Presented by

Alice Grandin, Airbus
alice.grandin@airbus.com

Prepared by

F.Dezitter, A.Grandin, Airbus & HAIC Consortium

HAIC - High Altitude Ice Crystals
Lycée Henri Matisse Project

International Field Campaign Follow-up

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HAIC & Lycée Henri Matisse Project
Content

- HAIC – High Altitude Ice Crystals
- HAIC SP2 – High IWC F/T Campaigns
- International Field Campaign Location Selection
- International Field Campaign Preparation
- Next steps

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HAIC Context

- Commercial aircraft have been experiencing **jet-engine powerloss events** while flying in the vicinity of deep convective cloud since at least the early 1990s.

- In 2004, the **Engine Harmonization Working Group** (EHWG) was established to look at the effects of supercooled large droplets and glaciated and mixed phase icing conditions on engines. This working group established that this suspected engine icing phenomenon was present in both commuter and large transport category aircraft, and in all types/manufacturers of engine. It proposed a **draft of regulation to FAA/EASA in 2009.**

- This new envelope is for the moment dedicated to Engines, but should be **applicable soon to other Aircraft equipments as Air Data Probes** (Eurocae WG89 is working on an update of ETSO C16a, SAE AC-9C on update of AS8006).

The whole aeronautical industry needs to anticipate the **regulation change**, and to develop acceptable **means of compliance.**

In coordination with airworthiness authorities, engine manufacturers, systems suppliers, airframers, research institutes and universities, HAIC - High Altitude Ice Crystals L2 project was submitted on 1st December 2011, successfully evaluated by the European Commission and officially started on 1st August 2012.

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HAIC Top Level Objectives

- **HAIC** (High Altitude Ice Crystals) is a 4 years integrated project comprising 34 partners representing the European stake-holders of the aeronautical industry from eleven European countries and 5 partners from Australia, Canada and the United States

- The goals of HAIC are
  - **To face challenges related to the evolution of regulation according to mixed phase and glaciated icing conditions** by characterising high IWC environments and developing the Acceptable Means of Compliance (test facilities and numerical tools),
  - **To improve aircraft operation** by developing appropriate detection and awareness technologies to be fitted on aircraft and able to alert the flight crew when an aircraft is flying in and **to continuously enhance international flight safety**

- HAIC is also promoting **international cooperation and collaboration** thanks to the involvement of key international organizations and companies as partners of the project or through the **HAIC Advisory Board**.

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HAIC Technical Objectives

Different technical aspects have to be studied to allow compliance with new rule (1/2):

- **Characterize, optimize, enhance and select the most sophisticated cloud microphysics probes** to measure mixed phase and glaciated icing conditions during flight tests and to calibrate icing wind tunnels.
- **Measure and Characterize the microphysical properties of core or near-core regions of deep convective clouds,** including cloud liquid and ice water contents, particle size distributions and particle shapes.
- **Upgrade European icing wind tunnels to allow reproduction of mixed phase and glaciated icing conditions** to allow the Aeronautical industry performing qualification of equipments..
- **Understand and model involved physical phenomena** and **Develop numerical tools** to simulate the impact of mixed phase and glaciated icing conditions on aircraft components (mainly engines and probes) for supporting both design and certification phases.

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HAIC Technical Objectives

Different technical aspects have to be studied to allow compliance with new rule (2/2):

- **Develop and validate mixed phase and glaciated icing conditions awareness and detection technologies** to alert the crew of flight in these particular icing conditions or to adapt the flight path well in advance in order to avoid such weather conditions.
- Assess the proposed mixed phase and glaciated icing environment as defined in Appendix D and P in light of the analysis of the research flight tests performed as part of the HAIC project and **provide recommendations to regulatory bodies.**.

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HAIC WBS

- The work is split into 7 sub-projects:

SP7 Consortium Management, Technical Management and Integration
- WP7.1 : Strategic & Technical Management
- WP7.2 : Consortium Administration
- WP7.3 : Dissemination & Plans for exploitation

SP1 Instrumentation
- WP1.1 SP1 Coordination
- WP1.2 Instrumentation Specification
- WP1.3 Selection of instrumentation for F/T Campaigns
- WP1.4 Selection of instrumentation for IWT calibration
- WP1.5 Intercomparison of F/T and IWT/T instrumentation

SP3 Spaceborne Observation & Nowcasting of High IWC regions
- WP3.1 SP3 Coordination
- WP3.2 Geostationary spaceborne retrievals of High IWC
- WP3.3 Polar orbiting spaceborne retrievals of High IWC
- WP3.4 Nowcasting of tropical convection

SP4 High IWC Detection & Awareness Technology
- WP4.1 SP4 Coordination
- WP4.2 Awareness & Detection Technology specification
- WP4.3 Awareness System Development (Radar)
- WP4.4 Detection System Development

SP6 High IWC Tools & Simulation Development
- WP6.1 SP6 Coordination
- WP6.2 Tools Specification
- WP6.3 Ice particles trajectory model
- WP6.4 Ice particles impingement model
- WP6.5 Ice particles accretion model
- WP6.6 Integration into industrial environment
- WP6.7 Capability Assessment

SP5 High IWC Test capability Enhancement
- WP5.1 SP5 Coordination
- WP5.2 Test capability specification
- WP5.3 Technology ice crystal generation
- WP5.4 Calibration of test facilities
- WP5.5 WT/T for technology validation

SP2 High IWC F/T Campaigns
- WP2.1 SP2 Coordination
- WP2.2 F/T for High IWC characterization
- WP2.3 F/T for validation of new technologies
- WP2.4 Microphysical properties of HighIWC regions

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HAIC Results

- The results of this work will provide (1/3):
  - A **characterization of the microphysical properties of core or near-core regions of deep convective clouds** based on a unique flight test dataset in deep oceanic convective storms.
  - A set of experimental and numerical capabilities as **Acceptable Means of Compliance (AMC)** for the qualification and certification of future aircraft products (mainly probes and engines)
    - **Four complementary upgraded European icing test facilities (TRL6)** with improved representativeness of simulated mixed phase and glaciated icing conditions and covering the whole flight and icing envelope (Low speed / High speed ; Sea level / Altitude),
    - A **unique numerical model** for ice particle trajectory, impingement and accretion and **mature research and industrial simulation tools (TRL6)** to support pre-design, design and certification of equipments and systems (mainly engine and probes).

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HAIC & Lycée Henri Matisse Project
HAIC Results

- The results of this work will provide (2/3):
  - A set of **awareness and detection technologies** to be fitted on aircraft and able to alert the flight crew when an aircraft is flying in such weather conditions.
    - A **pre-operational space-borne remote detection and nowcasting application of glaciated icing conditions (TRL6)** based on imagery of geostationary MSG-SEVIRI satellite observations, validated with space-borne active and passive cloud observations from LEO and GEO missions and integrated into a pre-operational application for detection of Rapidly Developing Thunderstorm (RDT),
    - An **upgraded on-board weather radar (TRL6)**, based on current state-of-the-art X-band airborne weather radar equipment, to raise awareness to the flight crew of the encounter of glaciated icing conditions and ultimately to adapt well in advance the flight path to avoid such weather conditions
    - **Two to four mixed phase and glaciated icing conditions detectors (TRL6)**, depending on selection performed as part of the project, to alert the crew of flight in these particular icing conditions

HAIC

- The results of this work will provide (3/3):
  - An **assessment of the relevance of the proposed mixed phase and glaciated icing environment** as defined in Appendix D and P and a **set of recommendations** to regulatory bodies (EASA/FAA) in light of the atmosphere characterization performed as part of the project

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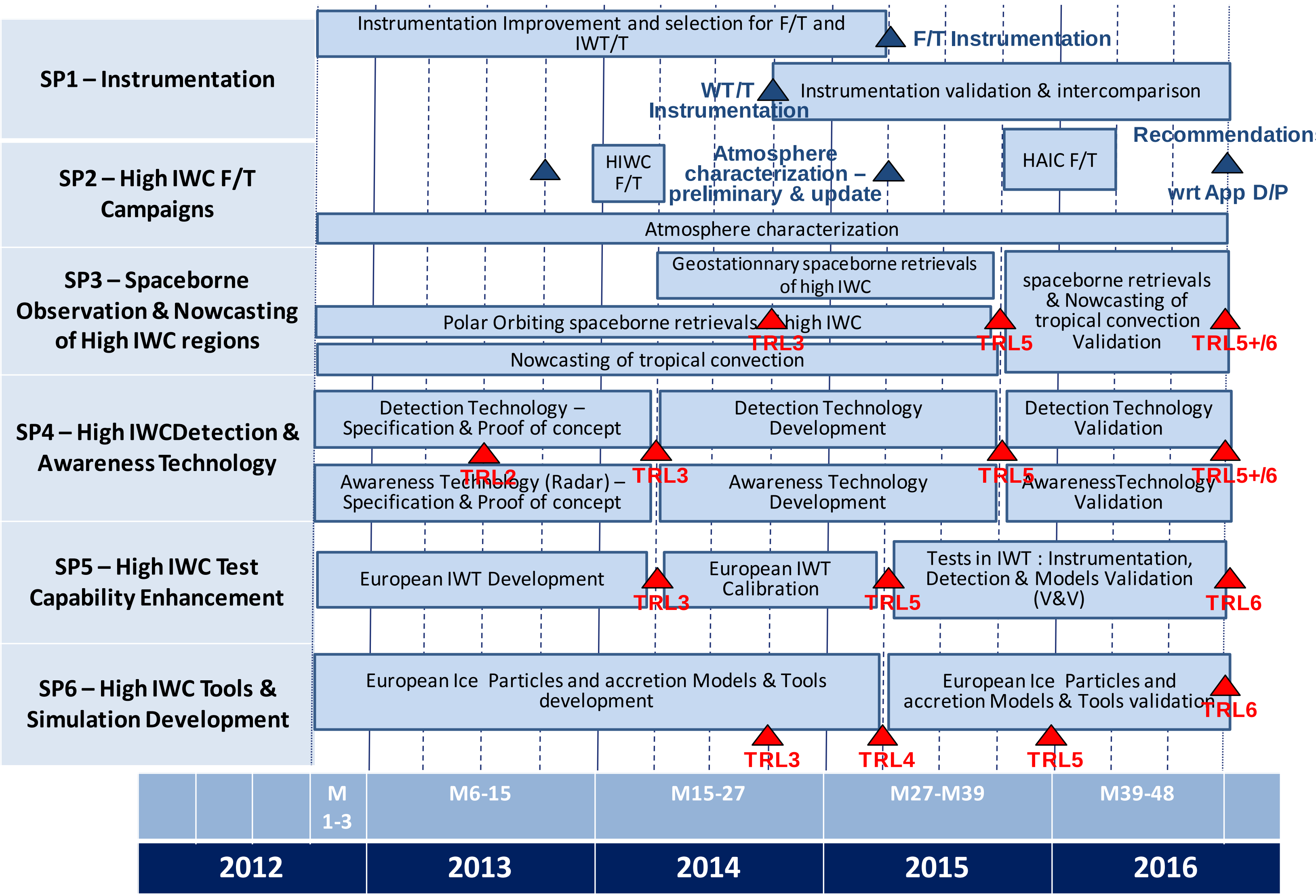
HAIC Roadmap



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HAIC Partners

AIRBUS
SAFRAN Snecma
CIRA
ONERA THE FRENCH AEROSPACE LAB
DGA
DASSAULT AVIATION
EADS
TECHNISCHE UNIVERSITÄT DARMSTADT
CNRS CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE
THALES
DLR
METEO FRANCE Toujours un temps d'avance

Executive Board

Australian Government Bureau of Meteorology
Esterline
IRSN INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE
SEA
Cranfield UNIVERSITY
VON KARMAN INSTITUTE
Rockwell Collins Building trust every day
INCAS
Honeywell
Koninklijk Nederlands Meteorologisch Instituut Ministerie van Infrastructuur en Milieu
NLR
ATMOSPHERE
TAI
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Technische Universität Braunschweig
PIAGGIO AERO
GKN
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Environment Canada
Met Office

Advisory Board

HAIC

HAIC & Lycée Henri Matisse Project
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- **HAIC SP2 – High IWC F/T Campaigns**
  - **Overview**
  - **Objectives, Activities & Expected Results**
  - **WBS and Roadmap**
  - **Technical Focus: International Field Campaign**

- International Field Campaign Location Selection
- International Field Campaign Preparation
- Next steps

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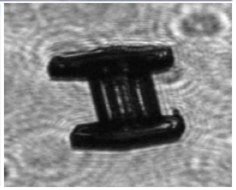
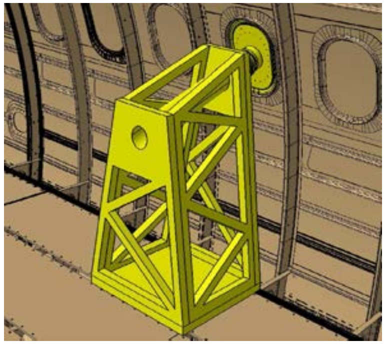
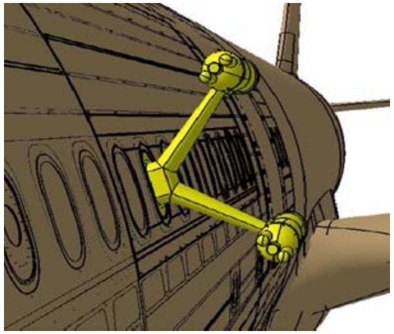
HAIC SP2 Overview

- **Measure and Characterize the microphysical properties of core or near-core regions of deep convective clouds,** including cloud liquid and ice water contents, particle size distributions and particle shapes.

