The Ice Crystal Icing Hazard & Risk Mitigation:
Delta Air Lines' Perspective

Bob Culver, Chief Line Check Pilot &
Tom Fahey, Mgr. Meteorology
Friends/Partners Aviation Weather (FPAW)
19 November 2015
Las Vegas, NV

Ice Crystal Icing (ICI)

What is it?
&
What can we do about it?

Airframe Icing Conditions

Question:
What Temperatures & Cloud Conditions produce Airframe Icing?

Answer:
Temps Warmer than - 40C & Liquid Cloud droplets below freezing.

Typical Icing Requires Super-cooled Liquid Droplets

- Liquid freezes on contact with cold wings & fuselage surfaces.
- Ice crystals, regardless of size, do not adhere to a cold airframe

Source: NASA-Lewis/FAA/NCAR-RAP

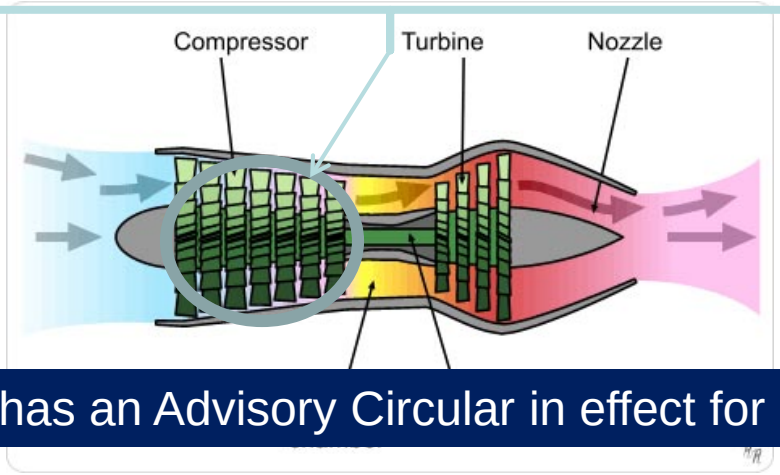
Ice Crystal Icing (ICI) Conditions

Meteorology & Jet Engine Perspectives

Question:
What conditions produce Ice Crystal Icing (ICI)?

Short Answer:
High Concentrations of Ice Crystals,
also called High Ice Water Content (HIWC)

Ice Crystals Build-up in Compressor



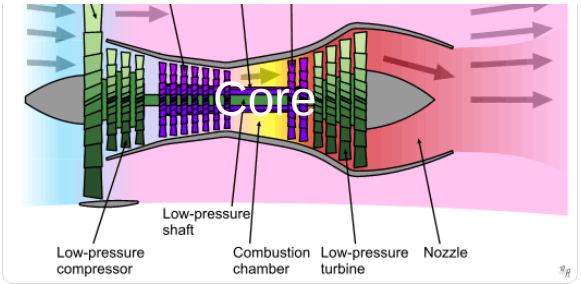
FAA has an Advisory Circular in effect for B787

