Leibniz Gemeinschaft

Der Senat

22. November 2022

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. Der für das TROPOS zuständigen Gruppe stand eine von der Einrichtung erstellte Evaluierungsunterlage zur Verfügung. Die wesentlichen Aussagen dieser Unterlage sind in der Darstellung (Anlage A dieser Stellungnahme) zusammengefasst.

Wegen der Corona-Pandemie musste der für den 3. und 4. Februar 2022 vorgesehene Evaluierungsbesuch am TROPOS in Leipzig entfallen. Die Bewertung erfolgte im Rahmen eines Ersatzverfahrens, das der Senatsausschuss Evaluierung (SAE) in Umsetzung eines Grundsatzbeschlusses des Senats vom 31. März 2020 eingerichtet hat. Der Senat hält in diesem Grundsatzbeschluss fest, dass das Ersatzverfahren ein Notbehelf ist und ausschließlich auf Einrichtungen angewendet wird, die im Regelturnus von sieben Jahren evaluiert werden. Die Bewertungen, auf deren Grundlage der Senat Stellung nimmt, sind auf zentrale Kernfragen der Entwicklung und Perspektive einer Leibniz-Einrichtung fokussiert. Ausführliche Einschätzungen und Schlussvoten zu Teilbereichen und Planungen für „kleine strategische Sondertatbestände“ müssen regelmäßig entfallen.

Die Bewertungsgruppe erstellte den Bewertungsbericht (Anlage B). Das TROPOS nahm dazu Stellung (Anlage C). Der Senat der Leibniz-Gemeinschaft verabschiedete am 22. November 2022 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) erforscht die komplexen physikalischen und chemischen Prozesse in der untersten Schicht der Erdatmosphäre in Bezug auf Aerosole, Wolken und deren Wechselwirkungen. Dazu wird in vier Abteilungen Expertise in Atmosphärenphysik, Chemie, Modellierung und Fernerkundungsmethodik zusammengeführt. TROPOS verfolgt mit dem von ihm erarbeiteten breiten und grundlegenden Verständnis über Aerosole und Wolken das Ziel, wesentliche Zusammenhänge im

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

System Mensch–Umwelt–Klima besser zu verstehen. Die Arbeiten haben eine hohe Bedeutung für die Umweltpolitik, von der Regulierung anthropogener Treibhausgasemissionen bis hin zur Vorhersage von Unwettern.

Seit der vergangenen Evaluierung hat TROPOS seine vielfältigen Aktivitäten bei der Entwicklung und dem Betrieb von Forschungsinfrastrukturen, in der Forschung und im Wissenstransfer erfolgreich weiterentwickelt und sehr gute **Arbeitsergebnisse** erzielt:

— Die grundlegenden Instrumente, die das Institut eigenständig entwickelt und weltweit einsetzt, sind außerordentlich innovativ. Die damit erzeugten Resultate werden international nachgefragt. Von hoher Bedeutung sind u. a. die mobilen und stationären Messeinrichtungen (z. B. das Observatorium Melpitz) oder die beiden atmosphärischen Simulationskammern am Institut (LACIS-T und ACD-C).

  TROPOS ist in vielfältige nationale wie internationale Kooperationen und Konsortien eingebunden, besonders hervorzuheben ist die paneuropäische Forschungsinfrastruktur ACTRIS *(Aerosol, Clouds and Trace Gases Research Infrastructure).* An dem kontinuierlichen, äußerst erfolgreichen Aufbau des Netzwerks ist das Institut seit zwei Jahrzehnten maßgeblich beteiligt. Das BMBF nahm das Vorhaben 2019 auf die Nationale Roadmap für Forschungsinfrastrukturen auf und fördert die von TROPOS koordinierte Beteiligung deutscher Forschungsinstitute (ACTRIS-D) in den Jahren 2021–2029 mit im Schnitt 9,5 Mio. €/Jahr, davon 2,7 Mio. €/Jahr für TROPOS. Die Planungen zu ACTRIS-D und zur Weiterentwicklung der übrigen Forschungsinfrastrukturen sind klar konturiert.

— TROPOS nutzt seine ausgezeichneten Technologien für Experimente und hochwertige Langzeit-Beobachtungen weltweit sowie zur Entwicklung eigener Modelle der Atmosphärendynamik. Hervorzuheben sind beispielsweise die Forschungsarbeiten zu eiskeimbildenden Partikeln, zum Staubgürtel in der nördlichen Hemisphäre, zum marinen Beitrag zu troposphärischen Aerosolpartikeln und zu Rauch in der Atmosphäre, wie er durch Waldbrände entsteht. Die Ergebnisse werden regelmäßig in internationalen Fachzeitschriften publiziert; eine noch breitere Sichtbarkeit kann durch weitere systematische *scientific reviews* und eine stärkere Veröffentlichung in multidisziplinären Publikationsorganen erreicht werden.

— Es wird begrüßt, dass TROPOS sein Engagement im Wissenstransfer in den vergangenen Jahren verstärkt hat, z. B. durch bürgerwissenschaftliche Projekte. Nach wie vor berät das Institut Behörden bei aktuellen gesundheitsrelevanten Fragen, beispielsweise zur Luftverschmutzung und im Zusammenhang mit der SARS-CoV-2-Pandemie zur Ausbreitung von Virusaerosolen.

Die weitere Verbesserung des Verständnisses von Aerosolen und ihren Wechselwirkungen mit Wolken, das TROPOS erarbeitet, ist für die Geowissenschaften insgesamt äußerst bedeutsam. Dies sollte die **wissenschaftliche Strategie** künftig noch stärker prägen. Die derzeitige Vielfalt der Forschungsprojekte sollte das Institut künftig deutlich fokussierter daran ausrichten, inwieweit sie zu einem Austausch mit anderen geowissenschaftlichen Teildisziplinen führen und einen Beitrag zu übergreifenden wissenschaftlichen Fragen

der Erdsystemforschung leisten.[2] Vor allem bei den Arbeiten zur numerischen Modellierung ist es wesentlich, Anschlüsse an Entwicklungen außerhalb des Instituts zu sichern, wie im Bewertungsbericht näher erläutert. Mit einer solchen noch stärkeren Einbettung seiner eigenen Forschungsarbeit in größere wissenschaftliche Zusammenhänge würde TROPOS die Verbindung zwischen den Einzelprojekten und den übergreifenden Zielen des Instituts wie dem Schutz des Klimas und der Gesundheit stärken.

Diese Empfehlung zur strategischen Entwicklung sollte TROPOS auch bei der weiteren Ausgestaltung eines geplanten Antrags für zusätzliche Mittel der institutionellen Förderung aufgreifen („kleiner strategischer Sondertatbestand“ in Höhe von dauerhaft 3,7 Mio. €/Jahr). Im Anschluss an den Bewertungsbericht unterstützt der Senat das Ziel, die ausgezeichneten neuen Möglichkeiten von ACTRIS für die Bearbeitung neuer wissenschaftlicher Fragestellungen am Institut nutzbar zu machen.

Für die derzeitigen Aufgaben ist die institutionelle Förderung auskömmlich (9,6 Mio. €/Jahr im Schnitt 2018–2020). Für seine Arbeit warb TROPOS mit 36 % des Gesamtbudgets für laufende Arbeiten sehr erfolgreich **Drittmittel** ein (5,5 Mio. €/Jahr im Schnitt 2018–2020 für Forschungsprojekte und aus Leistungen für Aufträge). Erfreulicherweise gelang eine signifikante Steigerung des Anteils an DFG-Mitteln.

Wissenschaftlerinnen sind im Bereich „Forschung und wissenschaftliche Dienstleistungen“ mit einem Anteil von 36 % an den Mitarbeitenden (in der Phase nach Abschluss der Promotion nur 27 %) noch deutlich unterrepräsentiert. Der Senat erwartet, dass das Institut die Neueinstellung von wissenschaftlich Beschäftigten für eine weitere Verbesserung der **Gleichstellung** nutzt. Eine sehr positive Entwicklung ist, dass mit der Berufung einer Abteilungsleiterin im vergangenen Jahr auf dieser Ebene inzwischen Geschlechterparität erreicht ist. Es wird auch begrüßt, dass nun alle vier Abteilungsleitungen gemeinsam mit der Universität Leipzig berufen sind.

Die **Förderung** der Promovierenden geschieht in einem gut strukturierten Ausbildungsprogramm. Begrüßt wird dabei insbesondere die 2017 erfolgte Verstetigung der Leipziger Graduiertenschule „Clouds, Aerosols and Radiation“. Der hohe Anteil von Doktorandinnen und Doktoranden aus dem Ausland belegt die Attraktivität des Instituts für die Qualifizierungsphase.

Die Erfüllung der Aufgaben von TROPOS ist in dieser Form an einer Hochschule nicht möglich. Eine Eingliederung in eine Hochschule wird daher nicht empfohlen. 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 nimmt zur Kenntnis, dass sich TROPOS bereits intensiv mit dem Bewertungsbericht befasst hat. Er erwartet, dass das Institut und seine Gremien die Empfehlungen,

[2] S. inzwischen zur Entwicklung einer auf Integration von geowissenschaftlichen Teildisziplinen angelegten Erdsystemwissenschaft: Leopoldina: Erdsystemwissenschaft – Forschung für eine Erde im Wandel (Zukunftsreport Wissenschaft, Halle, 30.06.2022).

insbesondere in Bezug auf die wissenschaftliche Strategie, bei der künftigen Entwicklung berücksichtigen.

3. Förderempfehlung

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

14 January 2022

Annex A: Status report

Leibniz Institute for Tropospheric Research, Leipzig (TROPOS)

Contents

1. Key data, structure and tasks

Key data

Year established:	1992
Admission to joint funding by Federal and *Länder* Governments:	1992
Admission to the Leibniz Association:	1992
Last statement by the Leibniz Senate:	2015
Legal form:	non-profit association
Responsible department at *Länder* level:	Saxon State Ministry for Science, Culture and Tourism (SMWK)
Responsible department at Federal level:	Federal Ministry of Education and Research (BMBF)

Total budget (2020)

€ 9 842 000 institutional funding

€ 4 499 300 revenue from project grants

€ 811 200 revenue from services

Number of staff (2020)

103 individuals "research and scientific services" (and 19 scholarship recipients)

29 individuals "science supporting staff (laboratory, technical support etc.)"

15 individuals "science supporting staff (administration)"

Mission and structure

Statutory mission (quoted from the Statutes): "The object of the Leibniz Institute for Tropospheric Research is to carry out investigations in the troposphere and to promote scientific knowledge in this field. TROPOS closely works with institutes that work in the same or similar field. There is an especially close professional relationship, combined with joint appointments, with the University of Leipzig. […] The objective of this statutes is particularly realized through:

- the execution of scientific research and development projects,
- cooperation with other domestic and foreign research institutes, universities and universities of applied sciences,
- the education and further training of young researchers,
- the organization of lectures and discussions,
- publishing the scientific results in magazines, books and other scientific publications."

TROPOS' research programme consists of the two sections 'aerosol' and 'aerosol-cloud interactions', for which they perform process studies and trend analyses. The Institute is

organised in four departments, each of which reports directly to the director: (1) Atmospheric Chemistry Department, (2) Experimental Aerosol and Cloud Microphysics Department, (3) Modelling of Atmospheric Processes Department, (4) Remote Sensing of Atmospheric Processes Department. The director himself is head of department n°4.

2. Overall concept and core results

The Institute's activities are aimed at researching aerosol- and cloud-related physical and chemical processes from the molecular scale and microscale to regional and global scales. **TROPOS' profile** in exploring the mechanisms of tropospheric aerosol and cloud life cycles with their interactions and impacts in the coupled human-environment-climate system is classified by the Institute as globally unique.

For its **methodical basis** (laboratory studies, field studies, numerical models, satellite remote sensing), the Institute has established a worldwide unique research infrastructure of atmospheric observatories, mobile measurement platforms, simulation chambers, analytical laboratories and high-power computing capacity. This allows TROPOS – beyond the projects in Saxony, Germany, and Europe – to explore global hot spots of air pollution and climate change. The Institute combines the acquisition of knowledge with innovation and is engaged in developing and applying new measurement methods. In particular, the findings provide a contribution to the understanding of tropospheric processes and their respective impacts on weather, climate, ecosystem integrity, and human health.

Besides increasing research activities concerning smoke aerosol and its global impact on climate in the Northern and Southern Hemisphere, TROPOS is – with regard to **climate change** – engaged in

- the Northern Hemisphere dust belt: The Institute pursues experimental work related to mineral dust. Many long-term observations as well as modelling studies reach from the tropical Atlantic via the Mediterranean to Central Asia.
- polar and marine environments: These areas have gained increasing interest in recent years because of their extraordinary sensitivity to climate change and their potential to both temporarily buffer global warming and enhance regional warming through feedbacks. TROPOS underlines its development of mobile observatories for shipborne operations, which are regularly deployed in the entire Atlantic Ocean including the Central Arctic and the surroundings of the Antarctic continent.
- Central Europe: TROPOS operates its Research Station Melpitz (in Northern Saxony) for permanent observations, campaign-like topical field experiments and as a testbed for the development of instruments to be applied in long-term measurements and process studies worldwide. In future, TROPOS will also use Schmücke Cloud Observatory (in the Thuringian Forest) as a permanent measuring station.

