A physically based model for actual evapotranspiration of an *actual* grass field closely resembling FAO *hypothetical* reference grass non-advective conditions suitable for remote sensing applications

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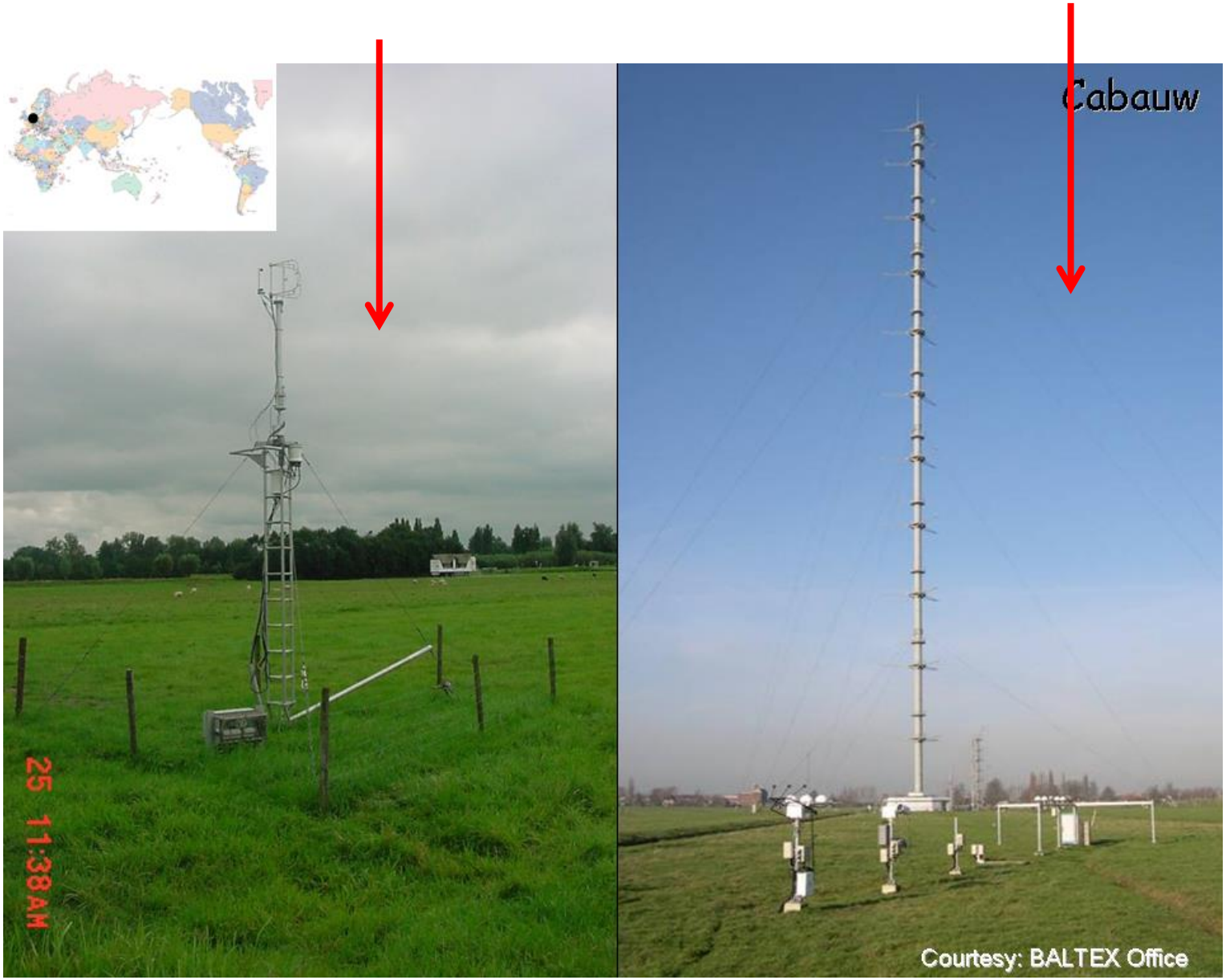
This work can be regarded a theoretical derivation of the empirical **Makkink** methodology presented on earlier LSA SAF Workshops and applied successfully by de Bruin, Trigo et al. (2010) in Ethiopia

It is about actual evapotranspiration of well-watered grass , surrounded by similar grass, near the 200 m tower of KNMI for 2007-2012



Objectives

To presant A physically based model for actual ET of grass resembling closely hypothetical FAO reference grass, used in irrigation practice,

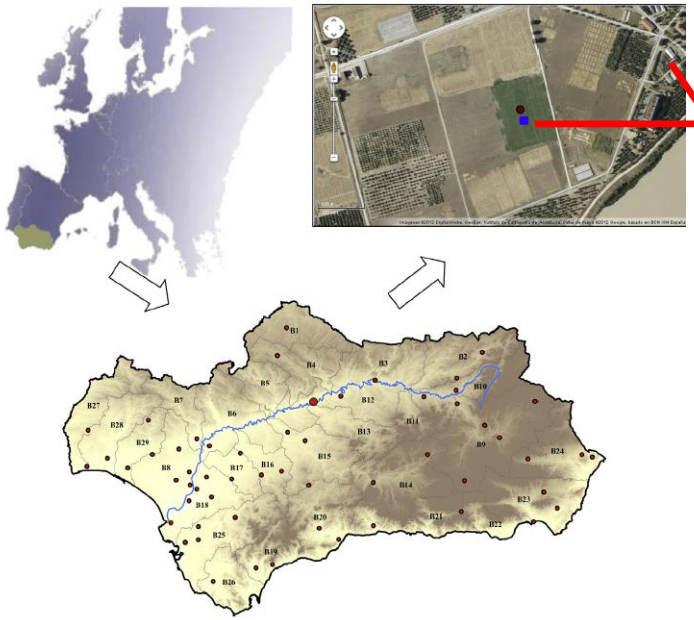
Our results confirm the thermodynamic approach by Schmidt (1915), published 100 year ago!!

This talk is meant to honor the work of Wilhelm Schmidt

Strahlung und Verdunstung an freien Wasserflächen; ein Beitrag zum Wärmehaushalt des Weltmeers und zum Wasserhaushalt der Erde.

Von Wilhelm Schmidt.

It is also about actual daily actual ET of the irrigated IFAPA Lysimeter grass field near Cordoba surrounded by dry terrain in summer season and Cordoba RIA site, for 2007-2009



IFAFA

RIA

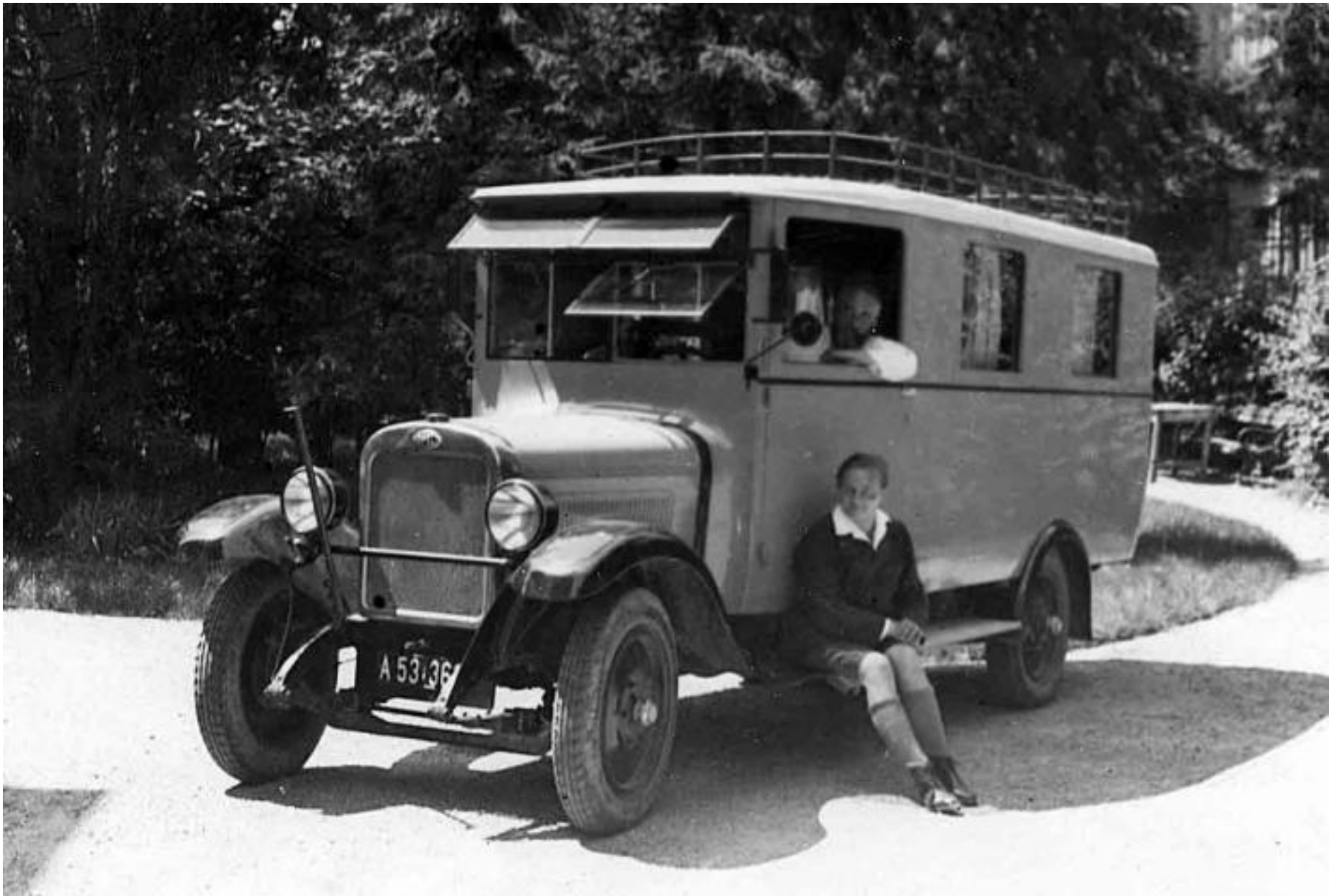
Andalucia RIA network of agro-met. stations

