

# LASE CAMEX-4 Water Vapor, Aerosol, and Cloud Data Analyses and Applications to Hurricane Characterization

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CAMEX-4 Workshop  
November 20-22, 2002  
Huntsville, AL



Funding provided by Dr. Ramesh Kakar, NASA Program Manager for Atmospheric Dynamics and Remote Sensing

# LASE Measurements during CAMEX-4

- Acquired data on 13 science flights
- Measurements in vicinity of 2 hurricanes (Erin, Humberto) and 2 tropical storms (Chantal, Gabrielle)

Date	Flight Number	Flight Duration (hours)	Objectives	Tropical Storm/Hurricane	LASE Measurements
8/15	5	4.8	Transit to JAX	N/A	Extensive data (4.0 hrs) (aerosol, wv, clouds distrib). Mostly clear sky across country.
8/18	6	3.5	Andros Island Calibration Flight	N/A	3.5 hours of LASE data. Excellent Atmospheric conditions with some cirrus.
8/20	7	7.5	Convection Emphasis with vertical structure, also rainband patterns flown	TS Chantel	+6.5 hrs of aerosol, Wv and cloud distro. Lots of clouds from approx 19:30 UT to end of mission.
8/25	8	2.0	Instrument test flight	N/A	+1.0 hrs of aerosol, wv, cloud distro. Fairly clear skys. Lots of aerosol fine structure.
9/03	9	5.0	KAMP #1 Convective structure of a precipitating system	N/A	+3.0 hrs of aerosols, wv, and cloud distro. Lots of structure, clouds, and cirrus above the DC-8.
9/06	10	1.0	Instrument Check/Convection	N/A	0.5 hrs of aerosols, wv, and cloud distro. Lots of clouds above and below DC-8 and other structure
9/07	11	5.0	KAMP #2, Convection in precipitating storm	N/A	+4.5 hrs of aerosols, wv, and cloud distro. Lots of clouds above and below DC-8
9/09	12	5.0	KAMP #3, Convection in precipitating storm.	N/A	+4.5 hrs of aerosols, wv, and cloud distro. Lots of clouds above and below DC-8.
9/10	13	8.0	Optimal data assimilation to collect comprehensive data on winds, temp, and moisture structure of the storm.	Hurricane ERIN	8.0 hrs of aerosols, wv, and cloud distro. Occasionally in and out of cirrus clouds. Excellent data set.
9/15	14	8.0	Optimal data assimilation and to map flow fields and thermodynamic fields in a rotated pattern.	TS GABRIELLE	+7.5 hrs of aerosols, wv, and cloud distro. In and out of cirrus above and below DC-8. Excellent data when not in the clouds.
9/19	15	5.0	KAMP #4, Sample a convective system to obtain radar and microphysics data	N/A	4.5 hrs of aerosols, wv, and cloud distro. In and out of cirrus above and below Dc-8 throughout this flight. When not in clouds, has good data.
9/22	16	8.0	QPE mission and to map the conditions near a developing storm center, including flow fields and thermodynamics.	TS HUMBERTO	7.0 hrs of aerosols, wv, and cloud distro. In and out of cirrus above and below DC-8. Lots of excellent data and structure when not in clouds.
9/23	17	7.5	COVES #1, Convection, structure, and mapping of the inner storm	Hurricane HUMBERTO	6.0hrs of aerosols, wv, and cloud distro. Excellent data when not in the storm. Lots of structure.
9/24	18	8.0	COVES #2, Convection, structure, and mapping of the storm	Hurricane HUMBERTO	7.0hrs of aerosols, wv, and cloud distro. Exceklent data when not in the storm. Lots of structure.

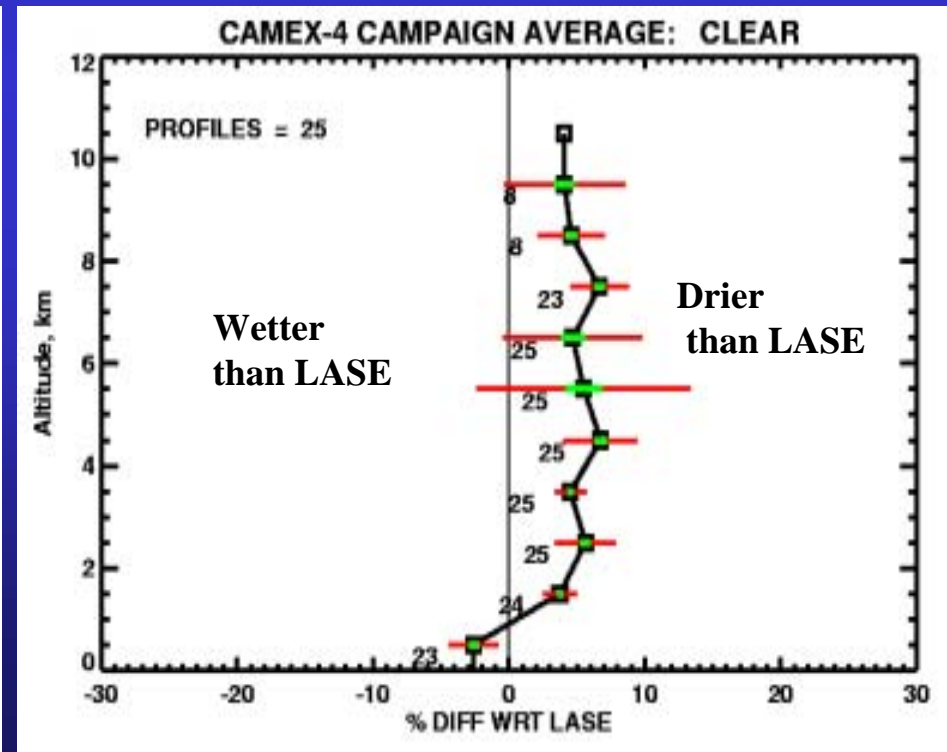
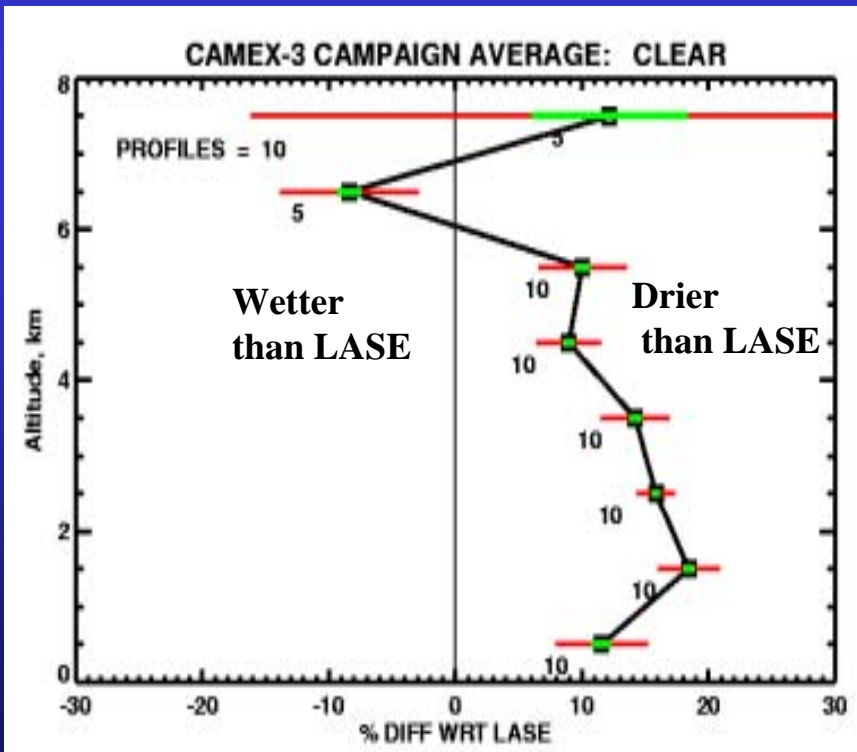
# LASE Assessment of CAMEX-3 DC-8 Dropsonde Water Vapor

## CAMEX-3 (1998)

- 10 LASE/dropsonde comparisons
- Periodic dropsonde dry bias
- Dropsonde ~15% drier on average
- Dropsonde dry bias may be due to outgassing of packaging material

