GAW Mountain Observatories in Detection of Atmospheric Changes

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Abstract

The Global Atmosphere Watch (GAW), the long-term global atmospheric chemistry programme of the World Meteorological Organization (WMO), focuses on greenhouse gases, ozone, UV, aerosols, selected reactive gases, and precipitation chemistry and their role in climate, weather, air quality and long range transport/deposition of air pollution. GAW is a partnership involving contributors from around 80 countries, and coordinating activities and data from 24 Global GAW stations, several hundred regional stations and about 20 contributing stations. Information on stations is available from the GAW Station Information System (GAWSIS). High altitude surface-based observatories on mountains, ice sheets or plateaus are a critical part of the GAW global atmospheric chemistry observation system. These include South Pole, Mauna Loa (Hawaii), Izana (Tenerife), Mt. Cimone (Italy), Jungfraujoch (Switzerland), Zugspitze-Hohenpeissenberg (Germany), Sonnblick (Austria), Mt. Waliguan (China), Assekrem (Algeria) and Mt. Kenya (Kenya). These stations are located in background areas where global climate change can be detected on one hand and, on the other they are located in separate air sheds and thus offer different perspectives on regional air chemistry and transport. Long-term observations are necessary to determine trends in atmospheric constituents. In addition, due to the need to detect small changes, the measurements require excellent accuracy, which is obtained through the WMO calibration and standardization facilities. The global networks are still incomplete and should be augmented with continuous measurements on the continents, the Arctic, the tropics, and the oceans. GAW products include the WMO Greenhouse Gas and Antarctic Ozone Bulletins.

Keywords: Mountain Observatories; Ozone; Halocarbon; Boundary Layer; GAW

Introduction

The Global Atmosphere Watch (GAW) programme was established in 1989 by the World Meteorological Organization (WMO) to address the issue of atmospheric change. GAW focuses on global long-term measurements of greenhouse gases (GHGs; CO_2, CH_4, N_2O, CFCs, etc.), ozone, UV, aerosols (chemical and physical properties, AOD), selected reactive gases (CO, VOC, NO_X, SO_2), and precipitation chemistry. It systematically monitors atmospheric chemical and physical parameters globally. In addition, GAW carries out analysis and assessments and develops predictive capacity.

▲ *Jungfraujoch Research Station, Switzerland, part of the GAW network.*

High mountain observatories are very suitable for the measurement of greenhouse gas trends. These stations are normally in the free troposphere (see below section Locating origin of air mass). GAW stations such as Mauna Loa (US), Mt. Waliguan (China), and Izana (Spain) are measuring the global background of for instance carbon dioxide (CO_2), which is constantly rising. It is very important to make long-term measurements, as otherwise one would not note changes that are significant in the decadal picture but small from year to year.

In this paper, a closer look is taken at ozone, at the tracing of air masses, and the detection of pollution hot-spots on GAW mountain observatories.

Trends in Tropospheric Ozone

Intensive analysis of surface ozone data combined with different primary trace gases and meteorological parameters at Hohenpeissenberg Meteorological Observatory led to the assumption that not local or regional, but rather supra-regional, hemispherical or even global increase of tropospheric ozone determine the increasing trend of the average values at the Hohenpeissenberg Observatory. This thesis is supported by the fact that also other stations in the northern hemisphere, to a large extent uninfluenced by regional effects, show increasing mixing ratios (*Figure 1*). There is no trend at Pallas (Finland), only a weak trend at Barrow (Alaska) and a somewhat stronger trend at Mauna Loa (Hawaii), but not as pronounced as at the Hohenpeissenberg. The neighboring station “Schauinsland” in the Black Forest (Germany) approximately on 1200 m a.s.l. along with the station Ryori (Japan), all in mid-latitudes, show a similar positive trend in ozone mixing ratios as the Hohenpeissenberg site. Also the high-alpine stations Jungfraujoch (Switzerland), Sonnblick (Austria) and Zugspitze (Germany) have similar upward gradients, though at higher concentrations caused by the higher elevation. The Zugspitze trend is somewhat more pronounced caused by the longer time series.

