# Satellite Detection and Nowcasting High-altitude Ice Crystals

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High-altitude Ice Crystals Formation

Strengthen the updraft

1) Less time to grow by condensation
2) Supersaturation w.r.t. liquid water increases, so smallest drops don't evaporate
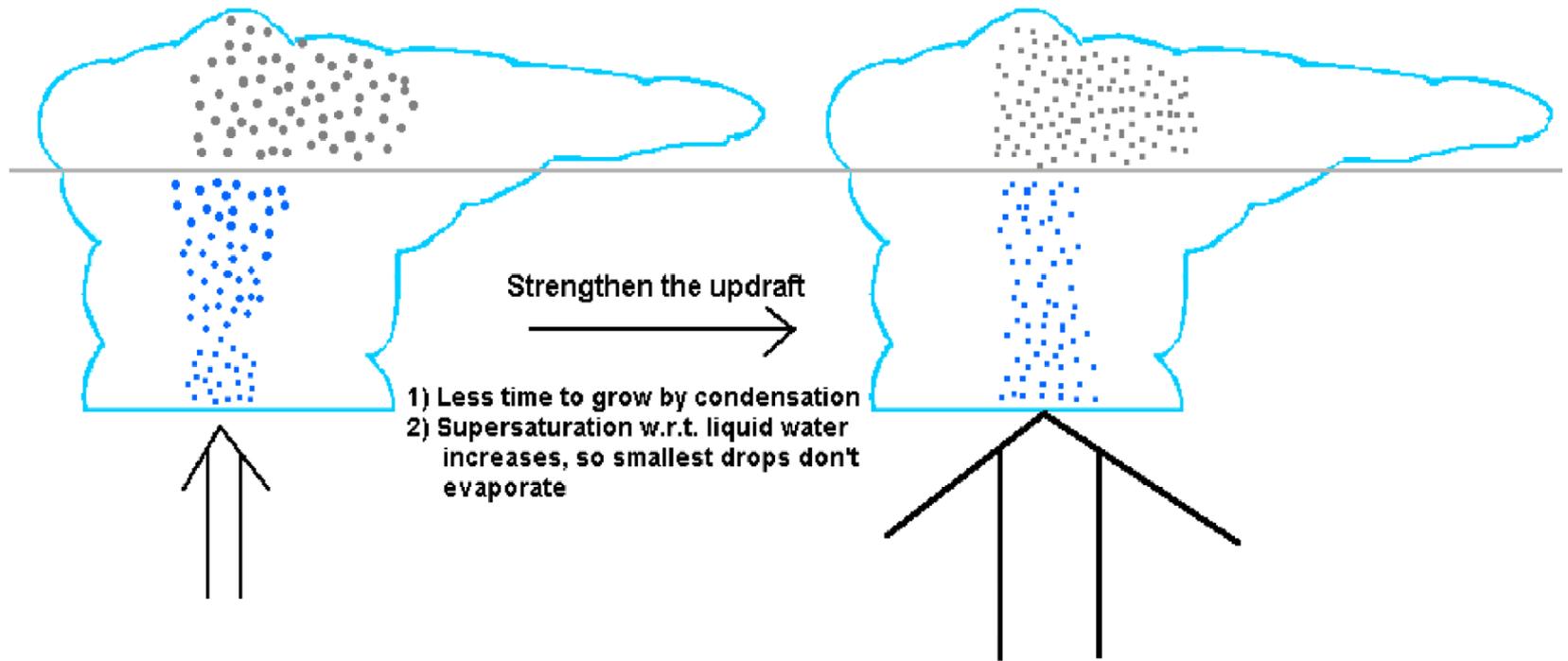
High-altitude Ice Crystals Hazzard
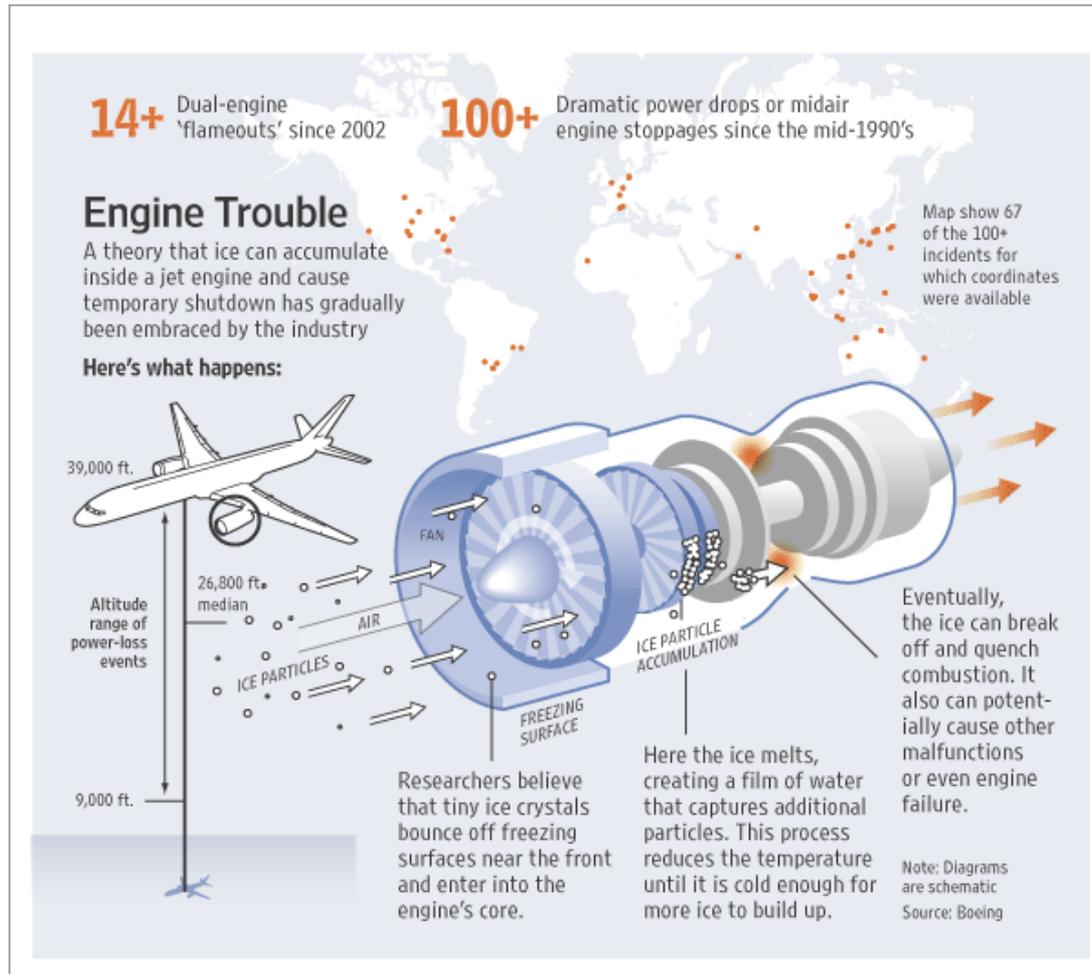
A. Pastor, Wall Street Journal: Airline Regulators Grapple With Engine-Shutdown Peril
https://www.wsj.com/articles/SB120753403340593953

