Overview of Altus Cumulus Electrification Study (ACES) and the Altair

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Project Overview

- Study thunderstorms using General Atomic's Altus II UAV.
- Exploit unique capabilities of Altus to conduct thunderstorm studies.
- PI-led, end-to-end experiment encompassing all aspects of mission implementation and execution.

Support and Development

Sponsor

– NASA's Office of Earth Science (Code Y)

Program

– Uninhabited Aerial Vehicle (UAV)-based Science Demonstration Program (UAV SDP) managed by Ames Research Center (ARC)

SDP Goals

– Conduct high quality science research using UAVs.

– Demonstrate utility of UAVs for Earth science and applications observations.

– Build confidence in UAV platforms through scientifically useful demonstrations.

Key Science Objectives

- Investigate lightning – storm relationships
  - quantify connections (updraft strength, precipitation, ice mass, storm height, latent heat release, precursors to severe weather events)
- Support validation of space-based lightning sensors
  - fill measurement void (observations last collected in early 1980's)
- Study storm electrical output
  - quantify contribution of thunderstorm to global circuit
- Benefit science relevant to NASA's Earth Science themes
  - themes include Global Water and Energy Cycle, Climate Variability and Predictability, Atmospheric Chemistry, and Disaster Management

Technology Demonstration

- Demonstrate the utility and promise of UAVs for investigating thunderstorms and other weather phenomena.
- Provide demonstration of real-time monitoring and control of a UAV science payload.
  - e.g., electric field monitored from the aircraft during ACES flights

Aircraft Selection

Altus II UAV

Pilot Console

Ground Control Station

Advantages of Altus for Storm Observations

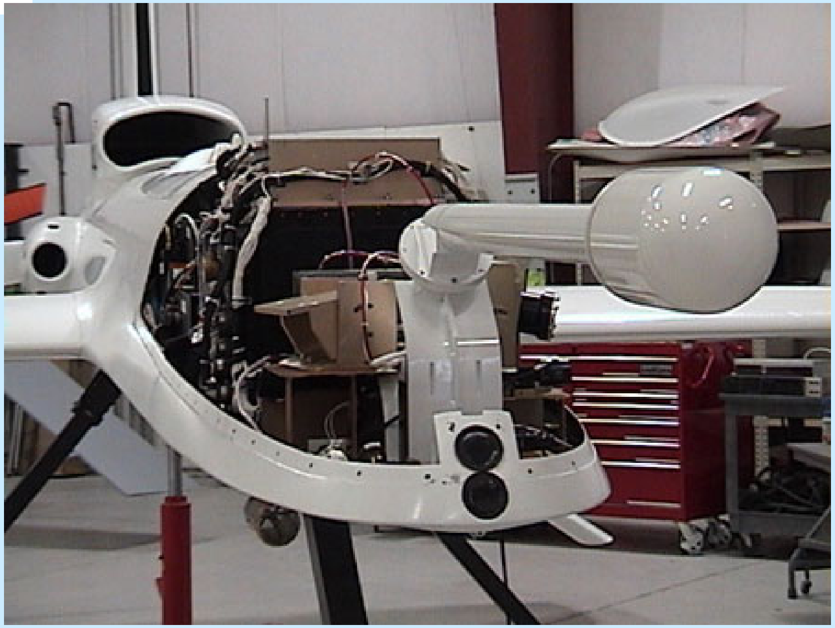
- High altitude flight
  - 40,000 to 55,000 feet flight level
  - "cloud top" perspective
- Continuous observation of storms
  - long-duration flights combined with slow flight speeds
- Rapid response
  - operational flexibility for changing weather conditions
- Reduced risk to personnel
  - no pilot and/or passengers are placed at risk

