

Efficiency of the South-Asian-monsoon energy pump into the Upper Troposphere, and its downstream effects

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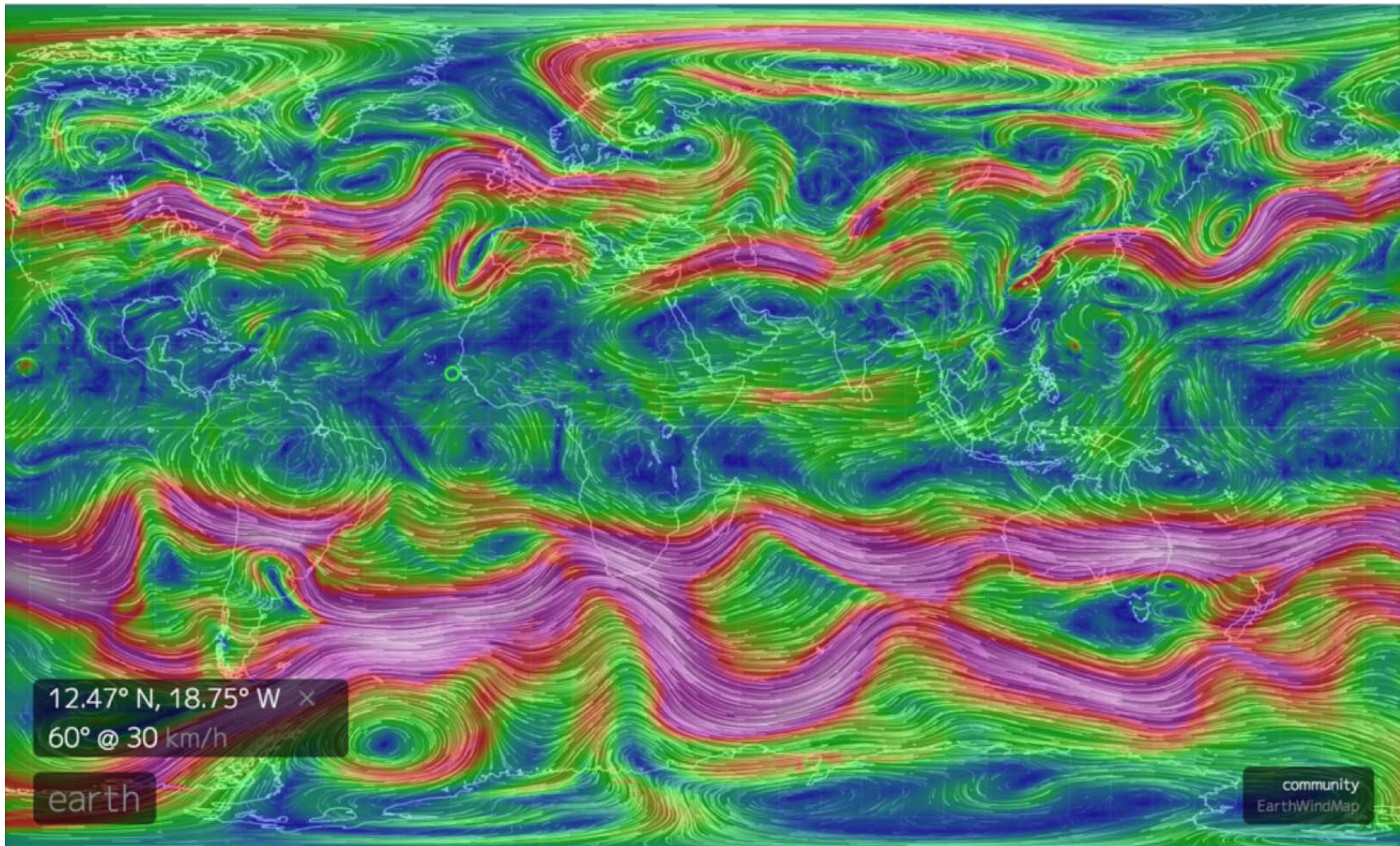
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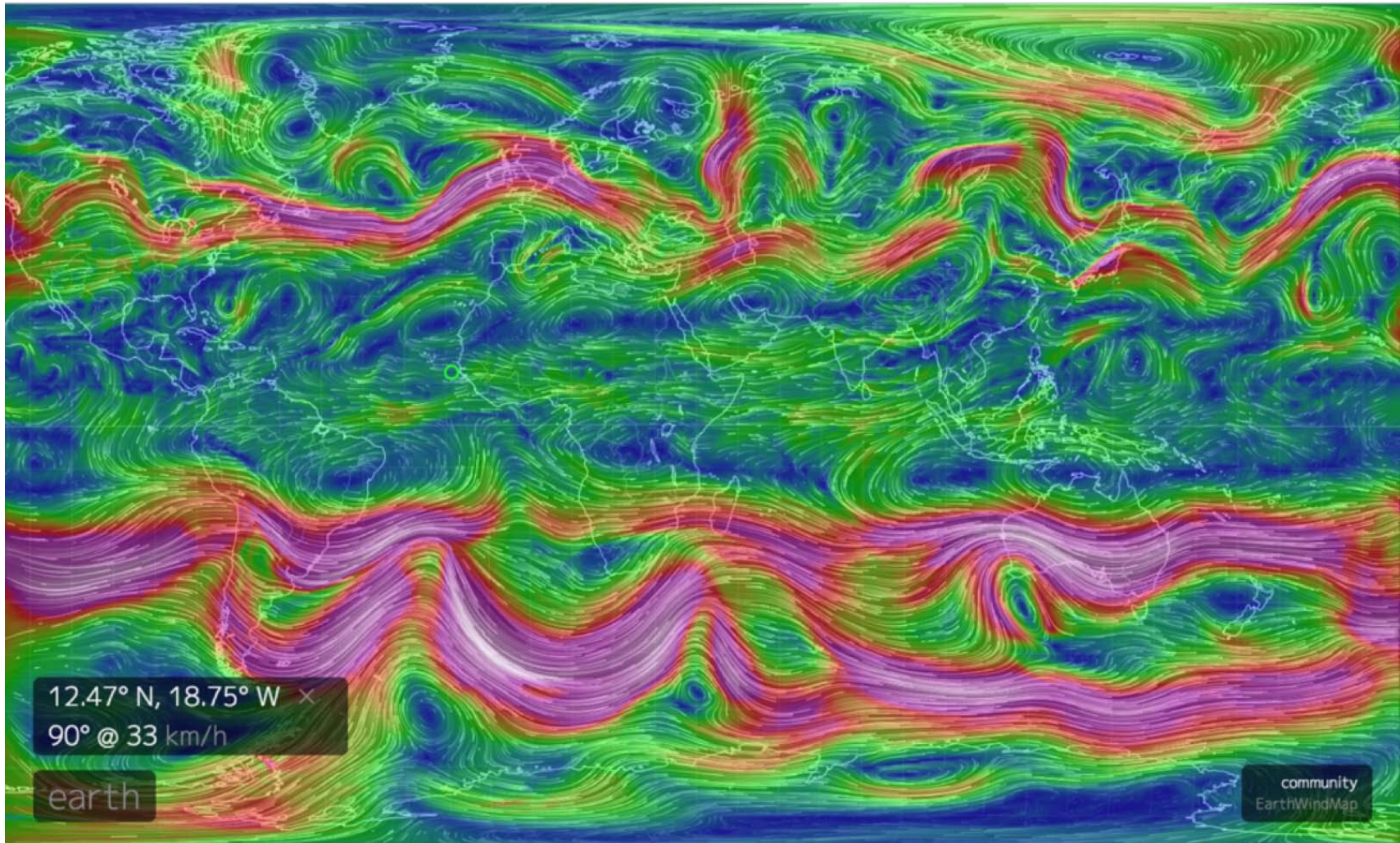
Outline

