ENVIRONMENTAL EFFECTS VERSUS INTERNAL PHYSICAL PROCESSES DURING THE INTERRUPTED RAPID DECAY OF HURRICANE JOAQUIN

JOAQUIN 3-5 GROUP

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Acknowledgments
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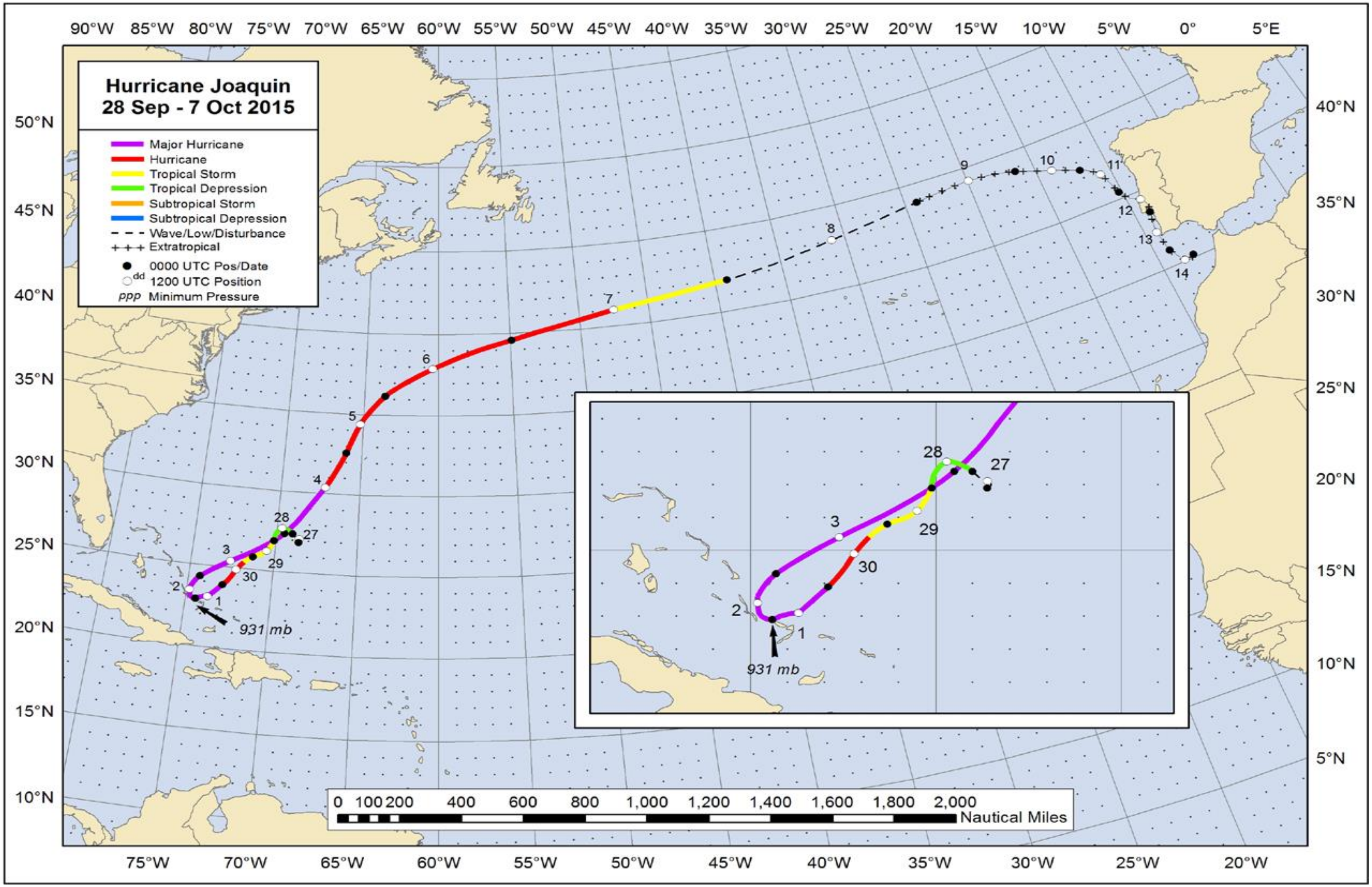
OUTLINE

- Synoptic description of Hurricane Joaquin during 3-5 October 2015
- Environmental factors contributing to interrupted rapid decay
- Internal physical processes offsetting rapid decay tendency (PRELIMINARY)

BEST-TRACK FOR HURRICANE JOAQUIN (2015)

- Focus is on intensity changes during the period 3 October – 7 October



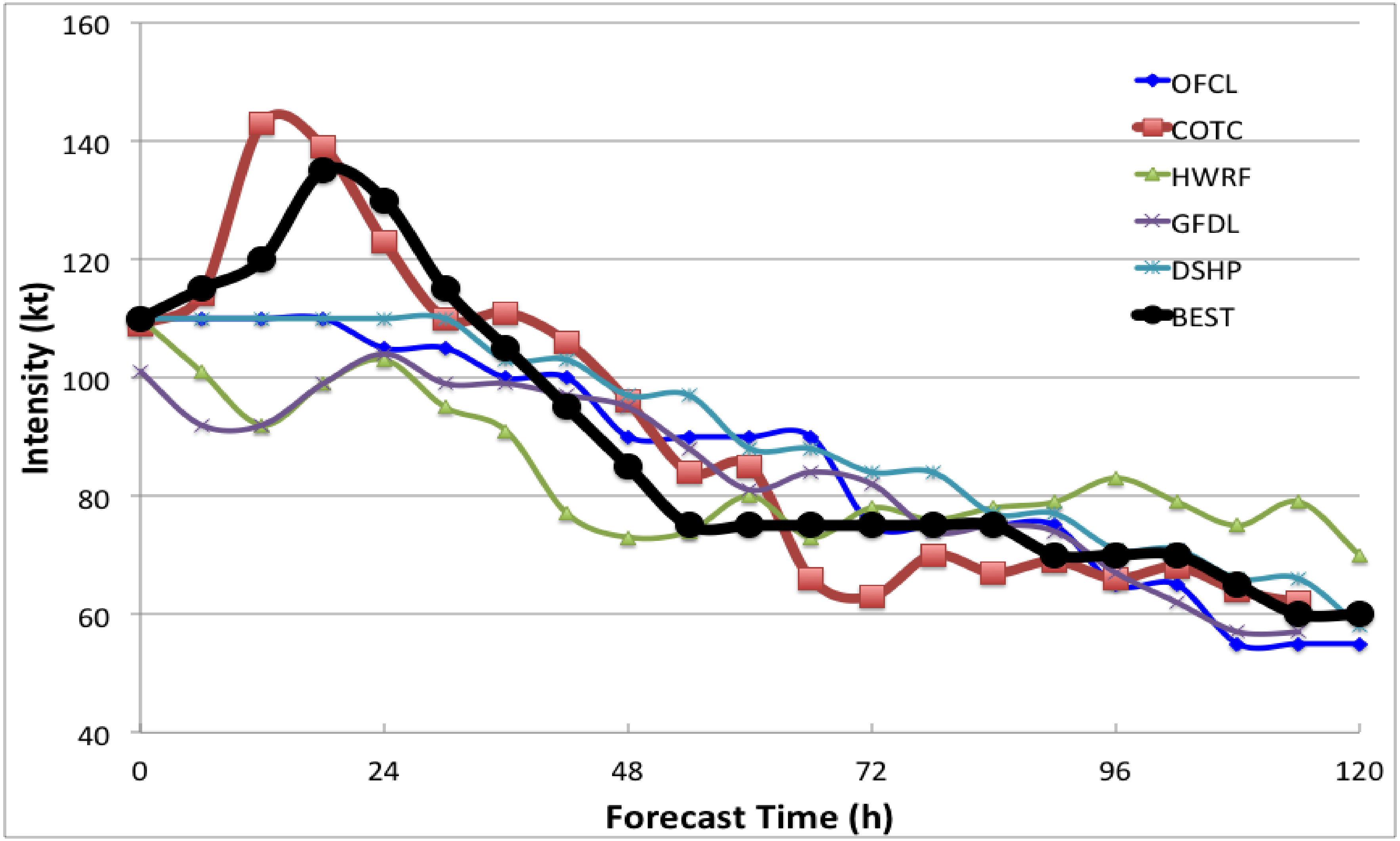
NHC BEST-TRACK FILE FOR HURRICANE JOAQUIN, 3-7 October 2015

