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Evaluating evaporation components in flux data and model output

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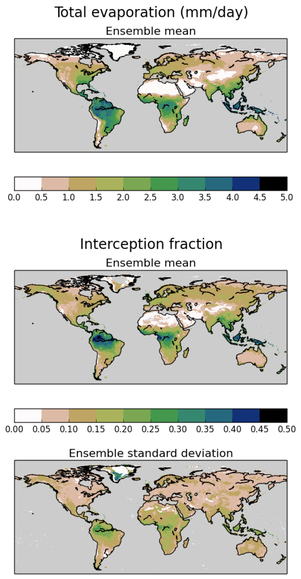
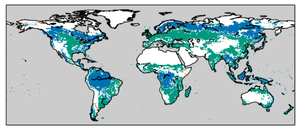
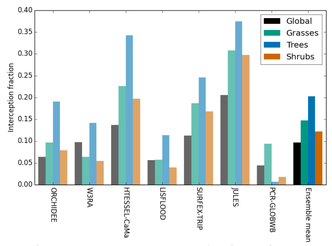


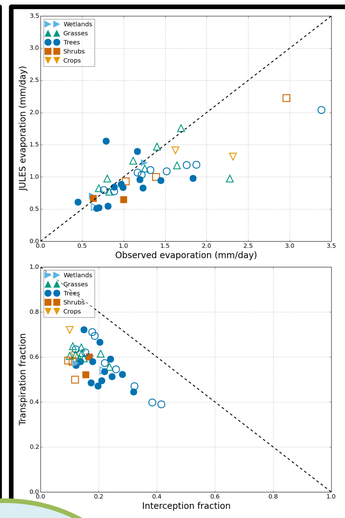
Motivation: Model uncertainty

Earth2Observe [1] is a project combining observations and modelling to assess global water resources. As part of this seven global models, forced with WFDEI 0.5° resolution meteorological data [2], have been used to estimate daily evaporation globally for the years 1979-2012. We have calculated the overall mean total evaporation and interception from each of the models, and used these to find an overall interception fraction. We see a wide range of estimates of interception fraction between models, ranging from 5% to 20% globally, with an ensemble mean of 10%. Areas dominated by trees generally have higher interception than grasses and shrubs, with the ensemble mean approaching 50% in the Amazon basin. The variation between models is largest in tropical regions, where evaporation is high and canopy capacity is large.

This study intends to use site observations to validate the models and investigate the sources of model uncertainty.

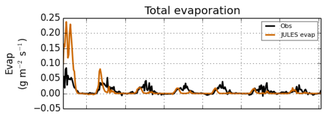


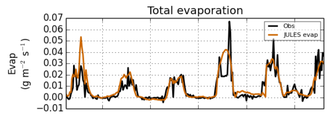


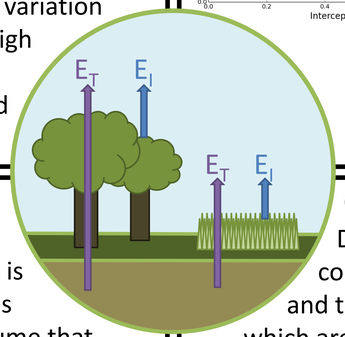


Flux data

In order to test the models against observations, we use data from Fluxnet sites, gap-filled according to the Protocol for the Analysis of Land Surface models (PALS) [3]. We ran JULES [4] at these sites and compared the modelled total evaporation with observed latent heat flux over the full run. JULES reproduces the evaporation well, but underestimates for sites with high observed evaporation. JULES estimates interception fraction of between 10% and 45%, with trees having higher interception fraction than other vegetation types. However, we do not have observations of interception fraction at these sites, so we wish to investigate whether the signal of the different components is detectable in the total latent heat flux measurements. As open-path IRGAs (open symbols) are not able to provide reliable flux measurements when the canopy is covered with water, we select only the sites which have closed-path IRGAs (closed symbols).



