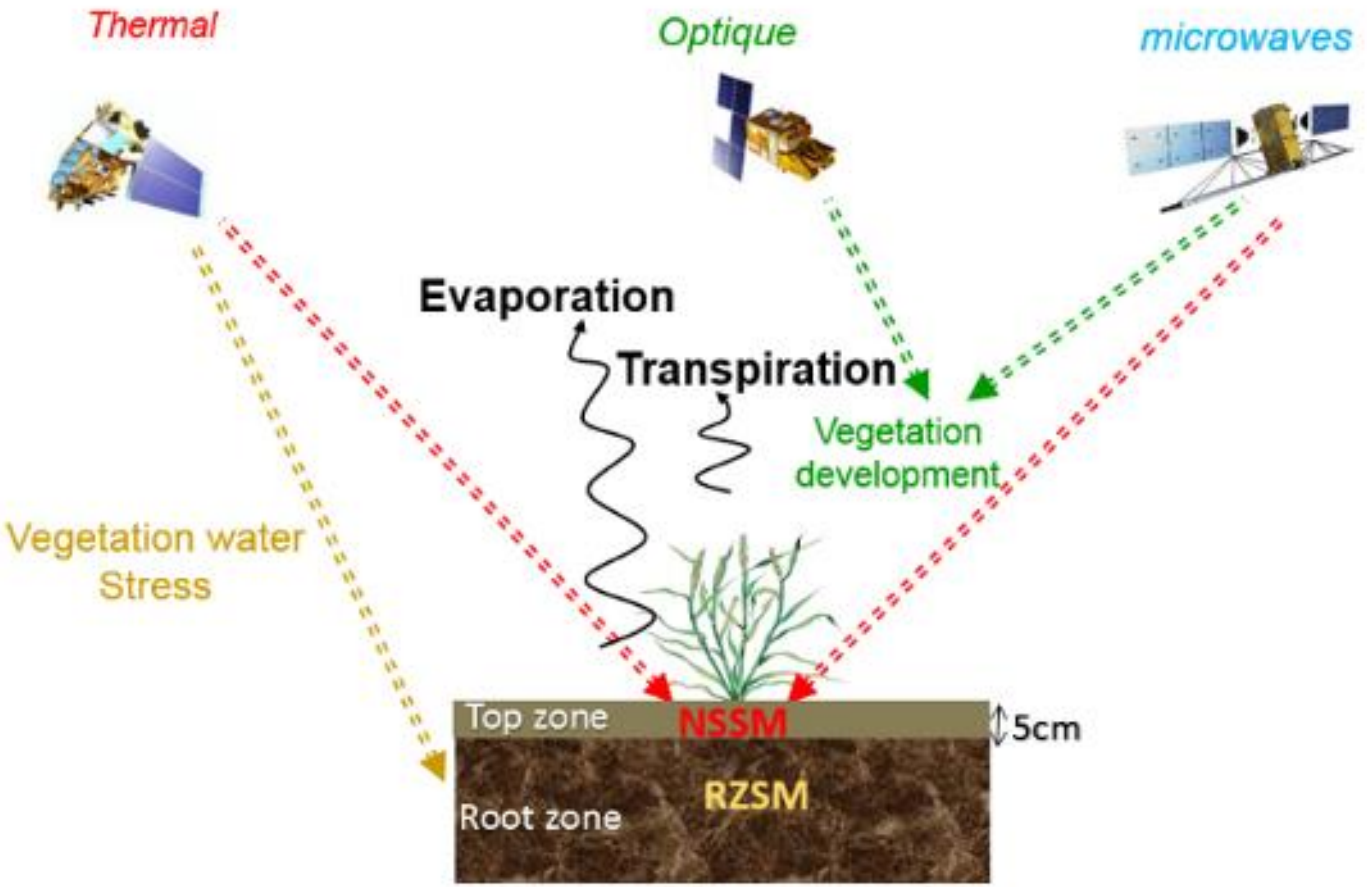
Evapotranspiration retrieval from space

Water and energy budget pathways

RS ET: what can RS offer ?



Water and energy pathways for RS ET

Vegetation development (vegetation indices NDVI)

Surface temperature as a signature of water stress

Water balance (e.g. SAMIR)

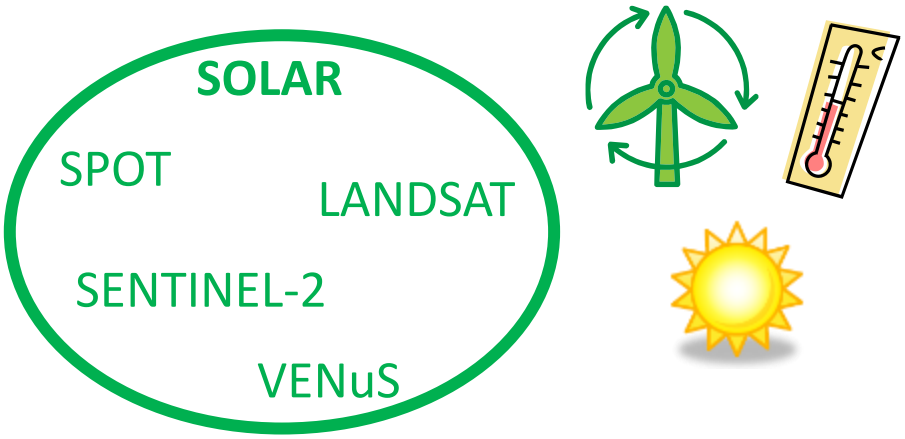
Irrigation inversion

Energy balance (e.g. SPARSE)

Potential EvapoTranspiration (ET_p)

Actual EvapoTranspiration (ET_a)

1. Water budget pathway



Vegetation development
(vegetation indices NDVI)

Water balance (e.g. SAMIR)

Irrigation
inversion

Potential or crop EvapoTranspiration (ET_p or ET_c)

Actual EvapoTranspiration (ET_a)

SAMIR (Satellite Monitoring of Irrigation)
FAO56 method / dual coefficient approach

