World Meteorological Organization

Working together in weather, climate and water

Global Atmosphere Watch (GAW) Applications

Alexander Baklanov

and Aerosol and NRT Application SAGs (see on slides),

Atmospheric Research & Environment (ARE) Branch

Research Department (RES), WMO, Geneva

VAAC "Best Practice" Workshop 2016

Buenos Aires, Argentina

25-27 April 2016

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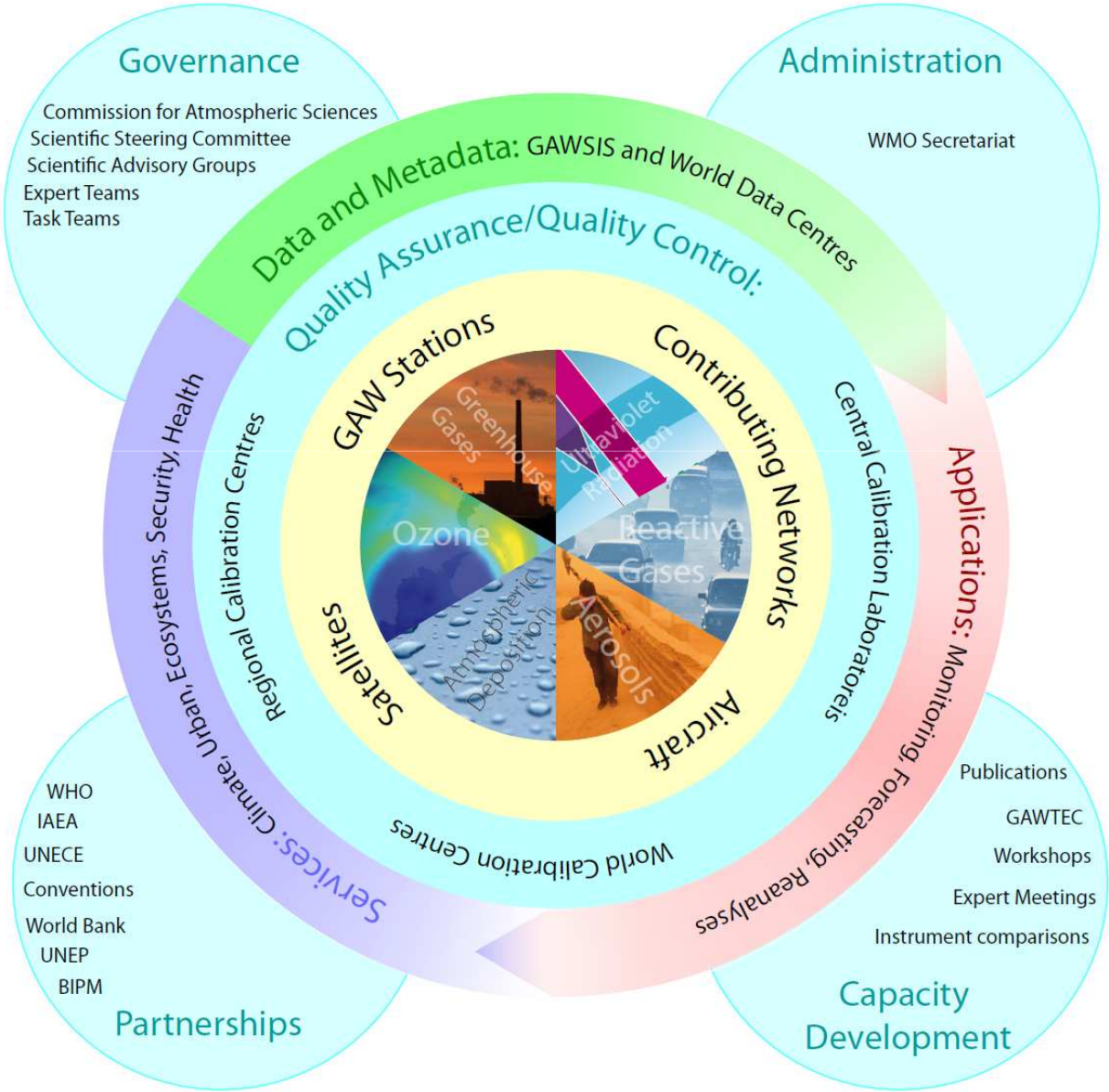
THE GAW MISSION

- Systematic long-term monitoring of atmospheric chemical and physical parameters globally
- Analysis and assessment
- **Development of predictive capability**

(GURME and Sand and Dust Storm Warning System)

and now for chemical weather (e.g. incl. **volcanic ash**)



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Overview of the Structure of GAW

- More than 100 countries have registered **more than 800 stations** with the GAW Station Information System (**GAWSIS**). Established 26 years ago.
- Various **GAW expert groups and central facilities** exist under the oversight of the WMO Commission for Atmospheric Sciences (CAS) and its Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee (EPAC SSC).
- **8 Scientific Advisory Groups** (SAGs) to organise and co-ordinate GAW activities by parameter and application, and the Expert Team on World Data Centres (ET-WDC).
- 4 Quality Assurance/Science Activity Centres (QA/SACs) perform network-wide **data quality and science-related functions**.
- 35 Central Calibration Laboratories (CCLs) and World and Regional **Calibration Centres** (WCCs, RCCs) maintain calibration standards and provide instrument calibrations and **training** to the stations.
- **6 World Data Centres** archive the observational data and metadata, which are integrated by the GAW Station Information System (GAWSIS).
- **GAW Training** (GAWTEC): More than 270 persons trained from 58 countries

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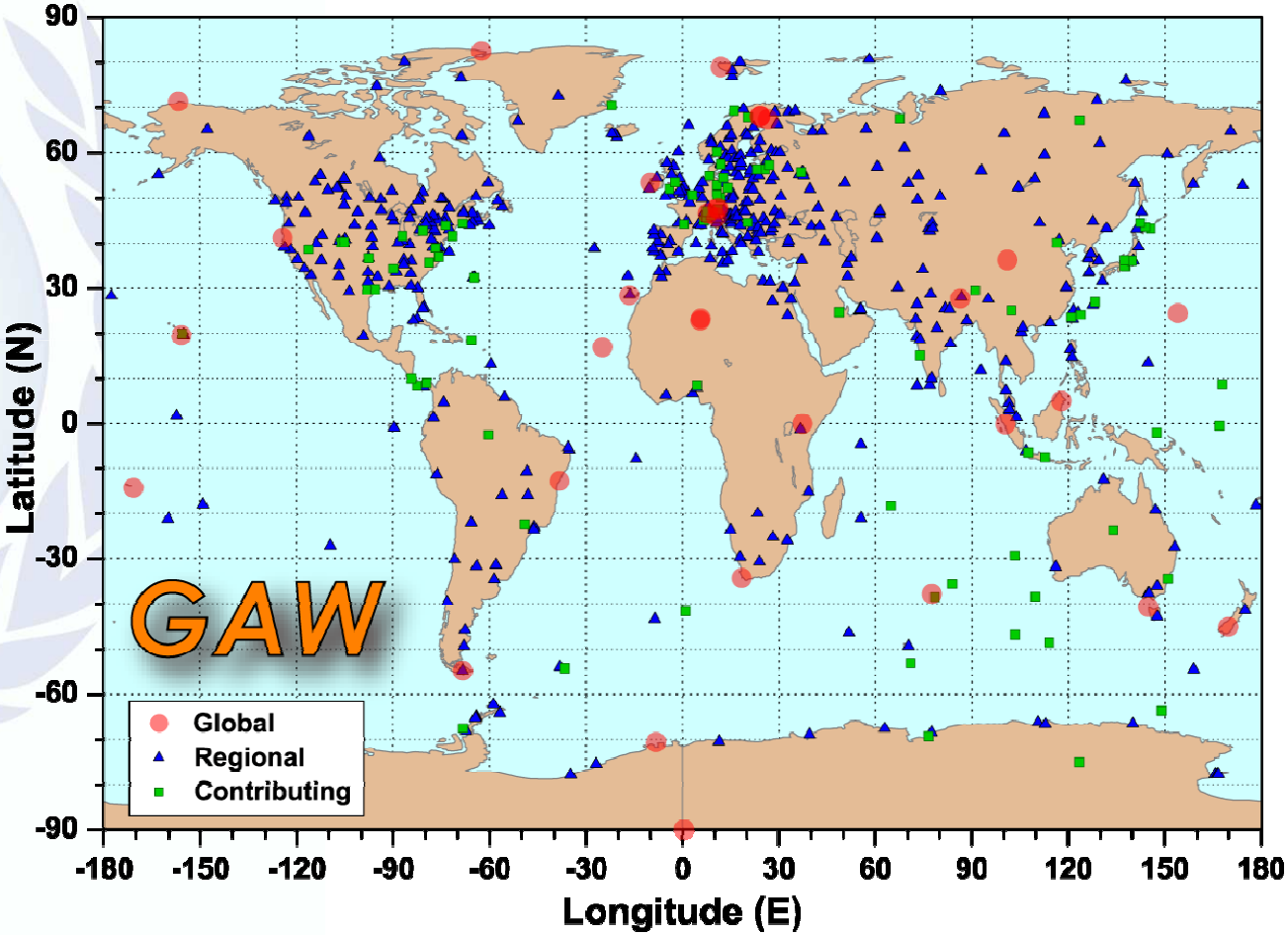
GAW stations network

Versatile station information is available through the GAW Station Information System GAWSIS (http://gaw.empa.ch/gawsis/).



