Reanalysis and Observation Feedback at the GMAO

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Nov 2014

Core-Climax Coordination Meeting Towards Exchanging Reanalysis Observation Feedback and Blacklists

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National Aeronautics and Space Administration

Current Reanalysis Status

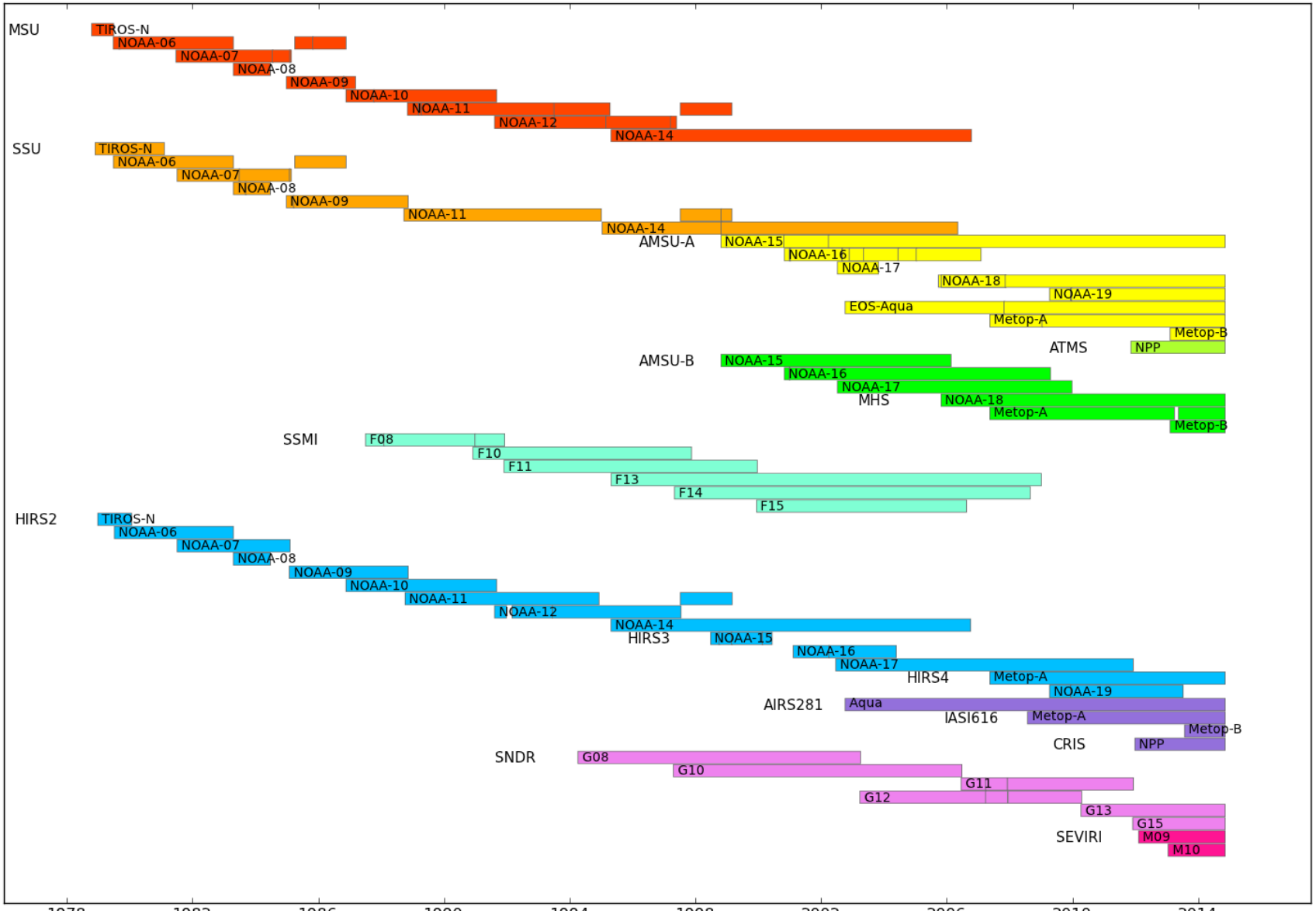
- MERRA (one)
  - Still Running
    - Nominally 2 weeks behind realtime
  - Frozen system circa 2007
    - GSI 3D-Var, GEOS-5 finite volume, 0.5°x0.67°, 72 hybrid-eta levels to 0.01 hPa
    - local version 5.2.0
  - No preparation for future instruments
    - Lacking NOAA-19, Both Metops, SNPP, GPSRO
    - One of the key initial drivers for MERRA2
  - As instruments go, so will the quality of the system
  - Offline land, aerosol, and ocean products
  - Plans are to halt the system at some point to force people to MERRA2

Current Reanalysis Status

- MERRA2
  - Four streams in progress, > 60% complete
  - Based on a 2014 system
    - GSI 3D-Var, GEOS-5 cubed-sphere interpolated to 0.5°x0.625°, 72 hybrid-eta levels to 0.01 hPa
    - local version 5.12.4
  - Key Updates:
    - More observations – through Metop-B/SNPP, and potential to incorporate JPSS and Metop-C (no SSMIS), Aura OMI & MLS, GPSRO
    - Reprocessed satellite data (e.g. Wentz SSMI v7, SBUV v8.6)
    - Aerosol assimilation and Aerosol-model interaction (AVHRR pre-EOS, MODIS post-EOS)
    - Improved hydrology (balanced Precip/Evaportation)
    - External precipitation correction (keeps LandSfc in line, only affects aerosols over ocean)
    - Vortex Relocation

Satellite Radiances

MERRA-2



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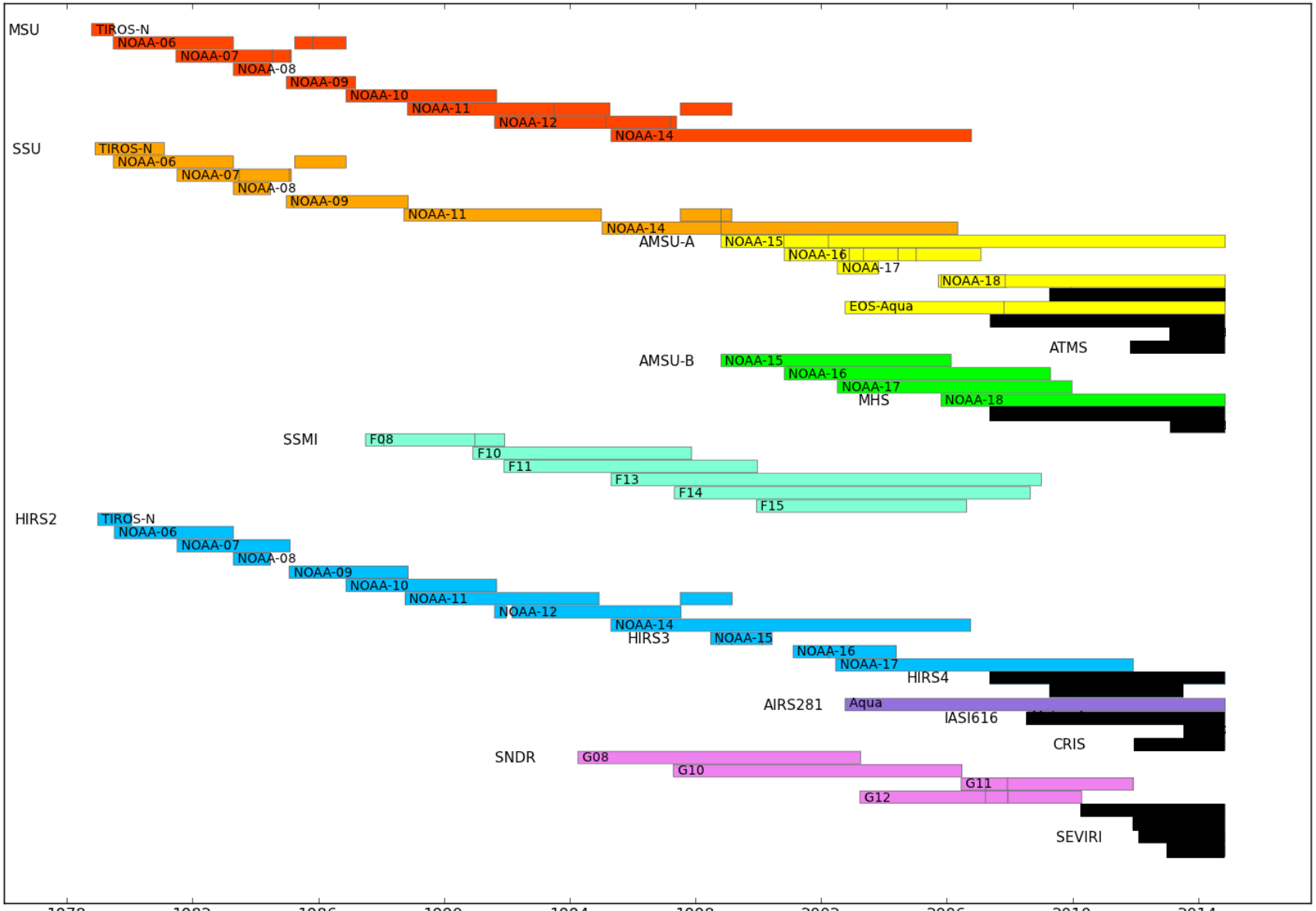
Satellite Radiances

