Reprocessing with the S-NPP VIIRS Common Matchup Tool

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Motivation: Assessing Impact of VIIRS Algorithm and LUT Changes is Difficult

- VIIRS, the Visible Infrared Imaging Radiometer Suite on the Suomi NPP satellite, measures cloud and aerosol properties, ocean color, sea and land surface temperature, vegetation indices, ice fraction and temperature, fires, Earth's albedo.

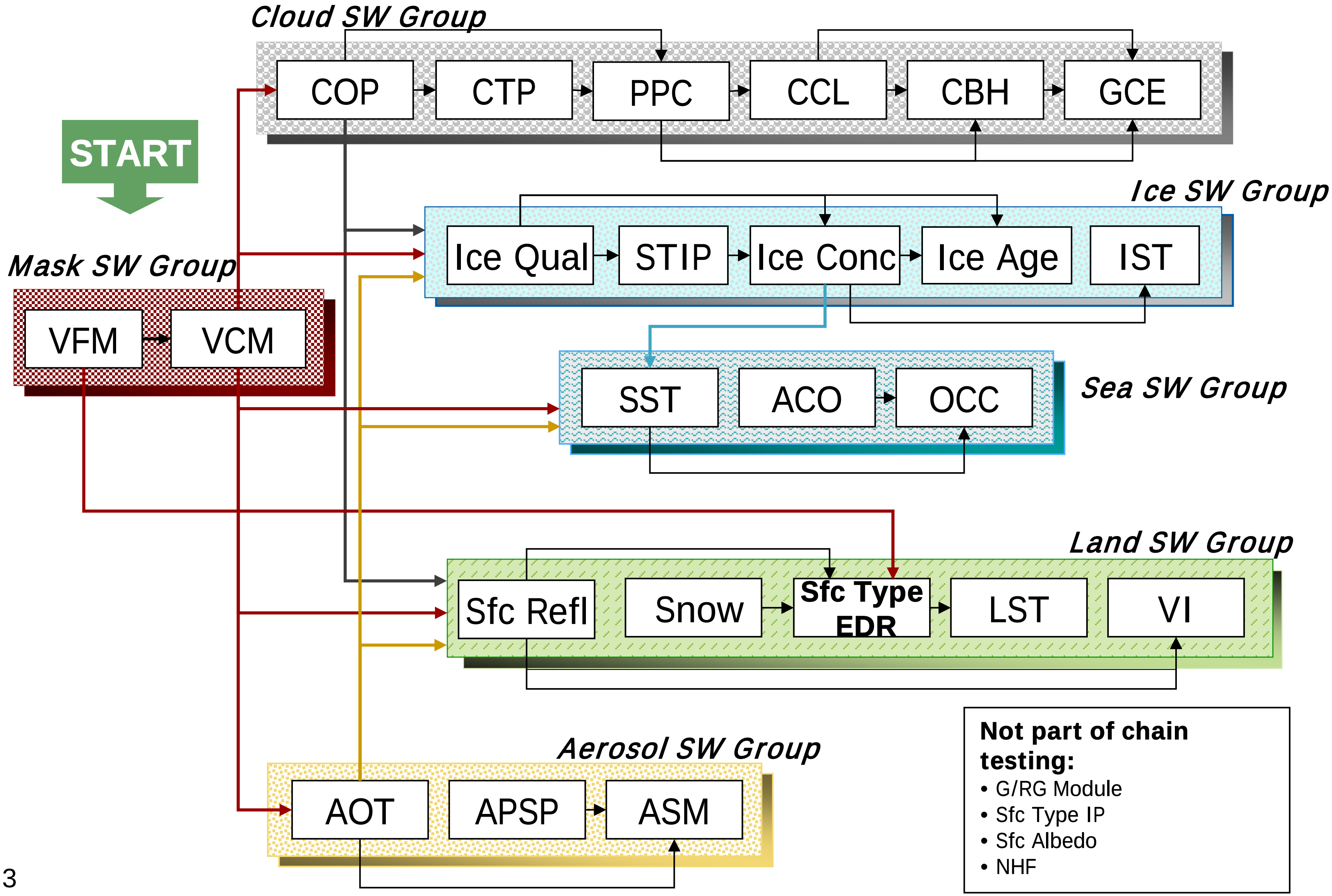
- The VIIRS data processing chain is complex.
  - dozens of algorithms
  - hundreds of look-up tables (LUT's), configurable parameter files, seed files
  - LUT's periodically updated; need schedules of effectivity

- Upstream LUT's and algorithms affect numerous downstream products.

- Difficult to assess effect of LUT, algorithm changes on product quality.
  - Computationally intensive to run granules spanning a wide variety of conditions (seasons, land types, cloud fraction)
  - Need *in situ* data to assess product quality at each candidate granule.

- These difficulties are part of the reason VIIRS does not yet have a climate record.

Simplified VIIRS Algorithm Chain



Not part of chain testing:
- G/RG Module
- Sfc Type IP
- Sfc Albedo
- NHF

Solution, Part I: VIIRS Common Matchup Tool

- Needed: an efficient way to run portions of the VIIRS algorithm chain.

- Our solution: only reprocess small cutouts produced by the VIIRS CMT.

- The VIIRS Common Matchup Tool is implemented in the following PGE's currently running on GRAVITE:
  - Aerosol Optical Thickness, Cloud Mask, Surface Reflectance, Vegetation Index—Aeronet matchup
  - Land Surface Temperature—SURFRAD matchup
  - Ice Surface Temperature—campaign matchup (ad hoc)
  - Surface Reflectance, Vegetation Index—Aeronet matchup and 6S inversion

- Each matchup PGE runs daily. Output from one matchup run consists of an HDF 5 file for the governing VIIRS algorithm (for example, aerosol optical thickness).

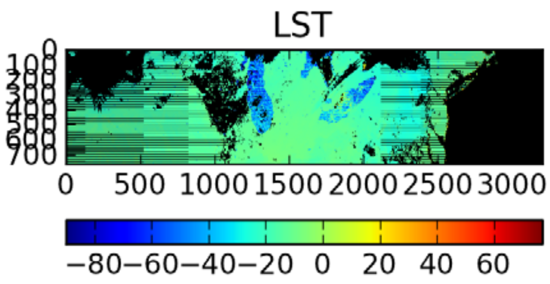
- The HDF 5 file contains cutouts around each pixel matched to *in situ* data for every input used by the governing VIIRS algorithm.