Concerning **tropospheric processes**, TROPOS relies heavily on synergies in field and laboratory measurements as well as in modelling:

- In field experiments, TROPOS investigates the role of different aerosol sources in aerosol composition, processing, distribution, and aerosol-cloud interaction and clouds, including

their full physical and chemical life cycles. These studies cover varying environments, from pristine oceans to deserts and heavily polluted megacities.

- Laboratory experiments, increasingly performed under realistic environmental conditions, resolve specific and coupled multiphase processes in order to understand the formation and aging of aerosol particles as well as aerosol-cloud interactions.
- Satellite remote sensing serves as an interface between the local aerosol and cloud properties and their large-scale distribution and propagation. In the area of algorithm development for improved process understanding, synergies between satellite and ground-based remote sensing as well as radiative forcing experiments are a major focus.
- In the field of numerical modelling, the focus is on the application and further development of atmospheric aerosol models of different scales and complexities. Process-resolving physical and chemical models are combined with dynamical models at multiple scales. These studies bring laboratory and field results into a broader context, aiming at understanding the formation, fate, and feedbacks of particles in the troposphere.

Finally, **transfer of science and technology** is a significant part of TROPOS' commitment. The Institute sets quality standards in aerosol and aerosol-cloud interaction measurement technologies, builds international capacity, consults environmental agencies and works directly with citizens. Next to **air quality**, aerosol particles, clouds, and climate change, a specialized competence also exists in questions of health effects of aerosol particles, including investigations of and informing about the spread of the SARS-CoV-2 coronavirus through aerosol transmission.

TROPOS provides policy advice on specific events (e.g. the United Nations Climate Change Conferences COP24 and COP25) and expert hearings. The Institute plays an active role in the publicity campaigns of the German Climate Consortium (DKK), the "Klimanavigator", and the Leibniz Association.

School events, pupil internships, and teacher trainings are conducted in the context of the MINT initiative (an initiative to strengthen the subjects of science, technology, engineering, and mathematics at school and highschool level). To reach the general public through media, on average 15 press releases are published per year, resulting in approximately 200 reports in print, online, tv, radio, and other media annually.

Results

As result of its research, TROPOS records 541 publications between 2018 and 2020. In addition to one monograph and one edited volume, 301 articles were published in peer-reviewed journals, 56 articles in other journals and 171 working and discussion papers.

The institute refers to the following main results since the last evaluation:

Development of research infrastructures

TROPOS established and leads ACTRIS-D (the German contribution to the European Aerosol, Clouds and Trace Gases Research Infrastructure). With 25 M€ from the Federal Ministry of Education and Research TROPOS' research facilities – observation sites, mobile platforms, atmospheric simulation chambers, and calibration laboratories – will be upgraded or newly

established until 2029. This allows TROPOS to strengthen its role in the research field of aerosol and clouds at national and international level and to perform front-line atmospheric research over the next decades. For an optimum and sustainable use of the new research infrastructure, the Institute will strive for additional funds via an *extraordinary item of expenditure* ('Sondertatbestand').

The Institute already contributes a variety of technology to ACTRIS, such as its fully automated PollyNET lidar stations (portable stations for Light Detection And Ranging) or the simulation chambers with which TROPOS already participated in EUROCHAMP-2020 (a HORIZON-2020 infrastructure project which aimed at a better integration of simulation chambers for studying atmospheric processes).

TROPOS leads the development of strategy, guidelines, and labelling process for ACTRIS National Facilities (i.e. the European network of stations, simulation chambers, and mobile platforms) and has been strongly involved in defining the role of the ACTRIS Central Facilities (i.e. the common calibration and data centres). TROPOS is also leading the implementation of the European Centre for Aerosol Calibration, one of the six ACTRIS Topical Centres.

Research (strongly linked to climate change)

Mineral dust in the "Dust Belt": TROPOS has a broad expertise on mineral dust aerosol, its atmospheric distribution and its effects on the Earth radiation balance and on ice formation in mixed-phase clouds. For this purpose, TROPOS has continuously been establishing more permanent measurement stations (like in Dushanbe in Tajikistan) and is in particular a partner of the Cape Verde Atmospheric Obervatory (CVAO) since 2006.

- Following a series of studies on the dust outflow from the western Sahara across the Atlantic, a new focus was set to cover the dust belt eastwards, from the tropical Atlantic across the Mediterranean Sea to Central Asia. This advancement opened the door to investigate sources, transport, and interaction with clouds for substantially different mineral dust types and mixtures of aerosol particles.
- New analytical methods to determine the chemical composition of mineral dust led to identification of dust chemical footprints. These results allow further insights in for instance the contribution of mineral dust to air pollution.
- TROPOS developed a new parameterization for dust emission via fire-induced pyro-convection and for fluvial deposits, which are now being implemented in large-scale atmospheric models.

Ocean-atmosphere interactions: The topic of ocean-atmosphere interactions has extensively been investigated within various marine field campaigns and was combined with the development and application of innovative sampling and analytical methods.

- TROPOS explored the upper layer of the ocean and showed inter alia, that it might play a driving role in the enrichment of important organic-matter compounds relevant for marine aerosol.
- Detailed box model simulations have been carried out to study the chemical multiphase processing of dimethyl sulfide (a sulphur compound that outgases from the upper layer of the ocean into the atmosphere). The results lead to a revision of current models.

- Linkages between the chemical composition and microphysical properties have been revealed. TROPOS' recent studies provide wide information about the concentration and composition of atmospheric-relevant organic matter components in the diverse marine compartments (seawater, aerosol particle, cloud water) for the first time.

Polar regions: TROPOS investigates aerosol and aerosol-cloud interaction in the dramatically warming Arctic and in the so far underexplored Antarctic. The Institute was involved in planning and operating the transregional Collaborative Research Centre (CRC/TR) 172 "Arctic Amplification: Climate Relevant Atmospheric and Surface Processes and Feedback Mechanisms, (AC)^3", led the Polarstern expedition PS106 (PASCAL). It also participates continuously in the one-year ice drift PS122 as well as in long-term Arctic ground-based and airborne observations in Svalbard and Greenland, all part of the larger international MOSAiC project (MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate). The Institute acted as a partner in further national and international projects like the Antarctic Circumnavigation Expedition (ACE) of the Swiss Polar Institute.

Biomass-burning smoke: This research area focuses on the distribution, physical and chemical properties, transport processes, and climate effects of smoke aerosol. This is TROPOS' response to increasing, severe forest fires such as the North American fires of summer 2017 and the Australian bushfires of 2020. The Institute not only draws on its expertise in remote sensing, but also uses ground-based campaigns such as the recent Melpitz twin site woodburning experiment or the operation of the Leipzig Biomass Burning Facility (LBBF). In the context of the smoke observations in the Southern and Northern Hemispheres, TROPOS was able to identify and characterize the large-scale impacts of such strong wildfires as well as previously unknown processes like radiative lifting of aerosol layers into the stratosphere. An extensive series of kinetic measurements of compounds emitted from biomass burning is being undertaken with the aim to construct a dedicated multiphase mechanism for a better modelling of biomass burning and its effects on the atmosphere.

Research (tropospheric process studies – aerosol-cloud interactions)

Mixed-phase clouds: Research on physical aerosol-cloud interaction has gained increasing importance in the Institute's research portfolio over the last decade.

- TROPOS developed an atmospheric simulation chamber (LACIS-T; Turbulent Leipzig Aerosol Cloud Interaction Simulator), in whose thermodynamically controlled setup the turbulent cloud-aerosol interaction can be studied in more detail.
- New remote-sensing instrumentation and its consequent synergistic use have led to new insights into ice-formation processes in mixed-phase and cirrus clouds and to revision of recent and prevalent models.
- New off-line techniques for the determination of the concentrations of ice nucleating particles were intensively used, yielding results about these particles in remote environments such as the Arctic, the Southern Ocean, or the outflow region of the Saharan desert, but also in highly polluted areas such as Beijing.

Warm clouds: TROPOS uses newly developed lidar techniques as well as the helicopter-borne platform ACTOS (Airborne Cloud Turbulence Observation System) to study aerosol-cloud-interaction in real environments. This enables in-situ observations of detailed and co-located aerosol and cloud microphysical properties, which enables the direct assessments of aerosol-cloud interaction and the role of turbulent conditions in the formation and dissolving of cloud droplets in warm (i.e. non-ice containing) clouds.

Research (tropospheric process studies – chemical processes)

Multiphase chemistry: TROPOS points to this research topic as its key expertise; several highly-cited literature reviews on (i) tropospheric multiphase chemistry processes, (ii) tropospheric NO_3 radical chemistry of biogenic volatile organic compounds and (iii) the impact of acidity of particles and clouds were compiled. Among a number of new methods, technologies, and findings, TROPOS emphasizes that multiphase chemical mechanisms resulting from laboratory measurements have been continuously developed and applied during process modelling for realistic atmospheric conditions to investigate their impacts on air quality and climate. For this purpose, TROPOS designed a new aqueous phase mechanism (CAPRAM4.0). The Institute also expanded the existing mechanism generator GECKO-A to the aqueous phase enabling that the organic chemistry in CAPRAM4.0 can automatically be generated according to a predefined mechanism protocol.

Gas-phase chemistry: In the field of gas-phase chemistry, based on the state-of-the-art flow system and latest mass spectrometric techniques, a more direct insight into atmospheric oxidation processes became possible. Due to detection below parts per quadrillion level, overcoming the flaws in mechanistic studies of the past, TROPOS discovered in collaboration especially with experts from quantum chemistry a series of novel gas-phase processes.

Secondary organic matter: Secondary organic matter is one of the least understood components of atmospheric particles. A newly developed method combining liquid-phase fractionation with ultrahigh-resolution mass spectrometry allowed for unprecedented insights into the vast molecular diversity of these organic compounds. For continental aerosol, a kinetic approach for modelling secondary organic aerosol formation considering particle size and viscosity was developed, evaluated by chamber measurements, and applied for Central Europe.

Research results related to transfer (air quality and health):

TROPOS strongly contributes to world-wide stationary and mobile high-quality measurement of aerosol microphysical properties. The 'TROPOS aerosol backpacks' were created for mapping pollutant concentrations in urban areas and determining personal exposure. They also led to the creation of recommendations for high-quality mobile measurements suited for scientific investigations and to citizen participation in air-pollution mapping. The mobile measurements have been extended to investigate respiratory tract deposition dose (RDD) in different microenvironments and the effects of different factors on RDD.

Impacts between air pollution and health have been elucidated specifically in the Phillippines through black carbon measurements (i.e. measurements of the blackness of carbonaceous particles in the atmosphere).

In Germany, TROPOS pursues research on the reduction of air pollution primarily through the coordination of the German Ultrafine Aerosol Network (GUAN). In cooperation with the Saxonian State Office for the Environment (LfULG), the Institute is furthermore involved in specific projects to refine strategies of air-pollution mitigation in Saxony. A new type of air-pollutant drone was developed with TROPOS' participation, which can be used flexibly and will also be able to investigate the vertical distribution of various air pollutants in the future. Besides, TROPOS evaluates existing technical solutions to improve air quality. It has furthermore given advice to the public through outreach and scientific societies on the spread of infectious viruses through aerosol particles.

In the course of these efforts, TROPOS has recently carried out aerosol measurements indoors and outdoors of 40 households (one week in two different seasons) in order to give recommendations concerning particle concentrations and emission rates.

3. Changes and planning

Development since the previous evaluation

TROPOS followed the general goals as formulated in its strategy plan as well as in the recommendations from the last evaluation. As one core element of its progression, TROPOS participated in the development of ACTRIS and took a leading role in the German participation (ACTRIS-D). TROPOS' internationally demanded aerosol simulation chamber ACD-C now continues to be so in the ACTRIS follow-up projects ACTRIS-IMP and ATMO-ACCESS.

Major scientific advances have been achieved by the campaign-based exploration (for partly one year or longer) of so far under-explored geographical regions, strongly supported by modelling activities also in a global context. On this matter, the Institute underlines its increasingly succeeding cross-departmental cooperation, adressing the full range of physical and chemical processes in the targeted research topics.

