NILU Norsk institutt for luftforskning
Norwegian Institute for Air Research

POGEQA
Plateforme d'Observation GEostationnaire pour la Qualité de l'Air
Observing Air Quality from the Geostationary Orbit

Assessing additions to the future observing system: the role of OSSEs

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Thanks to MAGEAQ/POGEQA Team (esp. M. Claeyman)

SPARC Data Assimilation Workshop

Met Office, Exeter, UK, 21-23 June 2010

STAE TOULOUSE

www.nilu.no

Outline

- Issues requiring Earth Observation, EO (e.g. Satellites)
  - Numerical Weather Prediction, NWP (dynamics, O_3)
  - Air Quality, AQ (O_3, CO, NO_x, aerosol)
  - Volcanic ash
  - Ocean pollution
- Nature of future Global Observing System (GOS)
  - Different systems, with advantages/disadvantages: ground-based, satellites
  - Balance of science, users, cost
- Role of data assimilation
  - Observing System Experiments (OSEs)
  - Observing System Simulation Experiments (OSSEs)
- Examples of OSSEs
  - SWIFT – stratospheric winds and O_3
  - MAGEAQ – AQ (lower troposphere O_3 and CO)
- Conclusions and way forward

Issues requiring EO

NWP

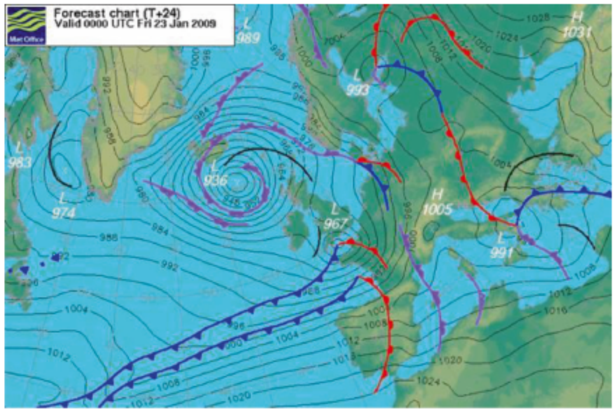
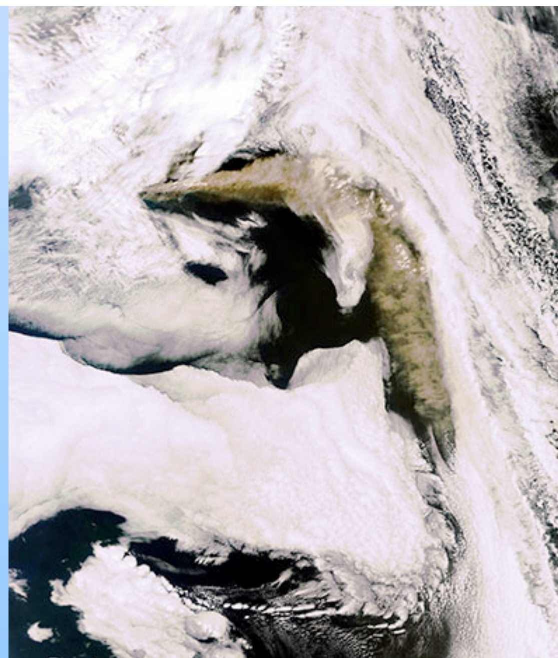
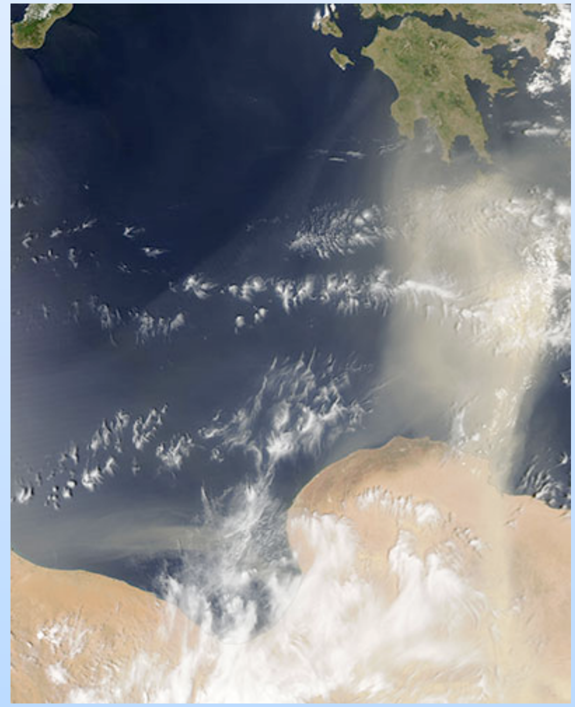


Fig. 4 Example of forecast mean sea level pressure chart for the North Atlantic and Europe. The contours show pressure in hPa and the coloured lines with symbols show fronts (*blue*: cold front; *red*: warm front; *purple*: occluded front)

Ash



Dust



Oil

Nature of the future GOS

Envisat

2.3B€ !

You are given 2.3 BEuros for Envisat to observe the Earth System

What does this buy?

(1)Norwegian Oil fund Dec 2009:

2.6 Trillion NOK, 333 BEuros

<1% of fund

(2) 1 “Fergie”: 500,000 pounds

4600 Fergies

What do you need to consider? NOT value of Envisat

BUT added value of Envisat above what else will be available

-> INCREMENTAL VALUE

THIS IS TRUE FOR ANY ADDITION TO THE GOS

Observation types used by ECMWF for NWP

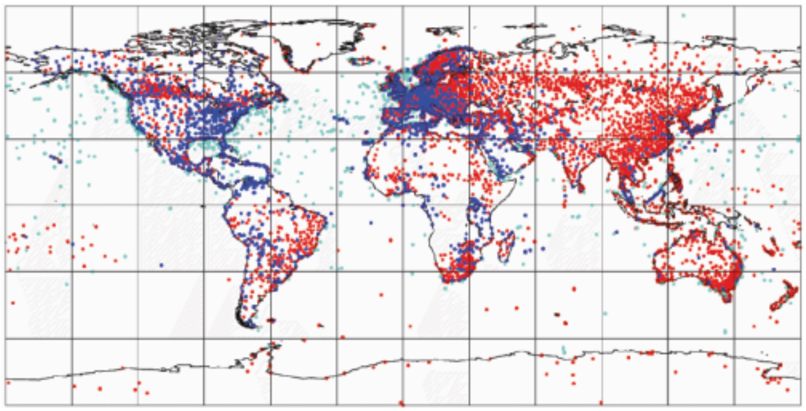


Fig. 1 Typical data coverage of surface observations, 20070301 0900-1500 UTC, showing 16,550 SYNOP (*red*), 1,937 SHIP (*cyan*) and 12,383 METAR (*blue*)

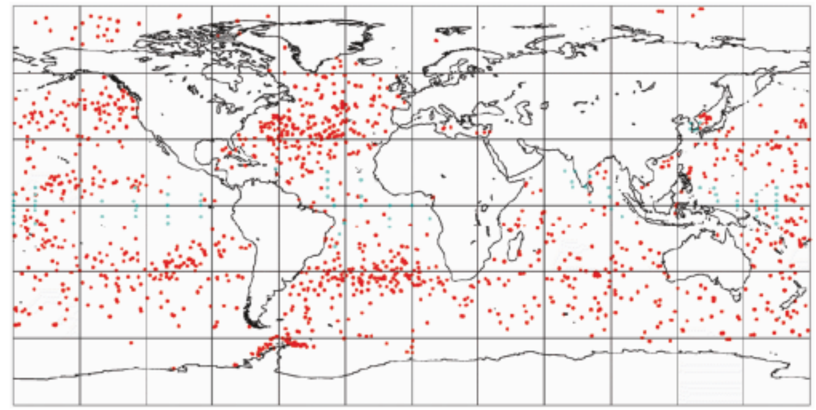


Fig. 2 Typical data coverage of buoy observations, 20070301 0900-1500 UTC, showing 5,686 drifting buoys (*red*) and 140 moored buoys (*cyan*)

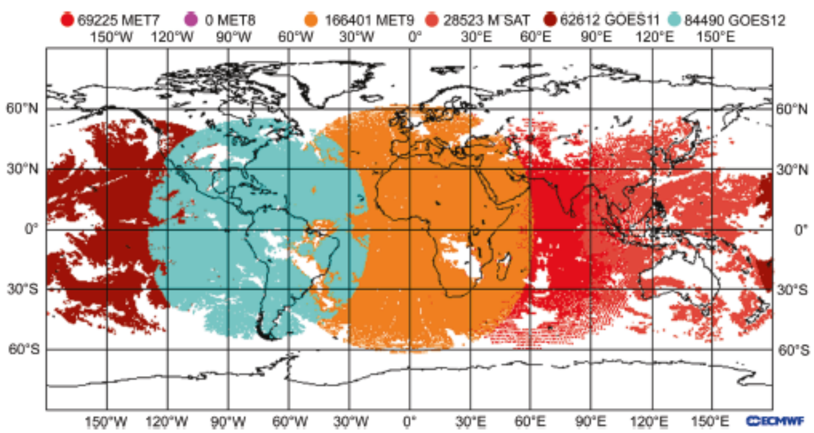


Fig. 6 Typical data coverage provided by the Geostationary constellation: GOES-11 (*brown*), GOES-12 (*cyan*), Meteosat-7 (*red*), Meteosat-9 (*orange*) and MTSAT (*red–orange*)

