Observations, lecture 14

Planning the Future Observing System for Water Vapour

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Outline

- Why is it important to evaluate expensive future missions such as ESA's Envisat (or other observing platforms):

  Quantify added value from new observations in comparison to Global Observing System (GOS)

- Use of data assimilation:

  Different approaches to evaluating future missions. Observing System Simulation Experiments (OSSEs) and Observing System Experiments (OSEs)

- Example of an OSSE:

  The proposed SWIFT instrument, measuring stratospheric winds and ozone

- Overview

The Global Observing system

•Important to evaluate future missions (e.g. ESA's Envisat)

Quantify incremental value from new observations

in comparison to Global Observing System (GOS)

Scientific value (also value of expensive missions)

•Use of data assimilation to design/evaluate GOS:

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

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

•Observing System Simulation Experiments (OSSEs): future missions

Other techniques besides OSSEs: information content; ensembles (see later)

•Illustrative example of an OSSE

The planned CSA SWIFT instrument, measuring stratospheric winds and ozone

Importance of evaluating future EO missions

Envisat

2.3B€ !

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

What does this buy?

(1) Norwegian Oil fund June 2009:

270 BEuros

1% of fund

(2) WAVACS Summer School 2009: 70KEuros

30,000 summer schools!

Hooray!

BUT...

How can you check if this is a good use of money?

How can you quantify value?

What do you need to consider?

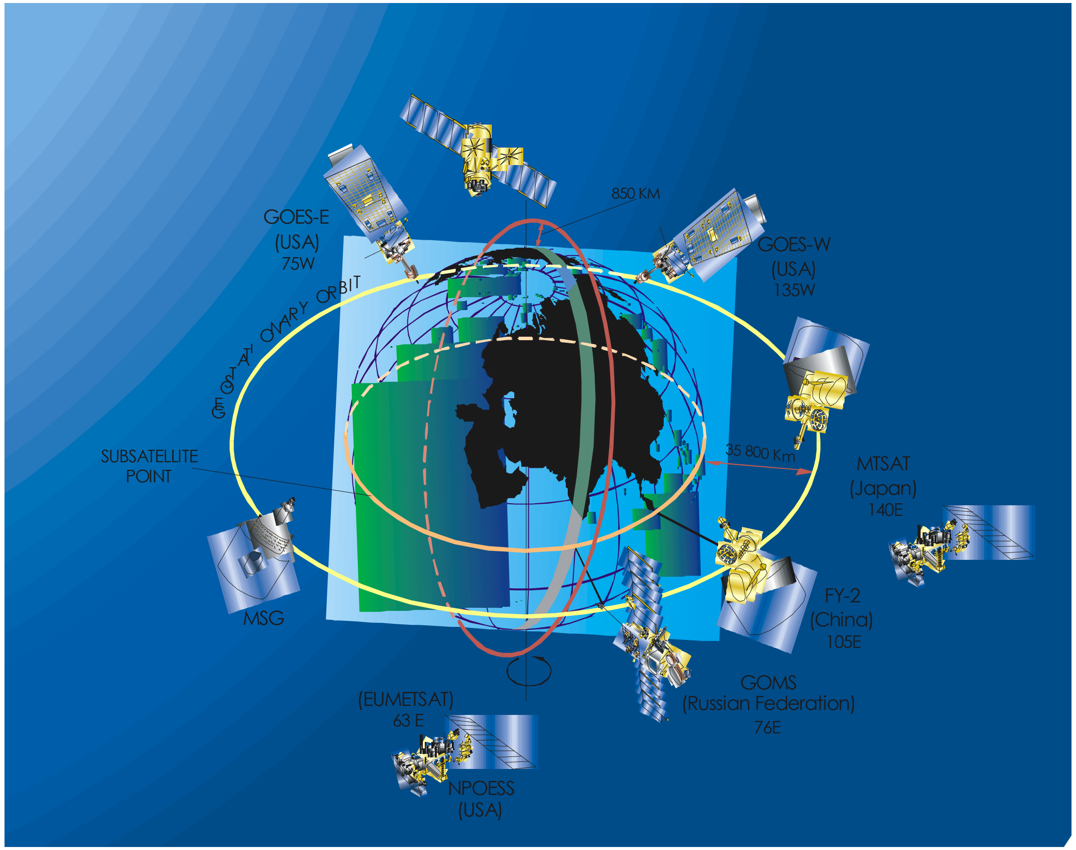
NOT the value of Envisat

BUT added value of Envisat above what else will be available

-> INCREMENTAL VALUE

THIS IS TRUE FOR ANY ADDITION TO GLOBAL OBSERVING SYSTEM

Example: Global Earth Observing system (GOS) for 2008-2010



What will the GOS be like?

