Glory

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Observability Meeting

NRL Monterey, CA

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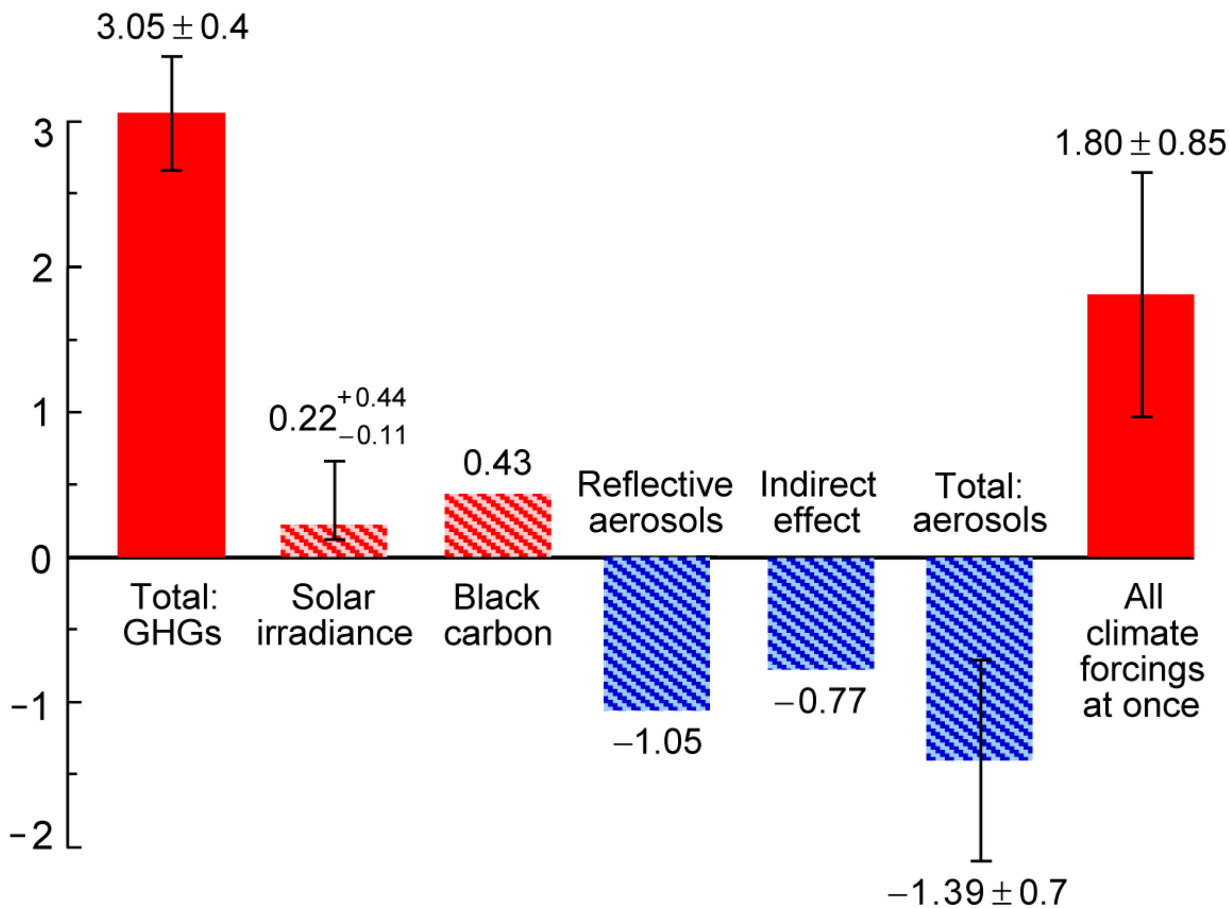
The uncertainties in our understanding of TSI and aerosol climate forcings are unacceptably large

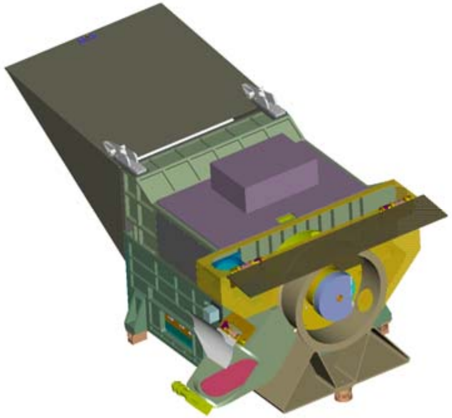


Effective climate forcings (W/m^2) (1880–2003)

Hansen *et al*., *Science* **308**, 1431–1435 (2005)

Glory mission provides timely key data for climate change research

The Glory Mission Objectives are to:



- ✓ *Quantify the role of aerosols as natural and anthropogenic agents of climate change by flying APS*

