

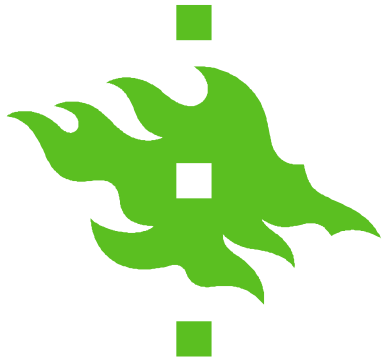


# FROM LEAF-LEVEL FLUORESCENCE TO REGIONAL GPP:

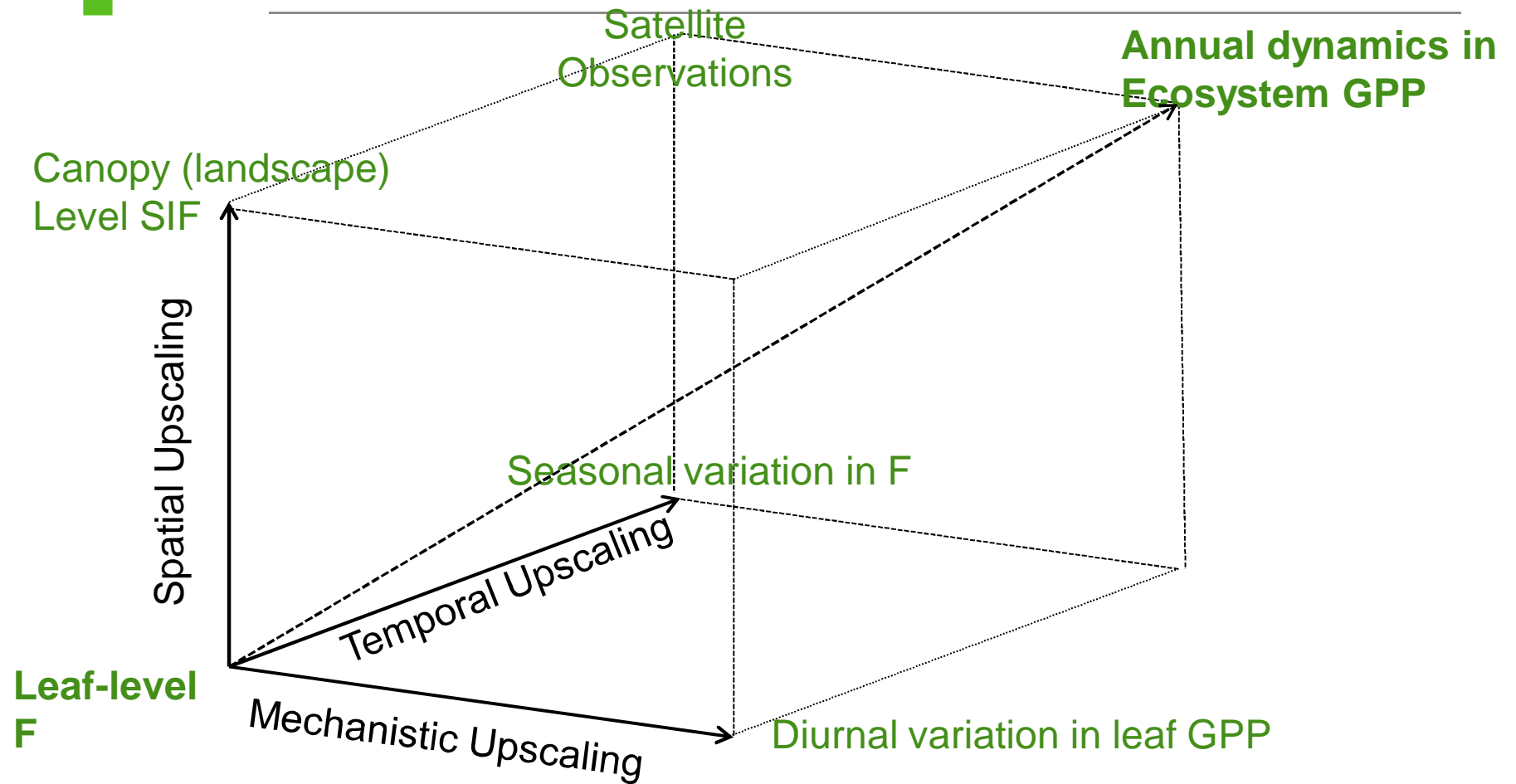
## Open Questions and Challenges

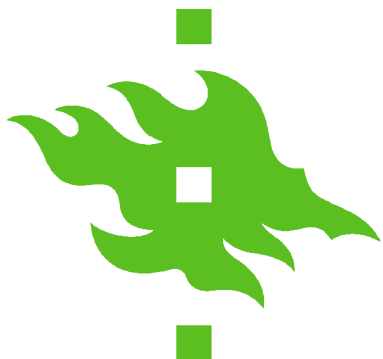
Albert Porcar-Castell  
(University of Helsinki)

New Methods to Measure Photosynthesis from Space  
August 26-31, 2012 | Caltech/Keck Institute for Space Studies



# To go from leaf-level F to pixel level GPP we need to upscale our knowledge in three directions:





# To go from leaf-level F to pixel level GPP we need to upscale in three directions:

## (I) Spatial Upscaling

---

Pixel level F

Spatial Upscaling

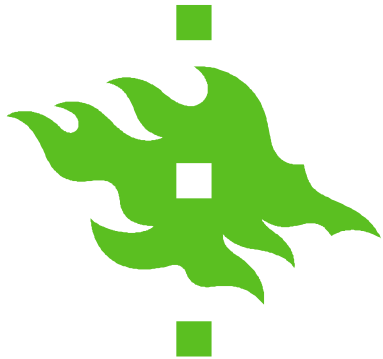
### Challenges:

- Jump from active to passive F (below)
- RS-based parameterization of canopy structure?
- Within canopy gradients
- Inter-specific variation issues
- Other... (you know actually better than I)

### Tools:

- Radiative Transfer Theory
- Canopy architectural models?
- Plant allometric relations/decission-making?
- Other?

