

**2006-2009 Final Report
International Global Atmospheric Chemistry (IGAC) Project
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PARTICIPANTS

Tim Bates at NOAA-PMEL is the P.I. on this grant and acted in an advisory role to IGAC for its duration. Sarah Doherty, IGAC Executive Officer, is the primary participant on this project, working 75-100% time on IGAC activities over the past three years. Some support is provided by an administrative staff at NOAA-PMEL (~10% time) and a graphic designer at the University of Washington Dept. of Atmospheric Sciences works (as needed for IGAC newsletter layout).

While these are the people whose pay is covered under this grant there is much wider body of participants in the IGAC project. The project activities are guided and, in many cases, implemented by the IGAC Scientific Steering Committee, which acts on a volunteer basis. (See table below for a list of IGAC SSC members in 2006-2009).

IGAC Scientific Steering Committee Membership, 2006-2009

Name	Country	Years	Expertise
Gufran Beig	India	2008-present	Urban air pollution, chemical transport modeling, middle atmosphere trends
John Burrows	Germany	2003-2007	Remote sensing, air quality, photochemistry
Jen-Ping Chen	China-Taipei	2006-present	Aerosol physics & aerosol-cloud interactions
Jim Drummond	Canada	2008-present	Ground-, aircraft-, balloon- & satellite-based remote sensing; radiative transfer
Nikolai Elansky	Russia	2006-present	Field measurements, trace species, toxins
Maria Cristina Facchini	Italy	2008-present	Chemical processes in multiphase atmospheric systems (aerosols and clouds); organic aerosols & CCN
Graham Feingold	USA	2008-present	Aerosols-cloud interactions; field measurements
Sandro Fuzzi (co-chair 2003-2006)		2003-2006	Organic aerosol (bio- & marine), aerosol-cloud interactions
Laura Gallardo-Klenner	Chile	2003-2008	Inverse modeling, air quality, UT/LS, aerosol-cloud interactions
Allen Goldstein	USA	2009-present	in-situ observations; organic gases and aerosols; biosphere-atmosphere fluxes of reactive trace gases
David Griffith	Australia	2007-present	Gas phase species, remote sensing, FTIR spectroscopy, isotopic fractionation

Achuthan Jayaraman	India	2003-2007	Aerosols, modeling, field measurements, air quality
Maria Kanakidou	Greece	2006-present	Gas-particle interactions, modeling, atmos. oxidizing capacity
Abdourahamane Konare	Côte d'Ivoire	2008-present	Aerosols & climate; interfacing measurements & modeling; emissions inventories
Yutaka Kondo	Japan	2007-present	Air quality, trace gases, ozone, field measurements, remote sensing
Kathy Law (co-chair 2007-present)	U.K.	2003-present	Photochemistry, UTLS, integration of field measurements/modeling
Karla Longo	Brazil	2009-present	Model development; biomass burning; emissions; chemical processes
David Lowe	New Zealand	2003-2006	Photochemistry, trace gases, atmos oxidizing capacity
Celine Mari	France	2007-present	Mesoscale modeling, atmospheric chemistry and dynamics interactions
Randall Martin	Canada	2005-2007	Remote sensing, air quality, photochemistry
Olga Mayol-Bracero	Puerto Rico	2009-present	Organics; field measurements; dust; black carbon
Paul Monks	U.K.	2008-present	Satellite observations, field measurements, photochemistry, chemical kinetics
David Parrish	USA	2003-2007	Photochemistry, trace gases, field measurements
Kobus Pienaar	South Africa	2009-present	In-situ observations of deposition; biosphere-atmosphere interactions
Stuart Piketh	South Africa	2005-2008	Biosphere-atmosphere interactions, aerosol-cloud interactions
Graciela Raga	Mexico	2005-2008	Air quality, modeling, aerosol-cloud interactions
Philip Rasch (co-chair 2005-2008)	USA	2003-present	Modeling aerosols, aerosol-cloud interactions, UTLS
Eric Wolff	U.K.	2003-2007	Photochemistry, air-ice chemical interactions, paleo
Tong Zhu (co-chair 2009-present))	China-Beijing	2007-present	Air quality, kinetics, biosphere-atmosphere exchanges

ACTIVITIES AND FINDINGS

Implementation of the IGAC project science plan is via four main pathways:

1) Tasks – Research activities with a specific set of scientific goals that are achievable in a 3-4 year timeframe, with requirements around data accessibility, data QA/QC, multi-national inclusion, and capacity-building components. Tasks are proposed to and endorsed by the IGAC SSC and are reviewed annually and on an as-needed basis.

2) Workshops – IGAC will co-sponsor (e.g. by providing organizational and/or financial assistance) focused workshops on specialty topics. In most cases, there is a requirement that these workshops be structured to produce a tangible outcome, such as journal publication(s) or research plan(s).

3) Initiatives – This implementation mechanism is new to IGAC in 2006. Here the SSC identifies areas in atmospheric chemistry that are in need of attention but which are not currently

being addressed by the community. The idea is to try to use a “top-down” approach to initiating an activity which, in the end, will require engagement by the research community.

4) Communications/Networking – This covers a myriad of activities, including biennial conferences, a newsletter (mailed to ~3500 researchers around the world), our web page, and miscellaneous networking activities conducted throughout the year.

Initiatives

Atmospheric Chemistry & Climate (AC&C)

AC&C is a joint activity of IGAC and WCRP’s SPARC project with the goal of improving understanding of chemistry-climate interactions for improved prediction of climate and air quality. It was first proposed as such at the joint IGBP/WCRP Steering Committee meeting in 2006 and has since been developed into specific plans through a series of planning workshops. In its first phase, AC&C includes a set of activities aimed at improving the representation of chemistry-climate interactions/processes in models and (new as of early 2009) a parallel effort to produce a report “Bounding the Role of Black Carbon in Climate”. We expect the outcomes of AC&C to constitute an important contribution to the next IPCC Assessment (AR5), with contributions also to the next WMO Ozone Assessment.

Following are the three modeling activities developed under AC&C through a series of workshops (see below) and interim discussions.