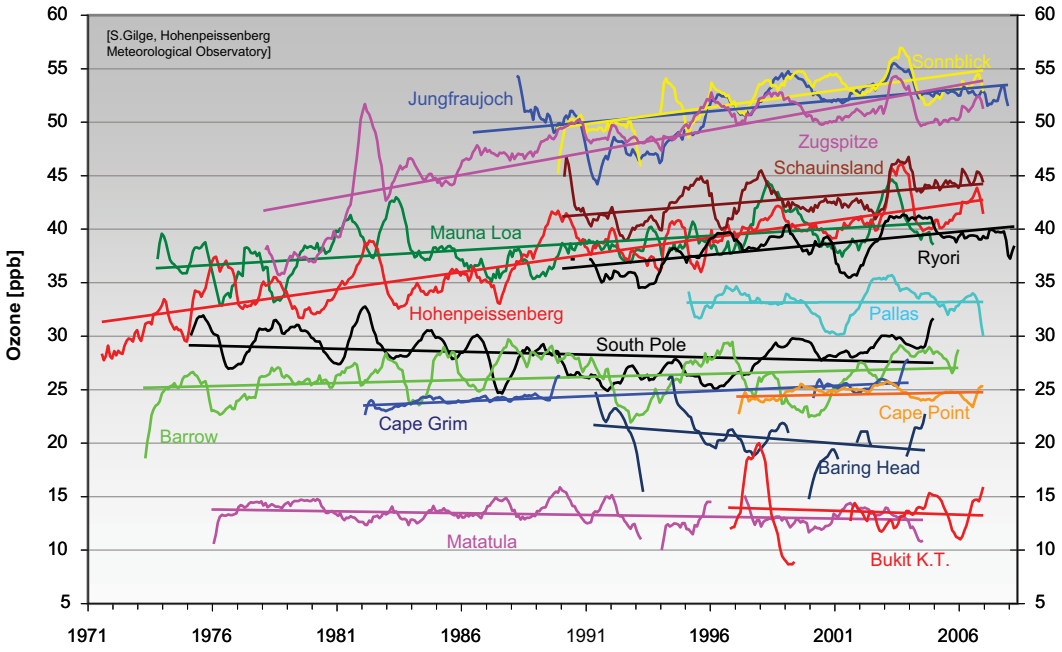

Figure 1: Time series (12 month running mean and linear trend) of near surface ozone at different GAW sites (Source: Gilge, 2007; World Data Centre for Greenhouse and Related Gases (WDCGG) of GAW programme, http://gaw.kishou.go.jp/wdcgg.html).

As expected, the temporal development at the South Pole station is independent of the trend in the northern hemisphere: with still an overall negative trend, the measured values have been slightly rising since the 1990s. The stations Bukit Koto Tabang (Indonesia) and Matatula, situated on 14° S in the Pacific, show a weak decrease besides a very small concentration level. Also Baring Head (New Zealand), situated in the moderate latitudes of the southern hemisphere, shows a downward trend in mixing ratios. The sites Cape Point (South Africa) and Cape Grim (Australia) show a slightly increasing trend. Unfortunately the southern hemisphere data are limited and the existing time series are sometimes interrupted.

In summary, the stations at the moderate latitudes in the northern hemisphere (where most of the anthropogenic emissions take place) show a positive trend, which cannot be observed in the southern hemisphere and in high latitudes of northern hemisphere.

Locating Origin of Air Mass

At high altitude stations free tropospheric conditions prevail normally. However, this is not always true and it is important to note during which time of the year and at which time of the day measurements are taken. To properly assess this challenge, a study based on aerosol climatology has been car-

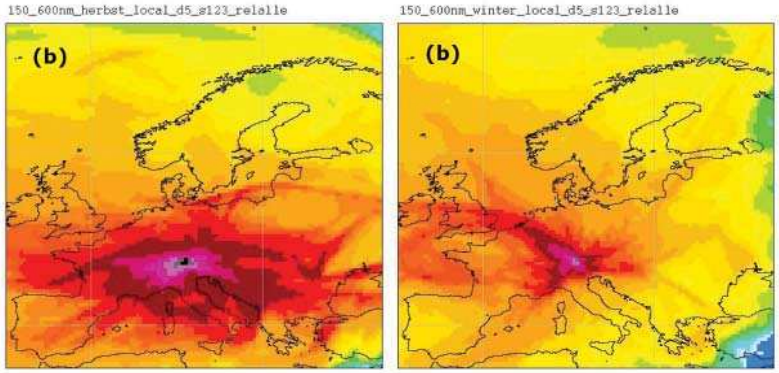

Figure 2: Source receptor relationships, boundary layer, left during autumn, right during winter at Zugspitze, Germany.

