Occultations for Probing Atmosphere and Climate: Setting the Scene

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ARS CliSys Research Group

Atmospheric Remote Sensing and Climate System — ARS CliSys — on the art of understanding the climate system

(founded 1996, status September 2002)

IGAM

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Andrea Steiner

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Sabine Tschürtz

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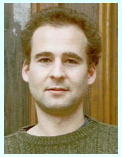
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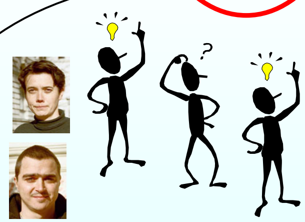
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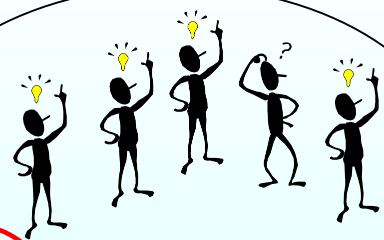
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OPAC: Setting the Scene

outline

- on the principle of occultation measurements
- important methods (GNSS, LEO-crosslink, Stellar, and Solar/Lunar)
- unique properties for unique contributions to atmo&clim research
- areas of use in atmospheric and climate, and beyond
- highlight: relevance for climate monitoring and research
- concluding remarks

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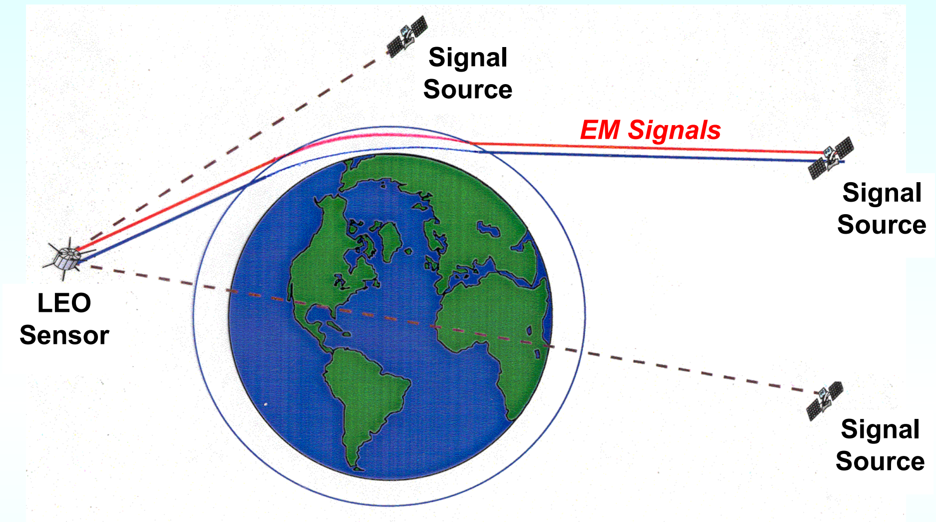
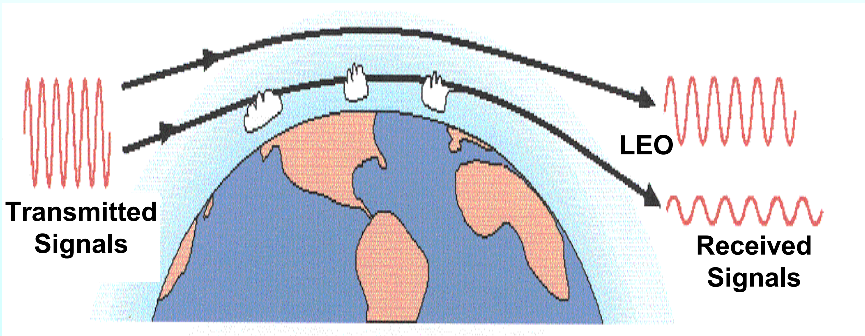
on the principle of occultation measurements



[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 atmo&climate parameters such as temperature *T*, humidity *q*, ozone O_3 and geopotential height *Z* (among others!).

Inversion of occultation data

- is a virtually well-posed and close to linear problem solved by
- direct inversion/retrieval or
- data assimilation.

