Icing detection from geostationary satellite data over Korea and Japan using machine learning approaches

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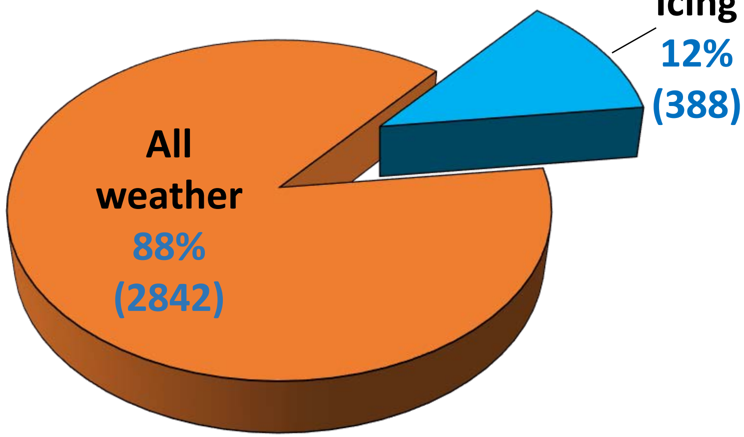
Contents

INTRODUCTION

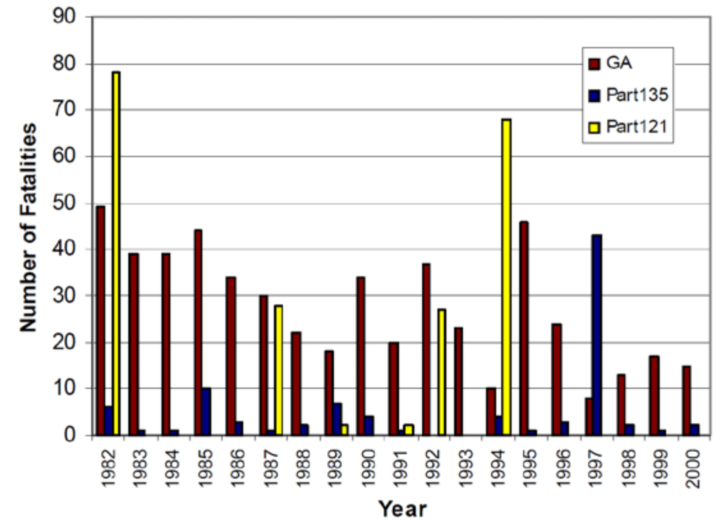
- Aviation accidents caused by icing

Total weather accident (1990-2000)



< source : 1990-2000 Aviation accident statistic >

Airframe icing accident fatalities (1982-2000)



< source : NASA Subsonic Aircraft Safety Icing Study >

January 27, 2009, at 4:37 a.m. CST, an ATR 42-320 (N902FX)

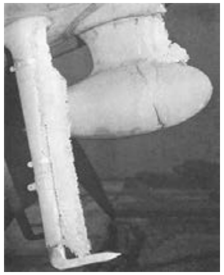
- 12% of the total weather accidents are caused by icing
- Fatal accidents occur every year

⇒ <u>Critical issues for aviation safety</u>

INTRODUCTION

- What is icing?

Super-Cooled Droplet (SCD) clouds



Super-Cooled Droplet (SCD) occurs under 0˚C and stable condition.

When SCD collides on an object, SCD turns into ice form, which is ‘Icing’.

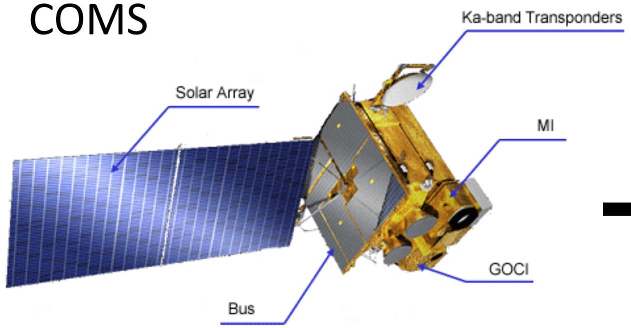
Natural phenomenon, but too dangerous.

