Necessary and Sufficient Conditions for Tropical Cyclogenesis:
Will we get answer from GRIP-PREDICT-IFEX?

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NASA grant NNX09AC44G
1. Describe the time evolution of inner core thermodynamic properties (All PGI Cases + previous years)

2. Describe the relationship between deep convective episodes and the time evolution of the thermodynamic characteristics of the developing inner core (*Karl* and *Matthew*)
   - Is the developing disturbance moistened as a result of deep convection?
   - What ultimately determines the fate of the disturbance?

Synthesize in-situ (dropsonde) data from all P-G-I and USAF aircraft, conventional IR data, as well as data from numerous passive microwave instruments.

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**Projects**

- **NSF/NCAR PREDICT:** Pre-Depression Investigation of Cloud Systems in the Tropics (P)
- **NASA GRIP:** Genesis and Rapid Intensification Processes (G)
- **NOAA IFEX:** Intensity Forecast Experiment (I)

Coincident and consecutive flights provide a high *temporal* and spatial resolution dataset of tropical cyclogenesis and rapid intensification events.
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Data and Methodology

Manually tracked 925, 850, 700, 600 hPa vorticity maxima (VM)
In NCEP FNL analysis
– all analyses based on 850 hPa VM

1. Dropsonde Dataset
– All 1700 PGI and USAF drops included – both DEV & NDEV
– Also: Gert (2005), Nuri (2008), Fay (2008), Kyle (2010), Danny (2009), TD02 (2010), Bonnie (2010)….and more to come.
– TOTAL: 2546
– Interpolated to 17 pressure levels
– All drops before/after genesis included
– p, z, T, Td, Tv, θ, θe, θv, θes, RH, w, ws, q, u-, v-wind, wind dir/spd
– Time before/after genesis (NHC TD classification)
– Radial distance from 850 hPa VM (pouch) center
– Includes coincident NCEP FNL model analysis and NCEP/NCAR reanalysis profile – time/space correction with zonal phase speed of wave

How well does the model (re)-analysis represent the genesis environment?
Data and Methodology

All Genesis Drop Locations Relative to 850 hPa VM

(dlat [deg.] vs dlon [deg.])

Total 2204
Data and Methodology

Pre-Genesis Drop Locations Relative to 850 hPa VM

![Graph showing drop locations relative to 850 hPa VM.](image)
Data and Methodology

Post-Genesis Drop Locations Relative to 850 hPa VM
Developing vs. Non-developing

- **Moisture**
  - DEV B and DEV A have higher midlevel $\theta_e$ – moisture – than NDEV
  - DEV A has higher low level $\theta_e$ – moisture – than DEV B & NDEV

- **RH**
  - NDEV has lower RH at mid-levels than DEV B & DEV A

- **Temperature**
  - Little difference b/w DEV & NDEV; DEV B slightly cooler at low-levels
Anomaly: Mean Inner Core – Mean of Environmental (3-7°) Soundings from all PGI Flights

Midlevel $\theta_e$ is higher than the environment and will increase slightly each day; very little increase at low-levels.
Warm core is developing at mid- to upper-levels as many as 3 days before formation.

Increase in $\theta_e$ anomaly at mid-levels is attributed to a small increase in moisture.
No noticeable increase in relative humidity during the formation process at mid-levels; only a slight increase at low-levels.
Summary and Conclusions

• Developing disturbances exhibit greater moisture and RH at mid-levels than non-developing disturbances

• The developing inner core exhibits greater $\theta$ & $\theta_e$ (moisture) than the surrounding environment; warm core seen up to 3 days prior to genesis
  – wvMR increases 1-2 g/kg at mid-levels prior to formation

• Once the inner core is moist, diurnal convection does little to further increase inner core moisture in the pre-cursor disturbance (i.e., there is little evidence to support ‘progressive moistening’)

• For genesis, wave vorticity must be predominately from curvature

• VM & pouch must be vertically aligned

• May be that the combination of these conditions occur less frequently
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MULTIPLE PATHWAYS TO TROPICAL CYCLOGENESIS
Dropsonde-NCEP FNL
Dropsonde-NCEP/NCAR Reanalysis