A refined, objective approach for characterizing ICI event conditions and application to Appendix D data collection

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Science Plan: Engine Event Driven Flight Strategies

- Since its conception, the science plan objectives have been focused on the needs identified by the Engine Icing Working Group
- With time, a better and better understanding has been acquired about the weather associated with engine events, new data has been presented to the EIWG and HAIC/HIWC science teams
- New learning and analysis techniques need to be applied to old events to finally integrate our knowledge

Can We Identify Clouds with HIWC?

- A recent study presented in Grzych et al. 2015 showed the frequency that commercial flights potentially encounter HIWC cloud
- 10,025 flight tracks in the tropical Asia-Pacific region analyzed for IR-ER transects >= 100 km
- None had ice crystal icing
- Cruise level (FL390-FL410)
- Results: 60 MCS's

0.59% of the flights encountered potential HIWC clouds with no adverse effects

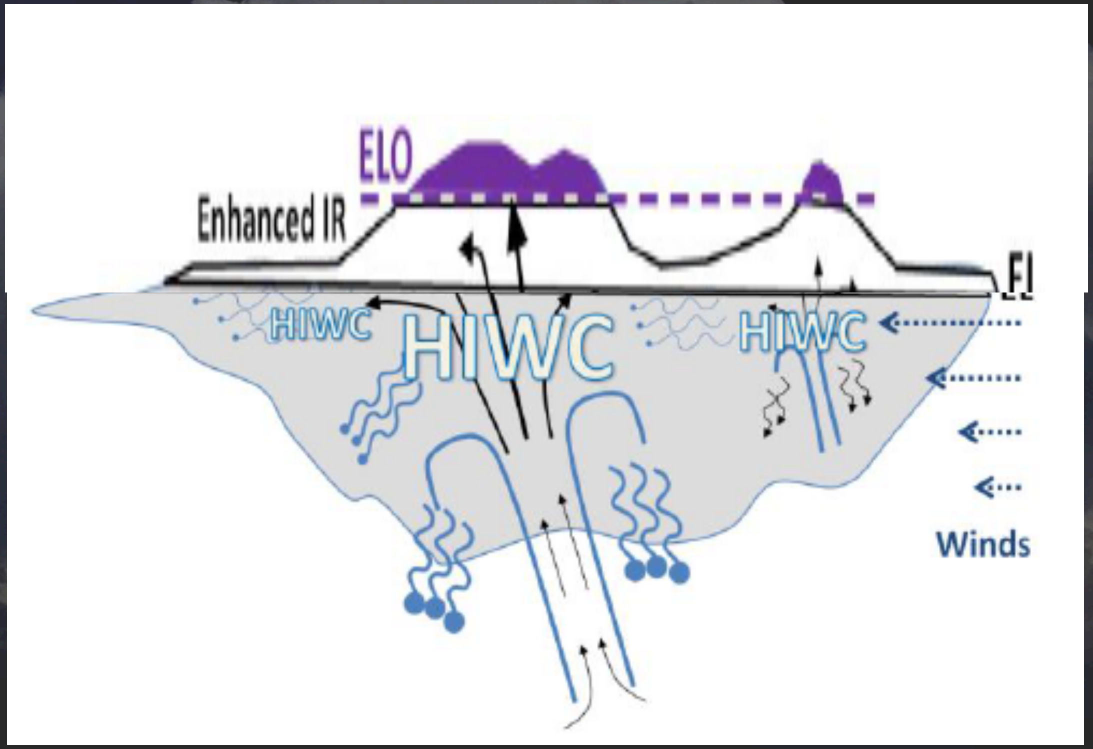
What makes these 60 encounters different from ICI events?

