An Analysis of Cumulus Cloud-Top Properties for 0-1 hour Convective Initiation Nowcasting using Himawari-8 Infrared and Visible Fields

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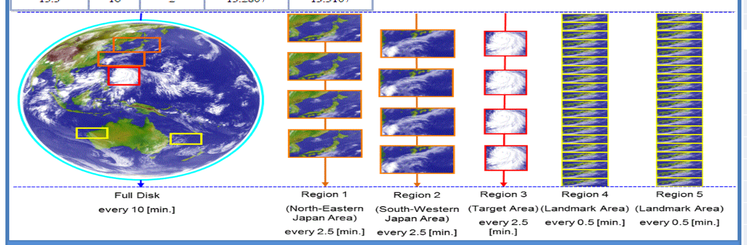
Introduction

- Short-term, 0-1 hour Convective Initiation (CI) forecasting remains a significant challenge after years of research
- New generation of geostationary satellites dictate that we need to understand the utility of these data in research and operational meteorology
- The study goal is to understand how the improvements in spatial, temporal, and spectral resolutions can be utilized in detecting and forecasting CI. ***Himawari-8*** satellite is the primary instrument used, in advance of GOES-R

Himawari-8 and AHI

Wave length [μm]	Himawari-8/9 Band number	Spatial resolution at SSP [km]	Central wave length [μm] AHI-8 (Himawari-8)	AHI-9 (Himawari-9)
0.47	1	1	0.47063	0.47059
0.51	2	1	0.51000	0.50993
0.64	3	0.5	0.63914	0.63972
0.86	4	1	0.85670	0.85668
1.6	5	2	1.6101	1.6065
2.3	6	2	2.2568	2.2570
3.9	7	2	3.8853	3.8289
6.2	8	2	6.2429	6.2479
6.9	9	2	6.9410	6.9555
7.3	10	2	7.3467	7.3437
8.6	11	2	8.5926	8.5936
9.6	12	2	9.6372	9.6274
10.4	13	2	10.4073	10.4074
11.2	14	2	11.2395	11.2080
12.4	15	2	12.3806	12.3648
13.3	16	2	13.2807	13.3107

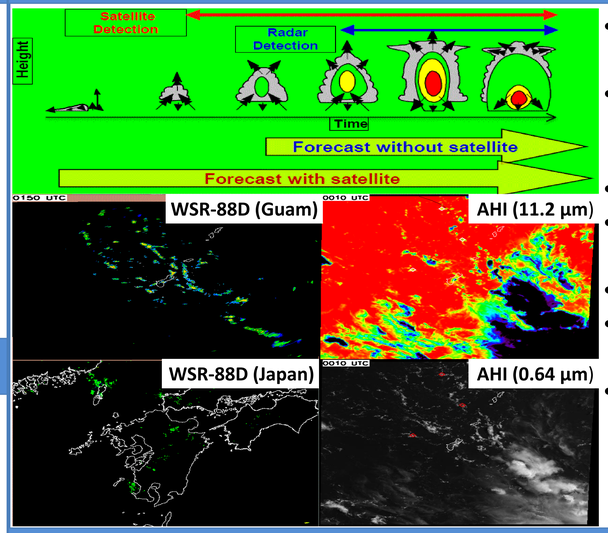
- Spectral Resolution: 16 bands – 12 bands are used (1.6 to 13.3 μm)
- Spatial Resolution: 0.5 to 2 km – improvement from current GOES 1 to 4 km
- Temporal Resolution: 10 min full-disk; 2.5 min rapid-scan in Japan & 30 sec for two target areas (future work)



Objectives

- Understand which spectral channel differences and their time trends ("interest fields") are useful in observing attributes associated with the CI process
- How those satellite "interest fields" characteristics differ in various regions (Tropics vs. Mid-Latitudes)
- CI forecasting improvements with AHI "interest fields"

Data & Methodology



- ***CI Definition: 35 dBZ or above radar echo at the surface or –10°C height*** (Roberts and Rutledge 2003, Mecikalski and Bedka 2006, Walker et al. 2012)
- Primary Dataset: WSR-88D in Guam (S-band) and Japan (C-band) , AHI Imagery – 0.64 and 11.2 μm

