REAL TIME CLOUD DRIFT WIND CALCULATION AND APPLICATION IN THE AUSTRALIAN REGION

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ABSTRACT

This paper is the first report of the generation in the Australian Region of cloud drift wind vectors using hourly High Resolution facsimile (HR-FAX) and half-hourly Stretched-Visible and Infrared Spin Scan Radiometer (S-VISSR) images from the Japanese Geostationary Meteorological Satellites, GMS-3 and GMS-4. It describes the techniques used in the wind calculation, in particular for height assignment and quality control. It also records the accuracy of the vectors with appropriate qualification. These locally generated high resolution wind data are now being assimilated in real time into a test version of the operational regional forecast system and evidence is presented from this assimilation experiment indicating that they have the potential to modify the operational analysis in a manner which benefits numerical weather prediction.

INTRODUCTION

Cloud drift winds have been derived using sequential GMS imagery at the Bureau of Meteorology in Melbourne from 1987 (Le Marshall et al., 1988). Before 1989, GMS High-Resolution Facsimile (HR-FAX) analogue data were received in Melbourne and were subsequently digitised and navigated and then used to generate winds. With the HR-FAX system, images were usually available from GMS at 3-hourly intervals and it was only during times of "Special Observations", which were usually requested from the Japanese Meteorological Agency (JMA) by the Bureau of Meteorology in times of severe weather, that hourly imagery, suitable for cloud drift wind calculation, were available for processing.

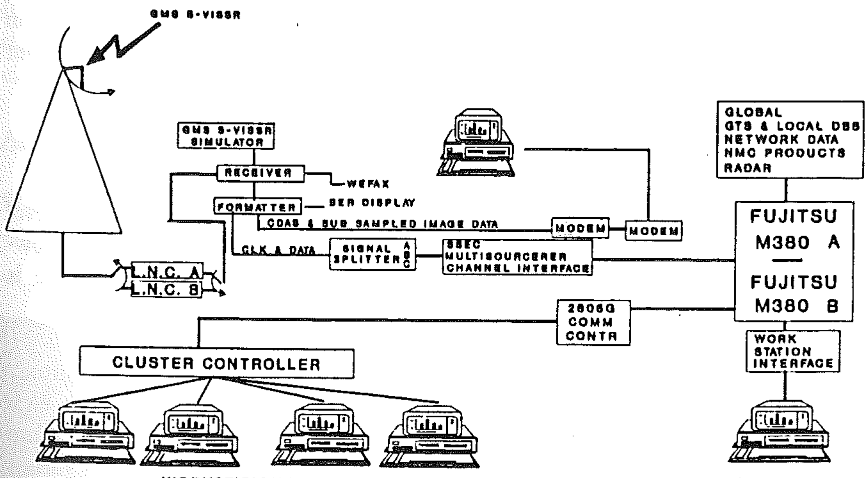


Figure 1 : GMS S-VISSR reception and processing system

In 1989, the Bureau of Meteorology established a GMS S-VISSR reception facility at World Meteorological Centre (WMC), Melbourne. The GMS data were fed through a high-speed channel interface to the Bureau's mainframe where the data were routinely ingested, radiometrically calibrated, navigated and placed on disc in cyclic data sets by the Australian Region McIDAS system (ARM), (Le Marshall et al., 1987). A schematic diagram of the S-VISSR reception and processing facility is seen in figure 1. After the implementation of this system, a new automatic real time method for calculating cloud drift winds was implemented. In this system, targets were automatically chosen from GMS images, usually separated by half an hour. These targets could be edited or supplemented by manually selected targets. Cloud drift winds were then automatically calculated by a target correlation technique and height assignment and quality control of the wind vectors were determined using temperatures and wind fields from the operational Regional Assimilation Prognosis System (RASP) (Mills and Seaman, 1990).

These two cloud drift wind calculation systems were designed to provide timely high resolution winds for the operational regional forecast system which has an operation cutoff of T+2.5 hours. They are described in the following sections and the quality and utility of winds from the S-VISSR system in the Australian Region are discussed.

THE COMPUTATION OF WIND VECTORS

The HR-FAX Processing System

Hourly GMS-3 HR-FAX infrared (IR) and visible (VIS) images from "special observations" were digitised at the Bureau in Melbourne to produce 5000 by 5000 pixel images, with 256 radiance levels. The HR-FAX wind system can still be used for these early (pre-1989) images which have been archived within the Bureau of Meteorology. In this system, the digitised imagery was initially navigated and calibrated and then target selection was usually done manually. The position and brightness temperature fields associated with the area defined by the cursor were then used to produce wind vectors. The cloud top height was assigned using a threshold value for the minimum population size of a brightness temperature range, at the cold end of the cloud brightness temperature distribution. This threshold brightness temperature was assigned to the cloud top, and, using a predetermined temperature profile field generated for the target area was used to estimate the cloud height.