Leaf level F



# To go from leaf-level F to pixel level GPP we need to upscale in three directions:

## (II) Temporal Upscaling

**Weeks-Months:** What processes are behind the long-term dynamics in F?

↑ sustained NPQ, Photoinhibition, reorganization in the thylakoids, pigment contents,...)

Temporal Upscaling

### Challenges/risks:

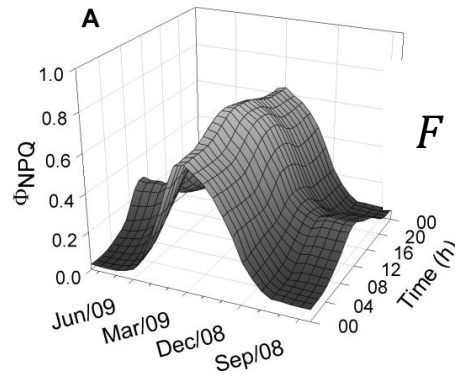
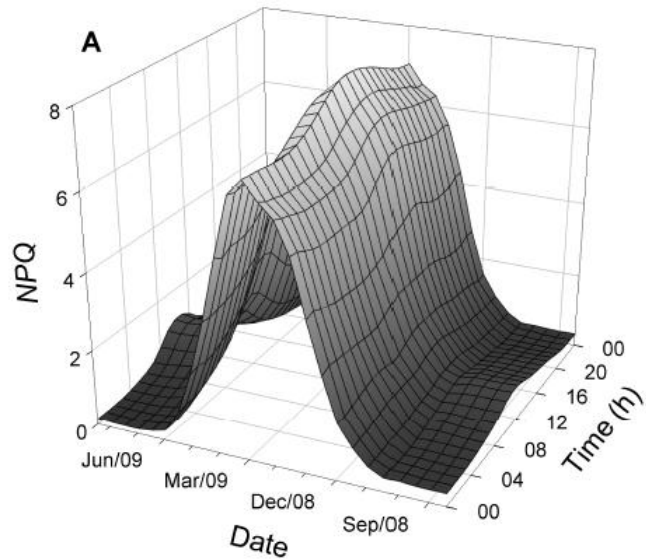
- Existence of yet uncharacterised seasonal processes that decouple diurnal and seasonal time-scales? (e.g. seasonal changes in absorption cross sections of PSII:PSI)
- Species-specific changes in F associated to the seasonal adjustment in chlorophyll content. Positive (enhanced leaf absorptance ), negative (enhanced reabsorption) effect, neutral?

### Tools:

- Long-term observational studies to follow the biochemical, biophysical, and optical properties of the foliage over the seasons
- Theoretical frameworks to interpret the resulting data

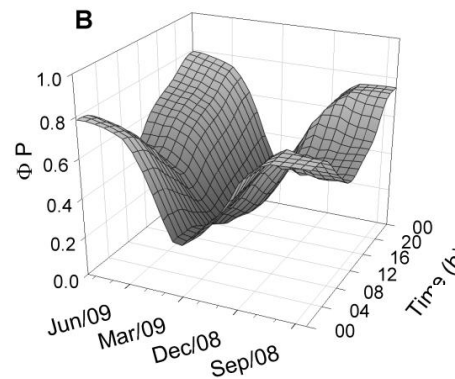
**Picoseconds-Hours:** Processes behind the short-term dynamics in F?  
(Excitation transfer steps, Fast kinetics OJIP raise, Light Induction dynamics,  $qE$ ,  $qT$ ,  $qI$ ,...)

# Long-term observational studies. Continuous Active Fluorescence Monitoring

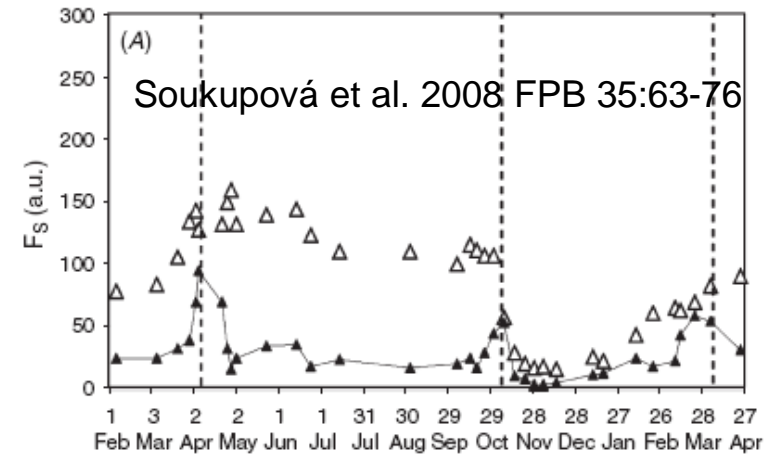
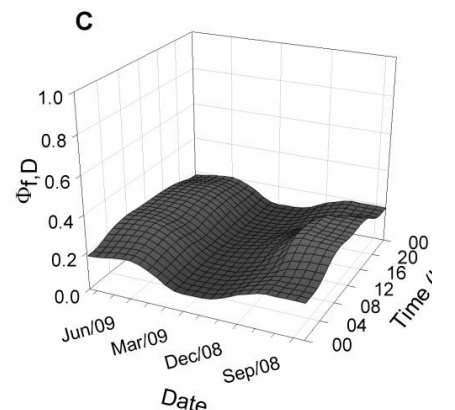
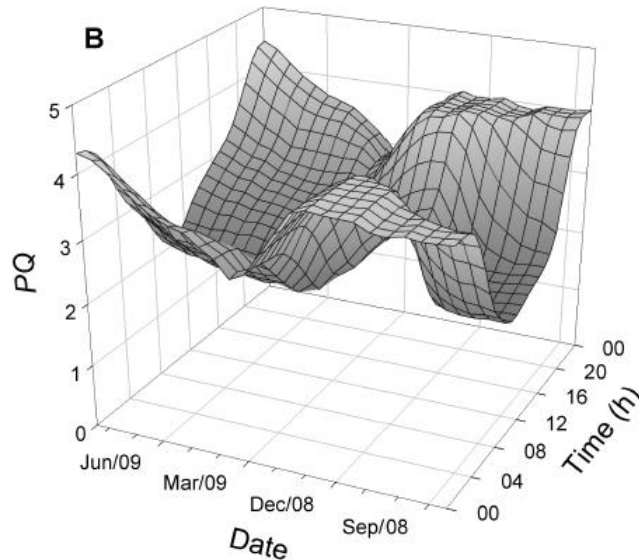