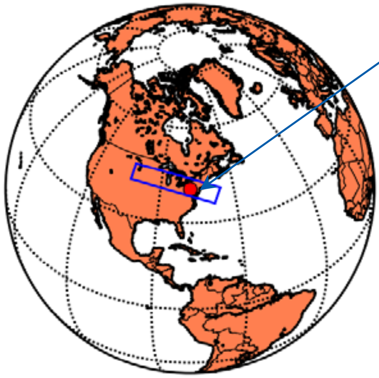
- <u>The HDF 5 file contains all information needed to reprocess a cutout from sensor data record (SDR) to environmental data record (EDR).</u>

Example of LST Cutout

- 11 x 11 pixels of `/All_Data/VIIRS-LST-EDR_All/LandSurfaceTemperature` in °C

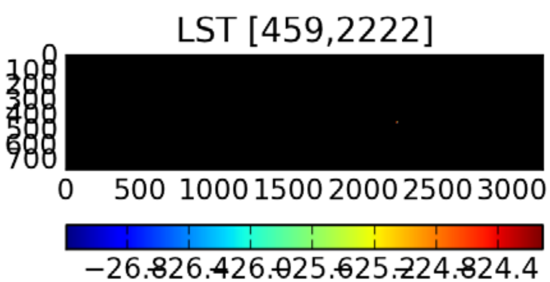
Full granule; 768 x 3200 pixels

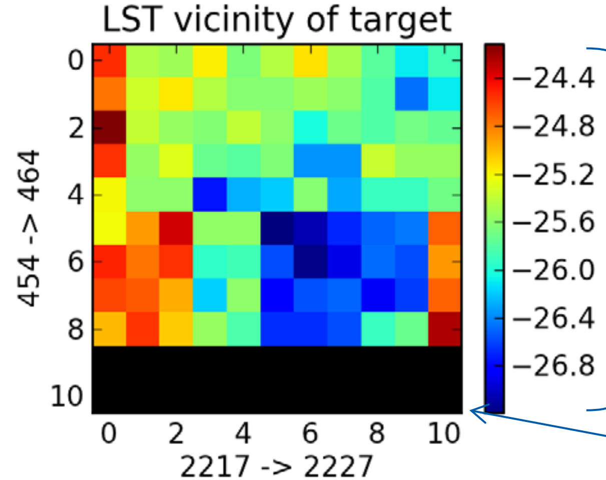




Penn State SURFRAD observation matched in time and space to pixel in center of 11 x 11 cutout.

Full granule where all pixel values replaced with fill except cutout centered at 459, 2222





11 x 11 cutout

bowtie region

LST, AOT, SR, EVI cutouts

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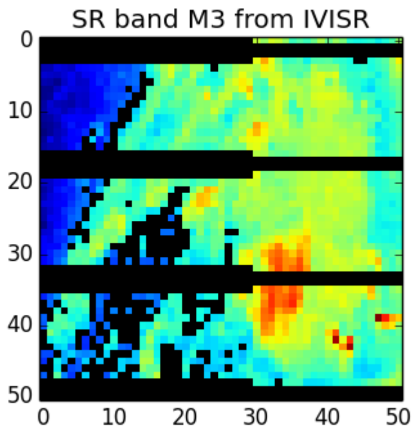
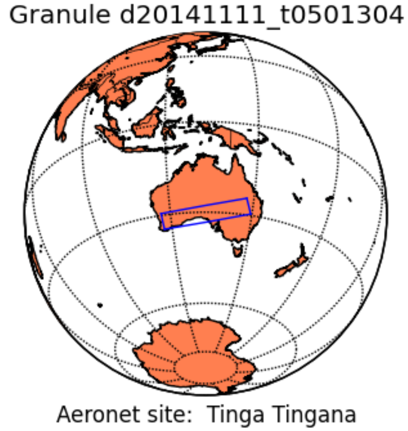
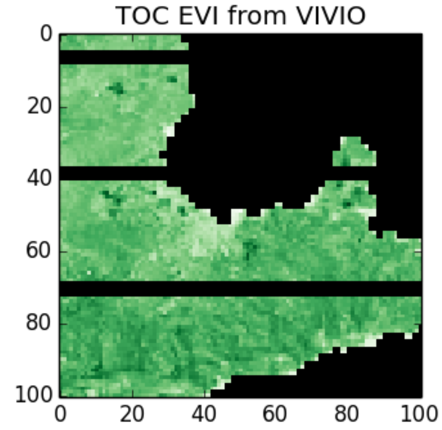
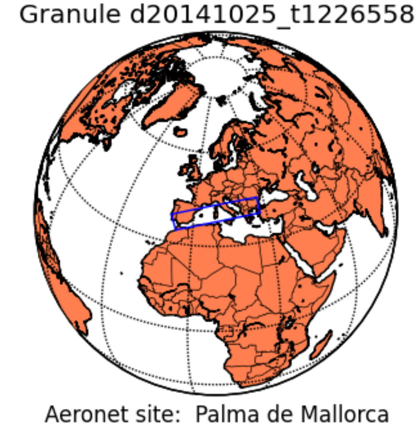
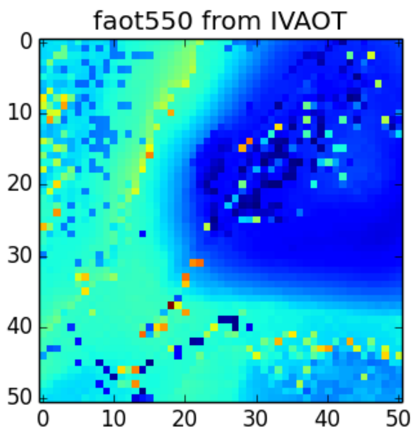
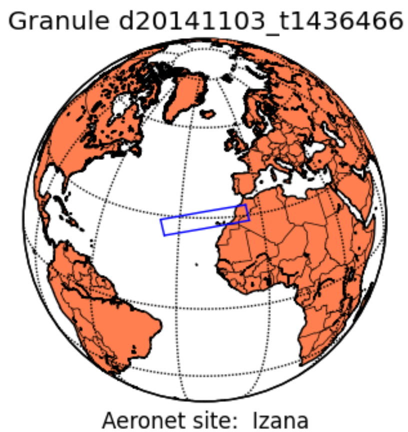


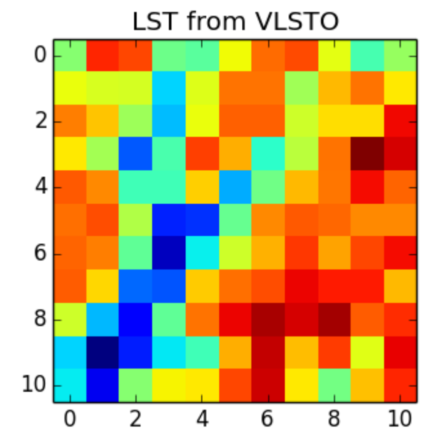


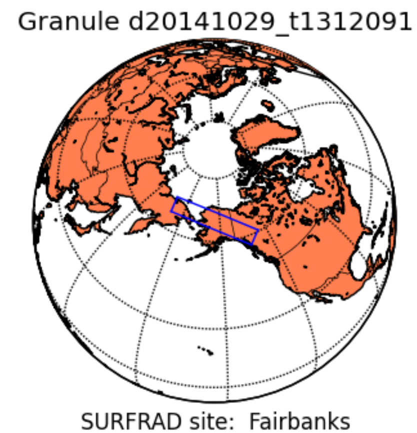












S-NPP travels in daytime ascending orbit. Cutouts appear w/North on bottom edge; South on top.

