OPAC-IROWG 2022

Wegener Center

UNI GRAZ

Climate Change Graz

Field of Excellence
University of Graz

OPAC-IROWG 2022 • Seggau Castle, Leibnitz, Austria • 8-14 September 2022
Slides on 20 Years of OPAC Reflections • Opening Talks Session • 8 Sep 2022
Weblink–original OPAC-1 presentation "OPAC: Setting the Scene" (16 Sep 2002)
https://wegccon.uni-graz.at/opac1/pdf_presentation/opac1_gottfried_kirchengast_44_presentation.pdf
Weblink–OPAC-1 Springer Book intro article "OPAC: Setting the Scene" (publ 2004)
https://wegcwww.uni-graz.at/publ/wegcpubl/arsclisys/2004/wegc_gk-springerbookopac1-p1y2004.pdf

Revisiting the 2002 Opening "OPAC: Setting the Scene" Twenty Years Later: A 2022 Reflection on What's Achieved and What's Next

Gottfried Kirchengast

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Let's Go – Approach and Aims of these Reflections…

Kept promise, same slides => the one talk more to listen than to watch :-)

Twenty years ago in September 2002, I was opening the First International Workshop on Occultations for Probing Atmosphere and Climate (OPAC-1) in Graz, Austria, with a twelve-slides welcome & introduction presentation "OPAC: Setting the Scene". A written version derived from that presentation also served, under the same title, as the introductory article to the Springer Proceedings Book that well documented the status of and plans in the OPAC field at that time.

In this talk I will use the original 2002 presentation, intentionally unmodified, and relations to the associated introductory article in the Proceedings Book, to reflect from my view on what we as "OPAC-IROWG scientific community" have achieved with reference to that scene painted in 2002 and what's next if we refresh the scene.

My overall aim for sharing reflections in this way is twofold: 1.) to contribute a bit to (re)vitalizing our broader awareness of the enormous utility that occultation data bear for applications in climate monitoring and research, atmospheric (re)analysis and numerical weather prediction, atmospheric physics, dynamics and chemistry, and also in the fields of ionospheric, space weather and planetary science. 2.) to contribute a bit to (re)raising our awareness on which of our research and application activities perhaps deserve highest and collective priority, if measured in terms of their value for user communities, and which are more driven by personal preferences and interests, including research topic inertia, and hence appear more off-track from user needs.

Monday, September 16, 2002

08:00-09:00	**Registration**	(also Sunday evening registration possible; see note above) (also poster mounting time)
09:00-09:40	**Welcome and Opening Event**	
09:40-10:30	Opening Session	**Occultation Science: An Introduction and Review** (Chair: **B. M. Herman**)
09:40-10:00	OCCULTATIONS FOR PROBING ATMOSPHERE AND CLIMATE: SETTING THE SCENE [view abstract] [view presentation] **G. Kirchengast**	
10:00-10:30	OCCULTATION SCIENCE FROM THE SIXTIES TO PRESENT ***(invited)*** [view abstract] **T. Yunck** and W. Melbourne	
10:30-11:00	**Coffee Break**	(and poster mounting time)

(OPAC-1 Welcome & Opening, 2002; cut from Sci Programme – thanks Ben, Tom!)

Occultations for Probing Atmosphere and Climate: Setting the Scene

Gottfried Kirchengast

ARSCliSys Research Group, IGAM, University of Graz, Austria
(*www.uni-graz.at/igam-arsclisys*)

Talk at OPAC-1/Session “Occultation Science: An Introduction and Review“; Sept. 16, 2002; Univ. of Graz, Graz, Austria.

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)

Thanks to...