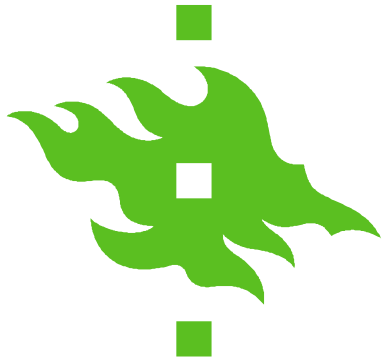
$$F = \beta I_{ML} A a_{II} \frac{k_f}{k_f + k_D + k_{NPQ} + k_P}$$

$$k_{NPQ} = \left( \frac{F_{mR}}{F_m'} - 1 \right) (k_f + k_D)$$



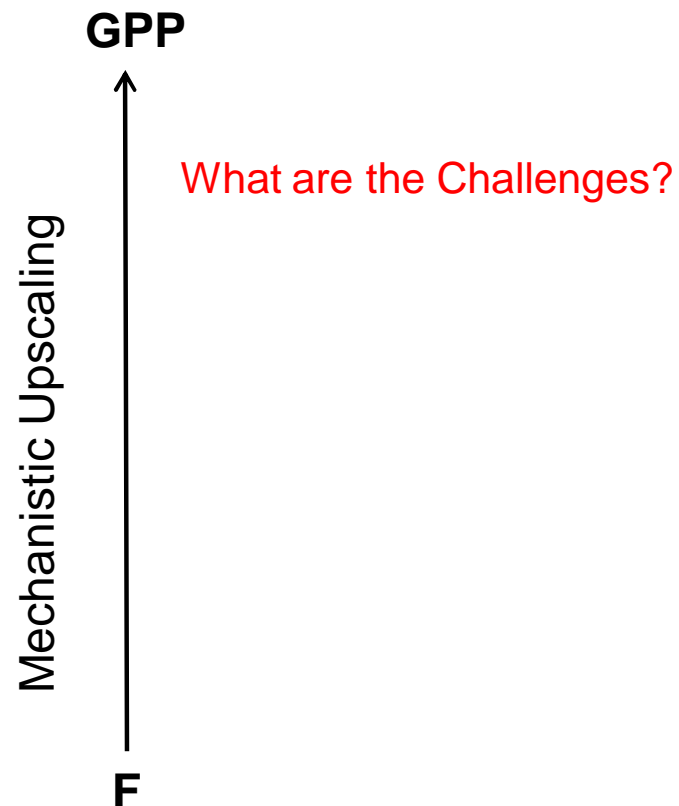
$$k_P = \left( \frac{F_{mR}}{F} - \frac{F_{mR}}{F_m'} \right) (k_f + k_D)$$

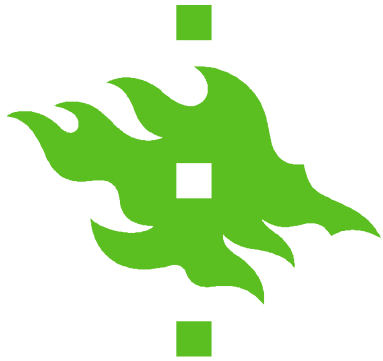




## To go from leaf-level F to pixel level GPP we need to upscale in three directions: (III) Mechanistic Upscaling

---





# Challenges of Mechanistic Upscaling from SIF to GPP

F

- The photochemical Yield ( $\Phi P$ ) is obtained by comparing the emission of F in the presence (F') and in the absence (Fm) of photochemistry, typically using a pulse of saturating light (but also with destructive methods: DCMU or 77K).

- **CHALLENGE 1:** How to get from SIF to  $\Phi P$  using SIF?

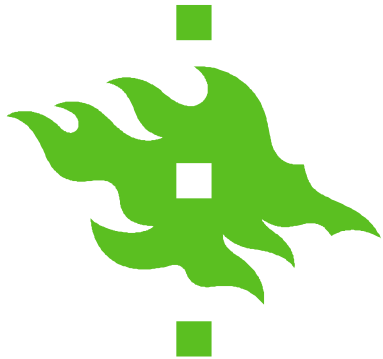
- Fluorescence emission is assumed to emanate from PSII, but it is well established that the contribution of PSI can be up to 30-45% at the Fo F' state depending on the detection wavelength.

- **CHALLENGE 2:** What is the contribution of PSI to the measured SIF signal at the measurement wavelength? How does this contribution change over time?

$\Phi P$

- Down from PSII, energy is further partitioned into pathways other than carbon assimilation. Photorespiration dynamics in particular will decouple ETR from GPP.

- **CHALLENGE 3:** Can we quantify and model/parameterize the dynamics of photorespiration?

