Ever since a Boeing 747 temporarily lost all four engines in an ash cloud in 1982, the International Civil Aviation Organization (ICAO) has stipulated that skies must be closed as soon as ash concentration rises above zero. The ICAO's International Airways Volcano Watch uses computerised pollution dispersal models to predict ash cloud movements, and if any projections intersect a flight path, the route is closed.

But although it is certain that volcanic ash like that hanging over northern Europe can melt inside a jet engine and block airflow, nobody has the least idea about just how much is too much. After a week of losing millions every day, airlines are starting to ask why we can't do better.

It need not be this way, concedes Jonathan Nicholson at the UK's aviation regulator, the Civil Aviation Authority. "There may be a non-zero safe ash level for commercial jets, of so many particles of a certain size per minute," he told New Scientist, "but we just don't know."

Denis Chagnon, spokesman for the ICAO, agrees, but says that isn't regulators' fault. "This has to be established by the engine makers themselves, because they produce the affected equipment. And that has not been done," he says.

But in many cases, the reports conflicted when it came to how high the ash clouds were, making it difficult to issue appropriate warnings, according to Tupper, who helps run the Darwin VAAC. The Darwin VAAC analyzed these different reports in a 2007 paper in the journal Weather and Forecasting. Part of the difficulty, they reported, stemmed from the high ice content in the clouds, which made them difficult to track — highlighting a key problem, Tupper says. A VAAC’s ability to provide warning is only as good as the data it can amass.

No eruption is simple, he says: An ice- or water-rich ash cloud, such as the Manam cloud, may be undetectable for days or even weeks after an eruption, but is potentially still dangerous. “It’s a brave meteorologist who would keep a warning going for that long without any verification from observations,” he says. And there’s the problem of seeing through other meteorological phenomena to track more elusive ash: For example, anvil-shaped thunderstorm clouds can obscure satellite detection of lower eruption clouds. Or water-rich ash clouds may even resemble thunderstorms themselves.

One needed improvement, Tupper says, is better integration of satellite-based, ground-based and pilot-based observations and systems — a sentiment discussed at the World Meteorological Organization’s 4th International Workshop on Volcanic Ash, which met in New Zealand in 2007. Many of the remotest volcanoes, deep in the Pacific or high in the Arctic, are largely unmonitored by ground-based systems — often because they pose little threat to populations on the ground, and so are not considered a priority. “We are grappling with the issues of how these observatories might monitor remote volcanoes to the necessary standard,” he says. But that means realigning both priorities and (often scarce) funding.

The system works — but imperfectly, Guffanti says. Over time, she adds, ICAO’s system of volcano monitoring and ash cloud detection has decreased the frequency of dangerous encounters between airplanes and volcanoes. But there are many unmonitored volcanoes, for which the agencies can give no early warning. “Satellite remote sensing has inherent physical limitations,” she says. Part of it is physics — certain laws cannot be thwarted. For example, no matter how scientists fine-tune a satellite’s ability to see certain wavelengths, its UV sensor is only going to work in the daytime. And ash coated with ice is not as visible to satellites as uncoated ash.

“It doesn’t matter how smart or good the people are; models are just that,” Guffanti says. “They’re models, not absolute predictors.”

The first effect that the dust had on the Rolls Royce engines of BA009 was to change the shape of the blades by abrasion and so impair the efficiency of compression. Because it had been the first to be shut down, engine no. 4 was the least damaged in this respect. Ash filtered into and blocked the aircraft's pitot tubes – forward-pointing instruments that use outside air pressure to work out the aircraft's speed – so explaining why the crew received conflicting airspeed readings. Environmental control system ducts were worn away from the inside by the abrasive dust, explaining why the floor vents had appeared to be smoking. And in the engines themselves, the swirl vanes surrounding the fuel nozzles, which turn the fuel into a mist before burning, were also clogged. This meant that although the nozzle was able to pass fuel at the design flow-rate, the clogged vanes inhibited its atomisation, making re-starting of the engines more difficult than usual.

