**Application of the Marsupial Paradigm to Tropical Cyclone Formation from Northwestward Propagating Disturbances**

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**INTRODUCTION**

Dunkerton et al. (2009) recently proposed a new paradigm for the formation of a tropical cyclone within the critical layer of a tropical easterly wave. Through a survey of 55 named storms over the Atlantic and East Pacific during 1998-2001, they showed that the critical layer of the wave is important to tropical storm formation, and that the intersection of the trough axis and the critical surface of the wave -- the center of the cat’s eye in the wave critical layer -- is the preferred location for tropical cyclone formation.

Based on the marsupial paradigm, Wang et al. (2009) proposed a real-time forecast method to predict the track of the possible genesis locations within zonally propagating waves using global model operational data. They showed that the genesis location of a tropical storm can be predicted using global model forecast data up to three days in advance with less than one degree error when and if genesis occurs.

**RESULTS**

Nakri (2008)

Nakri formed at 14Z May 27, 2008 over the western North Pacific.

The critical latitude for 2D propagating waves is defined as

\[ \hat{k} \cdot (V - C \hat{k}) = 0 \]

where the wave-relative flow is zero in the direction of the wave propagation.

The "trough axis" should be modified as

\[ \hat{n} \cdot (V - C \hat{k}) = 0 \]

That is, the relative flow in the direction perpendicular to the wave propagation direction is zero along the modified trough axis.

The parcel trajectories show that there is a closed Lagrangian circulation similar to what is depicted by the translated streamlines, in contrast with the open wave pattern in the Earth-relative frame.

The wave’s gyre-pouch captures the moisture gradient on its northern and western boundaries.

Genesis of Nakri occurred near the center of the moist, convectively active gyre-pouch.

Erika (2009)

Despite persistent deep convection and "winds to around tropical storm strength" (NHC) on August 30-31, formation of Erika was not declared till Sep 1 because it lacked a well-defined low-level center of circulation in the Earth-relative frame.

If viewed in the wave co-moving frame of reference, a well-defined low-level closed circulation with abundant moisture and strong cycloidal relative vorticity had formed more than two days before the disturbance was declared as a tropical storm.

**A Few Other Examples**

Fig. 6 GFS total precipitable water (TPW) (left) and TRMM (right) superimposed on the translated streamlines at the genesis time for Rambam (2008) (top), Linfa (2009) (middle), and Kompasu (2010) (bottom). The black dot indicates the genesis location.

These cases show that:

i) the wave pouch of a northwestward propagating disturbance is a region of strong rotation and weak deformation;

ii) the pouch has high moisture content;

iii) convection becomes organized within the pouch, and tropical storms formed near the center of the wave pouch.

Our diagnoses suggest the marsupial framework can apply to tropical cyclone formation from northwestward propagating disturbances.

**Summary**

- A wave-tracking algorithm is developed for northwestward propagating waves which, on occasion, play a role in tropical cyclogenesis over the western oceans.
- To obtain the Lagrangian flow structure, the frame of reference is translated obliquely with the precursor disturbance. Trajectory analysis suggests that streamlines in the obliquely translated frame of reference can be used to approximate flow trajectories.
- Diagnoses of meteorological analyses and satellite-derived moisture and precipitation fields show that the marsupial framework (Dunkerton et al. 2009) for tropical cyclogenesis in tropical easterly waves is also relevant for northwestward propagating disturbances as are commonly observed in the tropical western Atlantic, Gulf of Mexico and western North Pacific.