Uncertainties in estimates of fAPAR for photosynthesis ($fAPAR_{PSN}$) when approximated with $fAPAR_{canopy}$, NDVI and EVI

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MODIS Science Team Meeting, June 6-10, 2016

Outline

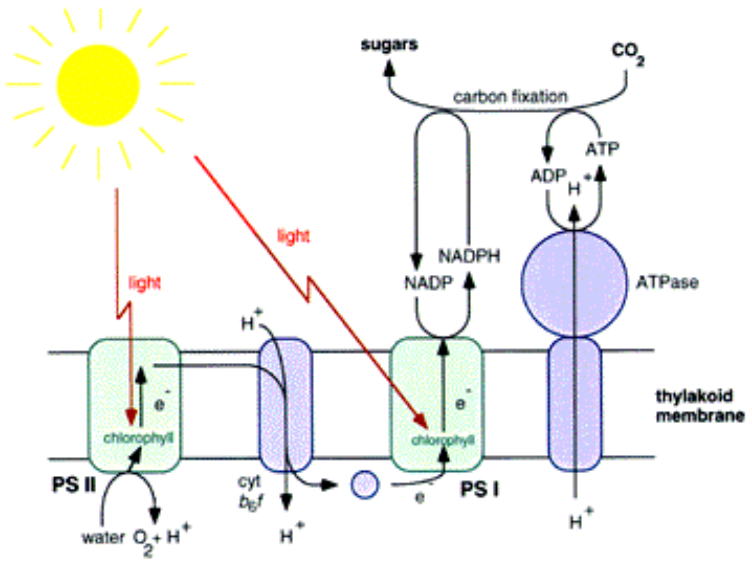
- **Introduction to the retrieval algorithm**:

The advanced Radiative Transfer Model: Leaf Level, Canopy Level, and Pixel Level

Retrievals: Cover fractions of vegetation, soil, snow and surface water, and fAPARs ($fAPAR_{canopy}$, $fAPAR_{PV}$, $fAPAR_{NPV}$)

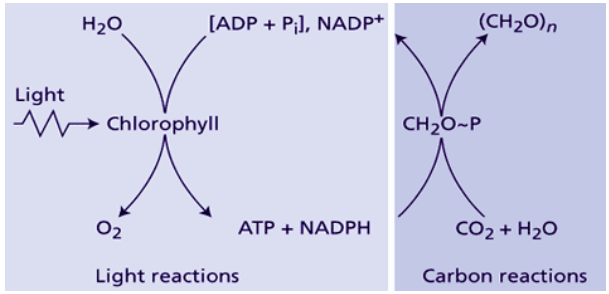
- **Prototype Product Development with Hyperion images**
- **Product Development with MODIS images and uncertainties in various estimates of fAPAR for photosynthesis ($fAPAR_{PSN}$)**
- **Summary**

Advanced radiative transfer model



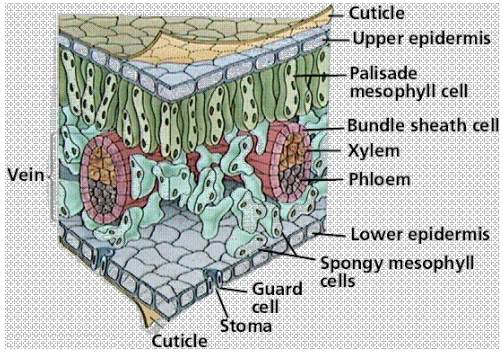
light energy

$6\ CO_2 + 12\ H_2O \Rightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O$



http://photoscience.la.asu.edu/photosyn/education/photointro.html

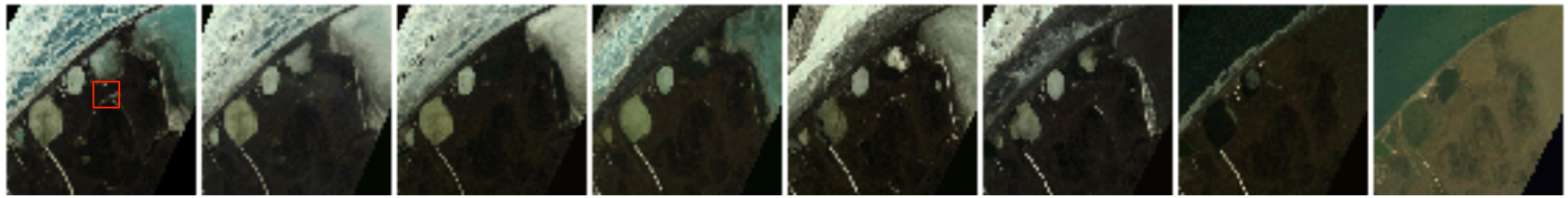
Only the PAR absorbed by chlorophyll of the canopy, not the PAR absorbed by the foliage or by the entire canopy, is potentially available for photosynthesis.

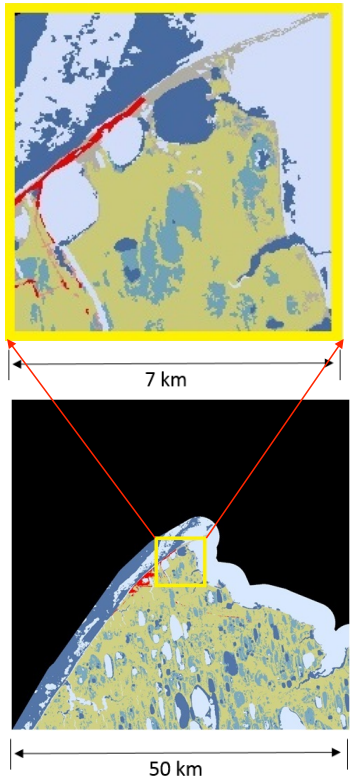


A leaf contains PV (i.e., chl), and NPV components, including non-photosynthetic pigments, cell walls, veins, etc.

Advanced radiative transfer model

2013	2013	2013	2012	2011	2008	2010	2009
163	168	171	172	173	175	189	201





NLCD Land Cover Classification Legend

- 11 Open Water
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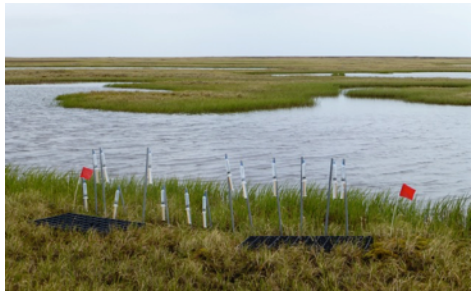
- 73 Lichens*
- 74 Moss*
- 81 Pasture/Hay
- 82 Cultivated Crops
- 90 Woody Wetlands
- 95 Emergent Herbaceous Wetlands

* Alaska only



July 12, 2013

Aug 22, 2011

Aug 30, 2014

Sept 25, 2011

http://ngee-arctic.blogspot.com/

NLCD 2001 land cover map (center: the US-Brw site)

Advanced RTM vs. traditional RTM for fAPAR retrieval

Traditional RTM	Our Advanced RTM
Consider only Canopy and Soil	Considers canopy, Soil, **Snow, and Surface Water.** Therefor, it also works for critical regions (High Latitude regions, ABoVE, HMA, coastal regions, wetlands, etc) and critical time periods (winter).
Need plant functional type/land cover type as input for retrieval	Does not need
Assume that leaf optics of each type is fixed anywhere and anytime, and pre-determined	Leaf optics is retrieved for each observation since leaf components (chlorophyll, dry matter, etc.) change seasonally and spatially even for same type
Retrieve $fAPAR_{canopy}$	Retrieves $fAPAR_{canopy}$, $fAPAR_{chl}$ (i.e., $fAPAR_{PV}$ or $fAPAR_{PSN}$) and $fAPAR_{NPV}$

