# The Global Atmosphere Watch (GAW) *Reactive Gases* Measurement Network

Martin Schultz[1], Hajime Akimoto[2], Jan Bottenheim[3], Brigitte Buchmann[4], Ian Galbally[5], Stefan Gilge[6], Detlev Helmig[7], Hiroshi Koide[8], Alastair Lewis[9], Paul Novelli[10], Christian Plass-Dülmer[6], Tom Ryerson[10], Martin Steinbacher[4], Rainer Steinbrecher[11], Oksana Tarasova[12], Kjetil Tørseth[13], Valerie Thouret[14], Christoph Zellweger[4]

[1] Institute for Energy and Climate Research, Forschungszentrum Jülich, Germany
[2] Asian Center for Atmospheric Pollution,
[3] retired; formally at Environment Canada, Toronto, Canada
[4] Swiss Federal Laboratories for Materials Science & Technology, Dübendorf, Switzerland
[5] CSIRO, Aspendale, Australia
[6] Deutscher Wetterdienst, Hohenpeissenberg, Germany
[7] Institute of Arctic and Alpine Research, University of Colorado, Boulder, USA
[8] Japan Meteorological Agency, Tokyo, Japan
[9] York University, York, United Kingdom
[10] NOAA, Boulder, Colorado, USA
[11] Karlsruhe Institute for Technology, Garmisch-Partenkirchen, Germany
[12] World Meteorological Organisation, Geneva, Switzerland
[13] Norwegian Institute for Air Research (NILU), Kjeller, Norway
[14] Laboratoire d'Aérologie, CNRS and Université Paul Sabatier Toulouse III, Toulouse, France

# What is the Global Atmospheric Watch (GAW) Program?

- GAW is a partnership involving contributors from 100 countries.
- GAW implements and coordinates observations of atmospheric chemical composition and related physical parameters, quality control, training, data dissemination …..

## GAW focal areas:

- Stratospheric Ozone and vertical ozone distribution
- Greenhouse Gases (*$CO_2$ and its isotopes , $CH_4$ and its isotopes, $N_2O$, $SF_6$, CFCs*)
- Reactive Gases (*$O_3$, CO, VOC, $NO_x$, $SO_2$*)
- Precipitation Chemistry
- Aerosols (*chemical and physical properties, AOD*)
- UV Radiation

# What is the Global Atmospheric Watch (GAW) Program?

- GAW is a partnership involving contributors from 100 countries.
- GAW implements and coordinates observations of atmospheric chemical composition and related physical parameters, quality control, training, data dissemination …..

## GAW focal areas:

- Stratospheric Ozone and vertical ozone distribution
- Greenhouse Gases (*$CO_2$ and its isotopes , $CH_4$ and its isotopes, $N_2O$, $SF_6$, CFCs*)
- *Reactive* Gases (*$O_3$, CO, VOC, $NO_x$, $SO_2$*)
- Precipitation Chemistry
- Aerosols (*chemical and physical properties, AOD*)
- UV Radiation

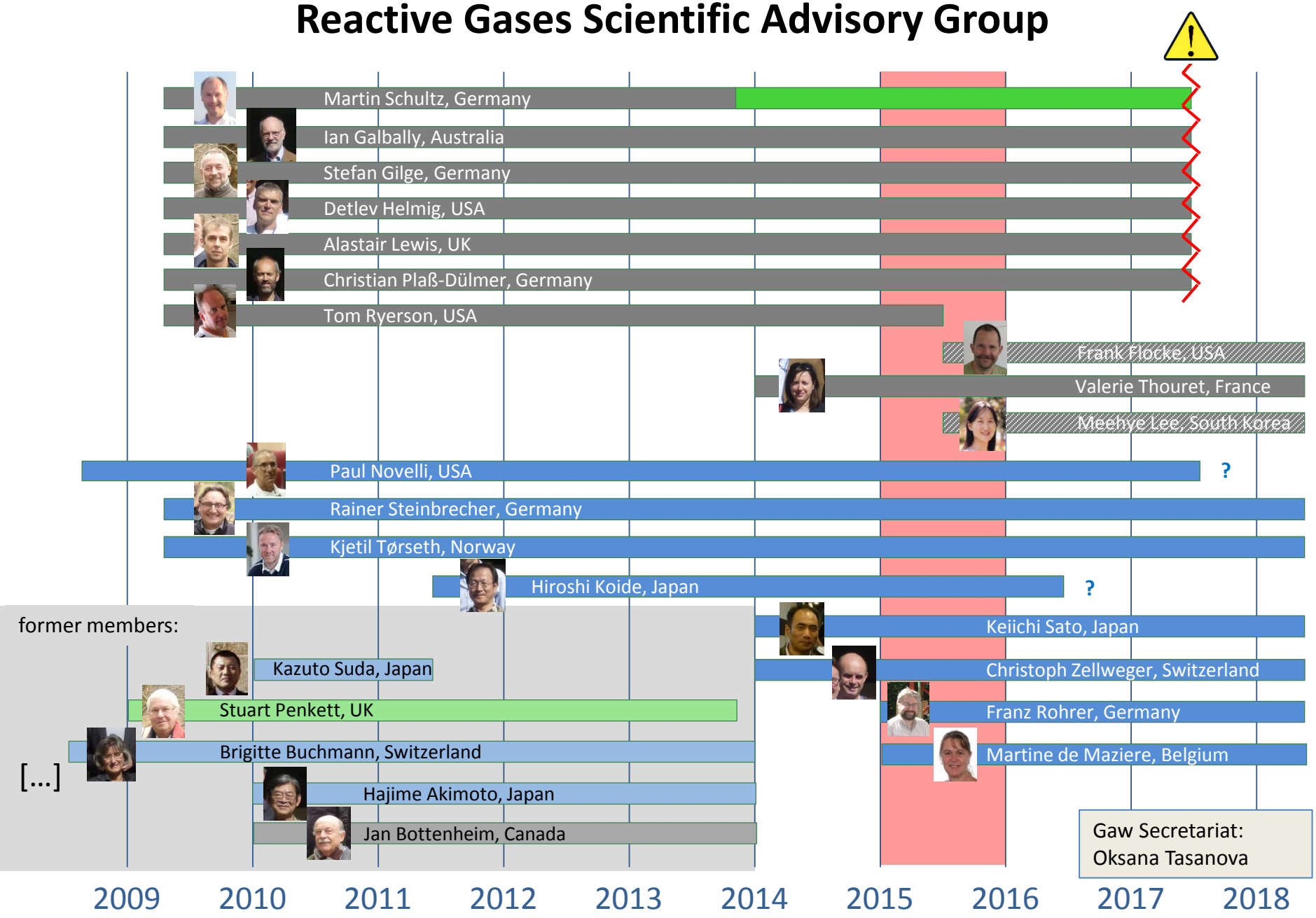
## Reactive Gases included in WMO - GAW

- **Ozone**
- **Carbon Monoxide**
- **Volatile Organic Compounds (VOC)**
- **Nitrogen Oixides ($NO/NO_2/NO_y$)**
- **Sulfur Dioxide ($SO_2$)**

