

MODIS/VIIRS Science Team Meeting

Silver Spring, MD - May 18-22, 2015

Vegetation Indices AVHRR to MODIS to VIIRS

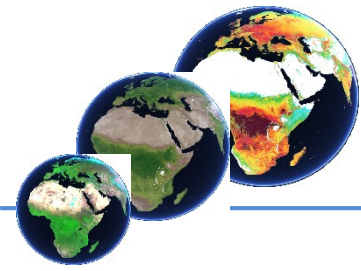
Kamel Didan¹, Compton Tucker², Armando Barreto¹, Jorge Pinzon³
Nikolay Shabanov*

¹University of Arizona, ²Goddard Space Flight Center, ³SSAI/GSFC

*Nikolay participation is no longer certain

And special acknowledgement to Alfredo Huete*, University Technology Sidney

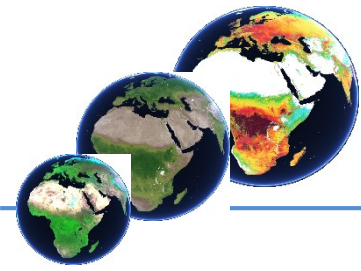




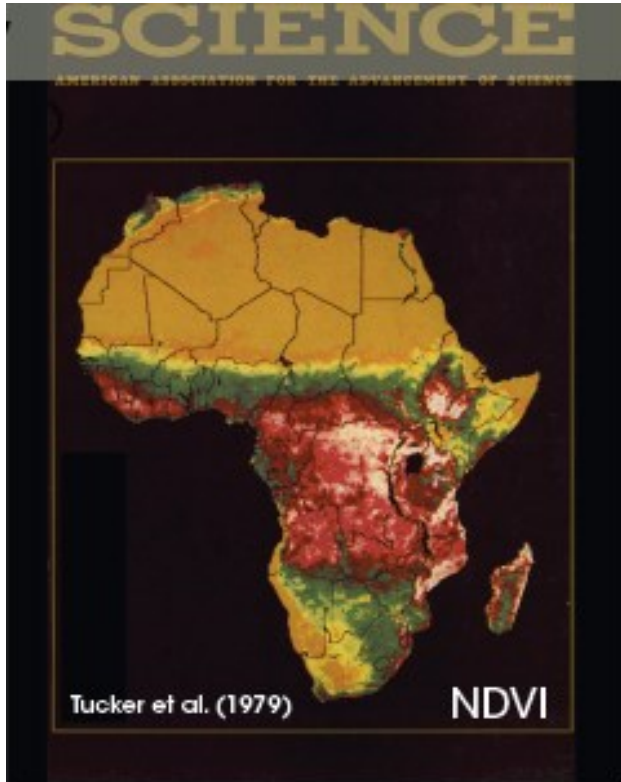
Main Points

- **To orient you here is a summary of this talk**
 - 34+ year VI record (AVHRR, MODIS, VIIRS)
 - How do these records compare?
 - How did we do things so far?
 - What have we learned?
 - Can we do things better with VIIRS?
 - Continuity?





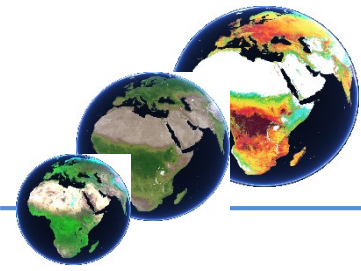
So it all started in the late seventies



Phenological measurements from satellite radiometry:
 - global 25+ year time-series
 - spatial integrated view

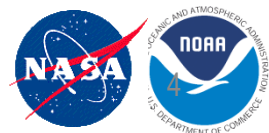
- **Heritage in AVHRR (C. J. Tucker)**
- VIs are estimates of the visible light absorbed by plant canopies adjusted by their structure measured by the reflected NIR
- Approximates photosynthesis, so over time $\Sigma NDVI = \sim GPP$
- Captures all biotic and abiotic factors that control photosynthesis
- After 34+ years later?
- **MODIS VI Paper (Huete, Didan, et al., 2002)**
 - ~2600+ citations [\[HTML\] Overview of the radiometric and biophysical performance of the MODIS vegetation indices](#)
 A Huete, K Didan, T Miura, EP Rodriguez, X Gao... - Remote sensing of ..., 2002 - Elsevier
 We evaluated the initial 12 months of vegetation index product availability from the Moderate Resolution Imaging Spectroradiometer (MODIS) on board the Earth Observing System-Terra platform. Two MODIS vegetation indices (VI), the normalized difference vegetation index (... Cited by 2621 Related articles All 10 versions Web of Science: 1586 Cite Save More
- **AVHRR GIMMS (Tucker, Pinzon, et al, 2005)**
 - ~1200 citations [An extended AVHRR 8-km NDVI dataset compatible with MODIS and SPOT vegetation NDVI data](#)
 CJ Tucker, JE Pinzon, ME Brown... - ... Journal of Remote ..., 2005 - Taylor & Francis
 Daily daytime Advanced Very High Resolution Radiometer (AVHRR) 4-km global area coverage data have been processed to produce a Normalized Difference Vegetation Index (NDVI) 8-km equal-area dataset from July 1981 through December 2004 for all continents ... Cited by 1180 Related articles All 9 versions Web of Science: 721 Cite Save More
- **Northern Greening (Myneni,..., Tucker, et al., 1997) – NDVI based**
 - ~2500+ citations [\[PDF\] Increased plant growth in the northern high latitudes from 1981 to 1991](#)
 RB Myneni, CD Keeling, CJ Tucker, G Asrar... - Nature, 1997 - ecocast.arc.nasa.gov
 Variations in the amplitude and timing of the seasonal cycle of atmospheric CO2 have shown an association with surface air temperature consistent with the hypothesis that warmer temperatures have promoted increases in plant growth during summer1 and/or plant ... Cited by 2523 Related articles All 22 versions Web of Science: 1534 Cite Save More
- **Highest citations in land related studies are VI related/driven**
- **It is the highest searched/ordered/used data too**

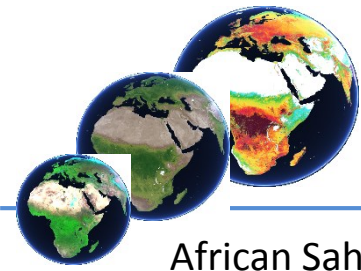




Reflections

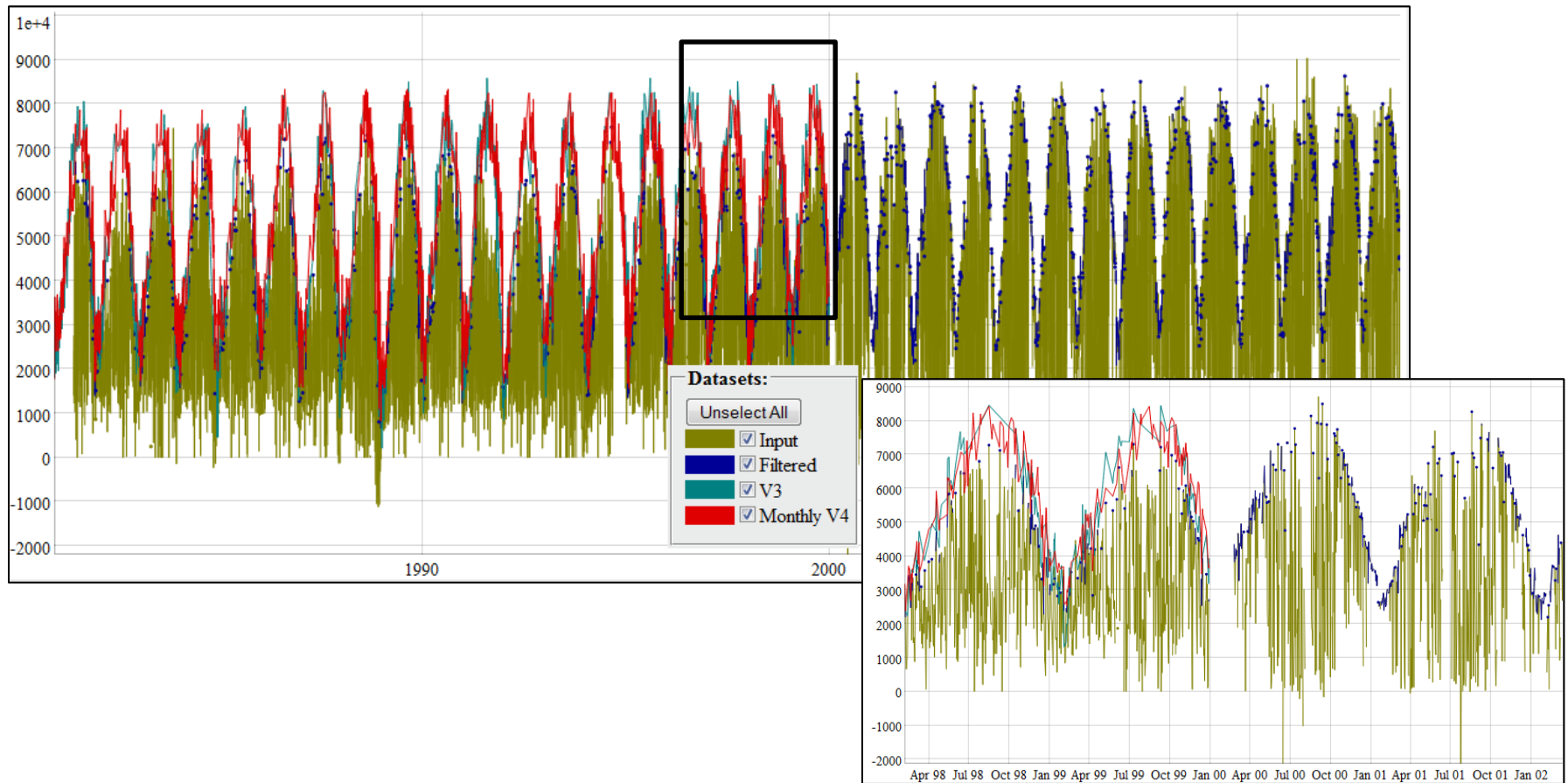
- **VIIs constitute probably one of the longest if not the longest consistently generated data record (RS based)**
 - With 34+ years of Multi-sensor VI Records (AVHRR, MODIS T/A, and now VIIRS, there are others but none with the same rigor and/or consistency)
 - Potential to go another 25-30 years with VIIRS (S-NPP, JPSS, 2038)
 - Highly valuable, unique, and simple with absolutely no assumptions about anything, long term VI data record (NDVI, EVI and now EVI2)
 - Support to probably one of the largest multidisciplinary science user communities (from farmers to modelers)
- **Around 2006**, a concept was proposed to reorganize our efforts around notions of climate/environmental **measurements** and avoid the sensor specific context
- **With this wealth of consistent data the questions become**
 - What have we done right vs wrong
 - What have we learned
 - Can we do things better
 - What are the implications of what we do in general

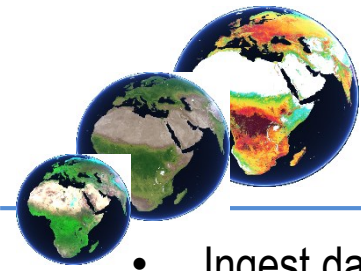




Longest RS Record

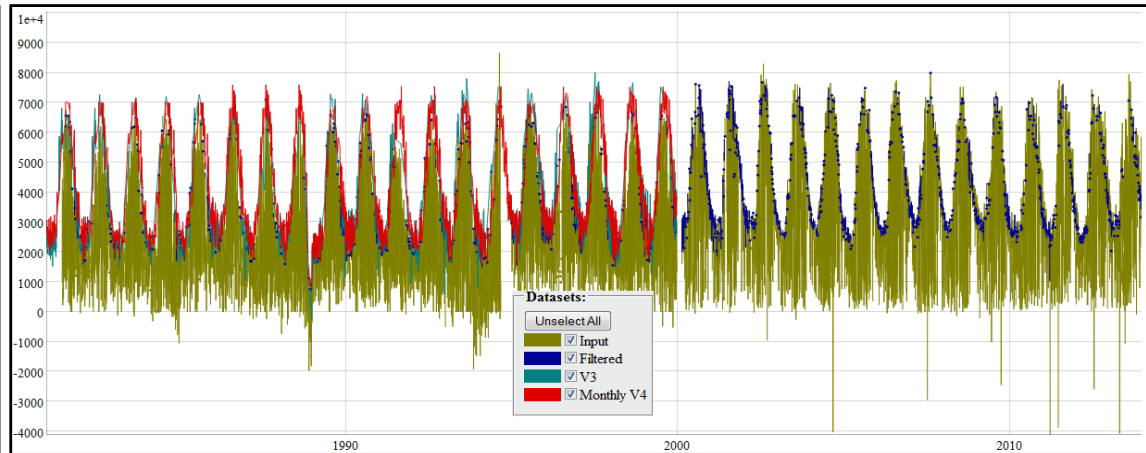
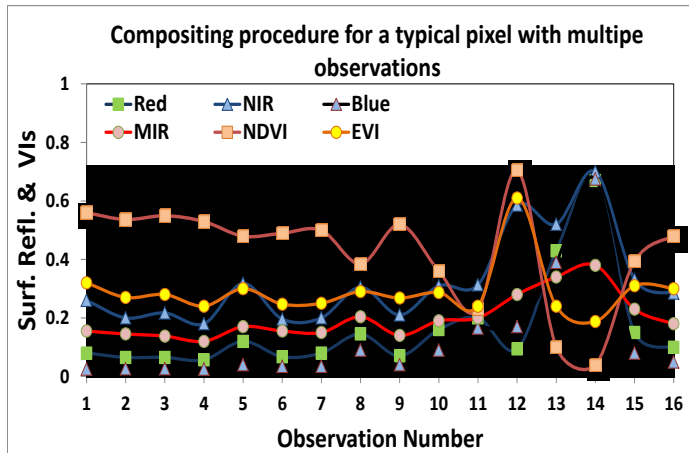
African Sahel region - NDVI Multisensor Daily Time Series (AVHRR, MODIS, VIIRS)
(vip.arizona.edu)



