Exploiting Sentinel 3 Data for Estimating GPP Across Europe Using the Quantum Yield (QY) Model: An Approach from the Sen4GPP Project

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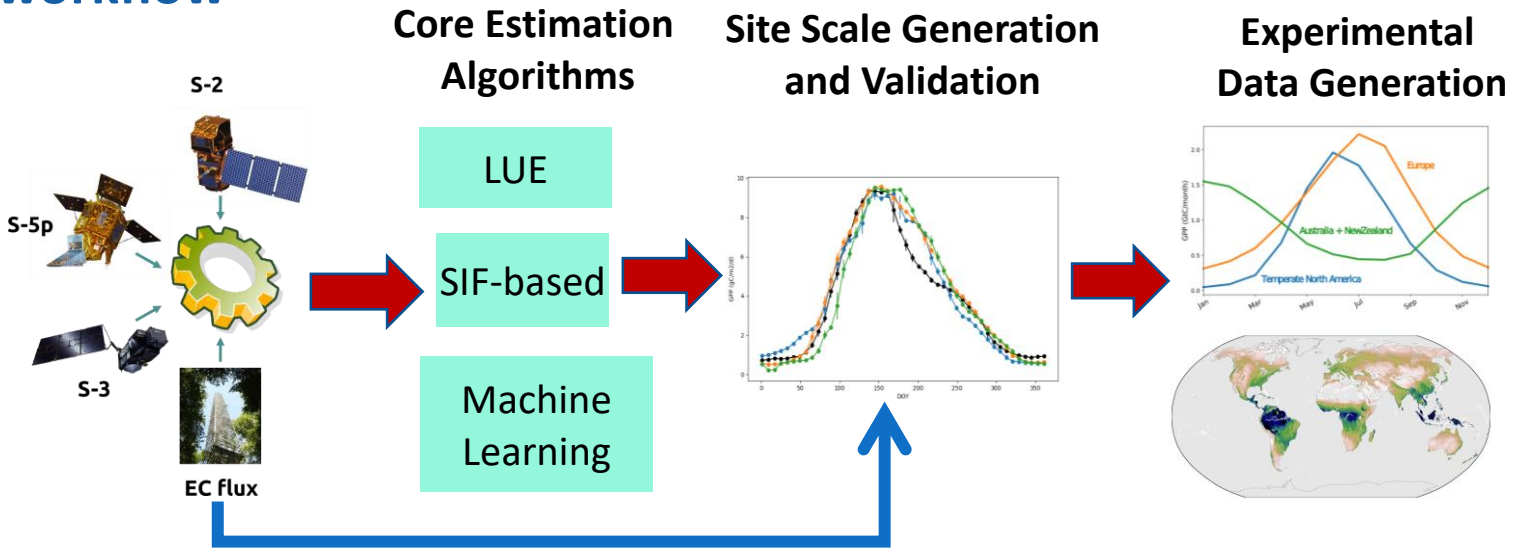
Sen4GPP Project

- Accurate estimation of gross primary productivity (GPP) is **important in understanding the global carbon cycle and its response to environmental change**
- The **Sen4GPP Project** aims to exploit the complementary information provided by the Sentinel missions (***Sentinel-2, Sentinel-3 and Sentinel-5P***), and other ***EO*** and ***in-situ*** data to improve quantification of terrestrial ecosystems GPP at multiple spatial and temporal resolutions

Sen4GPP workflow



Light Use Efficiency (LUE) Approach – The Quantum Yield Model

(*Based on the SCARF Model; Ogutu et al, 2013*)

- $QY\_GPP = PAR * FAPAR_{chl} * [PC_3 \alpha_3 fD_3 \Psi_e + (1-PC_3)\alpha_4 fD_4]$
  - $FAPAR_{chl}$: Fraction of photosynthetic active radiation absorbed by green/chlorophyll in the canopy – derived from inversion of flux data and up-scaled using S2/3 Chlorophyll Index (S2/OTCI)
  - PC_3 : Percentage of C_3 plants, $\mathbf{1-PC_3}$ represents the percentage of C_4 plants in a pixel
  - α_3 and α_4 : Quantum yields for C_3 and C_4 plants respectively,
  - Ψ_e: Influence of temperature and leaf CO_2 concentration on the maximum quantum yield of C_3 plants
  - fD_3 and fD_4 : Influence of Vapour Pressure Deficit on C_3 and C_4 photosynthesis respectively

Deriving $FAPAR_{chl}$ from Inversion of Flux Tower data(*Chiwara et al., 2018; Ogutu and Dash, 2013, Hanan et al., 2002*)

- From Previous Equation:

$$FAPAR_{chl} = \frac{\epsilon}{[PC_3\alpha_3 f_{D3}\Psi_e + (1 - PC_3)\alpha_4 f_{D4}]}$$

Where:

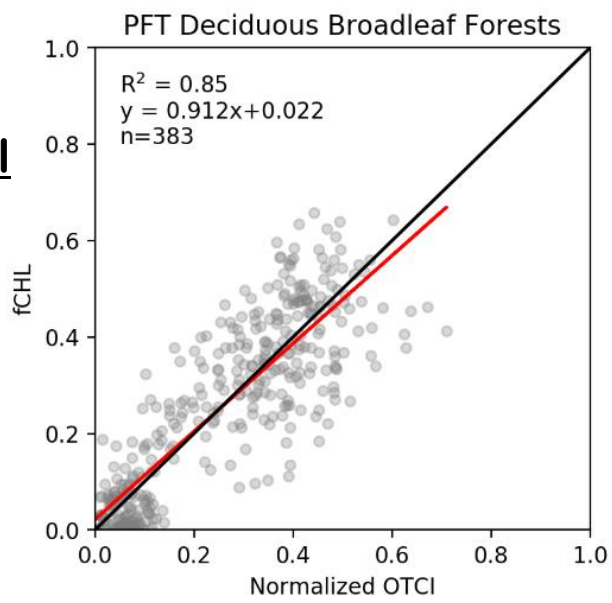
- ϵ = Slope of *in-situ* GPP vs PAR(from flux tower data) (ecosystem LUE)
- f_D = Influence of VPD on photosynthesis
- α_3 and α_4 = Quantum yield terms for C_3 and C_4 respectively
- Ψ_e = Influence of Temperature and Leaf CO_2 concentration on photosynthesis in C_3 plants

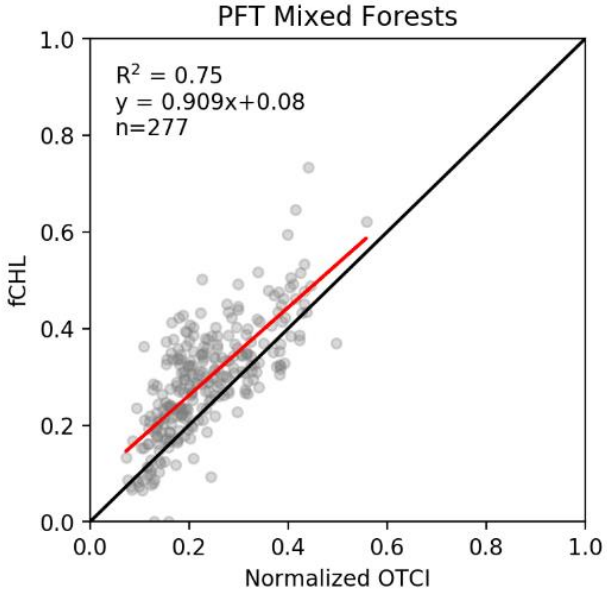
- **$FAPAR_{chl}$** derived at ***30% of sites***

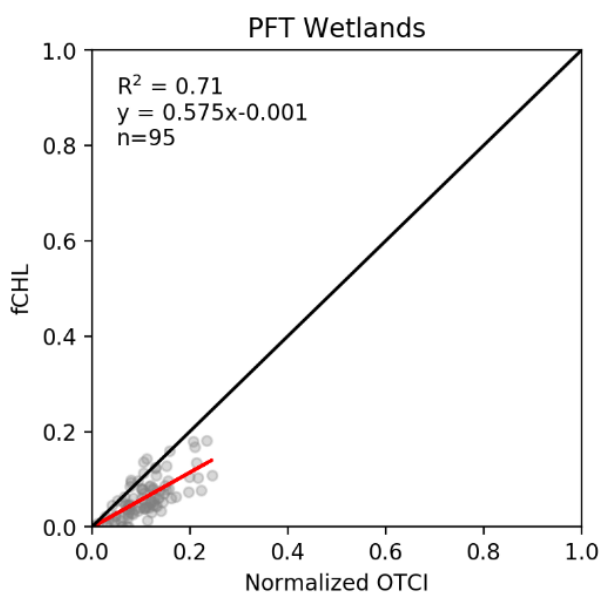
- To up-scale - Related to ***S3-OLCI Terrestrial Chlorophyll Index-OTCI*** at these sites to generate PFT specific and 'Global' Equation

