Evapotranspiration (ET) and Vegetation Index (VI) relationship in different vegetation systems:

the feasibility of using satellite-derived VI to estimate ET

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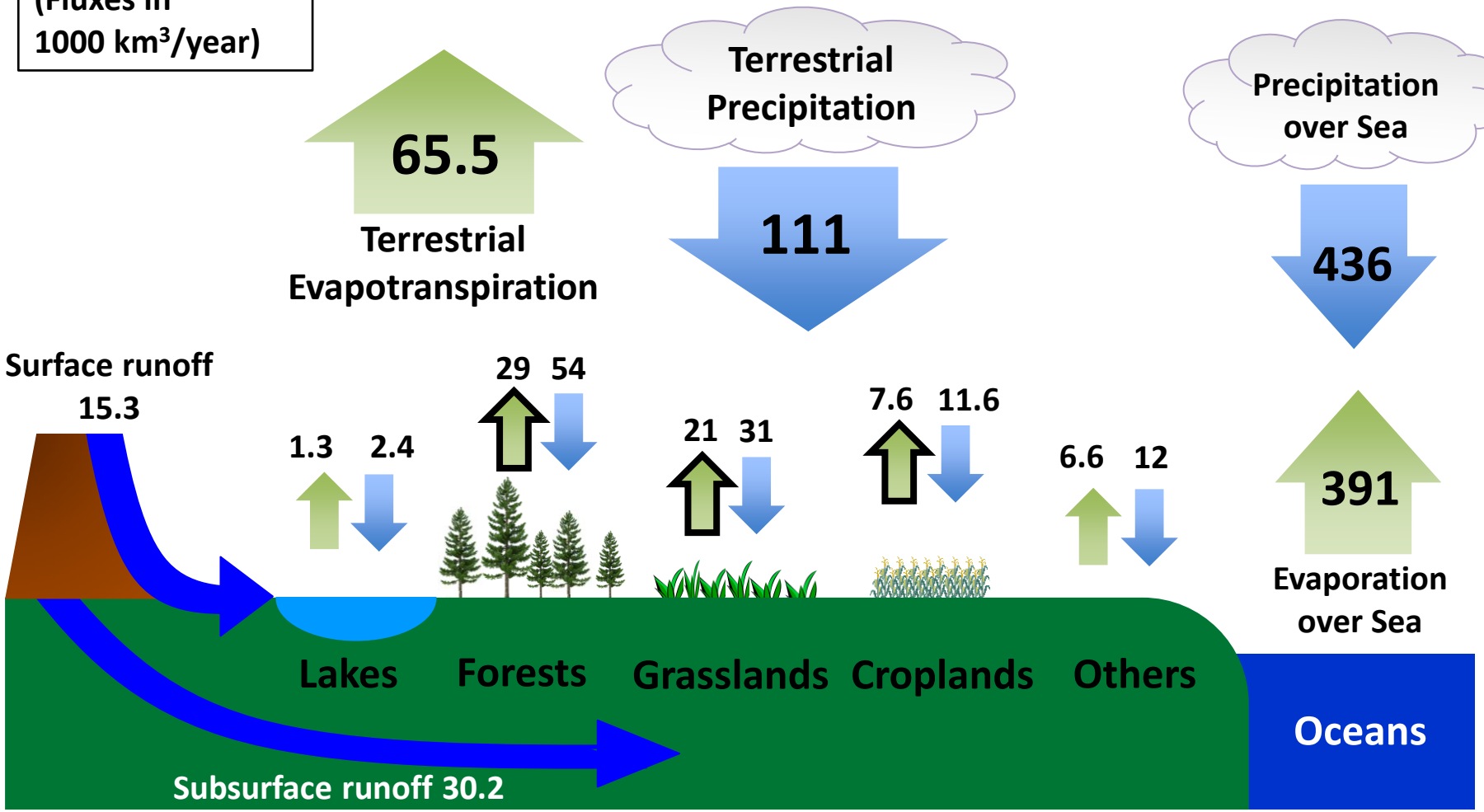
ET in the Global water cycle

(Fluxes in 1000 km^3/year)

Oki and Kanae, Science (2006)



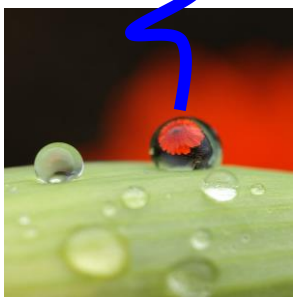
Nearly 60% of the total terrestrial precipitation is lost through ET mostly by vegetation

Factors affecting ET

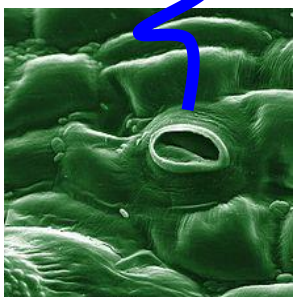
Allen *et al.* (2006)

ET – Two simultaneous processes:

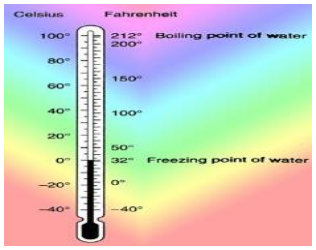
Direct evaporation



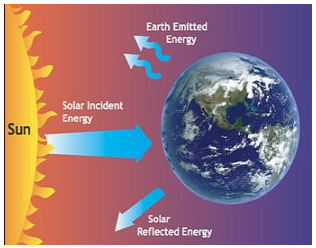
Transpiration through plant stomata



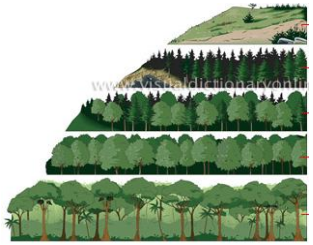
Wind speed



Air temperature and humidity



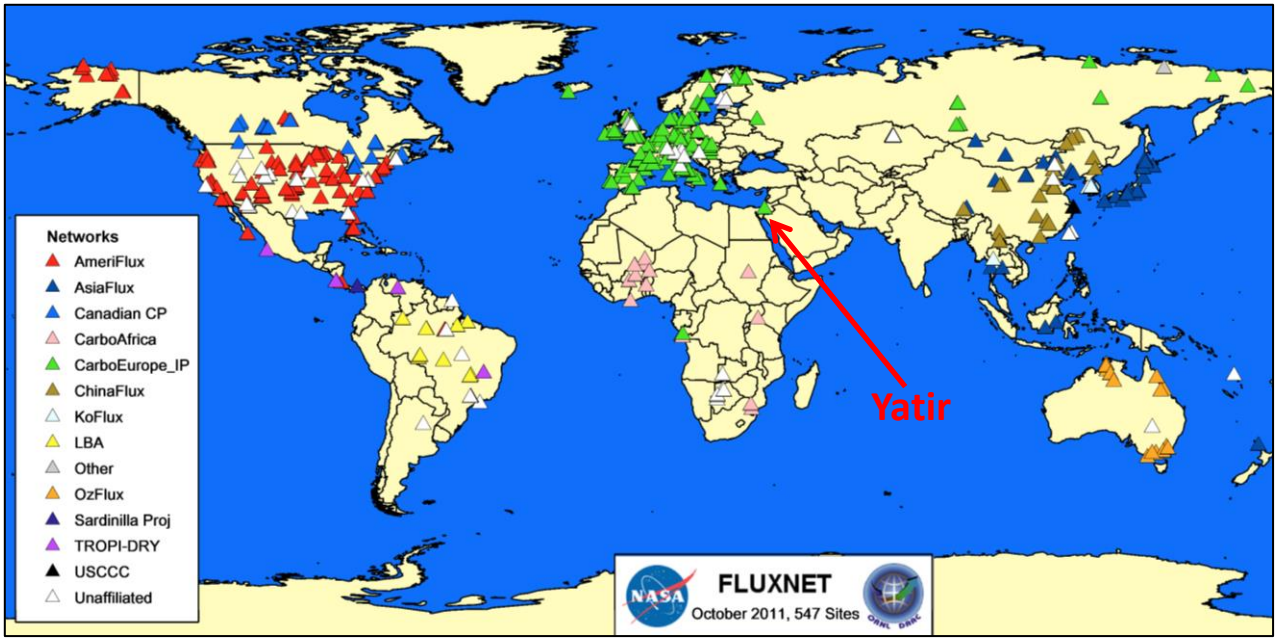
Solar radiation



Vegetation type and topography

Spatial estimation of ET is essential for understanding how these factors affect the water efficiency of different vegetation systems