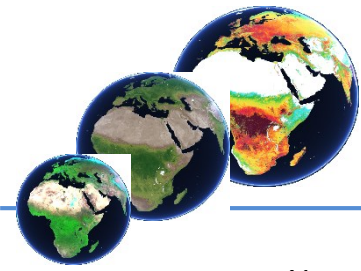


Here is how we've done things so far

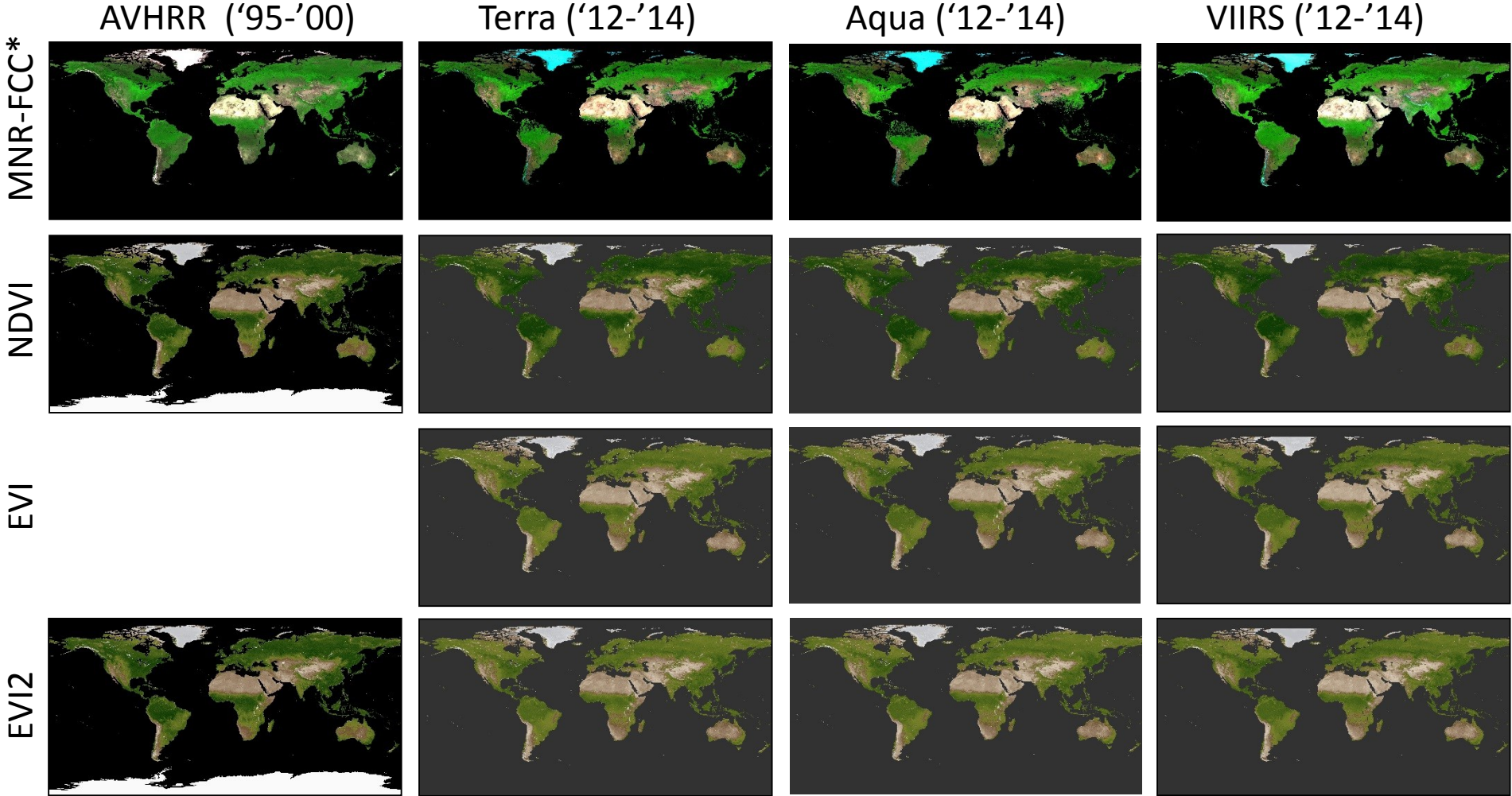
- Ingest daily data
 - Atmosphere correction (partial [AVHRR] to ~full [MODIS, VIIRS])
- Per-pixel QA characterization (partial [AVHRR], extended [MODIS, VIIRS])
- Compositing over predefined periods (optimized for cloudy regions or sensor revisit period)
 - Select the highest NDVI (to avoid cloud, heavy aerosols, etc...) – MVC [AVHRR]
 - QA driven, Maximum Value Composite, and Constrained View (mitigate BRDF)
- This still leaves considerable amount of poor data (>50% is still challenging to work with)



African Sahel region - NDVI Multisensor Time Series (AVHRR, MODIS, VIIRS)
(vip.arizona.edu)



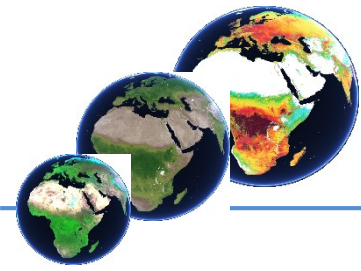
CURRENT RECORDS AVHRR-MODIS-VIIRS (SUMMER)



Mid August

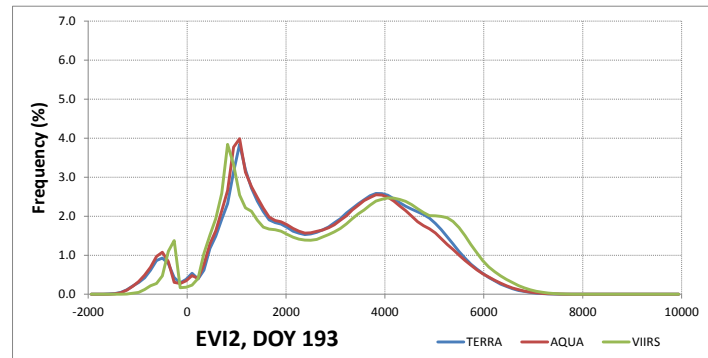
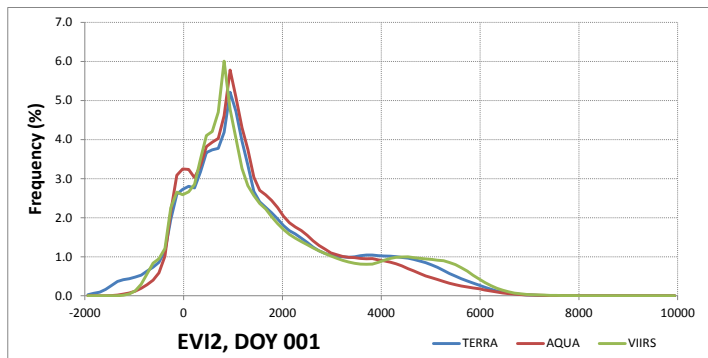
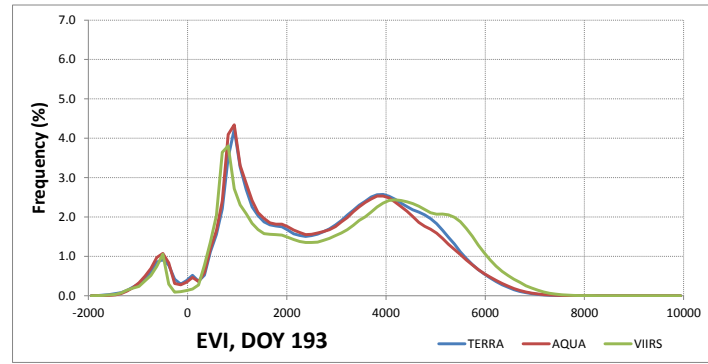
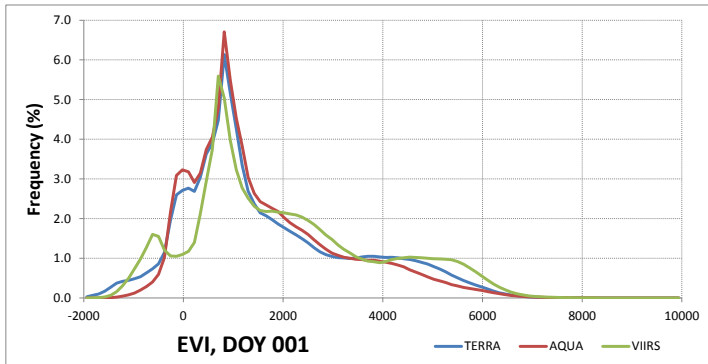
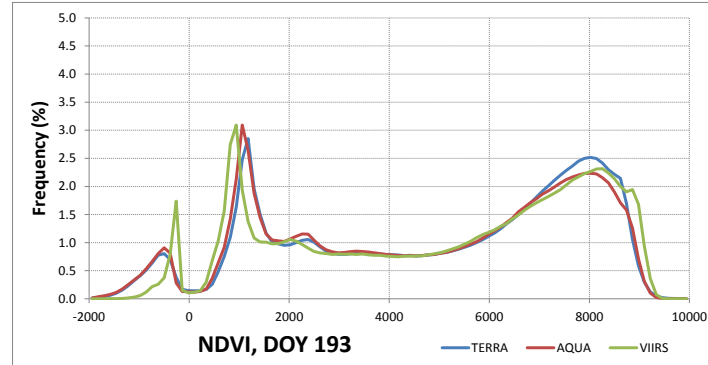
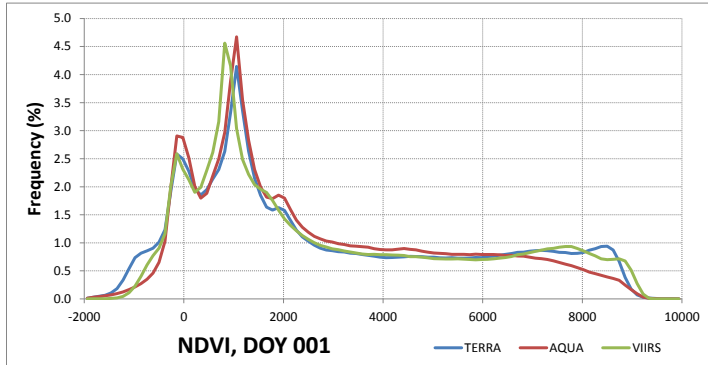
*AVHRR MNR FCC was generated by correlating the VIS/NIR using the MODIS MNR~ f(VIS, NIR) relation





MODIS T/A-VIIRS (Summer)

