First Activities of the Simulation Laboratory 'Earth and Environmental Sciences'

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Outline

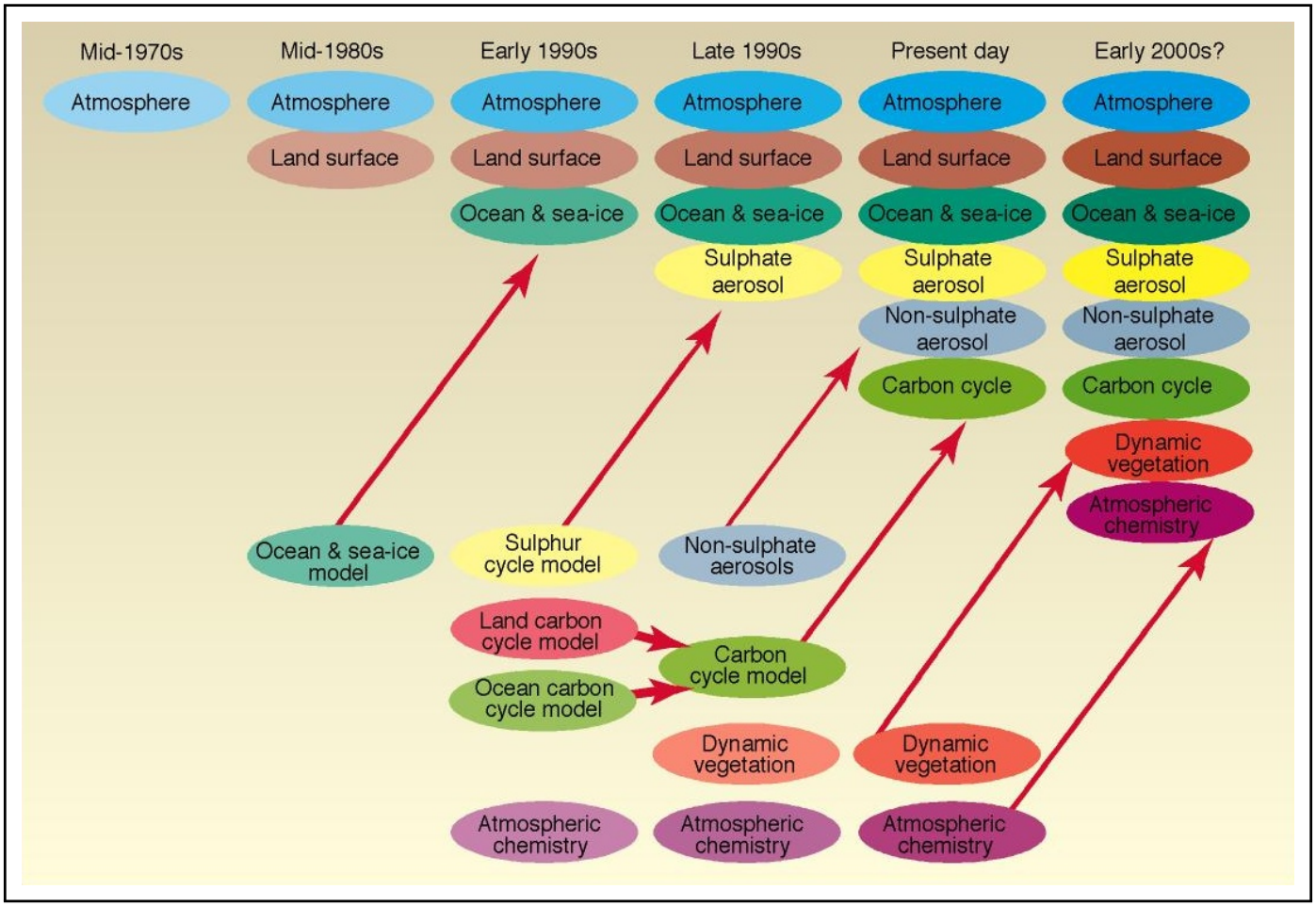
1. First activities of the SimLab ‘Earth and Environmental Sciences’
2. Remote sensing of the Earth’s atmosphere: Applications and resource requirements
3. Summary and possible collaborations

Modelling and observing the Earth system

*The SimLab 'Earth and Environmental Sciences' is tasked to support **HPC modelling activities** for the Earth system and **large-scale data processing** of EO data.*

