Monitoring the changing environment of the 21st Century: the role of OSSEs in determining the future global observing system

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Outline

- Importance of Air Quality (AQ)
    - Societal concern: pollution, health impact
- AQ information : chemistry (O_3), transport (CO), emissions (CO)
- Spatio-temporal scales of AQ: constraint on observations
- Global Observing System (GOS)
    - Elements (satellite platforms, ground-based platforms,...)
- Assessment of new observing systems
    - Observing System Simulation Experiments (OSSEs)
- Geostationary (GEO) & Low Earth Orbit (LEO) missions to monitor AQ
    - Proposed MAGEAQ mission (other examples)
    - Example: OSSEs for MAGEAQ
    - Further work: multi-spectral approach; LEO; GEO constellations
- Conclusions

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Importance of AQ

Why monitor & forecast AQ?

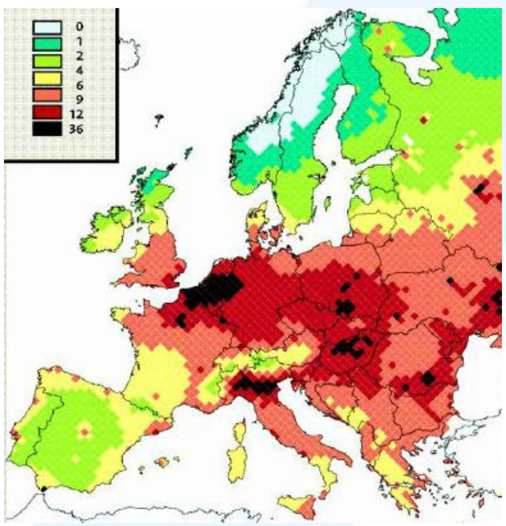
French Air Quality Law (12/1996), article 1 : «Every citizen has the right to breathe air which does not harm his/her health».


LE MONDE/SAMEDI 20 SEPTEMBRE 2003/15

RÉGIONS

2003, une année historique pour les pics de pollution

des niveaux importants d'ozone et de dioxyde d'azote ont relevés depuis plusieurs jours en Ile-de-France et dans d'autres régions, le gouvernement doit publier, en octobre, un décret destiné à renforcer les mesures de prévention



Reduction in life expectancy by PM pollution (months, EU document)


Impacts économiques des pathologies liées à la pollution

Étude d'impact sur les coûts que représentent pour l'Assurance maladie certaines pathologies liées à la pollution

Illustration avec l'asthme et le cancer

Rapport d'analyse

afsset

agence française de sécurité sanitaire de l'environnement et du travail

Octobre 2007

Heat wave 2003, Europe: post-crisis analyses have shown that bad AQ played a deleterious role in the number of deaths

Annual cost to French health care system for asthmas & cancers directly related to AQ is estimated between 300 & 1300 MEuros for 2006 (AFSSET, 2007)

Paris, France

In 2011, 458000 premature deaths in Europe were attributed to particulate matter in the air

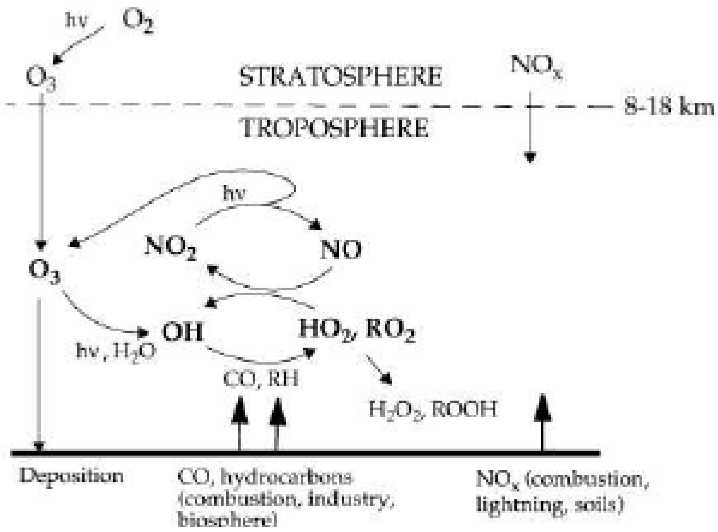
Europe: Overall annual cost health impacts, mortality, morbidity (from atmospheric pollution)
1.575 trillion USD - *WHO, 2015*

Thanks Philipp Schneider

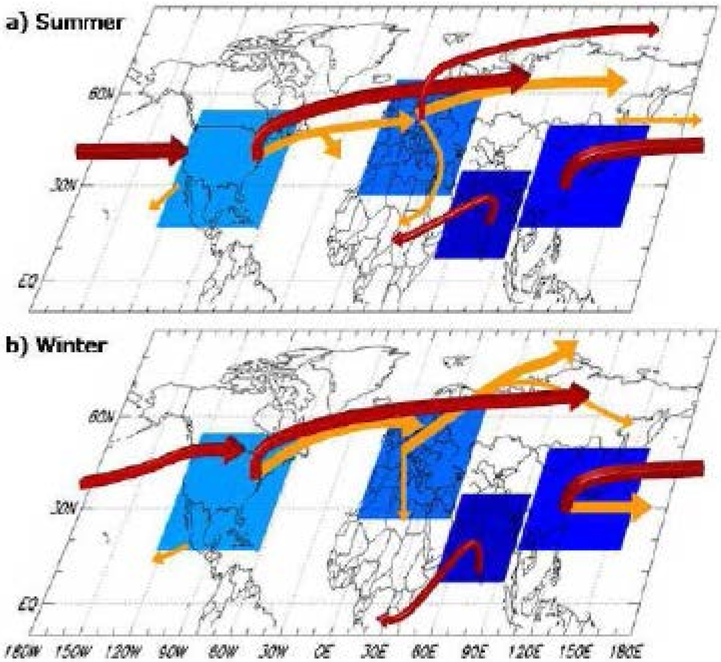
The Guardian

AQ information

Tropospheric chemistry: O_3
Transport: CO, O_3
Emissions: CO



Schematic, tropospheric O_3 chemistry:
Coupling, O_3 & various chemical cycles
Jacob (2000)

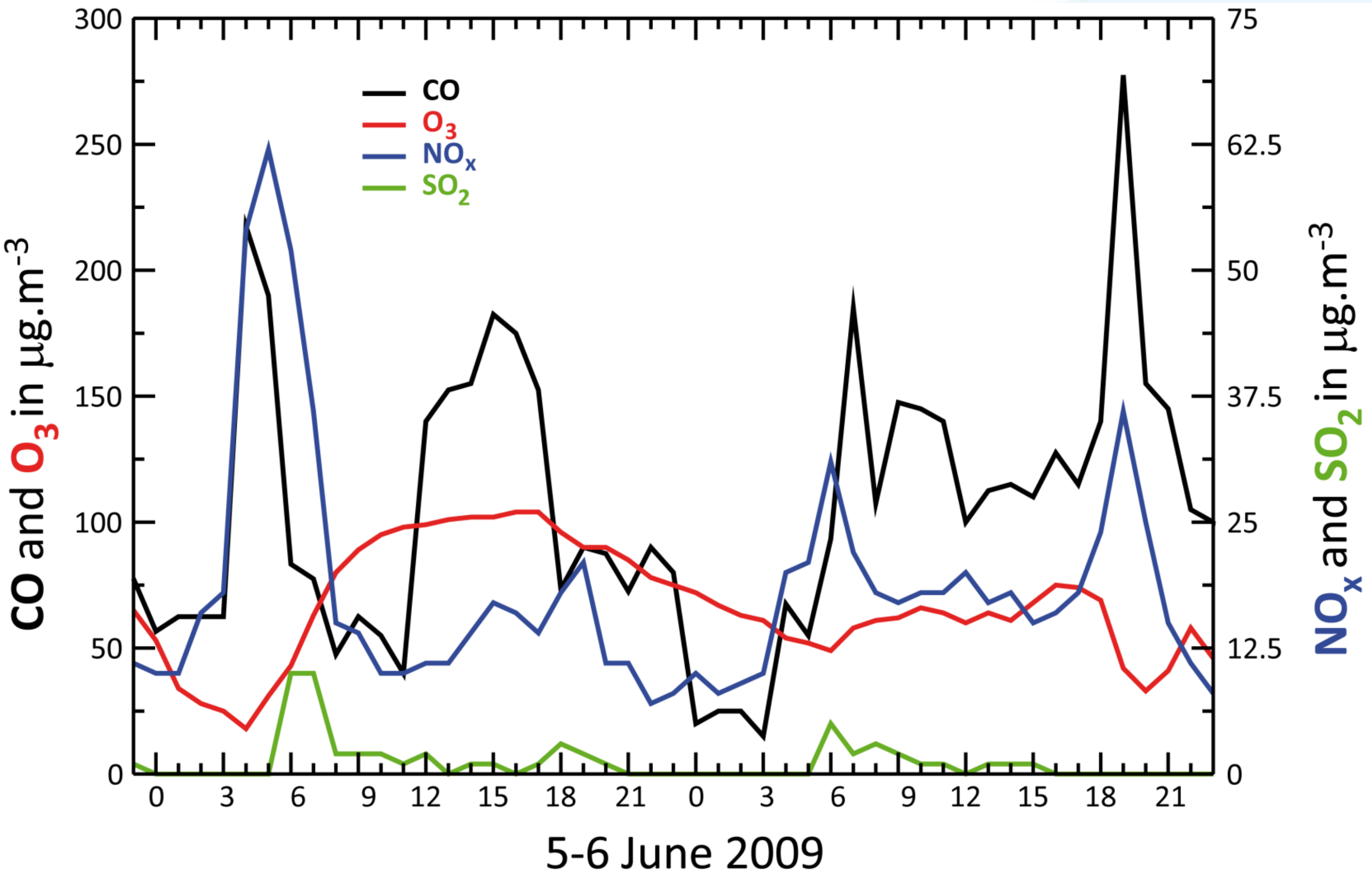


NH intercontinental transport pathways
Arrows approximate pathway magnitude
Summer (JJA) & Winter (DJF)
based on simulations

Boxes indicate regions used in HTAP studies
Light arrows: transport nr surface (< 3 km ht)
Dark arrows: transport higher up (>3 km ht)
HTAP (2007)

AQ spatio-temporal scales

High resolution spatio-temporal sampling at continental/regional scales



Temporal Variability
< 1 hour

Spatial Variability
< ~10 km

Temporal variability: O_3 (red), CO (black), NO_x (blue), SO_2 (green), 6-7 Jun 2009 (Reims, France). Data obtained from French reference AQ databases; Measurements made & validated by local network of Reims Atmo-Champagne-Ardenne

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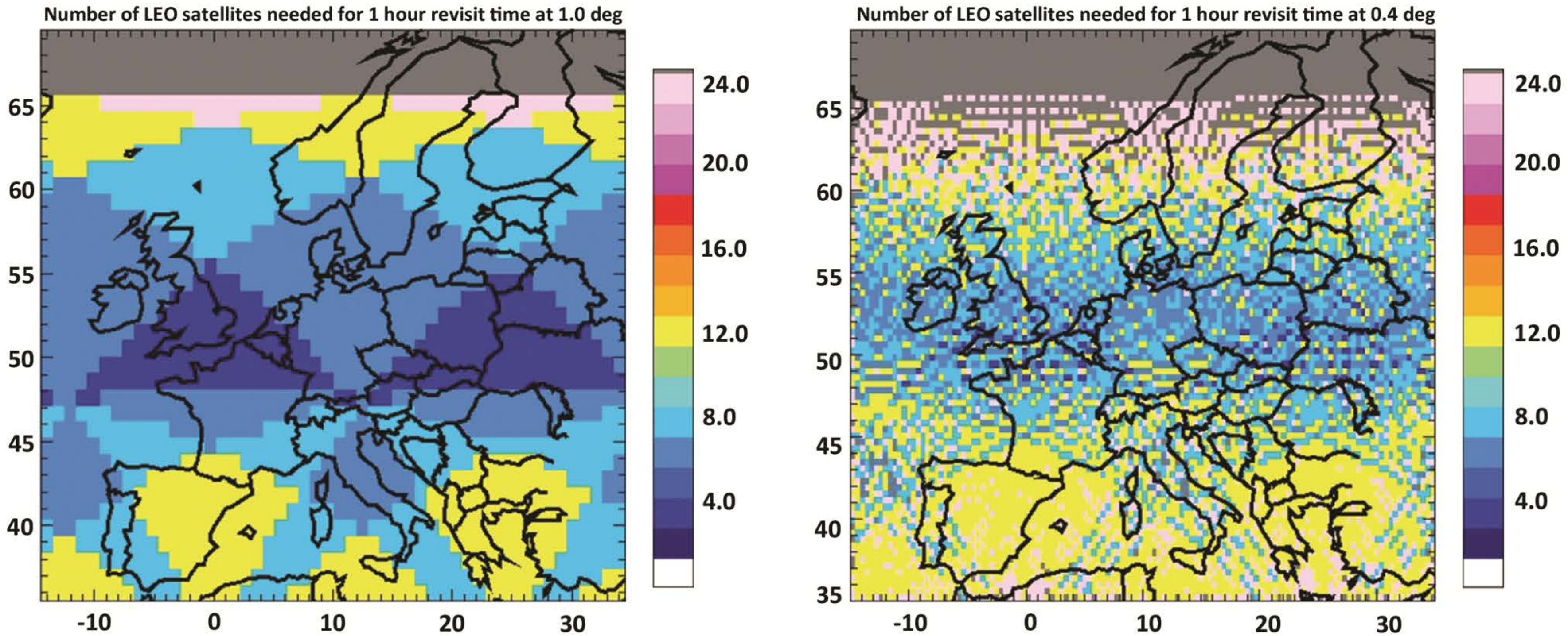
Global Observing System

Satellites + in situ (g-based, aircraft)

The case for a GEO platform for AQ: GEOs vs LEOs



LEOs required for 1-hr revisit time over Europe

Left: 1º x 1º (~100 km); right: 0.4º x 0.4º (~40 km)

Least number of LEOs required is 3 (dark blue regions), but only for v. small regions in area

For 1-hr revisit time & < ~10 km resolution, least number of LEOs > 10. Only 1 GEO is required

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Assessment of new observing systems

Incremental value of added observation type/platform (e.g., for NWP, AQ)

AQ: adding 1 GEO/LEO or a ground-based system to the GOS

- How do we quantify added value – monitoring, cost?

