Multi-Instrument Inter-Calibration (MIIC) framework

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Outline

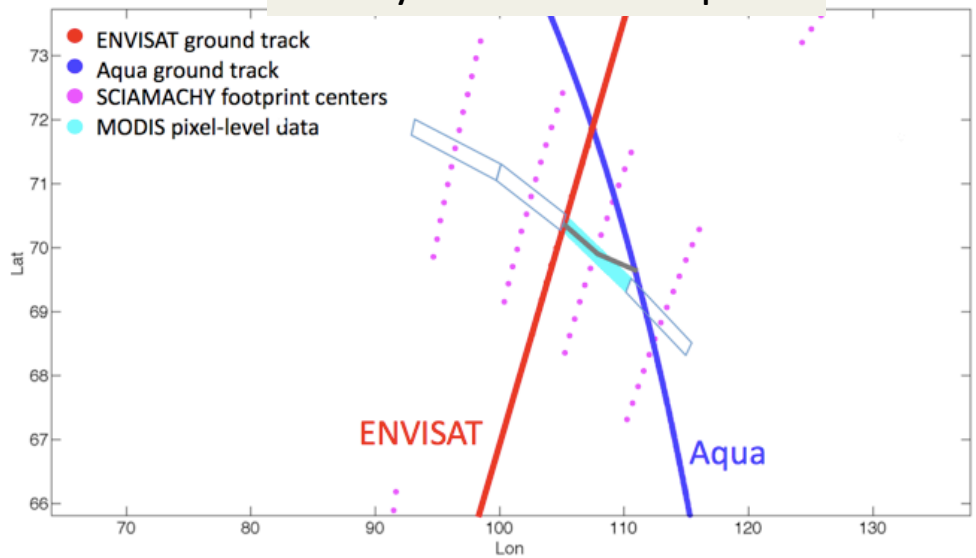
- CERES geostationary inter-calibration heritage
- MIIC inter-calibration framework objectives
- Build 1 (LEO-GEO) Status
- Build 2 (LEO-LEO) Plans and Future Goals
  - Costy

CERES geostationary calibration approach

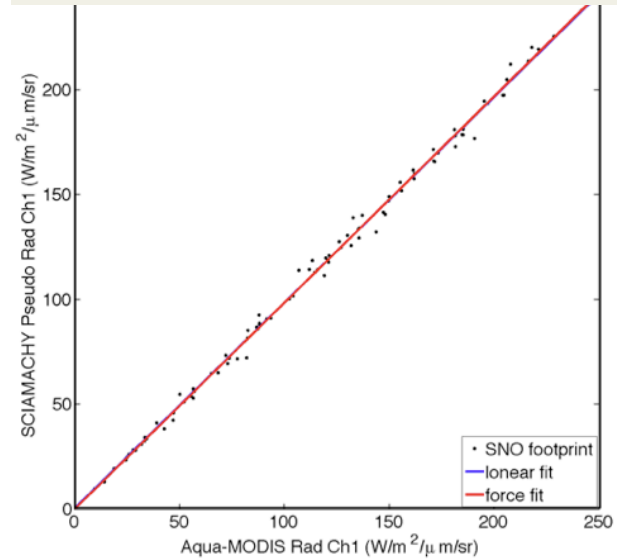
- CERES uses geostationary derived broadband fluxes to infer the diurnal flux in between CERES measurements on Terra and Aqua
  - SSF1deg CERES single satellite only monthly mean product
  - SYN1deg CERES Terra&Aqua&GEO monthly mean product, GEO fluxes normalized to CERES
  - EBAF product derived from SYN1deg and the net imbalance is adjusted to the ocean heat storage
- CERES uses a multi-method calibration approach for GEO visible sensors
  - All methods tied to Aqua-MODIS calibration
  - Each method is independent, allowing a self-consistency check
- CERES will use CLARREO when available
  - Have developed a method to calibrate GEO visible sensors with SCIAMACHY hyper-spectral radiance