Himawari-8 Satellite

	Band	Wavelength [µm]	Quantization [bit]	Spatial Resolution (km)
VIS	1	0.46	11	1km
VIS	2	0.51	11	1km
VIS	3	0.64	11	0.5km
	4	0.86	11	1km
	5	1.6	11	2km
	6	2.3	11	2Km
IR4	7	3.9	14	2Km
IR3	8	6.2	11	2Km
IR3	9	7.0	11	2Km
IR3	10	7.3	12	2Km
	11	8.6	12	2Km
	12	9.6	12	2Km
IR1	13	10.4	12	2Km
IR2	14	11.2	12	2Km
	15	12.3	12	2Km
	16	13.3	11	2Km

Similar to ABI for GOES-R

R G B band **Composited**

0.51 µm (Band 2) instead of ABI's 1.38 µm

Water vapor

SO_2
O_3

Atmospheric Windows

CO_2

True Color Image

Himawari-8 Satellite

| Band 01, 02, 03	Clouds, low cloud and fog, winds, vegetation, snow cover etc.
Band 04	Daytime vegetation / burn scars, flood / standing water, aerosol detection over water, winds, snow cover
Band 05	Daytime cloud top phase and particle size, snow cover, flood / standing water
Band 06	Daytime cloud / land properties, cloud particle size, vegetation, snow cover
Band 07	Surface and clouds, low clouds and fog at night, fires and hot spots, winds
Band 08	High level atmospheric water vapour, turbulence, winds, rainfall
Band 09	Mid level atmospheric water vapour, winds, rainfall
Band 10	Lower level water vapour, winds, rainfall, sulphur dioxide
Band 11	Total water for stability, cloud phase, dust, sulphur dioxide, rainfall
Band 12	Total ozone, turbulence, winds
Band 13	Surface features, clouds, Tropical Cyclone intensity (Dvorak)
Band 14	Sea surface temperature, clouds, convective cloud top signatures, rainfall, volcanic ash detection, winds.
Band 15	Total water, volcanic ash detection, sea surface temperature
Band 16	Air temperature, cloud heights and amounts, volcanic ash height

Study Data

- between April 2015 and October 2016
- 14 icing cases reported by pilot
- justified with the measured static air temperature (SAT) anomalies

