97th AMS Annual Meeting, 25 January,2017

Validation and Data Assimilation of Himawari-8 Rapid Scan Atmospheric Motion Vectors for Typhoon

Koji Yamashita
Numerical Prediction Division, Japan Meteorological Agency (JMA)
kobo.yamashita@met.kishou.go.jp

1. Motivation

- The Meteorological Satellite Center of Japan Meteorological Agency (JMA/MSC) has produced operational Himawari-8 Atmospheric Motion Vectors (AMVs) since July 7th, 2015 [1].
- The AMVs are produced using three sequential satellite images with time interval of 10 minutes.
- JMA/MSC also started producing Himawari-8 Rapid Scan Atmospheric Motion Vectors (RS-AMVs), as trial, using operational rapid scan observation with time interval of 2.5 minutes over Japan area and a small domain covering a typhoon in the western North Pacific (Fig 1(A)).
- RS-AMVs for typhoon make it possible to capture its divergence compared with operational AMVs (Fig 1: Shown by red circle).
- Expected to Improve of typhoon analysis and forecasting skills using its RS-AMVs

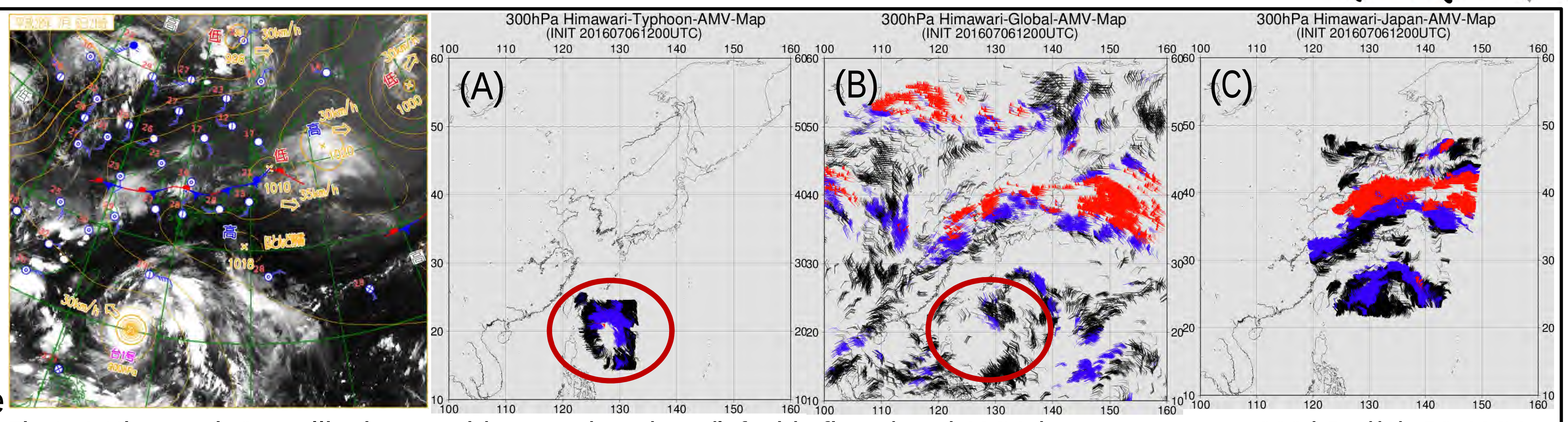


Fig 1. A Himawari -8 satellite image with a weather chart (left side figure) and AMV data coverages on 300 hPa ((A): RS-AMVs for typhoon (about 4 km res.), (B): Operational AMVs (about 50 km res.), (C): RS-AMVs for Japan area (about 5 km res.)) at 12 UTC 6 July 2016 in case study of typhoon Nepartak. (AMV: Red：≧ 50kt,Blue：≧ 30kt, Black：< 30kt)

2. Investigated the quality of RS-AMVs for 5 typhoons using dropwindsonde and rawinsonde observations and the forecasts of the JMA's global Numerical Weather Prediction (NWP) system

2.1 RS-AMV

- Every 10 minute RS-AMV with almost QI (quality indicator [2]) >= 85 same as operational NWP system using three sequential satellite images with time interval of 2.5 minutes over a small domain covering a typhoon in the western North Pacific
- RS-AMVs which passed gross error check by forecast are only used.