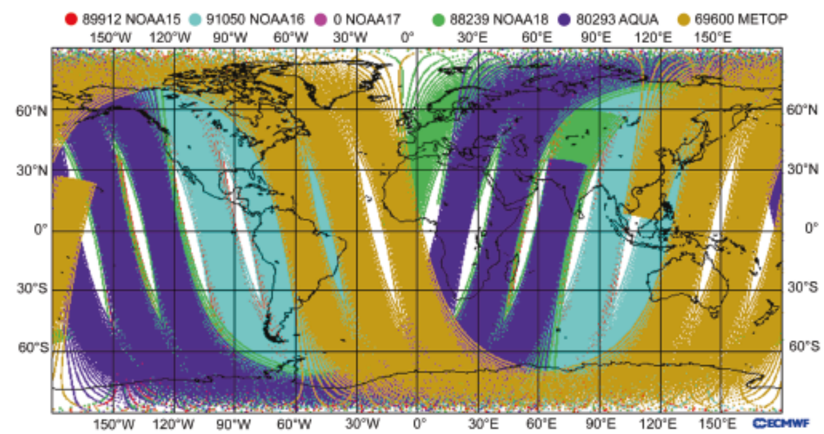


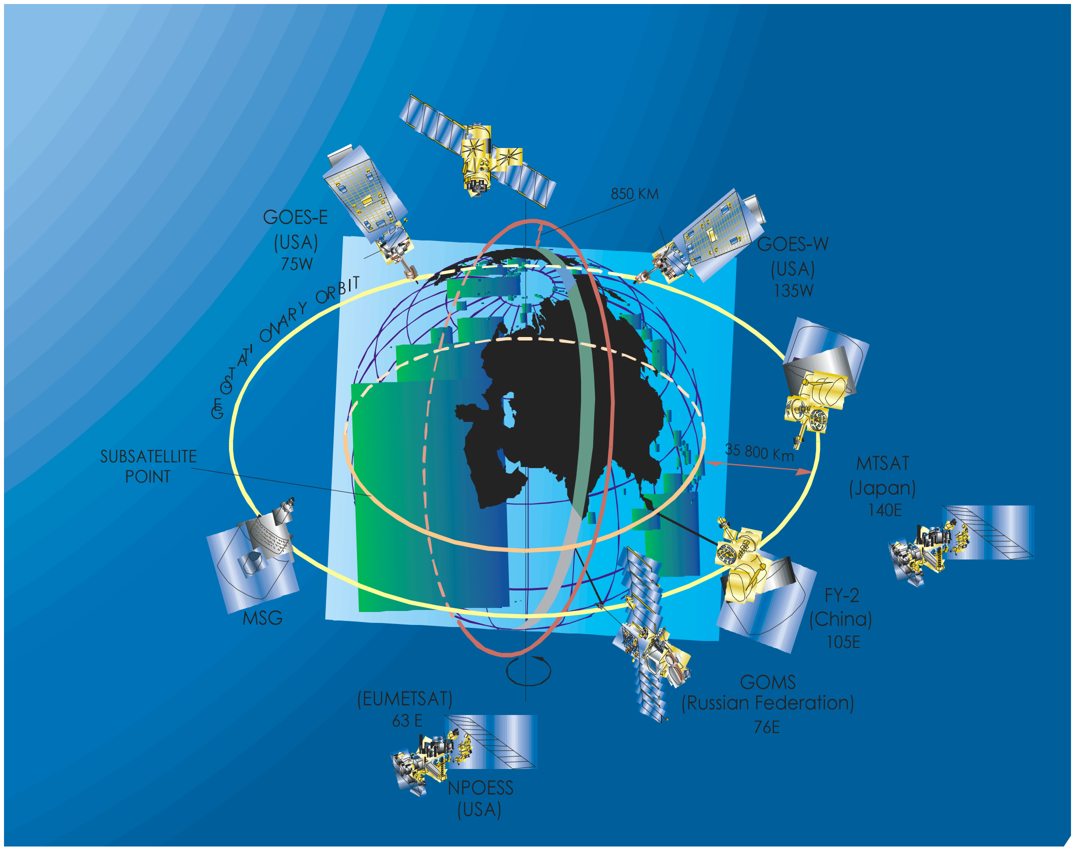
Fig. 7 Typical data coverage provided by the LEO (Low Earth Orbit) constellation of AMSU-A instruments from NOAA, AQUA and METOP satellites: NOAA-15 in *red*, NOAA-16 in *cyan*, NOAA-18 in *green*, AQUA in *violet* and METOP in *brown*

Thépaut and Andersson, 2010 © Springer (The Global Observing System)

Generally need to include a representative/significant subset of these observations:

Applies for NWP-related OSSEs; not necessarily so for AQ-related OSSEs (see later)

Global Earth Observing system (GOS) for 2008-2010



What will the GOS be like?

Existing & planned satellite missions

What type of observations to include?

Conventional: ground-based, sondes, aircraft

Satellites: operational, research

Examples of observation requirements (chemical species):

What do we have now? What do we need?

-> impacts design of future GOS

Based on several documents (e.g.):

- IGACO (chemical species, AQ, O_3 loss)
- Capacity study (successor is ESA Camelot study)
- Expert team on evolution of GOS (LEOs, GEOs, ground network)
- GCOS (Global Climate Observing System, ECVs)
- GEOSS (Societal Benefit Areas, e.g., health for AQ)

Scientists:

- Identify characteristics of GOS (strengths/weaknesses)
- Come up with "wish list" – dependent on science themes (but role of users)
- Competing requirements & cost constraints
- Back to original question: How do we quantify added value?

SWIFT (NWP)/MAGEAQ (AQ) missions:

- Choice of measurements – do they add value?
- Errors in measurements for scientific benefit – what errors can we allow?

IGACO

Relevance to AQ

Target/threshold (needed)

ATMOSPHERIC SPECIES IN GROUP 1 TO BE MEASURED BY AN INTEGRATED GLOBAL OBSERVING SYSTEM													
Atmospheric Region	Requirement	Unit	H_2O	O_3	CH_4	CO_2	CO	NO_2	BrO	ClO	HCl	CFC-12
1. Lower troposphere	Σx	km	5/25	<5/50	10/50	10/500	10/250	0/250	50			
	Σz	km	0.1/1	0.5/2	2/3	0.5/2	0.5/2	0.5/3	2			
	Σt		1hr	1hr	2hr	2hr	2hr	1hr	1hr			10d
	precision	%	1/10	3/20	1/5	0.2/1	1/20	10/30	10			2*
	trueness	%	2/15	5/20	2/10	1/2	2/25	15/40	15			4*
	delay		(1)/(2)	(1)/(2)	(1)/(2)	(1)/(2)	(1)/(2)	(1)	(2)			
2. Upper troposphere	Σx	km	20/100	10/100	50/250	50/500	10/250	30/250				
	Σz	km	0.5/2	0.5/2	2/4	1/2	1/4	0.5/3				
	Σt		1hr	1hr	2hr	2hr	2hr	1hr				
	precision	%	2/20	3/20	1/10	0.5/2	1/20	10/30				
	trueness	%	2/20	5/30	2/20	1/2	2/25	15/40				
	delay		(1)/(2	(1)/(2)	(1)/(2)	(1)/(2	(1)/(2)	(1)				

Courtesy IGACO 2004

(1) Hours (NWP, AQ);

(2) days-weeks (O_3 loss,….);

(3) months (climate research)

N.B. Definition of target (best case)/threshold (minimum to be useful)

Relevance to stratospheric O_3

Target/threshold (needed)

ATMOSPHERIC SPECIES IN GROUP 1 TO BE MEASURED BY AN INTEGRATED GLOBAL OBSERVING SYSTEM													
Atmospheric Region	Requirement	Unit	H_2O	O_3	CH_4	CO_2	CO	NO_2	BrO	ClO	HCl	CFC-12
3. Lower stratosphere	Δx	km	50/200	50/100	50/250	250/500	50/250	30/250	100	100	50/250	1000
	Δz	km	1/3	0.5/3	2/4	1/4	2/5	1/4	1	1	1/4	
	Δt		1d	1d	6-12hr	1d	1d	6-12hr	6hr	6hr	6-12hr	10d
	precision	%	5/20	3/15	2/20	1/2	5/15	10/30	10	10	5/10	6
	trueness	%	5/20	5/20	5/30	1/2	10/25	15/40	15	15	15	15
	delay		(1)/(2	(1)/(2)	(1)/(2)	(2)/(3)	(2)/(3)	(1)	(2)	(2)		

Courtesy IGACO 2004

(1) Hours (NWP);

(2) days-weeks (O_3 loss,...);

(3) months (climate research)

N.B. Definition of target (best case)/threshold (minimum to be useful)

Role of Data Assimilation

•Use of data assimilation to design/evaluate GOS:

Masutani et al. 2010 (Observing System Simulation Experiments)

•Observing System Experiments (OSEs): impact of elements of existing GOS:

Remove one observation type at a time (e.g. impact of satellite data)

Work at Met agencies (ECMWF, Met Office) – importance of satellite data (NH & SH)

•Observing System Simulation Experiments (OSSEs): future missions

Preparation for future missions (ESA, NASA) – additions to GOS

•Illustrative examples of OSSEs

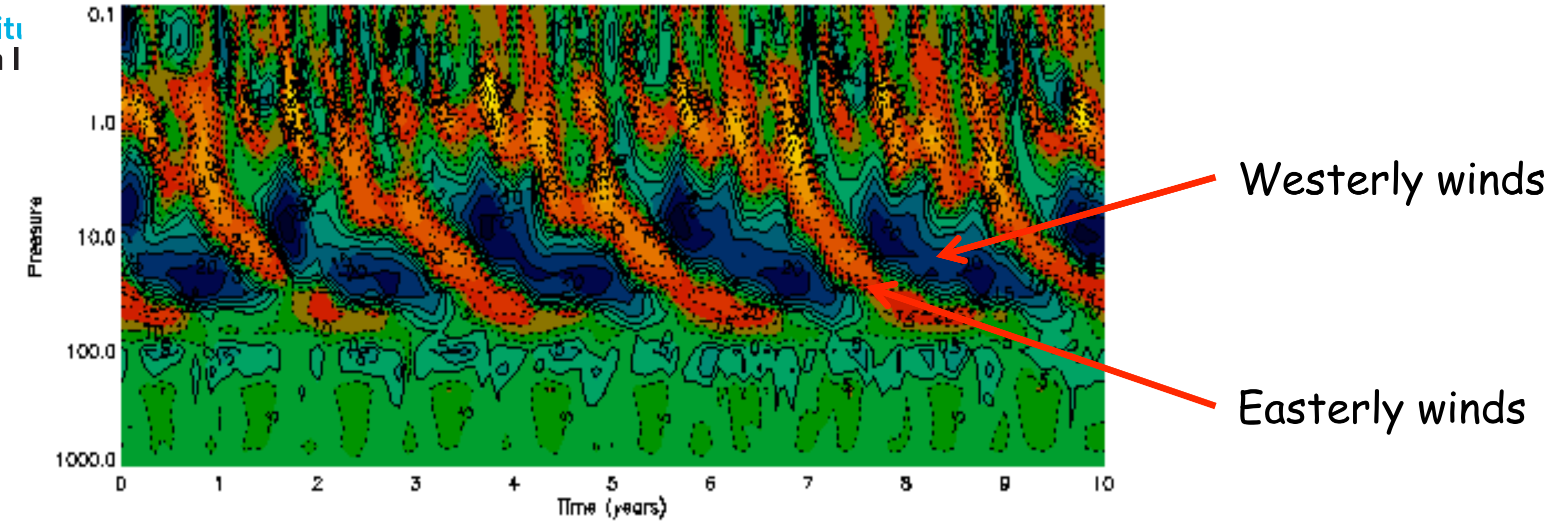
The planned CSA SWIFT instrument, measuring stratospheric winds and O_3

