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

Effective climate forcings (W/m²) (1880–2003)

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.
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 ($\pm 0.02$)
- Effective radius ($\pm 10\%$)
- Effective variance ($\pm 50\%$)
- Spectral behavior of the aerosol refractive index ($\pm 0.02$)
- Particle shape
- Single-scattering albedo ($\pm 0.03$)

Cloud retrievals
- Optical thickness ($\pm 8\%$)
- Effective radius ($\pm 10\%$)
- Effective variance ($\pm 50\%$)
- Cloud phase/particle shape

For two modes
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.

\[
\frac{2\pi r_{\text{eff}}}{\lambda}
\]

Effective size parameter = \(2\pi \frac{\text{effective radius}}{\text{wavelength}}\)
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 $+50.5^\circ$ to $-63^\circ$ (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
Glory APS Data Products

- aerosol optical thickness (uncertainty of \( \leq 0.04 \) or \( \leq 15\% \))
- effective radius (uncertainty of \( \leq 0.15 \mu m \) or \( \leq 15\% \))
- effective variance of the size distribution (uncertainty for spherical aerosols of \( \leq 0.35 \) or \( \leq 60\% \))
- refractive index (uncertainty for spherical aerosols of \( \leq 0.03 \))
- single-scattering albedo (uncertainty of \( \leq 0.04 \))
- column number density (uncertainty for spherical aerosols of \( \leq 40\% \))
- 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 \( \leq 0.2 \) or \( \leq 10\% \))
- cloud particle effective radius (uncertainty for liquid-water clouds of \( \leq 2 \mu m \) or \( \leq 15\% \))
- effective variance (uncertainty for liquid-water clouds of \( \leq 0.07 \) or \( \leq 50\% \), 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 \( \leq 40\% \))
- 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
The Afternoon Constellation consists of eight U.S. and international Earth Science satellites that fly within approximately ten minutes of each other to enable concurrent science. The joint measurements provide an unprecedented sensor system for Earth Observations.
Basis of TSI proxies is recent measurements

- 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.
Space-borne TSI record relies on continuity

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

Launch support segment
- VAFB

Space segment
- GPS
- TDRSS

Science/user community
- GSFC DAAC

Ground segment
- Poker Flat, AK
- South Point, HI / Perth, AUS

MOC
- TIM SOC LASP
- Orbital Sciences

NASA IONET
- APS/CC SOC GISS