Advanced radiative transfer model

$$fAPAR_{canopy} = fAPAR_{PV} + fAPAR_{NPV}$$

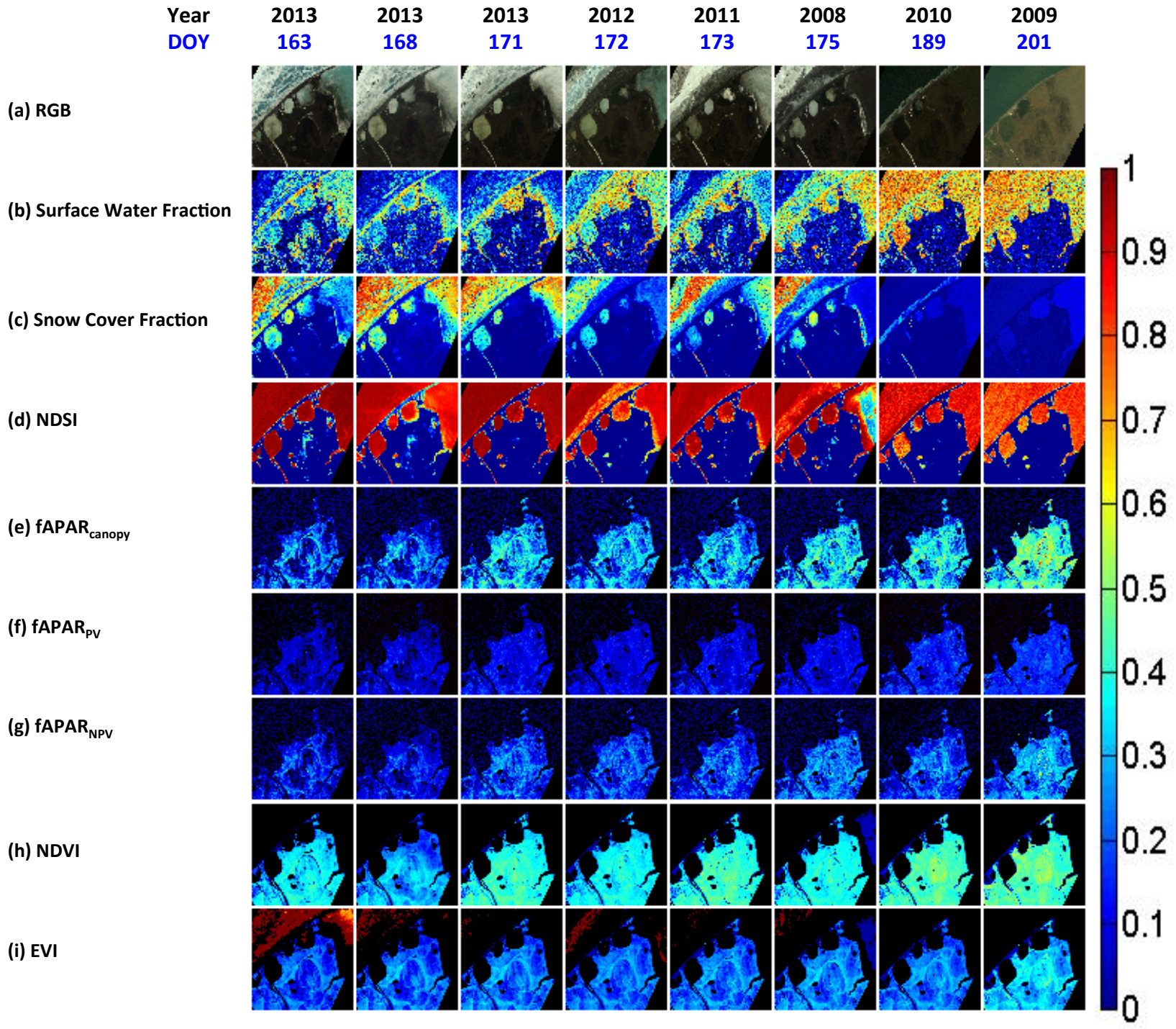
$$fAPAR_{PV} = fAPAR_{chl}$$

$$fAPAR_{NPV} = fAPAR_{brown\ pigment} + fAPAR_{dry\ matter} + fAPAR_{stem}$$

$$NDVI = \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + \rho_{red}}$$

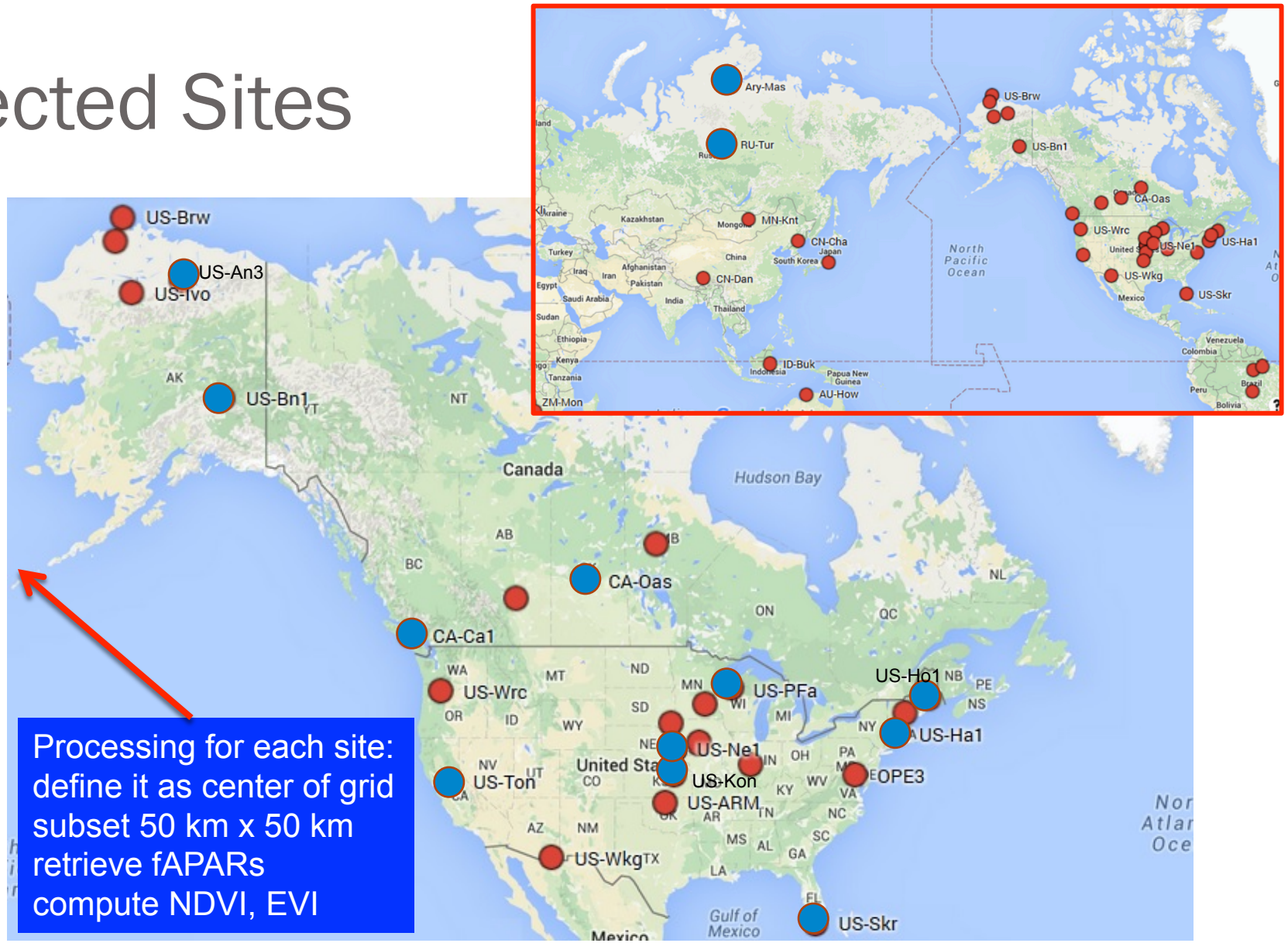
$$EVI = 2.5 \times \frac{\rho_{NIR} - \rho_{red}}{1 + \rho_{NIR} + 6 \times \rho_{red} - 7.5 \times \rho_{blue}}$$

$$NDSI = \frac{\rho_{green} - \rho_{SWIR}}{\rho_{green} + \rho_{SWIR}}$$


Year
DOY
2013
163
2013
168
2013
171
2012
172
2011
173
2008
175
2010
189
2009
201
(a) RGB
(b) Surface Water Fraction
(c) Snow Cover Fraction
(d) NDSI
(e) fAPAR$_{canopy}$
(f) fAPAR$_{PV}$
(g) fAPAR$_{NPV}$
(h) NDVI
(i) EVI
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