Specific tasks of the SimLab

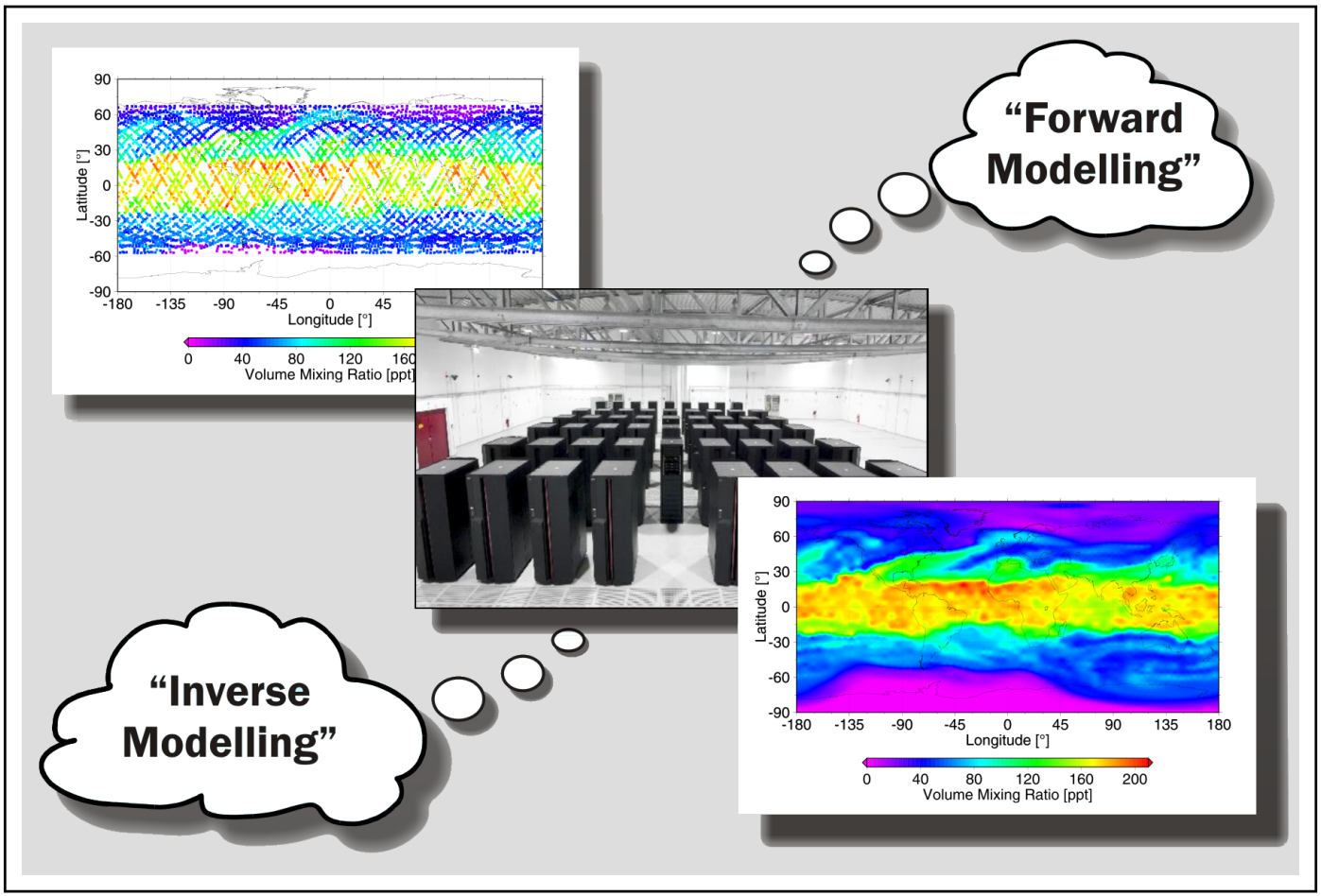
*Development of **coupling tools** and **upscaling / downscaling methods** for sub-component models of the Earth system...*