- **Validate mixed phase and glaciated icing conditions awareness and detection technologies** to alert the crew of flight in these particular icing conditions or to adapt the flight path well in advance in order to avoid such weather conditions



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HAIC SP2 Objectives, Activities & Expected Results

SP2 High IWC Flight tests Campaigns

Lead: Airbus
Partners: AI-F, AI, AI-D, BoM, CNRS, CIRA, DASSAV, ATM, DLR, INCAS, ONERA

Objectives

- Organize, manage and conduct two flight test campaigns in 2014 and in 2016.
  - In the first flight test campaign planned Q1 2014, it brings an aircraft equipped with active remote sensing (airborne Doppler cloud radar) and in situ microphysics probes with the primary objective to provide 99th percentile total water content statistics, as a function of distance scale, to industry and regulators
  - In the second flight test campaign, SP2 brings for the first time a Flying Test Platform (large payload and long endurance Airbus flight test A/C) to the industrial and scientific community for validation and demonstration of the maturity of the technologies (up to TRL6) developed within HAIC project
- Characterize the microphysical properties of High IWC regions

Main Activities

- Prepare and Conduct two field experiments (HAIC/HIWC International F/T campaign in Q1 2014 & Airbus F/T campaign in Q1/2 2016)
- Process aircraft data and retrieve geophysical parameters from the two experiments
- Statistical analysis of aircraft data to assess Appendix D/P
- Support to maturity demonstration of SP1 / SP4 technologies

Main Expected Results

- Comprehensive characterization of High IWC regions and assessement of Appendix D/P
- Demonstration in representative environment of the performances of the technologies developed as part of SP1 (instrumentation) and SP4 (detection system, radar)

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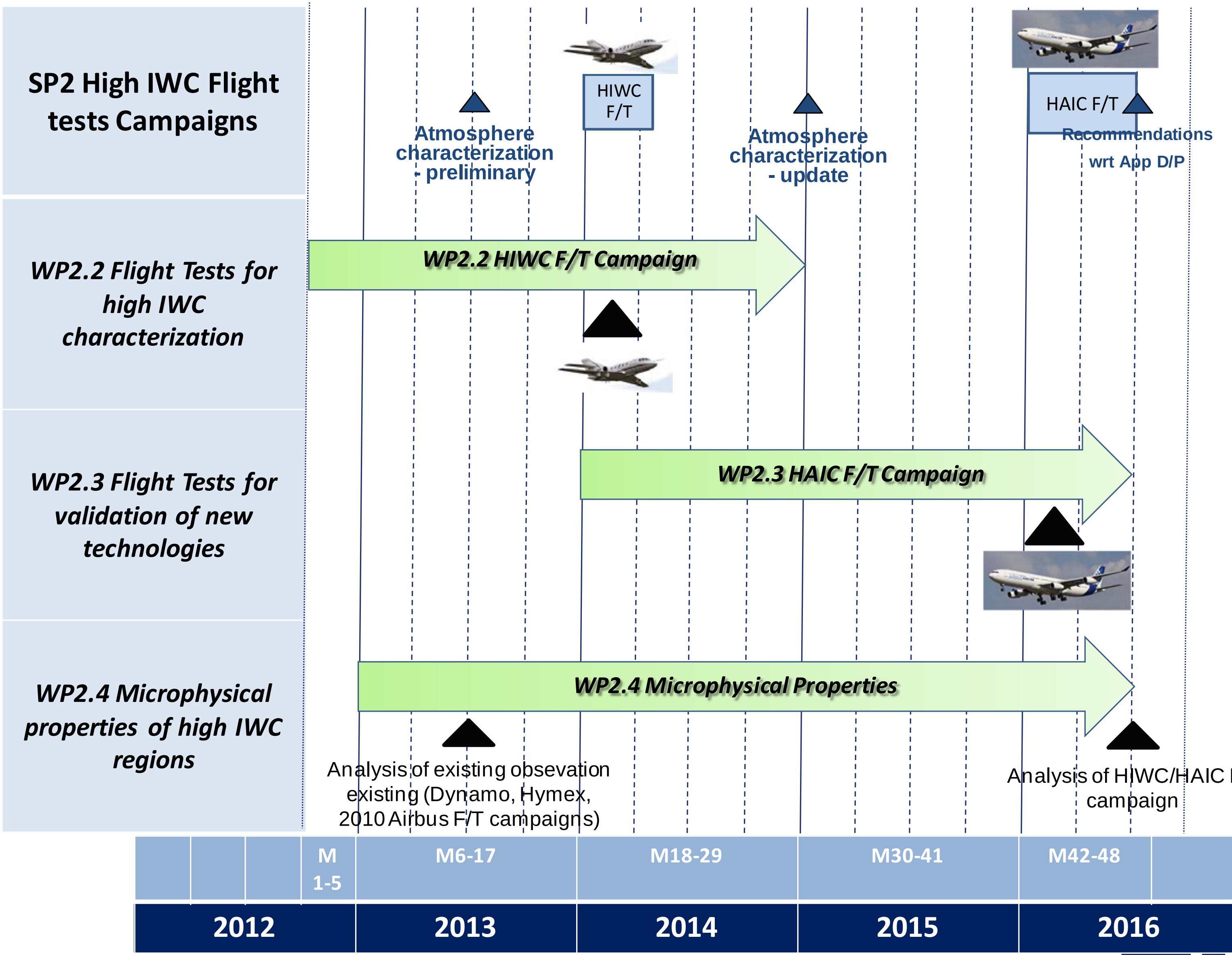
HAIC SP2 WBS and Roadmap



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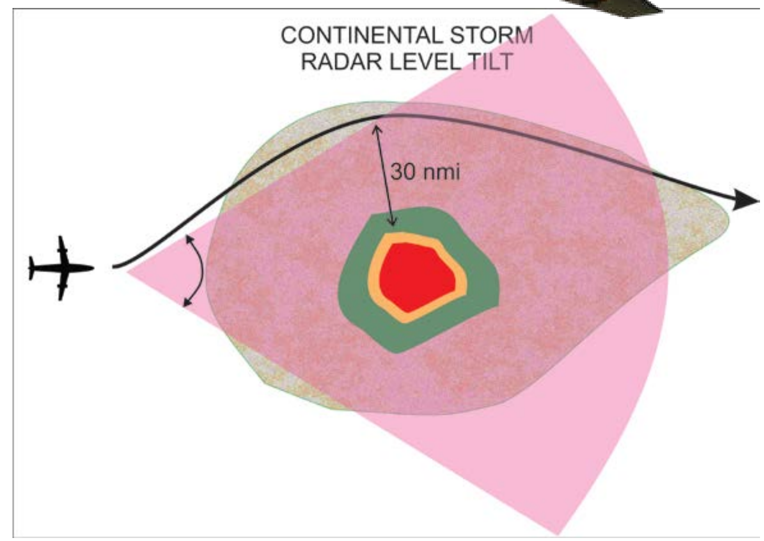
HAIC SP2 Technical focus: International field campaign

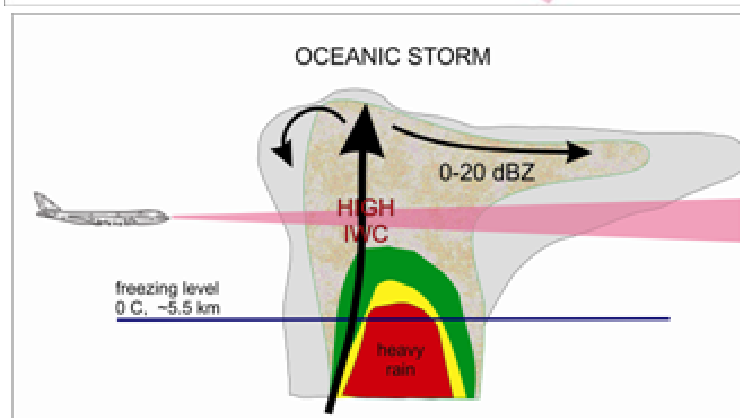
- An **international HAIC/HIWC field campaign** planned Q1 2014 (2 months campaign / 200F/H incl. ferry flight)

- Primary objective is to provide **99th percentile total water content statistics**, as a function of distance scale, to industry and regulators



- **Two types of convection** for sampling :
  - Oceanic convection (primary focus)
  - Continental convection (secondary focus)

- **Three flight levels** for sampling:
  - -50°C: a typical cruise altitude for commercial jet aircraft
  - -30°C: a mid-altitude with possibly intermediate particle size
  - -10°C: a low flight level to sample the cloud just above the melting layer



Courtesy of HIWC

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HAIC SP2 Technical focus: International field campaign

- The field campaign is the result of an **international collaboration** between the HAIC and HIWC projects and involves necessary **expertise** in a wide range of skills and the **main stakeholders** in the field, whether they are based in Europe, North America, Australia or Japan.

HAIC / EASA	HIWC
•SAFIRE Falcon 20 & 130F/H	•70F/H
•Set of instrumentation (CDP, 2D-S, PIP, CPI, HSI, Robust,…), Cloud remote sensing (RASTA)	•IKP as reference TWC meas., SEA IWC/ICD, spare probes (CDP, 2D-S,…)
•Remote support for Nowcasting	•Nowasting / Forecasting
•Logistics (A/C)	•Logistics (nowcasting / forecasting, offices,…)
A shared management of the field campaign PI HIWC: W.Strapp / PI HAIC: A.Schwarzenboeck	

HAIC
High Altitude Ice Crystals

Federal Aviation Administration

European Aviation Safety Agency

National Aeronautics and Space Administration

Environment Canada

Transport Canada

NRC-CNRC Aerospace

CSIRO

Australian Government Bureau of Meteorology

NCAR

SEA

HAIC & Lycée Henri Matisse Project
HAIC SP2 Technical focus: International field campaign

- A total of **200F/H** are expected. They include:
  - 50F/H for ferry flight from and to Toulouse
  - 150F/H on site for atmosphere sampling

- A **complex funding organisation**
  - 100F/H funded by HAIC
  - 70F/H funded by FAA
  - 30F/H funded by EASA

HAIC High Altitude Ice Crystals

Federal Aviation Administration

European Aviation Safety Agency

National Aeronautics and Space Administration

Environment Canada

Transport Canada

NRC-CNRC Aerospace

CSIRO

Australian Government Bureau of Meteorology

NCAR

SEA

HAIC & Lycée Henri Matisse Project
HAIC SP2 Technical focus: International field campaign

- The purpose of these tests is to collect cloud data in deep convective clouds to fulfil the **industry and scientific objectives** below, as outlined in the HIWC Science Plan and the HAIC DoW.

- Industry objectives

Industry Objectives	HAIC	HIWC	Priority
E1: Characterize 99th percentile TWC and particle size for FAA/EASA regulatory objectives	**X**	**X**	**P0**
E2: Flight-Deck Recognition of the High-IWC Environment Incl. IDS & WXR	X (partially)	X (partially)	P2
E3: Development of Tools to Nowcast the High-IWC Environment	**X (partially)**	**X**	**P1**

HAIC & Lycée Henri Matisse Project
HAIC SP2 Technical focus: International field campaign

- Science objectives

Science Objectives	HAIC	HIWC	Priority
S1: Characterize the microphysical and thermodynamic properties of core or near-core regions	**X**	**X**	**P1**
S2: Determine the small ice particle formation mechanisms and importance to bulk microphysical properties	X	X	P2
S3: Determine the temporal and spatial evolution of the mixed-phase	X	X	P2
S4: Validate and improve ground remote sensing algorithms of cloud properties		X	P2
S5: Validate and improve satellite remote sensing algorithms of cloud properties	**X (partially)**	**X**	**P1**
S6: Improve cloud resolving model simulations		X	P2
S7: 3D high-resolution characterization of the dynamical and microphysical properties of ice clouds (RASTA / T-Matrix)	**X**	**X**	**P1**

HAIC

Master Schedule

The field campaign will take place from **January 15, 2014 to March 14, 2014 (2 months campaign)**

Items	Schedule
Falcon 20 ferry flight from Toulouse	January 8 to January 12, 2014
Instruments installation, Power ON and Ground tests	January 13 to January 14, 2014
Start of the campaign	January 15, 2014
Preliminary F/T in dry air and high IWC regions	*January 15 to January 17, 2014*
HAIC/HIWC Field Campaign	*January 18 to March 14, 2014*
End of the campaign	March 14, 2014
Instruments unmounting	March 15 to March 16, 2014
Falcon 20 ferry flight back to Toulouse	March 17 to March 21, 2014

HAIC & Lycée Henri Matisse Project
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  - **Operational constraints**
  - **Location Selection**

- International Field Campaign Preparation
- Next steps

HAIC

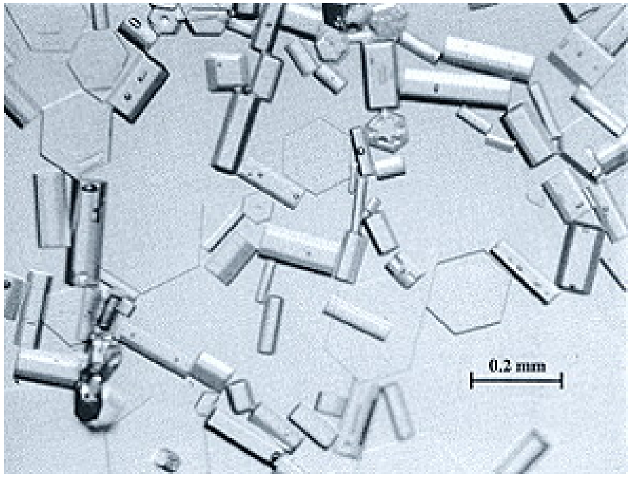
- What are we looking for?