- Extreme rapid decay from 135 kt to 85 kt in 30 h interrupted at time of WB-57 mission on 4 October
- During this rapid decay period the translation speed decreased from ≥ 17 kt to <11 kt and heading changed 30 deg

Date/Time (UTC)	Latitude (◦N)	Longitude (◦W)	Pressure (mb)	Wind Speed (kt)	Translation Heading/ Speed (kt)
03/0000	24.3	74.3	943	115	51.7◦ / 8.1
03/0600	24.8	73.6	945	120	56.3◦ / 10.9
03/1200	25.4	72.6	934	135	57.6◦ / 17.0
03/1800	**26.3**	**71.0**	**934**	**130**	**50.2◦ / 17.3**
04/0000	27.4	69.5	941	115	34.9◦ / 18.4
04/0600	28.9	68.3	949	105	32.2◦ / 17.8
04/1200	30.4	67.2	956	95	26.4◦ / 13.4
04/1800	**31.6**	**66.5**	**958**	**85**	**22.8◦ / 10.9**
05/0000	32.6	66.0	961	75	18.4◦ / 10.6
05/0600	33.6	65.6	964	75	22.4◦ / 8.6
05/1200	34.4	65.2	964	75	32.3◦ / 10.7
05/1800	**35.3**	**64.5**	**964**	**75**	**38.8◦ / 11.6**
06/0000	36.2	63.6	967	75	52.1◦ / 13.1
06/0600	37.0	62.3	970	75	58.6◦ / 17.5
06/1200	37.9	60.4	974	70	63.7◦ / 20.9
06/1800	38.8	58.0	974	70	70.6◦ / 25.3
07/0000	39.6	54.9	974	70	