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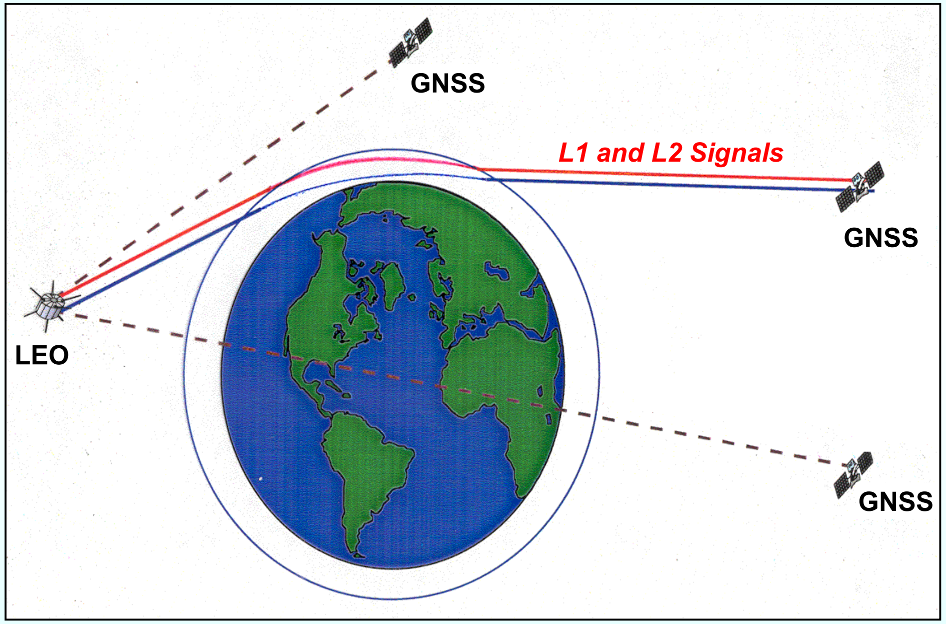
important methods

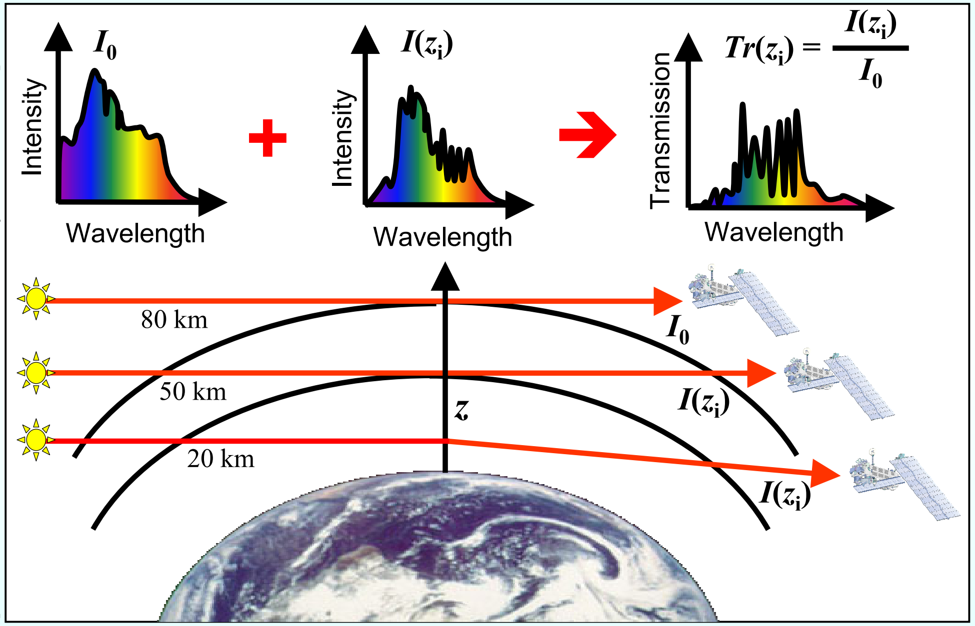
The methods comprise GNSS occultation, LEO-crosslink occultation, as well as Stellar and Solar/Lunar occultation

