SYNOPTIC APPLICATIONS OF NEPH-ANALYSES FROM
ARTIFICIAL SATELLITES

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Abstract: This paper refers briefly to the forecast problem in the Australian region and the vital part likely to be played by satellite cloud photography when adequate experience has been gained in interpretation.

The U.S. Weather Satellite TIROS II is described and the interpretation of four neph-analyses obtained during the period December 1960 to January 1961 is discussed in relation to the appropriate M.S.L. synoptic analysis. Reference is made also to some apparent inconsistencies.

1. INTRODUCTION

Short period or 24 hour forecasting in Australia, as well as the longer range forecasts, is often difficult due to the presence of extensive ocean regions to the west and south where synoptic data is almost non-existent (Fig. 1).

Over the 2000 miles of Indian Ocean to the west, reports are available as routine only from Amsterdam Island (38°S, 78°E) and Kerguelen Island (49°S, 70°E) roughly 1500 miles distant; and from Marion Island (47°S, 38°E) a further 1000 miles westward. To the south and southwest reports are available from a few stations on the Antarctic coastline, 1500 miles distant. Reports from ships are quite inadequate to bridge these gaps since the shipping lanes for the most part skirt the coastline of the Australian Bight, and ships en route from South African ports to Melbourne or Perth are relatively few.

Australian meteorologists therefore approach the task of analysis over the Indian and Southern Oceans with no great confidence. Such success as is achieved is a product of long experience and of the meticulous care with which the sequence of reports from each station is studied. The passage of the polar frontal systems through Marion Island, Amsterdam Island and Kerguelen Island is closely
Fig. 1. Chart showing successive sub-satellite paths of Tiros II over the Australian region on 4th January 1961, orbits are at 98 minute intervals.
watched by detailed study of their 3 hourly reports and linked where possible to the great depressions which skirt the "coastline" of Antarctica.

The validity or otherwise of these analyses is frequently not evident until demonstrated by conditions some 24-36 hours later over western or southern Australia. It is abundantly evident also that a careful analysis of frontal systems in the Amsterdam Island and Kerguelen Island region is not necessarily adequate for forecasts over southern Australia. Information is generally lacking concerning the development of waves on fronts in the region between Amsterdam Island and the West Australian coast. Even in the southern areas of the Australian Bight cyclogenesis has occurred unexpectedly on not infrequent occasions with resultant forecast failures in the southeastern States. A major factor here is perhaps the frequency of occurrence of jet maxima at latitudes south of the continent with consequent uncertainty of analyses at upper levels.

It can be seen from the foregoing that the introduction of an aid such as cloud photographs from artificial satellites is an epoch-making event in Australian and world meteorology. The location of significant cloud patterns over the oceans has application not only to the frontal systems affecting southern Australia but with equal importance also to the detection and tracking of tropical cyclones.

2. INTERPRETATION OF SATELLITE PHOTOGRAPHS

The ultimate aim of cloud photography from satellites is to locate significant synoptic patterns over the earth's surface and particularly over the oceans. It is not certain at this stage how far this conception may be extended to the point where particular cloud patterns on photographs may be recognised as 'models' which may be immediately associated with various types of fronts, or whether absence of cloud or the presence of strato-cumulus cloud may be associated with regions such as the forward or rear portions of anticyclones. However it is already evident that the major rain and wind systems in both tropical and extra-tropical regions have in many cases characteristically significant cloud features on satellite photographs. These features are the spiralling cumuliform lines and the well defined vortex.

It is reasonable to expect that accuracy in synoptic analysis over oceanic regions will depend on the extent to which these models may be applied and to the experience which has been acquired in interpretation of the cloud photographs both as regards patterns of cloud and cloud types.
A project designed to gain experience in interpretation from satellite neph-analyses is to be carried out by the Australian Bureau of Meteorology at the invitation of the National Aeronautics and Space Administration and the United States Weather Bureau during observations with the meteorological satellite TIROS II.