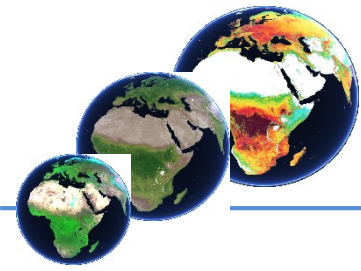
Using only the 3 yrs of overlap



Largest differences

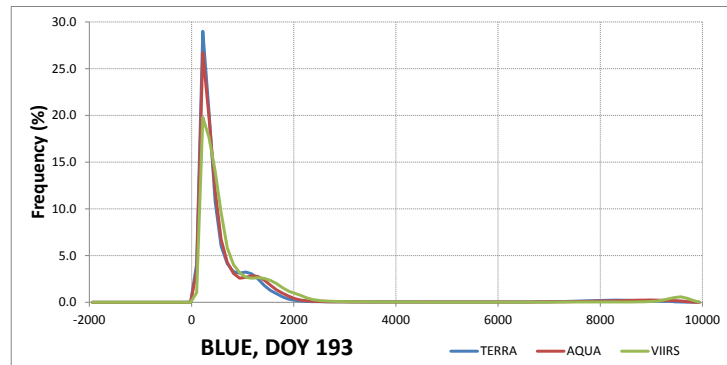
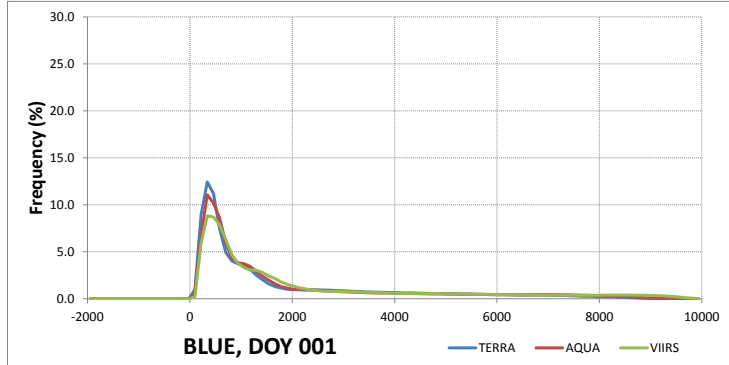
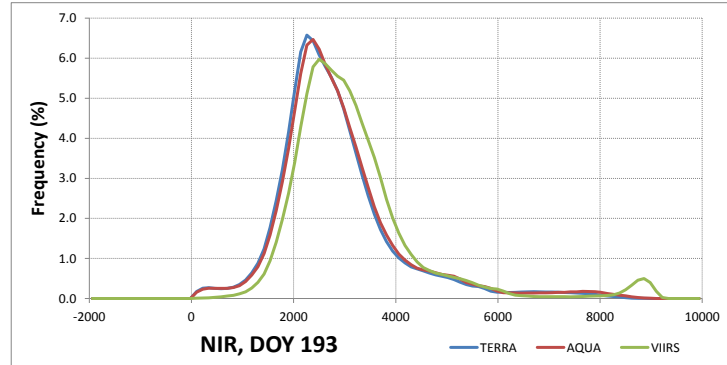
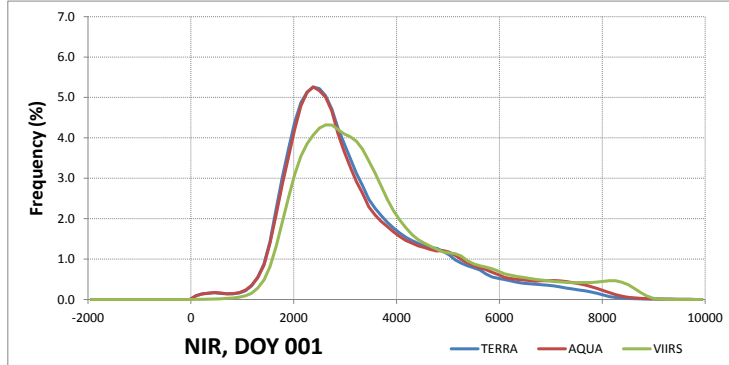
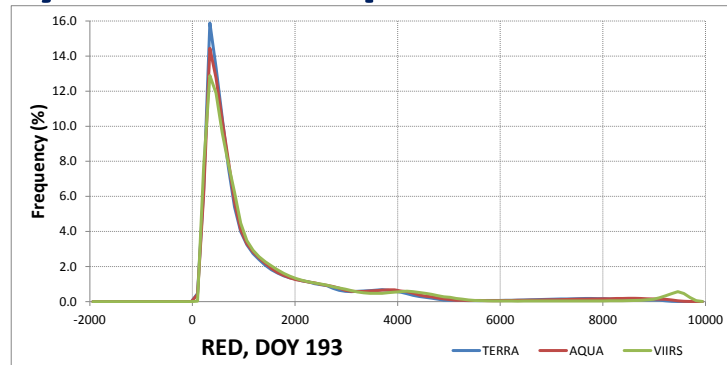
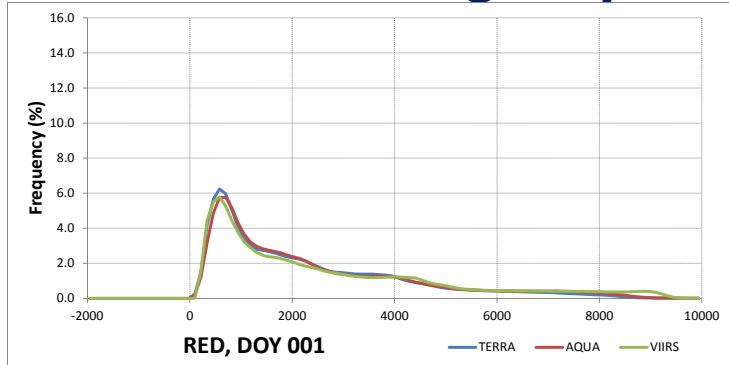
at the low and high ends

- Tropics
- Deserts
- Snow/Ice
- VIIRS higher at the higher end lower at the lower end

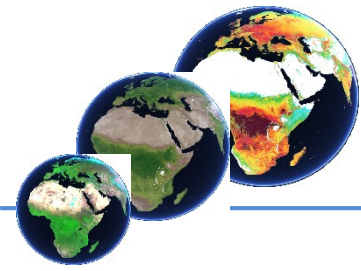


MODIS T/A -VIIRS (LSR)

Using only the 3 yrs of overlap



Largest differences
in the NIR and Blue



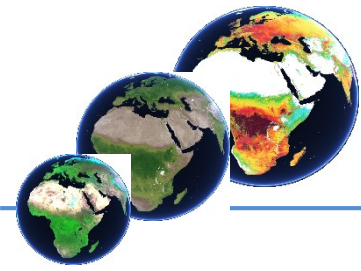
AVHRR-MODIS-VIIRS Differences (Winter)

VIIRS - Sensor

	AVHRR	Terra	Aqua
NDVI			
EVI	<p>Legend</p> <p>< -2000 -2000 -1500 -1000 -500 -250 0 250 500 1000 1500 2000 > 2000</p>		
EVI2			

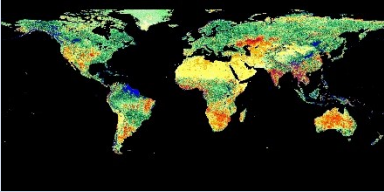
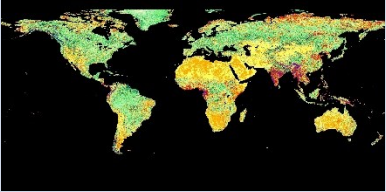
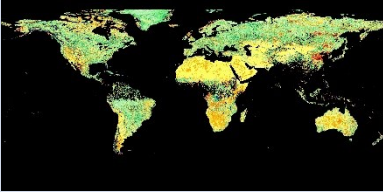
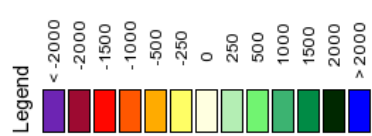
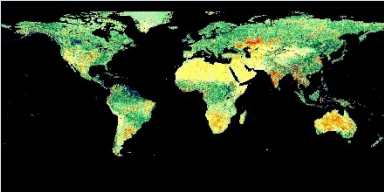
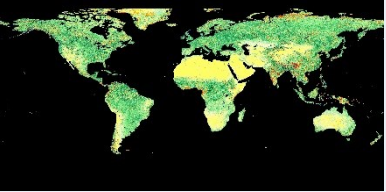
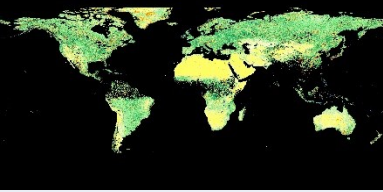
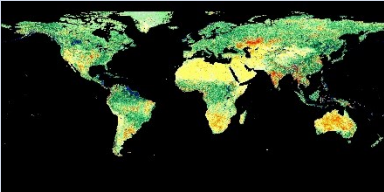
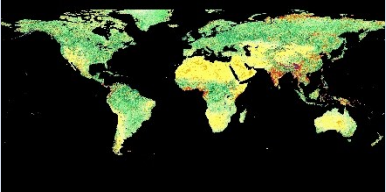
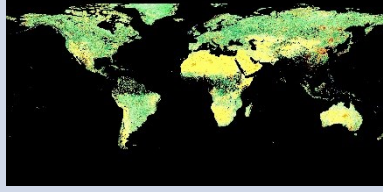
Largest differences over

- Snow/Ice
- Residual clouds

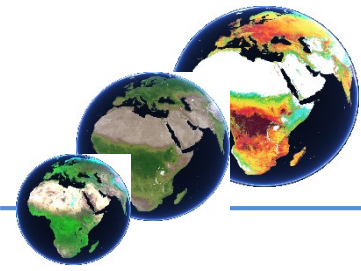


AVHRR-MODIS-VIIRS Differences (Summer)

VIIRS - Sensor

	AVHRR	Terra	Aqua
NDVI			
EVI	 		
EVI2			

Diff < 2-5%
Larger in NDVI than
EVI/EVI2

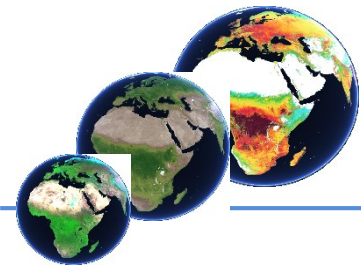


AVHRR-MODIS-VIIRS Differences (Winter)

VIIRS - Sensor

	AVHRR	Terra	Aqua
Red			
NIR			
Blue	<p>Legend</p> <ul style="list-style-type: none"> < -2000 -2000 -1500 -1000 -500 -250 0 250 500 1000 1500 2000 > 2000 		

- Largest differences
- Snow/Ice (AVHRR)
 - Residual clouds
 - AVHRR Red (Snow)
 - NIR differences



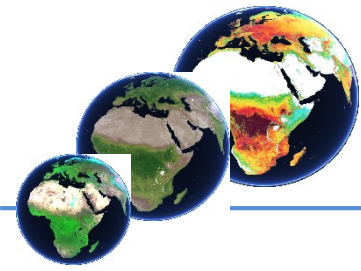
AVHRR-MODIS-VIIRS Differences (Summer)

VIIRS - Sensor

	AVHRR	Terra	Aqua
Red			
NIR			
Blue			

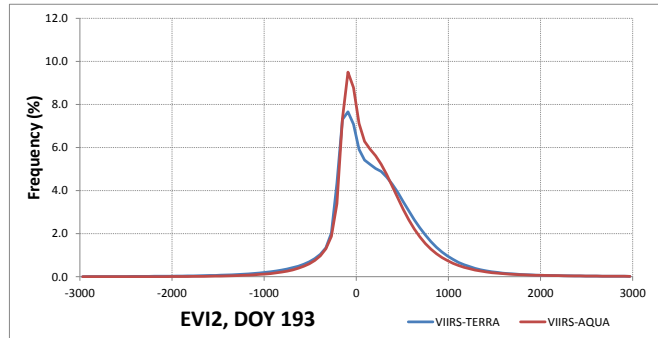
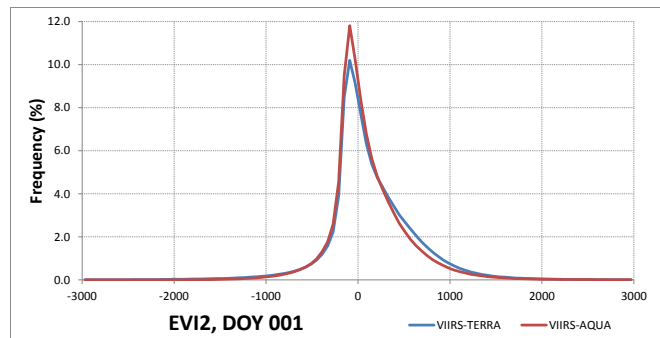
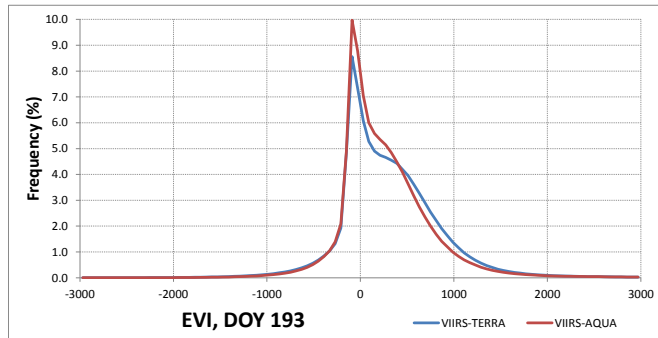
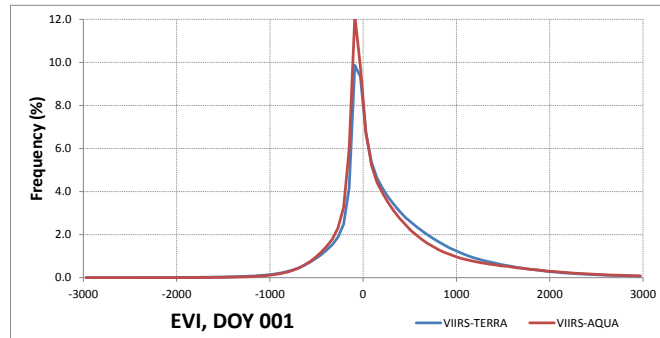
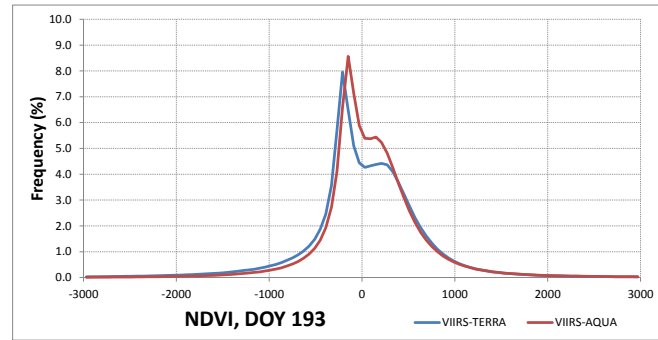
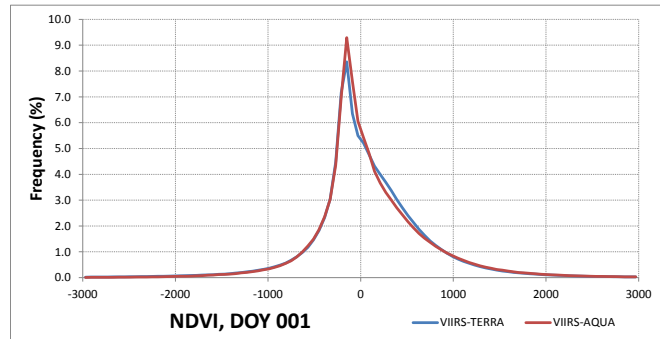
Diff < 5%