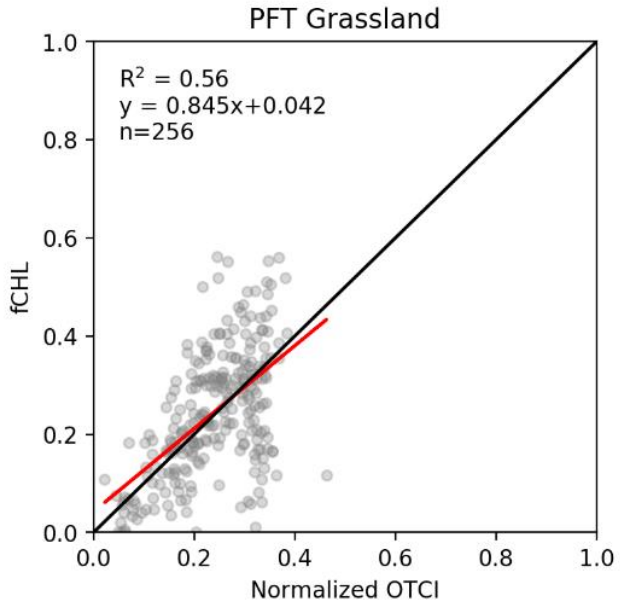
- Tests to optimise the relationship(varying max PAR value, varying quantum yield terms, compositing window, pixel size/grid etc.)

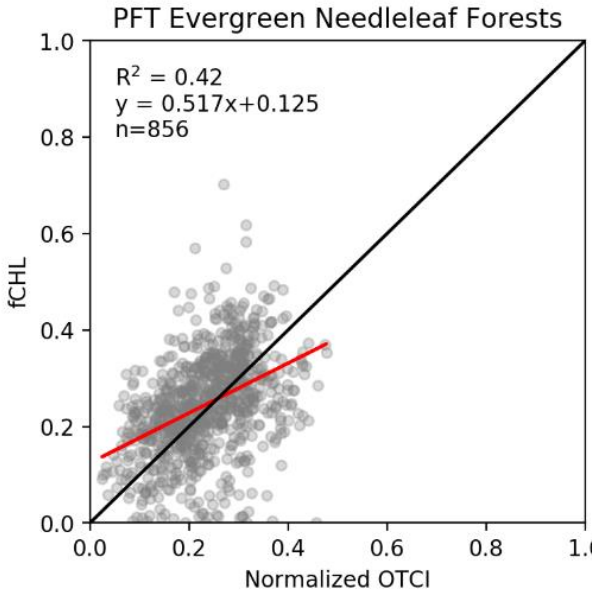
Relationship between $FAPAR_{chl}$ and S3- OTCI (PFT Specific)

