Sensors and Programs for Inflight Icing

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Boulder, CO

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Washington, DC
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Acknowledgements

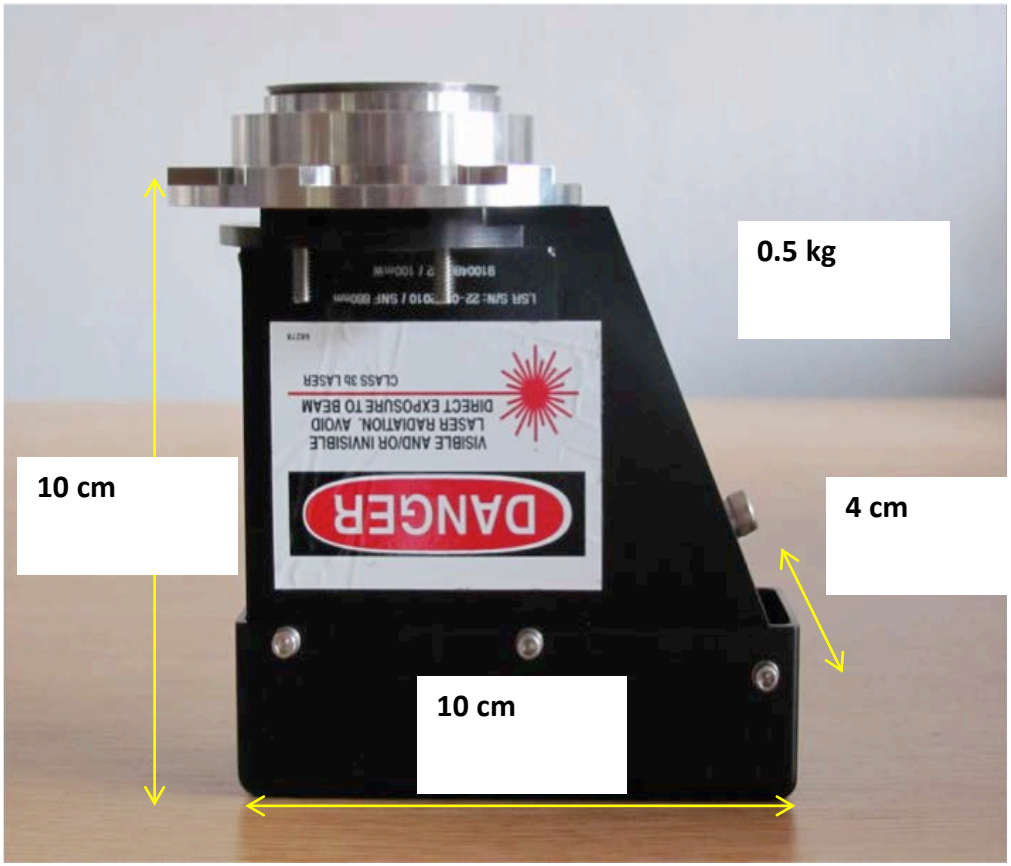
- Karl Beswick and Martin Gallagher, University of Manchester.
- Adam Durant, Satavia
- IAGOS Team

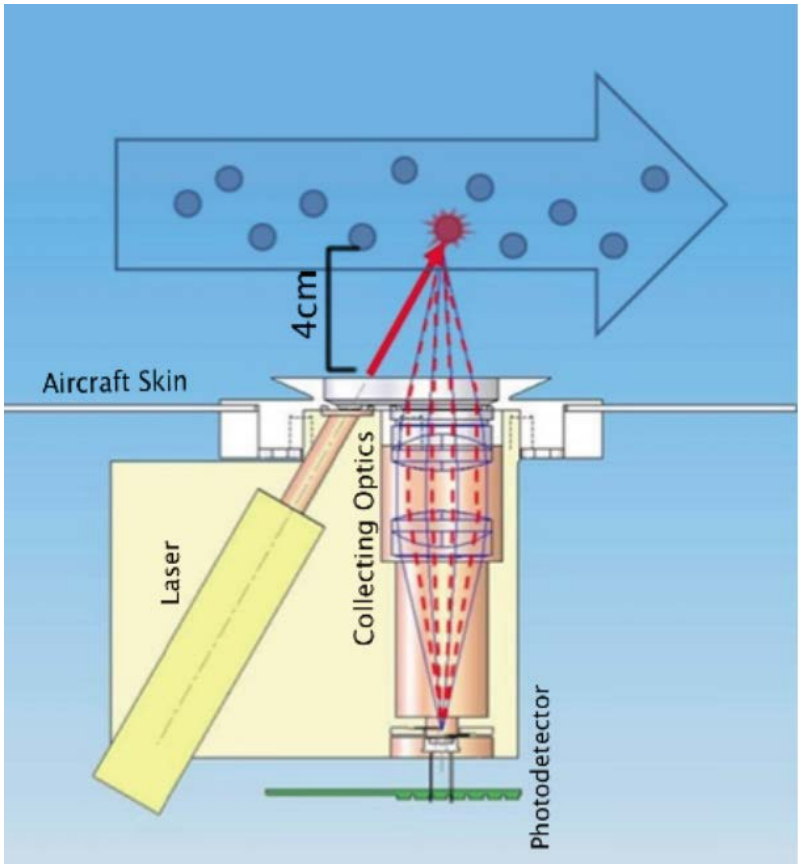
Outline

- Instruments for routine measurements of cloud microphysical properties from commercial aircraft.
- In-Progress programs that implement cloud measurements.
- Applications of real-time cloud measurements
- Challenges

Instruments for routine measurements of cloud microphysical properties from commercial aircraft.

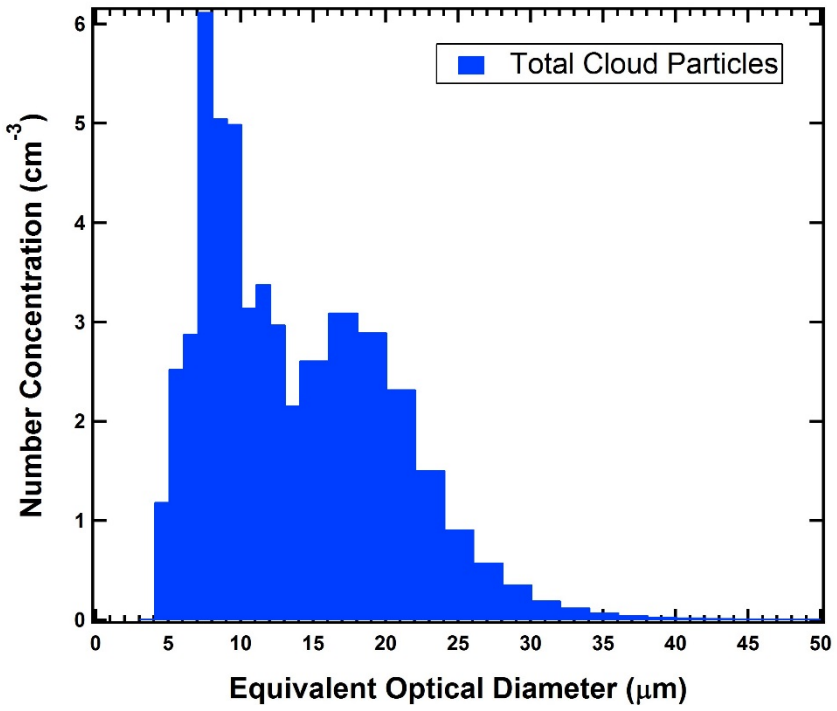
The IAGOS Backscatter Cloud Probe (BCP-100)