  Consider added value of addition to GOS above what else would be available

  -> INCREMENTAL VALUE: TRUE FOR ANY ADDITION TO THE GOS

- Use DA to quantify additions to GOS (& GOS design):

  Masutani et al. 2010: Observing System Simulation Experiments (OSSEs)

  Timmermans et al. 2015: OSSEs for AQ

  Concept related to Observing System Experiments (OSEs, cf. NWP)

OSSEs applied to assess various proposed GEO missions:
GEO-CAPE, TEMPO (NASA)
MAGEAQ (ESA EE8 - proposed), CarbonSat (ESA EE8 - candidate)

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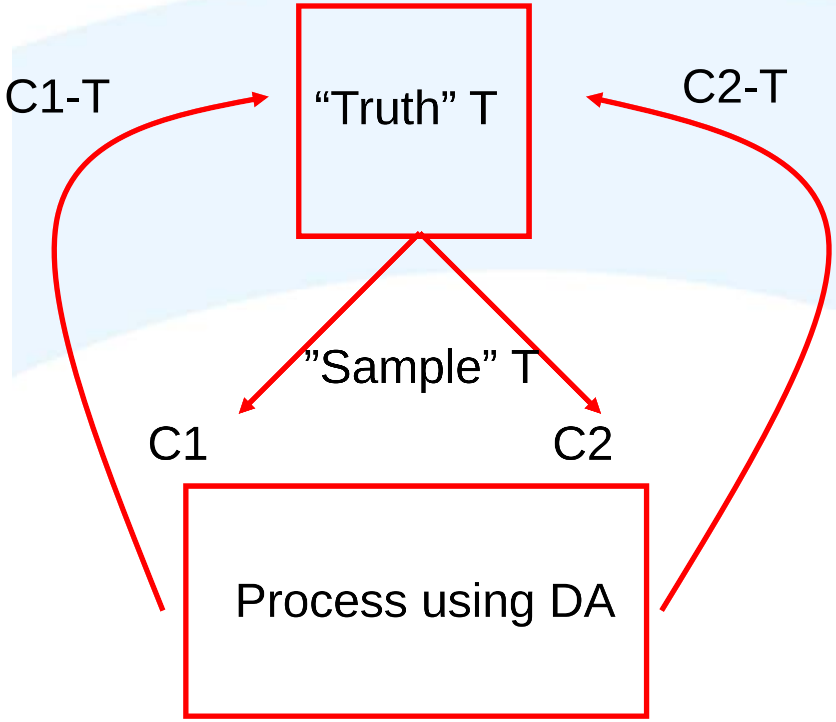
OSSE set-up

- Simulated atmosphere ("truth"; T – "Nature Run"): using model, analyses
- Simulated observations of instruments appropriate to study, including errors: using T
- Assimilation system: using a model
- Expt C1: all observations + new type
- Expt C2: all observations
- Performance of C1 v C2



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

Fewer observations for AQ in GOS (v NWP); 1 obs type vs free model run

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Note shortcomings of an OSSE:

- Complex (comparable to DA system) -> alleviate problem: “reduced OSSE” (e.g., profiles instead of radiances for NWP)

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

- “Incest” (same model for “truth” and DA)-> alleviate problem: different models to construct “truth” & perform DA (BUT model bias?)

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

- Need to check realism of “Truth”; evaluate/calibrate OSSE
  For AQ OSSEs “truth” evaluated against ground-based stations

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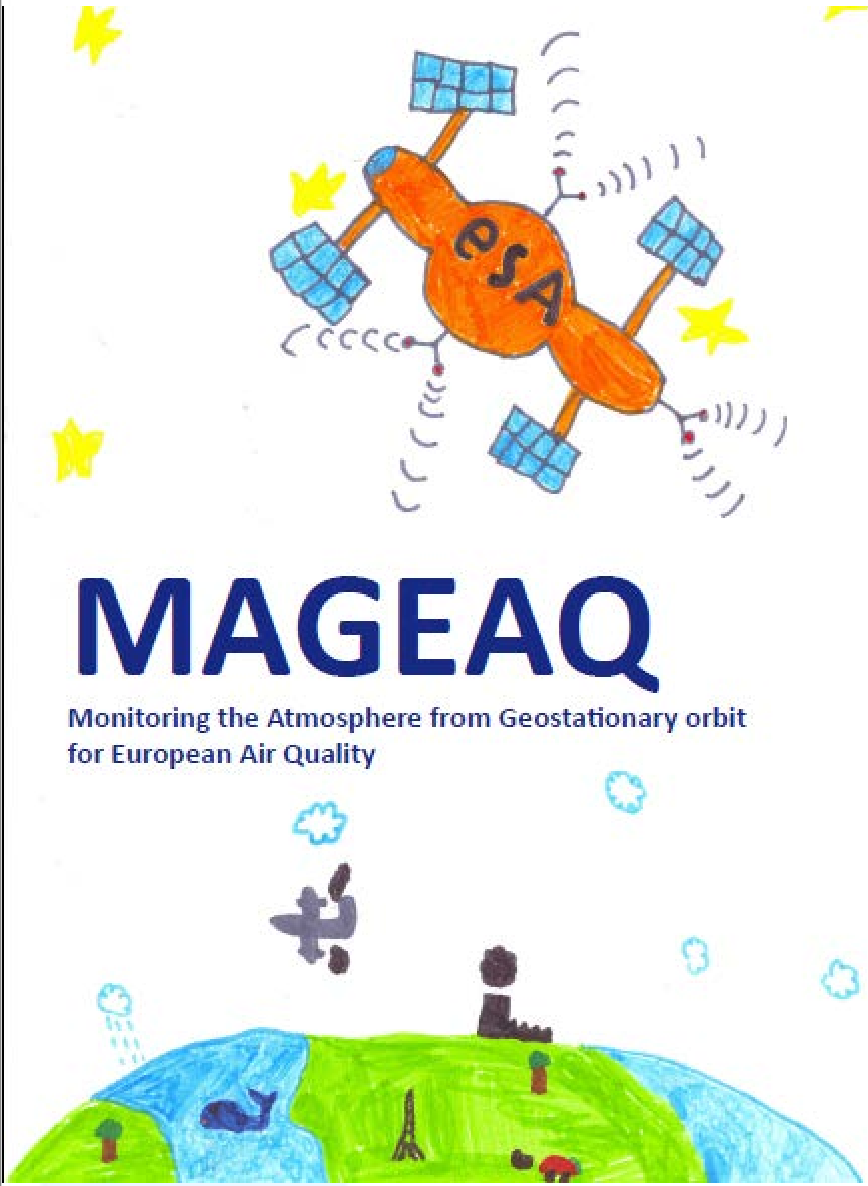
GEO missions for AQ

Proposed MAGEAQ mission for 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**

Other proposed/planned GEOs for AQ:

- GEO-CAPE: NASA (2020)
- TEMPO: NASA (2018-2019)
- MP-GEOSAT: Korea (2017-2018)
- AQ-Climate: JAXA (2020)

MAGEAQ-TIR OSSEs (no VIS component): *Claeyman et al., AMT, 2011a, b*

- Truth (Nature Run): MOCAGE AQ model (CTM)
- Assimilate 1 obs (O_3, CO) - C1: MAGEAQ-TIR or MTG-IRS; C2: free model run
- Study sensitivity to initial conditions, atmospheric forcing & emissions

- test skill of datasets to simulate ”truth” under various conditions
- Results for 2 month average (July & Aug 2009)
- Note: MTG-IRS optimized for NWP, MAGEAQ-TIR for AQ purposes

Experiment	Atm. Forcing	emissions	Initial condition	Assim
T	ARPEGE analysis	GEMS	free run	No
EXP 1a	ARPEGE forecast 48h	GEMS	free run	No
EXP 1b	ARPEGE forecast 48h	GEMS	free run	GEO-TIR2
EXP 1c	ARPEGE forecast 48h	GEMS	free run	GEO-TIR
EXP 2a	ARPEGE analysis	GLOBAL	free run	No
EXP 2b	ARPEGE analysis	GLOBAL	free run	GEO-TIR2
EXP 2c	ARPEGE analysis	GLOBAL	free run	GEO-TIR
EXP 3a	ARPEGE analysis	GEMS	changed every week	No
EXP 3b	ARPEGE analysis	GEMS	changed every week	GEO-TIR2
EXP 3c	ARPEGE analysis	GEMS	changed every week	GEO-TIR
EXP 4a	ARPEGE forecast 48h	GLOBAL	changed every week	No
EXP 4b	ARPEGE forecast 48h	GLOBAL	changed every week	GEO-TIR2
EXP 4c	ARPEGE forecast 48h	GLOBAL	changed every week	GEO-TIR

Expts:

Truth (T)
Free run (a)
MTG-IRS (b)
MAGEAQ-TIR (c)

Claeyman et al., AMT, 2011b

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Validation of ”Nature Run”
Top 4 plots CO
Bottom 4 plots O_3

Errors vs ground-based data comparable to Prev’Air forecast errors

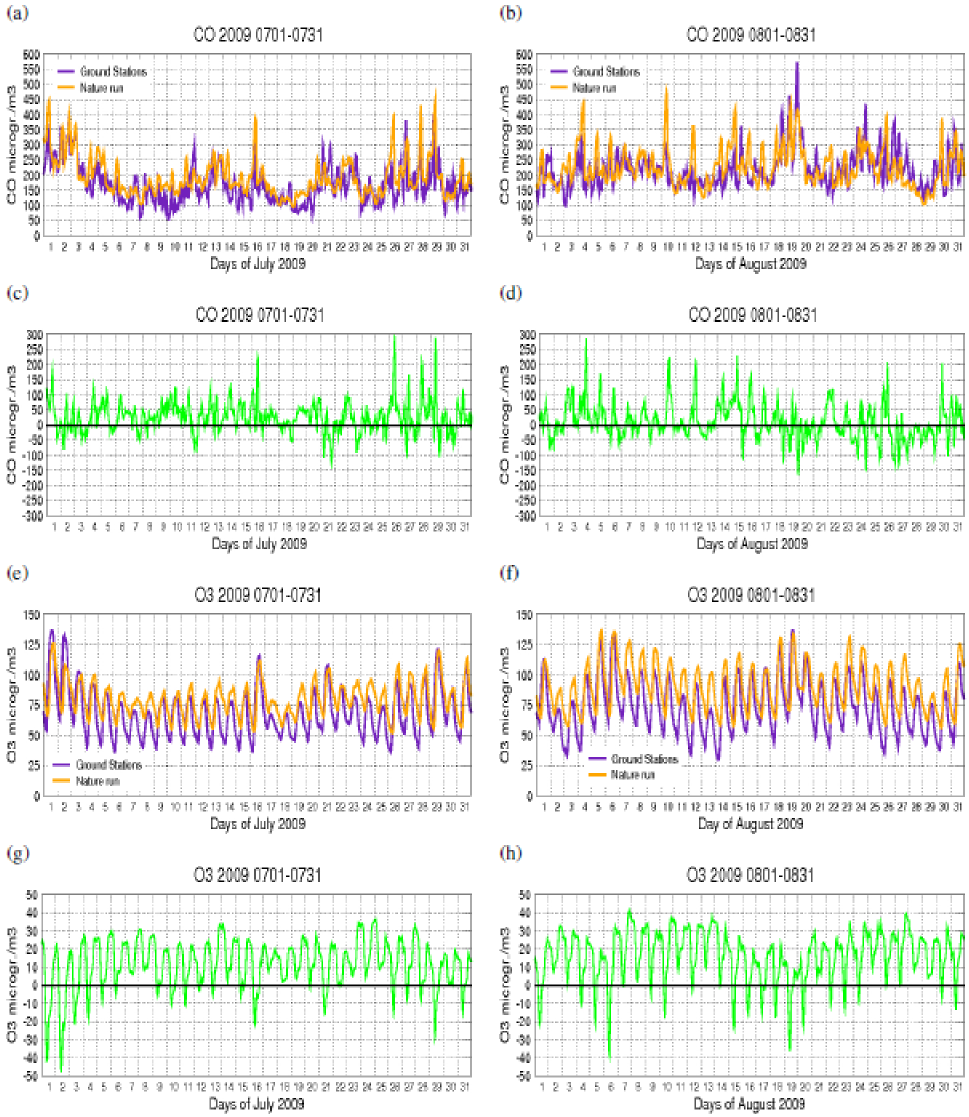

Fig. 3. Timeseries of the CO concentrations from the nature run (orange) and measured by ground based stations (purple), averaged each hour over France in July 2009 **(a)** and August 2009 **(b)** and respective differences between the nature run and the surface observations – **(c)** and **(d)**. **(e)–(h)** are as **(a)–(d)** but for O_3. For CO, all types of ground based stations are considered because of their limited numbers, whereas for O_3 only “rural” ground stations are considered in order to be closer to the model resolution of $0.5° \times 0.5°$.