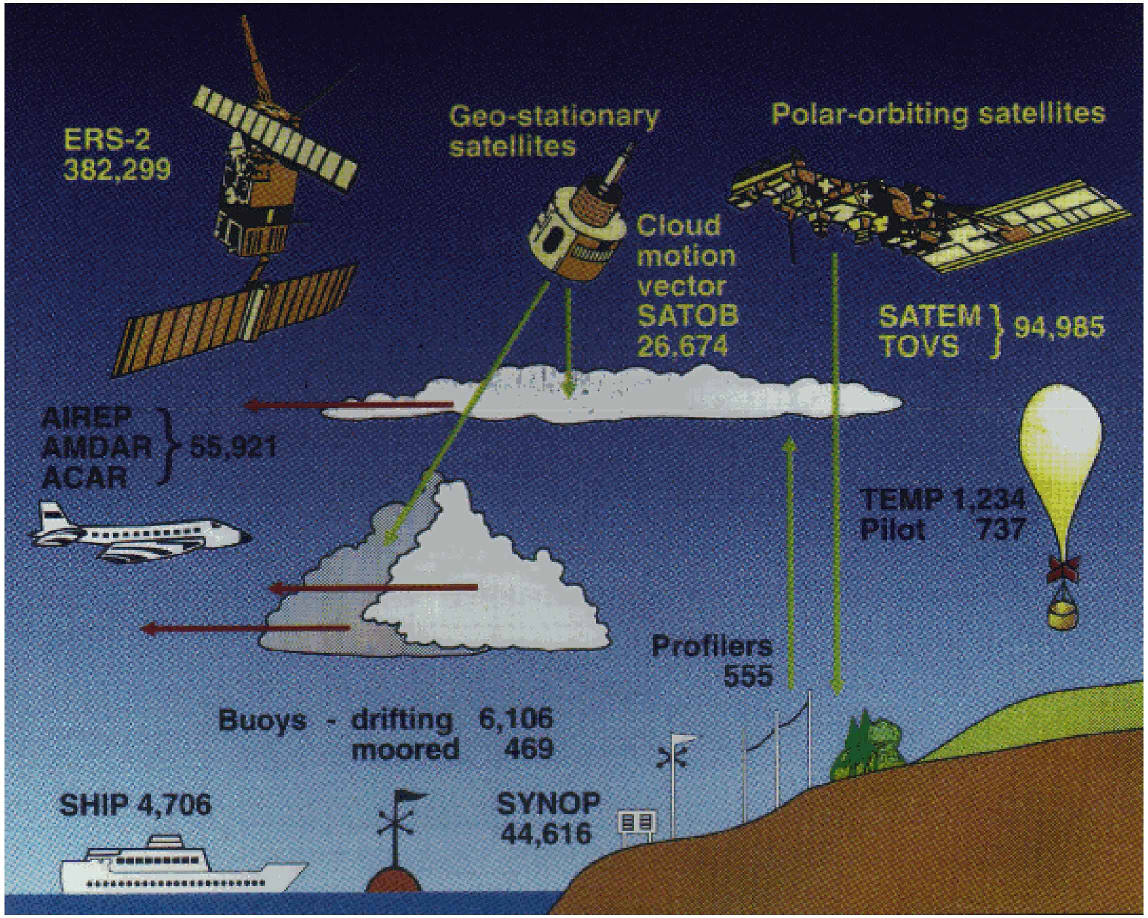
Existing & planned satellite missions

What type of observations to include?

Conventional: ground-based, sondes, aircraft

Satellites: operational, research

Example: Observation types used by Met Office for NWP



Examples of observation requirements (chemical species):

What do we have? What do we need?

Based on several documents:

- IGACO
- Capacity study (successor is ESA Camelot study)
- Expert team on evolution of GOS
- GCOS (Global Climate Observing System)

Scientists:

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

IGACO

Group 1: O_3, H_2O, CO_2, CO, NO_2, BrO, ClO, HCl, N_2O, CFCs, $ClONO_2$ & aerosol optical properties.

What do we have:

•Reasonably comprehensive set of global observations for both troposphere & stratosphere using sparse number of Low Earth Orbit satellites (LEOs), ground-based networks & aircraft measurements

•Good atmospheric modelling capabilities

•Good network of ground-based & satellite observations that only require maintenance & some gaps to be filled. Routine aircraft observations but not yet comprehensive enough

•Data assimilation "in good shape"

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
2. Upper troposphere	Δx	km	20/100	10/100	50/250	50/500	10/250	30/250				
	Δz	km	0.5/2	0.5/2	2/4	1/2	1/4	0.5/3				
	Δt		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)				
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)		

(1) Hours (NWP);

(2) days-weeks (O_3 loss,…);

(3) months (climate research)

Courtesy IGACO 2004

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

Group 2: CH_4, HCHO, VOCs, SO_2, HNO_3, OClO, NO, CH_3Br, the halons, and $j(NO_2)$ and $j(O^1D)$.

What do we have:

- All current satellites are in experimental "demonstration" mode & only have limited lifetime.

- Some ground-based *in situ* measurements.

- Except for CH_4, global network sparse.

- Next 10 years need to be spent developing instrumentation & putting monitoring infrastructure in place.

Target/threshold (needed)

ATMOSPHERIC SPECIES IN GROUP 2 TO BE MEASURED BY AN INTEGRATED GLOBAL OBSERVING SYSTEM													
Atmospheric Region	Requirement	Unit	NO	HNO_3	C_2H_6	CH_3Br	Halons	HCFC-22	$ClONO_2$	HCHO	SO_2	UVA $j(NO_2)$ UVB $j(O^1D)$
2.	Δx	km	30/250	10/250	50					10	10	50/500
	Δz	km	0.5/3	1/3	2					0.5	0.5	3**
Upper troposphere	Δt		1hr	1d	1hr						1hr	1hr
	precision	%	10/30	10/30	10					10	5	10
	trueness	%	15/40	15/40	15					15	10	15
	delay		(1)	(1)/(2)						(1)	(1)	
3.	Δx	km	30/250	50/250		500	500	1000	50/250			
	Δz	km	1/4	1/4		5	5	5	1/4			
Lower stratosphere	Δt		12hr	12hr		3d	3d	3d	6-12hr			
	precision	%	10/30	10/30		4	4	8	20			
	trueness	%	15/40	15/40		8	8	15	30			
	delay		(1)	(1)/(2)								

Courtesy IGACO 2004

**: *in situ* measurements

Courtesy IGACO 2004 Aerosol requirements

Theme		Unit	Aerosol Optical Depth (VIS+IR)	Aerosol Extinction Coefficient (VIS)	Aerosol Absorption Optical Depth (VIS)	PM1, PM2.5, PM10
a, d	Δx	km	1/10	10/100	1/10	
	Δz	km		0.5/1		
Climate Studies and oxidising capacity	Δt		global daily	global weekly	global daily	
	precision		0.005/0.01	0.005/0.01 km^{-1}	0.002/0.01	
	trueness		0.01/0.02	0.01/0.02 km^{-1}	0.004/0.02	
	delay		weeks	weeks	weeks	
b	Δx	km	0.25/1	0.5/2		0.25/1
	Δz	km		0.1 in PBL		0.1 in PBL
Air quality (PBL and free trop)	Δt		regional hourly	regional daily		regional sub-daily
	precision		0.005/0.01	0.005/0.01 km^{-1}		1/10 $\mu g\ m^{-3}$
	trueness		0.01/0.02	0.01/0.02 km^{-2}		1/10 $\mu g\ m^{-3}$
	delay		near real-time	near real-time		near real-time
c	Δx	km	10/100	10/100		
	Δz	km		1/2		
Ozone depletion (UT/LS)	Δt		10d	10d		
	precision		$10^{-5}/10^{-4}$	$10^{-6}/10^{-5}$ km^{-1}		
	trueness		$10^{-5}/10^{-4}$	$10^{-6}/10^{-5}$ km^{-1}		
	delay		days	days		

Target/threshold (needed)

Capacity

Observation requirements (see http://www.knmi.nl/capacity)

Capabilities (what do we have), focus on water vapour

•***Water Vapour.*** Water vapour soundings adequate for NWP will be performed in cloud-free scenes by MetOp/NPOESS. The operational system will not provide useful water vapour data above the tropopause, and vertical resolution in the upper troposphere will not be sufficient for future research applications.

