# Linking Satellite Ammonia Retrievals with the AIRPACT Air Quality Modeling System.

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## Introduction

Ammonia (NH3) is an important atmospheric pollutant that is emitted primarily from decay of animals and vegetables. The National Aeronautics and Space Administration (NASA) Aura satellite houses the Tropospheric Emission Spectrometer (TES), which has recently been used to retrieve ammonia spectra and derive nadir profiles. AIRPACT (Air Indicator Report for Public Awareness and Community Tracking) is a decision support system for air quality managers in the Pacific Northwest (Figure 1). AIRPACT-forecast ammonia is compared to TES retrievals of ammonia concentration. Ozone (O3), a criteria pollutant of the Environmental Protection Agency (EPA) was also observed because of its availability in both AIRPACT and TES.

## Methods

AIRPACT is based on 2002 emissions with forward projection to 2005. Using this, five points with the highest NH3 emission rate were found. After finding these points and looking through TES data sets for a period with consecutive days and a variety of meteorological activities, July 2010 data swaths ranging from the 18th -30th were used for comparison with AIRPACT. For five selected high NH3 emissions sources as found in AIRPACT, TES swaths from each day (Figure 2) were analyzed and points that fell within 72 km were recorded. From the ten TES points selected, three data points were determined valid via a TES quality flag. The TES algorithm has a quality flag where data points with Degrees of Freedom of Signal (DOFS) less than .1 or with Average Cloud Optical Death greater that 2 (*TES L2 Data User's Guide*) are not to be accepted .

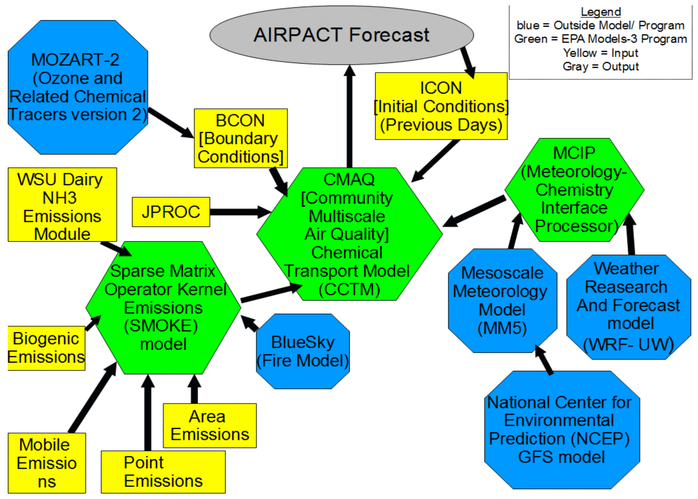


Figure 1: Layout of AIRPACT System

Table 1: TES and AIRPACT Points of Interest

| Location (name, state) | Alias | Emission Rate at major Source (moles $s^{-1}$) | Date | Time |
|---|---|---|---|---|
| 52 km east of Columbia Dairy Farms, Oregon | Location 1 | 23.470 | July 24th | 200 PST |
| 68 km east of Burney, California | Location 2 | 380.769 | July 24th | 1400 PST |
| 24 km south of Columbia Dairy Farms, Oregon | Location 3 | 23.470 | July 26th | 1400 PST |

Once the appropriate TES points were determined, AIRPACT pixels closest to the corresponding TES point were found and had their corresponding NH3 and O3 profiles recorded. Locations where TES overpasses and AIRPACT pixels matched are listed in Table 1. TES ammonia retrieval method is explained in Figure 4. NH3 concentration maps were made for several days to observe overall patterns of dispersion and movement (Figure 5 & Figure 6).

## Ammonia Analysis

Ammonia dissolves in water droplets in the atmosphere, then reacts in aqueous form. Once in aqueous form, NH3 can react with sulfur dioxide, to form ammonium sulfate or react with nitrogen dioxide to form ammonium nitrate (Renard et al.).

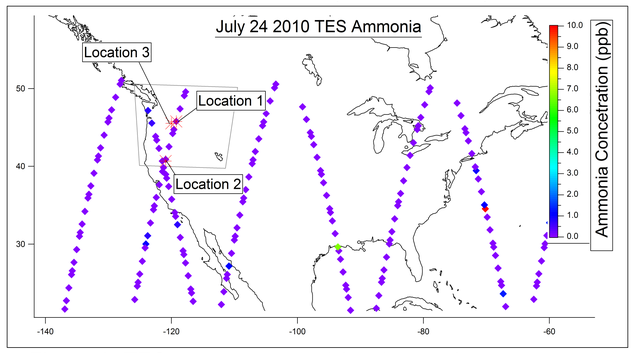


Figure 2: TES overpasses and 3 points on interest

The profiles for NH3 from TES and AIRPACT are typically similar (Figure 3). The Surface NH3 values for Location 1 were 2.74 ppb for AIRPACT and 1.01 ppb for TES. For Location 3, surface readings were 0.60 ppb for AIRPACT and 0.73 ppb for TES. Location 2 had somewhat of a larger disparity between the profiles for NH3 concentration. AIRPACT showed the surface concentration as 0.31 ppb, while TES showed 3.74 ppb for the surface. Compared to the other locations this is quite large, but the difference is roughly one magnitude greater. The differences in resolution for AIRPACT and TES played a role in the differences. Each AIRPACT cell is 12 km x 12 km, while the pixel for TES gas retrievals is 5.3 km x 8.3 km nadir (straight down). In a study by Shepard et al. (2011) TES retrievals were compared to GEOS (Goddard Earth Observing System)- Chem model results, TES typically produced higher NH3 values. One limitation was the limited number of points and days that had valid data. Another large issue was the large difference in altitude for which AIRPACT and TES produced values for ammonia. AIRPACT had more values at pressures greater than 600 hPa, or closer to the surface, while TES had the majority of values less than 500 hPa. Applications of this process for different days and species would be next in testing the strength of the link between AIRPACT and TES.