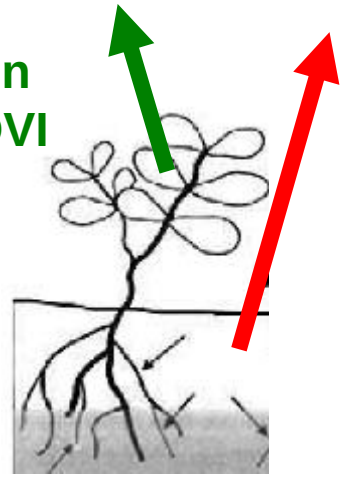
$$ET = (Kcb*Ks + Ke) * ET_0$$

« climatic » evaporative demand

Transpiration

Kcb = f(vegetation development ~NDVI

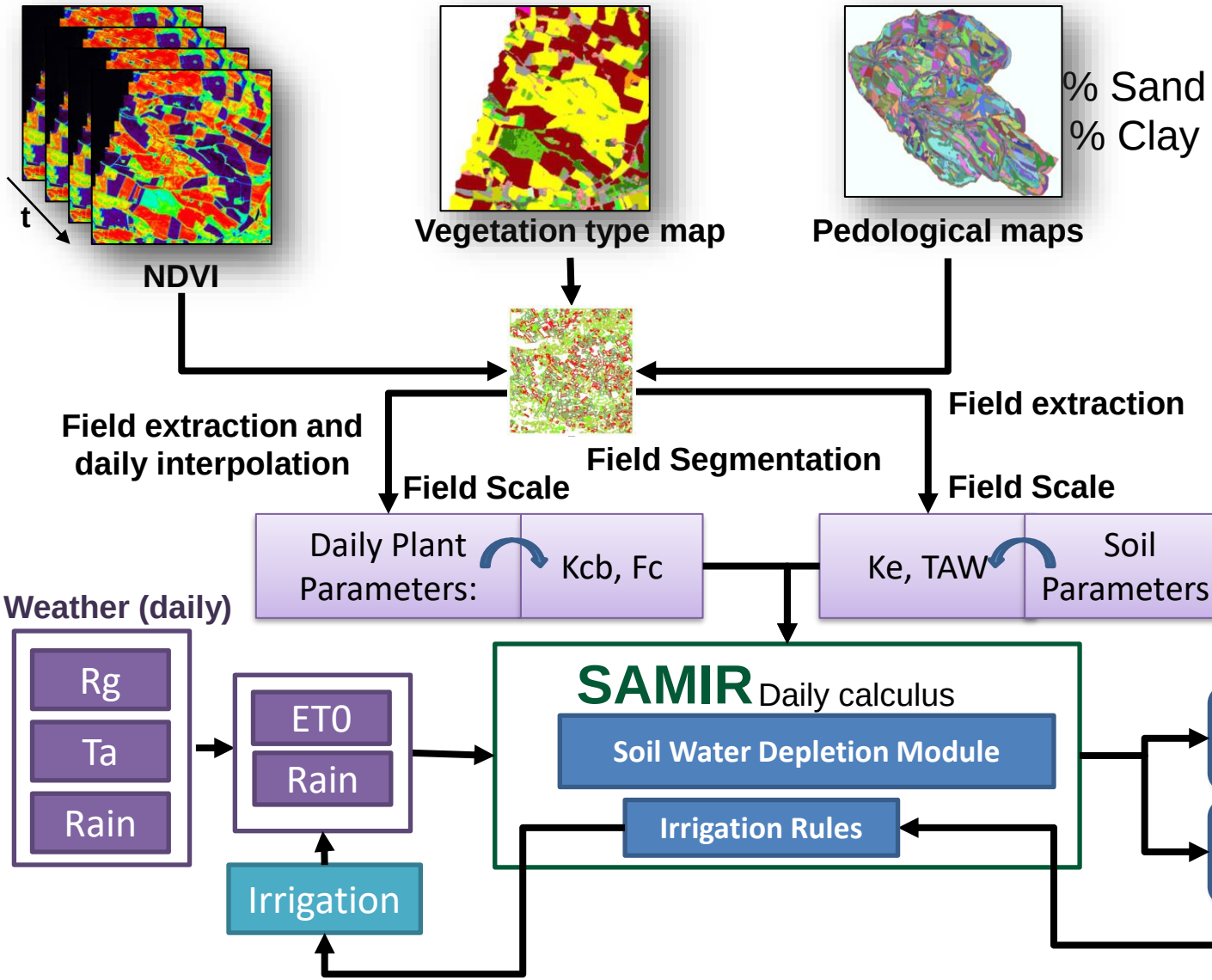
Ks = f(root-soil moisture)



