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b  
UNIVERSITÄT  
BERN

OESCHGER CENTRE  
CLIMATE CHANGE RESEARCH

**HFSJG**  
Hochalpine Forschungsstationen  
**Jungfraujoch & Gornergrat**

# Today's activity at Jungfraujoch

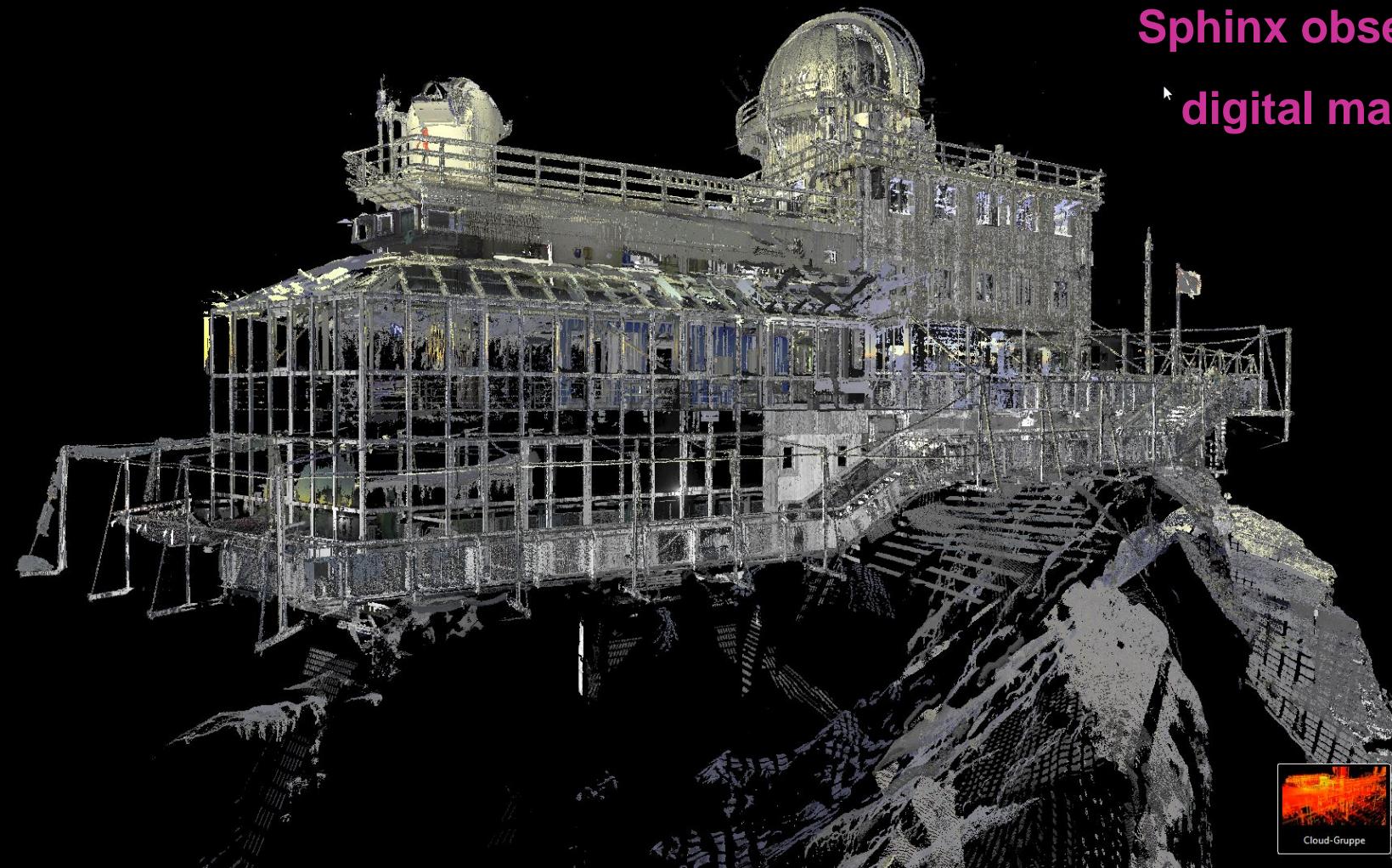
**Jungfraujoch: EPS Historic Site 2019**  
**Symposium, February 7<sup>th</sup>, 2019**

Markus Leuenberger<sup>1,2</sup>  
HFSJG Team and diverse Research Institutes

- (1) Internationale Stiftung High Altitude Research Station Jungfraujoch and Gornergrat (HFSJG)
- (2) Climate and Environmental Physics, Physics Institute, University of Bern and Oeschger Centre for Climate and Climate Change Research

