Atmospheric Chemistry Subgroup (ACSG) Report to WGCV-21

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Working Group on Calibration & Validation

CEOS WGCV Plenary

Beijing, China

15-17 October 2003

NASA

CEOS and IGOS

CEOS established six Pilot Projects to assess the feasibility of achieving the objectives of IGOS. The “Ozone Project” resulted in the following:

WMO-GAW No. 140 - WMO/CEOS Report on a Strategy for Integrating Satellite and Ground- based Observations of Ozone

1) IGOS-P Atmospheric Chemistry theme

2) CEOS WGCV Subgroup on Atmospheric Chemistry (ACSG)

CEOS
Committee on Earth Observation Satellites

IGOS Integrated Global Observing Strategy

WMO #140 focused on an integrated system for observing ozone and related key atmospheric parameters

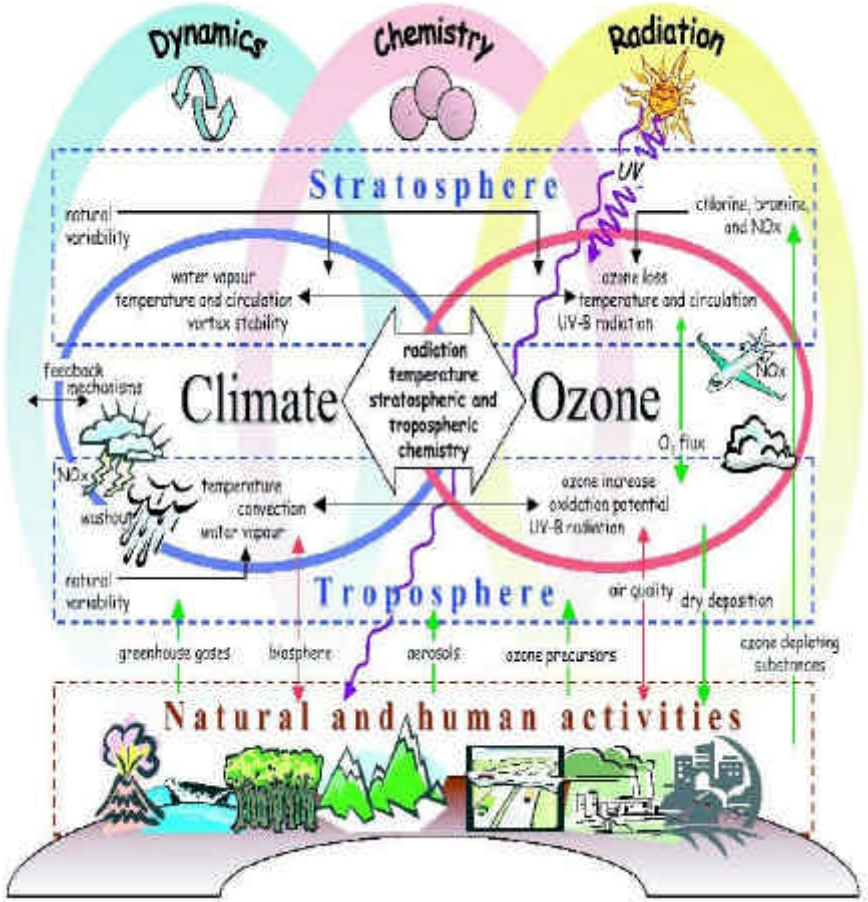
Theme: Long term continuity and spatial comprehensiveness of key observations needed for environmental research and climate applications

- Considered atmospheric chemistry in connection with ozone depletion, air quality, and climate change
- Compiled science and user requirements
- Catalogued research and operational missions (ground and space)
- Defined an integrated approach, which incorporates satellite and ground based observations highlighting missing components
- Recommended research needed to improve understanding so that observations can be properly interpreted

Goal: Use improved data and knowledge for informed policy making decisions

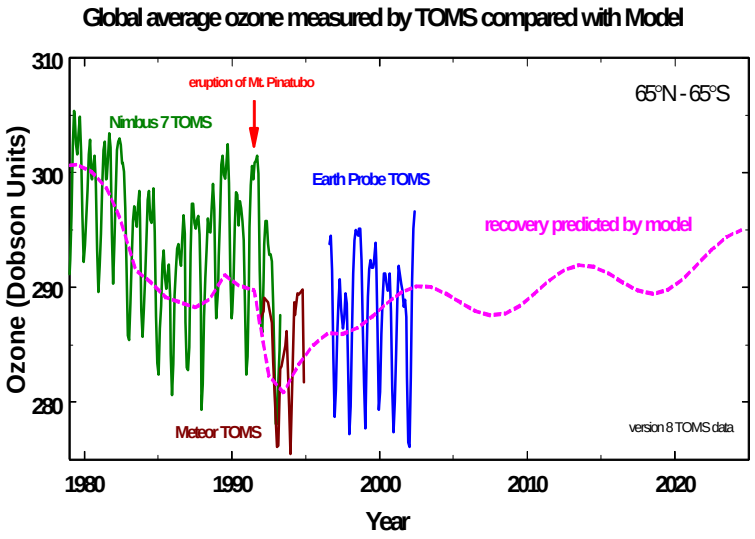
Atmospheric Chemistry connects Air quality, Ozone depletion, and Climate

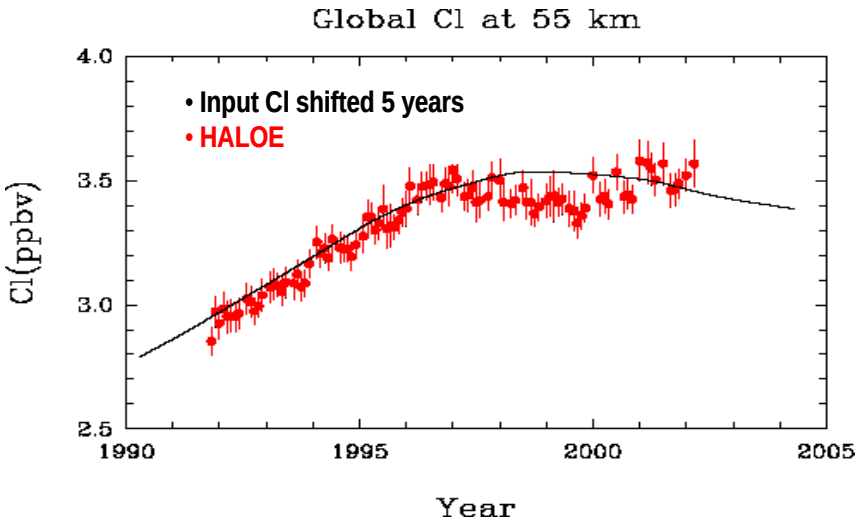
- Troposphere and stratosphere connect chemistry and climate
- The boundary between the two is critical layer for investigation
- High spatial resolution is needed to identify sources and sinks and transport between layers (UT/LS and PBL/FT)
- Validation requirements become even more stringent because of the need to separate atmospheric layers
- A combination of traditional and new validation assets are needed



