Institute for **G**eophysics, **A**strophysics, and **M**eteorology / **U**niversity of **G**raz
Atmospheric **R**emote **S**ensing and **Cli**mate **Sys**tem Research Group
ARSCliSys — on the art of understanding the climate system

OPAC-1 Workshop • Sep 16-20, 2002 • Graz, Austria

...some background slides...

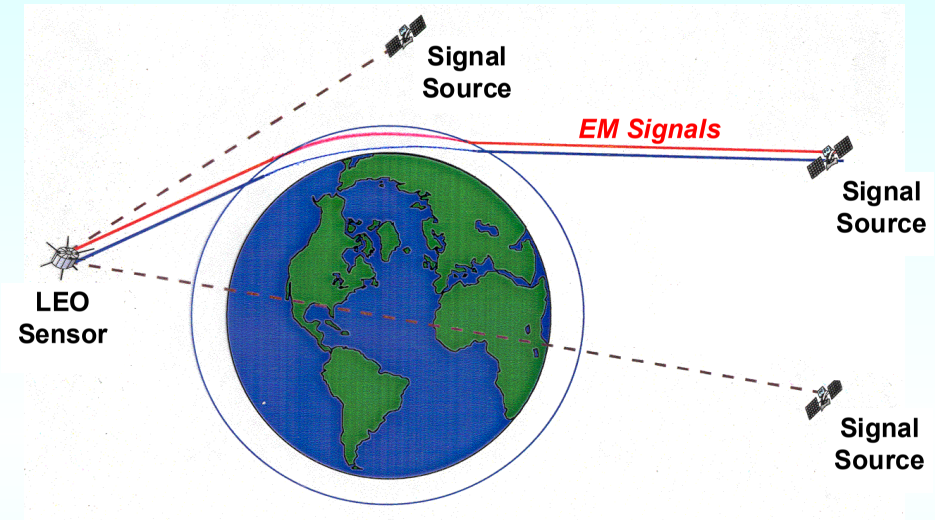
(some focus on climate applications; still reasonably conveying general background)

(gathered by G. Kirchengast,
ARSCliSys Research Group,
IGAM/Univ. of Graz, Austria)

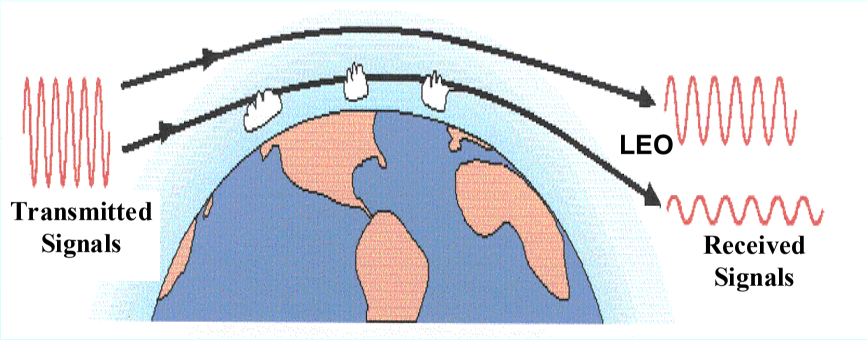
Main source (slides slightly adapted): Presentation “Climate Change Monitoring by GNSS Occultation - An Observing System Simulation Experiment“ by Kirchengast et al., Session “Earth Science Applications of Reflected and Refracted GPS Transmissions”, AGU 2001 Spring Meeting, Boston, MA, U.S.A., May 30, 2001.

The GNSS Occultation Method (and Close Friends)

General Measurement Principle and Geometry



[basic figures from D. Feng, Univ. of Arizona, priv. communications, 2001 (modified)]



Occultation Methods

- exploit extinction and/or refraction of electromagnetic signals along limb paths
- providing measurements of transmission and/or Doppler shift profiles
- leading via absorption or column density, bending angle, and (complex) refractivity
- to key climate parameters such as temperature, humidity, ozone, and geopotential height.