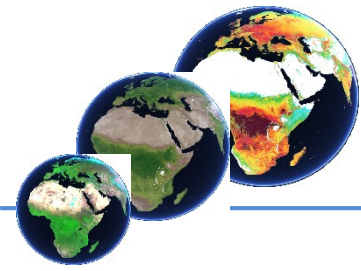
Mostly < 2.5%



MODIS T/A -VIIRS Difference

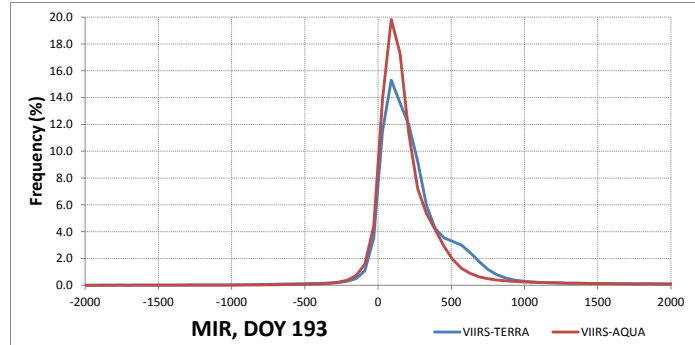
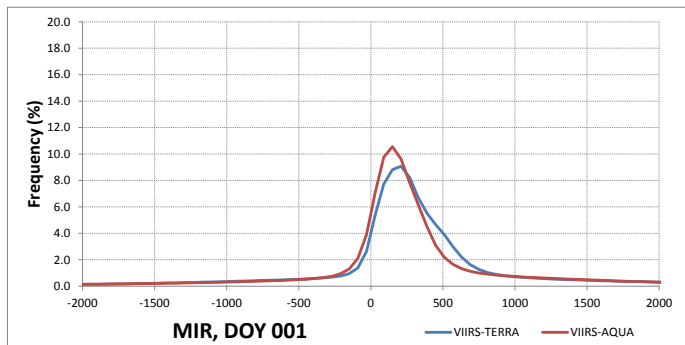
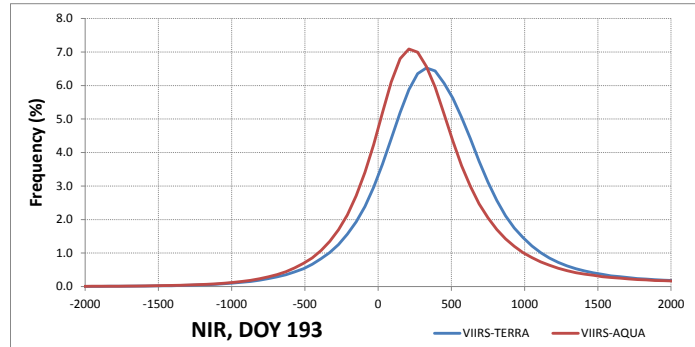
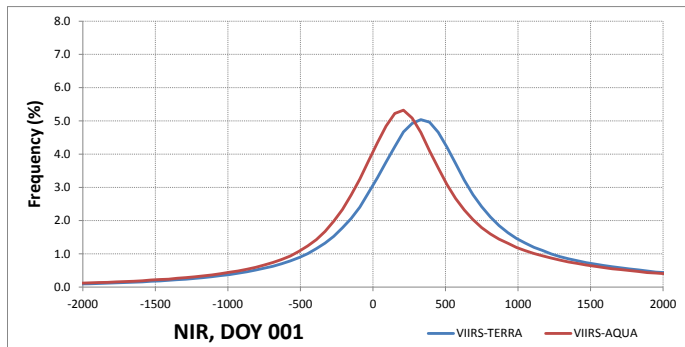
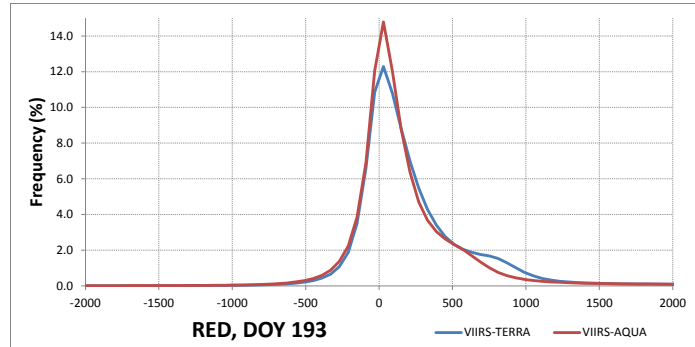
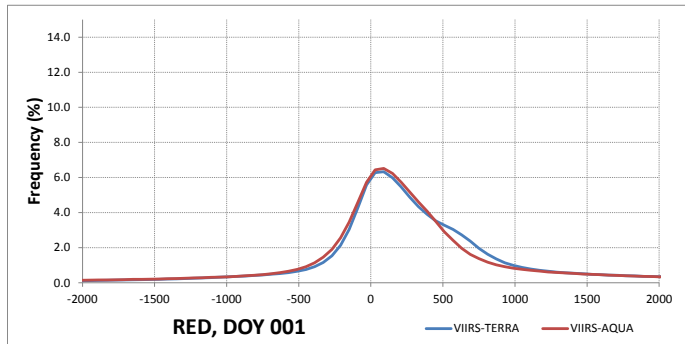
Using only the 3 yrs of overlap



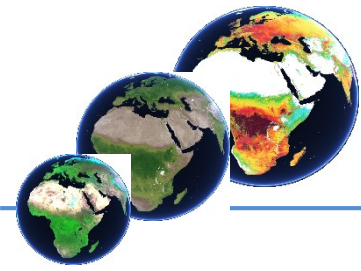


MODIS-VIIRS Difference (LSR)

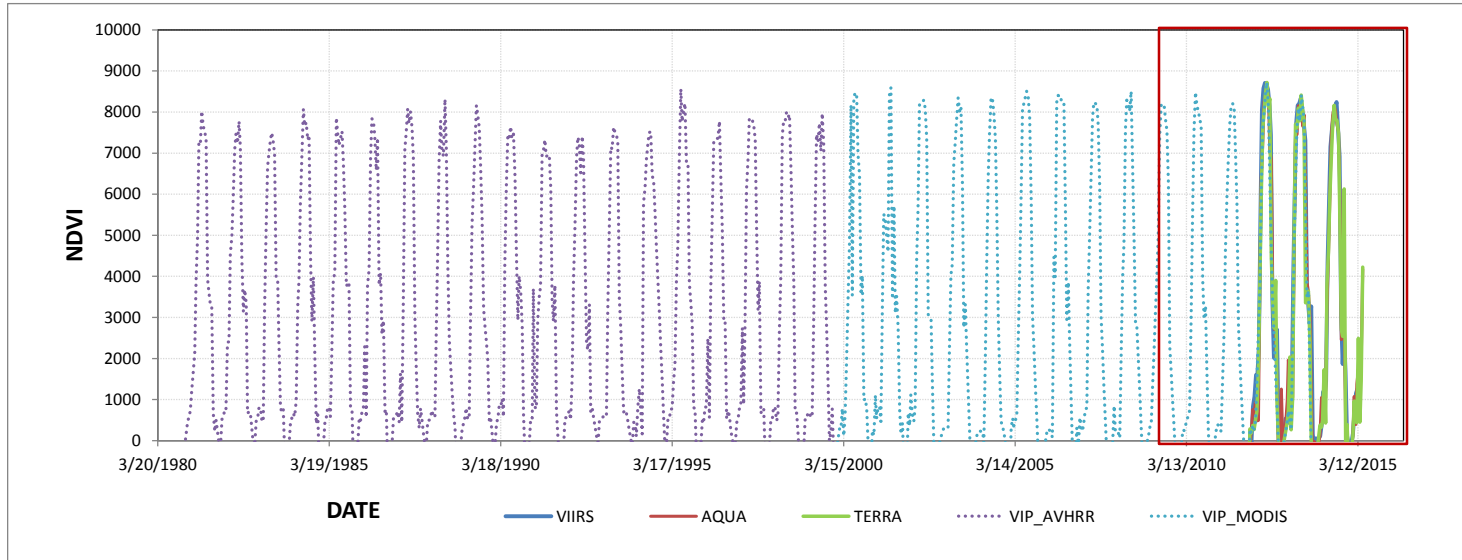
Using only the 3 yrs of overlap



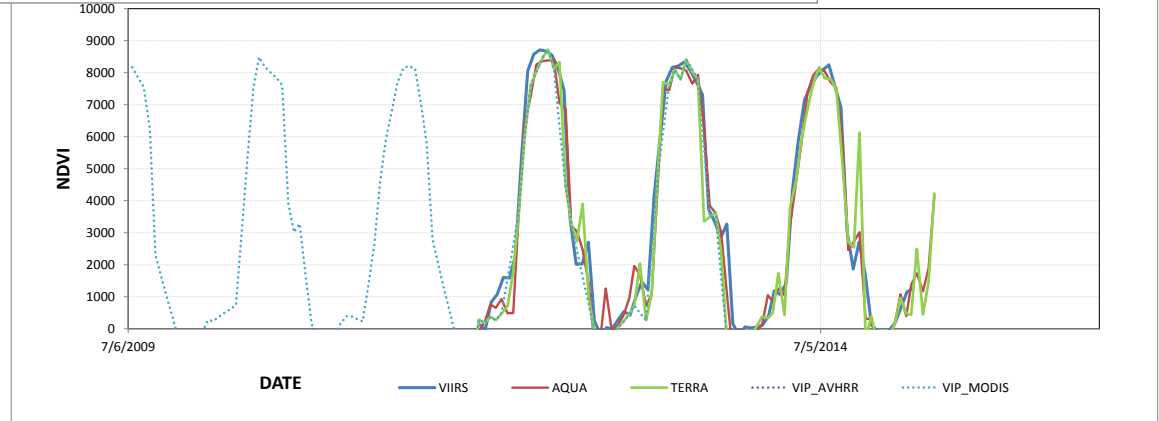
VIIRS NIR higher

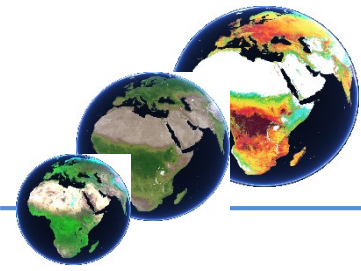


Time Series Performance (Taiga)

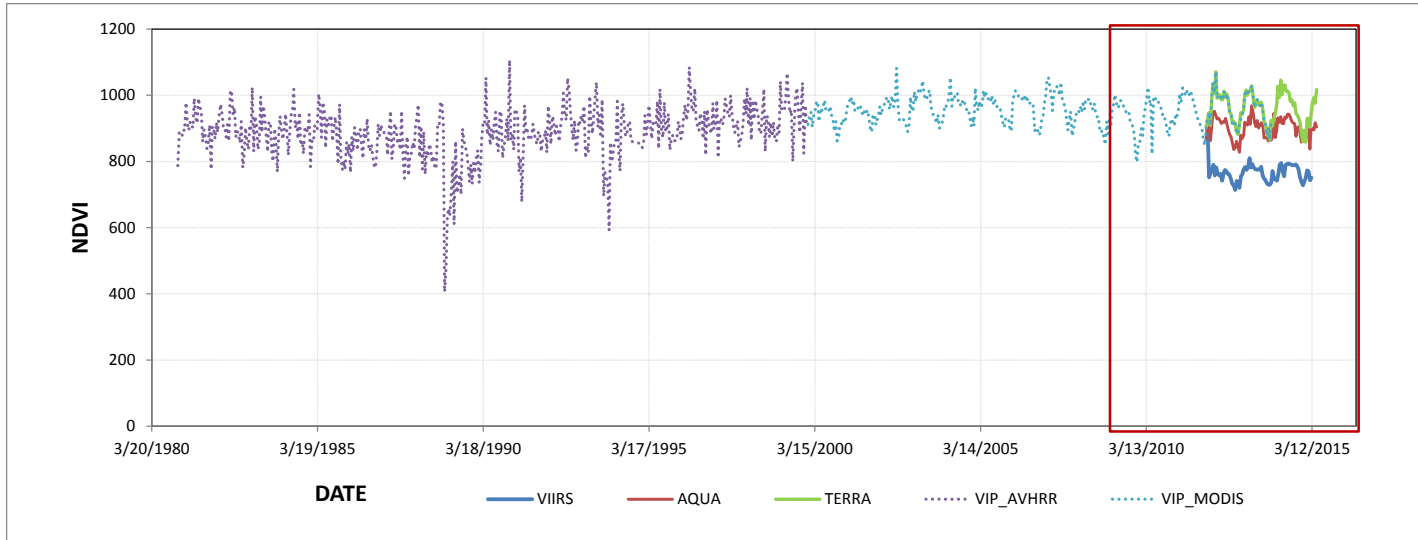


Replicates the shape and dynamic range

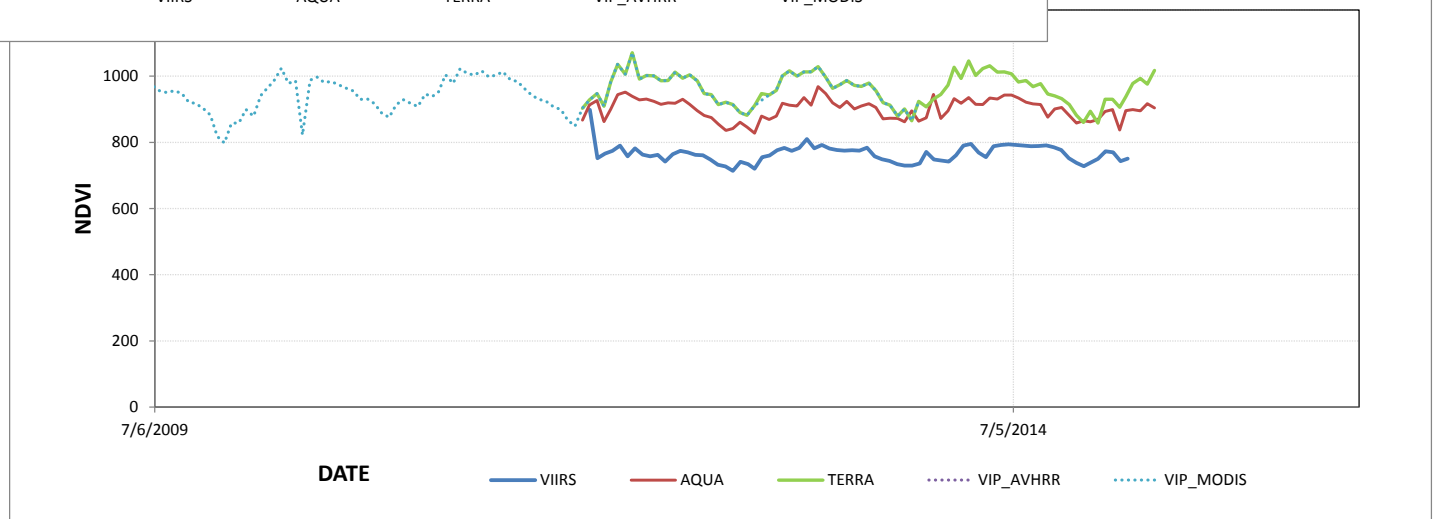


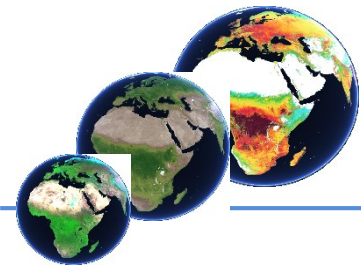


Time Series performance (Desert)