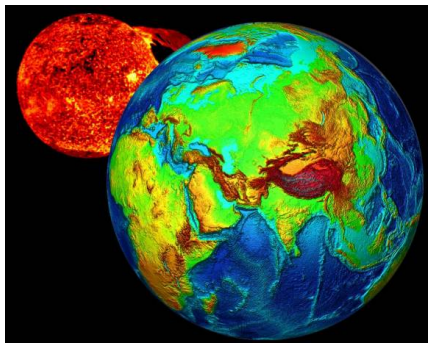
(IPCC, 3rd Assessment Report, 2001)

Specific tasks of the SimLab

Inverse modelling* / *data assimilation *is a another link for activities from different research fields...*



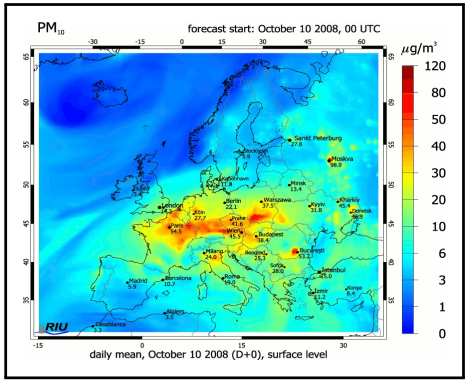
Current projects on Juelich supercomputers



Solar effects in Earth system models

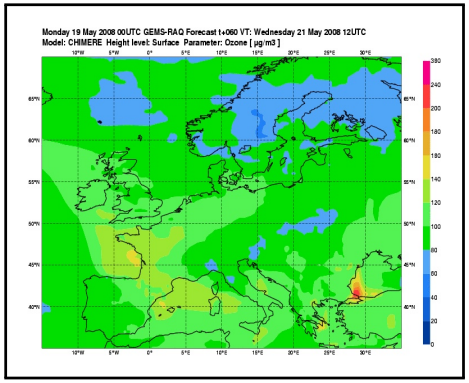
U. Langematz et al.
University of Berlin

A. Baumgaertner et al.
Max Planck Institute for Chemistry



Data assimilation for air quality forecasting

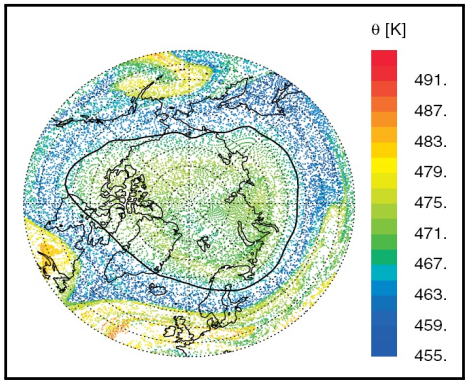
H. Elbern et al.
University of Cologne



Global and regional climate modelling

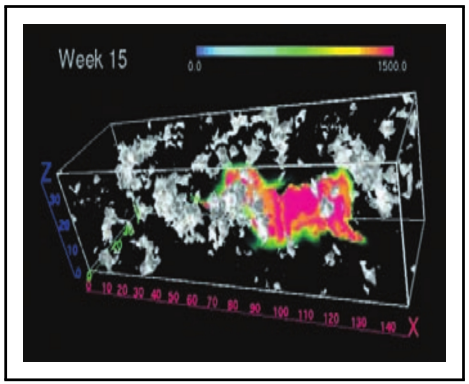
M. Schultz et al.
Research Centre Juelich (ICG-2)

Current projects on Juelich supercomputers



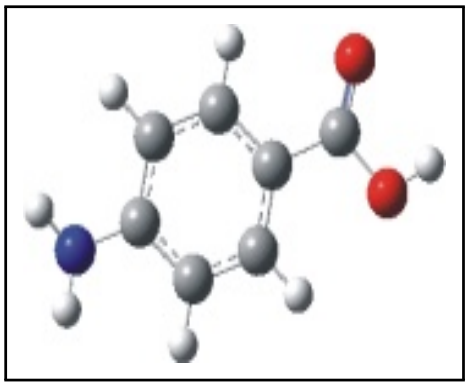
Chemical Lagrangian Model of the Stratosphere