Spatial estimation of ET – FLUXNET stations



Tonzi ranch (California)

Kellogg Biological Station at the Michigan State University. Photo credit: Bill Krasean

Limitations:

- Cover – only few stations in Africa and Asia, one station in the entire middle east (**Yatir**, **Israel**)
- Radius of measurement **<** 1 km
- Limited to horizontal and uniform terrains

Remote sensing can overcome these spatial drawbacks

Two main approaches using satellite remote sensing

Glenn *et al.* (2010)

A. VI

(Empirical)

Vegetation index (VI)
from solar reflection

Reported error 10 – 30% for both approaches (within FLUXNET error)

Kalma *et al.* (2008)

B. Meteorological

(Physical-based)

Solving the energy balance equation – **preferred by the atmospheric science community**

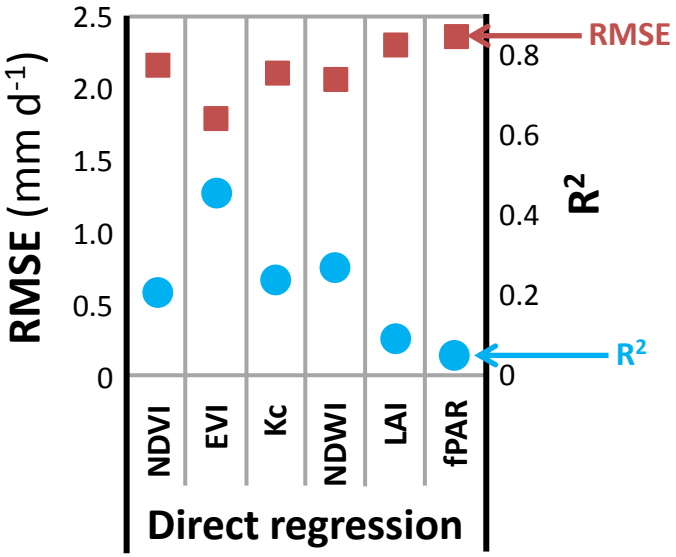
Skin temperature
from thermal bands

+

meteorological data

VI approach has the advantage of not requiring meteorological data

VI approach does not always work – recent study

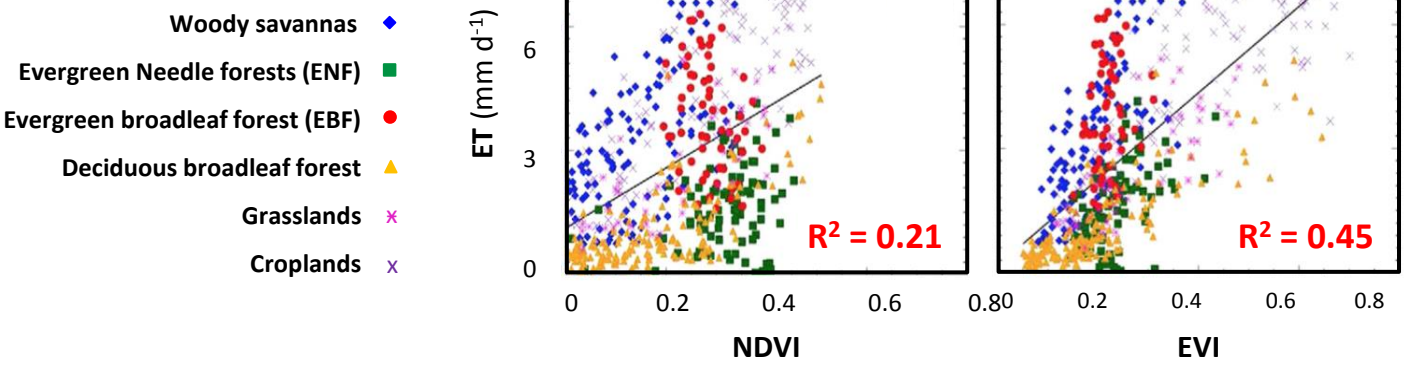


Yebra *et al.* (2013)

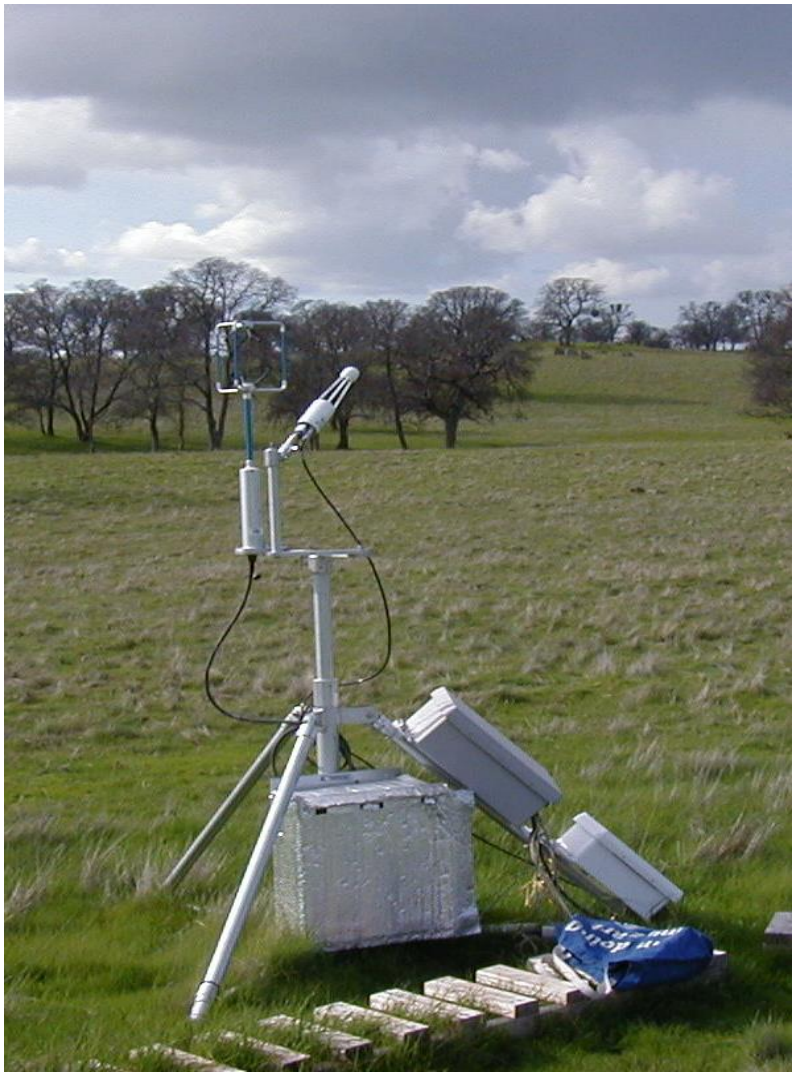
Direct regression of 6 different vegetation measures against ET from 16 FLUXNET sites covering different vegetation systems

<u>Results:</u> Large RMSE with low R^2 for all VIs

<u>Our work:</u> what is the meaning of the VI-ET relation and what are the limitations of the VI approach?

