Leibniz-Gemeinschaft

Der Senat

26. November 2015

Stellungnahme zum Leibniz-Institut für Troposphärenforschung, Leipzig (TROPOS)

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Vorbemerkung

Die Einrichtungen der Forschung und der wissenschaftlichen Infrastruktur, die sich in der Leibniz-Gemeinschaft zusammengeschlossen haben, werden von Bund und Ländern wegen ihrer überregionalen Bedeutung und eines gesamtstaatlichen wissenschaftspolitischen Interesses gemeinsam gefördert. Turnusmäßig, spätestens alle sieben Jahre, überprüfen Bund und Länder, ob die Voraussetzungen für die gemeinsame Förderung einer Leibniz-Einrichtung noch erfüllt sind.[1]

Die wesentliche Grundlage für die Überprüfung in der Gemeinsamen Wissenschaftskonferenz ist regelmäßig eine unabhängige Evaluierung durch den Senat der Leibniz-Gemeinschaft. Die Stellungnahmen des Senats bereitet der Senatsausschuss Evaluierung vor. Für die Bewertung einer Einrichtung setzt der Ausschuss Bewertungsgruppen mit unabhängigen, fachlich einschlägigen Sachverständigen ein.

Vor diesem Hintergrund besuchte eine Bewertungsgruppe am 18. und 19. Februar 2015 das TROPOS in Leipzig. Ihr stand eine vom TROPOS erstellte Evaluierungsunterlage zur Verfügung. Die wesentlichen Aussagen dieser Unterlage sind in der Darstellung (Anlage A dieser Stellungnahme) zusammengefasst. Die Bewertungsgruppe erstellte im Anschluss an den Besuch den Bewertungsbericht (Anlage B). Das TROPOS nahm dazu Stellung (Anlage C). Der Senat der Leibniz-Gemeinschaft verabschiedete am 26. November 2015 auf dieser Grundlage die vorliegende Stellungnahme. Der Senat dankt den Mitgliedern der Bewertungsgruppe und des Senatsausschusses Evaluierung für ihre Arbeit.

1. Beurteilung und Empfehlungen

Der Senat schließt sich den Beurteilungen und Empfehlungen der Bewertungsgruppe an.

Das Leibniz-Institut für Troposphärenforschung (TROPOS) erfüllt sehr erfolgreich seinen **Auftrag**, die physikalischen und chemischen Eigenschaften und Prozesse in der Troposphäre zu erforschen, insbesondere Aerosole, Wolken und deren Interaktion. Seit der letzten Evaluierung hat sich das Institut sehr gut entwickelt. Die abteilungsübergreifende Zusammenarbeit wurde empfehlungsgemäß verbessert. Die Integration von Expertise in Atmosphärenphysik, Chemie, Fernerkundungsmethoden und Modellierung gelingt nun sehr gut und zeichnet das TROPOS im internationalen Vergleich aus. Eine weitere Stärke des Instituts ist die Kombination von Feld- und Laborexperimenten mit Modellierungsarbeiten.

In den vier Abteilungen werden durchgehend sehr gute **Leistungen** erbracht. Die Forschungsergebnisse werden überwiegend in international angesehenen Fachzeitschriften veröffentlicht. Das TROPOS stellt seine Geräte regelmäßig externen Wissenschaftlerinnen und Wissenschaftlern zur Verfügung. Diese wertvolle Infrastrukturleistung trägt maßgeblich zur exzellenten internationalen Vernetzung des Instituts bei. Darüber hinaus übernimmt das TROPOS wichtige Aufgaben für die wissenschaftliche Fachgemeinschaft, indem es die Messinstrumente und -techniken weiterentwickelt sowie in Gremien zur Definition von internationalen Standards mitwirkt, oftmals in führender Rolle. Weiteres

[1] Ausführungsvereinbarung zum GWK-Abkommen über die gemeinsame Förderung der Mitgliedseinrichtungen der Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz e. V.

Potenzial besteht beispielsweise in der Miniaturisierung von Instrumenten und in der Entwicklung von Messgeräten für unbemannte Fluggeräte und Forschungsballons. Das Institut sollte angesichts seiner hervorragenden, innovativen Arbeiten in der Geräteentwicklung eine aktivere Patentierungspolitik verfolgen.

Bei der Einwerbung von **Drittmitteln für Forschungsprojekte** ist das Institut sehr erfolgreich und kann auf ein umfangreiches und sehr ausgewogenes Portfolio von Mittelgebern verweisen. Insbesondere die konstant hohe Einwerbung von Mitteln der DFG und der EU ist erfreulich.

Die **Planungen** des TROPOS für seine zukünftigen Forschungsarbeiten wurden in einem überzeugenden Strategiepapier zusammengeführt. Allerdings könnte das Institut auf Grund seiner Leistungen und seiner Expertise über die Auswirkungen von Aerosolen und Wolken noch ambitionierter bei der Verbesserung der Vorhersagen von Wetter- und Klimaentwicklungen mitwirken. Auch in anderen Bereichen ist es in der Lage, signifikant zur Klärung komplexer und gesellschaftlich wichtiger Fragen beizutragen, beispielsweise zu den gesundheitlichen Auswirkungen einer Belastung der Troposphäre mit Schadstoffen. Die Anstrengungen, zu einer besseren Verknüpfung wissenschaftlicher Modelle für die lokale, regionale und globale Skala beizutragen, sollten weiter intensiviert werden.

Das TROPOS unterhält sowohl national als auch international zahlreiche ertragreiche **Kooperationsbeziehungen**. Es ist sehr erfreulich, dass das Institut sich auch in führender Rolle an Konsortien und Netzwerken beteiligt, insbesondere auf europäischer Ebene. So ist es ein zentraler Partner im EU-Netzwerk ACTRIS (*Aerosols, Clouds, and Trace Gases Research Infrastructure Network*) und seit Juni 2015 in dessen Nachfolger ACTRIS-2. Unter anderem übernimmt das TROPOS in diesem Netzwerk die Koordination für den Bereich Fernerkundung und betreibt das Kalibrierzentrum für Aerosolphysik. Der Senat befürwortet nachdrücklich die vom Institut angestrebte Aufnahme von ACTRIS in die ESFRI-Roadmap (*European Strategy Forum on Research Infrastructures*) und die dafür erforderliche Aufnahme in die nationale Roadmap für Forschungsinfrastrukturen.

1997 hatten die Regierungschefs zur Sicherung der Qualität der Forschung unter anderem beschlossen, dass alle Forschungseinrichtungen einen flexiblen Personalhaushalt erhalten sollen, damit die Einrichtungen neue Herausforderungen annehmen und sich dem gebotenen Wettbewerb stellen können. Dieses wichtige Ziel wurde von Bund und Ländern in Bezug auf die Leibniz-Einrichtungen in den „Mindestanforderungen an Programmbudgets“ konkretisiert. Der Senat hat das Land Sachsen bereits verschiedentlich an die Beschlusslage erinnert, unter anderem in seiner letzten Stellungnahme zum TROPOS. Er erwartet nach wie vor, dass die **Verbindlichkeit des Stellenplans** nach Maßgabe der entsprechenden Bund-Länder-Vereinbarungen aufgehoben wird. Dies ist auch dringlich, damit die Mittelaufwüchse aus dem Pakt für Forschung und Innovation sachgerecht und flexibel auch für den personellen Ausbau verwendet werden können. Das Aufsichtsgremium unter dem Vorsitz des Sitzlandes wird gebeten, bis zum 31. Dezember 2016 über die Umsetzung der Empfehlung zu berichten.

Durch eine aktive Rekrutierungspolitik und zielgerichtete Beratungsangebote ist es dem TROPOS in den vergangenen Jahren gelungen, den **Anteil von Frauen** auf Postdoc-

Ebene und in Leitungspositionen zu erhöhen. Um diese ersten Erfolge auszubauen, sollte das Institut seine Anstrengungen konsequent aufrechterhalten.

Der **wissenschaftliche Nachwuchs** am Institut wird sehr gut betreut und gefördert. Es ist sehr erfreulich, dass zahlreiche Absolventinnen und Absolventen im Anschluss an ihre Qualifikationsphase Möglichkeiten finden, ihre wissenschaftliche Karriere an anderen Einrichtungen sowohl im In- als auch im Ausland fortzusetzen. Umgekehrt gelingt es dem TROPOS auch, in erheblichem Umfang ausländische Wissenschaftlerinnen und Wissenschaftler zu gewinnen. Dies trägt zum wissenschaftlichen Austausch und zur hervorragenden nationalen und internationalen Vernetzung des Instituts bei. Das TROPOS sollte sich im Rahmen seiner Möglichkeiten dafür einsetzen, dass auch den Promovierenden, die in der Fakultät für Physik und Geowissenschaften der Universität Leipzig eingeschrieben sind, eine kumulative Dissertation ermöglicht wird. Bisher steht diese Option nur den in der Fakultät für Chemie und Mineralogie eingeschriebenen Promovierenden offen.

Insgesamt ist das TROPOS mit seinen Leistungen ein wichtiger und international anerkannter Akteur in der Troposphärenforschung. Insbesondere die Integration der verschiedenen relevanten Fachdisziplinen und die Kombination von Feld- und Laborexperimenten mit Modellierungsarbeiten sind Alleinstellungsmerkmale. Mit seinen herausragenden stationären und mobilen Messgeräten stellt das Institut der wissenschaftlichen Fachgemeinschaft wichtige Forschungsinfrastrukturen zur Verfügung. Die Erfüllung dieser Aufgaben ist in der Form an einer Hochschule nicht möglich. Eine Eingliederung des TROPOS in eine Hochschule wird daher nicht empfohlen. Das TROPOS erfüllt die Anforderungen, die an eine Einrichtung von überregionaler Bedeutung und gesamtstaatlichem wissenschaftspolitischem Interesse zu stellen sind.

2. Zur Stellungnahme des TROPOS

Der Senat begrüßt, dass das TROPOS beabsichtigt, die Empfehlungen und Hinweise aus dem Bewertungsbericht bei seiner weiteren Arbeit zu berücksichtigen.

3. Förderempfehlung

Der Senat der Leibniz-Gemeinschaft empfiehlt Bund und Ländern, das TROPOS als Einrichtung der Forschung und der wissenschaftlichen Infrastruktur auf der Grundlage der Ausführungsvereinbarung WGL weiter zu fördern.

30 January 2015

Annex A: Status Report

Leibniz Institute for Tropospheric Research, Leipzig (TROPOS)

Contents

1. Structure, Tasks, and Institutional Environment

Development and funding

The Leibniz Institute for Tropospheric Research (TROPOS) was founded in 1992. 50 % of its institutional funding is provided by the Federal Government, 50 % by the States (*Länder*). The national importance of TROPOS was confirmed by the German Council of Science and Humanities in 2000 and by the Senate of the Leibniz Association in 2008.

Responsible department at *Länder* level: Saxon State Ministry for Science and the Arts, Dresden

Responsible department at federal level: Federal Ministry of Education and Research (BMBF), Bonn

Mission and tasks

According to its statutes, TROPOS' mission is to carry out investigations in the troposphere and to promote scientific evidence in this area. The aim is thus to foster the understanding and predictability of the properties and processes in the tropospheric multiphase system.

In order to fulfil its mission, TROPOS pursues an interdisciplinary research approach, combining atmospheric physics, chemistry, and modelling. Empirical studies are performed both in the field and in the laboratory. TROPOS also develops and applies novel measurement techniques and standards.

Legal form and organisation

TROPOS is a registered non-profit organisation (*eingetragener Verein*). The Director represents the institute and manages the institute's day-to-day affairs. He is appointed by the Board of Trustees for a five-year term; reappointment is possible.

The department heads, the deputy head of the Department "Remote Sensing of Atmospheric Processes" (which is headed by the Director), and the Head of Administration form the Executive Board, which meets regularly with the Equal Opportunities Officer to discuss all relevant scientific and operational matters, share information from the departments, and make joint decisions on all major issues.

The Scientific Advisory Board (SAB) advises the Board of Trustees and the Director on all important scientific and structural matters. It develops proposals and recommendations on the institute's areas of research and on its work planning (cf. Chapter 6).