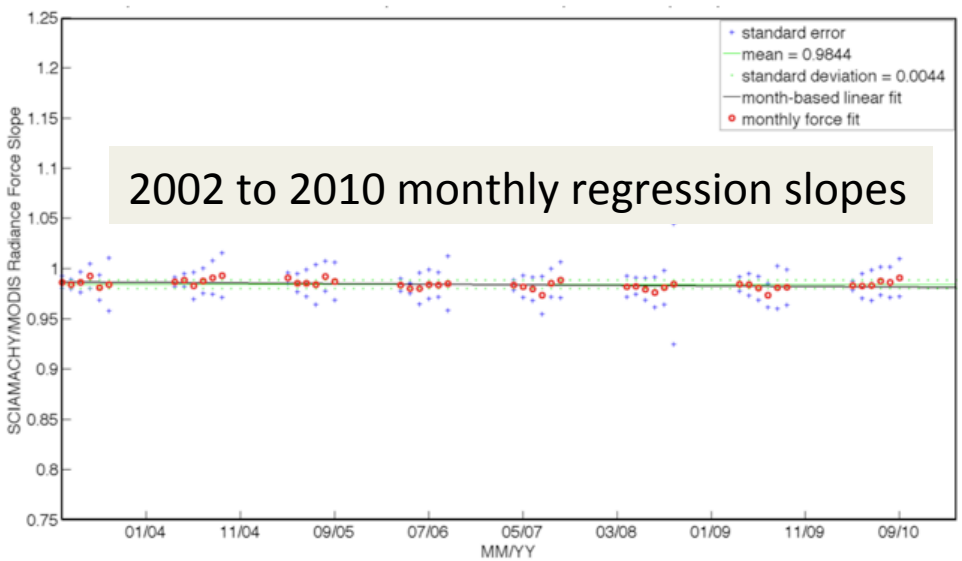
SCIAMACHY Aqua-MODIS inter-calibration

Nearly SNO SCIA footprint



July 2010 radiance pair regression



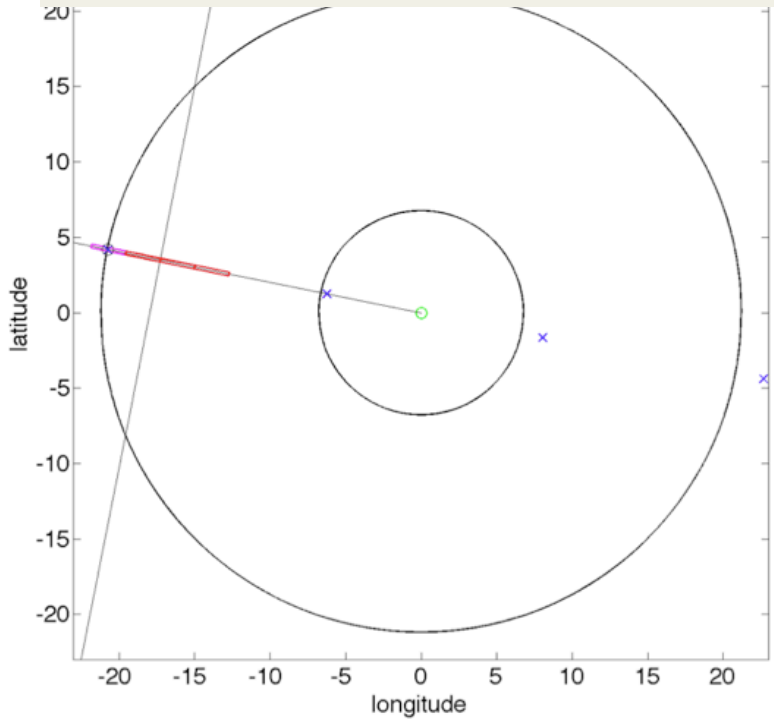


2002 to 2010 monthly regression slopes

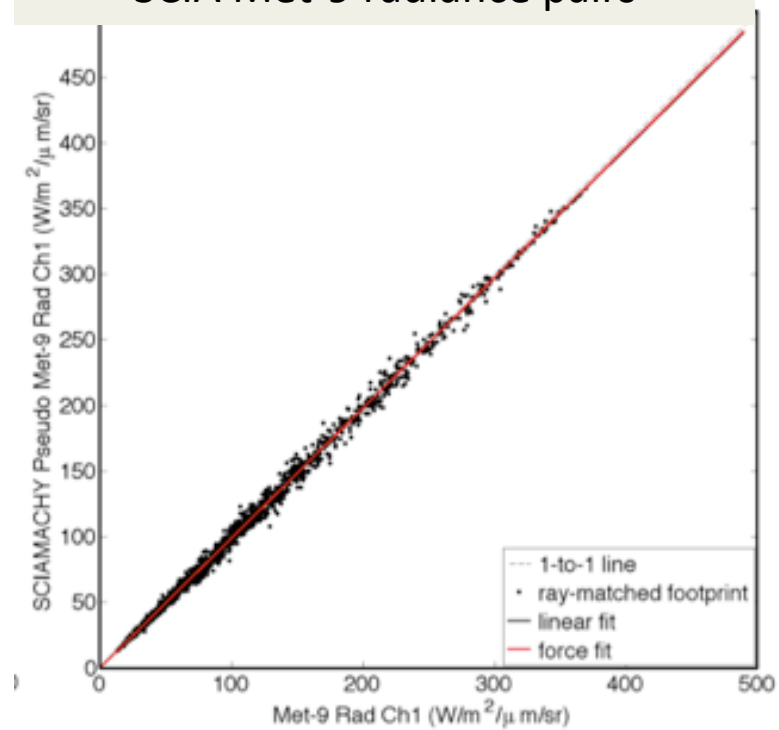
- SCIA/MODIS relative stability within 0.2%
- absolute calibration difference of 0.9844 within the 2% uncertainty stated for each sensor

SCIAMACHY Meteosat-9 inter-calibration

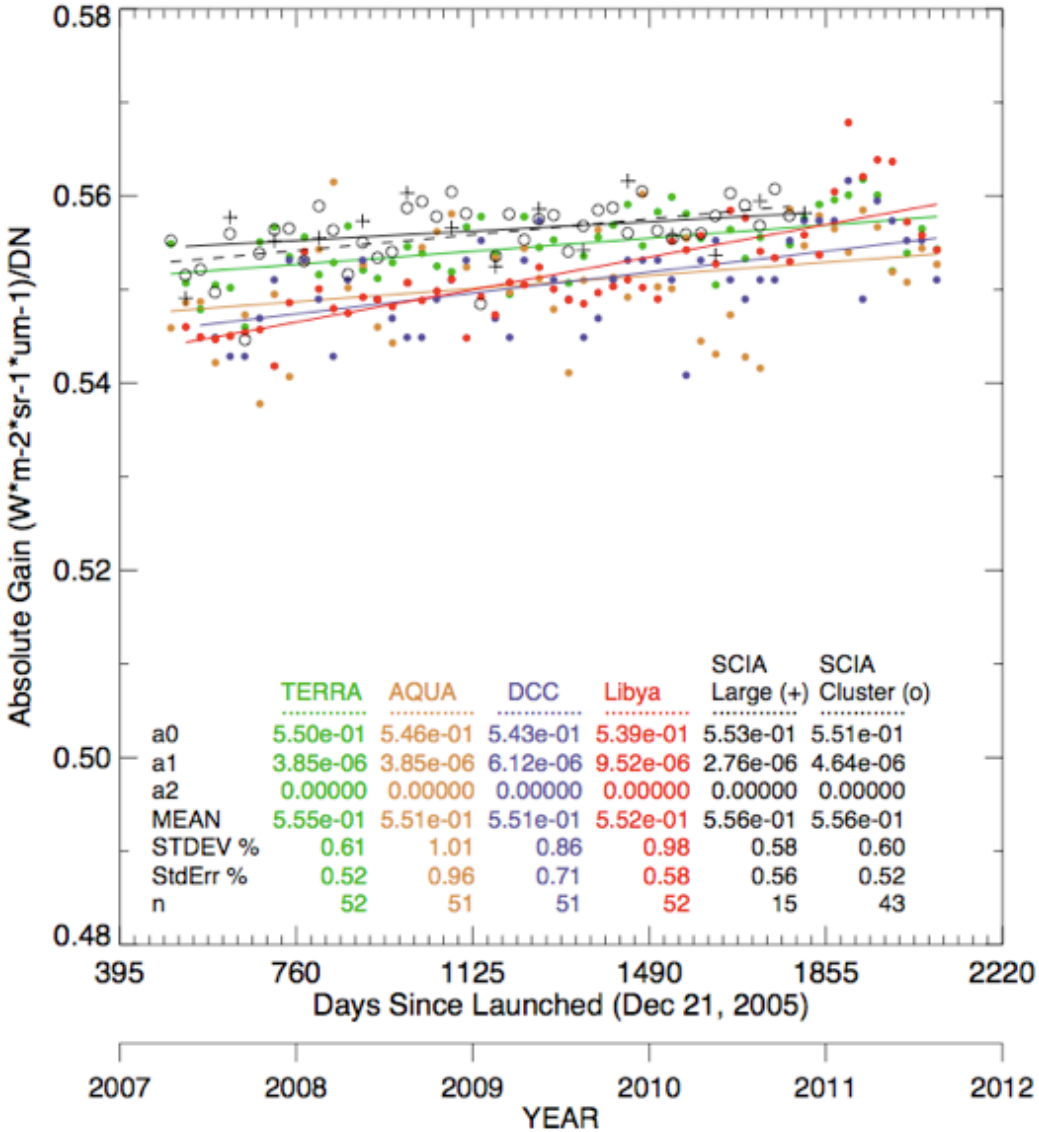
Ray-matched GEO/SCIAMACHY footprint locations