Validation of NR important

Claeyman et al., 2011b AMT

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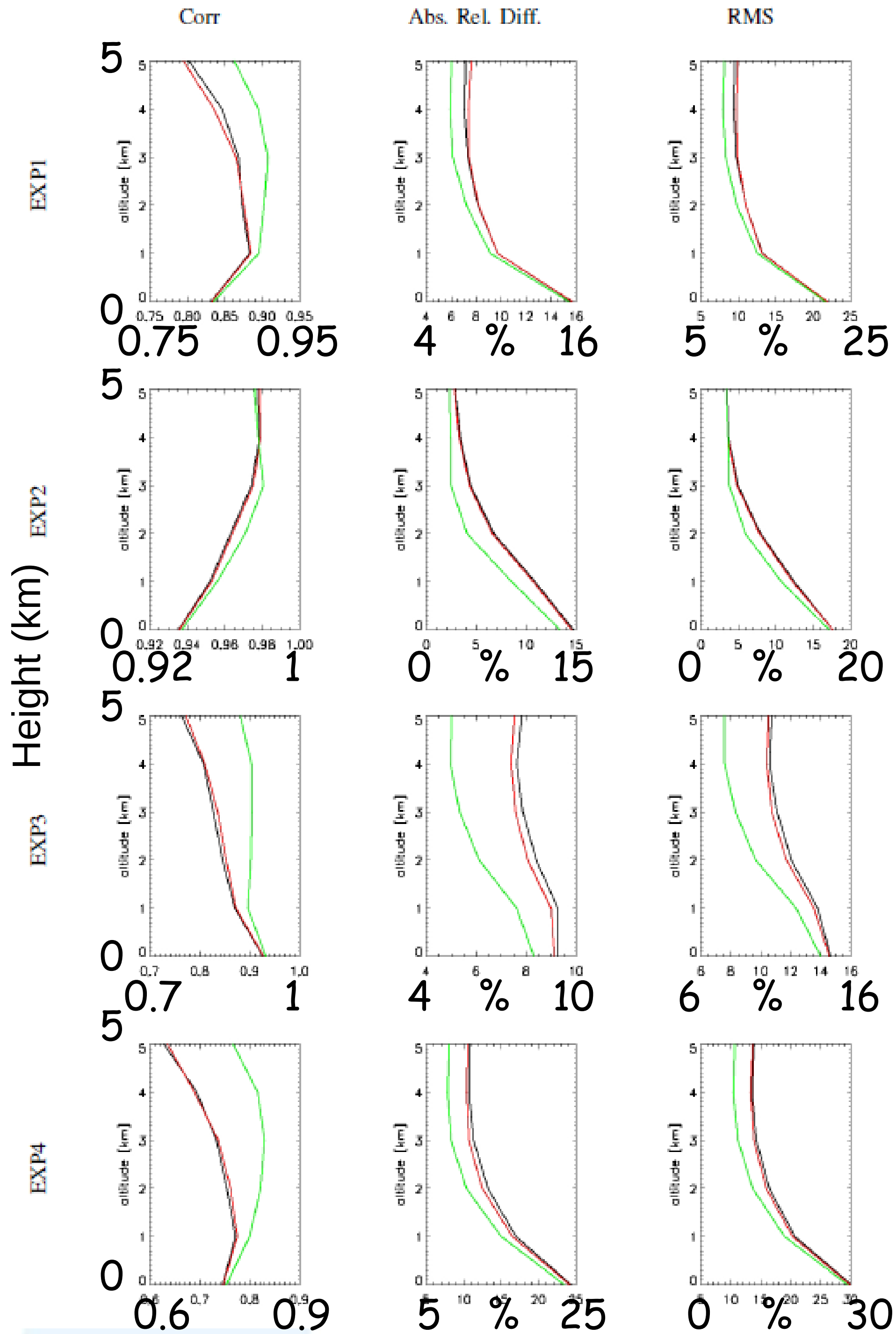
OSSE results: quantify performance



Impact of adding 1 obs (O_3) - Profile, 0-5 km ht

Expts 1-4: v Nature Run (Truth: T)

Correlation (left column)
Bias (middle column)
RMS (right column)

Black: free model run v Truth
Red: MTG-IRS v Truth
Green: MAGEAQ-TIR v Truth

Generally, MAGEAQ-TIR is better, improvement smaller over 0-1 km ht
VIS should improve 0-1 km ht

Claeyman et al., AMT, 2011b

Table 4. Correlation, bias and RMS in % calculated for ozone and CO LmT column between the nature run and the control run (a), between the nature run and GEO-TIR2 assimilation run (b) and between the nature run and the GEO-TIR assimilation run (c) for the 4 experiments averaged over 2 months (July and August 2009).

Experiment	Ozone Corr.	Ozone Bias (%)	Ozone RMS (%)	CO Corr.	CO Bias (%)	CO RMS (%)
EXP1a	0.793	0.19	10.42	0.780	−1.02	6.78
EXP1b	0.800	1.84	10.41	0.814	−0.08	6.27
EXP1c	0.823	0.58	9.64	0.849	−0.10	5.54
EXP2a	0.935	8.60	5.31	0.919	8.46	5.22
EXP2b	0.936	8.41	5.22	0.934	6.24	4.45
EXP2c	0.948	5.74	4.56	0.935	3.59	4.12
EXP3a	0.693	2.07	12.98	0.693	1.73	8.13
EXP3b	0.715	1.66	12.56	0.757	1.59	7.13
EXP3c	0.798	1.26	10.48	0.841	0.75	5.65
EXP4a	0.528	7.78	17.27	0.545	7.11	11.41
EXP4b	0.554	7.16	16.74	0.616	6.23	10.28
EXP4c	0.650	5.77	14.51	0.732	3.91	8.16

Summary of OSSE results
LmT column: surface – 3 km

Exp a: Free model run
Exp b: MTG-IRS
Exp c: MAGEAQ-TIR

MAGEAQ-TIR significant impact vs MTG-IRS

Need to include VIS for LmT

Claeyman et al. , AMT, 2011b

Multi-spectral approach

GEO TIR+VIS vs GEO TIR (Europe domain)

Surface

Red: GEO TIR

Blue: GEO TIR+VIS

Green: A priori

All vs ref state

0-1 km col.

Benefit of TIR+VIS for ozone

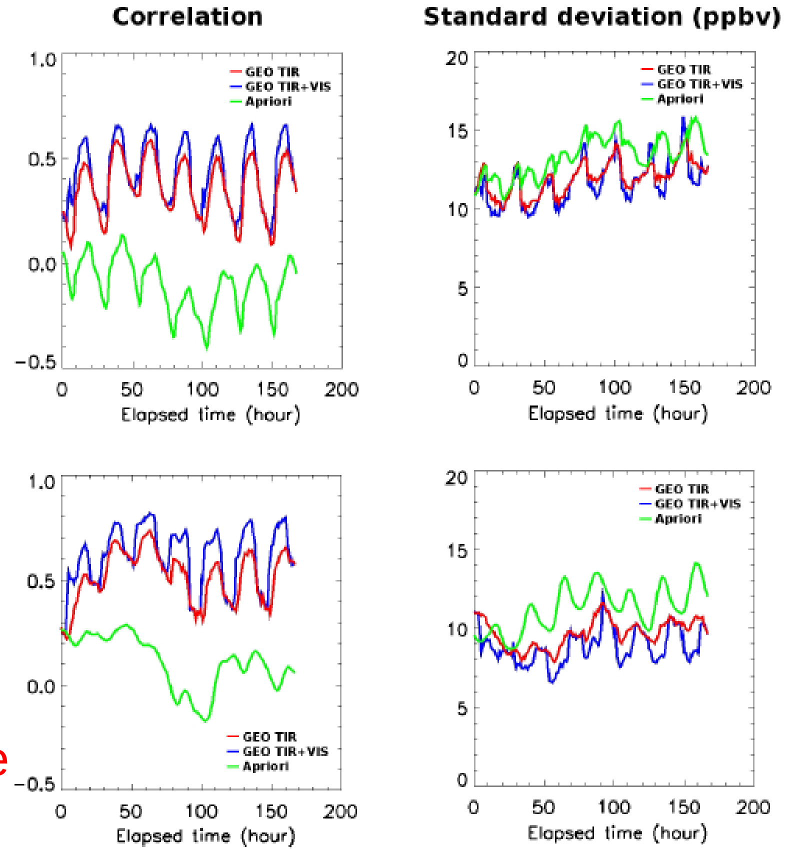


Figure 8. Time series of ozone correlation (left column, dimensionless) and standard deviation (right column, ppbv) between GEO TIR (red lines), GEO TIR+VIS (blue lines) and the reference state. This is calculated for all pixels of the red square domain (see Fig. 2) for the period between 9 to 15 July 2009. The green line shows the results obtained with the a priori. The first row corresponds to the surface ozone results and the second row corresponds to the 0–1 km ozone column results.

Hache et al., 2014, AMT

These issues are being studied by MUSICQA project

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LEO- S5P

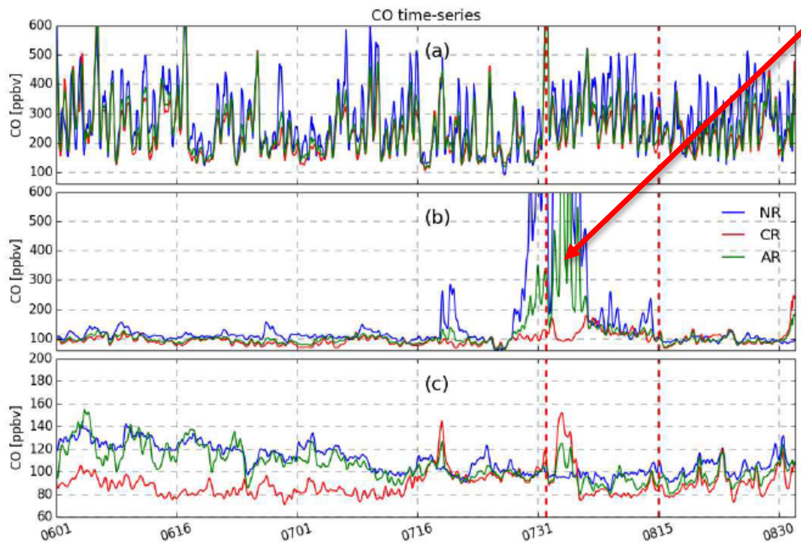
Forest fires

OSSEs for CO (DA of total column): Summer 2003 (JJA)

Truth: NR – blue

Model: CR - red

DA: AR – green



Paris

Portugal

Eastern Europe

Figure 10: *Time-series for CO concentrations in surface air issued from NR, CR and AR over three different locations defined in figure 12: Top panel for box (a), middle panel for box (b), and bottom panel for box (c).*

Headline message: Significant improvement from S5P over summer for CO information in the lowermost troposphere, even at the surface.

