UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE

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SUBJECT: Assessing the Impact of Losing Legacy Satellites on NOAA Global & Regional NWP

Scope:

This memo provides a brief summary of a quantitative and qualitative assessment of the impact(s) that could result from the decommissioning of the Polar Operational Environmental Satellites (POES) legacy sensors manifested on NOAA-15, -18, and -19. The impacts of decommissioning these satellites are centrally applicable to global NWP system skills, but we will also mention other applications. A separate memo will discuss impacts on other applications. Based on this assessment, and based on a few rounds of technical experts' discussions and studies, recommendations are provided in this memo. It is important to note that this assessment and recommendations are made from a strictly technical/scientific perspective. Other considerations, such as cost of maintenance, ground processing, security requirements, etc., were not accounted for, although they were discussed.

Important note: *This memo was developed based on the deliberations and discussions among the core-SAT (U.S. federal employees only), following fact-finding and discussions of results and scientific facts, with the general SAT (which includes NOAA and other U.S. agencies SMEs, including NESDIS and other LOs, as well as academic and other partners).*

Executive Summary:

- ***Fact:*** There is evidence to suggest that decommissioning the legacy sensors will have significant negative impacts on global NWP. This significant impact has been verified using different modeling systems by different NWP centers (NOAA, NASA, DoD/NRL) and by using different datasets producing forecasts over different periods of time. See details below.
- ***Fact:*** Other NOAA applications (beyond NWP) will also experience a significant degradation of performance due to reduced spatial and temporal measurement coverage. Impacts include reductions in: accuracy of quantitative precipitation forecasts, reduced quality of the blended total precipitable water (TPW) product, and the availability of microwave imagery.
- ***Fact:*** Supplemental imagery from POES supports National Weather Service (NWS) Alaska Region mission activities, such as volcano monitoring and ice analyses. Additional imagery that POES provides helps meteorologists maintain situational awareness over northern Alaska, where geostationary satellite imagery is at poorer resolution due to the local zenith angle effects.
- ***Fact:*** In addition to forecast skill impact, the decommissioning of legacy sensors will have a direct negative impact on the robustness and resiliency of the overall global observing system.

- ***Fact:*** International partners, including ECMWF and the UKMO, have assessed the potential impacts of not having data from U.S. legacy sensors on their systems. These were presented at different venues and were found to be consistent with results found in U.S. studies.

- ***Fact:*** The NWP negative impact of removing the legacy sensors from the assimilation system, was found to be even bigger than the impact of removing the entire NOAA-20 suite of sensors (CrIS and ATMS).

- ***Recommendation:*** NOAA, if feasible, should maintain operation of the legacy POES sensors for as long as reasonably possible in order to avoid the significant negative impacts on NWP and other NOAA applications.

Background:

Legacy POES satellites (NOAA-15, NOAA-18, and NOAA-19), as well as DoD sensors on the DMSP satellites, are potentially scheduled for decommissioning due to growing operating costs and IT security requirements. Currently, the legacy POES ground system was given a waiver for IT security through 2022. Observing System Experiments (OSE) Studies have been conducted by NOAA/NESDIS, NOAA/OAR, DoD/NRL, and NASA/GMAO to assess the impact of the loss of these satellites on NWP users. The full details of the experiments undertaken, as well as the list of sensors that were used (or denied) in the data denials experiments by the different centers, are described in the accompanying briefing document cowritten by representatives from NOAA, NASA and DoD.

Findings:

All regional and global data denials studies (OSE experiments) show significant degradation in various forecast parameters as verified against several standard references. Detailed information about the findings of these OSEs is included in the accompanying document. In some cases, it was demonstrated that other components of the satellite global observing system can partially compensate for the loss of legacy POES, but significant impacts remain. Removal of the legacy sensors also introduced gaps in overall satellite spatial coverage. Below are some important highlights from these studies.