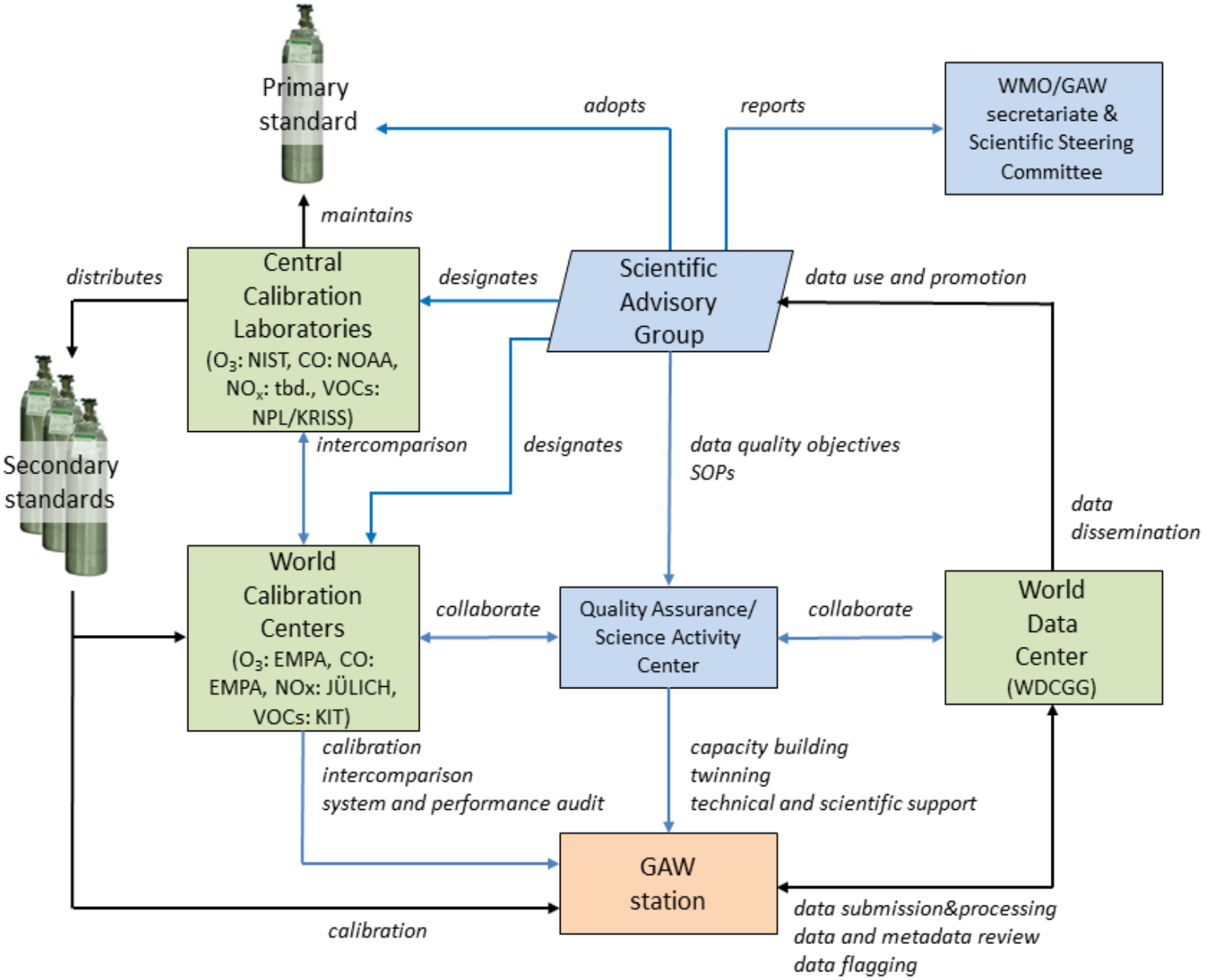
Motivation:

- Direct Greenhouse Gases
- Precursors to Greenhouse Gases
- Aerosol Production
- Tracers for Methane
- Tracers for FF, BB, O&NG, Volcanoes…

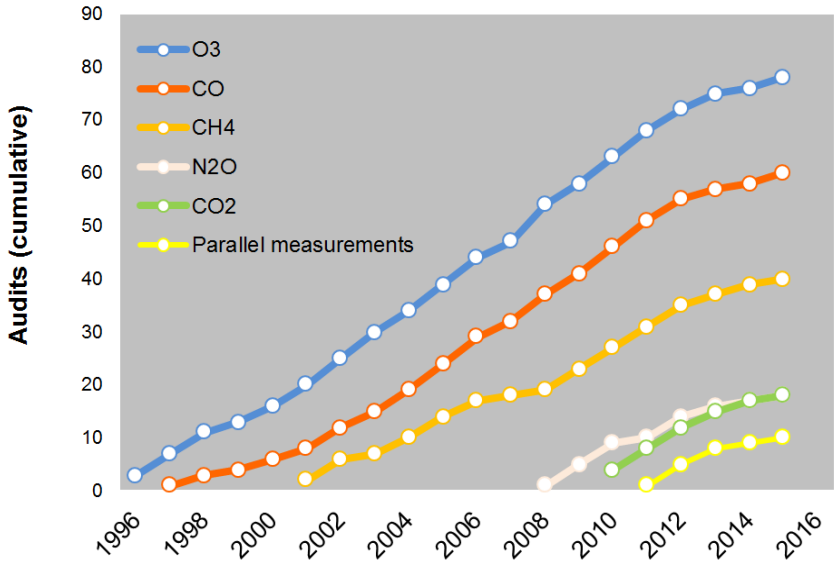
# Reactive Gases Scientific Advisory Group




Reactive Gases Scientific Advisory Group Meeting Malta, 2011


Primary standard
adopts
reports
WMO/GAW secretariate & Scientific Steering Committee
maintains
distributes
Central Calibration Laboratories ($O_3$: NIST, CO: NOAA, $NO_x$: tbd., VOCs: NPL/KRISS)
designates
Scientific Advisory Group
data use and promotion
Secondary standards
intercomparison
designates
data quality objectives
SOPs
data dissemination
World Calibration Centers ($O_3$: EMPA, CO: EMPA, NOx: JÜLICH, VOCs: KIT)
collaborate
Quality Assurance/ Science Activity Center
collaborate
World Data Center (WDCGG)
calibration
intercomparison
system and performance audit
capacity building
twinning
technical and scientific support
GAW station
calibration
data submission&processing
data and metadata review
data flagging