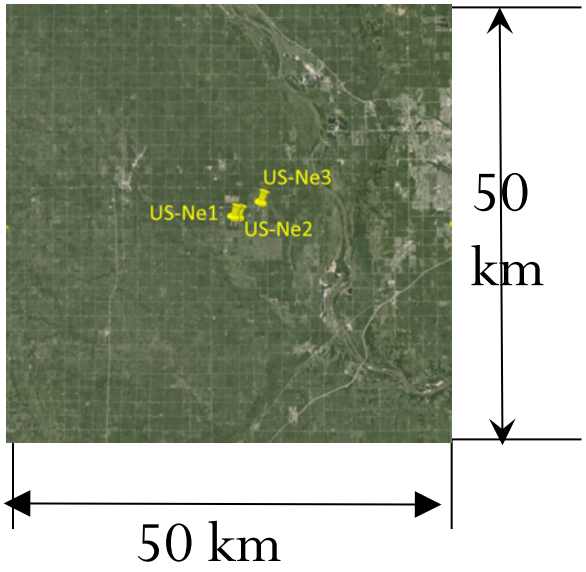
Selected Sites

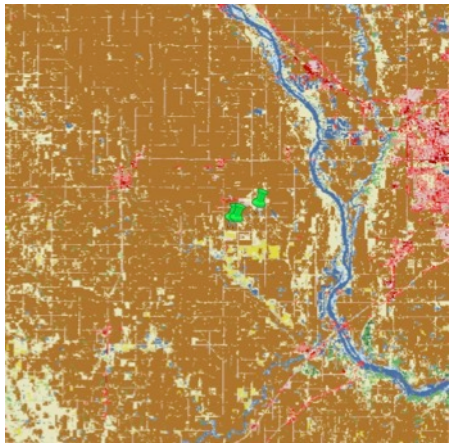
Site Code
US-Ne1
US-Ha1
US-Brw
US-An3
US-Prr
US-Bn1
Ary-Mas
US-Kon
US-Ho1
US-PFa
US-Skr
US-Ton
CA-Ca1
CA-Oas
RU-Tur



Go to Summary

Study area: 50 km x 50 km surrounding the US-Ne1 crop flux tower site (US-Ne1) in Nebraska



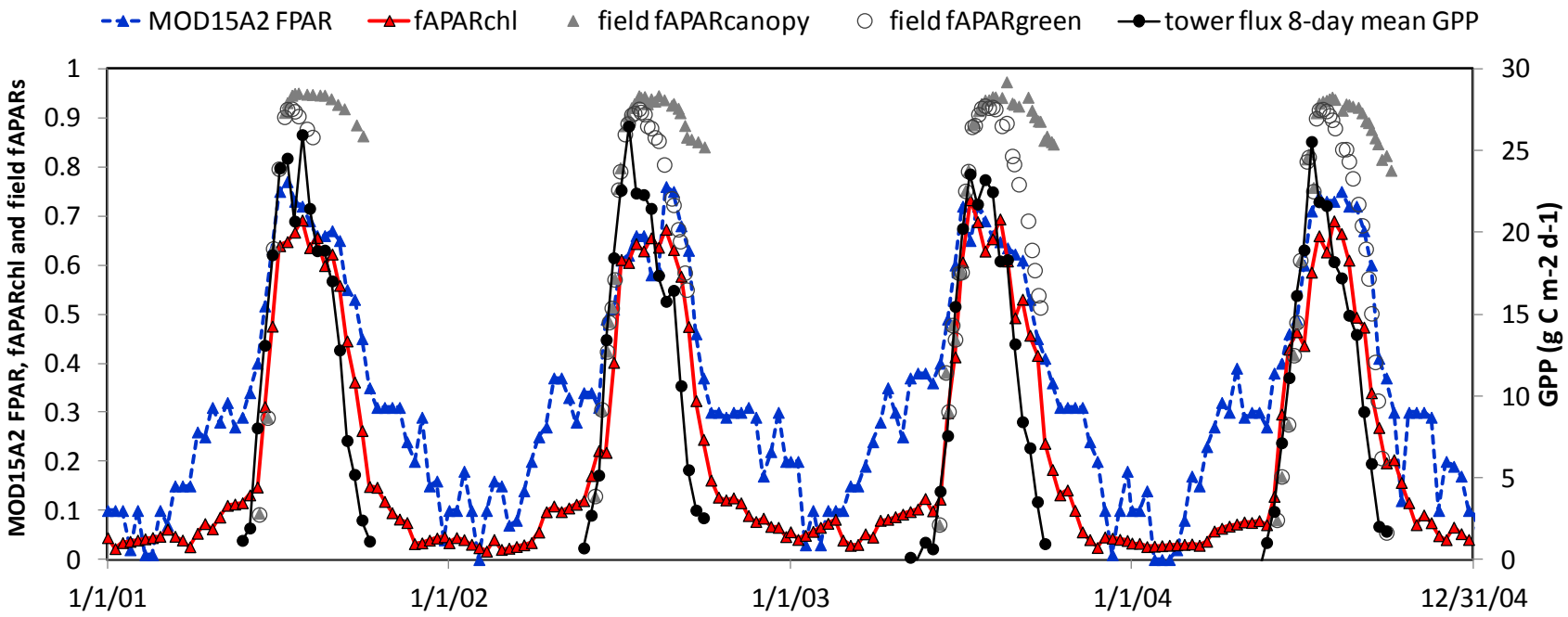


NLCD 2006

2006 NLCD Class (center: Nebraska US-Ne1)	Percent(%)
71 Grassland/Herbaceous	12.16
82 Cultivated Crops	70.95

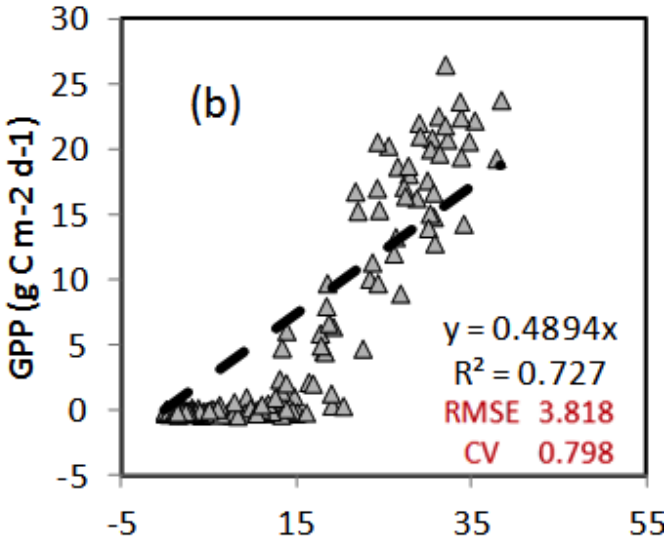
There are three crop flux tower sites in this study area. We pick up US-Ne1 as the center of this area

US-Ne1: field measurements, RTM retrievals and tower GPP from 2001 – 2004

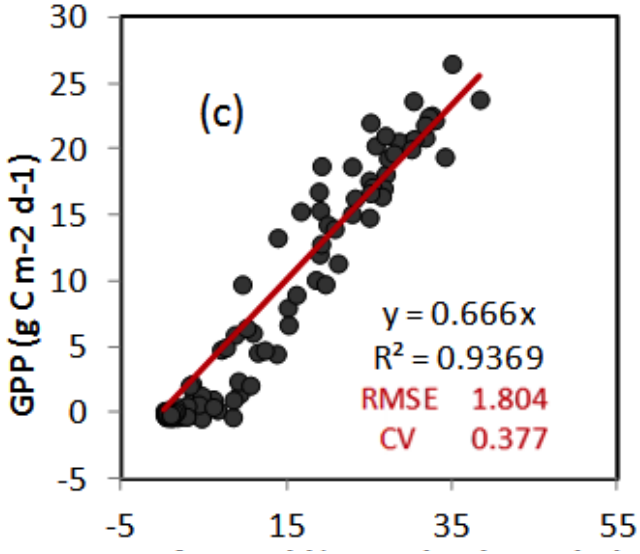


- Retrieved $fAPAR_{chl}$ matches well with tower GPP while MOD15A2 FPAR does not.
- MOD15A2 FPAR does not agree well with field $fAPAR_{canopy}$. It has earlier green-up and late fall-off, compared to tower GPP, $fAPAR_{chl}$, and field $fAPAR_{canopy}$. It overestimates field $fAPAR_{canopy}$ in spring and fall, but underestimates field $fAPAR_{canopy}$ in summer.

