# GOME / SCIA Workshop

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# GOME Measurements of Tropospheric $SO_2$

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# $SO_2$ in the Atmosphere

## Atmospheric Relevance:

- $SO_2$ is oxidized to $H_2SO_4$ which solved in water acts as aerosol and CCN (→ link to climate)
- At large concentrations, $SO_2$ is affecting human health
- Together with $HNO_3$, H2$SO_4$ is main reason for Acid Rain

## Sources:

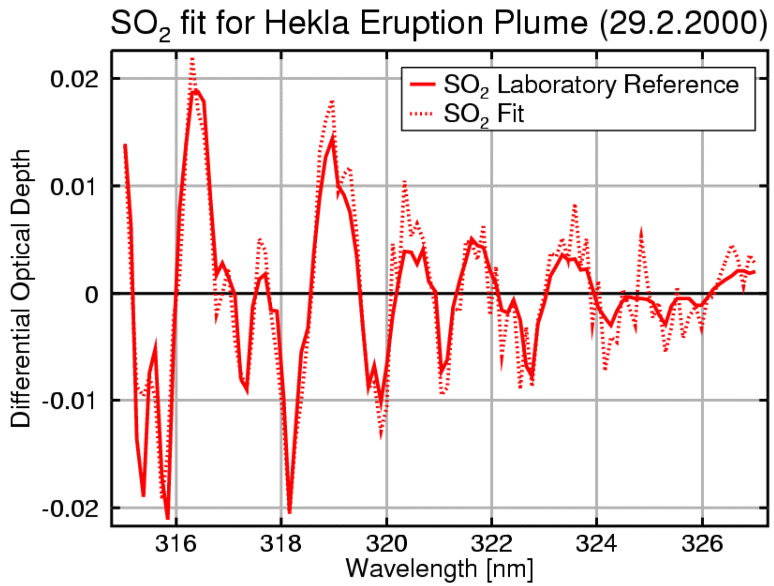
- volcanic eruptions
- oxidation of sulphur gases produced by decomposition of plants
- fossil fuel burning, in particular of sulphur rich coal
- emissions of refineries of oil and natural gas
- nonferrous smelting industry

**Today, anthropogenic emissions dominate!**

# GOME $SO_2$ retrieval: Basics

## 1. Determination of $SO_2$ amount in measurement:

- DOAS (Differential Optical Absorption Spectroscopy)
- fitting window 315 - 327 nm
- based on work by Eisinger et al. 98 and Holtet et al., 2000




## 2. Determination of averaged light path

- a priori assumptions on albedo, vertical profile, aerosols, ...
- computation of Airmass Factor

## 3. Determination of integrated Vertical Column

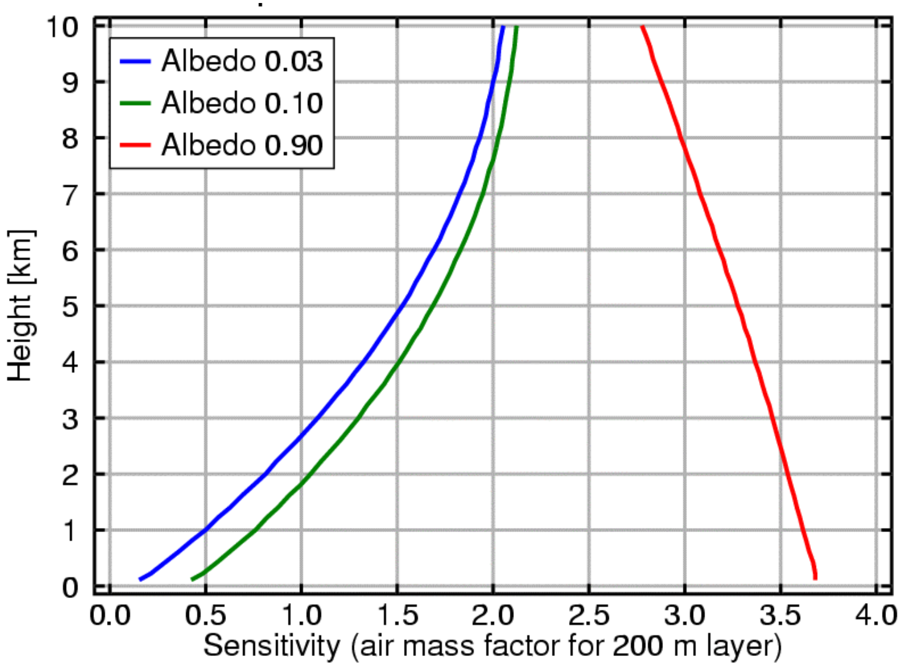
# GOME $SO_2$ retrieval: Challenges

**Challenges:**

- low signals in the UV (low solar output, large atmospheric absorption)
- interference from strong ozone absorption
- low sensitivity to boundary layer (small surface albedo, strong Rayleigh scattering)
- large impact of boundary conditions:
  - surface albedo
  - aerosol type and profile
  - vertical $SO_2$ distribution
- small absorptions for $SO_2$ from pollution
  - Ø low signal to noise
  - Ø interference from instrumental artefacts