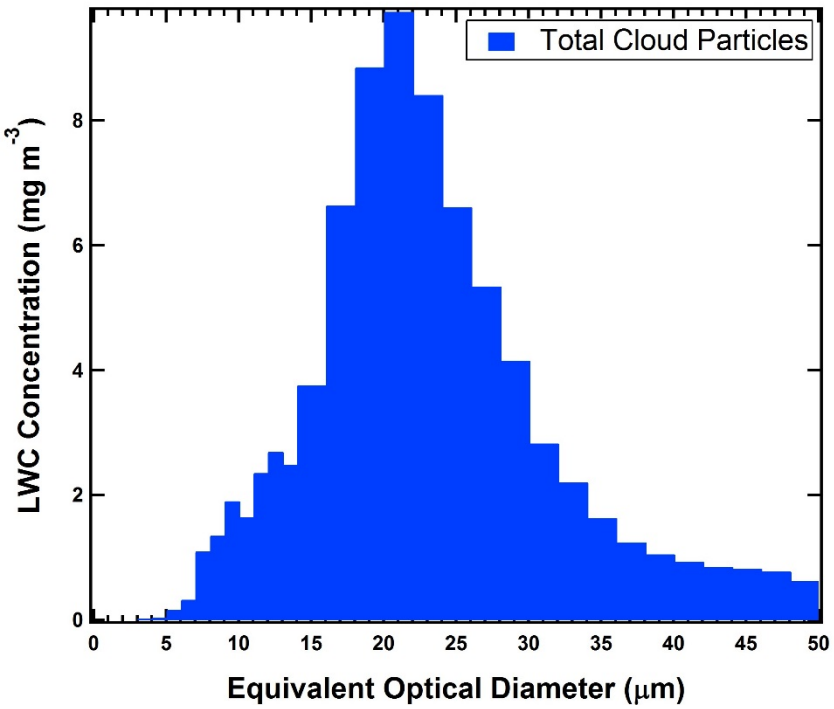




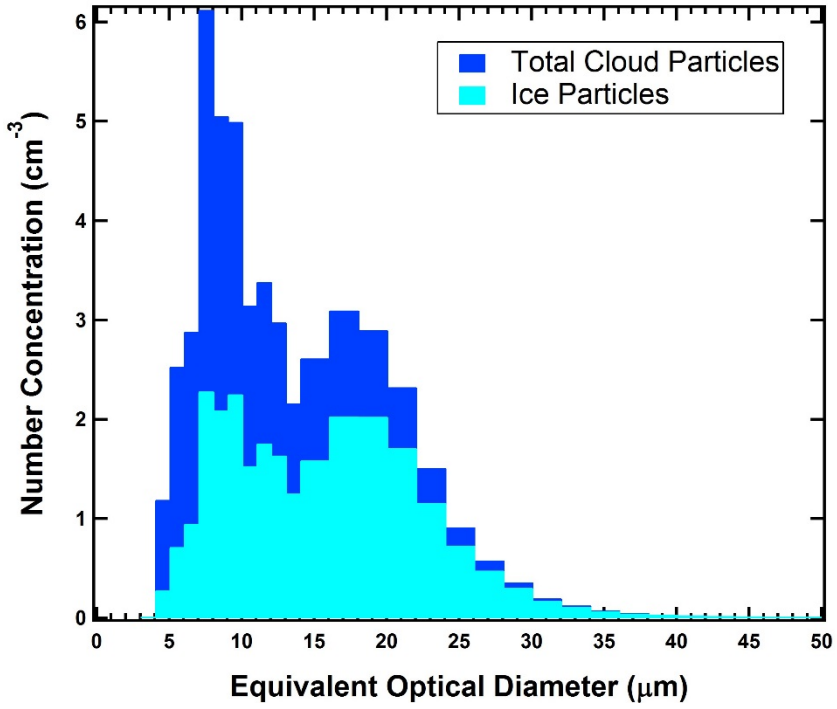
Beswick et al., AMT, 2014

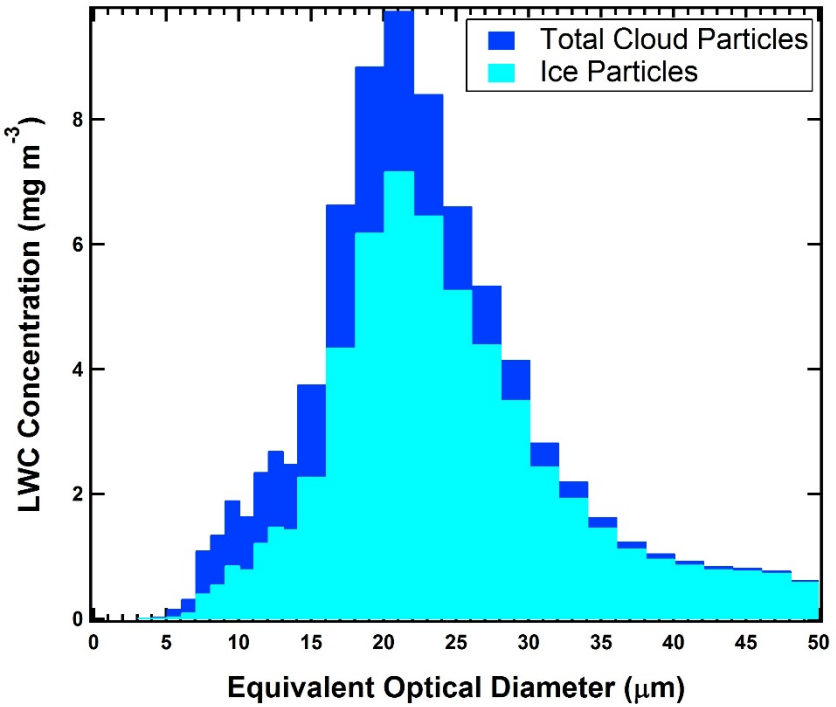
The BCP measures the diameter of each particle and creates a size distribution of number and LWC concentration





The Backscatter Cloud Probe with Polarization Detection (BCPD) is a BCP that distinguishes liquid droplets from ice crystals and volcanic ash.





In-Progress programs that implement cloud measurements

Extending the Database: IAGOS - CORE

Permanent installations in the avionic bay of A340/A330

Weight: 120 kg Operation: Continuous

Installation aboard A340/A330

First flight of LH D-AIGT on 8 July 2011

www.iagos.org

Photograph by courtesy of A. Karmazin

In-service Aircraft for a Global Observing System

IAGOS

IAGOS Partners

JÜLICH FORSCHUNGSZENTRUM	Forschungszentrum Jülich, D Coordination
CNRS CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE	Laboratoire d'Aérologie, CNRS, Toulouse, F
UNIVERSITY OF CAMBRIDGE	University of Cambridge, U.K.
DLR	Deutsches Zentrum für Luft- und Raumfahrt, Oberpfaffenhofen, D
MANCHESTER 1824	University of Manchester, U.K.
	Max-Planck-Gesellschaft, D
KIT	Karlsruhe Institute of Technology, D
TROPOS	Leibniz-Institut für Troposphären-forschung, Leipzig, D
Lufthansa	Deutsche Lufthansa AG, D
AIRBUS	AIRBUS, Bristol, UK and Toulouse, F
BRITISH AIRWAYS	British Airways plc, U.K.
enviscope	*enviscope* GmbH, Frankfurt, D
METEO FRANCE	Météo France, Toulouse, F
WMO	World Meteorological Organization, Genva, CH

Associated Airlines

Lufthansa	1st IAGOS-CORE 2011 IAGOS-CARIBIC 2 MOZAIC since 1994
CHINA AIRLINES	MoU signed 2008; 2nd IAGOS-CORE 2012
AIR FRANCE	MoU signed 2012 3rd IAGOS-CORE, 03 2013 1 MOZAIC -2008
BRITISH AIRWAYS	Partner
IBERIA	MoU signed 2012 5th IAGOS-CORE, 08 2013
CATHAY PACIFIC	MoU signed 2012 4th IAGOS-CORE, 07 2013
Air Namibia	MOZAIC since 2005
Austrian	MOZAIC -2006
SOUTH AFRICAN AIRWAYS	Interest in collaboration
QANTAS	Interest in collaboration
Philippine Airlines	Interest in collaboration

IAGOS

No North American Airlines!

