Remote Sensing Level 2+ Data Quality: NASA overview

G. Leptoukh with the help of
F. Lindsay, C. Lynnes, J. A. Gualtieri, Q. Tong, R. Bagwell
NASA Goddard Space Flight Center

Outline

- Why so much attention to Data Quality (DQ) now?
- Why so difficult?
- Major challenge: perceived DQ vs. the actual DQ
- Level 3
- Data provider vs. User perspective
- Data quality vs. Quality of Service
- Quality Indicators (QI) for Remote Sensing (RS) Data:
- Quality control/assurance vs. assessment
- Technology to capture (ontology), ISO
- Presenting quality
- Validation
- Data Quality harmonization issues
- NASA efforts: Uncertainty Analysis program and other initiatives
- ESIP IQ cluster
- Recommendations

Why so much attention to Data Quality now?

- In the past, it was difficult to access satellite data.
- Now, within minutes, a user can find and access multiple datasets from various remotely located archives via web services and perform a quick analysis.
- This is the so-called Data Intensive Science.
- The new challenge is to quickly figure out which of those multiple and easily accessible data are more appropriate for a particular use.
- However, our remote sensing data are not ready for this challenge – there is no consistent approach for characterizing quality of our data.
- This is why data quality is hot now.

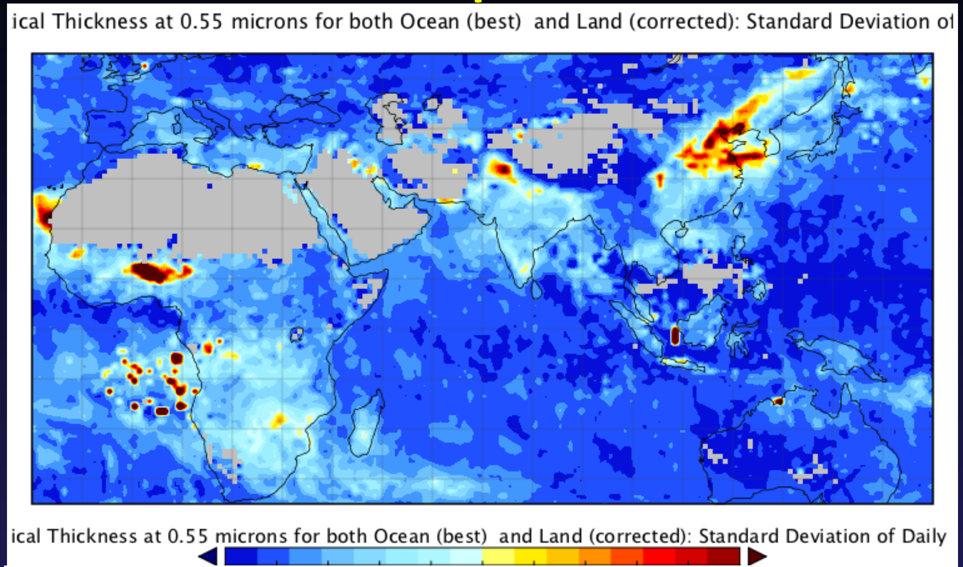
Why so difficult?

- Quality is **perceived differently** by data providers and data recipients.
- **Many different qualitative and quantitative aspects** of quality.
- No comprehensive **framework** for **remote sensing Level 2 and higher data quality**
- **No preferred methodologies** for solving many data quality issues
- Data quality aspect had lower priority than building an instrument, launching a rocket, collecting/processing data, and publishing a paper using these data.
- Each science team handled quality differently.

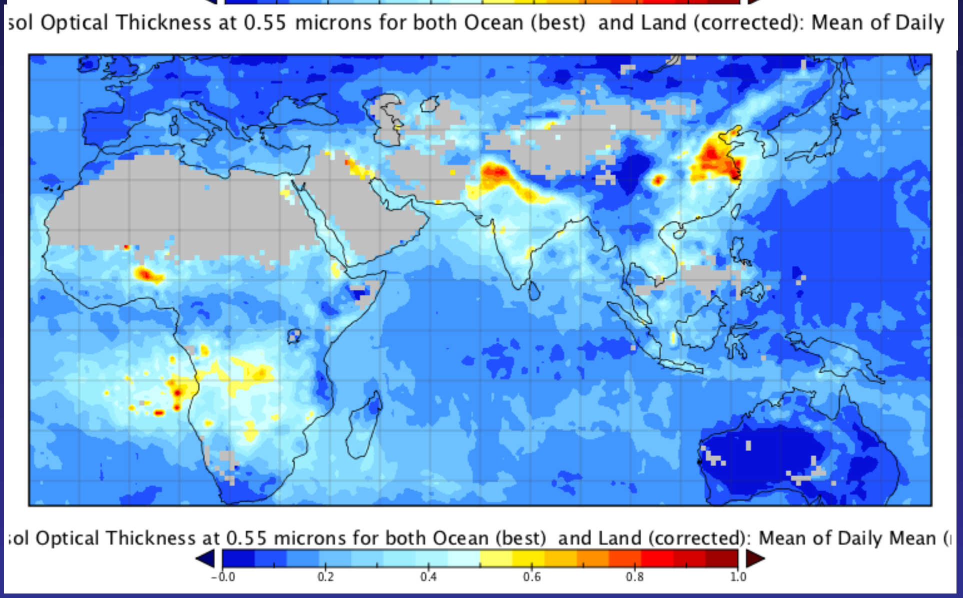
Expectations for Data Quality

- What do users want?
  - Gridded non-gappy data with error bars in each grid cell
- What do they get instead?
  - Level 2 swath in satellite projection with some obscure quality flags that mean nothing to users
  - Level 3 monthly data with a lot of aggregation (not always clearly described) and standard deviation as an uncertainty measure (fallacy)

Level 3 grid cell standard deviation is difficult to interpret due to its dependence on magnitude



MODIS AOD std



MODIS AOD

Different perspectives

Data providers: demigods looking from above

We have good data

We have good data

I need good new data … and quickly. A new data product could be very good, but if it is not being conveniently served and described, it is not good for me…
So I am going to use whatever I have and know already.

User

Data provider vs. User perspective

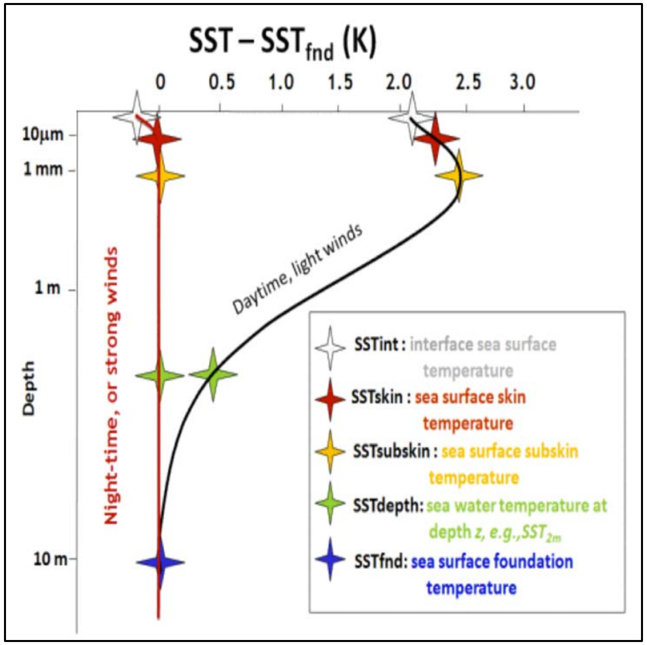
- Algorithm developers and Data providers: solid science + validation
- Users: fitness for purpose
  - **Measuring Climate Change**:
    - *Model validation*: **gridded contiguous data with uncertainties**
    - *Long-term time series*: **bias assessment** is the must , especially sensor degradation, orbit and spatial sampling change
  - **Studying phenomena using multi-sensor data:**
    - **Cross-sensor bias** is needed
  - **Realizing Societal Benefits through Applications:**
    - *Near-Real Time for transport/event monitoring* - in some cases, **coverage and timeliness** might be more important that accuracy
  - **Educational** (generally not well-versed in the intricacies of quality) – **only the best products**

Sea Surface Temperature (do we always measure the same?)

