Tropospheric Emissions:
Monitoring of Pollution

Status of TEMPO & TEMPO Products to Support AGES

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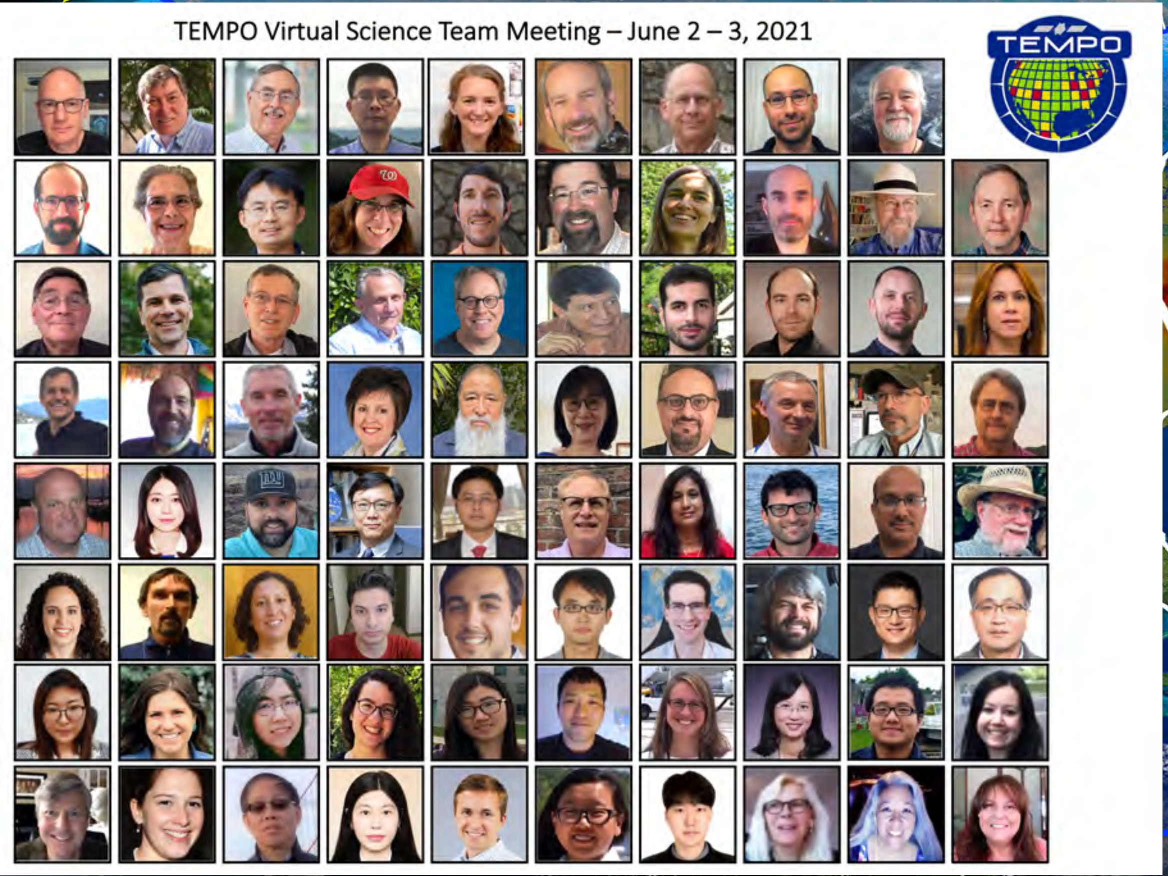
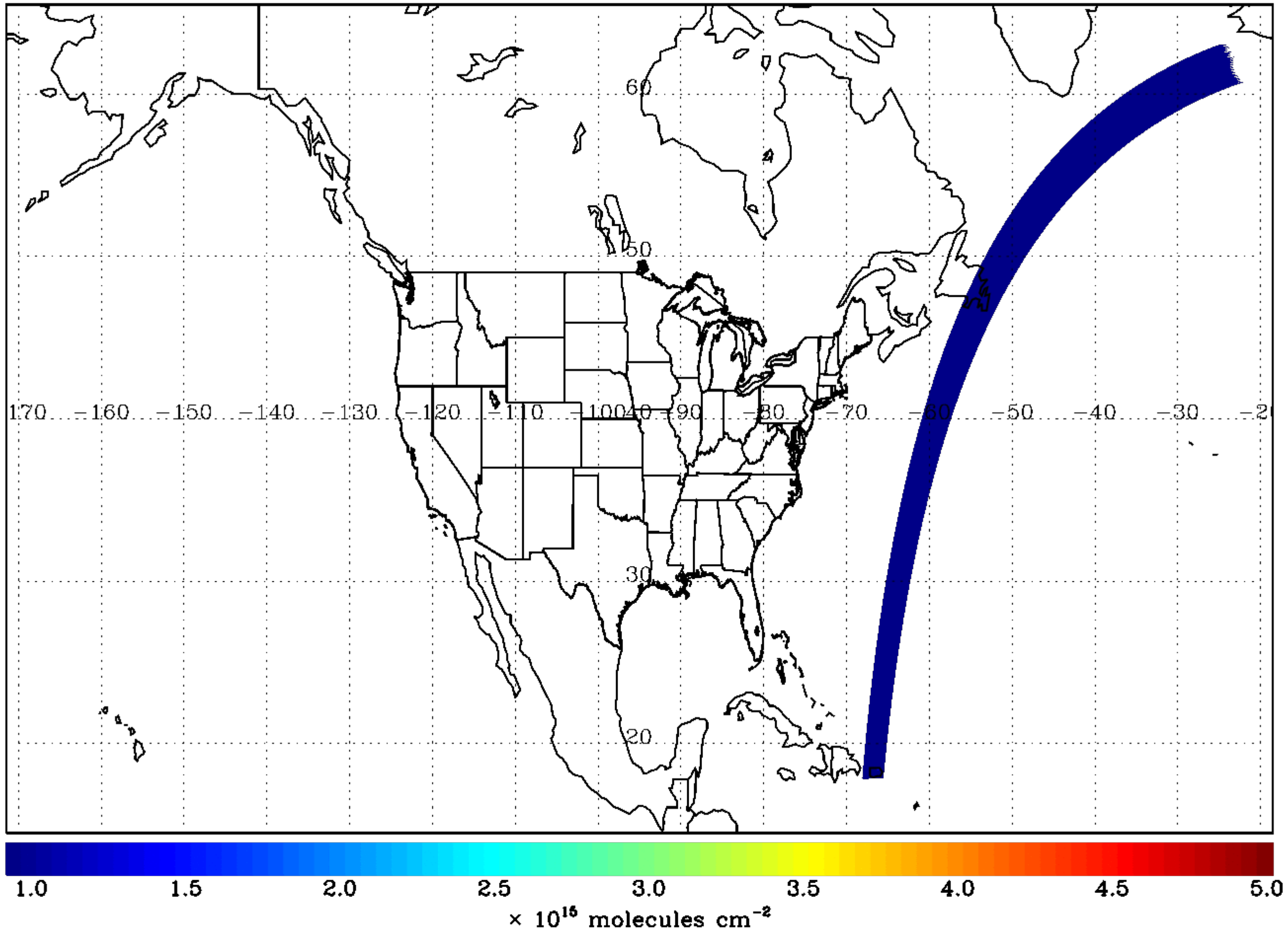