Decadal (1980-2009) Hindcast

Four separate hindcasts are planned:

- ~ Inert tracers (CFCs and N₂O): To quantify the importance of changing emissions, tropospheric meteorology and stratosphere-troposphere exchange variability
- ~ Aerosols: To test models’ accuracy in reproducing observed past trends in concentrations, chemical composition, optical properties, and aerosol optical depth; to study the effects of trends in emissions; and to understand the impact on aerosol trends of changing meteorology (& natural emissions) vs. changing anthropogenic emissions.
- ~ Tropospheric Ozone: To understand the effect of large changes over the last few decades in stratosphere-troposphere exchange, emissions, and climate.
- ~ Methane: To try and match observed trends and variability and quantify the importance of changing anthropogenic and natural emissions and OH variations.

Activity on Vertical Distributions

There are particularly large uncertainties in modeled distributions of trace species in the upper troposphere, even when the same emissions are used. Species at these altitudes are radiatively important, and aerosols that make it to these high altitudes will have a longer lifetime and therefore a large integrated impact. The initial set of model runs for this activity are designed to understand convection and scavenging processes, as these are among the most uncertain and largest “knobs” in the models affecting distributions in the upper troposphere.

Scenarios Activity

A set of “New Scenarios” of emissions Representative Concentration Pathways (RCPs) are being prepared for the next IPCC assessment. This activity will provide well-evaluated distributions of chemically-active trace species for use in models. This activity will also include an Atmospheric Chemistry & Climate Model Intercomparison Project (ACC-MIP) to complement the CMIP portion of the IPCC AR5 simulations. This activity would include diagnostics from the CMIP5 simulations and from additional runs of the composition-climate models, archiving more detailed data on the processes governing the behavior of gas-phase and aerosol species. Additional specific time-slice experiments are also being designed to enable the use and participation of chemistry-transport models.

Representatives from AC&C have been working with the groups generating the Representative Concentration Pathways (RCPs) that will be used in IPCC AR5 and with the

AIMES GEIA project, to assure that the AC&C model runs use emissions data sets that are coordinated with those for the long-lived greenhouse gases in AR5, and that they are internally consistent. This has constituted a major effort that will be extremely valuable going into AR5.

Report on "Bounding the role of Black Carbon in Climate"

A new effort under AC&C, started in early 2009, is to produce a report by July 2010 on black carbon and climate. The goal is to summarize the state of the science of black carbon aerosol as a climate-forcing agent and, specifically, the implications for mitigation decisions. This initiative began in response to a persistent call for such a published summary both from the science community and from policymakers and non-governmental organizations (NGOs) who are interested in the possibility of reducing anthropogenic climate forcing in the near-term (10-20 yrs) by addressing aerosol emissions.

The paper is expected to address:

- emission inventories by sector, with uncertainties;
- estimates of black carbon forcing, including choices of forcing metric;
- IPCC AR4 black-carbon forcing estimates and needed modifications to these estimates, including resolution of model differences when possible;
- extent to which model-derived concentrations and forcing are supported or challenged by observations;
- relationship between decreases in black-carbon-rich sources and decreases in associated radiative forcing;
- effect of co-emitted species (e.g., sulfate and organic carbon) on net radiative forcing from specific sources;
- cloud changes attributable to black carbon, presently known as aerosol direct, indirect and semi-direct forcing;
- radiative forcing of black carbon deposition on snow (i.e., albedo reduction).

The paper is also expected to briefly address issues around the feasibility of mitigating global black carbon sources – particularly in developing countries.

Lead authors for the paper are now confirmed and in a first teleconference in June, 2009 a draft outline of the paper was discussed. A first meeting of lead authors is planned for September, 2009 at NOAA in Boulder, Colorado and a second meeting in January 2010 (dates/location TBD).

Aerosols, Clouds, Precipitation & Climate (ACPC)

IGBP's iLEAPS (Integrated Land-Ecosystem Atmosphere Process Study) project, IGAC and the WCRP GEWEX (Global Energy and Water Experiment) project are jointly leading this effort which was first proposed at the joint IGBP/WCRP Steering Committee meeting in 2006. It aims specifically to address the impact of anthropogenic aerosols on precipitation processes. The first ACPC workshop was held in October 2007 in Boulder, Colorado. There it was decided that an ACPC Science Plan and Implementation Strategy would be formulated by a Steering Committee with 2-3 members each from iLEAPS, IGAC and GEWEX. Over the past year, the SP&IS was refined through a series of meetings of the ACPC Steering Committee members, taking place January, 2008, October, 2008 and April 2009 in Bern, Switzerland. The ACPC SP&IS was distributed for external review by members of the community in April 2009 and we are awaiting these reviews. The SP&IS will go through final revisions in July/August 2009 and will be submitted to the iLEAPS, IGAC and GEWEX Steering Committees thereafter, followed by an effort to secure funding for the research delineated therein.

Mega-cities Assessment

A new effort in 2008-9 is an initiative to produce an assessment report on the role of Mega-cities in atmospheric chemistry. In the context of IGAC, Mega-cities effectively act as large point

sources of anthropogenic emissions, with emissions type varying significantly depending on, e.g., the level of economic development, local regulations, weather/climate-driven energy demands, and the level of industrial vs. agricultural vs. domestic activity within the urban area. Their impact at the regional to global-scale on air quality and climate in turn depend not only on the type and magnitude of their emissions but the local geography and meteorology.

Both intensive studies of specific mega-cities (Mexico City, Los Angeles, Beijing, and others) and long-term monitoring have provided new understanding of the role of mega-cities in climate and air quality. The IGAC Mega-cities Assessment effort aims to collate the key findings about the atmospheric chemistry in specific mega-cities around the globe; point out where additional studies are needed; compare and contrast atmospheric chemistry in different types of mega-cities (e.g. Los Angeles in the 1970's vs. Los Angeles present-day vs. Beijing present-day); elucidate how lessons learned in carefully studied mega-cities might translate to other less-studied mega-cities; and provide an integrated view and synthesis of the role of mega-cities in regional to global air quality and climate.