# Sphinx observatory

## digital mapping



Cloud-Gruppe

# Tourism

>1'000'000  
Visitors/year



# Science

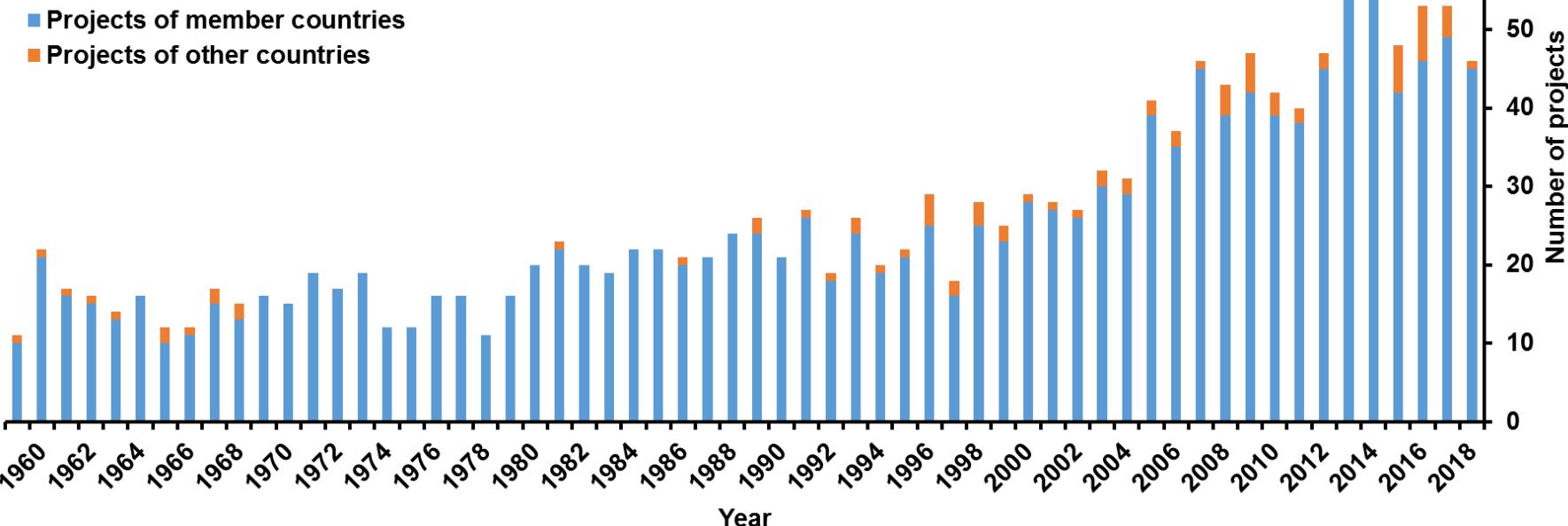
~1000 person-  
days/year

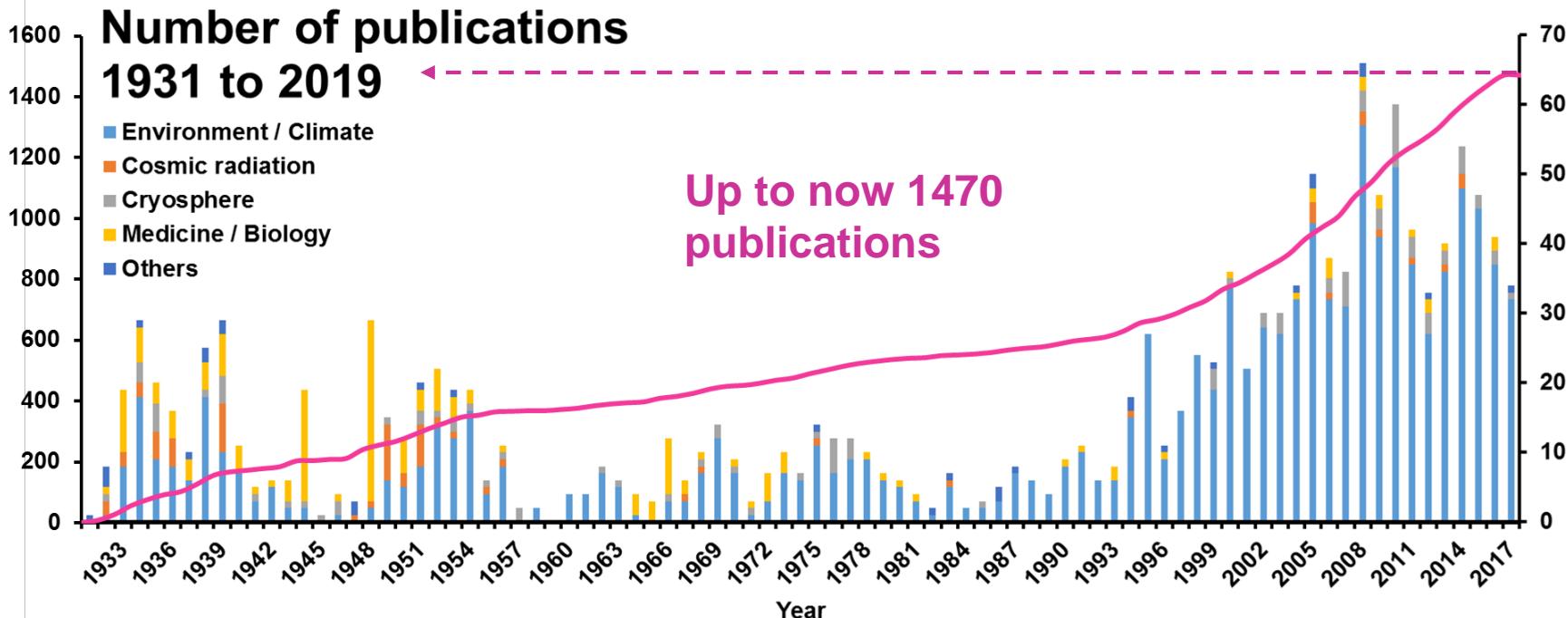
**HFSJG**

High Altitude Research Stations  
**Jungfraujoch & Gornergrat**

# Number of Projects at Jungfraujoch

## 1959 to 2019





# Jungfraujoch – International Monitoring



**GAW:** Global Atmosphere Watch of WMO

**NABEL:** National Air Pollution Monitoring Network

**AGAGE:** Advanced Global Atmospheric Gases Experiment

**EMEP :** European Monitoring and Evaluation Programme

**ICOS:** Integrated Carbon Observation System

**ACTRIS:** European Infrastructure for the observation of Aerosol, Clouds, and Trace gases

# Trace gases in the Atmosphere

Lukas Emmenegger, Martin Steinbacher und viele andere  
Empa (Federal Laboratory for Material Science and Technology)  
Labor für Luftfremdstoffe / Umwelttechnik



Materials Science & Technology

# Reactive und Greenhouse Gases @ Jungfraujoch

More than 70 continuous time series

**Halogenated  
Hydrocarbons**

Montreal & Kyoto  
Protokolle

**Greenhouse  
Gases**

$\text{N}_2\text{O}$     $\text{CH}_4$     $\text{CO}_2$   
 $^{13}\text{C}$  &  $^{18}\text{O}$  in  $\text{CO}_2$

**Reactive  
Gases**

Ozone   CO    $\text{SO}_2$   
 $\text{NO}_2$    NO    $\text{NOy}$   
H<sub>2</sub>   VOC



Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra

Bundesamt für Umwelt BAFU

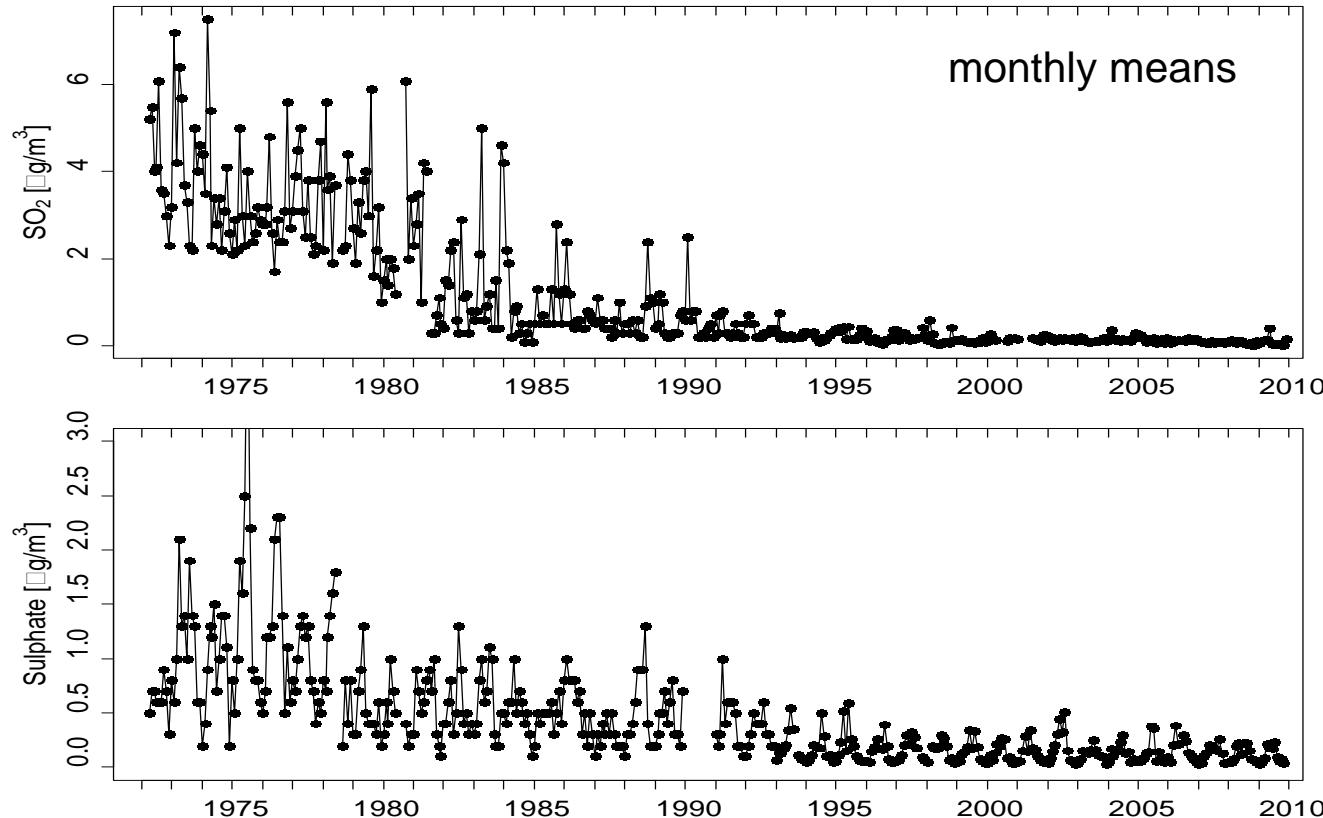


FONDS NATIONAL SUISSE  
SCHWEIZERISCHER NATIONALFONDS  
FONDO NAZIONALE SVIZZERO  
SWISS NATIONAL SCIENCE FOUNDATION

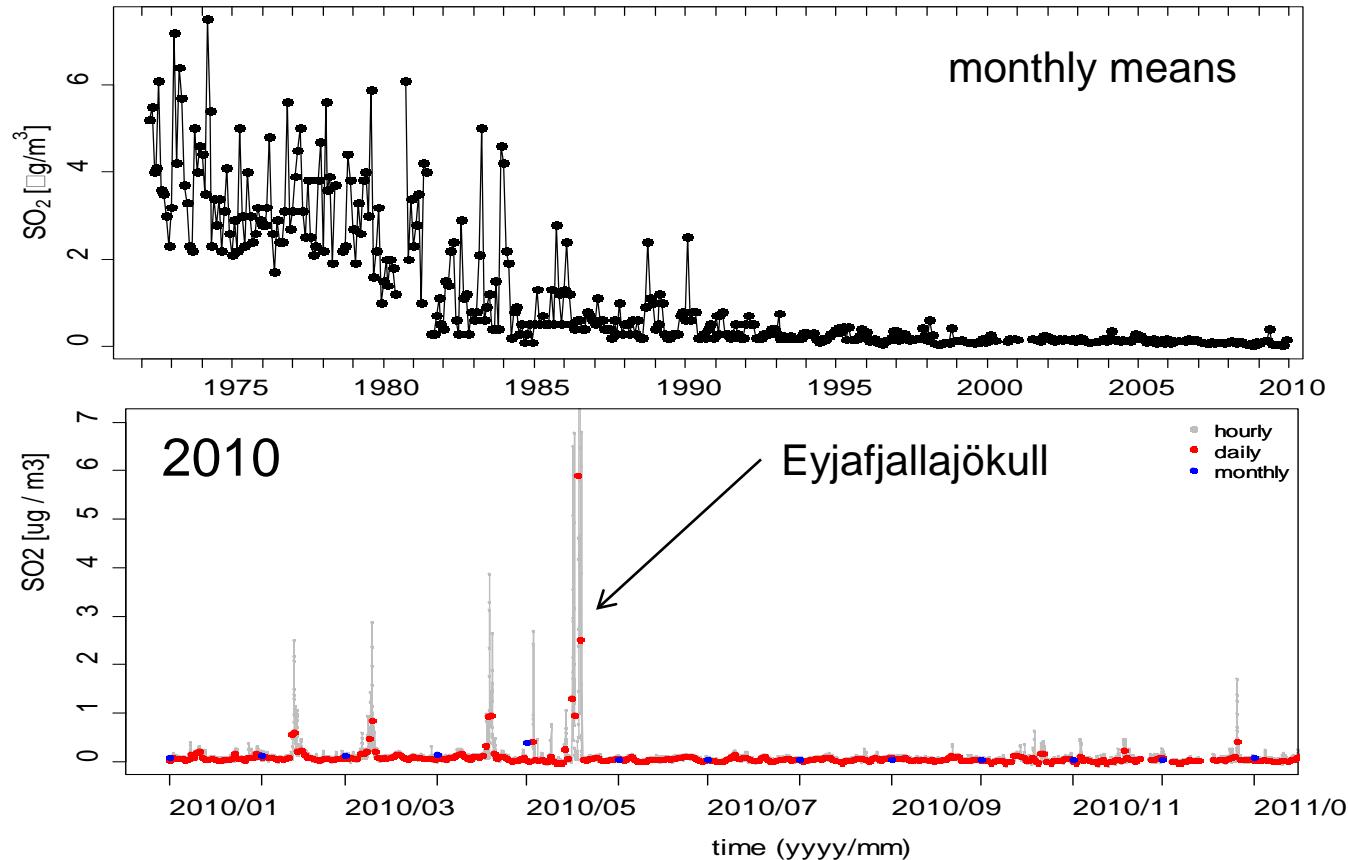


Materials Science & Technology

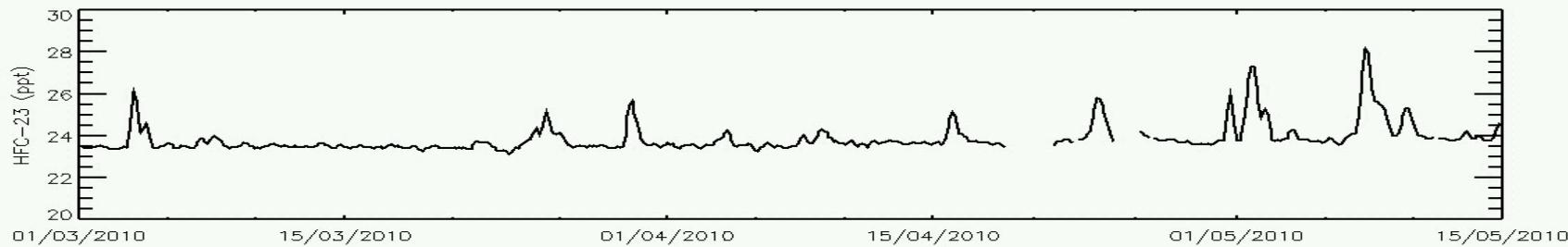
# Longest time series at Jungfraujoch



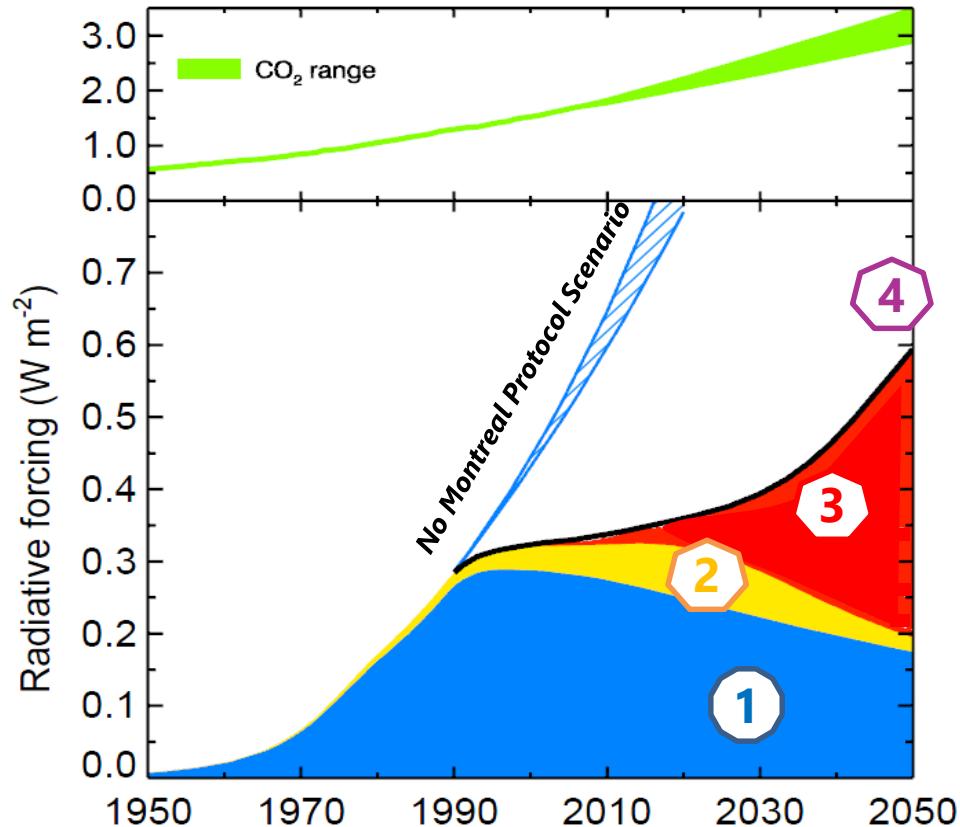
# Longest time series at Jungfraujoch



# Measurements and source regions, e.g HFC-23 (Fluoroform)



# Four generations of halogenated Hydrocarbons



4<sup>th</sup> generation halocarbons  
(HFOs)

3<sup>rd</sup> generation halocarbons  
(F-gases = HFCs, PFCs, others)

2<sup>nd</sup> generation halocarbons  
(HCFCs)

1<sup>st</sup> generation halocarbons  
(CFCs)



# Four generations of halogenated Hydrocarbons

## 1. Generation

## 2. Generation

## 3. Generation

## 4. Generation

### Montreal Protocol

CFCs, Halons  
 $\text{CCl}_4$ ,  $\text{CH}_3\text{CCl}_3$ ,  
 $\text{CH}_3\text{Br}$

HCFCs

HFCs  
PFCs

HFOs

Ozone destroying substances

Kyoto  
Protocol

### Greenhouse gases

#### **Chlorofluoro- carbons**

CFC-11	H-1211
CFC-12	H-1301
CFC-13	H-2402
CFC-113	$\text{CH}_3\text{CCl}_3$
CFC-114	$\text{CCl}_4$