- The NESDIS study examined impacts on the global FV3GFS model. There were day-one impacts for all studied parameters (heights, temperature, and vector winds) in the northern hemisphere and even larger impacts for the southern hemisphere out to Day 5. The study also indicated negative impacts on forecasted surface vector winds in the tropics.
- The OAR study was a one-month OSE using the Rapid Refresh (RAP) North American model. Removing the POES data resulted in a 6% degradation in the normalized impact metric for temperature, moisture and wind. There is also a modest reduction in radiance observations and a modest degradation in forecast skill.
- The NRL study focused on Navy Global Environmental Model (NAVGEM). Denying POES data in NAVGEM showed a significant degradation for global precipitable water and vector winds when ECMWF analyses were used as reference.
- The GMAO study looked at Goddard Earth Observing System (GEOS-5) models. The forecast skill score showed dramatic deterioration in predictive skills due to the removal of POES. There was a significant drop in the early-to-mid period of the 5-day forecast and a significant deterioration up to the 48-hour forecast.
- Aside from NWP, users in the NWS have general concerns about how the premature conclusion to the POES program will challenge support for certain mission services. Other impacts to decommissioning the legacy POES and DMSP satellites could include:

    - (a) A decrease in skill of hurricane track forecasts due to loss of additional microwave imagery that provides detail of the internal structure of developing and mature cyclones;
    - (b) A decrease in the quality of ice analyses due to the loss of high-resolution visible, high-resolution infrared window, and passive microwave imagery that is only available from low-earth orbiting (LEO) satellites;
    - (c) A decrease in meteorologist situational awareness due to the reduction in supplemental (LEO) satellite imagery for monitoring deep convection and mid-high clouds;
    - (d) A decrease in the detectability and prediction of extreme weather events, particularly in data sparse (e.g., oceanic) areas and Southern Hemisphere;
    - (e) A gap in climate data, particularly the T(p) climate series, due to a discontinuity in the longstanding POES data without replacement;
    - (f) A decrease in accuracy of blended TPW due to fewer inputs in cloudy fields of view and less inputs overall;
    - (g) A decrease in the accuracy of quantitative precipitation forecasts (QPFs) due less frequent sampling of rain rate, TPW retrievals, and the aforementioned decreased accuracy of multi-source blended TPW products; and

- (h) Less frequent imagery over Alaska and the poles, potentially decreasing the consistency of weather services due to less optimal geostationary satellite coverage.

Note: Other sensors are planned to be added in the assimilation system (Metop-SG for example), which may help fill the gaps. However, when COSMIC-2 and Aeolus additions were assessed, their added values were smaller than the loss of skills from legacy sensors. Impact studies were completed by removing the legacy sensors all at once, which would have a bigger impact than letting instruments and satellites to fail on their own, one by one.

Example of Impact: As an illustration of the degradation of forecasting skill, the following example (see Figure 1) represents the impacts on the NOAA system (GDAS), undertaken by Garrett et al. 2020. The overall score shown in Figure 1 concatenates the averaged RMSE and AC score for all forecast hours (0-168hr) for height, temperature, wind, and relative humidity at several layers (including 250, 500, 700, 850, and 1000 hPa) for the entire experiment period.

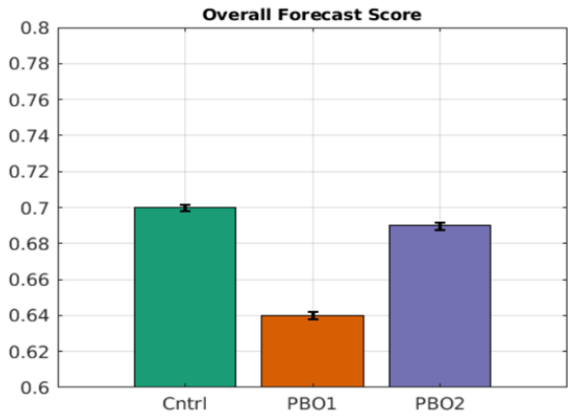

Figure 1. Overall score of forecast skill of the NOAA GFS system. The control run -operational configuration as of October 2020- (green: Cntrl) is compared to (1) the data denial experiment (red: PBO1) - where legacy sensors are removed, (2) the data denial experiment where NOAA-20 has been removed from the data assimilation system (blue: PBO2). A higher score indicates a better forecast skill. The uncertainties of the scores are represented by the error bars on the histogram bars.

In this example above, the impact of removing the legacy sensors from the NOAA data assimilation system results in a statistically significant negative impact. This impact is actually found to be much more significant than the impact of removing the NOAA-20 sounders (CrIS and ATMS).

Recommendation:

Given the facts above, it is recommended that NOAA maintain the legacy sensors as long as possible in order to avoid the significant impacts from losing these sensors, and plan for continuity of these capabilities to mitigate the risk of losing these vital data when the legacy POES missions finally end.

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