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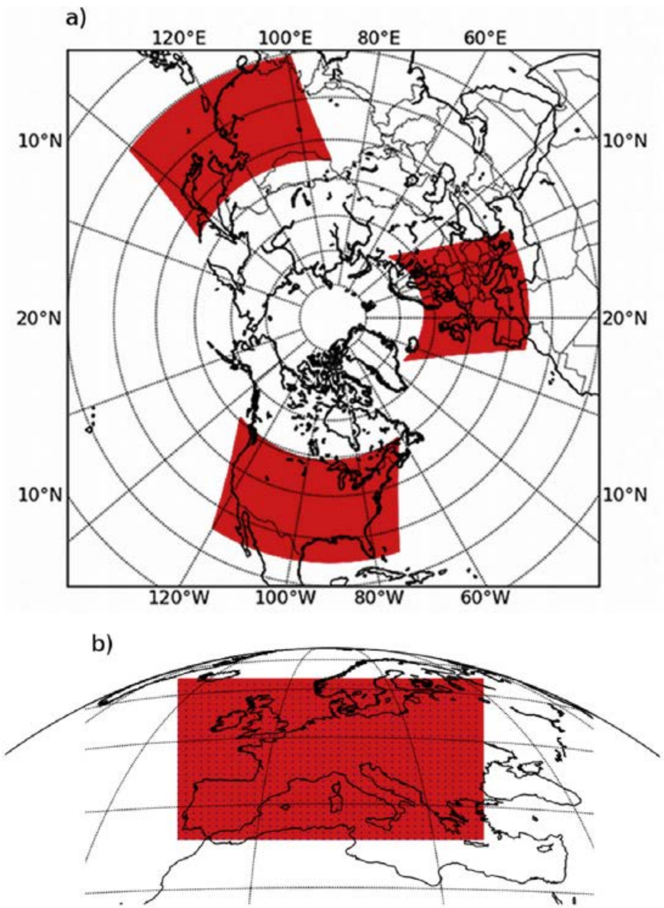
ISOTROP report, *Abida et al., 2015*

GEO Constellation



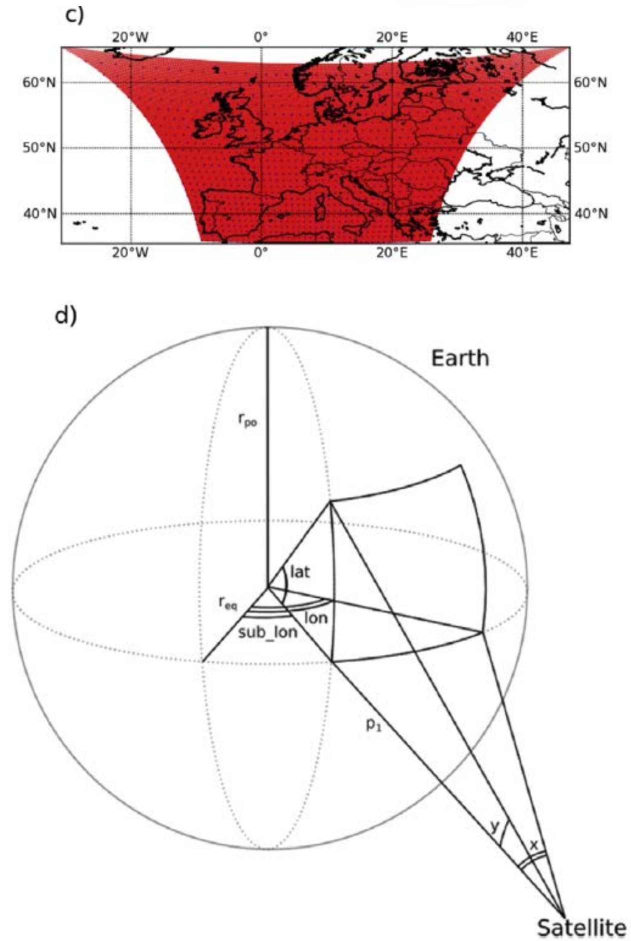


Fig. 4. a) Geostationary constellation measurement domain a) Polar projection. b) GEO-EU domain in a geostationary projection, red dots are the full resolution footprints, purple dots are plotted every 100th pixels. c) is the same as b) but in an equidistant latitude–longitude cylindrical projection. d) Geometrical sketch of the geostationary projection. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Barre et al., 2015 – see Edwards/Worden talk

Conclusions

"The air quality OSSEs performed hitherto provide evidence of their usefulness for evaluation of future observations although most studies published do not meet all the identified requirements. Especially the evaluation of the OSSE set-up requires more attention; the differences between the assimilation model and the simulated truth should approximate differences between models and real observations. Although this evaluation is missing in many studies, it is required to ensure realistic results. Properly executed air quality OSSEs are a valuable and cost effective tool to space agencies and instrument builders when applied at the start of the development stage to ensure future observations provide added value to users of Earth Observation data."

Timmermans et al. (2015) – see Curier presentation

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Extra slides

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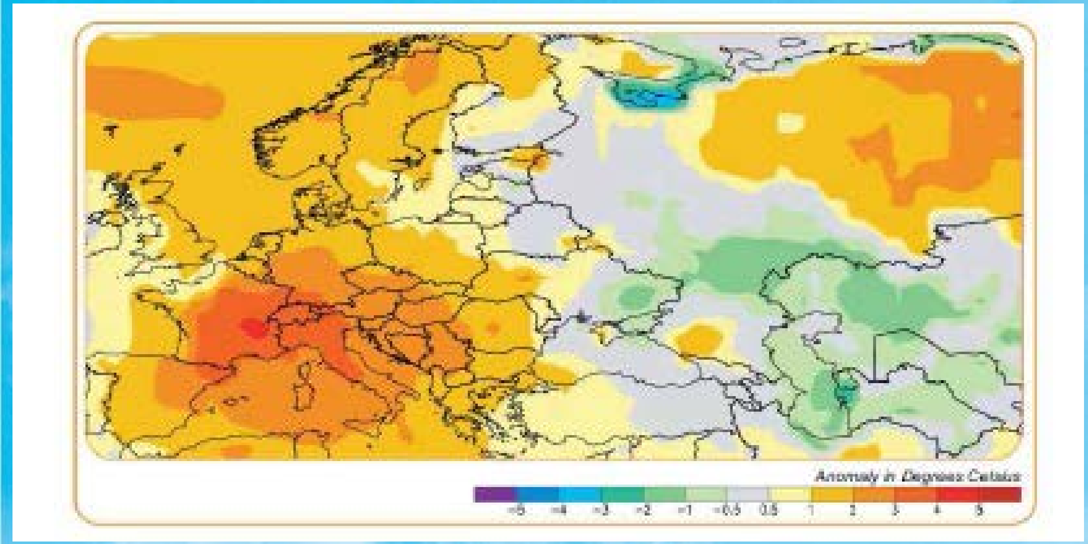
for luftforskning

Societal concern: health (European Summer of 2003)



Temperature anomaly (ºC)
June-Aug 2003 (Europe)
Climatological base period 1998-2003

Red +ve anomalies;
Blue –ve anomalies

(Courtesy UNEP)

Estimated European heat wave of 2003 caused loss of 14802 lives (mainly elderly) in France (http://www.grid.unep-ch/product/publication/download/ew_heat_wave.en.pdf)

High temperatures increase tropospheric O_3 amounts, & anticyclonic conditions ensured their persistence (*Vautard et al.,* 2005)

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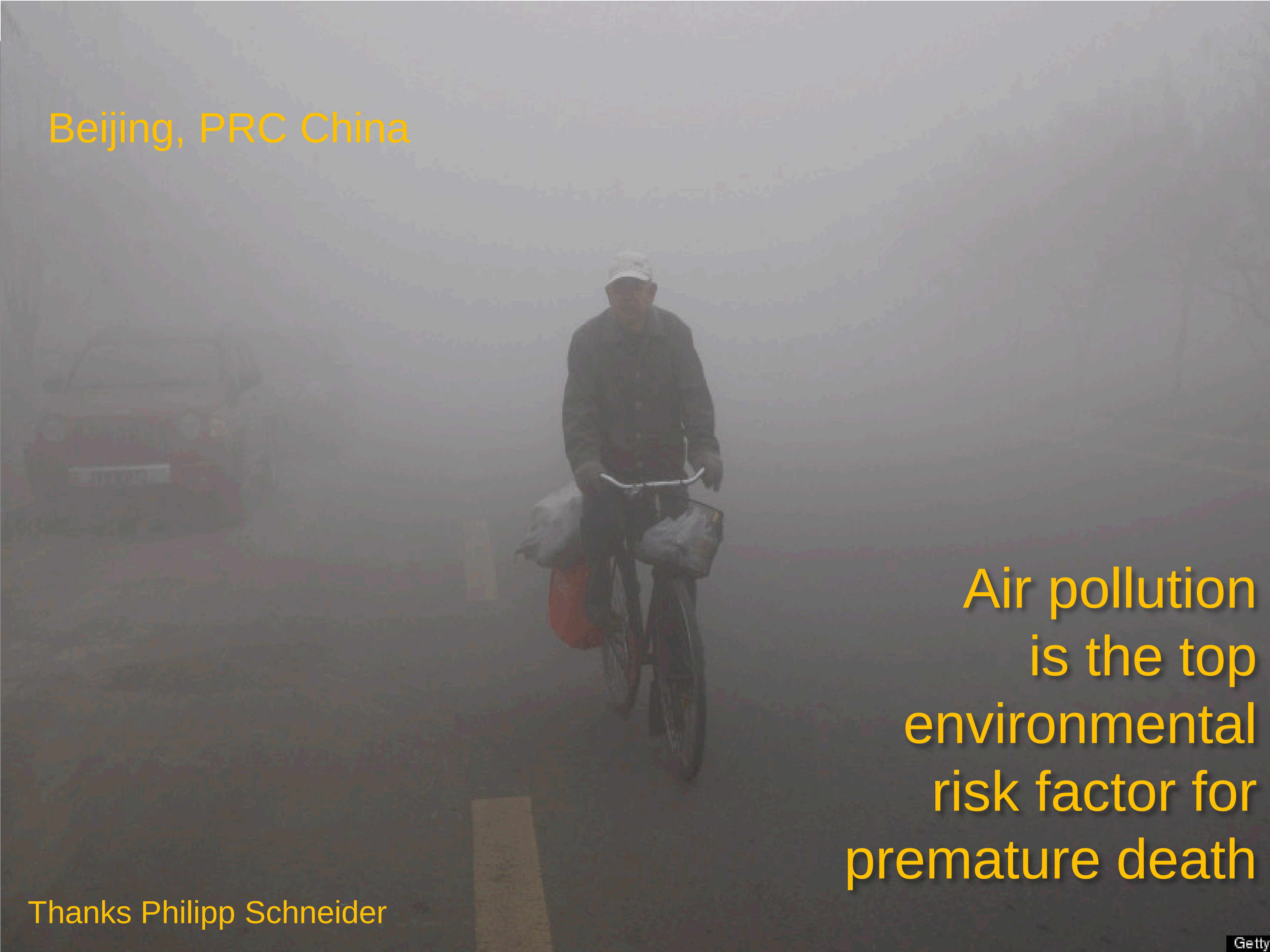
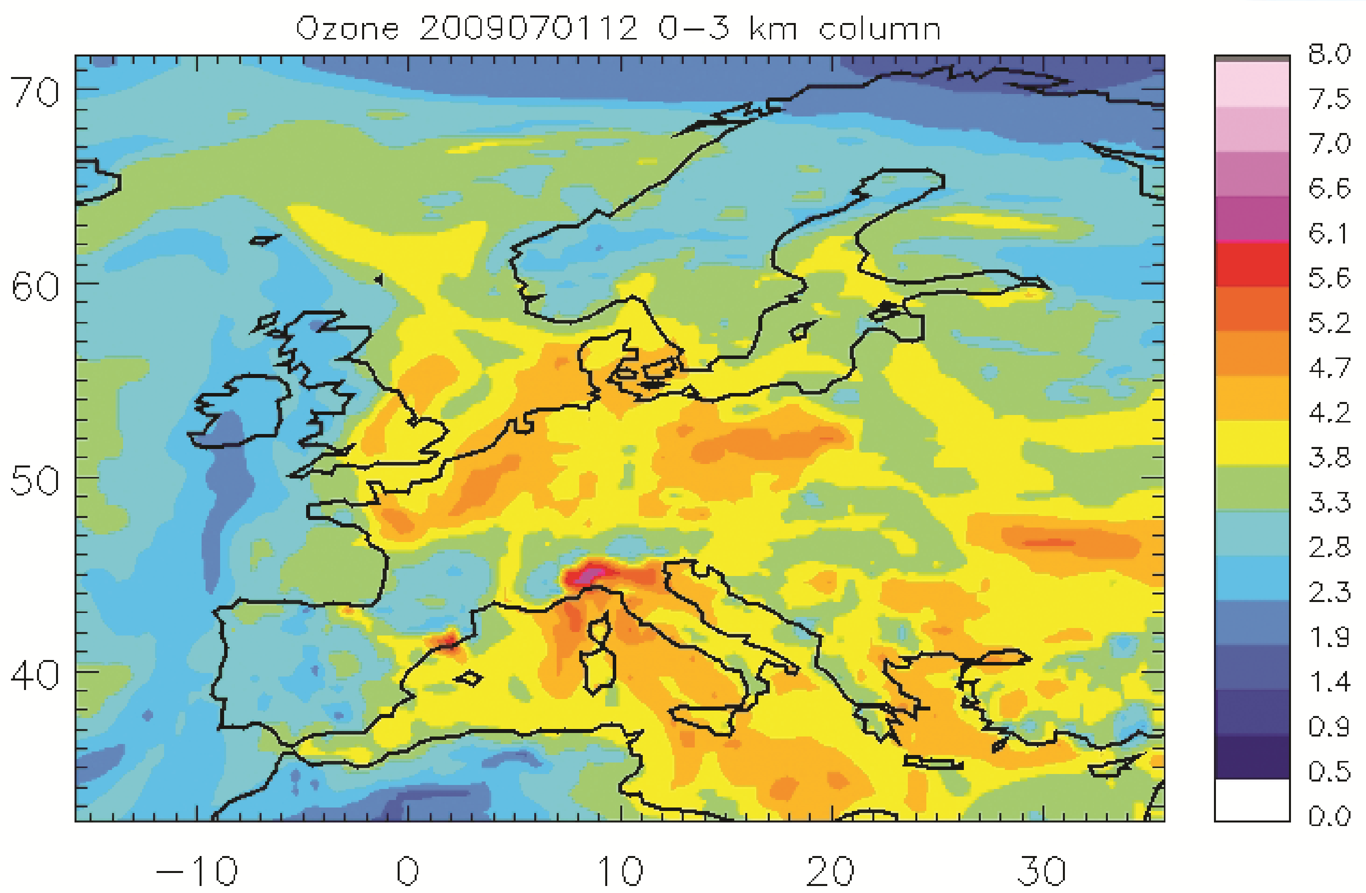
Europe: Overall annual cost health impacts, mortality, morbidity (from atmospheric pollution) – 1.575 trillion USD
WHO, 2015


