Application of Synthetic TEMPO Products at NASA SPoRT to Accelerate Use in Air Quality and Public Health Decision Support

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https://weather.msfc.nasa.gov/tempo/

Introduction & Motivation

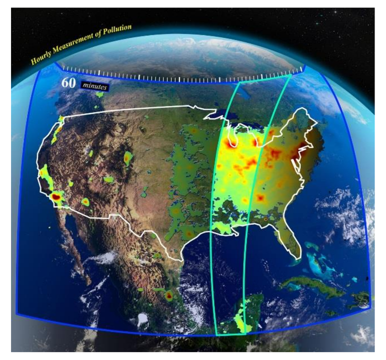


Figure 1. TEMPO Field of Regard (FOR) over the greater North America (blue box). Scanning pattern of TEMPO highlighted by green box and arrow indicating scan direction.

- TEMPO mission is set to launch in March 2022, and will be hosted on a commercial geostationary communications satellite with a Field of Regard (FOR) over North America for allowing hourly daytime monitoring (Fig. 1)

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

Table 1. TEMPO baseline L2 data products.

- TEMPO will measure radiances in the UV (290-490 nm) and VIS (540-740 nm) with a spectral resolution and sampling of 0.6 and 0.2 nm, respectively, for retrieving aerosol and cloud parameters, along with the major elements in tropospheric O_3 chemistry cycle (Table 1)
- Multi-spectral capabilities from UV to VIS will help distinguish between boundary layer, free tropospheric, and stratospheric O_3

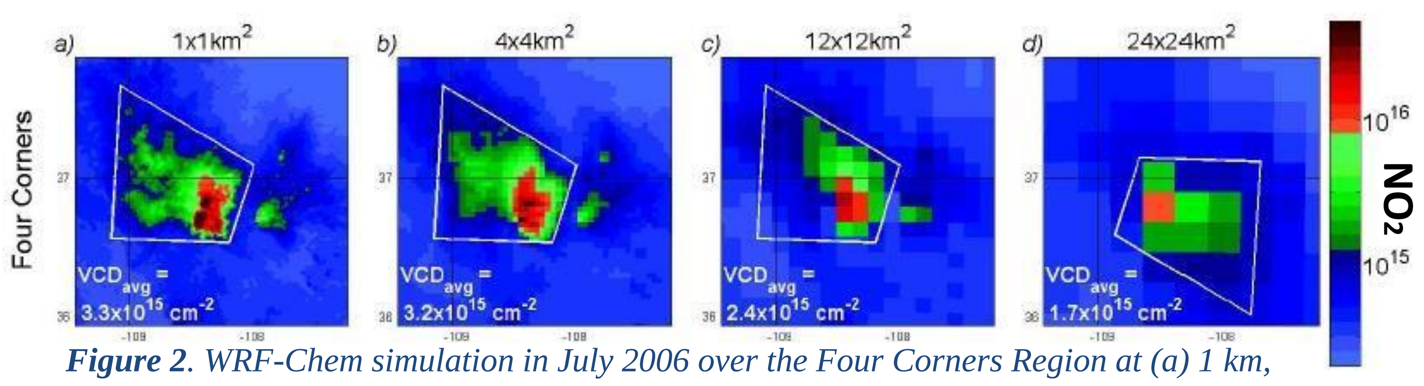


Figure 2. WRF-Chem simulation in July 2006 over the Four Corners Region at (a) 1 km, (b) 4 km, (c) 12 km, and (d) 24 km model resolution. NO_2 column is averaged over a sub-domain (white box). Adapted from Valin et al. (2011).