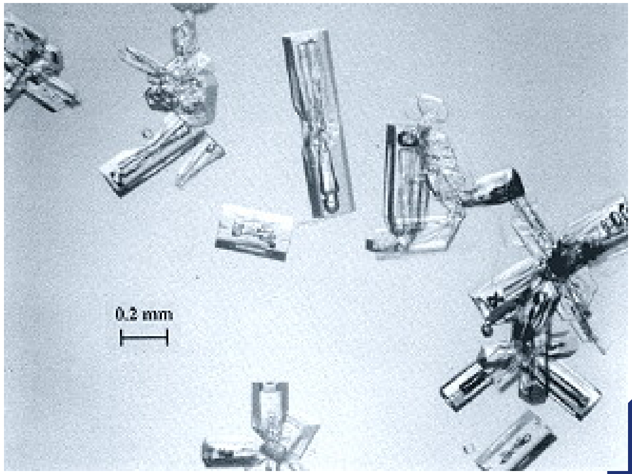
Ice Crystals in Atmosphere

- What is an ice crystal?

Ice crystals are various macroscopic crystalline formations with a basic hexagonal symmetry, depending on the condition of temperature and vapour pressure. Ice crystals are common in the atmosphere with the high clouds being formed almost entirely of ice crystals. Ice crystals are created by the formation of a crystalline structure about microscopic nuclei or by the freezing of very small supercooled droplets.

Ice particles may be in the form of individual ice crystals, aggregates of crystals such as snowflakes, or crystals that have collided with supercooled water droplets to form more dense and spherical particles such as graupel and hail. Ice particles can span a very large size range, from microns to centimeters.



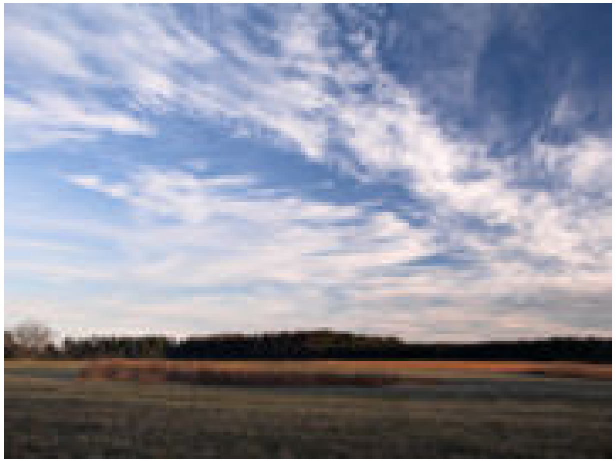


- Where can we find ice crystals?

Ice particles are mainly encountered in high levels of atmosphere (above the freezing level estimated at ~20000 ft for a standard atmosphere).

This means that ice particles are present in:

- high altitude clouds (cirrus, cirrostratus, cirrocumulus),
- aircraft contrails (condensation trails – artificial cirrus clouds) ,
- deep convective complexes (anvils of thunderstorms, tropical storms…)



Pending on Ice Water Content (IWC) of these clouds, the encountered conditions will have more or less important consequences on Aircraft.

High altitude clouds (cirrus, cirrostratus, cirrocumulus)

Typical values and measured ranges of the physical and optical properties of Cirrus clouds:

Property	Typical	Measured range
Cloud base height*	12 km	6-18 km
Cloud thickness*	1.5 km	0.1 to 3 km
Cloud center altitude*	13 km	6 to 18 km
Crystal concentration	30 L^{-1}	10^{-4} to 10^{4} L^{-1}
Ice water content	0.025 gm^{-3}	10^{-4} to 1.2 gm^{-3}
Crystal length	250 mm	1 to 8000 mm
Extinction coefficient*	0.08 km^{-1}	0.03 to 0.3 km^{-1}
Optical depth*	0.063	0.01 to 0.2
Temperature	– 70 °C	–20 °C to – 80 °C

(* Obtained using Multiwavelength lidar system[1] located at Space Physics Laboratory, VSSC, Trivandrum)

Other high altitude clouds have got equivalent IWC.

International research is working on cloud resolving models to be able to predict clouds physical properties (for example Crystal-Face NASA research project) and to anticipate climate evolutions.

High altitude clouds are almost well known (even if cloud resolving models are still evolving) and their IWC is very low. Therefore, they cannot be at the origin of ice particles icing issues.

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International Field Campaign Location Selection

Aircraft Contrails (Condensation Trails)

Models have been developed by international research to characterize contrails.

These models can be used to predict whether contrails will form or not under reported meteorological conditions at flight altitude. They give the minimum relative humidity (with respect to water per conventional standard) that is required at flight altitude for contrails to form.

They also give the expected size of ice particles emitted from aircraft ranges. Results are between 30 and 200 microns.

IWC of contrails are directly linked to the emission of water vapour from the aircraft (main contributors are the engines) but also depends on temperature. Results indicate that the IWC in contrails is very low (around 0,03g/m3). Therefore, they cannot be at the origin of ice particles icing issues.

All these research projects have been launched in order to model Earth Climate and the Albedo of clouds and contrails. (for Global Warming research)

HAIC & Lycée Henri Matisse Project
International Field Campaign Location Selection

<u>Deep Convective Complexes (Anvils of Thunderstorms, Tropical Storms…)</u>

Convective weather is caused by deep lifting and condensation of air in an unstable atmosphere, something resulting in one or more of the following:

- Deep cloud and large anvil regions
- Areas of strong wind shear and turbulence
- Lightning
- High condensed water contents
- Heavy precipitation and hail

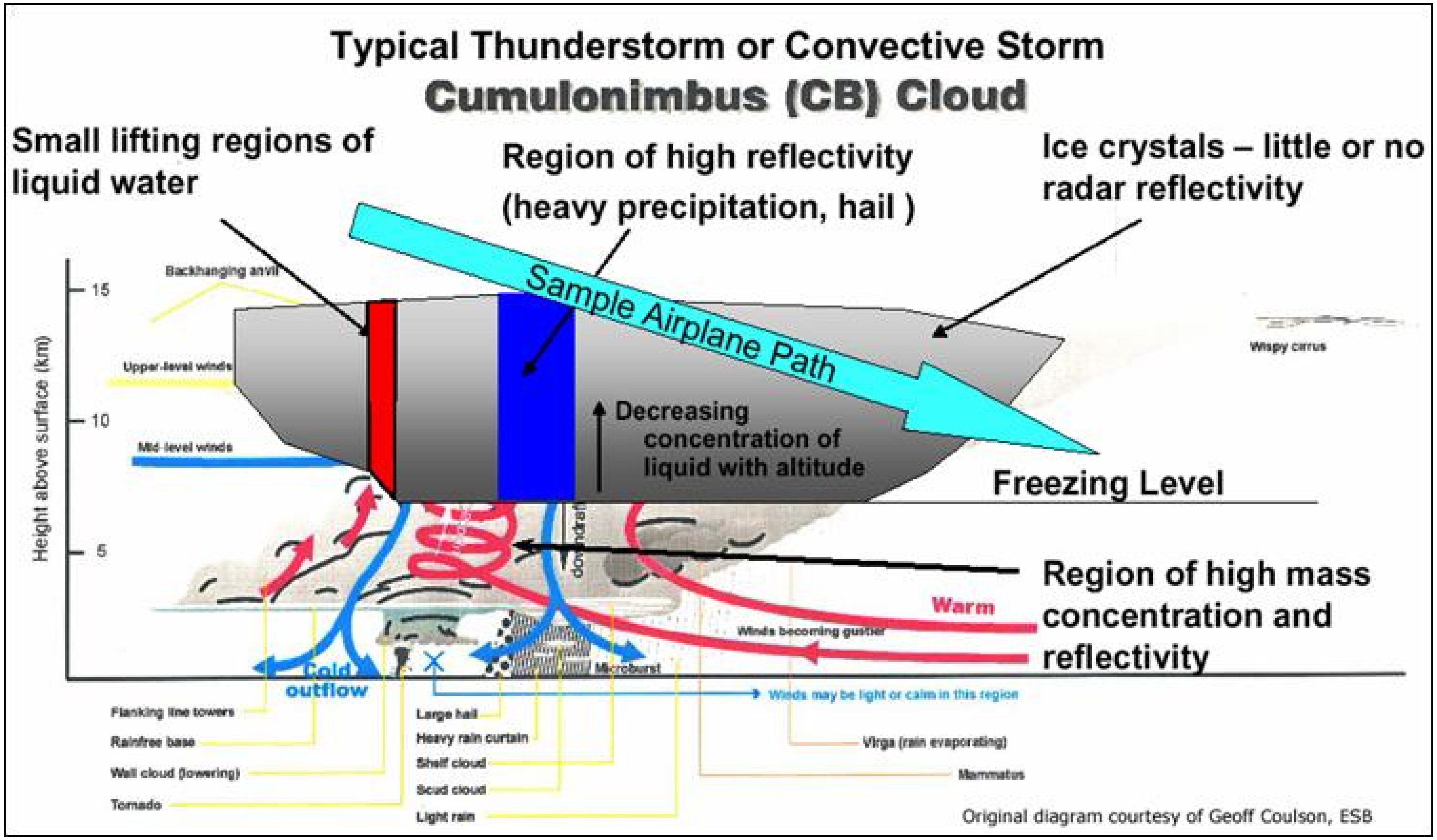



Deep convective clouds can be found on a variety of scales:

- Isolated Cumulonimbus (CB), often thunderstorms, and can be thought of as the building block for convective weather.
- CBs can organize into mesoscale convective complexes (MCCs) and squall lines, spanning hundreds of miles.
- Tropical storms are usually composed of convective elements rotating around a central low pressure center, leading to vast areas of mid-to-high altitude cloud ejected from convective cores.
- More severe tropical storms are known as hurricanes or typhoons convective weather.

Deep Convective Complexes (Anvils of Thunderstorms, Tropical Storms…)

Diagram of ice particles in a convective cloud:



Above the freezing level, the convective cloud may be dominated by small ice particles. (and/or mixed phase conditions)

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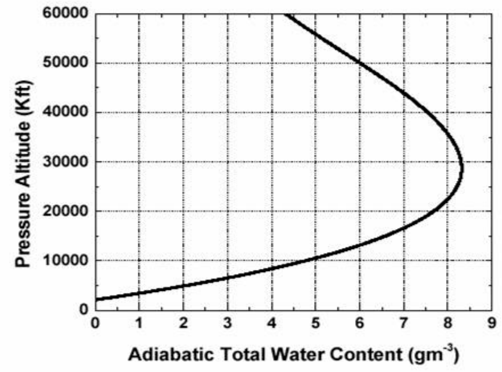
International Field Campaign Location Selection

Deep Convective Complexes (Anvils of Thunderstorms, Tropical Storms…)

Deep convective clouds can contain deep updraft cores that transport low-level air high into the atmosphere, during which water vapor is continually condensed as the temperature drops. In doing so, these updraft cores may produce localized regions of high liquid water content (LWC) and/or ice water content (IWC).

The IWC reaches a **maximum of about 9 g/m^3** at around 30,000 feet, and thereafter decreases with altitude.



Calculated adiabatic TWC in an air parcel, for a surface temperature of 35° C and a dewpoint of 30° C

These ice particles are invisible for onboard weather radar and or not detected by ice detectors. When flying in these conditions, pilot will see visible moisture but no airframe icing, and ice particles will look like rain on the windshield.

Due to high Ice Water Content (IWC) of these clouds, the encountered conditions may have important consequences on Aircraft.

HAIC

HAIC & Lycée Henri Matisse Project
International Field Campaign Location Selection

- What are the campaign objectives?

Industry Objectives	HAIC	HIWC	Priority
E1: Characterize 99th percentile TWC and particle size for FAA/EASA regulatory objectives	**X**	**X**	**P0**
E2: Flight-Deck Recognition of the High-IWC Environment Incl. IDS & WXR	X (partially)	X (partially)	P2
E3: Development of Tools to Nowcast the High-IWC Environment	**X (partially)**	**X**	**P1**

Science Objectives	HAIC	HIWC	Priority
S1: Characterize the microphysical and thermodynamic properties of core or near-core regions	**X**	**X**	**P1**
S2: Determine the small ice particle formation mechanisms and importance to bulk microphysical properties	X	X	P2
S3: Determine the temporal and spatial evolution of the mixed-phase	X	X	P2
S4: Validate and improve ground remote sensing algorithms of cloud properties		X	P2
S5: Validate and improve satellite remote sensing algorithms of cloud properties	**X (partially)**	**X**	**P1**
S6: Improve cloud resolving model simulations		X	P2
S7: 3D high-resolution characterization of the dynamical and microphysical properties of ice clouds (RASTA / T-Matrix)	**X**	**X**	**P1**

HAIC

- TRMM Products

The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA) designed to monitor and study tropical rainfall.