ICI Process in a Jet Engine

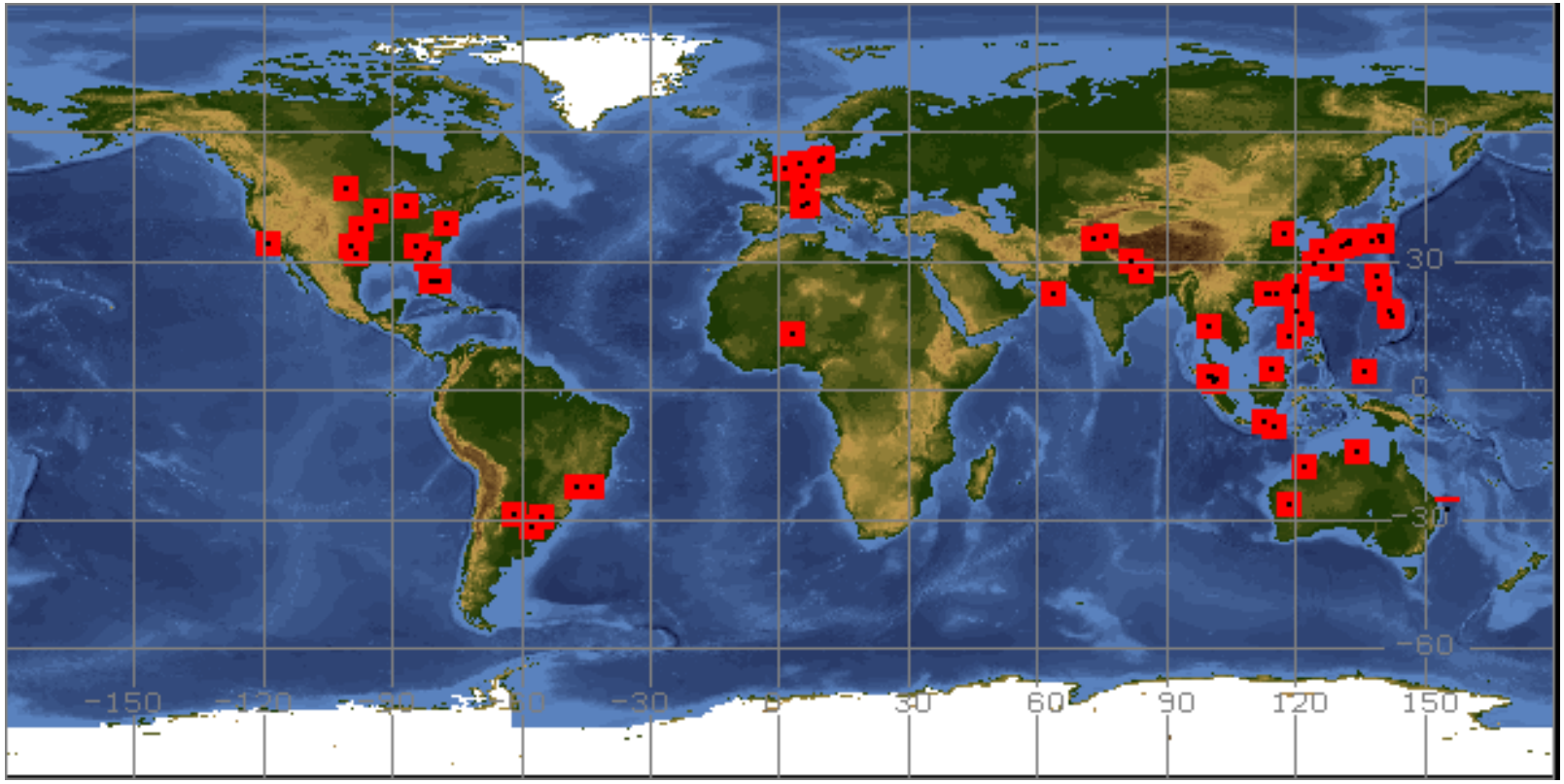
What is the physical process producing ICI risk?

- Portions of Engine Compressor are above freezing
  - Very small ice crystals are ingested into the engine →
- Ice crystals partially melt & stick to warmer engine surfaces
  - Ice crystals melt as they impact the warm internal engine components →
  - If, encounter persists, a thin film develops over parts of the engine →
  - This enables further capture of ice crystals →
- If prolonged Encounter: Engine Temperature is reduced < 0C:
  - Ice crystals begin to aggregate →

Ice can block flow into engine core or shed into core →
Leading to various engine malfunctions
(engine vibration, power loss or damage)



Where have ICI incidents occurred?



- 67 events shown worldwide (some overlaid) by Boeing 1990's-2009.
- Well over 100 events have been identified.
- **The greatest # of events have occurred in Asia Inter-port area.**

Source: *"Weather Conditions Associated with Jet Engine Power Loss & Damage Due to Ingestion of Ice Particles: What we've Learned Through 2009" by Matthew L. Grzych & Jeanne G. Mason, The Boeing Company*

Ice Crystal Icing (ICI) Awareness

Weather & Operating Conditions

Question:

What weather/flying conditions produce most Ice Crystal Icing (ICI)?

Answer:

- Deep convective systems over both ocean & land in a Tropical Airmass
- ICI potential increases with denser convection & extended exposure.
- Typically, at cruise level altitudes & in clouds, above strong convection where little or no weather radar returns observed at flight altitude.

