Slow Atmospheric Oscillations Confirmed

A disturbance that travels through the tropics every 40 to 50 days seems to modulate the Indian monsoon and influence the jet stream

It is an axiom of meteorology that no part of the atmosphere stands alone; everything is interconnected. It is a frustration of meteorology that major, sometimes catastrophic, atmospheric effects arise from the complex interconnection of numerous, subtle, and obscure causes. El Niño has recently become a prominent example of how elusive changes in the ocean and atmosphere can sometimes lead to dramatic shifts in the behavior of the atmosphere, sending abnormal weather through the entire system.

It now seems that another prominent phenomenon, whose existence long eluded meteorologists and whose significance is only now becoming apparent, sets the circulation of the tropics pulsating at a far faster pace than the irregular 3- to 8-year recurrence time of El Niño. From a satellite's perch, the new phenomenon appears as a wave of cloudiness that first develops every 40 to 50 days in the Indian Ocean, intensifies as it sweeps eastward into the Pacific at up to 30 kilometers per hour, and peters out in the eastern Pacific. Other meteorological observations can follow the disturbance through the tropics around the globe.

In the process of circuiting the tropics, this 40- to 50-day oscillation can set parts of the atmosphere as far off as the poles pulsating at roughly the same frequency. It apparently can also play a role in triggering the onset and withdrawal of the Indian monsoon, causing monsoon rains to pause in midseason, and reshaping the jet stream that plays a central role in North American weather.

The 40- to 50-day oscillation was the serendipitous discovery of Roland Madden and Paul Julian of the National Center for Atmospheric Research (NCAR) in Boulder, Colorado. Not that it is a terribly subtle, difficult-to-detect phenomenon that might be swamped by all the other variability of the atmosphere. Fifteen kilometers over Canton Island in the central Pacific, where the east-west or zonal wind may vary by 30 kilometers per hour from season to season, the 40- to 50-day oscillation can vary the wind over a range of 90 kilometers per hour, reversing the wind's direction in the process. In terms of wind changes, the oscillation is one-third to one-half as powerful as the changes accompanying a good-sized El Niño event.

The problem with finding the oscillation was that whenever meteorologists studied a record long enough to contain a sufficient number of cycles, they usually worked with monthly averages that obliterated any sign of the oscillation. Madden and Julian stumbled on it in 1971 while broadening earlier studies of tropical atmospheric waves having periods of less than 14 days. They had no trouble tracing its variations in pressure and zonal wind from the Indian Ocean to the eastern Pacific and, at least at higher altitudes, all the way around the globe. They could not find any evidence of the oscillation extending much beyond 10° north or south of the equator, although they presumed that such a strong disturbance must extend beyond the tropics.

The oscillation may be an El Niño–like atmospheric phenomenon without the El Niño's warming of the ocean.

From the wind and pressure variations, Madden and Julian inferred that the disturbance could be a center of intensifying updraft—accompanied by clouds and precipitation—that propagates eastward from the Indian Ocean until it eventually dissipates over the eastern Pacific. Driven by heating at the surface, air would rise toward the "ceiling" of the troposphere at the troposphere-stratosphere boundary, level off, and then fall back toward the surface and the lower troposphere, forming a closed circuit or convection cell. As it passed through the tropics, this convection cell would temporarily amplify a similar cell that is a permanent feature of the tropical Pacific. A wave in the troposphere-stratosphere boundary might then carry the disturbance the rest of the way around the globe to touch off the next oscillation, they speculated.

It was an interesting idea, everyone now recalls, but it was apparently not interesting enough to prompt any additional work for 8 years. Explanations for the hiatus vary. Madden and Julian had exhausted the available data. It was only a tropical phenomenon, at a time when many considered the weather patterns of the mid-latitudes (where most meteorological research was done) and the tropics separate and independent. And fluctuations that were so much slower than day-to-day weather variability were not a hot topic among meteorologists.