- Standard Sea Surface Temperature products are based on regressions that match satellite measurements with in-situ measurements from ships and buoys.
- But, satellite sensors measure surface properties at depths

1μ – 1mm (SST_skin, SST_sub-skin), while in-situ measurements are at depths of 1-5 m (SST_depth)

- Surface is affected by diurnal cycle, wind, ice…
- Data Quality indicators should account for effects of match up process in building regression, which is a source of error often not made explicit.
  - Completeness – do the in-situ measurements cover the range of conditions that the regression must cover
  - Method of converting surface properties to SST_depth



Source	Depth	Spatial	Temporal	Factors
Ships/ Buoys	1-5m	line 5-20km/	min .. hours	diurnal cycle
Infra Red Satellite Sensor	3.7-12 μ	[25.. 0.5]×[25..0.5] km^2	IFOV	diurnal cycle Atmosphere Clouds, salinity
Microwave Satellite Sensor	6-11GHz	[5..100]×[5..100] km^2	IFOV	diurnal cycle surface wind Salinity

Data Quality must record measurement factors and their affect on data product

Different kinds of reported and perceived data quality

- Pixel-level Quality (reported): algorithmic guess at usability of data point (some say it reflects the algorithm "happiness")
  - Granule-level Quality: statistical roll-up of Pixel-level Quality
- Product-level Quality (wanted/perceived): how closely the data represent the actual geophysical state
- Record-level Quality: how consistent and reliable the data record is across generations of measurements

Different quality types are often erroneously assumed having the same meaning

Different focus and action at these different levels to ensure Data Quality

General Level 2 Pixel-Level Issues

- How to extrapolate validation knowledge about selected Level 2 pixels to the Level 2 (swath) product?
- How to harmonize terms and methods for pixel-level quality?

AIRS Quality Indicators

0 Best
1 Good
2 Do Not Use

Data Assimilation
Climatic Studies

Purpose

Match up the recommendations?

MODIS Aerosols Confidence Flags

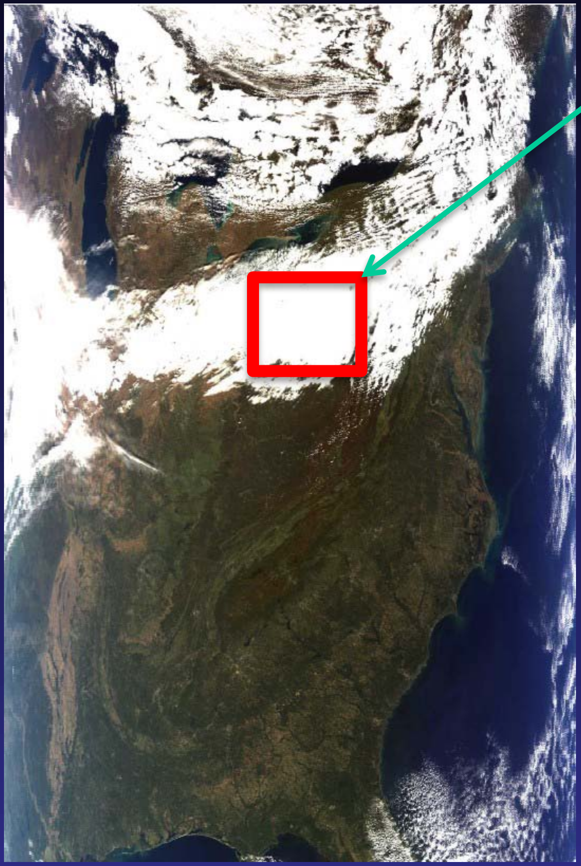
Ocean		Land	
3	Very Good	3	Very Good
2	Good	2	Good
1	Marginal	1	Marginal
0	Bad	0	Bad

Use these flags in order to stay within expected error bounds

Ocean	Land
±0.03 ± 0.10 t	±0.05 ± 0.15 t

The Dubious Meaning of File-Level Quality Statistics

Percent Cloud Cover?



Study Area

Is L3 quality different from L2 quality?

- If L2 errors are known, the corresponding L3 error can be computed, in principle
- Processing from L2→L3 daily → L3 monthly may reduce random noise but can also exacerbate systematic bias and introduce additional sampling bias
- However, at best, standard deviations (mostly reflecting variability within a grid box), and sometimes pixel counts and quality histograms are provided
- Convolution of natural variability with sensor/retrieval uncertainty and bias – need to understand their relative contribution to differences between data
- This does not address sampling bias

Differences in L3 from different sensors due to processing

- Spatial and temporal binning (L2→L3 daily) leads to *Aggregation bias*:
  - Measurements (L2 pixels) from one or more orbits can go into a single grid cell → different within-grid variability
  - Different weighting: pixel counts, quality
  - Thresholds used, i.e., > 5 pixels
- Data aggregation (L3D → L3monthly → regional → global):
  - Weighting by pixel counts or quality
  - Thresholds used, i.e., > 2 days

While these algorithms have been documented in ATBD, reports and papers, the typical data user is not immediately aware of how a given portion of the data has been processed, and what is the resulting impact

Quality Indicators (QI) for Remote Sensing (RS) Data:

- We need to differentiate quality of:
  - Content: the actual science geophysical values
  - Service: formats, metadata, documentation, archive, and delivery

- Example of a generic QI completeness:
  - Content: spatial, temporal, spectral,…
  - Service: complete archive, full metadata, complete documentation, complete set of subsetting, …

Data Quality vs. Quality of Service

- A data product could very good,
- But if not being conveniently served and described, is perceived as not being so good…

User perspective:

- There might be a better product somewhere but if I cannot easily find it and understand it, I am going to use whatever I have and know already.

