SNPP VIIRS Green Vegetation Fraction Validated Maturity Review

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Outline

- Team members
- Algorithm/product description
- Product requirements
- JPSS data products maturity definition
- Evaluation of algorithm performance to specification requirements
- Identification of processing environment
- Users & user feedback
- Documentations (science maturity check list)
- Conclusion
- Path forward
- References
- Appendix

JPSS GVF Team Members

Name	Organization	Roles and Responsibilities
Marco Vargas	NOAA STAR	GVF Algorithm Lead
Zhangyan Jiang	NOAA STAR/IMSG	Algorithm and Cal/Val Support
Mingshi Chen	NOAA STAR/IMSG	Algorithm and Cal/Val Support
Ivan Csiszar	NOAA STAR	STAR Land Team Lead
Michael Ek	NOAA NCEP/EMC	User readiness
Yihua Wu	NOAA NCEP/EMC	User readiness
Weizhong Zheng	NOAA NCEP/EMC	User readiness
Hanjun Ding	NOAA OSPO	PAL
Walter Wolf	NOAA STAR	STAR ASSISTT Team Lead
Valerie Mikles	NOAA STAR IMSG	STAR ASSISTT QA
Qiang Zhao	NOAA STAR IMSG	STAR ASSISTT Land Support

SNPP VIIRS Green Vegetation Fraction Algorithm/Product

SNPP VIIRS Green Vegetation Fraction (GVF) Algorithm

– VIIRS GVF algorithm is a modified version of Gutman and Ignatov's (1998) GVF algorithm
– VIIRS GVF algorithm uses VIIRS I1, I2 and M3 surface reflectance bands as input
– VIIRS GVF is derived form EVI

The Enhanced Vegetation Index (EVI)

$$EVI = G \frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{red}}}{\rho_{\mathrm{NIR}} + C_1 \cdot \rho_{\mathrm{red}} - C_2 \cdot \rho_{\mathrm{blue}} + 1}$$

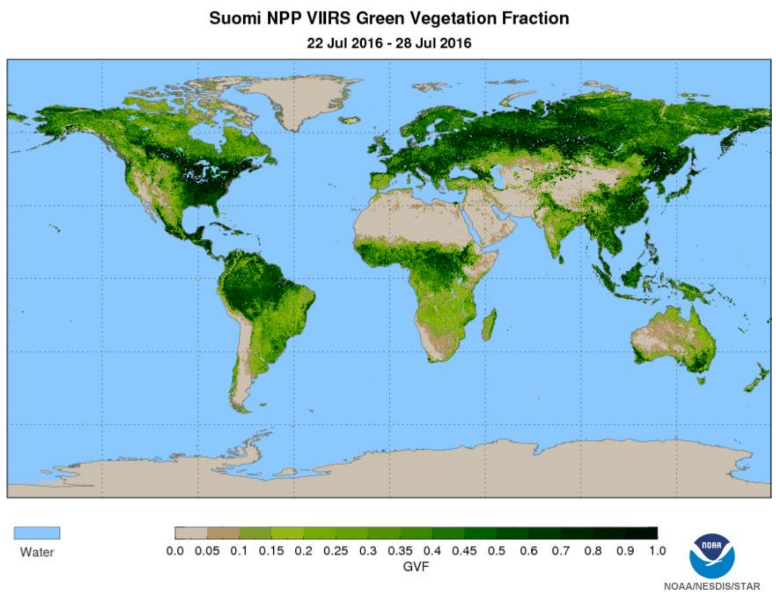
The Green Vegetation Fraction

$$GVF = \frac{EVI - EVI_0}{EVI_\infty - EVI_0}$$

NDE SNPP VIIRS GVF Output

1. *Weekly Global GVF 4-km resolution*
2. *Weekly Regional GVF 1-km resolution*
   (Lat 7.5°S to 90°N, Lon 130°E to 30°E)

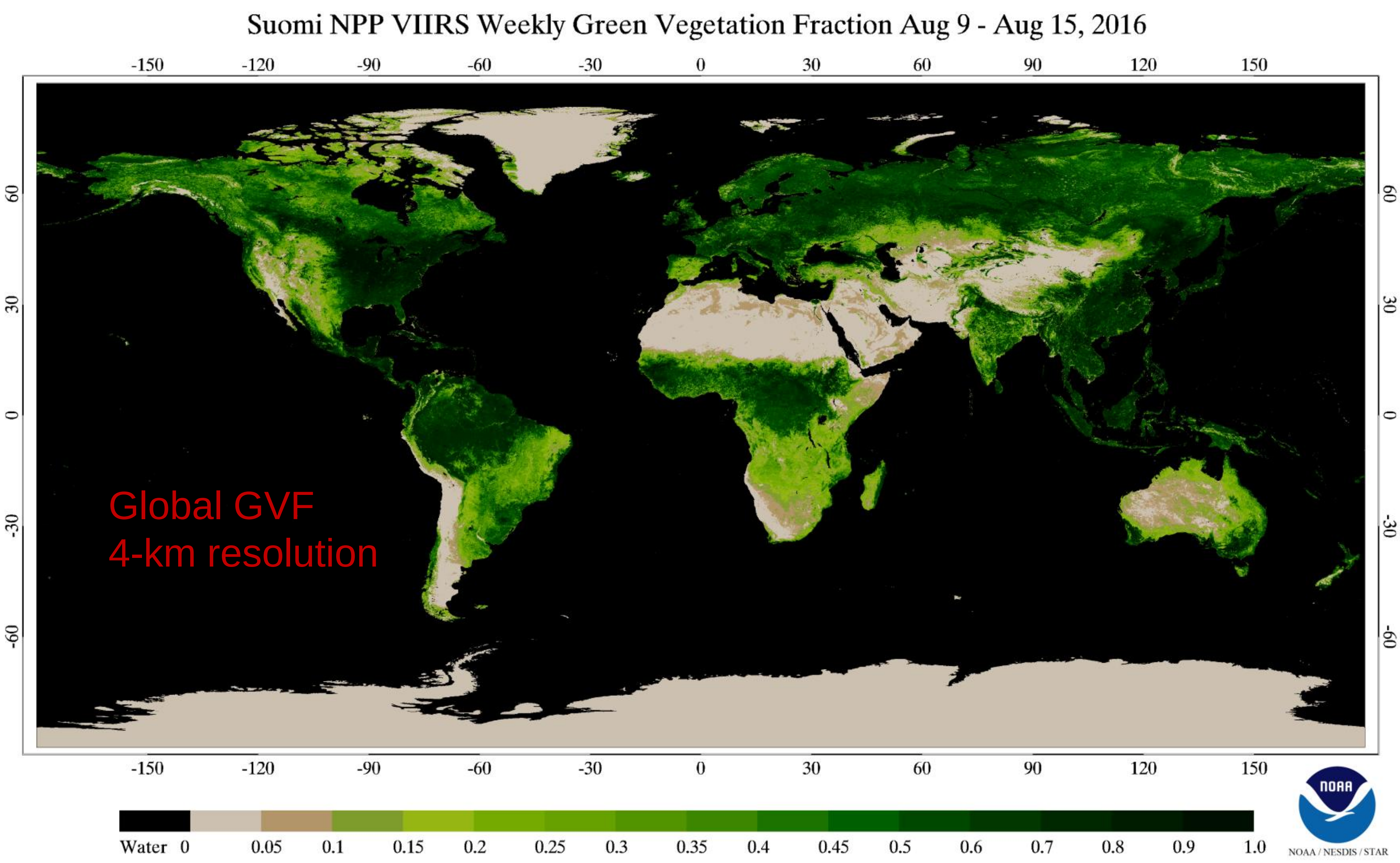
– Weekly (updated daily) GVF products
– Projection: Lat/Lon
– Output file format: NetCDF4
– VIIRS GVF available at NOAA/CLASS



GVF Useful Parameter for Biogeophysical Models

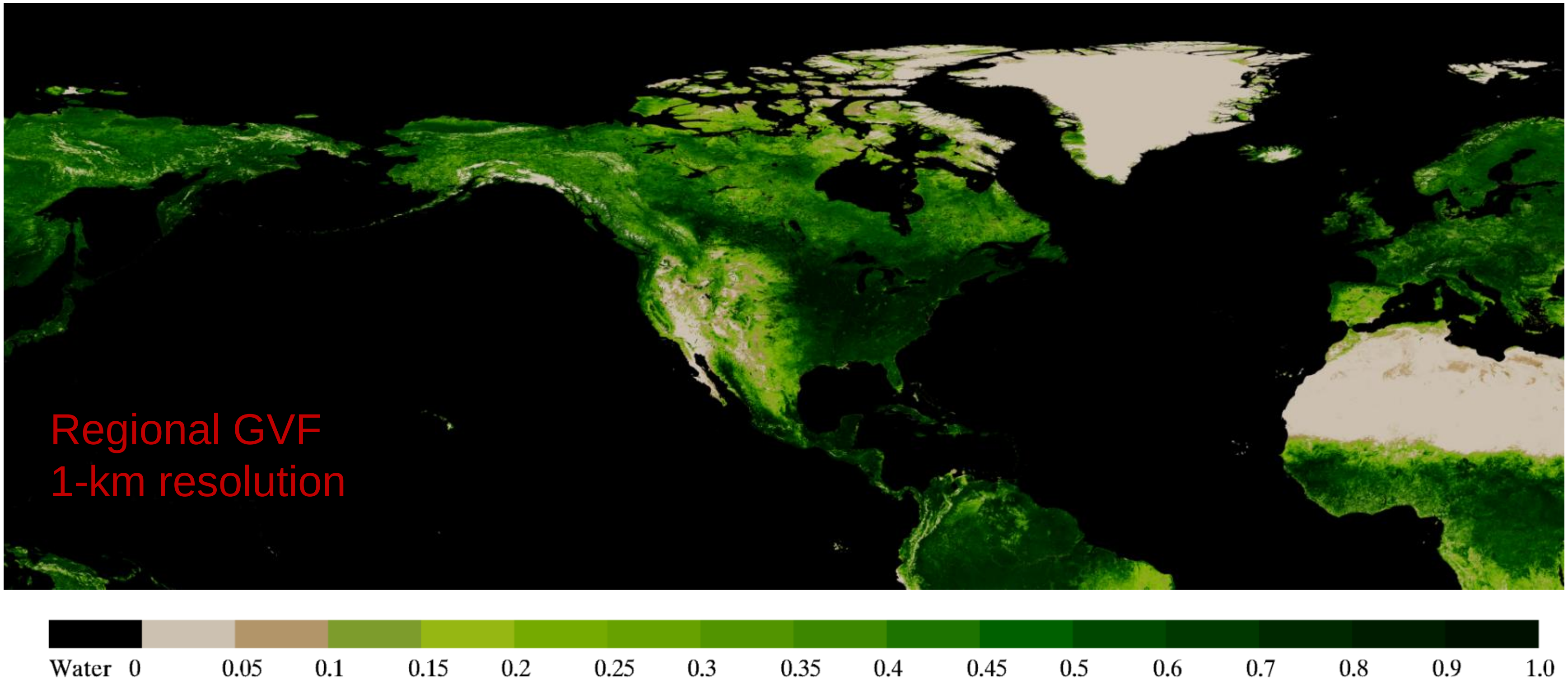
- GVF is an important parameter for the Noah land-surface model (LSM), which is coupled with the NOAA weather and climate models that are run at NCEP
- VIIRS GVF provides a better characterization of the surface in the Noah LSM compared to the current AVHRR GVF climatology. All operational NCEP models would benefit, e.g. better forecasts of near-surface winds, temperature, and humidity forecasts
- STAR Land Team members (Vargas/Csiszar) are collaborating with NCEP EMC to demonstrate that using the new VIIRS GVF instead of the operationally used AVHRR GVF climatology in NCEP NWP models will improve the performance of NOAA's operational environmental prediction suite

NDE SNPP VIIRS GVF Operational Product



NDE SNPP VIIRS GVF Operational Product

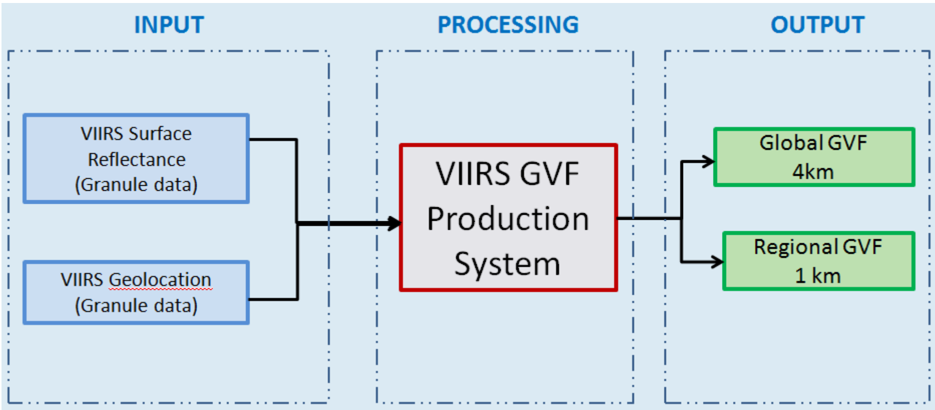
Suomi NPP VIIRS Weekly Green Vegetation Fraction Aug 9 - Aug 15, 2016

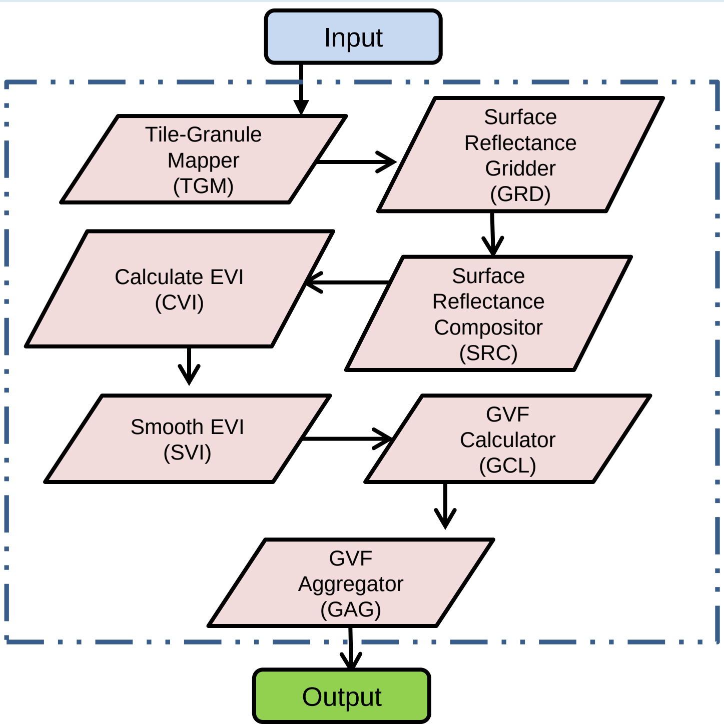


Regional coverage Lat 7.5°S to 90°N, Lon 130°E to 30°E

NDE VIIRS GVF Production System Process Flow

Context Layer of the Software Architecture

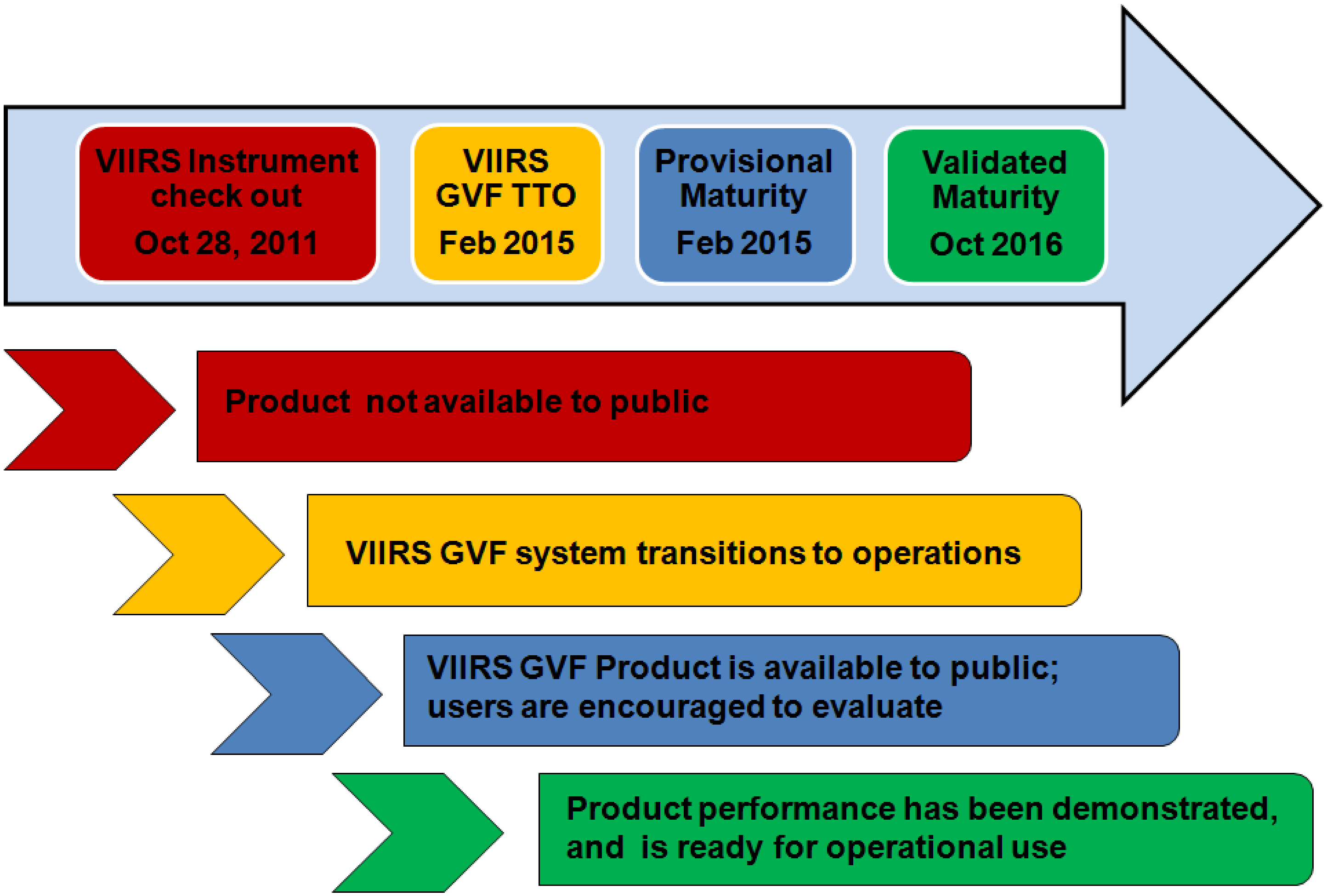




The NDE SNPP VIIRS GVF production system consists of 7 software units

1. Tile-Granule Mapper (TGM)
2. Surface reflectance gridder (GRD)
3. Surface reflectance compositor (SRC)
4. Calculate EVI (CVI)
5. Smooth EVI (SVI)
6. GVF calculator (GCL)
7. GVF aggregator (GAG)

VIIRS GVF Product Timeline



GVF Requirements Summary (L1RD-S)

Table 5.5.2 - Green Vegetation Fraction (VIIRS)		
EDR Attribute	**Threshold**	**Objective**
a. Horizontal Cell Size	16 Km	4 Km (global), 1 Km (regional)
b. Vertical Reporting Interval	NS	NS
c. Mapping Uncertainty, 3 Sigma	4 Km	1 Km
d. Measurement Precision		
1. Global	15%	8 %
2. Regional	15%	8 %
e. Measurement Accuracy		
1. Global	12%	5%
2. Regional	12%	5%
f. Measurement Uncertainty		
1. Global	17%	10%
2. Regional	17%	10%
g. Refresh	24 Hours	24 Hours
		v2.5, 1/23/13
Notes:		

Source: Level 1 Requirements Supplement – Final Version: 2.10 June 25, 2014

Requirements from JPSS ESPC Requirements Document (JERD) Volume 2 - Science Requirements

Attribute	Threshold
Measurement Accuracy	
1) Global	0.12
2) Regional	0.12
Measurement Precision	
1) Global	0.15
2) Regional	0.15
Measurement Uncertainty	
1) Global	0.17
2) Regional	0.17

Source: ESPC JERD Volume 2: Science Requirements – Version: 2.0 Mar 31, 2016

VIIRS GVF Performance

- VIIRS GVF product performance requirements from JPSS L1RD supplement (threshold) versus observed/validated

Global APU Estimates

Attribute	Threshold	Observed/validated
Measurement Accuracy		
1) Global	0.12	0.080
2) Regional	0.12	0.071
Measurement Precision		
1) Global	0.15	0.084
2) Regional	0.15	0.070
Measurement Uncertainty		
1) Global	0.17	0.116
2) Regional	0.17	0.100

JPSS Data Products Maturity Definition

JPSS/GOES-R Data Product Validation Maturity Stages – COMMON DEFINITIONS (Nominal Mission)

1. Beta
- Product is minimally validated, and may still contain significant identified and unidentified errors.
- Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
- Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

2. Provisional
- Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

3. Validated
- Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).
- Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
- Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
- Product is ready for operational use based on documented validation findings and user feedback.
- Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

Evaluation of Algorithm/Product Performance to Specification Requirements

- Test datasets: Landsat, FLUXNET/AmeriFlux, PhenoCam, Google Earth satellite images and AVHRR
- Cal/Val activities for evaluating algorithm performance:
  1. VIIRS GVF vs. Landsat derived GVF for APU calculation
  2. Temporal profile intercomparison over PhenoCam and FLUXNET/AmeriFlux sites
  3. VIIRS GVF vs. Google Earth derived GVF
  4. Temporal profile intercomparison with operational AVHRR GVF and AVHRR GVF climatology (used by NCEP/EMC in their land models)

Data and Methods

- Reference GVF data was derived from 350 Landsat 7 ETM+ images distributed globally over 30 EOS validation core sites (different seasons)
- Landsat 7 ETM+ surface reflectance data downloaded from http://earthexplorer.usgs.gov/
- Time period: 9/1/2012 - 9/1/2016
- Decision-tree classification method used to classify the Landsat images
- Landsat classified images reprojected to the VIIRS GVF projection and GVF calculated
- Landsat derived GVF provides higher resolution vegetation information compared to the VIIRS GVF products
- Generated comparative statistics (Accuracy, Precision, Uncertainty)
- Time series intercomparison VIIRS vs. Landsat GVF

GVF Validation Sites

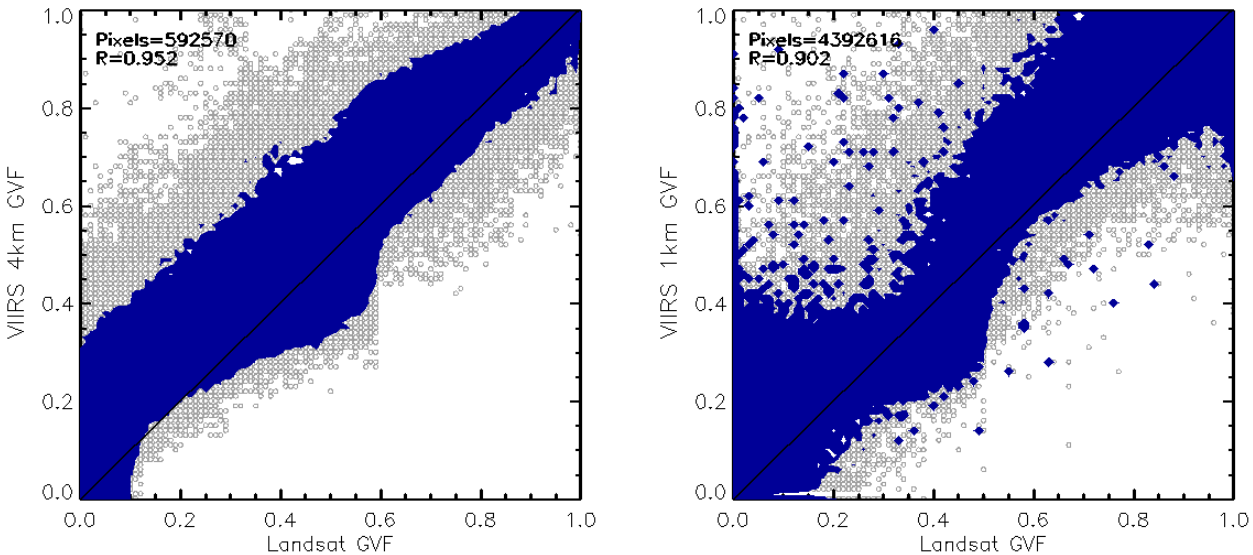
The EOS Land Validation Core Sites are intended as a focus for land product validation over a range of biome types (http://landval.gsfc.nasa.gov/coresite_gen.html)

VIIRS vs. Landsat GVF Global APU and Cross-plots

Global APU Estimates

Attribute	Threshold	Observed/validated
Measurement Accuracy		
1) Global	0.12	0.080
2) Regional	0.12	0.071
Measurement Precision		
1) Global	0.15	0.084
2) Regional	0.15	0.070
Measurement Uncertainty		
1) Global	0.17	0.116
2) Regional	0.17	0.100

VIIRS vs. Landsat GVF Cross-plots

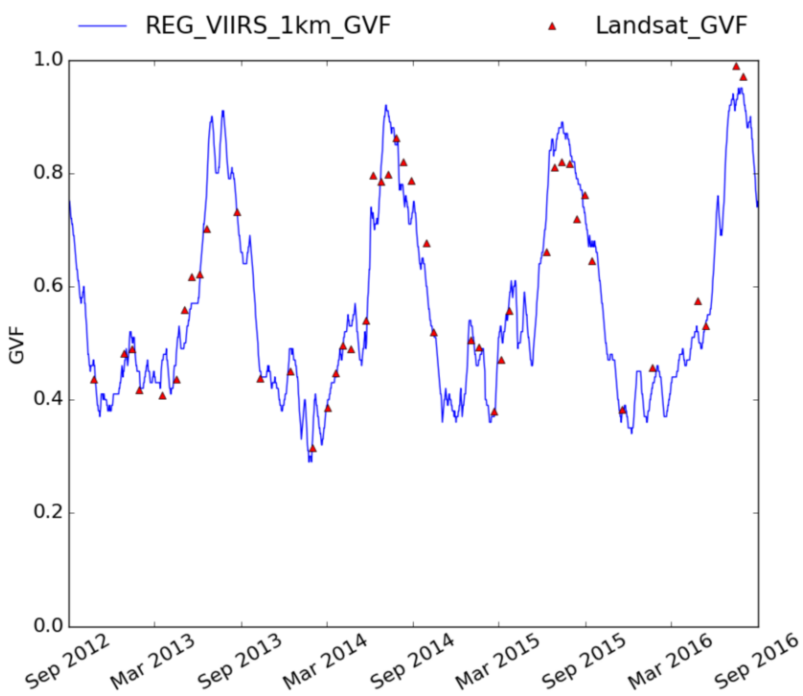


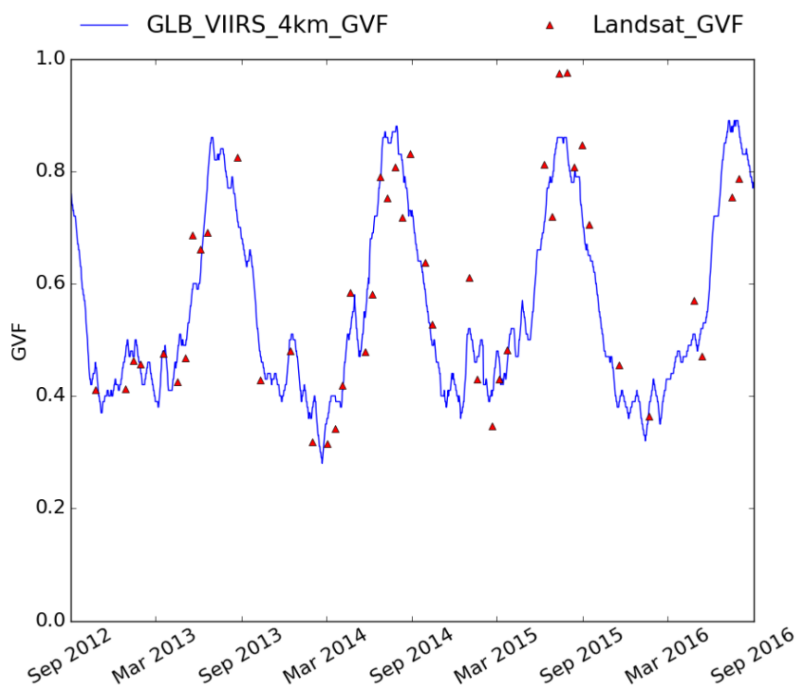
VIIRS GVF vs. Landsat GVF
Temporal Profile Evaluation

GVF Time Series Inter-Comparison VIIRS vs. Landsat 7/ETM+

Site: BARC, MD,USA (39.03º,-76.85º)

Surface type: broadleaf cropland



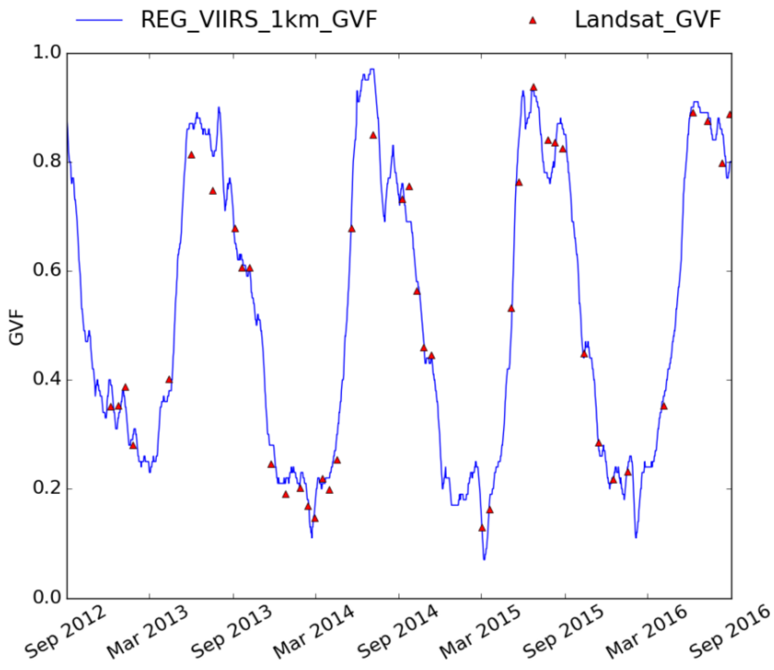


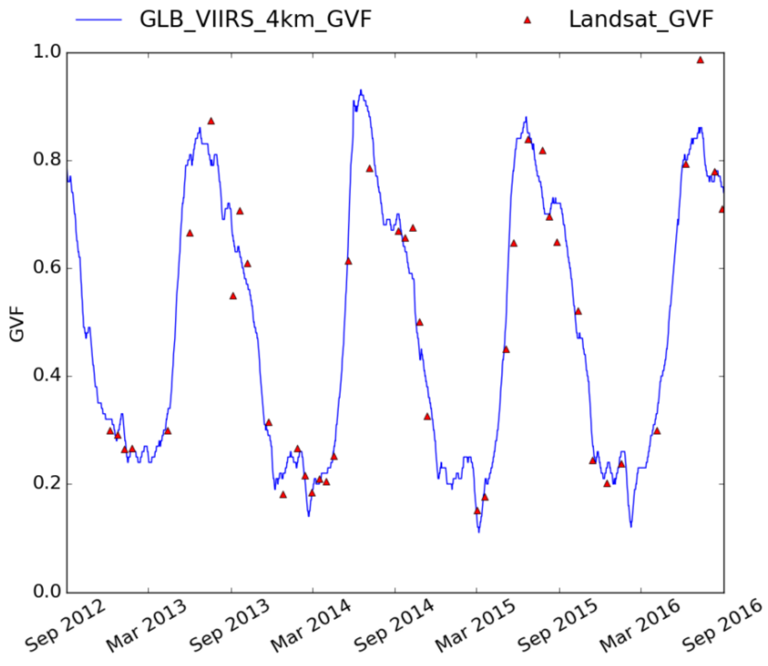
VIIRS GVF vs. Landsat GVF
Temporal Profile Evaluation

GVF Time Series Inter-Comparison VIIRS vs. Landsat 7/ETM+

Site: Howland, ME,USA (45.2º,-68.73º)

Surface type: needleleaf forest



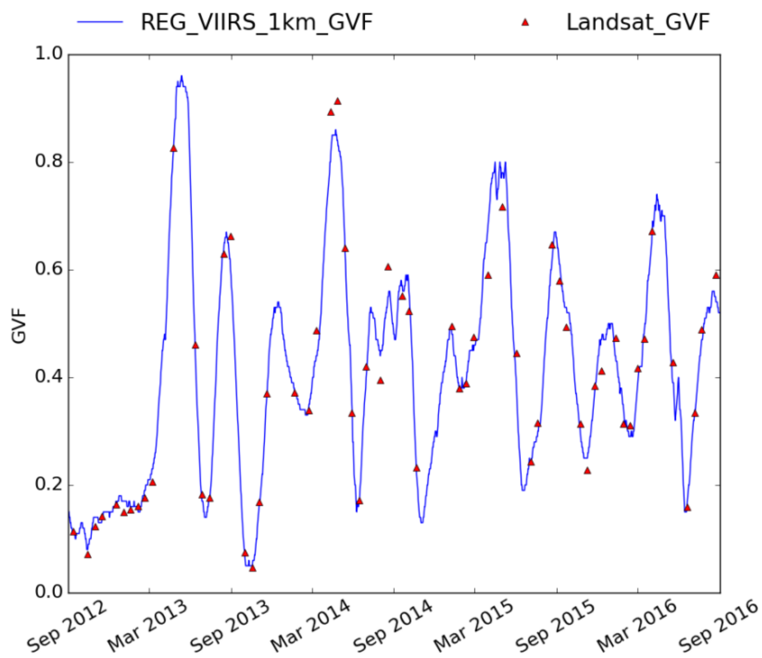


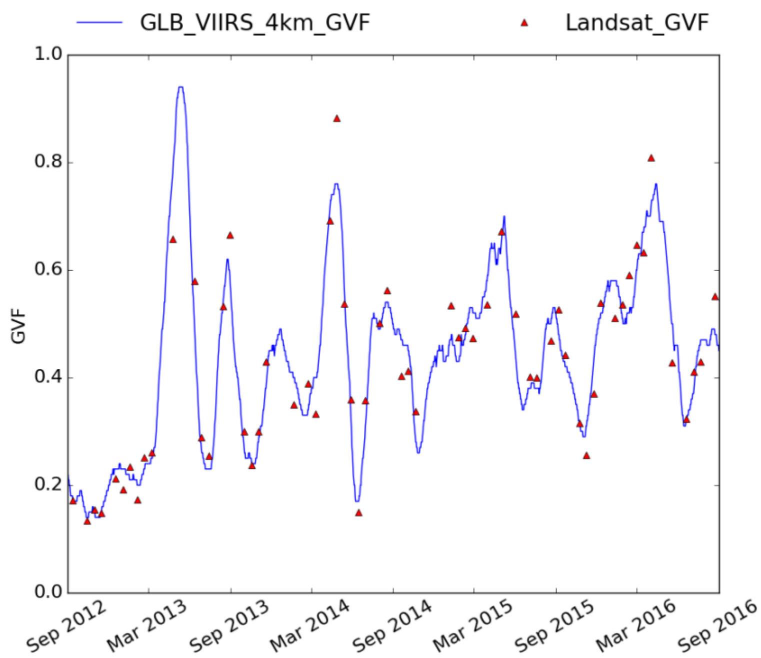
VIIRS GVF vs. Landsat GVF
Temporal Profile Evaluation

GVF Time Series Inter-Comparison VIIRS vs. Landsat 7/ETM+

Site: ARM/CART, OK, USA (36.64º, -97.5º)

Surface type: Grass/Cereal Crop



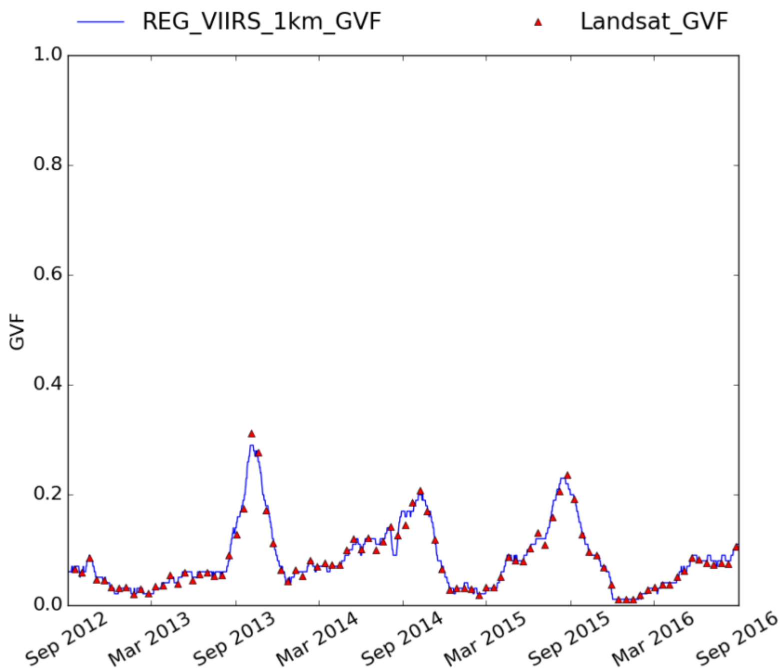


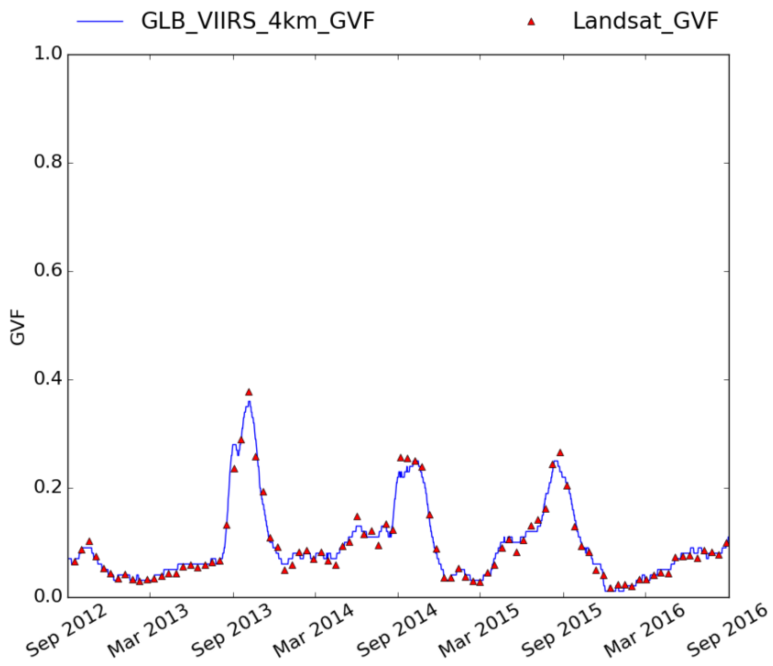
VIIRS GVF vs. Landsat GVF Temporal Profile Evaluation

GVF Time Series Inter-Comparison VIIRS vs. Landsat 7/ETM+

Site: Jornada, NM, USA (32.6º, -106.86º)

Surface type: shrubland





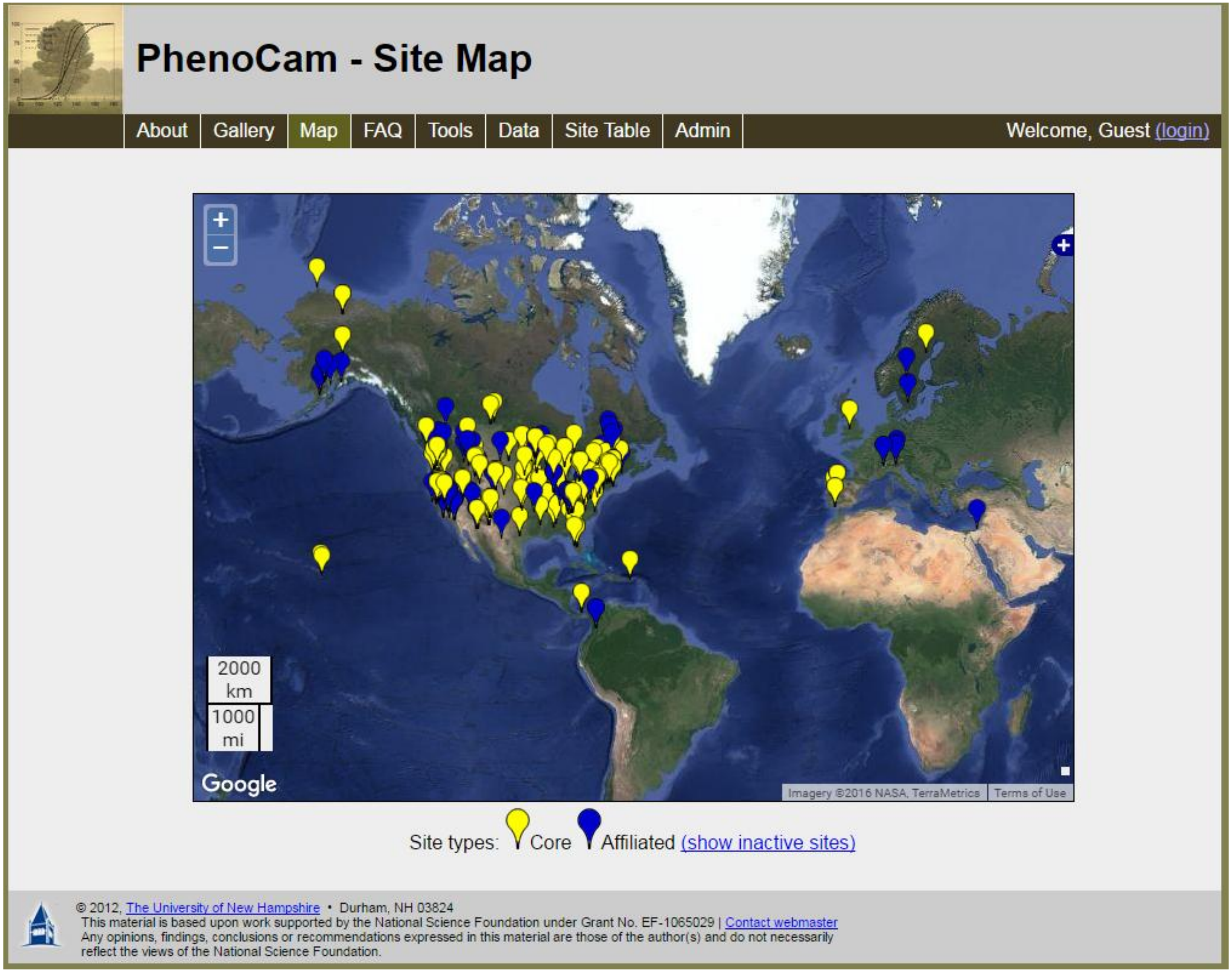
Conclusion

- VIIRS GVF calculated APU performance parameters meet the L1RDS requirements over time and across seasons
- APU performance parameters were calculated from global data using Landsat derived GVF as reference
- VIIRS GVF temporal profiles visually compare well with the Landsat derived GVF counterparts

Temporal Profile Evaluation
VIIRS GVF vs. PhenoCam Greenness Index (GCC)

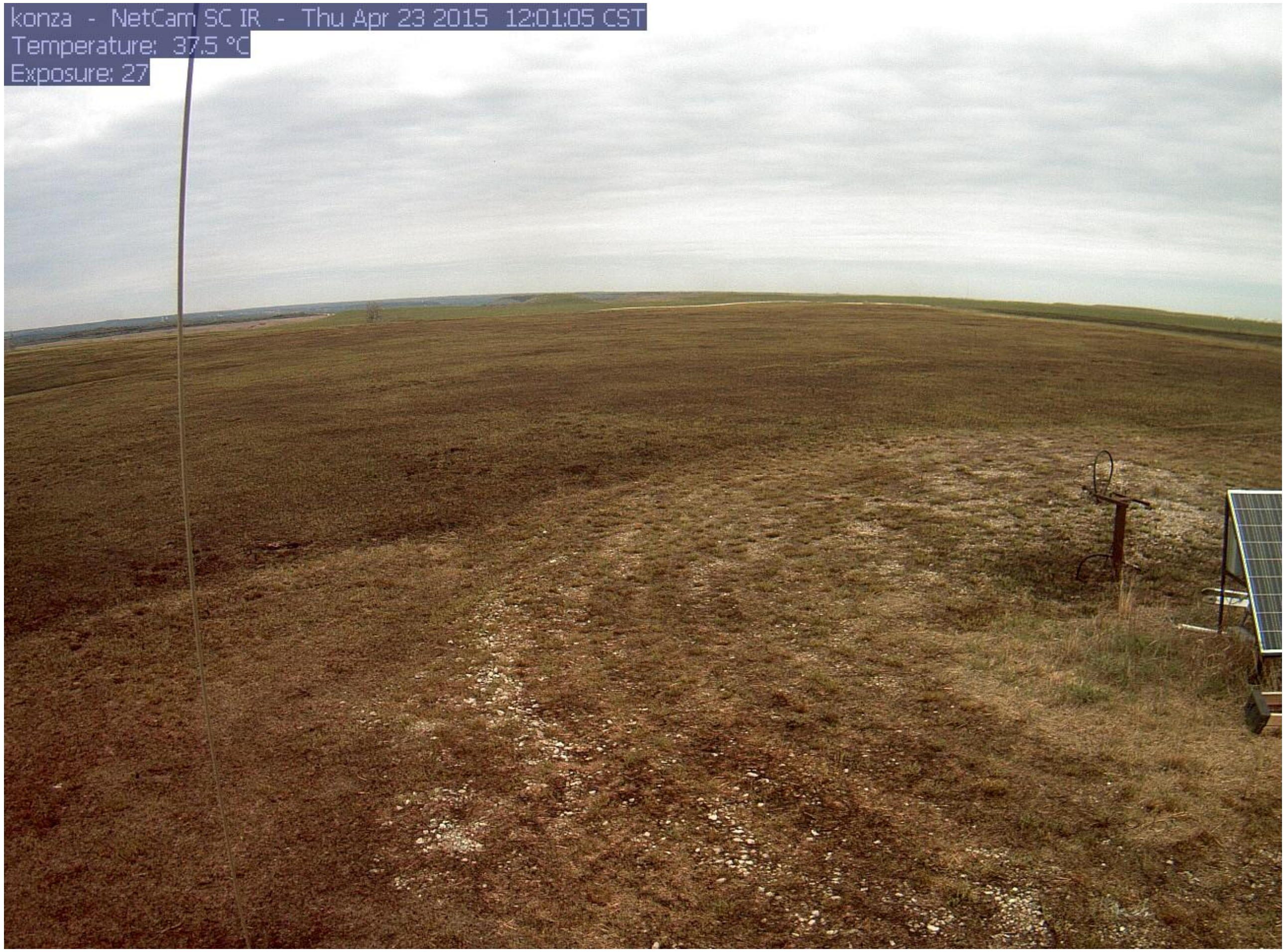
- The PhenoCam Network provides automated, near-surface remote sensing of canopy phenology across north America and Europe
- PhenoCam Images are uploaded to the PhenoCam server every half hour
- Canopy greenness indices provide information about the amount of foliage present, and its color
- Canopy phenology can be monitored and quantified
- PhenoCam images can be downloaded from: https://phenocam.sr.unh.edu/webcam/network/download/
- Daily images were acquired from different PhenoCam sites at noon for this analysis

PhenoCam Sites



https://phenocam.sr.unh.edu/webcam/network/map/

PhenoCam image at Konza - 4/23/2015

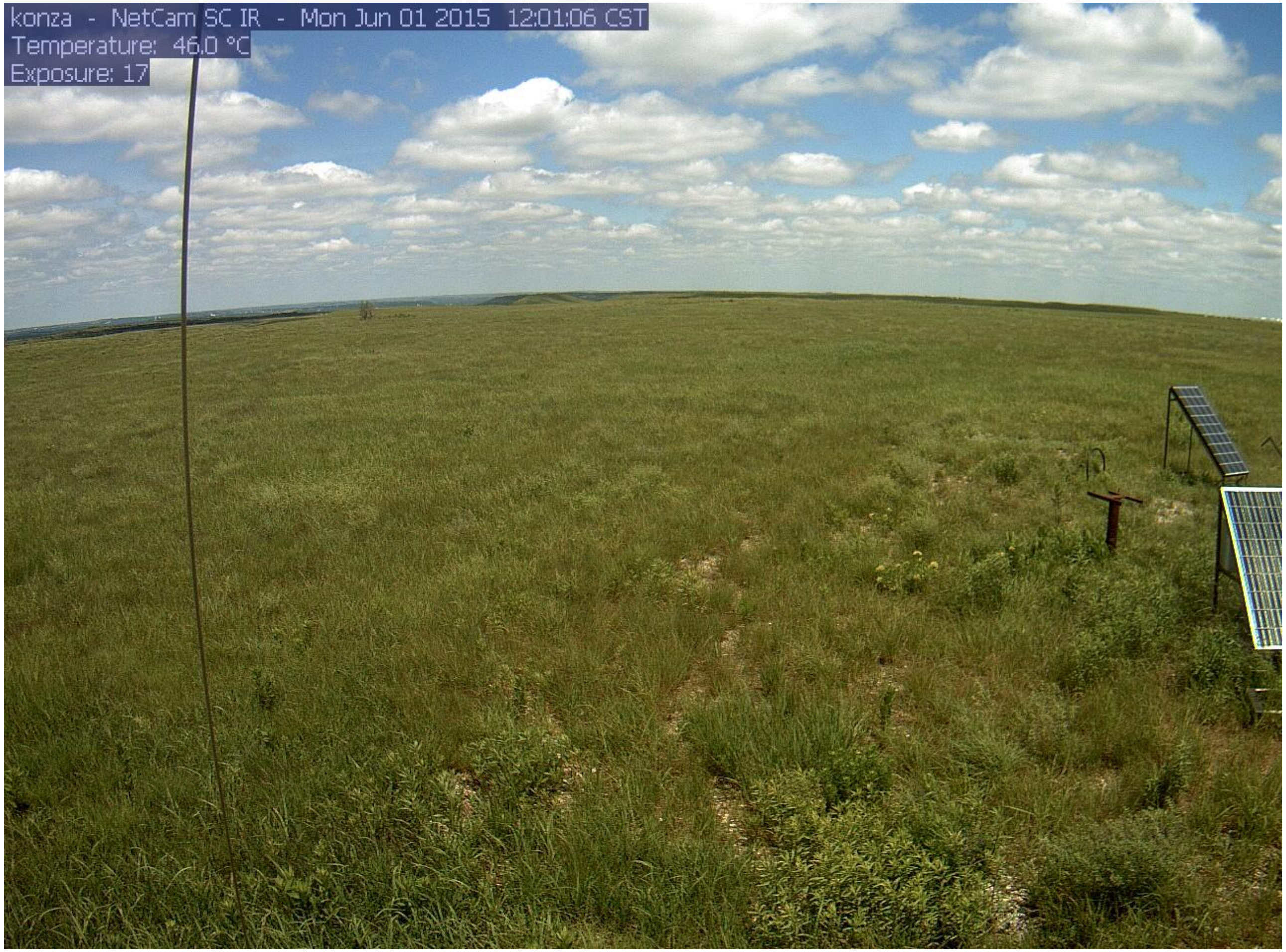


Surface Type: Grassland

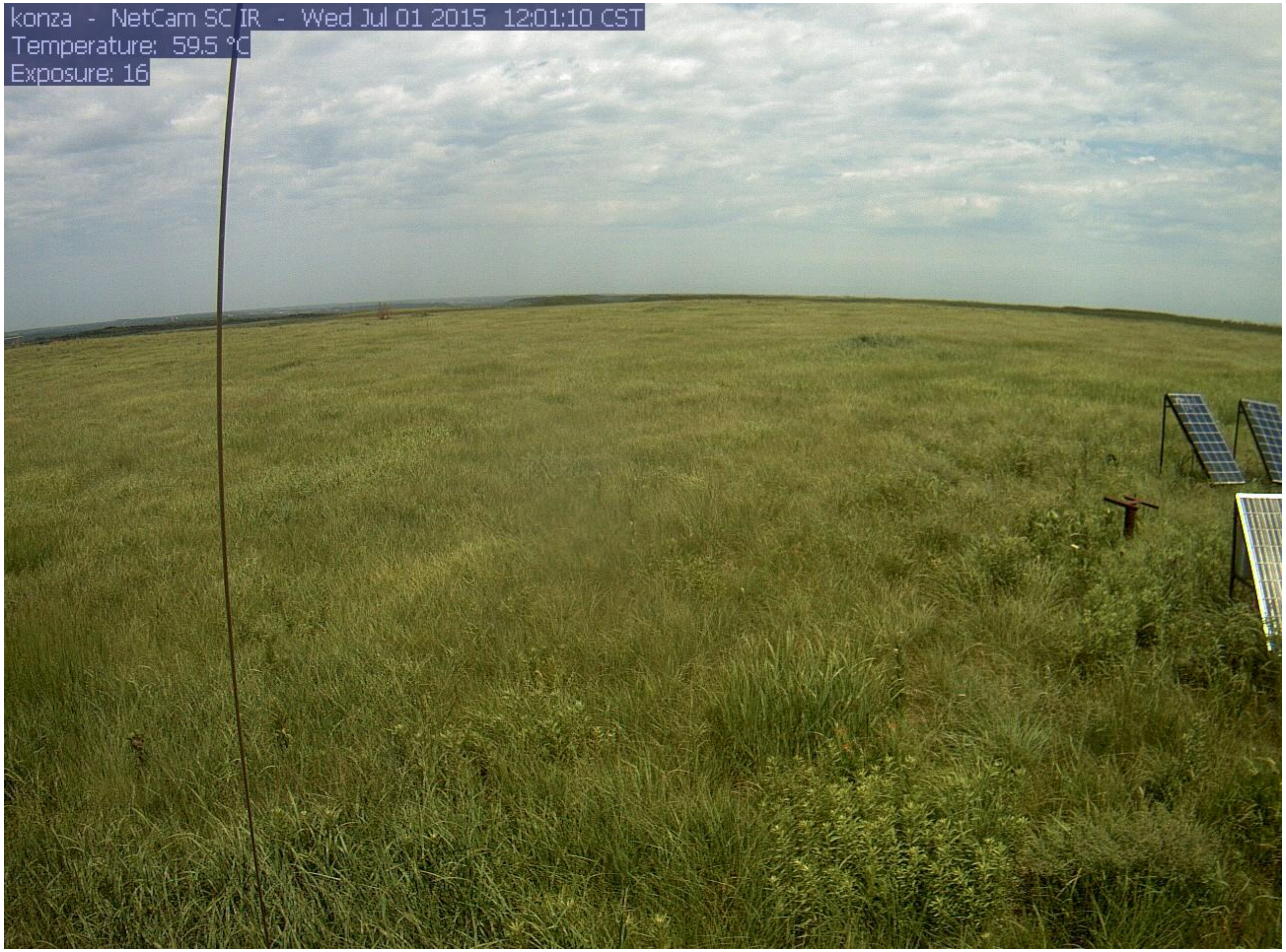
PhenoCam image at Konza - 4/30/2015

PhenoCam image at Konza - 5/1/2015

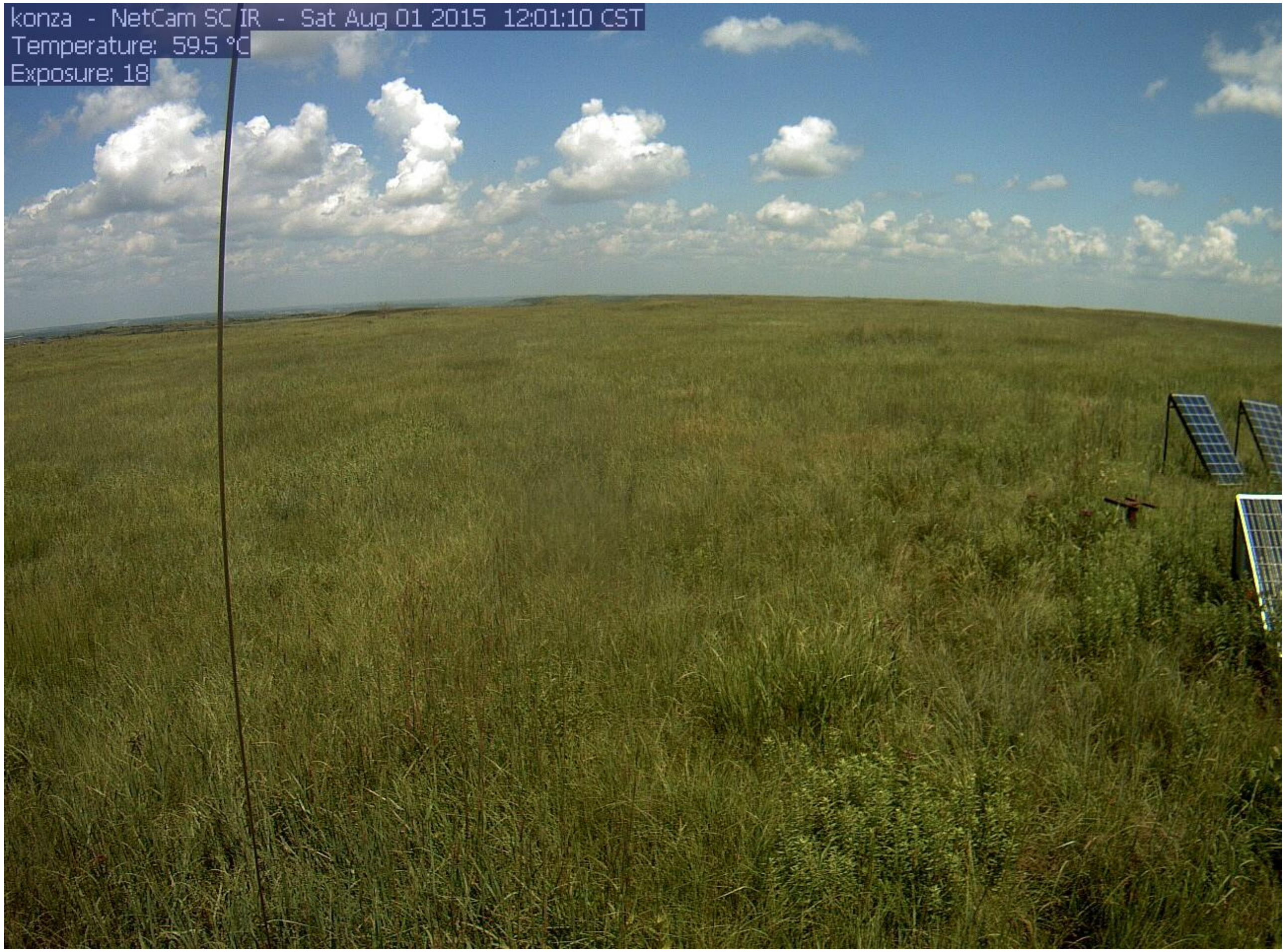
PhenoCam image at Konza - 6/1/2015



PhenoCam image at Konza - 7/1/2015

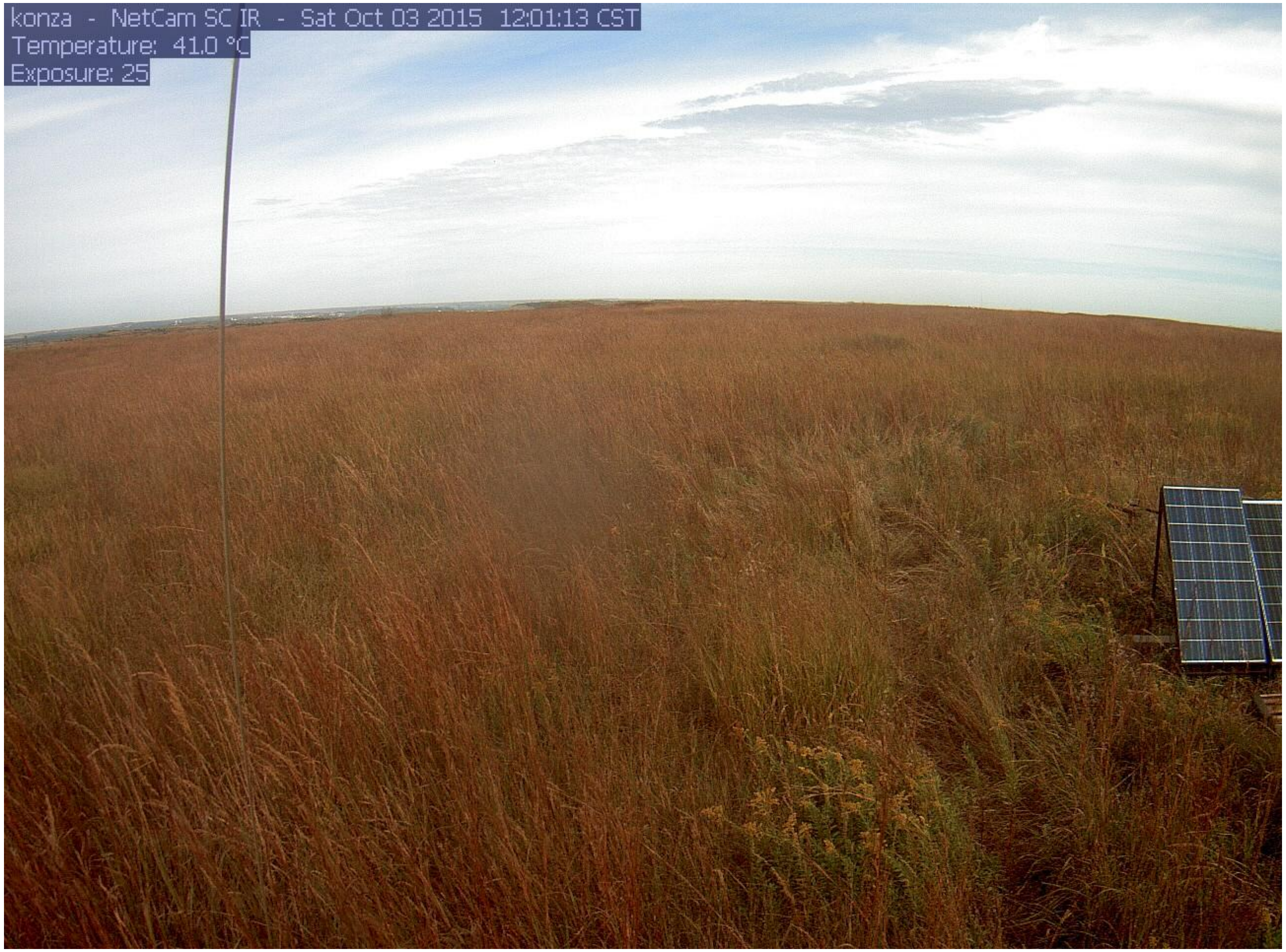


PhenoCam image at Konza - 8/1/2015



PhenoCam image at Konza - 9/1/2015

PhenoCam image at Konza - 10/3/2015



PhenoCam image greenness Index

- Green Chromatic Coordinate

  GCC = G/(R+G+B)*

  – R: digital number of the red channel
  – G: digital number of the green channel
  – B: digital number of the blue channel
- GCC measures the relative (or normalized) brightness of the green channel
  - GCC = 0.33 for white or grey pixels
  - GCC = 0.4 - 0.5 for green pixels (green is the dominant channel)

* Klosterman et al., Evaluation of remote sensing of deciduous forest phenology at multiple spatial scales using Phenocam images. Biogeosciences, 2014, 11, 4305-4320.
* Richardson et al., Near-surface remote sensing of spatial and temporal variation in canopy phenology. Ecological Application, 2009, 19(6), 1417-1428.