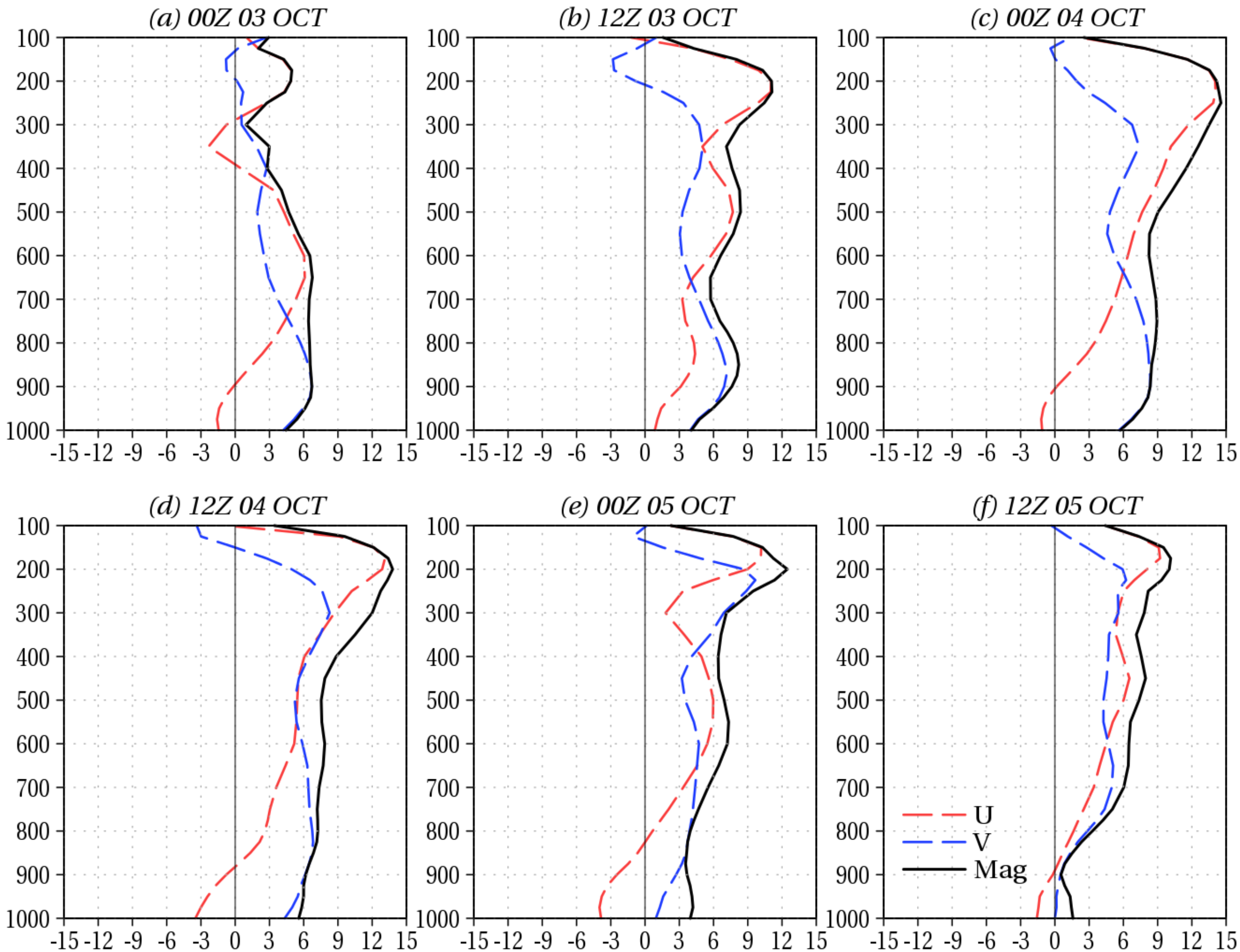
11L INTENSITY GUIDANCE AT 1800 UTC OCTOBER 02, 2015 AND BEST TRACK INTENSITY

- Only COAMPS-TC predicted the early rapid intensification, rapid decay, and interrupted decay
- After poor early forecast, HWRF predicted interrupted decay, but then with some diurnal intensifications
- Other guidance products did not predict early intensification and then only steady decay



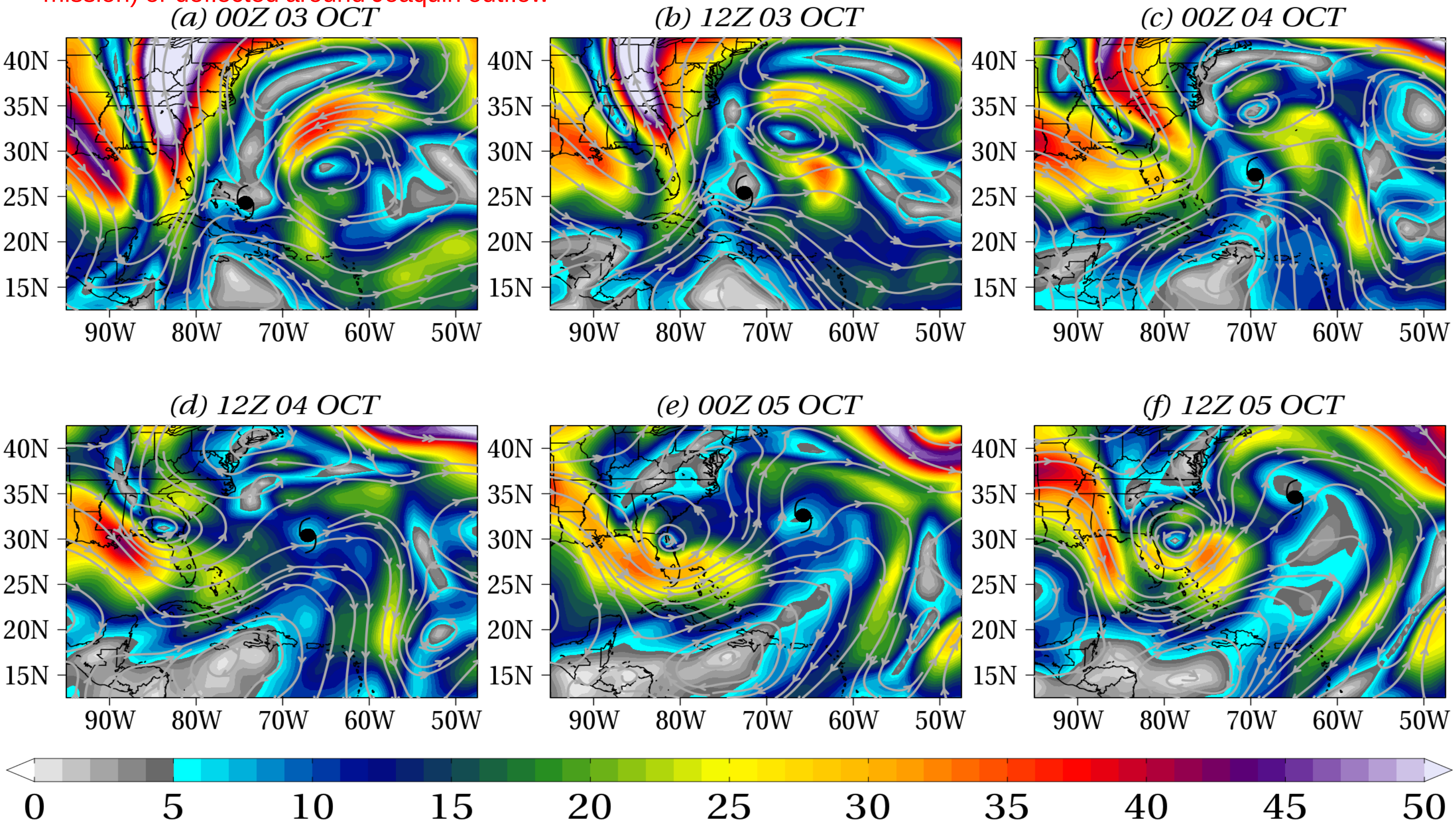
STEERING FLOW EVOLUTION (ERA-INTERIM), FROM 00 UTC 3 OCTOBER TO 12 UTC 5 OCTOBER

- Defining steering flow as 900-500 mb layer flow, the zonal (*U*, red) and meridional (*V*, blue) components are consistent with northeast motion, and the magnitudes (black line) are generally consistent with translation speed variations
- Implied vertical wind shear (VWS) is at first near-zero on 3 October, but then VWS is concentrated in upper-troposphere on 4 October and at 0000 UTC 5 October with relatively small VWS at 1200 UTC 5 October



