Air Quality and assimilation in the Euro-Mediterranean region

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With a contribution from NILU colleagues

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ICTP, Trieste, Italy

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Outline

- **Why?** Why is air quality (AQ) important?
  - Challenges for the 21st Century
- **What?** What is needed to understand air quality?
  - Tools: Observations, models & bringing them together – data assimilation
- **How?** How do we use these tools?
  - Air quality conditions: "best" state & "best" forecast
  - Monitoring air quality, now and future: the "best" observing system
  - Examples from data assimilation
- **Where are we going?** Future developments
  - Higher spatio-temporal resolution: serving the citizen - you
- **Conclusions**
  - Data assimilation key to understanding and addressing problems associated with AQ

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Why?

Challenges for the 21st Century

Climate change

Air quality

Water resources

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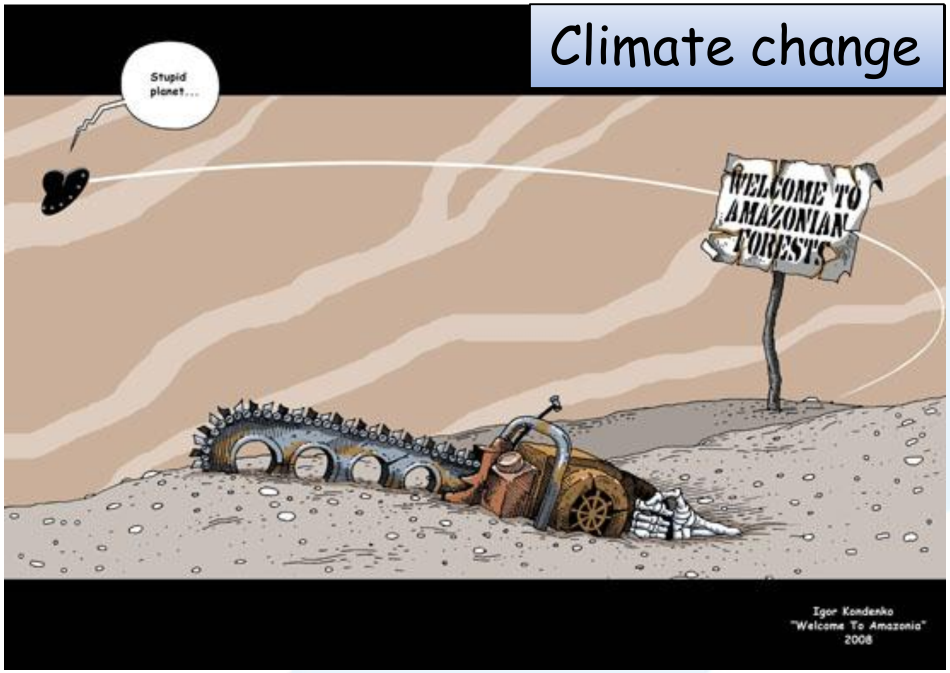
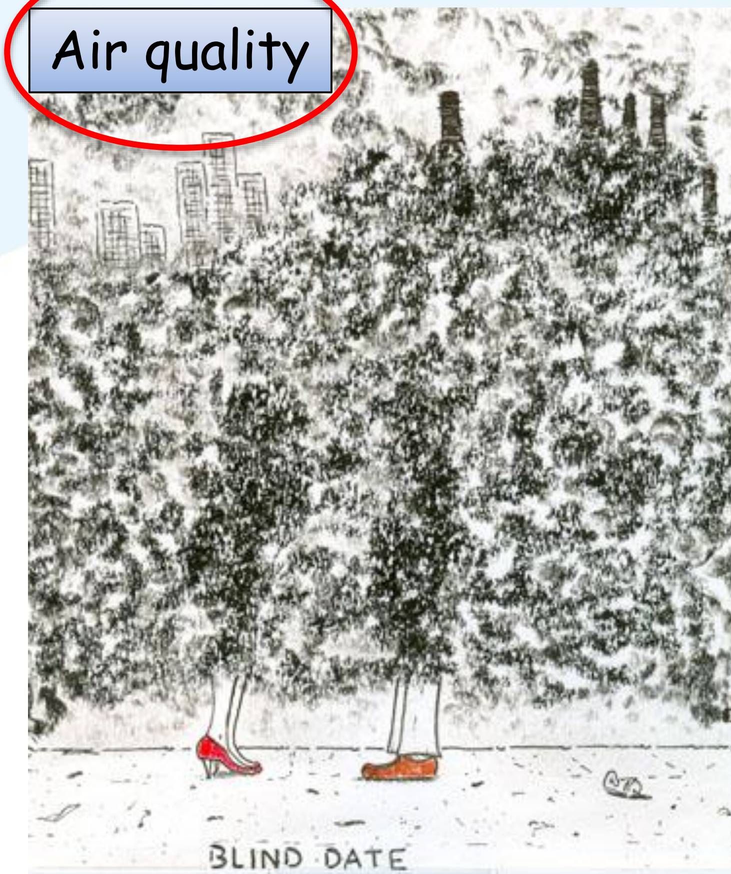
Laugh or cry…

Climate change



Water resources

Air quality



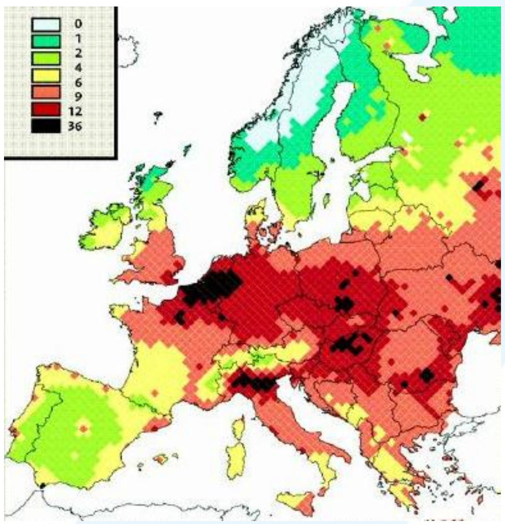
French Air Quality Law (12/1996), article 1 : «Every citizen has the right to breathe air which does not harm his/her health » & drink good wine!


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)

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)

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BETTER GROWTH
BETTER CLIMATE
The New Climate Economy Report
THE SYNTHESIS REPORT

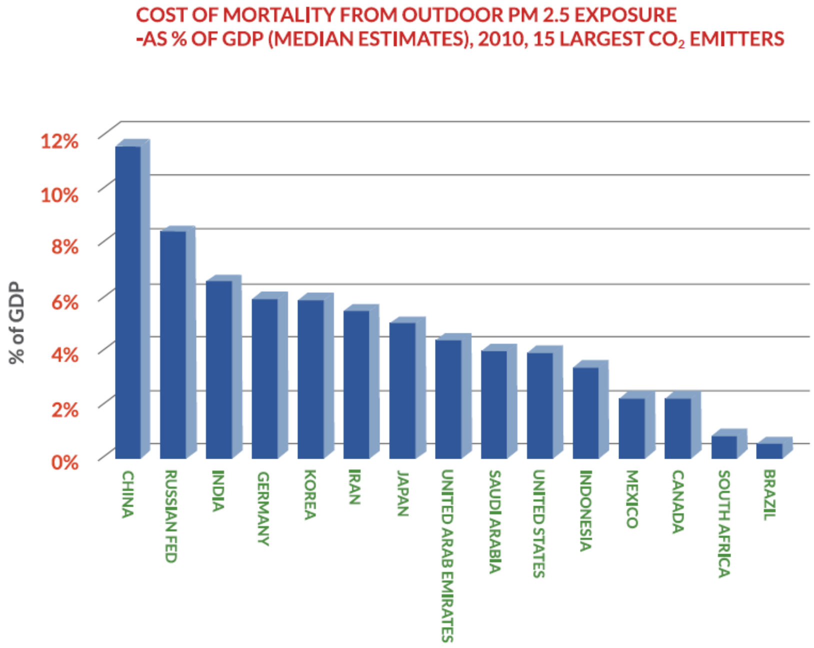
www.newclimateeconomy.report
www.newclimateeconomy.net

Link economy/AQ...

Figure 1
Three critical economic systems and three key drivers of change

Note: Cities include urban transport, land use includes forests and innovation includes economy-wide innovation.

Figure 3
Cost of mortality from outdoor air pollution, 2010



Note: The estimate is for mortality from particulate matter ($PM_{2.5}$) exposure in particular, which was also the focus of recent World Health Organization mortality estimates. Source: Hamilton, 2014.[42]

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Cost evolution

Abstract

This paper estimates the global damage costs of air pollution over a 150-year time period, from 1900 to 2050, focusing exclusively on air pollution of anthropogenic origin. Outdoor air pollution in urban centers and indoor air pollution from burning of solid fuel indoors are included, with damage costs made separately for developed and developing country groupings. Outdoor air pollution impacts include damages to health, crops, buildings and visibility, while indoor air pollution impacts include damages to health and additional time required for household members to collect biomass.

This study estimates the total damage costs of air pollution to be US$ 3.0 trillion in 2010, or 5.6% of Gross World Product (GWP). These losses are equivalent to US$ 430 for every person on the planet. Damage costs are divided almost equally between indoor and outdoor air pollution at the global level; while around two-thirds of the damages are to the populations of developing countries. Health-related damages account for 85% of total damages. Global damage costs are on a downward trend: starting from around 23% of GWP in the year 1900, the damage costs are predicted to fall to below 3% of GWP by 2050.

Given the pervasiveness of the current economic and energy paradigm, and the rapidly urbanizing world (further exposing populations to outdoor air pollution), mitigating damage costs in the future remains a challenge. Further decline from the current levels of economic damage will require successful implementation of policies that are environmentally sustainable, but that do not significantly compromise strategies to reduce poverty in developing countries.

Air Pollution

Global Damage Costs of Air Pollution from 1900 to 2050

Guy Hutton, PhD

Assessment Paper
Copenhagen Consensus on Human Challenges
2011

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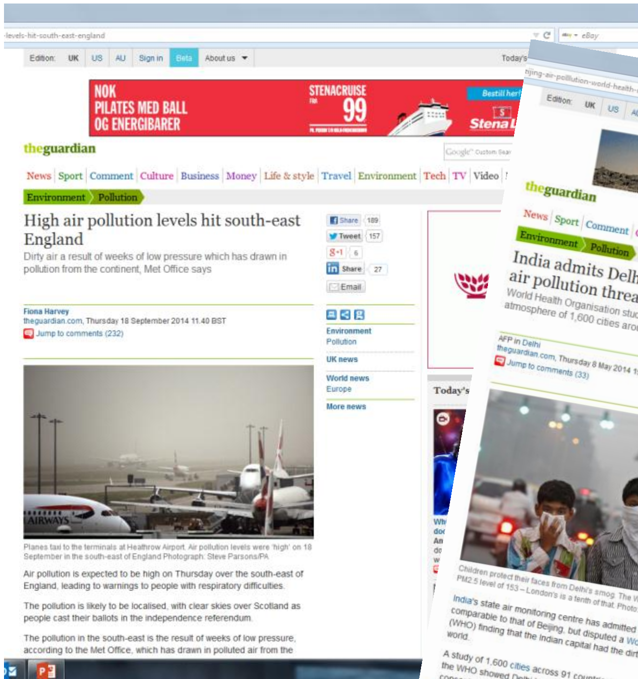
And recent news…



Societal costs of air quality are large
Need to act
Need information

From «The Guardian»

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And the Med?