IAGOS Fleet (October 2013)

Lufthansa D-AIHE

CARIBIC since June 1997

Lufthansa D-AIGT

CORE-1, July 2011

China Airlines B-18806

CORE-2, June 2012

Air France F-GLZU

CORE-3, June 2013

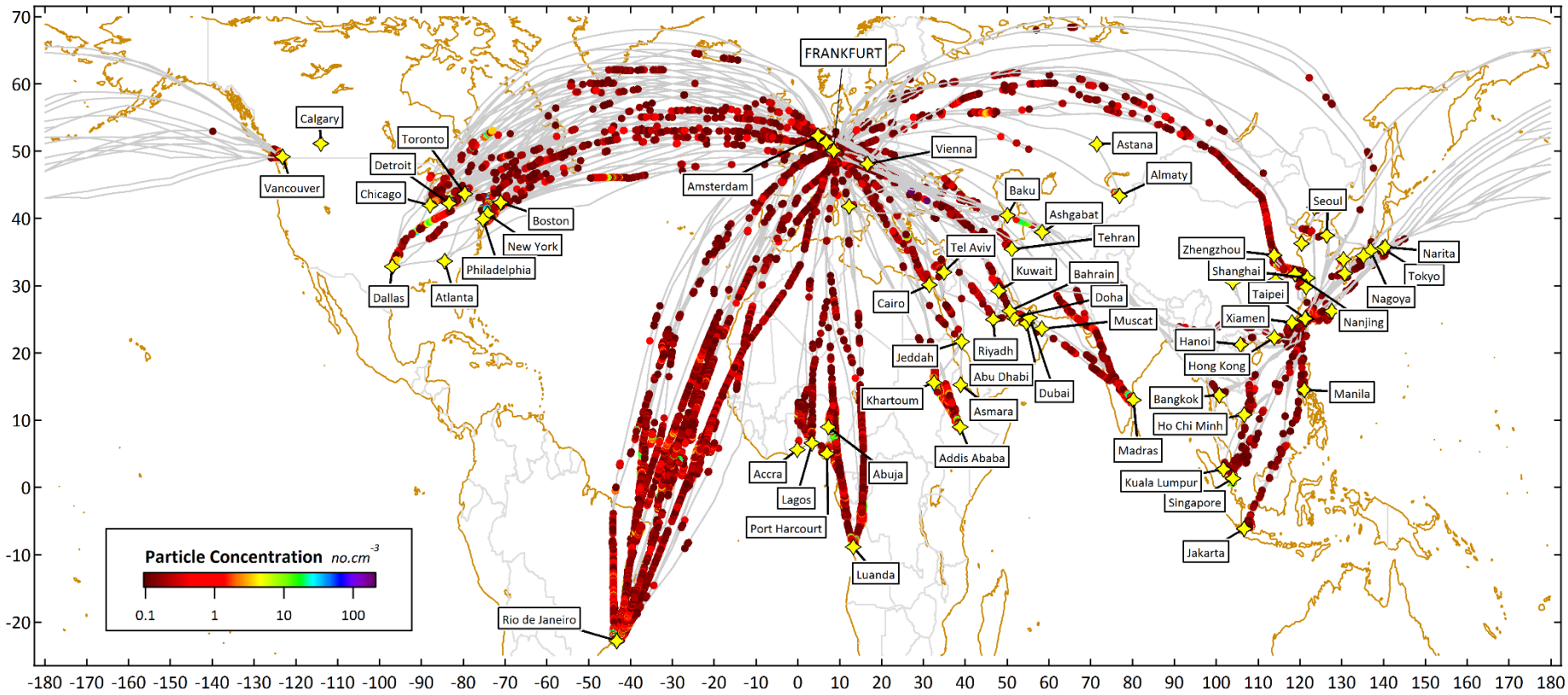
Cathay Pacific B-HLR

CORE-4, Aug 2013

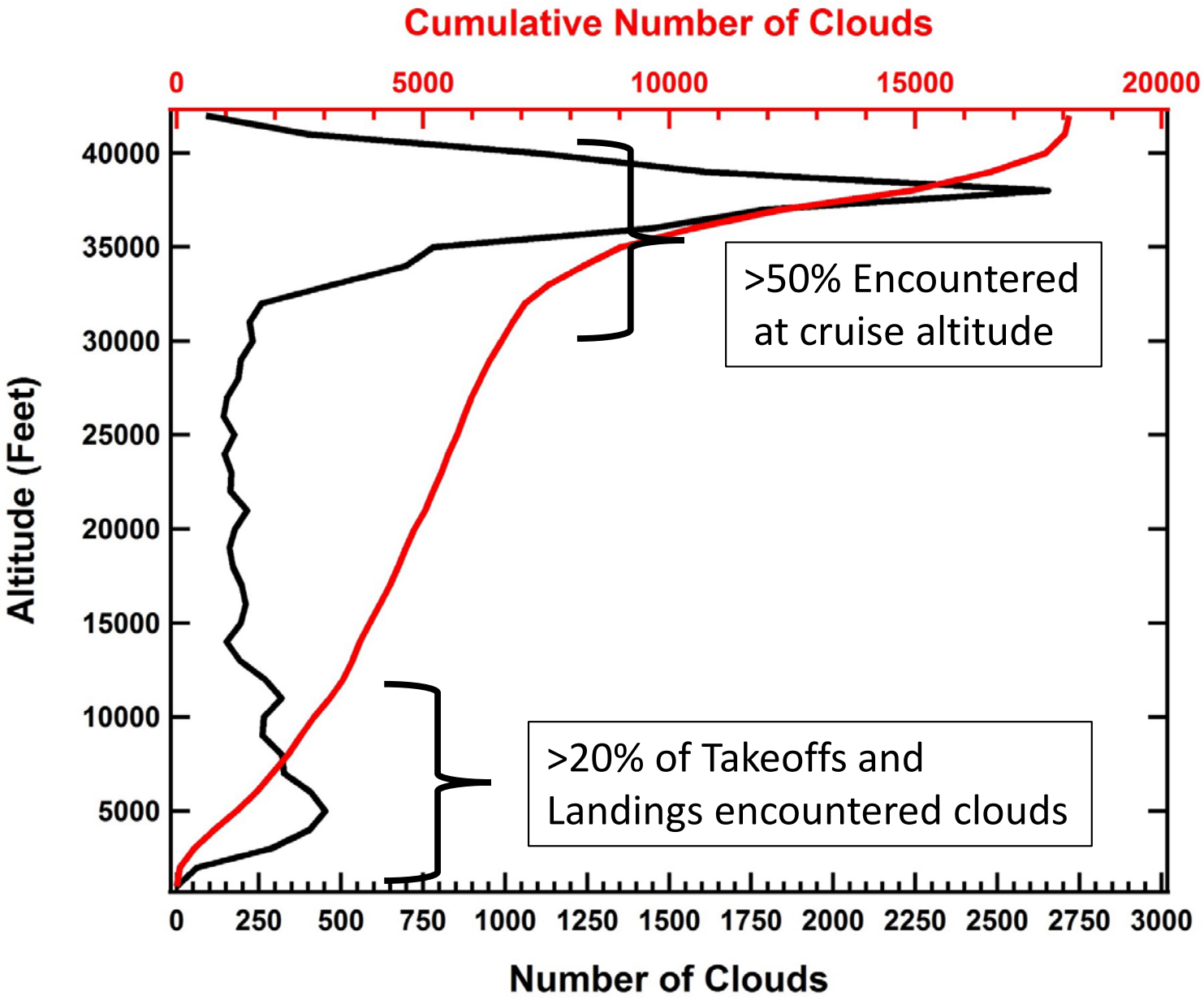
IBERIA EC-GUQ

CORE-5, Oct 2013

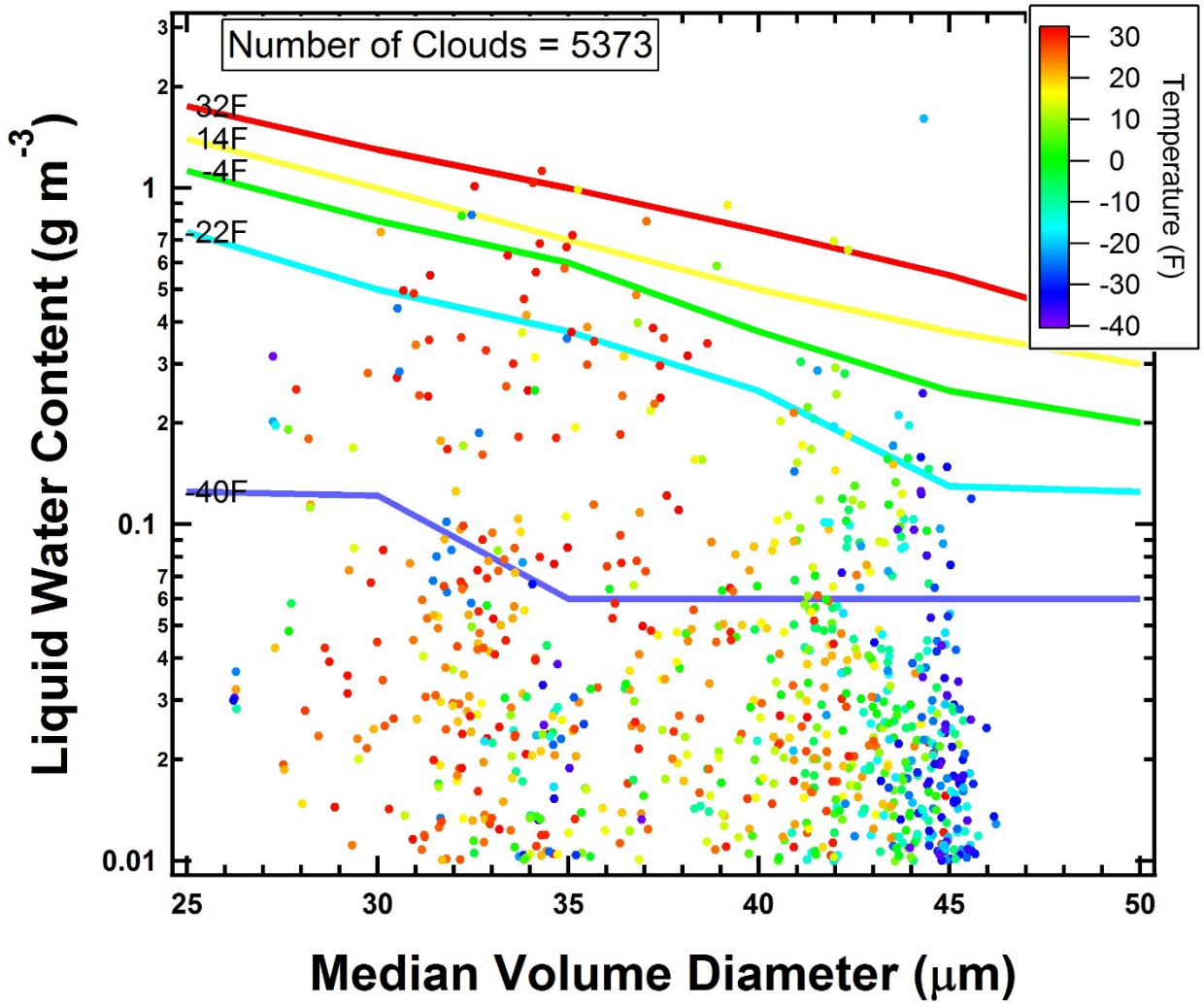
Flight Trajectories from 2012-2014
