A Test of the ECMWF Model in Tropical Synoptic-Scale Diagnosis

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ABSTRACT

The originally disseminated ECMWF-FGGE analyses for January and February 1979 are used to study the model performance in the deep tropics. Vertical velocities representing both the normal-mode initialized and uninitialized synoptic-scale flow are compared to directly observed IR radiance from the TIROS-N polar orbiting satellite. This comparison, based on the correlation between cloudiness and vertical motion, is made in the Pacific sector for composites of 1) the intertropical convergence zone, 2) the South Pacific convergence zone, and 3) Northern Hemisphere tropical intrusions. When compared to the uninitialized version, initialization diminishes the magnitude of diagnosed vertical motions in the tropics and Southern Hemisphere by a factor of 2 to 4. For synoptic-scale events away from the equator, especially at upper levels, the patterns of vertical motion are quite similar to each other and correlate moderately well with the radiance observations. Poor correlations in the deep tropics indicate that the original ECMWF-FGGE analyses within 10° of the equator are deficient on the synoptic scale and should be interpreted with caution in this domain.

1. Introduction

The study of synoptic-scale weather systems in the tropics suffers from a general problem of sparse data coverage. This problem is especially acute over vast stretches of the tropical oceans where much of the interesting weather occurs. Although some data enhancement experiments have been conducted in the tropics (e.g., GATE, WAMEX, BOMEX), they have usually encompassed small areas and short time periods. The only significant exception to this rule has been the year-long First GARP Global Experiment (FGGE) performed in 1979. The FGGE greatly increased the quality and quantity of data over the tropics and much of the Southern Hemisphere. However, even this enhancement was uneven in space and time, making it problematic to use the raw data for the study of synoptic-scale events.

To make best use of limited data, synoptic studies of the tropics will increasingly rely on the output from general circulation models (GCM's). As part of an analysis/forecast cycle a GCM can provide the first-guess field for an optimum interpolation analysis of the data at a given time. The first-guess field is typically a 6- or 12-h forecast generated from the previous analysis. Studies have shown that this method can generally yield more realistic representations of the synoptic-scale flow than would be possible using the synoptic hour data alone or using climatology as a first-guess field (Lorenc, 1981).

The data collected during FGGE has been analyzed by an analysis/forecast cycle utilizing a GCM developed by the European Center for Medium-range Weather Forecasting (ECMWF). The ECMWF model has been widely used and tested, but mostly in midlatitude studies (Bengtsson and Simmons, 1983). There is some uncertainty whether the model, as used to generate the FGGE dataset, adequately depicts the synoptic-scale flow in the deep tropics because the effects of latent heating are largely eliminated through the initialization process, described below, at the beginning of each forecast (Puri and Bourke, 1982). Since much current and future research will be based on the original ECMWF-FGGE analyses, it is important that we gain some appreciation for how well they represent synoptic-scale patterns in the tropics.

One of the few ways to give a detailed independent check of model performance is to compare vertical motions diagnosed by the model to the cloudiness or radiance patterns derived from direct satellite observations. Low radiance values, indicative of cloud tops in the upper troposphere, are usually associated with upward motions at the 300-mb level, as can be seen, for example, from the GATE analyses presented by Reed et al. (1977). Conversely, high radiance appears under cloud-free or low cloud conditions of widespread subsidence. Intermediate values may be associated with cloud tops and upward motions which do not extend much above 500 mb. In any case, if the model analysis diagnoses significant upward motion on the synoptic scale, there should be some cloudiness observed in that area or the adequacy of the depiction must be questioned.