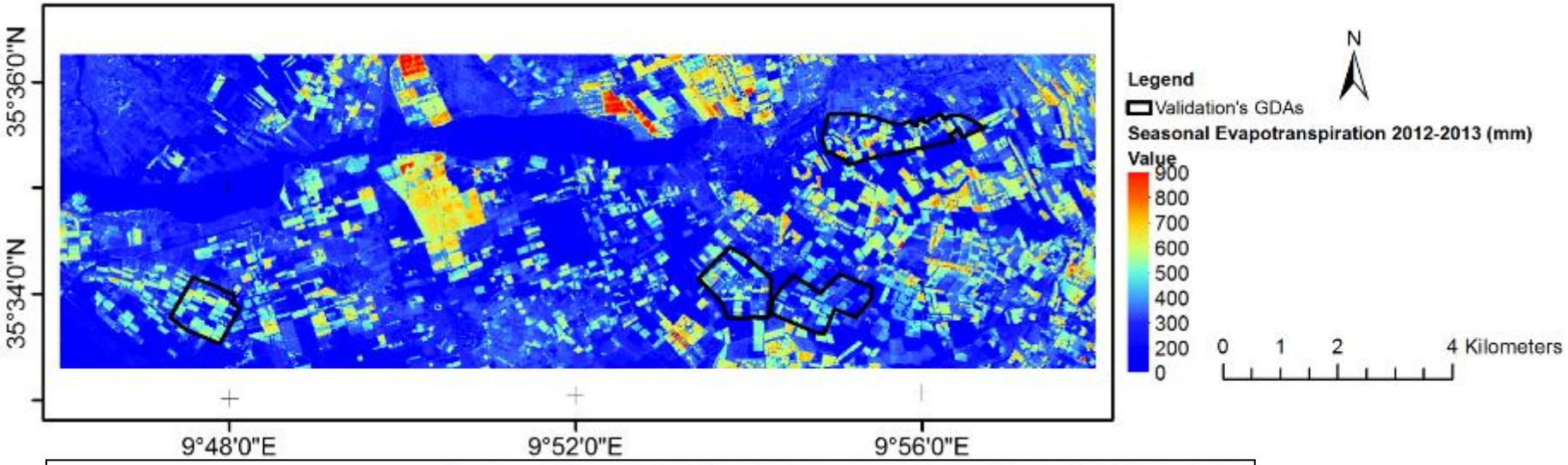
Evaporation

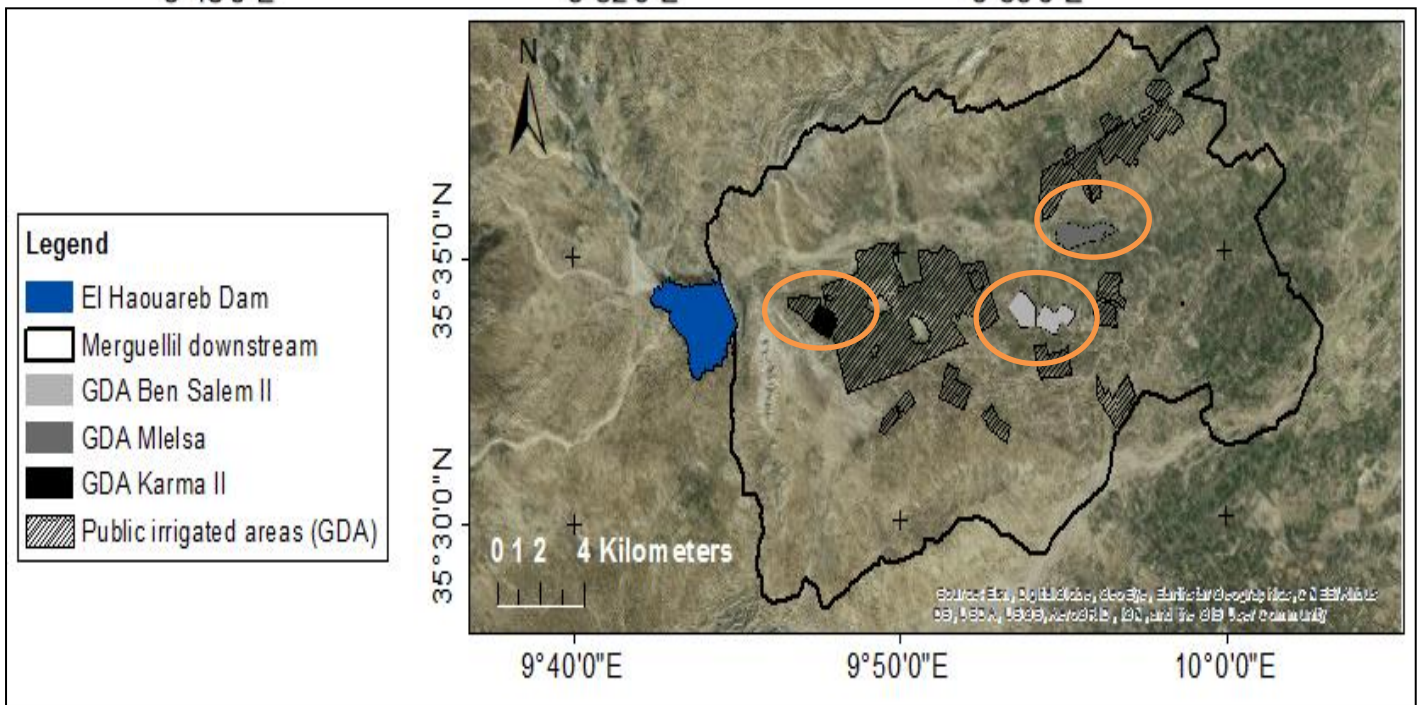
Ke = f(top-soil moisture)

Satellite : Kcb = a*NDVI + b

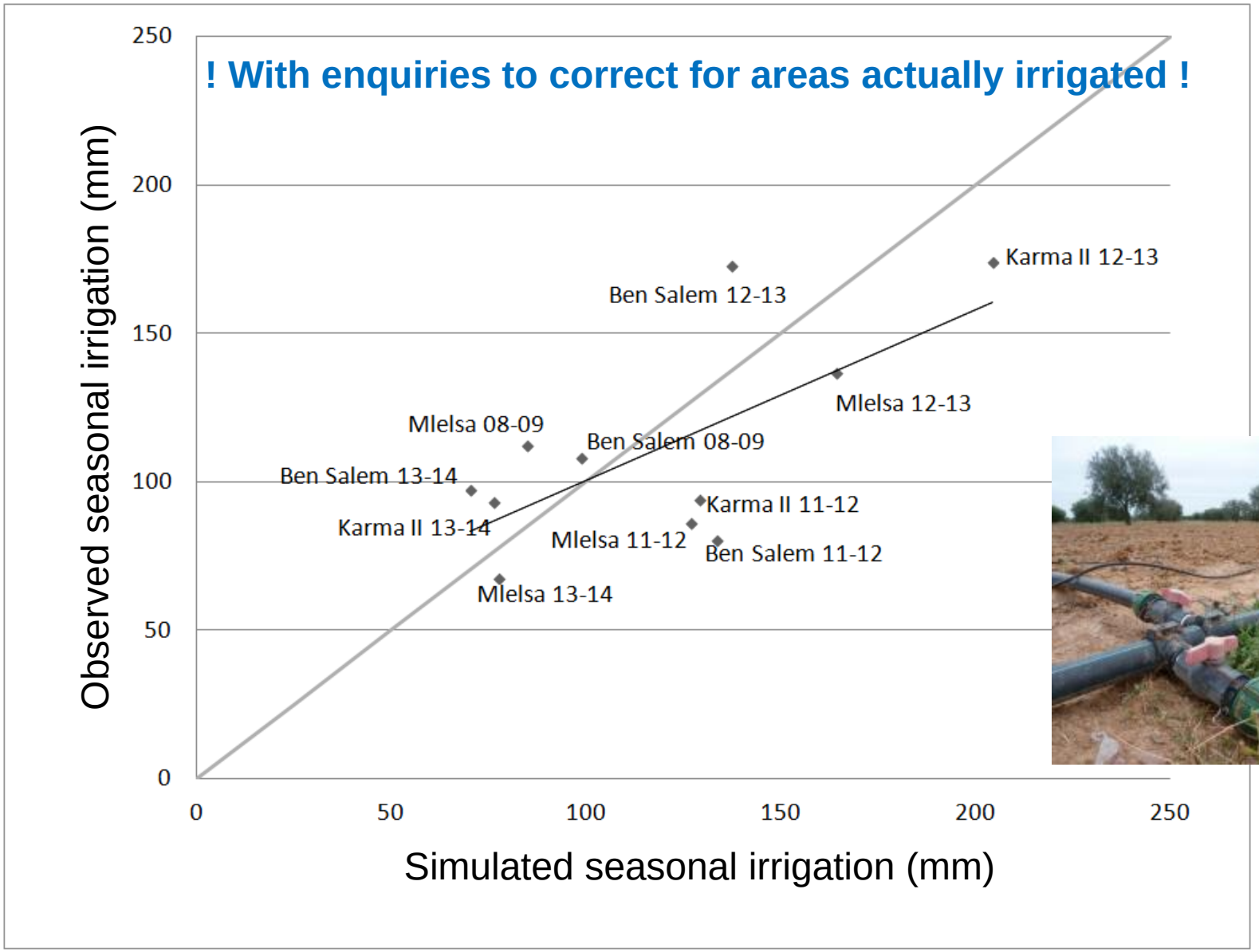

t
NDVI
Vegetation type map
Pedological maps
% Sand
% Clay
Field extraction and daily interpolation
Field Segmentation
Field extraction
Field Scale
Field Scale
Daily Plant Parameters:
Kcb, Fc
Ke, TAW
Soil Parameters:
Weather (daily)
Rg
Ta
Rain
ET0
Rain
Irrigation
SAMIR Daily calculus
Soil Water Depletion Module
Irrigation Rules
Field Scale
ETR (daily)
Depletion (daily)

