Verification of WAFS Icing Products

20 April 2009

Prepared by the NOAA/ESRL/GSD Forecast Verification Section,
Earth System Research Laboratory
Outline of Discussion

• Motivation and Background
• Assessment Strategy
• CloudSat-based Icing Diagnostic
• Phase 1 Analysis
• Phase 2 Analysis
• Summary
Assessment Background

• Assess the WAFC Washington and WAFC London global icing products

• Understand performance with respect to operational decisions regarding oceanic flights

• Compare performance of automated grids to that of the SigWx Charts
Assessment Strategy

• Build icing diagnostic based on satellite product(s)

• **Phase 1:** Understand product in data rich CONUS region
  – Intercompare new icing diagnostic with PIREPs and CIP
  – Goal: build understanding of product for use in data poor areas
  – Study period: November 07 through January 08

• **Phase 2:** Extend to global domains
  – Apply new icing diagnostic to the data sparse domains
  – Intercompare with Washington and London grids; Sig Wx Charts
  – Study period: November 08 through January 09
CloudSat-based Icing Product (CLIP)
CloudSat

On-board instrument: CPR-Cloud Profiling Radar (94 GHz radar)

Objectives:

・Evaluate the representation of clouds in weather and climate prediction models.

・Evaluate the relationship between cloud liquid water and ice content and the radiative properties of clouds.

・Evaluate cloud properties retrieved using existing satellite measurements and promote the development of new remote sensing methods for observing clouds.

・Contribute to an improved understanding of the indirect effect of aerosols on clouds by investigating the effect of aerosols on cloud formation.
CloudSat Standard Data

- Radar Backscatter Profiles (reflectivity)
- Cloud Geometrical Profile (shape and size)
- Cloud Classification (types of cloud)
- Cloud Water Content (includes liquid and ice)
- Cloud Optical Depth (radiative property)
- Radar-Lidar Cloud Geometrical Profile
- Radar-Lidar Cloud Classification
- Fluxes and Heating Rates (indirect products?)
Typical CloudSat passes over CONUS domain
CLIP Methodology

Retrieval of icing conditions using CloudSat data:

1. Locate clouds using cloud geometric and reflectivity data (CloudSat)
2. Classify cloud types using cloud classification data (CloudSat)
3. Find vertical temperature distribution along CloudSat track (GFS)
4. Icing condition is defined according to cloud types:
   Sc, St: area 0 — -10 degrees
   As, Ac: area 0 — -20 degrees
   Cu, Ns, Deep convection: area 0 — -25 degrees
   High clouds, Ci, Cs, Cc: no icing

[These thresholds are estimated based on the studies by Rauber and Tokay (1991); and Politovich (1996)]
Case study
by Geerts (2008)

2. Tabazadeh et al. (2002; PNAS): observed SWL near -40° in the atmosphere.


Phase 1 Study

Case 1: Dec. 23 2007
Case 2: Jan. 10 2008
Case 3: Dec. 13 2007
20071223

GFS Temperature

CloudSat Classification

New Icing Diagnostic (CLIP)

CONUS CIP
PIREP report a single layer of icing at 4.6 km
PIREP report a single layer of icing at 4.0 km
PIREP report a single layer of icing at 3.4 km
20080110

GFS Temperature

CloudSat Classification

New Icing Diagnostic (CLIP)

CONUS CIP
PIREP report a single layer of icing at 6.1km

PIREP report a single layer of icing at 0.7km
20071213

GFS Temperature

CloudSat Classification

New Icing Diagnostic (CLIP)

CONUS CIP
PIREP report a single layer of icing at 2.0km

PIREP report a single layer of icing at 1.0km
# 2x4 Contingency Table

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Non-convective Clouds in the 10 to 20kft Layer

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Bias = CIP/CLIP = 1.23
Convective Clouds in the 10 to 20kft Layer

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Bias = CIP/CLIP = 1.36
All Clouds in the 10 to 20kft Layer

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Comparison with Previous CIP Study
Phase 1 Summary: Understanding of CLIP

- Primary quantitative comparison to Current Icing Potential (CIP)
  - CIP is current operational grid diagnostic over CONUS
  - Strong agreement between CLIP and CIP for Phase 1 study

- PIREP case studies
  - Significant agreement
  - Disagreement example: CLIP diagnosed cloud, too warm

- Important details …
  - CLIP agreed most strongly at CIP Trace (~0.1) threshold
  - Little difference in agreement: coastal vs. continental
  - Vertical, horizontal windows in matching mechanics
    - Matched to horizontal and vertical scales in Phase 2
  - Primarily studied non-convective icing at mid-level
Phase 2 Discussion

• Background Information
  – Forecast descriptions (US, UK, SigWx)
    • Attributes, issuances
  – Matching mechanics
  – Stratifications