Beijing, PRC China
Air pollution
is the top
environmental
risk factor for
premature death
Thanks Philipp Schneider
Getty



Spatial Variability
< ~10 km

Map of O_3 partial column (0-3 km; height above model surface) over Europe, 12 UTC, 1 Jul 2009 (10^{17} molec.cm^{-2}). Map derived from MOCAGE CTM

Note heavily polluted region in Po Valley

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Global Observing System

Observation types used by ECMWF, NWP

In situ

Surface

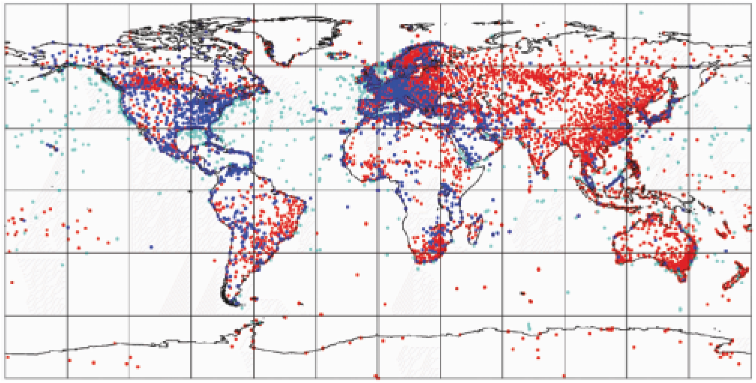


Fig. 1 Typical data coverage of surface observations, 20070301 0900-1500 UTC, showing 16,550 SYNOP (*red*), 1,937 SHIP (*cyan*) and 12,383 METAR (*blue*)

Buoy

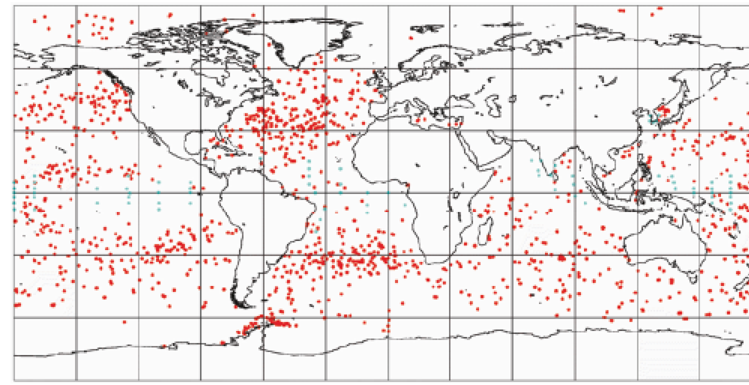


Fig. 2 Typical data coverage of buoy observations, 20070301 0900-1500 UTC, showing 5,686 drifting buoys (*red*) and 140 moored buoys (*cyan*)

Satellite

GEO

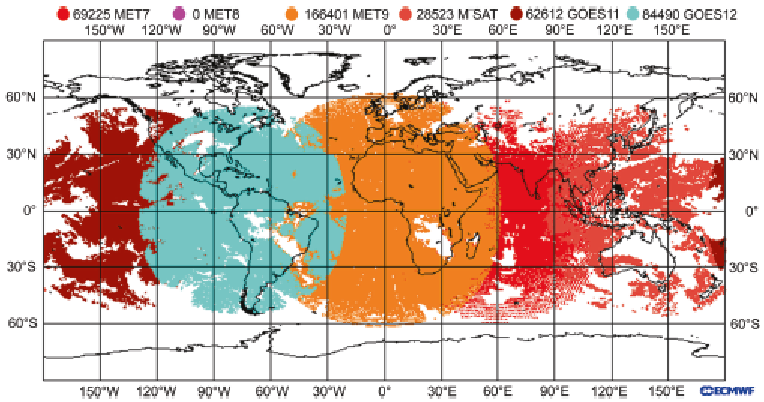


Fig. 6 Typical data coverage provided by the Geostationary constellation: GOES-11 (*brown*), GOES-12 (*cyan*), Meteosat-7 (*red*), Meteosat-9 (*orange*) and MTSAT (*red–orange*)

LEO

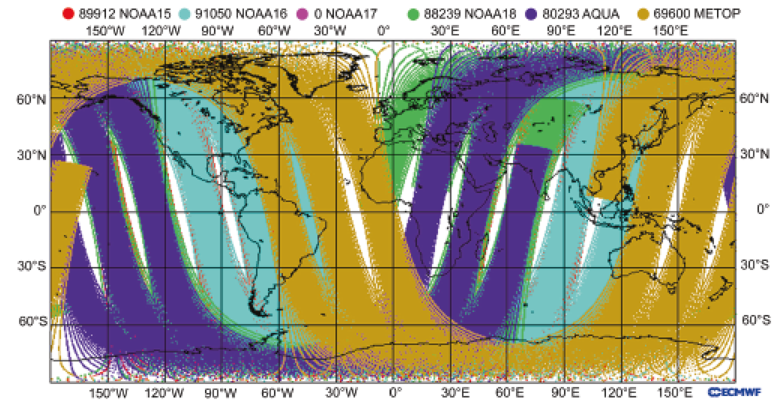


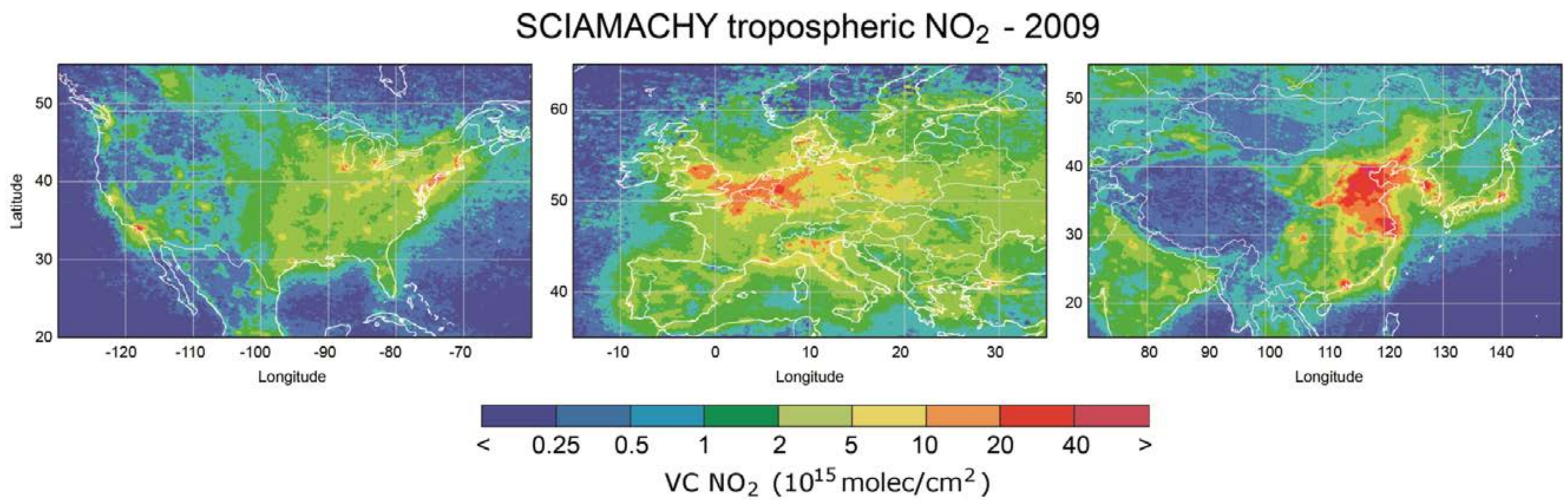
Fig. 7 Typical data coverage provided by the LEO (Low Earth Orbit) constellation of AMSU-A instruments from NOAA, AQUA and METOP satellites: NOAA-15 in *red*, NOAA-16 in *cyan*, NOAA-18 in *green*, AQUA in *violet* and METOP in *brown*

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

Consider: elements of GOS for AQ (focus on satellite platforms: LEO & GEO)

Ground-based network also important (e.g. ozone measurements)

Demonstrated value of space-borne AQ measurements (note averaging period)



NO_2 tropospheric densities, averaged for 2009, from SCIAMACHY (LEO platform). Left: USA; Middle: Europe; Right: China. Units: 10^{15} molecules.cm^{-2}. Fig. A. Richter. © Copyright 2012, American Meteorological Society (AMS) *Lahoz et al. 2012 (BAMS)*

Other LEOs: IASI (O_3, CO); MOPITT (CO); TES (O_3); GOME & OMI (NO_2, NO_x)
Aerosol products from GEOs for NWP (no tracer measurements from GEOs)

Issues:

- Lack ht-resolved regional/continental scale information, O_3 &, until recently, CO
- Concs. AQ species in PBL (planetary boundary layer) a priority (*IGACO 2004*)

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MAGEAQ characteristics:

- GEO platform
- Multi-spectral concept for lowermost troposphere (incl. PBL)
- O_3: TIR+VIS

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).

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MAGEAQ v other GEO platforms (note: dates from 2010)

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.

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Quantifying significance

We are interested in the performance of C1-T vs C2-T

If we have enough statistics we could do hypothesis testing – examples:

- *Claeyman et al. 2011b* – AQ, ozone and CO
- *Lahoz et al. 2005* – stratospheric winds and ozone

We used the two-sample hypothesis z-test defined as:

$$Z = \frac{\overline{|\mathrm{CR} - \mathrm{NR}|} - \overline{|\mathrm{AR} - \mathrm{NR}|}}{\sqrt{\frac{\sigma^2_{\mathrm{CR-NR}}}{N} + \frac{\sigma^2_{\mathrm{AR-NR}}}{N}}} \quad (2)$$

where NR is the nature run dataset, CR is the control run dataset, AR is the assimilation run dataset, σ is the root-mean square (RMS) and N is the number of grid points. Vertical lines indicate absolute value.

Claeyman et al.