ICI Awareness Tools

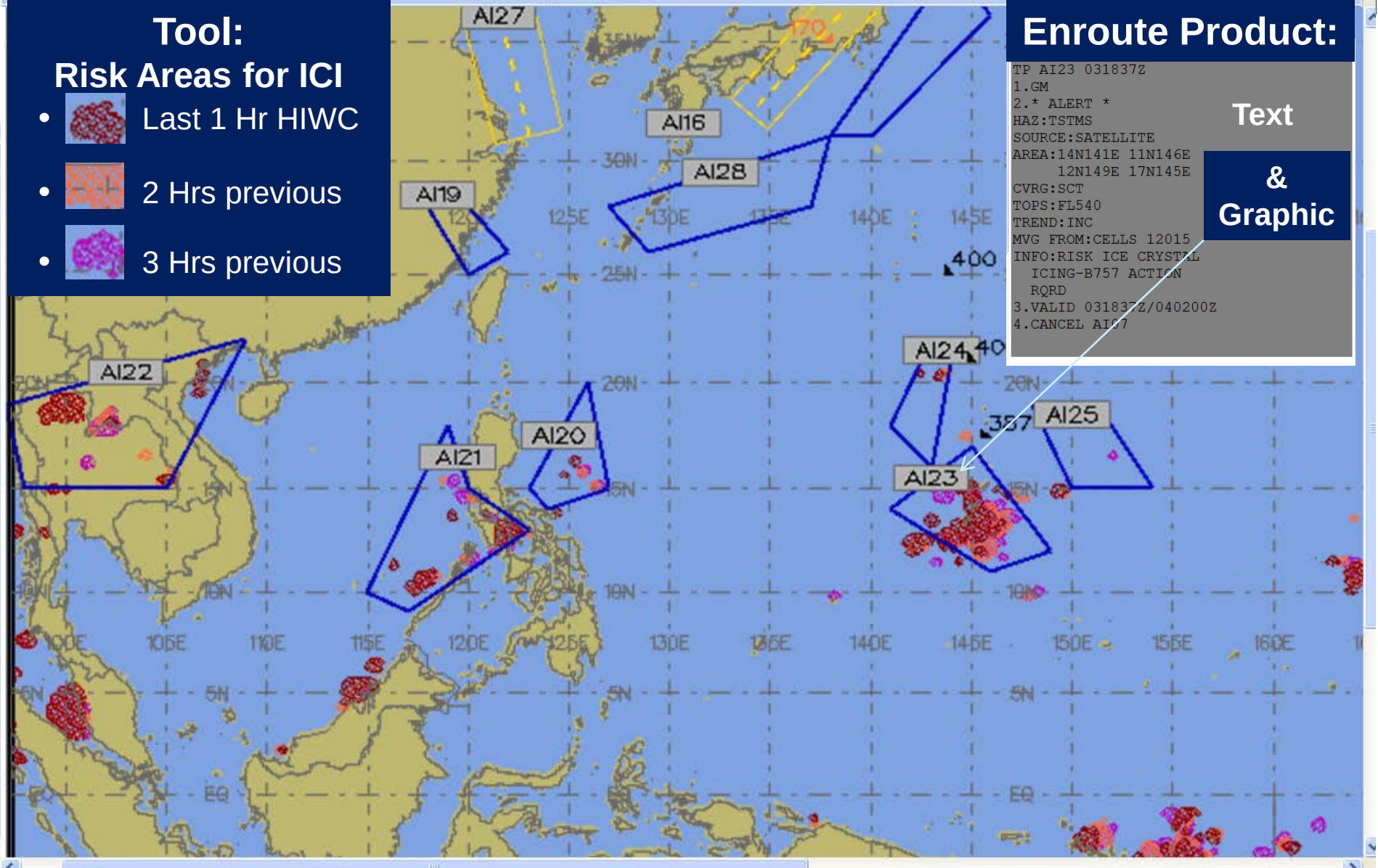
- **Radar:** Tactical ICI avoidance is a challenge because not easily identified on radar.
- **HIWC:** Areas of High Ice Water Content (HIWC) are being estimated & provided by some aviation weather vendors.