TROPOS' supervisory committee is the Board of Trustees, which consists of three voting members. The chair is appointed by the responsible department at *Länder* level; the deputy chair is appointed by the responsible federal department. The third voting member is appointed by TROPOS' General Assembly. The Board of Trustees makes all decisions concerning matters of fundamental scientific, economic, or organisational significance to the institute and determines the guidelines for the institute's activities.

Research structure

In 2013, TROPOS' departmental structure was changed from three to four departments: "Chemistry of the Atmosphere", "Experimental Aerosol and Cloud Microphysics", "Modelling of Atmospheric Processes", and "Remote Sensing of Atmospheric Processes".

For organising the research activities, TROPOS has defined two programme areas: "Aerosols" and "Aerosols and clouds". Within each of these programme areas, topics are divided between "Process studies at small temporal and spatial scales" and "Long-term process and trend analysis", thus leading to a two-by-two matrix research structure.

The research work is supported by joint workshops, the Information Technology Group, the library, and the Melpitz research station.

National and international scientific environment

According to TROPOS, the institute is unique in carrying out linked investigations of physical and chemical processes of atmospheric aerosols and clouds in the laboratory, in the field, and in models. There is some methodological and thematic vicinity to other Leibniz institutes – the Leibniz Institute for Atmospheric Physics (IAP), the Leibniz Institute for Baltic Sea Research Warnemünde (IOW), and the Potsdam Institute for Climate Impact Research (PIK) – as well as with other national research institutions such as the Karlsruhe Institute of Technology (KIT), the Forschungszentrum Jülich, the Max Planck Institute for Chemistry, the Max Planck Institute for Meteorology, the Max Planck Institute for Biogeochemistry, and the German Aerospace Center (DLR). Similar approaches in atmospheric remote sensing are pursued at the universities of Bonn and Cologne.

Internationally, TROPOS mentions the following institutions covering similar research topics: the California Institute of Technology in Pasadena, California, the NOAA Earth System Research Laboratory in Boulder, Colorado (both in the USA), the Paul Scherrer Institute in Villigen (Switzerland), the Institute of Researches on Catalysis and Environment in Lyon, the *Laboratoire Interuniversitaire des Systèmes Atmosphériques* in Paris (both in France), the University of Helsinki (Finland), the University of Manchester, the University of Reading, the School of Earth and Environment at Leeds University (all three in the UK), and the Royal Netherlands Meteorological Institute in De Bilt (The Netherlands).

National interest and justification for funding as a non-university institution

According to TROPOS, the institute has established itself as a major, internationally renowned player in aerosol and cloud research. It tackles scientifically and socially relevant problems caused by the polluted atmosphere and contributes to a better understanding of aerosol and aerosol-cloud processes in anthropogenically polluted as well as in climatically and ecologically sensitive regions. The results can provide a sound scientific basis for implementing air quality and climate improvement measures.

TROPOS regards its research programme, which combines physical and chemical aspects both in the laboratory and in the field with modelling approaches, as more comprehensive than typical university-based efforts. The institute's work is based on large-scale

scientific infrastructure, which requires significant investments and running costs and thus can only be maintained and developed further at an independent institution outside the setting of a university.

2. General concept and profile

Development of the institution since the last evaluation

Since its foundation in 1992, TROPOS has developed a clear research profile. It focuses on the physical and chemical processes of aerosol and cloud particles. In 2010, following the appointment of the new Director and head of the Department "Atmospheric Physics", a new focus on observations of marine aerosols and aerosol-cloud interaction was established. Furthermore, a new satellite remote sensing working group was established to complement the ground-based remote sensing activities. In 2012, the new head of the Department "Modelling of Atmospheric Processes", with expertise in dust and aerosol transport modelling, was appointed.

During the departmental restructuring in 2013 (cf. Chapter 1), the former Department "Atmospheric Physics" was split up: two of its former working groups, "Tropospheric Aerosols" and "Clouds", now form the new Department "Experimental Aerosol and Cloud Microphysics"; the other two of its former working groups, "Ground-based Remote Sensing" and "Satellite Remote Sensing", now form the Department "Remote Sensing of Atmospheric Processes". This new organisation is expected to foster closer cooperation between the working groups.

Research at TROPOS is organised in departments and programme areas (cf. Chapter 1). While departments differ in their methodological expertise, they all contribute to the programme areas. They synchronise the observational and theoretical research activities, share and discuss the consequences of new findings, and plan joint research projects in order to better resolve and understand physical and chemical processes in the tropospheric multiphase system.

TROPOS considers its interdisciplinary approach, the combination of both laboratory and field experiments with modelling work, and the focus on application-oriented basic research with strong societal relevance as particular strengths that set it apart from other research institutions worldwide. Most of its measurement facilities have a strong mobile component so that TROPOS is able to focus its expertise on regional hotspots of scientific interest. According to TROPOS, this facilitates the initiation and maintenance of fruitful international cooperation and enables the institute to often play a leading role in joint research programmes at national, European, and international levels.

Results

Research

Research highlights from the past years include new insights into atmospheric ice and new particle formation processes, exceptional natural or anthropogenic phenomena, urban air quality issues and measures, volcanic ash plumes, and cross-border pollutant

transports. Many contributions arose within the context of large national and international laboratory studies and field campaigns.

TROPOS mainly aims to publish its research results in international peer-reviewed journals. Despite the additional costs, it encourages Open Access publishing. The results are also regularly presented at national and international meetings and conferences.

During the reporting period (2011 to 2013), 270 articles were published in peer-reviewed journals, 55 contributions to edited volumes or monographs, ten work or discussion papers, and three articles in other journals. Two volumes were edited by TROPOS researchers. For detailed indicators of the publication record cf. Appendix 2.

Scientific services and infrastructure tasks

TROPOS provides scientific services to the international community by controlling and recommending quality standards for remote sensing and by developing and disseminating *in situ* aerosol particle and cloud droplet measurement techniques, e. g. during international calibration workshops.

The institute provides access to its laboratory and field infrastructures. TROPOS' research site Melpitz has frequently been used by visiting scientists as a platform and infrastructure. This also holds for the Airborne Cloud Turbulence Observation System (ACTOS). In the area of laboratory experiments, both the LEAK (*Leipziger Aerosolkammer*, a large simulation chamber for investigating aerosol processes) and the LACIS (Leipzig Aerosol Cloud Interaction Simulator) installations have been part of EU infrastructure initiatives and are frequently visited by external researchers to perform campaign-like measurements. The same holds for the aqueous-phase laboratory of the Chemistry Department.

Furthermore, TROPOS sometimes performs contract research campaigns for assessing the particulate matter load at industrial workplaces or for identifying the sources of smells in the environment by model applications or measurements.

Scientific consultancy, knowledge and technology transfer

According to TROPOS, several of its projects involve a strong scientific consultancy component. Examples range from advising space agencies in developing and validating remote sensing of the troposphere, establishing innovative measurement techniques for use by environmental agencies, interaction with state authorities in view of Low Emission Zones and general issues of air pollution to memberships in scientific advisory boards and adjunct faculty positions in foreign universities. The institute also participates in regional, federal, and European parliamentary activities.

TROPOS is actively engaged in the DKK (*Deutsches Klimakonsortium*), the *Klimanavigator*, and within the Leibniz Association. It also fosters human capacity building through international schools, workshops, and twinning partnerships.

Transfer of science and technology mostly takes place in the fields of lidar technology, establishment of innovative aerosol measurements, and consultancy in regenerative energy infrastructures. According to TROPOS, opportunities for direct economic exploi-

tation of its results are limited. The institute holds one patent on an optical installation with a transmitting and receiving installation.

Academic events and public relations

During the reporting period (2011 to 2013), TROPOS scientists organised or co-organised 30 scientific meetings and conferences. Among these were the 16th International Conference on Clouds and Precipitation (ICCP-2012) in Leipzig and the International Radiation Symposium (IRS 2012) in Berlin, both with about 500 participants. TROPOS was also actively involved in several events in the framework of the European "Year of the Air" initiative in 2013.

TROPOS considers it one of its obligations to make science understandable to the general public in order to allow interested citizens to take part in the knowledge society. To this end, it has devised a communication strategy aimed at raising its profile among the public, political and social organisations, and the scientific community, establishing itself as a centre of excellence for key themes such as air quality and particles as well as clouds and climate change, creating long-term awareness for environmental and climate issues and the associated problems, and building a positive image for the Institute.

The institute has implemented various measures to address different target groups: international, national, and local politicians, public authorities, interest groups and associations, young researchers, pupils, and the general media. For example, it has contributed to regional air control plans and the review of the EU Air Quality Framework Directive, participates in parliamentary evenings, and regularly organises school visits and Girls' Days. During the reporting period, it has issued 15 press releases per year. TROPOS researchers and their work were featured in about 100 publications in print media, radio, and television per year.

Strategic work planning for the next few years

According to TROPOS, physical and chemical processes related to aerosol and clouds continue to be a major uncertainty in understanding and predicting weather and climate. In view of increasing urbanisation, industrialisation, and agricultural land use as well as changes in aerosol processes as a consequence of climate change, the institute expects a growing need for research on anthropogenic and natural aerosols, their chemical and physical processing, their long-range transport, their interaction with clouds and the entire atmosphere, and their exchange with other compartments of the Earth system. Further challenges lie in finding appropriate metrics for comparing modelling and measurement results, in matching laboratory conditions with those in the real atmosphere, in assessing the coupling of the gas phase with particle and cloud-chemical processes, in accounting for the complexity of multiphase chemical reactions and their coupling to microphysics, and in resolving cloud turbulence and its effect on cloud microphysical properties and processes.

In the field, experiments in highly polluted regions and in sensitive areas with little or no local information on aerosols will continue to be a major part of TROPOS' research activities. This will be contrasted with studies in low-pollution global regions. The insti-

tute's research station at Melpitz will be further developed into a European prototype supersite for the integration of *in situ* measurements, vertical characterisation, and modelling of the atmosphere ("Melpitz Column").

Laboratory investigations will continue to focus on understanding and quantifying cloud microphysical and chemical processes, with a shift to systems more complex and closer to atmospheric systems and conditions. This will include the effects of turbulence on cloud-microphysical processes.

Model studies will focus on aerosol distribution, processes, and interactions in both polluted and unpolluted key regions with particular emphasis on absorbing aerosols and natural aerosol species. This includes investigating aerosol radiative effects as well as aerosol-cloud interactions.

TROPOS sees its four departments as ideally suited to resolve the complex issues on the vertical structure, microphysics, and dynamics of aerosols and clouds and to relate those to ground-based observations and to regional-scale modelling and satellite remote sensing, thus establishing a most complete picture of the complex tropospheric multiphase system. International collaboration will continue to play an important role in its research efforts.

Appropriateness of facilities, equipment, and staffing

In 2013, TROPOS' revenue was about € 12.9 million, including € 8.3 million (65 %) in institutional funding, € 3.8 million (29 %) in revenue from project funding grants, and € 779k (6 %) in revenue from services. In addition, there were € 1.3 million miscellaneous revenue and € 450k in revenue for construction projects. During the reporting period, about one third of third-party funding was raised from the federal and *Länder* governments and another third from the German Research Foundation (DFG); about one fifth was raised from EU programmes (cf. Appendix 3).

With the construction of a multifunctional building in 2011 and the now finalised plans for a new chemistry laboratory (to be completed by 2016), TROPOS considers its spatial resources as generally adequate. It mentions, however, that the additional running costs associated with these two buildings (€ 170k per year) will have to be financed from the budgetary increase according to the German Joint Initiative for Research and Innovation (*Pakt für Forschung und Innovation*).

The strategic expansion of the Melpitz research station as a European Leibniz research infrastructure ("Melpitz column") will incur additional running costs over the next few years, which, according to the institute, might lead to a reduction in scientific investments.

TROPOS estimates the total additional operational costs needed to ensure the operation of the current and future infrastructure without reducing resources for research at € 250k per year.

Capital expenditure and material resources are described as good. However, TROPOS expects a growing demand for technical and IT resources.

