# The Critical Role for Satellite Derived Cloud Products for Determining the Flight Icing Threat to Aircraft

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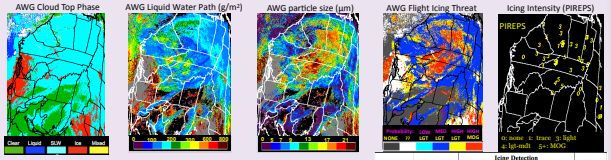
## GOES-R AWG Flight Icing Threat Algorithm

### AWG Cloud Parameters Correlate with Aircraft Icing

- Retrieved cloud phase, LWP, CPS are basis for a satellite Flight Icing Threat (FIT) Algorithm
- Algorithm estimates probability for icing in two intensity categories
- Works well for single-layer unobscured SLW-topped clouds

Smith et al., 2012: Determining the flight icing threat to aircraft with single-layer cloud parameters derived from operational satellite data. *J. of Appl. Met. and Clim.* In Press.



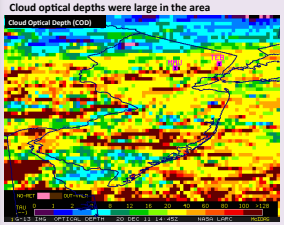

| Validation Data | Day/Night | Icing Detection All Clouds POD | Icing Detection All Clouds Accuracy | Icing Detection Unobscured POD | Icing Detection Unobscured Accuracy | Icing Intensity Accuracy |
|---|---|---|---|---|---|---|
| PIREPS | Night | 56% | 56% | 64% | 63% | NA |
| PIREPS | Day (All) | 62% | 61% | 98% | 93% | 58% |
| PIREPS | Day (Filtered) | 62% | 61% | 99% | 94% | 67% |
| NIRSS | Day | 76% | 73% | 100% | 90% | 77% |
| TAMDAR | Day | 45% | 72% | 87% | 53% | NA |

- Thin clouds eliminated from FIT based on retrieved optical depth
- Pilot reports confirm the icing threat deduced from satellite data
- CTH and other parameters define vertical boundaries for icing
- CPS not yet exploited. Example below illustrates current issues.

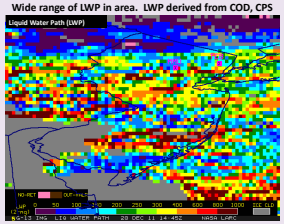
## GOES-13 Analyses at Time of a Recent Fatal GA Accident

A six-passenger single-engine turboprop crashed due to severe icing conditions near Morristown, NJ (MMU) after departing nearby Tetersboro airport (TEB). All five passengers were killed. GOES-R cloud products can improve icing diagnoses for cases like this.

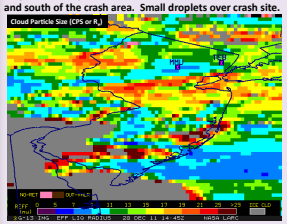
**Cloud optical depths were large in the area**



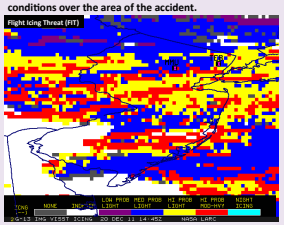

**Wide range of LWP in area. LWP derived from COD, CPS**



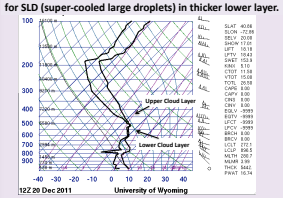

**Large water drops retrieved from GOES 3.9 um channel north and south of the crash area. Small droplets over crash site.**



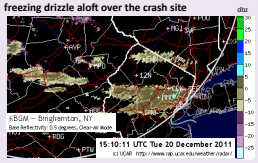

**Satellite icing analysis indicated wide range of icing conditions over the area of the accident.**




**RAOB indicated two cloud layers and favorable environment for SLD (super-cooled large droplets) in thicker lower layer.**




**Radar reflectivity indicative of small ice crystals or freezing drizzle aloft over the crash site**



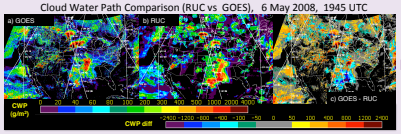

**GOES-13 3.9 um channel sensitive to particle size (CPS) at cloud top. Small droplets in upper layer probably obscure large droplets below, and reduce the retrieved LWP and FIT estimate. CPS derived from GOES-R ABI 2.2 um channel may improve FIT estimates – sees deeper into cloud!**

## Why Satellite Cloud Products are Critical

### Cloud models not accurate at the scales needed

- Advanced modeling systems (i.e. NOAA RUC/RR) assimilate observations of cloud boundaries (satellite CTH, METAR), precipitation (radar), RH (raob, aircraft, gps)
- Mass fields (e.g. IWP, LWP) from satellite are not assimilated operationally
- Accurate icing diagnoses require accurate estimates of cloud water content

