Libera science overview and updates

Maria Hakuba

CERES STM, Apr 27, 2022

LASP
Jet Propulsion Laboratory
California Institute of Technology

Libera's overarching Science goals

OG1: Enable seamless continuity of the CERES Earth Radiation data record.

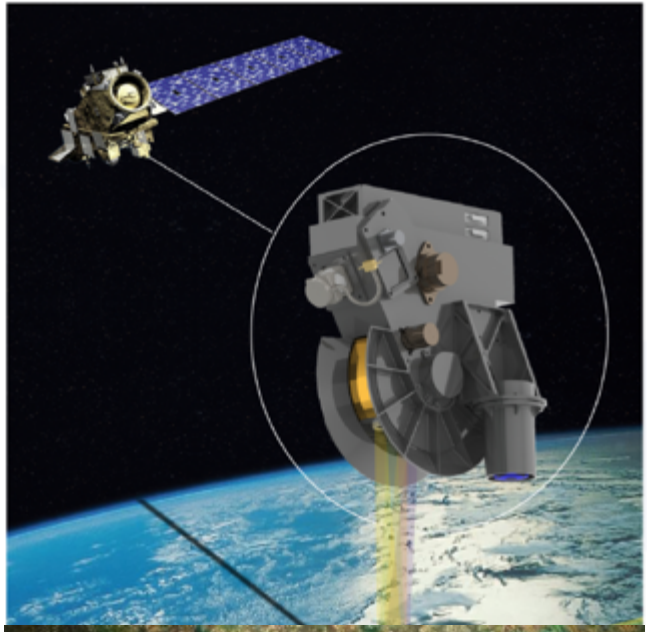
- Measurement of TOT, SW and LW with same characteristics as CERES.
- On JPSS-3 with VIIRS to enable state-of-the-art flux conversion.

OG2: Advance the development of a self-contained, innovative & affordable observing system.

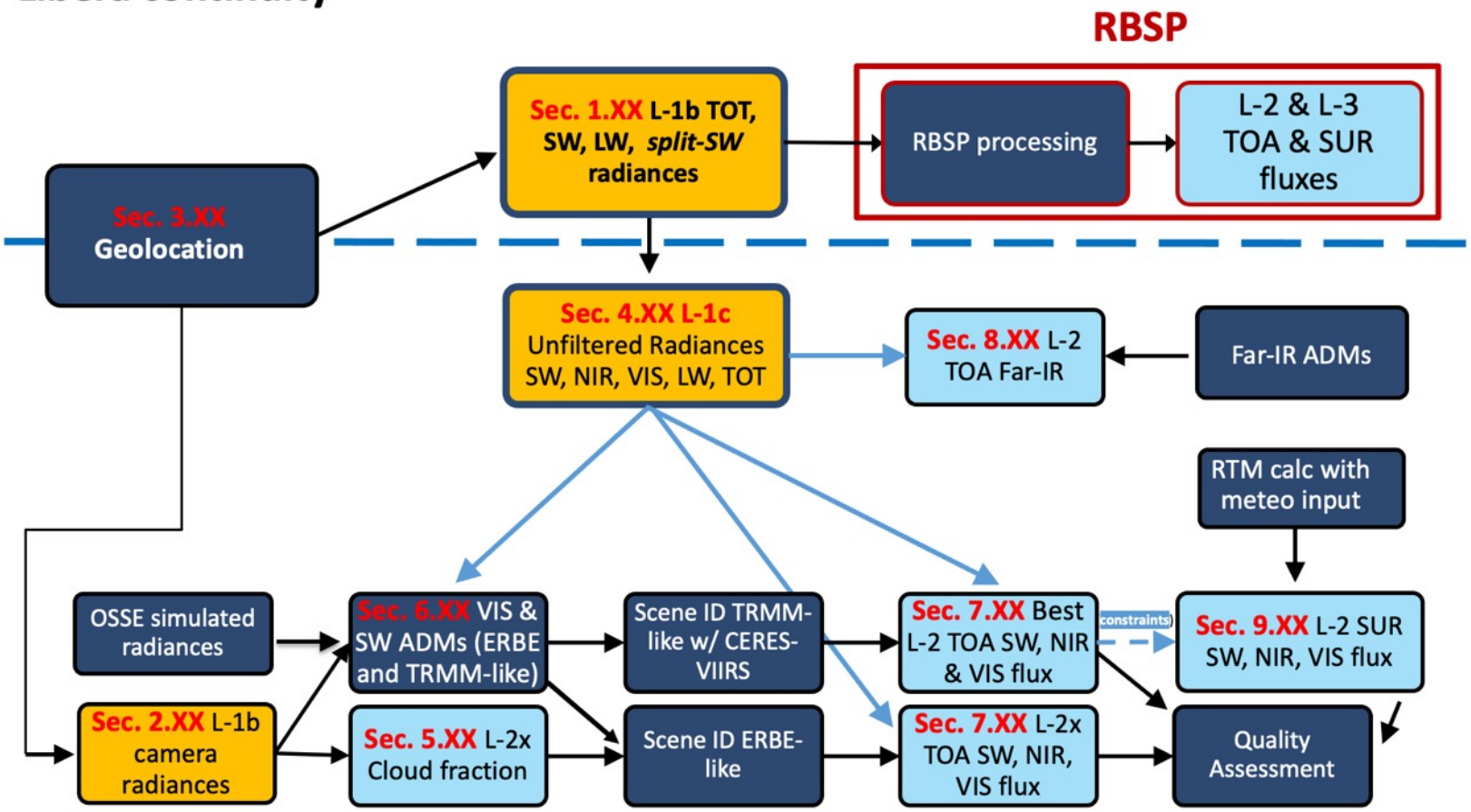
- Miniaturized high-accuracy radiometers (ESRs with VACNT detectors)
- Wide field-of-view camera for Scene context and split-SW ADM development.

OG3: Provide new and enhanced capabilities that support extending ERB science goals.

- Additional split-SW channel to quantify shortwave near-IR and visible radiative flux deposition in the climate system.
- Far-IR retrieval to provide information on upper-tropospheric contribution to ERB variability especially near the poles.