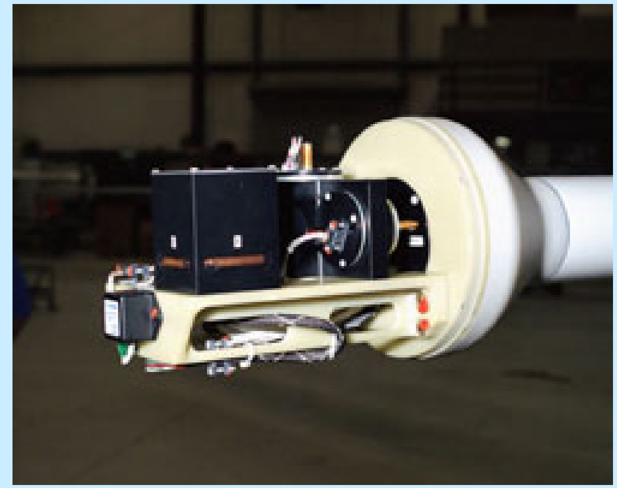
ACES Payload

Sensor	Measurement	Performance	Power (W)	Mass (kg)	Volume (cc)	Heritage
Electric field mills (6 sensors)	DC electric field: 3 axis (x, y, z)	<10 Hz <1V/m – 15kV/m	2.8	21.8	16,000	ER-2, ALTUS, other aircraft
Electric field change meters (4 sensors)	AC electric field: 3 axis	1 Hz – 100 kHz	3.0	1.81	7,500	ER-2, ALTUS, other aircraft, ground based
Optical pulse sensor (2 sensors)	Optical lightning transients	320 – 1,100 nm	0.8	2.50	2,250	ER-2, ALTUS, ground based
Gerdien conductivity probe	Conductivity	$3x10^{-13}$ – 10^{-11} S/m	3.0	1.36	1,100	ALTUS,UAV (Navy Swallow), rockets
Magnetic search coil	AC magnetic field: 3 axis	100 Hz – 100 kHz >1.3 pT@ 10 kHz	0.3	0.91	1,650	ALTUS, Swallow, rockets
Fluxgate Magnetometer	DC magnetic field: 3 axis	0 – 100 Hz >10 nT	0.2	0.45	100	ALTUS
Accelerometer	Acceleration 3 axis	+/- 4 G	0.1	0.45	55	ALTUS, other aircraft, rockets
Flight Payload Data System (FPDS)	N/A	64 Ch @ 100 Hz 16 Ch @ 100 kHz	368	70	156,000	ALTUS
Total Payload			378	163 (360 lb)	184,655 (6.8 cu ft)	

Altus can accommodate payloads up to 800 W, 400 lb, and 18.6 cu ft.
Payload enhanced by the addition of 3 cloud cameras (down, left, right).

