4th LANDSAF Workshop, Toulouse, 15-17 November 2010

First results of the LAND-SAF project* on reference crop evapotranspiration

Henk de Bruin[1] and Isabel Trigo[2]

1) *Associate Professor Emeritus, Wageningen University, The Netherlands; Visiting Professor King's College, London, UK; Freelance Consultant Bilthoven, The Netherlands*

2) *Instituto de Meteorologia, Lisbon, Portugal*

***Project VS0802**

With contributions of P. GAVILAN, A. MARTÍNEZ-COB, M. P. GONZÁLEZ DUGO M. A. JITAN, T. ENKU NIGUSSIE C. VAN DER TOL and A. GIESKE

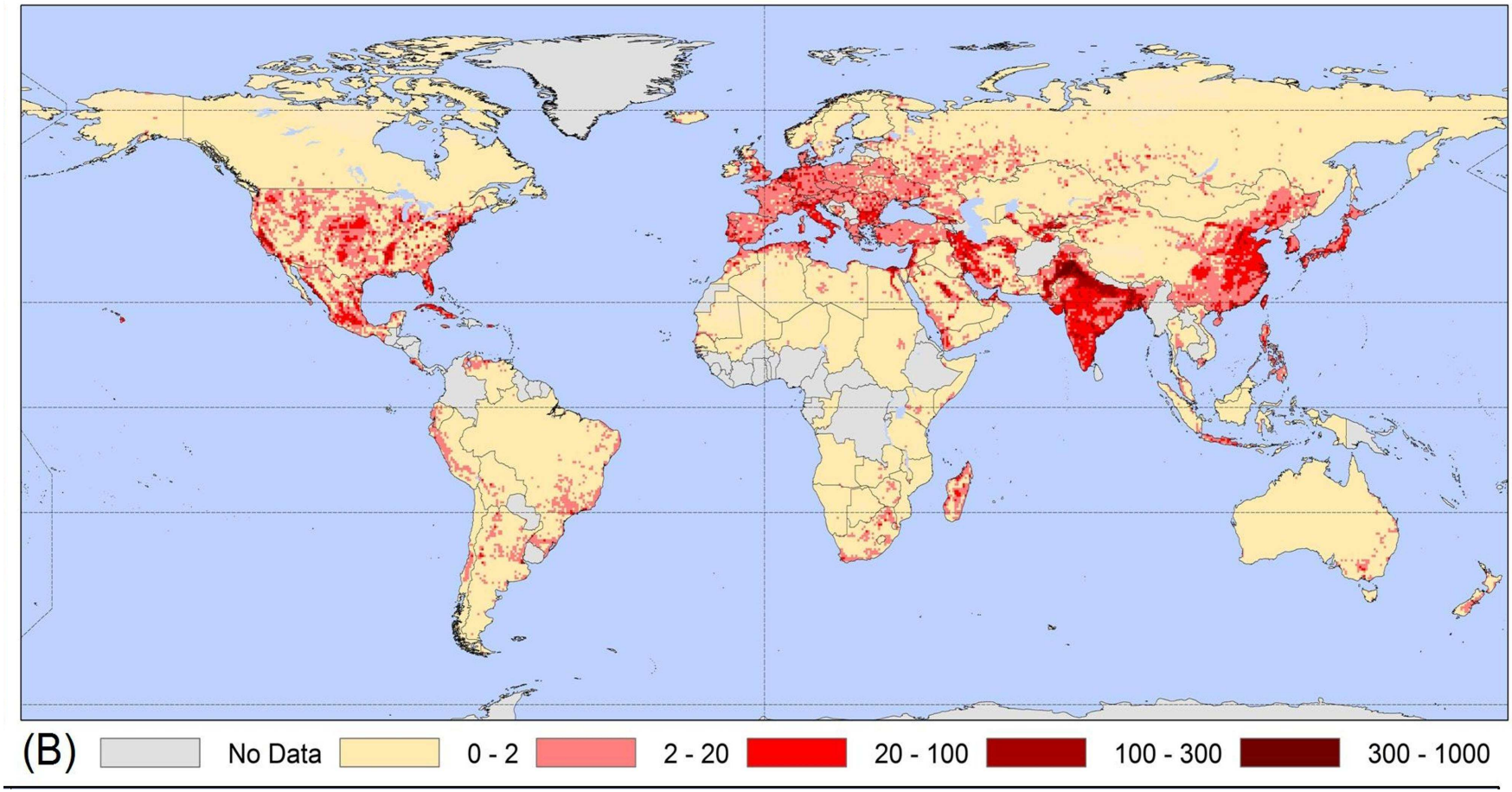
Scope and Background

At least 80% of available fresh water is used for agriculture, i.e. **irrigation** in semi-arid regions

