International Civil Aviation Organization

NINETEENTH MEETING OF THE METEOROLOGY SUB-GROUP (MET SG/19) OF APANPIRG

Bangkok, Thailand, 3 – 6 August 2015

Agenda Item 6.3: Research, development and implementation issues in the MET field

6.3) Forecasts, advisories and warnings

VERIFICATION OF TS SIGMET WITH SATELLITE PICTURES

(Presented by Hong Kong, China)

SUMMARY

This paper presents the method used in Hong Kong, China to verify TS SIGMET using deep convection satellite pictures. The method allows verification to be carried out in a systematic and objective manner and enables full automation to be achieved.

1. INTRODUCTION

1.1 Playing the functional role of a meteorological watch office, the Airport Meteorological Office (AMO) of the Hong Kong Observatory (HKO) issues SIGMET to warn the occurrence or expected occurrence of specified en-route weather phenomena which may affect the safety of aircraft operations in its area of responsibility, the Hong Kong FIR, in accordance with ICAO Annex 3 and ASIA/PAC Regional SIGMET Guide. In particular, TS SIGMET is issued to warn of the occurrence of thunderstorm or cumulonimbus (Cb) cloud.

1.2 With a strong commitment to quality assurance and continuous improvement, the HKO seeks to objectively gauge the performance (in particular accuracy) of forecasts and warnings it issued and identify areas for future improvement. The HKO had long implemented a TAF verification system. The software has since been shared with 24 States. Lately the HKO introduced the verification of SIGMET in its forecast verification suite.

2. METHODOLOGY

"Ground Truth"

2.1 Although the Hong Kong FIR is not particularly large in area, its south-most tip lies more than 600 km from the coast of southern China and is thus beyond the coverage of HKO's radars and lightning detectors. In view of the extensive coverage of satellite, satellite pictures are used for the diagnosis of the occurrence of thunderstorm or Cb clouds. As MTSAT, or its replacement Himawari-8, does not contain lightning information, the deep convection product derived from channel differencing is used as a proxy for identifying the occurrence of thunderstorm or Cb over Hong Kong FIR.

2.2 The basis for the deep convection product is that emissive radiation from lower clouds is heavily absorbed in the IR3 channel, i.e. water vapour (wavelength ~ 6.7 um), but not much affected in the IR1 channel. As such, the higher the clouds, the smaller the difference in IR1 and IR3 temperature. Deep convection area is thus taken to be the area where the difference in the temperature values between the two infrared channels, i.e. IR1-IR3, is less than or equal to 1K. It is taken as the "ground truth" with the deep convection area indicated in red (see Figure 1).

Warning-based verification

2.3 The SIGMET warning area is first decoded. Figure 2 shows, in green, the warning area (inside the Hong Kong FIR) for the following TS SIGMET issued by the HKO at 2200 UTC, 22 June 2015:-

WSSS20 VHHH 222200 VHHK SIGMET 7 VALID 222200/230200 VHHH- VHHK
HONG KONG FIR EMBD TS FCST N OF N1800 AND W OF E11600 TOP FL400
MOV N 10KT NC=

2.4 All deep convection satellite pictures taken from 15-minute time before the start time of the validity period to the end of the SIGMET validity period (MTSAT satellite pictures are often available at around 30-minute intervals, so a satellite picture taken more than 15 minutes before the start time of the validity period is regarded not representative of the situation within the validity period, hence not used) are overlaid, and a composite is generated to map out the actual area of deep convection within the validity period of the TS SIGMET (see Figure 3).

2.5 The map, formed by overlaying the warning area onto the composite map of actual area of deep convection will contain pixels of three colors, namely red, green and yellow (red plus green) which signifies the areas of miss (red), false alarm (green) and hit (yellow), respectively (see Figure 4). Accordingly, a verification score can be computed basing on the counts of different color pixels.

Observation-based verification

2.6 The aforesaid warning-based verification allows TS SIGMET to be verified such that the areas of hit, miss and false alarm pertinent to individual TS SIGMET are identified for forthwith scoring. However, a comprehensive view of the performance could only be obtained if all deep convection satellite pictures falling outside the validity period of any TS SIGMET (except the 15-minute time slot before the end time) are also checked for the actual occurrence of deep convection. It is because any actual occurrence of deep convection (subject to certain criterion) not warned by any TS SIGMET should also be recognized as miss.

Exclusion of validity periods of TC SIGMET

2.7 Considering the small size of the Hong Kong FIR compared with the dimension of a tropical cyclone, no matter whether it is warning-based or observation-based verification, all time periods during which TC SIGMET had been valid are excluded. It is because Cb clouds associated with a tropical cyclone reaching tropical storm intensity should normally be warned in TC SIGMET instead of TS SIGMET. Moreover given a deep convection satellite picture, there is no easy algorithm that can automatically identify which cloud mass is associated with a tropical cyclone, and hence should be covered by a TC SIGMET and which is not.