Inversion of Occultation Data

is a virtually well-posed and close to linear problem solved by

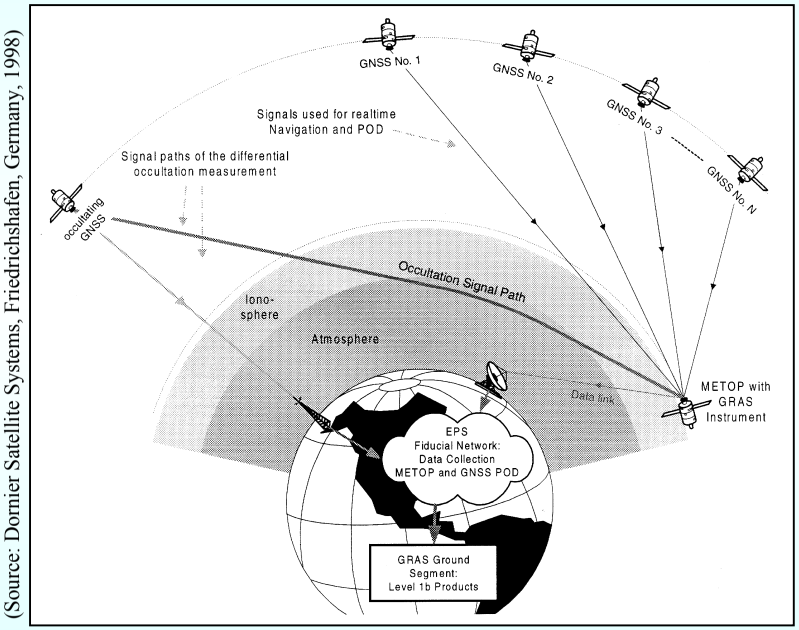
- direct inversion or
- data assimilation.

The GNSS Occultation Method (and Close Friends)

Close Friends in Occultation Measurement Principle

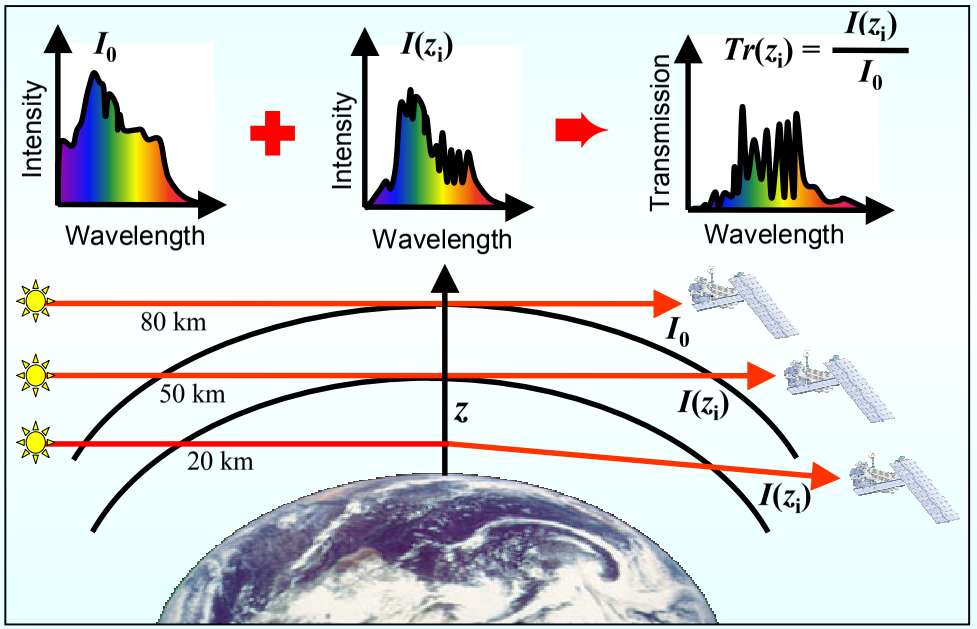
The methods comprise GNSS Occultation, LEO cross-link Occultation, as well as Stellar and Solar (& Lunar) Occultation