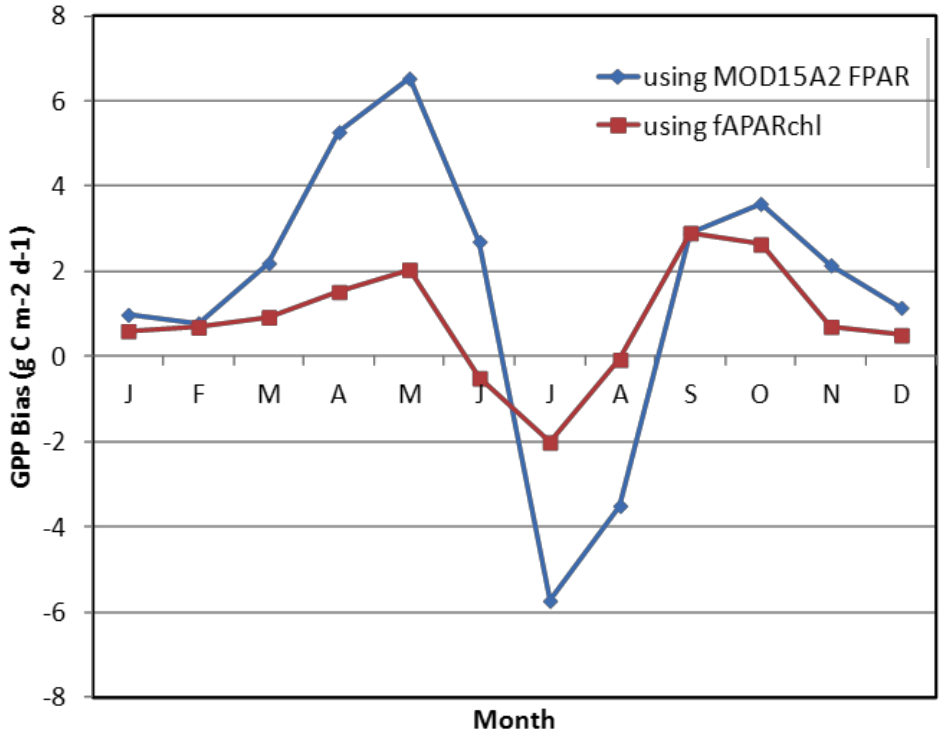
US-Ne1: GPP estimation performance with MOD15A2 FPAR vs. fAPARchl



(MOD15A2 FPAR)*PPFD (mol m-2 d-1)

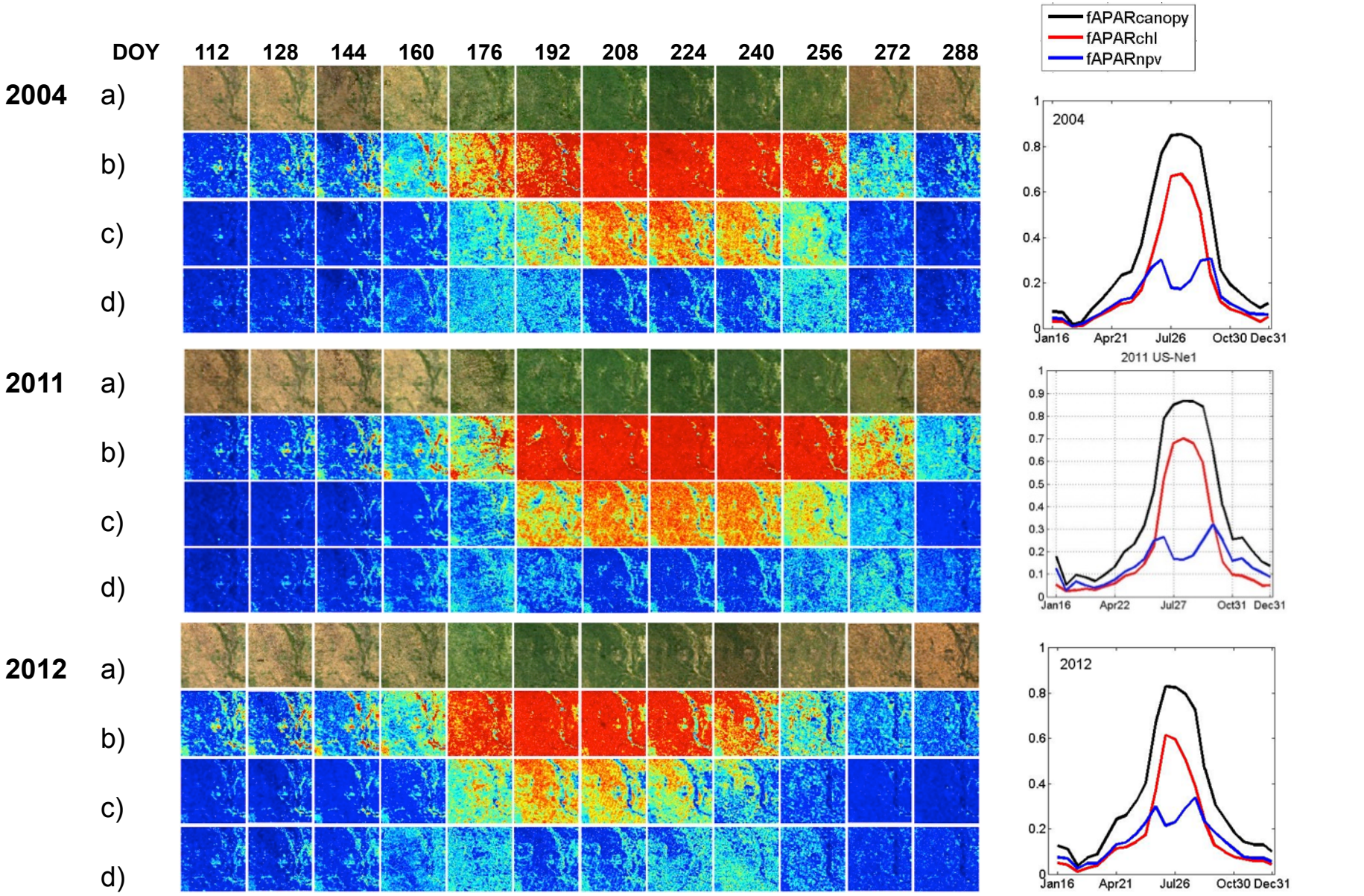


$fAPAR_{chl}$*PPFD (mol m-2 d-1)



Positive bias (overestimation) was observed in spring and fall. Negative bias (underestimation) was observed in summer. By replacing MOD15A2 FPAR with $fAPAR_{chl}$, biases were reduced.