3. TIROS II - WEATHER SATELLITE

The Tiros II artificial weather satellite is an 18 sided polygon, shaped like a pill box, with dimensions of 42 inches diameter by 19 inches height, weighing 280 lbs and powered primarily by solar cells.

The satellite was launched on 23 November 1960 and achieved its objective of a roughly circular orbit with an altitude of about 400 miles. The period of rotation of such an orbit around the earth is 98 minutes and the satellite speed about 17000 miles per hour. Tiros II is spin stabilized.

It is equipped with two television cameras designed to photograph the earth's cloud cover during daylight conditions. These cameras are different in coverage and resolution. The camera axes are parallel to the spin axis, which is in general not normal to the earth's surface. On those occasions when the spin axis and the camera are pointing downwards towards the centre of the earth (zero nadir angle) the wide angle camera views an area approximately 750 miles on a side with a resolution of 1.5 to 2 miles; the narrow angle camera views an area approximately 75 miles on a side in the zero nadir angle position but with resolution of about 0.15 to 0.2 miles. When the camera is looking at higher nadir angles the extent of the coverage is increased while the resolution decreases.

The command and data acquisition centres are located at Belmar, New Jersey and San Nicolas Island, California. When the satellite is on orbit within a certain range of either of these stations, instructions are issued to the cameras to take pictures at a specific future time and to store them in a magnetic tape recorder. The pictures are read out at the next orbital pass within range of the data acquisition station, recorded on tape and in parallel on film by photography of a monitor screen. Orbits within range of the command stations are shown in Fig.2 as 'sub-satellite paths', i.e. orbital paths projected to the earth's surface. Fig.1 also shows a series of consecutive sub-satellite paths of Tiros II over the Australian region on 4 January 1961.
Fig. 2 Sub-satellite paths of orbits within range of command station
A number of photographs were obtained of clouds in the Australian region and some of these cases are referred to later in this paper. It was not practicable to obtain transmission to Australia of the actual satellite photographs. However the Meteorological Satellite Laboratory were most cooperative in the despatch of coded neph-analyses as interpreted from the photographs. These coded messages which indicated areas of overcast, broken or scattered cloud and clear sky were received by teletype at Central Analysis Office, Melbourne, in some cases as soon as four hours after satellite photograph time.

The function of the Central Analyses Office in this experiment was to identify particular areas of interest coincident with satellite orbits and to request photographs where practicable in relation to solar illumination. Decisions as to practicability in regard to programming requirements and to camera orientation were made by the U.S. Weather Bureau. The extent to which the Australian requests were met was most gratifying. A large number of neph-analyses were, in fact, forwarded without specific request on a routine basis and these will be the subject of exhaustive study and correlation with our analyses over ocean regions to the west and south of the continent. In the meantime several situations have been selected for preliminary discussion in the following section.

4. SYNOPTIC APPLICATIONS

(a) Cessation of heat wave conditions over southeast Australia.

The most prolonged heat wave in December for forty-three years persisted over southeast Australia from 24-31 December 1960 with temperatures exceeding the century daily in most districts. Fig. 3 shows the M.S.L. synoptic situation.

The heat wave was associated with a blocking high over the Tasman Sea. The 'block' was typically represented on upper charts (Fig. 4) although not in the classical sense of a zonal flow upstream splitting into two westerly branches with approximately equal mass transport north of the upper cold low and south of the warm high. Nevertheless, the Tasman anticyclone at M.S.L. remained blocking from 25-30 December 1960 when it commenced to move eastward and lose intensity.