Need for information

Main challenges to society require information for an intelligent response, including making choices on future action examples:

- <u>Air Quality</u>
- Climate change – economy/AQ
- Impact of extreme weather
- Environmental degradation
  Loss of natural habitat, impact on biodiversity, impacts of pollution (water, air)

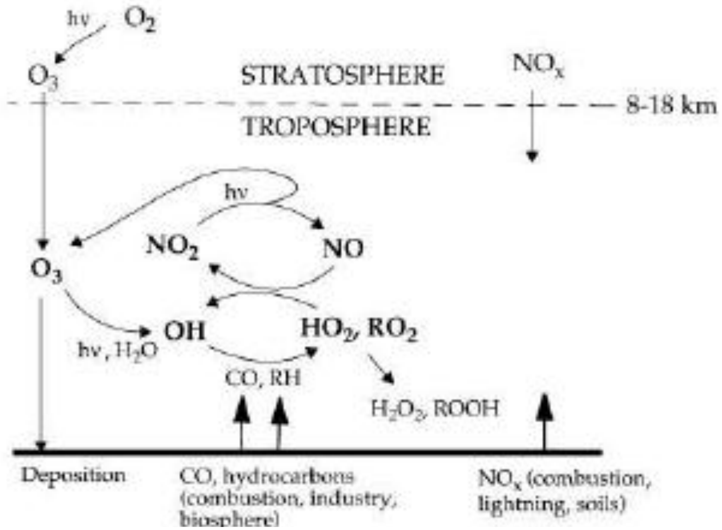
We can take action according to information obtained:

- Future behaviour of system of interest, future events – prediction
- Test understanding of system & its dynamic response & adjust understanding – hypothesis testing
- Assess the Earth Climate System (e.g. air quality) – monitoring

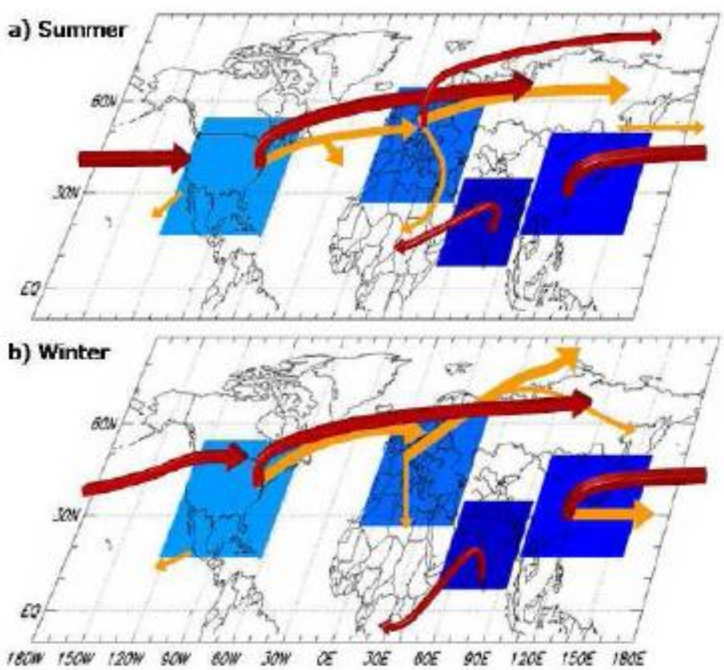
What?

What is needed to understand Air Quality?

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



Schematic of tropospheric O_3 chemistry illustrating coupling between O_3 & various chemical cycles. Jacob (2000)



Intercontinental transport pathways in NH. Arrows approximate magnitude of pathways for 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)

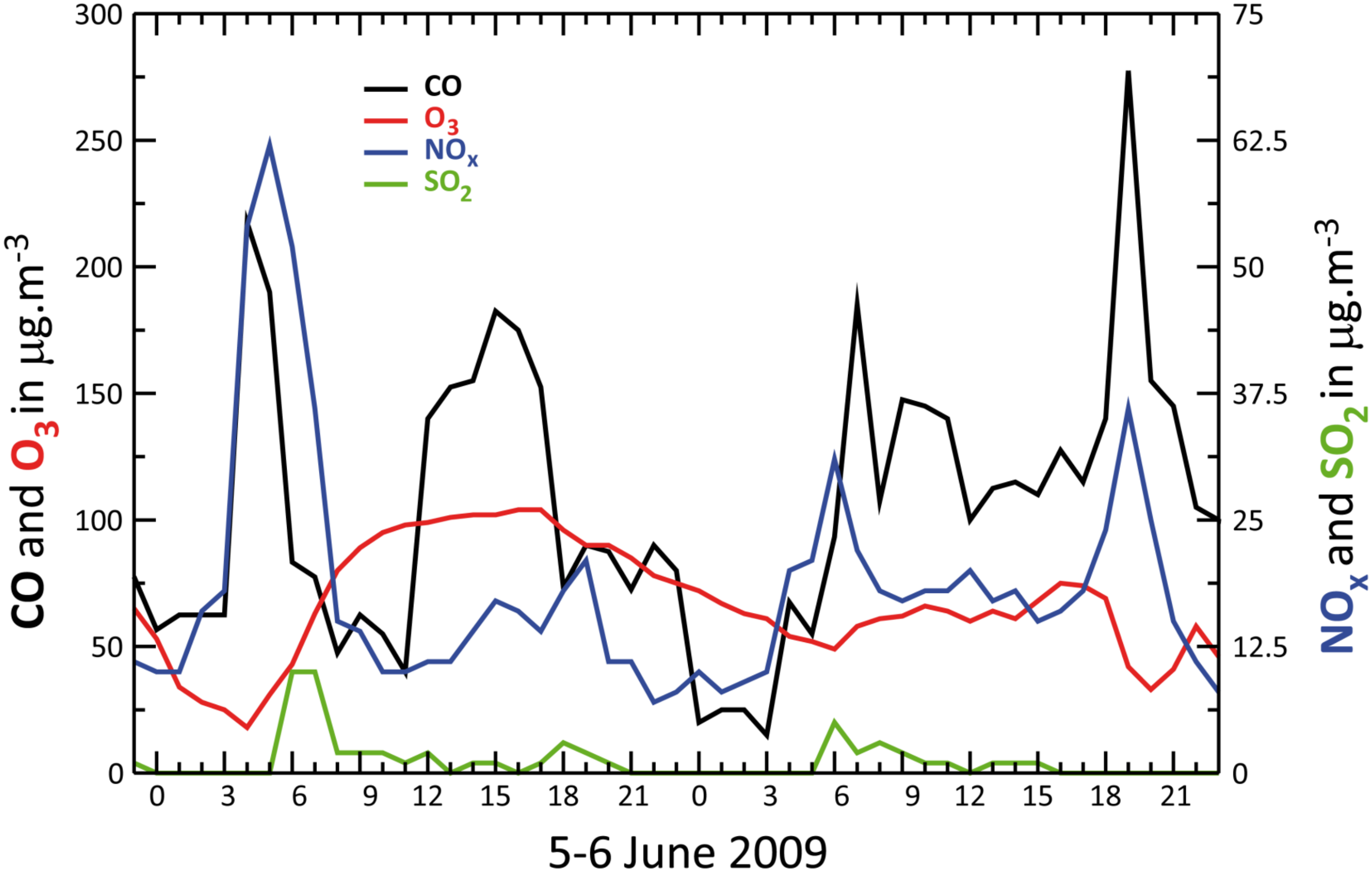
HTAP (2007)

Observations, models & their combination:

Data assimilation

AQ spatio-temporal scales

High resolution spatio-temporal sampling at continental/regional scales



Temporal Variability
< 1 hour

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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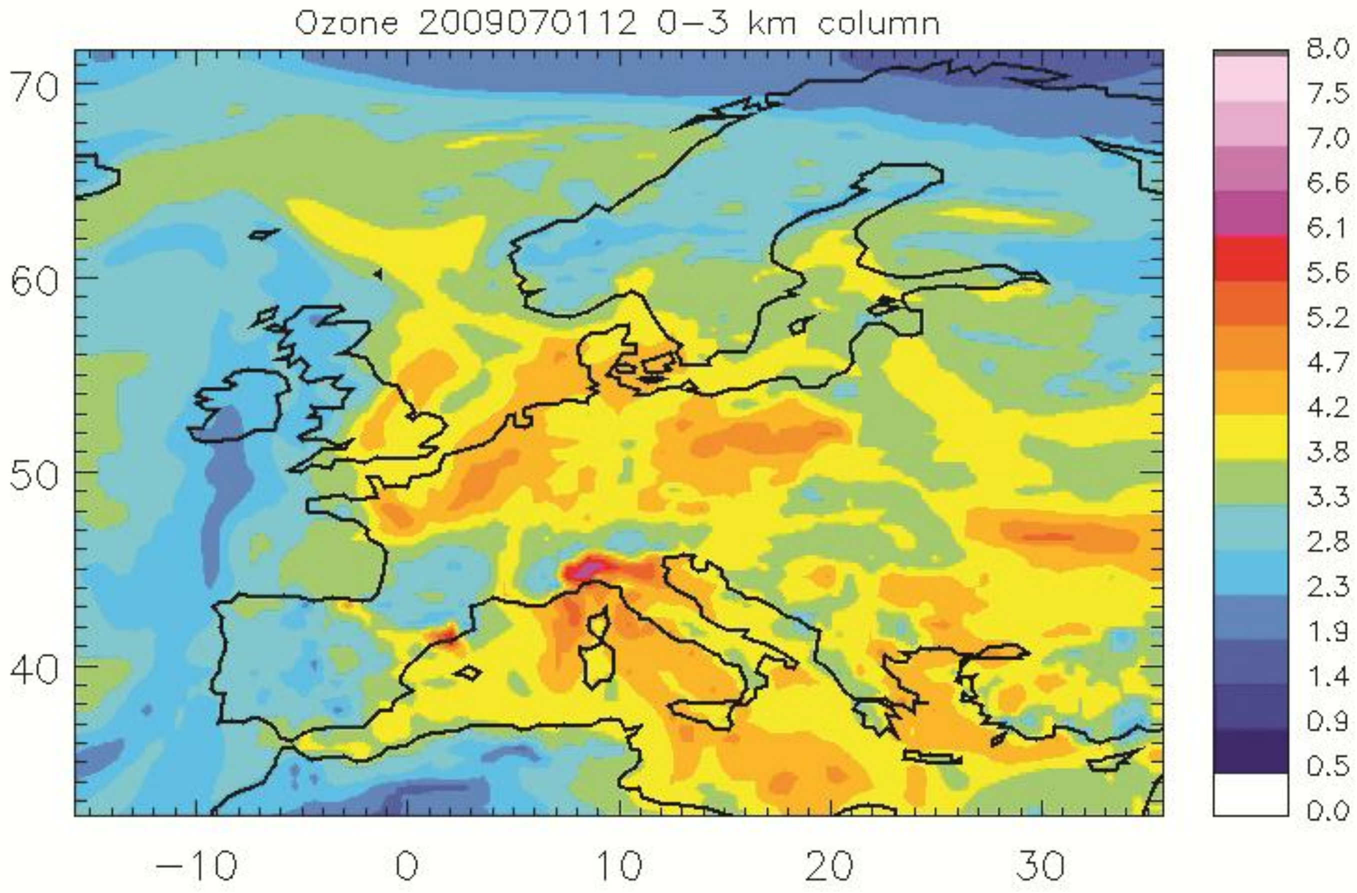

Spatial Variability
< ~10 km

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 the Po Valley & influence of transport in Mediterranean

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Global Observing System

Observation types used by ECMWF for NWP

In situ

Surface

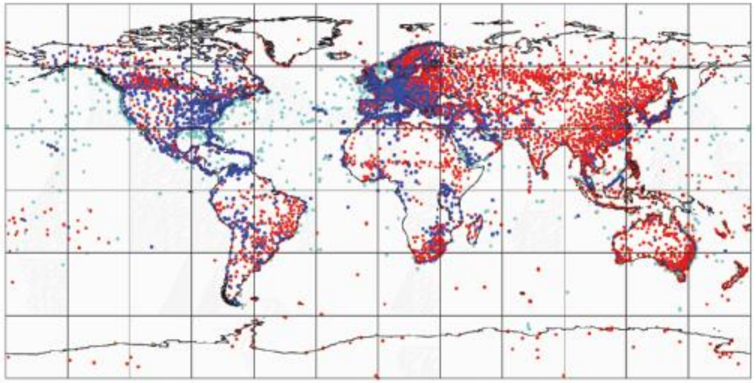

Fig. 1 Typical data coverage of surface observations, 20070301 0900-1500 UTC, showing 16,550 SYNOP (*red*), 1,937 SHIP (*cyan*) and 12,383 METAR (*blue*)

