Phenology and gross primary production of maize croplands from chlorophyll light absorption, solar-induced chlorophyll fluorescence and CO2 flux tower approaches

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BACKGROUND

Sun-induced fluorescence (SIF) is a novel remote sensing signal that is reemitted from active chlorophyll molecules. Using high-resolution spectrometers, we can now measure this chlorophyll fluorescence from space, which can, in turn, be used to quantify photosynthetic activity globally. The first global maps of chlorophyll fluorescence from GOSAT and GOME-2 (Joiner et al., 2011; 2013) opens the door to a new, unexplored field of research that couples remote sensing with vegetation sciences. **In this poster, we used CO2 flux observations from flux towers to calibrate SIF retrievals to estimated maize productivity, and compare it with FPARchl-based Vegetation Photosynthesis Model (VPM) and a process-based terrestrial biosphere model (SCOPE) .**

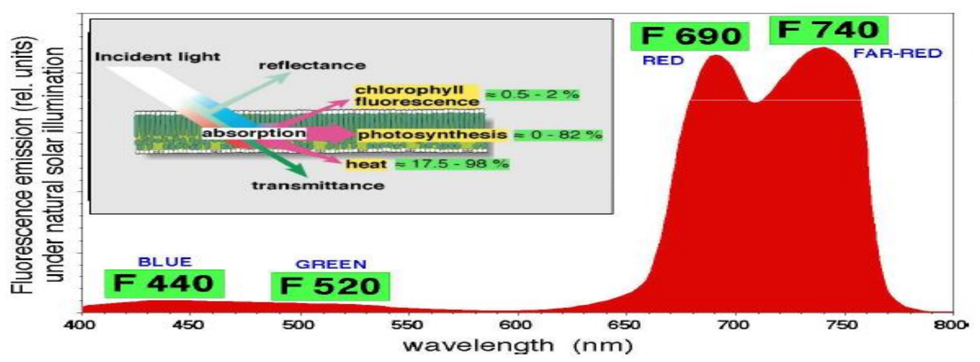


Fig. 1. The fate of light within leaves. Light energy absorbed by chlorophylls of photosystems can be used to drive photochemistry. Alternatively, absorbed light energy can be lost as chlorophyll fluorescence or as heat (FLEX).

MATERIALS & METHODS

Flux tower based GPP estimates covering the period of 2007–2011 were extracted from three cropland sites at Mead, Nebraska, USA. The sites are spatially homogeneous which enable direct comparisons with the SIF observations. Two sites (USNe2 and USNe3) were calibrated between GPP and SIF for maize (Fig.2c), and the third site (USNe1) was used to evaluate the performances, and compared to VPM and SCOPE model simulations.

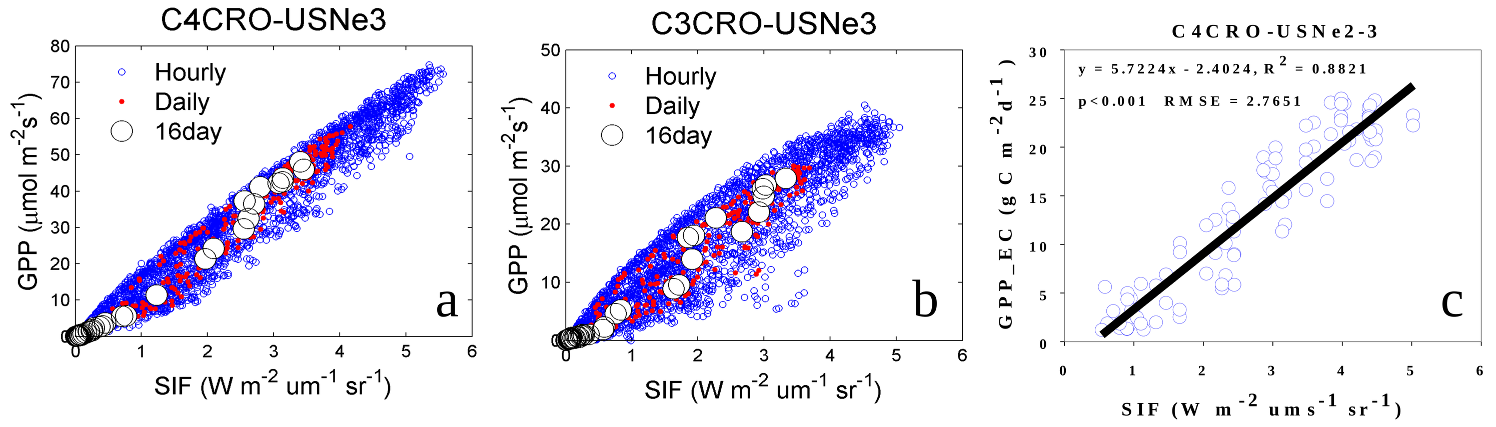


Fig. 2. Relationships between GPP and SIF: A) and B) from SCOPE simulations; C) from flux tower measurements and GOME-2 observations.