→ **Accurate observation and monitoring are required**

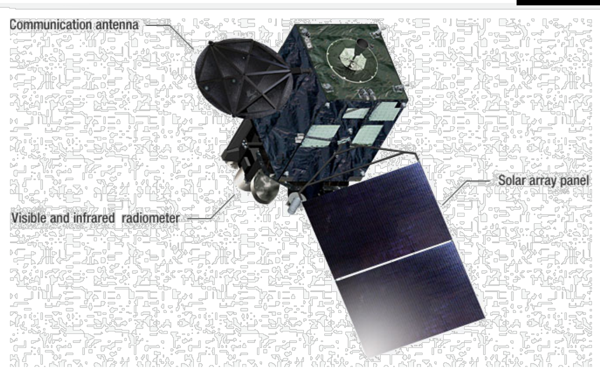
INTRODUCTION

- GEO-KOMPSAT-2 (GK-2A)

COMS



Himawari - 8

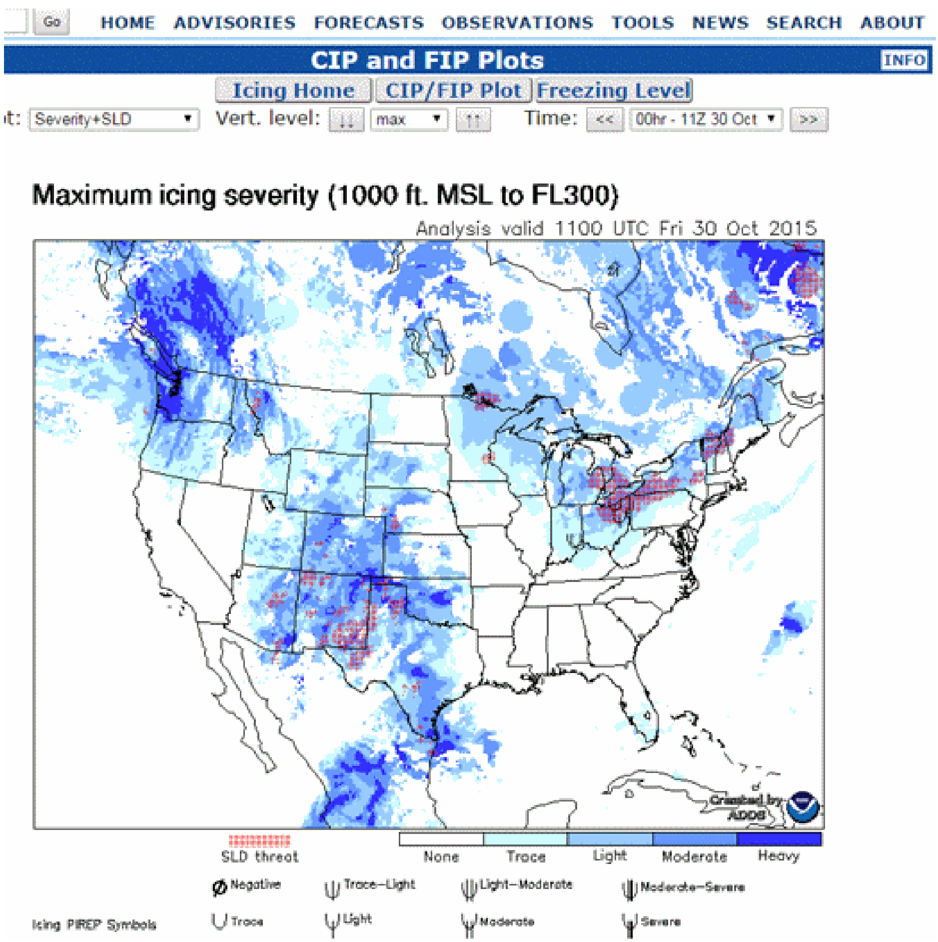


It can be good proxy data for GK-2A icing product!!