#### **Hydrochlorofluoro- carbons**

HCFC-21	HCFC-133a
HCFC-31	HCFC-124
HCFC-22	HCFC-132b
HCFC-141b	
HCFC-142b	

#### **Hydrofluorocarbons Perfluorocarbons**

HFC-23	SF6
HFC-32	CF4
HFC-134a	PFC-116
HFC-125	PFC-218
HFC-245fa	PFC-318
HFC-365mfc	others

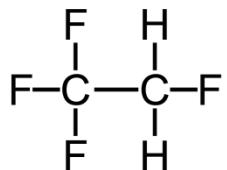
#### **Hydro(chloro)fluoro- olefines**

HFO-1234yf
HFO-1234zeE
HCFO-1233zdE

# Reduce HFC Emissions



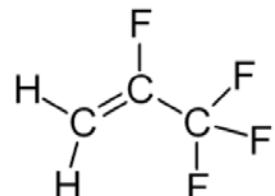
**HFC-134a**



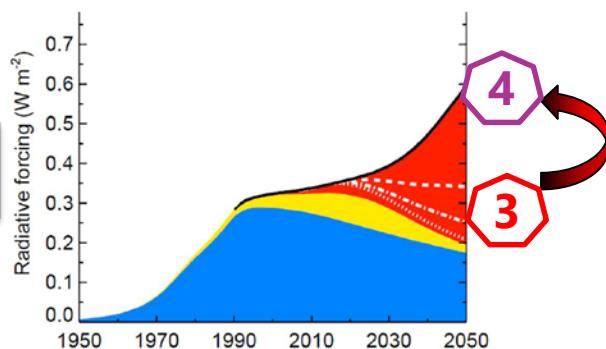
Atmospheric lifetime: 14 years  
GWP<sub>100</sub>: 1500

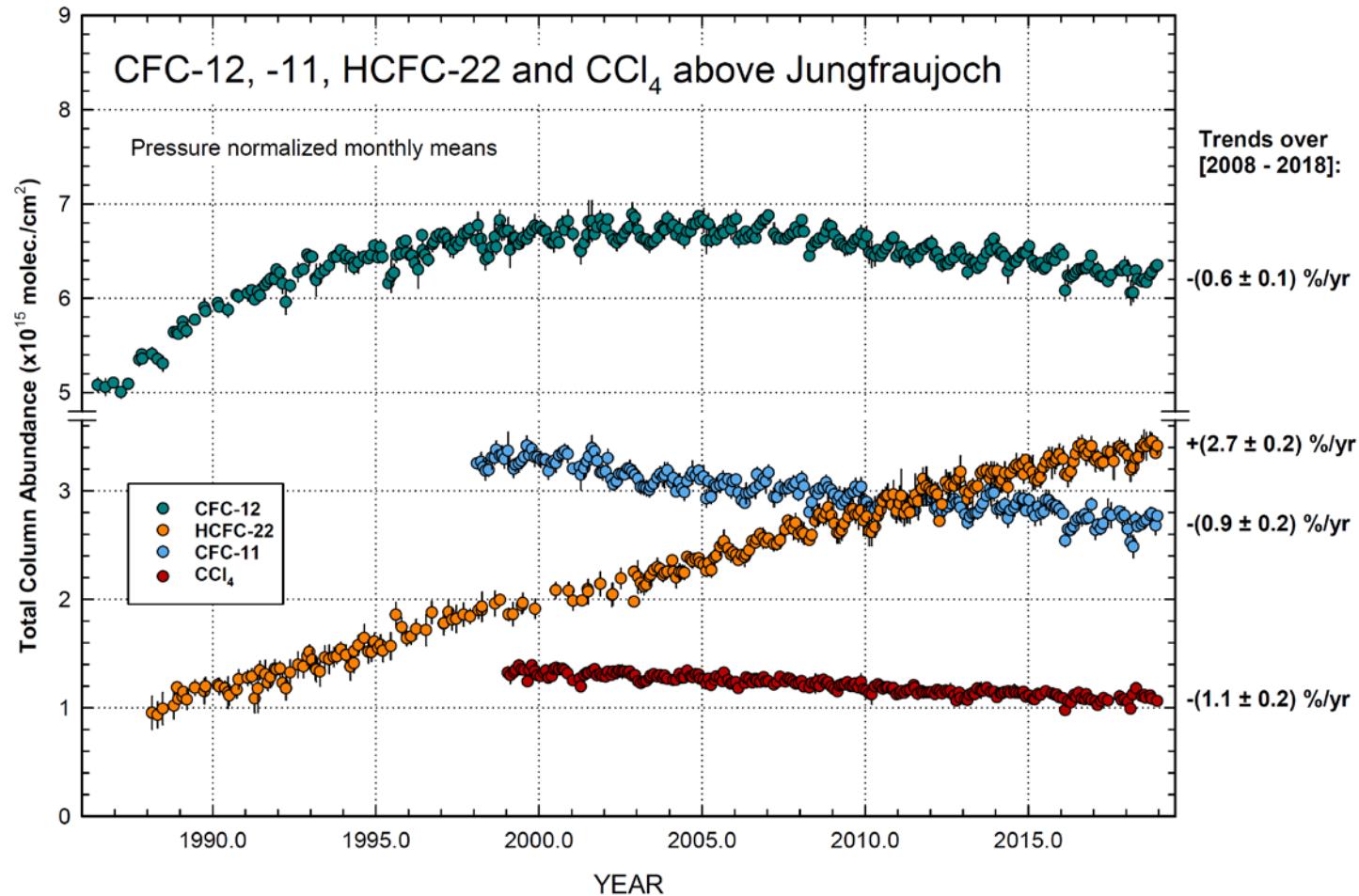
## Short-lived HFOs (Hydrofluoro-olefines)