Buoy

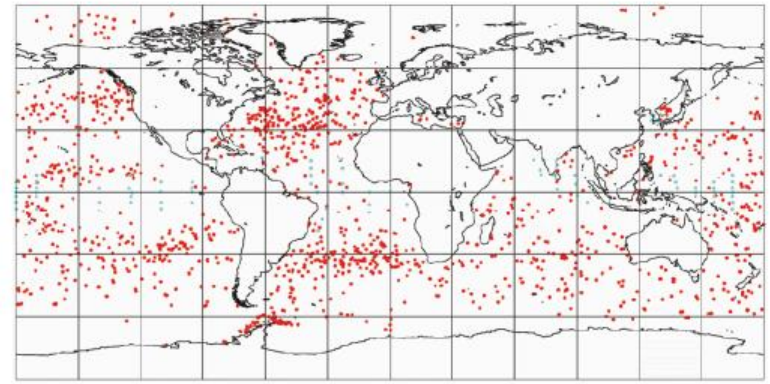

Fig. 2 Typical data coverage of buoy observations, 20070301 0900-1500 UTC, showing 5,686 drifting buoys (*red*) and 140 moored buoys (*cyan*)

Satellite

GEO

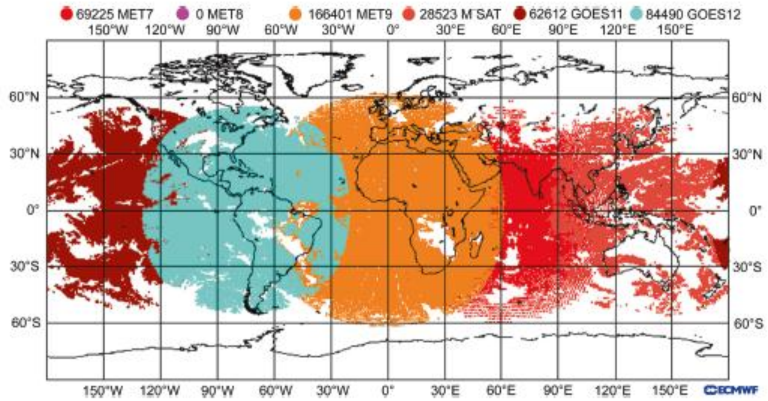

Fig. 6 Typical data coverage provided by the Geostationary constellation: GOES-11 (*brown*), GOES-12 (*cyan*), Meteosat-7 (*red*), Meteosat-9 (*orange*) and MTSAT (*red–orange*)

LEO

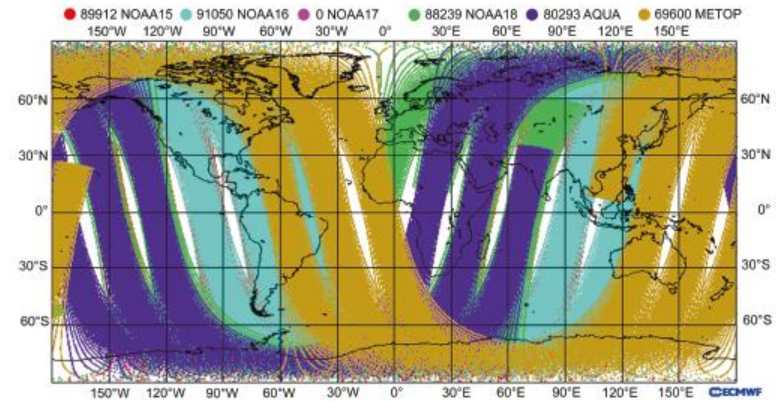

Fig. 7 Typical data coverage provided by the LEO (Low Earth Orbit) constellation of AMSU-A instruments from NOAA, AQUA and METOP satellites: NOAA-15 in *red*, NOAA-16 in *cyan*, NOAA-18 in *green*, AQUA in *violet* and METOP in *brown*

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)

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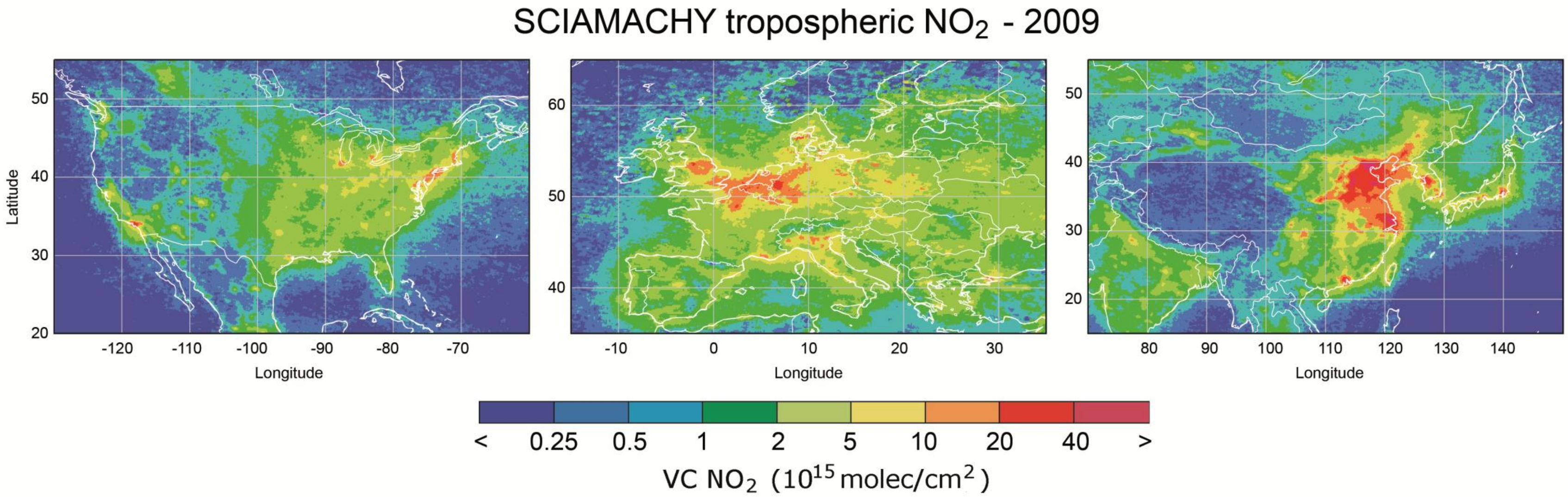
Demonstrated value of space-borne AQ measurements (note averaging period)



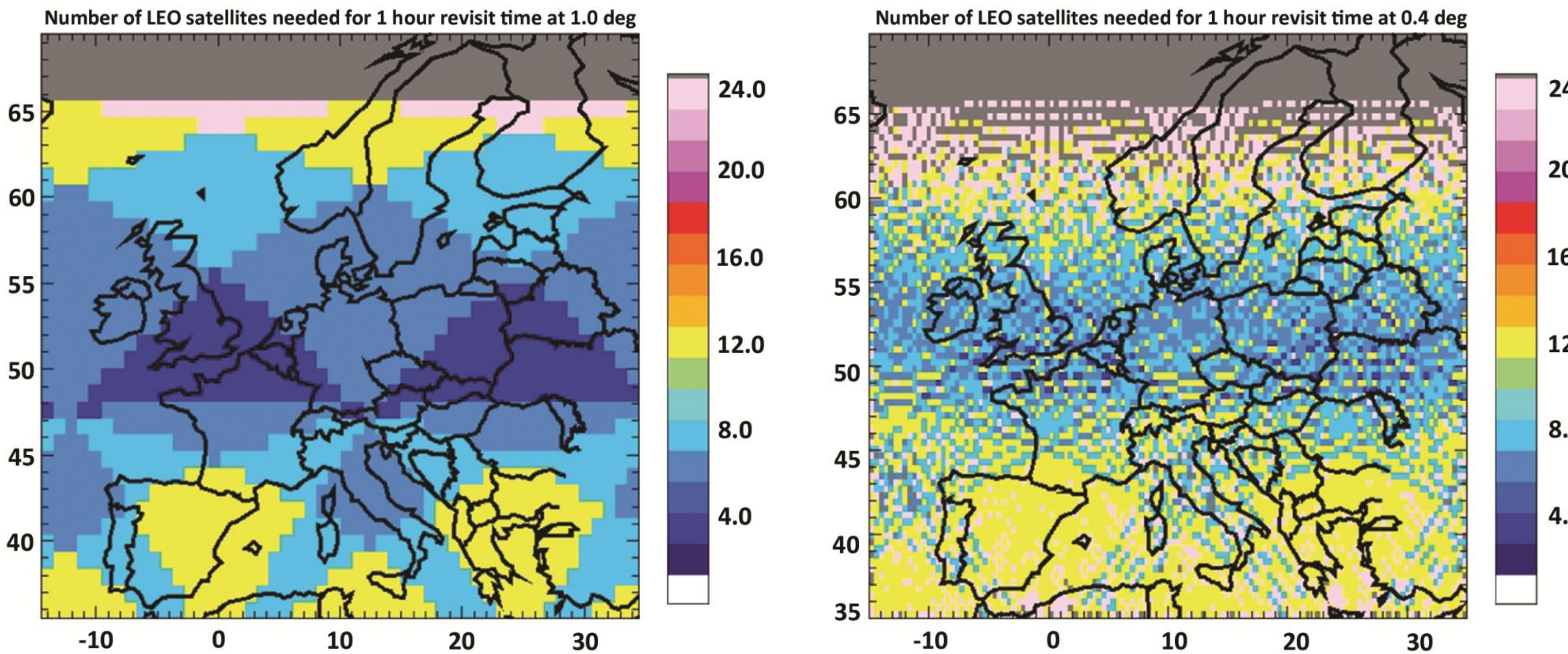
NO_2 tropospheric densities, averaged for 2009, from SCIAMACHY (LEO platform). Left: USA; Middle: Europe; Right: China. Units: 10^{15} molecules.cm^{-2}. Fig. A. Richter.
 Lahoz *et al.* 2012 (BAMS)

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 of ht-resolved regional/continental scale information, O_3 and, until recently, CO
- Concentrations AQ species in PBL (planetary bdry layer) a priority (IGACO 2004)

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



LEOs required for 1-hr revisit time over Europe.
Left: 1° x 1° (~100 km); right: 0.4° x 0.4° (~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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Observations of Air Quality:

In situ data + satellite data → The Global Climate Observing System

Why we need air quality observations – for USA (& generally)

Observational Needs

1. Although local and regional observation and emissions reduction efforts are generally well advanced in the United States, there is a need to improve characterization of pollutants from distant/international sources to better evaluate their contribution to domestic air quality.
2. There is a need for enhanced atmospheric, deposition, and effects monitoring to understand deposition impacts on aquatic and terrestrial ecosystems.
3. There is a growing need to document global changes in climate that have the potential to affect the natural release or atmospheric processing of pollutants.
4. There is a need for greater attention to precursors of ozone and particulate matter in order to accurately assess the success of emissions control strategies.
5. There is an ongoing need for more cost effective means of compliance monitoring, to reduce financial burdens on state and local governments.
6. There is a need for vertically resolved observations of ozone, particulate matter (including its composition), and their precursors, to evaluate and improve air quality modeling.

AQ Observation systems in the USA – Nov 2013

Committee on Environment, Natural Resources, and Sustainability
OF THE NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

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How? – how do we use these tools?

Use observational and model information + errors: Data Assimilation

Used in many areas, including:

- Weather forecasting
- Air quality forecasting
- Design of the GCOS:
  Observing System Simulation Expts
  OSSEs
  met agencies, space agencies
- Monitor the Earth System/test models/ case studies: reanalyses

«Best» state, «best» forecast

Lahoz, W.A., and P. Schneider, 2014: Data Assimilation: Making sense of Earth Observation. *Front. Environ. Sci. - Atmospheric Science*, doi: 10.3389/fenvs.2014.00016.

