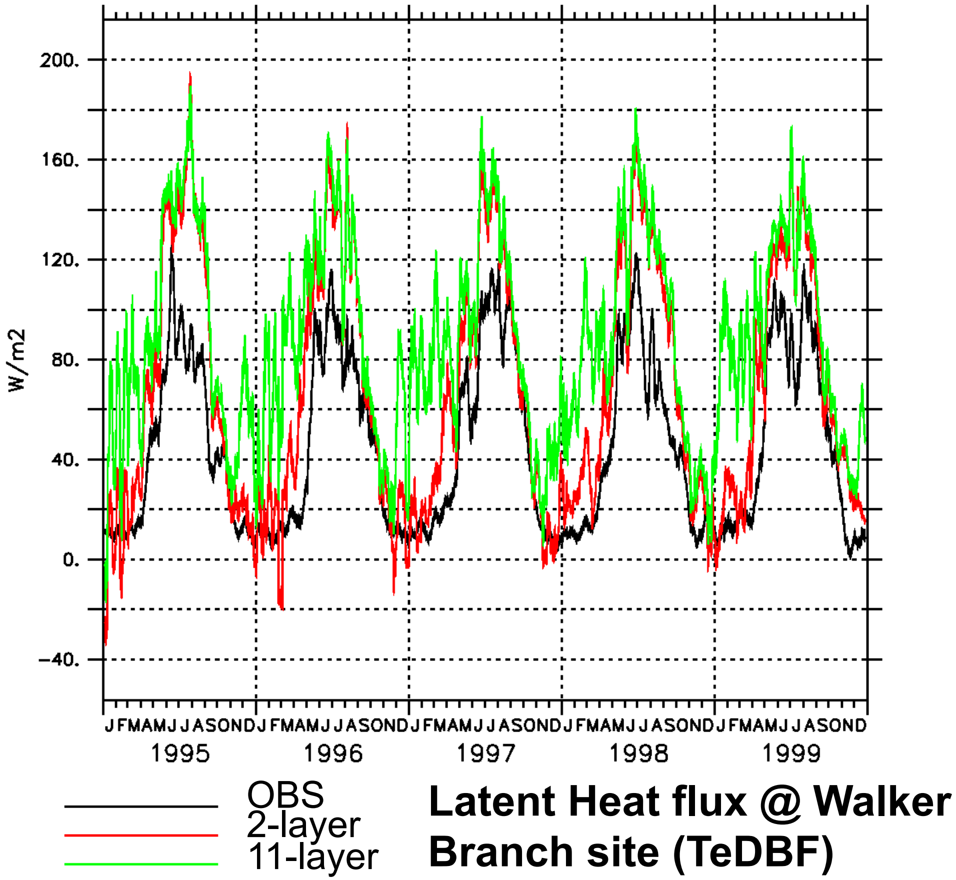
Modification of the aerodynamic resistance formulation

A possible solution for reducing the bias on evaporation

N. Vuichard - LSCE

Context

- Shifting from the 2-layer hydrological scheme to the 11-layer one increases latent heat flux for some PFT's
  - That is due to the evaporative component
  - It acts at winter time for deciduous trees when no canopy coverage



Latent Heat flux @ Walker Branch site (TeDBF)