Crop water requirements

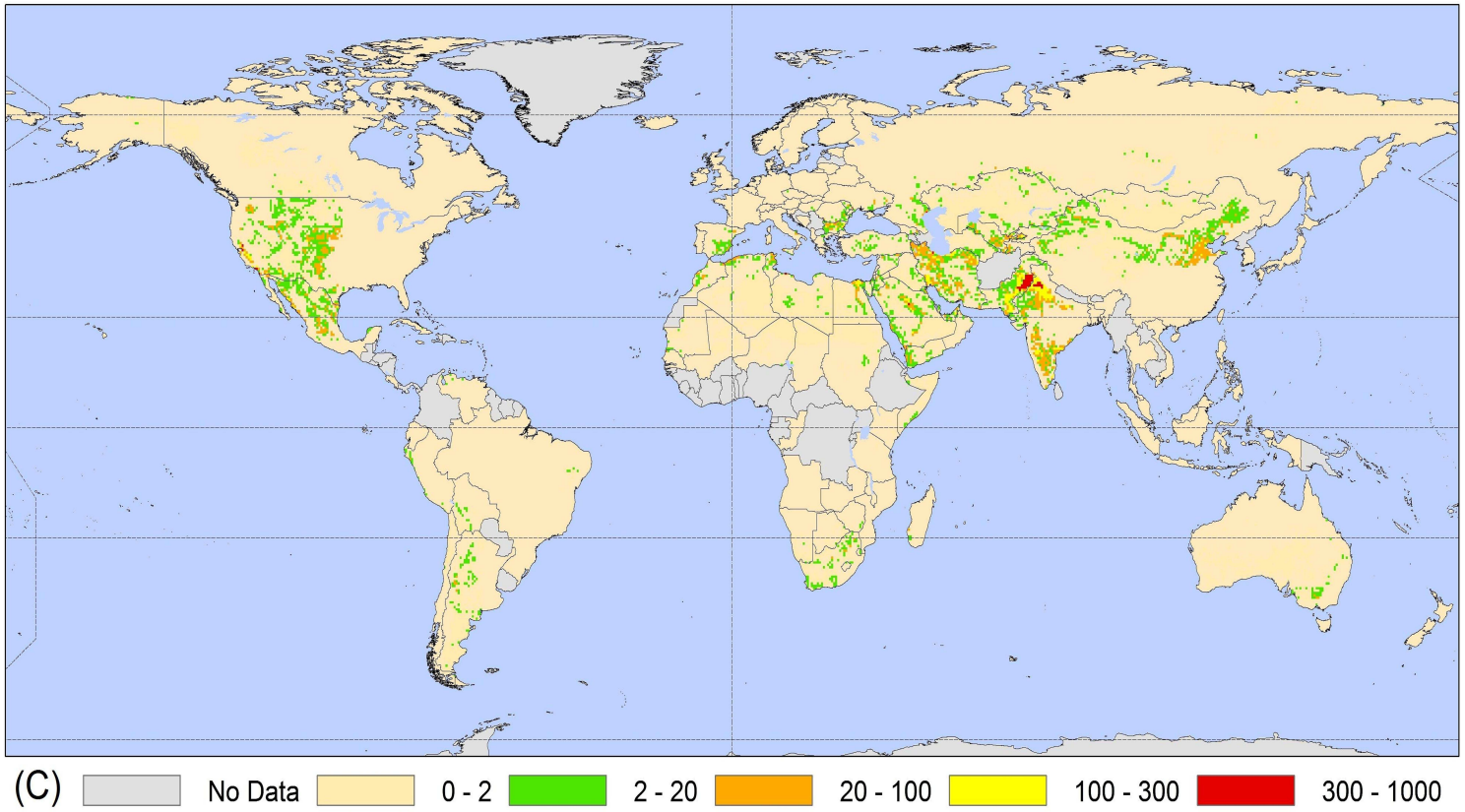
are estimated using the methodology described in a FAO by Allen et al., 1998:

Total groundwater abstraction for the year 2000; mm/year



From: Yoshihide Wada, et al., 2010

