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An Investigation into the Infrared Water Vapour Radiance Data

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INTRODUCTION

Since the launch and the operational start of the new GOES-West satellite, the water vapour channel image data has been received on a regular basis at the Pacific Weather Centre. This data is received four times daily at 0515Z, 1115Z, 1615Z, and 2315Z.

Although these images are considered experimental, they have been used with satisfactory results in operational weather forecasting. Among the uses are an aid to locate jet streams and other upper atmospheric synoptic scale features. Additionally, the images can detect changes in moisture content before any clouds have formed. Therefore they are able to sense high level increases in moisture content associated with a developing system or advection of moisture from the subtropical latitudes. Both may be preludes to precipitation events.

Unfortunately the information acquired as indicated above is subjective in nature. More use could be made of quantitative information. For this reason it was decided to further investigate the water vapour radiance data through a direct comparison with corresponding radiosonde data.

BACKGROUND

In November 1980, GOES-4 was launched with a new Visible-Infrared Spin-Scan Radiometer (VISSR). This new instrument called the VISSR Atmospheric Sounder (VAS), will be carried on all future GOES satellites. One of the new features of the VAS is an experimental 6.7 um infrared water vapour channel sensor which the National Environmental Satellite, Data and Information Service (NESDIS) began providing to users twice daily in October 1981. The 6.7 um water vapour channel imagery of VAS was chosen since it directly augments the standard 11.5 um infrared by providing the operational meteorologist with additional information for diagnosing and monitoring upper tropospheric flow.

Energy measured by the VAS at 6.7 um represents the integrated radiant energy emitted by water vapour through a deep layer of atmosphere. The amount of energy detected by the satellite sensor depends on the temperature and moisture profile of the column of atmosphere being sensed. Low radiation levels (cold) appear white in the imagery; high radiation levels (warm) appear dark grey. The dark zones in the 6.7 um imagery represent areas which are relatively dry aloft. When this occurs, the sensor measures the radiance of a water vapour layer centred at a lower level in the atmosphere. See Figure 2 for an example.

The height of the level of the water vapour being observed cannot be determined since the amount of radiation received by the satellite is a function of both the atmosphere's water vapour content and its temperature. This makes it difficult to determine from the satellite imagery how deep into the atmosphere the sensor "sees" or the degree of low-level moisture present. However, an abbreviated description of the interpretation guidelines commonly applied to each of the different grey shades was given by Joseph Steronka et al (1973). Table 1 was constructed after examination of 58 radiosonde soundings at 15 mid-latitude and sub-tropical stations in relation to the grey shades in the 6.7 um imagery.

For a standard atmosphere, the maximum return at 6.7 um is centred near the 400 mb level with 80 percent of the energy coming from a layer bounded by the 620 mb level and the 240 mb level (see Figure 1). The height of the level of maximum contribution varies from about 8 km in the tropics to near 4 km in the polar latitudes. A computation of the contribution function for a wide variety of typical soundings at various latitudes indicates that the range in the level from which the principal contribution arises is approximately 3 km at a given station in the mid-latitudes. Given the above, it can be seen that the atmospheric transmission of 6.7 um radiation is a sensitive function of the atmosphere.

COMPARISON OF UPPER LEVEL SOUNDING DATA TO THE INTENSITY LEVEL OF THE WATER VAPOUR CHANNEL RADIANCE

It would be useful if some definite correlation could be found between the amount and level of moisture in an atmospheric layer and its intensity level. An attempt was made therefore, to compare some upper level soundings with the radiance intensity level taken from the water vapour channel image.

Figures 3 through 7 are a few of the upper level soundings examined with their moisture channel readings. They do not represent all the soundings examined but they do serve to illustrate the problems in attempting an interpretation of the moisture channel pixel intensity. The 400 mb level is plotted as this, on average, represents the level of maximum contribution. The cloud top temperature (as taken from the infrared picture) is indicated as additional information.