In any case, things picked up around 1980. Tetsuzo Yasunari of Kyoto University reported 40- to 50-day fluctuations in cloudiness over the Bay of Bengal and adjacent India, prompting Julian and Madden to publish some old equatorial cloudiness data supporting their model of enhanced convection. Then Klaus Weickmann of the University of Wisconsin at Madison pointed to satellite observations of 30- to 60-day fluctuations in tropical cloudiness that tended to propagate eastward into the central Pacific.

Weickmann also found that during some winters the cloudiness fluctuations were accompanied by fluctuations in the breadth of jet streams far to the north over East Asia, the North Pacific, and North America. John Anderson of the University of Illinois and Richard Rosen of Atmospheric and Environmental Research, Inc., of Cambridge, Massachusetts, also found the association of tropical and mid-latitude oscillations by demonstrating that they work together through their variations in the zonal wind to slow and speed up the rotation of the earth by a few tenths of a millisecond.

In a recent extension of his work, in cooperation with John Kutzbach of Wisconsin, Weickmann has confirmed the existence of year-round oscillations over the tropical Pacific and the wintertime connection with the mid-latitude jets. At times, Weickmann and Kutzbach can even trace the cloudiness as it skips to South America, northwest Africa, equatorial Africa, and finally back to the Indian Ocean. Weickmann suggests that the link or teleconnection between the surge of tropical Pacific convection during the passage of the disturbance and mid-latitude jets may act to shift weather patterns over North America. He cites as an example an apparent teleconnection that brought severe cold over the United States in late December 1981 through January 1982.

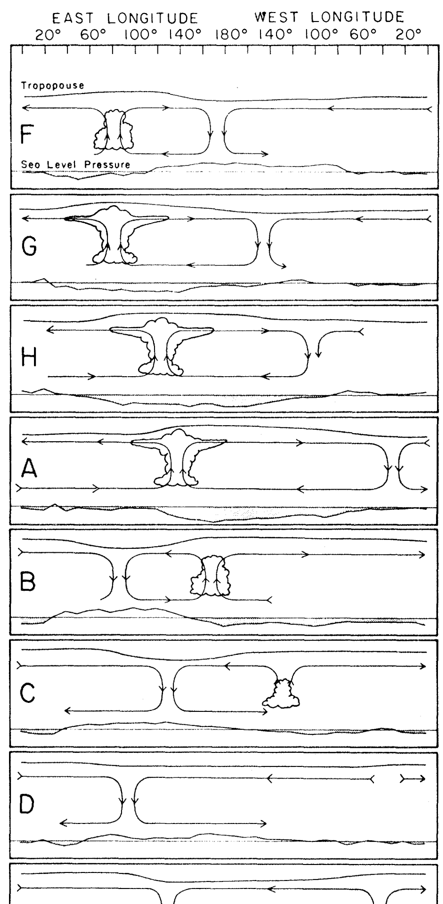
A more thoroughly substantiated influence of the oscillation on weather beyond the tropics is its modulation of the summer monsoon over India. Resembling a huge sea breeze drawn across the subcontinent by solar heating of the Tibetan Plateau, the moisture-laden monsoon winds spread vital rains across India in June, July, and August, if all goes well. It now appears that the 40- to 50-day oscillation can affect the timing of the monsoon and even trigger lulls in the midst of it. T. N. Krishnamurti and D. Subrahmanyam of Florida State University plotted wind patterns observed during MONEX, the intensive summer monsoon experiment held in 1979, and confirmed Yasunari's earlier suggestion of a northward propagation of the oscillation to the Himalayas at 30°N.

Near the surface during MONEX, the poleward propagation of the oscillation took the form of alternating wind patterns marching northward, one tending to reinforce and strengthen the monsoon winds and the next, arriving 30 to 50 days later, tending to nullify and weaken them. This progression continues with or without a monsoon, so the change of seasons still ultimately controls its comings and goings, not the more rapid oscillation. But the monsoon did weaken once and strengthen twice in time with the propagating oscillation, the weakening at midsummer turning into a full-fledged break or lull in monsoon rains. The arrival of monsoon rains, the timing of which can be crucial to Indian farmers, also occurred when favored by the oscillation, as did their withdrawal. Thus, knowing when the oscillation next favors a change in monsoon behavior might have real economic effects.