Ozone recovery will be difficult to detect and to explain

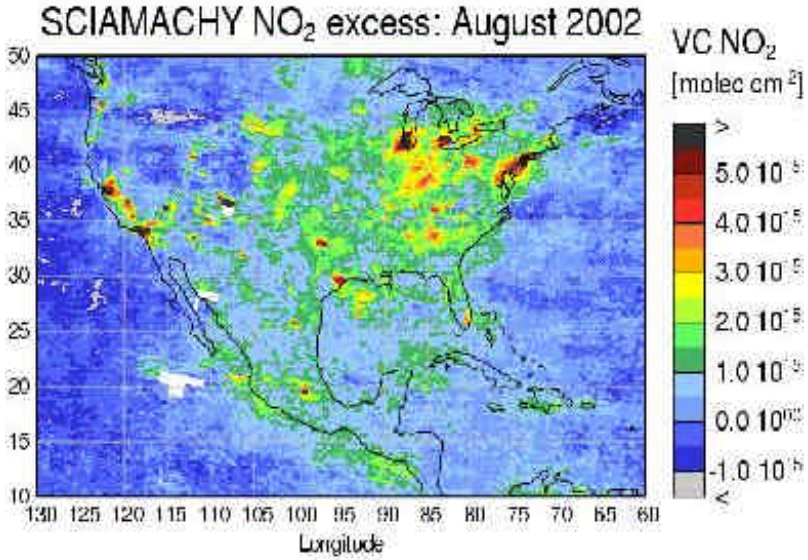
- Detected ozone change matches models reasonably well
- Ozone recovery will be slower than the decrease detected to date
- In order to explain ozone change other active chemical species must be monitored
- UARS/HALOE measured HCl in stratosphere which matches expected decrease based on CFC phase out.
- HCl measurements will be continued by Aura/HIRDLS using a different technique

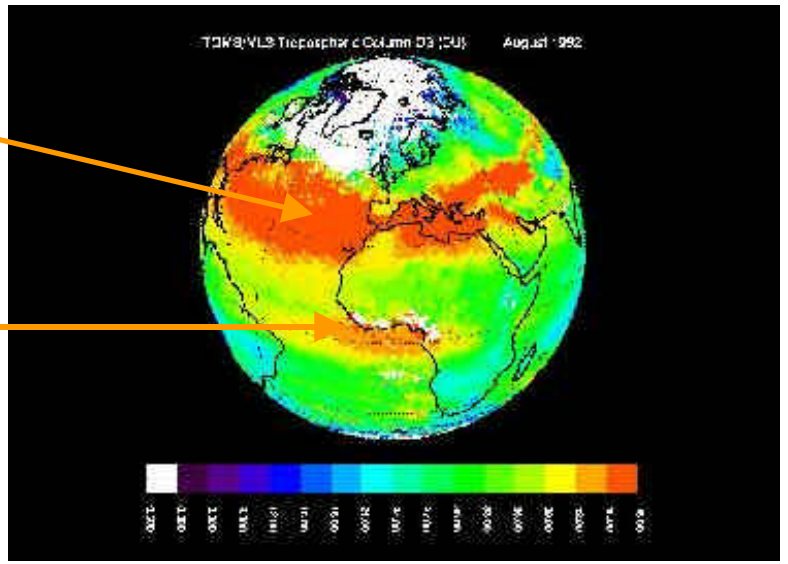




Air Quality and Climate are connected

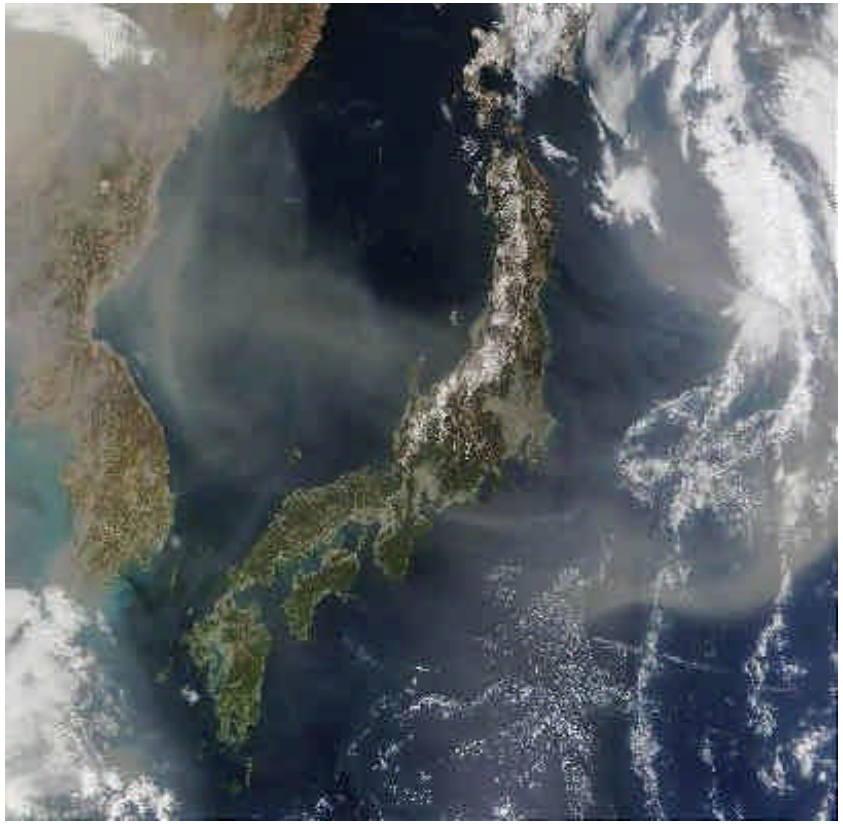
- Chemically active gases are also green house gases. Aerosols play a role in tropospheric chemistry
- Better observations are needed to improve emission inventories used in air quality assessments and forecasts
- Aerosols play a role in chemistry and climate
- Intercontinental transport of pollution (natural and anthropogenic) need to be included in climate models