Alongside with the mentioned results and the necessary developments (e.g. the extension of in-situ measurements from the surface to measurements in the atmospheric profile via balloons or the modifications of the modular multiphase chemistry model CAPRAM), TROPOS highlights its successful upgrade of the LACIS cloud chamber (Leipziger Aerosol and Cloud Interaction Simulator) to LACIS-T, enabling controlled studies of cloud microphysical processes like droplet formation, growth, and freezing in turbulent environments, as well as the investigation of entrainment/detrainment processes at cloud boundaries. Furthermore, TROPOS implemented the new German numerical weather prediction and climate model ICON (ICOsahedral Non-hydrostatic model), which is jointly developed at the DWD and MPI for Meteorology, into the Institute's model chain.

As a final outstanding point, TROPOS refers to its direct investigations in human health impacts, in particular with regards to the pollution from wood burning, effects of mineral

dust, indoor/outdoor, inhale/exhale contrasting studies, as well as with virus aerosol transmission studies. The TROPOS aerosol expertise has also led to several studies and public statements concerning the threat of indoor virus transmission, especially but not exclusively in the context of the COVID-19 pandemic. Besides, TROPOS developed new transfer tools to raise public awareness of the concept of air quality, e.g. by a user platform for further analysis and exchange with scientists at TROPOS, wich can be used for citicen science and other forms of knowledge transfer

Strategic work planning for the coming years

The Institute will apply its expertise in process investigations of the tropospheric multiphase system to larger scales and within the context of all relevant Earth system compartments, especially by the ACTRIS project and the specific plans for an ACTRIS-based special item of expenditure.

Nevertheless, TROPOS will continue to do basic research on physical and chemical processes related to aerosol and clouds. Ongoing climate change and strong variability of air pollution call for more research on anthropogenic and natural aerosol species, their chemical and physical processing, their long-range transport, interactions with clouds and the entire atmosphere, and exchanges with other compartments of the Earth system such as vegetation and the ocean surface.

TROPOS will extend its efforts concerning the determination of ice nucleating particles concentrations in contrasting environments (along with their role in precipitation formation), the transport of wildfire-smoke aerosol, and the in-situ investigation of aerosol-cloud-turbulence interactions at higher altitudes, especially at cloud level.

TROPOS' future research activities will be oriented towards six regional foci: (1) dust-belt investigations from Cape Verde via the Mediterranean to Tadjikistan, (2) strong air pollution in African areas or important source regions for biomass-burning aerosol or dust, (3) air pollution including particles and trace gases with adverse health effects in East Asia, especially on China, (4) research in the coupled ocean/sea or ice/atmosphere systems in the fragile polar ocean region together with the exploration of interactions as well as feedbacks within the Northern mid latitudes, (5) research in the Southern Hemisphere to better understand the role of different aerosol types on aerosol-cloud interaction and climate forcing by contrasting the Northern Hemisphere, (6) establishing a long-term measurement site at the Antarctic Neumayer III station.

In this context, TROPOS' observational field work will firstly centre around its upgraded sites Melpitz (focus on continental aerosol and clouds), the CVAO (focus on dust and marine aerosols), and the Schmücke Cloud Observatory (for the world's first cloud observatory for time-series observation of the processing of gas-phase constituents by clouds and aerosol-cloud-turbulence interaction). More detailed measurements of gas-phase and particle constituents will be possible, particle physics measurement capabilities will be extended, the allocation of remote-sensing equipment will put the measurements into a wide spatiotemporal context.

In the light of decreasing regional and global biodiversity, a further strategic goal is to foster the analysis of the abundance and diversity of primary and secondary biogenic

aerosol particles, their sources, transport mechanisms, and interaction specifically with clouds and the general climate system. In addition to existing cooperations with the German Centre for Integrative Biodiversity Research (iDiv) and the Faculty for Life Sciences at the Leipzig University. In 2022 TROPOS plans to provide a basis for these collaborations by means of a strong contribution to the currently planned DFG Collaborative Research Centre "Biodiversity Buffers for Climate Extremes" and a TROPOS-led proposal for a Leibniz Science Campus on "Bioaerosols in a Changing Earth System". These plans are integrated in an initiative in form of a cluster of excellence at Leipzig University.

Technical developments especially in the area of mass spectrometry are currently leading to a large number of new insights into processes that appeared firmly established in atmospheric research in the past. Consequently, bigger updates are required which will have to be based on the thorough examination of elementary reactions, the careful formulation of multiphase mechanisms and the coupling of physical and chemical processes. This will inter alia affect the current models for aerosols, clouds, and their interaction. New mass-spectrometric techniques will be used for simulation chamber experiments, but also for the study of aqueous-phase processes where a near-realtime identification of molecular products will be the desired near-future aim.

Planning for additional funds deriving from institutional funding

Anthropogenic aerosols, their short-lived precursor gases, and their interaction with clouds still pose the largest uncertainties on the assessment of climate warming and future-climate predictions. Supported by the TROPOS Scientific Advisory Board and the Board of Trustees, TROPOS strives for a "minor extraordinary item of expenditure of a scientific-strategic nature" ("kleiner Sondertatbestand inhaltlich-strategischer Natur", STB) entitled: *ACTRIS@TROPOS – Sustainable long-term observations of aerosol, clouds, and reactive trace gases for climate and air-quality research*.

TROPOS aims to bring the understanding of chemical as well as physical processes related to aerosols and aerosol-cloud interactions together with long-term observations and the investigation of trends to better grasp the global impacts and improve climate predictions. The STB ACTRIS@TROPOS will enable the Institute to gain the full scientific benefits from the new and upgraded infrastructure at TROPOS. The ACTRIS facilities at TROPOS are embedded in the scientific departments and strongly connected to their disciplinary expertise and scientific development. They will be used to gain new insights under three topical pillars:

(i) Aerosols, clouds, and climate: This pillar aims at understanding long-term developments of aerosol and cloud properties, occurrences, and impacts on radiation and precipitation in the changing climate system at different spatiotemporal scales.

(ii) Multiphase and multi-compartment interactions: This pillar aims at understanding multiphase and multi-compartment interaction processes in the changing Earth system, based on a strong coupling of process-oriented field studies, related laboratory experiments, and process-resolved modelling. TROPOS will expand its recent research on short-term phenomena at the microscale and will integrate it into larger spatial and temporal scales.

(iii) Air-quality processes, trends, and impacts: This pillar addresses research on the scientific basis of air pollution, its effects, and its coupling to climate change. In collaboration with its European research partners, TROPOS aims at a substantial extension of stationary and mobile measurements and accompanying high-resolution modelling to capture the broad spectrum of physical and chemical properties of atmospheric trace constituents relevant for air quality.

With the STB, three cross-departmental research teams will be established, allowing transdisciplinary work on the three topics by emerging researchers. TROPOS will invest in the infrastructure it already uses, both nationally (e.g. Melpitz) and internationally (e.g. Cape Verde Atmospheric Observatory), permanent and mobile (e.g. OCEANET, the mobile shipborne aerosol and cloud remote-sensing platform). The implementation, coordination, and operation of the facilities strictly follows the ACTRIS procedures and requirements, which assure the continuous long-term access to well-defined, standardized, and quality-controlled data products.

„Extraordinary item of expenditure“: summary of funds planning

	2025	2026	2027	2028	Permanently
Own funds + additional funds = “extraordinary item of expenditure”	3,202 k€	3,226 k€	3,444 k€	4,013 k€	4,013 k€
Own funds from existing funding by institution (3% of TROPOS core budget)	320 k€	320 k€	320 k€	320 k€	320 k€
Additional funds of institutional funding	2,882 k€	2,906 k€	3,124 k€	3,693 k€	3,693 k€

4. Controlling and quality management

Facilities, equipment and funding

In 2020, TROPOS’ institutional funding was 9.8 M€. TROPOS points out that the institutional funding and its devlopment is not sufficient to cover the increases in tariff wages and prices. Modernisation of the Institute’s IT facilities in recent years has also led to higher costs over the past few years (investments and operating resources) and must lead to a corresponding increase in the IT budget in the future.

In addition to the institutional funding, a total of 4.5 M€ was spent from revenues of project grants (corresponding to 30 % of the overall budget). The revenues consisted of 2.1 M€ from the DFG, 0.1 M€ from the Leibniz Competition, 1.1 M€ from the Federal or *Länder* governments, 1.0 M€ from the EU and the rest from other resources. Revenues for services are 5 % of the overall budget. The commercial exploitation of results is not among the major goals of TROPOS. No patents or property rights were registered in the reporting period. One existing patent in 2018 and 2019 expired in 2020 and was not renewed.

TROPOS provides a broad range of research facilities. These also include laboratories, simulation chambers as well as field measurement sites and mobile experimental platforms.

TROPOS states that its building resources are generally adequate (construction of a mul-

tifunctional building in 2011, new Atmospheric Chemistry laboratory in 2017, current redevelopment of the old laboratory building). Operating costs for the two new buildings have to be financed by the institutational funding (343.3 k€ per year).

The IT group – cooperating closely with the IT departments of the neighbouring research institutions – currently consists of a staff of four and is administratively assigned to the Modelling Department, but the whole Institute is highly dependent on and benefits from a powerful IT infrastructure. Using computer equipment along with computationally expensive models and acquiring, processing, as well as archiving large amounts of data is constantly increasing at TROPOS. Tasks in other IT areas such as the network topology or the security concept are continuously updated, considering increased bandwidth needs and the requirements for expanding cyber security. In order to identify new challenges at an early stage, the Institute maintains an IT user group consisting of the IT group and representatives of the scientific departments, who meet regularly.

Organisational and operational structure

The Director, representing the Institute judicially and extrajudicially in all matters that concern it, is appointed by the Board of Trustees for a maximum term of five years (and may be reappointed). He is bound by the resolutions of the Board of Trustees and must adhere to the business plans (programme budgets).

In order to jointly discuss important issues, the Director convenes monthly confidential consultations with the Heads of the Departments and the Head of Administration in the Executive Board.

TROPOS established a Scientific Forum in 2018, in which the Heads of the Departments, the Head of Administration, the Working Group Heads and representatives of the workshops regularly inform each other about the status of scientific work and discuss plans for new acitivities.

The task of the Scientific Council, which consists of elected scientists representing the four research departments, is to promote the communication of scientific work and to advise and support the Executive Board in scientific matters.

Quality Management

In its internal quality management, TROPOS follows the "multiple-eye" principle and the recommendations for ensuring "good scientific practises", as formalised by the DFG with its memorandum "Safeguarding good scientific practises". Furthermore, the TROPOS Executive Board selects an Ombudsperson to ensure best scientific practise. Since the foundation of the Institute in 1992, no violation of best practise has been detected.

Led by the TROPOS working group "Research Data", a guideline for the handling of research data ensures long-term preservation and sufficient documentation of all collected research data in the sense of good scientific practise and according to the FAIR principles (Findable, Accessible, Interoperable, and Re-usable). Whenever possible, TROPOS makes use of well-recognised external research data archives in order to meet these principles. TROPOS participates in the development of the data management initiative NFDI4Earth.

Because of the orientation of TROPOS towards application-oriented basic research (the "Leibniz-approach"), the publication of the research results is mainly carried out in the international peer-reviewed scientific literature. TROPOS' website provides access to a database of all publications. Despite the massive additional costs, TROPOS encourages Open Access journal publishing. A publication prize is awarded to the best refereed publication by a junior researcher each year. Especially young researchers are encouraged to present their results at important national and international meetings and conferences.

Interdepartmental projects are promoted annually. In an in-house "call for proposals" the best project is recommended for funding by the Scientific Council. This has been a highly successful measure to promote interdepartmental collaboration, especially among younger PostDocs. The success of the project is monitored after about two years.

At the beginning of each budget year (=calendar year), the approved institutional funding is distributed to the four research departments for self-management. The investments per department have already been reviewed and approved by the Scientific Advisory Board in the planning phase. The decision on the actual use of the total budget provided per department is the responsibility of the Department Heads or the responsible persons appointed by them. The departments themselves monitor compliance with the budget with the support of the administration.

Quality management by advisory boards and supervisory board

External quality control is provided by the Bord of Trustees and the Scientific Advisory Board; both organs meet at least once a year.

The Board of Trustees consists of the state representative (chair) and federal representative (deputy chair) and one scientific member who is elected to the Board of Trustees for a four-year term of office (and can be reelected once).

The Director and the Board of Trustees are advised by the Scientific Advisory Board. It consists of at least six but no more than ten members. The Board of Trustees appoints the members of the Scientific Advisory Board after consultation with the Director. Members serve a four-year term of office and can be reappointed for one further term.

5. Human Resources

TROPOS has established a personnel development plan that comprehensively regulates the formal and specific measures for the orientation, general development, and career development of employees. A cost-neutral increase in the staffing plan was implemented in order to secure technical personnel for the operation of the department's work and to consolidate scientific personnel to operate the mobile stations of the Remote Sensing Department.

In response to the demands of the Senate of the Leibniz Association to remove the binding nature of the staffing plan, the State of Saxony has replaced it with an institute-specific quota of permanent appointments to basic budget funds. TROPOS states that this has only led to a slight increase in flexibility, as the quota corresponds to the current staffing plan (see chapter 8, no 8).

