

Observations of Cirrus Evolution from
Convective Outflow during the
Tropical Warm Pool International Cloud Experiment
(TWP-ICE)

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Greg McFarquhar * Sally Benson

Based on contributions from Brian Soden and Min Deng.

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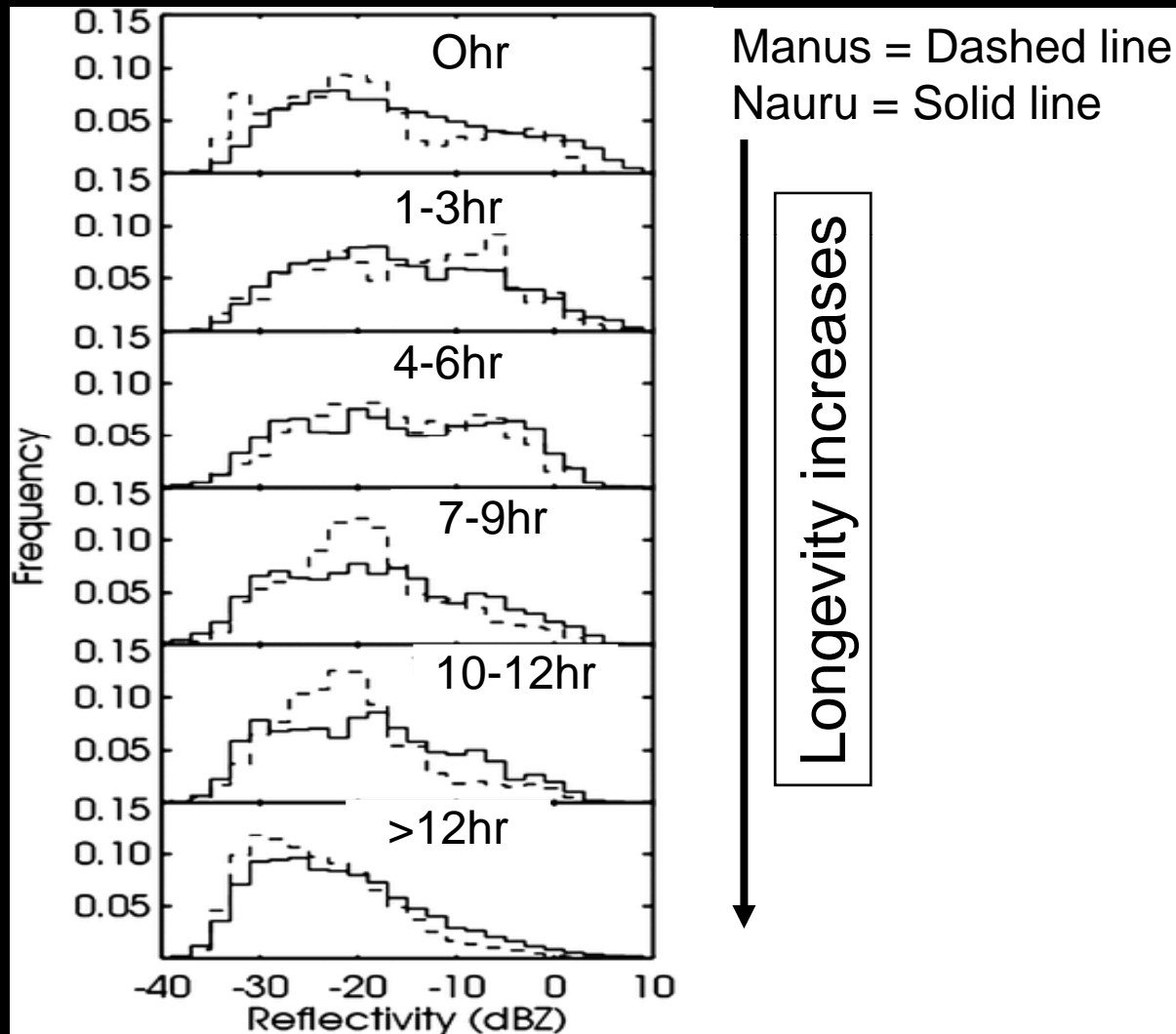
Cirrus Evolution Study

A tropical landscape featuring several palm trees of varying heights against a bright blue sky filled with scattered white clouds. The foreground shows a green lawn and a paved path. The overall scene is bright and sunny.

