CGMS

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Prepared by EUMETSAT
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RESULTS FROM STUDIES SUPPORTING POLAR PLATFORM ORBIT CONSIDERATIONS

Currently, data from a large number of instruments flown on polar platforms are used in numerical weather prediction, nowcasting and climate applications. However, in many cases the platforms are flown in similar orbits or maintained by research organisations rather than operational organisations. In order to increase the impact of this data, an optimised configuration of the relevant platforms in the future would be desirable and in line with the Vision for the GOS in 2025 and would support the Revision of the CGMS Baseline for GEO, LEO and HEO satellites (CGMS-38 WMO-WP-03).

This paper will introduce some work done relevant to polar platform satellite configuration, in particular a study on "ATOVS Orbit Constellation Observation System Experiments" performed under a EUMETSAT fellowship at ECMWF.

Action/Recommendation proposed:

In view of the results presented in this paper, emphasising an improved impact of satellite data through optimised orbit allocation, and noting that the total lack or loss of observations for a specific orbit has a larger negative impact than the sum of the impact of individual instruments would suggest, the CGMS Operational Satellite operators are proposed to reconsider and coordinate the current orbit allocation and payload deployment strategy.

Results from studies supporting polar platform orbit considerations

1 INTRODUCTION

Currently, data from a large number of instruments flown on polar platforms are used in numerical weather prediction, nowcasting and climate applications. However, in many cases the platforms are flown in similar orbits or are maintained by research rather than operational organisations. In order to increase the impact of this data, an optimised configuration of the relevant platforms in the future would be desirable and in line with the Vision for the GOS in 2025 and support the Revision of the CGMS Baseline for GEO, LEO and HEO satellites (CGMS-38 WMO-WP-03).

This paper will introduce some work done relevant to the polar platform satellite configuration, in particular a study on “ATOVS Orbit Constellation Observation System Experiments performed by Enza di Tomaso under a EUMETSAT fellowship at ECMWF”.

2 SUMMARY OF ATOVS Orbit Constellation Observation System Experiments

In order to characterise the benefit for NWP of having ATOVS data from three evenly-spaced orbits versus data from a less optimal coverage, and to be able to assess the benefit for NWP of assimilating ATOVS data from more than three satellites, ECMWF on behalf of EUMETSAT conducted a set of ATOVS Orbit Constellation Observing System Experiments. For the study selected microwave sounding instruments flown in a polar orbit were considered with respect to their equatorial crossing time. The study covered the period from14 April to 9 August 2009 and experiments were run with the ECMWF model at T255 resolution with a 12 hour assimilation window.. Figure 1 gives an overview of the satellites available: the NOAA series, NASA’s Aqua and the European Metop-A