High Ice Water Content Awareness

A Tool & a Delta Meteorology Product

Tool:
Risk Areas for ICI

- Last 1 Hr HIWC
- 2 Hrs previous
- 3 Hrs previous



Enroute Product:

```
TP AI23 031837Z
1.GM
2.* ALERT *
HAZ:TSTMS
SOURCE:SATELLITE
AREA:14N141E 11N146E
     12N149E 17N145E
CVRG:SCT
TOPS:FL540
TREND:INC
MVG FROM:CELLS 12015
INFO:RISK ICE CRYSTAL
  ICING-B757 ACTION
  RQRD
3.VALID 031837Z/040200Z
4.CANCEL AI07
```

Text

&

Graphic

2 Delta Meteorology Products Used

Pre-flight & En Route

Preflight

Depiction Product contains

- Forecast of tstrm coverage & area

Process

- Dispatchers consider alternative routes to avoid psbl ICI when:
  - BKN (>=50%) tstrm coverage fcsted &
  - Flt route through tstrm area is 100NM or greater in distance.

En Route

TP Product contains

- Report of current tstrm activity

Added Situational Awareness

- If High Ice Water Content (HIWC) area, 100nm or greater present:

"INFO" is added

Example: TP Message

TP CB19 051441Z
1.CBA
2.* ALERT *
HAZ:TSTMS
SOURCE:SATELLITE
AREA:02N071W 00N068W
02N066W 04N070W
CVRG:BKN
TOPS:FL450
TREND:NC
MVG FROM:CELLS VRBL
INFO: RISK ICE CRYSTAL
ICING-B757 ACTION RQRD
3.VALID 051441Z/060000Z
4.CANCEL NONE

Why the Attention?

An ICI Event

- On 09 November 2014 a Delta B757-200 operating from Japan to Mariana Islands experienced an engine irregularity & then diverted to Iwo Jima.
- Post event analysis determined that ice crystal icing was a factor in the engine shut down.

A Boeing 757 Aircraft

- Although ICI can occur on any aircraft on any Delta fleet:
  - Fleets other than the B757 have engine auto re-ignite / restart capability.
- On B757 fleet “continuous ignition” must be activated manually.

ICI Operating Procedures
Newly Developed

A Coordinated Effort Between:

Meteorology

Dispatch

Pilots

ICI Operating Procedures
Newly Developed

Multi Layered Approach

1. Strategic Avoidance

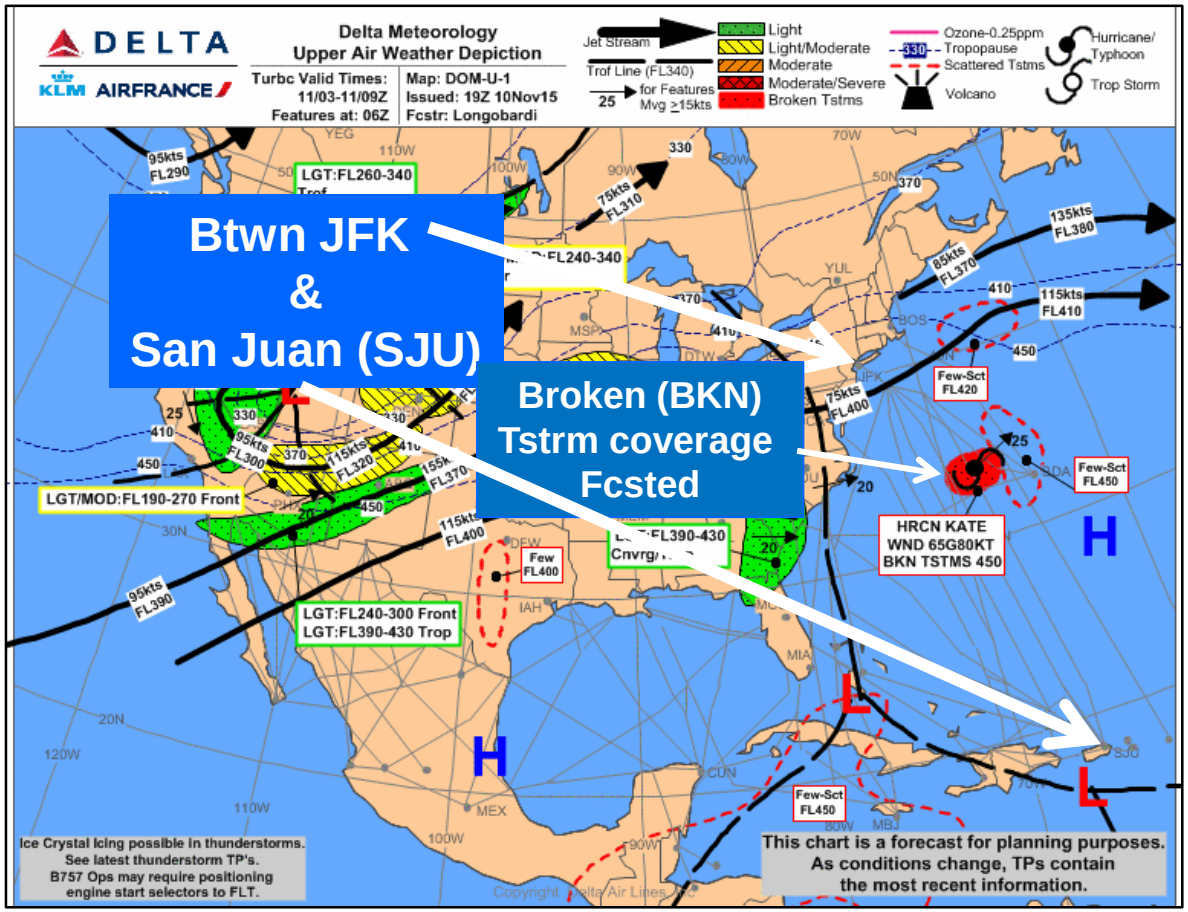
2. Tactical Avoidance

3. Mitigation if Encountered

ICI Operating Procedures
Strategic Avoidance

Pilot Preflight Planning example:
at 00z for JFK-SJU Flight

Upper Air Depiction: Issued at 19z Features Valid 06z



TP - Issued & Valid 23z

Included in preflight paperwork

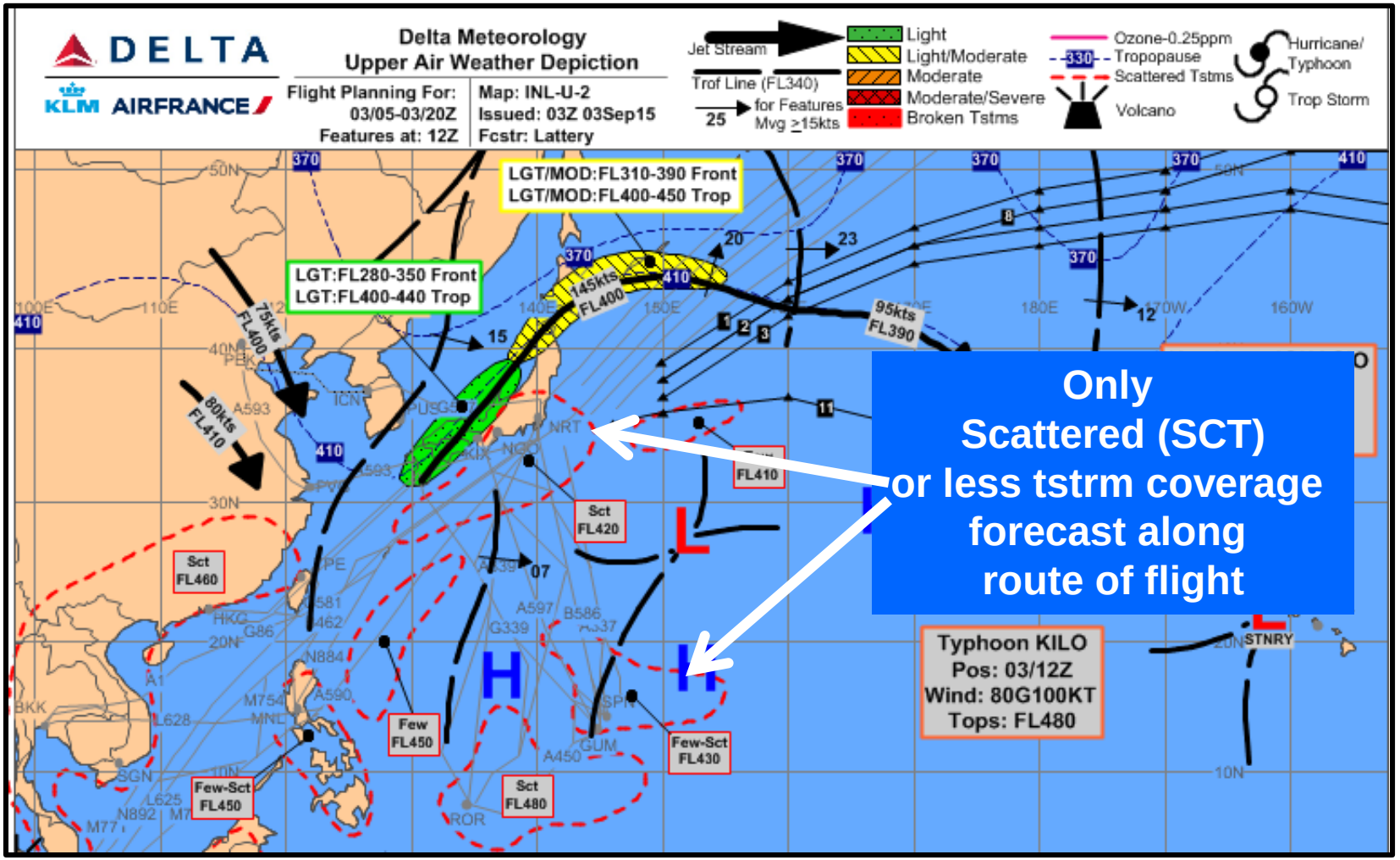
TP CB36 102306Z
1.BD
2.* ALERT *
HAZ:TROP STORM
NAME:KATE
LAT/LON:32.5N072.7W
TIME:POSN AT 10/2100Z
MVG FROM:23026
WIND:SFC 60G75KT
TREND:NC
…
INFO:RISK ICE CRYSTAL ICING-B757 ACTION RQRD
3.VALID 102306Z/110900Z
4.CANCEL CB29

