

weather.msfc.nasa.gov/tempo/



Tropospheric Emissions:
Monitoring of Pollution
Hourly Measurement of Pollution



Smithsonian Astrophysical
Observatory



<http://tempo.si.edu/>



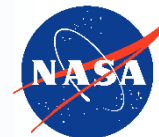
Tropospheric Emissions: Monitoring of Pollution (TEMPO) Mission

Health & Air Quality Applications Program Review
September 19, 2022

Aaron Naeger

TEMPO Deputy Program Applications
Lead

U.S. Government sponsorship acknowledged.

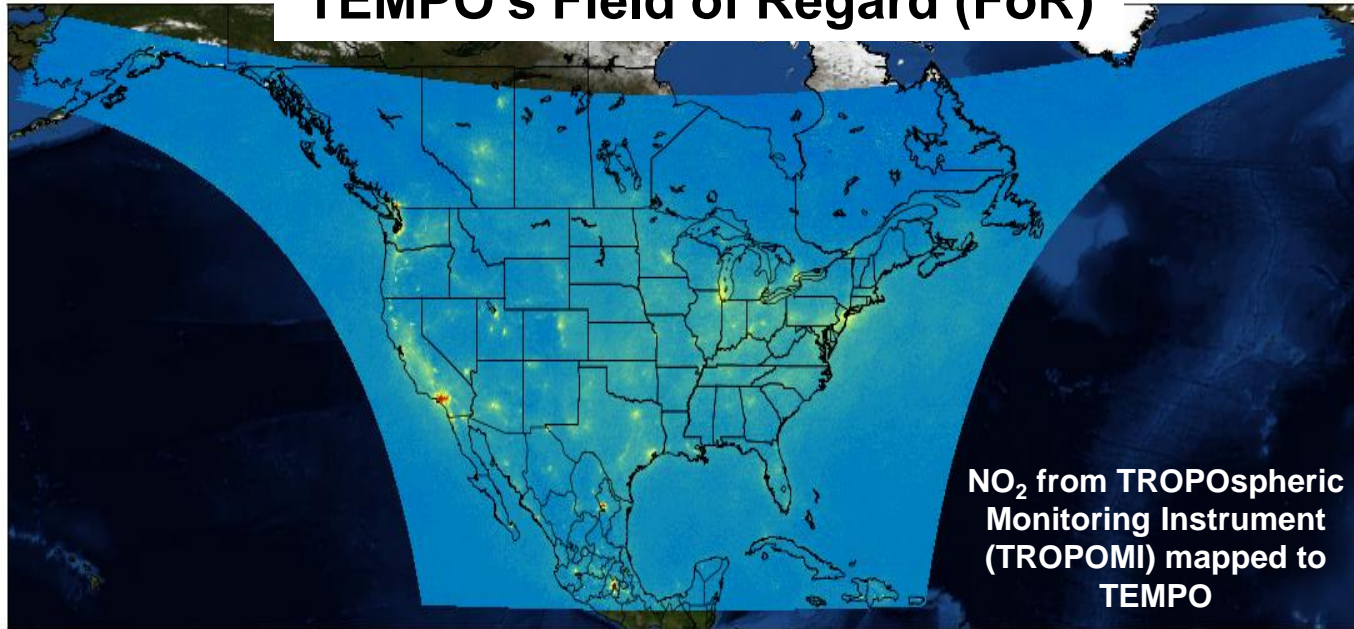




TEMPO Mission Highlights

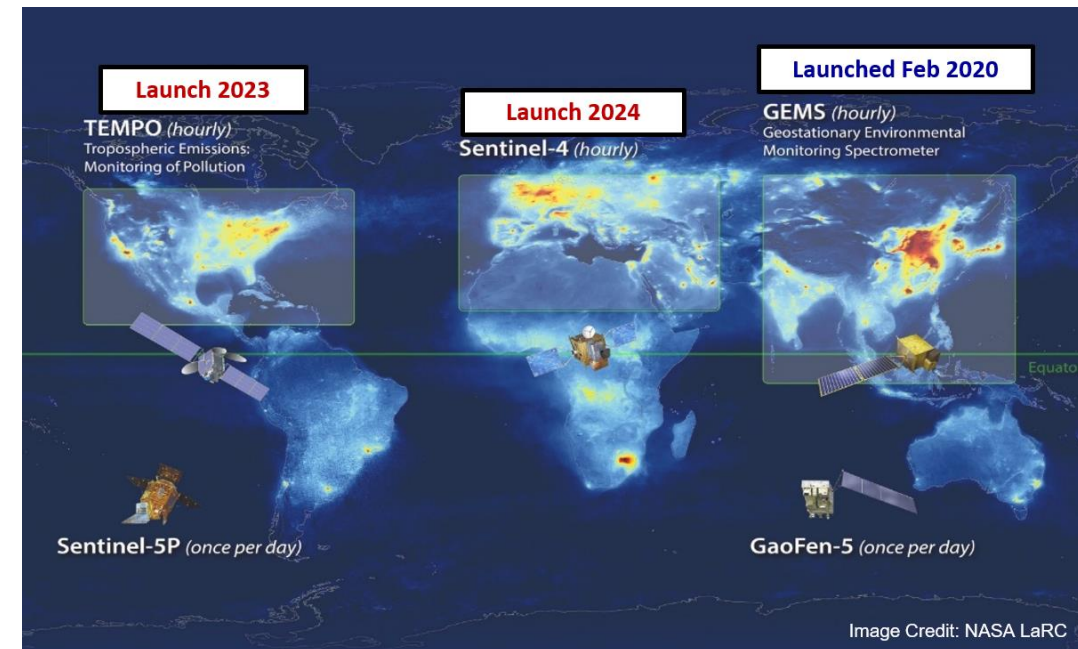


TEMPO's Field of Regard (FoR)



- ❑ Capability to distinguish between boundary layer from free tropospheric and stratospheric O₃
- ❑ TEMPO instrument integration with host satellite, Intelsat 40e, was recently completed in June
- ❑ Launch expected early March 2023 to 91°W longitude (Baseline mission: 20 months)
- ❑ Member of a geostationary satellite constellation for observing pollution over Northern Hemisphere

- ❑ NASA's first Earth Venture Instrument (EVI) selected in 2012 & first host payload
- ❑ TEMPO will observe atmospheric pollution every daylight hour at high spatial resolution from Geostationary Earth Orbit
- ❑ UV/Visible grating spectrometer will be sensitive to **policy-relevant pollutants (NO₂, SO₂, O₃)** and aerosols





