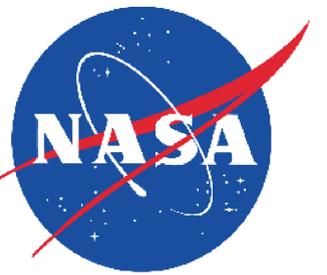




# Analysis of Rapidly Developing Low Cloud Ceilings in a Stable Environment

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## Project Objectives

- Improve forecast for shuttle de-orbit burn GO/NO GO decision
- Formulate a database of nighttime events with rapidly-developing ceilings below 8000 ft
- Identify the onset and dissipation times
- Document the atmospheric regimes favoring the rapid, stable cloud formation

## Methodology

- Developed code to identify inversions in the Cape Canaveral, FL evening and morning radiosonde in the lowest 8000 ft
  - Recorded the height & strength of inversions, and mean wind, shear & RH in layer beneath inversion
- Wrote code to examine hourly observations at the Shuttle Landing Facility
  - Identified all ceilings (BKN/OVC) with heights below 8000 ft
  - 2200 to 1200 UTC (focusing on nighttime hours)
  - Eliminated cases with obvious fog-burn-off, widespread clouds/precipitation
  - Recorded cases with possible ceiling formation
- Formulated a database of possible low ceiling development cases
  - Combined cases with possible ceiling formations and low-level inversions
  - Looked for days with high mean RH below inversion
  - Identified 70 possible cases with low ceiling formation
- Examined infrared satellite imagery for the 70 possible cases
  - Confirmed whether each day had development or advection
    - Very difficult with infrared imagery
  - Identified 4 cases with rapid ceiling formation



Space Shuttle Atlantis lands at night at Kennedy Space Center on 21 Sep 06

## Space Shuttle Flight Rules for Ceilings/Visibility

Ceiling / Visibility (kft)/(sm)			Redundant Microwave Landing System (MLS)	Single-String MLS	No MLS
KSC, EDW, NOR, Abort Once Around, Daily Primary Landing Site (PLS) Selection (all sites)	Concrete	Day	≥8/5 (WX RECON Required)	≥10/7	
		Night		<b>NO-GO</b>	
	Lakebed	Day		≥10/7	
		Night		≥15/7	NO-GO
Return To Launch Site (RTLS), Trans-oceanic Abort Landing (TAL)	Concrete	Day	≥5/4 RTLS ≥5/5 TAL	≥10/7	
		Night	(WX RECON Required)	<b>NO-GO</b>	
Augmented Contingency Landing Site / East Coast Abort Landing / Emergency Landing Site			0/0	≥8/5	
Pre-deorbit: One Auxiliary Power Unit (APU) failed OR Attempt two APU's procedure			≥10/7		

## Data and Period of Record

- Cape Canaveral, FL evening and morning radiosondes
- Hourly surface observations at the Kennedy Space Center Shuttle Landing Facility
- Archived infrared satellite imagery every 15-30 minutes
- Nighttime events only beginning at 2200 UTC
- Cool-season months of November to March, 1994 to 2005 (12 total cool seasons)

## Definitions

- Rapid development
  - Ceiling forms in less than 90 minutes
- “Event days”
  - Low ceiling violations at Kennedy Space Center (KSC) Shuttle Landing Facility (SLF)
  - Rapid development confirmed by examining infrared satellite imagery
- “Non-Event days”
  - Low ceiling violations at SLF
  - Rapid development did NOT occur
  - Low ceilings from mechanisms besides rapid development