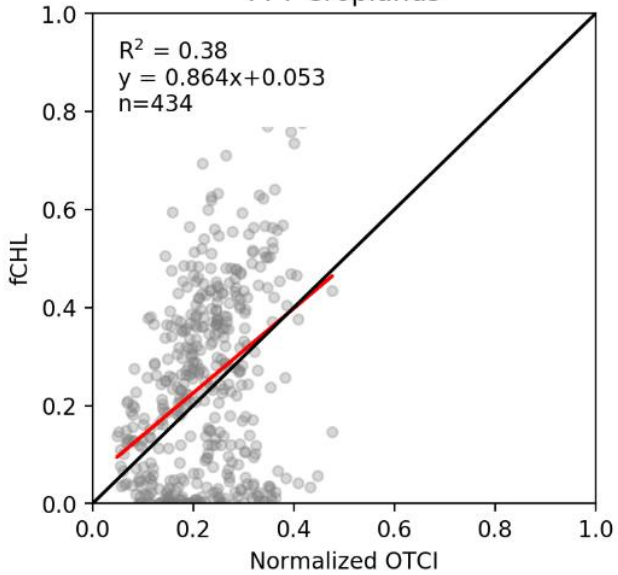




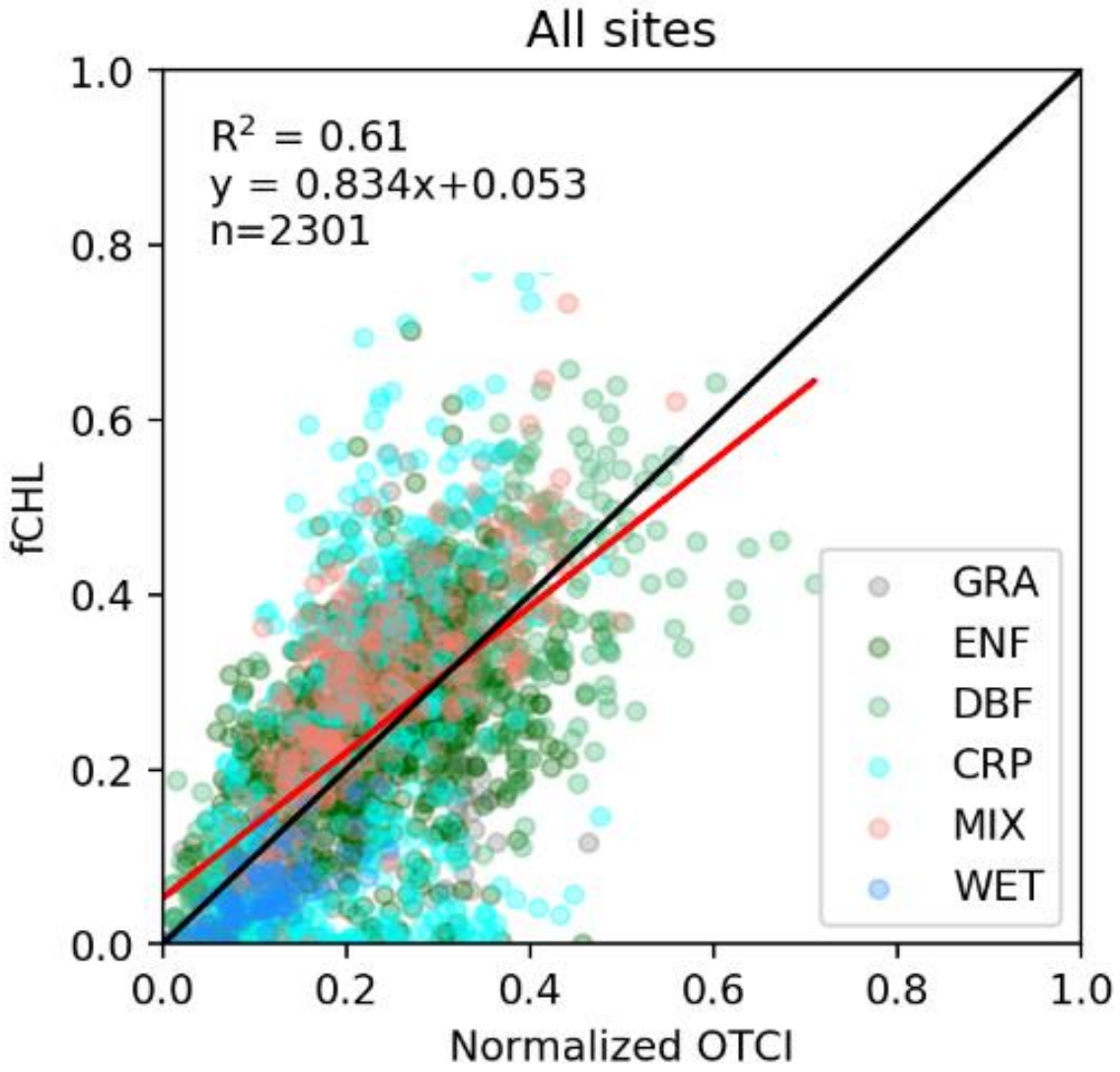




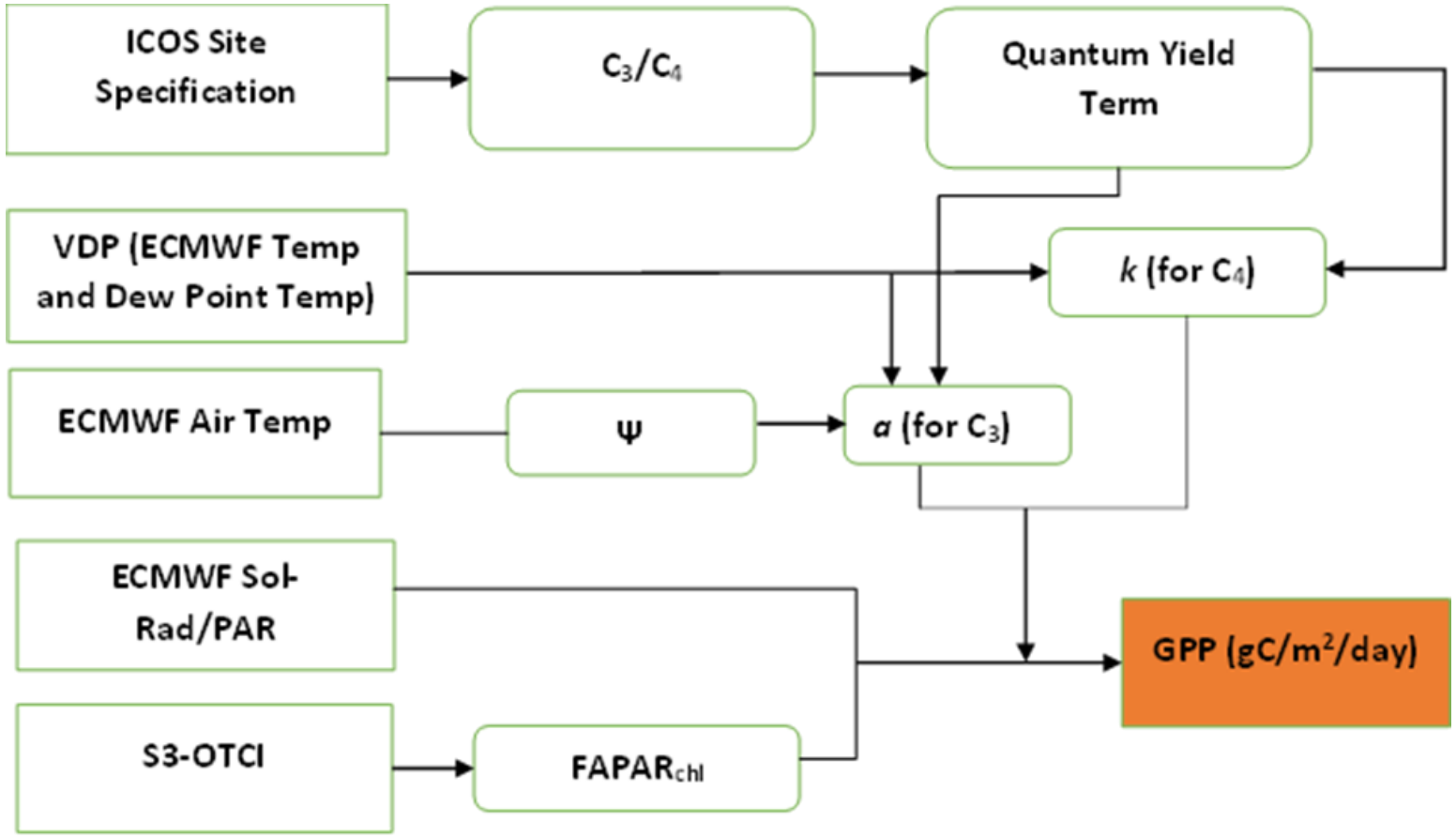




Relationship between $FAPAR_{chl}$ and S3- OTCI ('Global')

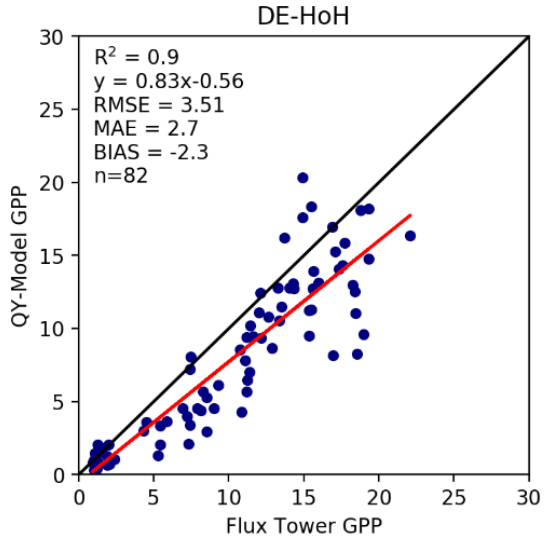


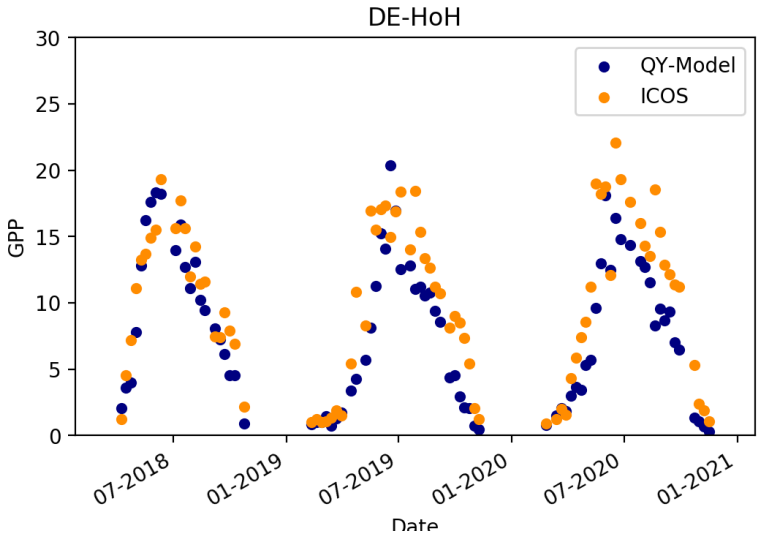
Implementation and validation of the QY Model



- ***$FAPAR_{chl}$ = 0.834OTCI + 0.053*** *(Global relationship-from Previous Slide)*

Sample of Site Level Comparisons (QY Model output vs. Flux Tower GPP)





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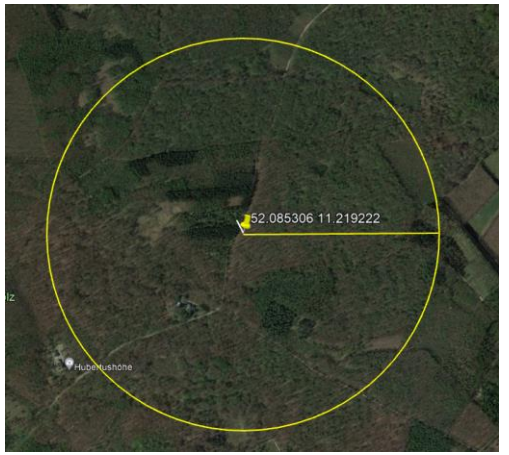