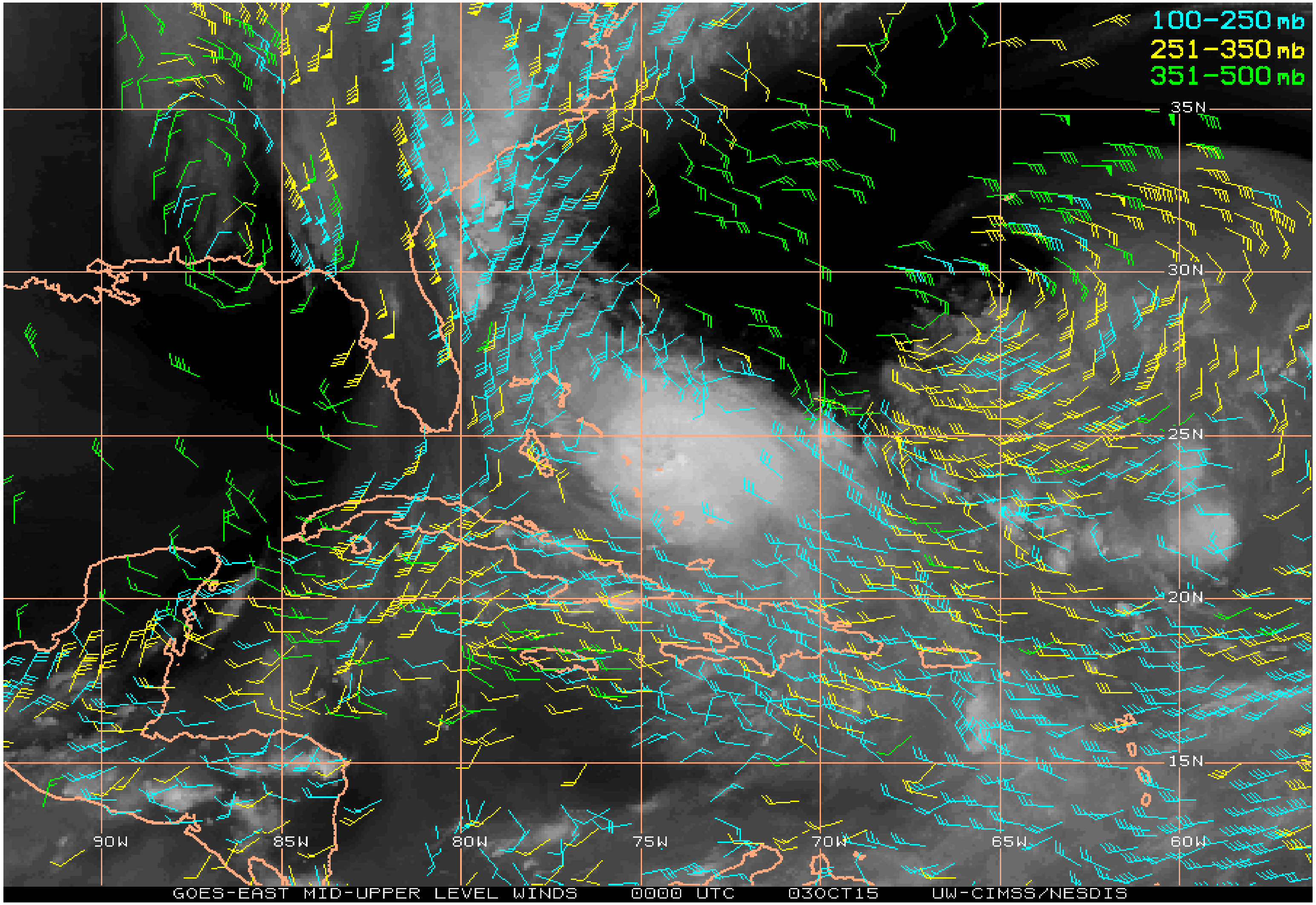
UPPER-TROPOSPHERIC (200 MB ERA-INTERIM) STREAMLINES AND ISOTACHS (M/S, scale at bottom) FROM 00 UTC 3 OCTOBER TO 12 UTC 5 OCTOBER

- Joaquin at 00Z 3 October was in null region between two troughs in east-west direction and two ridges in north-south direction, but with outflow channels toward north and to the southeast
- Nearing max intensity at 12Z 3 October, southwesterly flow approaching Joaquin isdeflected into southeast outflow channel
- For remainder of period, the southwesterly flow is either directed through (especially 12Z 4 October just prior to WB-57 mission) or deflected around Joaquin outflow



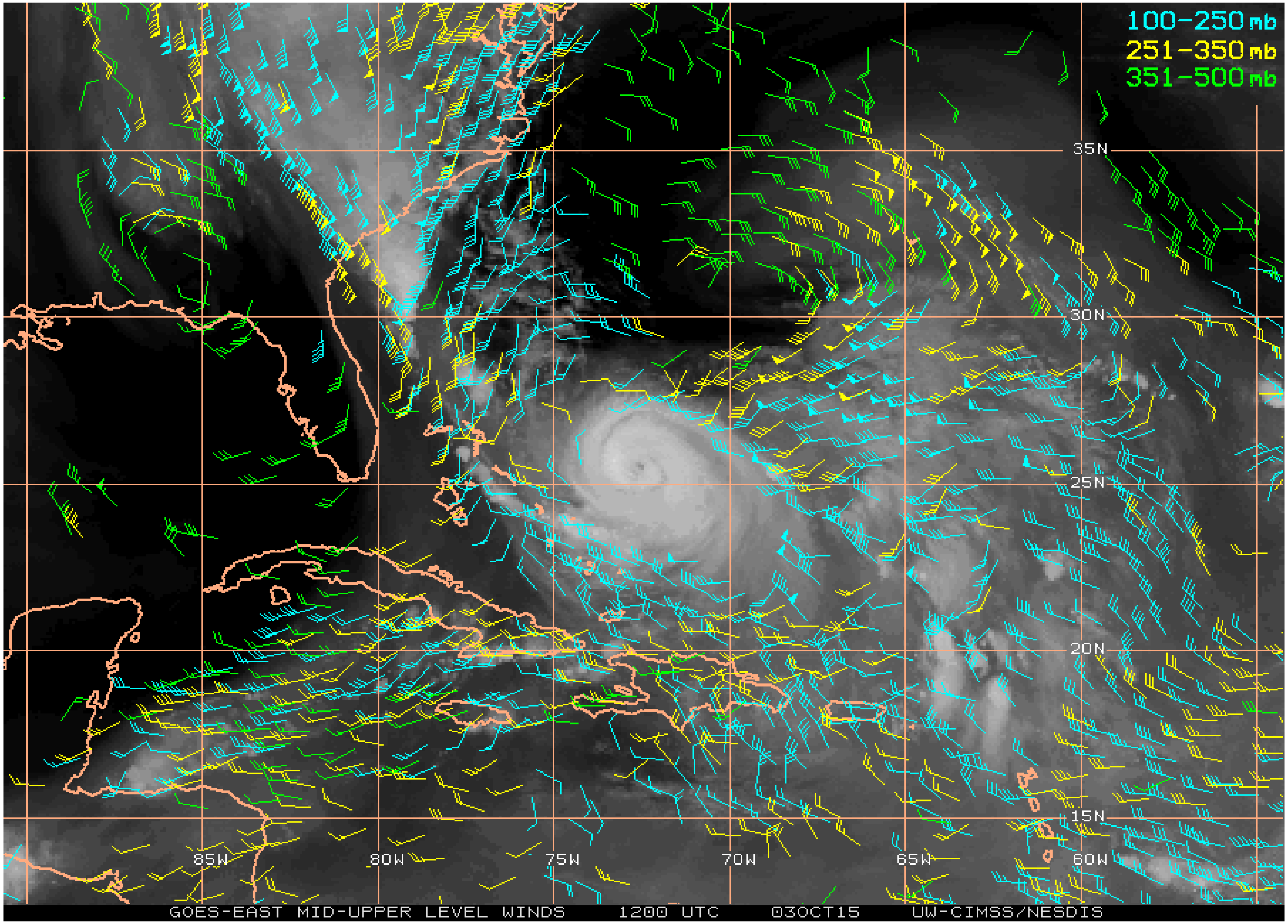
CIMSS ATMOSPHERIC MOTION VECTORS (AMVs) IN UPPER-TROPOSPHERIC TO MID-TROPOSPHERIC LEVELS AT 0000 UTC 3 OCTOBER