# Audits by WCC-Empa from 1996 - 2015




*System and performance audits by WCC-Empa (sfc. ozone and CO):*


Mt. Waliguan (China), $O_3$, CO, $CH_4$, Sept 2009


Lauder (New Zealand), $O_3$, CO, $CH_4$, $CO_2$, $N_2O$, March 2010


Cape Grim (Australia), $O_3$, CO, $CH_4$, $CO_2$, $N_2O$, March 2010


Mt. Kenya (Kenya), $O_3$, CO, June 2010


Cape Point (South Africa), $O_3$, CO, $CH_4$, $CO_2$, March 2011


Zugspitze (Germany), $O_3$, CO, $CH_4$, $CO_2$, $N_2O$, June 2011


Hohenpeissenberg (Germany), $O_3$, CO, $CH_4$, $CO_2$, July 2011


Bukit Kototabang (Indonesia), $O_3$, CO, $CH_4$, $CO_2$, November 2011

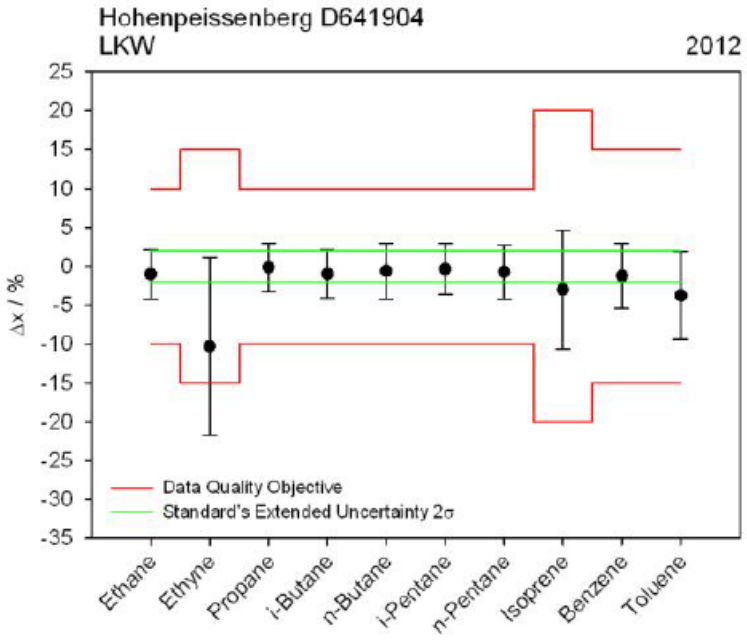

Pallas (Finland), $O_3$, CO, $CH_4$, $CO_2$, April 2012

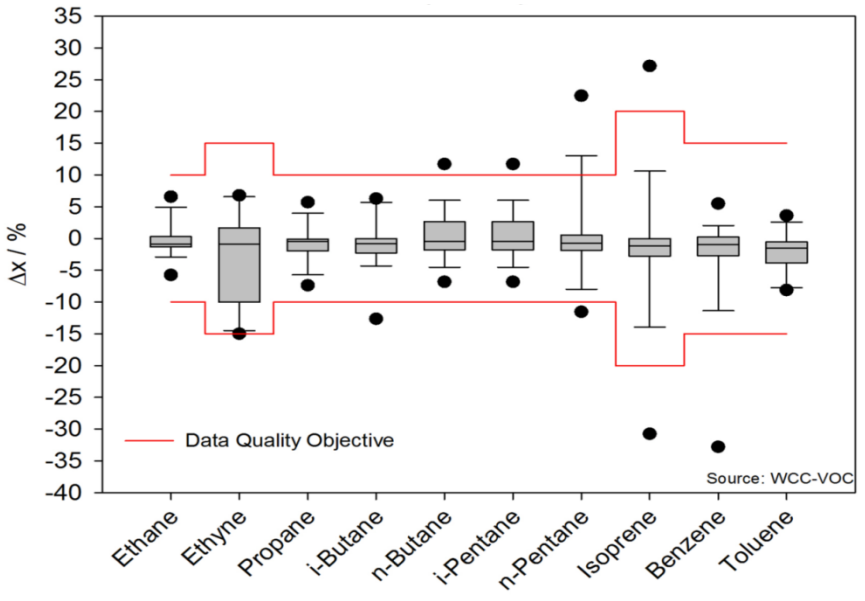

Zeppelin Mountain (Norway), $O_3$, CO, $CH_4$, $CO_2$, August 2012


Mt. Cimone (Italy), $O_3$, CO, $CH_4$, $CO_2$, $N_2O$, September 2012


Cape Verde (Cape Verde), $O_3$, CO, $CH_4$, $CO_2$, $N_2O$, December 2012

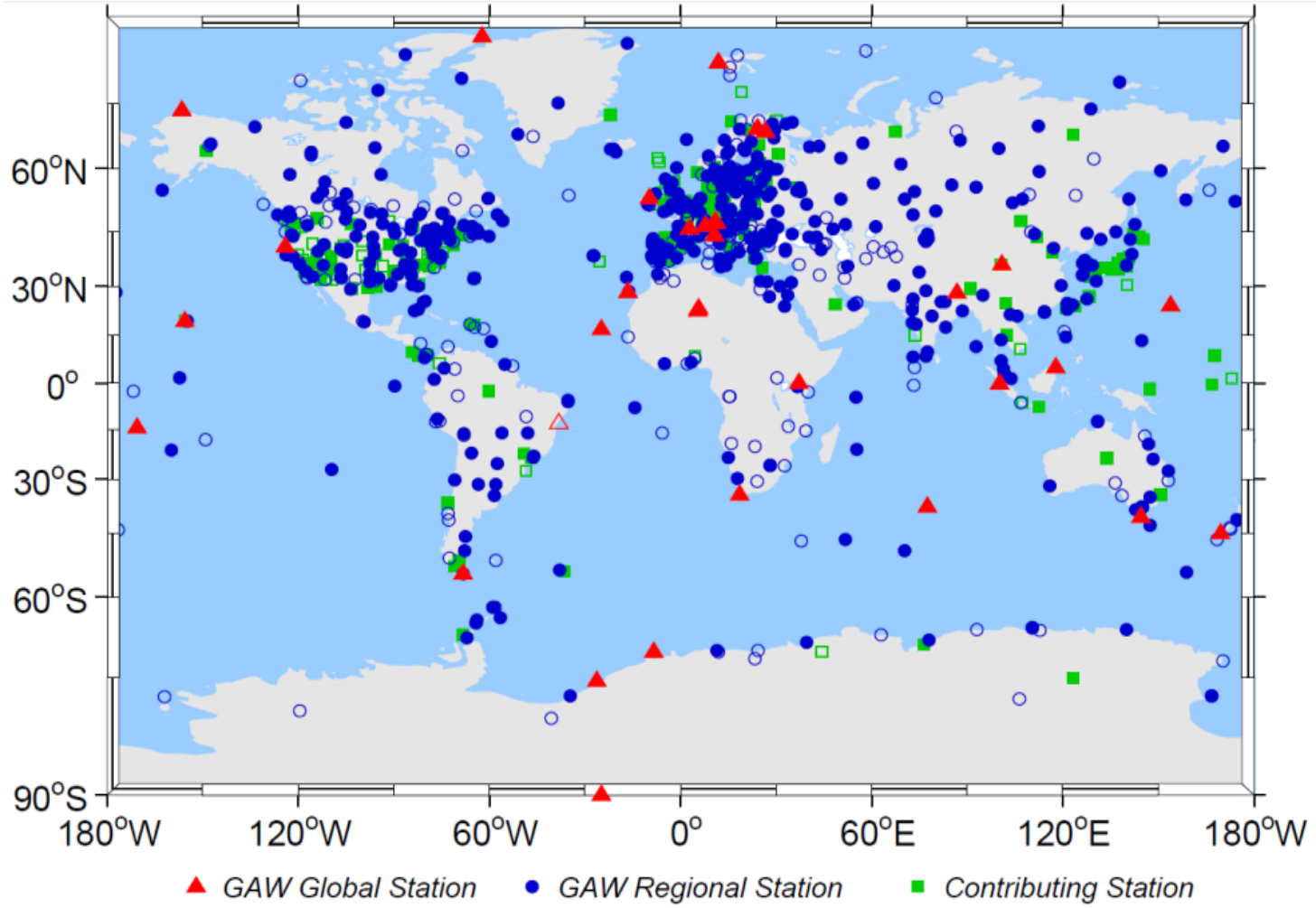
# VOC Audit Results

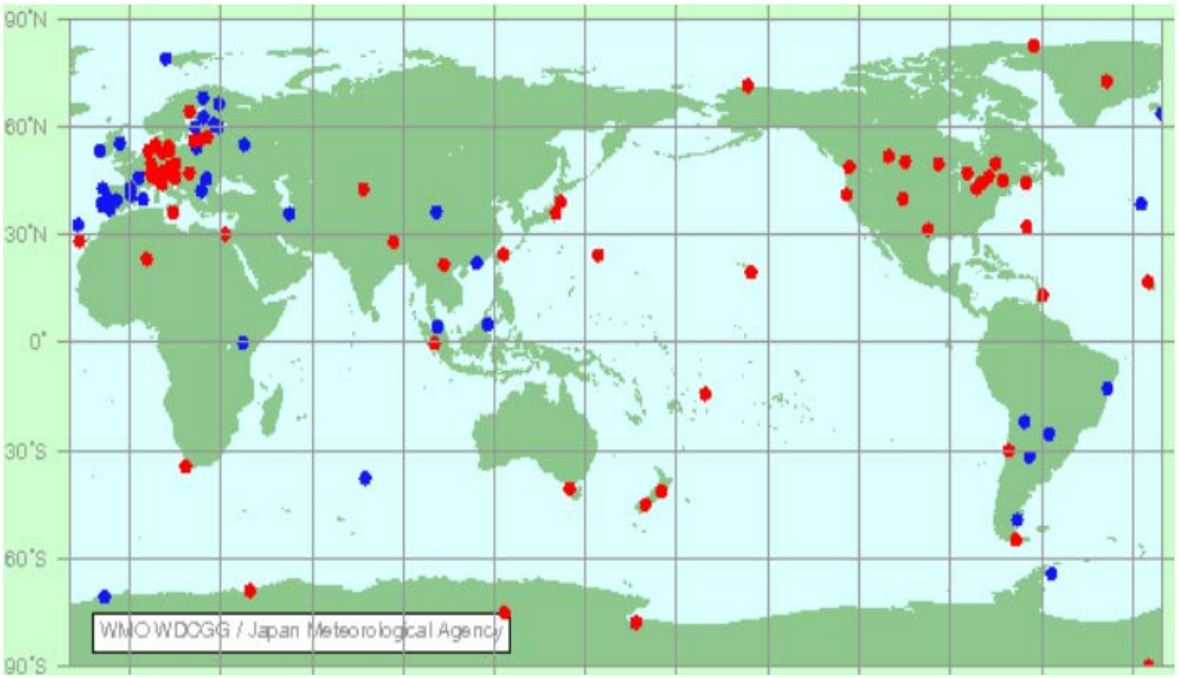



Statistical distribution of results from 19 audits performed at 12 facilities around the globe since 2007. The boundaries of the boxes indicate the 25$^{th}$ and 75$^{th}$ percentiles. The horizontal lines within the boxes mark the medians, whiskers (error bars) above and below the boxes indicate the 10$^{th}$ and 90$^{th}$ percentiles. The black dots show the extreme deviations. The red line represents the GAW data quality objectives for network compatibility (WMO, 2007).