Leading scientific and administrative positions

Scientific department heads are jointly appointed professors with the University of Leipzig. Due to the personal change of the previous holder, the position of Head of Administration was filled as of 1 October 2019. The position of head of the "Aerosols" working group (EG 15) was converted into a W2 professorship to head the "Experimental Aerosol and Cloud Microphysics" department. This position was filled as of 1 September 2021.

Staff with a doctoral degree

TROPOS offers fixed-term positions based on third-party funding for young scientists with a doctoral degree. Promising young scientists are encouraged to apply for their own funding. Short-term gaps in external funding are usually covered by the TROPOS budget. The Institute can offer only few exceptional scientists a long-term perspective. It occasionally offers half-position permanent contracts usually covering the remaining half by third-party funding.

In 2020, a W2 professorship with tenure track at the *Freie Universität Berlin* was offered to a TROPOS scientist. She is granted leave of absence from TROPOS for the initial five-year temporary appointment period.

Doctoral Candidates

Dissertation projects are realized in the framework of the structured doctoral training programme. The dissertation is officially guided by a doctoral committee, which is nominated by the University Faculties. Doctoral candidates have the opportunity to participate in summer or winter schools that are often organized or co-organized by TROPOS scientists. In 2017, an initially third-party funded Leibniz Graduate School was generalized to a permanent Leipzig Graduate School "Clouds, Aerosols and Radiation" jointly with the Leipzig Institute for Meteorology.

Over the past five years, an average of seven PhD graduations and eight Diploma/Master and Bachelor studies have been completed at TROPOS per year. The average length of doctorates that were completed since the last evaluation is 4 years and 4 months. Recently, TROPOS has established an Alumni Network and offers the PhD students annual meetings with Alumni to discuss career paths inside and outside academia.

Science supporting staff

TROPOS provides continuous training for the supporting staff and job-related skills (e.g. time management), which has been intensified since 2021. In addition, TROPOS employees can participate in qualification programmes of the Leibniz Association. A master craftsman training course is currently taking place in the mechanical workshop.

The Institute continues to participate in dual training (at the moment, one chemical laboratory technician and one electronics technician for operating technology).

Equal opportunities and work-life balance

The implementation of the Equal Opportunities Agreement, the Framework Recommendation on Equal Opportunities for Women and Men at the institutes of the Leibniz Association and the DFG Research-oriented Equal Opportunities Standards has been regulated since 2010 by an Equal Opportunity Plan which is evaluated and updated every four years. The new plan (August 2021) already meets the criteria required from 2022 on for educational institutions and research organizations wishing to participate in Horizon Europe.

Since 2021, TROPOS has appointed the position of a Disability Representative to further address intersectional issues of inequality. The Equal Opportunities Representative participates in all human resources, organisational and social matters, regularly informs all female scientists about the Leibniz Mentoring for Female Scientists and supports the visibility of female scientists in databases.

As of 31 December 2020, the proportion of women in "research and scientific services" was 34 % (35 out of 103 persons): 51 % (24 out of 47 persons) of the doctoral candidates (including scholarships) and 28 % (17 of 60 persons) of the scientists in non-executive positions (including Postdoc-scholarships) were women. On leading positions, since September 2021, 2 of the 4 department heads are female scientists (one of the male department heads is at the time the TROPOS director); none of the 4 working group leaders is female.

An important role in achieving a good work-life balance is seen by 90 % of the workforce in the flexible working hours. Teleworking is also being offered. Events and meetings at TROPOS are restricted to the Institute's core working hours and should be also offered as online format at request. For the psychological risk assessment at the Institute, the digital COPSOQ questionnaire (Copenhagen Psychosocial Questionnaire) is used for staff surveys every 3–4 years.

Since 2011, TROPOS is certified by "berufundfamilie" audit. As one of several measures to support families, for employees on a fixed-term contract continued employment is guaranteed for at least three months after taking parental leave, regardless of the nature of the project financing, and help is also offered for parents returning to work.

6. Cooperation and environment

Cooperation with Universities

An intensive partnership is fostered with the University of Leipzig. Apart from the fact that the Department Heads are jointly appointed on professorships at this university, TROPOS actively supports the Bachelor and Master education in the fields of Meteorology (mostly), Chemistry and Physics. Approx. 20 senior scientists from TROPOS contribute to various courses and thesis supervisions on the Bachelor and Master level. Institutionally, TROPOS was strongly and with participation from all departments involved in the formation of the Collaborative Research Cluster TR 172 "Arctic Amplification". Currently, TROPOS participates in the preparation for a Collaborative Research Cluster "Biodiversity

Buffers for Climate Extremes" as part of the planned Excellence Initiative "Breathing Nature" of the University of Leipzig.

In addition, TROPOS cooperates on different fields and in different ways (e.g. for simulation chamber studies or field campaigns) with a number of national and international universities. Within Germany, these include: *Freie Universität Berlin*, the Universities of Bayreuth, Bielefeld, Braunschweig, Düsseldorf, Frankfurt a. M., Cologne, Mainz, Munich (LMU), Oldenburg, Rostock, Tübingen als well als the Technical Universities of Darmstadt and Dresden.

On a European level, TROPOS cooperates with the Universities of Aarhus, Basel, Clermont-Ferrand, Copenhagen, Cork, Eastern Finland (Kuopio), Evora, Helsinki, Hertfortshire, Innsbruck, Leeds, Lubljana, Lyon, Manchester, Marseille, Orléans, Oxford, Paris 12, Prague, York, Warsaw, Zürich (ETH) as well as with the Technical Universities of Vienna and Cyprus.

Globally, studies are carried out together with universities in Bolivia, Canada, Cape Verde, Chile, China, Ethopia, Israel, Japan, Morocco, the Philippines, and the USA.

Cooperation within the Leibniz Association

Within the Leibniz Association, TROPOS is involved in the coordination of the Leibniz Research Alliance "Crisis in a globalized world" and is a strong partner within the Leibniz Research Alliance "Infections '21". In addition, TROPOS is partner in the Leibniz Research Networks "Mathematical Modelling and Simulation (MMS)" and "Integrated Earth System Research (iESF)". In the funding line of the Leibniz Competition, the Institute was successful with the projects "Marine biological production, organic aerosol particles and maritime clouds: a process (MarParCloud)", "Assessment of health effects of dust microbial transport, Case study: Cabo Verde (Dust-Health)", and "Abundance and Fate of Synthetic Materials in Atmospheric sub-10 µm Particles (Airplast)".

Cooperation with further partners

The manifold national and international cooperation projects include other non-university partners such as observatories or marine centres. Particularly worthy of mention is the European Space Agency (ESA), a strong partner for the planning, retrieval, development, and validation of various space missions.

Some of the cooperation projects are headed or coordinated by the Institute itself (e.g. the global aerosol-climate model ECHAM-HAMMOZ, the network of automated lidar measurement stations PollyNET, a cooperation-cluster with New Zealand called GoSouth).

In Germany, TROPOS is involved in a number of DFG-funded projects such as the Collaborative Research Cluster "Arctic Amplification: Climate Relevant Atmospheric and Surface Processes and Feedbacks", the Research Group BASS (Biogeochemical processes and Air–sea exchange in the Sea-Surface microlayer), or the Priority Programme PROM (Polarimetric Radar Observations meet Atmospheric Modelling).

Besides the involvement in the forementioned ACTRIS, TROPOS cooperates nationally and internationally with long-term contributions to marine atmosphere observations

onboard German research vessels and German research aircraft. Furthermore, it participates actively in the European Roadmap Infrastructure IAGOS. With the development of the ACTRIS national facilities, more and more partnerships are being developed, e.g. with the Ocean Science Center Mindelo and the Academy of Science of Tajikistan on aerosol in-situ and remote-sensing observations.

To strengthen the transfer of TROPOS science into industry and society, especially in the area of air quality and health, TROPOS is engaged in the planning of a Helmholtz Centre for Climate Action and Innovation - Research and Engineering (CLAIRE).

Institution's status in the specialist environment

As internationally leading institutes in its scientific environment TROPOS indicates the Institute of Meteorology and Climate Research (IMK) at the Karlsruhe Institute of Technology (KIT), the Max Planck Institute for Chemistry (MPI-C), the Institute of Atmospheric Physics (IPA) of the German Aerospace Center (DLR) as well as the Forschungszentrum Jülich (FZJ).

7. Departments of TROPOS

Department 1: Atmospheric Chemistry

[25.5 FTE Staff, thereof 13.3 FTE Research and scientific services, 4.2 FTE Doctoral candidates, and 8.0 FTE Service staff; furthermore 8.0 FTE Scholarship recipients, thereof 4.0 FTE Doctoral candidates, 4.0 FTE Post-doctoral researchers]

In its research, the Atmospheric Chemistry Department (ACD) addresses the tropospheric multiphase system with its classic subdivisions of field measurements, laboratory studies and multiphase modelling, aiming at a quantitative understanding of the processes underlying the observations. Tropospheric multiphase chemistry is a highly topical area of work with many linkages in environmental sciences and science as a whole. TROPOS ACD has been very active since the last evaluation of TROPOS, and has continued to establish itself as one of the leading groups in this field in Germany, Europe and world-wide. ACD is now established as an atmospheric chemistry group with its full width of approach, from molecular mechanism to model development, well connected within TROPOS and with the scientific community outside, while focusing on atmospheric chemistry related to aerosol particles and clouds. TROPOS ACD was involved in many field campaigns since 2015 covering clouds (HCCT evaluation, Schmücke kompakt, MarParCloud), aerosol particle measurements in the Arctic (PASCAL, MOSAiC), the Antarctic (PI-ICE, ACE-SPACE), in Germany (Leipzig PM, Melpitz woodburning, ISOSOA), and internationally (Wangdu, Mt. Tai, (China), TRACE (D-CZ project), Morocco ATLAS, DUSTRISK, PHOSDMAP) and many more. Strong progress was made in understanding a variety of gas phase, aqueous phase, heterogeneous and particle phase processes and to substantially advance tropospheric multiphase modelling with CAPRAM, including new modules for the multiphase chemistry of aromatics, isoprene oxidation products, mercury-containing species, HONO formation and more. Finally, TROPOS ACD moved to its new laboratory building in 2017, which led to big improvements in its laboratory infrastructure.

Department 2: **Experimental Aerosol and Cloud Microphysics**

[37.6 FTE Staff, thereof 24.0 FTE Research and scientific services, 6.6 FTE Doctoral candidates, and 7.0 FTE Service staff; furthermore 10.0 FTE Scholarship recipients, thereof 9.0 FTE Doctoral candidates, 1.0 FTE Post-doctoral researchers]

The Experimental Aerosol and Cloud Microphysics Department has a worldwide reputation in the field of in-situ measurements of physical properties of aerosols and clouds, in both laboratory and atmosphere. Innovative laboratory studies are used for investigating small scale effects and for performing in-depth process studies under reproduceable conditions with the highest possible precision. Field measurements around the globe are carried out under a wide range of climatic conditions to provide information on overarching questions, such as if and how much changing environmental conditions (at times of global warming) affect aerosol and cloud processes and vice versa. The department's globally recognized expertise in the field of instrument and technology development makes it a highly welcome partner on international field expeditions, both on the ground and in the air, as well as with respect to using TROPOS' unique laboratory facilities. In addition, results on the subject of air quality are increasingly being incorporated into concrete recommendations for decision-makers. In the future, successful work will be extended to the global scale considering environments such as the polluted Northern hemisphere versus the cleaner southern hemisphere. Furthermore, greater attention will be paid to the vertical distribution and long-term trends of aerosol and cloud properties in order to better understand aerosol-cloud-interactions from the laboratory to the synoptic scale.

Department 3: **Modelling of Atmospheric Processes**

[24.7 FTE Staff, thereof 12.0 FTE Research and scientific services, 5.4 FTE Doctoral candidates, and 7.3 FTE Service staff; furthermore 1.0 FTE Scholarship recipients, thereof 1.0 FTE Doctoral candidates]

Numerical modelling contributes significantly to the main research fields of TROPOS, with a focus on understanding aerosol processes as well as aerosol-radiation and aerosol-cloud interactions. Effects of aerosol on climate and air quality are explored across multiple scales with process-, regional and global modelling studies. A core topic of the Modelling Department is the advancement of the understanding of the processes that are controlling the abundance of natural aerosol species and their impacts on the atmospheric system (climate, meteorology and atmospheric chemistry). Considered natural aerosol species include mineral dust, aerosol particles from marine emissions, and smoke from wildfires, and these are studied in relation to anthropogenic aerosol species and their effects. A particular focus of detailed aerosol process studies has been on the formation and transformation of secondary organic aerosol particles, including the role of multiphase processes in urban environments. At larger scales, important progress has been made in understanding the emission, transport and effects of mineral dust aerosol. On the one hand, new parameterizations were developed to better understand dust aerosol emissions from sources that have received little attention to date, such as river beds in arid regions, dust mobilization from wildfires and from agricultural soils. On the other hand, model studies investigating the role of dust as a controlling factor for ice formation in clouds have been

advanced. In addition to investigations of ice and precipitation formation in mixed-phase clouds, expertise in modelling the effects of aerosol particles on clouds and climate has been expanded to include the dynamic effects of aerosol-radiation interactions as a key topic relevant to climate and weather research. Model developments include extending the regional chemical transport model to the urban microscale by a novel approach for efficient air quality modelling, which is available, e.g., for citizen science projects. The department is actively engaged in leading national and international modelling consortia and represents an important cooperation and contact partner for the German Weather Service (DWD) as well as for local authorities.