## CAMEX-4 (2001)

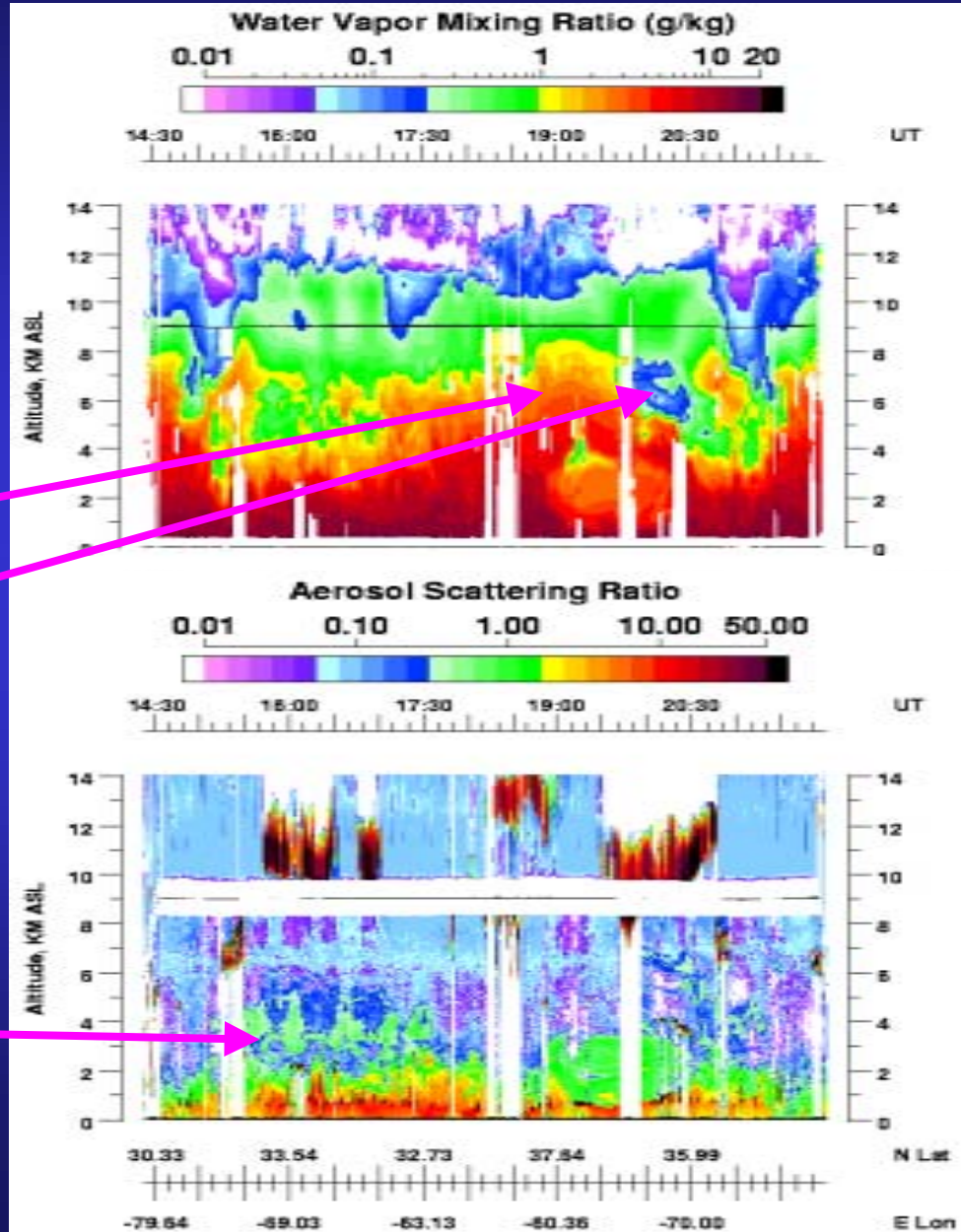
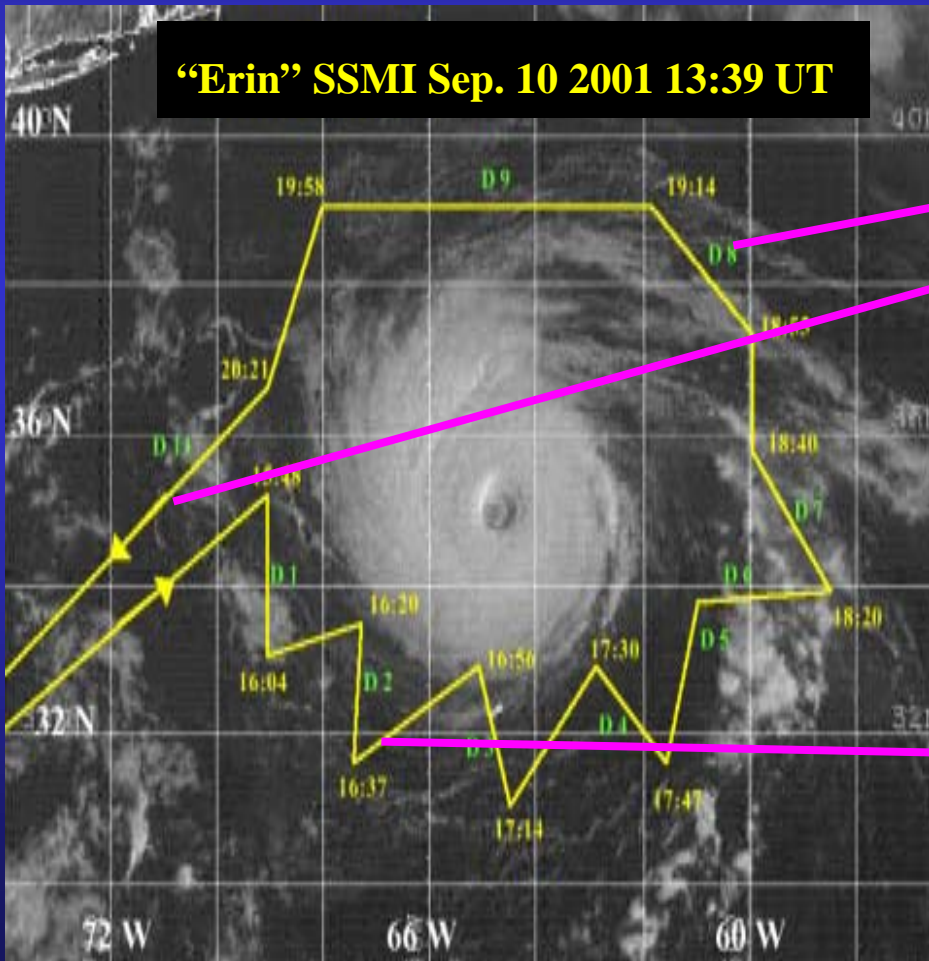
- 25 LASE/dropsonde comparisons
- Dropsonde dry bias reduced
- Dropsonde ~ 5% drier on average



# CAMEX-4 Hurricane Erin "Optimal Data Assimilation" Flight

- High water vapor northeast of storm
- Mid-upper level dry region associated with cold trough southwest of storm
- Elevated aerosol layer south of storm