## Previous Work

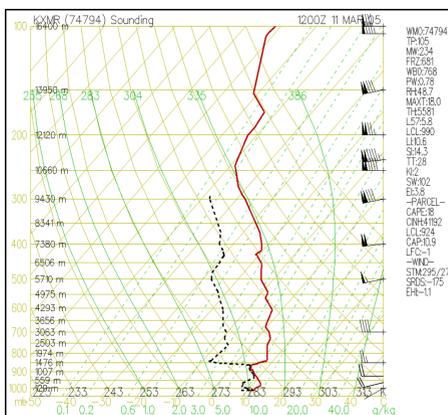
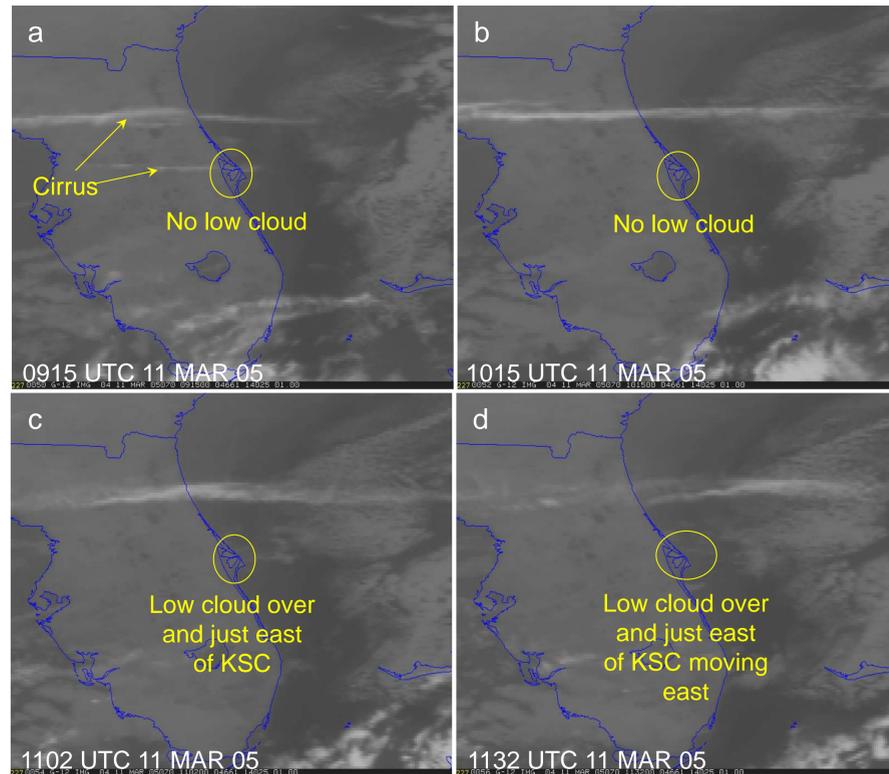
- Considered **daytime** only events
- Used **1 km visible** satellite imagery
- Identified atmospheric regimes favoring rapid, stable cloud formation
  - 85% of events had veering winds
  - Mean inversion strength 4.0 °C
  - Average onset time 1403 UTC

## Current Work/Preliminary Results

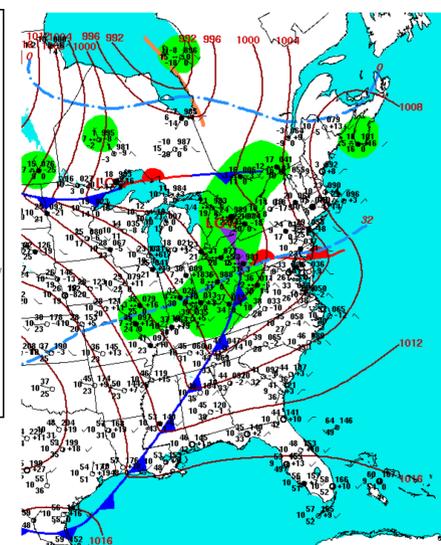
- Considered **nighttime** only events
- Used **4 km infrared** satellite imagery
- Identified atmospheric regimes favoring rapid, stable cloud formation
  - 75% of events had veering winds
  - Mean inversion strength 1.5 °C
  - Onset times: 0100, 1038, 1100, 1200 UTC