R. Müller et al.
Research Centre Juelich (ICG-1)



Transport in soils and aquifers

M. Herbst et al.
Research Centre Juelich (ICG-4)



Quantum chemical modelling at soil-water interfaces

H. Lewandowski et al.
Research Centre Juelich (ICG-4)

Other activities of the SimLab

- **User support related to HPC inquiries**
  - assist in porting user code to Juelich supercomputers
  - arrange contact to local experts for coding, tuning, etc.
- **Organize informative meetings**
  - on visualization / geographic information systems
  - on automatic differentiation tools / adjoint compilers
- **Teaching activities**
  - Lecture on ‘Inverse Modelling of Atmospheric Remote Sensing Data’ (University of Wuppertal, Germany)
  - advise Ph.D. students and mathematical trainees
- **Preparation of research proposals**
  - to get access to HPC resources
  - to get project funding

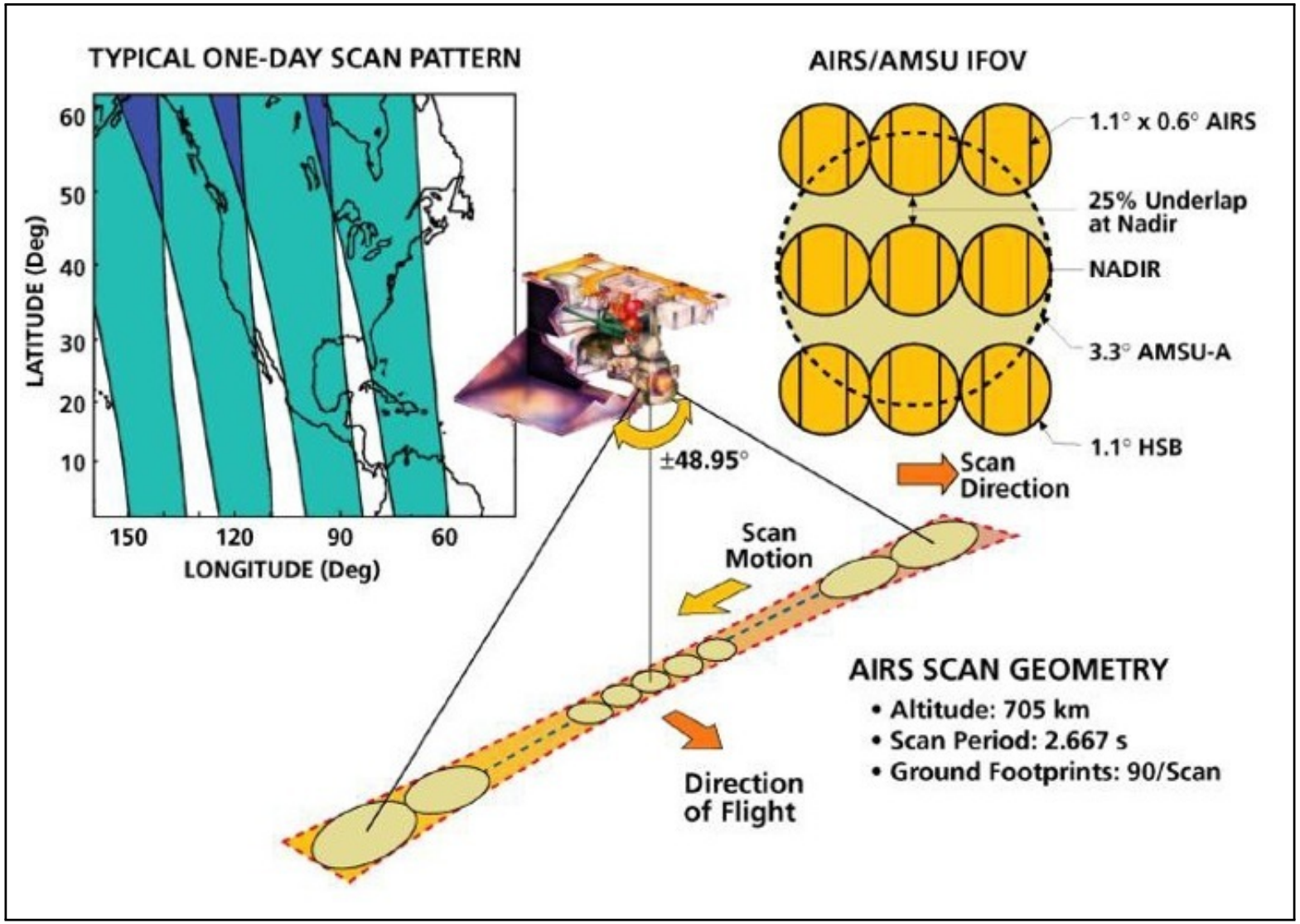
Atmospheric remote sensing

- Analysis of infrared remote sensing measurements of the Earth's atmosphere.
- Development of radiative transfer algorithms and instrument forward models.
- Inverse modelling of remote sensing measurements: Retrieval of atmospheric data.
- Assessment studies for new experiments.