In deep convection area with constant altitude, significant jump in SAT
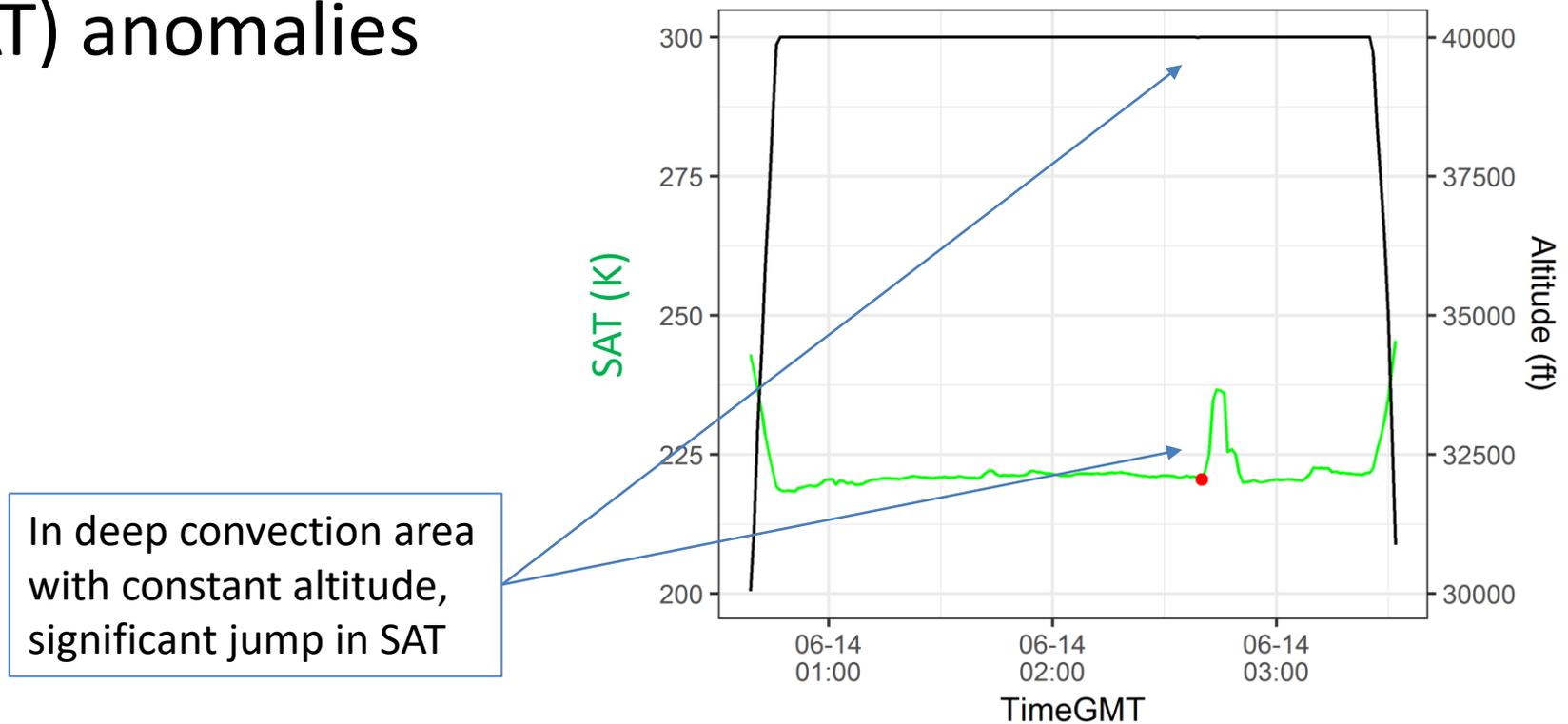
Study Data

- 19 null cases chosen
- flight path passed through deep convection, but no anomalies in SAT

In deep convection area with constant altitude, constant SAT
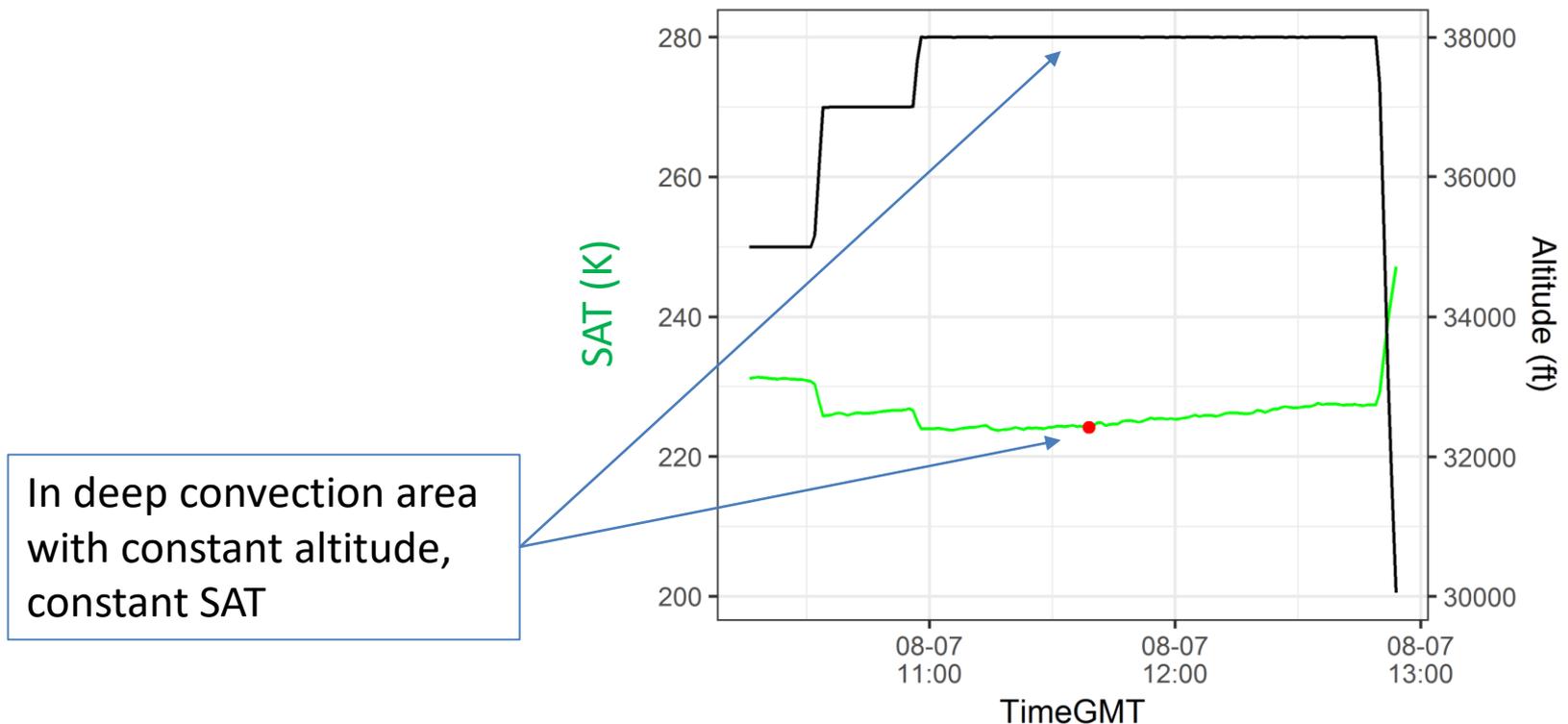
Random Forest