The VPM is a satellite-based production efficiency model and it estimates GPP as follows (Xiao et al., 2004):

$$GPP_{VPM} = \varepsilon_g \times FPAR_{chl} \times PAR$$

where LUE (ε_g) was down-regulated by temperature (T_{scalar}) and water stress (W_{scalar}) from satellite-derived LSWI as:

$$\varepsilon_g = \varepsilon_0 \times T_{scalar} \times W_{scalar}$$

$$T_{scalar} = \frac{(T - T_{min})(T - T_{max})}{[(T - T_{min})(T - T_{max})] - (T - T_{opt})^2}$$

$$W_{scalar} = \frac{1 + LSWI}{1 + LSWI_{max}}$$

$FPAR_{chl}$ is estimated from EVI for the Mead irrigated site (USNe1) according to *Zhang et al. (2015)*:

$$FPAR_{chl} = 1.30 \times (EVI - 0.14) \qquad EVI > 0.14$$

$$FPAR_{chl} = 0 \qquad EVI <= 0.14$$

MATERIALS & METHODS

We also used a process-based coupled photosynthesis-fluorescence model, Soil Canopy Observation of Photosynthesis and the Energy balance (SCOPE), to model maize GPP by assimilating satellite observations of SIF from GOME-2. The assimilation is through a key control parameter of photosynthesis model, the maximum rate of carboxylation (V_{cmax}) . Seasonally-varied V_{cmax} was retrieved, and then used to simulate GPP with SCOPE.

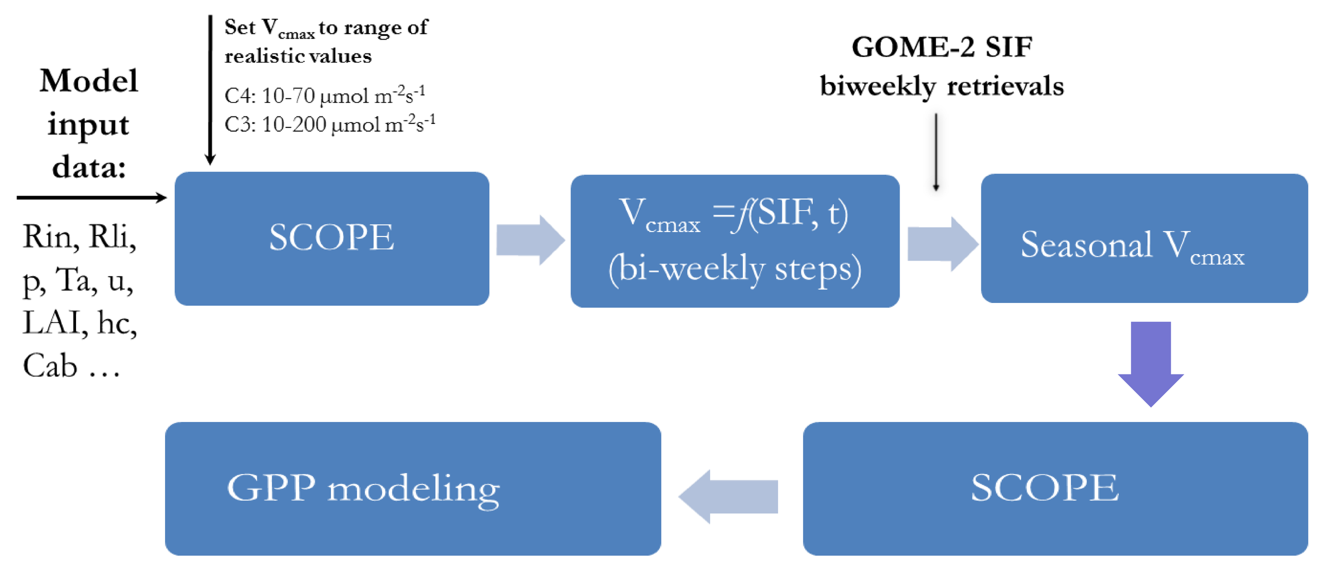
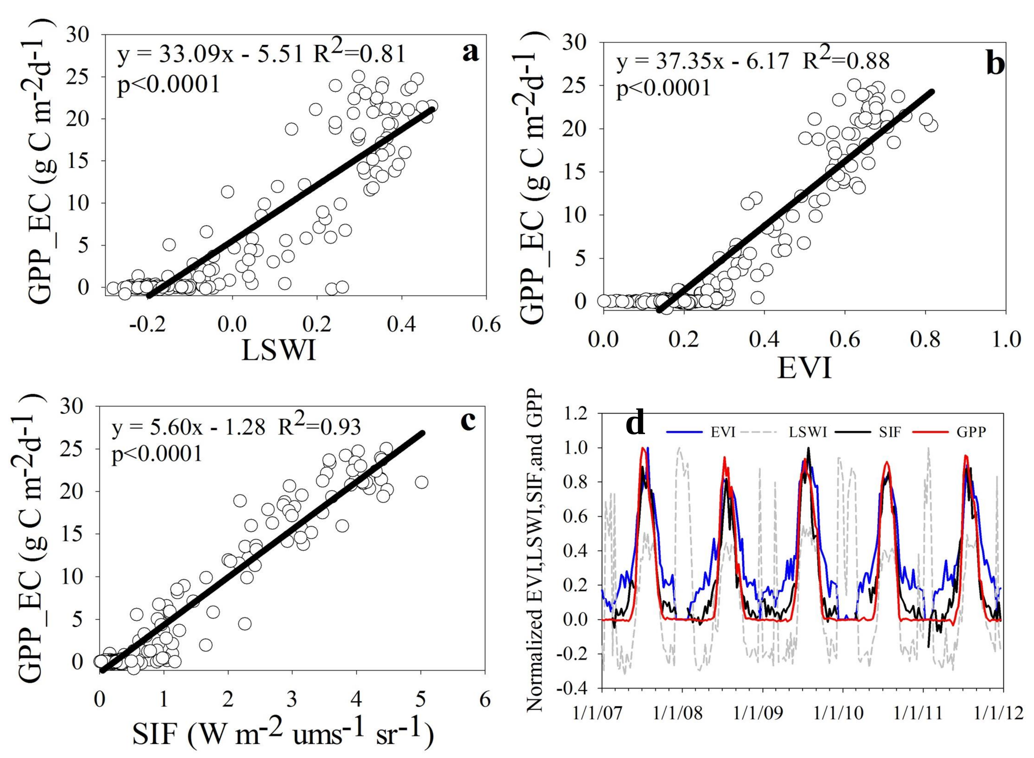