2.2 Dropwindsonde and rawinsonde (sonde)

- Dropwindsonde Observations for Typhoon Surveillance near the Taiwan Region (DOTSTAR) project which is priority Typhoon Research Project of National Science Council (NSC) of Taiwan is performed in the yellow area (Fig 2-1).
- Dropwindsonde observations which passed gross error check by forecast are only used.
- Rawinsonde observations which passed gross error check by forecast are only used in the yellow area (Fig 2-1).

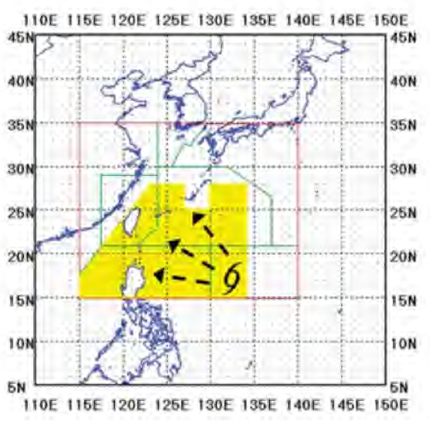


Fig 2-1. The area (shaded) for proposed typhoon surveillance in DOTSTAR (Source: [3])

2.3 Forecast

- 6-hour wind forecast from previous model run in the JMA's global NWP system (see Subsection 3.1)

2.4 Method and case studies

- Comparison of each their sonde wind and wind forecast with AMV winds within 100 km radius of a sonde position or a forecast model grid position
- Within 60 minute observation time
- Within 25 hPa vertical distance
- Six case studies including five typhoons (Figure 2-2: Soudelor, Goni, Dujuan in 2015, Nepartak and Megi in 2016)

Soudelor: 945 hPa 00UTC 6/8/2015	Soudelor: 945 hPa 12UTC 6/8/2015	Goni: 935 hPa 12UTC 20/8/2015	Dujuan: 925 hPa 12UTC 27/9/2015	Nepartak: 900 hPa 12UTC 6/7/2016	Megi: 950 hPa 00UTC 26/9/2016

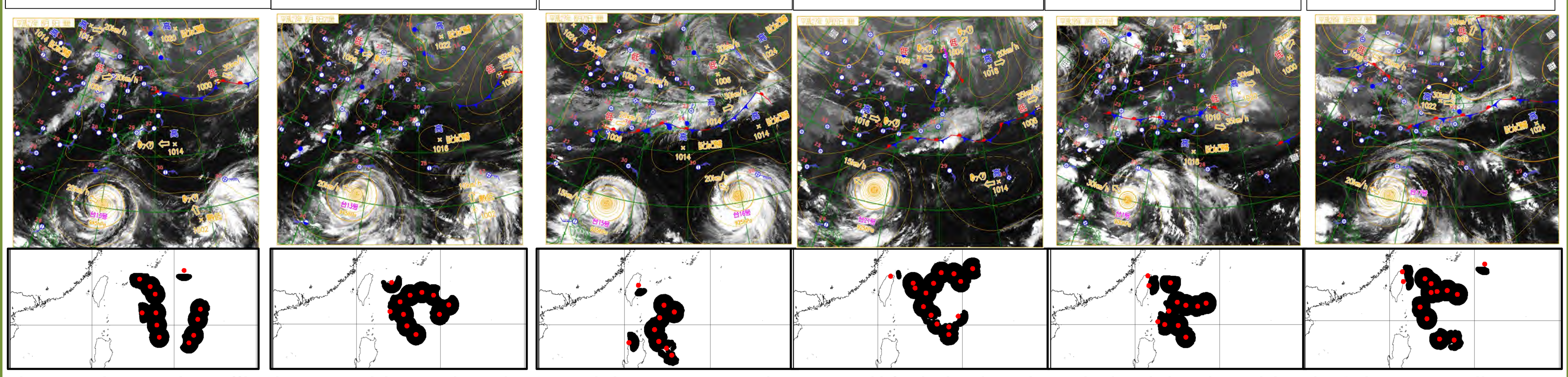


Fig 2-2. Himawari satellite images with weather charts and data coverages (RS-AMVs (black dots) and sonde (red dots) positions) of six case studies including five typhoons