PhenoCam Image Region of Interest (ROI)

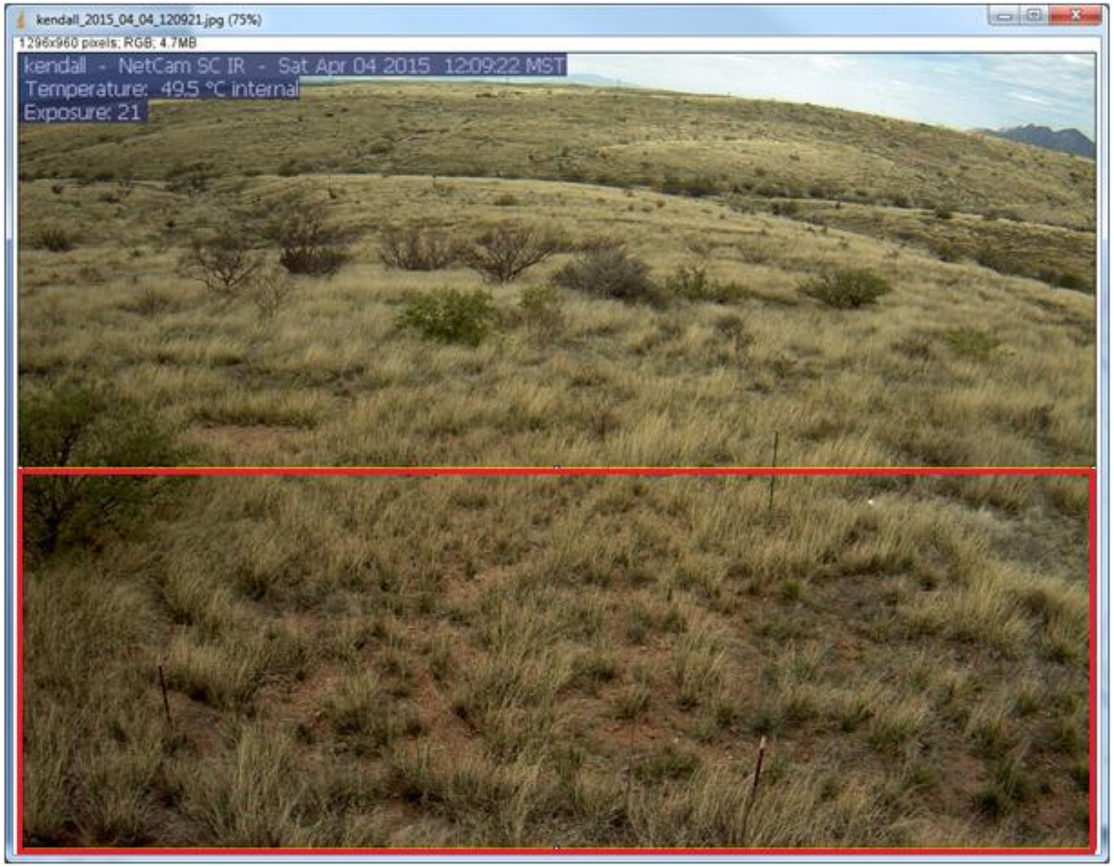


Image size (pixels): 1296 x 960

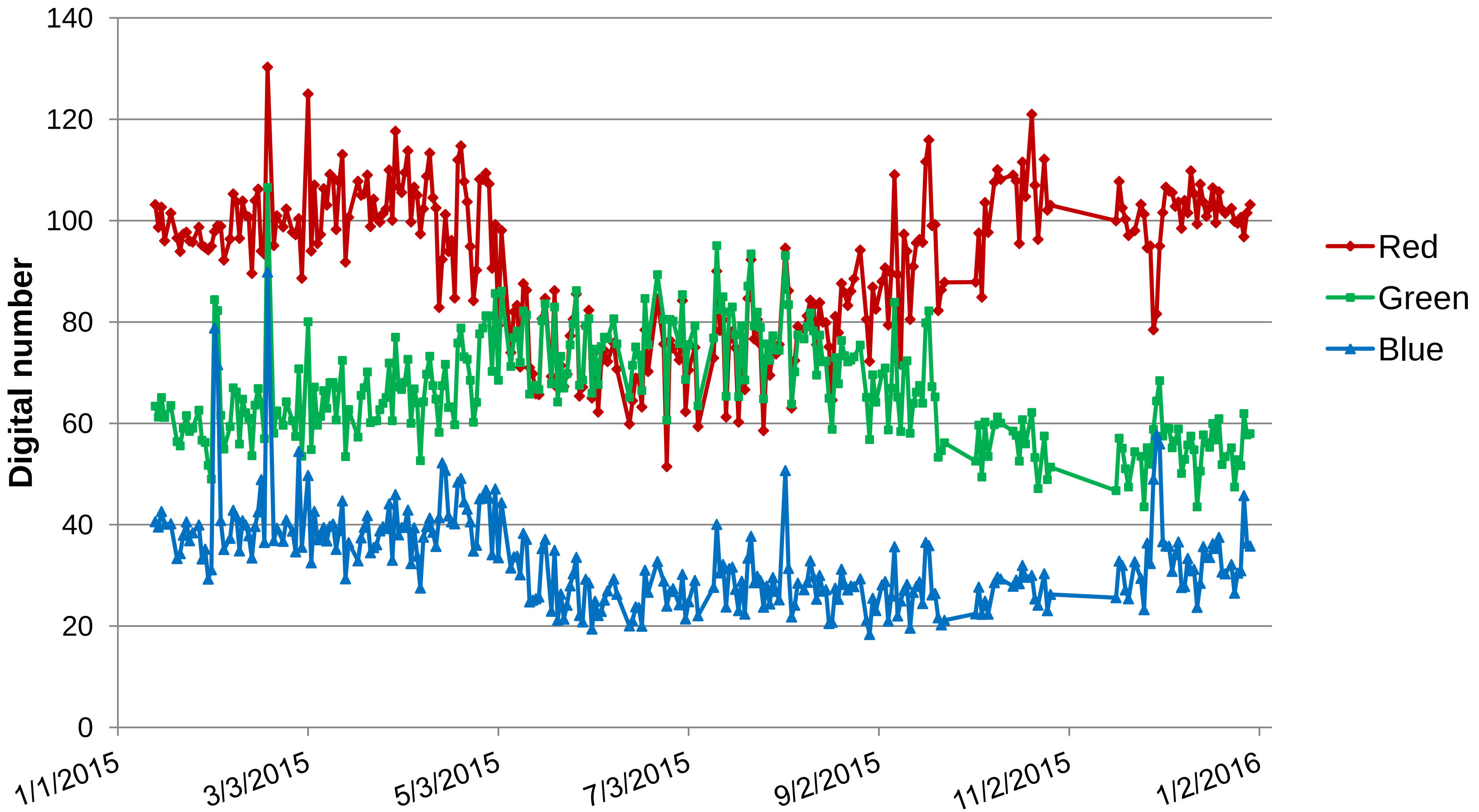
ROI: lower part of the image (Rows 500-960)

- Close to the camera
- Can see the bare soil

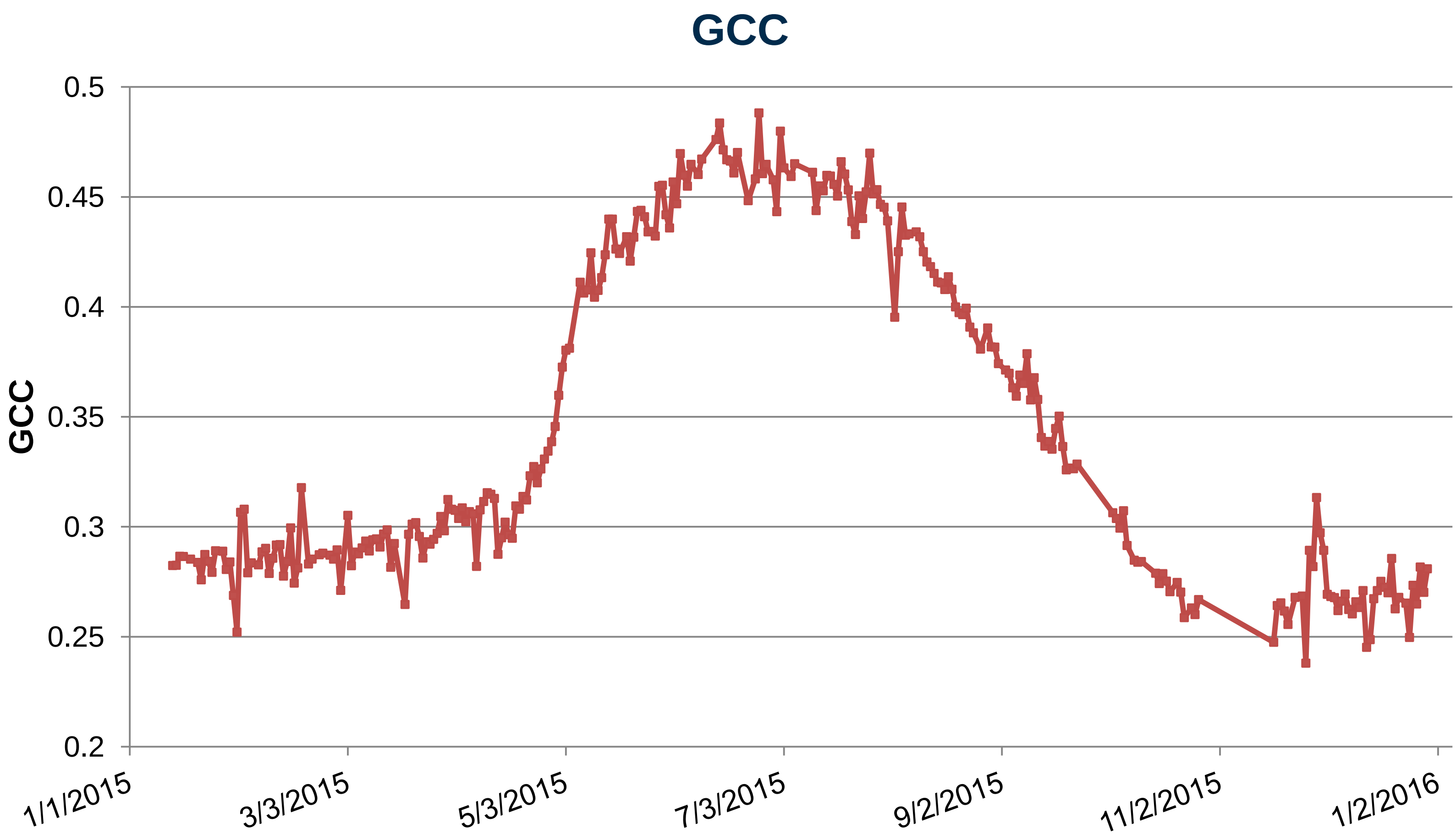
Method:

1. Calculate GCC for each pixel in ROI
2. Calculate mean GCC within ROI for each day
3. Compare time series of GCC with GVF

PhenoCam RGB values at Konza



PhenoCam GCC index at Konza (Grassland/Crop)



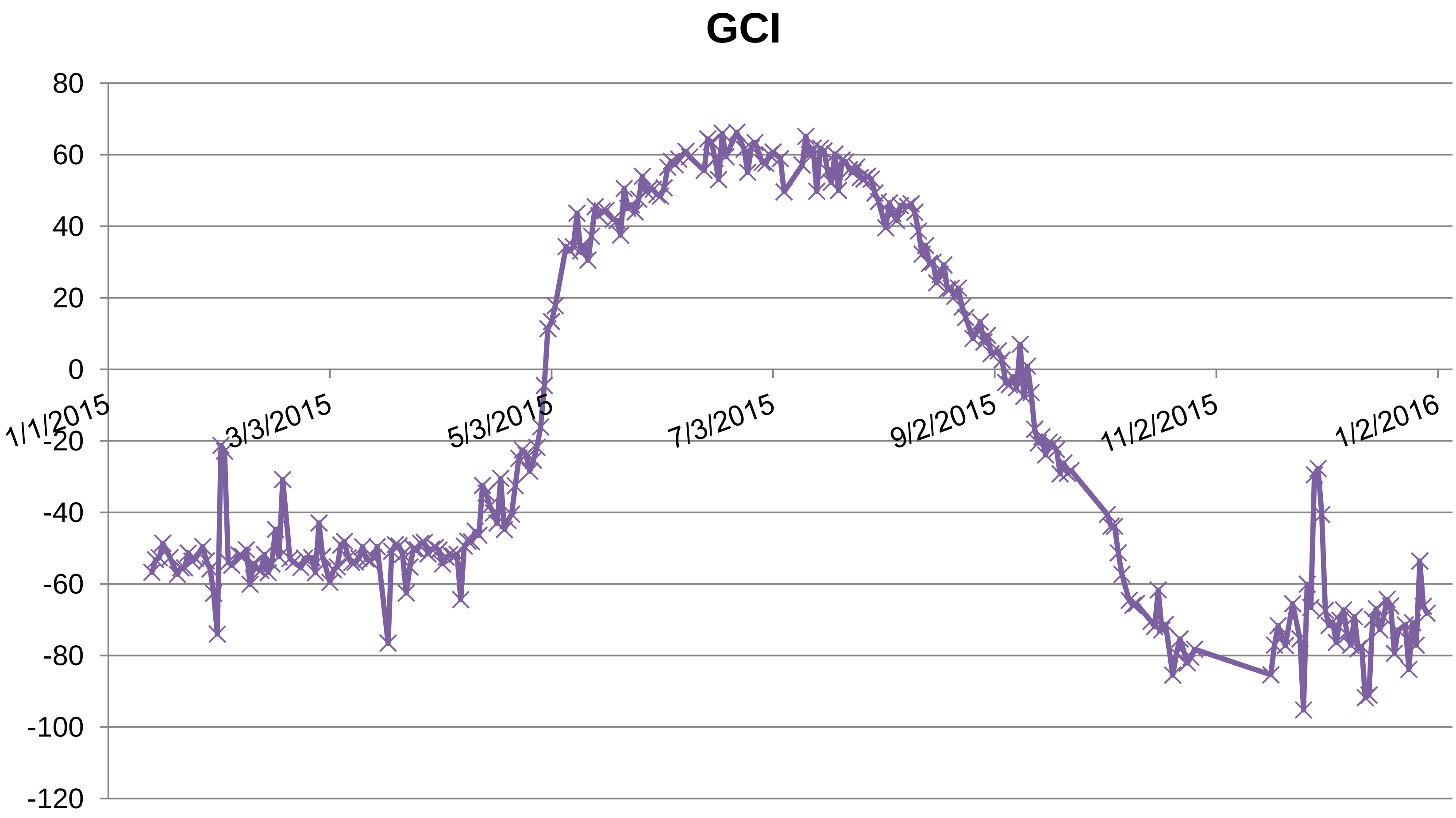
Green Chromatic Coordinate (GCC) Index

GCC = G/(R+G+B)

GCC = 0.33 for white or grey pixels

GCC = 0.4-0.5 for green pixels (green is the dominant channel)

Green Color index (GCI) at Konza



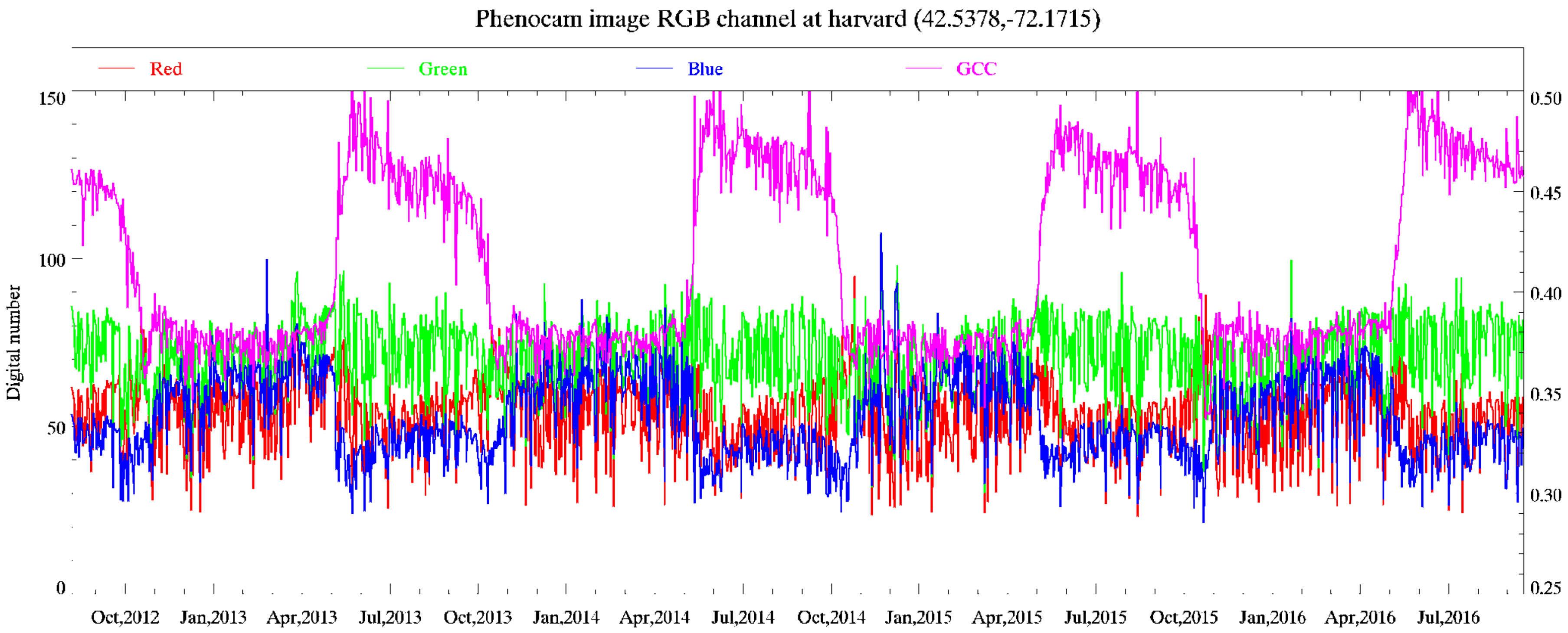
Green Color Index (GCI)

GCI = 3 * Green – 2 * Red - Blue - 20

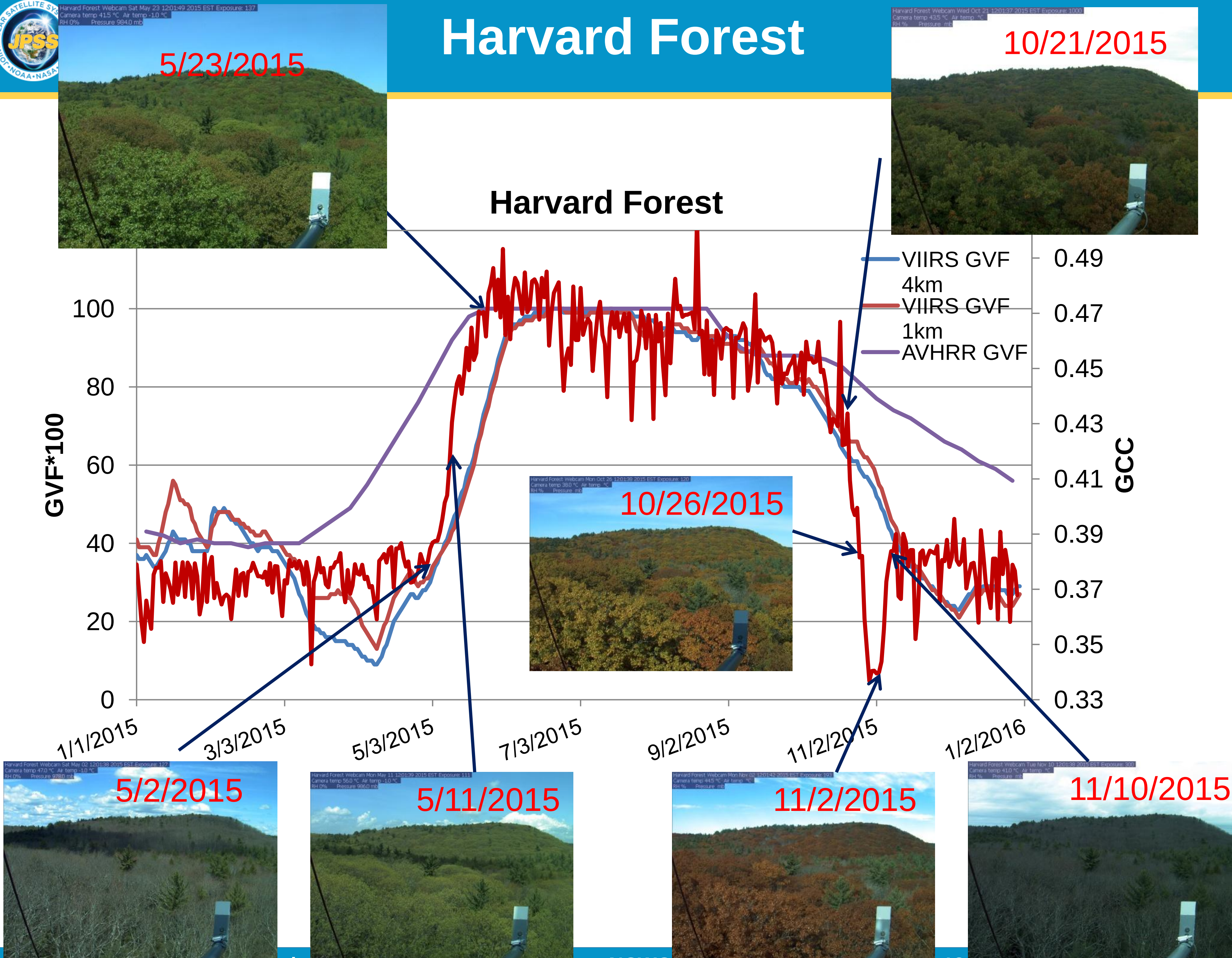
If GCI > 0 then pixel is classified as green

GVF = percentage of pixels where GCI > 0

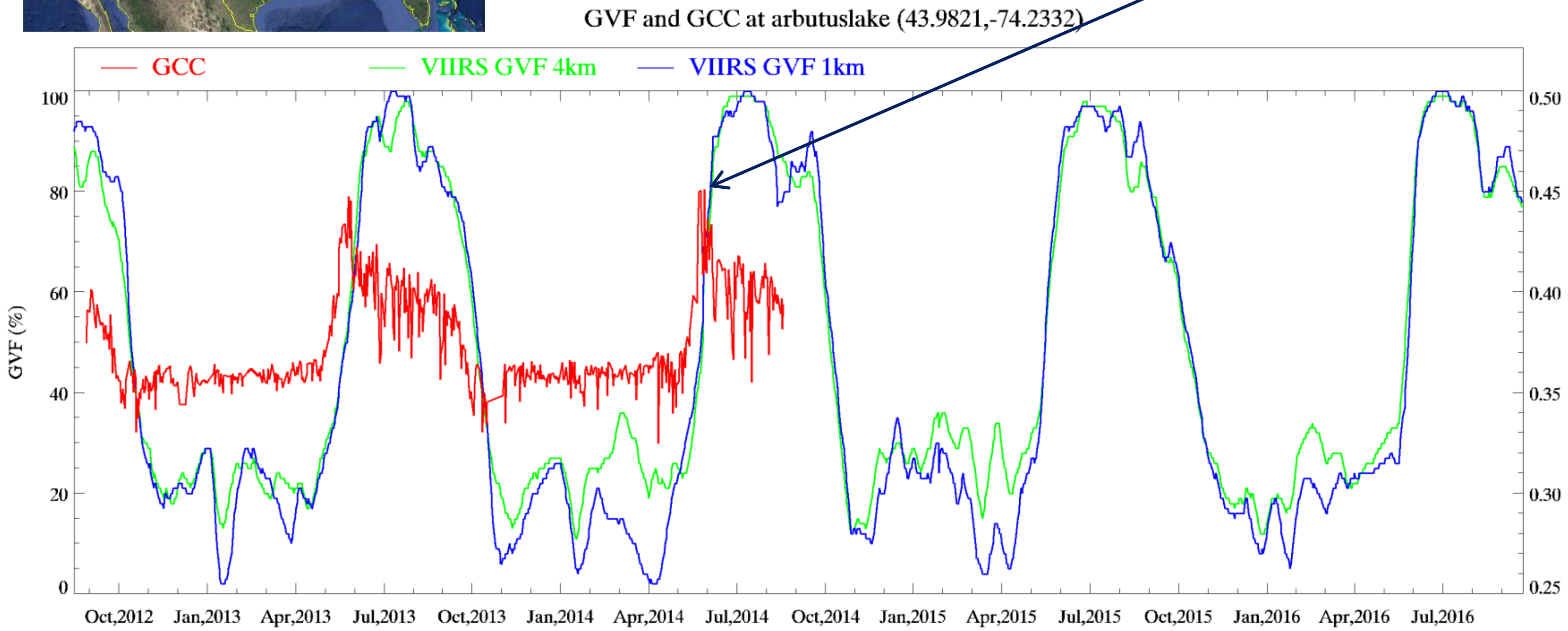
PhenoCam R,G,B and GCC Temporal Profiles at Harvard Forest



Harvard Forest



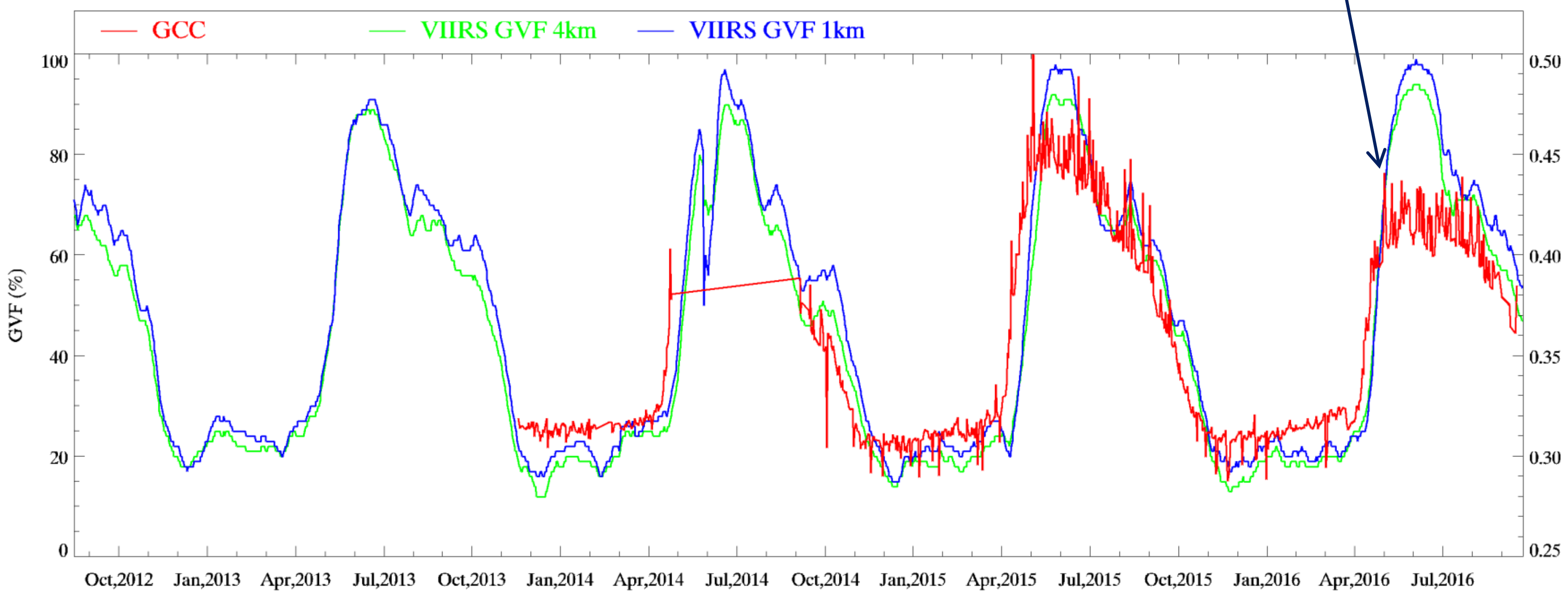
Arbutus Lake (NY, USA)



Bull Shoals (MO, USA)

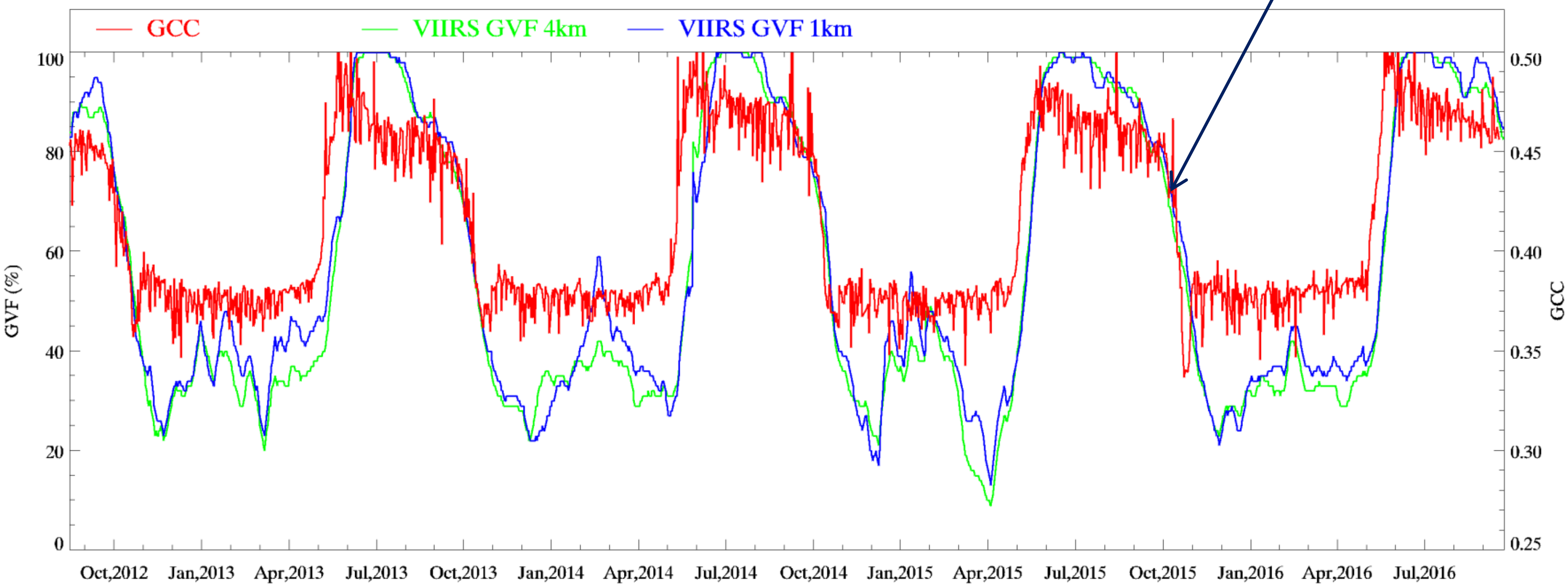
5/17/2016

GVF and GCC at bullshoals (36.5628,-93.0666)

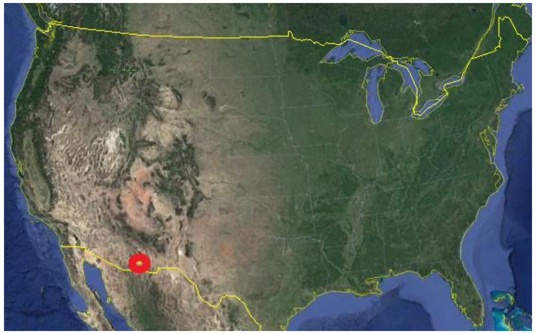


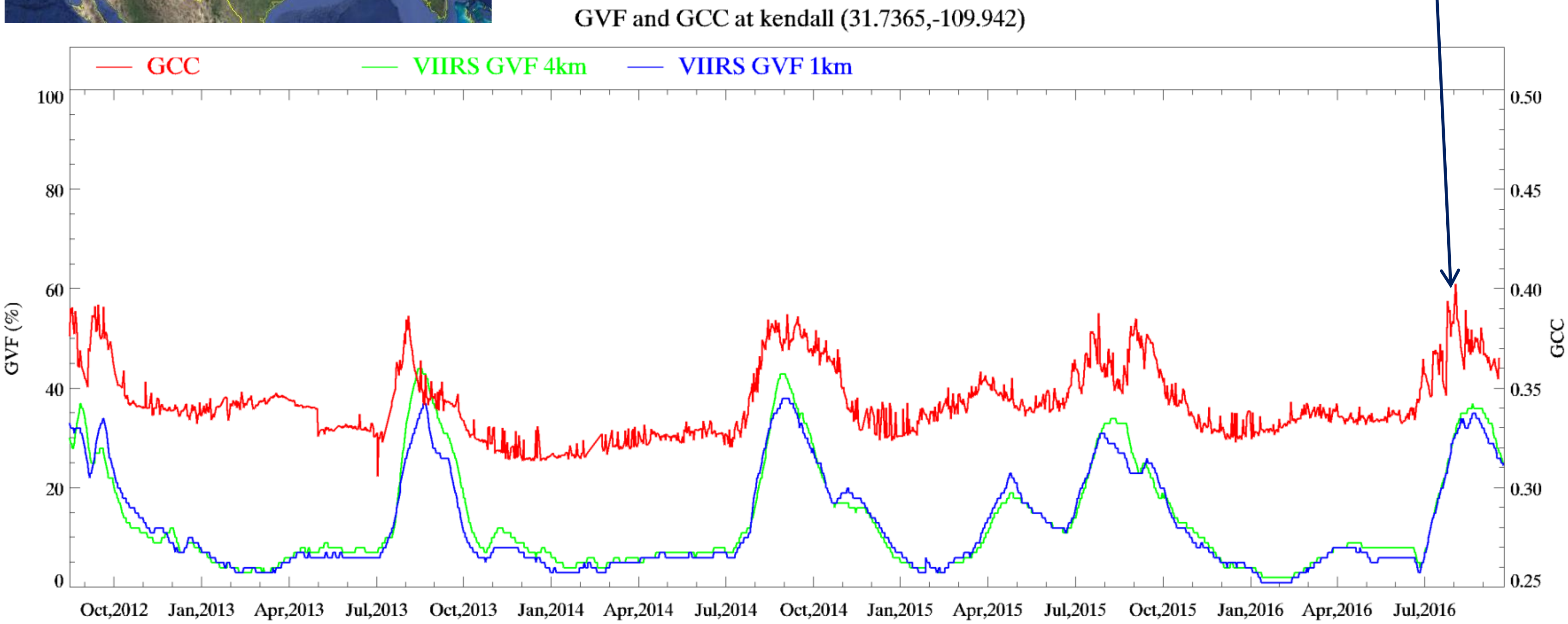
Harvard Forest (MA, USA)

GVF and GCC at harvard (42.5378,-72.1715)

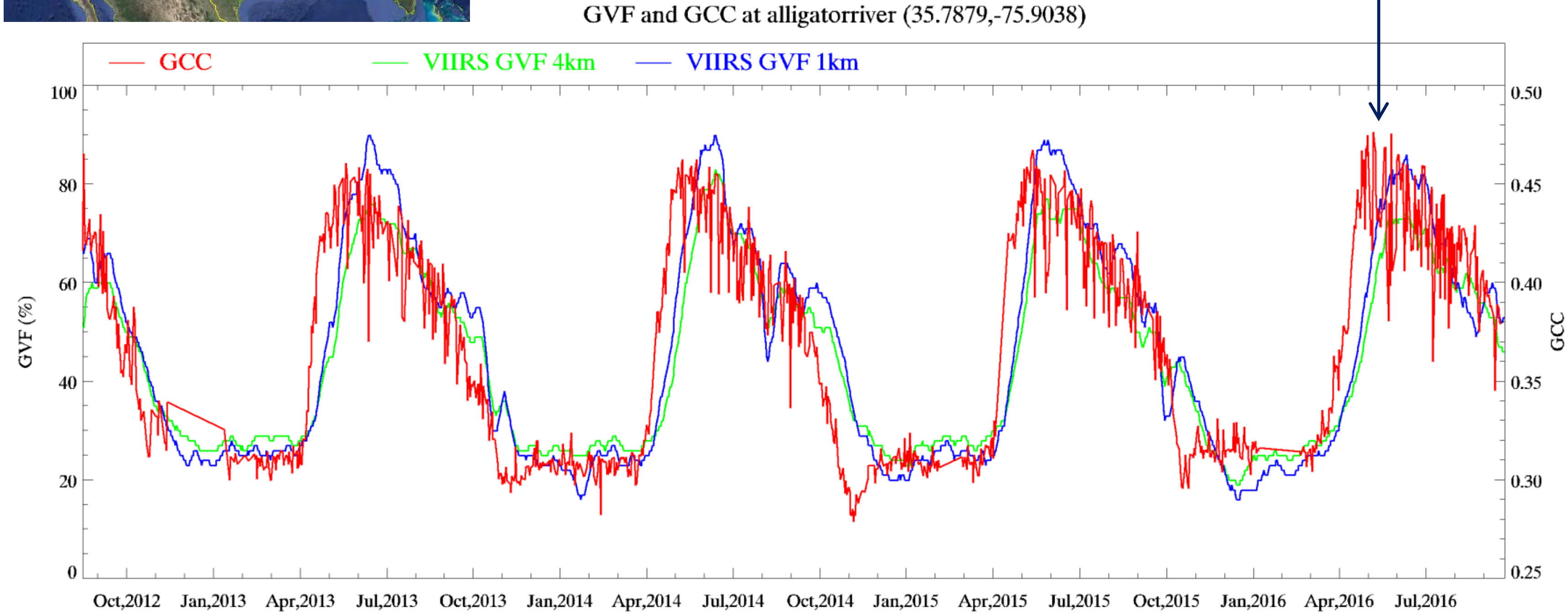


Kendall (AZ, USA)



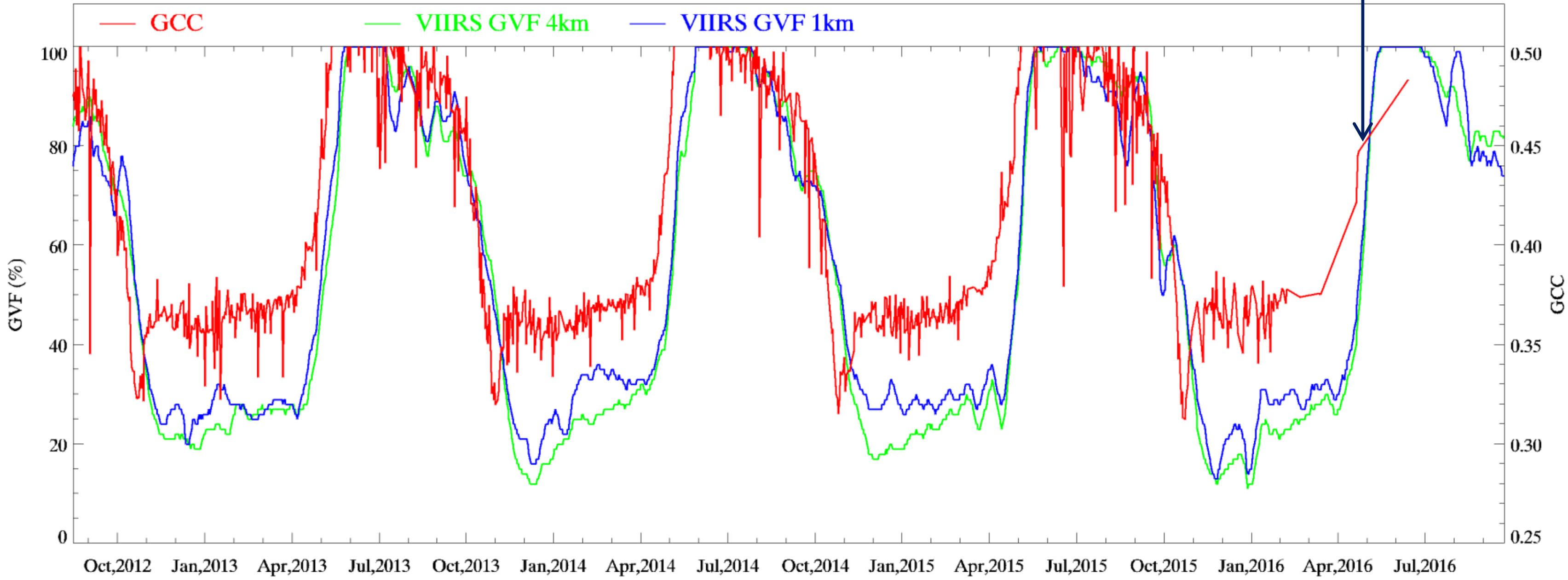


Alligator River (NC, USA)



Coweeta (NC, USA)

GVF and GCC at coweeta (35.0596,-83.4280)



Conclusion

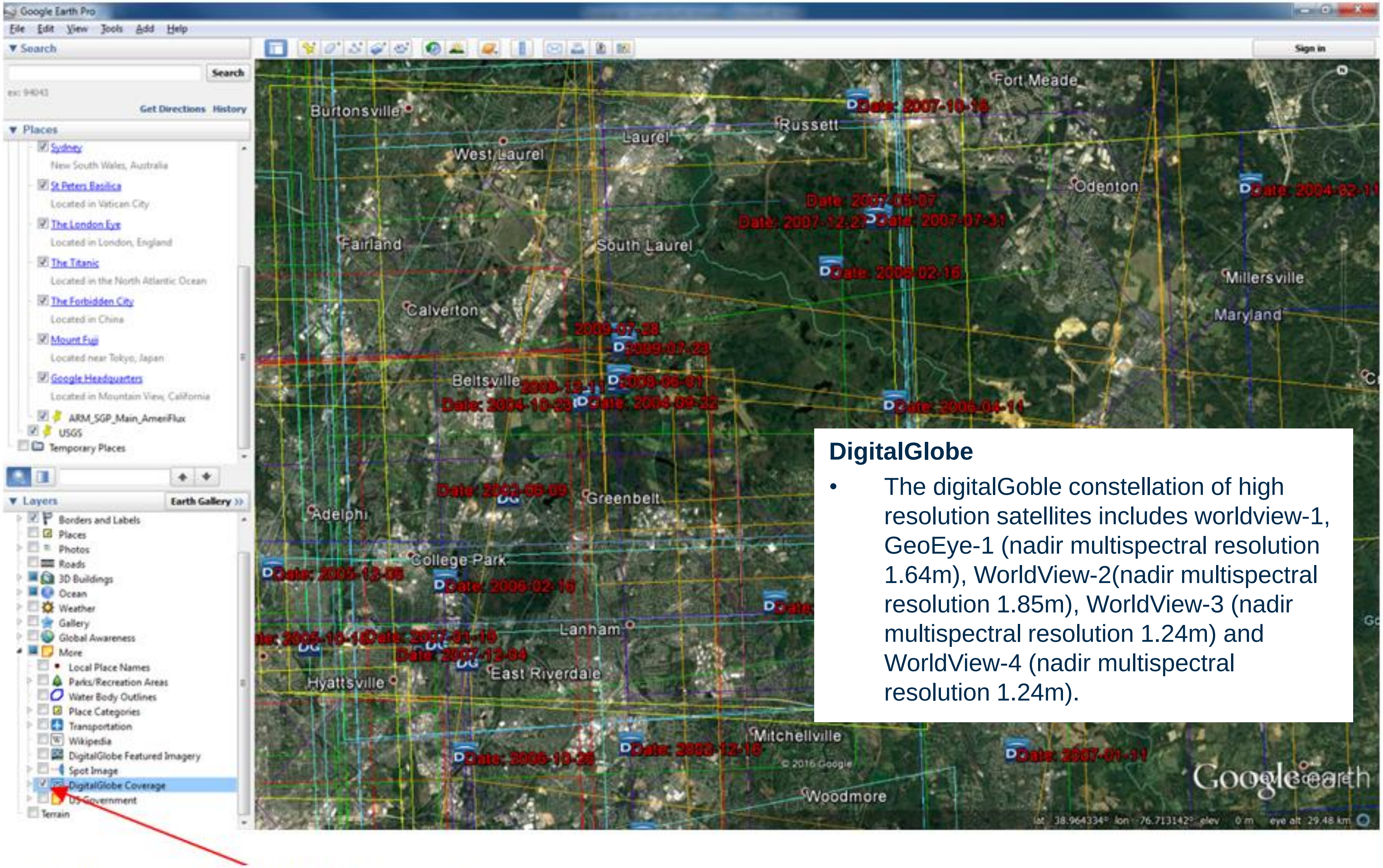
- PhenoCam images can be used for monitoring vegetation phenology and validating temporal profiles (seasonal variation) of VIIRS GVF products
- VIIRS GVF timing of greening up and browning down are comparable to those observed in the temporal profiles of GCC from PhenoCam tower data

VIIRS GVF vs. Google Earth Derived GVF

Data and method

- High resolution (~1m) RBG satellite images are available on Google Earth over the internet
- Google Earth images over VIIRS GVF pixels (areas of 0.036° x 0.036°) were downloaded from Google Earth
- Green pixels on the high resolution Google Earth images are extracted using the Green Color index (GCI)
- GVF derived from Google Earth satellite images is compared with VIIRS GVF
- 15 EOS land validation core sites and 15 PhenoCam sites were selected for GVF validation

Data sources of Google Earth images



DigitalGlobe

- The digitalGoble constellation of high resolution satellites includes worldview-1, GeoEye-1 (nadir multispectral resolution 1.64m), WorldView-2(nadir multispectral resolution 1.85m), WorldView-3 (nadir multispectral resolution 1.24m) and WorldView-4 (nadir multispectral resolution 1.24m).

Fig.1. A map of DigitalGlobe coverage

Data sources of Google Earth images

SPOT

- SPOT 6 and SPOT 7 (1.5m & 6m resolution)

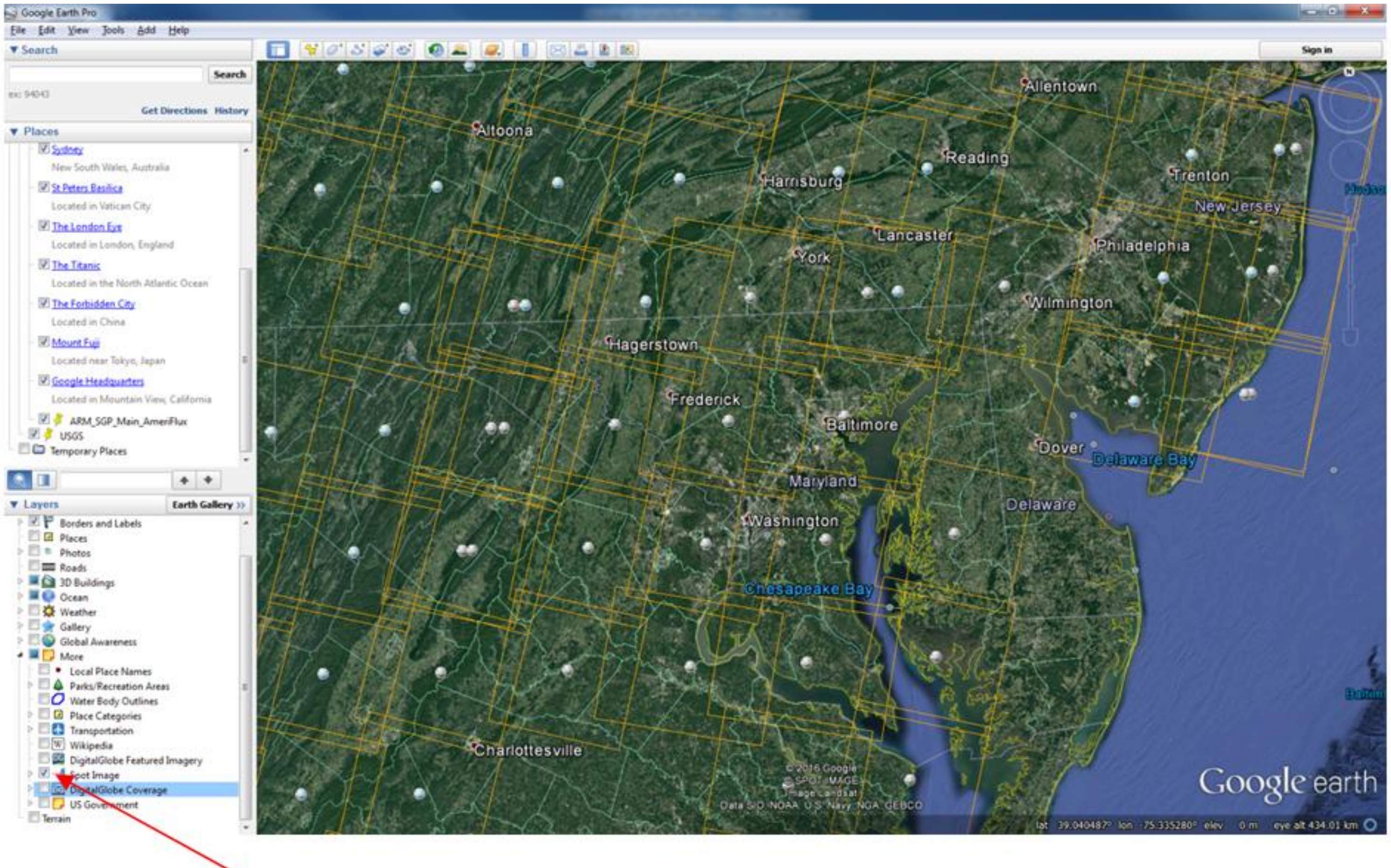
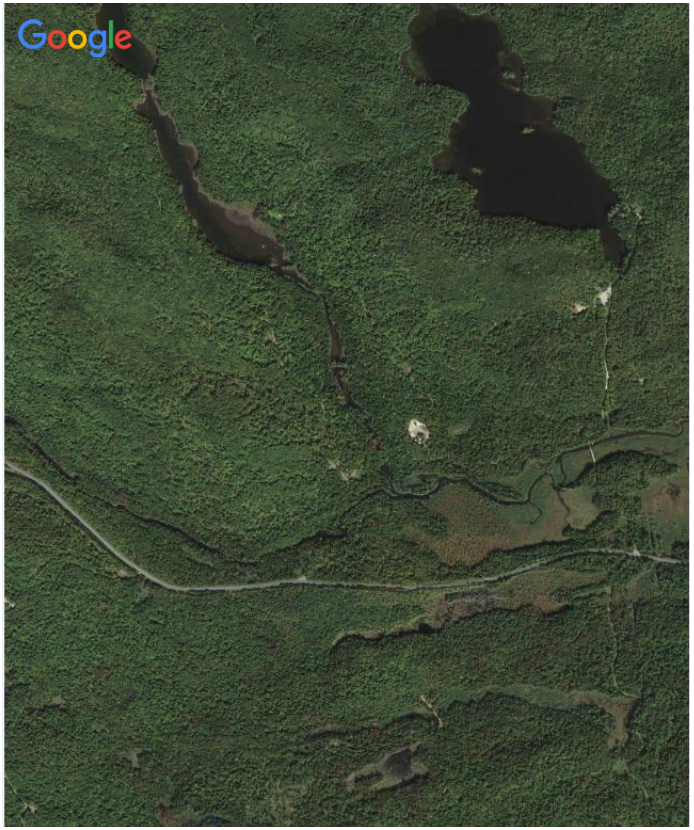


Fig.2. A map of Spot image coverage

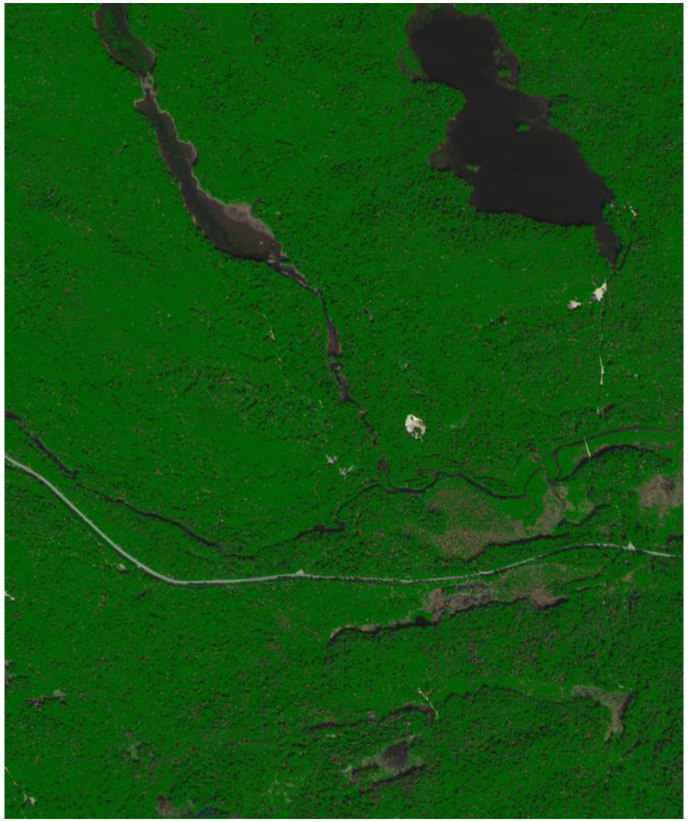
(Image Source: Google Earth)

Arbutus lake (NY, USA)



Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

(9/26/2015)



Classified image
(vegetated pixels: bright green)

Google Earth GVF=0.669
VIIRS GVF=0.66

(Image Source: Google Earth)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image
(vegetated pixels: bright green)

(1/3/2015)

Google Earth GVF=0.0047
VIIRS GVF=0.01

(Image Source: Google Earth)

Bald mountain 1 (CA, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (green vegetation: bright green)

(7/15/2016)

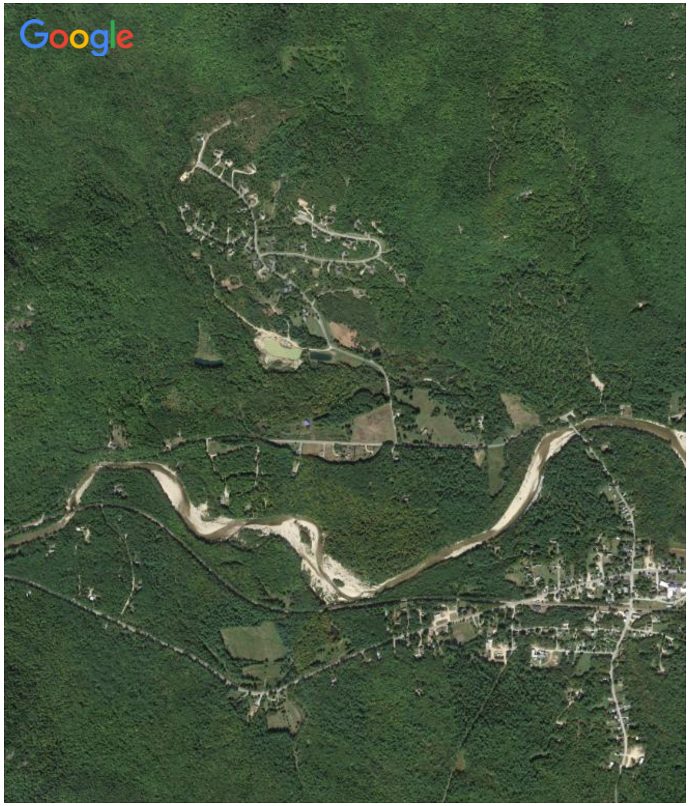
Google Earth GVF=0.2174
VIIRS GVF=0.27

(Image Source: Google Earth)

bbc 7 (NH, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)



(9/18/2013)

Google Earth GVF=0.8294
VIIRS GVF=0.75

(Image Source: Google Earth)

Cedar creek (MN, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)

(4/25/2015)

Google Earth GVF=0.223
VIIRS GVF=0.29

(Image Source: Google Earth)

Coweeta (NC, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)

(10/19/2015)

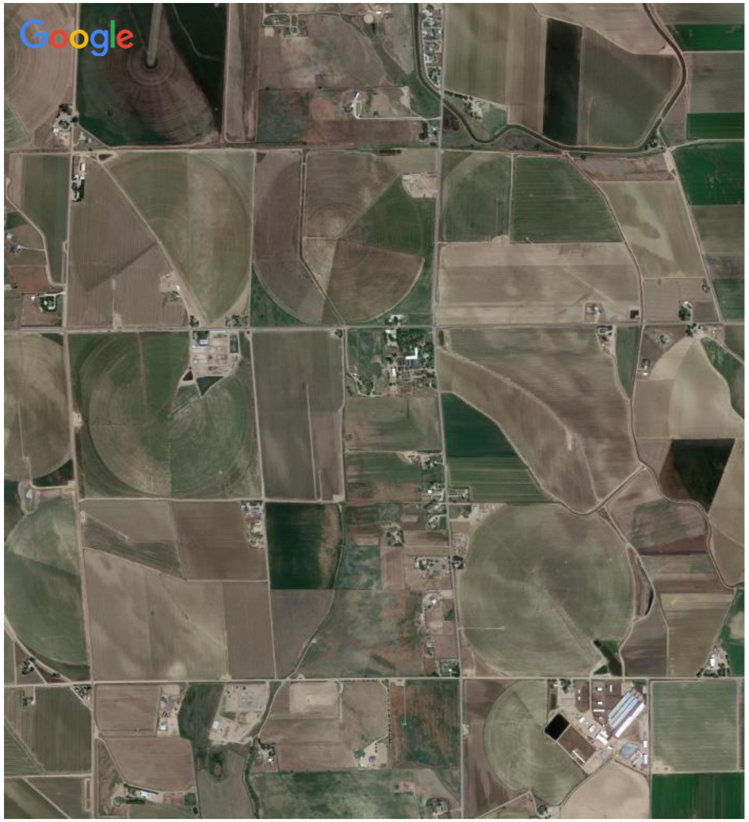
Google Earth GVF=0.6109
VIIRS GVF=0.60

(Image Source: Google Earth)

Cperuvb (CO, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)



(6/19/2014)

Google Earth GVF=0.22
VIIRS GVF=0.49

(Image Source: Google Earth)

Kendall (AZ, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)

(1/3/2015)

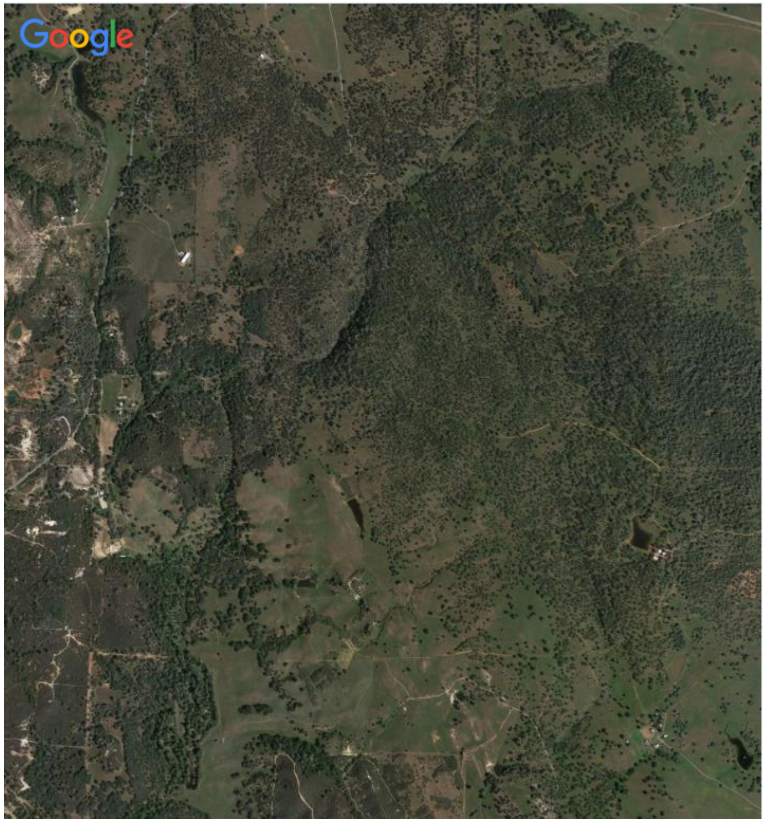
Google Earth GVF=0.036
VIIRS GVF=0.06

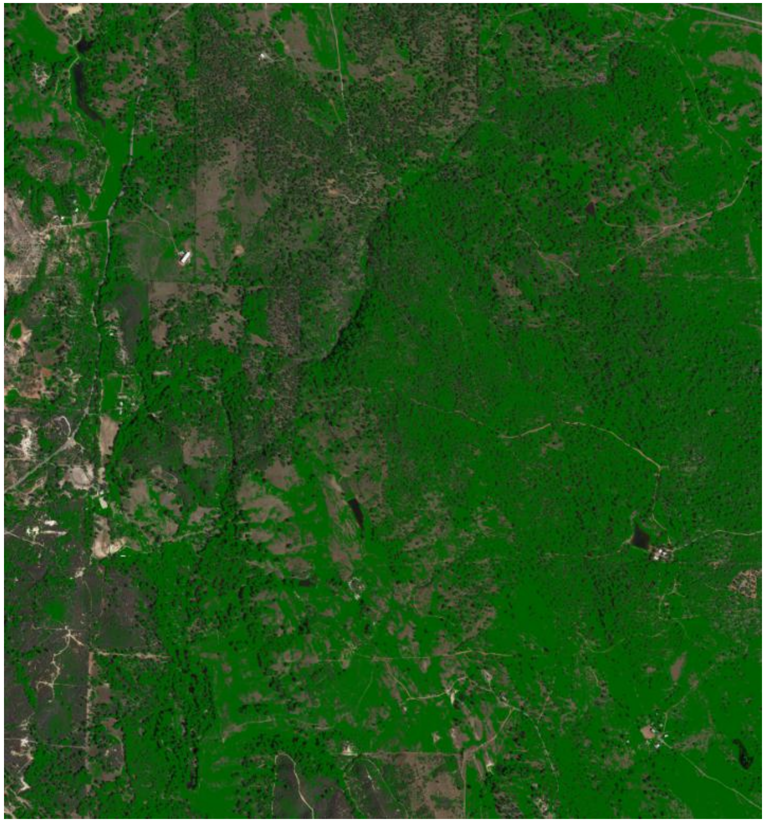
(Image Source: Google Earth)

Tonzi (CA, USA)

Google Earth image over a
0.036°x0.036° VIIRS GVF pixel

Classified image
(vegetated pixels: bright green)





(4/16/2015)

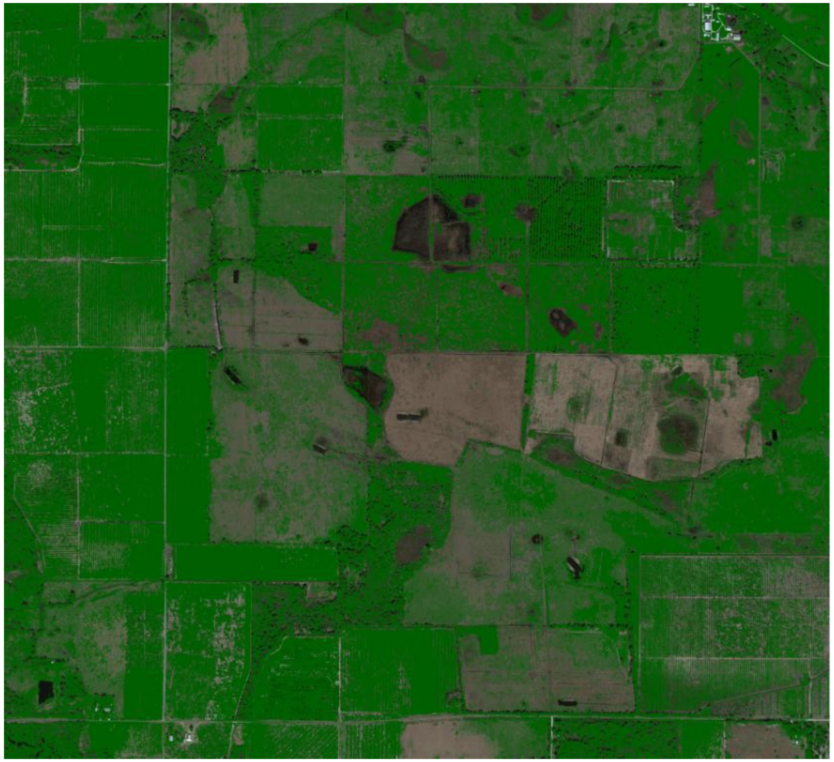
Google Earth GVF=0.535
VIIRS GVF=0.49

(Image Source: Google Earth)

Ufona (FL, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)



(2/4/2016)

Google Earth GVF=0.561
VIIRS GVF=0.49

(Image Source: Google Earth)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)

(3/9/2015)

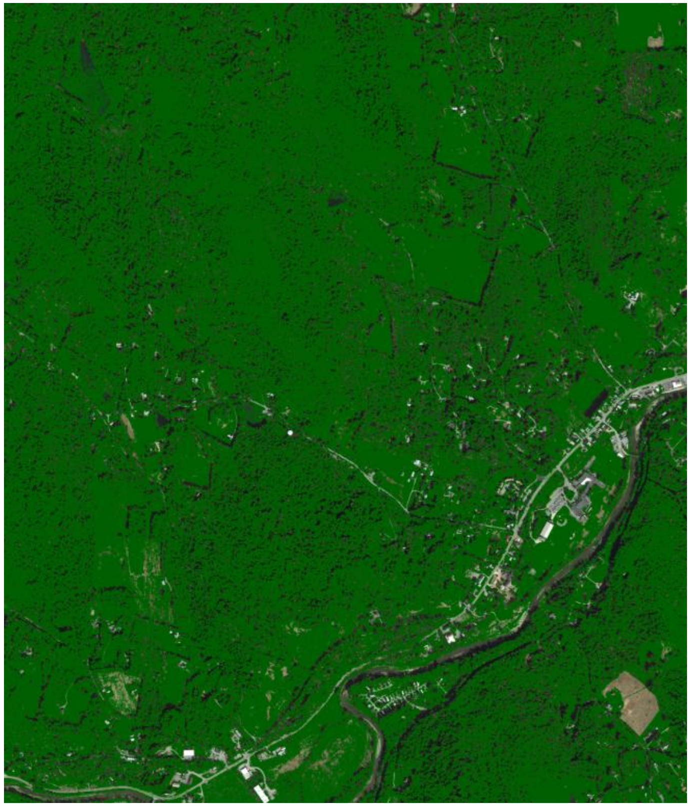
Google Earth GVF=0.01
VIIRS GVF=0.07

(Image Source: Google Earth)

Woodstockvt (VT, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)



(9/19/2013)

Google Earth GVF=0.743
VIIRS GVF=0.69

(Image Source: Google Earth)

Maricopa agricultural center (AZ, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)

(12/26/2014)

Google Earth GVF=0.1012
VIIRS GVF=0.10

(Image Source: Google Earth)

Mead (NE, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)

(5/5/2016)

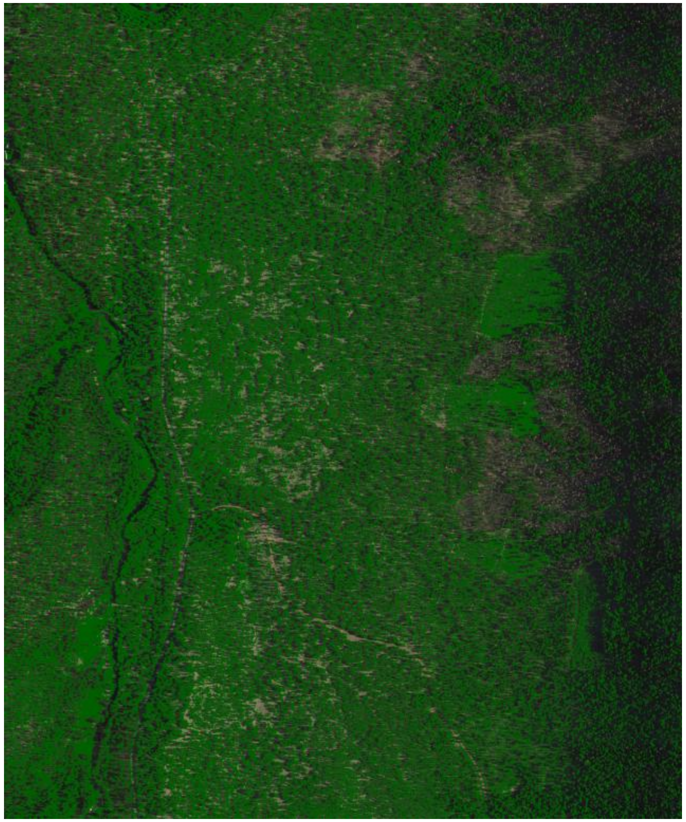
Google Earth GVF=0.2909
VIIRS GVF=0.42

(Image Source: Google Earth)

Metolius/cascades - old pine (OR, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)



(6/28/2016)

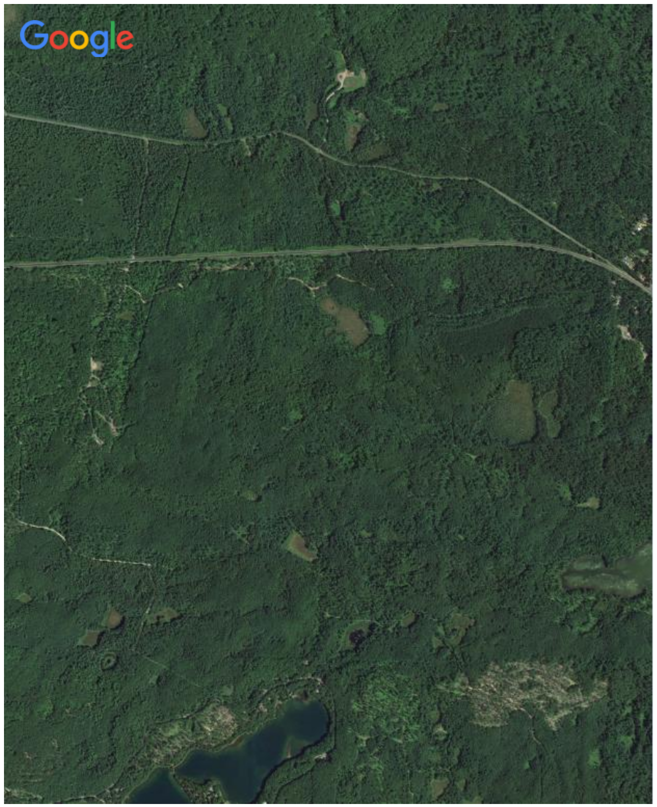
Google Earth GVF=0.4108
VIIRS GVF=0.41

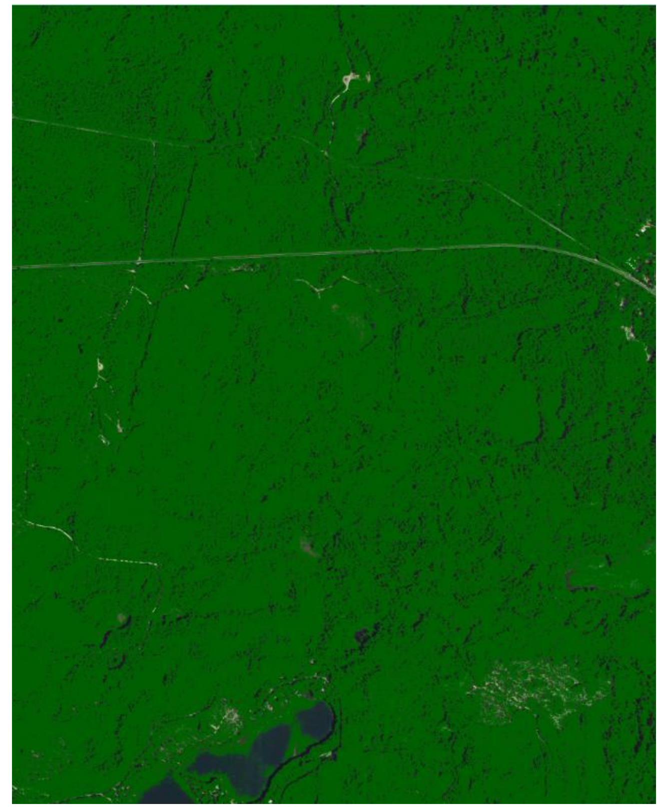
(Image Source: Google Earth)

Wisc: NRL LTER (WI, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)





(7/26/2016)

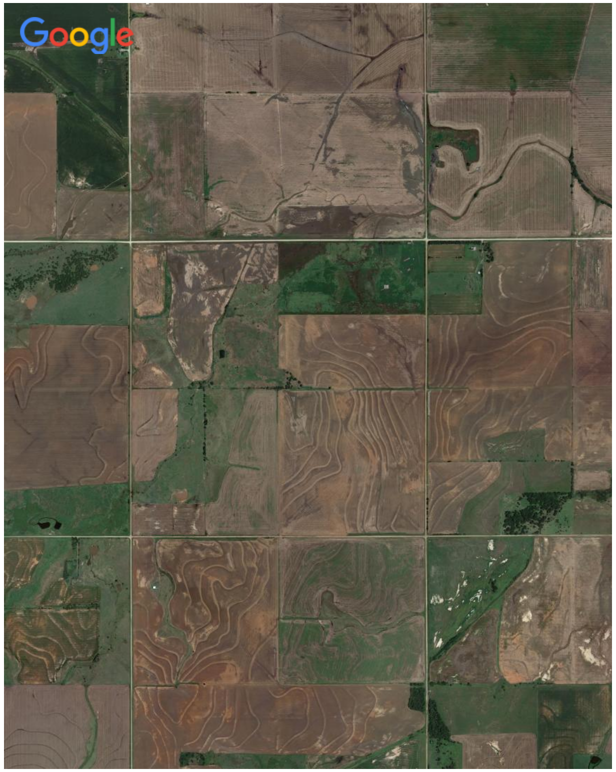
Google Earth GVF=0.866
VIIRS GVF=0.91

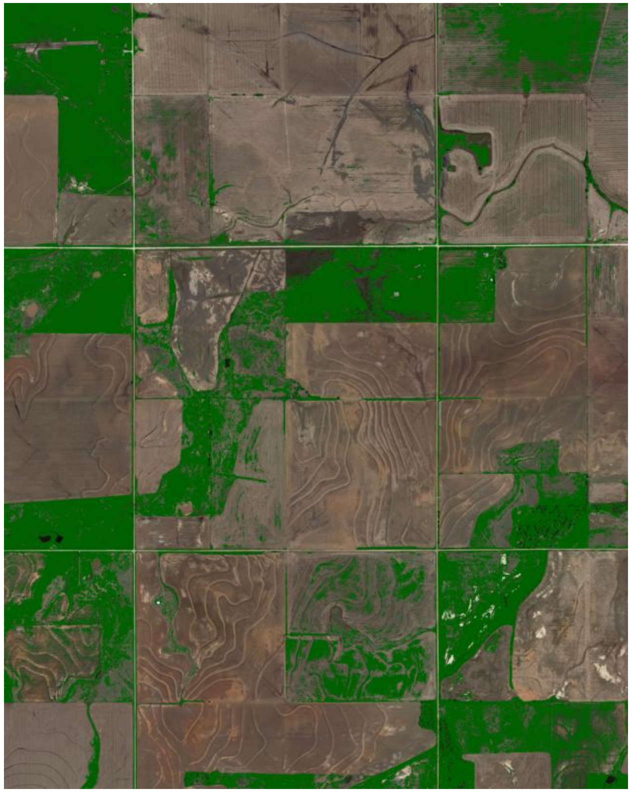
(Image Source: Google Earth)

ARMa/CRT SGP (OK, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)





(7/12/2015)

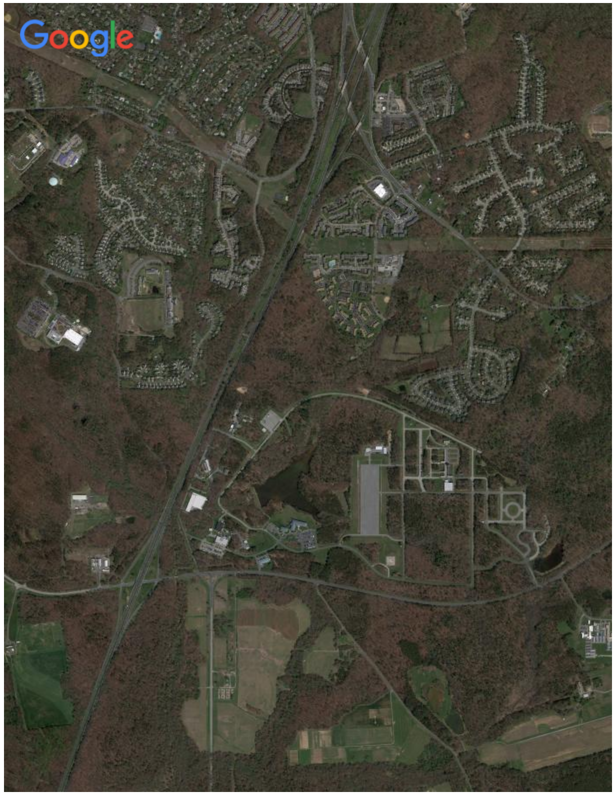
Google Earth GVF=0.22
VIIRS GVF=0.39

(Image Source: Google Earth)

BARC, USDA ARS (MD, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)



(4/15/2016)

Google Earth GVF=0.26
VIIRS GVF=0.40

(Image Source: Google Earth)

Barton Bendish, East Anglia (UK)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)

(1/1/2016)

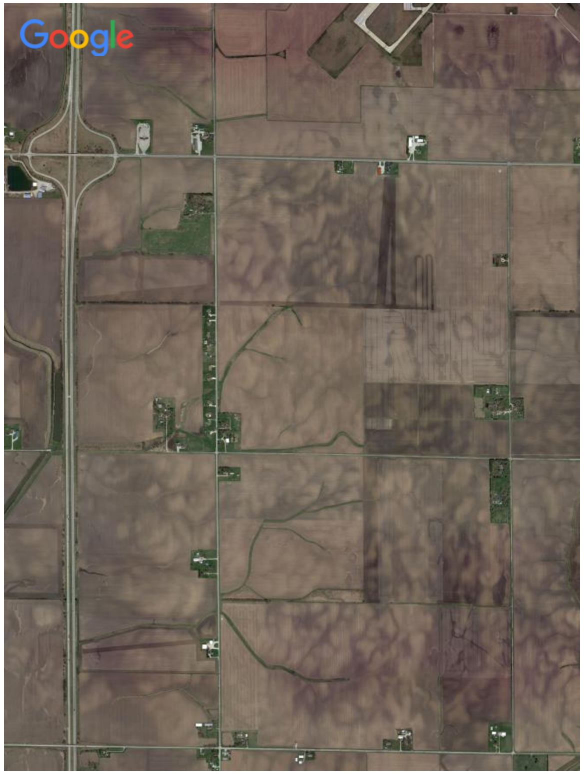
Google Earth GVF=0.64
VIIRS GVF=0.51

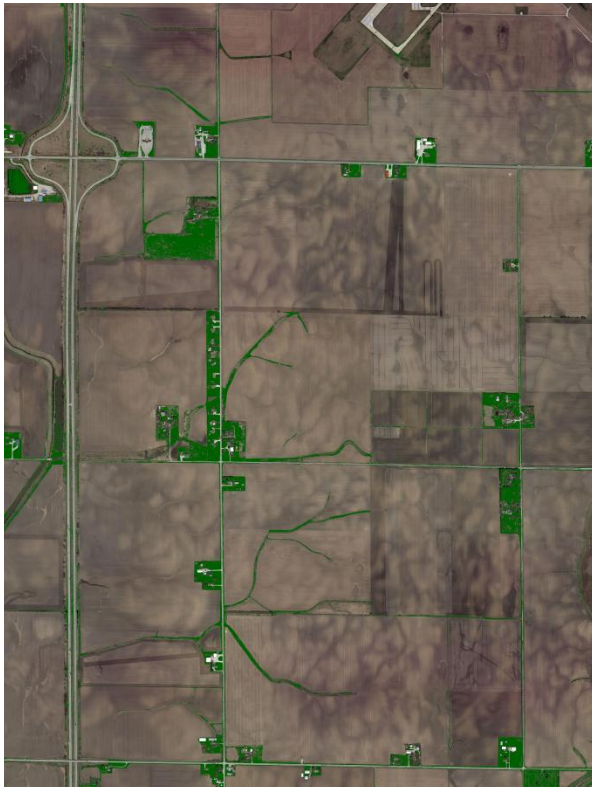
(Image Source: Google Earth)

Bondville (IL, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image
(vegetated pixels: bright green)





(4/19/2014)

Google Earth GVF=0.04
VIIRS GVF=0.16

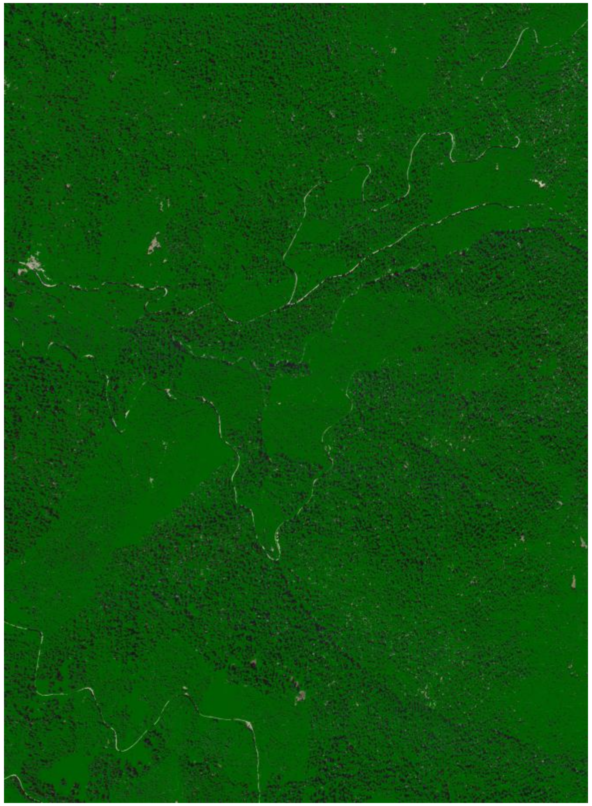
(Image Source: Google Earth)