TROPOS sees a need of twelve additional positions. Seven of these shall be funded from the existing budget. Additional funding is required for the following five positions, four of them permanent (a-d) and one as a fixed-term position for six years (e):

a) one position (E8) in addition to the existing three in the Information Technology Group; currently, a fourth position is financed by the scientific departments

b) one additional position (E8) in the administration for support in purchasing and finances

c) one additional scientific position (E14) in the Department "Chemistry of the Atmosphere" for field measurements and multiphase modelling

d) one additional scientific position (E14), one half position each in the Department "Experimental Aerosol and Cloud Microphysics" and the Department "Remote Sensing of Atmospheric Processes" to upgrade current 50-percent positions to full positions

e) one additional scientific position (E14) for six years in the Department" Experimental Aerosol and Cloud Microphysics" for work at the Leipzig Aerosol Cloud Turbulence Tunnel (LACTT).

3. Subdivisions of TROPOS

Department "Chemistry of the Atmosphere" (13.5 full-time equivalents [FTE] in research and scientific service, 5.2 FTE doctoral candidates, 10.0 FTE service staff)

Profile and development

This department explores the tropospheric multiphase system, using field measurements, laboratory studies, and multiphase modelling. According to the institute, the importance of this work has increased in the past years. In order to gain new insights into molecular systems, the technical equipment was expanded, e. g. through the acquisition of different mass spectrometers and the reconstruction of different flow reactors.

Field experiments concentrate on aerosol studies to characterise air quality-related processes in developed regions as well as global hotspots and on atmospheric experiments exploring the foundations of current atmospheric chemical subject areas.

In the laboratory, investigations of aqueous-phase processes including radical oxidant, non-radical oxidant, and organic accretion reactions are performed. Recently, work with laminar flow tubes was taken up. According to TROPOS, the department operates one of the leading installations for the study of organic compounds in the troposphere, including the formation and processing of secondary organic aerosols (SOA), the *Leipziger Aerosolkammer* (LEAK).

Multiphase modelling focuses on liquid-phase reaction mechanisms, aerosol-cloud interactions, marine aerosol chemistry, and mineral dust chemistry.

Results

In the area of field measurements, TROPOS has organised, carried out, and evaluated the Hill-Cap Cloud Thuringia (HCCT-2010) experiment in 2010. Experiments at the Cap

Verde Atmospheric Observatory (CVAO) measurement station and the Cap Verde Ocean Observatory (CVOO) have yielded insights into seasonal patterns in the mineral dust and marine aerosol chemical compositions as well as the export of organic compounds from the ocean to the atmosphere. With the TROPOS research station at Melpitz, novel results concerning changes in particle air pollution at different spatial and temporal scales could be obtained. Field measurements in highly polluted areas (mainly China) have provided detailed pictures of molecular aerosol composition.

In the laboratory, the department's flow tube studies yielded major results on nucleation processes, the chemistry of so-called Criegee intermediates, and the formation of extremely low-volatility organic compounds (ELVOC). The LEAK chamber has provided detailed studies of SOA constituents, paving the way to quantitative modelling of SOA. In the aqueous chemistry laboratories, various radical reactions have been investigated and work on photochemical systems and on multiphase amine chemistry was performed.

In the multiphase modelling section, a new halogen chemistry module (CAPRAM-HM2; based on CAPRAM, Chemical Aqueous Phase Radical Mechanism), a tropospheric amine chemistry module, and a chemical mechanism generator were developed. The multiphase mechanisms were applied to model field campaigns such as HCCT-2010.

During the reporting period (2011 to 2013), there were 66 articles in peer-reviewed journals, two contributions to edited volumes or monographs, five work and discussion papers, and three other articles. About forty percent of these publications were co-authored with scientists from other departments.

Work planning

According to TROPOS, the construction of the new chemistry building and the subsequent relocation of the existing laboratories will lead to the consolidation of the ongoing activities and foster new developments at the same time. The institute intends to strengthen the connection and synergies between field and laboratory studies and multiphase modelling further and to expand the links to the other TROPOS departments.

In the area of field measurements, participation and organisation of air pollution experiments in areas of global importance is intended. Studies of the development of air pollution in Eastern Europe will be continued. CVAO will be developed further, and extended participation in ship cruises is planned to investigate the ocean surface as a source of relevant compounds in the atmosphere. Cloud chemistry, including aerosol-cloud interaction, will remain an important subject of study. The trend towards real-time measurements will continue. In turn, classical particle sampling will be reduced.

Concerning laboratory experiments, LEAK will be converted into a twin aerosol chamber (LEAK 2), and new experiments for the investigation of surface- and liquid-phase chemical phenomena will be built. Flow tube reactors will be developed further. In aqueous-phase studies, a new experiment for the study of interfacial chemistry is being set up. TROPOS expects organic phase particle chemistry to form a new subject of dedicated study in the future. This will require the development of proxy solvent work; a pilot study has already been performed successfully. In analytical chemistry, it is expected that

hyphenated techniques will gain importance, while mass spectrometry will remain the main method of detection.

In multiphase modelling, TROPOS plans to develop CAPRAM into a model system to be used increasingly for interpreting own field campaigns. All multiphase models will be adapted to run on multi-CPU computers. Besides numerical tools, other computational tools will be developed, such as automated mechanism generation systems, automated analysis systems, and automated mechanism reduction systems.

Department "Experimental Aerosol and Cloud Microphysics" (16.5 full-time equivalents [FTE] in research and scientific service, 8.7 FTE doctoral candidates, 14.4 FTE service staff)

Profile and development

This department was established in 2013, comprising the two working groups "Atmospheric Aerosols" and "Clouds" of the former Department "Atmospheric Physics". The main areas of work are (1) climate-relevant optical properties of tropospheric aerosols, (2) spatio-temporal variations and trends in atmospheric aerosols, observation networks, and air quality, (3) aerosol-cloud interactions, and (4) dynamics, turbulence, and their influence on cloud microphysics. Investigations are conducted in the laboratory and all over the globe from the boundary layer up to the tropopause region, across different spatial and temporal scales.

TROPOS lists the following recent developments in the work programme: consolidation of tropospheric long-term observations in networks and implementation of quality assurance systems and data provision; a shift of focus in fundamental aerosol-cloud interaction process studies towards heterogeneous ice nucleation; addition of a strong field component to the aerosol-cloud interaction-related research efforts; increasing execution of *in situ* atmospheric aerosol and cloud measurements on board mobile observation platforms; investigations of aerosol-cloud interactions involving turbulence and cloud dynamics.

Results

Optical properties of Saharan dust particles were linked to the hygroscopic properties. The mass-specific aerosol absorption coefficient in the troposphere over Central Europe was found to show little variation, enabling the simplification of the treatment of aerosol absorption in large-scale atmospheric models.

New insights were gained on new particle formation and transformation processes in anthropogenic hotspot areas. Temporal trends in the tropospheric aerosol could be derived and the relevance of specific aerosol formation and transformation processes established. Climatological *in situ* information on the properties and abundance of aerosol particles in the upper troposphere of the northern hemisphere were obtained.

The Leipzig Aerosol Cloud Interaction Simulator (LACIS) yielded new and important quantitative insights into the processes of aerosol particle activation and heterogeneous ice nucleation. Further investigations were carried out on the activation behaviour of

marine aerosols, on the influence of aerosol particles and thermodynamic parameters on cloud formation and cloud properties, and on the activation and aerosol processing in orographic clouds.

Significant progress was made concerning the *in situ* characterisation of small-scale cloud dynamics and local turbulent structures and their influence on the thermodynamic, microphysical, and radiative cloud properties. It could be shown that cloud turbulence should be interpreted locally instead of using cloud averages.

The department constantly develops novel instrumentation. In the past years, these efforts have resulted in the following instruments: Fast Condensation Particle Counter (20 Hz) for airborne deployment, LED-based integrating nephelometer for enhanced thermal stability, thermally stabilised optical particle spectrometer for ice particle detection (TOPS-ICE), Ice Roughness Investigation System (IRIS), Pumped Counterflow Virtual Impactor (CVI) for ice particle separation (IN-CVI), and Airborne CVI for HALO (High Altitude and Long Range Research Aircraft) flight conditions (HALO-CVI).

The department is also active in the development of quality assurance programmes for physical measurements of atmospheric aerosol particles. For example, it hosts the WMO-GAW (World Meteorological Organization – Global Atmosphere Watch) World Calibration Centre for Aerosol Physics (WCCAP). It regularly provides scientific advice to political stakeholders.

During the reporting period (2011 to 2013), there were 138 articles in peer-reviewed journals, seven contributions to edited volumes or monographs (including editorships), seven work and discussion papers, and one other article. About a quarter of these publications were co-authored with scientists from other departments.

Work planning

Established *in situ* measurement techniques and investigations will systematically leave the ground and go into the vertical dimension. The aim is to better understand and quantify aerosol properties, aerosol transport, modification, and aerosol-cloud interactions. For the aerosol and cloud microphysical instruments, miniaturisation and a certain level of automation are envisioned.

Tropospheric aerosol properties, in particular optical properties, will remain a focal area in the years to come. TROPOS plans to investigate the influence of particle mixing state, composition, hygroscopicity, and non-spherical shapes on aerosol optical properties. In order to discriminate between black carbon, brown carbon, and mineral dust, a broader approach is planned for the investigation of light absorption at multiple wavelengths. An international air quality experiment will be conducted in Manila (Philippines) in 2015. Also, plans have been mounted to characterise the emission of agricultural dust in vulnerable ecosystems into the lower troposphere as well as aerosol emission and entrainment over the ocean.

At the Leipzig Aerosol Cloud Interaction Simulator (LACIS), the ice nucleation behaviour of more complex and atmospherically relevant aerosol particles (e. g. soil dusts, ashes, etc.) will be investigated. Additional freezing modes, longer time scales, and lower ice

nucleus (IN) number concentrations will be considered in this context. The efforts concerning the *in situ* quantification of the spatial variability and temporal trends in atmospheric CCN (cloud condensation nucleus) and especially IN properties will be intensified. This will include significant vertical profiling activities. Ground-based and airborne investigations of cloud particle residues in mixed-phase and ice clouds will continue.

Investigations concerning cloud dynamics, turbulence, and their influences on cloud microphysics will continue to focus on warm boundary-layer clouds. A new element in the research on turbulence-cloud microphysics interactions is the Leipzig Aerosol Cloud Turbulence Tunnel (LACTT). Currently, a humid turbulent wind tunnel allowing investigations of cloud droplet activation and freezing processes under turbulent flow conditions is being built.

Department "Modelling of Atmospheric Processes" (9.5 full-time equivalents [FTE] in research and scientific service, 3.7 FTE doctoral candidates, 8.0 FTE service staff)

Profile and development

This department develops and applies efficient and accurate models that are used to study the processes controlling aerosol distributions and their effects as well as models describing detailed multiphase processes in the atmosphere. In this context, observational data from laboratory and field studies and from remote sensing are utilised. In 2012, a new head of the Department "Modelling of Atmospheric Processes" was appointed.

The two main areas of work are (1) aerosol transport, air quality, and climate relevance, including high-resolution computations of aerosol sources and transport as well as interactions with atmospheric processes, and (2) aerosol-cloud interactions, including process studies of aerosol particle interactions with cloud droplets and ice formation, the impact of multiphase processes in clouds on the atmospheric chemistry, and chemical ageing of particle surfaces.

In the past years, work on the distribution and impact of aerosol properties relevant for the atmospheric radiation budget has become an additional focus of research. Emphasis has shifted from model development and numerical methods towards model applications, including their use in evaluating and interpreting field measurements.

Results

In aerosol transport modelling (including sources, transformation, and deposition processes), the aerosol/chemistry transport model MUSCAT developed at TROPOS was used by coupling it online to the operational weather model COSMO of the German National Meteorological Service (*Deutscher Wetterdienst*, DWD). COSMO-MUSCAT was used, e. g., in the Air Quality Model Evaluation International Initiative (AQMEII) and for topical issues of energy and environmental policy. Natural aerosol types (Saharan dust, volcanic ash, marine aerosol) were parameterised in the model to study their roles in the atmospheric system. Further results include investigations of the effect of absorbing aerosol on atmospheric dynamics, the development of computational approaches for connecting the spatio-temporal distribution of aerosol mass concentrations with the distributions of

cloud condensation nuclei (CCN) and ice nuclei (IN), and preparations for regional-scale investigations of the indirect cloud effect.

In order to use liquid-phase chemistry mechanisms in 3D transport simulations, the COSMO-MUSCAT model was extended by a cloud chemistry parameterisation. The atmospheric model ASAM was developed for explicit consideration of orography and obstacles in large-eddy simulations. It was further improved by implementing split-explicit time integration methods and by using graphics processing units.