Among TRMM products, one gives interesting data for campaign location selection: **RAINFALL CLIMATOLOGY PRODUCT.**

Images hereafter are the result of averaging all available monthly 0.25°x 0.25° 3B43 merged TRMM and Other sources estimates. The images cover the globe from 50° North to 50° South.

http://trmm.gsfc.nasa.gov/trmm_rain/Events/trmm_climatology_3B43.html

HAIC & Lycée Henri Matisse Project
International Field Campaign Location Selection

- <u>TRMM Products</u>

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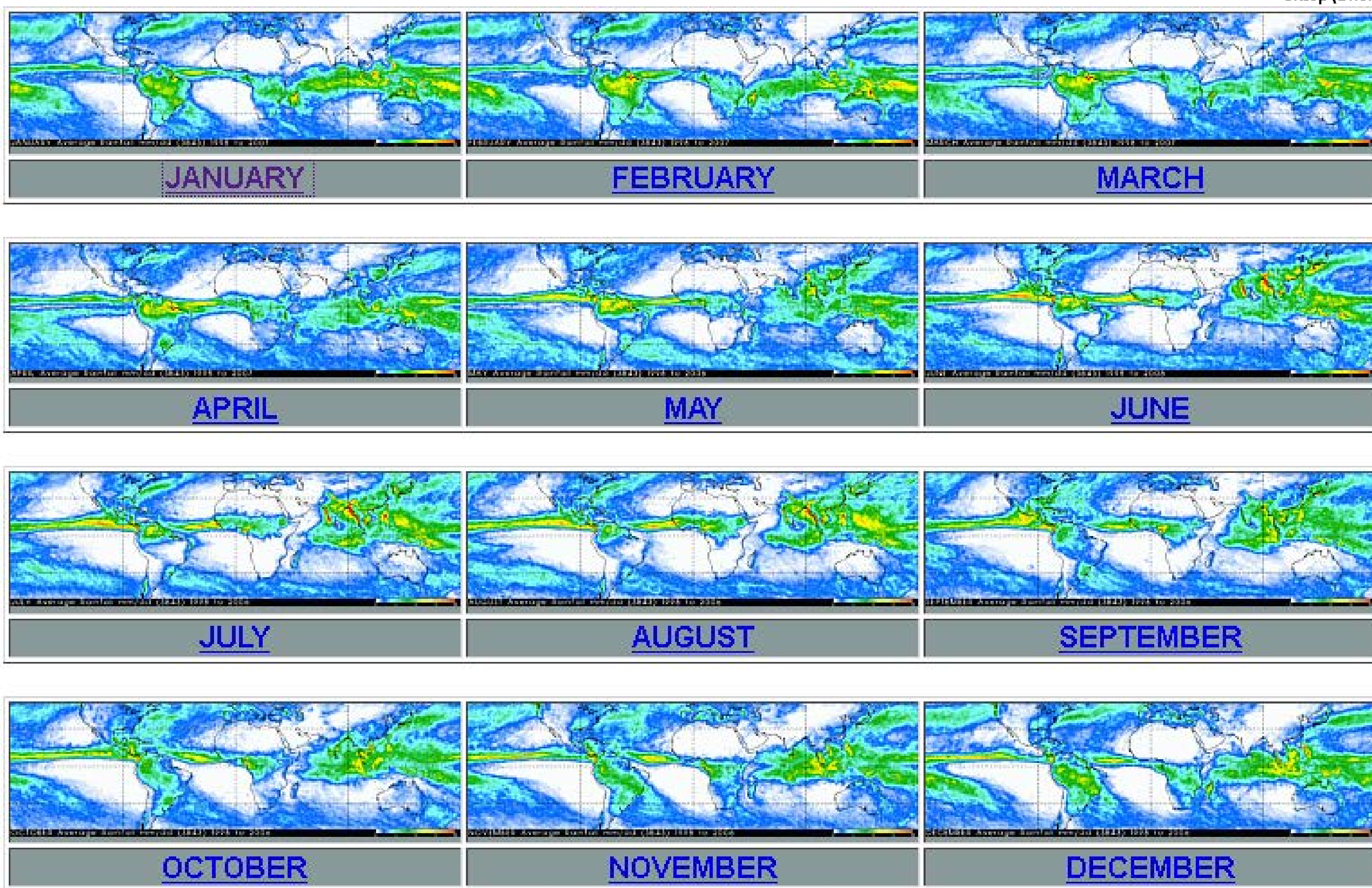

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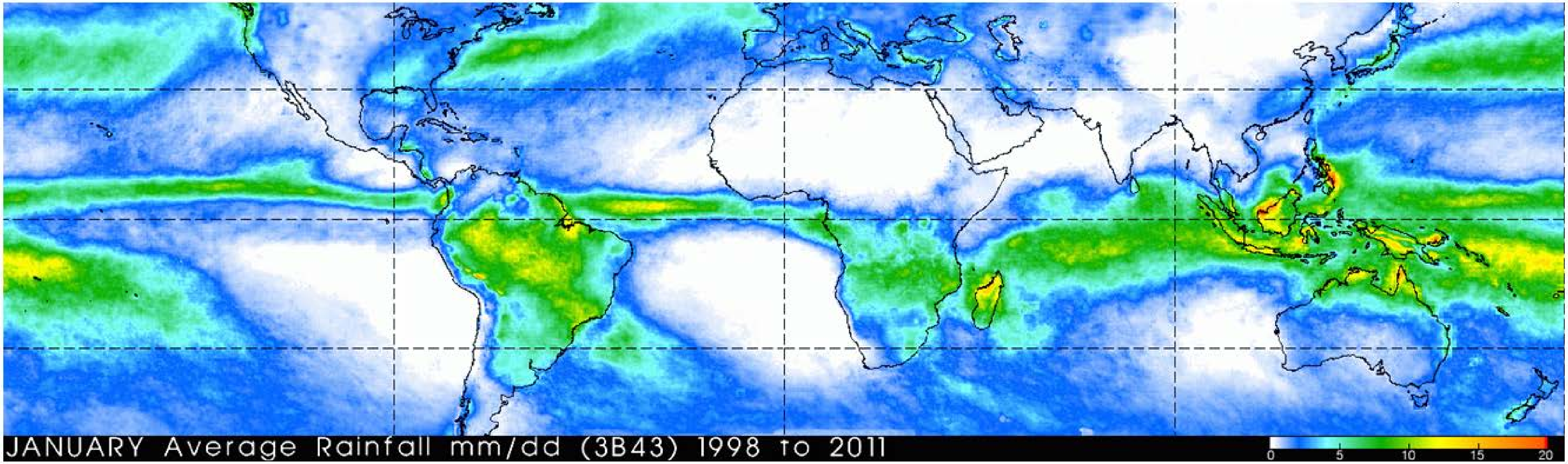
International Field Campaign Location Selection

- <u>TRMM Products</u>



HAIC

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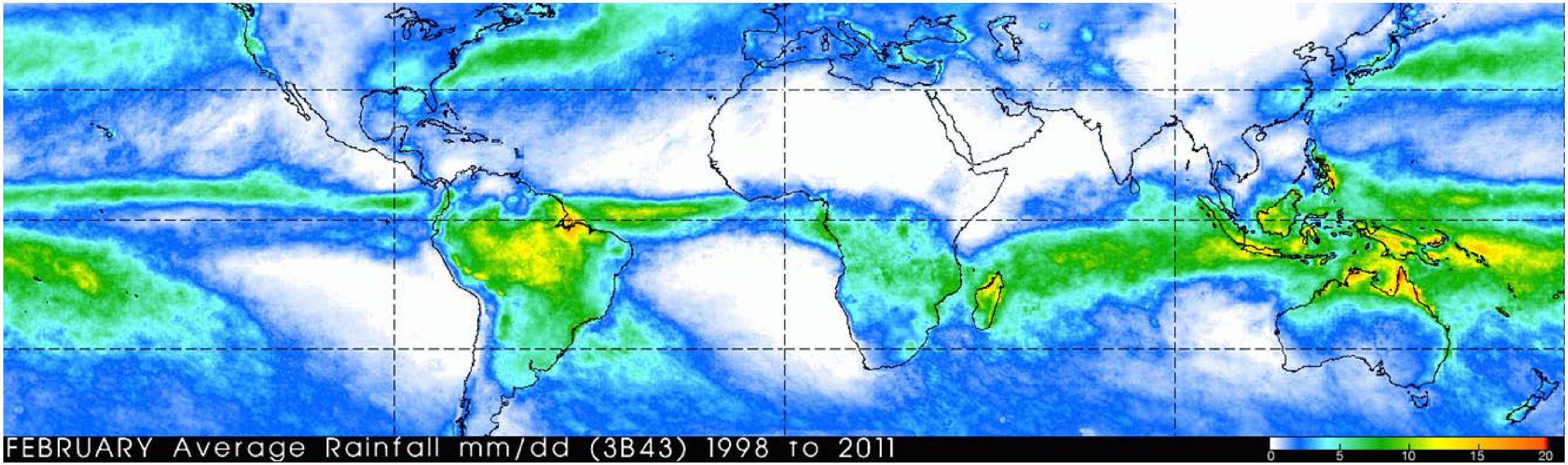
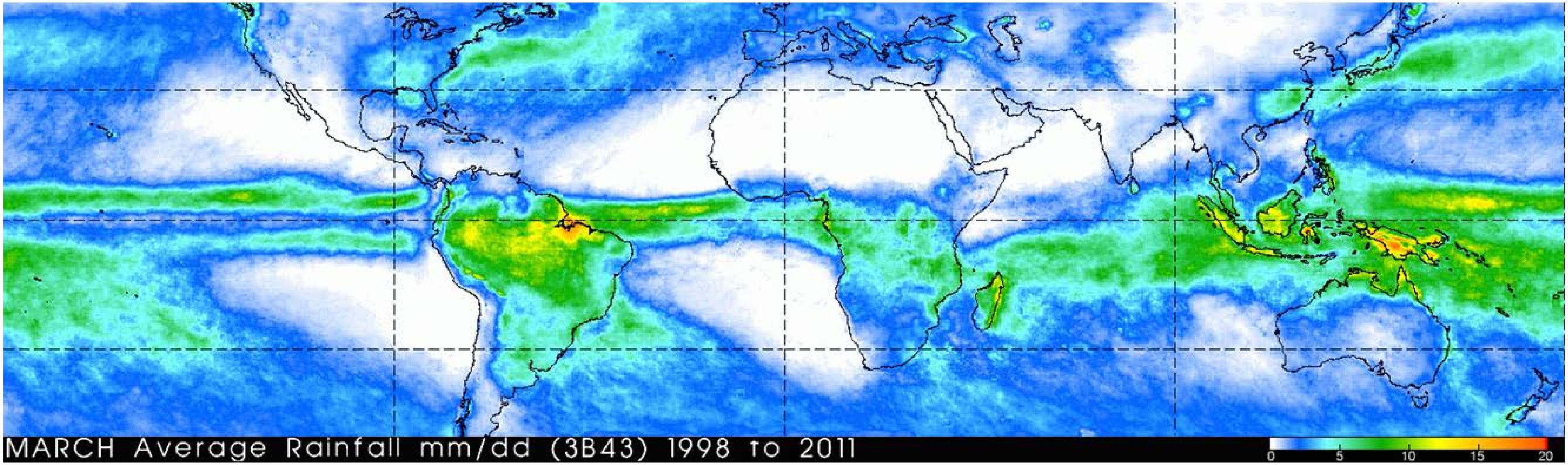
International Field Campaign Location Selection

- <u>TRMM Products</u>



HAIC & Lycée Henri Matisse Project
International Field Campaign Location Selection

- <u>TRMM Products</u>



- <u>Operational Constraints</u>

What are operational constraints that need to be considered for campaign location selection?

Need for easy flight planning and relations with ATC (unique FIR).

Need for ground facilities

Need for meteorological support

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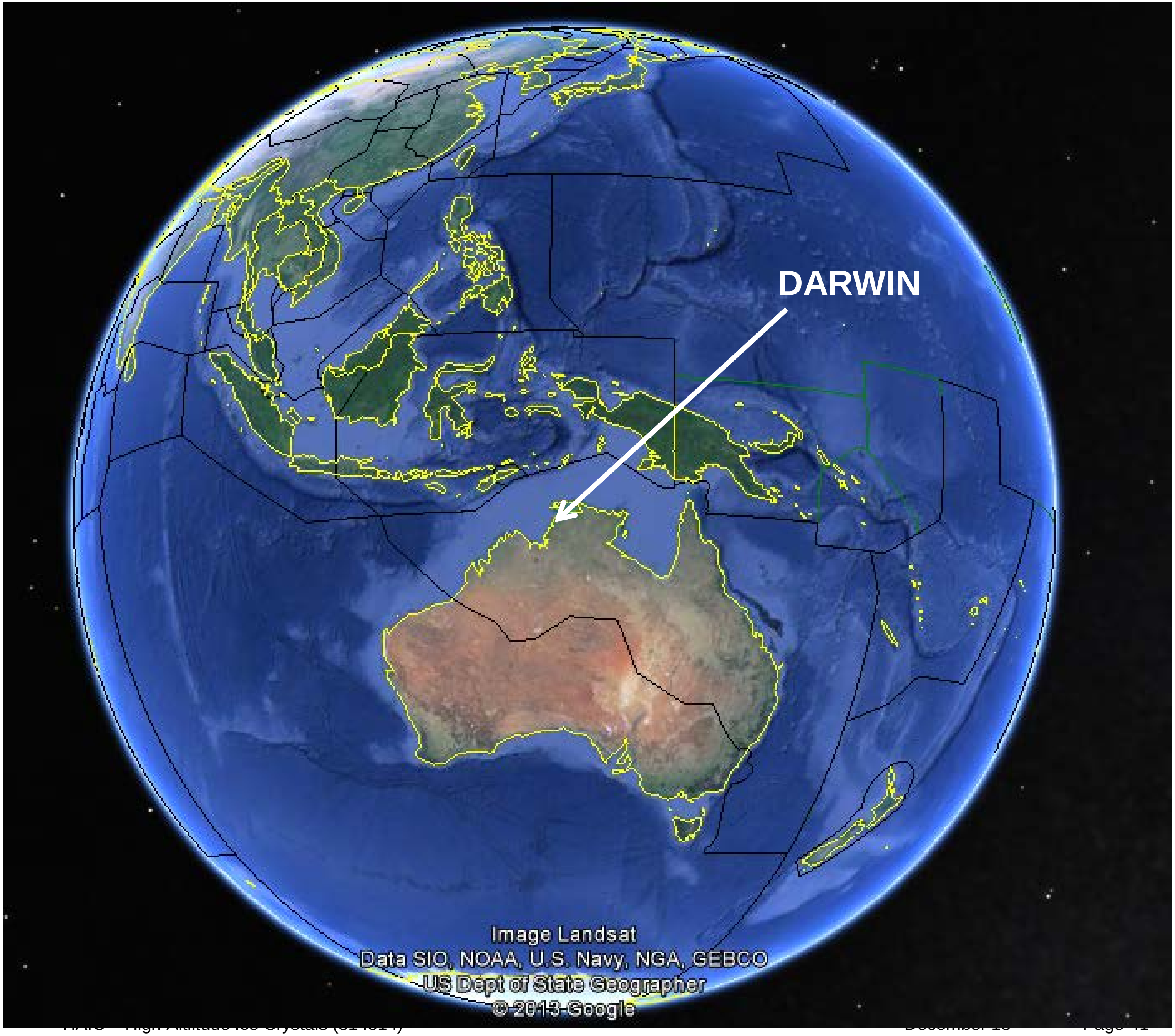
International Field Campaign Location Selection