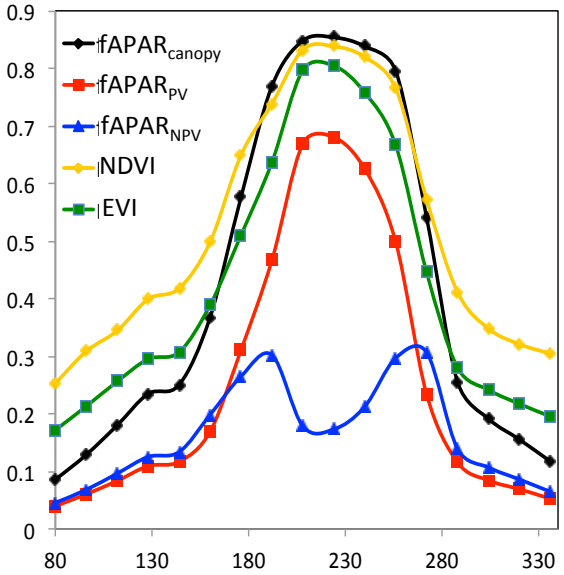
Study area: 50 km x 50 km surrounding the US-Ne1 crop flux tower site (US-Ne1) in Nebraska

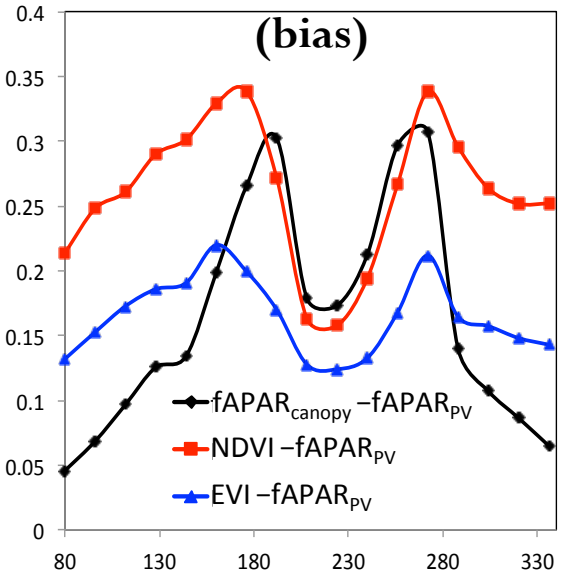


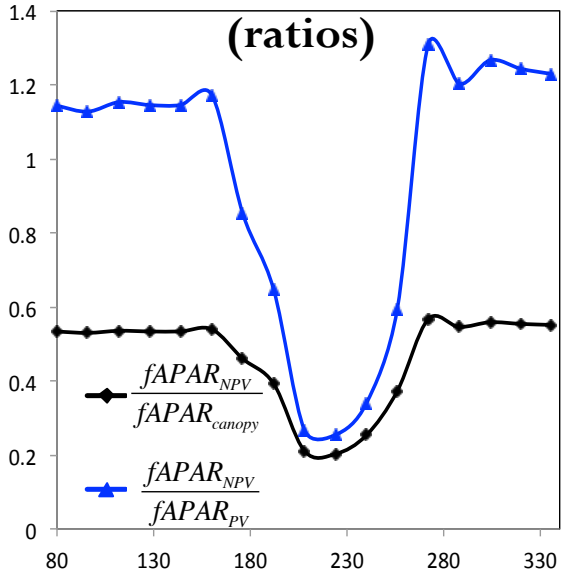
a) RGB images , b) maps of $fAPAR_{canopy}$, c) maps of $fAPAR_{PV}$, and d) maps of $fAPAR_{NPV}$.

return

2004 US-Ne1





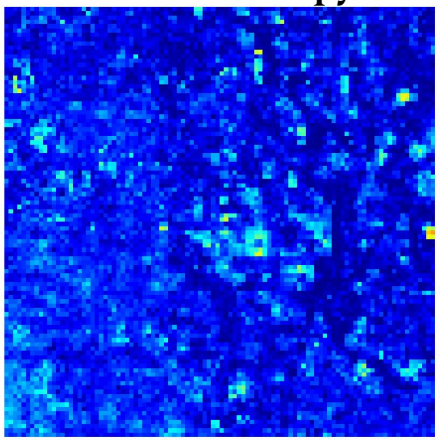


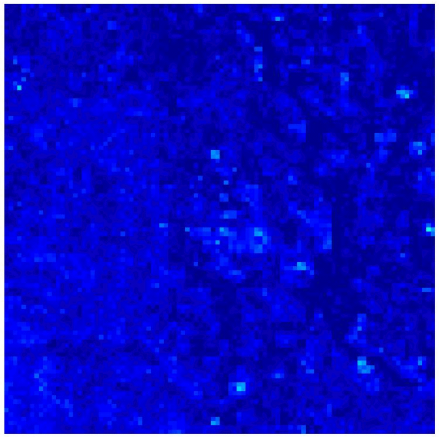
- Bias from fAPAR$_{canopy}$ quantitatively equals to fAPAR$_{NPV}$. Bias from NDVI is (NDVI-fAPAR$_{PV}$) and bias from EVI is (EVI-fAPAR$_{PV}$).
- From May to October, maximum bias comes from NDVI, then fAPAR$_{canopy}$, then EVI.
- During peak of growing season, minimum bias from fAPAR$_{canopy}$, NDVI and EVI were 0.17, 0.15 and 0.12, respectively.
- During peak of growing season, minimum ratio of fAPAR$_{NPV}$/fAPAR$_{canopy}$ is 0.2, and the ratio of fAPAR$_{NPV}$/fAPAR$_{PV}$ is 0.25.