- Poleward outflow channel from Joaquin in association with western trough over U.S.
- Southeastward outflow channel in association with ridge to south and southwest quadrant of a broad UL trough to east



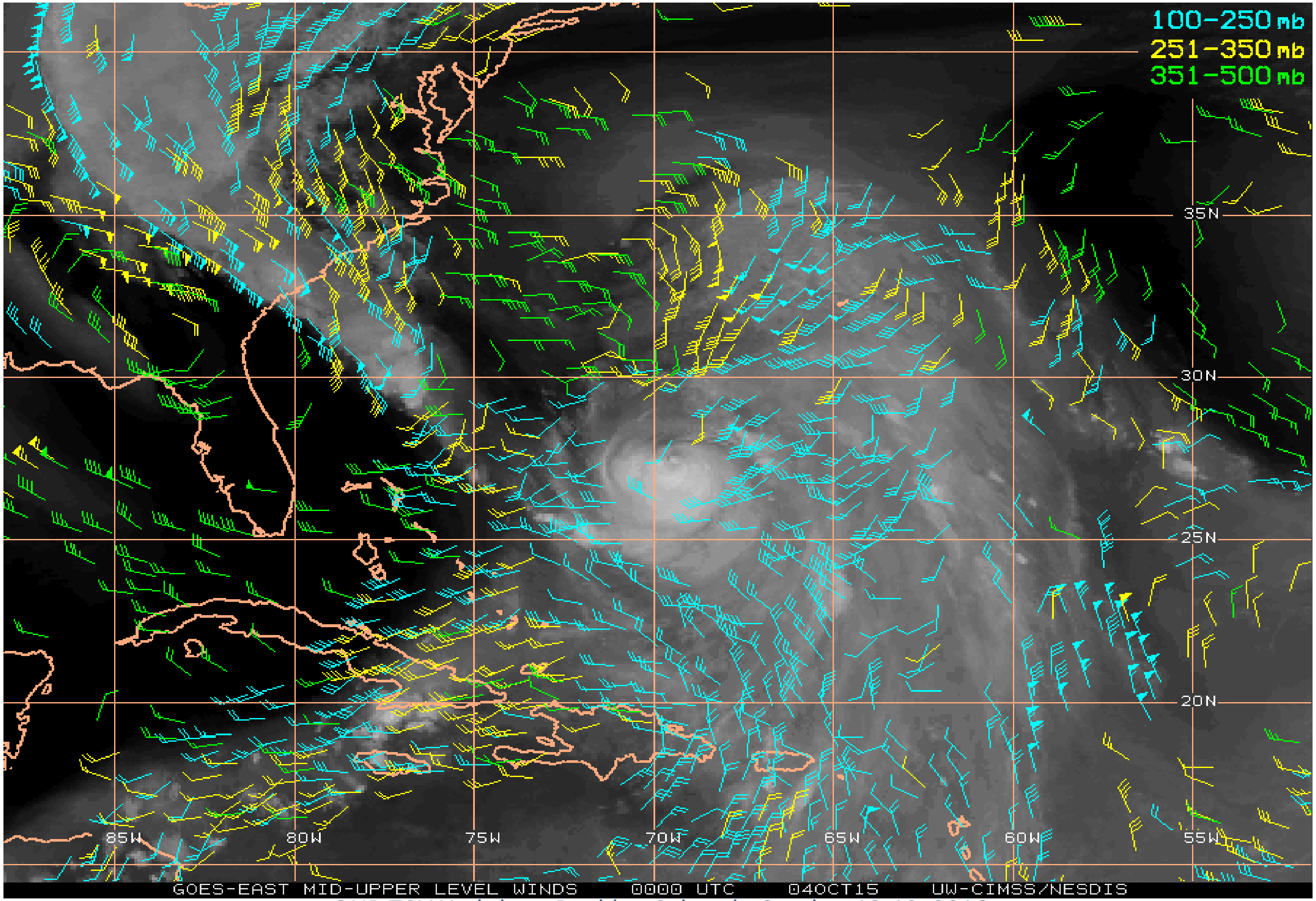
CIMSS ATMOSPHERIC MOTION VECTORS (AMVs) IN UPPER-TROPOSPHERIC TO MID TROPOSPHERIC LEVELS AT 1200 UTC 3 OCTOBER

- Poleward outflow channel from Joaquin at 0000 UTC 3 October has become disconnected
- Southwesterly flow in 100-250 mb layer (blue vectors) is deflected to the east by the Joaquin outflow well away from the center
- Predominant outflow channel is to the northeast and east, which is inconsistent with the ERA-Interim analysis