SAMIR simulates ET and Irrigation





Irrigated perimeters over a main gauged borehole

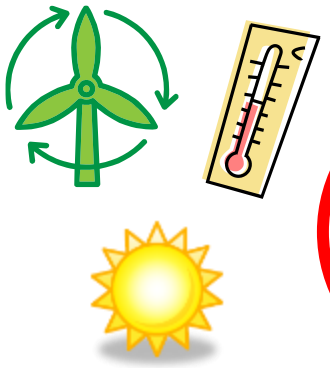


(Saadi et al., RS2015)

→ 25% mean absolute difference

→ Overall difference: 111 mm irrigation observed for 118 mm simulated

2. Energy budget pathway



TIR

ASTER

LANDSAT 7-8

SENTINEL-3

MODIS

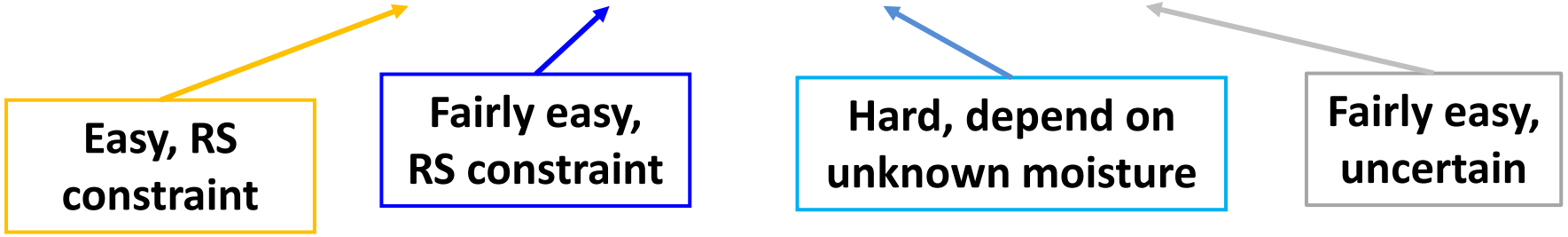
Surface temperature as a signature of water stress

Energy balance (e.g. SPARSE)

Actual EvapoTranspiration (ET_a)

The energy budget equation

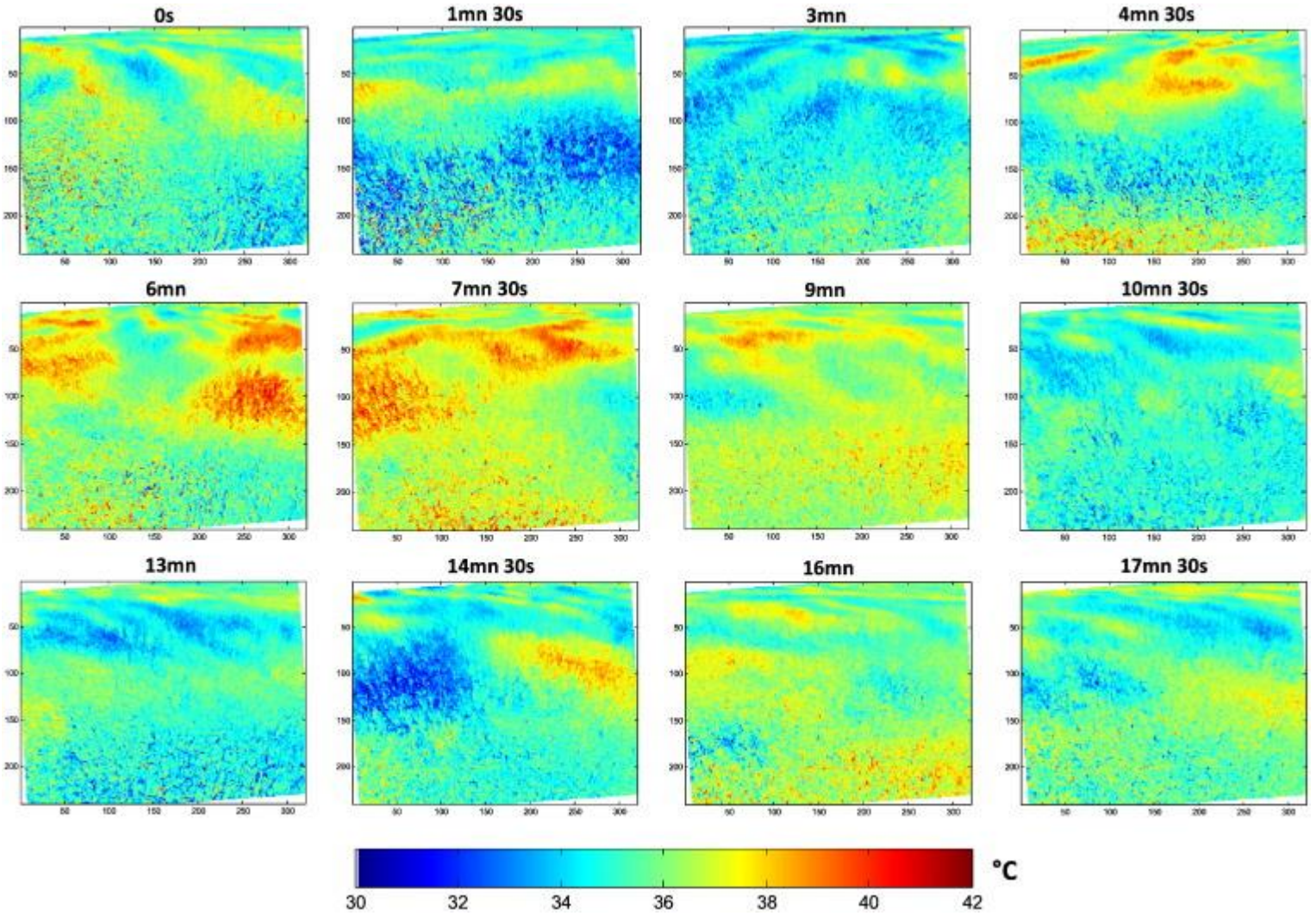
$$\mathbf{Rn}(Ts) = \mathbf{H}(Ts) + \mathbf{LE}(Ts) + \mathbf{G}(Ts)$$