LOC – OPAC-1 Local Organizing Committee

LOC

Andrea Steiner

LOC

Sabine Tschürtz

LOC

Gottfried Kirchengastl

Christoph Bichler

LOC

Ulrich Foelsche

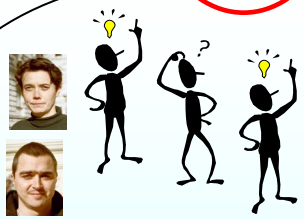
Johannes Fritzer

LOC

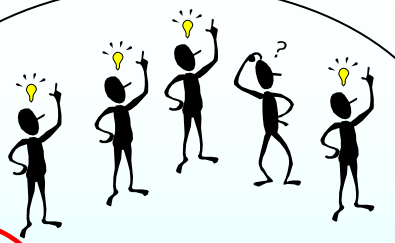
Marc Schwärz

Members (at IGAM)

- Head
- 2 Senior Scientists
- 2 Post-Doc Scientists
- 5 Ph.D. Students
- 1 M.Sc. Student
- 1 Admin. Assistant



Colleagues at IGAM



Colleagues Worldwide

LOC

Christian Retscher

LOC

Christoph Rehrl

LOC

Josef Ramsauer

LOC

Armin Löscher

LOC

Andreas Gobiet

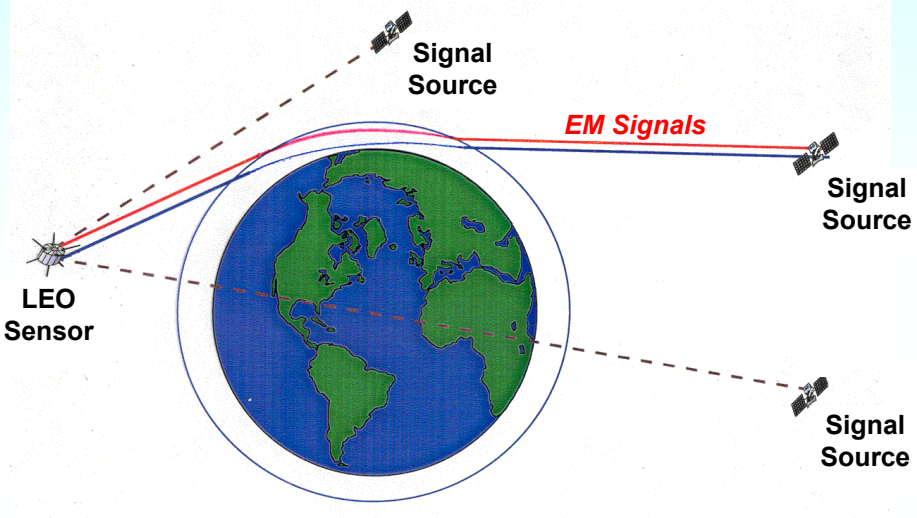
OPAC: Setting the Scene

outline

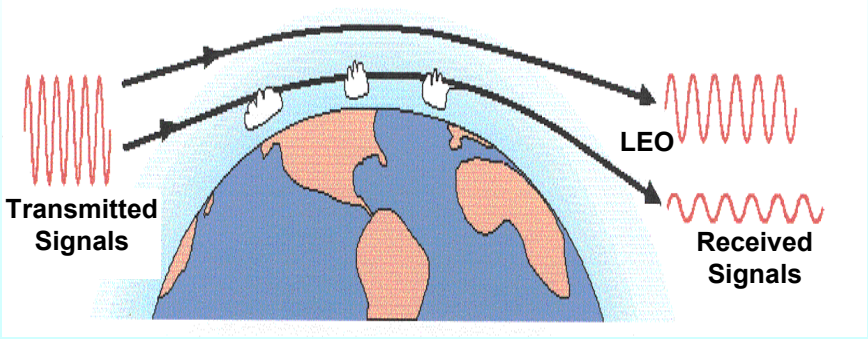
- on the principle of occultation measurements
- important methods (GNSS, LEO-crosslink, Stellar, and Solar/Lunar)
- unique properties for unique contributions to atmo&clim research
- areas of use in atmospheric and climate, and beyond
- highlight: relevance for climate monitoring and research
- concluding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

OPAC: Setting the Scene

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!).