ICI Radar Operating Procedures

Strategic Avoidance

Pilot Preflight Planning example:

NRT-GUM Flight



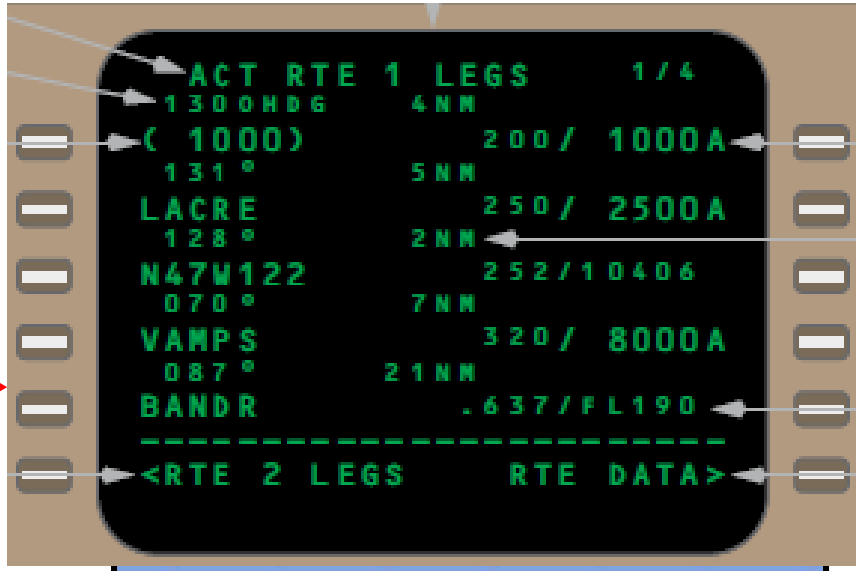
Operating in ICI conditions
Tactical Avoidance

Cockpit Preparation
En Route NRT- GUM

Text of TP

TP **AI23** 031837Z
1.GM
2.* ALERT *
HAZ:TSTMS
SOURCE:SATELLITE
AREA:14N141E 11N146E
12N149E 17N145E
CVRG:SCT TOPS:FL540
TREND:INC MVG
FROM:CELLS 12015
INFO:RISK ICE CRYSTAL ICING-B757 ACTION RQRD
3.VALID 031837Z/040200Z
4.CANCEL AI07