HAIC

************* BREAK *************

HAIC & Lycée Henri Matisse Project
Content

- HAIC – High Altitude Ice Crystals
- HAIC SP2 – High IWC F/T Campaigns
- International Field Campaign Location Selection

- **International Field Campaign Preparation**
  - **Logistics**
  - **Aircraft**
  - **Instrumentation**
  - **Ground support**
  - **Campaign organisation**

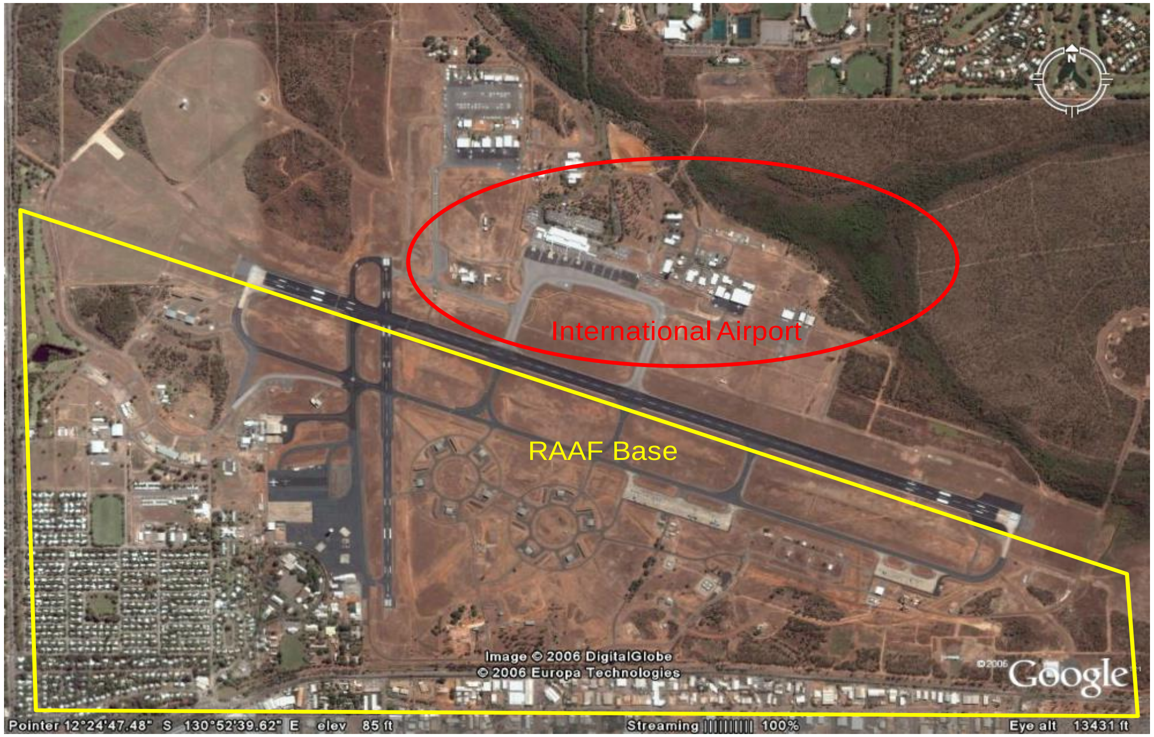
- Next steps

HAIC

Logistics

Darwin airport is split into 2 parts:

- RAAF Military base
- Civil area managed by Northern Territory. It is in this area that the office of Pearl Aviation and associated hangar are located



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HAIC & Lycée Henri Matisse Project
International Field Campaign Preparation

Logistics

Arrangements have been made with Pearl Aviation.

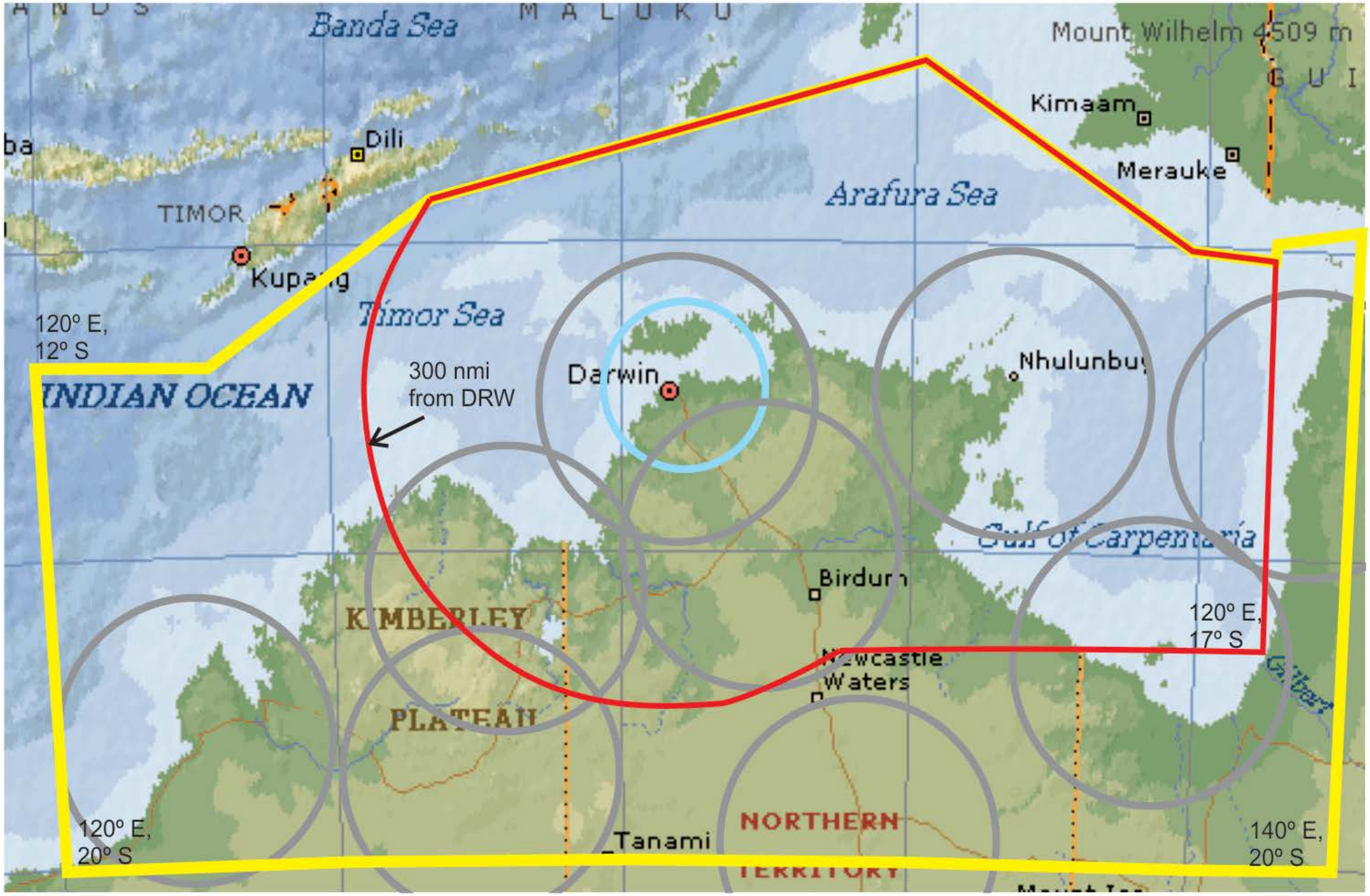
The SAFIRE Falcon 20 will be located in Pearl Aviation hangar. The hangar is closed and the aircraft will be thus protected from atmospheric conditions (monsoon,...). A workshop area will be installed along the wall (10m long maximum).

Two offices (twice 25m²) located on the first floor with windows and air conditioning will be rent for the SAFIRE team. They could be also used for crew briefing before flight. Kitchen is available on the ground floor but need to be shared with people hosted at Pear Aviation.

Negotiations are on-going for internet connexions, phone, power supply…

Logistics

Operational area:



Logistics

- Air services Australia provides all Air Traffic Control (ATC) services within the Australian Flight Information Region (FIR) with the exception of designated airspace that is controlled by Defense. This service is provided through two TAAATS Centers in Brisbane and Melbourne and a number of Terminal Control Units (TCU's) at major airports.
- Darwin Airport is a joint Defence / public use Airport with the Terminal Control Unit staffed by RAAF ATC personnel.
- The Brisbane TAAATS Centre has responsibility for ATC operations in the area of interest for the HIWC Study and they have been briefed on relevant background and the planned field campaigns

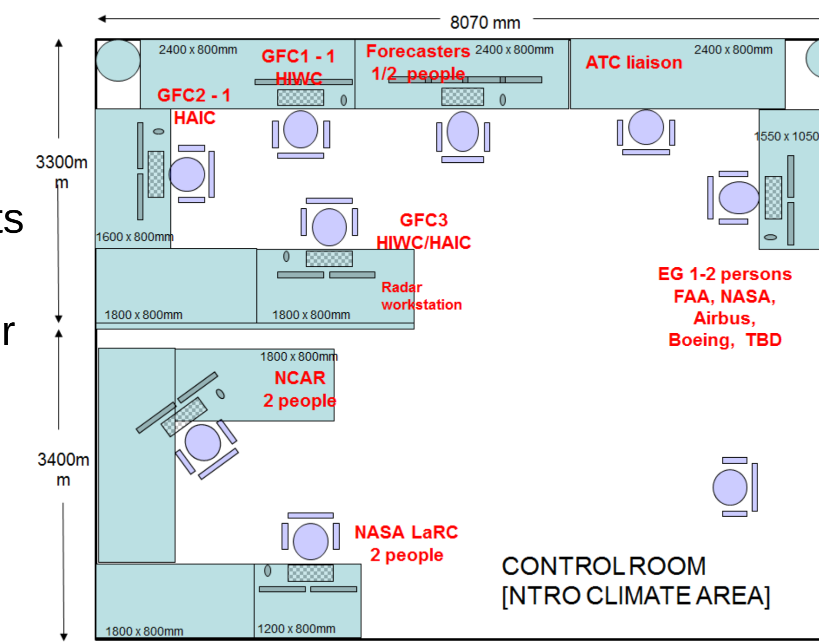
Note: according to F20 range limitation, alternative airport near the Gulf of Carpentaria and to the west of Darwin shall be considered to enable refuelling to maximize effective measurement time

HAIC & Lycée Henri Matisse Project
International Field Campaign Preparation

Logistics

- **Operations Control Centre** for the field campaign will be established in the **Bureau of Meteorology Regional Office**. NTRO will be used for briefing and flight guidance

- Following skills and expertises will be available
  - BOM, Boeing and Coriolis Weather to provide forecasting support
  - BOM will also provide model and radar products
  - NCAR and MET-FR to provide nowcasting support for flight planning and to collect data for verification.
  - NASA LaRC to provide satellite-based cloud products to be used for a variety of functions including flight planning, real-time mission coordination, and input to nowcasting tools



Logistics

In addition to the two Pearl Aviation offices, a meeting room ($60m^2$) will be also rent at the Rydges hotel.

Fares have been negotiated for stay at the Rydge's hotel for all campaign participants.

Visas & Passports explanations have been provided to all participants.

Airport access badges will be requested pending on visas delivery.

Each participant is in charge of his travel preparation and hotel booking / car rental.

Up to 45 participants at the same time are expected.