**HFO-1234yf**

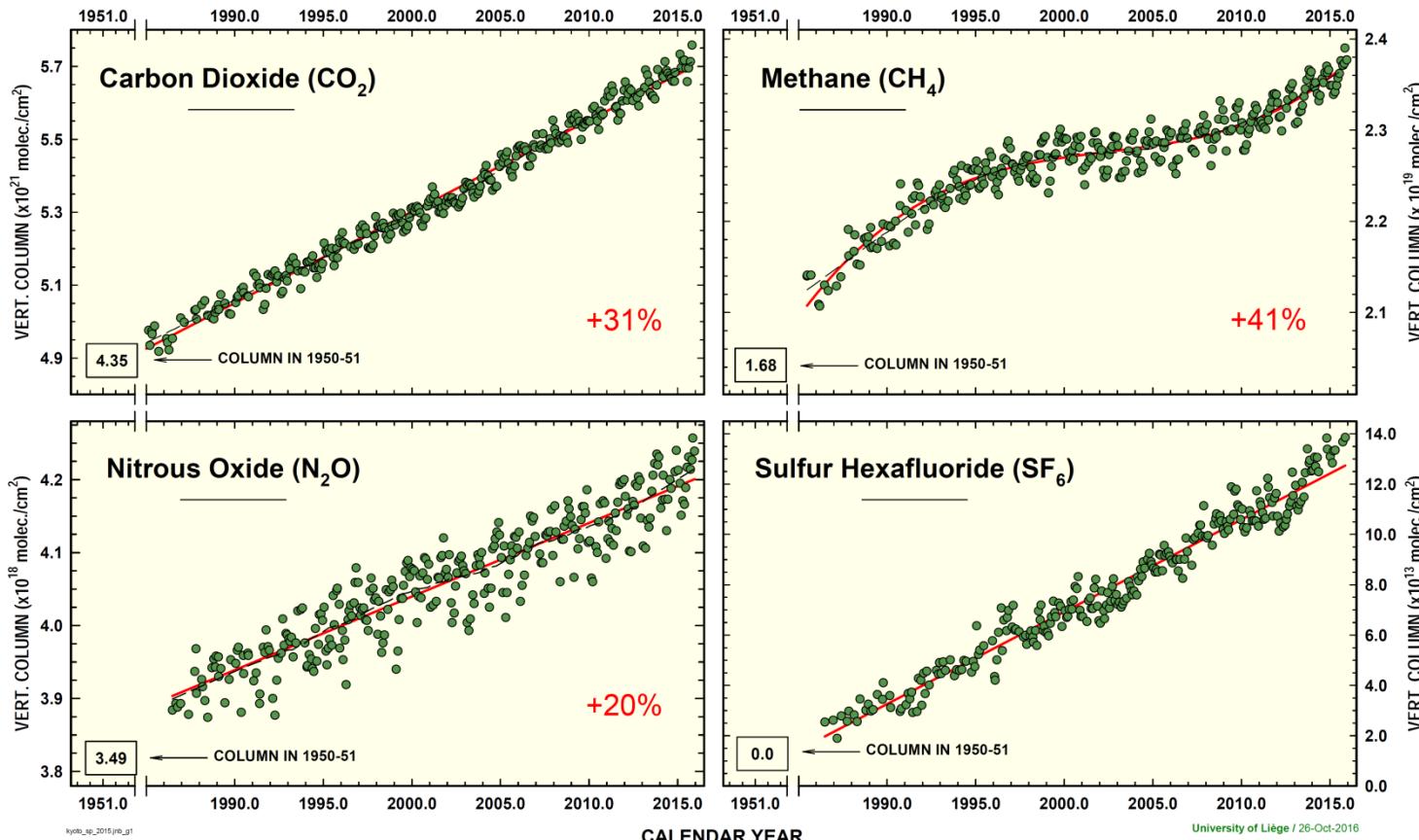


Atmospheric lifetime: 8-16 days  
GWP<sub>100</sub>: <1





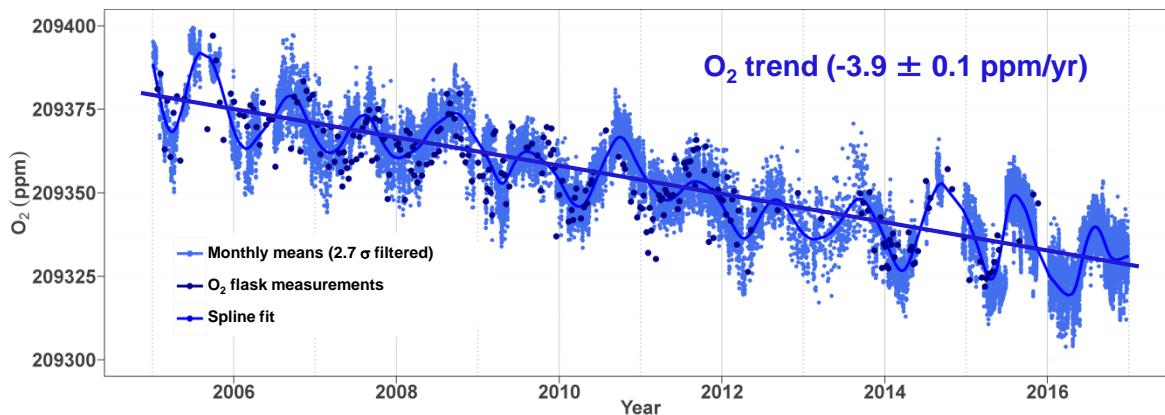
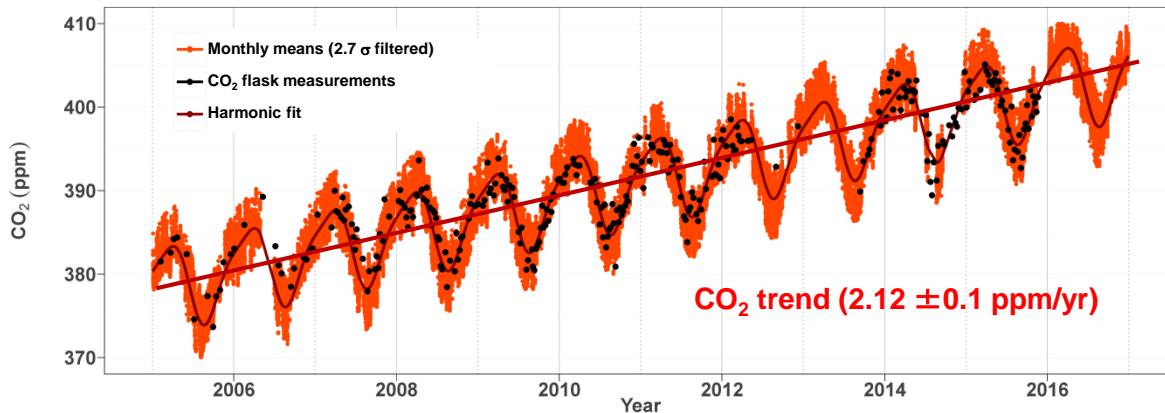
## KYOTO-PROTOCOL RELATED MEASUREMENTS AT THE JUNGFRAUJOCH



# Flask and in-situ CO<sub>2</sub> and O<sub>2</sub> measurements

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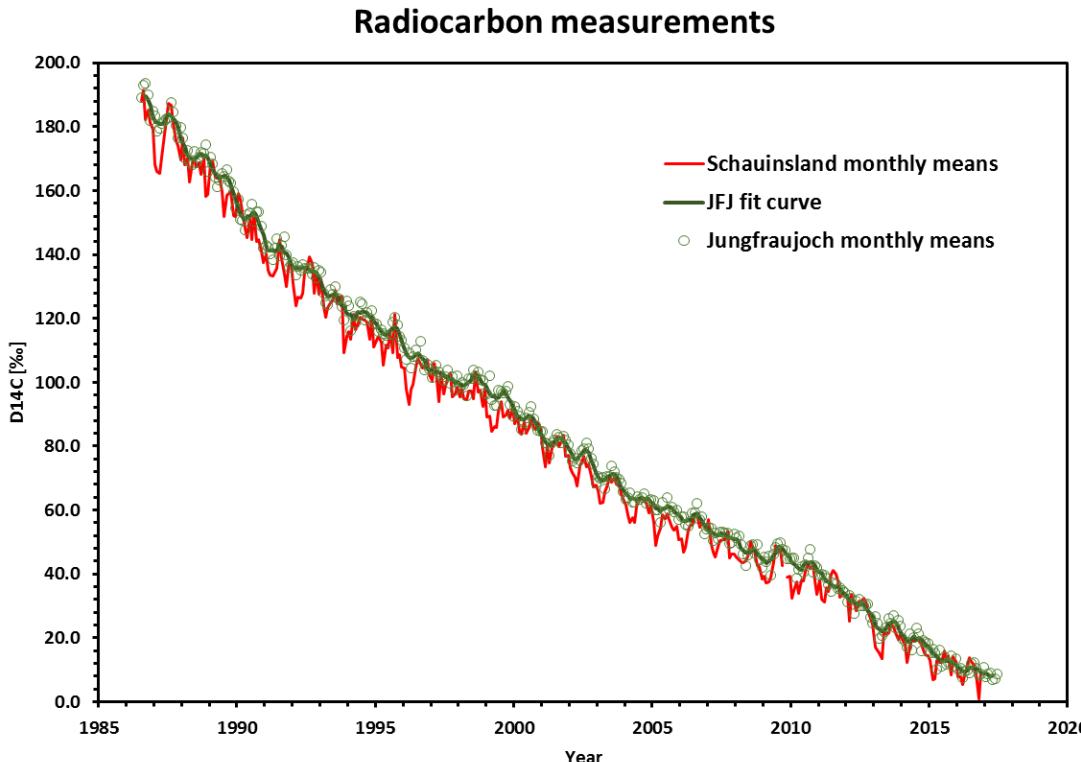


Linked cycles  
Carbon – Oxygen

through

- Fossil fuel combustion (long-term trend)
- Photosynthesis-Respiration (seasonality)