Aircraft and satellite measurements also contribute to the observations

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GAW Aerosol Variables - Continuous

- Column and profile
  - Multi-wavelength aerosol optical depth (AOD)
  - Vertical distribution of aerosol backscattering and extinction
- Chemical (in two size fractions)
  - Mass and major chemical components
- Optical coefficients at various wavelengths
  - Light scattering and hemispheric backscattering
  - Light absorption
- Physical
  - Number size distribution and total concentration
  - Cloud condensation nuclei number concentration at various super-saturations

Aerosol SAG Chair: Paolo Laj, CNRS, France

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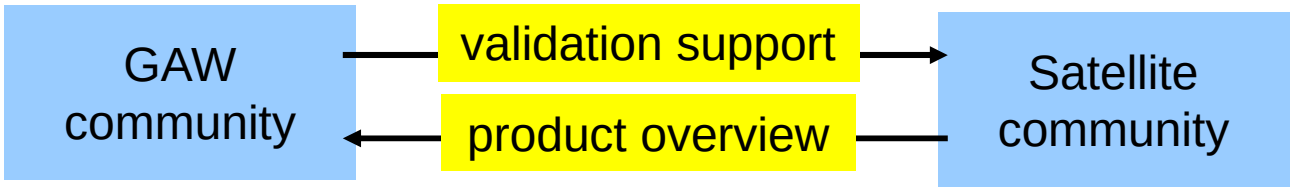
World Data Center for Remote Sensing of the Atmosphere

Satellite “one stop shop” for aerosols

- Support easier access to satellite datasets by the GAW community
- Promote GAW datasets for satellite product validation

Support from WDC-RSAT for WMO-GAW

- Link different GAW-relevant data sets with each other and with models
- Cooperate with other international actors on interoperability (NASA, CNES)
- Assign ‘Digital Object Identifiers’ (DOI) to data sets
- Develop techniques to provide stations with satellite-based data and information products
- Develop computing-on-demand applications
- Develop and test strategies and techniques to validate satellite data sets



wdc
for remote sensing of the atmosphere

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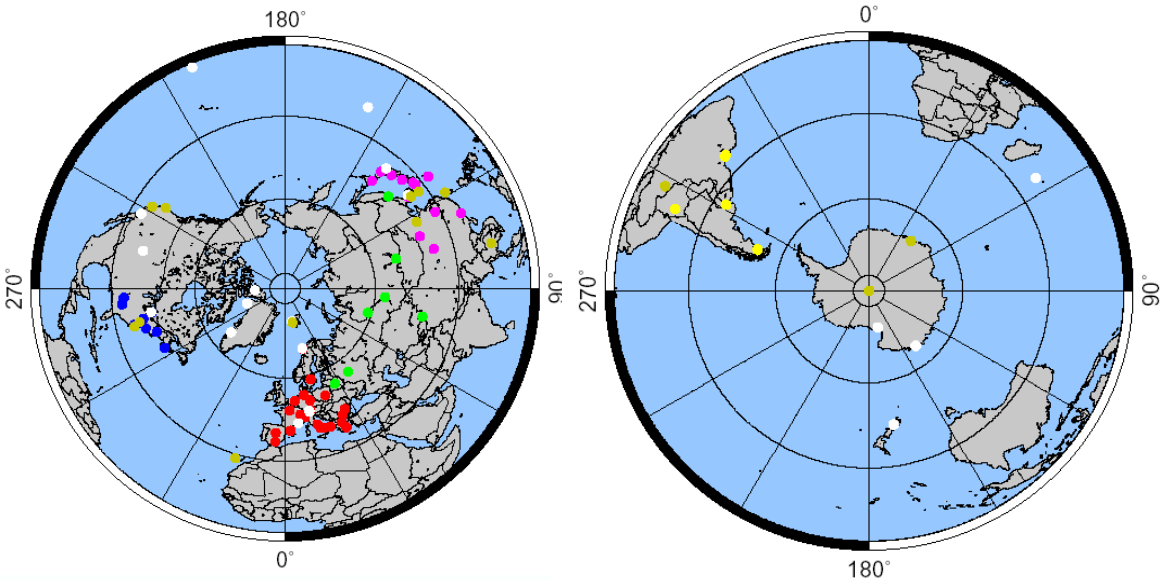
GAW Aerosol Lidar Observation Network

GALION is organized as a Network of Networks, coordinating

- American Lidar Network (ALINE/LALINET), Latin America (●)
- Asian Dust and Aerosol Lidar Observation Network (AD-Net), East Asia (●)
- CIS-LINET, Commonwealth of Independent States (Belarus, Russia and Kyrgyz Republic) LIdar NETwork (●)
- Canadian Operational Research Aerosol Lidar Network (CORALNet), Canada (●)
- European Aerosol Research LIdar NETwork (EARLINET), Europe (●)
- Network for the Detection of Atmospheric Composition Change (NDACC), Global Stratosphere (○)
- CREST, Eastern North America (●)
- MicroPulse Lidar NETwork (MPLNET), Global (●)



Applications

- Climate research and assessment
- Impact on radiation
- Air quality
- Plumes from special events
- Support for spaceborne observations

GALION Co-chairs: Gelsomina Pappalardo, CNR & Ellsworth Judd Welton, NASA

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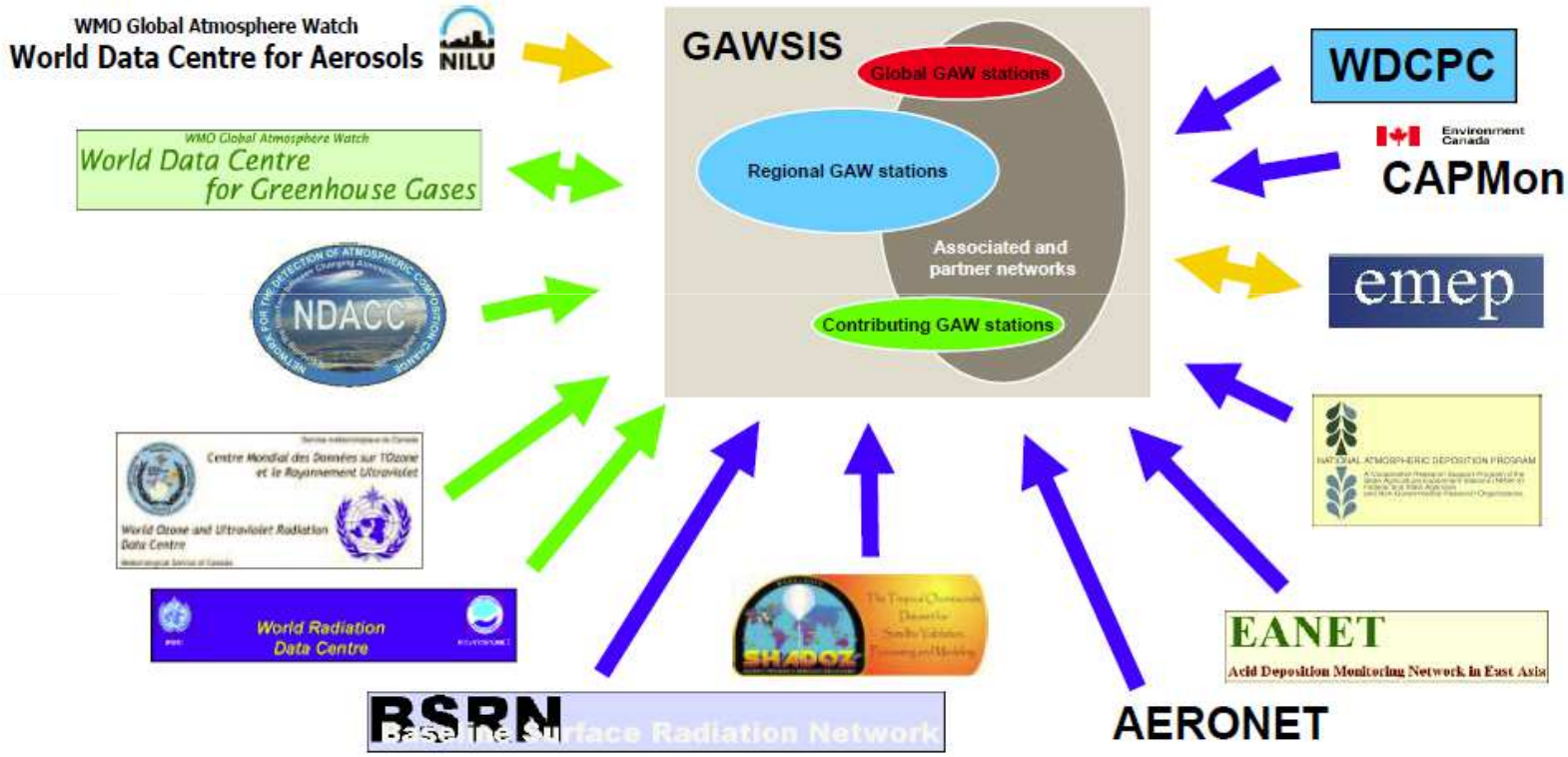
GAWSIS – Metadata Integration for WIS (WMO Information System)