Having such theoretical as well as practical implications, the 40- to 50-day oscillation is currently much discussed. Still, what makes it tick remains mysterious. It bears an enticing resemblance to El Niño events. Both involve modulation of the intensity and an eastward shift of the center of convection in the Pacific, and both seem to form similar teleconnections to mid-latitudes (*Science*, 7 May 1982, p. 608).

Carrying the analogy even farther, Peter Webster of Pennsylvania State University is suggesting that variations in the temperature of the sea surface, which obviously interact strongly with the atmosphere during an El Niño event, also generate the oscillation. Considerable sensitivity to geographic variations of sea surface temperature would be required, so Webster looks to the western Pacific, the warmest and thus the most responsive part of the tropical ocean. Still, as Webster is the first to admit, most researchers do not agree that ocean temperature differences will suffice. The 40- to 50-day oscillation may be an El Niño–like atmospheric phenomenon without an El Niño–like warming of the ocean.

Numerous other causes for the oscillation are being offered, but Anderson emphasizes that its unvarying period from season to season, most recently demonstrated by him, Duane Stevens of Colorado State University, and Julian, eliminates several prominent possibilities. One still in the running is that the period of the oscillation is determined by the nature of the atmospheric heat engine that carries energy away from the tropics. In another serendipitous discovery, B. N. Goswami of the Indian Institute of Technology in New Delhi and J. Shukla of the University of Maryland found that in their computer model of the global atmosphere, the convection cell carrying air away from the tropics—called the Hadley cell—oscillated with a period of between 20 and 40 days.



The passing of an oscillation

This 1972 schematic cross section through the tropics by Madden and Julian is still holding up well as a description of how the disturbance (enhanced convection represented by the cloud) associated with the 40- to 50-day oscillation propagates from west to east. Accompanying disturbances in sea level pressure and the tropopause are also represented. Reprinted from (3).

By changing how the model atmosphere worked, Goswami and Shukla concluded that the Hadley cell operated like a poorly designed governor trying to control the speed of an engine. As air in the low-level, return leg of the cell heads back toward the equator, it picks up moisture from the ocean, the condensation of which helps drive the cell's circulation. The faster the air returns, the more moisture there will be available to drive convection, and the faster the air will return—but only up to a point. The returning air would eventually cover the return leg of the cell too fast to have time to pick up a full load of moisture; less "fuel" would reach the tropics; and convection would slow. The period of oscillation created by this feedback would depend on the cell length, a dimension set by global circulation patterns.

Anderson is also looking toward the Hadley cell for a source of the oscillation, but his far simpler model can produce oscillations in the Hadley circulation without the inclusion of moisture and condensaton. In his model, if the Hadley cell is jostled by any of various tropical disturbances, such as storms, its circulation will oscillate with periods of between 30 and 60 days, much as a struck bell vibrates with a characteristic pitch. The oscillation's period seems to be determined by the time it takes the cell's winds to carry the momentum added by a disturbance around the circuit. Anderson notes, however, that for the model to produce the observed narrow range of periods, some interaction between the Hadley circulation and convection may be required. Neither Hadley cell mechanism explains why the disturbance propagates to the east.

Future research will continue to pursue the ultimate cause of the 40- to 50-day oscillation, but its effects on the rest of the atmosphere may prove to be just as interesting. Ka-Ming Lau of Goddard Space Flight Center, Greenbelt, Maryland, has suggested that the oscillation may play a major role in triggering El Niños. And the oscillation's teleconnections to mid-latitudes, the mechanism of which is poorly understood, will provide far more examples for study than those of the half-dozen well-observed El Niño events.—**Richard A. Kerr**

Additional Readings

1. J. R. Anderson, thesis, Colorado State University, Fort Collins (1984).
2. B. N. Goswami and J. Shukla, *J. Atmos. Sci.* **41**, 20 (1984).
3. R. A. Madden and P. R. Julian, *ibid.* **29**, 1109 (1972).
4. K. M, Weickmann, *Mon. Weather Rev.* **111**, 1838 (1983).