On the moisture channel image with a standard enhancement scheme, a pixel intensity reading near 200 would appear bright white, a reading near 175 would appear as a dull white or grey, and a reading near 135 would appear as a dark grey. Some sample counts are plotted in Figure 2. This agrees with Table 1.

An examination of Figures 3 through 7 will give some idea of the problems involved in attempting to determine the moisture content from the moisture channel pictures, and in attempting to apply any one set of rules.

Figures 3 and 4 both gave a pixel intensities near 206. Figure 3, however, indicates far more moisture in the middle and lower levels than in Figure 4.

This could be very important if the forecaster were attempting to estimate the potential for significant precipitation from the moisture channel picture alone.

Figures 5 and 6 also have similar readings near 176. Figure 5, however, indicates far more moisture in the levels below 700 mb, but with a similar moisture content at the very high levels above 400 mb.

Figure 7 has a fairly dry reading of 139. Although there is almost a complete lack of moisture at the middle and high levels, there is considerable moisture in the level below 850 mb.

Also plotted on Figures 3 through 7 is the level of the cloud tops estimated from the infrared cloud top temperatures. Figures 5 and 7 obviously give erroneous results and further illustrates the caution that must be taken when attempting to obtain meteorological information from the satellite images.

CONCLUDING REMARKS

The water vapour radiance data must be used with caution when examining the vertical moisture profile of an atmospheric column, especially in the middle and lower levels. The very dark grey or almost black areas are in nearly all cases indicative of dry air at the mid and high levels, but may be moist in the low levels. The radiance level, however, may give an indication of water vapour at the level of maximum response.

As well, the moisture channel, appears to have promising application techniques that could be of use to forecasters. Forecasters have noted initial sign of development and advection of high level moisture often manifest themselves on the moisture channel picture before any signs are evident on the infrared or visual pictures.

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3. "Application of Nimbus 4 THIR 6.7 um Observations to Regional and Global Moisture and Wind Field Analysis"; Joseph Steranka, et al; Journal of Applied Meteorology; March, 1973; Volume 12, Number 2.

4. "Experimental Moisture Channel Images at the Pacific Weather Centre"; Mert Horita; Pacific Region Technical Note 81-019, Sept. 22, 1981.

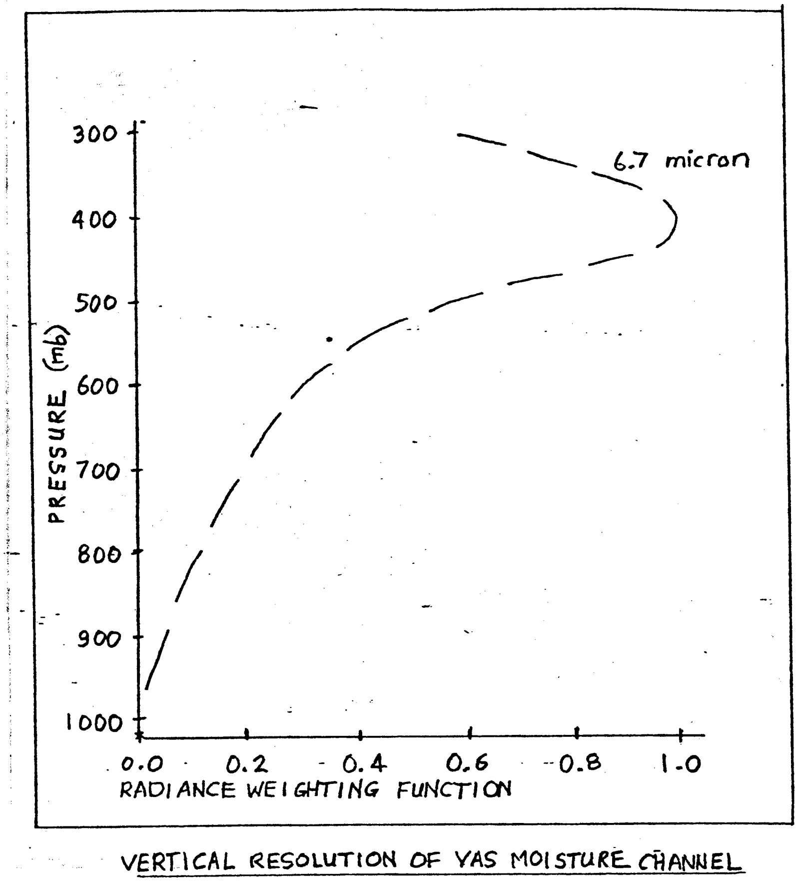

Figure 1

TABLE 1. Interpretation guidelines for 6.7-μm gray shades.