- **Suborbital mission: directly observe monsoon Water and Energy Transport**
- **The mission goal is to understand**
 - how efficiently the monsoon transports mass from lower levels to the upper troposphere over the subcontinent
- **Then, when the accumulated energy in the upper troposphere is transported westward or northeastward**
 - how the 200mb Tropical Easterly jet is established and how diffluence at the Atlantic end affects convection
 - and what enhances or inhibits the northeastward plumes
- **NASA Langley 3D Wind Lidar gives us the opportunity not to have to rely on model reanalysis, but instead to observe the circulation (and environment) directly**
- **JPL's Airborne Second Generation Precipitation Radar (APR-2) which measures the three-dimensional structure of rain within a swath that is about 10km wide (depending on the altitude of the plane) and extends from flight level down to the surface**
- **HAMSR (High Altitude MMIC Sounding Radiometer); MTHP (Microwave Temperature and Humidity Profiler); Yankee Environmental Dropsondes; MASC (Microwave Atmospheric Sounder)**

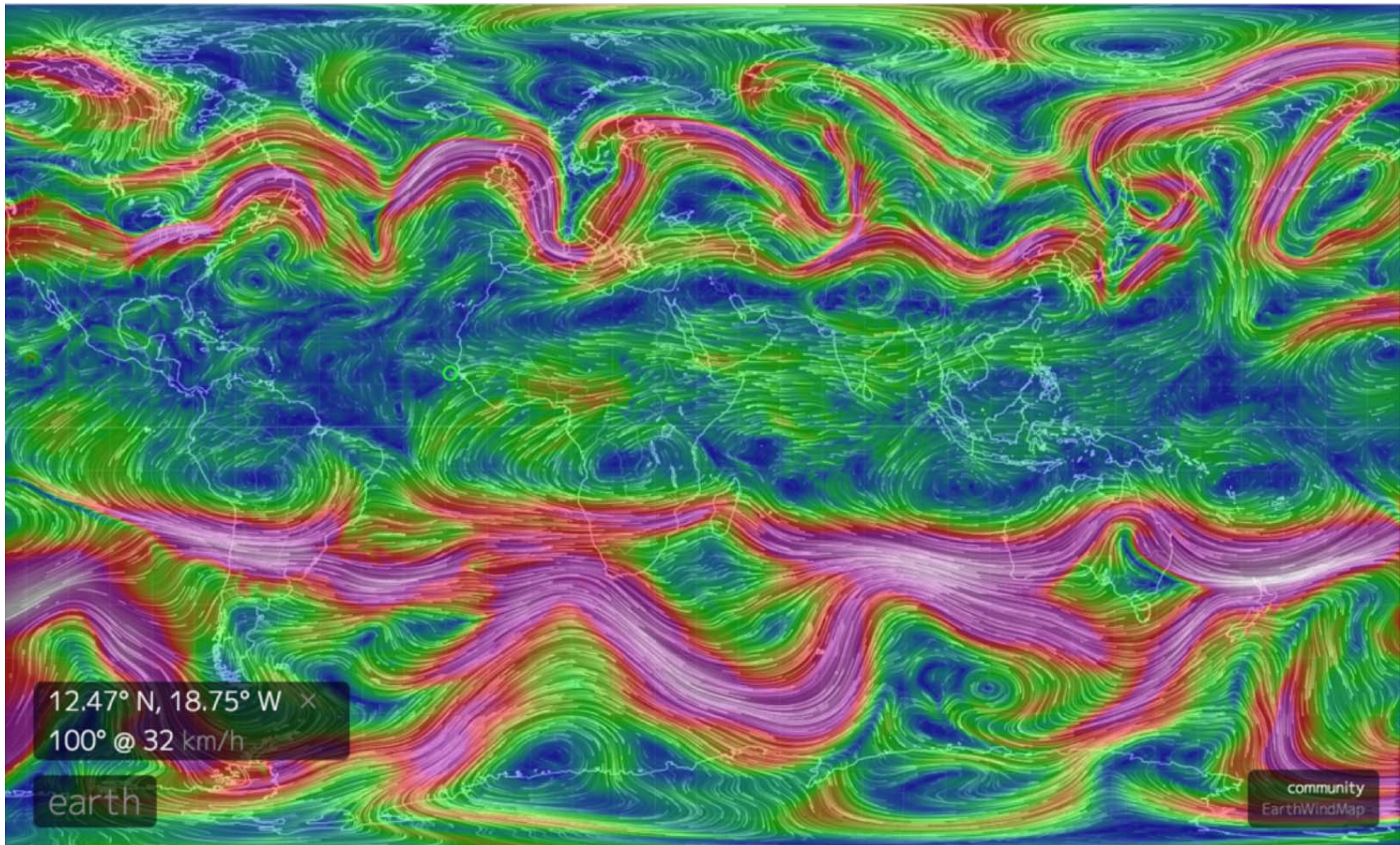
Start with few examples:
the 250 hPa flow during July 2016
(according to NCEP reanalysis)



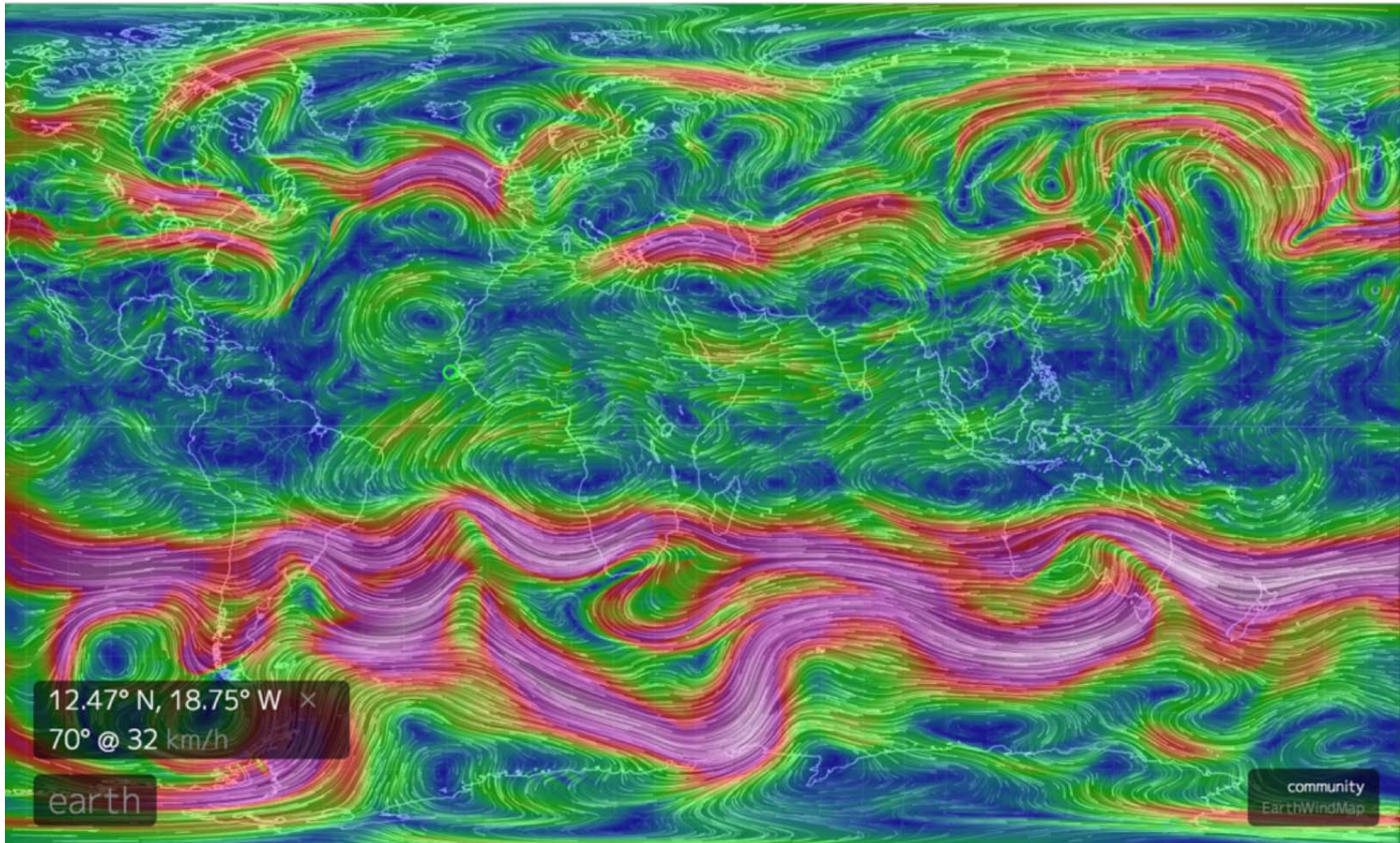
05 July 2016 Notice the Easterly Jet that starts over the southern tip of India (between 250 and 200 mb in the upper troposphere) and reaches over Somalia (still red, barely) before dissipating over Somalia