April 2007 to December 2010 SCIA Met-9 radiance pairs

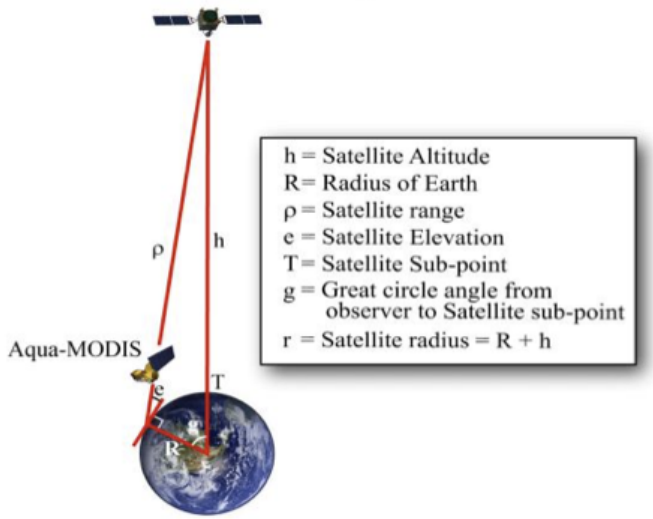


SCIAMACHY Meteosat-9 inter-calibration

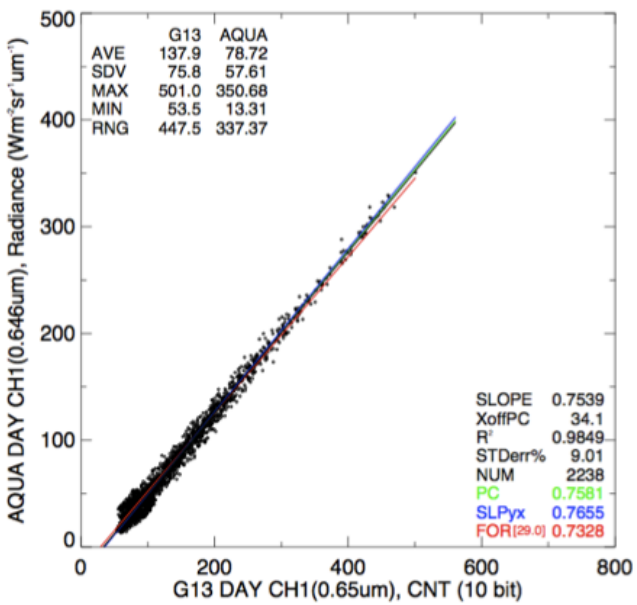


- All methods referenced to Aqua-MODIS 0.65µm calibration
- All method calibration gains are within 1% over the lifetime
- SCIAMACHY had the lowest standard error about the trend indicating the advantage of accounting for spectral response explicitly

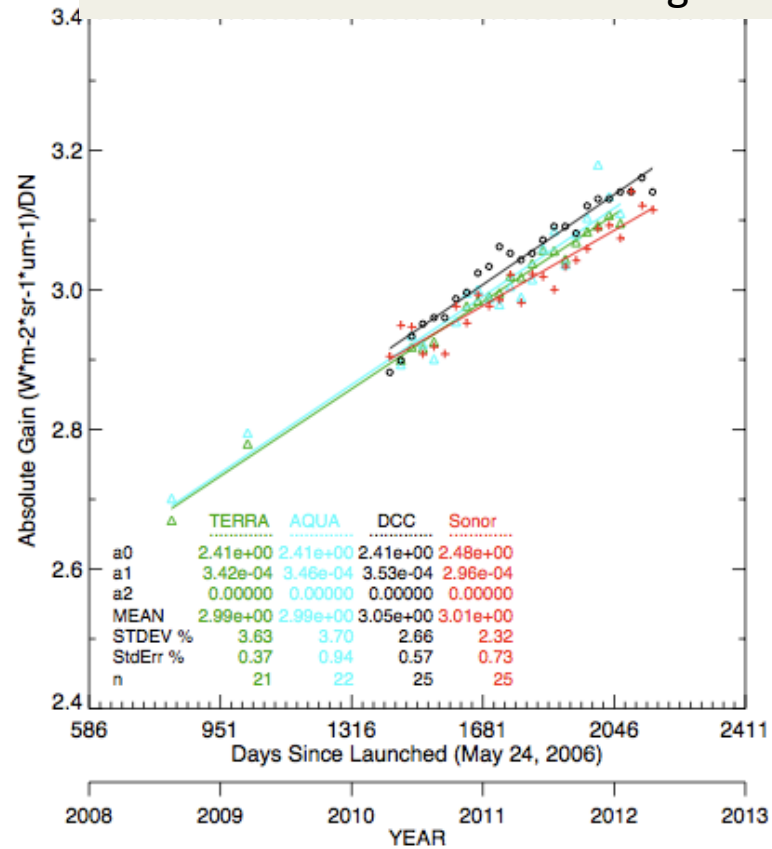
Aqua-MODIS GOES-13 inter-calibration



Jan 2011



GOES-13 visible calibration gains



MIIC Inter-calibration Methodology

- Use bore-sighted or ray-matched radiance pairs to inter-calibrate a reference sensor with to a target sensor
- CLARREO would be the future reference sensor
  - Excellent onboard calibration
  - Hyper-spectral radiances to take into account the spectral response function
- MIIC framework
  - Develops the common framework for CLARREO inter-calibration procedure, or any other such as GSICS
  - Allows inter-calibration of all sensors willing to participate
  - Allows anyone to inter-calibrate according to their application, without having to invest in computer and storage resources

GSICS

- Designed to uniformly calibrate operational sensors to a reference to achieve consistent cloud/radiative/aerosol retrievals
  - Each GPRC responsible to implement the GSICS procedure
- The IASI or AIRS inter-calibration with geostationary IR imagers is almost operational
  - Users can easily download the coefficient necessary to calibrate geostationary IR radiances to IASI or AIRS calibration
- Currently working on visible, microwave, and sounder inter-calibration
- CLARREO is hosting the next GSICS annual meeting
  - March 4-8, 2013, Williamsburg, Va
  - GSICS will be using CLARREO as the reference calibration
- Next GSICS workshop
  - The combined 2013 EUMETSAT Meteorological Satellite Conference and the AMS 19th Satellite Meteorology, Oceanography, and Climatology Conference, September 16-20, 2013, Vienna, Austria

MIIC framework advantages

- MIIC provides the ray-matching event software
  - To derive the data filenames and ray-match spatial domain
- MIIC averages the radiances into a common field of view or grid at the sensor archive center
  - Using opendap
- MIIC only downloads the matched gridded radiance data
  - Considerable reduction in data volume
  - Gridding performed only once per sensor pair, since MIIC also archives the matched radiances
- MIIC allows the user further matching criteria refinement
  - Using a web face interface to allow user to optimize the criteria
  - Computes the inter-calibration coefficients
  - Perhaps allow user defined spectral band adjustment factors, when inter-calibrating non hyper-spectral sensors
- Can easily be applied to compare retrieval parameters from two sensor, such as cloud optical depth, etc