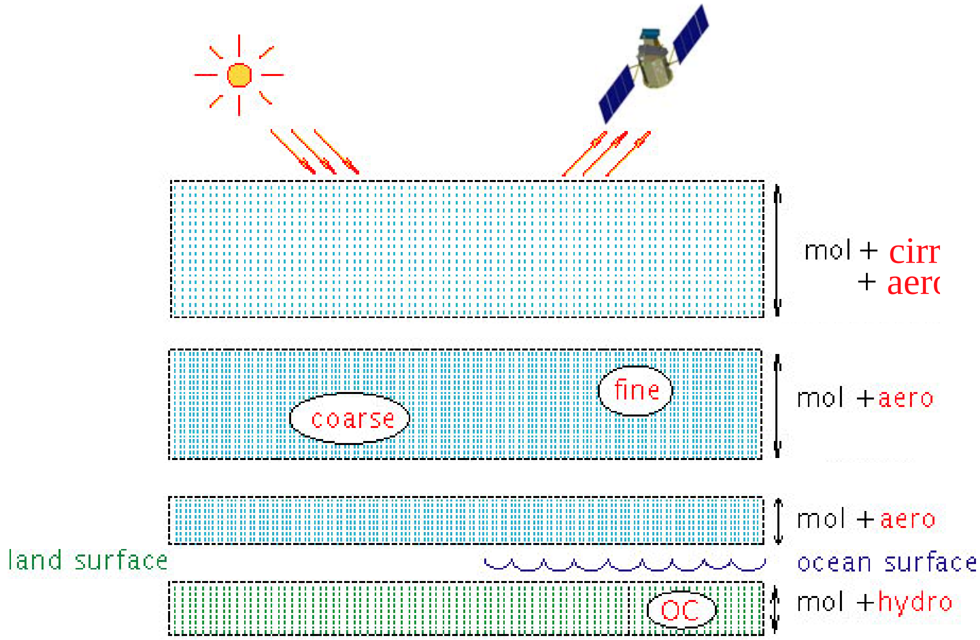
- ✓ *Continue measuring the total solar irradiance to determine its direct and indirect effects on climate by flying TIM*

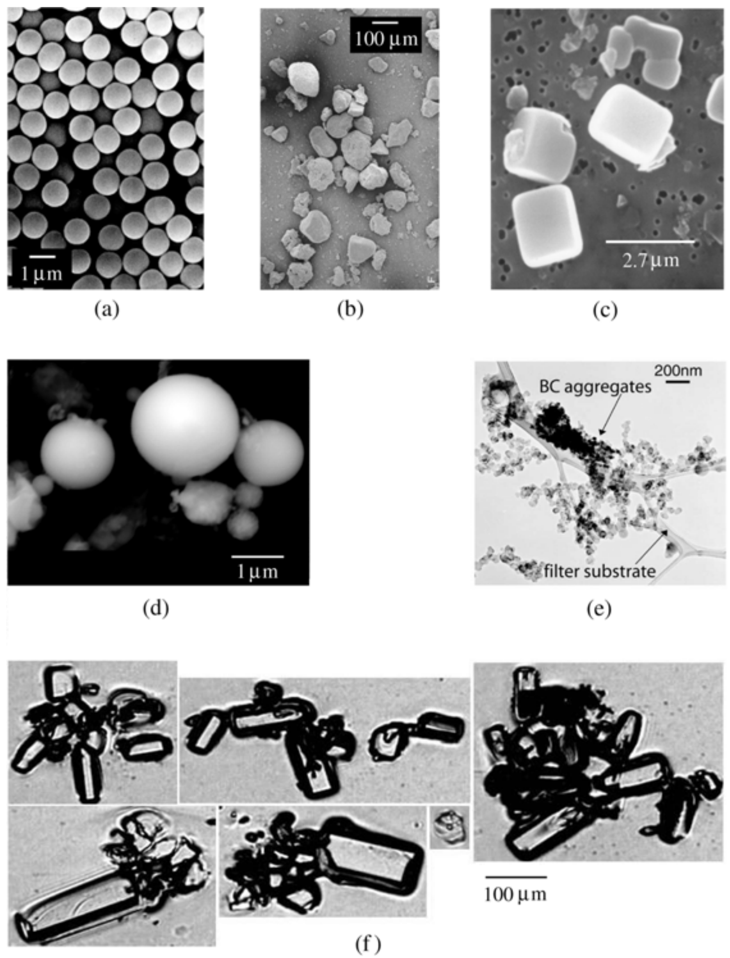
The main function of a satellite aerosol climatology

Provide an accurate, reliable, and comprehensive constraint on models in terms of long-term global distributions of aerosol:

1. Optical thickness
2. Size distribution
3. Chemical composition (via refractive index)
4. Single-scattering albedo

Aerosol remote sensing from space is an exceedingly complex problem





(a) (b) (c)
(d) (e)
(f)

APS science requirements

The APS science measurement requirements are driven by the need to be able to estimate and diagnose the radiative forcing caused by aerosols.

Science objectives

1. Global distribution of aerosol properties
2. Aerosol effect on radiation budget
3. Effect of aerosols on clouds and precipitation

Retrieval requirements

Aerosol retrievals

- Spectral optical thickness (±0.02)
- Effective radius (±10%)
- Effective variance (±50%)
- Spectral behavior of the aerosol refractive index (±0.02)
- Particle shape
- Single-scattering albedo (±0.03)

For two modes

Cloud retrievals

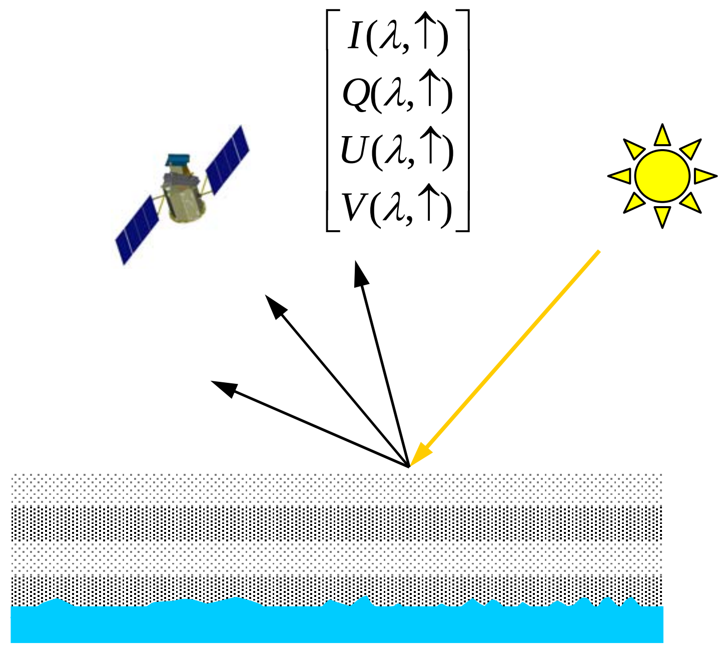
- Optical thickness (±8%)
- Effective radius (±10%)
- Effective variance (±50%)
- Cloud phase/particle shape