The proposed MAGEAQ instrument, measuring lower troposphere O_3 and CO

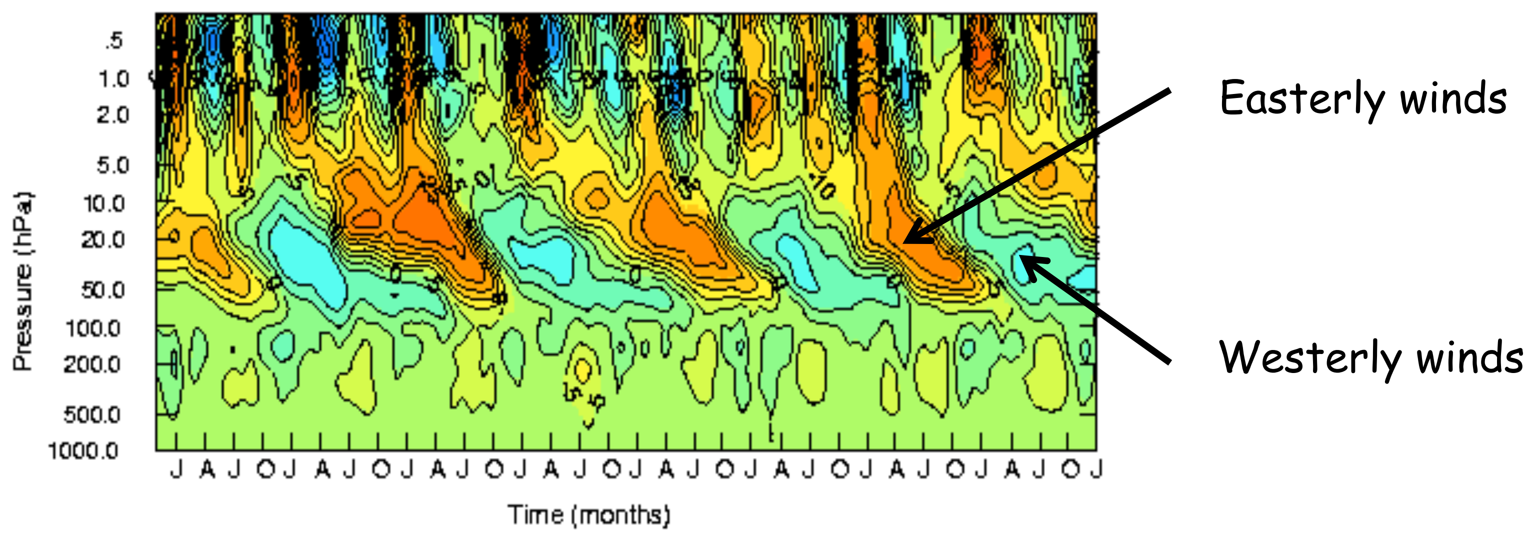
Motivate SWIFT OSSE: winds a current concern about GOS

- Lack of global observations of stratospheric winds in current operational meteorological system:
  - No sondes above 10 hPa (no global coverage anyway)
  - AMVs (Atmospheric Motion Vectors) from satellites in troposphere
  - Wind information from temperature nadir sounders in extra-tropics (troposphere/stratosphere) – BUT thermal wind relation breaks down in tropics
- We have no good current estimates of state of the tropical stratosphere:
  - Variability in the quasi-biennial oscillation (QBO) is underestimated
  - "Balanced" winds problematic for estimating variability of QBO

Although a focus is on tropical stratosphere, SWIFT could benefit extra-tropics, including representation of winter high latitude variability



“Realistic” quasi-biennial oscillations in the MO Unified Model



Met Office observational analyses of equatorial winds for Nov 1992 - Jan 2000

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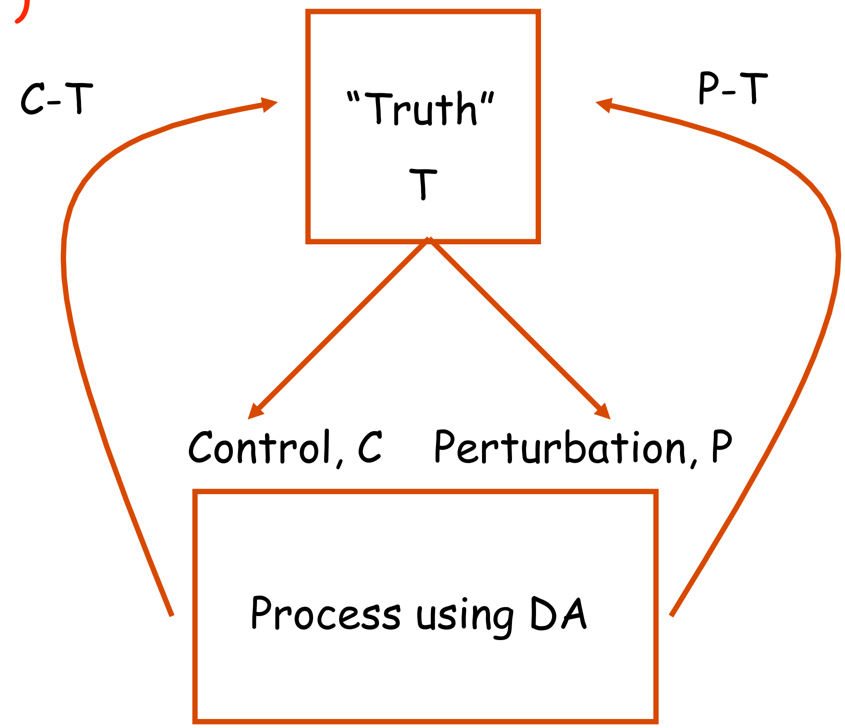
Satellite missions measuring winds

- Recent past: UARS – launched 1991
  - UARS WINDII: mesospheric winds
  - UARS HRDI: stratospheric winds, but impact marginal as observed winds not accurate enough compared to forecasts
- Future:
  - ESA ADM-Aeolus: launch 2011 (?) – OSSEs done (e.g. Tan et al. 2007)
  - CSA SWIFT: Shelved for the time being (R. Ménard pers. comm.)

Structure of an OSSE (e.g. SWIFT, NWP)

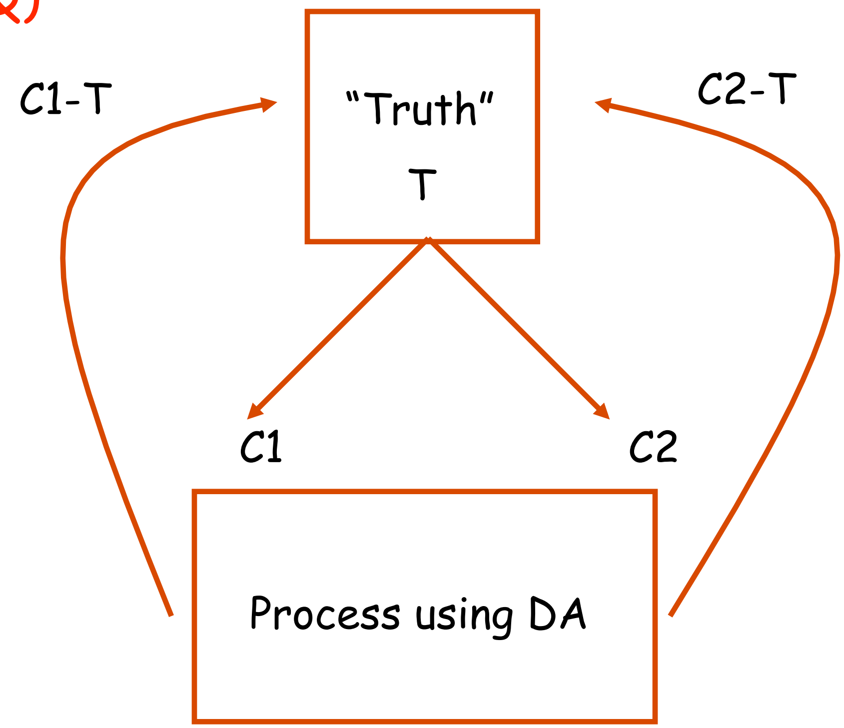
- Simulated atmosphere ("truth"; T): using a model, analyses
- Simulated observations of instruments appropriate to the study, including errors: using T
- Assimilation system: using a model
- Control experiment C: all observations except those under study
- Perturbation experiment P: all observations



OSSE goal: evaluate if the difference P-T (measured objectively) is significantly smaller than the difference C-T

Structure of an OSSE (e.g. MAGEAQ, AQ)

- Simulated atmosphere ("truth"; T): using a model, analyses
- Simulated observations of instruments appropriate to the study, including errors: using T
- Assimilation system: using a model
- Experiment C1: only observation type 1
- Experiment C2: only observation type 2
- Interested in performance of obs type 1



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

Note: fewer observations for AQ in GOS; very few operational systems for AQ

Note shortcomings of an OSSE:

- Expensive (cost ~ assimilation system) -> alleviate problem: "reduced OSSE" (e.g. profiles instead of radiances)

  Note: "reduced OSSE" generally only useful when observation of interest has relatively high impact (e.g. stratospheric winds)

- Difficult interpretation (model dependence) -> alleviate problem: conservative errors, several methods to investigate impact

- Incest -> alleviate problem: different models to construct "truth" & perform assimilation (BUT there could be bias between models)