4399 Flights; 20557 flight hours; 665 hours in cloud



From 2012-2014 Encountered 18,314 Clouds with Concentrations > 10 L^{-1}



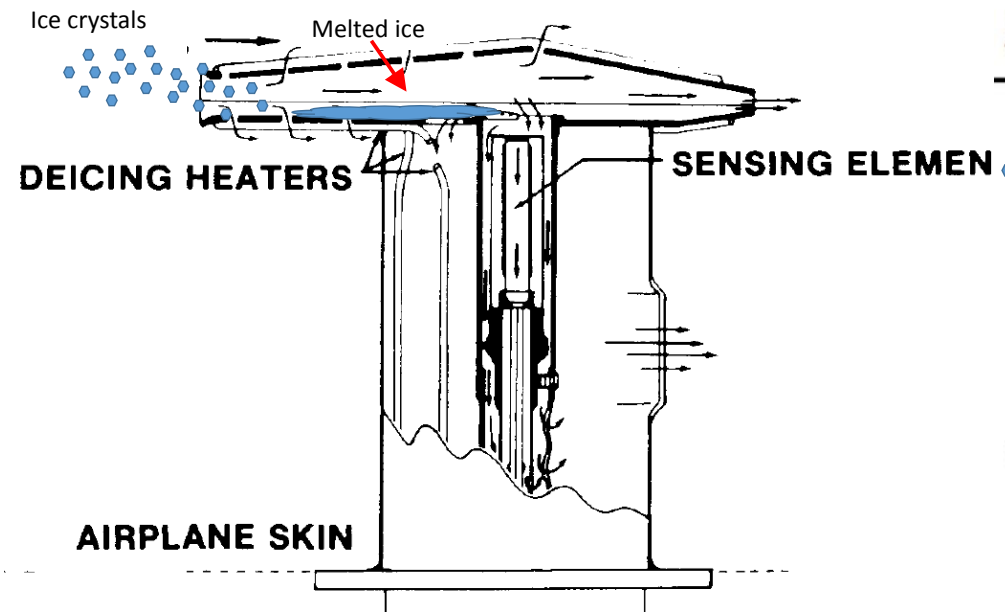
Cloud Measurements in Context of FAR Part 25 – Appendix C Intermittent Maximum (Cumuliform Clouds) 5373 In-Cloud Events with Potential for Icing



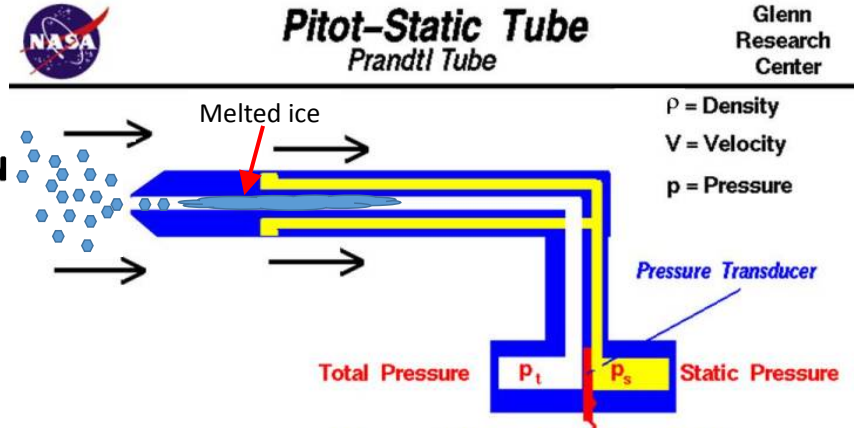
Data for Aircraft Safety & Operational Impacts