History, Motivation, Overview

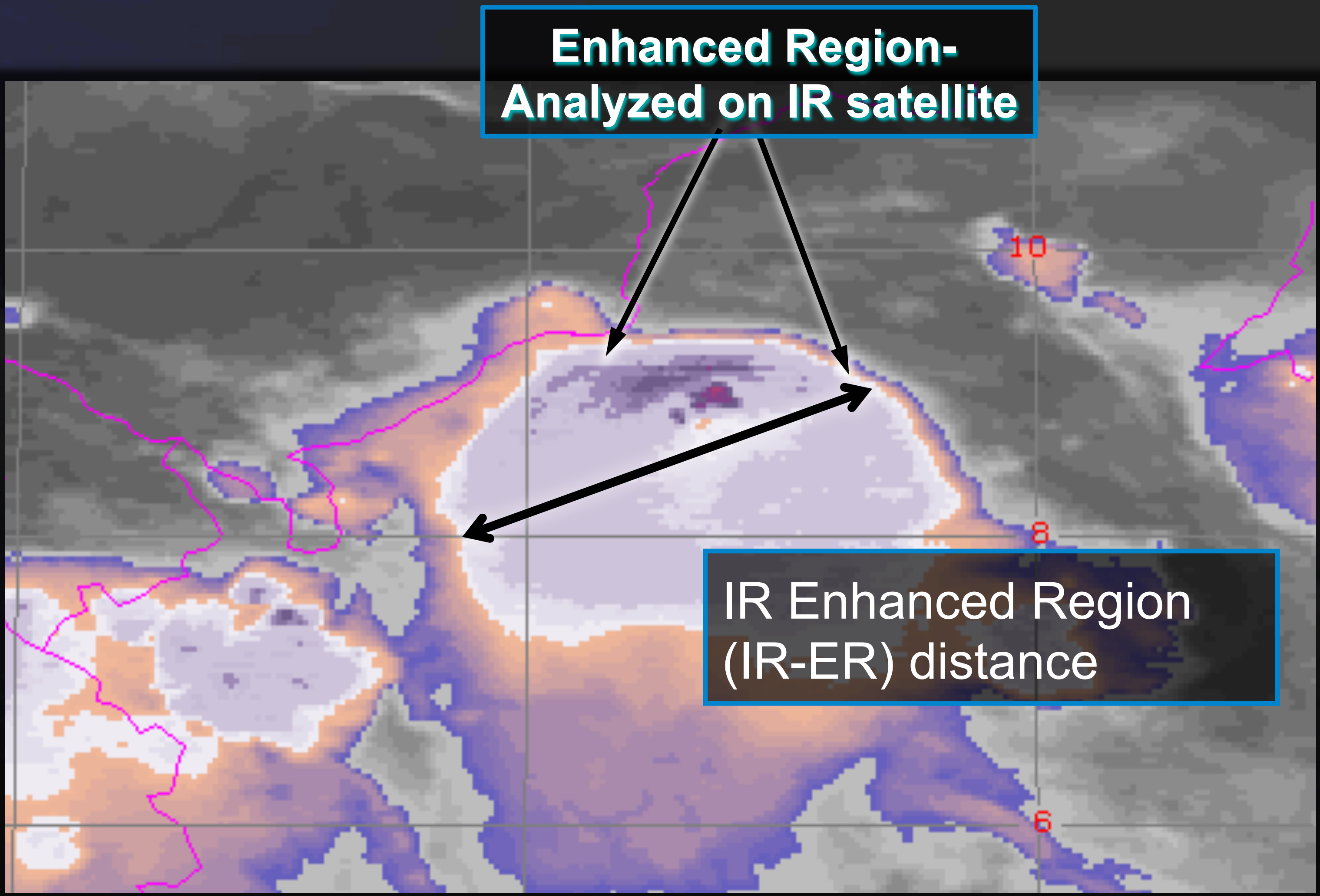
- **Boeing ICI database now includes over 150 events**
- **Have been subjectively analyzing each case as they occur for over 10 years**
  - Multiple individuals have contributed to analyses
  - Technology, knowledge, techniques, evolve over time
- **Propose to standardize an automated analysis technique to**
- **reanalyze Boeing ICI database objectively**
  - Include several more parameters plus convective time evolution
- **Attempt to define a refined set of environmental parameters related to ICI**
  - Do so by ICI event type (i.e. engine…, sensor..)
- **This provides the opportunity to analyze flight campaign environments – verify against event environment(s)**