Cascades/H.A.Handrews (OR, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

(4/19/2014)

Classified image (vegetated pixels: bright green)



Google Earth GVF=0.73
VIIRS GVF=0.65

(Image Source: Google Earth)

Changbai mountain (China)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)

(4/29/2014)

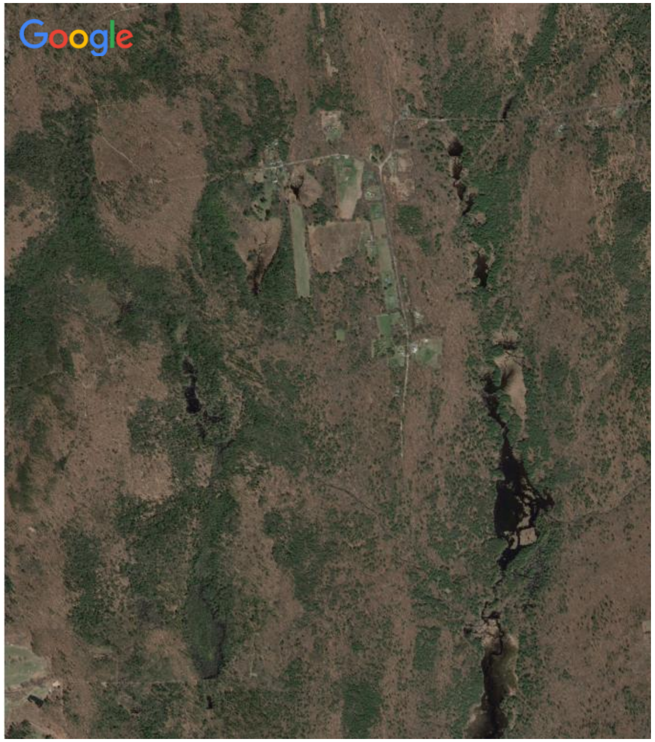
Google Earth GVF=0.13
VIIRS GVF=0.17

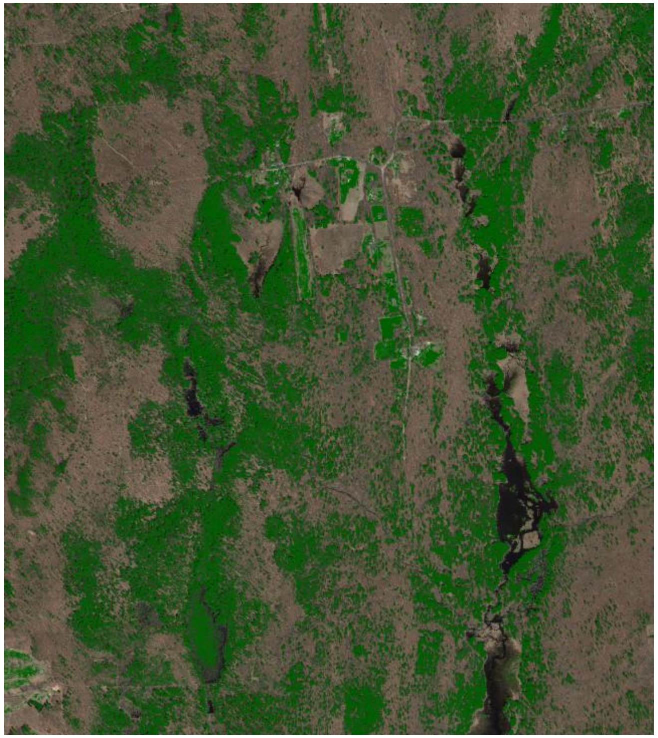
(Image Source: Google Earth)

Harvard forest (MA, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)





(4/27/2016)

Google Earth GVF=0.26
VIIRS GVF=0.34

(Image Source: Google Earth)

Howland (ME, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)

(5/15/2015)

Google Earth GVF=0.71
VIIRS GVF=0.53

(Image Source: Google Earth)

Konza (KS, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)

(8/13/2014)

Google Earth GVF=0.44
VIIRS GVF=0.55

(Image Source: Google Earth)

Park falls (WI, USA)

Google Earth image over a 0.036°x0.036° VIIRS GVF pixel

Classified image (vegetated pixels: bright green)

(5/10/2013)

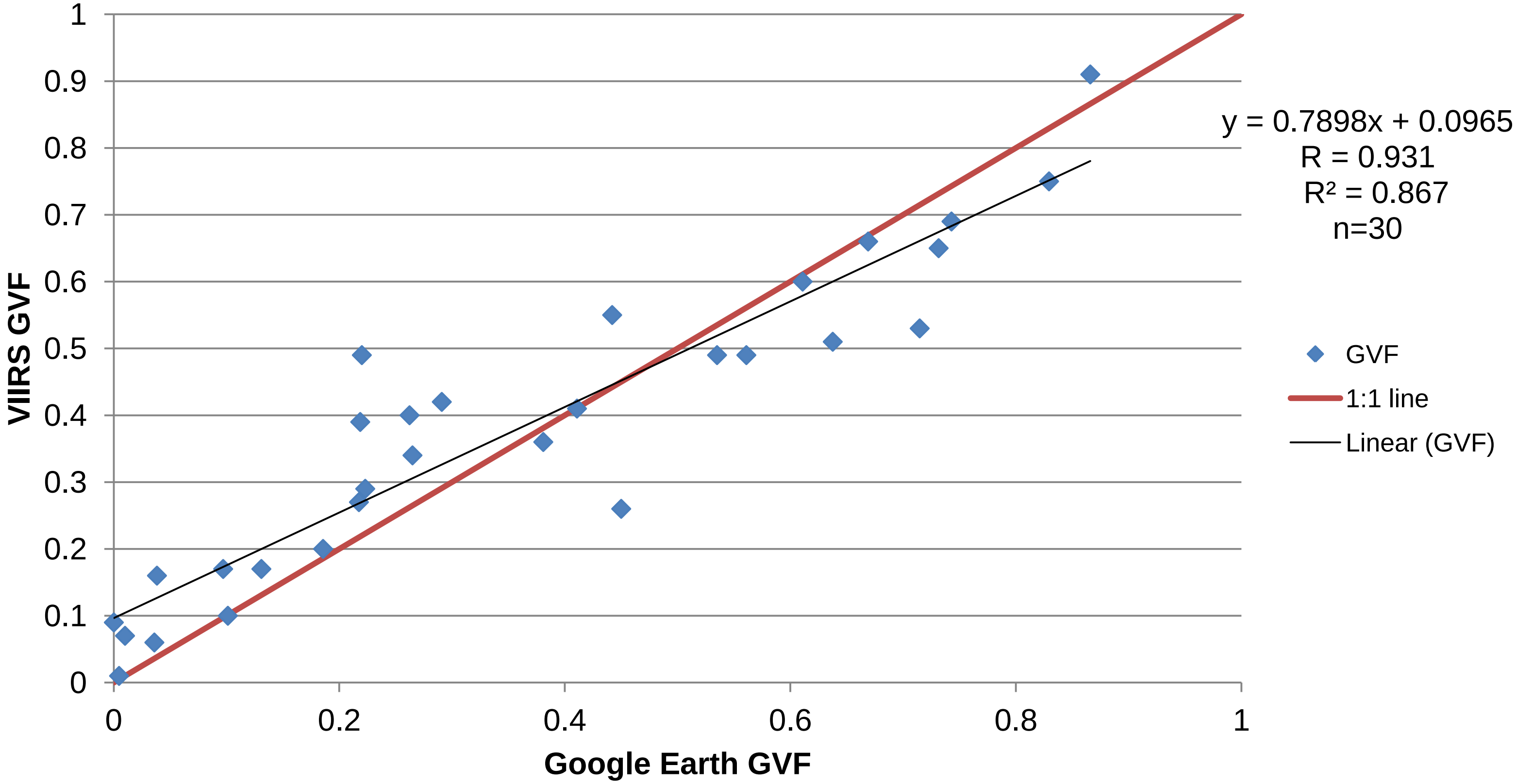
Google Earth GVF=0.38
VIIRS GVF=0.36

(Image Source: Google Earth)

VIIRS GVF vs. Google Earth Satellite Derived GVF

Site	VIIRS GVF	Google Earth GVF
Alligator River	0.26	0.45
Arbutus lake	0.66	0.669
Arizona grass	0.01	0.0047
Bald mountain 1	0.27	0.2174
bbc 7	0.75	0.8294
Cedar creek	0.29	0.223
Coweeta	0.60	0.6109
cperuvb	0.49	0.22
Fernow	0.17	0.097
Kendall	0.06	0.036
Tonzi	0.49	0.535
ufona	0.49	0.561
USGS EROS	0.07	0.01
woodstockvt	0.69	0.743
Jornada	0.09	0.00
Maricopa agriculture center	0.10	0.1012
Mead	0.42	0.2909
Metolius/cascades - old pine	0.41	0.4108
Wisc: NRL LTER	0.91	0.866
ARMa/CRT SGP	0.39	0.22
BARC, USDA ARS	0.40	0.26
Barton Bendish, East Anglia	0.51	0.64
Bondville	0.16	0.04
Cascades/H.A.Handrews	0.65	0.73
Changbai mountain	0.17	0.13
Harvard forest	0.34	0.26
Howland	0.53	0.71
Konza	0.55	0.44
Park falls	0.36	0.38

VIIRS vs. Google Earth GVF - Scatter plot



APU Summary Table

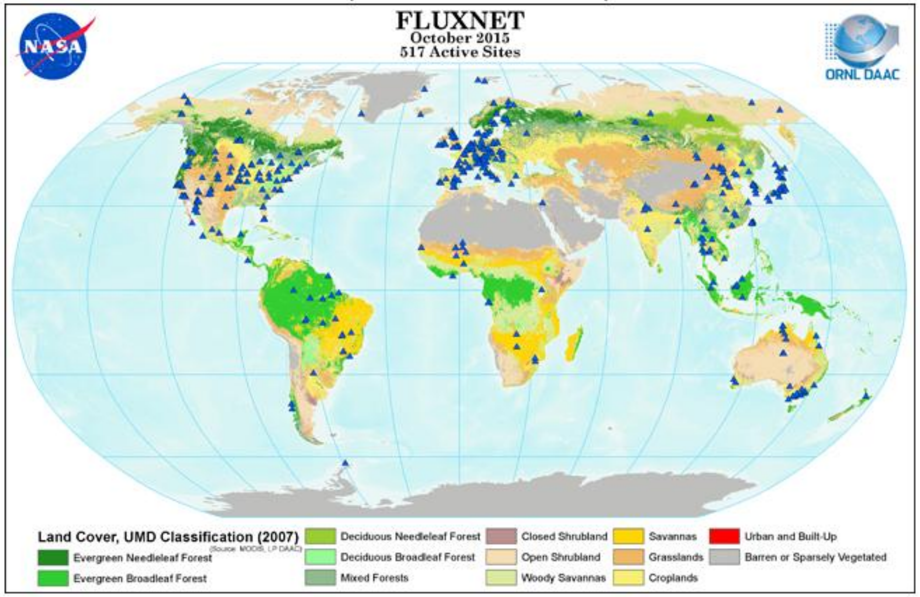
Attribute	Threshold	Calculated
Accuracy	0.12	0.0202
Precision	0.15	0.1010
Uncertainty	0.17	0.1014

Conclusion

- High resolution (~1m) green pixels from Google Earth RGB satellite images can be identified using a green color index
- GVF can be derived from Google Earth satellite RGB images
- Good agreement was found between VIIRS GVF and GVF derived from Google Earth satellite images with R = 0.931
- Calculated APU performance parameters derived using VIIRS and Google Earth Satellite derived GVF meet the JPSS L1RD-S specifications

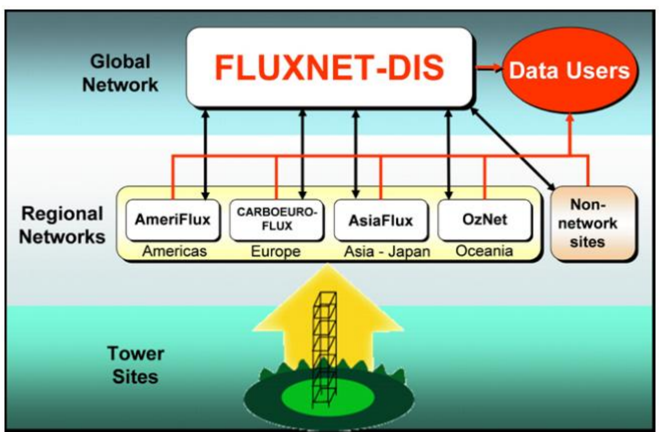
Temporal Profile Evaluation VIIRS vs. Ameriflux Derived GVF

FLUXNET Networks and Land Cover (MODIS UMD Classification)



https://fluxnet.ornl.gov/maps-graphics

FLUXNET Architecture



AmeriFlux Sites

http://ameriflux.lbl.gov/

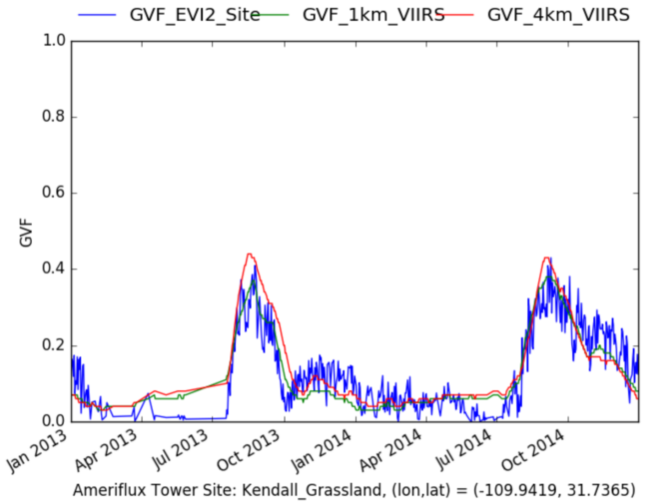
AmeriFlux

FLUXNET/Ameriflux

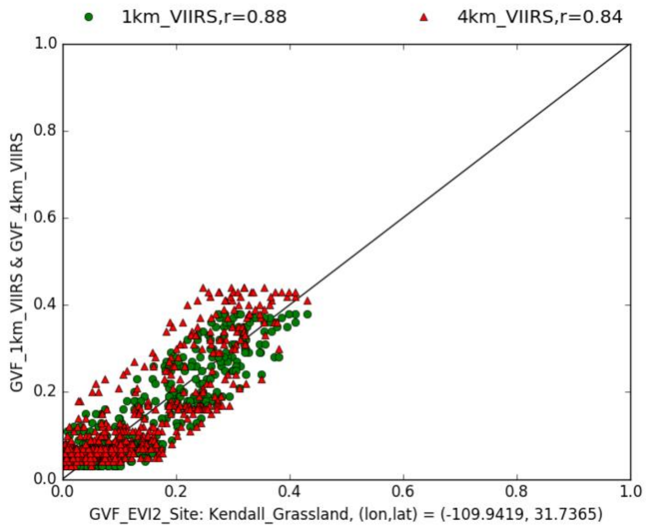
- FLUXNET/AmeriFlux provides well-calibrated time series measurements of various physical variables across a range of biomes
- FLUXNET/AmeriFlux provides data including shortwave solar radiation and photosynthetically active radiation (PAR) measurements above vegetation canopy throughout multiple years
- High-temporal resolution NDVI and EVI2 (2-band EVI) time series are computed from PAR & global radiation data (Wilson & Meyers 2007)
- FLUXNET/AmeriFlux derived vegetation indices and GVF can be used for validation of VIIRS vegetation indices and their derived products (e.g.,GVF)

VIIRS GVF vs. AmeriFlux GVF - Temporal Profile Evaluation

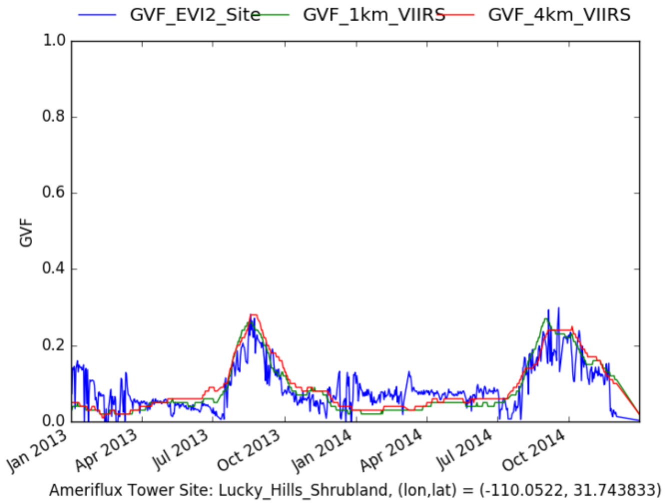
Walnut Gulch Kendall Grasslands



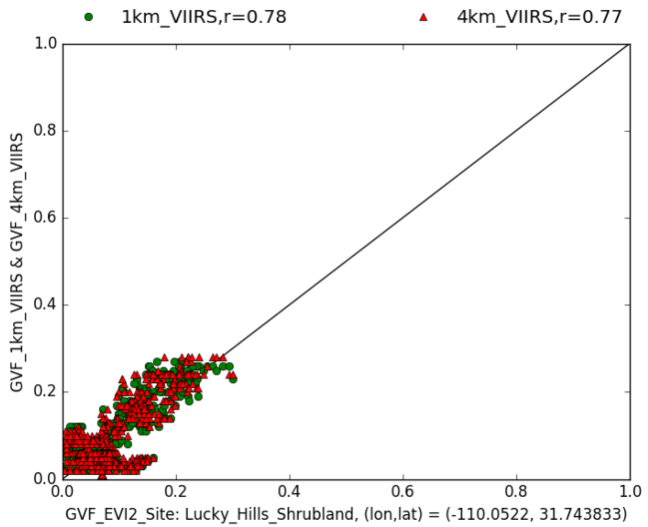
(Image Source: Google Earth)



Walnut Gulch Lucky Hills Shrubland

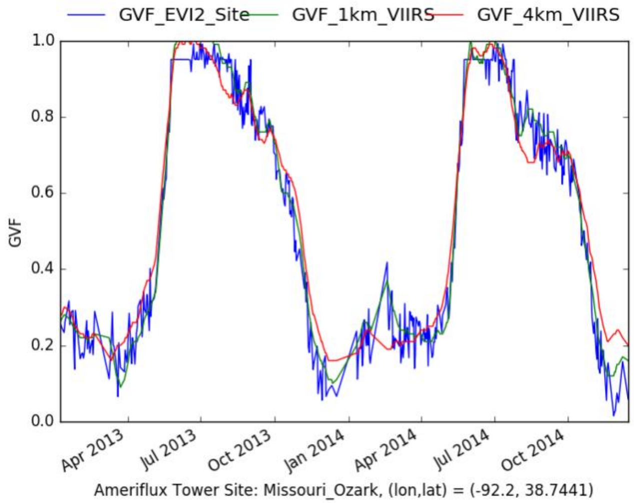


(Image Source: Google Earth)

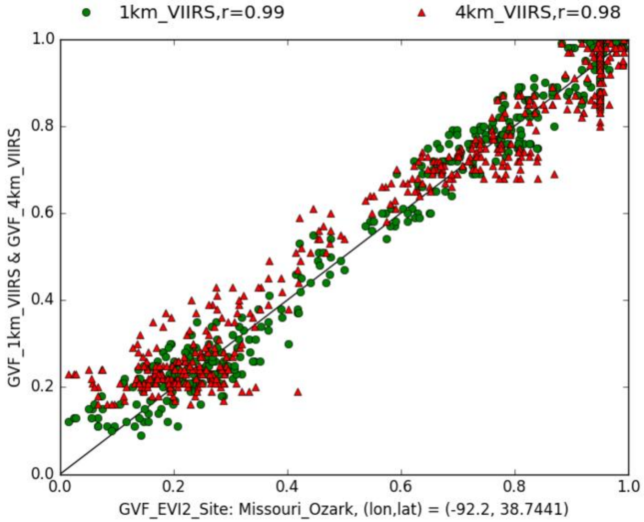


VIIRS GVF vs. AmeriFlux GVF - Temporal Profile Evaluation

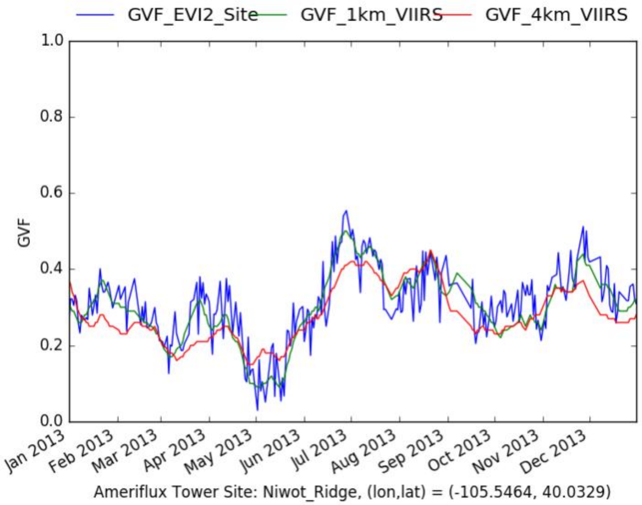
Missouri Ozark Site (Oak hickory forest)



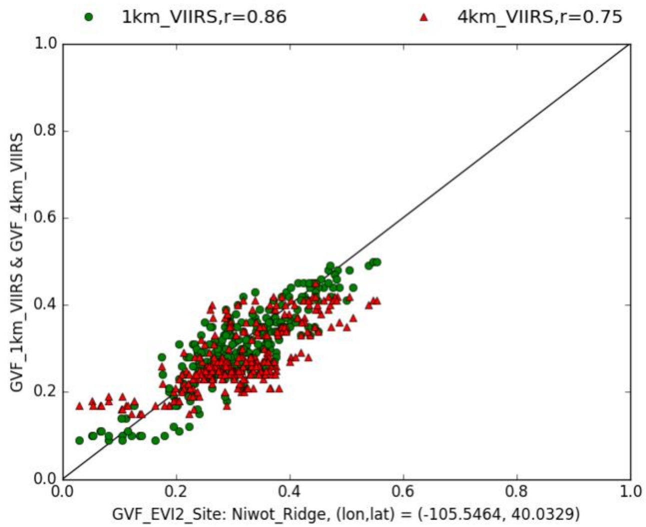
(Image Source: Google Earth)



Niwot Ridge



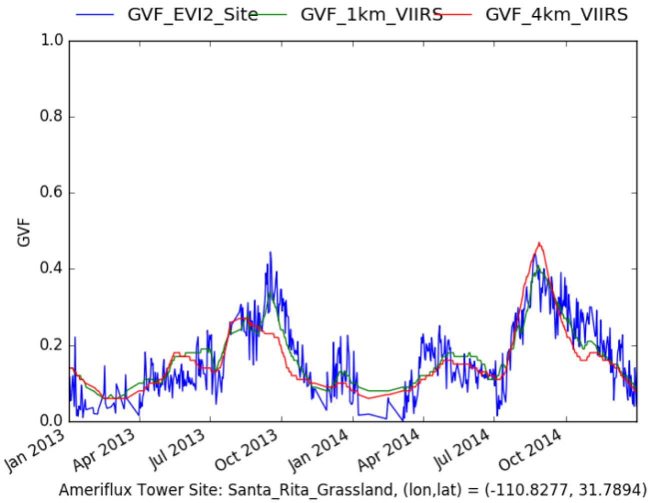
(Image Source: Google Earth)



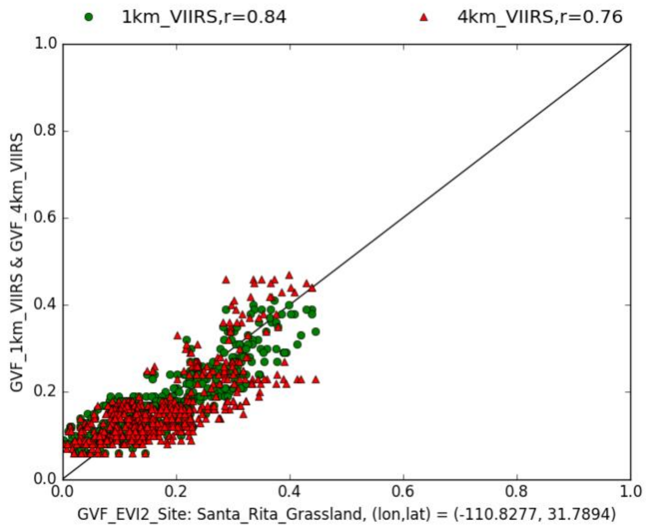
Alpine ecosystem in the southern Rocky Mountains, including extensive expanses of alpine tundra and subalpine coniferous forests

VIIRS GVF vs. AmeriFlux GVF - Temporal Profile Evaluation

Santa Rita Grassland

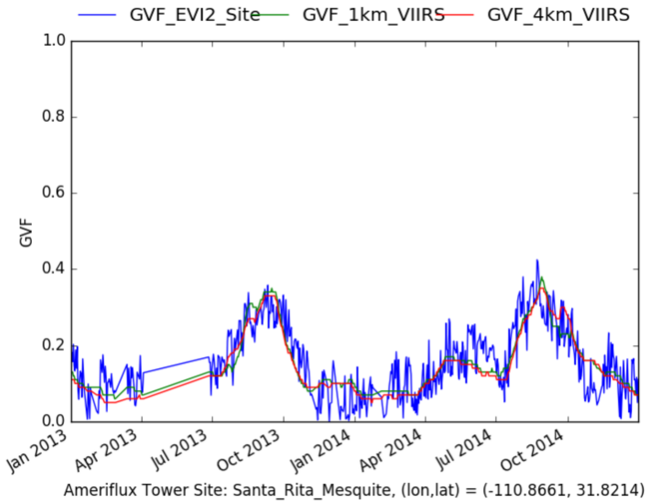


(Image Source: Google Earth)

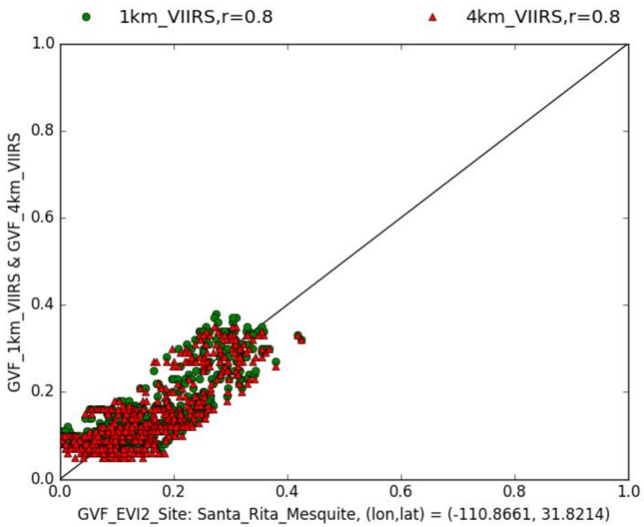


VIIRS GVF vs. AmeriFlux GVF - Temporal Profile Evaluation

Santa Rita Mesquite (shrubland)



(Image Source: Google Earth)

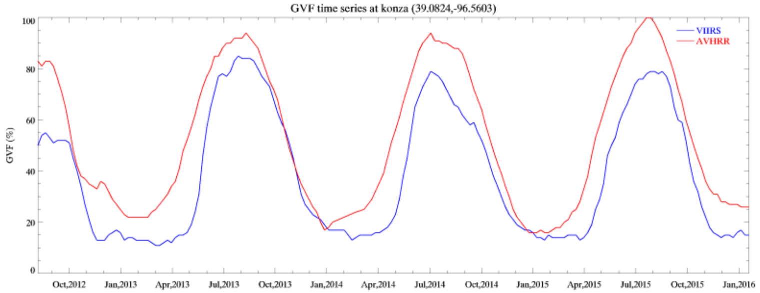


Conclusion

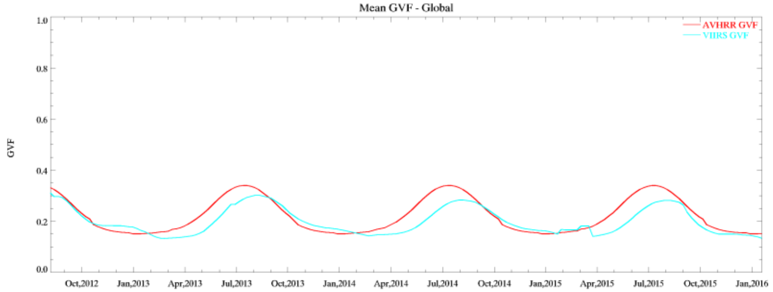
- Both VIIRS 1-km and 4-km GVF had visually comparable seasonal profiles to the tower GVF counterparts at multiple AmeriFlux sites
- Scatter plots show a strong positive correlation between the VIIRS and Flux tower derived GVF
- Tower radiation flux measurements can be used for monitoring and validating VIIRS GVF temporal profiles

Temporal Profile and Correlative Analysis
VIIRS vs. AVHRR GVF

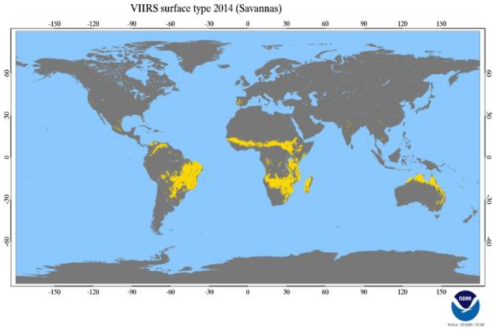
GVF Temporal Trajectories
VIIRS vs. AVHRR
Konza Validation Site



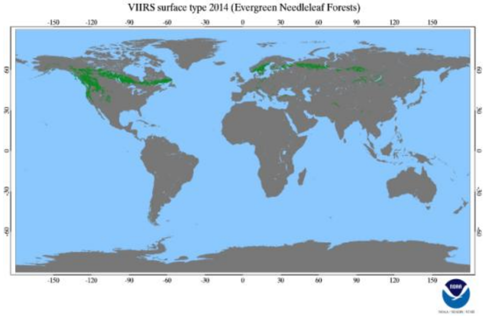
Global GVF Temporal Trajectories
VIIRS vs. AVHRR



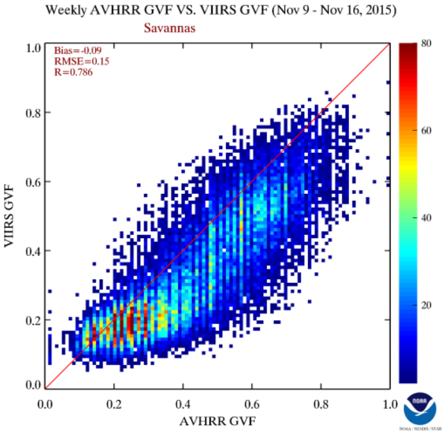
GVF Comparison by Surface Type
VIIRS vs. AVHRR

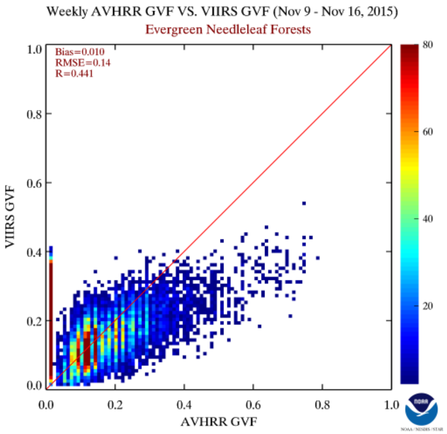


Savannas



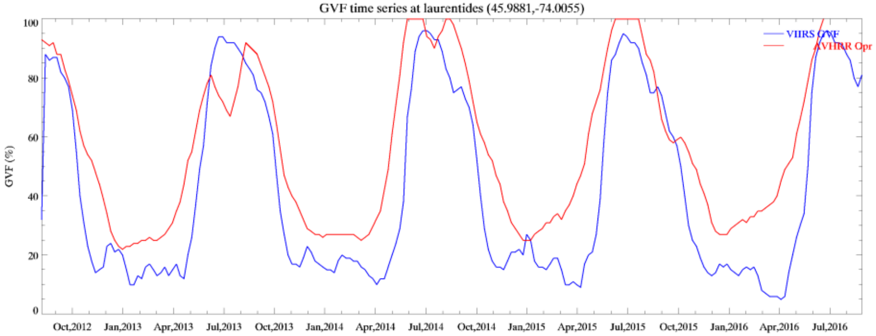
Evergreen Needleleaf Forests



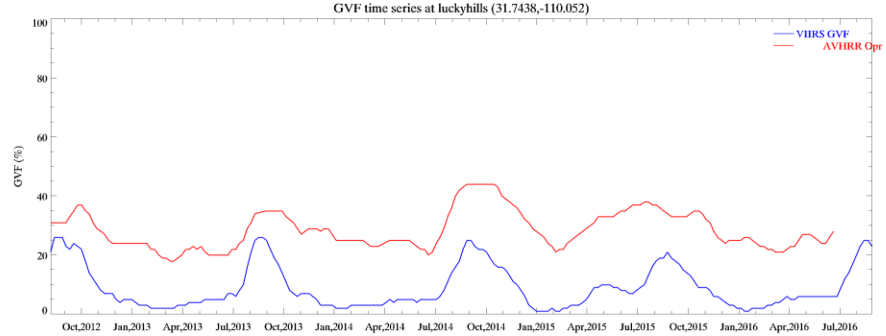


GVF VIIRS vs. AVHRR Temporal Profile Comparison at Select EOS Validation Sites

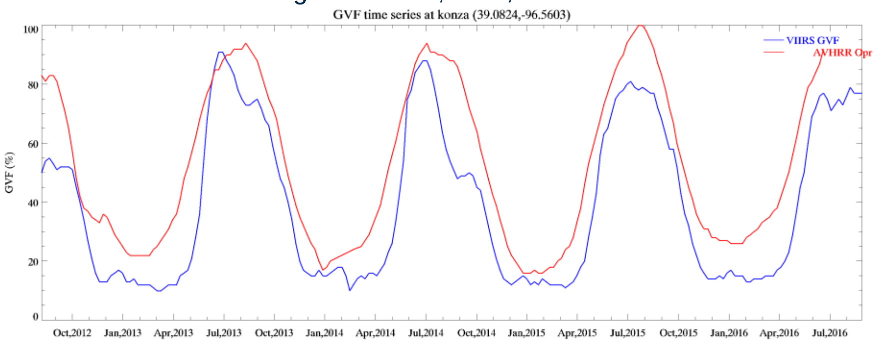
Laurentides Station of biology, U of Montreal, Quebec



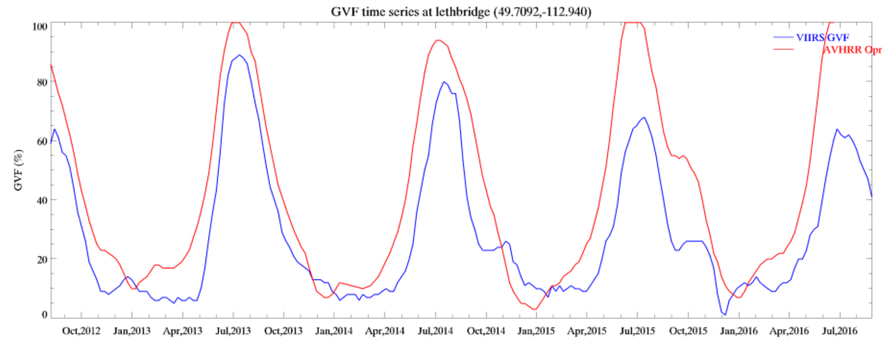
Walnut Gulch, Lucky Hills Shrubland, AZ



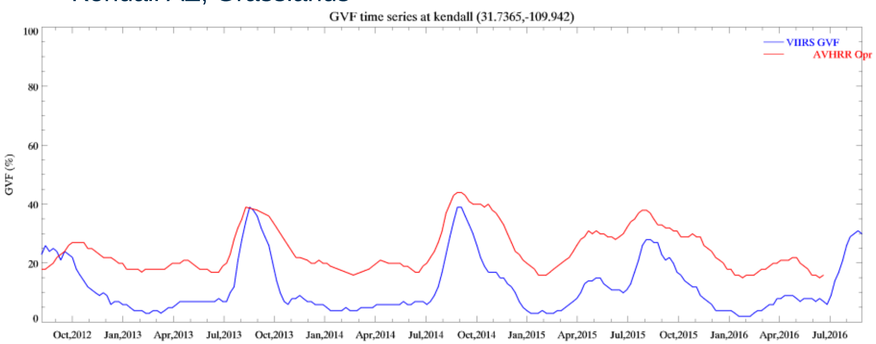
Konza Prairie Biological Station, KSU, KS



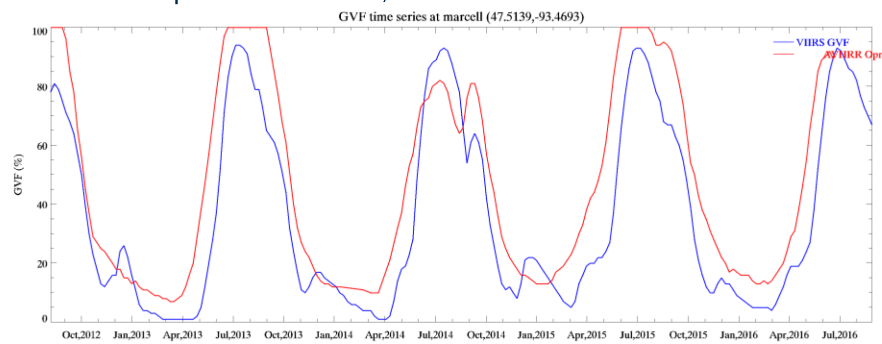
Grassland Ecosystem Site, Lethbridge, Alberta



Kendall AZ, Grasslands

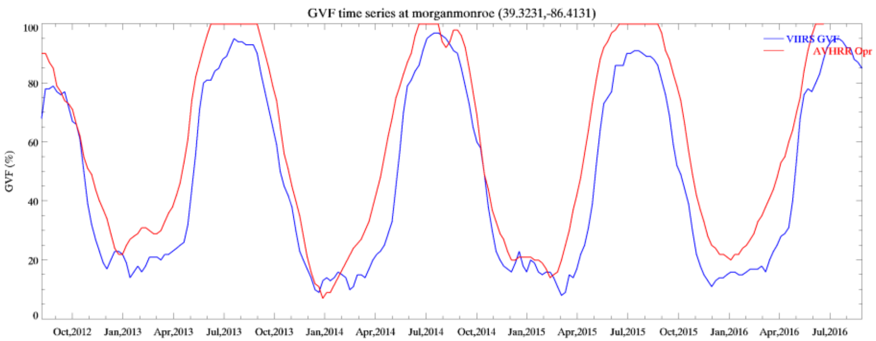


Marcell Experimental Forest, MN

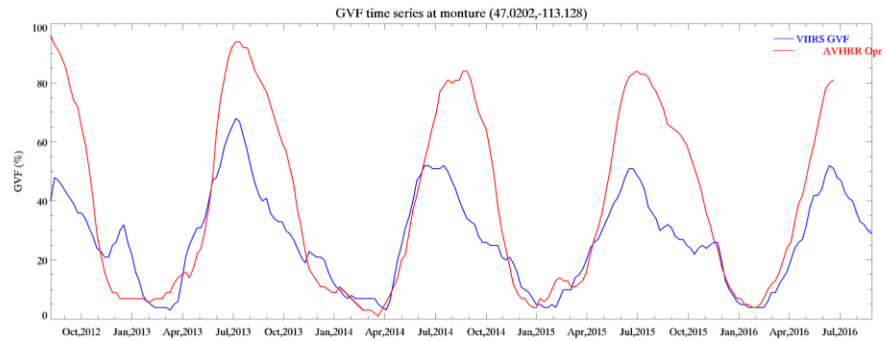


VIIRS vs. AVHRR GVF Temporal Profile Comparison at Select EOS Validation Sites

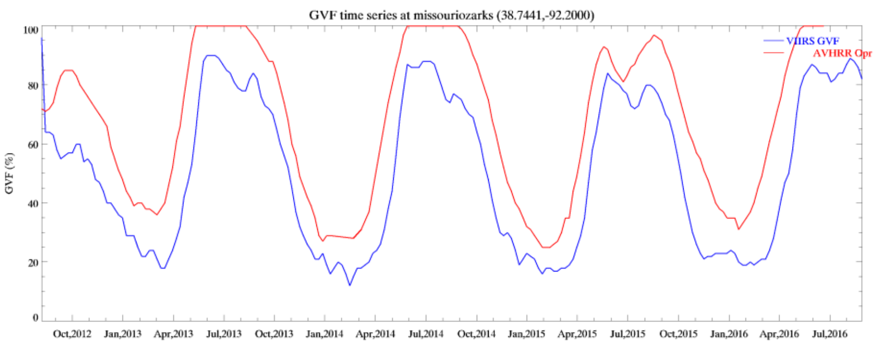
Morgan Monroe State Forest, IN



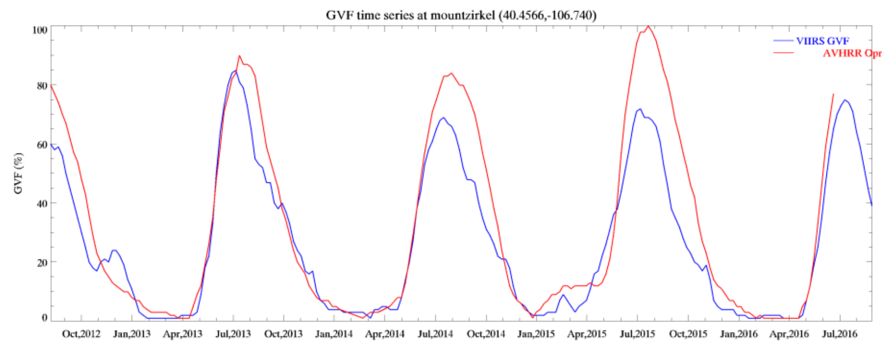
Lolo National Forest, Ovando, MT



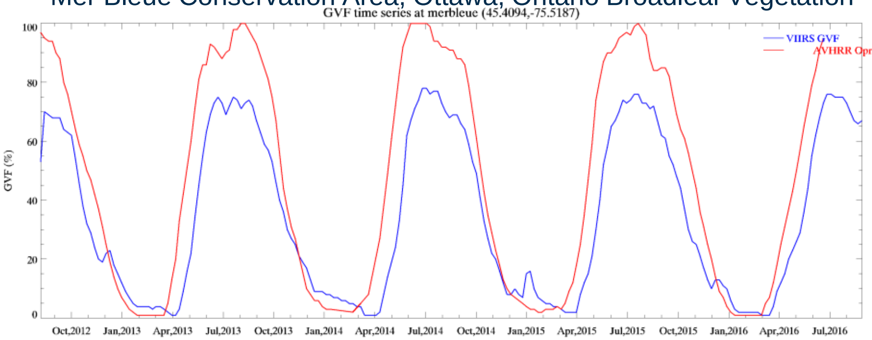
Missouri ozark Oak hickory forest U of Missouri, Ashland Wildlife, MO



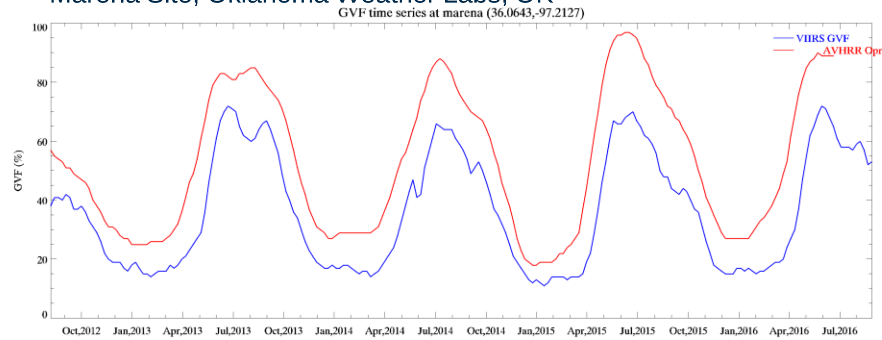
Mount Zirkel, Routt National Forest, CO



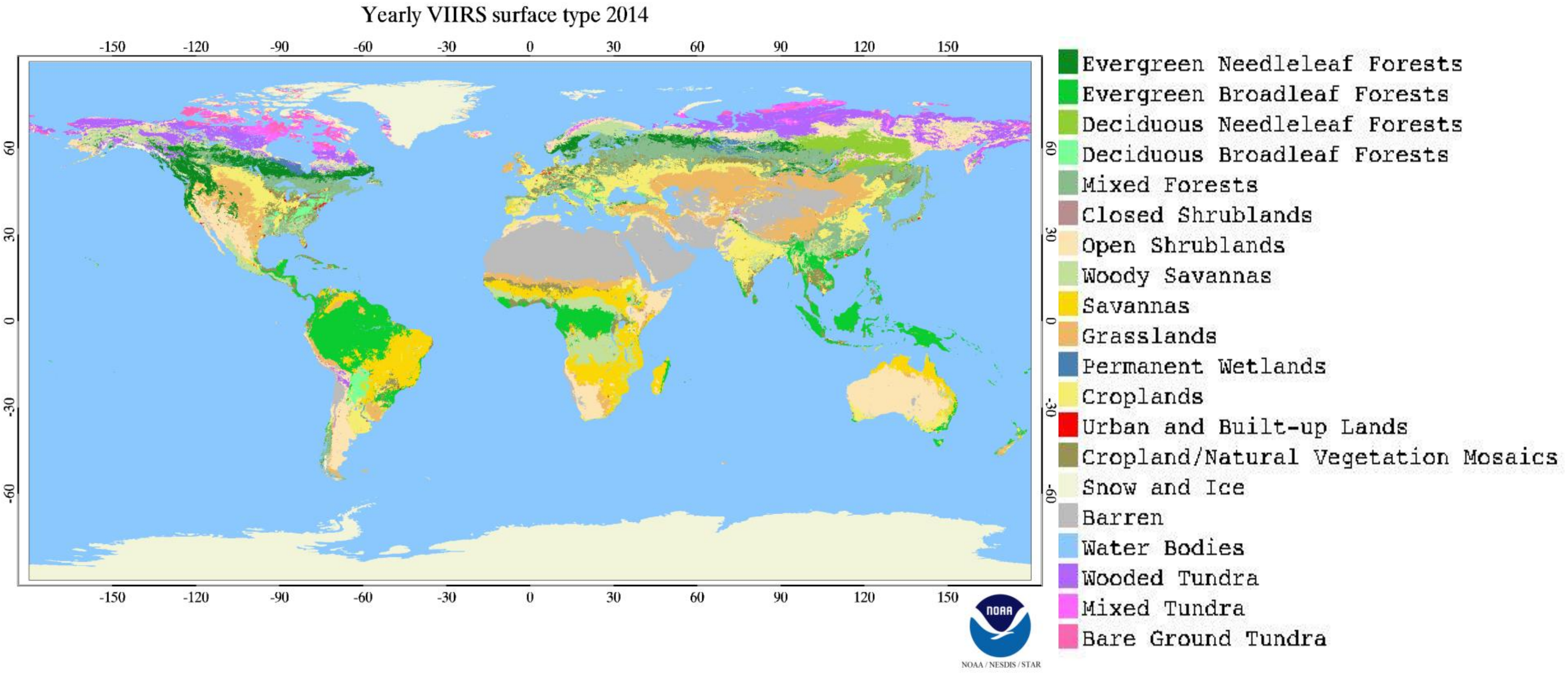
Mer Bleue Conservation Area, Ottawa, Ontario Broadleaf Vegetation



Marena Site, Oklahoma Weather Labs, OK



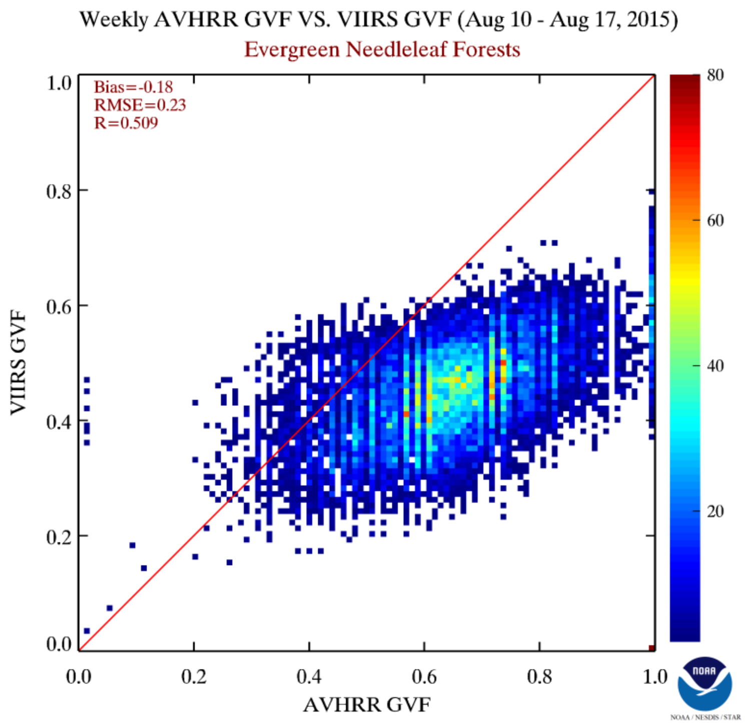
Surface Type Map (2014)



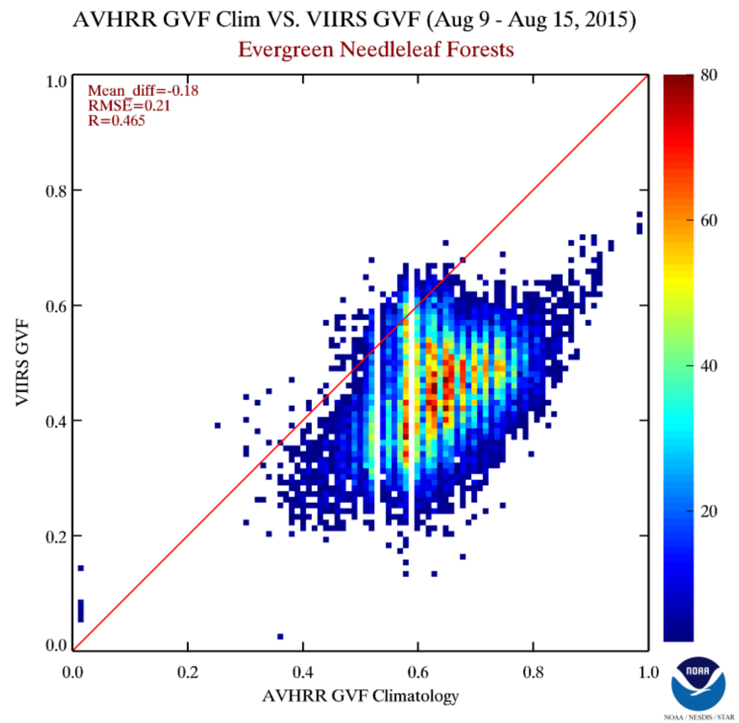
- 20 surface types
- Resolution: 0.144-degree

GVF scatter plots (VIIRS VS. AVHRR)

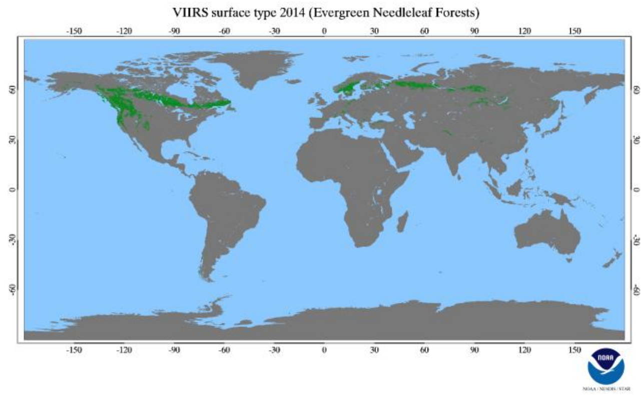
Evergreen Needleleaf forests



Operational AVHRR GVF

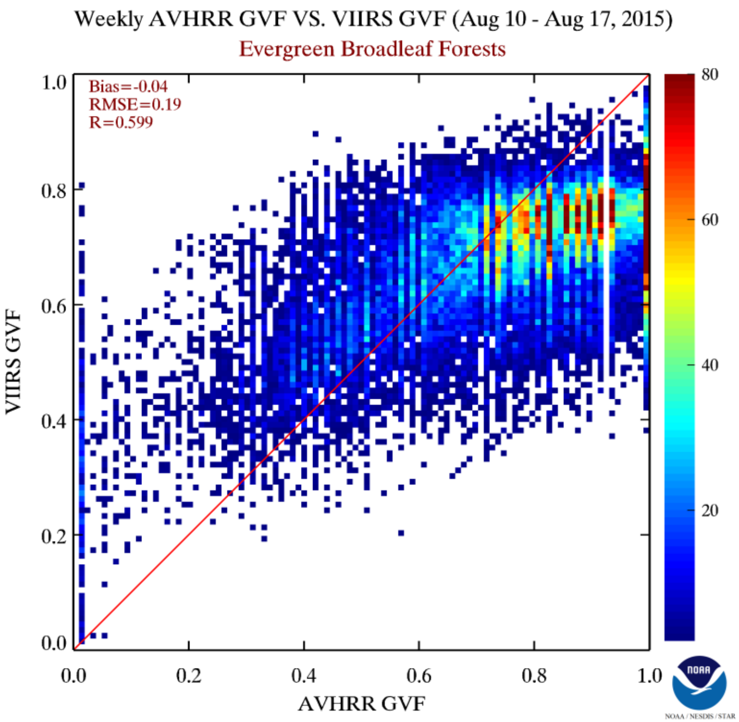


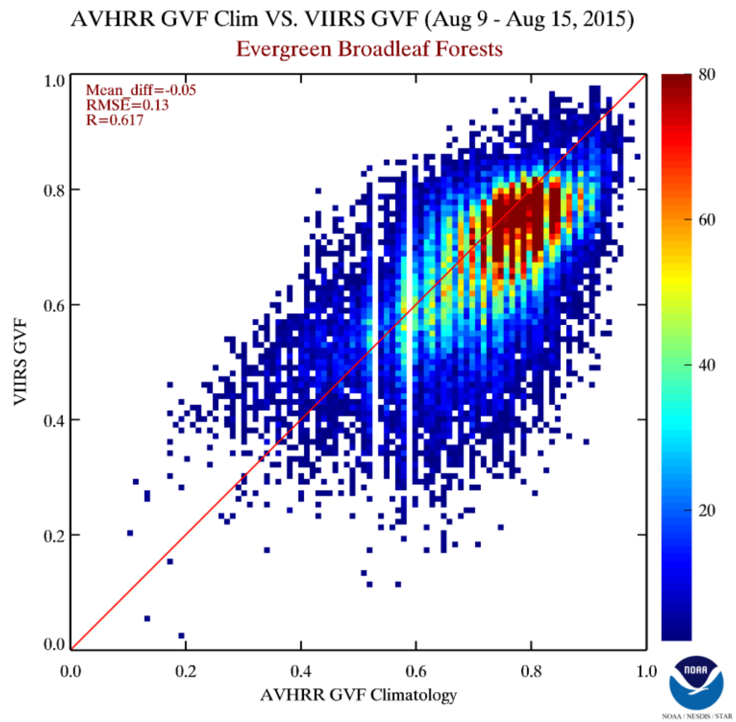
AVHRR GVF Climatology



GVF scatter plots (VIIRS VS. AVHRR)

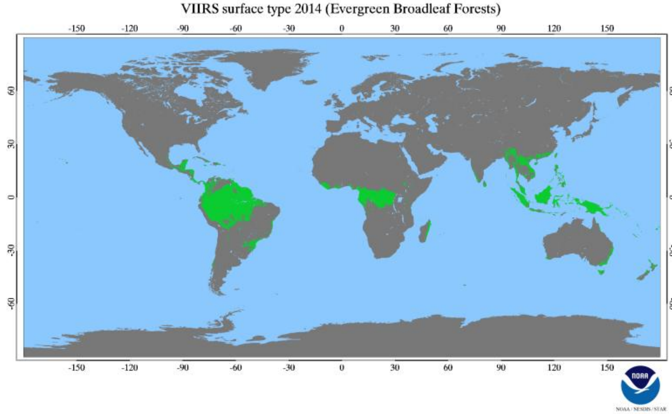
Evergreen Broadleaf forests





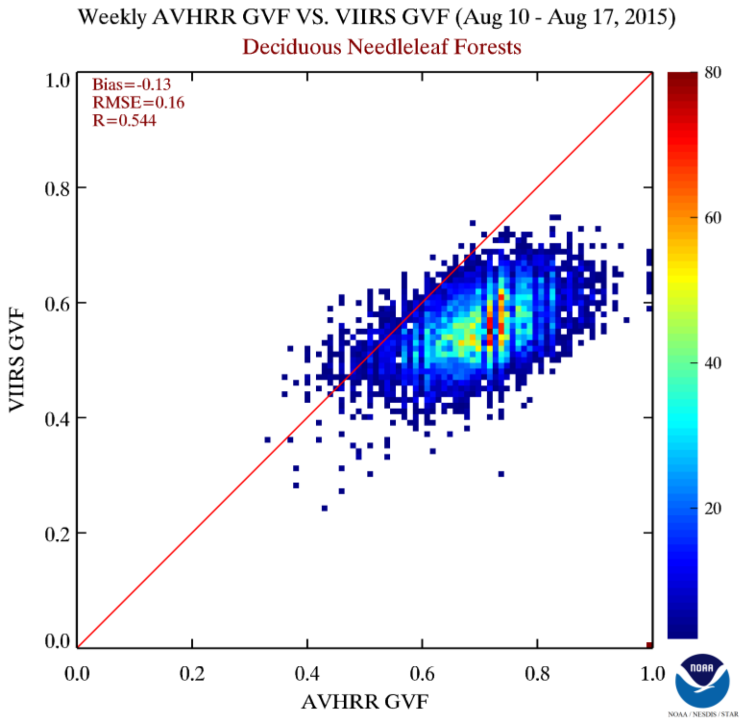
Operational AVHRR GVF

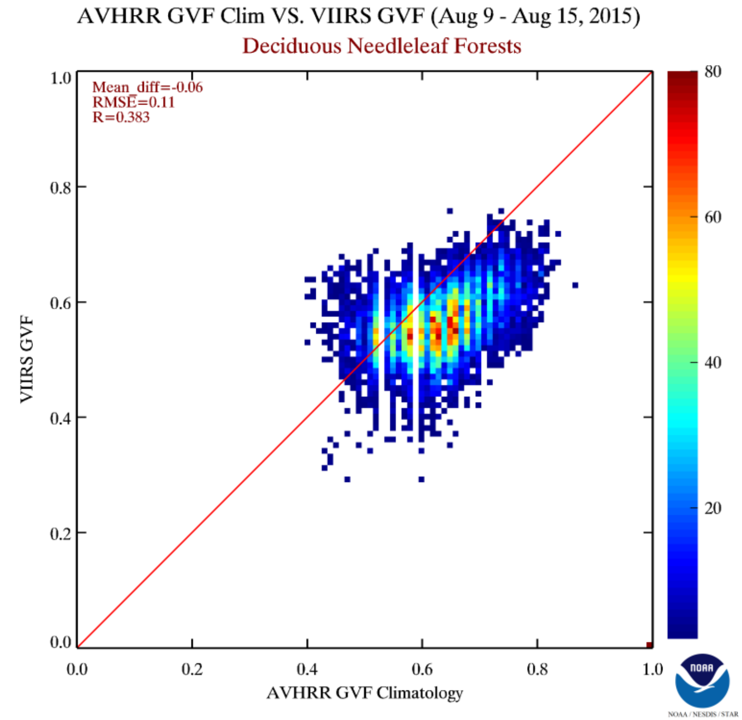
AVHRR GVF Climatology



GVF scatter plots (VIIRS VS. AVHRR)

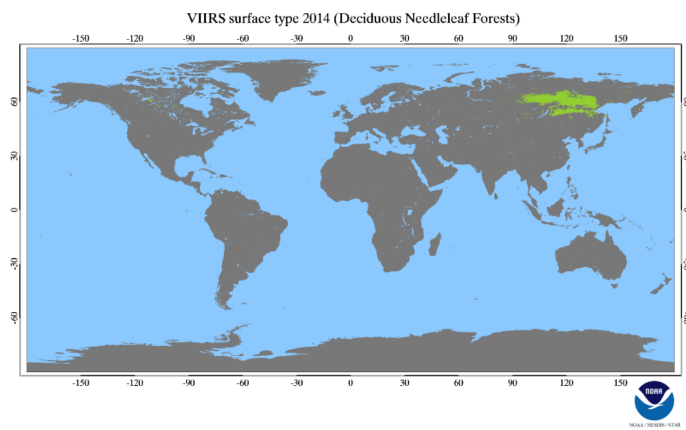
Deciduous Needleleaf forests





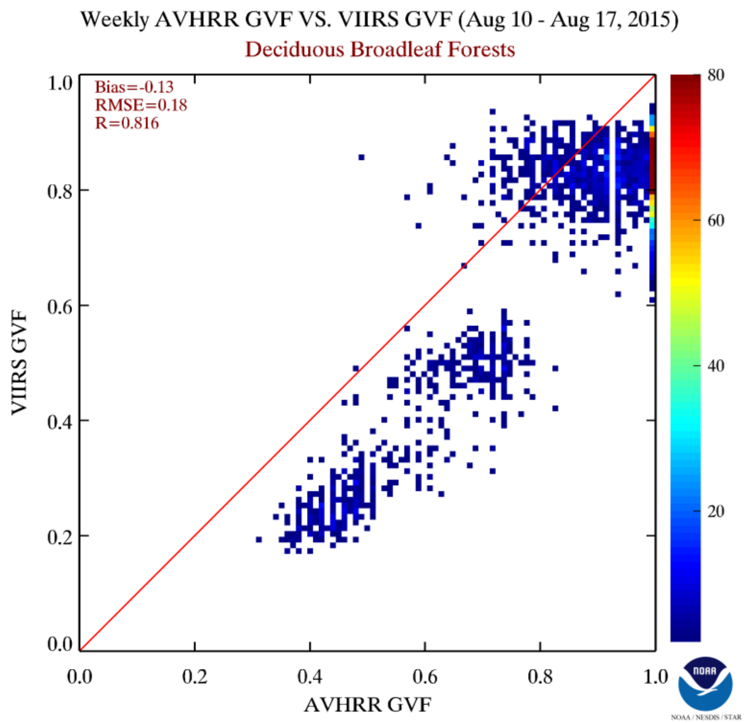
Operational AVHRR GVF

AVHRR GVF Climatology

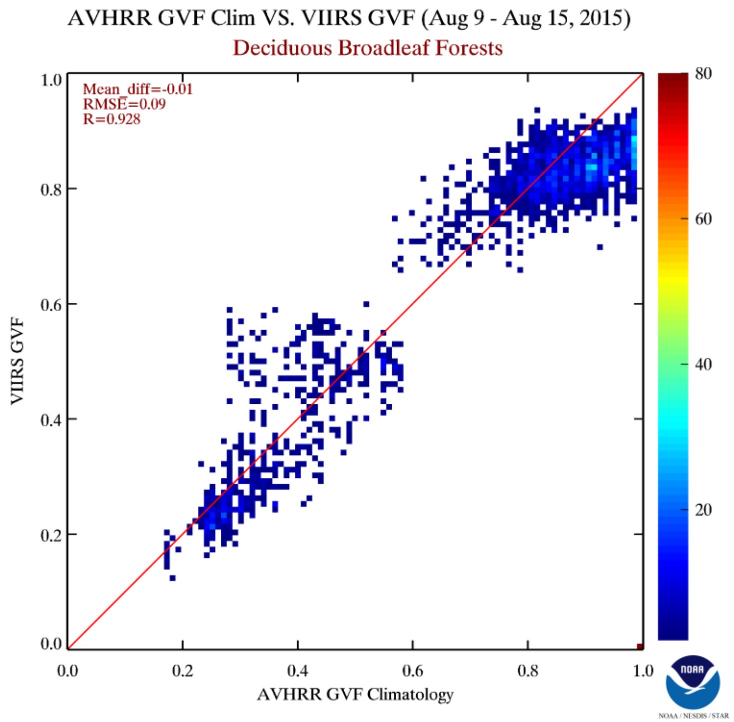


GVF scatter plots (VIIRS VS. AVHRR)

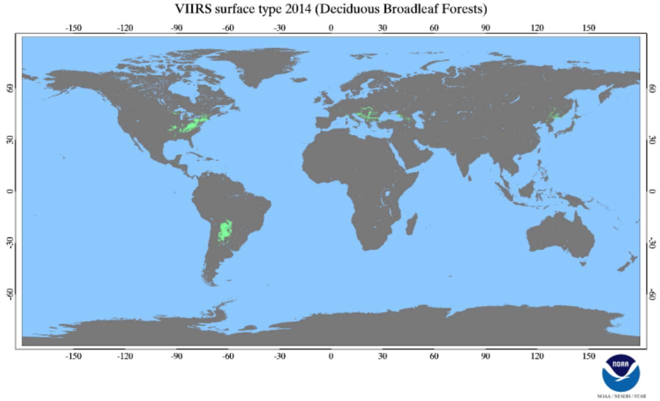
Deciduous Broadleaf forests



Operational AVHRR GVF

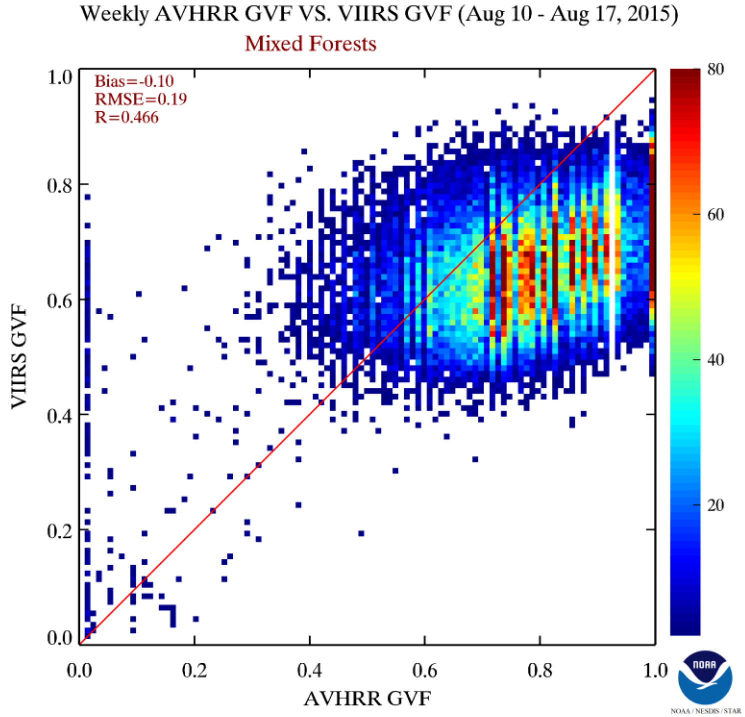


AVHRR GVF Climatology

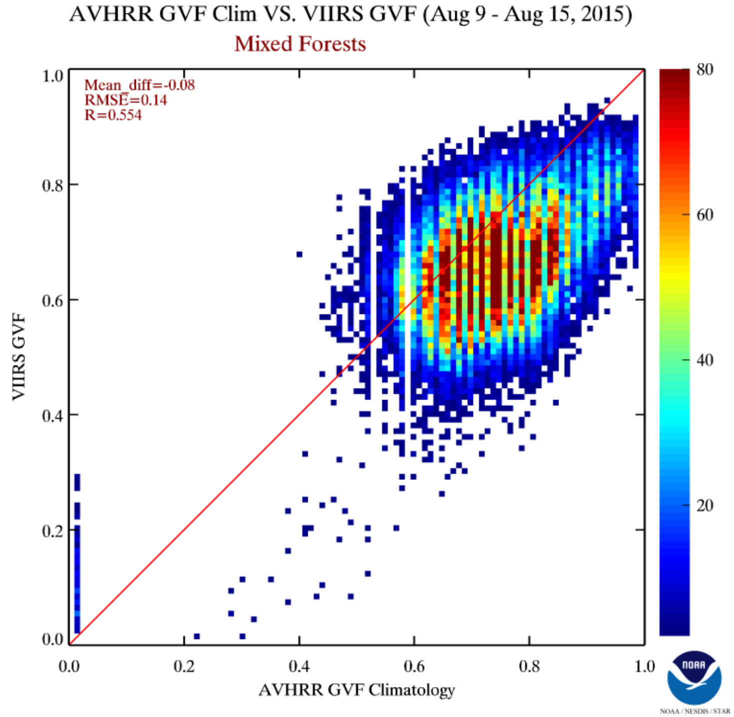


GVF scatter plots (VIIRS VS. AVHRR)

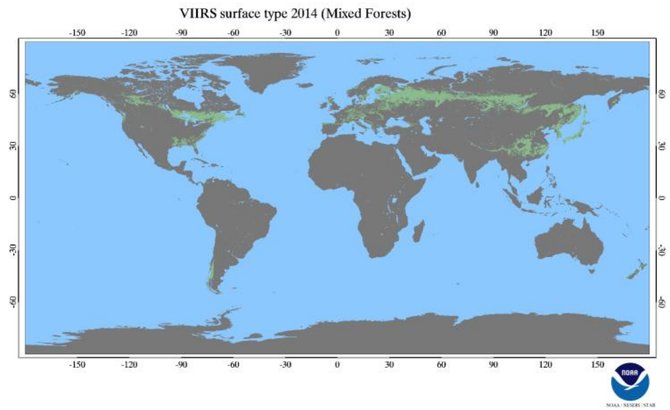
Mixed forests



Operational AVHRR GVF

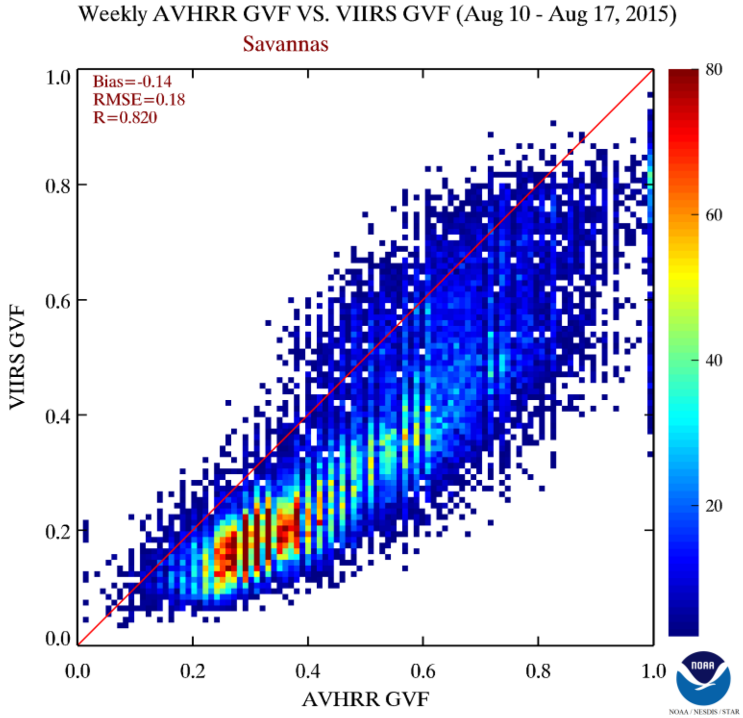


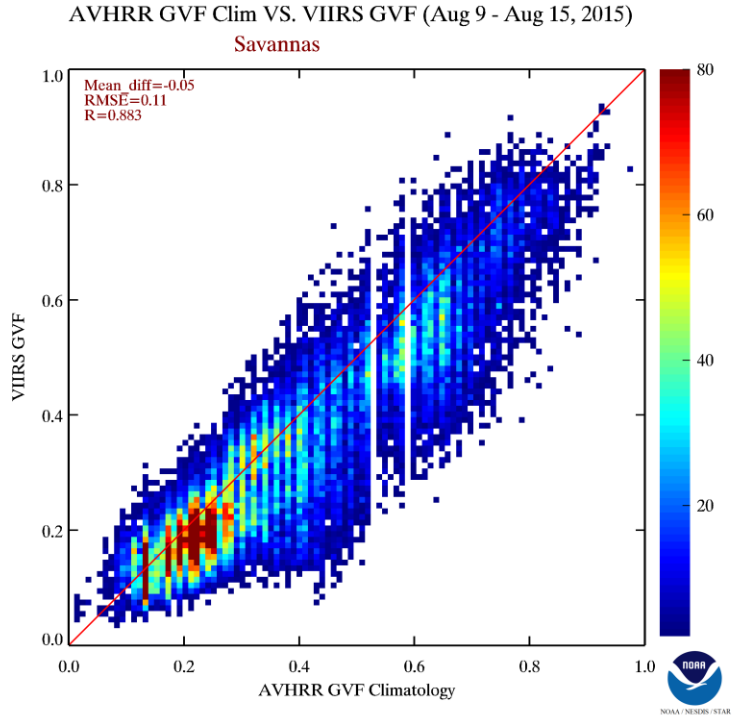
AVHRR GVF Climatology



GVF scatter plots (VIIRS VS. AVHRR)