- Monitoring will be accomplished at sub-urban scales with a spatial resolution of 2.1 x 4.7 km at the center of FOR (Fig. 2)

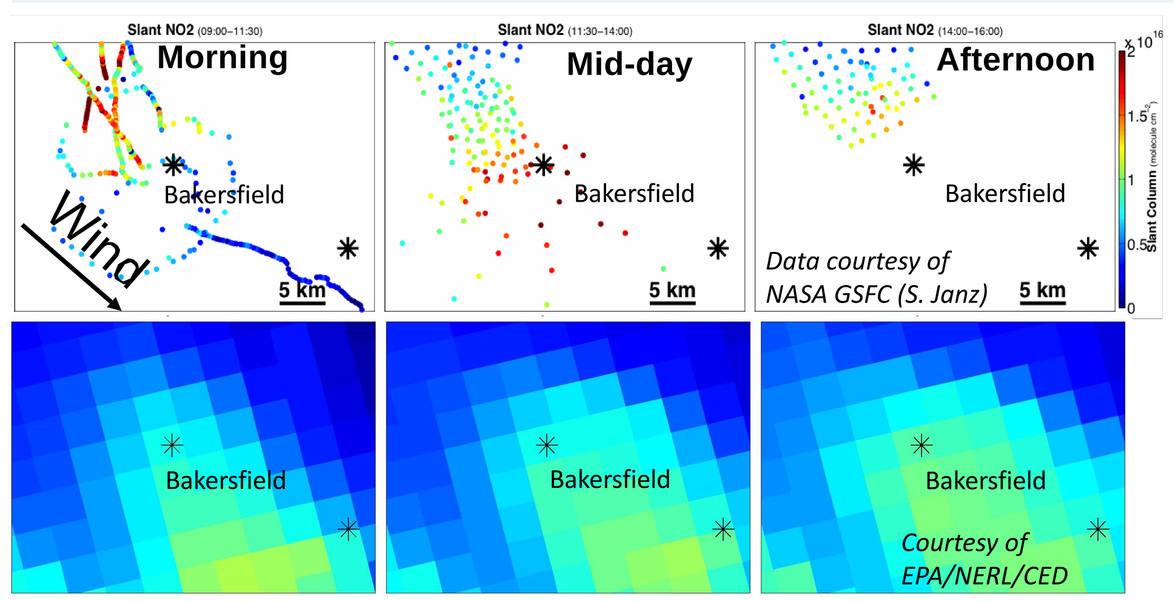
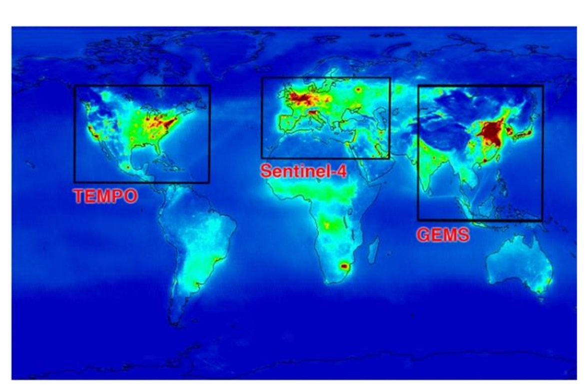


Figure 3. (top) Aircraft NO2 from 09 and 16 UTC for a high NO_2 transport event in January 2013. (bottom) CMAQ NO2 for about the same time. Figure adapted from 1st TEMPO Applications Workshop (L. Valin, EPA).

- High spatial, temporal, and spectral resolution of TEMPO will provide unprecedented daylight observations from space for effectively monitoring the diurnal varying emissions and chemistry that governs our air-quality conditions (Fig. 3)



- Complementary GEMS (to be launched March 2020) and Sentinel-4 (2023) will provide robust coverage across populated areas over Northern Hemisphere (Fig. 4).

Figure 4. Coverage of future geostationary spectrometers.