Department 4: Remote Sensing of Atmospheric Processes

[25.8 FTE, thereof 16.4 FTE Research and scientific services, 6.1 FTE Doctoral candidates, and 3.3 FTE Service staff]

The Department "Remote Sensing of Atmospheric Processes" (short: RSD, Remote Sensing Department) is working on active and passive remote sensing from ground and space, with focus on a) the characterization and long-range transport of atmospheric aerosol and b) the understanding of processes related to the interaction of aerosol, clouds, radiation, precipitation, and atmospheric dynamics. The department's scientific concept is based on a strong experimental expertise, own instrument and algorithm developments, as well as innovative synergistic observation approaches. A network of advanced lidar systems is used for long-term aerosol and cloud observations with a particular focus on the global dust belt. Dust properties were investigated in detail in the eastern Mediterranean and in Central Asia. Two multi-instrumented mobile facilities were deployed during long-lasting field experiments in the highly polluted eastern Mediterranean, the pristine Southern Ocean, and the High Arctic. With newly developed synergistic remote-sensing techniques, relationships between cloud properties, INP and CCN concentrations, as well as vertical-wind velocities could be established for these contrasting environments. The continuous, fully automated observations also revealed a strong increase in tropospheric and stratospheric smoke burdens in both hemispheres since 2017, related to the increasing global wildfire activity. Satellite observations from both geostationary and polar-orbiting satellite platforms were used to investigate the spatiotemporal distribution of aerosol, clouds, and radiative fluxes. The department's key topics include the evaluation of atmospheric models, the reconciliation of differences between ground- and satellite-based remote-sensing observations, and the investigation of the effects of small-scale cloud variability on spaceborne cloud retrievals and radiative flux observations.

8. Handling of recommendations from the previous evaluation

TROPOS responded as follows to the 10 recommendations of the last external evaluation (highlighted in italics, see also statement of the Senate of the Leibniz Association issued on 26 November 2015, pages B-3/B-5):

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.

Experimental and modelling work in recent years has contributed to a better understanding of the effects of aerosols and aerosol-cloud interactions in regions exposed to different anthropogenic stresses. TROPOS also contributes to the detection and especially to the understanding of the causes of air pollution in different regimes, increasingly in cooperation with local authorities, partners in environmental and medical sciences, and the interested public (see more detailed chapter 2).

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.

There is a very strong and still enhancing interaction of the Modelling Department's work with all other departments. In that respect models are both applied to research questions as well as further developed. Since the last evaluation, the application of new process parameterizations in global modelling, including studies of climate impacts, was significantly strengthened. For this purpose, global model studies with the aerosol-climate model ECHAM-HAMMOZ, and more recently, the ICON-HAM, were significantly increased allowing investigations of climate impacts. Effects of process parameterizations that are developed to simulate detailed chemical mechanisms and size-resolved aerosol processes and properties can thus be evaluated in simplified versions in an aerosol-climate model. A Department Head of TROPOS now owns the chair of the steering committee for HAMMOZ (TROPOS is the leading institution), is the lead author on the publication of the new HAMMOZ version, and is also a member of the steering committee for the DKK National Earth System Modelling Initiative (see also chapter 2 and chapter 7).

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 analyzing 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 has started a working group on the application of modern statistical methods (Big Data, Machine Learning). In addition, there is an internally funded interdepartmental

project on machine learning techniques. TROPOS is a cooperation partner of the Computing Center of the University of Leipzig in an initiative to build and operate an AI center at the Leipzig campus (see also chapter 2).

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.

TROPOS has actively approached the Leipzig iDiv center to strengthen a collaboration between biology and atmospheric research. TROPOS will lead the joint efforts with Leipzig University by establishing a Leibniz Science Campus "Bioaerosol in a Changing Earth System" (proposal submission 2022, envisaged start 2023). Anticipating this, Leipzig University already has established a junior professorship on "Biodiversity of the Atmosphere", where TROPOS provided members of the appointment committee; the position will be filled in April 2022. This is part of the plans for a Leipzig Cluster of Excellence called "Breathing Nature", to investigate the coupling of climate, biodiversity, and economy.

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 miniaturization and in the development of balloon-borne devices and instruments adapted to operation on unmanned aerial vehicles.

TROPOS has significantly developed field, laboratory, and remote-sensing techniques that are also used internationally by numerous partners in joint measurement networks like PollyNET and in-situ aerosol characterization. TROPOS has further intensified the use of its own tethered balloons and UAVs from other institutes in recent years, developing an extensive collection of small payloads for this field of application. These systems are now successfully used worldwide, especially in polar research, and are constantly being further developed (see chapter 3).

6) At present, the institute does not apply for patents regularly. It should consider implementing a more active patenting strategy.

TROPOS currently employs one person on a temporary basis to perform transfer tasks, which include advising and assisting with patent applications (see chapter 4).

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.

TROPOS gratefully acknowledges the support of the external boards and the evaluation group in the successful application for the ACTRIS-D National Roadmap Project.

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.

The expansion of the staffing plan has been fully implemented. Thus, important core expertise at the institute as well as the technical operation were secured. In 2020, the state of Saxony has replaced the staffing plan with an institute-specific quota of permanent appointments to basic budget funds. However, this has only resulted in a slight increase in flexibility, as the quota corresponds to the current staffing plan and the latter thus continues to be the basis for personnel management.

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.

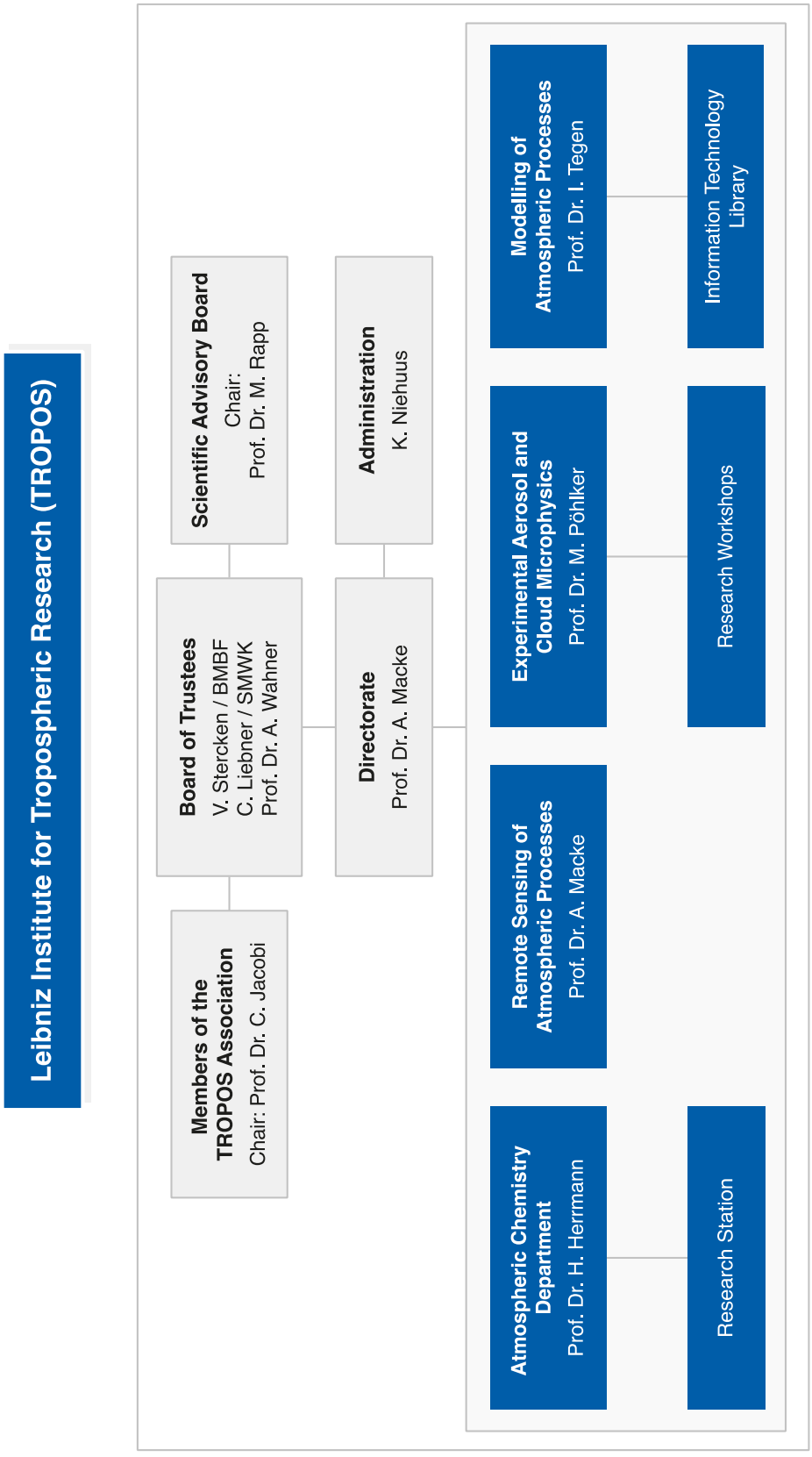
The proportion of women in the mid-level staff has improved in recent years. TROPOS has established a control and recruitment procedure to increase the proportion of women. Gender parity now exists among the scientific department heads (see chapter 5).

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.

Since the last evaluation, the Faculty for Physics and Geography at Leipzig University in 2016 has changed its PhD regulation to allow cumulative dissertations, which was not possible before. The slightly different regulations in the two responsible faculties at the Leipzig University are not seen as problematic. TROPOS encourages its doctoral students to write cumulative dissertations, but also sees the problems caused by small-scale publications and lengthy review processes.

Appendix 1

Organisational Chart



Appendix 2

Publications, patents, and expert reviews

	Period		
	2018	**2019**	**2020**[1)]
Total number of publications	176	167	198
Monographs	1	0	0
Individual contributions to edited volumes	7	1	3
Articles in peer-reviewed journals	94	91	116
Articles in other journals	31	11	14
Working and discussion papers	43	63	65
Editorship of edited volumes	0	1	0

Industrial property rights [2)]	**2018**	**2019**	**2020**
Patents (granted/applied)	1/0	1/0	0/0
Other industrial property rights (granted/applied)	0/0	0/0	0/0
Exploitation rights/licences (number)	0	0	0

	2018	**2019**	**2020**
Number of expert reviews	0	0	3

[1] Contributions that have been accepted for publication but not yet appeared are added in parenthesis.
[2] Concerning financial expenditures for revenues from patents, other industrial property rights and licences see Appendix 3.