ACES Payload

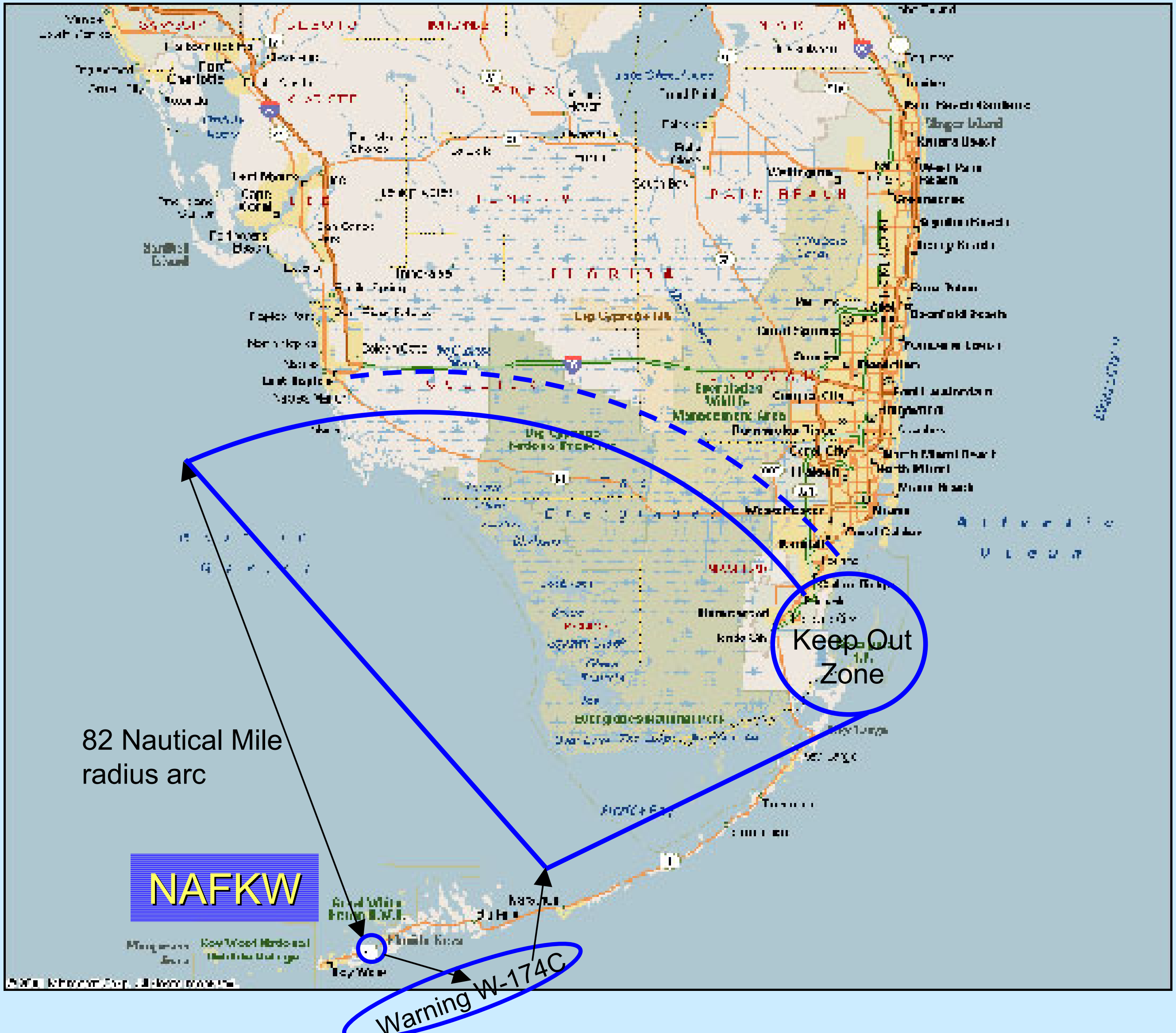




Experiment Design

- Conduct mission from Key West, Florida to take advantage of cost and resource sharing with another NASA program.
- Study thunderstorms that form over the Florida Everglades and nearby ocean.
- Utilize a large variety of ground- and satellite-based weather data to support both real time operations and science analyses.
- Nearby ocean provides for improved safety during loitering periods and lost link or emergency situations.

Location of Field Campaign



Field Campaign Objectives

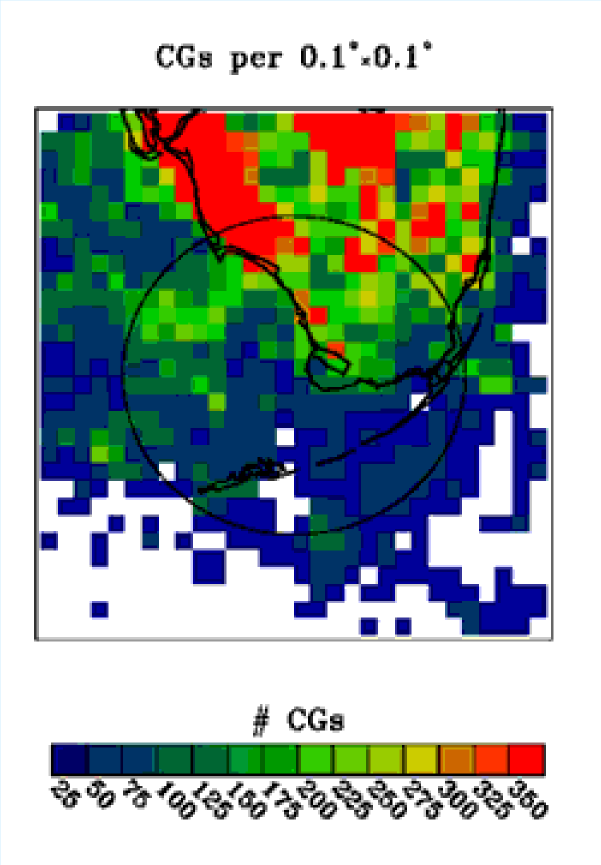
- Observe thunderstorms during August, 2002
- The duration of the observing period was approximately 4 weeks.
- Goal to complete 8 - 10 flights, each 6 - 8 hours in length (actually completed 11 science and 2 check flights).
- Altus required to be on station and at altitude (~40,000 to 55,000 ft) for 4 - 6 hours.

