Passenger jets collect data for research on climate change and pollution

Next time you settle in for a long flight, consider that instruments for sampling the outside air for atmospheric research may also be on board.

Two air-quality and climate-change research projects in Europe are joining forces, with the aims of securing long-term funding and expanding their data gathering to global coverage. MOZAIC (Measurements of Ozone and Water Vapour by Airbus In-service Aircraft) and CARIBIC (Civil Aircraft for the Regular Investigation of the Atmosphere Based on an Instrument Container) fly instruments on commercial jets to collect air samples and perform in-flight measurements.

Starting in September, the two projects will share management, funding, and data. And while they will maintain separate research thrusts, they will also take on a monitoring role for climate forecasting. A third research effort along the same lines is run out of Japan.

Global access

Since the mid-1990s MOZAIC and CARIBIC—and the predecessor to the current Japanese project, CONTRAIL (Comprehensive Observation Network for Trace Gases by Airliner)—have been hitching rides for their instruments in the cargoes of commercial jets. NASA ran a similar project in the 1970s, and weather services use commercial aircraft to gather pressure, temperature, and wind data, but not generally for research. Among the things the current experiments measure are ozone, water vapor, carbon monoxide, carbon dioxide, reactive nitrogen species, and aerosols. In the case of CONTRAIL, "the main purpose is to understand the global carbon cycle," says the project's coordinator, Toshinobu Machida of Japan's National Institute for Environmental Studies. Data from all three are used in climate-change and pollution studies. Other uses include validating satellite measurements and guiding computer models of various atmospheric chemical and physical processes.

"Wherever we fly, we get information that is otherwise not available," says CARIBIC coordinator Carl Brenninkmeijer of the Max Planck Institute for Chemistry in Mainz, Germany. "It's impossible to get all this information by means of satellite—the resolution is too coarse—or from ground stations." And flying instruments on passenger jets is cheaper and offers more frequent flights and wider global coverage than would be feasible with dedicated research planes.

LUFTHANSA

The air inlet system on the belly of the Lufthansa jet that takes data for CARIBIC is roughly 30 cm tall and has three intake probes, one each for water vapor and ice crystals, trace gases, and aerosols. MOZAIC's instruments, such as this module (below) for measuring nitrogen oxide, fly continuously and are swapped out every six weeks for servicing.

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Commercial airliners cruise at roughly the altitude of the tropopause, which, at 8–16 km depending on latitude and season, is the transition region between the troposphere and the stratosphere. "The tropopause is the barrier for exchange of chemicals such as chlorofluorocarbons, water vapor, and ozone," says Andreas Volz-Thomas, the chemist at Research Center Jülich who is coordinating IAGOS (In-service Aircraft for a Global Observing System), as both the new incarnation of MOZAIC and the umbrella for MOZAIC and CARIBIC are called. "It is the most climate-sensitive region, and changes in its dynamics may well influence ozone at Earth's surface."

With instruments for 15 experiments that sample more than 40 different gases, the CARIBIC cargo weighs 1.5 metric tons. Once a month project members haul it to the Frankfurt airport, where Lufthansa workers install it in an airplane with a built-in air inlet system. When the plane returns—from Toronto; Houston, Texas; Santiago, Chile; Chennai, India; or wherever—"we bring the mobile laboratory back to the institute, like a Trojan horse," says Brenninkmeijer. "We get data, air samples, aerosol samples. These are analyzed, and a month later we repeat the whole sequence."

In flight, "we have a rigorous system where we repeatedly sample at regular intervals," adds Brenninkmeijer, "and we are working on an air collector that is triggered by pollution plumes so that we can quickly take an air sample of that particular air mass for detailed analysis."

MOZAIC, by contrast, sports fewer instruments—its load is only about 150 kg—but flies on several planes, all the time. Every six weeks the MOZAIC team collects a storage disk of data from each plane.

"We have less instrumentation than CARIBIC, but we do a lot of measurements," says Research Center Jülich's Herman Smit, who is responsible for MOZAIC's water-vapor measurements. "Since 1994 we have collected data from more than 28 000 long-haul flights from which we get detailed information on

the seasonal variation and geographical distribution of substances that influence air quality and climate."

As MOZAIC enters a new phase as part of IAGOS, better, lighter-weight instruments are key, says Volz-Thomas. The aim is to reduce the total instrument weight to 100 kg while also expanding the measurement capabilities. "We have to keep transport costs at a limit acceptable to airlines—so far they have carried our instruments for free, and we hope they continue." The first IAGOS instruments are slated to fly next year. The aim is to raise enough funding to fly instruments on 20 planes within 10 years.

For its part, CONTRAIL combines air sampling and continuous measurement. Air samples are collected on twice-monthly flights between Tokyo and Australia and other equipment monitors CO_2 continuously. The project uses five planes.