General Quality Indicators (QI)

- These are objective (computable) aspects of data and provenance
- Common across many disciplines
- Some of them might be called 'figures of merit"
- Users of data, depending on usage, assert quality of data from these QI
- The same QI might be consider "good" for one usage and "bad" for another – "somebody's trash is another's treasure"

Data Quality Indicators (DQI)

Indicator	Description	How it is Measured
Accuracy	Data are correct, reliable, and certified relatively free of error	assessing standard error for quantitative data or documenting known measurement error or development of uncertainty models and "Monte Carlo" analysis to determine uncertainty for spatial models
Bias	One indicator is the difference between the conceptual, weighted average value of an estimator over all possible samples and the true value of the quantity being estimated	Expected vs. actual e.g. the closer the difference is to zero, the less amount of bias that exists (data is unbiased if the difference is zero)
Comparability	The degree to which different methods, data sets, or decisions agree or can be represented as similar	
Completeness	Data are of sufficient depth, breadth, and scope for the task at hand	The ratio of the number of incomplete items to the total number of items subtracted from 1
Consistency	Data are always presented in the same format and are compatible with the previous data	The ratio of the number of valid attribute values for data to the total number of data values subtracted from 1
Lineage	Date of origin of the sensor	Recent Old
Precision	Level of measurement and exactness for data (position, attribute, etc)	Low Medium High
Representativeness	Subset of the data that is representative of the entire population (quantitative)	Area of # of pixels minus area that cannot be used – result is representativeness - is it representative of the data?
Sensitivity	Variation in the value of one or more output variables due to uncertainty in one or more inputs	Level of degrade from conditions like snow, haze, low sun angle, cloud cover, lag time; depends on intended content, quality, and detail of desired information

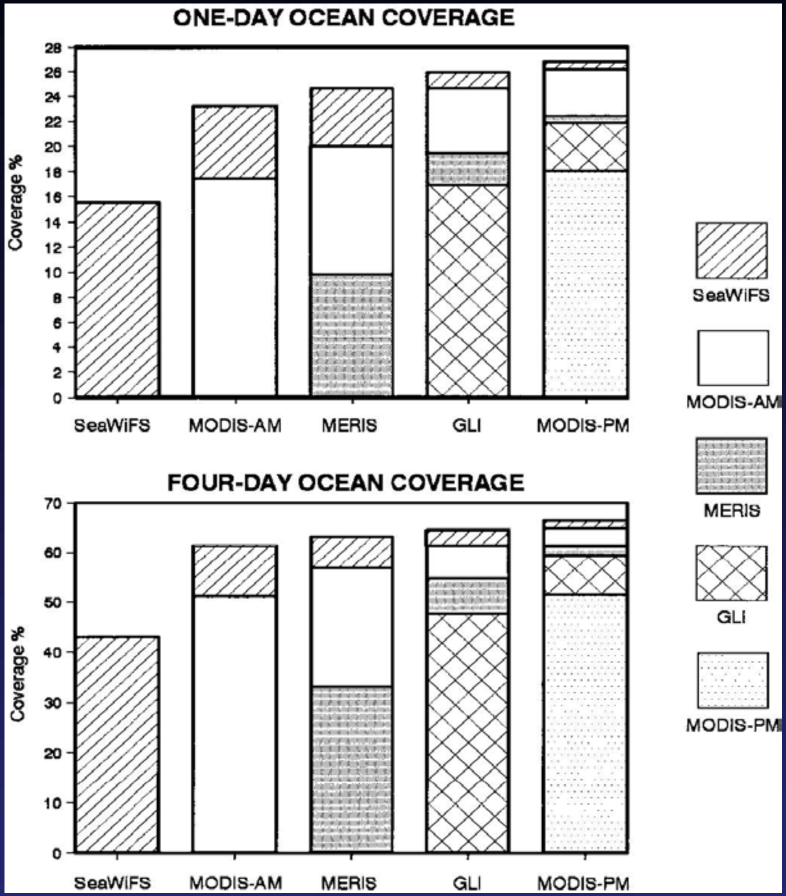
Remote Sensing Data Quality Indicators (DQI)

Indicator	Description	How it is Measured
Spatial Resolution	Variations in scale/size of the pixel, limited by sample spacing and sampling aperture size	Low (> 1 km) ← Land perspective Medium (100 m to 1 km) High (5 m to 100 m) Very High (< 5 m)
Spectral Resolution	Number and width of spectral bands in the sensing device	Number of bands (PAN, 1, 2, …) Bandwidths Location in the EM spectrum (V, IR, UV, …)
Revisit Time	Measure of the repeat cycle or frequency which a sensor revisits the same part of the Earth's surface	Frequent or Infrequent Every (x) number of hours/days
Radiometric Resolution	Smallest change in intensity level of radiation the sensor is able to distinguish	Number of discrete quantization levels used to digitize the continuous intensity value broader range (smaller increments) provides a better measure of variations in radiation intensity
Data Volume	Depends on number of bands, area of coverage, and resolution	Larger number of spectral bands/wide area of coverage (low spatial resolution) Smaller number of spectral bands/smaller area of coverage (high spatial resolution)
Area of Coverage	Region of the Earth from which the images are acquired	CONUS

Remote Sensing Data Quality Indicators (DQI)

Indicator	Description	How it is Measured
Sensor Footprint (IFOV)	Smallest area of ground that is sampled along a pathway (pixel size)	Large (250 – 1000 m) Medium (100 – 250 m) Small (< 100 m)
Sampling Rate	Determined by cross-track and in-track so the GSI equals the GIFOV ("over-sampling" indicates improvement in quality)	Low – (must use previous imagery) Medium High
Signal-to-Noise Ratio	Amount of recorded signal that is useable information (higher the ratio, less obtrusive the noise)	Low Medium High
Dynamic Range/Sensitivity	Variety of signal amplitudes available to differentiate intensity	Within minimum/maximum values With respect to the ratio of max/min
Technical Error	Striping, speckling, scan anomalies, etc.	Percentage existing before/after correction is applied
Dwell Rate (noise)	Shorter sensor rate will introduce noise in the output imagery	Short Long
Interference/Contamination	Unusable image segments due to clouds, haze, shadow, or derivation	Percentage of usable image
Accuracy	How close the measurements are to the reality	Various statistics (RMSE, % within 1 sigma)