Juelich Rapid Spectral Simulation Code (JURASSIC)

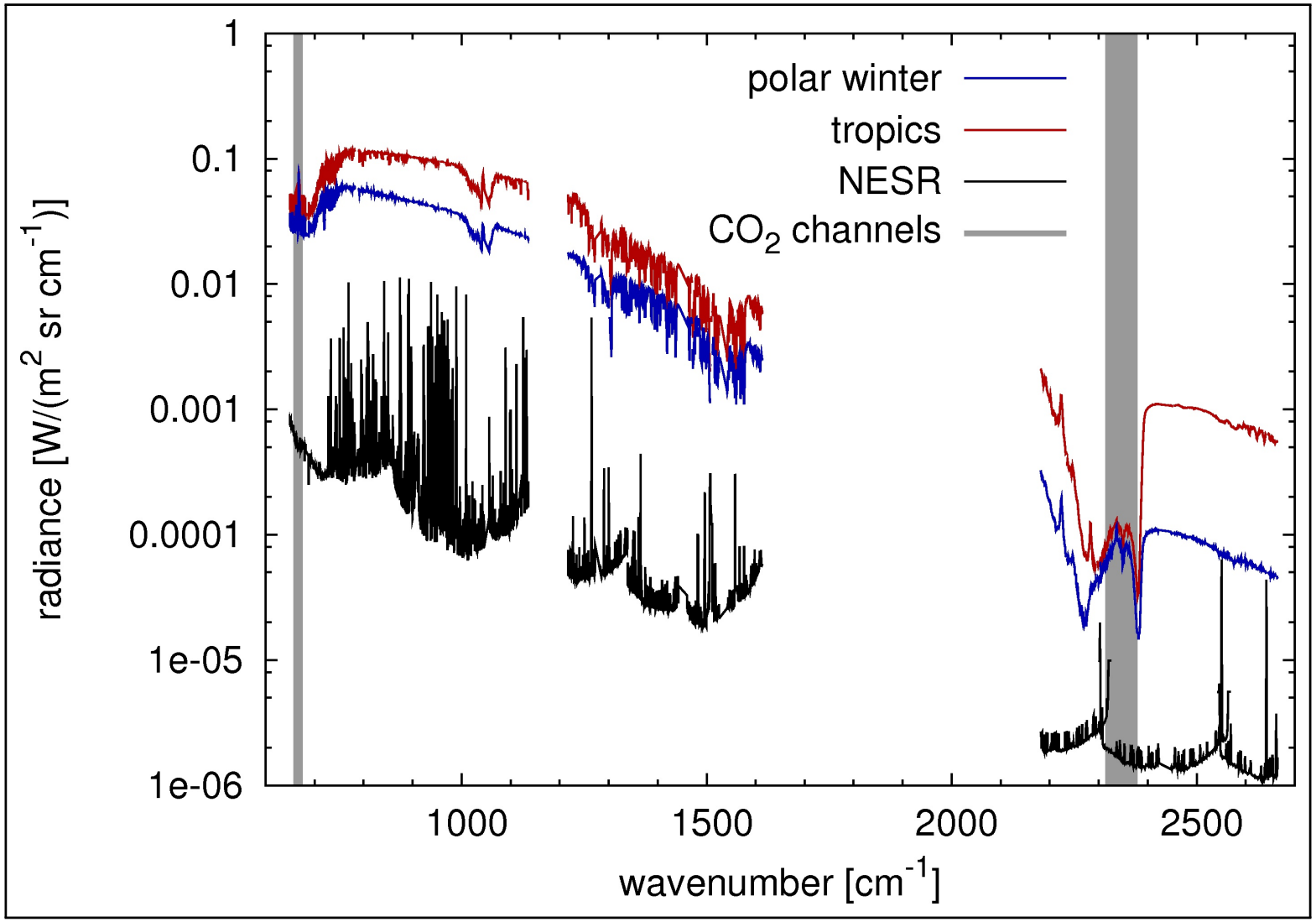
- **Fast radiative transfer model**:
  - emissivity growth approximation (EGA)
  - spectral mean emissivity from pre-calculated look-up tables
  - factor $\sim$ 1000 faster than line-by-line calculations
  - accuracy of $\sim$ 0.5%
- **Retrieval processor**:
  - to retrieve atmospheric data from radiance measurements
  - optimal estimation approach (MAP solution)
- **Parallelization:**
  - MPI to distribute individual retrievals among cores.
  - OpenMP for computation of forward model Jacobians.
  - OpenMP for linear algebra (GSL + ATLAS).
- **Wiki web site:**
  https://jurassic.icg.kfa-juelich.de

