UNIVERSITY OF TWENTE.

Scaling fluorescence from leaf to canopy

Christiaan van der Tol and Wouter Verhoef

Co-workers: Joris Timmermans, Anne Verhoef, Bob Su

FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

- What happens to fluorescence and photosynthesis when we scale from photosystem to canopy level?

- How does the shape of the spectrum of fluorescence change with scaling?

- What are the relations among
  - greenness (EVI or NDVI)
  - absorbed PAR
  - fluorescence
  - photosynthesis?

Photosystem

Light harvest for photosynthesis takes place in photosystems
Fluorescence is generated at photosystem level

Leaf

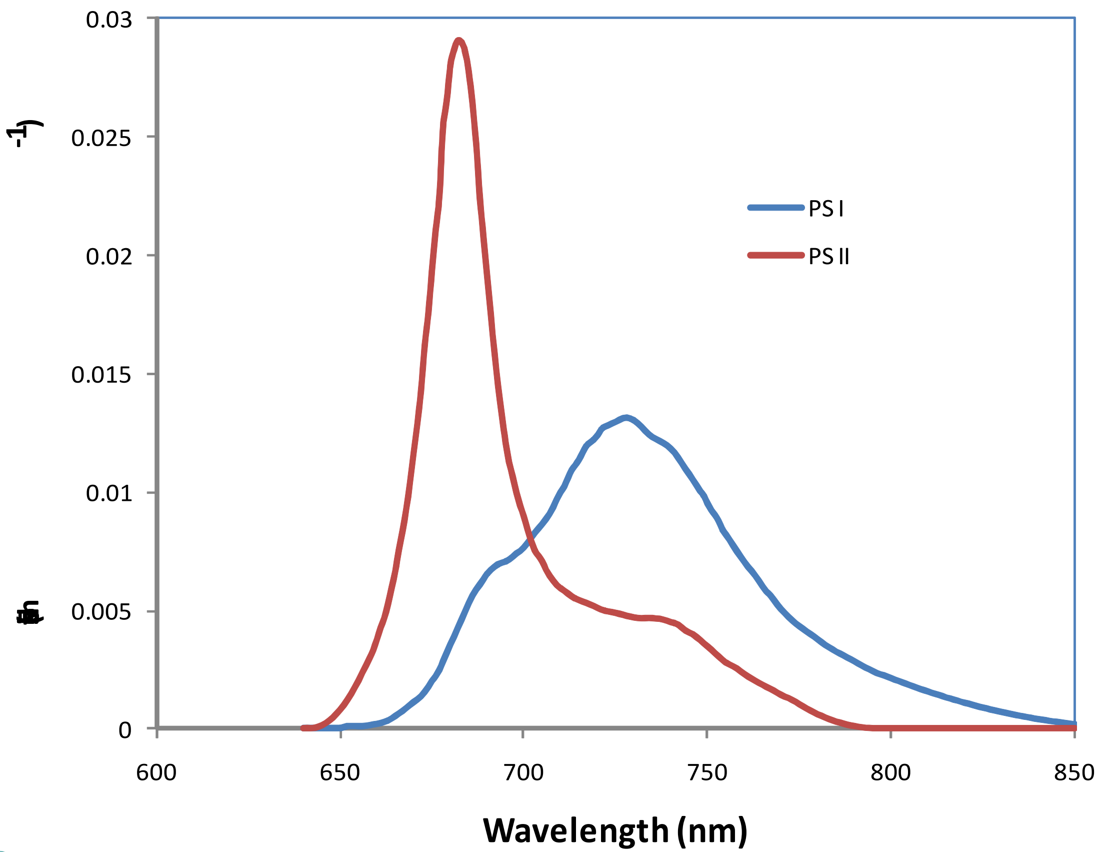
Photosynthesis models calibrated against measurements at leaf level
Active fluorescence measurements usually taken at leaf level

Canopy

Observations with flux towers at canopy level
Remote sensing: viewing the top of canopy

Photosystem level

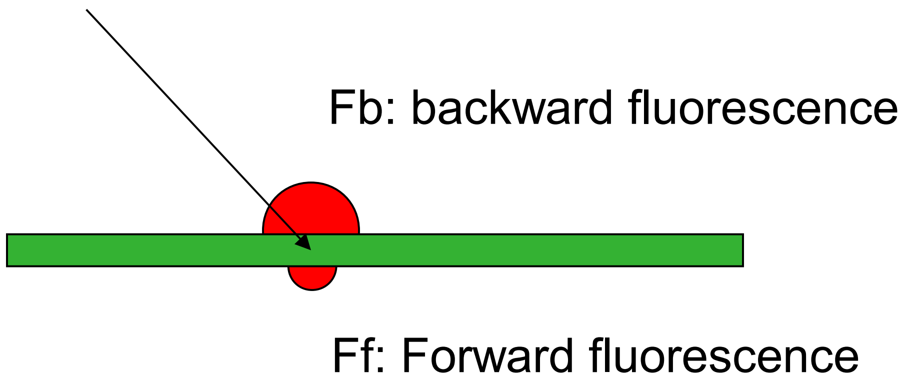
Fluorescence spectral distributions from photosystems I and II



Based on the literature

Croce et al. (1996, 2000) and Franck et al. (2002)