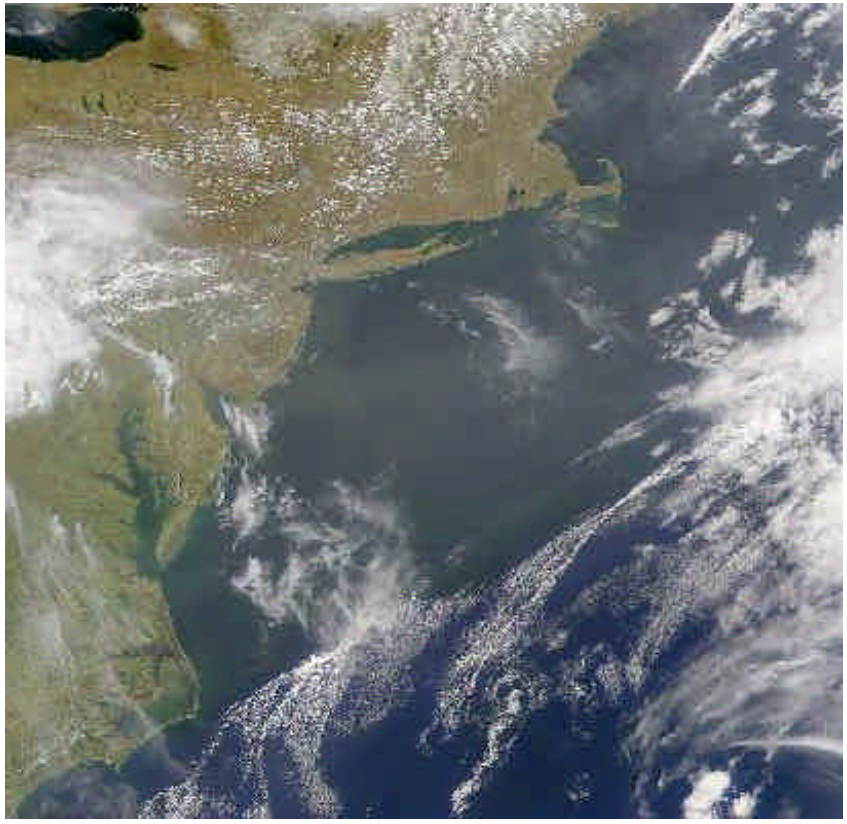


China dust storm circles globe

April dust cloud, started as a sand storm, swept across eastern China (MODIS)



Remnants of storm appears as haze over the mid-Atlantic coast of USA (SeaWIFS)

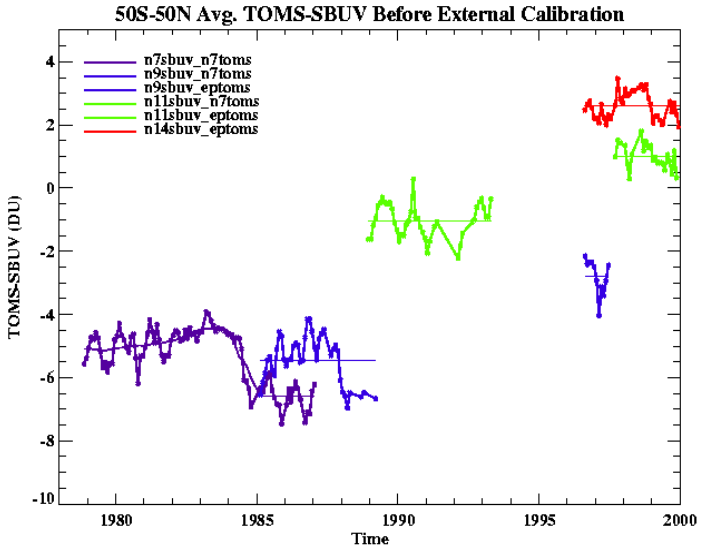


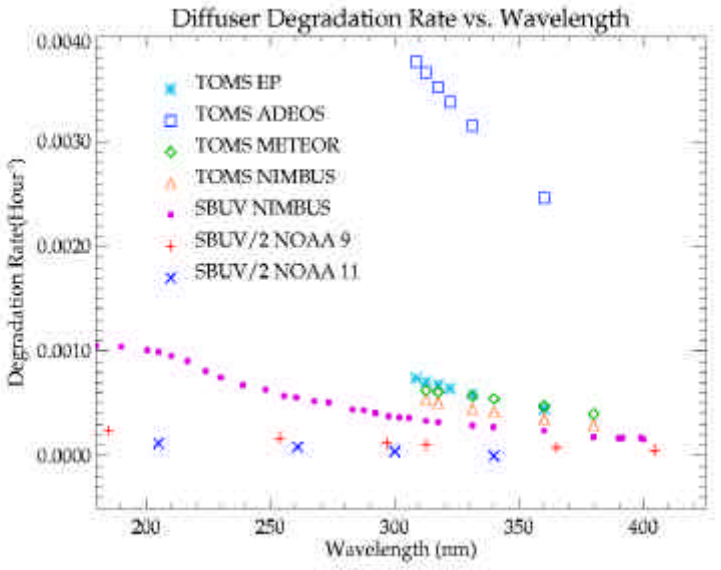
Detecting trends in Atmospheric Chemistry remains a challenge

Same type of satellite instrument flown repeatedly just barely meets requirement for trend detection.