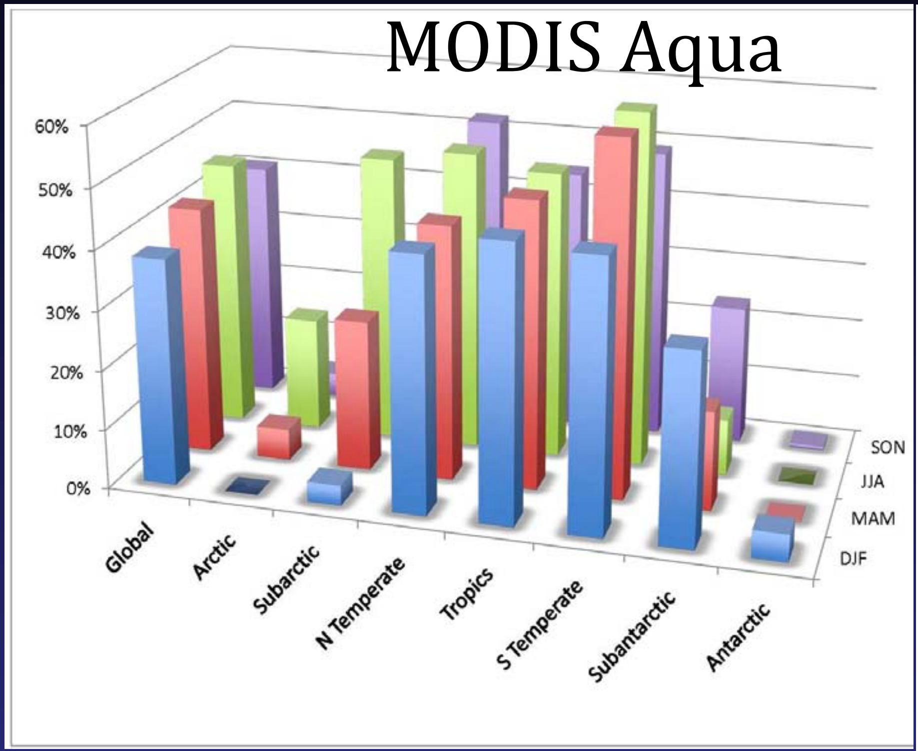
QI: Spatial Coverage: Ocean color

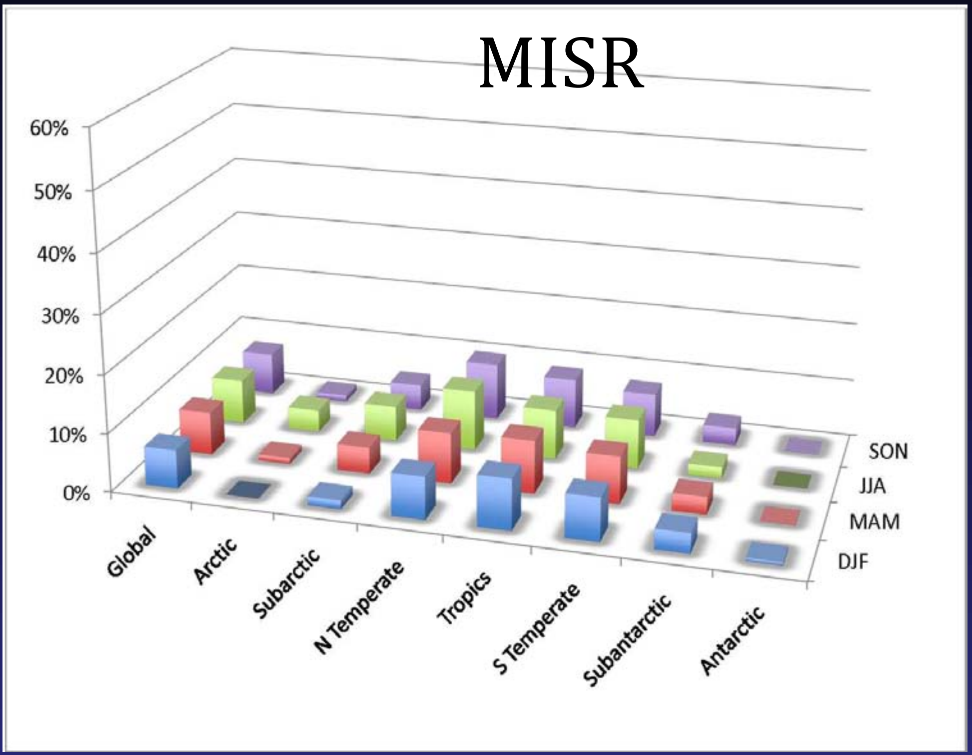


The graph illustrates spatial coverage achieved by single sensors (SeaWiFS, MODIS-Aqua, MODIS-Terra, MERIS, GLI) and by their combination (merging)

From: Gregg WW, Esaias WE, Feldman GC, et al. Coverage Opportunities for Global Ocean Color in a Multimission Era. IEEE TGRS. 1998;36(5):1620-1627.

QI: Spatial completeness (coverage): Aerosol Optical Depth (AOD)





Spatial coverage (%) for different latitudinal zones and seasons:
Due to a wider swath, MODIS AOD covers more area than MISR.
The seasonal and zonal patterns are rather similar

Level 2 uncertainty: error propagation vs. estimation

- Rarity: error propagation in L2 retrieval. Possible only when there are analytical formulae. Very difficult with thresholds and Lookup Tables. Input data errors usually unknown.
- Introducing Gaussian noise into algorithm parameters and input data and studying the spread.
- Other non-black-box methods?

Factors contributing to uncertainty and bias in L2

- *Physical*: instrument, retrieval algorithm, aerosol spatial and temporal variability, measuring geometry …
- *Input*: ancillary data used by the retrieval algorithm
- *Classification*: erroneous flagging of the data
- *Simulation*: the geophysical model used for the retrieval
- *Sampling*: the averaging within the retrieval footprint

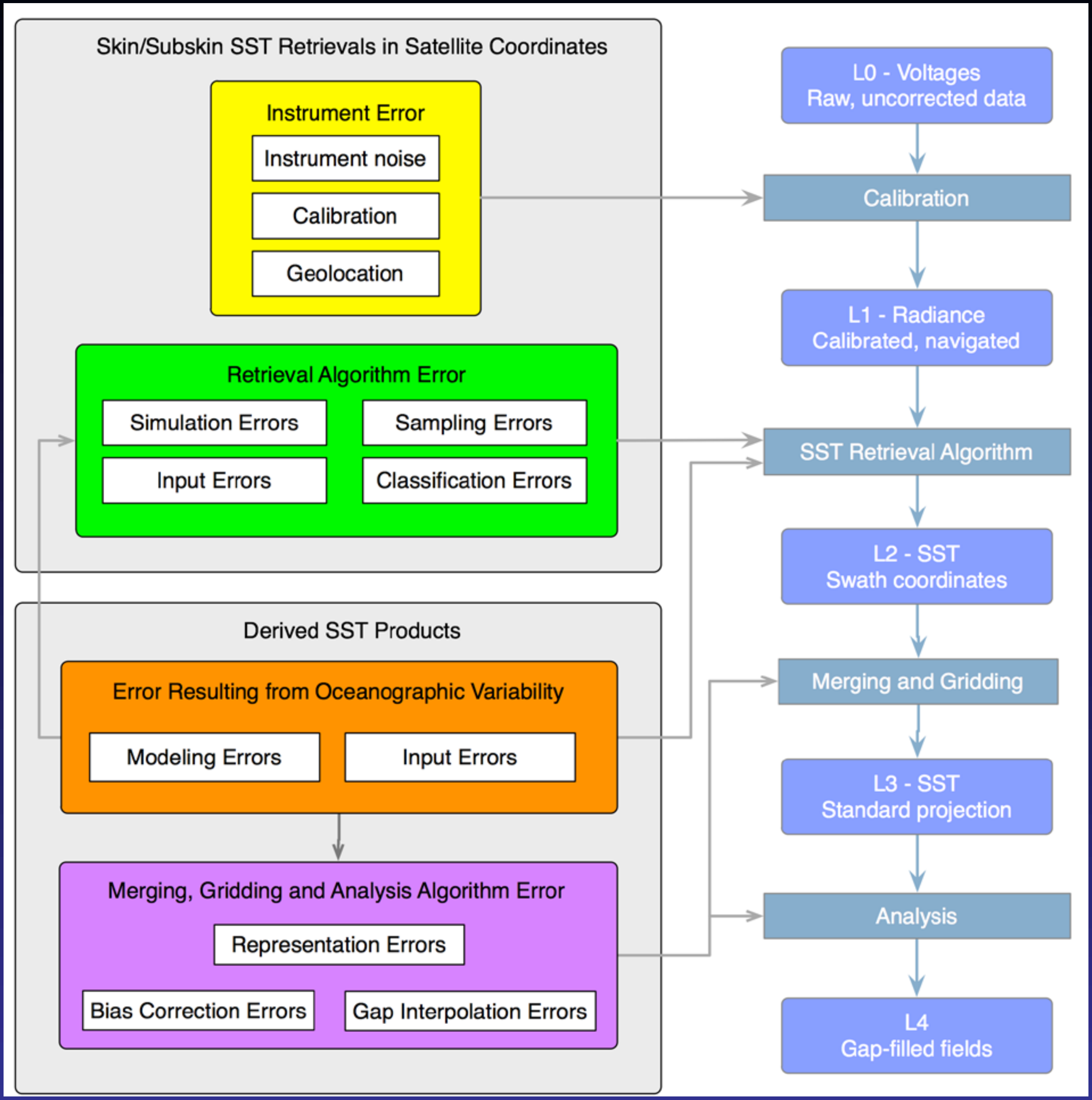
From the NASA SST study on error budget

Why can’t we just apply L2 quality to L3?