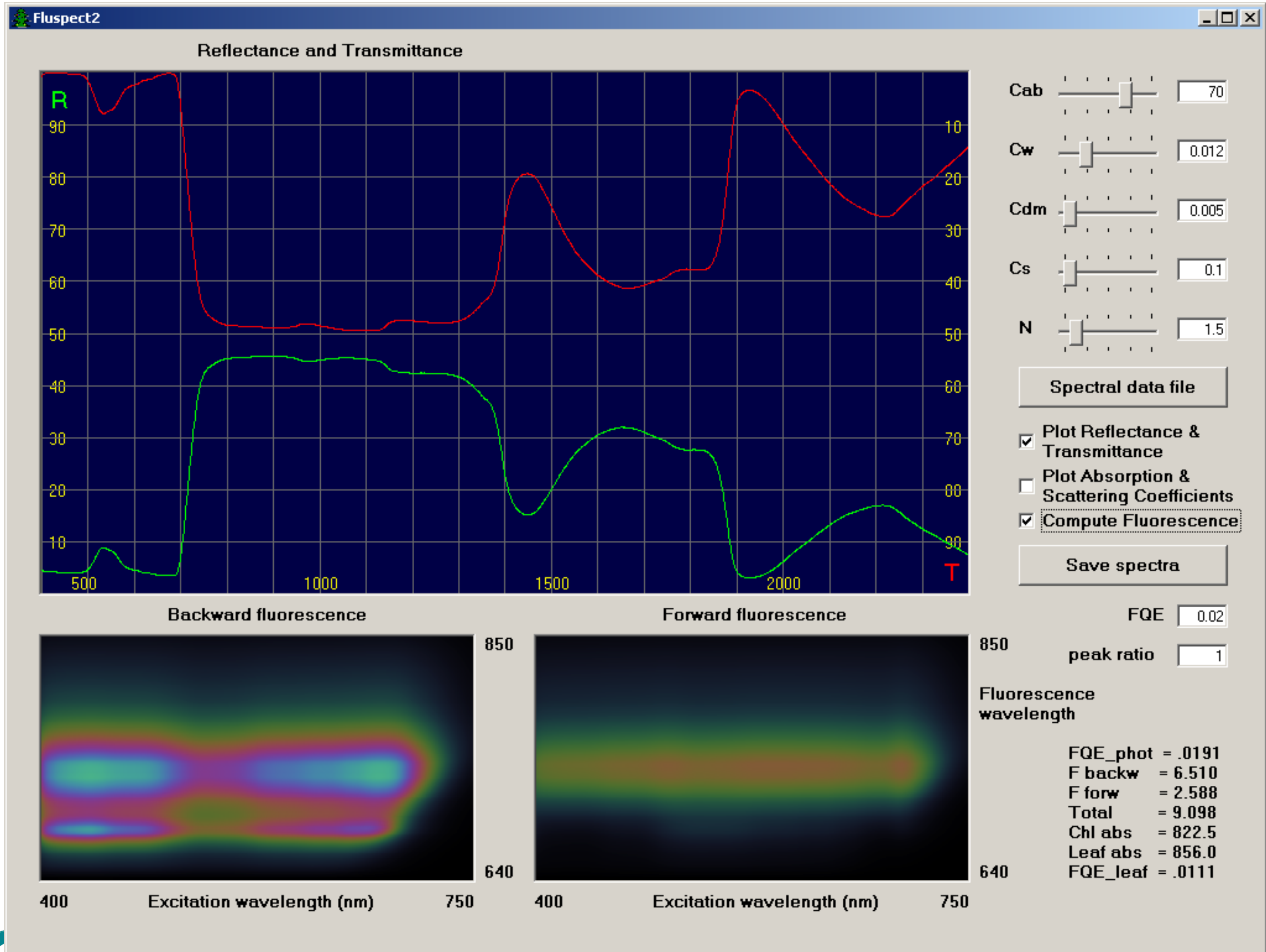
Leaf level



Two matrices Fb and Ff for irradiance -> fluorescence

Inc/ F	640	641 etc
400		
401 etc		

Leaf level: Fluspect model



Interactive version of the Fluspect2 model, programmed in Visual Basic 5

Parameters:

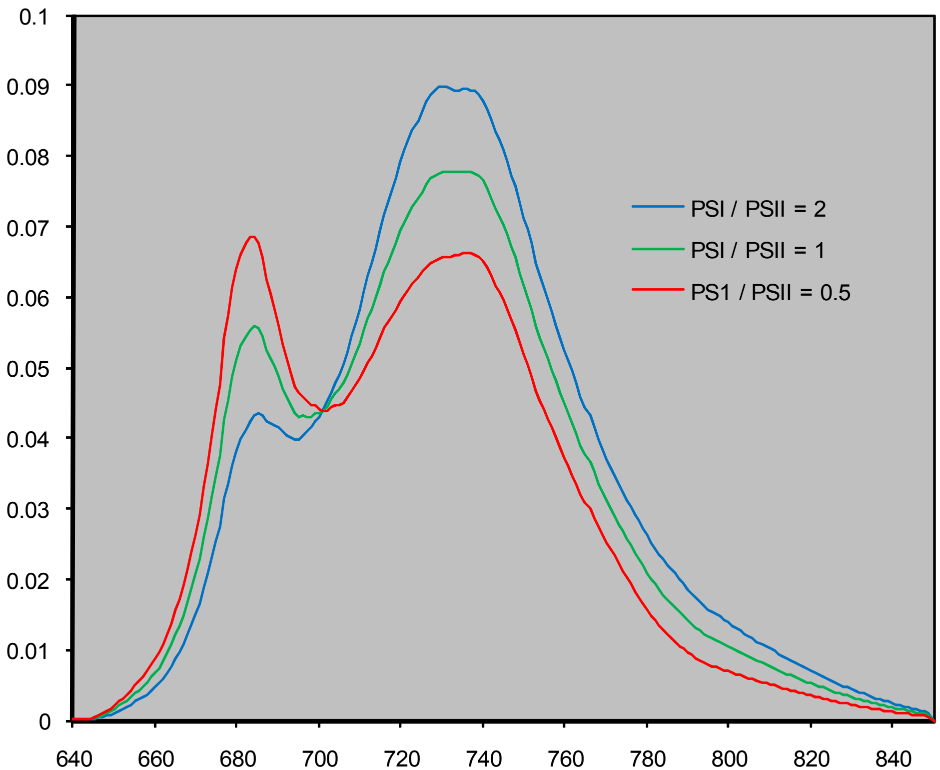
Cab, Cw, Cdm, Cs, N (PROSPECT)

FQE, PSI/PSII ratio (Fluspect)