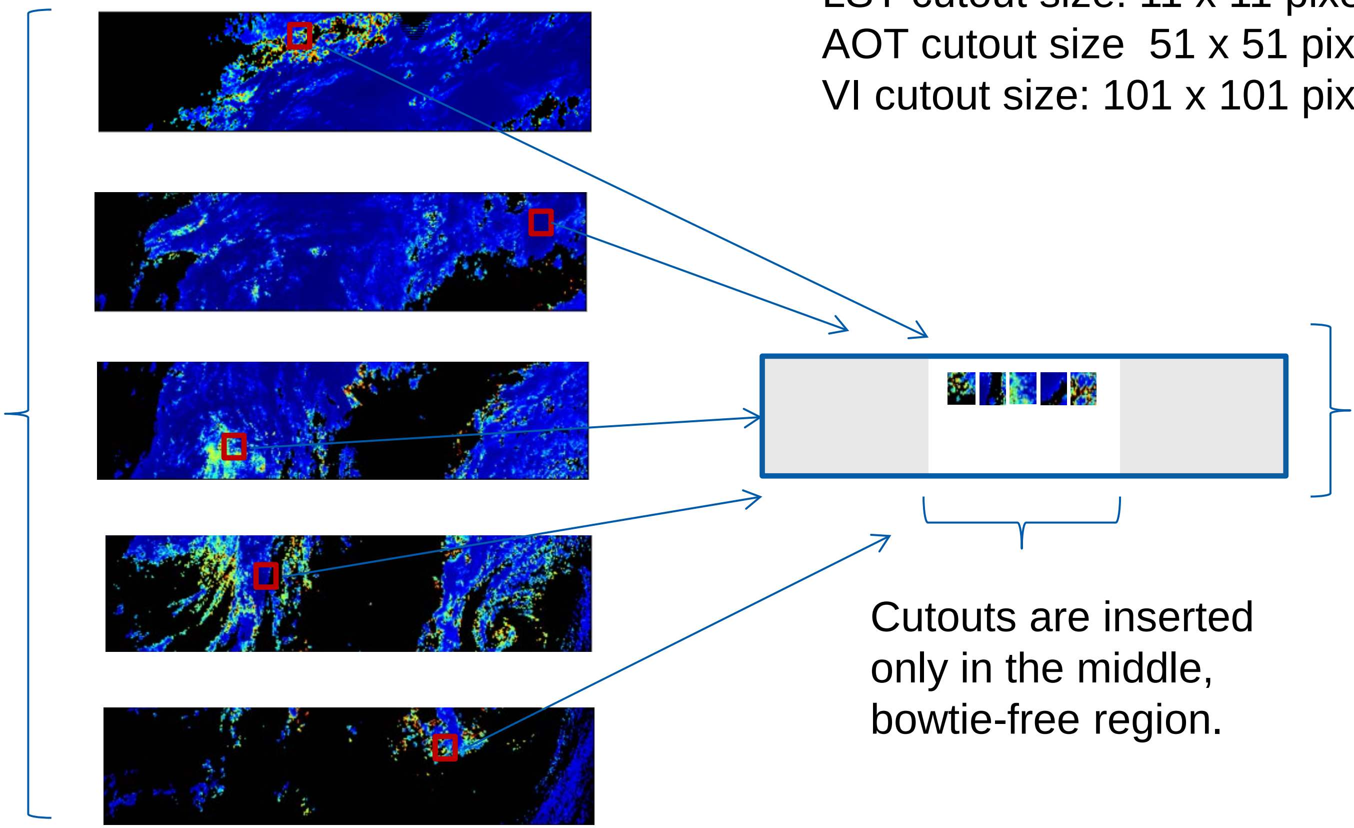
VIIRS Matchups at GRAVITE

- The VIIRS Common Matchup Tool has produced a wealth of cutouts with corresponding *in situ* data.
  - VIIRS results are reproducible with Algorithm Data Library (ADL) running on Linux.
  - Matchups cover a wide range of geographic sites, seasons, atmospheric conditions.
- VIIRS Common Matchup Tool outputs available from GRAVITE https://gravite.jpss.noaa.gov/login

PGE	VIIRS Product	Matchup Product Filename	PGE Active Since	# of complete Matchups as of 2014-11-02
Aeronet Matchup	AOT	ProEdrViirsAerosol_*.h5	2012-04-12	20,323
Aeronet Matchup	CM	PRO_VIIRS_CM_*.h5	2012-04-11	31,149
Aeronet Matchup	SR	PRO_VIIRS_SR_*.h5	2012-04-11	22,113
Aeronet Matchup	VI	PRO_VIIRS_VI_*.h5	2012-04-11	21,950
SURFRAD Matchup	LST	PRO_VIIRS_LST_*.h5	2012-05-01	63,313

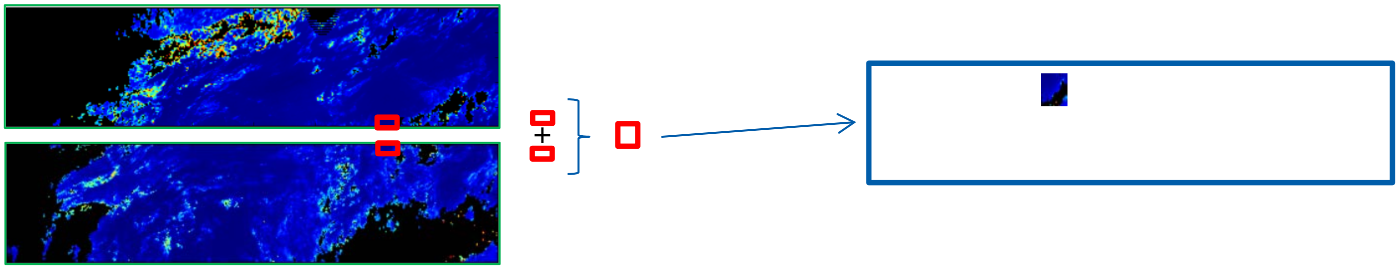
Solution, Part II: Recombine cutouts into SDR granules

- To reprocess rapidly, the VIIRS Reprocessing Tool creates new sensor data record (SDR) granules by packing together hundreds of cutouts.



Cross-Granule Cutouts

- The Common Matchup Tool saves all portions of cutouts that straddle granules in the in-track direction.
- The VIIRS Reprocessing Tool reassembles cross-granule cutouts and can reprocess them correctly.



Solution, Part III: Run ADL w/New Granules

- The VIIRS reprocessing tool reads an algorithm's XML files to determine which inputs are needed.
- The new cutout-populated SDR and IP (intermediate product) granules produce results at matchup sites 100's x faster than original granules because 100's of cutouts can be squeezed into an empty granule.
- Three months of VIIRS aerosol matchups reprocessed in 6 hours on one Linux computer.

Tool Validation

- The reprocessing software and scripts to set up the ADL runs can fail in many ways.

- Software was validated with two top-level tests:

  – Test 1: Fill the empty template granule with multiple copies of the same cutout.