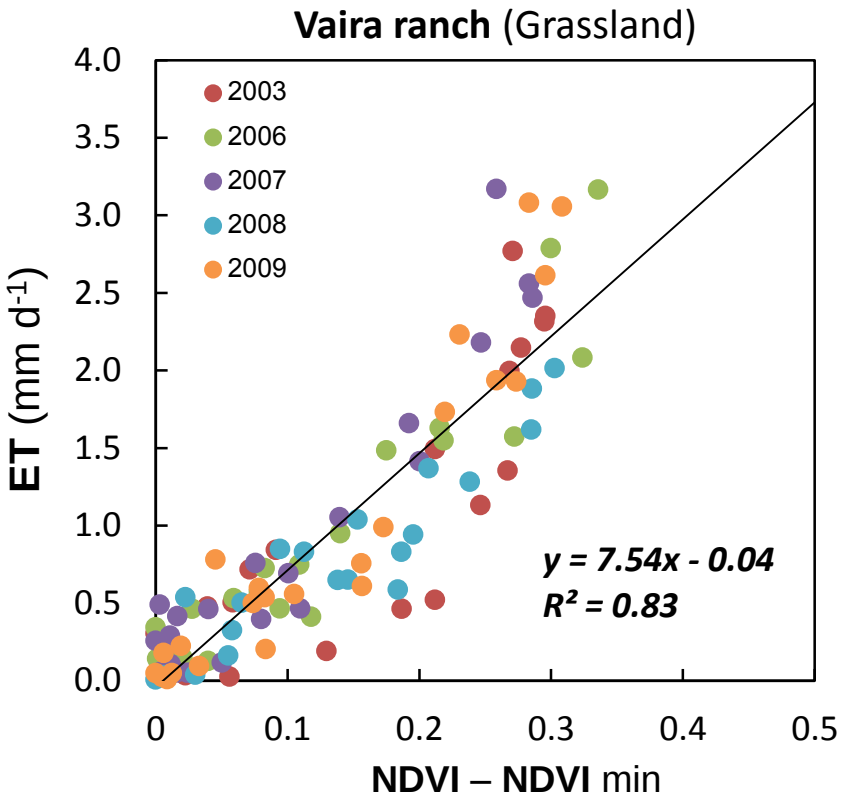


ET and NDVI relationship in grassland



Vaira ranch FLUXNET site (California)

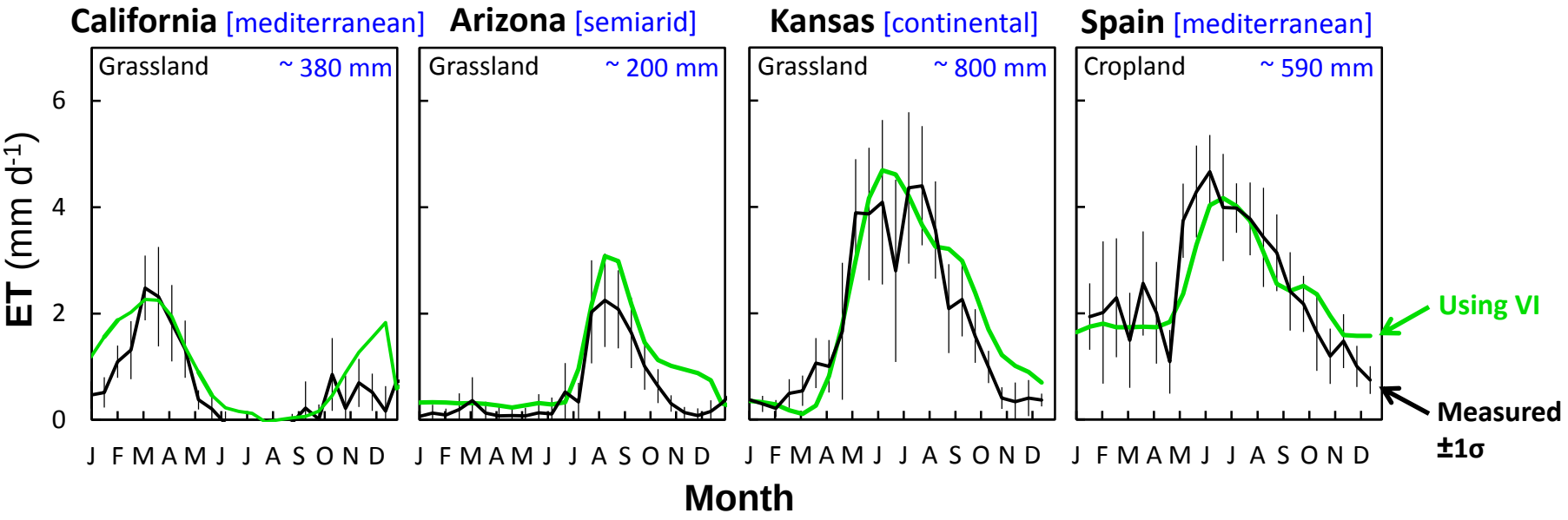
Helman *et al.*, (in prep)



Good correlation allows spatio-temporal estimation at the entire ecosystem

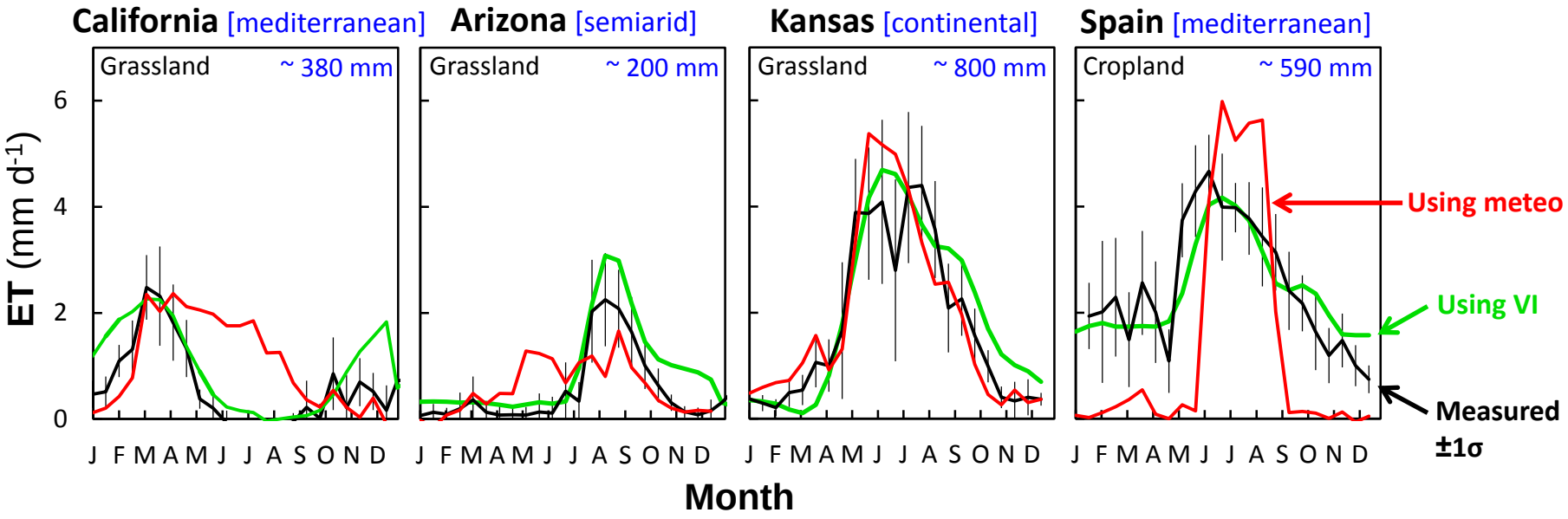
Validation – grassland and cropland

Jack-Knife cross-validation excluding 1 year in four sites :



VI vs. meteorological approach in grassland and cropland

Jack-Knife cross-validation excluding 1 year in four sites :

