MCTEX Field Campaign
November-December 1995

ATS786
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3/8/2021
MCTEX Overview

• Maritime Continent Thunderstorm Experiment
• November-December 1995
• Funded by:
  • Australian Research Grants Council
  • DoE
  • Additional funding from: NSF, NASA
• Primary science goal: “to understand the organization and evolution of tropical island convection in the Maritime Continent and its role in the atmospheric energy and moisture balance.”
Maritime Tropical Island Convection

• The Maritime Continent has long been recognized as an important contributor to global circulation and energy balance

• Although individual convective storms are much less than the Rossby radius of deformation (1000 km), the scene is at least that large
  • This results in individual storms “punching above their weight” and

• Understanding maritime island convection is important for understanding the convective system as a whole
Location and Justification

• Given MCTEX’s goal of examining tropical maritime land-oriented convection, location is critical.

• Persistent thunderstorms and infrastructure to support the deployment led to the selection of the site.

• Deployed to the Tiwi Islands in Australia, north of Darwin thanks to persistent island convection.
Hector the Convector

• Regular convection that appears over the Tiwi Islands in the SH Summer
• Named “Hector” in the 1940s by pilots during WWII
• Useful natural laboratory for studying island-forced natural convection in the Maritime Continent

Image Credit: Dakota Smith (via twitter), CIRA/RAMMB AHI imagery
Specific Science Objectives

• Examination of the life cycle of convection from initiation to mesoscale organization
• Investigation of processes related to cumulus parameterization
• Quantification of the water budget of island thunderstorms
• Improving satellite rainfall algorithms
• Examining ice processes and cloud electrification
• The role of the surrounding ocean on island thunderstorm development
• The interaction of tropical convection and radiative processes.
Instrumentation/Platforms

• Remote Sensing:
  • Cloud and rain radars
  • Radars from 5 cm to 3 mm wavelengths, including the BMRC/NCAR CPOL
  • Lidars, wind profilers, radiometers

• In Situ:
  • FIAMS Cessna 340A
  • RV Franklin (oceanography)
  • Rain gauges and surface stations
  • Aerosonde (fixed wing drone)
  • Radiosonde Observations
  • Balloon Borne Precipitation Particle Image Sensor
  • Electric Field Mills, lightning detection finders

• Numerical Modeling
Aerosonde

• Autonomous Aerosonde
  • Perhaps the first UAV for atmospheric science to utilize GPS?
  • Used Inmarsat for telemetry and communication
• Aerosonde carried pressure, temperature, and humidity sensors and used GPS to calculate wind
• Deployed to define the PBL circulations
  • Measurements primarily between 80 and 200m AGL

Balloon Borne Precipitation Particle Image Sensor

- Radiosonde with onboard particle imager
- Photographic imager
  - Imager has an IR beam that can be interrupted by particles >0.5mm in diameter
  - Once the IR beam is interrupted, flashes of different durations fire and images are transmitted to a TV
- Electric field particle sensor
  - As precipitation falls through an induction ring, the charge changes and is reported via LEDs on the video

Lightning Detection Equipment

Rotating van field mill
(measures electric field)

LLP station
(detects azimuth, polarity, and magnitude of CG lightning)
Sampling and Hectors Overview

• 20 total Hectors observed during the field campaign period
  • 11 IOP days with all instrumentation
• Hector rained for an average of 6:38 during MCTEX, with an average total rainfall of \(7.61 \times 10^7\) m\(^3\) (average rain rate of 4.2 mm hr\(^{-1}\))
• Easterlies dominated the low levels (<5km) with the flow reversing to westerlies with height
Convective Lifecycle Overview

• In most cases, prior to Hector’s formation, sea breeze formation and associated convection initiate first
  • Surface fluxes critical to moistening the PBL to generate this initial convection

• Two types of convective initiation/organization mechanisms identified for Hector:
  • Type A: Direct forcing from colliding sea breezes (less common, “nature’s backup mechanism”)
  • Type B: Indirect forcing from interactions between cold pools and sea breezes


Convective Lifecycle


Image Credit: Dakota Smith (via twitter), CIRA/RAMMB AHI imagery
Surface fluxes and moisture advection

