GOES-R AWG Product Validation Tool Development

Downward SW Radiation at Surface and Reflected SW Radiation at TOA

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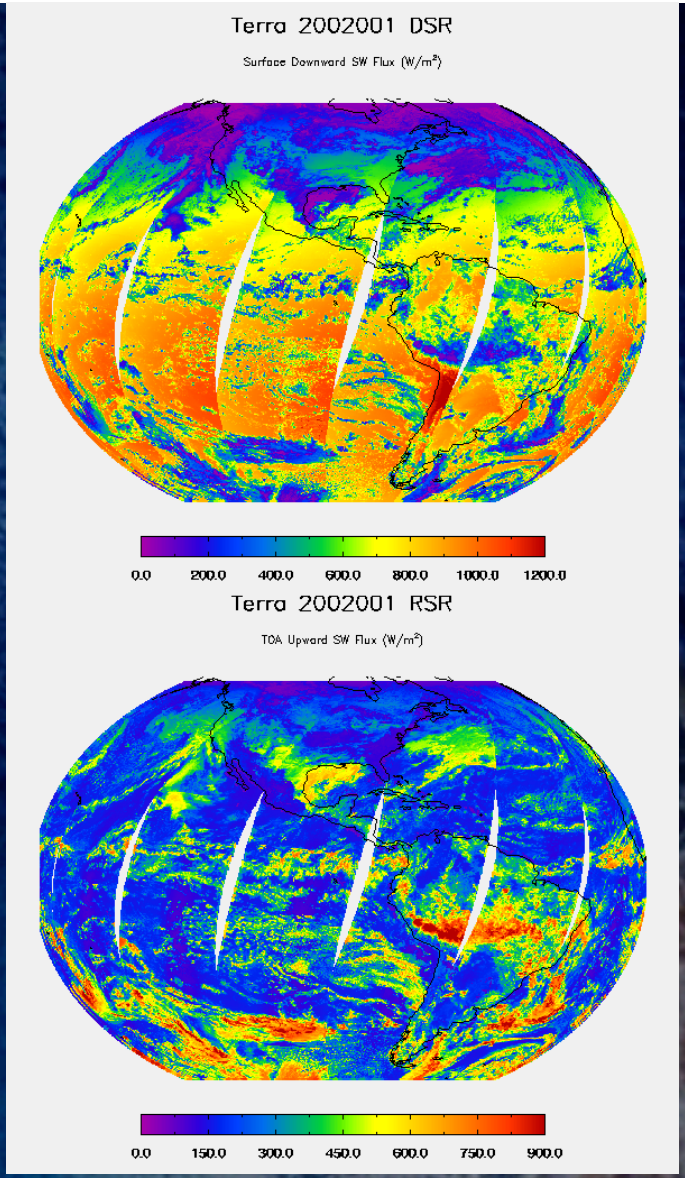
OUTLINE

- Products
- Validation Strategies
- Routine Validation Tools
- “Deep-Dive” Validation Tools
- Ideas for Further Enhancement and Utility of Validation Tools
- Summary

Products

- Shortwave Radiation Products:
  - Downward Shortwave Radiation at Surface (DSR)
    - CONUS: 25km/60min
    - Full Disk: 50km/60min
    - Mesoscale: 5km/60min
  - Reflected Shortwave Radiation at TOA (RSR)
    - CONUS: 25km/60min
    - Full Disk: 25km/60min

  Only daytime



Monitoring & Validation Background

- Functions of tools:
  - routine monitoring (may not need reference data)
  - routine validation (reference data, matchup procedure)
  - deep-dive validation (reference data, other correlative data, matchup)
- Basic elements:
  - data acquisition (ABI, ground, other sat products) (Fortran 90)
  - spatial and temporal matching (lots of possibilities) (Fortran 90)
  - analysis (computing statistics) (IDL)
  - present results (display maps, scatter plots, tables) (IDL)
- Validation strategy must consider unique features of product:
  - large range of values (0 – 1000+ W m^{-2})
  - primarily driven by cloudiness and solar position
  - these lead to relatively high correlation between ground and satellite data even when the retrieval has problems; correlation coefficient alone is not a very meaningful metric
    - calculate ABI metrics (accuracy, precision) and other widely-used metrics (std dev, root-mean-square error) to facilitate comparison with published results

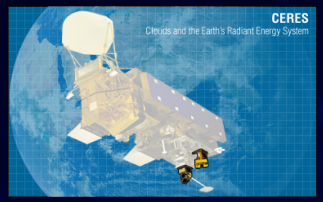
Validation Strategies
Reference Dataset (Ground)

- Ground Measurements
  - High-quality routine ground radiation measurements over Western Hemisphere used for validating ABI Shortwave Radiation retrievals are collected from 20 stations from SURFRAD (ftp://ftp.srrb.noaa.gov/pub/data/surfrad/) and BSRN (ftp://ftp.bsrn.awi.de/)