AIRS instrument on board NASA's Aqua satellite



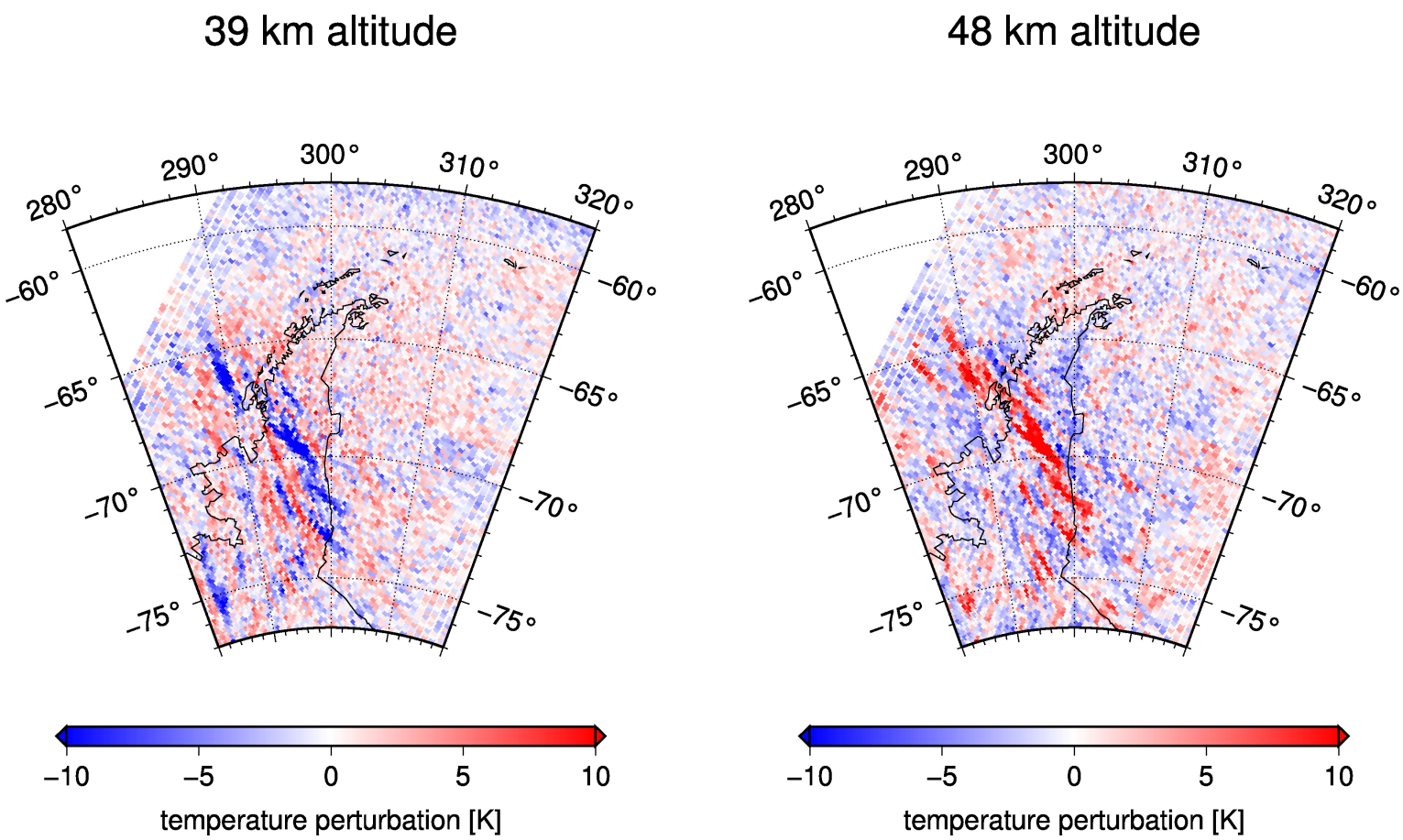
(Reference: http://www-airs.jpl.nasa.gov)