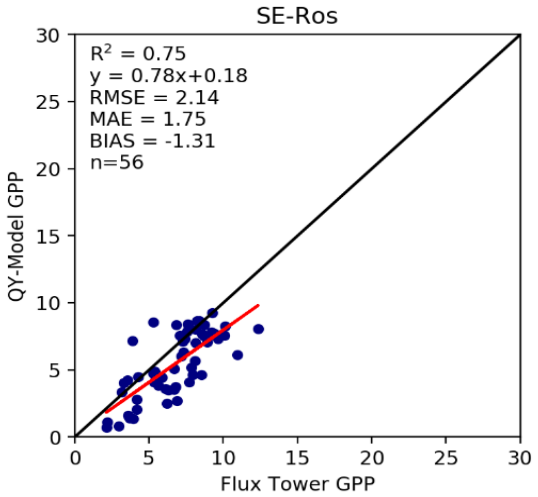

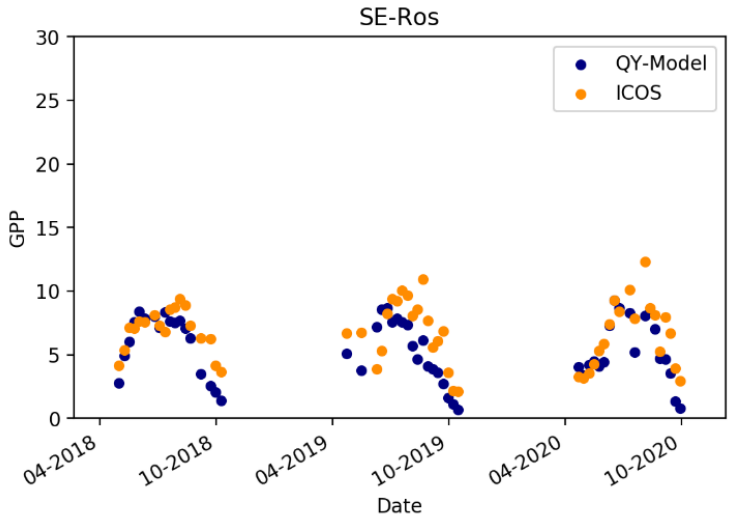

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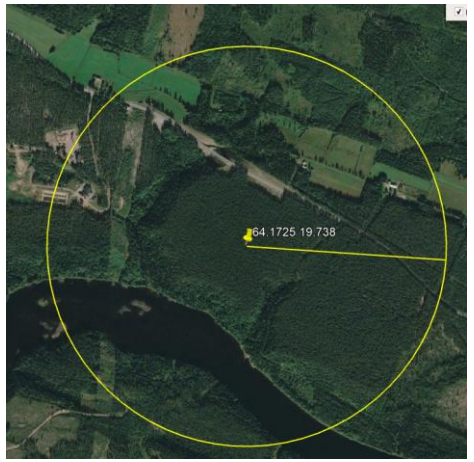
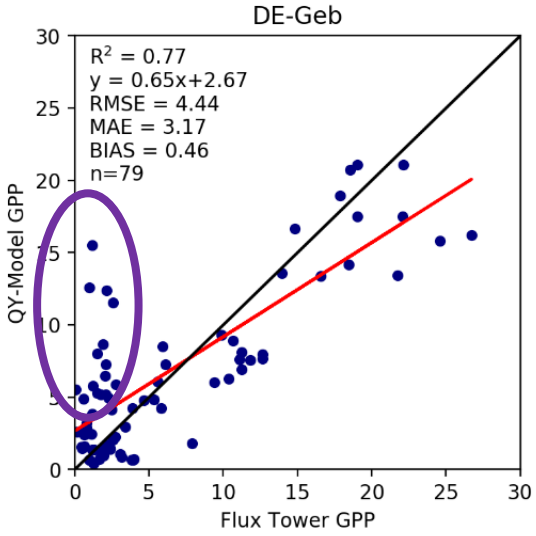
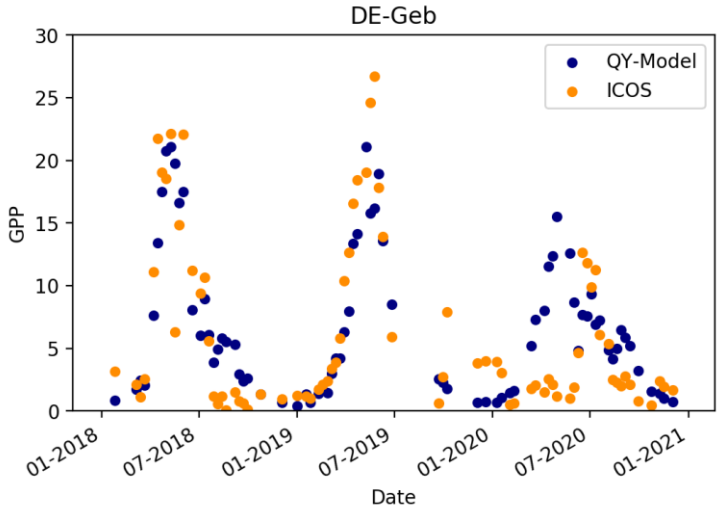


Sample of Site Level Comparisons (QY Model output vs. Flux Tower GPP)





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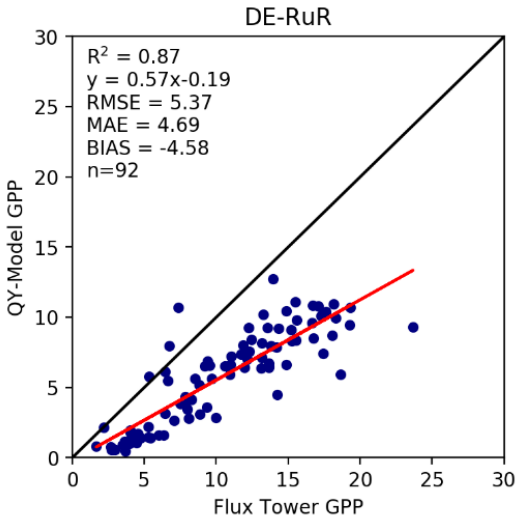
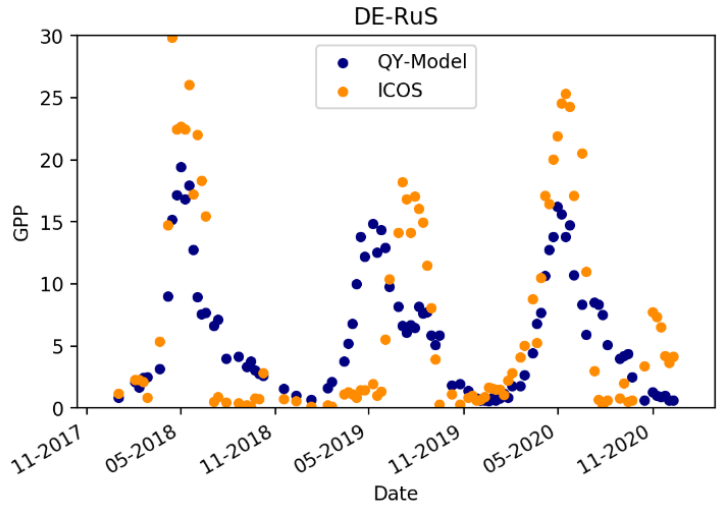
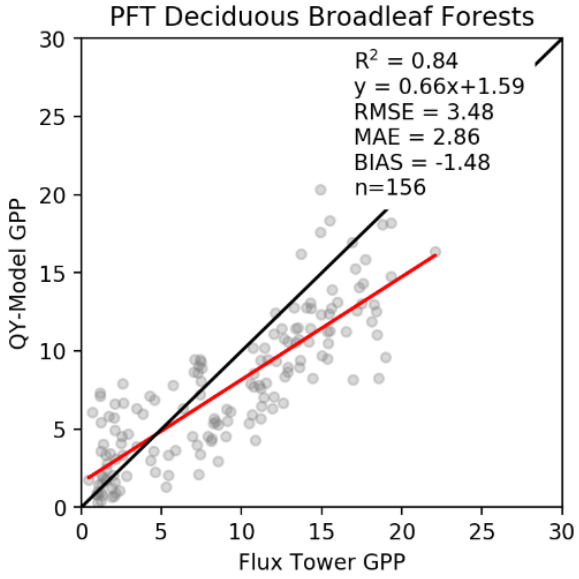
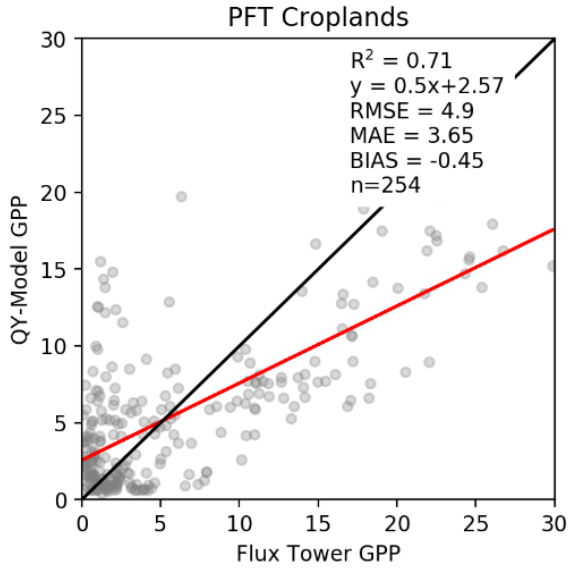