Appendix 3 Revenue and Expenditure

Revenue		2018			2019			2020[1]		
		k€	% [2]	% [3]	k€	% [2]	% [3]	k€	% [2]	% [3]
Total revenue (sum of I., II. and III.; excluding DFG fees)		**18,952.1**			**18,847.2**			**17,207.4**		
I.	**Revenue (sum of I.1., I.2. and I.3)**	**15,950.1**	**100%**		**14,495.4**	**100%**		**15,152.5**	**100%**	
1.	INSTITUTIONAL FUNDING (EXCLUDING CONSTRUCTION PROJECTS AND ACQUISITION OF PROPERTY)	9,538.0	60%		9,637.0	66%		9,842.0	65%	
1.1	Institutional funding (excluding construction projects and acquisition of property) by Federal and *Länder* governments according to AV-WGL	9,538.0			9,637.0			9,842.0		
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	5,765.5	36%	100%	4,115.2	28 %	100 %	4,499.3	30 %	100 %
2.1	DFG	1,423.2		25%	1,877.5		46%	2,090.3		46%
2.2	Leibniz Association (competitive procedure)	542.2		9%	188.5		5%	105.1		2%
2.3	Federal, *Länder* governments	3.332,1		58%	1,400.7		34%	1,105.3		25%
2.4	EU	468.0		8%	302.2		7%	1,026.1		23%
2.5	Industry	0.0		0%	0.0		0%	0.0		0%
2.6	Foundations	0.0		0%	92.7		2%	2.5		0%
2.7	*Other sponsors: (ESA)*	0.0		0%	253.6		6%	170.0		4%
3.	REVENUE FROM SERVICES	646.6	4%		743.2	5%		811.2	5%	
3.1	Revenue from commissioned work	646.6			743.2			811.2		
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		
II.	**Miscellaneous revenue** - Withdrawals of third-party funds from the previous year	3,002.0			4,351.8			2,054.9		
III.	**Revenue for construction projects** (institutional funding by Federal and *Länder* governments, EU structural funds, etc.)	0.0			0.0			0.0		

Expenditures		k€	k€	k€
Expenditures (excluding DFG fees)		**18,952.1**	**18,847.2**	**17,207,4**
1.	Personnel	9,075.5	9,515.5	9,825.2
2.	Material expenses	751.8	1,025.6	820.0
2.1	*Proportion of these expenditures used for registering industrial property rights (patents, utility models etc.)*	1.3	1.5	0.0
3.	Equipment investments	1,589.4	3,440.5	1,067.0
4.	Construction projects, acquisition of property	31.5	0.0	0.0
5.	Other operating expenses	7,265.4	4,624.7	5,249.1
5.1	Of which SB-Mittel into the following year, third-party funding income, etc.	6,785.8	3,902.9	4,728.4
DFG fees (if paid for the institution – 2.5% of revenue from institutional funding)		238.5	240.9	246.1

[1] Preliminary data: no
[2] Figures I.1, I.2 and 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 to 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 December 2020)

	Full time equivalents		Persons		Women		Foreigners
	Total	on third-party funding	Total	on temporary contracts	Total	on temporary contracts	Total
	Number	Percent	Number	Percent	Number	Percent	Number
Research and scientific services	**85.2**	**61.1**	**103**	70.9	35	88.3	**19**
1st level (scientific directors)	1.0	0.0	1	0.0	0	0.0	0
2nd level (department leaders or equi.)	2.0	0.0	2	0.0	1	0.0	0
3rd level (group leaders or equi.)	3.7	0.0	4	10.0	0	0.0	0
Junior research group leaders (if applicable)	0.0	0.0	0	0.0	0	0.0	0
Scientists in non-executive positions (A13, A14, E13, E14 or equivalent)	50.2	58.8	55	59.7	17	88.9	7
Doctoral candidates (A13, E13, E13/2 or equi.)	22.2	80.2	33	100.0	15	100.0	12
Service Scientists (E13/E14)	6.2	77.4	8	87.5	2	40.0	0
Science supporting staff (Laboratories, technical support etc.)	**28.3**	**0.0**	**29**				
Laboratory (E5 to E8, mid-level service)	8.8	0.0	9				
Workshops (E5 to E8, mid-level service)	8.0	0.0	8				
Library (E9 to E12, upper-mid-level service)	0.5	0.0	1				
Information technology - IT (E6 to E10, upper-mid-level service)	4.0	0.0	4				
Technical (large equipment, service) (E5 to E8, mid-level service and E9, upper-mid-level service)	7.0	0.0	7				
Science supporting staff (administration)	**14.0**	**0.0**	**15**				
Head of the administration	1.0	0.0	1				
Staff positions (directorate from E13, senior service)	2,0	0,0	2				
Staff positions (E5 to E8, mid-level service and E9, upper-mid-level service)	3.2	0.0	4				
Internal administration (financial administration, personnel, etc.) (E9, upper-mid-level service)	1.0	0.0	1				
Internal administration (financial administration, personnel, etc.) (E5 to E8, mid-level service)	4.8	0.0	5				
Building service (E5 to E8, mid-level service and E9, upper-mid-level service)	2.0	0.0	2				
Student assistants	6.3	100.0	24				
Trainees	**2.0**	0.0	2				
Scholarship recipients at the institution	**19.0**	100.0	19		9		18
Doctoral candidates	14.0	100.0	14		9		13
Post-doctoral researchers	5.0	100.0	5		0		5

1 June 2022

Annex B: Evaluation Report

Leibniz Institute for Tropospheric Research, Leipzig (TROPOS)

Contents

1. Summary and main recommendations

TROPOS investigates aerosols and aerosol-cloud interactions. The institute conducts physical and chemical process studies on small spatial and temporal scales in the troposphere as well as analyses of long-term trends. Research is based on four methodological pillars (satellite remote sensing, field studies, experiments in the laboratory and numerical modelling).

The institute is well known for its high quality observations of atmospheric composition and the underlying process dynamics. The extremely good research results are based on innovative measurement technologies and state-of-the-art infrastructure, which TROPOS also makes available to the international research community. As well as developing and using versatile mobile measuring instruments, the institute operates a number of important stationary facilities.

TROPOS uses these technologies in a large number of international collaborative ventures. A special role is played by the pan-European ACTRIS network (Aerosol, Clouds and Trace Gases Research Infrastructure). ACTRIS specialises in atmospheric process understanding and predictive models. TROPOS is the lead institution among the eleven research laboratories participating in ACTRIS-D, Germany's contribution to the project. Within the context of larger collaborative projects, TROPOS has successfully extended the number of its long-term measurement sites. TROPOS' excellent understanding of aerosols is the result of widespread and intensive experiments carried out on the basis of these networks. With regard to global measurements from in-situ to satellite remote sensing, TROPOS has conducted significant outreach in hitherto little-explored regions. It is also commendable that the institute is developing citizen science projects.

Since the previous evaluation, the institute has continued to investigate promising research topics like ice nucleating particles, on which further excellent work has been done. TROPOS has also successfully started work on topics like the Northern Hemispheric dust belt, the marine contribution to tropospheric aerosol particles and their role in aerosol-cloud interaction, and – with regard to the particularly strong wildfires of recent years – smoke in the atmosphere. These new topics in particular offer opportunities to make connections within research and knowledge transfer to issues that are highly relevant to society – from air pollution to health-related issues and climate change.

Institutional funding for the institute currently amounts to €9.7m p.a. (average 2018-2020). The average amount of revenue from project grants in 2018-2020 amounted to €4.8m p.a. with a significant part (€1.8m) coming from the German Research Foundation (DFG). TROPOS also succeeded in obtaining funding from the EU with an average of €0.6m p.a. over this period. This level of third-party income is appropriate for a Leibniz institution.

The structure of the scientific management team at TROPOS is very suitable for the size of the institute. One of the four department heads is the director of the institute and at the same time a W3 professor at the University of Leipzig. In 2021, the vacancy for the head of the Experimental Aerosol and Cloud Microphysics Department was filled jointly with the University of Leipzig for the first time, so that all four department heads are now jointly appointed with a university. With its structured doctoral training programme as

well as the support of a doctoral supervisory committee, TROPOS offers a good environment for training of young scientists, as evidenced by a high proportion of foreign doctoral candidates.

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

Changes and planning (chapter 3)

1. As recommended during the last evaluation, TROPOS aims at focusing its work on major overarching themes, such as climate change and health protection. A stronger connection should be developed between the major themes and the various individual projects.

   To achieve this, the institute is advised to develop strategic guidelines that provide a clear framework for its selection of field and laboratory studies over the next few years. This strategic clarification needs to happen quickly so that the welcomed increase in research opportunities, in particular those offered by ACTRIS, can be used in a targeted manner to work on topical scientific questions.

2. In this context, it is welcomed that TROPOS plans to extend its large-scale modelling even more than previously. The institute now needs to look closely at a number of associated methodological and technical issues. For instance, the aims TROPOS has set itself will require the use of high-performance computers, and suitable partner institutions will need to be found to operate them. In addition, the emergence of the German ICON model (ICOsahedral Nonhydrostatic) as a unique and highly promising multiscale modelling framework opens new avenues.

3. Within ACTRIS, TROPOS is expanding its top-end research infrastructure and thereby strengthens the European network. Naturally, the institute intends to make the most of the emerging possibilities for more advanced scientific analysis of new field observations and experimental results in order to answer new scientific questions. In this respect, it is indeed necessary to apply for increased institutional funding (ACTRIS@TROPOS, amounting to €3.7m per year additional funds, as a "minor extraordinary item of expenditure of a strategic nature"/"*Sondertatbestand*").

   The current plan for three topical pillars only serves to expand the ongoing work in the departments. It is important to go beyond this when submitting the application and to explain which new overarching scientific questions will be researched – questions that can be identified from the recommended strategic guidelines. Insofar as these objectives are taken into account, the review board is very supportive of an application for an increase in institutional funding for TROPOS.

Controlling and quality management (chapter 4)

4. TROPOS should further enhance its efforts to publish its research results in 'generalist' journals where they will be noticed not only in atmosphere research, but also in neighbouring disciplines. It is good to see that some departments also frequently publish systematic science reviews. TROPOS should make even more use of this or other suitable formats in future in order to further increase its international visibility and provide direction to the wider global scientific community.

Human resources (chapter 5)

5. TROPOS needs to improve its performance related to institutional gender equality. The proportion of women among the academic staff has increased only minimally since the previous evaluation: As of 31 December 2020, the academic staff consisted of 44 women (36%) and 78 men (64%). The status at 31 August 2014, on which the previous evaluation was based, lists 34 women (33%) and 69 men (67%). Even though it is extremely good to note the balanced gender ratio among the department heads achieved in 2021, the proportion of women among the scientific staff still drops from 50% at doctoral student level (24 out of 47 doctoral candidates) to 27% at advanced levels after the qualification phase, and only 13% among the scientific staff with permanent contracts.

2. Overall concept, activities and results

TROPOS investigates aerosols and aerosol-cloud interactions. The institute conducts physical and chemical process studies on small spatial and temporal scales in the troposphere as well as analyses of long-term trends. Research is based on four methodological pillars (satellite remote sensing, field studies, experiments in the laboratory and numerical modelling).

The institute is well-known for its high-quality observations of atmospheric composition and the underlying process dynamics. The extremely good research results are based on innovative measurement technologies and state-of-the-art infrastructure, which TROPOS also makes available to the international research community. As well as developing and using versatile mobile measuring instruments from balloon-borne devices and backpacks to mobile measurement platforms (with a focus also on the miniaturization of measurement instruments), the institute operates a number of important stationary facilities. These include atmospheric observatories like the Melpitz research station, which encounter international interest, but also noteworthy atmospheric simulation chambers, such as the turbulent cloud chamber LACIS-T (Turbulent Leipzig Aerosol Cloud Interaction Chamber for controlled studies of cloud microphysical processes) and the aerosol simulation chamber ACD-C (Atmospheric Chemistry Department – Chamber, a unique facility in Germany to study combustion atmospheric chemistry and aerosol toxicity).

TROPOS uses these technologies in a large number of international collaborative ventures. A special role is played by the pan-European ACTRIS network (Aerosol, Clouds and Trace Gases Research Infrastructure). ACTRIS specialises in atmospheric process understanding and predictive models. The participating institutions have been expanding the network for a long time and with increasing intensity. It currently involves 22 countries. In 2016, ACTRIS was included in the ESFRI roadmap (European Strategy Forum on Research Infrastructures), and in 2022 it will become a European Research Infrastructure Consortium (ERIC).

Within the context of larger collaborative projects, TROPOS has successfully extended the number of its long-term measurement sites (e.g. in Tajikistan as part of PollyNET, international network of automated Raman-polarization lidars for continuous aerosol profiling, coordinated by TROPOS).

TROPOS' excellent understanding of aerosols is the result of widespread and intensive experiments carried out on this basis. This approach of seeking to understand aerosols from their sources around the world has also provided the institute with the opportunity to participate in international, pioneering expeditions, such as MOSAiC in 2019.[1] With regard to global measurements from in-situ to satellite remote sensing, TROPOS has conducted significant outreach in hitherto little-explored regions. It is also commendable that the institute is developing citizen science projects.

3. Changes and planning

Development since the previous evaluation

The institute has continued to investigate promising research topics like ice nucleating particles, on which further excellent work has been done. TROPOS has also successfully started work on topics like the Northern Hemispheric dust belt, the marine contribution to tropospheric aerosol particles and their role in aerosol-cloud interaction, and – with regard to particularly strong wildfires of recent years – smoke in the atmosphere.

These new topics in particular offer opportunities to make connections within research and knowledge transfer to issues that are highly relevant to society – from air pollution to health-related issues and climate change. It is good to see that TROPOS is providing support to local authorities in the area of air pollution.

TROPOS achieved an enormous success with ACTRIS-D, Germany’s contribution to ACTRIS, the pan-European research infrastructure. The institute was heavily involved in ensuring the inclusion of ACTRIS-D on Germany's National Roadmap for Research Infrastructures (2019), after ACTRIS was included on the ESFRI Roadmap for Research Infrastructures in 2016. TROPOS is the lead institution among the eleven research laboratories participating in ACTRIS-D. To build up the necessary infrastructure in Germany, the Federal Ministry of Education and Research will invest a total of €86m between 2021 and 2029, almost a quarter of which will go to TROPOS facilities. With its leading participation, TROPOS will play an even more significant role in Europe in the area of research on climate forecasts and air quality in particular, as well as concerning the effects of aerosols on human health and the ecosystem.