Station	Network	Longitude	Latitude	Elevation[m]	Measurements Used
fpk	SURFRAD	-105.10	48.31	634	surface SW downward, upward fluxes; surface SW downward direct, diffuse fluxes; clear fraction; solar zenith angle; quality flag
sxf		-96.62	43.73	473	
psu		-77.93	40.72	376	
tbl		-105.24	40.13	1689	
bon		-88.37	40.05	213	
dra		-116.02	36.63	1007	
gwn		-89.87	34.25	98	
ber	BSRN	-64.667	32.267	8	surface SW downward fluxes; surface SW downward direct, diffuse fluxes;
bil		-97.516	36.605	317	
bou		-105.007	40.050	1577	
brb		-47.713	-15.601	1023	
cam		-5.3167	50.2167	88	
clh		-75.713	36.905	37	
flo		-48.517	-27.533	11	
iza		-16.9993	28.3094	2373	
ptr		-40.319	-9.068	387	
reg		-104.713	50.205	578	
rlm		-61.773	-11.582	252	
e13		-97.485	36.605	318	
sms		-53.8231	-29.443	489	

Validation Strategies
Reference Dataset (Satellite)

- Satellite Measurements



  - Clouds and the Earth's Radiant Energy System (CERES) Cloud and Radiative Swath (CRS) dataset are used: (1) measurements of TOA upward SW flux, and (2) calculation of Surface and Atmospheric Radiation Budget (SARB). http://eosweb.larc.nasa.gov/PRODOCS/ceres/level2_crs_table.html

Data Set Name	Description
CERES SW TOA flux - upwards	Derived RSR by angular correction of measured broadband SW radiance
Clear/layer/overlap percent coverage	Fraction of clear-sky and cloud within FOV
Shortwave flux – downward - total	Calculated SW downward fluxes at TOA, 70hpa, 200hpa, 500hpa, and the surface (tuned solution).
Shortwave flux adjustment at TOA – upward - total	Difference between tuned and unturned solution of upward flux at TOA
Shortwave flux adjustment at TOA – downward - total	Difference between tuned and unturned solution of downward flux at TOA

Validation Strategies
Collocation over Ground Stations

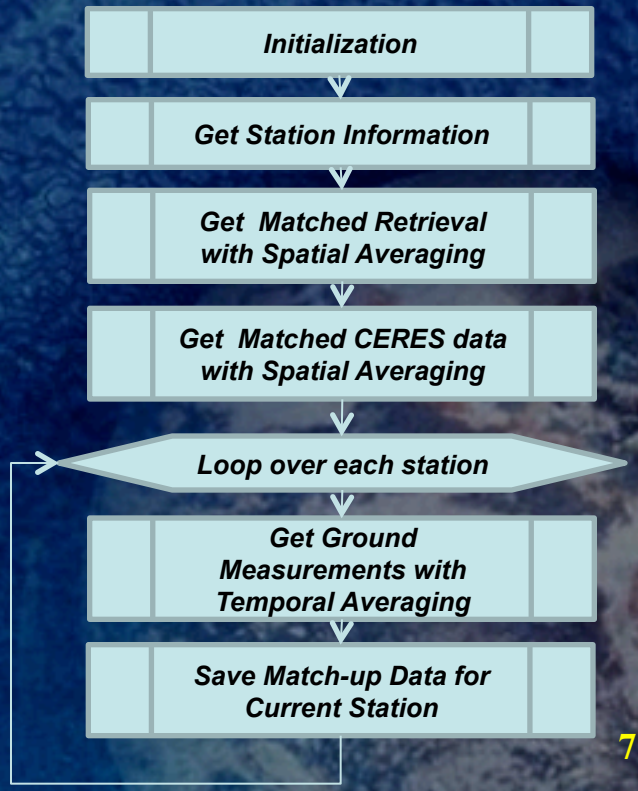
- Collocation of ABI retrievals and ground validation data is performed at the instantaneous time scale.
- Matching: satellite retrievals averaged spatially; ground measurements averaged temporally. Averaging window size is flexible.

Collocated Data

Match-up Data	Description
Ground measurement time	Mean observation time within the temporal averaging period
Number of retrievals	Sample size of retrievals for averaging
Ground mean fluxes	Averaged ground measurements of downward total/direct/diffuse and upward SW fluxes
Ground clear fraction	Mean ground clear fraction within the temporal averaging period
Ground GMT	Mean ground observation time
CERES measurement time	Mean CERES measurement time within the spatial averaging domain
Number of CERES footprints	Sample size of CERES data for averaging
Retrieval grid longitude	Longitude for each retrieval grid
Retrieval grid latitude	Latitude for each retrieval grid
Retrieved all-sky fluxes	TOA downward/upward, surface downward/upward, and surface diffuse SW fluxes for each retrieval within the averaging domain
QC Flag (Input)	Input quality flag for each retrieval
QC Flag (Retrieval)	Retrieval quality flag for each retrieval
QC Flag (Diagnosis)	Diagnosis quality flag for each retrieval
CERES longitude	Longitude for each CERES footprint within averaging domain
CERES latitude	Latitude for each CERES footprint
CERES measurement time	Nominal time of each CERES measurement
CERES RSR	CERES measured TOA upward SW flux for each footprint
CERES cloud fraction	Cloud fraction for each CERES footprint