The goal is to discover how tropical cirrus clouds are maintained and either evolve into persistent cloud entities or dissipate soon after leaving a convective cell.

Why are cirrus properties evolving similarly in Manus and Nauru?

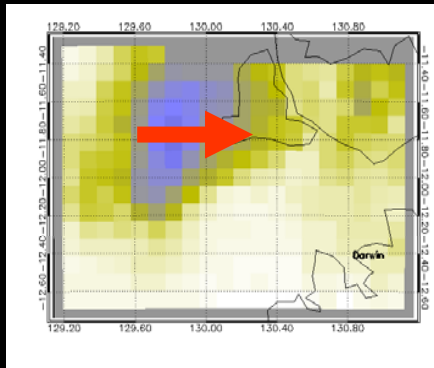
Layer-Mean Radar Reflectivity



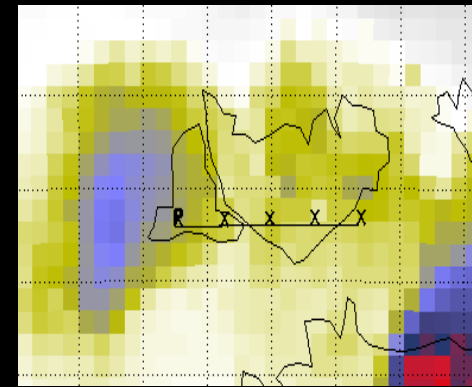
The frequency distributions of layer-mean radar reflectivity for different longevity are very similar at Manus and Nauru (Mace et. al 2006).