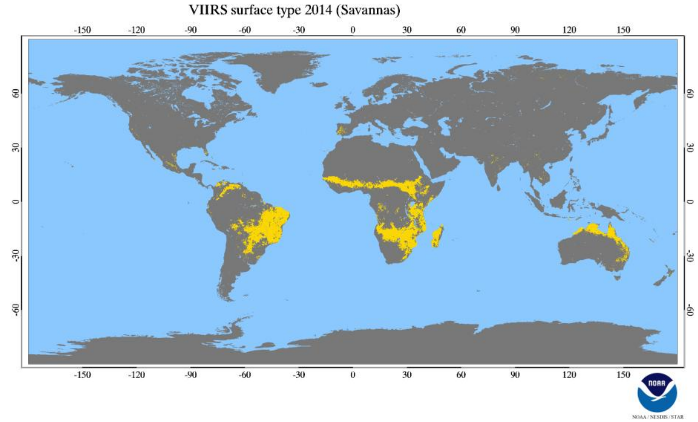
Savannas





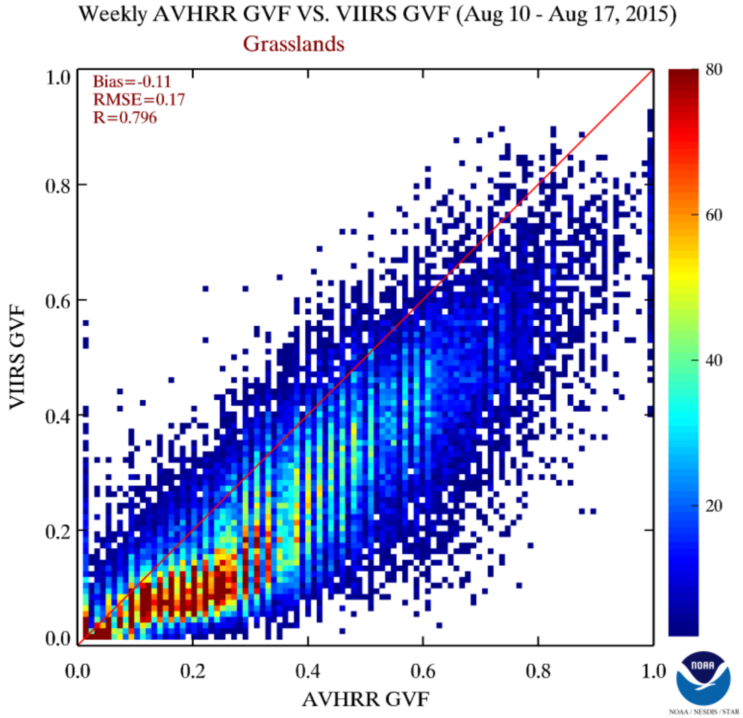
Operational AVHRR GVF

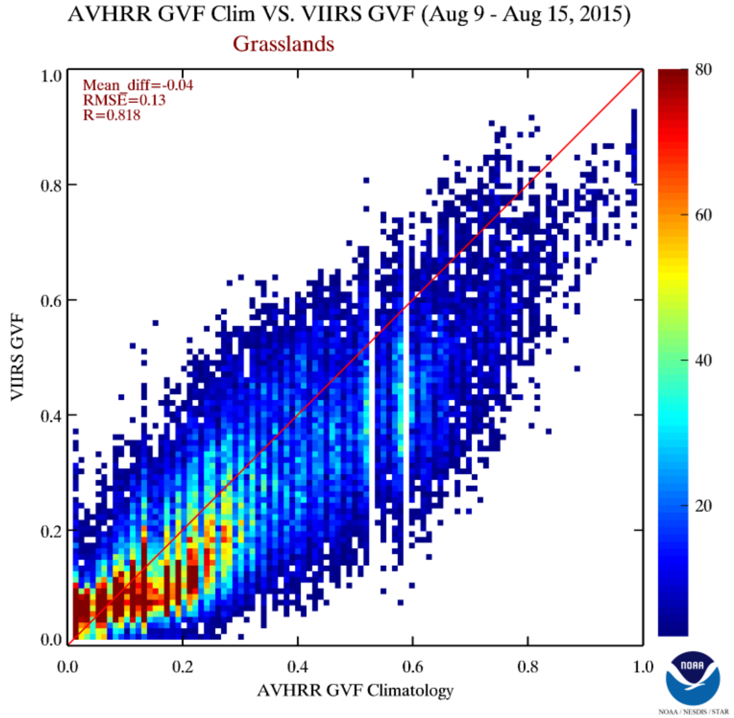
AVHRR GVF Climatology



GVF scatter plots (VIIRS VS. AVHRR)

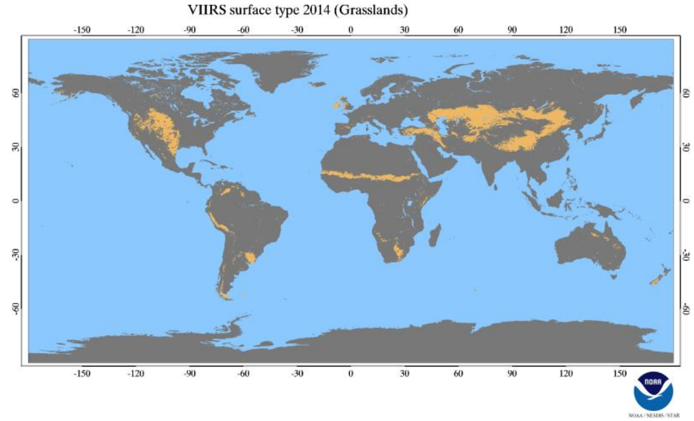
Grasslands





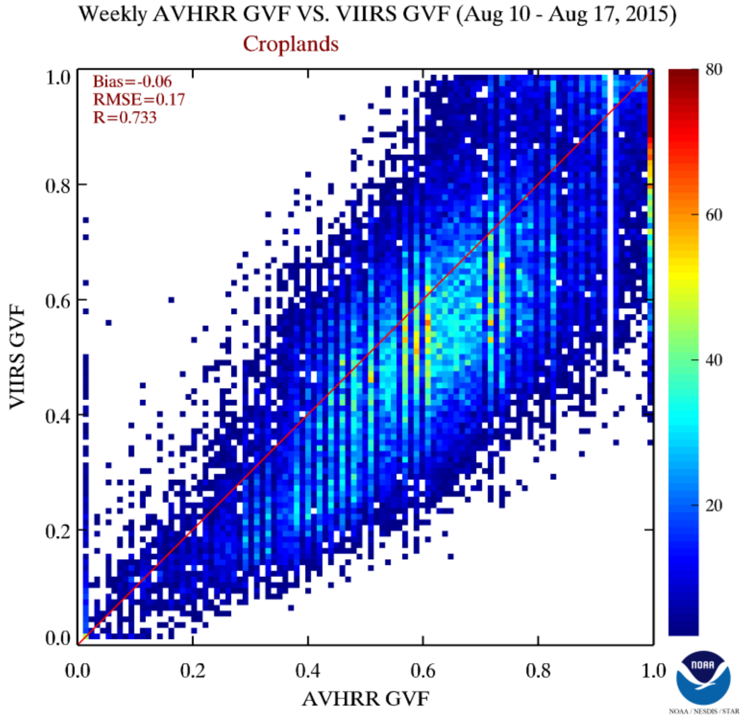
Operational AVHRR GVF

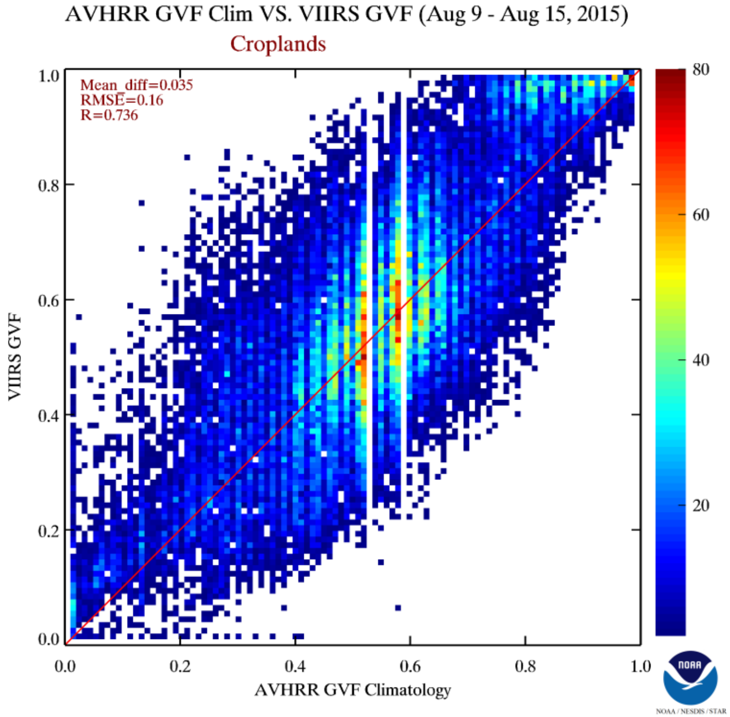
AVHRR GVF Climatology



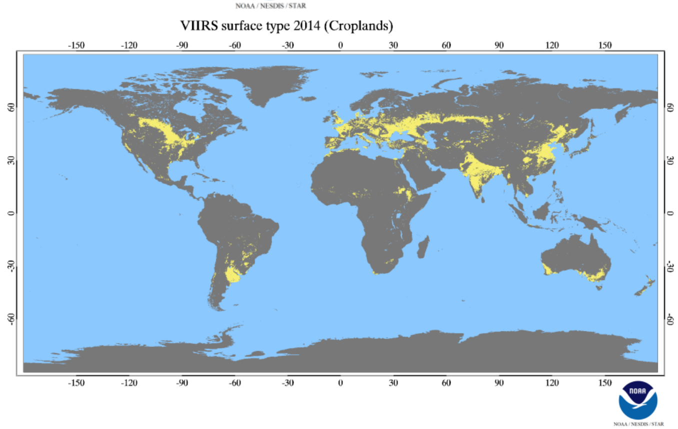
GVF scatter plots (VIIRS VS. AVHRR)

Croplands



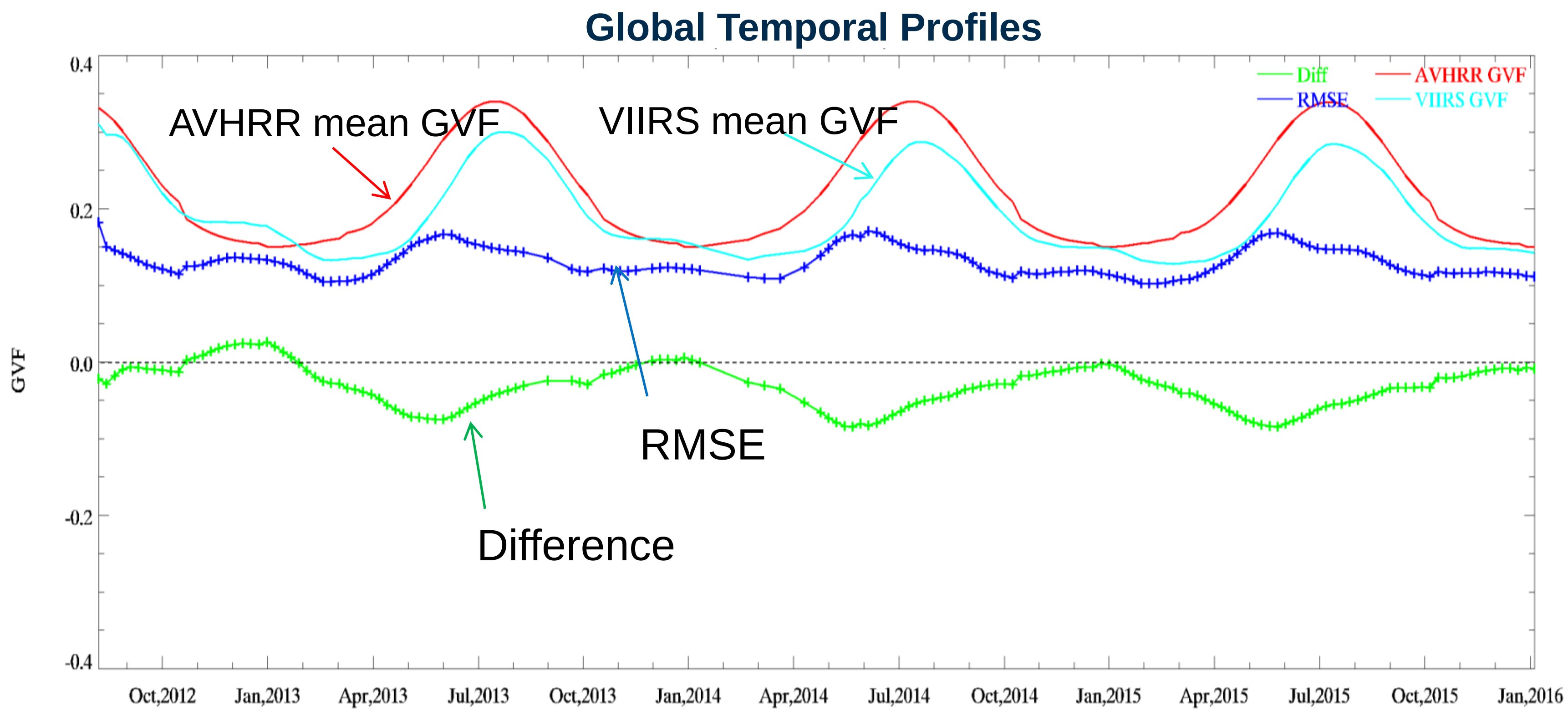


Operational AVHRR GVF



AVHRR GVF Climatology

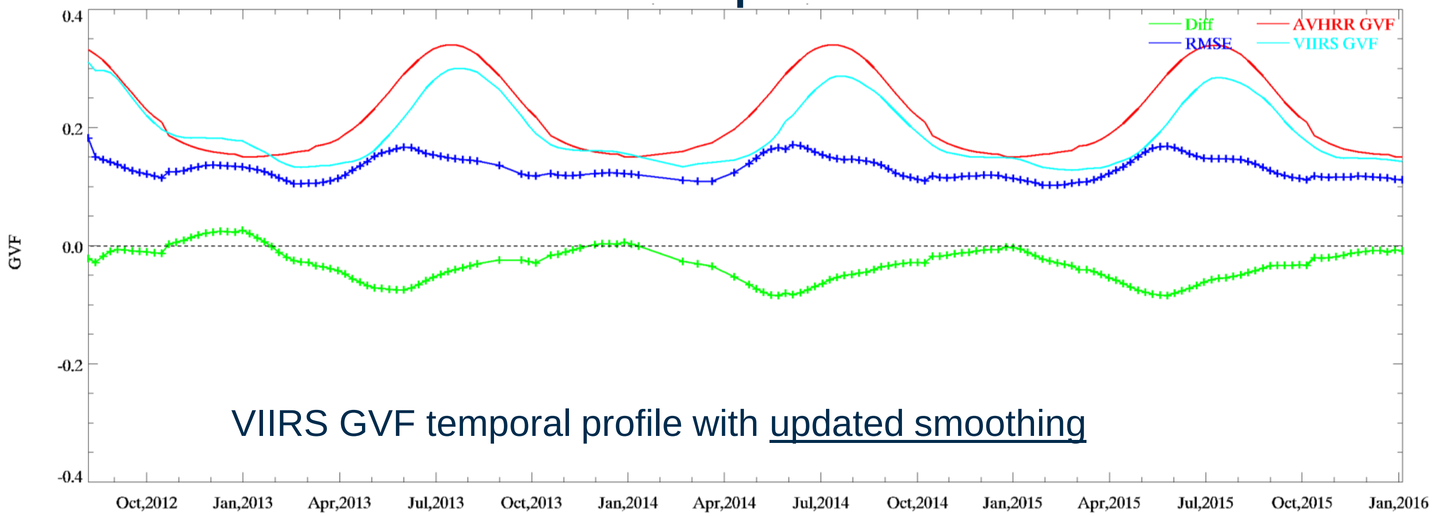
VIIRS vs. AVHRR Global Temporal Profiles



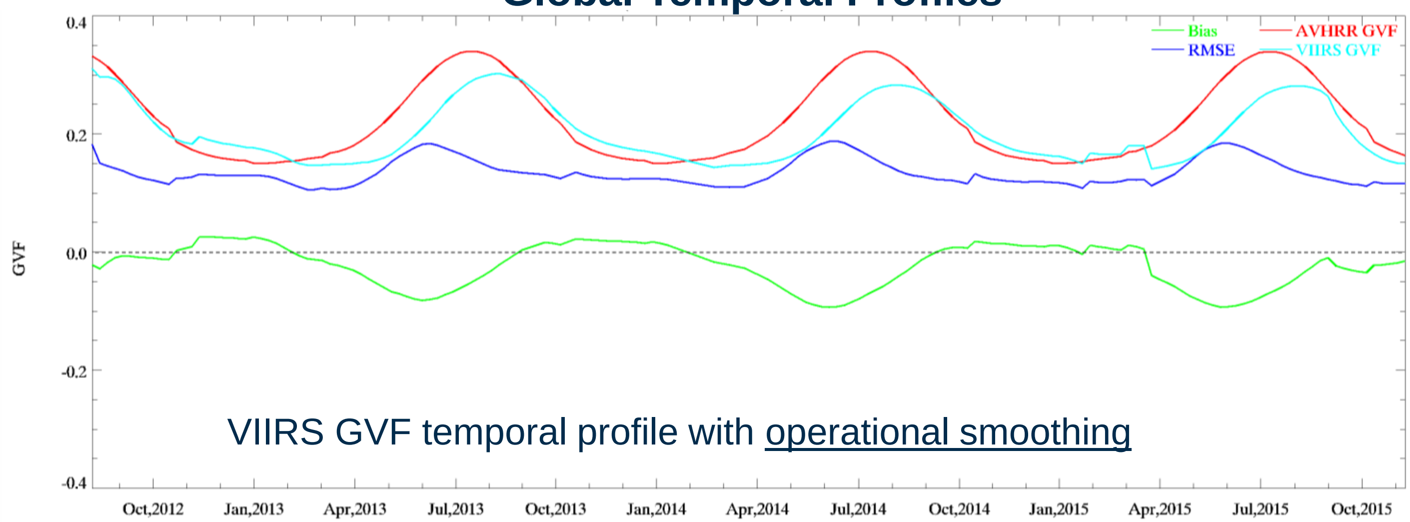
- AVHRR GVF greens up earlier than the VIIRS GVF
- AVHRR GVF is higher than VIIRS GVF in summer globally
- Negative GVF difference and relatively high RMSE in spring and summer, small difference and RMSE in other seasons

VIIRS vs. AVHRR GVF Global Temporal profiles (VIIRS GVF with and without updated smoothing)

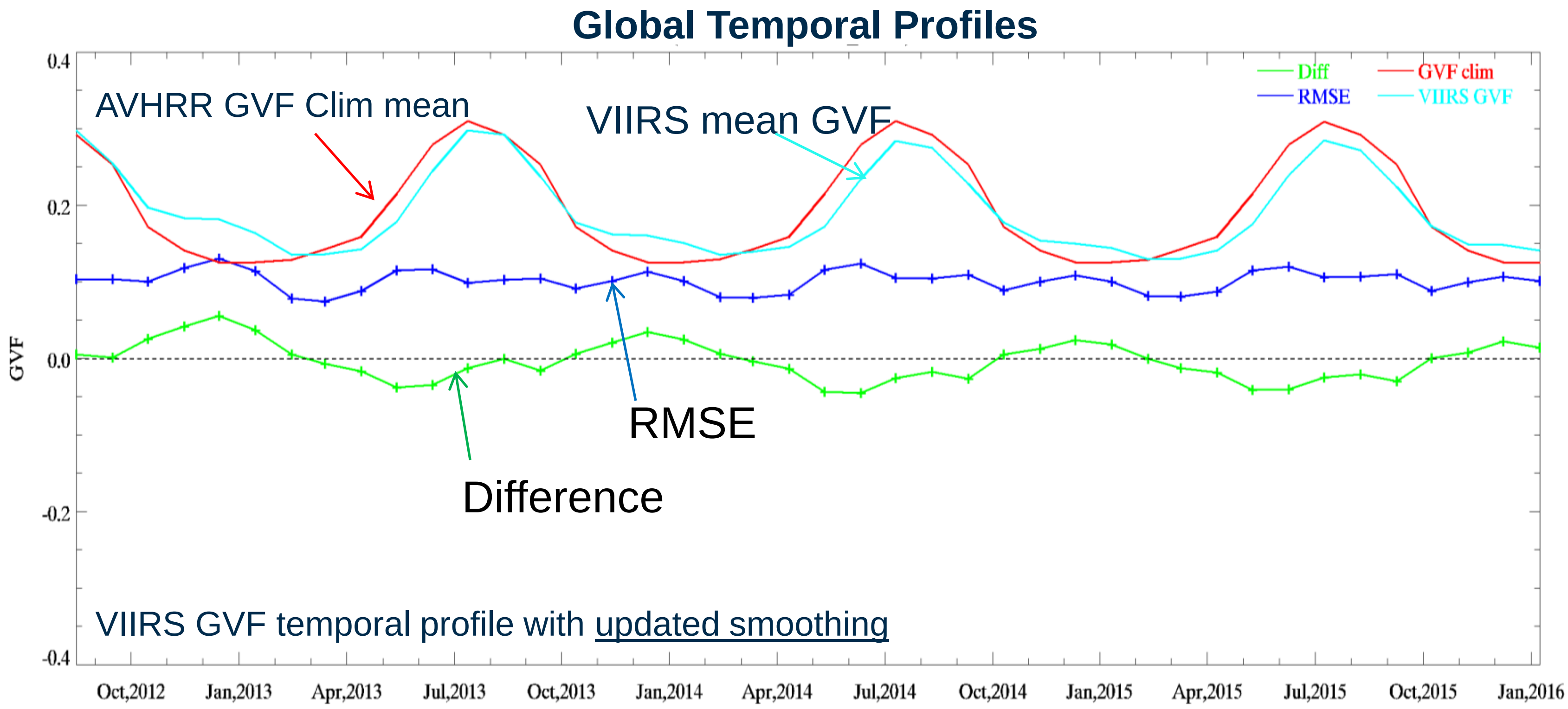
Global Temporal Profiles



Global Temporal Profiles

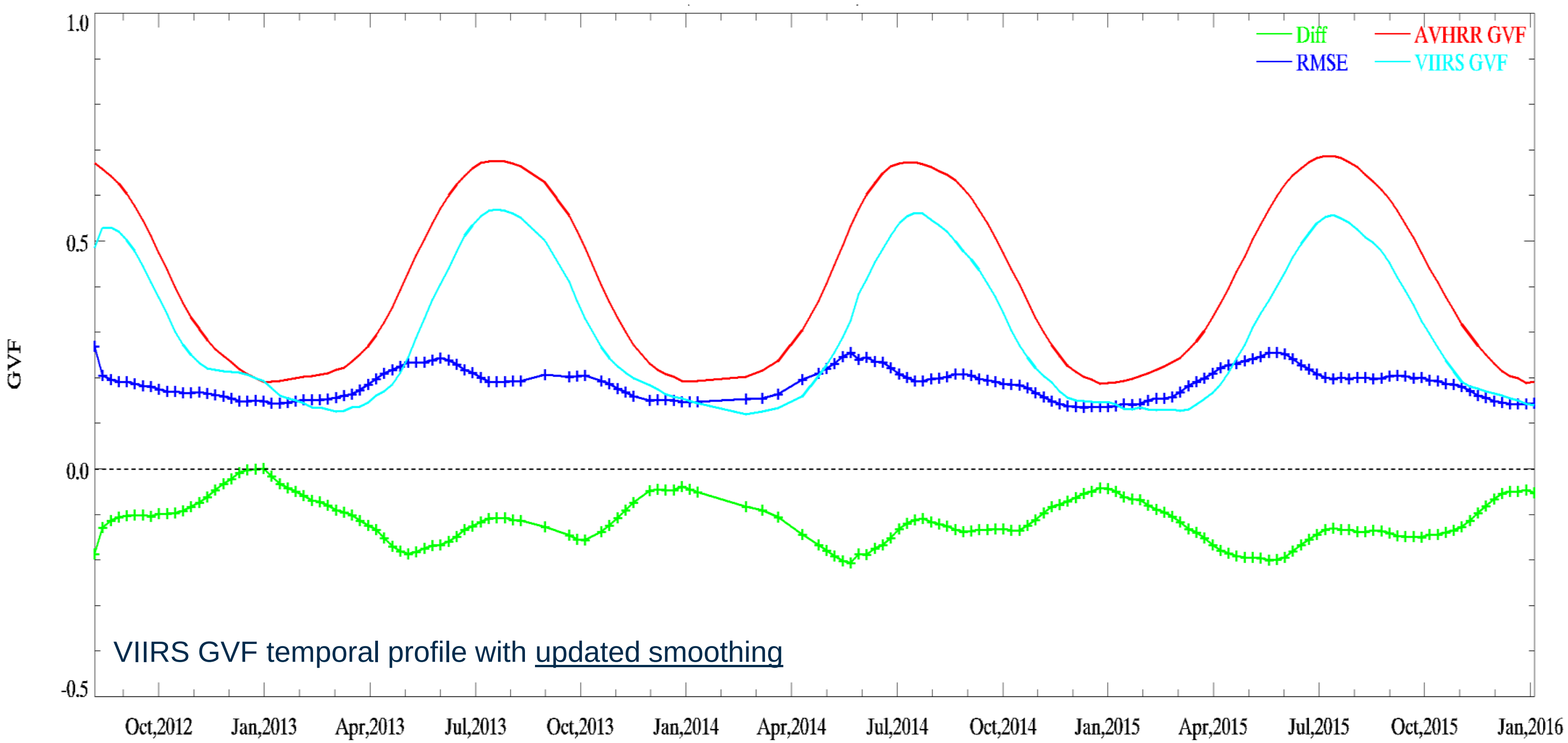


VIIRS vs. AVHRR GVF Climatology Global Temporal Profiles



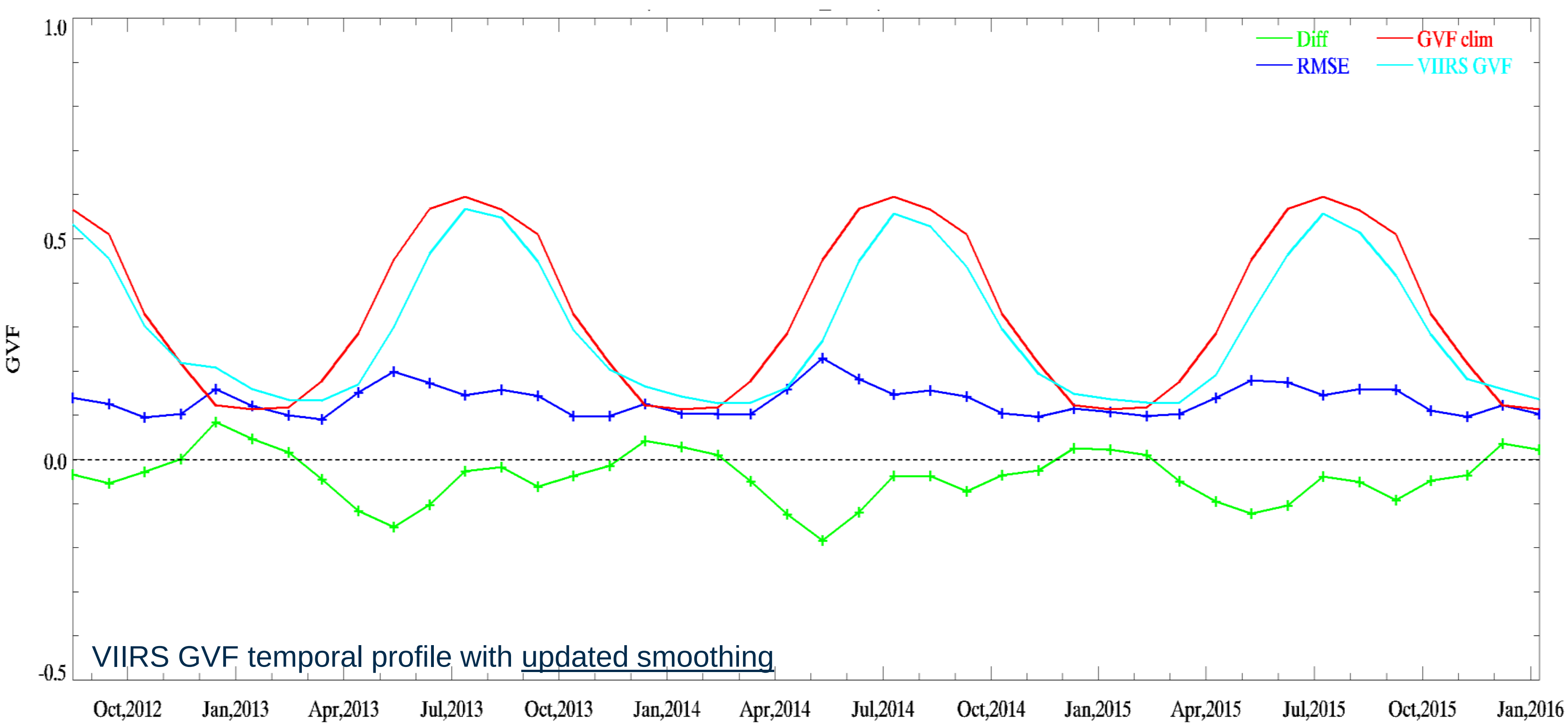
- Similar seasonal profiles between AVHRR GVF climatology and VIIRS GVF
- Small difference between AVHRR GVF climatology and VIIRS GVF
- AVHRR GVF climatology is slightly higher than VIIRS GVF in summer globally

VIIRS vs. AVHRR GVF Temporal Profiles - CONUS



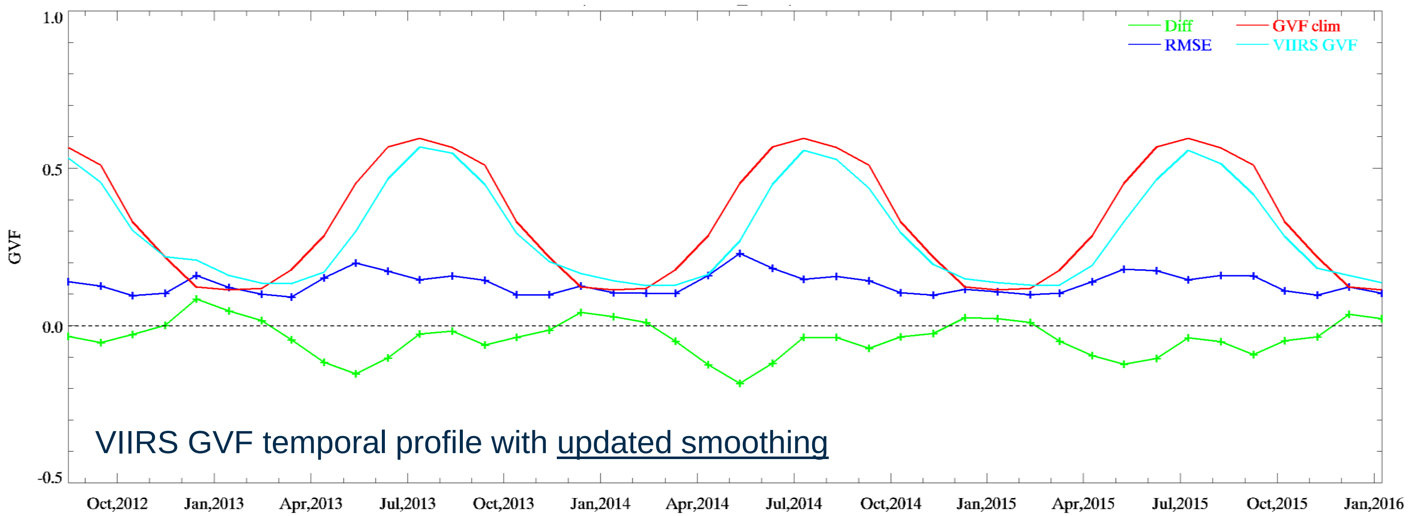
- AVHRR GVF is higher than VIIRS GVF in all seasons
- GVF difference is small in winter, big in spring and summer

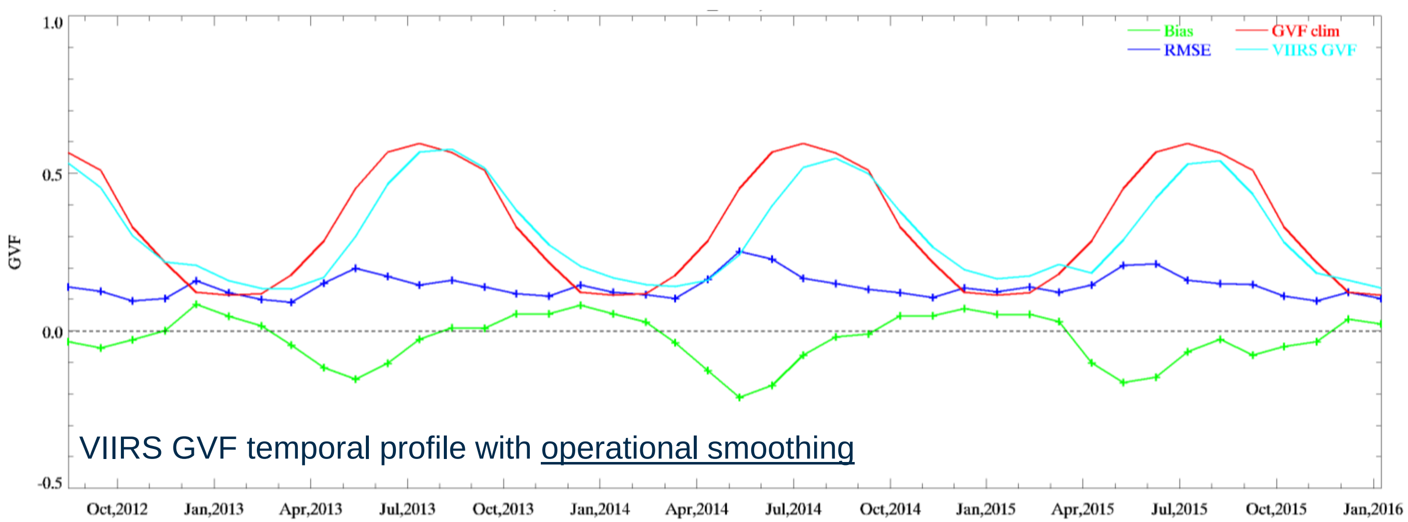
VIIRS vs. AVHRR GVF Climatology Temporal Profiles - CONUS



- Mean GVF climatology is slightly higher than VIIRS GVF
- Positive difference in winter and negative difference in spring and summer
- Small RMSE

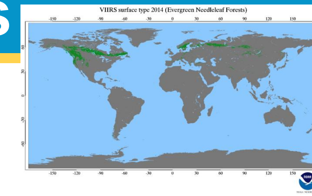
VIIRS and AVHRR GVF Climatology over CONUS
(VIIRS GVF with and without updated smoothing)

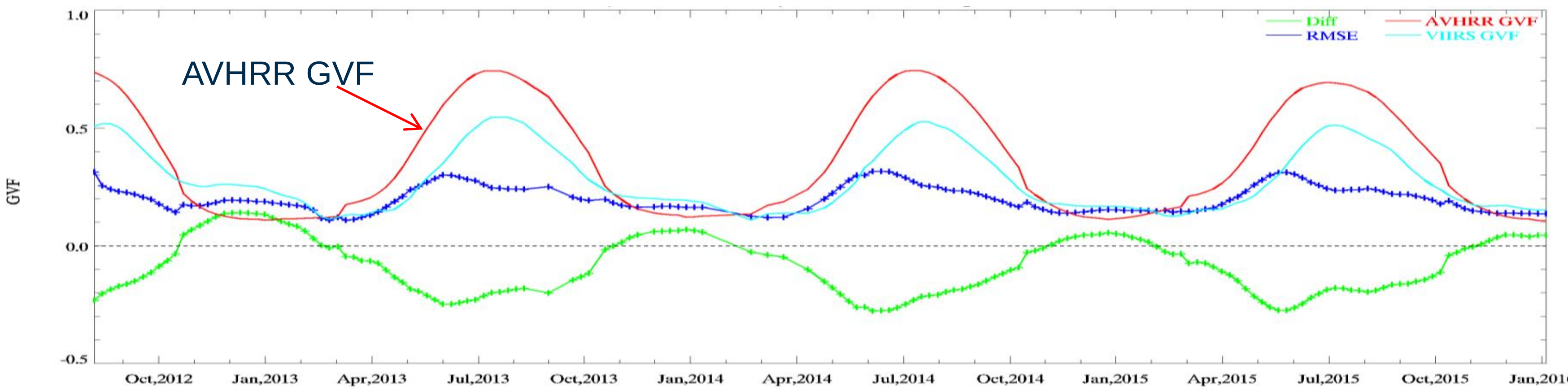


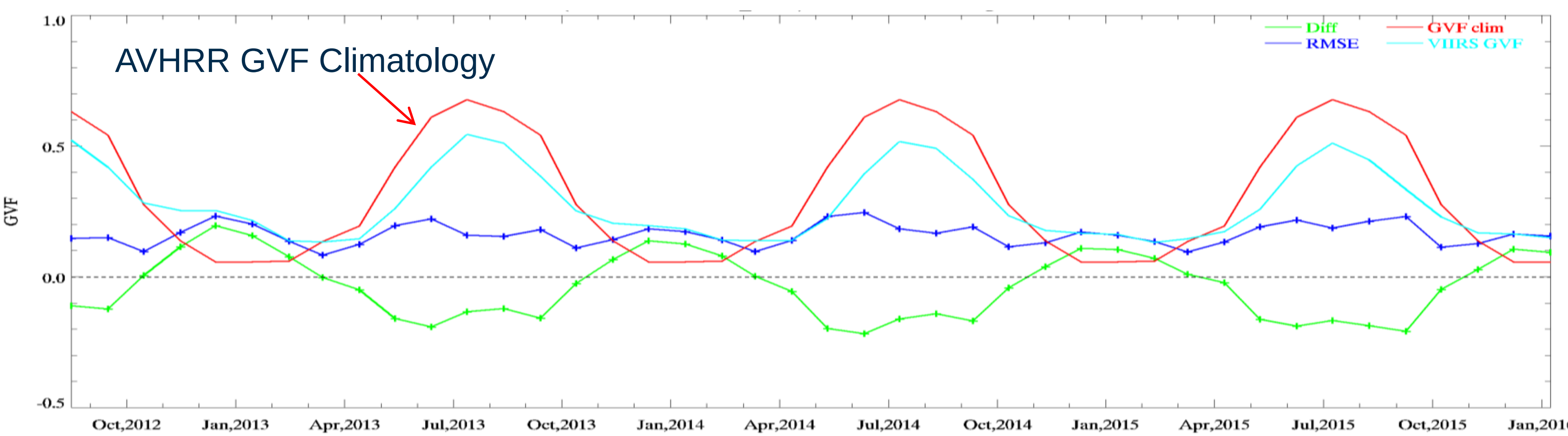


VIIRS vs. AVHRR GVF Temporal Profiles

Evergreen Needleleaf forests

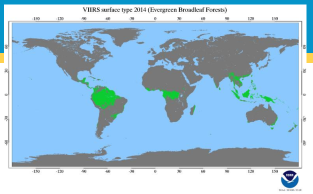


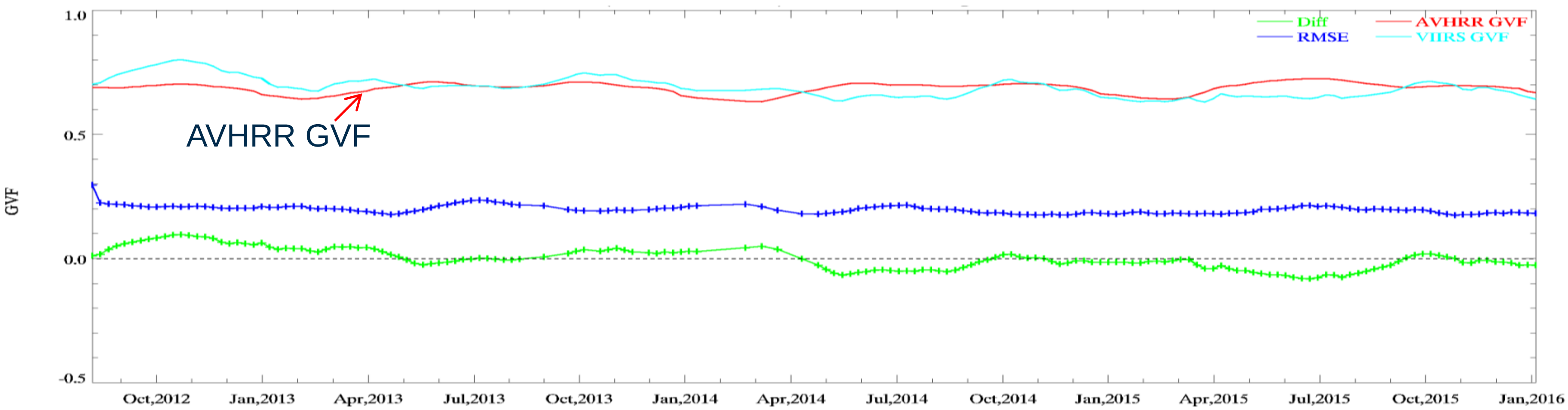


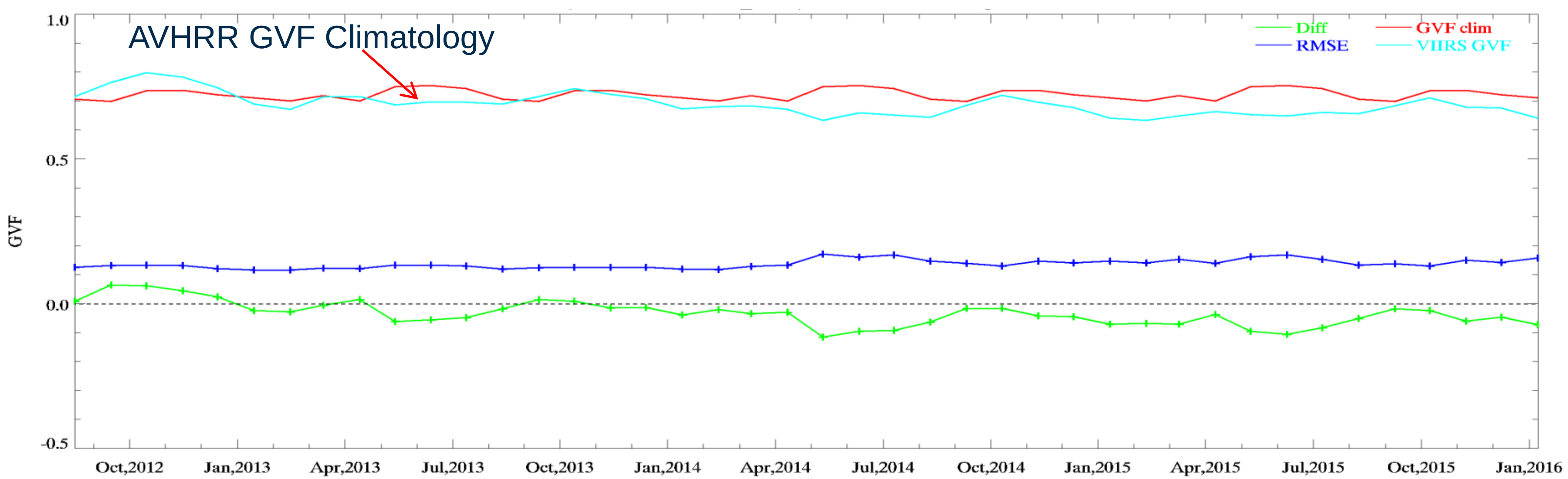


VIIRS vs. AVHRR GVF Temporal Profiles

Evergreen Broadleaf forests

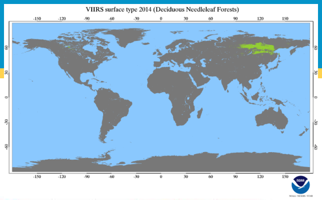


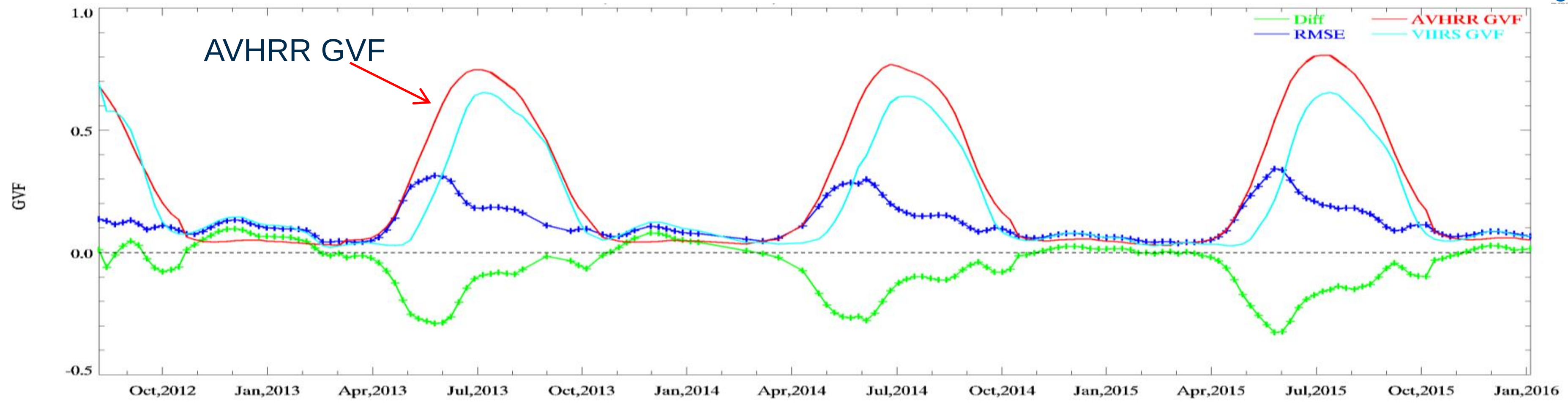


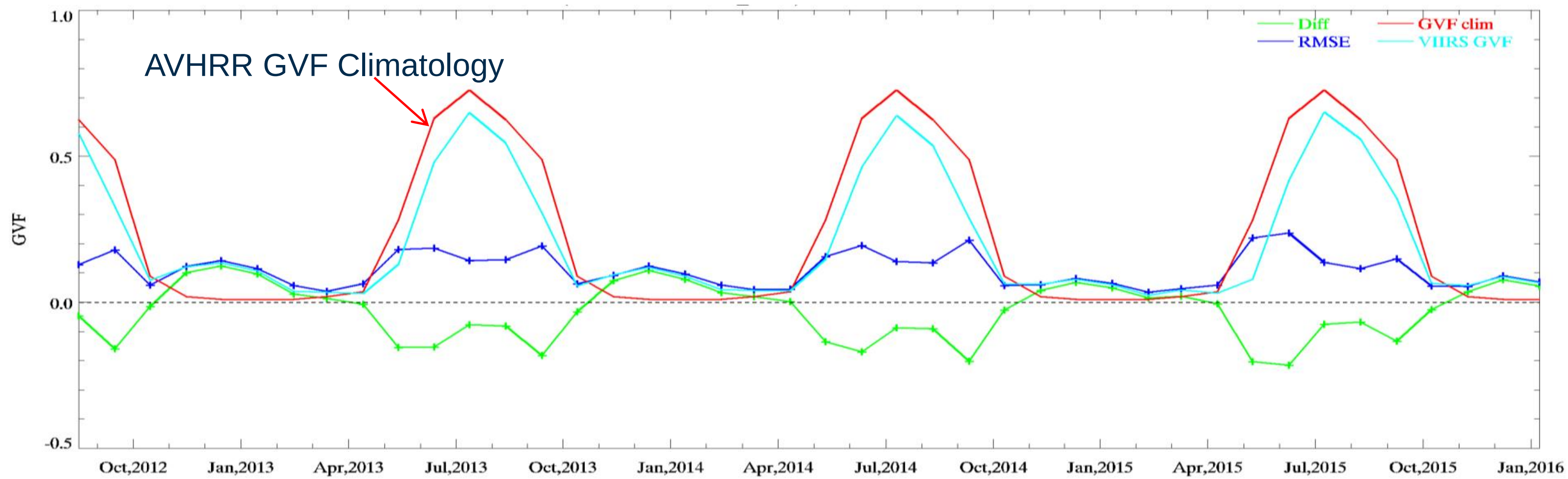


VIIRS vs. AVHRR GVF Temporal Profiles

Deciduous Needleleaf forests

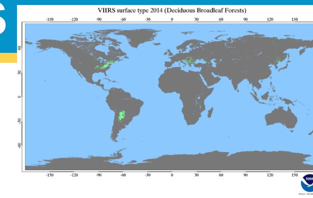


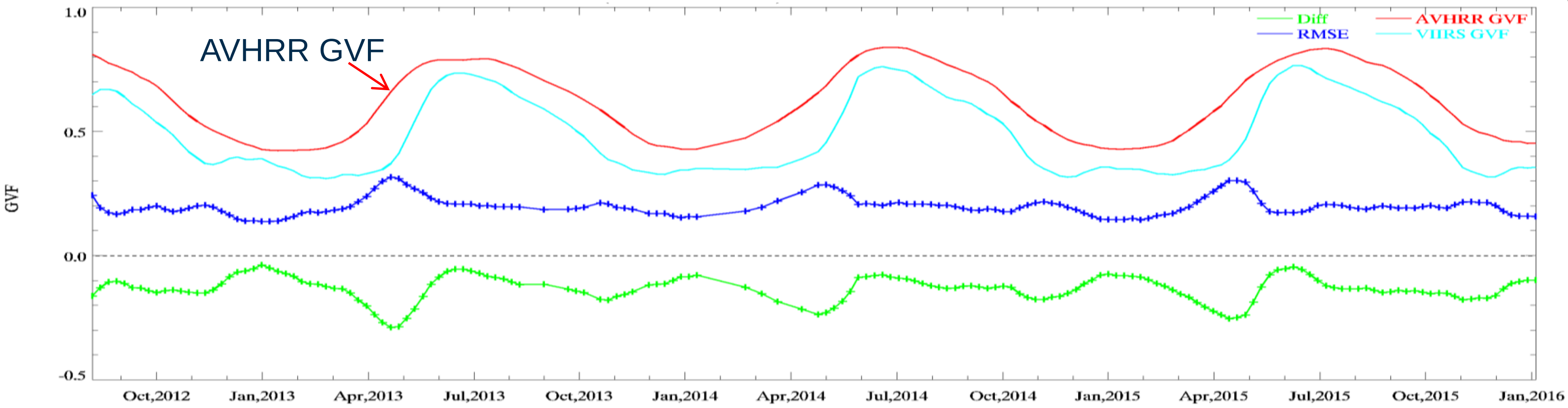


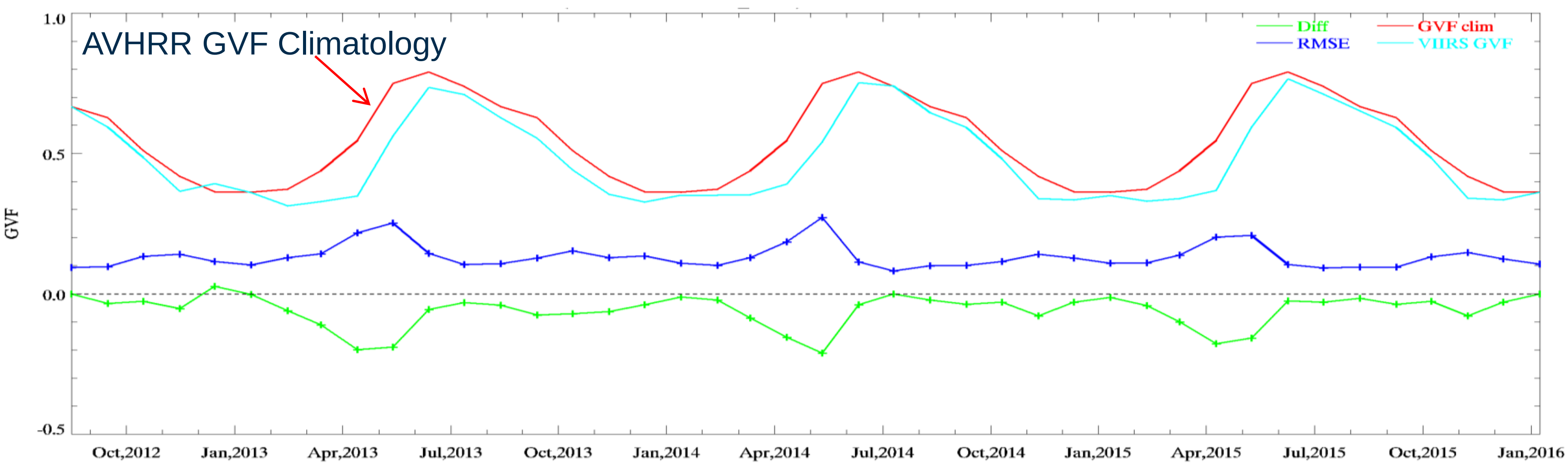


VIIRS vs. AVHRR GVF Temporal Profiles

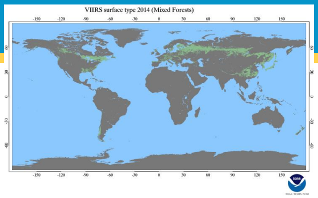
Deciduous Broadleaf forests

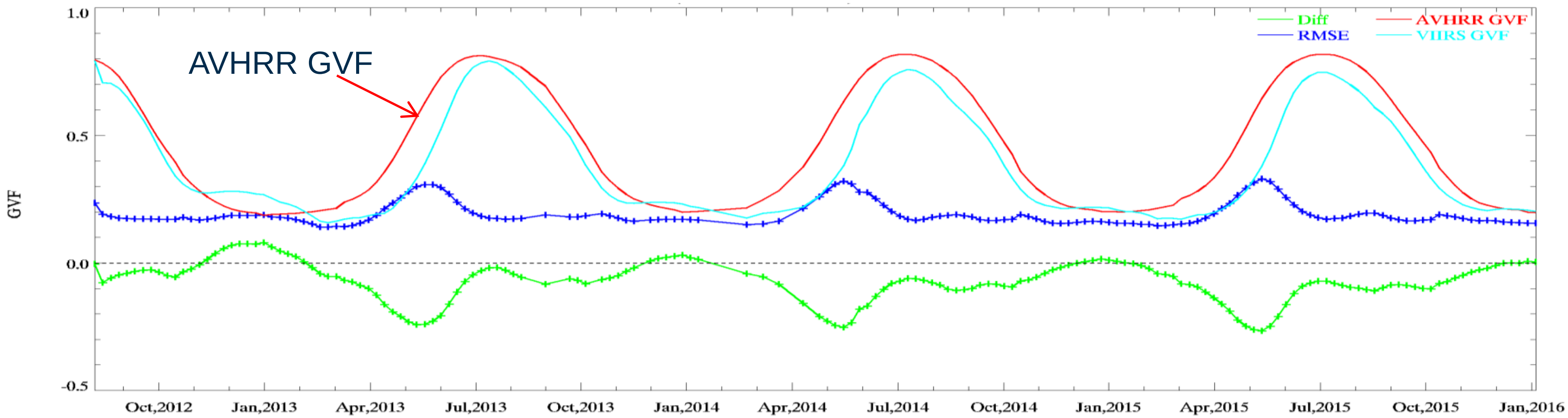


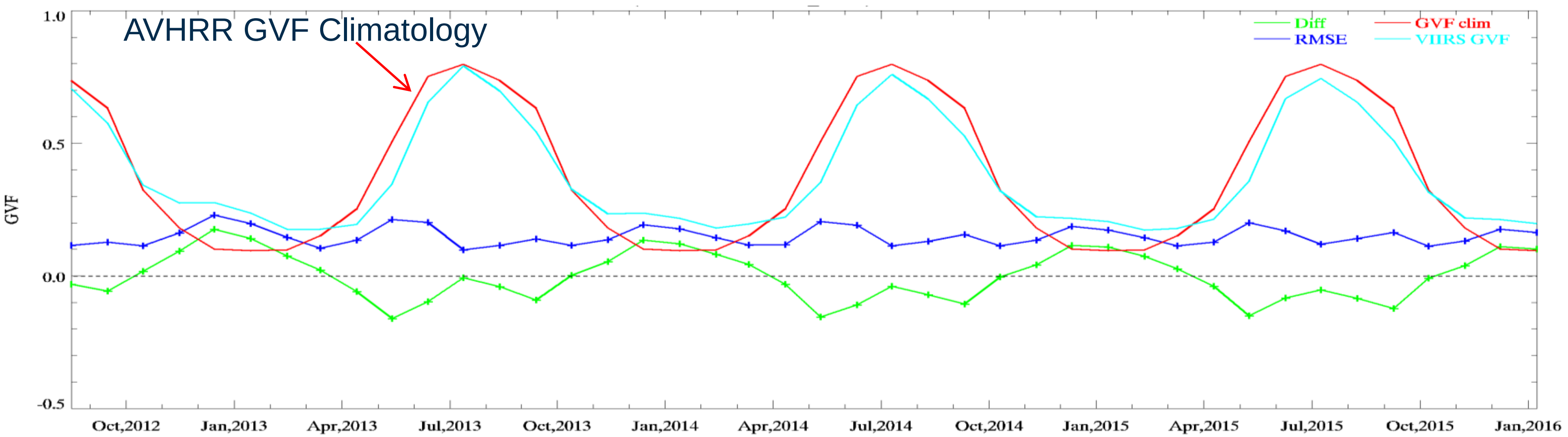




Mixed forests

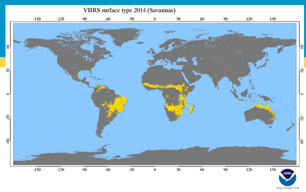


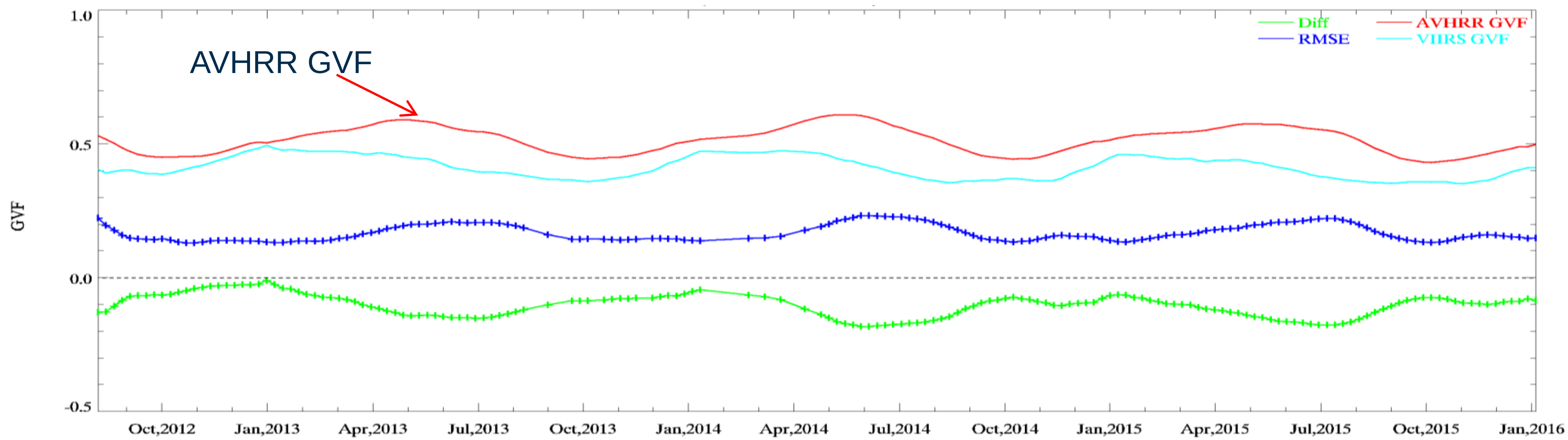


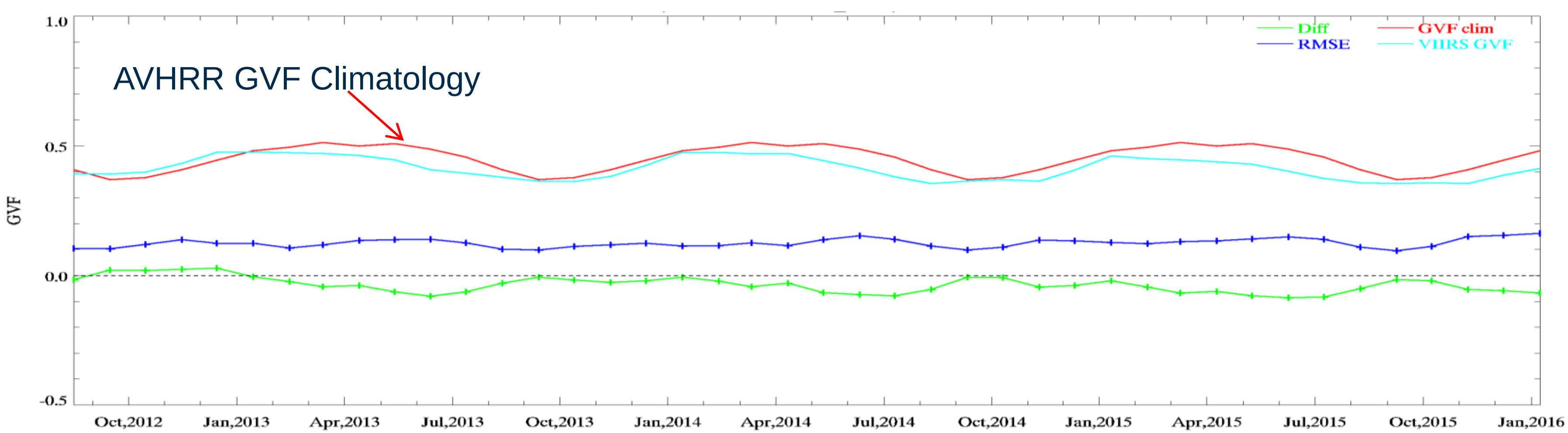


VIIRS vs. AVHRR GVF Temporal Profiles

Savannas

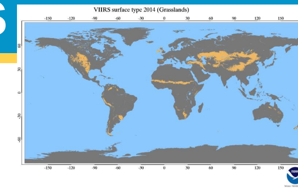


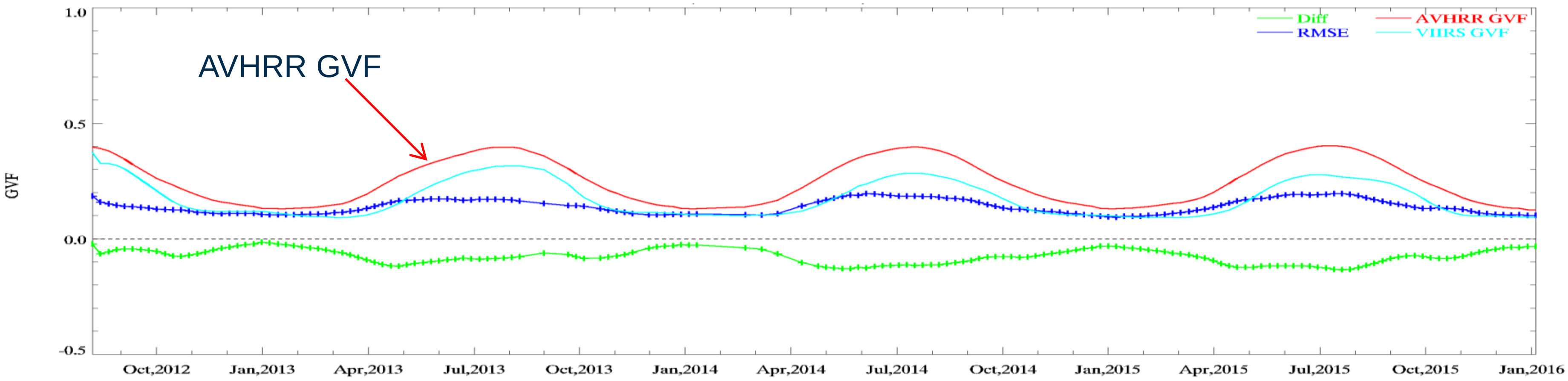


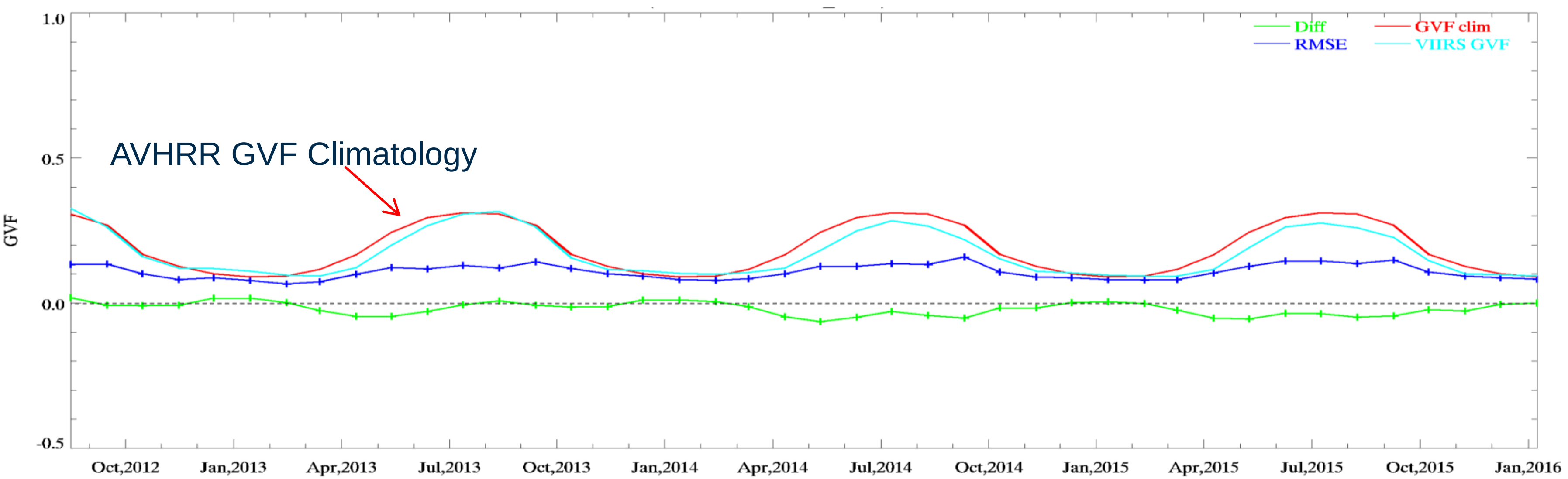


VIIRS vs. AVHRR GVF Temporal Profiles

Grasslands

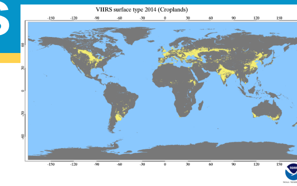


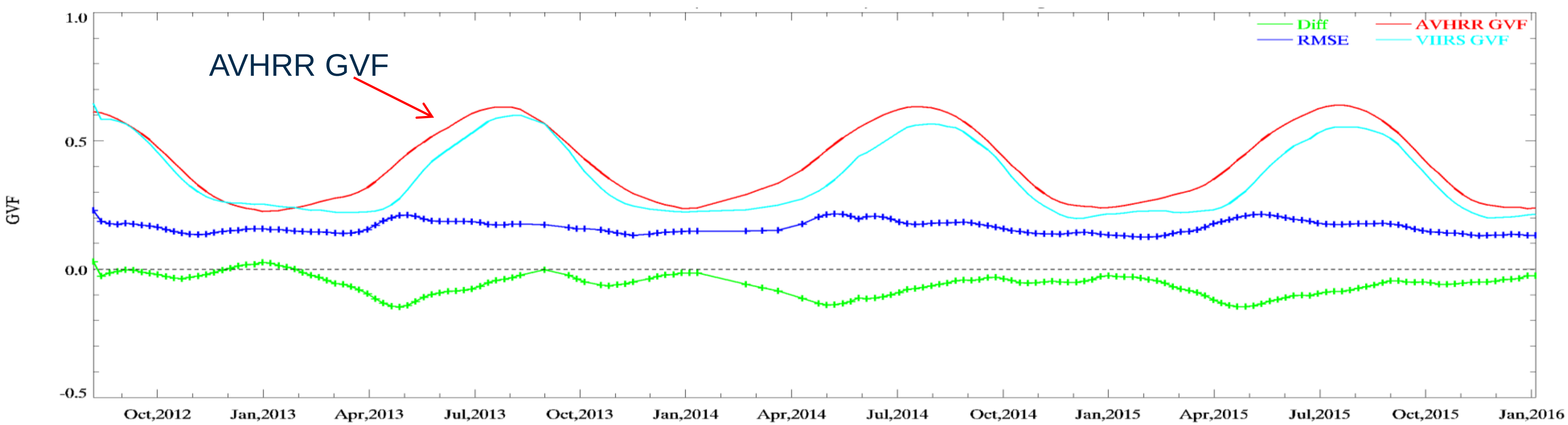


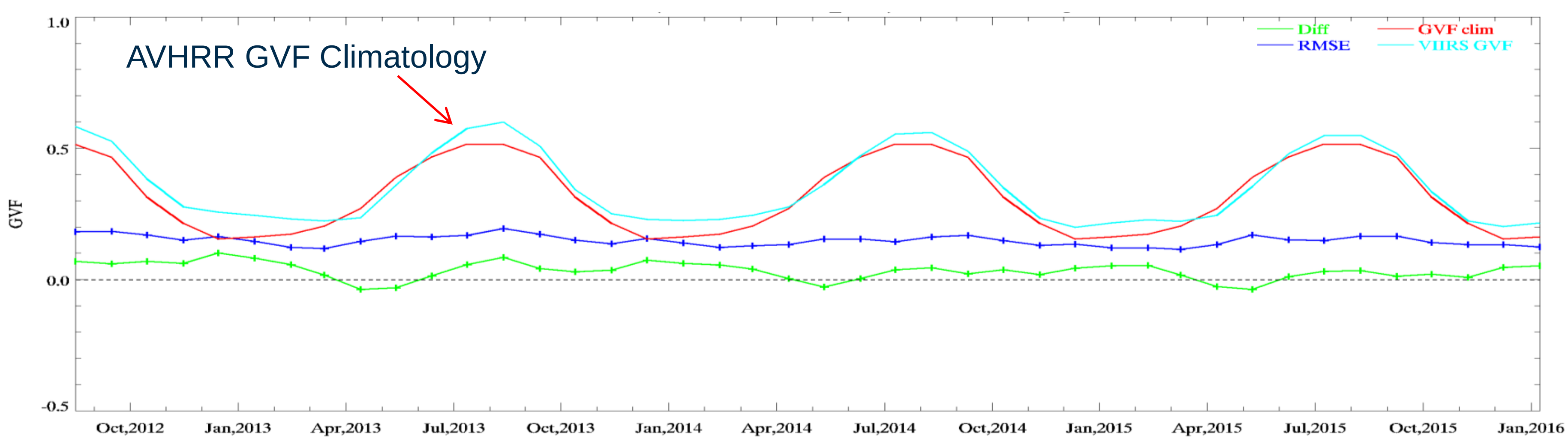


VIIRS vs. AVHRR GVF Temporal Profiles

Croplands







VIIRS vs. AVHRR GVF Comparison

Conclusion

- VIIRS vs. AVHRR GVF comparison revealed a fairly consistent shift in the representation of the phenological cycle/temporal profile
- The cause of this shift was found to be the smoothing technique used by the VIIRS GVF production system
- A new VIIRS GVF dataset was generated (using an updated smoothing algorithm) and was shown to reflect a more consistent phenology with AVHRR
- The amplitude of the AVHRR GVF is greater than the VIIRS GVF
- The length of the AVHRR GVF growing season is greater than VIIRS GVF
- AVHRR GVF climatology is closer to VIIRS GVF than the AVHRR GVF operational product

Algorithm Improvements

Improvements Since Algorithm Readiness Review (ARR) and Provisional Maturity

– Two algorithm improvements have been identified for implementation in the near future

a) Land Water Mask (artifacts found in inland water bodies)

b) An updated smoothing algorithm has been tested and implemented at the STAR development environment. The VIIRS GVF product with the updated smoothing algorithm is being generated experimentally at STAR