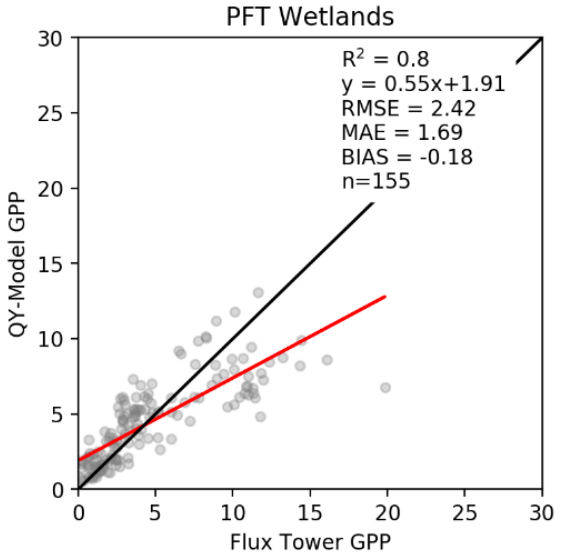


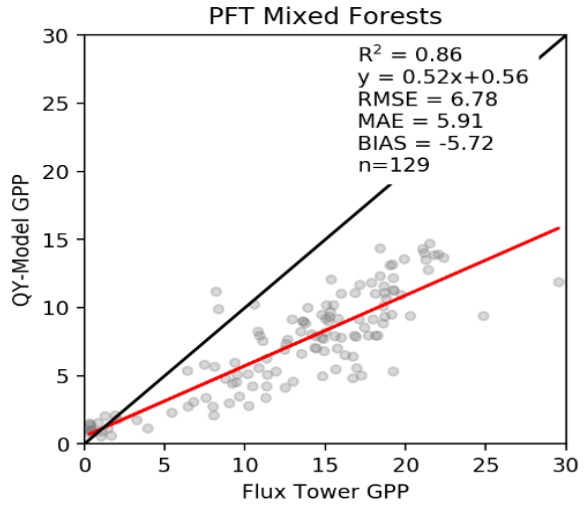
GRA

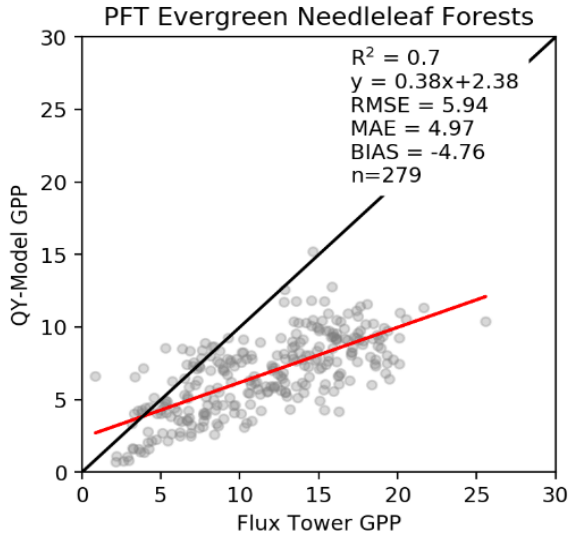
PFT Level Comparisons (QY Model output vs. Flux Tower GPP)

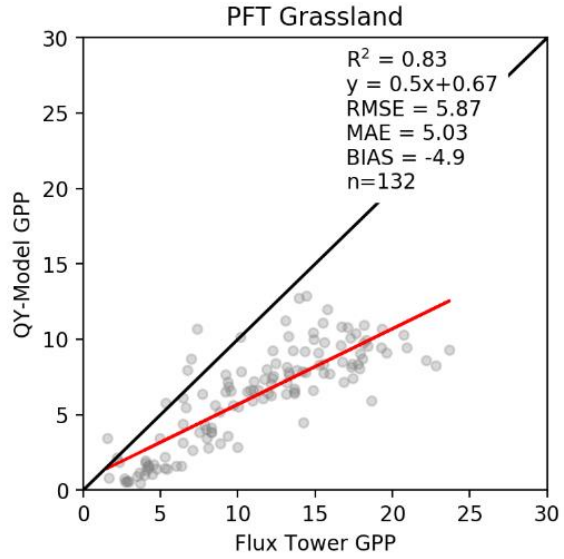






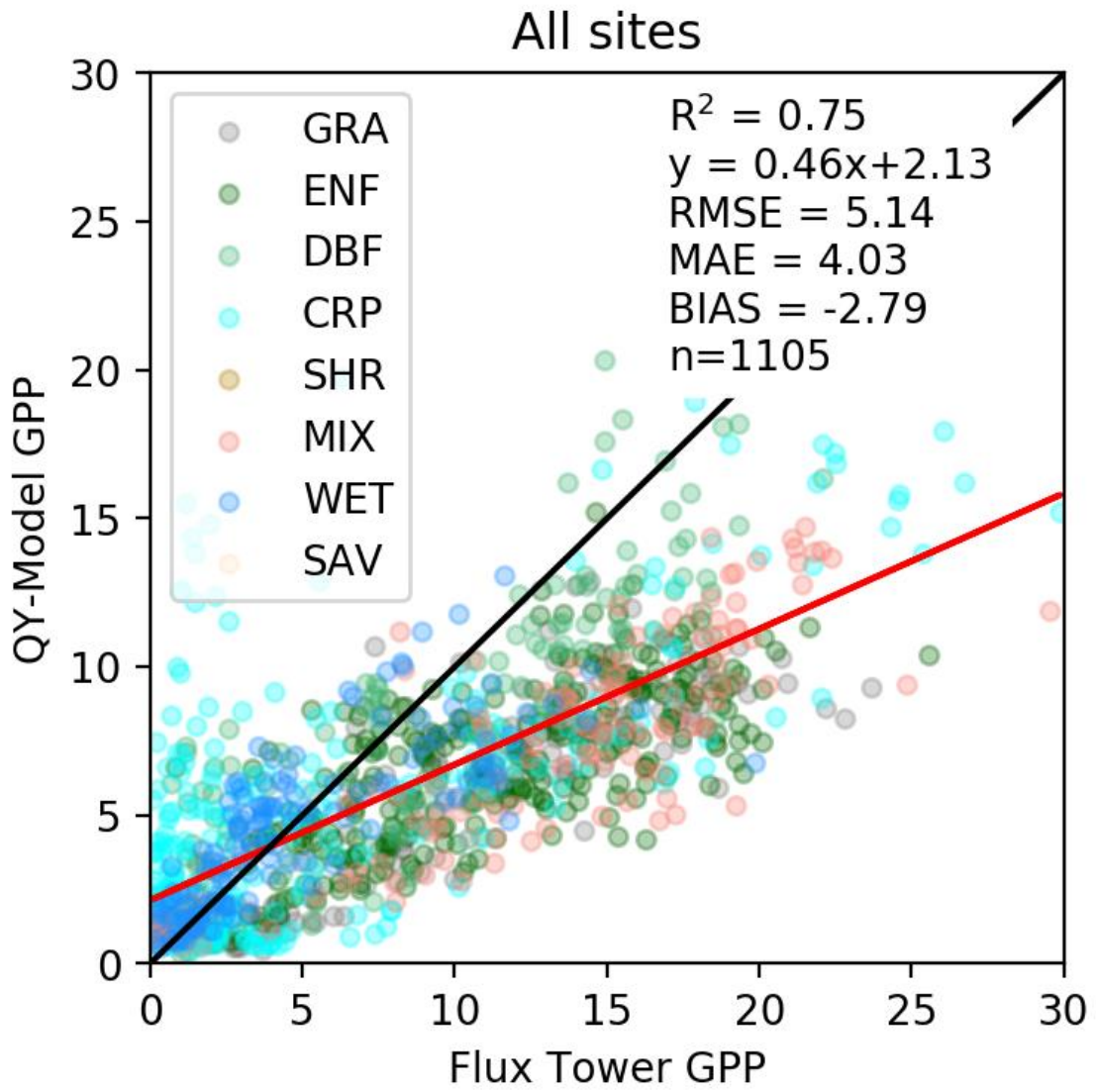






All Sites Comparison (QY Model output vs. Flux Tower GPP)