Stage 1:
Bootstrap sampling
2/3 data as training

Observations

Satellite channels B01-B16 and reported icing cases (CX flight data)

Training subset 1   Training subset 2   ......   Training subset M
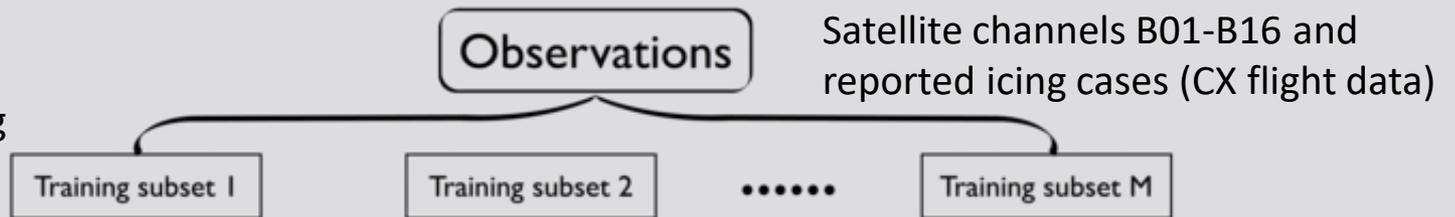
Stage 2:
Model training
Based on BT values and combinations

Tree t=1   Tree t=2   ......   Tree t=M

$p(P_d|v)$ P_d

v: covariates
● Split nodes
● Leaf nodes
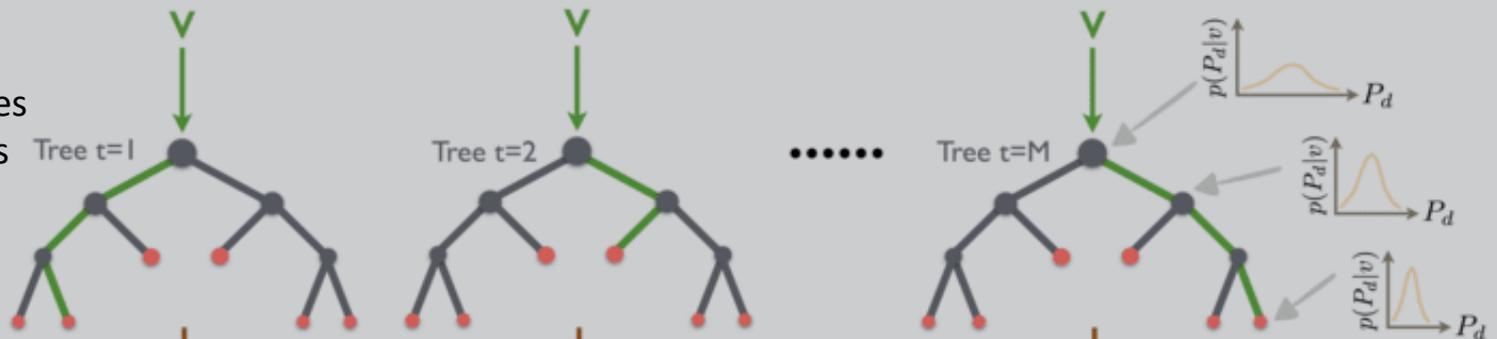
Stage 3:
Model forecasting