Regional Irrigation Advice (RIA)

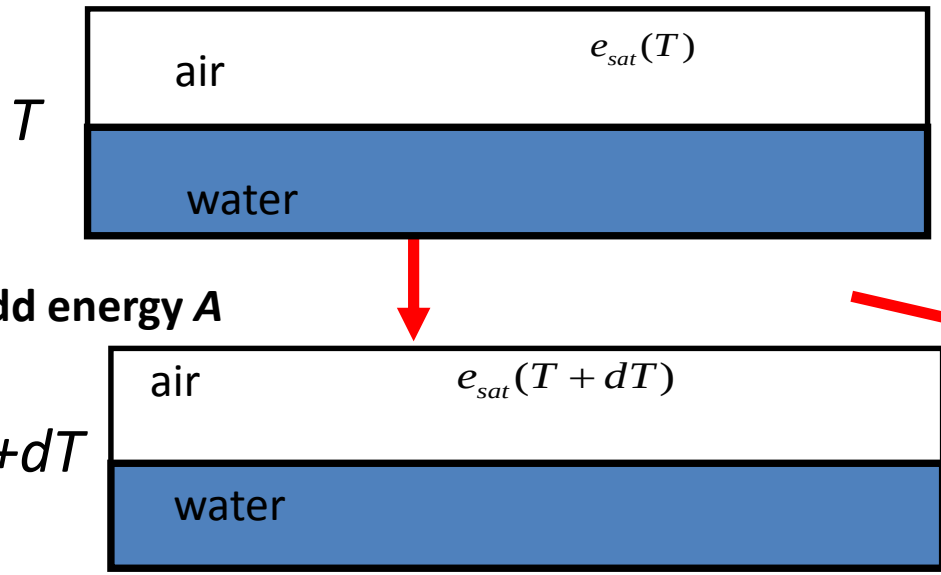
Cruz et al., (2014 a and b) applied successfully our **revised Makkink_advection** approach, for which a Schmidt-based ‘derivation’ will be presented (if time allows)

PART 1: no advection

Wilhelm Schmidt and his mobile micrometeorological station



Wilhelm Schmidt, 1915, Thermodynamica



RH=100%

$$s(T) = \left(\frac{de_s}{dT}\right)_T$$

$\lambda \approx 2.5.10^6 \ J/kg$ latent heat of vaporization

$\gamma = psych.const.$

$$\lambda E = \frac{s}{s+\gamma} A$$

At the top of the atmospheric boundary layer dry (ABL) air is entrained into the ABL, relative humidity over well-watered surfaces is always less than 100%, Therefore a correction must be applied.

We follow de Bruin&Holtslag (1983)

$$\lambda E = \frac{s(T)}{s(T)+\gamma} A + cor$$

In hydrology Priestley-Taylor

$$\lambda E = \alpha \frac{s(T)}{s(T)+\gamma} A$$

Part 1

Application of this Schmidt approach (or revised PT) to well-watered short grass growing in large fields (no advection); daily values

Then *A* = available energy = R_n = net radiation; soil heat flux G can be ignored

correction

$$\lambda E = \frac{s(T)}{s(T)+\gamma} R_n + 20$$

$$s(T) = \left(\frac{de_s}{dT}\right)_T$$

$$\lambda \approx 2.5.10^6 \ J/kg$$

$$\gamma = psych.const.$$

Physical picture: when water supply is not limited, evaporation is driven by thermodynamics, and depends on available energy and temperature

Keywords: conservation of energy and 'Clausius-Clapeyron'

Next we applied the Slob-de Bruin formula for net radiation for well-watered grass presented by de Bruin (1987)

R_{ext} is extraterrestrial radiation

$$R_{net} = (1 - 0.23)R_s - 110\frac{R_s}{R_{ext}}$$

R_s = global radiation

De Bruin et al. (2016) theoretical underpinning

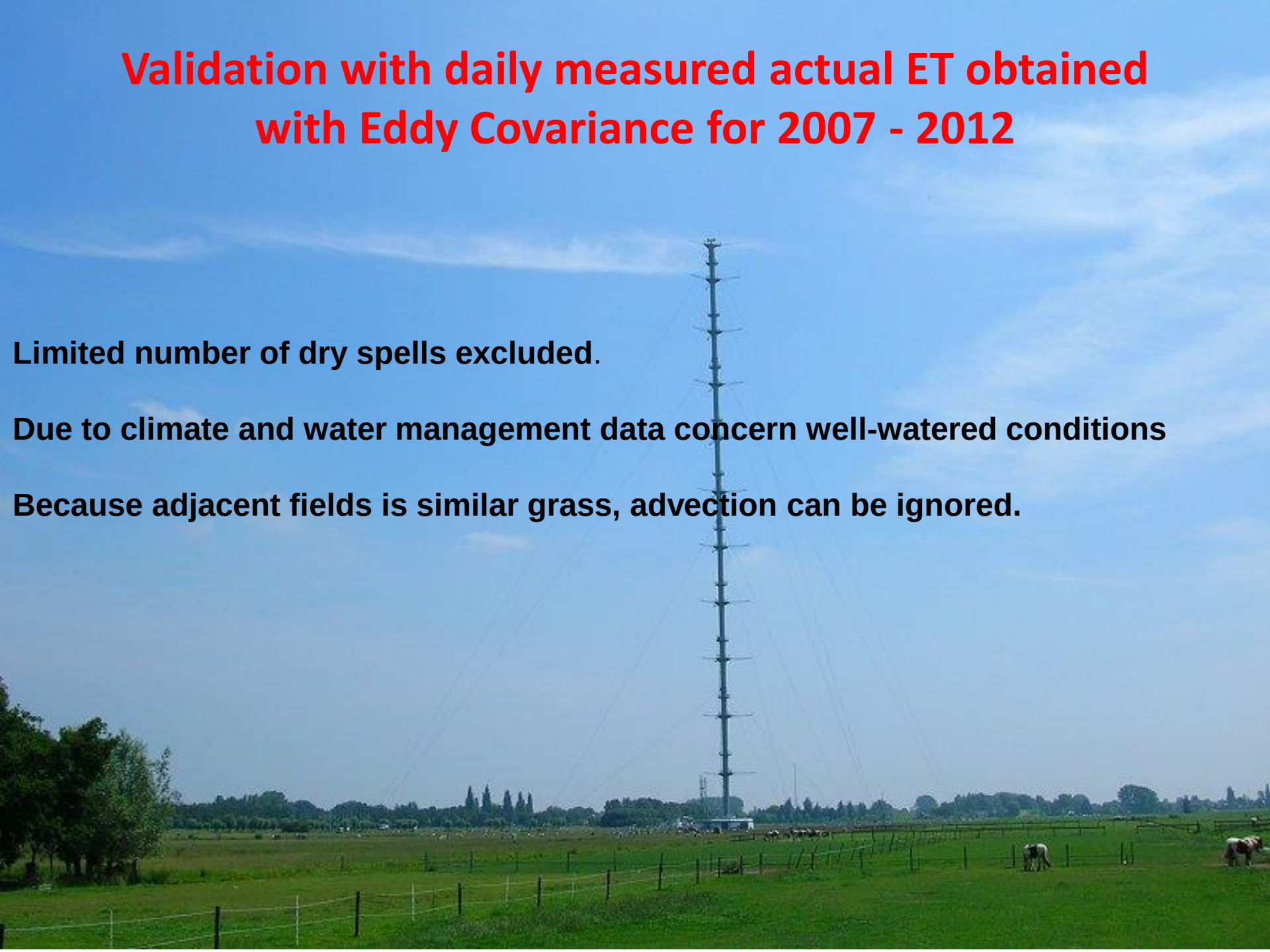
SEVERI-MSG

This leads to final formula

$$\lambda E = \frac{s(T)}{s(T)+\gamma}\left[(1-0.23)R_{sMSG} - 110\frac{R_{sMSG}}{R_{ext}}\right] + 20\ W/m^2$$

Input: R_{sMSG} and T = air temperature only

Validation with daily measured actual ET obtained with Eddy Covariance for 2007 - 2012