TEMPO Data Products



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Level	Product	Key Outputs	Res km ² *	Freq/Size
L0	Digital counts	Reconstructed digital counts	2.0 x 4.75	Daily/hourly
L1-b	irradiance	Calibrated & quality flags		daily
	radiance	Geolocated, calibrated, viewing	2.0 x 4.75	Hourly, granule
L2	★ Cloud	Cloud fraction, cloud pressure	2.0 x 4.75	Hourly, granule
	O ₃ (Ozone) profile	O3 profile, tropospheric & 0-2 km O3 column, errors	8.0 x 4.75 OR 8.0 x 9.5	Hourly, granule
	Total O ₃	Total O3, Aerosol Index, cloud fraction	2.0 x 4.75	Hourly, granule
	★ NO ₂ (Nitrogen Dioxide)	SCD, strat./trop. VCD, errors	2.0 x 4.75	Hourly, granule
	★ HCHO (Formaldehyde)		2.0 x 4.75	Hourly, granule
	C ₂ H ₂ O ₂ (Glyoxal)	SCD, VCD, errors	2.0 x 4.75	Hourly, granule
	H ₂ O (Water Vapor)		2.0 x 4.75	Hourly, granule
	BrO (Bromine)		2.0 x 4.75	Hourly, granule
	★ SO ₂ (Sulfur Dioxide)	SCD, VCD (PBL,TRL,TRM,TRU,STL)	2.0 x 4.75	Hourly, granule
	★ Aerosol	AAI, UVAOD, UVSSA, AOCH, VISAOD	8.0 x 4.75	Hourly, granule
	TEMPO/GOES-R Synergistic	Radiance, aerosol, cloud & mask, fire/hotspot, lightning, snow/ice, etc.	2.0 x 4.75	Hourly, granule
L3	Gridded L2	Same as L2	2 x 2 (TBD)	Hourly, scan
L4	UVB	UV irradiance, erythemal irradiance, UVI	TBD	Hourly, scan