GNSS occultation exploits refraction of radio signals along limb paths



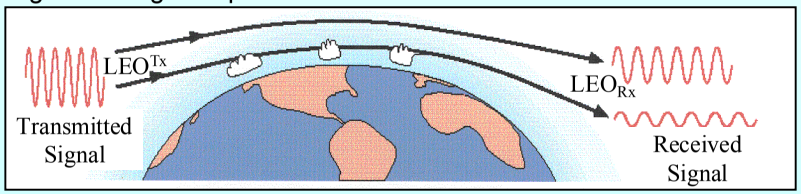
(Source: Dornier Satellite Systems, Friedrichshafen, Germany, 1998)

Stellar and Solar occultation exploit extinction of optical signals along limb paths



(Source: C. Zehner, ESA/ESRIN, Frascati, Italy, 2001; adapted)

LEO cross-link occultation exploits extinction & refraction of MW signals along limb paths



(Source: D. Feng et al., Inst. of Physics/Univ. of Arizona, U.S.A., 2001; adapted)

- Each of these complementary methods exploits the unique properties of the occultation principle.
- Each of them addresses a different height range/ different parameters with optimal sensitivity.

The GNSS Occultation Method (and Close Friends)

Promise for Climate Change Monitoring

Highly accurate monitoring of climatic changes in the thermal (T), moisture (q), ozone (O_3), and geopotential height (Z) structure throughout the full tropo-, strato-, and meso-sphere can be furnished **by** a constellation of 4 – 24 micro-satellites carrying

- GNSS radio occultation sensors (GRAS(+),BJ-GPS,...): T, Z (z<50km), q (z<8km)
- LEO cross-link occultation sensors (CALL,ATOMS,...): T,Z,q,O_3 (z<18km)
- UV-VIS-NIR stellar occultation sensors (GOMOS,COALA,...): T,Z,q,O_3 (15km<z<70km)
- MUV solar occultation sensors (SCIA-OCC,SMAS,...): T, Z, O_3 (55km<z<100km)

The occultation sensors deliver an unique combination of

- global coverage (equal observation density above oceans as above land)
- all weather capability of radio occultation (virtual insensitivity to clouds and aerosols)
- high accuracy and vertical resolution (e.g., T < 1K, q < 5% @ ~1 km resolution)
- long-term stability due to self-calibration (e.g., T drift < 0.1K/10yrs, q drift < 2%r.h./10yrs)

Joint evaluation and optimal fusion of the sensor data

- enables to monitor the climate evolution of the atmosphere with unprecedented quality

The GNSS Occultation Method (and Close Friends)

Relevance to the Global Climate Observing System

- A suite of spaceborne GNSS, LEO cross-link, Stellar and Solar occultation sensors has the capacity to become the leading backbone of the GCOS for observing climate change in T, q, O_3, and Z throughout the entire atmosphere up to ~100 km.

- It were a key contribution to at least 3 of the 9 "high priority areas for action" identified by the Intergovernmental Panel on Climate Change in the recent IPCC 2001 report:
  - *Sustain and expand the observational foundation for climate studies by providing accurate, long-term, consistent data including implementation of a strategy for integrated global observations.*
  - *Improve understanding of the mechanisms and factors leading to changes in radiative forcing.*
  - *Understand and characterize the important unresolved processes and feedbacks, both physical and biogeochemical, in the climate system.*