ACTRiS

SEVENTH FRAMEWORK PROGRAMME

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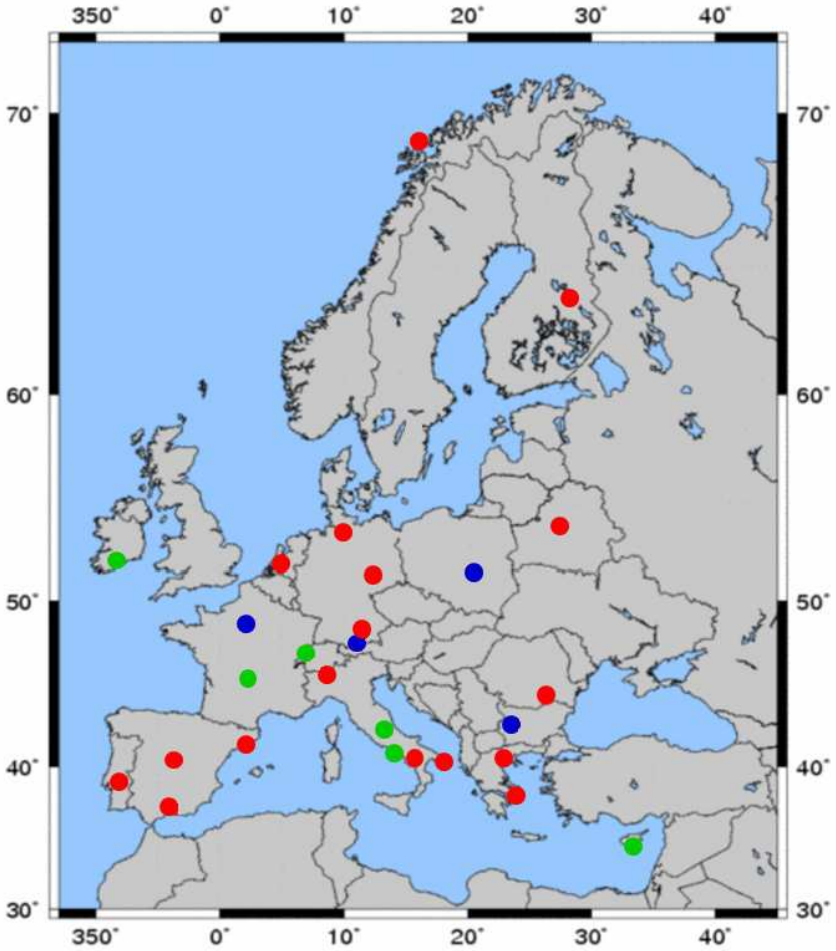
EARLINET (European Aerosol Research LIdar NETwork)



www.earlinet.org

- since 2000
- 27 lidar stations

-17 multiwavelength Raman lidar stations

-6 Raman lidar stations

- 4 single backscatter lidar stations

- comprehensive, quantitative, and statistically significant data base
- Continental and long-term scale

EARLINET *FP5* EARLINET-ASOS Sixth Framework Programme ACTRiS ACTRiS 2

2000 2006 2011 2015 2019

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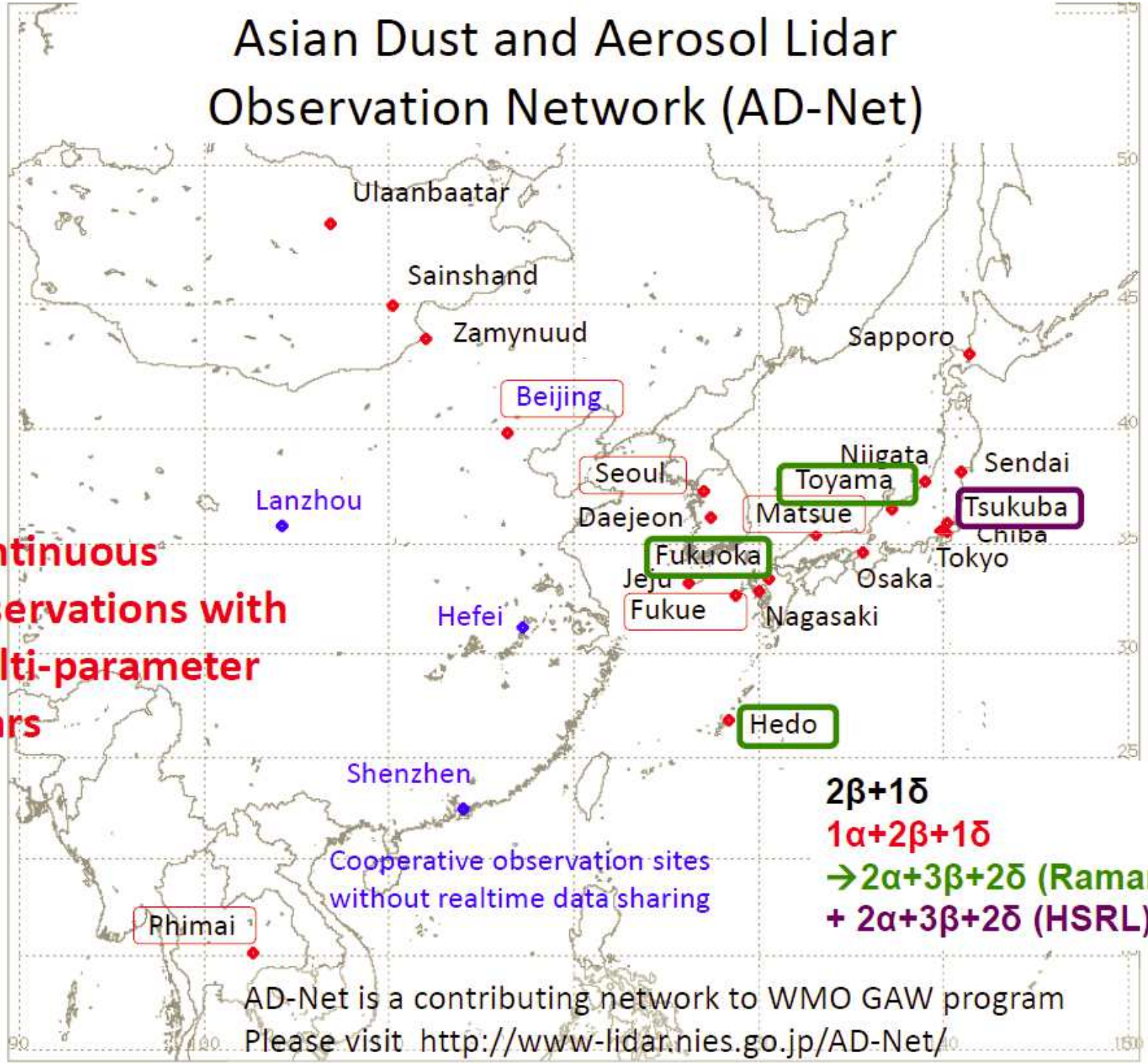
Asian Dust and Aerosol Lidar Observation Network (AD-Net)



Continuous observations with multi-parameter lidars

Cooperative observation sites without realtime data sharing

2β+1δ
1α+2β+1δ
→2α+3β+2δ (Raman)*
+ 2α+3β+2δ (HSRL)

AD-Net is a contributing network to WMO GAW program
Please visit http://www-lidar.nies.go.jp/AD-Net/