Example of AIRS radiance measurements



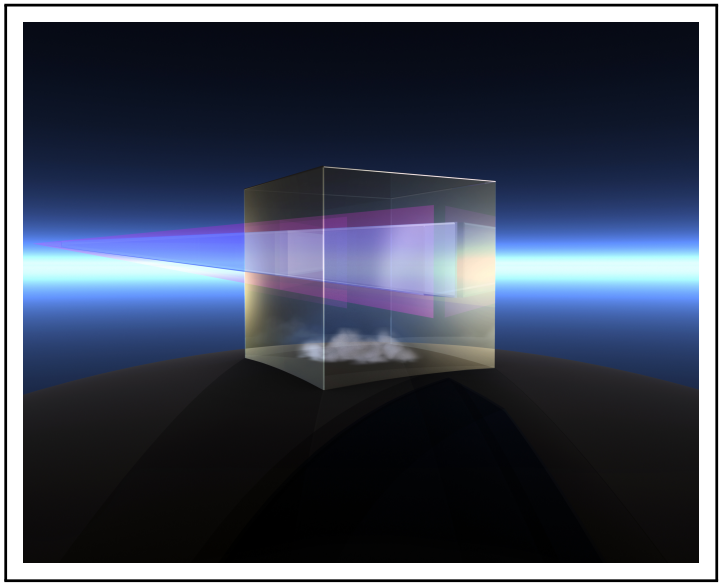
Example of retrieved temperature data

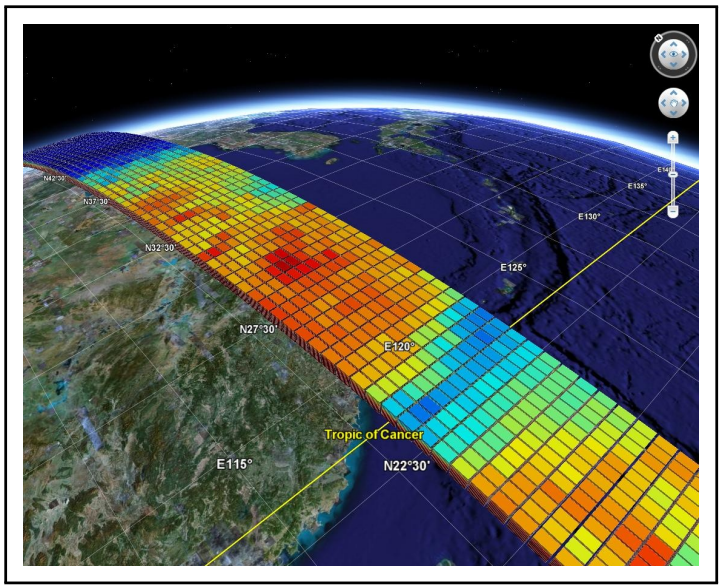
Gravity waves near Antarctic peninsula on 10-JUN-2003, 04:00 UTC...