Polarization Will Provide More Information About Aerosols

Glory APS strategy: exploit the polarization information content of reflected sunlight

Classification of passive remote sensing techniques by

1. Spectral range
2. Scattering geometry range
3. Number of Stokes parameters



Hierarchy of existing/planned instruments:

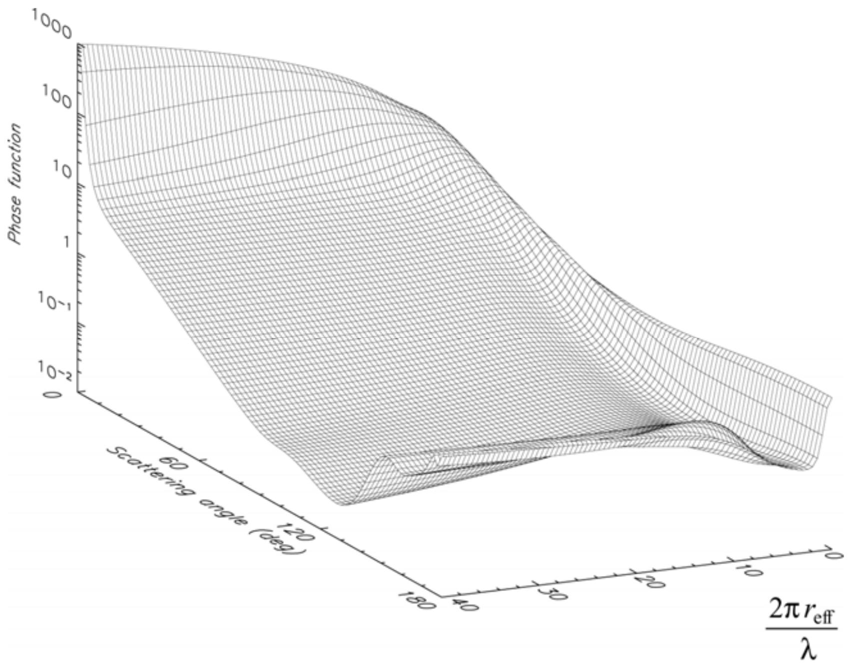
AVHRR ⇒ MODIS, MISR, VIIRS ⇒ Glory APS

Glory APS will be a bridge to NPOESS era measurements.

The measurement approach developed for the Glory mission is to use multi-angle multi-spectral polarimetric measurements because:

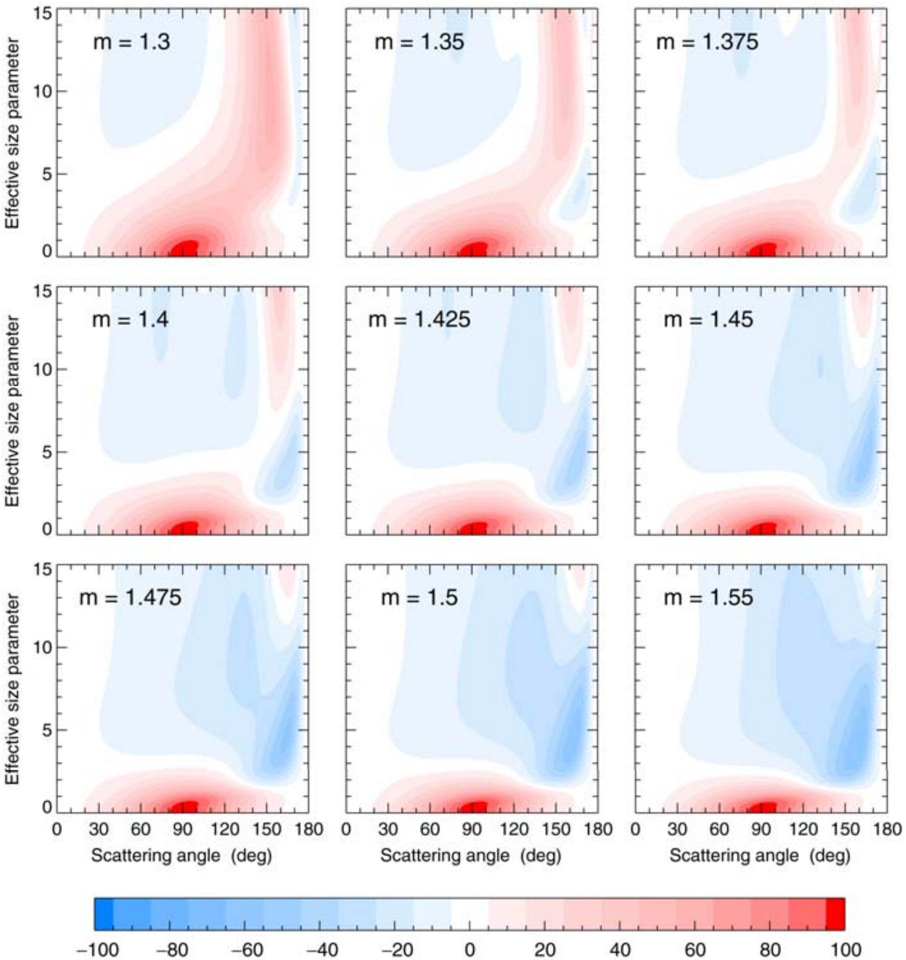
- Polarization is a relative measurement that can be made extremely accurately.
- Polarimetric measurements can be accurately and stably calibrated on orbit.
- The variation of polarization with scattering angle and wavelength allows aerosol particle size, refractive index and shape to be determined.