There was no evidence of any strong jet upstream nor any indications (having regard to the subjectivity of the analysis) of strong shear or curvature changes in the Australian Bight. In any event, a wave which formed on the front west of Tasmania during 29 December 1960 moved slowly eastward without deepening. This cool change moved over the Victorian coast on 31 December 1960, accompanied by a fall in temperature of 25 to 30°F.
Fig. 3. M.S.L. Analysis for 2300 Z on 28th December 1960

Fig. 4. 300mb. Contour — Isotach Analysis for 2300 Z on 28th December 1960
A neph-analysis obtained by Tiros II at 0257Z 29 December 1960 indicates a belt of overcast cloud orientated from northwest to southeast. The 0600Z Southern Ocean analysis for this date (as analysed without reference to the satellite picture) indicates a front with similar orientation. Fig. 5 shows the M.S.L. Southern Ocean 0600Z analysis with the superimposed neph-analysis for 0257Z 29 December 1960. The time difference is not critical in this case since the speed of the front in the section north of the wave was only about 12 kt. The location of the front on the analysis was arrived at largely by historical extrapolation over Southern Ocean waters from Amsterdam and Kerguelen Islands reports, together with indications of frontal passage through stations along the southern coastline of the Continent.

The neph-analysis implied that the front was located further east along lat. 40°S than analysed. This was largely substantiated later when the cool change moved into southern Tasmania earlier than anticipated.

The satellite picture in this respect appeared to present evidence which called for amendment of the M.S.L. analysis as described. At the same time there were features of the neph-analysis which seemed inconsistent with observations. Only scattered cloud was reported from stations in southern Tasmania at the time of the satellite photograph, which had been interpreted to show overcast conditions in this region. Also it was to be expected that the cold centre of the occluded cyclone (centre foreground in Fig. 5) would be associated with overcast cloud which would be evident in the southwest section of the picture frame and where in fact clear skies were reported. The centre of the cold low was definable with some precision in the isobaric analysis on this occasion due to the observation from the ship 'Magenta Dan' en route with the 1961 expedition to Antarctica. The Magenta Dan reported heavy overcast conditions in the vicinity of 55°S, 130°E.

These apparent inconsistencies perhaps highlight a factor which must be considered in the interpretation of the neph-analyses from Tiros II, i.e. the translation picture boundary error of about ± 2 or 3 degrees of latitude.

An interesting feature associated with this particular case concerns the belt of overcast cloud lying roughly parallel to the front. This cloud was located, as far as can be ascertained, ahead of the surface frontal boundary (allowing also for the time difference between the isobaric- and neph-analyses) and at 0257Z 29 December 1960 was pictured as almost entering the continent along the coastal fringe to the southeast. The speed of the front at
these latitudes was about 12 kt towards the east. Nevertheless, over-
cast conditions did not become apparent over the southern states at
any time during the following forty-eight hours until almost
immediately prior to the cool change, when skies became overcast due to
rapidly developing cumulo-nimbus.

The translational error could hardly have been responsible in
this case for such delay in appearance of an overcast cloud region of
largely frontal origin. On the other hand, the neph-analysis indicating,
perhaps significantly, 'overcast' instead of 'heavy overcast' may well
have been the interpretation of photographed strato-cumulus cloud which
formed in the warm northerly stream ahead of the front—a warm stream
moving over a considerably cooler ocean surface. Such cloud would not
be expected to form over any land areas as the front moved slowly east-
ward. It seems probable that the extensive cloud formation which was
photographed as preceding the front over the eastern Bight was not due
primarily to frontal activity. This was supported to some extent by a
'nil sferics' report in this region and to a greater degree by the
subsequent observations of predominantly clear skies over land stations
right up to the arrival of the cold front. The very rapid build-up of
cumulus cloud to the thunderstorm stage was apparently largely
triggered by diurnal heating due to prefrontal temperatures of about
100°F.

While it is not reasonable to draw general conclusions from a
particular case, it is evident that interpretation will require not
only familiarity with types of cloud patterns associated with various
frontal systems but will re-emphasize the influence of locality, of heat
and moisture exchanges and of stability on cloud formation.

(b) Location of a tropical cyclone over northeast Australian
waters.