HAIC & Lycée Henri Matisse Project
International Field Campaign Preparation

Aircraft

Falcon 20 GF registered F-GBTM	
Certificate of airworthiness "Special"	
Ceiling	FL410
Scientific cruise speed	360 - 400 kts (TAS) @ ~ FL350
Endurance	3.5 hours in flight
MTOW	14,5t
Payload	1200kg
Maximum scientific electrical load	8,4 kVA
Wingspan	16,32 m
Length	19 m
Height	5,37 m
Engines	ATF3-6A-4C
Noise	Level 3
APU	SAPHIR 4.2
Other features	RVSM
	ADS-B (October 2013) / Mandatory feature in Australia
	Honeywell weather Radar PRIMUS 660
	Iridium data link

SAFIRE

F20 limitations:

4 under wing pylons, limited fuselage harpoints and electrical cabling

Available power for scientific instrumentation: **8.4 kVA**

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International Field Campaign Preparation

Aircraft Instrumentation

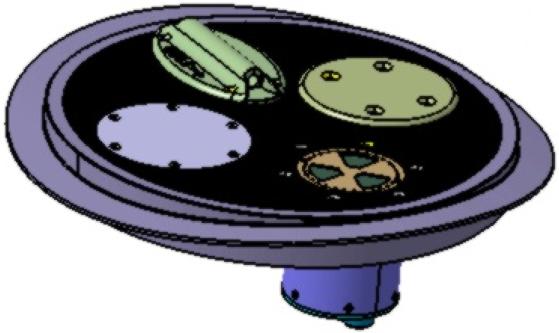
To measure adequately the atmospheric conditions, a set of instruments has been selected and adapted for campaign objectives. .

Measurement	Size range	Falcon-20
Meteorology		p, T, humidity (Licor, CR-2, WVSSII), v, pos.
Cloud active remote sens.		95 GHz Doppler cloud radar
Bulk cloud µ-phys		SEA LWC to replace Nevzorov probe
		Redesigned IKP
		ROBUST probe (mounted on CDP canister)
		SEA ICD ice crystal detector
		RICE (new model 0871LM5) - TBC
Single cloud particle µ-phys	Opt. spectrometry: (1-50 µm)	CDP-2 (spherical particles), *CPSPD (spherical & non-spher.)*
	CCD camera: high resolution (10-2000 µm)	*CPI (up to 2.3mm; 2.3µm pixel) HSI (8µm pixel, 500*500 pixel)*
	2D-array probes: intermediate particle sizes (100-1500 µm)	2D-S (10µm pixel, 128 photodiodes) *CIP (25µm pixel, 64 photodiodes)*
	2D-array probes:: large particle sizes (500-6000 µm)	PIP (100µm pixel)
Electrostatic field	Set of 6 field mill sensors	AMPERA (Onera)
Camera		1 camera is to be fitted in cockpit, in order to allow observation of effects on cockpit windows
F20 radar WXR		Data recorded through ARINC bus

AIC

Aircraft instrumentation

- **2D-S, CPI, CIP, PIP**
  - Objective: PSD measurement
  - Installation: Under wing



- **WSSI**
  - Objective: Humidity measurement
  - Installation: Top window

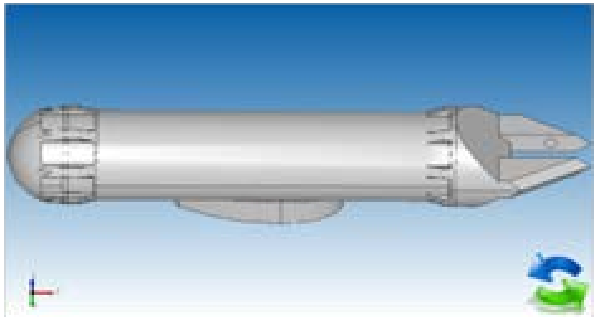
- **CDP/ROBUST**
  - Objective: PSD (1-50μm) and TWC measurement
  - Installation: Under wing

HAIC & Lycée Henri Matisse Project

International Field Campaign Preparation

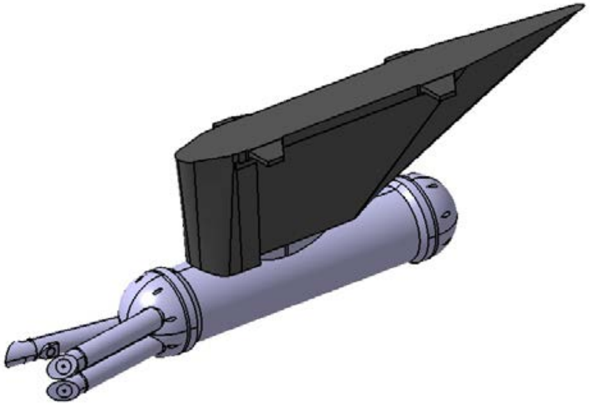
<u>Aircraft instrumentation</u>

- **CPSD**
  - <u>Objective</u>: Water phase discrimination, Needed for -10°C and -30°C flight levels
  - <u>Installation</u>: Under wing

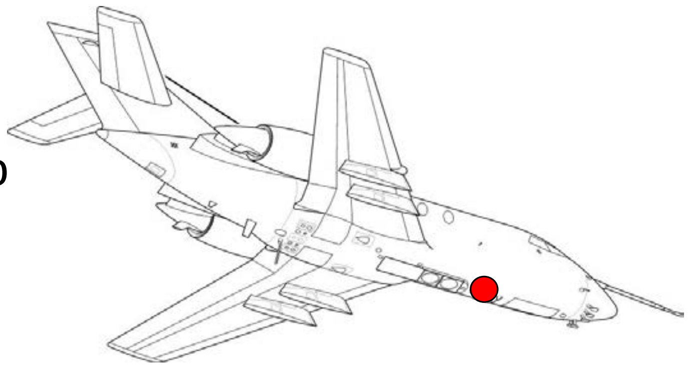


- **Iso-Kinetic Probe (IKP)**
  - <u>Objective</u>: Reference TWC measurement
  - <u>Installation</u>: Under wing

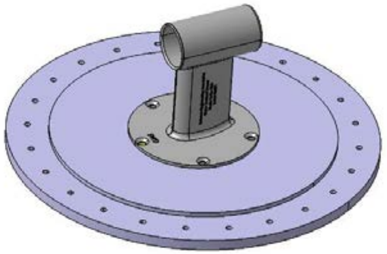
- **HSI**
  - <u>Objective</u>: PSD measurement (μm)
  - <u>Installation</u>: to alternate with IKP



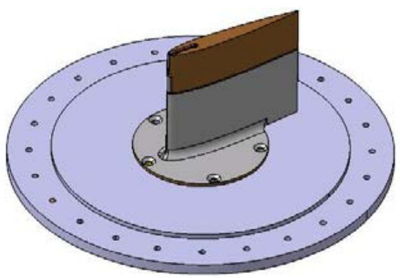
Aircraft instrumentation



- **SEA LWC**
  - Objective: additional on-board instrumentation to measure liquid water.
    - Direct measurement to support data collection for liquid and mixed phase conditions.
    - Needed for -10°C and -30°C flight levels
  - Installation: Belly aperture or to alternate with Robust probe under the wing (CDP/Robust)



- **SEA ICD**
  - Objective: ICD Performance assessment
  - Installation: Belly aperture or to alternate with Robust probe under the wing (CDP/Robust)



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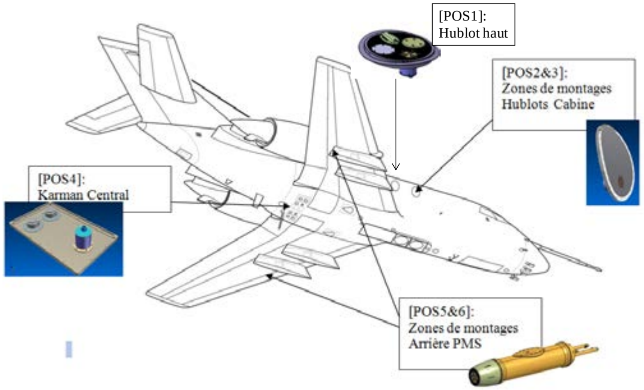
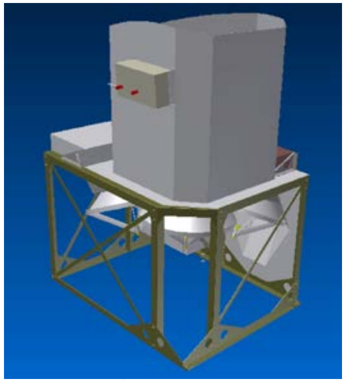
International Field Campaign Preparation

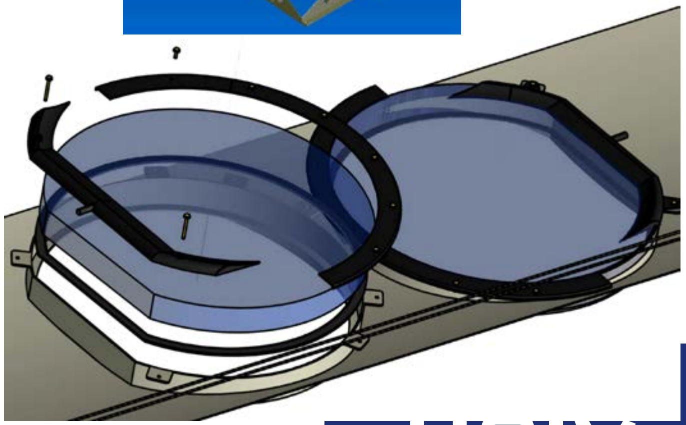


Aircraft instrumentation

- **AMPERA (Mill Field Sensor)**
  - Objective: Electric field measurement
  - Installation: 6 sensors on fuselage and PMS



- **RASTA2 (RAdar SysTem Airborne)**
  - Objective: Multi-beam 95 GHz Doppler cloud radar / three-dimensional (3D) wind and microphysical and radiative properties of clouds retrieval (IWC, visible extinction, particle size, terminal fall speed, concentration)
  - Installation: Cabin



Aircraft Instrumentation

All instruments cannot fit in the same time on Falcon 20. A selection has to be made in order to be able to reach campaign objectives, pending on each probe characteristics (size, weight, power consumption, etc.).

Configuration(s) of Aircraft is (are) to be defined… pending on flight objectives, probes characteristics and availability.

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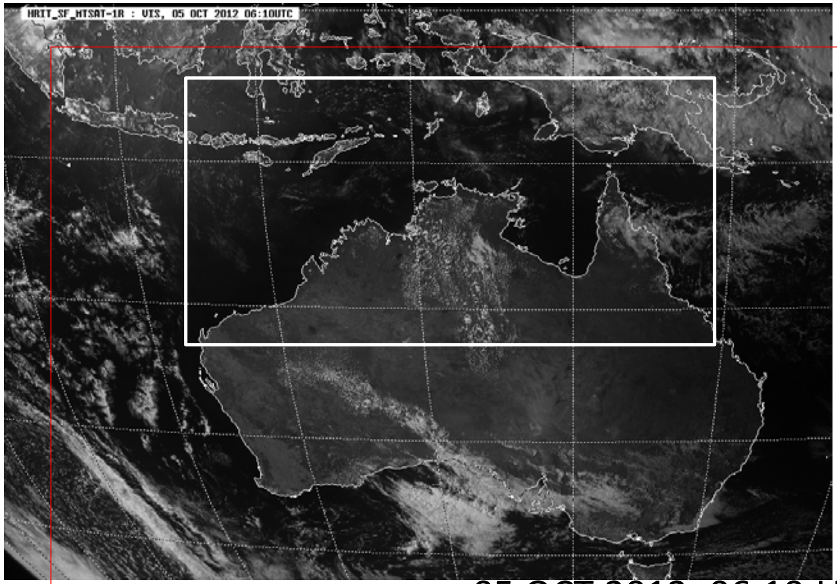
International Field Campaign Preparation

Ground Support

- **Observations Network**
  - The primary source of satellite data is **MTSAT** scans obtained from JMA. For the field campaign, special **10 min rapid scan data** will be provided to support flight guidance and research.
  - A large BOM research and operational **weather radars network** including C-Pol research polarimetric weather radar



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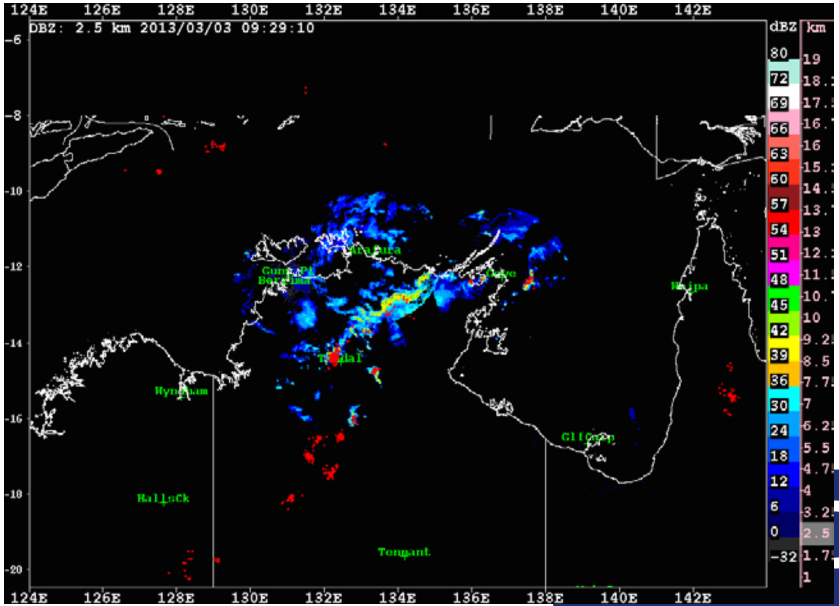