Identified core (high quality) ground sites for validation

flowchart



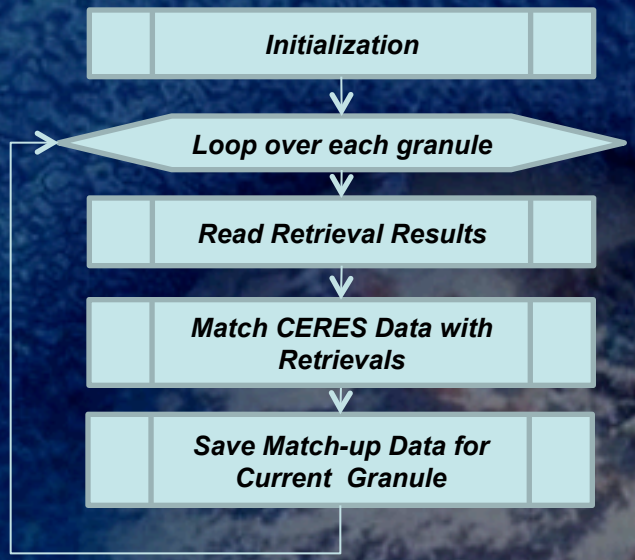
Validation Strategies

Collocation over Satellite Measurements

- Collocation with CERES is carried out by averaging CERES data to the retrieval grids on a daily basis.
- Current retrievals use MODIS data as input. CERES is on same platform; no need for temporal matching.

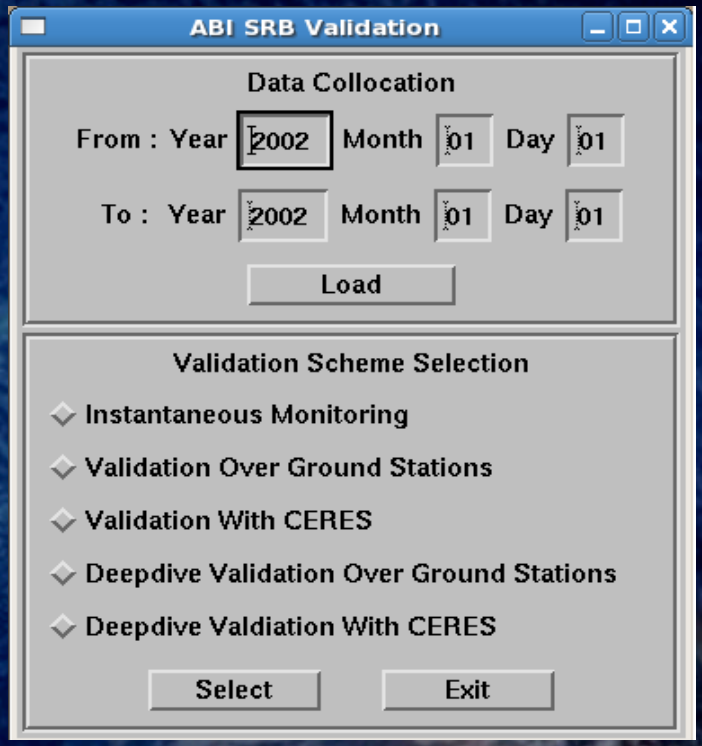
Match-up Data
Retrieved surface downward SW flux
Retrieved TOA upward SW flux
Retrieved surface upward SW flux
Retrieved atmospheric absorption
QC Flag (Retrieval)
QC Flag (Diagnostics)
CERES measured RSR
SARB tuned surface downward SW flux
SARB tuned TOA upward SW flux
SARB tuned surface upward SW flux
SARB tuned atmospheric absorption
SARB untuned surface downward SW flux
SARB untuned TOA upward SW flux
SARB untuned surface upward SW flux
SARB untuned atmospheric absorption
CERES cloud fraction
CERES surface type

flowchart



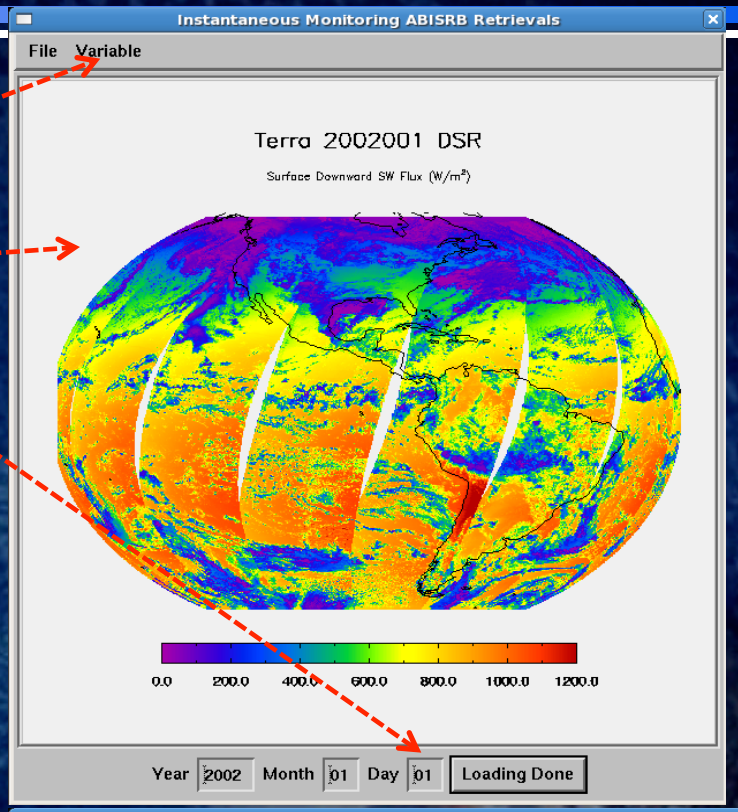
Validation Strategies
Tools , Statistics & Visualization