Weather at Florida Everglades

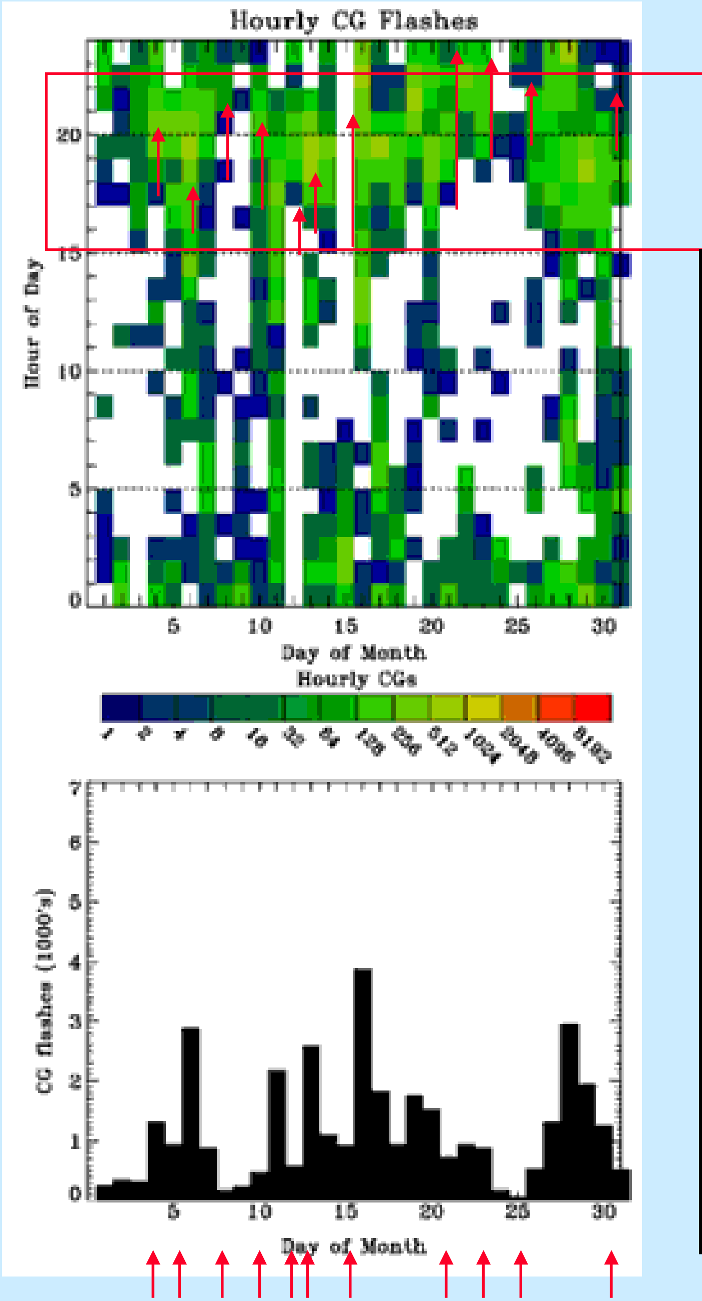
- Frequent thunderstorm occurrence in the early to late afternoon
- Summer thunderstorms in the Everglades area are small air-mass “pulse-type” variety
- Typical storm lifetime is 0.5 – 1.0 hours
- Typical storm dimensions are 10 km diameter, 12 km height
- Initiated by differential heating and classic sea breeze convergence (presence of Everglades suppresses activity compared to central Florida)

Distribution of Storms near Everglades

Aug 2002



Monthly Activity
(Daily Frequency)



Flight #	Date	Take-off (UTC)	Duration (hr:min)	Storm Passes
84 FCF	Aug. 02	1318	0:55	
85	Aug. 04	1714	3:00	6
86	Aug. 06	1521	1:30	+
87	Aug. 08	1724	3:30	6
88	Aug. 10	1632	3:18	20
89	Aug. 12	1449	1:24	4+
90	Aug. 13	1519	2:36	0
91	Aug. 15	1505	5:12	17
92	Aug. 21	1540	6:42	41+
93	Aug. 23	1812	4:30	27
94	Aug. 25	1854	2:24	0
95 FCF	Aug. 30	1457	1:06	0
96	Aug. 30	1903	1:42	0
Total	13 flights		37:48	115+