TEMPO Instrument and Operation

- Imaging grating spectrometer measuring solar backscattered Earth radiance: ~293-494 nm, ~538-741 nm
- Operate on geostationary communications satellite Intelsat 40e (IS-40e) at 91 ° W

TROPOMI NO_2 in 2018 over TEMPO FOR

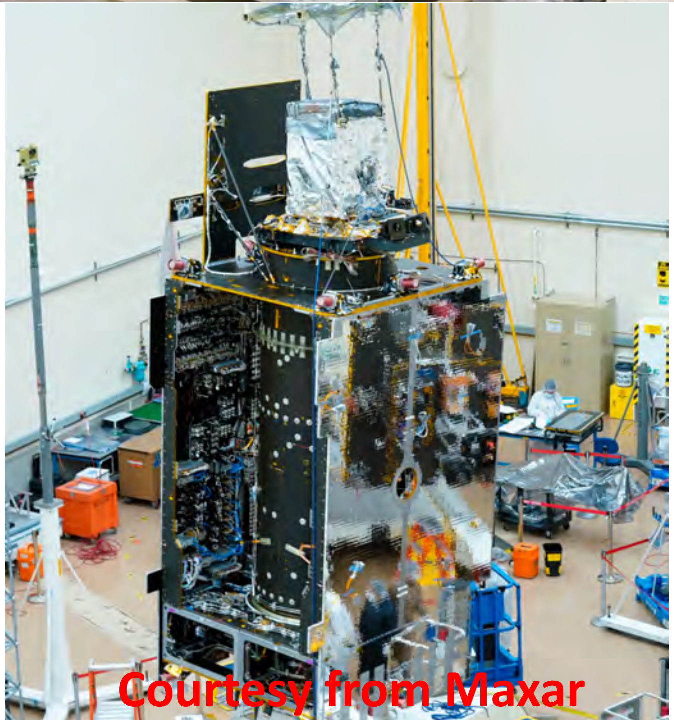


- Field of regard is optimized to cover both Puerto Rico and Canadian tar sands.
- S5p-TROPOMI NO2 product oversampled by Kang Sun.

- **Nominal:** Scan FOR in 1 hour with 10 granules
- ~ 2K N/S pixels x 1226 steps/hr, ~ 2.5 M pixels/hr, daily # spatial pixels ~TROPOMI
- 2 x 4.75 km^2 @center of FOR, from 8 km^2 at Mexico City to 21 km^2 at Canadian tar sands
- **Optimized scan:** in the early morning and late afternoon, daylight portion of FOR, higher temporal resolution
- **High-time scan (up to 25%):** selected portion of FOR at higher temporal resolution (e.g., <= 10 mins)

TEMPO Status

❑ NASA's first EVI selected in 2012 & first host payload.

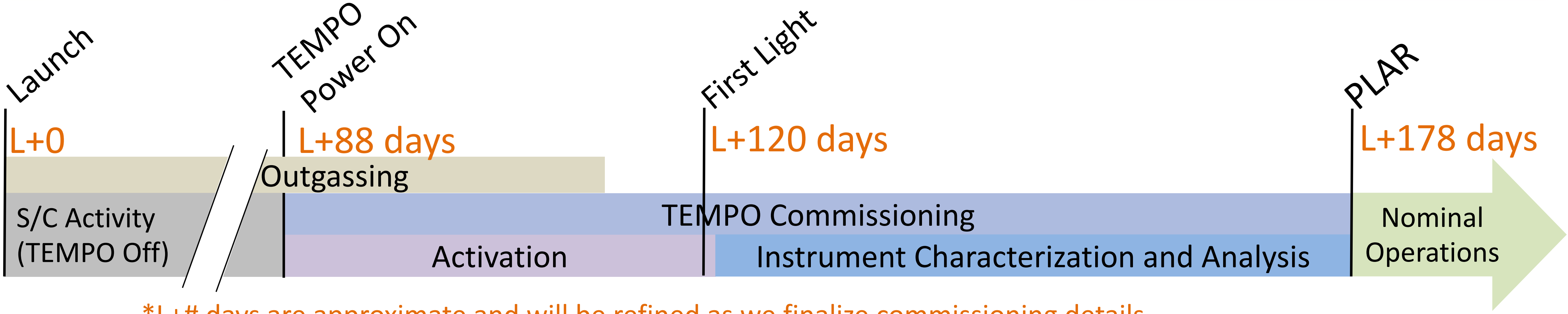


Crews recently completed the first fully integrated powered testing of TEMPO, instrument on Intelsat IS40e at Maxar Technologies' satellite manufacturing facility in Palo Alto, California.
Credits: Image courtesy of Maxar Technologies