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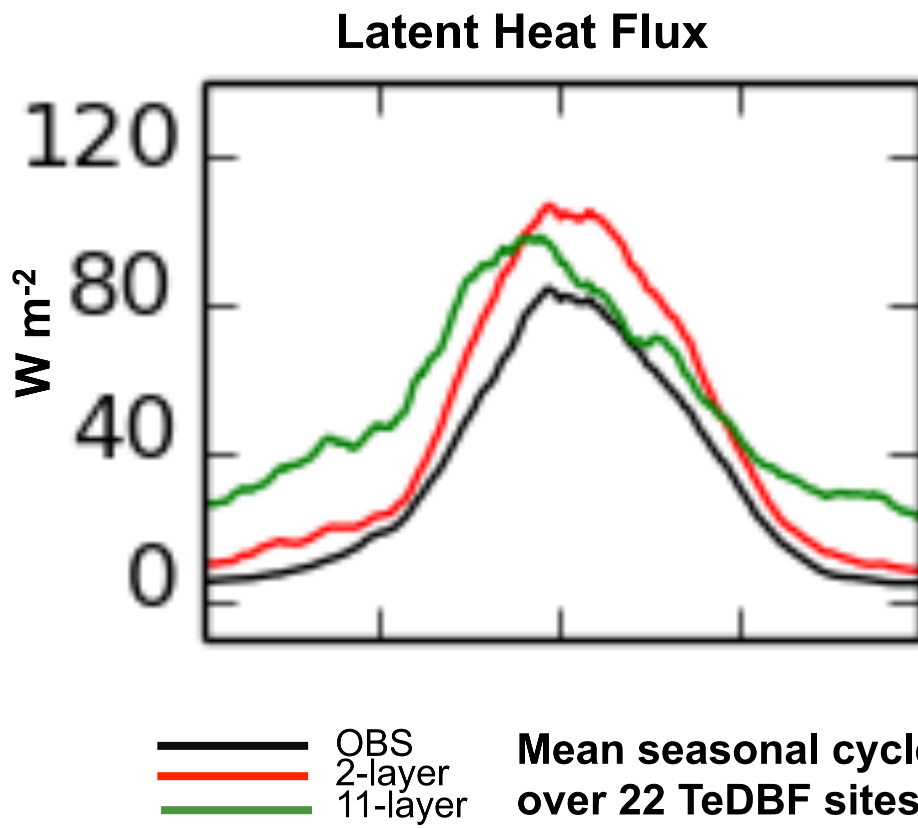


Mean seasonal cycle over 22 TeDBF sites

How evaporation is represented ?

- In the 2-layer scheme, there is an explicit soil resistance to evaporation

- In the 11-layer scheme, the potential evapotranspiration is the flux set as a boundary condition to the diffusion scheme.
  - Either the potential evapotranspiration can be supplied
  - Either a minimal evaporation flux is defined by setting the soil water content of the first layer to the residual

⇒***Different schemes, no direct comparison***

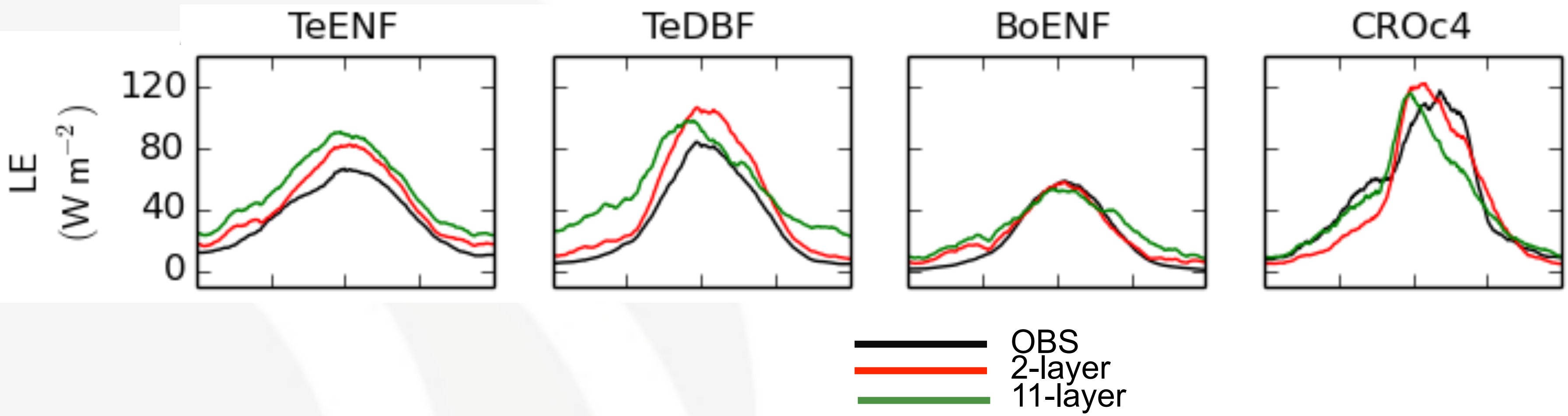
Many sources of uncertainties

- Only measurements of the evapotranspiration, no direct measurements of evaporation

- Evaporation and transpiration components are driven by the LAI which is computed by ORCHIDEE
  ⇒Differences between observed and modelled LAI

- Observed Energy budget is not closed by approx. 15-20%

Latent heat flux on different vegetation types



- Good performance of the 11-layer scheme over cropland sites, even during bare soil periods (only evaporation, no transpiration)