Grey shade	Relative moisture distribution
Dark or very light grey	Dry at all levels or moist only in the levels near the surface
Moderate grey	Dry at intermediate levels (700–500 mb), moist above and/or below
Bright white	Moist at all levels*

* Dense high and middle clouds can also give a bright white shade in the 6.7-μm imagery.

Table 1

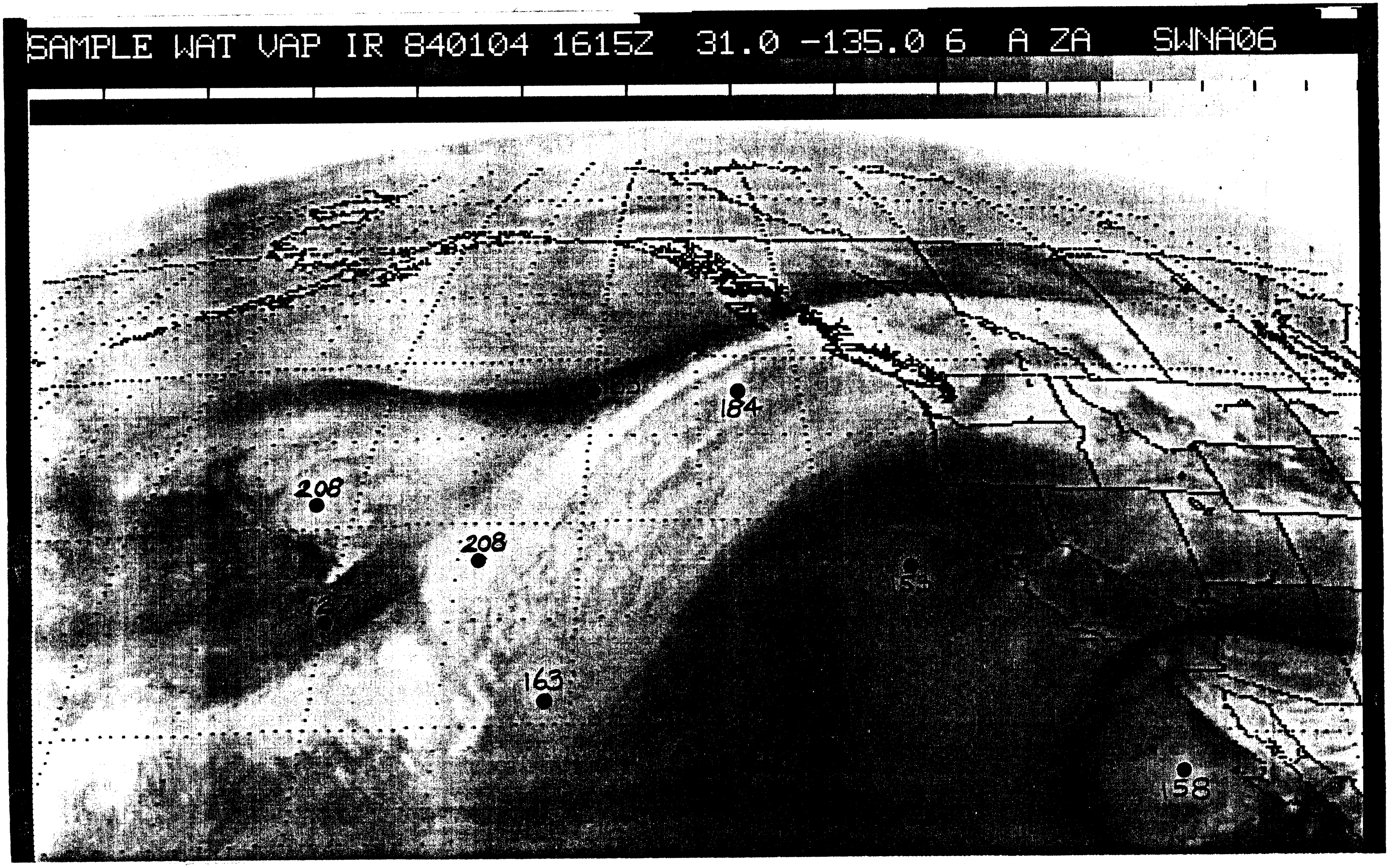

Figure 2

Sample water vapour picture with pixel intensities plotted for various grey shades.