Synthetic Data Development

- Synthetic TEMPO data generated from simulated gaseous and aerosol composition from GEOS-Nature Run (GEOS-NR)
- GEOS-NR spatial resolution of ~12 x 12 km2 spatiotemporally interpolated to finer TEMPO grid
- Profiles and vertical column amounts of species obtained from interpolation and algorithm effects

(TEMPO source code courtesy of C. Chan Miller, Harvard)

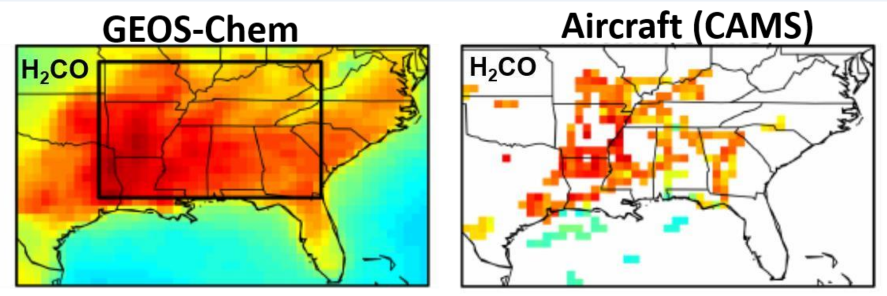


Figure 5. GEOS-Chem simulated H_2CO (left) versus aircraft retrievals of H_2CO (right) (Zhu et al., 2014).

- GEOS-Chem has been extensively validated during the NOAA Southeast Nexus (SENEX) and NASA Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC4RS) campaigns, which provides evidence of the realism of the synthetic TEMPO dataset

Methodology

1. Engage with spectrum of air-quality and public-health end users and stakeholders through outreach activities
2. Fully utilize synthetic TEMPO data for realizing local and regional applications and identifying needs of specialized / tailored products during pre-launch phase of the mission
3. Build framework for synthesizing TEMPO, GOES, and Multi-Angle Imager for Aerosols (MAIA) data for advancing air-quality and health applications

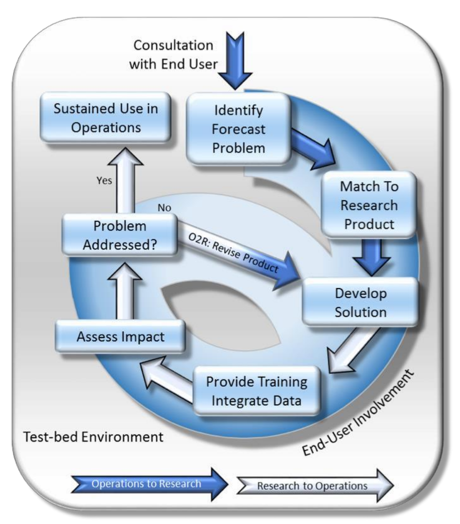


Figure 6. NASA SPoRT R2O/O2R paradigm

- NASA SPoRT has successfully transitioned unique observations from more than 40 satellite datasets to operational end users using established R2O/O2R paradigm that engages in solving forecast problems

Keys to successful day 1 readiness

- ➢ Data in end users' display system
- ➢ Targeted training
- ➢ Assessments to gather feedback from users for mission scientists

Pre-launch R2O/O2R activities can provide valuable input to mission scientists, algorithm developers, and guide products/capabilities