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The purpose of this study is to test the performance of the tropical portion of the standard ECMWF–FGGE analyses by comparing the diagnosed vertical motions to the radiance patterns associated with three major tropical weather systems: 1) the intertropical convergence zone (ITCZ), 2) the South Pacific convergence

| LST  | 0330 | 1530 | 1650 | 1650 | 1630 | 1530 | 1430 | 1330 | 1230 | 1130 | 130 | 0450 | 0430 | 0330 | 0230 | 0130 | 0030 | 2330* |
|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|-------|
|      |      |      |      |      |      |      |      |      |      |      |     |      |      |      |      |      |      |      |       |

* The cut between days on daytime IR images occurs near 130°W.
zone (SPCZ), and 3) the Northern Hemisphere tropical intrusion (described in the next section). The study is limited to the Pacific sector and the months of January and February of the FGGE year.

2. Method

a. Data

In this subsection we describe the three types of data used in this study: 1) model derived vertical velocities, $\omega_z$, representing the initialized wind field; 2) model derived vertical velocities, $\omega_z$, calculated from the uninitialized winds; and 3) satellite observed IR (infrared) radiances, $E$. The region of interest is primarily confined to the area $40^\circ$S to $40^\circ$N and $160^\circ$E to $120^\circ$W. This area encompasses most of the tropical and subtropical Pacific while avoiding as much land as possible. This is convenient because oceanic areas have a simple lower boundary condition, $\omega_{\text{surf}} = 0$, for the derivation of kinematic vertical velocities and the radiance data can be interpreted without the complications of land–sea differences in surface radiance. In addition, as we shall see, three distinct synoptic-scale weather patterns, common to this region, appear with some persistence during the period 1 January–28 February 1979.

The standard FGGE data set (designated III-b) was produced by a three-part repetitive procedure composed of an analysis, an initialization, and a forecast. In the first step the data within a 6-h window, centered on the map time, are analyzed by a three-dimensional multivariate optimum interpolation scheme (Lorenc, 1981). This analysis is then subjected to an adiabatic nonlinear normal-mode initialization which suppresses the high frequency gravitational modes and leaves the desired Rossby wave solutions (Williamson and Temperton, 1981). The initialized fields are then used to generate a 6-h forecast from the ECMWF model. To complete the cycle, the forecast serves as the first guess for the next analysis. More details about the model and procedure are given by Bengtsson et al. (1982).

The FGGE III-b data set, as supplied by ECMWF, consists of both basic analysis parameters and derived parameters available four times daily at 15 levels in the vertical (between 1000 and 10 mb) and a horizontal resolution of 1.875° in both latitude and longitude. The basic analysis parameters are uninitialized and consist of geopotential height, sea level pressure, and horizontal wind components. The derived parameters consist of temperature, relative humidity (up to 300 mb), and vertical velocity. Of special relevance to our study, this vertical velocity was derived by ECMWF using the kinematic (mass continuity) method from the initialized divergences. Thus, the vertical velocities do not correspond to the same three-dimensional flow as the horizontal winds. One flow is initialized, the other is not. Thus we can compare either flow's vertical motions to the satellite radiance; we have elected to compare both. The initialized vertical velocities were taken directly off the ECMWF tapes, while the uninitialized vertical velocities were calculated from the
Fig. 2. (a) Example of case used for compositing the ITCZ and (b) idealized synoptic model for ITCZ composite.
horizontal winds using the mass-balanced kinematic method suggested by O'Brien (1970).

The IR radiance values for each hemisphere were obtained for the TIROS-N polar orbiting satellite on a 125 × 125 grid equally spaced on a polar stereographic projection (available from the National Center for Atmospheric Research). This represents a resolution of about 200 km at the poles and 100 km at the equator. For our purposes these values were interpolated onto the 1.875° FGGE grid. Note that this represents a loss of resolution in the tropics; thus, IR data is not being "created" by the interpolation method. The radiance fields were generated twice daily, representing 0330 and 1530 local standard times. Fields for 2 January and 22, 23, and 24 February were unavailable. Many of the radiance maps also contained missing swaths, but these were distributed randomly such that most points in the Pacific sector were represented 60–75% of the possible times. Since the FGGE map times are at 0000Z and 1200Z, the radiance fields are not synchronous with the FGGE vertical motion fields. As can be seen in Table 1, the polar orbiting data spans 6 h of GMT over the domain of our Pacific sector. However, none of the radiance data are more than 4 or 5 h off the corresponding FGGE map time. Misalignments due to advection of the cloud field should not be significant on this time scale, except along the edge of the mid-latitude storm track, where translation speeds of 20 m s⁻¹ are not uncommon. Rapid convective development and dissipation could also be a problem in the tropics, but averaging the results over many synoptic events should minimize the bias as much as possible. Figure 1 offers a randomly chosen comparison between a TIROS-N IR radiance for 0330 local standard time