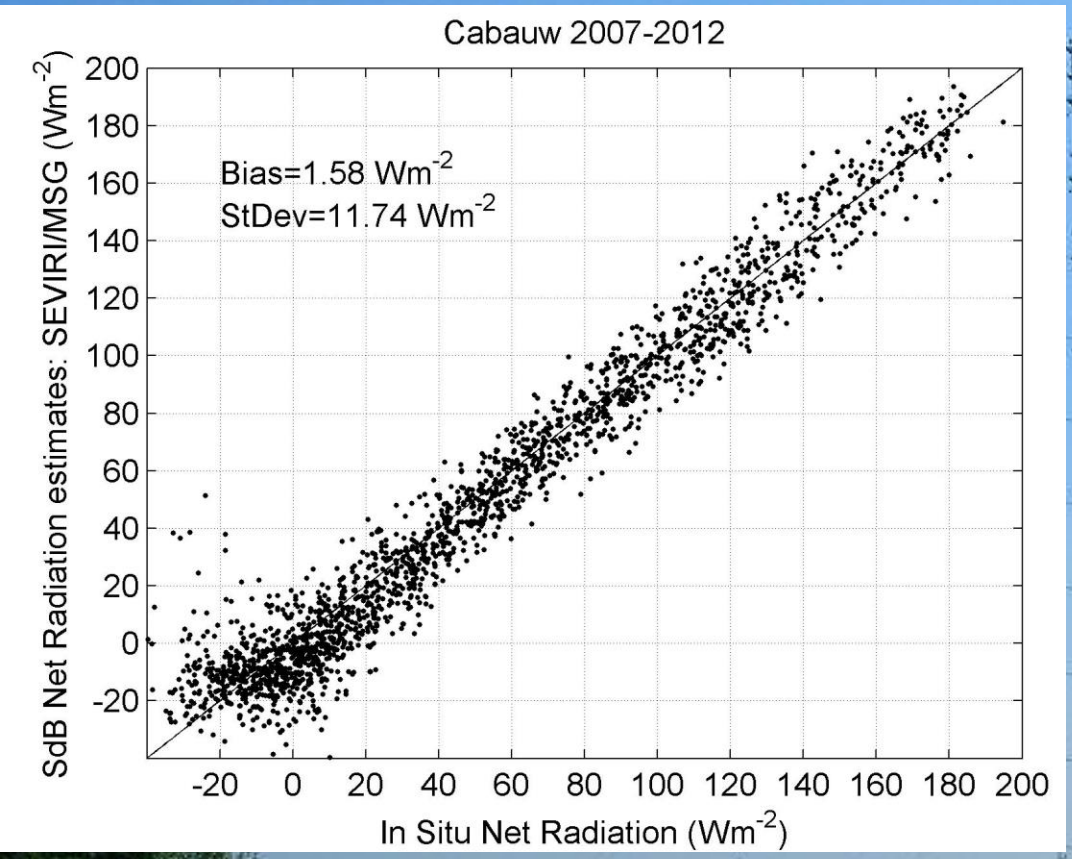


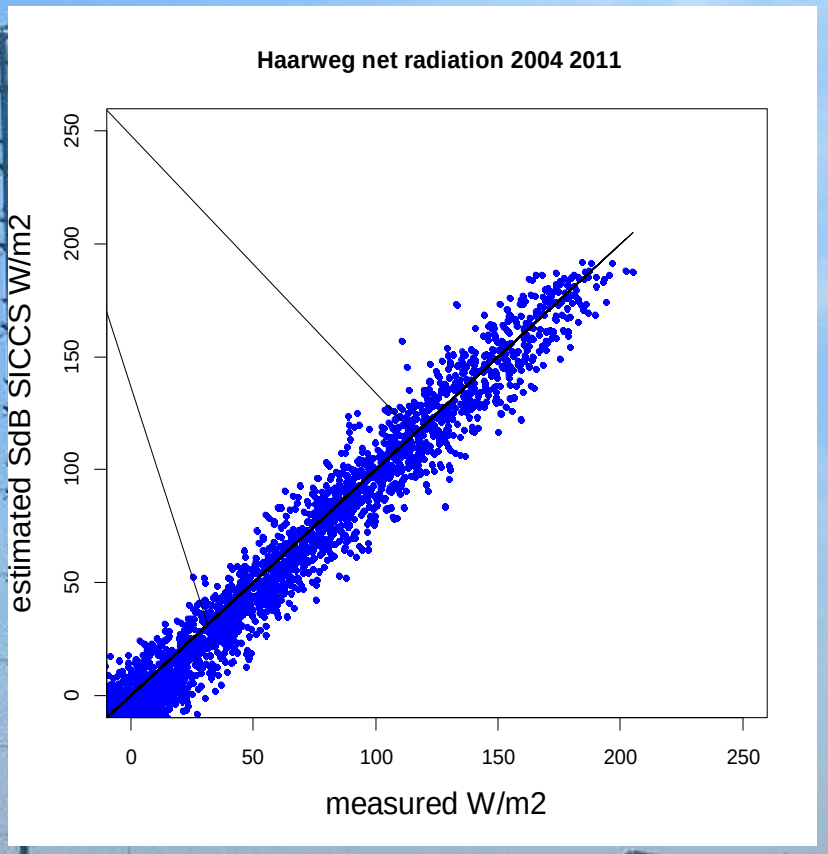
Limited number of dry spells excluded.

Due to climate and water management data concern well-watered conditions

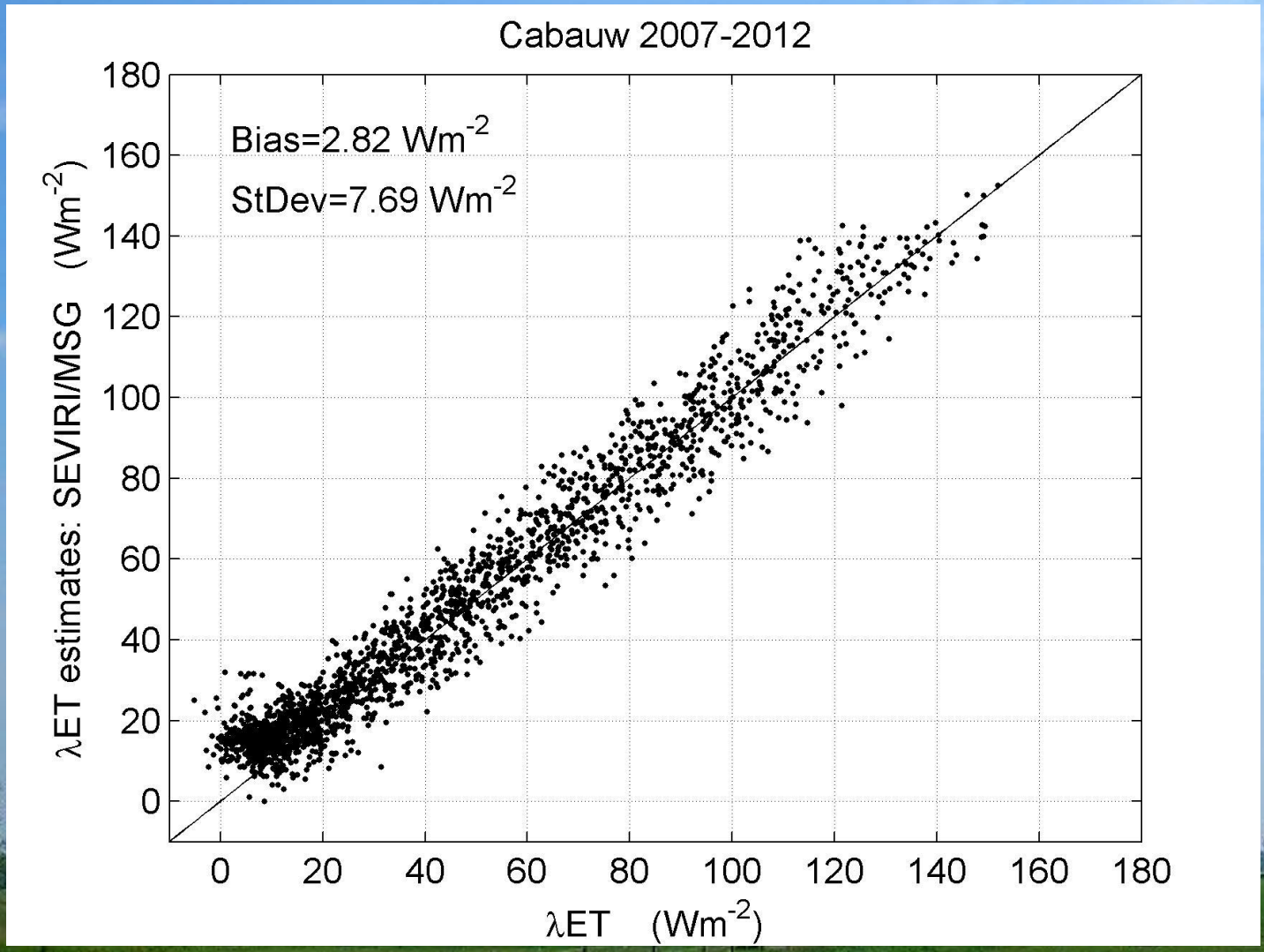
Because adjacent fields is similar grass, advection can be ignored.