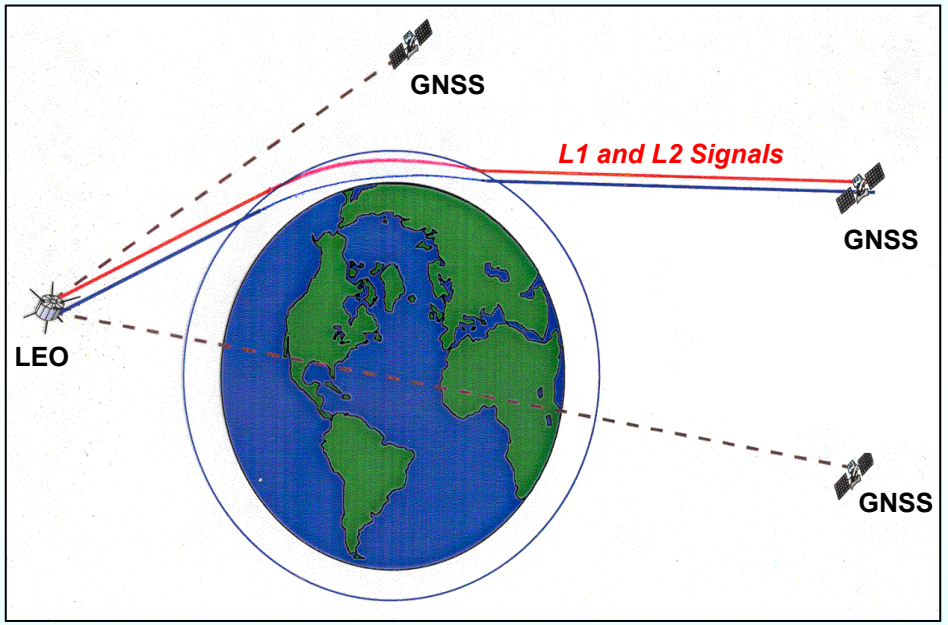
Inversion of occultation data

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

OPAC: Setting the Scene
important methods

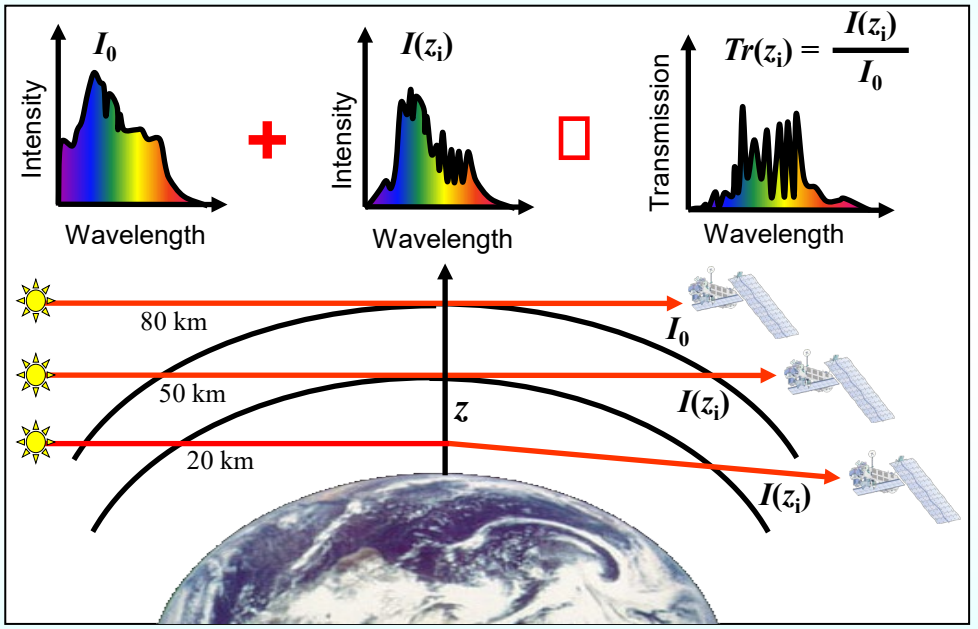
The methods comprise GNSS occultation, LEO-crosslink occultation, as well as Stellar and Solar/Lunar occultation