Aggregation to L3 introduces new issues where aerosols co-vary with some observing or environmental conditions:

- *Spatial*: sampling polar areas more than equatorial
- *Temporal*: sampling one time of a day only *(not obvious when looking at L3 maps)*
- *Vertical*: not sensitive to a certain part of the atmosphere thus emphasizing other parts
- *Contextual:* bright surface or clear sky bias
- *Pixel Quality*: filtering or weighting by quality may mask out areas with specific features

SST Error budget (from the white paper)



ISO Information Quality Standards (19100 series)

ISO 19131

- *Details on specifications (including Amendment 1, TS 2010-05)*

ISO 19115

- *Details on the reporting of quality assessment results as metadata*

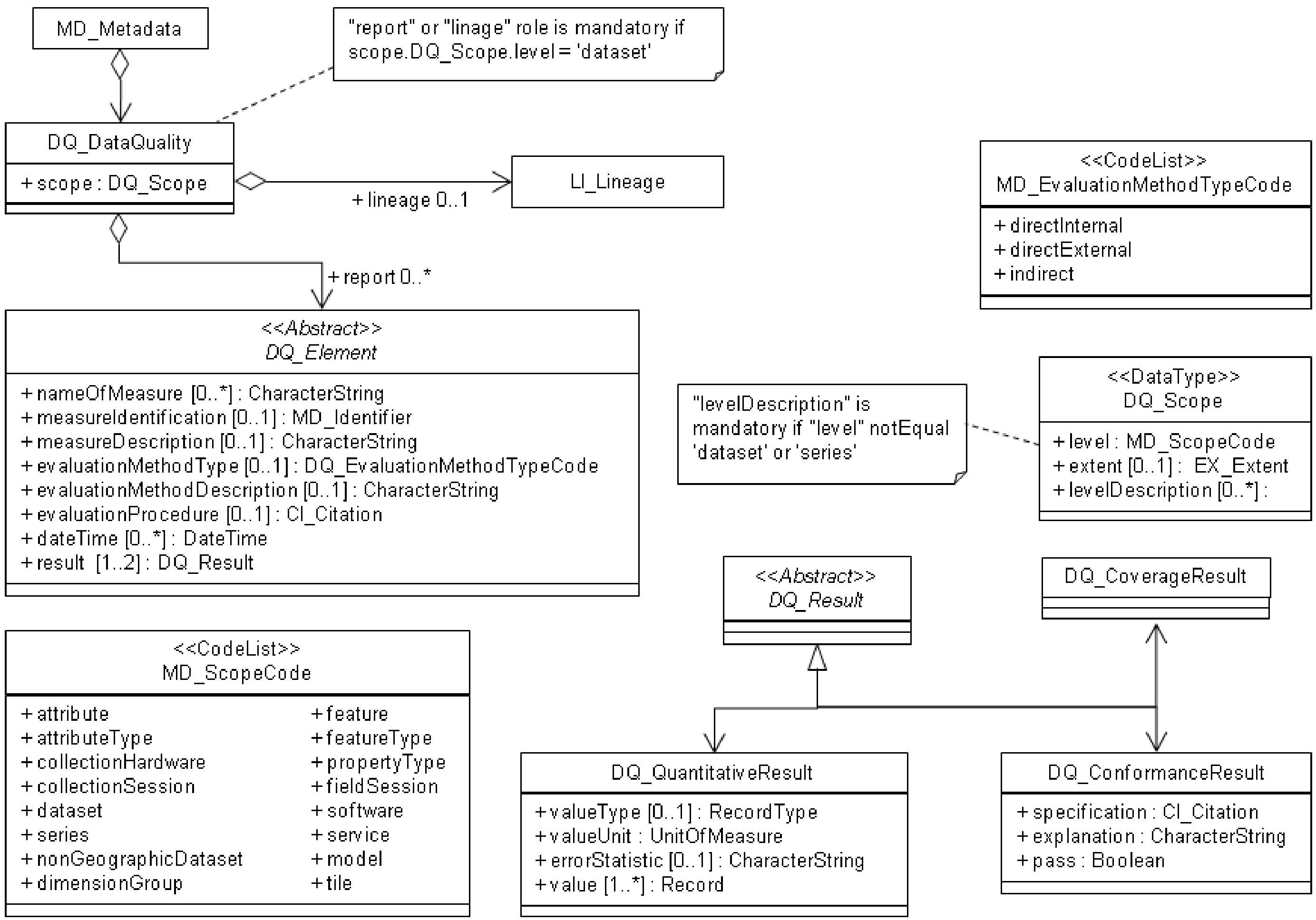
ISO 19139

- *Details on the implementation of metadata communication*

ISO 19157 **(NEW)**

- *Will essentially incorporate ISO 19113, 19114, and 19138*
  - *ISO 19113 - Details the principles for quality evaluation*
  - *ISO 19114 - Details the description of quality assessment methodologies*
  - *ISO 19138 - Details the description of quality assessment methodologies*
- *Scope establishes the concept of quality for geographic data, components for describing data quality, components and content structure of a register for data quality measures, general procedures for evaluating the quality of geographic data, and principles for reporting data quality*
- *Also provides* ***guidance on how to describe, evaluate, and report data quality***
- **Does not attempt to define a minimum acceptable level of quality for geographic data**