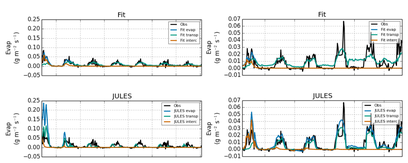




Conceptual model

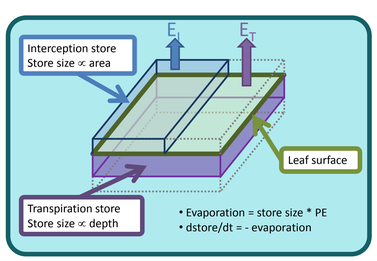
We construct a simple conceptual model, which consists of two coupled water stores:
1) transpiration store, which is effectively the root zone soil moisture 2) interception store, which is the water on the surface of the leaves. We assume that the portion of the canopy surface which is covered with water does not allow transpiration fluxes to pass through the stomata. We also assume that the total evaporation is proportional to the store size and to the evaporative demand, which is calculated using Penman-Monteith potential evaporation [5].

Constructing this as differential equations, and solving for the dry down, we find an expression for the total evaporation which depends on the potential evaporation, the capacities of the water stores, and the amount of water in each store at the end of each rainfall event.



In order to extract information about evaporation components from the flux data, we apply three methods

1. Full fit of conceptual model to drydown
2. Fit transpiration to day three onwards, then use to fit interception in first three days
3. Assume all of day 1 is only interception, day 2 onwards is only transpiration

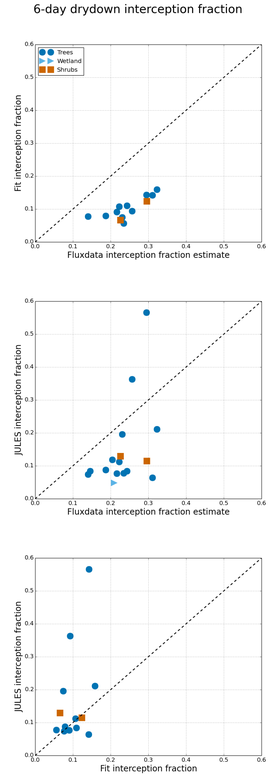


Interception | Transpiration | Inhibition of transpiration

$$E(t) = PE_I(t)\frac{I_0}{I_{tot}}e^{-\frac{1}{I_{tot}0}\int^{t} PE_I(t')dt'} + PE_T(t)\frac{T_0}{T_{tot}}e^{-\frac{1}{T_{tot}0}\int^{t} PE_T(t')dt'}\left(1-\frac{I_0}{I_{tot}}e^{-\frac{1}{I_{tot}0}\int^{t} PE_I(t')dt'}\right)e^{\frac{I_0}{T_{tot}I_{tot}}\int_0^{t} PE(t')e^{-\frac{1}{I_{tot}0}\int^{t'} PE_I(t^*)dt^*}}$$

Ongoing investigations

Due to the uncertainties in flux measurements and PE estimates, combined with the complexity of the interaction between interception and transpiration, method 1 provides estimates of interception fraction which are highly uncertain. Method 2, currently being investigated, implicitly includes assumptions about the maximum rate of dry down, and therefore places firmer constraints on the interception fraction. Method 3 provides a simple upper limit for interception, which guides our further investigations. We have compared the results from methods 2 and 3 with those from JULES, for the first 6 days of drydown. We see that the constrained fit estimates a much smaller interception fraction than our first-day upper limit. JULES, however, has a wider range of interception fraction, including some sites with interception higher than both the fit and the upper limit estimate. This suggests that JULES is overestimating the interception.



Concluding remarks

- Uncertainty on interception fraction between models globally, with estimates ranging from 5% - 20%.
- Fully fitting to flux data does not constrain parameters as data are noisy and interception and transpiration inversely correlated
- Constrained fits suggest model is overestimating interception fraction, and require further study
- Measurements of interception at flux sites will be used to validate the conceptual model

References: [1] Schellekens, J., E. et al (2015): A global water resources ensemble of hydrological models: the eartH2Observe Tier-1 dataset. Geoscience Data Journal, in review.
[2] Weedon, G. P. et al (2014): The WFDEI meteorological forcing data set: WATCH forcing data methodology applied to ERA-interim reanalysis data. Water Resources Research, 50 (9), 7505-7514.
[3] Abramowitz, G (2012): Towards a public, standardized, diagnostic benchmarking system for land surface models. Geosci. Model Dev., 5:819-827
[4] Best et al (2011): The Joint UK Land Environment Simulator (JULES), model description – Part 1: Energy and water fluxes, Geosci. Model Dev., 4, 677–699, doi:10.5194/gmd-4-677-2011
[5] Monteith, J. L. (1965): Evaporation and environment, in: 19th Symposia of the Society for Experimental Biology, University Press, Cambridge

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