Strategic work planning for the coming years

As recommended during the last evaluation, TROPOS aims at focusing its work on major overarching themes, such as climate change and health protection. A stronger connection should be developed between the major themes and the various individual projects.

To achieve this, the institute is advised to develop strategic guidelines that provide a clear framework for its selection of field and laboratory studies over the next few years. This strategic clarification needs to happen quickly so that the welcomed increase in research opportunities, in particular those offered by ACTRIS, can be used in a targeted manner to work on topical scientific questions.

[1] Multidisciplinary Drifting Observatory for the Study of Arctic Climate

In this context, it is welcomed that TROPOS plans to extend its large-scale modelling even more than previously. The institute now needs to look closely at a number of associated methodological and technical issues. For instance, the aims TROPOS has set itself will require the use of high-performance computers, and suitable partner institutions will need to be found to operate them. In addition, the emergence of the German ICON model as a unique and highly promising multiscale modelling framework opens new avenues.

It is good to see that TROPOS is using its expertise for scientific public policy consulting at national and international level, for example with the German Bundestag and at several UN climate change conferences. The results the institute has achieved so far offer further opportunities for research. For instance, TROPOS' results could find applications in the field of weather forecasts, which are becoming increasingly important in view of the rising number of severe weather events. TROPOS is encouraged to approach institutions such as *Deutscher Wetterdienst*, Germany's national meteorological service, for partnerships. In addition, in the context of the institute's strategic further development, TROPOS should continue to consider the social and political relevance of topics selected for consulting services.

Planning for additional funds deriving from institutional funding

Within ACTRIS, TROPOS is expanding its top-end research infrastructure and thereby strengthens the European network. Naturally, the institute intends to make the most of the emerging possibilities for more advanced scientific analysis of new field observations and experimental results in order to answer new scientific questions. In this respect, it is indeed necessary to apply for increased institutional funding (ACTRIS@TROPOS, amounting to €3.7m per year additional funds, as a "minor extraordinary item of expenditure of a strategic nature"/"*Sondertatbestand*"; see Status Report, p. A-10**).**

The current plan for three topical pillars only serves to expand the ongoing work in the departments. It is important to go beyond this when submitting the application and to explain which new overarching scientific questions will be researched – questions that can be identified from the recommended strategic guidelines. Insofar as these objectives are taken into account, the review board is very supportive of an application for an increase in institutional funding for TROPOS.

4. Controlling and quality management

Funding

TROPOS is adequately endowed with institutional funding for its current tasks. Since the previous evaluation, institutional funding has increased from €8m p.a. (average 2011-2013) to €9.7m p.a. (average 2018-2020).

Income from third-party funding for research infrastructure and research projects has risen since the previous evaluation from €3.0m p.a. (average 2011-2013) to €4.8m p.a. (average 2018-2020). The funds obtained from the DFG increased significantly (€1m to

€1.8m p.a.), as did third-party funding from the federal and state governments (€1m p.a. to €1.9m p.a.). TROPOS also succeeded in obtaining funding from the EU with an average of €0.6m between 2018 and 2020, a level similar to the situation seven years ago. Besides this, TROPOS reached income from commissioned work (€0.734m p.a. average 2018-2020, €0.964m p.a. average 2011-2013).

Overall, TROPOS currently generates around 36% of its current budget from third-party funding, which is a slight increase compared to the situation seven years ago (33% at the time). This level of third-party income is appropriate for a Leibniz institution.

Organisational and operational structure

TROPOS' organisational structures are appropriate. The institute is divided into four departments, each headed by a jointly appointed professor. Since the last evaluation, some of the departments have further intensified their cooperation. Opportunities for further synergies are explained in the comments on the individual departments (chapter 7).

Quality management

Both within the departments and across them, TROPOS has established suitable formats to enable presentation and discussion of research results and to ensure good scientific practice, including appropriate IT-backups.

TROPOS should further enhance its efforts to publish its research results in 'generalist' journals where they will be noticed not only in atmosphere research, but also in neighbouring disciplines. It is good to see that some departments also frequently publish systematic science reviews. TROPOS should make even more use of this or other suitable formats in future in order to further increase its international visibility and provide direction to the wider global scientific community.

Quality management by advisory board

The advisory board supports TROPOS in a committed and constructive manner and in accordance with the requirements of the Senate of the Leibniz Association. Critical monitoring of TROPOS' efforts to implement the strategic recommendations of this evaluation will be helpful for the institute's further development in the next few years.

5. Human Resources

At 31 December 2020, TROPOS employed 147 people, 103 of them in research and scientific services (cf. Status Report, A-26). It also employed 24 student assistants and 2 trainees, and supported 19 scholarship recipients. The state of Saxony has made the staffing plans more flexible in accordance with the federal-state agreements. A quota from the core budget for personnel costs was set, which can be adjusted annually in the budget. This regulation is initially valid until 2030 and will then be reviewed by the state of Saxony.

Leading scientific and administrative positions

The structure of the scientific management team at TROPOS is very suitable for the size of the institute. One of the four department heads is the director of the institute and at the same time a W3 professor at the University of Leipzig.

In 2021, the vacancy for the head of the department "Experimental Aerosol and Cloud Microphysics" was filled jointly with the University of Leipzig for the first time. A scientist with a very good reputation was recruited for the position. As a result, all four department heads are now jointly appointed with a university. A young female research group leader from TROPOS was appointed to a W2 professorship at FU Berlin.

In addition, a new administrative head of TROPOS was appointed in October 2019.

Doctoral candidates and staff with a doctoral degree

The high proportion of foreign doctoral candidates shows that TROPOS offers a good environment for training of young scientists. Of the total of 47 doctoral candidates (as at 31 December 2020), including both salaried and scholarship recipients, 25 came to the institute from abroad (53%). The average length of doctorates completed since the previous evaluation is 4 years and 4 months (a total of 14 doctorates between 2018 and 2020).

The doctoral students are integrated into a structured doctoral training programme and receive the support of a doctoral supervisory committee. In particular, there is the possibility of a doctorate at the Leipzig Graduate School for "Clouds, Aerosols and Radiation" (as part of the Research Academy Leipzig), which was permanently established in 2017 in collaboration with the Leipzig Institute for Meteorology. In addition, PhD students at TROPOS can participate in regular summer and winter schools, which are often organised or co-organised by TROPOS scientists. TROPOS also offers the PhD students annual meetings with alumni to discuss career paths inside and outside academia. Following up on the recommendations from the previous evaluation, since 2016 it has been possible to complete doctorates cumulatively at the Faculty of Physics and Geography of the University of Leipzig.

TROPOS offers fixed-term positions based on third-party funding for young scientists with a doctoral degree. In addition, there are permanent positions with contracts covering 50% of the working time, so that the remaining 50% must be financed through third-party funding. The previous evaluation recommended creating more permanent positions. Of the 55 scientists in non-executive positions, 28% had a permanent contract seven years ago; today this figure is 40.3%.

Equal opportunities and work-life balance

TROPOS needs to improve its performance related to institutional gender equality. The proportion of women among the academic staff has increased only minimally since the previous evaluation: As of 31 December 2020, the academic staff consisted of 44 women (36%) and 78 men (64%). The status at 31 August 2014, on which the previous evaluation was based, lists 34 women (33%) and 69 men (67%). Even though it is extremely good to note the balanced gender ratio among the department heads achieved in 2021, the proportion of women among the scientific staff still drops

from 50% at doctoral student level (24 out of 47 doctoral candidates) to 27% at advanced levels after the qualification phase, and only 13% among the scientific staff with permanent contracts.

6. Cooperation and environment

TROPOS has entered into numerous important and fruitful collaborations with universities and research institutes all over the world. As is common for Leibniz institutions, TROPOS cooperates closely with its local university, in this case the University of Leipzig. The institute is also strongly involved within the Leibniz Association (e. g. in the Leibniz Research Alliance "Crisis in a Globalised World" or the Leibniz Research Network "Mathematical Modelling and Simulation").

In the context of the recommended strategic clarifications, TROPOS should examine whether synergies can be achieved through more intensive collaboration with the Karlsruhe Institute of Technology, especially with regard to the AIDA cloud chamber, which is dedicated to longer time-scales. In intensifying its work on air quality, it is suggested that TROPOS seeks collaborations within the scientific community relating to health disciplines. In doing so, the institute could also examine whether it is worthwhile including toxicology.

7. Departments of TROPOS

Department 1: Atmospheric Chemistry

[25.5 FTE staff, of whom 13.3 FTE research and scientific services staff, 4.2 FTE doctoral candidates, and 8.0 FTE service staff; furthermore 8.0 FTE scholarship recipients, of whom 4.0 FTE doctoral candidates, and 4.0 FTE post-doctoral researchers]

The Atmospheric Chemistry Department addresses the tropospheric multiphase systems of aerosols and clouds, aiming at a quantitative understanding of the processes underlying the observations. Methodologically, the work focuses on field measurements, laboratory studies and multiphase modelling. The department's work, supported by third party funding with a high proportion of DFG funds, results in intensive publication activities. It is good to see that the department also systematically publishes internationally recognised science reviews.

The department uses excellent research infrastructures for its field measurements, which it develops and operates itself. Important observatories are, for example, the Melpitz Observatory, the Schmücke Cloud Observatory and the Leipzig Biomass Burning Facility (LBBF). As a co-leader, the department is also involved in an atmospheric science observatory in Cape Verde. These facilities are embedded in ACTRIS, providing additional value to them through open access data and transnational access opportunities. Remarkable research achievements have been made on this basis, for example on interactions between aerosols and clouds and ocean-atmosphere interactions.

Important questions are also being addressed for the coming years. Given the department's limited human resources, priority-setting among the large number of currently envisaged campaigns will be necessary. A stronger focus on selected scientific

topics would ensure sufficient capacity for the evaluation, analysis and publication of results also in the future. The strategic selection should be based on the overarching goals of TROPOS, after further refinement (see chapter 3).

The department has also achieved excellent results in its laboratory studies. Noteworthy, for example, is work on highly oxidised organic molecules (HOM). Key new insights have also been gained in understanding a wide range of processes in the gas phase, the aqueous phase and the particle phase. In particular, heterogeneous chemistry involving all three phases is an important focus of the department. In this multiphase research, the department should pay special attention to the ice phase, being extremely relevant for a better understanding of northern ozone, nitrogen and mercury cycles.

Tropospheric multiphase modelling is a highly relevant task of the department in order to exploit the experimental and laboratory data. In the past years, the department has especially improved its sophisticated and comprehensive multiphase chemistry mechanism CAPRAM (Chemical Aqueous Phase Radical Mechanism). The planning for further specifications is very demanding and must be approached with limited resources in mind. The efforts within the framework of cooperation, especially the increasing number of users, will put more strain on the department's capacities. Moreover, it is important to ensure that further model developments are compatible with overarching model frameworks, such as those currently being developed for air quality at the European level. This will enhance the impact of the work.

Department 2: **Experimental Aerosol and Cloud Microphysics**

[37.6 FTE staff, of whom 24.0 FTE research and scientific services staff, 6.6 FTE doctoral candidates, and 7.0 FTE service staff; furthermore 10.0 FTE scholarship recipients, of whom 9.0 FTE doctoral candidates, and 1.0 FTE post-doctoral researchers]

Department 2 performs in-situ measurements of physical properties of aerosols and clouds, in both laboratory and atmosphere. Laboratory studies are used for investigating small-scale effects and for performing in-depth process studies under reproducible conditions. Field measurements are carried out around the globe and under a wide range of climatic conditions. The department has a particular focus on aerosol characterisation, formation of CCN (atmospheric cloud condensation nuclei) and INP (ice nucleating particles), and on cloud formation and its climate effects. In its investigations of contrasting environments, the group pursues a powerful strategy of identifying the controlling physical, chemical or biological factors in various atmospheric processes. The addition of research on aerobiology, including studies on the ecosystem-atmosphere interaction, is important. The results are intensively published in high-quality journals (often in cooperation with other European leading groups). Without losing its commendable focus on open access journals, the institute should broaden its portfolio of publication outlets.

The department’s very strong experimental expertise is based on the excellent and internationally recognized instruments and infrastructure it has developed. Prominent results have been achieved in both the laboratory and field studies. An immense success is the development of LACIS-T, an important facility for studying aerosol-cloud

interactions under turbulent conditions. For its field campaigns, the department strives in particular to miniaturise its instruments, as noted in the previous evaluation (e.g. mobile aerosol backpacks). In addition, measurements have been extended through the use of helicopter- and balloon-borne systems. These efforts on developing vertical measurements should be increased.