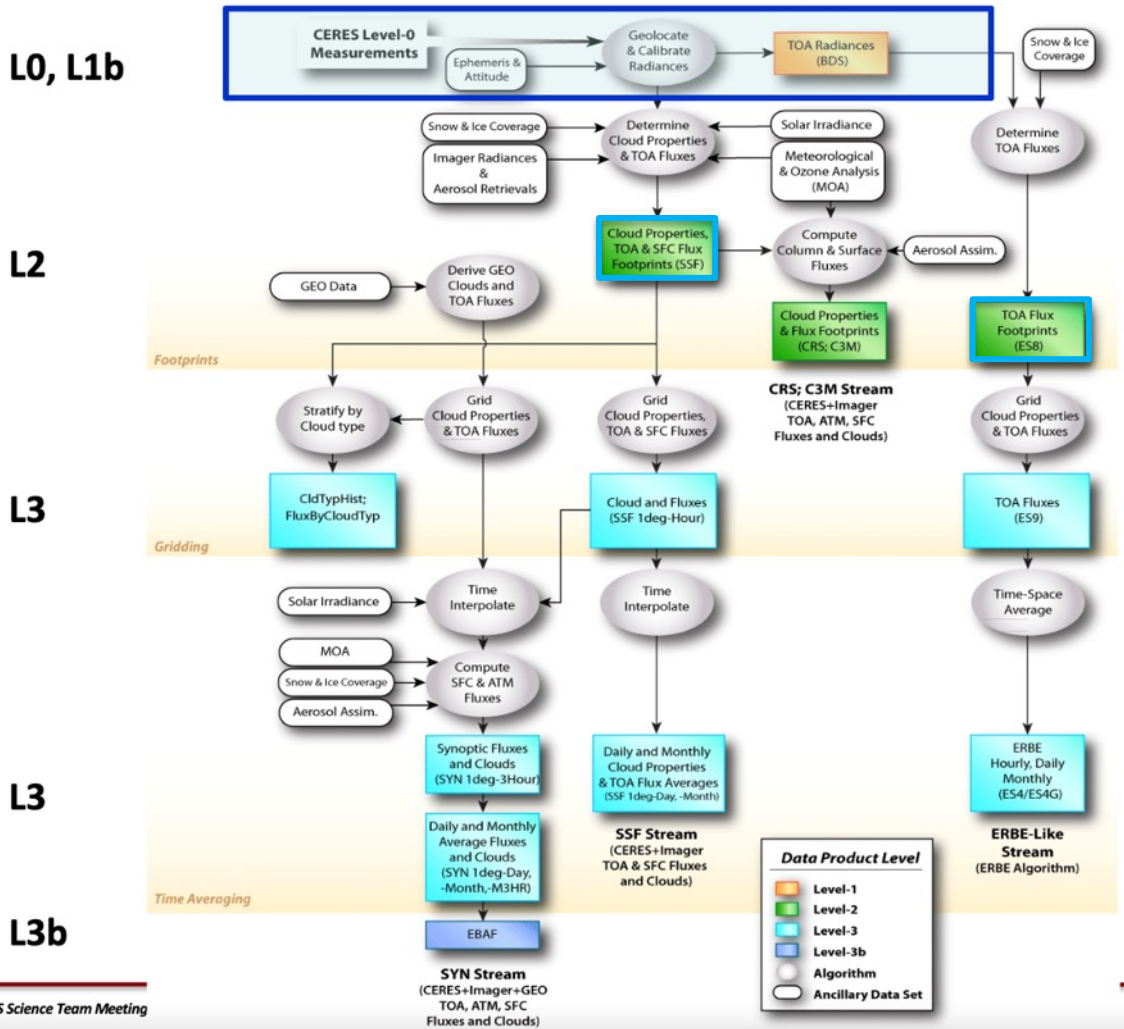


Libera continuity



Libera beyond L-1b

CERES Data Processing Flow



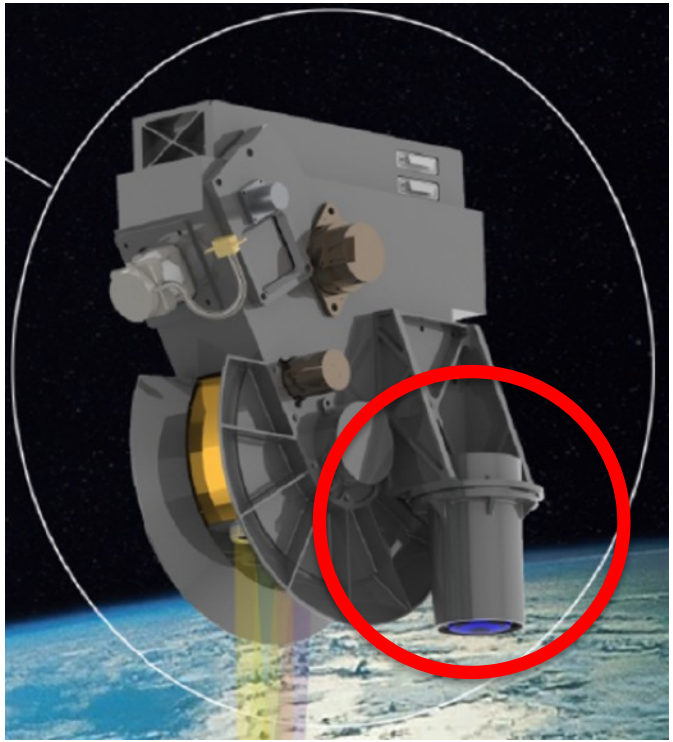
ADMs & camera application

OG2: Development of a self-contained, innovative & affordable observing system

Demonstrate feasibility of separating Libera from complex imagers so to fly on SmallSats

Science objective 2:

- Explore utility of scene identification from a small and cost-effective camera.
- **Develop angular distribution models (ADM) to facilitate shortwave near-IR and visible radiance-to-flux conversion.**



Monochromatic (555 nm) wide field of view (WFOV) camera provides images at ~1 km pixel resolution.

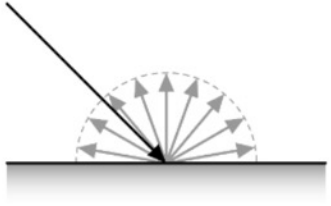
Angular distribution models (ADMs): the basics

- *Libera* will observe ***radiance R*** leaving a scene in a particular direction.

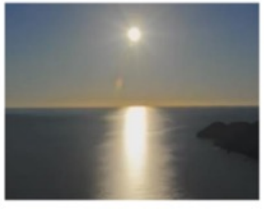
- Of primary scientific interest is radiance leaving the scene integrated over all directions in the hemisphere above the scene (flux or ***irradiance I***).

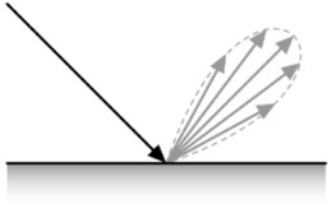
- The most simple case: ***isotropic***.