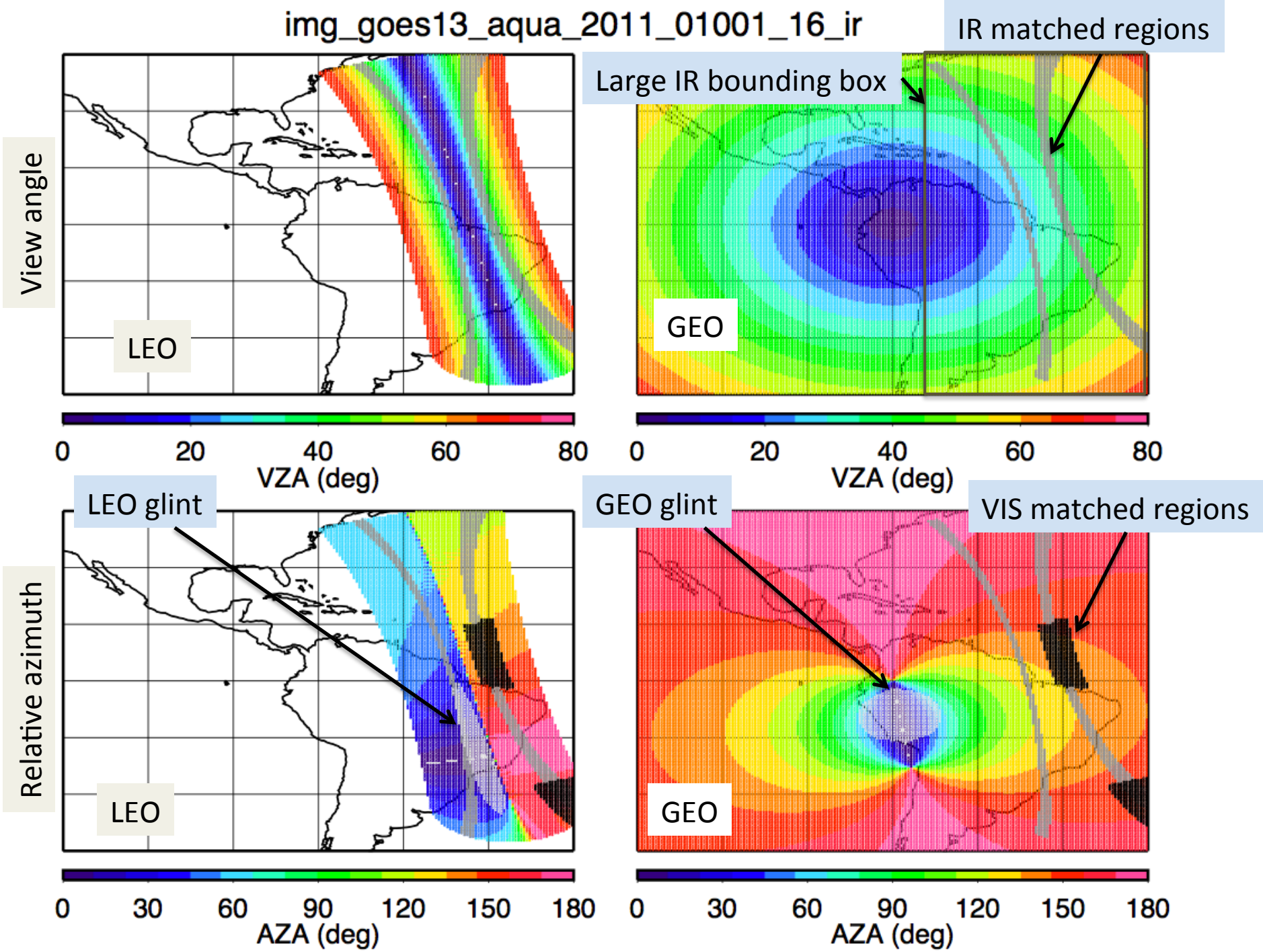
Build 1 LEO-GEO Matching Criteria

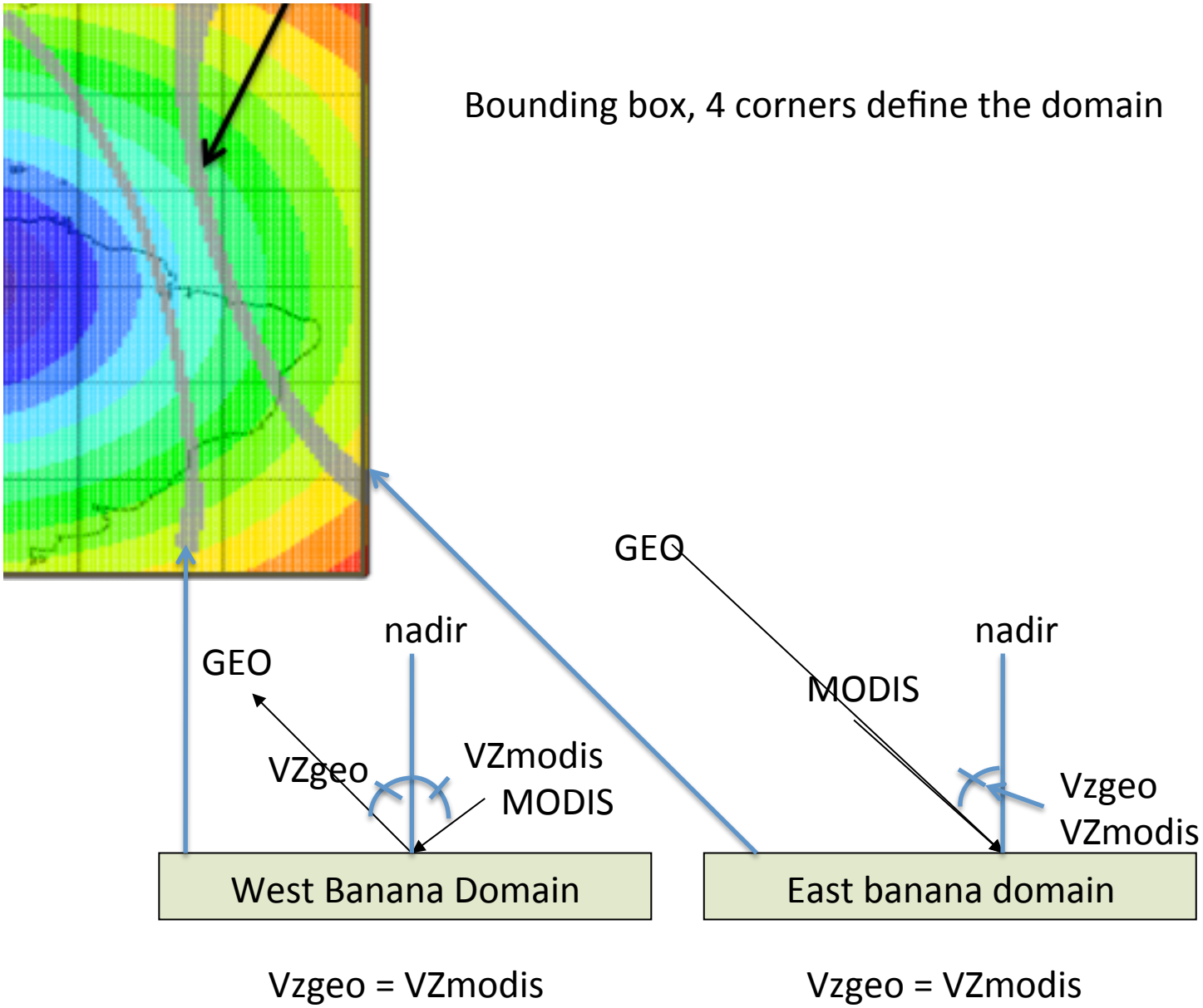
- Demonstrate by inter-calibrate GOES-13 and Aqua-MODIS
- Build apriori prediction code to provide radiance filename and associated matching spatial domain to send to opendap at the GOES-13 and Aqua-MODIS sensor archive
- Use Opendap to read the file and grid the data in 0.5° lat/lon regions within the matching spatial domain
- Within matching spatial domain compute or read the angle conditions and surface type, etc. and match angles
  - Visible use Abs(aza1-aza2)<15 and Abs(vza1-vza2)<15
  - IR Abs(vza1-vza2)<5
- Define database to archive regional sensor radiance pairs and associated parameters (angles, etc)
- Build web interface to plot the radiance pairs, with matching criteria functions and derive inter-calibration coefficients