YYYYMMDDHH		2015080600				2015080612			
Vs. Forecast		Count	ME	STD	RMSVD	Count	ME	STD	RMSVD
B03 AMV (Visible)	HL	115482	0.52	3.12	5.58	17381	-1.74	3.31	5.68
	ML	77119	0.13	2.72	5.32	792	0.77	3.98	7.38
	LL	132908	2.51	2.01	3.89	5765	0.14	1.56	2.27
B07 AMV (Infrared)	HL	208092	1.01	3.22	5.54	173485	-0.72	3.99	6.15
	ML	101521	0.24	3.10	5.17	38082	-1.99	2.99	4.92
	LL	31100	0.68	2.71	4.14	24978	-0.52	2.52	4.58
B08 AMV (Water Vapor)	HL	190570	0.50	3.40	5.81	208258	-0.18	4.34	7.01
	ML	305	0.17	3.01	5.23	473	-2.54	2.95	5.69
	LL	344	1.86	2.67	4.28	333	-1.16	2.76	4.68
B09 AMV (Water Vapor)	HL	277664	1.02	3.17	5.38	316263	-0.29	4.23	6.68
	ML	80197	-0.08	3.12	6.26	18968	-3.01	4.35	8.11
	LL	690	2.20	2.23	4.21	578	-1.06	2.52	4.30
B10 AMV (Water Vapor)	HL	500990	1.12	3.11	5.45	575641	-0.13	4.20	6.70
	ML	199301	0.13	2.76	5.86				
	LL	897	2.07	2.42	4.31	829	-1.30	2.71	4.68
B13 AMV (Infrared)	HL	478191	0.89	3.28	5.62	608236	0.33	4.06	6.69
	ML	160299	0.16	2.84	5.35	37673	-2.42	3.74	6.83
	LL	12151	0.31	2.56	3.94	4715	-1.10	2.82	4.83
B16 AMV (Water Vapor)	HL	–	–	–	–	–	–	–	–
	ML	–	–	–	–	–	–	–	–
	LL	–	–	–	–	–	–	–	–
Vs. Sonde		Count	ME	STD	RMSVD	Count	ME	STD	RMSVD
ALL AMV (B03-B16)	HL	104883	-2.23	3.94	8.77	132244	-5.03	5.51	11.28
	ML	31218	-2.94	3.97	9.89	9985	-4.17	5.34	10.14
	LL	17941	-1.37	2.97	4.93	2861	-2.37	4.03	7.45

YYYYMMDDHH		2015082000				2015092700			
Vs. Forecast		Count	ME	STD	RMSVD	Count	ME	STD	RMSVD
B03 AMV (Visible)	HL	43395	0.07	3.97	5.65	46961	0.23	5.04	6.74
	ML	7494	3.59	3.44	5.83	16605	-0.40	2.69	3.68
	LL	18142	1.86	2.54	3.82	88905	0.43	1.85	3.18
B07 AMV (Infrared)	HL	81300	0.23	3.93	5.82	77584	0.47	3.33	4.90
	ML	5293	2.46	4.37	6.66	40402	-1.12	2.85	4.32
	LL	2779	0.25	2.85	4.09	47603	-0.26	2.69	4.02
B08 AMV (Water Vapor)	HL	132181	-0.08	3.85	5.93	57566	-0.55	4.94	6.44
	ML	178	1.40	3.93	5.45	53	-0.95	2.42	4.57
	LL	213	1.94	2.78	4.30	79	0.34	2.10	3.27
B09 AMV (Water Vapor)	HL	113090	-0.25	3.96	6.06	105589	-0.29	4.76	6.21
	ML	7490	-1.18	4.41	6.77	7308	-2.16	3.13	5.09
	LL	196	2.09	2.95	4.45	194	-0.31	1.98	3.33
B10 AMV (Water Vapor)	HL	114967	0.04	4.04	6.17	165555	-0.07	4.47	5.95
	ML	9086	-0.37	4.37	6.75	25338	-2.58	2.88	5.36
	LL	195	1.50	3.11	4.51	268	-0.65	1.96	3.50
B13 AMV (Infrared)	HL	195886	0.04	4.08	6.16	166430	-0.01	4.43	6.00
	ML	8460	0.12	4.57	6.51	21175	-1.13	2.98	4.44
	LL	7415	0.00	2.57	3.49	17409	0.38	2.33	4.02
B16 AMV (Water Vapor)	HL	107536	-0.16	3.73	5.92	–	–	–	–
	ML	9375	-0.11	4.34	6.65	–	–	–	–
	LL	200	1.67	3.00	4.43	–	–	–	–
Vs. Sonde		Count	ME	STD	RMSVD	Count	ME	STD	RMSVD
ALL AMV (B03-B16)	HL	34626	-6.77	4.96	10.98	68276	-1.49	4.25	6.89
	ML	1358	-8.65	5.46	16.12	14662	-2.55	4.81	7.11
	LL	602	2.72	3.48	9.05	11039	-1.36	2.83	6.70