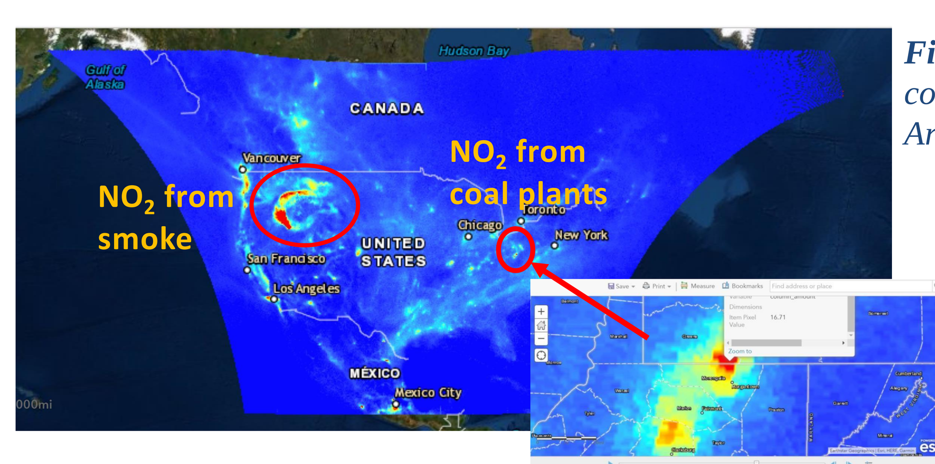


Figure 7. Synthetic TEMPO column NO_2 displayed in Esri ArcGIS platform at NASA SPoRT

- Users can retrieve geophysical values at pixel level for on-the-fly analysis

TEMPO Applications

A subset of TEMPO applications are shown here. A detailed list can be found in the TEMPO Green paper (Kelly et al., 2019)

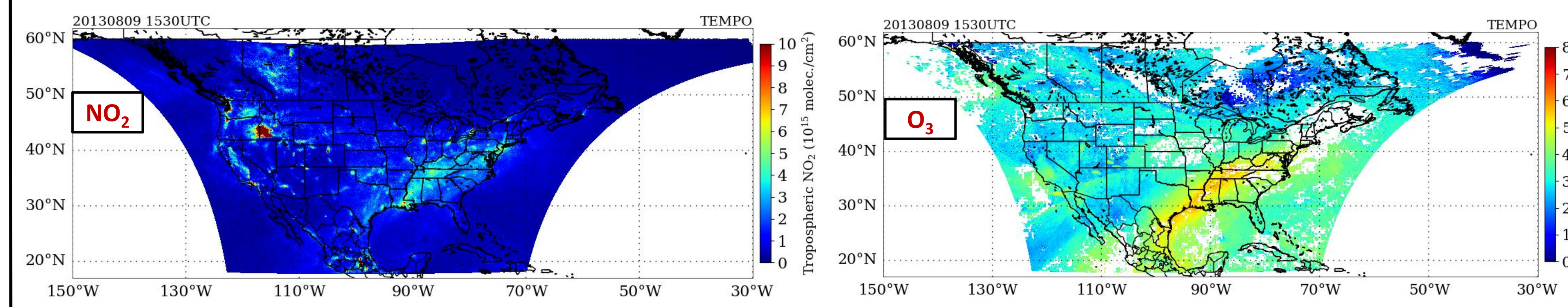


Figure 8. Synthetic TEMPO data products at ~1530 UTC 9 August 2013 including (left) tropospheric NO_2 and (right) tropospheric O_3. The complete FOR coverage shown here consists of 10 granules of individual data files that were stitched together. Cloud fraction from GEOS-NR is used to mask possible cloud contaminated pixels for tropospheric O_3.

- Synthetic file formats are identical to files planned for operational mission
- Ability to observe diurnal evolution of trace gases over FOR

Biomass burning

- Larger, more intense fires are a growing concern in our warming climate (Flannigan et al., 2013)
- ➢ **TEMPO will dramatically increase our capabilities to monitor biomass burning emissions and chemistry within smoke plumes through suite of hourly trace gases retrievals (NO_2,O_3,H_2CO)**