ESA's Earth Explorers: PREMIER mission

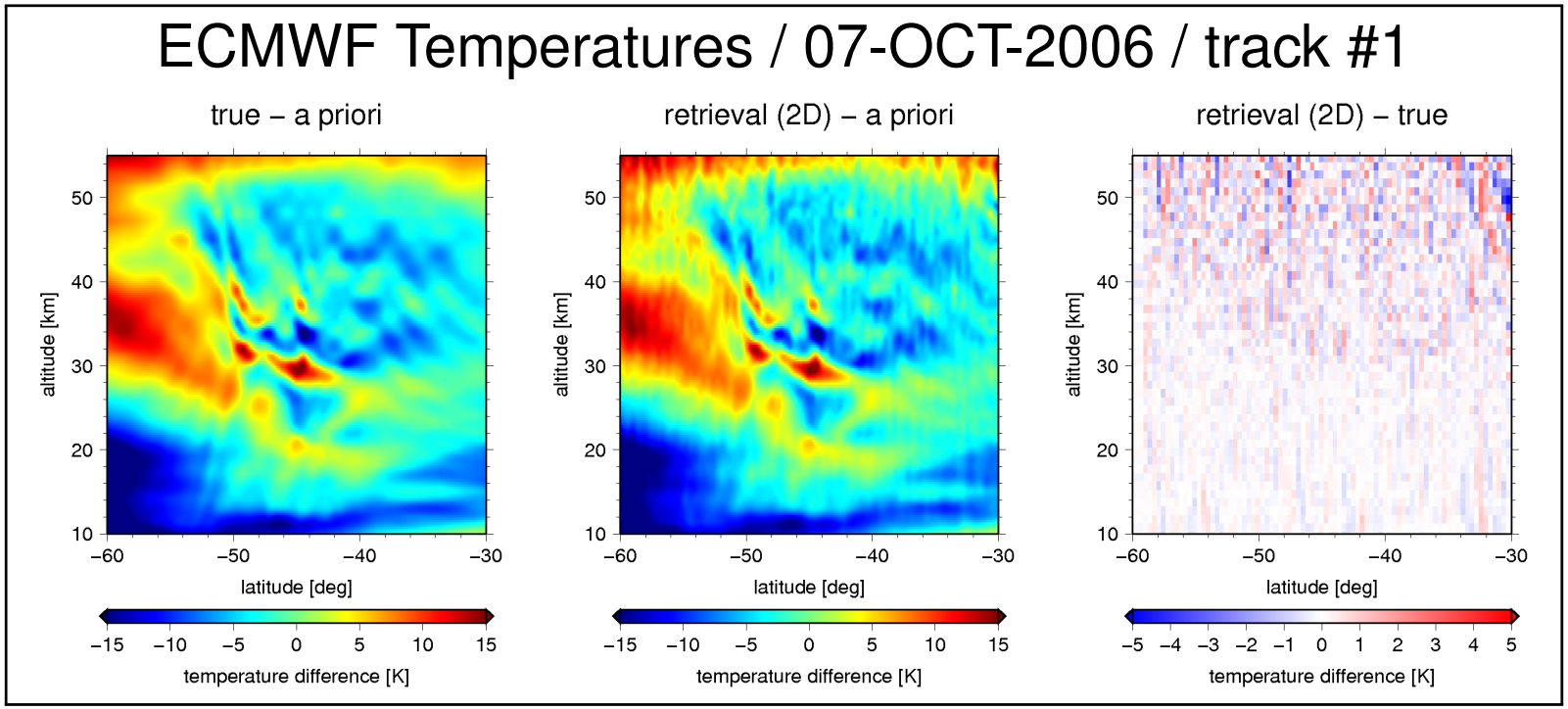
- Earth Explorers form the science and research elements of ESA's Living Planet Program.
- 2016 core mission:
  Six proposals undergoing assessment study, including PREMIER.





- PREMIER will use a 2D infrared detector array to sample the Earth's atmosphere with unprecedented spatial resolution for a limb-sounder:
  $0.5\,\text{km} \times 25\,\text{km} \times 50\,\text{km}$

Retrieval assessments for PREMIER



- Specifics of the PREMIER retrieval:
  - Tomographic problem: Same air volume sampled at different viewing angles while satellite moves on...
  - Typical problem size:
    10,000 observation $\times$ 10,000 state variables

Estimates of required resources

AIRS satellite experiment (2000 – 2010)

- total CPU time: $3,500,000$ h / complete mission
- disk storage: 50 TByte / complete mission
- memory per core: 500 MByte

PREMIER satellite experiment (2010 – 2020)

- total CPU time: $\sim 50,000,000$ h / complete mission
- disk storage: $\sim$ 500 TByte / complete mission
- memory per core: $\sim$ 4 GByte

Summary and possible collaborations

- **The Juelich Supercomputing Centre plans to establish a SimLab 'Earth and Environmental Sciences':**
  - support HPC modelling activities for the Earth system
  - support large-scale data processing of EO data
- **Potential collaborations (current supercomputing projects in Juelich related to Earth sciences):**
  - Atmosphere: climate modelling, chemical data assimilation, atmospheric process modelling
  - Lithosphere: transport processes in soil and ground-water
- **Focus of my work is on analysis of infrared remote sensing measurements of the Earth's atmosphere.**