groundwater depletion for the year 2000
mm/year



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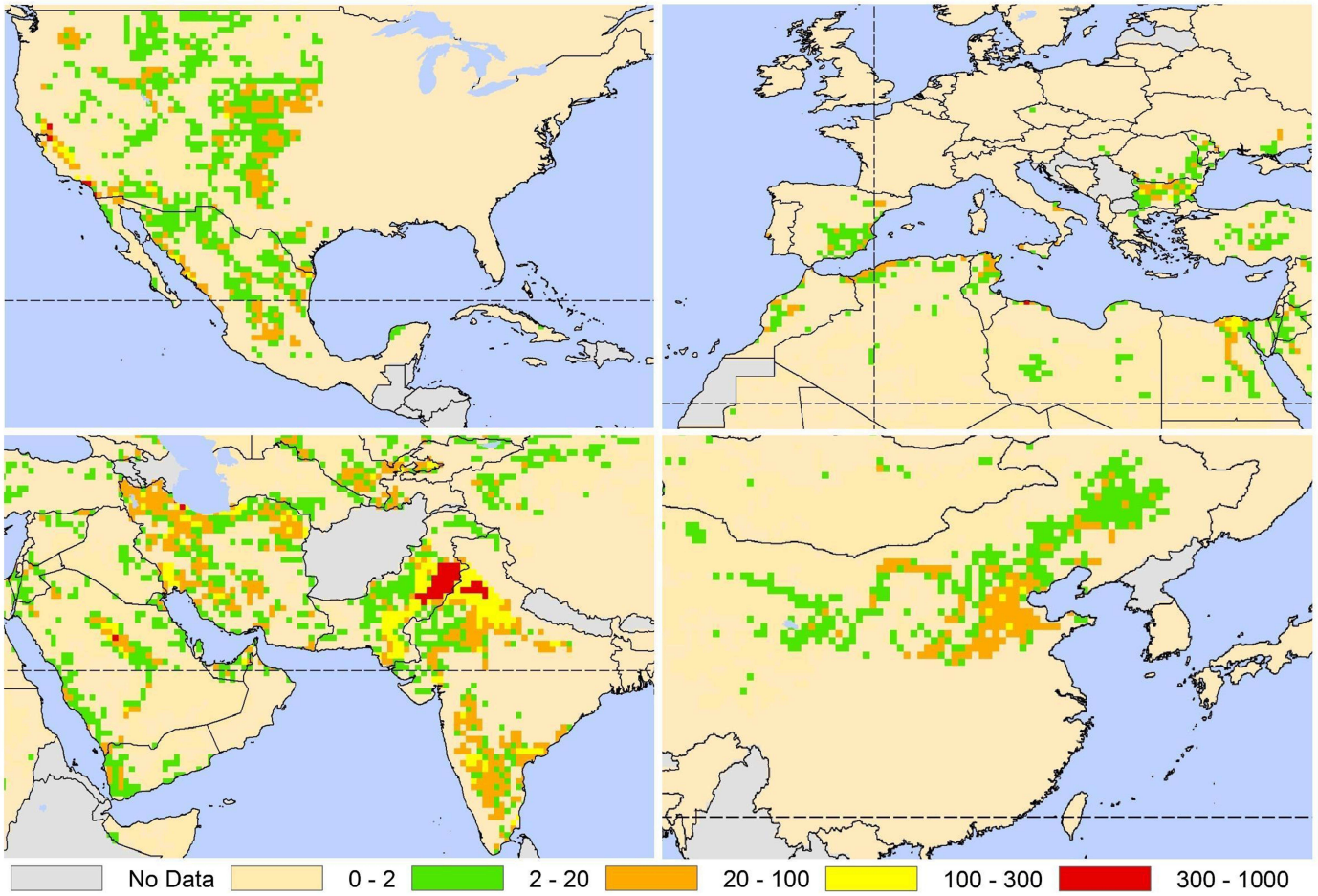
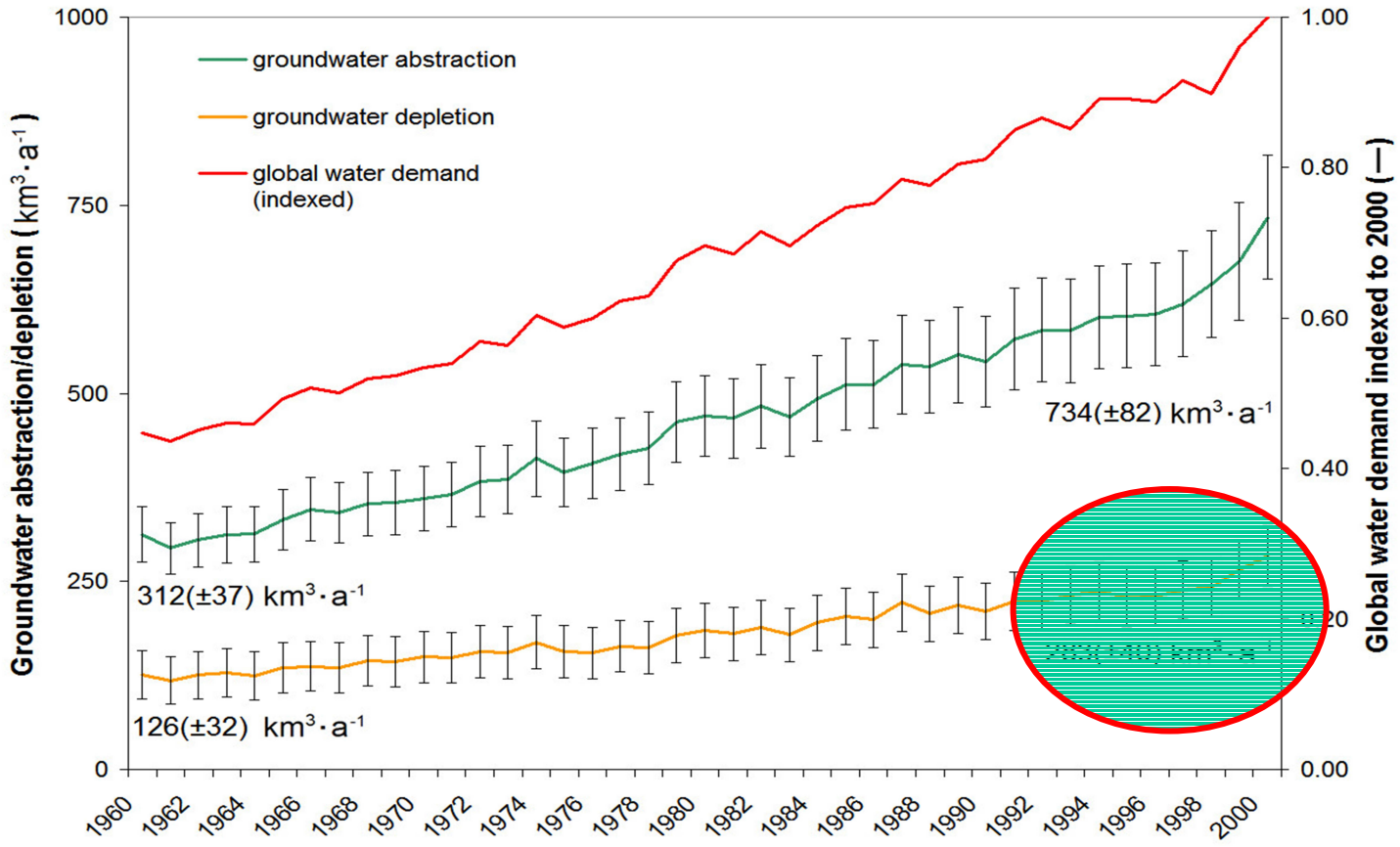
Groundwater depletion for the year 2000 mm/year