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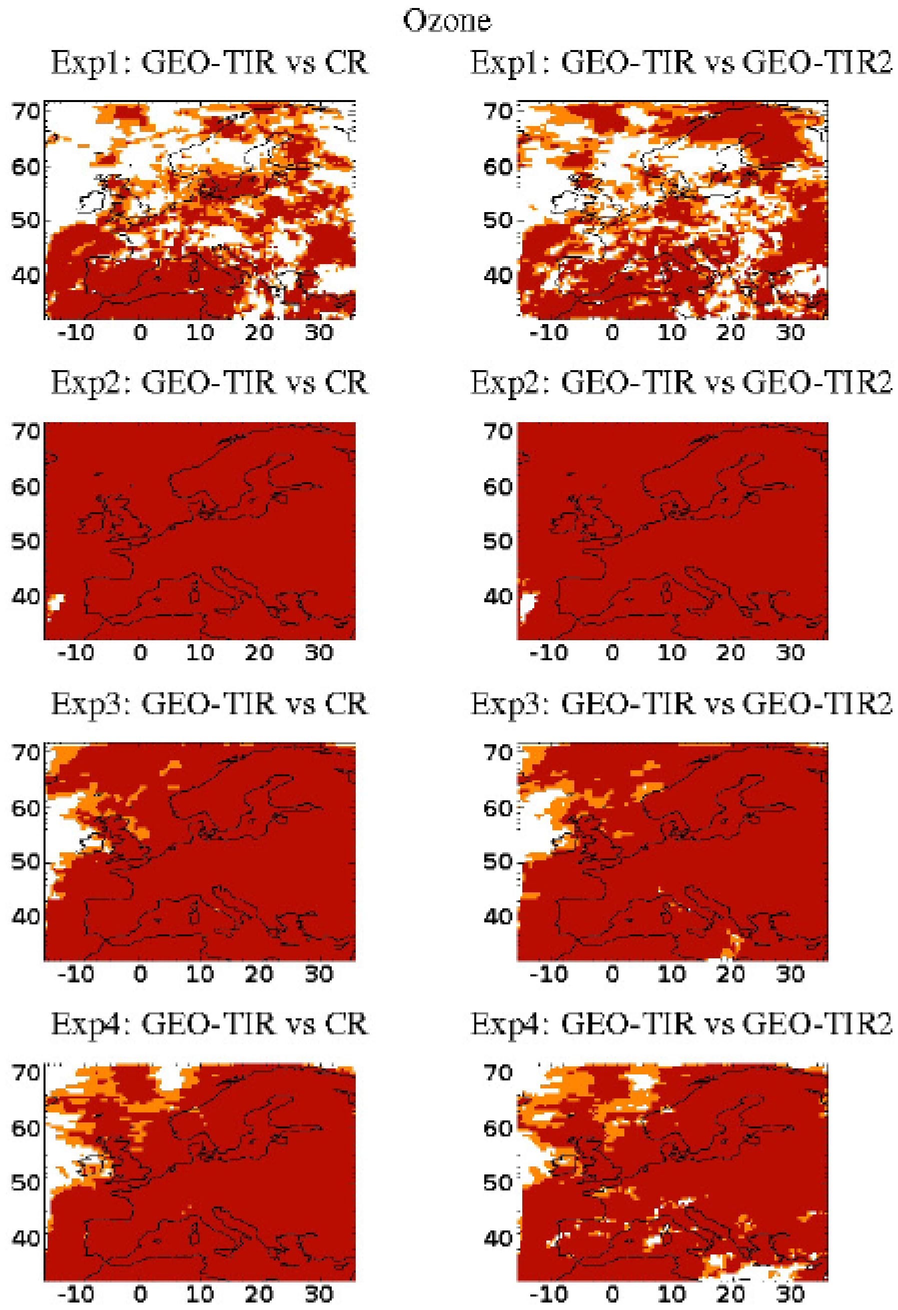
Ozone LmT column
0-3 km

Differences v NR

0.95 C.L. orange+red
0.99 C.L. red

CR: free model run

GEO-TIR: MAGEAQ
GEO-TIR2: MTG



Claeyman et al.

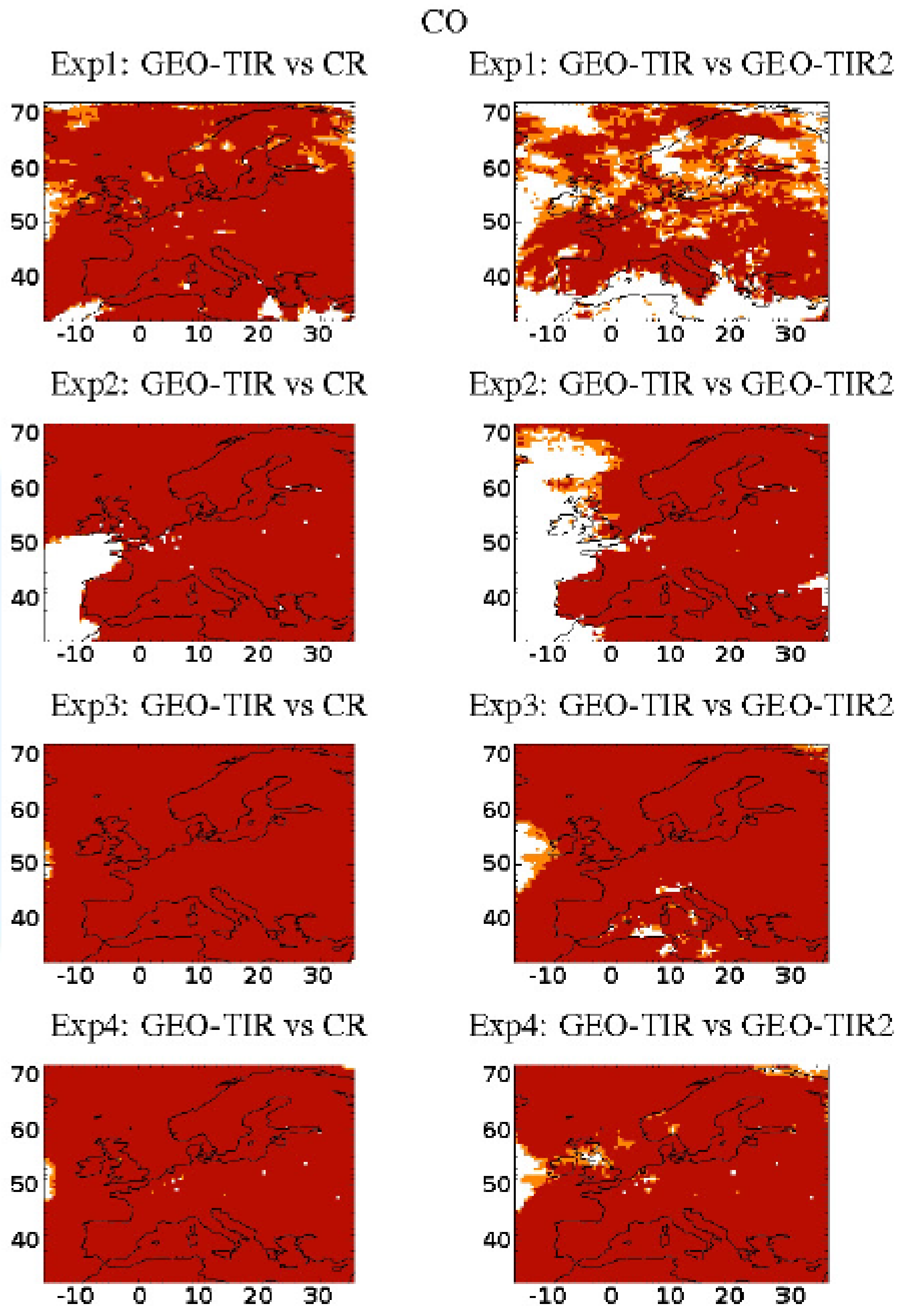
CO LmT column
0-3 km

Differences v NR

0.95 C.L. orange+red
0.99 C.L. red

CR: free model run

GEO-TIR: MAGEAQ
GEO-TIR2: MTG



Claeyman et al.

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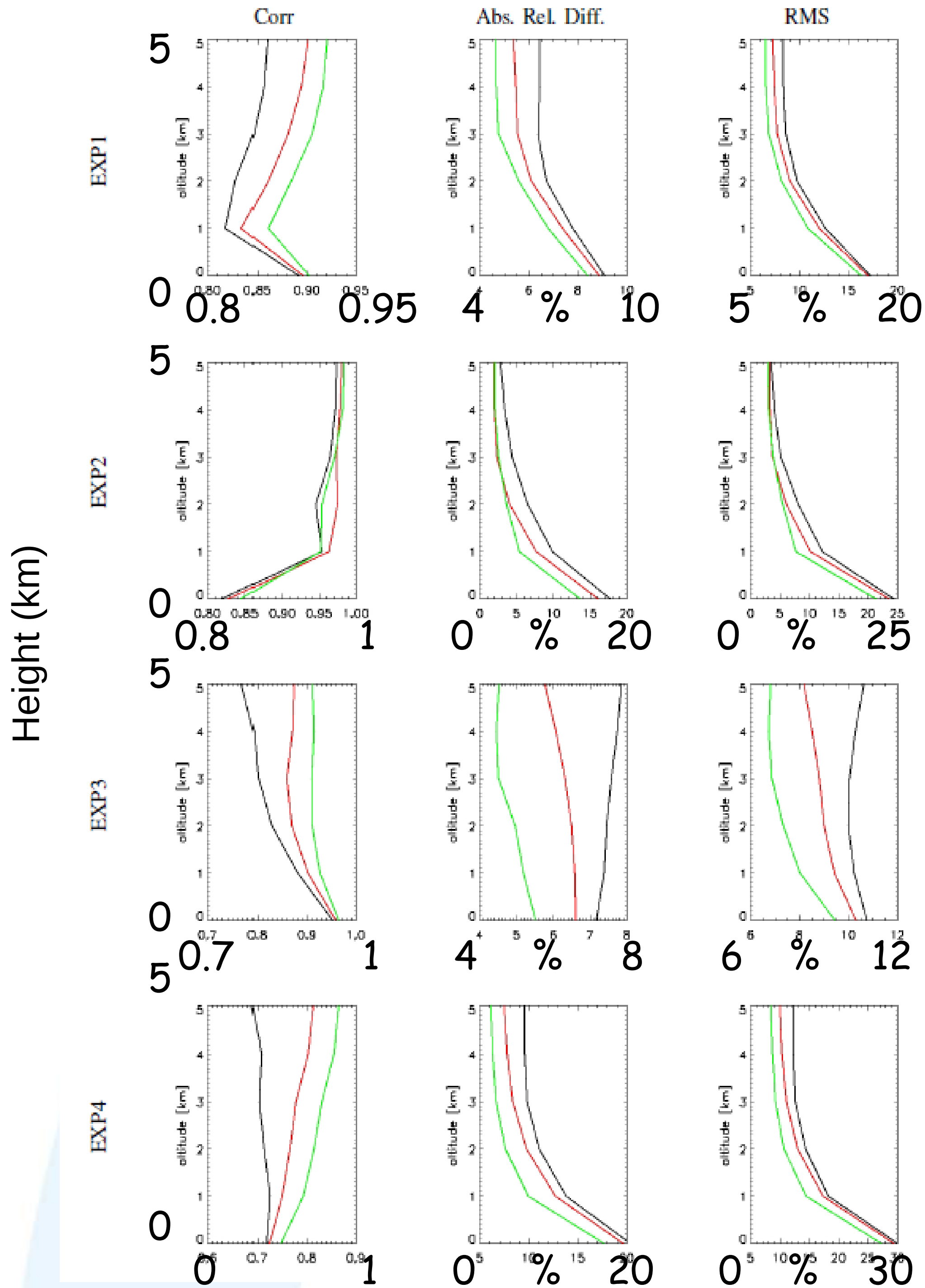

Impact of adding 1 obs (CO) - profile, 0-5 km ht

Expts 1-4: vs Nature Run

Correlation (left column)
Bias (middle column)
RMS (right column)

Black: free run (model) v Truth
Red: MTG-IRS v Truth
Green: MAGEAQ-TIR v Truth

Generally, MAGEAQ-TIR is better, impact for CO over 0-1 km ht slightly higher than for O_3

Claeyman et al., AMT, 2011b

Conclusions from MAGEAQ-TIR OSSE

•MAGEAQ-TIR generally closer to the ”Truth” than MTG-IRS (O_3, CO)
-improvement over large areas of Europe

BUT ht-dependent: instrument sensitivity (need multi-spectral approach)

•MAGEAQ-TIR can have significant impact on GOS & improve from MTG-IRS
-results suggest MAGEAQ-TIR provides better GEO platform for observing lowermost troposphere O_3 and CO than MTG-IRS (expected, but tested)

•Set-up only includes TIR, addition of VIS should improve surface sensitivity
•ESA/France resources for these expts (e.g. GEO v LEO v ground-based)

OSSEs integral part of MAGEAQ

- In line with ESA (ADM-Aeolus; CarbonSat; ISOTROP), NASA (GEO-CAPE, TEMPO), NCAR (GEO constellation) & NCEP (Masutani *et al.* 2010) approaches
- Follow up in MUSICQA