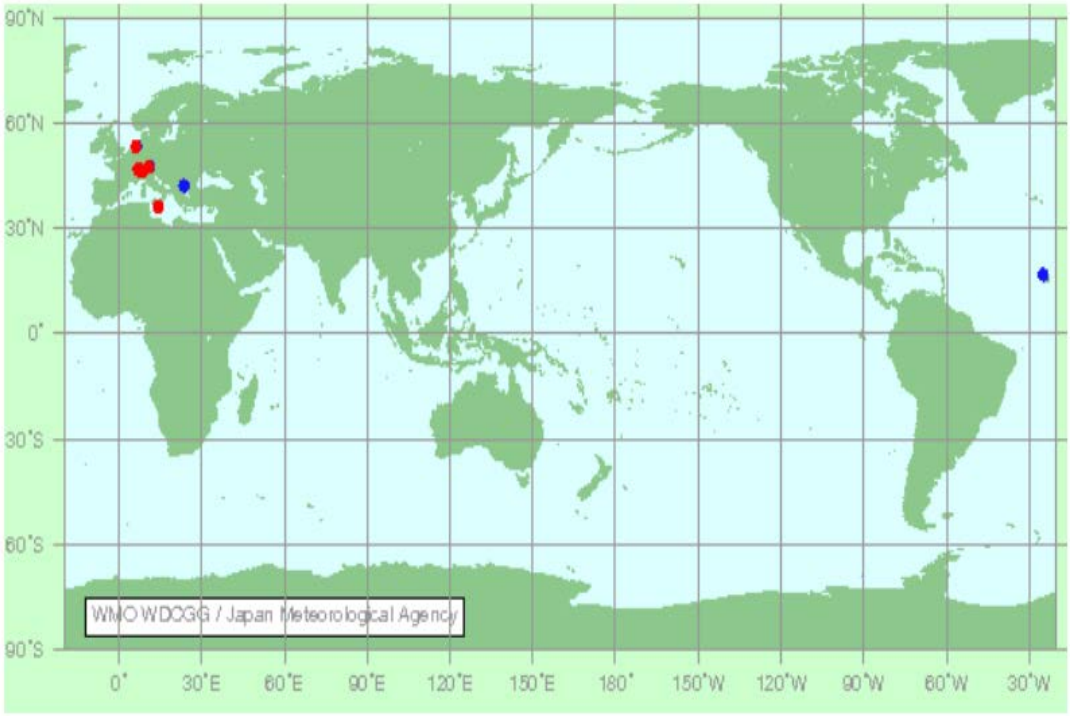
# Global GAW Station Network





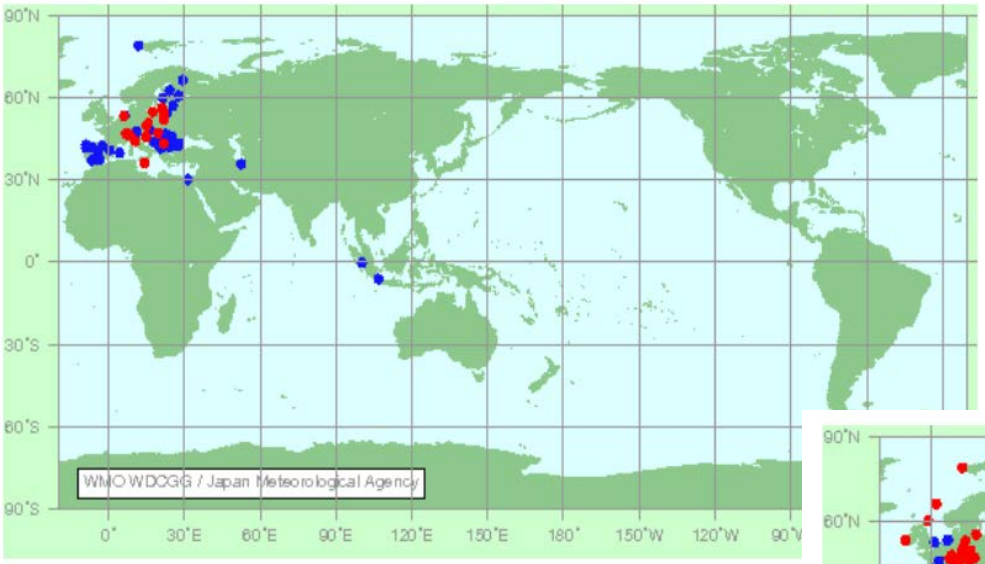

## Stations reporting data to WDCGG

*Surface Ozone*

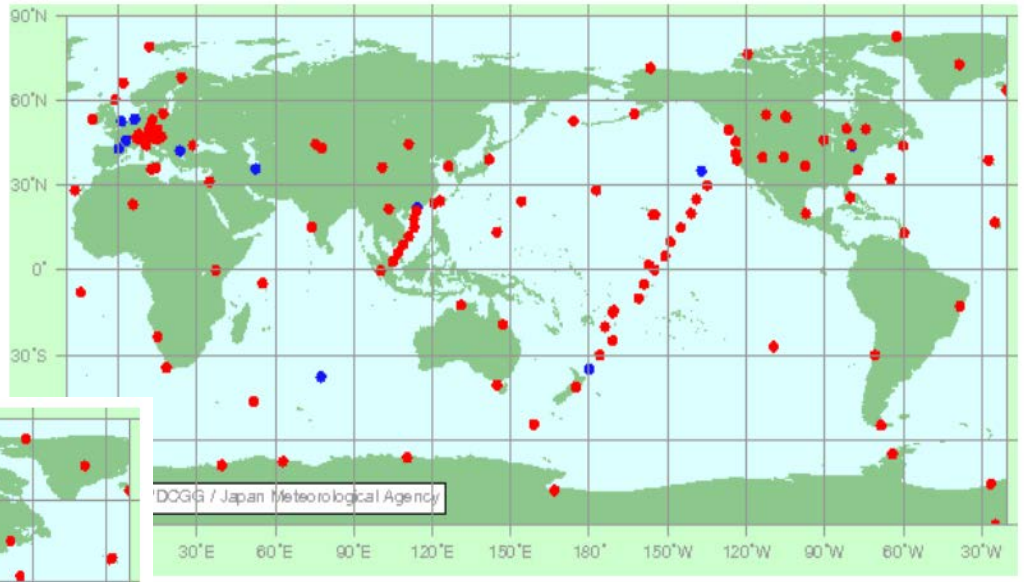