# Radiocarbon measurements



I. Levin, University of  
Heidelberg, Germany

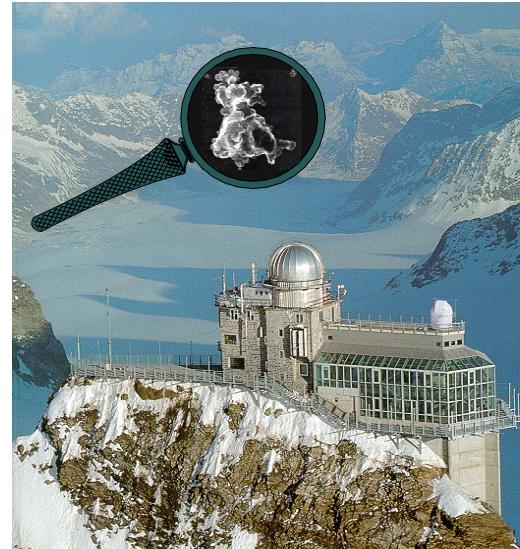
now part of ICOS

# Aerosols at the Jungfraujoch: Properties, trends and aerosol-cloud interaction

Urs Baltensperger and his group

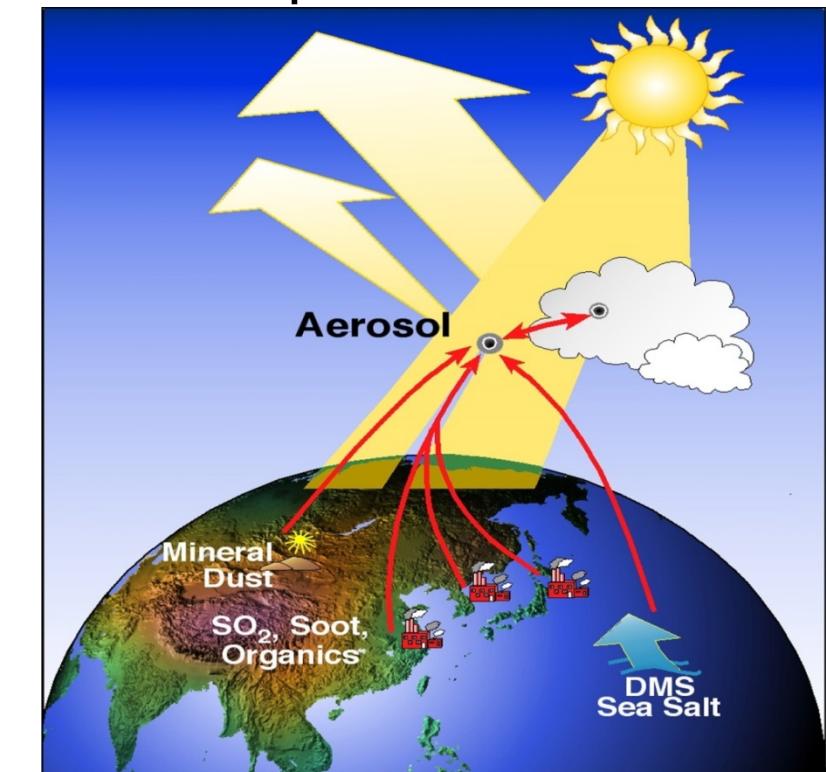
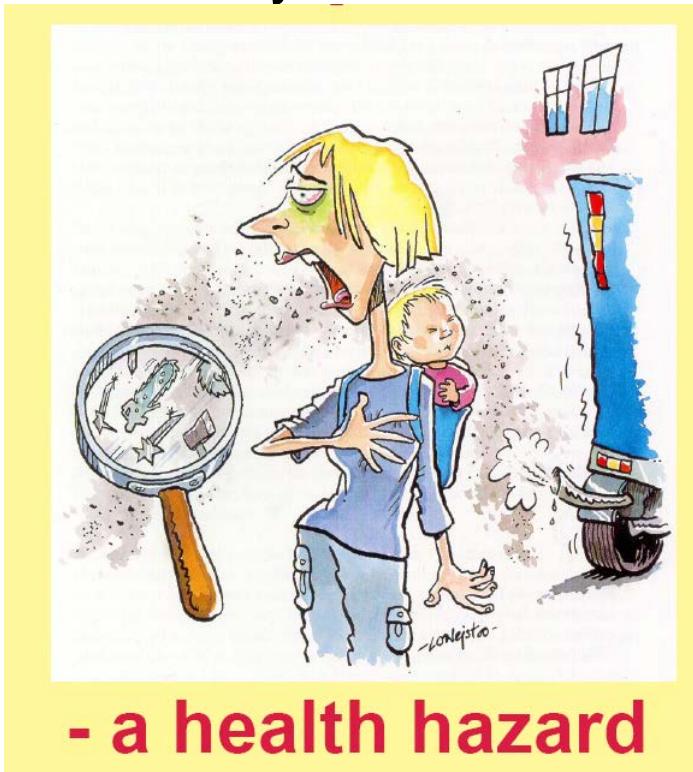
Laboratory of Atmospheric Chemistry

Paul Scherrer Institute, 5232 Villigen PSI, Switzerland



# Aerosols are solid or liquid particles in the atmosphere

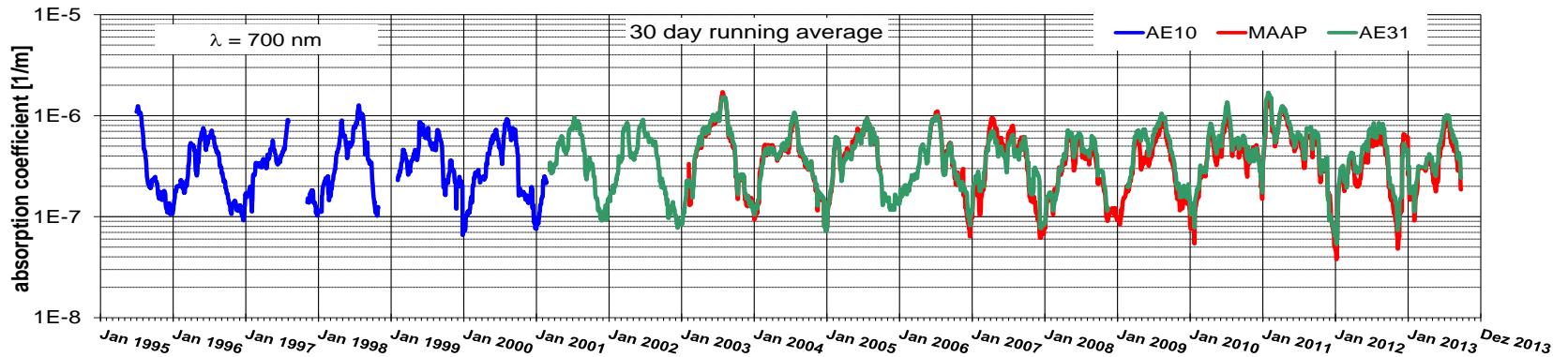
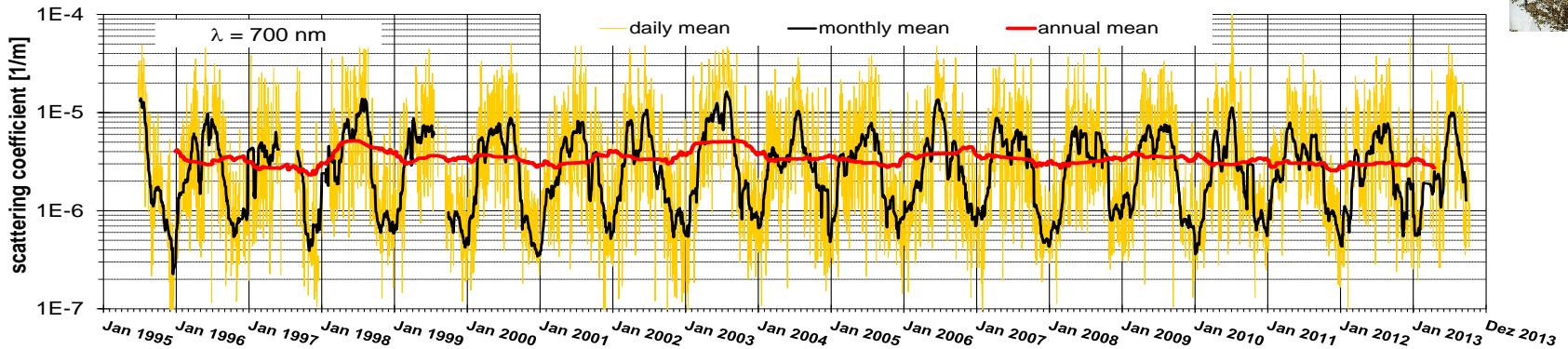
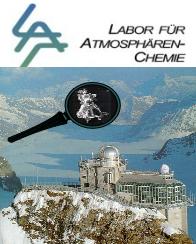
They affect our health and have an impact on climate