Polarization is very sensitive to aerosol particle size and refractive index



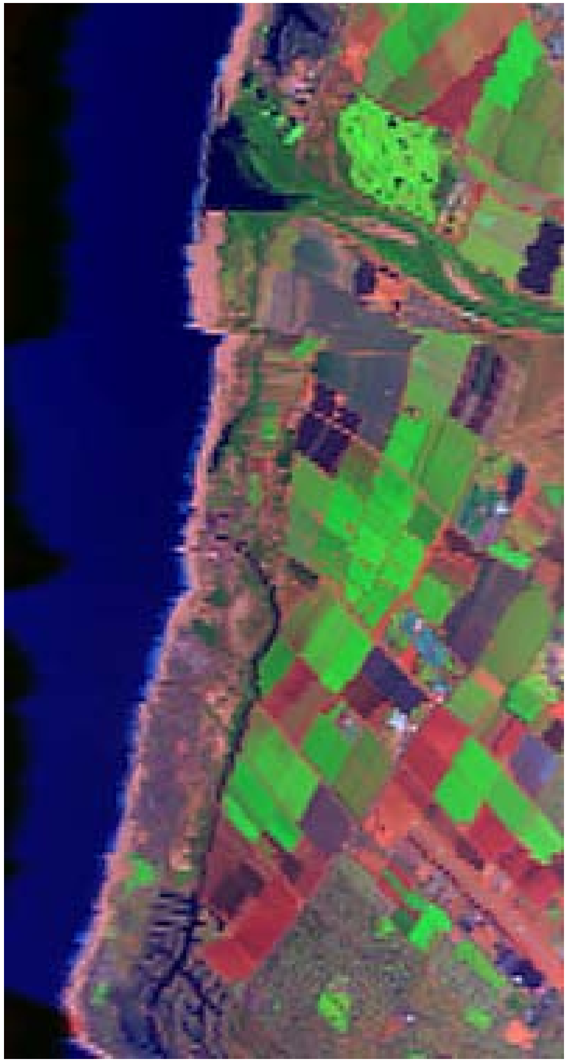
Scattered intensity (above) weakly depends on particle size and refractive index (not shown), whereas scattered polarization (right) can change not only in magnitude but even in sign with minute changes in radius or refractive index. The contour plots on the right demonstrate why multi-angle multi-wavelength measurements of polarization are so sensitive to aerosol microphysics and chemical composition.

–Q/I



effective size parameter = 2 π *(effective radius)/wavelength

Reduced Sensitivity to Surface Albedo Variability



Polarization observations are less affected by the surface and are more sensitive to aerosols than intensity measurements.

Glory APS Specifications

Type: Passive multi-angle photopolarimeter

Fore-optic: Rotating polarization-compensated mirror assembly scanning along orbit-track +50.5° to –63° (fore-to-aft) from nadir

Aft-optic: 6 bore-sighted optical assemblies, each with a Wollaston prism providing polarization separation, beamsplitters & bandpass filters producing spectral separation, and paired detectors sensing orthogonal polarizations

Directionality: ~250 views of a scene

Approx. dimensions: 60 x 58 x 47 cm

Mass/power/data rate: 53 kg / 36 W / 120 kbps

Spectral range: 412–2250 nm

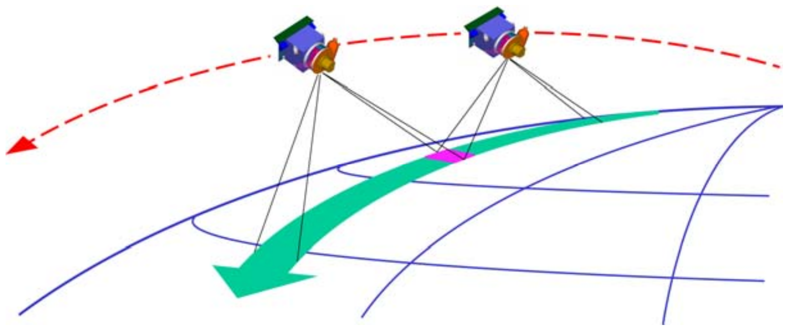
Measurement specifics: 3 visible (412, 443, 555 nm), 3 near-IR (672, 865, 910 nm), and 3 short-wave IR (1378, 1610, 2250 nm) bands; three Stokes parameters (*I*, *Q*, and *U*)

Ground resolution at nadir: 6 km

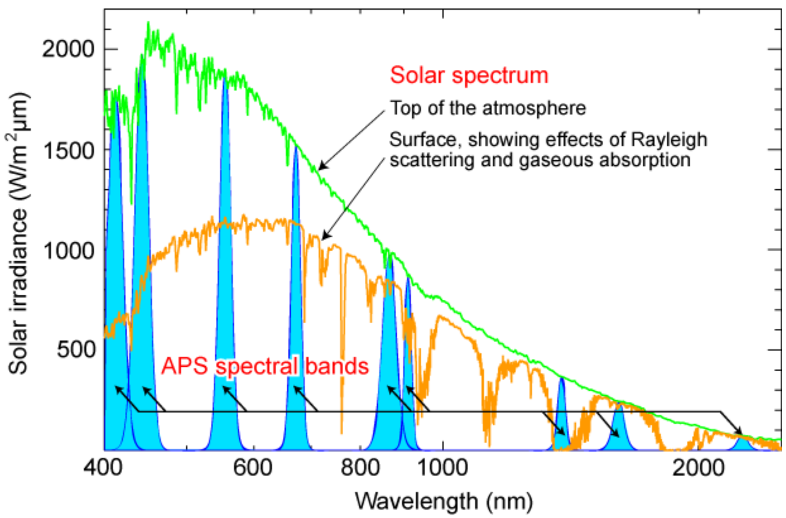
SNR requirements: 235 (channels 1 – 5, 8, and 9), 94 (channel 6), and 141 (channel 7)