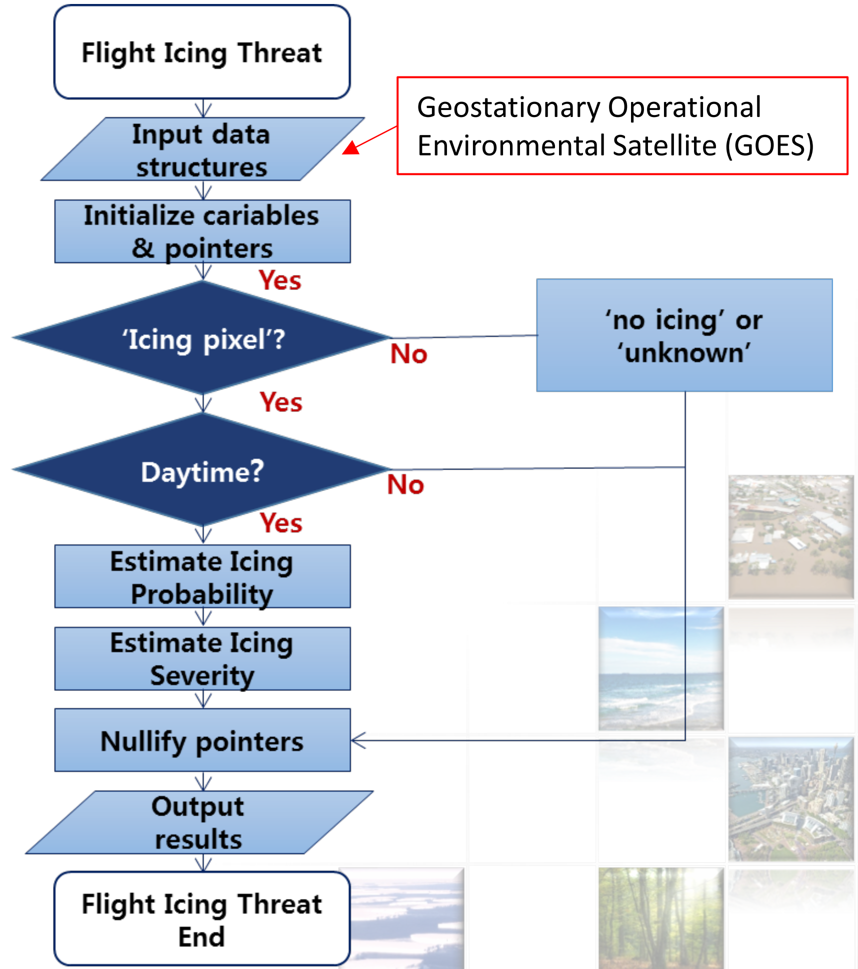
GK-2A

PREVIOUS STUDIES

- Current Icing Product/Forecast Icing Product (CIP/FIP)



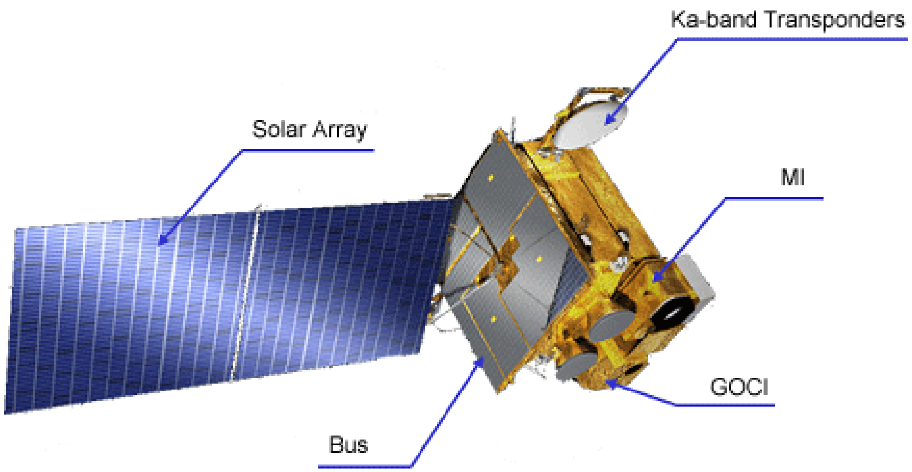
CIP/FIP operating map



CIP/FIP algorithm

PREVIOUS STUDIES

Communication, Ocean and Meteorological Satellite(COMS)