GNSS occultation exploits refraction of radio signals along limb paths



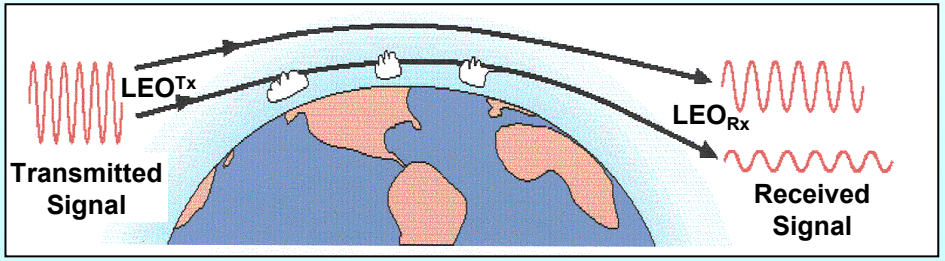
[Source: Basic fig. from D. Feng, Univ. of Arizona, 2001; modified]

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.

OPAC: Setting the Scene
unique properties (1)

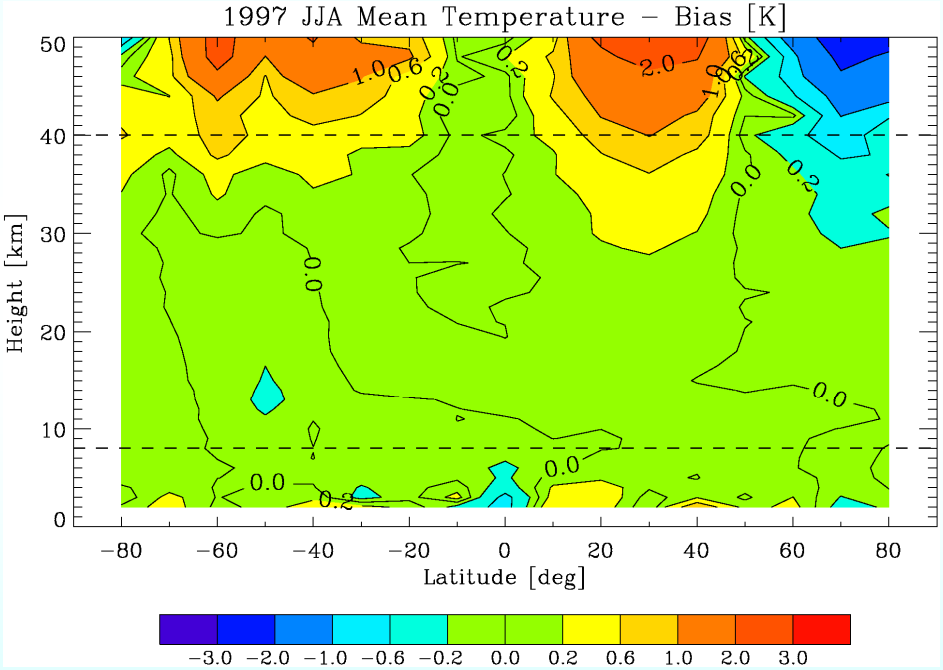
Unique contributions to atmosphere and climate research thanks to unique properties

- 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., d*T* < 1 K, d*q* < 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)

OPAC: Setting the Scene
unique properties (2)