# GOME $SO_2$ retrieval: Albedo Dependence

**Dependence of Airmass Factor on Albedo (no aerosols, SZA = 30°):**




surface albedo in UV is low

typical values are
0.03 over land,
0.06 - 0.10 over water,
up to 0.90 over ice

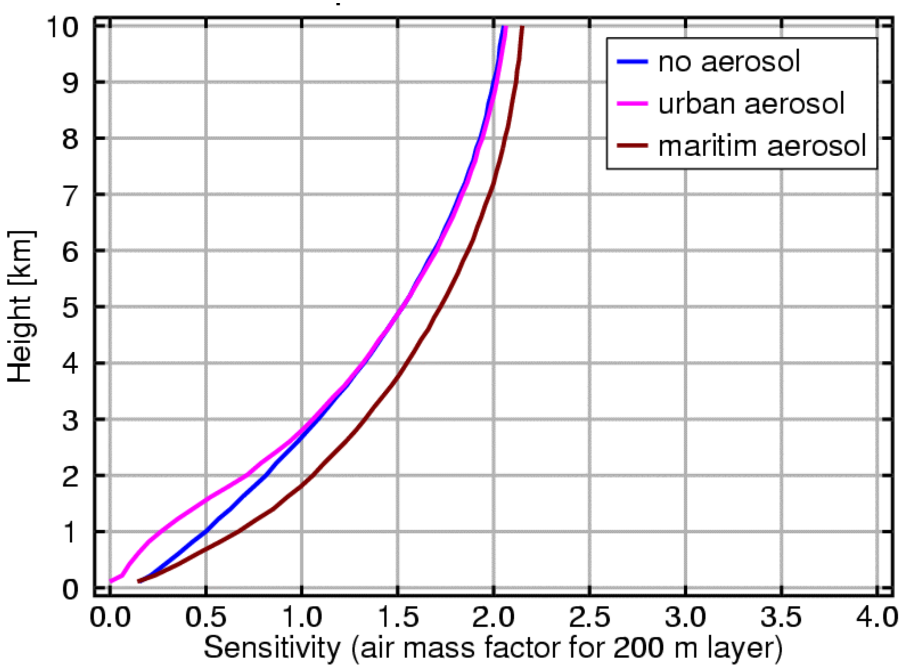
sea / land change in sensitivity for lowermost layers up to a factor of 2!

sensitivity over snow / ice up to a factor of 10 larger!