Satellite instruments from different agencies will provide important redundancy, but will impose special challenge for validation

Calibration diffuser degradation differ from one instrument to the next and is unpredictable

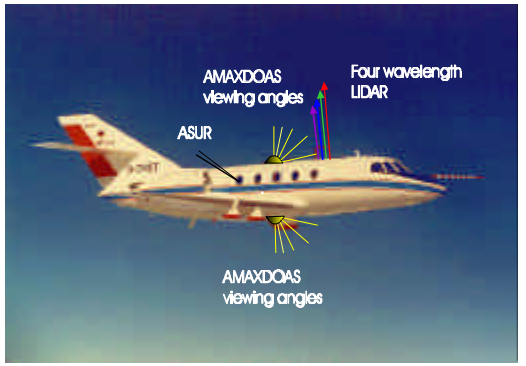




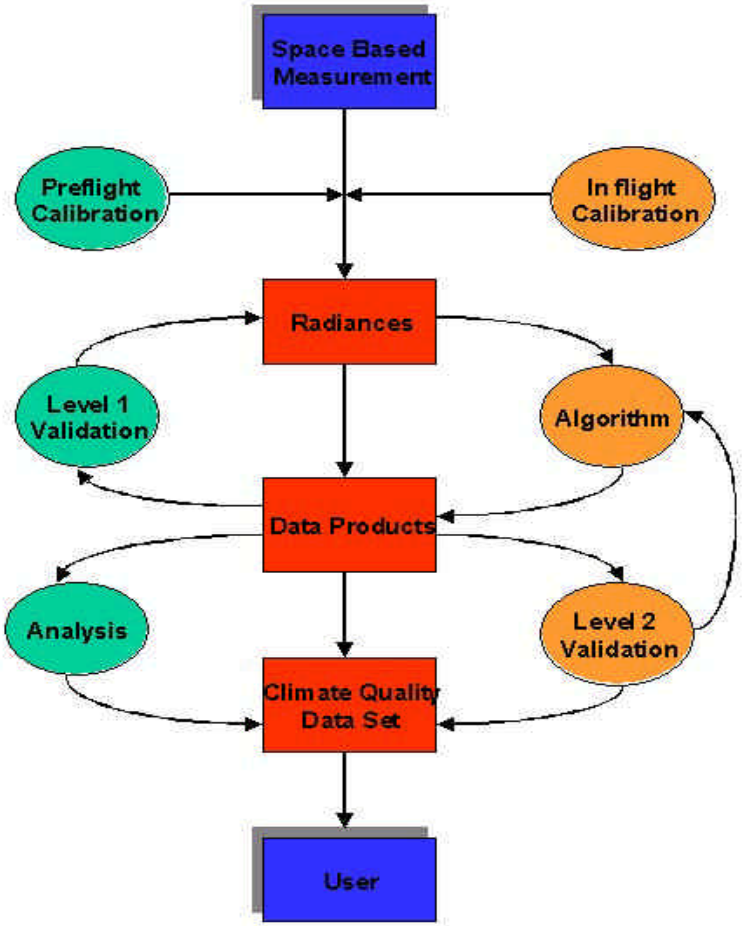
WMO #140 chapter dedicated to Calibration/Validation

- **End-to-end cal/val:**
  - National standards and procedures for pre-launch calibration
  - Pre launch with calibration scientist and user involvement
  - Validation criteria (coincidences, etc)
  - Data quality control and archiving for easy access by user
  - Post launch validation of Level 1 as well as Level 2 products
  - Algorithm and RTM comparisons and improvements
  - Science analysis with CTM and DA

- **General:**
  - Coordinated validation operations to enhance science and minimize gaps
  - Archival of validation data
  - Iterative process requires reprocessing
  - Space agency commitment for support for ground networks



End-to-End Cal/Val



WMO/GAW #140, Strategy for Integrating Satellite and Ground Based Observations of Ozone

Validation and data analysis is an iterative process

1. Prelaunch, inflight calibration, and Level 1 validation checks instrument sensitivity changes.

2. Level 2 comparisons and data analysis with chemical transport models and data assimilation validates geophysical data products.

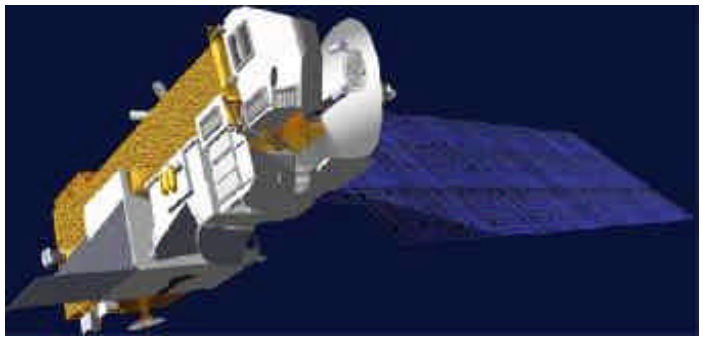
3. Long term validation for climate research requires reprocessing by reiterating through steps 1 and 2.

ACSG Goals

- **Insure accurate and traceable calibration of remotely sensed atmospheric chemistry radiance data and validation of higher level products, for application to atmospheric chemistry and climate research, from Earth Observing satellite missions.**

- **Support the calibration/validation recommendations of WMO/CEOS #140.**

- **21 instruments on 14 missions for observing atmospheric chemistry will be flown by 2015.**



Atmospheric Chemistry Satellite Timeline (21 instruments, 14 Missions)

Year

INSTRUMENT	MISSION	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TOMS	Earth Probe																
SAGE III	Meteor-3M																
→	ISS																
SMILES	ISS																
POAM	SPOT-4																
SBUV	Nimbus-7																
SBUV/2	NOAA-11																
	NOAA-14																
	NOAA-16																
	NOAA-17																
	NOAA-N																
	NOAA-N[1]																
ILAS-2	ADEOS-2																
SOFIS	GCOM-A1																
SWIFT	GCOM-A1																
OSIRIS	ODIN																
Microwave	ODIN																
ACE	SciSAT																
ERS-2	GOME																
GOMOS	ENVISAT																
SCIAMACHY	ENVISAT																
MIPAS	ENVISAT																
HIRDLS	EOS Aura																
MLS	EOS Aura																
TES	EOS Aura																
OMI	EOS Aura																
GOME-2	METOP																
OMPS	NPP																
OMPS	NPOESS																

ACSG Objectives-1

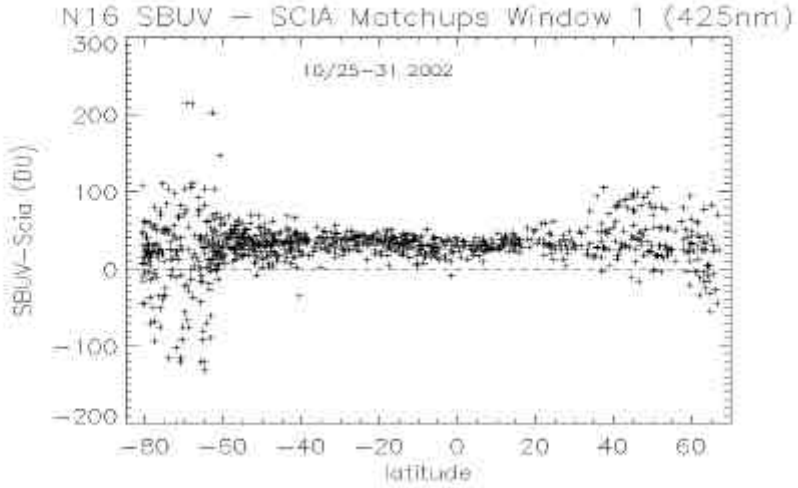
- **Promote international collaboration and technical exchange to ensure sufficient use and maintenance of calibration/validation resources required for atmospheric chemistry missions.**
- **Verify accurate scientific products encouraging an end-to-end approach to the calibration and validation of Level 1 and Level 2 data products and subsequent re-calibration and reprocessing.**
- **Ensure that validation sensors are calibrated to traceable national standards with documented statements of accuracy and repeatability**
- **Encourage interaction between calibration scientists and data users to enable a better understanding of data uncertainties and user requirements.**