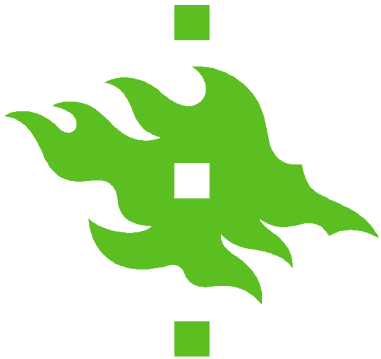


## CHALLENGE 1: How to bypass the lack of Saturating pulse capability in SIF?

---

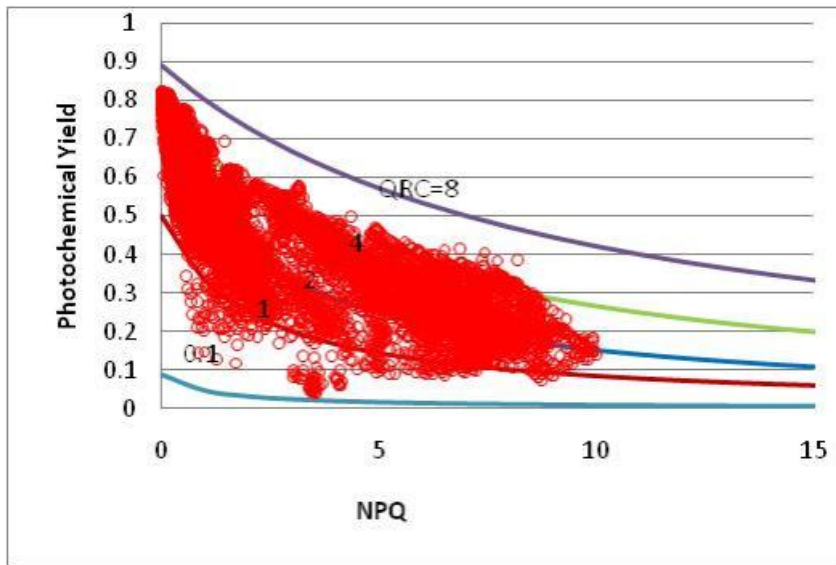
- A: F-Farquhar-type coupled models. Successfully implemented in the short-term (van der Tol et al. 2009 Agr. For, Met. 149:96-105, previous presentation), or Joe's model from yesterday. **But seasonal parameterization might be tricky.**
- B: Constraining NPQ via the PRI?





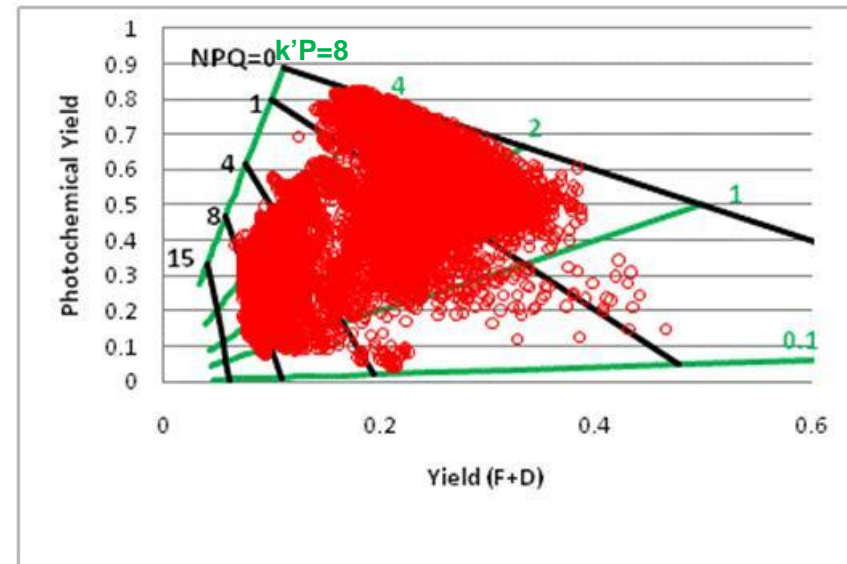
# Can we get to $\Phi P$ with PRI or SIF?

$$F = \beta I_{ML} A a_{II} \frac{k_f}{k_f + k_D + k_{NPQ} + k_P}$$



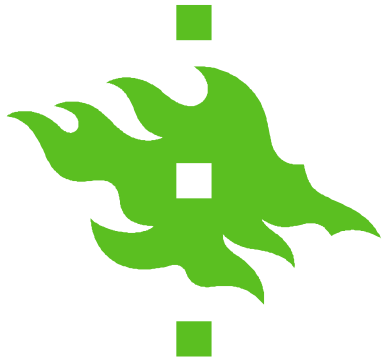
The **PRI** challenge

+

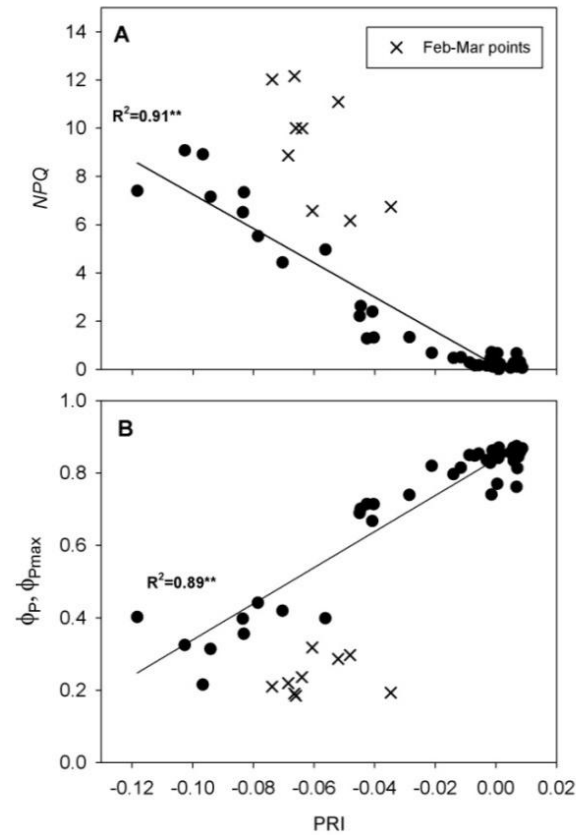
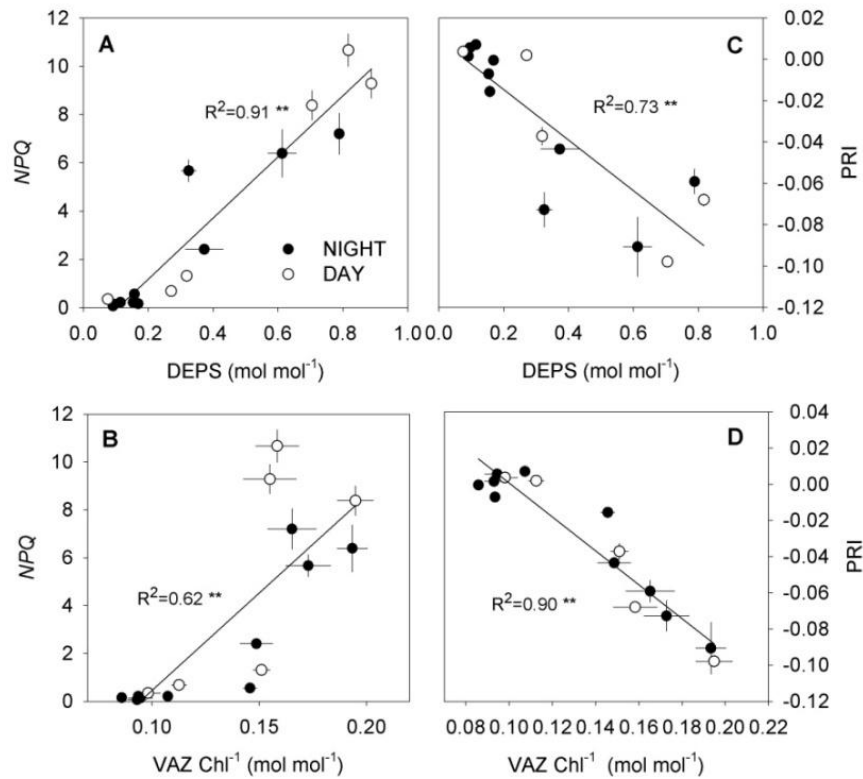