From: Yoshihide Wada, et al., 2010

Global groundwater abstraction and depletion and demand (km^3/year)

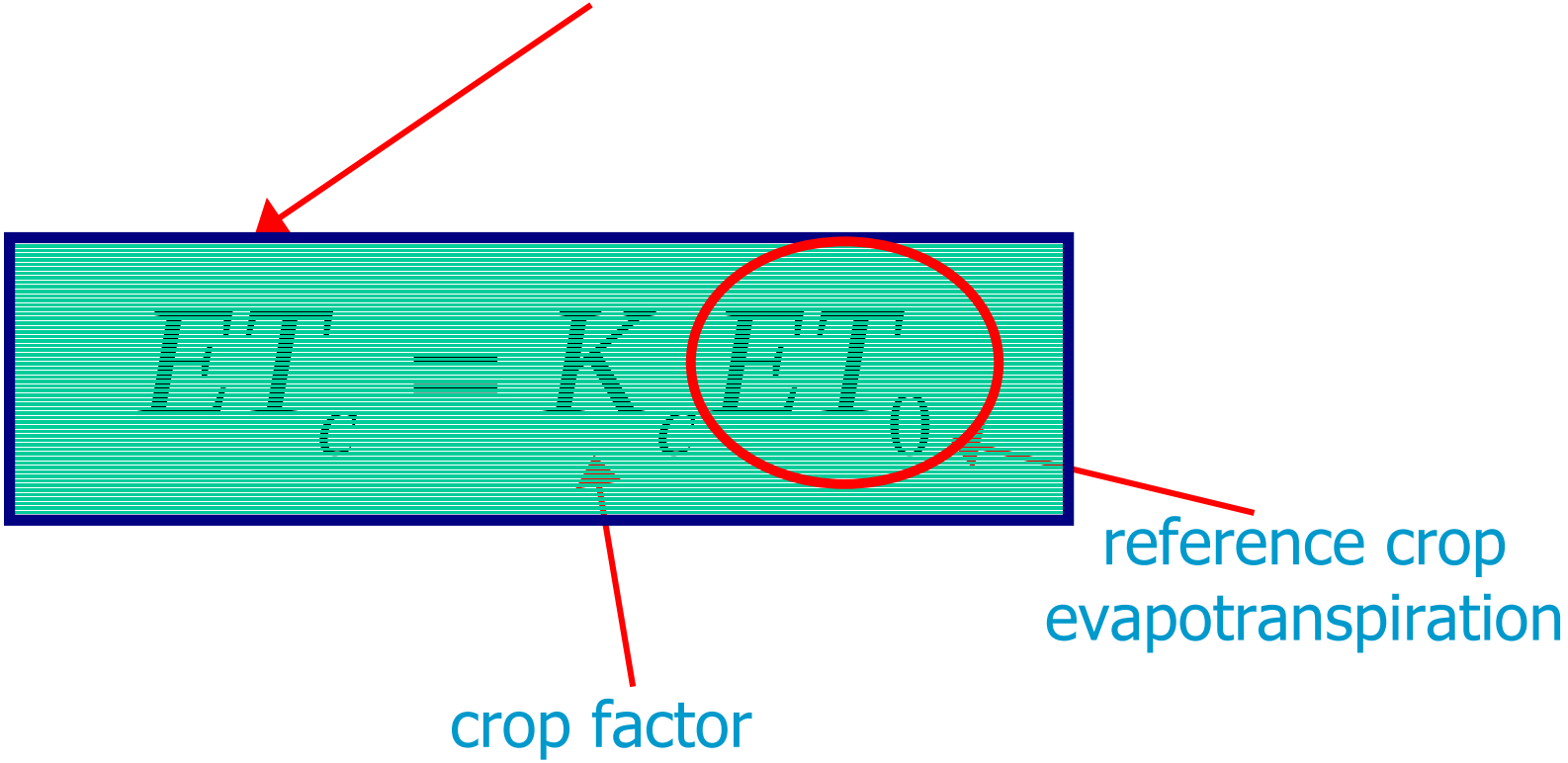


Demand index 2000 =1

Yoshihide Wada, et al., 2010 suggest that groundwater depletion contributes for 1/3 of the observed sea level rise (idea from Bart van den Hurk)

Background:

We adopt the semi-empirical **FAO -**method (**Allen** et al., 1998) to estimate **Crop water requirements**:



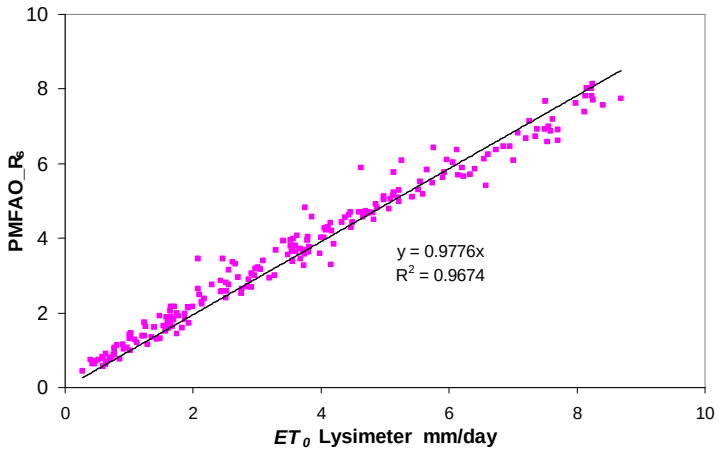
FAO: ET_0 is estimated using a version of the Penman-Monteith equation

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

albedo = 0.23,
roughness length for short grass,
neutral conditions assumed,
surface resistance r_s= 70 sm^{-1}

Result 1: FAO Penman-Monteith is the best! indeed!!!!

$$ET_o = \frac{0.408\Delta(R_{nest} - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$



But.....

Cordoba Lysimeter site data 2008

But.....

- ET_0 refers to ***hypothetical*** well-watered grass so meteorological input data must be collected over **well-watered grass**

- **In real-life in semi-arid regions FAO-grass weather stations hardly exist!!!!**

Examples well equipped station in practice

Station in Burkina Faso

Cordoba, Andalucia network

Objective

To develop a method to map *daily* and *weekly* ET_0 values using existing LANDSAF - products

LANDSAF Products used until now

- Daily accumulated **incoming solar radiation** R_s obtained through the integration of instantaneous values, estimated every 30-minute
- Air temperature at 2 m derived from ECMWF weather maps. Note that LANDSAF includes operational software tools to merge ECMWF and SEVIRI information.

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

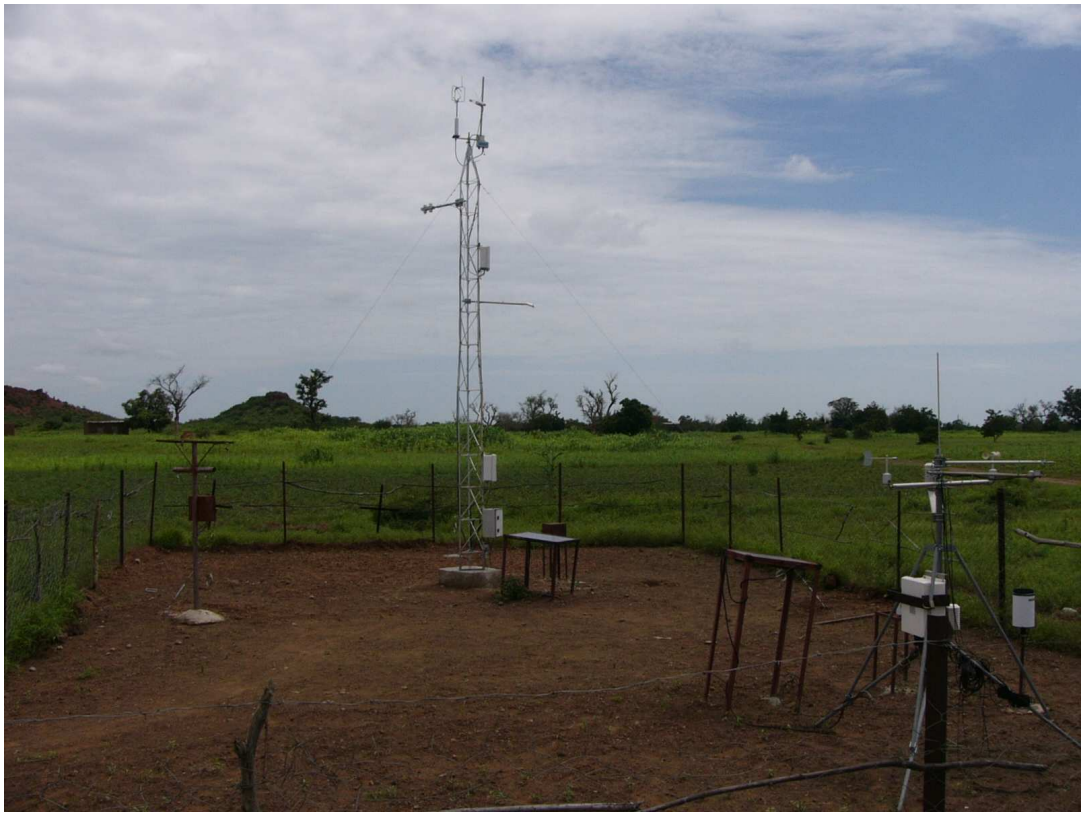
Approach

In literature it has been shown that radiation based estimates of ET_0 might be a fair alternative for the full **PMFAO** , notably the formulas proposed and by