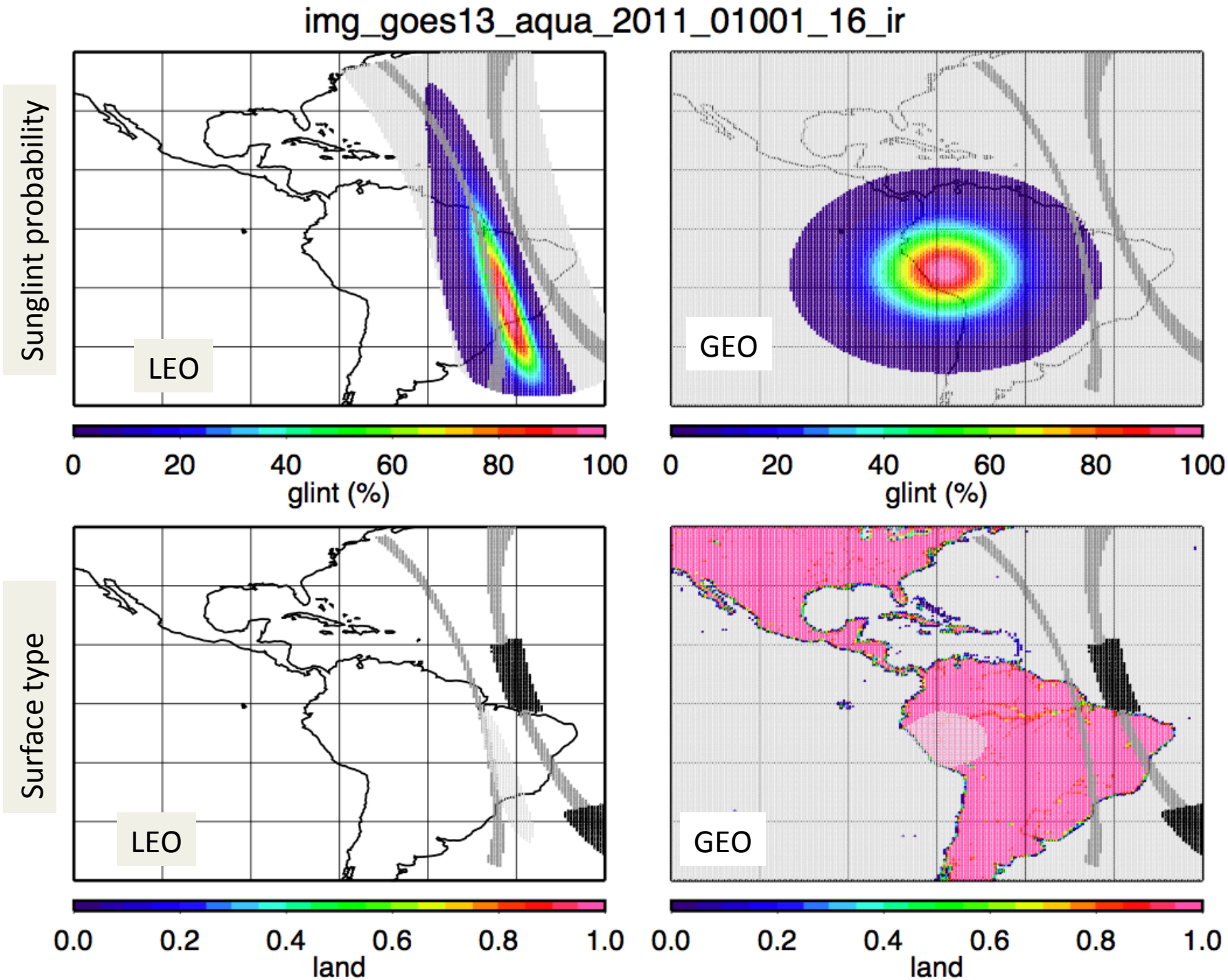
Predictor

(Roithmayr)

- Developed simulator for LEO and GEO instruments to predict matched space/time/ angle data samples for inter-calibration
- Use SGP4 (java) orbit propagator to predict spacecraft locations from TLEs
- Spin-off of CLARREO process developed for RS inter-calibration
- Critical feature of the MIIC framework to intelligently select IC events and limit downloading of remote data

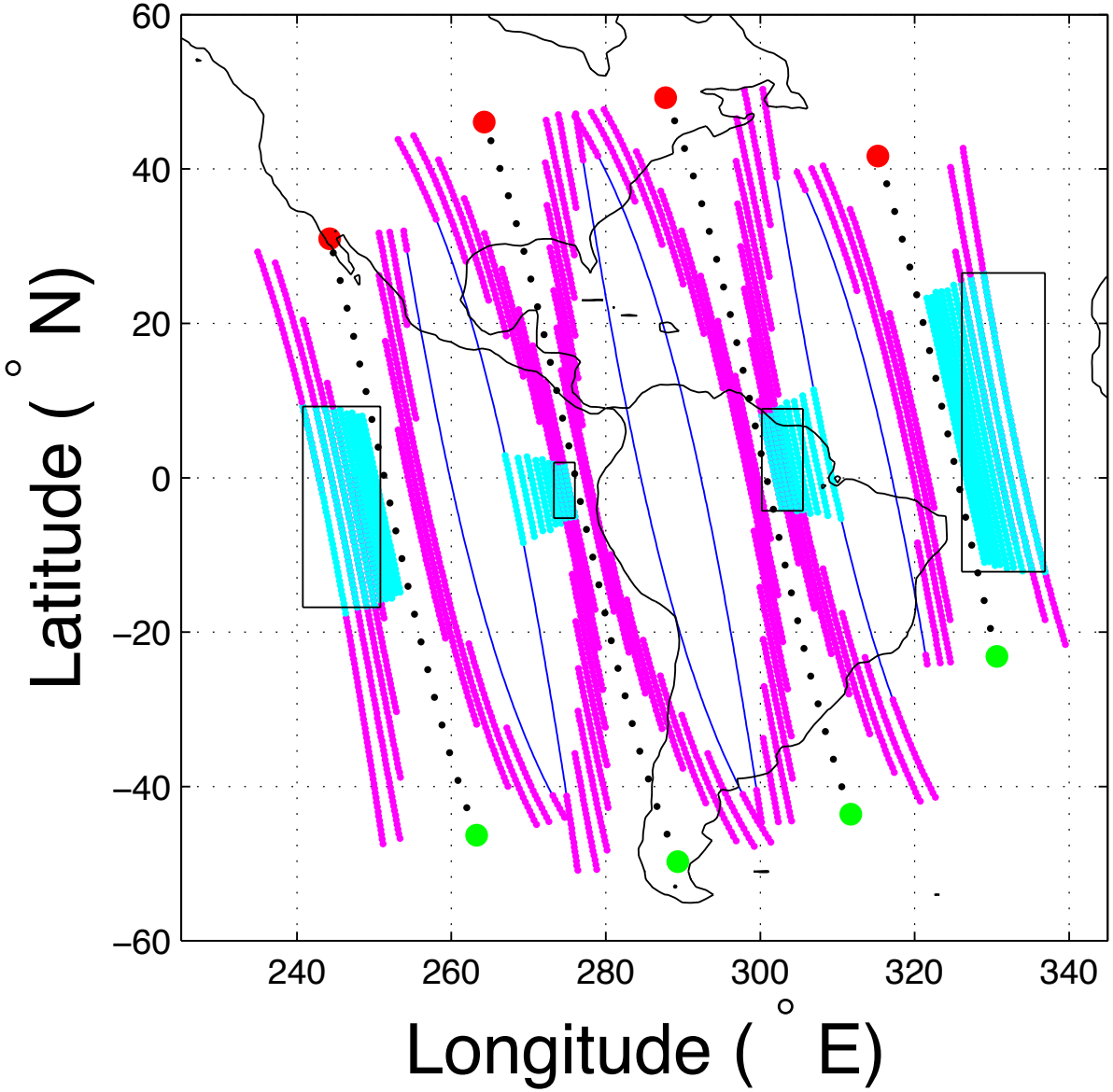

img_goes13_aqua_2011_01001_16_ir
IR matched regions
Large IR bounding box
View angle
LEO
GEO
0
20
40
60
80
VZA (deg)
LEO glint
GEO glint
VIS matched regions
Relative azimuth
LEO
GEO
0
30
60
90
120
150
180
AZA (deg)


