Lessons Learned and Initial Assessment of Small Satellite for Data Assimilation: Part II

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Motivation and Goals

This is a pilot study aimed at providing **NOAA** with guidance on the feasibility and viability of smaller, cost-effective satellites as a potential solution for meeting the regional-to-global requirements of the future operational satellite enterprise. One aspect of this project involves assimilating LIDAR wind observations to improve numerical weather prediction (NWP). Some specific goals include the following:

- Assimilate ADM-Aeolus winds into **FV3GFS** and assess impact, focusing on regions and time periods of high uncertainty in **FV3GFS** that coincide with ADM-Aeolus data coverage.
- Address, in coordination with JCSDA, the required flexibility and agility of the **GSI** data assimilation system.
- Address, in coordination with the Center for Satellite Applications and Research **(STAR)**, potential improvements in the O2R and R2O workflows and support systems.

For more details regarding the scope of this project and companion research goals see the poster by Ting-Chi Wu.

ADM Aeolus Satellite

ADM-Aeolus: Launched 22 August 2018

ALADIN: Atmospheric **LA**ser **D**oppler **IN**strument

Orbit: Sun-synchronous

Mean altitude: ~320 km

Local time: 18:00 ascending node

Inclination: 96.97°

Repeat cycle: 7 days/111 orbits

Orbits per day: ~16

Measurements: UV Doppler wind Lidar operating at 355 nm and 50 Hz PRF in continuous mode, with 2 receiver channels (HSRL):

- Mie receiver (aerosol and cloud backscatter)
- Rayleigh receiver (molecular backscatter)

L2b data: Horizontally projected, clear, Rayleigh LOS (**HLOS**) wind profiles

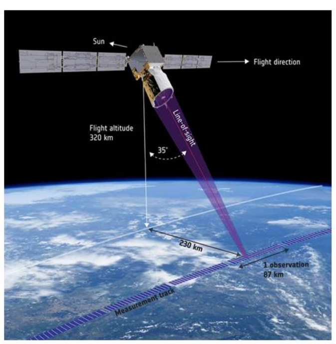

Figure 1: Aeolus measurement geometry: The wind is observed orthogonal to the satellite ground-track, pointing 35° off-nadir, away from the Sun. (Copyright: ESA/ATG medialab)

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Aeolus Data

To create the ADM-Aeolus observation file, **gdas.t06z.adm.tm00.bufr_d**, five **ECMWF** BUFR files were combined with an **NCEP** header that included the appropriate mnemonics that are necessary to be read and assimilated by **GSI**. Images of the orbital path for these observations and their vertical distribution are seen in figures 2 and 3 respectively. This initial experiment used the data as-is and did not take into account known issues in the data products. Future experiments will apply quality control preprocessing and take advantage of the improved data produced by future ADM reprocessing campaigns

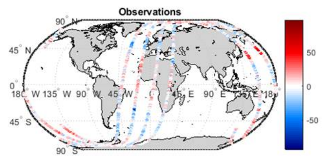

Figure 2: Ascending and descending paths for five observation files that have been included in initial assimilation tests.

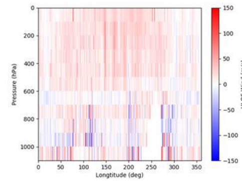

Figure 3: Vertical distribution of ADM-Aeolus observations shown in figure 2.

GSI Configuration and Initial Results

The initial code in **GSI** to read and assimilate Doppler Lidar wind observations was developed several years ago. Our experiments utilize this existing code and implemented some necessary format changes to conform to the **ECMWF** retrieval fields. A stand-alone **GSI** (ProdGSI – Aeolus_S4) is then able to assimilate ADM-Aeolus observations with the following configurations:

- Takes **FV3GFS NEMSIO** output (both first guess and ensemble) and generates a global analysis using hybrid 3D-EnVar
- read_lidar.f90 modified to read ADM-Aeolus BUFR file
- Initial experiments include assimilating conventional, satellite, and ADM-Aeolus observations
- Assimilation time: December 8, 2018 6Z
- Resolution: C768

Note: only ADM-Aeolus wind observations were assimilated in the results presented here.

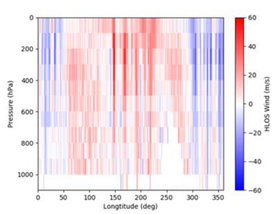

Figure 4: Similar to figure 3, this is the vertical distribution of ADM-Aeolus observations assimilated in **GSI**.

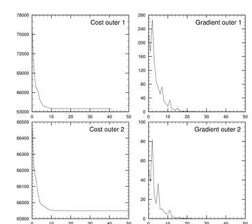

Figure 5: The minimization of the cost function shows **GSI** is performing well with the ADM-Aeolus observations.

DA Results (continued)

By assimilating horizontal, line-of-sight (**HLOS**) wind observations, we expect to see a greater impact in the zonal winds rather than the meridional winds in the **GSI** analysis. Early inspection of the data assimilation experiments confirms this assumption.

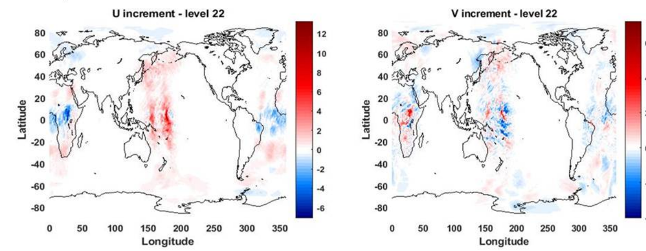

Figure 6: Analysis increments for the zonal and meridional winds resulting from the assimilation of **HLOS** winds.

Lessons Learned and Future Work

Improving NWP with the inclusion of small satellite observations has presented several challenges within this project:

Computational Resources: Obtaining HPC account access and allocation; compiling **FV3GFS** and **GSI** on these HPC's; identifying available support systems and coordinating with others who have already solved these issues

Data: Obtaining the small-sat data in the appropriate format (BUFR) for assimilation; modifying the DA system to read these data files; collaborating with members of the community focusing on CAL/VAL to understand the data quality

Data Assimilation: Determining how to leverage previous research regarding the assimilation of LIDAR winds and the steps required for ADM-Aeolus observations; identifying case study regions and time periods of high uncertainty in FV3GFS forecasts that coincide with ADM-Aeolus data coverage; assessing the quality of the assimilatoin results

While progress has been made with assimilating small satellite LIDAR winds, several steps and goals remain:

Approach: Adjust observation operators for ADM-Aeolus data as necessary; tune-up the GSI system to ADM-Aeolus data; evaluate necessary QC procedures with CAL/VAL team; perform cycled **FV3GFS/GSI** experiments

The Bigger Picture: Given the need for a quick turnaround of ADM-Aeolus and other new CubeSat/SmallSat data, we will address, in coordination with JCSDA, the required flexibility and agility of the GSI data assimilation system. We will work with partners at NOAA and NASA to facilitate the transition of this assimilation system into operations.

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