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Table 3. Cases used to form the SPCZ composite.

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Fig. 3. (a) Example of case used for compositing the SPCZ and (b) idealized synoptic model for SPCZ composite.
and the 1200 GMT GOES-W IR image for the same day. It is seen that the two depictions are quite similar despite the time differences.

b. Compositing technique

In this subsection we describe the method used to form composite vertical motion and radiance fields for the three aforementioned synoptic-scale features commonly observed in the tropical Pacific. These features are ideally situated to study the response of the ECMWF model as a function of latitude. The SPCZ occupies a semipermanent position in the Southern Hemisphere tropics and subtropics, the ITCZ is found just north of the equator, and Northern Hemisphere tropical intrusions occur regularly in the region near Hawaii. The composite technique has been widely used to gain a better understanding of synoptic features in regions where the data are sparse or the quality is questionable. In this instance we hope to gain a generalized picture of how the ECMWF model handles these three phenomena by averaging as many similar responses as can be clearly identified during the two-month period.

Using GOES-W full disk IR imagery, those areas which clearly showed a cloud band in the ITCZ system were chosen for compositing. The ITCZ system is defined such that the axis of the cloud band is east–west, the length of the band is approximately 3000 km, and the width is approximately 500 km. An example of a specific case and the idealized synoptic model is shown in Fig. 2. Twenty-five out of a possible 112 times (31 + 28 – 3 = 56 days, twice daily) were found generally to satisfy the above criteria. The specific cases are listed in Table 2. The origin of the coordinate system used to composite each case was defined as the FGGE grid point nearest to the center of the cloud pattern. The area of data then extracted for each case extended 10 grid points east and west of the origin, 6 grid points north, and 5 grid points south (approximately 38° in longitude by 20° in latitude). Composite fields of \( \omega \), \( \omega_u \), and \( E \) were formed by averaging the 25 values for each grid point at each of the eleven model levels (except \( E \), of course) between 1000 and 70 mb.

The SPCZ composite was formed in a similar manner. Those cases where this cloud system was clearly defined in the GOES-W images were selected. The cloud pattern was generally aligned northwest to southeast with a length of some 6000 and a width of 2000 km. During the period of study, 33 cases out of the 112 possible were found with a well-developed SPCZ (Table 3). Most of these cases, however, occurred before 21 January. Around this date the SPCZ suffered a major disintegration which left the system weak and disorganized for much of the remaining period (Vincent, 1982). Figure 3 shows an example of the SPCZ and the idealized synoptic model for the composite. For each case used to form this composite the coordinate origin was chosen to be the center of the cloud band at 20.625°S. The north–south axis extends from the equator to 41.25°S while the east–west axis extends 48.75° west and 30° east of the origin for a total longitude span of nearly 80°.

The Northern Hemisphere tropical intrusions are associated with midlatitude troughs in the upper troposphere which amplify equatorward (Anderson and Veltischer, 1966). These disturbances can reach far into the tropics in the region between the dateline and the West Coast of North America. Occasionally they affect a deep layer of the tropical troposphere and in many cases are associated with the Hawaiian kona storm phenomenon described by Simpson (1952). During January and February 1979 there were no less than 12 well-defined cloud shields in this region, extending in some cases down to the ITCZ at 10°N. In each instance the cloud band had a similar signature and could be linked to a coexistent or previous midlatitude disturbance. For our composite, the cloud system was considered to have a generally northeast to southwest tilt, with a length of some 3000 and a width of 2000 km. The synoptic model and GOES-W example are shown in Fig. 4. This cloud pattern was clearly recognizable in 45 out of the 112 available times (Table 4). To form the composite the coordinate origin for each case was taken as the grid point closest to the western edge of the cloud shield at 16.875°N. Data were taken in the region from the equator to 31.875°N with a longitudinal spread of 41.25° centered on the origin.