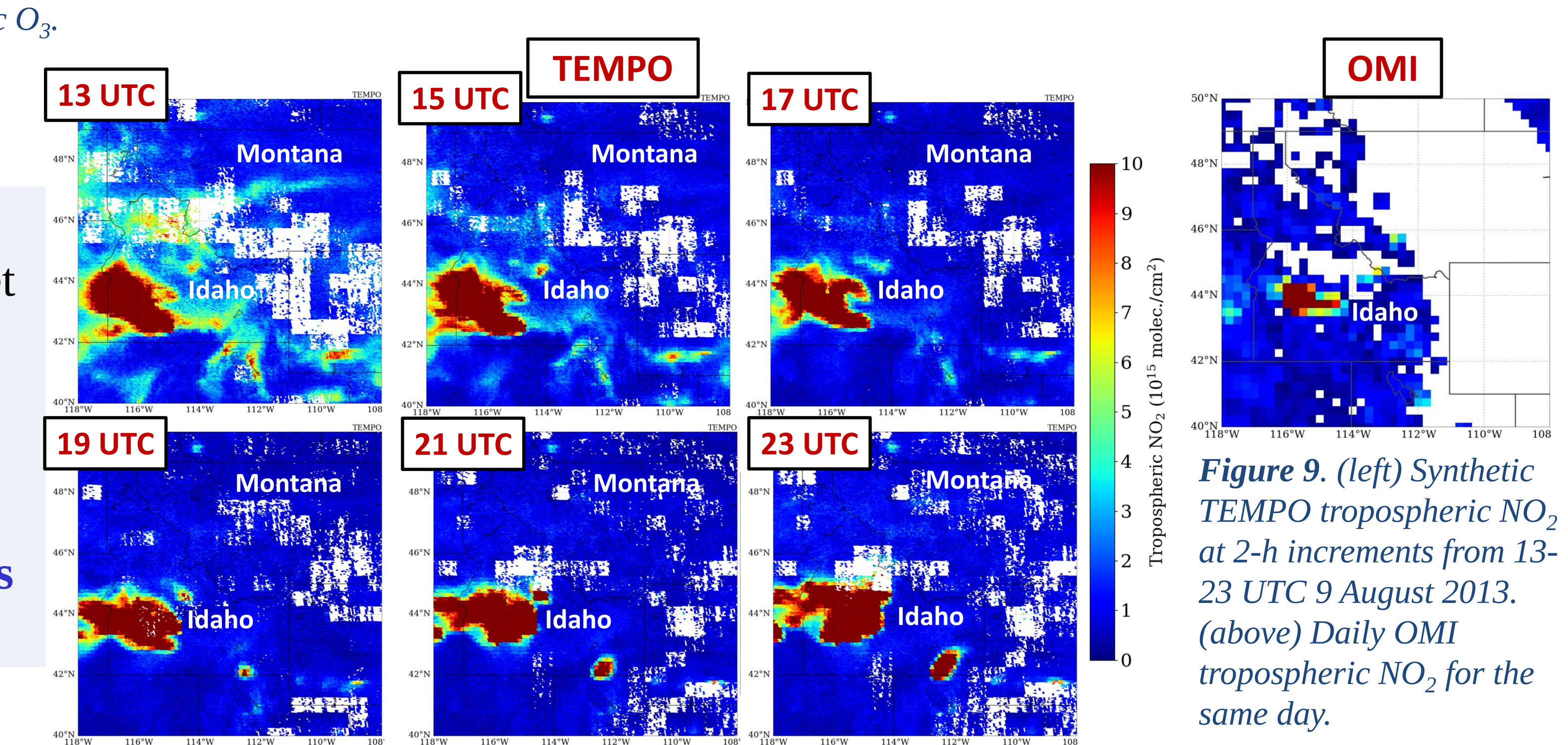


Figure 9. (left) Synthetic TEMPO tropospheric NO_2 at 2-h increments from 13-23 UTC 9 August 2013. (above) Daily OMI tropospheric NO_2 for the same day.