Despite shortcomings, high cost of EO missions means that OSSEs often make sense to space agencies

OSSE for SWIFT instrument

Lahoz et al. QJ 2005

SWIFT:

- Based on UARS WINDII principle (Doppler effect)
- 2 wind components using 2 measurements at ~90°
- Thermal emission (mid-IR) of ozone (1133 cm^{-1})
- Technology difficult to implement
- Global measurements of wind and ozone profiles (~20-40 km)

Addresses concerns about GOS winds

Provides information for scientific studies: e.g. tropical winds, transport, wintertime variability

Design of SWIFT OSSE

Models used:

- "Truth" (ECMWF directly, or forcing a CTM)
- Assimilation system (Met Office) (cf. incest)

Simulated observations:

Operational: C {MetOP, MSG, sondes, balloons, aircraft, surface}

Temperature, winds, humidity, ozone

SWIFT; C+SWIFT = P

Ozone, winds (stratosphere, conservative errors)

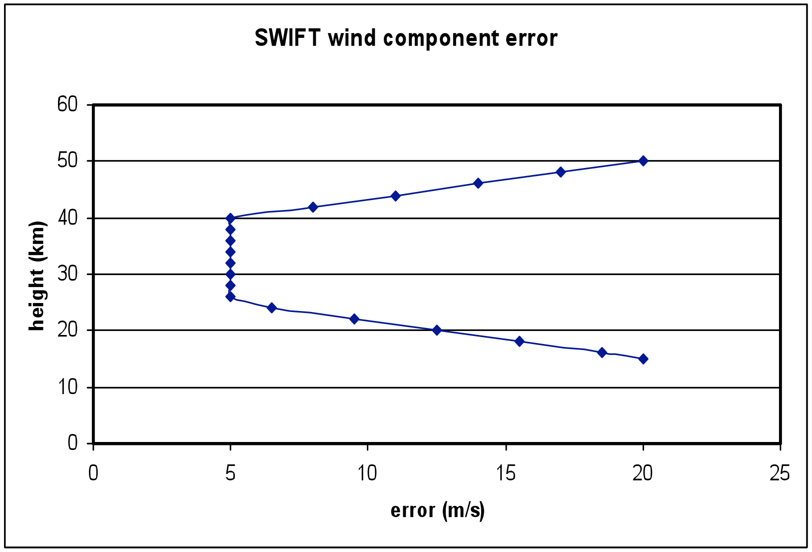
Several assimilation experiments; analyses evaluated

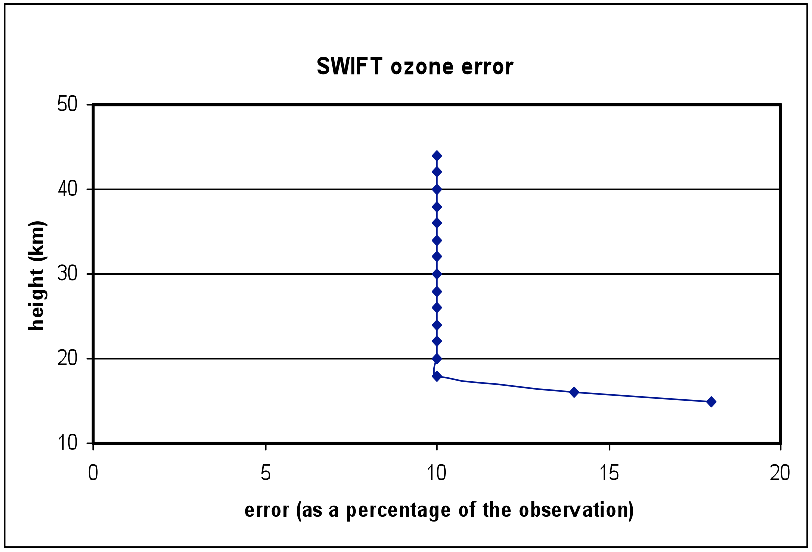
Qualitative & quantitative tests

SWIFT characteristics

- SWIFT: N - and S - observations (87°N-53°S, 53°N-87°S): non sun-synchronous orbit
- - winds 16-50km, every 2km approximately

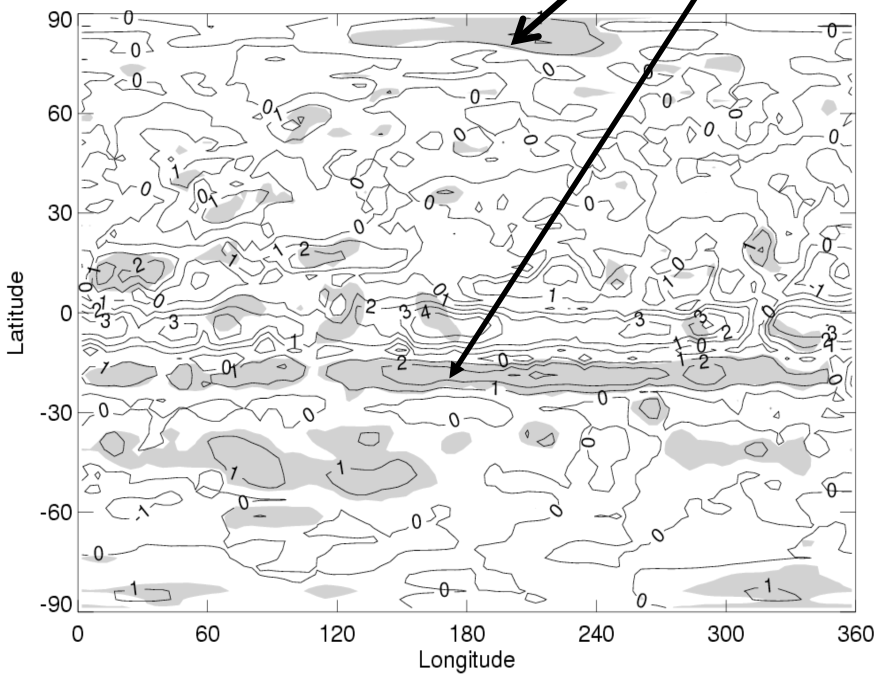
  - ozone 16-44km, every 2km approximately
- Errors: conservative; random; representativeness error considered to be relatively unimportant



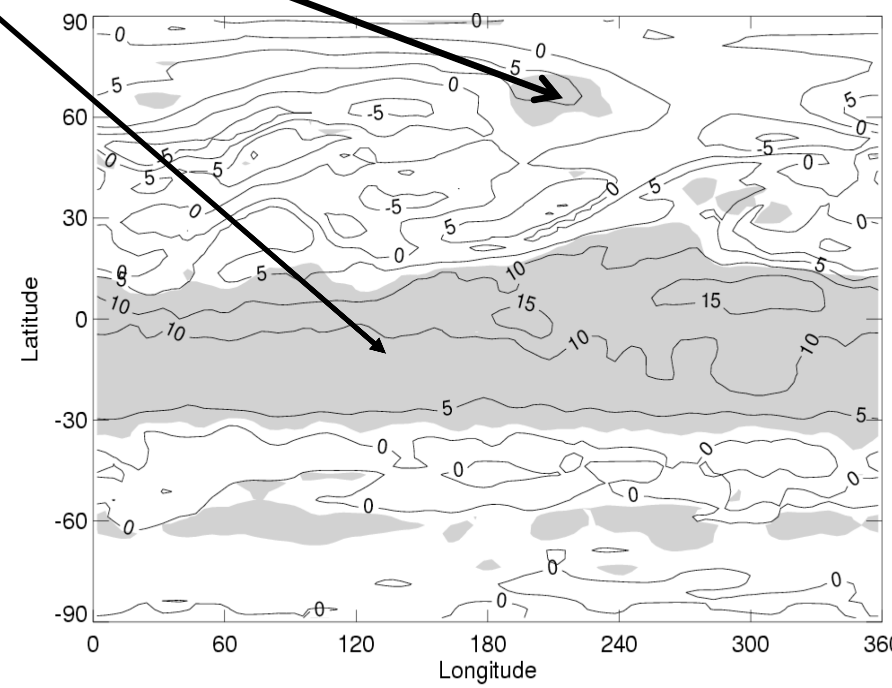


Significance tests

Areas > 5%



10 hPa



1 hPa

Y=Abs(C-T) -Abs(P-T); Zonal-wind (m/s); January 2000;
Shaded:95% C.L. & Y>0. Similar results for April 2000.

N.B. Some areas of -ve impact (information on data assimilation system)

New observations can degrade data assimilation system - not significant for SWIFT

Conclusions from SWIFT OSSE

- SWIFT winds
  - Significant impact in tropical stratosphere EXCEPT lowermost levels
  - Can have significant impact in extra-tropics when:
    - SWIFT observations available
    - Flow regime is variable (relatively fast changing)
  - Have scientific merit in that they improve:
    - Information on tropical winds
    - Wintertime variability (e.g. extra-tropics)
  - Useful for forecasting & producing analyses to help study climate change & its attribution:
    Better models, better initial conditions, model evaluation

- SWIFT ozone
  - Significant impact at 100 hPa & 10 hPa
    -> regions of relatively high vertical gradient

Some caveats discussed in *Lahoz et al. 2005*: care interpreting OSSEs

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AQ concerns

Motivate MAGEAQ OSSE

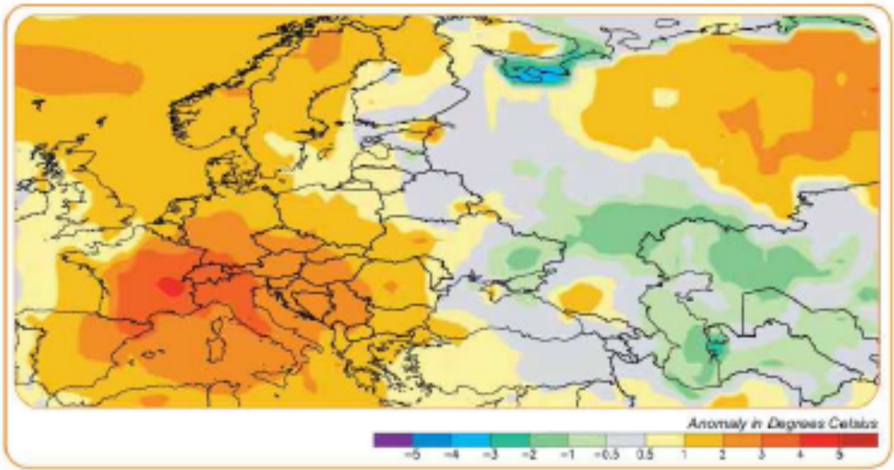

Fig. 3.1 (left): Temperature anomaly (°C) for June-Aug 2003 (Europe). Climatological base period is 1998-2003. Red denotes positive anomalies; blue denotes negative anomalies (Courtesy UNEP.)