*NOx*

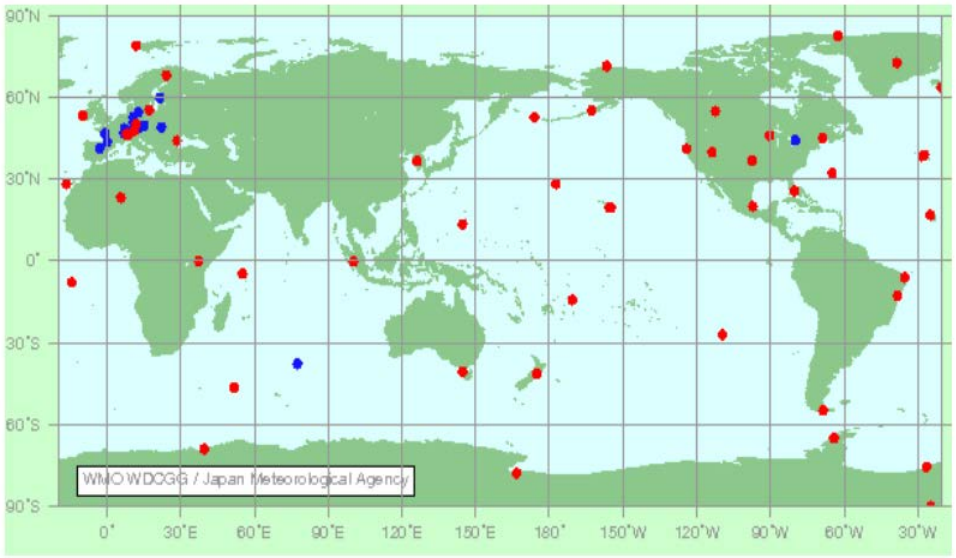
# Stations reporting data to WDCGG



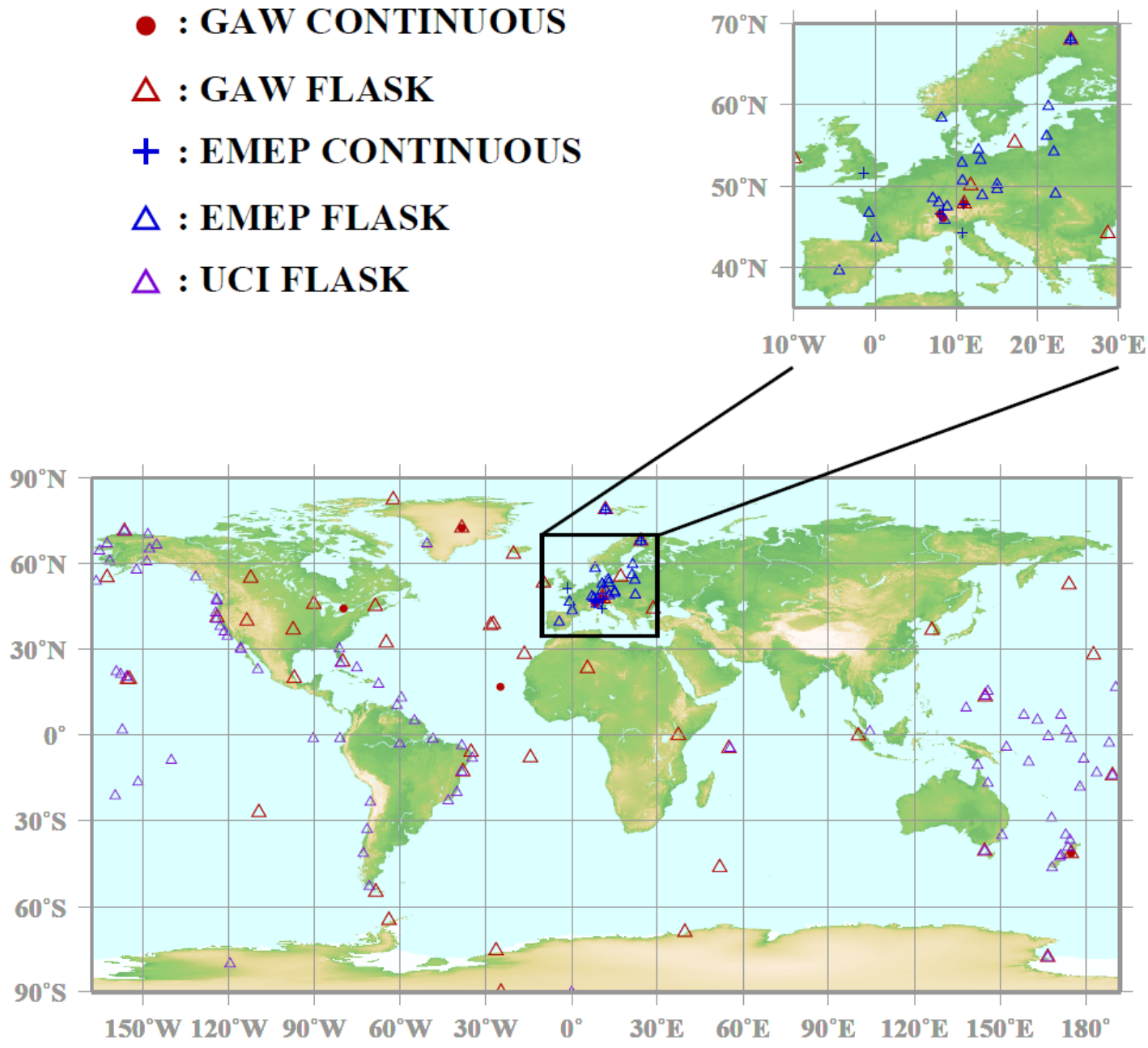

*CO*




$SO_2$



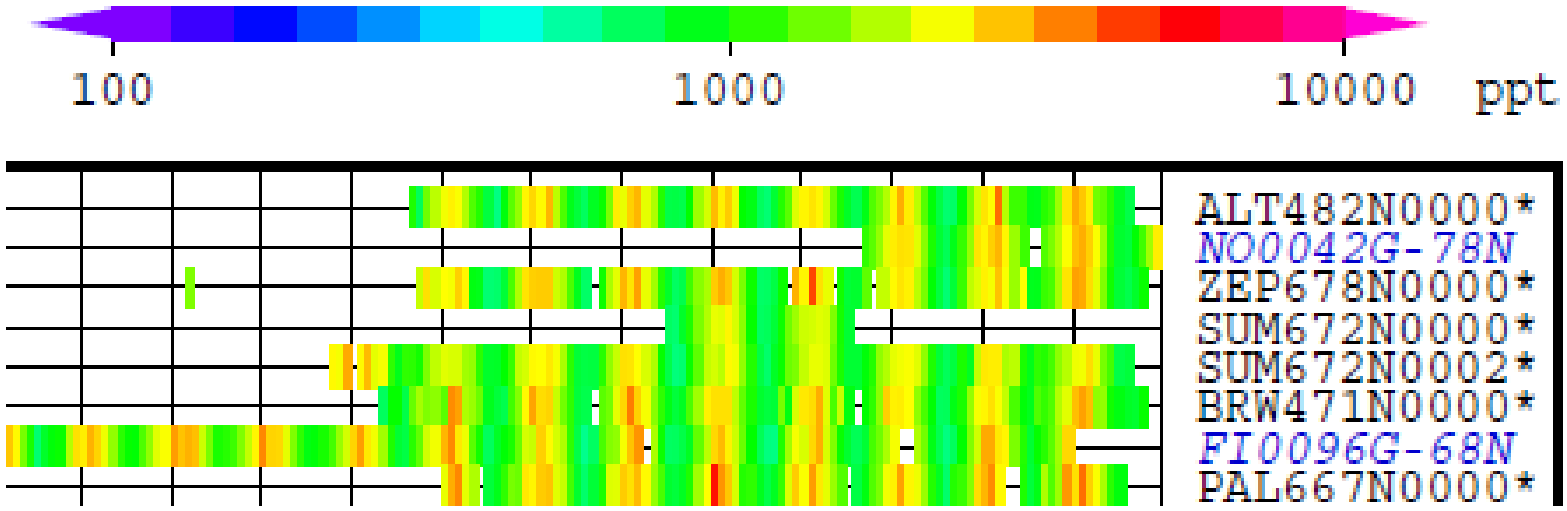

*VOC*