MERRA



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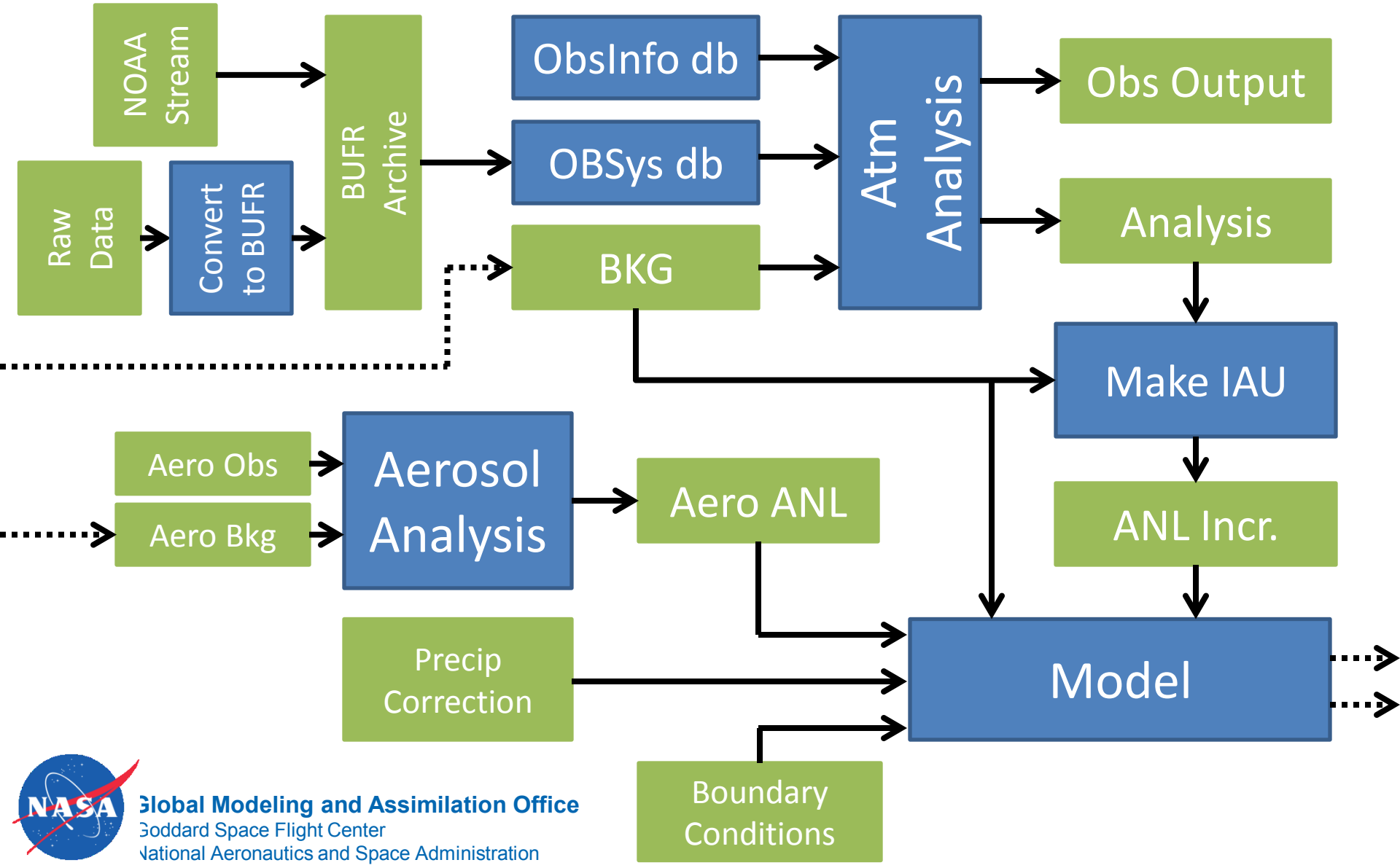
Mechanics of System



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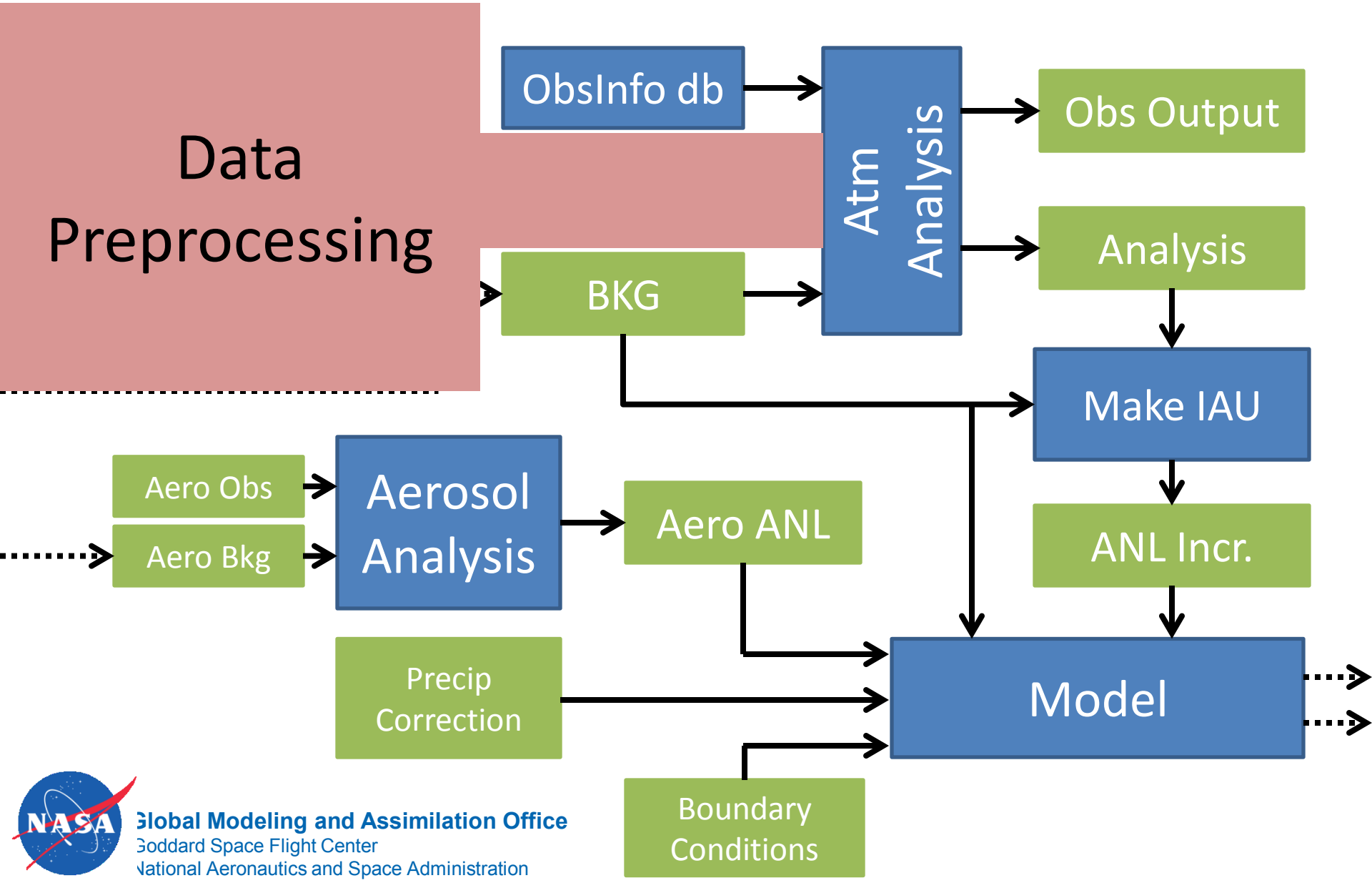