★ **Proposed near real-time products (latency ~2-3 hours)**

** Center of Field of Regard

SCD: Slant Column Density

VCD: Vertical Column Density

AAI: Aerosol Absorption Index

UVAOD/VISAOD: UV/VIS Aerosol Optical Depth

UVSSA: UV Single Scatter Albedo

AOCH: Aerosol Optical Centroid Height

Black text: Baseline products; **Orange text:** Additional / proposed products (pending funding in late 2022 or 2023)



Operational Timeline & Data Distribution



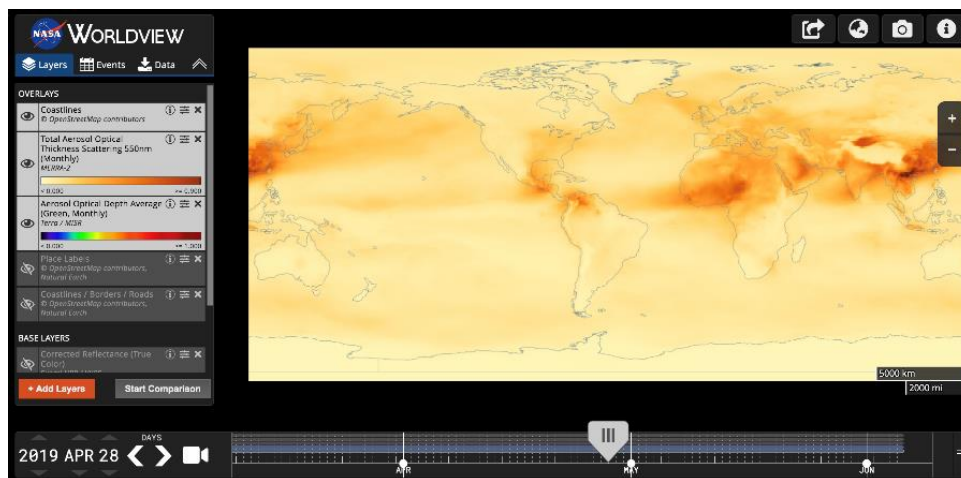
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Timeline based on March 2023 launch