    Does the same solution appear in the output?

  – Test 2: Fill the empty template granule with just one cutout, then reprocess both the template granule, and the original unmodified , fully populated IDPS granules.

    Do the outputs at the cutout location match?

- We were confident that the tool worked as intended after the tool passed both tests for a variety of VIIRS algorithms.

Results

- In the following charts, the blue lines represent original EDR and IP output by the Interface Data Processing Segment ,IDPS, which performs S-NPP ground processing.
- Red and green lines represent solutions from two different builds of ADL driven by inputs created with the VIIRS Reprocessing Tool.
- Results are in close agreement after IDPS switched over to the same algorithms used in the reprocessed runs.
- Results cannot match perfectly for two reasons
  1. Round-off differences between big-endian IBM RS/6000 computers (64 bit on-chip floating point ops) running IDPS v. little-endian, Intel-based (80 bit on-chip floating point ops) Linux machines running ADL.
  2. SDR's captured by the Common Matchup Tool are mostly scaled uint16's instead of floating point SDR's used internally by IDPS.

VIIRS Aerosol / AERONET Monthly Match-up Statistics over Land (EDR / Area Match-up)

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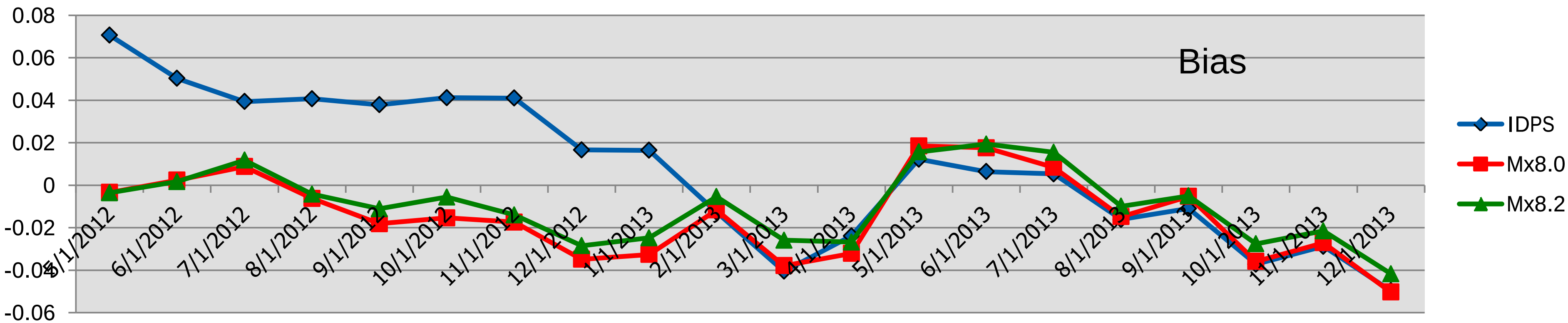
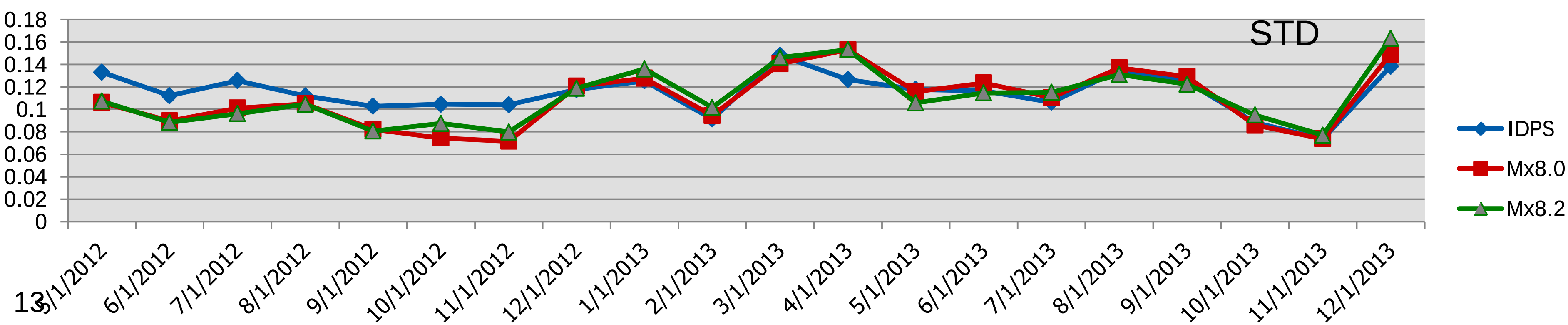
Land AOT at 550 nm EDR

Number of Match-ups	5/1/2012	6/1/2012	7/1/2012	8/1/2012	9/1/2012	10/1/2012	11/1/2012	12/1/2012	1/1/2013	2/1/2013	3/1/2013	4/1/2013	5/1/2013	6/1/2013	7/1/2013	8/1/2013	9/1/2013	10/1/2013	11/1/2013	12/1/2013
IDPS	208	182	305	345	563	798	288	368	620	431	538	750	830	794	1072	961	685	334	539	422
Mx8.0	66	58	213	278	511	618	222	287	412	374	376	533	569	538	777	741	485	293	444	210
Mx8.2	64	57	207	277	512	616	216	281	411	371	371	522	560	534	762	733	472	291	439	207
Bias																				
IDPS	0.0706	0.0503	0.0394	0.0407	0.0379	0.0412	0.041	0.0166	0.0164	-0.0127	-0.0405	-0.0239	0.0122	0.0064	0.0053	-0.0161	-0.011	-0.0372	-0.0288	-0.0497
Mx8.0	-0.0034	0.0024	0.0088	-0.0062	-0.0181	-0.0154	-0.0174	-0.0349	-0.0326	-0.0117	-0.0379	-0.0321	0.0185	0.0176	0.0084	-0.0148	-0.0053	-0.0359	-0.0271	-0.0503
Mx8.2	-0.0036	0.0017	0.0118	-0.0042	-0.0111	-0.0056	-0.014	-0.0285	-0.0248	-0.0054	-0.0259	-0.0268	0.0157	0.0194	0.0155	-0.0099	-0.005	-0.0276	-0.0215	-0.0417
STD																				
IDPS	0.1331	0.1121	0.1256	0.1119	0.1028	0.1045	0.1041	0.1176	0.1254	0.0913	0.1481	0.1265	0.1178	0.1164	0.1063	0.1347	0.1246	0.0881	0.0738	0.1383
Mx8.0	0.1061	0.0897	0.1011	0.1049	0.0822	0.0744	0.0716	0.1206	0.1277	0.0945	0.1407	0.153	0.1157	0.1235	0.1105	0.137	0.1292	0.0861	0.0737	0.1493
Mx8.2	0.1073	0.0884	0.0961	0.1045	0.0806	0.0874	0.0798	0.1188	0.1359	0.1017	0.1462	0.1532	0.1057	0.1147	0.1151	0.1309	0.1224	0.0949	0.0769	0.1633