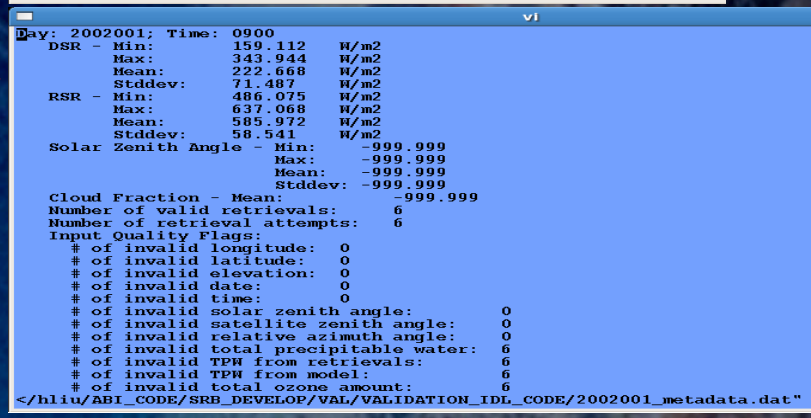
- Tools:
  - IDL GUI interface
    - Data Collocation
    - Instantaneous Monitoring
    - Validation over Ground Stations
    - Validation with CERES
    - Deep-dive Validation over Ground Stations
    - Deep-dive Validation with CERES
- Statistics:
  - Metadata
  - Accuracy/Precision
  - RMSE
  - Minimum/Maximum Error
- Visualization:
  - IDL GUI displays the intended plots.
  - Figures generated in PNG format (or GIF, JPEG, EPS if needed)



Routine Validation Tools
Instantaneous Monitoring

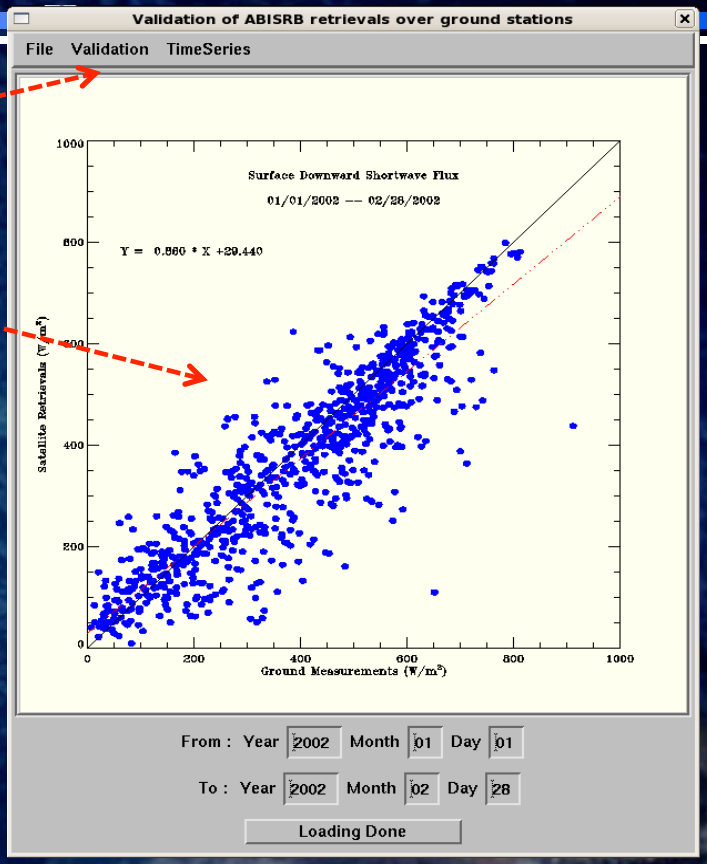
- Present retrieval results
  - Specify date & load data
  - Selection from ‘Variable’ menu
    - Primary Outputs (image)
      - DSR
      - RSR
    - Diagnostic Outputs (image)
      - Surface diffuse flux
      - Surface albedo
      - Clear-sky composite albedo
      - Clear-sky aerosol optical depth
      - Water cloud optical depth
      - Ice cloud optical depth
    - Quality Flags (image)
      - 66 flags (inputs, retrieval, diagnostics)
    - Metadata (ascii file output)
- Independent of validation truth; can be executed automatically by scripts once retrievals are available.