Method for Cloud Evolution Study

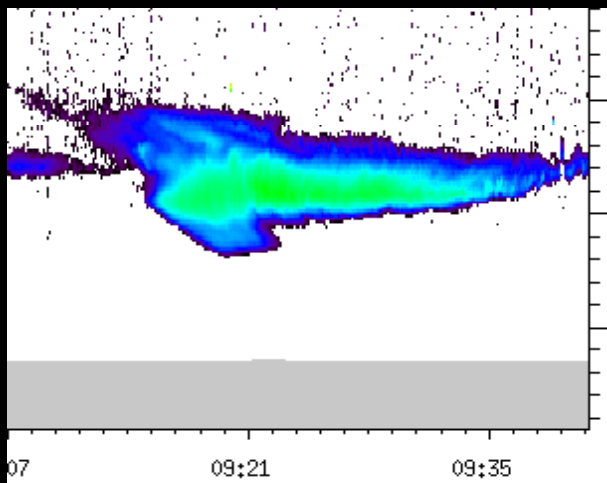
1. Flight Coincidences



2. Time since convection

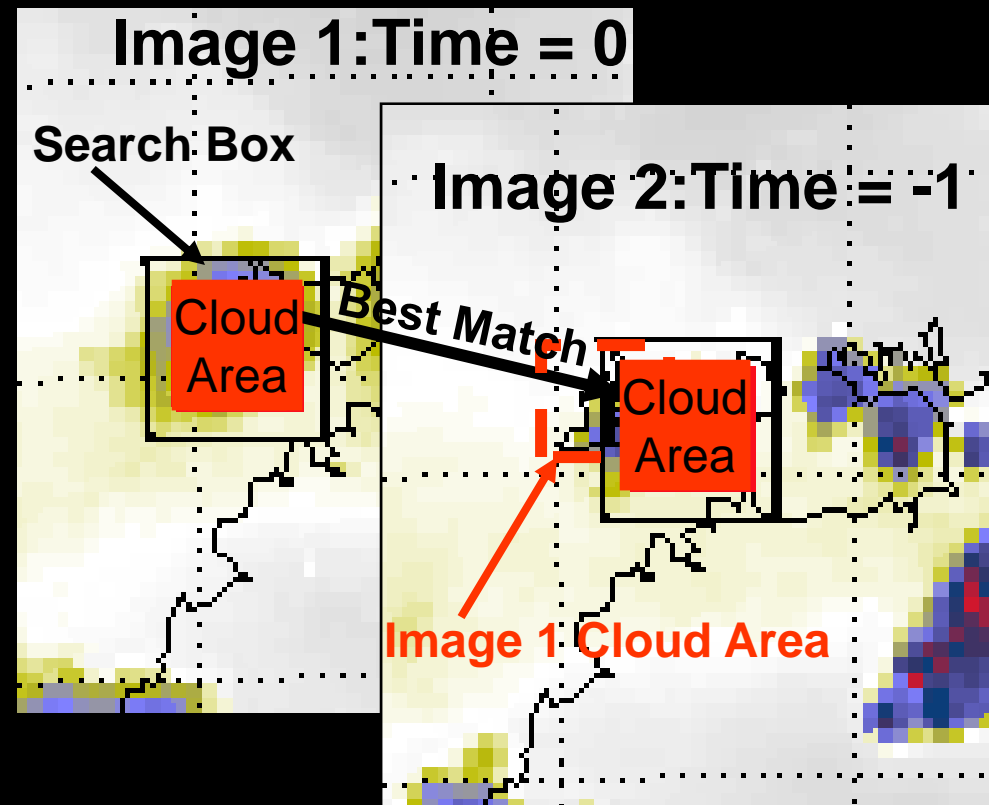


3. Twin Otter Flight Data (IWC) 4. Proteus Flight Data (CSI, CPI)



How do we track using water vapor imagery?

1. Define a cloud area (red box) around a center point at the initial time ($t = 0$).
1. For a previous time ($t = -1$), define a cloud area for every point within a search area (black box).
3. Choose the “best point” from the previous time.



Dissipating Anvil (10 February)

Track Path (10 Feb case)

Start time: Airplane
“P” intersects the
Cirrus “C”.

Next time: -1 hour

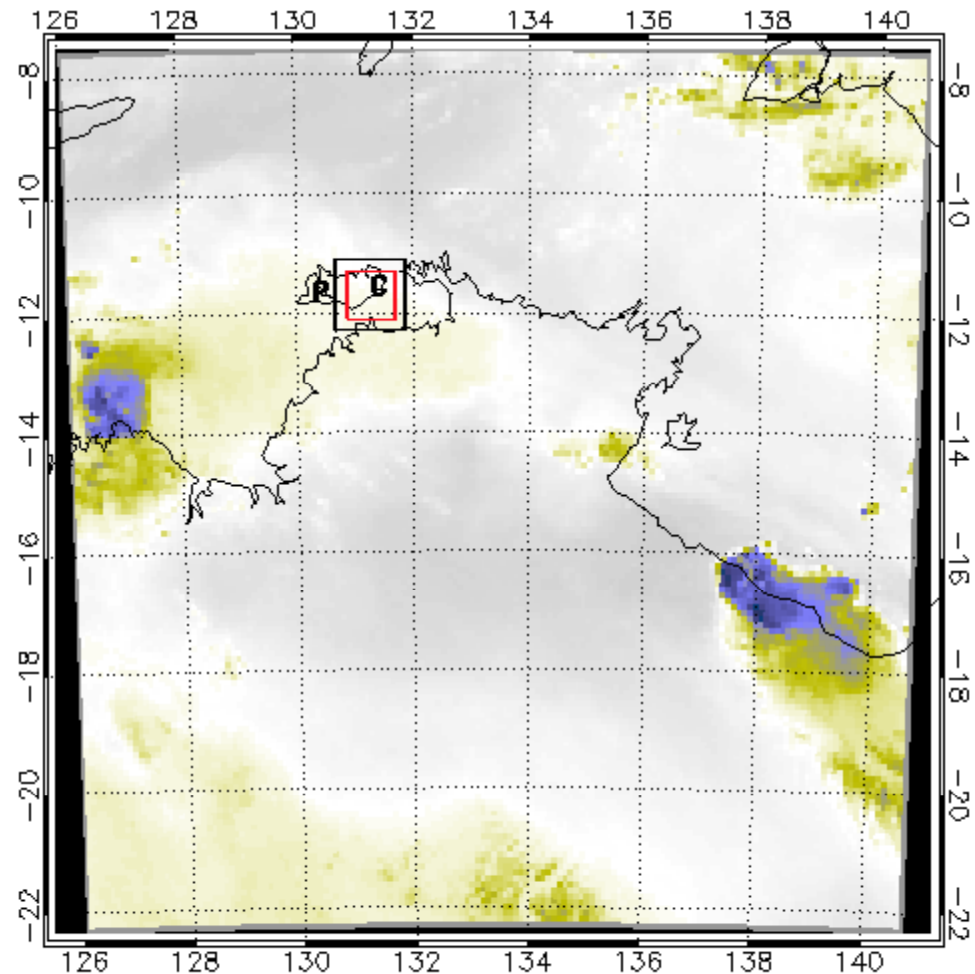
Watch the C (cirrus).