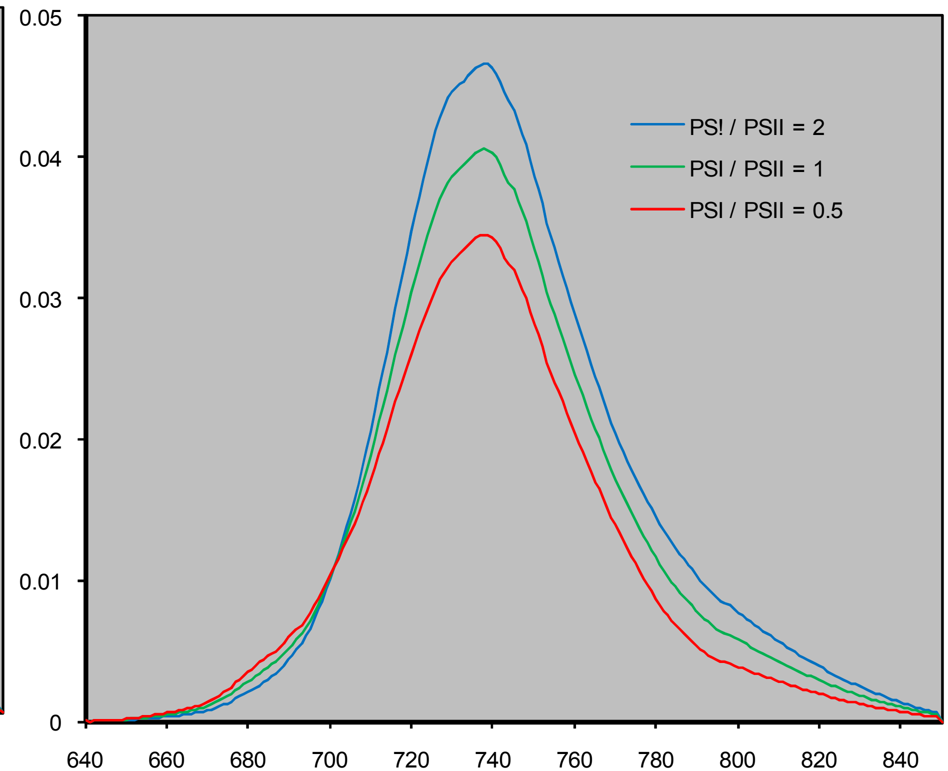
New development: Xanthophylls

Leaf level: sensitivity to peak ratio

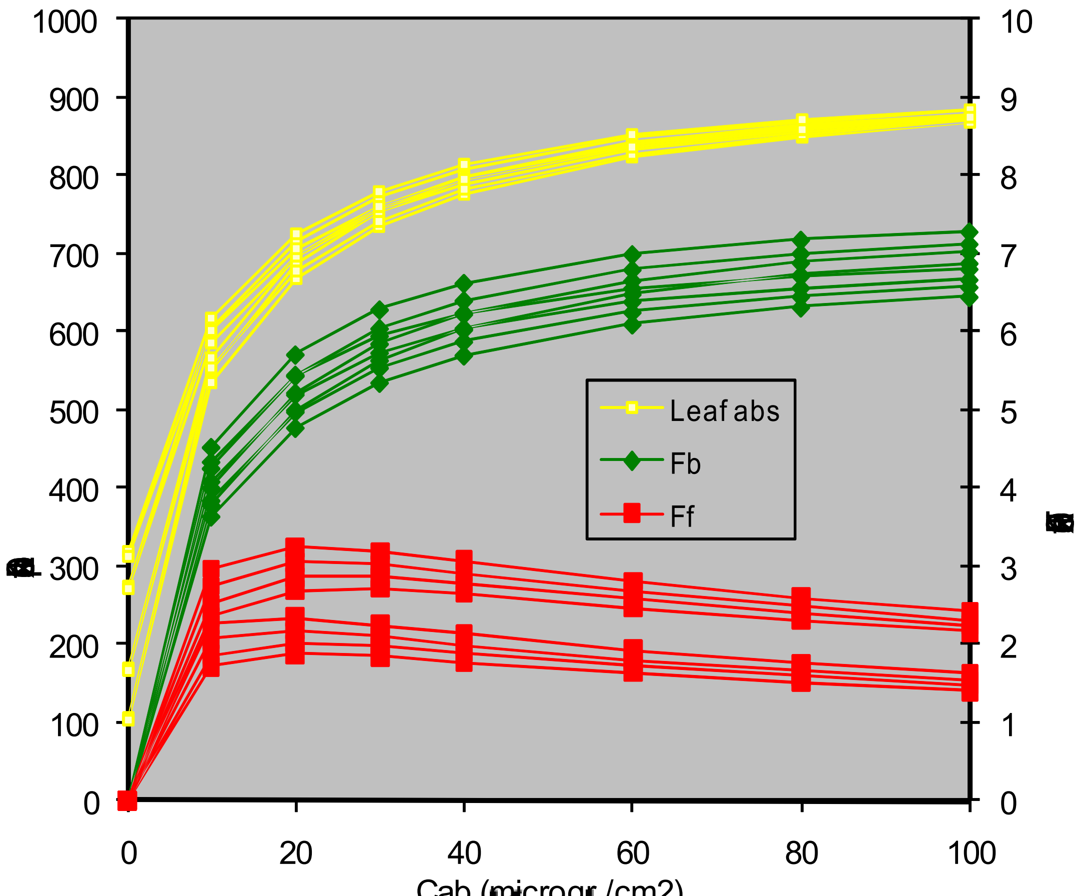
Backward



Forward



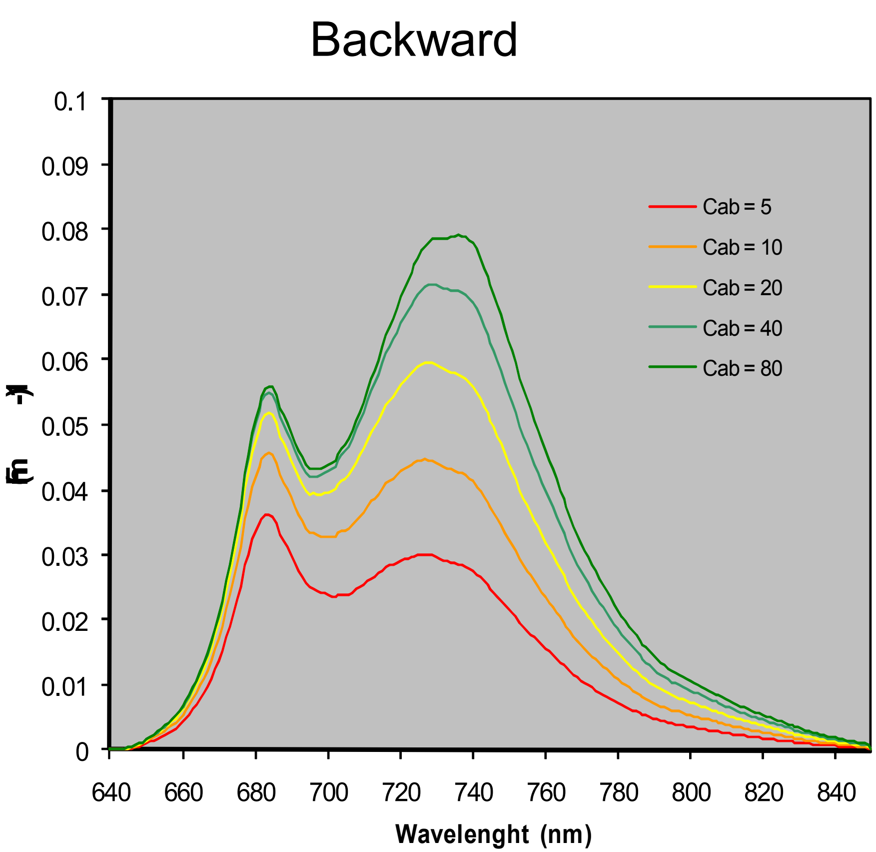
Leaf level: sensitivity to PROSPECT parameters