VIIRS Aerosol / AERONET Monthly Match-up Statistics over Land (EDR / Central Pixel Match-up)

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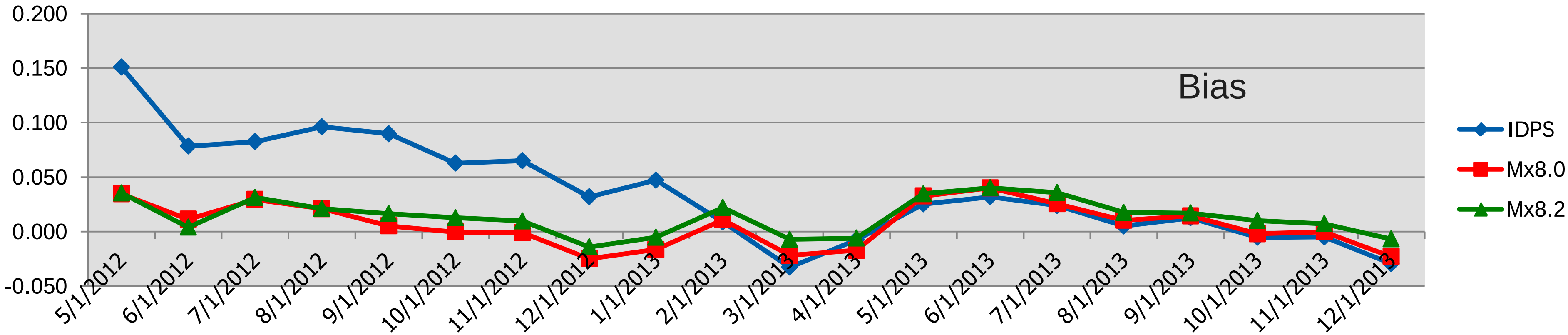
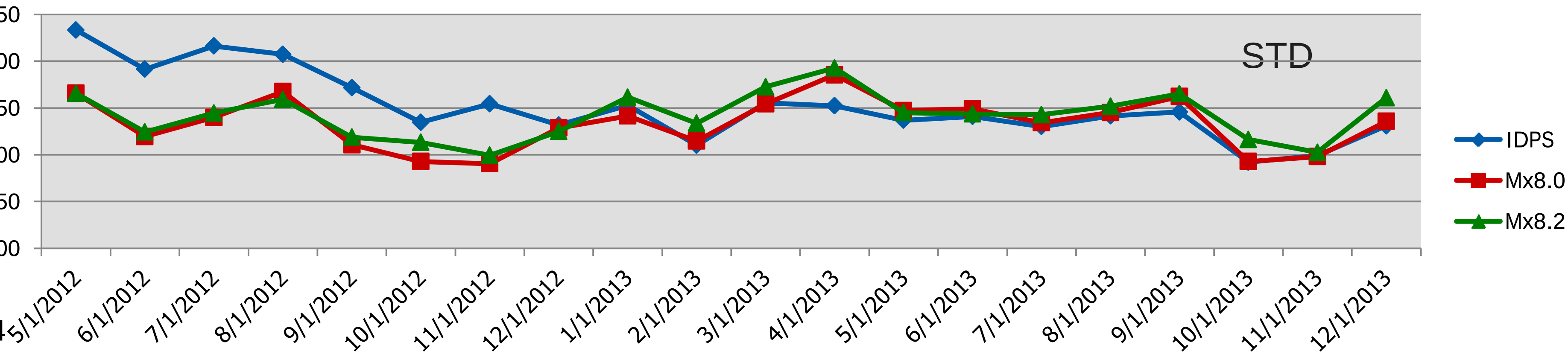
Land AOT at 550 nm EDR																				
Number of Match-ups	5/1/2012	6/1/2012	7/1/2012	8/1/2012	9/1/2012	10/1/2012	11/1/2012	12/1/2012	1/1/2013	2/1/2013	3/1/2013	4/1/2013	5/1/2013	6/1/2013	7/1/2013	8/1/2013	9/1/2013	10/1/2013	11/1/2013	12/1/2013
IDPS	159	139	224	236	431	641	208	290	446	279	390	527	620	579	829	712	539	261	414	319
Mx8.0	59	50	151	185	408	504	160	228	311	259	286	374	451	424	624	589	390	234	340	158
Mx8.2	59	49	151	184	404	494	157	226	309	253	277	367	436	416	614	577	383	232	336	155
Bias																				
IDPS	0.151	0.078	0.083	0.096	0.090	0.063	0.065	0.032	0.047	0.009	-0.033	-0.008	0.025	0.032	0.024	0.005	0.013	-0.005	-0.005	-0.029
Mx8.0	0.035	0.011	0.029	0.021	0.005	0.000	-0.001	-0.025	-0.016	0.011	-0.022	-0.017	0.033	0.040	0.026	0.010	0.014	-0.002	0.000	-0.023
Mx8.2	0.035	0.004	0.031	0.021	0.016	0.013	0.010	-0.014	-0.005	0.022	-0.007	-0.006	0.035	0.040	0.036	0.018	0.017	0.010	0.007	-0.007
STD																				
IDPS	0.233	0.191	0.216	0.207	0.172	0.135	0.154	0.132	0.153	0.110	0.155	0.152	0.137	0.141	0.130	0.141	0.146	0.092	0.099	0.131
Mx8.0	0.166	0.119	0.140	0.167	0.111	0.093	0.090	0.129	0.142	0.115	0.154	0.185	0.147	0.149	0.134	0.145	0.162	0.093	0.098	0.136
Mx8.2	0.166	0.124	0.145	0.159	0.119	0.113	0.100	0.125	0.162	0.134	0.173	0.193	0.145	0.144	0.143	0.152	0.165	0.116	0.103	0.161





VIIRS Aerosol / AERONET Monthly Match-up Statistics over Land (IP / Area Match-up)