Real-Time Weather Display

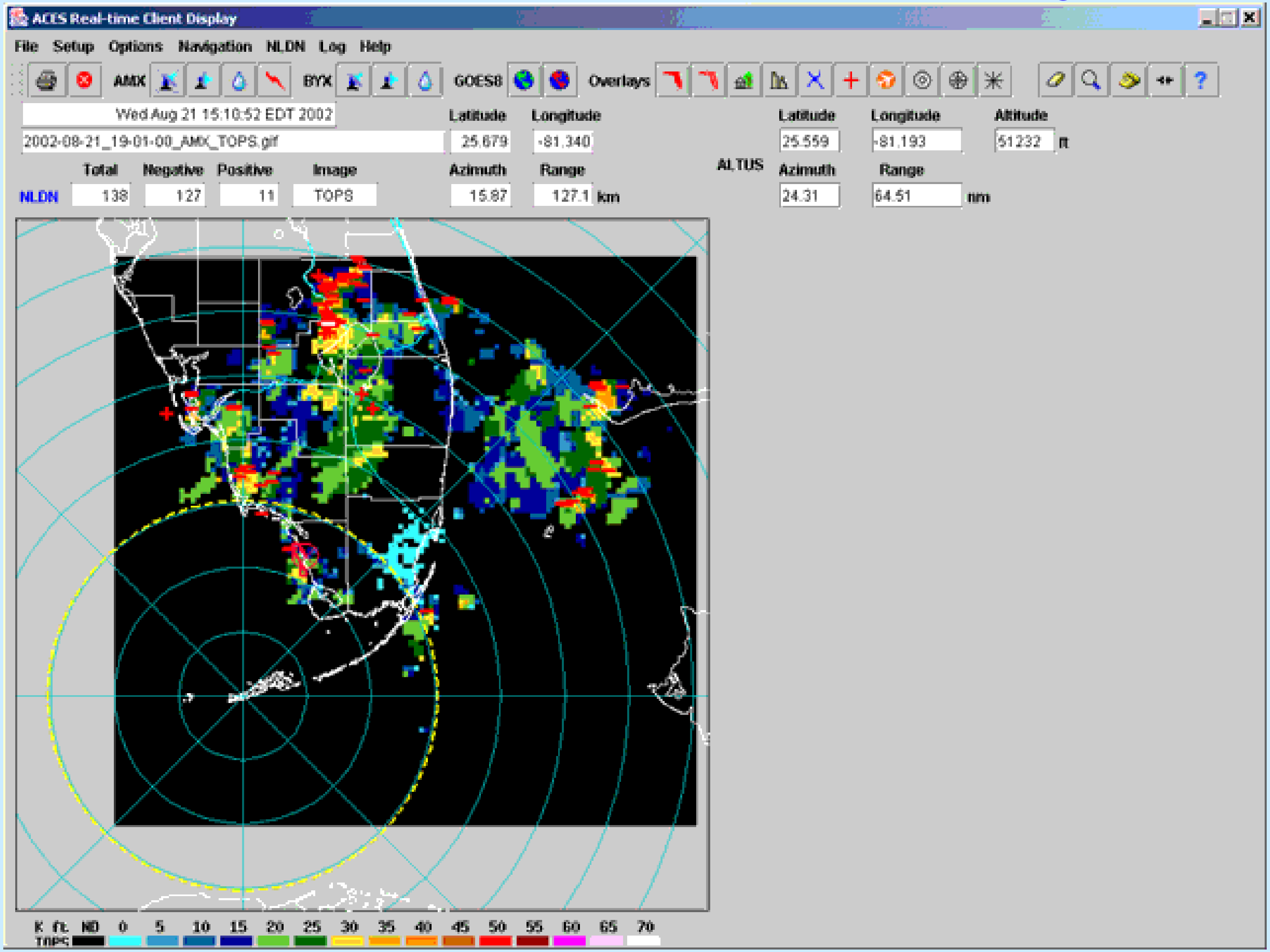
Supporting Data

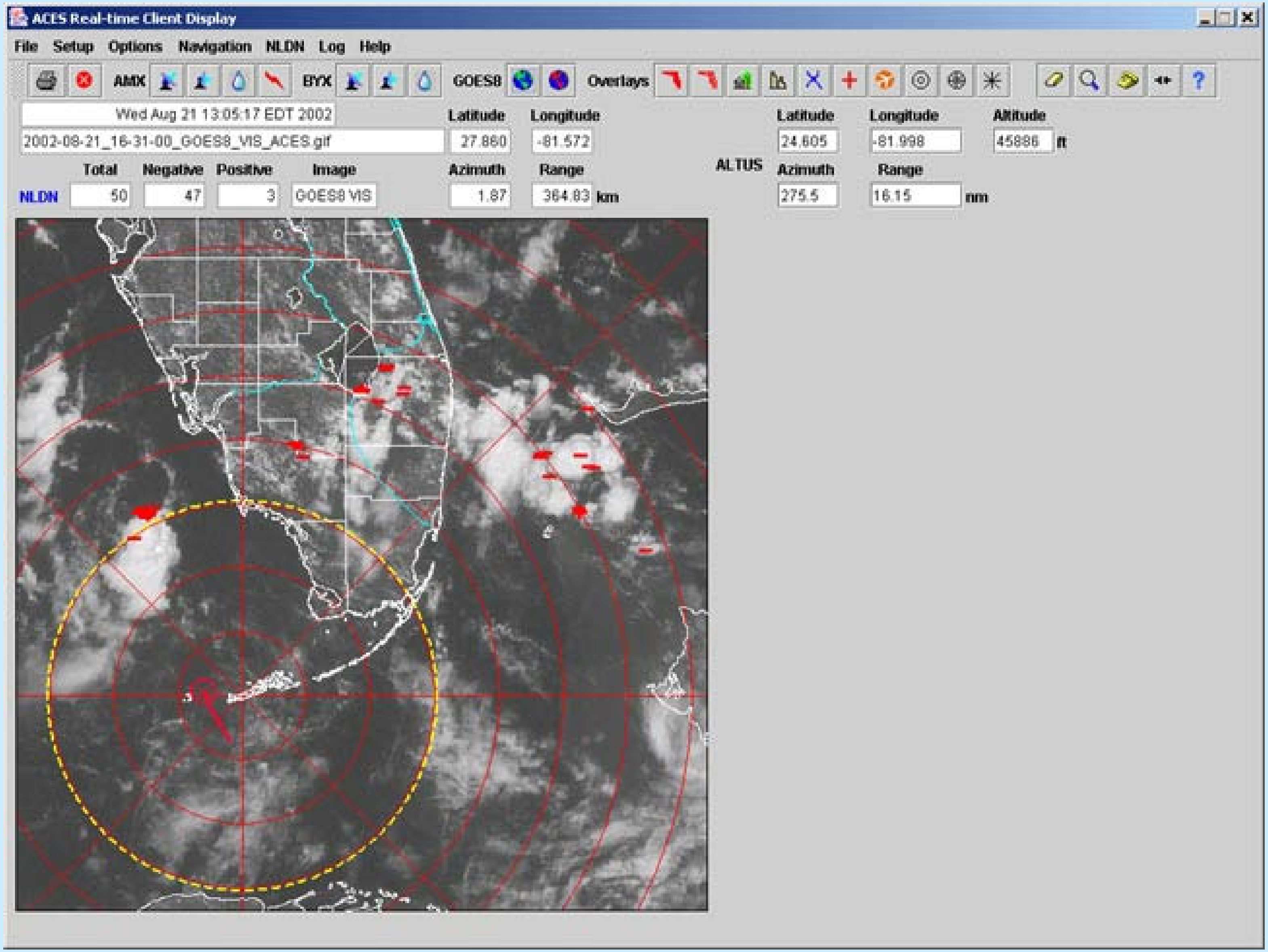
Product/Parameter		Latency	Primary Source
Radar	**WSR-88D (Miami, KW)**	**5-10+ min**	**MIDDS**
	NPOL (Ramrod Key)	**post mission analysis**	**FTP**
Lightning	**Cloud-to-ground (NLDN)**	**Real time**	**MIDDS**
	Total lightning (EDOT)	**post mission analysis**	**FTP**
Satellite	**GOES**	**15 min** **(5 min for rapid scan)**	**MIDDS**
Aircraft location	**INS/GPS from aircraft**	**Real time**	**Serial from Ground Control Station**