Test net radiation formula by Slob - de Bruin, for two grass sites: Cabauw and Haarweg (Wageningen)





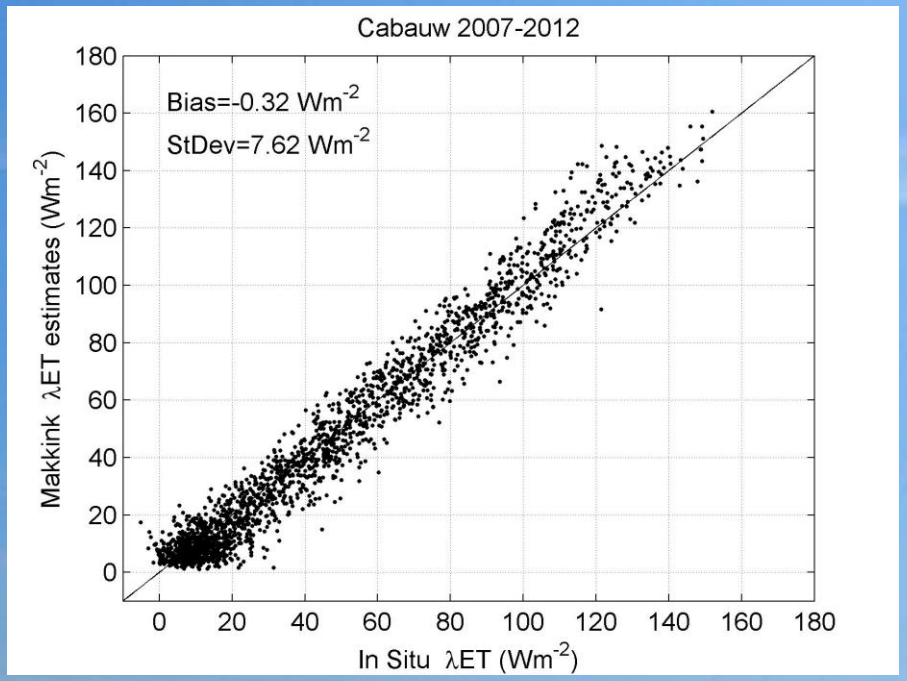
Test of our Schmidt based formula for actual *ET at Cabauw (no advection)*



Estimated from MSG Wm^{-2}

Measured with EC –EB method Wm^{-2})

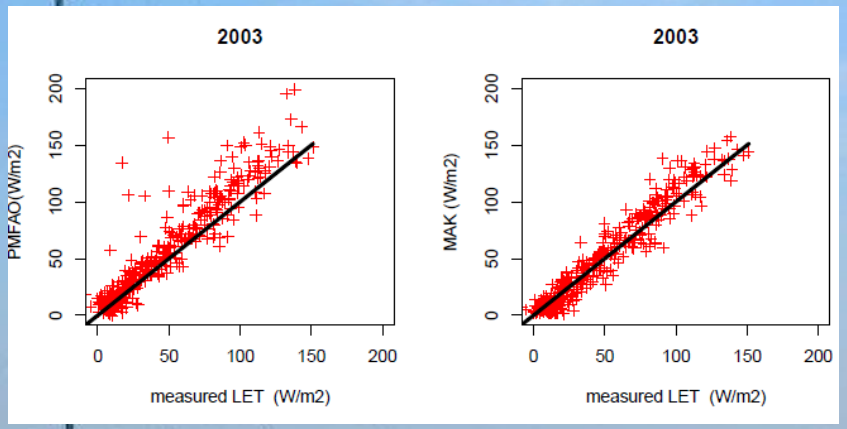
Test of our earlier Makkink: judge yourself



no waterstress

Dry 2003 waterstress

FAO PM ***Makkink***



Conclusion for Part 1 :

A physically based formula of Schmidt (or revised PT) yields good results for actual daily ET of grass resembling closely hypothetical FAO reference grass.

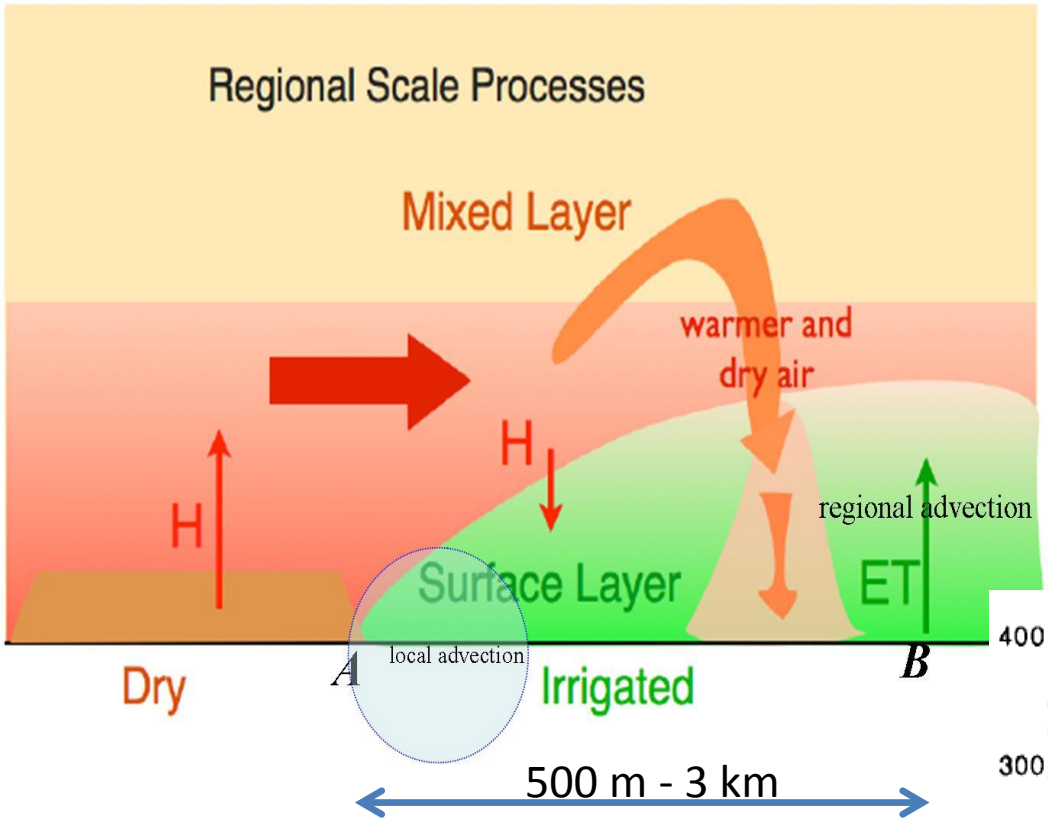
It requires (SEVIRI-MSG) global radiation and air temperature,

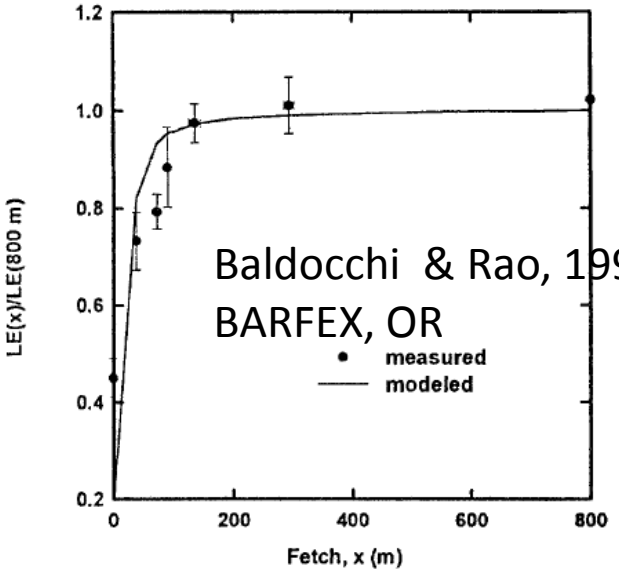
The standard error of about 8 Wm-2 corresponds to about 0.27 mm/day

The Slob - de Bruin formula for R_{net} of well-watered grass yields reliable results

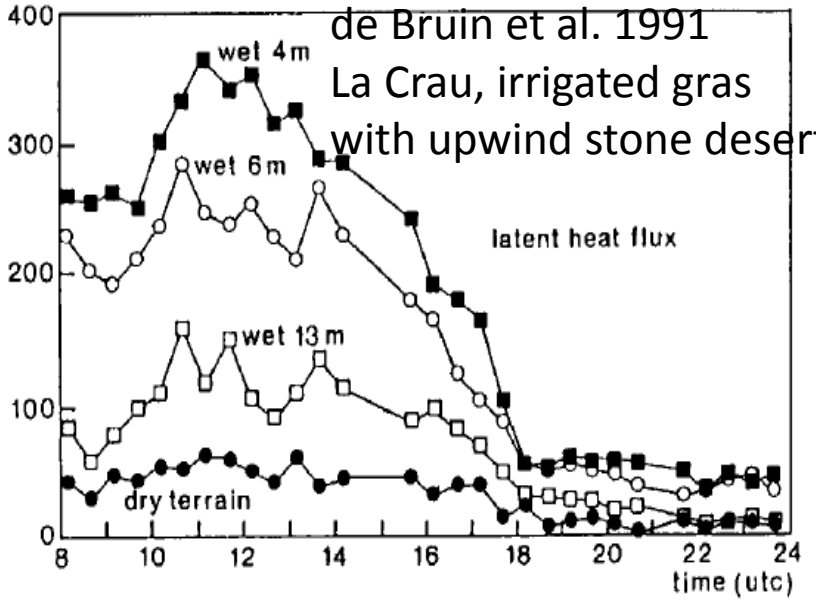
Next question is whether our formula is suitable for irrigation management practice in semi-arid regions based on FAO's crop-factor approach?