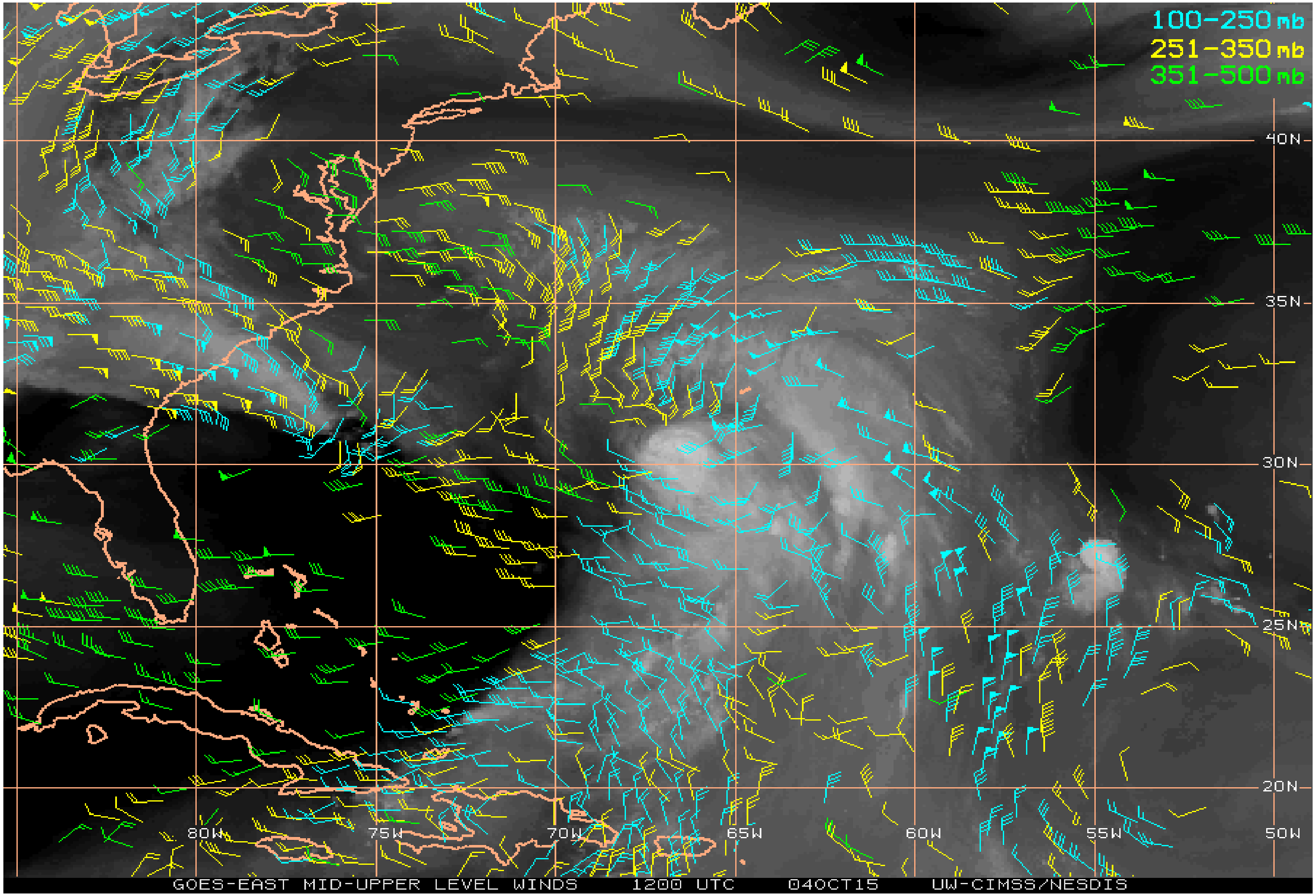
CIMSS ATMOSPHERIC MOTION VECTORS (AMVs) IN UPPER-TROPOSPHERIC TO MID TROPOSPHERIC LEVELS AT 0000 UTC 4 OCTOBER

- Outflow “burst” in entire eastern hemisphere of Joaquin as it was intensifying to maximum intensity of 135 kt at 1800 UTC 3 October
- Poleward outflow is at a lower elevation (251-350 mb, yellow arrows) and is not associated with the western trough – rather, it is part of the radial outflow burst
- Westerly environmental flow is directly impinging on western semi-circle and appears to have crossed over the southern semi-circle of Joaquin circulation in the 100-250 mb layer. As that flow turns southward to become a broad band of northerly flow, the AMVs cross the rainbands in that area at a large angle



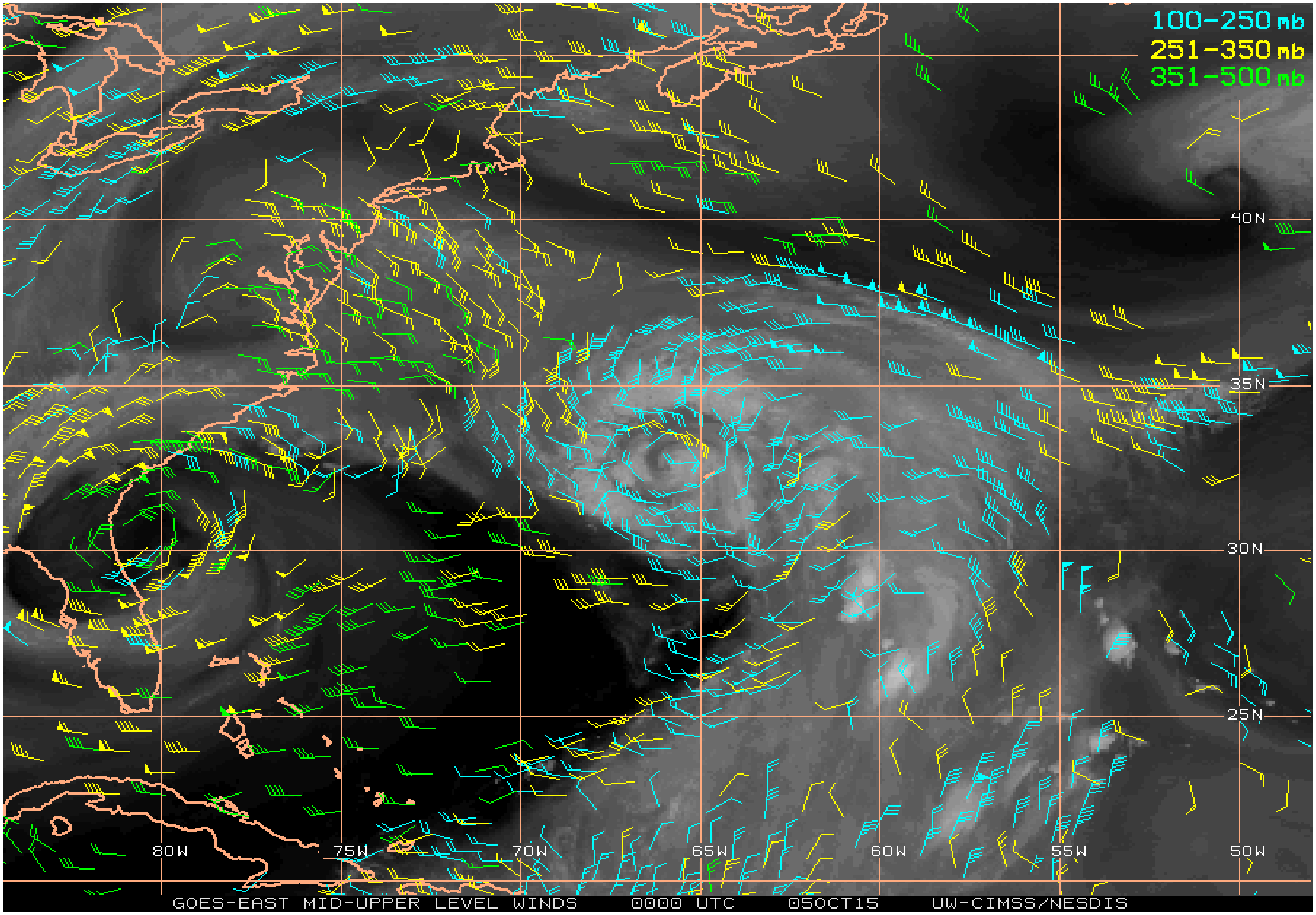
CIMSS ATMOSPHERIC MOTION VECTORS (AMVs) IN UPPER-TROPOSPHERIC TO MID TROPOSPHERIC LEVELS AT 1200 UTC 4 OCTOBER