Bounding box, 4 corners define the domain
GEO
nadir
VZgeo
VZmodis
MODIS
West Banana Domain
Vzgeo = VZmodis
GEO
MODIS
nadir
Vzgeo
VZmodis
East banana domain
Vzgeo = VZmodis


img_goes13_aqua_2011_01001_16_ir
Sunglint probability
LEO
GEO
0
20
40
60
80
100
glint (%)
Surface type
LEO
GEO
0.0
0.2
0.4
0.6
0.8
1.0
land

Predictor Enhancements

Aqua vs. GOES 13. Jan 2, 2011



Predict output file – used in Build 1

SAT=aqua SAT=goes13 BEGTIM=2010364 ENDTIM=2011035 DAILY NORAD UPDATES

YYYY	DDD	GMTeq	LONeq	SZAeq	NVS	NIR	LA latS	latN	lonW	lonE	gmtB	gmtE
2010	364	17.024	308.607	32.108	595	1262	-42.25	44.75	288.75	329.75	16.882	17.230
2010	364	18.676	283.720	32.603	135	1037	-41.75	44.75	261.75	302.25	18.534	18.882
2010	364	20.323	259.045	32.468	200	1226	-41.75	44.75	240.25	277.25	20.181	20.529
2010	365	16.097	322.495	31.977	671	1227	-41.25	44.75	301.75	329.75	15.955	16.303
2010	365	17.749	297.609	32.474	69	1087	-41.75	44.75	277.25	317.25	17.607	17.954
2010	365	19.396	272.934	32.339	192	1102	-42.25	44.75	249.25	290.75	19.254	19.602
2010	365	21.043	248.259	32.205	621	1143	-40.75	44.75	240.25	266.75	20.901	21.249
2011	1	16.822	311.497	32.338	602	1260	-41.25	44.75	291.25	329.75	16.680	17.027
2011	1	18.469	286.822	32.203	7	1036	-42.25	44.75	265.75	305.75	18.327	18.675
2011	1	20.116	262.147	32.069	109	1244	-41.75	44.75	240.25	280.25	19.974	20.322
2011	2	15.891	325.569	31.791	314	976	-40.75	44.75	304.75	329.75	15.749	16.097
2011	2	17.538	300.894	31.658	263	1114	-42.25	44.75	281.25	321.25	17.396	17.744
2011	2	19.190	276.007	32.153	250	1078	-41.75	44.75	252.75	294.25	19.048	19.396
2011	2	20.837	251.332	32.019	627	1184	-41.25	44.75	240.25	269.75	20.695	21.043
2011	3	16.611	314.798	31.561	596	1270	-41.75	44.75	294.75	329.75	16.469	16.817

Equator crossing time

Equator longitude

Equator solar zenith angle

# of visible angle matched regions

IR angle matched regions

Domain boundaries of IR

GMT of boundary

Server-side Gridding Function within Opendap

Equal Angle MODIS grid function arguments:

Grid cell size in degrees

[,GRID_VAR,var name,[band name, …]]

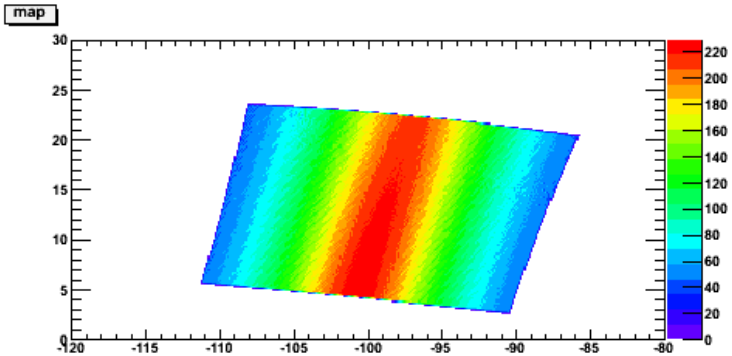
[,FILTER_VAR,var name,min,max]

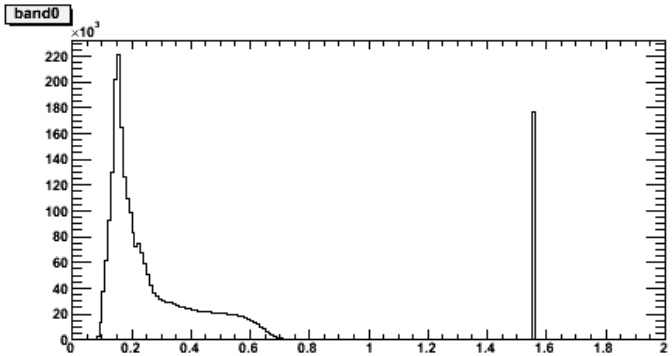
[,MIN_GRID_PTS,number min pts]

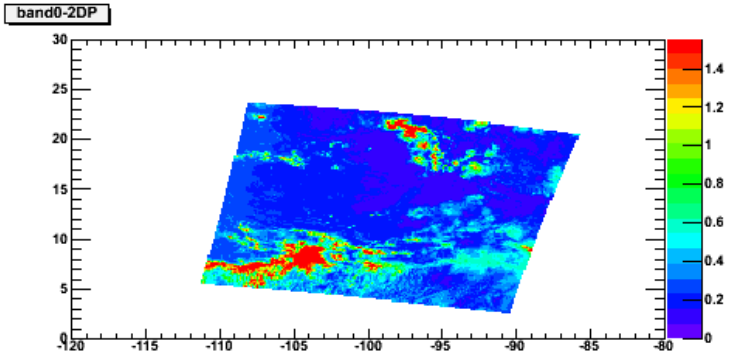
In client code build URL to retrieve EV_1KM_Emissive band 27, from -30 to 30 Lat, -100 to -80 Lon, grid on 0.5° grid:

http://clarreo-a.larc.nasa.gov:8480/opendap/data/SampleData/MODIS/MOD021KM.A2010277.1710.005.2010278082807.hdf?eamodisgrid(.5,GRID_VAR,EV_1KM_Emissive,%2227%22,FILTER_VAR,Longitude,-100,-80,FILTER_VAR,Latitude,-30,30)