Instantaneous evapotranspiration

$$LE = Rn(T_s) - G(T_s) - H(T_s)$$

Mismatch between inst. Tsurf & 30’ meteo forcing



ET(TIR) methods

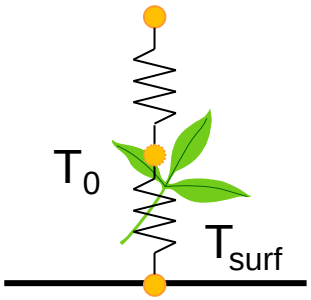
Single pixel models

Input = full meteorological forcing

Single pixel temperature

+ hypothesis on vegetation stress or greenness

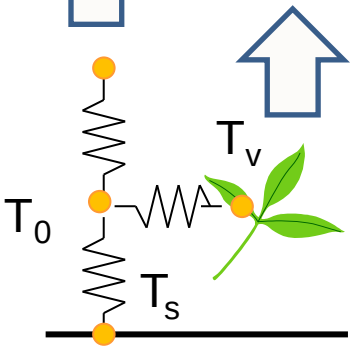
EvapoTranspiration



e.g. SEBS

Evaporation

Transpiration

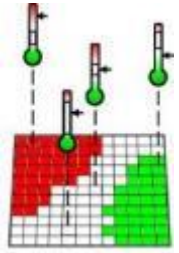


e.g. TSEB

Contextual models

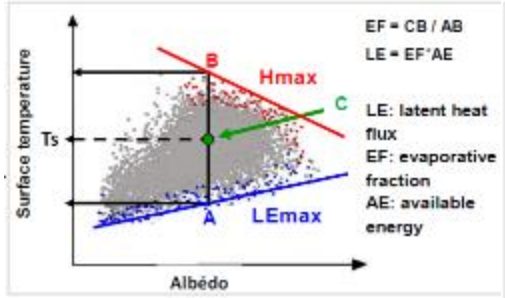
Input = reduced meteorological forcing

Temperature image with dry/wet edges identification



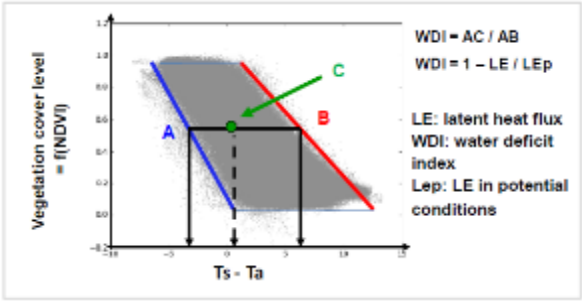
+ corresponding laws according to albedo or NDVI …

EvapoTranspiration



e.g. S-SEBI

Water availability

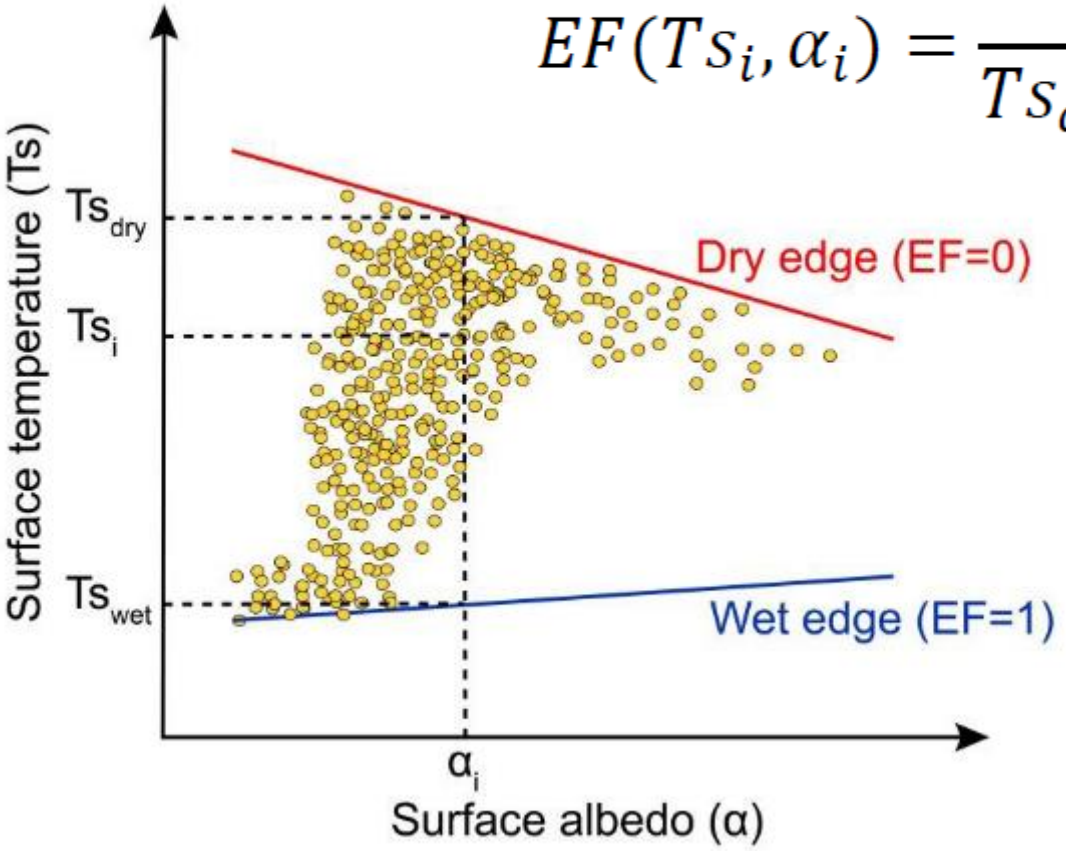


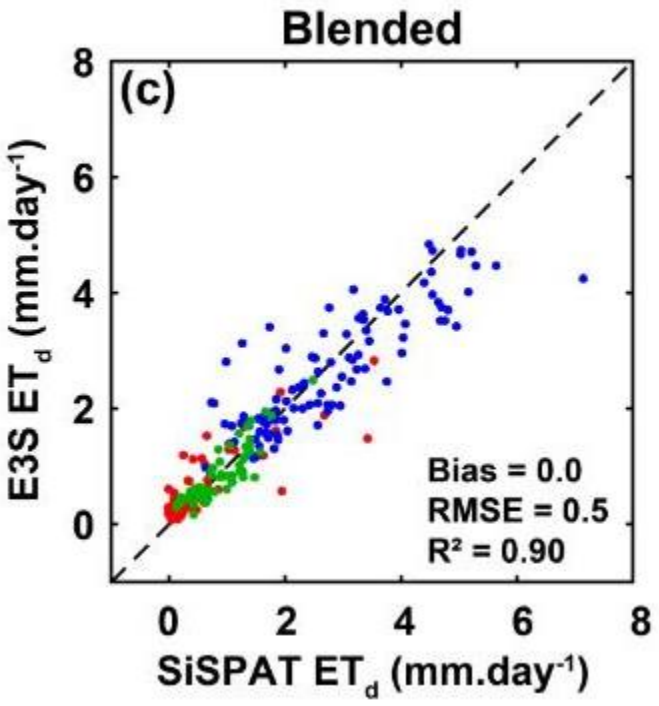
e.g. WDI

S-SEBI

$$LE = EF \,.\, (Rn - G)$$

$$EF(Ts_i, \alpha_i) = \frac{Ts_{dry}(\alpha_i) - Ts_i}{Ts_{dry}(\alpha_i) - Ts_{wet}(\alpha_i)}$$

