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

- 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

GOES-13 visible calibration gains

Jan 2011
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
Bounding box, 4 corners define the domain

West Banana Domain

East banana domain

Vzgeo = VZmodis

Vzgeo = VZmodis
Predictor Enhancements

Aqua vs. GOES 13. Jan 2, 2011
Predict output file – used in Build 1

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- **Equator crossing time**
- **Equator longitude**
- **Equator solar zenith angle**
- **# of visible angle matched regions**
- **Domain boundaries of IR**
- **# IR angle matched regions**
- **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://clarreoa.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

• 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<À^@^@^@^@^@À
```

```
MIIC Multi-tiered Architecture (test on ASDC web servers)
Build 1 Regression Matched Grid Samples NO angular filtering

Jan 1, 2011

MIIC Linear Regression

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).

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.