Access

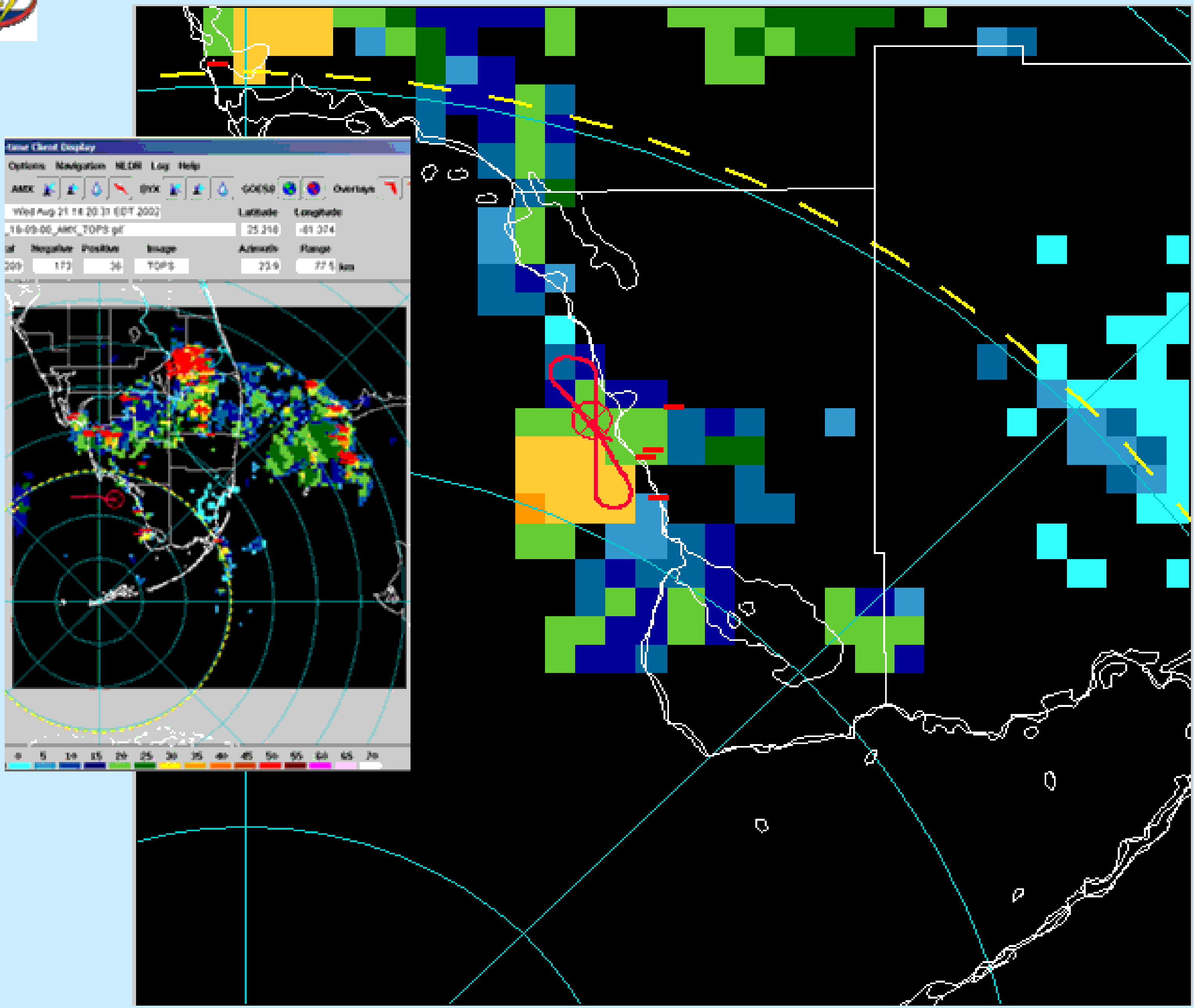
– Real time display products available to any project computer via LAN (requires Java application on local computer, display is platform independent)