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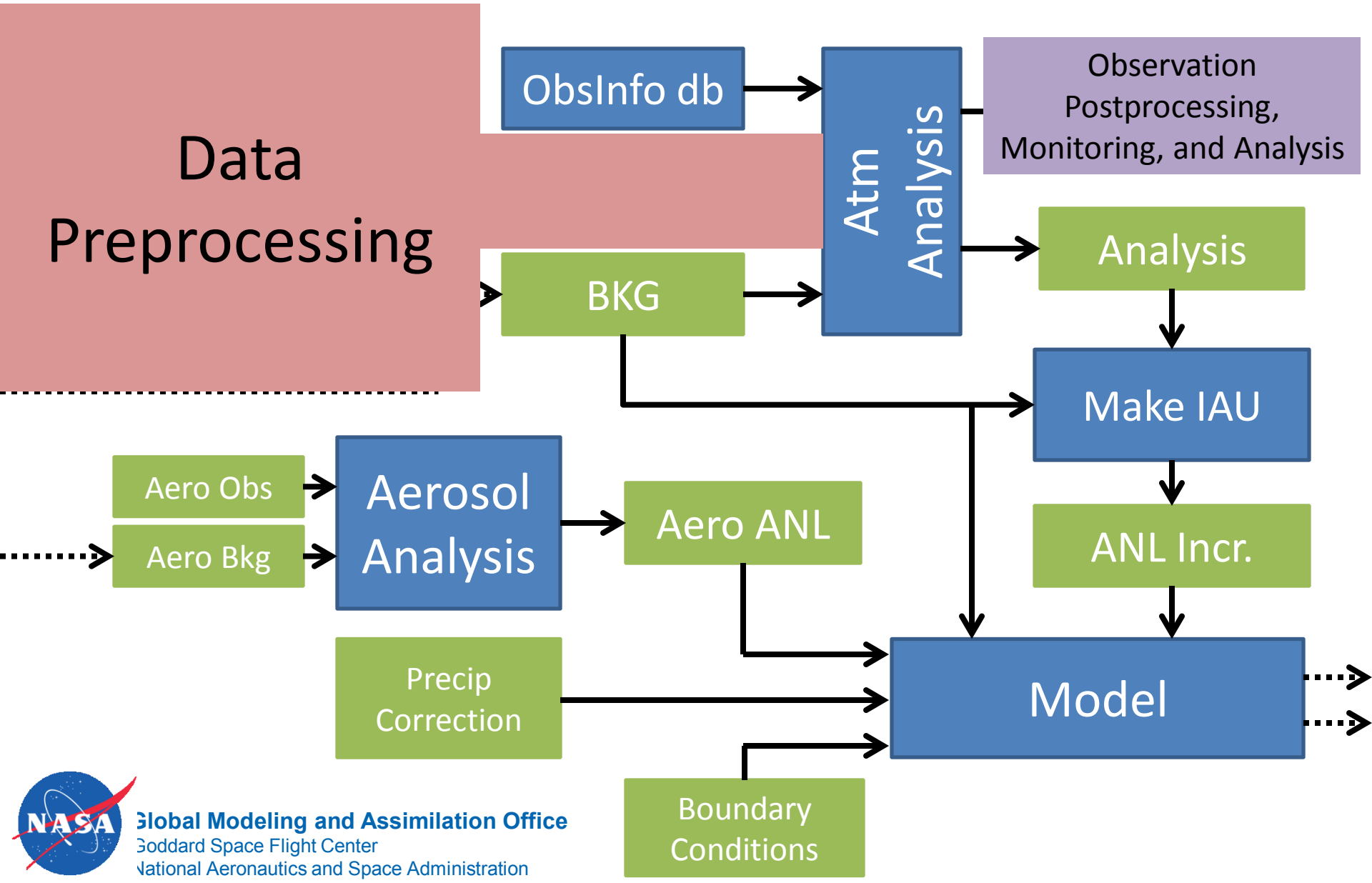

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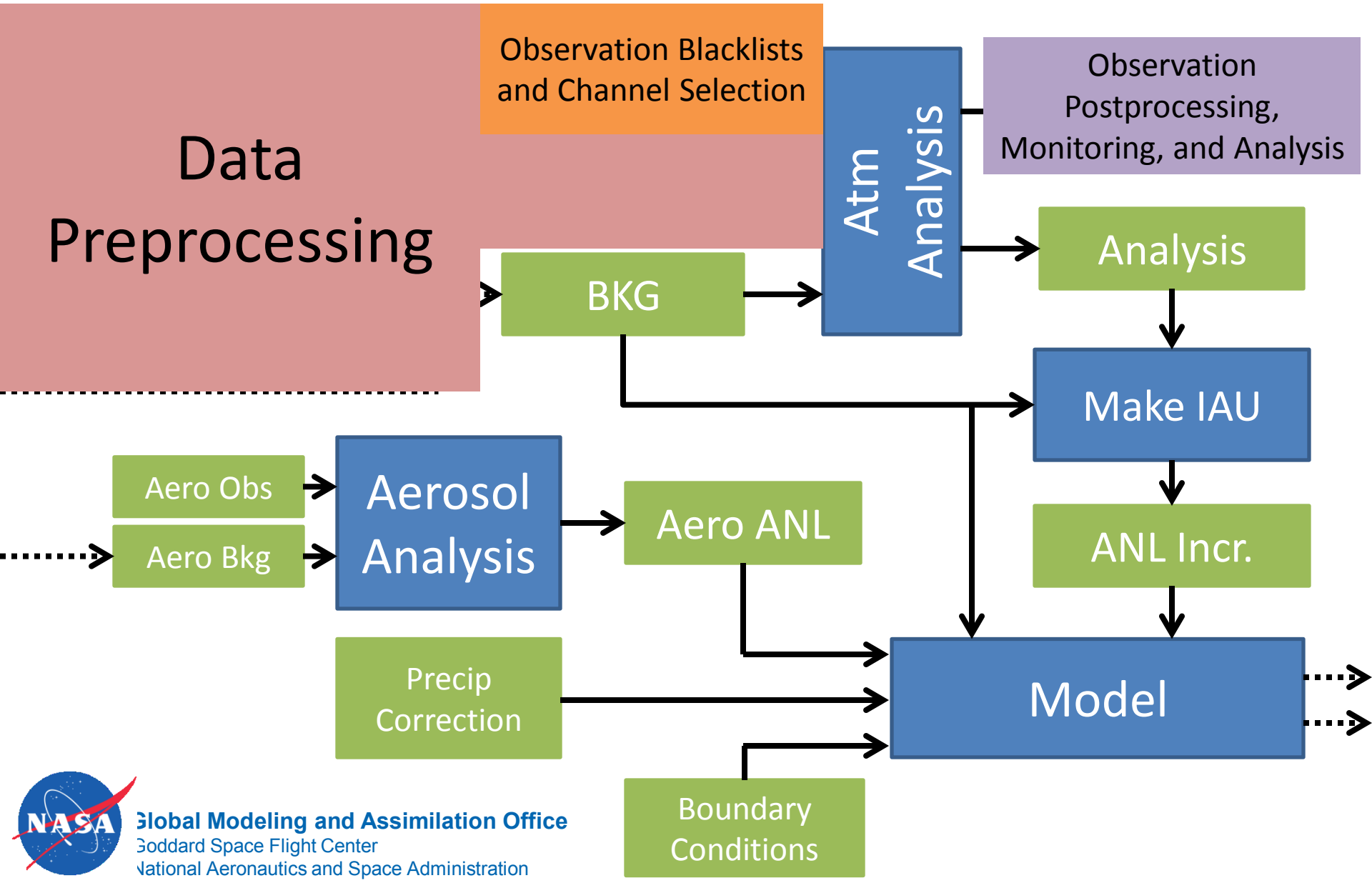

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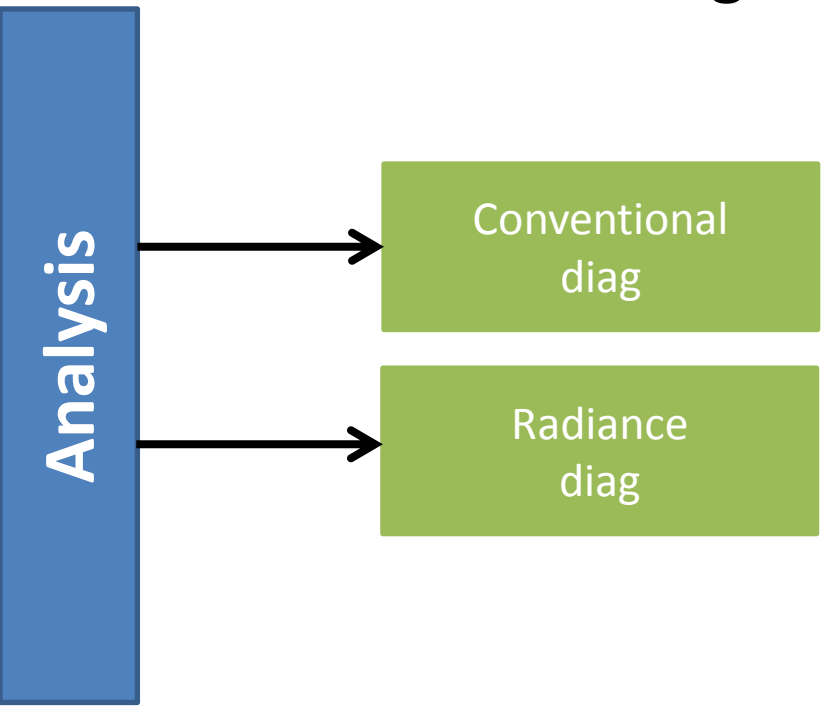
Pre-Processing: Staging/Storage of Input Data

- All files are handled in their inherent BUFR format
  - Most recent data through NESDIS
  - Most heritage data reprocessed/converted to bufr
- Templated files and directories
  - e.g. /path/to/file/CRIS/Y####/M##/D##/source.YYYYMMDD_HHz.bufr
- Driven by a simplified database (obsys.rc)
  - converts templates to actual paths and retrieves the data
  - System requires a file, so zero-length files hold missing data gaps that have been determined as unrecoverable

General Observation Feedback

- All Observations (conventional, O_3, GPS, radiance)
  - Written as 'diag' files of varying formats