Makkink and **Priestley-Taylor**, requiring air temperature and **incoming shortwave (DSSF)** and **net radiation**, respectively

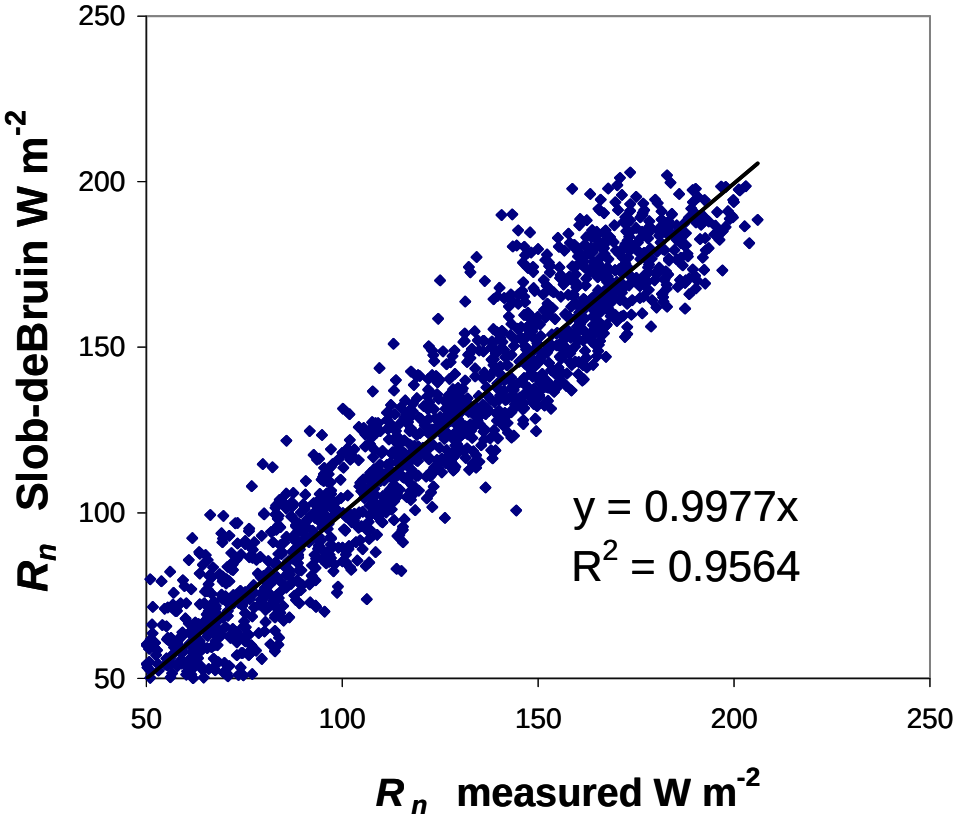
R_n versus R_s in case surface is not ideal *FAO-grass*

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

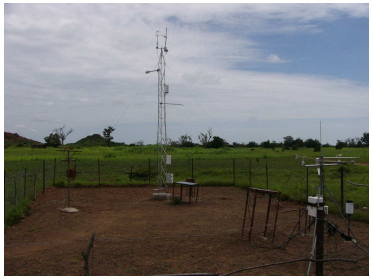


Result 2 of our project: Slob-de Bruin estimate of net radiation of well-watered 'FAO-grass', from solar radiation only works fine!

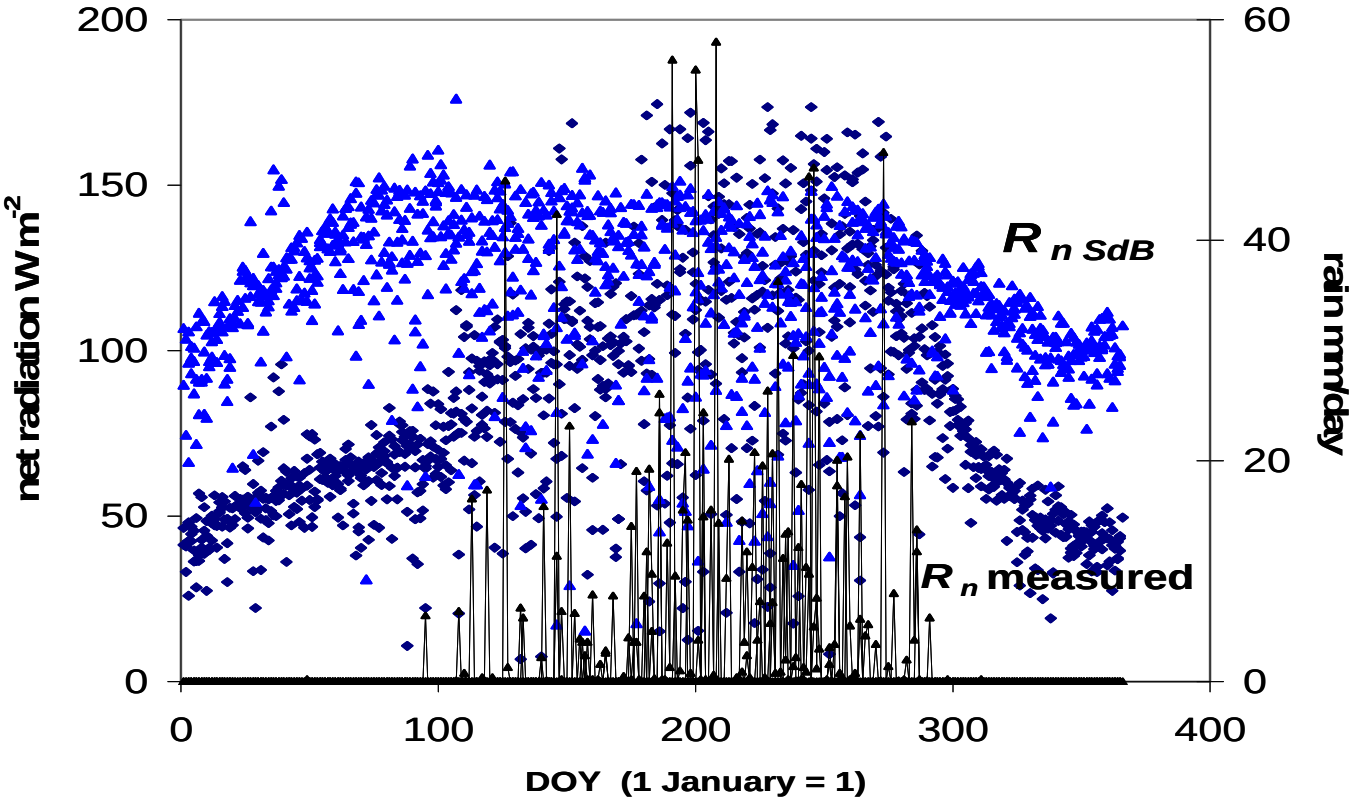
$$R_{ns} = (1 - 0.23)R_s - C\frac{R_s}{R_{so}}$$