- In reality, scenes are not perfectly isotropic. ADMs provide an ***anisotropic factor*** α that relates the observed radiance to irradiance.



$$I = \pi R$$



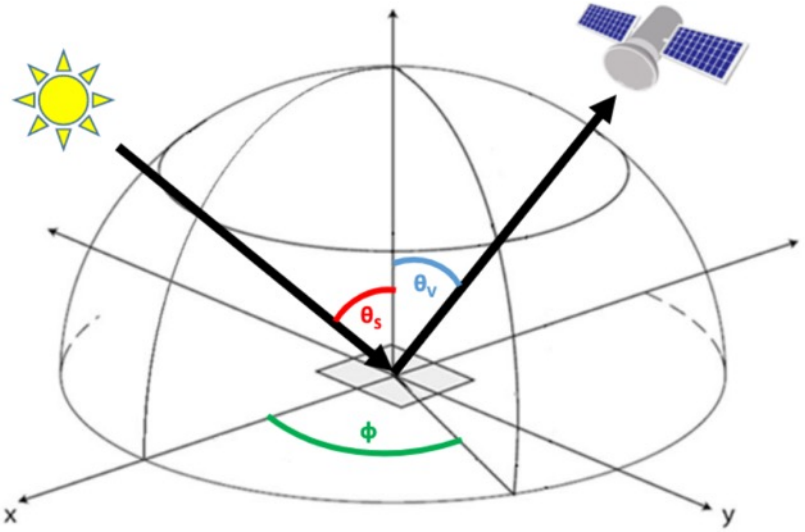


$$I = \frac{\pi R}{\alpha}$$

Solar ADMs: factors to consider

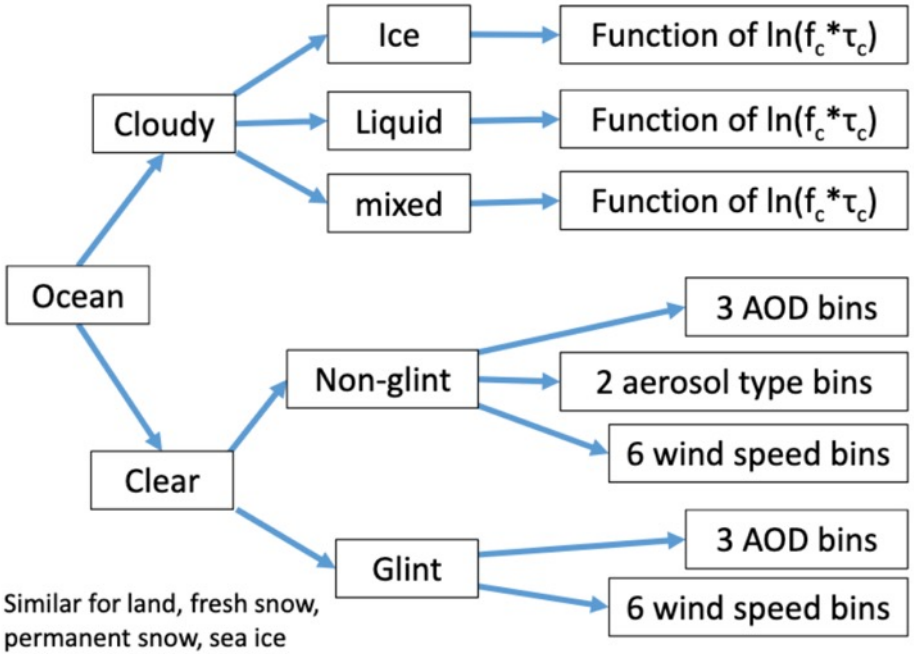
Solar-viewing geometry

- Solar zenith angle (θ_S)
- Viewing zenith angle (θ_V)
- Relative azimuth angle (ϕ)



Scene type

- eg. for ocean: Su et al., AMT, 2015



Similar for land, fresh snow, permanent snow, sea ice

Libera split-shortwave ADM approach

1. OSSE "*prior*" ADMs
   [pre-launch]
   - ERBE-like scenes: Based on RTM inputs
   - CERES-like scenes: Based on RTM inputs

2. Wide-field-of-view camera ADMs
   [shortly after launch]
   - ERBE-like scenes: Camera-derived cloud fraction
   - CERES-like scenes: **???**

   Q: How is scene type for CERES RAPS observations obtained?
   A: "Cookie dough"

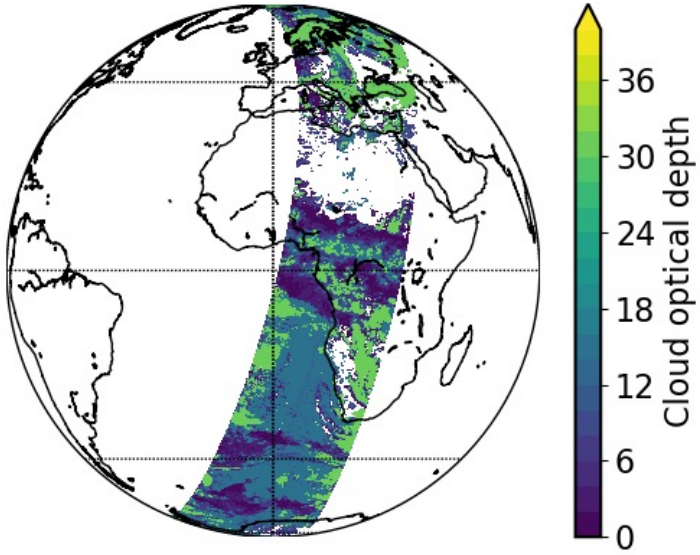
3. Primary split-SW radiometer RAPS ADMs
   [later in mission]
   - ERBE-like scenes: Camera-derived cloud fraction
   - CERES-like scenes: Obtain from RBSP, already produced for total SW processing

First look at CERES cookie dough

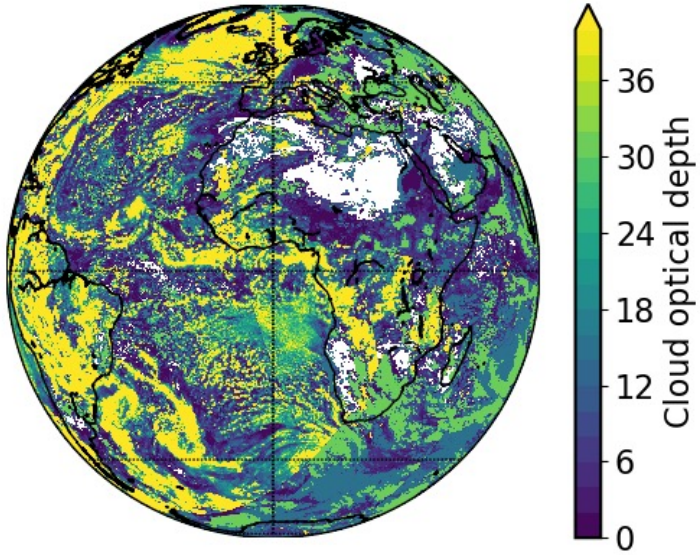
NOAA 20 (JPSS-1) 1st October 2021

"We use every fourth VIIRS imager pixel and every other scan line in processing."