**→ for quantitative results, vertical distribution and surface albedo must be known!**

# GOME $SO_2$ retrieval: Aerosol Dependence

## Dependence of Airmass Factor on Aerosol (albedo 0.03, SZA = 30°):



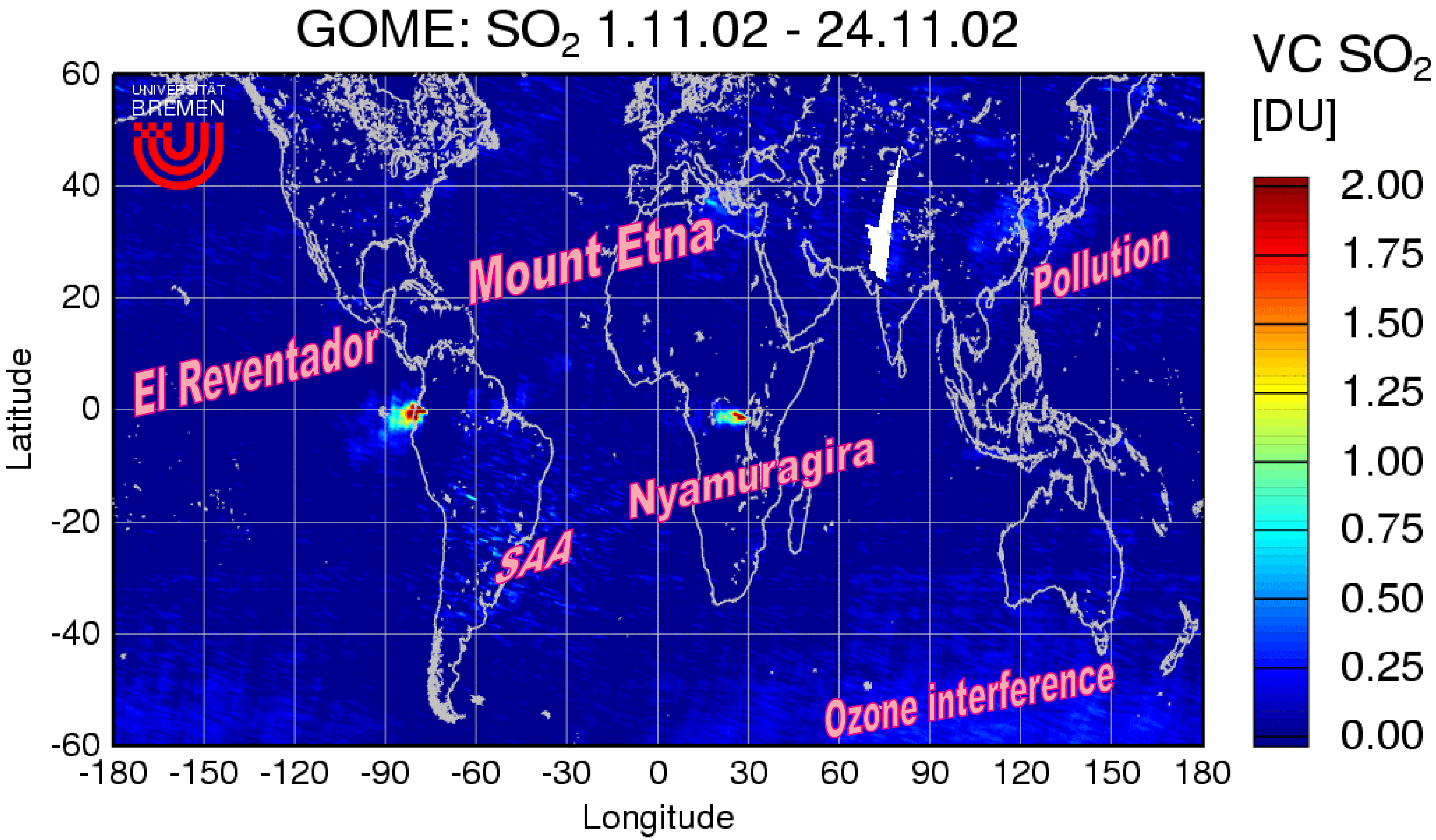

urban aerosols hide much of the $SO_2$ in the lowermost 2 km

reflective aerosols can actually enhance the sensitivity in the troposphere

more realistic settings might produce even more complex dependences

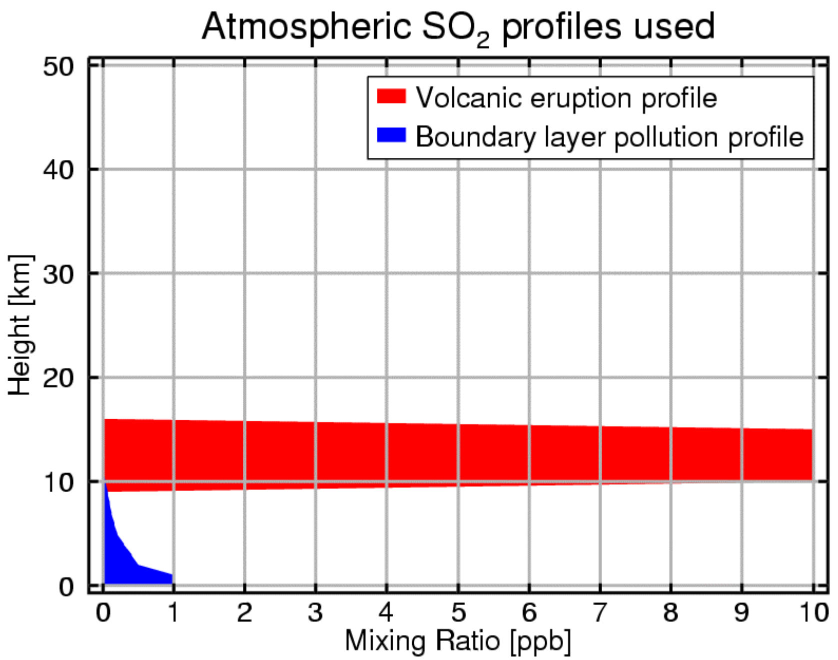
**→ in polluted situations, sensitivity to $SO_2$ in the boundary layer is very small!**