ACSG Objectives-2

- **Develop comprehensive data validation methods that employ ground, aircraft, balloon, and satellite measurements and data assimilation with chemical transport models.**

- **Recommend a network of validation sites and to encourage continuous observation and quality control of data through the use of standard procedures and inter-comparisons.**

- **Specify a comprehensive, consistent and quality- controlled multi-mission validation data base in an accepted format employing user friendly tools.**



ACSG - Status

- **Participants (15 members):**
  - **CNES, DLR, ESA, NASDA, NASA, KNMI, MSC, NOAA, (Eumetsat), IASB, EC, WMO, Un's. of Bremen, Toronto, Waterloo, NYU**

- **Meetings:**
  - **Past: May '02 (Ottawa), December '02 (Frascati), July '03 (Toulouse)**
  - **Next: May '04 (Frascati)**

- **Reports: NDSC Steering meeting (Toronto, Sept 2002)**
  NASA Headquarters (Washington DC, Jan '03)
  IGOS Atmospheric Chemistry theme (Geneva, Jan '03)
  IGOS " " " (Nordvijk, June '03)

- **Projects:**
  - **Cross mission (Envisat-Aura) AC Validation Data Center (*Approved*)**
  - **Continuity of Envisat validation assets for Aura validation (*Negotiations*)**
  - **Support from space agencies. Four projects submitted, two carried forward, one supported**
    - **Ground station cross calibration (*Approved*)**
    - **New sites for under- sampled locations (e.g. Northern tropics, Southern hemisphere (*Proposed*)**
  - **Collaboration on future operational missions: Metop, NPOESS, (*No Progress*)**

ACSG Activities (1)

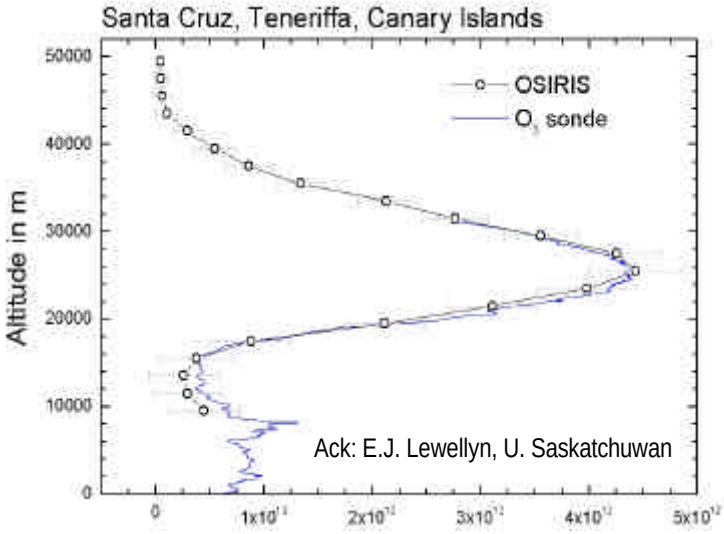
- **SOLVE-2 (Winter 2002/2003)**
  - **NASA, EC, and ESA support of SAGE-III and Envisat, (OSIRIS, ILAS-II)**
  - **DC-8, ER-2, balloons, and VINTERSOL (EC)**

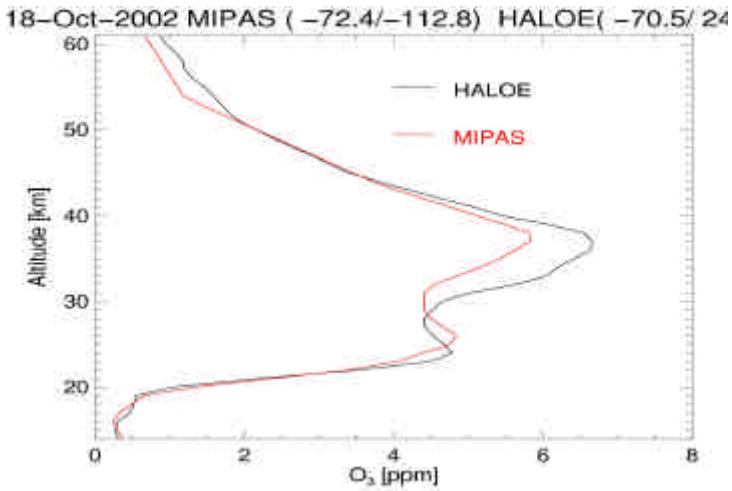
- **VINTERSOL**
  - **EC funded comprehensive science/validation aircraft and balloon campaigns**
  - **Arctic, spring 2003; tropics 2003 & 2004, Antarctic 2003**
  - **Available for Envisat, POAM, GOME, ODIN, ILAS-II**

ACSG Activities (2)

- **OSIRIS validation – Unfunded validation program, relies on existing capabilities through coordination (O_3, NO_2, OClO, and aerosols)**
  - **Two instruments: UV/VIS/NIR and SMR**
  - **Initial campaigns shows good performance**
  - **Comparisons with balloon sondes and POAM**

- **Envisat Validation – Major effort coordinated by ESA (ACVT)**
  - **Major delay in ground segment**
  - **MIPAS in good shape**
  - **GOMOS still has algorithm problems**
  - **SCIAMACHY major delays in calibration and algorithm updates**
  - **CNES plays major role with balloons**
  - **Science teams concerned by inadequate support to maintain validation and reprocessing**





ACSG Activities (3)

- **CNES – Science driven but provides validation**
  - **VINTERSOL, ACVT, ILAS-II, SOLVE**
  - **Balloons, ground based, and aircraft**
  - **Data assimilation**