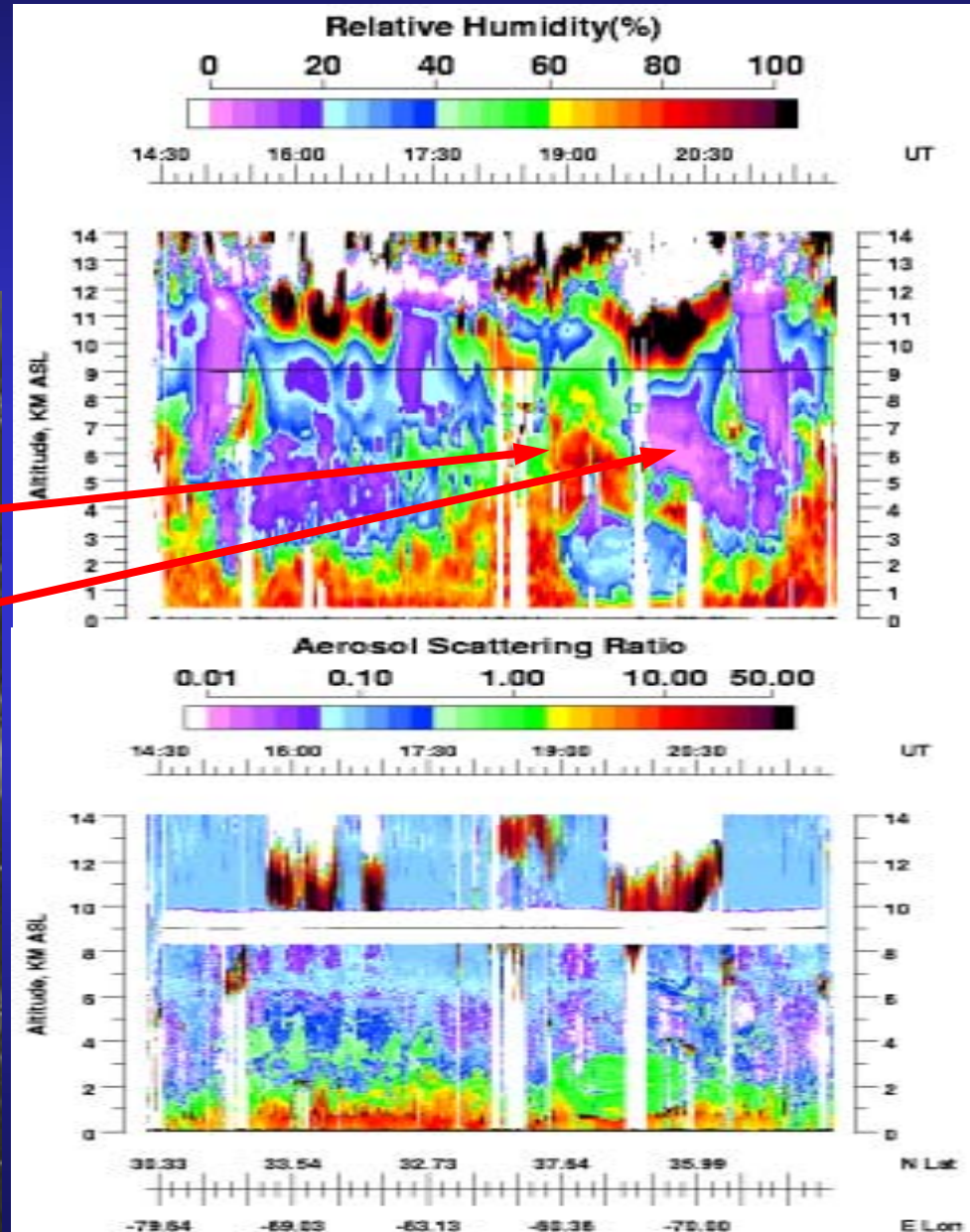
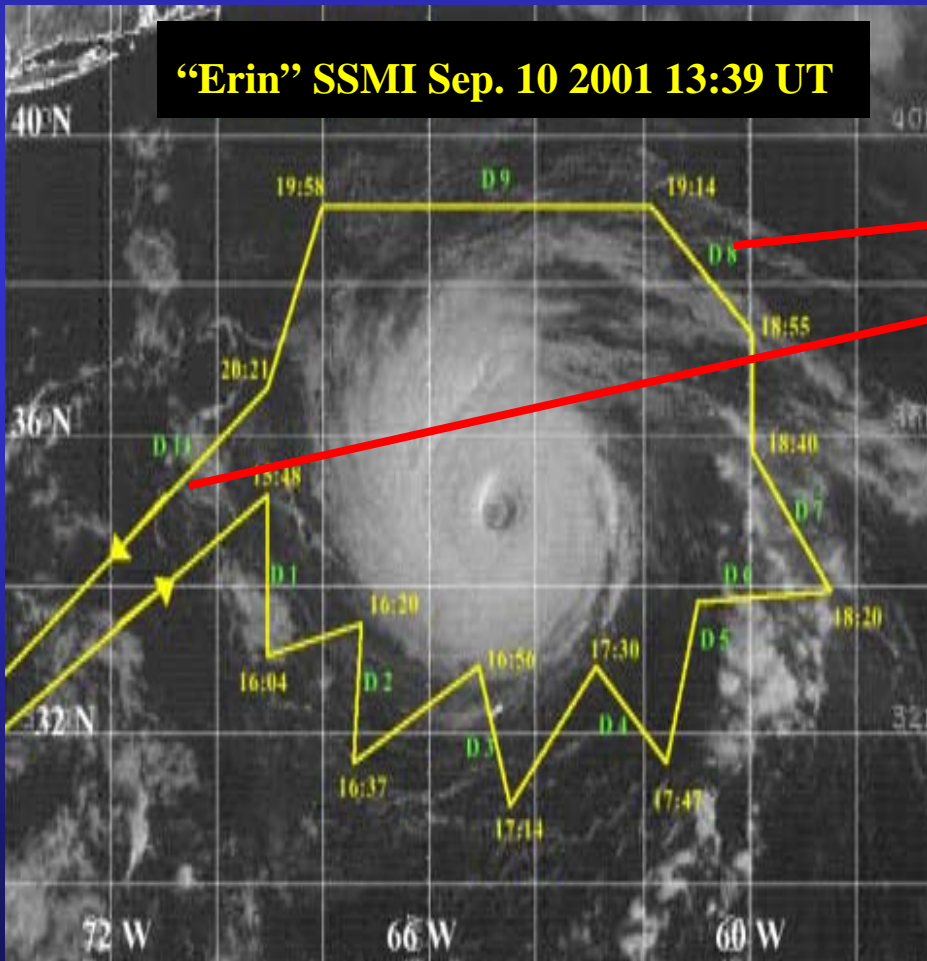
**"Erin" SSMI Sep. 10 2001 13:39 UT**