Searching for possible processes …

- That may explain the bias on evaporation
- Modelled differently for crops and forests PFT within ORCHIDEE

⇒ ***Aerodynamic resistance and the parameterization of the roughness height***

$$r_a = \frac{1}{\kappa^2 u_a}\left[\ln\left(\frac{z-d_0}{z_{0m}}\right)\ln\left(\frac{z-d_0}{z_{0v}}\right)\right]$$

where

- z is measurement height (m)
- u_a is wind speed (ms^{-1})
- k von Karman's constant
- d_0 is displacement height
- z_{0m} and z_{0v} the roughness heights for momentum and water vapor transfer

Roughness height calculation in ORCHIDEE

- Calculation of the averaged z_0 for a grid point
  - For true bare soil and "bare soil" of vegetated PFTs

    z_0 = 0.01 m   *weighted by tot_baresoil*
  - For grass and crops

    z_0 = 1/16 * height   *weighted by veget*
  - For trees

    z_0 = 1/16 * height   *weighted by veget_max*

⇒*One assumes that the trunk and the branches impact as a full canopy coverage on z_0*

- Search for literature supporting that z_0 varies with LAI
  - Ershadi et al. (2015) uses the formulation of Su et al. (2001)
  - An evaluation of different z_0 formulations by Liu et al. (2007)

Formulation of Su et al . (2001)

- Roughness height for momentum transfer

$$z_{0m} = h_c \left(1 - \frac{d_0}{h_c}\right) \exp\left(-\frac{\kappa}{\eta}\right)$$

where

- h_c is the canopy height
- η is the ratio of friction velocity to wind speed, defined as function of LAI

- Roughness height for water vapor transfer

$$z_{0h} = z_{0m}/\exp(\kappa B^{-1})$$

$$\kappa B^{-1} = \frac{\kappa C_d}{4 C_t \beta \left(1 - \exp\left(-\frac{n_{ec}}{2}\right)\right)} f_c^2 + 2 f_c f_s \frac{\kappa \eta z_{0m}/h_c}{C_t^*} + \kappa B_s^{-1} f_s^2$$

where

f_c the fraction of canopy coverage and f_s the fraction of soil coverage

Impacts on the energy budget

- On the latent heat flux

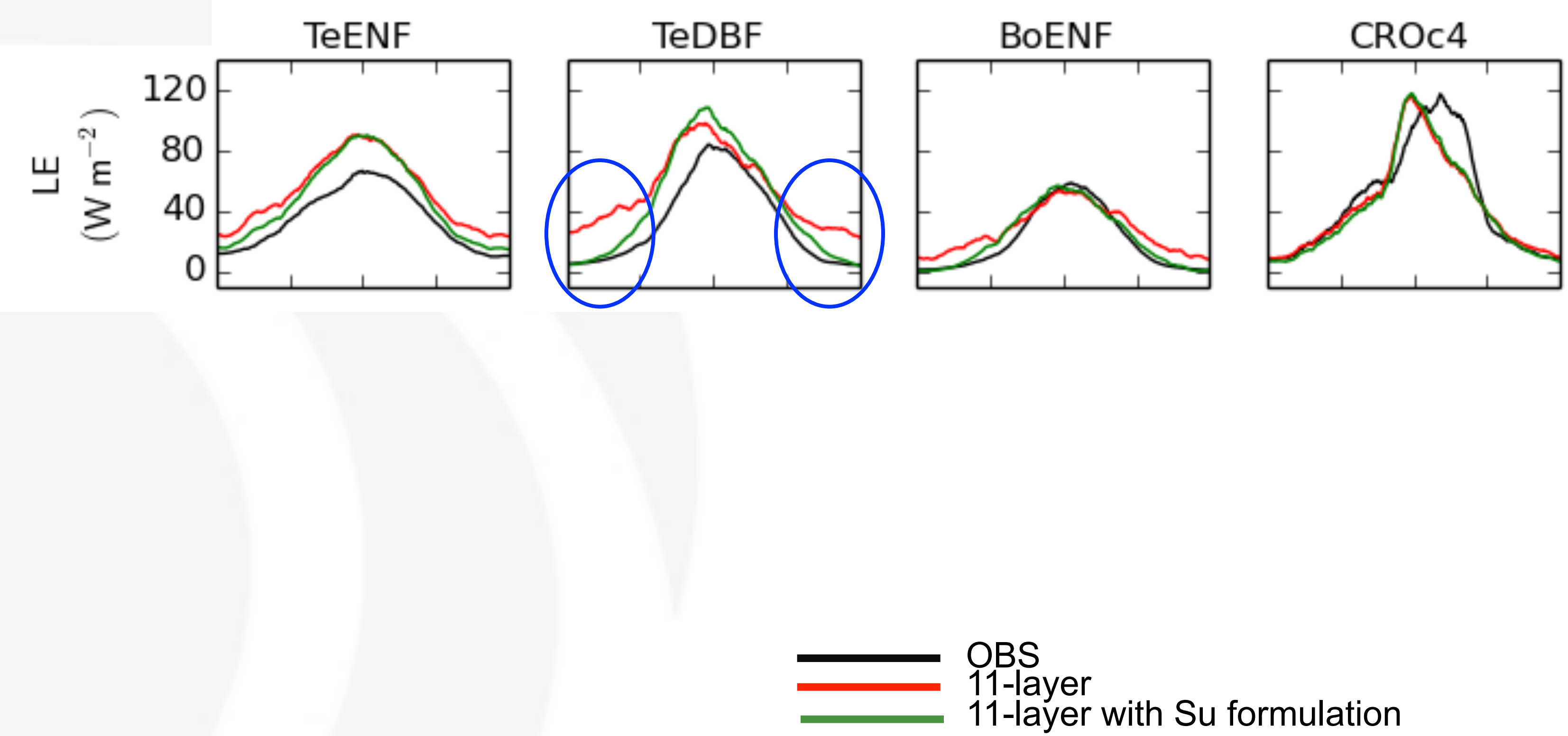
$$L.E_s^t = L\rho\,|\overrightarrow{v}|\,C_d\beta(q_1^t - q_{sat}(T_s^t))$$