The airplane “P” flew
through the cirrus that
has evolved from
convection 3 hours
ago.

Tracking Box on 6.7 Micron Brightness Temperatures 41 Feb 2006 02 UTC

193 205 218 231 243 256 269 281 294 307 320

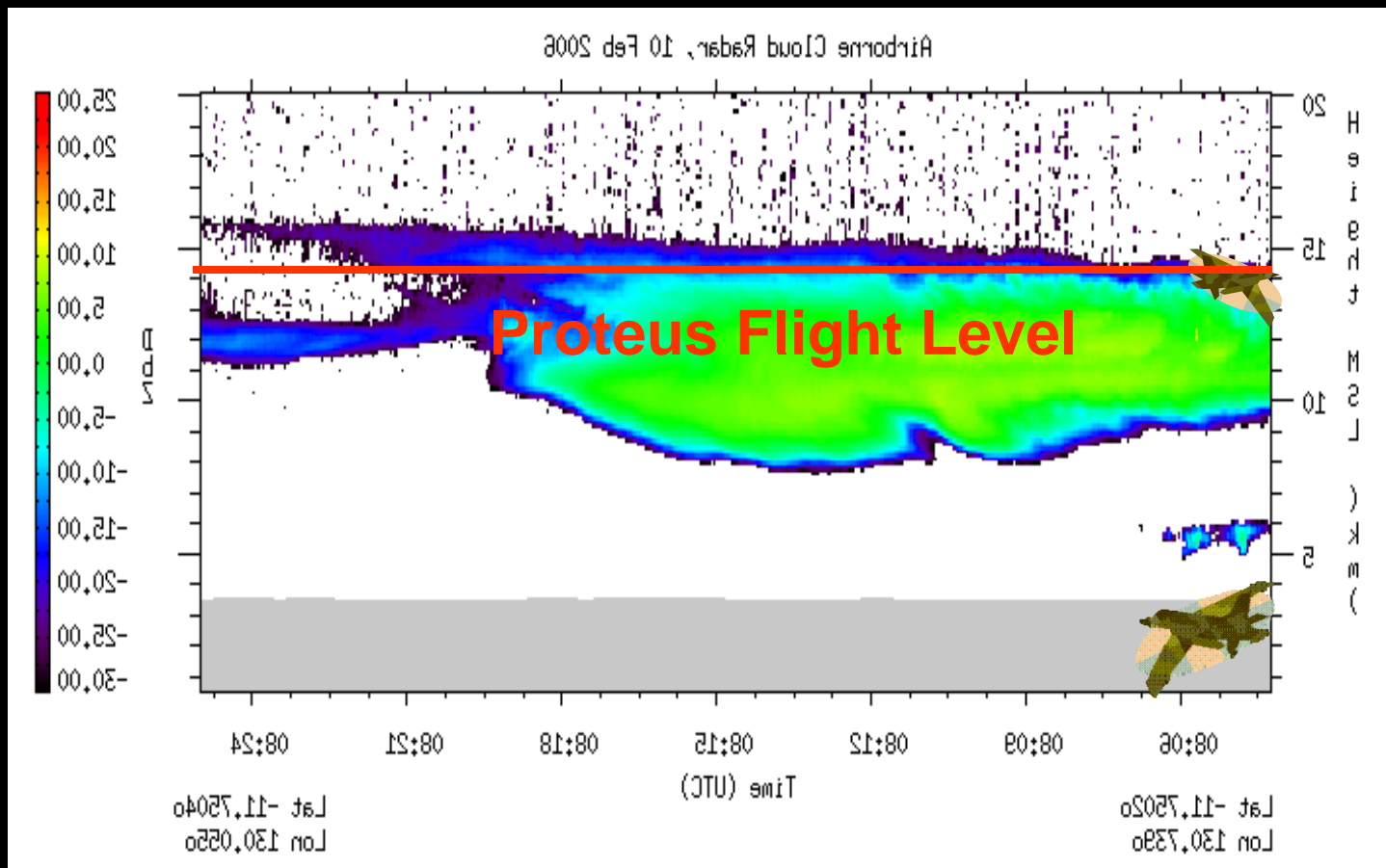
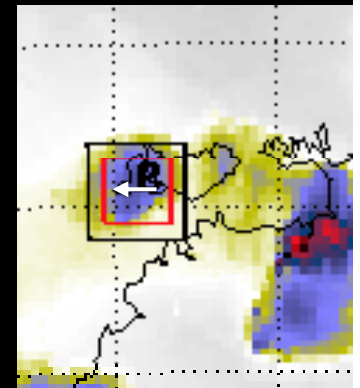
The tracked points Cor Lat: -11.6572 Cor Lon: 131.286
The changed variable is control to on