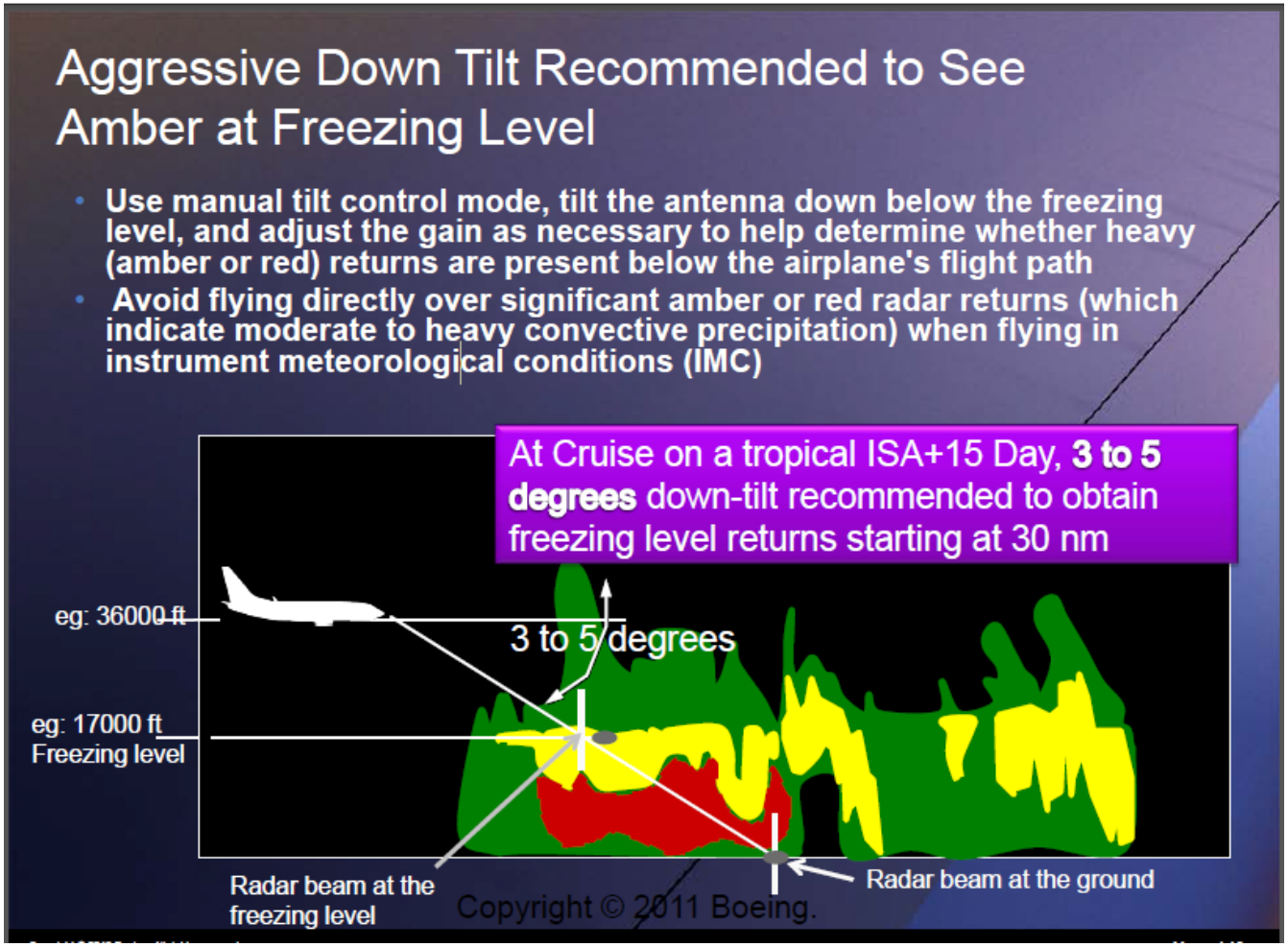
Cockpit



Ops Center View

Operating in ICI conditions
Tactical Avoidance

Radar Operation



Mitigation

When in IMC at or above xx,000’ and operating within an area identified by Boeing’s High Ice Water Content (HWIC) map:

ENGINE START SELECTORS ……FLT

Increases engine flameout protection.

ENGINE ANTI-ICE Switches……ON

Increases engine stall margins

In-flight restarts after ICI event

Question:
Should an in-flight restart be considered?

Answer: **Yes**

Typically there is no engine damage after the ice has been ingested and the engine may be restarted.

Conclusions

ICI is manageable.

Meteorology, Dispatch, and Pilot teamwork & training are key.