A detailed description of cloud microphysics is carried out using the Spectral Aerosol Cloud Microphysics model SPECS. Work at the process level revealed e. g. that surface diffusion of attached sulphuric acid and water molecules on mineral dust particles can significantly enhance the heterogeneous binary nucleation rate, in agreement with data from field studies.

During the reporting period (2011 to 2013), there were 37 articles in peer-reviewed journals, eight contributions to edited volumes or monographs (including editorships), two work and discussion papers, and one other article. About thirty percent of these publications were co-authored with scientists from other departments.

Work planning

Spatio-temporal aerosol distributions and their relevant optical properties will be further investigated with regard to their radiative effect on atmospheric dynamics. Emphasis will be put on light-absorbing aerosols and natural aerosol species. The characterisation of sources, transport, properties, and effects of mineral dust will also be the focus of the new research group “Dust at the Interfaces” funded by the Leibniz Association (competitive procedure).

Further studies, partly in cooperation with other departments, are envisaged on the impact of urban emissions, atmospheric transformations, and effects of long-range transport on air quality in densely populated areas. Contribution to a study of airborne transmission of infectious diseases via aerosol transport is planned in the framework of the Leibniz Research Alliance “Infections’21”.

Another goal is the quantitative description of aerosol-cloud regimes. The impact of particles on the evolution of clouds will be studied with the existing models. Modelling of freezing processes in clouds in which ice formation can be observed will be continued. In order to evaluate the modelled clouds, the model studies will be aligned with ground-based remote sensing measurements that provide relevant information on atmospheric properties.

For studies of chemical multiphase and physicochemical processes, which are performed in close cooperation with the Department “Chemistry of the Atmosphere”, the numerical solvers and the parallelisation of the extensive chemical mechanisms will be advanced. Emphasis will be put on describing the formation and transformation of secondary organic aerosols as well as the impact of chemical ageing processes on dust particle surfaces and their efficiency as ice nuclei.

Department "Remote Sensing of Atmospheric Processes" (14.7 full-time equivalents [FTE] in research and scientific service, 6.1 FTE doctoral candidates, 1.8 FTE service staff)

Profile and development

In 2013, the working groups "Ground-based Remote Sensing" and "Satellite Remote Sensing" (newly established in 2010) of the previous Department "Physics of the Atmosphere" were merged into this department. A major strategy is to combine the expertise in active and passive remote sensing as well as in ground-based and satellite-based remote sensing. Work in the department focuses on (1) aerosol characterisation and long-range transports, (2) vertical profiling and aerosol-cloud interaction, and (3) synergetic use of ground- and satellite-based remote sensing.

The expertise in lidar-based remote sensing of particle types has provided the basis for a new focus on ice formation processes under real environmental conditions. The satellite remote sensing activities aim at characterising the spatio-temporal evolution of clouds, aerosols, and radiation by means of satellite observations as well as ground-based and aircraft-borne measurements.

Synergies have been established between lidar-based remote sensing and active and passive microwave techniques. These activities have led to the establishment of the mobile land station "Leipzig Aerosol and Cloud Remote Observation System" (LACROS). The design and application of ground-based radiation flux stations for aerosol-cloud-radiation closure studies and the setup of a mobile radiation observation station have also instigated new experimental directions.

Results

The Saharan Mineral Dust Experiment SAMUM-2, which was coordinated by this department, led to improved understanding of dust emission, transport, and cloud interaction. As a follow-up, the department initiated SALTRACE (Saharan Aerosol Long-range Transport and Aerosol-Cloud interaction Experiment).

Progress was achieved with respect to parameterisation for ice nuclei concentrations. In this context, new polarisation-lidar-based techniques were developed. The "Dual Field of View" lidar technology, which allows active remote sensing of water cloud microphysical properties, was adopted and improved at TROPOS. According to the institute, this technology will enhance the identification of aerosol-cloud interactions as well as aerosol and cloud formation near the cloud base.

The mobile sea station OCEANET was established and deployed with the aim of retrieving the vertical aerosol structure of the troposphere in combination with the surface energy budget and basic thermodynamic and cloud information. Regular OCEANET campaigns were organised on board the German research vessel *Polarstern*. A highlight result of these cruises was the identification of colder ice nucleation in the southern troposphere than in the north.

According to TROPOS, the establishment of LACROS permits the extension of the basic research on cloud microphysical processes to optically thick cloud regimes. LACROS is

viewed as a vital strategic step towards the incorporation of a remote sensing supersite in the European ACTRIS (Aerosols, Clouds, and Trace Gases Research Infrastructure Network) activities.

Further results include insights into the spatial structure of boundary layer clouds together with the resulting surface energy budget fields. With a network of 100 autonomous pyranometers, surface fields of downwelling solar irradiance at high spatial and temporal resolution could be obtained.

TROPOS contributed to the establishment of a German volcanic ash warning system. It assumed a leading role in the European lidar network (EARLINET) and the European infrastructure project ACTRIS. In addition, the institute has been involved in consultancy projects, e. g. towards the development and application of the European cloud and aerosol research satellite (EarthCARE).

During the reporting period (2011 to 2013), there were 77 articles in peer-reviewed journals, 40 contributions to edited volumes or monographs (including editorships), and one other article. About 14 percent of these publications were co-authored with scientists from other departments.

Work planning

The department will maintain its close cooperation with the other TROPOS departments, in order to combine the indirect physical characterisations with *in situ* observations, laboratory studies, and modelling activities. New techniques and spectral regions will be explored to improve the distinction between fine- and coarse-mode particles and the resolution of aerosol and cloud characteristics during phase transitions.

Most of the ongoing successful projects will be continued, especially the large network activities, e. g. in the framework of Polly^{XT} (TROPOS' portable multi-wavelength Raman lidar system), EarthCARE, and ACTRIS. The OCEANET platform will be extended by adding a cloud radar and spectral surface irradiance measurement facilities for column retrieval and radiation closure studies.

The *in situ* chemical and physical aerosol characterisation will be coupled to the vertical column in order to better understand transport, ageing, and sedimentation processes of Saharan mineral dust and African biomass burning aerosol as well as aerosol-cloud interaction. A new focus will be set on aerosol-cloud interaction above cold upwelling coastal regions. Also, the air-land-sea interaction will be explored.

The *in situ* aerosol and trace gas measurements will be joined at the research station Melpitz. This "Melpitz column" will serve as the prototype for the European ACTRIS supersites with a standardised quality control scheme and shared access for the international community.

Further plans include investigations of the influence of microphysical processes on the life cycle of shallow and deep convection and detailed radiative closure studies in both clear-sky and cloudy conditions using ground-based as well as satellite observations.

4. Collaboration and networking

Collaboration with universities

TROPOS collaborates closely with the University of Leipzig. The heads of three departments ("Chemistry of the Atmosphere", "Modelling of Atmospheric Processes", and "Remote Sensing of Atmospheric Processes") hold joint professorships with the university. For the fourth department ("Experimental Aerosol and Cloud Microphysics"), a joint professorship is planned for 2020.

TROPOS scientists are involved in bachelor and master programmes at the University of Leipzig, mostly in meteorology, but also in physics and chemistry. For structured PhD education, the Leibniz Graduate School on "Clouds, Aerosols, and Radiation" was founded in 2012; it is part of the "Research Academy Leipzig".

TROPOS maintains close ties to Chinese universities through an associate professorship of one of the heads of the Department "Experimental Aerosol and Cloud Microphysics" at Peking University and adjunct positions of the head of the Department "Chemistry of the Atmosphere" at Fudan University and at Shandong University.

At the project level, TROPOS collaborates with scientists at numerous other universities worldwide.

Collaboration with other domestic and international institutions

TROPOS is engaged intensively in national and international cooperation, mostly in the framework of third-party-funded projects.

At national level, Max Planck institutes, Helmholtz centres, and government agencies are the most frequent collaborative partners. Important networks and projects include the German Ultrafine Aerosol Network (GUAN), the High Altitude and Long Range Research Aircraft (HALO), the Ice Nuclei Research Unit (INUIT), the High Definition Clouds and Precipitation for Climate Prediction (HD(CP)^2), and the Saharan Mineral Dust Experiment (SAMUM).

At international level, many projects are conducted in the framework of EU-funded projects and typically include a greater number of universities and non-university research institutions. Major endeavours include the EU projects ACTRIS (Aerosols, Clouds, and Trace Gases Research Infrastructure Network), BACCHUS (Impact of Biogenic versus Anthropogenic emissions on Clouds and Climate, towards a Holistic Understanding), EUROCHAMP-II (Integration of European Simulation Chambers for Investigating Atmospheric Processes), IAGOS (In-Service Aircraft for a Global Observation System; a European research infrastructure which has been included in the German national roadmap), and PhotoPaq (Demonstration of Photocatalytic Remediation Processes on Air Quality). TROPOS also participates in the Air Quality Model Evaluation International Initiative (AQMEII) and in Cosmics Leaving Outdoor Droplets (CLOUD) experiments conducted at CERN, and it operates the Cap Verde Atmospheric Observatory (CVAO) and the Cap Verde Ocean Observatory (CVOO) jointly with other institutes from Germany and the UK.

TROPOS' scientific infrastructures like the Melpitz research station, the Airborne Cloud Turbulence Observation System (ACTOS), the Leipzig Aerosol Cloud Interaction Simula-

tor (LACIS), and the *Leipziger Aerosolkammer* (LEAK) are frequently used for international collaborative projects.

Between 2011 and 2013, TROPOS hosted 95 guest scientists, usually for periods of one week to three months; more than eighty percent of these visitors were from other countries. In turn, 21 TROPOS scientists stayed at other institutions, all of them abroad, during this time period.

5. Staff development and promotion of junior researchers

Staff development and personnel structure

As of 31 August 2014, TROPOS employed 148 people (120 full-time equivalents [FTE]). In addition, there were two scholarship recipients, 27 student assistants, and one trainee. Among the staff, 103 (78 FTE) were scientists (including the scholarship recipients). Among the scientific staff, 33 % were women, 50 % were funded by third-party money, and about 80 % were employed on temporary contracts (cf. Appendix 4).

In 2010, the new Director and head of the Department "Atmospheric Physics" joined TROPOS. In 2012, the new head of the Department "Modelling of Atmospheric Processes" joined the institute.

Open positions for scientific personnel are announced in international media and electronic distribution lists. Open positions in technical areas are announced in the region of Leipzig.

According to TROPOS, the institute encourages and supports internal qualification of scientists and technical staff. To a certain degree, it awards higher qualification and performance: e. g., several technical positions were upgraded in the past years due to a certified performance of higher qualified-work.

Promotion of gender equality

TROPOS is committed to the principles of equal opportunities and a work environment that supports a family-work balance. Promoting equal opportunities has been anchored as a management and cross-sectoral task. Since 2010, an equal opportunities plan has been in place. Over the past years, the institute has made efforts to increase the proportion of women in senior scientific positions, promote young female researchers, and create a family-friendly work environment.

At the end of August 2014, 45 % of the 42 doctoral candidates (including scholarship recipients) and 25 % of the remaining 55 scientists in non-executive positions were female. One of six executive positions (17 %) was held by a woman (one of the three professorships; appointed in 2012). TROPOS considers the transition phase from the doctoral to the postdoctoral phase as particularly critical. According to the institute, only 25 % of the applicants at this stage are female. It attempts to counteract the decline in the proportion of female scientists by actively recruiting female postdocs and providing targeted support for applications. Participation of female researchers in qualification measures and mentoring programmes is actively promoted.

In order to promote a good family-work balance, TROPOS has implemented a number of measures, which are well accepted by the employees. For example, the institute allows for flexible working hours. Telework with external access to servers and databases is also possible. Five places per year at childcare establishments in Leipzig have been offered since 2014; the Institute also has a parent/child office. For employees on a fixed-term contract, continued employment is guaranteed for at least three months after taking parental leave, and help is offered to parents returning to work. Both in 2011 and in 2014, TROPOS received the "audit beruf**und**familie" certificate.

Promotion of junior researchers

Between 2011 and 2013, 56 academic degrees (diploma, Master's, Bachelor's) were completed under the supervision of TROPOS staff.

