Multi-Instrument Intercalibration Framework

CLARREO Science Team Meeting
April 16-18, 2013

Chris Currey (NASA), Constantine Lukashin (NASA),
Carlos Roithmayr (NASA), Dave Doelling (NASA)
Aron Bartle (Mechdyne), James Gallagher (OPeNDAP)

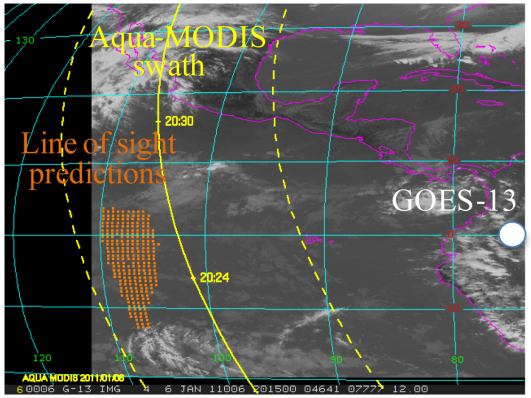
MIIC Framework

- The Multi-Instrument Intercalibration Framework is a collection of software designed to work in a distributed collaborative environment to *support* LEO-GEO and LEO-LEO intercalibration.
- The MIIC Framework leverages the OPeNDAP network protocol and server-side functions to *efficiently acquire matched event data* from within large volumes housed at remote data centers.
- Efforts are underway to extend services to access data from within the NOAA CLASS archive.

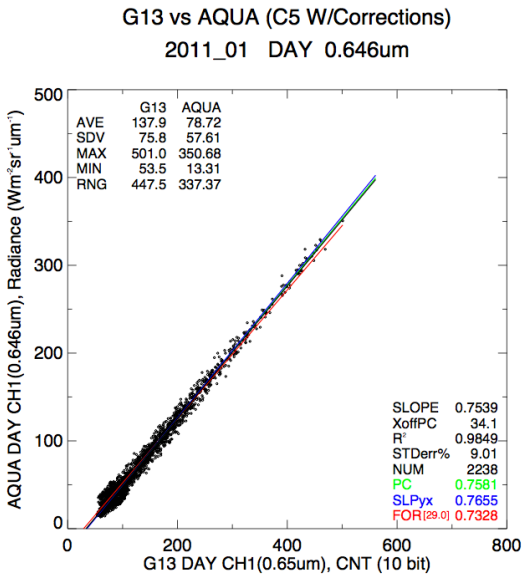
Funded by ROSES-2011 Advancing Collaborative Connections for Earth System Science (ACCESS), two year effort

LEO-GEO and LEO-LEO GSICS Use Cases

LEO-GEO Aqua-MODIS vs. GOES-13 (Doelling)

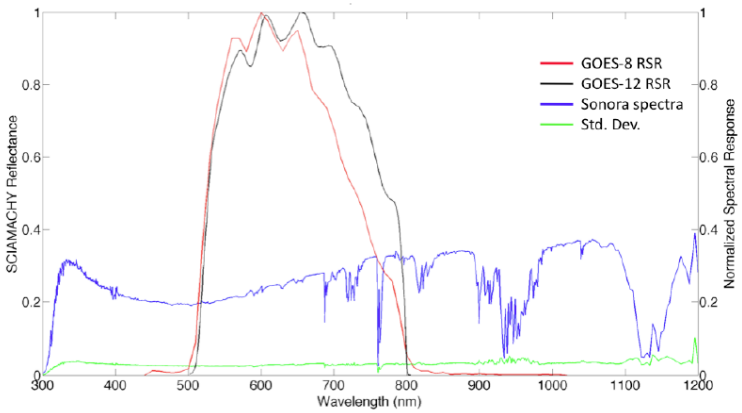


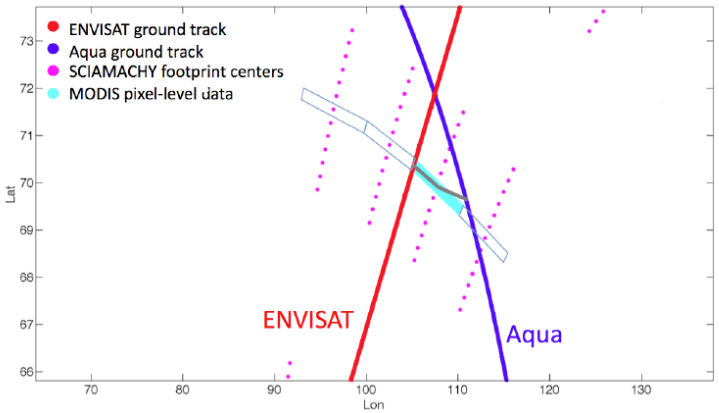
Gridding (0.5°)