- 70% validation sites



Conclusion and Future Sen4GPP work at UoS

- Overall, using Sentinel data in the QY-model results in good performance in various PFTs
- Expand model testing to AmeriFlux/other sites
- Sensitivity of QY model to model input variables, uncertainty characterisation, source of negative bias
- Implementation of the QY-model using S-2 data-heterogeneity
- Compare the QY-modelled GPP product with existing GPP products (MOD17 GPP, Terra-P GPP, Dry Matter Productivity products).
- Generation of Experimental Data and scientific application

Thank you

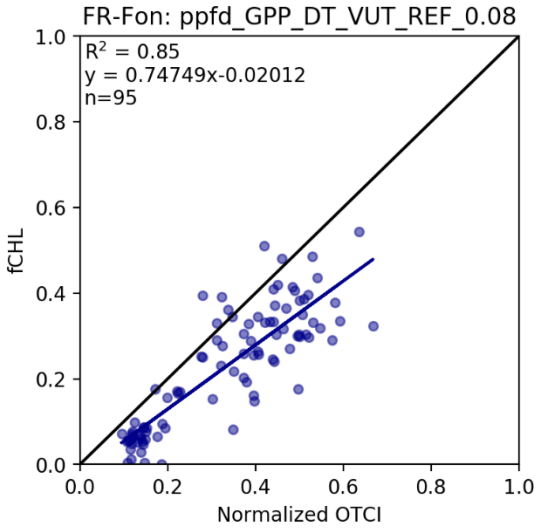
Extra Slides

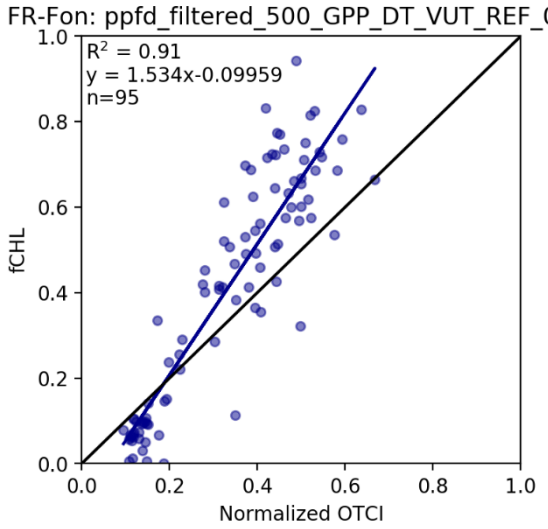
Challenges

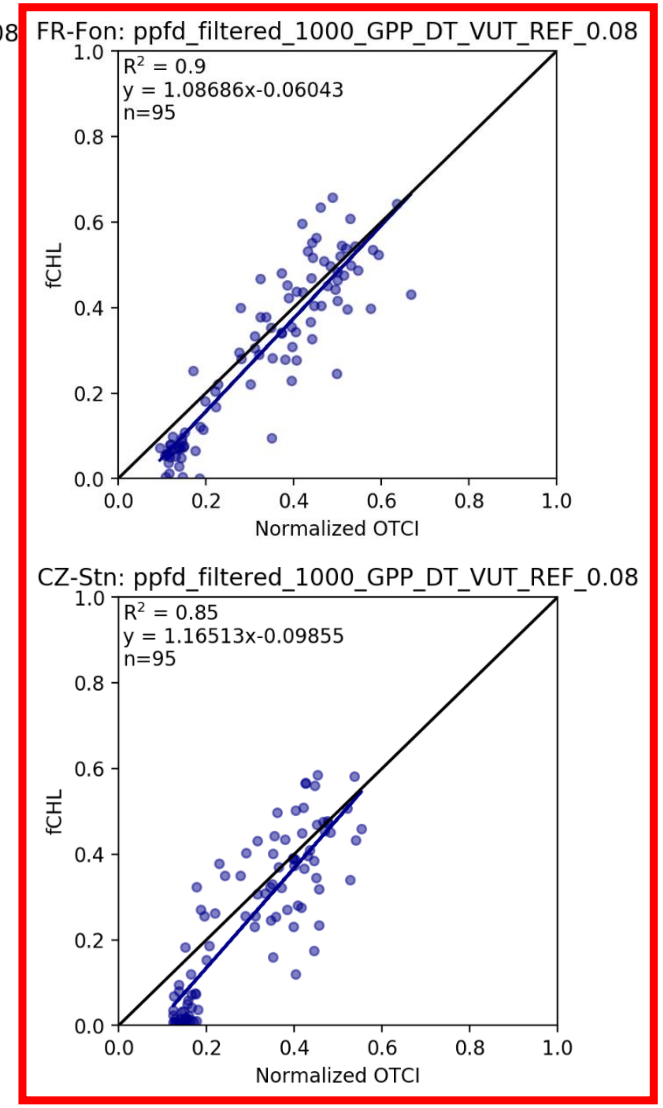
- Availability of C3/C4 maps
- *In-situ* data scarcity in the tropics (for model training and validation)
- Analysis Ready Data (e.g. Sentinel-3 surface reflectance, gridding of S-3 data)
- Reliance on meteorological data (at coarse spatial resolution)