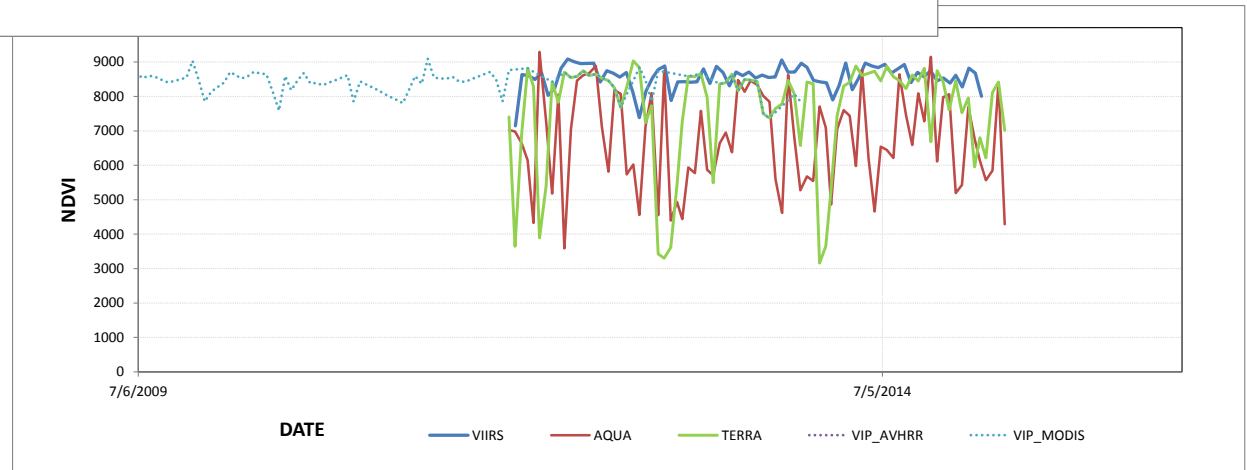
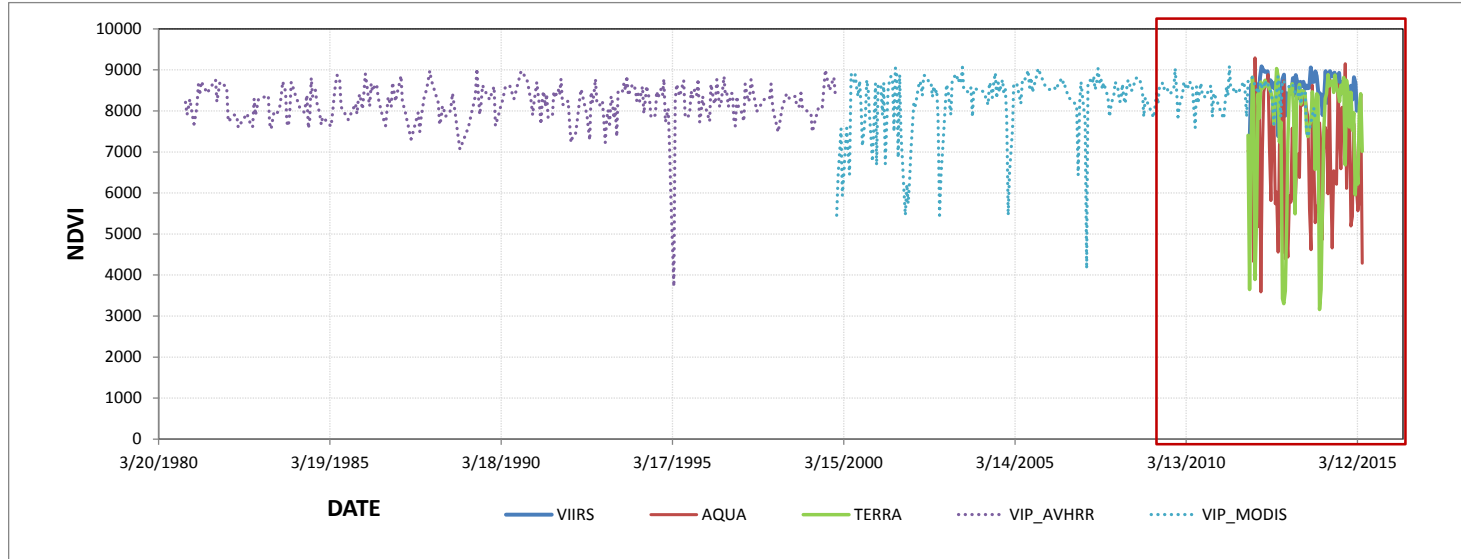


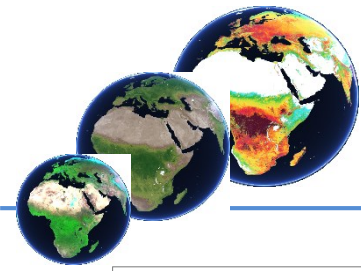
Different but not that bad (0.08-0.09, < 10%)



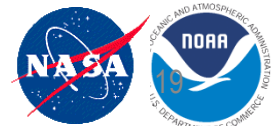
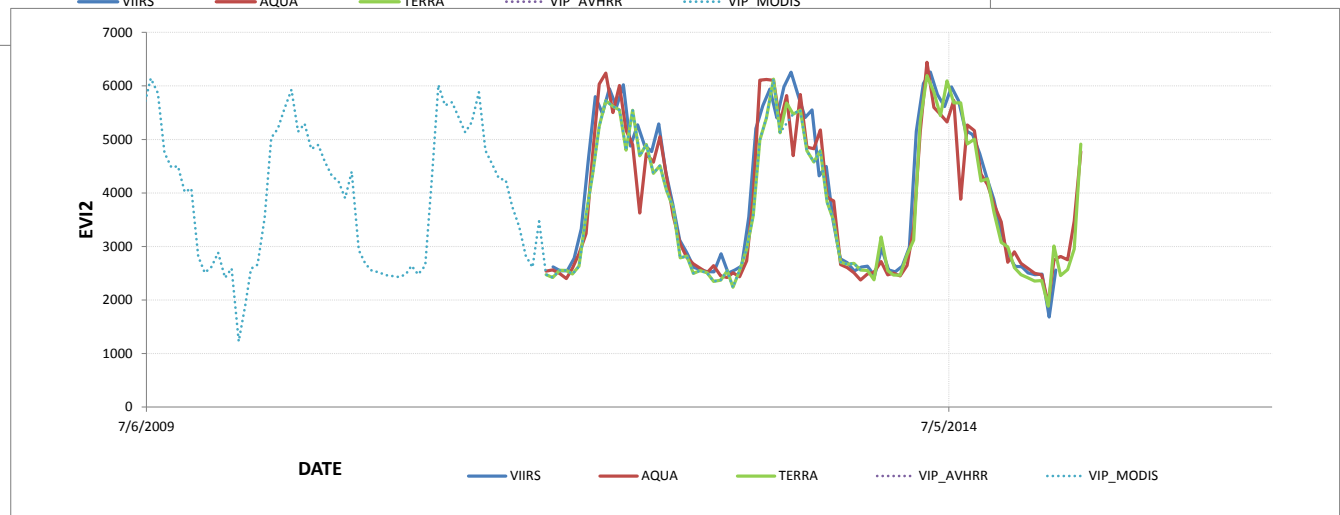
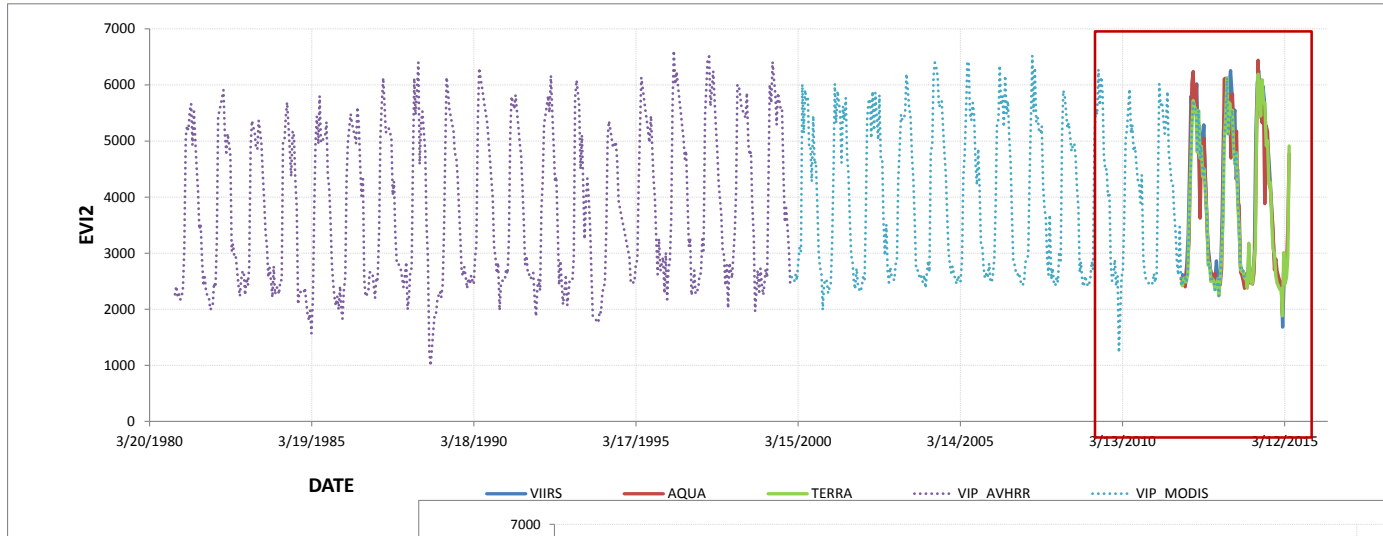


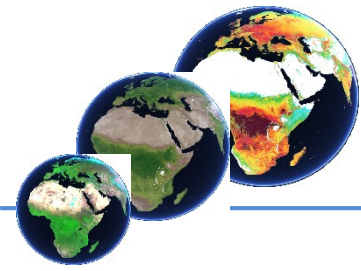
Time Series performance (Tropics)



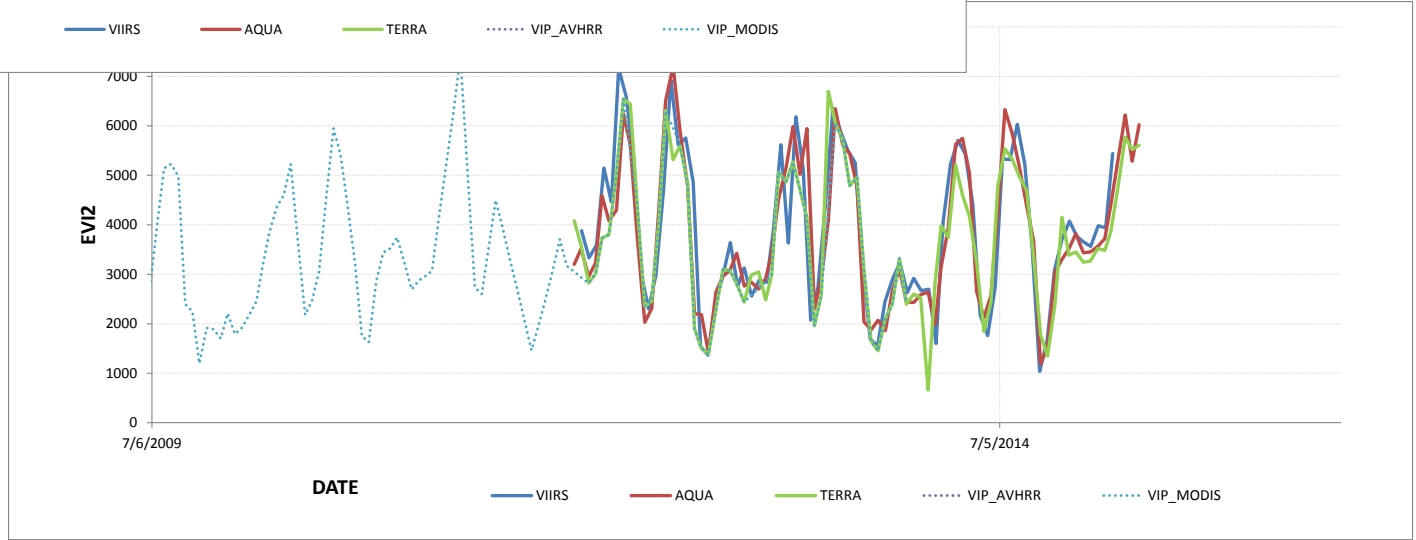
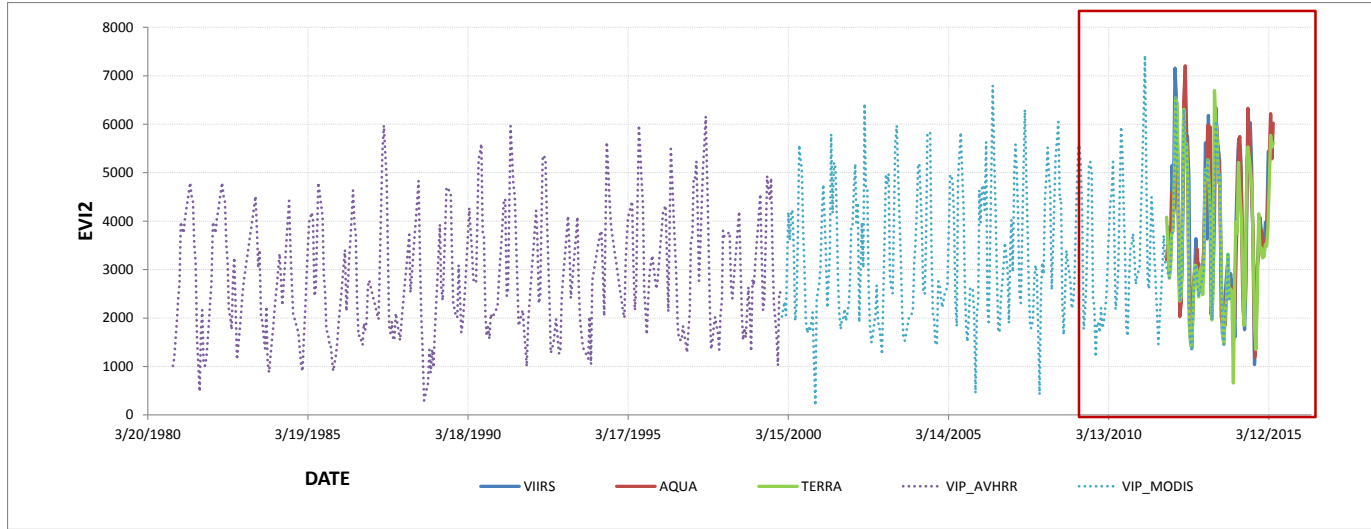