High Ice Crystal Impact on Aircraft Sensors

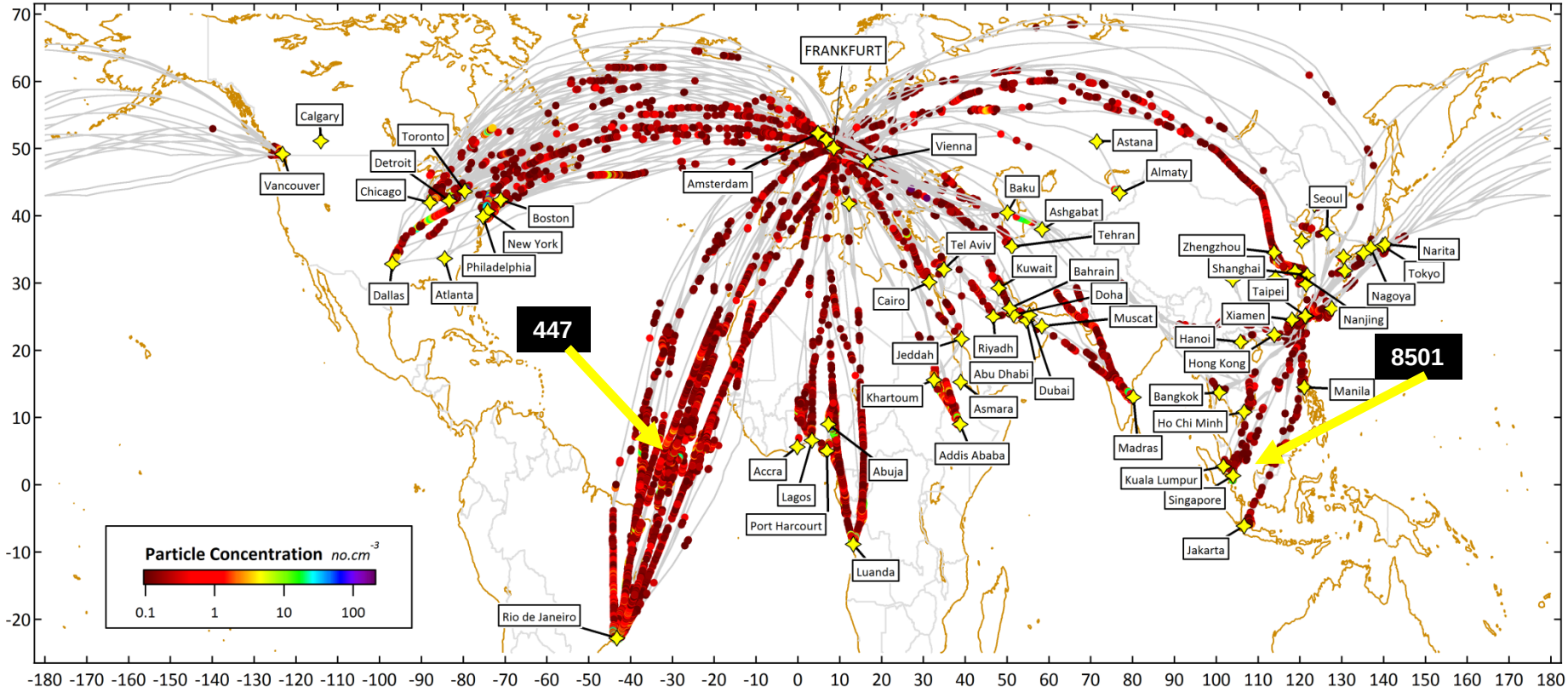
Impact on Temperature Measurements:
"Temperature Anomalies"



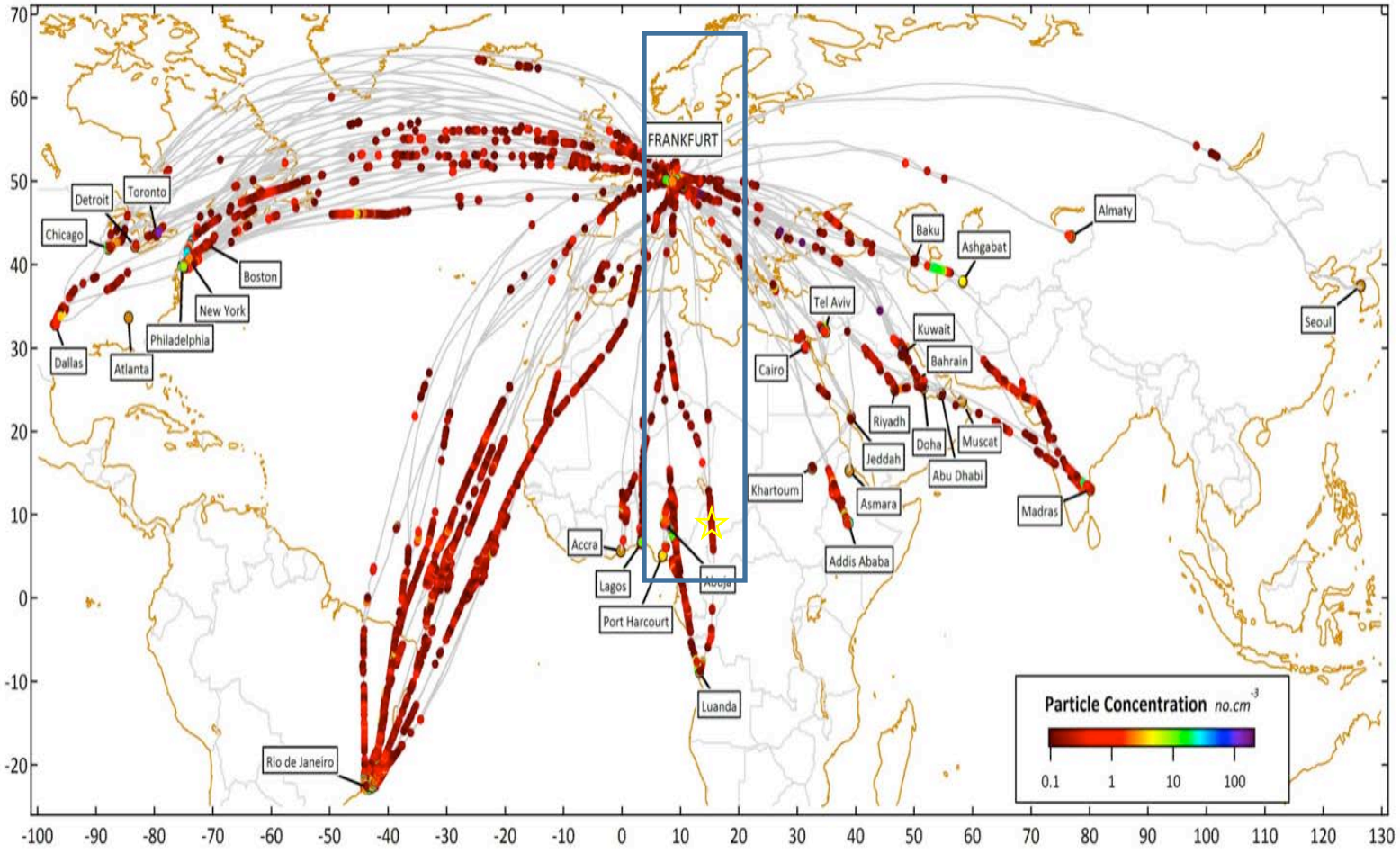
Impact on Airspeed Measurements:
"Indicated Airspeed Loss"



High Ice Crystal Concentrations Led to the AF447 and Possibly the Air Asia Flight 8501 Accidents