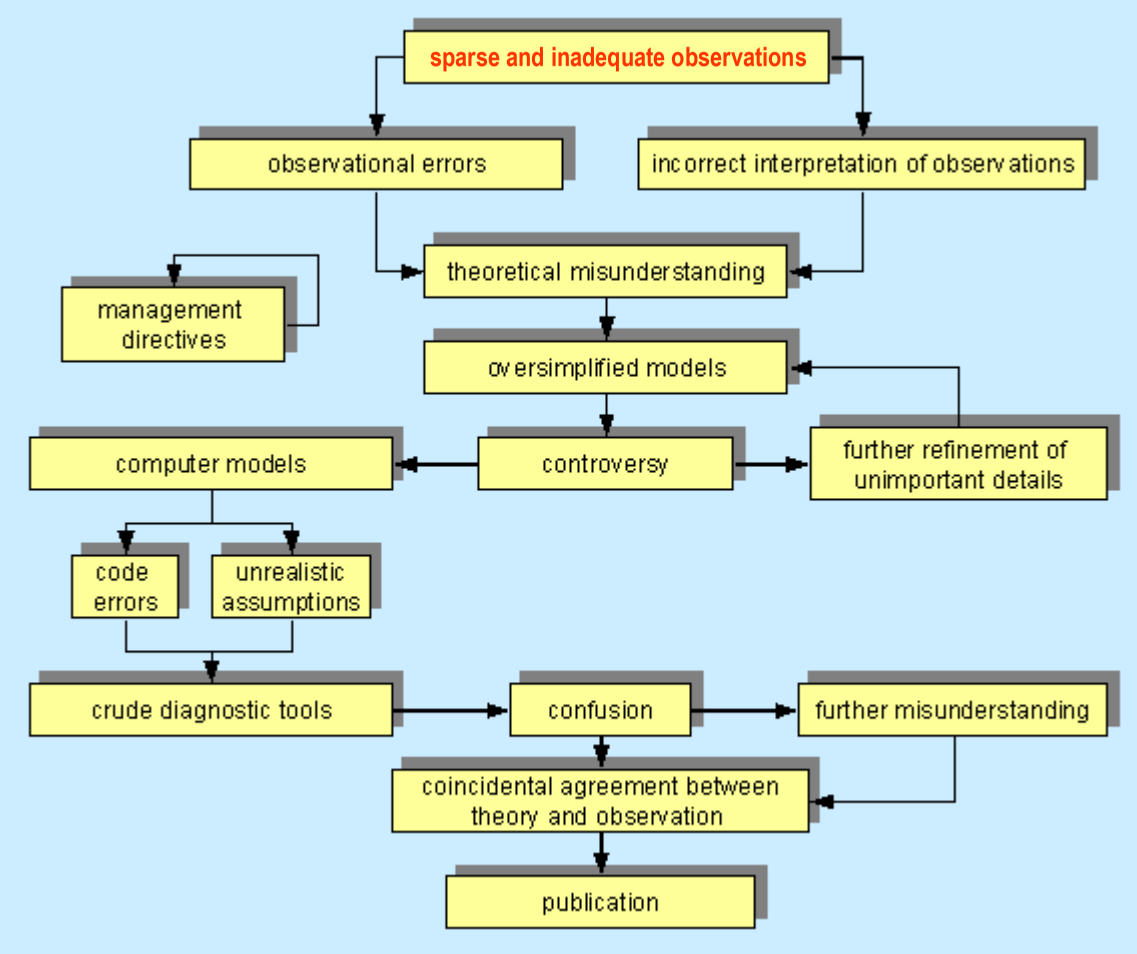
  (Cited from: "Summary for Policymakers", IPCC Working Group I, page 17)

- From the above methods, the GNSS occultation method is presently the most advanced one. It is thus an ideal first building block of the suggested GCOS occultation backbone and missions like ACE+ and COSMIC need be implemented with high priority.

On the Key Role of Adequate Data...

(Fig. received from: J. Lerner, priv.communications, 2001; slightly adapted)

Fatal Workflow... (only too true sometimes?)



***Occultations** cure right at the start.*