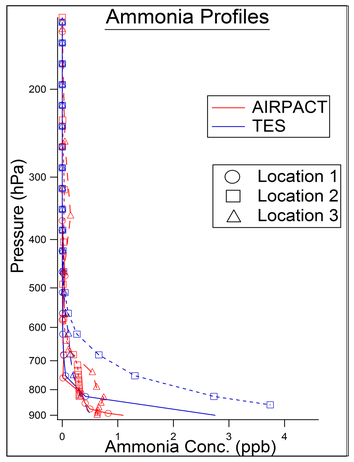


Figure 3: TES and AIRPACT Ammonia Profiles

**How TES Ammonia Retrieval Works**

- Primary sensitivity for retrieval is 700-900 hPa (Shepard et al.).
- Detectability for boundary layer mixing ratio is ~0.3 ppbv (Shepard et al.).
- Spectral residual differences measured in 960 $cm^{-1}$– 972$cm^{-1}$ range (Beer et al.).
- Ammonia abundance measure by taking difference between TES measured radiance and forward model radiance. Temperature, pressure, etc compensated for by TES retrieval algorithm (Beer et al.)
- Retrievals Based on optimal estimation approach that observes differences between radiative transfer and spectral radiances (Beer et al.)
- Significant seasonal and spatial variability across globe (Shepard et al.)

Figure 4: TES Ammonia Retrieval methods

## Ammonia Concentration Charts

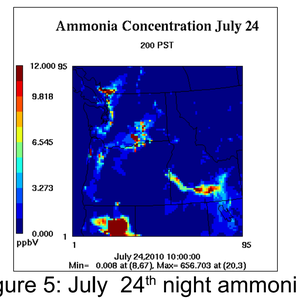


Figure 5: July 24th night ammonia

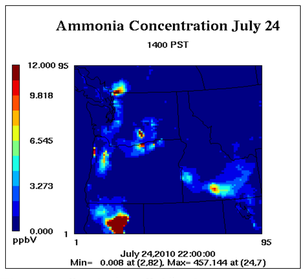


Figure 6: July 24th day ammonia

## Ozone Analysis

Ozone is a secondary pollutant, formed by photochemical reactions and other directly emitted emissions (specifically hydrocarbons and nitrogen oxides). Ozone typically quickly reacts with NO (nitrogen oxide) TES is one of the only instruments that currently can retrieve surface O3 from space. AIRPACT and TES ozone profiles (Figure 7) were obtained at the same locations as the NH3 profiles.

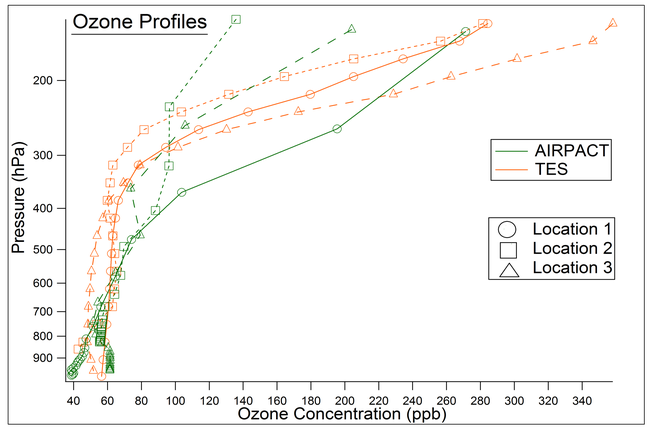


Figure 7: AIRPACT and TES Ozone Profiles

Location 1 had the largest difference proportionally between AIRPACT and TES for surface ozone. AIRPACT at the surface was 38.7 ppb, while for TES it was 56.5 ppb. Location 2 surface readings were 55.2 ppb for AIRPACT and 45.6 ppb for TES. Location 3 surface readings were 61.3 ppb for AIRPACT and 51.6 ppb for TES. Overall, the ozone profiles begin to diverge as the values move farther from the surface. Ozone surface concentrations, matched in time, are shown in Figure 8 and Figure 9.

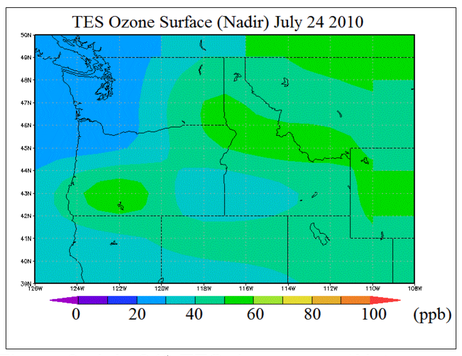


Figure 8: July 24th TES day ozone. *Note: "visualizations used produced with the Giovanni online data system, developed and maintained by the NASA GES DISC."

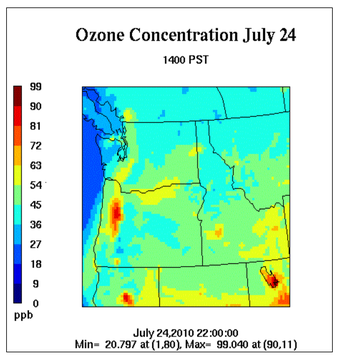


Figure 9: July 24th AIRPACT day ozone

## Conclusions

For both Ammonia and Ozone, TES and AIRPACT overall had very similar profile shapes at the selected locations. TES typically produced higher values at the surface for Ammonia. Ozone profiles were much more similar at the surface, then began to diverge around 400 hPa. For Ozone concentration across the AIRPACT domain, AIRPACT had much higher concentrations calculated along the southern and eastern border of the domain than TES did.

## References

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