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TRACKING OF TROPICAL INTRASEASONAL CONVECTIVE ANOMALIES

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Abstract— **A new algorithm based upon a multiple object tracking method is developed to identify, tracks and classify Tropical intraseasonal oscillations (TISO) on the basis of their direction of propagation. Daily NOAA Outgoing Longwave Radiation anomalies (OLRA) from 1979-2013 are Lanczos bandpass filtered for the intraseasonal time scale (20-100 days) and spatially averaged with eight neighboring point to get large spatial scales (~10^5 km^2). Tracking of TISO is performed by using a two-stage Kalman filter predictor-corrector. Two dominant components of the TISO (Eastward propagating and Northward propagating) are classified, and it is found that TISO remains active throughout the year. Eastward propagation of the TISO occurs from November to April with phase speed of ~4 m/s and Northward propagation of the TISO occurs from May to October at ~2 m/s in both Indian and Pacific Ocean basins.**

I. MOTIVATION

The Tropical Intraseasonal Oscillation (TISO) refers to variability on the time scale of 20-100 days, intermediate between the time scales traditionally associated with weather and climate. Physical understanding of TISO is a very important and challenging aspect of making predictions beyond the limit of instantaneous weather. TISO can be classified into two dominant components on the basis seasonality: (a) Madden Julian Oscillations (MJO); and (b) Monsoon Intra-seasonal Oscillations (MISO). The prevailing view of the dynamics of the MJO is that it is governed by the coupling of a moist Kelvin-Rossby wave to convective heating by boundary layer moisture convergence [9] although there is debate [7].

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In contrast, the dynamics of the MISO is governed primarily by barotropic cyclonic vorticity and easterly wind shear [5]. MJO and MISO occur in different seasons, at different latitudes and are governed by different mechanisms. MJO and MISO also have a different phase speed and direction of propagation. TISO has great importance because of its influence on the highly populated and largely agrarian economies of the tropics, where it regulates wet and dry spells of rainfall ([3]; [2]; [4]), which has a direct relationship with crop production. MJO also affects the tropical cyclone activity in all the ocean basins ([6]; [8]), El Nino Southern Oscillation (ENSO) as in [12] and extra-tropical weather and climate. Understanding of TISO is very crucial to realize the dream of seamless perdition. Most of the commonly used diagnostics to understand TISO consider dimensional reduction by seasonal and spatial averages or empirical orthogonal function decomposition. This approach may miss some information regarding direction of propagation, location and phase speed.

As an alternative, we examine TISO by tracking each event and compositing events on the basis of direction of propagation. The characterstics of TISO such as prefered geographical loaction of propagation, phase speed, life span, regions of initiation and dissipation and their seasonal and intraannual variability are analyzed in this study.

II. DATA AND METHOD

To identify and track TISOs, 34 years (1979-2013) of daily outgoing long-wave radiation (OLR) data from the National Oceanic and Atmospheric Administration (NOAA; 2.5° X 2.5° grid) is used. Anomalous OLR is considered a proxy for large-scale tropical convective anomalies [1] and [10], because negative OLR anomalies (OLRA) are well correlated with convective clouds. Daily OLR anomalies are obtained by removing the first four annual harmonics from the data at each gridpoint. The data is band pass filtered using a Lanczos filter in the 20-100 day band to obtain intraseasonal anomalies. Finally OLRA are spatially smoothed using a 9-point weighted average. An event is classified as TISO if it satisfies the following three criteria, which are quite similar to [9]: (a) Life span at least 20 days; (b) During its lifetime, the zonal dimension exceeds 30° longitude and the mean OLRA remains less than -15 W/m^2; (c) At the strongest stage, the zonal dimension exceeds 50° longitude and the central intensity is less than -25 W/m^2.