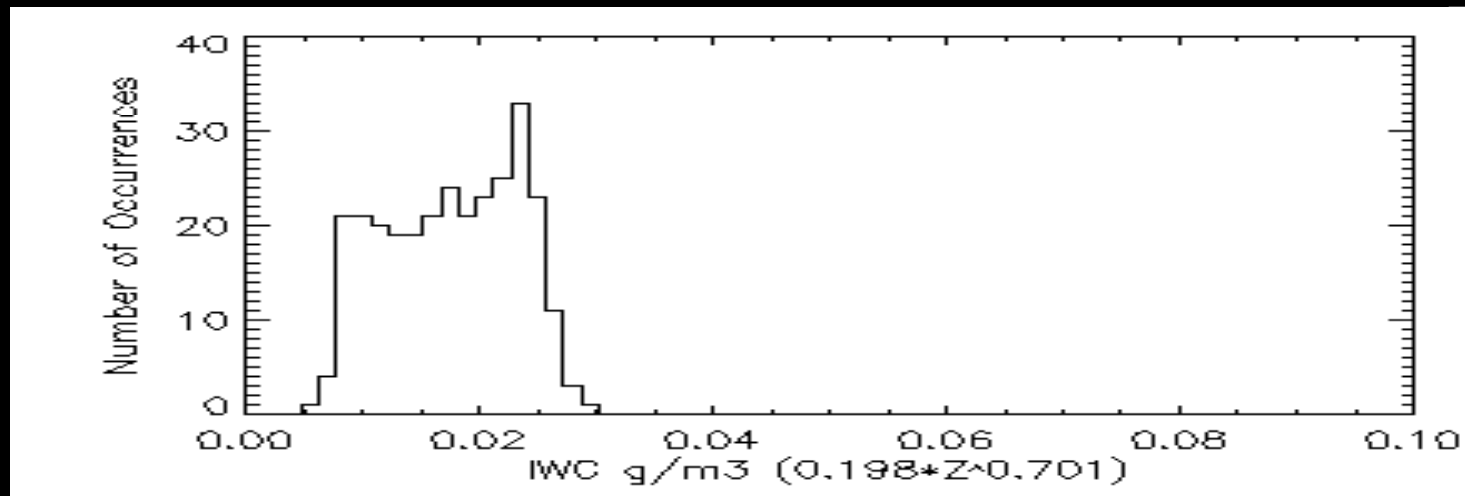
Airborne Cloud Radar on Twin Otter Aircraft

Purpose: To determine Ice Water Content from Z (Liu, Illingworth, 2000)
(10 Feb Case)