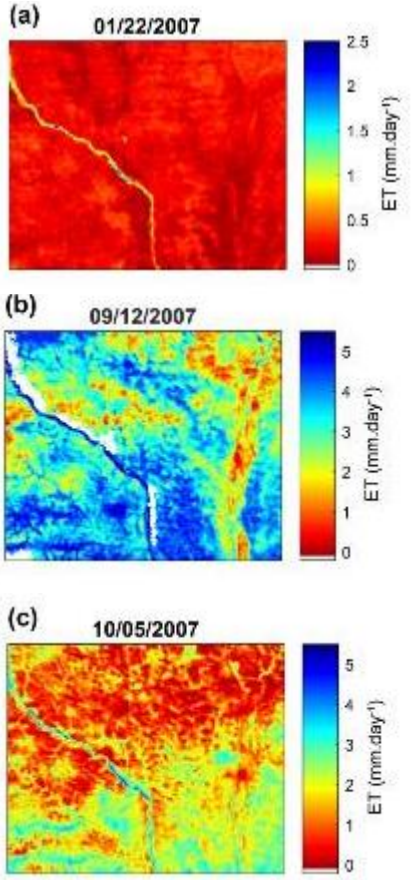




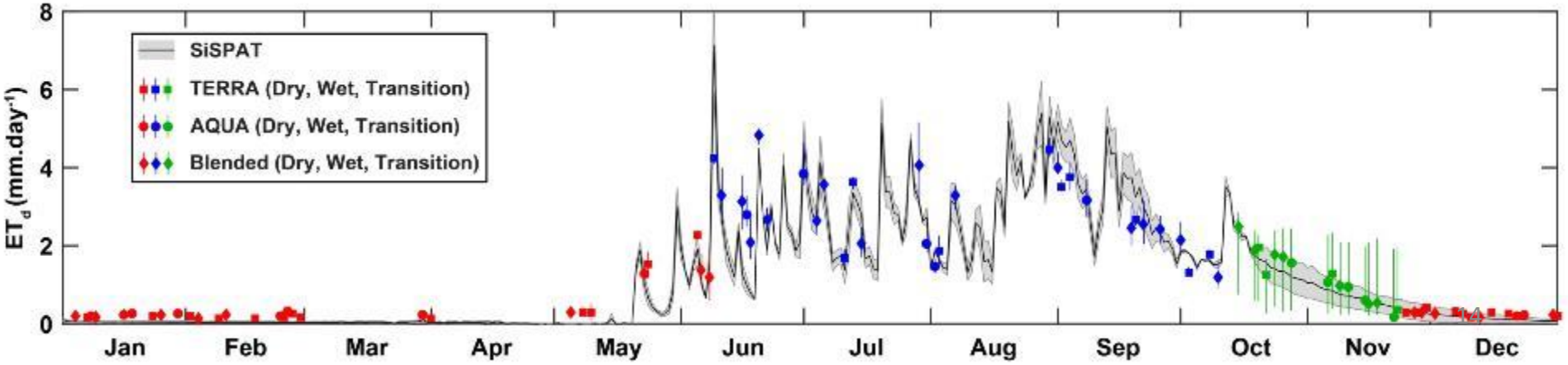
ET E3S vs. ET SiSPAT
Wankama pixel (2005-2008)

Dry Wet Transition

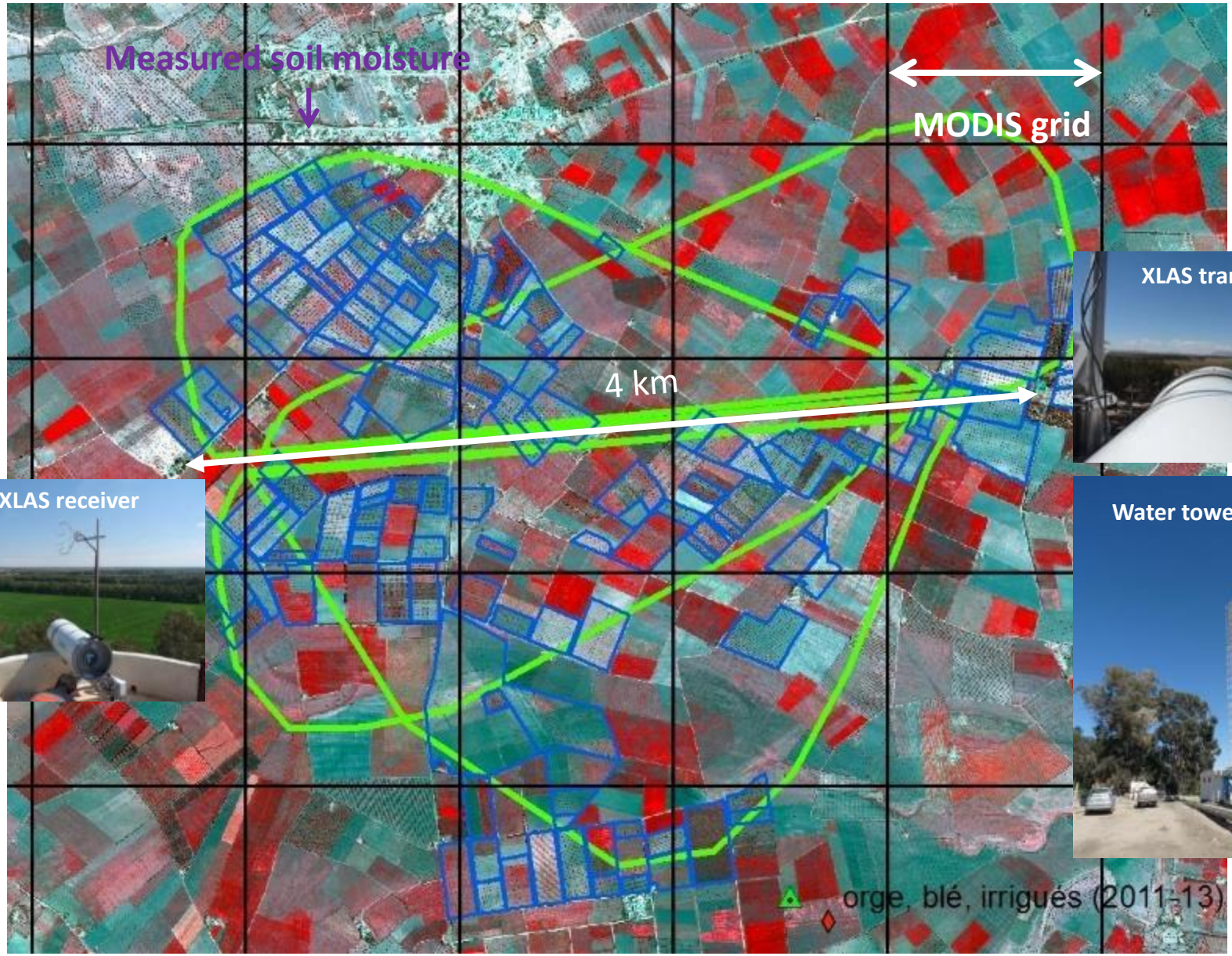
Daily ET maps (2007)