The three projects have different scientific emphases and "also have quite different flight routes," says MOZAIC coordinator Jean-Pierre Cammas of the CNRS Laboratoire d'Aérologie in Toulouse, France, which along with Jülich and France's national weather service is one of the project's main science partners. "The projects are complementary."

Blue skies research

Examples of CARIBIC research include using mercury measurements in three-dimensional global atmospheric transport models, characterizing aerosols in the upper troposphere and lower stratosphere, and deducing vertical profiles of gases from scattered light. "We have three tiny telescopes built into the pylon. We let in light, not air," says Ulrich Platt of the University of Heidelberg. "The advantage of spectroscopy is that you can see the unknown. We are looking in the near-UV at 300–400 nm." One highlight, he adds, "was finding precursors to OH [hydroxyl] radicals, which provide self-cleaning of the atmosphere. We have found that thunderstorms might contribute a lot to self-cleaning of the atmosphere."

In the aerosol intake, air is slowed from about 250 m/s to a few m/s so the particles don't smash into the walls of the collection tube. Nuclear physicist Bengt Martinsson of the University of Lund, Sweden, and colleagues analyze samples using transmission electron microscopy, particle-induced x-ray emission, and other methods to identify and quantify aerosols. "The picture emerges of little transport of particulate matter from low altitudes by deep convective systems," says Martinsson. Instead, he adds, aerosols in the upper troposphere are produced from gaseous precursors that have been transported up from lower altitudes.

Among MOZAIC's most important findings so far, says Cammas, is the presence of ice supersaturation. "The upper atmosphere is much wetter than we thought. It's quite important for the formation of cirrus clouds and the formation of contrails by aircraft. Contrails can generate other cirrus clouds, which could impact climate." MOZAIC also discovered high summertime levels of nitric oxide over the eastern coast of the US, says Volz-Thomas, and ozone levels depend on NO. "There is NO from automobile exhaust, brought up by convection. A lot comes from lightning, too, and there is NO from aircraft." Because of the incomplete vertical transport description in models, he adds, "the impact of aircraft on ozone is at least disputable."

Indeed, says Volz-Thomas, a big debate at the moment is whether it's true that "because of their additional effect on ozone, methane, and cloudiness, aircraft emissions influence climate three times more than the same amount of CO_2 emitted from a ground-based power plant." In a new emissions trading scheme, the European Commission (EC) plans to apply charges based on that assumption. "Airlines want to know if the factor of three is correct. Our data will help answer this."

Seeking sustainability

"We are trying to get IAGOS to be a global, sustainable infrastructure with long-term funding," says Volz-Thomas. "If you want to look at trends, you need 30 years or so of continuous record keeping. But funding agencies usually want to see something sexy, something new." IAGOS leaders put the cost of modifying aircraft, building new instruments, and running the project at about $10 million a year.

Making a united case for funding is one reason CARIBIC has teamed up with MOZAIC. Says Volz-Thomas, "We hope IAGOS will be an important part of the in situ infrastructure for the atmospheric part of GMES"—Global Monitoring for Environment and Security, a new European service expected to go online around 2012—"and GMES could help fund IAGOS." Gathering data with commercial airliners "is turning into a combination of research and monitoring climate," adds Cammas.

Starting in September, IAGOS has EC funding for four years to get countries to sign on to the project. "The main objectives are to prepare the legal and organizational framework for IAGOS and to raise funds for operating it over a long time," Volz-Thomas says. Potential sources of money are participating institutions, national funds, and, via GMES, the EC, he adds. "Will they consider this project important enough?"

Toni Feder

DOE urged to proceed more deliberately with global plan to expand nuclear power

Critics of the Global Nuclear Energy Partnership say the Department of Energy is rushing to commercialize unproven technologies.

In March the UK became the 21st country to sign a nonbinding "statement of principles" that attempts to address the conflicting Global Nuclear Energy Partnership goals of spreading nuclear energy generation throughout the world while preventing the spread of technologies needed to manufacture and recycle nuclear fuel to nations that don't already possess them. Signatories to the GNEP include the nuclear haves Russia, China, Japan, and France, have-nots like Senegal, Jordan, and Ghana, and nations that have relied on other countries for their nuclear fuel, including the former Soviet satellites Hungary, Bulgaria, and Lithuania.

Many experts believe that a vast expansion of nuclear power is the only plausible option for meeting the anticipated explosion in electricity demand from the developing world while mitigating global warming. According to one widely accepted computer model, the Mini Climate Change Assessment Model, stabilization of atmospheric carbon dioxide concentrations at 550 ppm—a level that many climate scientists fear is still too high—will require as many as 4000 new nuclear reactors, said Victor Reis, a senior adviser at DOE. "This is an area where the US can provide some serious leadership," Reis recently