During the same period, 21 doctoral dissertations were completed at TROPOS. At the end of August 2014, 42 doctoral candidates worked at the institute. In 2006, a structured PhD programme was set up and extended in the framework of the Leibniz Graduate School on "Clouds, Aerosols, and Radiation" in 2012. The school organises thesis committees, regular meetings, guest visits, and support for international students. TROPOS encourages and supports qualified young scientists financially to apply for external funding. Doctoral candidates often receive additional internal funding by TROPOS to finish their theses and corresponding scientific publications.

TROPOS supports highly qualified postdocs for a limited time following the PhD qualification and accompanies these young researchers with an individual mentoring within the departments. The institute does not provide tenure tracks due to the very small number of vacant permanent positions. Rather, young scientists are encouraged to apply for positions abroad to improve their qualification for future job applications. Furthermore, qualification and career opportunities are discussed during the annual employee discussions.

TROPOS also supports the habilitation programme for highly qualified scientists. Currently, three scientists at TROPOS intend to obtain their habilitation at the University of Leipzig.

Since the last evaluation, seven TROPOS scientists accepted external leading positions in Germany, France, Denmark, the UK, and China.

Vocational training for non-academic staff

TROPOS offers its employees general soft-skill courses and the possibility to apply for training courses according to their job-related needs. In addition, participation in qualification programmes of the Leibniz Association such as the "Leibniz Mentoring Programme", the "Qualification Programme for Administrative Management Personnel", and the workshops for EU consultants are supported.

Currently, TROPOS employs one chemical laboratory technician as an apprentice. Generally, the institute trains in the professions chemical laboratory technician, glass appara-

tus maker, and office administrator. During the reporting period (2011 to 2013), three apprentices successfully completed their vocational qualifications.

6. Quality assurance

Internal quality management

TROPOS follows a multiple-eye principle and endorses the recommendations for ensuring good scientific practice as formalised by the German Research Organisation (DFG). The Executive Board selects an ombudsman to ensure good scientific practice. The institute operates a data archive and back-up system to ensure long-term data availability and to enable the reproduction of published results.

The first level of quality control takes place at the senior scientist and postdoc level by frequent critical discussion of the scientific projects, their progress, results, and publication. The next level of quality assurance involves the department- or institute-wide presentation and critical discussion of the scientific projects and results in the context of seminars, meetings, and the biannual TROPOS retreat. The Director and the Executive Board represent the highest level of internal quality assurance. Within the latter, the overall performance of the institute, the departments, and specific research projects are continuously reviewed and discussed. The main focus is on performance, organisational and infrastructural issues. In addition to the above-mentioned measures, the department heads carry out yearly structured and certificated employee interviews. The main focus of these talks is on personnel issues like motivation, performance, or future plans. Quality issues are resolved in mutual agreement or with the inclusion of a third, independent person.

Quality management by the Scientific Advisory Board and Supervisory Board

The Scientific Advisory Board (SAB) consists of six to ten voting members. The members are appointed by the Board of Trustees on the basis of recommendations by the Executive Board. The term of office for SAB members is four years, with the possibility of extension for a second period. The SAB advises the Board of Trustees and the Board of Management on all important scientific and structural matters, on the research programme including the use of available resources, on national and international cooperation, and on the recruitment of managerial personnel. It evaluates the institute's programme budget and the research performance and work planning in written reports (audits).

The SAB generally meets once per year. The frequency of the audits is at the SAB's discretion. However, it must be ensured that the entire institute is audited at least once during a regular evaluation period of seven years and that the result is recorded in a formal audit report according to the guidelines issued by the Leibniz Association. The last such interim evaluation was performed by the SAB in April 2012.

Implementation of recommendations from the last external evaluation

In order to meet the Senate's recommendations of the last evaluation (below in *italics*; cf. *Senatsstellungnahme zum Leibniz-Institut für Troposphärenforschung e. V. (IfT)*, 9 July 2008; pp. 3f.), TROPOS has reacted as follows:

1. In the context of the imminent managerial change, the institute should strive to improve the cooperation between the departments and disciplines. To this end, it should draw up a long-term research concept defining the planned future areas of work in more detail and explaining how the departments intend to work together to achieve these research goals. In addition, a modification of the overall institutional structure, in order to strengthen interdepartmental work, should be contemplated.

Work at TROPOS has been structured in a new department-independent research matrix. Following an intensive strategic discussion, a comprehensive research concept was drawn up, which sets out a new scheme of main work themes for which all departments provide input (cf. Chapters 1 and 2). Collaboration between departments and disciplines is encouraged through regular topical meetings along the research matrix as well as during the regular meetings of the Executive Boards. An internal Scientists Board meets roughly every three months to discuss interdepartmental cooperation. Furthermore, an institute-wide two-day retreat, which takes place every two years, addresses all issues of departmental and interdepartmental work.

2. Considering the convincing research results, there is scope for further improvement with respect to the institute's publication output.

The publication output could be increased significantly.

3. The institute should explore whether the research cooperation with the University of Leipzig could be intensified further. The amount of teaching by scientific employees should not be increased further.

TROPOS pursues a strategy of working with its university partners – particularly the Leipzig Institute of Meteorology – to develop Leipzig into a national centre of research and teaching excellence for clouds, aerosols, and radiation. The amount of teaching has not increased.

4. The institute should make efforts to increase the proportion of women in executive positions.

Over the past years, the institute has made efforts to increase the proportion of women in senior scientific positions (cf. Chapter 5). In 2012, a woman could be recruited as the new head of the Department "Modelling of Atmospheric Processes".

5. The funders' plans for construction measures to remedy the shortage of office and laboratory space by 2010 are endorsed.

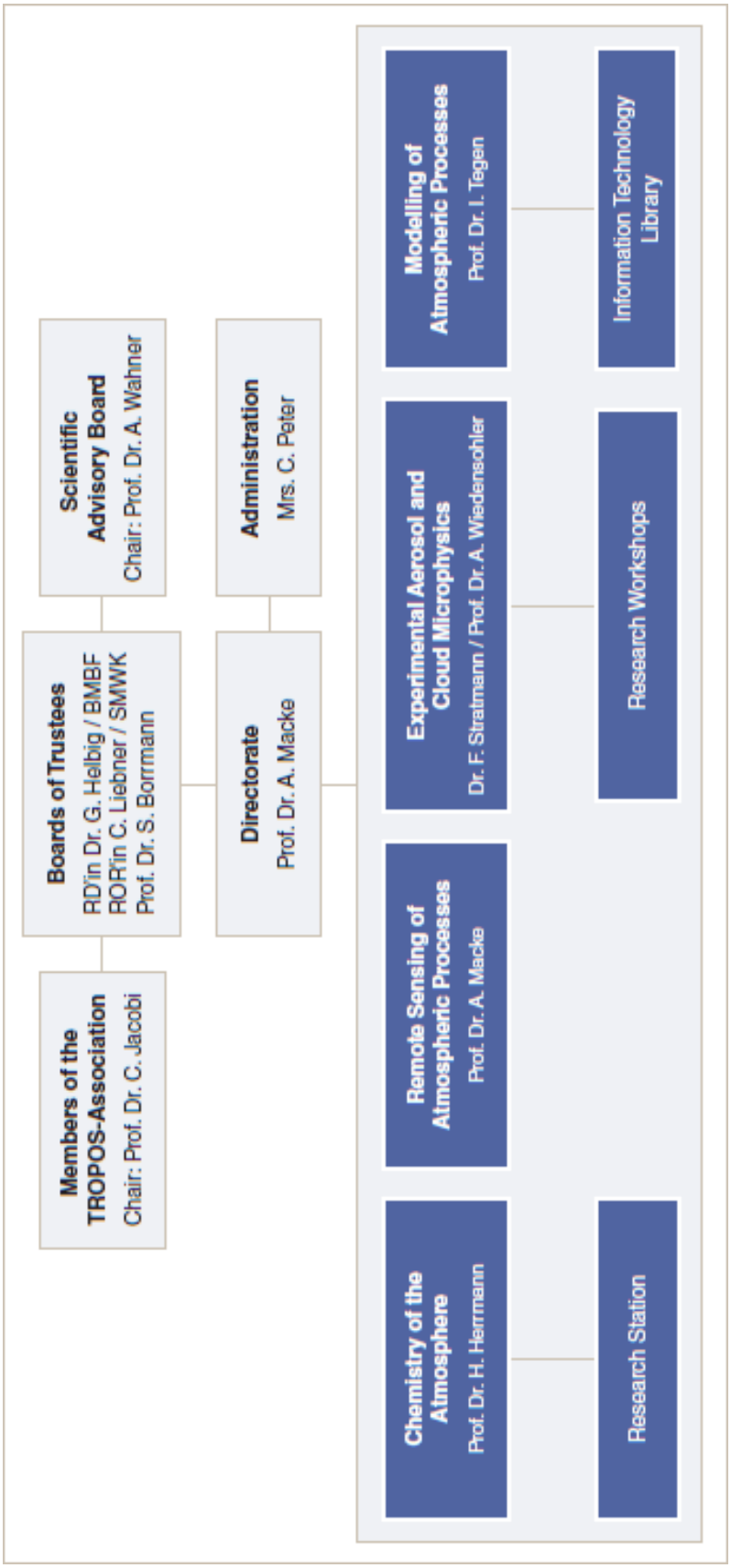
The lack of space has been rectified with the construction of the new multifunctional building.

6. The state of Sachsen should make the budget plans and the staff establishment plan more flexible.

This is outside the scope of the institute's responsibility. As of today, the Saxon State Ministry of Finance refuses a cost-neutral transition to a flexible staff establishment plan. Most of the budget plans have already been made more flexible.

Appendix 1

Organisational Chart



Appendix 2

Publications and patents

	Period		
	2011	**2012**	**2013**
Total number of publications	**108**	**124**	**108**
Monographs	0	0	0
Individual contributions to edited volumes	4	38	13
Articles in peer-reviewed journals	100	83	87
Articles in other journals	2	0	1
Working and discussion papers	2	2	6
Editorship of edited volumes	0	1	1
Number of publications per full-time equivalent (FTE) in 'research and scientific services' (not including doctoral candidates)	2,1	2,4	2,0

Industrial property rights (2011–2013) [1)]	Granted	Registered
Patents	1	2
Other industrial property rights	0	0
Exploitation rights/licences (number)	0	

[1] Concerning financial expenditures for revenues from patents, other industrial property rights, and licences, see Appendix 3.

Appendix 3

Revenue and Expenditure

Revenue		2011			2012			2013 [1]		
		k€	% [2]	% [3]	k€	% [2]	% [3]	k€	% [2]	% [3]
Total revenue (sum of I., II. and III.; excluding DFG fees)		**13,018.0**			**12,930.0**			**14,612.0**		
I.	**Revenue (sum of I.1.; I.2., and I.3.)**	**11,455.0**	100 %		**11,506.0**	100 %		**12,853.0**	100 %	
1.	Institutional Funding (excluding construction projects and acquisition of property)	7,730.0	67 %		7,859.0	68 %		8,305.0	65 %	
1.1	Institutional funding (excluding construction projects and acquisition of property) by Federal and *Länder* governments according to AV-WGL	7,730.0			7,859.0			8,305.0		
1.1.1	*Proportion of these funds received through the Leibniz competitive procedure (SAW procedure)* [4]	*395.0*			*38.0*			*0.0*		
1.2	Institutional funding (excluding construction projects and acquisition of property) not received in accordance with AV-WGL	0.0			0.0			0.0		
2.	Revenue from project grants	2,810.0	25 %	100 %	2,449.0	21 %	100 %	3,769.0	29 %	100 %
2.1	DFG	1,153.0		41 %	1,115.0		46 %	884.0		23 %
2.2	Leibniz Association (competitive procedure) [4]	0.0		0 %	152.0		6 %	600.0		16 %
2.3	Federal, *Länder* governments	855.0		30 %	565.0		23 %	1,468.0		39 %
2.4	EU	665.0		24 %	559.0		23 %	735.0		20 %
2.5	Industry	0.0		0 %	0.0		0 %	0.0		0 %
2.6	Foundations	0.0		0 %	0.0		0 %	0.0		0 %
2.7	European Space Agency (ESA)	137.0		5 %	58.0		2 %	82.0		2 %
3.	Revenue from services	915.0	8 %		1,198.0	10 %		779.0	6 %	
3.1	Revenue from commissioned work	910.0			951.0			727.0		
3.2	Revenue from publications	0.0			0.0			0.0		
3.3	Revenue from exploitation of intellectual property for which the institution holds industrial property rights (patents, utility models, etc.)	0.0			0.0			0.0		
3.4	Revenue from exploitation of intellectual property without industrial property rights	0.0			0.0			0.0		
3.5	Revenue from conferences	5.0			247.0			52.0		
II.	**Miscellaneous revenue** (e. g. membership fees, donations, rental income, funds drawn from reserves)	**887.0**			**1,174.0**			**1,309.0**		
III.	**Revenue for construction projects** (institutional funding by Federal and *Länder* governments, EU structural funds, etc.)	**676.0**			**250.0**			**450.0**		

Expenditures		k€	k€	k€
Expenditures (excluding DFG fees)		**13,018.0**	**12,930.0**	**14,612.0**
1.	Personnel	6,837.0	6,930.0	7,433.0
2.	Material expenses	2,251.0	2,502.0	2,541.0
2.1	*Proportion of these expenditures used for registering industrial property rights (patents, utility models,*	*7.0*	*6.0*	*4.0*
3.	Equipment investments	1,595.0	1,289.0	1,719.0
4.	Construction projects, acquisition of property	405.0	51.0	410.0
5.	"Reserves" (e. g. cash assets, unused funds)	1,174.0	1,309.0	1,668.0
6.	Miscellaneous items	756.0	849.0	841.0

DFG fees (2.5 % of revenue from institutional funding)	192.0	202.0	212.0

[1] Preliminary data: no

[2] Figures I.1., I.2. und I.3. add up to 100 %. The information requested here is thus the percentage of "Institutional funding (excluding construction projects and acquisition of property)" in relation to "Revenue from project grants" and "Revenue from services".