Monthly Calibration

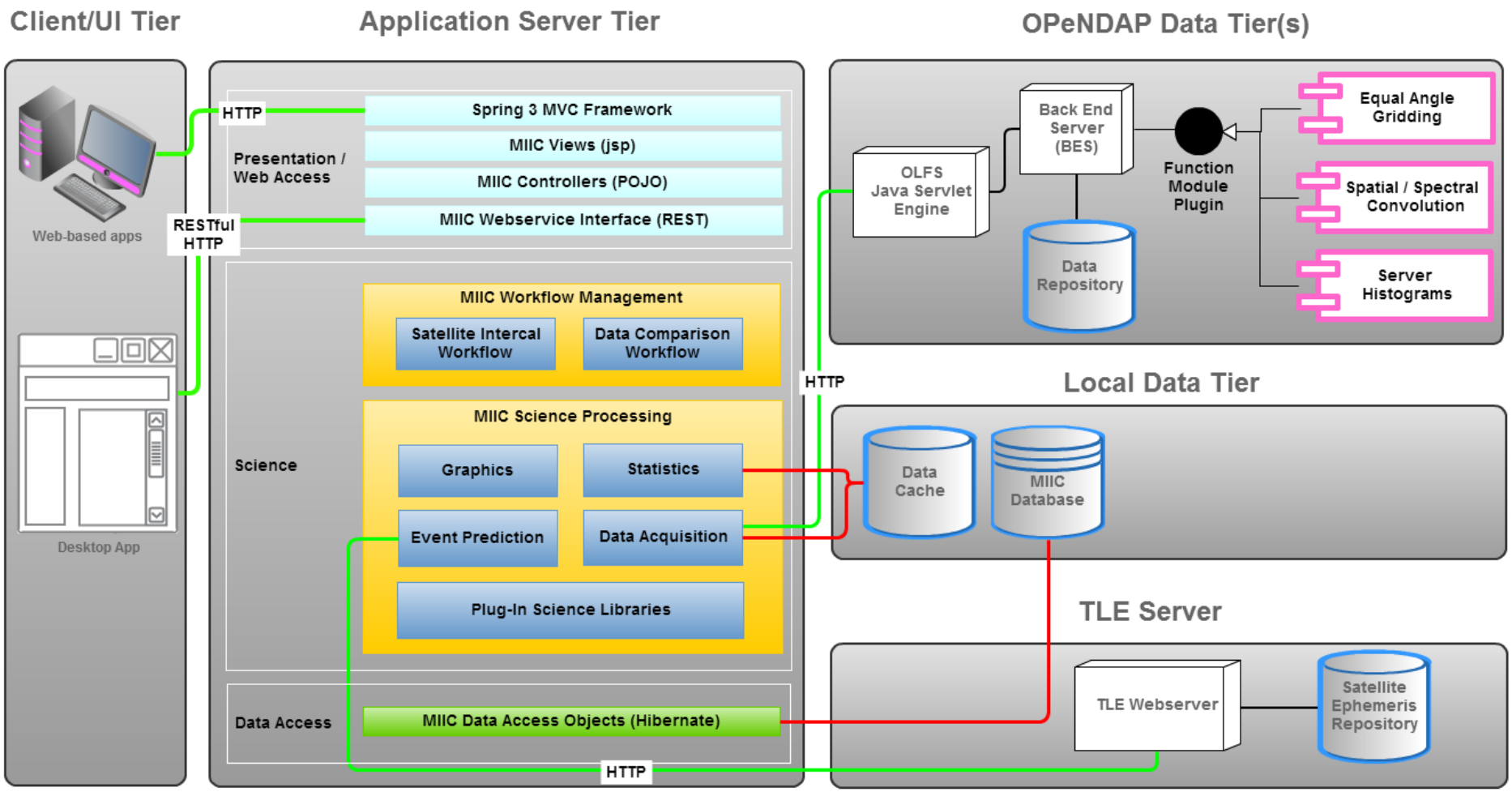
LEO-LEO Aqua-MODIS vs. Envisat-Sciamachy (Doelling)



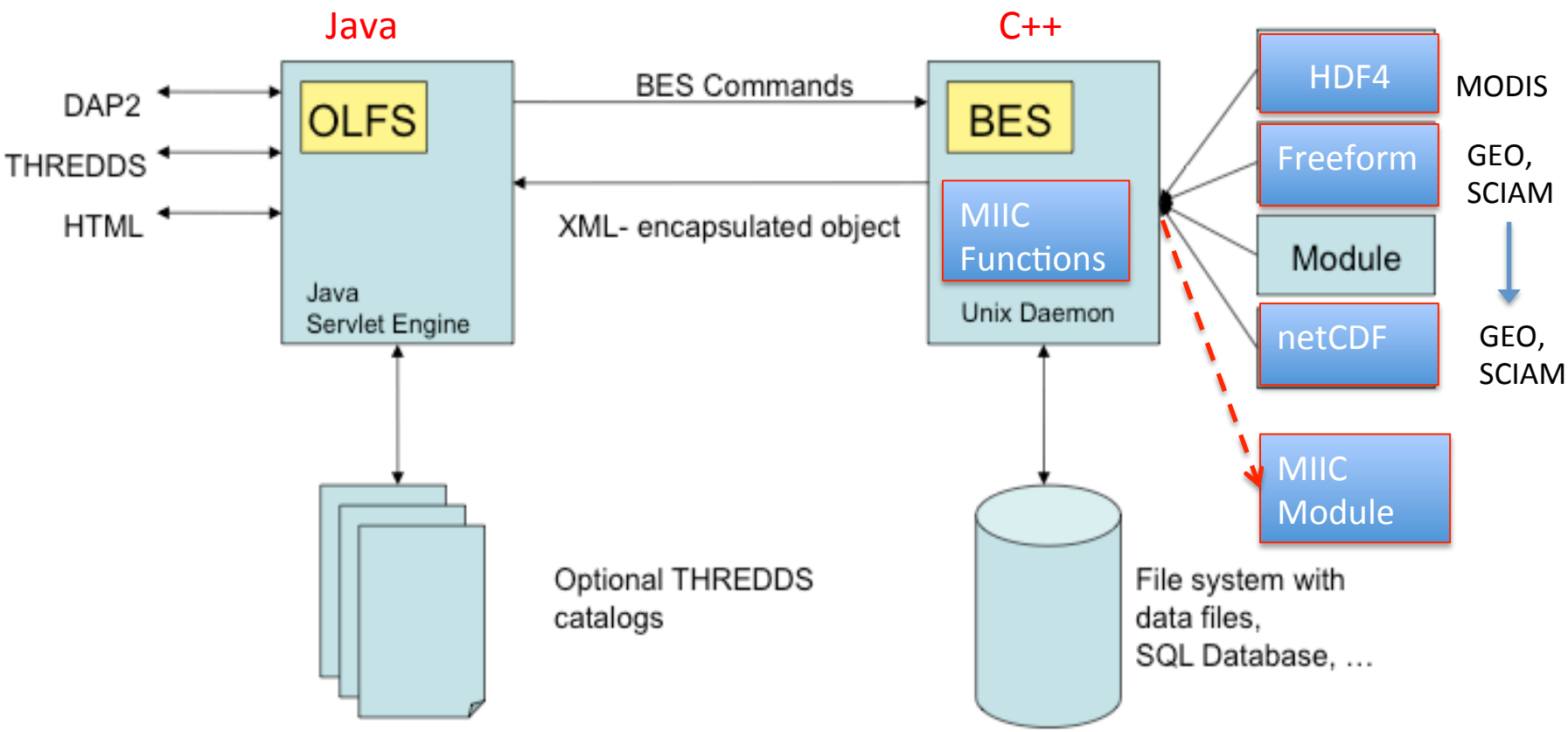


Spectrally convolve SCIAMACHY spectra with MODIS band 1 RSR to generate simulated reflectance, compare with MODIS pixels spatially convolved with SCIAMACY iFOVs