Conclusions

•Suitability of existing instrument technology depends on several factors including: (i) theme & application to be addressed; (ii) scope of satellite mission, including restriction on number of platforms, orbits, number & types of sensors and systems; (iii) importance & priority of particular observations, *i.e.*, what is the effect of not achieving particular observational requirements.

•CAPACITY study showed that, while many measurements are made and applications are addressed to various extents, there is scope for improving current techniques and bringing new types of sensor and observations to the available complement of instruments.

Expert team on evolution of GOS

Observation requirements:

According to latest CBS OPAG ET-EGOS (Expert Team on the Evolution of the Global Observing System) (WMO 2004), the vision for evolved GOS at the 2015 horizon & beyond suggests :

- Six operational Geostationary satellites (GEOs) with onboard multispectral imagers (Infrared/Visible - IR/VIS), some with hyperspectral sounders (IR);

- 4 operational low earth orbiting (LEO) satellites providing a uniform data coverage with onboard multispectral imagers (Microwave/Infrared/Visible/Ultraviolet - MW/IR/VIS/UV), sounders (MW), radio-occultation (RO) capabilities, some with hyperspectral sounders (IR), conical scan MW or scatterometers and altimeters;

•In addition, several R&D satellites will complement the operational constellation. Further LEOs with active and passive microwave precipitation and cloud measurements, and two LEOS with soil moisture and ocean salinity capability (e.g. SMOS, SMAP) will also become available within the next 10-year timeframe;

•Atmospheric composition missions, currently available with the Envisat-EOS satellites (as of 2009), will hopefully reach a more operational status towards and after 2015 (*e.g.* ESA Sentinels 4 and 5);

•Last but not least, a LEO with wind profiling capabilities will become available during this timeframe.

Moreover, the recent results obtained by a number of operational centres (*e.g. Healy and Thépaut 2006*) suggest that a GPS radio-occultation observing capability is now a high priority requirement, not only for NWP but also for reanalysis and climate applications.

GCOS

Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008

August 2009

GCOS-129

(WMO-TD/No. 1489, GOOS-173, GTOS-70)

Essential Climate Variables - ECVs

Table 5: List of Essential Climate Variables as given in the 2004 *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC* (IP-04).

Domain	Essential Climate Variables	
Atmospheric (over land, sea and ice)	**Surface:**	Air temperature, Precipitation, Air pressure, Surface radiation budget, Wind speed and direction, Water vapour.
	Upper-air:	Earth radiation budget (including solar irradiance), Upper-air temperature (including MSU radiances), Wind speed and direction, Water vapour, Cloud properties.
	Composition:	Carbon dioxide, Methane, Ozone, Other long-lived greenhouse gases, Aerosol properties.
Oceanic	**Surface:**	Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Current, Ocean colour (for biological activity), Carbon dioxide partial pressure.
	Sub-surface:	Temperature, Salinity, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton.
Terrestrial[26]	River discharge, Water use, Ground water, Lake levels, Snow cover, Glaciers and ice caps, Permafrost and seasonally-frozen ground, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (fAPAR), Leaf area index (LAI), Biomass, Fire disturbance.	

4 The Atmospheric Climate Observing System

Growth and decay of weather systems and changes-in-state of water between snow, rain, cloud and vapour give the atmosphere a unique role in the climate system. Heat, moisture and chemical species are moved around rapidly by winds. Cloud and water vapour feedbacks are major factors in determining the sensitivity of the climate system to forcings, such as from rising levels of greenhouse gases and from aerosols. To characterize the atmosphere at the land- and ocean-surface, measurements of temperatures, water vapour, wind, pressure, daily precipitation amounts and atmospheric composition ECVs, such as carbon dioxide, methane and aerosols, are needed. As precipitation is episodic and can be very localized, high-resolution observations are needed to create an accurate picture. Satellite observations are a unique source of global information on many ECVs, but in most cases do not extend sufficiently far back in time to give a full historical perspective and need to be complemented by *in situ* measurements, especially at lower levels over land. Instrumental and palaeo-reconstructions of temperature and precipitation are essential to provide the long-term perspective.

The three-dimensional structure of the atmosphere determines the nature and movement of weather systems. In the troposphere and lower stratosphere, balloon-borne instruments combined with groundtracking devices in a radiosonde network have traditionally measured temperature, water vapour and wind. Satellite measurements of radiances now complement these observations but require interpretation in geophysical terms for most applications. Because natural modes of variability, such as El Niño and the North Atlantic Oscillation, alter atmospheric circulation and storm tracks, it is vital to determine and understand such processes as they can obscure climate change detection.

Summary of Progress

Overall, there has been steady progress in maintaining and enhancing the atmospheric observing systems for climate. This is largely based on efforts by the national operators of networks and systems (both ground and space-based) providing surface and upper-air meteorological observations, measurements of greenhouse gases and measurements of other aspects of atmospheric composition. The global trend of declining *in situ* meteorological network performance prevailing through the 1990s has been halted or reversed in all regions. In spite of the overall progress, it must be stressed that some regions of the world, Africa in particular, have seen no significant improvement in observational coverage. Issues related to atmospheric observations from Voluntary Observing Ships (VOS) are discussed in the following Chapter on the Oceanic Climate Observing System.

One facet of the progress made has been improved reception of *in situ* observational data in international data centres. This is at least in part due to enhanced engagement by centres dedicated to monitoring *in situ* network performance, acting in liaison with both the network operators and the programmes responsible for the networks. For example, the work of the existing GCOS Surface Network (GSN) and GCOS Upper-Air Network (GUAN) Monitoring, Analysis and Archive Centres has been complemented by the establishment of nine CBS Lead Centres for GCOS covering all regions worldwide. Good progress in the implementation of Global Atmosphere Watch (GAW) networks for atmospheric composition ECVs has also been made. Nevertheless, there remain significant gaps in both network coverage and the frequency of reporting from existing stations, which is of particular concern with respect to understanding and predicting regional climate and climate change.