The S-VISSR Processing System

Velocity Estimation

Following the establishment of the GMS S-VISSR reception system, a new procedure for calculating cloud drift winds was implemented. This method has been developed from early work on the Man-computer Interactive Data Access System (McIDAS) at the Space Science and Engineering Center of the University of Wisconsin (Soumi et al., 1983). One key reason for the development of McIDAS was the derivation of cloud drift winds using sequential image frames from the GOES satellite. In the new ARM GMS S-VISSR cloud drift wind system, 20 x 20 pixel target areas for tracking are automatically chosen for three images, usually separated by half an hour. The infrared images are typically 2500 by 2500 pixels of 256 radiance levels. Potential target areas are examined and assessed against criteria which include maximum and minimum pixel values, the difference between maximum and minimum pixel values and the brightness temperature gradient maximum, which will act as a potential target for the cloud drift wind tracking (Emery et al., 1986).

Once a target has been selected, auto-tracking is performed, using winds from the operational RASP 6 or 12 hour prognoses for the Australian Region, to indicate the initial search areas for well correlated target areas. An RMS difference methodology is used to compare the arrays of brightness temperatures of the target and search areas in order to estimate motion. The first guess reduces the size of the search area necessary to obtain the wind vector, but it also constrains the results to lie within a certain range of the forecast wind field.

Height Assignment

The assignment of a pressure height to the wind field generated by tracking of cloud is often difficult. For the low level winds it would appear, from several studies, that cloud base pressure best represents the appropriate height for low-level cloud drift winds, while for the upper levels, when one uses cirrus cloud as tracers, cloud top pressure is appropriate.

The effect of varying emissivity at cloud top makes the height assignment using cloud field brightness temperatures difficult for high level winds. As a result, several methods have been used to provide height assignment for these high level clouds. The simplest is similar to that employed in the analogue HR-FAX system which specifies a minimum sample size (percentage of cloud population) for a temperature class at the cold end of the spectrum. The temperature of this coldest class above the minimum sample size is used to specify cloud top temperature. A second methodology used when examining cirrus cloud is to assume a distribution of emissivity with temperature similar to those reported in several observational studies, such as Allen (1971), Platt and Dilley (1981). With this approach, it has been assumed that the mean emissivity for a specified part (depending on temperature) of the cold tail of the distribution (usually just above the lowest 1.4%), is approximately 1. By estimating the representative brightness temperature for this part, pressure height is then obtained using the temperature fields of the relevant RASP prognosis. When using this method, a check is made to ensure that the brightness temperature distribution increases in a specified manner as the class temperature rises. More extensive tuning and testing of the height assignment methodologies are still underway and are using cloud height data from lidar observations of cloud base and top, for estimation of height assignment errors.

In the case of low cloud, it is well known that cloud detection and the assignment of cloud height over *land* using IR data only is difficult and these low level vectors are not commonly generated. However, in the scheme described in this paper, rather than using a check to delineate land and sea, a stability test is made to determine if the difference between the forecast surface temperature and the 850 hPa temperature is less than 9 K and the warmest pixel is within

6 K of the forecast surface temperature. This effectively eliminates all low vectors over land when there is a surface inversion. In the lower levels, cloud wind height is assigned to the cloud base height which, for partly cloudy conditions may be assigned in one of two ways. In one case, it is assumed to be a fraction (for this study, one third) of the respective cloud top height. By a study of situations where two populations, one associated with the ground, and the other from the cloud are clearly apparent, this value appears to be reasonable. An alternative method, currently being used, involves smoothing the histograms using Hermite polynomials, so that the two components of the histograms can be separated operationally to determine cloud base. The height assignment for the wind moves progressively from the base to the top of the cloud as one progresses from low to high clouds.

Wind Computation, Accuracy and Quality Control

There are several parts to the quality control in this system, and these can cause the rejection of the wind vectors. Quality control is fully automatic and relies heavily on the RASP. The wind data are accepted and errors assigned, based on several criteria, including the correlation between the brightness temperature arrays of the search and target areas, the differences between the two vectors relating to different pairs of half-hourly images and the deviation of the calculated wind vectors from the first guess field.