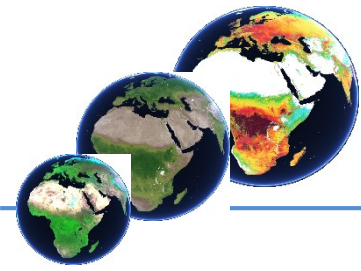
Time Series performance (Deciduous, Eastern US)





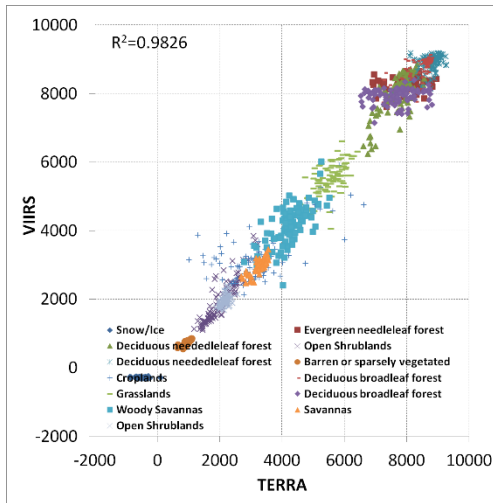
Time Series performance (Continuous crops, China)



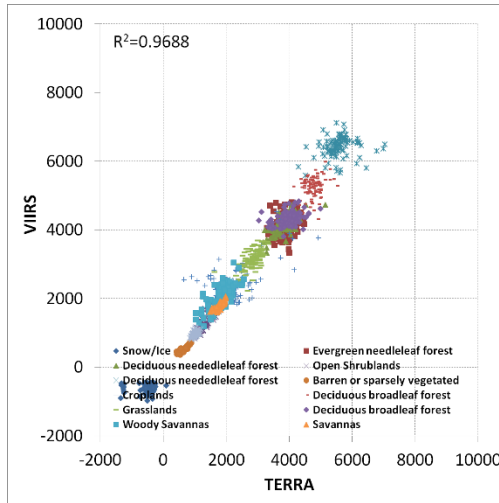


Data Records Correlations

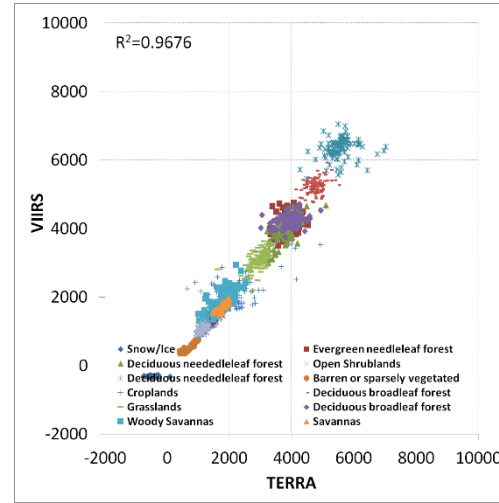
NDVI



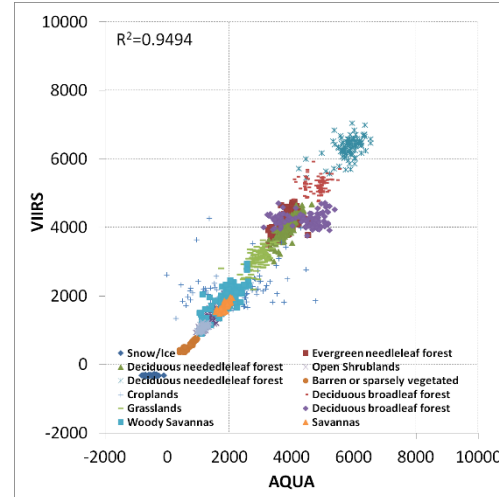
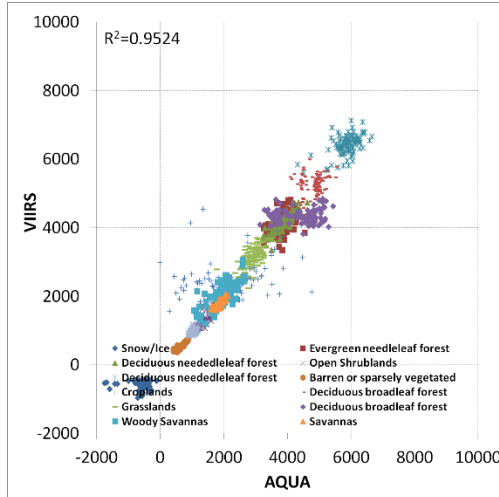
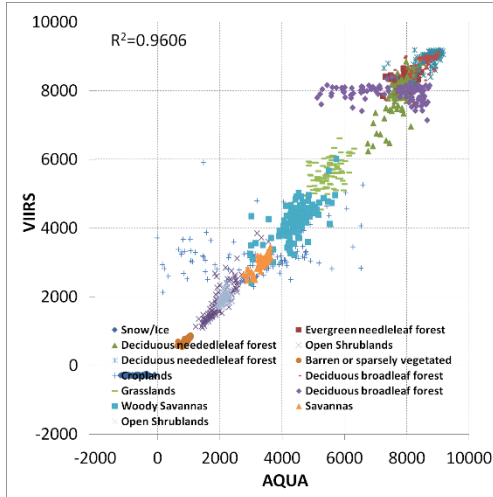
EVI

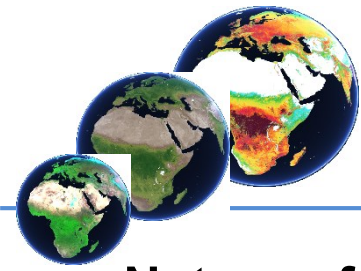


EVI2



$r^2 > 95\%$





Records Characterization

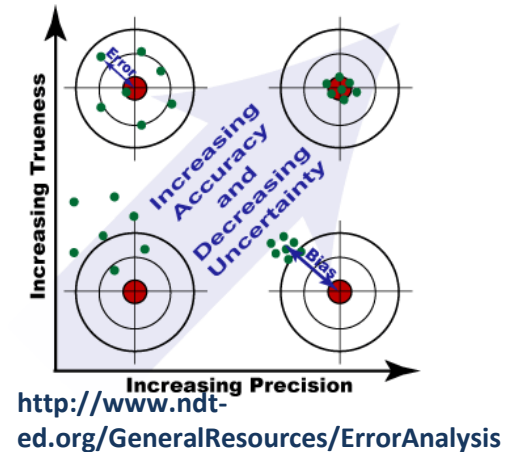
- Nature of data makes assessing error, uncertainty, precision very challenging

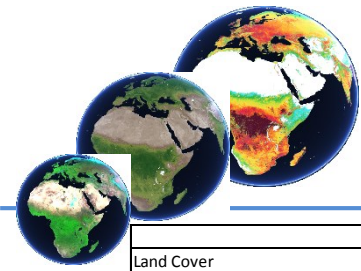
– Using field data

- Establish truth (perfectly corrected data)
- Compare against it using QA filtered data (validation, LPV method)
- Limited representation and scaling issues
- This is rather a validation of the algorithm under ideal conditions rather than real validation

– Statistical approach

- Calculate AVG, Calculate STDEV
- Uncertainty is a range between $AVG \pm STDEV$
 - Expressed as STDEV
- Precision = $(STDEV / AVG) * 100$
- Accuracy is the difference between the AVG and a true measurement (TERRA (long term average) was used as the true measurement)





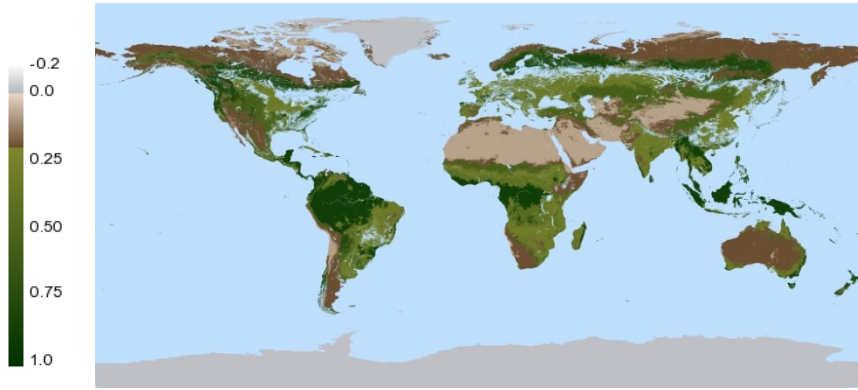
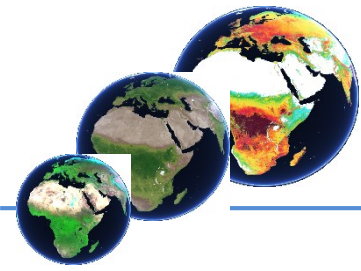
Global APU per LC class