Despite good overall progress, there remain some specific issues where methodological, technical or institutional problems persist. For example, accurate, frequent and consistent measurements of precipitation are yet to be achieved globally; regular exchange of climatologically-relevant data, including near-real time data, is still inadequate; and there remains significant room for improvement in the rescue of historical data and metadata.

A new development since 2004 has been increased emphasis on establishing reference-type networks that would provide anchor points for broader GCOS surface and upper-air networks. In particular, for observing the atmospheric column, important steps have been taken towards establishment of the GCOS Reference Upper Air Network (GRUAN). In addition, several Parties are in the process of setting up national climate networks of geographically well-distributed surface stations that provide high-quality observations of many, if not all, of the surface-based climate variables.

Satellite systems

Regarding satellite systems, improved instruments, international coordination and exploitation of datasets have led to an increasingly important contribution to global climate monitoring. Reprocessing and analysis of satellite-based climate data records is an ongoing activity required to improve the description of climate variability and trends. Observational capabilities of future satellite systems need to ensure continuity of the climate record, as well as provide new or improved measurements of some ECVs, such as cloud properties, aerosols and greenhouse gases. The space agencies working through CEOS, CGMS, and the WMO Space Programme have carefully set a path for the future to ensure a viable and homogenous flow of global remote sensing data which covers the needs of GCOS. In addition, they have developed important initiatives to ensure better calibration of instruments and reprocessing of the past climate record. All this requires extraordinary international cooperation, collaboration and commitment. It also requires an active and focused research programme and funding commitments by nations that are operating satellites.

Meeting the full range of objectives expressed in the IP-04, and especially the broader objectives of GCOS at the national level, will require much more attention on building capacity in developing and least-developed countries to ensure better observational coverage and use of climate data, especially on regional and national scales where information is required for the purposes of adaptation.

Upper-Air Observations

Observation of climate variables in the free troposphere and lower stratosphere characterizes the part of the atmosphere where dynamic and chemical processes relevant to weather and climate occur. As such, measurements of these variables are of particular importance for use in model predictions, as well as for validating satellite-based atmospheric profile information. Assessing the reliability of model-based predictions of climate change depends on the stability and accuracy of the individual measurements, as well as on their temporal and spatial (horizontal/vertical) coverage.

Examples of available data

Action A12 Availability of air humidity data worldwide

Good Progress

Action: Submit water vapour data from national networks to the International Data Centres.

Who: National Meteorological Services through WMO CBS and GCOS Analysis and Monitoring Centres with input from AOPC.

Time-Frame: Complete analysis of global-scale data by 2006.

Performance Indicator: Data availability in analysis centres and archive.

Significant progress has been made in the availability, and use of, water vapour data from global and national networks. NCDC holds historical data from over 20 000 synoptic stations globally in its Integrated Surface Dataset (ISD). In near-real time, a considerably larger volume of data is available from the synoptic network, for use in operational atmospheric analysis and reanalysis. Water vapour data are included in datasets held by NCAR, ICOADS, CRU and the reanalysis centres. The first near-global analyses of these data have been published by Dai (2006)[53] and Willett et al. (2008).[54] Willett's analysis was based on an intermediate, 5°x5° gridded monthly mean anomaly dataset for the period 1973-2003 (HadCRUH). Good agreement has been demonstrated between HadCRUH and reanalysis products over land, and HadCRUH values over sea are consistent with sea-surface temperature anomalies from 1982 onwards and with variations in total column water vapour from microwave imagery.

Good Progress

Action A20 GPS Radio Occultation measurements

Action: GPS RO measurements should be made available in real time, incorporated into operational data streams, and sustained over the long-term. Protocols need to be developed for exchange and distribution of data.

Who: Space agencies, in cooperation with CGMS, WMO CBS, the WMO Space Programme and AOPC.

Time-Frame: Exchange standards and protocols by 2006.

Performance Indicator: Volume of data available and percentage of data exchanged.

GPS-based meteorology has transitioned from research into a near global operational status. GPS RO measurements of the temperature- and humidity-sensitive atmospheric refractive index are now

a 6h period from GPS receivers. GRAS is the first instrument for which there is continuity until the end of the next decade, alone providing more than 600 occultations per day. A follow-on to the six-satellite COSMIC constellation is under discussion by space agencies, but has yet to be confirmed.

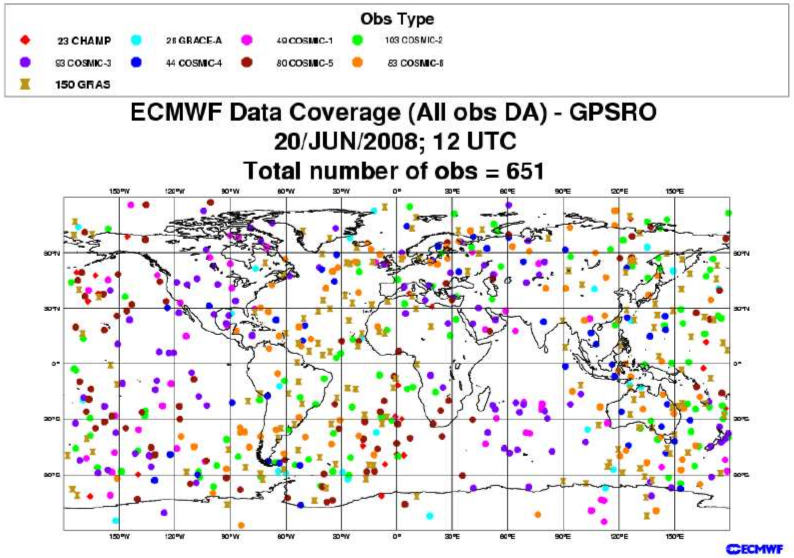


Figure 13: Data coverage by GPS Radio Occultation as received within a six-hourly period in June 2008 (Source: ECMWF).

Action A32 Satellite atmospheric composition measurements

Good-Moderate Progress

Action: Develop and implement a strategy to enable use of satellite data on atmospheric composition for climate by scientific users, regardless of source.