It should be kept in mind that averaged radiance and vertical motion fields may not be directly comparable if they are formed by a composite of dissimilar events. This is related to the nonlinear nature of the radiance response to vertical motions. Consider the average formed by the combination of two days with extreme conditions, one a cloud-free day associated with strong subsidence and the other a day of moderate convection with high-level outflow. While the average vertical velocity might be zero, the average radiance value would be similar to what we normally associate with middle-level clouds. The value of compositing similar synoptic events lies in the assumption that similar events will behave in similar ways and, thus, the nonlinear effects will be minimized.

3. Results

In this section we compare the structure and magnitude of the radiance and vertical motion fields for the three composite phenomena. Representative fields of the vertical velocities are shown at the 300 and 700 mb levels. These levels were chosen to indicate the ver-
Fig. 4. (a) Example of case used for compositing Northern Hemisphere tropical intrusions and (b) idealized synoptic model for the intrusion composite.

tical variation in the structure of each composite. In addition, we present the vertical structure of the correlation between the radiances observations and both vertical velocities for each composite. Finally, the latitudinal dependence of the correlation between radiance and vertical motion is illustrated for the entire two month period.

But first, to set the stage for the composites, it will be useful to look at the mean radiance for the two month period of this study. The mean should provide an indication of the relative time mean position and strength of the phenomena as well as the overall pattern of radiance over the Pacific of which they are a part. As shown in Fig. 5, there are centers of high radiance in the western North Pacific and eastern South Pacific associated with the suppressed cloudiness under the subtropical highs. The preferred position of the ITCZ is evident around $8^\circ$N as a band of low radiance between $170^\circ$ and $140^\circ$W. Another band of low radiance, the SPCZ, extends from $30^\circ$S, $140^\circ$W northwest to the
vicinity of 10°S, 170°W. Further west, the cloudiness over the maritime continent and the northern portion of Australia is part of the winter monsoon circulation. In the North Pacific the radiance values decrease with increasing latitude as the midlatitude Pacific storm track is approached. The frequent presence of Northern

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Hemisphere tropical intrusions is attested to by the lowered radiances east of the dateline in the subtropics. The composite radiance for the SPCZ cases is shown in Fig. 6. A well-defined band of low radiances extends southeast from the deep tropics through the compositing point. To the northwest the band merges into the
ascending branch of the winter monsoon positioned over northern Australia. Regions of higher radiance reside to the northeast and southwest of the band. Coldest mean cloud tops in the band, associated with the lowest radiance values, appear between 10° and 15°S with a minimum of 194 W m⁻². Radiances gradually increase along the band in the poleward direction, perhaps indicative of lower, warmer tropopause limiting the vertical extent of the convective development. However, this could also be a simple artifact of the composite method; points progressively removed from the compositing point can lose coherence due to variations in alignment among the individual cases making up the composite. January 1979 was unusual in the amount of cross-equatorial flow in the vicinity of the SPCZ (Vincent, 1982). Satellite film loops based on the GOES-W imagery show high-level cirrus sweeping across the equator directly from the SPCZ band near the dateline. On our composite this shows up as a branch of low values along the equator at a position 10–20° west of the composite origin.