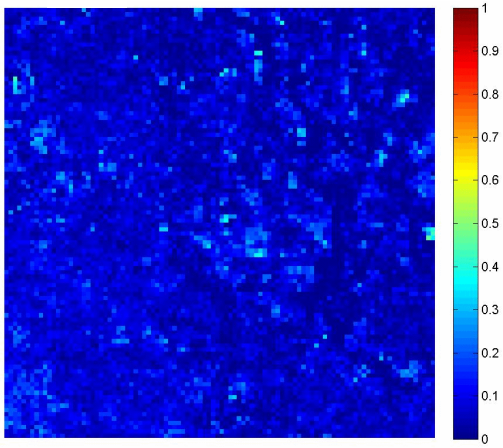
Movie 1

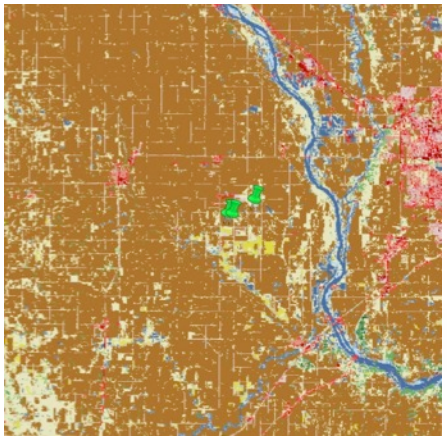
US-Ne1: 2004 016

$fAPAR_{canopy}$ $fAPAR_{PV}$ $fAPAR_{NPV}$









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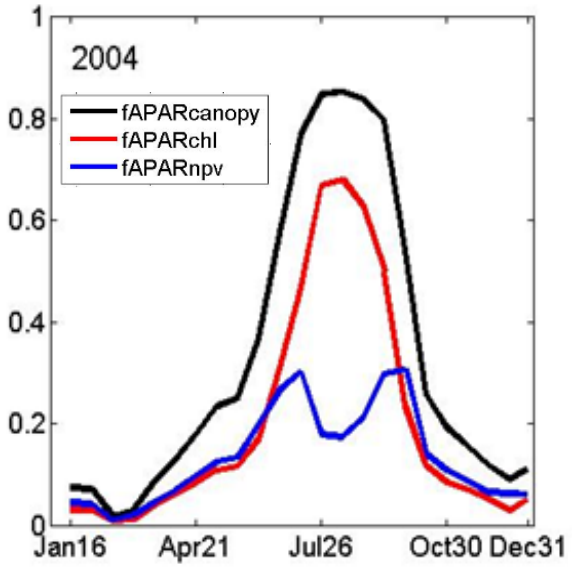
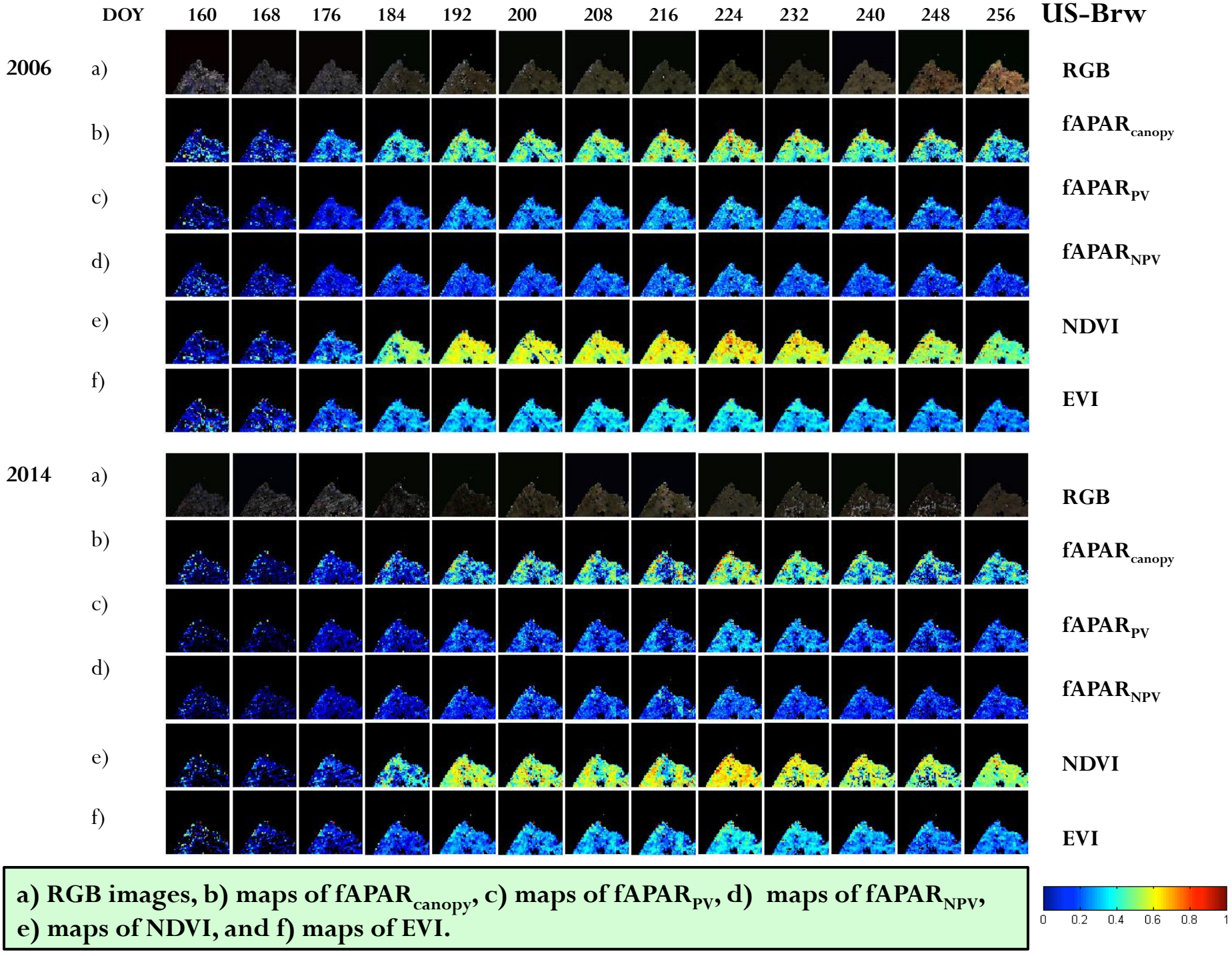


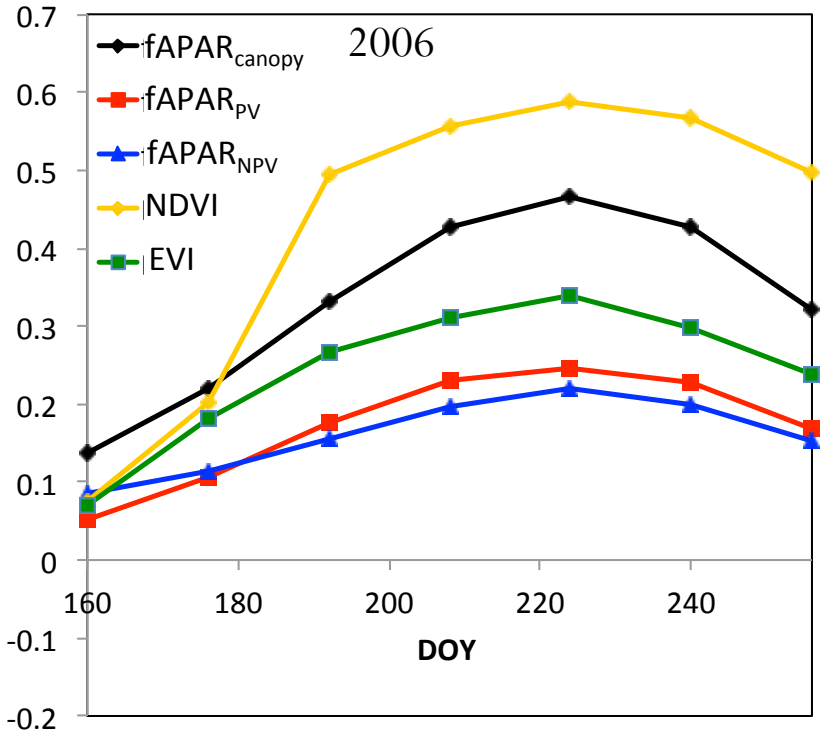
return

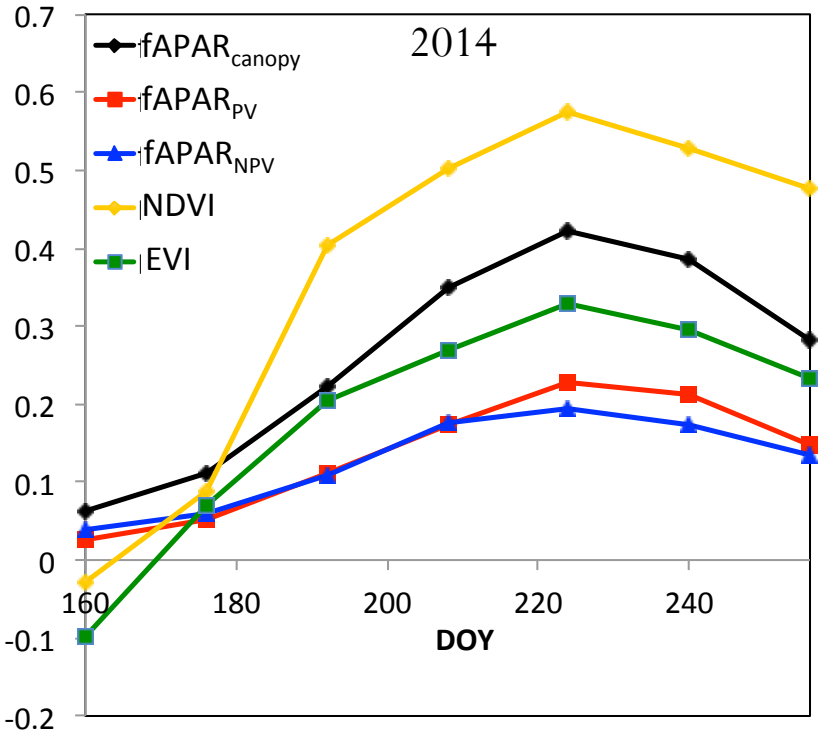


a) RGB images, b) maps of $fAPAR_{canopy}$, c) maps of $fAPAR_{PV}$, d) maps of $fAPAR_{NPV}$, e) maps of NDVI, and f) maps of EVI.