Daily ET time series (EVASPA forced by MODIS), Wankama pixel

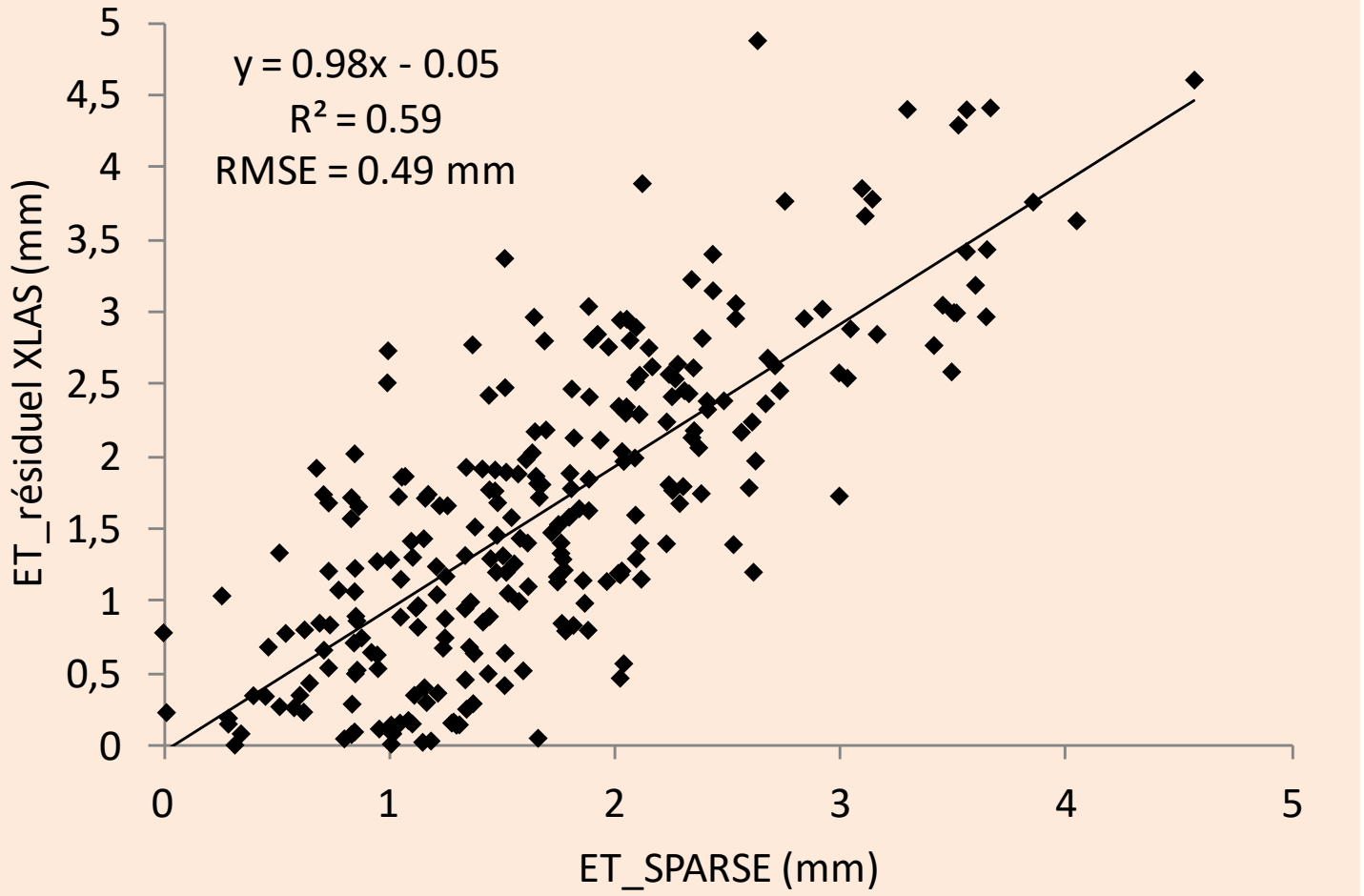


Scintillometer observations for MODIS pixel size



ET with the single pixel SPARSE model

$LE_{XLAS} = (Rn\text{-}G)_{MODIS} - H_{XLAS}$



Saadi et al., HESS2018

Available ET products

Product	Spatial resolution	Temporal resolution	Timespan
MOD16	500m	8-days	2001-present
WACMOS-MOD16	25km	day	2005-2007
PML V2	5km	8-days	2002-2019
WAPOR	250m	10-days	2009-present
GLEAM	25km	day	1980-2020
WACMOS-GLEAM	25km	day	2005-2007
WACMOS-PT-JPL	25km	day	2005-2007
WECANN	100km	month	2007-2015
GLDAS NOAH	25km	3-hours	2000-present
FLUXCOM RS	800m	8-days	2001-2015
FLUXCOM RS METEO	5km	day	2001-2010
FLUXNET MTE	5km	month	1982-2011
ALEXI	5km	week	2005-2012
SSEBOP	1km	10-days	2001-2017
DOLCE V2.1	25km	month	1980-2018
REA	25km	day	1980-2017