Forecast 1   Forecast 2   Forecast M

Stage 4:
Result aggregating
1/3 data as testing

Forecast

Pixel output: 0 (no icing) or 1 (icing)

Random Forest Results
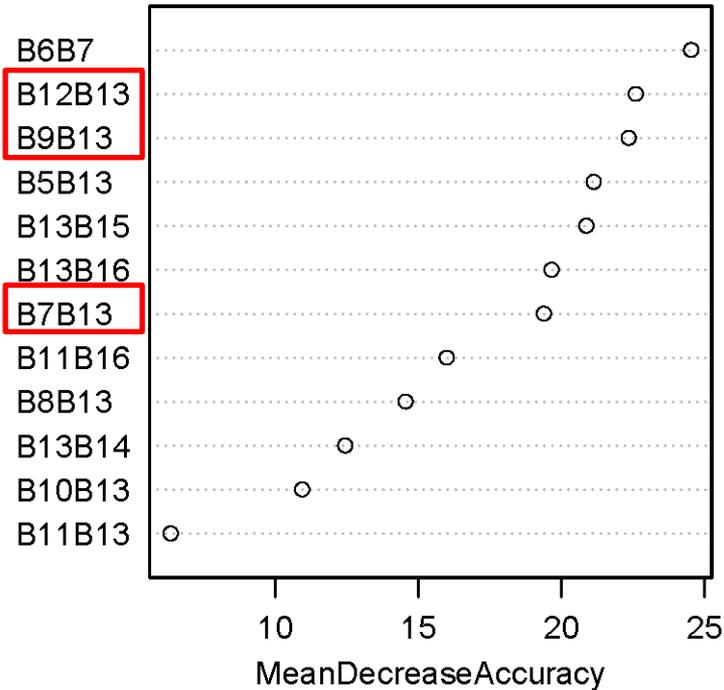
Most important channel in decision tree **accuracy** is ranked at the top
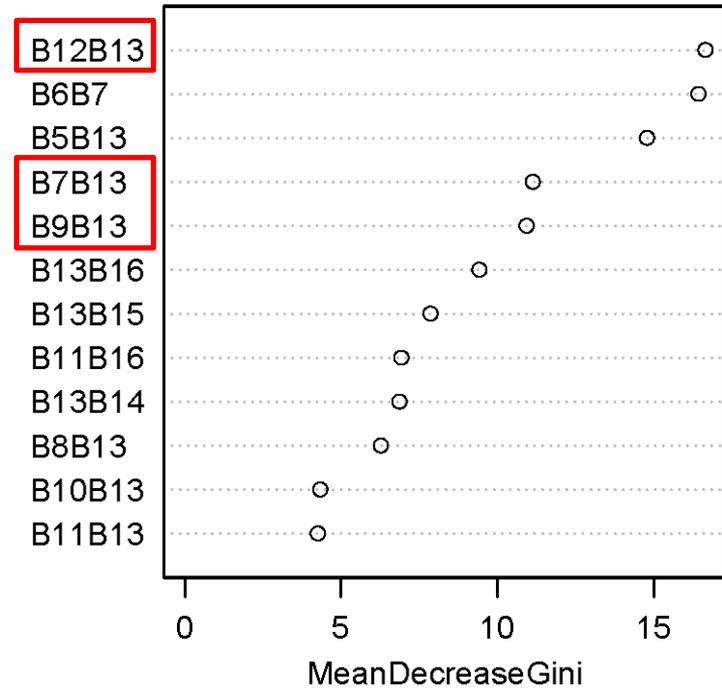
Most important channel in grouping **purest** trees (i.e. purest classes after classification) is given at the top

Split Windows Algorithm

Split Windows	Properties	Reference
B07–B13	ice particles sizes for very cold cloud tops	EUMETSAT Severe Storm RGB
B09–B13	deep convective activity of clouds	COMS Convective RGB
B05–B13	cloud phase (ice/water) information	COMS Cloud Product
B12–B13	deep convective activity of high clouds	Kwon *et al.*
B13–B15	cloud type classification (optical thickness)	NOAA 7 split-window
B13–B16	deep convective activity of high clouds	Kwon *et al.*

B05–B13 and B13–B15 are not used for graphical presentation because it is redundant with B12–B13, where B12–B13 is more useful in distinguishing icing cases.

B09–B13 and B12–B13 are used for detection of deep convection, the less important B13–B16 is not included in the split windows algorithm.

