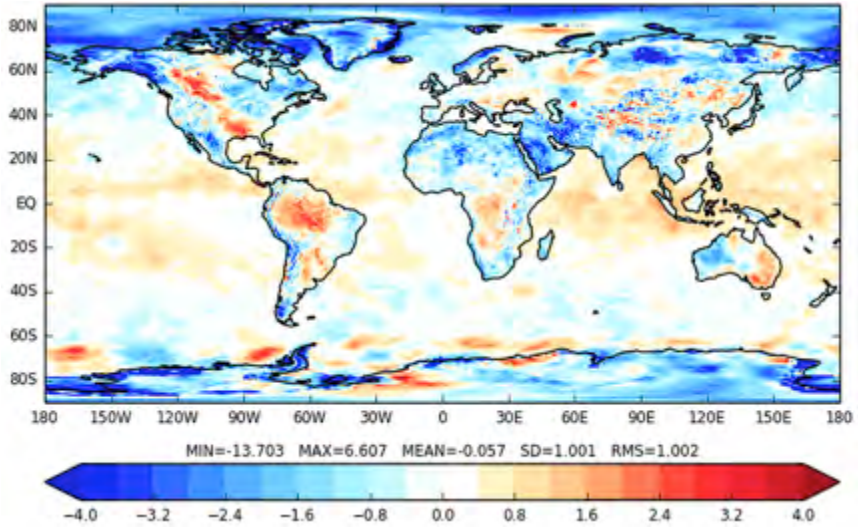
- GA7
- GA7 + veg. drag package
- Revised canopy-soil thermal coupling

Revised canopy-soil thermal coupling in JULES-GL8



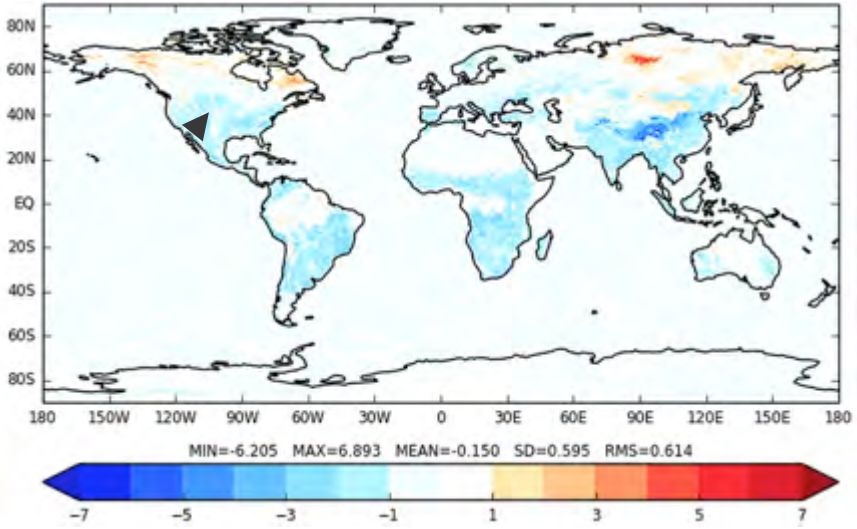
Unified Model errors using vegetation drag package

2m Air temperature:
Model minus Observations (K)



Nb Forecasts at T+120h

Model with vegetation drag package:
Change in Model error (K)



Global area-weighted MBE: -0.015 > -0.020 K
RMSE: 0.818 > 0.842 K

On land air temp. generally decreased over grassland, crops, savanna and shrubs.