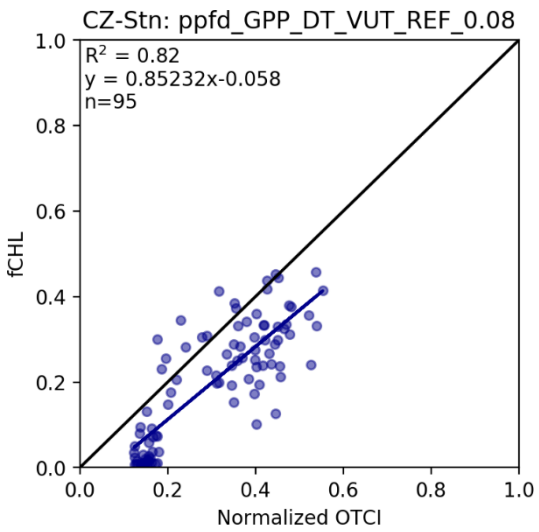
PPFD Restrictions

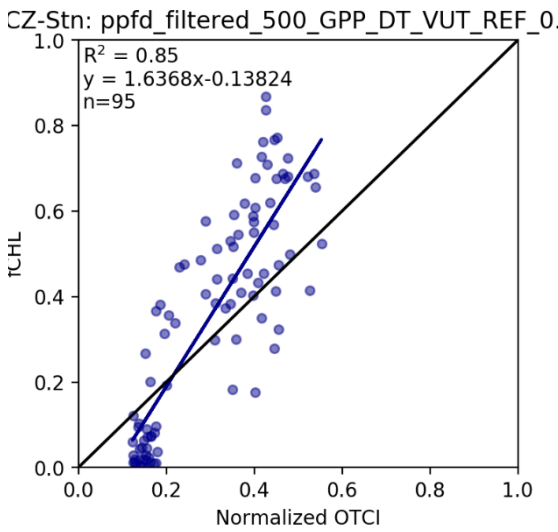
PPFD less than 1000 considered



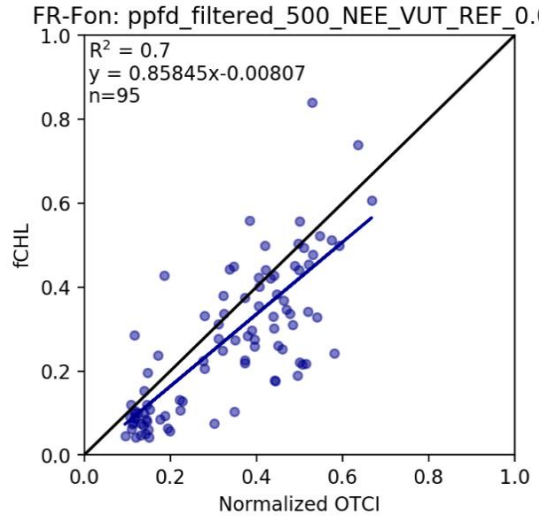


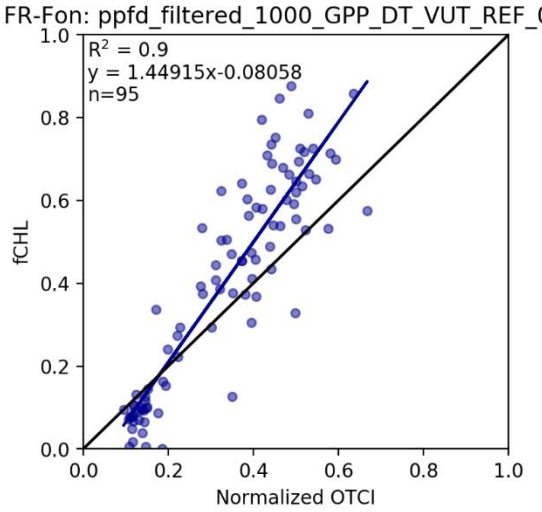


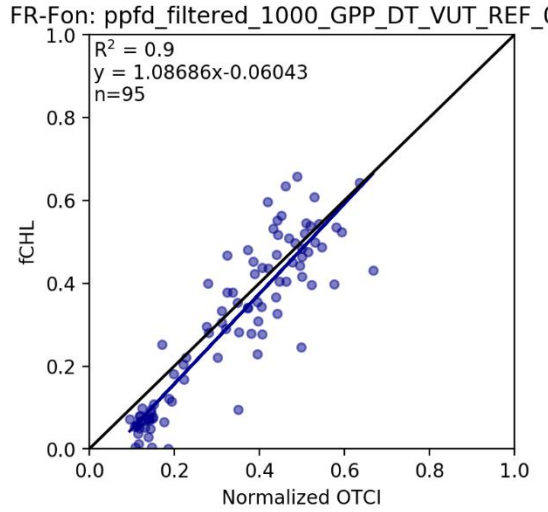


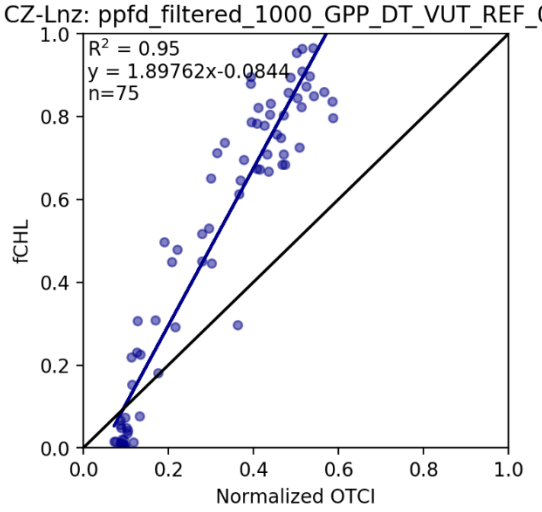


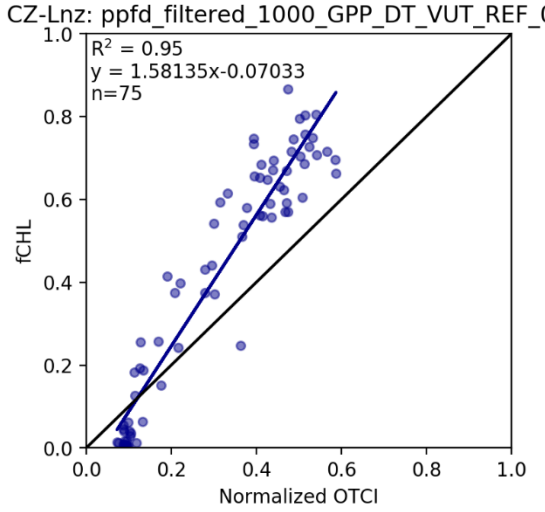
Quantum Yield Value

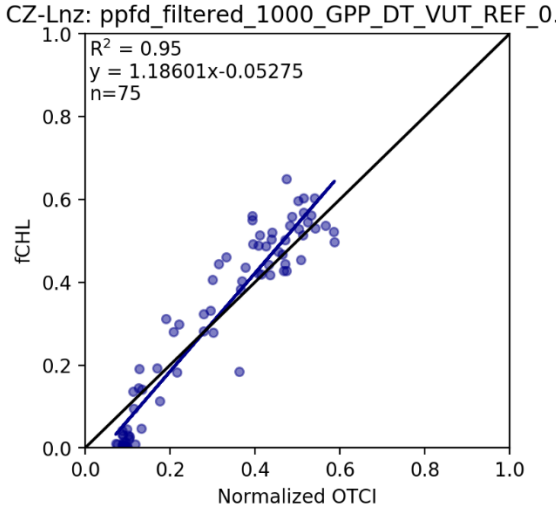