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[1] It is estimated the European heat wave of 2003 (Fig. 3.1) caused a loss of 14,802 lives (mainly elderly) in France (http://www.grid.unep.ch/product/publication/download/ew_heat_wave.en.pdf). High temperatures increased tropospheric O_3 amounts, and anticyclonic conditions ensured their persistence (Vautard et al., 2005). Reduction of life expectancy in the European Union (EU) as a consequence of $PM_{2.5}$ pollution has been estimated to be up to 36 months in heavily polluted regions such as the Benelux and the Po Valley (http://www.duh.de/uploads/media/EU_2005__02.doc). Studies in the USA provide evidence that a reduction of $PM_{2.5}$ can increase life expectancy (Pope et al., 2009).

[2] The annual cost to the French health system of asthma and cancer incidences directly attributable to AQ has been estimated to be 300 - 1300 million Euros for 2006 (AFSSET, 2007). Estimates of annual health damage (mortality, morbidity) due to air pollution in 2020 for the EU25 countries are estimated to range between 188 billion Euros and 608 billion Euros (http://www.cafe-cba.org/assets/baseline_analysis_2000_2020_05-05.pdf).

Air Quality needs

Chemistry (O_3), transport (CO, O_3) & emissions (CO) are important; role of stratosphere (influx of O_3)

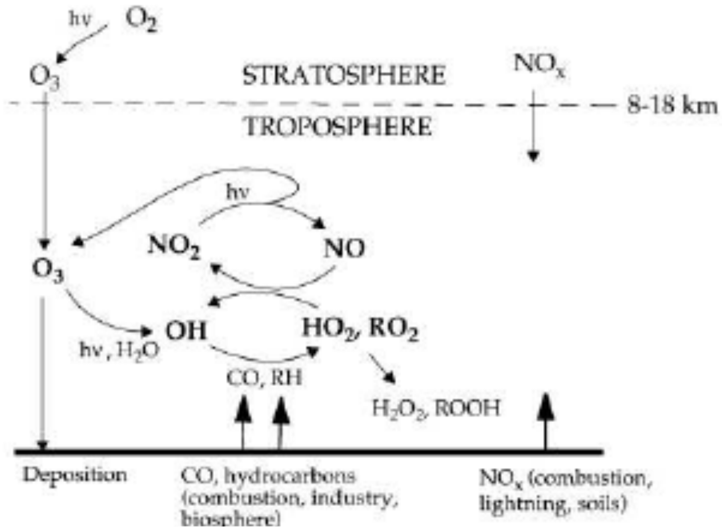


Fig. 3.4 (left): Schematic of tropospheric O_3 chemistry illustrating coupling between O_3 and various chemical cycles. (Jacob, 2000.)

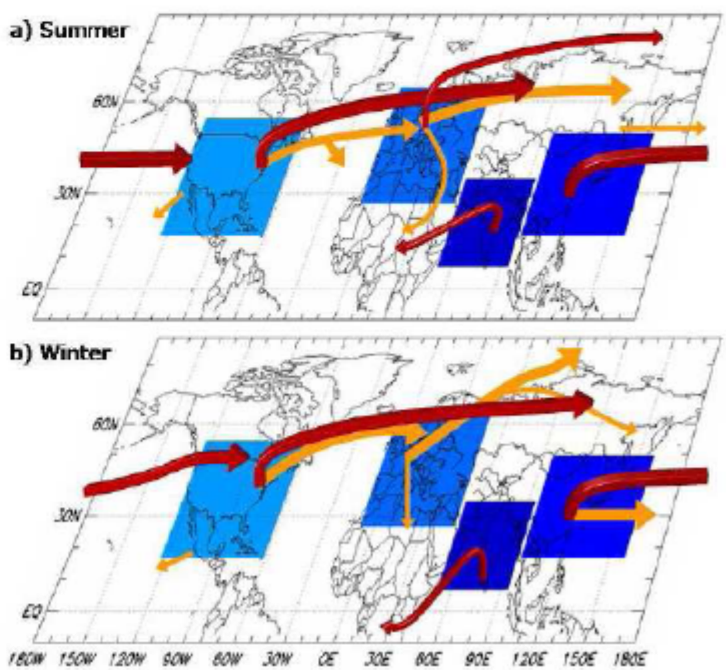


Fig. 3.5 (left): Intercontinental transport pathways in NH. Arrows approximate magnitude of pathways for Summer (June-July-Aug) and Winter (Dec-Jan-Feb) based on simulations. Boxes indicate regions used in HTAP (Hemispheric Transport of Air Pollution) studies. Light arrows: transport near the surface (<3 km height); dark arrows: transport higher in the atmosphere (>3 km height). (HTAP, 2007.)

Air Quality needs

High resolution spatio-temporal sampling needed

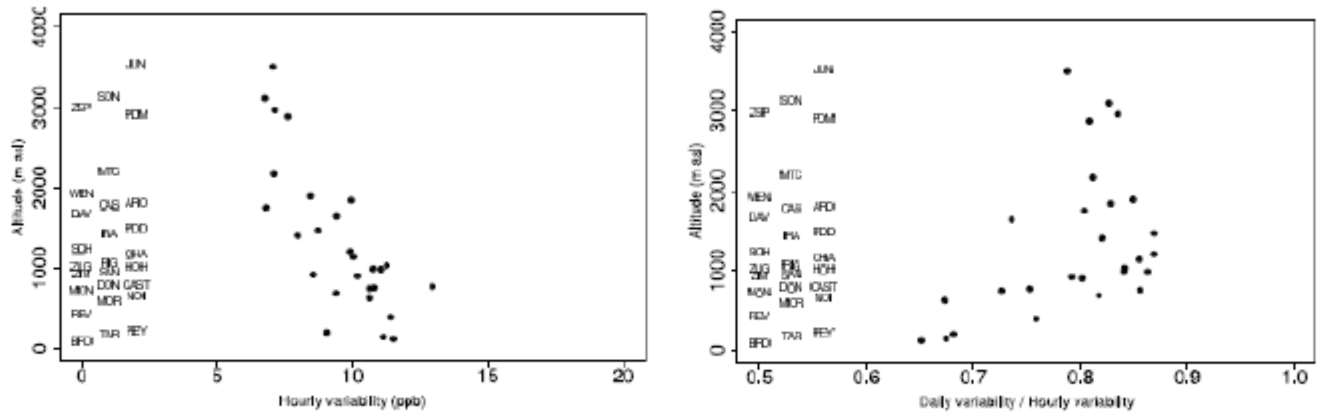


Fig. 3.2: Surface O_3 data from various European stations, over the period 2001-2004. Left, hourly variability (standard deviation, ppb); right, daily / hourly variability. Note hourly variability is larger than daily variability. (Chevalier et al., 2007.)