Example of ISO Data Quality



DQ_DataQuality

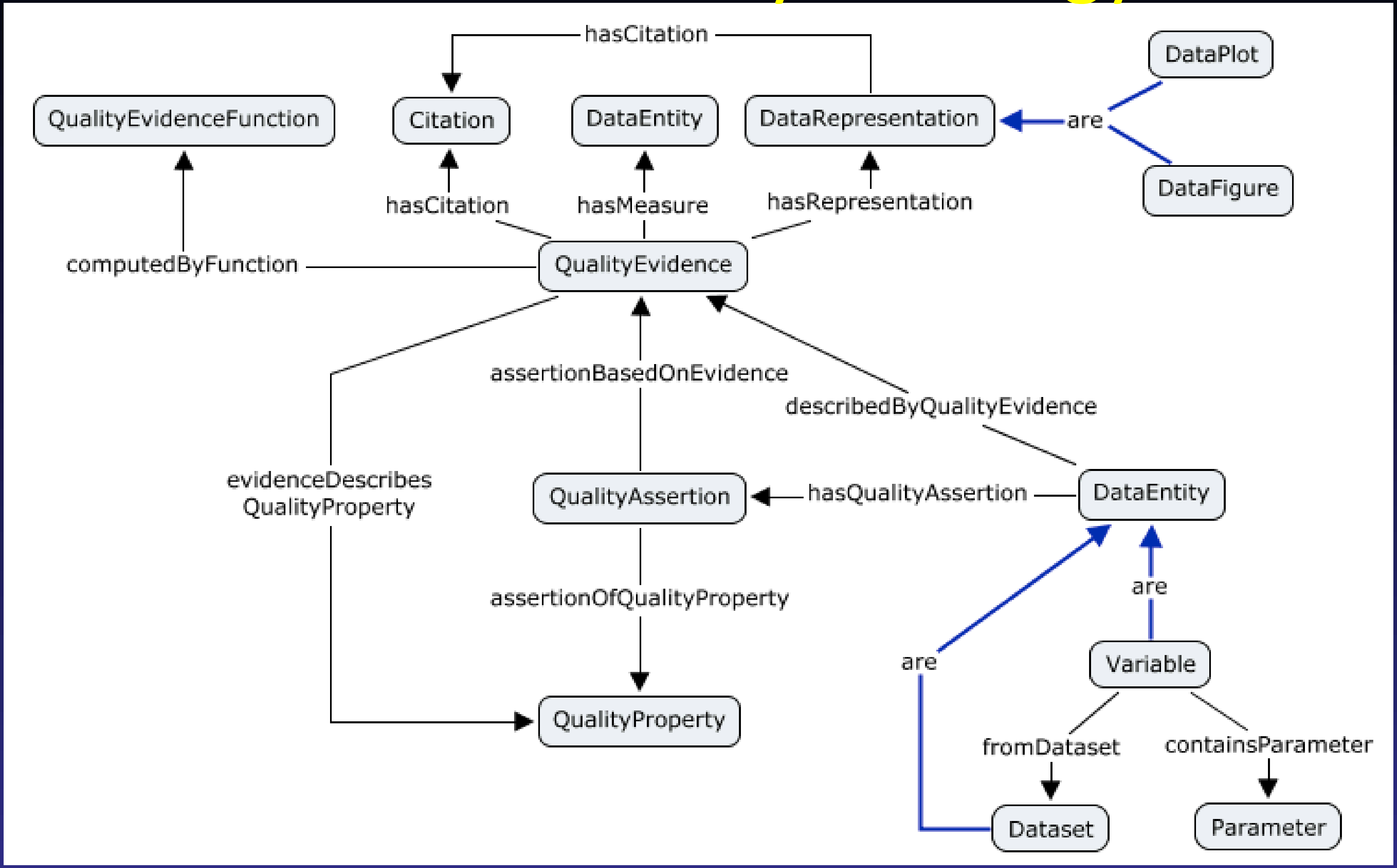
Example of ISO Usage

DQ_ element	DQ_ subelement	DQ_measure	DQ_conformance level	DQ_EvalProcedure Desc	DQ_value
Completeness	Omission	Number of missing items	Declared Quality Level (DQL) 2.5% (based on ISO 2959-4)	Stratified random sampling using inspection of field items	Accepted (Number of missing items = 1)
Logical consistency	Domain consistency	Number of items not in conformance with their value domain	0	Full inspection	Rejected (Number of incorrect items = 1)
Positional accuracy	Absolute of external accuracy	RMSE	2m	Random sample	Accepted (RMSE = 1.5m)

Product Quality Ontology Concepts

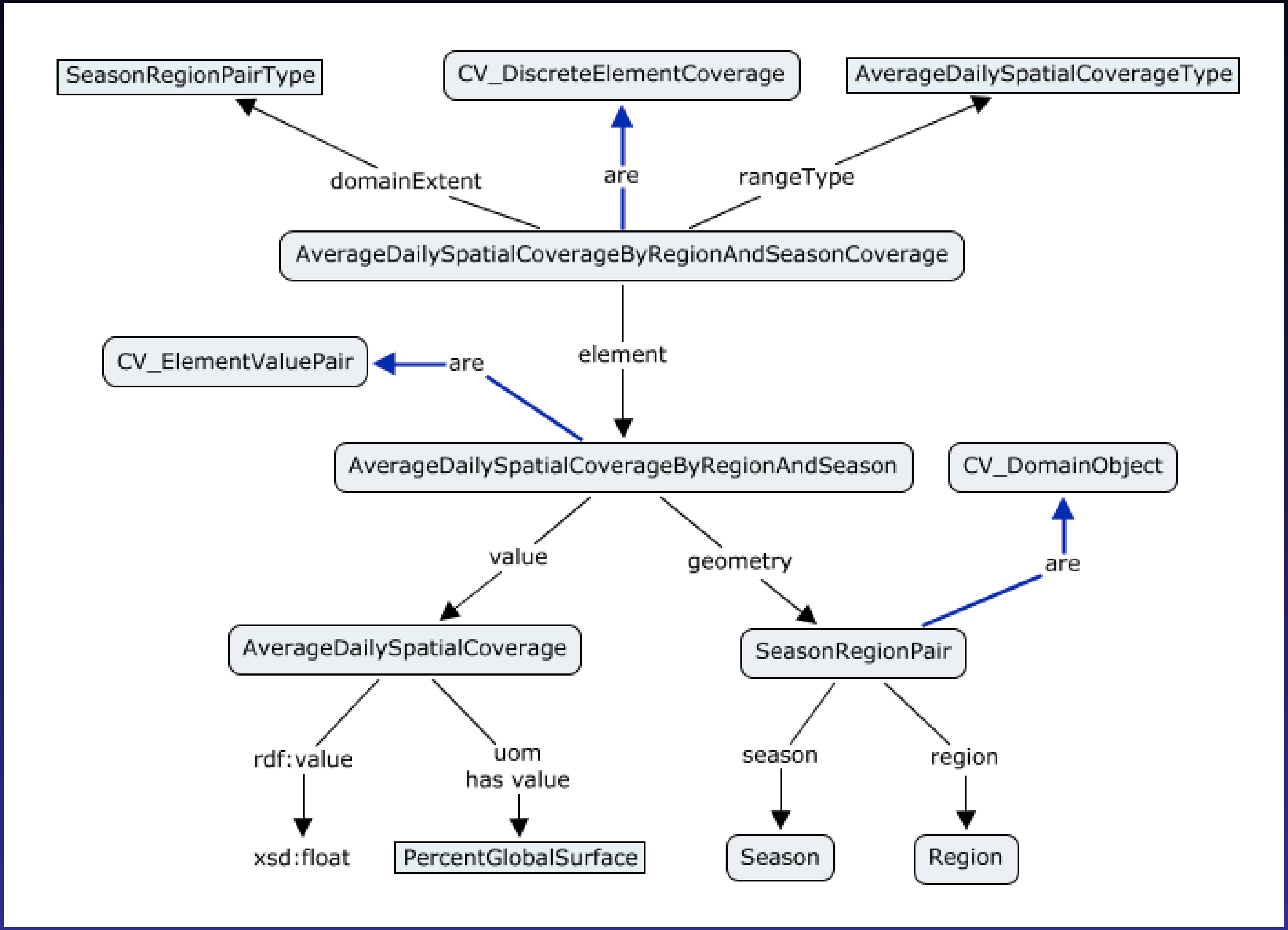
- Quality Property: aspect of quality
  - E.g. completeness, consistency, accuracy, representativeness
- Quality Evidence: measurable quantity that can be used to provide clues into quality of the data
  - E.g. average daily spatial coverage
- Quality Assertion: intuitive and ready-to-use expressions of quality (e.g. marginal, good, very good) computed from quality evidence
- Data Entity: anything from which quality evidence can be computed
  - E.g., dataset, variable

Product Quality Ontology



Based on IQ Qurator Information Quality Model

Average Daily Spatial Coverage By Region and Season in RDF



Data provider quality indicators vs. user QI

- EPA requirements for air pollution:
  - Very specific Quality Indicators, e.g., PM2.5 concentration
- Satellite-measured aerosols are characterized by aerosol scientists. Aerosol Optical Depth (AOD) is not the same as PM2.5
- Are these quality indicators compatible?
- Can one be mapped to another?
- Does very accurate AOD measurement correspond to accurate PM2.5? Usually not…

Users Requirements for SST Data Quality

The user of SST data has a range of applications they desire to use the data for (SST White Paper 2009), which shows for various applications, resolution and accuracy measures.