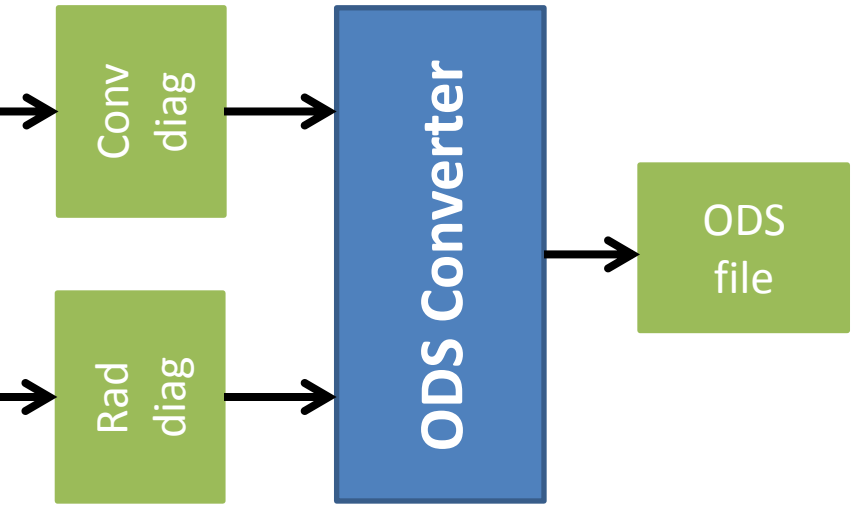


diag files:

- Fortan structures raw-dumped to files
- Advantage:
  - easily concatenated
- Disadvantages:
  - Structure changes, everything breaks
  - Not easily integrated into other languages
  - Not standardized or self-describing

General Observation Feedback

- All Observations
  - Diag files are then converted to 'ODS' files

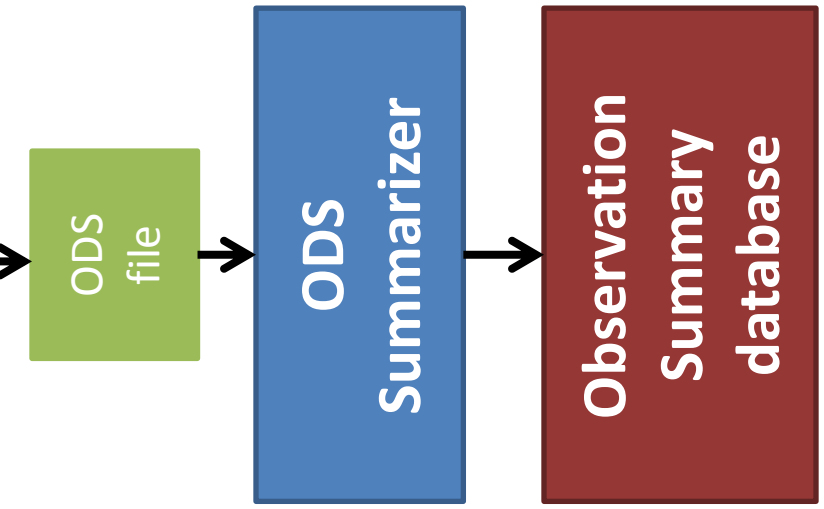


ODS files:

- HDF4 with set structure
- Advantage:
  - Unified structure for all obs
  - Self-describing
- Disadvantages:
  - Existing structure based on heritage groupings – requires post-processing
  - Structure itself not completely straightforward
  - Discards lots of information in diags

General Observation Feedback

- All Observations
  - ODS files are then summarized, and those summaries populate a database

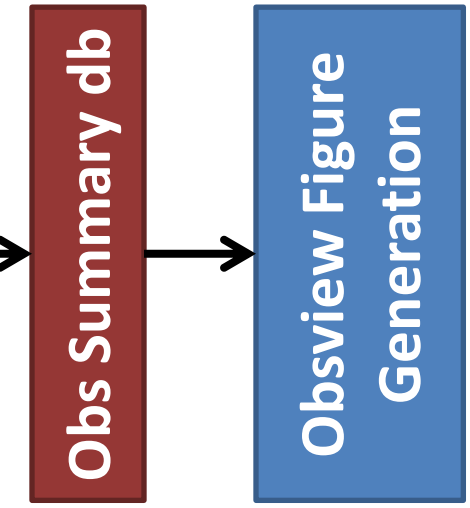


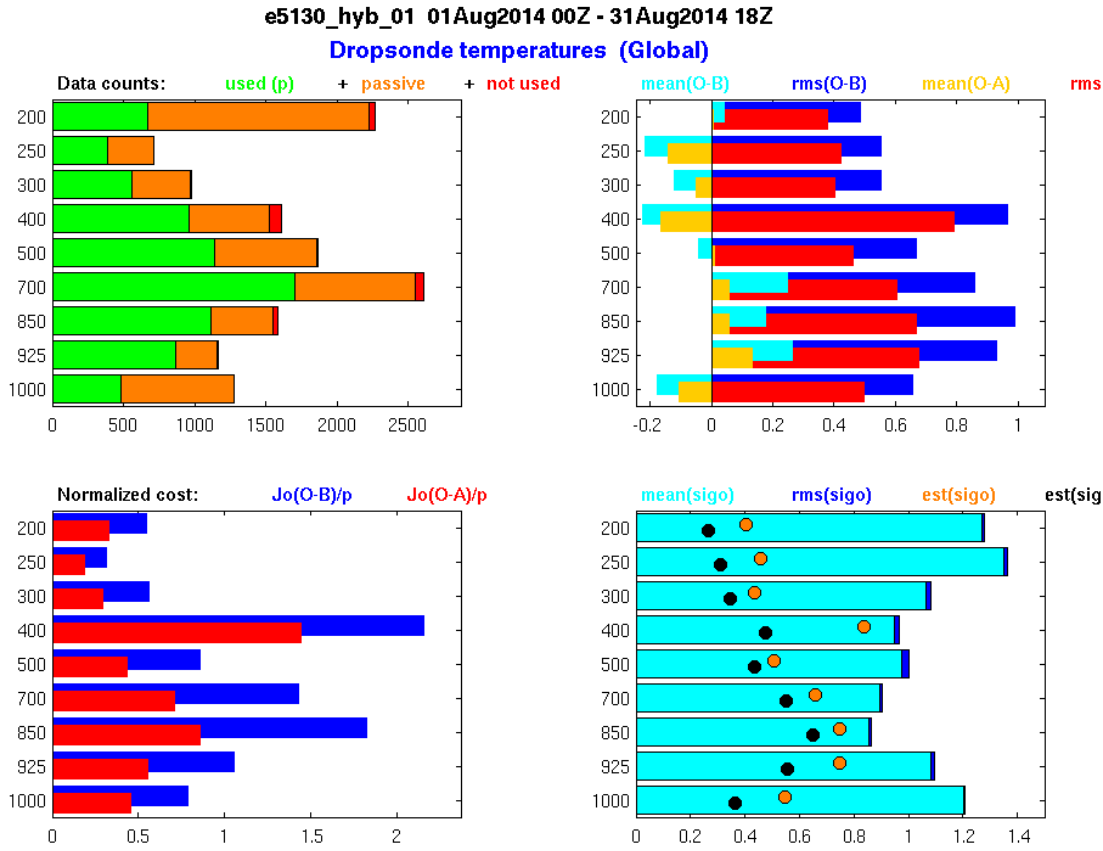
Obs Summary Database

- SQL database with basic summary information
- Advantage:
  - Database – no demigration
- Disadvantages:
  - Not easily interfaced among languages
  - Not easily queried without learning database
  - Limits of ODS extend into database regarding discarded info

General Observation Feedback

- All Observations
  - Database is then queried for a standard set of figures via python interface





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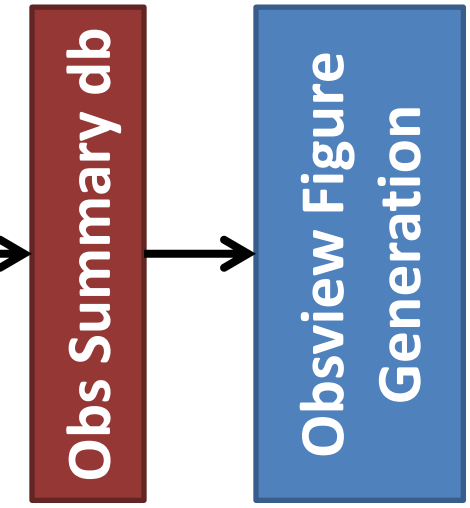