# CAMEX-4 Hurricane Erin "Optimal Data Assimilation" Flight

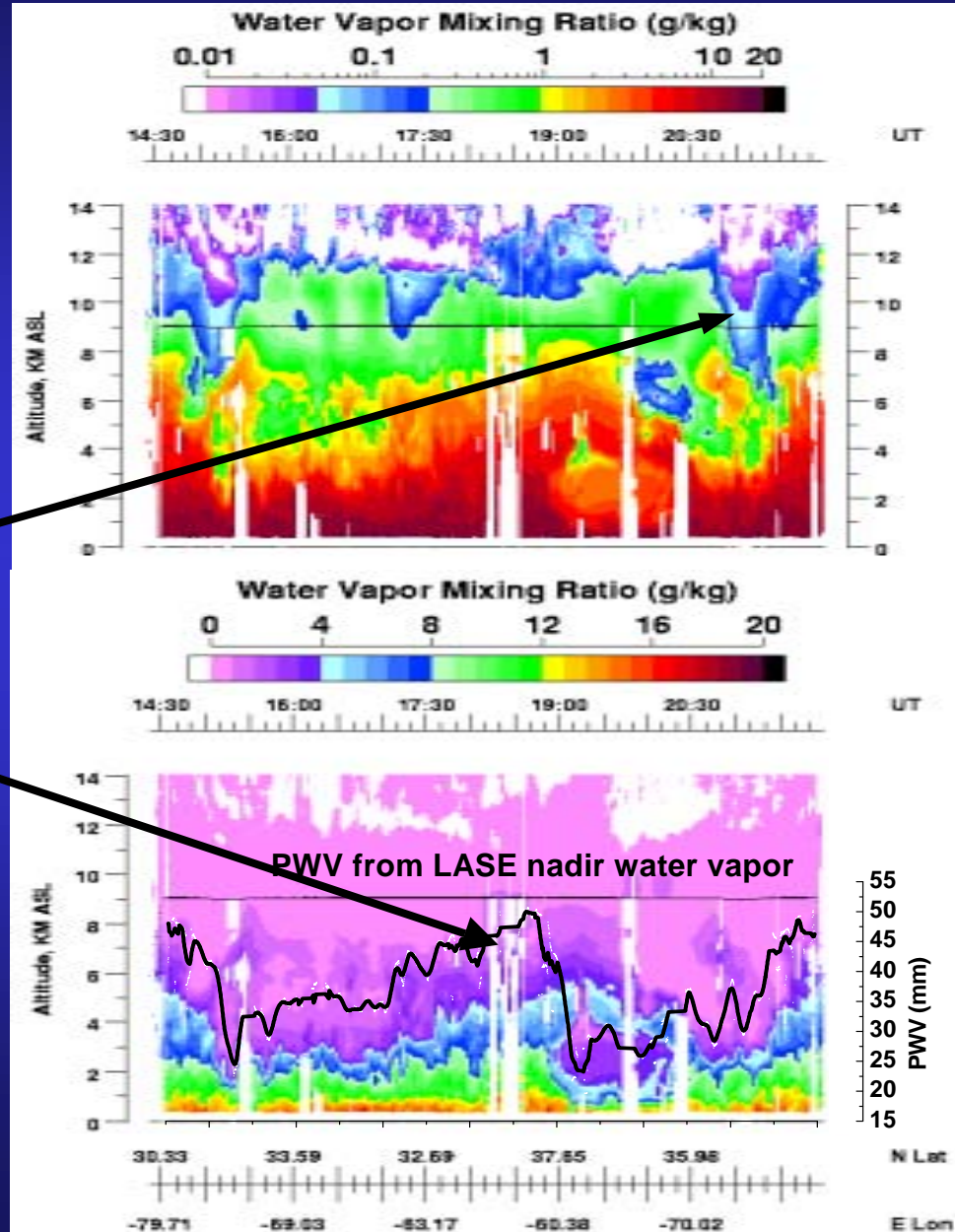
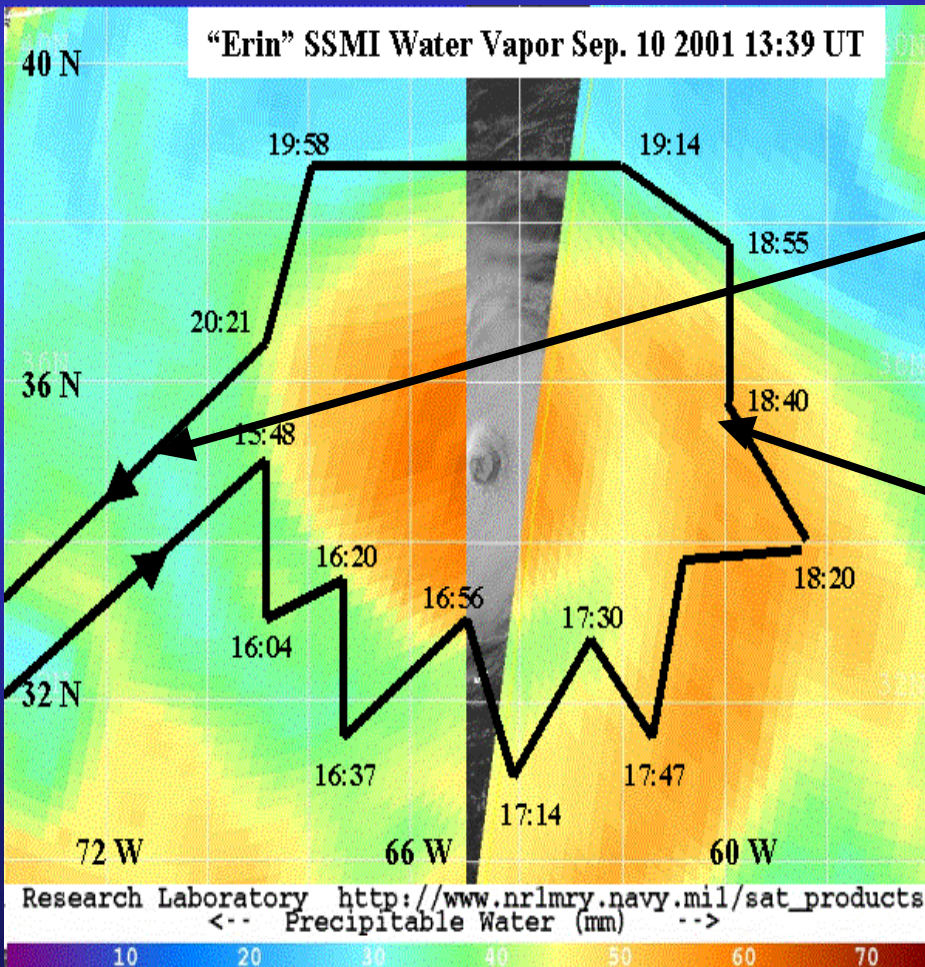
- High water vapor northeast of storm
- Mid-upper level dry region associated with cold trough southwest of storm

**"Erin" SSMI Sep. 10 2001 13:39 UT**



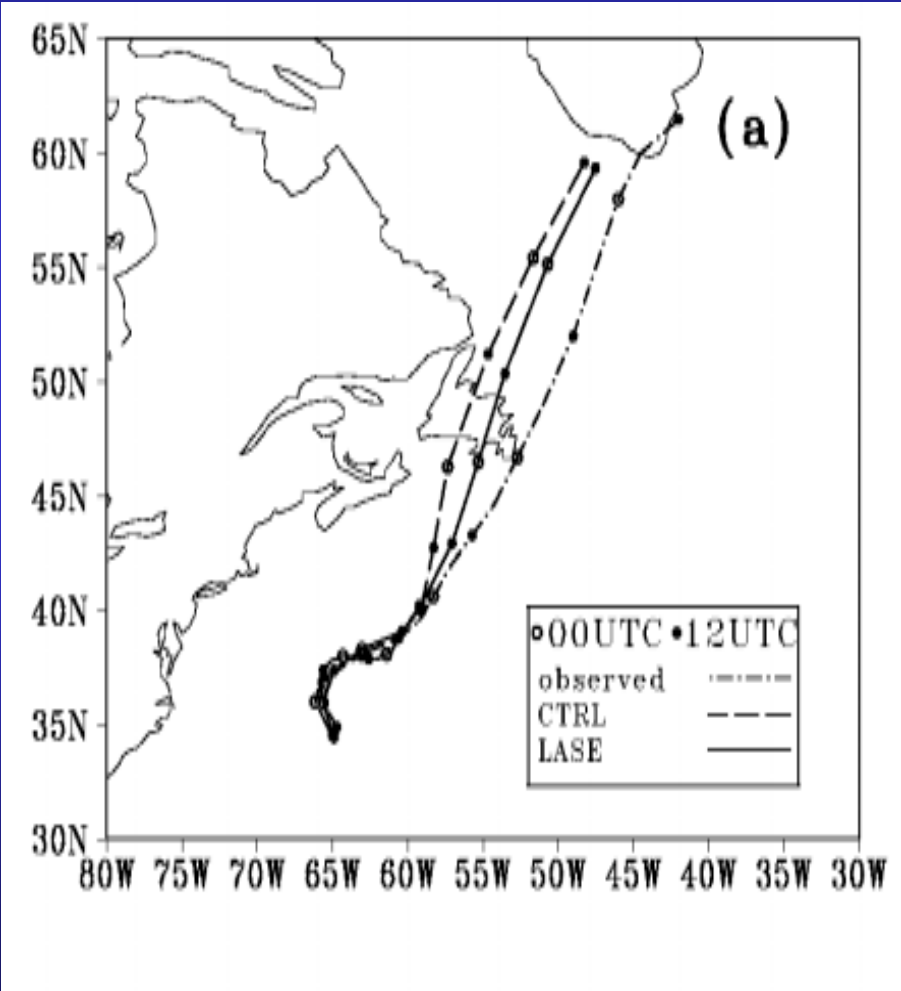
# CAMEX-4 Hurricane Erin "Optimal Data Assimilation" Flight

- High water vapor northeast of storm
- Mid-upper level dry region associated with cold trough southwest of storm
- Large variation in integrated water vapor