The uninitialized vertical velocity at 300 mb in Fig. 7a shows a vigorous region of ascent in good agreement with the radiance indications. Subsidence tightly
brackets the band. The portion equatorward of 15°S is relatively weak and disorganized. The pattern near the equator is very disorganized and somewhat contradictory. A region of subsidence at 5°S corresponds to the radiance minimum of 188 W m⁻². The prominent region of ascent, 30° due west of the composite origin also seems to be poorly reflected in the radiance data. A partial explanation for some of these problems lies in the nonlinear response of the radiance mentioned in section 2. The problem areas are situated far enough away from the compositing point that they could have been caused by events not directly associated with the SPCZ. However, the widespread weakness of the vertical motions in the deep tropics could indicate a problem with the analyses. The initialized vertical velocity at 300 mb in Fig. 7b is considerably damped in amplitude compared to the uninitialized version. Most of the gross features remain the same but the magnitudes have been generally reduced by some 60%. One curious exception occurs in one of the problem areas. Here, in the region of very low radiances, the subsidence has been increased by a factor of 3.

At 700 mb (Fig. 8), ω_u is almost identical in pattern and magnitude to ω_u at 300 mb. However, ω_i at 700
mb has been even more severely diminished; it is only 25% of the corresponding uninitialized values near the center of the composite. Neither of the 700 mb representations seems to pick up much activity in the equatorial zone. Considering the sizable signature in the radiance field in this region and the almost certain convective origin of the cloudiness, the bland depiction of the region equatorward of 10°S must certainly be considered a fault. Further away from the equator the composite seems to be relatively consistent with the observations and the two versions of the vertical motion tend to disagree only as to the magnitude of the velocities.

To gain some measure as to which depiction actually shows the modulation of vertical motion more in keeping with the radiance data, a simple correlation, \( R(k) \), was calculated at each model level:

\[
R(k) = \frac{\sum_{i=1}^{J} \sum_{j=1}^{I} X_{(i,j,k)} Y_{(i,j,k)}(I \cdot J) - (\sum_{i=1}^{J} \sum_{j=1}^{I} X_{(i,j,k)}) (\sum_{i=1}^{J} \sum_{j=1}^{I} Y_{(i,j,k)}) (I \cdot J)^2}{\sigma_X(k) \cdot \sigma_Y(k)}
\]

where \( X \) represents either initialized or uninitialized vertical velocities in the composite; \( Y \) represents the radiance; \( i, j, \) and \( k \) are grid indexes for the longitude, latitude, and height, respectively; and \( \sigma(k) \) is the standard deviation of the subscripted variable over the horizontal composite domain \((I \times J\) grid points) at each model level. Figure 9 shows the vertical structure of the correlation between the radiance field to \( \omega_u \) (solid line) and to \( \omega_i \) (dashed line) for the SPCZ composite. Although neither correlation explains a large amount of the variance, the uninitialized field seems to consistently outperform the initialized vertical velocities.

Figure 10 depicts the composite radiance for the Northern Hemisphere tropical intrusions. Since the compositing point was chosen along the sharp western edge of the cloud shield, it is not surprising that this corresponds to a very large gradient in the radiance field. The northeast–southwest alignment is clearly visible. The high radiance to the west reflects an almost complete absence of clouds while the low values to the east show the preponderance of high cloud tops and cirrus in the tropical intrusion. The cloud shield extends well into the tropics and seems to merge with an area of low radiance towards the west along the equator. Minimum radiance in the composite occurs near 18°N, about 10° east of the compositing point. No clear connection with the midlatitude storm track is indicated in this composite.

The 300 mb \( \omega_u \) pattern, shown in Fig. 11a, although somewhat noisy, is largely consistent with the radiance pattern. The maximum ascent of \(-1.95 \times 10^{-3}\) mb s\(^{-1}\) appears just southwest of the radiance minimum. The penetration of significant organized ascent deep into the tropics is clearly indicated. The subsidence is displaced to the north and east of the radiance maximum. The field of 300 mb \( \omega_i \) in Fig. 11b is smoother than the corresponding \( \omega_u \) field, but the amplitudes are similar over most of the domain. Only within 10° of the equator do we find large discrepancies. The initialized field is almost featureless near the equator and bears little resemblance to the radiance field in this region. At 700 mb the difference in representation is considerably larger. In Fig. 12a the uninitialized vertical velocities are similar to those found at 300 mb. The field also indicates that the region of ascent under the cloud shield covers a smaller area at lower levels; the upward motion is mostly confined south of 22°N. The initialized vertical velocities at 700 mb (Fig. 12b) are sharply scaled back. The ascent maximum has been reduced by more than 50% and the subsidence by 30%. Note also how the deep tropics are once again poorly handled.
Fig. 10. Composite of radiance for Northern Hemisphere tropical intrusions. Units are W m⁻².