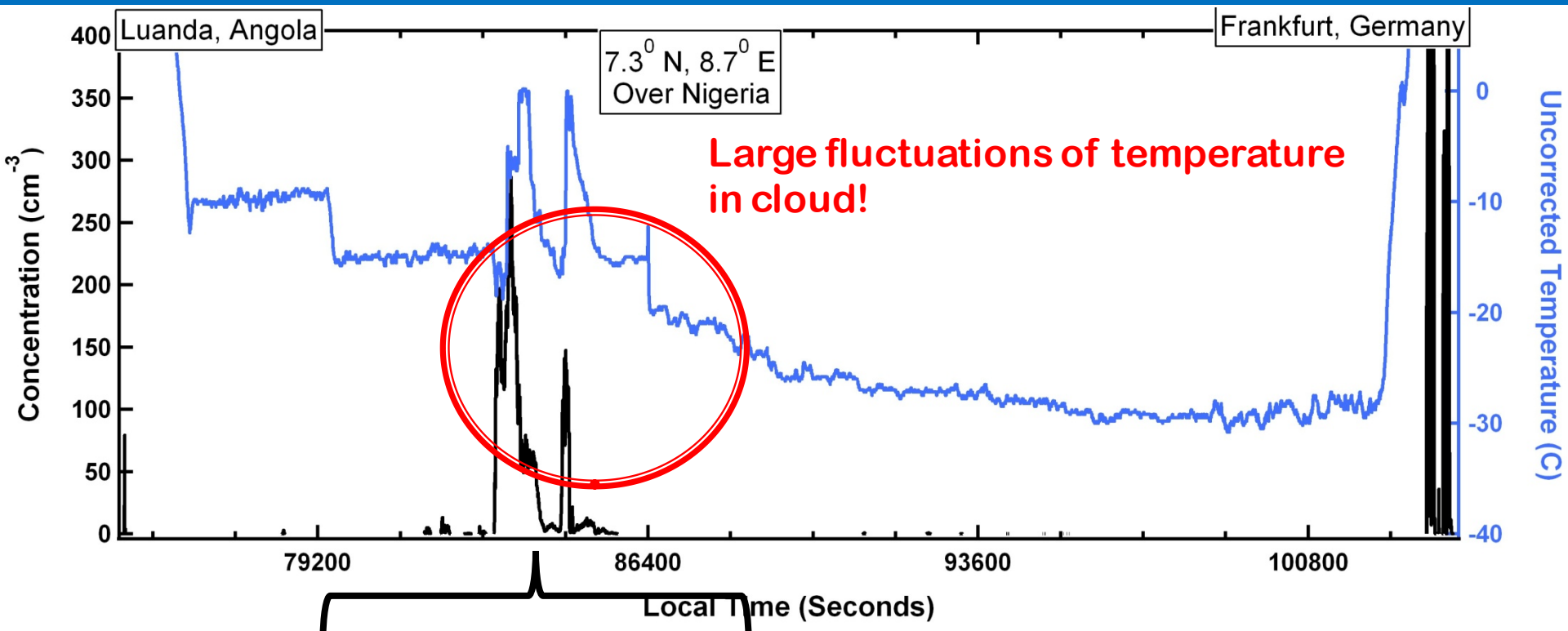


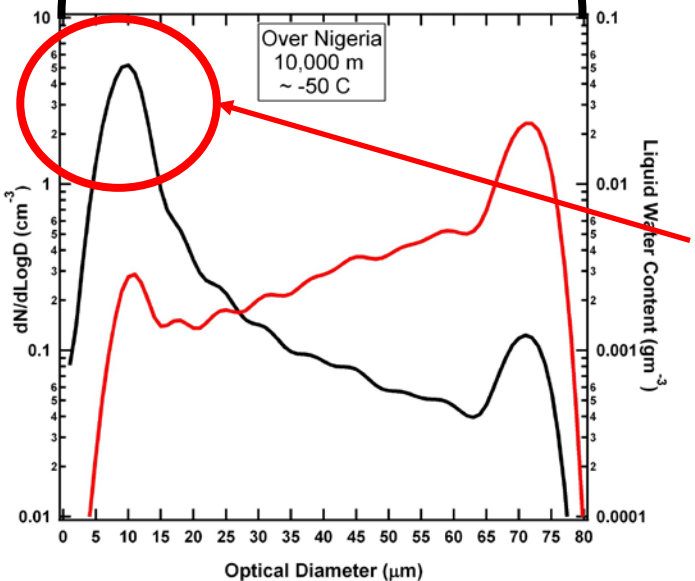
High Ice Crystal Concentrations and Sensor Anomalies are Not Isolated Phenomena.



Example from Flight from Luana, Angola to Frankfurt Flight May 18, 2012

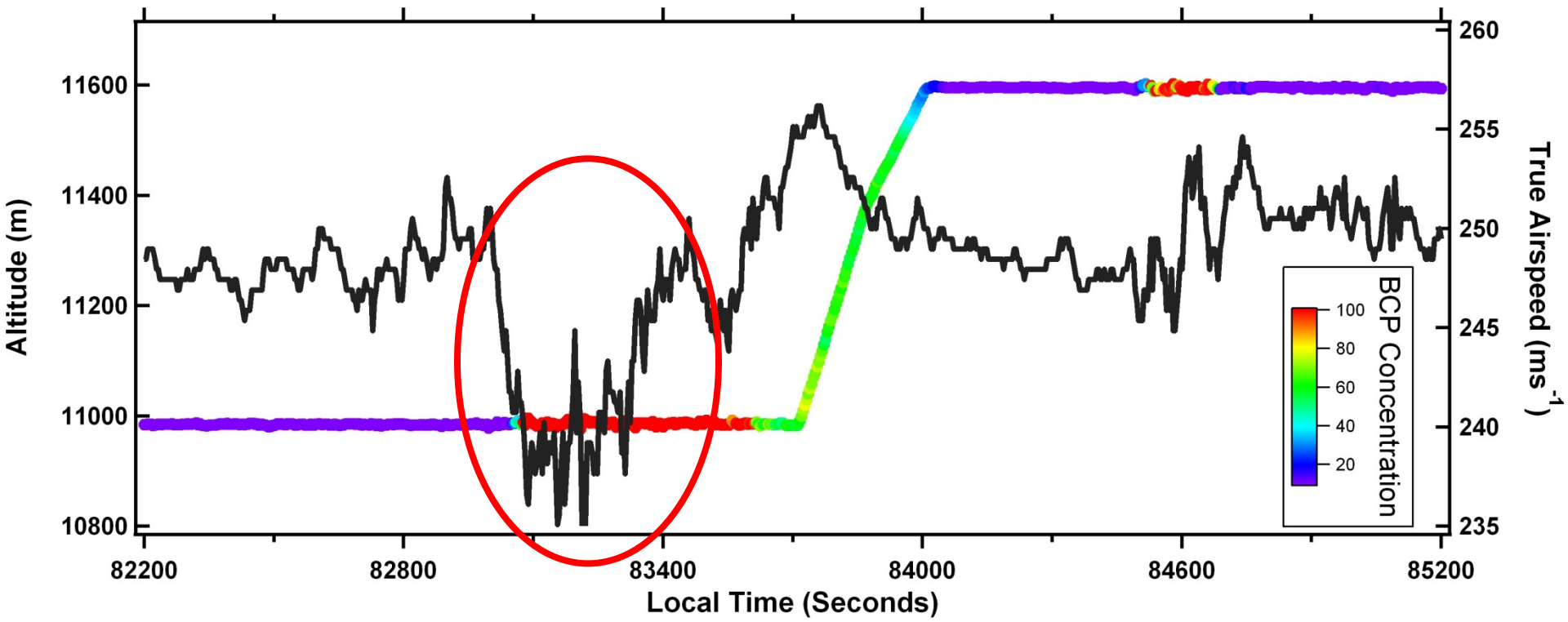
>300,000 particles per liter, Temperature Anomaly of +35^0 C