Sr. No	Class	Events	Ave. Speed	Ave. Life Span
1	Eastward	71	4.04	33
2	Northward	96	2.28	24

Table 1: Characteristics of Tropical intraseasonal oscillation

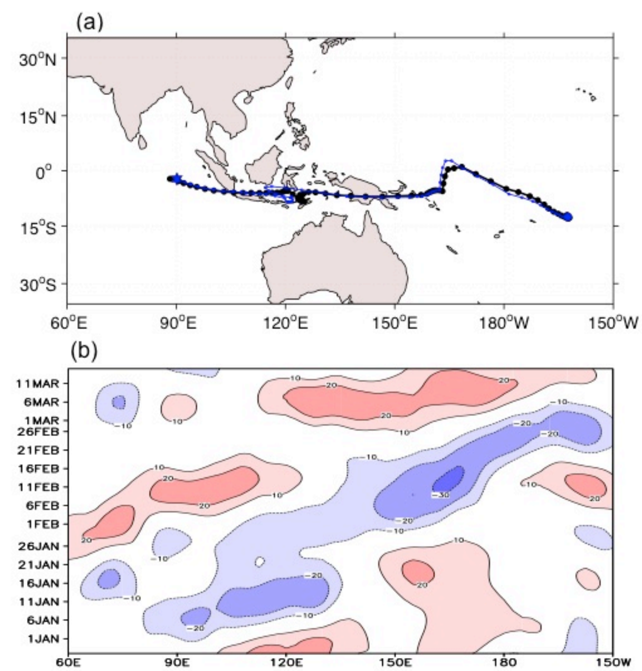

Figure (1): (a) Track of eastward propagating TISO identified visually (black) and identified by algorithm (blue), (b) Hovmoller diagram averaged between 15^{o}S-15^{o}N for the same dates as in (a)

A systematic framework using a motion-based multiple-object tracking algorithm, as given in [11], has been developed to identify, track and classify tropical intra-seasonal oscillations. The method is applied to intra-seasonally filtered daily and spatially smoothed OLRA data from 35°S to 35°N to track every individual TISO event.

The steps involved in tracking are as follows:

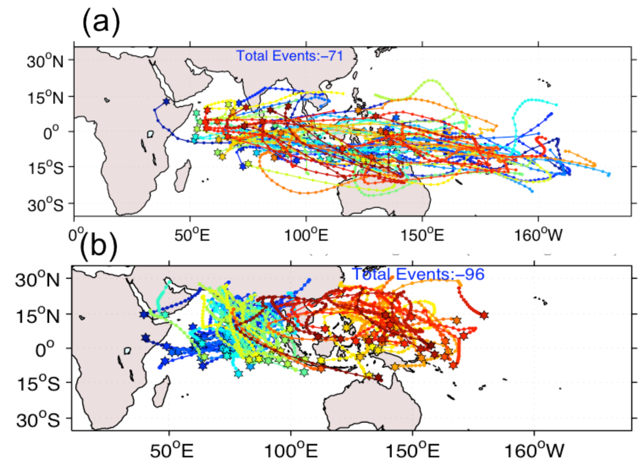

Figure (2): (a) Tracks of eastward propagating and (b) northward propagating TISOs identified by the algorithm

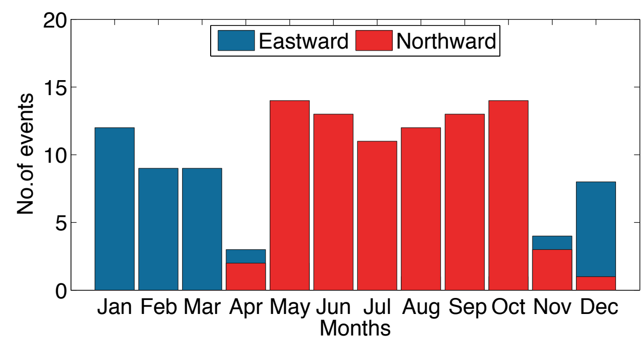

Figure (3): Frequency of occurrence of the eastward and northward propagating TISOs

1) To make this process autonomous, each daily frame is considered as an image from a static camera.
2) Group of connected pixels in each image is detected by using blob analysis after background subtraction, which is already performed during anomaly calculations. Group of connected pixels is considered as an object (clouds cluster)
3) The smallest size of cloud cluster (number of pixel), which can be tracked by algorithm, is controlled by a size threshold parameter currently set at size of 15 pixels.
4) Tracks are initialized for each region and properties like area, centroid, mean intensity (OLRA) and date are stored.
5) Cloud clusters can change size and shape, vanish or originate form frame to frame So after detection, the position and velocity of each centroid is predicted in the next frame using a

Kalman filter with constant velocity dynamical model.