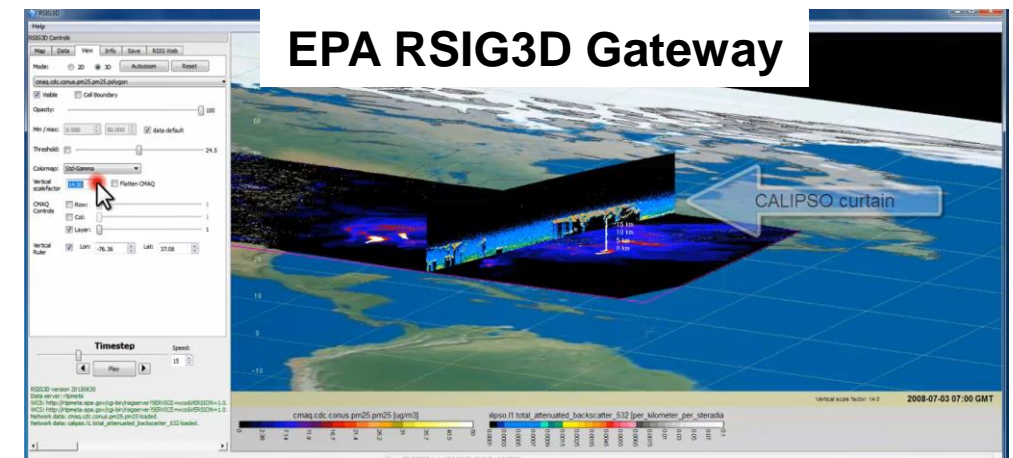


- ❑ TEMPO commissioning phase from mid-June – mid Sept 2023
- ❑ Nominal operation: ~6 months after launch
- ❑ Plan to release level 1b data ~4 months after commissioning phase (Jan 2024) and **level 2 and 3 data ~6 months after commissioning phase (March 2024)**
- ❑ Data will be **publicly available** via [NASA Earthdata Search](https://earthdata.nasa.gov) in netCDF4/HDF5 format
- ❑ Latency of standard (Offline) products ~3-6 hours, except for ozone profile (~24-hour latency)
- ❑ **Latency of ~2-3 hours for proposed near real-time (NRT) products**
- ❑ Baseline mission length is 20 months with possible 10+ year lifetime depending on senior review extensions

✓ [NASA WorldView](https://worldview.nasa.gov)



TEMPO imagery will be available in Worldview



TEMPO data can be served directly through the EPA RSIG.

<https://www.epa.gov/hesc/remote-sensing-information-gateway> 4

Adapted from slides at TEMPO STM 2020 & EAWNNov2021 (Jeff Walter, Tim Larson)



TEMPO Early Adopters Program



Success #1

Major growth of TEMPO user community with 300+ early adopters including 50+ AQ and health organizations

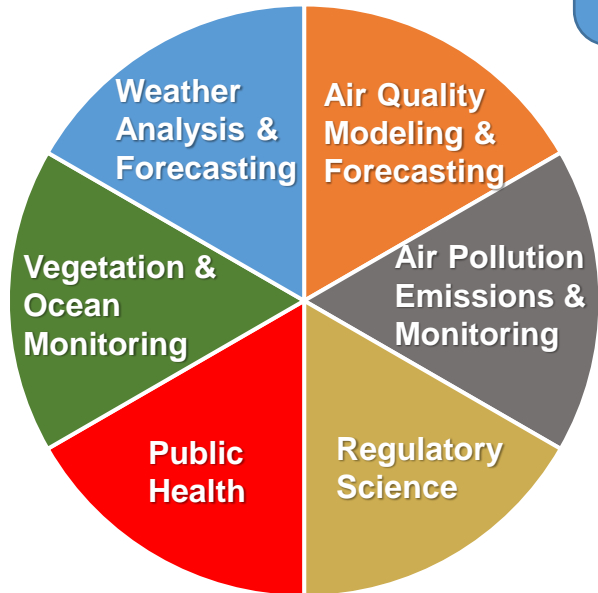
Success #2

Familiarized community on planned products and early development of tools through dissemination of proxy data

Success #3

Expansion of AQ and health application areas and addressed critical needs for NRT TEMPO data

Enhanced knowledge in TEMPO data and applications across user community including Community of Potential (e.g., Health and EJ groups)



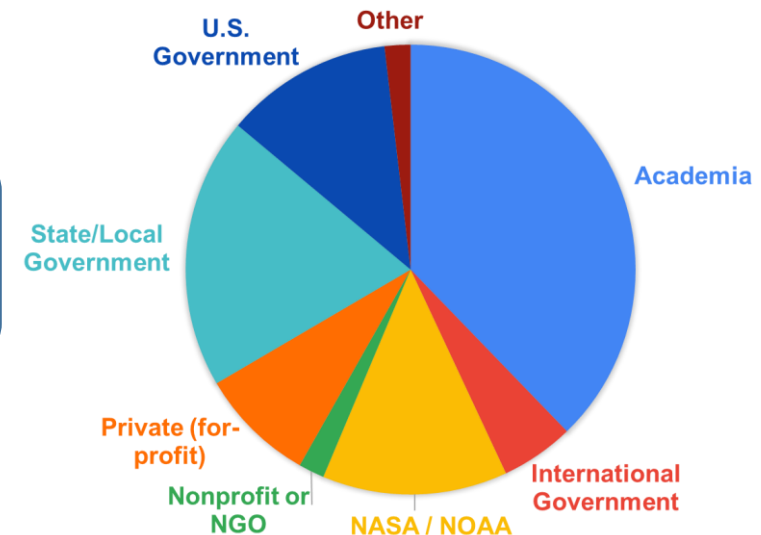
TEMPO Launch (March 2023)