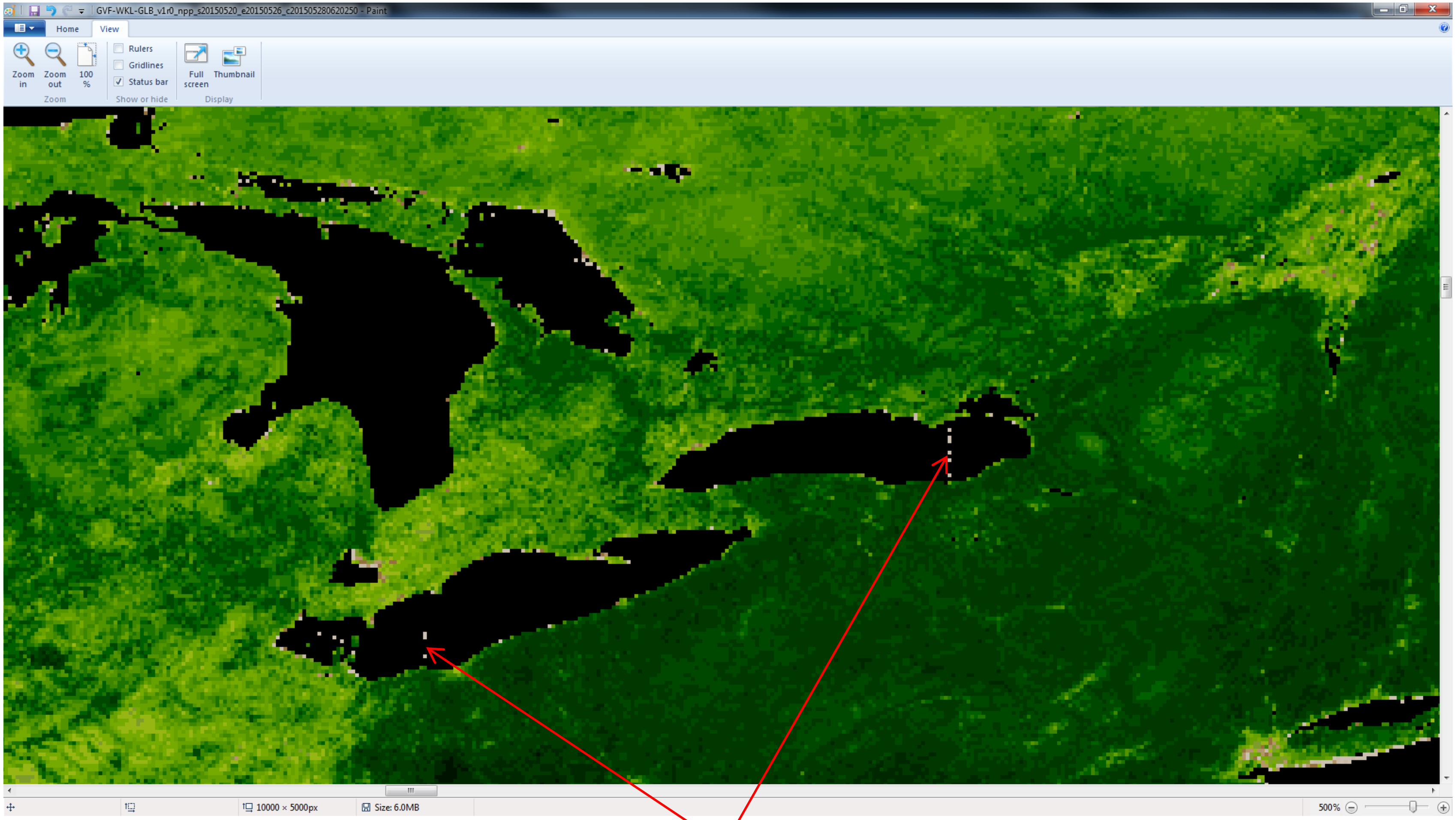
– LUT / PCT updates: None

Land Water Mask Artifacts

Investigation of the artificial dashed lines found on GVF imagery (lakes)

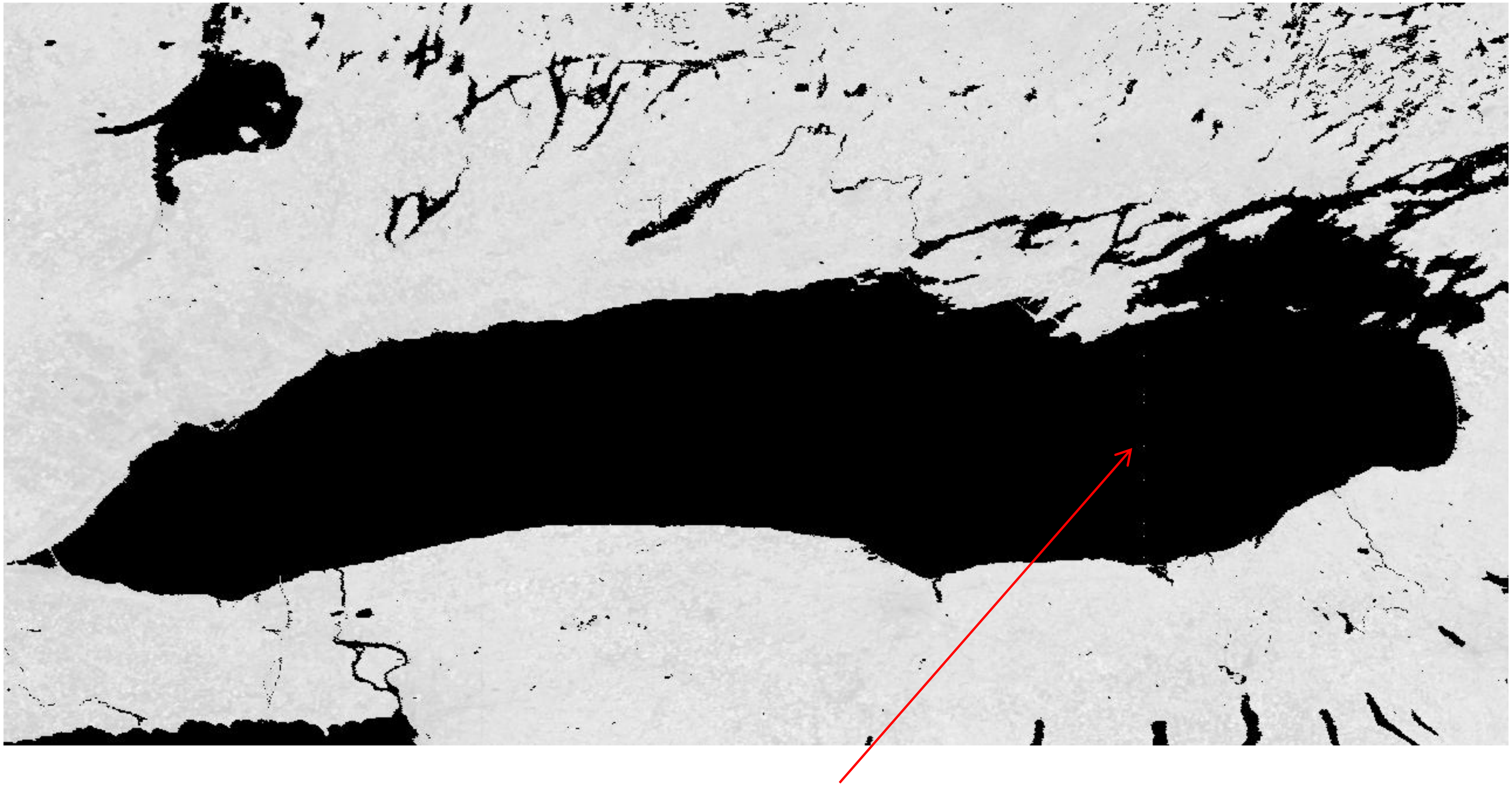
- We found some artificial dashed lines on GVF images
- Dashed lines were also found in the intermediate data (EVI and surface reflectance) from which GVF is derived
- We found that the dashed lines were also present in the GVF Land Water Mask (LWM) which had been derived from MODIS LWM data
- Modified the water mask files manually to eliminate the dashed lines on lakes
- Applied the updated LWM and evaluated the GVF imagery

Dashed lines on GVF files (inland water bodies)



Dashed lines found over the Lake Ontario and Lake Erie, where GVF=1%
5/26/2015

Dashed line on AS_EVI_p1 map



Dashed line on the EVI map of Lake Ontario 5/26/2015

EVI values on the dashed line

TableView - evi - / - C:\Users\zjiang\Documents\GVF\dash lines in the GVF maps\GVF-ASEVI-P1_s20150520_e20150526_h05v02_c201505280435210.h5

Table

0, 4332 = -32768

	4331	4332	4333	4334	4335	4336	4337	4338	4339	4340	4341	4342	4343	4344	4345	4346	4347	
3420	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3421	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3422	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3423	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3424	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3425	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3426	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3427	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3428	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3429	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3430	-32768	-32768	-96	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3431	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3432	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3433	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3434	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3435	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3436	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3437	-32768	-32768	-23	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3438	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3439	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3440	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3441	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3442	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3443	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3444	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3445	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3446	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
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3448	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3449	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3450	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
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3452	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3453	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3454	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3455	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3
3456	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-3

AS_EVI_P1 values on the dashed line over lake Ontario on 5/26/2015

EVI values on the dashed line

TableView - evi - / - C:\Users\zjiang\Documents\GVF\dash lines in the GVF maps\GVF-ASEVI-P1_s20150520_e20150526_h05v02_c201505280435210.h5

Table

3430, 4333... -96

	4331	4332	4333	4334	4335	4336	4337	4338	4339	4340	4341	4342	4343	4344	4345	4346	4347
3469	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3470	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3471	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3472	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3473	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3474	-32768	-32768	-33	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3475	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3476	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3477	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3478	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3479	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3480	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
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3482	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3483	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
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3486	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
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3488	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3489	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3490	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
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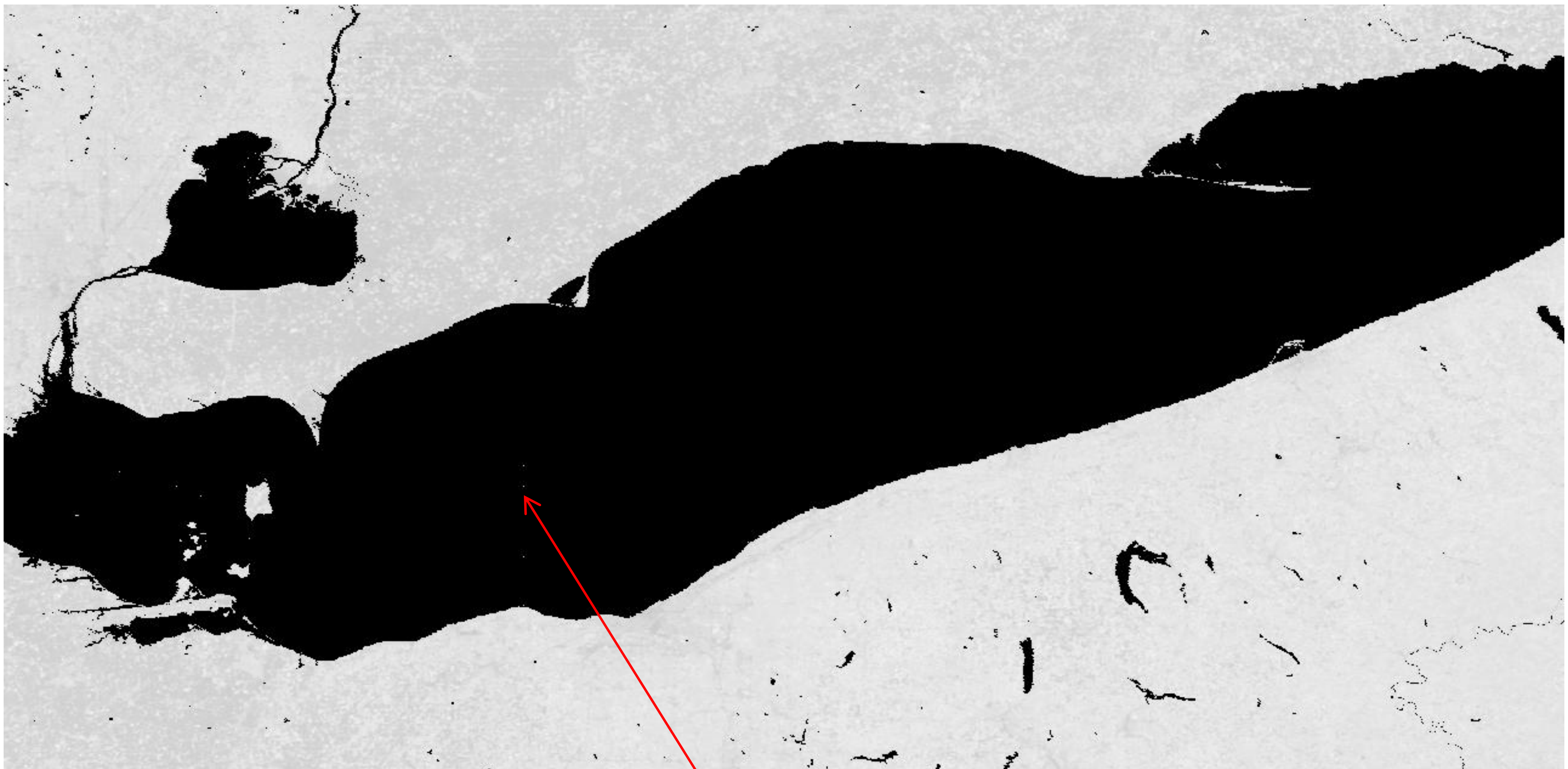
3492	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3493	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3494	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3495	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3496	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3497	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3498	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3499	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3500	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3501	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3502	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3503	-32768	-32768	-30	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3504	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768
3505	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768	-32768

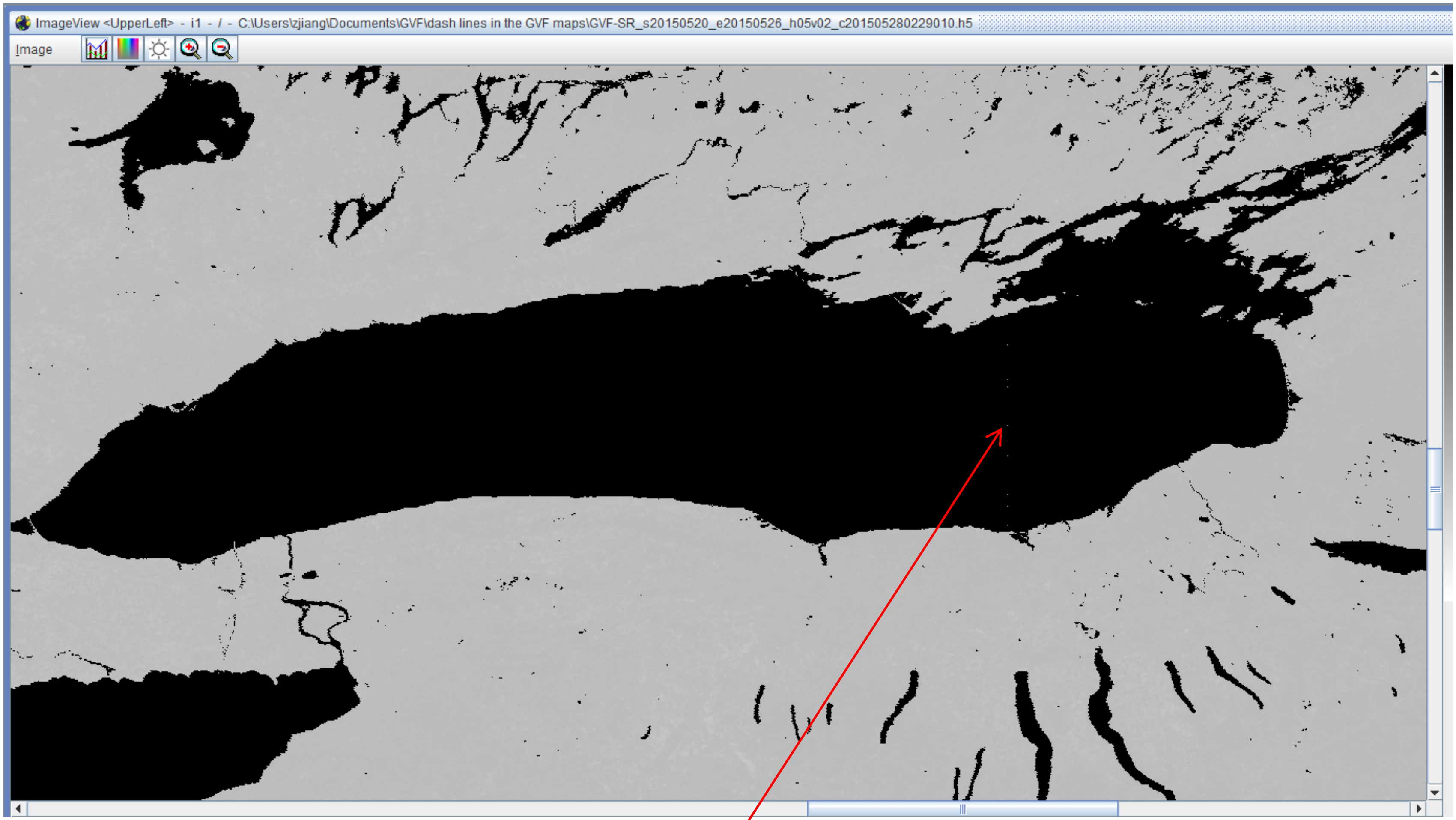
AS_EVI_P1 values on the dashed line over lake Ontario on 5/26/2015

Dashed line on AS_EVI_p1 map



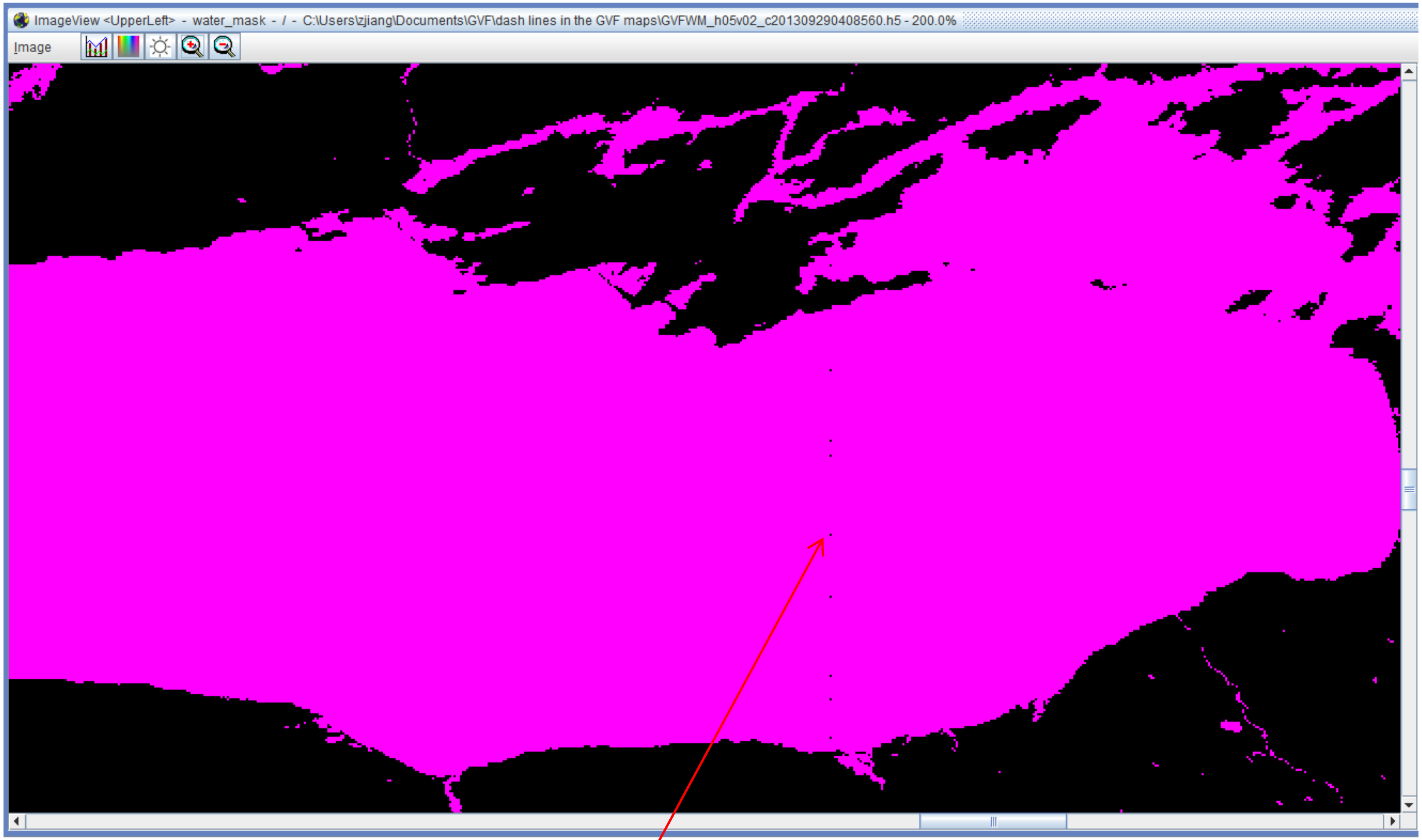
Dashed line on the EVI map of lake Erie 5/26/2015

Dashed line on weekly surface reflectance map



Dashed line on the weekly surface reflectance map over lake Ontario 5/26/2015

Dashed line on GVF water mask

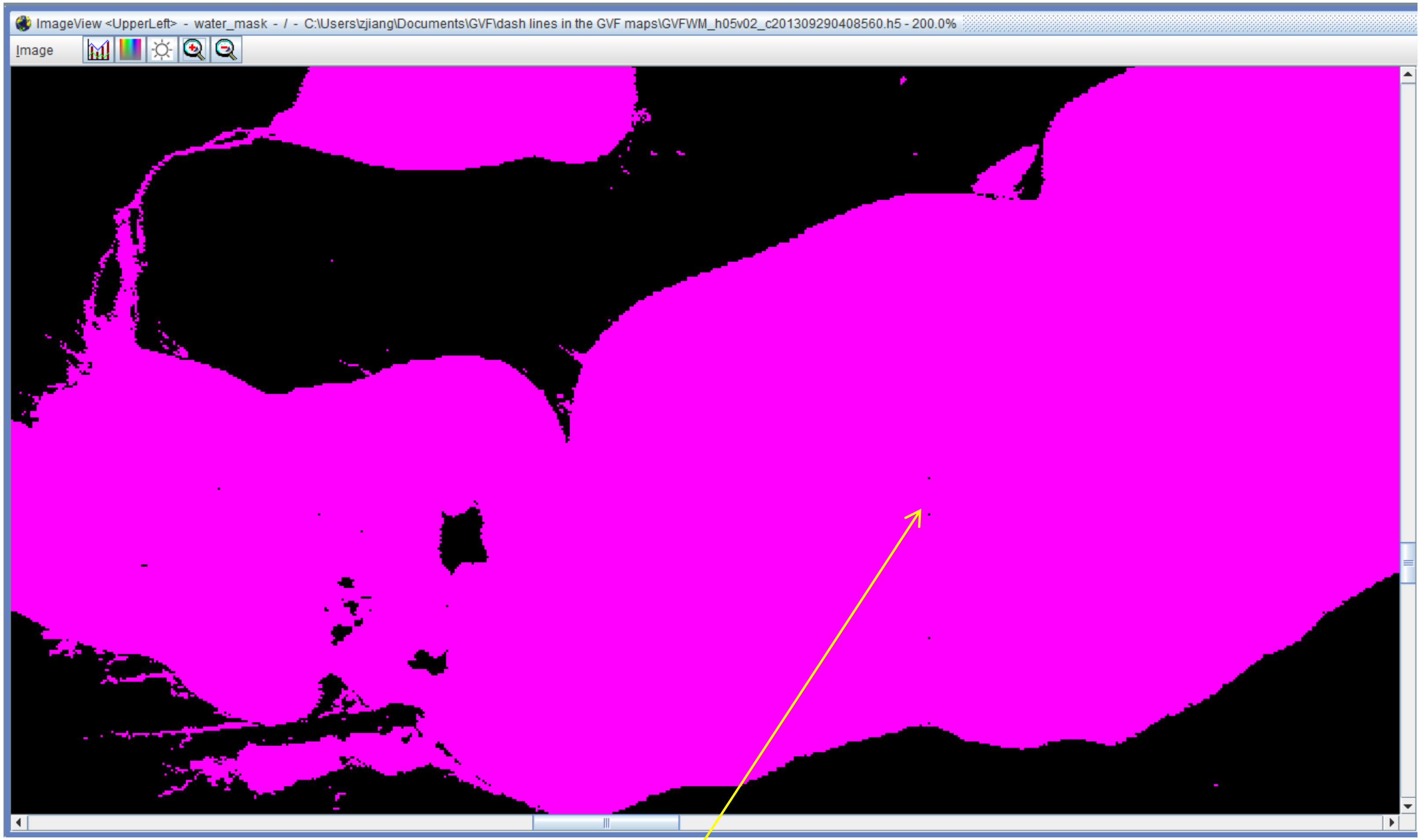


Dashed line on the water mask over lake Ontario
(/data/data049/jju/modis_watermask/in_gvf_tiles/GVFWH_h05v02_c201309290408560.h5)

MODIS water mask

Dashed line on the MODIS water mask over lake Ontario
(MOD44W.A2000055.h12v04.005.2009212173329.hdf)

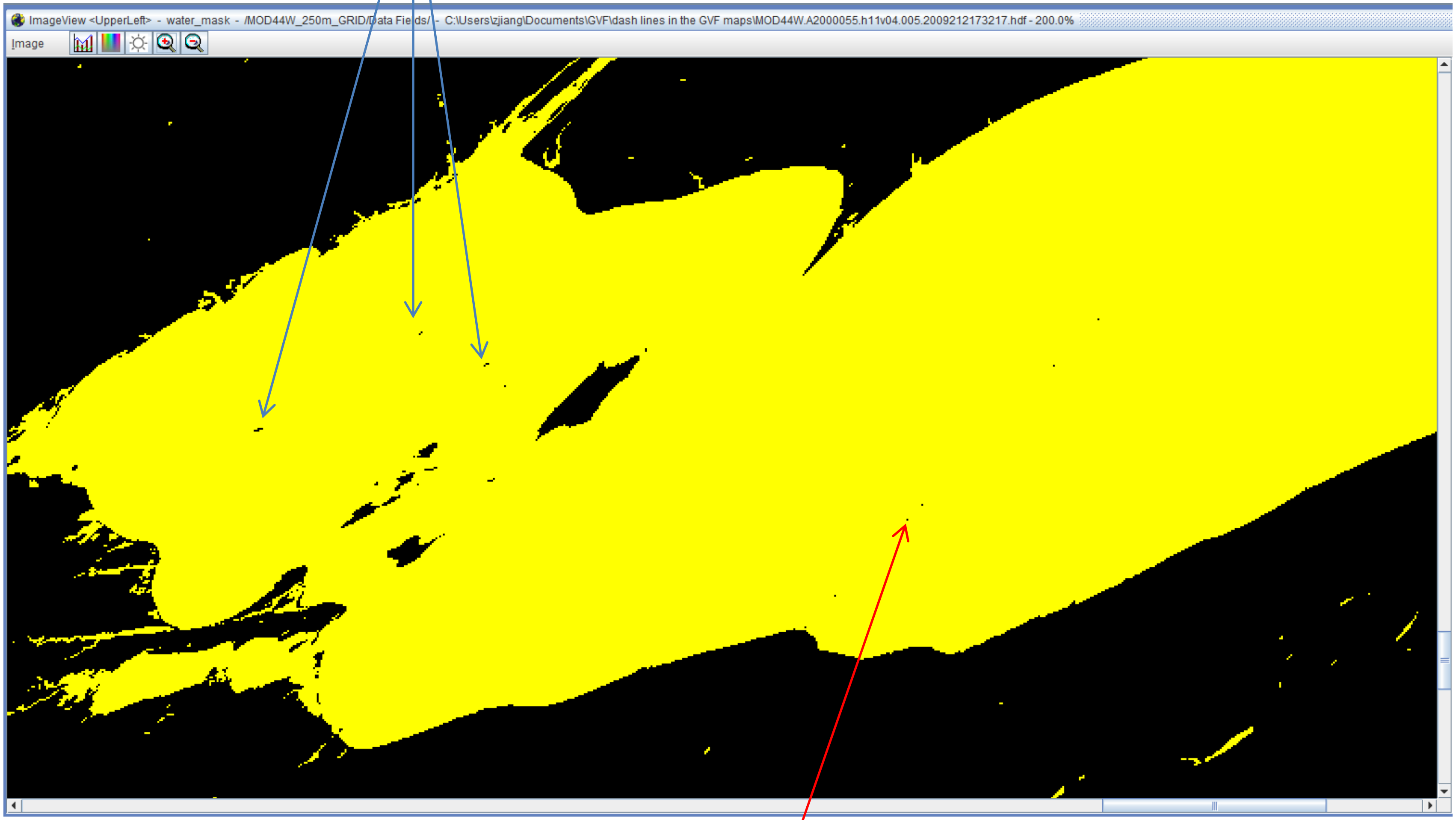
Dashed line on GVF water mask



Dashed line on the water mask over lake Erie (GVFWH_h05v02)

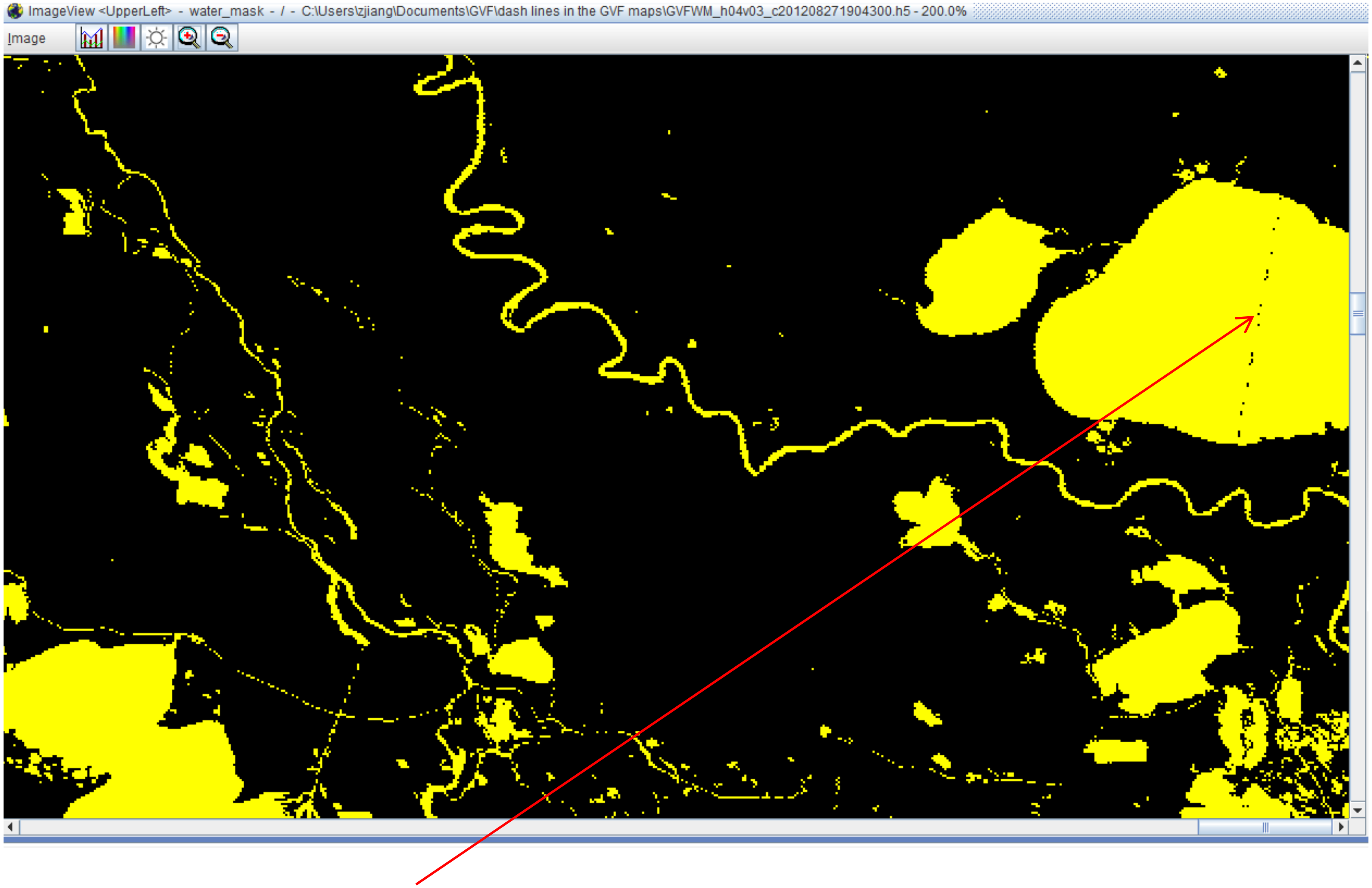
MODIS water mask

Small islands



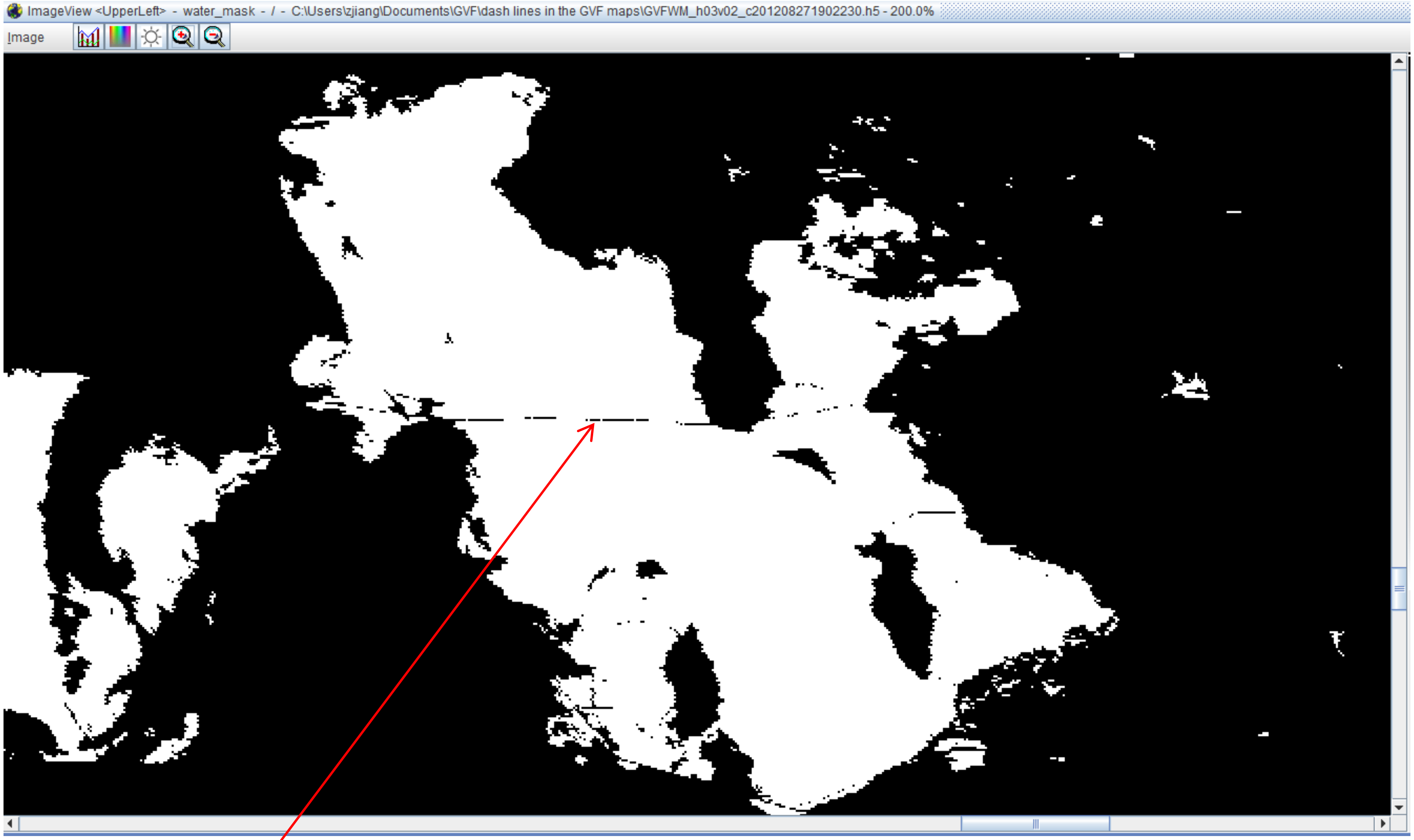
Dashed line on the MODIS water mask over lake Erie (MOD44W.A2000055.h11v04.005.2009212173217.hdf)

Dashed line on GVF water mask



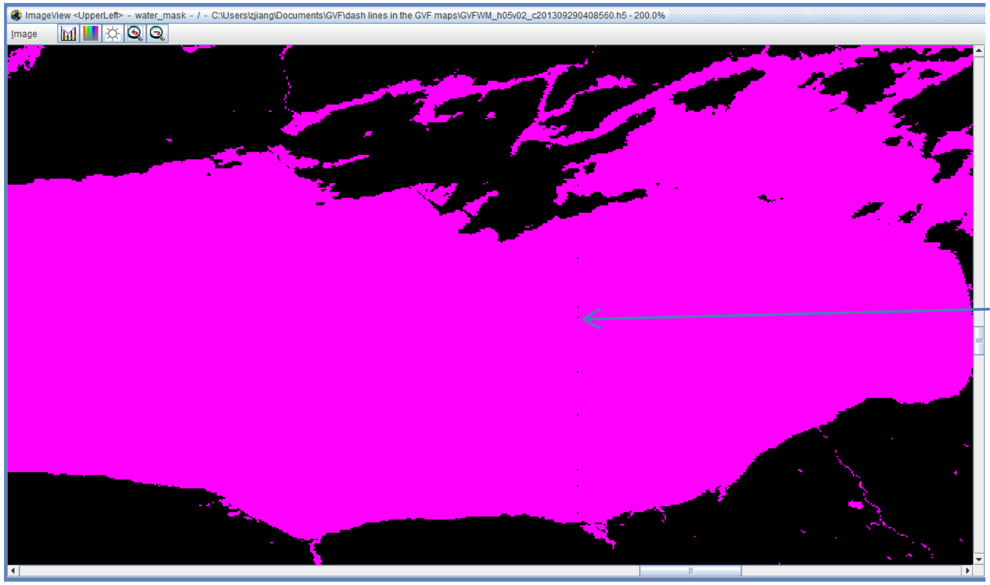
Dashed line on the water mask over lake Pontchartrain (GVFWH_h04v03)

Dashed line on GVF water mask

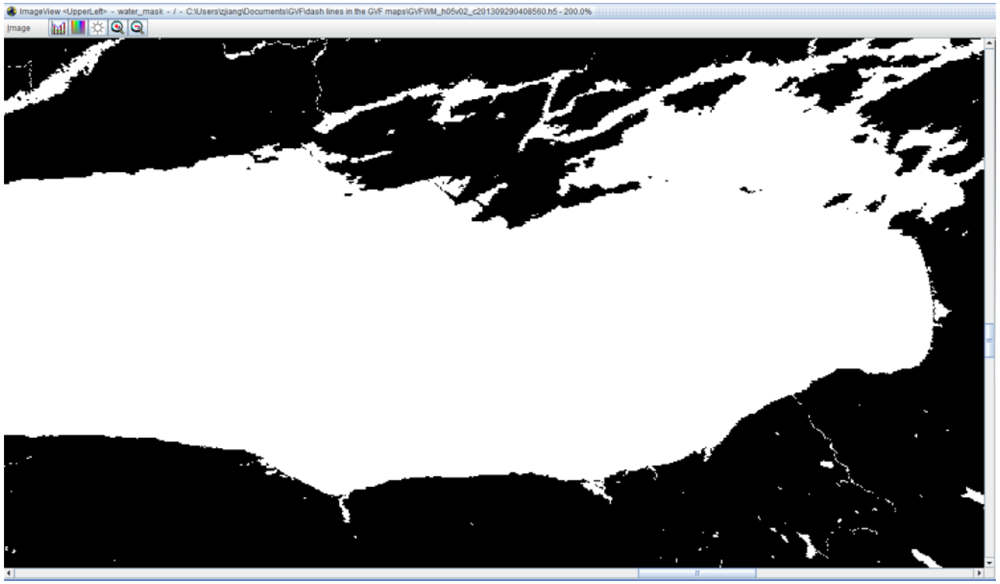


Dashed line on the water mask over the great salt lake (GVFWH_h03v02)

Modification of water mask (Lake Ontario)

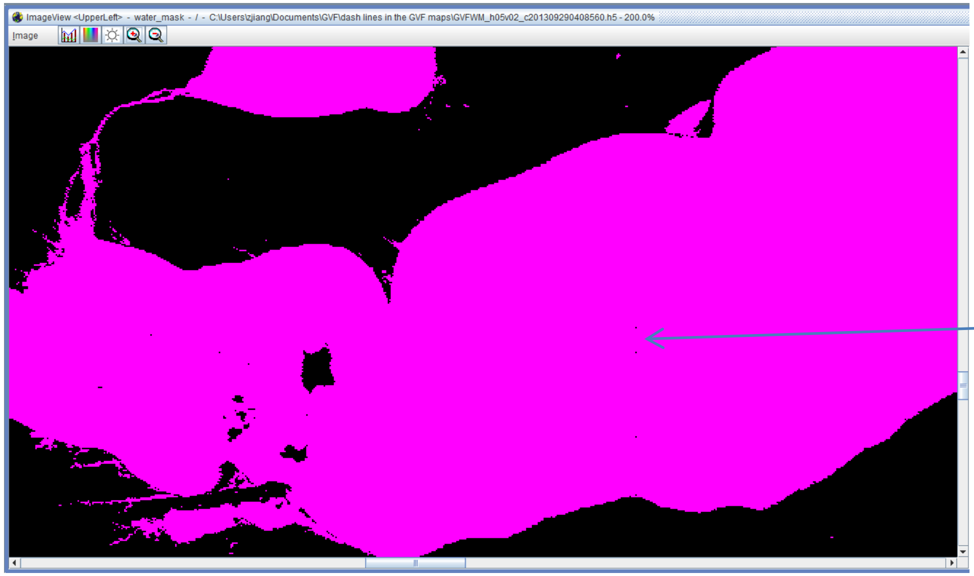


Original

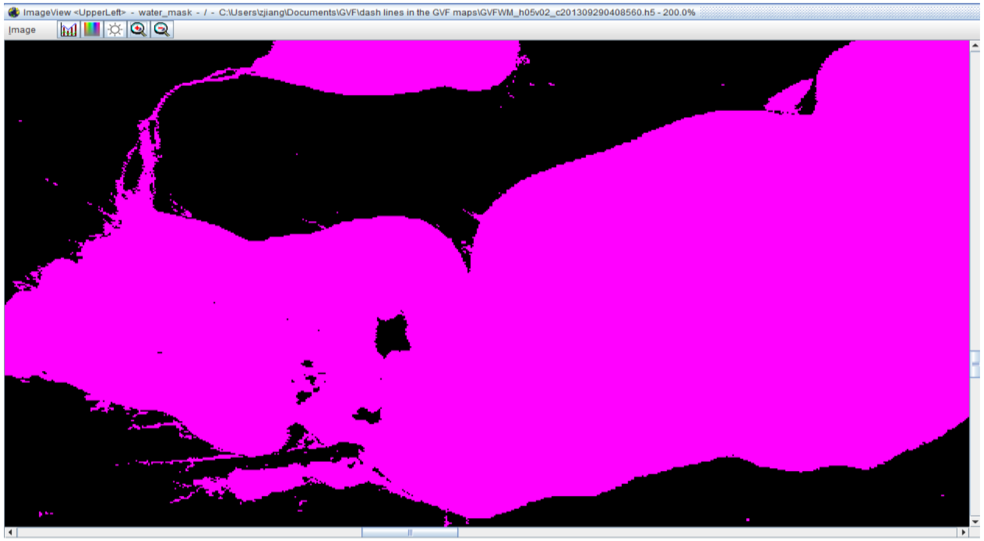


Modified

Modification of water mask (Lake Erie)

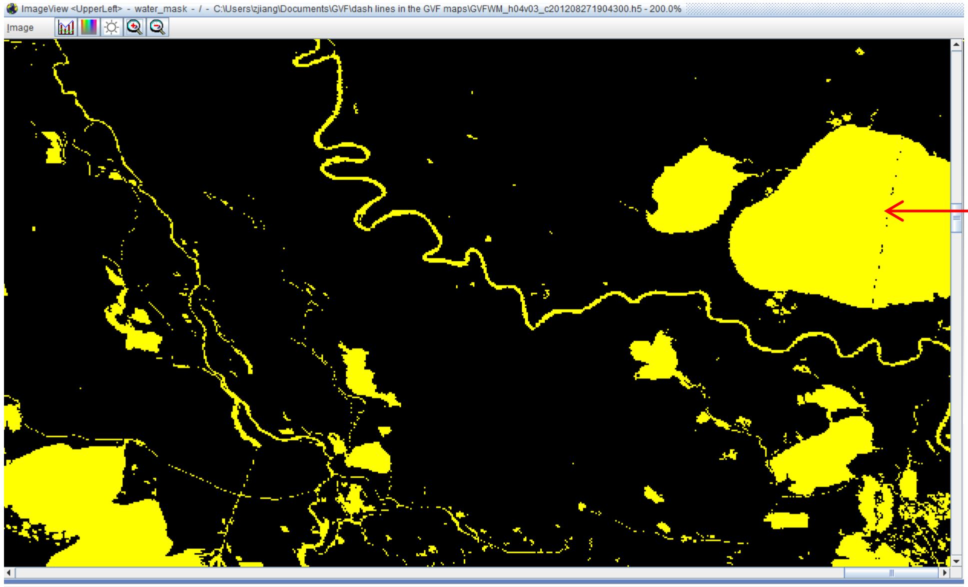


Original

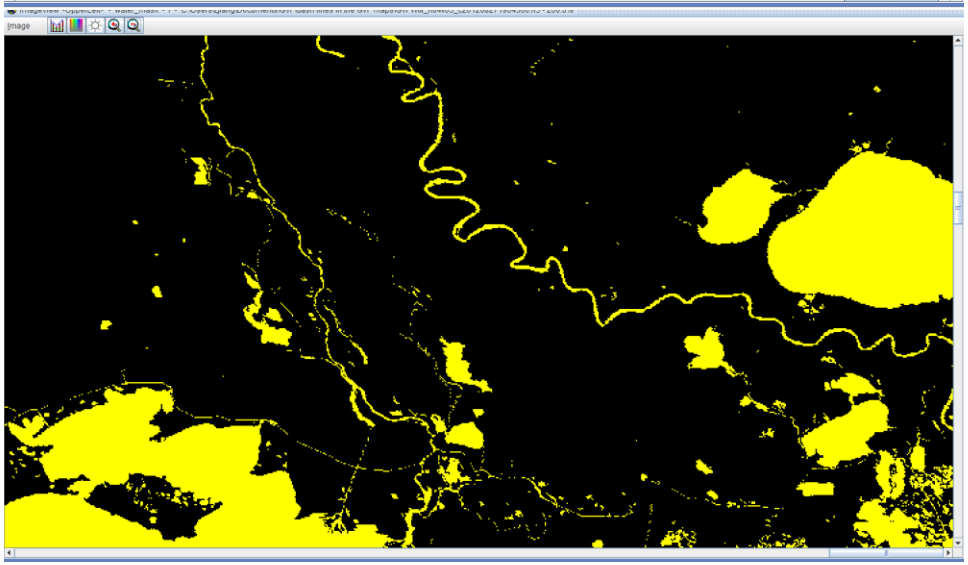


Modified

Modification of water mask (Lake Pontchartrain)

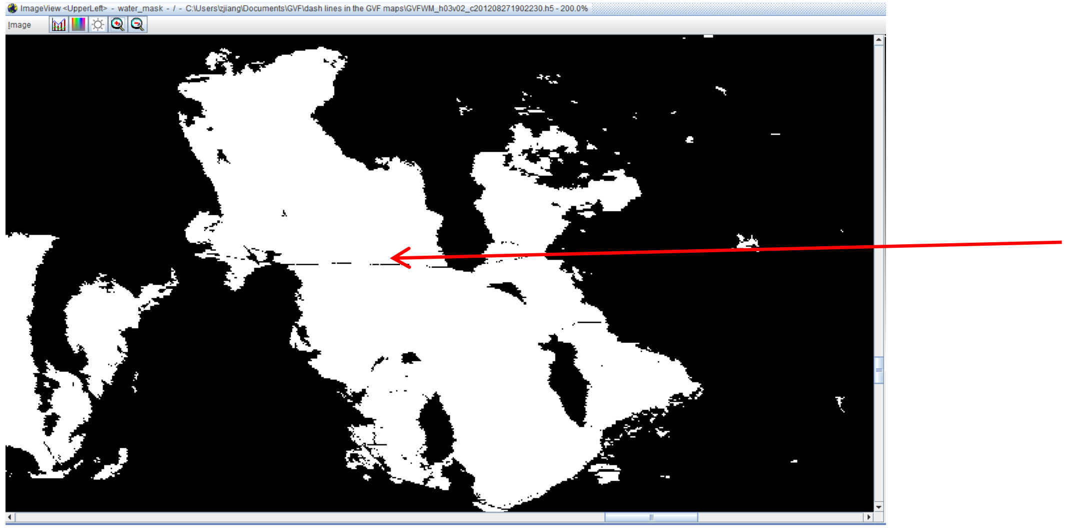


Original

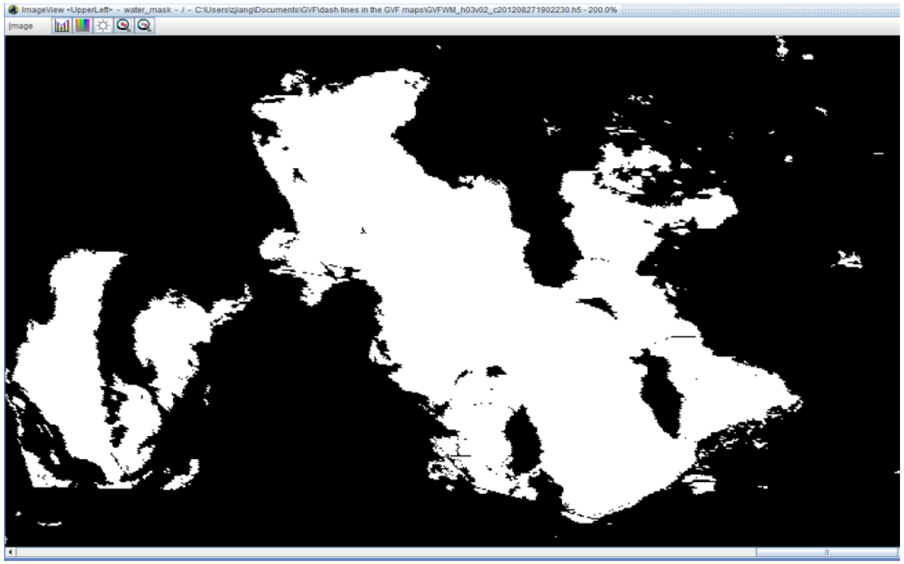


Modified

Modification water mask (Great Salt Lake)

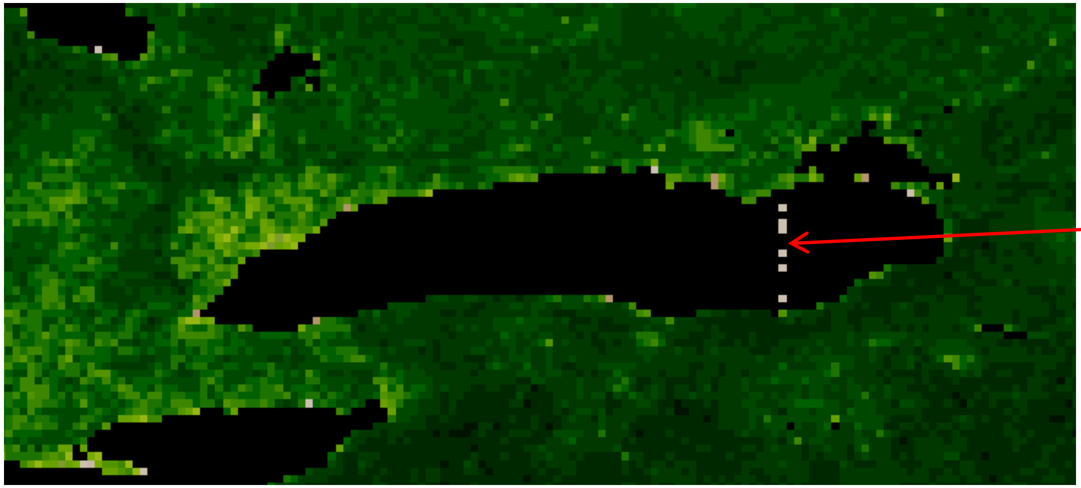


Original

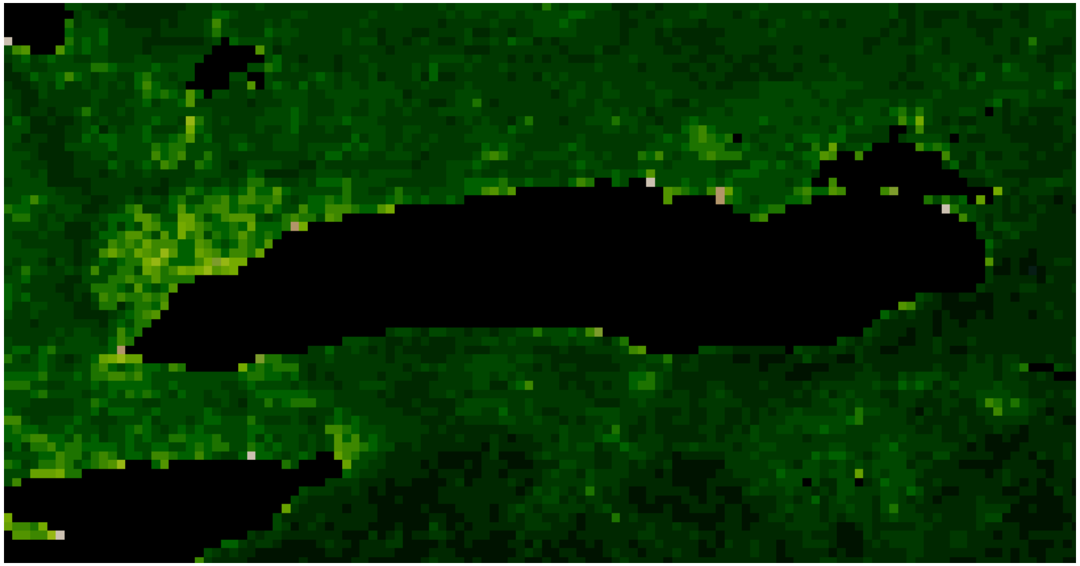


Modified

Evaluation of global GVF map (Lake Ontario)

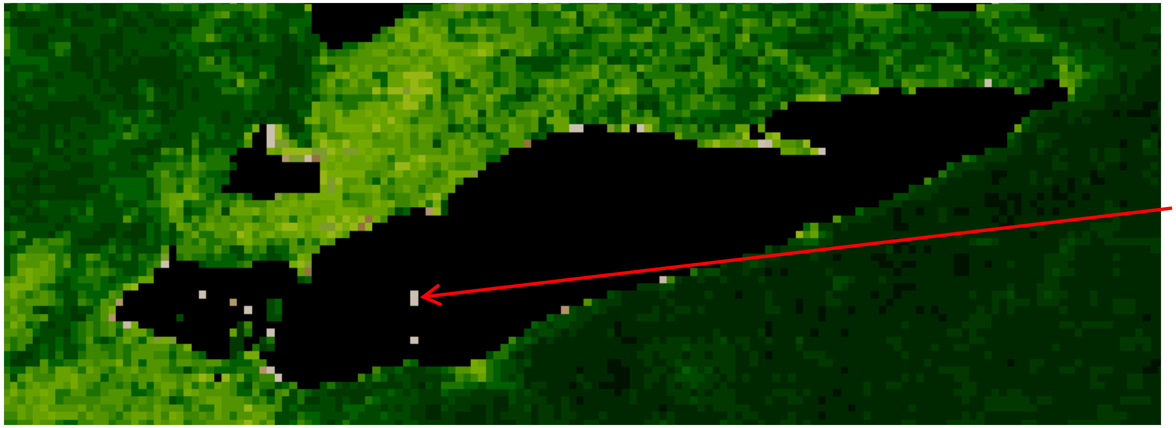


Original global GVF (20150602)

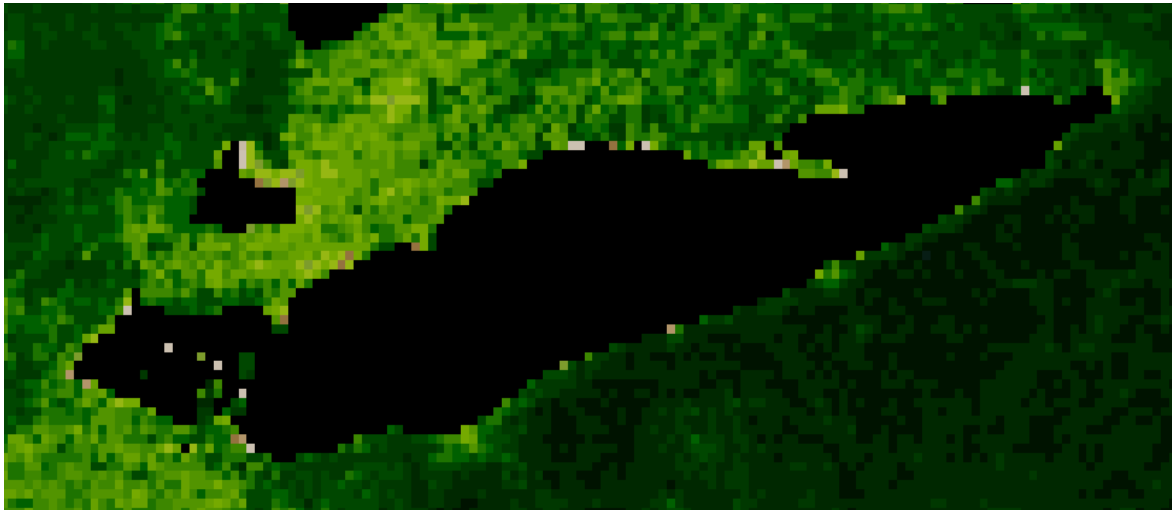


Modified global GVF (20150606)

Evaluation of global GVF map (Lake Erie)

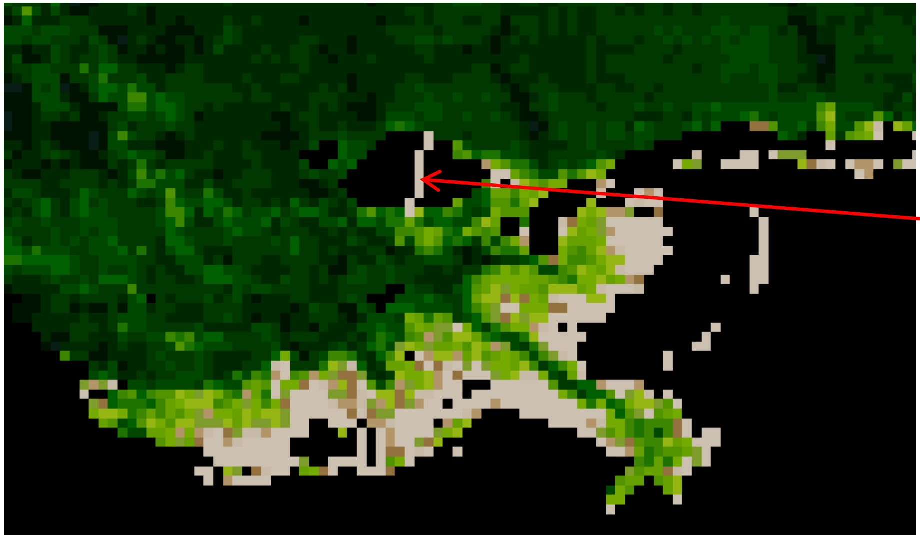


Original global GVF (20150602)

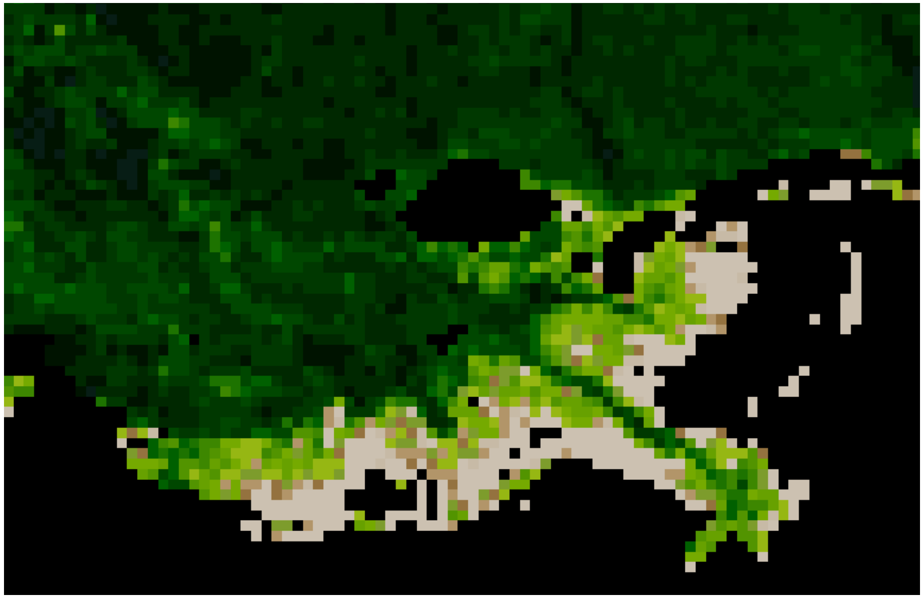


Modified global GVF (20150606)

Evaluation of global GVF map (Lake Pontchartrain)

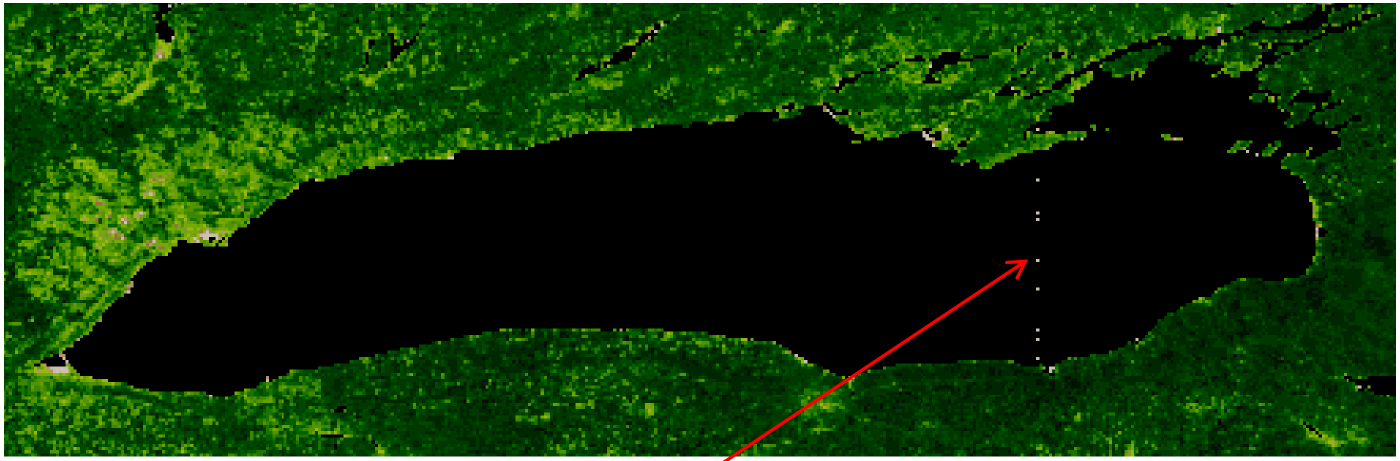


Original global GVF (20150602)

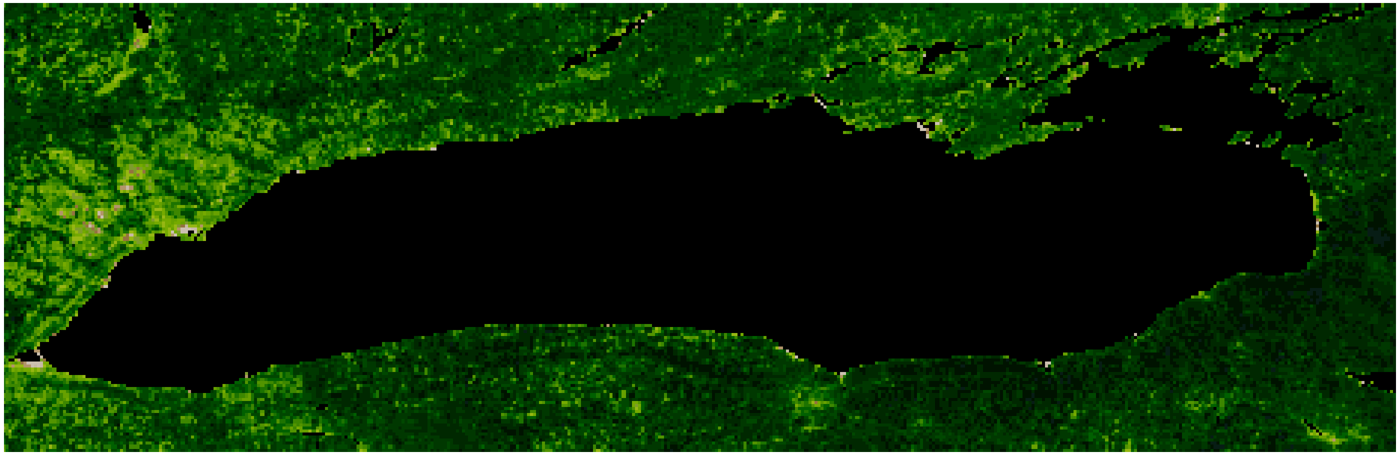


Modified global GVF (20150606)

Evaluation of regional GVF map (Lake Ontario)

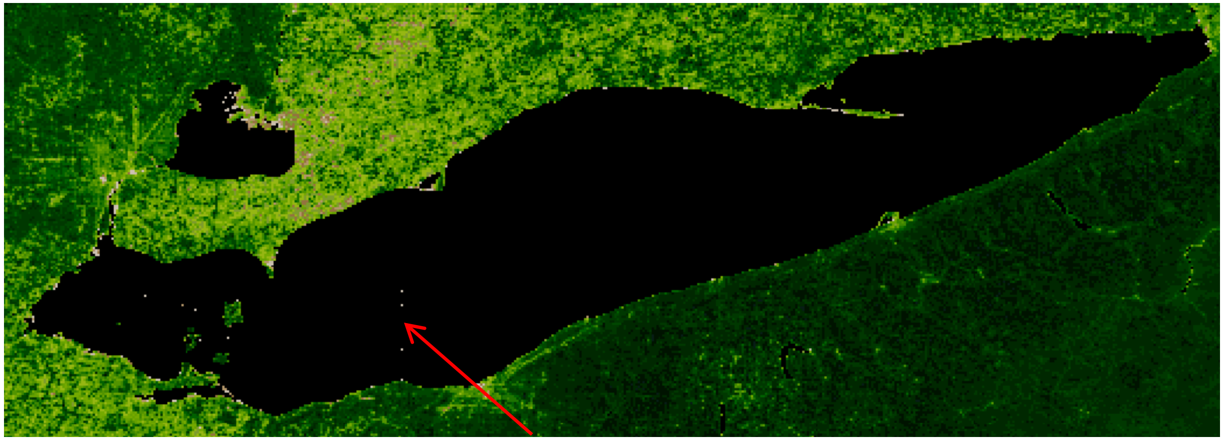


Original regional GVF (20150602)

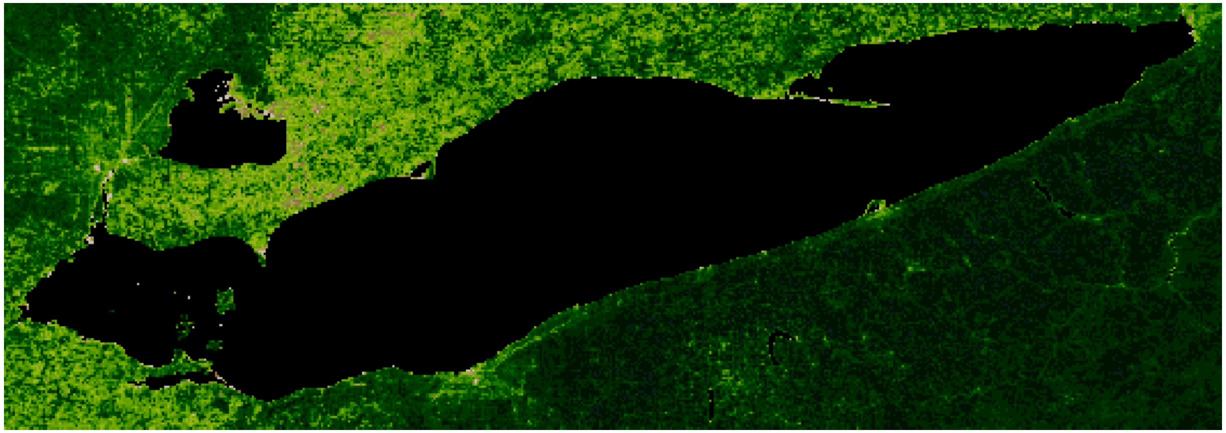


Modified regional GVF (20150606)

Evaluation of regional GVF map (Lake Erie)

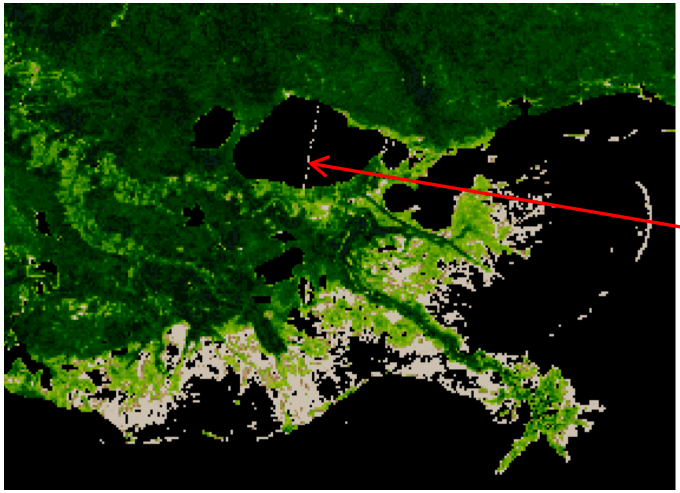


Original regional GVF (20150602)

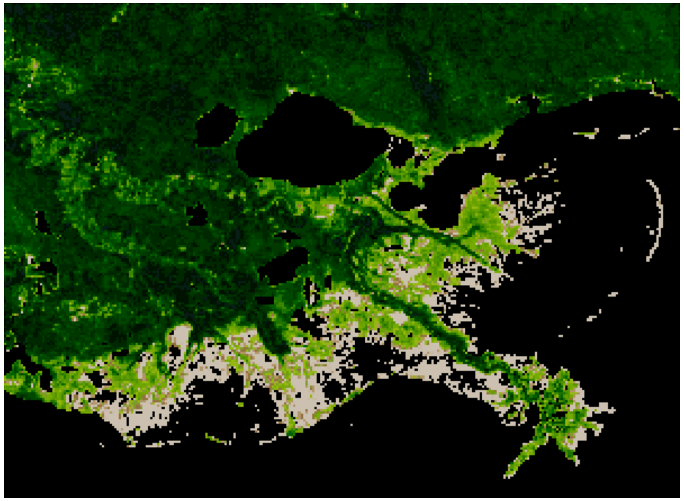


Modified regional GVF (20150606)

Evaluation of regional GVF map (Lake Pontchartrain)

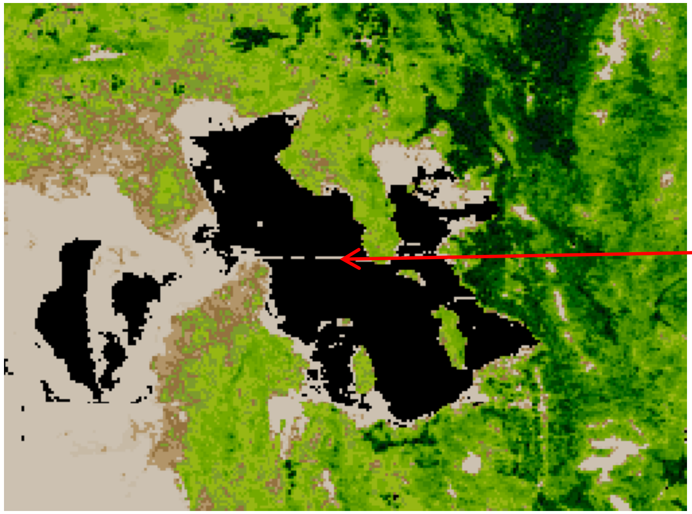


Original regional GVF (20150602)