Lead authors for the report have been identified and a first meeting was held in Beijing in May, 2009 to finalize the paper outline, identify additional authors, and finalize the structure of specific chapters. Drafts of some sections of the report have been written, others are in progress, and a second meeting is planned for November, 2009. We expect to have a final report (the form of which is still being decided) and Executive Summary ready for publication by July, 2010.

Mega-cities and Coastal Zone IGBP “Fast Track Initiative”

“Mega-cities and Coastal Zones” was selected as an IGBP “Fast Track Initiative” at their April 2009 Scientific Steering Committee meeting. It is being led by IGAC and the IGBP projects SOLAS (Surface Ocean Lower Atmosphere Study) and LOICZ (Land Ocean Interactions in the Coast Zone). FTIs are intended to be focused ~3-year efforts with concrete products, and IGBP provides some financial support for the FTI workshops.

Motivating this FTI is that many of the world's mega cities are situated adjacent to the coastal zone. They are inevitably large sources of emissions to the atmosphere and the oceans. The key issue to be addressed under this activity is whether the juxtaposition of large-scale urban emissions adjacent to a coastal environment results in specific, significant, complex and interlinked environmental problems of urban/regional air quality and sustainability of the coastal environment. For example, recent studies have shown that the interaction of halogens released from seasalt can alter photochemical ozone cycling. In turn, the cocktail of emissions from concentrated urban areas most certainly affect near-shore marine productivity, e.g. through the deposition of nitrogen and trace toxins.

The overarching scientific questions to be addressed under this initiative are:

- How do air-sea interactions (such as trace gas emissions and seasalt aerosol formation) within the coastal zone affect air pollution within and around mega cities?
- How do the interactions of large urban emissions and the marine boundary layer affect local climate?
- How do atmospheric deposition of both contaminants and nutrients from megacities affect the productivity of adjacent coastal waters?

There are of course also feedbacks between these issues such as changes in marine trace gas emissions due to changes in marine productivity which will also be addressed.

This initiative is just now in the planning stages, with the first workshop expected in February 2010 and a journal publication planned for late Spring/early Summer 2010.

IGAC Conferences & Workshops 2006-2009

IGAC contributes to the advancement of atmospheric chemistry and builds scientific capacity amongst young and developing country scientists by organizing and providing travel support for workshops and our biennial conference.

Travel costs for liaison activities were also covered with funds from this grant, allowing either an IGAC SSC member or the IGAC Executive Officer to attend the steering committee meetings of related projects (e.g. IGBP's iLEAPS, SOLAS, and AIMES Projects and WCRP's SPARC Project). We continue to consider such liaison travel to be critical to IGAC's goal of advancing atmospheric chemistry research within the context of the Earth system.

Following are the workshops and conferences organized or co-sponsored by IGAC under this grant:

> SPARC/GEWEX-GCSS/IGAC Workshop: Modelling of Deep Convection and of Chemistry and their Roles in the Tropical Tropopause Layer, June 12-15, 2006, Victoria, BC, Canada

> 9th IGAC Conference (joint with CACGP & WMO), 17-22 Sept. 2006, Cape Town, South Africa

- Theme: "Chemistry at the Interfaces"
- 410 participants; funding support to 77 young scientists (student or w/in 5 years of PhD) with funding from NASA, NSF, NOAA, ACCENT, WMO, CACGP & Seattle IPO.
- Special Young Scientists' Programme, including early ice-breaker, career center, and Young Scientists' Poster Contest.
- 4 winners of YS Poster Contest published articles based on their posters in the July, 2007 issue of IGAC Newsletter (*IGACtivities* No. 36).

> IGAC/SPARC Atmospheric Chemistry & Climate (AC&C) Initiative Scoping Meeting, August 7-9 2006, Boulder, Colorado, USA

> SPARC/IGAC Session: Atmospheric Chemistry & Climate, ESSP OSC, November 9-12, 2006, Beijing, China

> IGAC/SPARC Atmospheric Chemistry & Climate (AC&C) Initiative 1st Workshop, January 22-23, 2007, Geneva, Switzerland

> IGAC Halogens in the Troposphere (HitT) Task planning meeting, April 21, 2007, Vienna, Austria

> IGAC POLARCAT Task Planning Meeting, June 4-6, 2007, Paris, France

> IGAC/iLEAPS/GEWEX Aerosols, Clouds, Precipitation & Climate (ACPC) Initiative 1st planning meeting, October 8-10, 2007, Boulder, Colorado, USA

> IGAC/iLEAPS/GEWEX Aerosols, Clouds, Precipitation & Climate (ACPC) Initiative 2nd planning meeting, January 28-30, 2008, Bern, Switzerland

> POLARCAT/IGAC specialty workshop on "Short-lived Species and Arctic Climate" (SPARC) Workshop, November 5-8, 2007, Oslo, Norway

> Planning meeting for the IGAC AMMA-AC Task (African Monsoon Multidisciplinary Analysis – Atmospheric Chemistry), 26-30 November 2007, Karlsruhe, Germany

> IGAC/SPARC Atmospheric Chemistry and Climate session at the American Geophysical Union meeting, 11-14 December 2007, San Francisco, California

> Session organized by the Mega-cities: Asia Task Team: 7th International Symposium on Advanced Environmental Monitoring organized by the ADvanced Environmental Monitoring and

Research Center (ADEMRC), Gwangju Institute of Science and Technology (GIST), Korea, 25-28 February 2008, Honolulu, Hawaii

> IGAC HitT Task Special Session on Tropospheric Halogens, European Geophysical Union (EGU) conference, 13-18 April 2008, Vienna, Austria

> IGAC/SPARC Atmospheric Chemistry & Climate (AC&C) Initiative 3rd planning workshop, 9-14 June 2008, Washington, D.C.

> HitT/AICI/SPARC/IGAC workshop on lab studies/kinetics, 16-18 June 2008, Cambridge, U.K.