By 27 December 1960 the thermal trough had become well
established with east-west orientation at about 12°S. From 27 December
1960 to 2 January 1961 a few weak cyclonic circulations appeared to
form in this trough. On 3 January 1961 there were indications (from
'sferics' reports) of a deep moist layer in the region adjacent to the
northeast Australian coast. On this date also (see Fig.6) the M.S.L.
analysis for 0200Z showed a weak cyclonic circulation centred just off
the Queensland coast at about 20°S.

Since an initial cyclonic circulation and a deep moist layer
are two of the basic requirements for tropical cyclogenesis, the
satellite pictures for 0225Z 3 January 1961 are of particular interest.
Fig.6 shows superimposed on the analysis three regions of 'heavy over-
cast' cloud (the neph-analysis elsewhere within the picture boundary
Fig. 6 M.S.L. chart for 0200 Z. on 3rd January 1961 and super-imposed neph-analysis of overcast areas at 0225 Z.
indicated only scattered to broken cloud over the ocean) and all of these regions coincided with positive 'sferic' areas.

It is perhaps significant that at 2000Z 3 January 1961 the cyclonic centre appeared to be located further north at 17°S, 149°E.

The Tropical Cyclone Warning Centre at Brisbane subsequently issued cyclone warnings as the disturbance moved east to southeast, away from the continent, with only slight intensification prior to its filling by 7 January 1961. No further satellite pictures were available.

This case is an example of accurate determination of regions of heavy overcast cloud and augurs well for detection of cyclones by satellite photographs.

(c) Frontal Analysis over the Indian Ocean.

The analysis over the Indian Ocean area in the vicinity of reporting stations at Amsterdam and Kerguelen Islands is often capable of some objectivity. On other occasions, however, the nature of the frontal passages is obscure and the analysis cannot be uniquely determined.

An example of such a situation is given by Fig. 7, which shows the 0600Z M.S.L. analysis for the Southern Ocean for 2 January 1961 with the superimposed satellite neph-analysis for 0509Z. The analysis has here been adjusted to fit the 'heavy overcast' and 'overcast' formations in the Amsterdam Island vicinity, by cold and occluded fronts respectively, separated by a ridge where the 'clear air' sector occurs.

The major difference between this amended version and the original analysis is that the occluded front shown between Amsterdam Island and Kerguelen Island was located about 400 miles westward, thus not accounting for the 'overcast' reported by Tiros II southwest of Amsterdam Island.

This case is typical of the application of many satellite pictures to the Amsterdam Island - Kerguelen Island area.

No frontal interpretation can be presented for the 'overcast' along the meridional range 99-105°E. This cloud formation was supported by two ship reports of overcast conditions at 2300Z 1 January 1961 in this general area - one of which also reported showers. Both the location and the intensity of a cyclone to the north was not known with certainty, although the movement was probably westward. It is probable that a trough extended southward from the centre causing convergence cloud and showers.
Fig. 7 M.S.L. Southern Ocean analysis for 0600 Z. on 2nd January 1961 and superimposed neph-analysis of overcast areas at 0509 Z.
Fig. 8 M.S.L. analysis for 0600.Z. on 31st December 1960 and superimposed neph-analysis of overcast areas at 0404.Z.
(d) Location of fronts and convective cloud over the Australian continent.

Fig 8 shows the plotted locations of 'heavy overcast' and 'overcast' cloud from the satellite neph-analysis for 0404Z 31 December 1960. Superimposed on this is the amended 0600Z analysis for the Southern Ocean. Unplotted areas were reported as 'clear to scattered'. The amendment necessary consisted in the movement of the occluded frontal system about 300 miles to the east for consistency of cold and warm front location with the neph-analysis as shown.

The location of the northern cold front was confirmed as lying just inland from the Bight. The 'heavy overcast with breaks' confirms the widespread reports from ground observers of convective thunderstorm activity in the Queensland trough.

This example emphasizes the use of the satellite pictures for forecasting over settled areas. At a glance the forecaster can form an opinion as to the probable duration of rain from the width of the frontal cloud band. Also the widespread nature of convective storms can be much better appreciated through the camera eye than through the reports of sometimes widely distant ground observers.