Who: Space agencies, in conjunction with CEOS and CGMS, IGOS-P, and WMO Space Programme.

Time-Frame: 2005 for strategy, 2007 for facilitated use of data regardless of source.

Performance Indicator: Written strategy by 2005; straightforward use of data regardless of source by broad range of

Considerable progress has been made with the launch or planning of new operational instruments, such as GOME-2 on Metop, a number of high-spectral resolution infrared sounders and the GMES Sentinel series. There are also dedicated research-class missions addressing atmospheric composition, such as Aura and GOSAT (regrettably, an additional expected mission, OCO, suffered a launch failure). Under the auspices of the CEOS Atmospheric Composition Virtual Constellation (ACC), a series of workshops devoted to coordination across space agencies on satellite datasets and missions related to atmospheric composition was organized through 2007 and 2008. The 2008 workshop specifically focussed on the quality of datasets and gaps in the record. In addition, a series of instruments addressing atmospheric composition measurements is currently flying or in the planning stage, thereby ensuring continuous data supply in this area. CEOS is also leading a new GEO task which will consolidate data requirements for the next-generation of greenhouse-gas monitoring missions from space.

The development of international data exchange systems, such as WIS and the GEO Portal, and the existence of WMO Resolution 40 on data exchange as well as development of the GEO Data Exchange Principles is expected to facilitate the use of satellite data on atmospheric composition for climate. There is increasing recognition by space agencies of the importance of facilitating data access (see footnote 31).

The WDC-RSAT (World Data Centre for Remote Sensing of the Atmosphere) has been established at DLR, Germany, as a new WMO GAW World Data Centre. WDC-RSAT aims to store or link to all satellite data related to atmospheric composition.

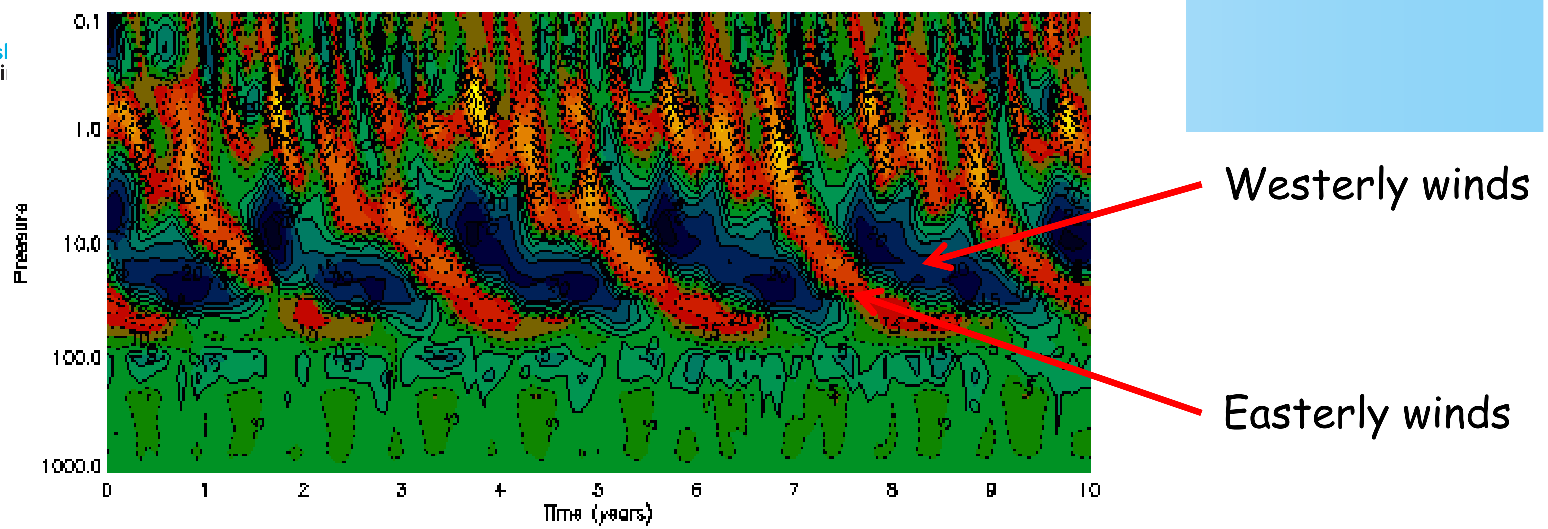
Motivate SWIFT OSSE: winds are a current concern about GOS

- 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

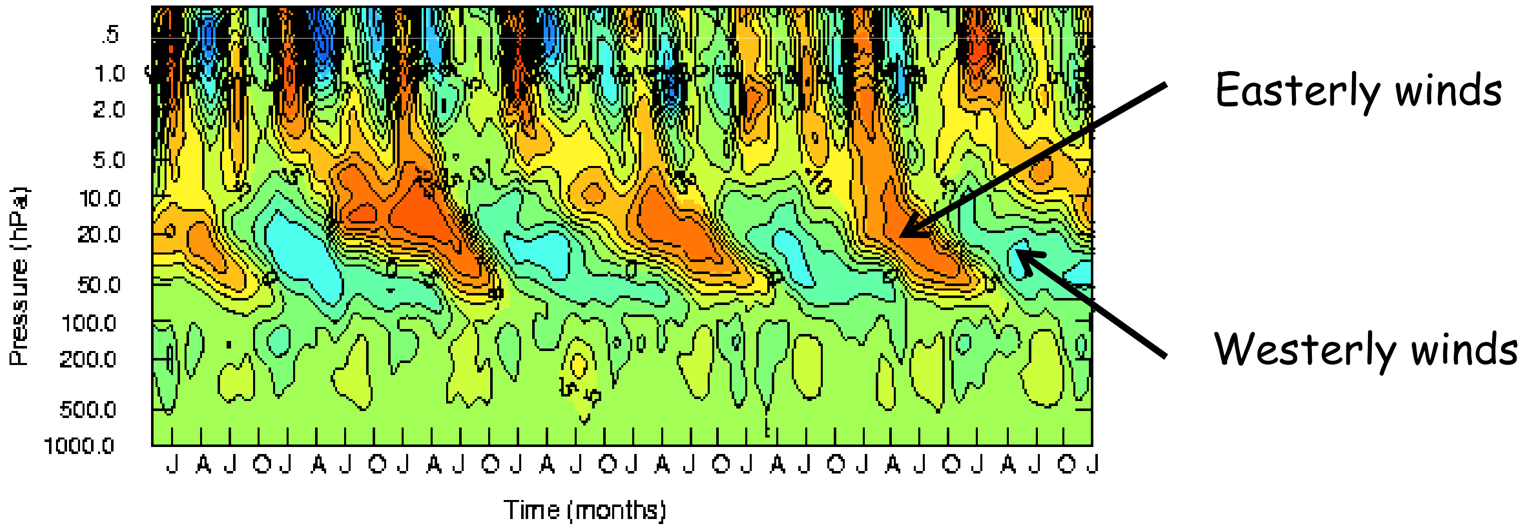
Although a focus is on tropical stratosphere, SWIFT can benefit extra-tropics, including representation winter high latitude variability