- **ACE – Launched 2004, no funded validation campaigns**
  - **Relies on existing validation infrastructure and collaboration-volunteer validation team in place**
  - **Ground based and satellite intercomparisons**

- **ADEOS/ILAS-II – Launched December 2002**
  - **Funded core experiments**
  - **Cooperative experiments and data exchange**

- **Ground based measurements – WMO/GAW**
  - **WMO sponsored GAW is a major ground based activity for ozone and other atmospheric constituents**
  - **Maintains quality control**
  - **Supports underdeveloped sites**
  - **Eureka shutdown (*CEOS support requested*)**
  - **WOUDC (Canada data center) is part of GAW**

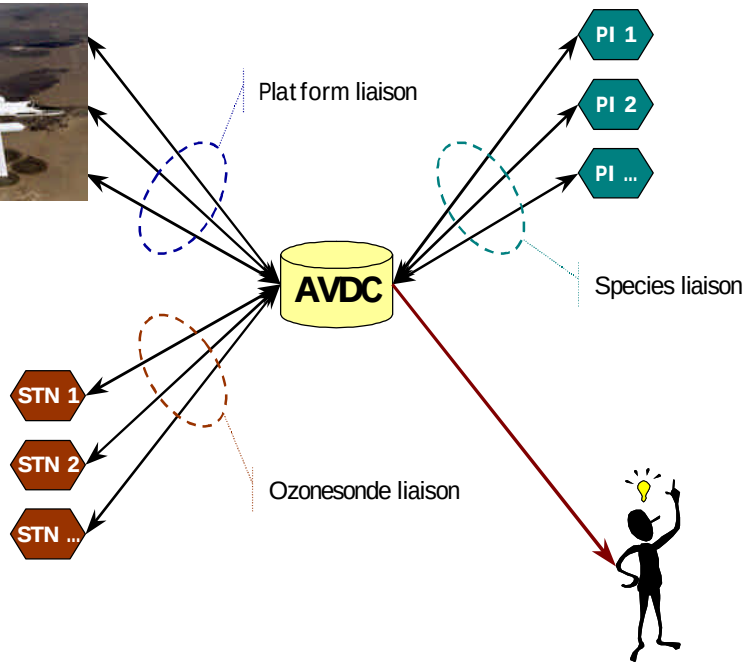
ACSG Activities (4)

Aura validation- Full NASA funding with collaboration expected

- Begins after commission phase (+ 6 months)
- Requirements established
- Implementation studies underway
- Two AO's: 1) New instrumentation - selected, 2) Implementation – not released
- 11 aircraft campaigns from 2004 to 2008
  - INTEX – Intercontinental transport off US East and West coasts
  - TC^3 – Tropical Composition & Climate Coupling (TTL)
- Emphasis on troposphere
- Balloons – Kiruna and Ft Collins, Texas
- Networks: WOUDC, NDSC, etc.
- Data Center modeled after Envisat/NILU

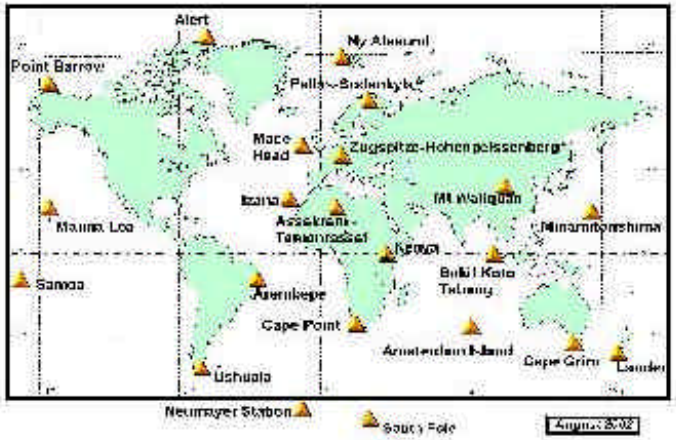
Aura Validation Data Center

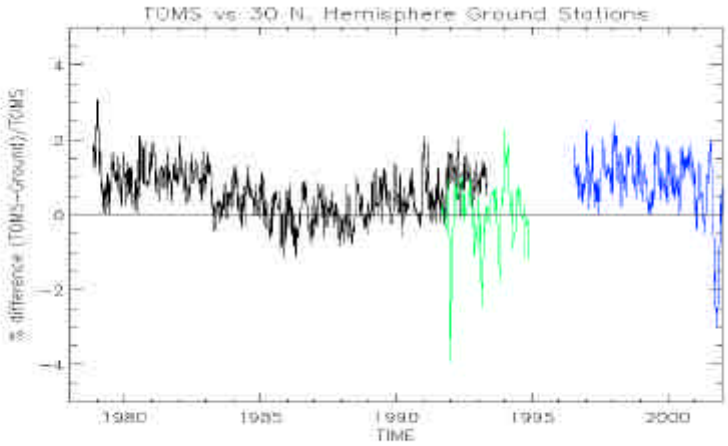
- Modeled after Envisat Cal/Val – NILU
  - Uniform data format
  - Web based input and accessibility
  - Conversion support tools
- Preliminary approval by NASA Hq
- Provides data source for smaller chemistry missions (ACE, ILAS-II
- Liaison provides “scientific” quality control
  - Central contact point
  - Data quality control and homogeneity
  - Feedback between Val PI/Mission
- Mission support: Field campaign deployment, orbit prediction, auxiliary data



Dobson Intercomparison

- Funds provided by NOAA/NESDIS will support two campaigns.
- Continue regular and regional intercomparisons
- Organized by NOAA/CMDL and the WMO
- 2003 includes: Argentina, Brazil, Peru, and Cuba
- 2004 includes: Egypt, Nigeria, Kenya, South Africa, Seychelles
- Dobson network plays a critical and continuing role for validating satellite ozone data





GOME-2 and OMPS Cal/Val

- Plans are being developed independently
- ACSG members have active role in reviewing Cal/Val plans
- Rely on established ground based networks
- Neither Eumetsat or IPO/NGST presently commit resources to insure availability validation resources.
- Both plans have comprehensive in-orbit calibration evaluation relying on heritage capabilities
- Cal/Val data centers are being considered for each
- GOME-2 has provision for cal/val analysis and reprocessing (both level 1 and 2) but are conducted by separate entities.
- OMPS has not yet defined provisions for reprocessing
- OMPS cal/val implementation is shared by IPO and NGST; details are TBD
- *No consideration be given to collaborative implementation*