Criteria for hit, miss and false alarm

2.8 As TS SIGMET is intended to warn pilots of frequent thunderstorm and Cb clouds that may affect aircraft operations and not isolated or well-separated Cbs, an area of around 800 km^2 (equivalent to 50 pixels in the current setting) is set as the minimum deep convection area requiring warning, i.e. if the total number of red and yellow pixels is less than 50, then the area of deep convection would be regarded as negligibly small and would not be counted towards hit or miss.

2.9 If the area of deep convection is not negligible, then it is subject to further test for hit and miss. For the SIGMET to be recognized as hit, the area of hit (yellow pixels) has to be larger than the area of miss (red pixel). If the contrary holds (i.e. the number of red pixel is equal to or smaller than the number of yellow pixel), then it is considered to be a miss instead.

2.10 To facilitate user interpretation, HKO's TS SIGMET seldom uses polygon. Even if polygon is used to depict the warning area, limited by the format of TS SIGMET where the warning area is represented at best by 7 points, it is inevitable that some finer details in the warning area cannot be reflected in the SIGMET resulting in false alarms. After consulting the users, it was agreed that an area of false alarm (green pixel) that is 5 times the area of deep convection (red plus yellow pixels) or more should be counted as false alarm. It should be noted that while it is considered as a false alarm, if there is sufficient overlap between the warned and actual deep convection locations, it is considered as a hit as well. As such, a TS SIGMET can be classified as a hit, miss, false alarm, hit with false alarm (over-warning) or both miss and false alarm (unmatched areas of warning and actual occurrence).

Performance measures

2.11 Probability of detection (POD, also known as "hit rate"), false alarm ratio and critical success index (CSI) are commonly used performance measures. For conventional binary forecasts/observations, each forecast is, exclusively, either hit (correct) or false alarm (incorrect) whereas each observation is, exclusively, either miss or correct rejection. In this context of TS SIGMET verification, however, we need to consider the hit-&-false-SIGMET and miss-&-false-SIGMET cases as well. In view of this complication, the performance is gauged using two separate sets of performance measures, one tends to be strict and the other tends to be generous. In Set A (strict), a hit-&-false-SIGMET and a miss-&-false-SIGMET are both counted as a false alarm. In Set B (generous), however, a hit-&-false-SIGMET is counted as a hit:-

Set A (strict):
POD_a: [EH] / ([EH]+[EM]+[DH]+[DM]+[MM])
FAR_a: ([FA]+[DH]+[DM]) / ([EH]+[EM]+[FA]+[DH]+[DM])
CSI_a: $1/(1/(1-FAR_a)+1/POD_a-1)$

Set B (generous):
POD_b: ([EH]+[DH]) / ([EH]+[EM]+[DH]+[DM]+[MM])
FAR_b: [FA] / ([EH]+[EM]+[FA]+[DH]+[DM])
CSI_b: $1/(1/(1-FAR_b)+1/POD_b-1)$

where,

Result status from warning-based processing:-
[EH]: exclusive hit
[EM]: exclusive miss
[FA]: false alarm
[DH]: dual hit-&-false-SIGMET (over warning)
[DM]: dual miss-&-false-SIGMET (unmatched areas of warning and actual occurrence)

Result status from observation-based:-
[MM]: miss

3. PRELIMINARY RESULT

3.1 The result of a test run of the described method for verifying TS SIGMET issued by the HKO in years 2013-2014 is follows :-

Year	Set A (strict)			Set B (generous)		
	POD_a	**FAR_a**	**CSI_a**	**POD_b**	**FAR_b**	**CSI_b**
2013	0.37	0.74	0.18	0.93	0.35	0.62
2014	0.39	0.75	0.18	0.93	0.42	0.56

3.2 The result suggests that HKO's TS SIGMET captured almost all the deep convections but the area tends to be too large. Noting the preliminary results, consideration is now being given for wider use of polygon to represent the SIGMET area to reduce the false alarm.

