TEMPO Early Adopters in Air-Quality Forecasting, Planning and Assessment, Pollution Emissions, Health, Agriculture, and Environmental Impacts: Applications and Decision Support

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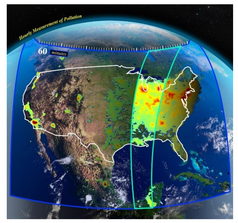
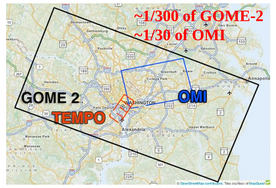
Background

- Tropospheric Emissions: Monitoring of Pollution (TEMPO) instrument is a NASA mission with an expected launch date of 2020 or 2021.
- To be hosted on geostationary communications satellite to maintain constant view of North America.
- East to West scan over Field of Regard (FoR) will be completed every daylit hour.
- Grating spectrometer will measure backscattered radiance in UV (290-490 nm) and visible (540-740 nm) with spectral resolution of 0.6 and 0.2 nm.
- Capability to retrieve aerosol/cloud parameters and major elements in O_3 chemistry cycle (O_3, NO_2, SO_2, H_2CO, $C_2H_2O_2$) plus H_2O, and UVB.
- Multi-spectral capabilities will help distinguish between boundary layer and free tropospheric and stratospheric O_3.
- Air-quality monitoring at sub-urban scales due to high spatial resolution (2.1 km in N-S, 4.7 in E-W at center of FOR).



TEMPO Field of Regard (FoR) over greater North America (blue box). Scanning pattern of spectrometer highlighted by green box and arrow indicating scan direction



Spatial resolution comparison between OMI, GOME-2, and TEMPO

Unprecedented capabilities of TEMPO will help effectively monitor the rapidly varying emissions and chemistry that governs our air-quality conditions.

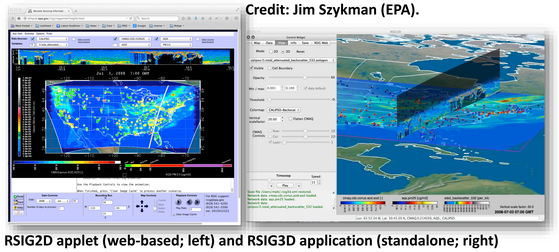
Data Products and Display

- O_3 profiles, tropospheric O_3 based on eXceL optimal-estimation method used for GOME and OMI.
- Method may be extended to SO_2, especially volcanic SO_2
- TOMS-type O_3 retrieval included for heritage.
- OMI heritage aerosol/cloud products: AOD, AAOD, Aerosol Index, Cloud Top Fraction, Cloud Top Pressure.
- Development of advanced/improved aerosol/cloud products
- Research products: UVB (OMI heritage) and city lights

Species/Products	Required Precision	Temporal Revisit
0-2 km O_3 (Selected Scenes) Baseline only	10 ppbv	2 hour
Tropospheric O_3	10 ppbv	1 hour
Total O_3	3%	1 hour
Tropospheric NO_2	1.0×10^{15} molecules cm^{-2}	1 hour
Tropospheric H_2CO	1.0×10^{16} molecules cm^{-2}	3 hour
Tropospheric SO_2	1.0×10^{16} molecules cm^{-2}	3 hour
Tropospheric $C_2H_2O_2$	4.0×10^{14} molecules cm^{-2}	3 hour
Aerosol Optical Depth	0.10	1 hour

Baseline data products

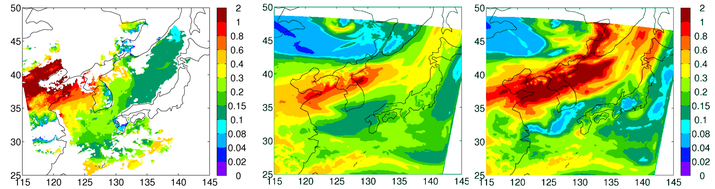
- TEMPO will use EPA's Remote Sensing Information Gateway (RSIG) for subsetting, visualization, and product distribution



Credit: Jim Szykman (EPA).

RSIG2D applet (web-based; left) and RSIG3D application (standalone; right)

Air Quality Forecasting



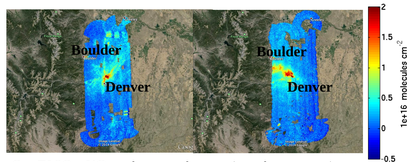
GOCI AOD from 27-29 August 2012 (left), WRF-Chem No Assimilation (middle), WRF-Chem Assimilation with MODIS+GOCI AOD (right).