The **SIF** Challenge

**= The PRI+F Solution?**



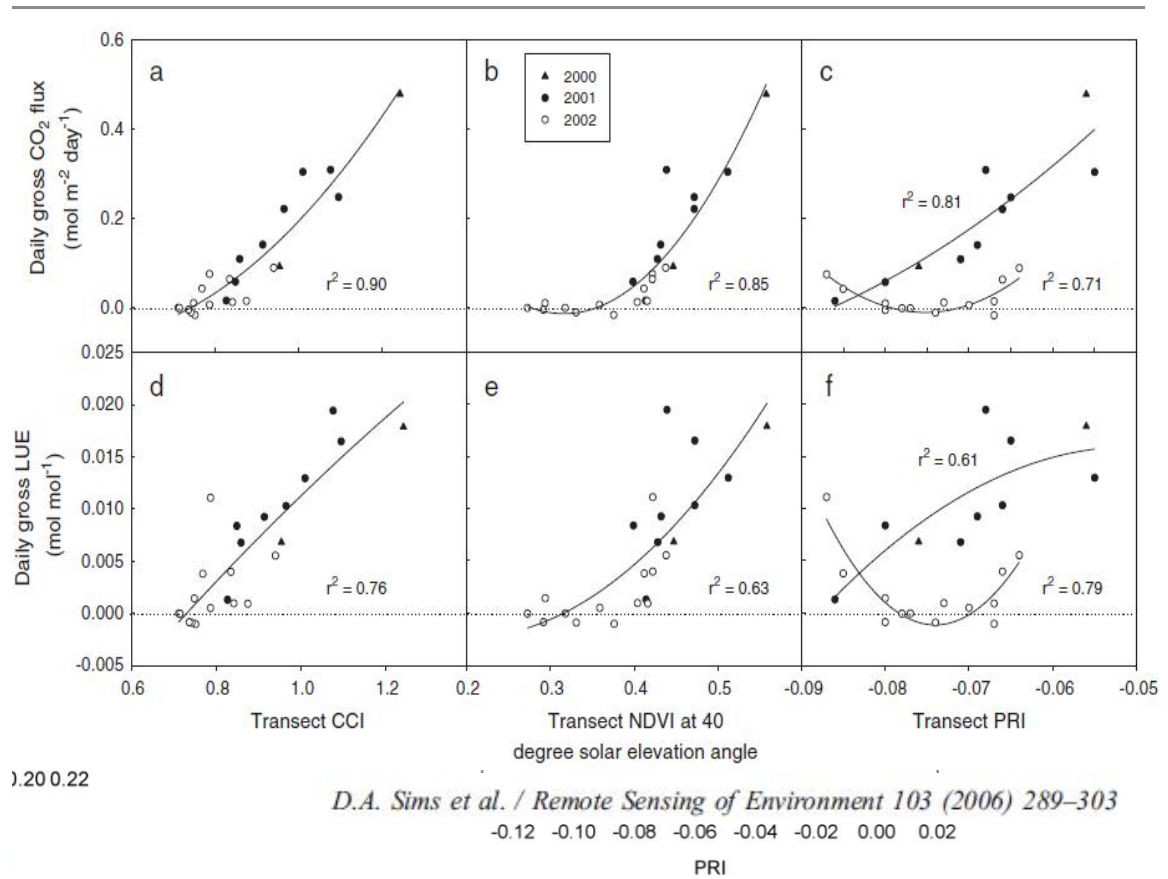
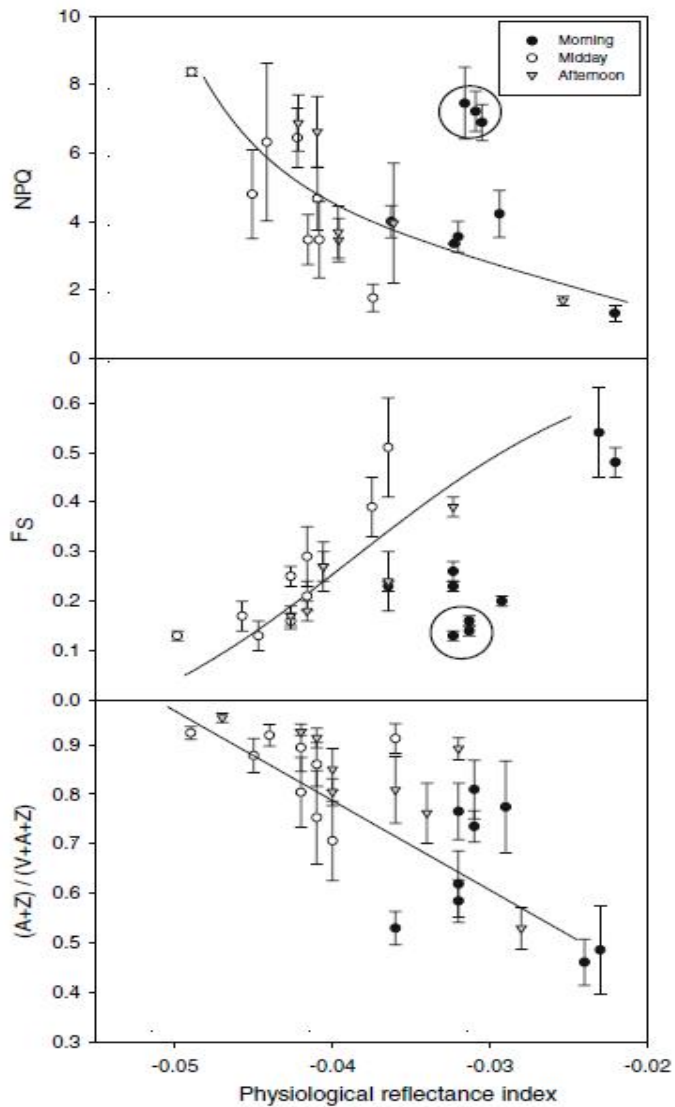
# Can we use the PRI to track the seasonality in NPQ?