Zaragoza daily data for a couple of years



Result 3: Net radiation over bare soil of furthermore very sophisticated station in Burkina Faso compared with Slob-de Bruin



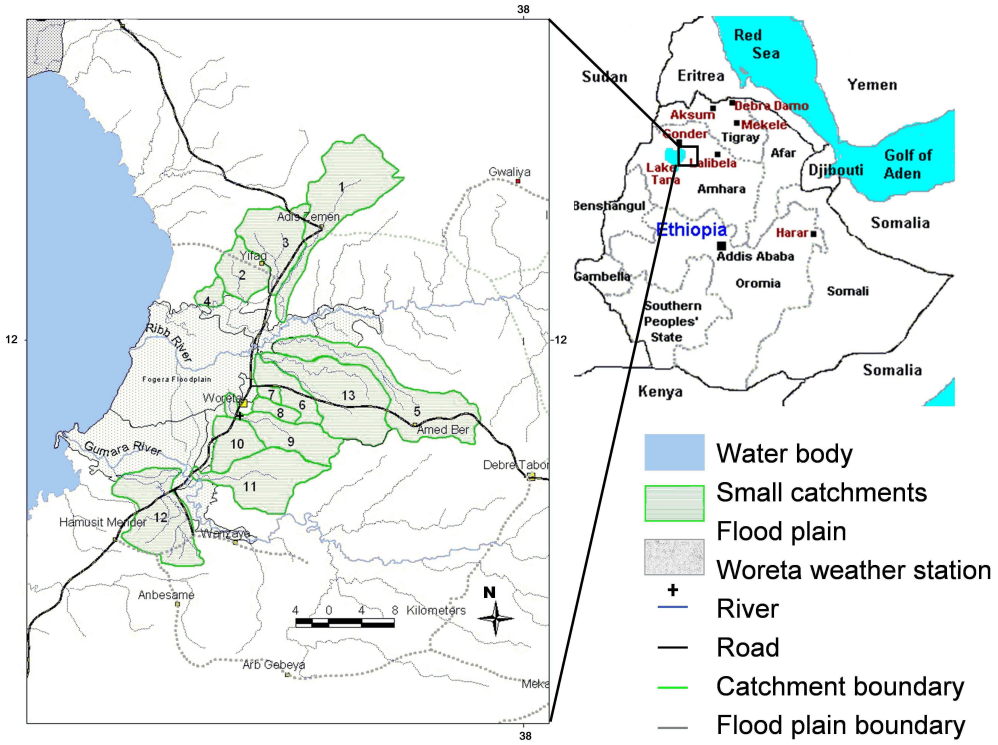
Result 2: measured net radiation NOT suitable for ET_0

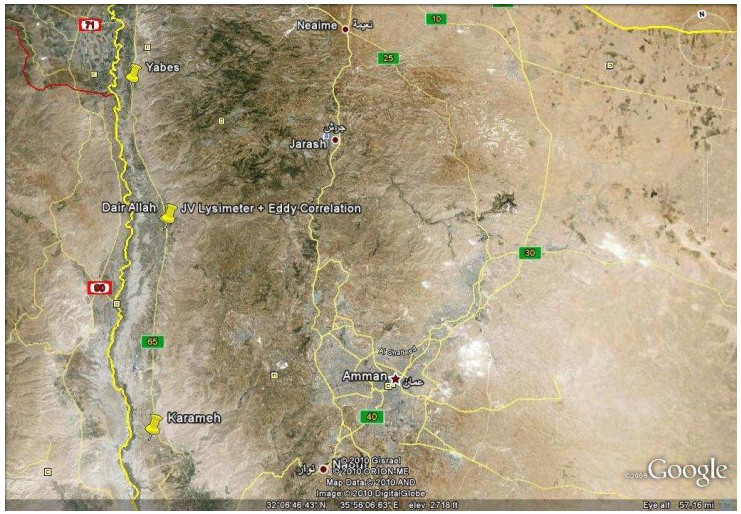
In 1957 **Makkink** proposed

$$ET_{well-watered\ grass} = a_M \frac{s}{s+\gamma} \frac{R_s}{L_v} = f_{MAK}(T, p) R_s$$

R_s = incoming solar radiation,

Result 4: Ethiopia and Jordan Valley

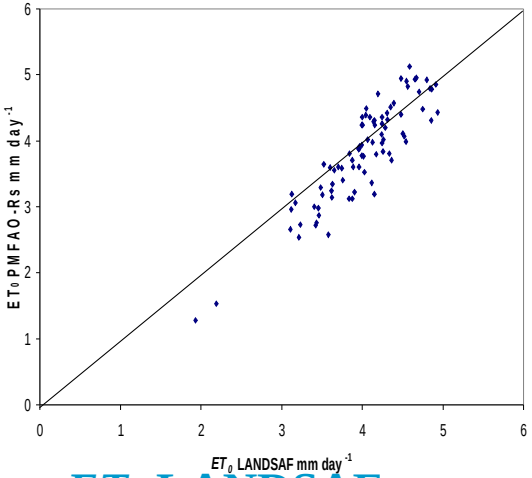




- Published in: **Hydrol. Earth Syst. Sci., 14, 2219–2228, 2010**

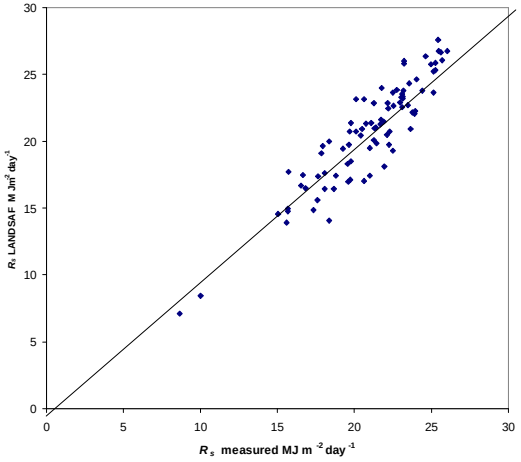
Test Makkink: Woreta, Ethiopia, 1650 m, wet season