Fig. 3. Assimilating satellite SIF observations into SCOPE to model maize GPP.

RESULTS

Fig.4c show stronger linear relation between maize GPP_EC and SIF. While LSWI and EVI showed more curvilinear relationships with GPP and saturated at higher values (Fig. 4a and b).

Meanwhile, SIF did a better job than reflectance-based vegetation indices for crop phenology (Fig. 4d).



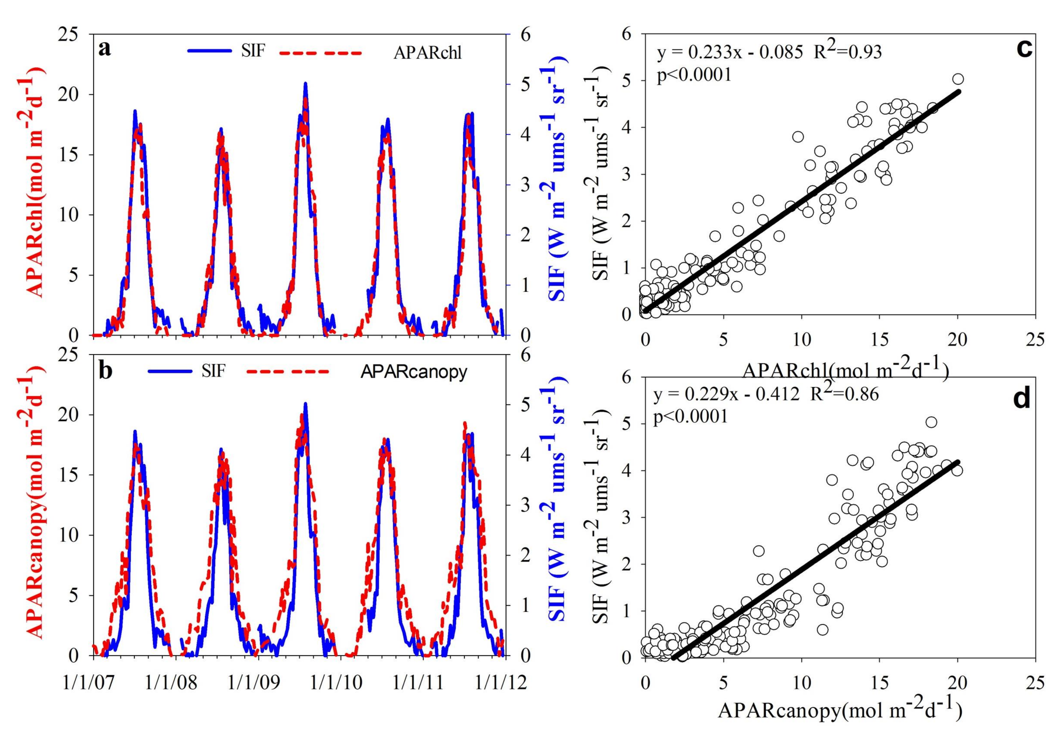


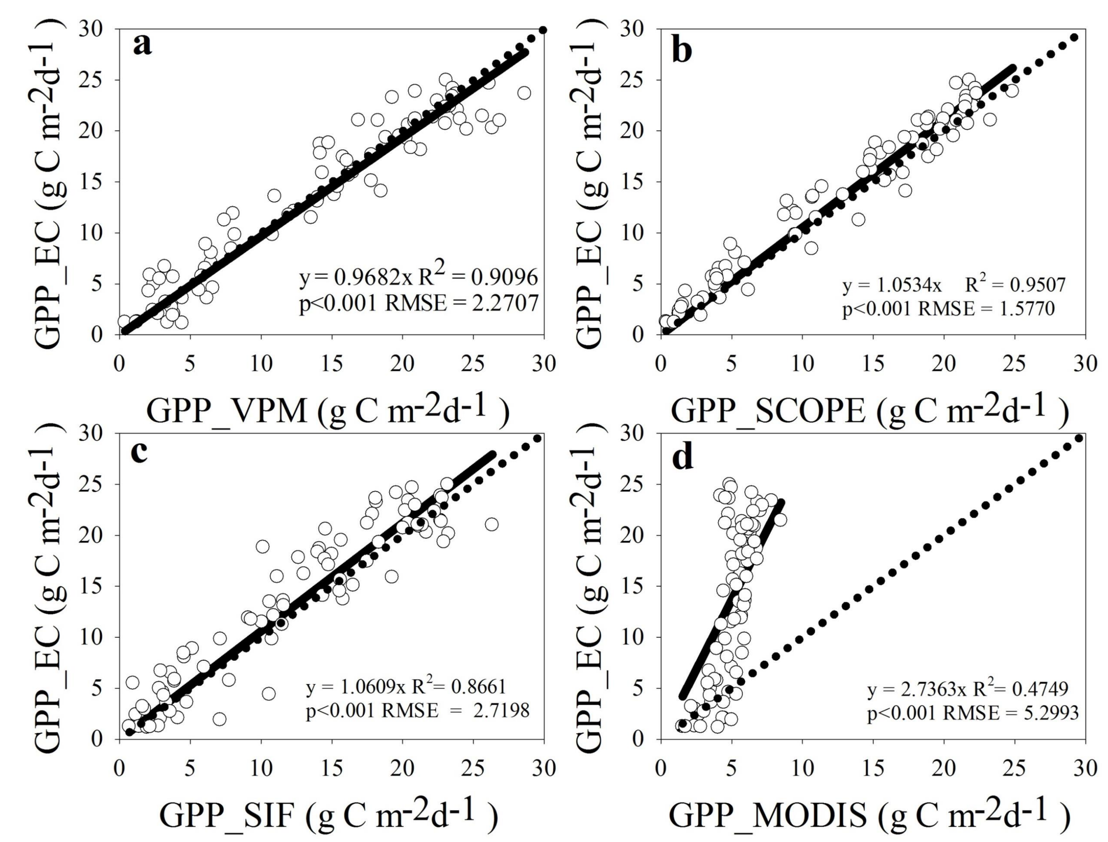
Fig.5 show that the seasonality of SIF was more consistent with $APAR_{chl}$.

The comparisons of $APAR_{canopy}$ and $APAR_{chl}$ with SIF suggested that space-borne SIF is more related to PAR absorbed by photosynthetic pigments and leaf chlorophyll.

RESULTS & CONCLUSIONS

Fig.6 shows that the three approaches (VPM, SCOPE and SIF) were highly consistent in their predictions of the seasonal dynamics and magnitude of GPP compared to tower-based GPP_EC.

There are higher positive correlations with GPP_EC (R^2 > 0.85) compared to the correlation between GPP_MODIS and GPP_EC (R^2 = 0.47).



CONCLUSIONS

- The new space-borne SIF observations can identify crop phenology compared to in situ GPP, indicating an additional way to monitor seasonal dynamics of vegetation photosynthesis.
- SIF is more related to PAR absorbed by photosynthetic pigments and leaf chlorophyll ($APAR_{chl}$) than that $APAR_{canopy}$.
- The results suggest that the new SIF can not only be used directly for maize GPP estimation without climatic ancillary information, but also to constrain process-based models for improving GPP modeling.

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