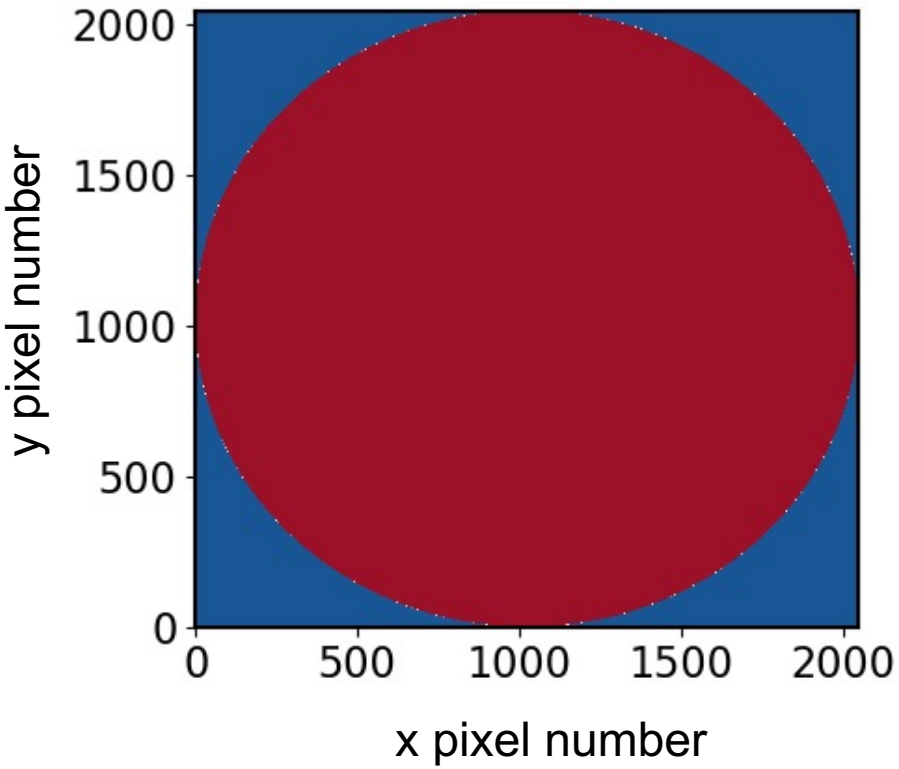
First hour



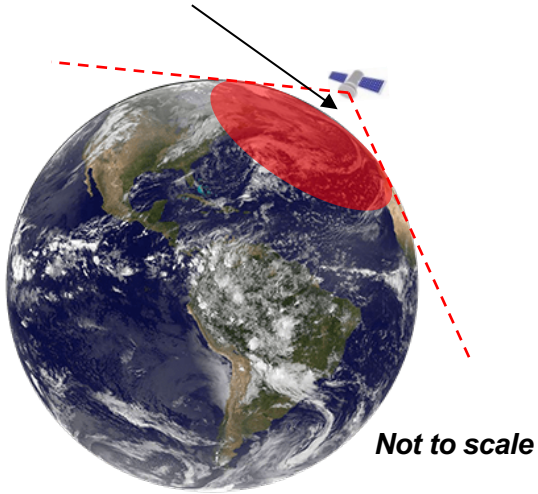
24 hours



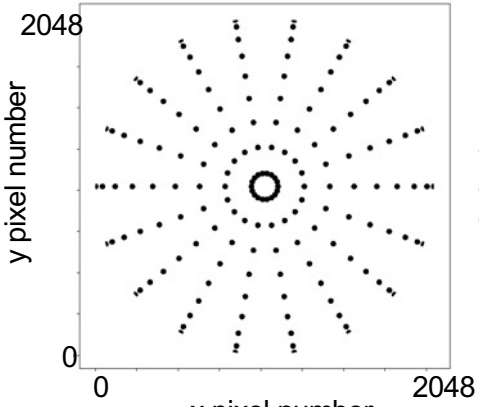
Camera sampling

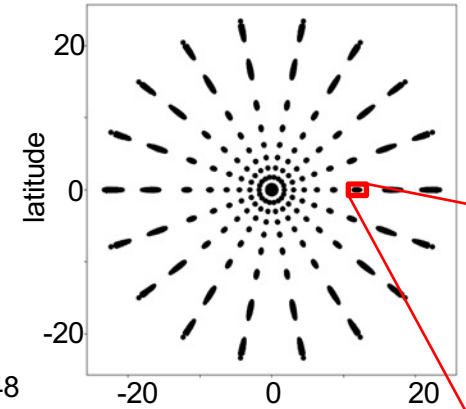


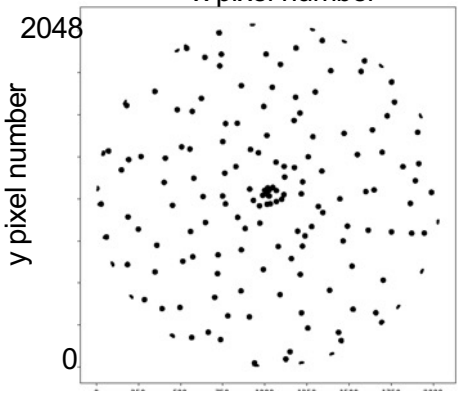
- 2048 × 2048 pixel array samples entire Earth disk
- Single channel: 555 nm
- < 1km resolution @ nadir
- Exposure every 5 secs
- 124° field of view, horizon-to-horizon (~6000 km @ surface)

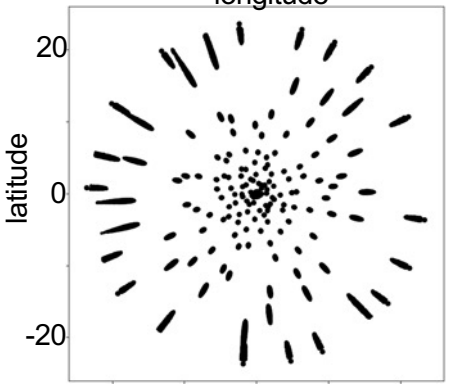


Camera ADM sampling

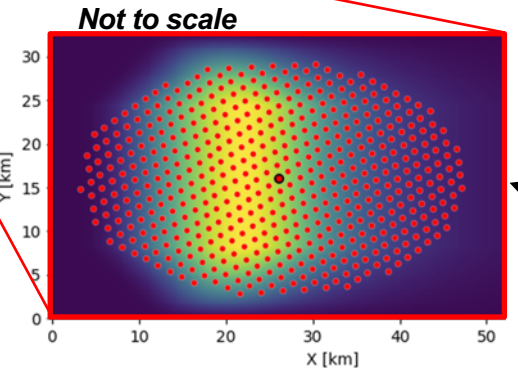






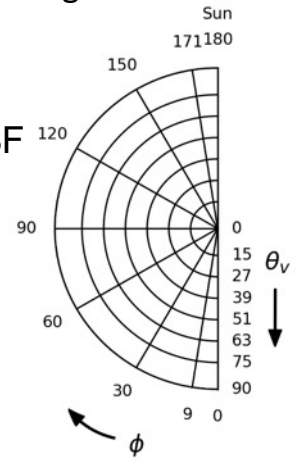


- Data rate limited! Can typically only downlink small fraction of pixel array
- Select “ADM samples”: groups of pixels in each angular bin encompassing Libera PSF