Porcar-Castell et al. (2012) *Early Online. Oecologia*  
 DOI 10.1007/s00442-012-2317-9

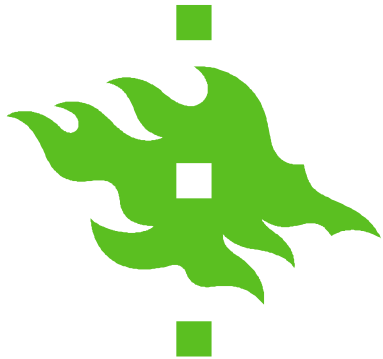


# Can we use the PRI to track the variability in NPQ?



D.A. Sims et al. / Remote Sensing of Environment 103 (2006) 289–303

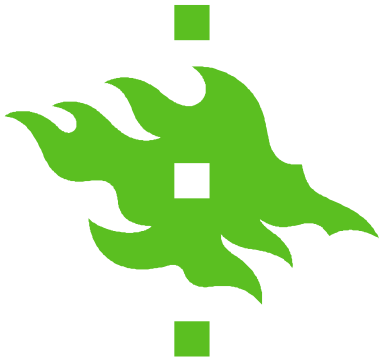
Peguero-Pina et al. (2008) Oecologia 156:1-11



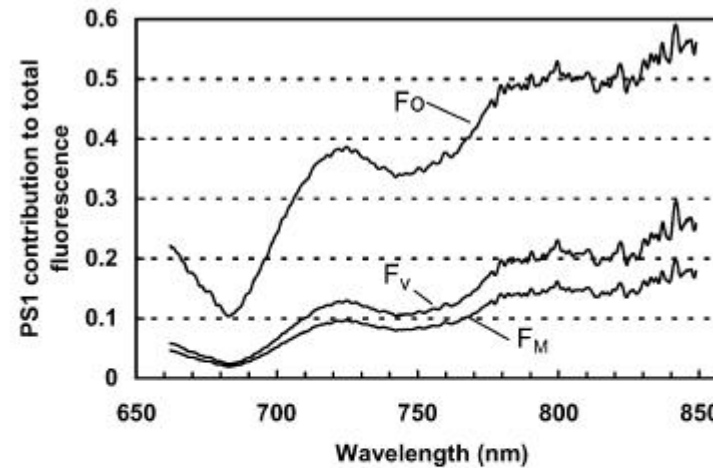
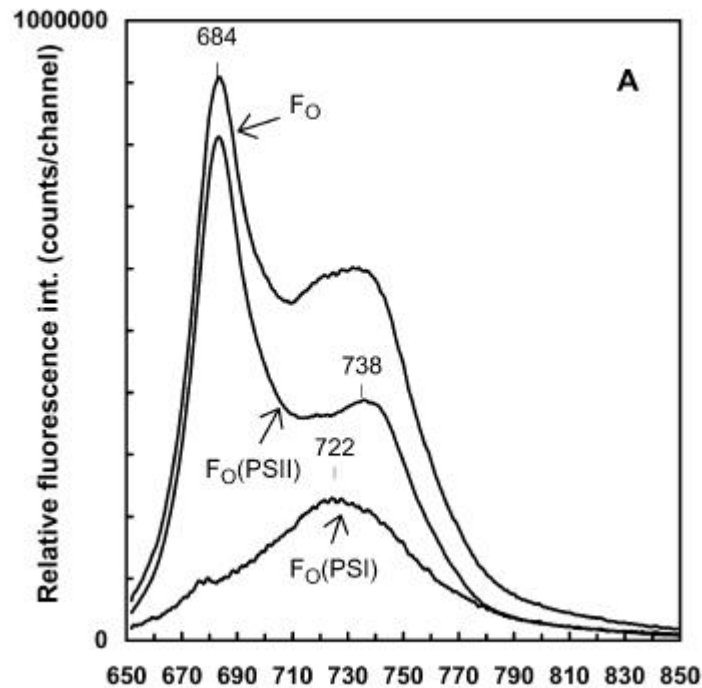
## CHALLENGE 1: How to bypass the lack of Saturating pulse capability in SIF?

