Monitoring air quality: The role of OSSEs in determining the future global observing system

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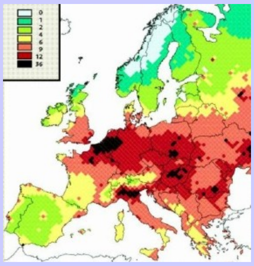
1. The Global Observing System (GOS) and Air Quality (AQ):

AQ depends on local contributions (emissions), chemistry, and transport processes; it is highly variable in space and time. Key lower-tropospheric pollutants include O_3, aerosols (e.g. PM), and O_3 precursors such as NO_x ($NO+NO_2$). Owing to its relatively longer lifetime, tropospheric CO provides information on sources of pollution and transport processes affecting AQ.

AQ impacts human society: high concentrations of O_3, PM, and NO_2 near the Earth's surface cause health problems (Fig. 1); health costs attributed to AQ are significant (Lahoz *et al.*, 2012).

To monitor, forecast, and manage AQ, observations are needed at temporal frequencies <1 hr, and spatial scales < ~10 km (Fig. 2; Lahoz *et al.*, 2012). The GOS for monitoring AQ includes surface networks, Low Earth Orbit satellites (LEOs), and geostationary satellites (GEOs). ***GEO is the only realistic space-based solution providing this information from space***, but important technical difficulties concerning instrument design must be overcome (Lahoz *et al.*, 2012).



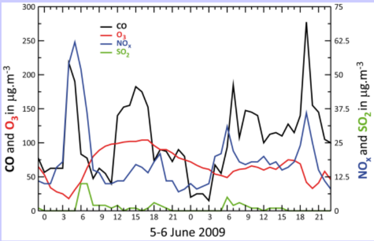


Fig.1 (above left): *Reduction in life expectancy by PM pollution (months, EU).*

Fig. 2 (above right): *Temporal variability: O_3 (red), CO (black), NO_x (blue), SO_2 (green), measured over period 5–6 Jun 2009 at Reims, France [x axis: hr; y axis: concentration ($\mu g\ m^{-3}$)]. © Copyright 2012, American Meteorological Society (AMS) Lahoz et al. 2012 (BAMS).*

2. The Observing System Simulation Experiment (OSSE) concept:

To assess the value of GOS elements for monitoring AQ, OSSEs are performed (Masutani *et al.*, 2010). They are increasingly used by space agencies to assess the incremental value of future missions. Only a few OSSEs for AQ have been performed (Edwards *et al.*, 2009; Timmermans *et al.*, 2009; Claeyman *et al.*, 2011a, b). In contrast to OSSEs for meteorology, OSSEs for AQ generally only consider one observation, chiefly owing to the sparsity of AQ observations. Elements of an OSSE for AQ are (Fig. 3):

- Simulated atmosphere ("truth" - "Nature Run"; T): using model, analyses;
- Simulated observations of instruments under study, including errors: using the Nature Run;
- Assimilation system: using a model (if possible, different from that used to create the Nature Run);
- Experiment C1: no observation assimilated (free run);
- Experiment C2: one observation type assimilated;
- Test the performance of assimilated observation.

The OSSE goal: evaluate if the difference C2-T (measured objectively) is significantly smaller than the difference C1-T.

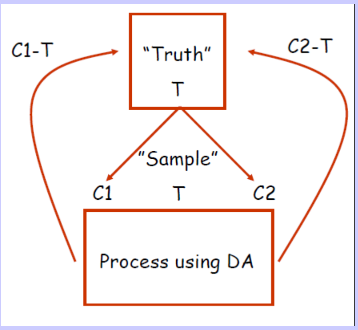


Fig. 3 (left): *Schematic for an OSSE.*

3. OSSE examples from proposed MAGEAQ GEO mission:

The relative merit of surface networks and satellite platforms (impact on the GOS, observing system vs cost), as well as the combination of surface network and satellite observations for AQ monitoring, is being studied in the POGEQA project using OSSEs. For example, the added value of the GEO MAQEAQ-TIR (thermal infrared) configuration has been compared against a configuration similar to the GEO MTG-IRS (Claeyman *et al.*, 2011a, b). Figure 4 show sample results for O_3 – CO is also tested.

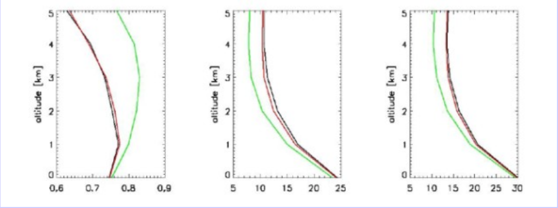


Fig. 4: *Correlation (left), absolute relative difference, % (middle), and root-mean-square (RMS) difference, % (right), between Nature Run & free run (black); between Nature Run & assimilation run of O_3 data from MTG-IRS (red) and between Nature Run & assimilation run of O_3 data from MAGEAQ-TIR (green). Height range, 0-5 km. Percentages are with respect to Nature Run. Assimilation runs set up with changes in meteorology, emissions & initial conditions.* ***Note improvement provided by MAGEAQ-TIR, but that this is less significant over the height range 0-1 km.***

The main conclusions from the OSSEs for MAGEAQ are:

- ***MAGEAQ-TIR is generally closer to the "Truth" than MTG-IRS for both O_3 and CO***. Improvement is over large areas of Europe but is height dependent. Improvement over the height range 0-1 km (see Fig. 4) would be expected from a TIR+VIS configuration (see also Natraj *et al.*, 2011);
- ***MAGEAQ-TIR can have a significant impact on the GOS*** and improve on the O_3 and CO information provided by MTG-IRS (Claeyman *et al.* 2011b).

4. Perspectives:

Building from these initial results, POGEQA is designing OSSEs to test various observing configurations (Lahoz *et al.*, 2012): various GEO platforms (MAGEAQ-TIR+VIS, MTG-IRS; Sentinel-4 UVN); constellation of GEOs; GEOs vs LEOs; surface networks vs satellite data (GEOs/LEOs).

OSSEs are an integral part of the POGEQA/MAGEAQ efforts. This approach is in line with that at ESA (ADM-Aeolus, CarbonSat missions) and NASA (GEO-CAPE mission), and with developments at the National Centers for Environmental Prediction (NCEP) (Masutani et al., 2010).

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