Cloud Water Path Comparison (RUC vs GOES), 6 May 2008, 1945 UTC




Model vs Obs

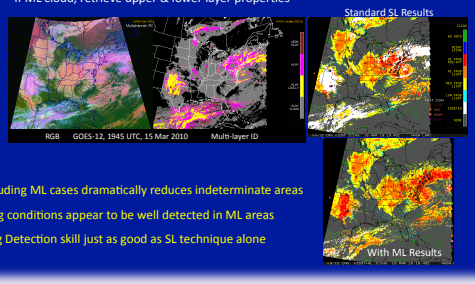
- Major weather systems well represented by model but instantaneous differences large on small scales
- Microwave/Active Remote sensing (CloudSat/CALIPSO/ARM sites) confirm that model uncertainties much larger than GOES uncertainties in many cases
- Mass fields from models are used in decision support systems (e.g operational CIP at AWC)

## Other Potential Satellite Capabilities for Icing

Pilot Reports Indicate that as much as 30-40% of atmospheric icing may be obscured from satellite view by high level cirrus and other ice clouds.

### NASA LaRC Multi-layer Icing Technique

- Modified CO2 Absorption Technique (MCAT; *Chang et al. 2010a,b*)
  - uses T(10.8) and T(13.3) only (day or night)
- Compare single layer VIS/NIR/IR retrievals to MCAT *(Chang & Li 2005)*
  - tau differences determine probability of ML
- If ML cloud, retrieve upper & lower layer properties

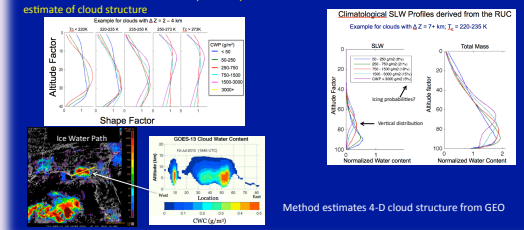



- Including ML cases dramatically reduces indeterminate areas
- Icing conditions appear to be well detected in ML areas
- Icing Detection skill just as good as SL technique alone

### New profiling technique being developed could help provide Icing information in high thick clouds.

CloudSat/ARM CWC profile climatology (75 cloud types) constrained with GOES-derived cloud products provides estimate of cloud structure

Cloud models could help partition liquid/ice mass

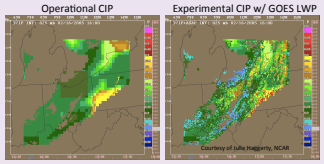



Method estimates 4-D cloud structure from GEO

## Satellite Products in Current & Future Fused Capabilities

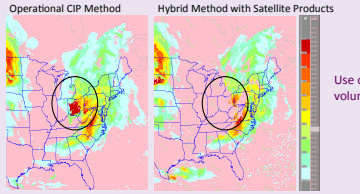
### Operational icing products use satellite data in rudimentary way

- In operational Current Icing Potential (CIP) at AWC, satellite radiances are used to identify the locations of clouds, their top altitude and phase (e.g. Ellrod radiance method to identify SLW)
- Physical retrievals of cloud microphysical parameters are not used but have been tested experimentally and found to improve the resolution of icing conditions and reduce over-warning




Results have been validated with research aircraft data and by icing forecasters

Better definition of the field gives more options to Pilots!




Use of satellite products reduces the volume of air classified as icing

The Future: MICRO to succeed CIP/FIP at AWC in GOES-R era

**MICRO**
*Model of Icing Conditions for Realtime Operations*
FAA AWRP InFlight Icing Product Development Team

- Target: a large North American domain, including AK with 1-4 km grid spacing
  - AK may be a separate domain
  - Terminal areas may also have separate systems
  - Goal is flexibility – should be easily transferred to other domains
- Updated analysis & forecasts every 5 min to 6 h, depending on lead time
  - Lead times will follow NextGen requirements

Satellite data are important input

Satellite cloud products are desired

**MICRO**
*Model of Icing Conditions for Realtime Operations*
FAA AWRP InFlight Icing Product Development Team

- Model analysis
  - T, winds, RH, W
  - Condensate species – water and ice
    - Eventually want complete size distributions
  - Precipitation amounts by precip. type
  - Cloud base and top
  - Convective parameters
  - Layer max LWC
  - Ice accretion rate on a standard body
- Ingest NWS convective forecasts, TAFs??

- Satellite
  - Vis, IR, trends
  - Cloud products!
- Radar
  - National: from MRMS
  - Terminal: from nearest Nexrad or TDWR
  - Dual Polarization!
- Lightning data
  - Identify convection
- METARs
  - T, ceiling, precipitation type
  - Use similarity set concept to match to grid

- The use of satellite data in 'fused' capabilities to diagnose icing conditions operationally has been hampered by the lack of 'operational' satellite cloud products.
- The FAA/AWRP Icing product development team has demonstrated positive impact for satellite cloud products and acknowledges their potential for operational use.
- Cloud products need to be 'operational' and in 4D Weather Cube
- Encouragement and funding needed to appropriately exploit the information content contained in satellite-derived cloud products.