- Predominant outflow channel is toward the north with the 100-250 mb layer vectors curving cyclonically and the 251-350 mb layer vectors curving anticyclonically
- Anticyclonically curved outflow channel branch to the southeast and then south is joined by some outflow to the east of the center
- Westerly environmental flow is encroaching on the southwest quadrant of Joaquin, and passing around the southern and southeastern quadrants [All features not well-represented in the ERA-Interim analyses]



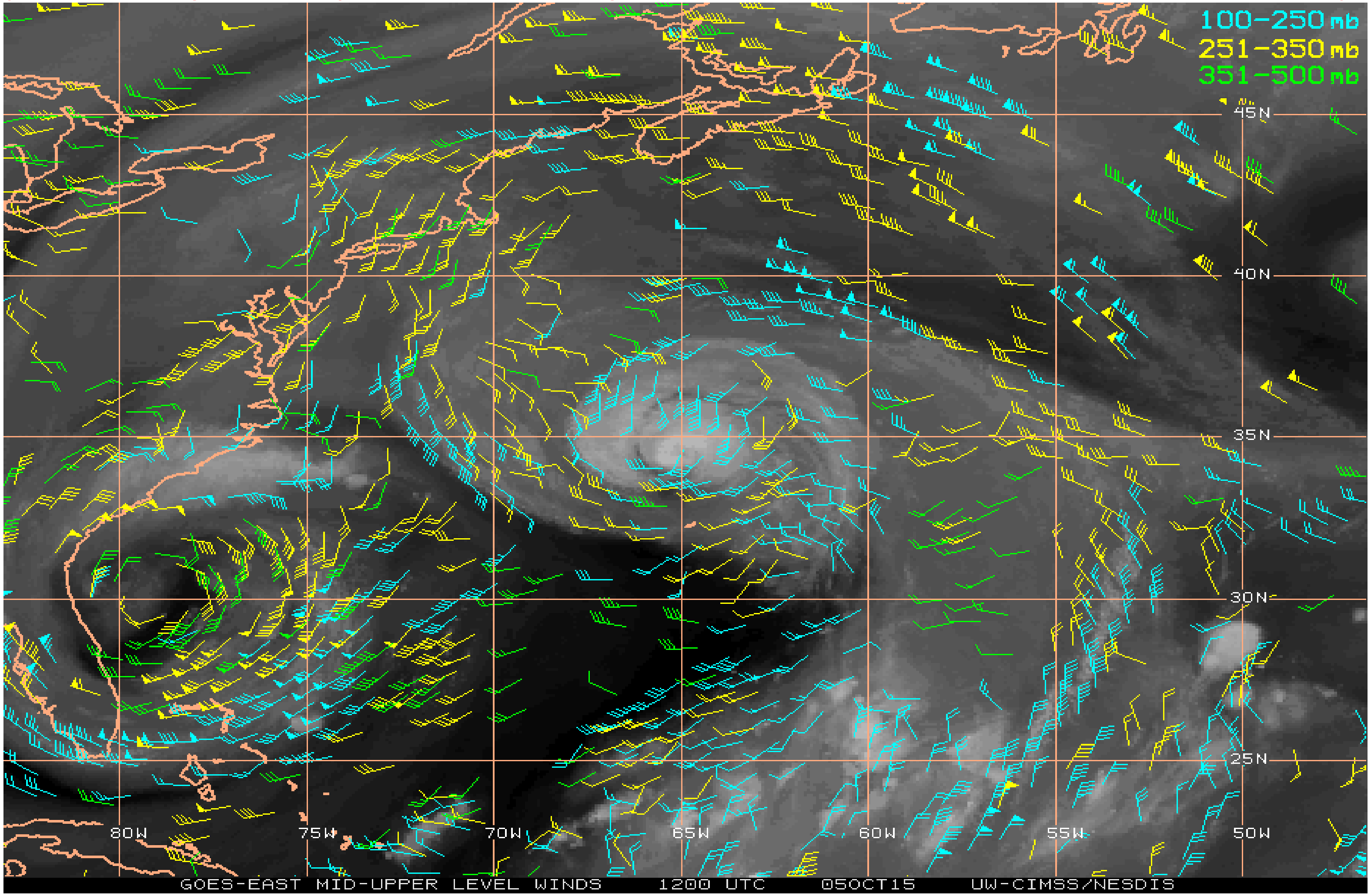
CIMSS ATMOSPHERIC MOTION VECTORS (AMVs) IN UPPER-TROPOSPHERIC TO MID TROPOSPHERIC LEVELS AT 0000 UTC 5 OCTOBER

- While the Joaquin circulation has greatly broadened, outflow is emanating from the northwestern semi-circle, and is crossing the rainbands at a large angle
- Environmental flow in 251-350 mb layer is approaching the far-southern quadrant of the Joaquin circulation, but it curves cyclonically around the southern quadrant and then sharply turns anticyclonically to well east of the center
- In contrast to 12 UTC 4 October, outflow is present in all quadrants