Polarization accuracy: 0.0015 at *P* = 0.2, 0.002 at *P* = 0.5

Repeat cycle: 16 days



APS angular scanning



APS spectral channels

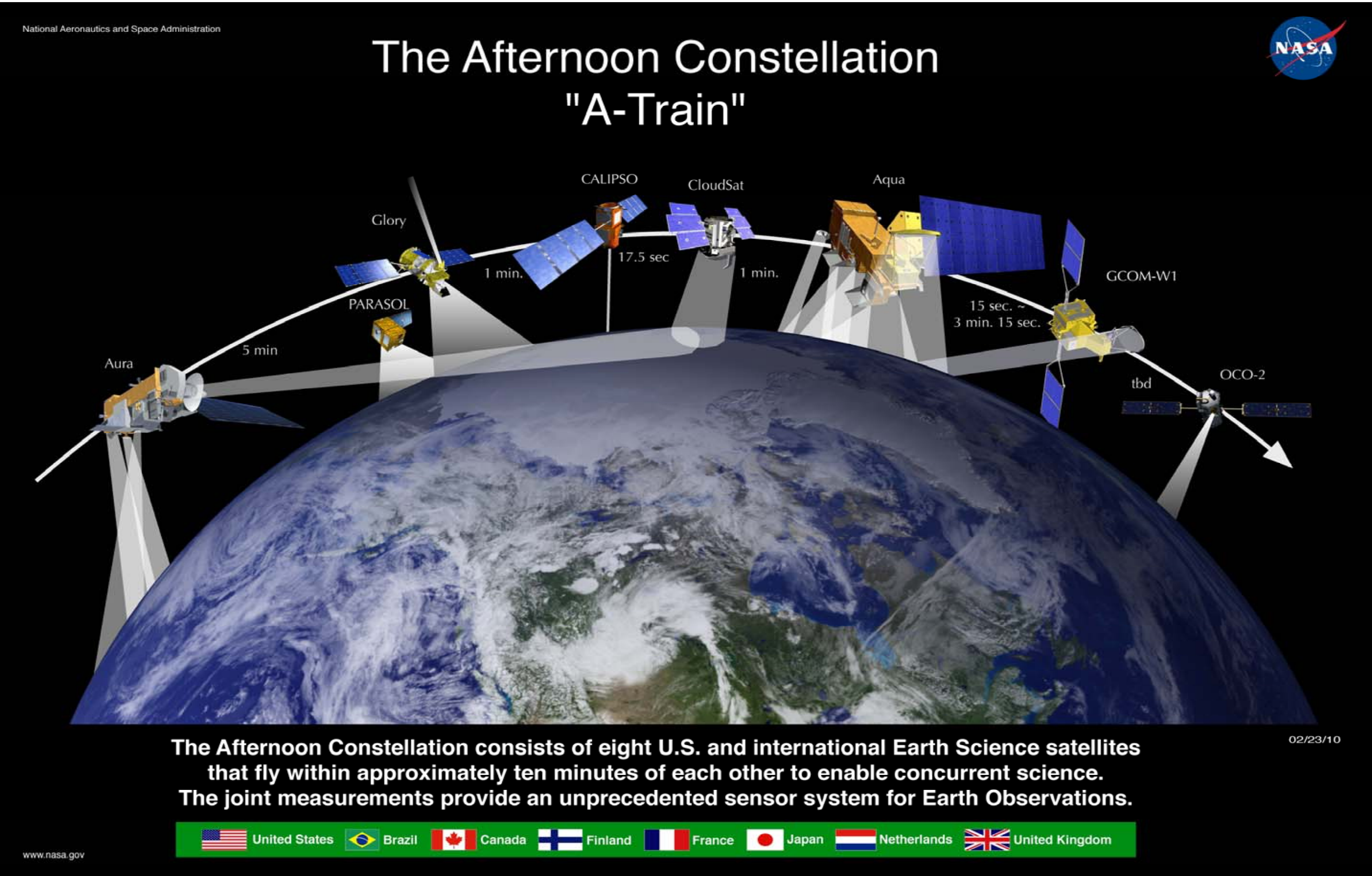
Glory APS Data Products

- aerosol optical thickness (uncertainty of ≤ 0.04 or ≤ 15%)
- effective radius (uncertainty of ≤ 0.15 μm or ≤ 15%)
- effective variance of the size distribution (uncertainty for spherical aerosols of ≤ 0.35 or ≤ 60%)
- refractive index (uncertainty for spherical aerosols of ≤ 0.03)
- single-scattering albedo (uncertainty of ≤ 0.04)
- column number density (uncertainty for spherical aerosols of ≤ 40%)
- shape (placement in one of several qualitative shape categories) for two modes of the aerosol population
- spectral behavior of the aerosol refractive index and single-scattering albedo
- cloud optical thickness (uncertainty of ≤ 0.2 or ≤ 10%)
- cloud particle effective radius (uncertainty for liquid-water clouds of ≤ 2 μm or ≤ 15%)
- effective variance (uncertainty for liquid-water clouds of ≤ 0.07 or ≤ 50%, whichever is greater)
- cloud phase (liquid water or solid ice)
- cloud particle shape (placement in one of several qualitative shape categories)
- column number density (uncertainty for liquid-water clouds of ≤ 40%
- Level 2 data latency will be 1-3 days