MIIC System Architecture



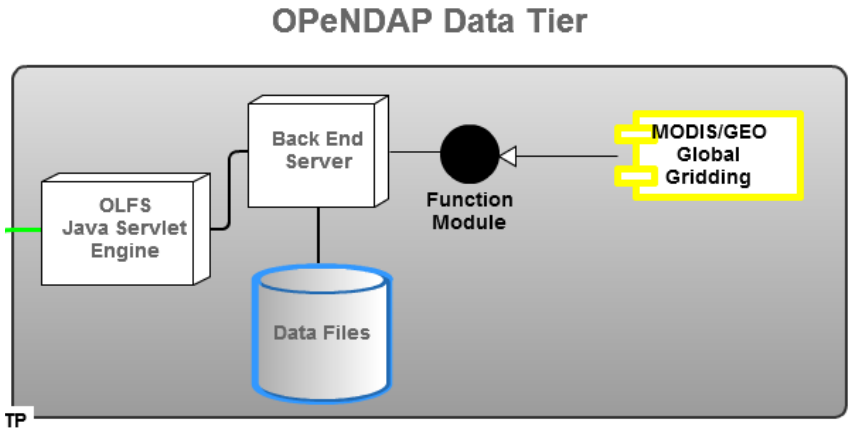
OPeNDAP Server w/ MIIC Server-side Functions



- Server deals with multiple file formats to create DAP2 objects for network transmission
- MIIC client queries THREDDS handler for directory contents
- OPeNDAP modified to package server-side functions into separate dynamic modules
- Performance issues with Freeform handler (binary files) -> use HDF or netCDF

OPeNDAP Data Tier: Server-side Functions

- Server-side function parameters defined within URL query string
- Example: Equal angle gridding



- http://…/MCIDAS.G-13.2011.01.01.2145.08K.bin.dods ← data URL
  ?eageogrid(.5, ← equal angle GEO grid, ½ degree
  GRID_VAR,TIME, ← scan time included in grid
  GRID_VAR, latitude, GRID_VAR, longitude,
  GRID_VAR, channel_data,"0", -99, ← channel 0, -99 is missing value
  FILTER_VAR, latitude,-35,10, ← include only lat from -35 to 10
  FILTER_VAR, longitude, -133,-104)

MIIC Web Services

- Event Prediction
- Data Acquisition
- Analysis

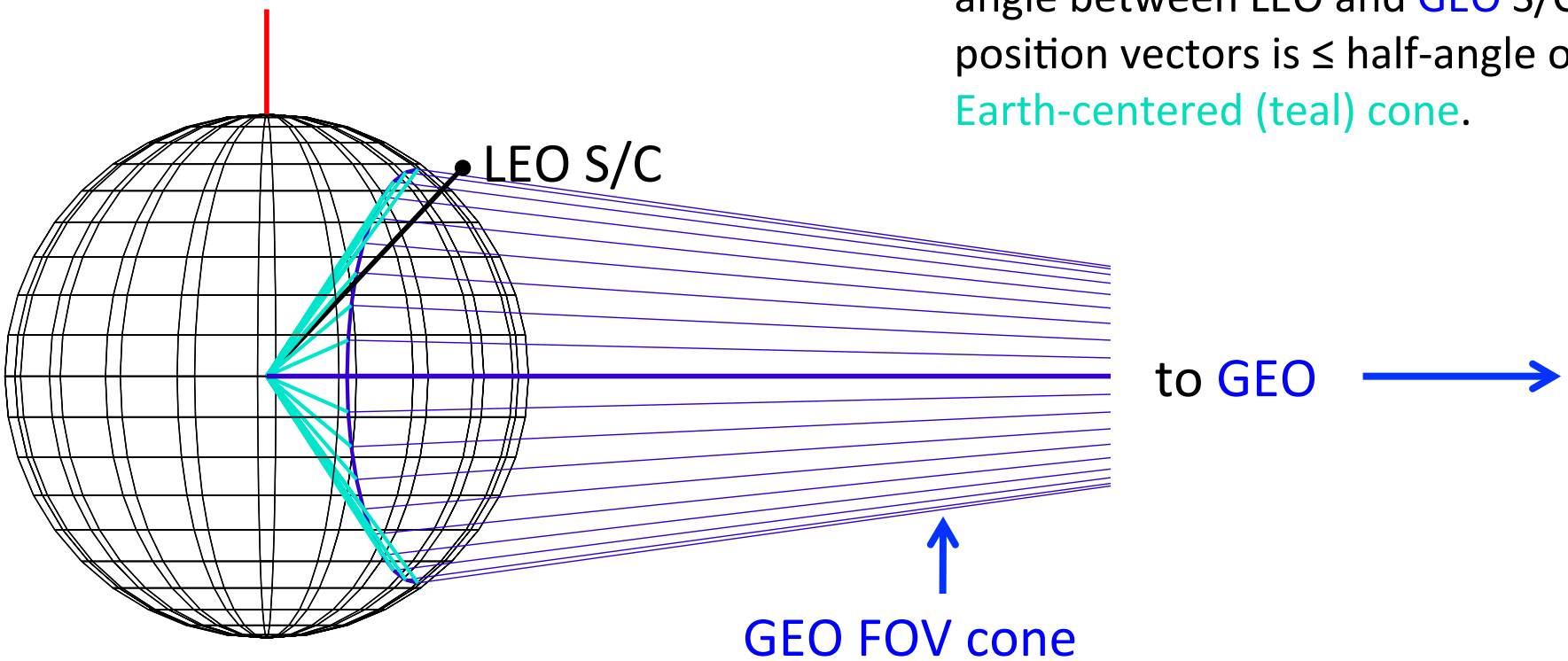
MIIC Event Prediction Services

- Determine locations and times when measurements from instruments on separate spacecraft have matched viewing conditions
- *Generates list* of matched events
- Each event defines filenames, lat-lon bounding box, instrument times entering/exiting box, and viewing conditions
- Key elements of Event Prediction algorithm
  - Daily Two-Line Elements (TLE) from NORAD
  - NORAD Simplified General Perturbations No. 4 (SGP4) orbit propagation
  - Geolocation algorithms
    - Determine when subsatellite point within field of view of second instrument
    - Determine when target point viewing angle differences within criteria
  - Works for both LEO-GEO and LEO-LEO