Methodology (based upon Mecikalski et al. 2010a,b)

- Obtain as many CI samples as possible (104 CI samples in Guam so far, ongoing work in Japan)
- Evaluate all available satellite interest fields – a total of 154 parameters for AHI (139 IR and 15 VIS reflectance fields)
- Eliminate redundant fields, using **correlation coefficient (CC) analysis** and **prior literature works**.
- Categorize all remaining fields into appropriate processes in developing cumulus clouds: **cloud depth, cloud-top glaciation and updraft strength**
- Perform **principal component analysis (PCA)** to further reduce fields and rank the unique, best fields for each attribute

All Himawari-8 AHI data were provided by the Japan Meteorological Agency under a Data Exchange Agreement with NOAA and the University of Alabama in Huntsville. We are grateful for this collaboration. POCs: Hiroshi Koide & Yasuhiko Sumida.

PCA Results (Guam)

		PC1	PC2	
IF1	6.2-10.4 μm	-0.35	------	
IF2	7.3-10.4 μm	-0.33	------	
IF3	6.2-6.9 μm	-0.30	------	
IF4	6.9-7.3 μm	-0.33	0.16	
IF5	6.2-7.3 μm	-0.33	------	
IF6	6.2-12.4 μm	-0.35	-0.10	
IF7	6.2-13.3 μm	-0.35	------	
IF8	7.3-12.4 μm	-0.32	-0.24	
IF9	7.3-13.3 μm	-0.29	-0.17	
IF10	8.6-12.4 μm	0.11	-0.69	
IF11	10.4-11.2 μm	------	0.26	
IF12	10.4-12.4 μm	0.12	-0.56	
	ExpVar (%)	67.90	13.70	***81.59***
	Eigenvalue	8.15	1.64	

	Top Fields
1	6.2-10.4 μm
2	6.2-13.3 μm
3	6.2-12.4 μm
4	6.2-7.3 μm
5	7.3-10.4 μm
6	6.9-7.3 μm
7	7.3-12.4 μm
8	6.2-6.9 μm

(Cloud Depth)

		PC1	PC2	
IF1	8.6 - 10.4 μm	0.50	0.52	
IF2	10-min 8.6 - 10.4 μm	0.52	-0.41	
IF3	Trispectral with 10.4 μm : (8.6-10.4) - (10.4-12.4) μm	0.50	0.48	
IF4	10-min Trispectral with 10.4 μm	0.49	-0.58	
	ExpVar (%)	75.37	16.19	***91.56***
	Eigenvalue	3.01	0.65	

	Top Fields
1	10-min 8.6 - 10.4 μm
2	8.6 - 10.4 μm
3	Trispectral with 10.4 μm : (8.6-10.4) - (10.4-12.4) μm
4	10-min Trispectral with 10.4 μm

(Glaciation)

		PC1	PC2	
IF1	10-min 10.4 μm	-0.42	------	
IF2	10-min 6.2 - 10.4 μm	0.42	------	
IF3	10-min 6.9 - 10.4 μm	0.41	0.15	
IF4	10-min 7.3 - 10.4 μm	0.34	0.38	
IF5	10-min 10.4 - 12.4 μm	------	-0.78	
IF6	10-min 6.2 - 6.9 μm	0.32	-0.26	
IF7	10-min 6.9 - 7.3 μm	0.33	-0.25	
IF8	10-min 6.2 - 7.3 μm	0.38	-0.29	
	ExpVar (%)	68.40	14.82	***83.22***
	Eigenvalue	5.47	1.19	

	Top Fields
1	10-min 10.4 μm
2	10-min 6.2 - 10.4 μm
3	10-min 6.9 - 10.4 μm
4	10-min 6.2 - 7.3 μm
5	10-min 7.3 - 10.4 μm
6	10-min 6.9 - 7.3 μm
7	10-min 6.2 - 6.9 μm
8	10-min 10.4 - 12.4 μm