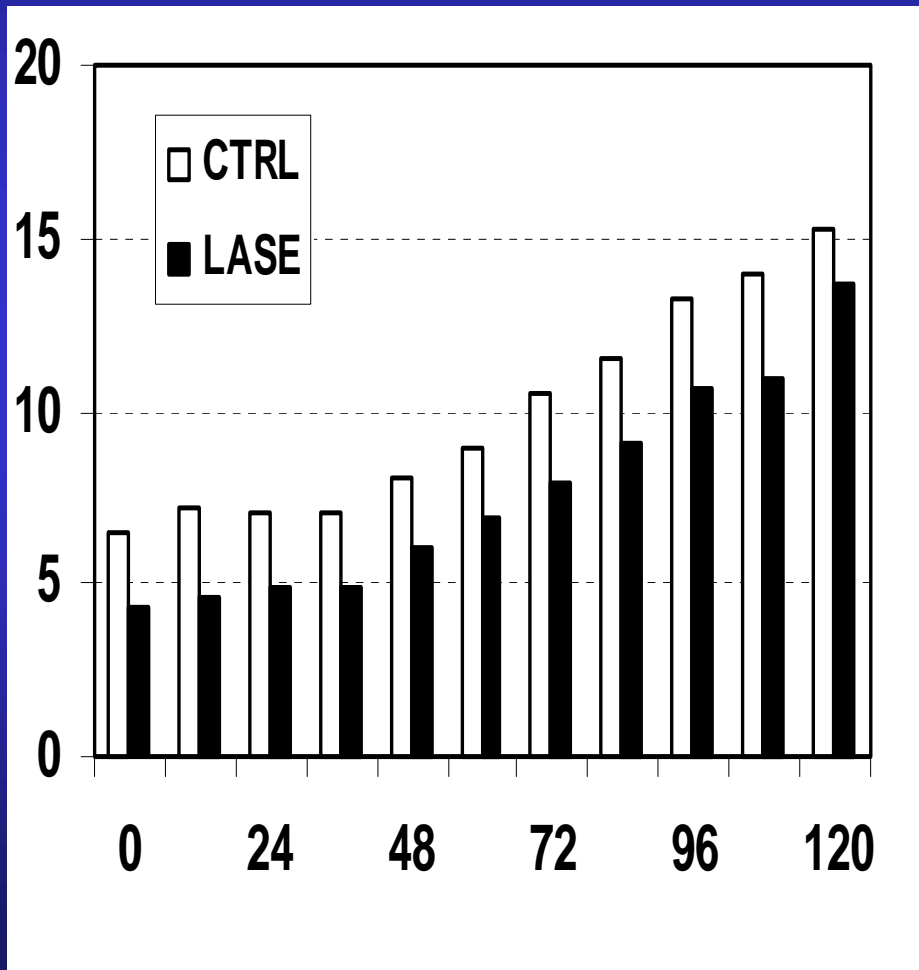


# FSU Model Results for Hurricane Erin using CAMEX-4 LASE Data

120hr forecast track of Hurricane Erin  
IC: 12UTC 10 Sep 2001

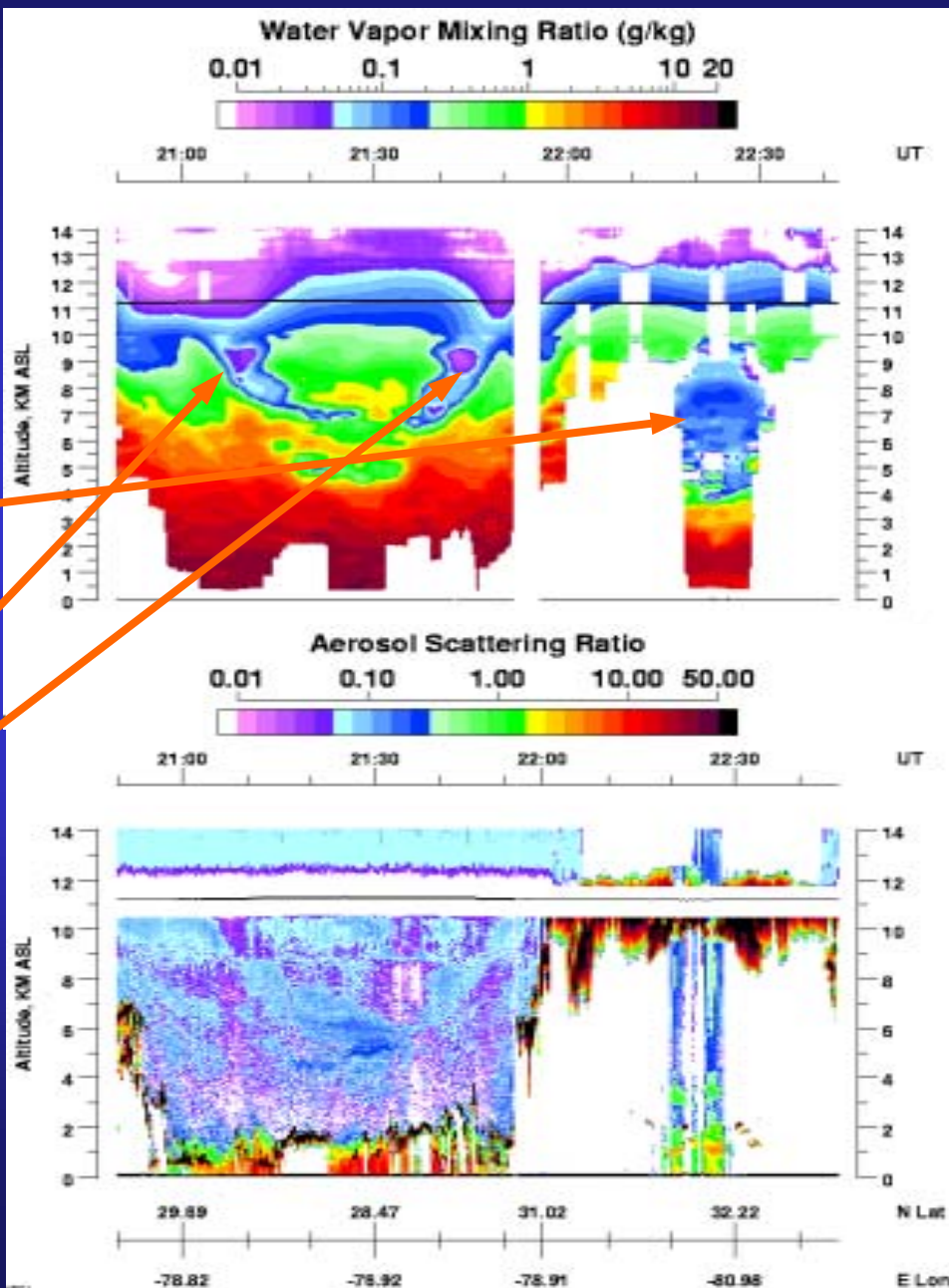
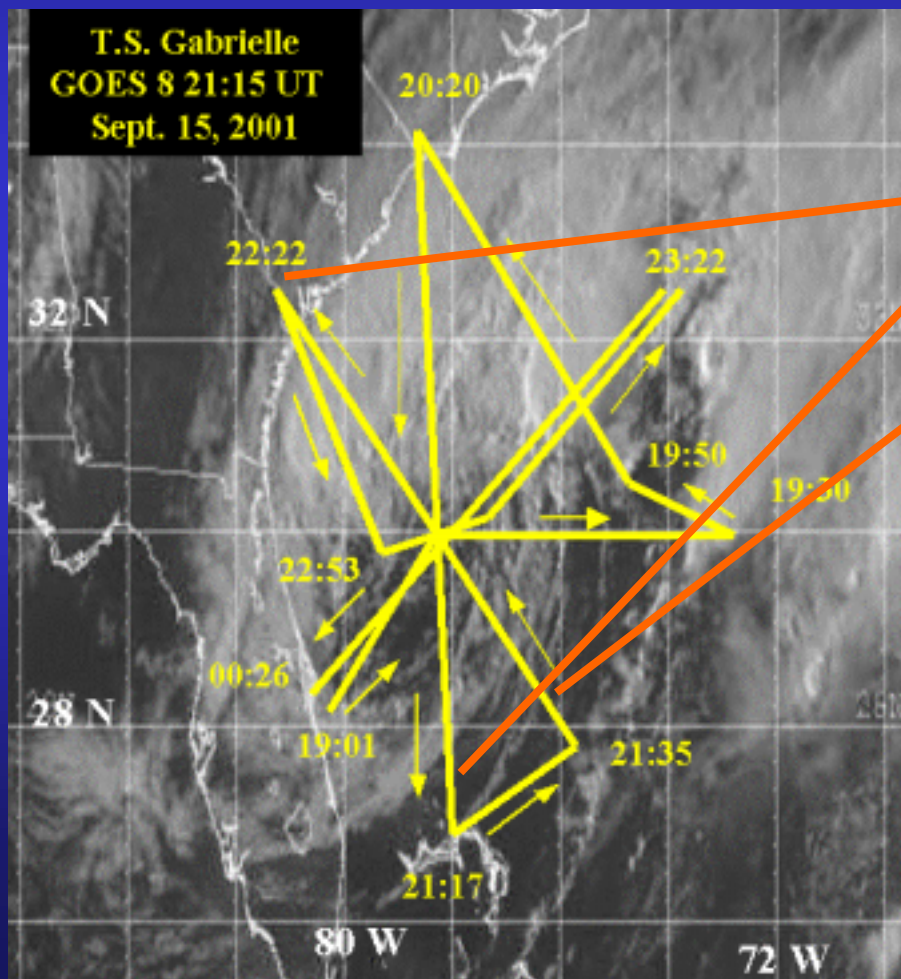