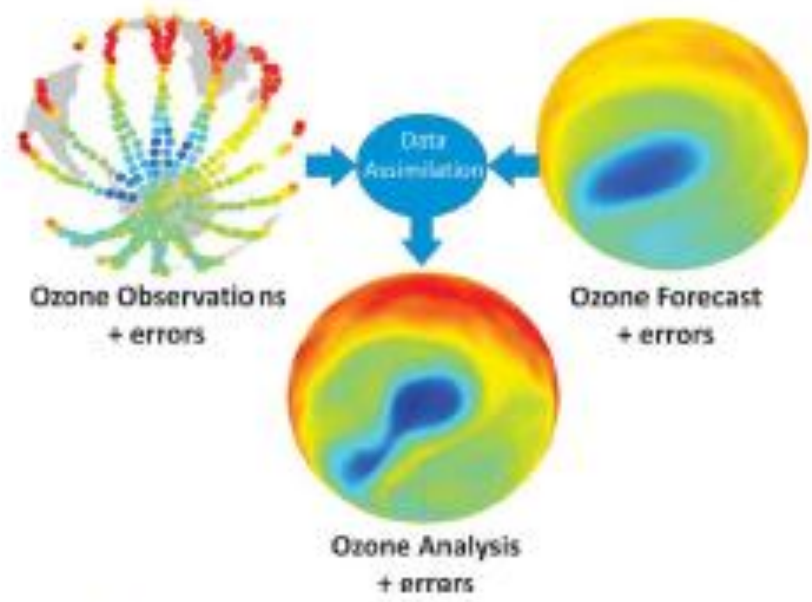

FIGURE 2 | Schematic of how data assimilation adds value to observational and model information. The data shown are various representations of the ozone distribution at 10 hPa (~30 km) on 23 September 2002, each of which has errors. **Upper left panel:** plot representing ozone data from a limb-viewing satellite. **Upper right panel:** plot representing a 6-day ozone forecast based on output from a data assimilation system. **Bottom panel:** plot representing an ozone analysis based on output from a data assimilation system. Blue colors represent relatively low ozone values; red/orange colors represent relatively high ozone values. The analysis is produced by combination of the observational and model information and their errors. Note how the analysis fills in the observational data gaps and captures the Antarctic ozone split, verified using independent data not used in the assimilation. By contrast, the ozone hole split is not captured in the 6-day ozone forecast. Based on material in Lahoz et al. (2010).

Mathematical basis for data assimilation

"Objective" way of filling in gaps by melding information from observations & model (+ errors) - Mathematical foundation – "best" solution

Bayesian approach →

$$\rho\left(\mathbf{x}_0 - \mathbf{x}_0^b | \mathbf{y}_k - \mathcal{H}_k(\mathbf{x}_k),\ k = 0, \ldots, N\right) =$$
$$= \alpha\rho\left(\mathbf{x}_0 - \mathbf{x}_0^b\right) \rho\left(\mathbf{y}_k - \mathcal{H}_k(\mathbf{x}_k),\ k = 0, \ldots, N | \mathbf{x}_0 - \mathbf{x}_0^b\right),$$

Two approaches: statistical linear estimation (SLE); ensembles (EnKF, PF)
SLE (var, sequential): Bayesian estimation when system linear & errors Gaussian
- A way to estimate the: Best Linear Unbiased Estimate (BLUE)

Variational methods (var) →

$$J = \frac{1}{2}[x - x^b]^T \mathbf{B}^{-1}[x - x^b] + \frac{1}{2}[y - H(x)]^T \mathbf{R}^{-1}[y - H(x)].$$

Sequential methods (KF) →

$$x_n^f = \mathbf{M}_{n-1} x_{n-1}^a;$$
$$\mathbf{P}_n^f = \mathbf{M}_{n-1}\mathbf{P}_{n-1}^a \mathbf{M}_{n-1}^T + \mathbf{Q}_{n-1};$$
$$x_n^a = x_n^f + \mathbf{K}_n[y_n - \mathbf{H}_n x_n^f];$$
$$\mathbf{K}_n = \mathbf{P}_n^f \mathbf{H}_n^T [\mathbf{R}_n + \mathbf{H}_n \mathbf{P}_n^f \mathbf{H}_n^T]^{-1};$$
$$\mathbf{P}_n^a = [\mathbf{I} - \mathbf{K}_n \mathbf{H}_n]\mathbf{P}_n^f.$$

Equivalent under only condition of linearity

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DA methods

Variational

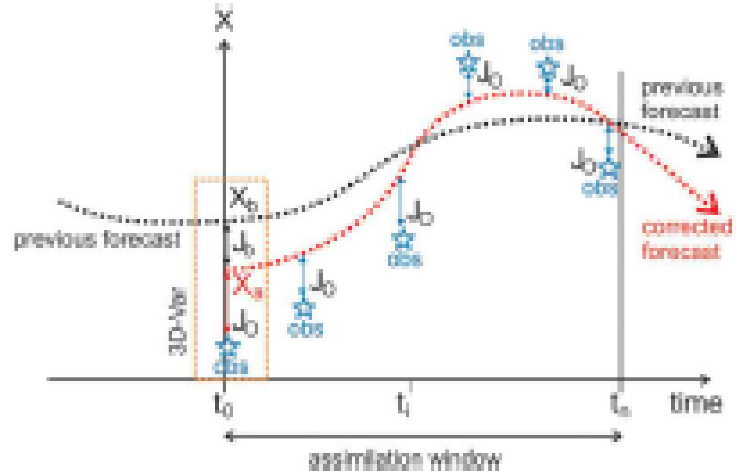

FIGURE 3 | Schematic diagram illustrating 4D-Var. Over the period of the assimilation window indicated 4D-Var is performed to assimilate the most recent observations (marked as blue stars), using a segment of the previous forecast as the background (black line—the background state x^b is the initial condition). This updates the initial model trajectory for the subsequent forecast (red line), using the analysis x^a as the initial condition. The box to the left identifies the special case of 3D-Var. Similar material can be found in http://www.ecmwf.int.

Ensemble

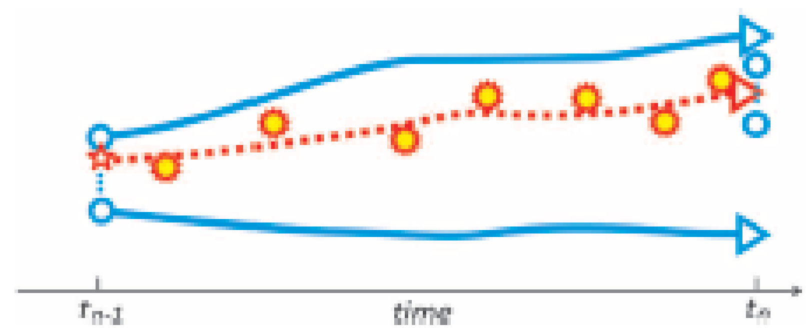

FIGURE 4 | Schematic showing the main elements of the EnKF, as implemented during the assimilation window (t_{n-1}, t_n). The blue unfilled circles to the left represent the range of the ensemble of analyses at time t_{n-1}; the full blue lines represent the range of ensemble forecasts using the ensemble of analyses at t_{n-1} as the initial states; the dashed red line represents a linear combination of the forecasts (using the red star as the initial state) used to provide the final state—the analysis, at time t_n. The red stars filled in yellow color represent the observations used during the assimilation window. The blue unfilled circles to the right represent the range of the ensemble of analyses at time t_n used for the next assimilation window. The spread of the ensemble members represents the forecast error. Based on material in Kalnay (2010).

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Lahoz and Schneider, 2014

Success of DA:

NWP:

2 day forecast improvement in c. 20 yrs

NH: 2 days in 28 yrs (2013-1985)

SH: 2 days in 16 yrs (2013-1997)

ECWMF

Operations: 1980-2013

Reanalyses: 1979-2013 (ERA-Interim)

1973-2001 (ERA-40)

Dee et al., BAMS, 2014

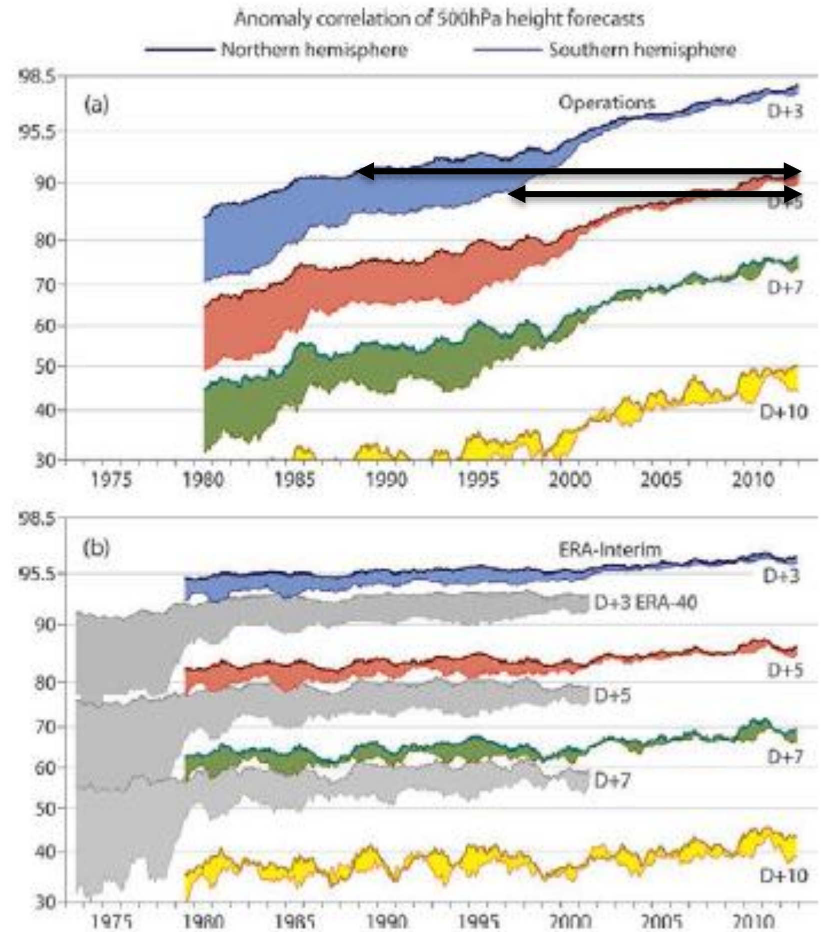

FIG. 1. Twelve-month running mean anomaly correlations (%) of 3-, 5-, 7- and 10-day 1200 UTC forecasts of 500-hPa height for the extratropical Northern and Southern Hemispheres from (a) ECMWF operations from Jan 1980 to May 2013 and (b) ERA-Interim from Jan 1979 to Apr 2013 and ERA-40 from Jan 1973 to Dec 2001. The shading shows the difference in scores between the two hemispheres at the forecast ranges indicated.