YYYYMMDDHH		2016070612				2016092600			
Vs. Forecast		Count	ME	STD	RMSVD	Count	ME	STD	RMSVD
B03 AMV (Visible)	HL	29904	1.04	2.60	3.87	195806	-0.79	3.89	5.86
	ML	2505	-0.16	1.64	2.49	25231	0.42	2.29	3.24
	LL	2284	0.52	1.51	2.29	65895	1.52	1.69	3.02
B07 AMV (Infrared)	HL	324575	0.55	2.16	3.58	227067	-0.68	3.68	5.39
	ML	78644	0.30	1.76	2.77	28167	-0.04	2.27	3.15
	LL	45793	-0.77	1.93	3.25	15902	0.28	2.16	3.02
B08 AMV (Water Vapor)	HL	611487	0.33	2.57	3.89	240746	-0.39	3.82	5.79
	ML	1130	0.35	1.72	2.91	224	0.41	2.26	3.55
	LL	973	-0.60	1.83	3.19	382	1.32	1.94	3.08
B09 AMV (Water Vapor)	HL	216988	0.22	2.76	4.23	172636	-0.77	3.81	5.85
	ML	14097	0.62	1.97	3.73	2367	-1.74	3.36	5.82
	LL	467	-0.59	1.85	3.16	317	1.22	2.09	3.23
B10 AMV (Water Vapor)	HL	365987	0.55	2.56	4.02	233564	-0.59	3.84	5.84
	ML	32972	0.71	2.09	3.94	5859	-1.06	3.15	4.95
	LL	709	-0.96	1.91	3.20	348	1.07	2.55	3.80
B13 AMV (Infrared)	HL	767000	0.29	2.50	3.80	462592	-0.46	3.81	5.74
	ML	79222	0.27	1.73	2.99	19547	-0.23	2.46	3.47
	LL	13950	-1.14	1.96	3.65	10042	-0.18	1.91	3.21
B16 AMV (Water Vapor)	HL	491540	0.47	2.39	3.72	289072	-1.08	3.92	5.91
	ML	97463	0.51	1.85	3.53	12575	-0.96	2.86	4.14
	LL	907	-0.83	1.96	3.22	304	0.40	2.81	3.87
Vs. Sonde		Count	ME	STD	RMSVD	Count	ME	STD	RMSVD
ALL AMV (B03-B16)	HL	247039	0.63	3.11	5.53	220304	-1.82	4.70	7.68
	ML	17446	-0.50	3.12	6.03	5434	-4.46	3.89	7.86
	LL	5481	0.58	3.35	5.01	3547	0.14	4.42	6.58

Tab 2-1. Validation results of RS-AMVs for typhoon against sonde winds and wind forecasts in six case studies. Bxx: Band number of Himawari-8 satellite, ME: Mean Error of wind speed [m/s], STD: Standard deviation of wind speed, RMSVD: Root mean square wind vector difference [m/s], HL:10-400 [hPa], ML:400-700 [hPa], LL:700-1000 [hPa]. Large RMSVD or ME is shown blue squares. Better score compared with other cases is shown a red square.