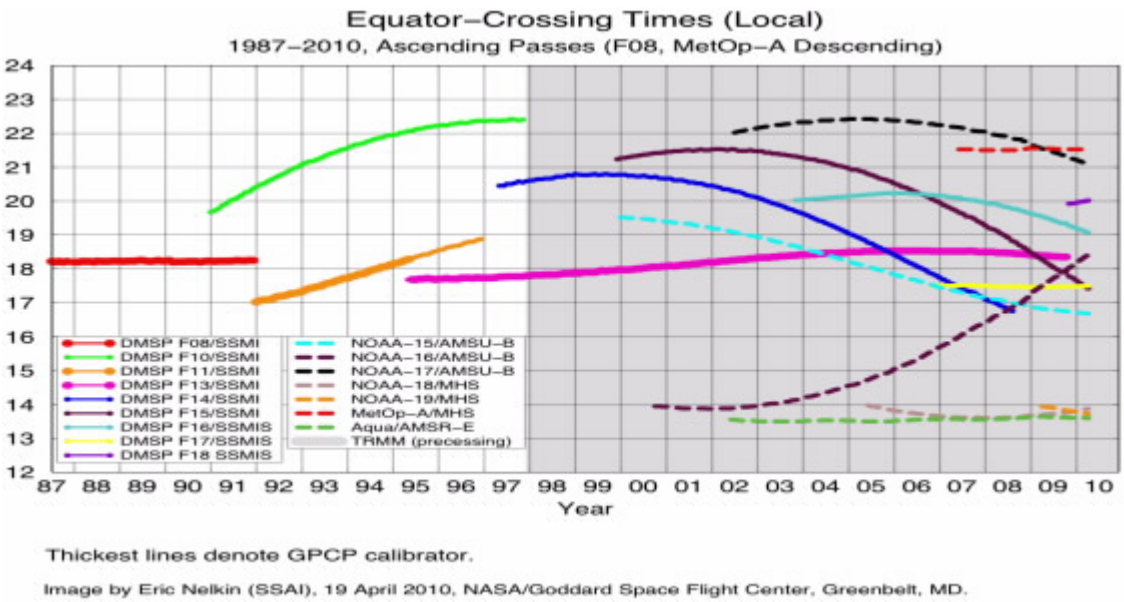

Figure 1. Current constellation of microwave sounders in low earth orbit.

The study used a baseline observation system in which all microwave sounder data was removed except for the Metop-A and the NOAA-18 AMSU-A and MHS

instruments. All other observations were used as in operations at the time. Figure 2 presents the availability of the ATOVS data for a 6-hour period, demonstrating the data availability from two polar orbiting satellites.

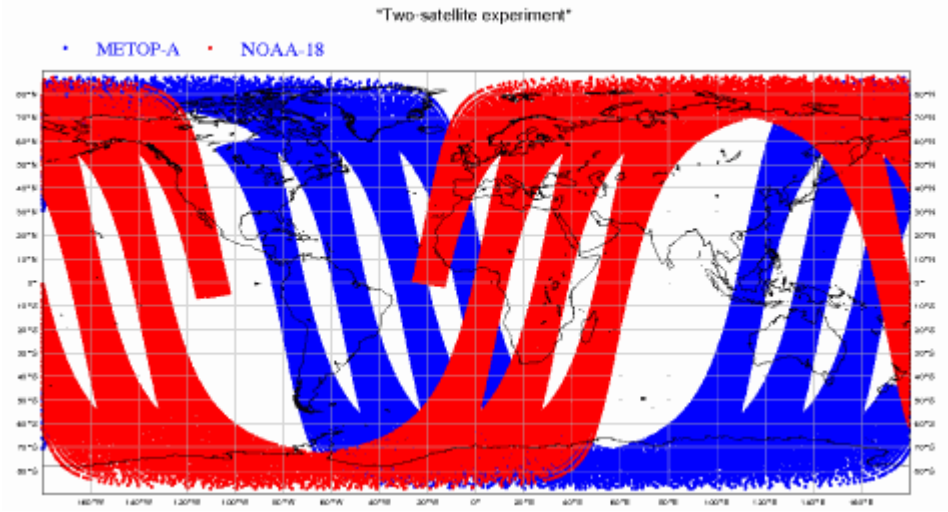

Figure 2. AMSU-A coverage for the baseline system (NOAA-18 and Metop) for a 6-hour period.

On top of this baseline two main experiments were conducted. The first added NOAA-19 AMSU-A data on top of the baseline and the second added NOAA-15 AMSU-A data on top of the baseline. These two experiments represent a non-optimal polar configuration (NOAA-19) and a more optimised configuration (NOAA-15) in terms of relative spacing of the orbits. Figures 3 and 4 show the AMSU-A data coverage for these two experiments for a 6-hour window, and even though the addition of NOAA-19 data does improve the data coverage, it is evident that the coverage is significantly better when the NOAA-15 data is added instead of NOAA-19.