Intensity errors (in m/s) of Hurricane Erin  
IC: 12UTC 10 Sep 2001



# CAMEX-4 Tropical Storm Gabrielle Flight

- Dry air between 7-11 km inhibited the rapid redevelopment of this tropical storm as it left the Florida coast



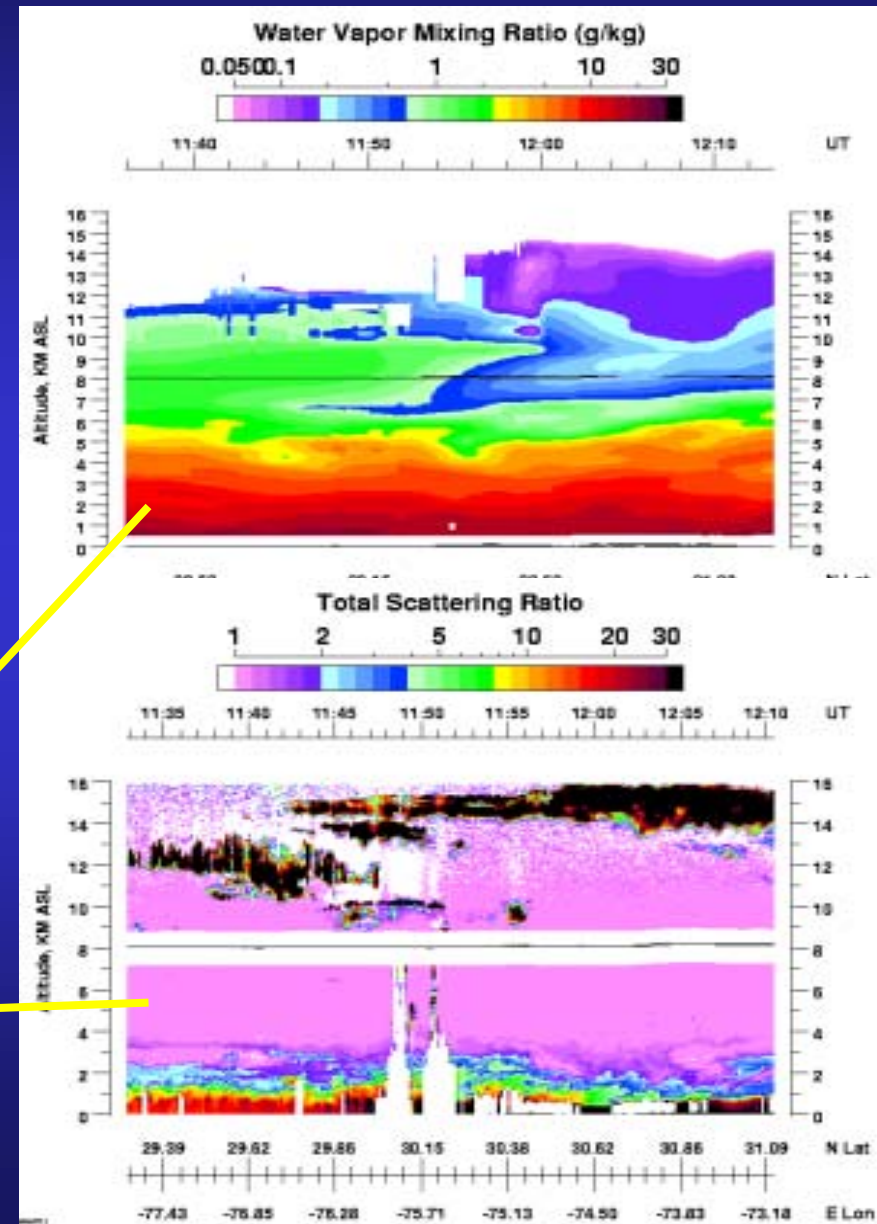
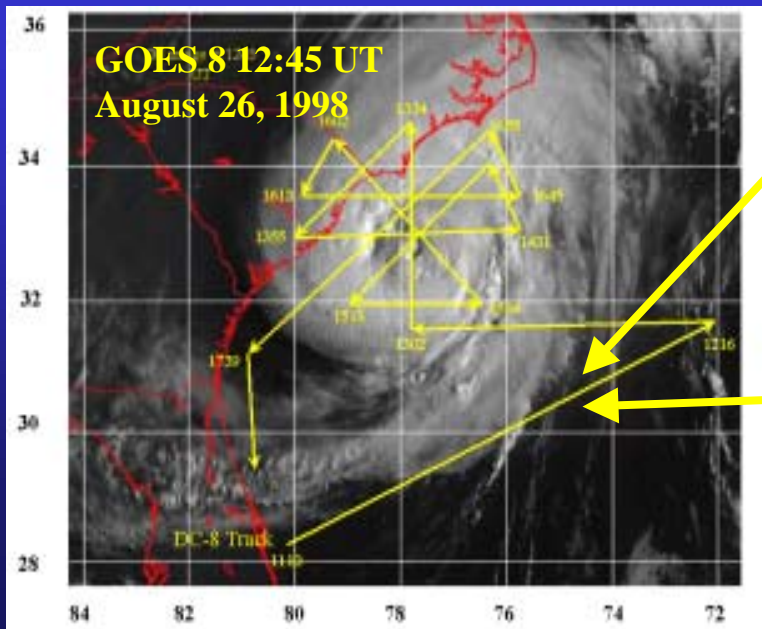
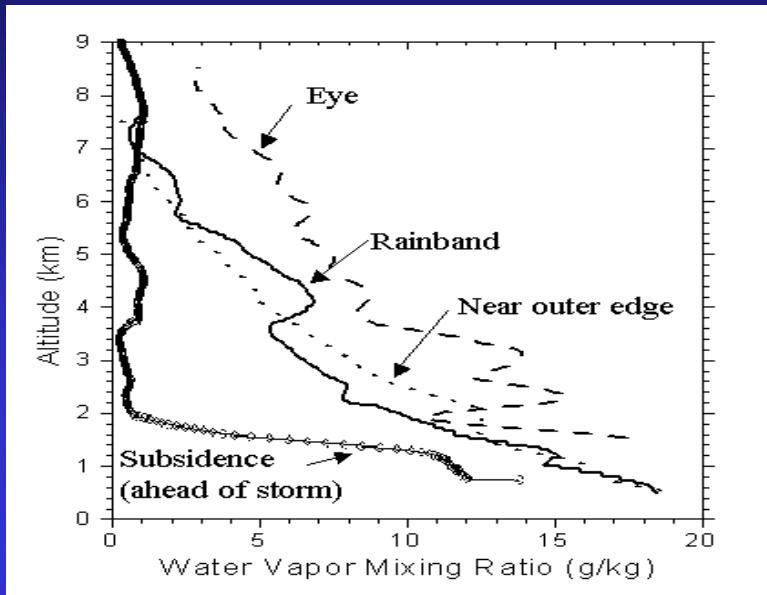


# Summary

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- **Processed LASE measurements from 13 science flights including 2 hurricane (Erin and Humberto) and 2 tropical storms (Chantal, Gabrielle)**
- **Archived nadir water vapor, and nadir and zenith scattering ratio data for all flights**
- **Compared LASE and dropsonde observations for CAMEX-3 and CAMEX-4**
- **Computed total precipitable water vapor and compared with MODIS observations**
- **Computed RH profiles using LASE water vapor and dropsonde temperature profiles**
- **Collaborating with FSU on impact of LASE on hurricane track and intensity predictions**
- **Preparing two papers (GRL/JGR) for publications with FSU and NASA Langley authors**
- **Comparing LASE measurements with SSMI and other satellite observations**
- **Extending LASE measurements near surface for comparison with near surface observations**
- **Collaborating with other studies**

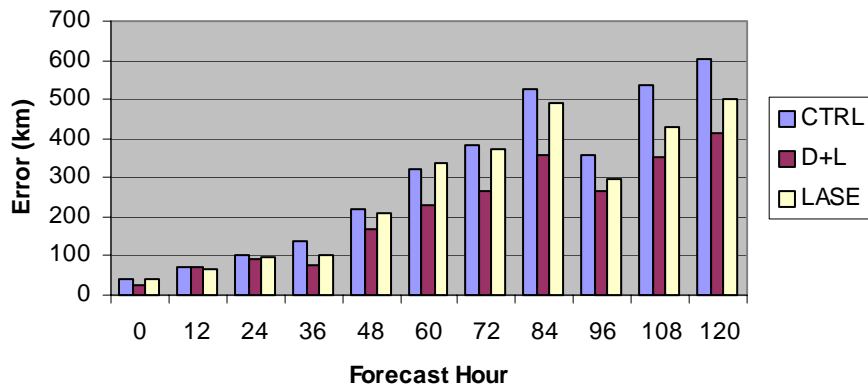
# LASE CAMEX-3 Measurements: Hurricane Bonnie Inflow