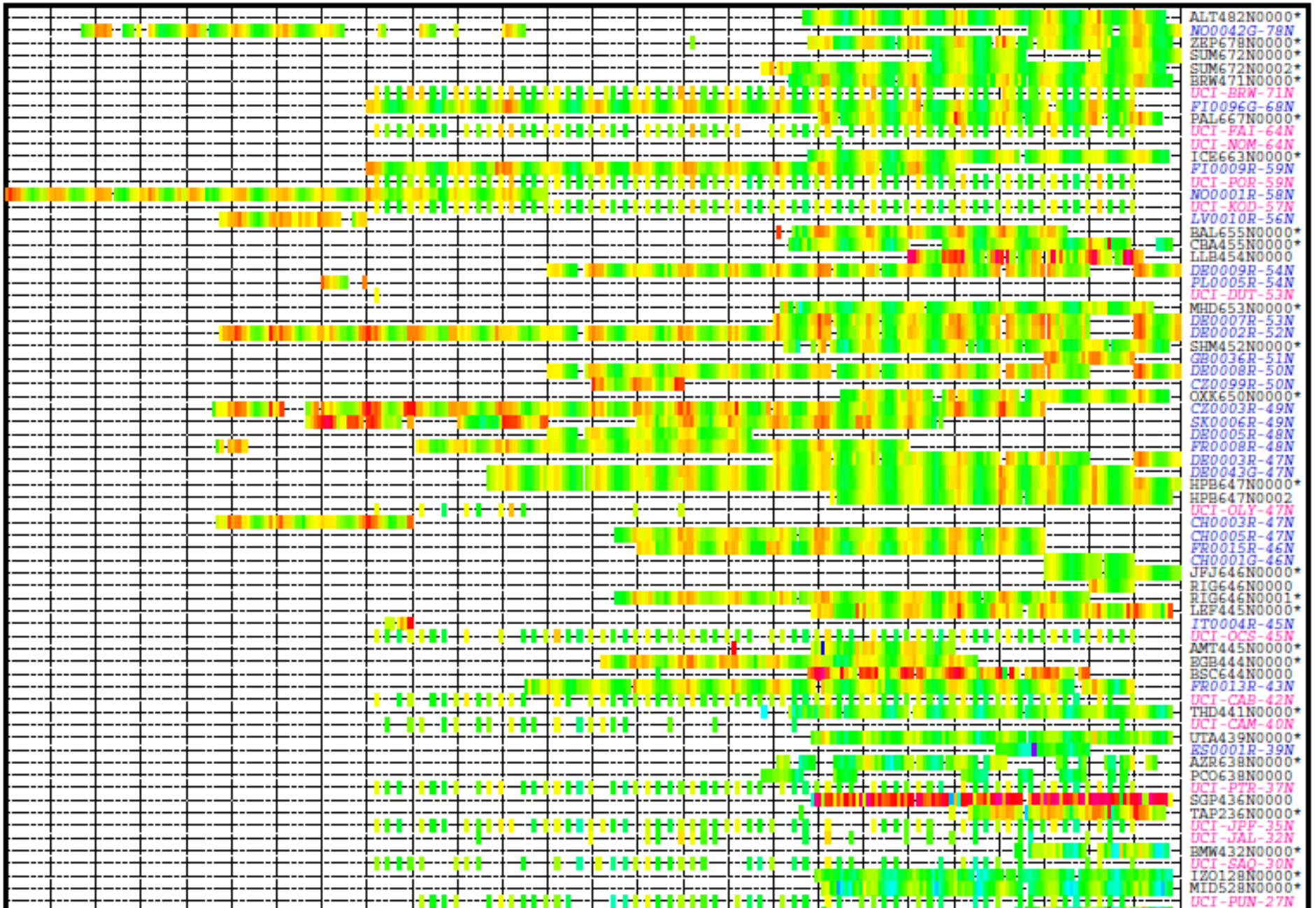

Extension of VOC data set in WDCGG archive

# Available Ethane Observations

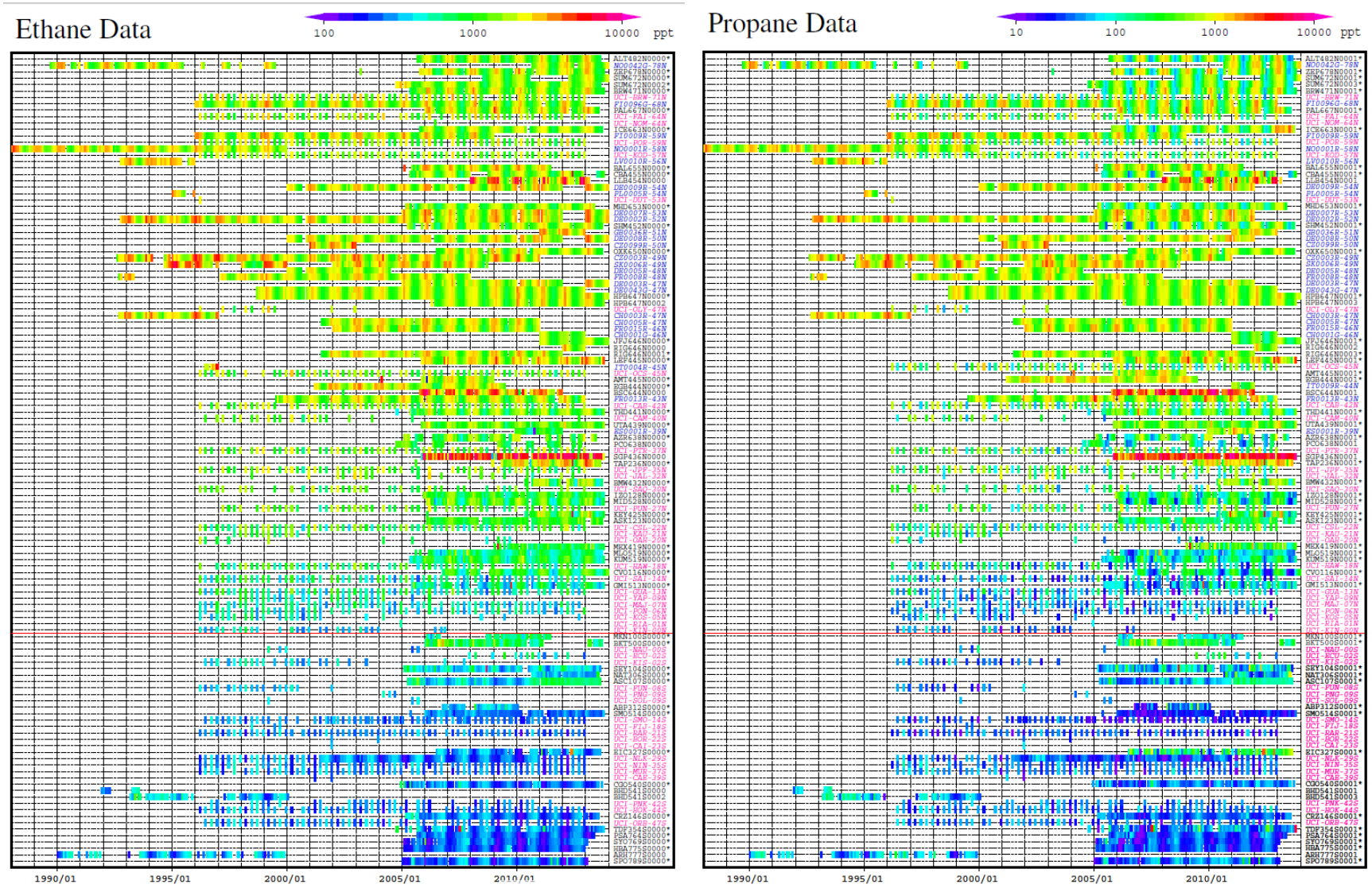
World Data Centre for Greenhouse Gases Summary