US-Brw

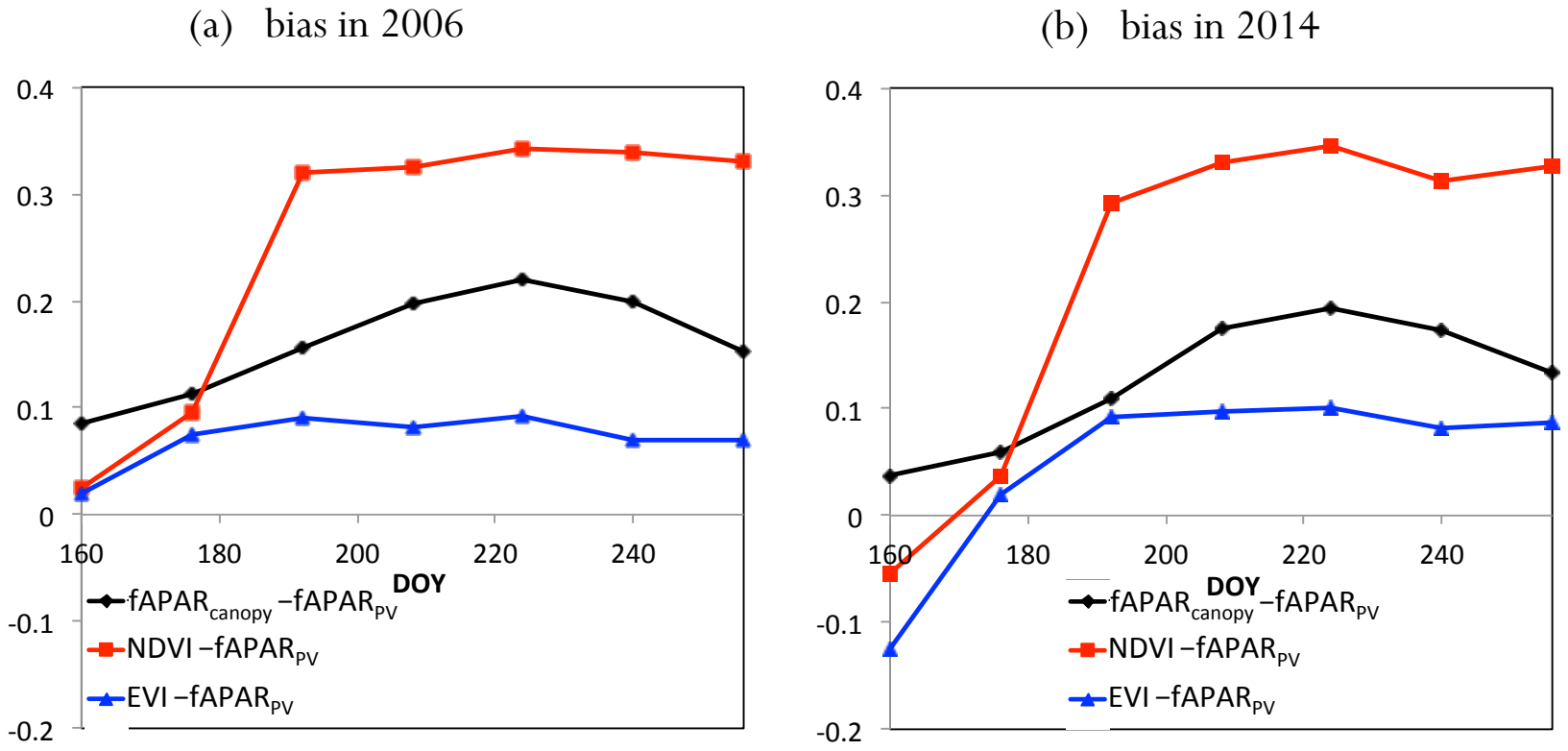
Overall seasonal profiles





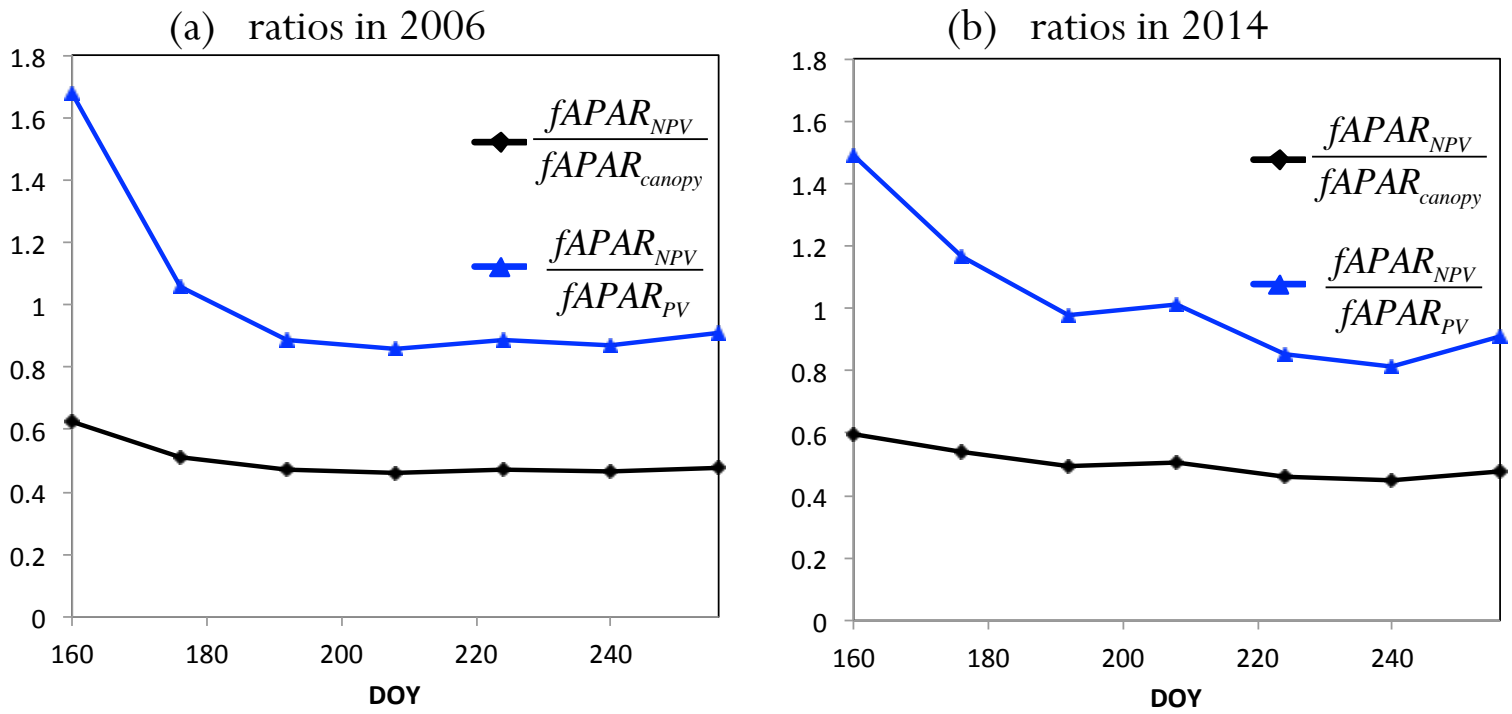
- **NDVI and EVI could be negative for some MODIS pixels of this area**
- **During peak of growing season, NDVI>fAPAR$_{canopy}$>EVI>fAPAR$_{PV}$>fAPAR$_{NPV}$**
- **fAPAR$_{PV}$ maximum value is about 0.24, NDVI 0.6, fAPAR$_{canopy}$ 0.47, EVI 0.35, fAPAR$_{NPV}$ 0.21**
- **In contrast to crop site US-Ne1, during growing season, fAPAR$_{NPV}$ increases with fAPAR$_{PV}$ until peak of growing season and decreases with fAPAR$_{PV}$ after.**

Biases



- **Bias from fAPAR$_{canopy}$ quantitatively equals to fAPAR$_{NPV}$. Red lines represent bias from NDVI and blue lines represent bias from EVI**
- **The biases change seasonally**
- **The bias from fAPAR$_{canopy}$ ranges from ~0.09 – 0.21, bias with NDVI can reach 0.35, bias with EVI can reach 0.1**