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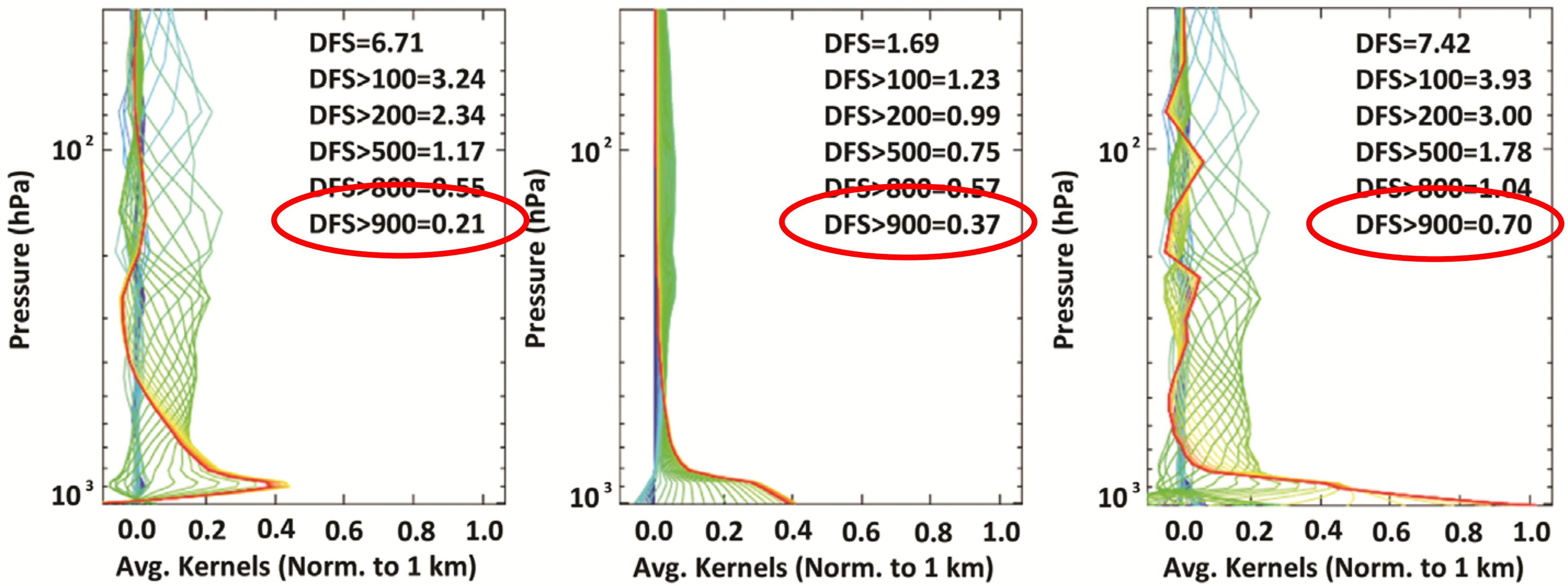
Multi-spectral approach



Representative averaging kernels (AVKs) for 6 nm sampling:
Left: TIR; Middle: VIS; Right: TIR+VIS: Degrees of Freedom for Signal (DFS)
Note information content (DFS) from lowermost troposphere increased for TIR+VIS

These issues are being studied by, e.g., *Natraj et al. (2011), Hache et al. (2014)* and MUSICQA project (TIR+VIS)

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ISOTROP

The general aim of the ESA ITT study "Impact of Spaceborne Observations on Tropospheric Composition Analysis and Forecast" is to assess the benefit of the LEO+GEO system for the understanding of local to regional scale tropospheric composition with a focus on Europe.

The first and main objective of this activity is to assess the value of a LEO+GEO satellite observation system measuring in the UV, visible, near infrared, and short wave infrared at nadir for tropospheric composition monitoring and forecast using a data assimilation scheme, using the Sentinel-4/-5 observation system as an example. The following questions shall be addressed in this context:

- What is the gain in model and forecast skill by assimilating observations from LEO and the availability of GEO data?
- What is the improvement for boundary layer concentrations?
- What is the improvement for long range transport of trace gases and its impact on boundary layer concentrations?
- What is the improvement for components from episodal sources and from temporally constant sources?
- What is the improvement regarding optimization of surface emission rates?

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Use of cross-OSSE concept (TNO/CNRM): O_3, CO, NO_2, HCHO

Proposed OSSE activities

ISOTROP (DOW): note cross-OSSE concept

Detailed description of tasks:

- Run OSSEs with the MOCAGE-PALM and LOTOS-EUROS data assimilation systems with the assimilation activated for target areas and periods. Appropriate in situ (ground-based) and satellite data (LEO/GEO) will be assimilated (data to be produced in WP2 and WP3).
- Change boundary conditions in OSSEs: (i) modified initial conditions; (ii) modified lower boundary conditions; and (iii) modified emissions.
- Compare the various OSSEs performed to the Nature Runs and Reference Runs for O_3, CO NO_2, HCHO: (i) CNRS/GAME, using TNO Nature Run; (ii) TNO, using CNRS/GAME Nature Run. Assess performance of the OSSEs using standard diagnostics as described in the technical part of the proposal.

Deliverables:

- C6: [T0+18] Various OSSE results (including modification of inputs) (data).
- D7: [T0+18] Description of performance of various OSSEs, including impact of the addition of various observational types (ground-based, satellite LEO and GEO) to the Global Observing System (document).

OSSEs for CO – Summer 2003 (JJA) (work for ozone, ongoing)

Value of CO column observations from S5P (LEO)
Use of data assimilation (DA) – statistics vs NR

No DA (CR) DA (AR)

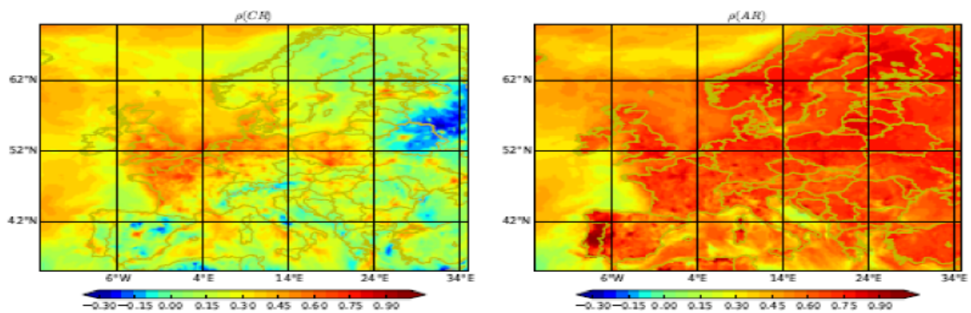

Figure 12: *Correlation coefficient between the CR and the NR (left) and between the AR and the NR (right) at the surface and for the summer period.*

NR from TNO – LOTOS-Euros

ISOTROP report, *Abida et al., 2015*

Obs simulations for AR

July 2006 CO

Surface-700 hPa column

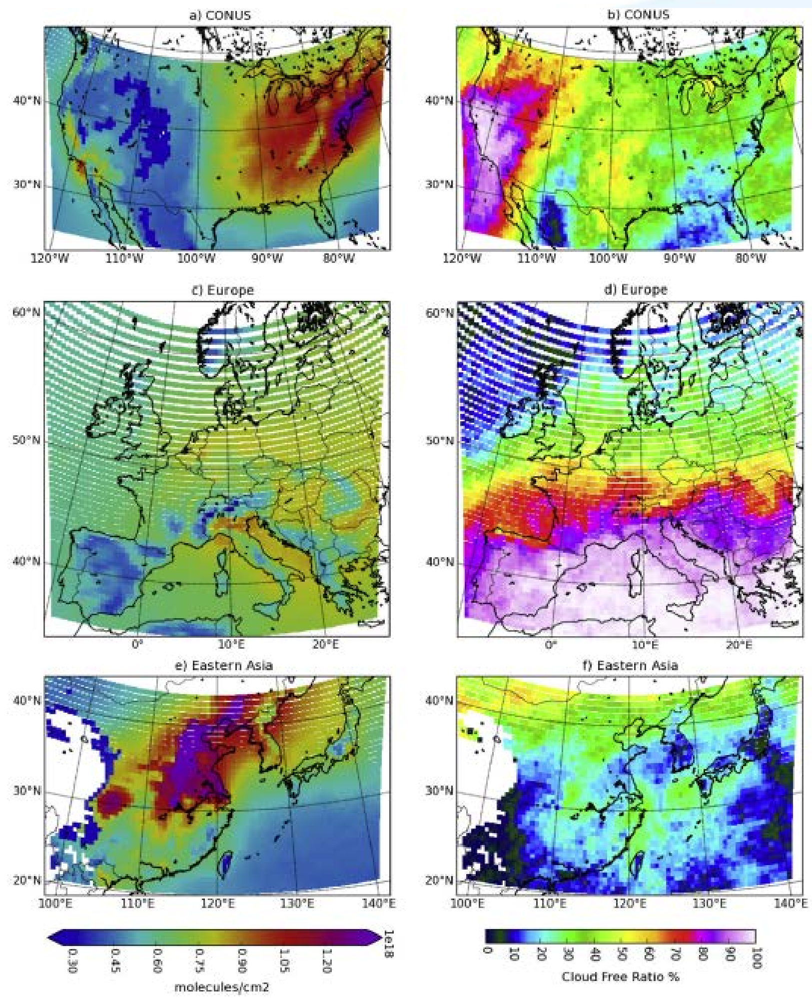

Fig. 12. Low-resolution observation simulations used for the assimilation runs. Left panels: July 2006 average retrieved CO surface-700 hPa partial column. Right panels: Cloud free ratio for July 2006.

Cloud-free ratio

Jul 2006

Cloudiness

Barre et al., 2015

MUSICQA

JLA, WAL & Samuel Quesada Ruiz

Work packages

WP1: Visible capabilities

- VIS – impacts of polarization, albedo & aerosol

WP2: SWIR capabilities

- SWIR - optimal characteristics for an instrument
- SWIR – CO

WP3: OSSEs

- TIR+VIS – ozone

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Follow up from POGEQA (funded by RTRA/STAE)

Several papers in POGEQA (c. 10) in ACP, AMT, BAMS

Papers in MUSICQA:

- Hache, E., J.-L.Attié, C. Tournier, P. Ricaud, L. Coret, W.A. Lahoz, L. El Amraoui, B. Josse, P. Hamer, J. Warner, X. Liu, K. Chance, M. Hoepfner, R. Spurr, V. Natraj, S. Kuwalik, and A. Eldering, 2014: The added value of a geostationary thermal infrared and visible instrument to monitor ozone for air quality. *Atmos. Meas. Tech.,* **7**, 2185-2201.
- Timmermans, R., W.A. Lahoz, J.-L. Attié, V.-H. Peuch, L. Curier, D. Edwards, H. Eskes, and P. Builtjes, 2015: Observing System Simulation Experiments for Air Quality. *Atmos. Env.,* in press.
- Hamer, P., K.W. Bowman, D. Henze, J.-L. Attié, and V. Marécal, 2015: The impact of observing characteristics on the ability to predict ozone under varying polluted photochemical regimes. *Atmos. Chem. Phys. Discuss.*, **15**, 4909-4971.

In preparation:

1-2 papers from Hache PhD thesis; 1-2 papers from ISOTROP project – link with MUSICQA work

Examples of missions measuring tropospheric pollutants
Generally LEOs: no tracer measurements from GEOs

- O_3: IASI tropospheric & total column (Boynard *et al.*, 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, 2010) – see later
- Aerosol products (Torres *et al.*, 2010) (Note: aerosol products from GEOs for NWP)

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OSSE results: impact of adding 1 data type (consider O_3, 0-3 km column)

Red/Blue: MAGEAQ-TIR closer/further from "Truth" (v model & MTG-IRS)

