The End-to-End OSSE of Ozone Mapping and Profiler Suite (OMPS) Limb Profiler

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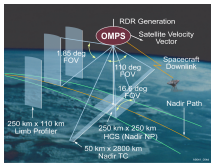
Introduction

The Ozone Mapping and Profiler Suite Limb Profiler (OMPS/LP) will fly on the NPOESS Preparatory Project (NPP) satellite, due to launch in October 2011. It provides ozone profiles with high-vertical resolution above cloud-top. This work describes an Observing System Simulation Experiment (OSSE) for the OMPS/LP instrument, using the GEOS-5 assimilation system. An assimilation of MLS ozone observations is used as the truth to derive OMPS/LP radiances at the tangent points of OMPS/LP observations. The OMPS/LP forward RT model, Instrument Models (IMs) and EDR retrieval model are introduced and pseudo-observations derived. These synthetic OMPS/LP observations are evaluated against the sampled truth, and the assimilations enable comparisons of the likely uncertainties in 3-D analyses of OMPS/LP data.

Instrument

Figure 1. OMPS Instruments FOVs



- **Limb Sensor**
  - NPP orbit: 833 km, 1330 Ascending Node
  - Triple-Slit prism spectrometer with 2-D CCD array
  - Spectral Range: 290 nm-1000 nm, with resolution from 2.7 nm UV to 35 nm NIR
  - Two separate apertures, two integration times (2x2 gain-ints) for the large dynamic range
  - Acquire about 7000 profiles per day
- **Specifications**
  - range of 0.1-10 ppm; from tropopause to 60 km
  - 3km vertical resolution, 250 km by 250 km footprint
  - Accuracy : 10% or 0.1 ppmv (15-50 km), 20% or 0.1 ppmv (>50 km or <15 km)
  - Precision: 3% or 0.05 ppmv (15-50 km), 10% or 0.1 ppmv (>50 km or <15 km)
  - 2% stability over 7 years

OMPS/LP OSSE - Schematic

Figure 2

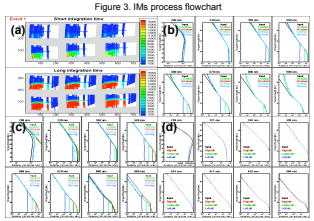
- **Generate TRUTH**
  - GEOS-5.2.0 (MERRA tag)
  - 1x1.25°L72 resolution
  - Conventional data & satellite radiances impact meteorology
  - Simple chemistry: O_3 P&L in GCM
  - MLS O_3 profiles (215-0.1hPa) and OMI TC assimilated
  - Hourly analysis output
- **Simulate Radiances**
  - Interpolate TRUTH to OMPS/LP observation points to 1-km profile
  - RT with pseudo-spherical atmosphere, multiple scattering, refraction, tangent shift, etc.
  - Random surface reflectance, cloud-top height simulated and aerosol selected from SAGE-II database

Validation

- **Assimilate Retrievals**
  - OMPS/LP data added to GSI in GEOS-5.6.1
  - The o3lev observer is used, same as for MLS
  - QC flag for poor-quality retrievals
- **Retrieve Profiles**
  - Rodgers' Optimal Estimation
  - Climatology as a-priori
  - First retrieve cloud-top height, tangent height, surface reflectance and aerosol distributions
  - Ozone profile retrievals
- **Apply Instrument Models (Fig-3)**
  - Instrument Simulator (3a-3b)
  - Deconvolution Model (3c)
  - Consolidation (3d)

The OMPS/LP Instrument Models

Figure 3. IMs process flowchart



- **Instrument, Deconvolution and Consolidation Models**
  - Instrument Model: the simulated radiances are mapped into CCD grids with noises, straylight for 2x2 gains-integration times (Fig. 3a), the 2x2 radiances rebuilt based on the "limit downloaded CCD" array signals (Fig. 3b)
  - Deconvolution Model: removes noises, straylight and deconvolves on the rebuilt 2x2 radiances (Fig. 3c)
  - Consolidation Model: reconstructs the radiance (SDR data) based on the 2x2 gains-ints radiances for each slit in maximizing the SNR without saturation