Fig. 11. Composite of 300 mb vertical velocities for Northern Hemisphere tropical intrusions: (a) uninitialized; (b) initialized. Units are 10⁻³ mb s⁻¹.
Both versions of the vertical motion field indicate the Northern Hemisphere tropical intrusions are not simple, vertically aligned systems. Apparently the low-level ascent is largely limited to the area south of the climatological subtropical ridge around 25°N. At upper levels, where the flow is westerly, the upward motion is not so confined. Interestingly, this area of westerly flow is also the only region we have looked at so far that has not suffered severe attenuation by the initialization procedure. Because the intrusions are associated with the subtropical extensions of midlatitude disturbances, perhaps Rossby waves, which are not affected by the ECMWF initialization, constitute the dominant organizing influence over the vertical motion field in this region. Figure 13 shows the vertical structure of the two correlations with the radiance observations for the Northern Hemisphere tropical intrusions. The uninitialized vertical velocities only hold a slight edge over the initialization in this instance.

The field of radiance composited for the ITCZ is shown in Fig. 14. The band of lowest radiance, corresponding to the coldest mean cloud tops, has a width of approximately 30° longitude. A region of high radiance appears just to the north of this band, while radiance values south of the band increase more gradually. Values at the core of the ITCZ are not as extreme as for the SPCZ composite indicating, perhaps, that the convection is either less intense in the ITCZ or more spatially intermittent. Compared to other winters, the period of our study may be one of relatively weak
ITCZ development and strong SPCZ activity (before 21 January). The low values of radiancy in the northeast portion of the ITCZ composite are probably associated with the approach of tropical intrusions. From inspection of the GOES-W imagery, the ITCZ becomes preferentially active in the eastern Pacific upon the approach of a strong intrusion. The full significance of this relationship is not understood at this time, but it seems likely that the intrusion facilitates convective outflow at upper levels ahead of its trough line.

Figure 15a shows the composite uninitialized vertical velocity for 300 mb. The overall pattern bears only moderate resemblance to the radiancy field. The values are weak compared to the previous composites, and regions of ascent and subsidence are only marginally associated with the east–west banded structure observed in the radiancy. The initialized 300 mb vertical velocities (Fig. 15b) also appear chaotic and indicate even weaker vertical motions. At 700 mb (Fig. 16) the \( \omega \) field is more realistic. Perhaps the convection was rather shallow during this period and carries its largest signature at lower levels. In any case, the ascent is clearly banded but many spurious features remain. The \( \omega \) at 700 mb seemingly bears little resemblance to the satellite observations.

One might think the uninitialized vertical velocities would still handle the vertical motions adequately in the near-equatorial region, but the 6-h first guess generated from the previous initialization does not allow time for full development of the convective field, and the observations are too few to correct this deficiency. Figure 17 shows the vertical structure of the correlations for the ITCZ. Both vertical velocities have lower correlations than were obtained for the other two com-

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**Fig. 13.** Vertical variation of the correlation of radiancy to the uninitialized (solid) and initialized (dashed) vertical velocities for the Northern Hemisphere tropical intrusion composite.

**Fig. 14.** Composite radiancy for the ITCZ. Units are W m\(^{-2}\).
posites. The initialized version, especially, explains almost none of the variance in the radiance field. It appears that the ECMWF-FGGE analyses are not able to depict the vertical motions in the region of the ITCZ with useful accuracy.