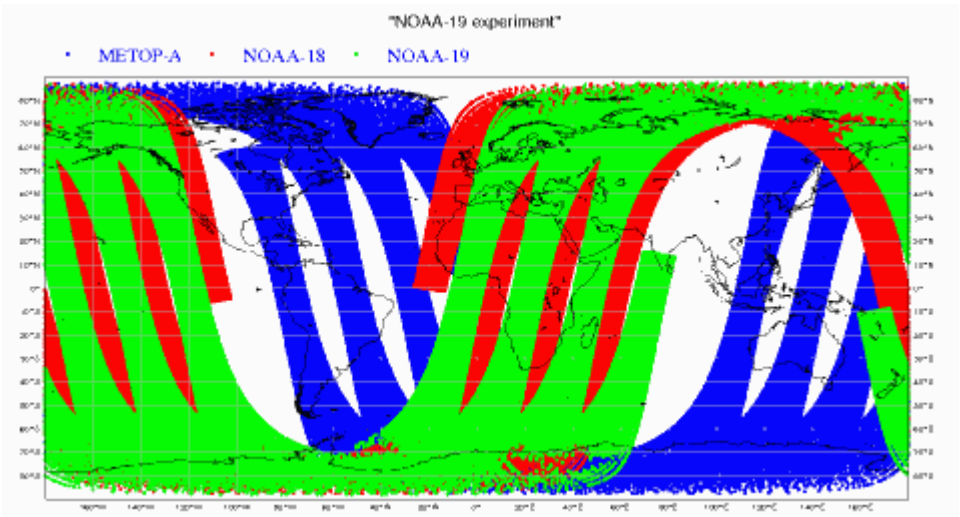

Figure 3. The AMSU-A data coverage when NOAA-19 is added to the baseline configuration:

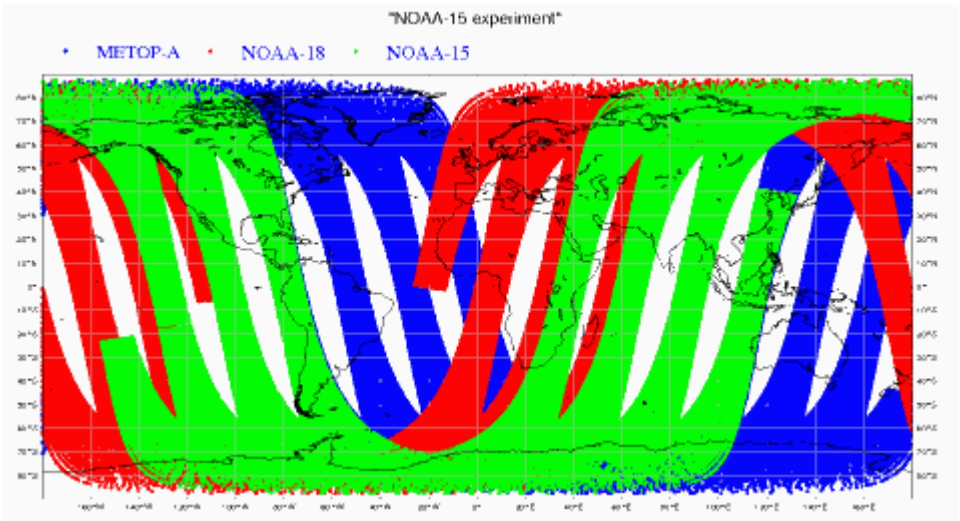

Figure 4. The AMSU-A data coverage when NOAA-15 is added to the baseline configuration:

The impact of adding data from a third microwave instrument showed a positive impact on both the analysis and the forecast. Figure 5 demonstrates this impact through a small improvement of the fit to temperature observations