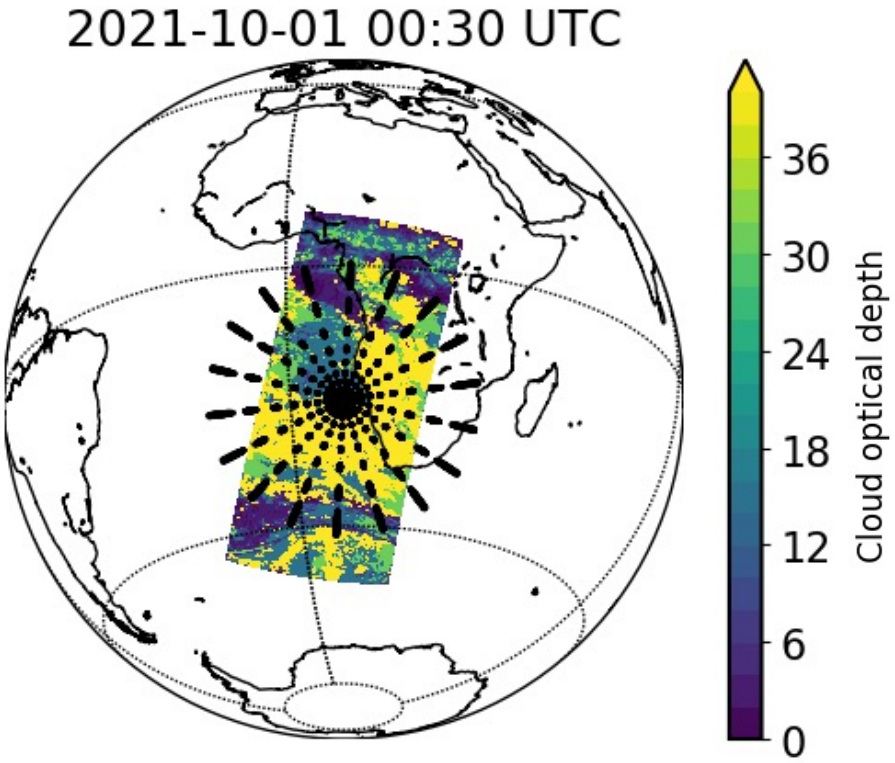
PSF

ERBE angular bins:

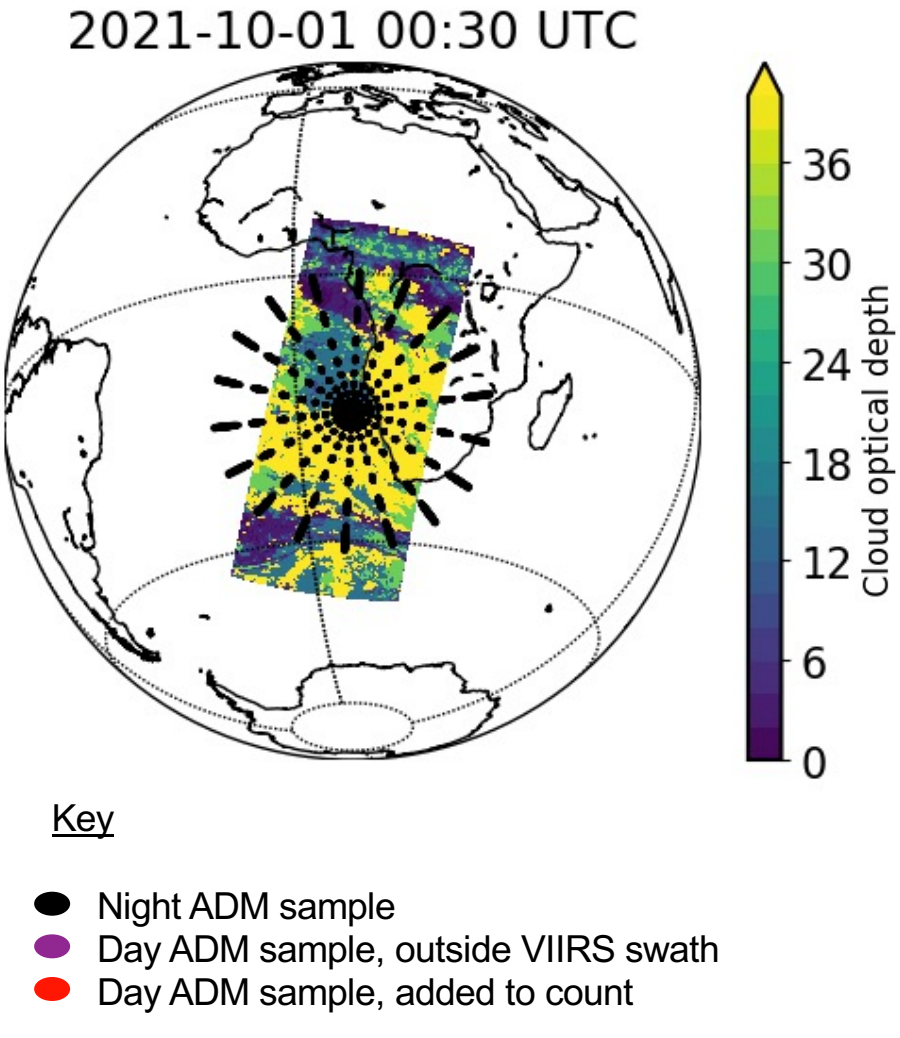


- We do not just want to sample the center of the angular bins: randomization (bottom row)