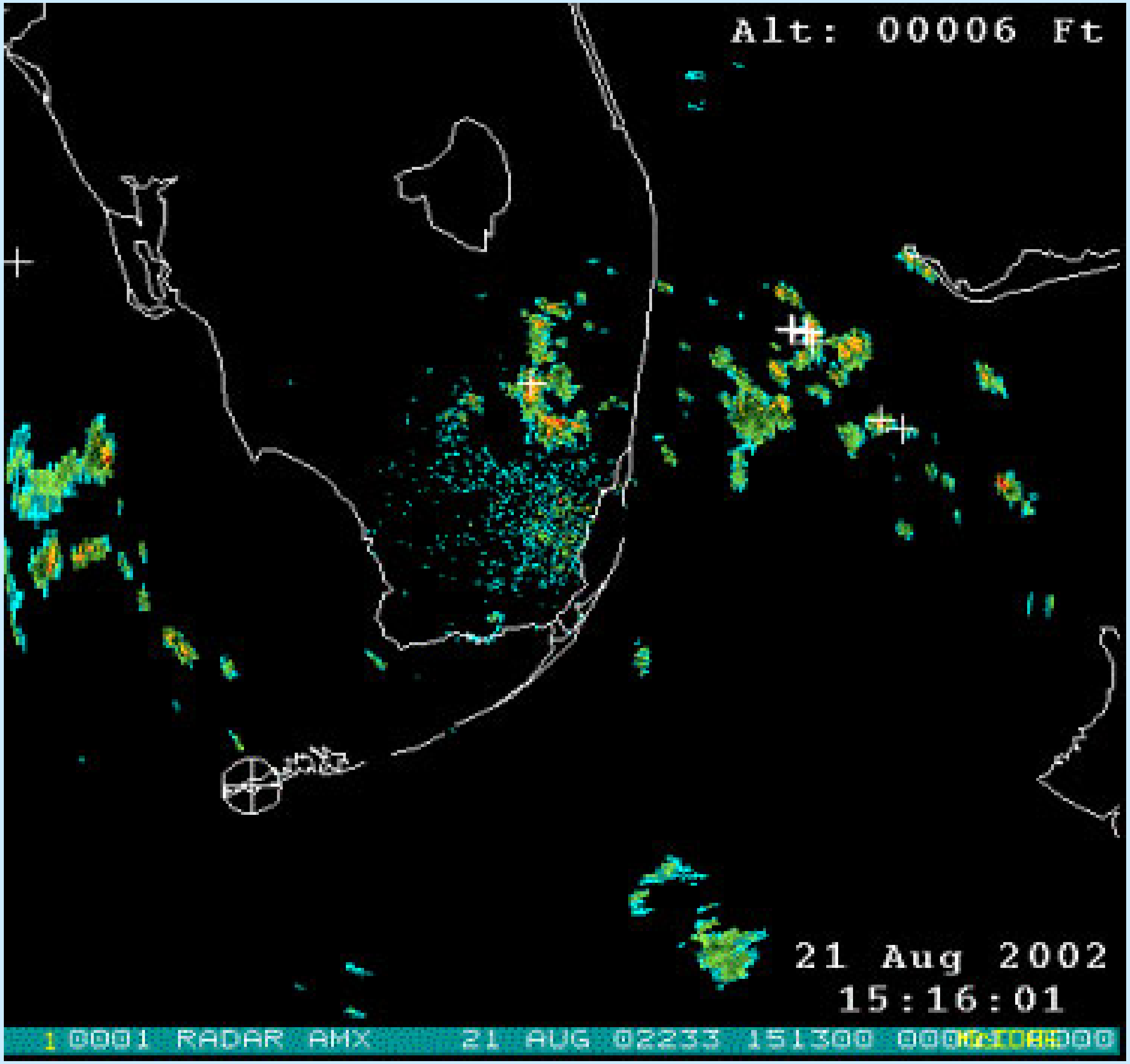
Real-Time Weather Display




ACES Real-time Client Display
File
Setup
Options
Navigation
NLDN
Log
Help
AMX
BYX
GOES8
Overlays
Wed Aug 21 13:05:17 EDT 2002
2002-08-21_16-31-00_GOES8_VIS_ACES.gif
Latitude
Longitude
27.860
-81.572
Azimuth
Range
1.87
364.83
km
Total
Negative
Positive
Image
NLDN
50
47
3
GOES8 VIS
ALTUS
Latitude
Longitude
Altitude
24.605
-81.998
45886
ft
Azimuth
Range
275.5
16.15
nm

The ALTUS Cumulus Electrification Study (http://aces.msfc.nasa.gov)




Alt: 00006 Ft
21 Aug 2002
15:16:01
1 0001 RADAR AMX 21 AUG 02233 151300

ACES Presentation Outline

- ACES Overview
- ACES Objectives
- Altus II and Payload
- FAA Approval Process
- ACES Campaign
- Conclusion

ACES Conclusions

- Demonstration of the UAV as a science platform flying in National Air Space
  - Minimum restrictions applied in COA (treated generally like a manned aircraft)
- Validated utility and promise of UAVs for scientific and operational weather research
  - High altitude, slow flight speed, and long duration
- Real-time weather display developed for ACES with aircraft tracking
  - Useful for precision weather research and other applications.
- Pilots and scientists co-located in Ground Control Station (GCS)
  - Improved execution and conduct of science mission

Future

- UAV capability that will enhance weather research
  - Over the horizon capability
  - TCAS (Traffic alert and Collision Avoidance Aystems)
  - Regulatory approval process to flying in national airspace
  - Reduced flight hour cost
- Altair (next generation science UAV) built by GA-ASI
  - More reliable and robust
  - Similar capabilities as the Altus

The Future - Altair

Pros

- Higher reliability, additional capabilities, greater safety
- Over the horizon capability, long duration missions
- TCAS (Traffic alert and Collision Avoidance System), ATC voice relay, redundant systems
- Larger payload (800 lbs), wing pods possible for add'l payload
- Improved regulatory environment

Cons

- Regulatory environment still uncertain
- Max altitude (52 Kft) a little lower than desirable