ACE+

Atmosphere and Climate Explorer

Based on GPS, GALILEO, and LEO-LEO Radio Occultation

Proposal to ESA in Response to the
Second Call for Proposals for Earth Explorer Opportunity Missions

by

Dr. Per Høeg
Atmosphere Ionosphere Research Division
Danish Meteorological Institute
Lyngbyvej 100, DK-2100, Copenhagen
Denmark

Telephone: +45 39 157 486
Fax: +45 39 157 460
E-mail: hoeg@dmi.dk

and

Prof. Gottfried Kirchengast
Institute for Geophysics, Astrophysics, and Meteorology
University of Graz
Universitaetsplatz 5, A-8010 Graz
Austria

Telephone: +43 316 380 5260
Fax: +43 316 380 9825
E-mail: gottfried.kirchengast@uni-graz.at

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Executive Summary

The ACE+ mission will contribute in a significant manner to Science Theme 2 – *Physical Climate* – and Science Theme 4 – *Atmosphere and Marine Environment* – of the ESA Living Planet Programme.

ACE+ will considerably advance our knowledge about atmosphere physics and climate change processes. The mission will demonstrate a highly innovative approach using radio occultations for globally measuring profiles of humidity and temperature throughout the troposphere and stratosphere. The mission will provide data of remarkably high accuracy, density and resolution, leading to new methods for testing and improving global climate models and predictions within the planned mission lifetime of 5 years.

A constellation of 4 small satellites, tracking L-band GPS/GALILEO signals and X/K-band LEO-LEO cross-link signals, will map the detailed refractivity profile and structure of the global atmosphere from the Earth's surface to the top of the stratosphere. Detecting predicted climate change trends of the troposphere within a decade requires refractivity accuracies corresponding to around a tenth of a Kelvin. We propose to test the predictive capability of global climate models by using atmospheric profiling occultation observations from the ACE+ constellation of satellites to search for and quantify forced climate signals, predicted by existing climate models. An important asset of utilising the radio occultation technique is its "all-weather" capability due to the long wavelengths involved (centimetre and decimetre waves). Furthermore, the measurements feature exceptional long-term stability due to their self-calibrating nature, a feature that is of key importance for climate change monitoring.

The ACE+ mission is very timely. It complies with the objectives and requirements for a wide range of international programmes and conventions, including: UN Kyoto Protocol, IPCC, WCRP CLIVAR and GEWEX programme, WMO GCOS (Global Climate Observing System), WMO satellite requirements, SPARC recommendations, EU GMES Programme, and several EU COST Actions.

The proposed mission will be highly complementary to other ESA missions and to other planned European observation systems with participation from EUMETSAT and EU. Moreover, it will place Europe in a leading role internationally, since other planned occultation-based observation systems will only provide additional temperature coverage if they eventually get approved. The LEO-LEO part would be a genuinely novel demonstration.

Finally, the ACE+ mission is based on comprehensive scientific and technical ESA studies since 1995, especially on the ACE (Atmosphere Climate Experiment) and related small satellite constellation missions, supplemented with results from recent ESA studies including on the proposed WATS Earth Explorer Core Mission. The ACE+ implementation is based on a strong heritage from previous satellite designs and foresees extensive use of commercial components. A European scientific core team of more than 10 institutions and a worldwide science user team of a dozen institutions support the proposal and are keen to realize its promise. Furthermore, an industrial consortium composed of leading companies from a range of ESA's smaller and larger member states and with substantial experience and success in implementing small satellite missions has been instrumental in preparing the proposal. Hence the overall risk of the project is considered to be low.

A concise summary of the scientific background, research objectives, observational requirements, mission elements, and system concept is given in the following summary sheet.

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Scientific Background

Accurate observations of humidity and temperature in the troposphere and stratosphere - including their variability - are highly important in climate change research (IPCC, 2001). ACE+ serves this need with its mission goals:

- To **monitor** climatic variations and trends at different vertical levels and for each season. This to improve our understanding of the climate system as well as to detect the different fingerprints of global warming;
- To **improve the understanding** of climatic feedbacks defining the magnitude of climate changes in response to given forcings;
- To **validate** the simulated mean climate and its variability in global climate models;
- To **improve** and tune - via data assimilation - the **parameterisation** of unresolved processes in climate models and to detect interannual variations in external forcing of climate.

Research Objectives

Main objectives:

- to establish a **highly accurate** and **vertically resolved climatology of humidity** in the troposphere with global all-weather measurements of its concentration,
- to establish a **highly accurate** and **vertically resolved climatology of temperature** in the troposphere and stratosphere with global all-weather measurements of its vertical structure,
- to support **research on climate** variability and climate change and on **validation and improvement of atmospheric models**,
- to support **advancements on NWP** (Numerical Weather Prediction),
- to support **analysis and validation of** data from **other space missions**,
- to **demonstrate a novel active** self-calibrating atmospheric **sounding method**.

Spin-off objectives:

- ionospheric climate & weather and space weather investigations,
- assessing and improving present water vapour attenuation models.

Mission Elements

Space segment:

Small constellation of micro-satellites each of them carrying two instruments:

- a precision L-band receiver and related antennae for GPS/GALILEO-LEO occultations,
- a precision X/K-band transmitter (on 2 sats) and receiver (on 2 counter-rotating sats) and related antennae for LEO-LEO occultations (3 frequencies).

Ground segment:

- Satellite operation and control
- Fiducial stations for Precise Orbit Determination
- Level 1b processing and archiving centre
- Science data centres for higher level product generation and for data assimilation

Data products:

Profiles of bending angle and absorption, and retrieved profiles of refractivity, humidity, temperature, and pressure as function of height. Data products will be made available to data assimilation centres in near-real time.

Observational Requirements

Horizontal coverage	global
Horizontal sampling	< 500 km (LEO-LEO per month)
Vertical domain	surface – 15 km (humidity) surface – 50 km (temperature)
Vertical sampling	0.5–1 km
Temporal sampling	< 12 hrs
Accuracy of humidity	< 0.025–1 g/kg rms
Long-term stability humid.	< 2% RH / decade
Accuracy of temperature	< 1 K rms
Long-term stability temp.	< 0.1 K / decade
Spatial distribution	homogeneous over each day
Local time distribution	homogen. over a few months
Mission duration	> 5 years

System Concept

- 4 micro-satellites
  - mass: ~130 kg
  - power: ~80 W
- in a stable constellation – to optimise the quality of occultation measurements (two counter-rotating orbits with 2 satellites each),
- two altitudes (650 km and 850 km) – to optimise the spatial distribution of occultations,
- orbits drifting in local time – to optimise the temporal (local time) distribution of occultations.

6. Annex

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