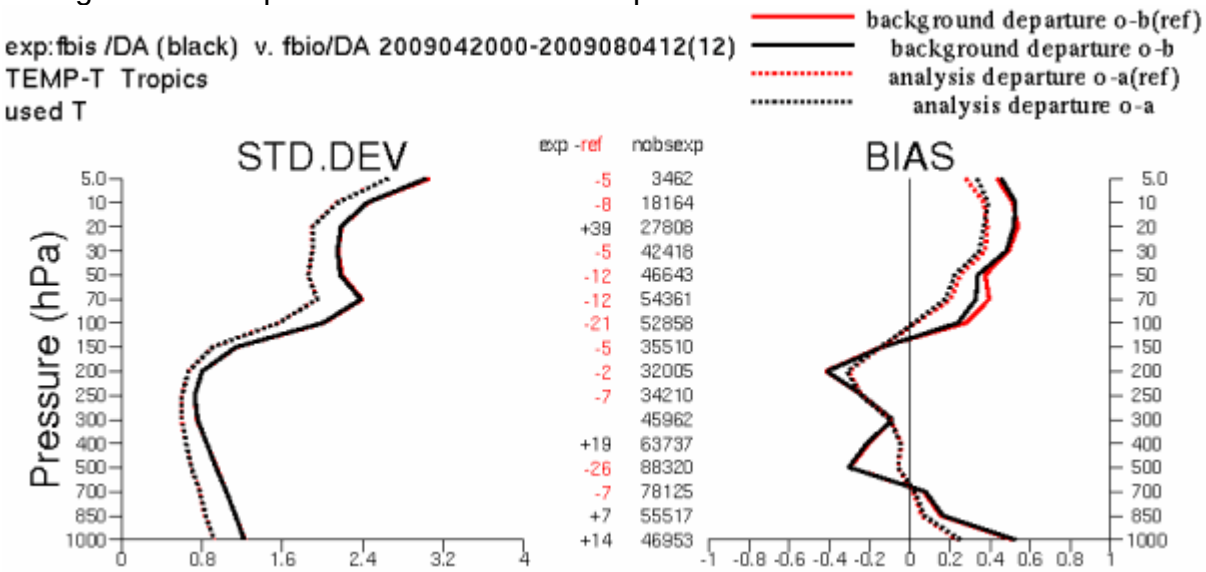

Figure 5. The fit to radiosonde temperature observations for the two (red) versus three (black) microwave sounder constellation.

Finally, the performance of using NOAA-15 instead of NOAA-19 was investigated in terms of forecast impact. Figure 6 shows the normalised differences of the root mean squared forecast error for the geopotential height forecasts between the two experiments, where negative values show a stronger positive impact from NOAA-15 (optimal) and positive values a larger benefit from NOAA-19 (non-optimal). The overall impact from NOAA-15 is slightly more positive than NOAA-19.