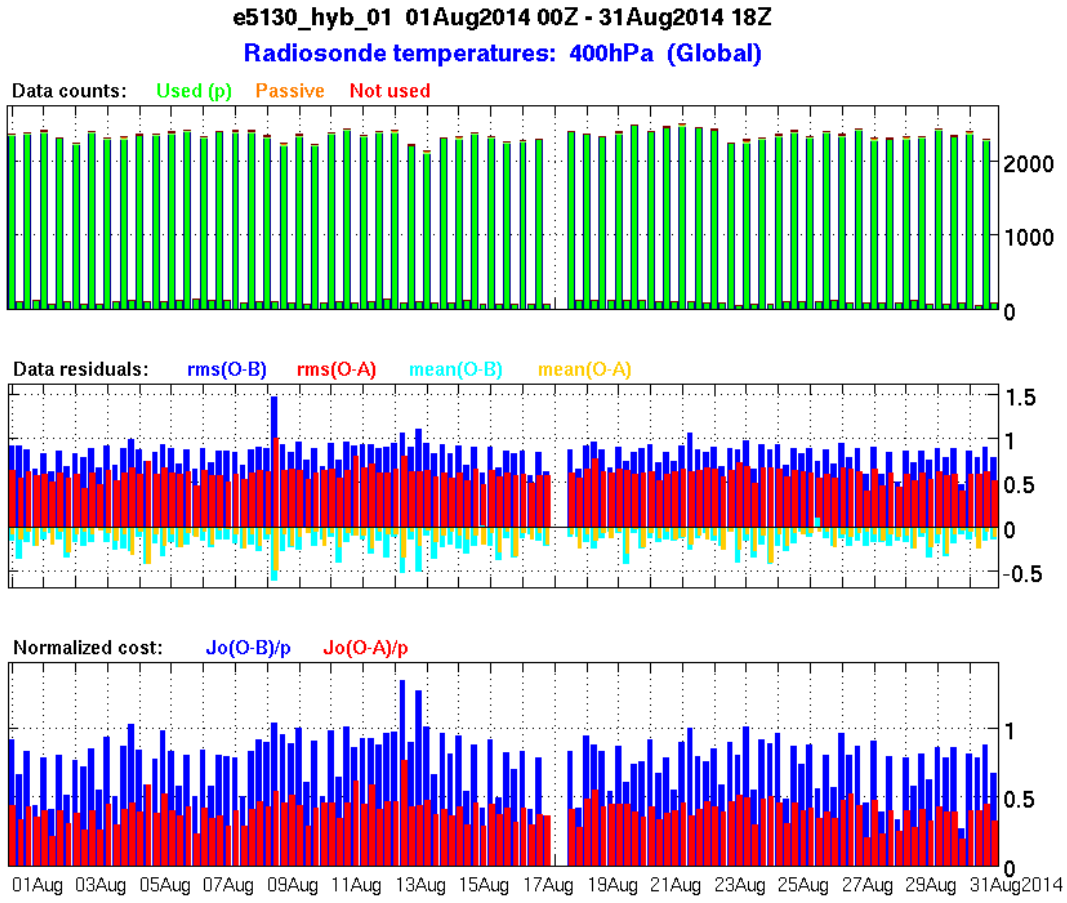

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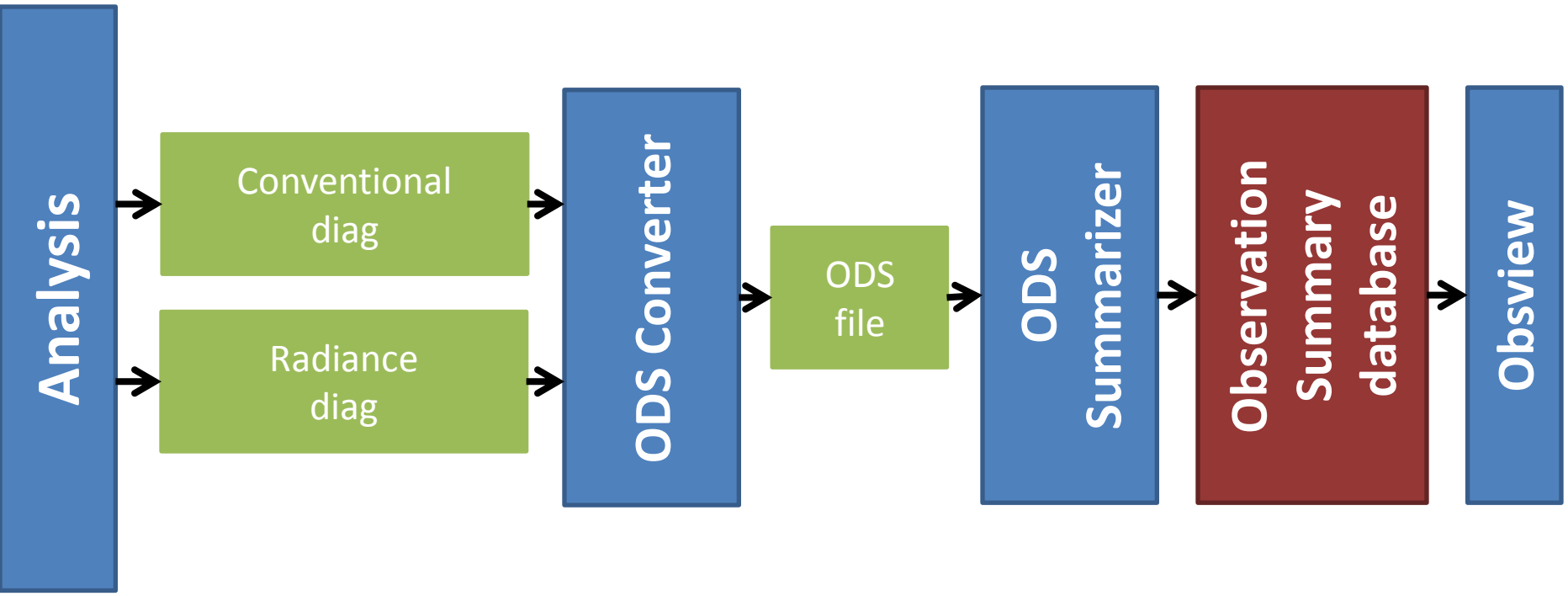
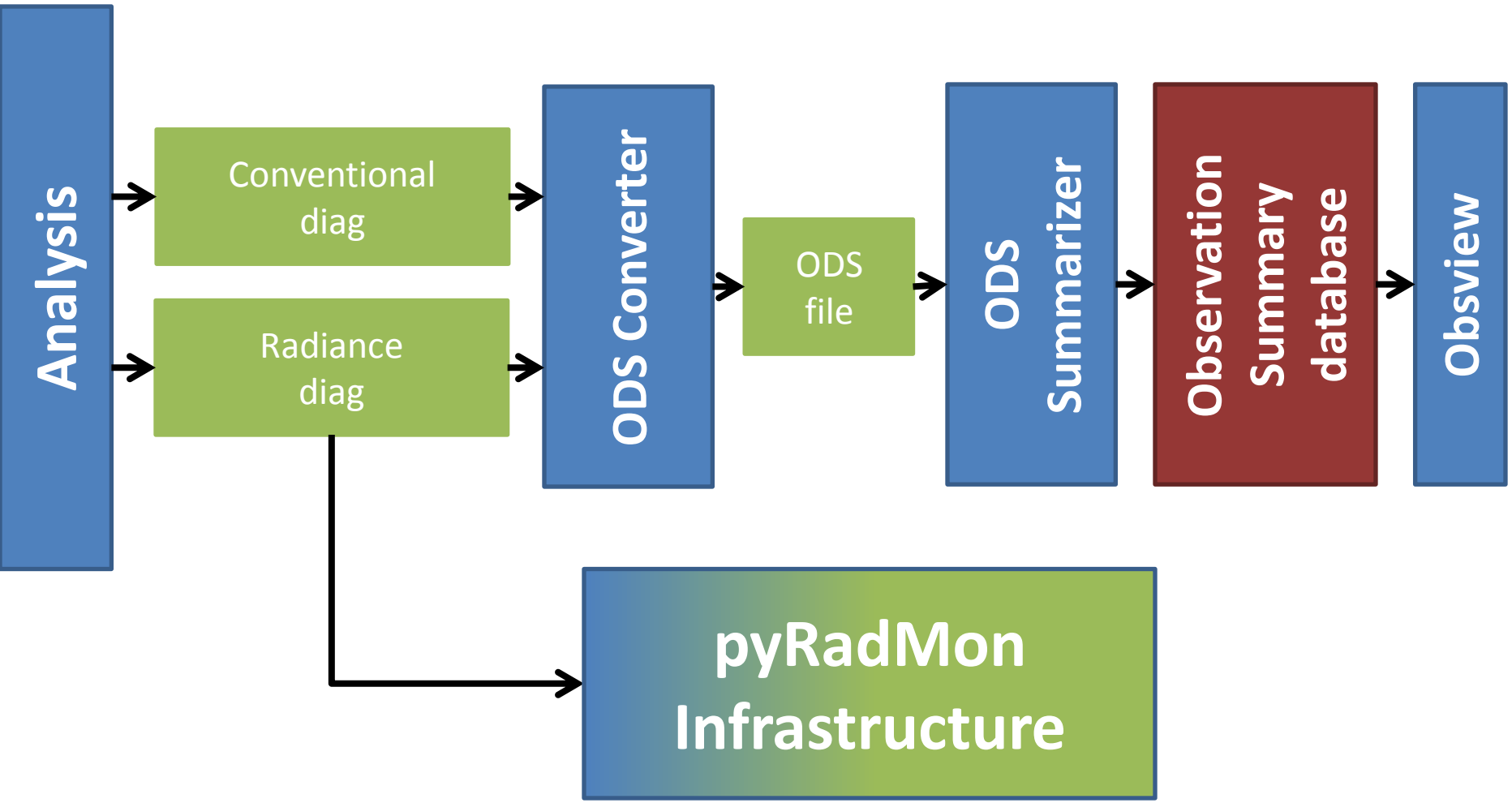
General Observation Feedback



Observation Feedback



Radiance Observation Feedback

- Why separate infrastructure for radiances?
  - Started as a simple program to monitor output with simplified ASCII table to provide channel-by-channel summaries
  - ODS files discard lots of information in diag files (surface characterization, bias corrections, qc outputs, etc.)
  - Diag files are large, cumbersome to deal with
  - Summaries can be stitched together to create long time series

Radiance Observation Feedback

- OK, so the infrastructure

ASCII Summary:

- Flexible Summary table
- Conversion is done in fortran due to diag constraints
- Advantage:
  - Easy to understand
  - Developed infrastructure to query with python
- Disadvantages:
  - Every instrument has two files (ges, anl) for every cycle means lots of files for reanalysis (order of millions for