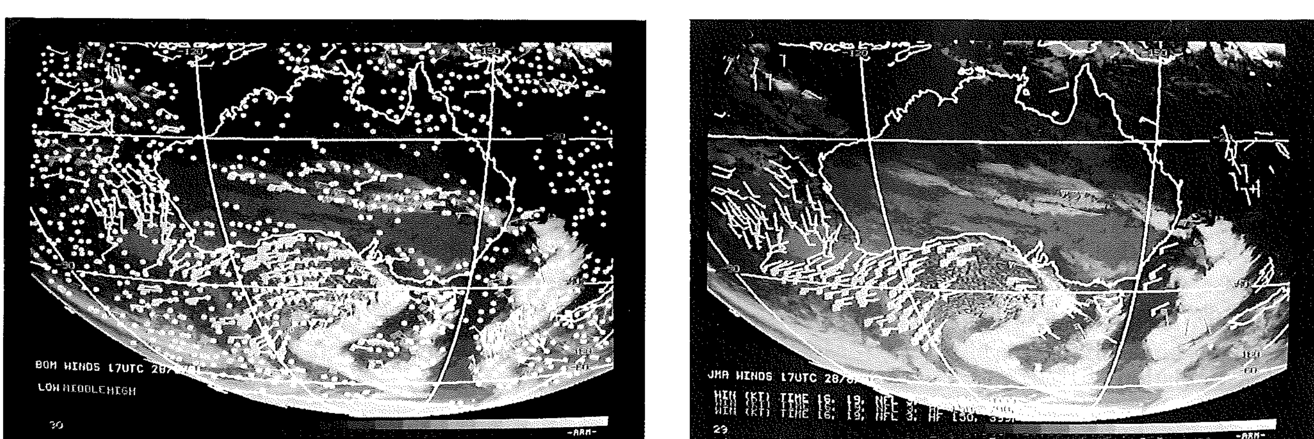
Quality control at the wind production stage is, to a significant degree, a practical compromise as an analysis system should be able to appropriately handle even poor data provided their error characteristics accompany the observation. In this system, the quality control is matched to the data assimilation component of the regional and global forecast systems used within the Bureau of Meteorology (BoM). As a result, checking using neighbouring data for example is not done because this is performed as part of the analysis cycle. It should be noted that in a simplistic sense, however, this may increase RMS errors associated with local cloud drift winds.

In the current system, after the initial quality control based on a consistency check of the vector pairs generated from consecutive image pairs, the final rejection criteria are velocity dependent and are based on departures from the RASP forecast of wind speed and direction. Rejection criteria for differences in the velocity estimates obtained from these consecutive images are, at present, fixed, and have been shown to include a small component, on occasions, due to image navigation errors. The quality control testing correlation between pixel brightness values between the target and search areas currently allows only correlations greater than 0.65.

It should be noted that, using these rejection criteria, comparison of the 6 and 12 hour forecast from the RASP, and the cloud drift winds at radiosonde sites, with the radiosonde observations themselves, shows that, in most cases, the cloud drift wind data are of greater accuracy than the 6 or 12 hour forecast.

An example

Winds from the S-VISSR processing system covering most of the southern hemisphere disk are shown in Fig. 2(a).



(a) (b)

Figure 2 (a) Automatically selected tracers (*) and low (yellow), middle (cyan) and high (magenta) level cloud drift winds generated at the BoM for 17 UTC on 28 August 1991. (b) Corresponding JMA winds available via the GTS in NMC at analysis time.

Here winds have been generated from 3 consecutive IR-GMS 4 images near 17 UTC on 28 August 1991 separated by half an hour. The example is from a continuous 4-D assimilation experiment run through part of 1991.The image shows cold fronts traversing waters south of the Great Australian Bight and the southern part of the Tasman Sea with the Sub Tropical jet over the continent. The tracers automatically selected from the cloud imagery are denoted by * and, using an operational model first guess, an appropriate subset of these tracers has been used to generate the winds also shown. The corresponding winds available from JMA via the GTS at analysis time are shown in Fig. 2 (b).

ACCURACY AND ASSIMILATION

Wind Accuracy

An indication of the accuracy of locally generated winds is given in Table 1. Here, the winds have been compared to colocated radiosondes (within 100 nautical miles) at the appropriate synoptic time (namely, 0, 6, 12, 18 UTC). Two periods are shown (2 - 14 July, 1 - 26 August) which correspond to the periods during which real time assimilation experiments were performed.

TABLE 1

Difference between locally generated cloud drift winds and colocated radiosonde observations (within 100NM) for 2 to 14 July and 1 to 26 August 1991.

	2 to 14 July		1 to 26 August	
Wind Level	Vector No.	Mean |Vector diff.|	Vector No.	Mean |Vector diff.|
Low : 950 - 700 hPa	478	4.95	1327	4.67
Middle : 699 - 400 hPa	38	7.71	59	6.18
High : 150 - 399 hPa	71	7.68	62	8.65

These verification data are typical of the results obtained around mid 1991 and can be compared to operational statistics provided by the Committee for Coordination of Geostationary Meteorological Satellites for Himawari (GMS) and other geostationary satellites. They indicate that the winds are of good quality. This conclusion is further reinforced by Table 2, which shows the differences between RAOB and satellite winds derived by both the JMA and BoM in cases where direct comparisons can be made (BoM and JMA winds both available). for Australian radiosonde stations.

