The Relationship between Regional Icing Distribution and Environmental Conditions

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Purpose

Icing is one of the worst weather events for pilots. Even very small amounts of ice on aircraft can increase drag, decrease lift, and limit airspeed. Icing is such as issue that evasive actions must be taken by many aircraft when it is noticed. Icing can occur in all seasons and all parts of the country, but in varying scenarios. A study was undertaken to examine the distribution of icing pilot reports (PIREPs) regionally by weather scenarios and season. This will provide information regarding which weather scenarios produce the most amounts of icing and the intensity associated with each scenario and region.

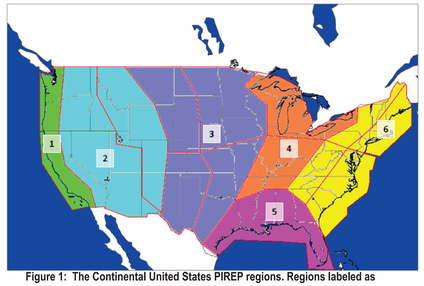

Figure 1: The Continental United States PIREP regions. Regions labeled as 1: West Coast 2: Intermountain West 3: Great Plains 4: Great Lakes and Ohio Valley 5: Southeast 6: East Coast and Appalachians

Methodology

- The Current Icing Product (CIP) is used to help detect where icing exists and its severity. CIP uses data from geostationary satellites, radar, lightning detection networks, PIREPs, numerical weather prediction models, and surface observations. This information is mapped on to a three-dimensional grid and combined to determine if any icing is possible.
- PIREPs provide information regarding the current state of the atmosphere. One piece of information is the icing severity at a given location on a scale of 0 to 8 (Appendix A).
- 80,539 icing PIREPs for the continental United States in 2008 were used to examine a high quantity of icing cases for this study. These reports were matched to the corresponding CIP weather scenario outputs (Appendix B).
- Charts show distribution of trace to heavy icing through all four seasons, providing information regarding which weather scenarios produce the most icing situations and the severity associated with those scenarios.
- Distribution of CIP scenarios by geographic location was also studied:
  - o The CONUS was divided into six regions (Fig. 1) and evaluated for different weather scenarios that produced icing in 2008.
  - o Normalization was achieved by taking the total number of PIREPs in each region divided by the total areal extent of the region.
  - o The data was then grouped by season.