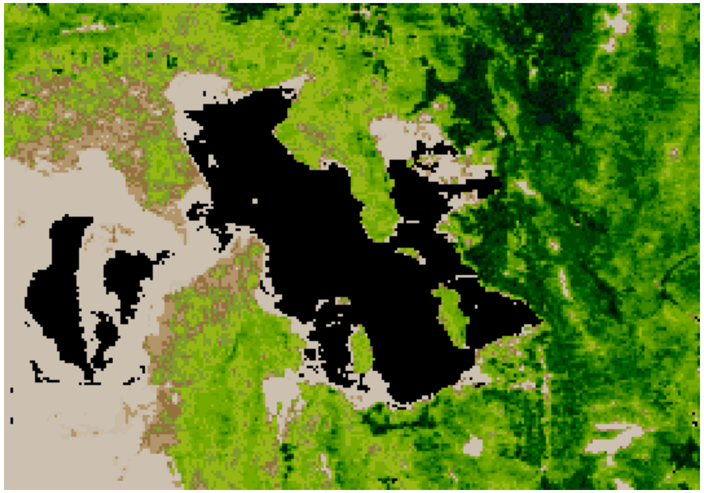


Modified regional GVF (20150606)

Evaluation of regional GVF map (Great Salt Lake)



Original regional GVF (20150602)



Modified regional GVF (20150606)

Improvements - Smoothing Algorithm (1/2)

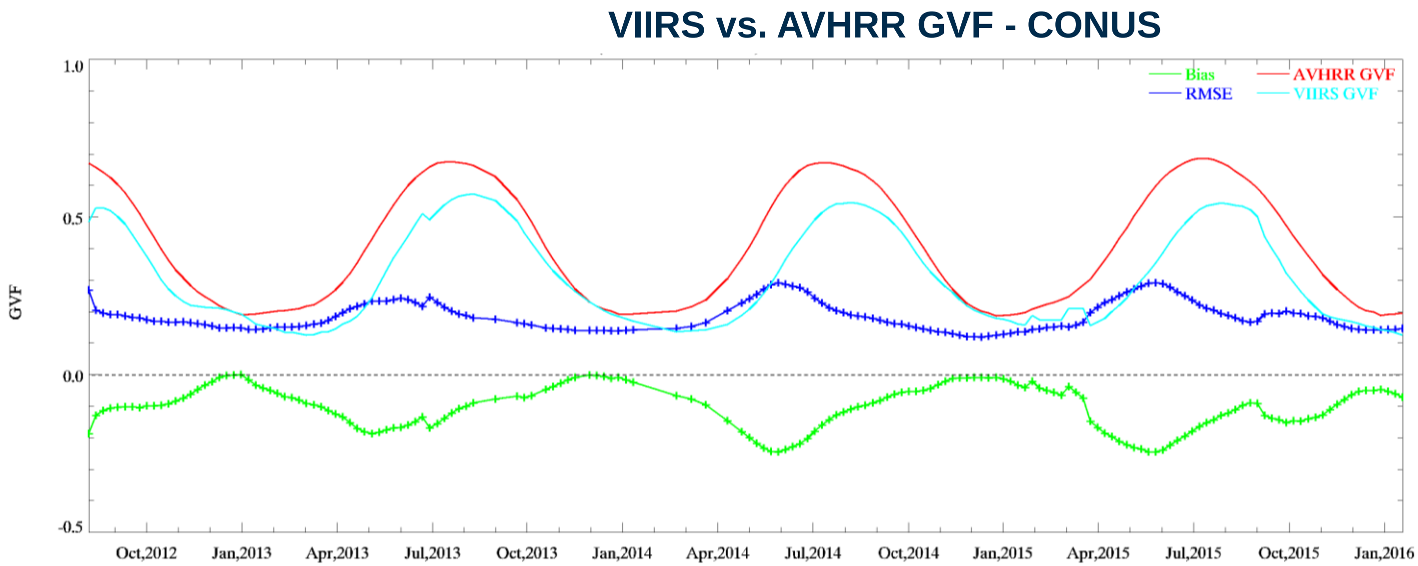
- Purpose of GVF smoothing:
  - (a) single out /extract the seasonal cycle
  - (b) suppress high frequency variations

- NCEP models require smooth input data
- VIIRS GVF adopted the first stage of the smoothing technique used by the operational AVHRR GVF production system
- The AVHRR GVF smoothing is performed in two stages
  1. NRT smoothing
  2. Updated smoothing (7 weeks later)

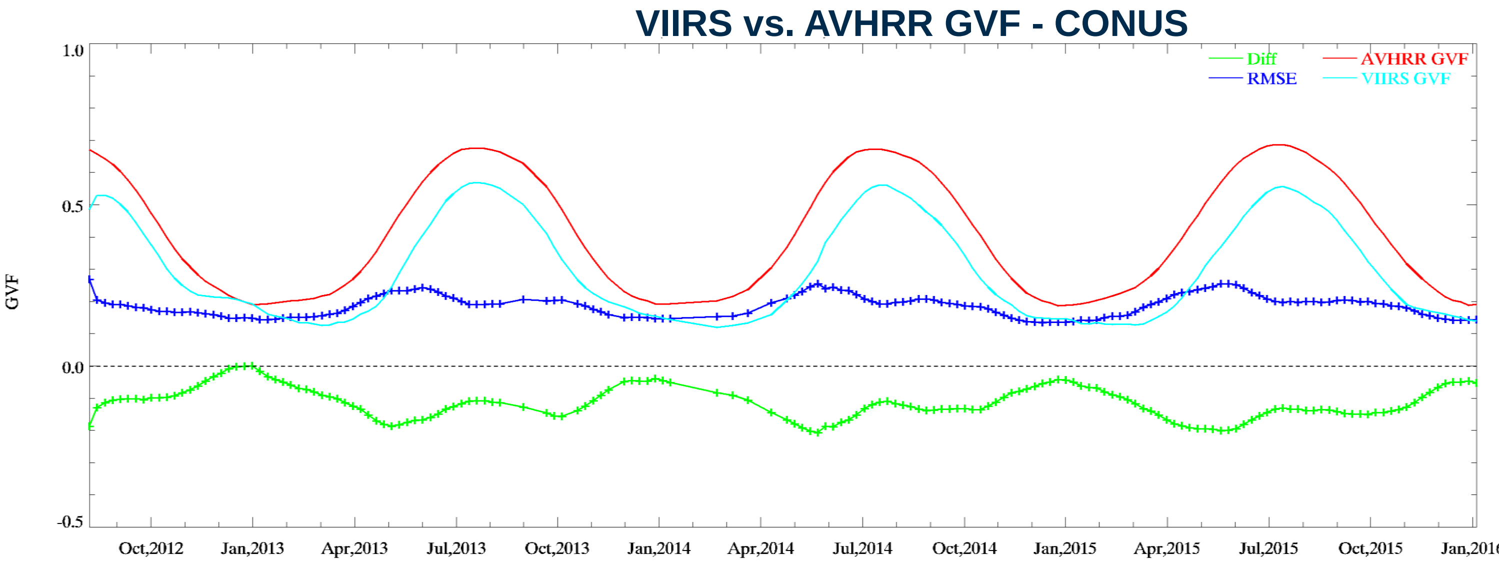
Improvements - Smoothing Algorithm (2/2)

- The AVHRR GVF system uses a smoothing algorithm that was developed by Jerry Sullivan(1993)
- AVHRR NRT smoothing shifts the VIIRS GVF seasonal cycle (~2 weeks)
- The <u>updated smoothing technique</u> for the VIIRS GVF was developed by Gorry (1990)

Improvements - Smoothing Algorithm

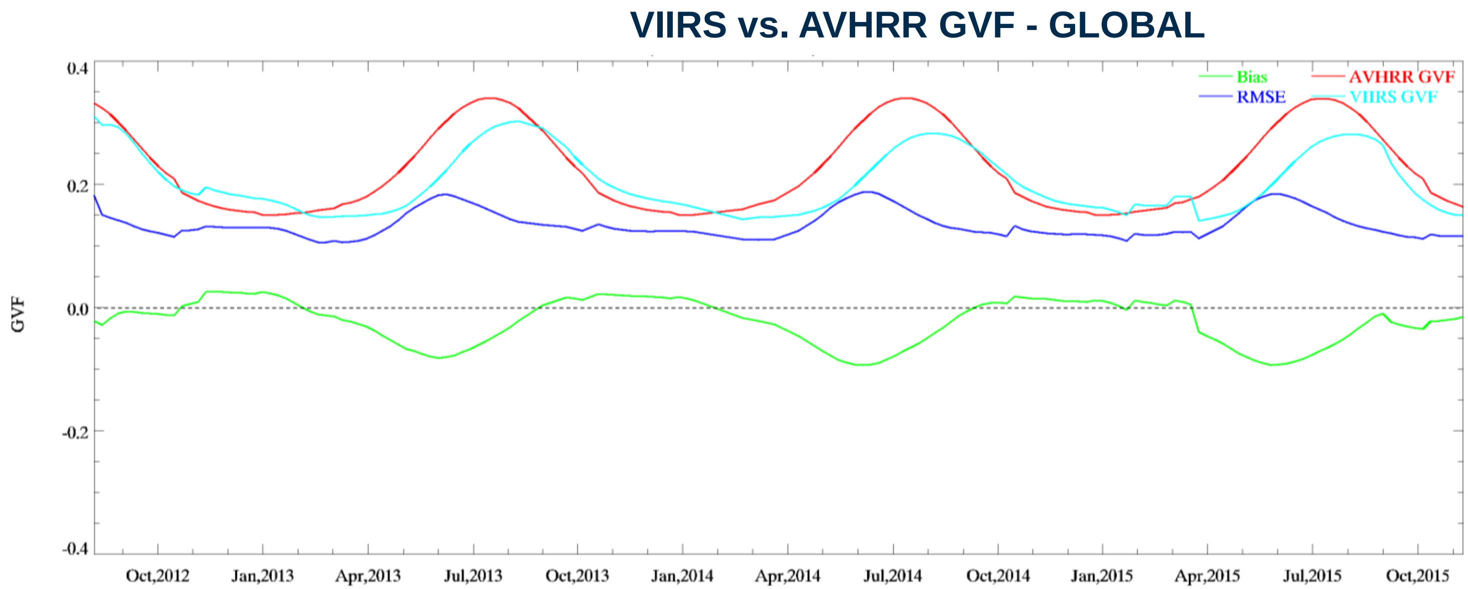


VIIRS GVF

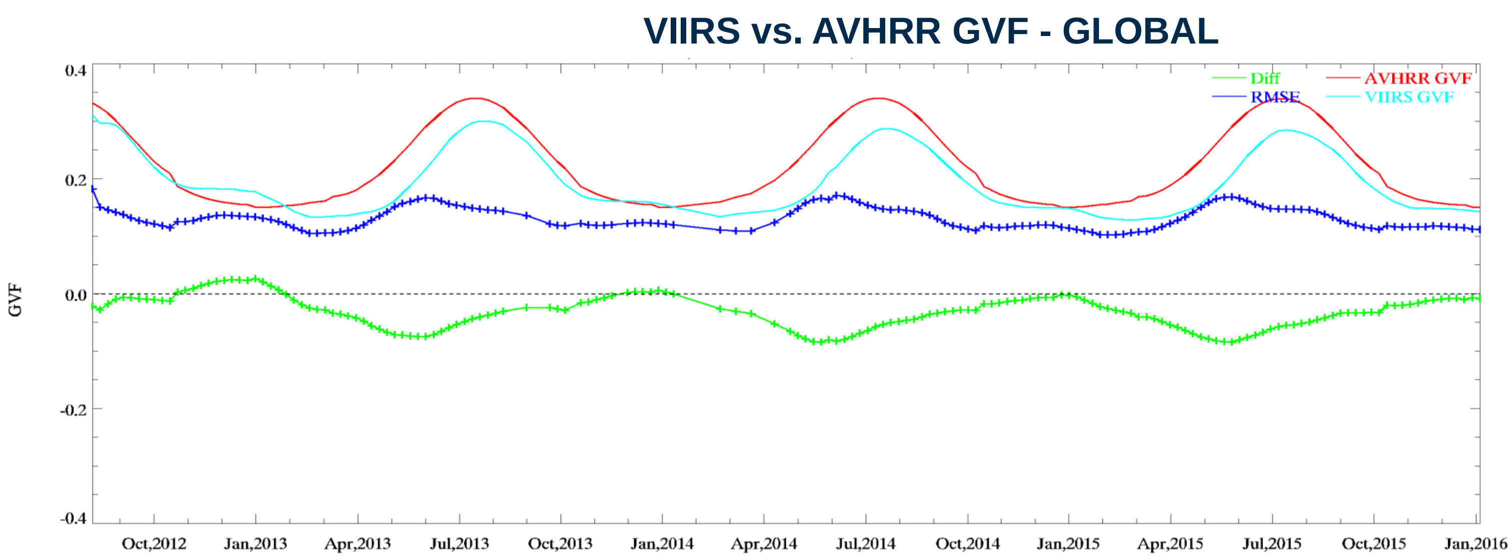


VIIRS GVF with updated smoothing algorithm

Improvements - Smoothing Algorithm



VIIRS GVF



VIIRS GVF with updated smoothing algorithm

Quality Flag Analysis/Validation

3.2 Science Products Performance

3.2.1 Normal Conditions

JERD-145 The science products (EDRs) produced by the NESDIS ESPC shall meet the data product performance requirements as specified in the JPSS Level-1 Requirements Document-Supplement unless an exclusion or degradation condition occurs.

JERD-2030 The EDR Accuracy, Precision, Uncertainty (APU) and Probability of Correct Typing (PCT) performance shall be assessed and validated against their requirements using correlative data.

JERD-2031 APU and PCT requirements shall apply only within the specified Measurement Range.

3.2.2 **Quality Flags**

JERD-2033 The science products shall include a quality flag describing the quality of the retrieval, with the exception of those products listed below:

-9-

JPSS NESDIS ESPC Requirements Document
Volume 2: Science Requirements

JPSS-REQ-1004
Effective Date Mar 31, 2016
Version 2.0

- Green Vegetation Fraction
- Ocean Color/Chlorophyll

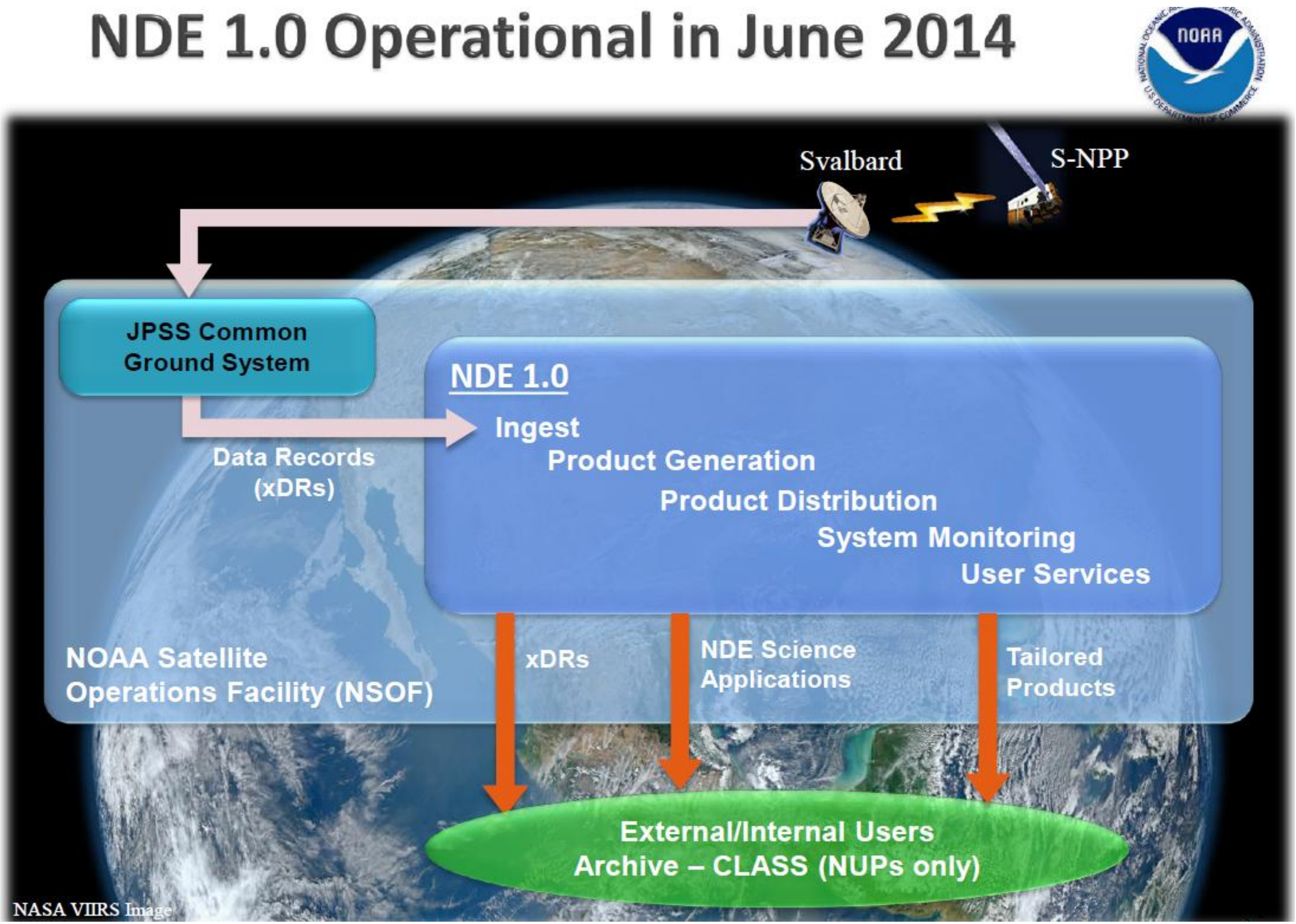
Note, the following AMSR-2 products are TBD: Snow Cover/Depth, Snow Water Equivalent, Soil Moisture, Sea Ice Characterization, and Surface Type.

Source: ESPC JERD Volume 2: Science Requirements – Version: 2.0 Mar 31, 2016

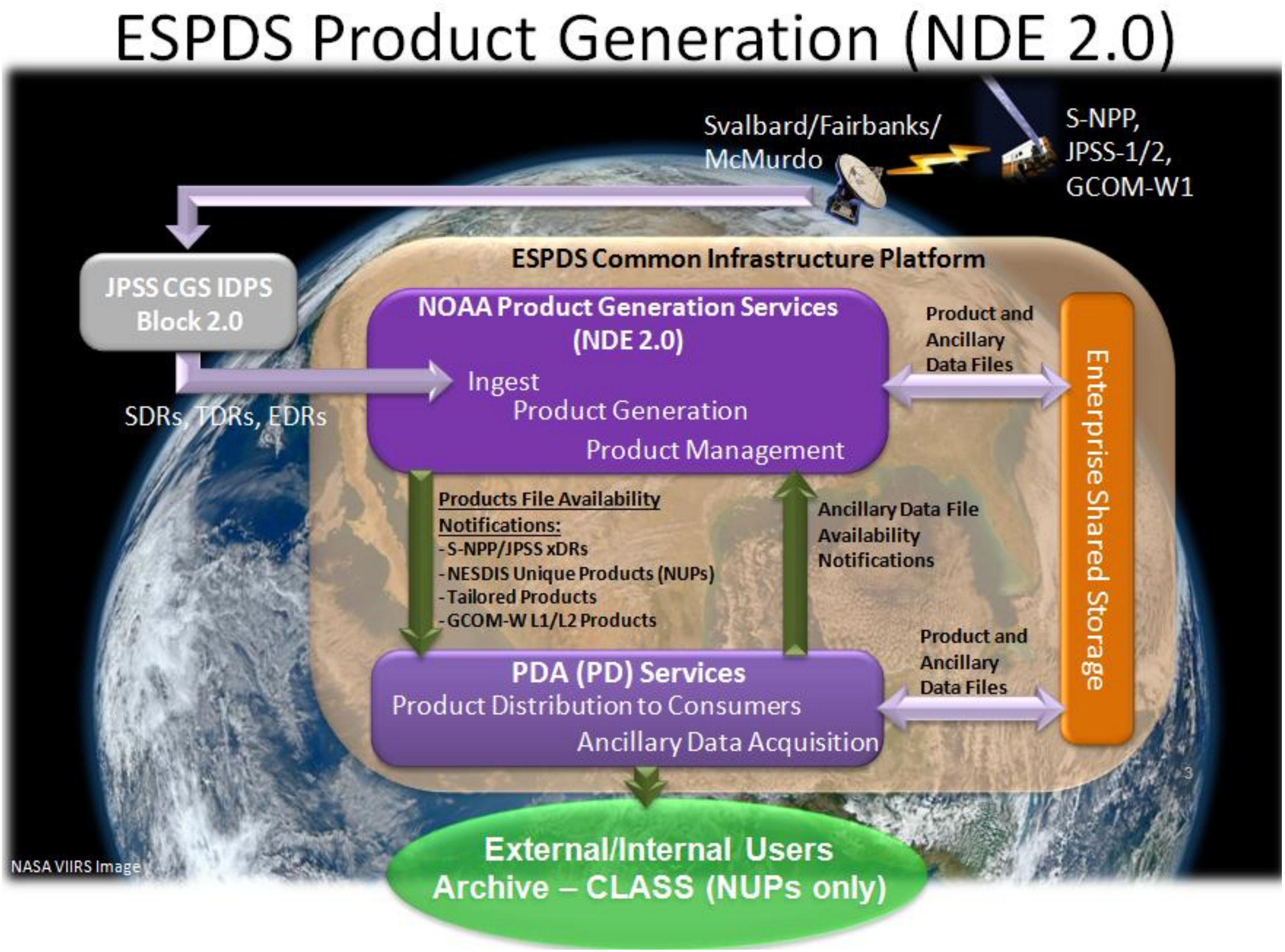
Identification of Processing Environment

- VIIRS GVF NUP is currently generated at NDE 1.0
  - NOAA Data Exploitation (NDE) 1.0 operational since June 2014
- ESPDS NDE 2.0 ORR Nov 2016
- ESPDS NDE 2.0 TTO Jan 2017
- There will be a transition period during which both NDE 1.0 and 2.0 will exist
- VIIRS GVF Algorithm version: 1.0
- Version of PCTs used: 1.0

Description of environment used to achieve validated maturity stage



NDE 2.0 (Evolution)



VIIRS GVF Users

- NCEP/EMC Land-Hydrology Team
- STAR/SMCD
- NASA SPoRT
- NOAA ESRL
- NOAA CLASS
- UMD

Users and User Feedback

Key User	Brief Summary
Mike Ek NCEP/EMC	The NCEP/EMC land group is testing your near-real time green vegetation fraction (GVF) product which meets our requirements for quality, timeliness, and resolution. As we in the EMC land group have discussed with you and your NESDIS/STAR colleagues, GVF is quite important for our Noah land-surface model (LSM) which is coupled with the NOAA weather and climate models that are run here at NCEP
Weizhong Zheng NCEP/EMC	I have done some preliminary tests with your weekly VIIRS GVF product in the NCEP GFS model. The results show a positive impact on reduction in errors of surface temperature and surface humidity, and slightly improvement of precipitation scores.
Tanya Smirnova NOAA/ESRL	Here at ESRL, we develop WRF-based operational Rapid Refresh (RAP) and High-Resolution Rapid Refresh (HRRR) with the main focus on severe weather that have an impact on aviation operations. This summer we started testing the real-time VIIRS-GVF to replace the MODIS climatology to explore if this product can improve RAP/HRRR surface predictions. The data is being ftp-ed from Jonathan Case ftp site at NASA SPoRT. I ran in parallel two version of RAP for a couple of weeks: one with the MODIS climatology from WRF and another with real-time VIIRS GVF. I have noticed substantial differences between the two products in the SW US and also in Canada and Alaska (see attached ppt). Also, VIIRS GVF has larger seasonal variations. All this affects the model performance, especially near the surface. The ppt has only preliminary results, and statistical verification hasn't been performed yet. We plan to introduce VIIRS GVF into the next implementation of RAP and HRRR (RAPv4 and HRRRv3) at NCEP. We greatly appreciate your work on producing this real-time product.
Jonathan Case NASA/SPoRT	Based on a 3-yr preliminary analysis that I presented at the 2015 National Weather Association annual meeting, the VIIRS GVF product over the CONUS responded realistically to anomalies in weather/climate regimes (e.g., California drought 2014-2015 and Spring 2013 cold anomaly and subsequent delay in green-up). The impacts were seen in both offline land surface model applications and numerical weather prediction models. I have transitioned the VIIRS GVF into NASA/SPoRT's real-time Noah land surface model runs using the NASA Land Information System framework. I also made the data available within the WRF NWP model and UEMS/WRF modeling framework for the broader community to use. Further, I recently served as a subject matter expert and gave a workshop in Nairobi, Kenya, and provided training on the use of VIIRS GVF within the UEMS/WRF model for simulations in eastern Africa. Visualization of the VIIRS GVF product over Eastern Africa has shown good behavior in depicting the variation in greenness in response to seasonal changes in the ITCZ location and corresponding rainfall.
CLASS	VIIRS GVF product archive and distribution

User Feedback

Impact of new weekly VIIRS GVF data on NWP - Mozilla Thunderbird

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From Weizhong Zheng - NOAA Affiliate <weizhong.zheng@noaa.gov>

Subject **Impact of new weekly VIIRS GVF data on NWP**

10/6/2016 3:31 PM

To Marco Vargas - NOAA Federal

Marco,

I have done some preliminary tests with your weekly VIIRS GVF product in the NCEP GFS model. The results show a positive impact on reduction in errors of surface temperature and surface humidity, and slightly improvement of precipitation scores.

Thanks,

Weizhong Zheng
Environmental Modeling Center
NCEP/NWS/NOAA
5830 University Research Court , #2028
College Park, MD 20740
TEL: 301-683-3694 (O)
FAX: 301-683-3703
Email: Weizhong.Zheng@noaa.gov

1 attachment: GVF_Zheng.ppt size unknown | Save

0%

User Feedback

Subject: VIIRS GVF User Feedback
From: "Case, Jonathan (MSFC-ZP11)[ENSCO INC]" <jonathan.case-1@nasa.gov>
Date: 8/25/2016 2:44 PM
To: "Marco Vargas - NOAA Federal (marco.vargas@noaa.gov)" <marco.vargas@noaa.gov>

Hello Marco,

Below is a brief explanation of the utility we've found in using the VIIRS GVF product over the last year. Also, attached to this email are a few slides illustrating some sample impacts and applications.

Sincerely,
Jonathan

"Based on a 3-yr preliminary analysis that I presented at the 2015 National Weather Association annual meeting, the VIIRS GVF product over the CONUS responded realistically to anomalies in weather/climate regimes (e.g., California drought 2014-2015 and Spring 2013 cold anomaly and subsequent delay in green-up). The impacts were seen in both offline land surface model applications and numerical weather prediction models. I have transitioned the VIIRS GVF into NASA/SPoRT's real-time Noah land surface model runs using the NASA Land Information System framework. I also made the data available within the WRF NWP model and UEMS/WRF modeling framework for the broader community to use. Further, I recently served as a subject matter expert and gave a workshop in Nairobi, Kenya, and provided training on the use of VIIRS GVF within the UEMS/WRF model for simulations in eastern Africa. Visualization of the VIIRS GVF product over Eastern Africa has shown good behavior in depicting the variation in greenness in response to seasonal changes in the ITCZ location and corresponding rainfall."

****

Jonathan Case; Research Meteorologist at ENSCO, Inc./NASA
Short-term Prediction Research and Transition (SPoRT) Center
320 Sparkman Dr., Room 3008; Huntsville, AL 35805
Emails: Jonathan.Case-1@nasa.gov (preferred) or case.jonathan@ensco.com
Voice: 256.961.7504 ; Fax: 256.961.7788

User Feedback

Subject: VIIRS GVF User Feedback
From: Tanya Smirnova - NOAA Affiliate <tanya.smirnova@noaa.gov>
Date: 8/29/2016 3:13 PM
To: Marco Vargas - NOAA Federal <marco.vargas@noaa.gov>

Hello Marco,

Here at ESRL, we develop WRF-based operational Rapid Refresh (RAP) and High-Resolution Rapid Refresh (HRRR) with the main focus on severe weather that have an impact on aviation operations. This summer we started testing the real-time VIIRS-GVF to replace the MODIS climatology to explore if this product can improve RAP/HRRR surface predictions. The data is being ftp-ed from Jonathan Case ftp site at NASA SPoRT. I ran in parallel two version of RAP for a couple of weeks: one with the MODIS climatology from WRF and another with real-time VIIRS GVF. I have noticed substantial differences between the two products in the SW US and also in Canada and Alaska (see attached ppt). Also, VIIRS GVF has larger seasonal variations. All this affects the model performance, especially near the surface. The ppt has only preliminary results, and statistical verification hasn't been performed yet.
We plan to introduce VIIRS GVF into the next implementation of RAP and HRRR (RAPv4 and HRRRv3) at NCEP.
We greatly appreciate your work on producing this real-time product.
Thanks,
Tanya

Attachments:

VIIRS_GVF_versus_MODISclimo_19jul16.pptx 27 bytes

User Feedback

Get Messages | Write | Chat | Print | Address Book | Tag

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From Michael Ek - NOAA Federal <michael.ek@noaa.gov>

Subject **VIIRS GVF product** 9/6/2014 12:53 PM

To Marco Vargas - NOAA Federal

Cc Weizhong Zheng - NOAA Affiliate <weizhong.zheng@noaa.gov>, Yihua Wu <yihua.wu@noaa.gov>

Marco,

The NCEP/EMC land group is testing your near-realtime green vegetation fraction (GVF) product which meets our requirements for quality, timeliness, and resolution. As we in the EMC land group have discussed with you and your NESDIS/STAR colleagues, GVF is quite important for our Noah land-surface model (LSM) which is coupled with the NOAA weather and climate models that are run here at NCEP.

GVF determines how the surface turbulent latent heat flux is partitioned into transpiration and direct evaporation, which influences the remaining terms of the surface energy budget that the Noah LSM calculates, i.e. surface net radiation, surface turbulent sensible heat flux, and ground heat flux. The surface net radiation is important for the atmospheric radiation budget, while the surface turbulent heat fluxes are communicated to the evolving atmospheric boundary-layer, affecting the development of clouds and convection; ground heat flux is a storage term which determines the thermal inertia of the soil, with time scales of hours to seasons. Our current GVF monthly climatology provides an approximate seasonal vegetation phenology for use in the Noah LSM, but a near-realtime GVF provides a more accurate current surface description, and consequently better surface fluxes calculated by the Noah LSM, with subsequent effects, i.e. on boundary layer, clouds and convection, with downstream affects on circulation systems, and in determining such quantities as low-level temperature, humidity and winds. The GVF product is therefore crucial, along with other surface characteristics such as land-use/vegetation type, soil texture, and albedo, and land states such as snow and soil moisture,

We look forward to our continued collaboration with you as we transition this GVF product for the Noah LSM into NCEP operations for our weather and seasonal climate models.

Weizhong, Yihua --anything to add or modify?

Thanks,

Mike

--

======================================
Dr. Michael B. EK, Research Meteorologist
Land-Hydrology Team Leader
Environmental Modeling Center (EMC)
National Centers for Environmental Prediction (NCEP)

NOAA Center for Weather and Climate Prediction (NCWCP)
5830 University Research Court, Room 2047 (W/NP2)
College Park, MD 20740 USA
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tel. +1.301.683.3957 (direct)
fax. +1.301.683.3703
email: michael.ek@noaa.gov
web: www.emc.ncep.noaa.gov
======================================

Documentation (Check List)

Science Maturity Check List	
ReadMe for Data Product Users	✓
Algorithm Theoretical Basis Document (ATBD)	✓
Algorithm Calibration/Validation Plan	✓
(External/Internal) Users Manual	✓
System Maintenance Manual (for ESPC products)	✓
Peer Reviewed Publications	✗
Regular Validation Reports	✓

Conclusion

- The SNPP VIIRS GVF products are performing well
- VIIRS GVF calculated APU meet the L1RDS requirements over time and across seasons
- VIIRS GVF temporal profiles match well the Landsat, PhenoCam, and FLUXNET counterparts
- known product anomalies and their recommended remediation strategies have been presented
- Based on the results presented we conclude that the SNPP VIIRS GVF product reached Validated maturity
- A Readme file for users has been written
- Product documentation (ATBD, external and internal user's manuals) is available
- VIIRS GVF product is ready for operational use based on documented validation findings and user feedback

Path Forward

- Submit CCR (OSPO/SPSRB) to update smoothing algorithm
- Submit CCR to update GVF land water mask
- Reprocess the VIIRS GVF record (after reprocessing the S-NPP VIIRS record by STAR)
- Develop JPSS1 VIIRS GVF for continuity with SNPP VIIRS GVF (ongoing)
- Continue working with NCEP/EMC to accelerate the use of the SNPP VIIRS GVF product in their land surface models
- Continue collaboration with other VIIRS GVF users (NOAA ESRL and NASA SPoRT)
- Integrate GVF into the NESDIS Enterprise Algorithm for Vegetation Products and generate 1km VIIRS GVF globally
- Begin VIIRS GVF LTM phase

More information on VIIRS GVF Product

- http://www.star.nesdis.noaa.gov/jpss/EDRs/products_VegIndex.php
- http://www.star.nesdis.noaa.gov/smcd/viirs_vi/gvf/gvf.htm
- http://www.star.nesdis.noaa.gov/jpss/gvf.php
- http://www.ospo.noaa.gov/Products/land/gvf/index.html
- http://www.nsof.class.noaa.gov/
- http://viirsland.gsfc.nasa.gov/Products/GVF.html

References

- Klosterman et al., Evaluation of remote sensing of deciduous forest phenology at multiple spatial scales using PhenoCam images. Biogeosciences, 2014, 11, 4305-4320.
- Richardson et al., Near-surface remote sensing of spatial and temporal variation in canopy phenology. Ecological Application, 2009, 19(6), 1417-1428.
- A., Gorry (1990). "General least-squares smoothing and differentiation by the convolution (Savitzky–Golay) method". Analytical Chemistry 62 (6): 570–573.
- Gutman, G., and A. Ignatov (1998). The derivation of the green vegetation fraction from NOAA/AVHRR data for use in numerical weather prediction models. Int. J. Remote Sensing 19, 1533-1543.
- Sullivan, J. (1993). Explanation of the filter that is presently used on NDVI weekly time series data to smooth out unrepresentative fluctuations from week to week. NOAA technical memorandum.
- Wilson, T. B., & Meyers, T. P. (2007). Determining vegetation indices from solar and photosynthetically active radiation fluxes. Agricultural and Forest Meteorology, 144(3-4), 160-179. doi:10.1016/j.agrformet.2007.04.001
- Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC). 2013. FLUXNET Maps & Graphics Web Page. Available online (http://fluxnet.ornl.gov/maps-graphics) from ORNL DAAC, Oak Ridge, Tennessee, USA Accessed November 5, 2013

Acknowledgements

- We acknowledge the following AmeriFlux sites for their data records: US-ARM, US-GLE, US-KFS, US-Ne1, US-Ne2, US-Ne3, US-NR1, US-SRM, US-Whs, and US-Wkg. Funding for AmeriFlux data resources was provided by the U.S. Department of Energy's Office of Science.
- We acknowledge PhenoCam for their data records
- We acknowledge USGS for distributing Landsat data
- We acknowledge Google Maps & Earth for the satellite images used in this presentation
- We acknowledge users of the VIIRS GVF (NCEP/EMC, NOAA ESRL, NASA SPoRT) for evaluating the VIIRS GVF product and for their feedback
- We acknowledge T. Miura from the University of Hawaii for providing the AmeriFlux tower data

Appendix A

VIIRS GVF User Feedback

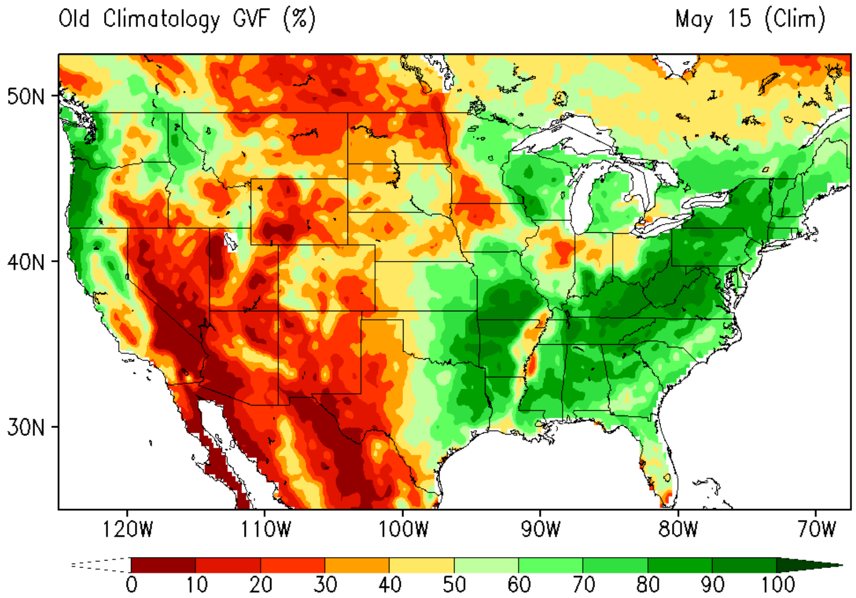
Impact of new weekly VIIRS GVF data on NWP

Provided by: Weizhong Zheng NOAA/NCEP/EMC

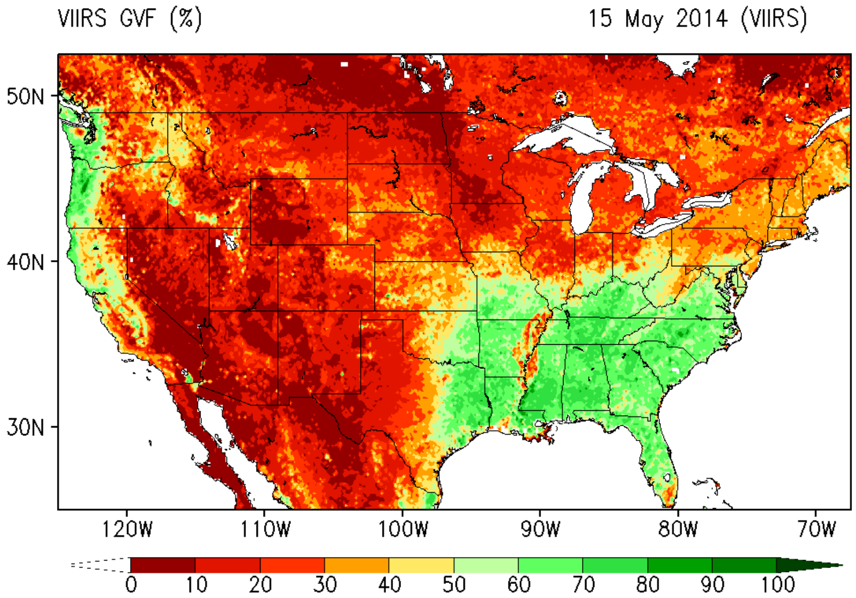
Incorporation of near real-time Suomi NPP Green Vegetation Fraction into the NCEP Models

Comparison of GVF between VIIRS and Clim 15 May 2014

Clim



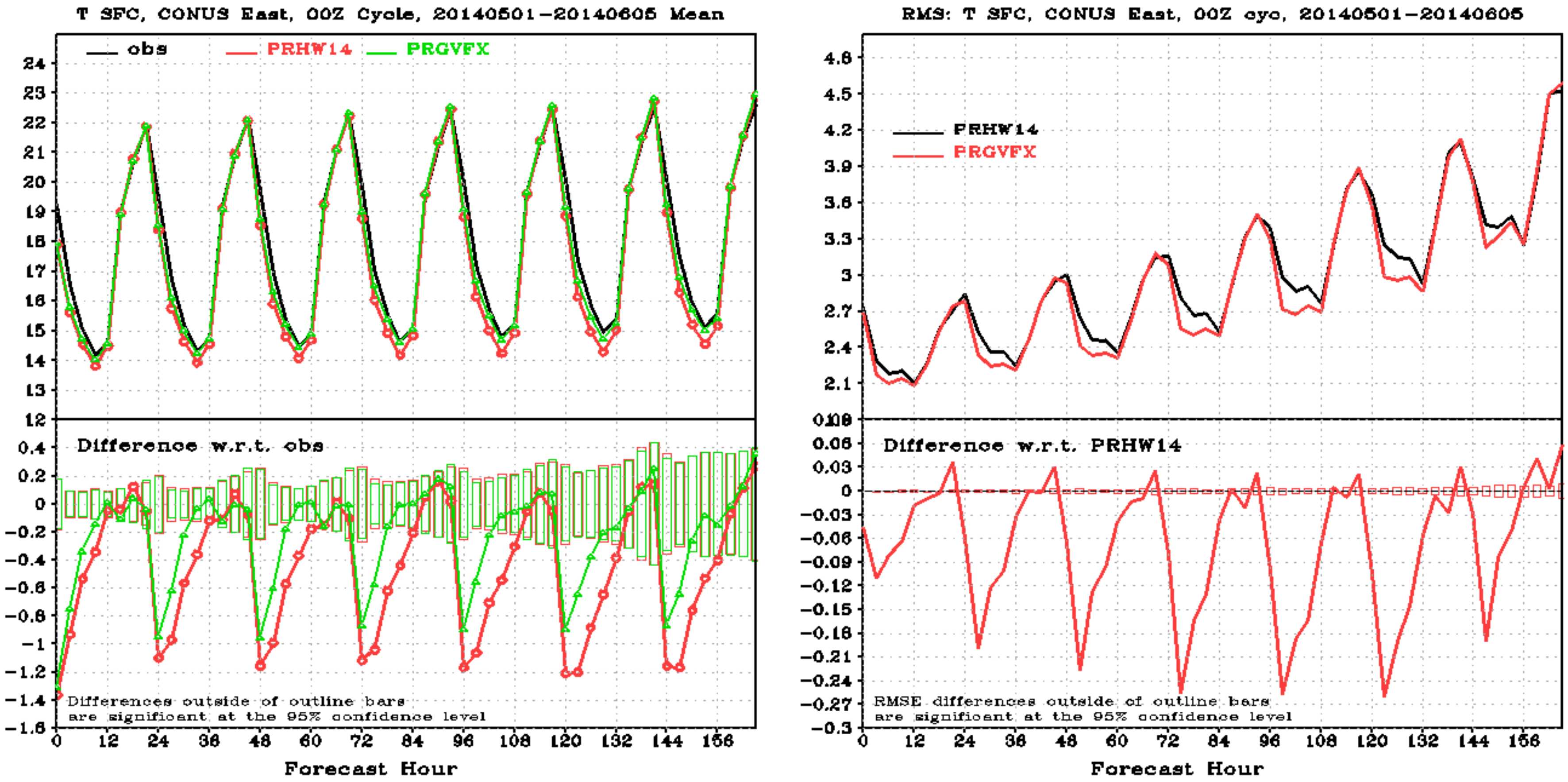
VIIRS



5yr mean AVHRR GVF in Ops NCEP models

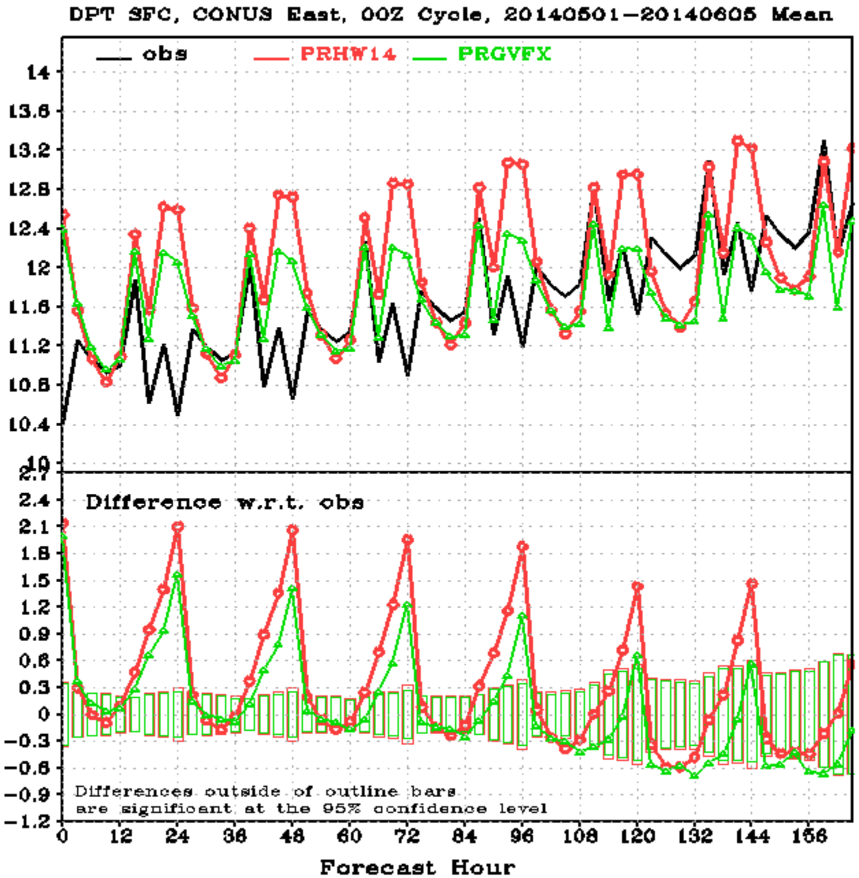
Near real-time VIIRS GVF (NOAA/NESDIS/STAR)

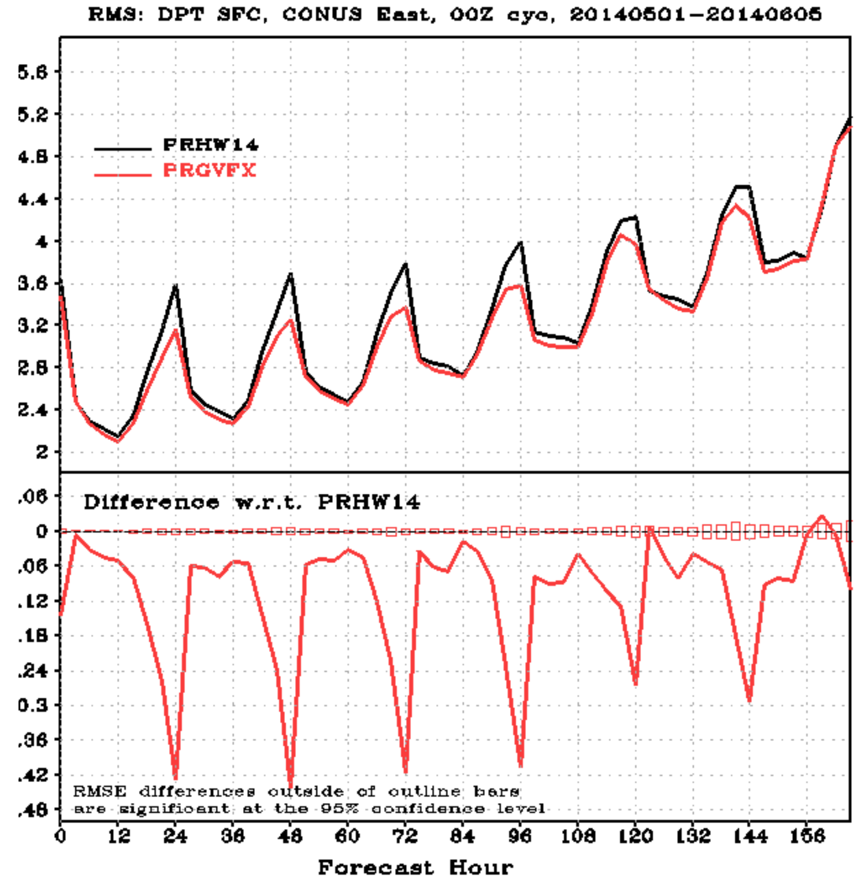
2-m air temperature and its RMSE   CONUS East



GFS: Reduced cold bias(~0.5 °C) and RMSE (~0.25 °C) in the afternoon and nighttime

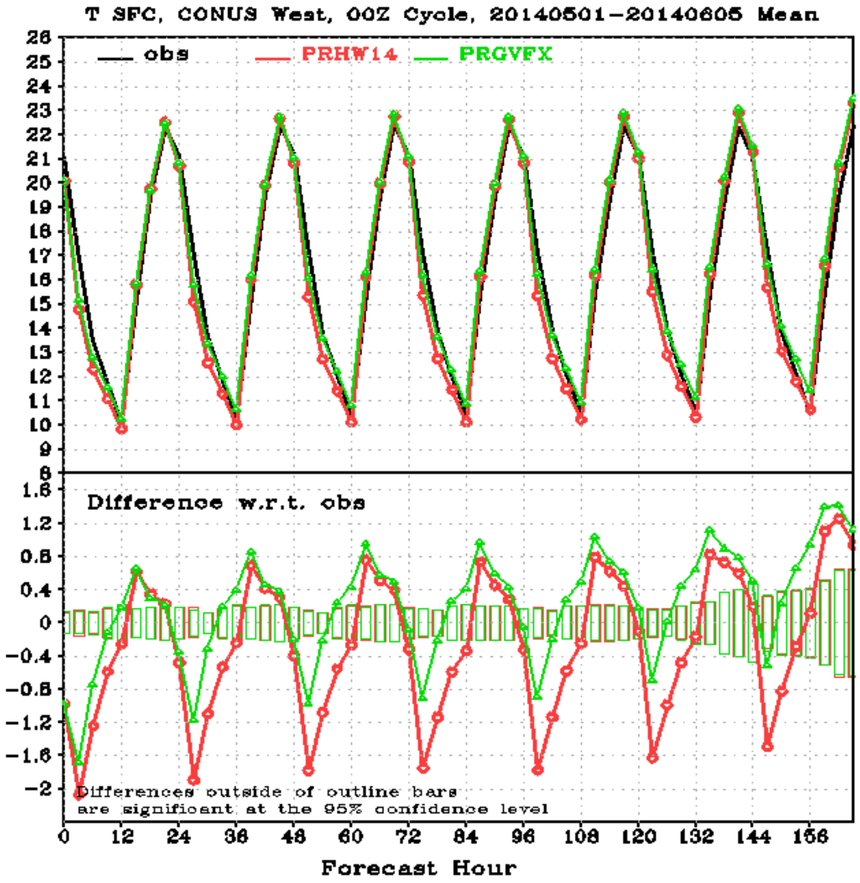
2-m dew point temp and its RMSE CONUS East

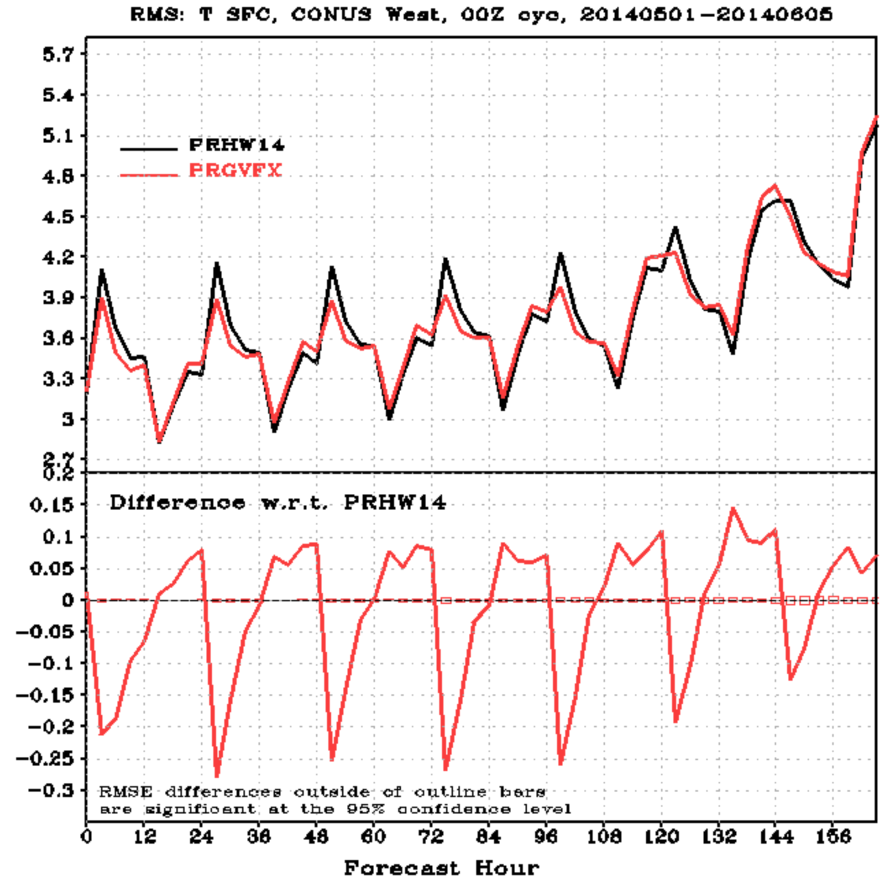




GFS: Reduced wet bias and RMSE in the afternoon and nighttime (~0.4 °C)

2-m air temperature and its RMSE CONUS West

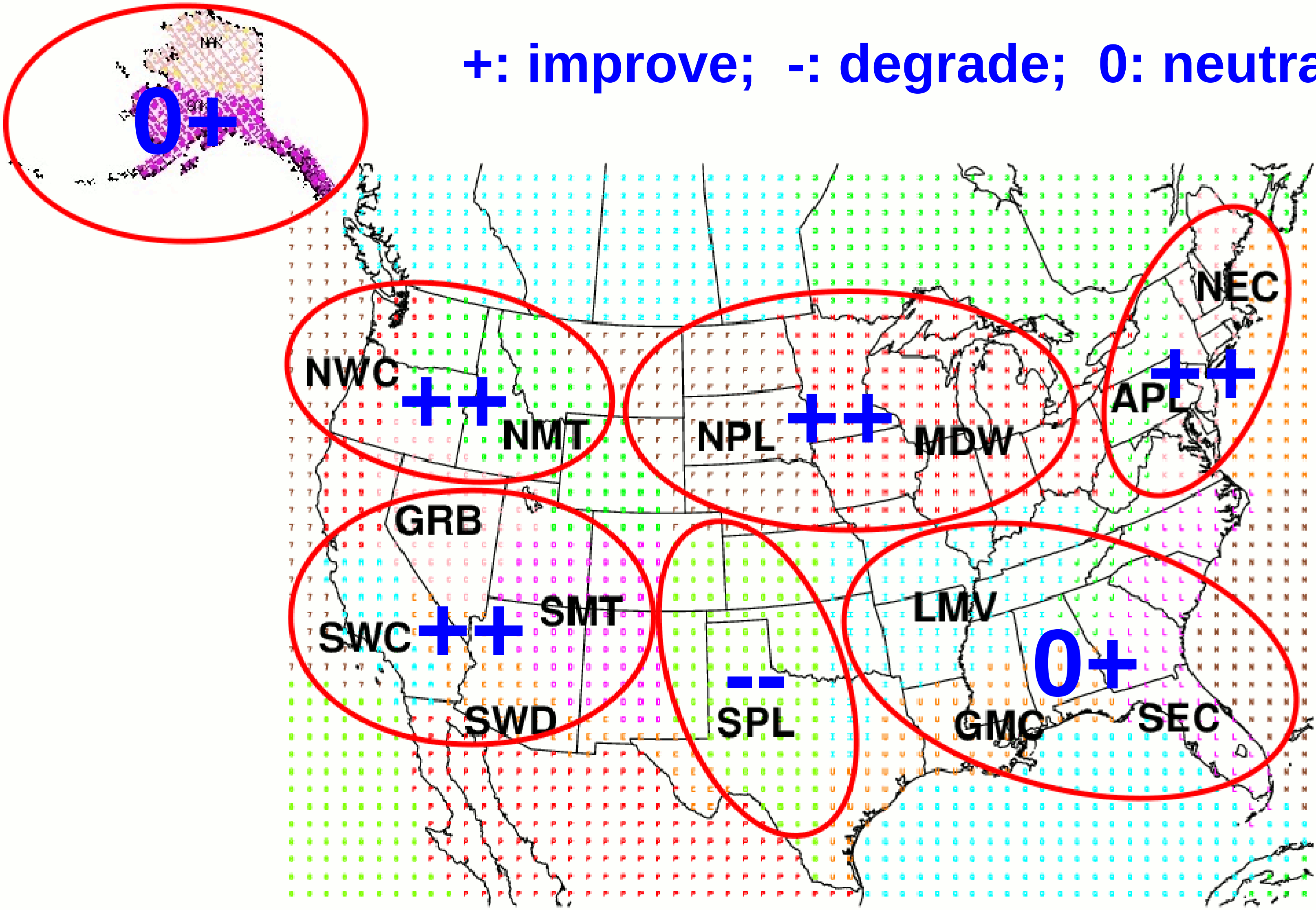




GFS: Reduced cold bias(~1 °C) and RMSE (~0.25 °C) in the afternoon and nighttime, but increase a little daytime RMSE.

Forecast Verification Statistics (FVS) regions

+: improve; -: degrade; 0: neutral



In general, the near real-time GVF shows a positive impact to reduce errors of 2-m air temperature in the GFS.

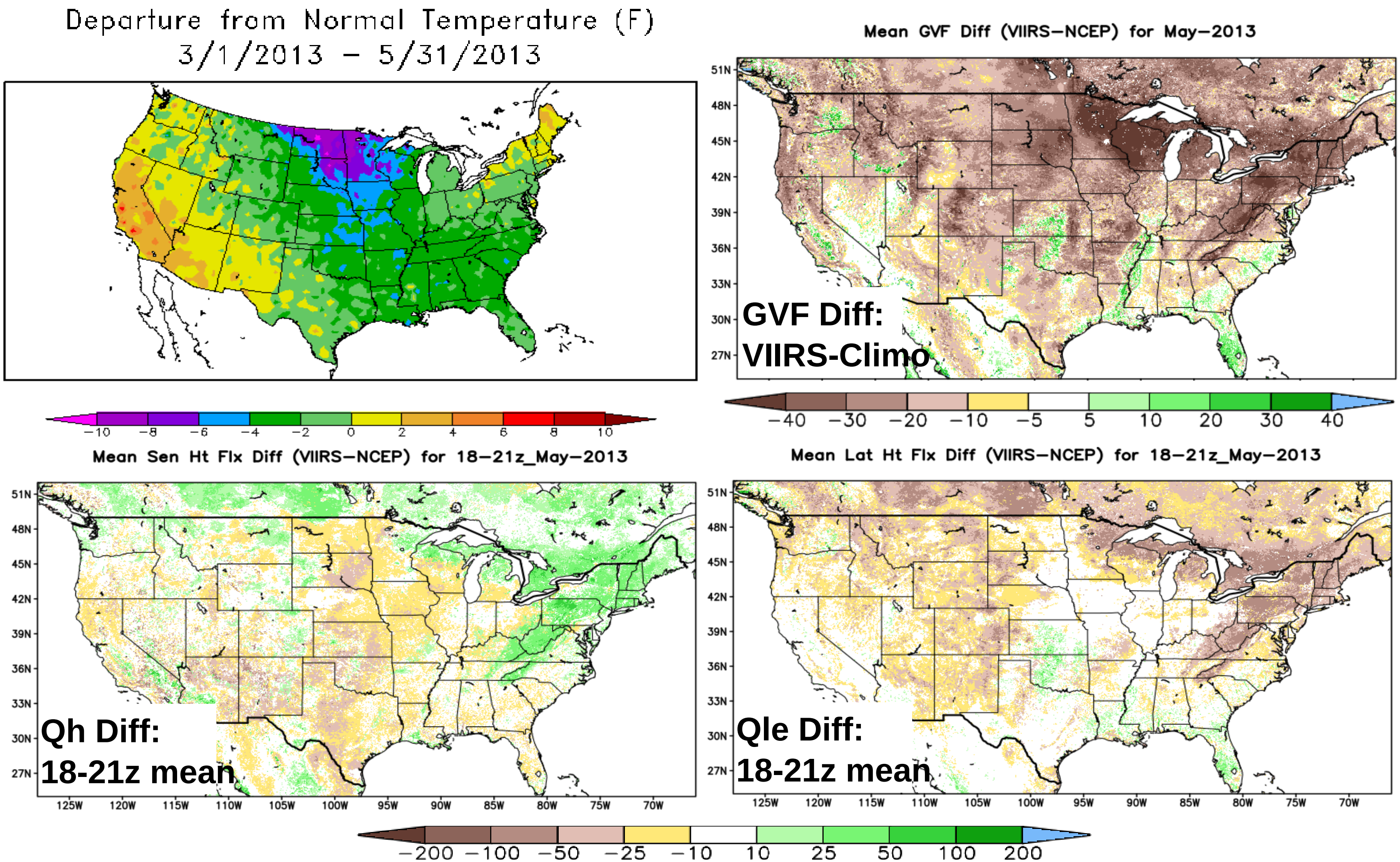
Appendix B

VIIRS GVF User Feedback

Sample impacts and applications

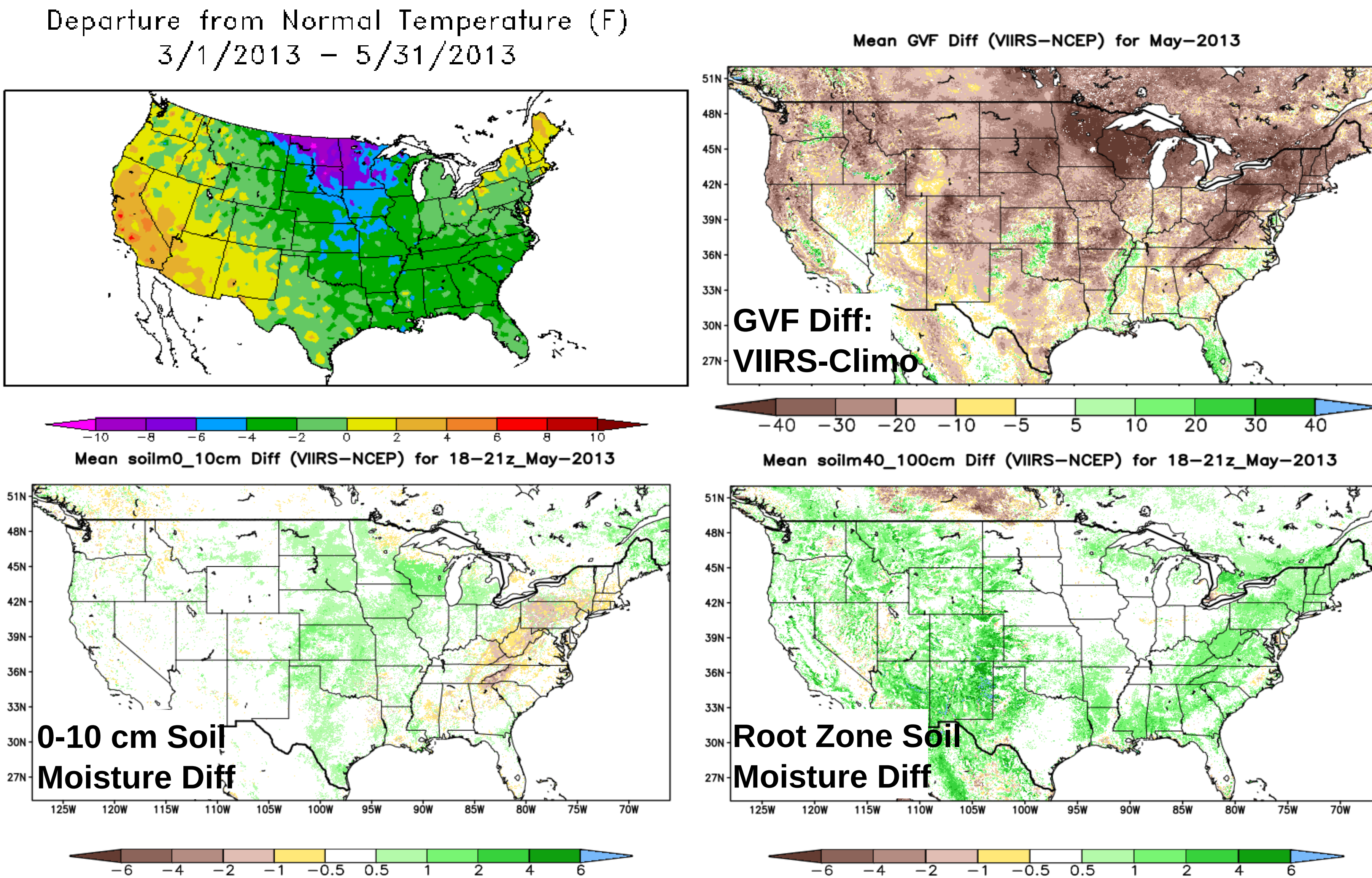
Provided by: Jonathan Case NASA/SPoRT

VIIRS GVF in LIS: Impact on Fluxes (May 2013)



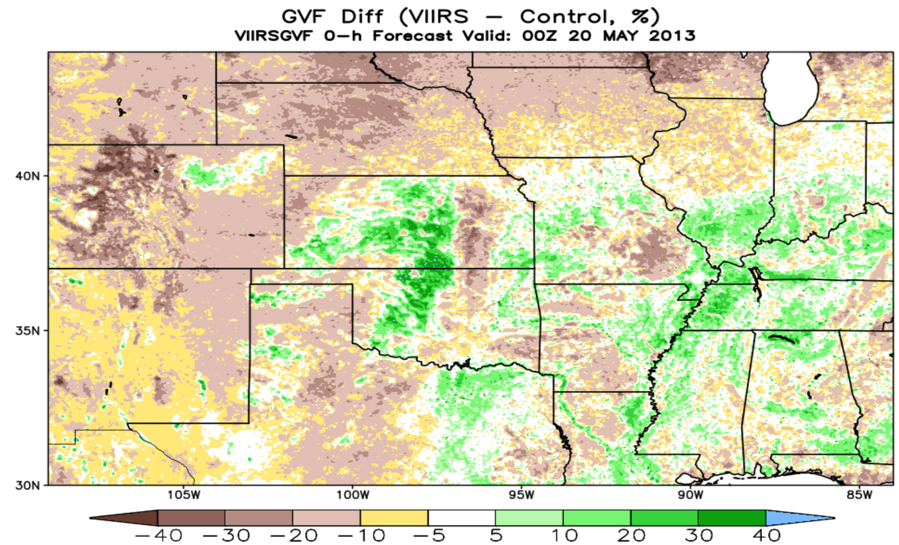
(above) Spring 2013 cold temperatures, delayed green-up, and impact on mean LIS-Noah heat fluxes (W m^{-2}) and soil moisture (%) in May.

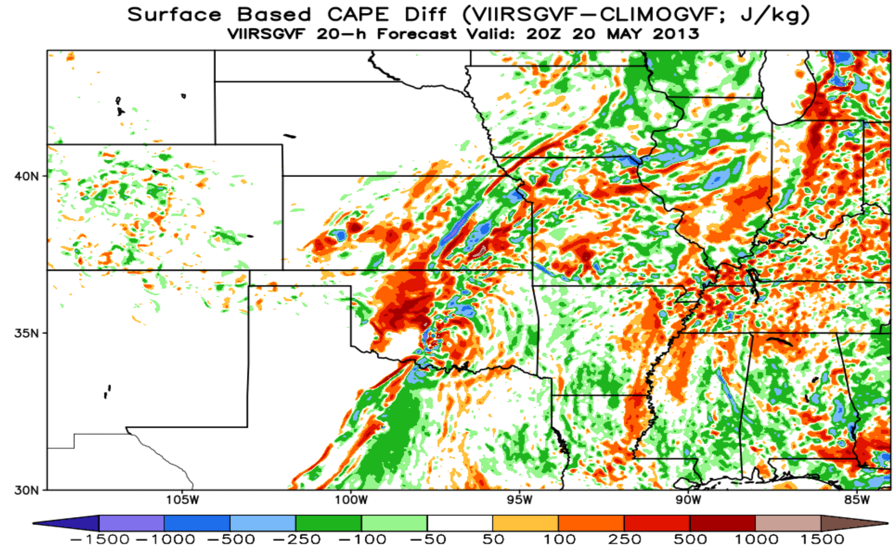
VIIRS GVF in LIS: Impact on Soil Moisture (May 2013)

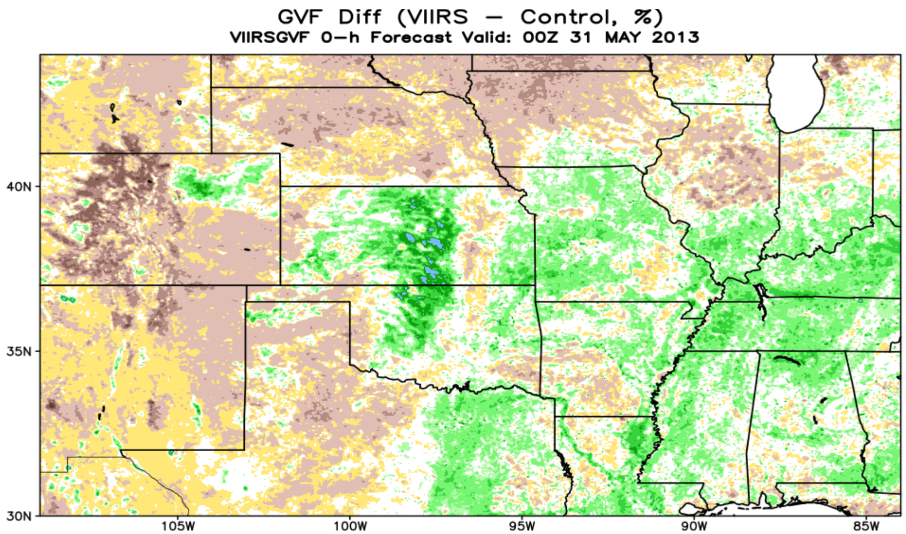


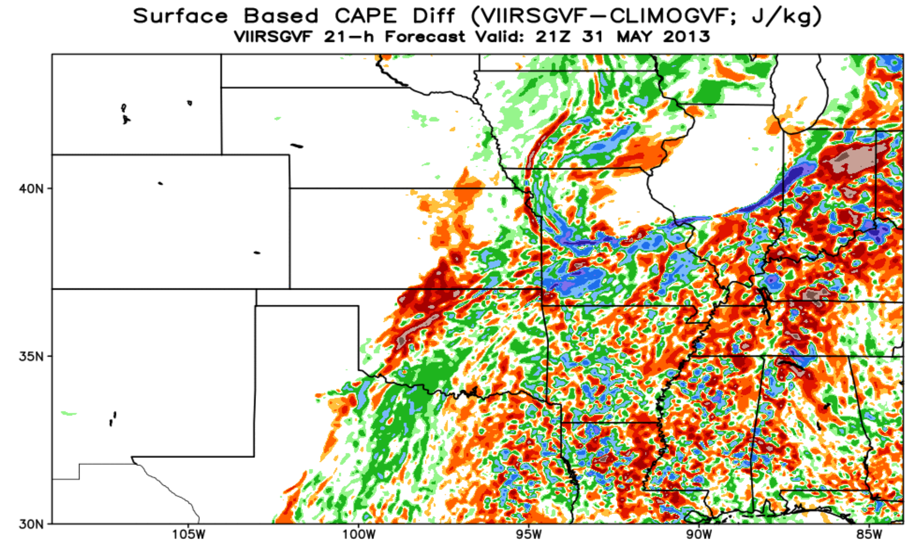
(above) Spring 2013 cold temperatures, delayed green-up, and impact on mean LIS-Noah heat fluxes (W m^{-2}) and soil moisture (%) in May.

VIIRS GVF in WRF Model: Impact on Convective Env.