MAGEAQ-TIR v model

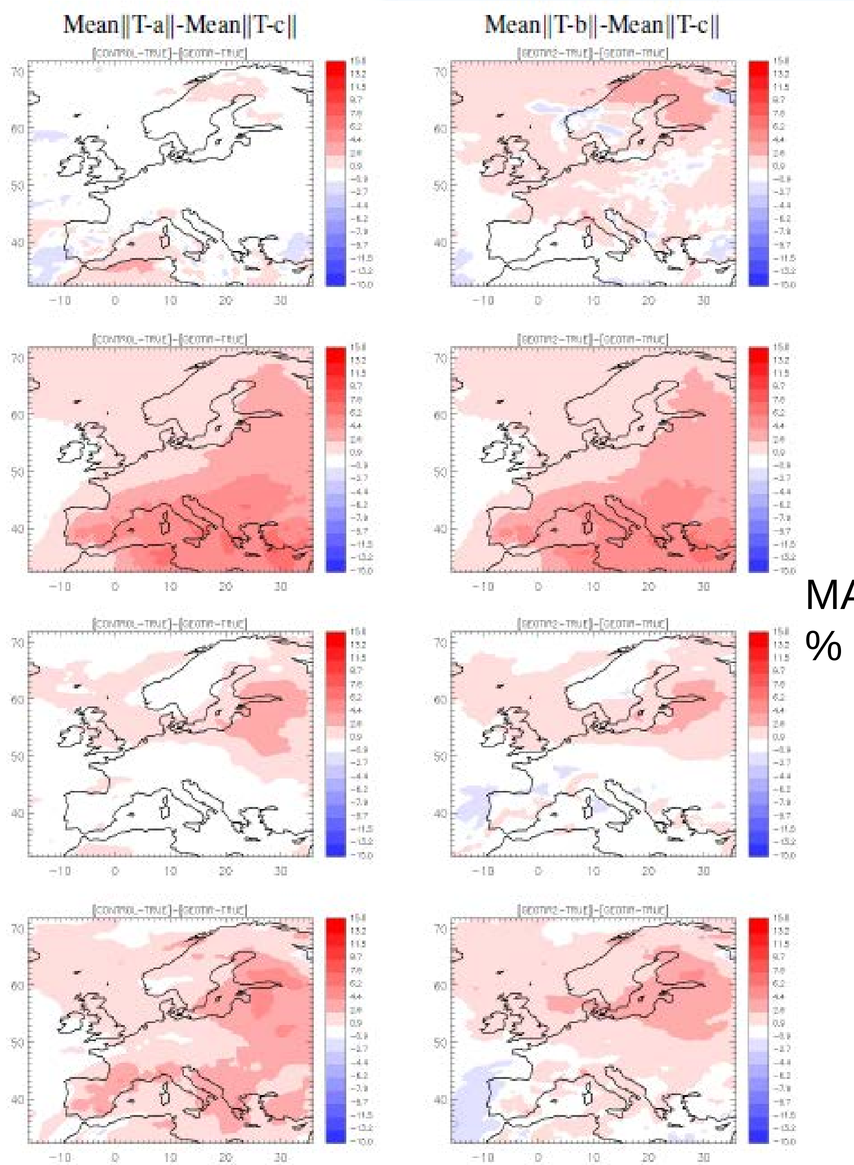
% of Truth

Exp 1

Exp 2

Exp 3

Exp 4



MAGEAQ-TIR v MTG-IRS

% of Truth

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OSSE results: impact of adding 1 data type (focus on O_3, 0-3 km column)

Red/Blue: MAGEAQ-TIR improves/degrades correlation v "Truth"

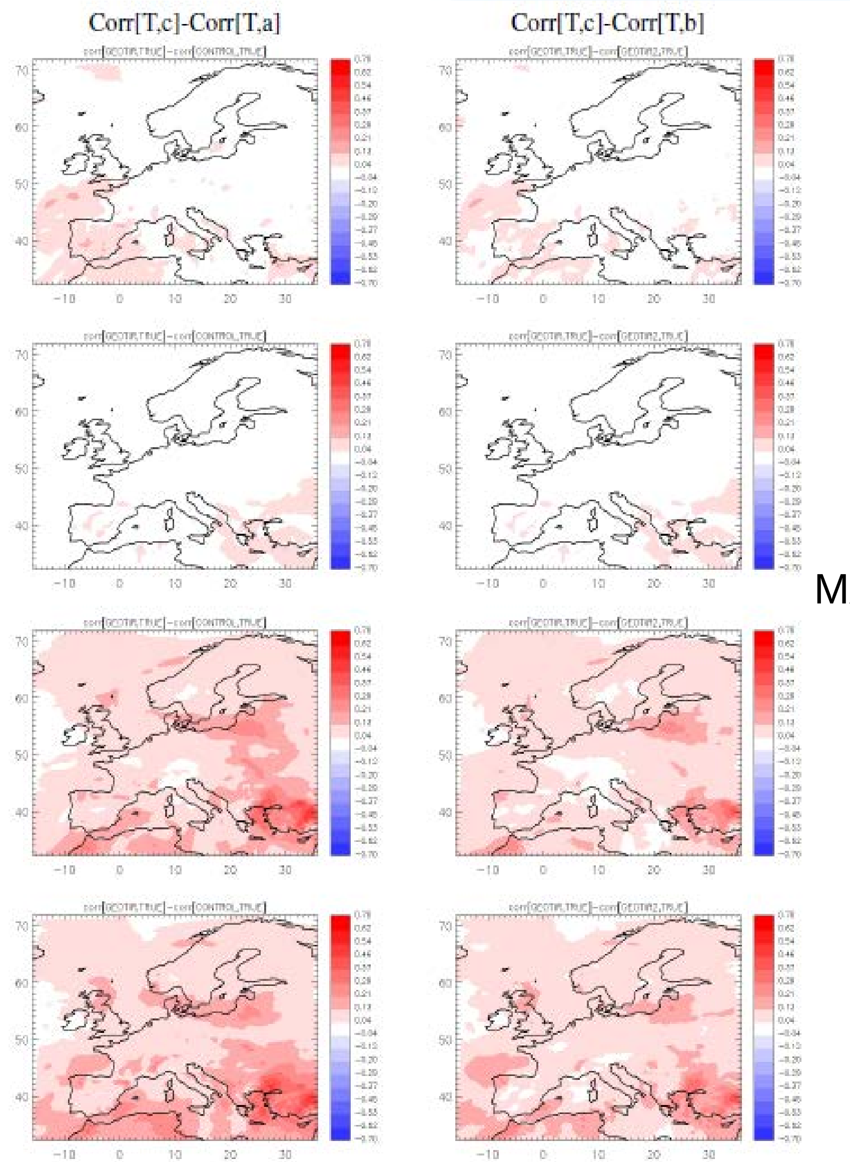
Exp 1

Exp 2

Exp 3

Exp 4

MAGEAQ-TIR v model



MAGEAQ-TIR v MTG-IRS

OSSE results: impact of adding 1 data type (CO, 0-3 km column)

Red/Blue: MAGEAQ-TIR improves/degrades correlation with Truth

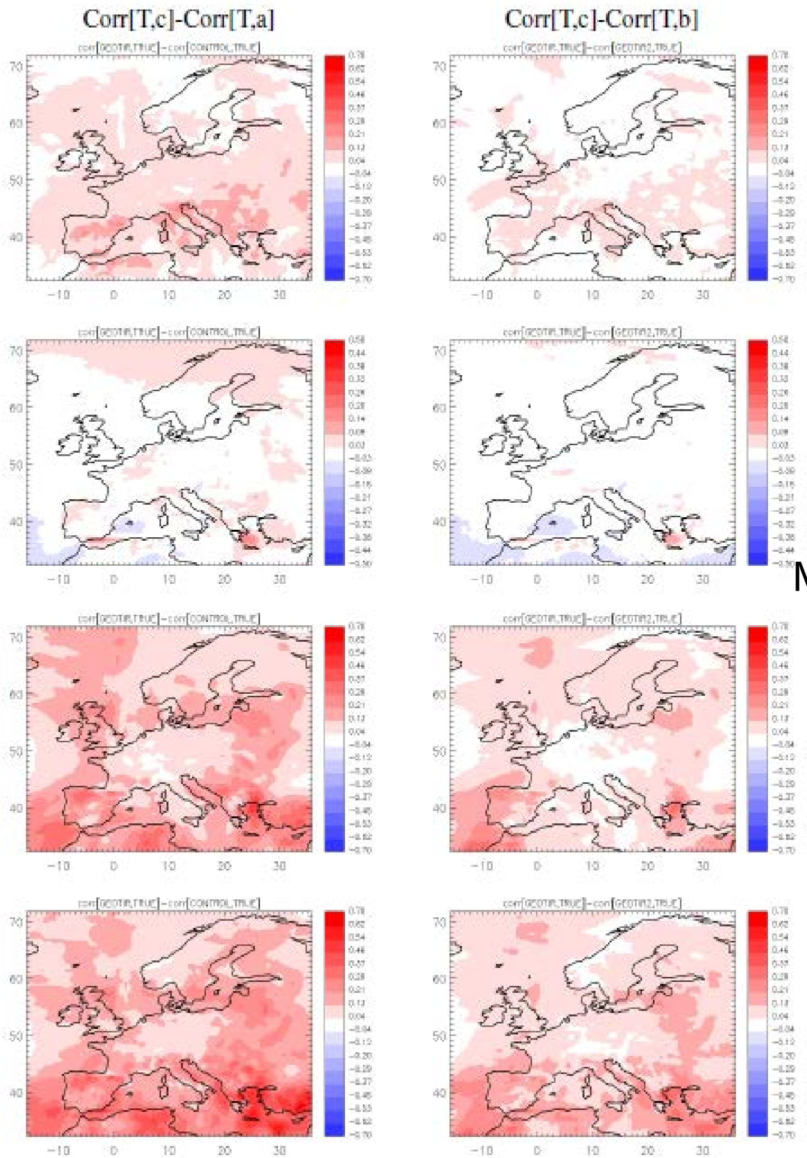
Exp 1

Exp 2

Exp 3

Exp 4

MAGEAQ-TIR v model



MAGEAQ-TIR v MTG-IRS

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OSSE results: impact of adding 1 data type (CO, 0-3 km column)

Red/Blue: MAGEAQ-TIR closer/further from Truth (vs free run & MTG-IRS)

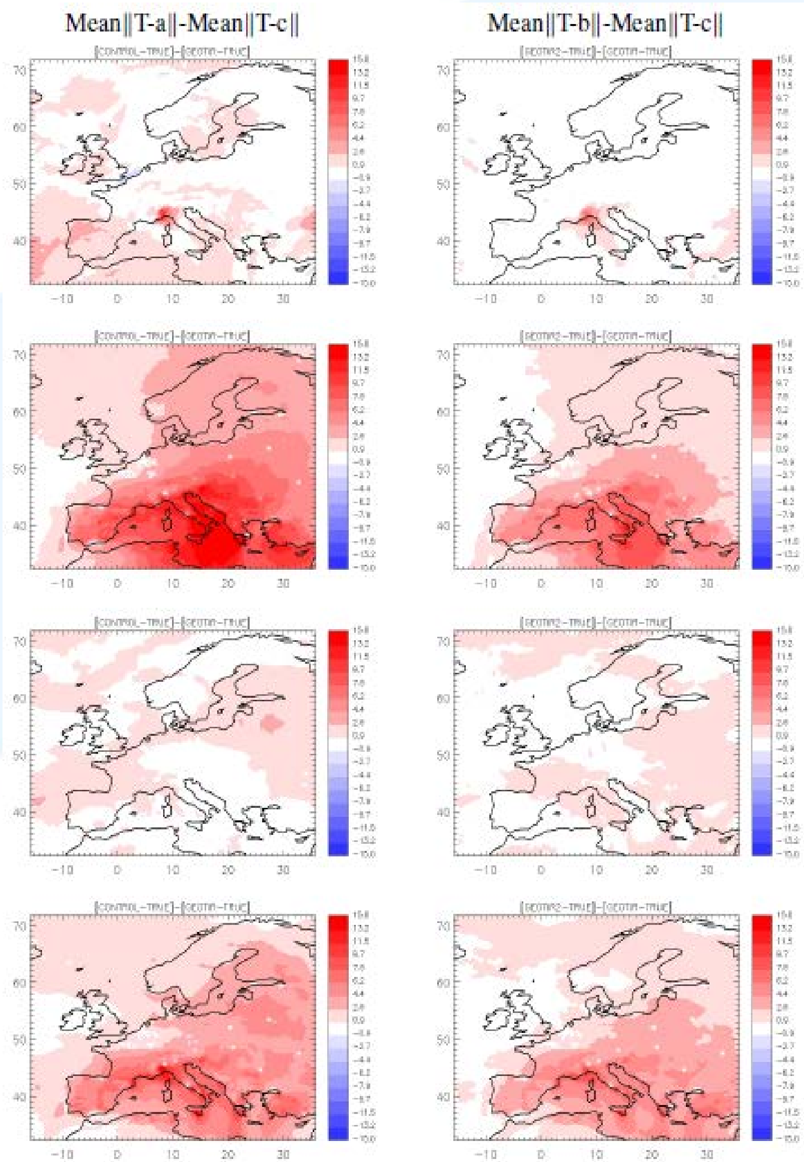
Exp 1

Exp 2

Exp 3

Exp 4

MAGEAQ-TIR v model



MAGEAQ-TIR v MTG-IRS

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Issues with a GEO platform that need to be addressed

Measurements of tropospheric near surface O_3 concentrations to desired precision levels is major current technical difficulty. (Also apply to LEOs)

Major missing components:

(i) ability to make precise O_3 measurements from nadir geometry using VIS Chappuis bands (SAGE-II in solar occultation – McCormick *et al.*, 1989);
(ii) capability to perform multi-spectral retrievals (improves sensitivity to different atmospheric altitudes) – see retrieval studies for combining OMI/TES measurements (Landgraf & Hasekamp, 2007; Worden *et al.*, 2007). Various combinations of wavelengths indicate such combinations are highly promising (Natraj et al., 2011; Hache et al., 2015)

Importance of TIR+VIS for MAGEAQ
Discussed in Lahoz *et al.* 2012 (BAMS)

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