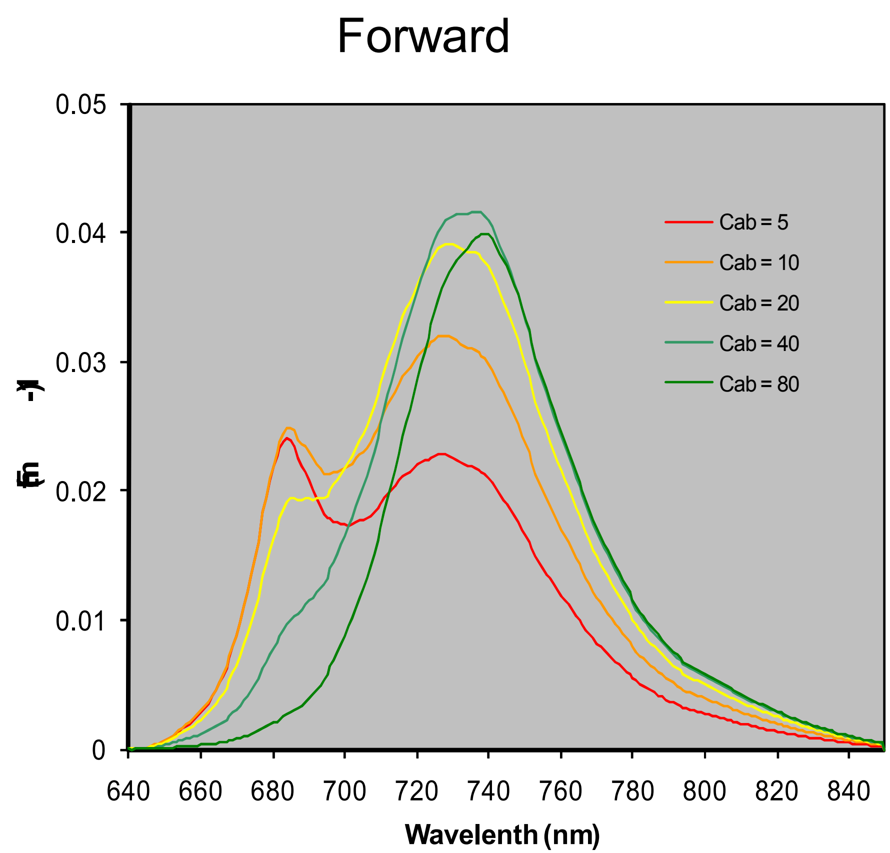


In this case other PROSPECT parameters (Cs, N, Cdm) were also varied

Yet the relation between Fb and leaf absorption remains quite strong

Leaf level: sensitivity to Chlorophyll concentration





Canopy level: radiative transfer modelling

4-stream radiative transfer:

direct radiation, diffuse upward, diffuse downward, in observation direction

Sunlit leaves:

P(viewing sunlit-side | sunlit) * direct radiance * Matrixb

P(viewing 'back'-side | sunlit) * direct irradiance * Matrixf

Shaded leaves:

P(viewing backside)*diffuse upward irradiance * Matrixf

P(viewing frontside)*diffuse upward irradiance * Matrixfb

P(viewing backside)*diffuse downward irradiance * Matrixf

P(viewing frontside)*diffuse downward irradiance * Matrixb

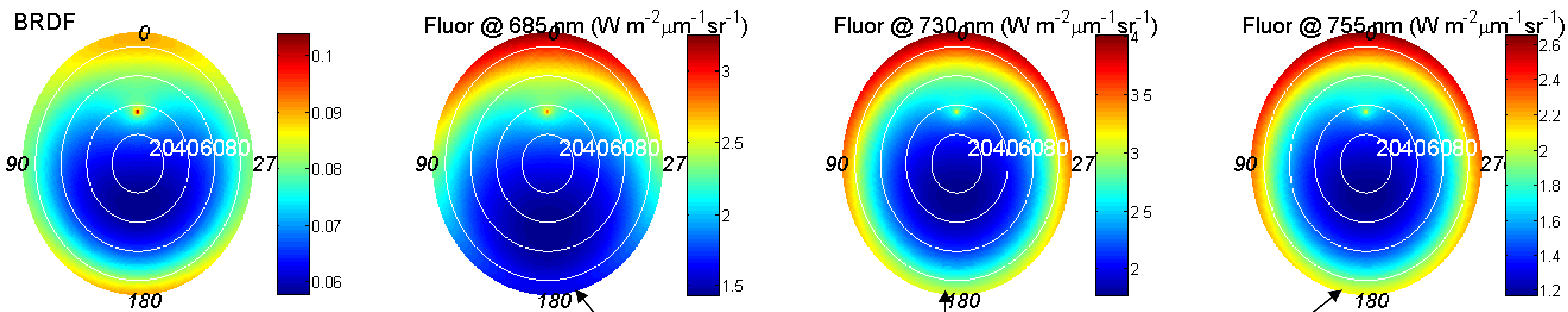
-- +

total F in viewing direction

What do we see at TOC?
For 3 wavelengths (BRDF and the two peaks: 685 and 730, and 755 nm)