HDFGroup Corrects OPeNDAP HDF4 Handler Scaling







Band 8, 405-420 nm, histogram

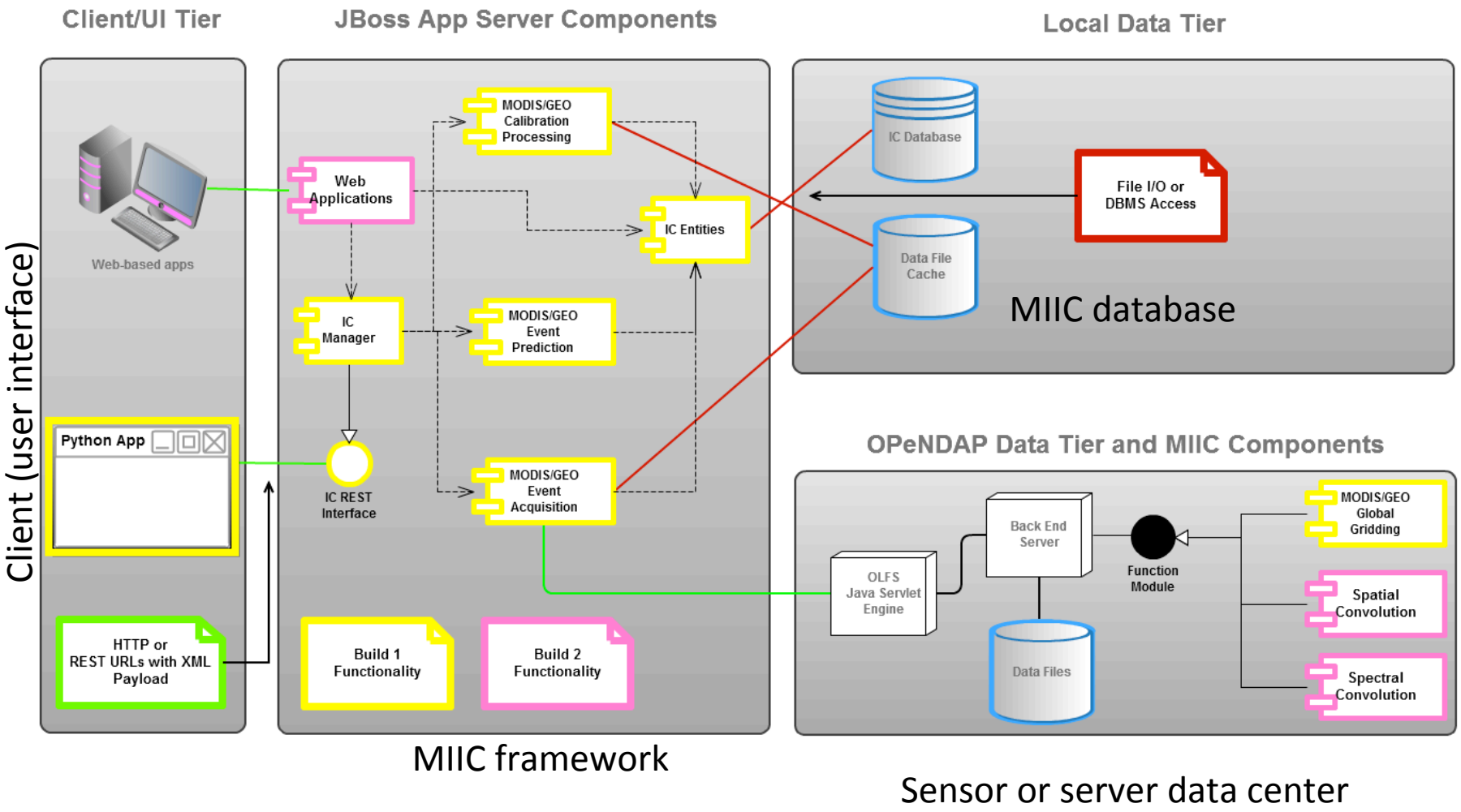
- HDF4 Handler incorrectly applied scale and offsets to MODIS flag values; here “Saturation Flag” scaled and included in the data
- *The HDFGroup, Kent Yang, corrected problem for next release*

Gridded output MODIS DataDDS

- Serialized object for network transmission
- Able to read and persist or archive in database on client

```
Dataset {
   Structure {
      Float64 GRID_Latitude[120];
      Float64 GRID_Longitude[40];
      Float64 EV_1KM_Emissive_27_MEAN[Latitude = 120][Longitude = 40];
      Float64 EV_1KM_Emissive_27_STD[Latitude = 120][Longitude = 40];
      Int32 EV_1KM_Emissive_27_COUNT[Latitude = 120][Longitude = 40];
   } Gridded_DATA;
} function_result_MOD021KM.A2010277.1710.005.2010278082807.hdf;
Data:
^@^@^@x^@^@^@xÀ=À^@^@^@^@^@À=@^@^@^@^@^@À<À^@^@^@^@^
@À<@^@^@^@^@^@À
```

MIIC Multi-tiered Architecture (test on ASDC web servers)