## Rapid Developing Ceiling Event

- Low cloud developed near SLF → moved slowly east



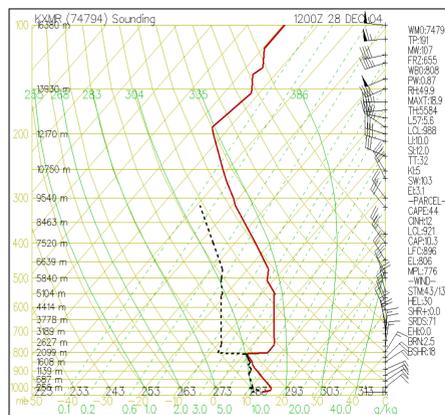
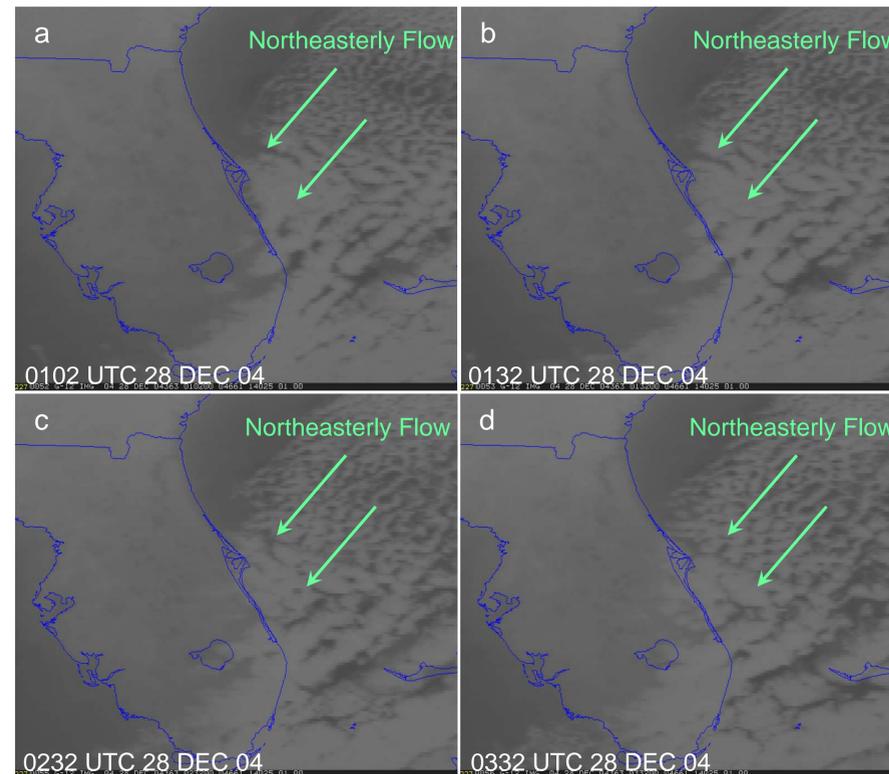
Morning Cape Canaveral Sounding



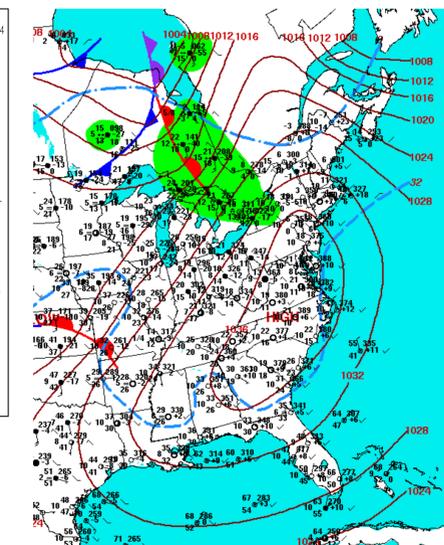
Daily Weather Map

## Advection Ceiling Event

- Onshore NE flow → low cloud moved west over SLF



Morning Cape Canaveral Sounding



Daily Weather Map

## Future Work

- Acquire and review more infrared satellite imagery
  - 100-125 cases total
- Review short wave infrared
  - Better signal than long wave?
- Consider looking at low level wind speed
  - Below the inversion?
- Determine forecast skill of veering/backing wind profile
  - Examine all cool-season days that meet pre-defined criteria
  - Find how many days had rapid ceiling development w/ veering winds
- Develop statistical forecast model from identified criteria
- Examine predictability of ceiling cessation times

One last note....using a 1 km visible satellite image makes it much easier to assess rapid development