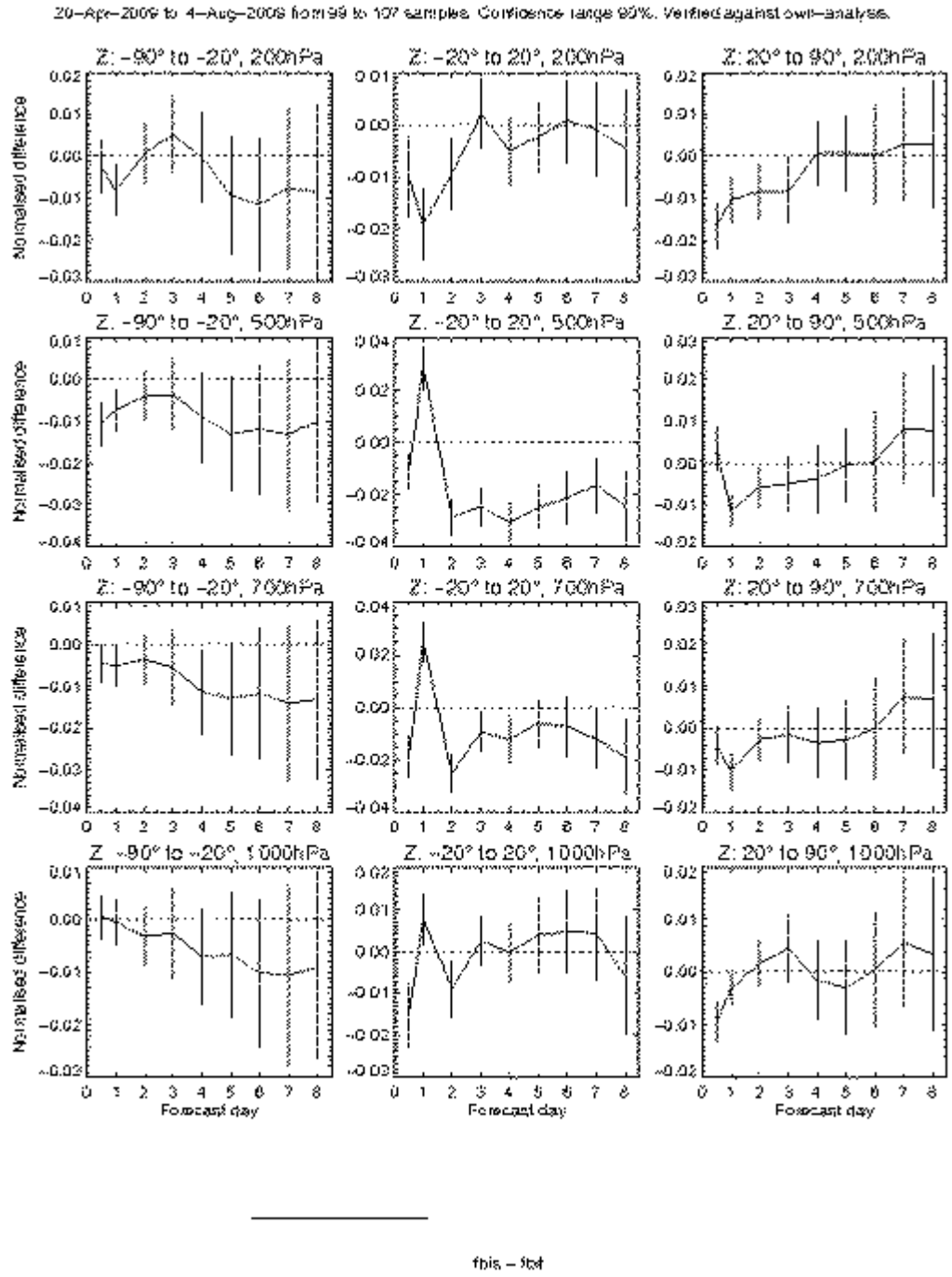

Figure 6. Normalised differences of the root mean squared forecast error between the NOAA-15 and NOAA-19 experiments for geopotential height over a range of pressure levels. Negative values show a stronger benefit from NOAA-15 and positive values a stronger positive impact from NOAA-19.

In addition to these two studies the impact of adding further microwave instruments was studied. The main conclusion of this study is that by increasing the amount of assimilated microwave sounding data beyond three instruments, further benefits were achieved.

In summary the main conclusions from the study are:

- ATOVS data in a more evenly-spaced orbit configuration give slightly better results in terms of forecast impact in the Southern Hemisphere than data from a less optimal coverage
- Both the assimilation of NOAA-15 and NOAA-19 observations have a positive forecast impact in the Southern Hemisphere in comparison to the use of just two satellites, and there is a clear additional advantage in assimilating all available ATOVS data from the seven satellites with some ATOVS instruments available for the study period.
- The benefit of evenly-spaced orbits is expected to be stronger in limited area systems where the coverage plays a more crucial role

3 ADDITONAL STUDIES

3.1 Recommendation for Metop Satellite Phasing

In preparation for the launch of the next Metop polar orbiting satellite (to be designated Metop-B after successful commissioning), EUMETSAT undertook a consultation process with its member states and studied the impact of various separation distances of two Metop- satellites in the same orbital plane. The main outcome from this study is that through careful considerations of the orbital configuration the amount of data used in any limited data assimilation window can be optimised. However, depending on specific instrument characteristics, the result may vary depending on the instrument in question (providing they fly on the same platform) and hence an overall trade-off maximising the positive impact on NWP may have to be taken and can have an impact on instrument deployment strategy (i.e. all instruments on one platform or a distribution of instruments of several platforms with differing orbits..