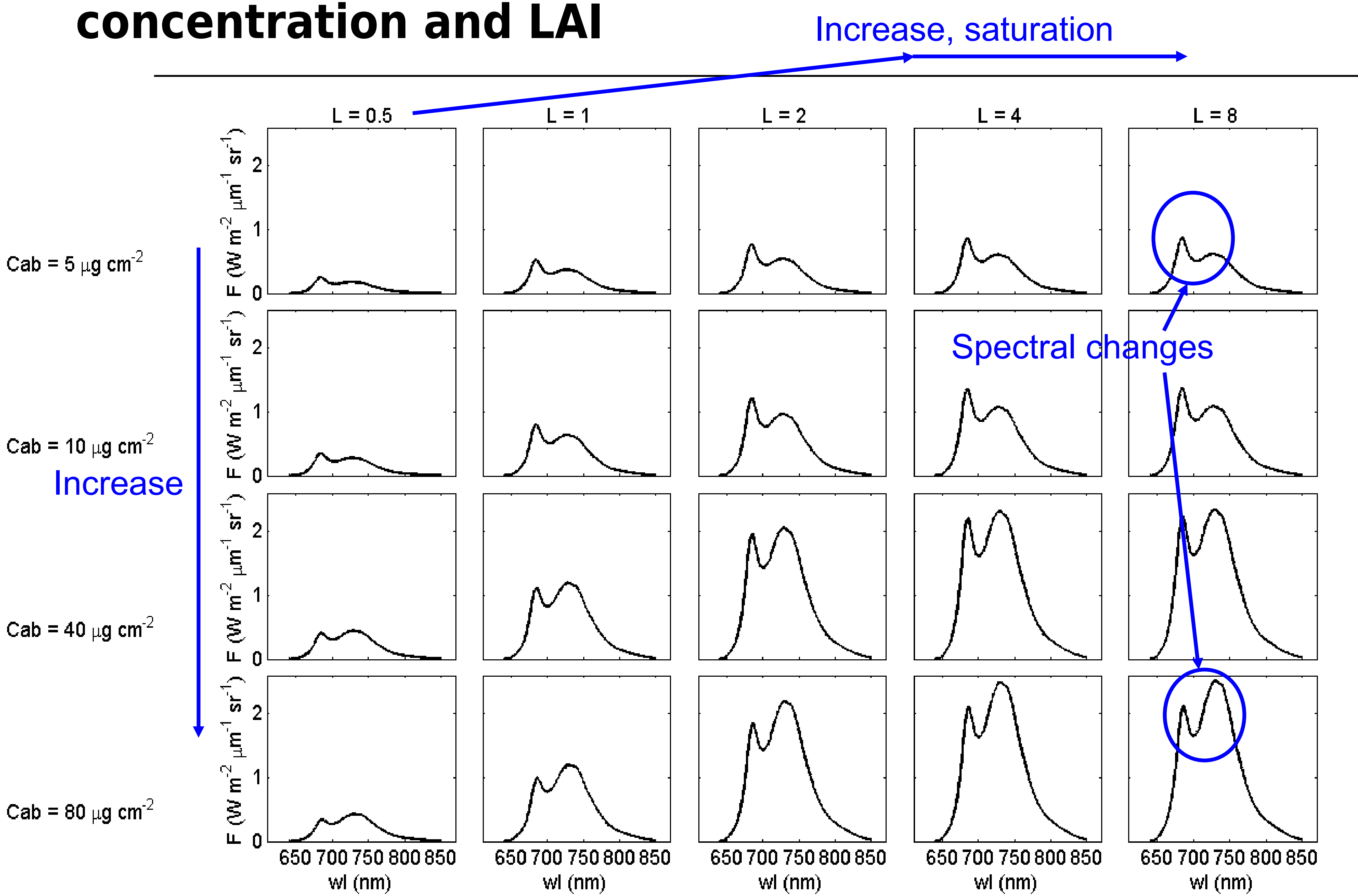
For LAI = 2, Cab = 60, R_{in} = 600 W m^{-2}