TABLE 2

Comparison of BoM and JMA winds with radiosondes (within 100NM) for 1 - 26 August, 1991. Data comprises 4 upper level, 9 middle level and 172 lower level winds.

Origin	No. of comps.	Mean |vector diff.|
BoM	185	4.16
JMA	185	5.55

The table shows that the BoM winds for the period 1 to 26 August 1991 in the Australian Region are of good quality in this case, exhibiting the smaller mean vector differences. Mean monthly statistics using CGMS verification criteria for the BoM winds are now being accumulated.

Wind Assimilation

Real time 4-D data assimilation experiments have been run in the Australian Region examining the impact of local high resolution cloud drift wind data on regional forecasts.

The regional data assimilation system (RASP) (Mills and Seaman, 1990) used in this study has been implemented over the Australian Region by the BoM, and provides initial state analyses for the operational limited area numerical weather prediction (NWP) model (Leslie et al., 1985). This NWP model is also used as the forecast component of the assimilation system. The configuration used in this study had a horizintal grid spacing of 150 km over the region with 11 analysis levels to 50 hPa and 15 forecast model sigma levels to 0.05. Data insertion frequency was 6 hours.

The system was a duplicate of that employed operationally by NMC and used the data assimilated by NMC in their operational forecasts but replaced any JMA winds available at analysis time by locally generated vectors. In this way, the NMC forecast could be used as the control.

During the period 23 UTC on 23 August to 11 UTC on 29 August 1991, twelve assimilation forecasts were run in real time in parallel with NMC operations. Examples of the wind fields used in the local wind and NMC assimilation systems are seen in figure 2. The forecasts were assessed by comparing the S1 skill scores (Teweles and Wobus, 1954) for the control and corresponding assimilation forecasts using NMC's operational verification grid. The results for 12, 24 and 36 hour forecasts can be seen in Table 3 where they have been verified against both the Assimilation and NMC analyses. With the S1 skill score, the lower the score, the better the skill of the forecast. The forecasts show a small improvement in skill for the local wind assimilation forecasts. The skill scores appear to be better in all cases when compared to the Assimilation analyses and worse in only two of nine categories when compared to the NMC analyses. These results, however, although consistent with earlier results during 1991, are from a limited sample and need to be substantiated by a longer series of forecasts. Such forecasts are already well underway.

TABLE 3

S1 skill scores for the local cloud drift wind assimilation (CDW/RASP) and matching Control (NMC) forecasts (RASP) for the period 23 UTC 23-8-91 to 11 UTC 29-8-91. Both the Assimilation and NMC analyses have been used for verification.

	S1 Skill Score (Assim. Anal.)			S1 Skill Score (NMC Anal.)		
Forecast Type	MSLP	500	300	MSLP	500	300
RASP (+12 hr.)	27.3	14.4	13.6	27.4	13.8	12.9
CDW/RASP (+12 hr.)	26.3	13.4	13.1	26.9	14.1	13.4
RASP (+24 hr.)	32.9	19.7	18.7	33.1	19.7	18.9
CDW/RASP (+24 hr.)	32.7	19.3	18.3	33.1	19.7	18.5
RASP (+36 hr.)	42.2	26.9	24.9	42.3	27.1	24.9
CDW/RASP (+36 hr.)	41.1	25.7	24.1	41.2	25.6	24.1

SUMMARY AND CONCLUSION

This paper has described the real time generation of cloud drift winds from hourly GMS HR-FAX imagery and from half-hourly GMS S-VISSR imagery. The automatic tracer selection, height assignment of winds and the quality control methodology for the winds have been described. The present real time scheme uses areas of maximum brightness gradient for tracking. The height assignment uses the characteristics of the target area brightness temperature histogram and the forecast temperature fields. The quality control system has been described, and it has been pointed out that data screening should not be done without considering the systems that use the data. To this end, a quality flag which assigns a wind error to the cloud drift winds has been developed.

Direct measurements of cloud drift wind RMS differences compared to radiosondes have also been provided. In comparison with other verification statistics (for example those from CGMS), they indicate that the winds are of good quality.

The accuracy and utility of data when added to the operational database have been illustrated to a limited extent by showing the impact of the data in a 4-D data assimilation experiment. Full quantification of the impact of these data in numerical analysis and prediction will be established after the completion of data assimilation experiments underway at the Bureau.

In conclusion, GMS S-VISSR data have provided the opportunity to generate high resolution wind data over the

Australian Region on a regular basis four times daily. The opportunity has been exploited and the accuracy of the resulting winds, in comparison to those of other wind producers appears to be good. Initial experiments indicate that these high resolution data have the potential to improve prognoses over the Australian Region. As a result, the prospects of improved forecast capability over the Australian Region in the near future, as a result of an enhanced cloud drift wind data base appear quite good.

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