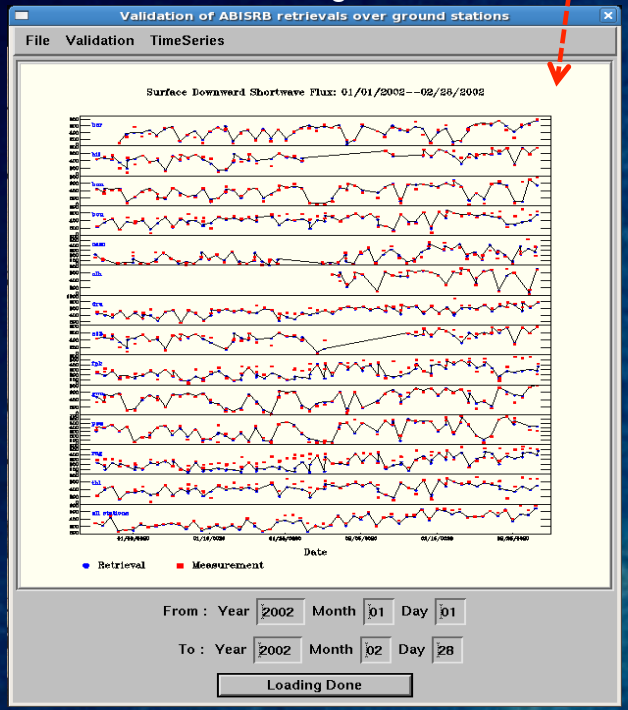


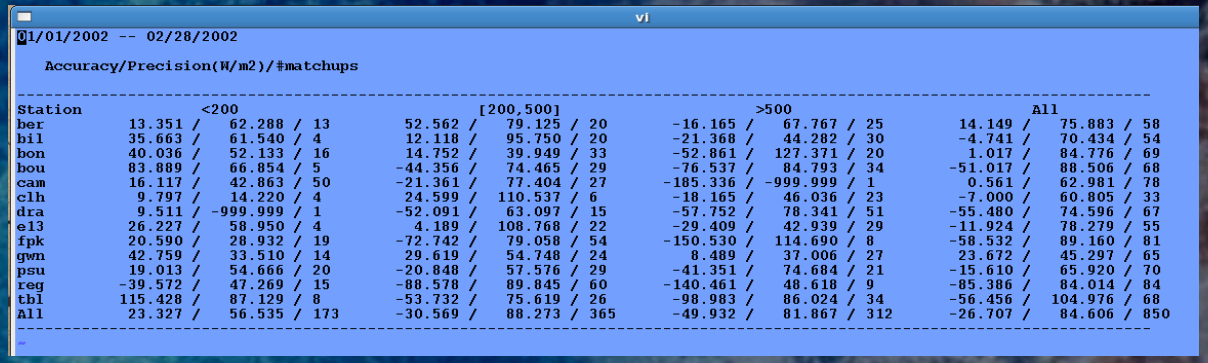


Routine Validation Tools
Validation Over Ground Stations

- Validates DSR&RSR for a period of time
  - Specify time period & load data
  - ‘Validation’ menu
    - Generate scatter plot of retrievals against measurements
    - Generate validation statistics and output to ascii file
  - ‘TimeSeries’ menu
    - Generate time series plots of retrieval and measurements over ground stations