- Previous research has shown large, positive impact of assimilating aerosol information from geostationary sensors.
- Surface concentrations, especially O_3, NO_2, and $PM_{2.5}$, and emissions at high spatial resolution from TEMPO will be very beneficial for air-quality forecasting.
- The suite of hourly aerosol and atmospheric composition data products from TEMPO will help resolve the large data gap issues in ground-based networks in the U.S.
- High spatial and temporal resolution of TEMPO will be valuable for regions of complex meteorological flows (i.e., mountain/valley flows, lake/sea breeze circulations.)
- Synergy between TEMPO and GOES-R will be critical for wildfires, lightning NO_x, volcanic ash, and aerosol/cloud interaction forecasting.

Pollution Emissions

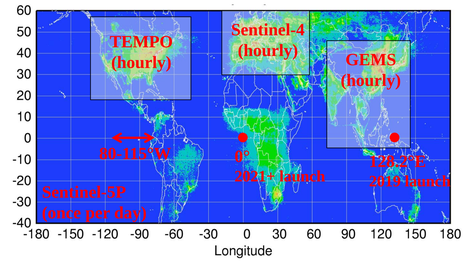
TEMPO benefits:

- High spatial resolution will allow evaluation of temporal variations, spatial mapping, and sector-specific emissions.
- Ability to resolve urban emissions and chemistry and monitor these complex source regions.



GeoTASO NO_2 slant column in the morning vs afternoon on 2 August 2014 over the Denver/Boulder areas. Preliminary data: C. Nowlan, SAO.

- Characterization of emissions from evolving sources, such as oil, natural-gas basins, and fires.
- Much improved emission inventories, which will help assess control strategies.
- Internationally integrated observatory strategy employing complementary approaches between geostationary spectrometers will help improve emission estimates at common confidence levels over the Northern Hemisphere and air quality assimilation systems and forecasts.

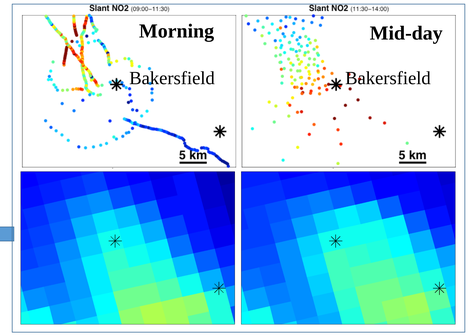


Approximate coverage of geostationary spectrometers with expected launch dates of 2018-2020.

Planning and Assessment

- TEMPO measurements will significantly improve the estimations of background air quality levels, which have been increasingly focused due to the more stringent ambient air standards.
- The unique TEMPO measurements will enhance our ability to capture the diurnal changes in air quality concentrations, improve our understanding of the weekday and weekend differences in NO_2 columns, and help better identify and define exceptional events.
- TEMPO data can be used for rigorous model evaluation activities, and for improving data assimilation and air-quality forecasts.

The aircraft measurements clearly reveal the poor performance of the CMAQ model during this high NO_2 transport event. The availability of TEMPO NO_2 will allow for similar model evaluation practices with nearly continuous measurements.



Aircraft measurements of NO_2 columns during morning and mid-day for a high NO_2 transport event in January 2013 (top). CMAQ model predictions of NO_2 for approximately the same times (bottom). Credit: Luke Valin (Columbia University/EPA)

Health, Agriculture, and Environmental Impacts

Health

- The high temporal resolution, expected accuracy, and spatial coverage of TEMPO data will benefit acute health-effect studies (e.g., asthma events linked to pollution) of $PM_{2.5}$, O_3, and NO_2.
- TEMPO's expected life is too limited to be appropriate for studying chronic effects (e.g., heart attacks linked to long-term exposure).
- TEMPO's spatial resolution is not adequate for studying the acute health effects of NO_2 – need oversampling methods to improve its spatial resolution.
- TEMPO retrievals must be converted to ground concentrations for studying the acute health effects from pollutants.

Agriculture and Environment

- TEMPO data will help quantitative understanding of local crop yield losses, along with spatial and inter-annual variability in losses, and for identifying regions where uses of O_3 resistant cultivars is valuable.
- TEMPO NO_x measurements can be used to characterize emissions from fertilizer applied to agricultural fields, which will facilitate assessments of the potential benefits of improved nitrogen use efficiency in fertilizer application for surface O_3 concentrations.

TOLNet, an international (USA and Canada) and interagency (NASA, NOAA, university) ozone-lidar observation network, provides highly time-resolved (few minutes) tropospheric-ozone vertical profiles for TEMPO validation and science.

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