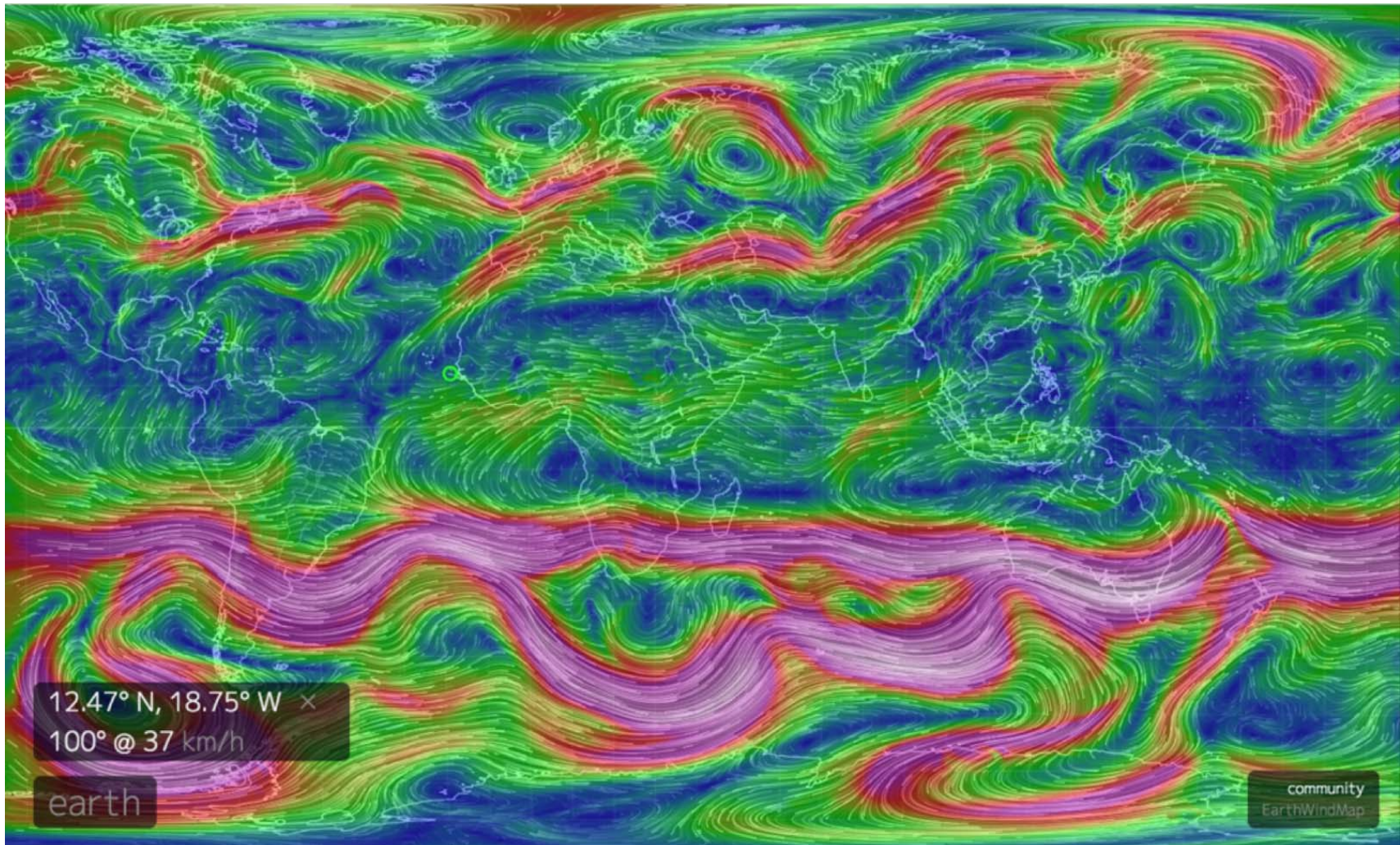
09 July 2016: Tropical Easterly Jet reaches from the Subcontinent all the way to the Atlantic coast of West Africa!