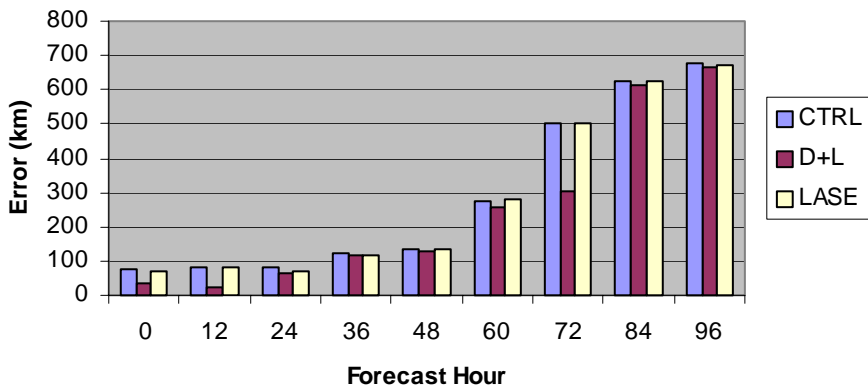
# Average FSU Forecast Track Errors

- CAMEX-3
- Hurricanes Bonnie, Danielle, Georges
- FSU Model Forecasts
- Models
  - CTRL = ECMWF data
  - D+L = Dropsonde + LASE
  - LASE = LASE only
- Dropsonde winds + LASE moisture has largest impact

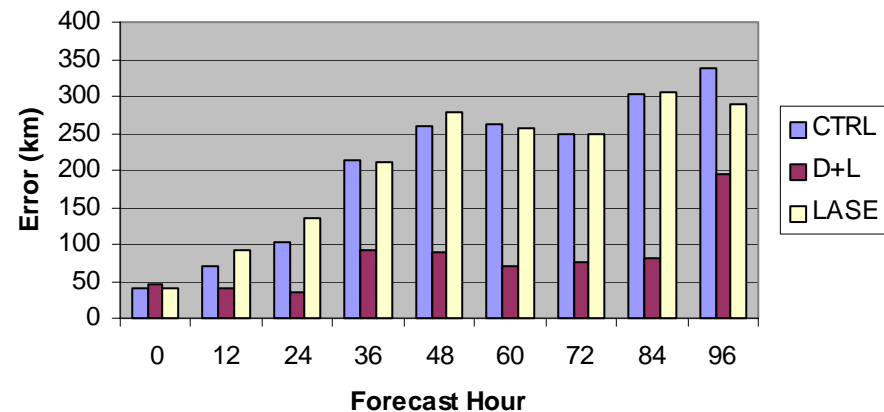
### Hurricane Bonnie



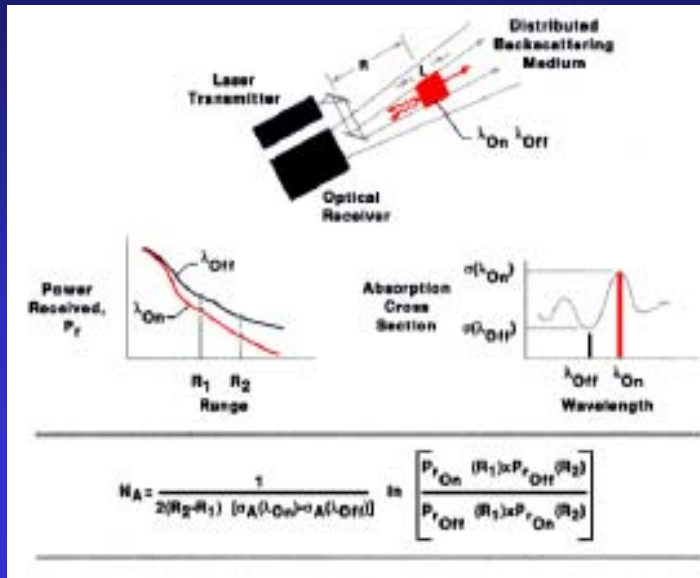
### Hurricane Danielle



### Hurricane Georges



# Lidar Atmospheric Sensing Experiment (LASE)



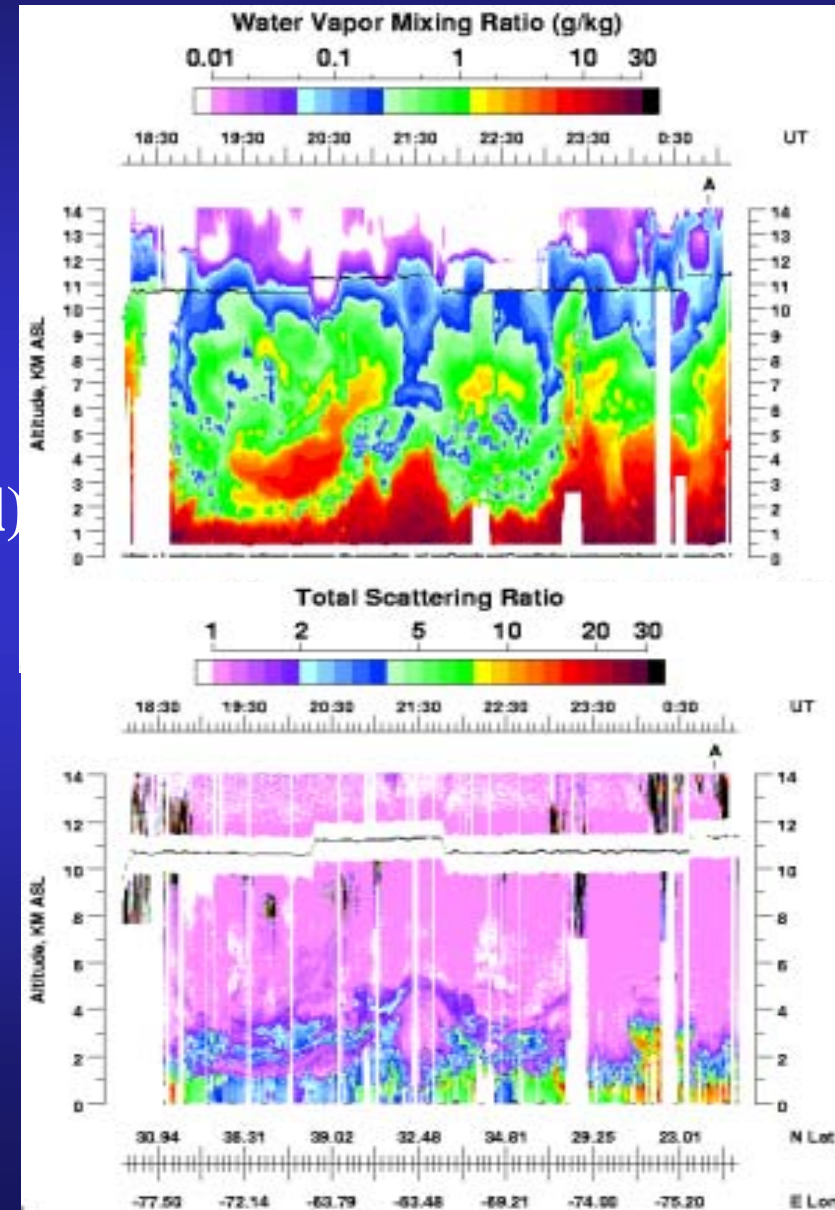
- Airborne Water Vapor DIAL
- Laser
  - 5 Hz doubled-pulsed Ti:sapphire
  - 100 mj (on and off lines)
- Wavelengths
  - 815 nm (on-off  $\lambda = \Delta\lambda = 40-70$  pm)
  - Three separate line pairs
- NASA ER-2, P-3, DC-8 aircraft
- Simultaneous nadir, zenith operations
- Real-time data analysis and display