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AQ: improved NO_2 estimates

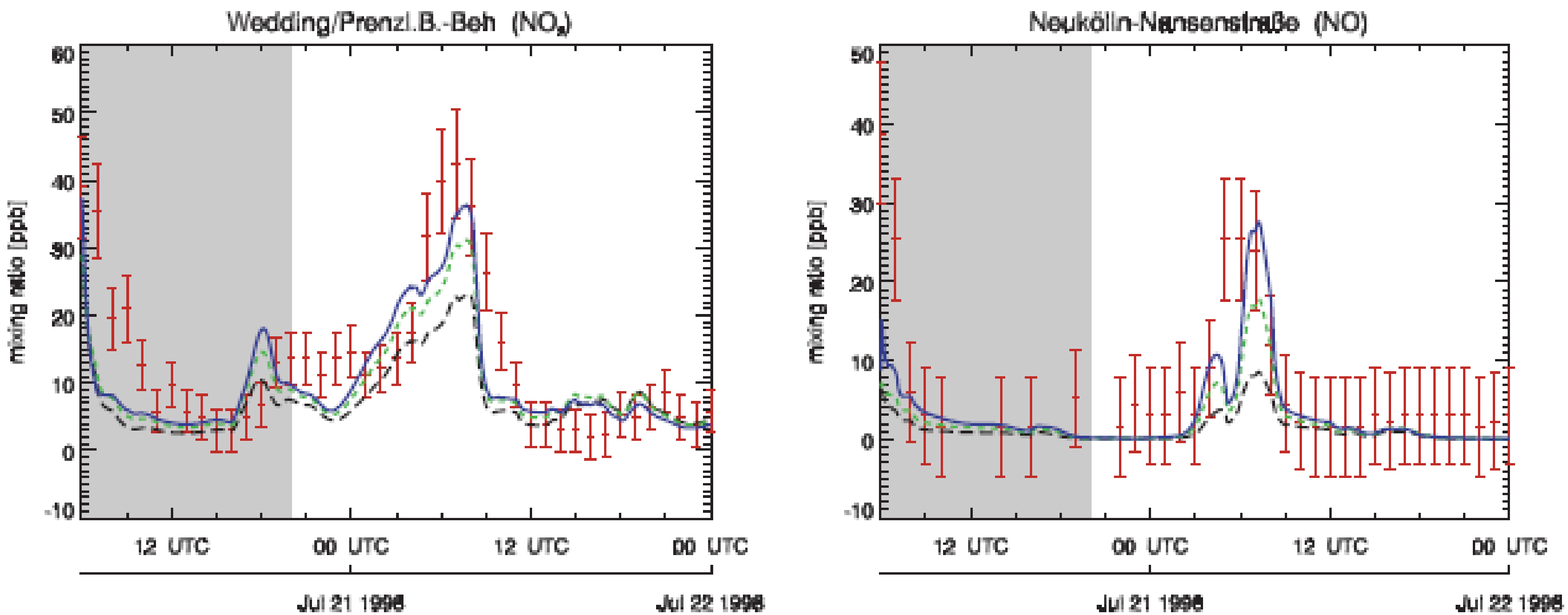

Fig. 3 Assimilation results for stations in the Berlin area obtained with a grid resolution of 6 km. (*left panel*: Wedding/Prenzl.B-Beh, NO_2; *right panel*: Neukölln-Nansenstraße, NO) *Green line*: first guess run, using an analysis obtained on a 18 km grid. *Blue line*: assimilation result based on an analysis on a 6 km grid. *Black line*: results for no data assimilation. Observations are given in red, and their error estimates as *vertical red bars*. Only the *grey shaded* time interval has been used for the assimilation; other observations are only used for quality control

Elbern et al., 2010: Inverse modelling and combined state-source Estimation for chemical weather. In Data Assimilation: Making Sense of Observations, eds. WA Lahoz et al, Springer.

Other AQ forecast systems: PREV'AIR (Rouïl et al., 2009) for ozone, PM
– use geostatistical interpolation

Incremental value of added observation type/platform

Approach:

- Identify characteristics of GOS (strengths/weaknesses)
- Come up with "wish list" – dependent on science themes (also users)
- Competing requirements & cost constraints (e.g. g-based vs 1 GEO for AQ)
- How do we quantify added value?

Generally, you do NOT consider value of extra platform/observation

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

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

- Use data assimilation (DA) to quantify additions to GOS (& GOS design):
  Masutani *et al.* 2010: Observing System Simulation Experiments (OSSEs)
  Concept related to Observing System Experiments (OSEs, cf. NWP)

OSSEs applied to evaluate added value of proposed/planned AQ missions (e.g., lower troposphere ozone, CO)

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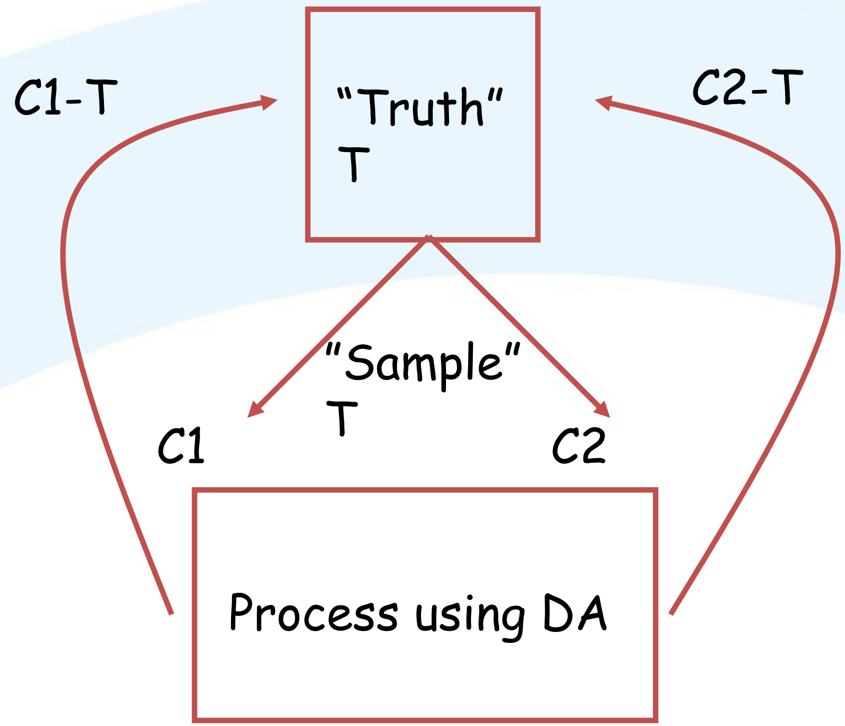
AQ OSSE set-up - generally consider 1 obs type

- Simulated atmosphere ("truth"; T – "Nature Run"): using model, analyses
- Simulated observations of instruments appropriate to the study, including errors: using T
- Assimilation system: using a model
- Expt C1: only observation type 1
- Expt 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

Fewer observations for AQ in GOS (v NWP); very few operational systems for AQ

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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)

  Note: "reduced OSSE" generally only useful when observation of interest has relatively high impact (e.g. lower trop O_3, CO)
- Difficult interpretation (model dependence) -> alleviate problem: conservative errors, several methods to investigate impact
- "Incest" (use same model for "truth" and assimilation)-> alleviate problem: different models to construct "truth" & perform assimilation (BUT there could be bias between models) – also "cross-OSSE"

> 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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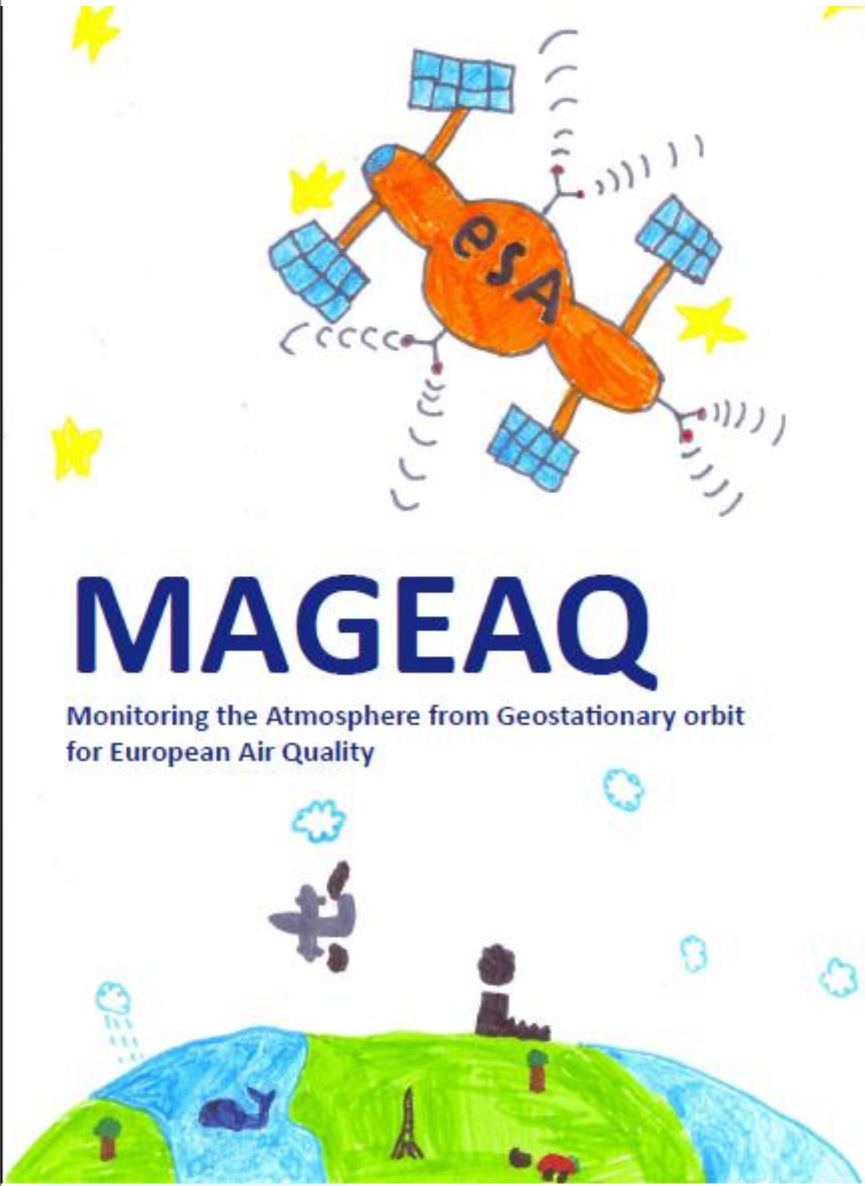
Proposed MAGEAQ mission for EE-8 (TIR+VIS, Ozone and CO)



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**

Involvement of Météo-France, KIT

Other proposed GEO missions for AQ:

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

Planned:

Sentinels 4, 5, 5-P, ESA (2017-2020)