Terminology / Definitions

- IR “Enhanced Region”
- Enhanced Level Overshoots (ELO)



IR Enhanced Region Example



Technique overview

- We' ve identified 3 types of analyses to include in the core logic. They are automated/objective procedures for

1. Extracting and compiling fundamental environmental parameter statistics
2. Tracking evolution of large scale (mesoscale in this case) convective features
3. Tracking embedded local storm features both spatially and temporally relative to ICI events (e.g. convective overshoots)

Fundamental Parameters

Routines will automatically extract the following fundamental parameters:

- Precipitable water (PW)
- CAPE
- Equilibrium Level Temperature (T_{EL})
- Cold point tropopause (CPT)
- Minimum cloud top temperature (CTT_{min})
- Storm relative anvil level wind shear
- Low level inflow winds
- Enhanced distance of aircraft track across $T <= T_{EL}$
- Area-equivalent diameters of enhanced cloud (D_{eq}).

Fundamental Parameters cont.

- **Parameters based on archived global NWP model and/or reanalysis data – constructed storm inflow soundings.**
- **Routine logic:**
  - Determine event cloud system centroid via IR imagery
  - Probe model grid low level winds centered on MCS
  - Determine "inflow" sub-grid where storm motion / wind convergence is maximized
  - Construct multiple soundings from within inflow sub-grid
  - Construct final representative inflow sounding being the average of a subset of inflow sub-grid soundings (example: subset may include only soundings with CAPE that fell in the upper quartile)

Large Scale Convective Features

- This objective will track the storm as a whole in a manner similar to a past technique developed by King and Strapp for assessing diurnal variability of Darwin-2014 clouds
- Apply automated procedure to create archive of "Mountain Plots" of practical cases from the Boeing data base
- Analysis will provide information on the timing of engine events related to the overall system life-cycle, including assessment of any diurnal tendencies
- Apply automated procedures (fundamental parameters, Mountain Plots, production of IR pictures with aircraft tracks) to Boeing event data base.

Local Storm Features

- **Attempt to track individual ELOs, and the relation of event aircraft to these ELOs**
  - Analysis will provide information on the timing and location of engine events relative to these local features, as in Bravin et al.
- **This analysis module will be for a subset of the Boeing database where adequate information is available, specifically:**
  - 30 minute or better satellite imagery
  - Aircraft track information and event time and location

Putting it all together

- Each step of the development process to be verified against subjective analysis
- Quality assurance checks
- Once verified, apply automated procedures (fundamental parameters, Mountain Plots, production of IR pictures with aircraft tracks and ELOs, ELO analysis) to the Boeing event data base
- Compile by event type (powerloss, damage, vibration, TAT, pitot, etc)
- Analyze results of global analysis for differences between regions, oceanic-versus continental clouds, vicinity of engine events to local features, diurnal effects etc.

Towards Better Understanding of ICI Env

- Not all clouds with ice crystals cause ICI events
- Furthermore, we believe not all clouds with *HIWC* cause ICI events
- This is likely due to a combination of weather, engine design, and varying avoidance procedures, flight deck tools (or lack of).
- We propose a standardized analysis procedure to refine the definition of ICI environments →

Towards Better Understanding of ICI Env Cont.

- Are the details of clouds/environments which cause engine core icing different from sensor error?
- This approach might also be leveraged for analysis of clouds associated with Pitot events
- The knowledge gained from this study could prove valuable to the development of the 99^{th} percentile total water content statistics and distance scales relevant for different systems for Appendix D revision