ET_0-FAO Penman Monteith

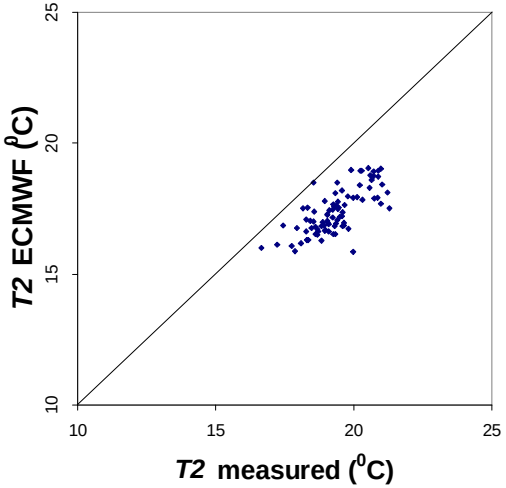


ET_0 LANDSAF

DSSF LANDSAF



DSSF measured



features: T_2 ECMWF and Air pressure effects in mountainous regions

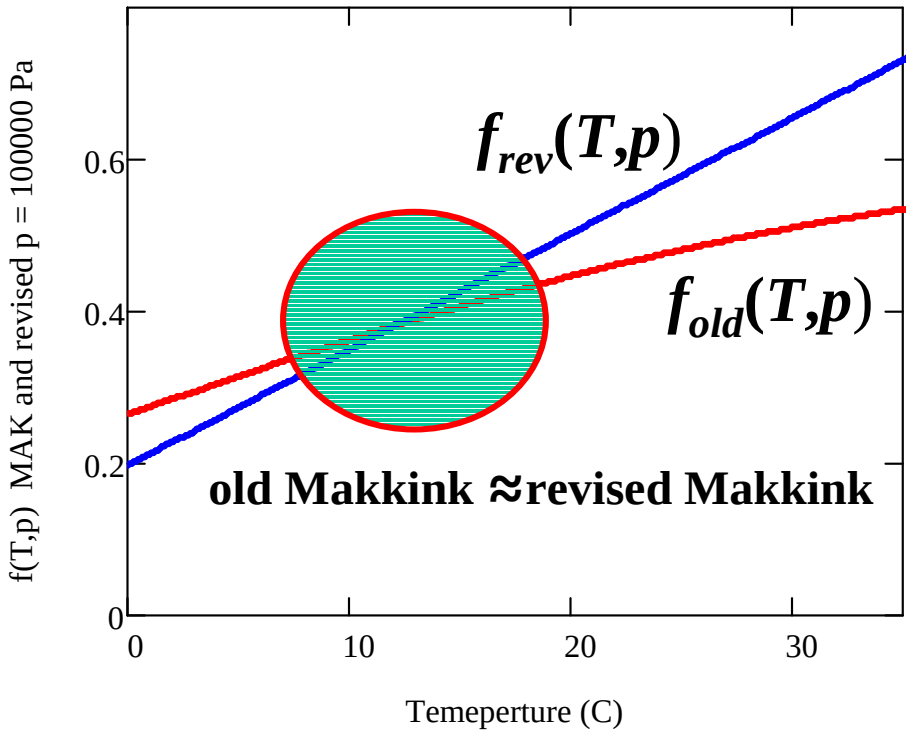
BUT..... under dry hot advective conditions
MAKKINK appears to underestimates ET_0

Ladies and gentlemen we have the honour to present you our novel revised Makkink Formula to estimate ET_0 for dry hot advective conditions