Source: [www.ecocouncil.dk](http://www.ecocouncil.dk)

<http://saga.pmel.noaa.gov/aceasia/>

# 20 years of continuous data at the Jungfraujoch, there are only very few stations with a similar long record





How to build a better battery  
through nanotechnology p. 1046

Making gene therapy  
affordable p. 1059

Colitis risk determined by  
genes and microbes p. 1116

# Science

\$15  
27 MAY 2016  
[sciencemag.org](http://sciencemag.org)



## THE BIRTH OF CLOUDS

How new particles form in the free troposphere p. 1109





Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra

Swiss Confederation

Federal Department of Home Affairs FDHA  
**Federal Office of Meteorology and Climatology MeteoSwiss**

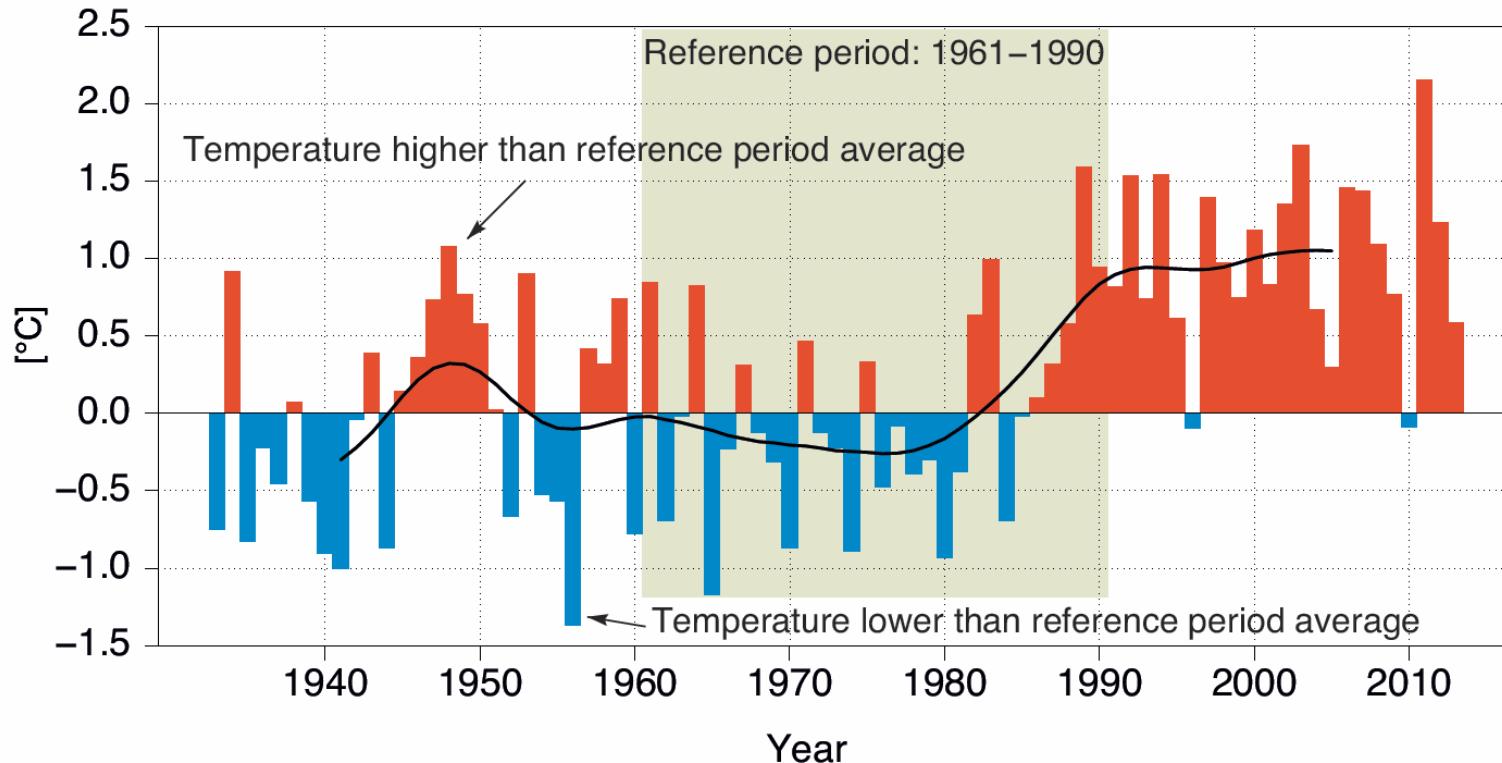
# [www.MeteoSwiss.ch](http://www.MeteoSwiss.ch)



Jungfraujoch: highest permanently manned  
meteorological station in Europe



# Long-term trend of climate time series of JFJ



# Glacier change of the Grosser Aletschgletscher

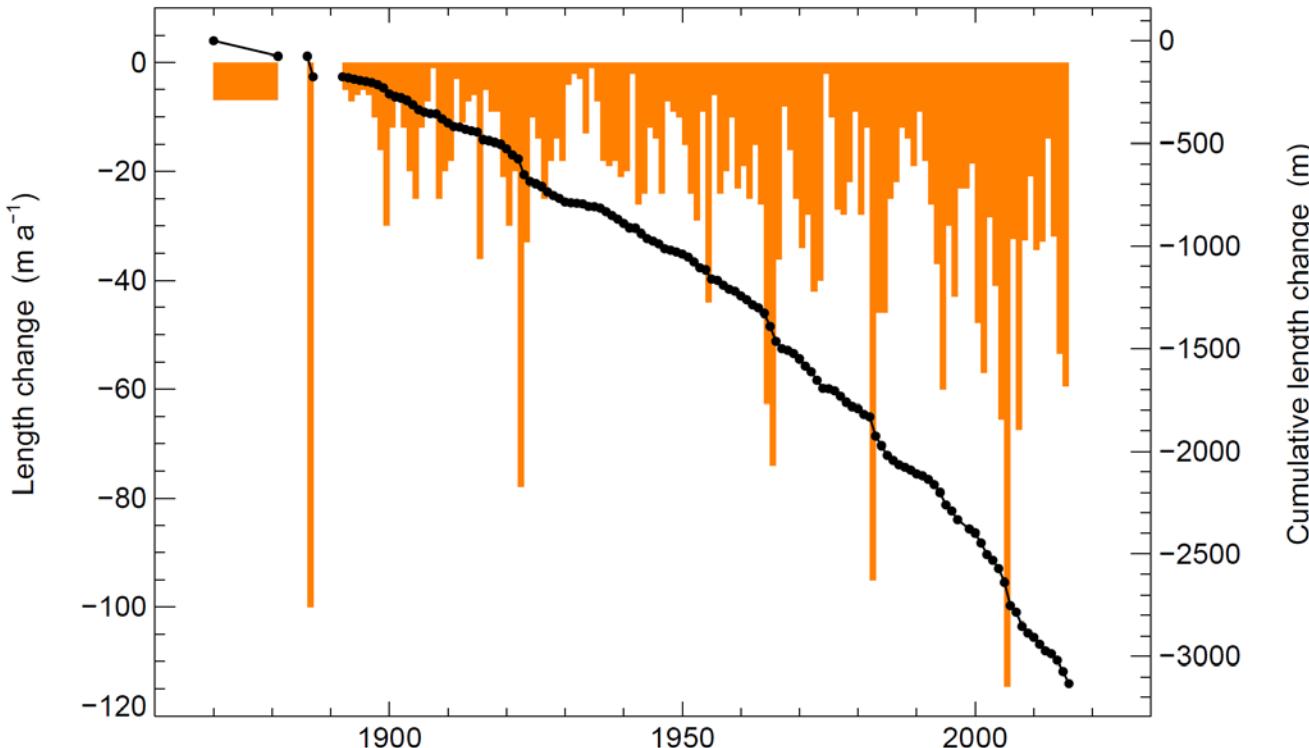
<http://glaciology.ethz.ch/messnetz/index.html>