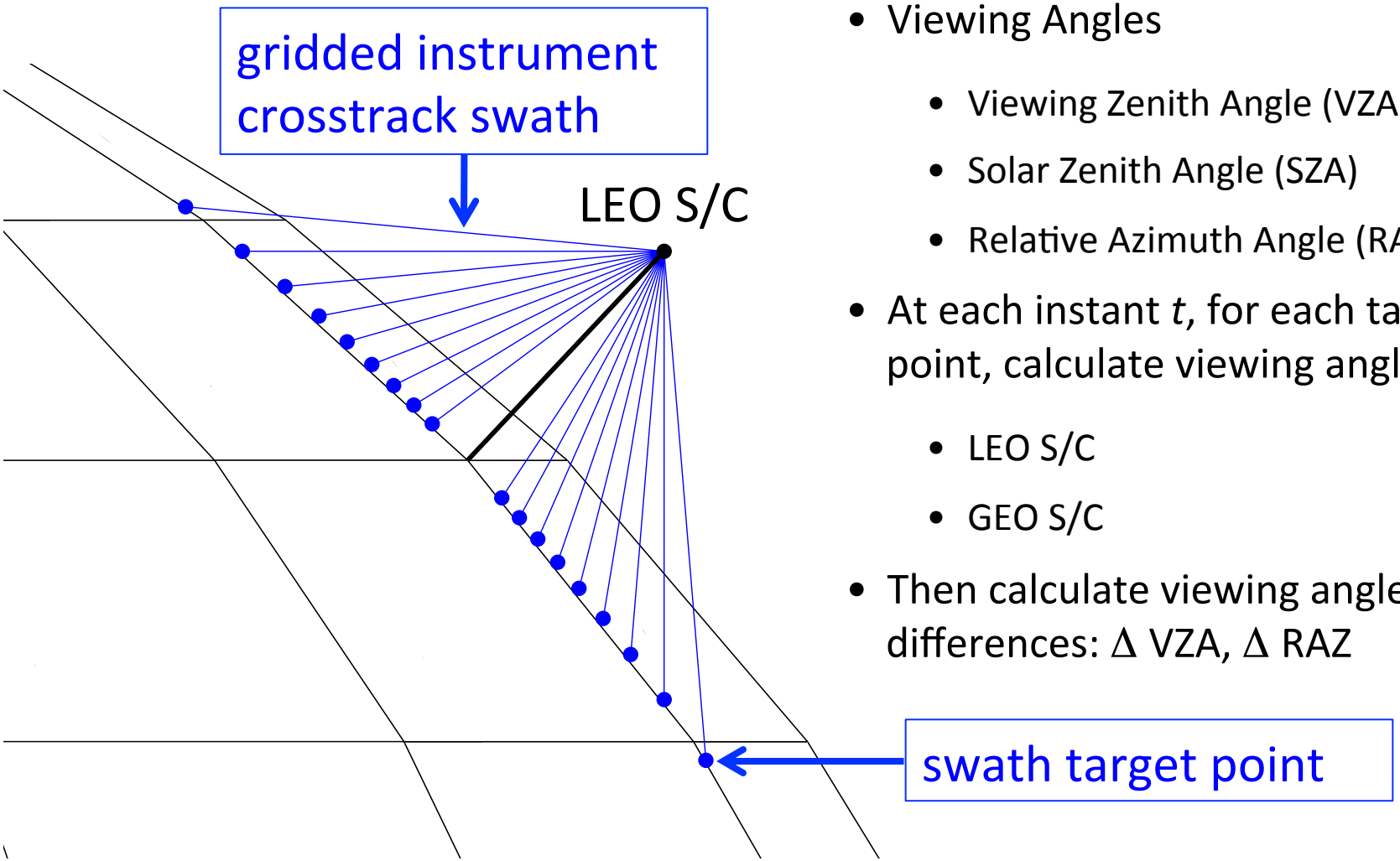
Intercal Cone (GEO vs. LEO)

When is LEO subsatellite point within GEO field of view?

Intercal can take place when angle between LEO and GEO S/C position vectors is ≤ half-angle of Earth-centered (teal) cone.