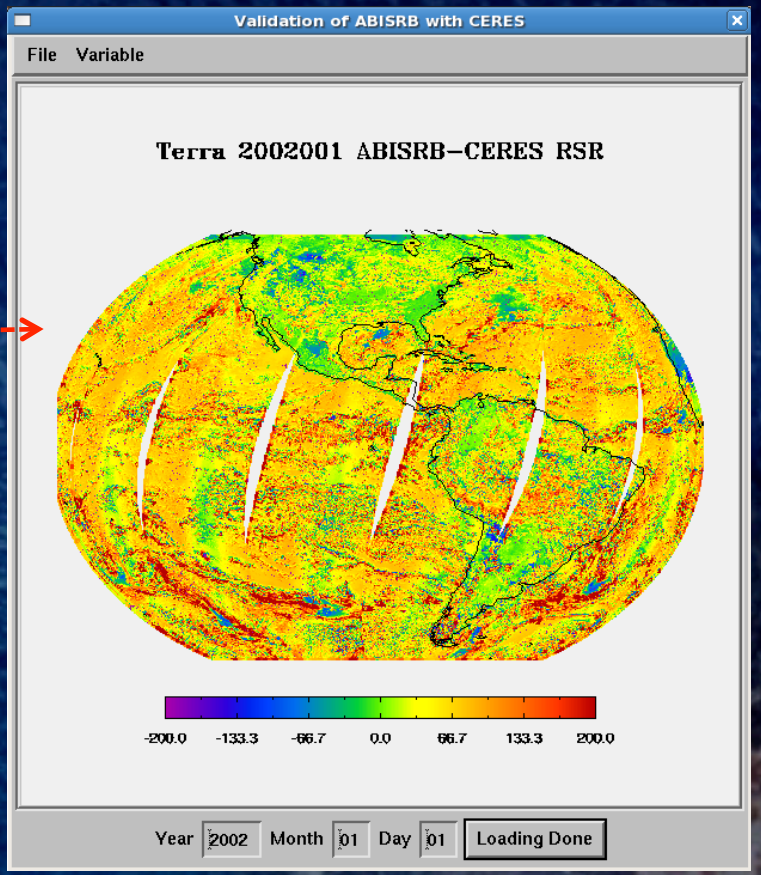


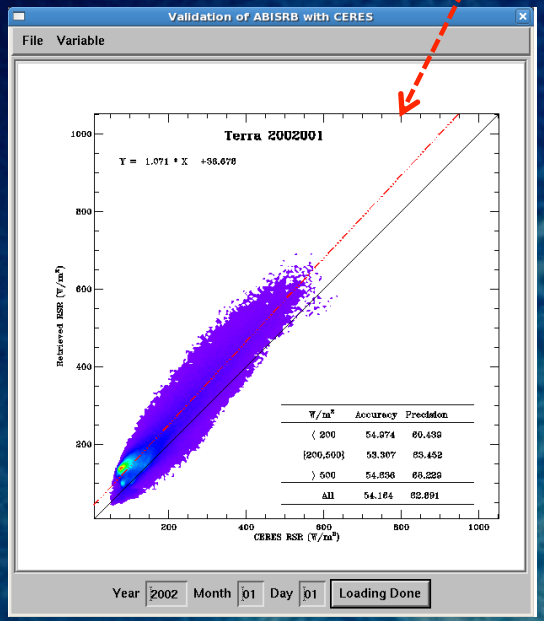


Station	<200	[200,500]	>500	All
ber	13.351 / 62.288 / 13	52.562 / 79.125 / 20	-16.165 / 67.767 / 25	14.149 / 75.883 / 58
bil	35.663 / 61.540 / 4	12.118 / 95.750 / 20	-21.368 / 44.282 / 30	-4.741 / 70.434 / 54
bon	40.036 / 52.133 / 16	14.752 / 39.949 / 33	-52.861 / 127.371 / 20	1.017 / 84.776 / 69
bou	83.889 / 66.854 / 5	-44.356 / 74.465 / 29	-76.537 / 84.793 / 34	-51.017 / 88.506 / 68
cam	16.117 / 42.863 / 50	-21.361 / 77.404 / 27	-185.336 / -999.999 / 1	0.561 / 62.981 / 78
c1h	9.797 / 14.220 / 4	24.599 / 110.537 / 6	-18.165 / 46.036 / 23	-7.000 / 60.805 / 33
dra	9.511 / -999.999 / 1	-52.091 / 63.097 / 15	-57.752 / 78.341 / 51	-55.480 / 74.596 / 67
e13	26.227 / 58.950 / 4	4.189 / 108.768 / 22	-29.409 / 42.939 / 29	-11.924 / 78.279 / 55
fpk	20.590 / 28.932 / 19	-72.742 / 79.058 / 54	-150.530 / 114.690 / 8	-58.532 / 89.160 / 81
gwn	42.759 / 33.510 / 14	29.619 / 54.748 / 24	8.489 / 37.006 / 27	23.672 / 45.297 / 65
psu	19.013 / 54.666 / 20	-20.848 / 57.576 / 29	-41.351 / 74.684 / 21	-15.610 / 65.920 / 70
reg	-39.572 / 47.269 / 15	-88.578 / 89.845 / 60	-140.461 / 48.618 / 9	-85.386 / 84.014 / 84
tbl	115.428 / 87.129 / 8	-53.732 / 75.619 / 26	-98.983 / 86.024 / 34	-56.456 / 104.976 / 68
All	23.327 / 56.535 / 173	-30.569 / 88.273 / 365	-49.932 / 81.867 / 312	-26.707 / 84.606 / 850

Routine Validation Tools
Validation with CERES

- Validates RSR over extended area for a specified date
  - Specify date & load data
  - Selection from 'Variable' menu
    - CERES RSR (image)
    - Retrieved RSR (image)
    - Retrieved-CERES RSR (image)
    - Accuracy/Precision (Scatter Plot)





"Deep-Dive" Validation Tools
Validation over Ground Stations

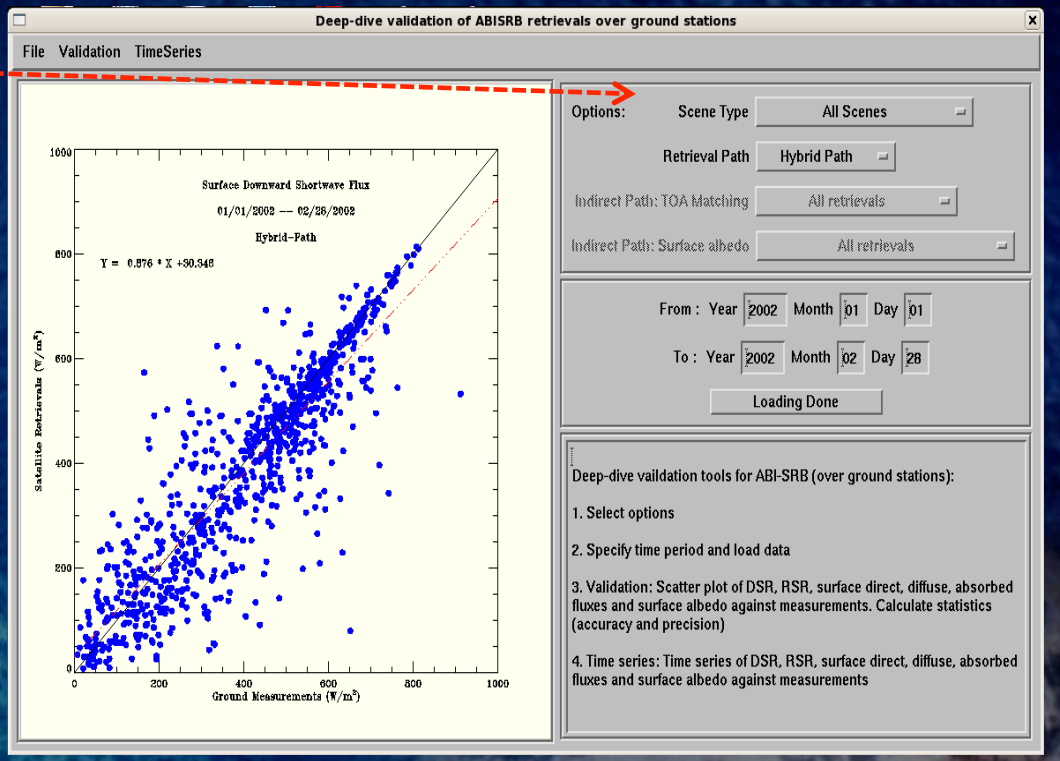
An expansion of routine validation over ground stations with diagnostic variables and various options