Satellite Image
and Flight Track



Ice Water Content Analysis from Radar Z (10 Feb Case)

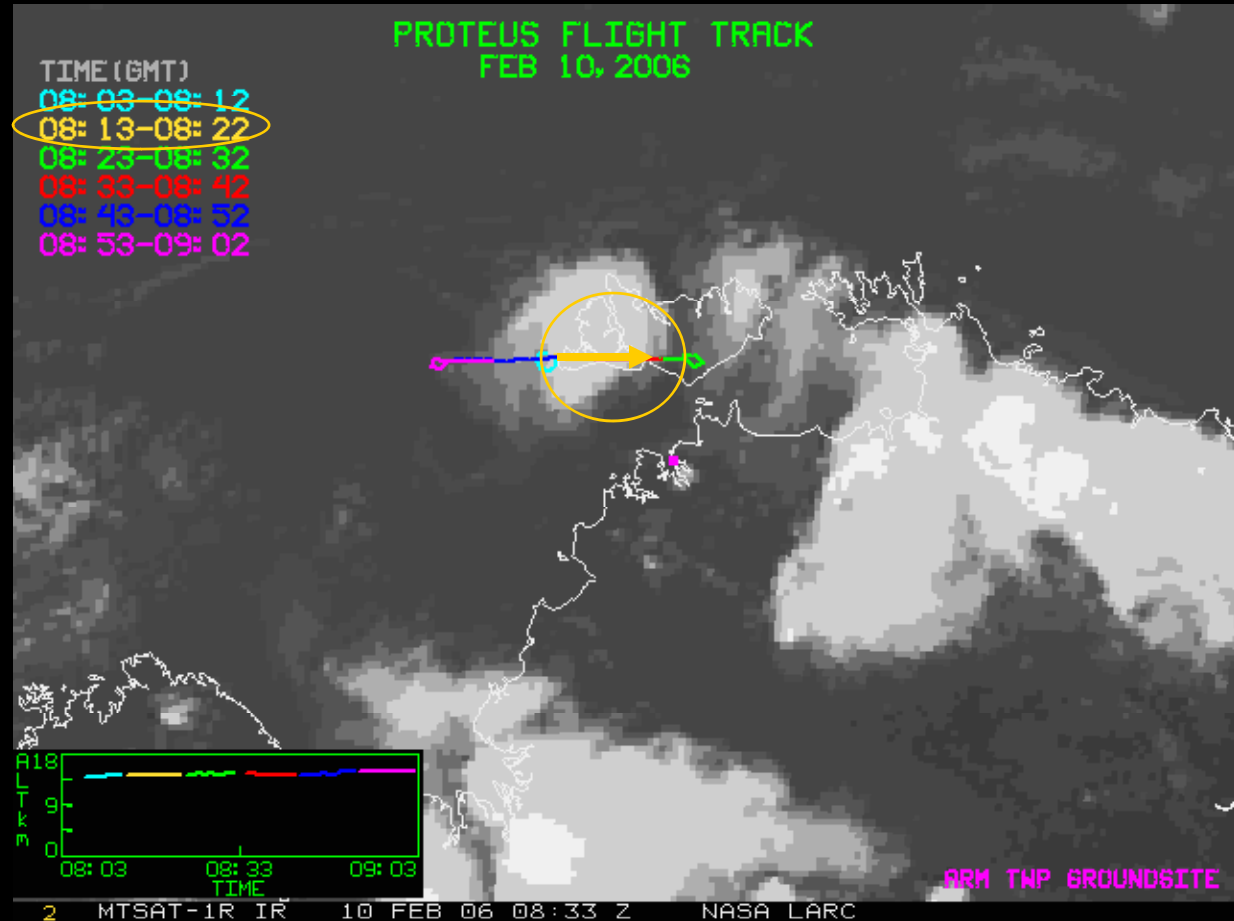


- Mean IWC = 15.4 mg/m³
- Standard Dev. IWC: 5.6 mg/m³
- Data Fraction: 1.0
- Proteus Altitude: 14.8 km