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Land AOT at 550 nm EDR

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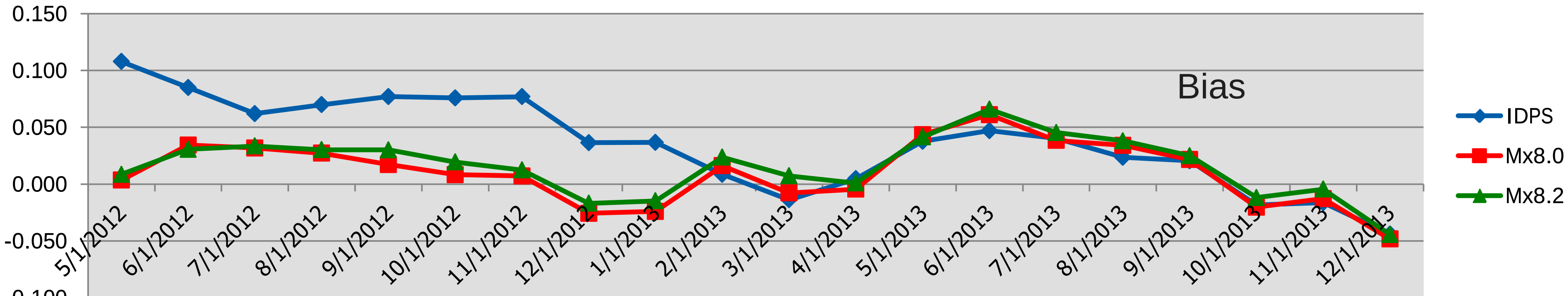
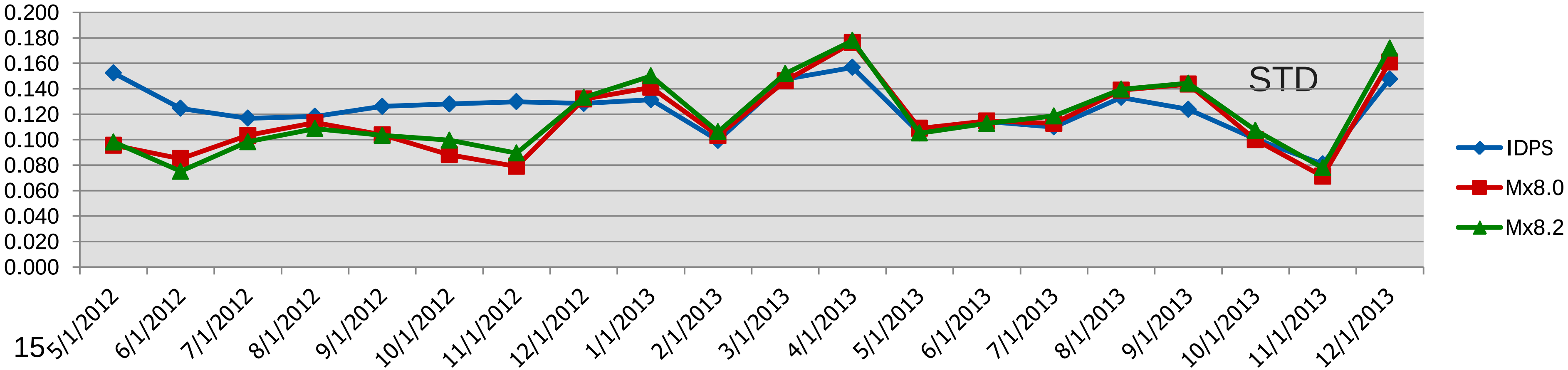
IDPS	174	146	242	304	470	672	247	296	497	347	401	548	611	549	764	690	497	251	370	303
Mx8.0	53	45	155	209	417	474	158	199	309	263	265	368	391	358	518	480	353	216	314	154
Mx8.2	52	43	153	207	413	469	156	196	307	255	258	358	383	354	509	470	350	213	308	151
Bias																				
IDPS	0.108	0.085	0.062	0.070	0.077	0.076	0.077	0.036	0.037	0.009	-0.014	0.005	0.038	0.047	0.040	0.024	0.021	-0.018	-0.016	-0.044
Mx8.0	0.004	0.034	0.032	0.027	0.017	0.008	0.007	-0.026	-0.024	0.016	-0.008	-0.005	0.044	0.061	0.038	0.034	0.021	-0.020	-0.013	-0.048
Mx8.2	0.009	0.031	0.034	0.030	0.030	0.019	0.012	-0.017	-0.015	0.024	0.007	0.001	0.042	0.066	0.045	0.038	0.025	-0.012	-0.005	-0.044
STD																				
IDPS	0.152	0.125	0.117	0.118	0.126	0.128	0.130	0.128	0.131	0.099	0.148	0.157	0.105	0.114	0.110	0.133	0.124	0.100	0.081	0.148
Mx8.0	0.096	0.085	0.103	0.113	0.104	0.088	0.079	0.132	0.141	0.103	0.146	0.176	0.109	0.115	0.113	0.139	0.144	0.100	0.071	0.161
Mx8.2	0.098	0.075	0.098	0.109	0.103	0.100	0.090	0.133	0.150	0.106	0.152	0.178	0.105	0.113	0.119	0.140	0.144	0.107	0.078	0.172





VIIRS Aerosol / AERONET Monthly Match-up Statistics over Land (IP / Central Pixel Match-up)

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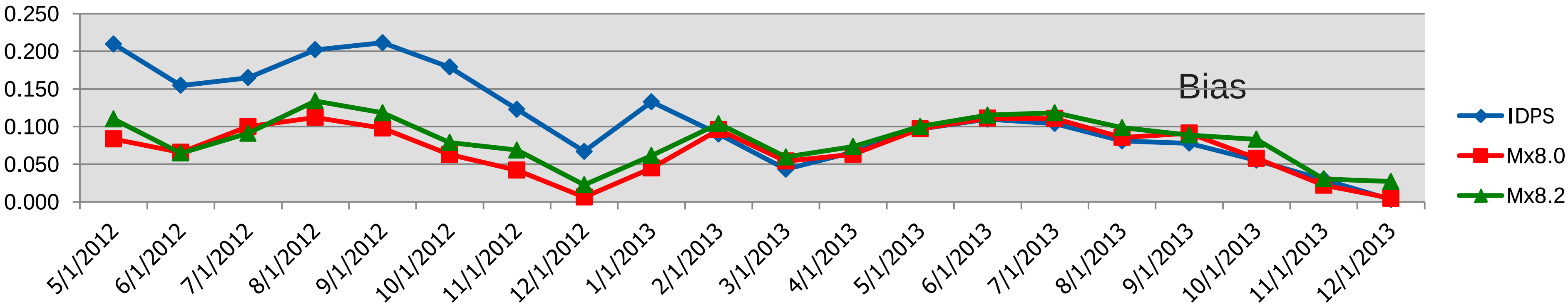
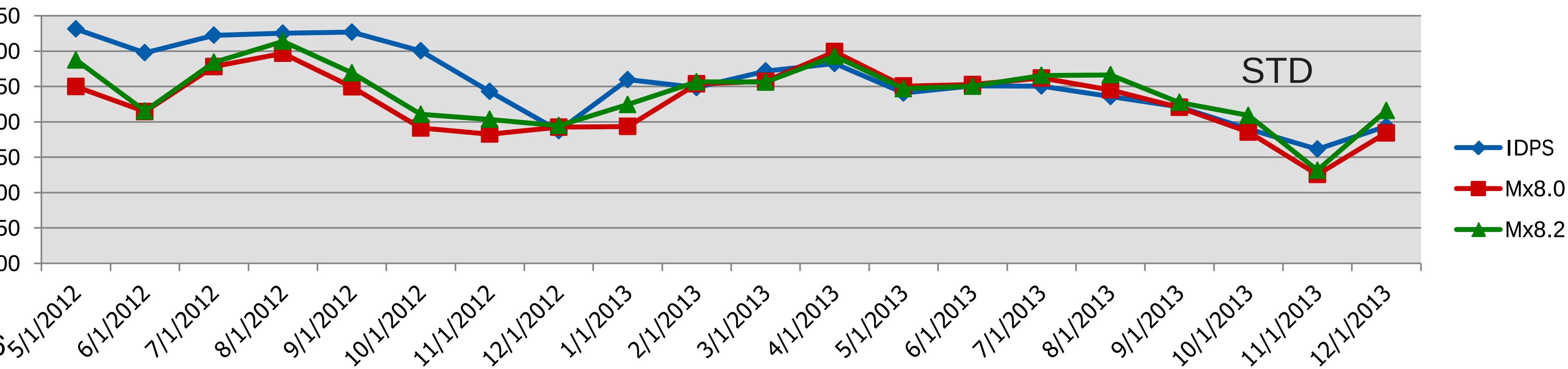
Land AOT at 550 nm EDR																				
Number of Match-ups	5/1/2012	6/1/2012	7/1/2012	8/1/2012	9/1/2012	10/1/2012	11/1/2012	12/1/2012	1/1/2013	2/1/2013	3/1/2013	4/1/2013	5/1/2013	6/1/2013	7/1/2013	8/1/2013	9/1/2013	10/1/2013	11/1/2013	12/1/2013
IDPS	167	139	248	253	401	601	195	248	366	245	360	466	571	538	778	700	495	234	365	291
Mx8.0	51	32	127	168	368	460	151	198	272	233	284	341	455	405	607	561	330	200	281	153
Mx8.2	51	32	124	166	359	454	148	196	268	231	268	324	435	391	590	546	321	197	276	152
Bias																				
IDPS	0.210	0.155	0.165	0.202	0.211	0.179	0.123	0.067	0.133	0.090	0.043	0.066	0.097	0.110	0.104	0.081	0.078	0.055	0.030	0.003
Mx8.0	0.084	0.066	0.100	0.112	0.098	0.063	0.042	0.006	0.045	0.096	0.054	0.063	0.097	0.111	0.111	0.086	0.091	0.058	0.022	0.005
Mx8.2	0.110	0.065	0.091	0.134	0.118	0.079	0.069	0.023	0.062	0.104	0.060	0.074	0.100	0.115	0.118	0.099	0.089	0.083	0.030	0.027
STD																				
IDPS	0.331	0.298	0.322	0.325	0.327	0.300	0.243	0.187	0.259	0.248	0.272	0.282	0.241	0.251	0.251	0.236	0.221	0.190	0.161	0.194
Mx8.0	0.250	0.214	0.278	0.297	0.249	0.191	0.183	0.192	0.193	0.254	0.257	0.299	0.251	0.253	0.262	0.245	0.220	0.186	0.125	0.184
Mx8.2	0.287	0.215	0.284	0.314	0.269	0.211	0.203	0.195	0.224	0.256	0.256	0.293	0.247	0.250	0.266	0.266	0.227	0.209	0.132	0.216