Penman-Monteith

Priestley-Taylor

Neural Network

Land Surface Model

Spatialization of flux tower measurements

Surface Energy Balance Models

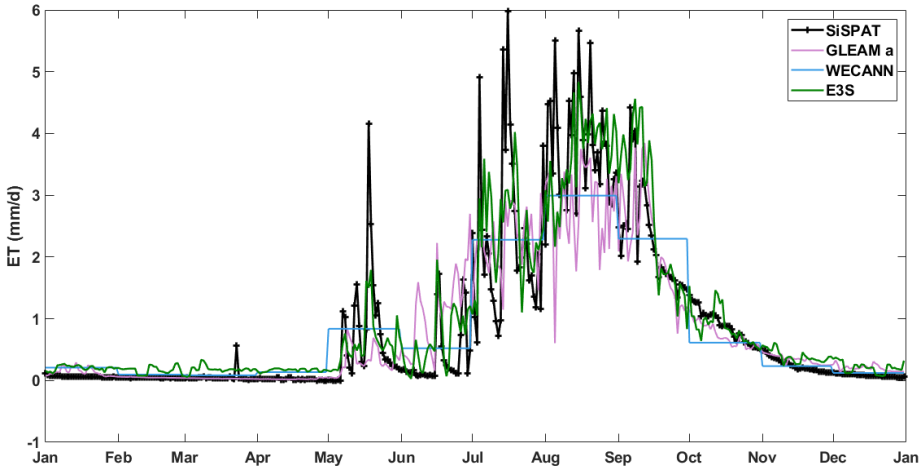
Data fusion

Courtesy J. Etchanchu

Local comparison

Wankama site (Niger) : 2007

Product	Bias (mm/an)	RMSE (mm/d)	R^2
MOD16	230	1.19	0.68
WACMOS-MOD16	193	1.09	0.52
PML V2	-93	0.80	0.64
GLEAM a	21	0.74	0.69
GLEAM b	17	0.72	0.70
WACMOS-GLEAM	-210	1.05	0.56
WACMOS-PT-JPL	201	1.07	0.71
WECANN	14	0.66	0.77
GLDAS NOAH	-58	0.92	0.55
FLUXCOM RS	-75	0.80	0.72
FLUXCOM RS METEO	-240	1.00	0.67
FLUXNET MTE	155	1.18	0.50
ALEXI	-153	1.14	0.47
SSEBOP	27	1.20	0.39
DOLCE V2.1	-131	0.85	0.66
REA	-186	0.94	0.68
E3S	-39	0.59	0.81



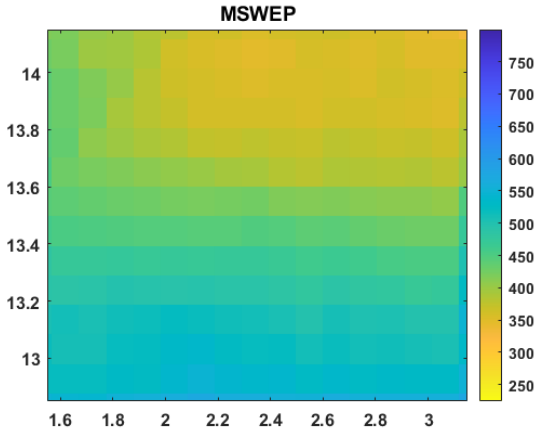
E3S(1km,1day):
→ Best scores

GLEAM (25km,1day), WECANN(100km,month):
→ Good scores but coarse resolutions

Courtesy J. Etchanchu

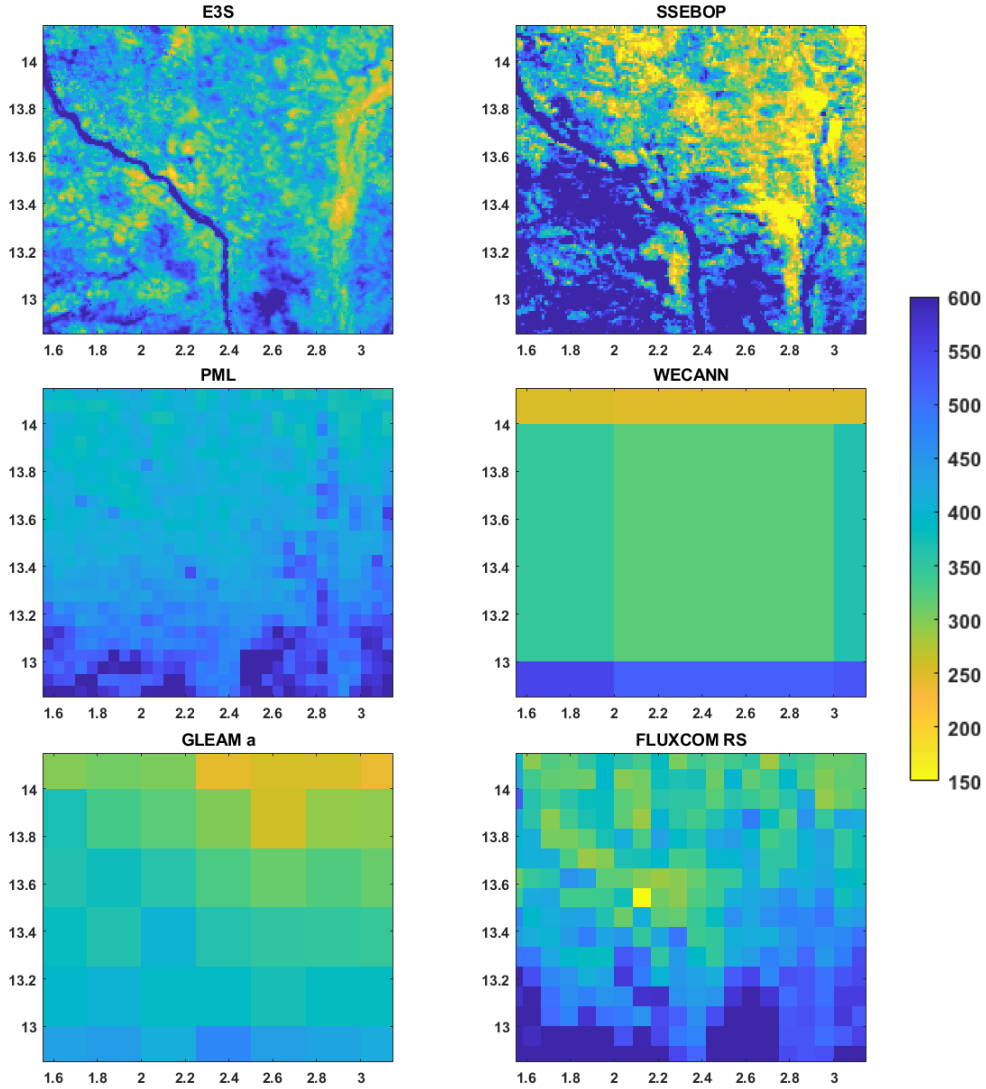
Spatial comparison

Niamey Square-Degree 2007



Annual rain spatial distribution

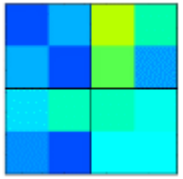
Annual ET



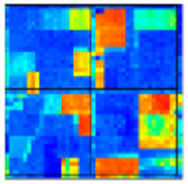
Courtesy J. Etchanchu

ET products: what do we have now and in the future ?

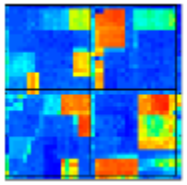
Need for an ET product at <100m (**plot size < 1ha**) every day or so
(rapid moisture change between **two successive rainfalls**)



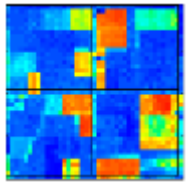
For the moment, we have MODIS and S3 temperature products
> **daily ET at 1km** with energy budget model with little unknown inputs



We also have ET values from NDVI data and water budget models at S2 pixel size
> But they rely on **many unknown** inputs incl. water inputs + model parameters



SEN4ET products use S3 ET data disagregated to S2
> But the method assumes that the **vegetation is unstressed**



TRISHNA and LSTM will provide Ts and thus ET estimates **every 1-3 days at <100 m** (less often possibly depending on clear sky conditions) !






1 km