Fluorescence directionality is different from BRDF

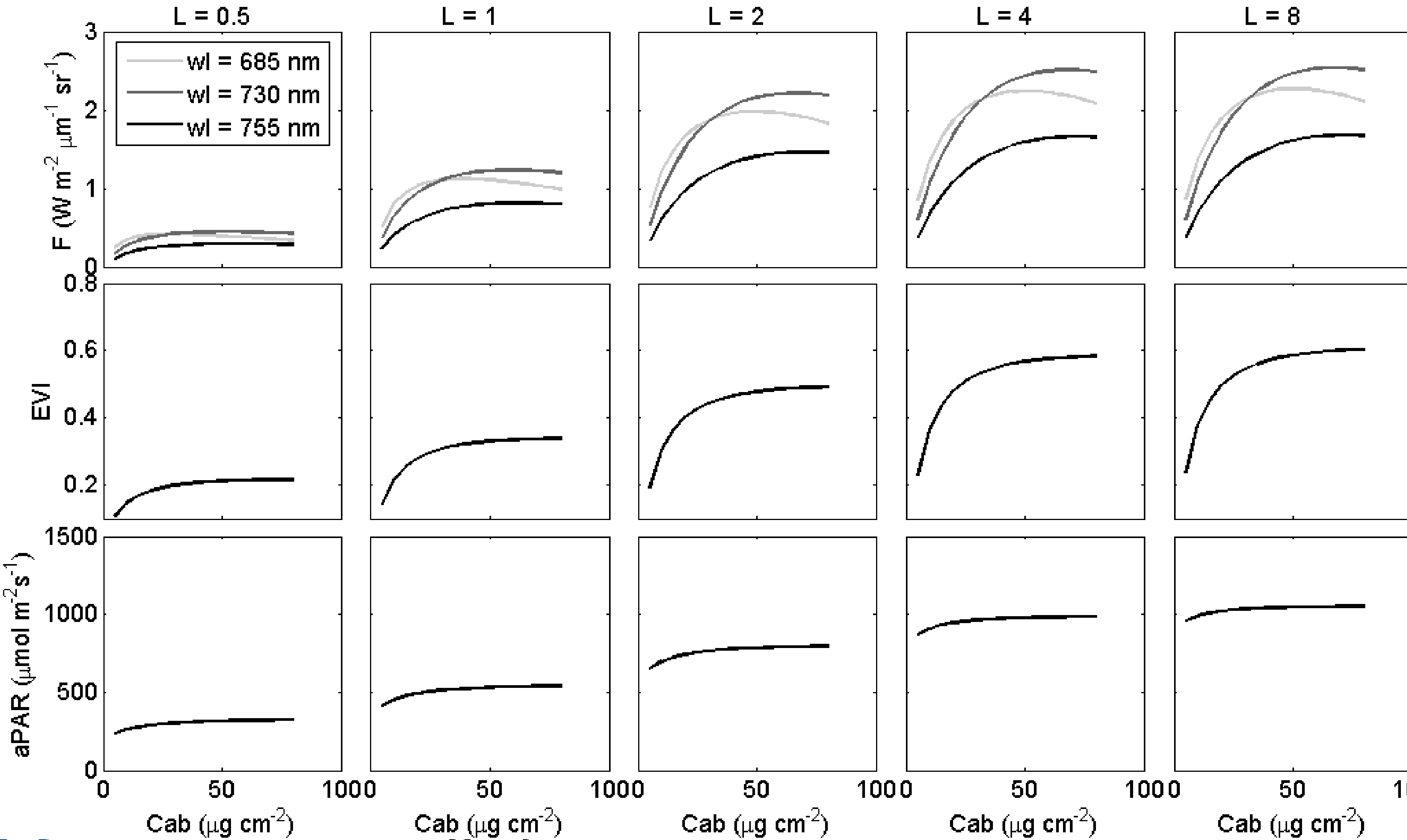


We see mainly the back of sunlit leaves

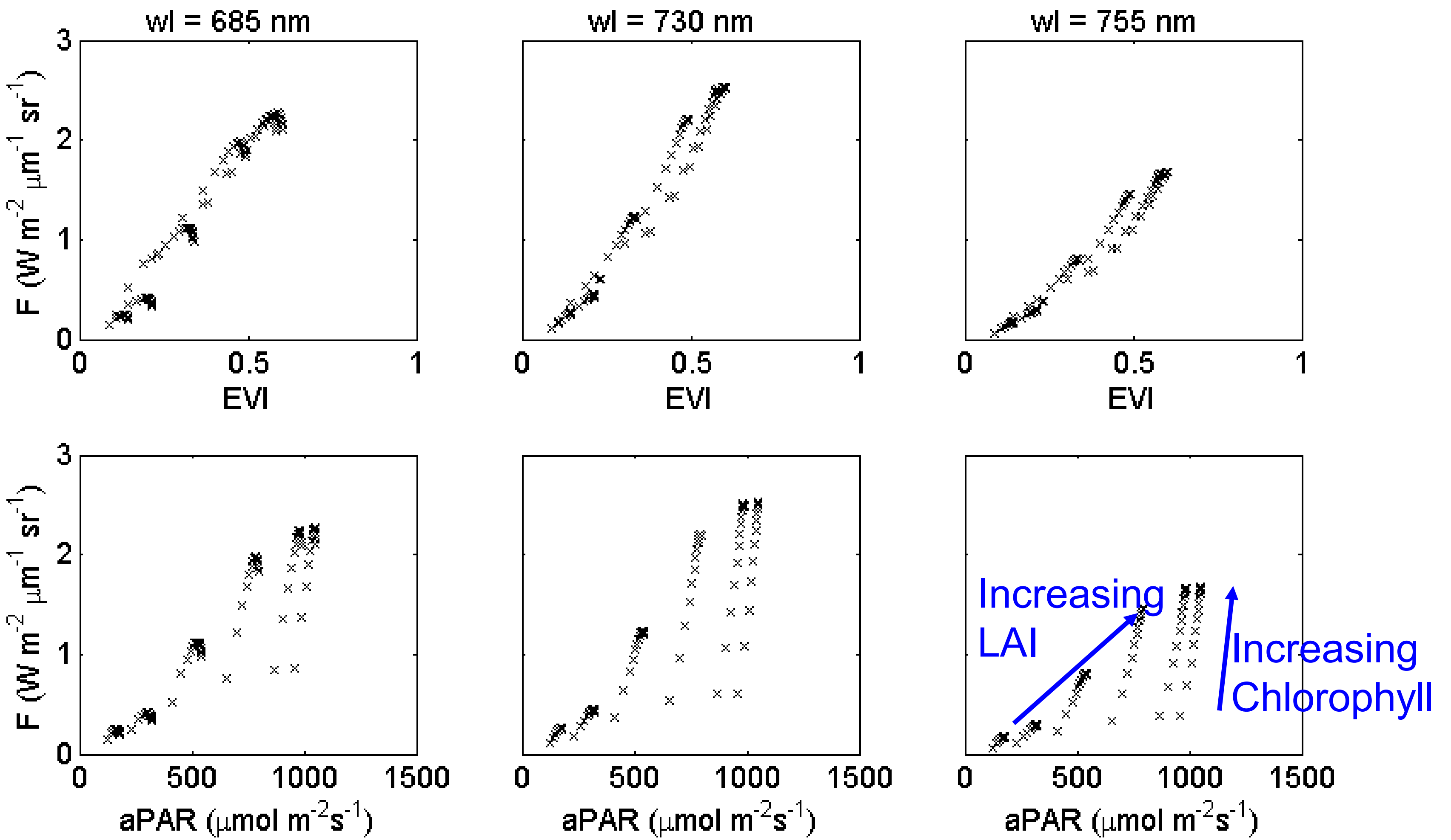
Canopy level: sensitivity to Chlorophyll concentration and LAI



Canopy level: and what about EVI and aPAR?



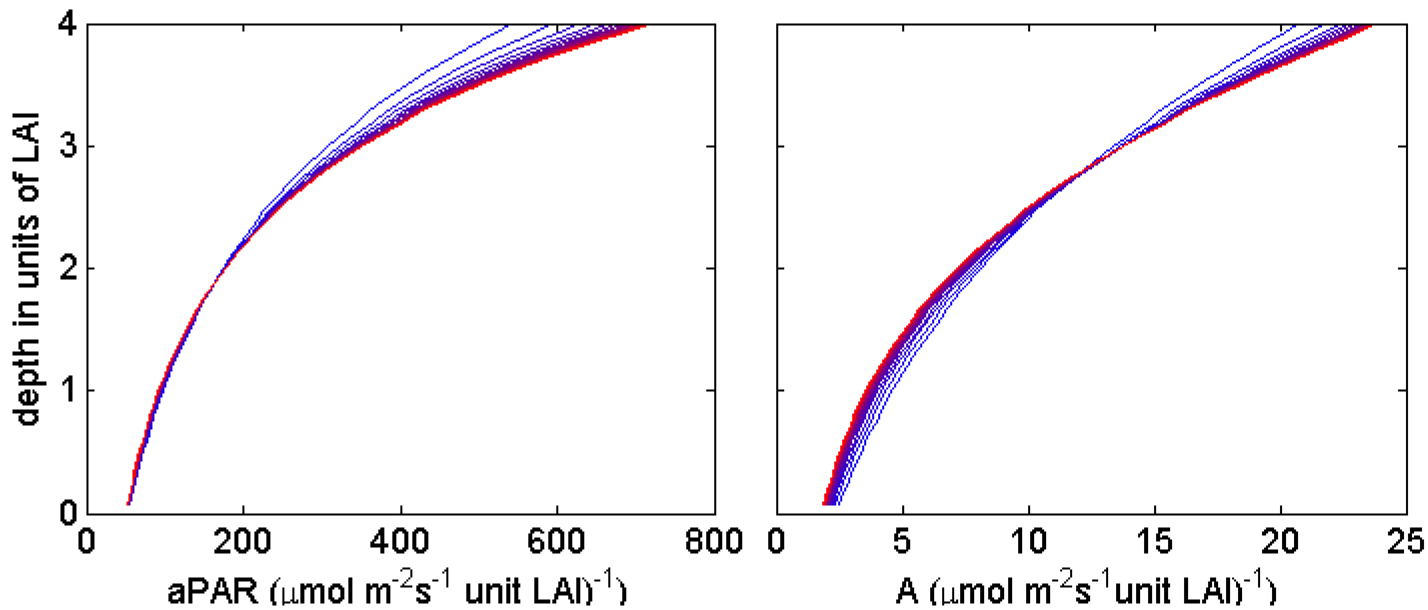
Canopy level: fluorescence versus EVI and aPAR



What about photosynthesis?