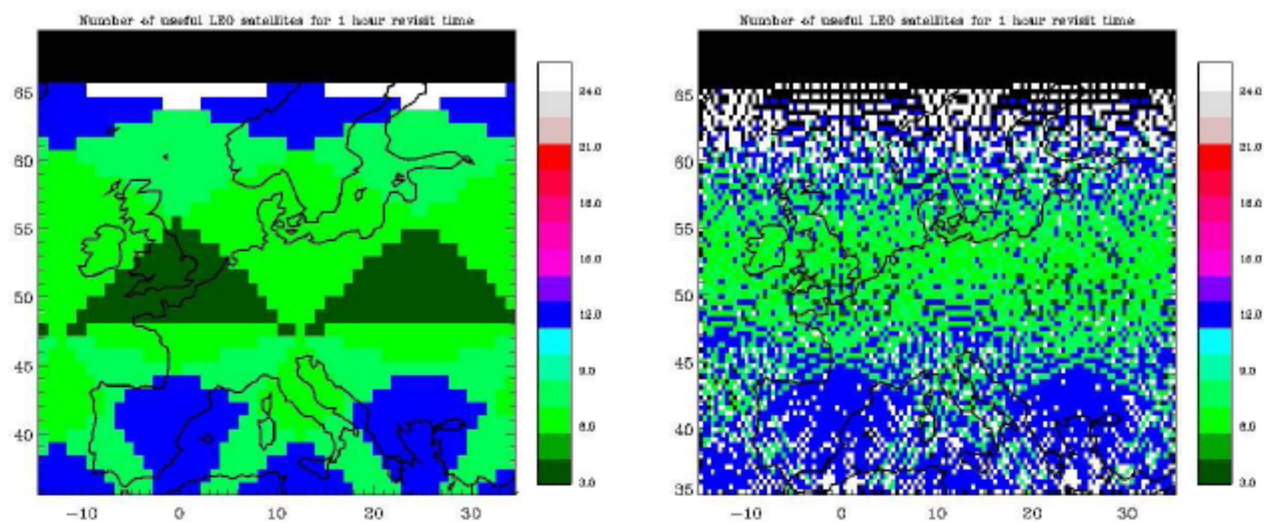


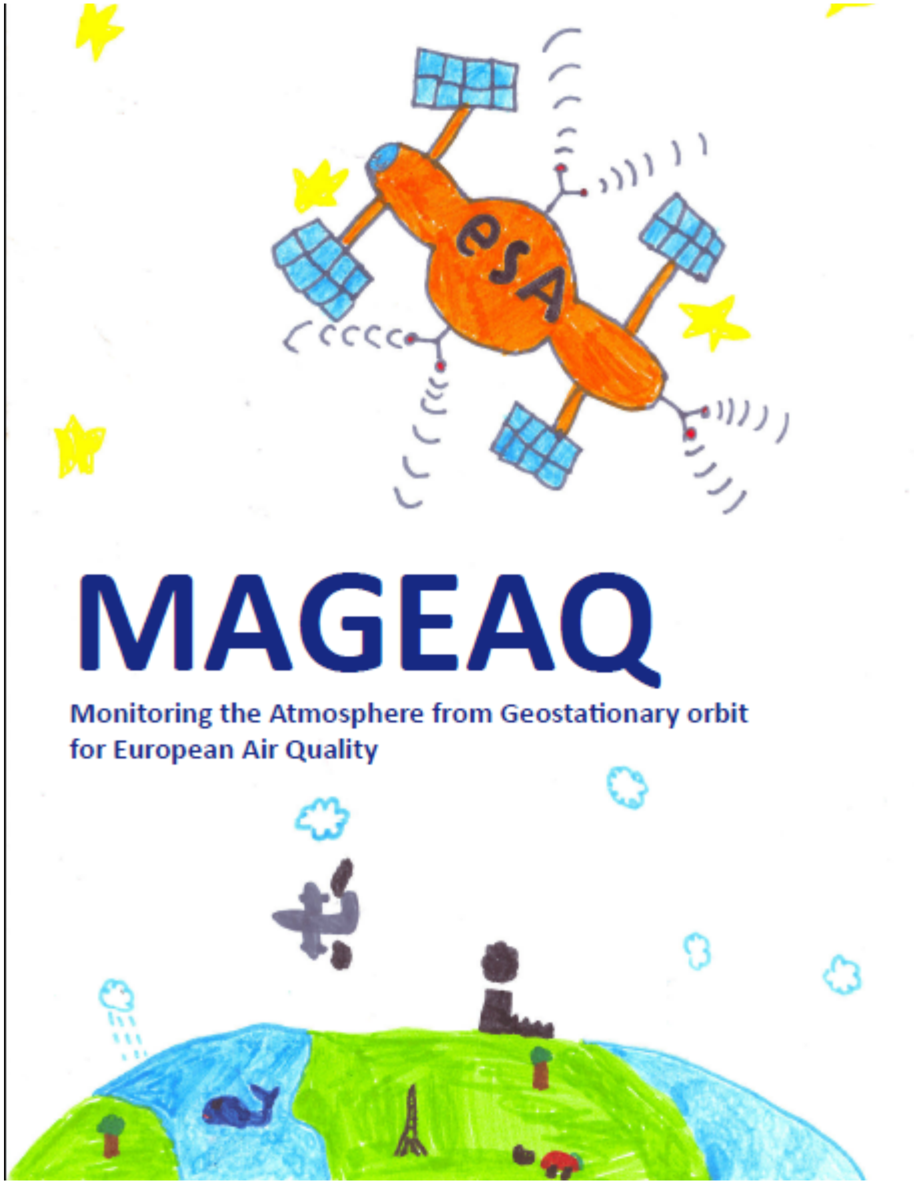
Fig. 3.3: Useful LEOs (drifted orbits) required for 1 hour revisit time. Left, $1^o \times 1^o$ resolution; right, $0.4^o \times 0.4^o$ resolution. In both cases, the least number of LEOs required is 3 (dark green regions). The least number of LEOs required for <15 km resolution would be 3. By contrast, only 1 GEO is required for 1 hour revisit time.

Missions measuring tropospheric pollutants (generally LEOs)

- O_3: IASI tropospheric & total column (Boynard et el., 2009) & lower tropospheric partial column information (Eremenko et al., 2008; Dufour et al., 2010) & TES tropospheric information (Worden et al., 2007)
- CO: IASI tropospheric information (Fortems-Cheiney et al., 2009) & MOPITT tropospheric profile & total column information (Deeter et al., 2010)
- NO_2/NO_x: GOME, SCIAMACHY and OMI total column information (Richter et al., 2005; Konovalov et al., 2006, 2008)
- Aerosol products (Torres et al., 2010)

- Lack of height-resolved regional/continental scale information for O_3 and, until recently, for CO
- Obtaining concentrations of AQ species in PBL (planetary boundary layer) a priority (IGACO 2004)

MAGEAQ – A candidate for ESA EE-8



Principal Investigators	V.-H. Peuch (lead scientist), Météo-France, Toulouse, France J. Orphal, IMK, KIT, Karlsruhe, Germany
Co-Investigators	J.-L. Attié, LA, CNRS/Univ.Toulouse, France K. V. Chance and X. Liu, Harvard-SAO, Cambridge, USA D. Edwards, NCAR, Boulder, USA H. Elbern, FZ Jülich, Germany J.-M. Flaud, LISA, CNRS/Univ.Paris12, France W. Lahoz, NILU, Kjeller, Norway
Science Team	**Many scientists in Europe, USA, Canada, Japan and Korea**

MAGEAQ characteristics

Observation requirements and geometry	
Domain covered	15°W-35°E, 35°N-65°N
Space resolution	10km x 10km at 45° (target) ; 15km x 15km (threshold)
Time resolution	1h (target); 2h (threshold)
Duty cycle	Higher than 90% of observational time
Ozone sensor	
Objectives	2 (target) to 3 (goal) pieces of information in the troposphere. Accuracy: 10% (target) for 0-6 km column, 20% (threshold). Height-resolved information in lower troposphere
Channel 1 (TIR)	Centred 1060 cm^{-1}, 40 cm^{-1} wide
Channels 2 to 9 (VIS)	8 broadband channels from 450 to 690 nm
CO sensor	
Objectives	2 pieces of information separating lower and upper free troposphere. Accuracy: 5% (target) for 0-6 km column, 15% (threshold)
Channel 10 (MIR)	Centred 2130 cm^{-1}, 40 cm^{-1} wide

Table 3.2: Summary of MAGEAQ mission requirements. For spectral resolution/spectral sampling/signal to noise ratio, see Section 4 (Mission Assumptions and Technical Requirements).

Mission	PBL O_3	Lowermost free troposphere O_3	PBL CO	Lowermost free troposphere CO
MAGEAQ	Good	Good	PBL sensitivity under condition of high thermal contrast; adequate	Good
Sentinel-4/UVN	Poor	Adequate: only column information	No	No
MTG/IRS	No	Poor	No	Adequate
SEVIRI	Poor	No	No	No
GEO-CAPE	Good	Good	Good	Good

Table 3.4: Information on O_3, CO from different existing/planned GEOs. No: to our knowledge, no information is possible for AQ. Poor: some information available and likely will have a small impact toward improving AQ. Adequate: measurements provide information on AQ, and likely this is the best we can do from a technical/instrument point of view. Good: measurement is state-of-the-art.

MAGEAQ OSSEs:

•Truth is provided by MOCAGE AQ model (CTM)

•DA runs assimilate 1 dataset, C1: MAGEAQ, or C2: MTG-IRS; (O_3, CO)

- common for lower troposphere AQ OSSEs (e.g. Edwards et al. 2009 for GEO-CAPE)

•Study sensitivity to initial conditions, atmospheric forcing and emissions

- test skill of datasets to simulate the truth under various conditions

•Results are for 2 month averages (similar results for 1 month averages) – robustness

•Note: MTG/IRS optimized for NWP, MAGEAQ for AQ

EXP	Atm. Forcing	emissions	Initial condition	Assim
REF	ARPEGE analysis	GEMS	free run	No
ARPFOR	ARPEGE forecast 48h	GEMS	free run	No
EMIGLOB	ARPEGE analysis	GLOBAL	free run	No
INITMODIF	ARPEGE analysis	GEMS	changed every week	No
ARPFOR-MAGEAQ	ARPEGE forecast 48h	GEMS	free run	MAGEAQ-IR
EMIGLOB-MAGEAQ	ARPEGE analysis	GLOBAL	free run	MAGEAQ-IR
INITMODIF-MAGEAQ	ARPEGE analysis	GEMS	changed every week	MAGEAQ-IR
ARPFOR-MTGIRS	ARPEGE forecast 48h	GEMS	free run	MTG-IRS
EMIGLOB-MTGIRS	ARPEGE analysis	GLOBAL	free run	MTG-IRS
INITMODIF-MTGIRS	ARPEGE analysis	GEMS	changed every week	MTG-IRS

OSSE results: impact of adding one data type (O_3)

Red: MAGEAQ closer to the truth than MTG-IRS (test of significance later)