(Updraft Strength)

		PC1	PC2	PC3	
IF1	1.6 μm	0.38	0.32	0.13	
IF2	10-min 1.6 μm	0.38	-0.30	0.15	
IF3	2.3 μm	0.31	0.29	-0.32	
IF4	10-min 2.3 μm	0.33	-0.21	-0.22	
IF5	3.9 μm	------	------	0.39	
IF6	10-min 3.9 μm	------	0.33	0.15	
IF7	1.6 - 2.3 μm	0.25	0.18	0.44	
IF8	10-min 1.6 - 2.3 μm	0.24	-0.23	0.40	
IF9	2.3 - 3.9 μm	0.27	0.23	-0.44	
IF10	10-min 2.3 - 3.9 μm	0.23	-0.39	-0.28	
IF11	1.6 - 3.9 μm	0.39	0.31	------	
IF12	10-min 1.6 - 3.9 μm	0.32	-0.43	------	
	ExpVar (%)	34.03	25.08	20.92	***80.03***
	Eigenvalue	4.083	3.010	2.511	

	Top Fields
1	1.6 - 3.9 μm
2	1.6 μm
3	10-min 1.6 μm
4	10-min 2.3 μm
5	10-min 1.6 - 3.9 μm
6	2.3 μm
7	2.3 - 3.9 μm
8	1.6 - 2.3 μm

(Visible Reflectance)

- The added 10.4 μm (channel 13) band is widely useful in understanding CI attributes due to its little sensitivity to water vapor
- All three water vapor channels (6.2, 6.9 and 7.3 μm) provide some level of contribution to CI forecasting

Critical Values (Guam; Mean and S.D)

Rank	CI Interest Fields	Mean (K)	Std dev (K)
1	6.2-10.4 μm	-31.2	8.59
2	6.2-13.3 μm	-22.3	6.25
3	6.2-12.4 μm	-30.1	8.22
4	6.2-7.3 μm	-15.3	4.07
5	7.3-10.4 μm	-15.9	4.94
6	6.9-7.3 μm	-6.4	2.78
7	7.3-12.4 μm	-14.8	4.64
8	6.2-6.9 μm	-8.9	1.50

(Cloud Depth)

Rank	CI Interest Fields	Mean (K)	Std dev (K)
1	10-min 8.6 - 10.4 μm	0.2	2.70
2	8.6 - 10.4 μm	-1.6	1.87
3	Trispectral with 10.4 μm	-2.7	2.08
4	10-min Trispectral with 10.4 μm	0.4	3.38

(Glaciation)

Rank	CI Interest Fields	Mean (K)	Std dev (K)
1	10-min 10.4 μm	-5.1	4.83
2	10-min 6.2 - 10.4 μm	4.6	4.12
3	10-min 6.9 - 10.4 μm	4.1	3.55
4	10-min 6.2 - 7.3 μm	1.6	2.28
5	10-min 7.3 - 10.4 μm	3.0	2.60
6	10-min 6.9 - 7.3 μm	1.1	1.78
7	10-min 6.2 - 6.9 μm	0.5	0.88
8	10-min 10.4 - 12.4 μm	-0.2	1.82

(Updraft Strength)

Rank	CI Interest Fields	Mean	SD
1	1.6 - 3.9 μm	0.1495	0.068
2	1.6 μm	0.1883	0.070
3	10-min 1.6 μm	-0.0070	0.057
4	10-min 2.3 μm	0.0072	0.035
5	10-min 1.6 - 3.9 μm	0.0030	0.062
6	2.3 μm	0.1186	0.044
7	2.3 - 3.9 μm	0.0799	0.049
8	1.6 - 2.3 μm	0.0696	0.053

(Visible Reflectance)

Future Works

- Conduct similar statistical analyses for Japan & examine the differences in ranking the best fields for CI and their critical values – Tropics. Vs. Mid-Latitudes
- **Apply the results to real GOES-R data to understand their improvements in CI detection over the Western Hemisphere**
- Utilize 2.5-min & 30 sec rapid scan data in Japan to understand their usage in CI nowcasting