[3] Figures I.2.1 bis I.2.7 add up to 100 %. The information requested here is thus the percentage of the various sources of "Revenue from project grants".

Appendix 4

Staff

(Basic financing and third-party funding / proportion of women, as of 31 August 2014)

	Full-time equivalents		Employees		Female employees	
	Total	on third-party funding	Total	on fixed-term contracts	Total	on fixed-term contracts
	Number	Percent	Number	Percent	Number	Percent
Research and scientific services	**76.9**	50	**101**	80	**32**	89
Professors / Direct. (C4, W3, or equivalent)	1.0	0	1	100	0	
Professors / Direct. (C3, W2, A16, or equivalent)	2.0	0	2	0	1	0
Academic staff in executive positions (A15, A16, E15, or equivalent)	3.0	0	3	0	0	
Junior research group leaders / junior professors / post-doctoral fellows (C1, W1, A14, E14, or equiv.)	0.0		0		0	
Scientists in non-executive positions (A13, A14, E13, E14, or equivalent)	48.2	55	55	72	14	82
Doctoral candidates (A13, E13, E13/2, or equiv.)	22.7	54	40	100	17	100
Service positions	**34.2**	15	**37**			
Service scientists (from E13, senior service)	4.3	64	5			
Laboratory (E5 to E8, mid-level service)	9.8	10	10			
Laboratory (E9 to E12, upper-mid-level service)	2.0	0	2			
Workshops (E5 to E8, mid-level service)	4.0	25	4			
Workshops (E9 to E12, upper-mid-level service)	4.0	0	4			
Library (E9 to E12, upper-mid-level service)	0.6	0	1			
Information technology - IT (E5 to E8, mid-level service)	1.0	0	1			
Information technology - IT (E9 to E12, upper-mid-level service)	4.5	0	5			
Programming support (E9 to E12, upper-mid-level service)	2.0	0	2			
Secretariats departments (E5 to E8, mid-level service)	2.0	18	3			
Directorate	**1.5**	0	**2**			
Assistant (E5 to E8, mid-level service)	0.8	0	0.8	*		
Public relations (E5 to E8, mid-level service)	0.2	0	0.2	*		
Public relations (E9 to E12, upper-mid-level service)	0.5	0	1			
Administration	**7.6**	0	**8**			
Head of administration	**1.0**	0	1			
Staff positions (E9 to E12, upper-mid-level service)	1.0	0	1			
International administration (financial administration, personnel, etc.) (E5 to E8, mid-level service)	3.6	0	4			
Building service (E5 to E8, mid-level service)	2.0	0	2			
Student assistants	**7.2**	18	**27**			
Trainees	**1.0**	0	**1**			
Scholarship recipients at the institution	**1.0**	0	**2**		**2**	
Doctoral candidates	1.0	0	2		2	
Post-doctoral researchers	0.0	0	0		0	

* Fractional numbers result from splitting of work duties.

27 July 2015

Annex B: Evaluation Report

Leibniz Institute for Tropospheric Research, Leipzig (TROPOS)

Contents

1. Summary and main recommendations

The Leibniz Institute for Tropospheric Research (TROPOS) very successfully investigates the physical and chemical properties and processes in the troposphere with a special emphasis on aerosols, clouds, and their interaction. The institute's long-term goal is to elucidate their impacts on the weather and climate system in order to improve the quality of forecast and climate models.

Since the last evaluation, the institute has developed very well and has managed to improve the cross-departmental collaboration. The integration of expertise in atmospheric physics, chemistry, remote sensing, and modelling is very successful and singles TROPOS out by international comparison. Another of the institute's strengths is the combination of experimentation in the field and the laboratory together with modelling studies. For this purpose, a wide range of methods and tools are used, so that processes can be considered, analysed, and understood from various points of view.

Very good work is conducted in all four departments. Research results are published for the main part in internationally recognised journals. Furthermore, the institute is intensively and successfully involved in developing measurement instruments and techniques as well as international measurement standards. Thus, it plays an essential role in the atmospheric research and observations community. TROPOS enables other scientists to benefit from its array of both stationary and mobile state-of-the-art equipment, which it develops continuously. This valuable infrastructure service also plays a major role in the institute's excellent international networking. The institute should continue to put strong emphasis on strategic collaborations with suitable partners. Participation in consortia and networks such as ACTRIS (Aerosols, Clouds, and Trace Gases Research Infrastructure Network) has proved to be an asset both for TROPOS and its partners. However, when continuing to develop such welcome collaborations, the institute should define clearly the amount of resources it can dedicate given the limits on funding.

The institute's plans for its future research, which have been compiled in a detailed strategy paper, are convincing. TROPOS is encouraged to place more emphasis on introducing its scientific results into cross-cutting academic debates. Both the experimental and the theoretical work as well as the modelling done by the institute could help to produce fundamental contributions to answering complex scientific and socially important questions if combined with research being conducted in neighbouring disciplines at the institute. This is not only true for efforts in climate and weather research, but also for promising research projects on the impact of tropospheric processes on health, for example.

Special consideration should be given to the following main recommendations in the evaluation report (highlighted in **bold face** in the text):

GENERAL CONCEPT AND PROFILE

1. Beyond the detailed questions and aims contained in its strategy paper, TROPOS should strive to realize ambitious goals with respect to overarching questions and topics of societal relevance. Indeed, the institute can make major contributions to

research on aerosol and cloud impacts on climate and weather systems as well as to research on health-related issues such as air quality and toxic cycling in the atmosphere.

2. The institute should also turn its attention to large-scale atmospheric modelling from local to regional to global. It is recommended that TROPOS make use of its excellent modelling expertise to develop and enhance the synergism between models at these scales.
3. In order to exploit the valuable data from measurements and modelling fully, TROPOS would do well to augment its expertise and usage of modern statistical methods for analysing large amounts of data. The institute needs to devise a clear strategy indicating to what extent this can be done in-house and whether targeted collaborations with external partners are necessary.
4. TROPOS is involved in research that might benefit from in-depth expertise in aerobiology, e. g. work on biological ice nuclei or the transmission of infectious diseases. It is recommended to build access to expertise either internally or via collaboration with external partners.
5. It is of great importance and value that TROPOS will continue its excellent engagement in developing innovative, high-quality instrumentation and methods as well as in providing research infrastructure to other research institutions, including in particular universities. Further great potential exists for the future, e. g. in the area of instrument miniaturisation and in the development of balloon-borne devices and instruments adapted to operation on unmanned aerial vehicles.
6. At present, the institute does not apply for patents regularly. It should consider implementing a more active patenting strategy.

COLLABORATION AND NETWORKING

7. TROPOS is a core partner in the EU network ACTRIS (Aerosols, Clouds, and Trace Gases Research Infrastructure Network). The rationale and plans to develop ACTRIS into an open network are convincing. It will be important to ensure the sustainability of TROPOS's contribution to ACTRIS once current EU funding runs out. Thus, the institute's attempts to put ACTRIS on the German national roadmap for European research infrastructures should be supported.

STAFF DEVELOPMENT AND PROMOTION OF JUNIOR RESEARCHERS

8. Without delay, TROPOS must be given the opportunity to create further permanent positions within the scope of current institutional funding in order to effectively address important long-term infrastructure and scientific needs. The *Land* Saxony should be able to expedite the extension of the staffing plan, which has not been adjusted for years; this is therefore recommended as a first step on the path to improving the management options open to the Directorate in personnel matters. In addition, it is a matter of urgency to abolish the obligatory nature of the staffing plan in accordance with the relevant agreements between the Federal and *Länder* Governments, as had already been recommended in the evaluation seven years ago.

9. During the last few years, the institute has made efforts to increase the percentage of women at postdoc level and in leadership positions by pursuing an active recruitment policy and providing dedicated counselling services. The institute should build on its initial successes and continue along the path towards a better gender balance.
10. The regulations governing cumulative dissertations (doctoral theses by publication) vary from one faculty to another. The members of TROPOS staff who are also faculty members at Leipzig University should use their influence to enable all doctoral candidates to complete a cumulative dissertation.

2. General concept and profile

Profile and development since the last evaluation

TROPOS very successfully fulfils its mission to improve the understanding of properties and processes in the troposphere, focussing very convincingly on aerosols, clouds, and their interactions. The institute's long-term goal is to elucidate the impact of these processes on the weather and climate system in order to improve the quality of forecasting. The institute thus operates in a field of crucial social relevance.

TROPOS excels by international comparison thanks to its unique approach of integrating expertise in atmospheric physics, chemistry, ground-based and satellite remote sensing, as well as modelling. The combination of field and laboratory experiments also facilitates excellent outcomes. In this context, the institute works intensively and exceptionally successfully on the development of measurement techniques and international standards. These tasks, which also benefit the specialist scientific community, require long-term expertise and commitment and a concomitantly sustainable employment of resources.

TROPOS has developed very well since the last evaluation and made considerable progress in all areas. Cross-departmental collaboration was improved, allowing the strengths of its integrated approach to come into fuller effect. The institute should perpetuate this process, for example by linking experimental investigations more directly with modelling.

In addition to in-house cooperation, the institute has also developed its collaborations with external partners. In numerous joint projects, TROPOS is excellently connected with other research institutions around the world. In the European context, in particular, it plays an important role and provides essential infrastructure with its array of both stationary and mobile equipment (see Status Report, p. A-5).

Results

Research and additional research-based results

During the last few years, TROPOS has produced very good research outcomes. The fact that these outcomes have largely been published in internationally recognised, peer-reviewed journals indicates the extent of the institute's ability to compete at

international level. The institute's excellent networking is demonstrated by many joint experimental studies with external partners and the corresponding joint publications.

Infrastructure tasks, scientific consultancy, knowledge and technology transfer

TROPOS provides essential services for the international specialist community. It is, for example, very active on specialist teams developing and recommending quality standards for *in-situ* and remote sensing observations in the atmosphere. Also it engages well in the development and dissemination of new instrumentation and measurement techniques. Furthermore, TROPOS offers training in the use of state-of-the-art instruments, inside and outside Europe.

TROPOS's excellent facilities and equipment are regularly used by external scientists. They include the Melpitz research site and large laboratory facilities like the *Leipziger Aerosolkammer* (LEAK), the Leipzig Aerosol Cloud Interaction Simulator (LACIS), the Leipzig Aerosol Cloud Turbulence Tunnel (LACTT), and the aqueous-phase laboratory as well as the mobile Airborne Cloud Turbulence Observation System (ACTOS), which is usually used in the context of collaborative projects.

