Overview

- Laboratory Air Pollution / Environmental Technology
- Measurement Programme @ Jungfraujoch

Examples of results
- Detection of Trends / success of reduction measures
- Emission Estimations
- Analysis of Global Change impacts / Early warning

Future Activities
Lab’s Approach

Measurements & Models

- **Trace gas detection**
  (low concentrations: ppq = 10^{-15})

- **Flux measurements**
  (spectra @ kHz)

- **Satellite data**
  (OMI column; 24 x 13 km²)

Goals

- **Emission Estimation**
- **Long-range Transport**
- **Trend Analysis**

**Lab’s Approach**

- **MEDUSA**
  - Interspecies correlation
    (known emission inventory)
  - Inverse modelling
    (Lagrangian Particle Dispersion model)
  - Statistical Approaches
    (receptor models)

\[
x_{ij} = \sum_p \tilde{g}_{ip} \tilde{f}_{pj} + \sum_{p'} \tilde{g}_{ip'} f_{q} + e_{ij}
\]
Jungfraujoch – NETWORKS: CH, EU, world

Swiss Air Pollution monitoring network, NABEL

Global Atmosphere Watch, GAW, WMO

AGAGE

Advanced Global Atmospheric Gases Experiment

Materials Science & Technology
## Jungfraujoch: Greenhouse Gases & Reactive Gases

<table>
<thead>
<tr>
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<th>Recommended for GAW</th>
<th>Jungfraujoch</th>
<th>funding</th>
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<tr>
<td><strong>Greenhouse gases</strong></td>
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<tr>
<td>CH₄</td>
<td></td>
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<td>NABEL (FOEN, Empa)</td>
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<td>N₂O</td>
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<td>NABEL (FOEN, Empa)</td>
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<td>CFCs</td>
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<td>HCFCs, HFCs</td>
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<td>SF₆</td>
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<td>NABEL (FOEN, Empa)</td>
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<tr>
<td>CO₂</td>
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<td><strong>Reactive gases</strong></td>
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<td>VOCs</td>
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<td>PAN, HNO₃, OVOCs, H₂</td>
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<td>Empa, ETH Zurich, NABEL (FOEN, Empa)</td>
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*Note: The table indicates the presence or absence of measurements for each gas at Jungfraujoch.*
Non - CO2- Greenhouse Gases

Montreal Protocol

• CFCs: Fluorochlorocarbons:
  CFC-11, CFC-12
  CFC-113

• HCFCs: Hydrofluorochlorocarbons
  HCFC-141b, HCFC-124, HCFC-22, HCFC-142b,

• Halones: (containing bromo-atoms):
  H-1301, H-1211

• 1,1,1-Trichloroethane
• Carbon tetrachloride (CCl₄)

Kyoto Protocol

• HFCs: Hydrofluorocarbons:
  HFC-125, HFC-134a
  HFC-152a, HFC-23
  HFC-365mfc, HFC-245fa
  HFC-227ea

• PFCs: perfluorocarbons
  CF₄, C₂F₆

• SF₆: sulfur hexafluoride:
**Jungfraujoch (Switzerland)**

Global fixed station in WMO RA VI - Europe

46.5469N 7.3879E (3580 m a.s.l.)

**Description**

The high alpine research station Jungfraujoch is situated on a mountain saddle between the two mountains Jungfrau (4158m asl) and Monch (4099m asl). The station is located in the center of Europe at an altitude of 3580m asl and is surrounded by highly industrialized regions at much lower altitudes. This special geographical situation offers the opportunity to monitor background concentrations but also to investigate the transport of anthropogenic pollutants from the boundary layer to the free troposphere.

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**Measurement Program**

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<th>Type</th>
<th>Parameter</th>
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<th>End</th>
<th>Details</th>
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<td>Light scattering coefficient</td>
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<td>Sun-tracking photometry</td>
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Trend Detection for Protocol Verification

**Sulfur dioxide SO₂**

**Acid Rain**

**CFCs**

**Ozone Depletion**

**Greenhouse Gases**

**Global Warming**

**"OECD – Program"**

**Montreal - Protocol**

**Kyoto - Protocol**

- **SO₂ (µg/m³)**

- **HFC 134a**
- **1,1,1-Trichlorethan**

- **+ 0.6 mW/m²/y**
- **- 0.3 mW/m²/y**
Longest records at JFJ

Sulphate [µg/m³]

TSP [µg/m³]

Jungfraujoch
JFJ CO time series (one hourly data) from 1996 to 2007 - The light blue curve represents a fitted baseline and the orange line the trend (after Thoning, et al., 1989, Novelli, et al., 1998; Novelli, et al., 2003)

- 21.3% carbon monoxide decrease from 1996 to 2007 at JFJ
- Corresponds to an annual decrease of 1.78% - or 2.66 ppb/year
CO – Emissions Inventories vs. Measurements

- CO decrease mainly because of reduction of emissions
- Traffic influenced sites in Switzerland (BER, LAU) show strongest CO decrease
- Decrease at JFJ less pronounced, most likely due to influence of long-range transport
- Global scale events, e.g. enhanced biomass burning in 1998, is visible in JFJ data

JFJ is well situated to study both large-scale changes and regional air quality
Contributions of European countries

- Switzerland: 30%
- France: 26%
- Italy: 23%
- Germany: 12%
- United Kingdom: 6%
- Spain: 2%
- Other Countries: 1%