6) To associate the position of a given cloud cluster to a cloud cluster in next frame, the assignment problem is solved by calculating the minimum distance between the predicted cloud cluster and all other cloud cluster in that frame.
7) Distance of association, is a maximum threshold up to which two cloud cluster can be associated. We are using 6 grid points in the algorithm
8) A correction is applied on the basis of measurement and prediction variance, and re-labeling is performed.
9) A cloud cluster is presumed to be dead if none of the cloud clusters from the current frame is assigned (not found within the distance of association) to a cloud cluster from the previous frame.
10) A cloud system is called newly originated, if it is not assigned to any track and a new track is initialized.
11) For all the cloud systems in the current frame, the position of each is again predicted and the algorithm repeats.

After obtaining all the tracks, they can be classified according to the objective criteria like propagation direction, lifetime, and intensity. Each class of tracks can be used to develop climatology for that class. The climatology of each class can used to investigate the dynamical characteristics of that class by compositing it with other variables.

III. Evaluation

In this section we summarize the results of applying the objective-tracking algorithm to daily NOAA OLR data from 1979-2013. As shown in Table 1, the objective method identifies 71 eastward-moving and 96 northward-moving TISOs. The average speed for eastward-moving TISOs is 4.0 m/s, with duration of about 33 days. Northward-moving TISOs propagate at about 2.0 m/s and last about 24 days before dying in the high latitudes. Both the speed and average life span of events detected by the objective-tracking algorithm are in good agreement with results reported in previous studies [9] and [4]. Fig (1a) is showing an eastward propagating event identified by visual analysis and than algorithm is ran for those dates. As we can see that algorithm successfully identified the same event. The very same event can also be confirmed with conventional hovemoller diagram in Fig (1b). Advantage of detection with algorithm is that we can save more information about the event like start date, end date, exact geographical location of the track, velocity, intensity and size of the cloud cluster on each day as compared to hovemoller identification. This information about each TISO event may help us to understand better about it in further analysis. Fig. (2) shows the tracks of eastward-moving TISOs from objective-tracking algorithm. Tracks from the method look similar in term of geographical location of occurrence, initiation and dissipation as in previous [5] and [2]. Most eastward-moving tracks are found south of the equator between 0° and 15° S, beginning in the western to central Indian Ocean and propagating eastward to the South Pacific Convergence Zone (SPCZ). Northward propagation can be seen in both of the ocean basins, while initiation more often occurs in the Indian Ocean. Two types of northward propagation happen in the Indian Ocean sector: (a) Moving northward immediately after initiation; and (b) Moving eastward at first, then turning northward. TISOs originating in the Pacific Ocean sector propagate directly northward only. After initiation, northward propagating TISOs die after crossing 20°N. Eastward-moving TISOs occur more often in boreal winter (NDJFMA), but they can occur throughout the year (Fig. 2). Northward propagation is more common in boreal summer (MJJASO), but sometimes it occurs in November and December.

In this method of tracking, no assumption is made regarding seasonality of TISO. Events are solely classified on the basis of direction of propagation, and therefore seasonality is confirmed naturally. We are not missing any event that happens outside the predefined season as opposed to other conventional methods. Advantage of this method over hovemoller and any index identification method (MJO identified using any area averaged index) is that it can give us actual track of a MJO event with daily position of centroid (center of mass of cloud system), mean intensity (OLR), minimum intensity (OLR), daily phase speed, size of tracked cloud cluster (number of grid points), positions of initiations and dissipations, actual date occurrence and number of days that event remains active for, which is not possible in both of above mentioned methods. This method has some limitations; such as it cannot track an event that bifurcates into two tracks, which are possible in some TISO cases. Sometimes algorithm can lose track of TISO when it becomes weak while crossing maritime continent.

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