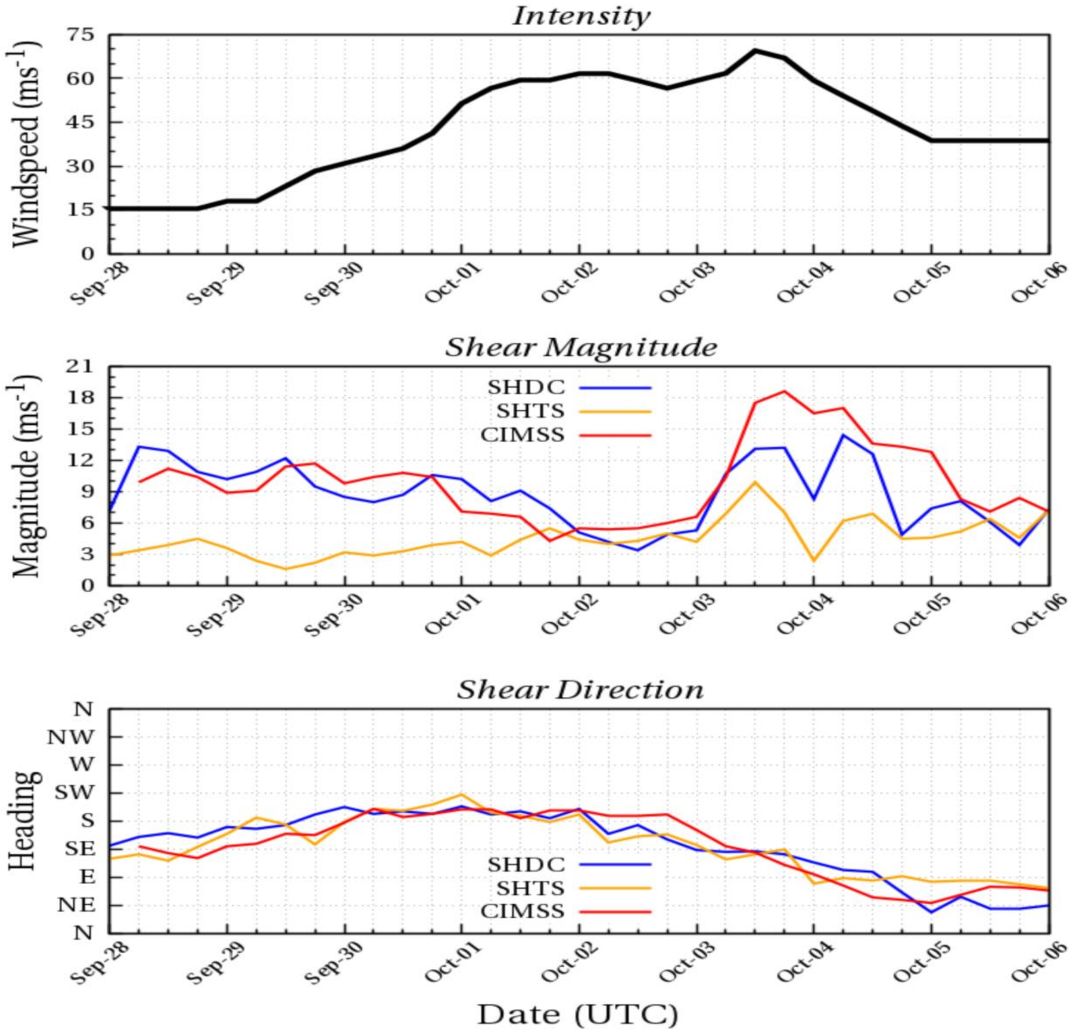


CIMSS ATMOSPHERIC MOTION VECTORS (AMVs) IN UPPER-TROPOSPHERIC TO MID TROPOSPHERIC LEVELS AT 1200 UTC 5 OCTOBER

- Central convection and rainbands are more compact than at 0000 UTC 5 October as Joaquin has re-achieved the signature of a tropical cyclone with less evidence of negative environment effects
- Outflow in the 100-250 mb layer is predominantly in the northern quadrant
- **SUMMARY:** Many aspects of the outflow in the 100-250 mb layer are not well-depicted in the ERA-Interim streamline analyses, which might be anticipated due to the divergent nature of outflow and the horizontal scale of those analyses



JOAQUIN INTENSITY AND VERTICAL WIND SHEAR FROM SHIPS AND CIMSS



- Shallow SHIPS (SHTS) magnitude is small except for two 6-h periods, which is consistent with ERA-interim anals
- Deep SHIPS (SHDC) and CIMSS magnitudes are similar except during 12 UTC 3 October to 00 UTC 5 October, and both have maximum values within 6 h of maximum intensity of Joaquin (indicative of lagged response?)

EVIDENCE FOR ENVIRONMENTAL CONTROL

- During study period of 3-5 October, the environment around Hurricane Joaquin had rapid changes that may have affected the translation speed and direction, the intensity, and the structure of Joaquin
  - ERA-Interim analyses of the steering flow variations appear to have well represented the translation speed and direction changes
  - Influences of the upper-tropospheric VWS variations from the ERA-Interim are less certain
  - Asymmetries in the CIMMS 100-250 mb layer AMVs are not well-represented in the ERA-Interim 200 mb streamlines and isotachs

- Intensity of Joaquin generally increased and decreased in concert with the SHIPS and CIMSS deep-layer VWS decreases and increases, respectively, but the near coincidences of the maxima in intensity and VWS imply a 12-h lagged response to VWS

- Larger CIMSS VWS estimates during 12 UTC 3 Oct to 12 UTC 4 Oct appear to be dependent on the AMVs well into environment, but nearer the inner core the AMVs are deflected around the cirrus canopy and are not exposing the inner core to such large VWSs, which may explain the near coincidence of CIMSS VWS and Joaquin intensity maximum

- Above results motivate SAMURAI/COAMPS-TC Dynamic Initialization (SCDI) approach (Hendricks et al presentation) to take full advantage of the high spatial and temporal AMVs, which is expected to provide a much better depiction of the outflow layer and VWS

STUDIES OF ROLE OF CONVECTION

- Dave Ryglicki has recently documented a specific convective structure in a number of cases of rapid *development* in conditions of moderate VWS. His conceptual model of this convective structure is the framework for the convective structure that may have existed in Joaquin when the VWS decreased to a condition of moderate VWS.

- Microwave imagery indicates an upshear opening of the eyewall early on 4 October when the VWS was large, but an outer rainband appeared to cyclonically wrap into that opening when moderate VWS was present at the interruption of the rapid decay of Joaquin.

- In the absence of aircraft radar coverage, alternate sources of the convective distribution will be explored:
    - Vertical motion from HDSS soundings (Conner Nelson presentation)
    - Convective rain from HIRAD ??

- COAMPS-TC integrations from initial conditions generated by the SCDI analyses of the complete TCI-15 data sets will provide convective heating distributions

FUTURE PLANS FOR VORTEX STRUCTURE

- Since outflow is the key to the intensity changes in this study, the Brian McNoldy and Chris Velden study comparing the AMVs with the HDSS soundings throughout the depth of the outflow layer will provide guidance for incorporation of the high spatial and temporal AMVs created by CIMSS in the SCDI analyses of Joaquin.

- Because of the importance of vortex structure and structure change for the Navy at sea and ashore, the HIRAD surface wind speeds in swaths along the WB-57 flight path will “anchor” the SCDI analyses of Joaquin.

- In conjunction with the HIRAD surface wind swaths, the HDSS soundings will specify the inflow layer of the secondary circulation, and the HDSS soundings with the high temporal and spatial resolution AMVs from CIMSS will specify the outflow layer of the secondary circulation.

- In addition to the Zero Wind Center positions and accurate translation speed and direction from the HDSS soundings in Joaquin, Creasey and Elsberry are examining these HDSS soundings for evidence of a mesoscale vortex along the eyewall.