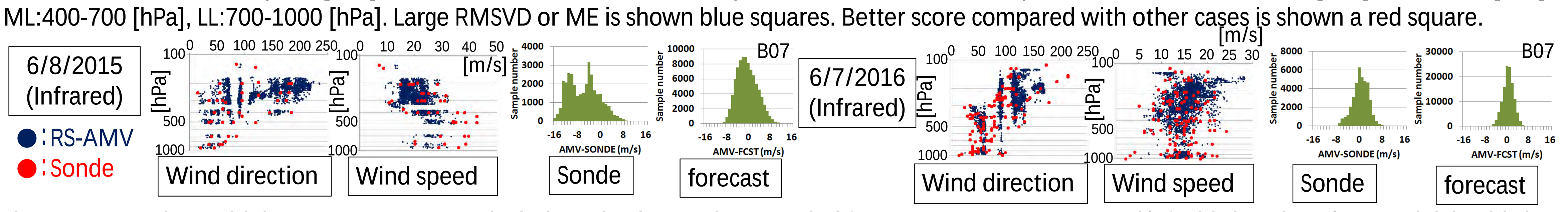


Fig 2-3. Comparison with between RS-AMVs and wind sonde observations or wind forecasts on 6 August 2015 (left side) and 6 July 2016 (right side). Wind vertical distributions against sonde at 1104 UTC and wind speed departure histograms against sonde or forecast on 200 hPa at 1200 UTC are shown.

2.5 Results

- Negative biases for RS-AMV wind speed against wind sonde observations (especially mid and lower level AMVs) and against wind forecasts in case of typhoon Soudelor and Dujuan
- Large RMSVDs for RS-AMVs compared with operational AMVs (RMSVD: 5-6 [m/s]) against wind sonde observations
- Good accuracy in case of typhoon Nepartak compared with other cases (Tab 2-1 and Fig 2-3)

3. Observing System Experiments (OSEs) of RS-AMVs for typhoon using JMA's global NWP System

3.1 Configuration of JMA's global NWP system

Data Assimilation System for Global Spectral Model	
Method	four-dimensional variational data assimilation
Resolution and Layers (inner model)	TL319L100 (hydrostatic reduced Gaussian grid, horizontal resolution approx. 55 km, model top 0.1 hPa)
Assimilation window	6 hours (±3hours, time slots approx. 1 hour)
Typhoon bogus data	Used
Global Spectral Model	
Resolution and Layers	TL959L100 (hydrostatic reduced Gaussian grid, horizontal resolution approx. 20 km, model top 0.01 hPa)
Forecast domain	Globe
Forecast range (initial time)	84 hours/264 hours (00, 06, 18 UTC/12 UTC)

3.2 Experimental Design (Main differences)

- CNTL
  - Himawari-8 AMVs are used with 100kmSPOB (100-km super-observation technique) for Japan and the surrounding areas and 200km thinning for the other regions.
  - The other AMVs are used as 200km thinning.
- TEST
  - CNTL + Himawari-8 RS-AMVs for typhoon which are used with 100kmSPOB
- Period (Case study for Nepartak)
  - Assimilation : From 1 July to 20 July 2016
  - Forecast : From 1 July to 8 July 2016

3.3 Results of OSEs

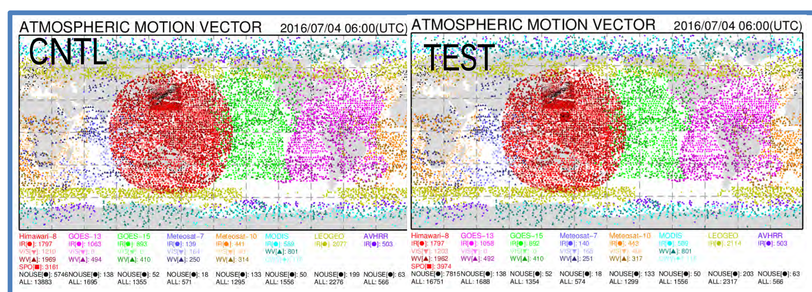


Fig 3-1. AMV data coverage after QC in CNTL and TEST at 12 UTC July 4 2016.

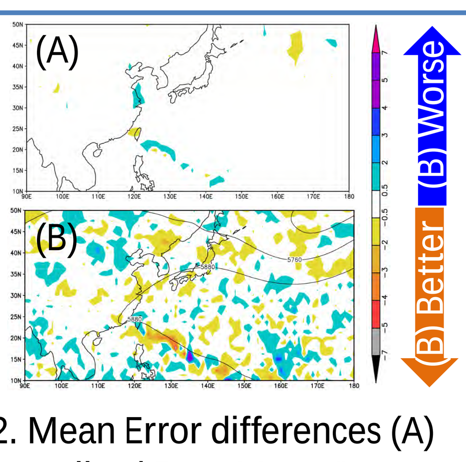


Fig 3-2. Mean Error differences (A) and normalized Root Mean Square Error differences (B) between TEST and CNTL at 12- hour forecast lead times on 500 hPa.