Example for unique properties: performance of GNSS occultation



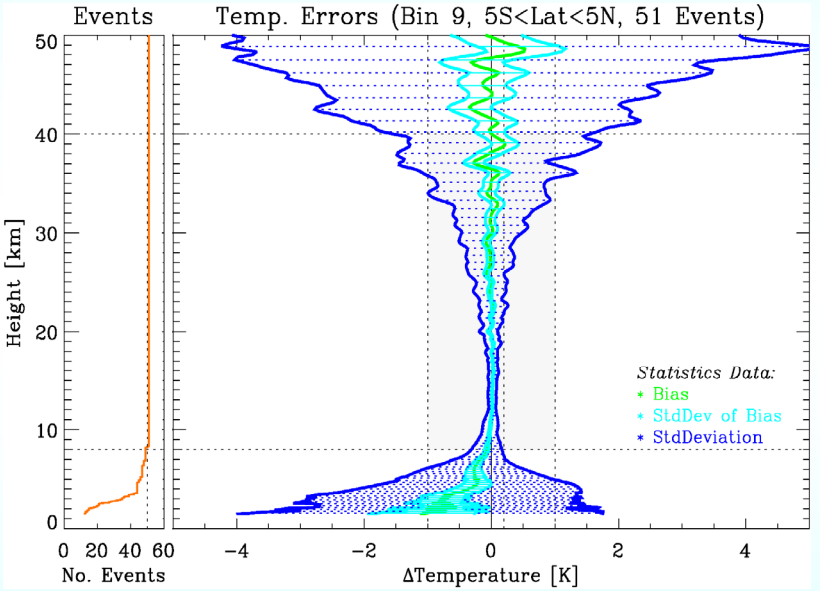


Illustration of retrieval performance using GNSS-LEO occultation data (realistic end-to-end simulations; *left:* lat-height slice of temperature errors of ~50 profile mean, *right:* vertical error structure at equator)

OPAC: Setting the Scene
areas of use (1)

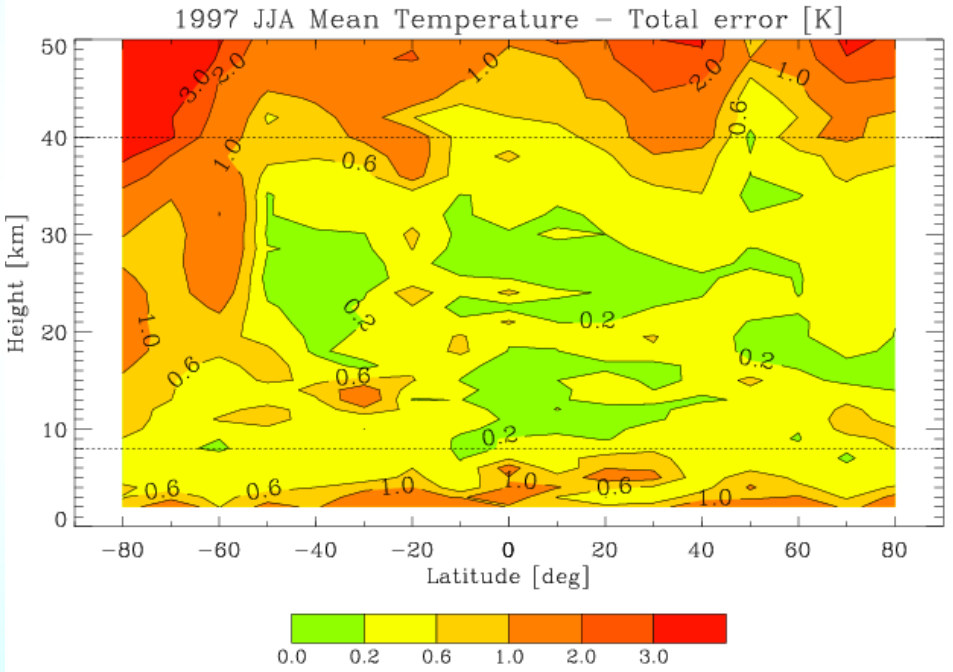
Areas of use in atmosphere and climate, and beyond

- **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)

OPAC: Setting the Scene
areas of use (2)

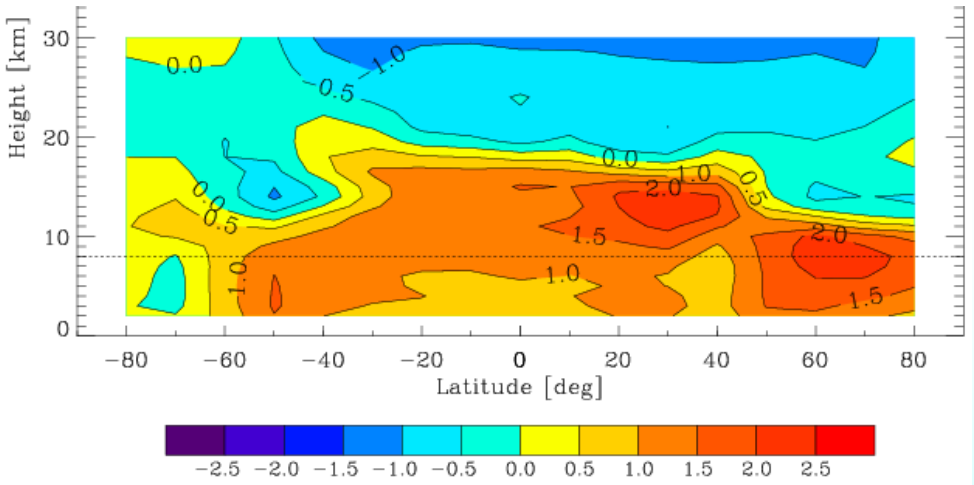
Example for areas of use: climate change monitoring by GNSS occultation