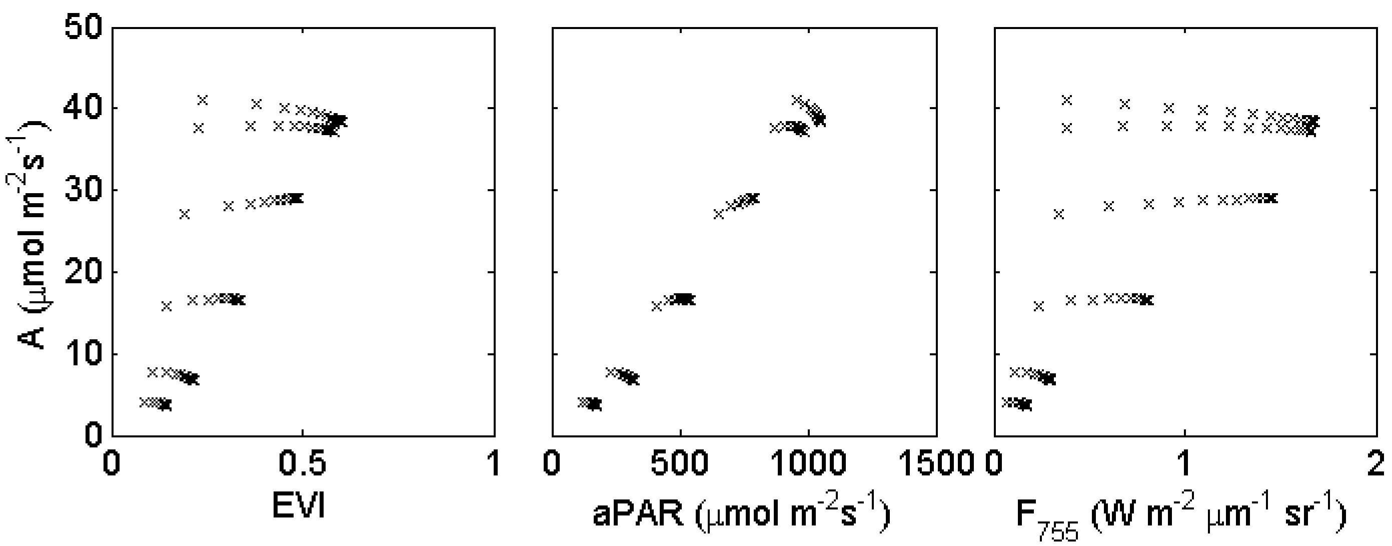
From low to high Cab concentrations…

Increasing Cab -> more photosynthesis in upper leaves, but less in lower leaves. Net effect: photosynthesis not very sensitive to Chlorophyll (if Vcmax etc. are constant!)



… thus canopy photosynthesis does not seem sensitive to chlorophyll.

But: In the model leaves are not shade or sun adapted

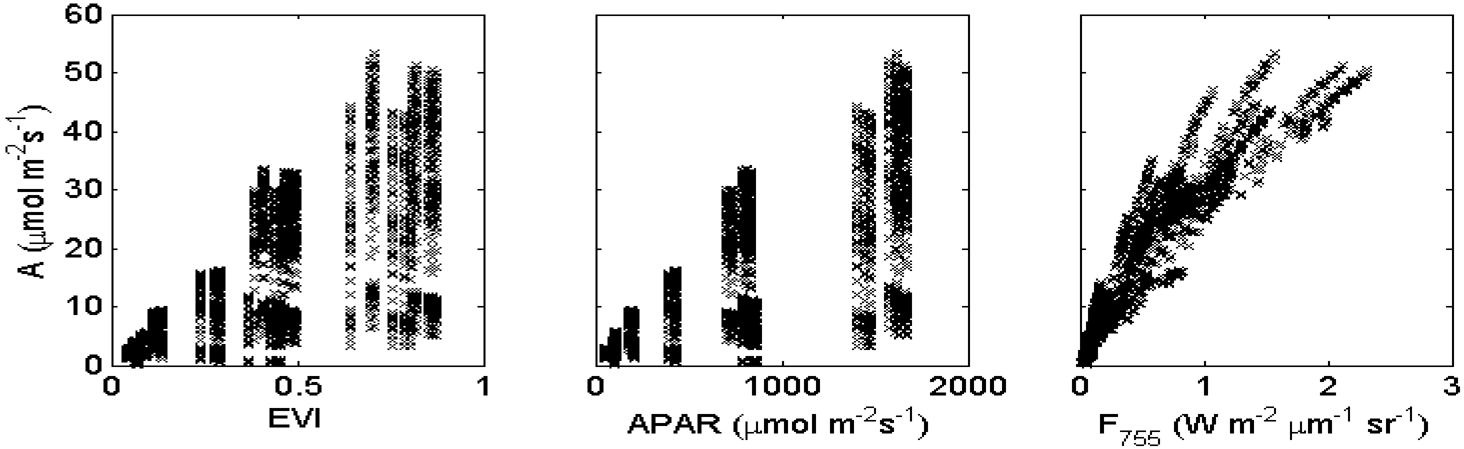


Weather conditions, V_{cmax} and stomatal conductance

Look-Up table with $4^6 = 4096$ elements, regular grid.

▪ R	= [50, 100, 400, 800]	W m^{-2}
▪ ea	= (5:5:20)	hPa
▪ Cab	= (20:20:80)	ug cm^{-2}
▪ V_{cmax}	= (20:50:170)	umol m^{-2} s^{-1}
▪ [illegible]	= (250:250:1000)	mol H_2O (mol CO_2)$^{-1}$

F closer related to photosynthesis than EVI or aPAR.