> 10th IGAC Conference, 7-12 Sept. 2008, Annecy France

- Theme: "Bridging the Scales in Atmospheric Chemistry: Local to Global"
- Special joint sessions with WCRP-SPARC & joint reduced registration fees. ~30 participants attend both conferences.
- 525 participants; funding support to 63 young scientists (student or w/in 5 years of PhD) with funding from NASA, NSF, NOAA, ACCENT, WMO, ESA & Seattle IPO.
- Free real-time web-casting of plenary sessions + all talks posted to web
- Special Young Scientists' Programme, including early ice-breaker, career center, and Young Scientists' Poster Contest.
- 3 winners of YS Poster Contest published articles based on their posters in the January, 2009 issue of IGAC Newsletter (*IGACtivities* No. 40).

> Aerosols, Clouds, Precipitation & Climate (ACPC) planning meeting, 7-9 October 2008, Bern, Switzerland

> Special session on "Black Carbon: Air Quality and Climate Change" organized by Mega-cities: Asia Task Team, Better Air Quality (BAQ) Workshop, 12-14 November 2008, Bangkok, Thailand

> IGAC Halogens in the Troposphere (HitT) session, American Geophysical Union (EGU) conference, 15-19 December 2008, San Francisco, California

> European Geophysical Union (EGU) conference, 19-24 April 2009, Vienna, Austria

- IGAC/SOLAS AICI Task session "Boundary layers in high latitudes"
- IGAC/SOLAS HitT Task session "Atmospheric halogenated compounds and their chemical transformations"

> IGAC/POLARCAT Special workshop with policymakers on "Short-lived Pollutants and Arctic Climate" at POLARCAT data workshop, 4-6 June, 2009, Durham, New Hampshire, USA

IGAC SSC meetings

An effort has been made in the past three years to make the annual IGAC Scientific Steering Committee meeting more dynamic and participatory by soliciting the SSC more actively for new ideas. The result has been the start-up of many of the new activities listed above. Wherever possible, the SSC meeting includes the participation of local scientists and scientists from partner projects/programs. While IGBP provides some funds to cover the SSC meeting costs, this grant and funds from the European ACCENT project cover partial costs for every year's SSC meeting.

> 15-17 September 2006, Cape Town, South Africa
The SSC meeting was held in conjunction with the IGAC biennial Conference.

> 3-6 September, 2007, Leavenworth, Washington
Hosted by the IGAC Core Project Office, Seattle

> 5-9 May 2008, Cape Town, South Africa

The SSC meeting was held during the IGBP Congress, which included special sessions organized by IGAC on Mega-cities, Emissions, Lab Studies, and Atmospheric Chemistry and Climate.

2. Findings

Tasks

Activities within IGAC Tasks continued in 2006-09 to enrich our understanding of atmospheric chemistry in the Earth system. Following are brief summaries of the activities under IGAC Tasks during mid 2006 to 2009:

ITCT-2k4 Task (Intercontinental Transport and Chemical Transformation – 2004)

The major aims of the ITCT-2k4 Task were to investigate the oxidant and aerosol formation potentials (relative to dynamical processes) in plumes originating from anthropogenic and natural sources in order to quantify net pollutant export out of North America and pollutant import into regions downwind such as Europe. The organization and realization of ITCT-Lagrangian-2K4 comprised three steps: a review of previous results, instrument comparison activities (to ensure that measurements on the disparate platforms could be accurately integrated without confounding measurement uncertainties) and flight coordination during the field deployment. This plan required the close coordination of four aircraft deployed in North America (the NOAA WP-3D and the NASA DC-8), in the mid North Atlantic (the BAe-146) and in Europe (the DLR Falcon). In addition, data from the NOAA Ozone Lidar aircraft, the PICO-NARE surface site, MOZAIC measurements on commercial aircraft, from the European lidar network, and European surface sites were integrated into the analyses. Each of these platforms had its own regionally focused goals, but together they provided coverage during the complete transit of a polluted air mass across the North Atlantic.

The heart of this Task was a field campaign that took place in 2004. This Task was endorsed in 2003 and concluded in 2007 with the publication of papers in a special issue of the *Journal of Geophysical Research* which is devoted to the larger ICARTT program, of which the ITCT Lagrangian 2k4 Task is a part. The ITCT-2k4 articles are as follows:

- Arnold, S. R., et al., Statistical inference of OH concentrations and air mass dilution rates from successive observations of nonmethane hydrocarbons in single air masses, *J. Geophys. Res.*, **112**, D10S40, doi:10.1029/2006JD007594, 2007.
- Bousserrez, N., et al., Evaluation of the MOCAGE chemistry transport model during the ICARTT/ITOP experiment, *J. Geophys. Res.*, **112**, D10S42, doi:10.1029/2006JD007595, 2007.
- Cook, P. A., et al., Forest fire plumes over the North Atlantic: p-TOMCAT model simulations with aircraft and satellite measurements from the ITOP/ICARTT campaign, *J. Geophys. Res.*, **112**, D10S43, doi:10.1029/2006JD007563, 2007.
- Fehsenfeld, F. C., et al., International Consortium for Atmospheric Research on Transport and Transformation (ICARTT): North America to Europe—Overview of the 2004 summer field study, *J. Geophys. Res.*, **111**, D23S01, doi:10.1029/2006JD007829, 2006.
- Lewis, A. C., et al., Chemical composition observed over the mid-Atlantic and the detection of pollution signatures far from source regions, *J. Geophys. Res.*, **112**, D10S39, doi:10.1029/2006JD007584, 2007.
- Methven, J., et al., Establishing Lagrangian connections between observations within air masses crossing the Atlantic during the International Consortium for Atmospheric Research on Transport and Transformation experiment, *J. Geophys. Res.*, **111**, D23S62, doi:10.1029/2006JD007540, 2006.
- Ravetta F., G. Ancellet, A. Colette, H. Schlager, Long-range transport and tropospheric ozone variability in the western Mediterranean region during the Intercontinental Transport

of Ozone and Precursors (ITOP-2004) campaign, *J. Geophys. Res.*, **112**, D10S46, doi:10.1029/2006JD007724, 2007.