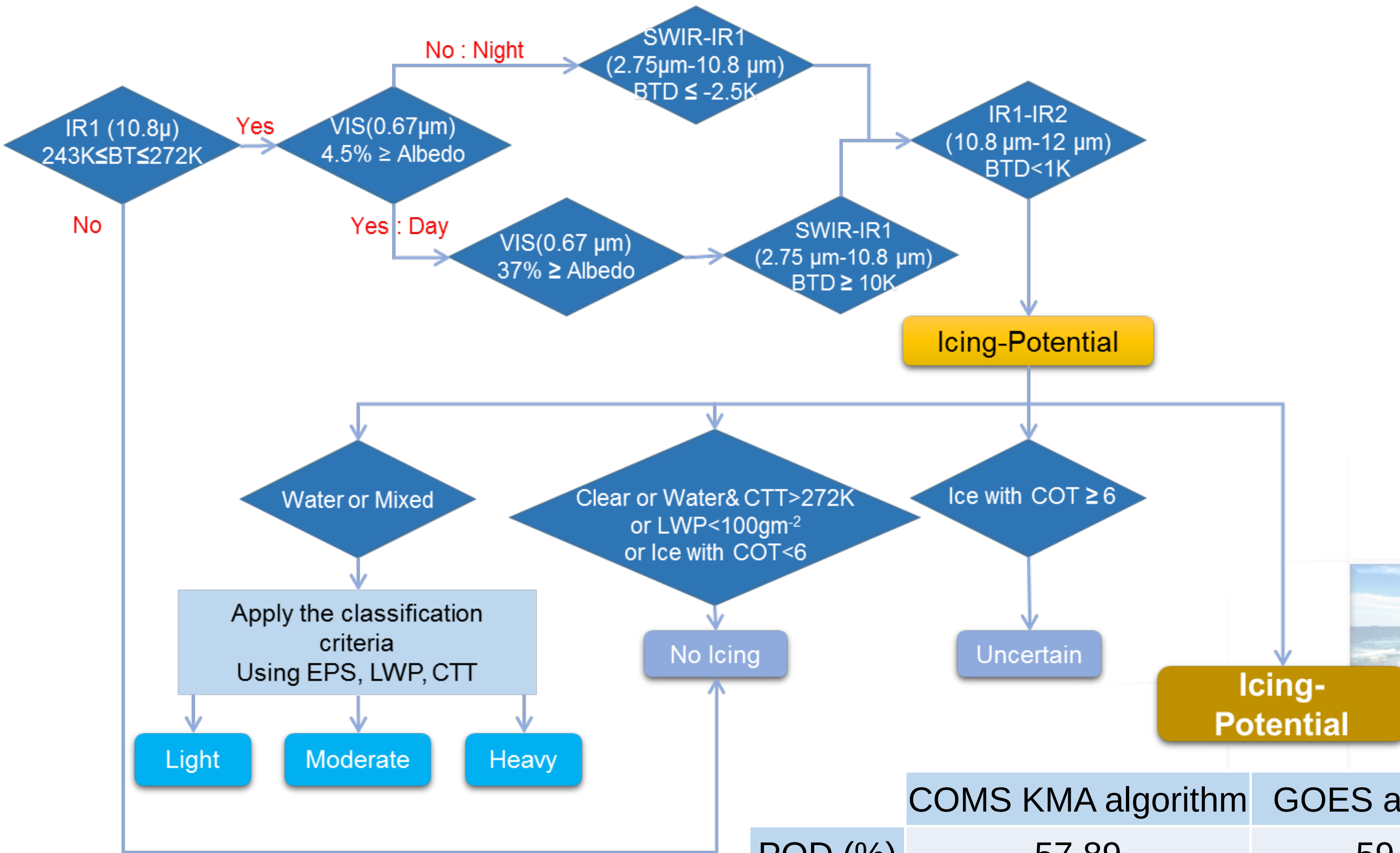


GOES - Imager		**COMS – MI**	
Band	Bandwidth, µm	Band	Bandwidth, µm
Vis	0.55−0.75	Vis	0.55−0.80
ShortWave	3.80 - 4.00	ShortWave	3.5−4.0
Moisture	6.50 - 7.00	WaterVapor	6.5−7.0
IR-1	10.20 - 11.20	IR-1	10.3−11.3
IR-2	11.50 - 12.50	IR-2	11.5−12.5

Computation Sources	Contents
Upper tropospheric humidity	Vapor amount in the upper troposphere
Cloud analysis	Estimation of shapes & amount of clouds & characteristics of cloud particles
Cloud top temperatures & heights	Estimate the temperatures & heights at the cloud tops

PREVIOUS STUDIES

- Communication, Ocean and Meteorological Satellite(COMS)



COMS KMA algorithm

	COMS KMA algorithm	GOES algorithm
POD (%)	57.89	59.90
FAR (%)	99.02	5.51

POD :Probability Of Detection
FAR : False Alarm Rate

RESEARCH CONTENT

1. GOAL OF RESEARCH
   - ➢ To develop icing detection models using COMS and Himawari-8 based on machine learning approaches

2. RESEARCH PROCESS
   - ➢ Icing reference data
     - ✓ Relied only on the PIREPs data as reference
   - ➢ Cloud-related variables are determined
     - ✓ L1B data, Cloud analysis data, and Upper atmospheric variables
   - ➢ Machine learning approaches
     - ✓ Decision Trees(DT), Random Forest(RF), Support Vector Regression(SVR)

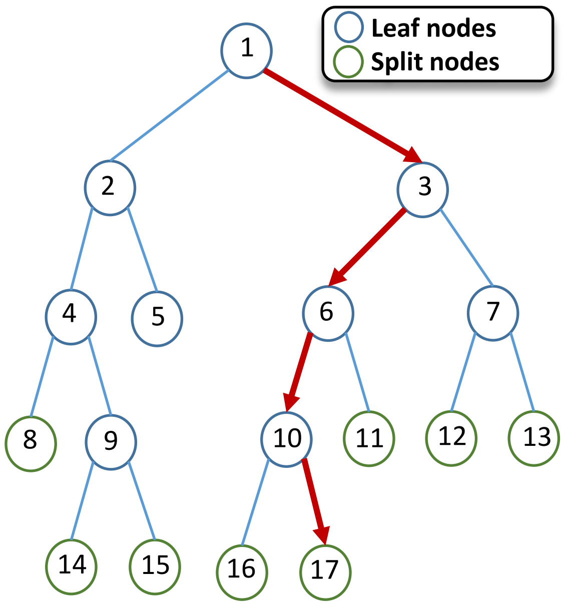
3. THREE ICING MODELS
   1) **Icing masking model using COMS data**
   2) **Icing altitude estimation using COMS data**
   3) **Icing masking model using Himawari-8 data**