IGOS-P Atmospheric Chemistry Theme (IGACO)

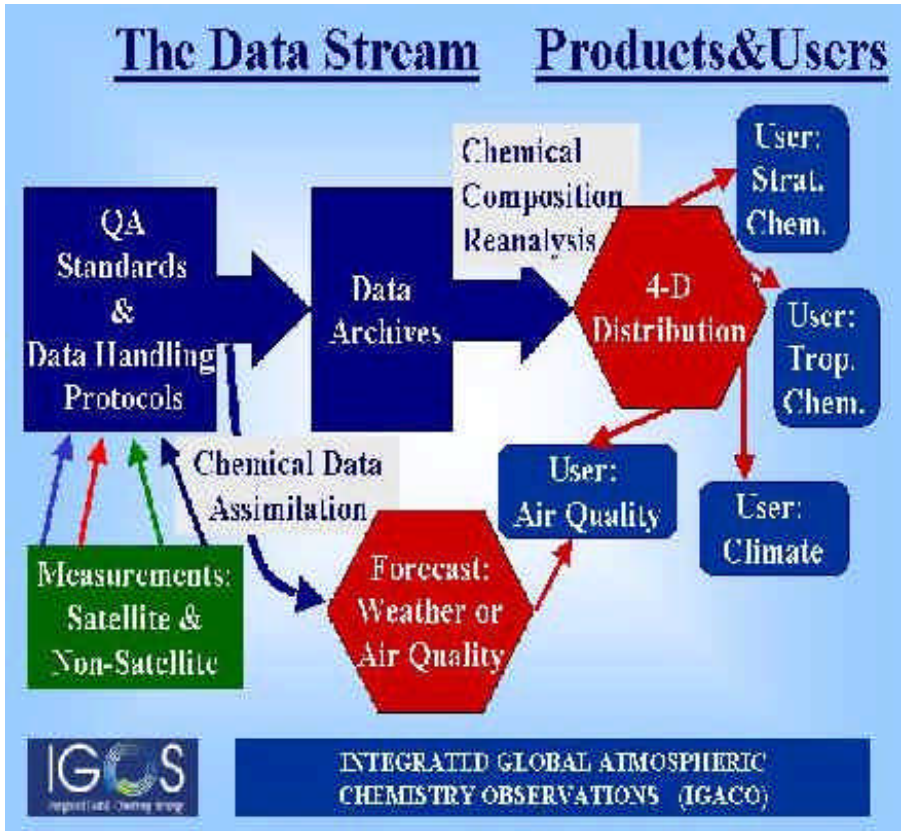
Integrated Global Atmospheric Chemistry Observations

- **Focus on science requirements for atmospheric chemistry observations and demonstrate the need for integration of ground and space components**
- **Progress report to CEOS/SIT June 2003**
- **Theme completed November 2003**
- **Submitted to IGOS in December 2003**

IGOS Integrated Global Observing Strategy

IGACO Theme - Outline

- **Strategy for deploying an Integrated Global Atmospheric Chemistry Observation System (IGACO)**
- **Outlines science issues:**
  - **Ozone change**
  - **Air quality**
  - **Climate**
- **Measurement requirements**
  - **Constituents**
  - **Accuracy**
  - **Spatial and temporal resolution**
- **Observing system: Combine**
  - **Ground based**
  - **Aircraft: routine**
  - **Satellite: varying orbits**
  - **Validation**
- **Models and data accessibility**
- **Recommendations**



IGACO Recommendations - Summary

- **Establish minimum satellite, ground and aircraft flight programs, with modeling to produce integrated observing system.**
- **Develop algorithms to produce accurate chemical species profiles from the boundary layer to the stratosphere**
- **Develop and improve present modeling and assimilation techniques to make an integrated global observing system possible**
- **Establish end-to-end quality control and validation to ensure the data are reliable for their intended purpose**
- **Harmonize and data collection and storage to ensure readily accessible for modeling, assimilation, forecasting and for policy development.**

IGOS Integrated Global Observing Strategy

Action Items from ACSG-2, 3 (sample)

- Continue to pursue CEOS support to appeal to agencies for sustained ground station support. At the present time recommendations are being bounced between CEOS and IGOS
- Refine recommendation for aerosol stations with interested parties at Goddard and WMO.
- Consider universal policy for publication, referencing and citation of validation data.
- Encourage participant to ACSG from Eumetsat
- Begin coordination of validation planning between Metop and NPOESS
- Seek continued support for validation of Envisat chemistry observations
- Coordinate Aura and Envisat validation activities and consider ACE and ILAS-II
- Seek support to re-open Eureka ground station in Canada

Closure of Eureka ASTRO station

Arctic Stratospheric Ozone Observatory

- State-of-the-art equipped station for atmospheric chemistry observations
- Unique capability for Atmospheric Chemistry mission Cal/Val
- Operated by Environment Canada since 1993
- Month balled (closed) in 2002 for financial reasons
- Dismantling is planned for 2004
- ***<u>Request strong and urgent recommendation to re-open by WGCV to CEOS</u>***

Instruments to be installed if reopened

Polar Environment Atmospheric Research Laboratory

Equipment	Composition	Dynamics	Clouds & Aerosols
Rayleigh/Mie/Raman Lidar (T. Duck)	Tropospheric H2O	Gravity waves	Clouds, aerosol extinction, density, size distribution
Solid-state Ozone Lidar (J. Whiteway)	Tropospheric & lower strat. O3		
VHF Radar (W. Hocking)		Turbulence and winds, 0.4-15 km	Polar mesosphere summer echoes (PMSE)
Millimeter Cloud Radar (D. Hudak)		Vertical velocities	Cloud reflectivities
Spectral Airglow Temperature Imager Interferometer (G. Shepherd)		Winds 87-94 km, gravity waves	
All-sky Imager (W. Ward, S. Melo)		OH airglow	
Michelson Wind Interferometer (W. Ward, G. Shepherd)		Winds 87-94 km, gravity waves	
Fourier Transform IR Spectrometer (K. Strong)	Many constituents		Solar absorption in infrared
UV-visible Grating Spectrometer (K. Strong)	O3, NO2, BrO, elevated OClO		
Atmospheric Emitted Radiance Interferometer (K. Strong)	H2O		Downwelling spectral radiance
Photometer Package (N. O'Neill)	H2O column		Aerosol optical depth
Aerosol Mass Spectrometer (J. Sloan)			Ground level aerosol
Brewer Spectrometer (T. McElroy)	O3, SO2		
Microwave Radiometers (K. Walker, P. Bernath)	H2O, ClO, and O3 profiles	Temperature profiles	
GPS Receiver (R. Langley)	Precipitable water		
Near IR Photometer (T. Llewellyn, D. Degenstein)	Mesospheric O3		