Camera sampling projected onto cookie dough

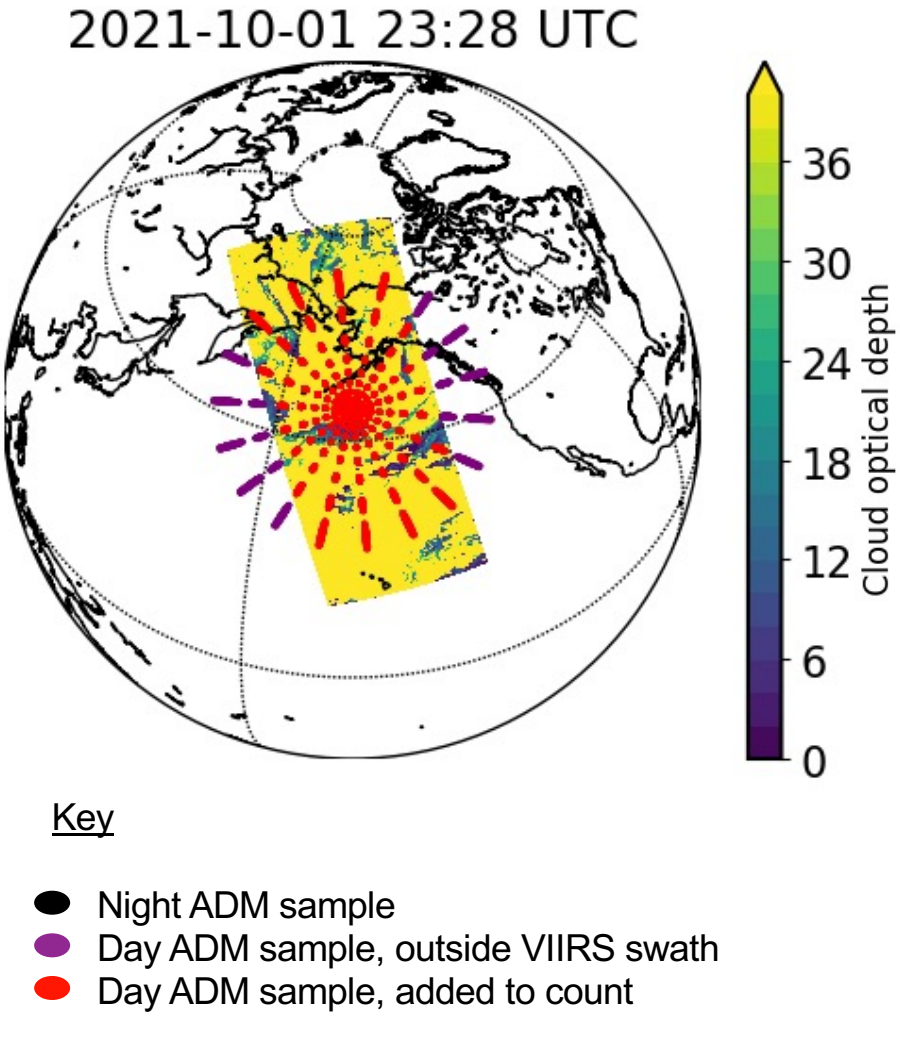


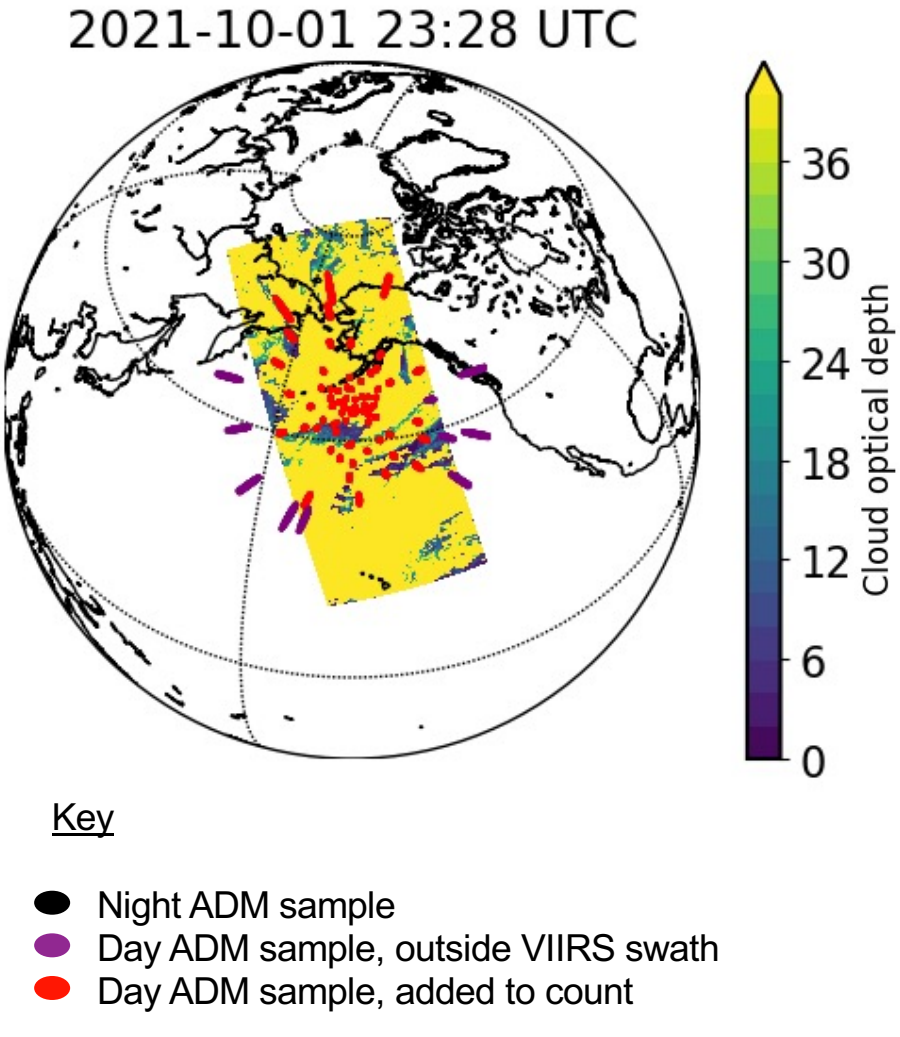
- Select cookie dough +/- 9 min of camera observation time (~15 min for satellite to traverse camera FOV)



Key

- Night ADM sample
- Day ADM sample, outside VIIRS swath
- Day ADM sample, added to count


2021-10-01 23:28 UTC
Cloud optical depth
36
30
24
18
12
6
0
Key
Night ADM sample
Day ADM sample, outside VIIRS swath
Day ADM sample, added to count
Clear sky
Partly cloudy
Mostly cloudy
Overcast
Ocean
Land
Snow
Desert
98.2 %
100.0 %
100.0 %
100.0 %
100.0 %
100.0 %
100.0 %
100.0 %
96.4 %
98.2 %
96.4 %
98.2 %
98.2 %
98.2 %
100.0 %
100.0 %
Counts
10^3
10^2
10^1
10^0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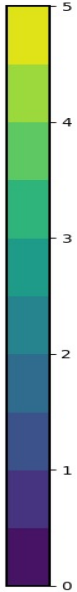
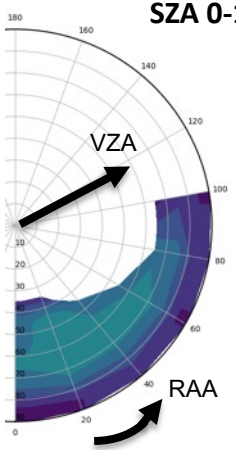
Ocean
Land
Snow
Desert
100.0 %
Counts
10^3
10^2
10^1
10^0

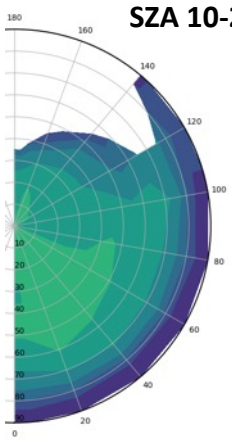
‘Traditional’ RAPS sampling over 1 year (2020) of FM5 SSF data

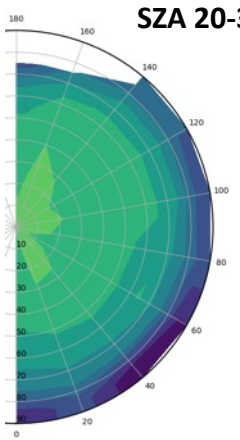
Mathew Van Den Heever (LASP, CU Boulder)

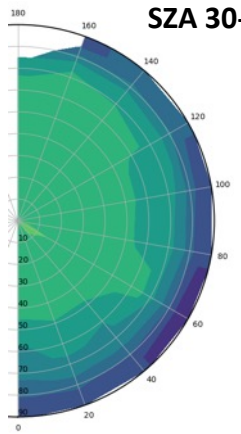
Ocean, Clear Sky, First Day of Month – 1 year sampling using