Carbonmonoxide @ Jungfraujoch (Jun 02 – Dez 04)
An advection of clean maritime air masses from low northern latitudes led to low CH$_4$, CO, and CHCl$_3$ and elevated H$_2$ mixing ratios on October 1$^{st}$. 
CH$_4$ at JFJ - Influence of Air Mass Origin

Measurements + Trajectories

Jungfraujoch only
CH$_4$ at JFJ - Influence of Air Mass Origin

Measurements + Trajectories

Jungfraujoch only

WMO WDCGG data summary, WDCGG report #30 (2006)
CH4 and N2O at JFJ and AGAGE sites

MC: Mace Head (53°N); JFJ (46°N), TH: Trinidad Head (41°N); RP: Ragged Point, Barbados (13°N); CM: Cape Matatula, American Samoa (14°S); CG: Cape Grim (40°S).
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- PFCs: perfluorocarbons
  - CF₄, C₂F₆

- SF₆: sulfur hexafluoride:
Influence of the Montreal-Protocol on Climate

$\text{CH}_3\text{CCl}_3$
Trichlorethan

CFC-12

Steinacher et al. 2008
Renewed European emissions of HCFC-141b?

HCFC 141b banned in Europe since 2003

Jungfraujoch (CH)  Mace Head (IRE)  Ny-Alesund (N)

Renewed European emissions of HCFC-141b?
Foam blowing agent HFC-152a: Emissions from Europe

National Communications to UNFCCC

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<td>Spain</td>
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<td>Spain</td>
<td>177 t</td>
<td>187 t</td>
<td>170 t</td>
<td>113 t</td>
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Benefit of long-term series compared to short-term campaigns

Ozone-destroying trichloroethane

Air-plane Campaign W-Europe
Air-plane Campaign Creta
according to campaigns and long-term measurements

0.3 - 3.4 Gg/Jahr
4 years continuous measurements
Jungfraujoch / Mace Head

> 20 Gg/year
4 days aircraft observations above Europe

Reimann et al., Nature (2005)
**Independent verification of Emissions**

**European H(C)FCs emissions: Jungfraujoch vs. inventories**

![Bar chart showing emissions of HFC-134a, HFC-125, HFC-152a, and HCFC-141b from 2000 to 2006. The chart compares emissions from Jungfraujoch with EU inventories.](chart.png)

- **HFC-134a**: 2000-2006 emissions
- **HFC-125**: 2000-2006 emissions
- **HFC-152a**: 2000-2006 emissions
- **HCFC-141b**: 2000-2006 emissions

**Detailed Emissions Data**

- **HFC-134a**
  - 2000: 20 kt/year
  - 2001: 22 kt/year
  - 2002: 24 kt/year
  - 2003: 26 kt/year
  - 2004: 28 kt/year
  - 2005: 30 kt/year
  - 2006: 32 kt/year

- **HFC-125**
  - 2000: 4.5 kt/year
  - 2001: 5.5 kt/year
  - 2002: 6.5 kt/year
  - 2003: 7.5 kt/year
  - 2004: 8.5 kt/year
  - 2005: 9.5 kt/year
  - 2006: 10.5 kt/year

- **HFC-152a**
  - 2000: 3.5 kt/year
  - 2001: 4.5 kt/year
  - 2002: 5.5 kt/year
  - 2003: 6.5 kt/year
  - 2004: 7.5 kt/year
  - 2005: 8.5 kt/year
  - 2006: 9.5 kt/year

- **HCFC-141b**
  - 2000: 10.5 kt/year
  - 2001: 11.5 kt/year
  - 2002: 12.5 kt/year
  - 2003: 13.5 kt/year
  - 2004: 14.5 kt/year
  - 2005: 15.5 kt/year
  - 2006: 16.5 kt/year

**Source**

Air Pollution/Environmental Technology Laboratory

Materials Science & Technology Laboratory
New foam blowing HFCs at Jungfraujoch

- HFC-245fa (pentafluoropropane)
- HFC-365mfc (pentafluorobutane)

Air Pollution/Environmental Technology Laboratory
Instrument development
(fast and high-precision (QCL) laser spectroscopy)

CH$_4$, N$_2$O, CO$_2$, H$_2$O, NO$_2$

$^{13}$C$^{16}$O$^{16}$O, $^{12}$C$^{18}$O$^{16}$O, $^{14}$N$^{15}$N$^{16}$O, $^{15}$N$^{14}$N$^{16}$O

Simulated $\nu_3$ ro-vibrational bands of the CO$_2$
JFJ future Atmospheric ICOS site?

First time continuous time series of CO₂ Isotopes

ICOS: Integrated Carbon Observation System: Ecosystem & Atmospheric Sites: ESFRI
Atmospheric Site: CO₂, 13CO₂, 18CO₂, CH₄, N₂O, H₂, O₂/N₂, SF₆, 222Radon,

CH Funding for Long-term EU infrastructure Programme (ESFRI): ?
Current Cooperations

Greenhouse Gases & Reactive Gases

University of Bern

MeteoSwiss

PSI

ETHZ (Lohmann)

ETHZ (Peter, Stählein)

GIRPAS

BIRA

AGAGE
MIT, CSIRO, SCRIPPS, University of Bristol

Materials Science & Technology
Papers Jungfraujoch 2007-2008


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and

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- MeteoSwiss, BAFU, SNF
- all research partner AGAGE/NOAA team