RESEARCH CONTENT

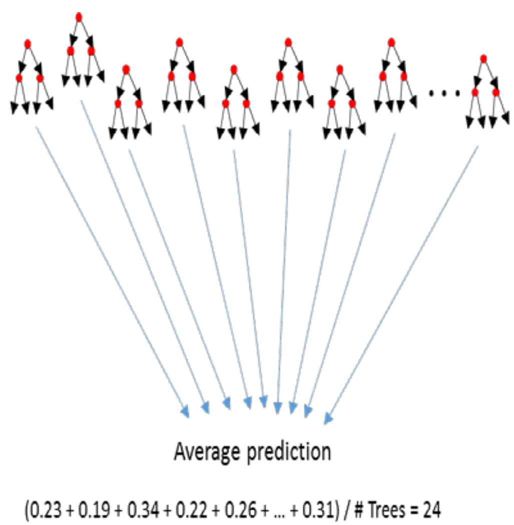
❖ Machine Learning

Machine Learning is a sort of the artificial intelligence (AI). Machine learning develops a model that learns from and makes prediction of data

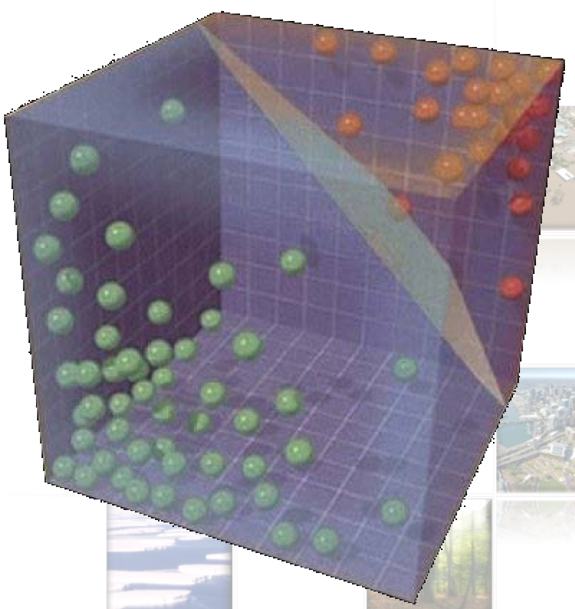
1. Decision Trees (DT)



2. Random Forest (RF)



3. Support Vector Regression (SVR)



1) Icing masking model based on COMS

- Data and Methodology

- Reference dataset was prepared based on the PIREPs
  - Consisted of 22 icing sites and 169 non-icing sites acquired from PIREPs between 1 Apr 2011 and 5 Sep 2015

- Input variables from the Level-1b and Level-2 data

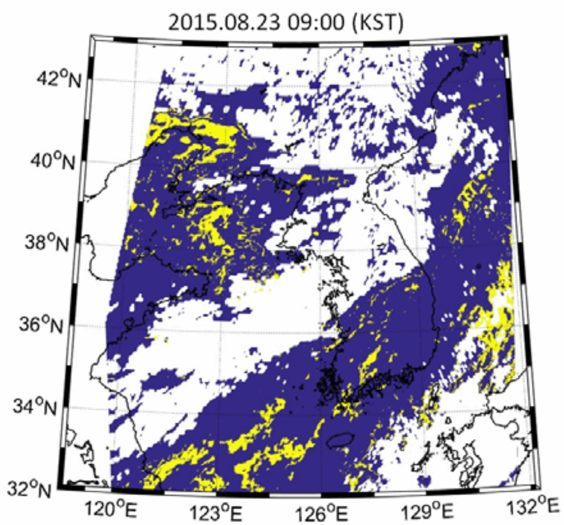
Level-1b	Level-2
Visible	Cloud Optical Thickness; COT
Shortwave Infrared (SWIR)	Cloud Top Temperature; CTT
Water Vapor (WV)	Cloud Top Height; CTH
Infrared1 (IR1)	Upper Tropospheric Humidity; UTH
Infrared2 (IR2)	Cloud Effective Radius; CER
BTD1 (SWIR - IR1)	Cloud Phase; CP
BTD2 (IR1-IR2)	