Then we have to deal with ambiguity in FAO definition of grass reference ET concerning the role of advection. "Legally speaking", i.e. looking at the formal definition of grass reference, advection should be excluded, but FAO's formula for crop reference ET is calibrated with data gathered under advective conditions





Baldocchi & Rao, 1995,
BARFEX, OR

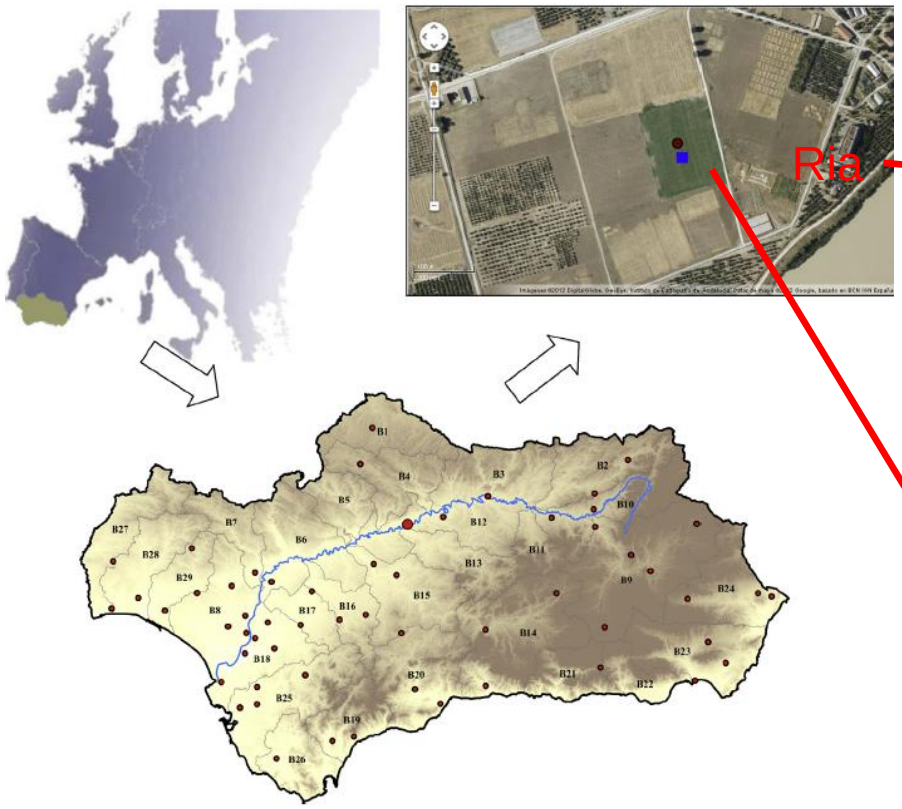


de Bruin et al. 1991
La Crau, irrigated gras
with upwind stone desert

Eddy covariantie method NOT applicable due to verticale divergention of water vapor flux

Lysimeters should be used!

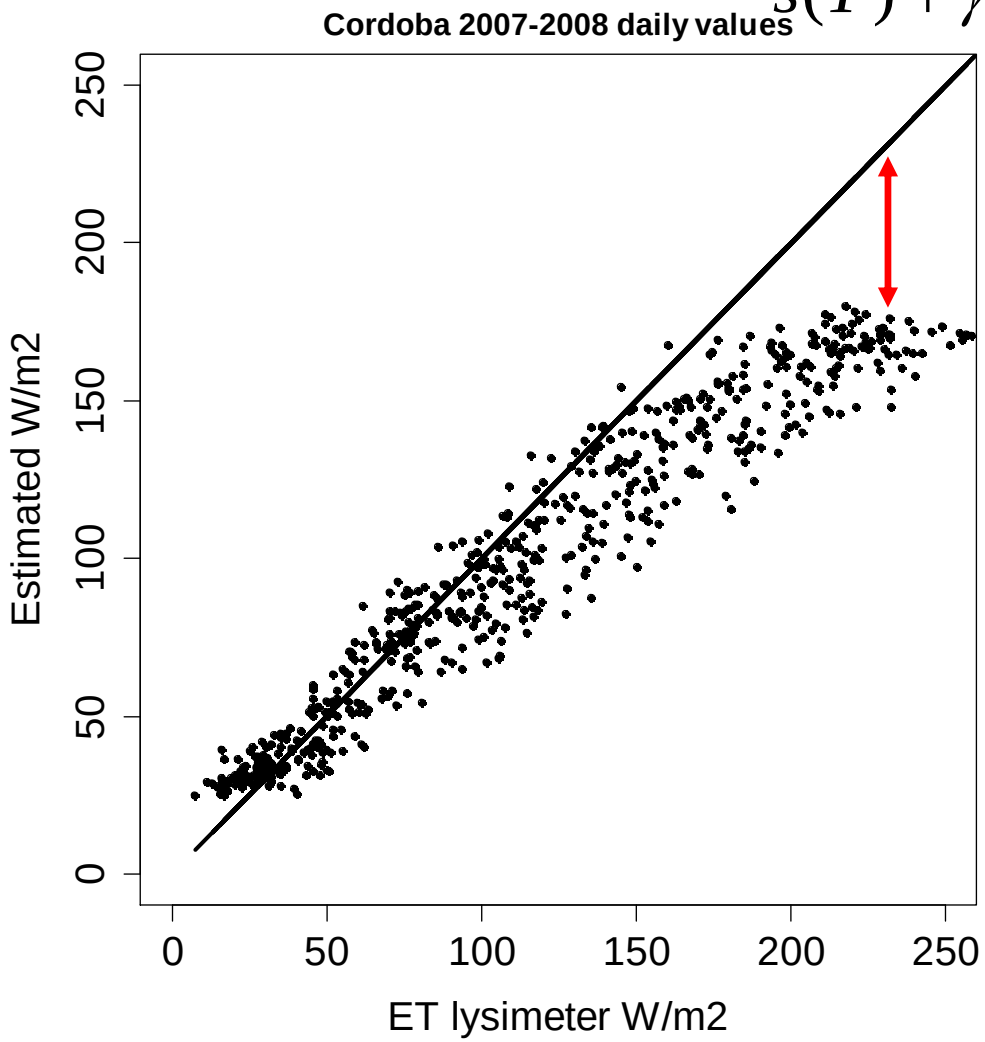
PART 2:
IFAPA Lysimeter and RIA site, Cordoba



Andalucia RIA network of agro-met. stations

Test Schmidt without advection

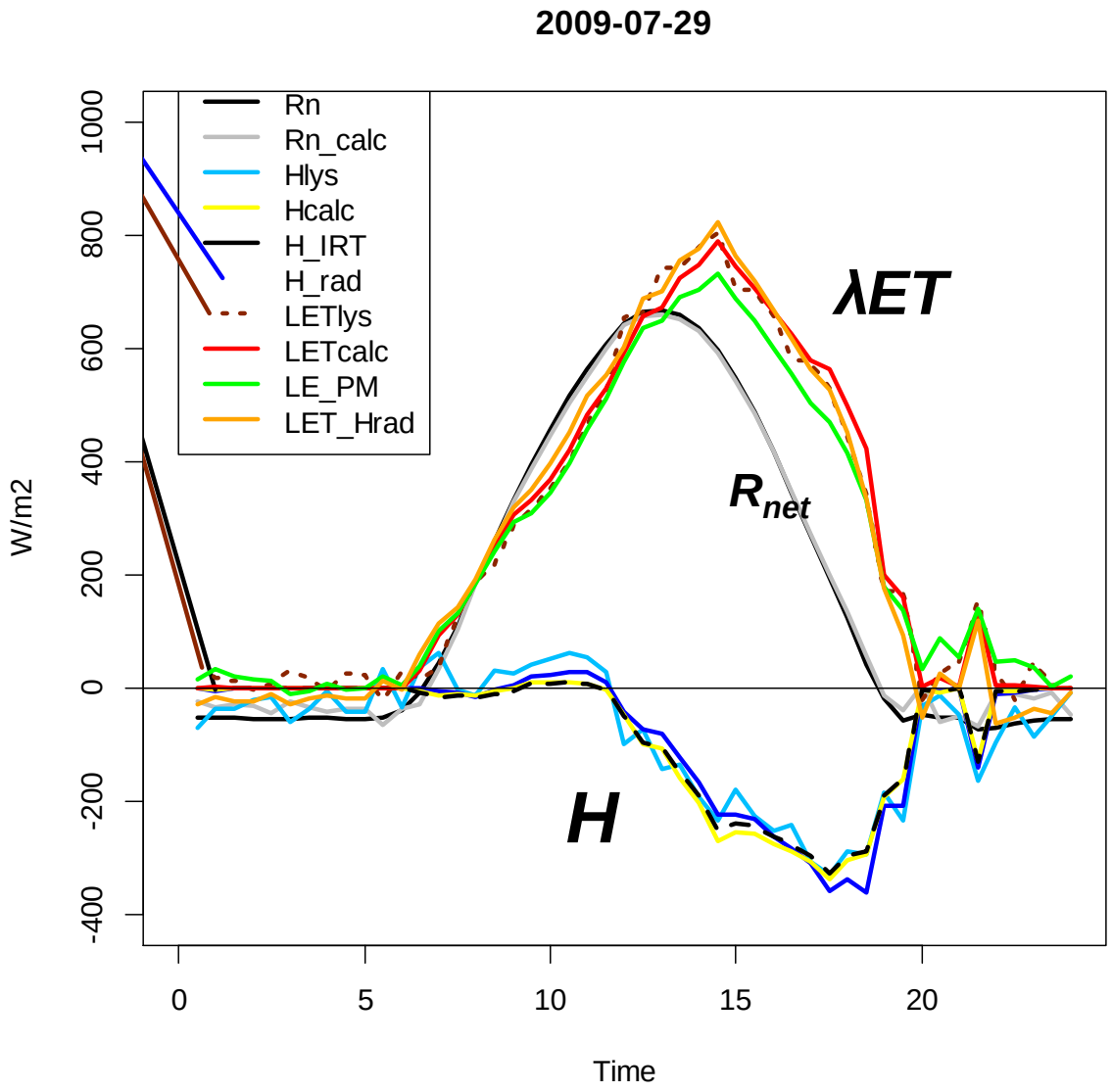
$$\lambda E = \frac{s(T)}{s(T)+\gamma} R_{net} + 20\ W/m^2$$