Mobile source emissions and attribution

- ➢ **Improved characterization of mobile source emissions will be realized from TEMPO data**
- ➢ **More robust source attribution studies by tracking emissions and transport in polluted regions**

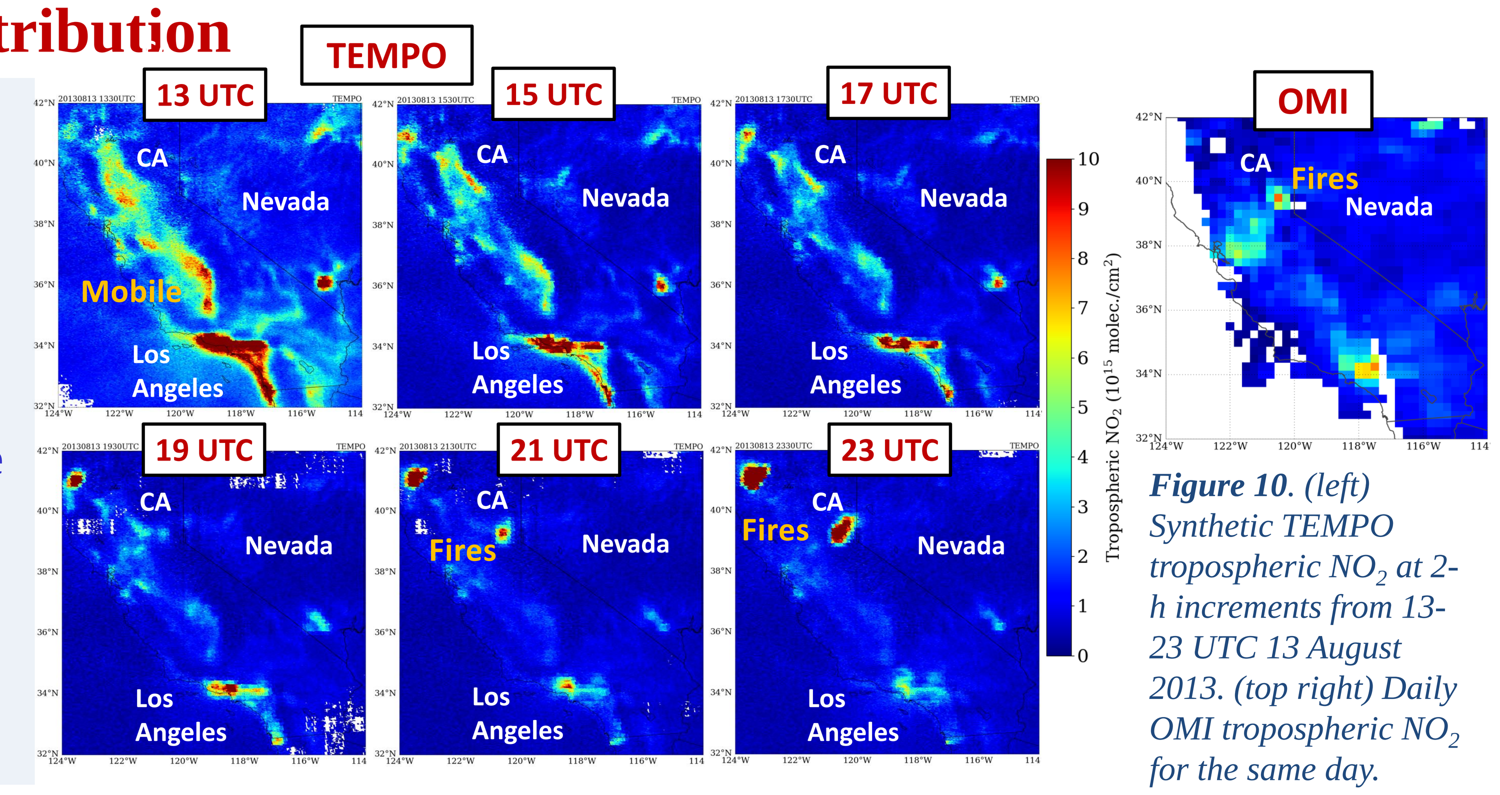


Figure 10. (left) Synthetic TEMPO tropospheric NO_2 at 2-h increments from 13-23 UTC 13 August 2013. (top right) Daily OMI tropospheric NO_2 for the same day.