Excluded for training data through the result of tests

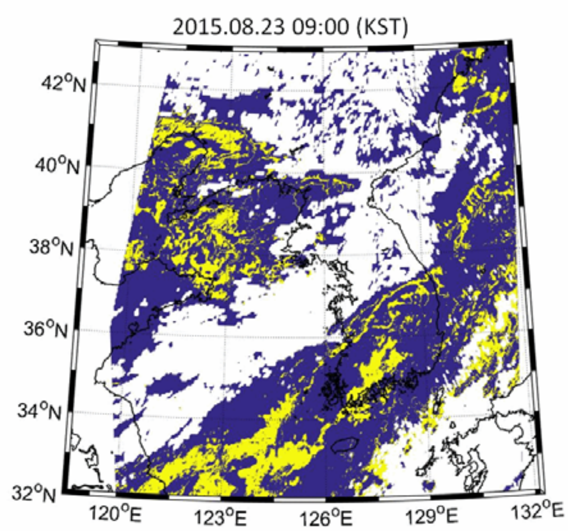
1) Icing masking model based on COMS

- Results

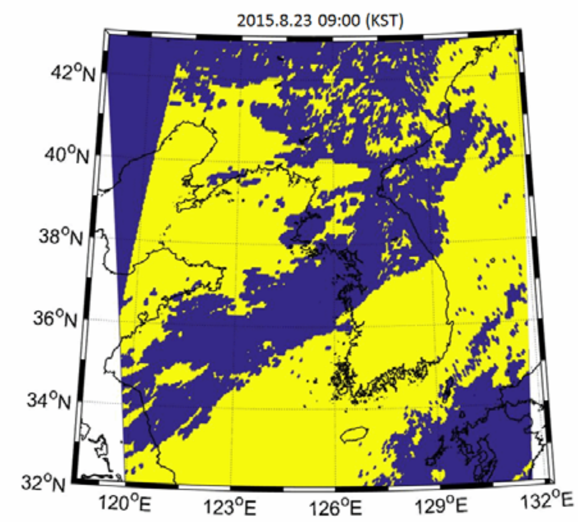
Non-icing
Icing



Random Forest



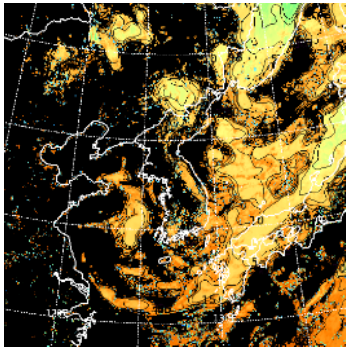
Decision Trees



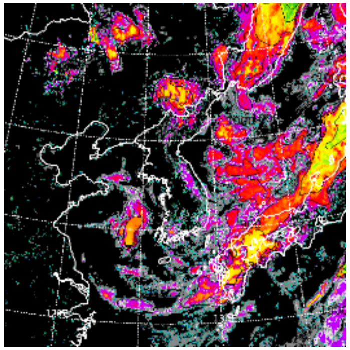
KMA algorithm

2) Icing altitude estimation based on COMS

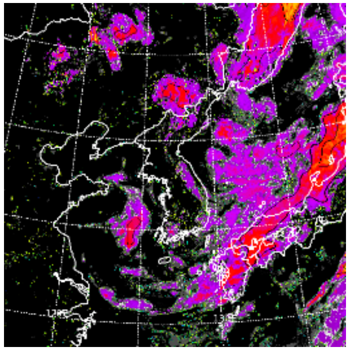
- Data and Methodology



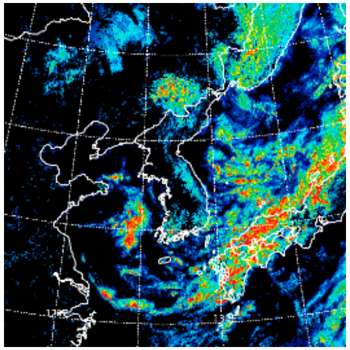
Cloud Top Temperature (CTT)



Cloud Top Pressure (CTP)



Cloud Top Height (CTH)



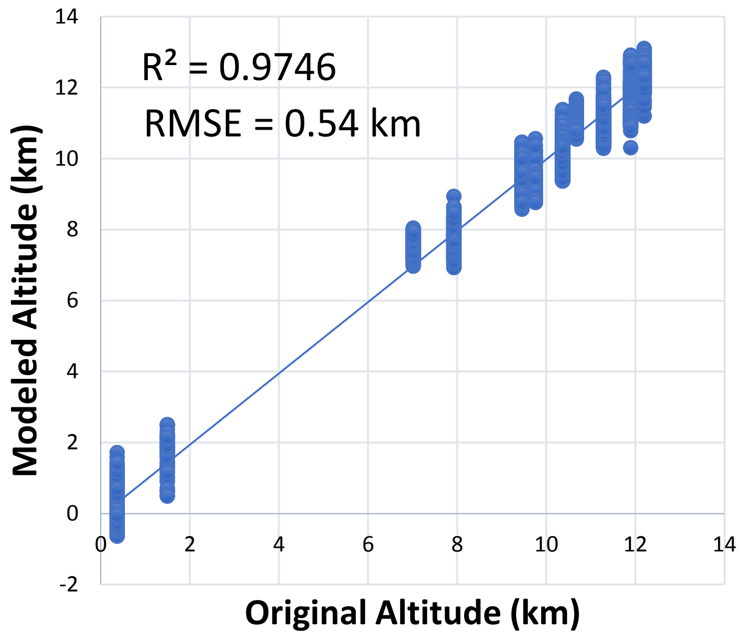
Cloud Optical Thickness (COT)