# Ethane Data


100
1000
10000
ppt
ALT492N0000*
NO0042G-78N
ZEP678N0000*
SUM672N0000*
SUM672N0002*
BRW471N0000*
UCI-BRW-71N
FI0096G-68N
PAL667N0000*
UCI-FAI-64N
UCI-NOM-64N
ICE663N0000*
FI0009R-59N
UCI-POR-59N
NO0001R-58N
UCI-KOD-57N
LV0010R-56N
BAL655N0000*
CBA455N0000*
LLB454N0000
DE0009R-54N
PL0005R-54N
UCI-DUT-53N
MHD653N0000*
DE0007R-53N
DE0002R-52N
SHM452N0000*
GB0036R-51N
DE0008R-50N
CZ0099R-50N
OXK650N0000*
CZ0003R-49N
SK0006R-49N
DE0005R-48N
FR0008R-48N
DE0003R-47N
DE0043G-47N
HPB647N0000*
HPB647N0002
UCI-OLY-47N
CH0003R-47N
CH0005R-47N
FR0015R-46N
CH0001G-46N
JFJ646N0000*
RIG646N0000
RIG646N0001*
LEF445N0000*
IT0004R-45N
UCI-OCS-45N
AMT445N0000*
EGB444N0000*
BSC644N0000
FR0013R-43N
UCI-CAB-42N
THD441N0000*
UCI-CAM-40N
UTA439N0000*
ES0001R-39N
AZR638N0000*
PCO638N0000
UCI-PTR-37N
SGP436N0000
TAP236N0000*
UCI-JPF-35N
UCI-JAL-32N
BMW432N0000*
UCI-SAQ-30N
IZO128N0000*
MID528N0000*
UCI-PUN-27N

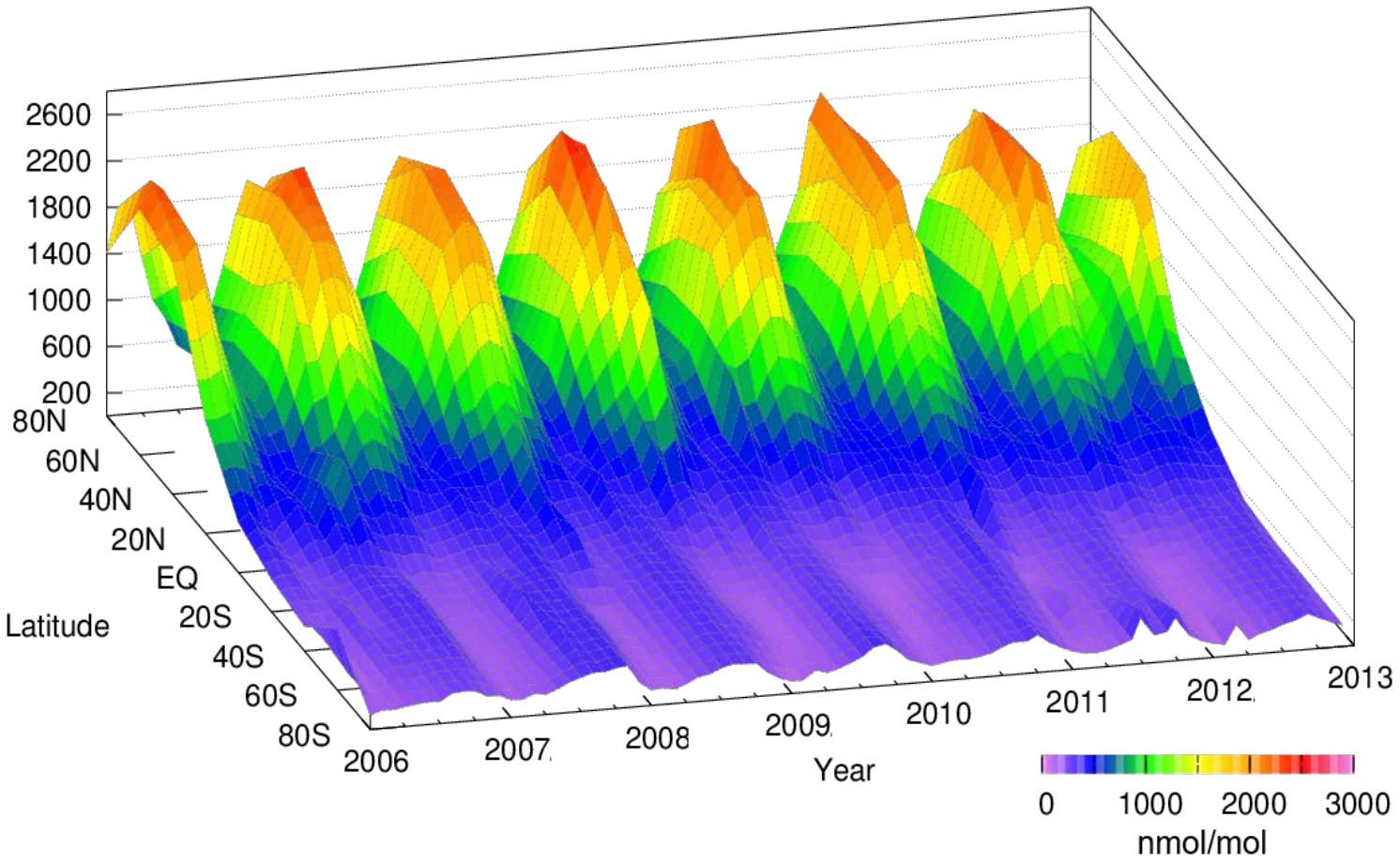
# Extension of VOC data set in WDCGG archive




~120 data series each

*Figure: H. Koide, WDCGG*

# Global Distribution of Ethane



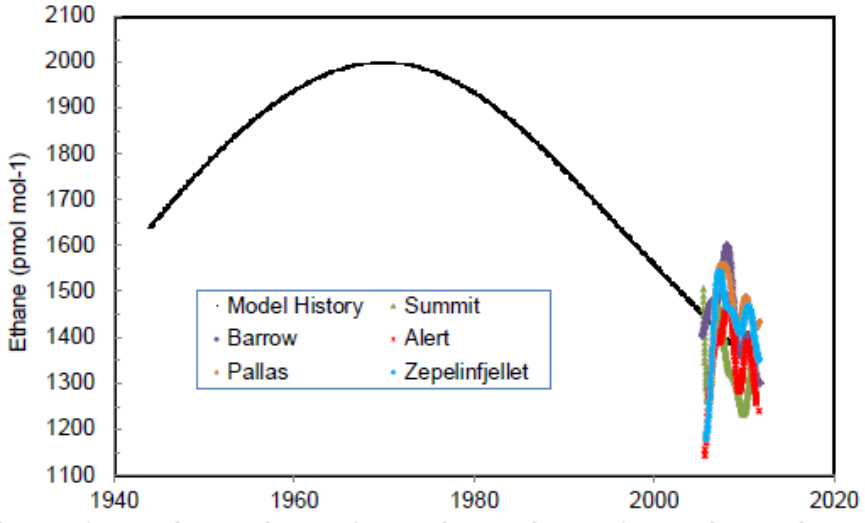
Atmos. Chem. Phys., 14, 1463–1483, 2014
www.atmos-chem-phys.net/14/1463/2014/
doi:10.5194/acp-14-1463-2014