• Analysis
  – Comparison of US and UK grids
    • Qualitative cases
    • Quantitative
  – Comparison of grids to SigWx
  – Supplementary comparison of US grid/FIP in CONUS
Phase 2
Background Information
WAFS Gridded Forecasts

• Model-derived global forecasts
  ➢ Washington (GFS)
  ➢ London (UKMET)

• 3-hour time intervals
  ➢ T+6, 9, 12, 15, 18, 21, 24, 27, 30, 33, and 36 hours

• Recommended use 1 hour 30 minutes before and after each time step

• Automatically updates and cancels the corresponding forecast issued six hours earlier
Phase 2 Analysis
Stratifications

- Geographic domain
  - Global, N. Atlantic, N. Pacific
- Flight level
  - All, FL100, FL140
- Cloud type (as diagnosed by CloudSat)
  - All, Convective, Non-convective
- Algorithm threshold
  - 0.1, 0.3, and 0.5
- Lead time
  - All leads 6, 12, ..., 36-h individually
Domains
Phase 2 Analysis
Comparison of Global Icing Grids
WAFS Mean Icing
Vertical Cross Sections Along CloudSat Path in Atlantic Domain

WAFS-UK

Cloud Classification

WAFS-US

CLIP
WAICS Maximum Icing
WAFS Mean Icing

UK/FL100

US/FL100

UK/FL140

US/FL140
Vertical Cross Sections Along CloudSat Path in Atlantic Domain
Comparison of Performance: Geographic Domain
(Statistics for 0.1 threshold, all lead times, FL100/140, all cloud types)

Most notable difference in Global domain bias
Comparison of Performance: Geographic Domain
(Statistics for all lead times, FL100/140, all cloud types)

Thresholds: 0.1, 0.3, and 0.5
UK points clustered - little difference between thresholds
Comparison of Performance: Lead Time

(Statistics for 0.1 threshold, FL100/140, Atlantic domain, non-convective clouds)
Comparison of Performance: Cloud Type
(Statistics for 0.1 threshold, FL100/140, 
12- and 18-hr leads, Global domain)

Both algorithms perform better for convective icing
Comparison of Performance: Cloud Type
(FL100/140, 12- and 18-hr leads, Global domain)

ROC Thresholds: 0.1, 0.3, and 0.5
Confirms algorithms perform better for convective icing
Comparison of Performance: Flight Level
(Statistics for 0.1 threshold, 12- and 18-hr leads, Atlantic domain, non-convective clouds, max icing attribute)

Bias and FAR notably larger at FL140 for both algorithms
Comparison of Performance: Flight Level
(Statistics for 12- and 18-hr leads, Atlantic domain, non-convective clouds, max icing attribute)

ROC Thresholds: 0.1, 0.3, and 0.5
Confirms variation in performance by flight level
### “Naïve Operational” Comparison

Atlantic domain, 0.1 threshold, FL100/140, 12- and 18-hr leads, max icing intensity, non-convective clouds

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Phase 2 Analysis
Comparison of Global Icing Grids and SigWx Chart
WAFS Mid Level SIGWX

00z, 06z, 12z, 18z

- Thunderstorms/CB
- Tropical Cyclones
- Mod/Sev Turb (CAT or IC)
- Mod/Sev Icing
- Tropopause Heights
- Jetstreams (80kt and above depicted)
- Jet Depth
- Volcanic Eruptions
- Widespread Sand/Dust storms
- Release of Radioactive Materials
Comparison of Performance: SigWx Chart
(Statistics for 0.1 threshold, FL100/140, SigWx issuances/lead, Atlantic domain)

UK and US grids appear to outperform the SigWx icing product;
Note that SigWx doesn’t forecast ‘trace icing’
Comparison of Performance: SigWx Chart
(FL100/140, SigWx issuances/lead, Atlantic domain)

ROC Thresholds: 0.1, 0.3, and 0.5
Confirms algorithms seemingly outperform SigWx product
Phase 2 Analysis
Comparison of US Icing Grid and Forecast Icing Potential (FIP) over CONUS Domain
Diagnostic Comparison: Forecast Icing Potential (FIP)
(Statistics for 0.1 threshold, FL100/140, 6- and 12-hr leads, CONUS domain)

FIP seemingly outperforms the US algorithm over CONUS at the 0.1 threshold
Diagnostic Comparison: Forecast Icing Potential (FIP)  
(Statistics for FL100/140, 6- and 12-hr leads, CONUS domain)

ROC Thresholds: 0.1, 0.3, and 0.5  
Slopes might indicate more information in algorithm below 0.1
Overall Summary

• CLIP diagnostic shown to agree strongly with CIP over the CONUS domain, at the trace threshold

• The UK icing grid appears to outperform the US icing grid at the 0.1 threshold for both the max and mean attributes

• Both icing grids appear to outperform the SigWx icing product

• A diagnostic comparison of the US icing grid with FIP over CONUS seems to indicate information in the algorithm below the 0.1 potential threshold
  – Adjust algorithm or calibrate output?