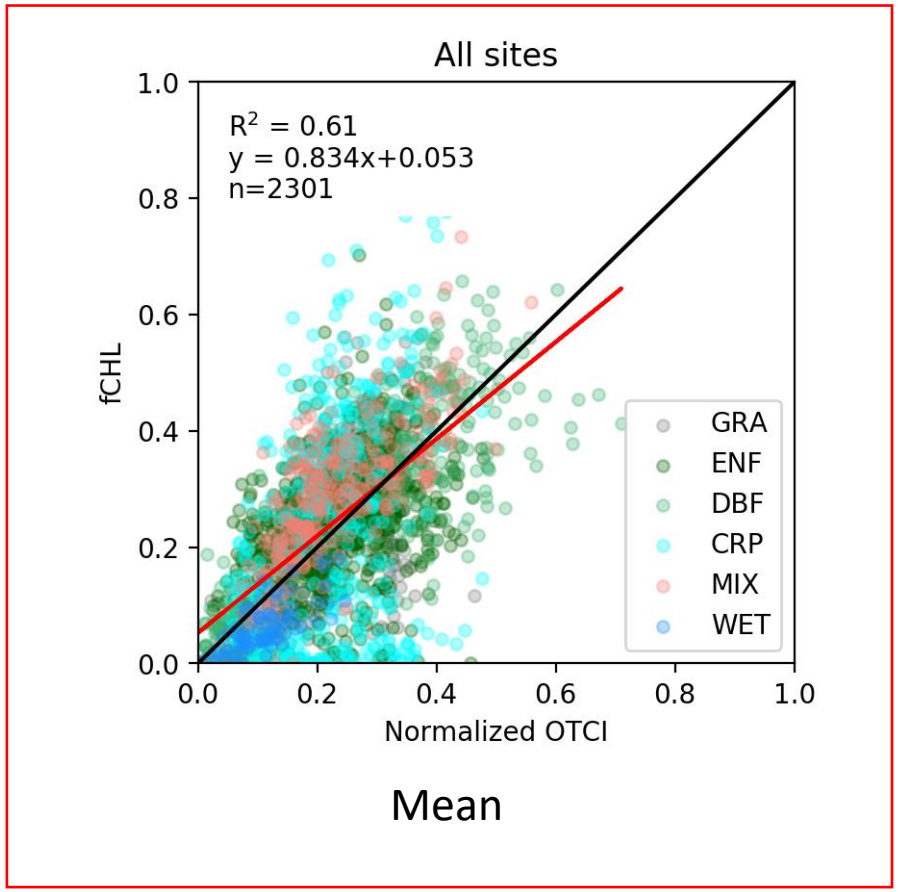


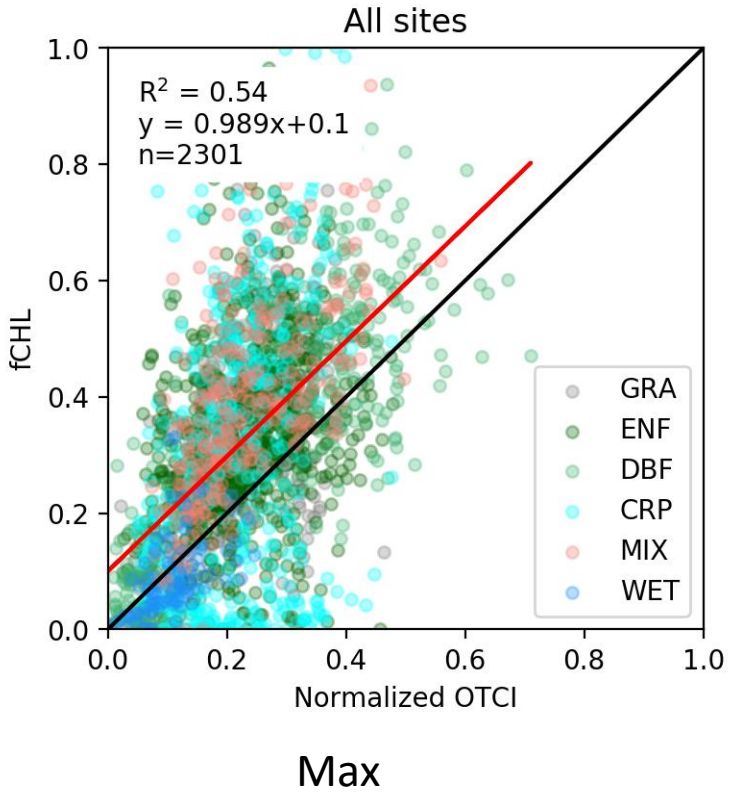




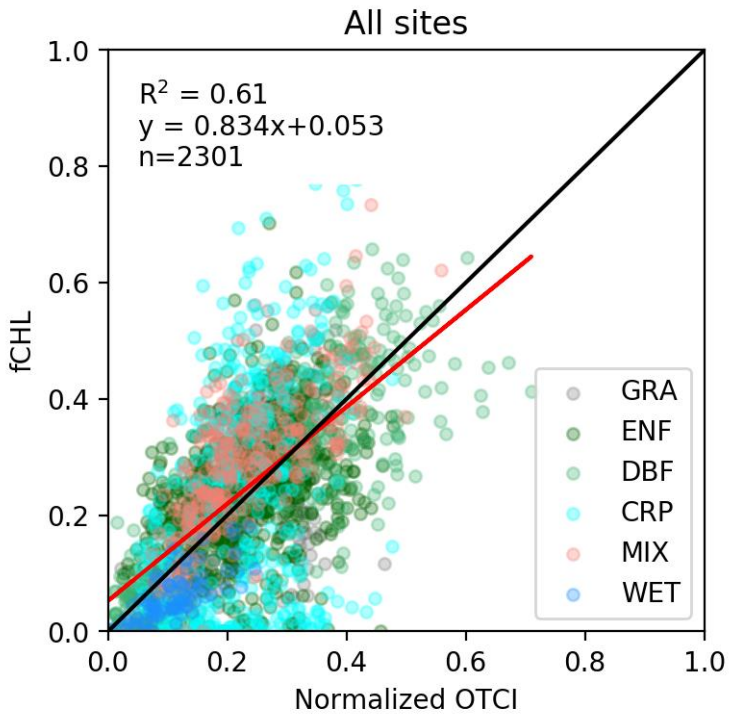


Mean vs maximum $FAPAR_{chl}$ for 8 day window

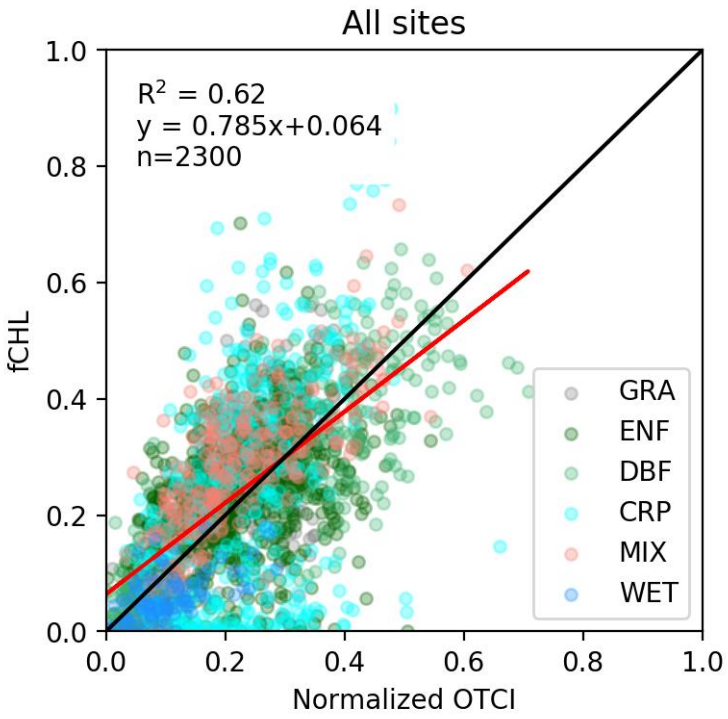




1500m x 1500m or 500m x 500m OTCI

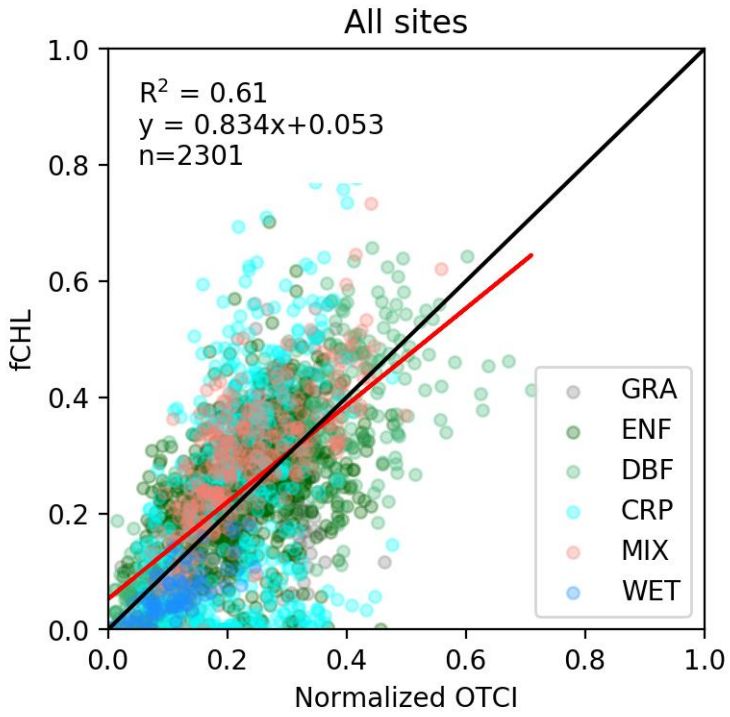


3 x 3

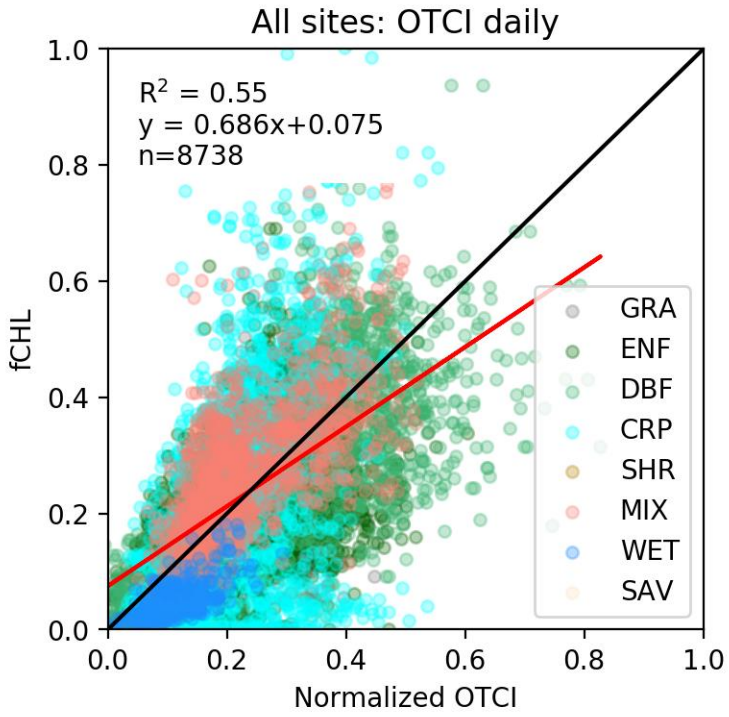


1 x 1

8 day vs daily extractions of OTCI



8 day



Daily

3 x 3 OTCI or OGVI