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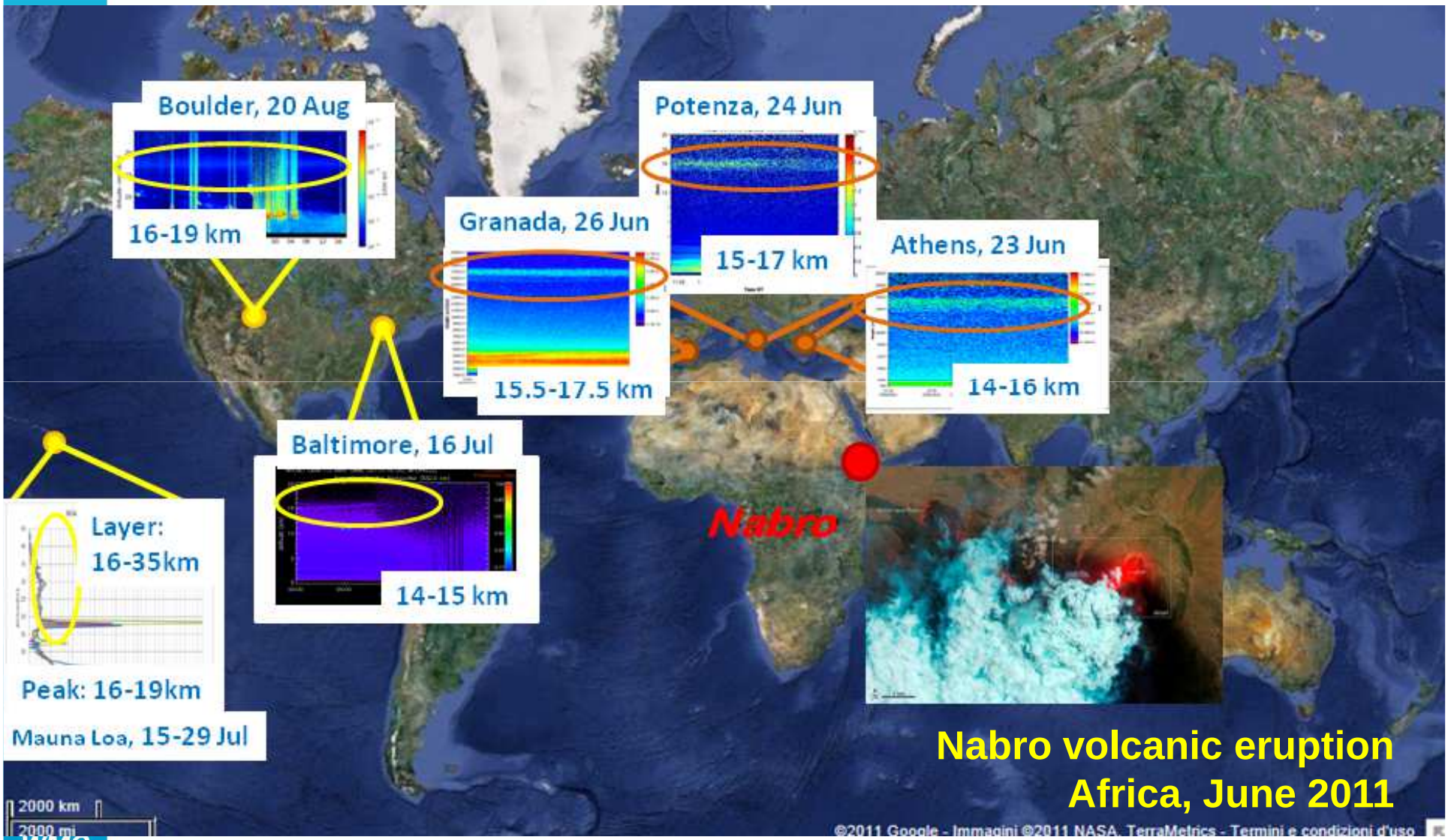
GALION Observations of Volcanic Aerosol



Nabro volcanic eruption Africa, June 2011

Sawamura et al., ERL 2012

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Volcanic eruptions

Measurements based on alerting system.

Monitored eruptions:

- ✓ **Etna 2001**
- ✓ **Etna 2002**
- ✓ **North Pacific ring (2008-2010)**
- ✓ **Eyjafjallajökull 2010**
- ✓ **Grimsvotn 2011**
- ✓ **Nabro 2011**

Relational database about identified volcanic layers is freely available at:

www.earlinet.org

Pappalardo et al., ACP 2013

Courtesy of Gelsomina Pappalardo

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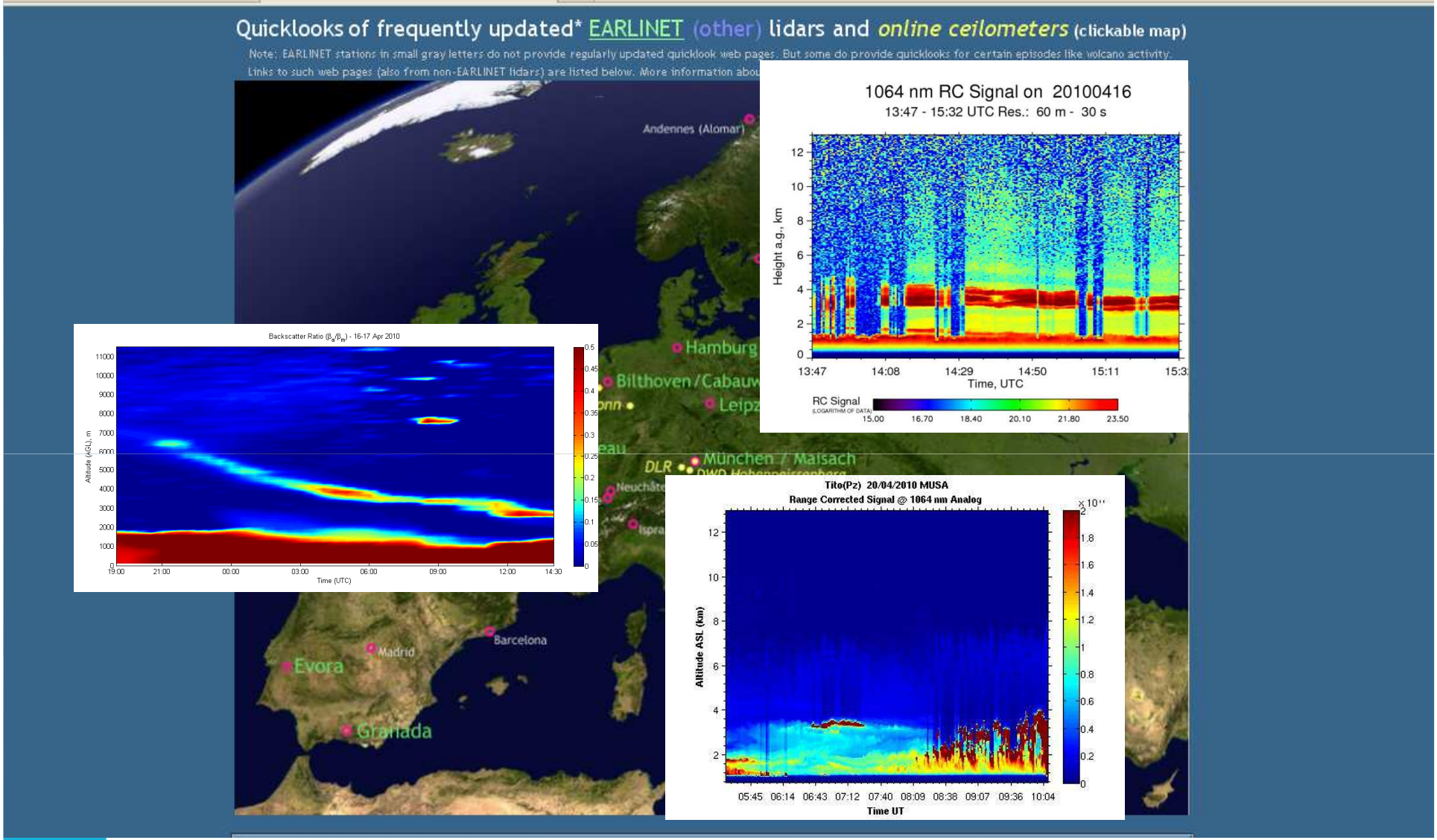
EARLINET for E15: NRT quicklook



Quicklook made available almost in near real time on the EARLINET website

Courtesy of Gelsomina Pappalardo

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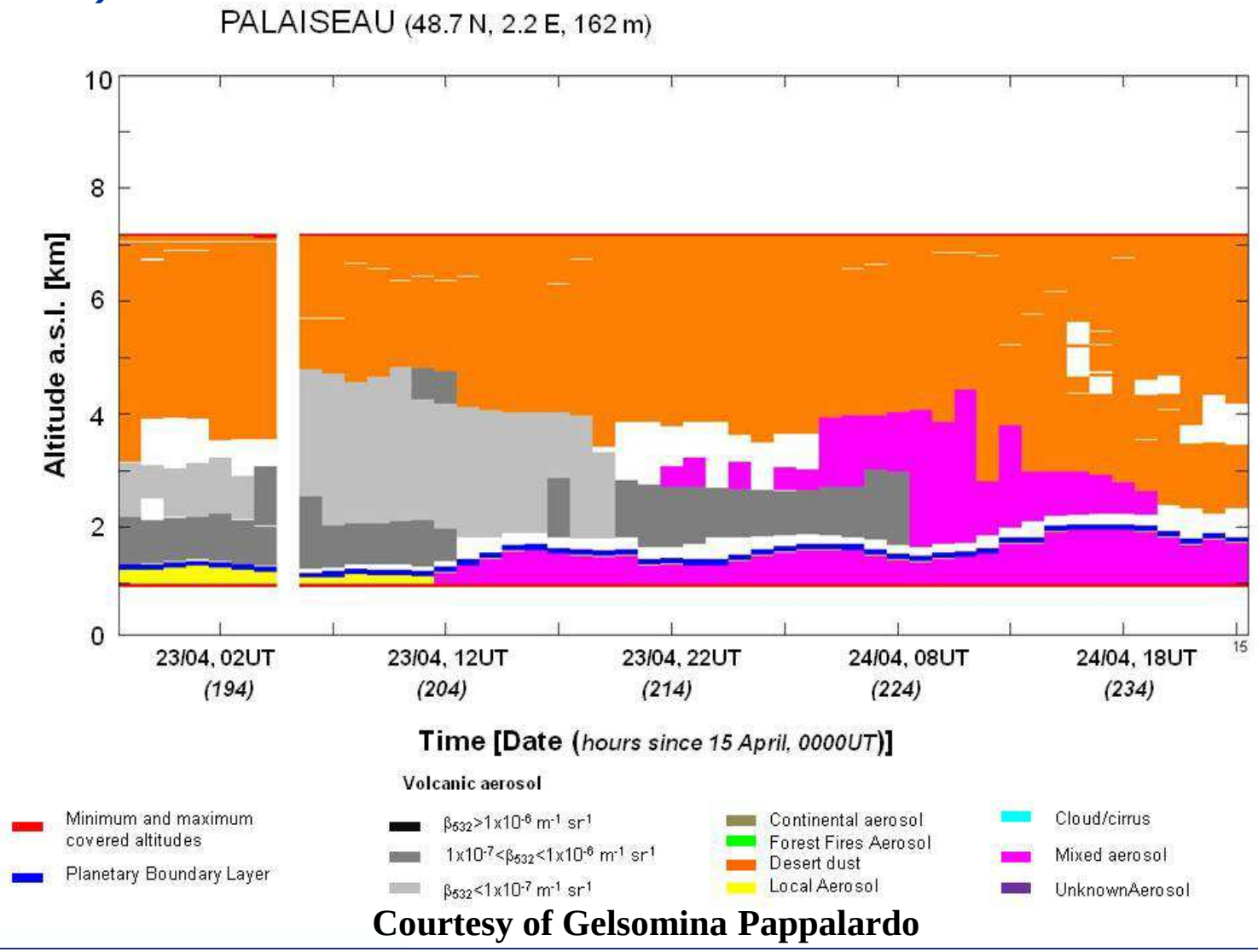
Volcanic mask