Overarching Goal

Maximize and accelerate the value of TEMPO data for societal benefit

Extend TEMPO mission lifetime

EARLY ADOPTERS BY AFFILIATION



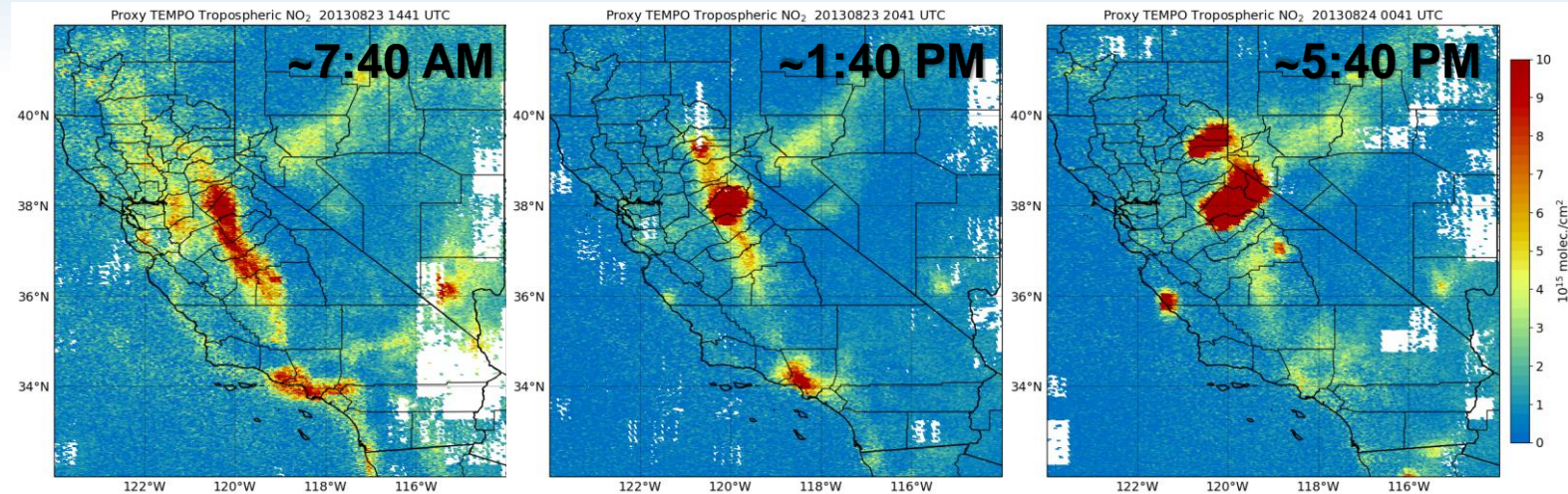


TEMPO Proxy Data & Special Operations



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- ❑ TEMPO proxy level 2 NO₂, HCHO, and O₃ products currently available in NASA Earthdata for TEMPO team (Early Adopters)
- ❑ Tools developed to aid early adopters in processing, analyzing, and visualizing the proxy data
- ❑ Plan to release additional proxy data (SO₂, H₂O)
- ❑ Up to 25% of TEMPO's observing time will be devoted to special operations with sub-hourly frequency (e.g., ≤ 10 min) over selected portion /slice of FoR (reduced E/W spatial coverage)
- ❑ Pre-loaded scans easily initiated a few days (potentially a few hours) prior to an event and will commence during TEMPO's commissioning phase (June – Sept 2023)
- ❑ Planning is being done now to coordinate and balance the special operations (**living TEMPO Green Paper** - https://weather.msfc.nasa.gov/tempo/green_paper.html)
- ❑ Community is encouraged to submit an experiment request and become a co-author on Green Paper