AQ OSSEs

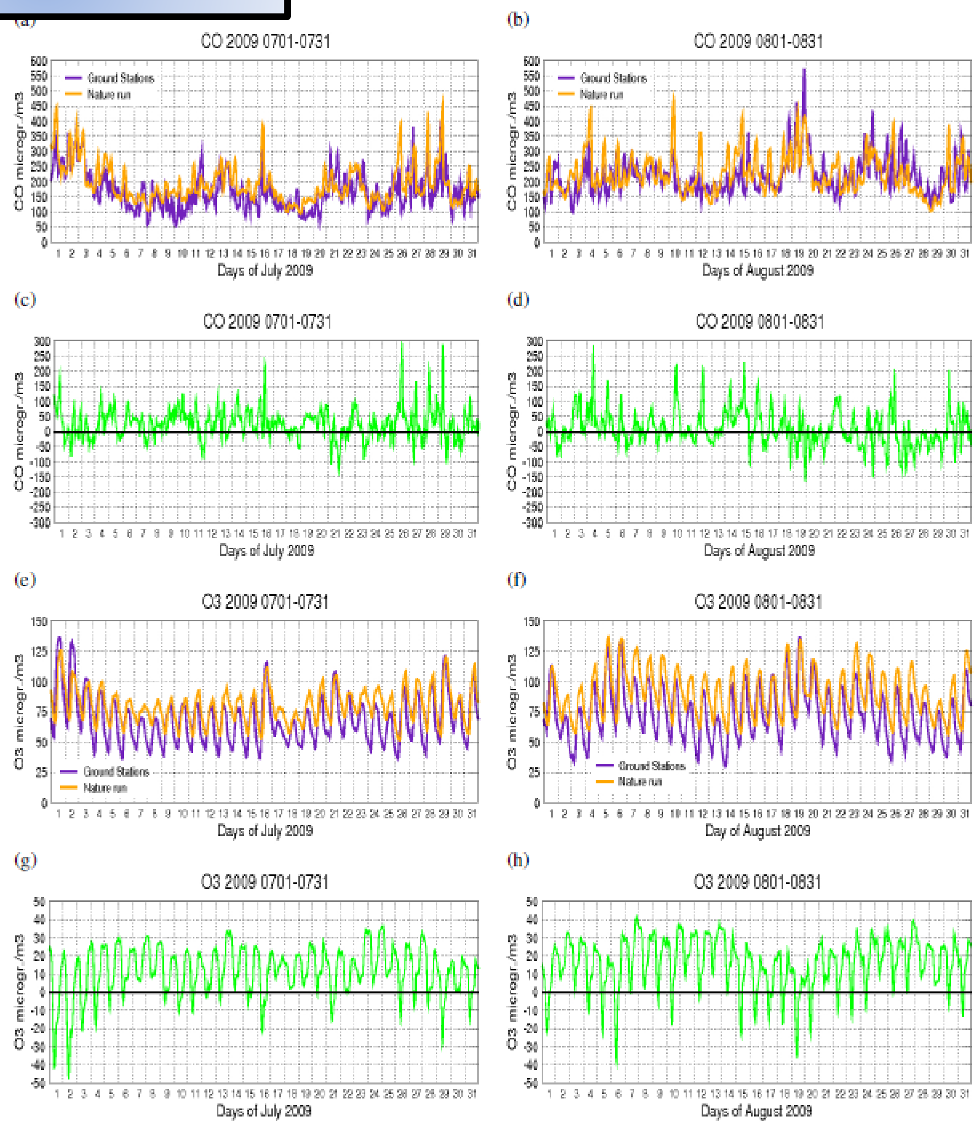


Fig. 3. Timeseries of the CO concentrations from the nature run (orange) and measured by ground based stations (purple), averaged each hour over France in July 2009 **(a)** and August 2009 **(b)** and respective differences between the nature run and the surface observations – **(c)** and **(d)**. **(e)–(h)** 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 "Nature Run"
Top 4 plots CO
Bottom 4 plots O_3
From *Claeyman et al. (2011)*

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

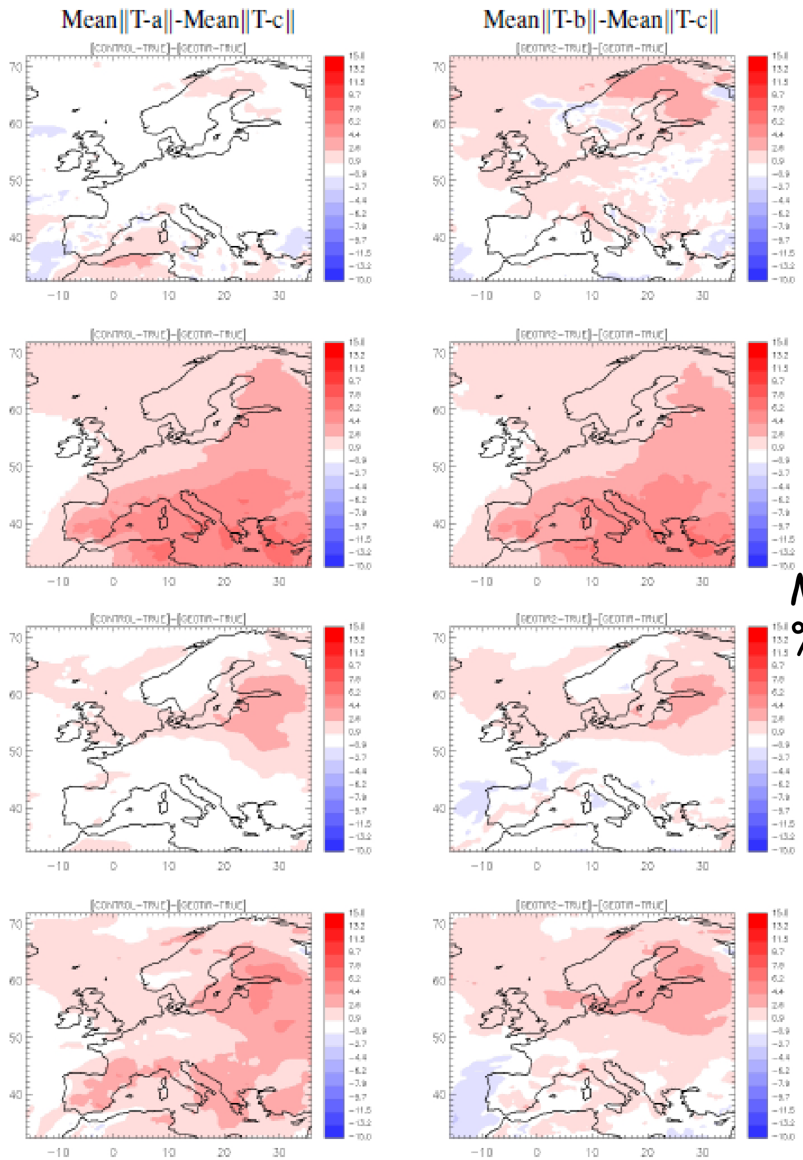
Red/Blue: MAGEAQ-TIR closer/further from "Truth" (v model & MTG-IRS)

Exp 1

Exp 2

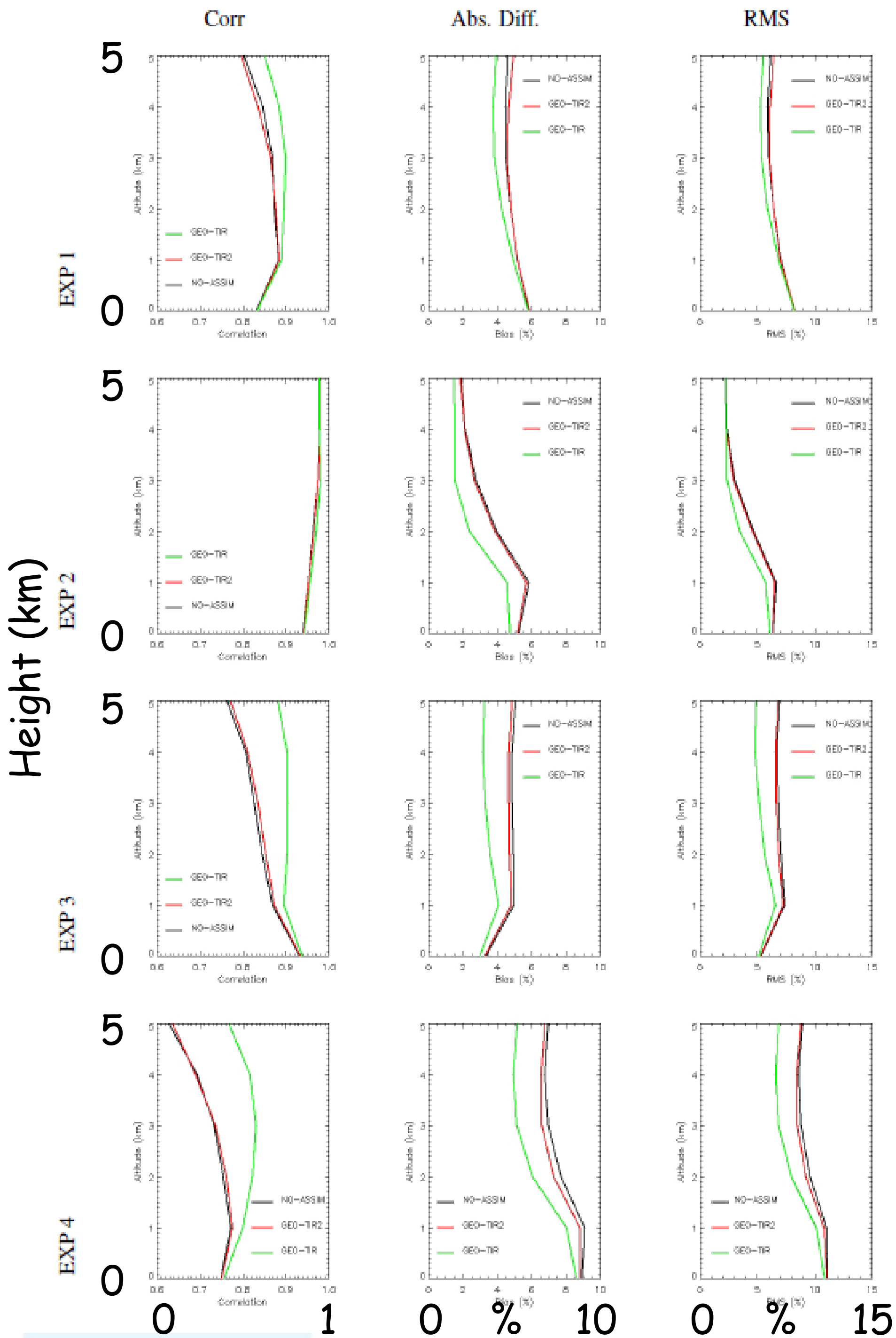
Exp 3

Exp 4



MAGEAQ-TIR v model
% of Truth

MAGEAQ-TIR v MTG-IRS
% of Truth



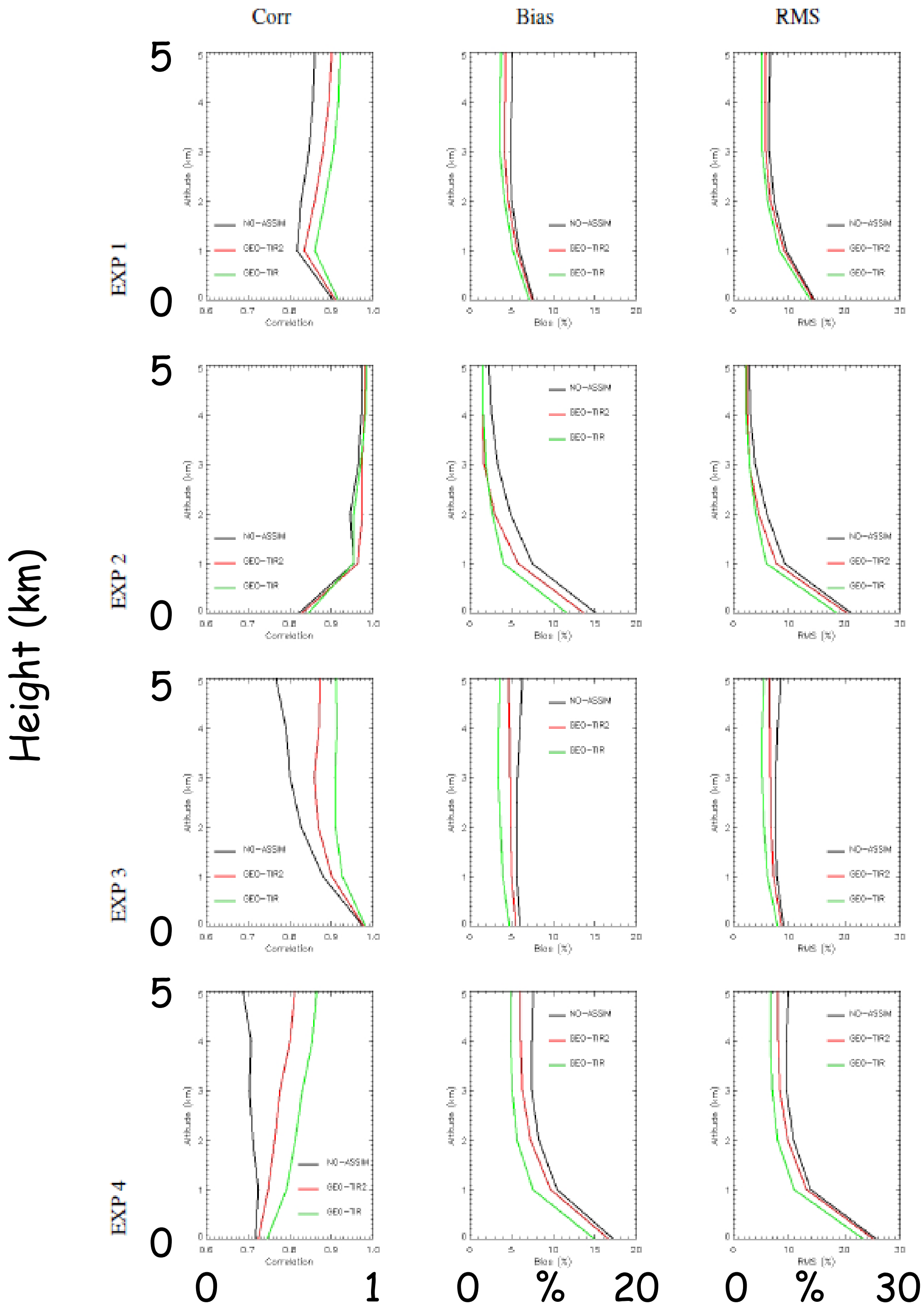
OSSE results: impact of adding 1 data type (O_3, profile, 0-5 km ht)
Results v Nature Run (Truth)