15 July 2016: Tropical Easterly jet diverging towards the equator

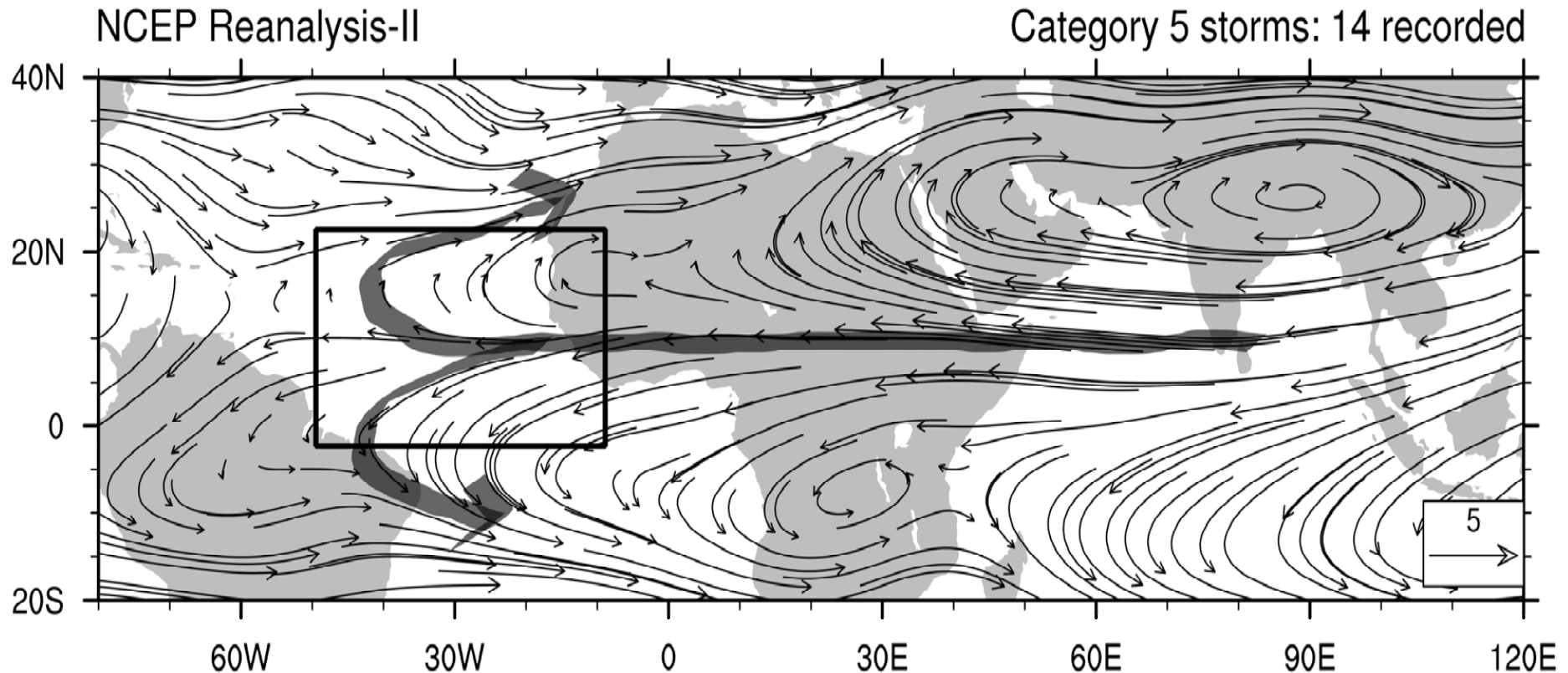


27 July 2016: Depression appears to organize northwest of West African coast



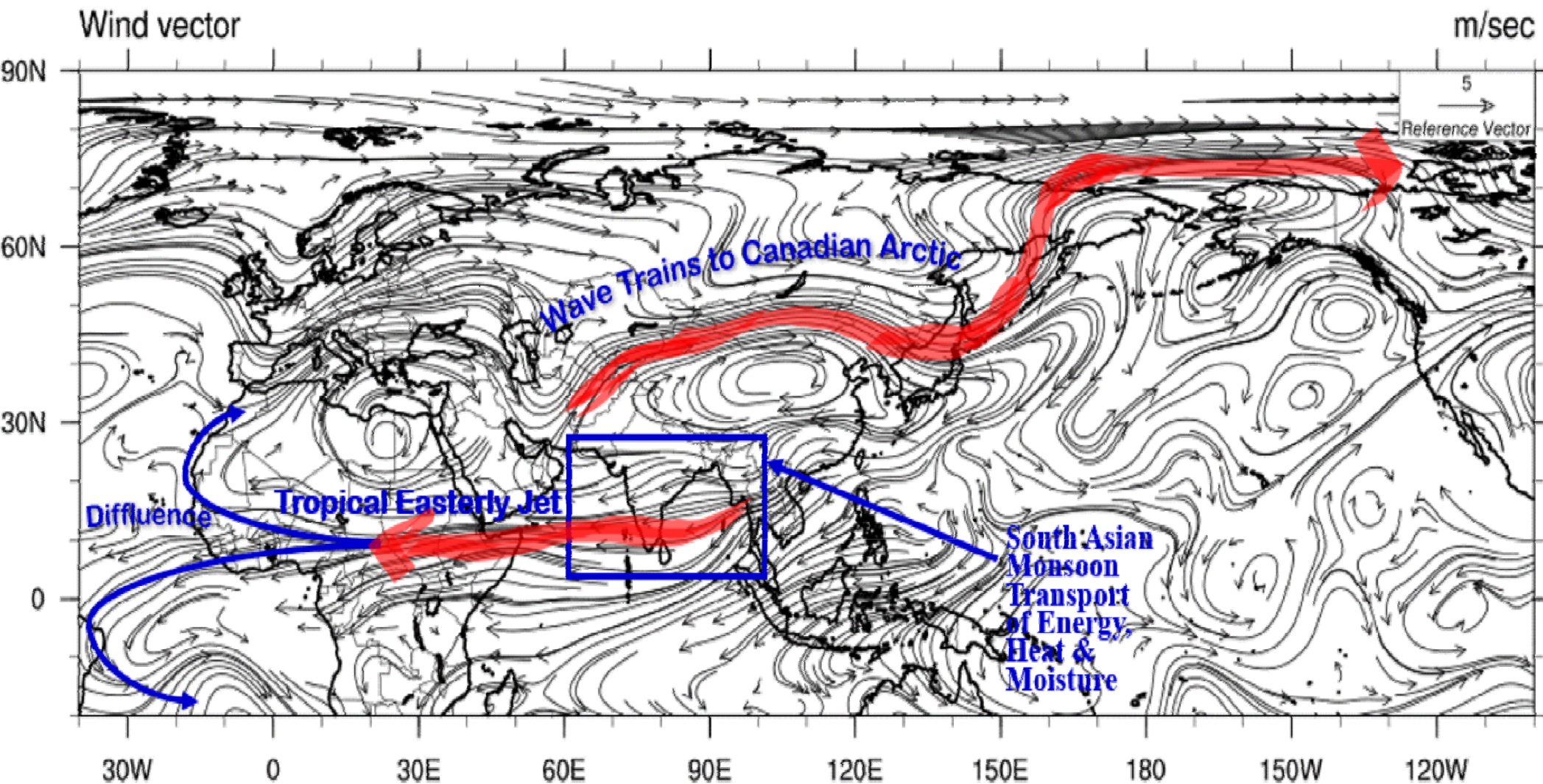
31 July 2016: Depression dissipates East of the Windward Islands, before reaching hurricane intensity

Historical average 200-hPa circulation for July, according to NCEP:
200hPa daily averaged winds: 1979-2014

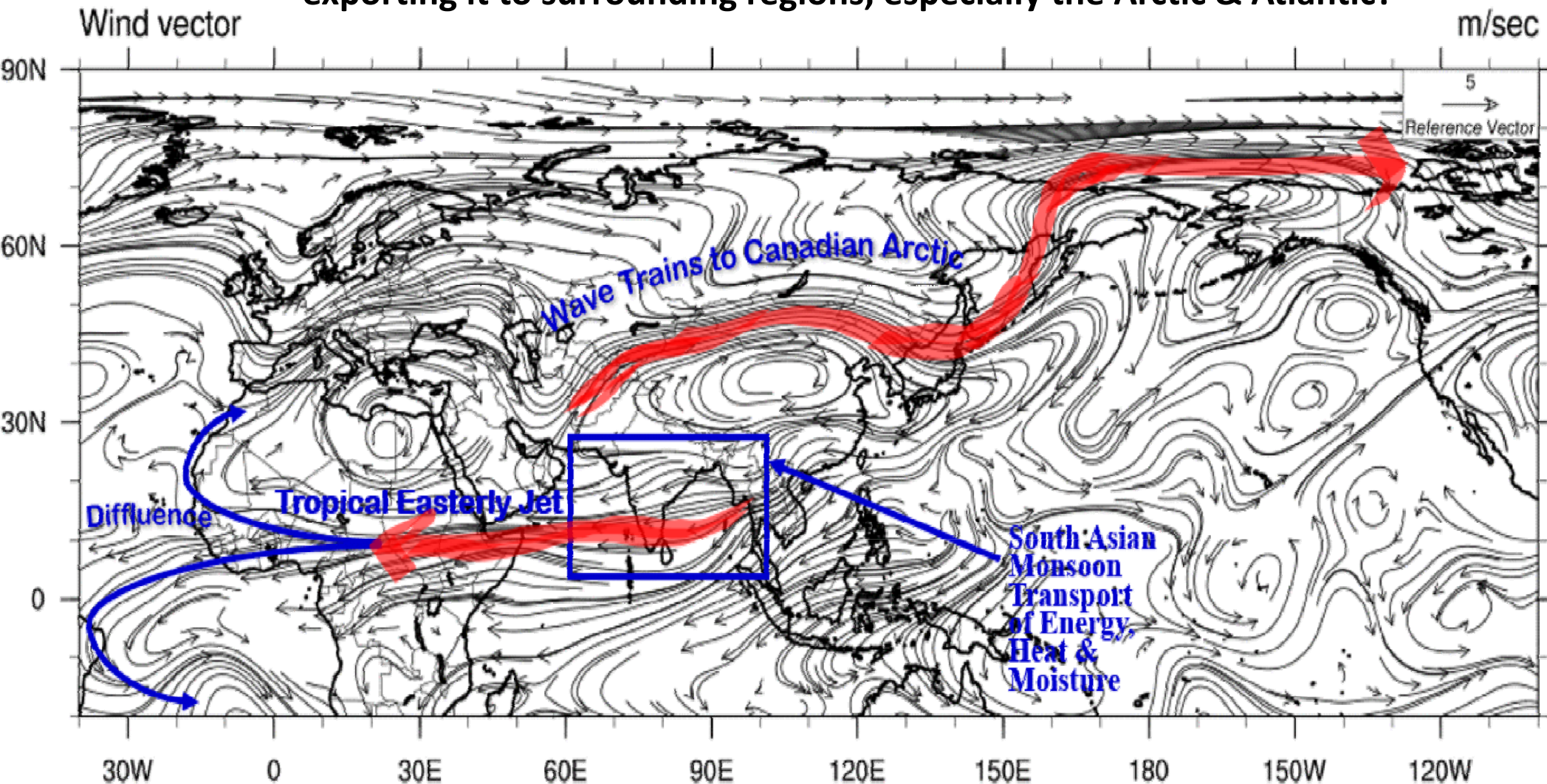


The Upper-Level Tropical Easterly Jet on the previous slides is quite typical, but details are still not established – models (including NCEP and ECMWF) do not agree as to onset of jet, development of jet, onset and magnitude of diffluence over Atlantic coast, etc. Current analyses rely exclusively on model, for lack of anything more specific.