---

- A: Fluorescence-Photosynthesis coupled model? Successfully implemented in the short-term (van der Tol et al. 2009 Agr. For, Met. 149:96-105), or Joe's model from yesterday. But seasonal parameterization might be tricky
- B: Constraining NPQ via the PRI? One possibility, but decoupling between NPQ and PRI occurs under severe stress at the seasonal time-scale
- C: Bottom-up mechanistic modelling? (we are working on it)
- D: What else?

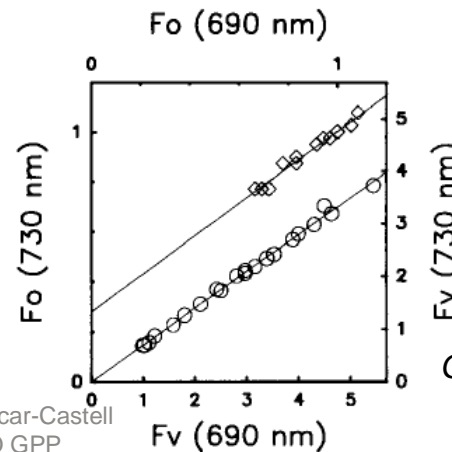


## CHALLENGE 2: What is the contribution of PSI to the measured SIF signal at the measurement wavelength and how does this contribution change over time?



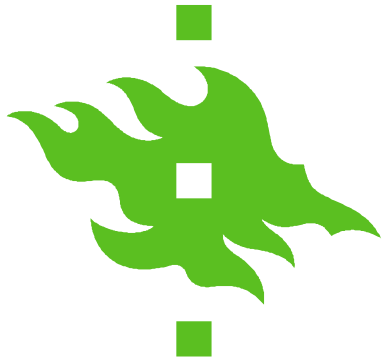
How does this change over the year?

*F. Franck et al. / Biochimica et Biophysica Acta 1556 (2002) 239–246*



NPQ does not seem to Operate in PSI during Light induction, does this hold at the seasonal scale?

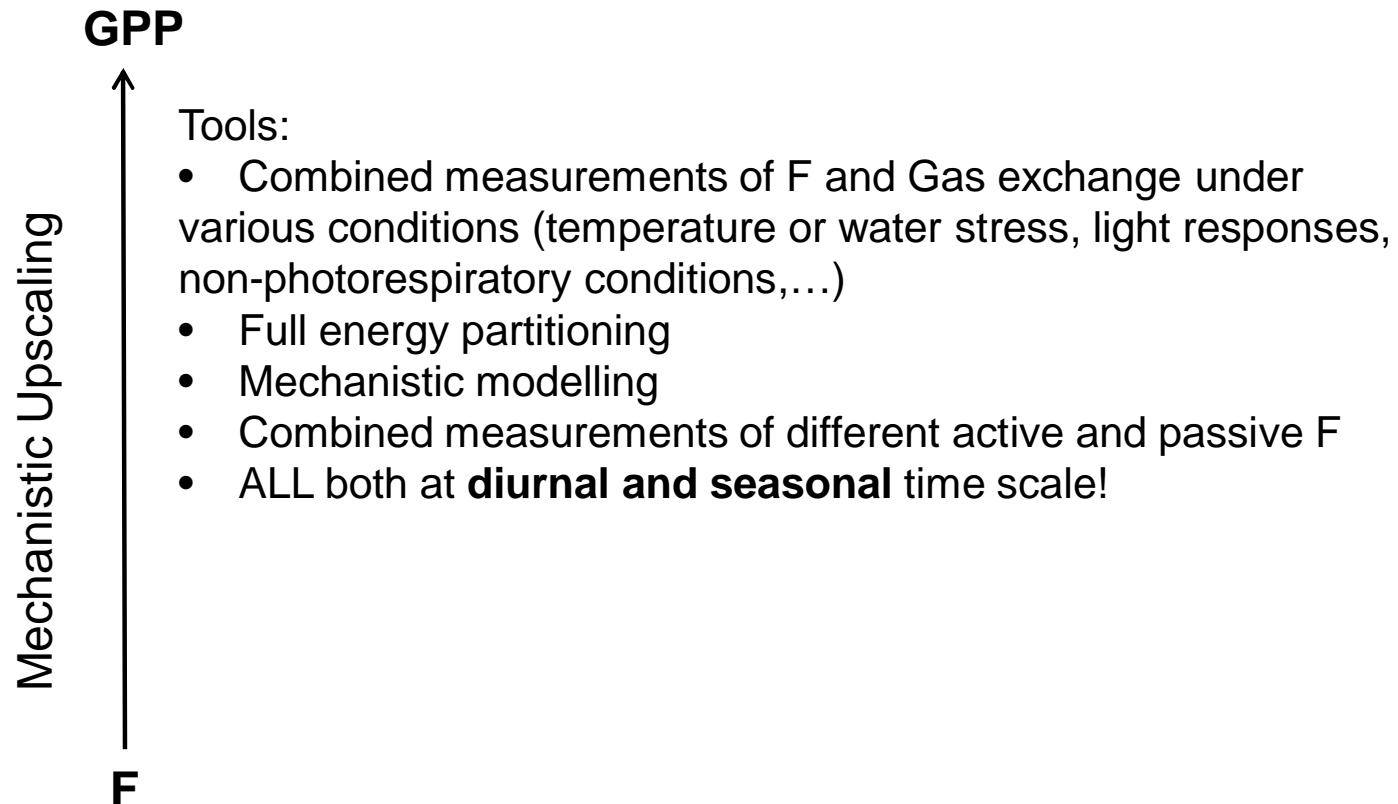
*Genty et al. 1990, Phot. Res 26:133-139*