MIIC framework

Sensor or server data center

Build 1 Regression Matched Grid Samples NO angular filtering Jan 1, 2011

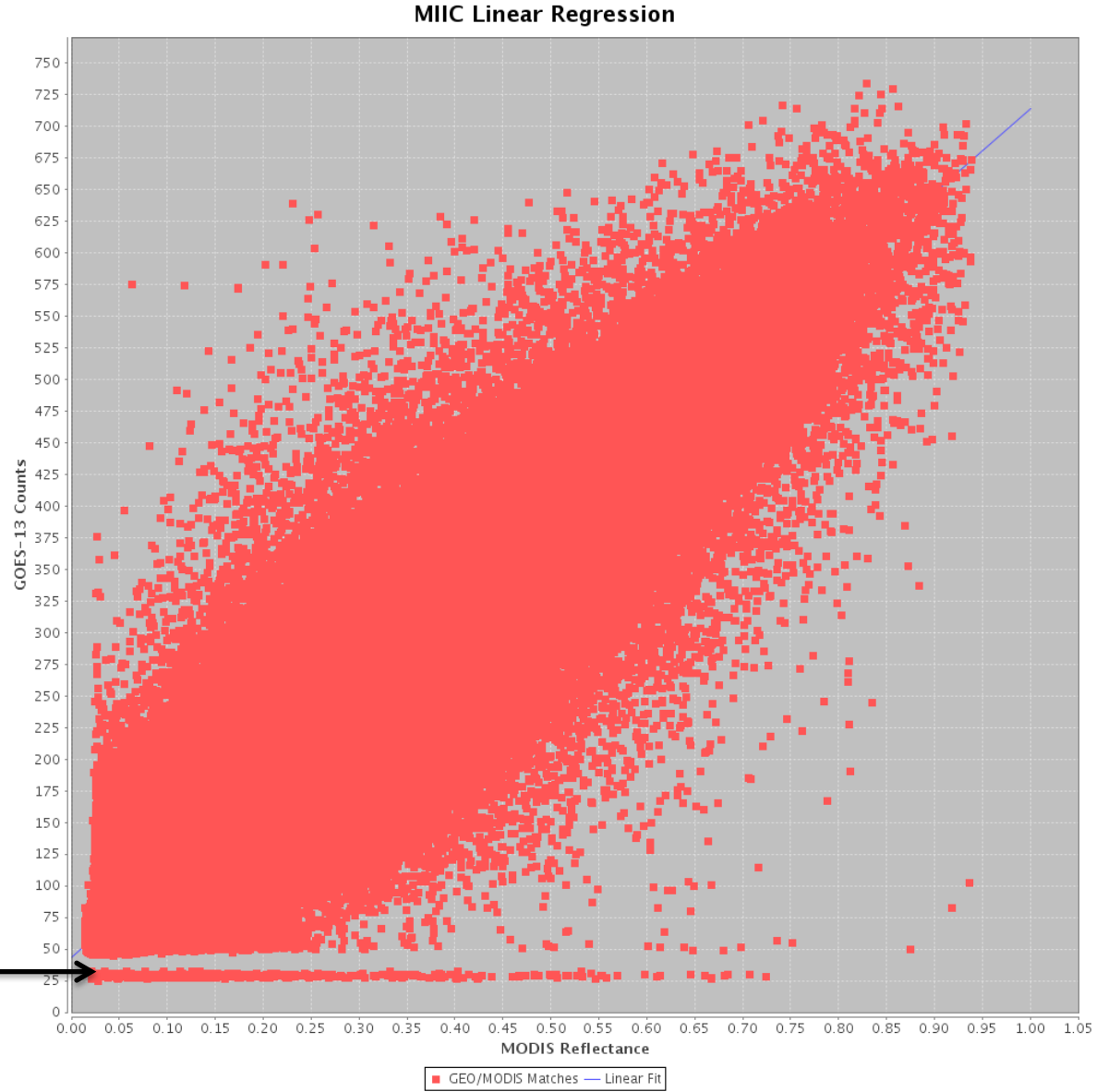
N = 830,862

R2 = 0.89

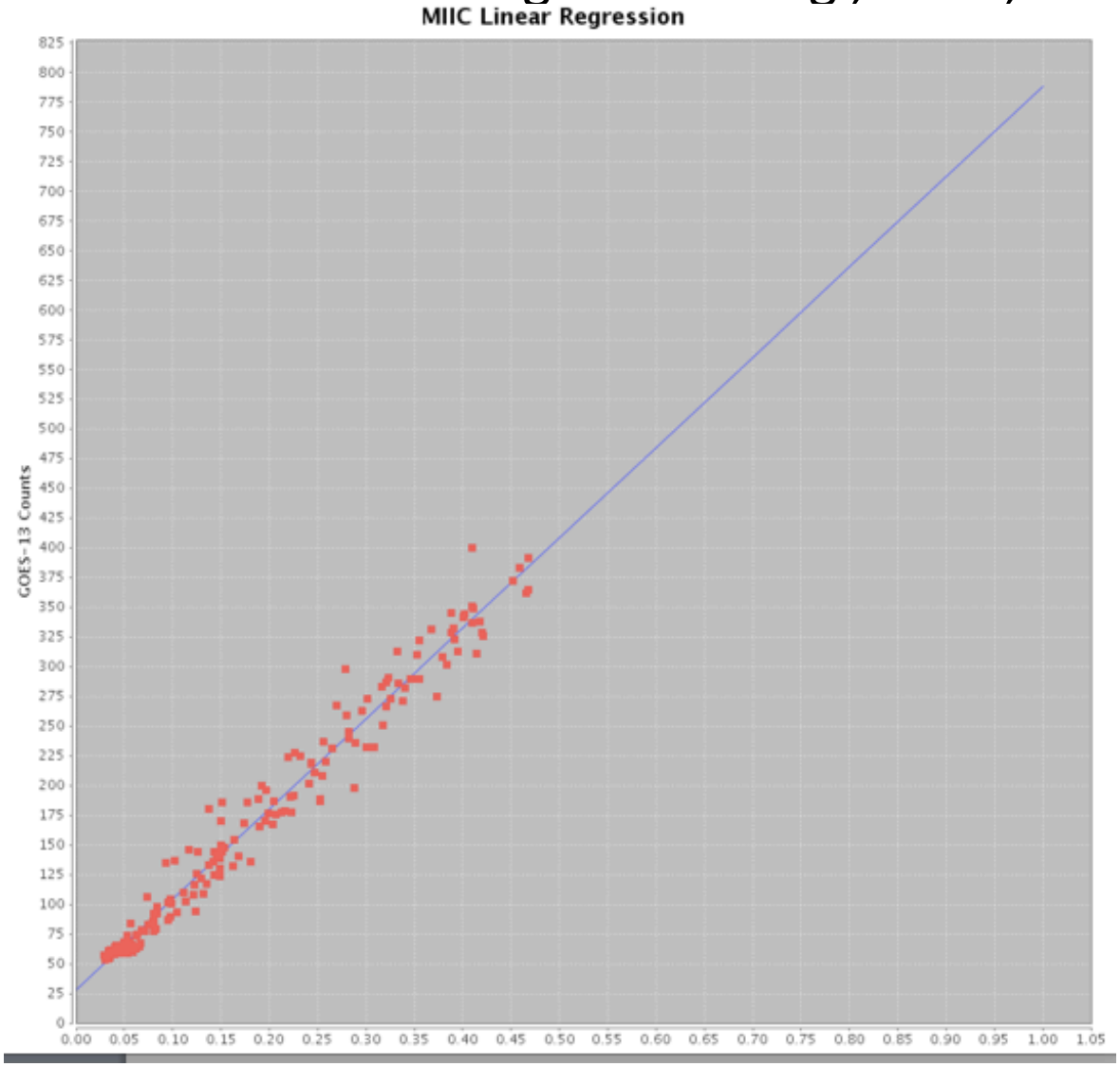
A = 670.8

B = 43.4

GEO space views



Build 1 Regression Matched Grid Samples with angular filtering but no land or glint filtering , Jan 1, 2011



Build 1 Status

- Implemented OPeNDAP server-side gridding and angular filtering functions for both MODIS (HDF4) and GEO (binary)
- Developed prototype MIIC Client (Java) to process heritage IC Plan
- Developed LEO-GEO Event Predictor algorithm (verified in Matlab)
- Developed initial client filtering classes
- Processed one month of G-13/Aqua MODIS with initial linear regression algorithm

MIIC Framework Build 2 & Future Plans

1. MIIC Framework, Build 2 (2013):

- Implement LEO-LEO orbital inter-calibration event predictors (Client).
- Develop spectral and spatial convolution functions (OPeNDAP remote servers).
- Implement CLARREO RS IC sampling approach: cookie-cutting (OPeNDAP remote servers).
- Extend statistical analysis methods: polynomial and Gaussian fits, noise reduction (Client).
- Implement Histogram library: 1D and 2D frequency distributions and averages (Client).
- Improve user interface: production and graphics (user terminal).
- Implement multi-process computing on High Performance Cluster (Client, SGE work flow).
- Test MIIC framework performance on the LaRC ASDC web servers.
- Optimize the MIIC framework software architecture.

2. MIIC Framework future plans:

- Target available NASA AO: ACCESS and AIST in 2014, possibility for direct funding.
- Extend the framework for Comparative Data Analysis (observations and climate models).
- Implement empirical PDM plug-in for RS inter-calibration (database).
- Develop new Work Flow Engine: Object Distributed Computing.

3. MIIC Framework project goals:

- Provide a prototype for the Earth Science data analysis Framework (open source).
- Synergy: science algorithms + modern software design + IT computing technology.

MIIC Multi-tiered Architecture