GNSS occultation exploits refraction of radio signals along limb paths



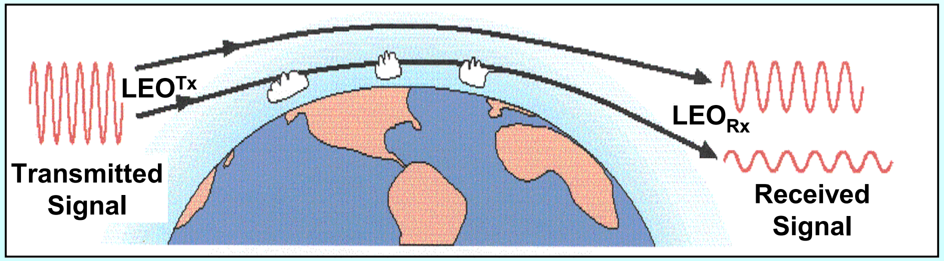
[Source: Basic fig. from D. Feng, Univ. of Arizona, 2001; modified]

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



[Source: C. Zehner, ESA/ESRIN, Frascati, Italy, 2001; modified]

LEO-crosslink 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; modified]

- 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.

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unique properties (1)

Unique contributions to atmosphere and climate research thanks to unique properties

➡ long-term stability due to intrinsic self-calibration of occultation data:
- self-calibrated transmission profile measurements (normalised intensity)
- self-calibrated Doppler shift profile measurements (time standard)

(detecting, e.g., T drifts < 0.1K/decade, q drifts < 2%/decade)

➡ high accuracy and vertical resolution resolving atmospheric fine structures (achieving, e.g., dT < 1 K, dq < 5% @ ~1 km height resolution)

➡ global and even coverage, equal over both oceans and land (providing, e.g., the same data quality above antarctica as above Europe)

➡ all-weather capability, i.e., virtual insensitivity to clouds and aerosols (if using radio wavelengths > 1 cm such as, e.g., the ACE+ mission)

➡ dense array of profiles from constellations of satellites (allowing, e.g., regional climate monitoring and improved NWP)

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unique properties (2)