A methodology for volcanic mask has been developed (*Mona et al, ACP 2012*)

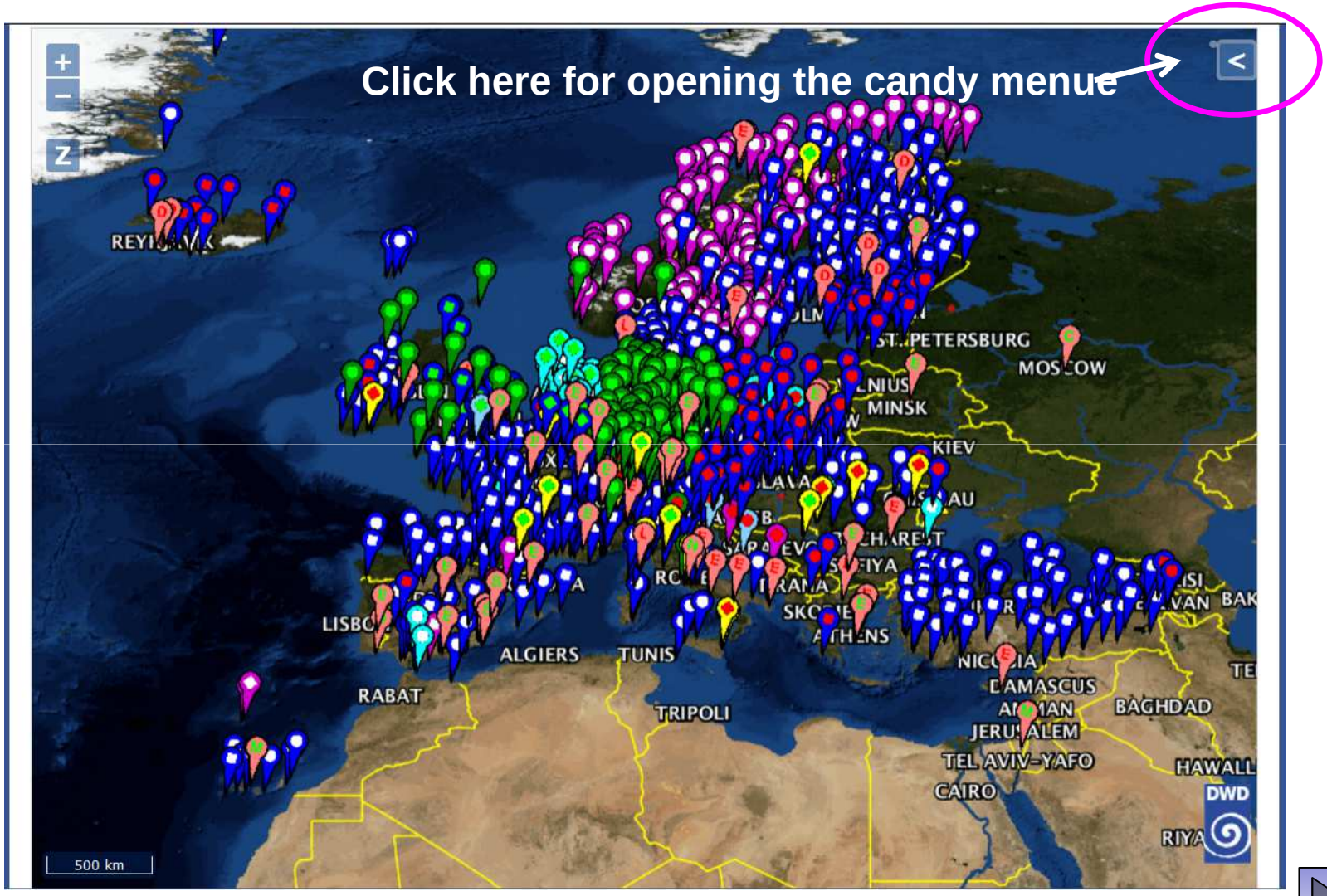
This methodology has been applied to the whole network (*Pappalardo et al., ACP 2013)*



Courtesy of Gelsomina Pappalardo

Ceilometer network – www.dwd.de/ceilomap

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



About 2180 Lidars und ceilometers globally (April 2016): 2016 ceilometers and 160 Lidars

Courtesy of Werner Thomas, DWD

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The way forward

Operational ground-based lidar networks are a fundamental component of an integrated observing system to be used in case of natural hazards

GALION/EARLINET stations could be used as "core sites" for the operational networks based on less advanced lidar instruments (including ceilometers).

For a better harmonization, a coalition of research and an operational/regulatory observational system is needed.

At European scale EARLINET is cooperating with other RIs and Met Services (EUMETNET).

Relevant role for model evaluation and data assimilation (including support to VAAC) and for the improvement of satellite retrievals

GALION, the GAW Aerosol Lidar Observation Network, at global scale: federated approach (improve interoperability among the contributing lidar networks in terms of data QA and data access).

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Courtesy of Gelsomina Pappalardo

EARLINET

WMO feasibility study toward a WMO intercomparison of volcanic ash observation tools

- In December 2014, the 13th meeting of the WMO-CIMO management group has nominated Météo-France in conducting a feasibility study about an inter-comparison of instruments for the detection of aerosols and volcanic ash.
- The management group and task team are established.
- This was initially focused on lidars and ceilometers. Since WMO-CIMO requested a widening of the scope: Space-based systems and in-situ measurements
- May 2016, WMO, Geneva: A meeting is arranged as a face-to-face and supplemented by webconf
- The goals will be to discuss about progress, difficulties and specific issues and to discuss further the issues
- The deliverable of the Task Team is the feasibility study requested by WMO-CIMO based on the LET report and on other documents (and) covering the perimeter required.

Courtesy of Florence Besson and Pablo Ristori

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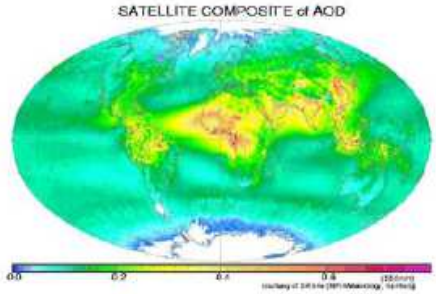
Integrated Global Aerosol Observing System

Global Products

RI for Calibration & Quality Assurance

Data Archival and/or Access Facilities (e.g. WDCA; WDC-RSAT)



Real-Time Data Delivery

Reanalysis

Satellites:
MODIS, CALIPSO, MISRMSG

Aircraft: IAGOS

Surface-based :
Remote sensing: AOD
Remote Sensing: GALION
In situ: PM, optical, etc
In situ: chemistry

Data Assimilation By Forecast Models (e.g. MACC; SDS-WAS etc.)