The staff at TROPOS provide high-quality scientific consultancy. One particularly noteworthy recent contract involved advising state authorities on the introduction of low-emission zones. Other target groups regularly seeking the institute's expertise include, for example, space agencies, environmental agencies, UN science agencies such as the World Meteorological Organization, political bodies at regional, federal, and European levels, and universities.

Academic events and public relations

By regularly organising international workshops, conferences, and instrument intercomparisons, TROPOS undertakes important tasks on behalf of the scientific community. This degree of engagement indicates just how much importance the institute attaches to national and international networking.

Public outreach activities are excellent. TROPOS has identified various target groups ranging from political decision-makers at various levels via authorities, organisations, and associations to school students, non-scientists, and the general public. The measures tailored to the respective groups have proved effective.

Strategic work planning for the next few years

In the coming years, TROPOS intends to continue focussing on its established strengths. This is a plausible decision. In a strategy paper, the institute identified a host of scientific themes and questions it intends to prioritise in the mid-term. The microphysics of aerosols and clouds, their chemical composition, distribution, and dynamics will continue to play an important role. Aerosol-cloud interaction at high- and low-pollution regions will be studied with high-resolution measurements. An important goal is to distinguish microphysical forcing from meteorological forcing in the evolution of clouds. In modelling, TROPOS plans to focus on the further development of process studies and to continue refining its exceptional regional-scale models.

Whilst the overall research agenda in general is reasonable as well as feasible, **beyond the detailed questions and aims contained in its strategy paper, TROPOS should strive to realize ambitious goals with respect to overarching questions and topics of societal relevance. Indeed, the institute can make major contributions to research on aerosol and cloud impacts on climate and weather systems as well as to research on health-related issues such as air quality and toxic cycling in the atmosphere** (see below)**.** In tackling such topics, it should be deliberated systematically whether external partners should be approached and, if so, which. In view of its competencies, TROPOS should be confident enough to claim a significant role for itself in common endeavours.

For example, beyond refining the existing regional-scale models, **the institute should also turn its attention to large-scale atmospheric modelling from local to regional to global. It is recommended that TROPOS make use of its excellent modelling expertise to develop and enhance the synergism between models at these scales.** One major venture in this direction is the ICON (icosahedral non-hydrostatic) general circulation model suitable for weather, climate, and environmental research initiated by the Max Planck Institute for Meteorology and the *Deutscher Wetterdienst* (DWD). TROPOS should aim to play an active role in this project.

In order to exploit the valuable data from measurements and modelling fully, TROPOS would do well to augment its expertise and usage of modern statistical methods for analysing large amounts of data. The institute needs to devise a clear strategy indicating to what extent this can be done in-house and whether targeted collaborations with external partners are necessary.

TROPOS is involved in research that might benefit from in-depth expertise in aerobiology, e. g. work on biological ice nuclei or the transmission of infectious diseases. It is recommended to build access to expertise either internally or via collaboration with external partners. Already, TROPOS is a member of the Leibniz research network "Infections in the 20th Century", which promises to yield interesting and relevant results. These efforts should be continued and, if possible, enhanced. In addition, TROPOS should explore whether and how the institute's observational, experimental, and modelling expertise could be applied to other health-related issues such as atmospheric cycling of semi-volatile persistent organic substances, e. g. pesticides or other (potentially) toxic substances.

It is of great importance and value that TROPOS will continue its excellent engagement in developing innovative, high-quality instrumentation and methods as well as in providing research infrastructure to other research institutions, including in particular universities. Further great potential exists for the future, e. g. in the area of instrument miniaturisation and in the development of balloon-borne devices and instruments adapted to operation on unmanned aerial vehicles. The plans to develop the research station at Melpitz into a European prototype supersite ("Melpitz Column") for the integration of *in-situ* surface and vertical profile measurements with satellite observations and modelling of the atmosphere are endorsed. It is very positive that financing could be secured through EU funding.

At present, the institute does not apply for patents regularly. It should consider implementing a more active patenting strategy. At the very least, seminars on patenting should be offered to the members of the scientific staff.

Appropriateness of facilities, equipment, and staffing

Overall, the level of TROPOS's institutional funding (2013: approx. € 8.3 million) is appropriate. The facilities, in particular, are outstanding. It is welcomed that TROPOS intends to extend its role in European infrastructure networks such as ACTRIS. At present, it is not possible to say whether this will require new positions or how such positions could be financed.

During the last few years, TROPOS has been very successful in its efforts to acquire third-party funding for research projects (2013: approx. € 3.8 million). The institute can boast a balanced portfolio of third-party funds from various sources. The constantly high level of funding from the DFG and the EU is pleasing.

3. Subdivisions of TROPOS

"Chemistry of the Atmosphere" Department

In this department, the chemistry of the tropospheric multiphase system is explored very successfully. In this area, the department has established itself as an internationally highly recognised research group. The excellent combination of expertise in field studies, laboratory experiments, and modelling has led to numerous significant results, e. g. on seasonal patterns of atmospheric mineral dust, on the formation of sulphuric acid in the atmosphere, and on the chemistry of Criegee intermediates. Coupled gas-particle process studies were performed successfully, leading to novel insights into nucleation processes. The noteworthy work on liquid-phase mechanisms is unique and follows a long-term perspective, especially with the development of the CAPRAM (Chemical Aqueous Phase Radical Mechanism) model. The department is encouraged to fill the current gap in knowledge on surface processes. This will be facilitated by the conversion of the *Leipziger Aerosolkammer* (LEAK) into a twin chamber, which will enable TROPOS to perform novel experiments on both surface- and bulk-phase processes.

The implications of the ongoing work for climate research and the relation to regional and global health issues could be emphasised more confidently. Indeed, TROPOS can contribute to these topics significantly, as its past work has already shown. The very good collaboration with the other departments, in particular the groups working on aerosol physics, on modelling, and on satellite remote sensing, should be maintained and fostered further.

Overall, the department's performance is rated as "very good".

"Experimental Aerosol and Cloud Microphysics" Department

This department covers a wide range of topics in aerosol and aerosol-cloud interaction research, including microphysical and optical properties of aerosols, ice formation processes and precipitation formation, turbulence, and mixing processes in clouds.

Amongst the highlights of the generally high-quality work are the successful atmospheric observations and process studies in regions of the globe where few observations exist and gaps need to be filled. The wind tunnel and the cloud chamber are key facilities for large international collaborative projects such as BACCHUS (Impact of Biogenic versus Anthropogenic emissions on Clouds and Climate, towards a Holistic Understanding) and INUIT (Ice Nuclei Research Unit); the experiments have yielded important insights into the processes of ice nucleation, which is critical to weather and climate, yet very poorly understood. Intriguing initial results on the relevance of biological factors in nucleation processes have been obtained. This novel topic should be pursued further. To this end, it will be necessary to enhance the biological expertise in this department or, alternatively, to seek support from external collaborative partners. The studies on atmospheric aerosol trends and processes are very promising and should be continued in close collaboration with the "Modelling of Atmospheric Processes" Department.

Besides conducting experimental research, this department devotes significant effort to the development and calibration of observational instruments and techniques. With this excellent work, the institute not only advances its own research capabilities, e. g. for work on aerosol-cloud interaction with the Airborne Cloud Turbulence Observation System (ACTOS), but also plays a pivotal role in running or equipping numerous observatories worldwide, including those of the international Global Atmosphere Watch programme of the World Meteorological Organization that coordinates aerosol observations globally. If TROPOS intends to further advance the miniaturisation of *in-situ* instrumentation, e. g. for vertical profiling, it is encouraged to develop a clear and focussed strategy and especially to consider including partnerships to develop and market such instruments.

Overall, the department's performance is rated as "very good".

"Modelling of Atmospheric Processes" Department

This department fulfils two important tasks very successfully: firstly, to develop and apply models for understanding weather and climate processes using data from experimental and atmospheric measurements; secondly, to develop and improve the institute's portfolio of atmospheric models at various spatial scales from local to regional to global.

In the past, very good progress has been made with respect to the parameterisation of processes, both microphysical and chemical, in models. The institute has gained great recognition for its meso-scale modelling work. One of the main models, the COSMO-MUSCAT (Consortium for Small-scale Modelling – Multiscale Chemistry Aerosol Transport Model), has advanced our understanding of the interaction between aerosol and clouds, gases and atmospheric dynamics significantly. It is very positive that TROPOS has started examining the three-dimensional processes in more detail, as this will become increasingly important in the future.

TROPOS is encouraged to continue the sub-grid-scale parameterisations of processes not resolved in the models in order to contribute to the improved accuracy and

understanding of the influence of physicochemical processes at different spatial scales. A clear strategy should be developed further for combining the department's own excellent expertise with that of external partners.

It will be an important challenge in the coming years to move on to two-way coupling of models at different scales. In the long term, TROPOS should strive to improve the linkage of local- and regional-scale process models with global-scale models. Already, very good efforts have been made in this respect by contributing to the global climate model ECHAM and the new versatile ICON model for climate and weather, both of which should take into account atmospheric gases and aerosols. The department needs to continue to strengthen its links to other research groups and larger model consortia in order to pursue these projects further and integrate the outcome from models developed at TROPOS into existing global-scale models. To achieve this, it will be necessary to clearly define the institute's future role in international efforts to develop chemical transport models as well as weather and climate models with aerosols coupled to radiation, clouds, and precipitation.

Overall, the department's performance is rated as "very good".

"Remote Sensing of Atmospheric Processes" Department

This department develops state-of-the-art methodology, ranging from lidar and radar instruments to airborne instrumentation and evaluation of satellite measurements. It applies these methods and instruments to gain insights into aerosol properties and horizontal and vertical transport mechanisms, to obtain vertical profiles of the atmospheric properties, and to elucidate the life cycles of clouds as well as aerosol-cloud interactions.

The working group "Ground-based Remote Sensing" has been one of TROPOS's important pillars since the institute was founded. It harbours world-leading expertise on lidars, especially RAMAN lidars, and has been a major driver of research on surface-based profiling of aerosols at international level. Since the establishment of EARLINET (European Aerosol Research Lidar Network), it has played a pivotal role in this network aimed at providing a comprehensive data base for aerosol distributions on a continental scale.

The working group "Satellite Remote Sensing" was only established in 2010. This addition to the methodological portfolio opens new avenues of research in remote sensing of atmospheric processes. The group has been involved in European Space Agency (ESA) missions. For example, it has made noteworthy contributions to the preparation of the third-generation meteorological satellite (Meteosat).

One future goal will be to improve the interaction between ground-based and satellite remote sensing. Both groups will certainly profit from such synergies, allowing for more comprehensive studies of atmospheric processes.

In order to cope with the large amount of heterogeneous data expected to derive from different types of remote measurements, profound expertise in modern statistical data analysis will be essential, as TROPOS has recognised. Insofar as this cannot be provided

in-house, the department will need to seek collaborations with external partners. In addition, for the continued development of intricate measurement instruments, access to additional engineering capacities will be helpful.

Overall, the department's performance is rated as "very good".

4. Collaboration and networking

Collaboration with universities

TROPOS's cooperation with Leipzig University has been intensified in line with recommendations and is now very good. Scientifically, the two institutions are linked by a common focus on clouds, aerosols, and radiation. It is very positive that TROPOS is involved in a new DFG Transregio Initiative to analyse the coupling processes that contribute to the Arctic amplification of changes in climate.

Currently, three of the four heads of department hold joint appointments. Plans to establish a further joint appointment in the fourth department are welcomed.

TROPOS staff are also intensively involved in teaching at Leipzig University. The Leibniz Graduate School on "Clouds, Aerosols, and Radiation" is part of the Research Academy Leipzig. At present, it offers seven of the institute's doctoral students the option of a structured training programme. As intended, TROPOS should strive to integrate all its doctoral candidates in the graduate school.

Collaboration with other universities, especially abroad, could open up further opportunities for conducting research projects in various locations. TROPOS's close links to several Chinese universities is an excellent example of how this can generate benefits for all. In accordance with its research interests, the institute is encouraged to try and establish similarly close collaborations with other institutions.

Collaboration with other domestic and international institutions

Both nationally and internationally, TROPOS is excellently connected. Not least thanks to its exceptional equipment (see Chapter 2, section on infrastructure tasks, scientific consultancy, knowledge and technology transfer), the institute is a highly sought-after partner in scientific measurement campaigns. This is reflected, amongst other things, in the striking number of visiting researchers at TROPOS, mostly from abroad.