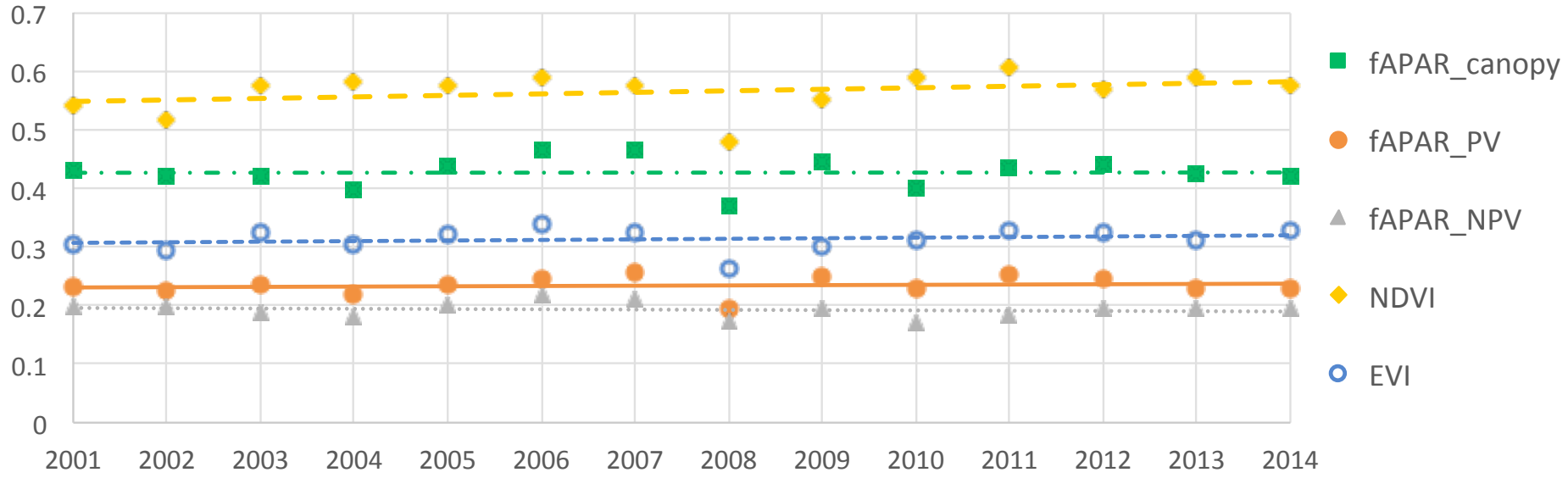
Ratios



- **The ratio of $fAPAR_{NPV}/fAPAR_{canopy}$ > 40% for whole growing season**
- **The ratio of $fAPAR_{NPV}/fAPAR_{PV}$ >80% in July and August**

US-Brw

Long term trend:



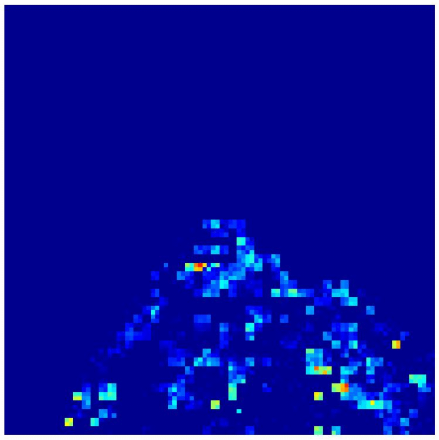
- **NDVI: increasing**
- **EVI: very slightly increasing**
- **$fAPAR_{canopy}$: flat**
- **$fAPAR_{PV}$:flat**
- **$fAPAR_{NPV}$:flat**
- **IF long-term NDVI is increasing, it does not necessarily mean it becomes greener or has greater photosynthetic capacity**

Movie 2

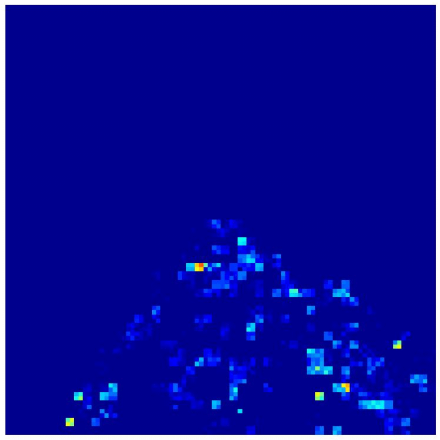
2001 160

US-Brw

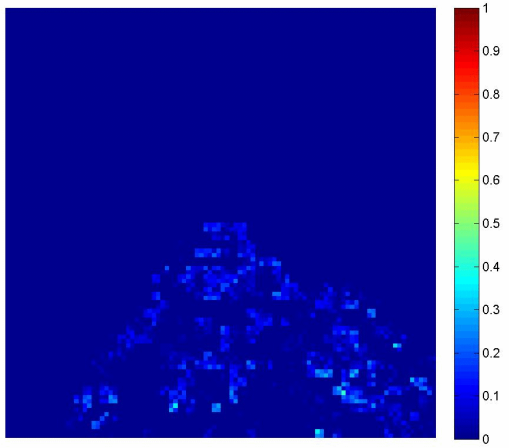
fAPARcanopy



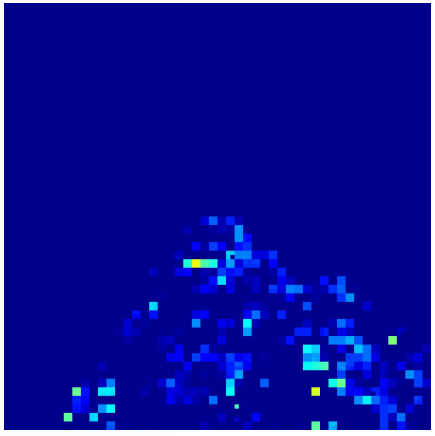
$fAPAR_{PV}$



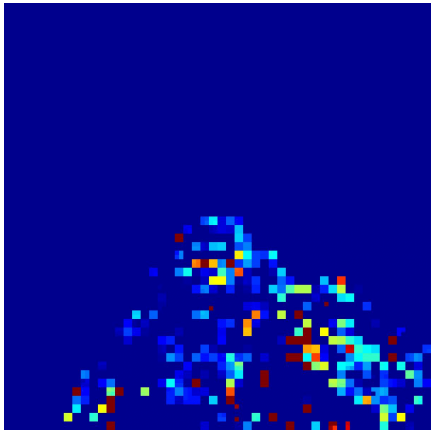
$fAPAR_{NPV}$

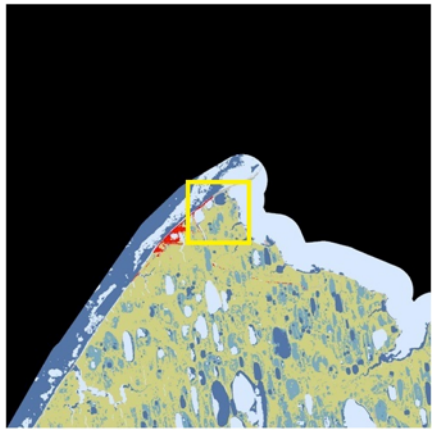


NDVI



EVI





return

Summary

- Uncertainties in estimates of fAPAR for photosynthesis are significant when approximated with $fAPAR_{canopy}$, NDVI and EVI
- The uncertainties change with plant functional types, spatially and temporally
- During peak of plant growing season, the $fAPAR_{NPV}$ can be as much as 20% - 50% of $fAPAR_{canopy}$, and 25% - 100% of $fAPAR_{PV}$.
- Shape of seasonal $fAPAR_{NPV}$ profile changes with plant functional types (US-Ne1 has a unique bi-modal shape)
- The algorithm can be modified for VIIRS to produce the $fAPAR_{canopy}$, $fAPAR_{PV}$ and $fAPAR_{NPV}$ products.
- Long term trend of NDVI might be different from long term trends of $fAPAR_{canopy}$, $fAPAR_{PV}$ and/or $fAPAR_{NPV}$. What should be used to indicate long term trends?

Thank you!