- Real E., et al., Processes influencing ozone levels in Alaskan forest fire plumes during long-range transport over the North Atlantic, *J. Geophys. Res.*, **112**, D10S41, doi:10.1029/2006JD007576, 2007.
- Reeves C. E., et al., Alkyl nitrates in outflow from North America over the North Atlantic during Intercontinental Transport of Ozone and Precursors 2004, *J. Geophys. Res.*, **112**, D10S37, doi:10.1029/2006JD007567, 2007.

IGAC/SOLAS Air Ice Chemical Interactions Task (AICI):

The AICI Task was endorsed in 2003, and finished its first phase in 2007. The task commenced in 2006 with several important field campaigns, the results of which were synthesized via a series of IGAC-sponsored workshops (see “Activities” section). The AICI Task Team played an important coordinating role for atmospheric chemistry within the International Polar Year (IPY). Phase I of AICI concluded with publication of a Special Issue of *Atmospheric Chemistry and Physics*. The Task has now continued into Phase II as “AICI-IPY” with a new set of objectives determined by the outcomes of Phase I.

Under AICI-IPY, the Task leads will maintain communication between all those producing new AICI data under AICI-IPY; to further entrain (through communication, workshops and special sessions) laboratory, remote sensing and modeling teams, to study these problems; and to organize, along with POLARCAT and OASIS, a major post-IPY workshop to again review our knowledge, and to provide a tangible deliverable from AICI-II which would highlight, and provide a record of, the AICI component of IPY.

The five AICI papers published in *Atmospheric Chemistry and Physics*, (http://www.atmos-chem-phys.net/special_issue80.html) are:

- Grannas, A.M. et al., An overview of snow photochemistry: evidence, mechanisms and impacts, *Atmos. Chem. Phys.*, **7**, 4329-4373, 2007.
- Domine, F. et al., Snow physics as relevant to snow photochemistry, *Atmos. Chem. Phys.*, **8**, 171-208, 2008.
- Anderson, P. S. and W. D. Neff, Boundary layer physics over snow and ice, *Atmos. Chem. Phys.*, **8**, 3563–3582, 2008, *Atmos. Chem. Phys.*, **8**, 4115-4115, 2008.
- Simpson, W. R. et al., Halogens and their role in polar boundary-layer ozone depletion, *Atmos. Chem. Phys.*, **7**, 4375-4418, 2007.
- Steffen, A. et al., A synthesis of atmospheric mercury depletion event chemistry in the atmosphere and snow, *Atmos. Chem. Phys.*, **8**, 1445-1482, 2008.

African Monsoon Multidisciplinary Analysis – Atmospheric Chemistry (AMMA-AC) Task

AMMA-AC is a component of the larger AMMA project. AMMA (the African Monsoon Multidisciplinary Analysis) is an international integrated multidisciplinary project that aims at addressing both fundamental scientific questions related to the understanding of the West African Monsoon (WAM) variability and the impacts and practical issues related to prediction and decision-making activity. The IGAC Task AMMA-AC specifically addresses the atmospheric chemistry component of AMMA. 2006 was a key year for AMMA, with the organization of four airborne campaigns during the dry and wet seasons. Five aircraft were deployed during the wet season and one during the dry season, plus intensive measurements were made at ground sites throughout the region. Measurements, data analysis, synthesis and manuscript preparation continue to present day.

The size, comprehensiveness (crossing many scientific disciplines as well as the human dimension) and many institutional players involved in AMMA make it difficult to isolate the IGAC AMMA-AC Task contributions specifically. IGAC SSC member Céline Mari is one of the lead organizers of the atmospheric chemistry studies within AMMA, and IGAC has helped co-sponsor several AMMA-AC workshops, in particular supporting the attendance of African scientists. We have received very positive feedback from the AMMA Task team that IGAC's support of these scientists has been critical to the mission's success, as well as to building scientific capacity in West African nations.

In 2008 there were many publications and findings from the AMMA study. A Special Issue of the *Journal of Geophysical Research - Atmospheres* covered the AMMA dry season Special Operation Period (SOP0), the focus of which was aerosol and radiation measurements. (African Monsoon Multidisciplinary Analysis Special Observation Period 0: The Dust and Biomass-Burning Experiment (DABEX), *J. Geophys. Res.*, 113 (D23), 2008). A Special Issue of Atmospheric Chemistry and Physics (ACP) is in processes, currently as 15 articles in review under ACPD.

Scientific highlights from AMMA-AC:

- little evidence of SOA formation even through high isoprene
- MCS are efficient for the wet removal of aerosol particles and create favorable conditions for nucleation of new particles
- fresh MCS outflows were sampled (lightning NO_x, burst of nucleation)
- aged outflow (aging of air masses in relation with long-range transport)
- several golden days for MCS identified (coordinated flights 5-6-7 August, 11 August, 14-15 August, ...)
- urban survey revealed gaps in the current emissions inventories with missing anthropogenic sources (aircraft measurements + ground-based measurements)
- several occurrences of intrusions of biomass burning plumes from the southern hemisphere (predicted by forecasts, observed by aircrafts, satellites and ozonesoundings)
- evidences of transport of biomass burning emissions in the TTL region
- nocturnal advection of vegetation products (isoprene) observed by the UK-BAe146.
- evidences of NO_x emissions by soil
- ozone minimum observed by the MOZAIC aircrafts above the ITCZ (daily flights between Windhoek and Frankfurt AIR NAMIBIA)

Polar Study using Aircraft, Remote Sensing, Surface Measurements and Models, of Climate, Chemistry, Aerosols, and Transport (POLARCAT) Task

The field campaigns for POLARCAT began in March 2007 and culminated with intensive measurement campaigns in Spring and Summer 2008 (all in the Arctic region). Data from these campaigns is still being analyzed and synthesized, so it is too early for a balanced report on the scientific results obtained during the various campaigns but a few publications on the first results have already appeared. However, in an initial data workshop (June, 2009, New Hampshire, USA; see above) several things became clear: There is a distinct separation between pollutants aloft and those in the boundary layer. Pollution aloft is highly aged and is characterized by a "background" level of aerosol/ozon/CO, with periodic events which lead to higher levels of aerosols and ozone, characterized by a higher organic fraction (aerosols) than the background aerosol. The high organic-to-black carbon fraction (OC:BC) indicates that these events are dominated by biomass burning emissions. The boundary layer appears to be characterized by lower concentrations of aerosol that are more influenced by anthropogenic pollution than the aerosol in the free troposphere. It is not clear to what extent pollutants in the free troposphere are mixed down into the boundary layer. At least during the period of the field measurements, it appears that biomass burning plays a large role in generation of the Arctic Haze. Important open questions remain, e.g. about the representativeness of the field measurements; sources of pollution to the eastern vs. western Arctic; transport processes; the fraction of biomass burning emissions which are "natural" vs. "anthropogenic", and the fraction which are due to agricultural vs. forest burning.