1. Data Uses/Applications
2. Air Quality Warnings
3. WMO SDS-WAS Assessments
4. WMO SDS-WAS Warnings
5. Aerosol Bulletins
6. Surface and air transport
7. Improved Weather Forecasts
8. Improved Climate Prediction

Observation Optimization

Air/Surface Exchange & Emissions

GAW Report No. 207

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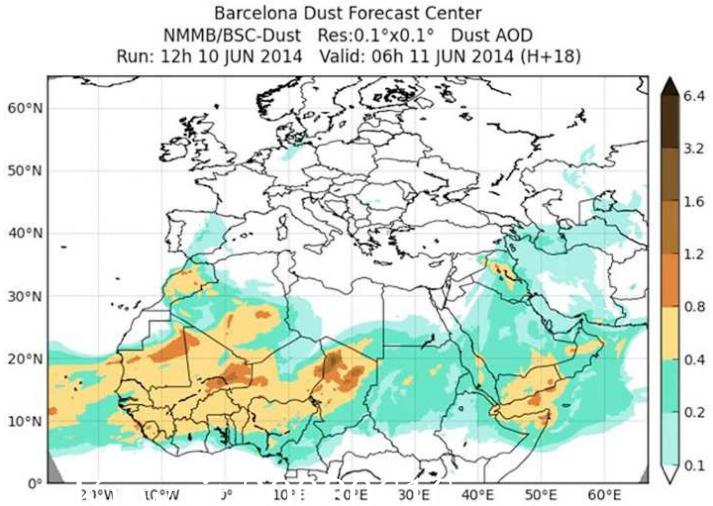
Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS)



❑Objectives:

- **To enhance the ability of countries to deliver:**
  - timely and quality forecasts of sand and dust storms,
  - observations of aerosols: sand and dust
  - information and knowledge to users

through

an international partnership of research and operational experts and users

❑**Global Coordination**: Three Regional Nodes (North Africa, Europe and Middle East Node, (East) Asian Node and Pan-American Node) need global coordination to exchange information and enhance collaboration. The West Asian Node will also be established in near future.

❑**First Operation Centre opened in Spain:** The Barcelona Dust Forecast Centre was inaugurated in 2014.

❑**Trust fund**: to ensure the global coordination activity on SDS-WAS.

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Recommendation from Satellite Research Community

- VAACs, VOs, and the remote sensing research community are encouraged to form collaborative links for training and interpretation of events.
- The volcano ash community is encouraged to formulate requirements (parameters, data formats, latency, possibly sites) to the GALION (WMO Global Atmosphere Watch Lidar Observation Network) and the ground-based aerosol network should also be considered.
- The providers of volcanic ash detection and retrieval products should liaise with data assimilation centres to foster modelling and forecasting capabilities.

WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS

OPEN PROGRAMME AREA GROUP ON INTEGRATED OBSERVING SYSTEMS

INTER-PROGRAMME EXPERT TEAM ON SATELLITE UTILIZATION AND PRODUCTS

SCOPE-Nowcasting Pilot Project 2 : Globally consistent Volcanic Ash Products

Meeting on the Intercomparison of Satellite-based Volcanic Ash Retrieval Algorithms

Madison WI, USA

29 June – 2 July 2015

FINAL REPORT

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http://www.wmo.int/pages/prog/sat/documents/SCOPE-NWC-PP2_VAIntercompWSReport2015.pdf

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GAW SAG on NRT Modelling Applications

- SAG will contribute to enhancing exchanges between the GAW community and different end-user and modeling communities requested atmospheric composition data, especially for near-real-time data applications on regional to global scales.

Science Advisory Group members:

Vincent-Henri Peuch, co-chair, ECMWF, UK
Frank Dentener, co-chair, JRC, HTAP, Italy
Arlindo Da Silva , NASA, USA
Georg Grell, NOAA, USA
Mathew Hort, Met Office, UK
Michaela Hegglin, UniReading, UK
Michail Sofiev, FMI, Finland
Paul Makar, ECCC, Canada
Taichu Tanaka, Japan, ICAP
Zhou Chunhong, CMA, China
Alexander Baklanov - WMO Secretariat representative

Ex-officio from other SAGs:

Greg Carmichael, Iowa Uni, USA – Chair GAW SSC
Angela Benedetti, ECMWF – SDS-WAS
Gelsomina Pappalardo, Italy - Aerosol SAG
Johannes Kaiser, MPIC, Germany - IBBI
Veronique Boucher, ECCC, Canada - GURME SAG
Valerie Thouret, France - GHG SAG

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Research experience in VA modeling and DA

- ECMWF Atmosphere Copernicus Service – global forecast and DA
- WRF/Chem community – NOAA, NCAR, etc.
- Japan, China, Canada, Finland, France, UK, …. – DA for VA and other aerosols
- Experience from SDS-WAS: sand and dust storms advance modelling and DA
- What the research community can help for VAACs? A dialog is needed.

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GAW Modelling SAG tasks for VA prediction

- Analysis of new scientific achievements and recommendations for VA models improvements
- NRT availability and use of GAW and other available observation data for VA modelling (Lidars, ceilometers, satellite, aercraft, in-situ,..)
- Models evaluation and inversion methods for source-term estimation
- Data assimilation for volcanic plume transport modelling and prediction (VA, SO2, ..)
- Linkage of the satellite and modelling research communities for VA satellite retrivals use in VA modelling
- Collaboration with VASAG/VAACs, CIMO team is needed

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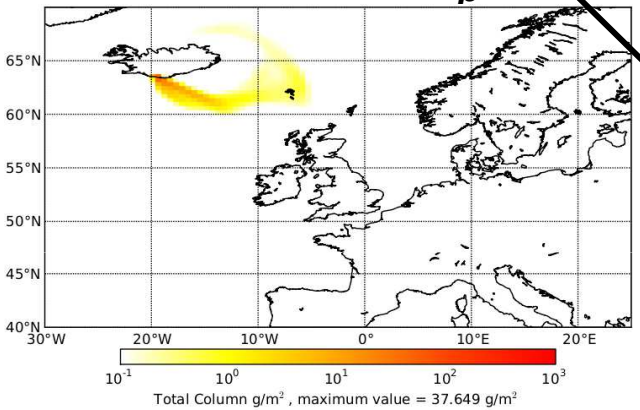
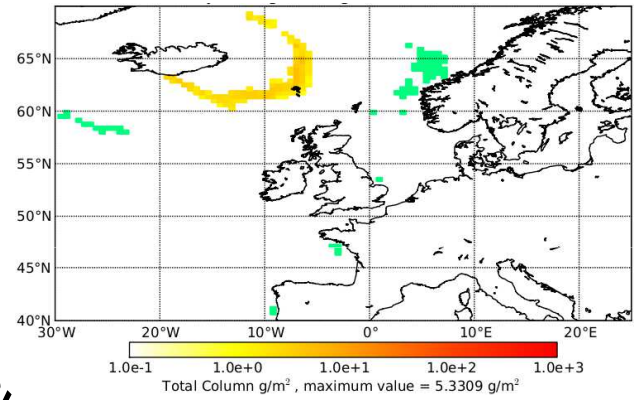
Inversion

Making model = Observations (sort of)

Model predicts observations as function of **e**: $o_p(e)$



Observational Data (satellite column loads)

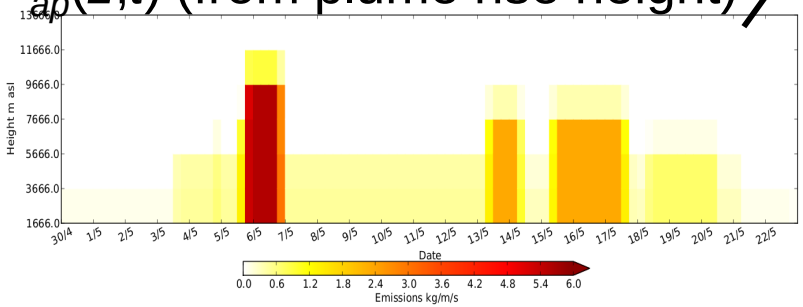


$$o_p(e) \approx o_a$$

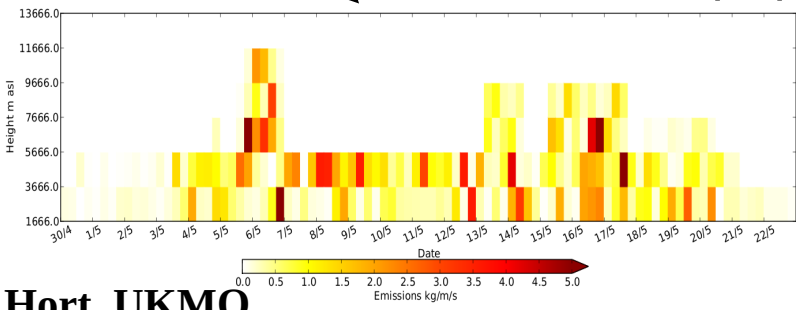
$$e \approx e_{ap}$$

Inversion calculation

A priori view of emissions $e_{ap}(z,t)$ (from plume rise height)



Best fit estimate of emissions **e**(z,t)

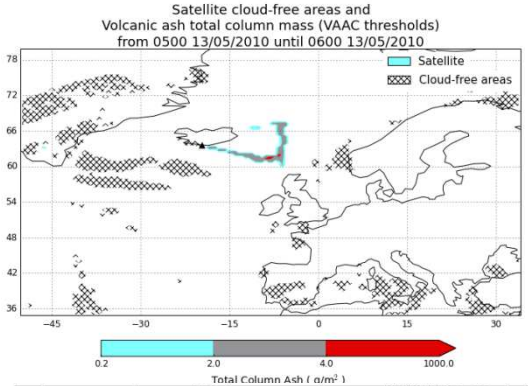


Courtesy of Matthew Hort, UKMO

Uncertainty

Representation

Courtesy of Matthew Hort, UKMO



Changing size distribution

Coarse

Default

Fine

Probability of exceedence (%)