Conclusions

- Results from PGE's based on the VIIRS Common Matchup Tool are a rich source of calibration and validation data. They contain everything needed to reprocess and perform QC.

- Reprocessing only cutouts makes it practical to assess quality changes for many products over numerous algorithm and/or LUT changes, for long durations of VIIRS observations.

- By enabling rapid assessment of algorithm and LUT changes over the entire collection of VIIRS data, the Common Matchup and Reprocessing Tools can play important roles in the creation of a VIIRS climate data record.

THE VALUE OF PERFORMANCE.

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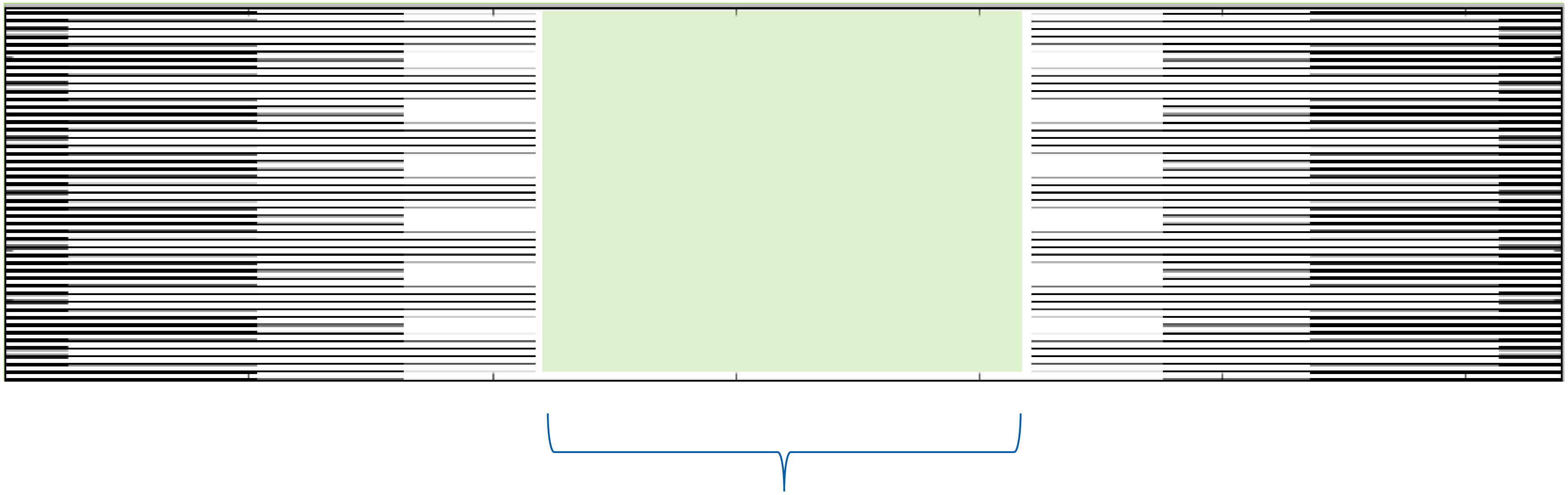
Acronyms on chain diagram

AOT	aerosol optical thickness
APSP	aerosol particle size parameter
ASM	atmospheric suspended matter
CBH	cloud base height
CCL	cloud cover layers
COP	cloud optical properties
CTP	cloud top parameters
GCE	generate cloud environmental data record
IST	ice surface temperature
LST	land surface temperature
OCC	ocean color/chlorophyll
PPC	perform parallax correction
Sfc Refl	surface reflectance
Sfc type	surface type
SST	sea surface temperature
STIP	surface temperature intermediate product
VCM	VIIRS cloud mask
VFM	VIIRS fire mask
VI	vegetation index

Bow Tie Free Region

- Cutouts are inserted in the central portion of template matrices to avoid bowtie issues.