- On the sensible heat flux

$$F_{H,s}^t = \rho\,|\overrightarrow{v}|\,C_d(H_1^t - H_s^t)$$

With C_d the drag coefficient = $(r_a u_a)^{-1}$

Evaluation at site level (1)



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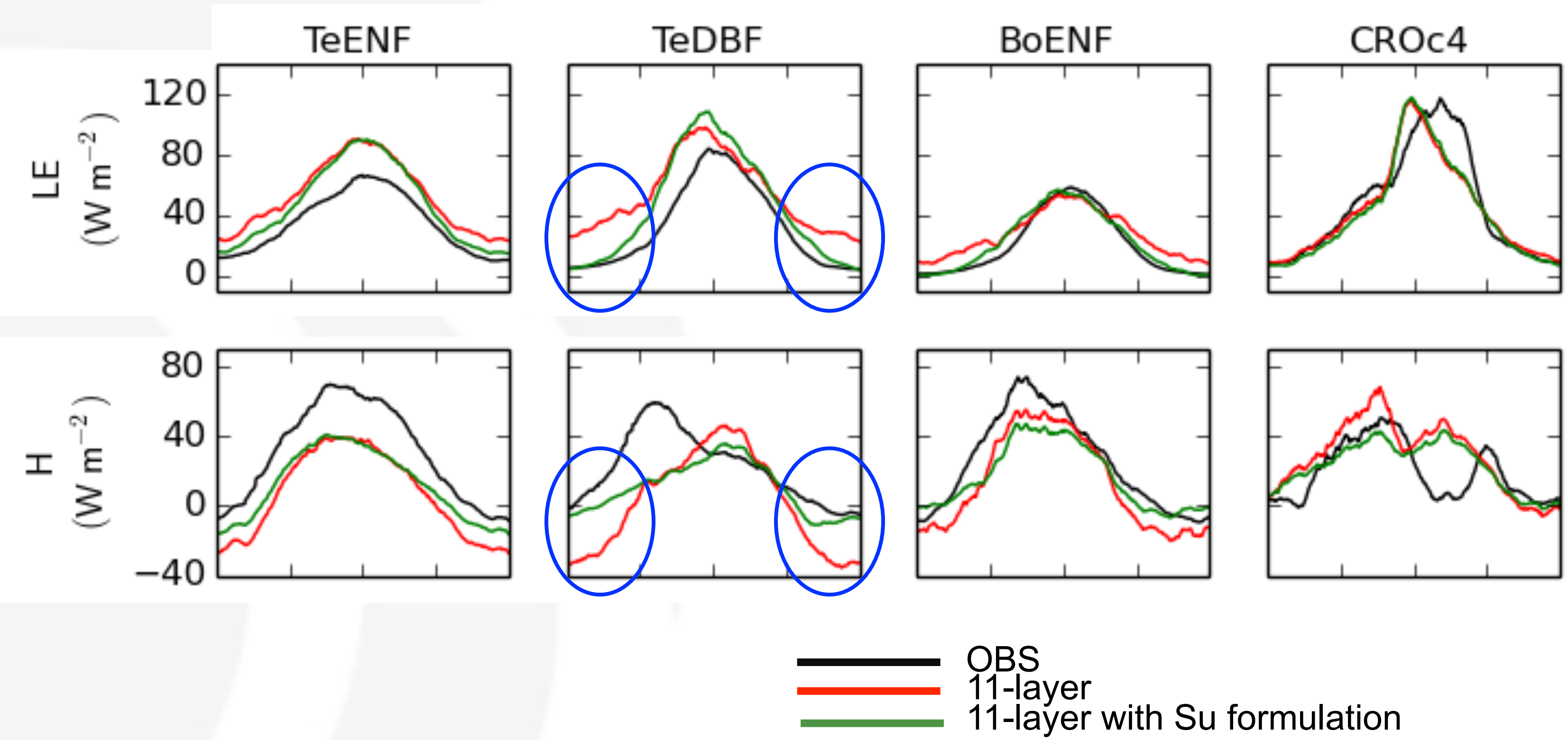