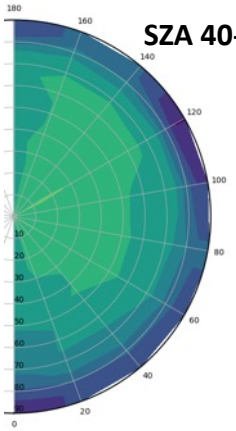


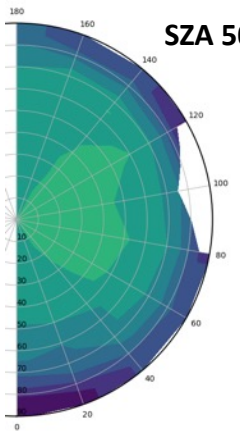


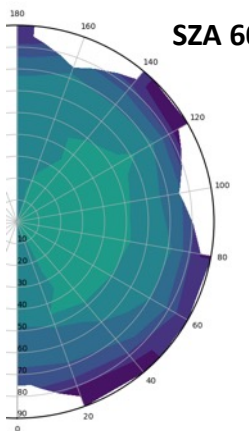


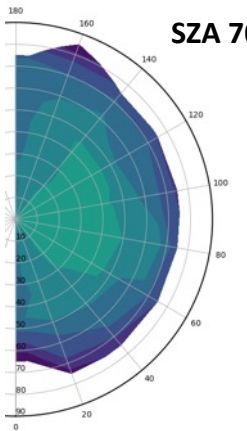


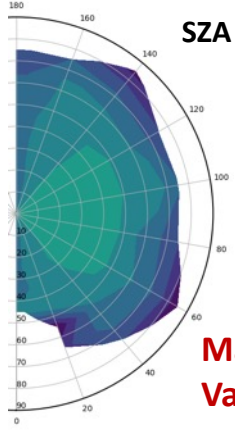
SZA	1 count [%]	8 counts [%]
0 - 10 degrees	30	18.89
10 – 20 degrees	87.78	83.33
20 – 30 degrees	97.78	94.44
30 – 40 degrees	98.89	97.78
40 – 50 degrees	100	98.89
50 – 60 degrees	98.89	95.56
60 – 70 degrees	96.67	90
70 – 80 degrees	88.89	84.44
80 – 90 degrees	96.67	82.22
Total	87.28	82.84











Mathew
Van Den Heever

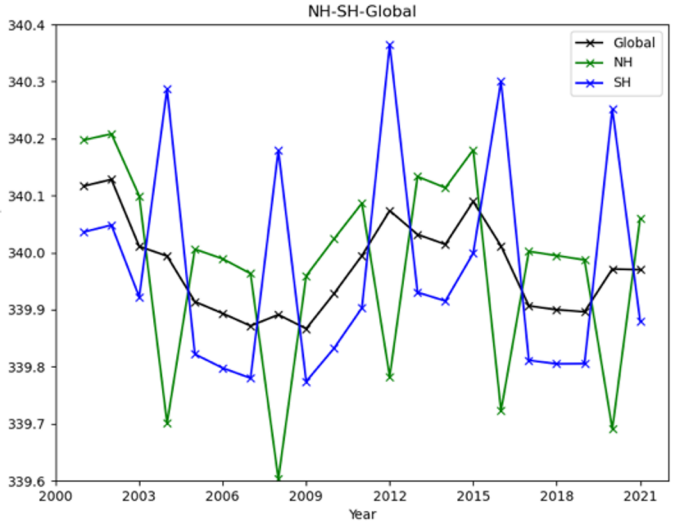
ADM sampling preliminary conclusions

- Camera ADM sampling projected onto one day of “cookie dough” containing retrieved scene properties from VIIRS (produced by CERES team)
- Each camera “ADM sample” assigned a ERBE-like scene type by mapping to VIIRS/cookie dough data
- ERBE scenes and angular bins are well sampled in < 1 day.
  - ***First quantification of the “dense angular sampling”!***
- Provides skeleton for operational code
- Key outstanding issues:
  - Only implemented for ERBE-like scene types, ultimately will be used with CERES-like scene types
  - Simple averaging over pixels, need to implement PSF weighting
  - Variability on different days/seasons
  - Explore SZA bin dimension

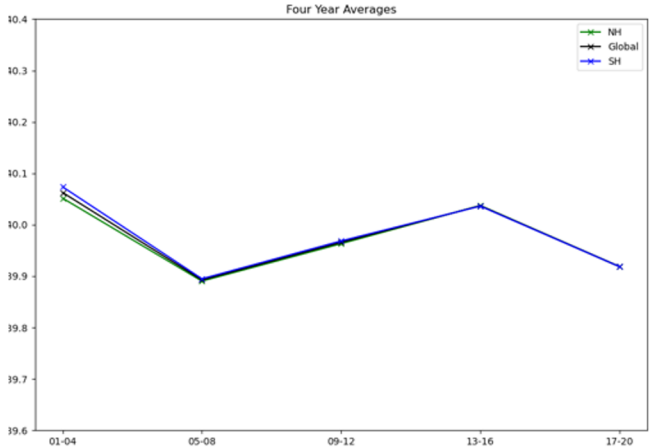
Hemispheric symmetries - Annual averaging

Matt Watwood (LASP, CU Boulder)

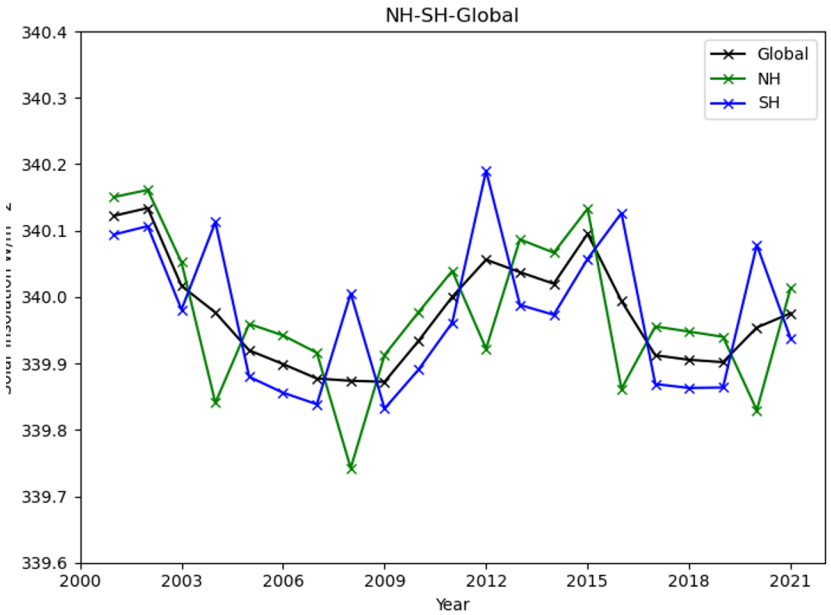
- Literature commonly cites a hemispheric difference of around 0.68 Wm^{-2} in incoming solar radiation
- This is not a physical:
  - This difference is reduced to 0.02 Wm^{-2} if yearly averages are calculated using monthly weights based on the # of days in a month (e.g., Datseris & Stevens, 2021)
- Kepler's Laws define that each hemisphere should receive the same amount of energy over a year
  - The SH has a 'warmer' summer and a 'colder' winter + NH has a longer summer