Following the eruption of the Eyjafjallajökull volcano (“the Volcano”) in Iceland on

April 14, 2010, European countries began withdrawing air traffic service and closing airspace as the ash

cloud spread eastward. The resulting restrictions on civil flights in 23 countries across most of northern

and central Europe stranded passengers across the globe and severely disrupted air transport operations

for several days. Over 300 airports, representing 75 per cent of European air traffic, closed.

EUROCONTROL estimated that more than 100,000 flights were cancelled affecting the travel plans of

around 10 million passengers. The airlines estimated their losses in the order of $1.7 billion, the airports

at $400 million, and Air Navigation Service Providers at $200 million with wider impacts to the general

economy.

That, the following tasks be included in the work programme:

a) improve collaborative decision making among the

VAACs to improve harmonization of products and

services;

b) improve model performance to a reasonable extent,

and investigate the use of ensemble modelling;

c) better define source parameters for models by working

with the International Union of Geophysics and

Geodesy who support the world wide Volcano

Observatories;

d) review of existing contingency plans in ICAO Regions

to ensure there is harmonization between Regions and

services provided;

e) further evaluation of engine tolerance to ash to better

define areas of ash concentration that has to be

supported with associated improvement in model

output;

f) understanding of uncertainty or probabilistic

forecasting of ash concentration and how it affects

decisions on fly or no fly zones; and

g) review of existing procedures and practices on the

provision of information to Flight Crews and Airline

Operations Centres to support their operational

decisions for time critical messages.

\* Globally, volcanic ash clouds rise to cruising altitude about 11 times per year. This number is considered a low estimate, given gaps in reporting of volcanic activity, and the fact that clouds and nighttime conditions can mask detection.

\* About 300 flights per day carry roughly 10,000 passengers over the Ecuadorian volcanic corridor, according to Hugo Yepes of Ecuador's Instituto Geofisico. The November 2002 eruption of El Reventador hurled ash up to 60,000 feet, which spread in two directions from wind shearing, threatening aviation routes for thousands of square miles.

\* About 475 airports are located within 100 kilometers (62 miles) of volcanoes that have erupted since 1900. Over the last 60 years, volcanic activity disrupted operations 108 times at 75 of those airports.

\* There are some 100 active volcanoes dotting the Northern Pacific region, where air traffic has grown greatly in recent years. There are more than 200 airline flights per day flying downwind of those volcanoes, putting tens of thousands of passengers and millions of dollars of air cargo at risk every day, according to Tom Miller of the U.S. Geological Survey (USGS).

\* On average, about four to five eruptions will occur annually among these Northern Pacific volcanoes. Ash from these volcanoes will rise to contaminate air routes above 30,000 feet about four to five days per year.

\* An average of five advisories of volcanic activity are issued daily to the world's aviation community.

In the early morning hours of February 28, 2000, the National Aeronautics and Space Administration

(NASA) DC-8 Airborne Sciences research airplane inadvertently flew through a diffuse plume of

volcanic ash from the Mt. Hekla volcano. There were no indications to the flight crew, but sensitive

onboard instruments detected the 35-hr-old ash plume. Upon landing there was no visible damage to the

airplane or engine first-stage fan blades; later borescope inspection of the engines revealed clogged

turbine cooling air passages. The engines were removed and overhauled at a cost of $3.2 million. Satellite

data analysis of the volcanic ash plume trajectory indicated the ash plume had been transported further

north than predicted by atmospheric effects. Analysis of the ash particles collected in cabin air heat

exchanger filters showed strong evidence of volcanic ash, most of which may have been ice-coated (and

therefore less damaging to the airplane) at the time of the encounter. Engine operating temperatures at the

time of the encounter were sufficiently high to cause melting and fusing of ash on and inside

high-pressure turbine blade cooling passages. There was no evidence of engine damage in the engine

trending results, but some of the turbine blades had been operating partially uncooled and may have had a

remaining lifetime of as little as 100 hr. There are currently no fully reliable methods available to flight

crews to detect the presence of a diffuse, yet potentially damaging volcanic ash cloud.