- Options:
  - Scene types
    - all; snow ; clear ; water cloud; ice cloud
  - Retrieval path
    - Hybrid path
    - Direct path only
    - Indirect path only
      - TOA matching (all; succeed; failed)
      - Surface albedo (all; succeed; failed)
- 'Variable' menu (DSR & RSR)

  Generate scatter plot of retrieval against measurements

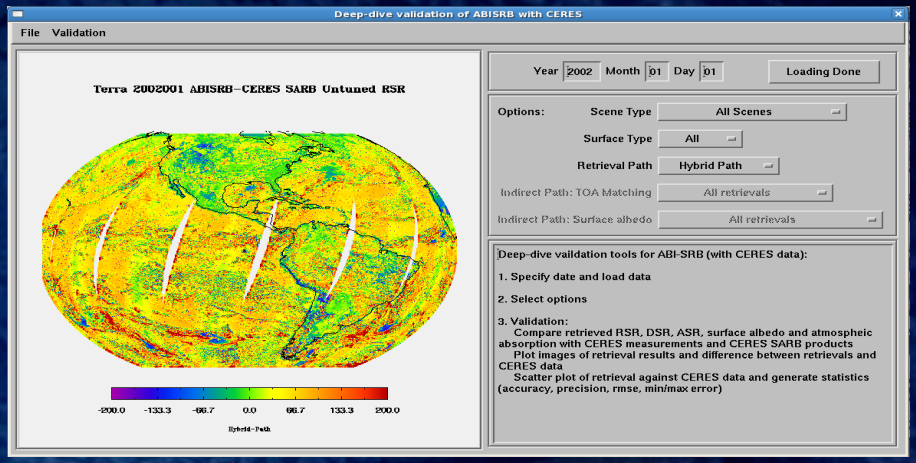
  Generate validation statistics and output to ascii file
- 'TimeSeries' menu (DSR & RSR)

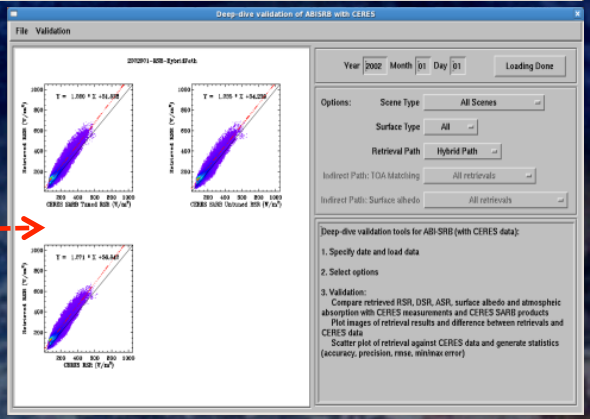
  Generate time series plots of retrieval and measurements over ground stations
- Specify date & load data

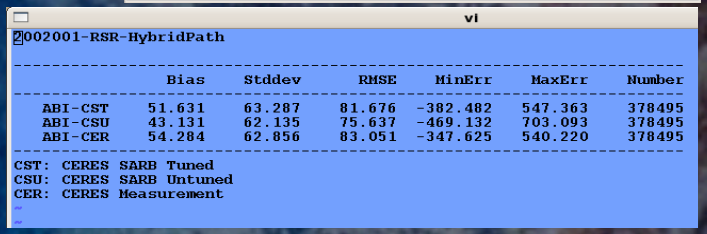


"Deep-Dive" Validation Tools
Validation with CERES

- An expansion of routine validation with CERES including cross validation against NASA SARB satellite products
  - Options:
    - Scene types
      - all; snow ; clear ; water cloud; ice cloud
    - Retrieval path
      - Hybrid path
      - Direct path only
      - Indirect path only
        - TOA matching (all; succeed; failed)
        - Surface albedo (all; succeed; failed)
  - Specify date & load data
  - Selection from 'Validation' menu
    - Reflected SW Radiation at TOA (RSR)
      - Retrieval; Retrieval-CERES; Retrieval-SARB Tuned; Retrieval-SARB Untuned;
      - Statistics (Scatter plot; Statistics in ascii file)
    - Downward SW Radiation at Surface (DSR)
      - Retrieval; Retrieval-SARB Tuned; Retrieval-SARB Untuned; Statistics
    - Absorbed SW Radiation at Surface (ASR)
      - Retrieval; Retrieval-SARB Tuned; Retrieval-SARB Untuned; Statistics
    - Absorbed SW Radiation in Atmosphere (ABS)
      - Retrieval; Retrieval-SARB Tuned; Retrieval-SARB Untuned; Statistics
    - Surface SW Albedo (ALB)
      - Retrieval; Retrieval-SARB Tuned; Retrieval-SARB Untuned; Statistics