The best remote sensing ground station to support A/C flight Guidance

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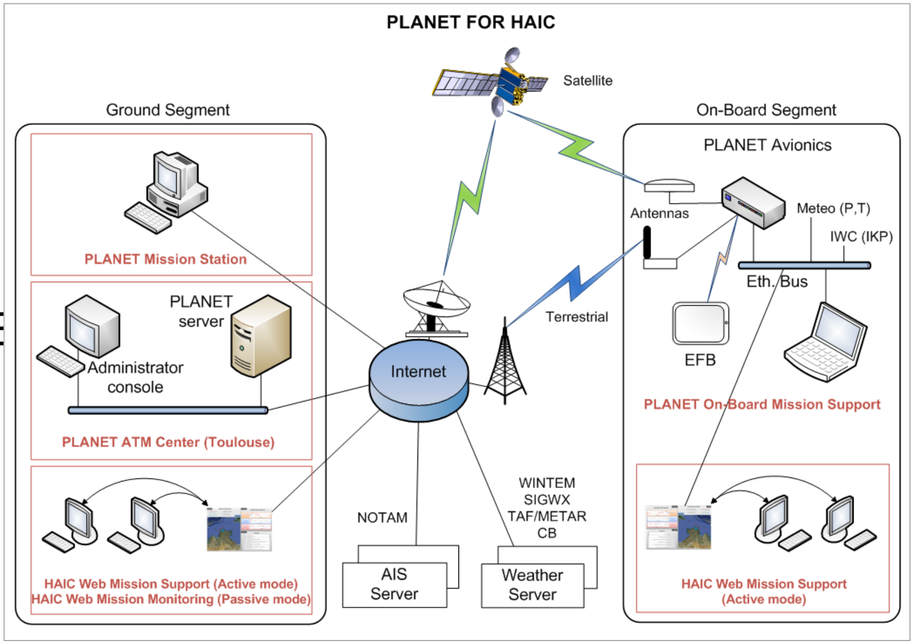
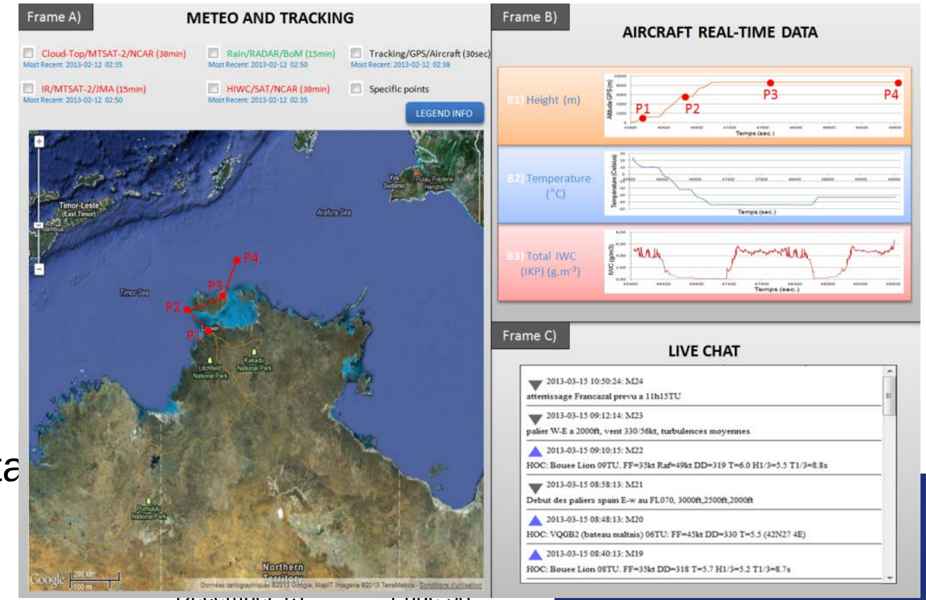
International Field Campaign Preparation

Ground Support

- **Flight Guidance**
  - Main tool for A/C guidance will be **PLANET** developed by ATMOSPHERE
  - The PLANET solution provides:
    - **Flight Preparation** including upload of all regulatory information (METAR/TAF, SIGWx, WINTEM), NOTAMS on the ground.
    - Automatic **In flight update of weather and aeronautical information** (METAR/TAF, Weather Objects, NOTAMS).
    - **Messaging services** between the ground and the air or between aircrafts.
    - **Monitoring (including tracking) for Flight Operation and Mission Management**, including avionics bus data downlink.





Campaign Organisation

- The **HAIC/HIWC international field campaign** is the result of an international collaboration in between HAIC and HIWC. As such a large number of people and skills all over the world are involved in the preparation of the campaign and in its daily operation. It is then important that a clearly defined management structure is in place so that there is a protocol for decision making.

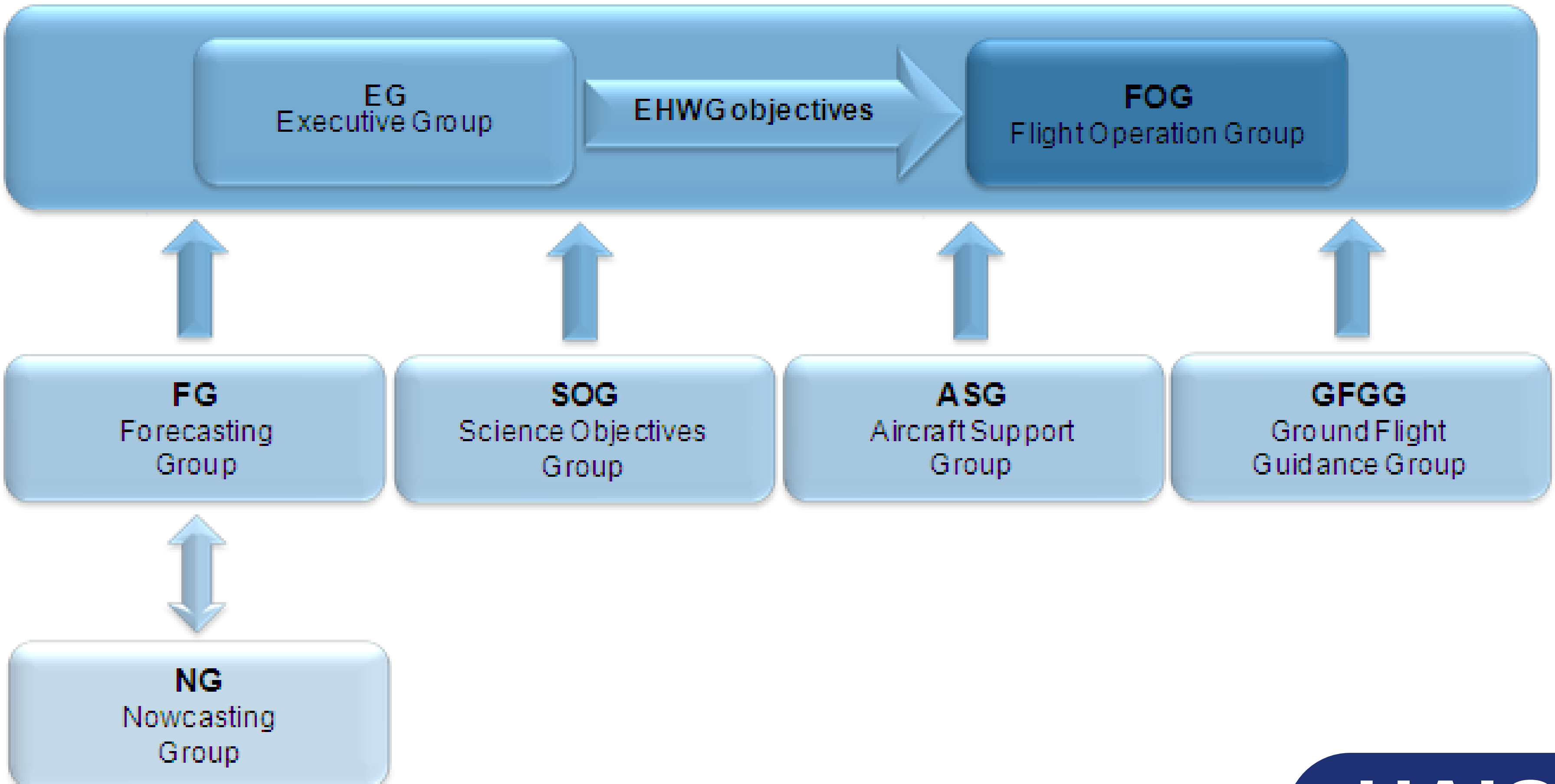
- The **Decision Making Process** is designed to reach the following objectives:
  - Coordinate and manage the field campaign
  - Ensure timely and qualitative achievement of the field campaign objectives, including risk mitigation, recovery plans and quality control
  - Provide decision making mechanisms

- The **Decision Making Process** is also designed to ensure **simple, efficient and quick decision making**.

- To achieve these objectives, several groups with clear **role and responsibilities** were defined.

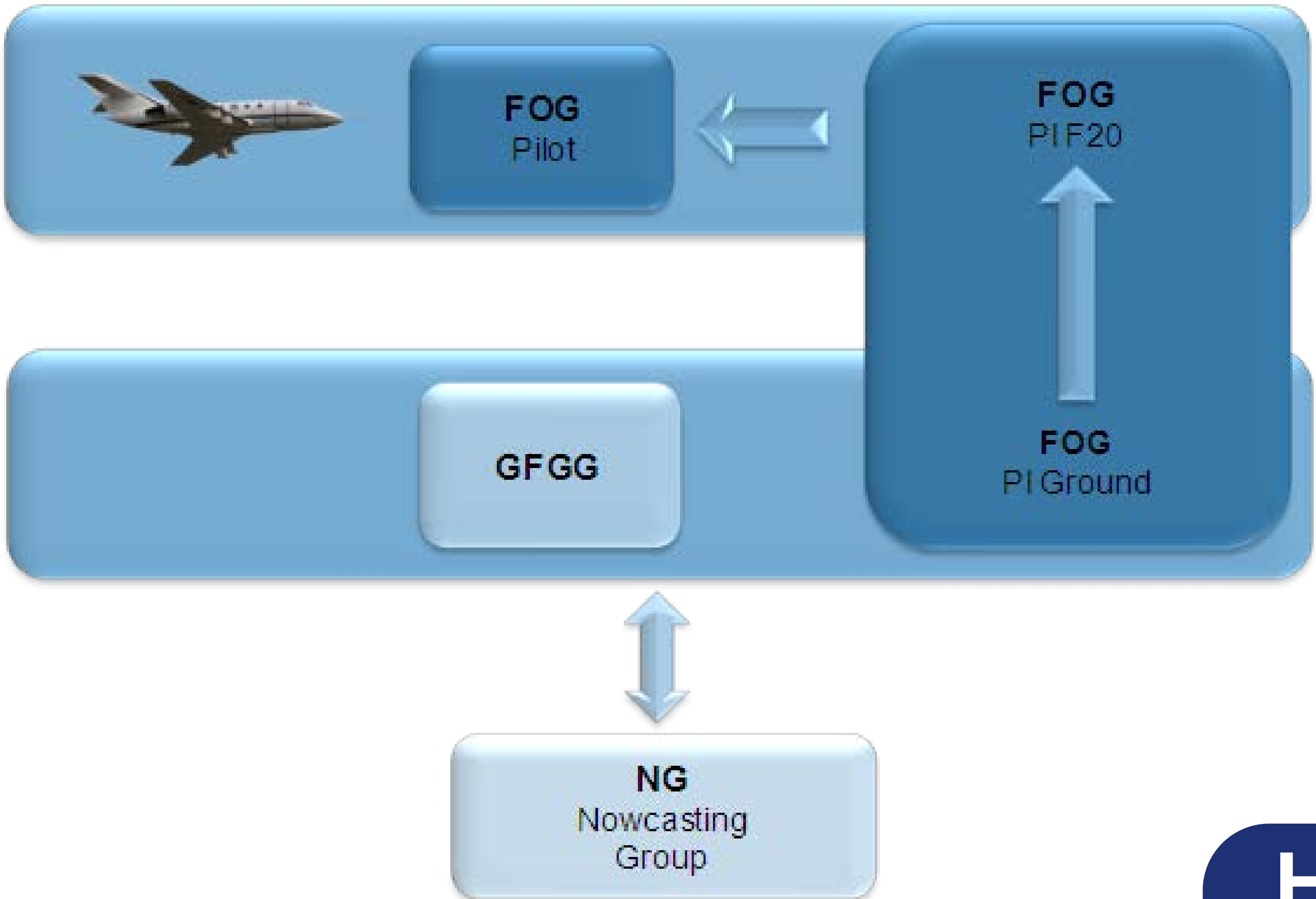
Campaign Organisation

Pre-flight Decision making process



Campaign Organisation

In-flight Decision making process



Campaign Organisation

- **Flight Plan** (*as originally defined by W.Strapp in HIWC science plan)*
  - Objective is to collect data in high IWC areas of deep convective clouds, **similar to those that cause engine and probe events,** to assess validity of Appendix D/P 99th percentile TWC versus distance scale, and particle size
  - EHWG have identified the types of clouds that are of most interest, including the percentage of desired cases:
    - 60%: tropical oceanic airmass during monsoon, **deep convection over ocean**, preferably imbedded in MCS with anvil penetrating above tropopause with scale of > 100 nmi. Expectation is that this cloud category will be the least vigorous, and the F20 will be able to fly over the cores.
    - 25%: **tropical oceanic airmass over land**. There may be more vigorous and may require sampling further from core.
    - 15%: break-type isolated **continental convection** (e.g. Hector); expected to be able to sample only anvil away from core