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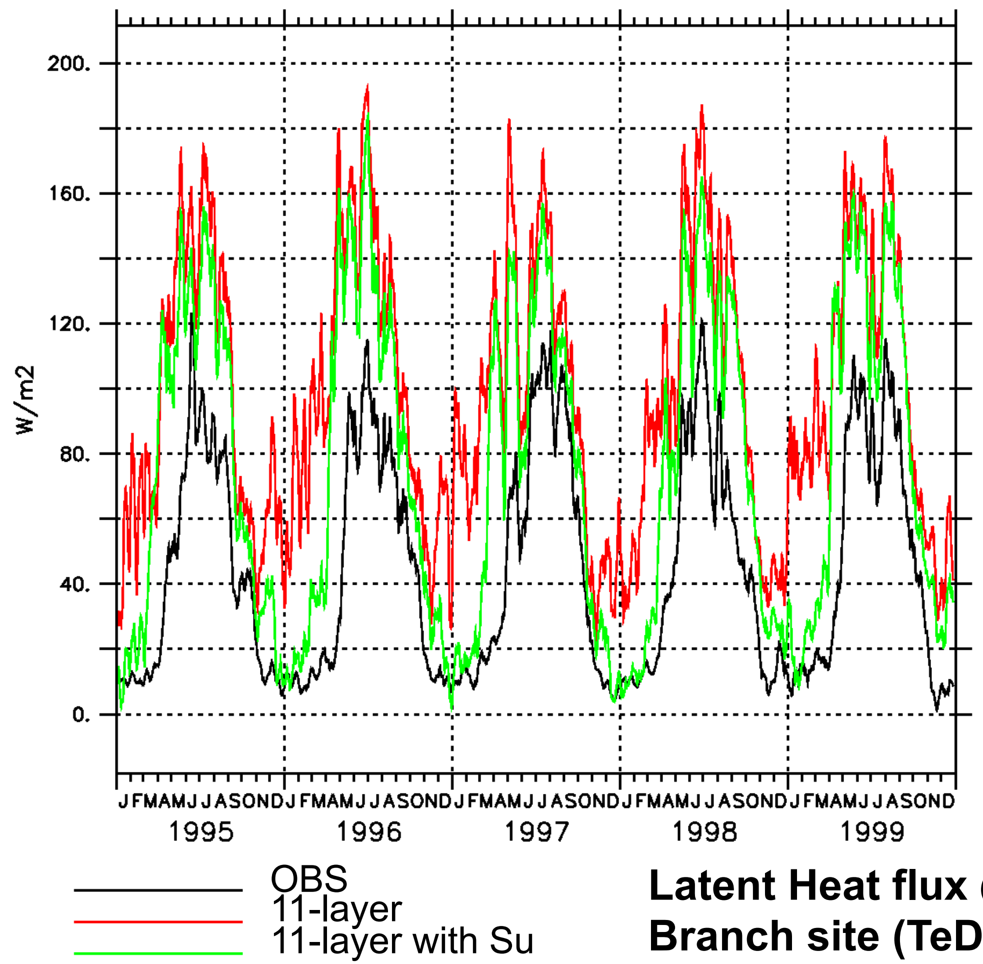