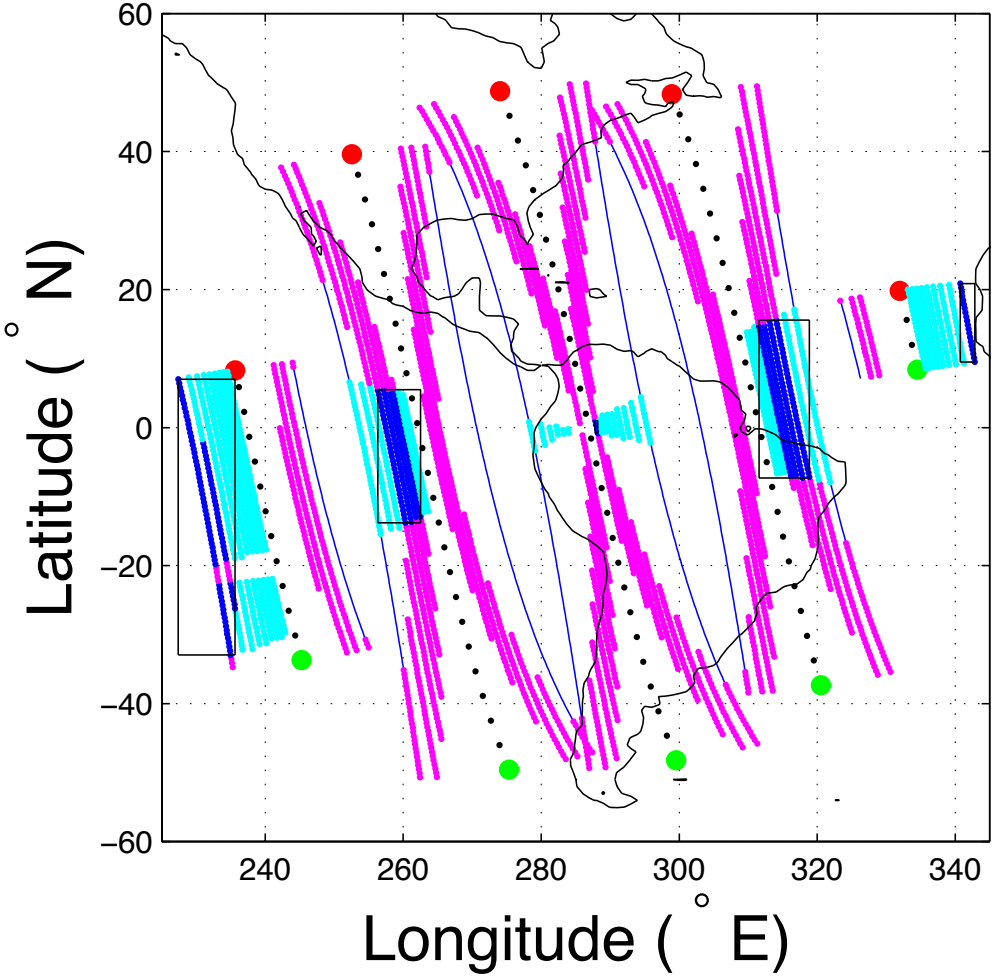
Points to be Checked for Angle Matching



- Viewing Angles
  - Viewing Zenith Angle (VZA)
  - Solar Zenith Angle (SZA)
  - Relative Azimuth Angle (RAZ)
- At each instant *t*, for each target point, calculate viewing angles for
  - LEO S/C
  - GEO S/C
- Then calculate viewing angle differences: Δ VZA, Δ RAZ

LEO-GEO Event Prediction (Build 1)