Radar Data provided courtesy Steve Denardo and Richard Austin
Analysis by Jay Mace

Cloud Spectrometer and Impactor (CSI) (10 Feb Case)

- Cloud Water Content from the CSI instrument = 2.38 mg/m^3
- Start time (hh:mm:ss): 8:17:10 UTC
- End time: 8:19:48 UTC



2/10/2006 Max Size. <----->200microns focus gt 25 and cutoff lt 6



Cirrus Ice Crystals
↔ = 200 microns

**Two seconds of
Cloud Particle
Imager data while
flying through the
decaying cirrus
anvil.**

**Notice the few plate
like crystals and
many irregular
spheres.**

Persistent Cirrus (29 January)

Track Path (29 Jan case)

Start time: Airplane
“P” intersects the
Cirrus “C”.

Next time: -3 hours

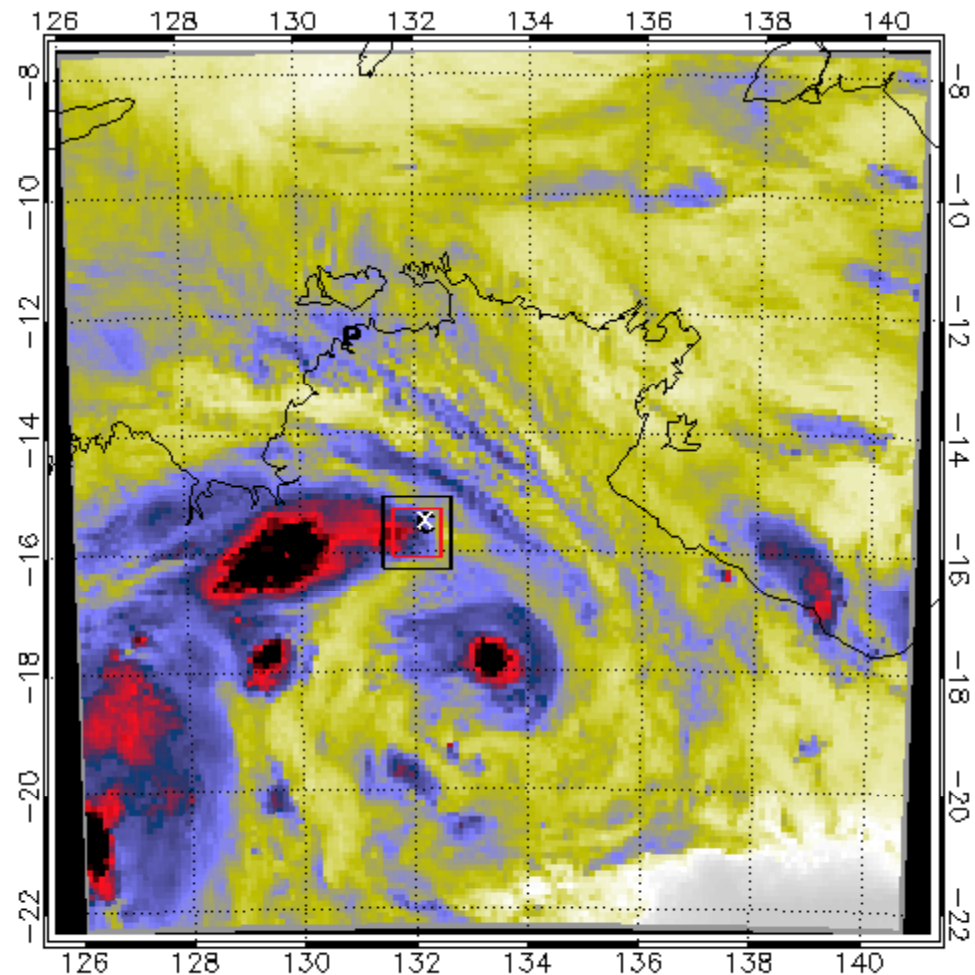
Watch the C (cirrus).

The airplane “P” flew
through the cirrus that
has evolved from
convection 14 hours
ago.