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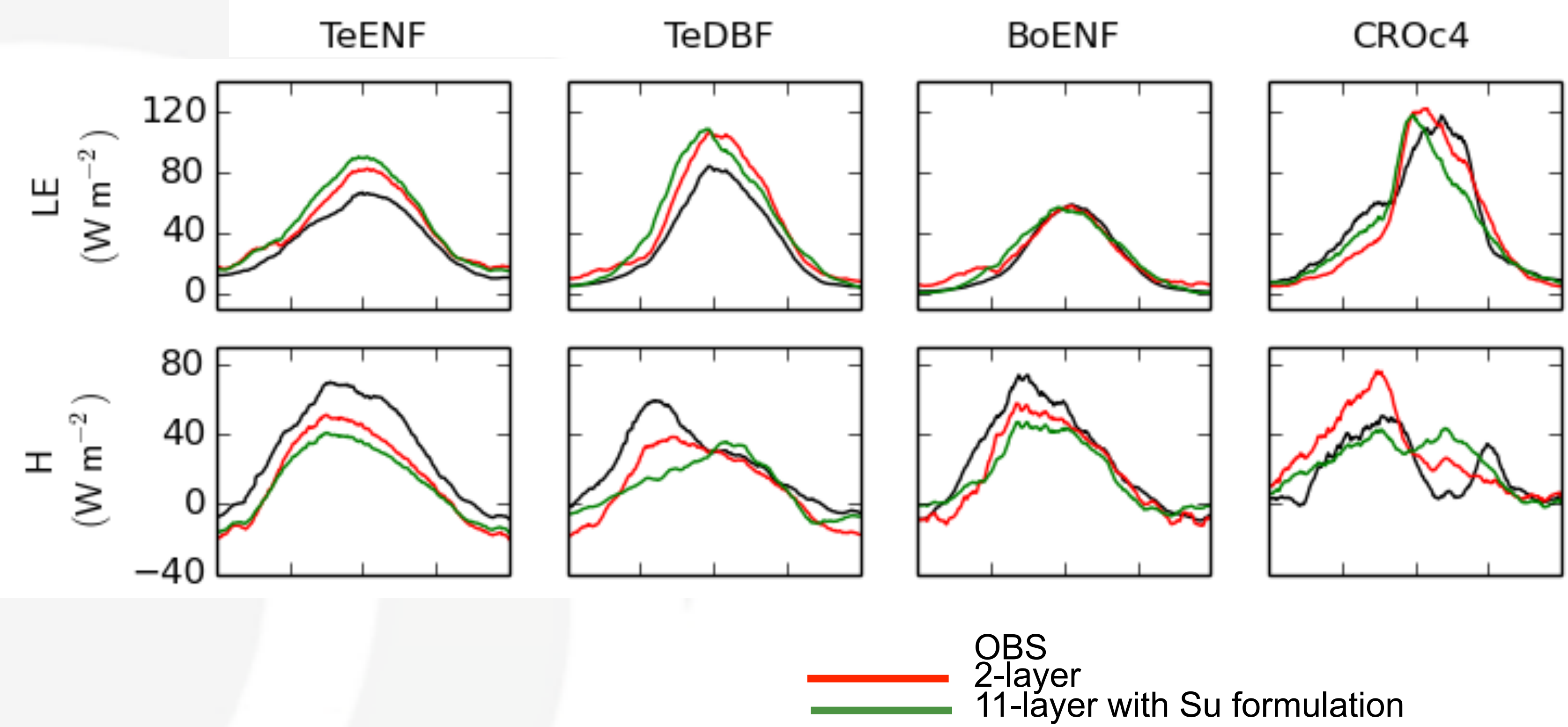
Evaluation at site level (2)



Conclusion & Perspectives

- Accounting for a roughness height varying with the canopy coverage
  - can correct alone for the bias on evaporation
  - a soil resistance can be added but it is not needed

- Implementation of the formulation of Su et al.
  - Relatively complex
  - More simple formulations could be envisaged ?

- Work on the water stress on GPP
  - Can now be envisaged

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Thank you !

Thanks to Vladislav Bastrikov for the post-treatment scripts and plots