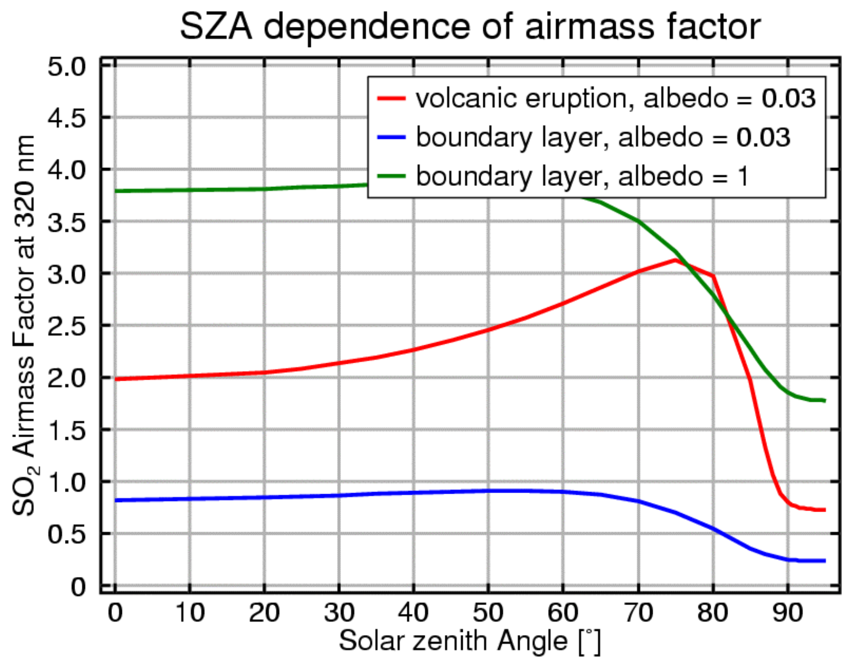
# GOME $SO_2$: The Global View



# $SO_2$ retrieval: Basic Scenarios

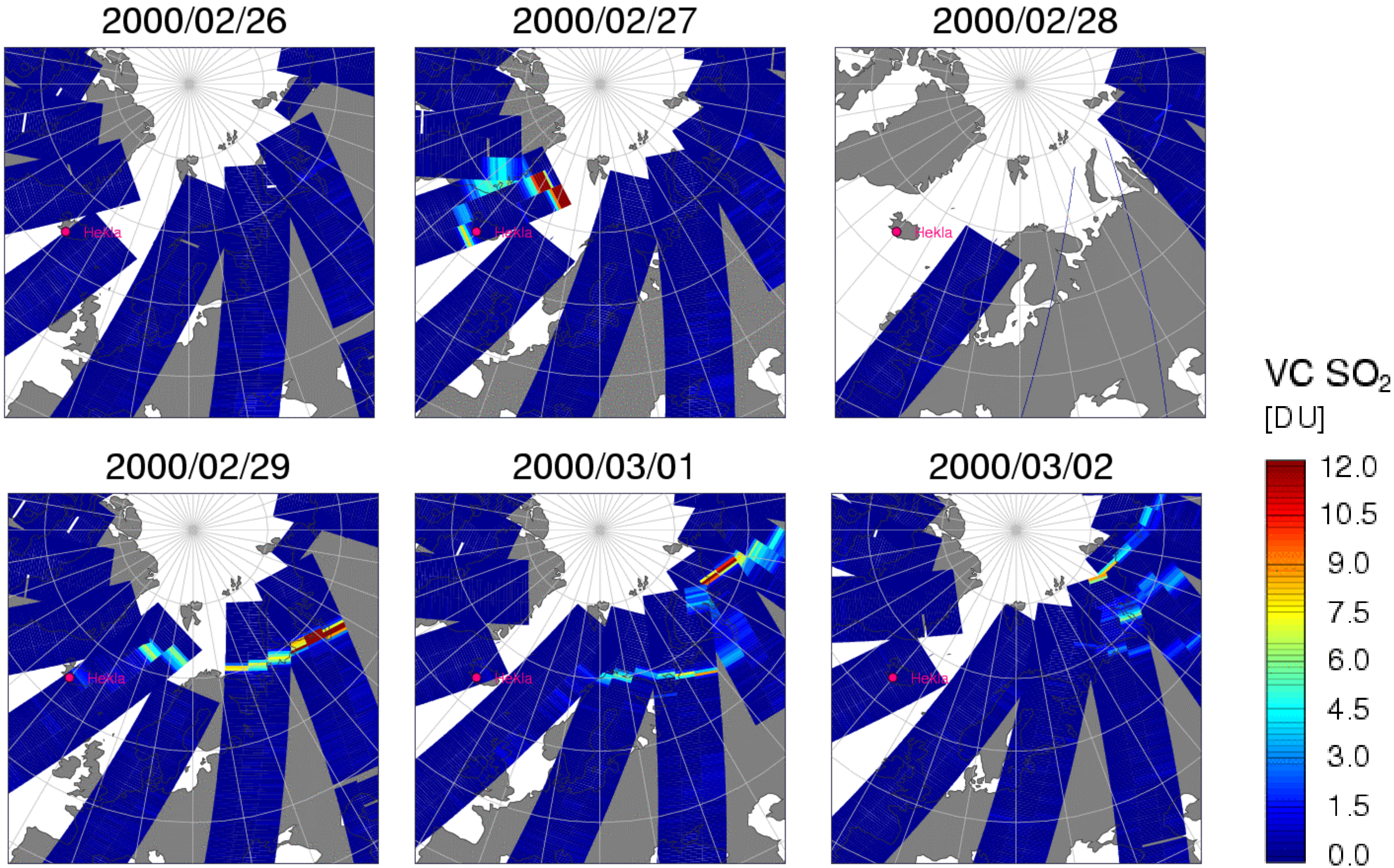
**Two scenarios have been selected: Volcanic and Pollution, both with a surface albedo of 0.03**