(e) Location of an extra-tropical vortex over the Indian Ocean.

As stated earlier in this paper, one of the three synoptic reporting stations in the South Indian Ocean is Marion Island (Fig 1). In the 36 hour period preceding 0600Z 18 December 1960, there was strong ionospheric activity which caused a 'blackout' of radio transmissions of weather reports from this particular station. During this period the 0600Z M.S.L. analysis for the Southern Ocean was completed for the Marion Island region by extrapolation from the next preceding analysis 24 hours earlier. The extrapolation was necessarily highly subjective since it was taken from the far southwest Indian Ocean, a region where analysis cannot be done with confidence from Australia. When the neph-analysis was obtained it indicated a cloud area containing a vortex and spiralling cumuliform clouds in a region where our analysis merely indicated a ridge of high pressure. The Southern Ocean analysis was accordingly amended to indicate a strong circulation about an occluded low centred at the vortex. The subsequent history of frontal passage through Amsterdam Island verified the existence of the low in the general locality indicated by the picture.
This is an example of the magnitude of errors which can be made in analysis over ocean regions. In this case the error was due to the absence of reports from Marion Island, through or near which the low must have passed during the 'blackout' period. However, the potential value of satellite photographs can be gauged when it is appreciated that for Australian meteorologists wide regions of the Indian and Southern Oceans are in a condition approaching a permanent 'blackout'.

(f) Cases presenting apparent inconsistencies.

Although specific cases of inconsistency will not be discussed here in detail, reference should be made to neph-analyses which have not lent themselves readily to interpretation. This may be due largely to a newly found inadequacy of appreciation of the various conditions, other than frontal, under which clouds may occur over ocean regions.

However, neph-analyses over the continent on some occasions appeared inconsistent with ground observations of cloud (e.g. neph-analysis of 0510Z 30 December 1960 when clear skies reported by neph-analysis appeared at variance with broken cloud reported by observers). Also the location of the vortex referred to under (d) did not fit, as well as expected, the mutually consistent observations of two whaling ships in the locality. In this regard the picture translation error may have been an important consideration.

In considering such cases also regard must be taken of the NASA News Release Statement of 6 December 1960 to the effect that only 5 to 10 per cent of wide-angle pictures were meteorologically useful. (The decision of the Bureau of Meteorology to request wide-angle pictures was based on our expectation of limited access to programmes and the greater likelihood of coverage of a particular area of interest with a camera whose picture frame was of the order of 750 miles in width as against 75 miles for a narrow-angle camera). 'Meteorological usefulness' of satellite pictures is a relative quality which must be considered in relation to availability of data from other sources. It cannot be doubted that over our ocean regions, a very large proportion of the wide-angle pictures were useful to Australian meteorologists.

5. SUMMARY

A large number of neph-analyses as interpreted from Tiros II photographs have been made available to the Bureau of Meteorology from the Meteorological Satellite Laboratories of the U.S. Weather Bureau over the December to January period of 1960/61.
Some of these have provided general confirmation of our Southern Ocean analyses. Some have presented features which have called for re-analysis in a manner which has been verified by later history. Others have not lent themselves to ready interpretation of current or later analyses and a full appreciation of these will require closer study. Finally a few neph-analyses have apparently been at variance with observations.

Interpretation of neph-analyses or cloud photographs for use in analysis will involve not only a study of cloud patterns for models to be associated with various types of fronts and cyclonic vortex-spiral systems, but also an attempt to identify the types of cloud represented and the nature of the cloud producing mechanism, i.e. whether fronts, convergence turbulence or convection.

The utility of satellite photographs when their interpretation is more thoroughly understood is likely to have far-reaching and scarcely foreseeable effects on extended range and day-to-day forecasting. In Australia the opportunity of participating in the Tiros II experiments has laid the ground work to this end.