Aqua vs. GOES 13. Jan 1, 2011

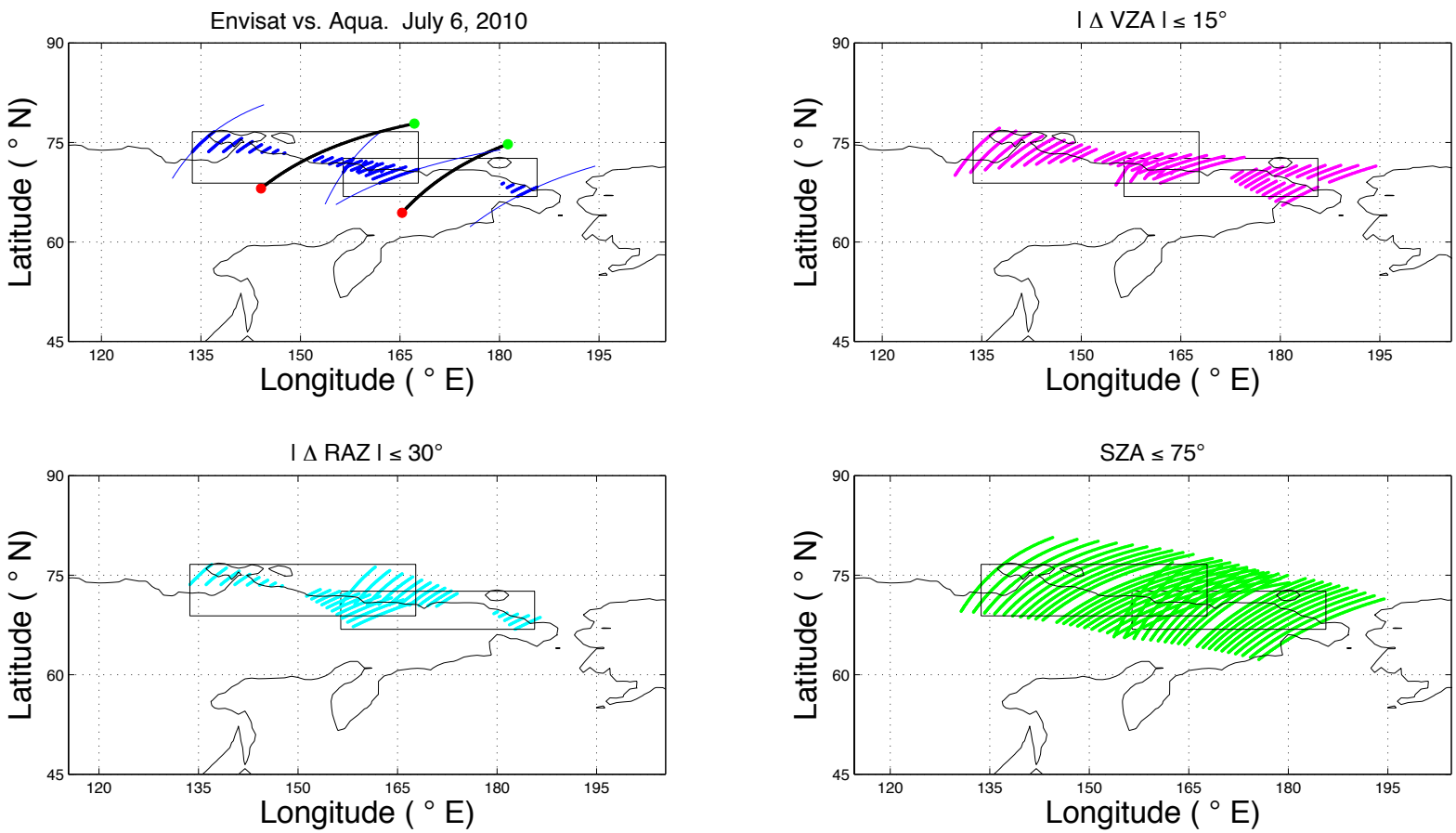


• • • Aqua ground track

Aqua swath

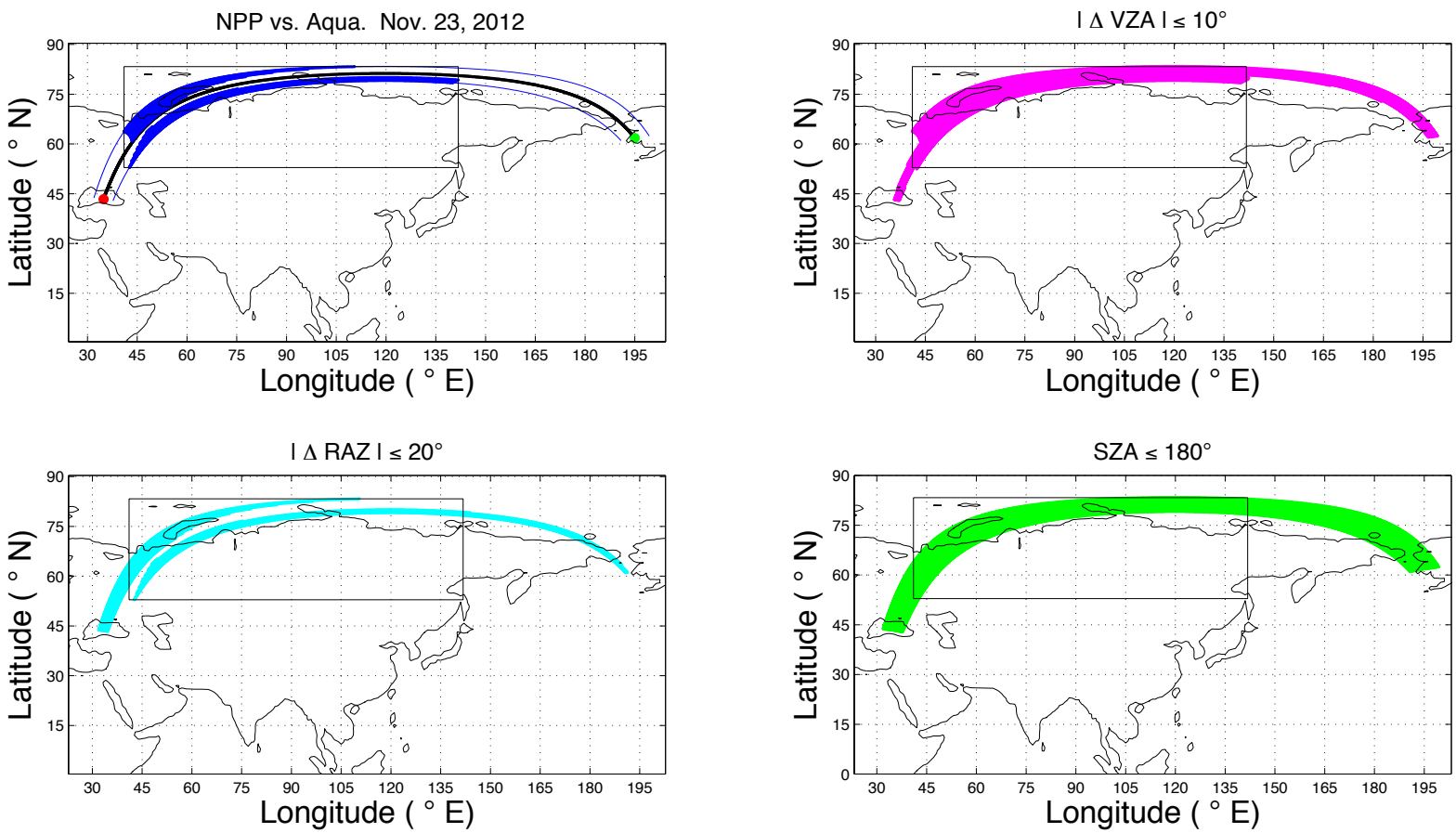
- |Δ VZA| ≤ 10°
- |Δ RAZ| ≤ 20°
- |Δ VZA| ≤ 10° and |Δ RAZ| ≤ 20°

LEO-LEO Event Prediction (Build 2)
Envisat SCIAMACHY - Aqua MODIS



Rectangle defines lat-lon box that meets all criteria (top left), SZA ≤ 75°, |Δ RAZ| ≤ 30°, |Δ VZA| ≤ 15°, |Δ T| ≤ 2.5 min.

LEO-LEO Event Prediction Aqua – NPP
(Support future CLASS use cases)