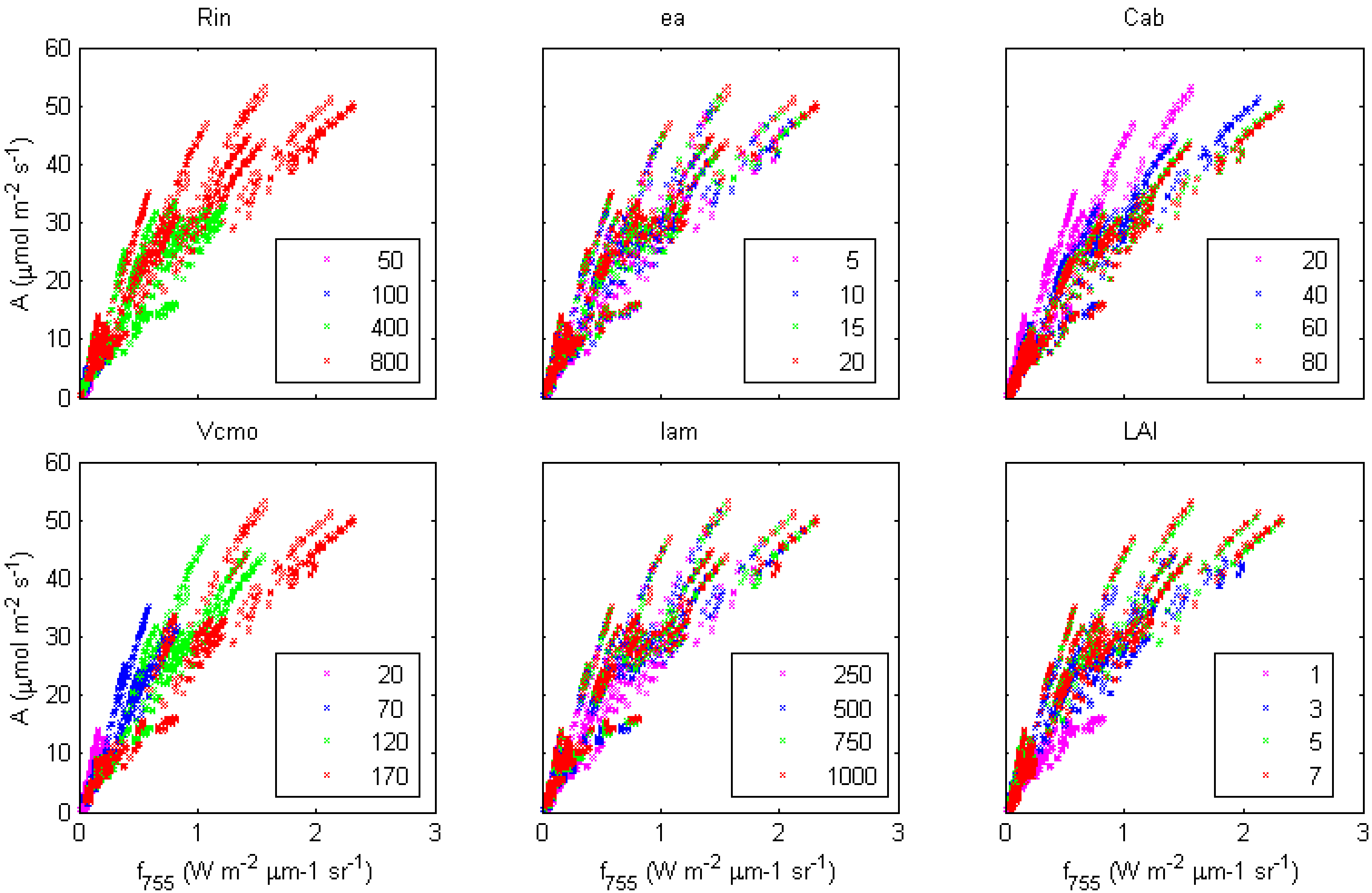


Same data, but different colors specify values of variables

Chlorophyll seems to spoil the 1:1 relation, if it is known the parameter space can be reduced

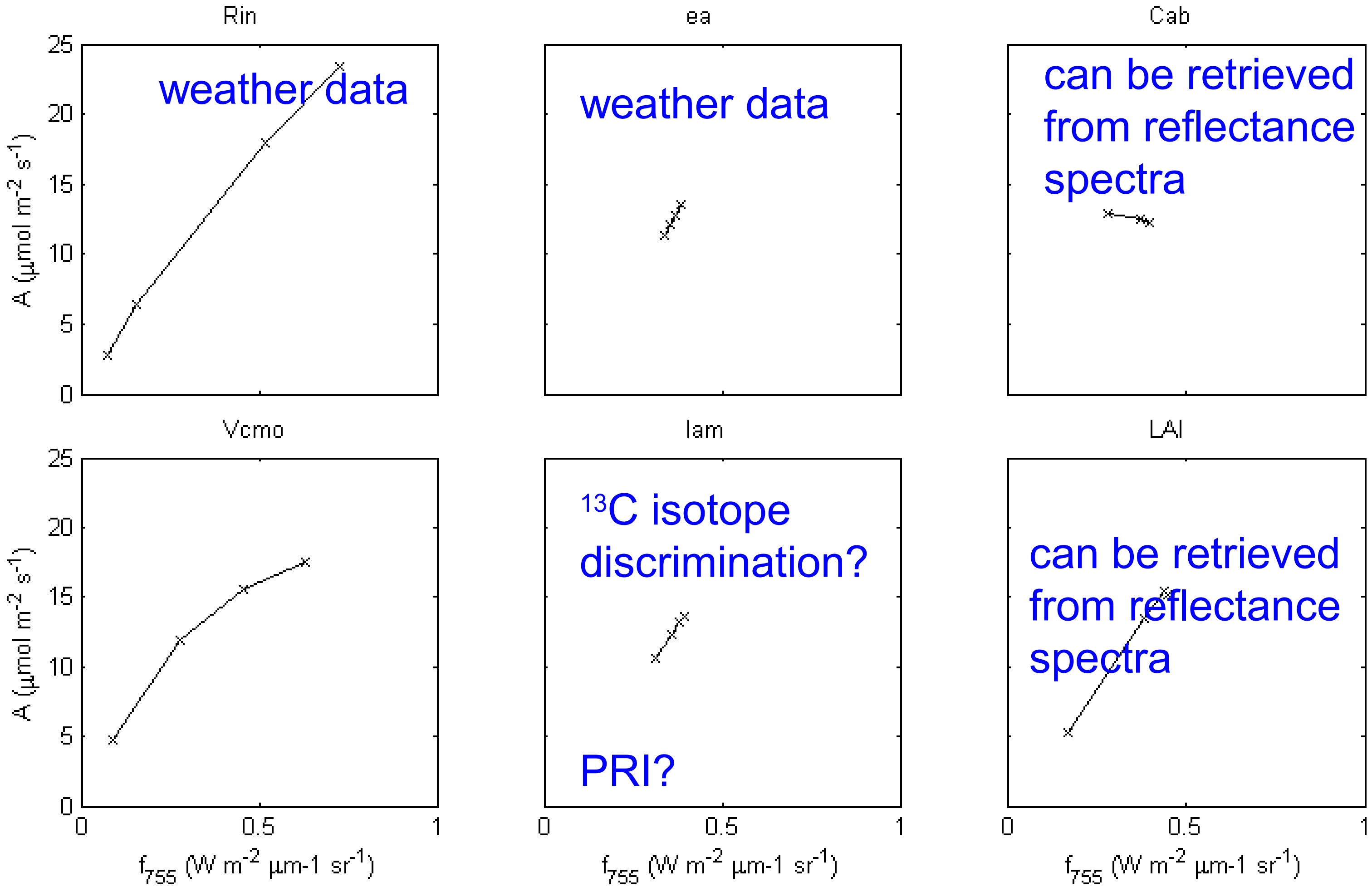
..
st

f's



Averages over all parameters but one

sensitivity to one parameter at the time



Farquhar, Von Caemmerer and Berry (1980)

However, there are two key parameters which, although often correlated in vivo, show important genotypic and phenotypic variation. These are the RuP_2 carboxylase capacity of the leaf ($V_{c_{max}} = \rho k_c E_t$) and the electron transport capacity ($J_{max} = \rho j_{max}$). The way in which these two capacities vary, absolutely, and in ratio may well be a key to our understanding of the ecophysiology of plants.