- Cloud Top Temperature (CTT), Cloud Top Pressure (CTP), Cloud Top Height (CTH), and Cloud Optical Thickness (COT) are related to the internal properties of clouds such as temperature and particles
- Distribution of cloud internal properties is related with the vertical icing potential
- Altitude of icing from the PIREPs as a dependent variable
- Input variables: L1B and CTT, CTP, CTH, and COT data
- Modeling approach: Support Vector Regression (SVR)

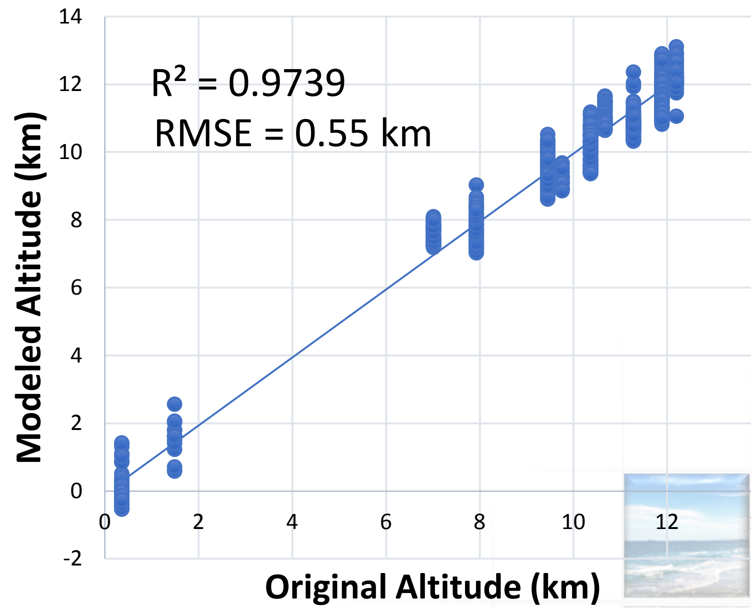
2) Icing altitude estimation based on COMS

- Result

Calibration



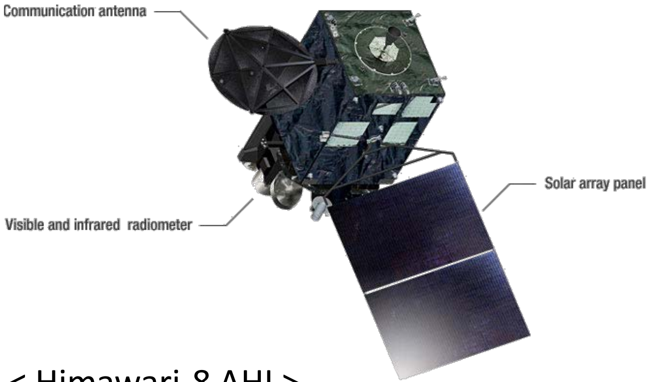
Validation



Errors are generally within ±300m vertically, which is the significant level of icing from PIREPs.

3) Icing masking model based on Himawari-8

- Himawari-8



- Geostationary satellite of JMA, launched in October, 2014
- Provide data from July 2015
- Images of 16 channels are provided for weather observations and environmental mornitoring
- Spatial resolution ranges from 0.5km to 2km
- Temporal resolution ranges from 0.5min to 10min
- Has similar channel characteristics with GEO-KOMPSAT-2 (GK-2A), so it is good proxy data for GK-2A

< Himawari-8 AHI >

Channel	Centerwavelength[µm]	Bandwidth[µm]	Resolution[km]
1	0.4703	0.0407	1
2	0.5105	0.0308	1
3	0.6399	0.0817	0.5
4	0.8563	0.0345	1
5	1.6098	0.0409	2
6	2.257	0.0441	2
7	3.8848	0.2006	2
8	6.2383	0.8219	2
9	6.9395	0.4019	2
10	7.3471	0.1871	2
11	8.5905	0.3727	2
12	9.6347	0.3779	2
13	10.4029	0.4189	2
14	11.2432	0.6678	2
15	12.3828	0.9656	2
16	13.2844	0.5638	2

	Observations per timeline	Time cycle [min.]	Observations per day
Full Disk	1	10	144
Japan Area	4	2.5	576
Target Area	4	2.5	576
Landmark Area	20	0.5	2,880
Landmark Area	20	0.5	2,880