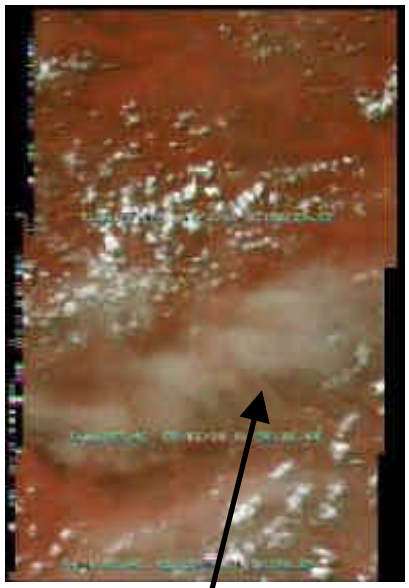
Status of efforts to re-establish facility

- **Support for temporary reopening by Canadian Foundation for Climate and Atmospheric Science (CFAS) in early 2003**
- **Consortium of five Canadian Universities proposal to the Canada Foundation for Innovation to re-equip Eureka as part of CANDAC**
- **Support declined by Natural Science and Engineering Research Council because of funding limitations**
- **Proposal to CFAS for operations submitted this year**
- **Canadian Space Agency will provide funding for maintenance to serve cal/val requirements for its chemistry missions**
- ***Need CEOS recommendation for support of facility to potential funding agencies***

Validation of aerosol characteristics

- Optical thickness
- Single scattering albedo
- Absorption coefficients
- Height distribution
- Size distribution
- Angstrom exponent

- **This maybe too much for ACSG**
- **Possible new subgroup for aerosols**



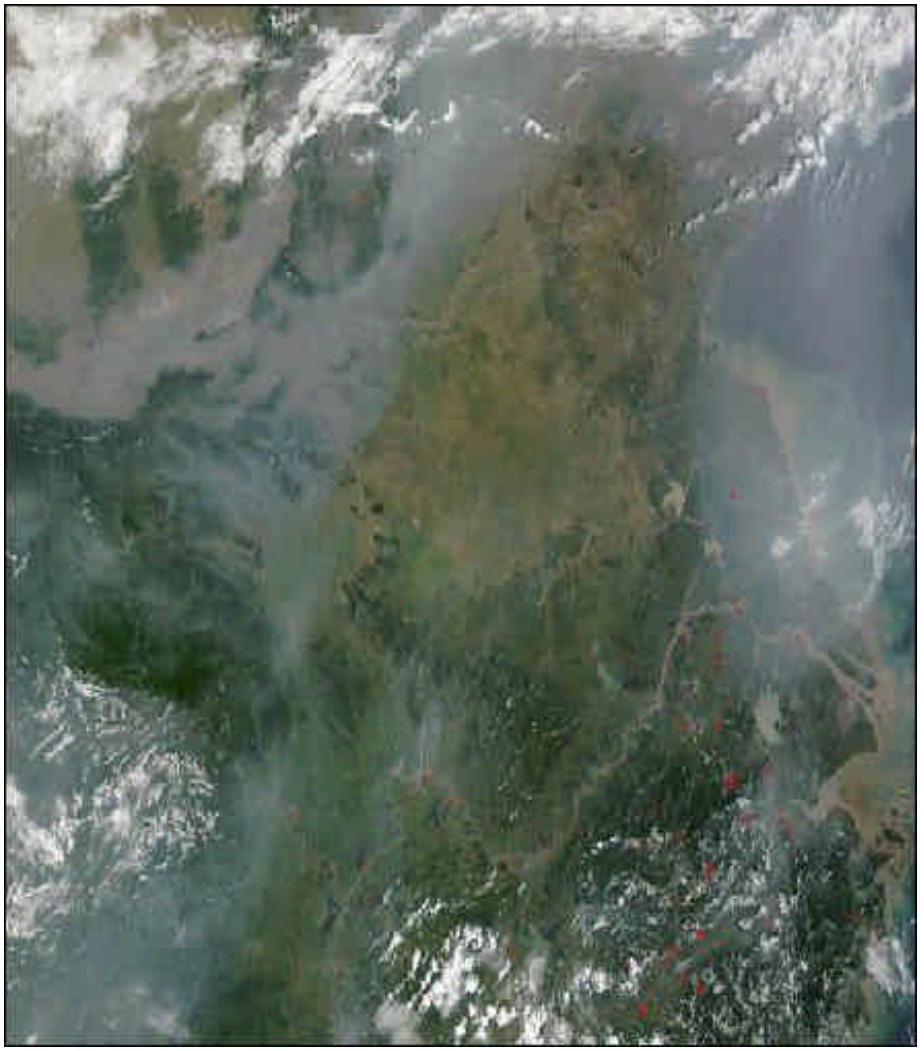
Burning in Brazil
(*Image taken from Space Shuttle Columbia*)

TOMS
SeaWIFS
MODIS
MISR
MERIS
SCIAMACHY
ICESat

OMI
POLDER
Calipso
Parasol
GOME-2
VIIRS
OMPS

Asia dust and smoke

- **Satellite instruments: MODIS, MISR, MERIS, SeaWIFS, TOMS, AVHRR**
- **Validation Instruments**
  - **Cimel**
  - **Micro pulse lidar**
  - **Sun photometer**
  - **Shadow band radiometer**
- **Networks**
  - **Aeronet**
  - **ARM**
- **Aircraft campaigns**
  - **CRYSTAL, TARFOX, SAFARI**



ACSG Recommendations to CEOS
- Summary-

- **Stable funding needed for ground based network to continue quality and timely validation data.**
- **CEOS letter of Support for Eureka ground station**
- **ESA and national partners provide resources for long term satellite data validation (possible EC participation)**
- **Better phasing of satellite data processing to include algorithm implementation during commissioning phase followed by validation phase.**
- **Coordination of validation activities for next generation operational systems: Metop and NPOESS**
- **Need Eumetsat representative on ACSG**
- **Include aerosol validation in ACSG or form new subgroup**