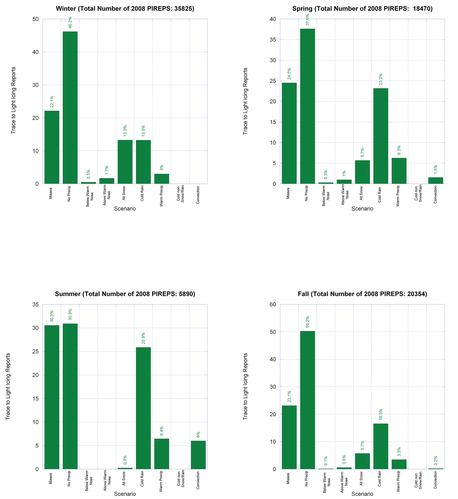

Figure 2: The distribution of icing scenarios by season

Season	No Precip		Below Warm Nose		Above Warm Nose		All Snow	
Winter	Great Lakes and Ohio Valley	33.9%	East Coast and Appalachians	44.5%	Great Lakes and Ohio Valley	52.4%	Great Lakes and Ohio Valley	46.8%
	West Coast	27.1%	Great Lakes and Ohio Valley	33.3%	East Coast and Appalachians	25.2%	West Coast	19.8%
	Great Plains	14.0%	Great Plains	14.4%	Great Plains	12.9%	Great Plains	12.9%
	Intermountain West	9.9%	Southeast	7.4%	Southeast	7.9%	Intermountain West	10.5%
	East Coast and Appalachians	9.7%	West Coast	x	Intermountain West	1.4%	East Coast and Appalachians	10.2%
	Southeast	5.4%	Intermountain West	x	West Coast	0.5%	Southeast	0.8%
Spring	Great Lakes and Ohio Valley	32.4%	Great Lakes and Ohio Valley	60.1%	Great Lakes and Ohio Valley	44.7%	Great Lakes and Ohio Valley	43.1%
	West Coast	20.9%	East Coast and Appalachians	22.3%	Great Plains	32.3%	West Coast	23.3%
	East Coast and Appalachians	16.0%	Great Plains	7.7%	East Coast and Appalachians	21.3%	Great Plains	19.8%
	Great Plains	15.1%	Southeast	1.2%	West Coast	1.3%	Intermountain West	9.4%
	Intermountain West	9.9%	West Coast	x	Intermountain West	0.3%	East Coast and Appalachians	3.9%
	Southeast	5.4%	Intermountain West	x	Southeast	x	Southeast	0.5%
Summer	Great Lakes and Ohio Valley	27.1%	West Coast	x	West Coast	x	West Coast	86.9%
	Intermountain West	17.7%	Intermountain West	x	Intermountain West	x	Intermountain West	13.1%
	West Coast	16.9%	Great Plains	x	Great Plains	x	Great Plains	x
	Great Plains	13.5%	Great Lakes and Ohio Valley	x	Great Lakes and Ohio Valley	x	Great Lakes and Ohio Valley	x
	Southeast	12.3%	Southeast	x	Southeast	x	Southeast	x
	East Coast and Appalachians	11.2%	East Coast and Appalachians	x	East Coast and Appalachians	x	East Coast and Appalachians	x
Fall	Great Lakes and Ohio Valley	40.2%	East Coast and Appalachians	41.4%	Great Lakes and Ohio Valley	49.3%	Great Lakes and Ohio Valley	46.8%
	Great Plains	17.7%	Great Plains	33.4%	Great Plains	30.1%	Great Plains	20.6%
	West Coast	13.8%	Great Lakes and Ohio Valley	25.2%	East Coast and Appalachians	13.7%	Intermountain West	7.2%
	East Coast and Appalachians	12.0%	West Coast	x	West Coast	6.96%	West Coast	2.6%
	Intermountain West	10.4%	Intermountain West	x	Intermountain West	0.5%	Southeast	<1%
	Southeast	5.9%	Southeast	x	Southeast	x	East Coast and Appalachians	<1%
Season	Cold Rain		Warm Precip		Cold Non Snow/Rain		Convection	
Winter	West Coast	62.6%	Great Plains	52.1%	Great Lakes and Ohio Valley	66.3%	Great Lakes and Ohio Valley	100%
	Great Lakes and Ohio Valley	21.4%	Great Lakes and Ohio Valley	21.3%	Great Plains	33.7%	West Coast	x
	East Coast and Appalachians	11.4%	East Coast and Appalachians	8.5%	West Coast	x	Intermountain West	x
	Intermountain West	3.6%	Great Plains	8.1%	Intermountain West	x	Great Plains	x
	Southeast	0.0%	Southeast	3.3%	Southeast	x	Southeast	x
	Great Plains	0.9%	Intermountain West	3.1%	East Coast and Appalachians	x	East Coast and Appalachians	x
Spring	Great Lakes and Ohio Valley	33.5%	West Coast	38.2%	West Coast	x	Southeast	32.2%
	West Coast	27.6%	Great Lakes and Ohio Valley	28.6%	Intermountain West	x	Great Lakes and Ohio Valley	25.8%
	East Coast and Appalachians	16.2%	East Coast and Appalachians	14.3%	Great Plains	x	West Coast	17.6%
	Great Plains	10.4%	Great Plains	8.6%	Great Lakes and Ohio Valley	x	East Coast and Appalachians	12.0%
	Intermountain West	7.4%	Intermountain West	4.7%	Southeast	x	West Coast	7.2%
	Southeast	4.5%	Southeast	4.0%	East Coast and Appalachians	x	Intermountain West	5.2%
Summer	Great Lakes and Ohio Valley	28.7%	West Coast	36.1%	West Coast	x	Great Lakes and Ohio Valley	29.1%
	West Coast	20.3%	Great Lakes and Ohio Valley	22.6%	Intermountain West	x	Southeast	21.2%
	Southeast	16.9%	Intermountain West	15.4%	Great Plains	x	Intermountain West	16.5%
	Intermountain West	15.7%	Great Plains	11.7%	Great Lakes and Ohio Valley	x	Great Plains	15.4%
	Great Plains	8.9%	Southeast	10.8%	Southeast	x	East Coast and Appalachians	11.1%
	East Coast and Appalachians	7.7%	East Coast and Appalachians	5.4%	East Coast and Appalachians	x	West Coast	6.7%
Fall	Great Lakes and Ohio Valley	36.9%	Great Lakes and Ohio Valley	37.1%	West Coast	x	Intermountain West	46.4%
	West Coast	27.6%	West Coast	32.6%	Intermountain West	x	Great Lakes and Ohio Valley	34.9%
	East Coast and Appalachians	17.8%	Great Plains	12.1%	Great Lakes and Ohio Valley	x	Great Plains	8.3%
	Great Plains	10.9%	East Coast and Appalachians	11.7%	Great Lakes and Ohio Valley	x	East Coast and Appalachians	6.2%
	Intermountain West	6.0%	Southeast	6.0%	Southeast	x	Southeast	5.1%
	Southeast	5.8%	Intermountain West	5.3%	East Coast and Appalachians	x	West Coast	x

Table 1: Distributions of the regional weather scenarios. Highlighted areas indicate regions with the highest number of icing events.