Example for unique properties: performance of GNSS occultation

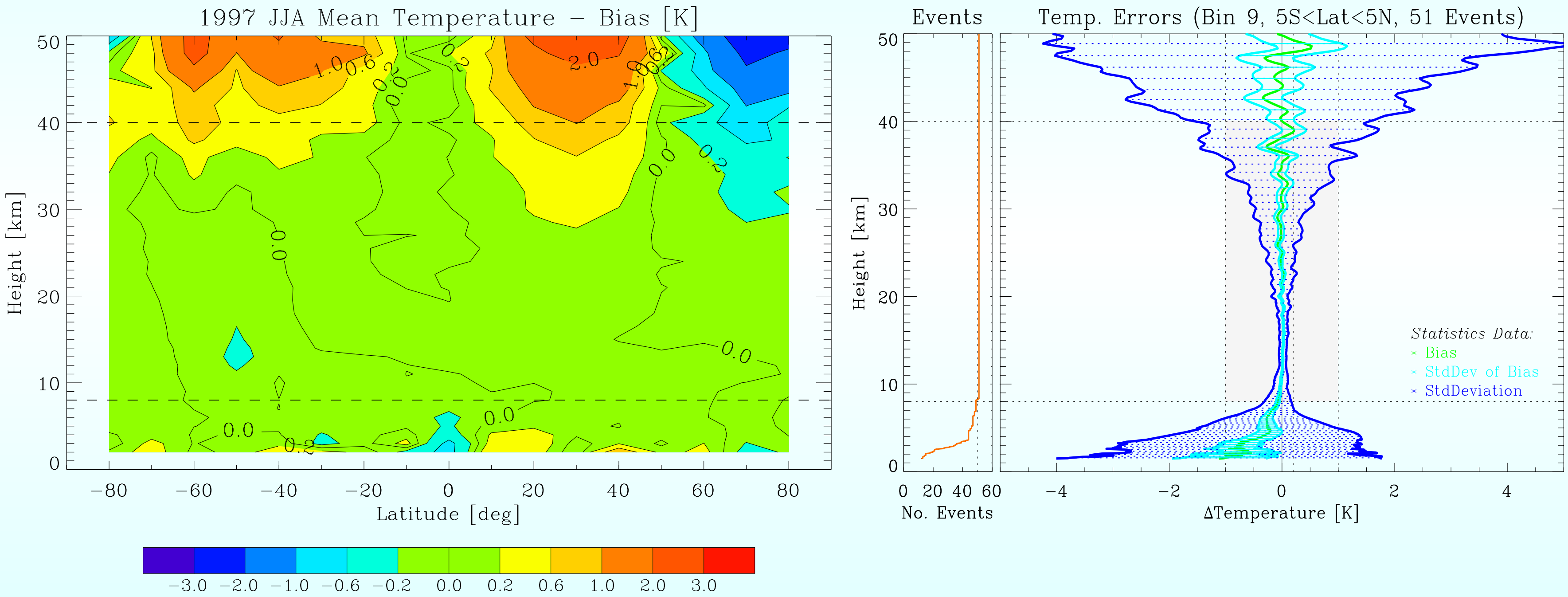

Illustration of retrieval performance using GNSS-LEO occultation data (realistic end-to-end simulations; *left:* lat-height slice of temperature errors of ~50 profile mean, *right:* vertical error structure at equator)

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areas of use (1)

Areas of use in atmosphere and climate, and beyond

➡ **climate monitoring and research**
(monitoring of climate variability and change; global climatology algorithms and products, e.g., on *T*, *q*, O_3, aerosol; climate model validation and improvement; anthropogenic climate change detection and attribution; climate process studies, e.g., on climate feedbacks, tropopause changes, external climate forcings)

➡ **atmospheric physics and chemistry**
(all kinds of atmospheric process studies, e.g., on gravity waves, tropo-/stratosphere exchange, ozone chemistry, aerosol and cloud physics)

➡ **operational meteorology**
(numerical weather prediction, atmospheric analyses, improving models)

➡ **ionosphere, space weather, and planetary research**
(ionosphere, space, and planets weather and climate studies)

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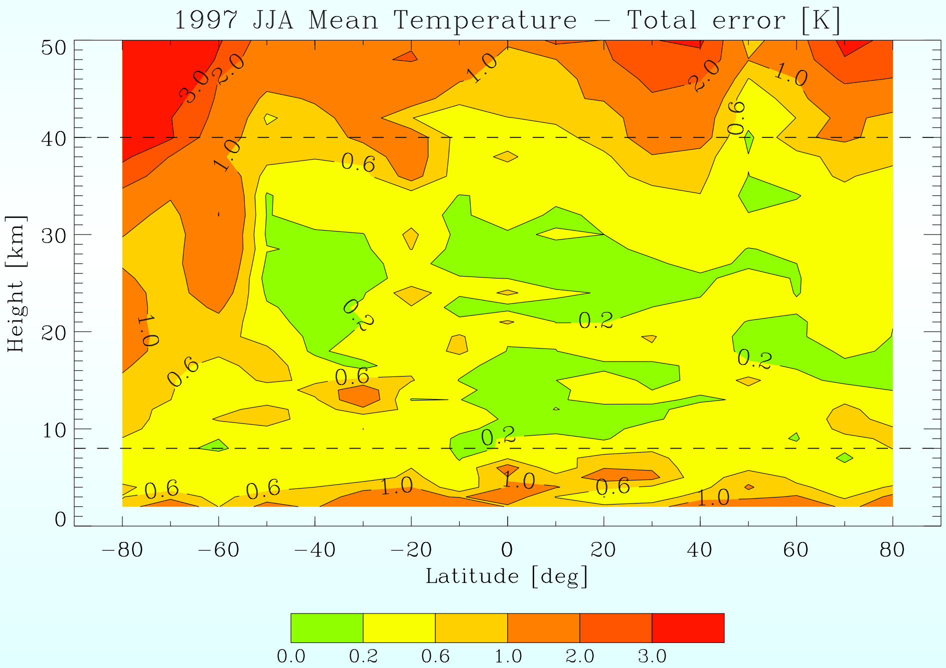
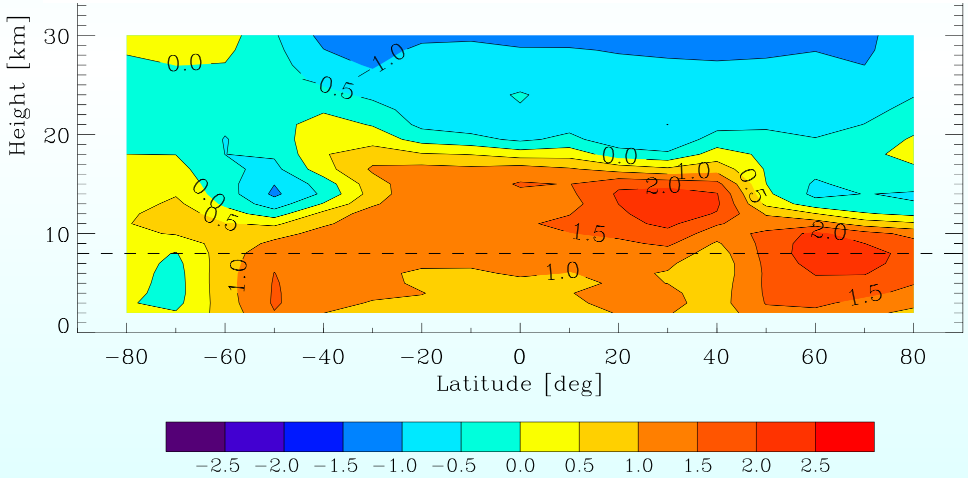
areas of use (2)