To get an appreciation for the relative latitudinal dependence of the relationship between radiance and the two vertical velocities, we have formed correlations using all of the available data for the two month period. The value of the correlation at a given latitude, $R(j)$, was formed by correlating the data over all of the available times and along the longitudinal domain of 160°E to 120°W:

$$R(j) = \frac{\sum_{i=1}^{I} \sum_{m=1}^{M} X_{(i,j,m)} Y_{(i,j,m)} / (I \cdot M) - \left( \sum_{i=1}^{I} \sum_{m=1}^{M} X_{(i,j,m)} \right) \left( \sum_{i=1}^{I} \sum_{m=1}^{M} Y_{(i,j,m)} \right) / (I \cdot M)^2}{\sigma_X(j) \cdot \sigma_Y(j)}$$

where, as before, $X$ represents either initialized or uninitialized vertical velocities; $Y$ represents the radiance; $i$, $j$, and $m$ are indexes for the longitude, latitude, and time, respectively; and $\sigma(j)$ is the standard deviation of the subscripted variable over the time/longitude do-
main ($I \times M$ points) at each latitude. This ensemble correlation will take into account both the temporal and spatial nature of the variance.

The result for 300 mb is shown in Fig. 18a. Correlation of the radiance to $\omega_p$ is given by the solid line, and the correlation to $\omega_0$ is dashed. Note the poor performance in the deep tropics. Values in the Northern Hemisphere subtropics can be noticeably improved by lagging the radiance field by three grid points ($5.625^\circ$ longitude) with respect to the vertical velocities. These supplemental correlations are labeled in the figure as LAG 3. This region corresponds to the high-level westerlies mentioned previously. With these data included, the area of poor correlations in the deep tropics is especially emphasized. At 300 mb, at least, the overall performance of the two vertical velocities are not substantially different, in terms of correlations with the radiance observations.

Figure 18b shows the correlation results for 700 mb. Here the initialization has a rather drastic effect south of $15^\circ$N. The LAG 3 variant offers improvement only north of $25^\circ$N, again a region of predominating westerlies. A striking feature of Fig. 18b is the limited region of poor correlations near $22^\circ$N. A search of the GOES-W IR imagery for January and February 1979 reveals that this latitude was the preferred location for the appearance of cirrus associated with the subtropical jet and cirrus blowoff from the convection in the tropical intrusions to the south. Thus, there is reason to suspect that this correlation minimum is a real feature and
that it indicates that the 700 mb vertical velocities have little relation to the radiance in this latitude band.

4. Conclusions

The main conclusion of this work is that the currently available (August 1985) ECMWF analyses for the FGGE year are probably not suitable for certain types of synoptic research within a zone 20° wide, centered on the equator. Outside this zone the analyses quickly start to capture the vertical motions associated with large cloud masses in synoptic disturbances. The uninitialized vertical velocities seem to offer more realistic depictions based on direct pattern comparisons and correlation statistics with the independent satellite observations. The initialized vertical velocities may be suitable away from purely tropical regimes, such as at the upper levels in the Northern Hemisphere tropical intrusions.

The ECMWF model is generally recognized as a reasonably good GCM and additional improvements have been aggressively sought and implemented by ECMWF. Although some of the problems with the tropical FGGE analyses, such as a 20% under-prediction of tropical rainfall, have been known for some time (Bengtsson and Simmons, 1983), this is the first study, to our knowledge, which actually compares specific synoptic events to independent observations. A new, improved analysis of the FGGE year by ECMWF is currently being processed. However, this study may be of use in interpreting the large amount of work already performed or in progress on the original dataset. Additionally, this work can serve to gauge the relative improvement in the new analyses when they are released. The ECMWF model and other comprehensive data assimilation schemes utilizing GCM’s will continue to offer new and exciting opportunities for synoptic studies in regions previously unworkable due to data sparsity.
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