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, improvement smaller over 0-1 km ht

VIS should improve 0-1 km ht



OSSE results: impact of adding 1 data type (CO, profile, 0-5 km ht)
Results 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

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
From *Claeyman et al. (2011)*

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

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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
- see work by Natraj et al., Hache et al. (and see later slides)

OSSEs integral part of MAGEAQ

- in line with ESA (ADM-Aeolus; CarbonSat; ISOTROP), NASA (GEO-CAPE) & NCEP (Masutani *et al.* 2010) approaches

- Use OSSE concept (with/without data assimilation) for AQ monitoring -> develop monitoring network over Euro-Mediterran: satellite, in situ

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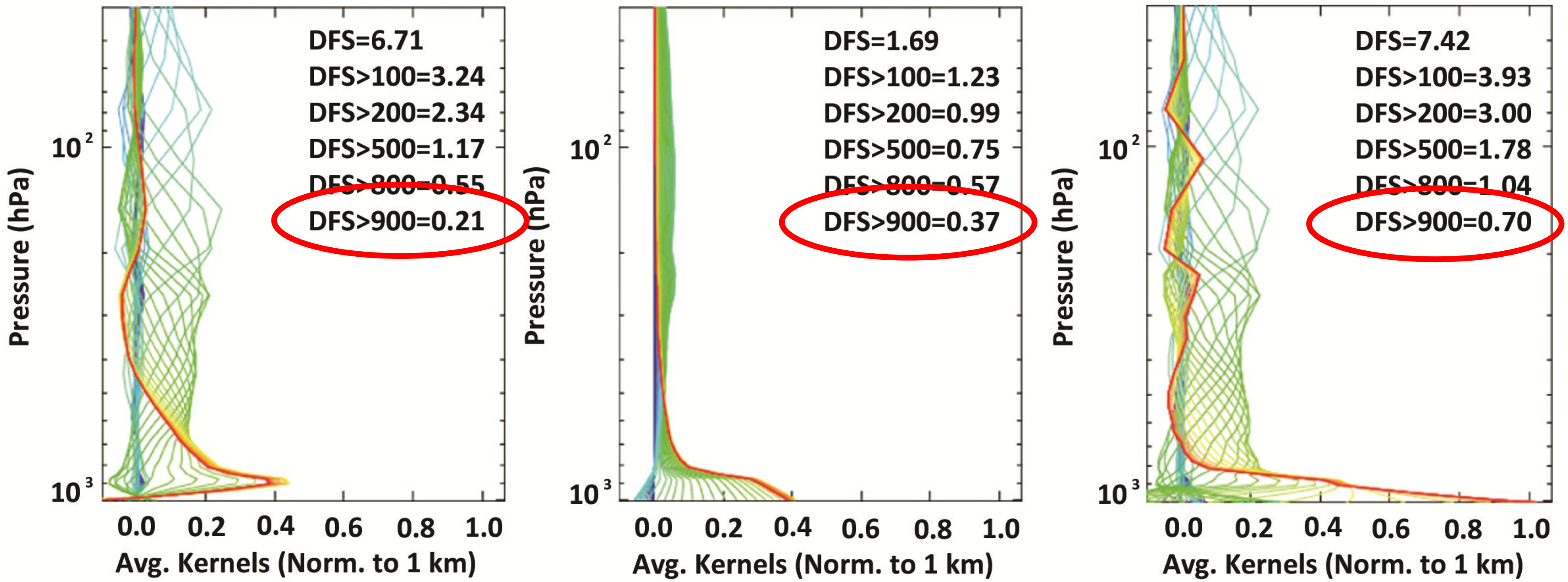
TIR vs TIR+VIS



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 POGEQA/MUSICQA projects

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Timmermans et al. (2014) – review paper on AQ OSSEs

Impact of TIR+VIS: GEO over Europe to monitor tropospheric O3

OSSE concept – no data assimilation BUT potential for future DA work

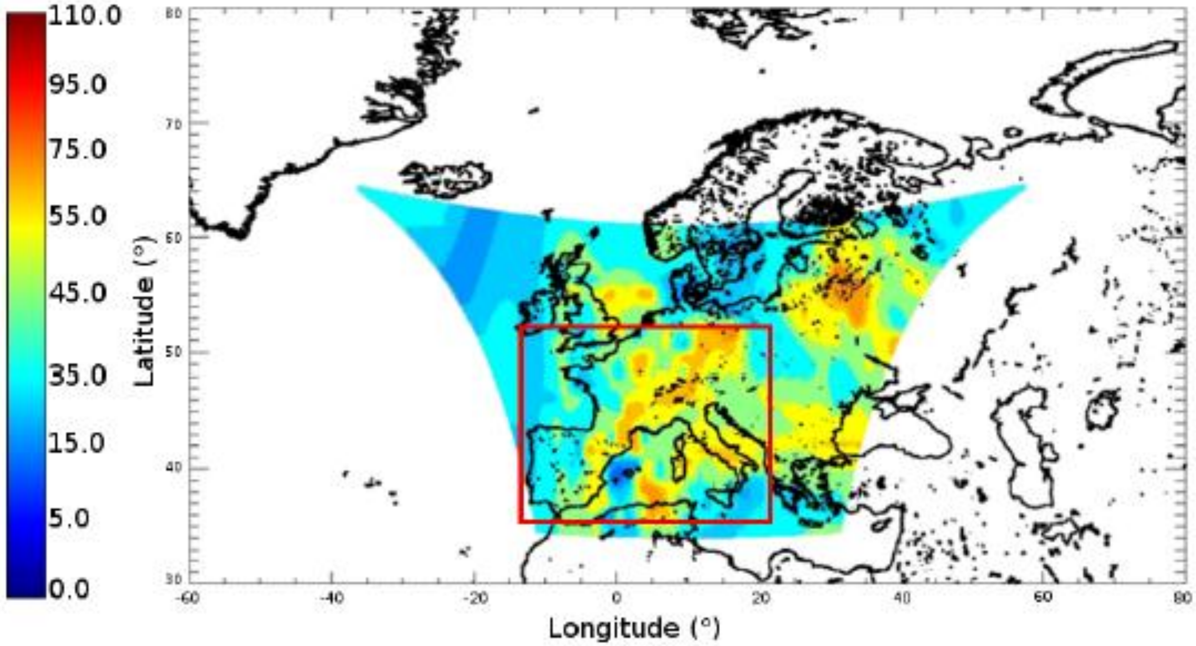

Figure 2. Image of the surface ozone field from MOCAGE 11 July 2009 at 12:00 UTC simulated with the field of view and the spatial resolution of the MAGEAQ geostationary instrument (~ 15 km × 15 km). The colour bar indicates the ozone concentration in parts per billion by volume (ppbv), with red/blue indicating relatively high/low values. The red square indicates the domain of ozone simulation with the MOCAGE grid (0.5° × 0.5°).

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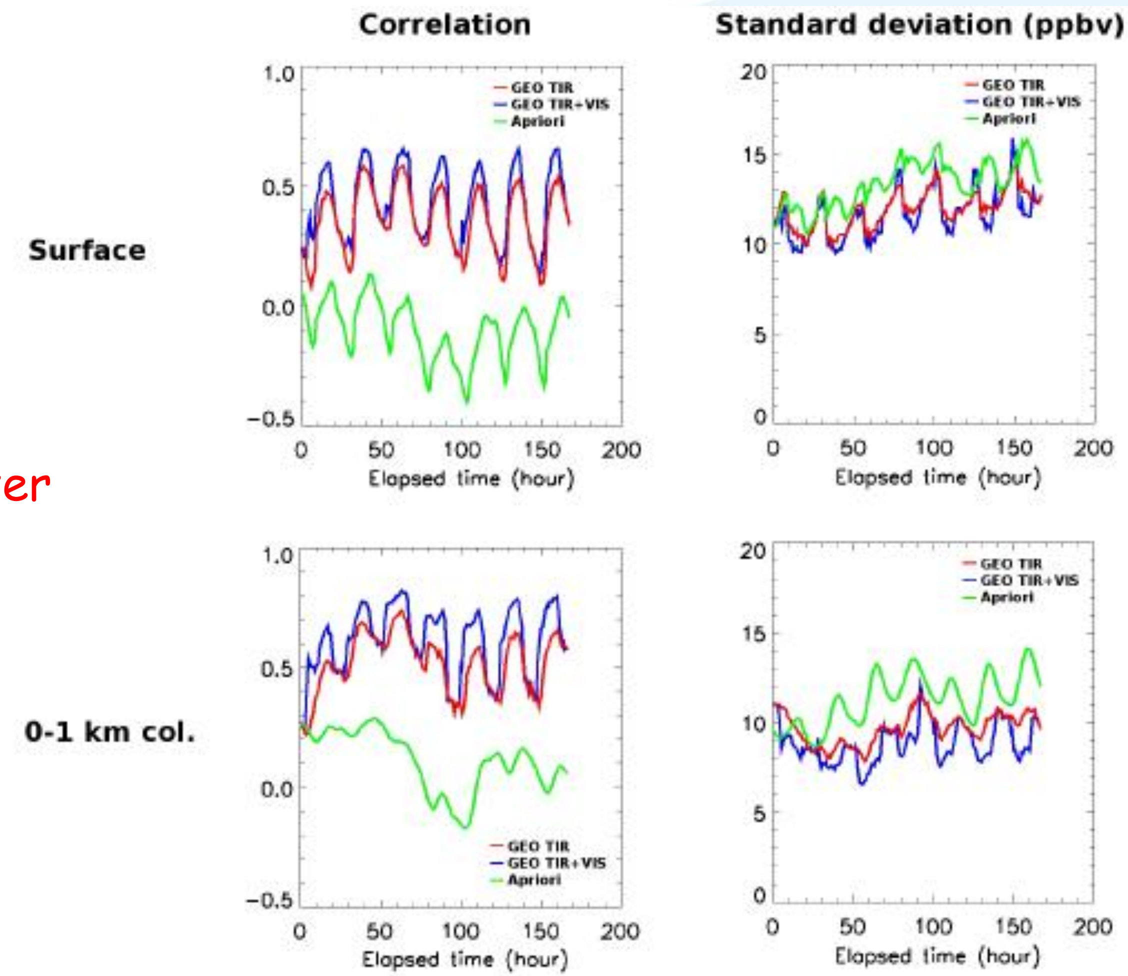
Hache et al., 2014

GEO – correlation vs NR: TIR (red) vs TIR+VIS (blue) & a priori (green)

TIR+VIS better



A priori:
Average MOCAGE
CTM profiles

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.

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Hache et al., 2014

PD: Prob. detection
FAR: false alarm rate

Daytime pixels over land - surface

Table 3. Air quality monitoring results for GEO TIR and GEO TIR+VIS. For all the pixels of the red square domain (land and sea pixels together) in Fig. 2, the land pixels, and the sea pixels, we calculate the accuracy (ACC), the probability detection (PD) and the false alarm rate (FAR). See Sect. 3.2 for more details. Bold values represent the best values in the comparison between GEO TIR and GEO TIR+VIS.