Example for areas of use: climate change monitoring by GNSS occultation

Arbitrary but reasonable GNSS occultation based temperature error field realization for a single JJA season
(atmospheric evolution based on ECHAM4-MA T42L39 Testbed experiment)



Arbitrary but reasonable JJA season temperature trend field realization for the period 2001–2025
(climate evolution based on long-term ECHAM4 T42L19 GSDIO experiment including transient anthropogenic forcings due to greenhouse gases, aerosols, and tropospheric ozone)



- GNSS occultation based JJA *T* errors are expected to be < 0.5 K in most of the core region (8–40 km) northward of 50°S.

- 2001–2025 JJA *T* trends are expected to be > 0.5 K per 25 yrs in most of the core region northward of 50°S.

➡ **Significant trends (95% level) expected to be detectable within 10–20 years in the core region**

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highlight: relevance for climate monitoring and research

*...from the 9 **"high priority areas for action"** noted in the recent **IPCC 2001 report** (Summary for Policymakers, IPCC Working Group I, page 17):*

*"- **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."*

➡ **Such accurate, long-term, consistent data** on 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 (BJ-GPS,AGRAS,...): T, Z (z<50km), q (z<8km)
- LEO-crosslink occultation sensors (CALLS,ATOMS,...): T,Z,q,O_3 (z<20km)
- UV-VIS-NIR stellar occultation sensors (GOMOS,COALA,...): T,Z,q,O_3 (15km<z<70km)
- UV-VIS solar/lunar occ. sensors (SAGE,SCIA-OCC,SMAS,...): T,Z,O_3 (50km<z<100km)

➡ **A suite of occultation sensors has the capacity to become the leading backbone of the Global Climate Observing System (GCOS) for observing climate change in *T*, *q*, O_3, and *Z* throughout the entire atmosphere up to ~100 km.**

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concluding remarks (1)

Occultation methods provide key contributions to a better understanding of the Earth's atmosphere and climate system and to better prediction of its future evolution.

OPAC-1 is set to help advance these contributions!

"The good method is like a sack (bag): it retains everything.
The better method is like a sieve (filter): it only retains what matters."

(after Hellmut Walters)

Deutsches Originalzitat (Hellmut Walters):
„Das gute Gedächtnis ist wie ein Sack:
es behält alles.
Das bessere Gedächtnis ist wie ein Sieb:
es behält nur, worauf es ankommt."

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concluding remarks (2)

Finally, having the scene now set, let’s start....

Dear OPAC-1 Participant, Dear Colleague,

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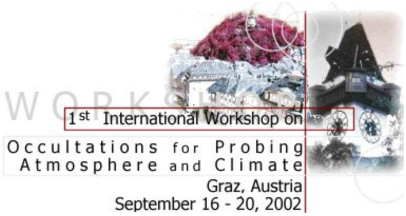
Thank you for coming!

Welcome to OPAC-1!



Welcome to Graz!