E.H. Kwon, B.J. Sohn, J. Schmetz, P. Watts, Intercomparison of height assignment methods for opaque clouds over the tropics, Asia-Pacific J Atmos Sci (2010) 46: 11. doi:10.1007/s13143-010-0002-7

Split Windows Algorithm

VIS Band 03 > 0.4

No   Yes

Night-time: without VIS   Day-time: with VIS (lower FAR)

Blue: high cloud tops (regions with ice crystals)   **Blue**: high cloud tops (regions with ice crystals)
6.5K < Band 12–Band 13 < 19K   6.5K < Band 12–Band 13 < 19K

                                                Yellow: small ice crystals
                                                Band 07–Band 13 > 50K

Split Windows Algorithm Verification

Algorithm	POD	FAR	True skill statistics
Himawari-8	0.55	0.13	**0.42**
CIP (NCAR)	0.76	0.33	**0.43**
SIGMA (Meteo-France)	0.59	0.26	0.33
GDCP (NASA)	0.76	0.67	0.09

M. Chapman, A. Holmes and C. Wolff, Verification of aviation icing algorithms from the second alliance icing research study, 12th Conference on Aviation Range and Aerospace Meteorology
https://ams.confex.com/ams/Annual2006/techprogram/paper_104158.htm

Nowcasting

20170903_0340_ici
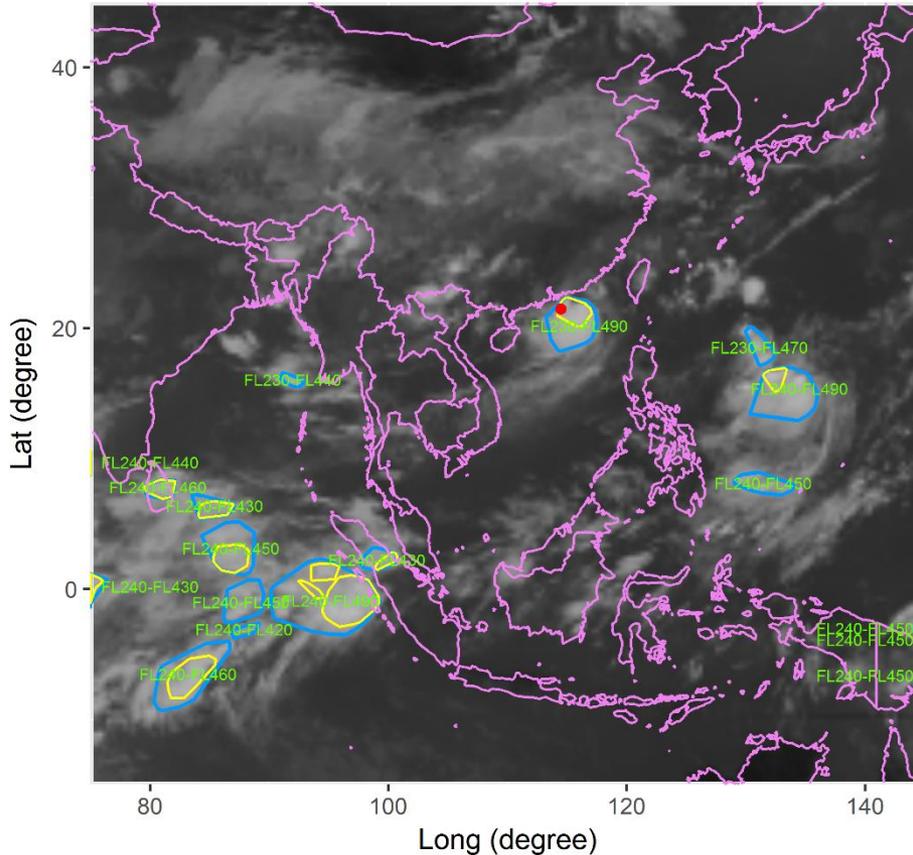
20170903_0340_ici_fcst hr:1
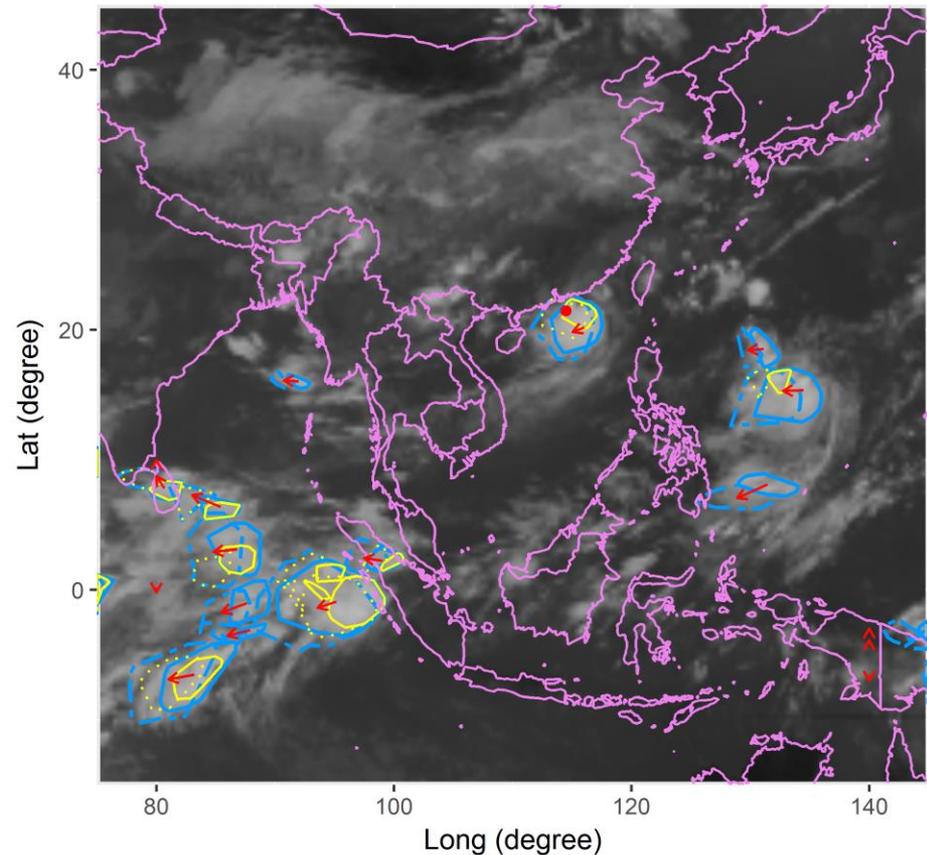
Deep convection for high clouds
19 > B12 (9.6 μm)–B13 (10.4 μm) > 6.5 in blue;
Small ice particles for very cold cloud tops
B07 (3.9 μm)–B13 (10.4 μm) > 50 in yellow.