	GEO TIR			GEO TIR+VIS		
	ACC	PD	FAR	ACC	PD	FAR
Global data	70.78	28.72	**10.81**	**75.37**	**49.45**	13.29
Sea pixels	65.62	10.40	**1.55**	**70.69**	**26.56**	3.08
Land pixels	74.48	47.86	**16.39**	**78.72**	**73.36**	19.44

$$\mathrm{ACC} = 100 \times \frac{(R_{1}\_S_{1} + R_{0}\_S_{0})}{N}$$

$$\mathrm{PD} = 100 \times \frac{R_{1}\_S_{1}}{R_{1}}$$

$$\mathrm{FAR} = 100 \times \frac{R_{0}\_S_{1}}{R_{0}},$$

TIR+VIS overall better

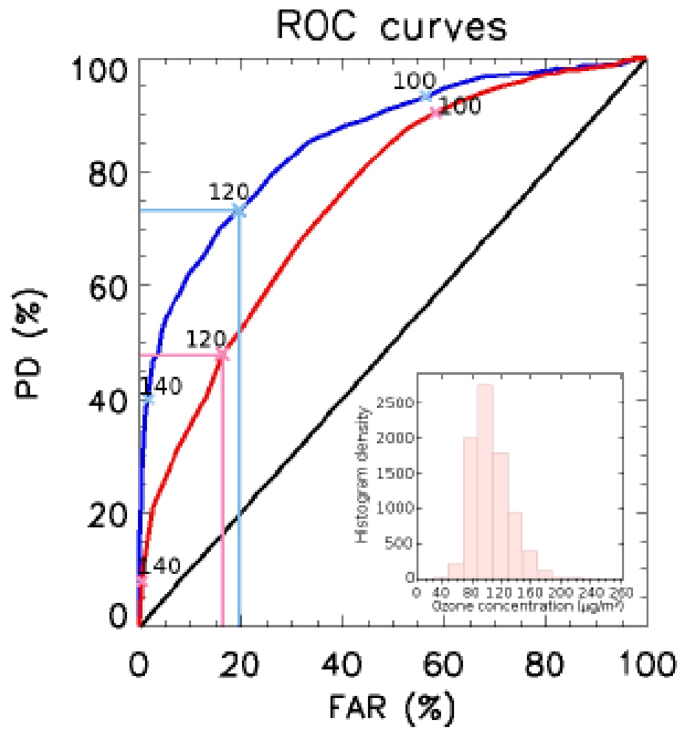


Figure 12. Receiver operating characteristic (ROC) curves, that represent the probability of detection (PD) vs. the false alarm rate (FAR) considering the pixels for daytime (07:00–17:00 UTC) over land at the surface. In black is plotted the equal likelihood line, in blue the ROC curve for GEO TIR+VIS and in red the ROC curve for GEO TIR. The ROC curves are calculated for air quality purposes, and we highlight the value corresponding to the European threshold (2008/50/CE) for health protection of a surface ozone concentration of 120 µg m^{-3}, measured for the daily maximum of the 8 h running average of the surface values. As a complementary information, two other thresholds (100 and 140 µg m^{-3}) are highlighted. Also the histogram of the distribution of the daily ozone maximum of the 8 h running average of the surface values of the reference state is shown.

Blue: TIR+VIS
Red: TIR

R1: no. Ref pts > Th

R1_S1: both ref & sim > Th

R0: no. Ref Pts < Th

R0_S1: Ref pts < Th & sim > Th

Hache et al., 2014

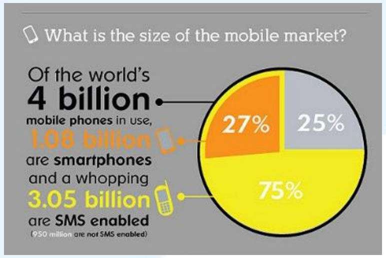
Where are we going?

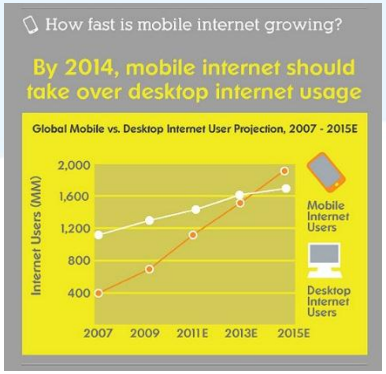
A new environmental information system using citizens - you

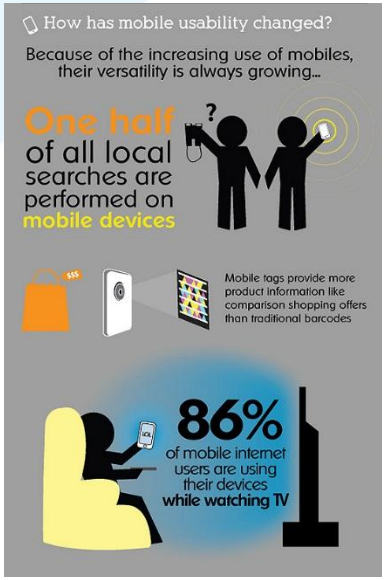
EC Green Week, Brussels, 2013

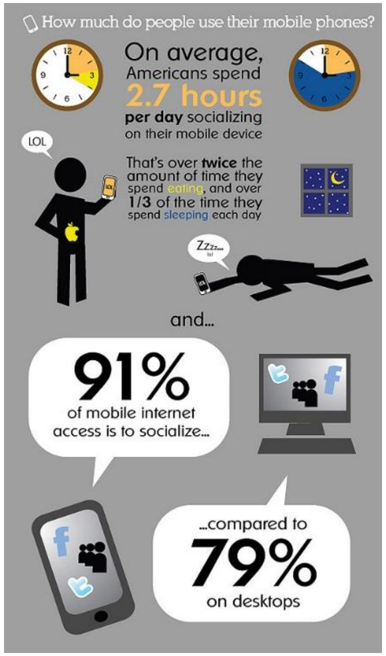
Motivation

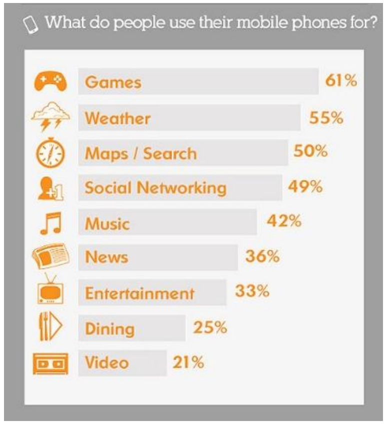
- *Growth* in mobile use
- *Change* in mobile usage
- *Increasing* range of features











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Source: http://www.smartinsights.com/mobile-marketing/mobile-marketing-analytics/mobile-marketing-statistics/

In EU, several new initiatives funded by FP7:

CITCLOPS, CITI-SENSE, COBWEB, OMNISCIENTIS, WESENSEIT

http://www.citi-sense.eu – Lahoz, 2013

E.g. Citizen Science activities in environmental sciences -> 19th C:

- Observations by amateurs (birds & butterflies) – health of environment

21st C -> Technologies (internet, smartphones) & growth of usage
- increased potential benefits from Citizen Science activities ->

Opportunity to extend range of obs platforms available to society, spatio-temporal scales (10s m, <1 h) highly relevant to citizens: use smartphones to submit obs information on immediate environment (e.g. AQ, weather)

Potential value of Citizen Science high (science, education, social and policy aspects) but largely untapped (for citizens, policy makers)

Developments at Met centres: WOW project Met Office, UK – snow obs
http://wow.metoffice.gov.uk
And more…

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ir throu... ×

g-clean-city-air-through-local-initiatives

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European Commission

HORIZON 2020

The EU Framework Programme for Research and Innovation

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What is **Horizon 2020** ?

Helping clean city air through local initiatives

Published by newsroom editor on Thursday, 09/10/2014

Although Europe's air quality has improved over the last 25 years, pollution is still prominent - particularly in cities. Cleaning the air is more difficult than before, as most people can no longer smell or see the pollution. However, the European Union (EU)-funded research project CITI-SENSE is harnessing novel technologies to detect contaminated air and share the data in real- time.

The goal of the CITI-SENSE project is to give citizens the tools to 'sense' their environment through new devices, such as smartphones, raising awareness of areas where pollution exists. The project could allow people to assess progress and take action to improve the situation, effectively displaying the positive impact a healthy environment has on the quality of life.

Alena Bartonova is senior scientist at NILU - Norwegian Institute for Air Research and project coordinator of CITI-SENSE. According to Bartonova, the project is inspiring people to relate to their natural environment in a systematic and scientifically defendable way. "It will motivate us all to become active stewards for a good environment," she says. "We have initiated a dialogue between the technical, scientific and social aspects of environmental information, production, and use."

A key aspect of CITI-SENSE is the development of 'citizen's observatories' used to empower local people to contribute to environmental governance. This will give them and other project stakeholders like schools, NGOs and local authorities a forum to exchange results as well as to discuss and receive additional information on related issues.

The project team is working with businesses involved in technology in order to cover the development of sensors for air quality, platforms for sensor deployment, communication solutions between the sensors and other systems, as well as data collection tools related to smartphones. The CITI-SENSE team has already developed a number of prototypes that use monitoring and information technologies, data interpretation and information content. Moreover, the researchers are developing methods on how to support the engagement and participation of local users with the help of these technologies.

Search

#H2020

net-it-be @NetItBeEU

EU-Brazil #H2020 joint call on #cloud, experim platforms and HPC - want to know more? Join session at 2 pm, Net Futures Village #ICTpropDay

12m

Internet Experiments @netXperiment

EU-Brazil #H2020 joint call on #cloud, experim platforms and HPC - want to know more? Join session at 2 pm, Net Futures Village #ICTpropDay

12m

EC Software & Cloud @CnectCloud

EU-Brazil #H2020 joint call on #cloud, experim platforms and HPC - want to know more? Join session at 2 pm, Net Futures Village #ICTpropDay

12m

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Challenges to be met in Citizen Science

Data providers and users: Match requirements - need for dialogue, understanding & education – Workshops/seminars

Uncertainty information: Convey uncertainty in a user-friendly way – visualization key – App development in CITI-SENSE & elsewhere

Observational information: Merge global and local information – DA/DF work at NILU

Added value information: Merge observational & model information & their errors - weather forecasts, air quality forecasts; assess – DA work at NILU

Data security & privacy: Address in CITI-SENSE & elsewhere

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Opportunities from AQ information

Also applies outside USA

Opportunities

1. Satellite sensing of air quality and emissions is rapidly maturing in its capability to augment and extend the spatial and temporal coverage offered by fixed-site monitoring networks and short-term special studies, allowing for unprecedented, high value ventures into satellite-based, ecosystem-characteristic measurements. U.S. agency geostationary missions in the near future will provide coverage at scales highly relevant to urban air quality, presenting notable future opportunities for analysis and integration.
2. Air quality models are increasingly able to reliably augment direct observations with credible spatial, temporal, and compositional information lacking in direct measurements.
3. Open access policies are providing enhanced access to observational data, metadata, and processing tools, facilitating harmonization and consolidation of disparate datasets and collaboration among previously unrelated research teams.

AQ Observation systems in the USA – Nov 2013

Committee on Environment, Natural Resources, and Sustainability
OF THE NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

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Conclusions

To note…

« A system that makes no errors is not intelligent »

« Risk Savvy », Gerd Gigerenzer

Data assimilation key to understanding & addressing AQ
For example, monitoring AQ over the Euro-Mediterranean area

And now for something completely different…

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What did data assimilation ever do for you?

- Analyses: best estimate of the state (process studies, climate studies)
- Analyses: initial state for a forecast (NWP, air quality - AQ)
- Evaluation: observations & models – error assumptions, bias
- Data monitoring: change in instrument characteristics
- Quantification: estimate changes in quantities, estimate transport,...
- Impact of current observations: OSEs – met agencies
- Impact of future observations: OSSEs – met agencies, space agencies

What did data assimilation ever do for us?

Well, it got me talking to you...

Beautiful Norwegian blue over there...

NILU Norsk institutt for luftforskning

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