Atmospheric Chemistry and Physics Open Access

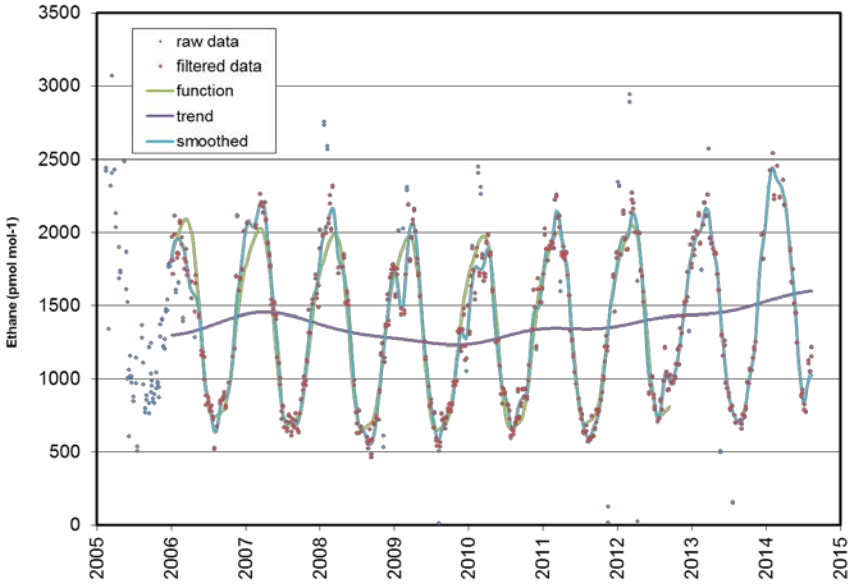
# Reversal of Ethane Trend in Northern Hemisphere

## Reconstruction of Northern Hemisphere 1950–2010 atmospheric non-methane hydrocarbons

D. Helmig[1], V. Petrenko[1,2], P. Martinerie[3], E. Witrant[4], T. Röckmann[5], A. Zuiderweg[5], R. Holzinger[5], J. Hueber[1], C. Thompson[1], J. W. C. White[1], W. Sturges[6], A. Baker[7], T. Blunier[8], D. Etheridge[9], M. Rubino[9], and P. Tans[10]




Ethane at Summit, Greenland, 2005 - 2015



An *Elementa* Special Feature

# Reactive Gases in the Global Atmosphere

Frank Flocke, Guest Editor • NCAR Earth System Laboratory

## Published Articles

*Additional articles under review*

### Global distribution and trends of tropospheric ozone: An observation-based review

**O.R. Cooper • D.D. Parrish • J. Ziemke • N.V. Balashov • M. Cupeiro • I.E. Galbally • S. Gilge • L. Horowitz • N.R. Jensen • J.-F. Lamarque • V. Naik • S.J. Oltmans • J. Schwab • D.T. Shindell • A.M. Thompson • V. Thouret • Y. Wang • R.M. Zbinden**

Review — *Atmospheric Science*

### Ozone in the Atlantic Ocean marine boundary layer

**Patrick Boylan • Detlev Helmig • Samuel Oltmans**

Research Article — *Atmospheric Science, Ocean Science*

## Insights from contributions to the World Meteorological Organization Global Atmosphere Watch program

GAW

Reactive trace gases in the Earth atmosphere can have adverse effects on human health, environment and materials, they influence regional climate and are involved in many biogeochemical cycles. Atmospheric chemical reactions also play an important role in cleansing the atmosphere from anthropogenic and natural emissions. Assessing the importance and impacts of

# General requirements to GAW stations

1. The station location is chosen such that, for the variables measured, it is regionally representative and is normally free of the influence of significant local pollution sources.

2. There are adequate power, air conditioning, communication and building facilities to sustain long term observations with greater than 90% data capture (i.e. <10% missing data).

3. The technical support provided is trained in the operation of the equipment.

4. There is a commitment by the responsible agency to long term observations of at least one of the GAW variables in the GAW focal areas (ozone, aerosols, greenhouse gases, reactive gases, UV radiation, precipitation chemistry).

5. The GAW observation made is of known quality and linked to the GAW Primary Standard.

6. The data and associated metadata are submitted to one of the GAW World Data Centres no later than one year after the observation is made. Changes of metadata including instrumentation, traceability, observation procedures, are reported to the responsible WDC in a timely manner.

7. If required, data are submitted to a designated data distribution system in near-real-time.

8. Standard meteorological *in situ* observations, necessary for the accurate determination and interpretation of the GAW variables, are made with known accuracy and precision.

9. The station characteristics and observational programme are updated in the GAW Station Information System (GAWSIS) on a regular basis.

10. A station logbook (i.e. record of observations made and activities that may affect observations) is maintained and is used in the data validation process.

# Requirements to GAW Global stations

In addition to the characteristics of Regional or Contributing stations, a GAW Global station should fulfill the following additional requirements, namely

11. Measure variables in at least three of the six GAW focal areas.
12. Have a strong scientific supporting programme with appropriate data analysis and interpretation within the country and, if possible, the support of more than one agency.
13. Make measurements of other atmospheric variables important to weather and climate including upper air radio sondes at the site or in the region.
14. Provide a facility at which intensive campaign research can augment the long term routine GAW observations and where testing and development of new GAW methods can be undertaken.

| Compound | Measurement Guidelines<br>GAW Report Number | Other Documents<br>GAW Report Number |
|---|---|---|
| Ozone | 209 (WMO, 2013) | ozone sondes: 201 (WMO, 2011d); ozone (data) workshop: 199 (WMO, 2011c) |
| CO | 192 (WMO, 2010) | calibration scale: 206[a] (WMO, 2014b); network, QA/QC: 166[a] (WMO, 2006) |
| VOC | in preparation | general recommendations: 171[a] (WMO, 2007); sampling SOP: 204 (WMO, 2012a) |
| $NO/NO_2/NO_y$ | in preparation | general recommendations: 195[a] (WMO, 2011a) |
| $SO_2$ | -- | general recommendations: 143[b] (WMO, 2001) |
| Strategic Plan 2008-2015: 172 (WMO, 2007); Addendum 2012-2015: 197 (WMO, 2011b) | | |
| NRT data delivery (MACC): 189 (WMO, 2010) | | |

# Observations in GAW

GAW ***strives*** to implement “integrated” observing system including ground-based observations and satellite remote sensing integrated through models

Surface-based *in situ* and remote sensing observations are the backbone of the GAW network.

There are Global and Regional GAW stations and stations working within contributing networks.

Currently GAW coordinates activities and data from 29 Global stations, about 400 Regional stations, and 100 Contributing stations (http://gaw.empa.ch/gawsis/)

# QMF principles

- ✓ Full support of the GCOS Climate Monitoring Principles
- ✓ Network-wide use of only one reference standard or scale (primary standard). In consequence, there is only one institution that is responsible for this standard.
- ✓ Full traceability to the primary standard of all measurements made by Global, Regional and Contributing GAW stations.
- ✓ The definition of data quality objectives (DQOs).
- ✓ Establishment of guidelines on how to meet these quality targets, i.e., harmonized measurement techniques based on Measurement Guidelines (MGs) and Standard Operating Procedures (SOPs).
- ✓ Establishment of MGs or SOPs for these measurements.
- ✓ Use of detailed log books for each parameter containing comprehensive meta information related to the measurements, maintenance, and 'internal' calibrations.
- ✓ Regular independent assessments (system and performance audits).
- ✓ Timely submission of data and associated metadata to the responsible World Data Centre as a means of permitting independent review of data by a wider community.

# Network harmonization and Data Quality Objectives

The *primary objectives* of the GAW Quality Management Framework (QMF) are to ensure that the data in the World Data Centers, which are used in particular in support of decision making, are **consistent, of known and adequate quality**, supported by comprehensive metadata, and sufficiently complete to describe global atmospheric states with respect to spatial and temporal distribution.

- There is no central GAW database where requirements to the **network specification (x, y, z)** are stored. The only source of spatial requirements is IGACO strategy. These requirements are currently reflected in the OSCAR database
- "Numeric" requirements to the **quality of data** (uncertainty/compatibility, delivery time) are included in the measurement guidelines for individual parameters in the form of Data Quality Objectives (relevant to each individual station or network compatibility)
- The set of GAW observations application areas is to be clarified and approved by CAS this year and requirements are to be reviewed by SAG in a view of those applications.

# Central Facilities

**Five types** of central facilities:

- Central Calibration Laboratories (CCLs)
- Quality Assurance/Science Activity Centres (QA/SACs)
- World Calibration Centres (WCCs)
- Regional Calibration Centres (RCCs)
- World Data Centres (WDCs)