- **Instrument delivery by Ball Aerospace in Nov. 2018**
- **Host satellite provider: Maxar selected in July 2019**
- **Host: Intelsat 40e selected in 02/2020.**
- **TEMPO sensor integrated onto IS-40e on 11/17/2021, and integration completed on 6/30/2022.**
- **TEMPO Ground Systems to be ready in Oct./Nov. 2022**
- **Operation/Mission Readiness Review (ORR/MRR) in Dec. 2022**
- **Launch on SpaceX Falcon 9 around 3/1/2023 (TBD)**
- **Nominal operation will start in 9/2023 after spacecraft and TEMPO commissioning.**

TEMPO

Commissioning Timeline & Data Release Plan



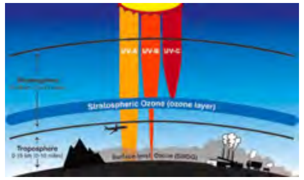
*L+# days are approximate and will be refined as we finalize commissioning details

Activity	Intelsat
LEOP: Orbit Transfer	2 Weeks
Spacecraft Bus IOT	1 Week
Payload IOT	4 Weeks
Drift to Location	4 Weeks (TBD) 60º drift to 91ºW
Commercial Services (Onboarding Customers)	1 Week
TEMPO Commissioning Begins	Expect L+12 Weeks

- **TEMPO commissioning: 06-08/2023, first light ~7/1/2023**
- **Nominal operation after PLAR: ~9/2023**
- **Plan for initial public release of baseline products at ASDC (L1b in ~4 mons, L2/3 in ~6 mons after PLAR): L1b, 1/2024; L2/3, 3/2024**
- **Provide baseline data products to validation team priori to the public release via ASDC.**

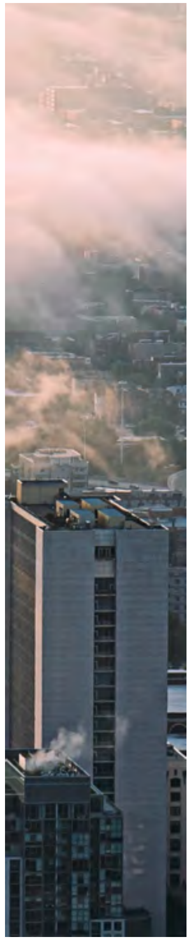
TEMPO Data Products

(Inc. Proposed NRT & Additional Products)





Level	Product	Algorithm	Major Outputs	Res km² *	Freq/Size
L0	**Digital counts**	Raw to L0	Reconstructed/reformatted digital counts	2.0 x 4.75	Daily/hourly
L1-b	**Irradiance** NRT	SAO L0-1	Calibrated & quality flags		daily
	Radiance NRT	SAO L0-1	Geolocated,calibrated, viewing,geolocation&quality flags	2.0 x 4.75	Hourly, granule
L2	**Cloud** NRT	OMI O2-O2	Cloud fraction, cloud pressure	2.0 x 4.75	Hourly, granule
	O_3 profile	SAO O3 profile	O3 profile, total/strat/trop/0-2 km O3 column, errors, a priori, AKs	<= 8.0 x 4.75**	Hourly, granule
	Total O_3	TOMS V8.5	Total O3, AI, cloud fraction	2.0 x 4.75	Hourly, granule
	NO_2 NRT	SAO trace gas, BU strat/trop sep.	SCD, strat./trop. VCD, error, shape factor, scattering weights	2.0 x 4.75	Hourly, granule
	H_2CO NRT	SAO trace gas	SCD, VCD, error, shape factor, scattering weights	2.0 x 4.75	Hourly, granule
	$C_2H_2O_2$	SAO trace gas		2.0 x 4.75	Hourly, granule
	H_2O	SAO trace gas		2.0 x 4.75	Hourly, granule
	BrO	SAO trace gas		2.0 x 4.75	Hourly, granule
	Aerosol NRT	**OMAERUV+UI AOCH**	AAI, UVAOD, UVSSA, AOCH, VISAOD	**8.0 x 4.75**	**Hourly, granule**
	SO_2	OMSO2 PCA	SCD, VCD (PBL,TRL,TRM,TRU,STL)	2.0 x 4.75	Hourly, granule
	TEMPO/GOES-R Synerg. product	GOES-R products on TEMPO pixels	Radiance, aerosol, cloud & mask, fire/hotspot, snow/ice, rainfall, precipitable water, land/sea surface T, lightning	2.0 x 4.75	Hourly, granule
L3	**Gridded L2**	SAO L2-3	Same as L2	2 x 2 (?)	Hourly, scan
L4	**UVB**	GEMS/GSFC UVB	UV irradiance, erythemal irradiance, UVI	TBD	Hourly, scan