As with AMMA, the POLARCAT project is sponsored/supported by many agencies, and IGAC's role has been to add value to the standing activity. As an IGAC-endorsed Task, POLARCAT workshops have benefited from travel support from the IGAC Core Project Office for young scientists. In addition, we have helped organize and provide funding support for a series of specialty workshops associated with POLARCAT, on "Short Lived Pollutants and Arctic Climate" (SPAC). The SPAC workshops have focused on the role of black carbon, ozone and methane on Arctic warming and have included discussions between scientists and liaisons to the policy-making community (e.g. from government agencies and non-governmental organizations). As there is now serious consideration at both the national (e.g. passage by the U.S. House of Representatives of the ACES/Waxman-Markey bill) and international level (e.g. advisory statements emerging from the 2009 Arctic Council meeting) to mitigate global warming by reducing black carbon, ozone and methane in the Arctic, it is important that the policy-making community be well informed as to the status of scientific knowledge on this topic, and IGAC has and will continue to play a critical role in this regard. (See also the AC&C activity on Bounding the Role of Black Carbon in Climate).

Deposition of Biogeochemically Important Trace Species (DEBITS) Task

DEBITS is a long-standing program of IGAC. In 2003, it entered its second phase, with a new emphasis on:

- determining, at the regional scale and mainly through measurements, the atmospheric removal rates via dry and wet deposition of biogeochemically important trace species;
- working out atmospheric budgets of key elements (S, N, Ca, Cl-) at the regional scale;
- establishing the chemical and physical factors that regulate these deposition fluxes and to identify parameters to be included into regional and global atmospheric chemistry models.

The role of the DEBITS task is to coordinate measurements and synthesize data from three measurement campaigns: LBA (eastern South America; esp. the Amazon); IDAF (IGAC DEBITS Africa); and DEBITS Asia (CAAP, "Composition and Acidity of Asian Precipitation" and CAD, "Composition of Asian Deposition").

For 2006-2009, measurements continued in these three DEBITS research networks. A DEBITS workshop was held in South Africa in September, 2006, in coordination with the IGAC Open Science Conference, and there results from the three networks was shared.

- As an example of DEBITS science, the following are results from the IDAF network (IGAC DEBITS in Africa):
 - Martins, J.J. et al., Long-term measurements of sulphur dioxide, nitrogen dioxide, ammonia, nitric acid and ozone in southern Africa using passive samplers, *S. African J. Sci.*, **103**, 336-342, 2007.
 - Spatial distribution of pollutants in southern Africa indicate strong anthropogenic contributions on the Mpumalanga Highveld.
 - Long term annual trends in pollutant concentrations decreased 1994 to 2004, after which a steady increase is observed. (This may be linked to the energy crisis in South Africa)
 - Seasonal trends in pollutant concentrations show maxima during winter time mainly due to increase energy use and biomass burning.
 - Galy-Lacaux, C. et al., Long Term Precipitation Chemistry and Wet Deposition in a Remote Dry Savanna Site in Africa (Niger), *Atmos. Chem. Phys.*, **9**, 1579-1595, 2008.
 - Long term monitoring of wet deposition in a dry savanna of Niger
 - Characterization, interannual and seasonal variation of deposition fluxes
 - Interpretation and relation to main sources of atmospheric gases and particles
 - Adon, M. et al., Long term measurements of nitrogen dioxide, ammonia, nitric acid in Africa using passive samplers, *Atmos. Chem. Phys. Disc.*, submitted 2009.
 - Characterization and quantification of gases concentrations

- Quantification of levels in non perturbed sites of west central African sites representative of dry and wet savannas and forested ecosystems
- Internnual and seasonal variations according variations of climatological parameters and emission sources
- Focus on nitrogenous gases: Zoom on the sahelian dry savanna ecosystems (Mali and Niger), experimental and modeling approach of nitrogenous gases emissions from soils.
- Liousse, C. et al., African Aerosols Modeling during the EOP-AMMA campaign with updated biomass burning emission inventories, *Atmos. Chem. Phys. Disc.*, submitted 2009.
 - Major trends observed during AMMA/IDAF programs over Africa using both surface, vertical measurements and satellite data are well reproduced by the ORISAM/TM4 global model associated with the updated AMMA biomass burning emissions.
 - Seasonal variations of modeled and measured BC concentrations at Djougou (Benin), Lamto (Côte d'Ivoire) and Banizoumbou (Niger) sites.
 - Comparisons between modeled and observed size resolved (PM25 and PM10) atmospheric concentrations of mineral and organic species over Djougou (Benin, Western Africa) and Amersfoot (South Africa, PhD JJ. Martins) for intensive and extensive periods of measurement. Chemical speciation of rain obtained at Lamto (Ivory Coast) is well reproduced by the model.
- Liousse C. and C. Galy-Lacaux, Urban Pollution in Western Africa, submitted to IGBP letter, December 2008.
 - Recent measurements of gas and particle atmospheric concentrations in a few capitals of Western Africa in the frame of IDAF, AMMA and POLCA programs have shown unexpected levels of pollution which are much higher than the WMO alert level. For example BC concentrations downtown Bamako are 10 times higher than that measured in Paris.