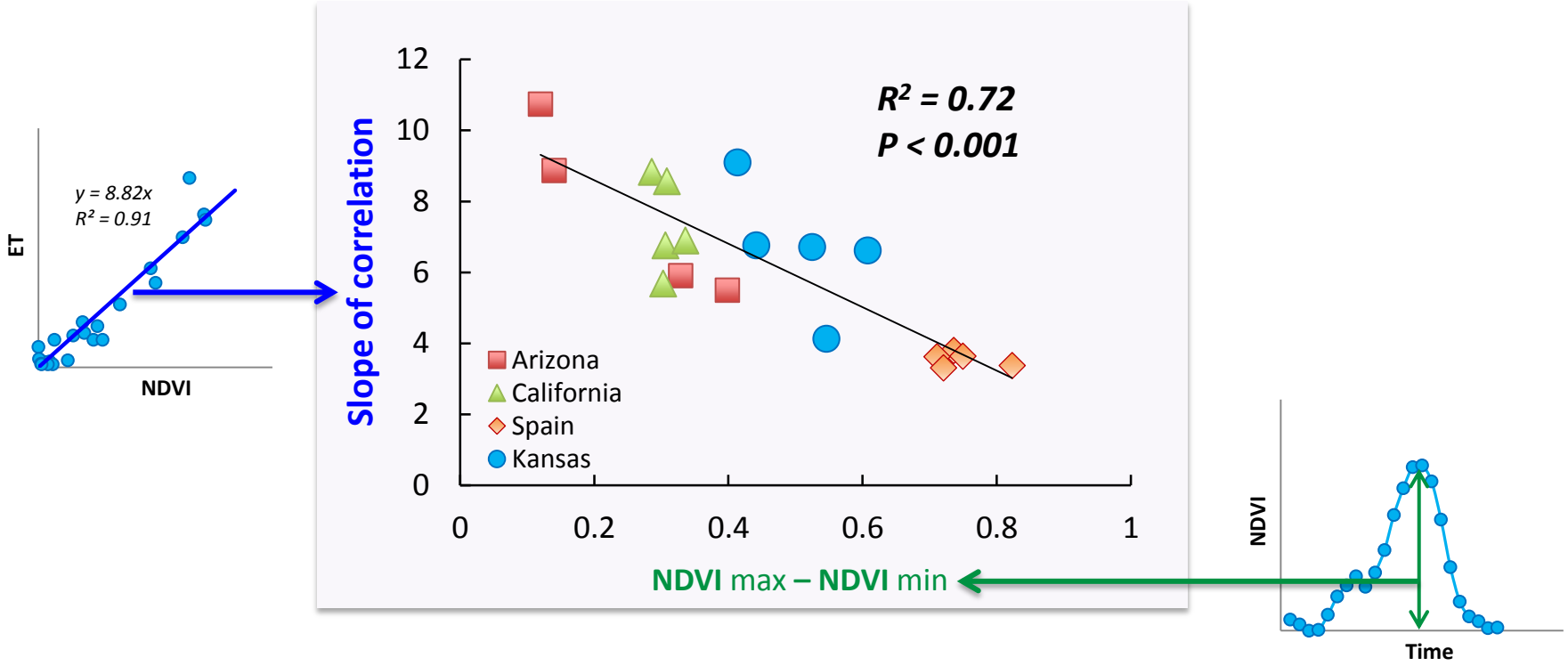


	VI		Meteo	
	R^2	RMSE	R^2	RMSE
California	0.90	0.48	0.30	0.60
Arizona	0.68	0.60	0.13	1.03
Kansas	0.83	0.68	0.81	0.74
Spain	0.76	0.59	0.49	1.94
Mean MAE		~ 0. 6 mm d^{-1}		~ 1.1 mm d^{-1}

VI approach performs better than MODIS meteorological product in grasslands & croplands

Relationship between sites

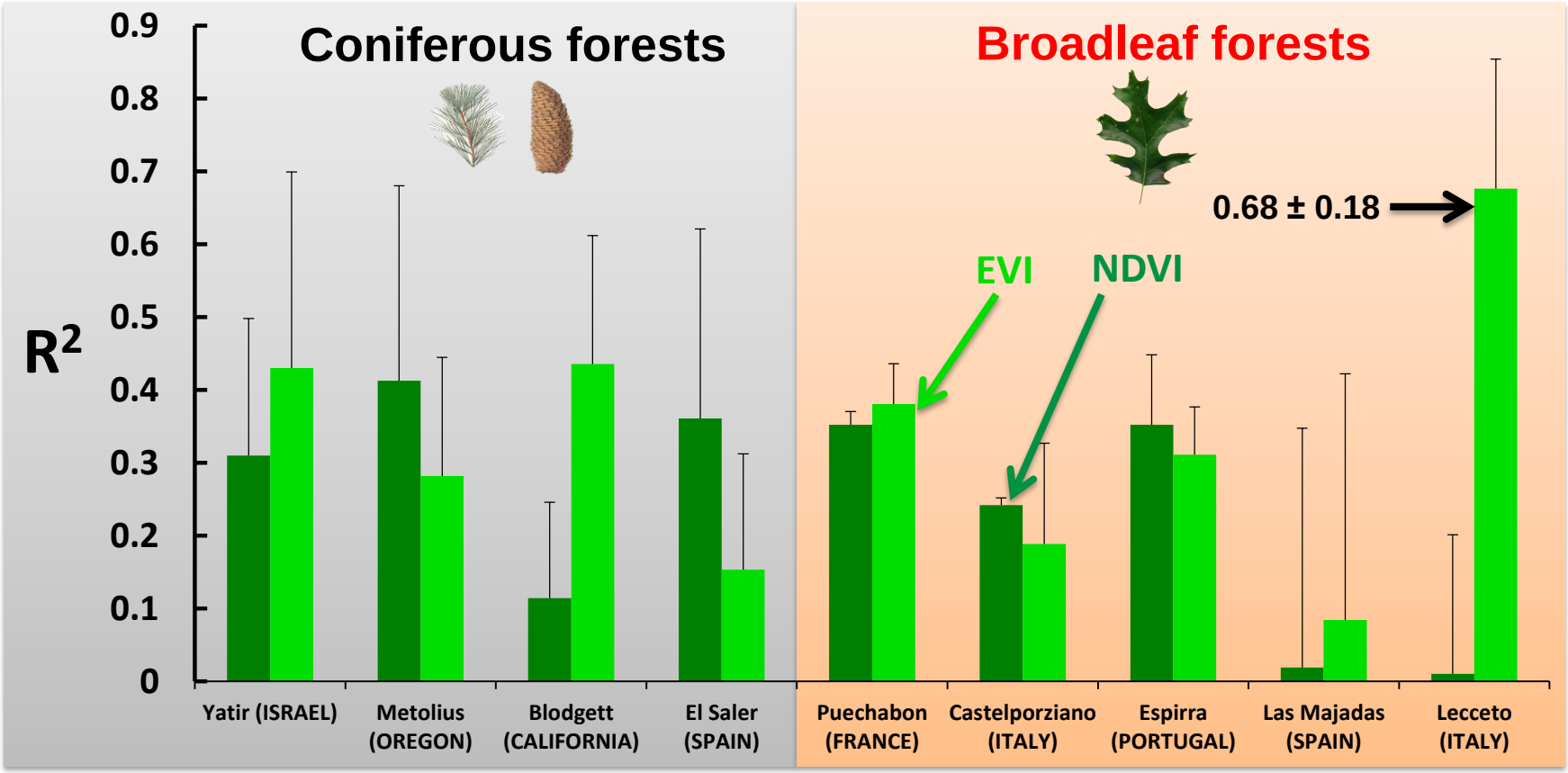
Relationship between slope obtained from local calibration and NDVI seasonal magnitude



Linear relationship between sites – promising for estimating ET in other annual vegetation systems without the need for local calibration

VI – ET in complex vegetation systems (Forests)

Average R^2 obtained from regressing ET against NDVI and EVI for each year separately in 4 coniferous and 5 broadleaf evergreen forests