The department has a key role in the further development of ACTRIS. It has already made a strong contribution to the network's establishment by developing and running the European and internationally established WCCAP (World Calibration Center for Aerosol Physics) for the quality assurance of physical and optical aerosol measurements. For its future work, the department should carefully plan efforts to make maximum use of the enormous data flow emerging from ACTRIS. Closer cooperation with the "Remote Sensing" Department could therefore be promising.

The research output from this department is impressive, both in terms of quality and quantity, with important findings in key areas. The excellent work on ice nucleating particles, which opens up new relevant research questions, deserves a special mention. The ongoing studies on bioaerosols have the potential to provide significant insights into climate change. The department's work on air quality, soot and black carbon particles, as well as on climate relevant aerosol properties (e.g. CCN and INP) and health-relevant aerosol metrics, provides high potential for collaboration with the "Modelling of Atmospheric Processes" Department. The work is clearly related to climate and will, in principle, lead to improved climate predictions. Given this, the department should decisively direct its activities and developments in line with these strengths.

Department 3: **Modelling of Atmospheric Processes**

[24.7 FTE staff, of whom 12.0 FTE research and scientific services staff, 5.4 FTE doctoral candidates, and 7.3 FTE service staff; furthermore 1.0 FTE scholarship recipients, of whom 1.0 FTE doctoral candidates]

Department 3 pursues the important aim of translating the wide range of experimental and observational data from the other departments into numerical models, making these findings accessible for broader application. The department is also constantly testing and improving models in order, for instance, to close unavoidable gaps in data collection.

In recent years, work has been done within an extremely broad framework. Studies relate to natural aerosol species (dust, marine, biogenic and wildfires) and model their emissions and transport in the context of different spatial scales (local, regional and global), different applications (weather, climate and air quality) and different aerosol-cloud interaction processes (direct radiative, indirect radiative through clouds and ice nucleation by aerosols). This has led to important results. Worth highlighting are, for instance, insights into natural aerosol types and their interactions with anthropogenic pollution in relation to weather and climate, or into the effects of absorbing aerosols on cloud cover. The department's research performance is reflected in a very persuasive publication record.

In the context of the recommended further development of the entire TROPOS strategy, the institute should clarify which questions the department should now concentrate on. An important point of reference should be which projects can contribute most to the institute's

international modelling activities. Particular potential for this exists in relation to e.g. dust source emissions, sea salt emission processes and wildfire emissions. The work of the department should be made more visible and connectable by embedding it into the respective global efforts (especially through scientific reviews).

As already recommended in the last evaluation, a more strategic approach is especially essential given the rapid development of high-resolution atmospheric models, and the new opportunities around ICON. The department should distinguish its models more clearly from others or find linkages in order to complement them (e.g. with ICON-ART, a result of cooperation between DWD and KIT, or the wildfire module of the Copernicus Atmosphere Monitoring Service CAMS). Further or intensified national and international cooperation with other modelling efforts on aerosols, especially natural ones, should be considered (e.g. with KIT or MPI for meteorology), in order to make the results as usable as possible for practical application, e.g. in the work of *Deutscher Wetterdienst* or the IPCC. As the head of this department will likely retire around the next evaluation, the ultimate responsibility for the modelling strategy should be coordinated with the leadership of TROPOS, and not only within the department.

Department 4: Remote Sensing of Atmospheric Processes

[25.8 FTE, of whom 16.4 FTE research and scientific services staff, 6.1 FTE doctoral candidates, and 3.3 FTE service staff]

This department is working on active and passive remote sensing from ground and space – for aerosol monitoring and characterization, as well as process understanding. It develops an impressive and unique array of research instrumentation, which has been extended since the previous evaluation (e.g. with the addition of mobile measurements). Particularly noteworthy is the development of complex, ground-based lidar systems of outstanding quality, and their scientific use in synergy with excellent radars, pyranometer networks and spaceborne observations. These world-leading instruments are in demand by the international scientific community and are being used in ESA's EarthCARE project, for example.

On this basis, the department has further intensified campaigns and expanded spaceborne remote sensing. Important insights have been gained into INP and CCN, not least due to various closure studies that the department was able to conduct using its comprehensive approach. Besides aerosol-cloud interactions, the department has primarily performed studies on the influence of the major natural sources, such as dust, sea spray and wildfires. The department achieves excellent publication of its results in high-ranking journals.

As recommended in the previous evaluation, the department has intensified its cooperation with the “Modelling of Atmospheric Processes” Department. The joint focus with the “Experimental Aerosol and Cloud Microphysics” Department on natural background aerosol-cloud interactions offers significant potential to link the work of both groups even more closely in the coming years.

8. Handling of recommendations of the last external evaluation

TROPOS has successfully addressed the recommendations made by the Leibniz Association Senate in 2015 (see Status Report, p. A-20–22). The recommendations on overarching questions (recommendation 1), large-scale modelling (recommendation 2), collaborations with external partners concerning data (recommendation 3) and gender equality (recommendation 9) still apply in part.

Appendix

1. Review Board

Chair (Member of the Leibniz Senate Evaluation Committee)

Wolfgang **Cramer**	Institut Méditerranéen de Biodiversité et d'Ecologie Marine et Continentale (IMBE), Aix Marseille Université (France)

Deputy Chair (Member of the Leibniz Senate Evaluation Committee)

Ilse **Helbrecht**	Geography Institute, Humboldt University of Berlin

Reviewers

Richard **Bamler**	Remote Sensing Technology Institute, German Aerospace Center, Weßling
Leonard **Barrie**	Department of Geosciences, Stockholm University (Sweden)
Miikka **Dal Maso**	Aerosol Physics Laboratory, Tampere University (Finland)
Hans-Christen **Hansson**	Department of Environmental Science, Stockholm University (Sweden)
Daniela **Jacob**	GERICS - Climate Service Center Germany, Hamburg
Maria **Kanakidou**	Environmental Chemical Processes Laboratory, University of Crete (Greece)
Benjamin **Murray**	School of Earth and Environment, University of Leeds (UK)
Christoph **Schär**	Institute for Atmospheric and Climate Sciences, ETH Zürich (Switzerland)
Christiane **Schmullius**	Institute of Geography, University of Jena

Representative of the Federal Government (Deputy member of the Leibniz Senate Evaluation Committee)

Volker **Wiesenthal**	Federal Ministry of Education and Research, Berlin

Representative of the Länder *governments*

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20 July 2022

Annex C: Statement of the Institution on the Evaluation Report

Leibniz Institute for Tropospheric Research, Leipzig (TROPOS)

We appreciate the overall very positive comments of the evaluation board as well as the constructive suggestions to further improve the work at TROPOS. We are glad to see that the board recognizes that TROPOS achieves excellent understanding of aerosols arising from the Institute's leadership in intensive experiments and networks and thus provides significant outreach. We appreciate the recognition of the innovative measurement technologies and state-of-the-art infrastructure developed at TROPOS as basis for extremely good research results. In the following, we would like to take the opportunity to address specific points of the evaluation report for better clarification of our performance and strategic plans for the future research at TROPOS.

Regarding Section 7. department 3, last paragraph: "As the head of this department will likely retire around the next evaluation, the ultimate responsibility for the modelling strategy should be coordinated with the leadership of TROPOS, and not only within the department." In general, as the Director of TROPOS I see a general responsibility to coordinate the scientific strategy jointly with all departments. This responsibility is further emphasized by the fact that the heads of the three departments „Remote Sensing of the Atmosphere“ (who is also Director of the Institute), "Atmospheric Chemistry“ and „Modelling of Atmospheric Processes“ will all retire around the time for the next evaluation of TROPOS. Thus, all department heads already jointly work on the long-term strategy of the institute as a whole, which also affects the strategy of the individual departments.

The evaluation report suggests to develop strategic guidelines that provide a clear framework for the selection of field and laboratory studies. As written in our evaluation document, TROPOS has developed and continues to update the strategy paper "TROPOS 2030", which provides clear guidelines to our scientific visions and developments, also in light of the research questions that become feasible in the framework of ACTRIS. This strategic concept has also been addressed in section 3.3 of our evaluation document in the framework of the planned extraordinary item of expenditure ACTRIS@TROPOS. Here, we clearly define our long-term visions along three new cross-department research lines. This approach also forms the basis for the leadership of TROPOS in the national and European ACTRIS activities.

ACTRIS will also strongly benefit from our ongoing developments of regional to global ICON modelling and the new generation of satellite-based observations as synergistic drivers for an integrative understanding of aerosols and aerosol-climate interaction across all relevant scales. In this context, the Remote Sensing Department is involved in several boards for recent and future satellite missions.

We appreciate that the evaluation board also sees the need to find suitable partners to enable progress in high-performance computing. Corresponding networking has already been carried out at the national level. As written in our evaluation document, the Modelling Department uses resources at DKRZ and TU Dresden and also has the option of applying for computing resources at FZ Jülich. The German Climate Computing Centre DKRZ has been operating its new high-performance computing system since March 2022, tripling its computing power to 14 Petaflops. The use of the ICON model as a meteorological driver is central to the modelling strategy at TROPOS and the coupling of various modules devel-

oped in the Modelling Department with the ICON model is underway. Using the resources at DKRZ for future use of ICON with model resolutions ranging from convection-resolving to global makes particular sense as DKRZ is a main infrastructure for ICON model development and thus provides extensive support for external users. The Head of the Modelling Department is also a member of the Steering Committee of the German National Earth System Initiative, which coordinates the use of new high-performance computing methods for Earth system applications. As proposed, the TROPOS Modelling Department will continue and strengthen these efforts.

We partly understand the concern that the planned STB serves to expand the ongoing work within the departments. Indeed, our strategy to carry the TROPOS expertise of process understanding to the global scale and to health and climate related interlinked compartments of the Earth system requires the disciplinary strength of all departments. For that reason, the new positions are planned to be located in the existing departments (instead of founding a new department). However, as written in our document, the three new research groups, which make up the STB, are designed as cross-departmental teams which are, on the one hand, anchored in their departments, but, on the other hand, conduct their work as independent and overarching research teams. TROPOS has carefully designed this construction as outlined in its evaluation document intending to combine both disciplinary strength of the departments and adding new research dimensions along large-scale process understanding and compartment overarching research within the three new teams and topical pillars. We believe that the future development of research at TROPOS and its societal relevance will strongly benefit from the achievements along these new cross-departmental research topics, and that this development will substantially stimulate the national and international research to improve our understanding of the role of short-lived climate components in a critically changing complex Earth system.

The evaluation report suggests that TROPOS should seek collaborations within the scientific community relating to health disciplines. As written in our evaluation document, this has been successfully achieved in a number of projects and research alliances, e.g., with the IUF (Leibniz-Institut für Umweltmedizinische Forschung), the UKL (Universitätsklinikum Leipzig), the UFZ (Umweltforschungszentrum), as associated partner of the Leibniz Research Cluster ‘Infections’, with health authorities on the Philippines and on Cape Verde, where air pollution from industrial and natural sources provides major health problems. Especially the role of the aerosol path in the spread of the Corona virus has gained recent attention at TROPOS and will be further investigated by means of laboratory studies together with the UKL. Additional cooperation with the UKL and the "Leipzig cohort" is in the planning phase. Together with the UFZ and UKL, TROPOS is trying to establish a new research field on environmental stressors and social behavior.

The evaluation report encourages TROPOS to approach institutions such as *Deutscher Wetterdienst (DWD),* for partnerships. Besides a number of very successful joint projects, a formal cooperation agreement with the DWD has been established in January 2020 along five specific research topics in order to establish joint field campaigns and to support the operational weather forecast by means of parameterization development and evaluation.

The cooperation between TROPOS and DWD is expected to further expand in the future, also in the framework of ACTRIS.

Concerning the scientific departments, TROPOS very much appreciates the overall very positive assessment of the scientific developments and achievements. We would like to address the following more critical evaluation remarks.

The report further encourages ACD to ensure that its model developments are compatible with overarching model frameworks. We believe that CAPRAM has been strategically developed since its start along this goal, and will clearly continue to be further developed in a thoughtful manner considering integration and international demands.

We appreciate that the evaluation board recognizes the potential in the Modelling Department in investigating the role of aerosol sources on the global aerosol distribution and climate interaction. Here, the department will continue to develop a unique profile. The evaluation board further suggests a more strategic approach given the rapid development of high-resolution atmospheric models and the new opportunities around ICON. Indeed, ICON has been integrated as the central atmospheric driver for future model developments at TROPOS, including its multiscale capabilities. Along this development, cooperation with MPI for Meteorology and KIT have been established, already, and are expected to increase in the future.

We fully agree with the report statement that the cooperation of the Remote Sensing Department with the Department "Experimental Aerosol and Cloud Microphysics" on the topic of aerosol-cloud interaction offers significant potential. Both departments are working closely together in recent and in the planning of future joint field campaigns on closure studies for cloud-condensation and ice-nucleating particles from remote sensing and in-situ measurements. The development of air-borne in-situ and near-range remote sensing will further intensify this cooperation.