Schmidt no advection

Lysimeter measurements IFAPA

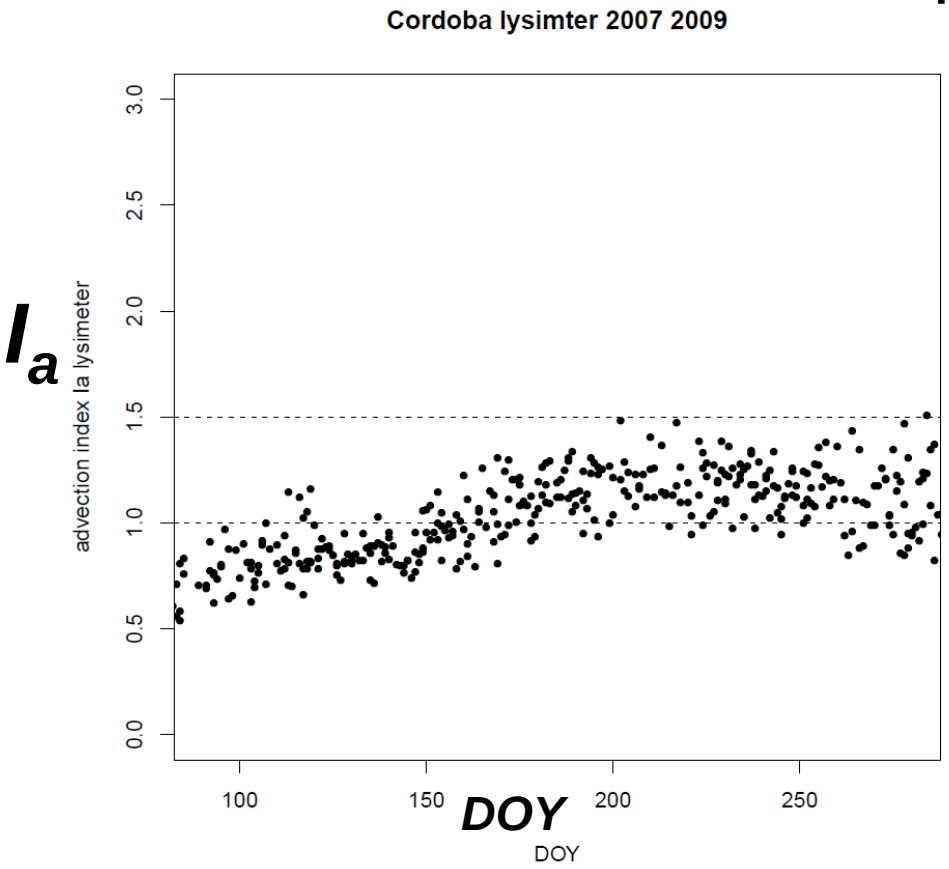
De Bruin and Gavilan (2016): models and measurements IFAPA site



Advection Index $I_a = \lambda ET/R_{net}$

De Bruin, Gavilan and Trigo (2016):

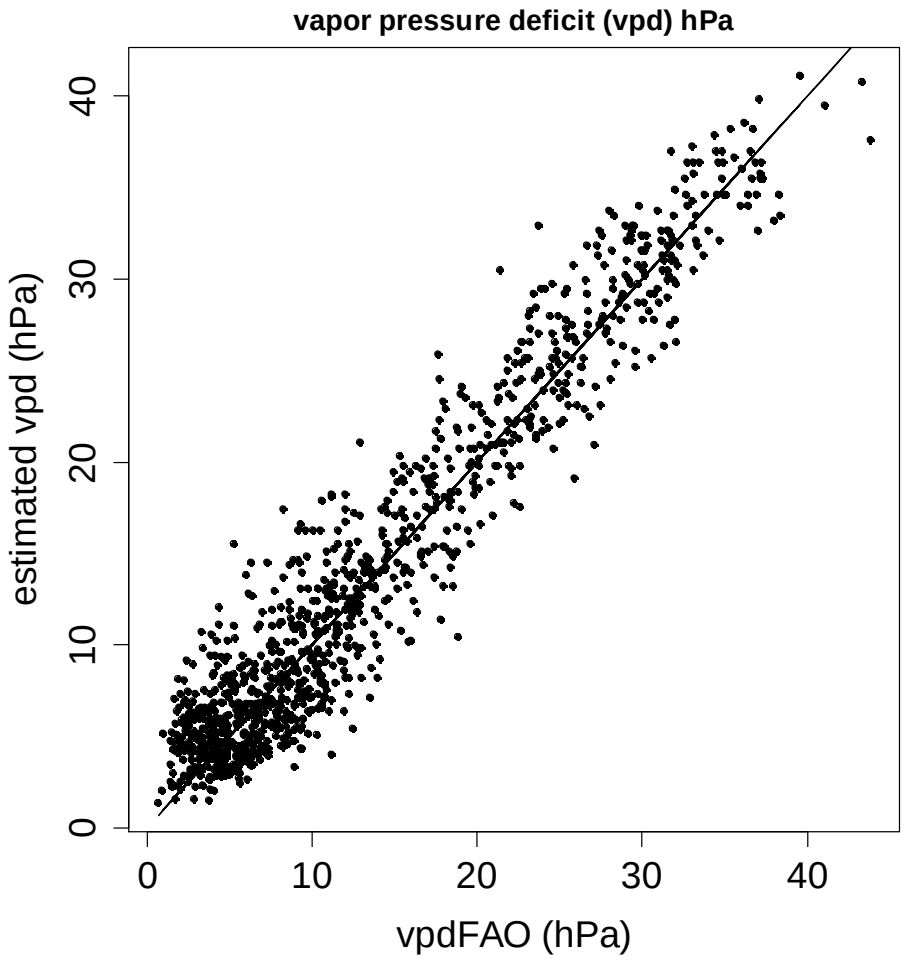
Adapted Schmidt (or revised PT) to advection



Besides R_n now horizontally advected sensible heat of upwind dry terrain is additional energy source term, Q_{adv}.

$$\lambda E = \frac{s(T)}{s(T)+\gamma}\left(R_n + Q_{adv}\right) + \beta \equiv \frac{s(T)}{s(T)+\gamma} R_n + B$$