It is clear that the users application requires different accuracy measures.

Application	Spatial Resolution Km	Temporal Resolution Hrs	Geolocation Accuracy Km	Absolute Accuracy (°K)	Relative accuracy
Climate Data Record				0.1	0.04°K-0.05°/decade
Numerical Weather Prediction	5	3		0.3	
GlobalOperations	0.25	3	0.1	0.1	0.05°K
Costal/Lake Operations	0.1	6	0.1	0.1	
Fronts	0.1	0.25	0.1	1	0.1°K
Climate Models	25	24	5	0.2	0.05°K/decade
Lakes	1	3	1	0.3	0.2°K
Air-sea fluxes	10	24	2	0.1	
Mesoscale	1	168		0.1	0.1°K
Submesoscale	0.1	24		0.1	0.1°K
Strictest	0.1	0.25	0.1	0.1	0.05°K 0.04°K/decade

User requirements provide for diversification of data quality indicators

Quality presentation: QI

About your selected parameters:

	Parameter A	Parameter B	What
Parameter name	Aerosol Optical Depth at 550 nm	Aerosol Optical Depth at 550 nm	
Dataset:	MODIS Aqua Daily Collection 5	MODIS Terra Daily Collection 5	Diff
Data-day definition	UTC(00:00-24:00)	UTC(00:00-24:00)	
Temporal resolution	Daily	Daily	
Spatial resolution	1 arc degree × 1 arc degree	1 arc degree × 1 arc degree	
Sensor	MODIS on Aqua	MODIS on Terra	
Platform:	Aqua (EOS PM-1) NASA Scientific Research Satellite	Terra (EOS AM-1) NASA Scientific Research Satellite	Diff
EQCT	13:30:00	10:30:00	Diff
Day time node	Ascending	Descending	Diff
Pre-Giovanni processes	ATBD-MOD-30	ATBD-MOD-30	
Giovanni processes	• G3 Data Retrieval • G3 Grid Subsetter • G3 Time Averaging • G3 Two Dimensional Map Plot	• G3 Data Retrieval • G3 Grid Subsetter • G3 Time Averaging • G3 Two Dimensional Map Plot	

- Table contains links to explanatory web pages
- Processes organized as a list

Note: Data provenance presentation should be tailored to the audience

From the Multi-Sensor Data Synergy Advisor (MDSA)

Title: *MODIS Terra C5 AOD* vs. *Aeronet* during *Aug-Oct Biomass burning-in Central Brazil, South*

(General) **Statement**: ***Collection 5 MODIS AOD at 550 nm*** **during *Aug-Oct* over Central South America *highly* over-estimates for *large AOD* and in non-burning season *underestimates* for *small AOD*, as compared to Aeronet; *good* comparisons are found at *moderate AOD*.**

Region & season characteristics: Central region of Brazil is mix of forest, cerrado, and pasture and known to have low AOD most of the year except during biomass burning season

***(Dominating factors leading to Aerosol Estimate bias)*:**

1. Large positive bias in AOD estimate during biomass burning season may be due to wrong assignment of Aerosol absorbing characteristics. (Specific explanation) a constant Single Scattering Albedo ~ 0.91 is assigned for all seasons, while the true value is closer to ~0.92-0.93.

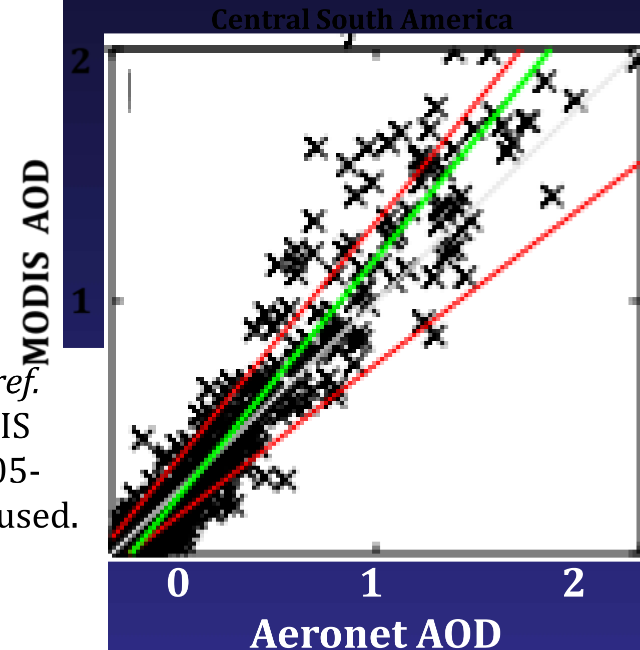
[Notes or *exceptions*: Biomass burning regions in Southern Africa do not show as large positive bias as in this case, it may be due to different optical characteristics or single scattering albedo of smoke particles, Aeronet observations of SSA confirm this]

2. Low AOD is common in non burning season. In Low AOD cases, biases are highly dependent on lower boundary conditions. In general a negative bias is found due to uncertainty in Surface Reflectance Characterization which dominates if signal from atmospheric aerosol is low.

(Example) : *Scatter plot* of MODIS AOD and AOD at 550 nm vs. Aeronet from *ref.* (Hyer et al, 2011) *(Description Caption)* shows severe *over-estimation* of MODIS Col 5 AOD (dark target algorithm) at *large AOD* at 550 nm during *Aug-Oct* 2005-2008 over Brazil. *(Constraints)* Only best quality of MODIS data (*Quality =3*) used. Data with scattering angle *> 170 deg* excluded. *(Symbols)* **Red Lines** define regions of *Expected Error (EE)*, ***Green*** *is the fitted slope*

Results: **Tolerance**= 62% within **EE**; RMSE=0.212 ; **r2**=0.81; **Slope**=1.00

For Low AOD (<0.2) **Slope**=0.3. **For high AOD** (> 1.4) **Slope**=1.54



Reference*:* Hyer, E. J., Reid, J. S., and Zhang, J., 2011: An over-land aerosol optical depth data set for data assimilation by filtering, correction, and aggregation of MODIS Collection 5 optical depth retrievals, Atmos. Meas. Tech., 4, 379-408, doi:10.5194/amt-4-379-2011

Sources of data quality information

What do we want to get from the documentation?

The known quality facts about a product presented in a structured way, so humans (and computers) can easily extract this information + links to data.