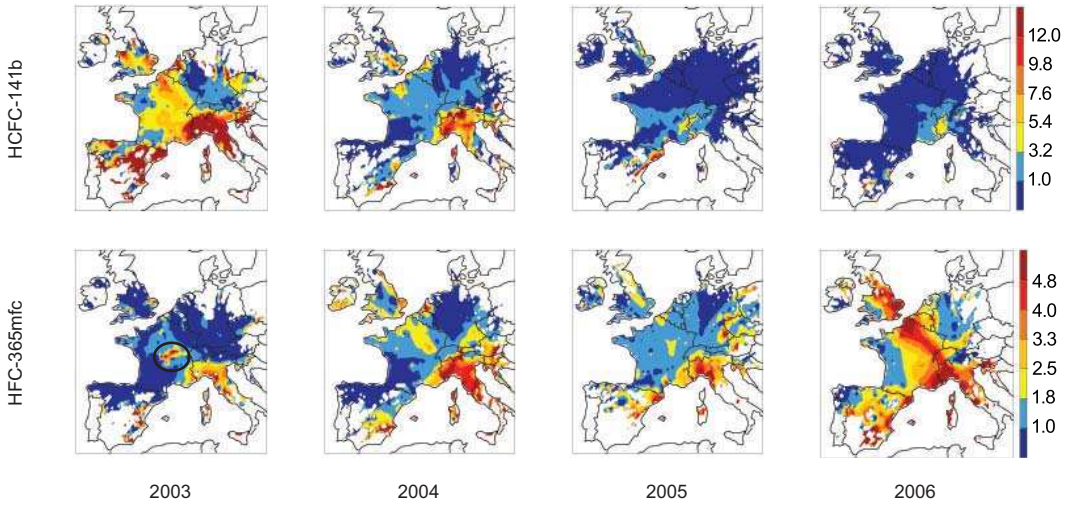

Figure 3: Distribution of HCFC-141b (top) and HFC-365mfc (bottom) between 2003 and 2006 as detected at Jungfraujoch. For HCFC-141b, the pollution strength is decreasing in most regions after this compound has been banned in 2003. HFC-365mfc, on the other hand, has been increasingly used as substitute for HCFC-141b after 2003. The result is an increased pollution strength of this halocarbon in many regions in Europe. The circle in the bottom left figure indicates the factory in France, which was the only producer of HFC-365mfc in 2003. Units are relative to the smallest emissions, having a given value of 1 (in blue).

ried out at Zugspitze, Germany, where GAW has two stations at 2650 m a.s.l. and 2950 m a.s.l. This study shows that Zugspitze station usually lays above the atmospheric boundary layer from October to February. Conditions of the lower free troposphere can be measured especially well during this time at night from 22h in the evening to 6h in the morning. During summer season, on the other hand, convection occurs usually starting at noon bringing up air masses with more particles from below the boundary layer. The measured particle number concentration is closely connected with the daily duration of radiation input (maximum at about 21st June) and not with temperature. The lowest particle number concentrations are then again observed during nighttime with a typical particle number concentration of 1500 P./cm^3 showing the influence of the continental boundary layer. For other times of the year the influence of the maritime boundary layer results in a typical particle number concentration of 1000 P./cm^3. A typical value for air from free troposphere is 500 P./cm^3.