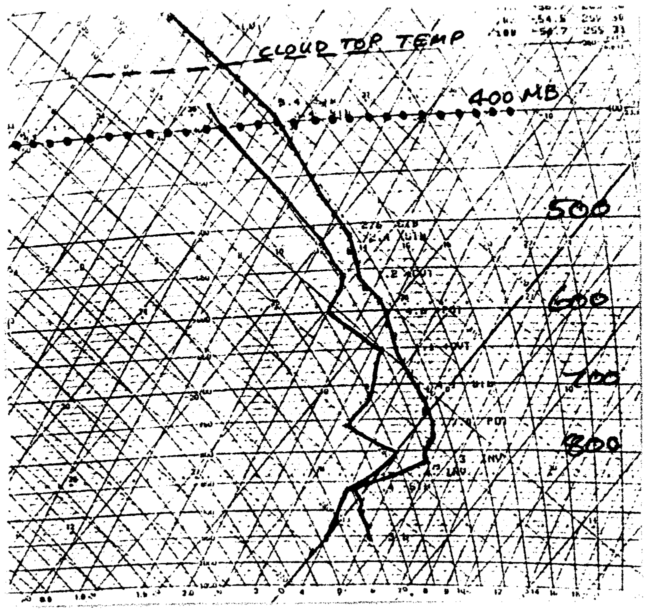

Figure 3

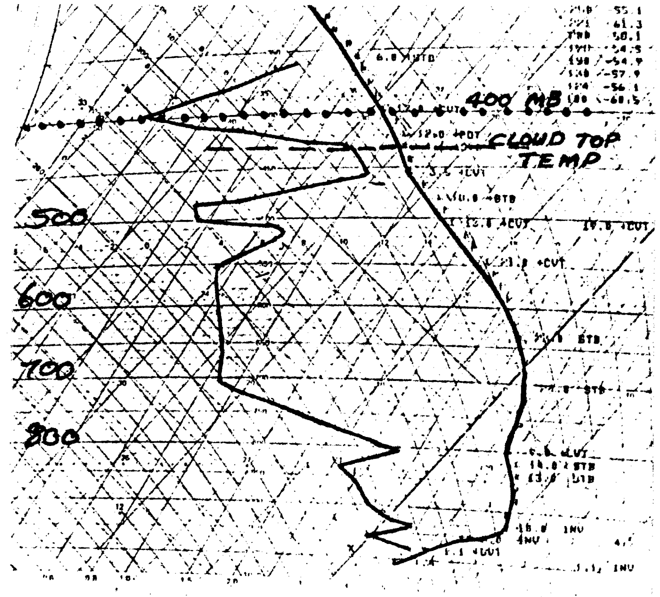

Figure 4

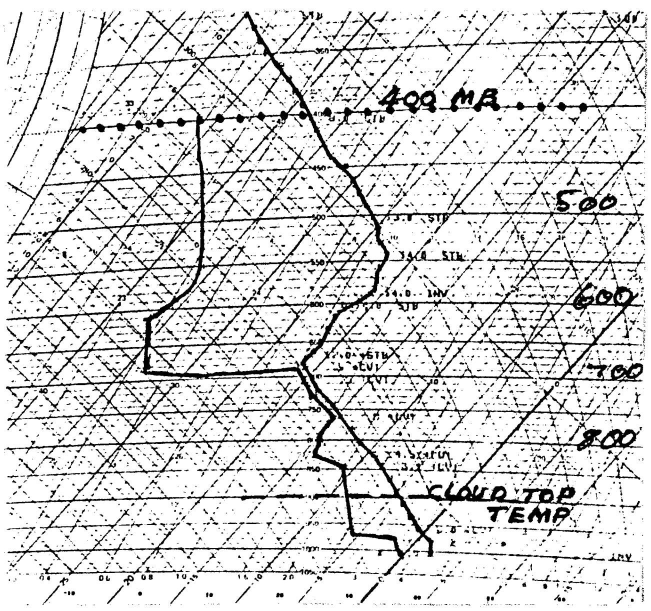

Figure 5

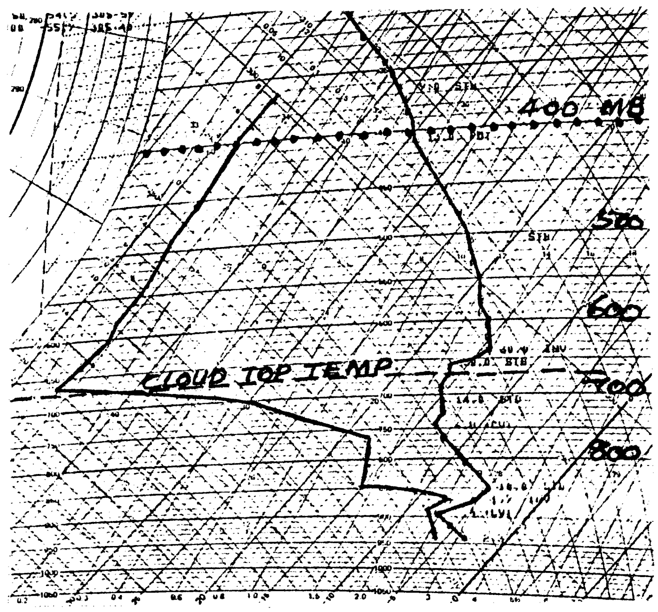

Figure 6

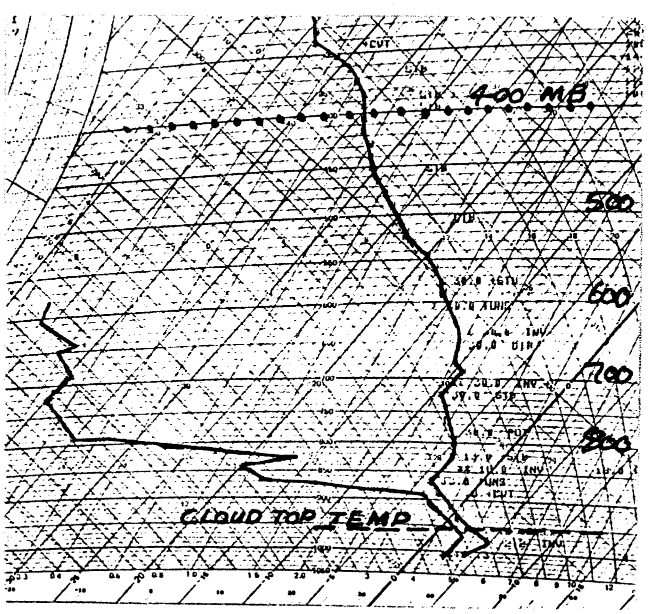

Figure 7

Sample radiosondes and their water vapour pixel intensity.

Figure 3 - Pixel intensity 206.
Cloud top temperature reading -40°C.

Figure 4 - Pixel intensity 206.
Cloud top temperature reading -25°C.

Figure 5 - Pixel intensity 175.
Cloud top temperature reading -5°C.

Figure 6 - Pixel intensity 175.
Cloud top temperature reading -16°C.

Figure 7 - Pixel intensity 139.
Cloud top temperature reading +13°C.