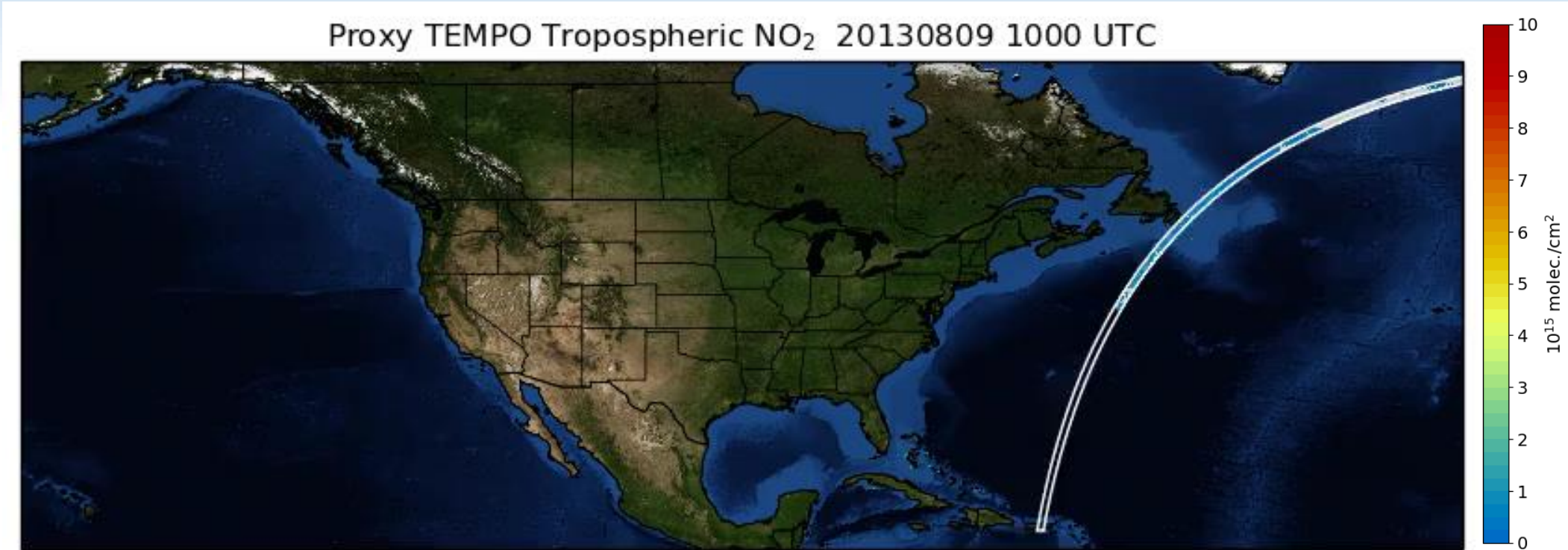


Experimental Opportunities

TEMPO Green Paper (pdf)

Experiment Request Form

TEMPO Scan Operations



- ❑ TEMPO will perform standard (nominal) East-West hourly daytime scans consisting of ~1226 mirror steps across the Field of Regard (FoR) over Greater North America
- ❑ Sub-hourly scans will also be performed:
 - 1) Optimized scans across the East and West during sunrise and sunset periods, respectively, when SZA is too high ($> 80^\circ$) over portions of the FoR to complete a nominal hourly scan
 - 2) **Special operations for dedicated experiments over a subset of mirror steps / time intervals (e.g., ≤ 10 minutes)**