Estimate *vpd and B* as function of RIA temperature

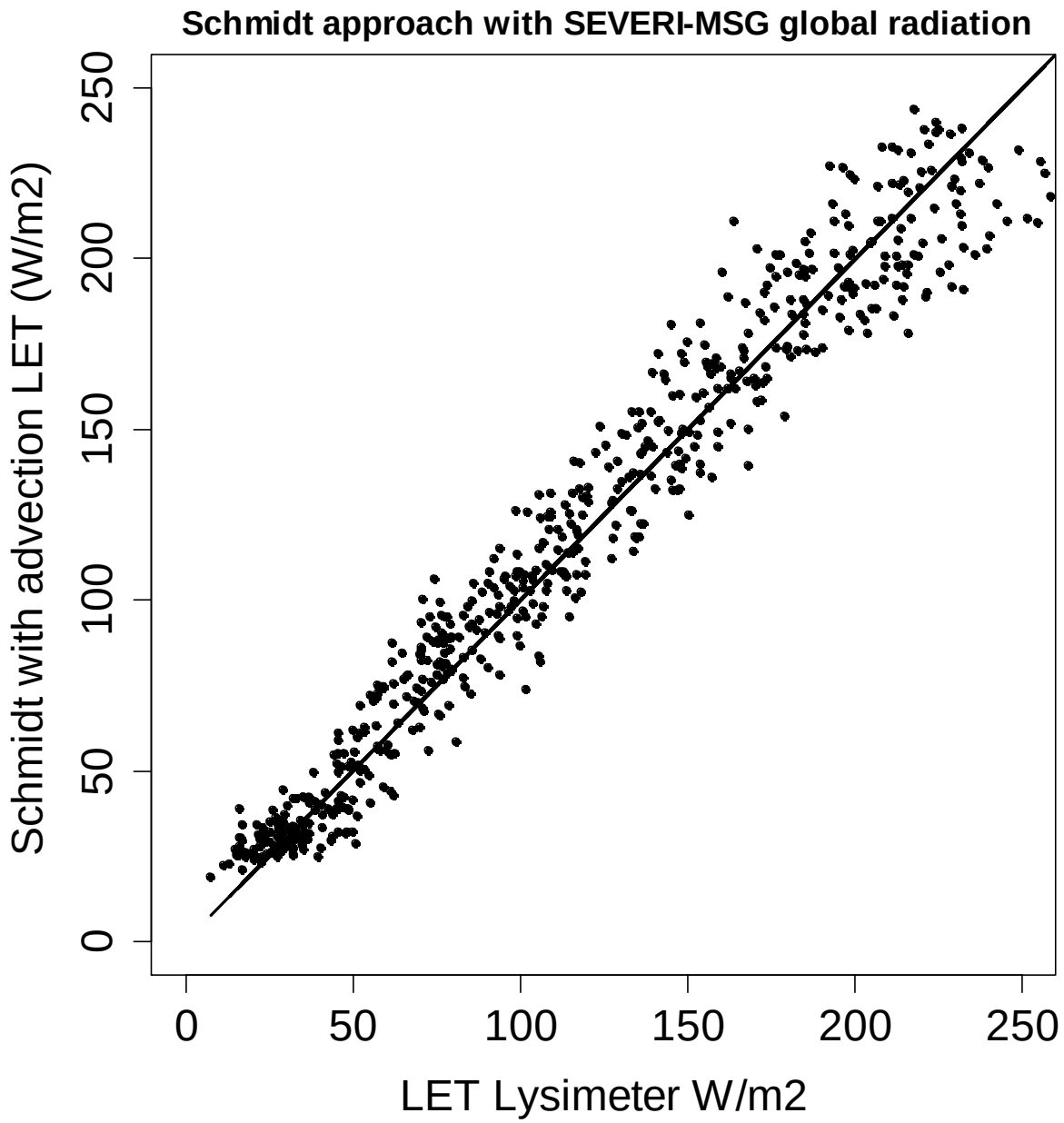


$$e_s(T) - e_a \equiv vpd$$

$$vpd_{est} = e_s(T)\left(1 - RH_{est}\right)$$

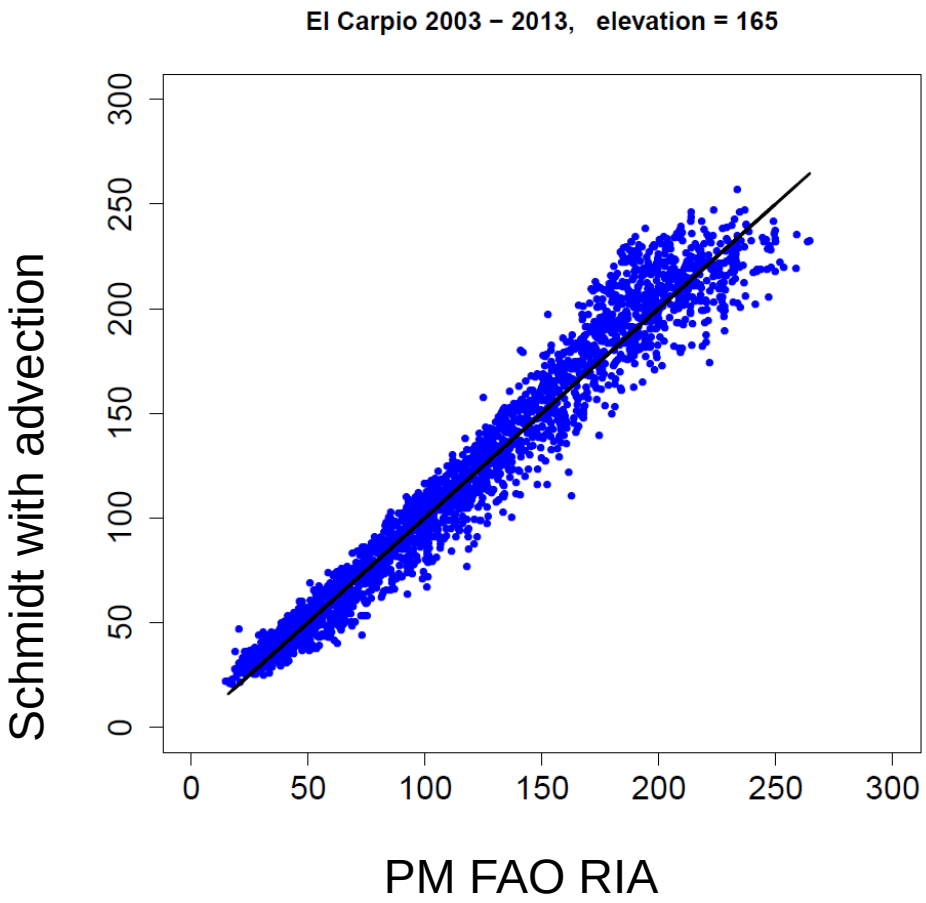
$$RH_{est} = 0.8 - 0.0217\,T_{RIA}$$

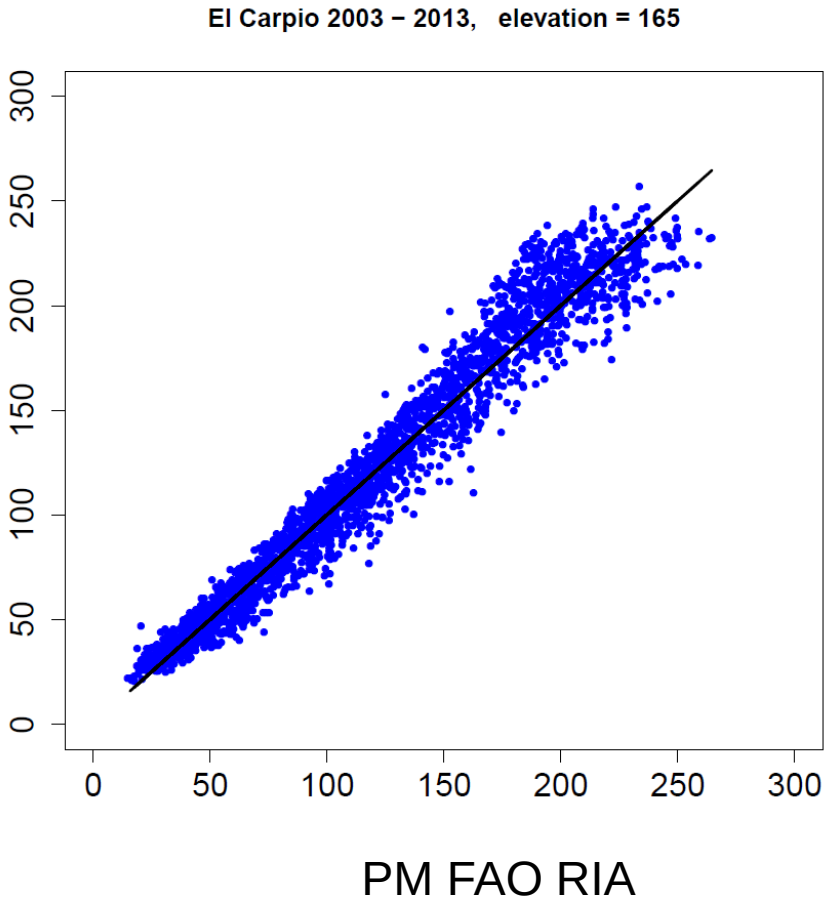
$$B = C\overline{u_2}vpd_{est}$$


Schmidt approach with SEVERI-MSG global radiation
Schmidt with advection LET (W/m2)
0
50
100
150
200
250
LET Lysimeter W/m2

Test RIA Cordoba and El Carpio

LET_{PM} > 1.25 R_n Slob de Bruin rejected





Conclusions part 2

The Schmidt approach can be extended to conditions with advection by introducing an additional energy term B.

This yields a simple formula for actual ET of the IFAPA well-watered grass site, requiring SEVERI-MSG global radiation and T_{RIA} only.

Discussions with the irrigation community is needed about the question whether or not our Schmidt approach extended for cases with advection and applied with MSG-SEVERI global radiation, is suitable for irrigation practice.

(^{0}C)

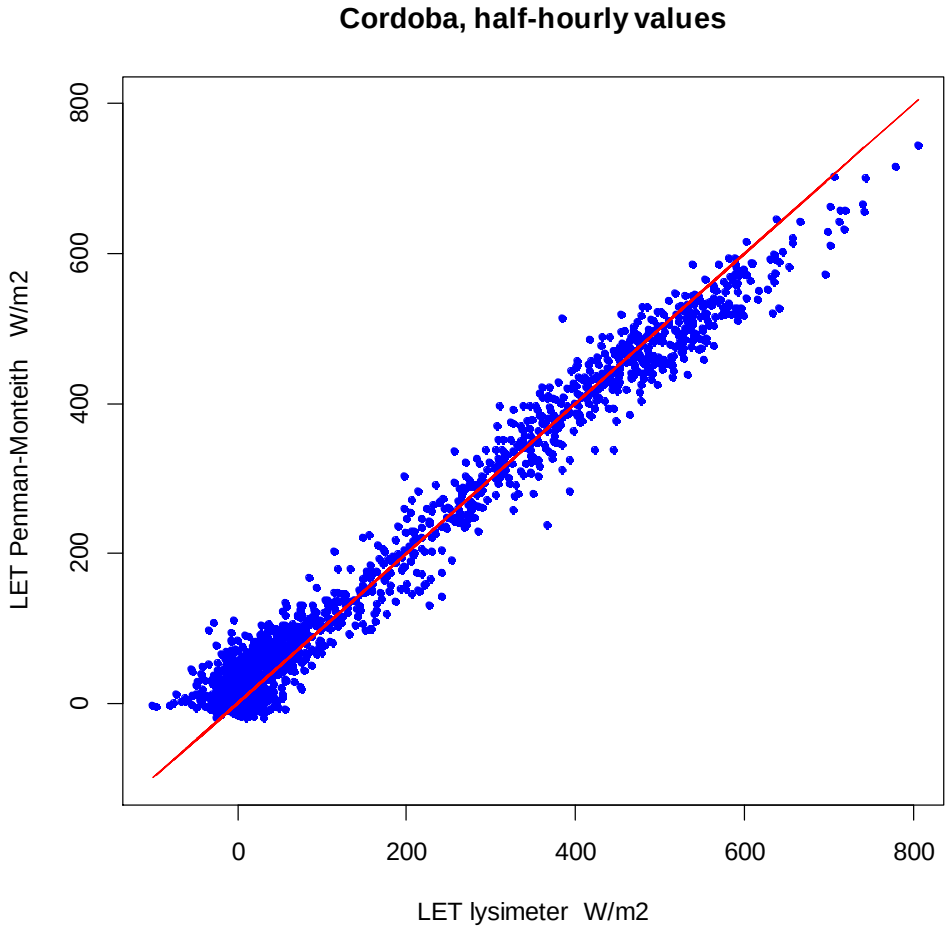
LET estimated from radiation, air temperature and wind speed