No Members 10 20 30 40 50 60 70 80 90 99 All Members

15%

Changing mass fraction

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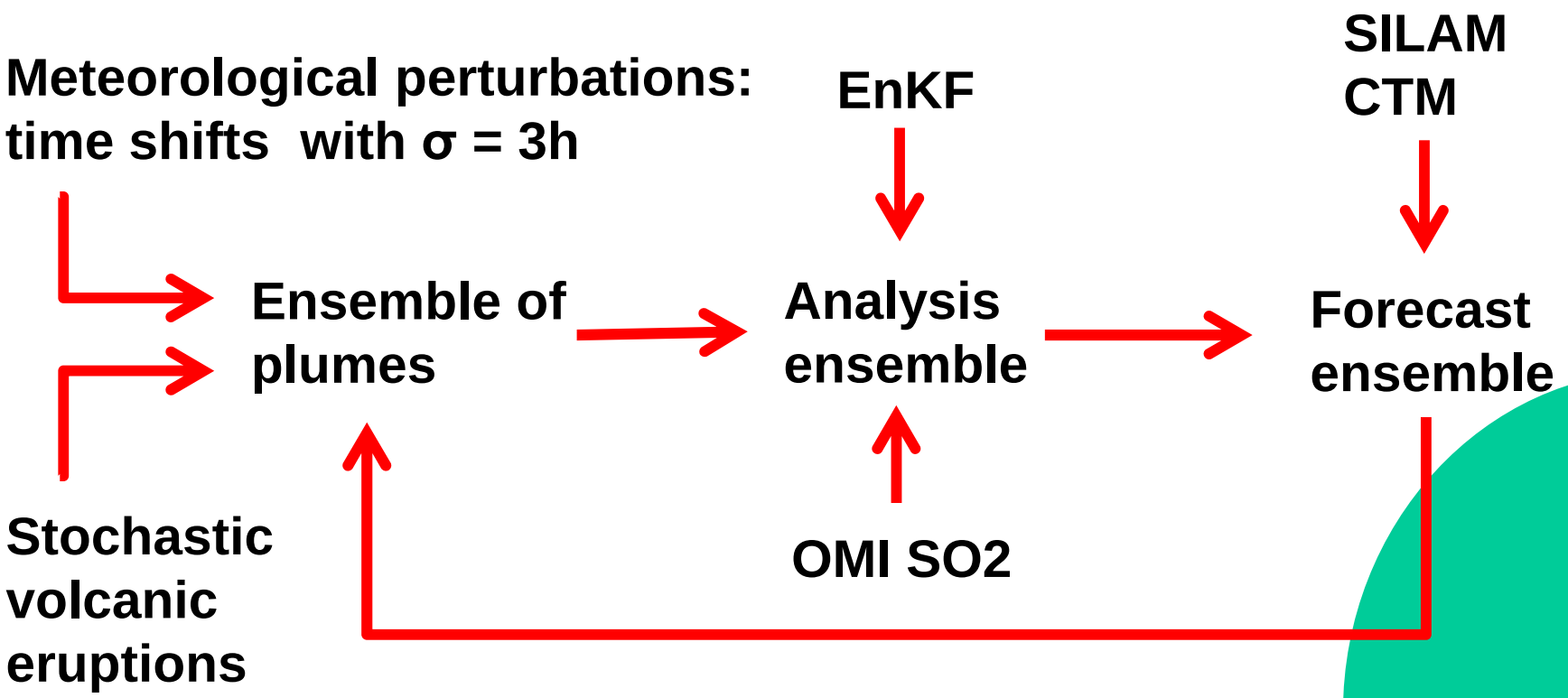
Data assimilation for predicting a volcanic tracer

- How to combine 2D map of column density retrievals of SO2 with transport modelling to obtain a realistic 3D prediction of a volcanic plume
- Can we do this without inverse modelling of the source term – instead, by continuously updating the prediction with observations?
- Can we provide error estimates accounting for both model and observation errors?
- Application to the Kasatochi SO2 release during 2 weeks following the eruption on 7-8 August 2008

Courtesy of Julius Vira, Nicolas Theys and Mikhail Sofiev

Ensemble assimilation for tracking a volcanic tracer



Courtesy of Julius Vira, Nicolas Theys and Mikhail Sofiev

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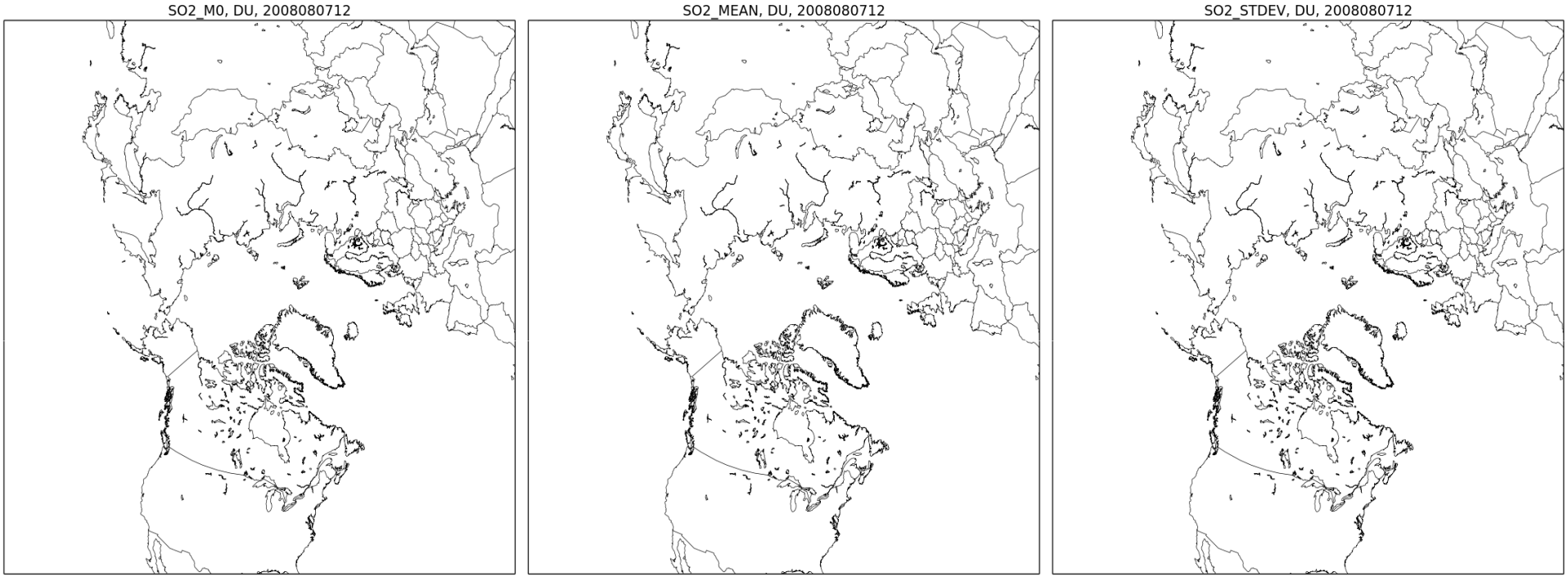
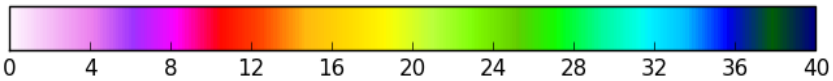
Kasatochi EnKF



Single member | Ensemble mean | Ensemble standard deviation

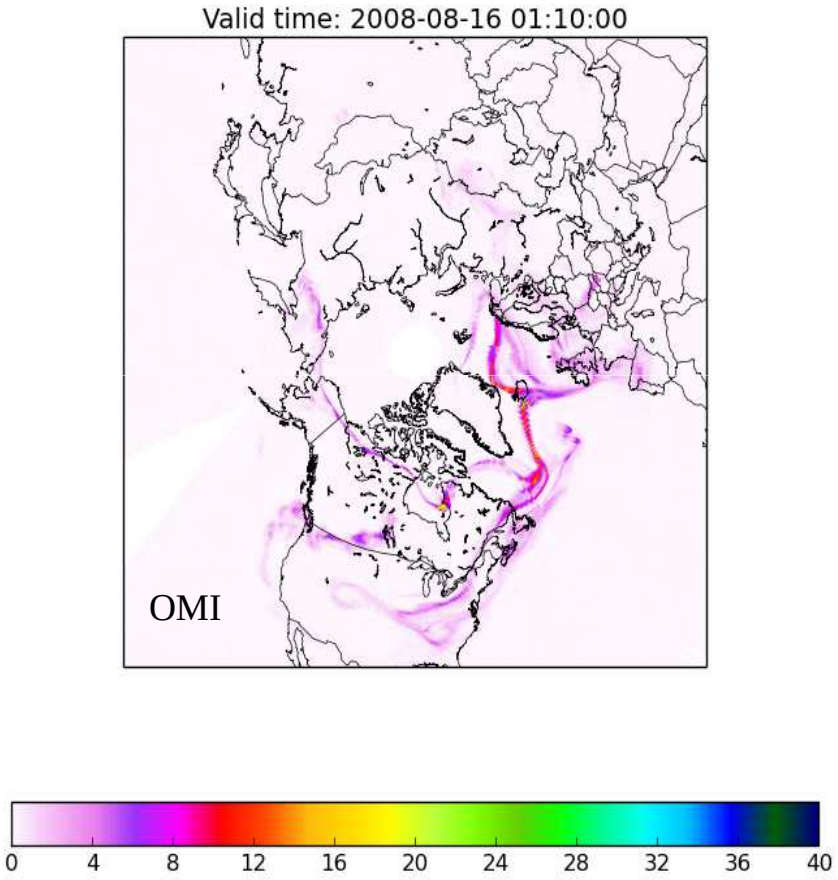
ECMWF oper meteo data
BIRA OMI SO2 product