- Hector needs an environment suitable for convection
  - Moisture, instability, and lift
- Simpson et al. (1993) suggested that ~450 W m$^{-2}$ evapotranspiration is needed to produce the instability and moisture for Hector
- Observations from MCTEX suggest that 450 W m$^{-2}$ of evapotranspiration is not reached
  - Instead, it seems that moisture advection from the sea breeze is important to prime the atmosphere for Hector

Average diurnal energy balance at the Savanna site at Maxwell’s Creek


PBL structure

• Because of the nature of Hector’s initiation, PBL structure is critical to early development
  • Small environmental changes resulted in substantial changes in Hector’s location

• In the morning, surface fluxes warm, mix, and moisten the PBL, but there is a competing drying effect from free troposphere entrainment

• PBL can assist with initial cloud organization, with Rayleigh-Bénard convection or convective rolls appearing on some days

• Hector’s outflow brings cooler, dryer air that results in a diverging flow before oceanic air advection takes over overnight

Initial convective initiation without external forcing

- Shallow convection initiates along the sea breeze fronts over the Tiwi Islands
  - The shear-relative orientation of the sea breeze front can determine how easy it is to reach the LFC
- Depending on favorability of the environment to deep convection:
  - Type A (3/14): Direct forcing of Hector by sea breeze collision
  - Type B (11/14): convection along sea breezes grows, produces cold pools, cold pools collide with existing fronts
- Hector is initiated and matures into a larger convective system

Type B CI

Fig. 16. Example of MCS on 28 Nov under conditions of near stagnation. Sea-breeze fronts are white and major gust fronts are red or green. Low-level radar reflectivity factor (dBZ) and surface station data (θe, q, wind) are plotted. The low-level environmental wind is light and variable (L&V). The wind scale for surface stations is located in lower-left corner of (a). This is one of the strongest Hectors during MCTEX. Note stage 5 collision of Bathurst (green) and Melville (red) gust fronts.
Cold pools: critical for Type B convection

- Detailed observations of two cold pools with RASS/wind profiler data
- Observed a 6K temperature drop (comparable to US Plains cold pools)
  - But cold pools are shallower than Great Plains
- Case 1 excited a gravity wave
  - Potential for convective initiation removed from the cold pool boundary
- Case 2 enhanced an existing weak cell

Cloud and Precipitation Microphysics

- Detailed microphysics observations were available from the Aerosonde
- Supercooled raindrops ($T = 0$ to $-20^\circ C$) were present in the convective cores
- “Massive ice production” observed within Hector
  - Suggested in the BAMS paper that this could be due to the Hallett-Mossop process or ejection of ice particles as graupel grows

Science Results: Cloud Electrification

• The mixed-phase region and ice production were conducive to cloud electrification

• No significant surface electric fields or lightning were associated with warm convection
  • Instead, electric field and flash rate were highly correlated to mixed-phase ice mass; supports noninductive charging theory

• Hector maintained its population of supercooled drops rather than instantly glaciating
  • Due to more intense updrafts?

Microphysical-Dynamical Link

- Glaciation of supercooled raindrops leads to release of latent heat and a strong microphysical-dynamical link
- New updrafts constantly transported liquid drops above the freezing level
  - Replenishment of supercooled water resulted in more persistent lightning

Science Results: Rain Measurement from Radar

- First measurements validating dual-pol rainfall measurements with C-band radar
- $K_{DP}$ rainfall estimates performed substantially better than reflectivity alone
- There are still biases due to changes in DSDs that aren’t picked up by radar

Observations of Cirrus

• First observations of cold tropical cirrus with LIDAR/Radiometer (LIRAD)
• Observations needed for parameterization in climate and mesoscale models
• Larger IR absorption in tropical cirrus vs. midlatitude cirrus
• Typical cloud depths of 3-4km

Summary

• MCTEX focused on all aspects of Maritime Continent island convection

• Advancements made in understanding of:
  • PBL structure and moisture and energy fluxes from islands
  • Convective initiation of island convection
  • Microphysics and the microphysical-dynamical link
  • Cloud electrification
  • Cloud radiation and anvil structure