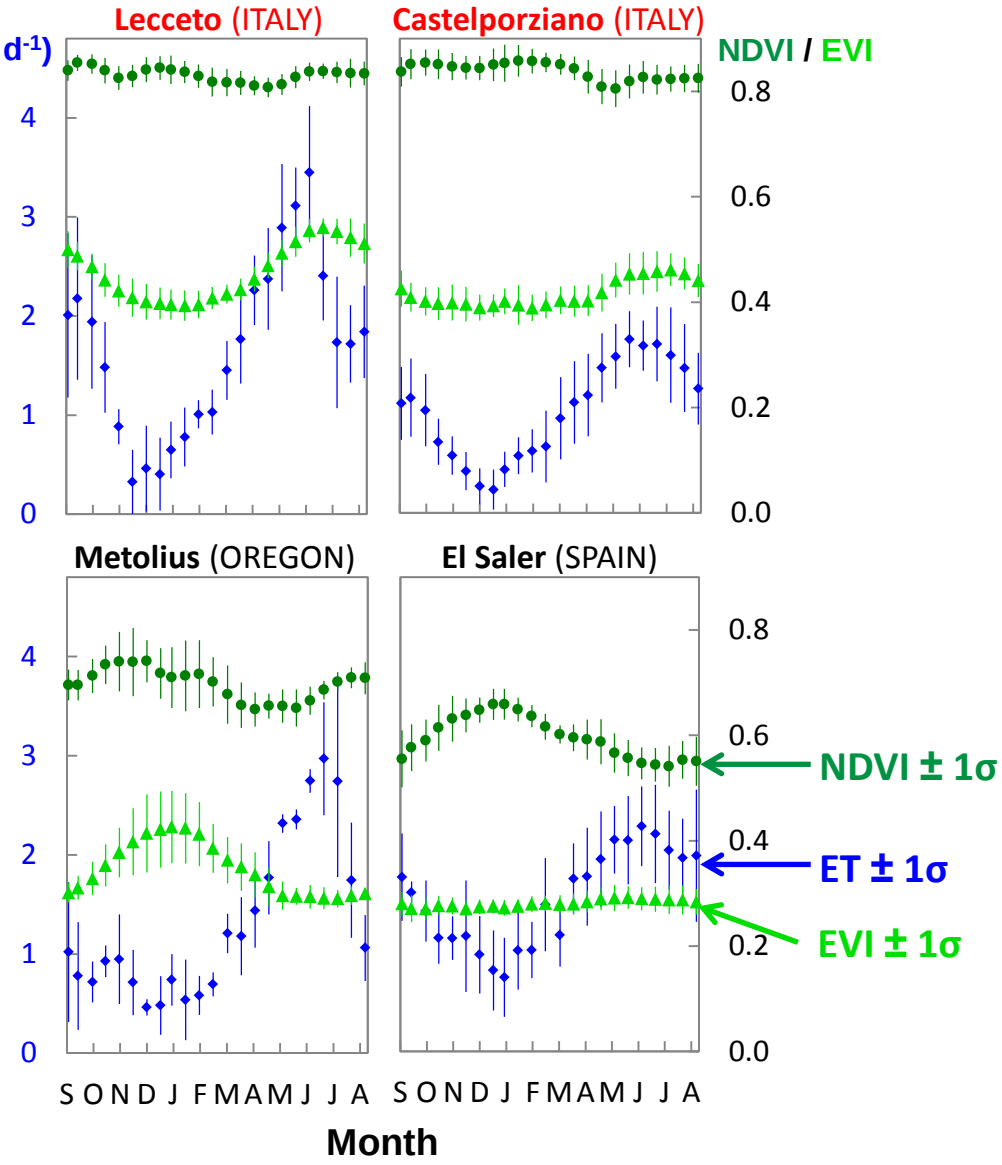


Relatively poor performance of VI approach in evergreen Mediterranean and semiarid forests…what can be the reason?