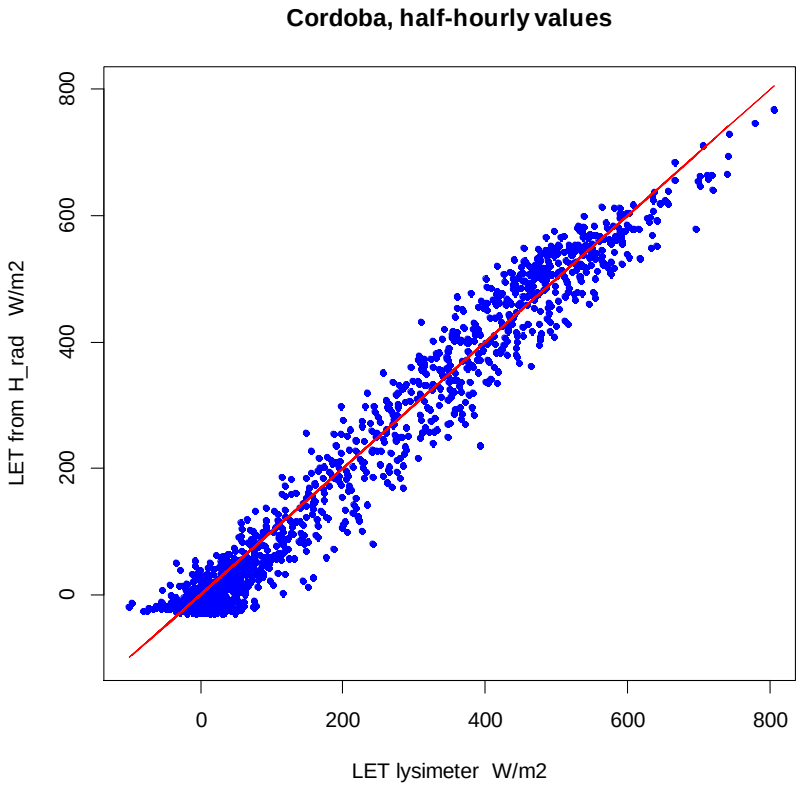
$$T_{srad} = \left[\frac{L^{\uparrow} - (1 - \varepsilon_s) L^{\downarrow}}{\varepsilon_s \sigma} \right]^{\frac{1}{4}} - 273.15 \qquad H_{Tsrad} = \rho c_p \frac{T_{srad} - T_a}{r_a (T_{srad}, T_a, u_2)}$$

$$\lambda ET_{Tsrad} = 0.9 R_{net} - H_{Tsrad}$$ daytime

$$\lambda ET_{Tsrad} = 0.5 R_{net} - H_{Tsrad}$$ nighttime

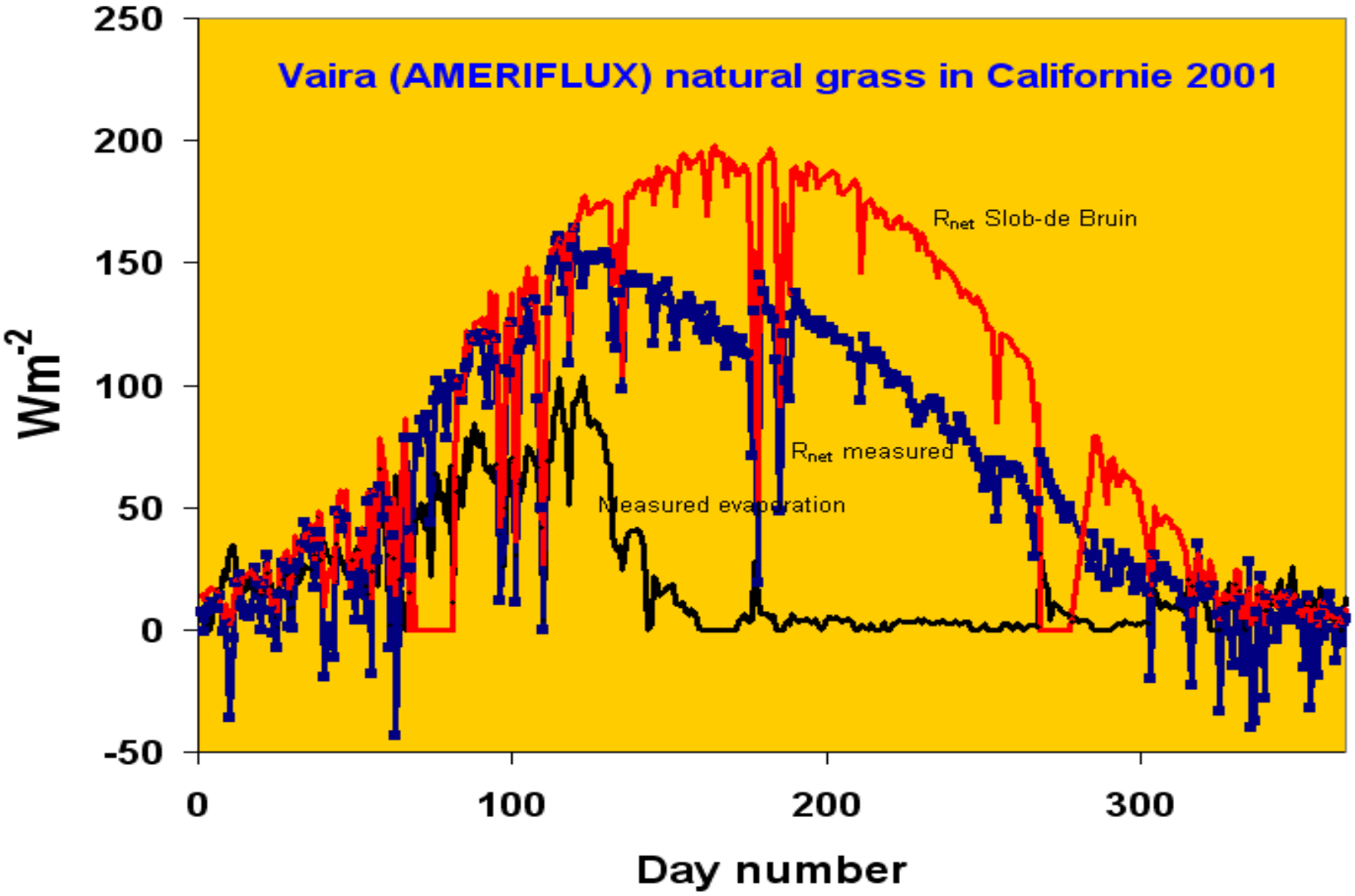
LET PM (left), *LET* from H_{rad} (right)





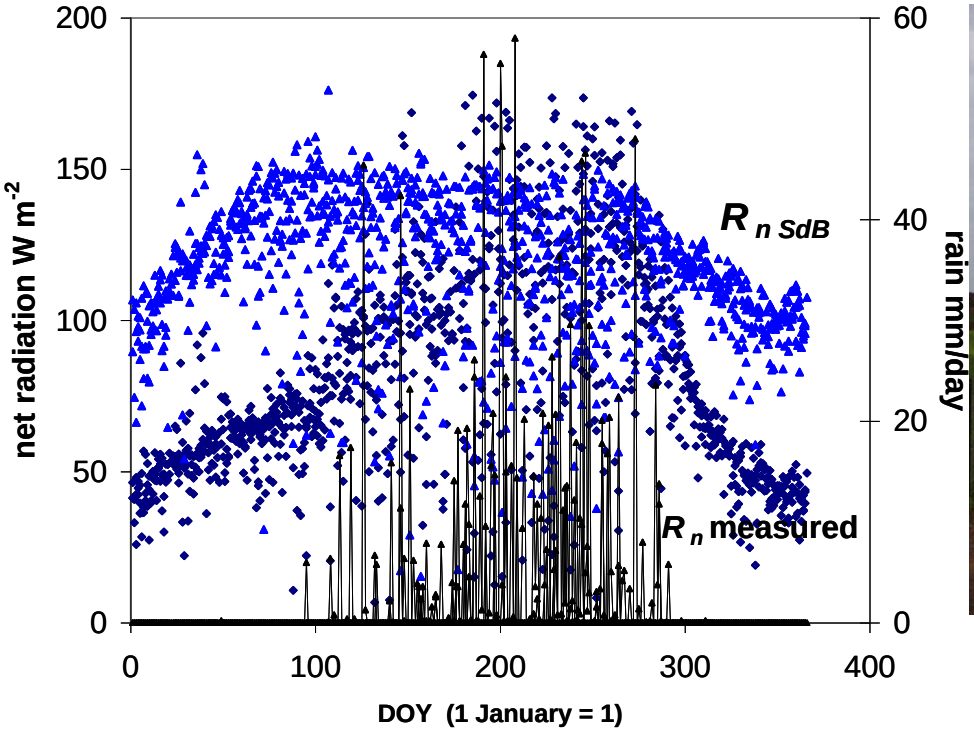
Over dry grass :

Measured net radiation < Slob-de Bruin!!!!



Burkina Faso

Effect of 'dryness' of the ground on net radiation is huge!!!!!!!!



Warning: If one applies ET_{ref}-FAO56 to non-FAO grass stations DO NOT USE THE MEASURED NET RADIATION.