Mega-cities: Asia Task

Three goals were established for this Task:

- 1) Characterize the temporal and spatial changes of aerosols, oxidants, and their precursors primarily by surface measurements near and downwind of urban centers. Temporal variations include diurnal variation, variations associated with synoptic scale disturbances, and seasonal variation.
- 2) Characterize the composition, mixing state, and physical properties of aerosol in urban air. Determine hygroscopic and radiative properties of aerosol in urban air. These characteristics are important in understanding impact of aerosol on the radiation budget.
- 3) Validate emission inventories of trace gases through comparisons of ratios of concentrations of trace species observed in urban air.

The period of this grant (2006-2009) consisted of major instrument inter-comparison campaigns, a series of intensive field campaigns, and ongoing monitoring. Inter-comparisons of various instruments (to measure O₃, CO, reactive nitrogen, and aerosols) that are being used throughout the Asia region were made in Guangzhou and Beijing in July-August 2006. Through this, methods and accuracies for measurement of aerosols (black carbon, inorganic, organic aerosols, and WSOC) were established for use across all Mega-cities: Asia measurements, allowing for improved individual measurements and making a vast array of measurements across Asia directly intercomparable.

An intensive campaign was conducted in July 2006 in the Pearl River Delta region by a collaborative science team from China (Mainland, Taiwan, Hong Kong), Germany (IFT, MPIC, and KFA), Japan (University of Tokyo, Ibaraki Univ., and NIES), Korea (GIST), and the U. S. (UCI). The objectives of the PRD July intensive campaign were to characterize temporal and spatial changes of aerosol, oxidants, and their precursors; to understand chemical composition, size distribution, hygroscopic properties, and optical properties of aerosols; to quantify ozone

formation by measurements and modelling; and to explore the relationship between species of aerosols and gaseous phase. The CAREBEIJING (Campaigns of Air Quality Research in Beijing) campaign also took place in 2006. This international campaign was conducted in Beijing and surrounding regions with many of the same participating organizations and major instruments that were used for the PRD campaign. This campaign focused on issues of air quality, with an eye toward the 2008 Olympics, held in Beijing. This campaign helped inform decisions which dramatically improved the air quality for the Olympic games. Ongoing measurements also continued in mainland China, China-Taipei, Japan, and Korea, with coordination and data-sharing via a Mega-cities: Asia web page.

In 2008-2009, papers on the two campaigns PRIDE 2006 and CAREBEIJING 2006 conducted in Pearl River Delta and Beijing were prepared /submitted for publication to international journals (JGR, ACP, Science). A number of papers were also published by the Korean and Hong Kong Mega-cities: Asia groups.

While data accessibility continues to be a problem, progress has been made through the efforts of the Task leads. Data now available for public access include: data from the Japanese study (IMPACT); data from the CAREBEIJING air quality study in Beijing; and data from 2 years of measurements in Hong Kong. Plans are in place to also archive and release data from measurements in Taiwan (2002-present).

Extensive ground based campaigns, detailed analyses, and modeling work were completed. Through these efforts, the goals 1) and 2) are being successfully achieved.

Some specific results are given below, as an example.

- From the Japan IMPACT study:
 - Understanding of the diurnal and seasonal variations of different types of PM1 aerosols and their precursor gases have been greatly improved and are interpreted in terms of emissions, formation, and meteorological conditions;
 - Understandings of factors controlling the levels of reactive gases have been improved.
 - Efforts to calculate distributions of different types of aerosol and ozone have been made by using regional scale models. This is an important step to systematically understand chemistry and transport of aerosol and ozone in Tokyo and surrounding regions.
 - Size distribution and mixing state of BC and the rate of coating in the plumes from mega-cities have been elucidated
 - Long-term measurements in BC showed dramatic decrease between 2005 and 2007, mostly likely due to regulation of particulate emissions from diesel vehicles.
- From the CAREBEIJING campaign:
 - Important features and causes of the variability of sub-micron (PM1) aerosol in the Beijing area in summer are now understood (Takegawa et al., JGR in press). This is an important step in understanding of aerosol formation processes in the mega-cities in northeastern China.
 - The important features of the aerosol observed near Beijing in summer are now well reproduced by a 3-D model (Matsui et al., submitted to JGR).
 - The optical properties in the Beijing urban area are determined by in-situ and remote observations.
 - It was demonstrated that spatial and temporal distribution of NO₂ over an urban area can be retrieved using an Imaging DOAS technique.
- From the China, Four-City Study (Hong Kong, Beijing, Shanghai, Lanzhou)
 - A VOC limiting chemistry was identified for producing high ozone (200 ppbv) in southern PRD and in Shanghai, with major contributors being toluene and xylene. NO_x appeared to have played an important role in the formation of very high conc. of ozone (300 ppbv) in downwind rural areas of Beijing;

- New particle formation was observed in relatively polluted air masses in Shanghai and Beijing.
- The investigators are now focusing on the interaction of gas, aerosol and cloud and the impact on regional climate and air quality using mountain-top and aircraft observation platforms.
- China-Taipei ongoing efforts include:
 - Investigating aerosol chemical and physical properties at seven ground stations.
 - Evaluating long-range transport of air pollutants and aerosols.
 - Investigating causes of the increasing ozone trends in Taiwan in the last decade.
 - Studying the heat-island effect over Taiwan's Western Plain.
- Korean ongoing efforts include:
 - Within Korea, this largely comprises monitoring visibility and air pollutant levels. Efforts have gone into making these measurements comparable to those in the other Mega-cities: Asia studies.
 - The Korean investigators also participated in the Pearl River Delta and CAREBEIJING campaigns (see above)
- Thailand
 - This is a new effort within Mega-cities: Asia. EC-OC and CO measurements started in Bangkok in March, 2007, in collaboration with the University of Tokyo, Japan.