Radiance Observation Feedback

- Table example:

ASCII Table Summary

```
!   Satellite/Sensor   YYYYMMDDHH    #chan
              ssmi_f08   1991010100       7
!ichan|  freq/wavenum|iuse|   #total obs|   #assim obs| Tb...
!     |              |    |             |             |   ...
      1    19.350GHz     1          4415          2151   2...
      2    19.350GHz     1          4415          1983   1...
      3    22.235GHz     1          4415          2092   2...
      4    37.000GHz     1          4415          1924   2...
      5    37.000GHz     1          4415          1735   1...
      6    85.500GHz    -1             0         -9999 -99...
      7    85.500GHz    -1             0         -9999 -99...
```

Radiance Observation Feedback

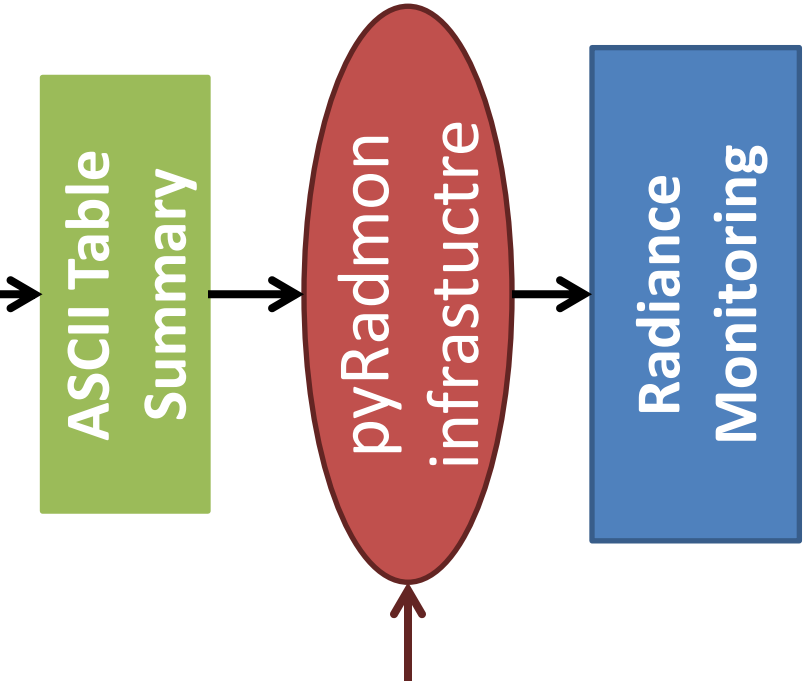
- Table example, Part 2:

ASCII Table Summary

O-F BC		Obs Error	Cost (Jo)	bc_total	..
mean	stddev	mean	mean	mean	st..
-0.715	1.914	2.884	0.523	0.514	1..
-0.142	2.842	3.250	0.783	2.263	2..
-0.688	2.533	2.639	1.048	0.836	1..
-0.689	1.640	2.638	0.479	0.684	1..
-0.037	2.876	3.138	0.850	0.047	2..
-9999.999	-9999.999	-9999.999	-9999.999	-9999.999	-9999..
-9999.999	-9999.999	-9999.999	-9999.999	-9999.999	-9999..

Radiance Observation Feedback

- Infrastructure initially designed for radiance monitoring package to replace existing system



Developed by summer intern Albert Huang

Old Radiance Monitoring:

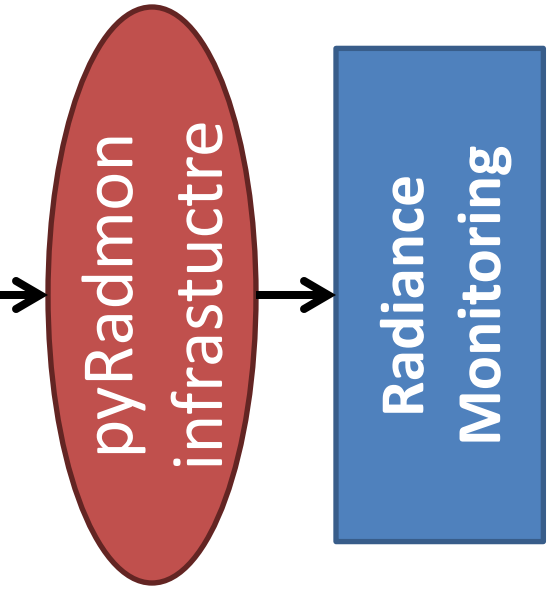
- Kludge of fortran, idl, grads, perl
- Difficult to maintain, inflexible

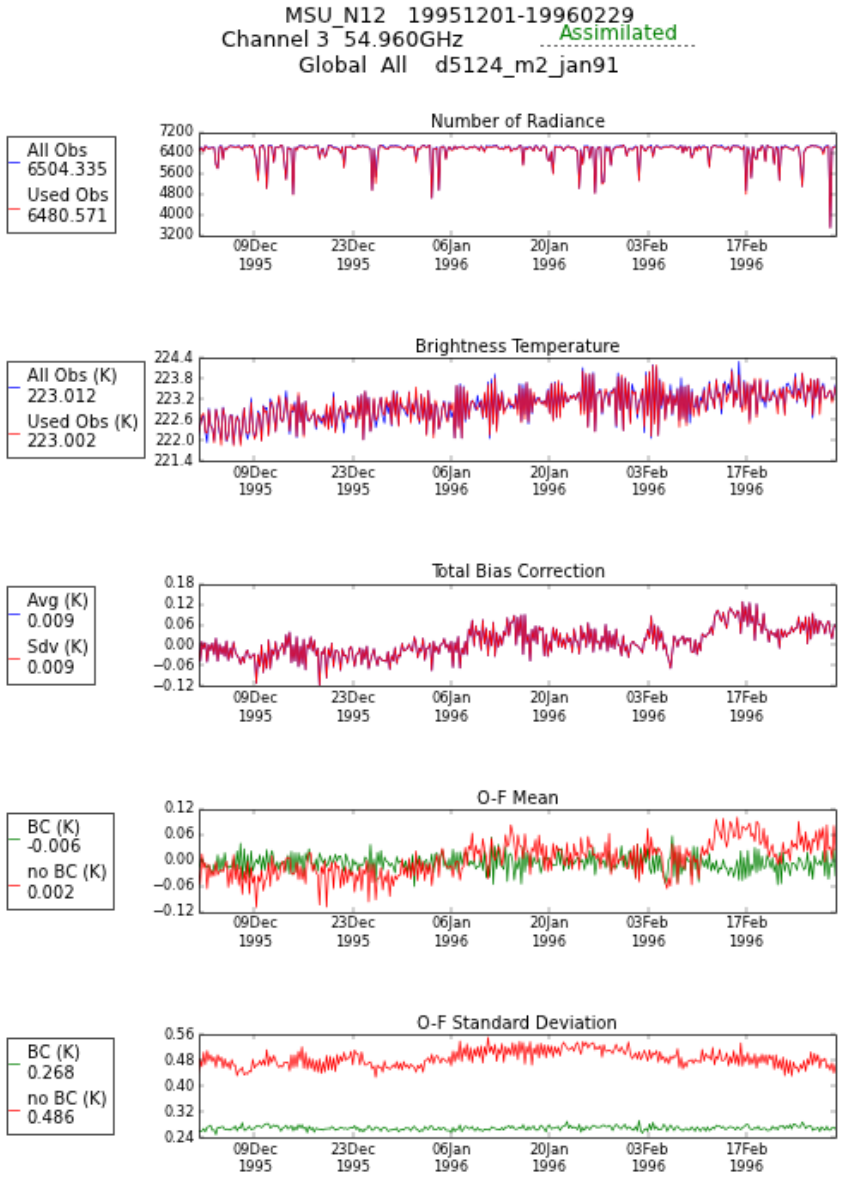
New System:

- Simplified to only python (and fortran if you include the diag2txt step)
- Super fast – internal parallelization for generating figures on a multicore node
- Driven by configuration files for easy expansion

Radiance Observation Feedback

- Example of Standardized output





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Radiance Observation Feedback

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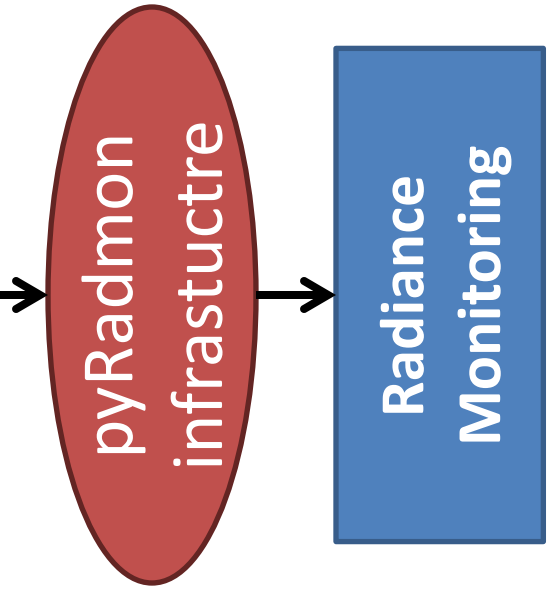