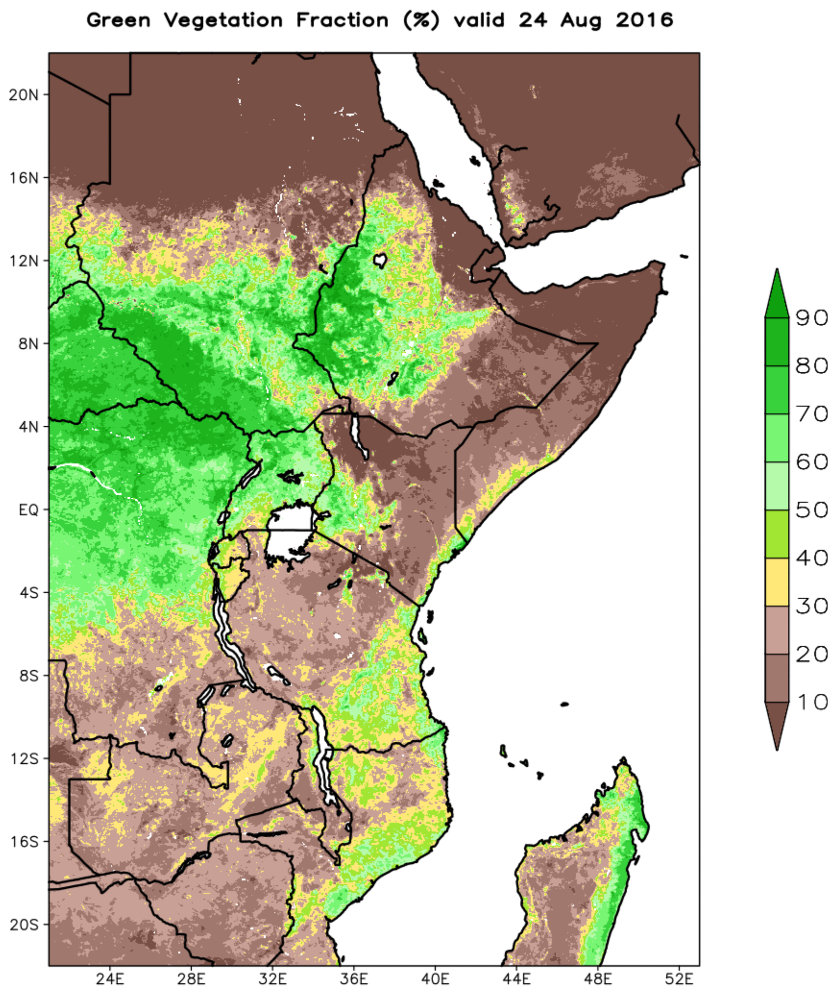


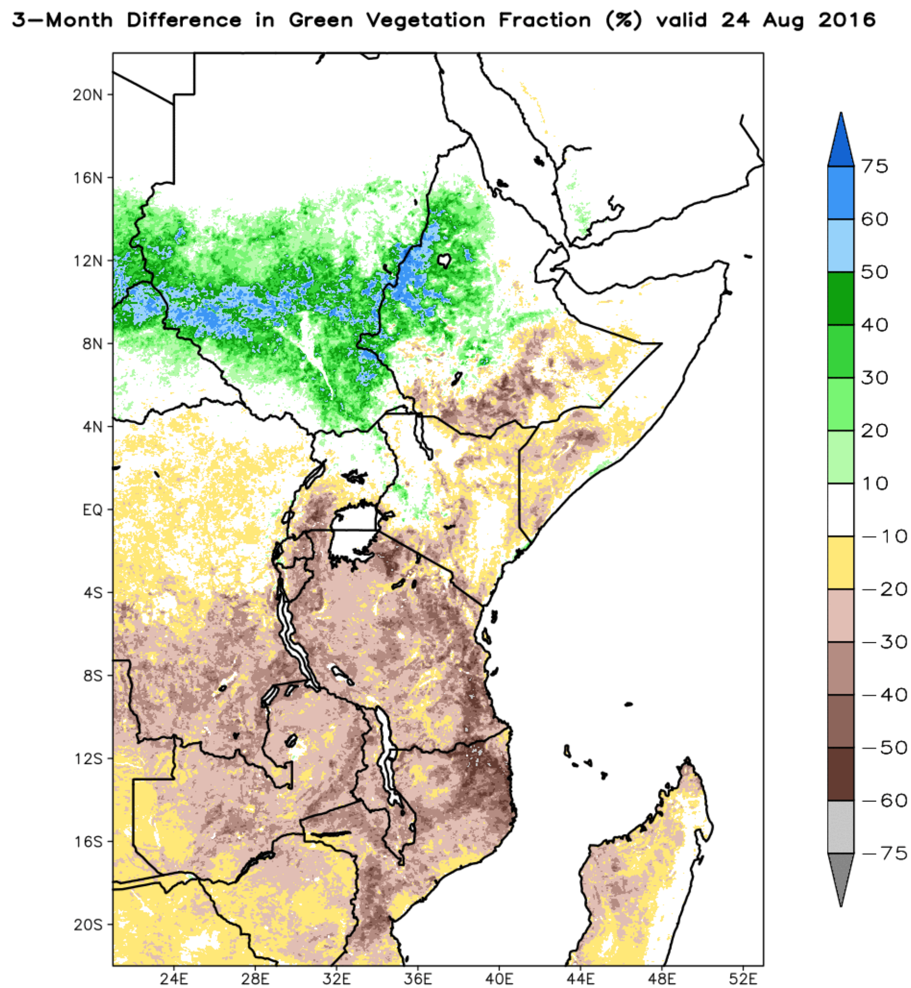


WRF model response associated with GVF diffs:

- Moore EF-5 tornado day (20 May 2013) and "Chaser-killer" tornado (31 May 2013)
- Higher GVF & CAPE, northern & western OK; Lower GVF & CAPE, central TX to southern OK
- Little difference in forecast precip (not shown)

VIIRS GVF for East Africa Model Runs





<u>VIIRS GVF temporal changes</u>:

- VIIRS GVF being used in LIS and WRF model applications for East Africa end users.
- VIIRS GVF composite on model grid (left) and 3-month change (right) depicts northward progression of Inter Tropical Convergence Zone and subsequent green-up to north and brown-down to south

Appendix C

VIIRS GVF User Feedback

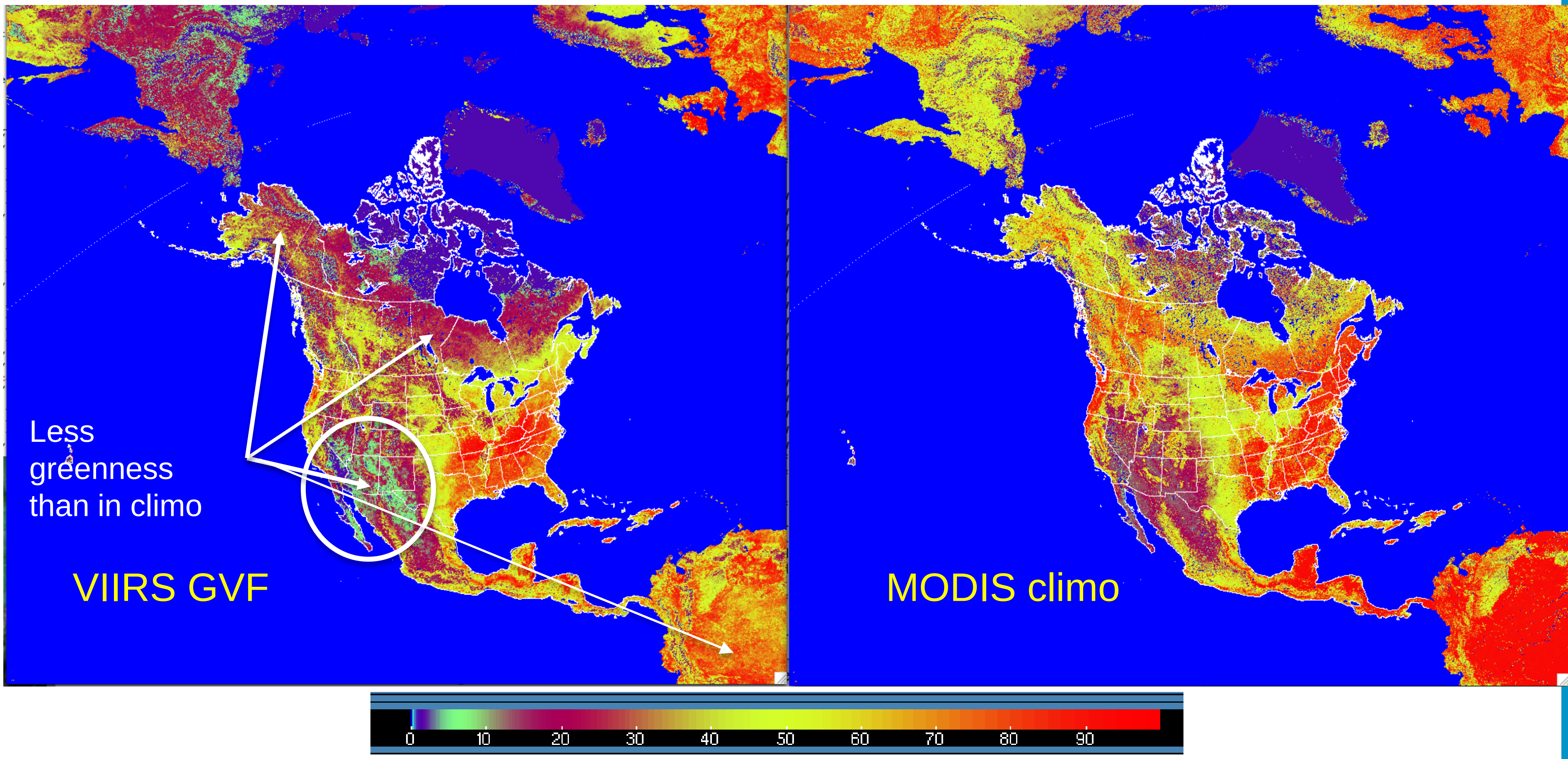
Sample impacts and applications

Provided by: Tanya Smirnova NOAA/ESRL

VIIRS GVF in Rapid Refresh (RAP)

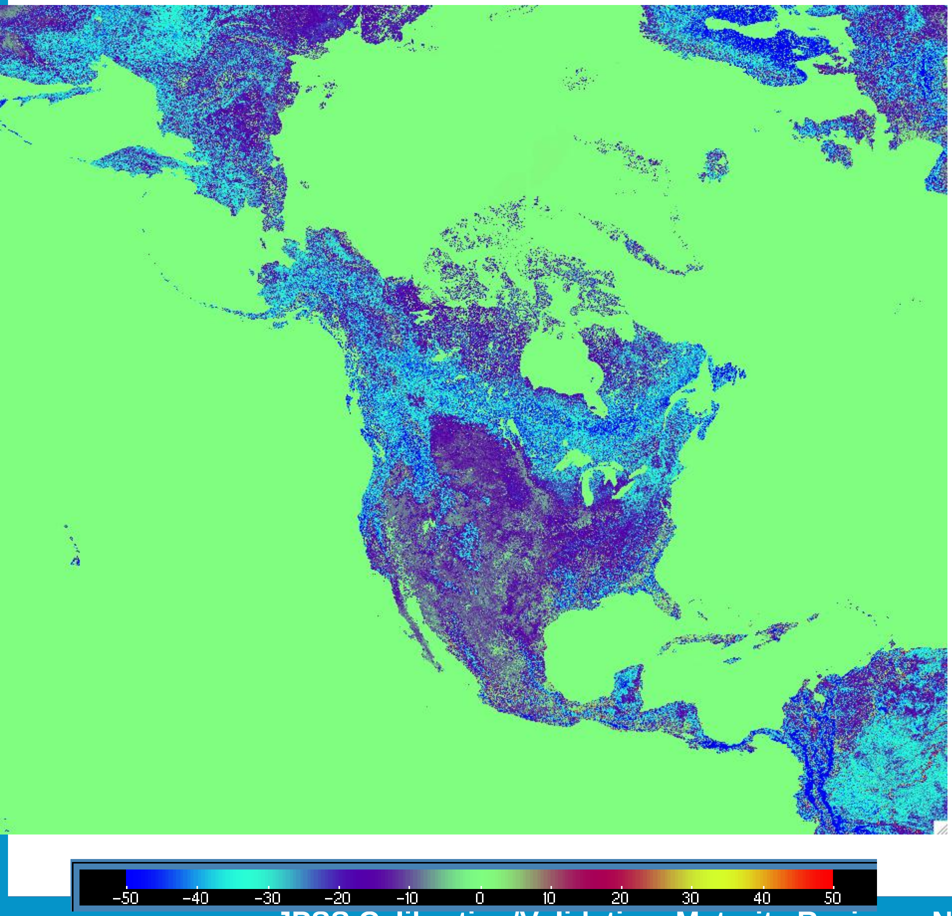
- NESDIS VIIRS global GVF at 4-km resolution is transferred daily to ESRL via NASA SPoRT ftp site.
- NASA SPoRT VIIRS GVF's data format is converted for ingest into WRF (Jonathan Case)
- Initial testing in cold-start RAP initialized from the GFS model
  - Daily replacing climatological MODIS greenness in geo_em.d01.nc produced by WRF Pre-processing System (WPS) with the real-time VIIRS GVF;
  - Annual climatological min/max greenness values are also replaced with the VIIRS GVF data.
- Future plans: implement in the cycled RAP and HRRR

VIIRS GVF versus MODIS veg. fraction climate
Valid at 0z June 20, 2016

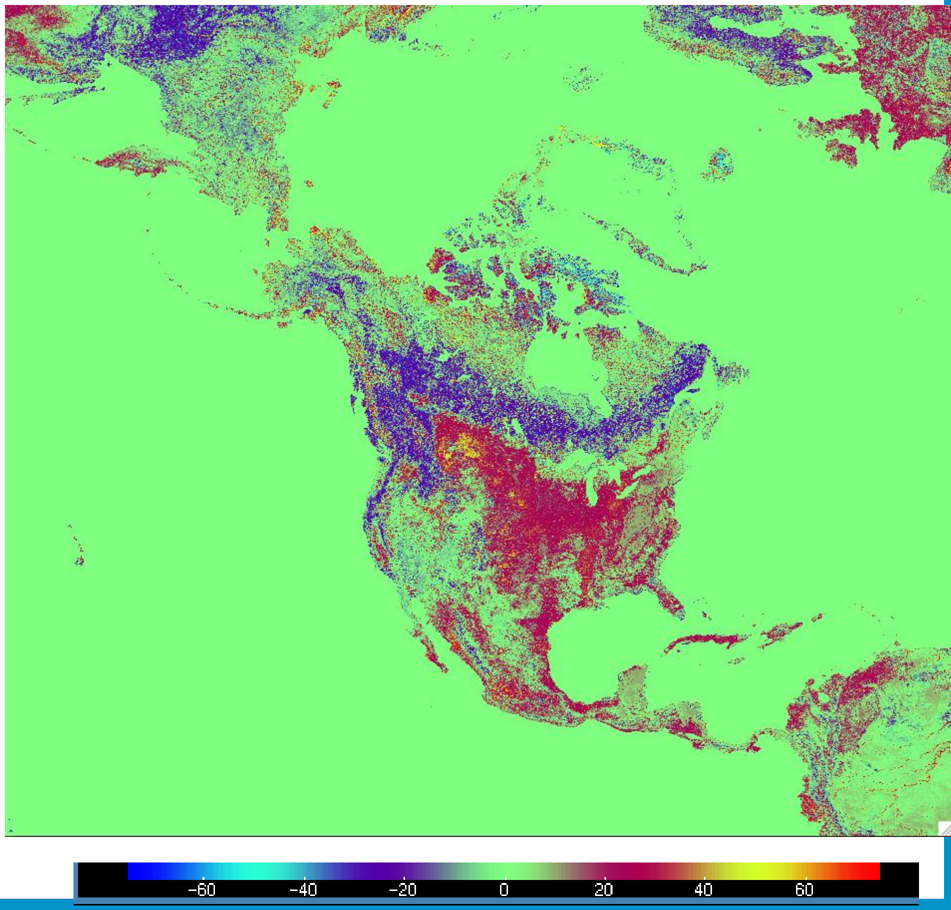


VIIRS SHDMIN and SHDMAX computed from the previous 10 months prior the current day – greater annual dynamic range than with MODIS

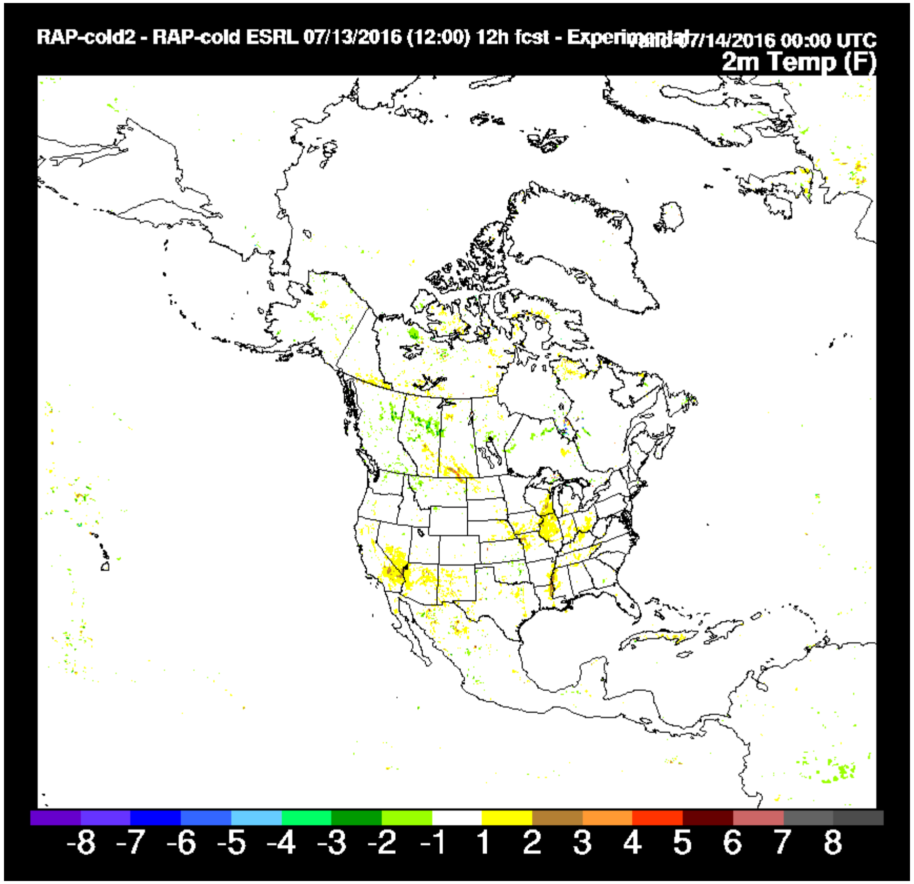
VIIRS GVF SHDMIN
minus MODIS climo

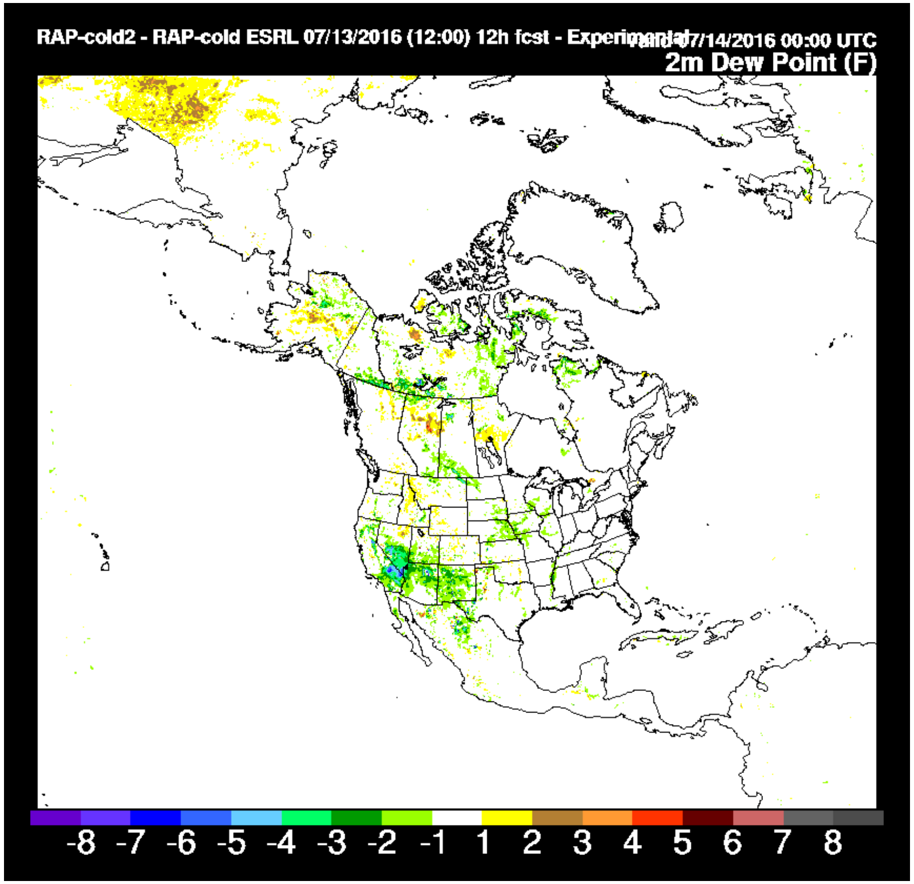


VIIRS GVF SHDMAX
minus MODIS climo

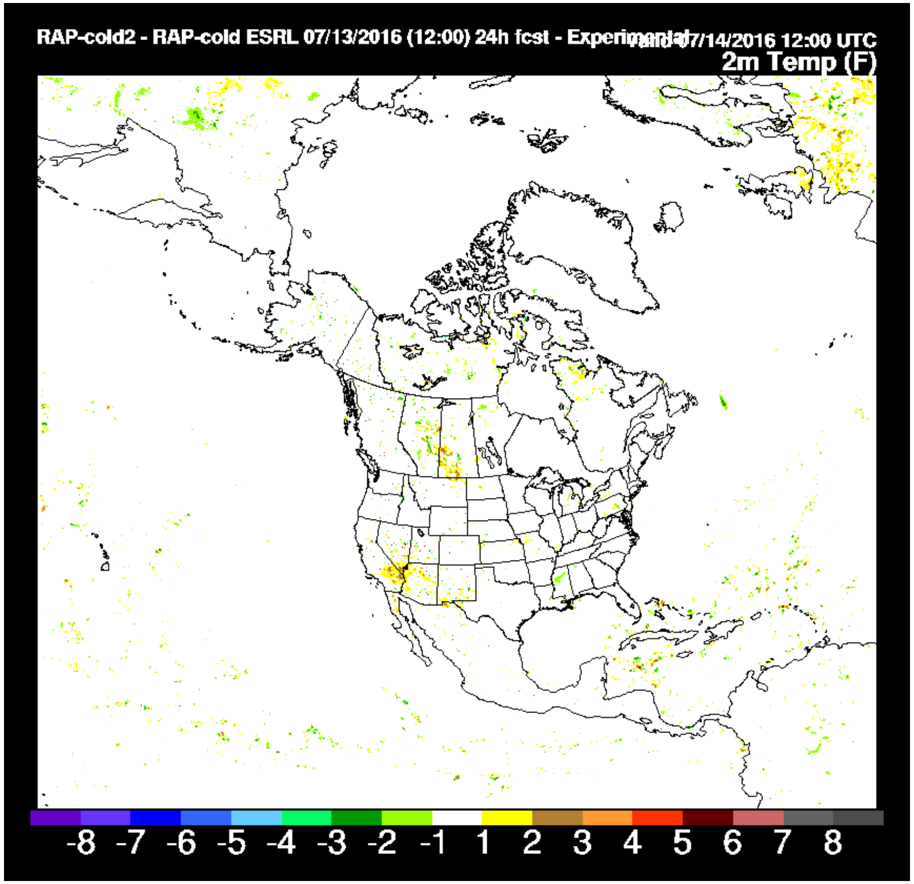


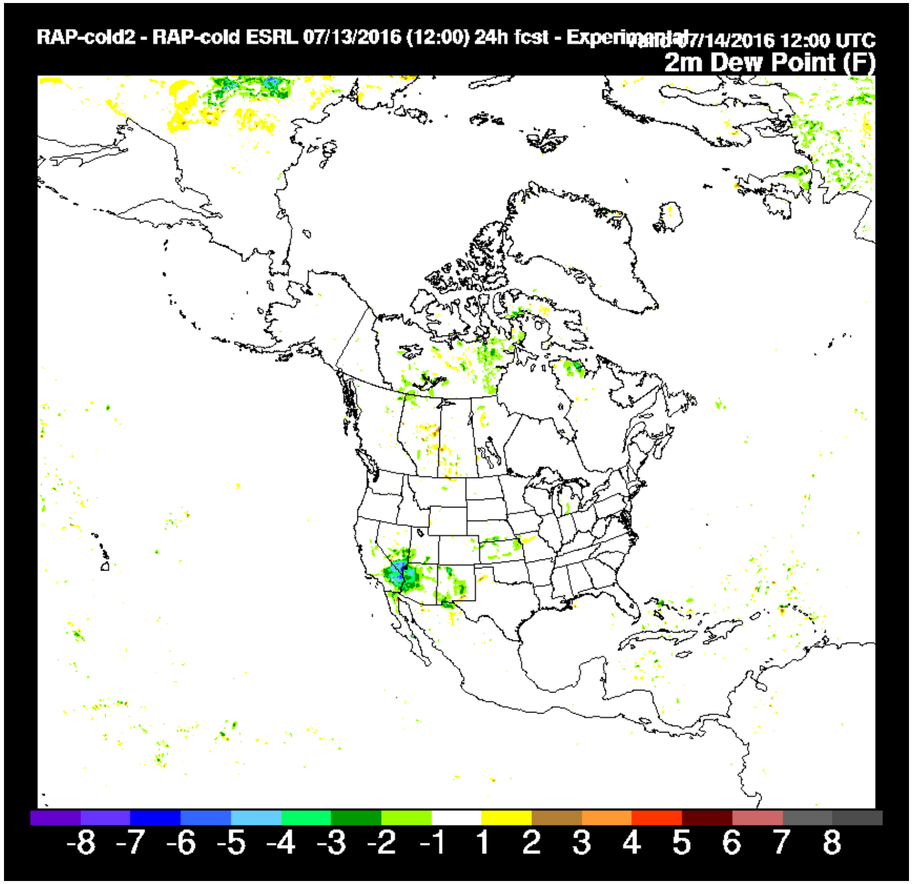
2-m temperature and dew point differences: VIIRS GVF minus MODIS climatology Valid at 00 UTC 14 July 2016





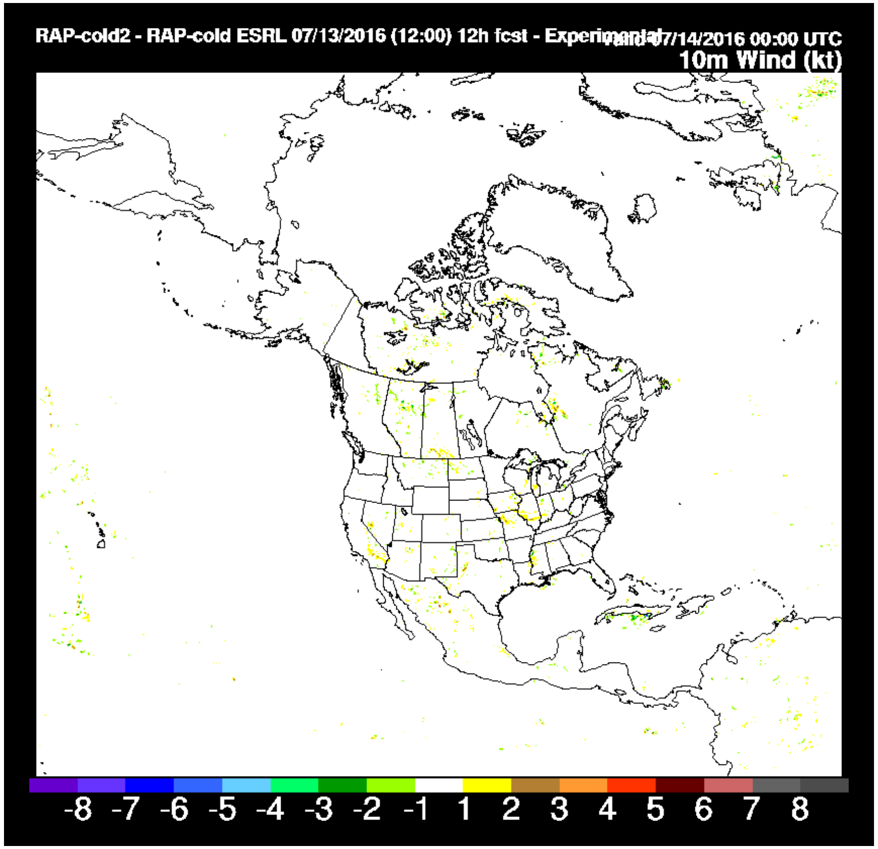
2-m temperature and dew point differences: VIIRS GVF minus MODIS climatology Valid at 12 UTC 14 July 2016



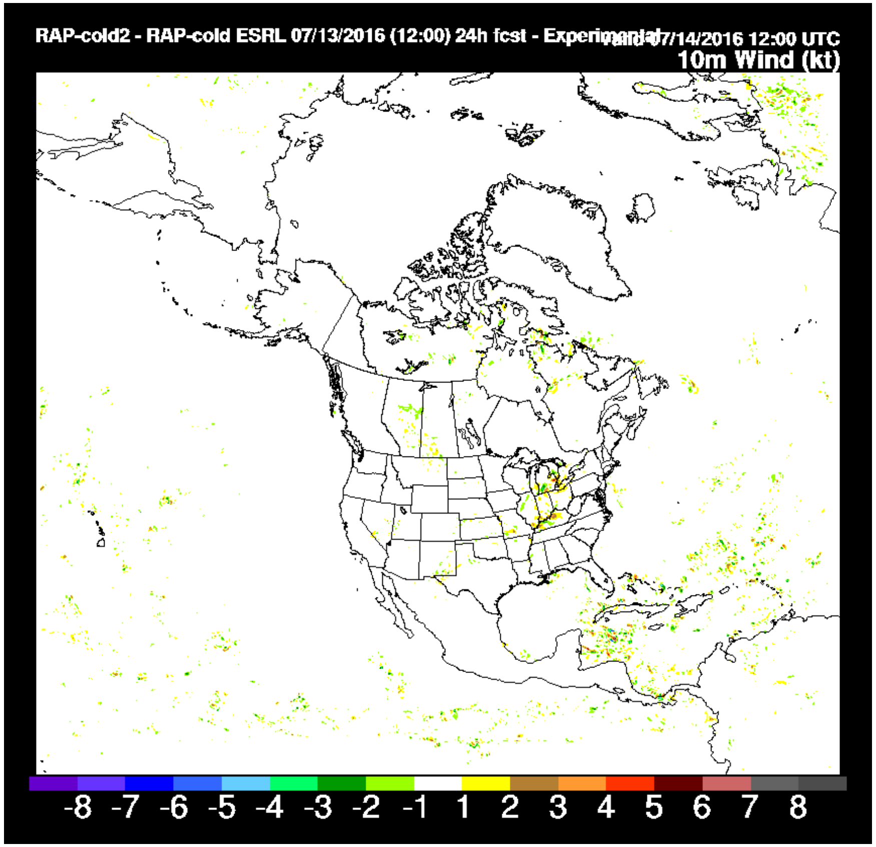


10-m wind speed difference:
VIIRS GVF minus MODIS climatology

Valid at 00 UTC 14 July 2016



Valid at 12 UTC 14 July 2016



Conclusions:

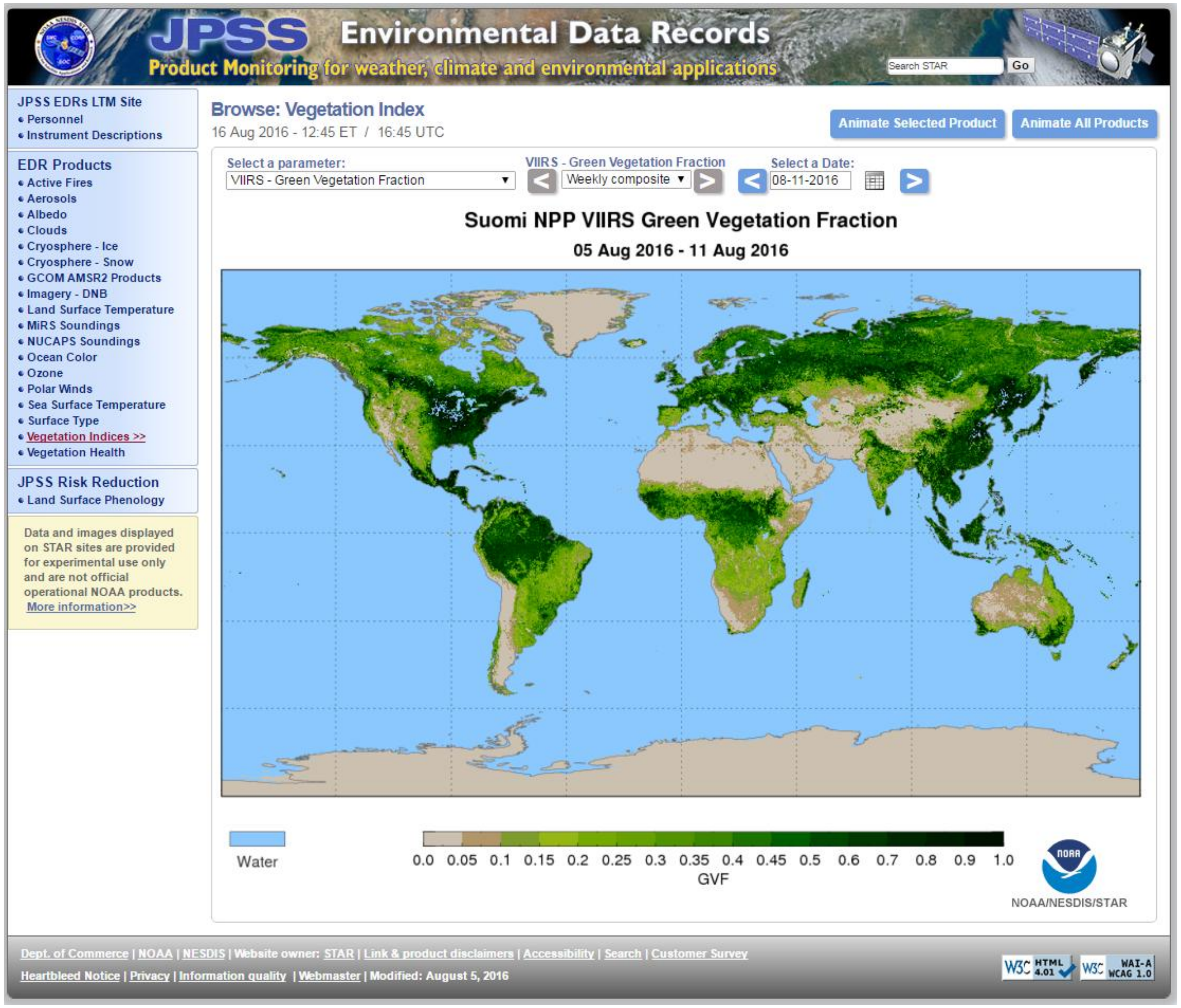
- Real-time VIIRS GVF reflects dryness in the SW of US, close to climatology in the Eastern US, significantly smaller greenness in Arctic and Alaska;
- The min/max VIIRS GVF has a greater seasonal/annual range;
- Roughness length (computed using real-time GVF and min/max range of GVF) is reduced in cropland/grassland areas, 10-m winds are slightly stronger;
- Smaller greenness leads to higher daytime 2-m T and lower 2-m dew point with dry soils, and the opposite with saturated soils: lower 2-m T and higher 2-m dew point.

Appendix D

VIIRS GVF Visualization Tools

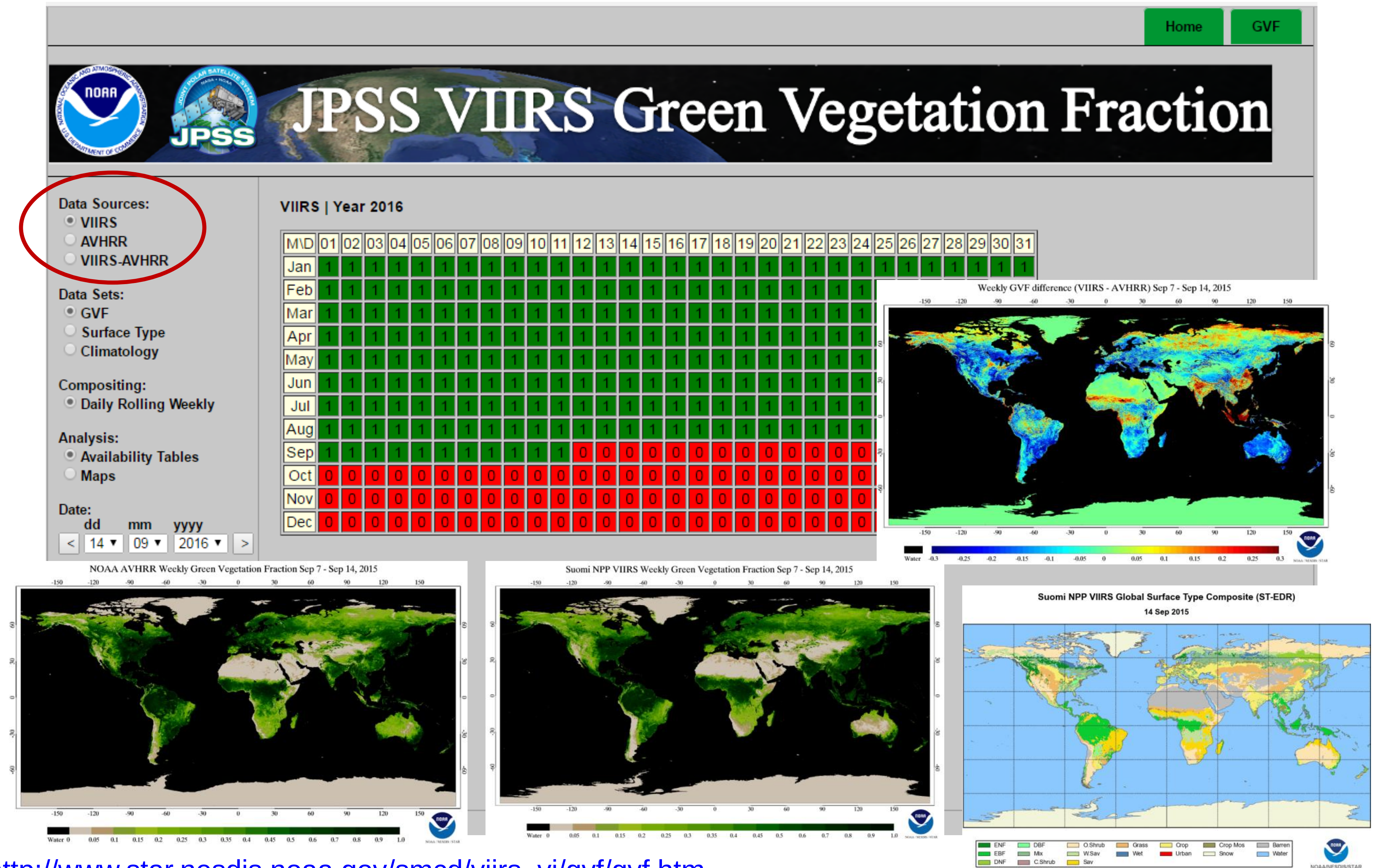
GVF Long Term Monitoring (LTM)

STAR/JPSS LTM Website



http://www.star.nesdis.noaa.gov/jpss/EDRs/products_VegIndex.php

STAR/JPSS VIIRS GVF Visualization Tool



http://www.star.nesdis.noaa.gov/smcd/viirs_vi/gvf/gvf.htm

Appendix E

NOAA Operational GVF Products

Intercomparison VIIRS GVF vs. AVHRR GVF

GVF Algorithm Comparison (AVHRR vs. VIIRS)

AVHRR GVF Algorithm

- Gutman and Ignatov (1998) developed the heritage GVF algorithm
- The GVF algorithm uses the AVHRR I1, I2 TOA reflectances as input
- AVHRR GVF is derived form NDVI
- Projection: Lat/Lon
- Temporal Resolution : weekly
- Spatial Resolution: 16 km
- Output file format: binary

The Normalized Difference Vegetation Index (TOA - NDVI)

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

The AVHRR Green Vegetation Fraction

$$GVF = \frac{NDVI - NDVI_0}{NDVI_\infty - NDVI_0}$$

SNPP VIIRS GVF Algorithm

- The VIIRS GVF algorithm is a modified version of the Gutman and Ignatov's (1998) GVF algorithm
- The VIIRS GVF algorithm uses the VIIRS I1, I2 and M3 TOC reflectances as input
- VIIRS GVF is derived form TOC EVI
- Projection: Lat/Lon
- Temporal Resolution : weekly (updated daily)
- Spatial Resolution: 4 km
- Output file format: NetCDF4

The Enhanced Vegetation Index (TOC - EVI)

$$EVI = G\frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + C_1 \cdot \rho_{red} - C_2 \cdot \rho_{blue} + 1}$$

The VIIRS Green Vegetation Fraction

$$GVF = \frac{EVI - EVI_0}{EVI_\infty - EVI_0}$$

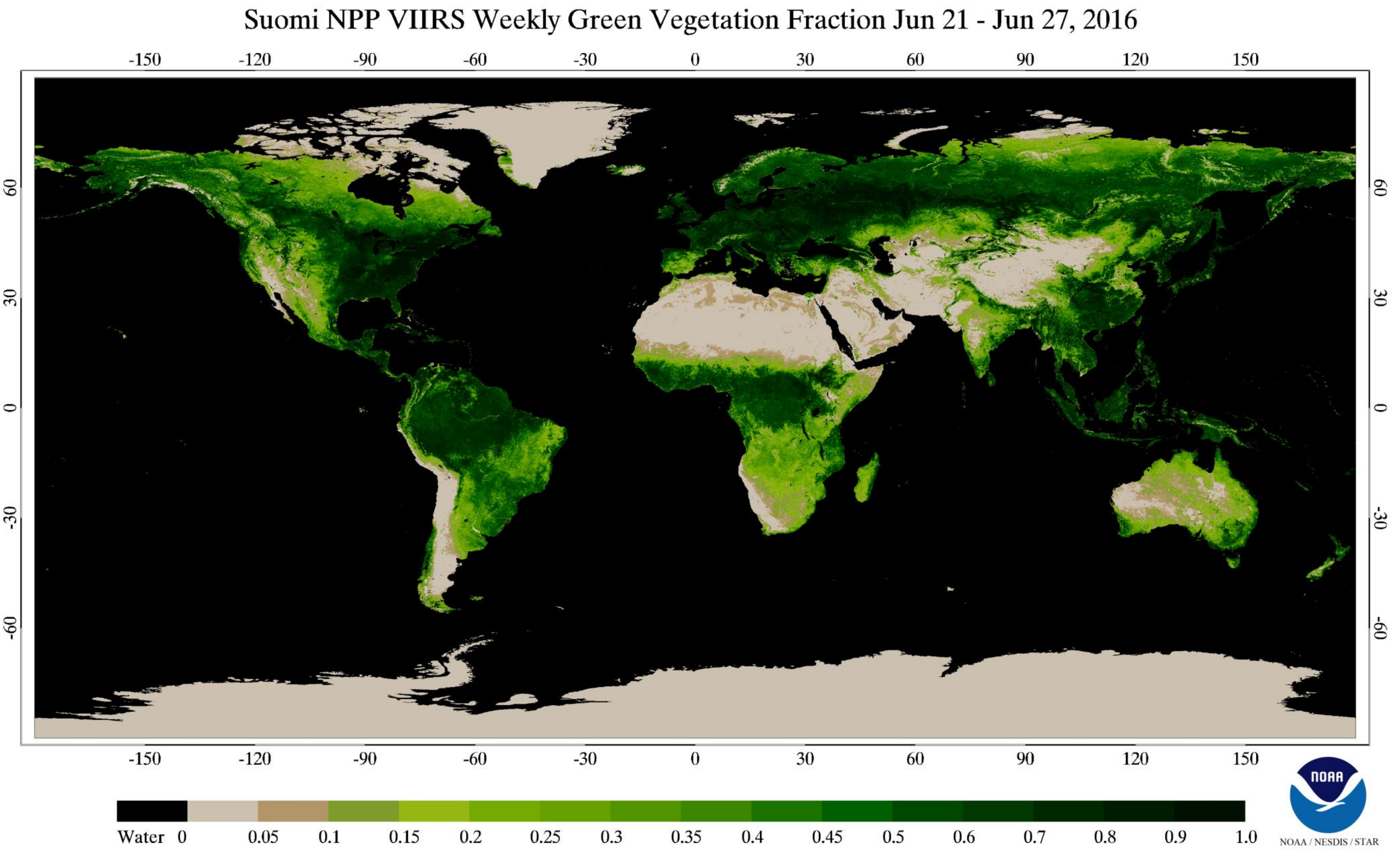
Challenges (1/2)

- There are significant differences between the two existing NOAA GVF operational products
- GVF products from different sensors (VIIRS and AVHRR)
  - VIIRS more advanced than AVHRR
- Different input data to the GVF Algorithms
  - AVHRR GVF is derived from NDVI and TOA reflectances
  - VIIRS GVF is derived from EVI and TOC reflectances
- Different smoothing techniques used by VIIRS and AVHRR GVF
- We found that the VIIRS GVF smoothing algorithm was introducing a shift in the annual cycle
- An improved smoothing algorithm has been implemented in the VIIRS GVF system run at the STAR Development Environment

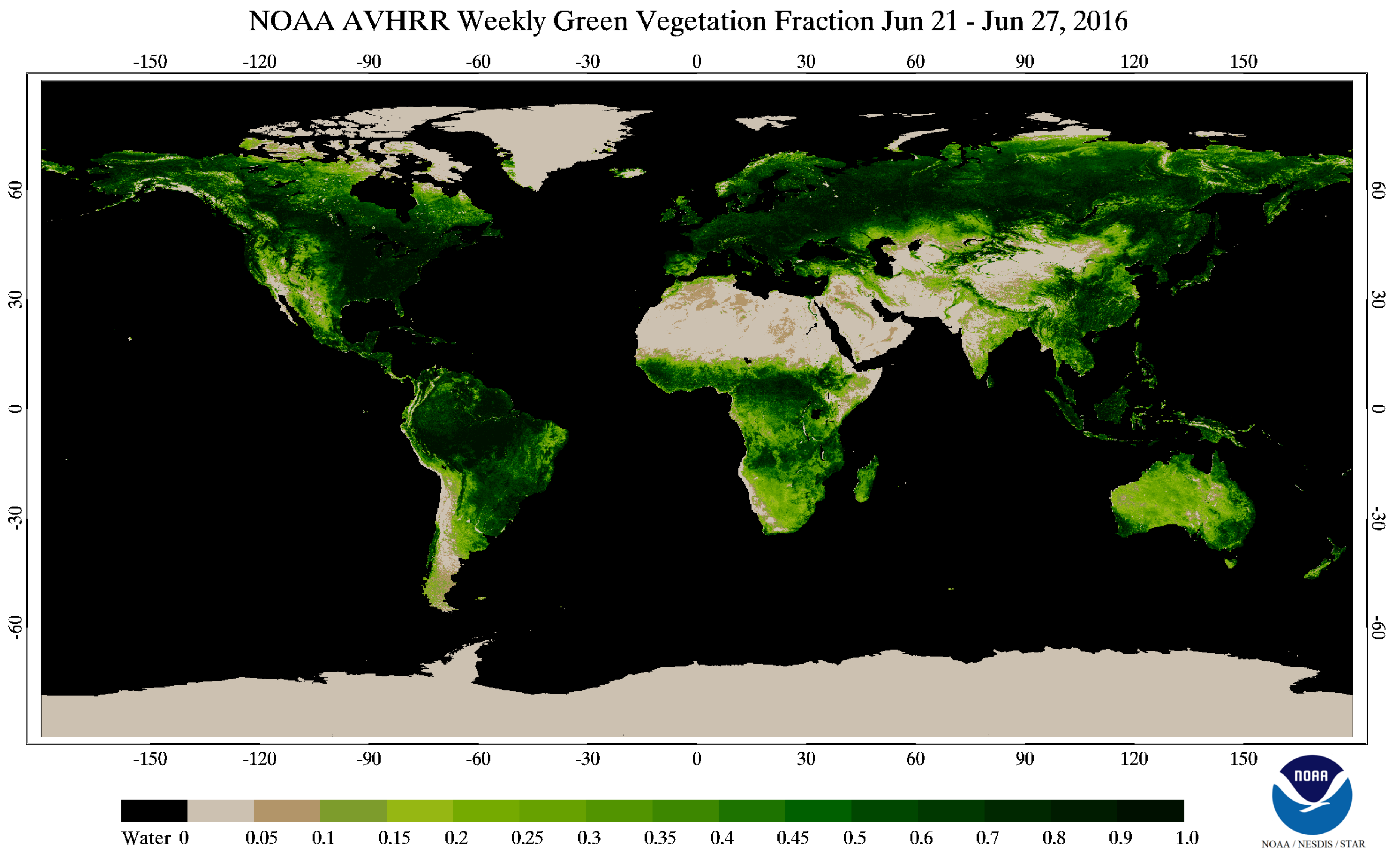
Challenges (2/2)

- Different GVF spatial resolution (4-km VIIRS vs. 16-km AVHRR)
- AVHRR GVF operational product has data gaps
- AVHRR GVF not produced above 60 deg latitude north in winter
- AVHRR GVF operational product is not NRT (two month delay)

VIIRS GVF 4-km resolution (summer)

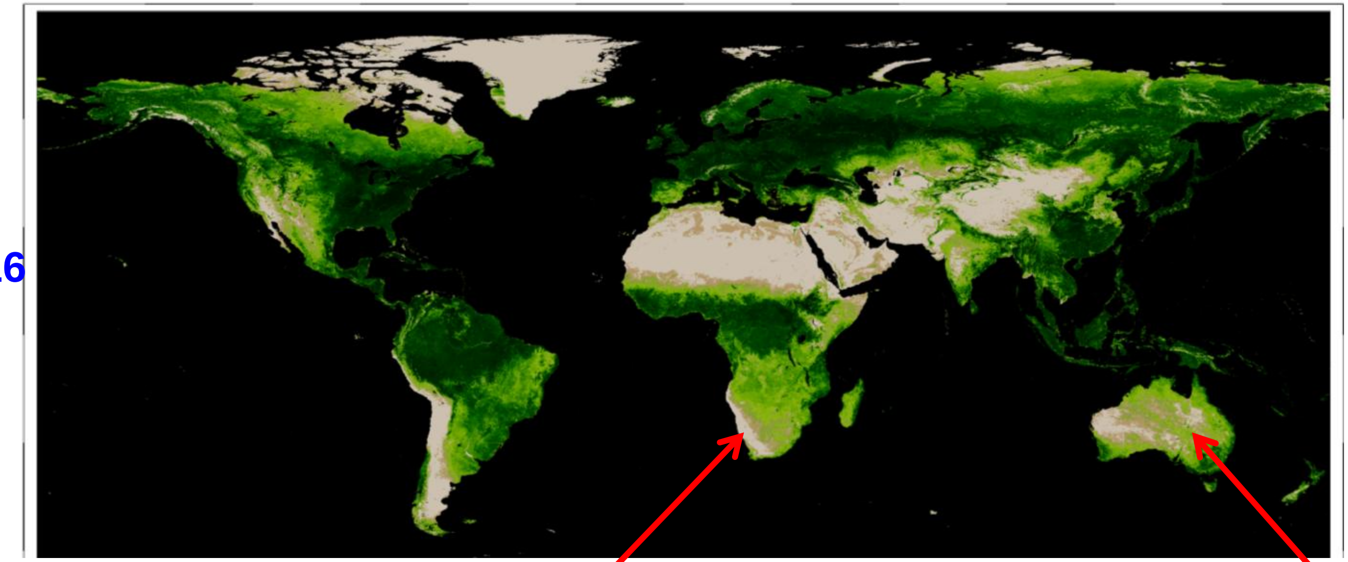


AVHRR GVF 16-km resolution (summer)

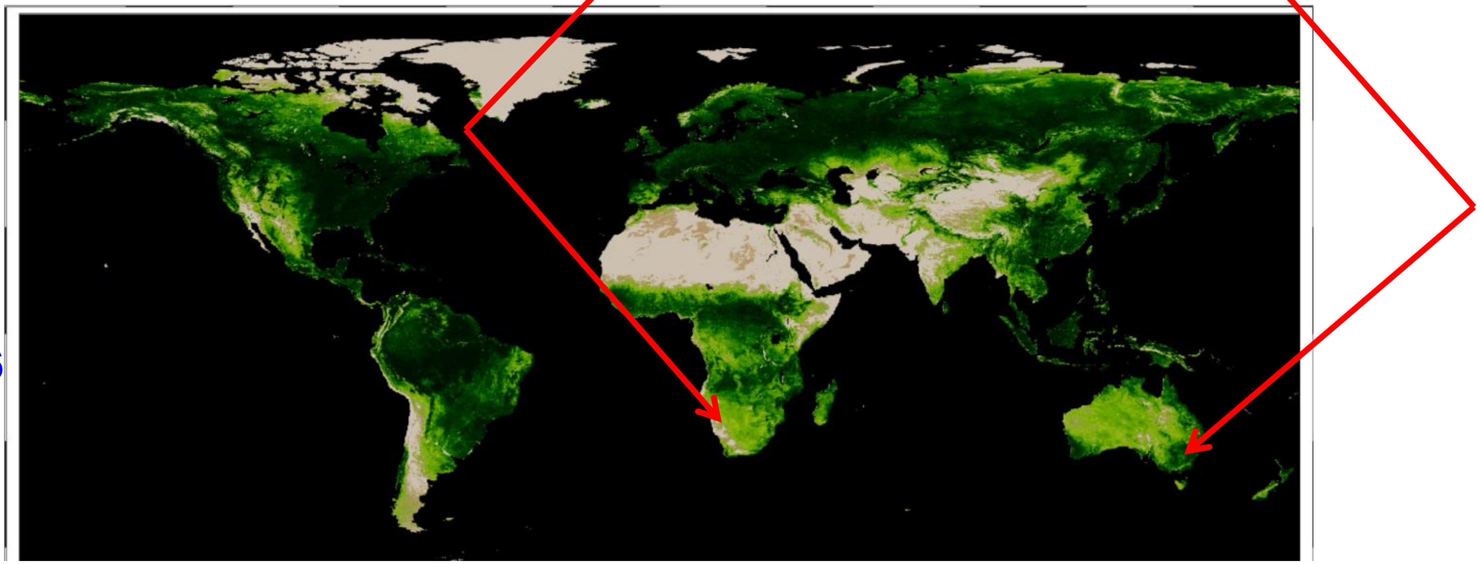


GVF Comparison - VIIRS vs. AVHRR

VIIRS GVF
4-km res.
June 21-27, 2016

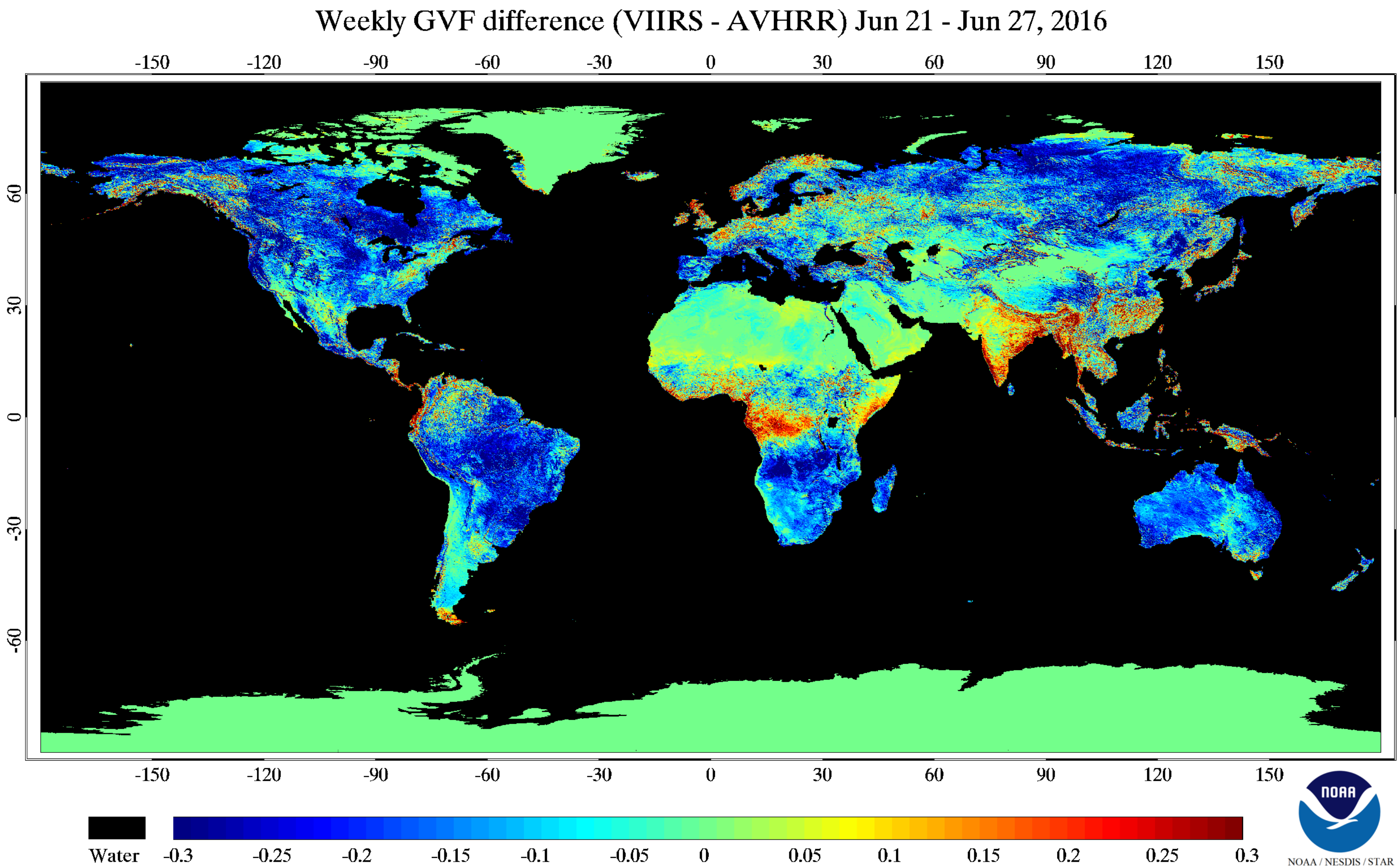


AVHRR GVF
16-km res.
June 21-27, 2016

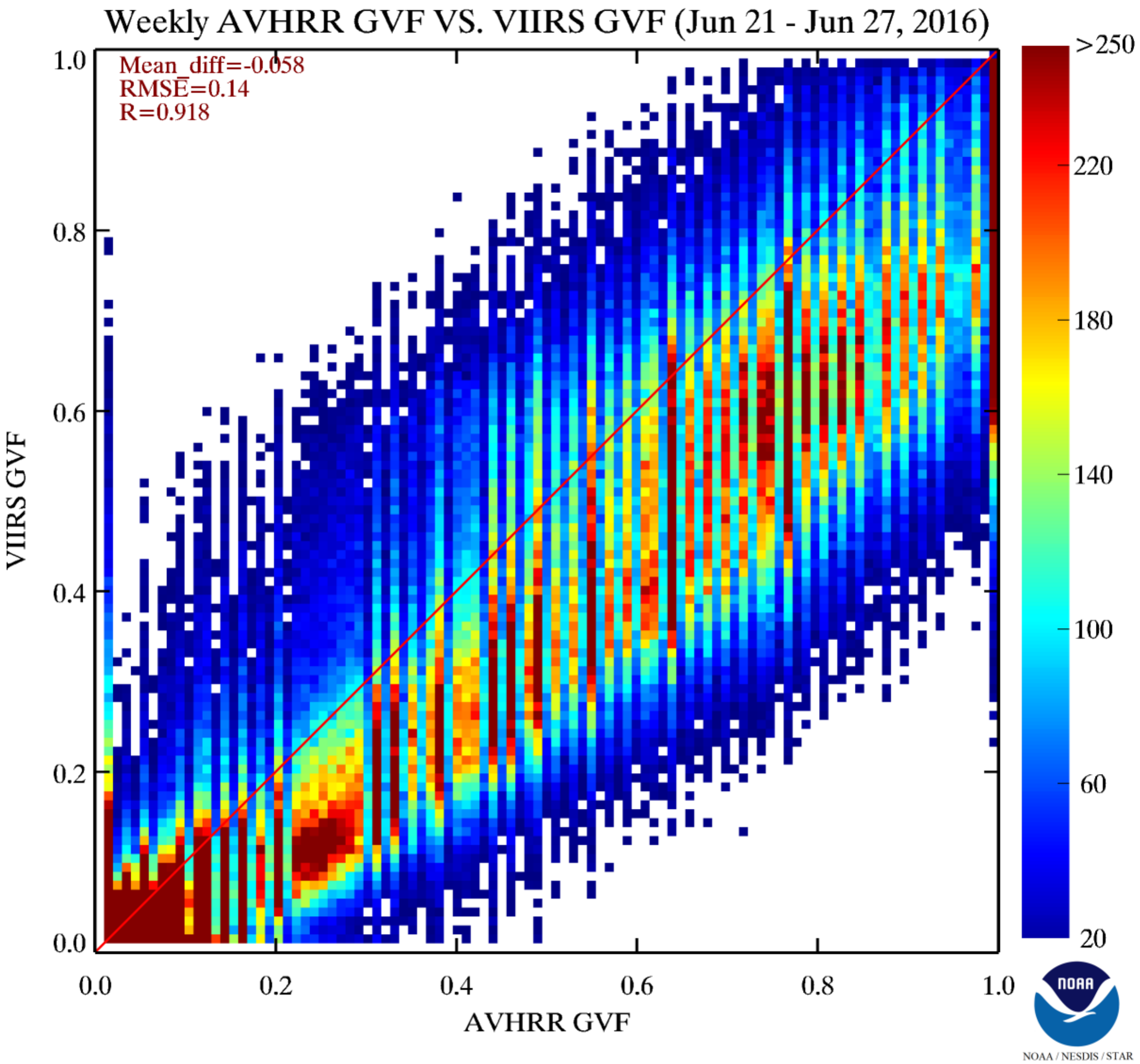


- Similar GVF pattern but different in south Africa and central Australia
- VIIRS GVF is more reasonable over deserts in south Africa and central Australia

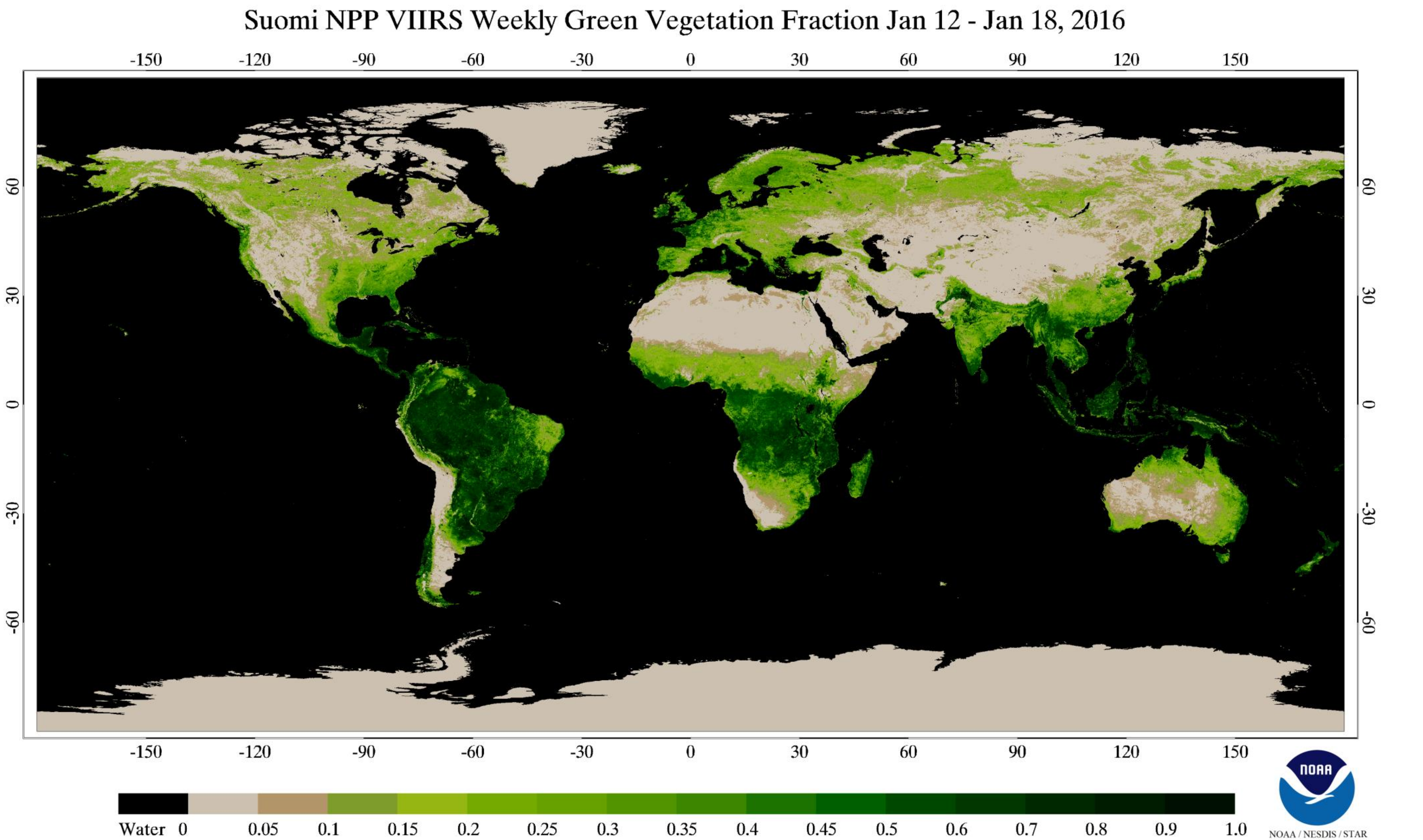
GVF Difference VIIRS minus AVHRR



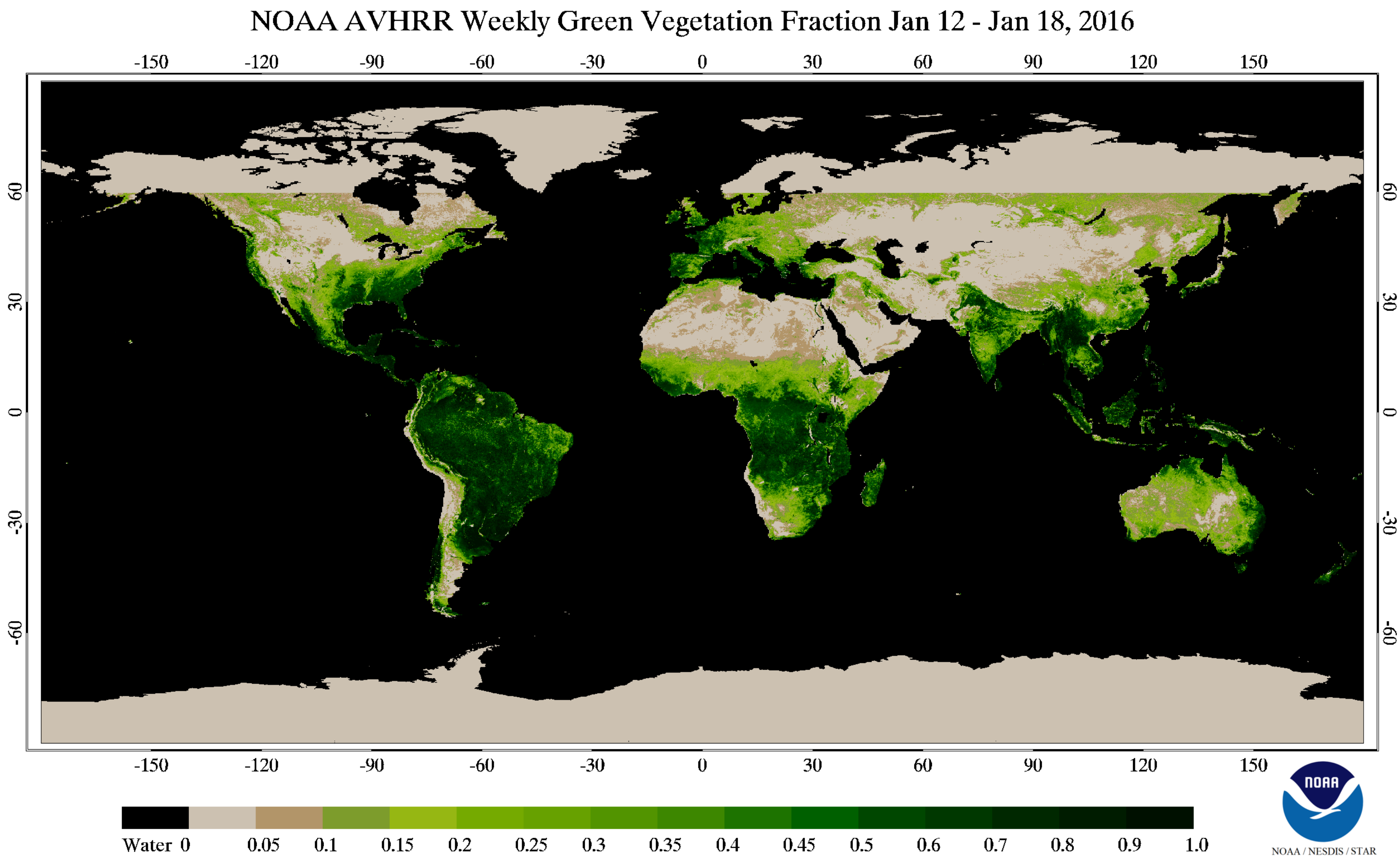
VIIRS GVF vs. AVHRR GVF



VIIRS GVF 4-km resolution (winter)



AVHRR GVF 16-km resolution (winter)

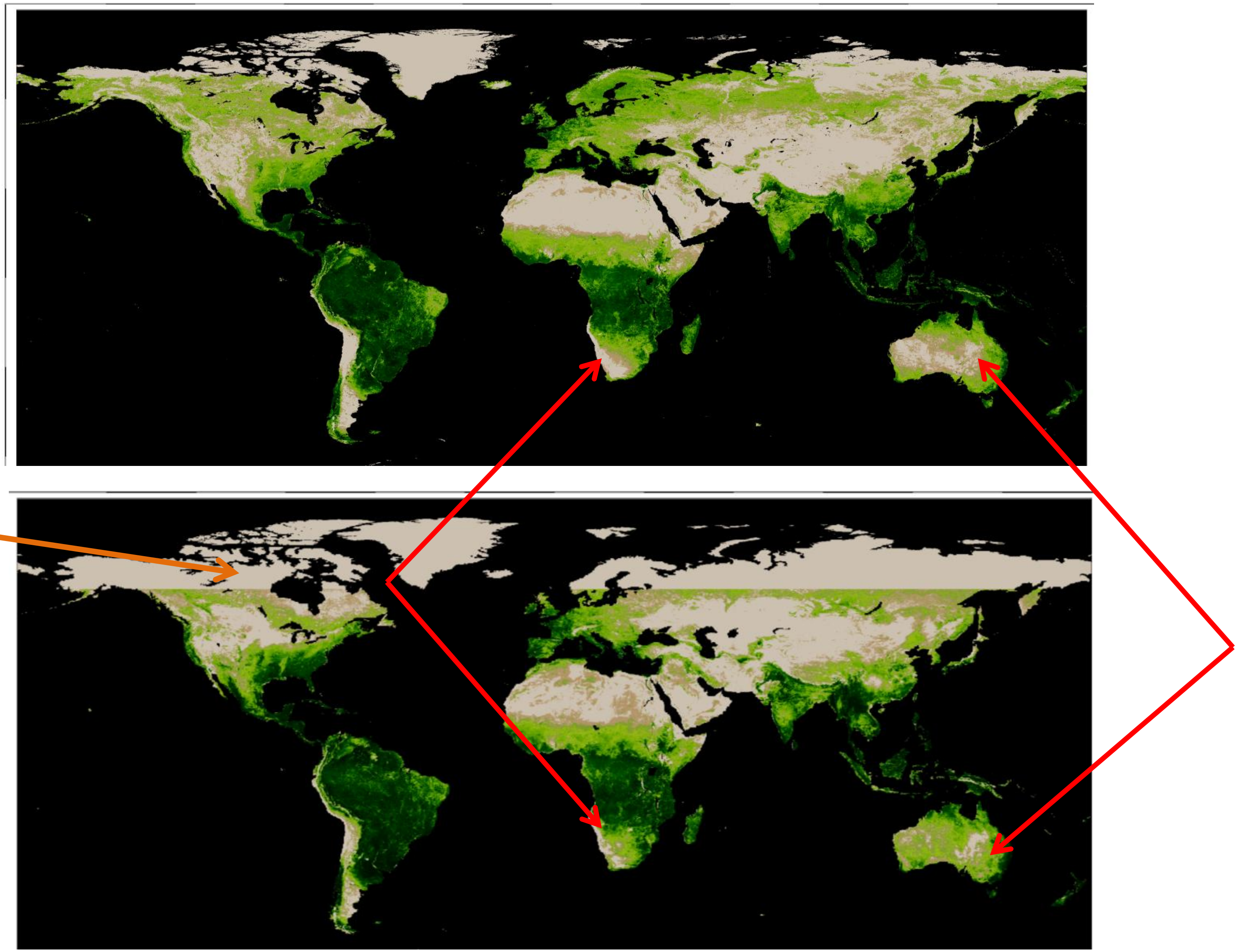


GVF Comparison - VIIRS vs. AVHRR

VIIRS GVF
4-km res.
Jan 12-18, 2016
(winter)