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



- 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.

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)



- 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**

OPAC: Setting the Scene

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.**

OPAC: Setting the Scene
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.

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."

OPAC: Setting the Scene
concluding remarks (2)

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

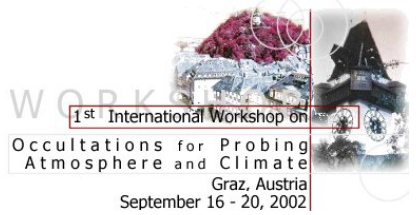
Dear OPAC-1 Participant, Dear Colleague,

"Christian Retscher, Mr." <christian.retscher@uni-graz.at>, "Stig Syndergaard, Dr." <ssy@atmo.arizona.edu>, "Sergey Sokolovskiy, Dr." <sergey@ucar.edu>, "Alejandro de la Torre, Dr." <delatorr@df.uba.ar>, "Michael Gerding, Dr." <mgerding@awi-potsdam.de>, "Benjamin Herman, Dr." <herman@atmo.arizona.edu>, "Robert Kursinski, Dr." <kursinsk@atmo.arizona.edu>, "Axel von Engeln, Dr." <engeln@uni-bremen.de>, "Dasheng Feng, Dr." <feng@atr sfc.nasa.gov>, "Andreas Rhodin, Dr." <rhodin@ lesier@iup.physik.uni-bremen.de>, "Pasquale Avino, D ieu.fr>, "Johanna Tamminen, Mrs." <johanna.tam uda@kurasc.kyoto-u.ac.jp>, "Laust Olsen, Mr." <lac " <johnsen@gkss.de>, "Alexandre Pavelyev, Dr." <pvlv Prof." <gurvich@omega.ifaran.ru>, "D ean-Loup Bertaux, Dr." <bertaux@aerov.jussieu.fr>, "Vi istian Rocken, Dr." <rocken@ucar.edu>, "Georg Be ns Wickert, Dr." <wickert@gfz-potsdam.de>, "Nc ki Kyrola, Dr." <erkki.kyrola@fmi.fi>, "Manfred "William Chu, Dr." <w.p.chu@larc.nasa.gov>, "Jos .nl>, "Andreas Gobiet, Mr." <andreas.gobiet@uni-graz. ed.kirchengast@uni-graz.at>, "Andrea K. Steiner, Dr lenberghe, Dr." <vandenb@ucar.edu>, "Chi O. A cher, Mr." <armin.loescher@uni-graz.at>, " on@dkrz.de>, "Martin Lohmann, Dr." <msl@dmi.dk>, " s Fritz, Mr." <hans.fritz@space.se>, "Hans-H "David Mimoun, Mr." <david.mimoun@space.alcatel.f lvestrin@esa.int>, "Antoni Rius, Dr." <rius@ieec.fc oph.bichler@uni-graz.at>, "Alexander Pavelyev, Dr. dmi.dk>, "Alain Hauchecorne, Dr." <alain.hauchecorne@aerov.jussieu.fr>, "Klaus Pfeilsticker, Dr." <Klaus.Pfeilsticker@iup.uni-heidelberg.de>, "Didier Fussen, Dr." <didier@oma.be>, "Charles Cot, Dr." <charles.cot@aerov.jussieu.fr>, "Fabrizio Cuccoli, Dr." <cuccoli@achille.det.unifi.it> ...

Thank you for coming!

OPAC-1

Welcome to OPAC-1!



Welcome to Graz!