Positions estimated using **atmospheric motion vectors (red arrows)** derived from Satellite pictures on 3 September 2017 at 0330Z and 0340Z.

Red dot showed the location of an icing event with moderate severity reported by pilot at 0345Z and FL250

Forecasting (+6 hours)

20161007_0600Z
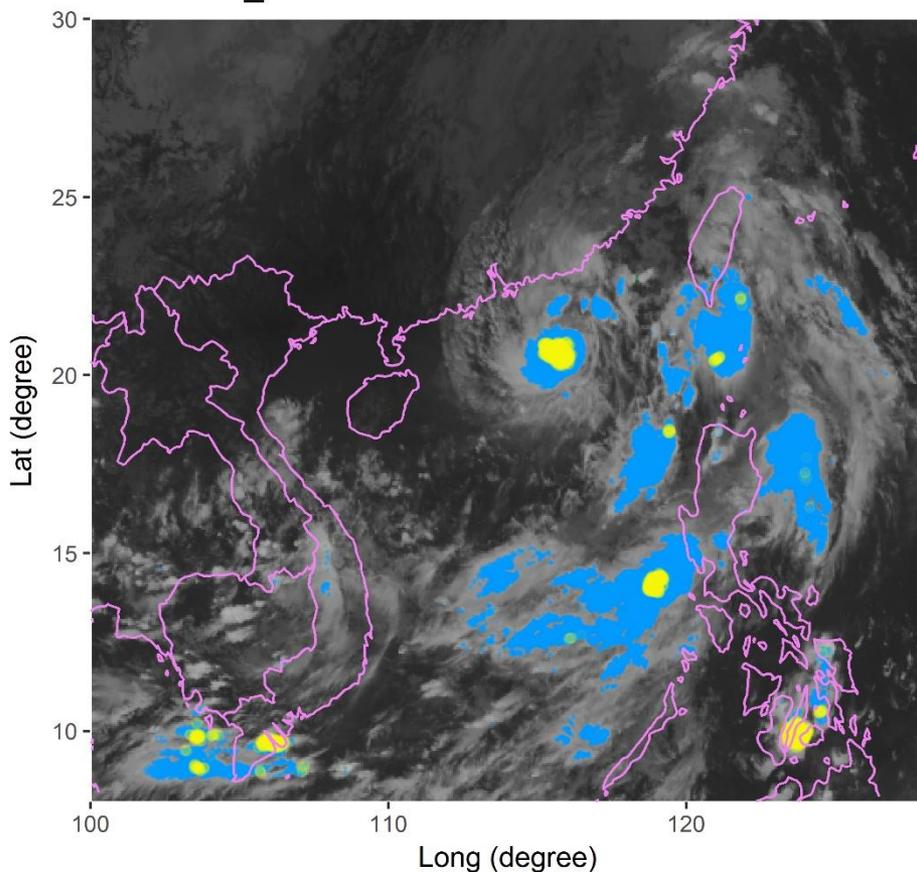
20161007_0600Z_sim_adjusted
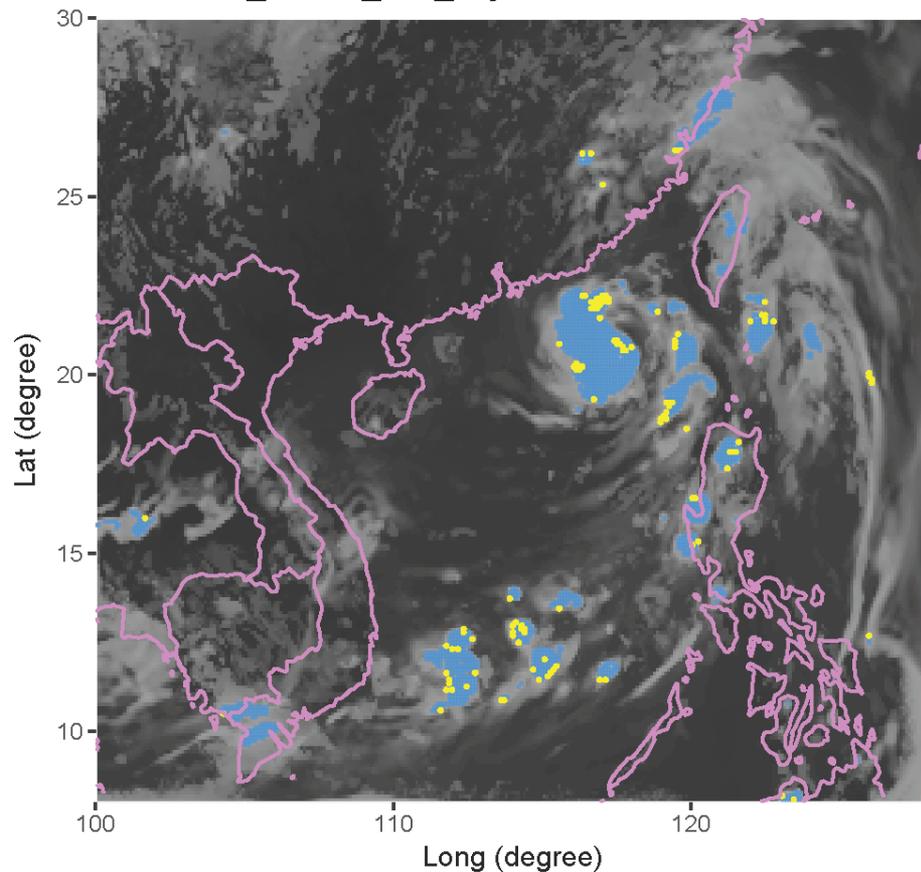
Deep convection for high clouds
19 > B12 (9.6 μm)–B13 (10.4 μm) > 6.5 in blue;
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B07 (3.9 μm)–B13 (10.4 μm) > 50 in yellow.