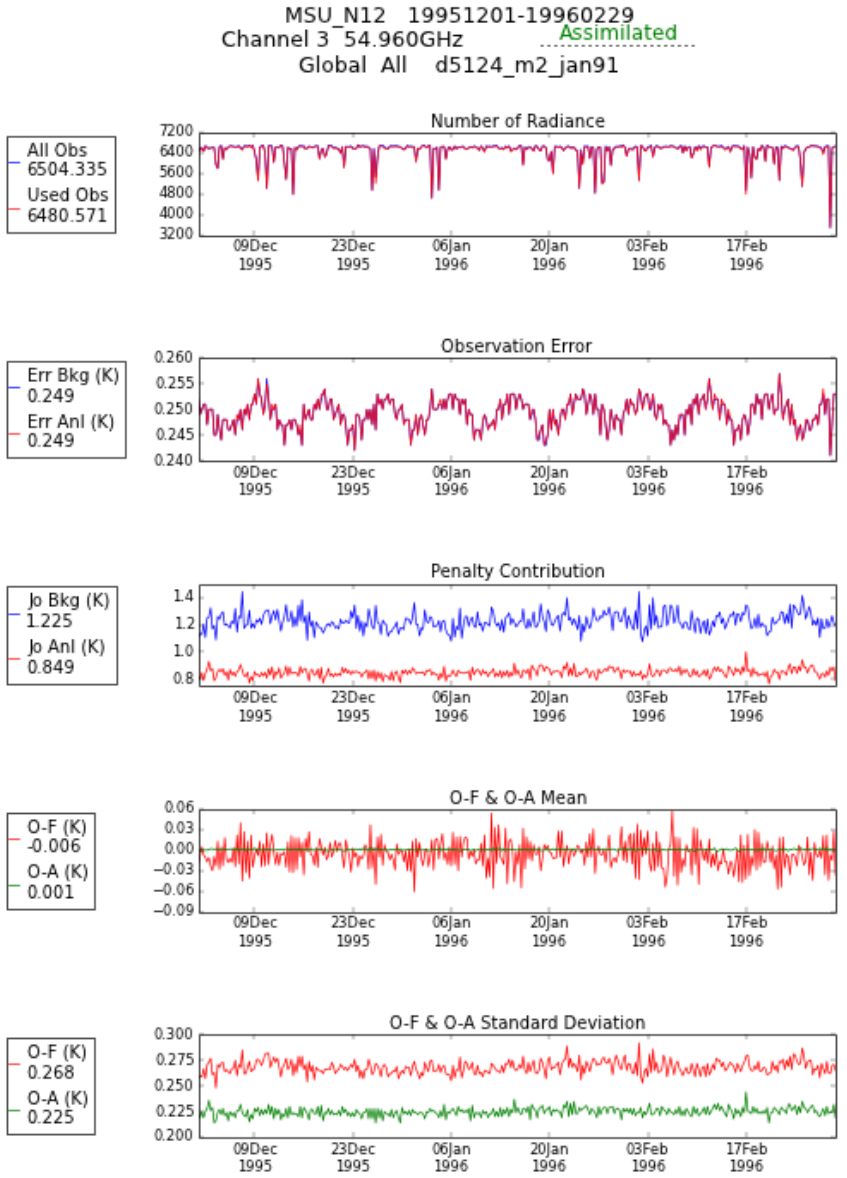

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Radiance Observation Feedback

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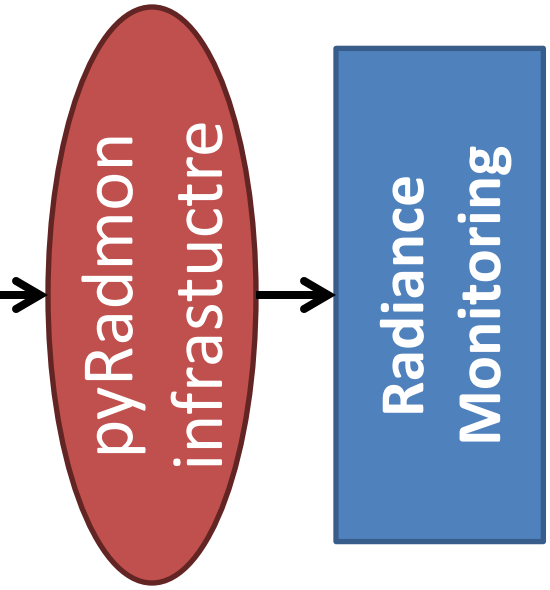

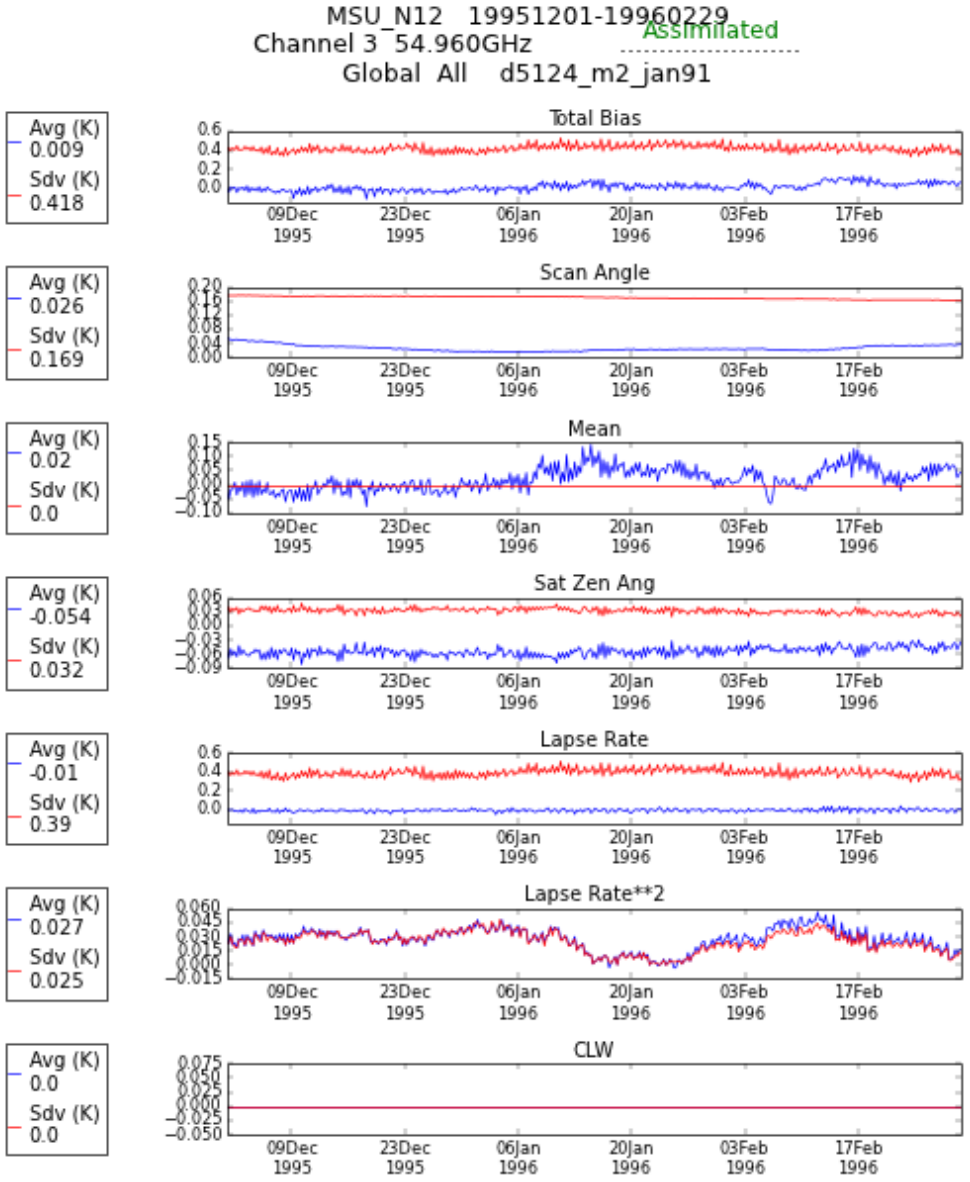

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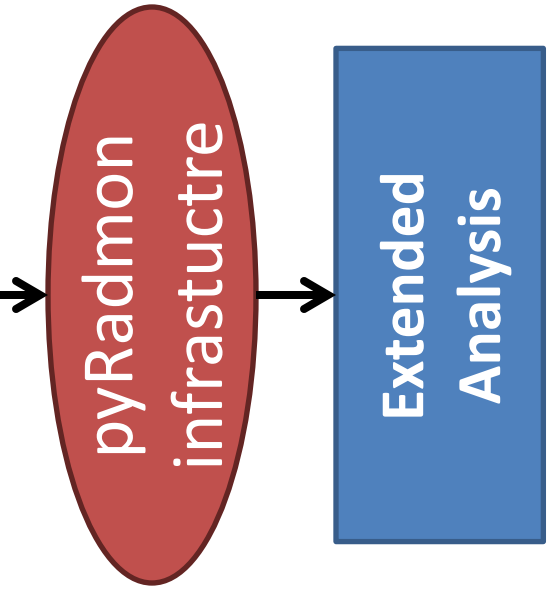
Radiance Observation Feedback