North branch of the monsoon upper-troposphere high, according to NCEP:



So how vast is the South-Asian monsoon, in terms of generating energy, heat and moisture and exporting it to surrounding regions, especially the Arctic & Atlantic?



Science Question

Objective 1: *Northward March of the South Asian Monsoon:* Investigate factors controlling the dynamics and physics of northward march of monsoon across South Asia as seen from the "isochrones" of rain and moisture at its forward edge.

A: What are the combined effects of total wind, divergent wind, convection, and environmental interactions on the march of the isochrones?

B: What are the dynamic and thermodynamic factors for variability of monsoon onset isochrone motion?

Objective 2: *Origin and evolution of the northward propagating intraseasonal waves from the equatorial Indian Ocean:* to understand dry and wet spells of the monsoon.

A. Investigate how the arrival of an eastward propagating Madden-Julian oscillation (MJO) divergence lobe, of the upper troposphere, excites and triggers the first formation of an active ISO wave.

B. The origin of ISO wave could also be related to the reflection of an atmospheric Kelvin wave as a Rossby gravity wave.

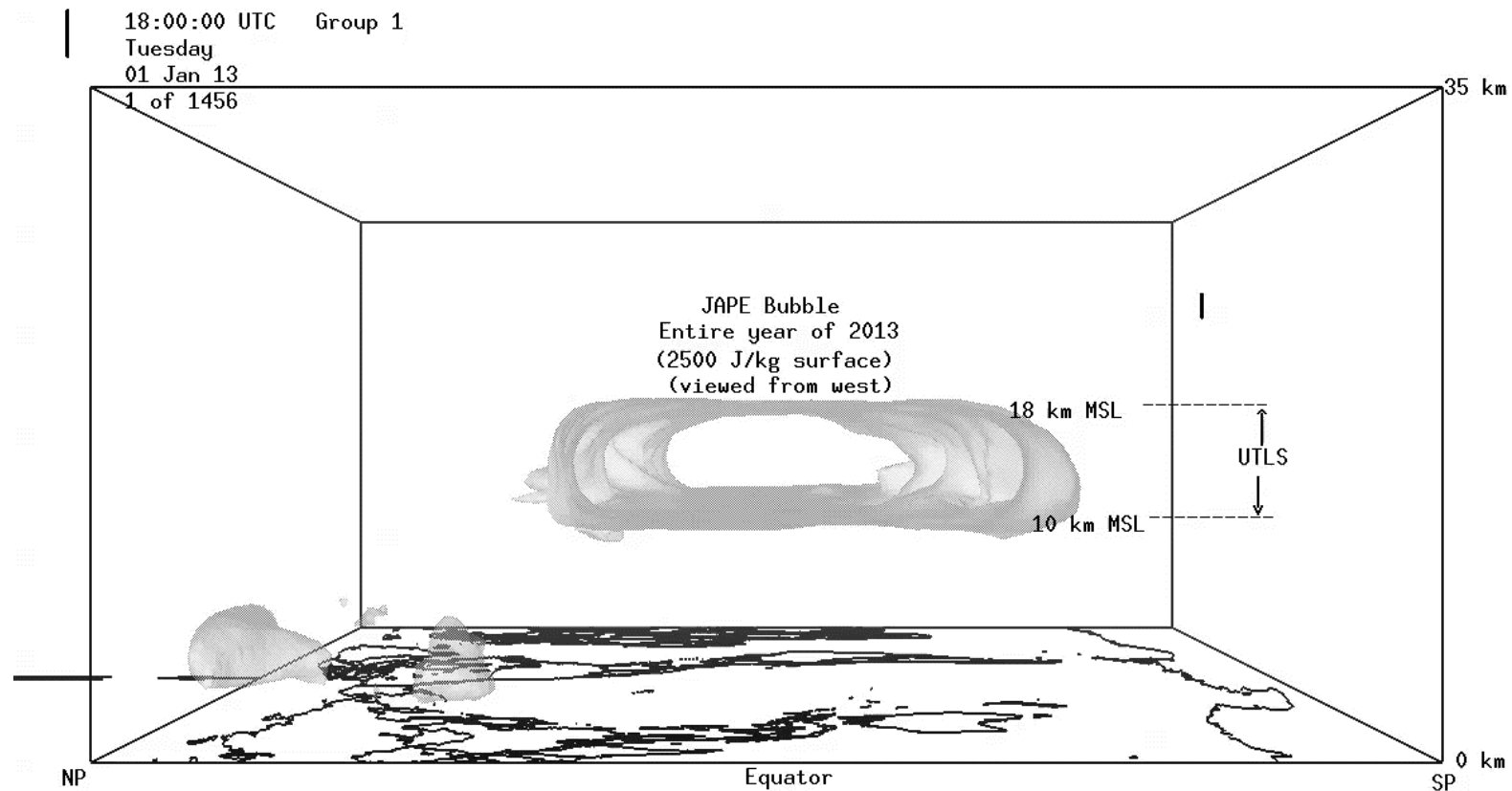
Objective 3: *Monsoonal downstream effects NE:* Investigate excess heat of the south Asian monsoon being conveyed via wave trains to the Arctic.

A. Link between wind over Arabian Sea and the structure of the Tibetan High?

B. Use wind to improve forecast of the pathway and magnitude of heat flux from India monsoons to the Arctic?

C. Land area measurements for extreme rain events and for the generation of vertical tubes of large heat content anomalies

G. Tripoli: Available Potential Energy bubble during 2013, from NCEP reanalysis (viewed from Western Indian Ocean looking East)



**How efficiently does monsoon transport mass from lower to upper troposphere over S. Asia?
Can we observe the relevant processes instead of relying only on model?**

NASA Airborne Convective Processes Experiment Campaign (CPEX)

- **NASA Program Sponsor, Dr. Ramesh K. Kakar**
- **Co-Program Scientists: Dr. Shuyi Chen at U. Washington; Dr. Ed Zipster at U. Utah**
- **Instruments:**
 - **DAWN (Doppler Aerosol WiNd lidar) – horizontal vector wind profiles**
 - **APR-2 (Airborne Precipitation Radar) – reflectivity, depolarization, wind/hydrometeor velocity**
 - **HAMSR (High Altitude MMIC Sounding Radiometer) – T & H₂O vapor & liquid profiles**
 - **MTHP (Microwave Temperature and Humidity Profiler) – T, RH**
 - **Yankee Environmental Dropsondes – P, T, RH, wind, SST**
 - **MASC (Microwave Atmospheric Sounder)**

CPEX Science Objectives

1. **Improve understanding of convective processes** including cloud dynamics, downdrafts, cold pools and thermodynamics during initiation, growth, and dissipation
2. **Obtain a comprehensive set observations, especially from DAWN**, in the vicinity of scattered and organized deep convection in all phases of the convective life cycle
3. **Improve model representation of convective and boundary layer processes** over the tropical oceans using a cloud-resolving, fully coupled atmosphere-ocean model
4. **Improve model assimilation of the wind, temperature and humidity profiles** from the wind lidar and dropsondes into numerical weather prediction models