VI and ET time series – looking for seasonality

Broadleaf forests

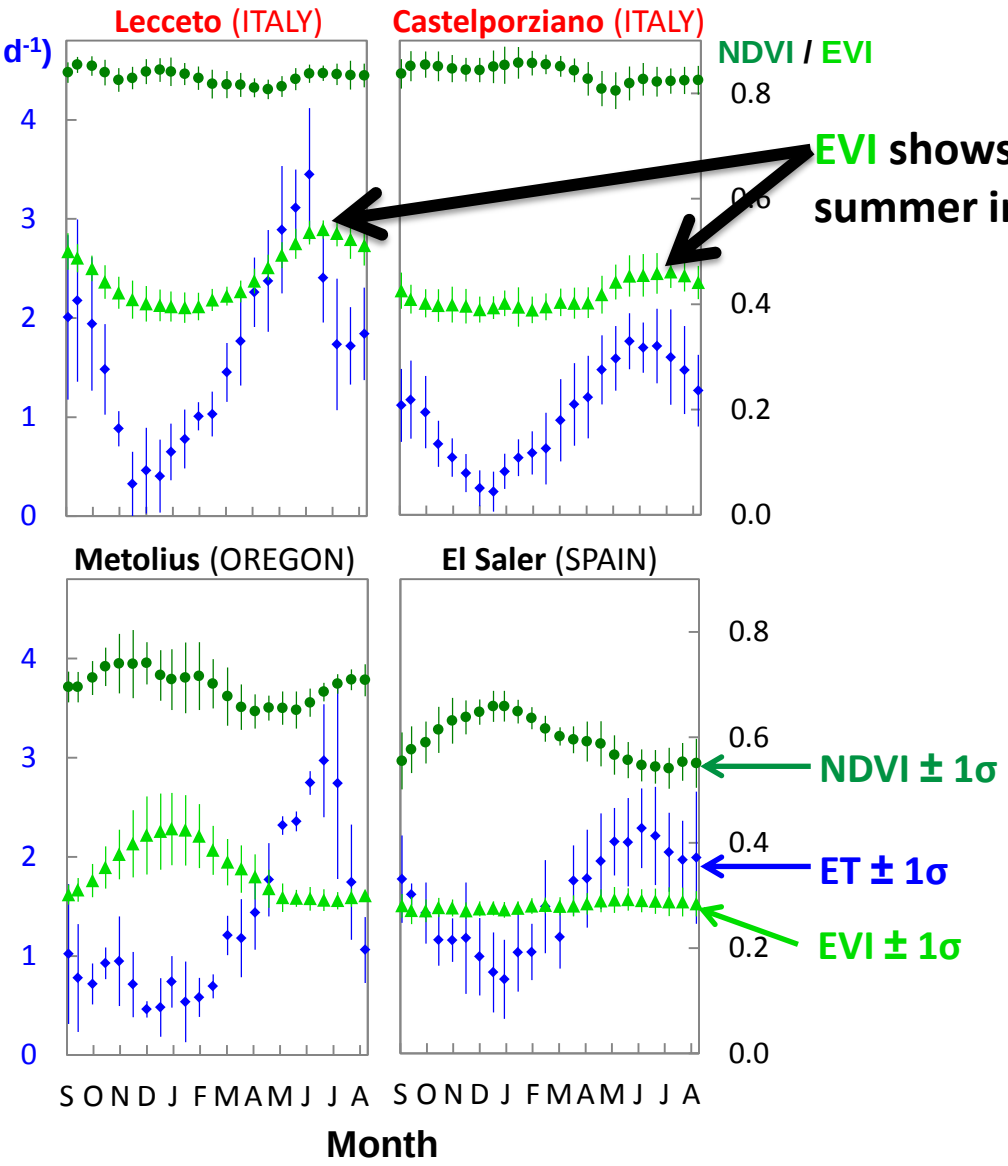
Coniferous forests



VI and ET time series – looking for seasonality

Broadleaf forests

Coniferous forests



EVI shows seasonality during summer in broadleaf forests

NDVI ± 1σ

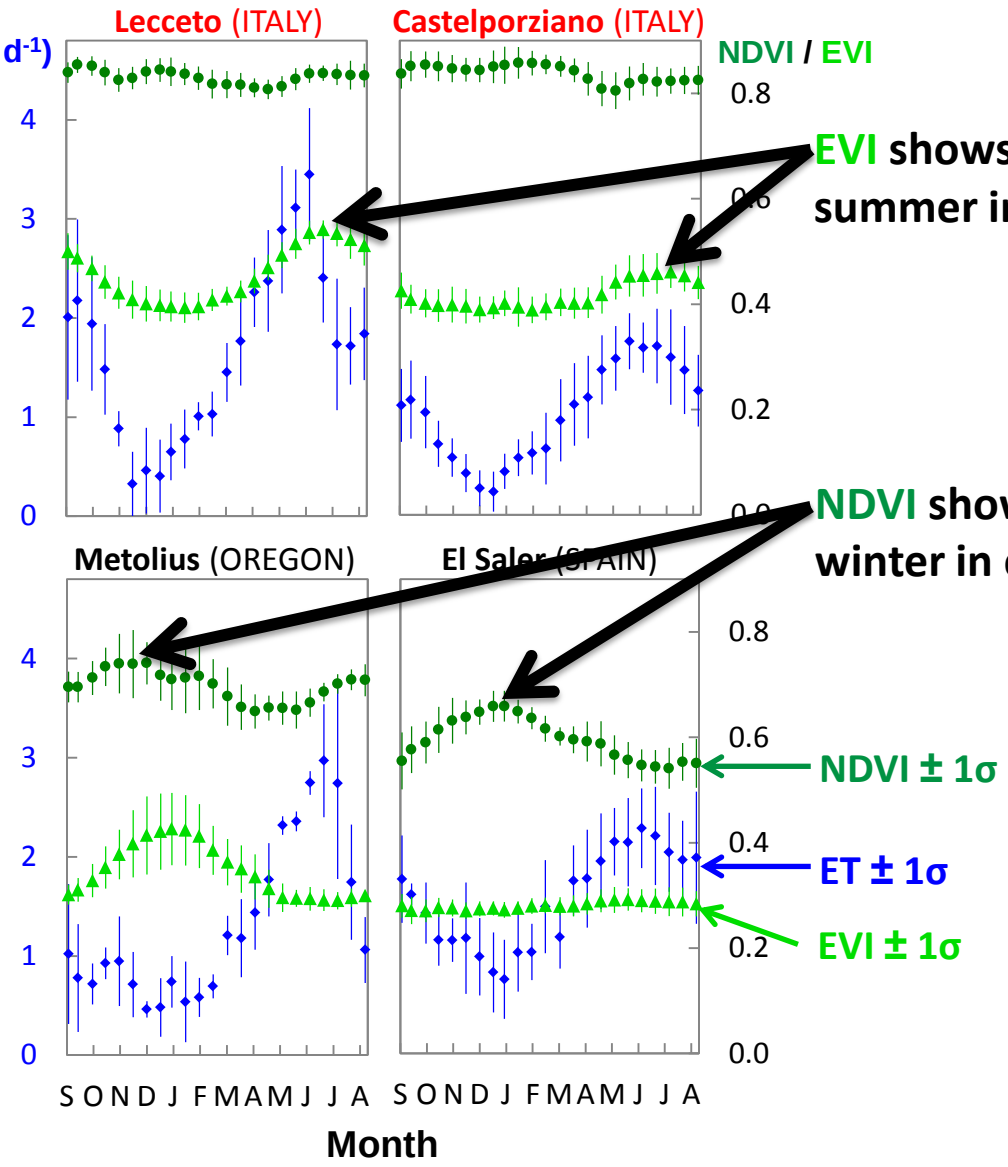
ET ± 1σ

EVI ± 1σ

VI and ET time series – looking for seasonality

Broadleaf forests

Coniferous forests



EVI shows seasonality during summer in broadleaf forests

NDVI shows seasonality during winter in coniferous forests

NDVI ± 1σ

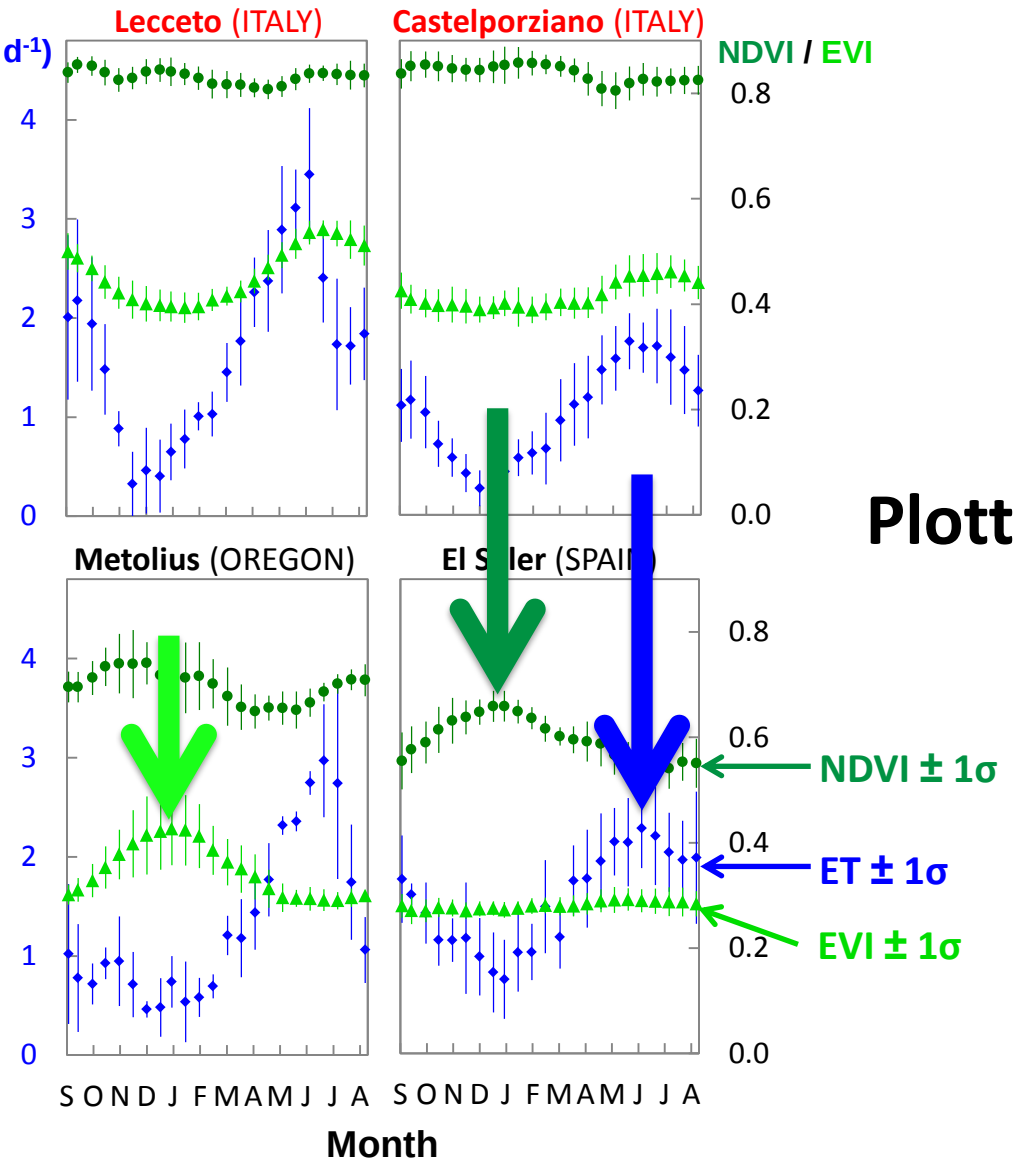
ET ± 1σ

EVI ± 1σ

VI and ET time series – looking for seasonality

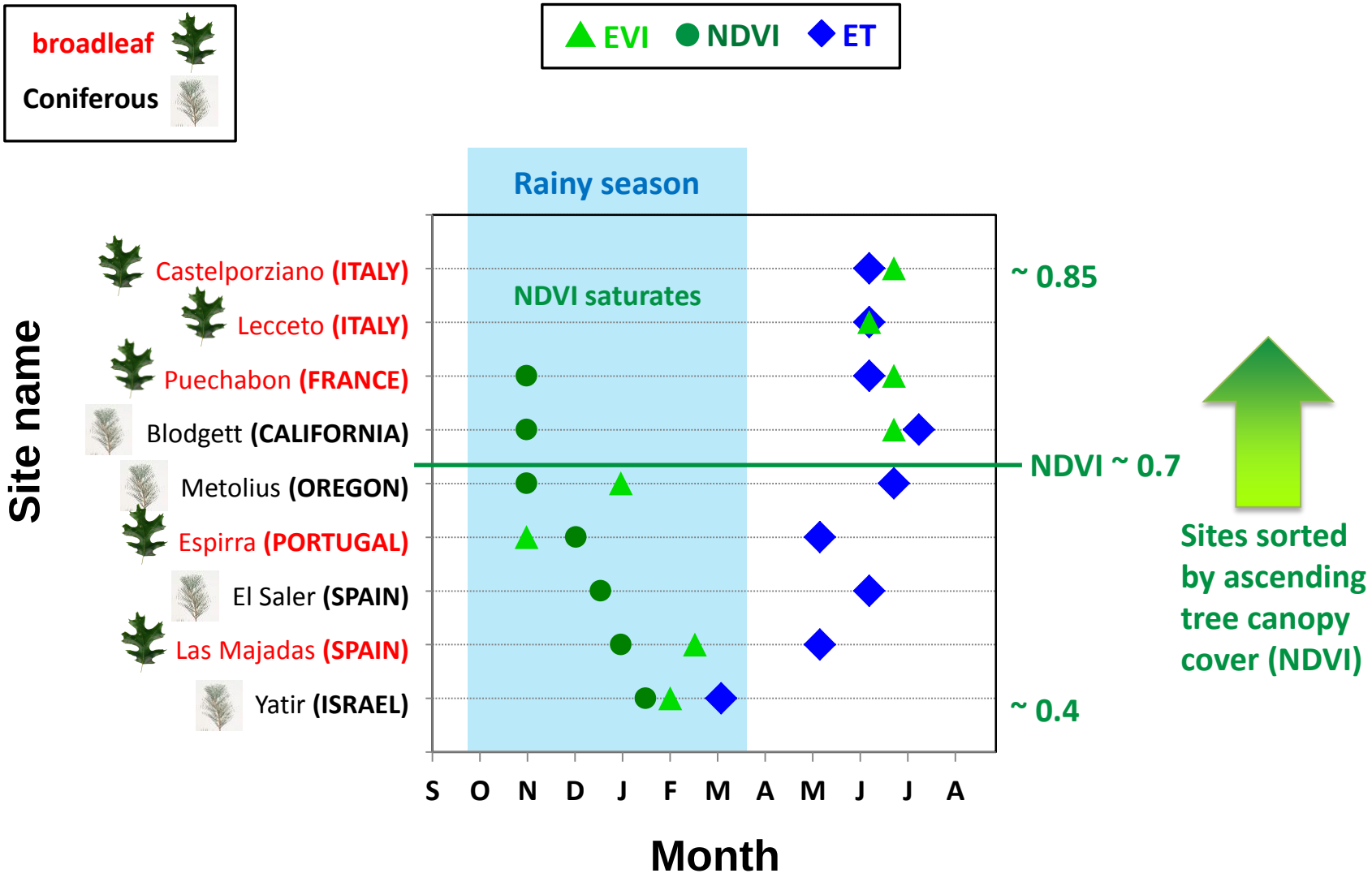
Broadleaf forests

Coniferous forests

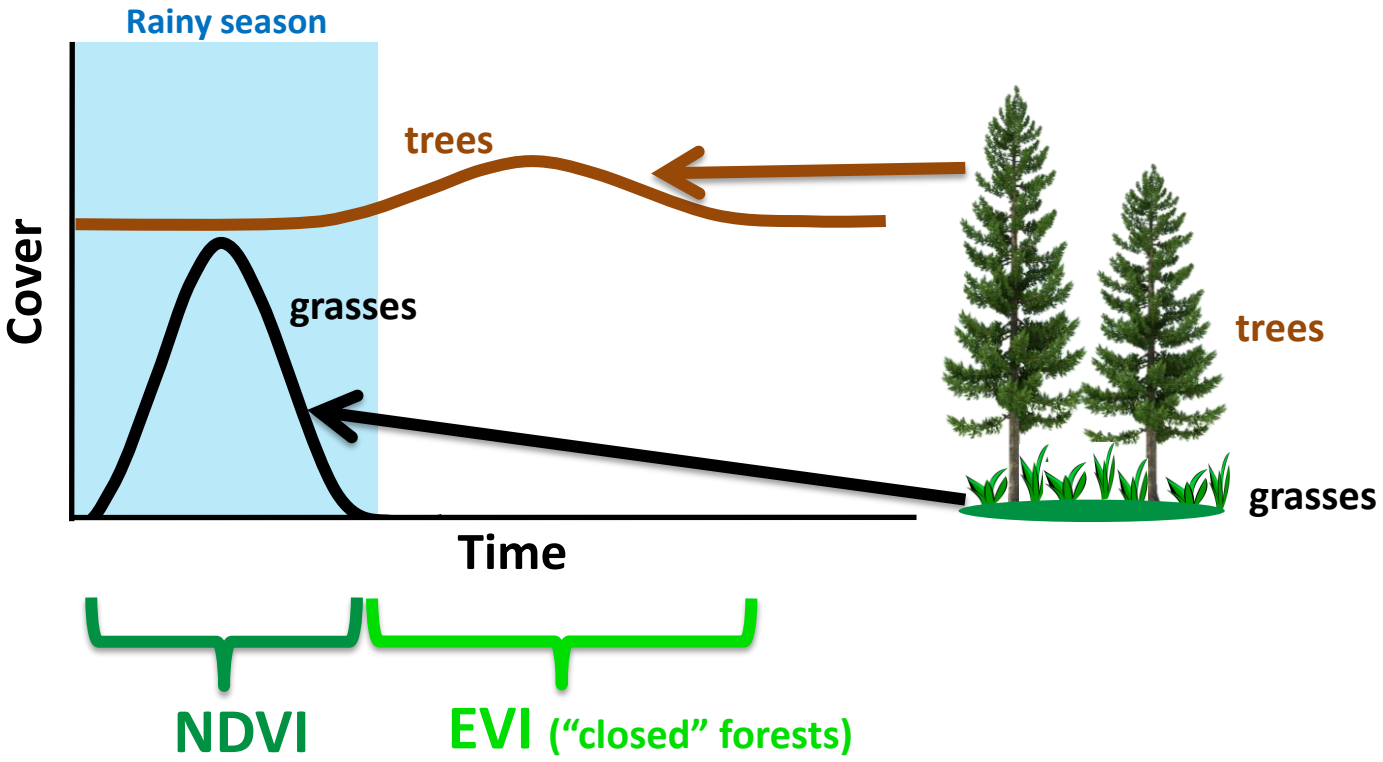