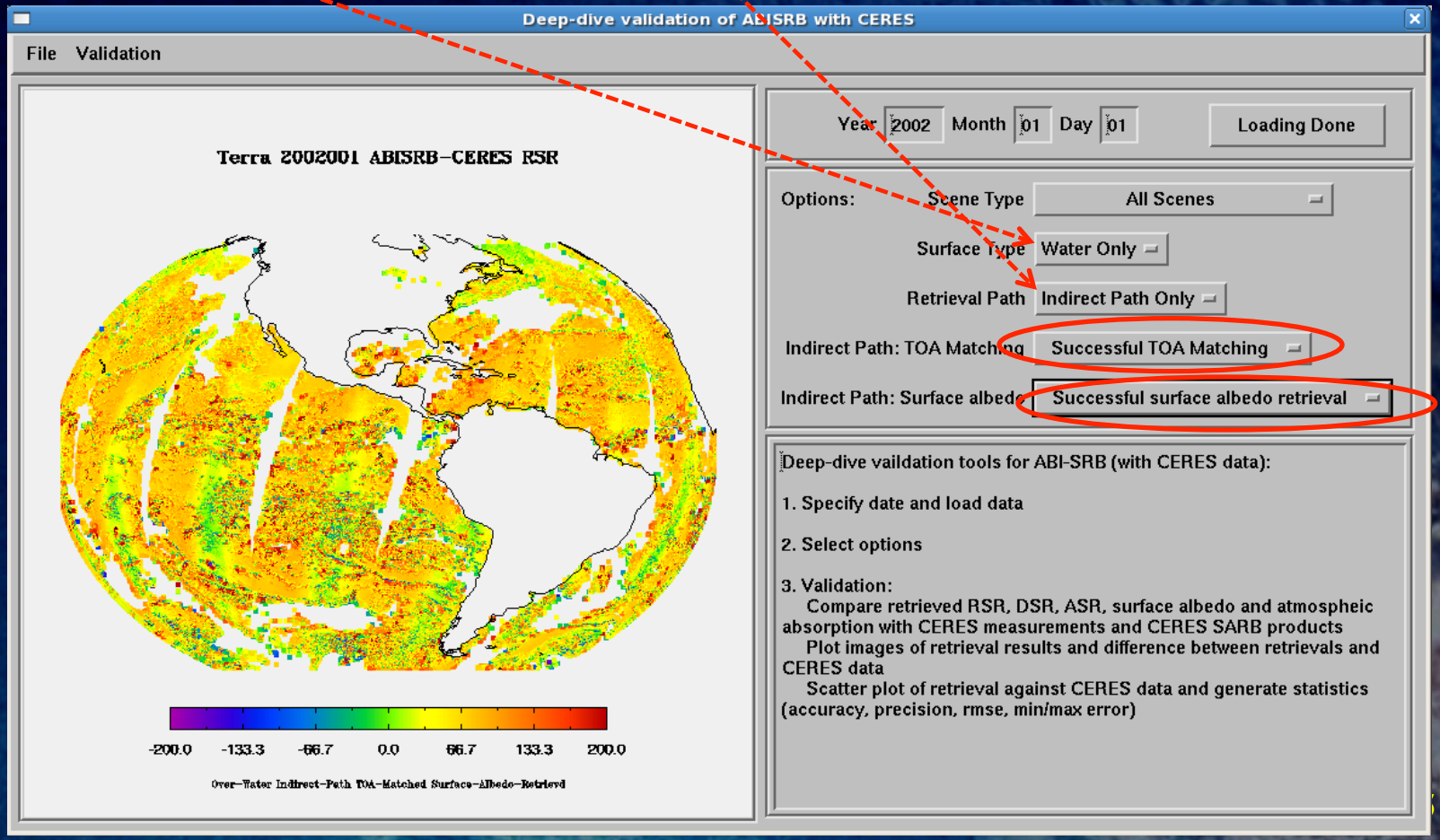






Example of Problems Identified

- Validation with CERES data shows RSR is overestimated over ***water*** surface in the ***indirect-path*** retrieval.
  - Narrowband reflectance to Broadband Albedo conversion over water needs to be improved.



Ideas for the Further Enhancement and Utility of Validation Tools

- Calculate and display
  - additional statistics (histograms)
  - temporal averages on different scales (daily, weekly, monthly)
- Identify signatures by which even non-experts can identify potential problems – needed for routine operational monitoring
- Implement automatic detection of possible systematic drift or continuous abnormal retrieval in routine validation.
  - establish “reference” (expected) statistics from good data
  - compare time series of actual statistics with reference stats
  - trigger action (e.g., sending warning email) when actual stats exceed reference stats + x std.
- Combine SW validation with LW radiation retrievals
  - check consistency
    - e.g., high RSR low OLR is expected for cloudy scenes
  - additional diagnostic information for deep-dive validation (LW radiation)
- Current tool uses retrievals from MODIS proxy data. Adjustment to tools for retrievals from geostationary orbit will be needed (data preparation).

Summary

- Current tools perform three functions:
  - routine monitoring of product
  - routine validation with reference data
  - deep-dive validation with reference and intermediate data
- Validation truth data have been identified and processed
- Planned enhancements include:
  - more stats
  - automatic detection of problems
  - checking consistency with LW