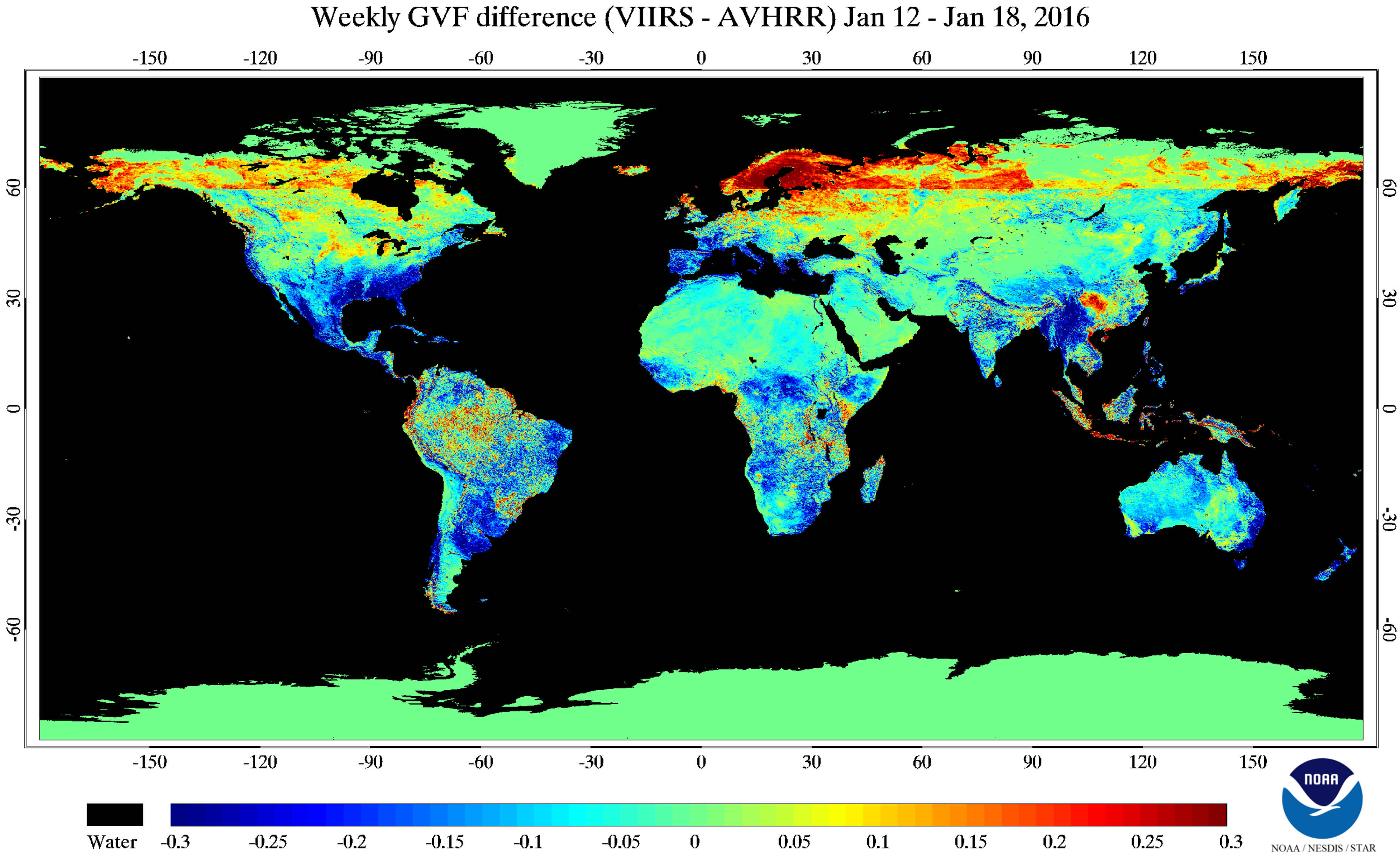
No AVHRR GVF data at high Latitudes in winter

AVHRR GVF
16-km res.
Jan 12-18, 2016
(winter)

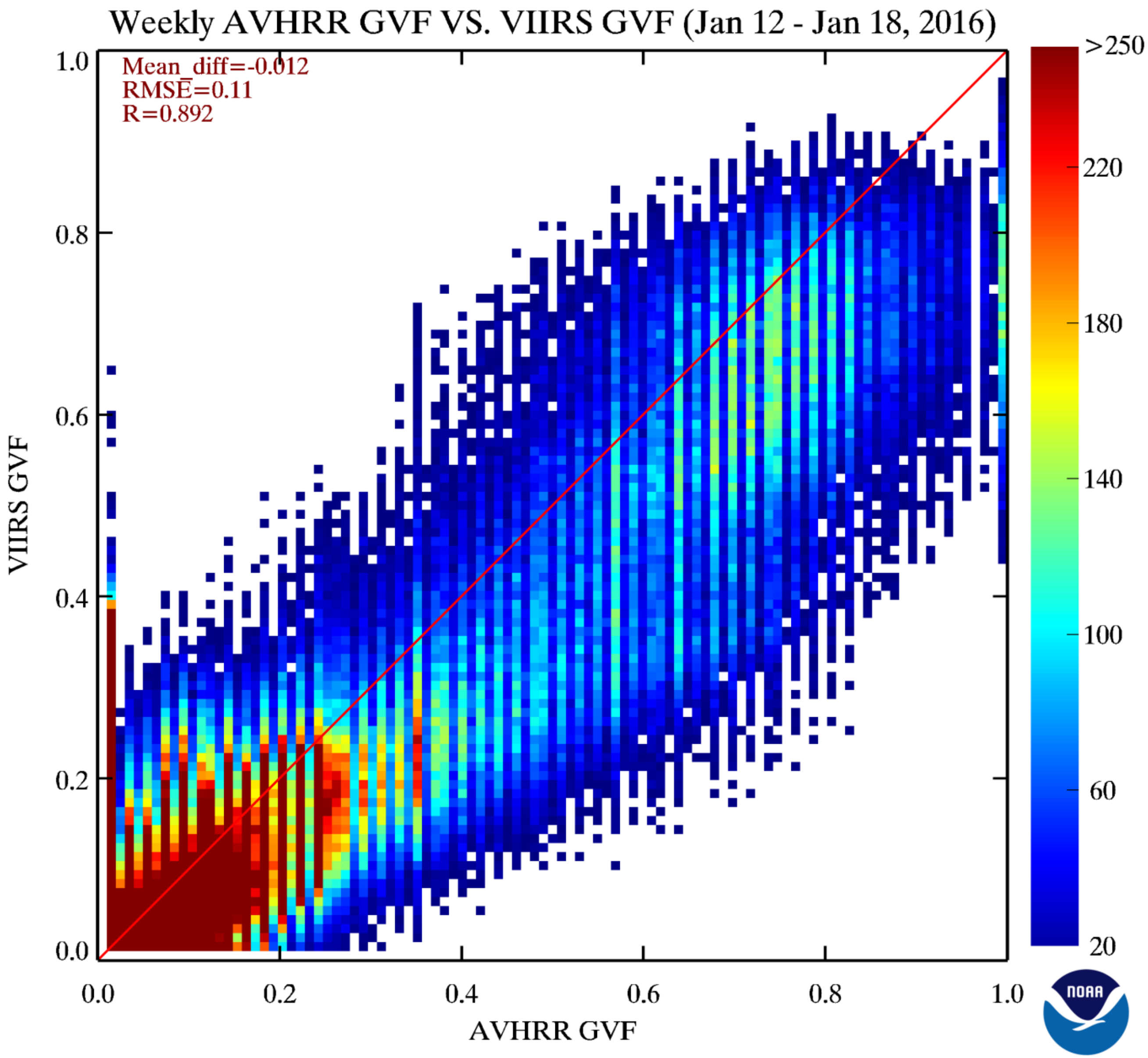


- Similar GVF pattern but different in south Africa and central Australia
- VIIRS GVF is more reasonable over deserts in south Africa and central Australia

GVF Difference VIIRS minus AVHRR



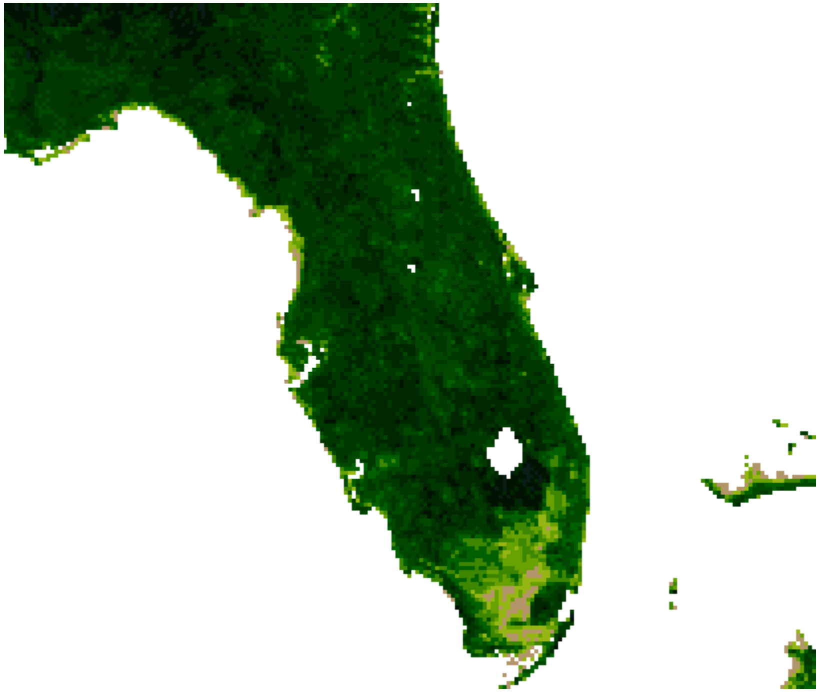
VIIRS GVF vs. AVHRR GVF



NOAA / NESDIS / STAR

Spatial Resolution Comparison
VIIRS vs. AVHRR GVF

16-km AVHRR GVF
9/3/2012



4-km VIIRS GVF
9/3/2012

- **VIIRS GVF has higher spatial resolution than AVHRR GVF**

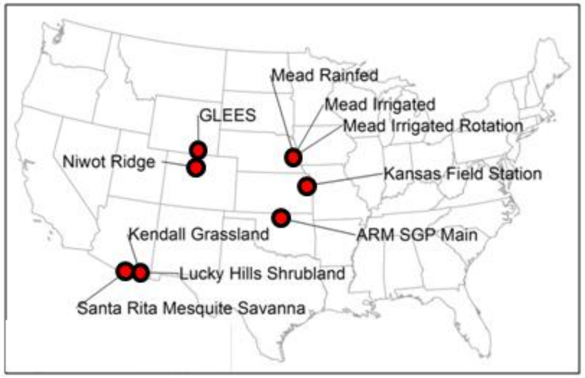
Additional Slides

Validation Sites Used in the Google Earth analysis

No.	Site name	State/Province, County	Biome	Latitude (degrees)	Longitude (degrees)
1	ARM/CRT SGP	OK, USA	Grassland/cereal crop	36.64	-97.5
2	BARC, USDA ARS	MD, USA	Broadleaf cropland	39.03	-76.85
4	Barton Bendish, East Anglia	UK	Broadleaf cropland	52.618	0.524
5	Bondville	IL, USA	Broadleaf cropland	40	-88.29
8	Changbai shan	China	Mountain forest	42.4025	128.0958
9	Park falls	WI, USA	Needleleaf forest	45.946	-90.272
11	Harvard forest	MA, USA	Broadleaf forest	42.5393	-72.1779
12	Cascades/H.A.Handrews	OR, USA	Moist needleleaf forest	44.24	-122.18
13	Howland	ME, USA	Needleleaf forest	45.2	-68.73
16	Konza	KS, USA	Grassland/cereal crop	39.08	-96.56
15	Jornada	NM, USA	Shrubland/Woodland	32.6	-106.86
20	Maricopa agriculture center	AZ, USA	Broadleaf Cropland	33.07	-111.97
21	Mead	NE, USA	Broadleaf Cropland	41.16505	-96.469
22	Metolius/cascades -old pine	OR, USA	Dry Needleleaf Forest	44.49	-121.62
32	Wisc: NRL LTER	WI, USA	Needleleaf Forest	46	-89.6
Phe6	Alligator river	NC, USA		35.7879	-75.9038
Phe8	Arbutuslake	NY, USA		43.98207	-74.2332
Phe14	Arizona grass	AZ, USA		31.5907	-110.509
Phe24	Baldmountain1	CA, USA		36.01833	-118.25
Phe38	bbc7	NH, USA		44.0646	-71.2881
Phe48	bullshoals	MO, USA		36.56283	-93.0666
phe57	Cedarcreek	MN, USA		45.4019	-93.2042
phe65	coweeta	NC, USA		35.05959	-83.428
phe68	cperuvb	CO, USA		40.52214	-104.776
phe84	fernow	WV, USA		39.0542	-79.6875
phe153	Kendall	AZ, USA		31.73652	-109.942
phe299	Tonzi	CA, USA		38.43092	-120.966
phe319	usgseros	SD, USA		43.7343	-96.6234
phe337	woodstockvt	VT, USA		43.61315	-72.5445
phe309	ufona	FL, USA		27.38348	-81.9509

AmeriFlux Study Sites

Site Name	Site Code	MAT (°C) / MAP (mm)	IGBP Land Cover	Reference
Mead Irrigated, NE	US-Ne1	10.07 / 790	Cropland	Suyker et al. (2004)
Mead Irrigated Rotation, NE	US-Ne2	10.08 / 789	Cropland	Suyker et al. (2005)
Mead Rainfed, NE	US-Ne3	10.11 / 784	Cropland	Suyker et al. (2004)
ARM SGP Main, OK	US-ARM	14.76 / 843	Cropland	Fischer et al. (2007)
Kansas Field Station, KS	US-KFS	12.00 / 1014	Grassland	Brunsell et al. (2008)
Kendall Grassland, AZ	US-Wkg	15.46 / 407	Grassland	Scott et al. (2010)
Santa Rita Mesquite, AZ	US-SRM	17.92 / 482	Woody Savanna	Scott et al. (2009)
Lucky Hills Shrubland, AZ	US-Whs	17.13 / 355	Open Shrubland	Scott et al. (2010)
GLEES, WY	US-GLE	0.80 / 525	Evergreen Needleleaf Forest	Frank et al. (2014)
Niwot Ridge, CO	US-NR1	0.43 / 595	Evergreen Needleleaf Forest	Monson et al. (2002)



Flux Tower GVF Algorithm vs. VIIRS GVF Algorithm

VIIRS GVF derived from EVI

$$GVF = \frac{EVI - EVI_0}{EVI_\infty - EVI_0}$$

$$EVI = G\frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{red}}}{\rho_{\mathrm{NIR}} + C_1 \cdot \rho_{\mathrm{red}} - C_2 \cdot \rho_{\mathrm{blue}} + L}$$

G = 2.5,C1 =6,C2 =7.5, L =1

Tower GVF derived from EVI2

$$GVF = \frac{EVI2 - EVI2_0}{EVI2_\infty - EVI2_0}$$

$$EVI2 = G\frac{\rho_{\mathrm{OIR}} - \rho_{\mathrm{VIS}}}{\rho_{\mathrm{OIR}} + C \cdot \rho_{\mathrm{VIS}} + L}$$

G= 2.5,C=2.4,L=1

$$\rho_{OIR} = \frac{GS_{\mathrm{out}} - PAR_{\mathrm{out}}}{GS_{\mathrm{in}} - PAR_{\mathrm{in}}}$$

$$\rho_{VIS} = \frac{PAR_{out}}{PAR_{in}}$$

GS_{in}, GS_{out} are incoming and outgoing global solar radiation (Wm^{-2})
PAR_{in}, PAR_{out} are incoming and outgoing Photosynthetically Active Radiation

APU Definitions

Note: 2.4.2 and 2.4.3 are imposed because, ideally, a measurement attribute requirement must be met for any true value of the parameter within the parameter range, not in an average sense over the parameter range.

2.4.4 To the extent practical, the collection of sample sets will be well populated and distributed across the EDR measurement range and will be geographically, seasonally, and phenomenologically diverse enough to be environmentally representative of observed conditions across the globe, throughout an annual seasonal cycle, and inclusive of important spatial and temporal variations commonly observed in any particular EDR.

2.5 Measurement Accuracy

Measurement accuracy is defined as the magnitude of the mean measurement error. For a sample set of N measurement errors, the measurement accuracy βN is given by the following formula:

$$\beta_N = |\mu_N|$$

where: μ_N is the mean measurement error, and |…| denotes absolute value. The mean measurement error μ_N is given by the following formula:

$$\mu_N = (\Sigma_{i=1,N}\ \varepsilon_i)/N$$

where: ε_i is the value of the measurement error for the i'th measurement and $\Sigma_{i=1,N}$ denotes summation from i = 1 to i = N.

2.6 Measurement Precision

Measurement precision is defined as the standard deviation (one sigma) of the measurement errors. For a sample set of N measurement errors, the measurement precision σ_N is given by the following formula:

$$\sigma_N = [\Sigma_{i=1,N}(\varepsilon_i - \mu_N)^2/(N - 1)]^{1/2}$$

where ε_i is the value of the measurement error for the i'th measurement, μ_N is the mean measurement error, and $\Sigma_{i=1,N}$ denotes summation from i = 1 to i = N.

2.7 Measurement Uncertainty

Measurement uncertainty is defined as the root-mean-square (RMS) of the measurement errors. It results from the combined effects of all systematic and random errors. Measurement uncertainty converges to the square root of the sum of the squares (RSS) of the measurement accuracy and precision in the limit of an infinite number of measurements. For a sample set of N measurement errors, the measurement uncertainty ξ_N is given by the following formula:

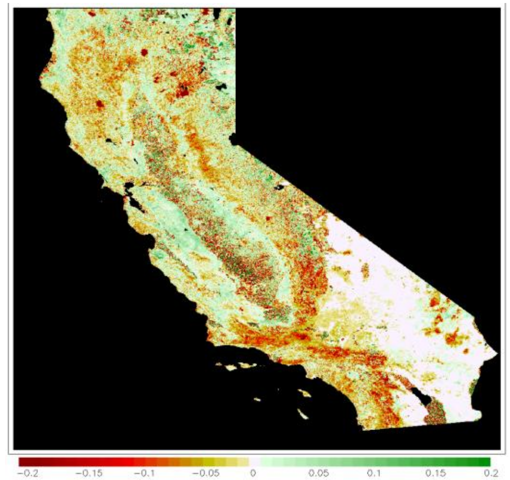
$$\xi_N = [\Sigma_{i=1,N}\,\varepsilon_i^2/N]^{1/2}$$

Source: Level 1 Requirements Supplement – Final Version: 2.10 June 25, 2014

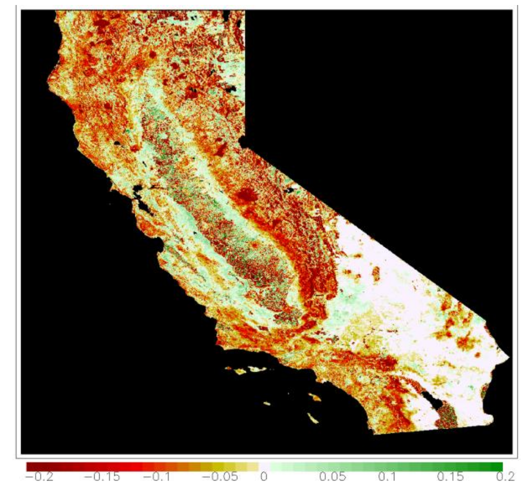
Monitoring Drought in California With SNPP VIIRS GVF

- California has been experiencing a severe drought since 2012
- Drought conditions develop gradually and they are often not identifiable immediately
- VIIRS Green Vegetation Fraction (GVF) can easily monitor <u>changes in vegetation density</u>

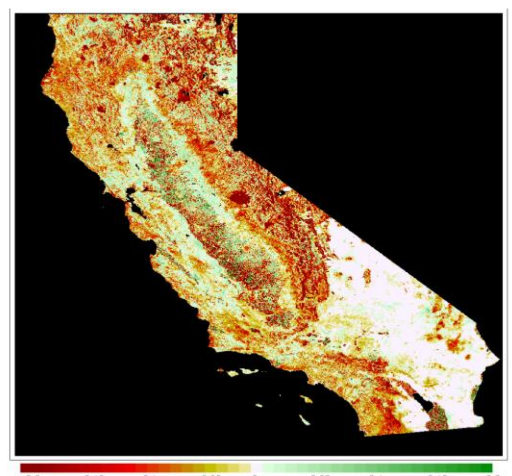
2013-08-15 minus 2012-08-15



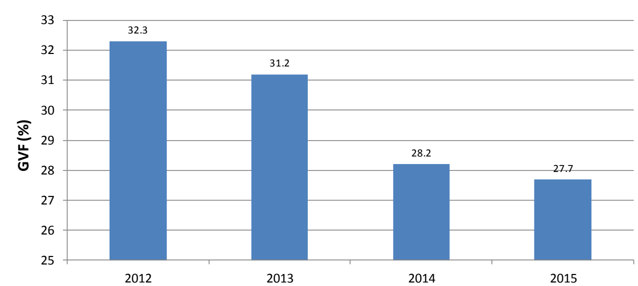
2015-08-15 minus 2012-08-15



2014-08-15 minus 2012-08-15



California mean GVF



California mean GVF in August decreased from 32.3% in 2012 to 27.7% in 2015

Evaluation of smoothing methods for improvement of the GVF smoothing algorithm

Two types of smoothing

1. General smoothing (or updated smoothing)
   – To smooth a data point using both past data (before the point) and future data (after the point)
2. Real time smoothing
   – To smooth a data point using only past data (before the point) because future data are not available

- Real time smoothing is more difficult than general smoothing in theory
- Data smoothed in real time are noisier than those smoothed by general smoothing. From this point of view, real time smoothing is a tentative solution when general smoothing is not available.

General smoothing

- Time

  $t=[-m, -m+1, -m+2, \ldots 0, 1, 2, \ldots, m]$

- Data

  $\text{Data}=[d_{-m}, d_{1-m}, \ldots., d_0, d_1, \ldots d_m]$

- Filter

  $\text{Filter}=[f_{-m}, f_{1-m}, \ldots., f_0, f_1, \ldots f_m]$

  The filter is symmetrical, i.e. $f_{-i}=f_i$

- Smoothed data for t=0 is calculated by convolution

$$s_{t=0} = \sum_{t=-m}^{m} f_t d_t$$

Real time smoothing

- Filter

  Filter=[f_{-m}, f_{1-m}, …., f_0, f_1, …f_m]

  The filter is not symmetrical

- Smoothed data for t=m

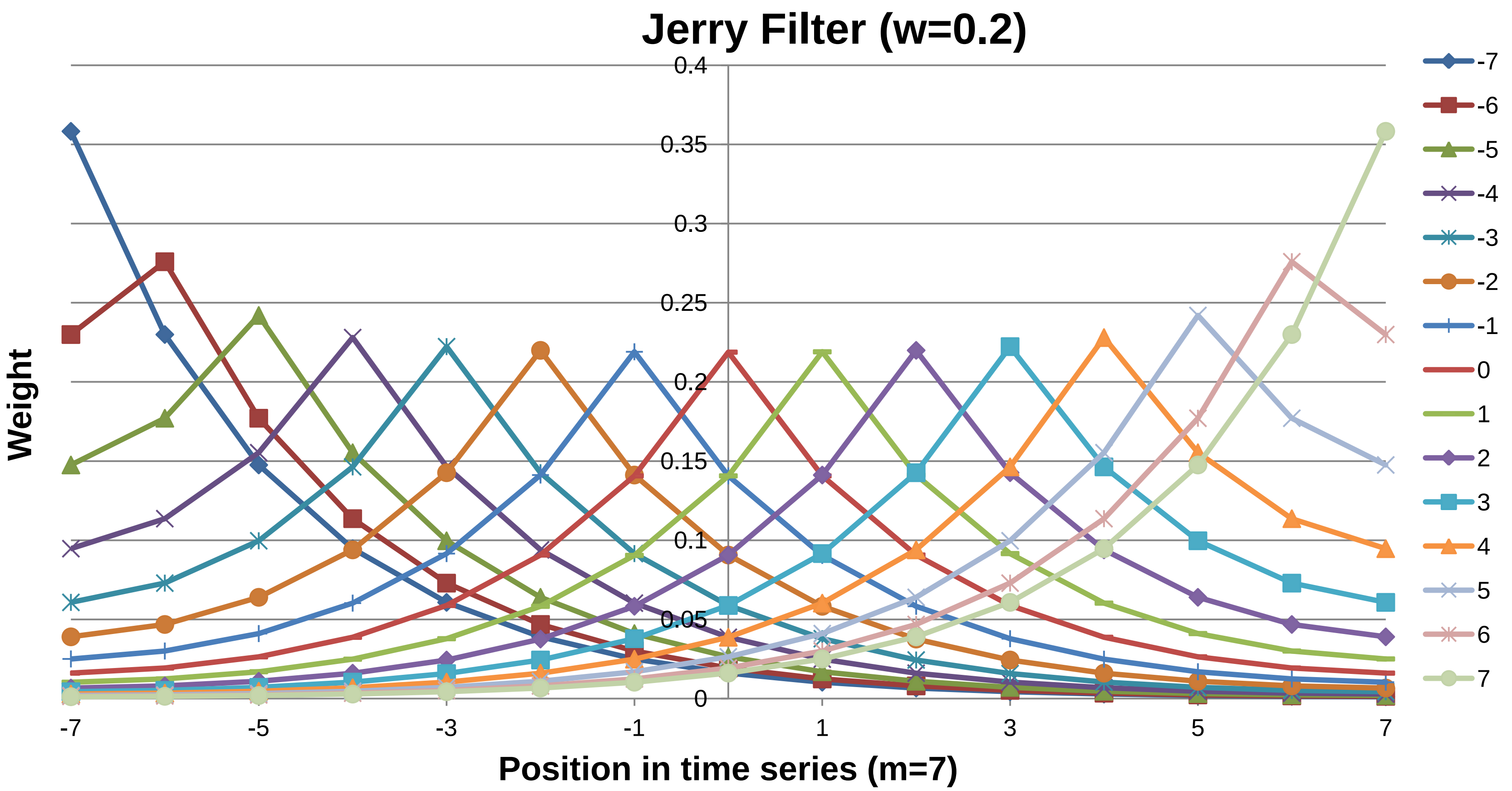
$$s_{t=m} = \sum_{t=-m}^{m} f_t d_t$$

Smoothing methods (1)

- The current smoothing algorithm used in the GVF system is developed by Jerry Sullivan (1993)
- Jerry's filter
  - No fitting function
  - Using the least squares technique
  - To achieve minimum smoothing error and best smoothness of the smoothed data (smoothness is weighted by a parameter, w)
  - Can be applied to both real time smoothing and updated smoothing

Sullivan, J. (1993). Explanation of the filter that is presently used on NDVI weekly time series data to smooth out unrepresentative fluctuations from week to week. NOAA technical memorandum, January 14.

Example of Jerry's filters



The filter for t=7 is the real time smoothing filter

The filter for t=0 is the updated smoothing filter (symmetrical)

Smoothing methods (2)

- The Savitzky-Golay filter

  The least squares calculations can be carried out by convolution of the data points with a filter (Savitzky & Golay, 1964)

  – Polynomial fitting function
  – Using the least squares technique
  – To achieve minimum smoothing error
  – Can be applied to updated smoothing, but not real time smoothing
  – Filter is symmetrical

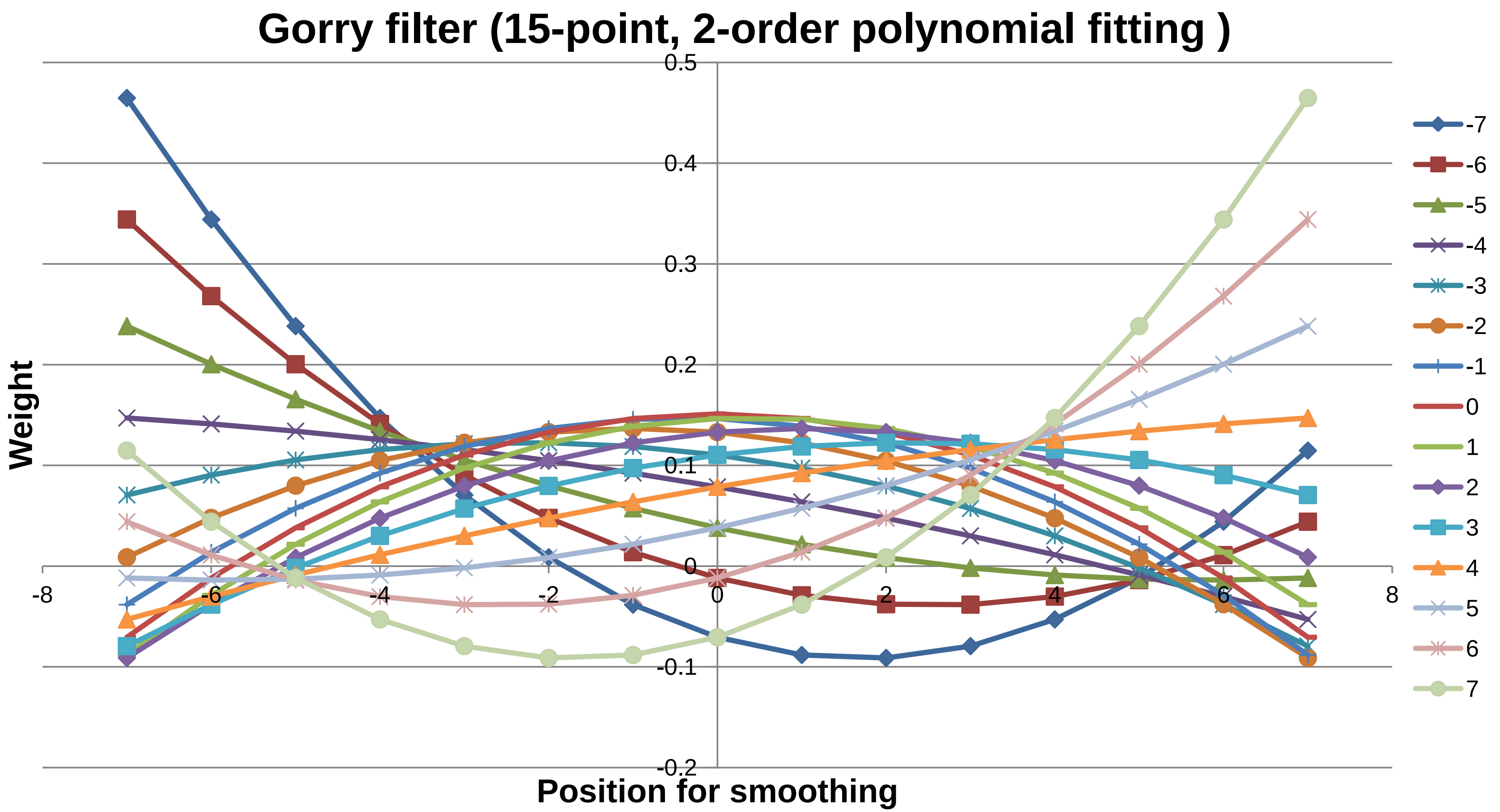
Savitzky, A., Golay, M.J.E. (1964). "Smoothing and Differentiation of Data by Simplified Least Squares Procedures". *Analytical Chemistry* **36** (8): 1627–1639

Smoothing methods (3)

- The savitzky-Golay approach suffers one major drawback: it truncates the data by *m* points at each end (Gorry, 1990)
- Gorry (1990) extended the convolution technique to cover all points in a time series based on the recursive properties of Gram polynomials
- The Gorry filter
  - Polynomial fitting function
  - Using the least squares technique
  - To achieve minimum smoothing error
  - Can be applied to both updated smoothing and real time smoothing
  - not symmetrical for acentric points

A., Gorry (1990). "General least-squares smoothing and differentiation by the convolution (Savitzky–Golay) method". *Analytical Chemistry* **62** (6): 570–573

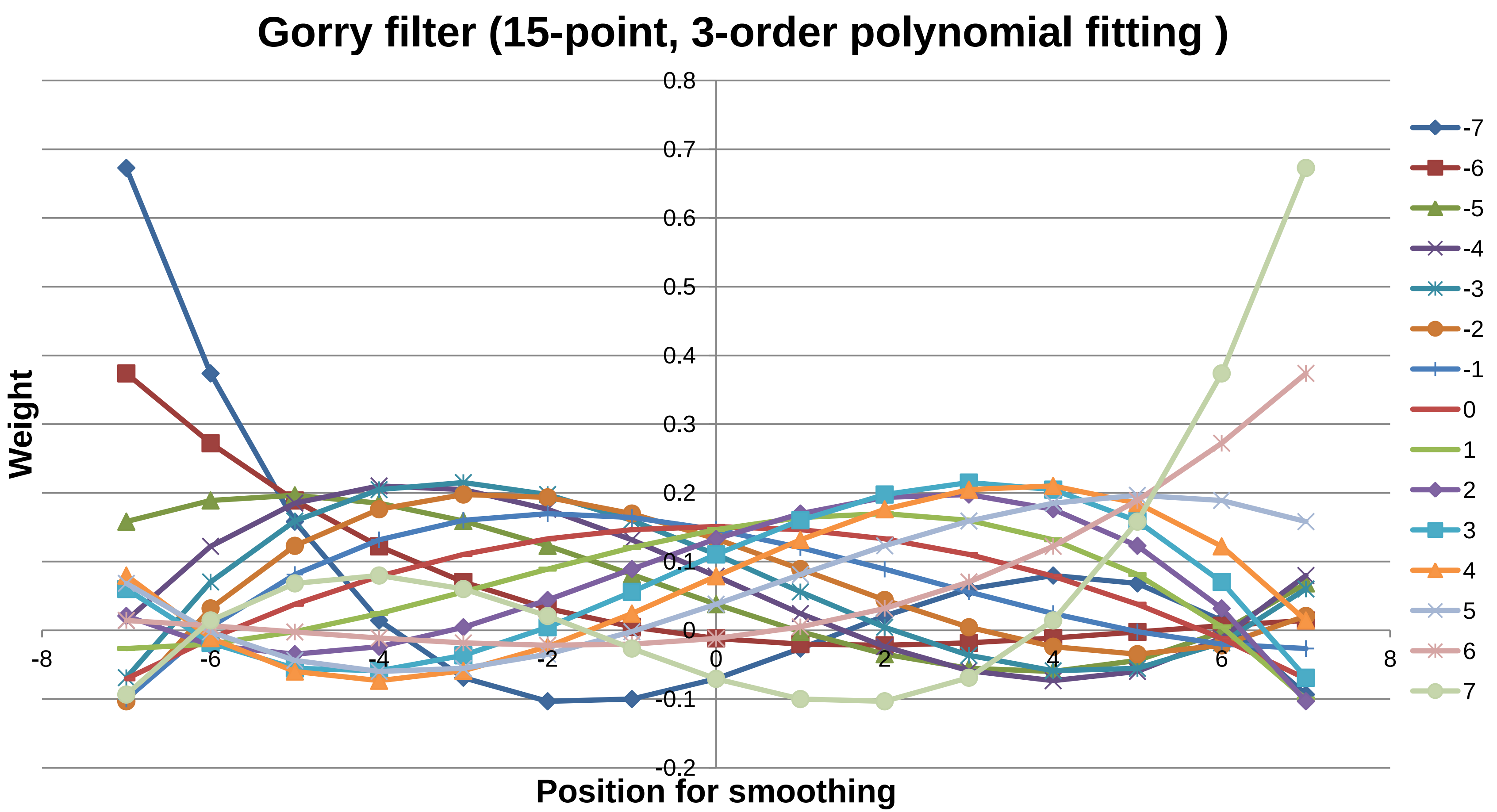
Example of Gorry's filters



The filter for t=7 is the real time smoothing filter

The filter for t=0 is the updated smoothing filter or S-G filter (symmetrical)

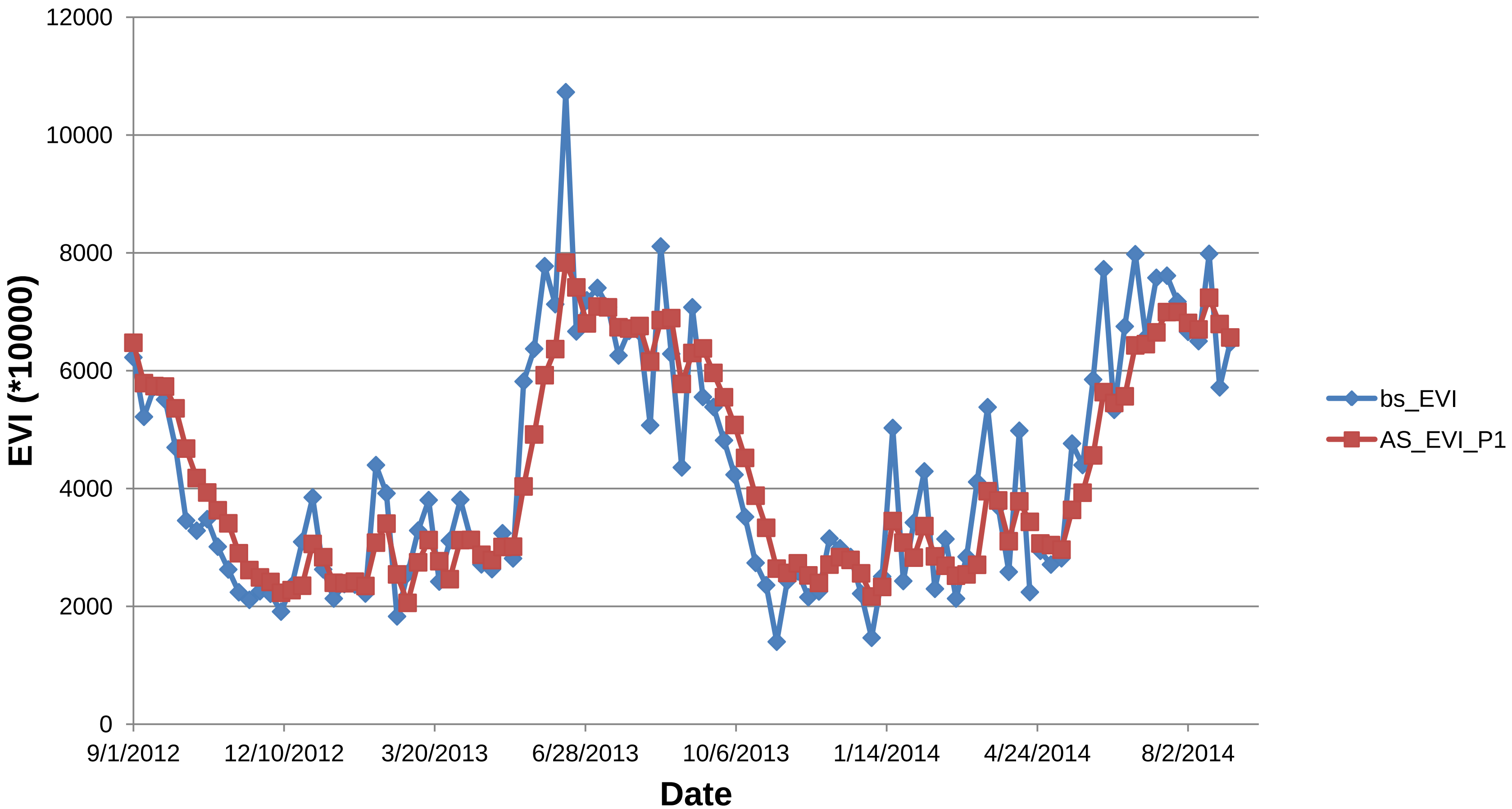
Example of Gorry's filters



The filter for t=7 is the real time smoothing filter

The filter for t=0 is the updated smoothing filter or S-G filter (symmetrical)

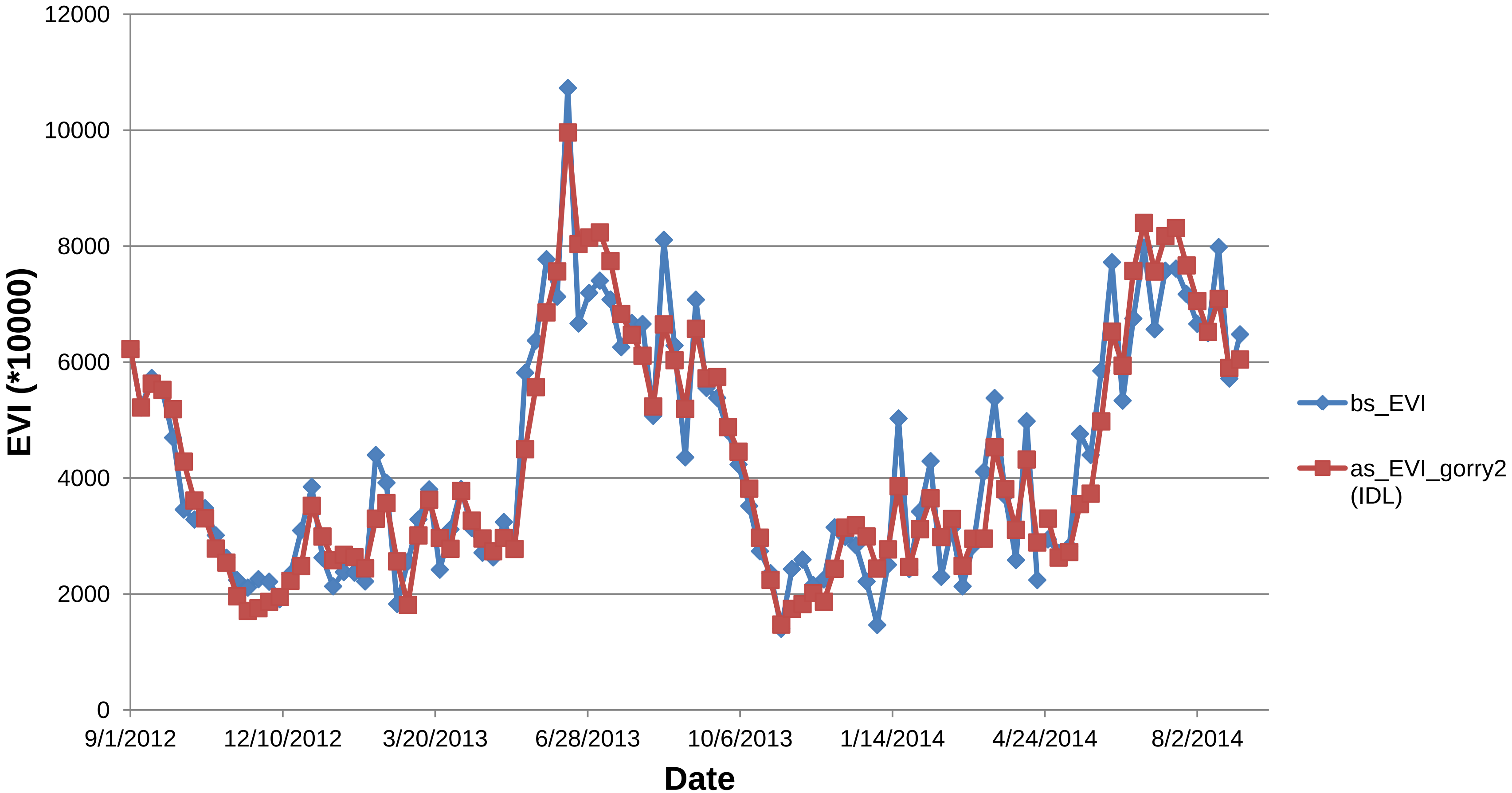
Current real time GVF smoothing (Jerry's filter)



AS-EVI-P1 is smoothed EVI by the Jerry filter

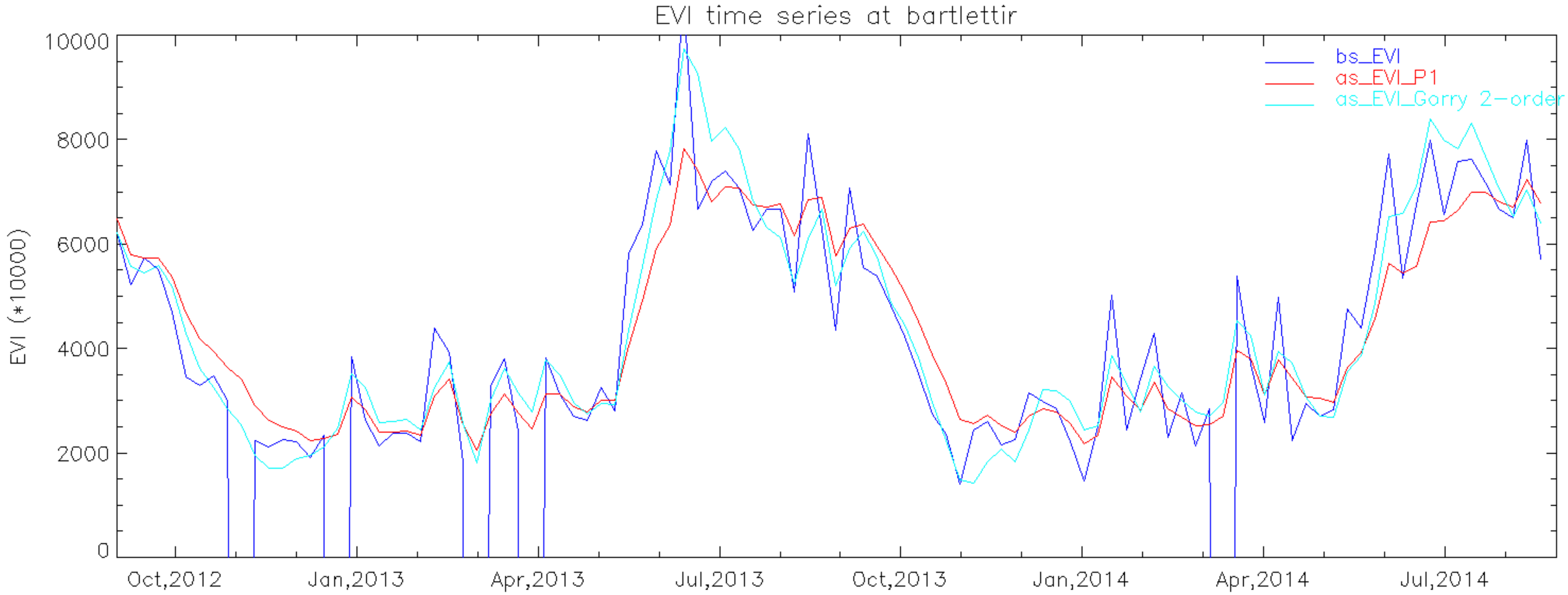
Peaks of AS-EVI-P1 are shifted to the right compared with the before smoothing EVI (bs_EVI)

Real time smoothing using Gorry’s filter



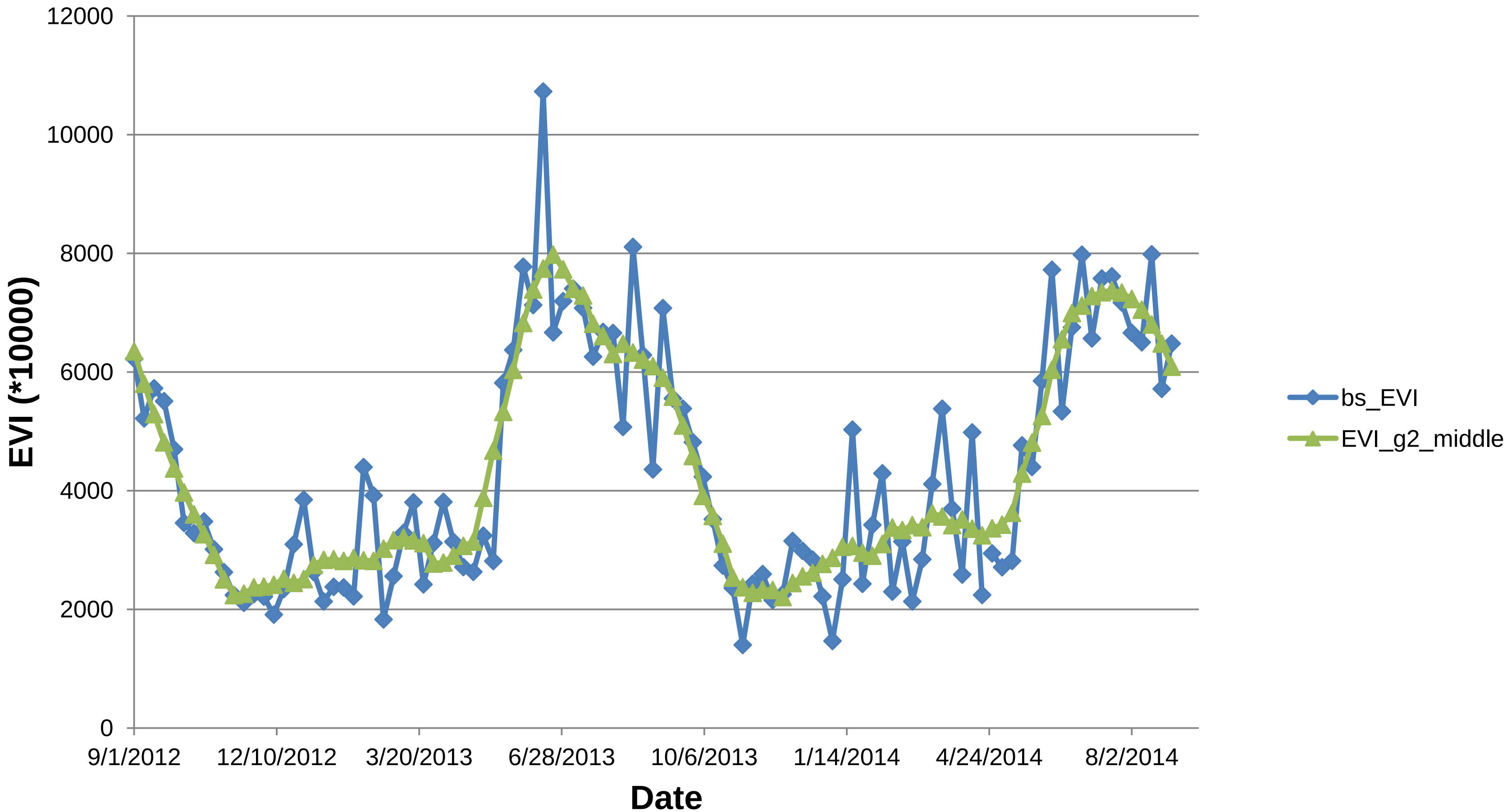
- AS-EVI-gorry2 (smoothed by 2-order Gorry’s filter) matched the before smoothing EVI (bs_EVI) very well

As_EVI_p1 Vs Gorry filter (2-order) at site bartlettir



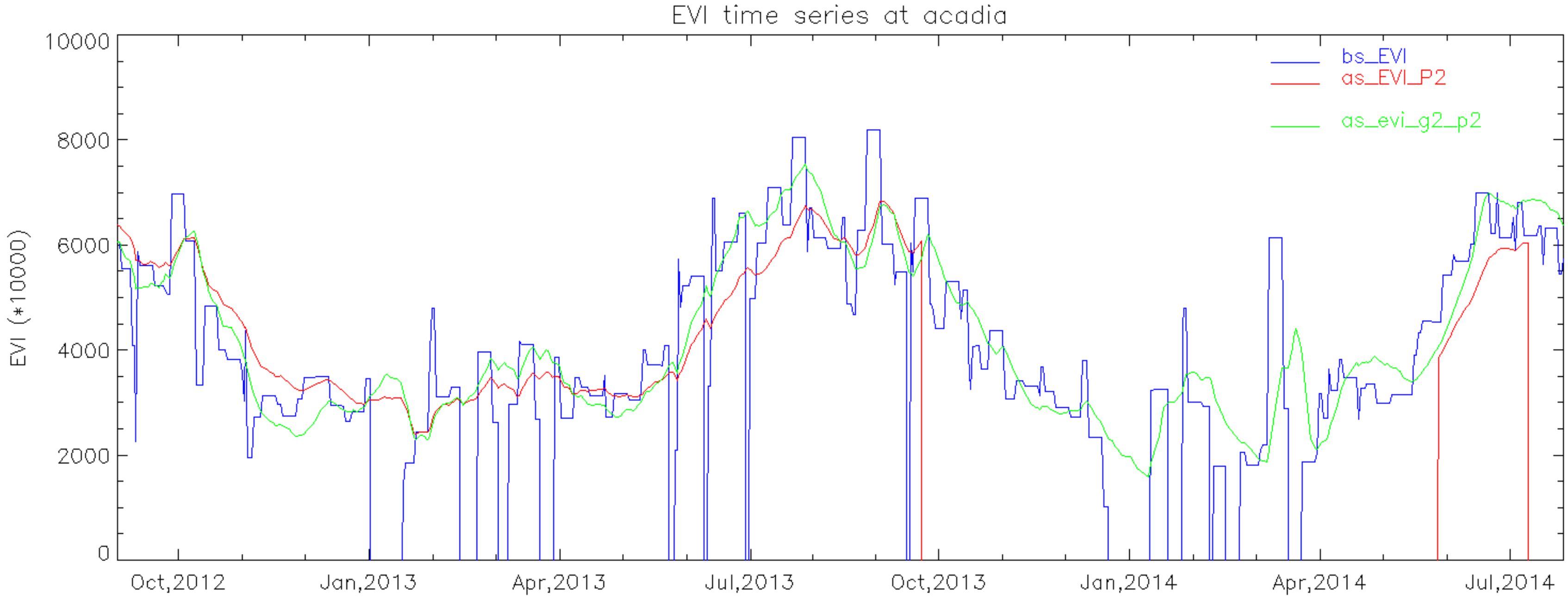
- AS-EVI-gorry2 is slightly noisier than AS-EVI-P1

Gorry's filter updated smoothing



- Updated smoothing using Gorry's filter is smoother than real time smoothing

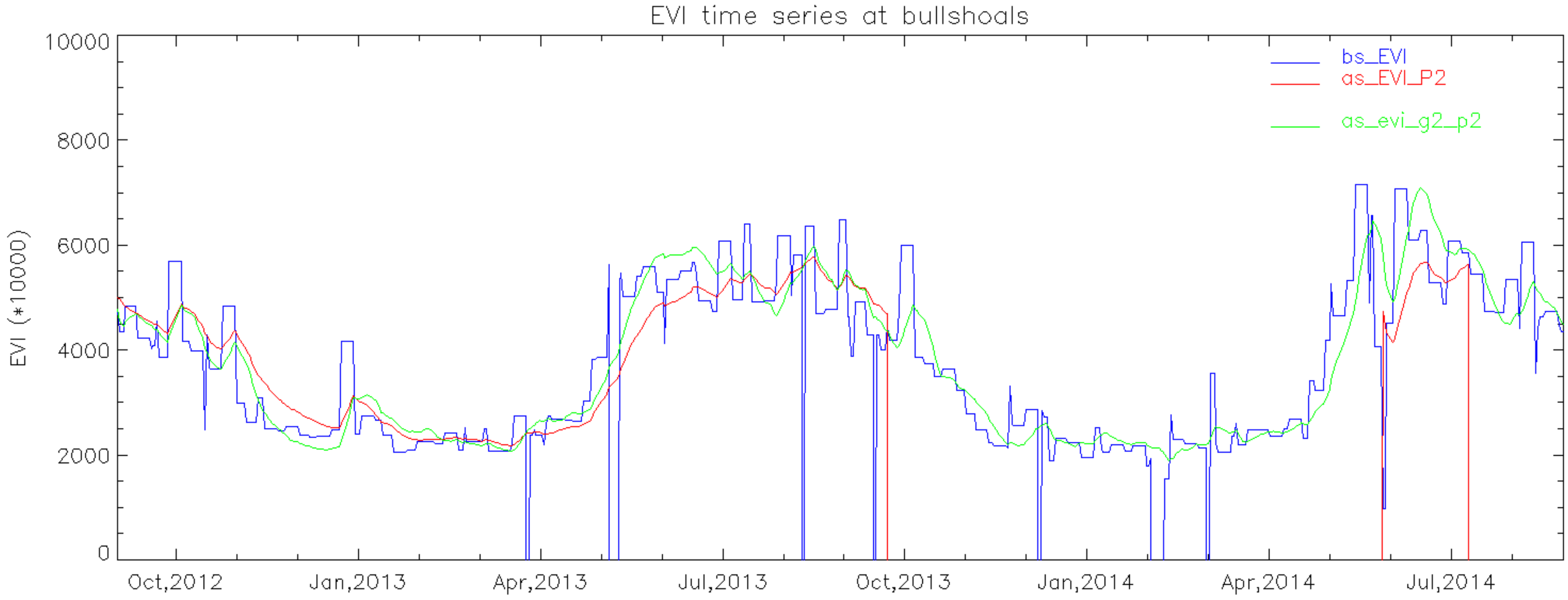
Comparison of phase-2 EVI smoothing (1)



As_EVI_P2 is the current phase-2 smoothed EVI
As_evi_g2_p2 is weekly average of smoothed EVI by the real time Gorry filter

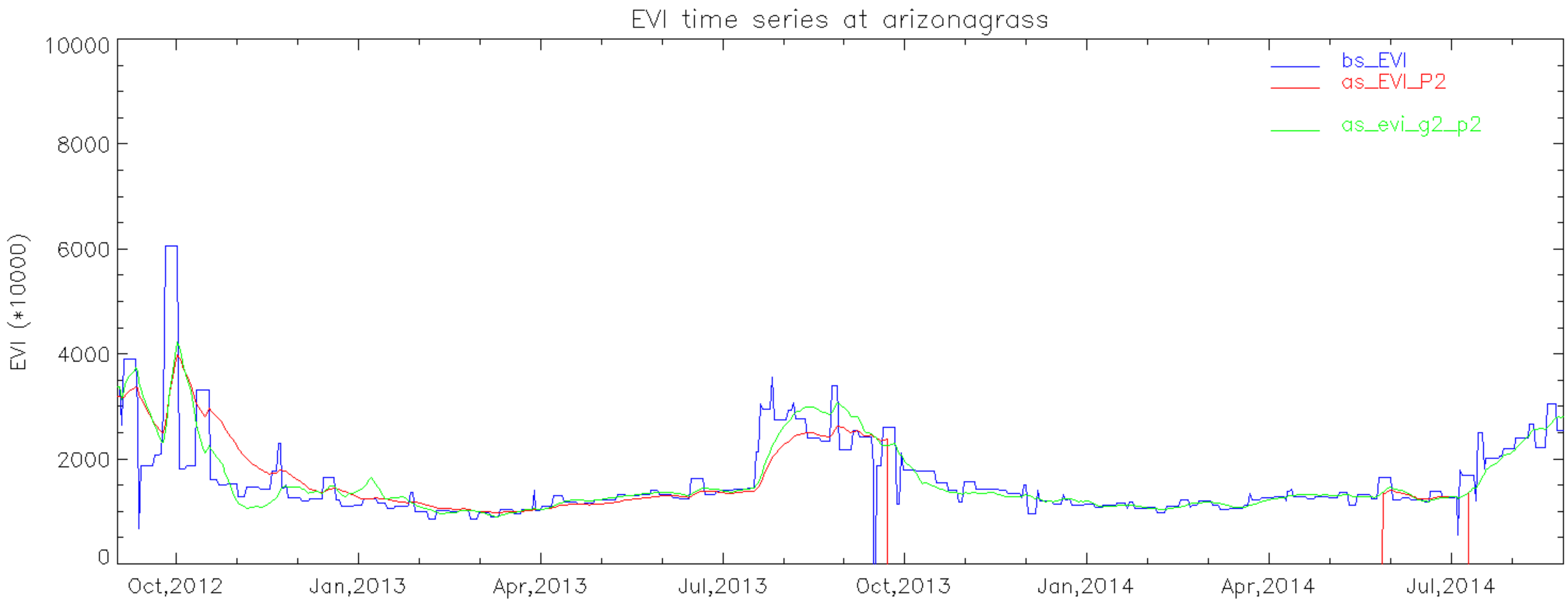
•As_evi_g2_p2 matched the bs_EVI better than the current As_EVI_P2

Comparison of phase-2 EVI smoothing (2)

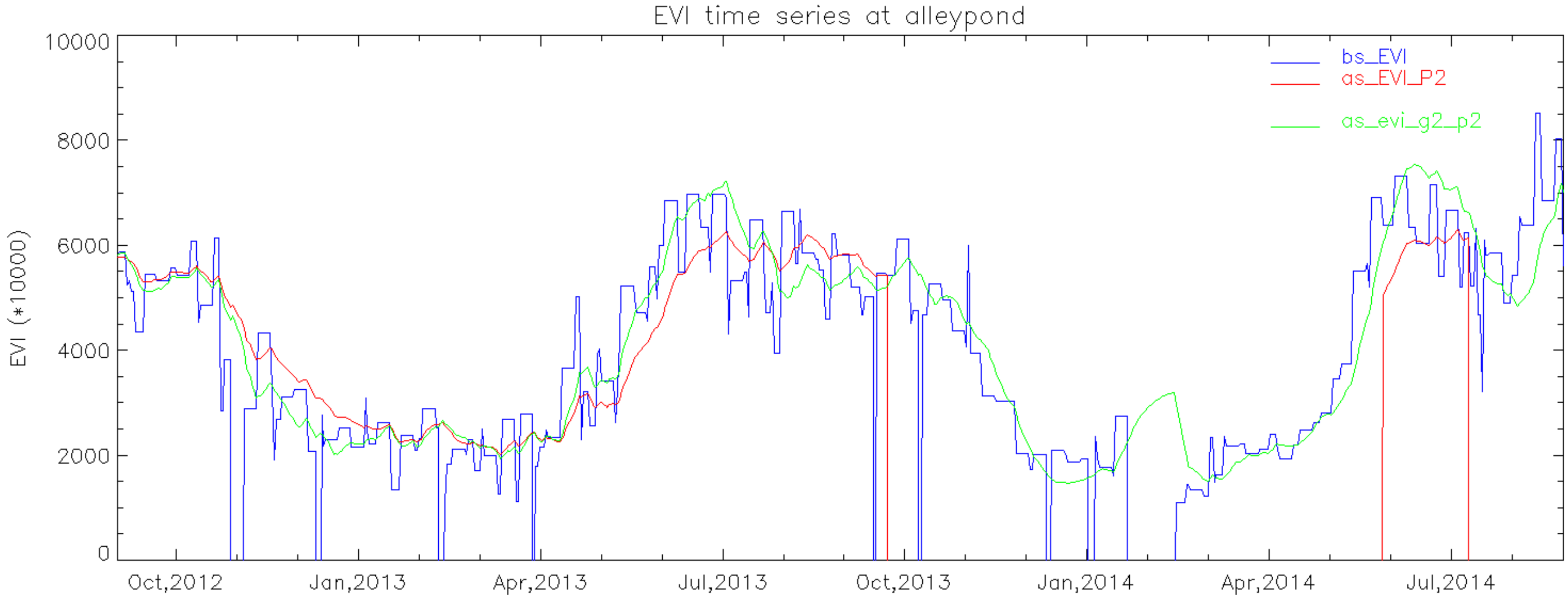


Phase-2 smoothed EVI is smoother than phase-1 smoothed EVI

Comparison of phase-2 EVI smoothing (3)



Comparison of phase-2 EVI smoothing (4)



Improvement of GVF smoothing algorithm

- Based on the comparison of the EVI time series smoothed by Jerry's filter and the proposed Gorry's filter, I recommend changing the current Jerry smoothing method to the Gorry smoothing method
- Keep the gap-filling and the median filter
- Then apply Gorry's filter (see next page)
- Keep the phase-2 weekly averaging of phase-1 EVI

Gorry's filter

- Define Gorry's filter for real time smoothing (m=7, 2-order polynomial fitting)

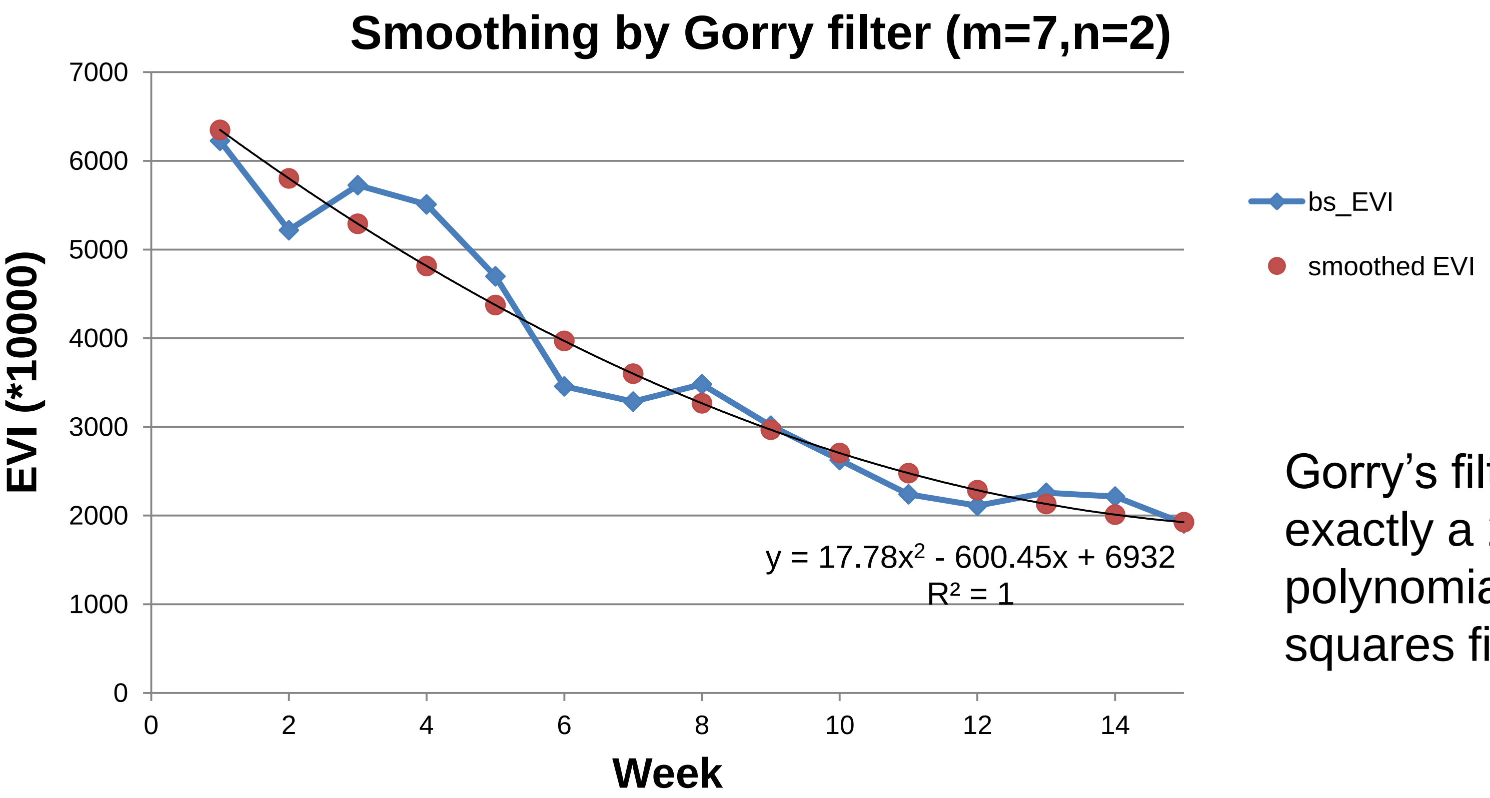
g_filter2=float_array(15)

g_filter2(0) = 0.114706
g_filter2(1) = 0.0441176
g_filter2(2) = -0.0117647
g_filter2(3) = -0.0529412
g_filter2(4) = -0.0794118
g_filter2(5) = -0.0911765
g_filter2(6) = -0.0882353
g_filter2(7) = -0.0705882
g_filter2(8) = -0.0382353
g_filter2(9) = 0.00882354
g_filter2(10) = 0.0705883
g_filter2(11) = 0.147059
g_filter2(12) = 0.238235
g_filter2(13) = 0.344118
g_filter2(14) = 0.464706

bs_EVI for the current week

If 15 weeks of EVI=[6226, 5218, 5726, 5509, 4698, 3457, 3285, 3481, 3013, 2626.5, 2240, 2111, 2257, 2214, 1911]
Then the smoothed EVI for the current week=g_filter2(0)*6226+g_filter2(1)*5218+……+g_filter2(14)*1911
=1925.661

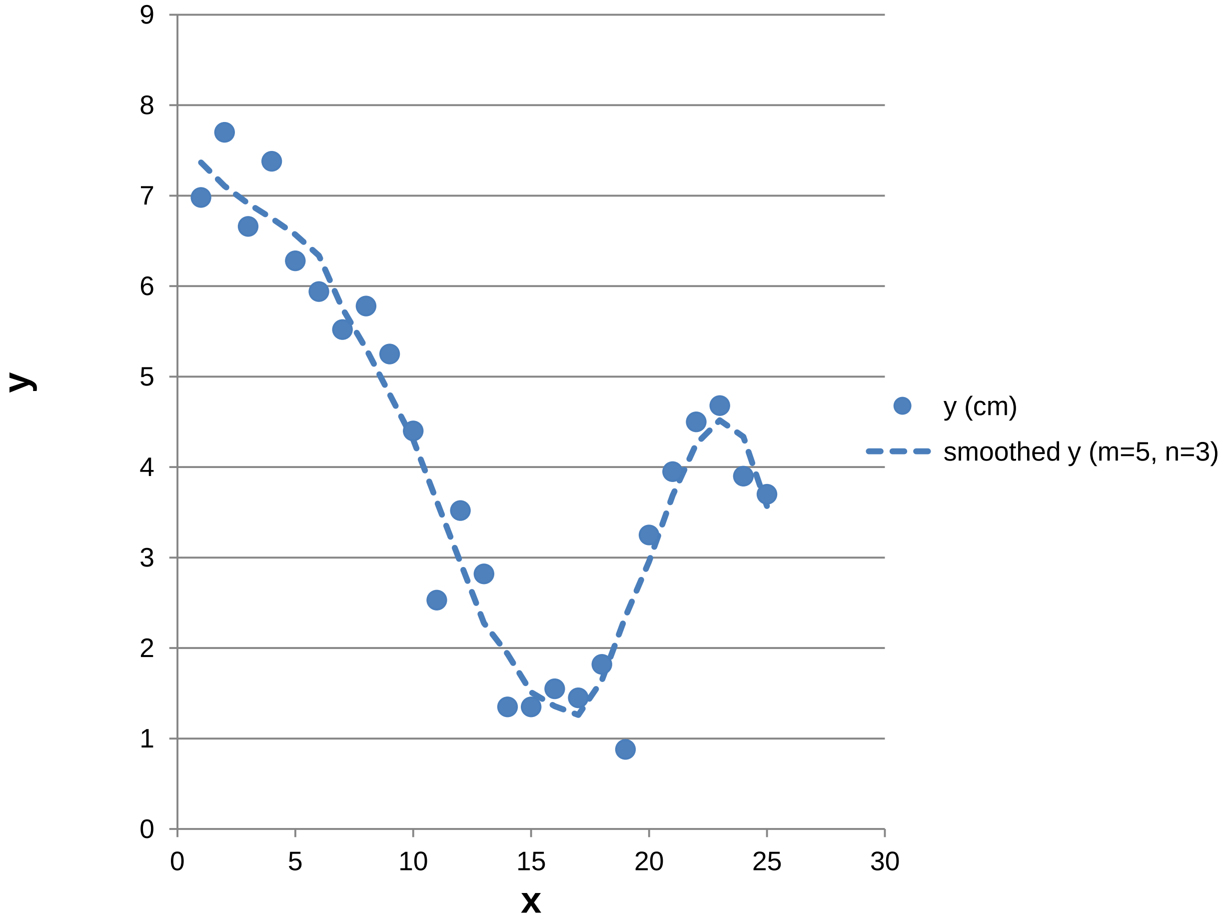
Example of Gorry Smoothing



Gorry's filter produces exactly a 2-order polynomial least squares fitting

EVI=[6226, 5218, 5726, 5509, 4698, 3457, 3285, 3481, 3013, 2626.5, 2240, 2111, 2257, 2214, 1911]
Smoothed EVI=[6349.312511 5802.196364 5290.647297 4814.647834 4374.219899 3969.350557 3600.027885 3266.27541 2968.079283 2705.449851 2478.369762 2286.851554 2130.897413 2010.498257 1925.661391]

Reproducing Fig. 2 of Gorry (1990)



GVF VIIRS vs. AVHRR Temporal Profile Comparison at Select EOS Validation Sites