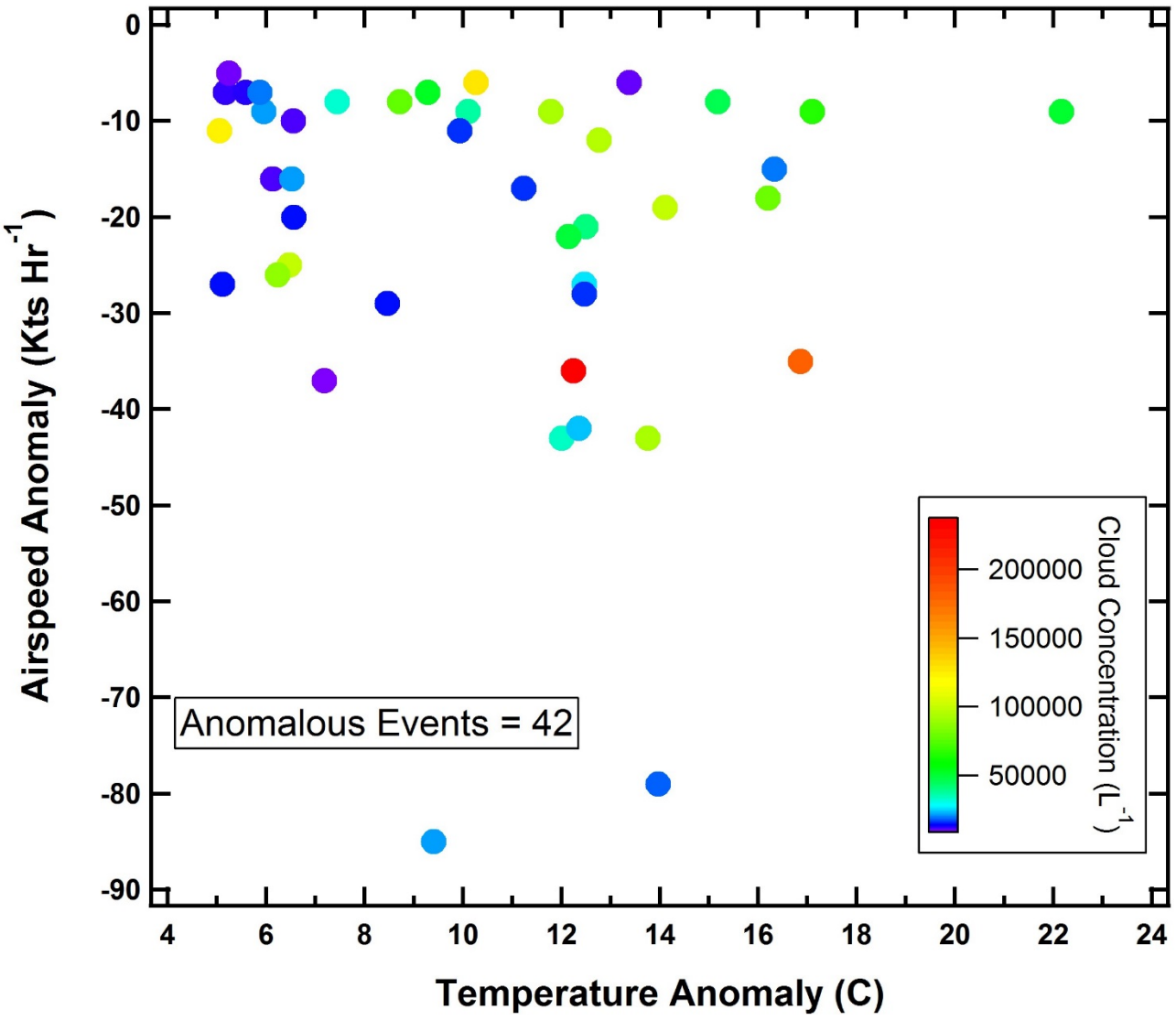
Most of the crystals are very small and would produce a very weak signal return from aircraft weather radar.

Aircraft takes avoidance action but remains in cloud for nearly half an hour.
Temperature measurements remain corrupted by melted ice crystals.
Pitot tube corrupted, 40 kt/hr decrease in indicated



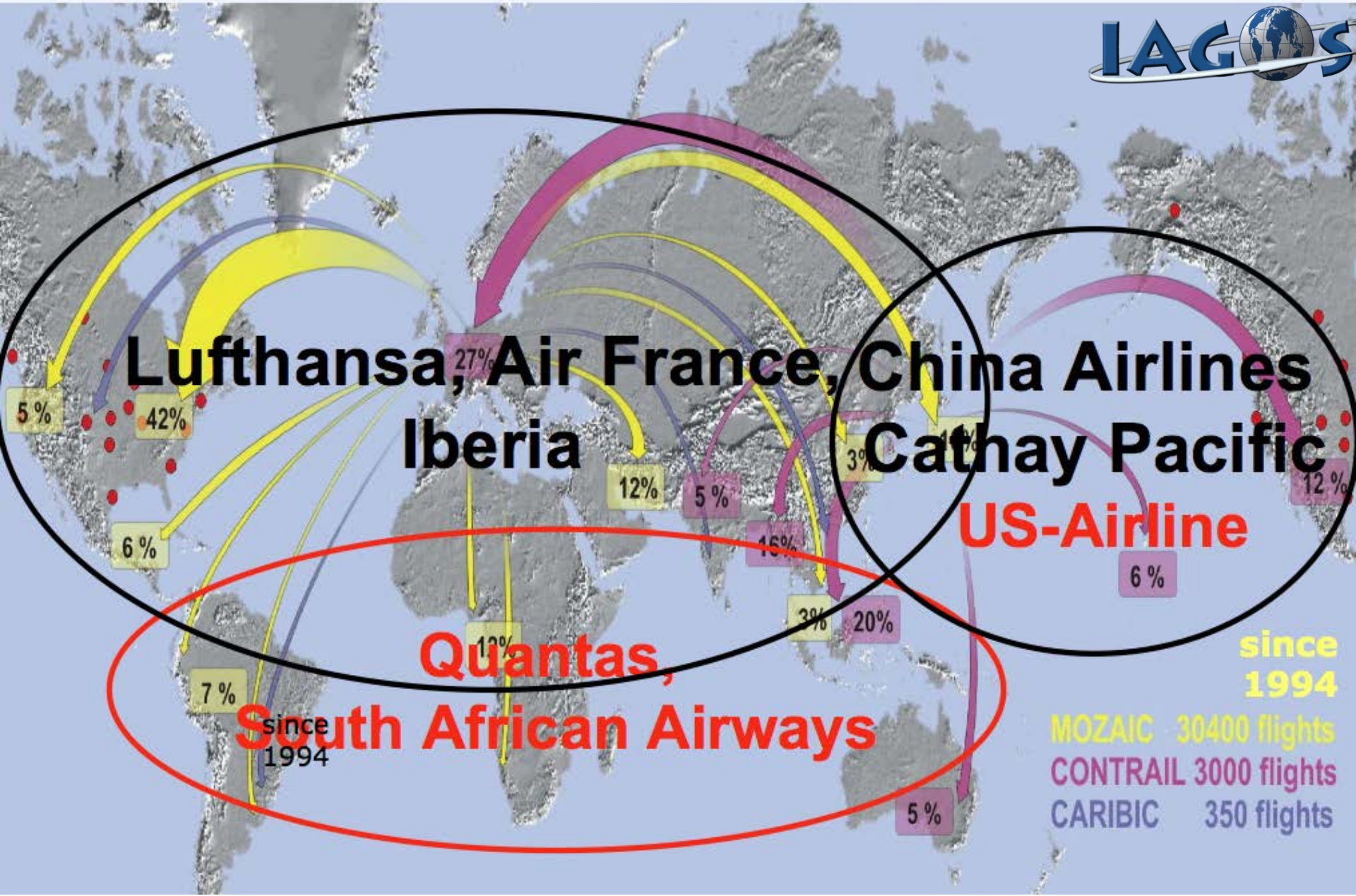
In three years, five IAGOS aircraft experienced 42 anomalous events.