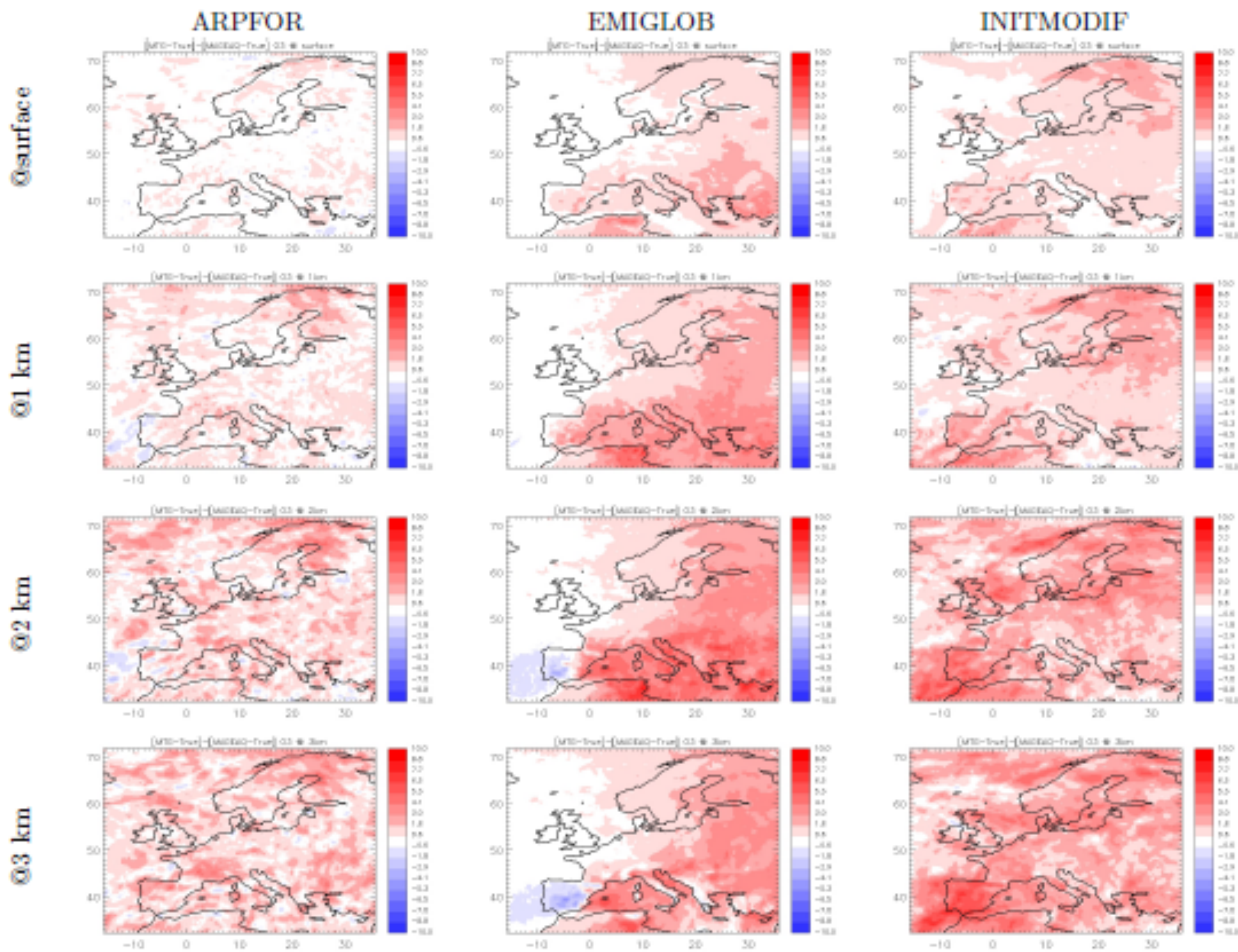


Figure 3: Plot of the difference (%) for O_3 ||MTG-minus-True|| - ||MAGEAQ-minus-T|| at surface, 1km, 2km and 3km for different experiments: changing the atmospheric forcings (ARPFOR), changing the emission (EMIGLOB) and changing the initial state (INITMODIF).

OSSE results: impact of adding one data type (CO)

Red: MAGEAQ closer to the truth than MTG-IRS (test of significance later)

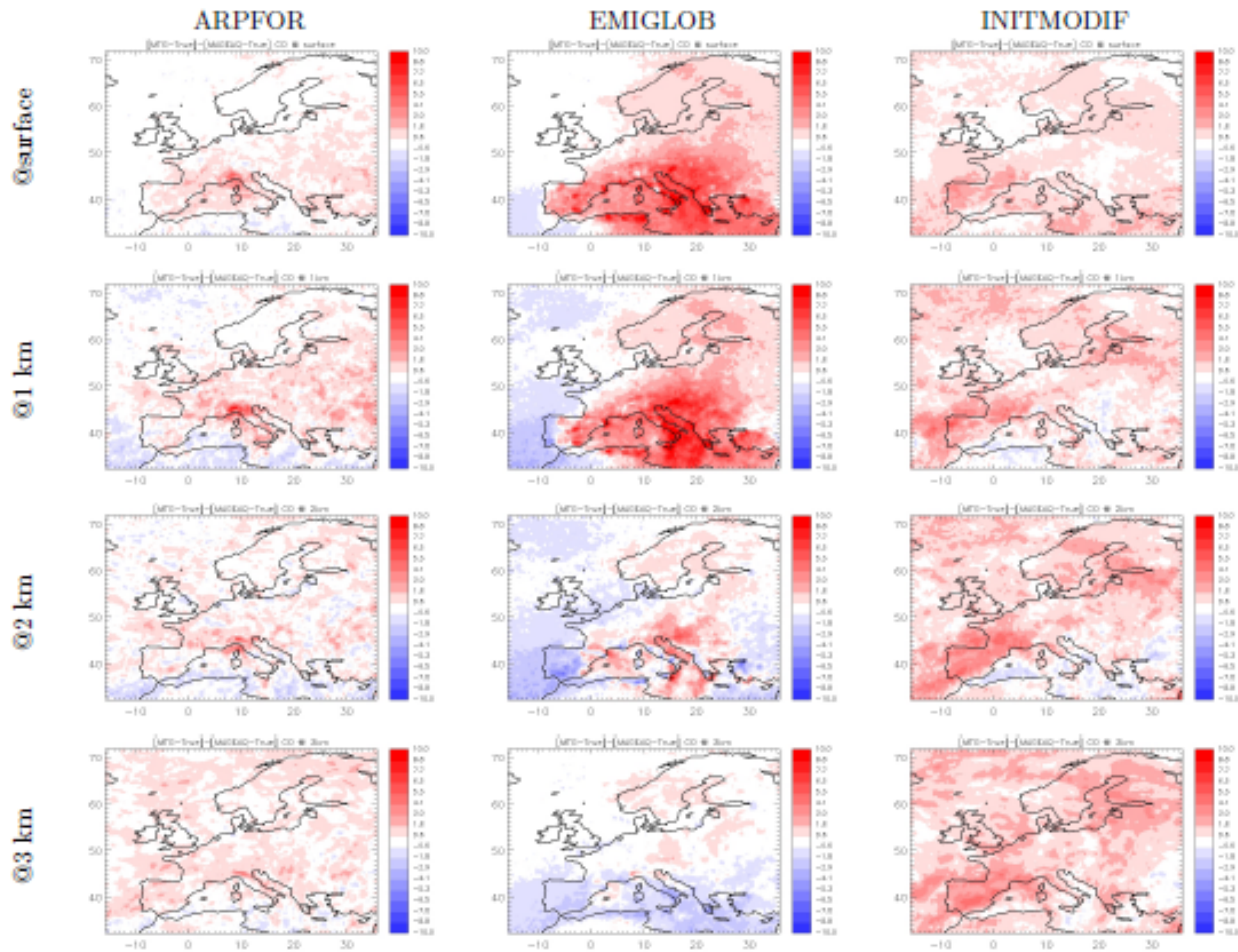


Figure 1: Plot of the CO mean difference (%) at 12h UTC, ‖MTG-minus-True‖ - ‖MAGEAQ-minus-T‖ at surface, 1km, 2km and 3km for different experiments: changing the atmospheric forcings (ARPFOR), changing the emission (EMIGLOB) and changing the initial state (INITMODIF).

OSSE results: impact of adding one data type (O_3)

Test of significance: Red indicates where differences between MAGEAQ & MTG-IRS are significant at 95% confidence level

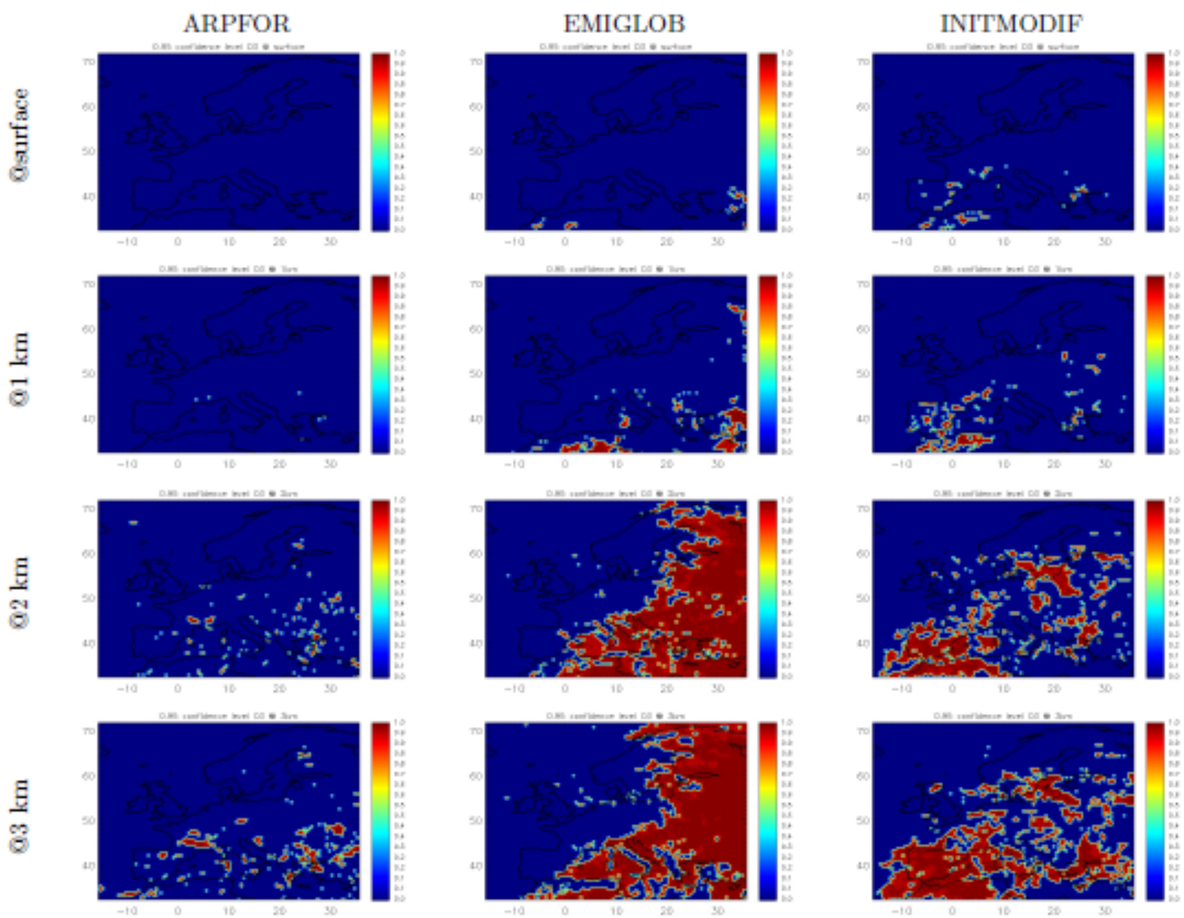


Figure 4: The red areas indicate where the difference between the means for O_3 ||MTG-minus-True|| - ||MAGEAQ-minus-T|| is significant at the 0.95 confidence level at surface, 1km, 2km and 3km for different experiments: changing the atmospheric forcings (ARPFOR), changing the emission (EMIGLOB) and changing the initial state (INITMODIF).