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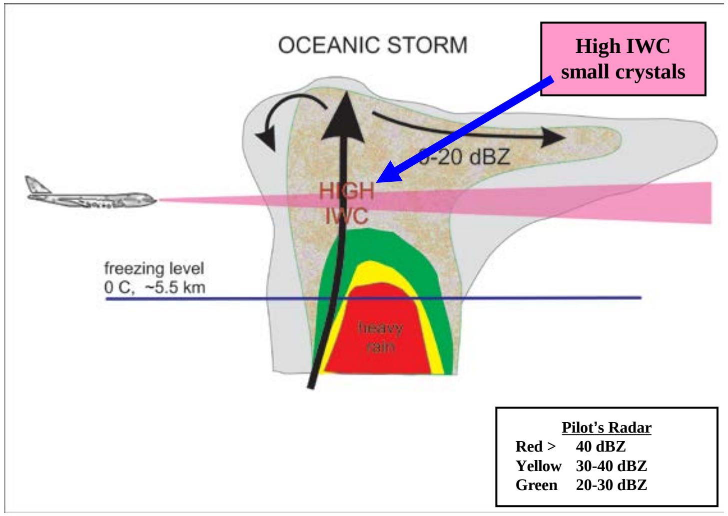
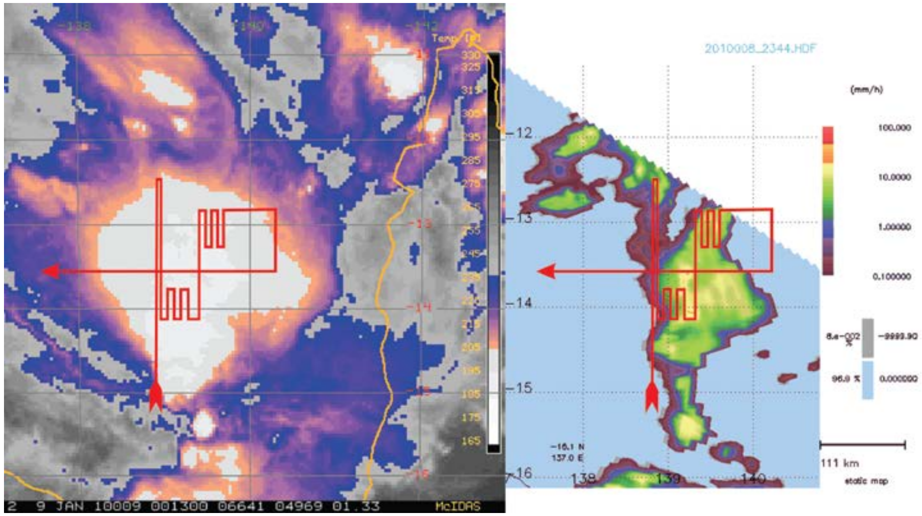
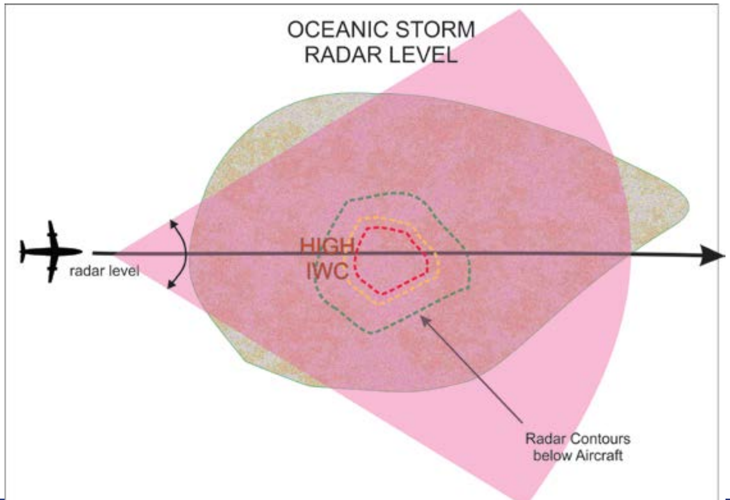
International Field Campaign Preparation

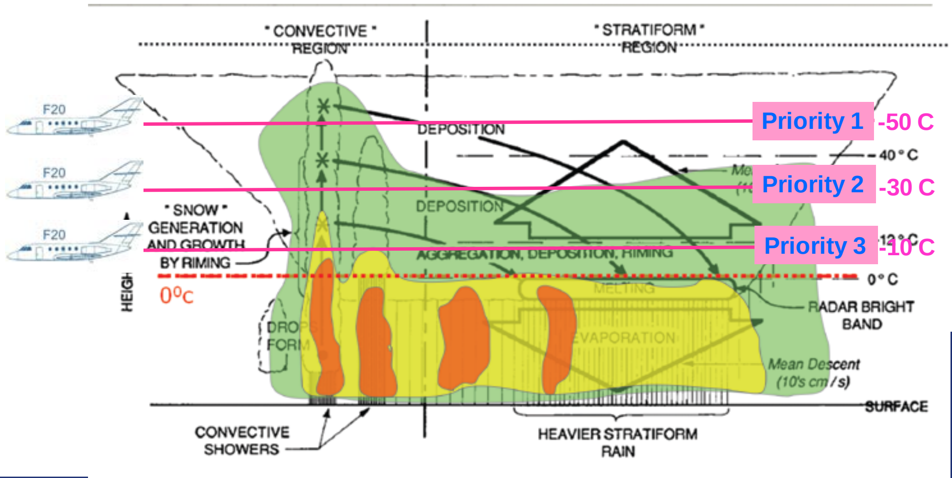
Campaign Organisation

- **Oceanic convection over ocean (~60% of F/H)**





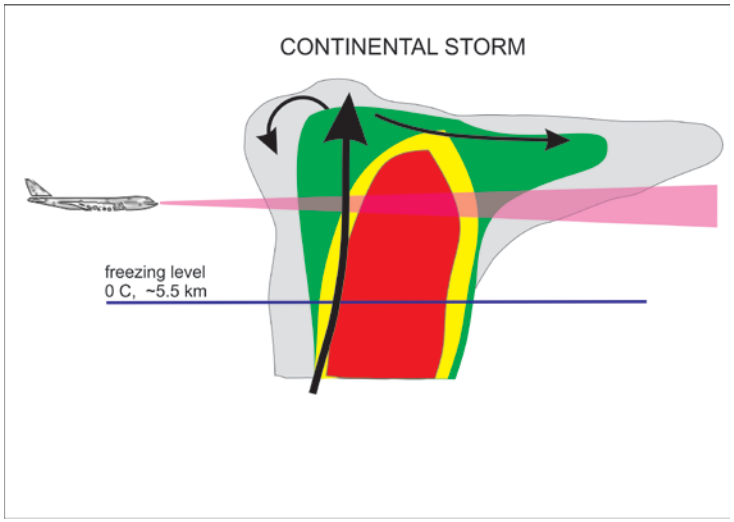


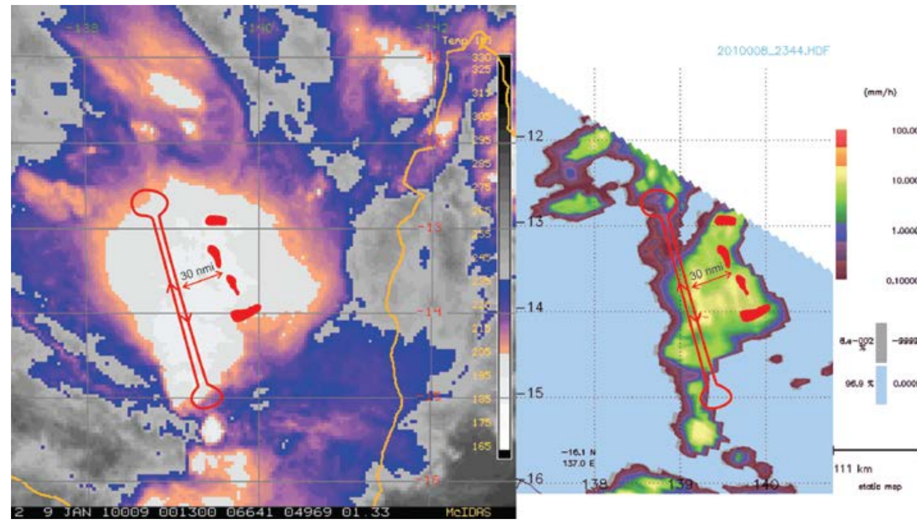


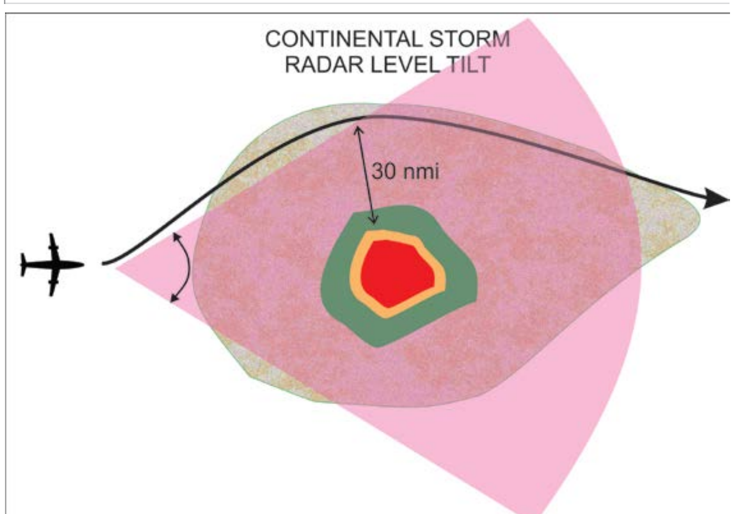
HAIC & Lycée Henri Matisse Project
International Field Campaign Preparation

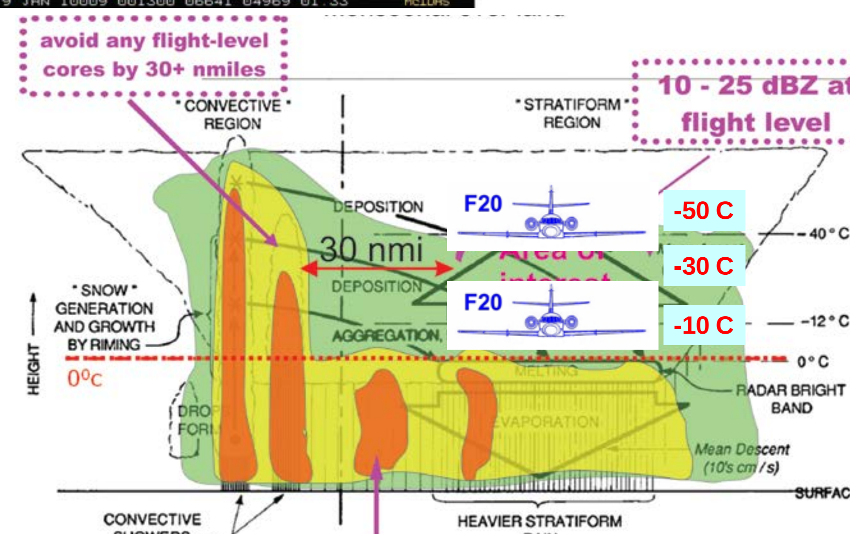
Campaign Organisation

- **Oceanic airmass over land (~25% of F/H)**



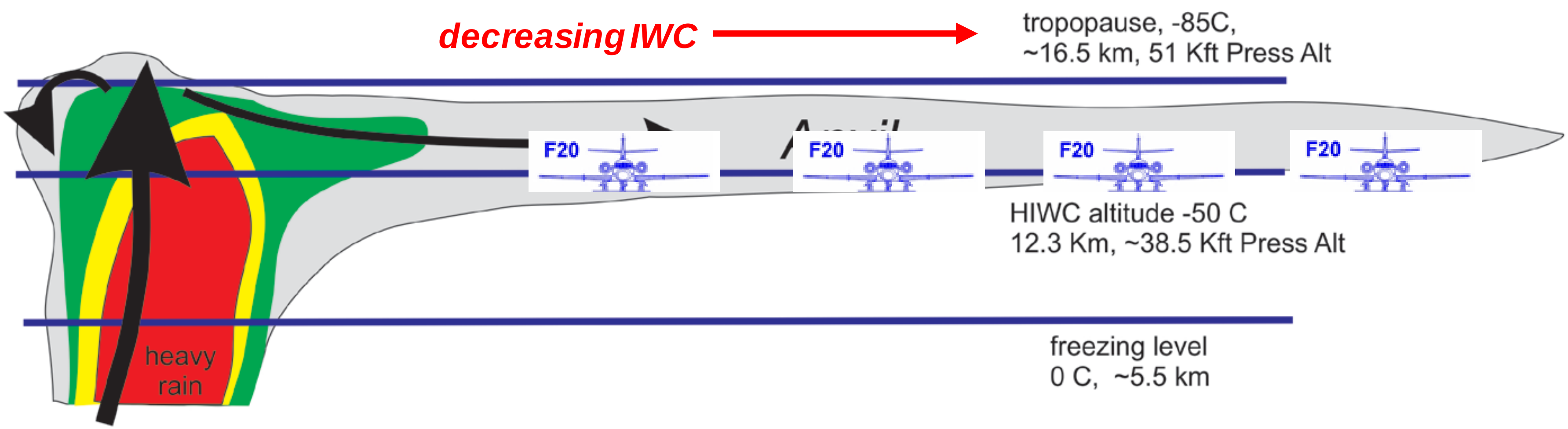






Campaign Organisation

- **Isolated Continental Convection in "Break" Periods (~15% of F/H)**



HAIC & Lycée Henri Matisse Project
Content

- HAIC – High Altitude Ice Crystals
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- **Next steps**

What are the next steps for our collaboration?

What do ***<u>you</u>*** want to do ?

- End of campaign preparation:
  -
  -
  -
- Campaign Follow-up:
  -
  -
- ???

HAIC