This is approximately 3 events per aircraft per year.



Mason et al. (2006) "46 engine rollback events associated with temperature sensor anomalies"

Future - Geographical Coverage



DAEDALUS
Aviation hazards awareness system

- Meteorological Hazard Situational Awareness Service for the Aviation Industry

- Hazards covered include **icing** and **volcanic ash**

- **Funded by European Space Agency Integrated Applications Promotion ARTES 20 Programme**

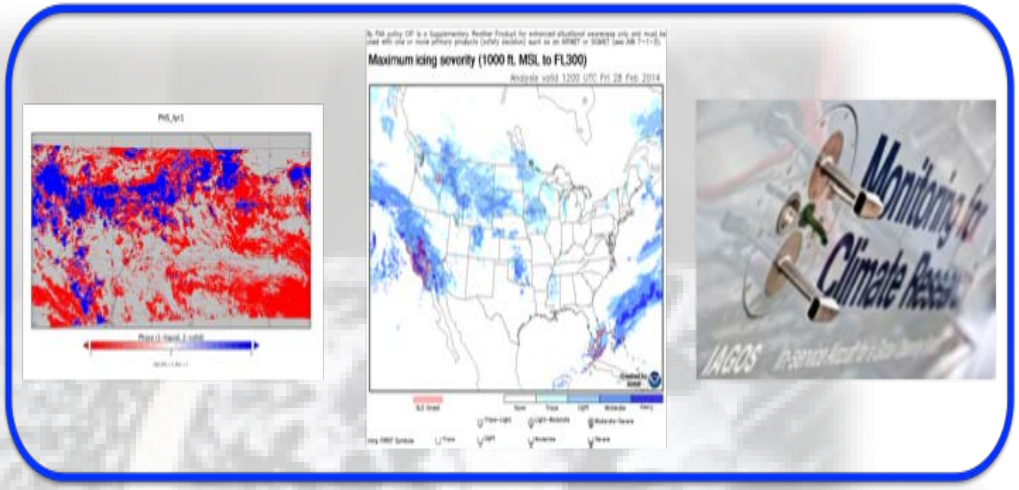
- 10 month Feasibility Study starting Jan 2015 with follow-on Demonstration Project planned for late 2015

- Project to develop service around **DMT BCPD cloud sensor** to support real-time operational response and safety of life considerations

- Strong focus on optimising aircraft-surface data communication

- Led by ***Satavia Ltd***., UK

EARTH OBS **NOWCAST** ***in situ* OBS**



Applications of real-time cloud measurements

Potential Applications

- Complement and enhance the TAMDAR icing measurements, i.e. icing measurements can be refined with mass size distribution differentiated by liquid/ice and closure between icing and size distribution measurements improve fidelity of the information.

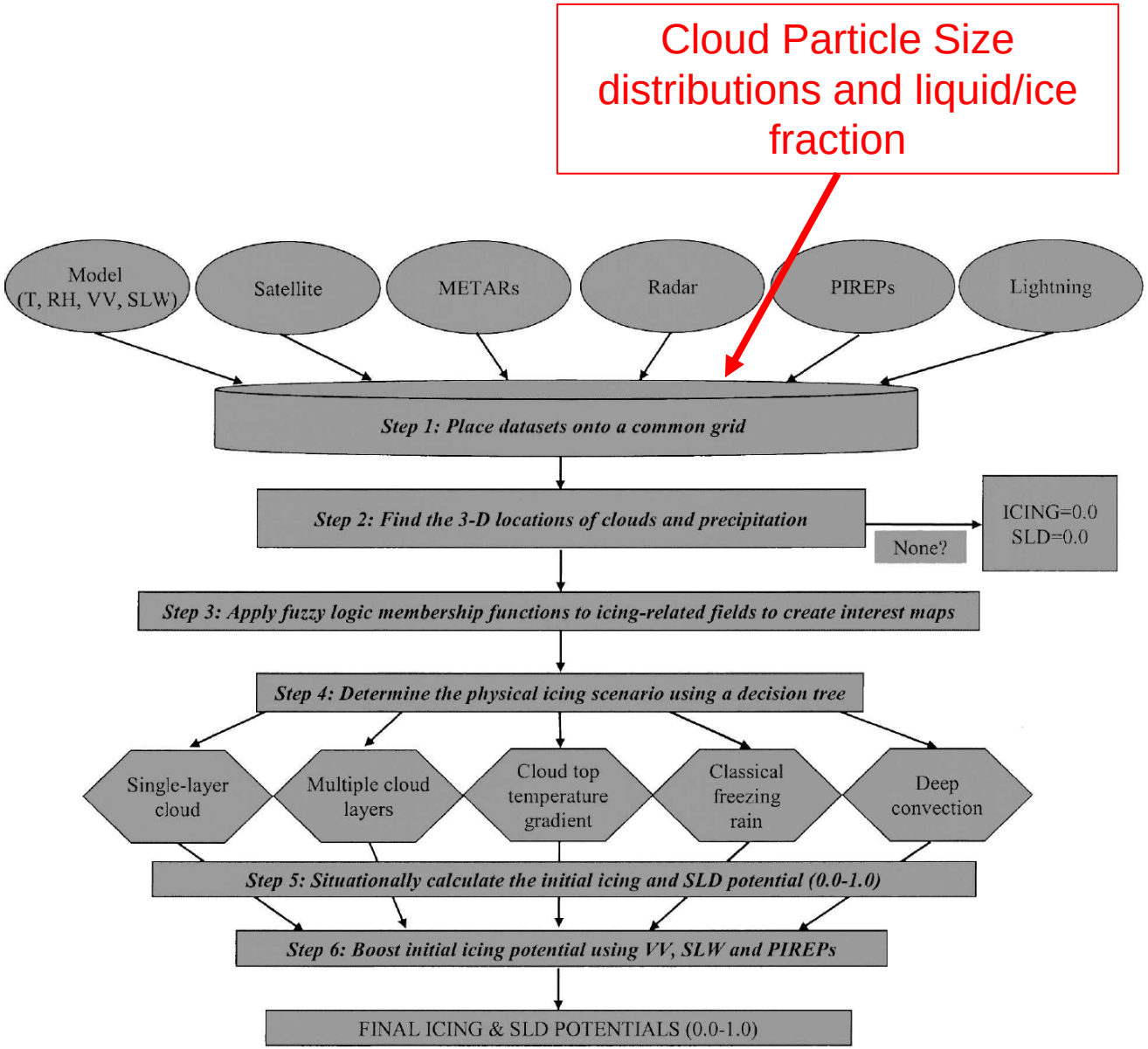
- Complementary information for flight crew interpretation of temperature and airspeed sensors. Presence of high ice crystal concentrations alerts flight crew to potential for sensor degradation.

- Aircraft black box information on cloud conditions?

- Information for ice mass (or volcanic ash) loading on engines.

- Complementary information to improve forecasts of Current Icing Potential (CIP)

Bernstein et al., 2005: Current Icing Potential: Algorithm Description and Comparison with Aircraft Observations, JAM, 44



Challenges

- Cost of integration on aircraft (STC, Interface with satellite link, data format, etc.).
- Acceptance by aircraft industry.
- Modification of models to assimilate and utilize cloud measurement information.
- Sensor maintenance.

Thank you for Listening

Photo Courtesy China Airlines