# LASE Water Vapor and Aerosol/Cloud Profiling on NASA DC-8

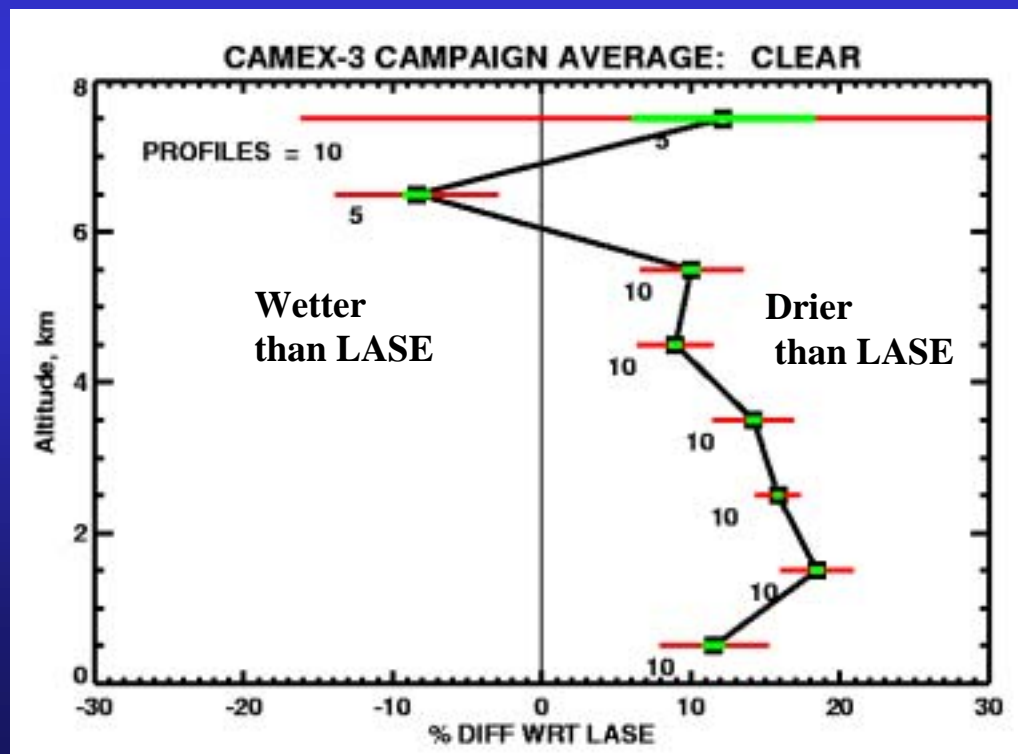
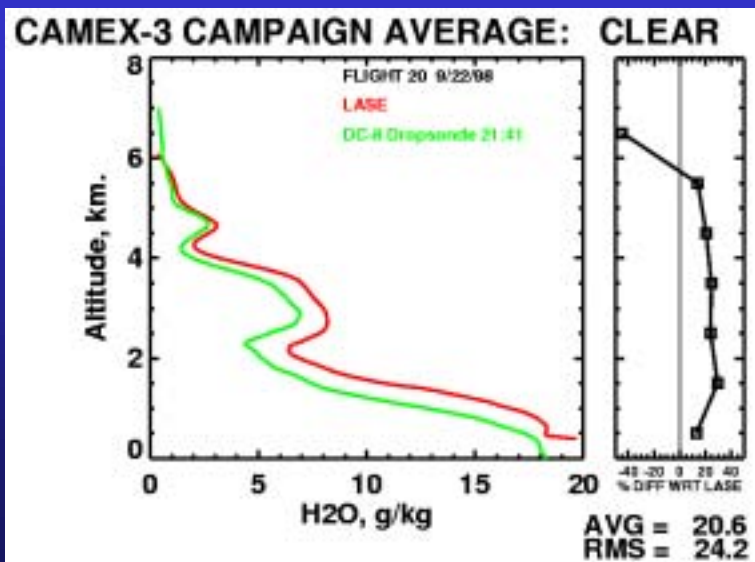
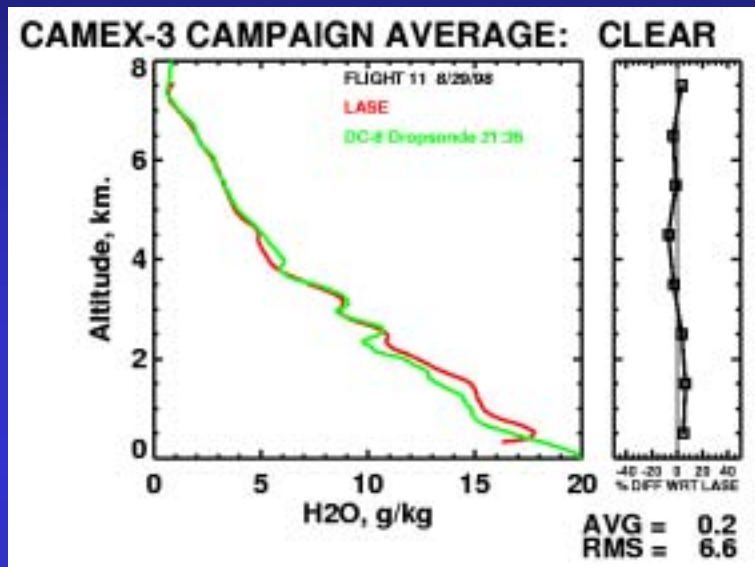
- **Water vapor profiles**
  - daytime and nighttime
  - 0.2 km to tropopause (12-14 km)
  - 0.01 to 25 g/kg
  - accuracy (6% or 0.01 g/kg)
  - resolution (variable)
    - 330 m (vertical)
    - 14 - 42 km (1-3 min) (horizontal)
  - DC-8 in situ used within +/- 1 km of plane
- **Aerosol/cloud profiles**
  - daytime and nighttime
  - 0.03 to 25 km
  - resolution (variable)
    - 30 m (vertical)
    - 200 m (horizontal)

CAMEX3 DC-8 Flight 7 T.S. Bonnie Synoptic Flow Aug. 21-22, 1998



# LASE Assessment of CAMEX-3 DC-8 Dropsonde Water Vapor

- Periodic dropsonde dry bias
- 10 LASE/dropsonde comparisons
- Dropsonde ~15% drier on average
- Dropsonde dry bias may be due to outgassing of packaging material



# LASE CAMEX References

## • Publications:

- Bensman, Edward L., “The impact of aircraft digital weather data in an adaptive observation strategy to improve the ensemble prediction of hurricanes”, Ph.D. Thesis, Florida State University, 2000.
- Rizvi S.R.H., E.L. Bensman, T.S.V. Vijay Kumar, A. Chakraborty, and TN Krishnamurti, “Impact of CAMEX3 data on the analysis and forecasts of Atlantic hurricanes”, *Meteo. Atmos. Phy.*, 79, 13-32, 2002.
- Kamineni, R., T.N. Krishnamurti, R.A. Ferrare, S. Ismail, and E.V. Browell, “Impact of high resolution water vapor cross-sectional data on hurricane forecasting”, to be submitted to *Geophys. Res. Letters*, November, 2002.
- Kamineni, R., T.N. Krishnamurti, R.A. Ferrare, S. Ismail, and E.V. Browell, “Impact of CAMEX-4 data on hurricane forecasting”, to be submitted to *J. Geophys. Res.*, December, 2002.

## • Presentations:

- “LASE measurements of water vapor, aerosols, and clouds, during CAMEX-3”, R.A. Ferrare, E.V. Browell, S. Ismail, W. Smith, W. Edwards, A. Moore, S. Kooi, V. Brackett, M. Clayton, S. Fastig, D. Harper, L. Petway, L. Matthews, D. Whiteman, F.J. Schmidlin, D. Lauritsen, R. May, *Optical Remote Sensing of the Atmosphere Technical Digest, Optical Society of America*, June 22-24, 1999, Santa Barbara, CA, 114-116.
- “Hurricane Water Vapor, Aerosol, and Cloud Distributions Determined from Airborne Lidar Measurements”, E.V. Browell, S. Ismail, and R.A. Ferrare, *Symposium on Lidar Atmospheric Monitoring, American Meteorological Society, American Meteorological Society, Long Beach, CA, January 9-14, 2000, 65-67.*
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- “LASE measurements of water vapor, aerosol, and cloud distributions in hurricane environments and their role in hurricane forecasting”, S. Ismail, E. V. Browell, R. A. Ferrare, S. A. Kooi, L. Brasseur, A. Notari, L. Petway, V. Brackett, M. Clayton, M. J. Mahoney, J. Halverson, S. Rizvi, T. N. Krishnamurti, and K. Rupa, *21st International Laser Radar Conference, Quebec City, Canada, July 8-12, 2002, Proceedings*, pp. 523-526.