TROPOS is a core partner in the EU network ACTRIS (Aerosols, Clouds, and Trace Gases Research Infrastructure Network). Besides contributing measurement data, TROPOS has also successfully adopted the important task of proposing and developing calibration standards. The institute runs two calibration centres for ACTRIS: one for lidars and one for optical properties of physical particles. **The rationale and plans to develop ACTRIS into an open network are convincing. It will be important to ensure the sustainability of TROPOS's contribution to ACTRIS once current EU funding runs out. Thus, the institute's attempts to put ACTRIS on the German national roadmap for European research infrastructures should be supported.**

The institute also plays an important role in other European networks like IAGOS (In-Service Aircraft for a Global Observation System) and EUROCHAMP (Integration of European Simulation Chambers for Investigating Atmospheric Processes). Mention should also be made of the institute's involvement in the IUPAC (International Union of Pure and Applied Chemistry) Task Group on Atmospheric Chemical Kinetic Data Evaluation to which TROPOS contributes, in particular, its expertise in the kinetics of reactions in liquid aerosols. Furthermore, the institute hosts the World Calibration Centre for Aerosol Physical Properties of the international Global Atmosphere Watch (GAW) programme coordinated by the World Meteorological Organization. In this capacity, TROPOS develops standards, conducts instrument intercomparisons and training workshops, and audits instruments and observational practices at global observatories operated in data-scarce regions and often by countries with emerging economies.

In the past, the institute has been a highly appreciated partner in the consortium running HALO (High Altitude and Long Range Research Aircraft). The projects conducted with HALO have produced very good scientific results. Recently, TROPOS decided to leave the consortium due to financial constraints. At present, it is still unclear whether the institute might consider rejoining. It would be excellent if additional funds could be obtained for this purpose.

In addition to Leipzig University, regionally, TROPOS also cooperates very successfully with partners such as the Saxon State Office for the Environment, Agriculture and Geology. When planning the introduction of low-emission zones in cities, the institute's expertise has proved seminal, and other projects on the impact of air pollution on human health and the climate have generated important insights. There is still potential for further promising collaborations in Leipzig and environs. For instance, TROPOS should examine whether it could cooperate with other departments at Leipzig University apart from the Department of Meteorology. There are also points of contact with the work of the Helmholtz Centre for Environmental Research (UFZ) which should be considerably better utilised.

5. Staff development and promotion of junior researchers

Staff development and personnel structure

The staff members at TROPOS are highly motivated. Their degree of work satisfaction and identification with the institute were clearly expressed in conversation.

The *Land* Saxony has prescribed a staffing plan which is now outdated. It does not reflect the pleasing growth in institutional funding resulting from the Joint Initiative for Research and Innovation. **Without delay, TROPOS must be given the opportunity to create further permanent positions within the scope of current institutional funding in order to effectively address important long-term infrastructure and scientific needs.** TROPOS has very plausibly justified its needs with a view to seven positions (see Status Report, p. A-8). **The *Land* Saxony should be able to expedite the extension of the staffing plan, which has not been adjusted for years; this is**

therefore recommended as a first step on the path to improving the management options open to the Directorate in personnel matters. In addition, it is a matter of urgency to abolish the obligatory nature of the staffing plan in accordance with the relevant agreements between the Federal and *Länder* Governments, as had already been recommended in the evaluation seven years ago.

Promotion of gender equality

At the end of August 2014, approx. 45 % of doctoral candidates were female. The proportion of women amongst postdoctoral scientists not holding leadership positions was 25 %. In 2012, one of TROPOS's senior female scientists was appointed head of the "Modelling of Atmospheric Processes" Department which entailed a professorship of the same name at Leipzig University. Since then, one of the six scientific leadership positions at TROPOS is occupied by a woman.

During the last few years, the institute has made efforts to increase the percentage of women at postdoc level and in leadership positions by pursuing an active recruitment policy and providing dedicated counselling services. The institute should build on its initial successes and continue along the path towards a better gender balance.

In order to improve the work-family balance, TROPOS has introduced numerous meaningful and constructive measures which are much appreciated by staff. It is pleasing that both in 2011 and in 2014, the institute was awarded the "audit beruf**und**familie" certificate.

Promotion of junior researchers

Junior researchers are very well supervised and trained at TROPOS. It is very pleasing that a significant proportion of junior researchers are recruited from abroad. This promotes international scientific exchange. Furthermore, many TROPOS scientists relocate to other research institutions abroad, or elsewhere in Germany, when they have completed their qualifications. This demonstrates how well the institute is connected.

Since 2006, a structured doctoral programme has been in place that was extended in 2012 in the context of the Leibniz Graduate School on "Clouds, Aerosols, and Radiation". It is very pleasing that it has been possible to ensure continued funding for the graduate school. Participation in the graduate school is voluntary. Currently, seven individuals are making use of the opportunity. TROPOS should encourage more of its doctoral candidates to participate. **The regulations governing cumulative dissertations (doctoral theses by publication) vary from one faculty to another. The members of TROPOS staff who are also faculty members at Leipzig University should use their influence to enable all doctoral candidates to complete a cumulative dissertation.**

Tenure track positions are not foreseen for postdocs. In view of the small number of permanent positions at the institute, this is understandable. Postdocs receive very good counselling on their career options and are supported in pursuing their goals. Junior researchers from TROPOS regularly manage to apply successfully for leadership positions at other institutions, most of them abroad.

Vocational training for non-academic staff

Non-scientific staff are offered a pleasingly diverse choice of continuing education options. Moreover, the institute provides training places in three occupational fields.

6. Quality assurance

Internal quality management

Internal quality management functions very well. The DFG's rules of good scientific practice are implemented. The archiving and storage of experimental data is exemplary, and long-term availability is guaranteed.

The institute cultivates a very good, open culture of debate. Scientists at all levels are involved in drawing up the research programme.

In order to promote networking amongst the departments, TROPOS has established a system allowing doctoral candidates and postdocs to apply for initial ideas projects. € 70k per annum are earmarked for this purpose. The tool has proved very successful and should be extended, if possible.

Quality management by the Scientific Advisory Board and Supervisory Board

The Scientific Advisory Board is constructive and very engaged in following the work of the institute. The minutes of the annual meetings are informative. However, in the report on the audit, which is conducted between evaluations in accordance with the regulations set down by the Leibniz Association Senate, the Board could have provided somewhat more detail on overarching aspects.

The Board of Trustees carries out its tasks as a supervisory body very effectively. It must now ensure that the obligatory staffing plan is abolished (see Chapters 2 and 5).

Implementation of recommendations from the last external evaluation

TROPOS has very successfully implemented the recommendations made by the Leibniz Association Senate. The obligatory staffing plan still needs to be abolished (see Chapters 2 and 5); however, this does not lie within the power of the institute.

Appendix

1. Review Board

Chair (Member of the Senate Evaluation Committee)

Jürgen **Troe**	Institute of Physical Chemistry, University of Göttingen and Max Planck Institute for Biophysical Chemistry, Göttingen

Vice Chair (Member of the Senate Evaluation Committee)

Hans **Spada**	Department of Psychology, University of Freiburg

Experts

Richard **Bamler**	Remote Sensing Technology Institute, German Aerospace Center, Weßling
Leonard **Barrie**	Bolin Centre for Climate Research, Department of Geological Sciences, Stockholm University (Sweden)
Klaus **Dethloff**	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Research Unit Potsdam
Ilan **Koren**	Department of Earth and Planetary Sciences, Weizmann Institute of Science, Rehovot (Israel)
Christoph **Kottmeier**	Institute for Meteorology and Climate Research – Troposphere Research, Karlsruhe Institute of Technology
Ulrich **Platt**	Institute of Environmental Physics, University of Heidelberg
Martin **Riese**	Institute for Energy and Climate Research: Stratosphere (IEK-7), Forschungszentrum Jülich
Cornelius **Zetzsch**	Atmospheric Chemistry, Bayreuth Center of Ecology and Environmental Research, University of Bayreuth

Federal Representative (Member of the Senate Evaluation Committee)

Friederike **Trimborn-Witthaut**	Federal Ministry of Education and Research, Bonn

Representative of the Länder *governments*

Uwe **Embert**	Bavarian State Ministry of Sciences, Research and the Arts, Munich

2. Guests

Representative of the responsible Federal Government Department

Gisela **Helbig**	Federal Ministry of Education and Research, Bonn

Representative of the responsible Länder *Department*

Christoph F. **Meier**	Saxon State Ministry for Science and the Arts, Dresden

Representative of the Leibniz Association

Ulrich **Bathmann**	Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Speaker of Section E of the Leibniz Association

Chairman of the Scientific Advisory Board

Andreas **Wahner**	Institute for Energy and Climate Research, IEK 8: Troposphere, Forschungszentrum Jülich GmbH

3. Representatives of collaborative partners (one-hour interview)

Beate A. **Schücking**	Rector, University of Leipzig
Norbert **Eichkorn**	President, Saxon State Office for the Environment, Agriculture and Geology, Dresden
Paolo **Laj**	Director, Le Laboratoire de Glaciologie et Géophysique de l'Environnement, Saint-Martin d'Hères (France), and co-coordinator of ACTRIS (**A**erosols, **C**louds, and **T**race gases **R**esearch **I**nfra**S**tructure Network)

13 October 2015

Annex C: Statement of the Institution on the Evaluation Report

Leibniz Institute for Tropospheric Research, Leipzig (TROPOS)

TROPOS acknowledges the constructive and detailed work and report of the Evaluation Board.

We appreciate that the Board recognizes the Institute as a whole as unique by international comparison, that the Board emphasizes the excellent international networking, the innovative and high-quality instrumentation and method development, the success in supporting scientific careers of women, as well as the excellent public outreach. TROPOS regards the strong recommendation of the Evaluation Board to increase the amount of permanent positions as a very important support.

We appreciate the specific recommendations to which this letter will respond in brief. In fact, some of the recommendations are already met to a certain extend with specific actions, while others are as well important, but are not achievable at satisfactory level with the current Institute budget. We are delighted to see that the Board shares our view concerning the crucial societal relevance of the Institute's research. TROPOS strives to disseminate its results in numerous bodies at the national level and is proactive on the European scale to share its knowledge about tropospheric processes and their impacts in health, radiation and climate as well as in the discussion of global impacts and measures, e.g. in China. Along the same line, we emphasize our involvement in the Leibniz Research Cluster "Crisis in a globalized world", where TROPOS seeks to strengthen the understanding of the inter-dependencies of environmental issues between scientific disciplines.

With regard to modelling, TROPOS is involved in the national development, validation and application of the multi-scale atmospheric model ICON, which will enable research of process-oriented to regional to global scale research Thus, 'going global' will be a natural continuation of our modelling activities, based on a proper process understanding in the interplay with the experimental work especially at TROPOS.

TROPOS recognizes the challenge posed by the increasing amount of observational data from current and next generation remote sensing observations from both ground and space, and acknowledges the need for professional technical and scientific handling of these amounts of data. The remote sensing department will continue to explore, develop, and apply suitable measures and methods, and establish collaborations to address this challenge.

Given the more recent findings on the important role of biological particles in the process of ice nucleation and the expertise in abiotic aqueous phase chemistry at TROPOS it is surely interesting to link towards the field of aerobiology. TROPOS will strengthen its already existing collaborations with national and international partners in this matter.

It is appreciated that the Evaluation Board emphasizes the importance of infrastructures developed and operated at TROPOS. In addition to third party funding a substantial amount of the Institute's budget has been devoted to the development and operation of such infrastructures in international networks. The long-term strategic plans aim at a unique platform for capturing the tropospheric column with a multitude of instrumentations that are open for access by the international scientific community.

Given the fact that the Evaluation Board asserts a very good development of our Institute since the last evaluation we find it however somewhat difficult to understand why some subdivisions have been downgraded from "excellent" respectively "very good to excellent" to "very good". In fact, all subdivisions have considerably improved in their key figures (publications, funding, internationalisation, board leader- and memberships, ...) compared to the last evaluation. From the very positive and strongly supportive evaluation report we are a bit at a loss concerning the reasons for this slightly inferior assessment.