Land Cover	VIIRS NDVI					TERRA NDVI					AQUA NDVI					
	AVERAGE	STDEV	UNCERTAINTY	PRECISION (%)	ACCURACY	AVERAGE	STDEV	UNCERTAINTY	PRECISION (%)	AVERAGE	STDEV	UNCERTAINTY	PRECISION (%)			
Snow/Ice	-0.029	0.001	-0.030	-0.028	-3.34	-0.013	-0.042	0.015	-0.057	-0.027	-36.102	-0.060	0.027	-0.087	-0.033	-41.413
Evergreen needleleaf forest	0.832	0.017	0.814	0.849	2.10	-0.028	0.803	0.042	0.761	0.846	5.280	0.383	0.028	0.355	0.411	2.961
Deciduous needleleaf forest	0.802	0.059	0.743	0.861	7.34	-0.028	0.774	0.044	0.730	0.819	5.741	0.386	0.029	0.358	0.415	4.737
Open Shrublands	0.196	0.062	0.133	0.258	31.81	0.008	0.204	0.047	0.157	0.251	23.175	0.137	0.026	0.111	0.163	24.711
Deciduous needleleaf forest	0.892	0.024	0.868	0.916	2.66	-0.012	0.880	0.028	0.852	0.907	3.155	0.587	0.037	0.550	0.624	4.107
Barren or sparsely vegetated	0.075	0.007	0.068	0.082	9.03	0.025	0.100	0.008	0.091	0.108	8.506	0.073	0.010	0.064	0.083	8.201
Croplands	0.323	0.066	0.257	0.390	20.58	0.003	0.327	0.102	0.225	0.429	31.229	0.220	0.094	0.126	0.315	51.444
Deciduous broadleaf forest	0.882	0.026	0.856	0.908	2.96	-0.036	0.846	0.034	0.812	0.880	4.066	0.479	0.030	0.449	0.508	3.979
Grasslands	0.550	0.049	0.501	0.599	8.85	0.004	0.554	0.044	0.510	0.598	7.897	0.290	0.028	0.262	0.317	7.908
Deciduous broadleaf forest	0.793	0.022	0.771	0.815	2.72	-0.022	0.771	0.058	0.713	0.829	7.523	0.441	0.059	0.382	0.501	13.959
Woody Savannas	0.416	0.057	0.359	0.473	13.77	0.009	0.425	0.051	0.374	0.476	12.091	0.195	0.035	0.160	0.231	13.443
Savannas	0.297	0.018	0.280	0.315	5.91	0.032	0.329	0.017	0.312	0.346	5.290	0.193	0.009	0.184	0.202	5.185
Open Shrublands	0.195	0.014	0.181	0.209	7.35	0.021	0.216	0.011	0.205	0.227	5.021	0.102	0.008	0.094	0.109	4.894
Land Cover	VIIRS EVI					TERRA EVI					AQUA EVI					
	AVERAGE	STDEV	UNCERTAINTY	PRECISION (%)	ACCURACY	AVERAGE	STDEV	UNCERTAINTY	PRECISION (%)	AVERAGE	STDEV	UNCERTAINTY	PRECISION (%)			
Snow/Ice	-0.055	0.012	-0.067	-0.043	-21.850	0.003	-0.052	0.030	-0.082	-0.022	-57.006	-0.060	0.027	-0.087	-0.033	-45.169
Evergreen needleleaf forest	0.408	0.031	0.377	0.439	7.589	-0.019	0.389	0.026	0.363	0.415	6.671	0.383	0.028	0.355	0.411	7.237
Deciduous needleleaf forest	0.415	0.028	0.387	0.443	6.703	-0.034	0.381	0.031	0.350	0.412	8.071	0.386	0.029	0.358	0.415	7.408
Open Shrublands	0.133	0.032	0.101	0.165	24.387	0.000	0.133	0.024	0.109	0.157	18.283	0.137	0.026	0.111	0.163	18.674
Deciduous needleleaf forest	0.642	0.030	0.613	0.672	4.610	-0.085	0.557	0.044	0.514	0.601	7.873	0.587	0.037	0.550	0.624	6.314
Barren or sparsely vegetated	0.061	0.008	0.053	0.069	13.163	0.014	0.074	0.010	0.064	0.084	13.614	0.073	0.010	0.064	0.083	13.003
Croplands	0.248	0.055	0.194	0.303	22.071	-0.024	0.224	0.069	0.154	0.293	31.028	0.220	0.094	0.126	0.315	42.892
Deciduous broadleaf forest	0.524	0.029	0.495	0.554	5.566	-0.051	0.473	0.024	0.449	0.497	5.167	0.479	0.030	0.449	0.508	6.252
Grasslands	0.312	0.030	0.282	0.342	9.596	-0.030	0.282	0.026	0.256	0.309	9.393	0.290	0.028	0.262	0.317	9.615
Deciduous broadleaf forest	0.435	0.020	0.415	0.455	4.646	-0.036	0.399	0.033	0.366	0.432	8.168	0.441	0.059	0.382	0.501	13.478
Woody Savannas	0.205	0.034	0.171	0.239	16.692	-0.022	0.183	0.032	0.151	0.215	17.355	0.195	0.035	0.160	0.231	18.069
Savannas	0.183	0.008	0.175	0.192	4.460	0.000	0.183	0.009	0.175	0.192	4.821	0.193	0.009	0.184	0.202	4.722
Open Shrublands	0.097	0.007	0.090	0.104	7.358	0.002	0.100	0.007	0.092	0.107	7.362	0.102	0.008	0.094	0.109	7.444
Land Cover	VIIRS EVI2					TERRA EVI2					AQUA EVI2					
	AVERAGE	STDEV	UNCERTAINTY	PRECISION (%)	ACCURACY	AVERAGE	STDEV	UNCERTAINTY	PRECISION (%)	AVERAGE	STDEV	UNCERTAINTY	PRECISION (%)			
Snow/Ice	-0.032	0.001	-0.033	-0.031	-3.467	-0.010	-0.042	0.012	-0.054	-0.029	-29.536	-0.054	0.015	-0.069	-0.038	-28.666
Evergreen needleleaf forest	0.406	0.029	0.377	0.435	7.099	-0.014	0.392	0.027	0.365	0.418	6.795	0.382	0.028	0.354	0.410	7.217
Deciduous needleleaf forest	0.399	0.036	0.363	0.435	9.058	-0.020	0.379	0.031	0.348	0.410	8.099	0.385	0.029	0.356	0.414	7.538
Open Shrublands	0.136	0.027	0.109	0.163	20.078	0.007	0.143	0.023	0.120	0.166	15.815	0.142	0.023	0.119	0.165	16.301
Deciduous needleleaf forest	0.634	0.030	0.604	0.664	4.726	-0.078	0.555	0.044	0.511	0.599	7.905	0.582	0.038	0.544	0.621	6.609
Barren or sparsely vegetated	0.063	0.010	0.053	0.073	16.189	0.018	0.081	0.013	0.068	0.094	16.410	0.078	0.012	0.066	0.091	15.723
Croplands	0.220	0.052	0.167	0.272	23.817	0.004	0.224	0.069	0.154	0.293	31.037	0.220	0.094	0.126	0.315	42.892
Deciduous broadleaf forest	0.522	0.022	0.500	0.545	4.283	-0.050	0.473	0.024	0.448	0.497	5.144	0.477	0.030	0.448	0.507	6.202
Grasslands	0.306	0.028	0.278	0.335	9.299	-0.015	0.291	0.027	0.264	0.318	9.293	0.290	0.028	0.262	0.318	9.585
Deciduous broadleaf forest	0.424	0.019	0.405	0.444	4.563	-0.029	0.395	0.033	0.363	0.428	8.323	0.438	0.062	0.376	0.499	14.047
Woody Savannas	0.194	0.033	0.162	0.227	16.765	-0.014	0.181	0.032	0.149	0.212	17.536	0.193	0.035	0.157	0.228	18.283
Savannas	0.176	0.009	0.167	0.185	4.944	0.007	0.183	0.010	0.173	0.193	5.322	0.190	0.009	0.181	0.199	4.854
Open Shrublands	0.106	0.008	0.098	0.114	7.367	0.007	0.113	0.009	0.104	0.122	8.163	0.113	0.010	0.104	0.123	8.405

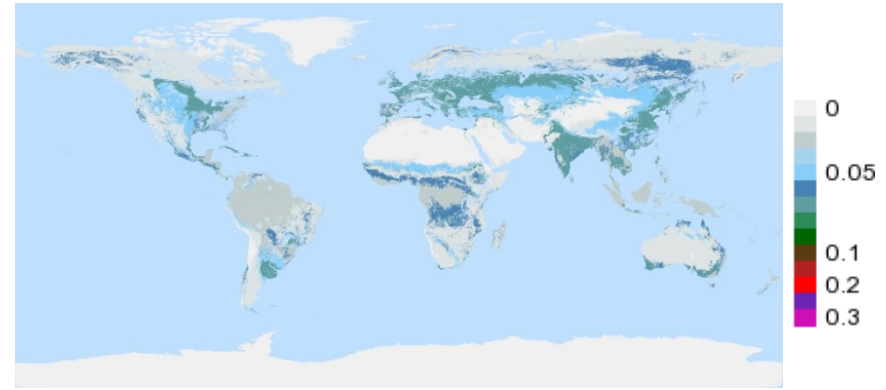
Remap values back on a LC map



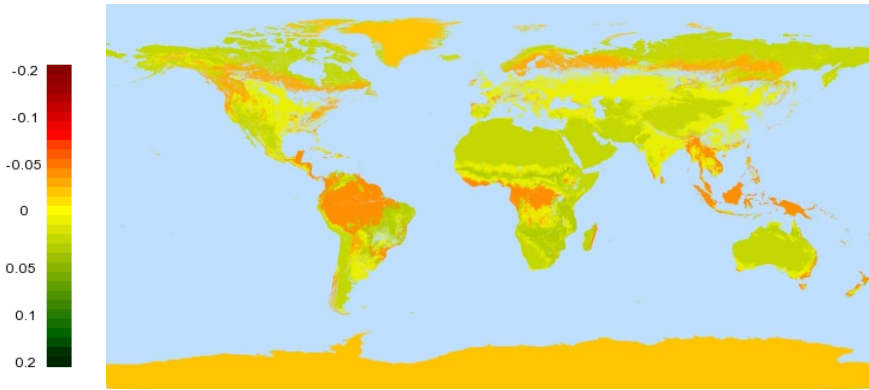
Global NDVI APU



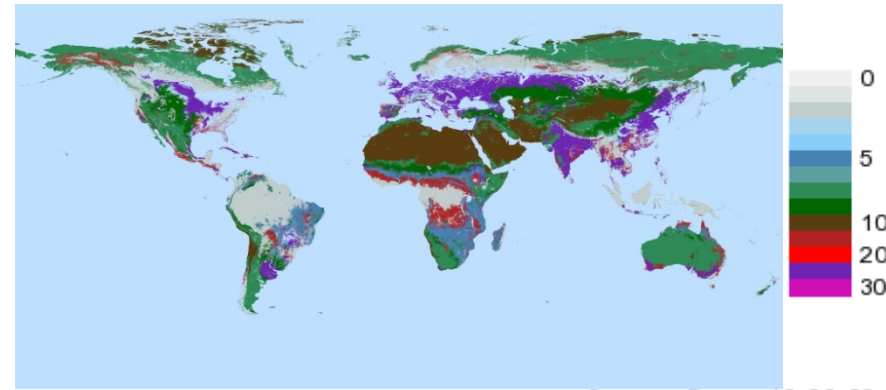
AVERAGE



STDEV



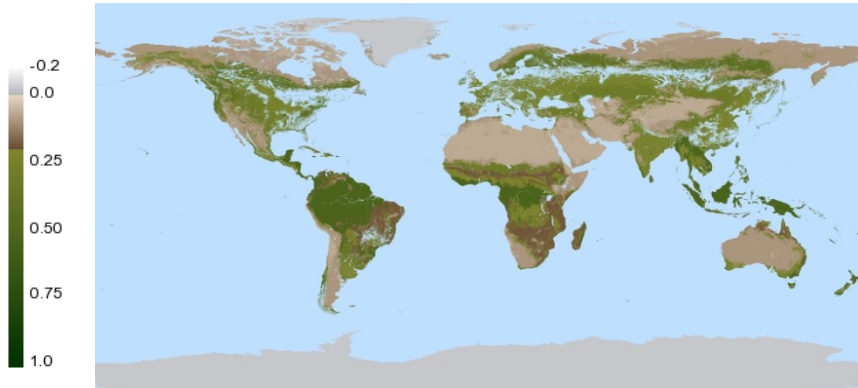
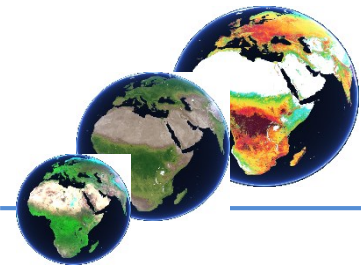
ACCURACY