Model run on 7 October 2016 at 0000Z, forecast hour: +6 hours. Simulated satellite channels have been adjusted using histogram matching method for observed and simulated pictures at 0000Z.

Forecasting (+9 hours)

20161007_0900Z
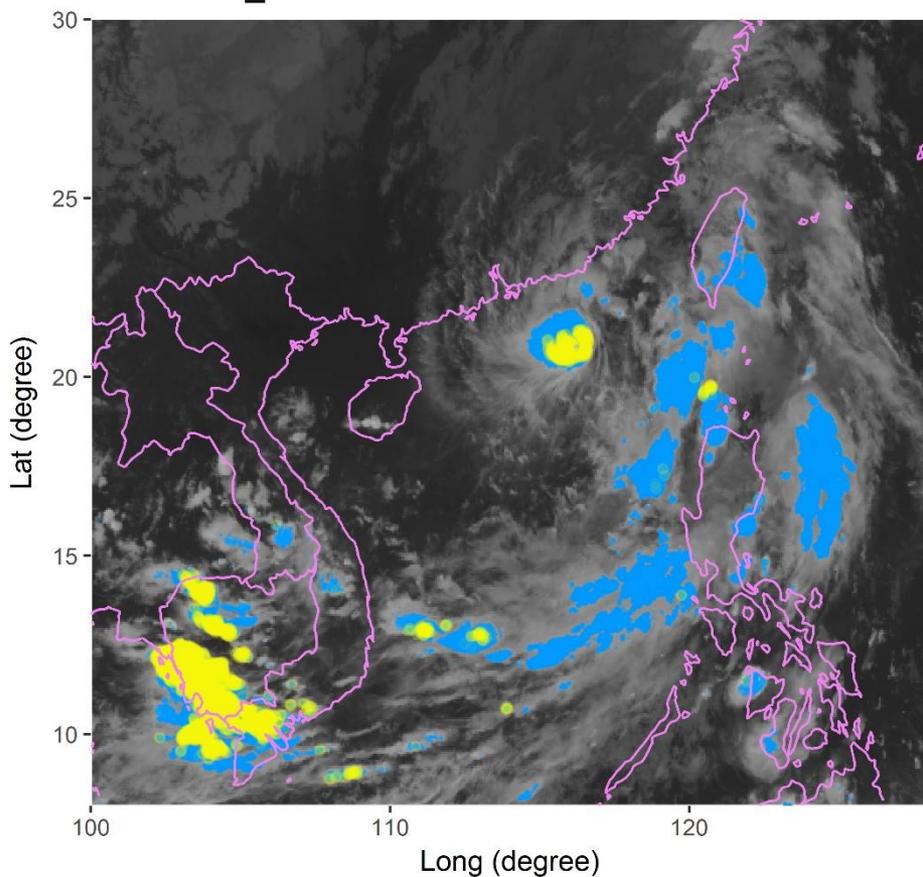
20161007_0900Z_sim_adjusted

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Model run on 7 October 2016 at 0000Z, forecast hour: +9 hours. Simulated satellite channels have been adjusted using histogram matching method for observed and simulated pictures at 0000Z.

Thank you