Plotting only the peak

Timing of peak in VI and ET in evergreen forests

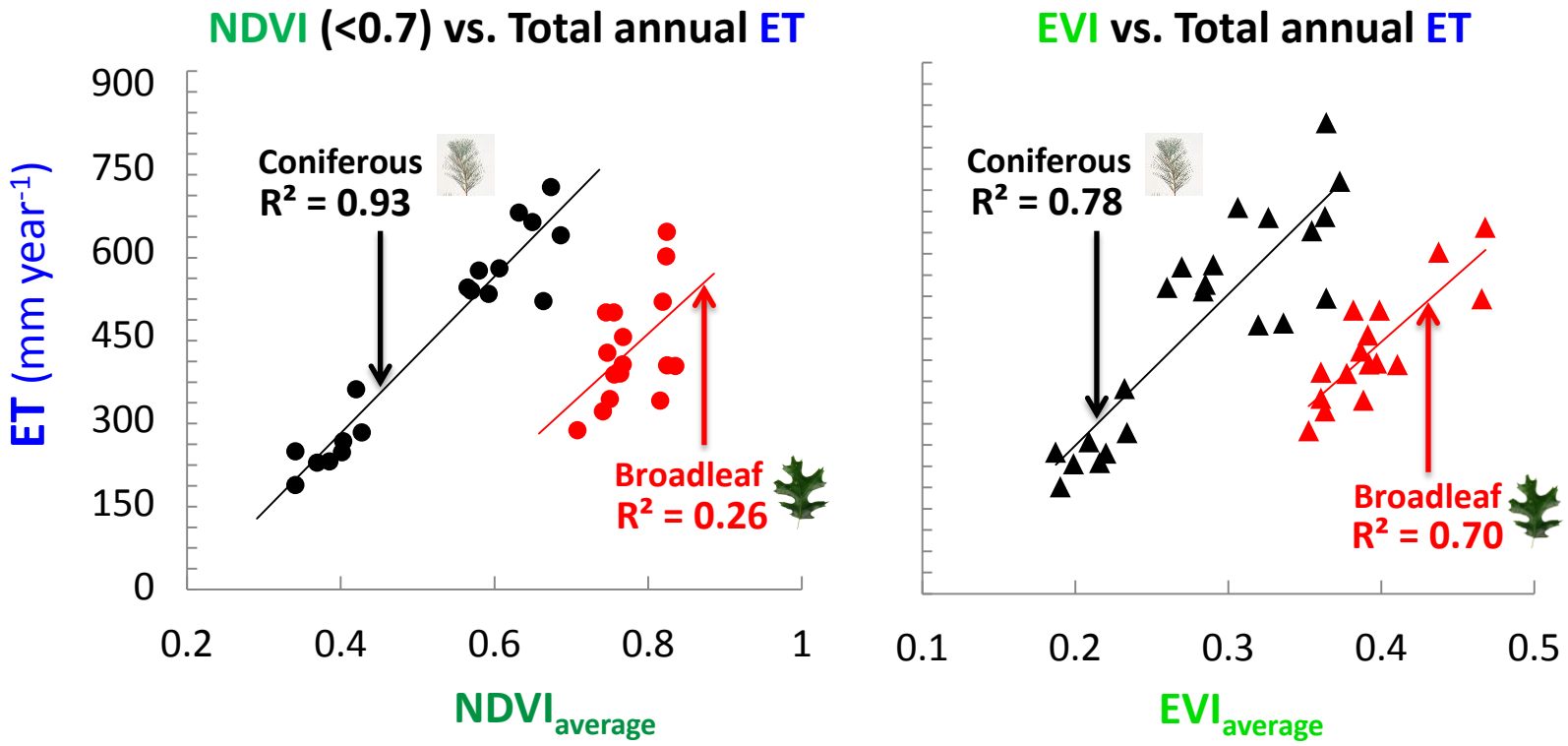


Different sensitivity of VI to trees and grasses within the evergreen forest



NDVI peaks during rainfall responding to annual herbaceous vegetation growth
EVI is more sensitive to tree phenology in "closed" forests (NDVI > 0.7)

Estimates of total annual ET in evergreen forests using the annual average of NDVI and EVI

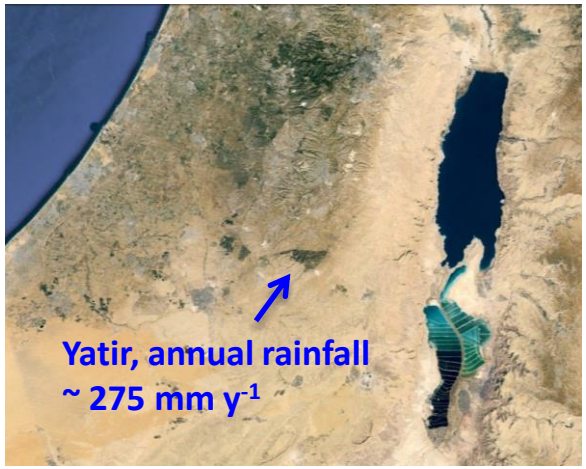


The average NDVI / EVI as a surrogate for total vegetation cover is a good indicator of the total annual ET in evergreen coniferous / oak forests

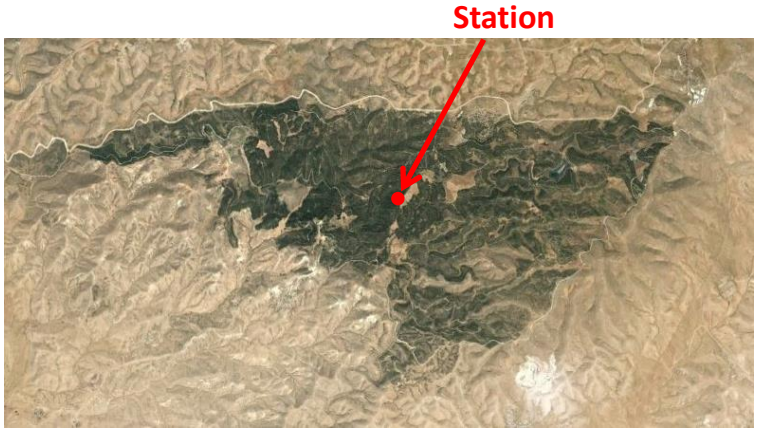
Water yield distribution at Yatir assessed from NDVI