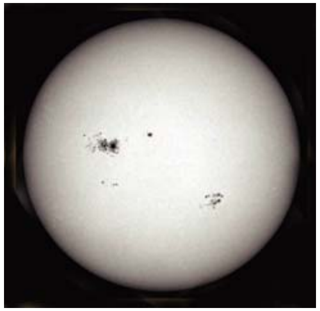
Glory APS challenges

- Coverage: APS is not an imager like MODIS or MISR
  1. Validation
  2. Assimilation
- APS has a relatively large pixel (~6 km at nadir)
  1. Cloud contamination is an issue
  2. Simultaneous retrieval of aerosols and clouds within the APS footprint?
- APS microphysical retrievals may be difficult to validate because of their accuracy

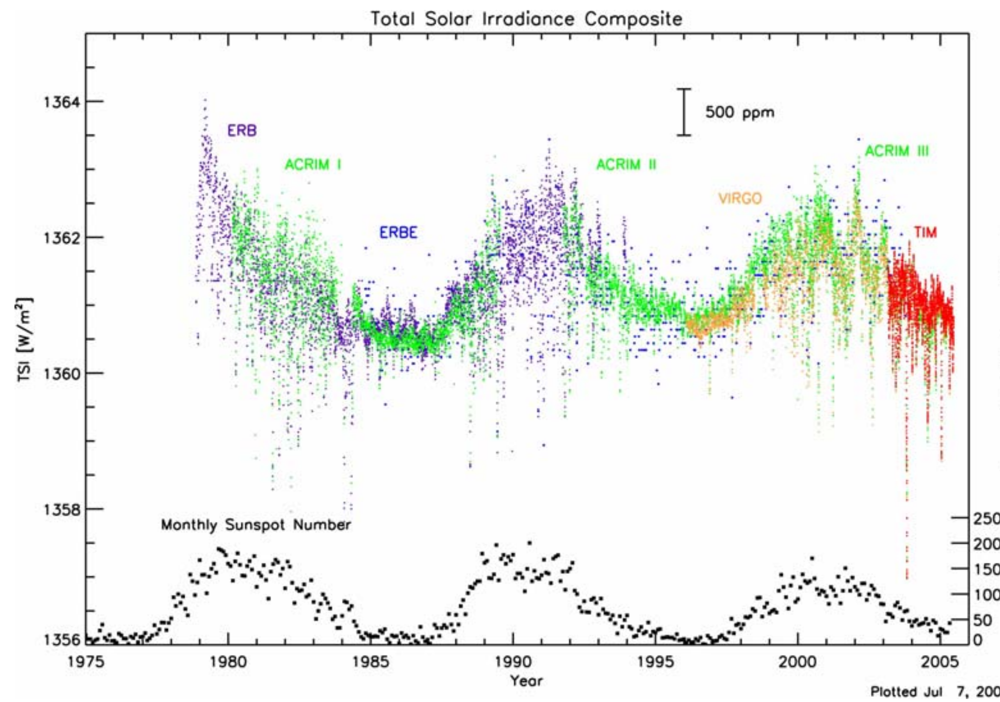
Glory in A-Train



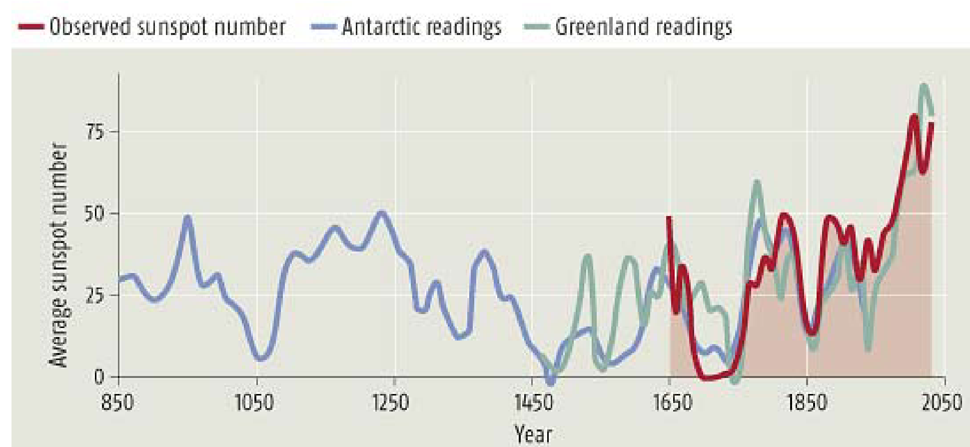
Basis of TSI proxies is recent measurements



The sunspot record is the longest (~ 400 years) observation related to climate.