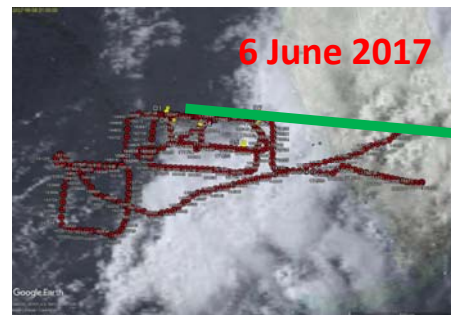
CPEX 2017: A Field Experiment to study Convective Processes in the Tropics 25 May – 24 June 2017

DC-8 based in Fort Lauderdale, Florida

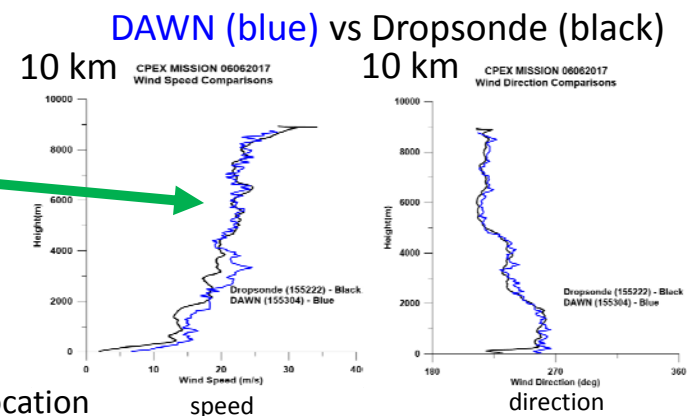
- DAWN is NASA's most capable airborne wind-profiling lidar
- Previously participated in NASA GRIP (2010) and Polar Winds (2014-15) airborne campaigns



LaRC DAWN on NASA DC-8

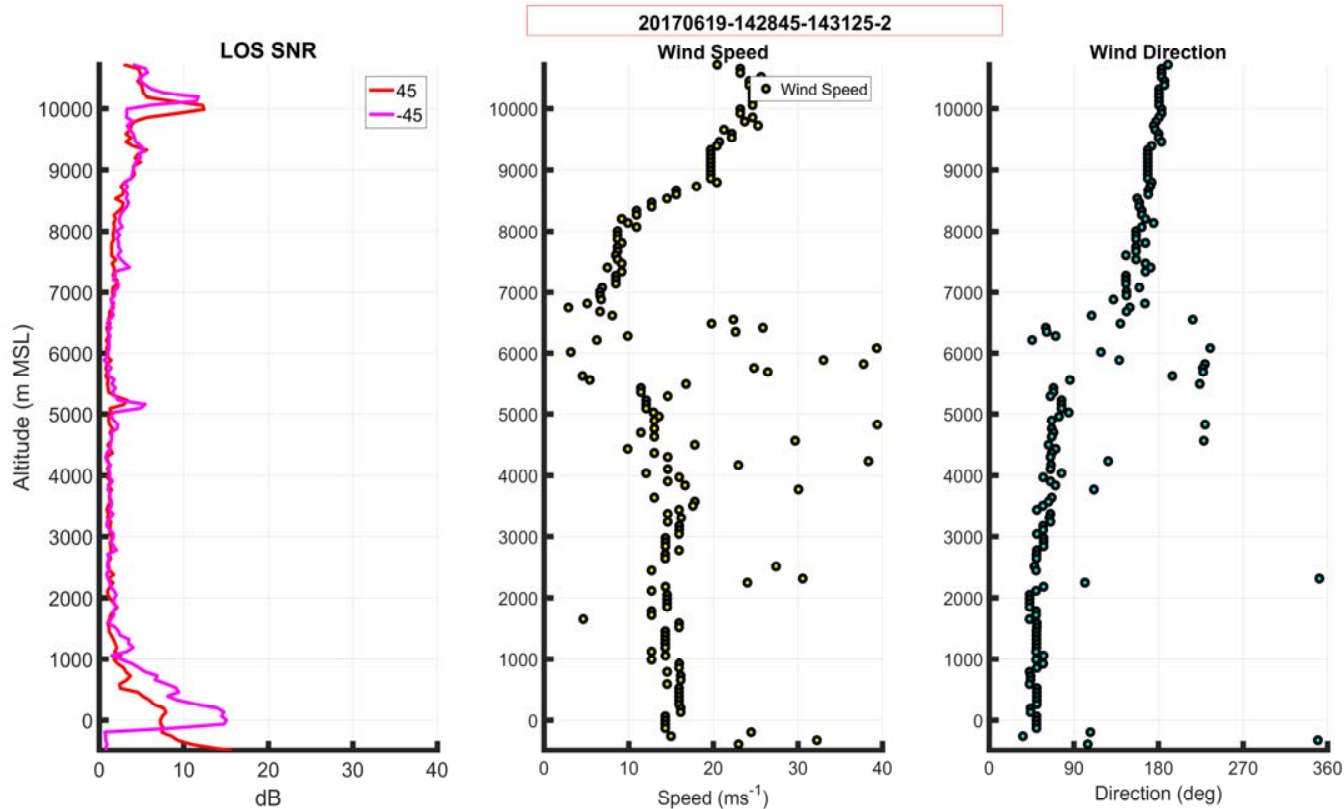


- Laser pulses at 2-micron wavelength and 10 Hz are eyesafe at any range; daytime observations are not compromised by solar background
- Data may be post-flight processed multiple times with various number of shots accumulated (horizontal resolutions), vertical resolutions, and wind search bandwidths for maximum information extraction
- CPEX science flights indicate excellent vertical coverage and agreement with dropsonde winds (e.g. from 9.5km in plots below)



Each red circle is a DAWN sounding location

CPEX: Example of Full 11 km Profile



L to R: DAWN SNR, Wind Speed, Wind Direction

(Quick look with no quality control or advanced signal processing,
which will add more coverage in the data gaps)

APR-2

Vertical resolution 60 m,
sampled every 30 m

Doppler resolution:
0.4 m/s @ 13.4 GHz
1 m/s @ 35.6 GHz

Beam widths:

3.8° @ 13.4 GHz

4.8° @ 35.6 GHz

Horizontal resolution
from a nominal 11 km flight level:

730 m @ 13.4 GHz

920 m @ 35.6 GHz

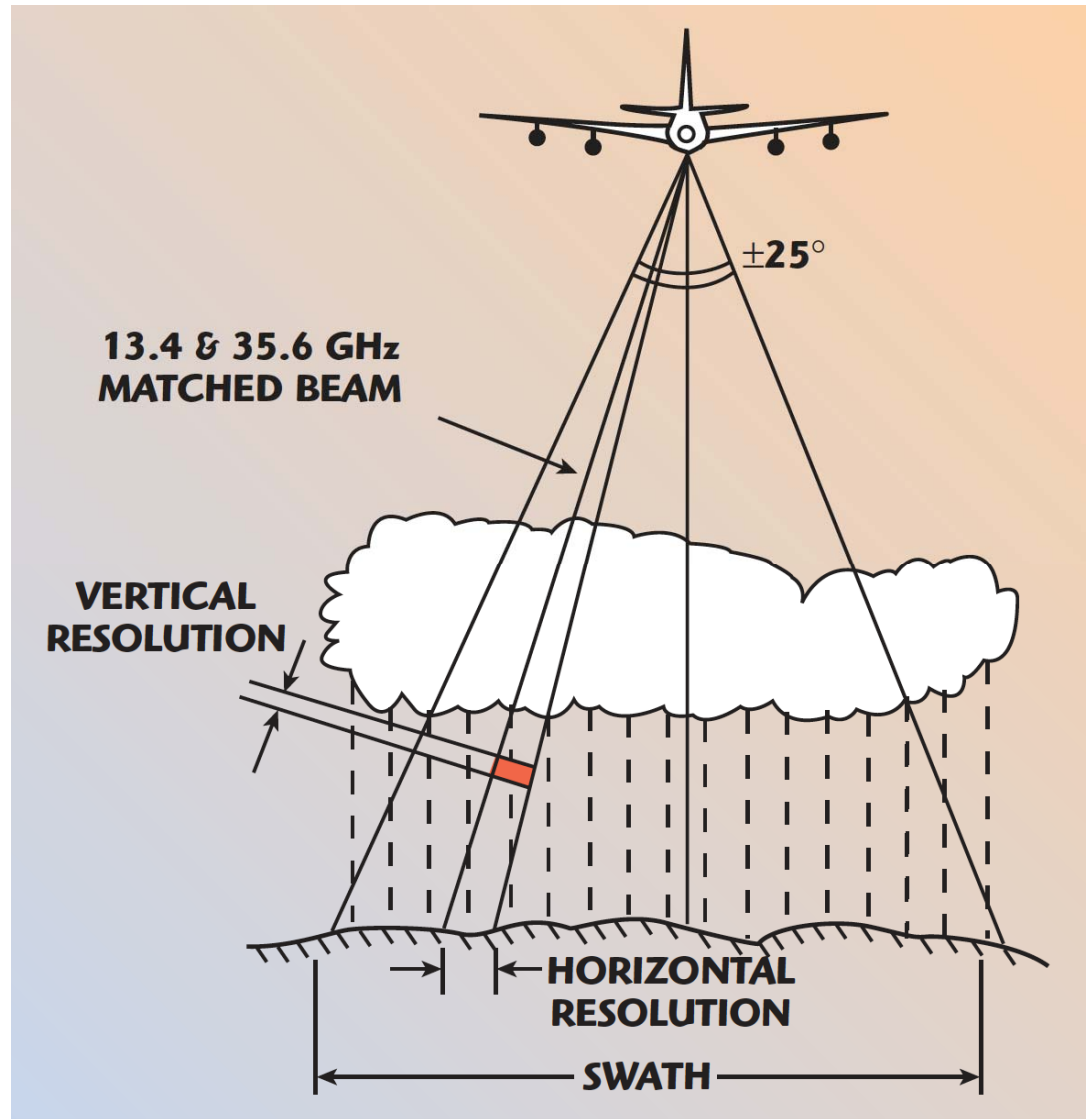
23 evenly-spaced samples (swath width ~ 10 km)

Detection threshold:

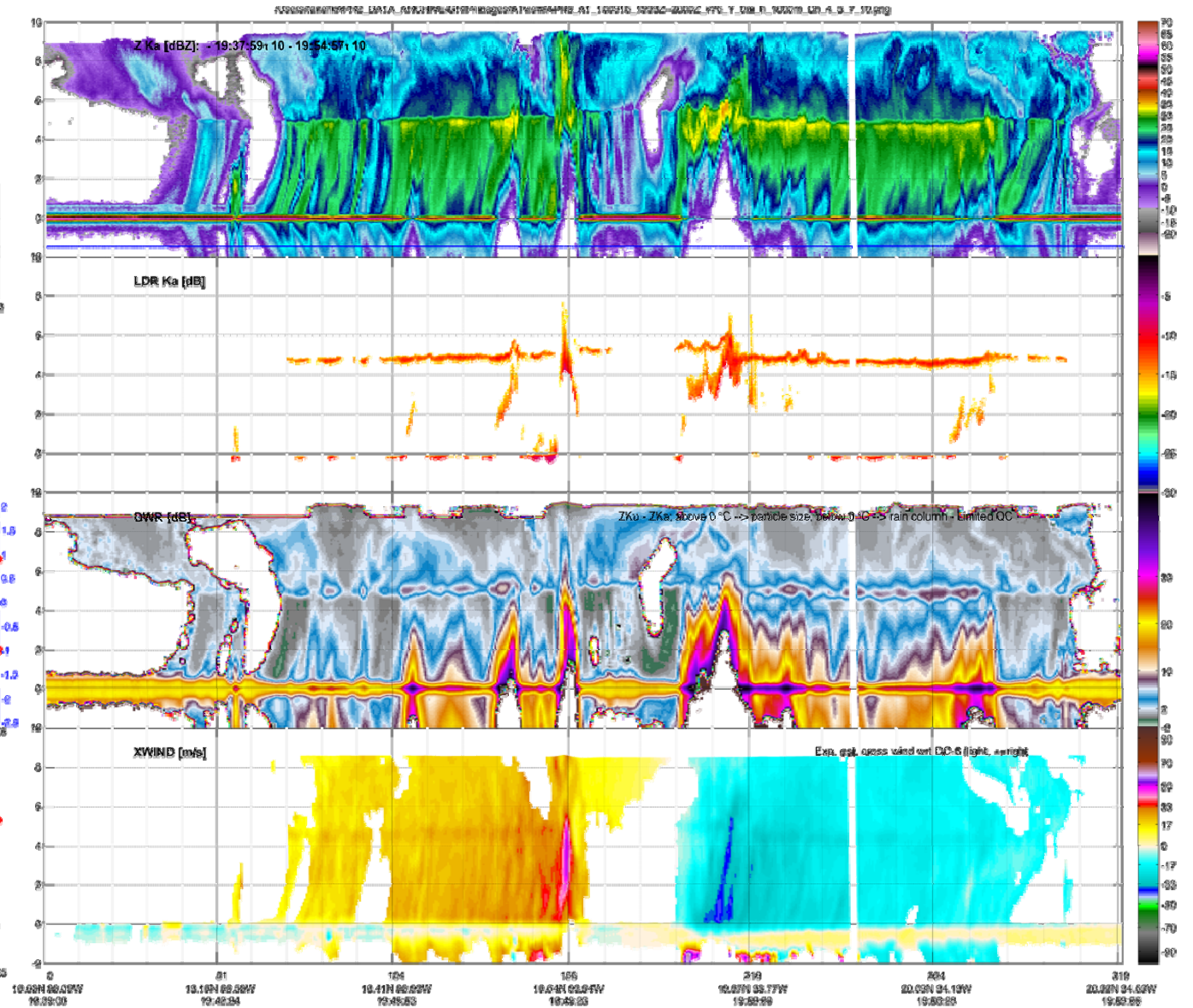
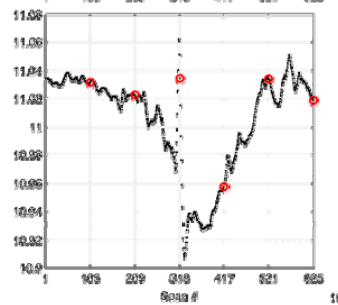
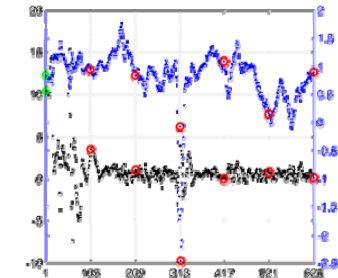
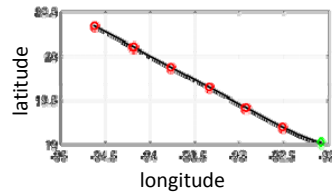
< 13 dbZ @ 13.4 GHz