Main reason for exposition is illustration of the OSSE concept

NILU
Norsk institutt for luftforsl
Norwegian Institute for Ai



"Realistic" quasi-biennial oscillations in the MO Unified Model



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

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
  - CSA SWIFT: launch after 2010?

NILU Norsk institutt for luftforskning
Norwegian Institute for Air Research

ADM-Aeolus

Doppler Wind Lidar (DWL)

1 component global wind profiles up to ~30 km

N.B. need data assimilation to get 2 components

- Better information to predict weather
- Global wind profiles for the entire planet, including remote areas lacking any ground-based weather station

Main objective:

- Correct major deficiency in winds in current GOS

- Increased skill in NWP
- Data needed to address WCRP key concerns:

Quantification of climate variability

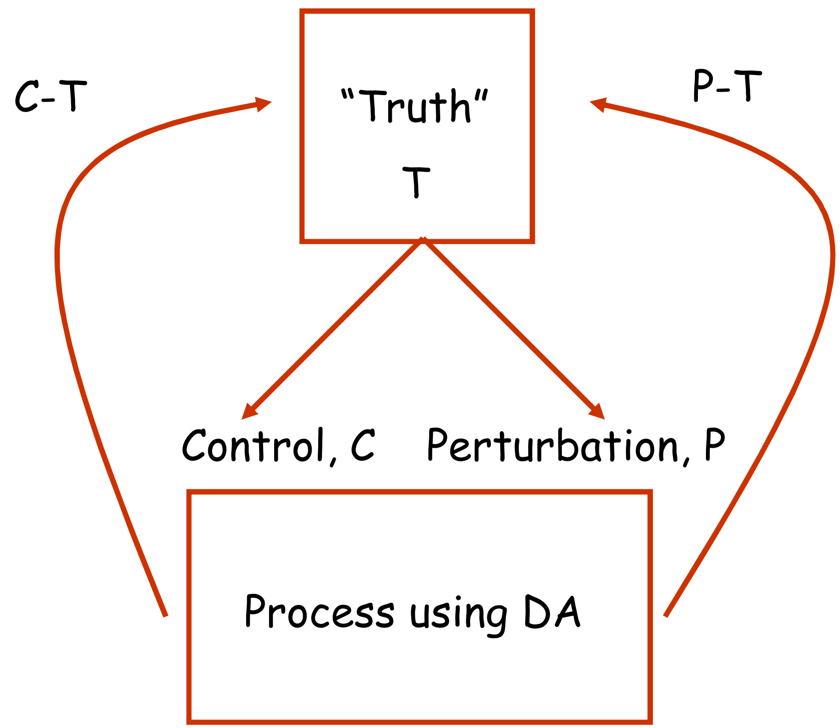
Validation & improvement of climate models

Process studies relevant to climate change

OSSEs done under auspices of ESA

Structure of an OSSE

- 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

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: evaluate proposed SWIFT instrument

Lahoz et al. QJ 2005

SWIFT:

- Based on UARS WINDII principle (Doppler effect)
- 2 wind components using 2 measurements at ~90^{o}
- 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

<u>Models used:</u>

- "Truth" (ECMWF directly, or forcing a CTM)

- Assimilation system (Met Office) (cf. incest)

<u>Simulated observations:</u>

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

Temperature, winds, humidity, ozone

SWIFT; C+SWIFT = P

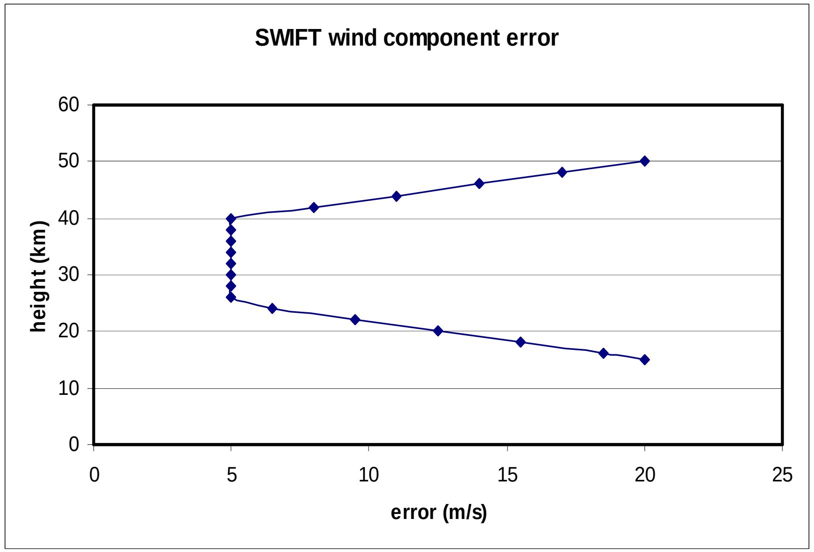
Ozone, winds (stratosphere, conservative errors)