Retrieval Errors Statistics

- **Retrieval Errors and Estimated Retrieval Error (ESD)**
  - The retrieved profiles are compared to the input profiles (TRUTH) from the MLS assimilation
  - The estimated retrieval error (ESD) is deducted from the residuals of the optimal estimation
  - Figure 4 shows the mean and STD of retrieval errors, and the mean of ESD: a) one month global, b) one month in 12 latitude zones (15° step)
  - About 200k events are retrieved for month of 09/2009, about 97.7% of total events

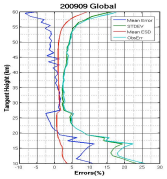


Figure 4a. Mean, STD and mean ESD for month of 09/2009 (~200k events)

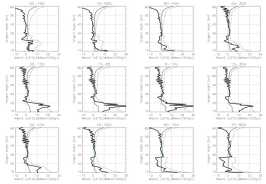


Figure 4b. Mean, STD and mean ESD for month of 09/2009 in 12 latitude zones (15° step)

Assimilation Experiments: The Observation Errors

- **Observation Errors**
  - In terms of the mean retrieval error (M), the standard deviation of retrieval error (S), and the mean of ESD (E), the observation error (OE) can be defined as:
    $OE = \mathrm{sqrt}(M^2+S^2)$ (1)
    Or, with consideration of the retrieval iterations:
    $OE = \mathrm{sqrt}(M^2+((S/E)\times ESD)^2)$ (2)
  - Two assimilations are performed, using Eq. (2). The first, called ObsErr1, assumes globally constant errors. The second, ObsErr2, uses OE for the 12 15°-wide latitude bands.
  - Additionally: S561 assimilates "TRUTH" sampled at OMPS/LP locations in GEOS-5.6.1

Assimilation Experiments: Preliminary Results

- **Ozone at 100 hPa**
  - Assimilated 100-hPa ozone distributions at 12Z on Sept. 16, 2009 are shown in Fig. 5.
  - Assimilation of both the OMPS/LP sampled "TRUTH" profiles and the retrieved OMPS/LP profiles result in similar ozone distributions to the TRUTH field.

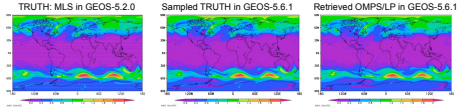


Figure 5. Assimilated ozone at 100hPa on Sept 16, 2009, as described on the headings

- **Analysis Errors**
  - Figure 6 shows the difference of the analysis from retrieved data to the TRUTH for 20090916_12Z at fields 5 hPa and 100 hPa
  - At 5 hPa, the errors are small in most of region. We can also see that the orbit track of OMPS/LP analysis "increment"
  - The errors at 100 hPa are bigger where the retrievals are most difficult in the Tropics.

Figure 6. Analysis error of retrieved ozone assimilation (ObsErr2) from TRUTH.

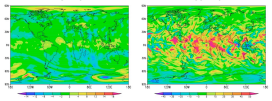
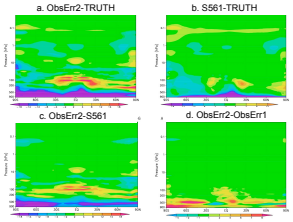


Figure 7. Zonal-mean differences of assimilated ozone.



- **Preliminary Results**
  - Figure 7 shows differences (%) in monthly zonal mean ozone fields in September 2009.
  - The largest departures from the "TRUTH" are in the lower stratosphere and the low troposphere (Fig. 7a,c)
  - Some of the tropospheric difference is from system differences (GEOS-5.2.0 & GEOS-5.6.1) and absence of OMI data in the OMPS/LP runs (Fig. 7a,b)
  - Specified observation error has largest impacts at lowest levels (Fig. 7d)

Summary

- Successfully implemented OMPS/LP radiance simulation, instrument models and EDR
- End-to-end OMPS/LP OSSE for ozone implemented into GEOS-5.6.1 system
- The OSSE is based on assimilated MLS ozone data being used as "TRUTH"
- Preliminary results show that the OMPS/LP data agree well with MLS in the middle and upper stratosphere
- In the lower stratosphere, especially in the Tropics, there is a larger discrepancy between MLS and OMPS/LP, which results in differences in the assimilated ozone
- Additional experiments are underway
- Interactions with the OMPS PEATE team have been mutually beneficial
- An operational version of the OMPS/LP system will be ready for NPP launch

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