The first phase of Mega-cities: Asia concluded in 2007, and a new set of goals were established for Phase II. This second phase of Mega-cities: Asia was endorsed at the 2008 IGAC SSC meeting. In Phase II, the Mega-cities: Asia task team will establish measurements of the outflow from the mega-cities in East Asia, in addition to continuation of Phase-I type studies within the urban areas. Results from Mega-cities Phase-I have allowed quantification of source strengths, understanding of the chemical characteristics in source regions, and understanding of the chemical processes taking place within the mega-cities. The focus of Phase II will be to link this knowledge on emissions and chemistry in the mega-cities to regional-scale air quality and climate. Specific efforts will be made to study the effects of air pollution on cloud formation and to strengthen modeling efforts in this region. This effort will be enhanced through coordination with the Monsoon Asia Integrated Regional Study (MAIRS), which is being implemented by the ESSP-START project.

PUBLICATIONS & PRODUCTS

Current IGAC activities, opportunities and related meetings (as well as general information about the organization) are posted on the IGAC web page (<http://www.igac.noaa.gov>) which is hosted by NOAA-PMEL and maintained by Sarah Doherty, IGAC Executive Officer.

While many peer-reviewed publications result from IGAC Tasks and activities (see "Activities and Findings"), the primary product resulting directly from this grant is the IGAC newsletter, *IGACtivities*. The printing and mailing of the newsletter is taken care of by Academia Sinica in Taipei, but Sarah Doherty (funded under this grant) is fully responsible for planning newsletter issues, recruiting article authors, and editing of the newsletter. A graphic designer at the University of Washington, Dept. of Atmospheric Sciences, is paid under this grant to do article layout.

All past issues of the newsletter (now numbering 41 in total) are downloadable from the IGAC web page (<http://www.igac.noaa.gov/newsletter/index.php>). The following newsletters were produced and were mailed to ~3,500 scientists as well as posted on our web page:

- Issue No. 36 [July, 2007] Articles from CACGP/IGAC/WMO Cape Town Conference poster award winners; Atmospheric Chemistry & Climate Initiative (AC&C); Network for the Detection of Atmos Composition Change (NDACC)

- Issue No. 37 [March, 2007] Special Issue on Satellite Retrievals of Tropospheric Chemistry
- Issue No. 38 [April, 2008] Special Issue on Mega-cities
- Issue No. 39 [September, 2008] Articles on Halogens in the Troposphere; Boundary Layer Processes; Aerosol, Clouds, Precipitation & Climate
- Issue No. 40 [January, 2009] Articles from IGAC Annecy Conference poster award winners; Report from Lab Studies Workshop
- Issue No. 41 [May, 2009] Articles related to the Atmospheric Chemistry and Climate Initiative: AeroCom; Gridded Emissions in Support of IPCC AR5; AC&C Model Intercomparison Project (ACC-MIP)

A further product resulting from this grant was a publication resulting from an invitational workshop held by IGBP, WCRP and GCOS October, 2007 in Sydney, Australia. This workshop included lead authors from IPCC AR4 WG1 and WG2 and other key scientists. The goal of the workshop was to seek recommendations on how these three international programs could address key gaps and uncertainties in research and observations that currently hinder our ability to detect, describe, understand, forecast, mitigate and adapt to human-induced climate change. Sarah Doherty (IGAC Executive Officer) was invited to participate in the meeting in a supporting role and is the lead author on a publication of the meeting outcome which was published in the Bulletin of the American Meteorological Society:

- Doherty, S. J., S. Bojinski, A. Henderson-Sellers, K. Noone, D. Goodrich, N. L. Bindoff, J. A. Church, K. A. Hibbard, T. R. Karl, L. Kajfez-Bogataj, A. H. Lynch, D. E. Parker, I. C. Prentice, V. Ramaswamy, R. W. Saunders, A. J. Simmons, M. Stafford Smith, K. Steffen, T. F. Stocker, P. W. Thorne, K. E. Trenberth, M. M. Verstraete, F. W. Zwiers, Lessons learned from IPCC AR4: Future scientific developments needed to understand, predict and respond to climate change, *Bull. Amer. Met. Soc.*, **90(4)**, 497–513, 2009.

CONTRIBUTIONS

3. Opportunities for training and development

IGAC Workshops, co-sponsored conference sessions and the biennial IGAC conference are all opportunities for training and development, particularly in that we make a point of providing support to young and developing country scientists to attend these meetings. See “Activities” section of the report for specifics on such meetings/workshops/conferences held over the past three years.

4. Outreach activities

IGAC engages the broader community via publication of a scientific newsletter, *IGACtivities*, and through our biennial conferences. *IGACtivities* is primarily comprised of scientific articles, summarizing recent research or the state of knowledge in a given area of atmospheric chemistry, in a way that is somewhat less formal and more accessible to the broader audience than is a journal article. (See “Publications & Products”).

IGAC’s biennial conferences are our primary mechanism for facilitating the dissemination of scientific information across our community. A special effort is made to engage young and developing country scientists in our conferences. Specific activities toward capacity-building include a special Young Scientists’ program at our conferences; providing financial support to young scientists in need to participate in our conferences; and providing funding support to individuals to attend IGAC co-sponsored workshops. Travel support is provided based on an

assessment of both need and merit. For workshops, in many cases key players have been able to attend only with IGAC financial support.

To make the organization's activities as international as possible, the conference location changes from year to year, reaching for broad geographic coverage. Past conferences have been held in Israel, Japan, the U.S., Australia, Italy, Greece, New Zealand, South Africa and France. The IGAC Seattle project office takes an active role in planning the scientific program and the young scientists' program, and other aspects of the meeting organization. Because the conference location (and therefore Local Organizing Committee and Scientific Program Committees) change with each conference, the "institutional memory" provided by the IGAC Core Project Office is of great importance to the success of the conference.

More recently, IGAC has started to also work more closely with the policy-making community. A first concrete step was made in this direction through the Short-lived Pollutants and Arctic Climate (SPAC) workshops (see "Activities" section), where we have actively engaged liaisons with the policy-making community in a discussion about the role of black carbon, ozone and methane in Arctic warming. In addition, we plan to produce "summary for policymaker" documents for three new activities: the Mega-cities Assessment, Mega-cities and Coastal Zones, and the AC&C project on Bounding the Role of Black Carbon in Climate.