3.2 Study on Observing System Experiments (OSEs) for the evaluation of degraded EPS/Post-EPS instrument scenarios

The main objective of this study performed by ECMWF (Bauer and Radnoti, 2009) was to assess the detrimental impact of a potential loss of the main EUMETSAT Polar System (EPS) instruments on global Numerical Weather Prediction (NWP) forecast skill. This impact has been evaluated through a set of Observing System Experiments (OSE) that simulate the expected observing system for the EPS/Post-EPS time frame. The impact of losing the individual Metop instruments IASI, ASCAT, HIRS, AMSUA and MHS has been evaluated for two periods, i.e. summer 2007 and winter 2008. For GOME 2 and GRAS later periods have been added to account for the delayed implementation of these observations in the ECMWF system. The experiments were based on the operational ECMWF model and four-dimensional variational data assimilation systems with slightly reduced spatial resolution.

The evaluation has been carried out by means of standard analysis and forecast verification that have been similarly applied in past OSE studies. In this study, the constellation has been simulated by only using microwave sounder data from Metop, Aqua and NOAA-18 in the reference observing system. Additionally, two microwave imagers were expected to be available from the DMSP/NPOESS morning orbit

platforms which were represented by DMSP F-13 and 14 here. Two advanced sounders (as from Metop and NPP) were accounted for in morning and afternoon orbits by IASI onboard Metop-A and AIRS onboard Aqua. HIRS will be discontinued after Metop-B and therefore only a single HIRS instrument has been kept. The HIRS observing capabilities are expected to be fully replaced by advanced infrared sounders in the future,

The verification with analyses was performed using both the experiment's own as well as the operational ECMWF analysis.

Most of the results were very similar in both periods. A major finding was that the combination of withdrawn instruments (either conventional sounders HIRS, AMSU-A, MHS or the entire set of instruments, i.e. conventional plus advanced sounders) produced a much stronger negative impact on the analyses than the denial of individual instruments. This implies that the complementary value of the Metop instruments is larger than the sum of the value of individual instruments.

Denying all Metop data led to an increase of 500 hPa geopotential height forecast errors of 2-4% in the Northern and 3-5% in the Southern hemisphere in winter. In summer the impact is stronger with 2-5% in the Northern and 6-9% in the Southern hemisphere. This impact lasts well into the medium range. Given the overall accuracy of geopotential forecasts, these numbers are very large and indicate the significant detrimental impact if the Metop satellite would be lost.

Denying the combined conventional sounders produced an increase in 500 hPa geopotential height forecast error of up to 2%. Denying IASI alone only showed a smaller effect but the forecast degradation remained significant with 1-3% in the Southern hemisphere when the operational analysis was taken for verification.

It should be noted that the satellite data used in this study do not represent an optimised orbit configuration as discussed in (CGMS-38 WMO-WP-03) and therefore the result will be slightly different when analysing the impact of an optimised orbit configuration. However, the study demonstrates the current capabilities in analysing the impact of available satellite data for NWP and can be used a starting point for detailed discussions on a future optimised GOS.

4 CONCLUSION AND RECOMMENDATION

The discussion paper introduces two separate studies relevant to the Vision for the GOS in 2025 and supports the Revision of the CGMS Baseline for GEO, LEO and HEO satellites (CGMS-38 WMO-WP-03). The studies demonstrate the current capabilities to analyse polar platform configurations in order to optimise their impact.

In view of the results presented in this paper, emphasising an improved impact of satellite data through optimised orbit allocation, and noting that the total lack or loss of observations for a specific orbit has a larger negative impact than the sum of the impact of individual instruments would suggest, the CGMS Operational Satellite operators are proposed to reconsider and coordinate the current orbit allocation and payload deployment strategy.

Reference: Bauer P. and G. Radnoti, 2009: Study on Observing System Experiments (OSEs) for the evaluation of degraded EPS/Post-EPS instrument scenarios (EUMETSAT Contract EUM/CO/07/4600000454/PS).