< 10 dbZ @ 35.6 GHz

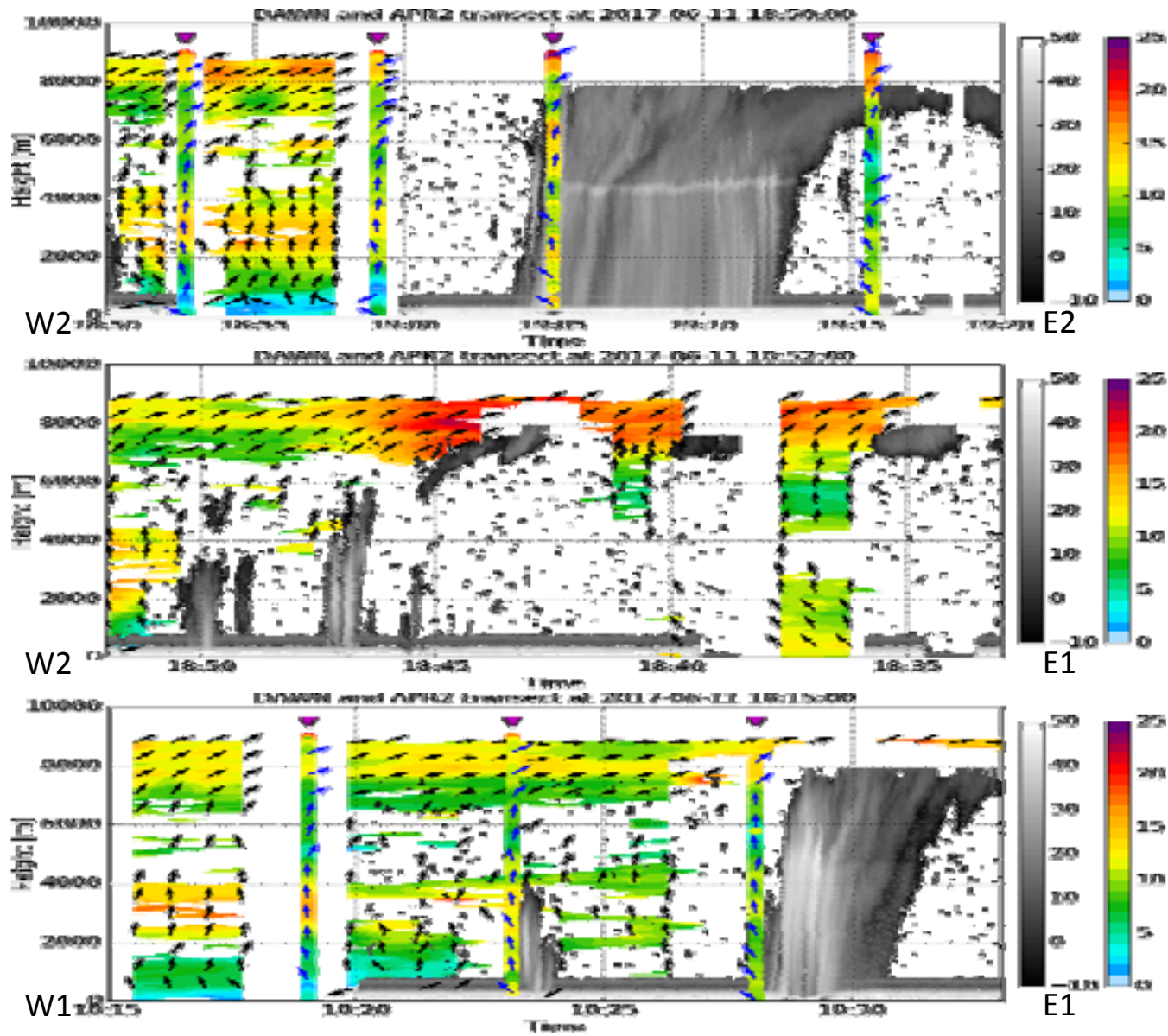
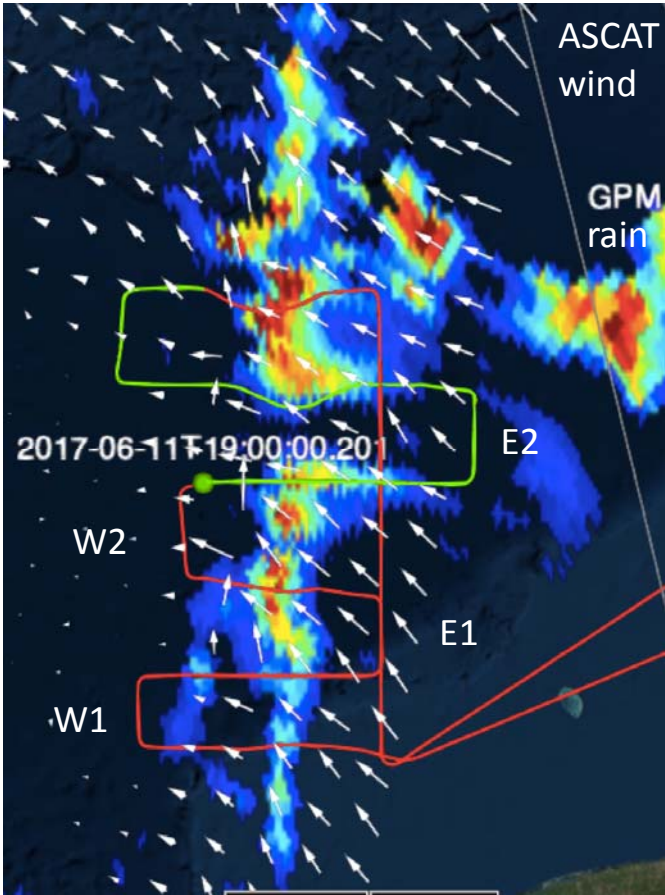
from nominal 11 km flight level



APR-2 Example: Hurricane Karl 16 sept 2010



2017 CPEX
(Convective Process Experiment)
Example: Squall Line over
Gulf of Mexico



Suborbital Mission Target Measurements and Partner Contributions

- Airborne profiling NASA DC-8 to observe 3-D winds, convection and aerosols
- WIND lidar and dropsonde (**NASA Langley Research Center**)
- Monitoring of 3-D winds entering leading edge of monsoon isochrone region
- Onboard radar to provide archives at high horizontal and vertical resolution of the radar reflectivity (**NASA Jet Propulsion Laboratory**)
- HAMSR (High Altitude MMIC Sounding Radiometer), MTHP (Microwave Temperature and Humidity Profiler), Yankee Environmental Dropsondes and MASC (Microwave Atmospheric Sounder) (**NASA DC-8**)
- **Ground radar volume scans**, soundings, **nowcasting** (**Proposed partner contribution from India**)
- Locations: **Arabian sea and Bay of Bengal (from Kochi base) for Monsoon** (June-July).
- Repeated flight observations, specifically regions between 15° N and 17° N, and over the foothills of the Himalayas, required to observe wind circulation and convection patterns.
- Separately, repeated flight observations between 10° N and 17° N near the African coast and eastern Atlantic (**from Cape Verde base**), required to observe wind circulation and convection patterns.
- **Current plan: two seasons in India and in Atlantic**

Suborbital Mission Objectives, Instruments and Proposed Partners

- The proposed suborbital mission is to collect and analyze observations to help improve our ability to model and forecast these crucial monsoonal transports and their downstream effects
- **Mission objectives:**
 - Observe and relate convective-scale to meso-scale changes in the three-dimensional circulation with the efficiency of the resulting convective transports (of air mass and heat) and the build-up of the large-scale anomalies
 - Observe how fluctuations in the monsoon large-scale upper-level outflow affect downstream convection, especially within African Easterly Waves (AEWs)
 - The observations will be tailor-made to help understand the controls of the northward march of the monsoon isochrones, the initiation and magnitude of heat towers over the subcontinent during the monsoon, and how the mostly zonal land-sea differential heating interacts with the meridional progress of the Intertropical Convergence Zone (ITCZ) to constrain the intensities of the northern and western outflows.
- **Instruments:**
 - DAWN (Doppler Aerosol WiNd lidar); APR-2 (Airborne Precipitation Radar); HAMSR (High Altitude MMIC Sounding Radiometer); MTHP (Microwave Temperature and Humidity Profiler); Yankee Environmental Dropsondes; MASC (Microwave Atmospheric Sounder)
- **Partners:**
 - Florida State University, NASA LaRC, NASA JPL, Simpson Weather Associates, others (USA)
 - Indian Space Research Organization (ISRO) Ministry of Earth Sciences (MoES) (India)

Thank you for your attention!
Questions?