4. ACTION BY THE MEETING

4.1 The meeting is invited to note the information contained in this paper.

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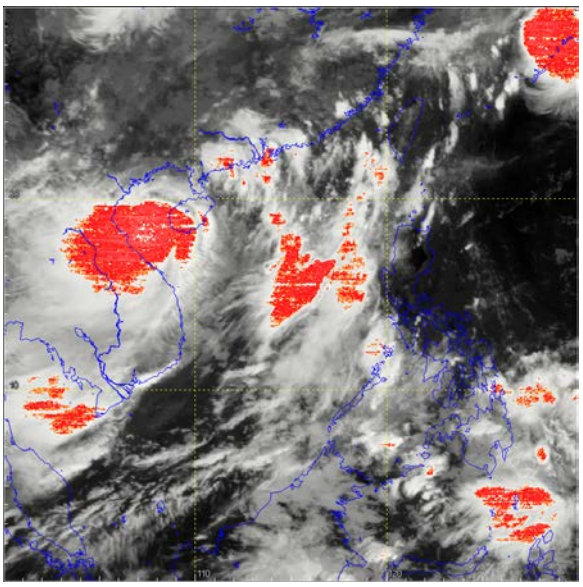

Figure 1. A satellite picture with deep convection highlighted in warm color according to the scheme IR1-IR3≤1K

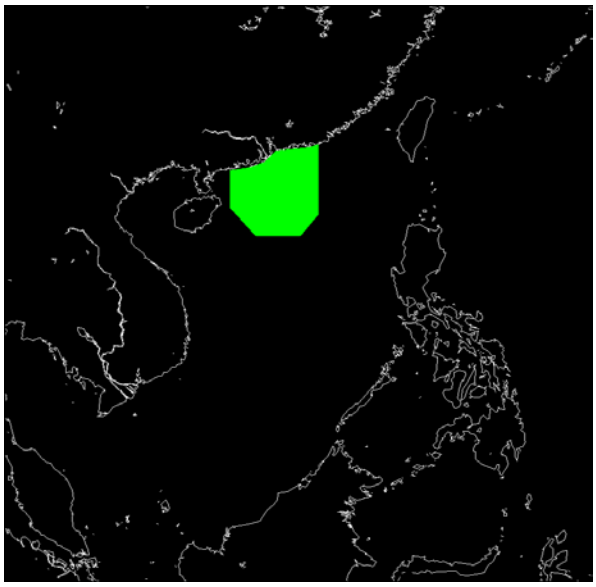

Figure 2. A digital canvas containing a warning area (green) given in the illustrative TS SIGMET

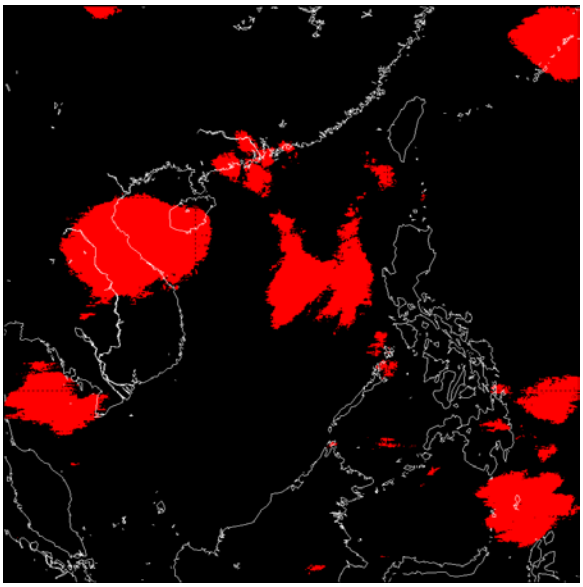

Figure 3. A composite image obtained by overlaying all red-green differential images of deep convection satellite pictures within the 4-hour validity period of the illustrative TS SIGMET

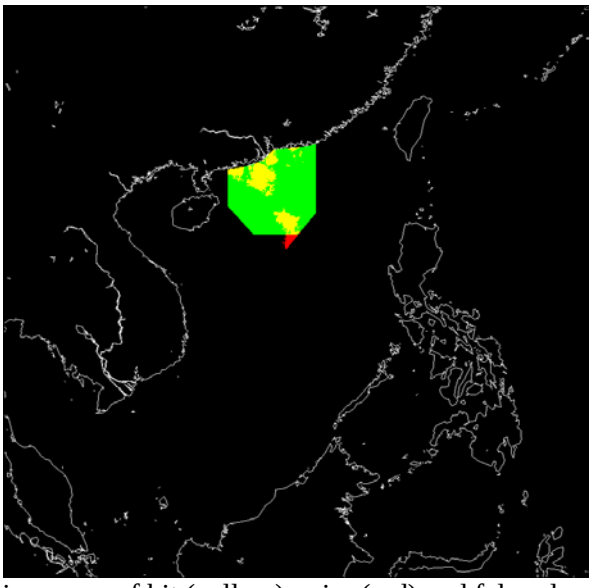

Figure 4. An image showing areas of hit (yellow), miss (red) and false alarm (green) obtained by overlaying figure 3 onto figure 2 and with the portion outside the Hong Kong FIR masked out