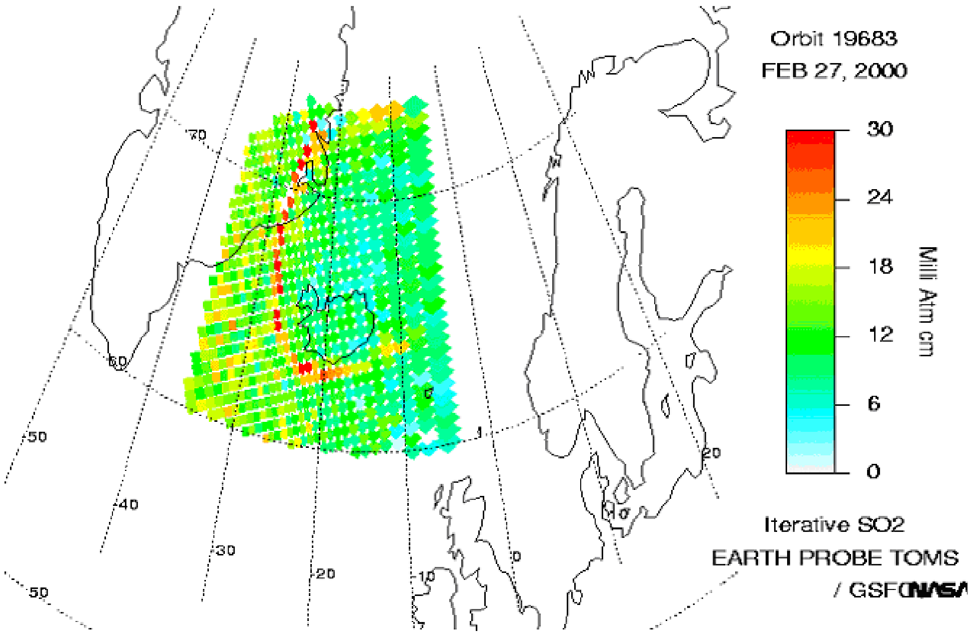

**→ Qualitative rather than quantitative analysis!**

# GOME $SO_2$: Hekla eruption

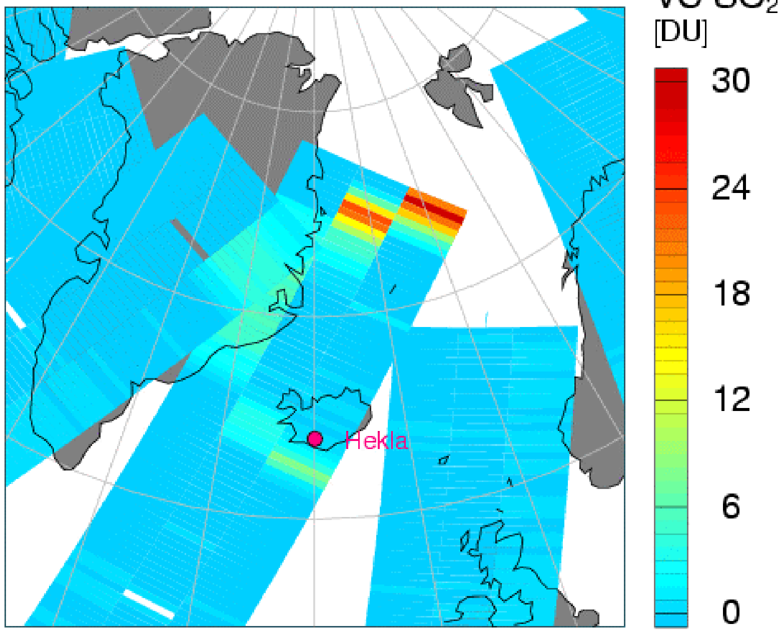


# Hekla eruption: Comparison GOME and TOMS

TOMS 2000/02/27



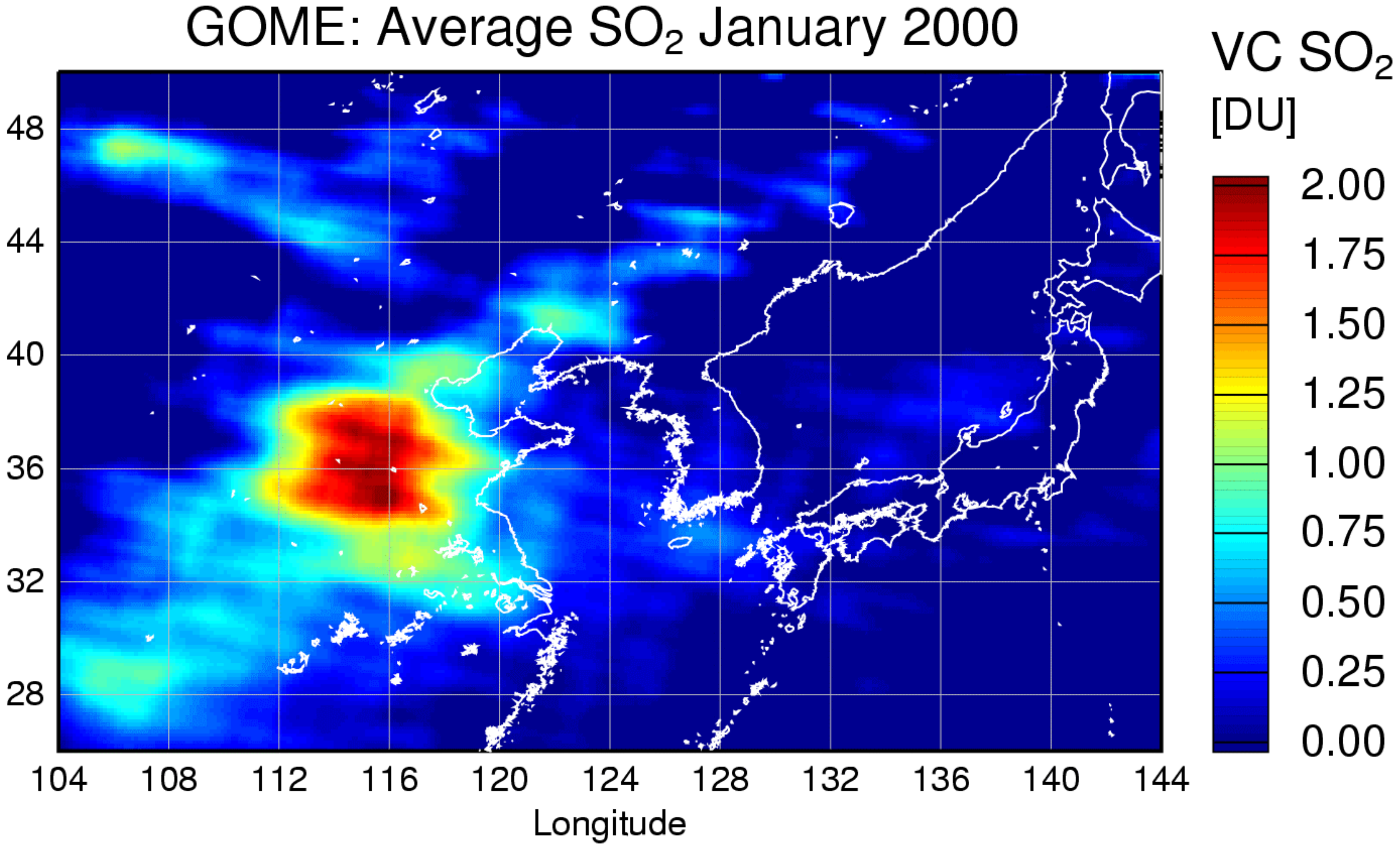

GOME 2000/02/27



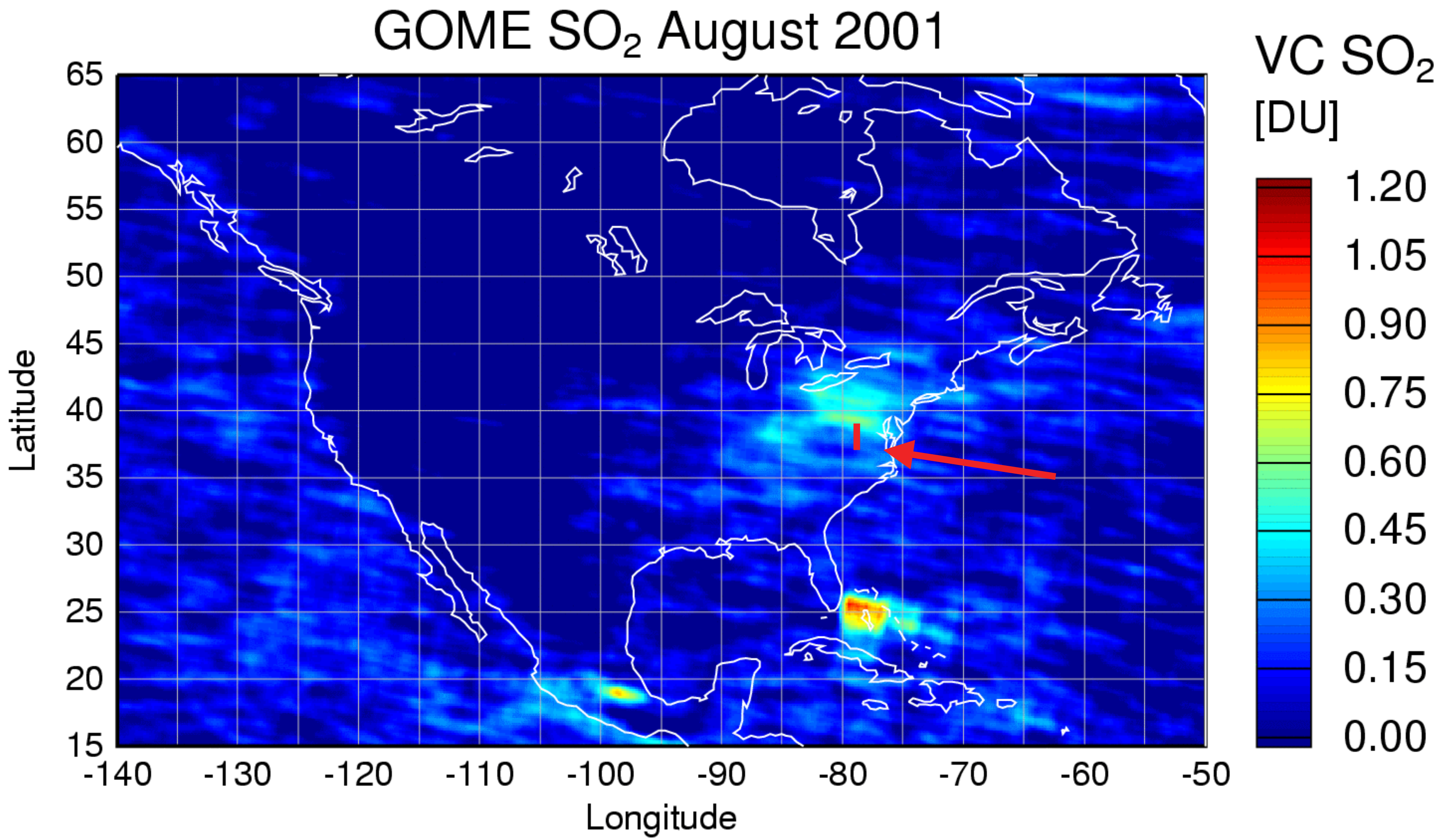

- **good qualitative agreement**
- **better spatial resolution from TOMS**

- **larger values from TOMS**
  - **Øoffset?**
  - **Øpixel size?**