The average WY distribution at Yatir for the period 2000 – 2012 is estimated using the total annual ET assessed from NDVI

WY = Rainfall – ET (in % from total rain)



Google Earth



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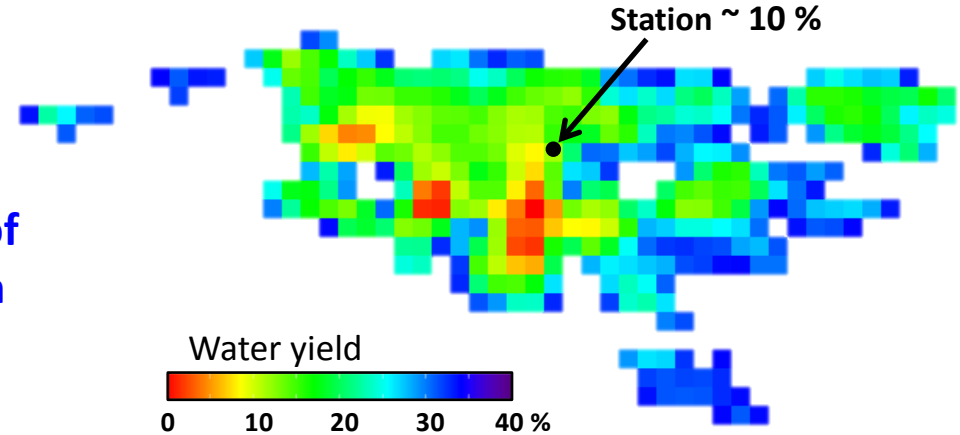

Estimated WY in the total area of Yatir is ~20% while in the station area is ~10%

Summary

- VI approach shows good performance in annual vegetation systems (grasslands and croplands)
- Poor ET – VI correlations in Evergreen forests
- NDVI and EVI mostly reflect seasonality in annual grasses in “open” forests while in “closed” forests (NDVI > 0.7) EVI is more sensitive to tree phenology
- Total annual ET can be estimated from the average NDVI in evergreen forests for water yield assessment

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