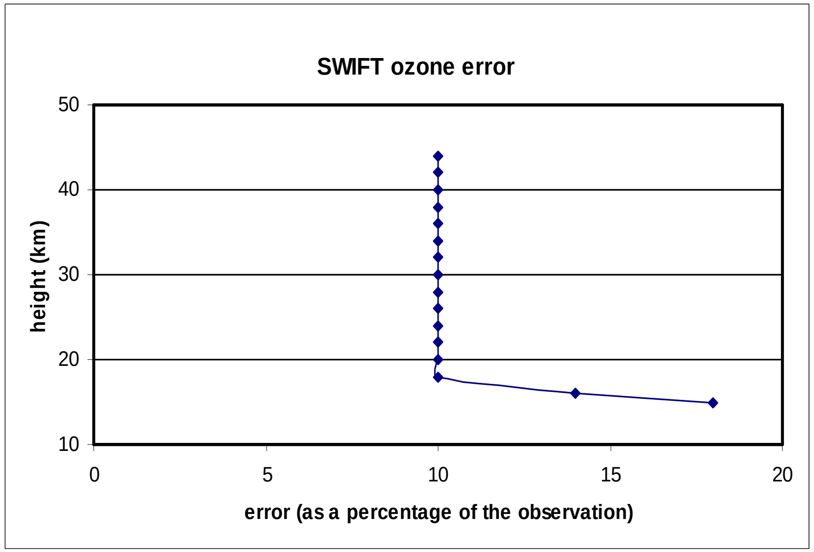
Several assimilation experiments; analyses evaluated.
Qualitative & quantitative tests

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

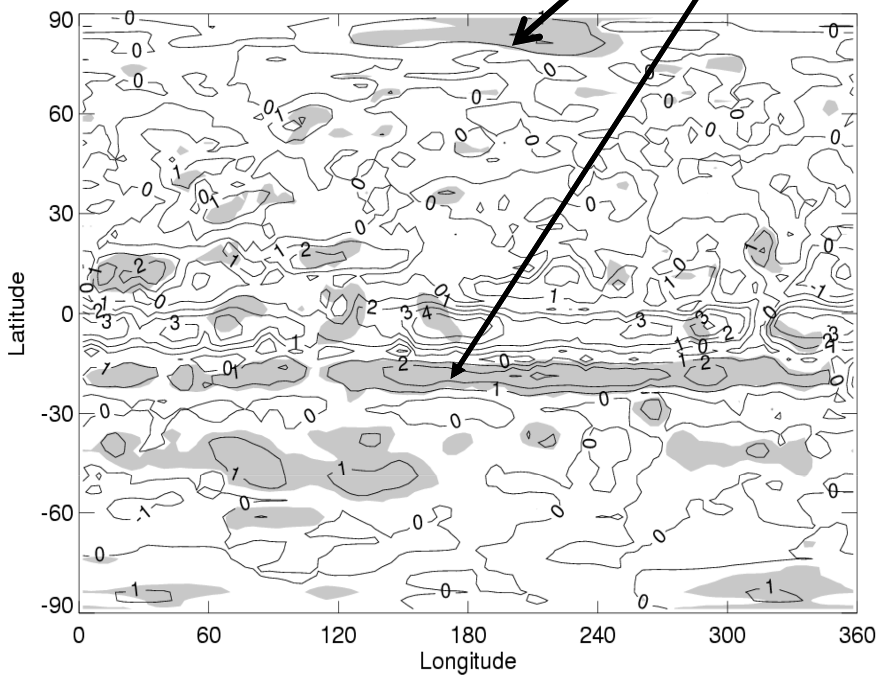
  - ozone 16-44km, every 2km approximately
- Errors: conservative; random; representativeness error considered to be relatively unimportant



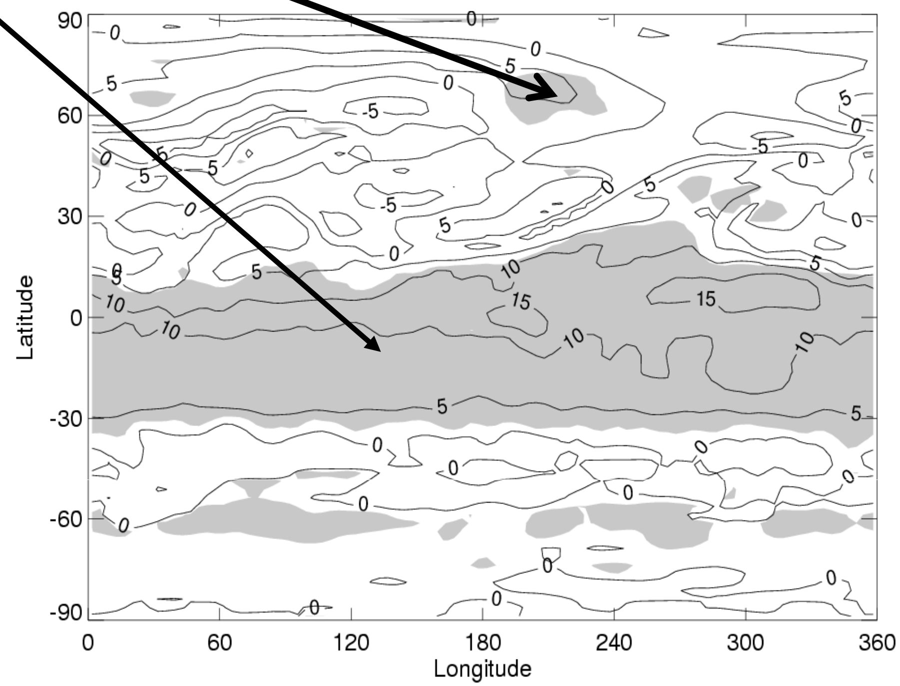


Significance tests

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

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

Alternatives to OSSEs

- Information content

Aim: evaluate the potential benefit of future sensors compared to other available sensors

Prunet *et al.* (1998) used approach to quantify impact of information content in simulated IASI radiances vs information content in TOVS radiances.

Impact of IASI radiances estimated by comparison of analysed errors (which include TOVS or IASI data) vs those of a background field (from model forecast excluding both TOVS and IASI data).

If observation type of interest has positive impact, analysed errors should be smaller than background errors.

By comparing errors of analyses including TOVS or IASI data, relative information content in these data can be evaluated, and assessment made of their relative benefit.

In principle, information content approach is simpler & less expensive to apply than an OSSE.