- Algorithm Theoretical Basis Documents (ATBD):
  - More or less structured
  - Usually out-of-date
  - Represent the algorithm developer perspective
  - Describe quality control flags but does not address the product quality aspects
- Regular papers:
  - To be published, a paper has to have something new, e.g., new methodology, new angle, new result. Therefore, by design, all papers are different to avoid rejection
  - Results are presented differently (usually without links for reliable data access)
  - Structured for publication in a specific journal – not standardized
  - Version of the data not always obvious while findings about the old version data usually are not applicable to the newest version

Recommendation:

- Establish a standard (maybe even a journal) for validation papers with links to data

Validation

- Measures: correlation coefficient, slope, offset, percentage within Estimated Error (EE), …
- “Compare and aggregate” vs. “Aggregate and compare” -> different results
- Validation results usually are not collected, captured, and presented consistently amongst various teams
- Validation data are not easily accessible
- The challenge is to consolidate and harmonize validation data and the colocated satellite data
- *Good examples: Aura Validation Data Center and Aeronet at NASA GSFC*

Validation of Level 3

- The usual:
  - Level 2: regress against the truth
  - Level 3: aggregate and then regress against the aggregated truth?
- Comparing a mean value in 1 deg grid box with data from stations in the same big area →*representativeness bias*
  - Increasing aggregation: spatial over satellite data and temporal over station data – works well only for large homogenous fields
- Comparing variance in the data with knowledge about atmospheric variability. *Comparison of retrieved maps with climatology can indicate systematic effects*
- Comparison with models (how ironic!) for initial validation

Doesn't look comprehensive enough…

Harmonization

To be able to compare and/or merge data from multiple sources, we need to harmonize:

- Quality Control flags
- Provenance
- Bias adjustment

….not addressed in this presentation to save time…

NASA Data Quality efforts

Data Quality NASA Management Context

- Data Quality Issue Premise
  - This issue has very high visibility
  - NASA recognizes the very real need for researchers and other interested parties to be exposed to explanatory information on data product accuracy, fitness of use and lineage.
  - NASA seeks to address this broad issue in concert with our US agency partners and other national space agencies and international organizations.
- NASA's Data Quality Management Framework
  - Program Managers at NASA HQ stated their support for NASA pertinent projects, teams and activities to address data quality (most of these are funded activities).
  - NASA ESDIS Project is taking a leadership role for the agency in the coordination of persons and activities working data quality issues. To date:

    A. Assembled a DQ team to develop strategies and products that further characterize DQ issues and coordinate/solicit for support for these issues.

    B. Begun our agency coordination of DQ issues with our established interagency and international science and data system bodies.

Data Quality NASA Management Context (White paper)

- What's needed, what's next?
  - Our first step is to complete a near-term 'inventory' of current data quality mechanisms, processes and system for establishing and capturing data quality information. Initial focus in on existing projects who have established practices that are found to be of value to their specific user communities (success oriented).
  - From this base information a follow on set of documents will be developed around the gaps and 'tall pole' topics that emerge from the inventory process. These products will serve as a basis for organizing and coordinating DQ topics coupled to available resources and organizations to address these topics.
  - NASA intends to use currently planned meetings and symposia to further the DQ issue discussion and a forum for learning of other practices and community needs.
- **To make headway in DQ NASA is seeking interested partners in joining our established teams and/or helping us coordinate and collaborate with other existing teams working these issues.**

Specific NASA efforts

- NASA Science Mission Directorate, Research Opportunities in Space and Earth Sciences 2010, Earth System Data Records Uncertainty Analysis :
  - Extend and enhance the use of Earth System Data Records, including Climate Data Records, through rigorous estimation of error in Earth System Data Records used by NASA communities.
  - Increase the science value of Earth System science measurements by identifying and validating systematic errors, and improving error estimations.
- The scope of problems include estimating, validating, and conveying:
  - Measurement differences between sensors or between sensors, validation measurements and/or models;
  - Measurement errors in merged data products;
  - Systematic errors in long-term Earth system science data records; and
  - Other contributions to Earth science measurement quality and quantification of uncertainties.
- The data methodologies or techniques employed by Earth System Data Records Uncertainty Analysis projects and their applicability to the problems being solved must be scientifically rigorous, peer-recognized, and substantiated.

Specific NASA efforts, cont.

- NASA Science Mission Directorate, Research Opportunities in Space and Earth Sciences ACCESS, ESTO, Making Earth Science Data Records for Use in Research Environments (MEaSUREs):
  - Specifically solicited proposal addressing provenance and uncertainty.
  - Consistently processed data across multiple sensors and missions
- Examples:
  - ACCESS: "AeroStat: Online Platform for the Statistical Intercomparison of Aerosols"
  - ACCESS: "Data Quality Screening Service (DQSS)"
  - ESTO: "Multi-sensor Data Synergy Advisor"
- White paper on SST Error budget
- White paper on Quality of NASA Remote Sensing Data:
  - Assessment of DQ handling by different disciplines
  - Developing recommendations for future missions
- Special 2010 and 2011 Fall AGU sessions on data uncertainty and quality

Earth Science Information Partners (ESIP) Federation IQ cluster

Objective:

- to bring together people from various disciplines to assess aspects of quality of remote sensing data.
- Learn and share best practices
- Build a framework for consistent capture, harmonization and presentation of data quality for the purposes of climate change studies, earth science and applications.
- ESIP Summer 2011 meeting, Santa Fe, NM

Conclusion

- Quality assessment of Level 2+ remote sensing data is very challenging
- Various approaches to address some aspects of data quality are not consistently applied
- A framework for consistent addressing quality of remote sensing data is needed
- Various DQ efforts have started at NASA and other organizations

Backups

Product Maturity levels (MISR example)

- **Alpha data product**
  - Prerelease designation used as a test bed to discover and correct errors affecting the operability of the associated production software at the DAAC.
  - Applies to entire products. Data products are visible to the science team, but not the public.
  - Not appropriate for scientific publication.
- **Beta data product**
  - Early release used to gain familiarity with data formats.
  - Intended as a test bed to discover and correct errors.
  - Minimally validated and still may contain significant errors
  - General research community is encouraged to participate in the QA and validation, but need to be aware that product validation and QA are ongoing.
  - Parameter may be used in publications as long as beta quality is indicated by the authors. Drawing quantitative scientific conclusions is discouraged. Users are urged to contact science team representatives prior to use of the data in publications, and to recommend members of the instrument teams as reviewers
  - The Data Quality Summary states estimated uncertainties.
  - May be replaced in the archive when an upgraded product becomes available, but should be reproducible upon demand.
- **Provisional data product**
  - Incremental improvements are still occurring. Obvious artifacts or blunders observed in beta product have been identified and either minimized or documented.
  - General research community is encouraged to participate in the QA and validation, but need to be aware that product validation and QA are ongoing.
  - Parameter may be used in publications as long as provisional quality is indicated by the authors. Users are urged to contact science team representatives prior to use of the data in publications, and to recommend members of the instrument teams as reviewers.

Product Validation levels (for MISR)

Validated data product

- Validation results have been published in the peer-reviewed literature.
- The Data Quality Summary states estimated uncertainties.
- The Data Quality Summaries are updated as new validation results become available, including all referenceable publications.
- Parameter, together with its published uncertainties, may be used to derive quantitative scientific conclusions that are suitable for publication.
- May be replaced in the archive when an upgraded product becomes available, but should be reproducible upon demand.
- Validated status occurs in three stages:
  - **Stage 1:** Product accuracy has been estimated using a small number of independent measurements obtained from selected locations and time periods and ground-truth/field program efforts
  - **Stage 2:** Product accuracy has been assessed over a widely distributed set of locations and time periods via several ground-truth and validation efforts
  - **Stage 3:** Product accuracy has been assessed and the uncertainties in the product well established via independent measurements in a systematic and statistically robust way representing global conditions