Results

- The statistics showed variations based on the season and type of precipitation occurring.
- Trends were examined based on what type of weather scenarios were occurring during trace to severe icing cases (Fig. 2)
  - o For all four seasons, the **non-precipitating** weather scenario was the highest cause for icing in 2008.
  - o **Cold rain** produced the second highest cause except in winter where **snow** and **cold rain** had equal percentages.
- Data comparing icing intensities associated with weather scenario plots were created by season and an annual average was calculated (Fig. 3).
  - o Instances were examined where there were enough PIREPs to make an appropriate decision. We concluded that the distribution of intensities did not vary based on the scenario.
- Distribution of icing scenarios compared to the six regions of CONUS (Table 1).
- Winter
  - o Great Lakes and Ohio Valley had the highest number of icing events for **no precipitation**, **above the warm nose**, **all snow**, **cold non snow/rain**, and **convection** largely due to how much this region receives enhanced Lake Effect features.
  - o West Coast had the highest number of icing events for **cold rain**, and **warm precipitation** due to more moderate temperatures in this region.
  - o East Coast and Appalachians had the most below the **warm nose** icing situations.
- Spring
  - o Spring trends were fairly consistent with winter.
  - o As the Great Lakes and Ohio Valley transition from colder weather to slightly warmer temperatures **below the warm nose** and **cold rain** features become more common in this region.
  - o **Convection** also becomes a dominat feature in the Southeast.
- Summer
  - o Great Lakes and Ohio Valley remain consistent with the majority of icing events classified as **no precipitation**, **cold rain**, and **convection** as temperatures continue to rise and the Great Lakes continue to contribute to the precipitation.
  - o **Warm Precipitation** continues to be a West Coast feature.
- Fall
  - o Great Lakes and Ohio Valley icing events mostly occur in **no precipitation**, **warm precipitation**, **cold rain**, **above the warm nose**, and **all snow**. The temperature transition can easily be seen within this area as the region transitions from hot/humid conditions to colder temperatures.
  - o East Coast and Appalachians regains the majority of **below the warm nose** icing conditions with the approach of winter.
  - o Intermountain West starts seeing more icing events due to **convection**.
- These results show a strong regional distribution of icing and reveal weather events that have higher likelihoods for icing. This information will help the developers in fine tuning the algorithm, which is essential as the CIP transitions to a more regionally driven icing diagnosis system. The information should also help the end-user more accurately interpret CIP output, and more effectively utilize it.

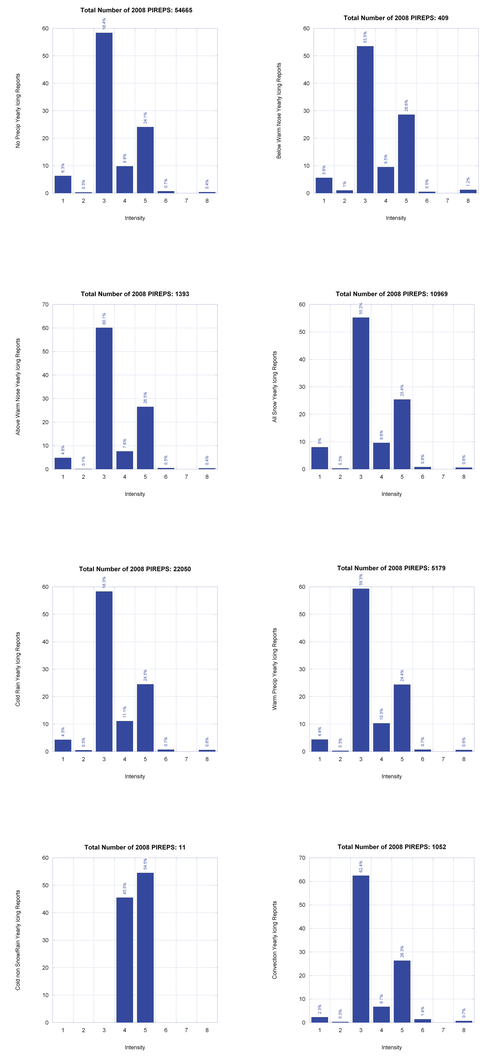

Figure 3: Distribution of icing intensities to weather scenarios

APPENDIX A: PIREP icing severity index

- 0 No icing
- 1 Trace icing
- 2 Trace to Light icing
- 3 Light icing
- 4 Light to Moderate icing
- 5 Moderate icing
- 6 Moderate to Severe icing
- 7 Heavy icing
- 8 Severe icing

APPENDIX B: CIP Severity Icing Scenarios

- **Non-precipitating Cloud – No precipitation is identified by the algorithm.**
- **Snow Only – The only precipitation type identified is snow.**
- **Cold Rain – The cloud top temperature is less than -12°C and either rain is identified as precipitation type or the 75th percentile of the reflectivity for the 4-km radar observations mapped to the grid box are greater than or equal to 5 dBZ.**
- **Warm Precipitation – The cloud top temperature is greater than or equal to -12°C and either the precipitation type is identified as non-snow or the 75th percentile reflectivity is greater than or equal to 5dBZ.**
- **Cold Non Snow/Rain – The cloud top temperature is less than -12°C, there is not a classical warm nose and the percipitation type identified is drizzle, freezing drizzle, freezing rain, or pellets.**
- **Classical Precipitation Above the Warm Nose – The cloud top temperature is less than -12°C, a classical warm nose is present, the precipitation type identified is not all snow, and the level in question is above the identified warm nose (inversion).**
- **Classical Precipiatation Below the Warm Nose – The cloud top temperature is less than -12°C, a classical warm nose is present, the precipitation type identified is not all snow, and the level in question is below the identified warm nose (inversion).**
- **Deep Convection – The distance to a lightning strike is less than or equal to 25 km.**

Acknowledgments

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