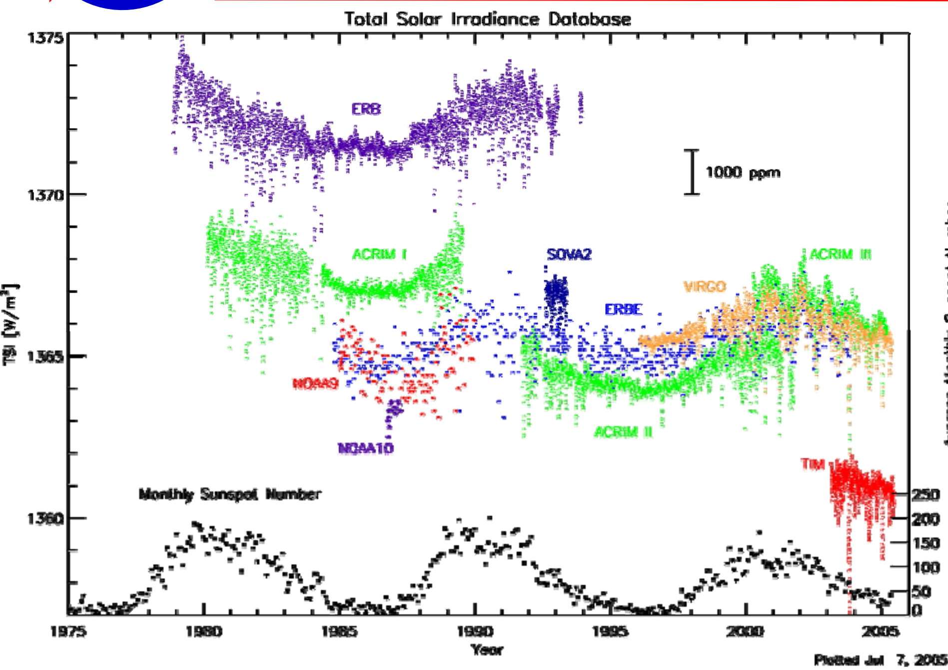


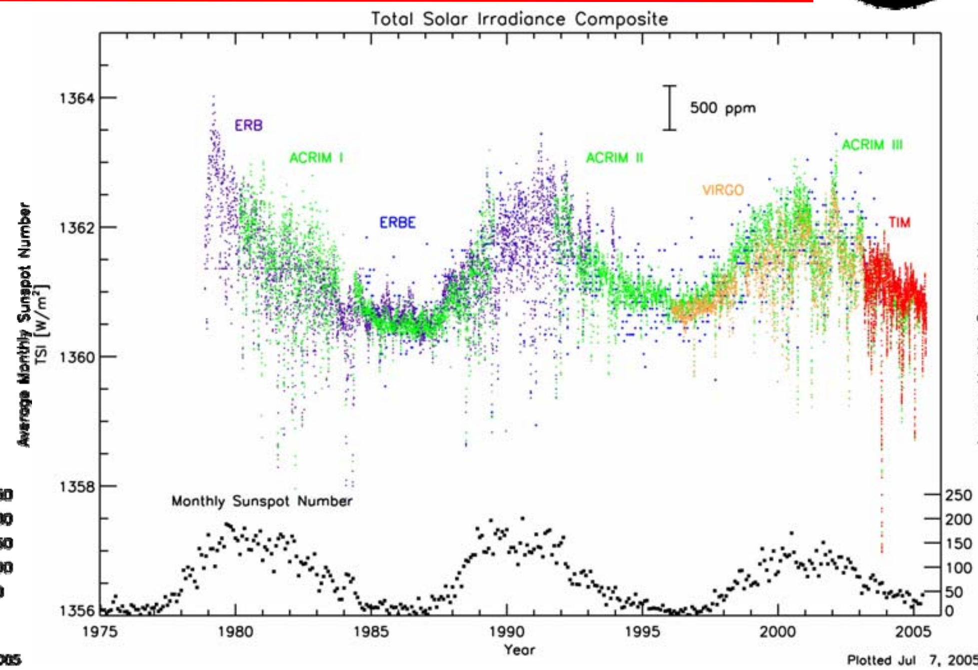
- Sunspot and cosmogenic isotope records give long-term TSI proxies to compare with climate.
- TSI proxies are extrapolations based on recent space-based observations.
  - TSI is compared to sunspot record for last 27 years.
  - Sunspot record is compared to cosmogenic isotopes for last 400 yrs.



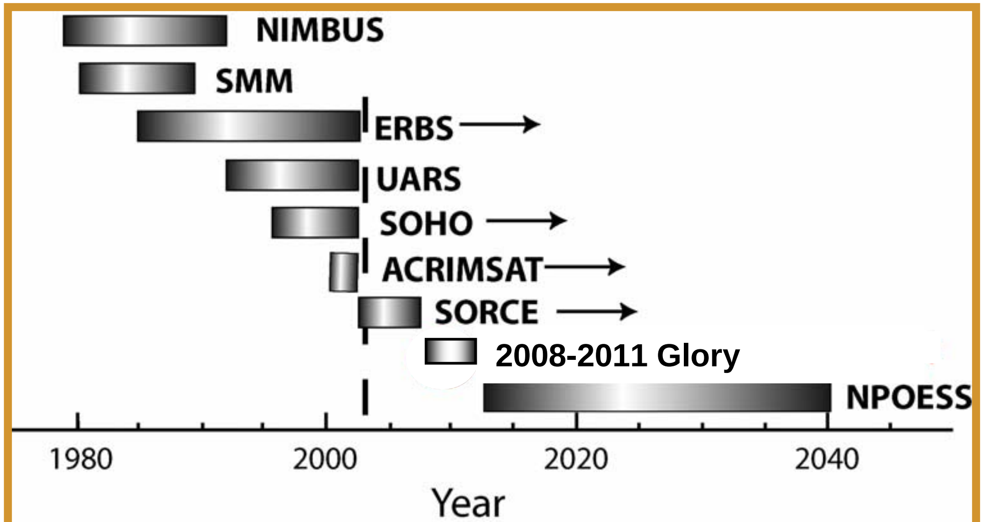
Back Up

Space-borne TSI record relies on continuity





TSI measurements need to be accurate and well-connected to the existing 27-year record.