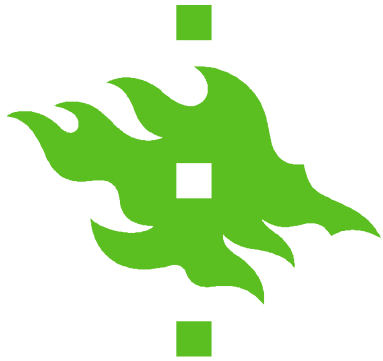


## To go from leaf-level F to pixel level GPP we need to upscale in three directions:

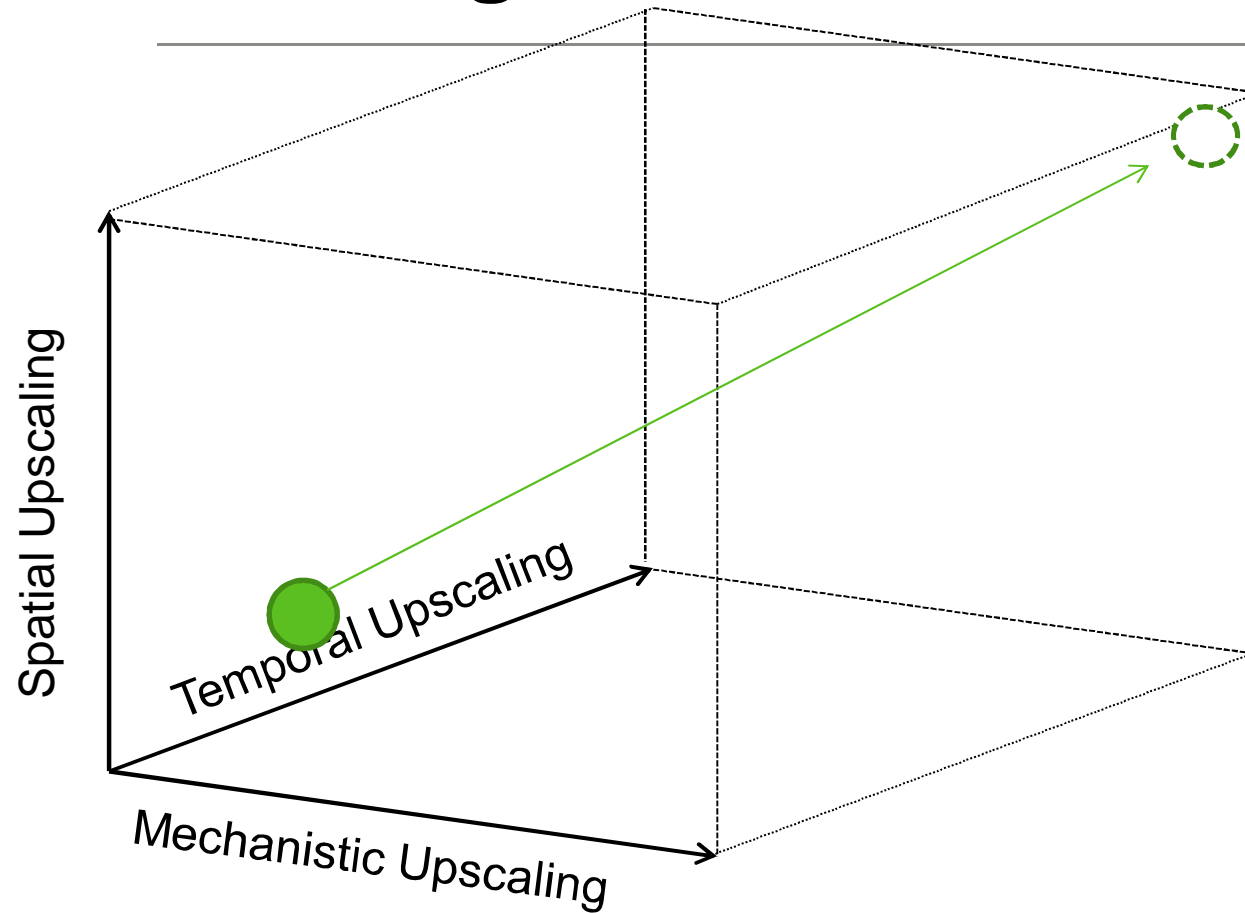
### (III) Mechanistic Upscaling

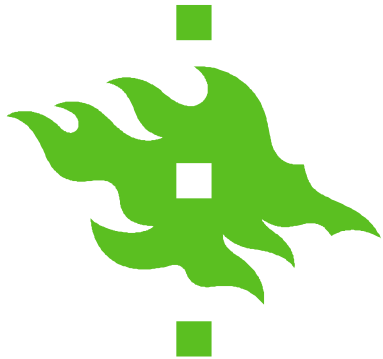
---





# Where we are and where we wanna go?



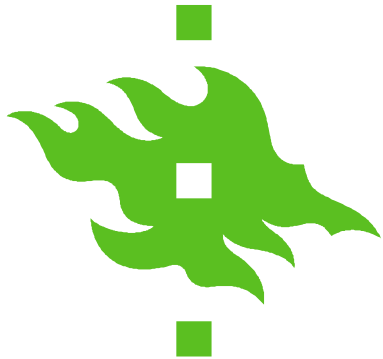


# How much experimental evidence do we have and how much do we understand about the link between F and photosynthesis?

Temporal Scale	ACTIVE FLUO	PASSIVE FLUO
Seconds-Minutes	VERY GOOD KNOWLEDGE	SOME KNOWLEDGE
Day/Days	VERY GOOD KNOWLEDGE	SOME KNOWLEDGE
Growing Season/Annual	REASONABLE KNOWLEDGE	VERY LIMITED KNOWLEDGE

SCALE OF INTEREST TO REMOTE SENSING





# Final Remarks

---

- Plenty of questions still remaining on the F-signal interpretation:
  - Do the seasonal changes in  $F_s$  and SIF go hand in hand, or do they decouple due to PSI dynamics?
  - How do we get from SIF or  $F_s$  to  $\Phi P$ ? Or do we really need to attempt to get  $\Phi P$ ? If SIF is an integrated expression of NPQ and APAR, perhaps it is already a good indicator of ETR for the spatiotemporal context (100's meters, few days)
- At least in boreal conditions the seasonal dynamics in  $F_s$  track pretty well GPP, (since NPQ is the main safety-valve under low-temperature stress), but how about decrease in GPP induced by water stress? (where both NPQ and photorespiration may function as safety valves, the later invisible to F)