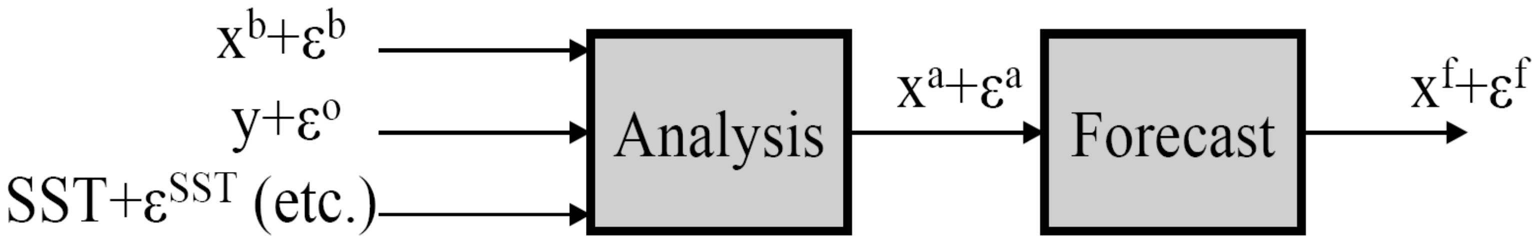
However, information content approach requires a realistic characterization of background & observation errors, which could be difficult to achieve.

Furthermore, it could be argued that OSSE approach provides a more complete test of the future sensors.

•Ensembles

Courtesy Andersson et al. ECMWF

Suppose we perturb all the inputs to the AN/FC system with random perturbations, drawn from the relevant distributions:

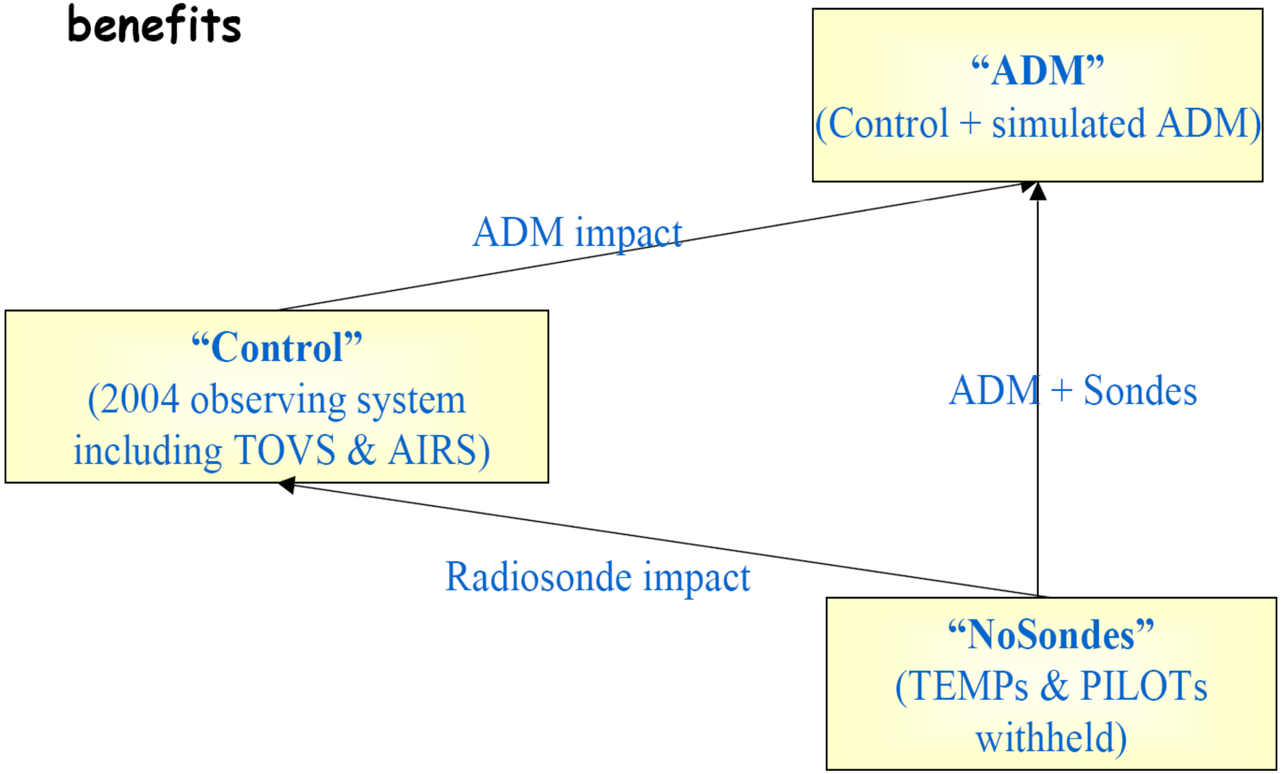


- **The result will be a perturbed AN and FC, with perturbations characteristic of AN and FC error.**
- **The perturbed FC may be used as the Bg for the next (perturbed) cycle.**
- **After a few days, the system will have forgotten the original initial Bg perturbations.**

Courtesy Andersson et al. ECMWF

ADM-Aeolus data impact DA ensemble experiments

- Impact = Spread(Ensemble-1) – Spread(Ensemble-2)
- A reduction in spread (negative values) should indicate data benefits



Courtesy Andersson et al. ECMWF

Ensembles approach, According to Andersson et al:

Advantages over OSSE approach include

- Only the future observing systems need to be simulated (this has to be done with great care, as in OSSEs)
- No need for a Nature Run (='truth') Need "truth" for simulated data
- Results are less sensitive to biases

Way forward:

Important to quantify value of future missions

All elements of the Earth System

-> participation of all actors: multi-disciplinary

-> quantify benefits: OSSEs & other methods

-> 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:

Before ozone hole, what would an OSSE on UARS focus on?

Final word

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., 2009

Prepare well…

Among the maxims on Lord Naoshige's wall there was this one: "Matters of concern should be treated lightly." Master Ittei commented, "Matters of small concern should be treated seriously." Among one's affairs there should not be more than two or three matters of what one could call great concern. If these are deliberated upon during ordinary times, they can be understood. Thinking about things previously and then handling them lightly when the time comes is what this is all about. To face an event and solve it lightly is difficult if you are not resolved beforehand, and there will always be uncertainty in hitting your mark. However, if the foundation is laid previously, you can think of the saying, "Matters of great concern should be treated lightly," as your own basis for action.

Hagakure, The Book of the Samurai

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