Measurements on particle number concentrations for particles between 10 nm and 800 nm were carried out from December 2004 to February 2008. The evaluation of this data accompanied by continuous transport modeling (Flexpart simulation, Prof. A. Stohl, Nilu) shows that the accumulation mode, which is based on aged air masses and usually transported a longer distance, receives quantitative contributions from the following source regions: Central Europe, including alpine region over 33%; Western, Southern, and Eastern Europe, each slightly below 20%; northern Europe, Atlantic, each below 5% (*Figure 2*). This result is valid during spring, summer and autumn when measurements are taken at noon time. It is not applicable for winter time as Zugspitze is then laying above the boundary layer.

The largest fraction of particles arrives from the European boundary layer or from the North Atlantic. Especially low number concentrations occurred with recent air or fast moving Atlantic air. High values, on the other hand, were measured in stationary air over the European continent. Maximum values were transported from Eastern European air. Despite of those high concentrations, the statistical influence on the mean number concentrations at Zugspitze was quite limited. Long range transport from distant continents only happen sporadically and show a low contribution to the annual mean values.

Locating Sources of Pollution

Measurements of a compound can be combined with trajectories to locate potential sources. Trajectory analysis looks at the route of the air mass to determine its origin. At Jungfraujoch, Switzerland, 3580 m a.s.l., a closer look has been taken at two halocarbons, HCFC-141b, which was banned in 2003, and its substitute HFC-365mfc (pentafluorobutane, Stemmler *et al.,* 2007). *Figure 3* (top row) shows that the pollution strength of HCFC-141b is decreasing in many regions in Europe after its ban. The pollution strength of HFC-365mfc, on the other hand, increased in many regions after its increased use as substitute (bottom row). The study could detect a factory in France, which was the only HFC-365mfc manufacturing site globally in 2003.

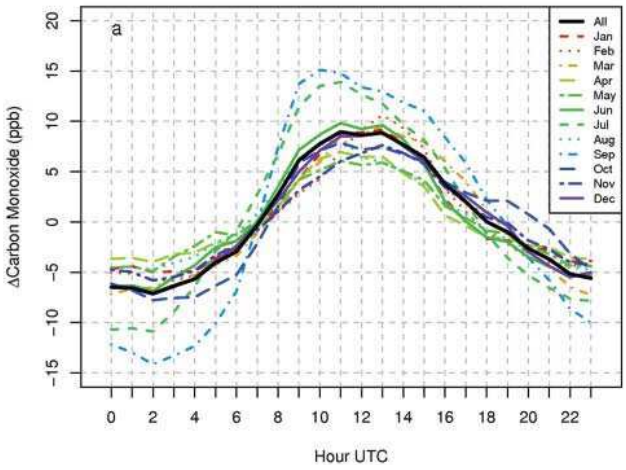

Figure 4: CO (ppb) diurnal cycle by season at Mt. Kenya GAW station for the period 2002-06 to 2006-06 (Source: Henne et al., 2008b).

Mount Kenya

As part of GAW the Kenyan Meteorological Department maintains a station at Mt. Kenya, (37.297° E, 0.062° S, 3678 m a.s.l.). Mt. Kenya exhibits a strong diurnal cycle all over the year. This is typical for mountains influenced by the atmospheric boundary layer during day-time. Slope winds dominate the site, carrying boundary layer air towards the top during day-time. Measurements on carbon monoxide (CO), which is not a greenhouse gas but strongly influences atmospheric chemistry, clearly show this diurnal cycle for all months (*Figure 4*). The wind flow is generally up the slope during day-time, carrying up CO, emitted within the atmospheric boundary layer, towards the top. During night time, the general wind direction is down-slope, carrying lower CO mixing ratios that are representative for the lower free troposphere (Henne *et al.,* 2008a). Henne *et al.* (2008b) illustrate that most of the air masses arriving at Mt. Kenya originate from the Indian Ocean, Southern and Eastern Africa and the Arabian Peninsula. Hardly any air is reaching Mt. Kenya from western or northern Africa. The site is only seldom directly influenced by pollution from biomass burning (the most important air pollution source in Africa) and therefore offers important baseline measurements in this data sparse region of the world.

Conclusion

Mountain observatories give a good picture of the chemical composition of the free troposphere and therefore provide relevant knowledge for climate change studies. Every station, however, has its individual characteristics, which is evident from pollutant source studies, diurnal and seasonal variations, and from observing the life cycles of chemicals.

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