- When averaged by days of the month there is still poor agreement year to year from the **leap years**
- This amounts to 0.1-0.25% error (left)
- Averaging over 4-years (right) demonstrates that this is a numerical artifact stemming from the leap year

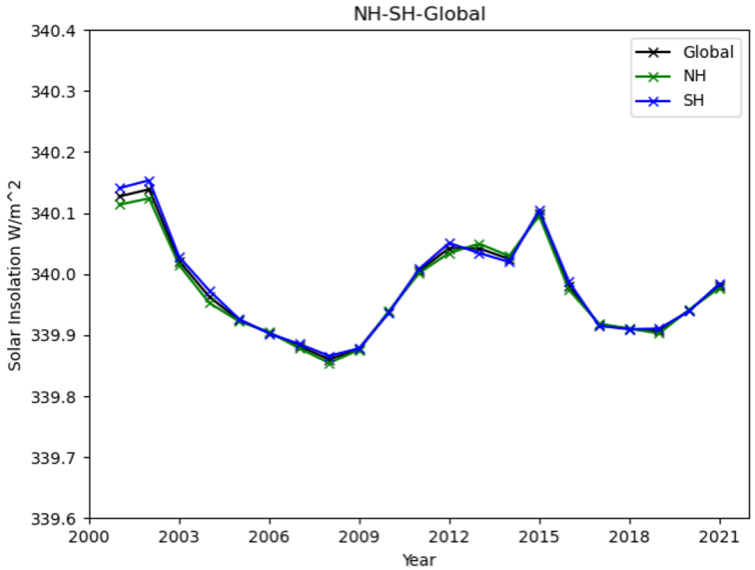


Fix #1
We weight February with 28.25 Days in Each Year



- The error persists but is now approximately halved.
- It may not be worth correcting more?

Fix #2
February can be Weighted to Minimize this Error



- Leap Year – February 27.45 Days
- Non Leap Year – 28.45 Days

- Can these be derived physically?

Hemispheric symmetries - Annual averaging: Thoughts and Questions

- Simplest answer is likely to calculate from daily data, but not all data products are available on that scale
  - A correction algorithm is needed when using monthly temporal resolution
- Has this issue been dealt with before? Feedback welcome!
  - **Matt.Watwood@lasp.colorado.edu**
- What other numerical considerations are important on these small numerical scales?

Summary

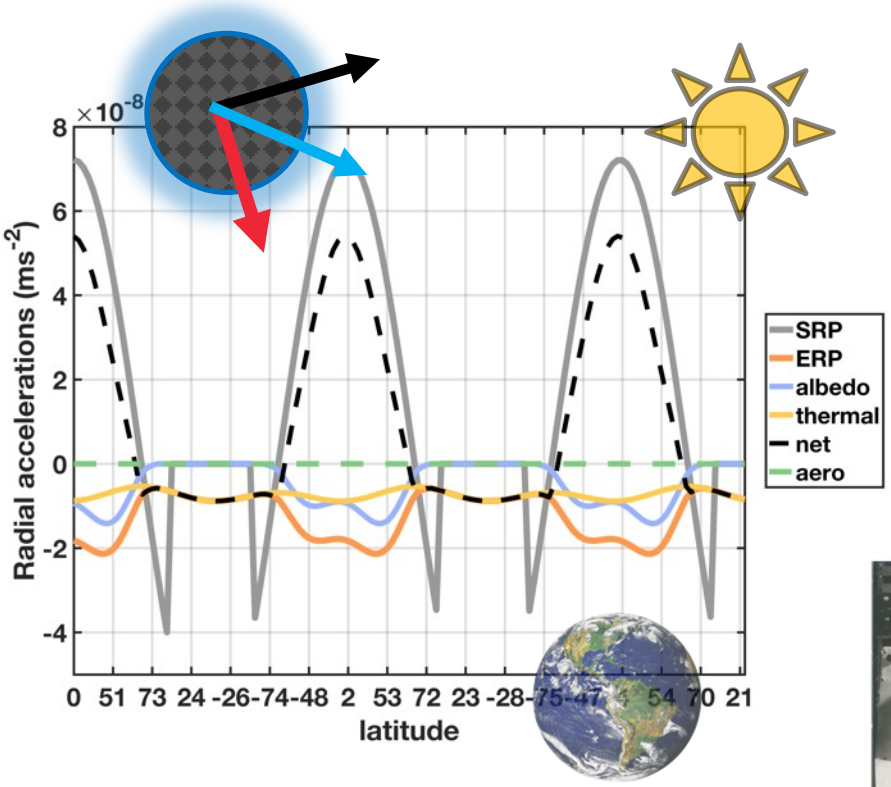
- Libera science overview
  - **Continuity is priority**, but Libera thinks of the future with innovation and “imager-separation” experiment!
  - ATBDs in good progress

- ADM sampling for split-SW channel **(Jake Gristey and Mathew Van den Heever)**
  - With the WFOV camera, ERBE scenes and angular bins are well sampled in < 1 day.
    - **First quantification of the “dense angular sampling”!**
    - Traditional RAPS 1-3 times a month per year is much slower and incomplete

- Hemispheric symmetries **(Matt Watwood)**
  - Small values require very accurate weighted arithmetic.
  - Solar irradiance is symmetric when weighted correctly
  - Leap years yield artifacts in annual mean solar irradiance.

Space Balls Update

Earth's Energy Imbalance via radiation pressure accelerations



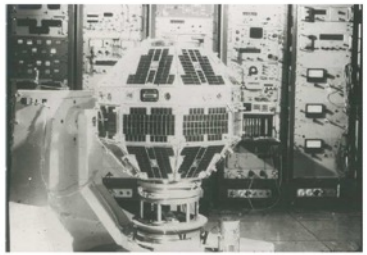
Is a high-accuracy measurement of Earth's Energy Imbalance (EEI) feasible via radiation pressure accelerations experienced in orbit?

Objectives:

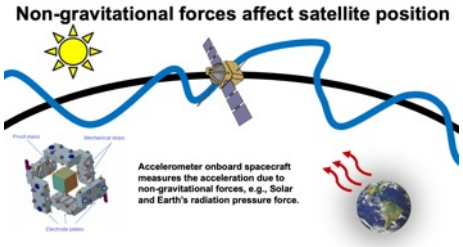
1. Build SB simulation environment using mission design software Monte
2. Enhance fidelity of force and shape models
3. Study measurement errors due to S/C and orbit characteristics, and confounding forces
4. Explore different sampling strategies

Theoretical Comparison Between Radiometric and Radiation Pressure Measurements for Determination of the Earth's Radiation Budget

T.H. Vonder Haar and E.A. Smith



CASTOR D5B Satellite



Potential European climatological satellite missions: SEOCS and BIRAMIS

G. DUCHOSSOIS

Department of Application Programmes, Directorate of Planning and Future Programmes, Eu Space Agency, 8 rue Mario Nikis, 75738, Paris Cedex 15, France

(*Received* 19 *December* 1979)