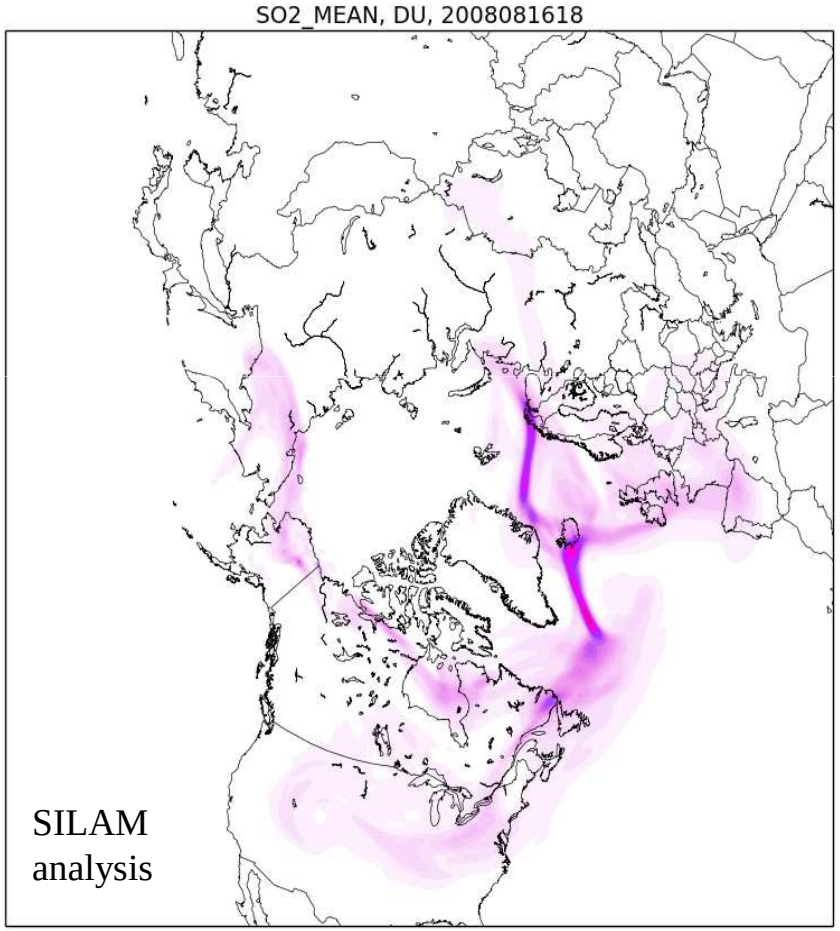


DU

Courtesy of Julius Vira, Nicolas Theys and Mikhail Sofiev

Aged plume vs observation, DU





Courtesy of Julius Vira, Nicolas Theys and Mikhail Sofiev

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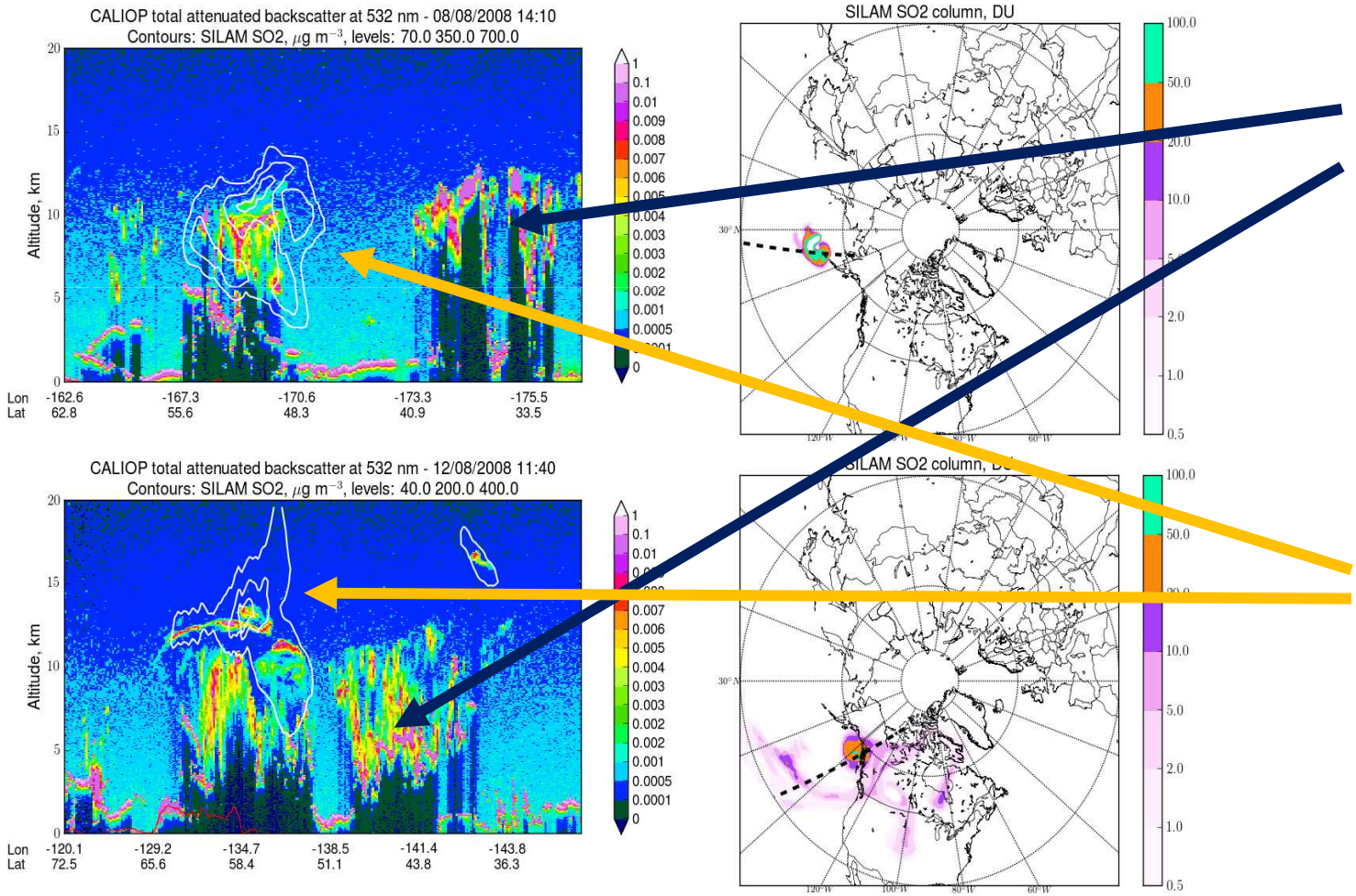
Vertical distribution: CALIOP Lidar data



Probably regular clouds

Analysis SO2 drawn in white contours

Courtesy of Julius Vira, Nicolas Theys and Mikhail Sofiev, FMI

Volcanic Ash Modelling At Environment Canada and Climate Change

- What ECCC currently does operationally for Volcanic Ash
  - Canadian Meteorological Centre is a Volcanic Ash Advisory Centre
  - LaGrangian dispersion model results are evaluated against, and calibrated with, available satellite data.
  - Simplified model output and interpretive text are posted to webpage (http://weather.gc.ca/eer/vaac/index_e.html).
- What ECCC is currently doing with regards to satellite data and assimilation of AQ variables (research)
  - Chemical Data Assimilation Group and Satellite Retrieval Group
  - Column O_3 assimilation currently being tested (with Trop/Strat capability)
    - Aim: improve surface O_3 and UV forecasts
  - Next goal likely NO_2
  - Satellite AOD data are being explored to see the extent to which they might help the $PM_{2.5}$ forecast.

Courtesy of Paul Makar, ECCC

Volcanic Ash Modelling At Environment Canada and Climate Change

- What we *could* be doing, if we had the right input data:
- Something similar to the Fireworks version of GEM-MACH
  - Fireworks: a parallel forecast of GEM-MACH which uses satellite data to estimate *forest fire* emissions and plume rise.
- We could do a parallel GEM-MACH forecast, which makes use of volcanic ash data from real-time satellite retrievals.
- This simulation could be run in feedback mode to forecast changes in the weather resulting from volcanic ash.
- Data needs: real time estimates of:
  - Mass of ash emitted, plume height
  - Estimates of the optical properties of the ash (either from retrievals or previous ground-based observations, in a database for each volcano).

Courtesy of Paul Makar, ECCC

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World Meteorological Organization

A United Nations Specialized Agency

Working together in Weather, Climate and Water

Thank you for your attention

GAW and WWRP publications available from:

http://www.wmo.int/pages/prog/arep/gaw/gaw-reports.html

and

http://www.wmo.int/pages/prog/arep/wwrp/new/wwrp_new_en.html

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