$$ET_{Makkink\_Old} = f_{MAK}(T, p)R_s$$

$$ET_{Makkink\_Revised} = f_{rev}(T, p)R_s$$

Novel $f_{rev}(T.p)$

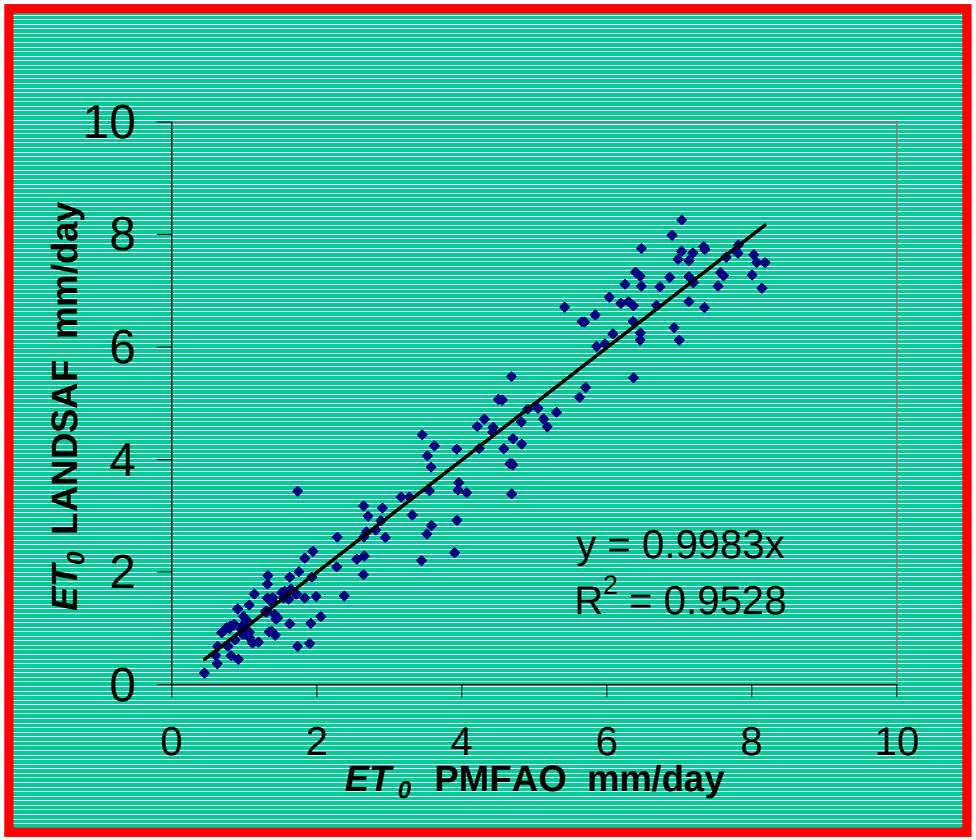


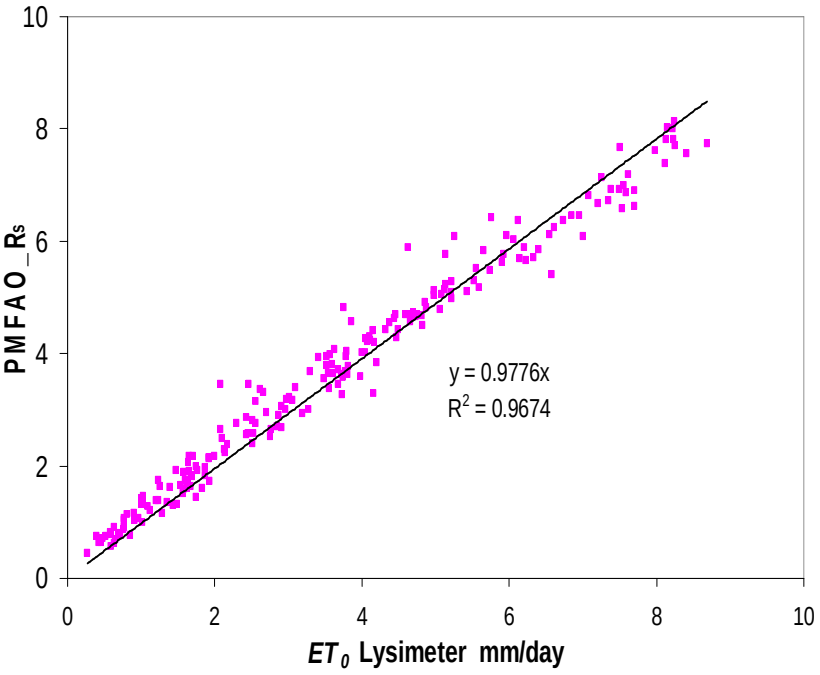
$$f_{rev} = a(p)(T-12)+b(p) \qquad a(p)=1.7\left.\frac{df_{old}(p,T)}{dT}\right|_{T=12}$$

b(p) chosen such that at 12 ^{0}C $f_{rev} = f_{old}$

Test revised Makkink for Cordoba Lysimeter site, 2008 under dry hot and advective conditions

Resul 5: Test of revised MAKKINK with *LANDSAF R_s and T_2 as input*





Cordoba, daily values, 2008

Results so far:

1. The FAO-Penman-Monteith method compares very well with lysimeter data
2. Slob-de Bruin method for net radiation of well-watered FAO-grass appears to work well
3. For any ET0 estimation method one should not use measured net radiation as input in semi-arid regions where the surface is never well-watered.
4. The old-Makkink appear to work well in the rainy season in Ethiopia
5. First results of LANDSAF revised Makkink approach are very promising, considering that
   - semi-empirical nature of revised Makkink
   - the small scatter for daily values, whereas weekly values are sufficient in practice
   - Our comparison with entirely independent lysimeter data
   - point value versus LANDSAF pixel size

but..... independent tests for other years or/and locations are needed.

Publications so far:

H. A. R. de Bruin, I. F. Trigo, M. A. Jitan, N. Temesgen Enku, C. van der Tol, and A. S. M. Gieske, 2010, *Reference crop evapotranspiration derived from geo-stationary satellite imagery: a case study for the Fogera flood plain, NW-Ethiopia and the Jordan Valley, Jordan,* Hydrol. Earth Syst. Sci., 14, 1–10, 2010

H.A.R. de Bruin, Isabel F. Trigo, P. Gavilan, A. Martínez-Cob & M. P. González-Dugo, *Reference crop evapotranspiration estimated from geostationary satellite imagery,* **IAHS** proceedings Hydrology and Remote Sensing Symposium, Jackson Hole, Septemeber 2010, USA

Z. Sun, M. Gebremichael, and H. A. R. de Bruin, 2010: *Mapping daily evapotranspiration and dryness index in the East African highlands using MODIS and SEVIRI data* Hydrol. Earth Syst. Sci. Discuss., 7, 6285-6303

H.A.R. de Bruin: R-scripts written in the open source language R allowing users who cannot afford to buy MATLAB to read and analyze data stored in compressed LANDSAF files

Planning next year

- More test of our revised Makkink approach in collaboration with IFAPA, Instituto de Investigación y Formación Agraria y Pesquera, CONSEJERÍA DE AGRICULTURA Y PESCA dr. Pedro Gavalan, dr. Ignacio Lorite and PhD-students:

1. for the Cordoba site but other years, 2009, 2010.
2. for other lysimeter sites in Spain
3. for other well-irrigated crops in Andalucía

Research on pressure effects in mountainous regions and accuracy ECMWF temperature

Research on improvement of revised Makkink approach using the full Penman-Monteith equation with Prof. Richard Allen. Collaboration needed with LANDSAF ET group of of Steven Dewitte

Potential Users

We have contact with potential users in Mediterranean countries a such as: Spain, Portugal, Italy, Croatia, Slovenia, Greece, Morocco, Tunisia, Israel, Syria, Jordan

In Africa: Ethiopia, South-Africa, Zimbabwe, Burkina Faso, Sudan and countries involved in the ESA TIGER project, in particular the Democratic Republic of Congo

In Brazil: The Sao Francisco River basin (approved project)

With Prof. Rick Allen proposals will be submitted for a a worldwide ET_0 project geostationary satellite imagery. LANDSAF/EUMETSAT can play a leading role here!!!!! The next GOES will be similar to MSG

Thanks for your attention