Glory TIM summary

Instrument type: absolute radiometer

Primary detector type: electrical substitution radiometer

Wavelength range: total

Resolution: N/A

Accuracy: 100 PPM

Precision: 10 PPM/year

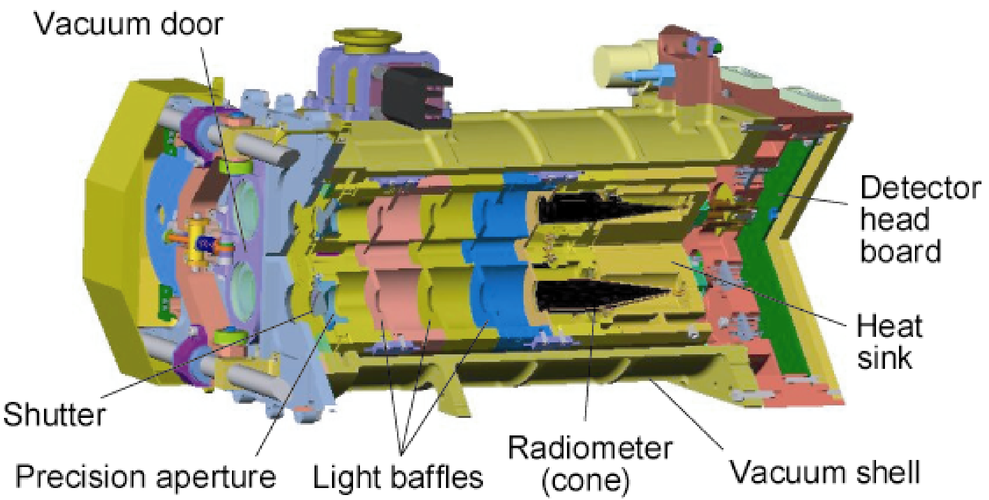
Dimensions (H × W × D): 17.7 × 27.9 × 27.2 cm

Mass: 7.9 kg

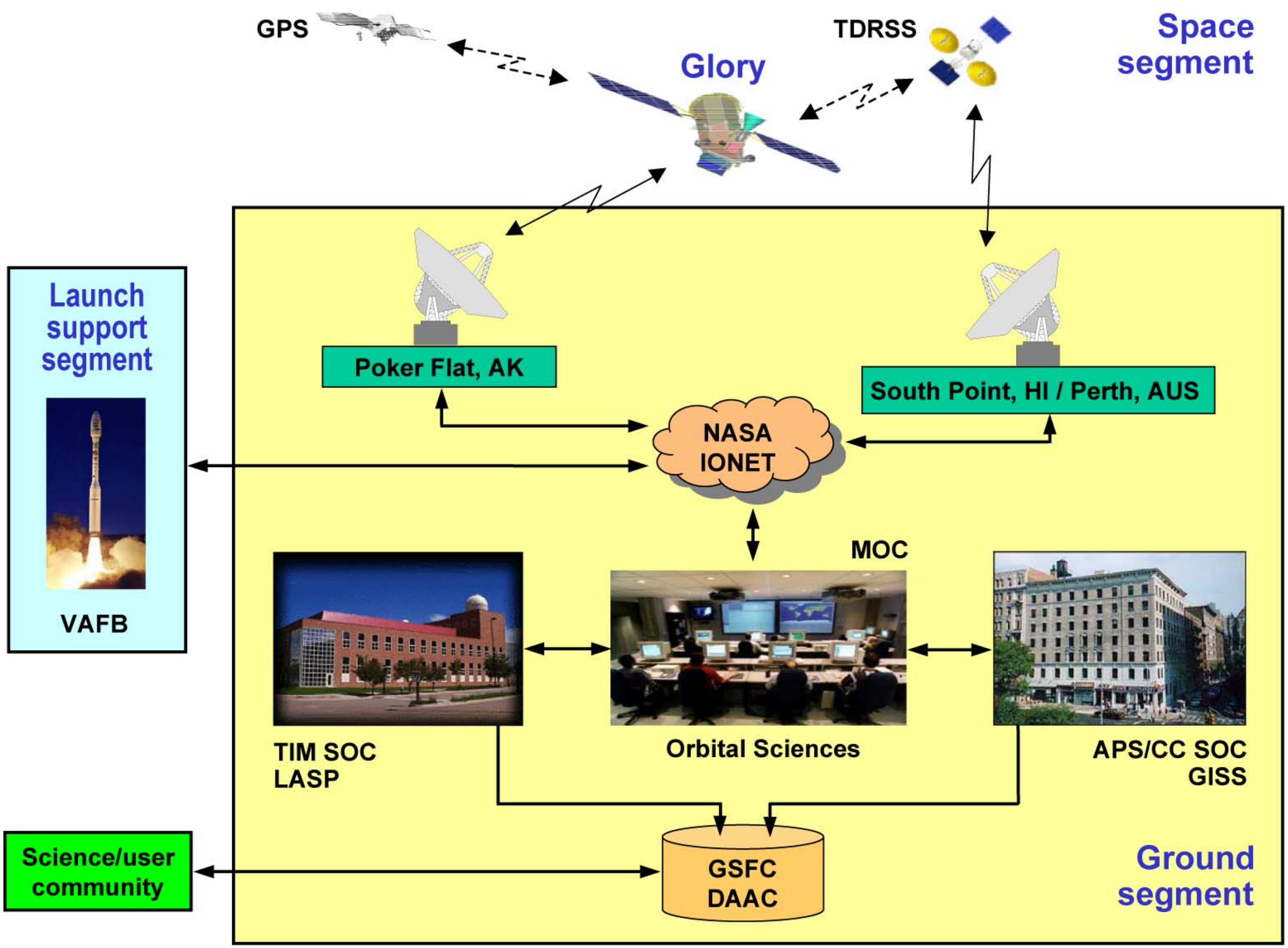
Power: 14 watts

Nominal data rate: 539 bps

Field-of-view: 12.8° (full cone angle)



Glory mission overview



Glory Data Product Flow