- pyradmon as an infrastructure is pretty easy, flexible

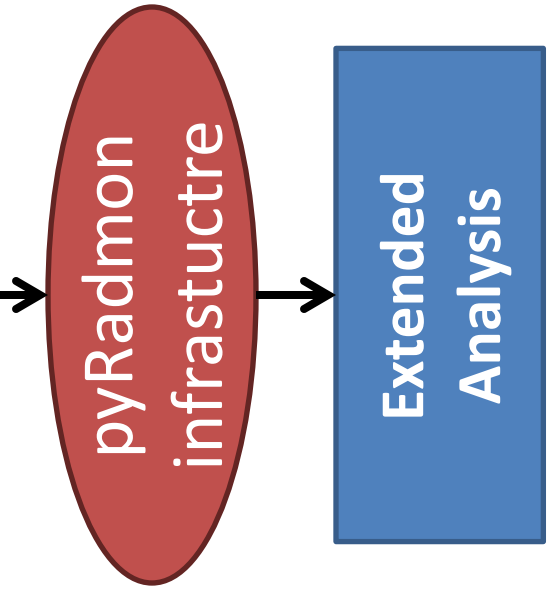


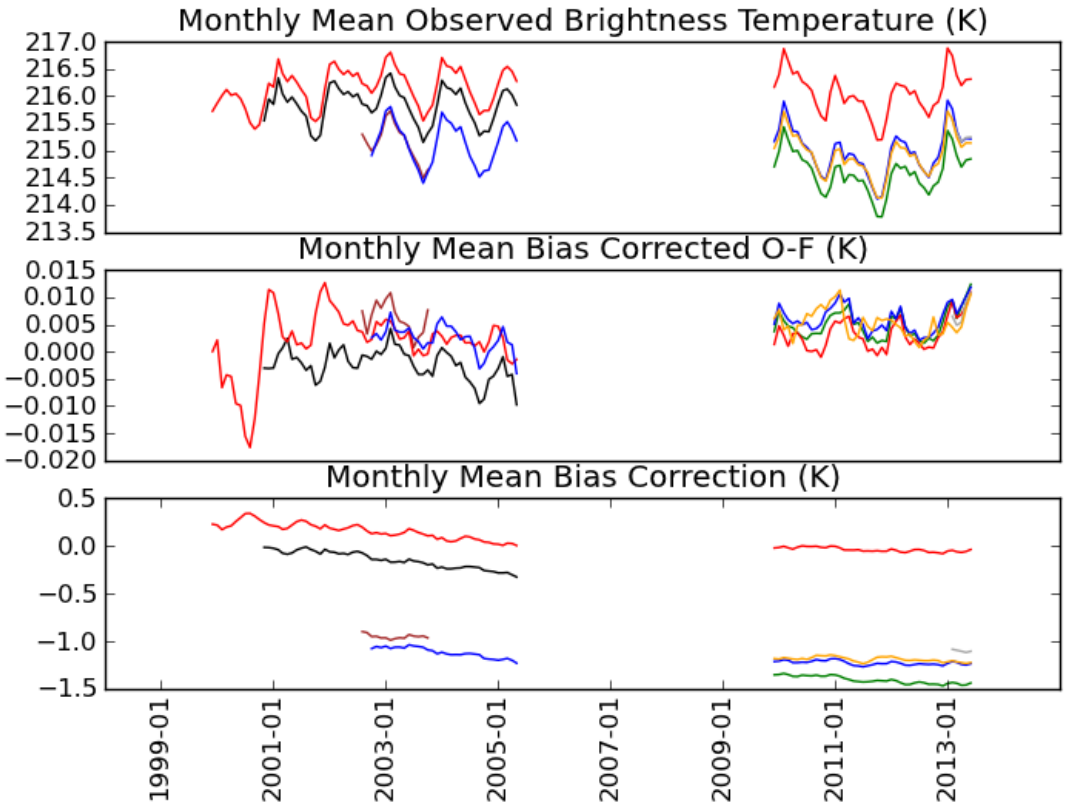
Steps to get data:

- Set up simple configuration file (templated paths to ascii tables, experiment ID)
- Single subroutine to read field or fields requested
- Incorporation in python because of matplotlib – free; good looking plots out of the box

Radiance Observation Feedback

- pyradmon as an infrastructure is incrediblv easy, flexible





Example time series of Mean Assimilated Tb, O-F, and bias correction for AMSU-A Ch. 8

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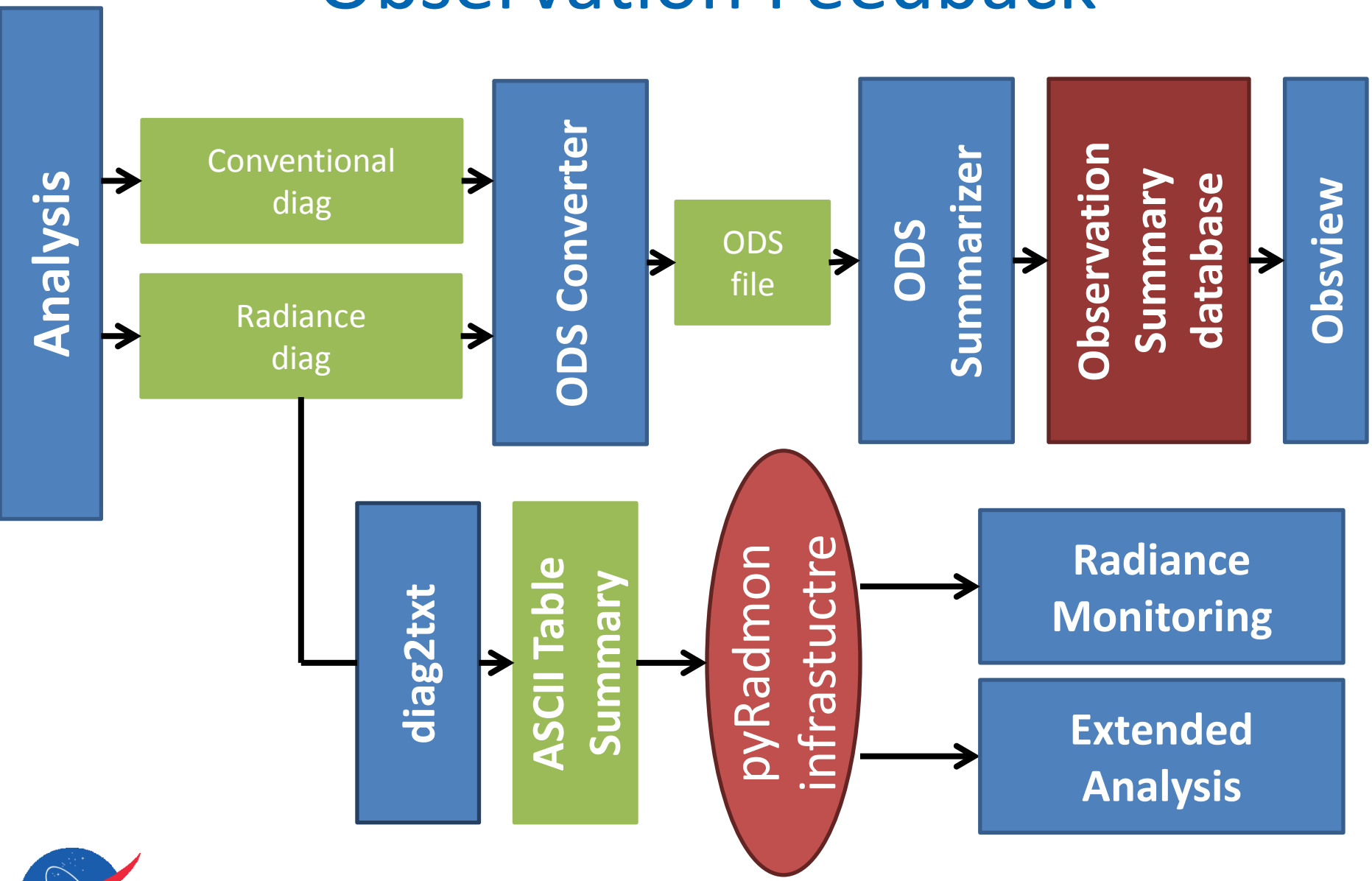
Observation Feedback



Additional Tools

- Gridded Innovations and Observations (GIO)
  - Spatially gridded observation statistics based off of ODS
  - Bias, standard deviations, and counts, generally monthly
- 'Radiance Spatial Plots'
  - Similar to GIO, except based on diag files primarily for bias correction information
  - An aggregator of diag files to create spatial plots of counts, observation, obs departure, obs error, bias correction (total and by term)
  - Used primarily in development
- FSO/Observation Impacts
  - Not run routinely, but the files necessary to run these later were retained

Users

- Well – this isn't the easiest question
- MERRA(1) had an atlas summarizing observation counts, departures, and cost for the entire system publically available
- Many obs files are archived locally, but not promoted/distributed via a distribution center
- Internally, MERRA(1) and M2 have had a fair amount of monitoring
  - Myself, D. Merkova, M. Bosilovich, S. Bloom, A. Conaty, G. Partyka, among others
- At the observation level, though, there isn't a lot of external collaboration

Users

- Why a lack of external collaboration?
  - Well, there wasn't a clear path from MERRA to M2
  - Mike B. did some great research, but much system development for M2 came straight from general forward processing development
  - This became my job about a year before M2 started – a lot of effort went to tightening up the input data
    - Lots of holes filled
    - certain data reprocessed
    - various sensitivities in MERRA evaluated
- Already steps are in place to make development for the next reanalysis more proactive