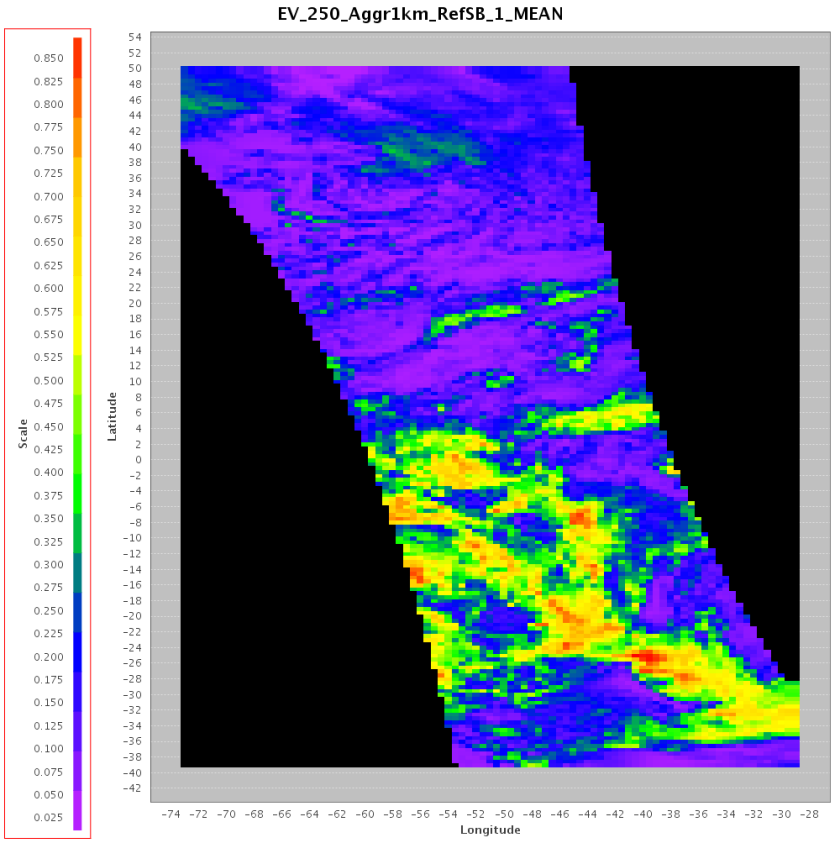


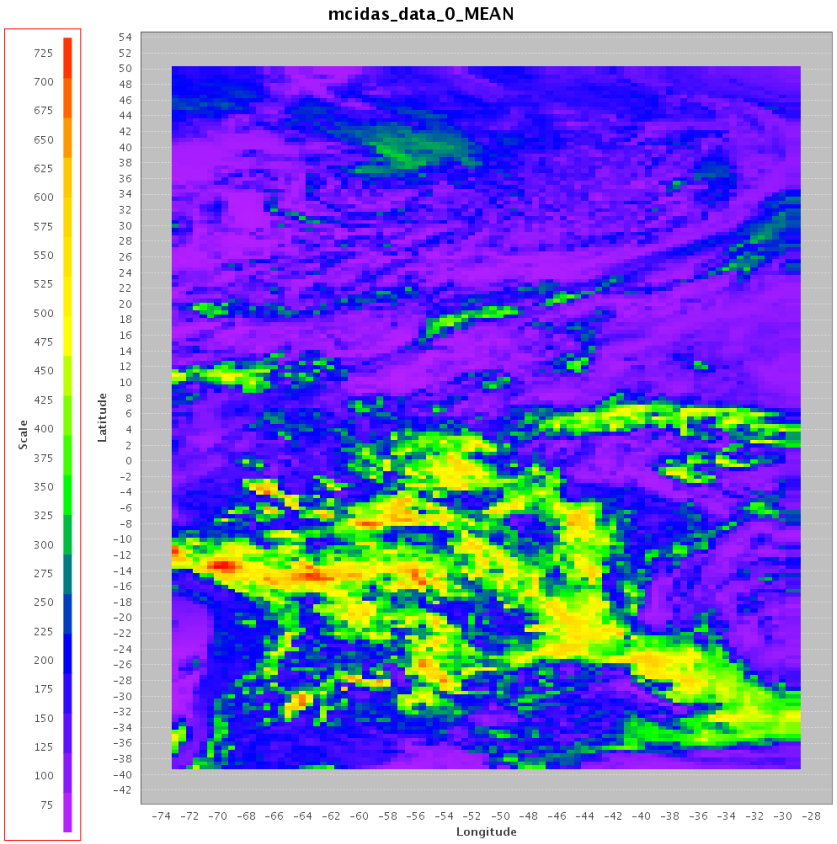
Rectangle defines lat-lon box that meets all criteria (top left), SZA ≤ 180°, |Δ RAZ| ≤ 20°, |Δ VZA| ≤ 10°, |Δ T| ≤ 30 sec., nighttime scene

MIIC Data Acquisition Services

- *Acquire matched samples* specified by the Event Predictor from remote data centers using the OPeNDAP network protocol
- Server-side functions average data into common field of view, grid, or bandpass at sensor archive center
  - *Acquire* equal angle gridded data
  - *Acquire* spectrally convolved data, pass in multiple RSRs
  - *Acquire* spatially convolved data, pass in FOVs
- Considerable reduction in transmitted data volume - for intercalibration typically < 0.1% data volume required
- Service good for users that just want the matched data, i.e., they have their own analysis programs
- Data returned to user in netCDF or HDF (TBD)