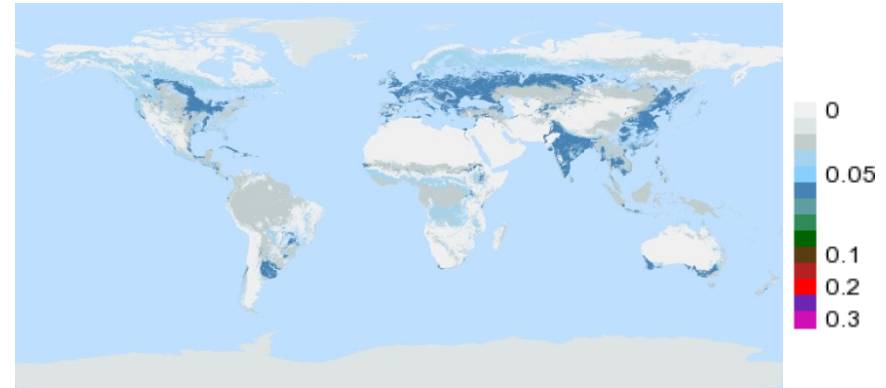
PRECISION



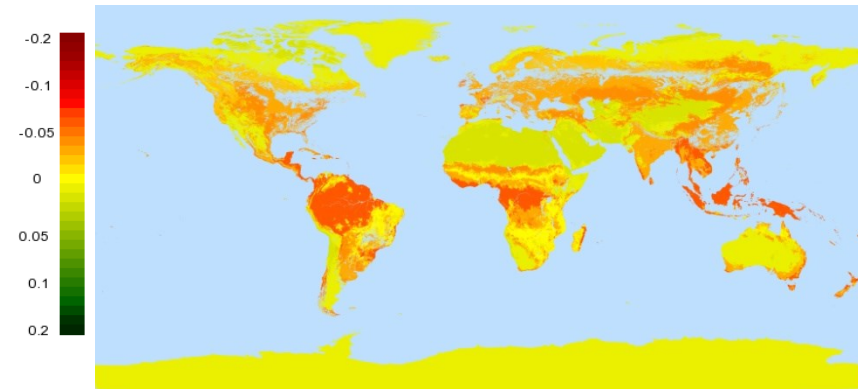
Global EVI APU



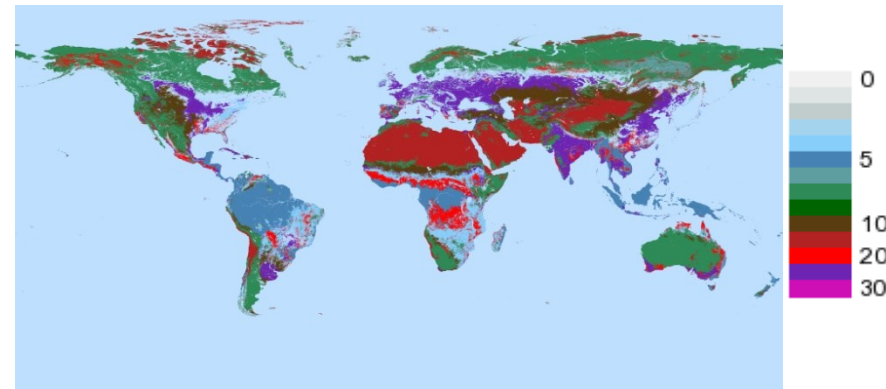
AVERAGE



STDEV

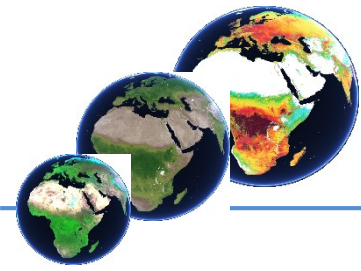


ACCURACY

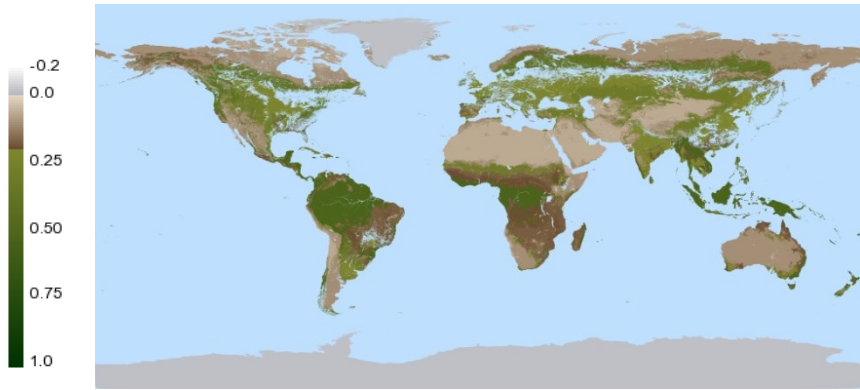


PRECISION

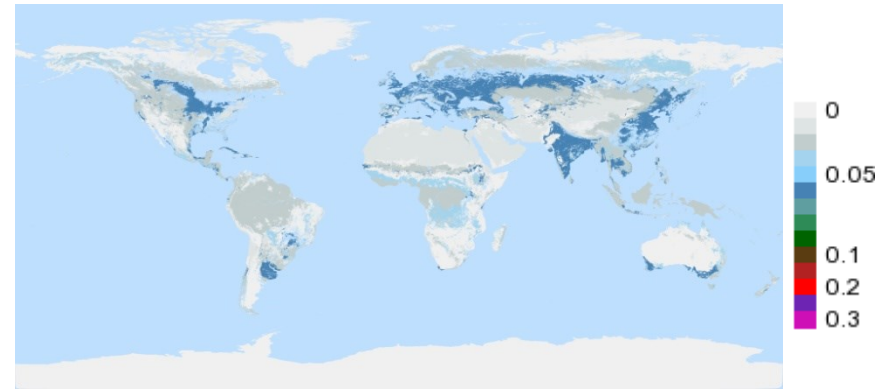




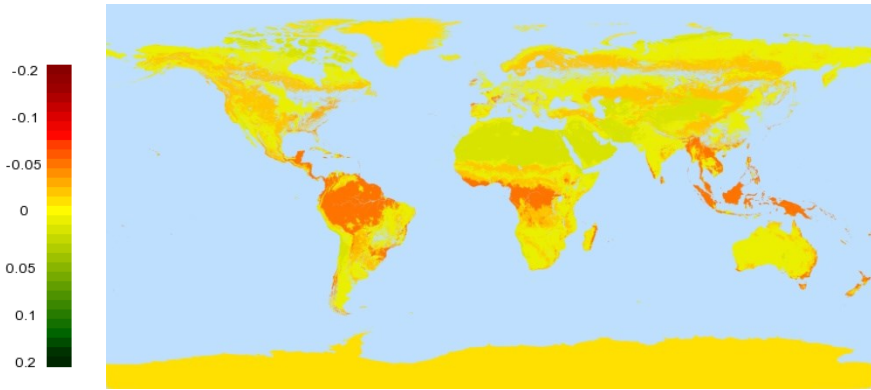
Global EVI2 APU



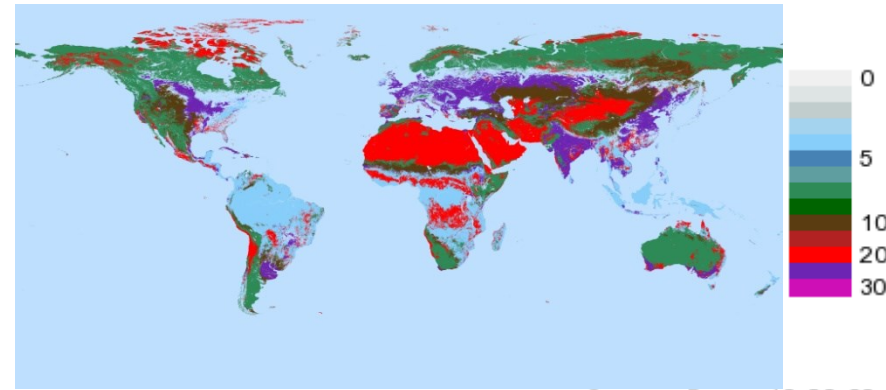
AVERAGE



STDEV

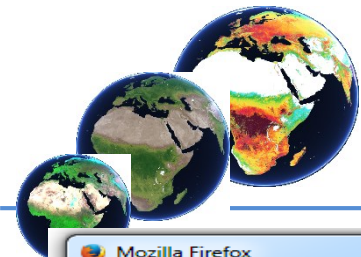


ACCURACY

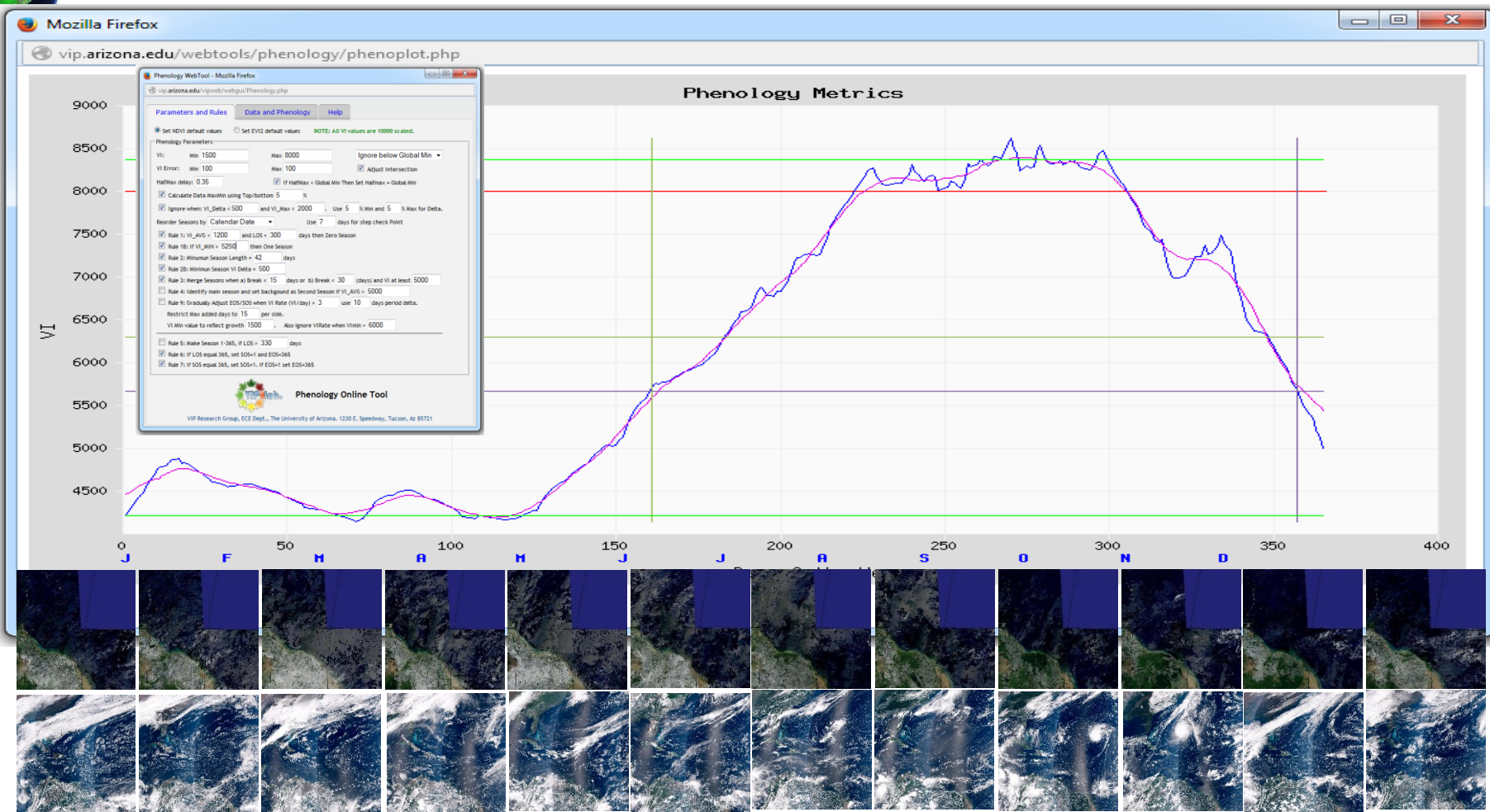


PRECISION (%)

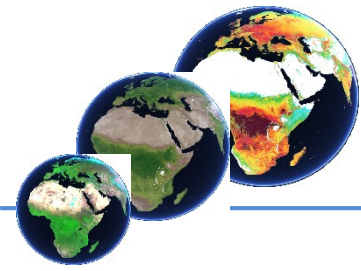




Residual clouds Implications on Vegetation Dynamics



Tropics (Suriname) yet residual clouds make it look like a crop with definite growing season shape



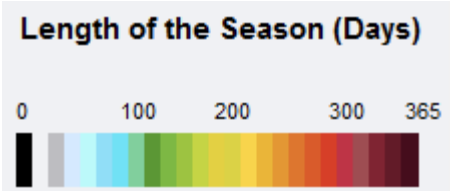
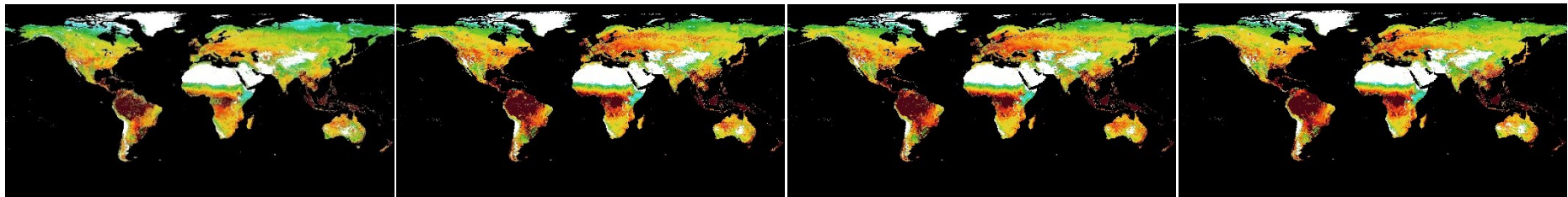
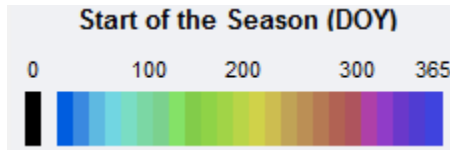
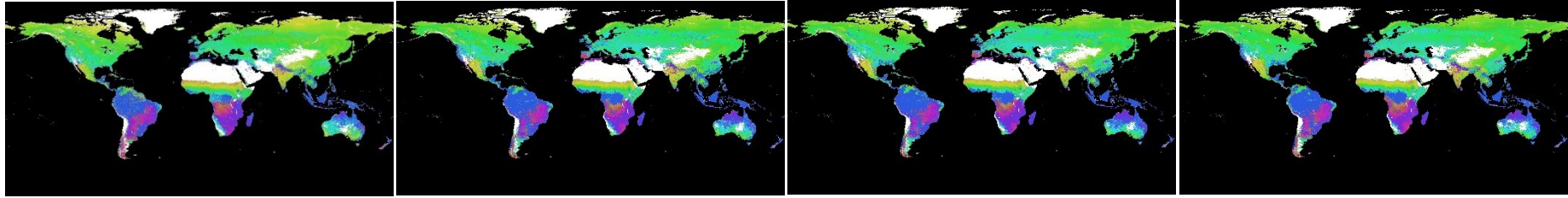
AVHRR-MODIS-VIIRS Phenology

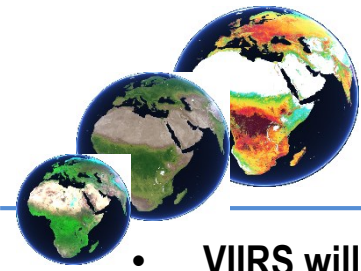
AVHRR '95

Terra '12-'14

Aqua '12-'14

VIIRS '12-'14

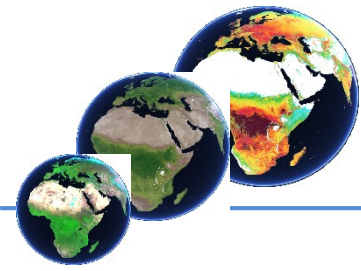




Learned lessons

- **VIIRS will definitely continue what MODIS has started (even AVHRR), However,**
- **Pervasiveness of Clouds, Aerosols, (especially at subpixel level)**
- **Compositing** is the only practical way to improve the data
 - Issues with Omission (Commission is actually OK, you simply discard)
 - Issues with predefined composite period
 - Snow/Ice background, especially early spring (partial melt)
- **What can we do**
 - Need to be aggressive with clouds flagging (masking)
 - It is by far the most impairing to the data record
 - Makes no sense to generate and distribute data with clouds. Thinking back why did we do it with MODIS?
 - Dynamic composite period and/or shorter period
 - Cannot treat Tropics the same as Sahel, US Southwest, Australia for example (why fixed 16 days)
 - Continuity of the indices (EVI3/EVI2, transition to full EVI2)
- **Focus on convergence in reprocessing**
 - The MODIS reprocessing strategy C3, C4, C5, C6 should probably not be repeated with S-NPP VIIRS
 - Need convergence plans or in response to validation/characterization findings? Need more flexibility
- **BRDF Correction** : Collective solution while knowing will not satisfy everyone (what method?, what level? etc...)
- **Gap filling** (needs creativity and more work)
- **Recall a MODIS/VIIRS Data user will face a simple decision [USE] or [DoNotUSE]**
 - We need to provide them with a better way to decide and eliminate potential mistakes by reducing “garbage” data





BACKUP SLIDES



Approach – Products interdependencies

- Level 3 native 375 m, and 500m, 1km, and CMG to maintain spatial continuity with MODIS
- 16-day, monthly, and new quasi-daily
- These choices may have to change to accommodate other land products, team consensus, feasibility, and interdependencies