- Bowtie region shown in black; cutout insertion zone shown in light green

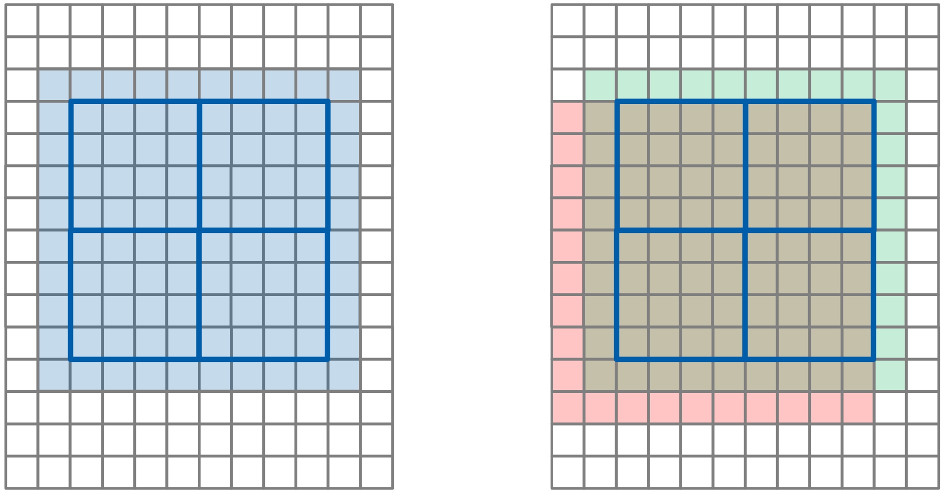


Center region = 768 x 1020

Full sized moderate resolution granule = 768 x 3200

Pixel Aggregation and Insert Location Realignment

- Some EDR products (for example aerosol optical thickness) are aggregations of multiple IP or SDR pixels.
- The VIIRS Matchup Processing Tool correctly positions the IP and SDR insertion location so that pixels to align to the original aggregation scheme.
- Must have pad pixels to allow repositioning without overlapping other cutouts.
- Example: 4 to 1 IP to EDR aggregation



Orange: original insert location
Green: insert location shifted to properly align to sets of four

Multiple Cutouts Per Granule

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- Reprocessing results are independent of a cutout’s location within the template h5 and granulated ancillary files (excluding bow-tie regions).
- To be conservative, cutouts are only inserted in the central portion of granule matrices where there are no bow-tie pixels.
- The number of cutouts that can be inserted into a template granule file is a function of the cutout size and the number of pad pixels one wishes to maintain between cutouts.

Product	Cutout Size*	Pad Pixels	# Cutouts in One Granule
AOT, CM, SR	51 x 51	9	187
AOT, CM, SR	51 x 51	17	135
LST	11 x 11	1	5,707
VI	7 x 7	1	13,697

*Moderate resolution; cutouts of datasets at imagery resolution are 2n-1 larger.

Example: Contents of an Aerosol Matchup File

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- The HDF 5 file produced by the aerosol optical thickness component of the AOT/CM/SR/VI—Aeronet matchup has cutouts from 20 VIIRS data files and 5 granulated ancillary files.

- VIIRS: [explain what each block means, geo, IP, SDR, EDR]
  - GAERO
  - GMTCO
  - IICMO
  - IVAMI
  - IVAOT
  - SVM01
  - SVM02
  - SVM03
  - SVM04
  - SVM05
  - SVM06
  - SVM07
  - SVM08
  - SVM09
  - SVM10
  - SVM11
  - SVM12
  - SVM15
  - SVM16
  - VAOOO

- Granulated Ancillary:
  - VIIRS-ANC-Optical-Depth-Mod-Gran
  - VIIRS-ANC-Preci-Wtr-Mod-Gran
  - VIIRS-ANC-Press-Surf-Mod-Gran
  - VIIRS-ANC-Temp-Surf2M-Mod-Gran
  - VIIRS-ANC-Tot-Col-Mod-Gran
  - VIIRS-ANC-Wind-Direction-Mod-Gran
  - VIIRS-ANC-Wind-Speed-Mod-Gran

Contents of an Aerosol Matchup File (2)

- All relevant datasets within a given file type are preserved. For example the `GAERO` file type provides these datasets to the AOT--Aeronet HDF 5 matchup file:

```
/All_Data/VIIRS-Aeros-EDR-GEO_All/Height
/All_Data/VIIRS-Aeros-EDR-GEO_All/Latitude
/All_Data/VIIRS-Aeros-EDR-GEO_All/Longitude
/All_Data/VIIRS-Aeros-EDR-GEO_All/QF2_VIIRSAEROGEO
/All_Data/VIIRS-Aeros-EDR-GEO_All/SCAttitude
/All_Data/VIIRS-Aeros-EDR-GEO_All/SCPosition
/All_Data/VIIRS-Aeros-EDR-GEO_All/SCVelocity
/All_Data/VIIRS-Aeros-EDR-GEO_All/SatelliteAzimuthAngle
/All_Data/VIIRS-Aeros-EDR-GEO_All/SatelliteRange
/All_Data/VIIRS-Aeros-EDR-GEO_All/SatelliteZenithAngle
/All_Data/VIIRS-Aeros-EDR-GEO_All/SolarAzimuthAngle
/All_Data/VIIRS-Aeros-EDR-GEO_All/SolarZenithAngle
```

Contents of an Aerosol Matchup File (3)

- Two dimensional datasets are cutout, while one dimensional and scalar datasets are copied in their entirety.
- A complete AOT—Aeronet HDF 5 matchup file has
  - 126 VIIRS product datasets
  - 8 granulated ancillary datasets
  - 161 in situ datasets
- Data drop-outs at NSIPS may result in missing datasets. In these cases, the cutouts cannot be reprocessed.
- A typical AOT—Aeronet HDF 5 matchup file
  - has approximately 45 matchups
  - is approximately 25 MB

VIIRS Matchup Reprocessing Tool Steps of Operation [redo as diagram]

- The VIIRS Matchup Reprocessing Tool operates in the following sequence:
  1. Read a list of desired cutouts (cutout offsets + matchup file name). These are typically chosen by the user based on matchup quality.
  2. Read a map file showing insert locations for a given cutout size.
  3. Create fill value populated VIIRS h5 granule files and binary granulated ancillary files for each required product (eg, `GMTCO`, `SVM03`, `VIIRS-ANC-Optical-Depth-Mod-Gran`).
  4. Loop over cutouts
     1. Select the next insert location from the location map
     2. Loop over VIIRS product file types at this cutout
        - Loop over datasets in this VIIRS product file
          - Insert the cutout for this dataset into the initially fill populated VIIRS h5 granule file at the current insert location
     3. Loop over granulated ancillary files
        - Insert the granulated cutout into the initially fill populated granulated ancillary file at the current insert location

- The newly-created h5 and granulated ancillary files can now be run through ADA and/or ADL.

- Reprocessed VIIRS products can then be compared to *in situ* data stored in the matchup files for performance impact.

Benefits

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- The VIIRS Matchup Reprocessing Tool can provide rapid cause-and-effect insight into algorithm, LUT, and parameter changes.

- The VIIRS Matchup Reprocessing Tool is efficient.
  – Storage: only VIIRS data in the immediate vicinity of *in situ* data is kept. Hundreds of such locations can fit in 100 MB.
  – Computational effort: A single VIIRS granule can be populated with hundreds of cutouts. An ADL run of one such granule takes less than a minute.

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