Matched LEO-GEO Gridded Event

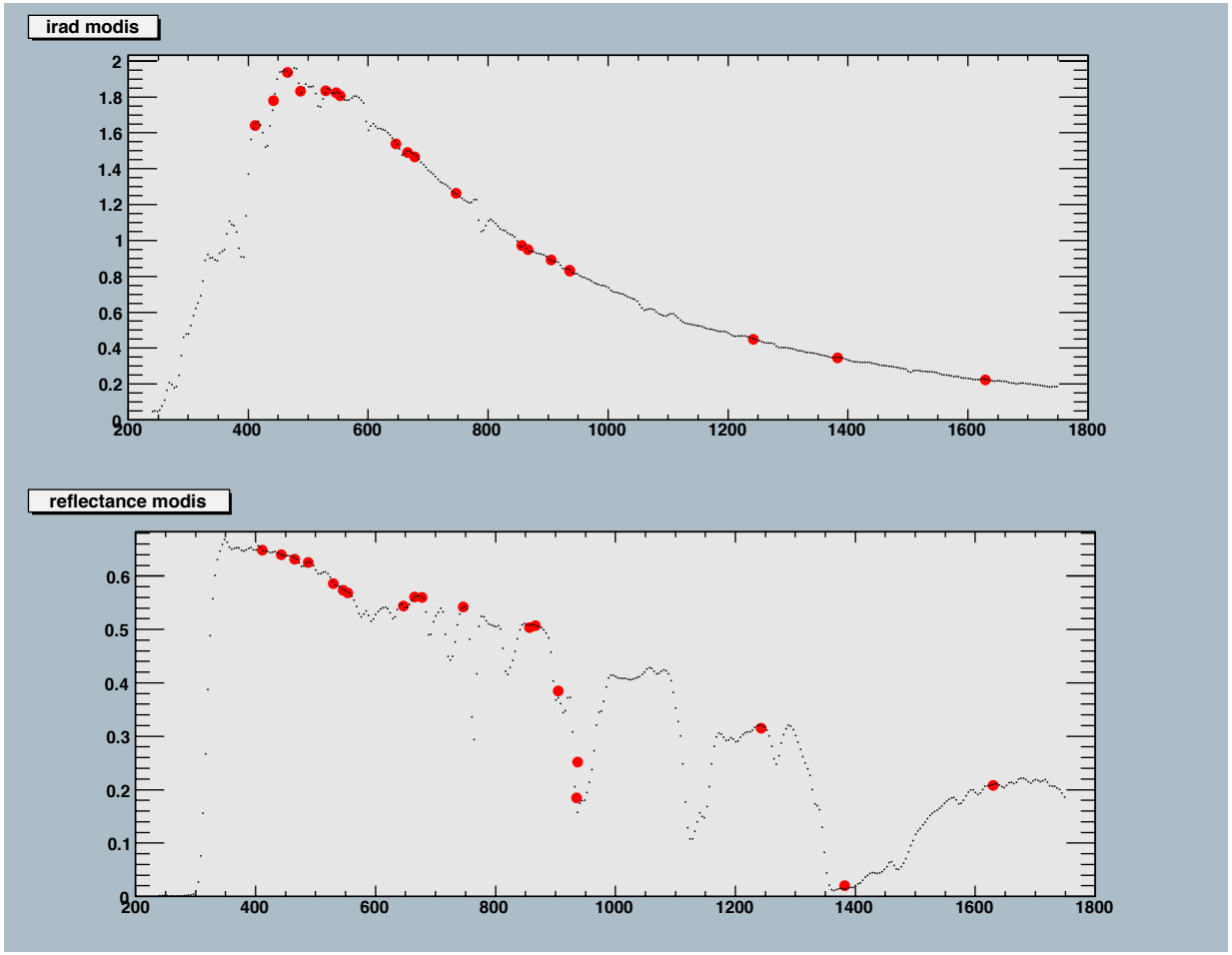




MODIS EV_250_Aggr1km_RefSB band 1 (620-670 nm), 2011-01-01 hour 16, multiple 5 min. granules

GOES-13 0.65 um , GOES-13 time 1645

Spectral Convolution Server-side Function
(MODIS RSRs + SCIAMACHY data)



- Server-side spectral convolution function testing with MODIS band 1 RSR
- OPeNDAP supports HTTP GET commands; must modify to support POST commands to pass in multiple large arrays of RSR values

Build 1 Test Results (LEO-GEO) and Lessons Learned

Test	OPeNDAP Servers (Data)	Staged Input #Files (GB)*	Transfer DODS Files (GB)	Reduction Factors	Bes Server Resident Memory (MB)	Download Time secs. (mins.)
Raw 1 server	dataserver2 (G-13, MODIS L1B)	9672 (1357)	808** (62.1)	12.0 (21.9)	161 MB, 141 MB	2216 (36.9)
Grid 1 server	dataserver2 (G-13, MODIS L1B)	9672 (1357)	808 (1.8)	12.0 (753.9)	143 MB, 143 MB	3974 (66.2)
Raw 1 server	clarreo-a (G-13, MODIS L1B)	9672 (1357)	808 (62.1)	12.0 (21.9)	273 MB, 127 MB	2339 (39.0)
Grid 1 server	clarreo-a (G-13, MODIS L1B)	9672 (1357)	808 (1.8)	12.0 (753.9)	219 MB, 273 MB, 127 MB	3519 (58.7)
Raw 2 servers	dataserver2 (G-13) clarreo-a (MODIS L1B)	744 (18) 8928 (1339)	808 (62.1)	12.0 (21.9)	163 MB, 140 MB	2058 (34.3)
Grid 2 servers	dataserver2 (G-13) clarreo-a (MODIS L1B)	744 (18) 8928 (1339)	808 (1.8)	12.0 (753.9)	195 MB, 196 MB, 465 MB, 459 MB	4680 (78.0) ~13 min. gap (64.0, 2nd run)

*MODIS L1B files (storage) per month: 8928 files (1339 GB); GEO 744 files (18 GB)
**130 GEO (6.1 GB) 678 MODIS (56 GB)
Client filtering: -vza 15 -raz 15

- 98% time spent in server-side functions + network transfer, 2% in client processing
- Prediction accounts for 22x reduction in data volume transferred, 34x reduction due to gridding
- Build 1 total reduction factor of 754

MIIC Analysis Services

- Current focus on intercalibration
  - Implement GSICS algorithms
  - Execute end-to-end LEO-GEO or LEO-LEO operations
  - Output linear regression statistics and plot
  - Persist calibration coefficients in database
  - Provide temporary disk caching of matched data
- Can evolve to support CLARREO-like mission and IC algorithms
- Follow-on proposals to expand client-side analysis capabilities
  - Workflow engine to run batch science jobs on cluster
  - Earth Science Analysis Library (Lukashin)

Future Plans

- Submit proposal to ROSES-2013 ACCESS:
  Multi-Instrument Intercalibration (MIIC) Framework Extensions and Deployment

  Chris Currey (NASA), Constantine Lukashin (NASA), James Gallagher (OPeNDAP), Aron Bartle (Mechdyne), David Doelling (NASA), Mike Little (NASA), Alan Hall (NOAA), Jay Morris (NOAA), Rosemary Baize (NASA), John Kusterer (NASA)

  - Deploy MIIC services at the Langley Atmospheric Science Data Center
  - Collaborate with NOAA NCDC to access data (CrIS, IASI, VIIRS, and GOES) from the CLASS archive using the MIIC services
  - Extend features:
    - Compare L2 data parameters
    - Libya-4, Dome C, and other GSICS defined surface targets
    - Generalized histogram data analysis to check quality of data
    - Additional atmospheric parameter and surface type filtering
    - Compare climate models/OSSE with observational data (TBD)

- Continue to collaborate with GSICS – presented at GSICS Annual meeting - positive feedback from heads of Research and Data Working Groups