Black: launch-ready baseline products; green/orange/purple: additional products

NRT (L1b <~1 hr, L2 cloud <~1.5 hr, L2/3 trace gas < ~2.5 hrs): from SNWG, NASA+NOAA OMB, NOAA to produce aerosol NRT

NRT data products timeline, 4-5 months behind baseline products (1/2024 start NRT processing, 6/2024: public release)

* Spatial resolution at center of FOR. ** Might be at 8 x 9.5 km²

Current Atmospheric Composition Capabilities & Examples of Applications for AGES

Baseline/NRT Products

- Cloud product: effective cloud fraction, optical centroid cloud pressure
- Total O3: total ozone, aerosol index
- O3 profile: profiles of partial O3 columns, total, stratospheric, tropospheric, & 0-2 O3
- NO2: total, stratospheric & tropospheric NO2
- HCHO: total HCHO
- Hourly, optimized scan & high-time scans with spatial resolution of 2 x 4.75 km^2 at center of field of regard

- Provide a broader spatiotemporal context from the satellite perspective

- Provide high temporal resolution measurements with high-time scans (~10 mins) over campaign regions

- Monitoring of emission sources & pollution transport

Satellite product support for AGES field campaigns

Describe how your products can support the campaigns (e.g., NRT provision of your products in support of flight planning):

- If TEMPO products look reasonable, use TEMPO data products from earlier measurements (1 day before or within the same day or NRT products if available) to provide broader spatiotemporal context, provide high temporal information with high-time scan, identification of pollution sources.

What scientific objectives you want to achieve as a satellite product developer?

- Validate retrieval and retrieval assumption (e.g., a priori)
- Understand the capabilities and limitations of our satellite products

Cite one or two examples on how past field campaigns helped with cal/val of satellite products:

- Measurements for validation: GCAS/GeoTASO, Pandora/MAXDOAS, LIDAR, HSRL-2, in-situ spirals, surface in-situ measurements, ozonesonde, etc.
- Nowlan et al. (2016, 2018), Judd et al. (2018, 2019, 2020) especially Judd et al. (2020) showed the use of GCAS/GeoTSAO + Pandora to validate TROPOMI
- Zhu et al. (2020): use aircraft measurements from 12 campaigns + GEOS-Chem to validate satellite HCHO retrievals

❑ Post AGES campaigns satellite data analysis

❑ How AGES campaigns can inform future & upcoming satellite product development

List science activities involving data from AGES campaigns

- Validate TEMPO products, assessing the retrieval accuracy and precision, systematic biases under different conditions, and retrieval assumptions
- Identify retrieval problems and improve the retrieval
- Support the evaluation of long-term consistency of satellite retrievals with future campaigns
- Understand the capabilities & limitations of TEMPO measurements
- Use TEMPO, AGES, and model simulation for scientific studies

Iterative process (first four items)