*u*<sup>b</sup>

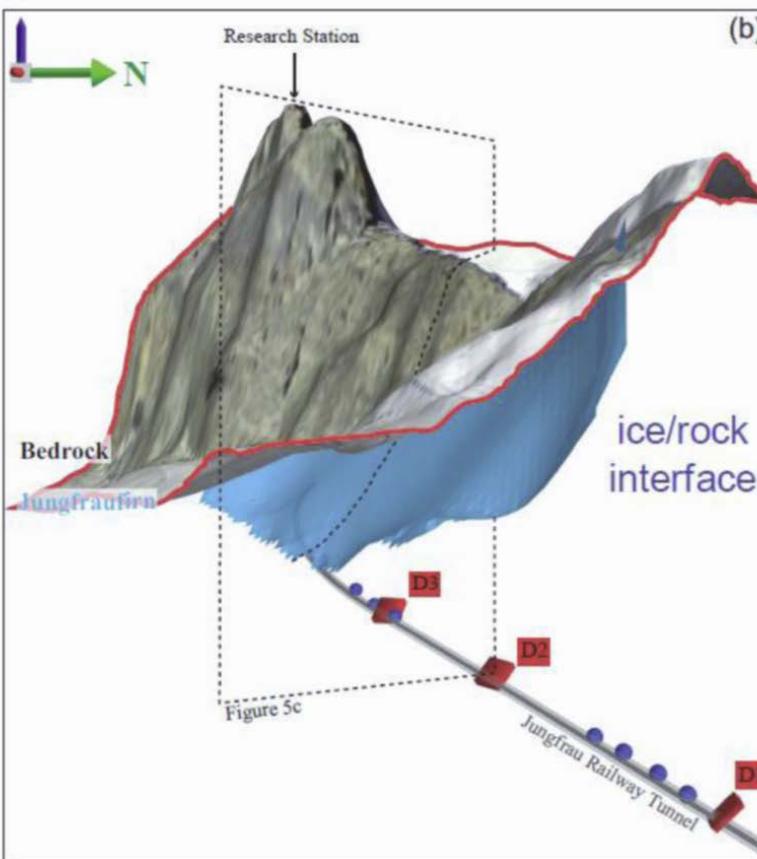
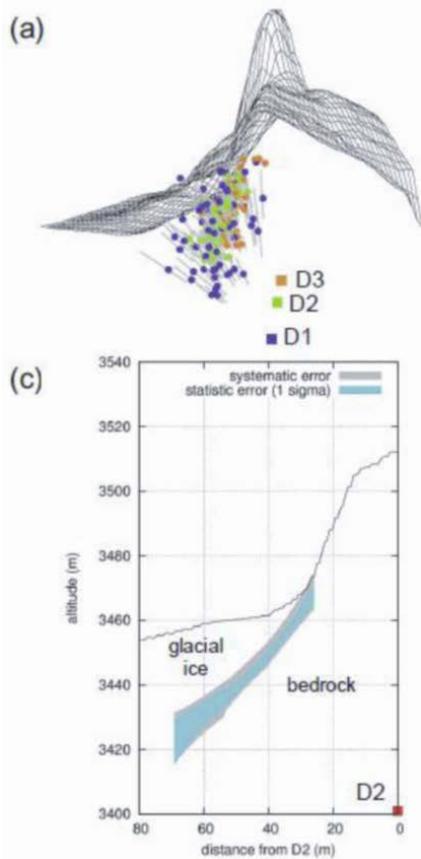
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Length variation measurements between 1870 and 2016



# Cosmic muon detection of glacier bedrock $u^b$

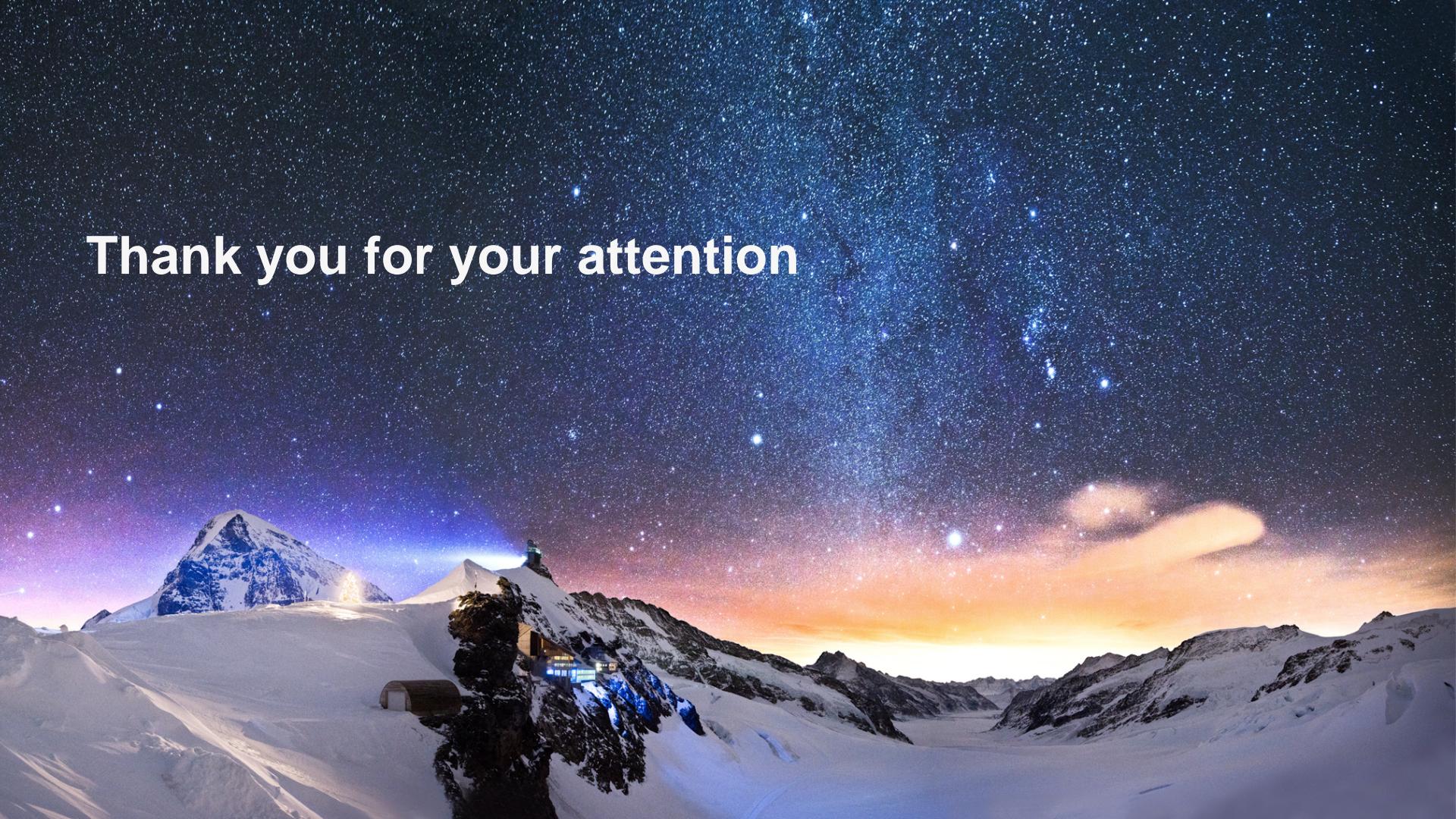


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Interdisciplinary application  
of cosmic muon flux using  
nuclear emulsion particle  
detectors

by Earth Sciences (geology  
and geomorphology) and  
Physics (particle physics  
methodologies)

to detect the glacier base.

The background image shows a vast, dark blue night sky filled with numerous stars of varying brightness. In the lower half of the image, a range of snow-capped mountains is visible. On the left, a large, rugged mountain peak rises prominently. In the center, a building with illuminated windows sits atop a rocky outcrop, with a bright light source visible above it. The sky transitions from deep blue at the top to a warm orange and yellow glow near the horizon, suggesting a sunset or sunrise.

Thank you for your attention