Convergences and divergences between data-driven GPP estimates and high-resolution SIF measurements across vegetation and climatic gradients

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Estimating global GPP

- Gross Primary Production (GPP) estimation vital to carbon cycle estimations
- FLUXCOM* project scales up data from FLUXNET fluxtowers, using meteo and RS data to provide a global GPP estimate
- Significant uncertainty in the FLUXCOM estimates remains

http://fluxcom.org/EF-Products/
Solar Induced Fluorescence (SIF)

- Excited chlorophyll dissipates absorbed energy via photosynthesis, heat and fluorescence
- SIF can be used as an indicator of photosynthetic activity at different scales, including via remote sensing (RS)
- Relationship between SIF and GPP an area of active research
Downscaled SIF

- No dedicated satellite currently measuring SIF (FLEX in 2022)
- Satellites capable of retrieving SIF suffer from a mixture of: course resolution, sparse sampling, short data archive
- We can improve resolution, e.g. GOME-2 0.5° SIF → downcaled via Duveiller & Cescatti* method → 0.05° SIF

* https://www.earth-syst-sci-data-discuss.net/essd-2019-121/
Downscaled SIF & GPP

- How can a contiguous, high-resolution, remotely sensed, long-archive SIF dataset improve our understanding the relationship with GPP?

- Contiguous: Investigate at a global scale

- High-resolution: Investigate in differing plant types

- Remotely-sensed: GPP is modelled. SIF is a real-time, observed proxy

- Long-archive: Investigate temporal trends & averaged spatial relationship

Mean growing season values between 2007-2014

downscaled J. Joiner et al, 2013 retrieval: https://www.atmos-meas-tech.net/6/2803/2013/
Downscaled SIF – FLUXCOM GPP relationships

- Spatial correlation between maximum SIF and GPP
- Spatial correlation between mean SIF & GPP
- Temporal correlation between SIF and GPP during the growing period
- Temporal correlation between mean growing period SIF and GPP between years
- Temporal correlation between maximum growing period SIF and GPP between years
- Mean: average growing seasons statistics
  Max: maximum photosynthetic potential

Climate

Plant type
Spatial relationship between SIF and GPP and breakdown by climate and plant type

- Global spatial SIF-GPP relationship
- No breakdown by climate/vegetation
- Apparent substructure and features
Spatial relationship between SIF and GPP and breakdown by climate and plant type

- Can break down between climates (top)
- Can break down by vegetation cover (sides)

This separates some of the substructure

High resolution enables breakdown by both...

Mean annual SIF

Mean annual GPP
Spatial relationship between SIF and GPP and breakdown by climate and plant type
Spatial correlation

- Global spatial correlation between SIF & GPP re-expressed via map

- Each pixel shows: Above (below): spatial correlation (taken from previous figure) between mean (max) SIF & mean (max) GPP during growing season [data taken 2007-2014]

- Notable lack of correlation in tropics and continental broad-leaf forests
Temporal correlation: trend between years

- Repeat for inter-annual temporal correlation between SIF & GPP at each pixel
- Each pixel shows: Above (below): temporal correlation between mean (max) SIF & mean (max) GPP over the years 2007-2014
- Similar lack of correlation in tropics and some continental areas
Temporal correlation: during growing season

- Repeat for intra-annual temporal correlation between SIF & GPP at each pixel
- Each pixel shows the correlation between SIF and GPP within a growing season [correlation at each pixel averaged over years 2007-2014]
- SIF and GPP out of step in the tropics
Spatio-temporal comparisons

- Correlation between SIF-GPP measurements highest within a growing period (red)
- Spatial correlations higher (blue/purple) than inter-annual trends (green/yellow)
- Spatial correlations higher for non-woody plants
- Significant areas of discrepancy in SIF-GPP (particularly equatorial broad-leaf forests)
- Paper out shortly (watch this space)
SIF-GPP and climate

- Given that there is reasonably strong correlation between downscaled SIF and FLUXCOM GPP, can we observe climate stress remotely in the SIF data?

- Investigate the deviation in downscaled SIF and FLUXCOM GPP from the multi-year mean [2007-2015] in terms of the # standard deviations. Plot as a function of the deviations from the climatic mean (2001-2017)

- Ongoing study...
SIF-GPP and climate

- Deviations of (2-week) GPP measurements between 2007-2015 in terms of the deviation from the climatic conditions (temperature and soil moisture).

- Observe many expected patterns: subtropics benefit from extra moisture; Continental regions benefit from temperature rises, etc.

- Can we detect these stresses remotely...
SIF-GPP and climate

- Deviations of (2-week) downscaled SIF measurements between 2007-2015 in terms of the deviation from the climatic conditions (temperature and soil moisture)
- Lower sensitivity to many of the expected patterns, but we can detect the stresses
- Analysis ongoing
Conclusions

• Downscaled SIF serves as a useful proxy for GPP

• Using downscaled SIF we can explore limitations of the FLUXCOM GPP dataset (e.g. equatorial forests)

• The relatively fine resolution of the downscaled SIF enables a global exploration of the spatio-temporal relationship between SIF and GPP at a level that distinguishes between differing land cover types

• Slight flattening of the spatial GPP-SIF relationship at high values – could result from saturation in absorbed PAR

• Potential for downscaled SIF as an RS measurement of climatic stress

• Pre-print out soon – link will appear here!
Thank you
Selection requirements and data

- The same pixels are used in each of the spatial and temporal analyses (N=1.5m)

- The growing season is defined via the NASA Vegetation Index and Phenology, the CCI-LC defines the plant functional type, koppen-geiger defines the climate classification

- The following requirements
  - At least 10 instances of valid SIF satellite observations of the pixel within the growing season.
  - Less than 40% of the expected number of satellite observations within a growing season are missing or invalid.
  - The dominant plant functional type covers at least 75% of the pixel.
  - At least six years of valid measurements satisfying the requirements.
  - Only the first growing season of each year is considered in regions with multiple growing seasons.
Distribution of spatio-temporal correlations – categorised by climate-vegetation

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**Mean SIF-GPP relationships**

**Max SIF-GPP relationships**