- Neutral typhoon track forecast impacts
- Degrade typhoon intensity forecast impacts

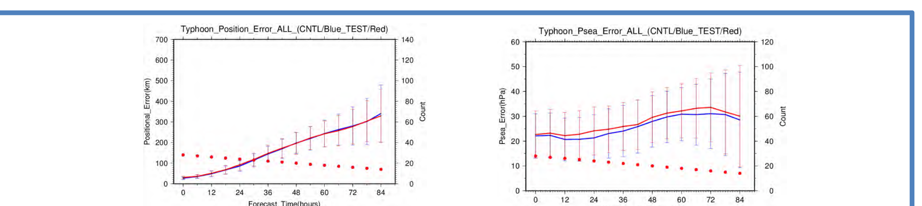


Fig 3-3. Average typhoon Nepartak track forecast errors (left side) and intensity (Psea) forecast errors (right side). Error bars represent a 95% confidence interval.

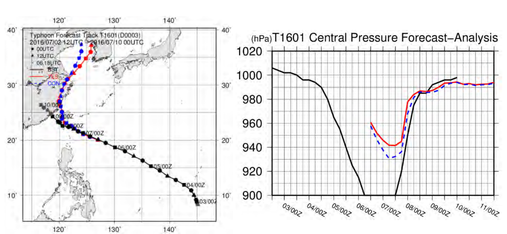


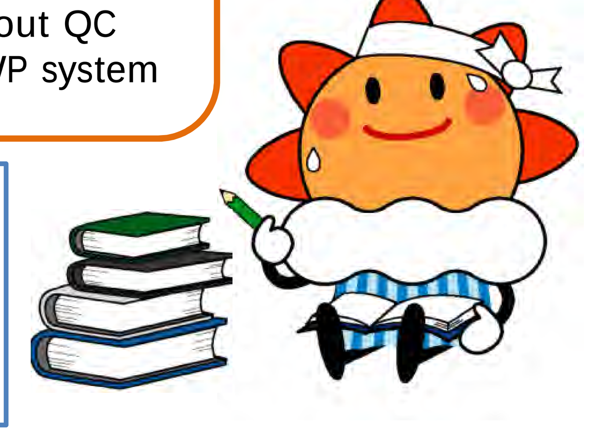
Fig 3-4. Typhoon Nepartak track and intensity TEST (red), CNTL (blue) and BST (black) forecasts initialized at 12 UTC on 6 July 2016.

Acknowledgements

DOTSTAR data are used in this study. JMA thanks to the data and DOTSTAR project.

Future considering

- How should we make the quality control (QC) system of RS-AMV for typhoon on NWP from sonde observation differences ?
- Continuing investigation of RS-AMV to find out QC
- Method for RS-AMV (100 km SPOB ?) in NWP system
- Any other ideas ?



References

[1] Bessho, K., K. Date, M. Hayashi, A. Ikeda, T. Imai, H. Inoue, Y. Kumagai, T. Miyakawa, H. Murata, T. Ohno, A. Okuyama, R. Oyama, Y. Sasaki, Y. Shimazu, K. Shimoji, Y. Sumida, M. Suzuki, H. Taniguchi, H. Tsuchiyama, D. Uesawa, H. Yokota, and R. Yoshida, 2016: An Introduction to Himawari-8/9 - Japan's New Generation Geostationary Meteorological Satellites. *J. Meteor. Soc. Japan,* 94, 151-183.
[2] Holmlund,K.,1998:The utilization of statistical properties of satellite-derived atmospheric motion Vectors to derive quality indicators. *Wea.Forecasting,*13,1093–1104.
[3] Wu, C.-C., P.-H. Lin, S. D. Aberson, T.-C. Yeh, W.-P. Huang, J.-S. Hong, G.-C. Lu, K.-C. Hsu, I.-I. Lin, K.-H. Chou, P.-L. Lin, and C.-H. Liu, 2005: Dropwindsonde observations for typhoon surveillance near the Taiwan Region (DOTSTAR): an overview. *Bull. Amer. Meteor. Soc.*, 86, 787-790.