Improved point-source inventories

- ➢ **Revolutionary monitoring of evolving pollution from point sources (e.g., industrial plants, oil fields)**
- ➢ **Significantly improved pollution inventories can lead to more realistic air quality forecasts**

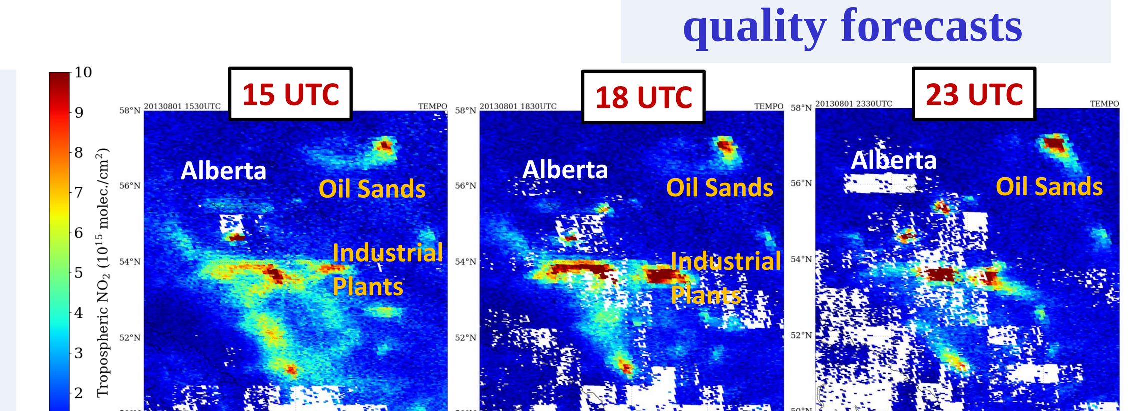


Figure 11. Synthetic TEMPO tropospheric NO_2 in morning, midday, and evening over Alberta, Canada on 2 August 2013.

Vegetation damage & O_3

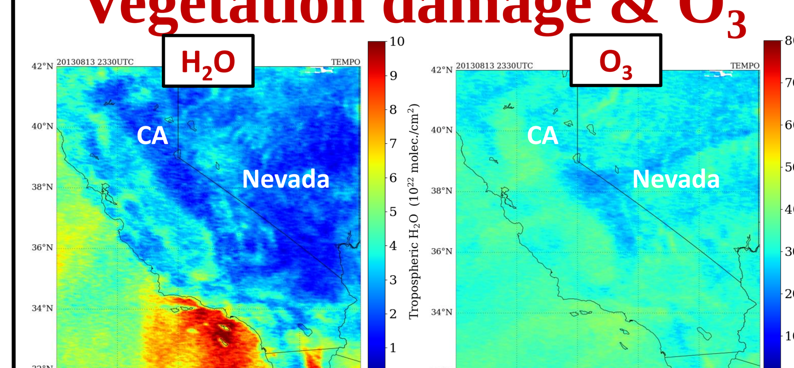


Figure 12. (left) Synthetic TEMPO tropospheric H_2O and (right) O_3 at ~2347 UTC 13 August 2013.

- Vegetation damage from O_3 amounts to several billion $ per year in U.S. (McGrath et al., 2015)
- ➢ **Detailed studies on O_3 impacts on vegetation from TEMPO data**

Summary and Future Work

Synthetic TEMPO data will play a key role in our active engagement with end users & stakeholders during the pre-launch mission phase, as the synthetic products will promote day 1 readiness for TEMPO data and help realize regional and local applications of the mission. Ultimately, these activities will advance the Applications Readiness Level (ARL) of TEMPO data prior to launch. We aim to extend the synthetic dataset to more recent periods (post-2017) to conduct assessments with TROPOMI data. Our upcoming analysis of GEMS data will also provide a sneak peek into future TEMPO applications.