The Swarm Cometh

Contrarian thoughts to conventional GSICS approaches for interoperable data sets

B. Guenther

bguenther@stellarsolutions.com

INTRODUCTION

- Not been in this community recently
  - So maybe you already are familiar with what I'll be talking about
- GSICS objectives are not new to me
  - See BACKUP charts if you want to see some of my contributions
- Comments are ramblings from a Remote Sensing specialist rather than calibration specialist

Putting focus on Environmental Parameters

- Very few measurements represent *Primary Data*
  - Solar Spectral Irradiance
  - Solar Constant
  - CERES/ERB/BBR* **
  - High spectral resolutions CrIS/IASA/AIRS may be very close to a *Primary Data* source for atmosphere constituents
- *Non-Primary Data* used in inference of GeoPhysical and environmental parameters

* 2 million lines executable code needed, need be cautious

** Also suggests direct measurement of heat flux into atmosphere from land and oceans may be important *Primary Data* source too.

Distinguishing *Primary Data*

- Consider GSICS Community as one focused on measurements and measurement strategies
- Whereas Climate and operational forecasts based on attributes of environmental parameters
  - Measurements and parameters are related but not the same
  - Of course the measurements are relevant to environmental parameters
  - Measurements generally are not directly the environmental parameters
- Not intending to challenge our thinking of role of calibration for *Primary Data* attributes

Thinking of remainder of measurements

- Community emphasizes calibration for all measurements
- Suggest *non-Primary Data* measurements have different context
  - Still remote sensing data
  - Heavily rely on models and RT computations to achieve data results
  - Frequently need ancillary and auxiliary data for interpretation
- Thesis: sensor calibration of secondary importance in measurement of *non-Primary Data*
- Characterization and uncertainty budgets continue to be important
- *Approaches here largely related to operational needs in NOAA*

Ocean Color example of one approach

- Space measurements not of sufficient accuracy for direct determination of geophysical parameters
  - Rely on tuning to MOBY
  - May need handle sensor polarization correction in somewhat *ad hoc* strategy
  - Constrained by physical principles
  - Ground pre-launch test results of fleeting importance
- Not intending to be careless in Ground calibration, merely recognizing that one must do more than the pre-launch calibrations

Even for Facility Instruments (VIIRS/MODIS)

- System Engineering emphasizes “Test As You Fly” philosophy
- VIIRS has ~ 14 month laboratory test campaign
  - Tests polarization, stray light, near and far-field scatter and radiometry characterized as if they all are orthogonal characteristics
  - Never full aperture with realistic earth-atmosphere scenes
- Fantastic progress from 1980’s where, for example, AVHRR spectral transmission obtained from strip charts (who remembers Gerber Variable Scales)
- Small sat and cube sat missions will have reduced Ground testing
- SWARMS will have even less Ground testing than small sat missions
- Enhanced on-orbit testing is necessary

NOAA Next Generation, beyond 2030

- Program of Record (POR, GOES and JPSS) extend to 2030 or 2035
- Performed Architecture Study for follow-on missions beyond POR
  - NOAA Satellite Observing System Architecture Study (N-SOSA)
- Recommendations for Hybrid Architectures
  - New measurements
  - Commercial opportunities
  - Energize new business practices
- Anticipated benefits
  - Lower costs
  - Quicker inclusion of advanced technologies
  - Agility in putting assets into Constellation

Adding context to N-SOSA studies

- NOAA resides with US Department of Commerce (DoC)
- NOAA budget very large part of DoC budget
- Space acquisition for NOAA very large part of NOAA budget
- U.S. Republican Administrations typically emphasis private sector solutions over public sector solutions to problems
- Extraordinary energy and effort currently going into private sector space efforts with small sat, cube sat enterprises
- Next U.S. Democratic Administration most likely temper but not roll-back small sat efforts for research and operational applications

New opportunities for Data Sets

- N-SOSA advocates for Data Buys opportunities
- Primary missions for NOAA are
  - Weather
  - Space Weather
  - Environmental Remote Sensing (excluding land mapping)
- Current US Numerical Weather Prediction models use highly thinned CrIS observations (~1/16 th)

Key Results of Study

- For most annual cost levels the most cost-effective satellite observing system architectures are derivatives of the current program of record, in that they maintain a very similar allocation of functions to orbits and generally maintain the current functions.
- Radical alternative constellations, such as MEO or LEO swarms, are generally not cost-effective at any funding level.
- In supporting terrestrial weather missions, adding new observational capabilities, such as Wind LIDAR, plays a larger role than large increases or performance improvements in existing collection types. Many existing collection types are operating close to their point of maximum cost-effectiveness.
- Adding high altitude, high inclination platforms (such as Molnyia or Tundra) carry relatively high cost effectiveness and can support multiple mission areas.
- In the space weather area the impact of maintaining an off-Earth-Sun-axis platform, such as an L5 platform, plays an outsize role.

RideShare opportunity on JPSS-2 launch

- NOAA issued RFI in June, 2018
- Schedule provided 18 months between selection and completion of build and test of instrument
- Vision is a cube-sat device (not necessarily a proto-type from a ‘SWARM “ of devices)
- With MODIS/VIIRS/CrIS at one end of complexity, cost and schedule (taking large fraction of decade to build first article, and ~ 2-3 years to build successive units)
  - This RideShare concept is in the middle
  - SWARM builders are designing to manufacture one unit every 1 – 2 weeks

Planet Labs is one mission

Science, Feb 23, 2017. On 14 February, …Valentine's Day … Planet … launched 88 shoebox-sized satellites on a single Indian rocket. They joined dozens already in orbit, bring the constellation of "Doves" as the tiny imaging satellites are known, to 144. Six months from now, *(after commissioning)* the company …able to image every point on Earth's landmass at intervals of 24 hours or less, at resolutions as high as 3.7 m…

SWARM missions

- Mainly considered business opportunities
  - Although some are Ego-driven
- Business opportunity directed by business plan
- Additional revenue stream for operational Agency Data Buy would be highly desirable

- Irony is that SWARM missions may be more important when “paired” with Government asset CLARREO-like asset, coupled with enhanced On-orbit vicarious calibrations to meet operational data quality demands

Expectation

- VIIRS-class sensors (Facility Instruments) may be things of the past
- Developing missions likely to be less expensive, faster, smaller
- Calibration and characterization of space-assets likely to be less well characterized on ground than are the current Facility Instruments
- Enhance On-orbit testing necessary
- Accuracy, stability, data interoperability will need to be facilitated with robust ground (vicarious) measurements
- Commercial efforts will become more prevalent, efforts guided by Business Plans
- What would become the role of GSICS groups?

BACKUP
Bruce Guenther

Background in Sensor Calibration

Community Contributions

- Supported Fred Nicodemus Self-Study Manuals
- Supported Jon Geist in development of quantum detectors in SWIR
- NASA representative to CEOS (when Susan Till was Chair)
- Convened **Workshop on Strategies for Calibration and Validation of Global Change Measurements** (with Butler and Ardanuy) in 1995
- Served as 1st EOS Terra Project Scientist

Research Contributions

- 1st use of NIST Synchrotron Storage Ring of solar spectral irradiance calibration (sounding rocket experiment)
- Early use of Argon Maxi-Arc for Shuttle SBUV calibration
- 1st use of T-SIRCUS for space-borne sensor (VIIRS)
- Calibration of SPOT 2 Image sensor
- ER-2 measurements used in calibration of 1st decade of the ISCCP
- Delivered 1st MODIS Terra Level 1B data products
- Served as VIIRS Chief Scientist in delivery of NPP VIIRS for flight