OSSE results: impact of adding one data type (CO)

Test of significance: Red indicates where differences between MAGEAQ & MTG-IRS are significant at 95% confidence level

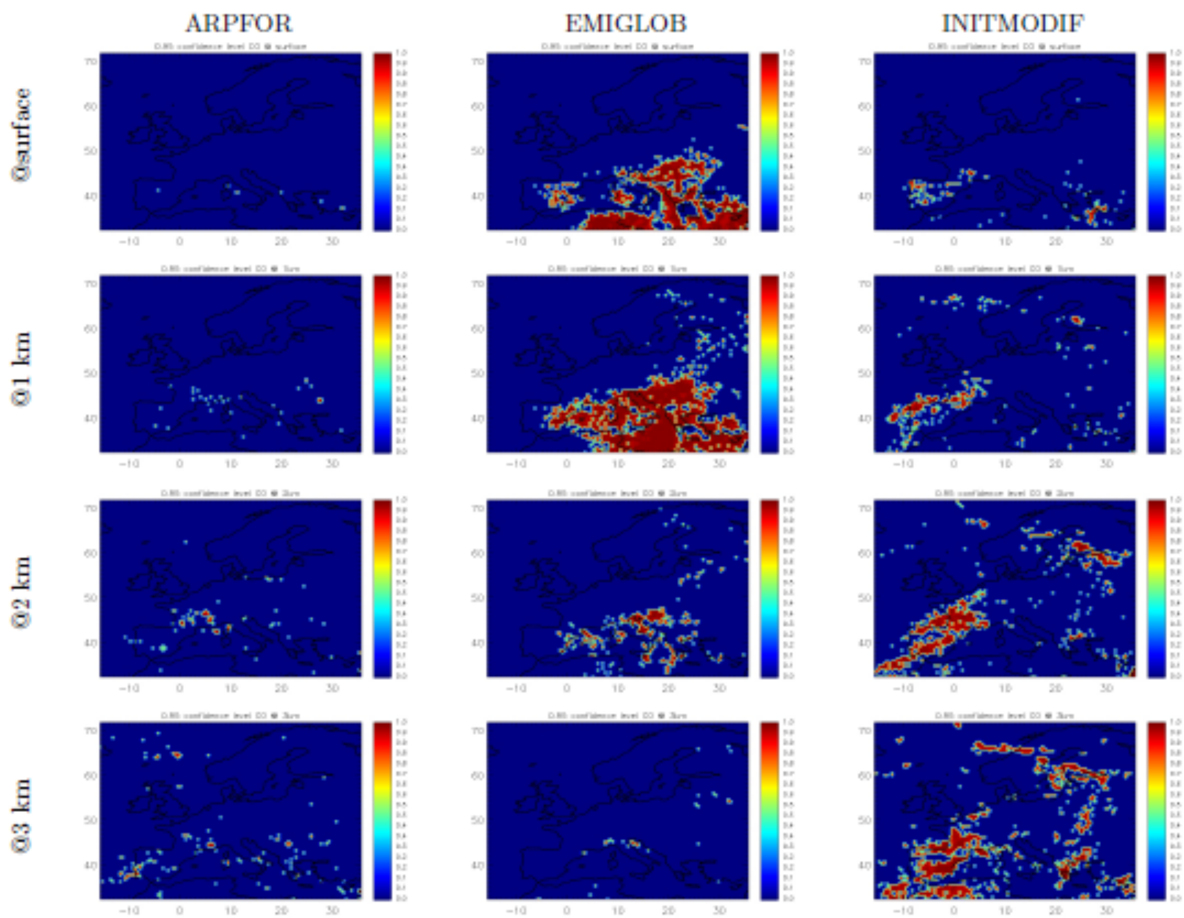
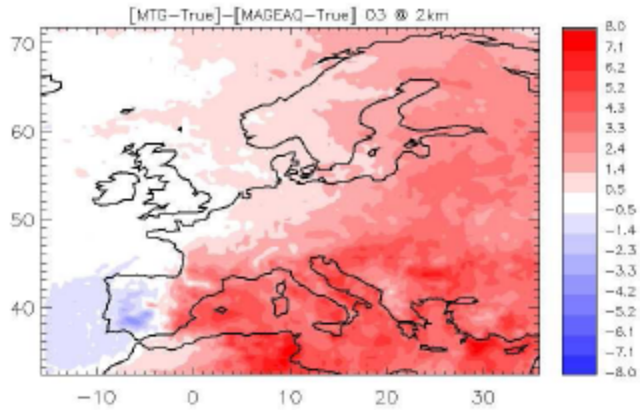


Figure 2: The red area indicates where the difference between the means for CO ‖MTG-minus-True‖ - ‖MAGEAQ-minus-T‖ is significant at the 0.95 confidence level at surface, 1km, 2km and 3km for different experiments: changing the atmospheric forcings (ARPFOR), changing the emission (EMIGLOB) and changing the initial state (INITMODIF).

OSSE results ("truth" is MOCAGE AQ model): impact of adding 1 data type



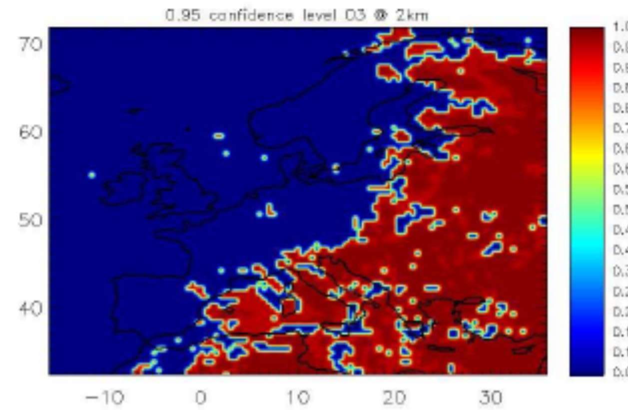
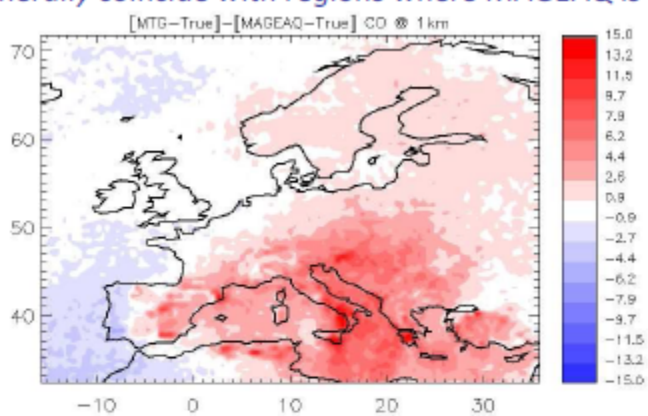


Fig. 3.14, O_3. Left, above: Difference (% with respect to "Truth") between abs(MTG/IRS-"Truth") and abs(MAGEAQ-"Truth") for one month (July) of data at 2 km height. Red indicates MAGEAQ is closer to the "Truth" than MTG/IRS, blue indicates MTG/IRS is closer to the "Truth" than MAGEAQ.

Fig. 3.15, O_3. Right, above: Test of significance of the performance of MAGEAQ and MTG/IRS. Red indicates regions where (MAGEAQ-"Truth") is significantly different than (MTG/IRS-"Truth") at the 95% significance level. Statistics based on one month (July) of data at 2 km height. Regions where this difference is significant generally coincide with regions where MAGEAQ is closer to the "Truth" than MTG/IRS.



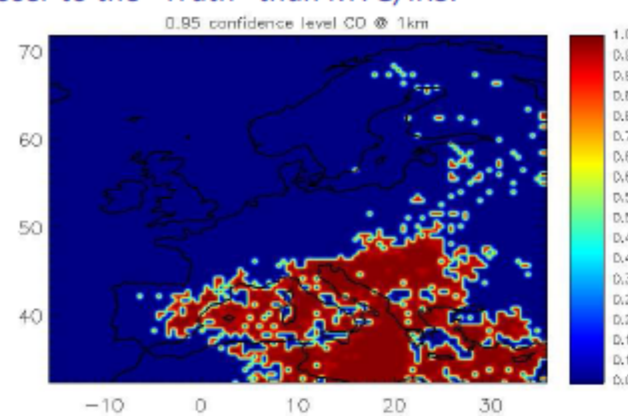


Fig. 3.16, CO. Left above: As for Fig. 3.14, except at 1 km height.
Fig. 3.17, CO. Right above: As for Fig. 3.15, except at 1 km height.

Edwards et al., 2009 – GEO-CAPE

Claeyman et al., 2010 - MAGEAQ

Conclusions from MAGEAQ OSSE:

•MAGEAQ generally closer to "truth" (MOCAGE) than MTG/IRS

•Significance tests (Lahoz et al. 2005)

- improvement from MAGEAQ over large areas of Europe but ht-dependent (instrument sensitivity) & expt-dependent (variability of analyses)

•MAGEAQ can have significant impact on GOS & improve that of MTG/IRS

•With caveats of OSSEs

-results suggest MAGEAQ provides a better GEO platform for observing lower troposphere O_3 and CO than MTG/IRS (to be expected, but gratifying)

•Further OSSEs needed to make this result more robust

•POGEQA will devote resources for this

As for ESA ADM-Aeolus, OSSEs form an integral part of MAGEAQ

Approach follows that of NCEP (Masutani et al. 2010): carefully constructed OSSEs can provide useful recommendations which influence the design of the future GOS

Way forward:

Important to quantify value of future missions

Applies to all elements of the Earth System

- Participation of all actors: multi-disciplinary
- Quantify benefits: OSSEs (and variants – Masutani et al. 2010)
- Caveats: set up experiments carefully (model dependence,...)

Increased use of OSSEs (NASA, ESA,...)

Use OSSEs as one more tool in the "tool-box" to prepare for a mission

Final word/conclusion

NCEP's experience with OSSEs demonstrates that they often produce unexpected results. Theoretical predictions of the data impact and theoretical backup of the OSSE results are very important as they provide guidance on what to expect. On the other hand, unexpected OSSE results will stimulate further theoretical investigations. When all efforts come together, OSSEs will help with timely and reliable recommendations for future observing systems.

Masutani et al., 2010, Observing System Simulation Experiments in "Data Assimilation: Making sense of Observations", Eds (Lahoz, Khattatov, Ménard), Springer