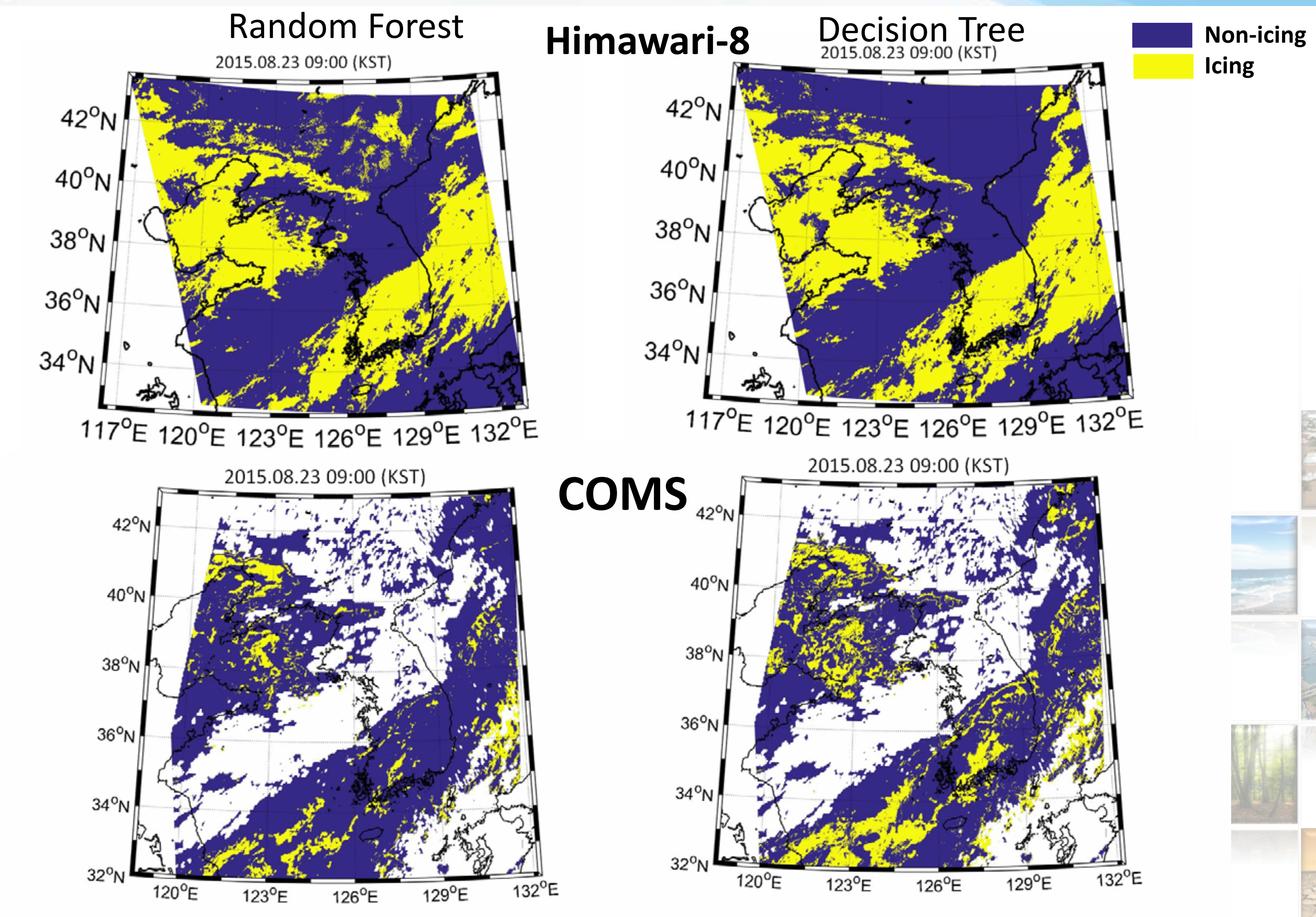
3) Icing masking model based on Himawari-8

- Data and Methodology

- Reference dataset
  - Consists of 2 icing sites and 7 non-icing sites acquired from PIREPs between 1 Jul 2015 and 31 Aug 2015
- Input variables: 16 channels from full disk images
- Very limited number of samples during 2 months

3) Icing masking model based on Himawari-8

- Result



CONCLUSION

- Icing masking model based on COMS by DT & RF approaches
  - Similar patterns by two models
  - Decision trees estimated icing more than random forest.
- Icing altitude model based on COMS by SVR approach
  - Errors are generally within ±300m vertically, which is the significant level of icing from PIREPs.
- Icing masking model based on Himawari-8 by DT & RF approaches
  - Similar patterns by two models
  - Much more icing areas were produced from Himawari-8 than COMS.
- Very limited amount of data based solely on PIREPs as reference
  - More PIREPs will be available in the future, but might not be sufficient for modeling
  - Will investigate if the CloudSat Icing Potential (CLIP) algorithm based on cloud type and vertical profile of temperature can be further improved to provide more reliable icing masks.

Thank you

Intelligent Remote sensing and geospatial Information Systems (IRIS)

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