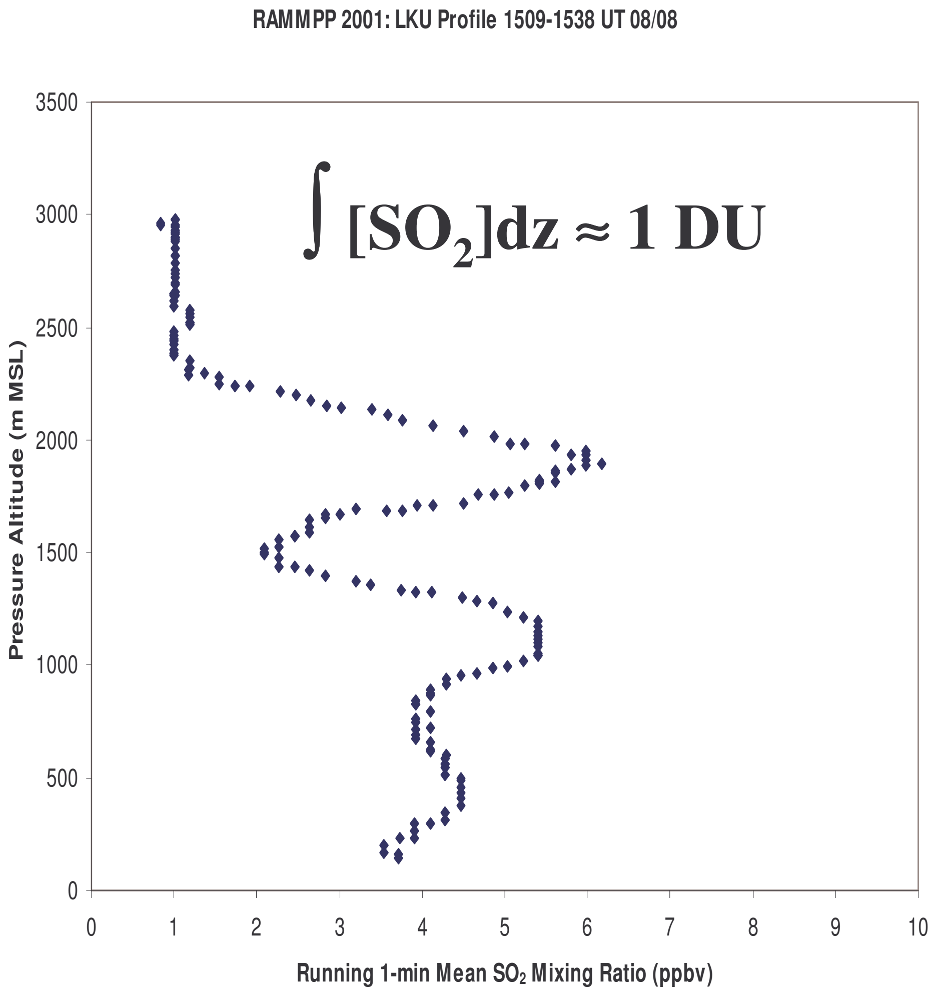
# GOME $SO_2$ : Pollution in China



# GOME $SO_2$ : Pollution in Eastern US



# Comparison with RAMMP in-situ Measurements




- air-borne in-situ measurements from Dickerson et al., University of Maryland
- flight from August 8, 2001
- vertical profile agrees well with assumptions in GOME analysis
- integrated column agrees well with GOME measurements
- more detailed comparisons are under way

# Summary

**Summary:**

- GOME measurements can be used to retrieve $SO_2$ columns with high sensitivity
- Both volcanic eruptions and strong pollution events can be observed
- GOME measurements for the Mt Hekla eruption compare well with TOMS results
- GOME measurements of pollution in the US compare well with airborne measurements
- The sensitivity of space-borne UV measurements towards the boundary layer is low with the exception of high albedo scenarios
- Quantitative results for pollution events can only be obtained if information is available on both the vertical distribution and the aerosol burden

# Acknowledgements


- TOMS data have been provided by **Arlin Krueger**, University of Maryland
- Airborne measurements have been provided by **Russ Dickerson**, University of Maryland
- GOME data analysis has been building on work done by **Michael Eisinger** (ESA) and **Hans-Inge Holtet** and **Bill Arlander**, NILU
- The GOMETRAN radiative transfer model has been provided by **Vladimir Rozanov** et al., University of Bremen