Tracking Box on 6.7 Micron Brightness Temperatures 28 Jan 2006 17 UTC

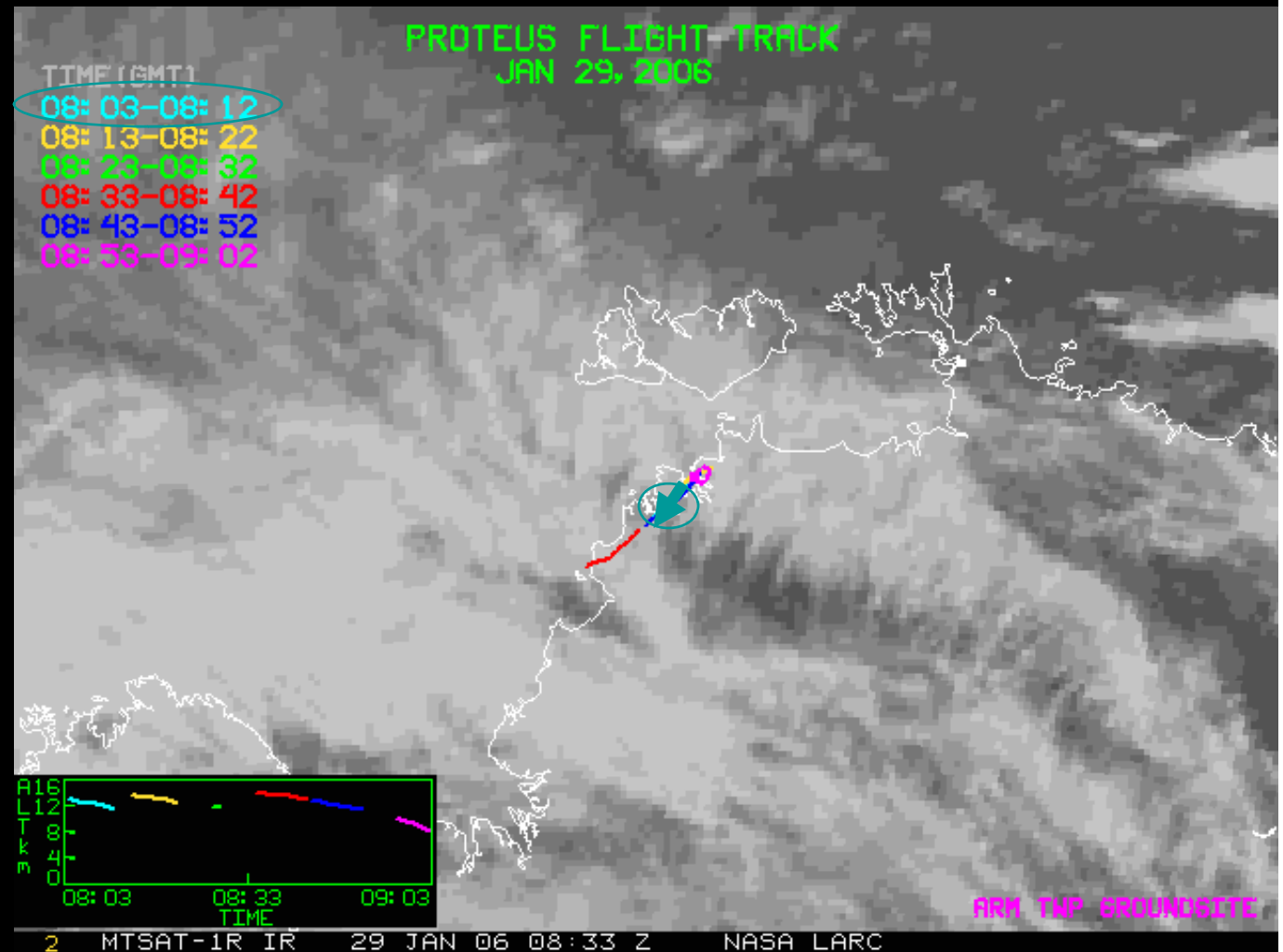
193 205 218 231 243 256 269 281 294 307 320

The tracked points Cor Lat: -15.6419 Cor Lon: 132.064
The changed variable is control to on

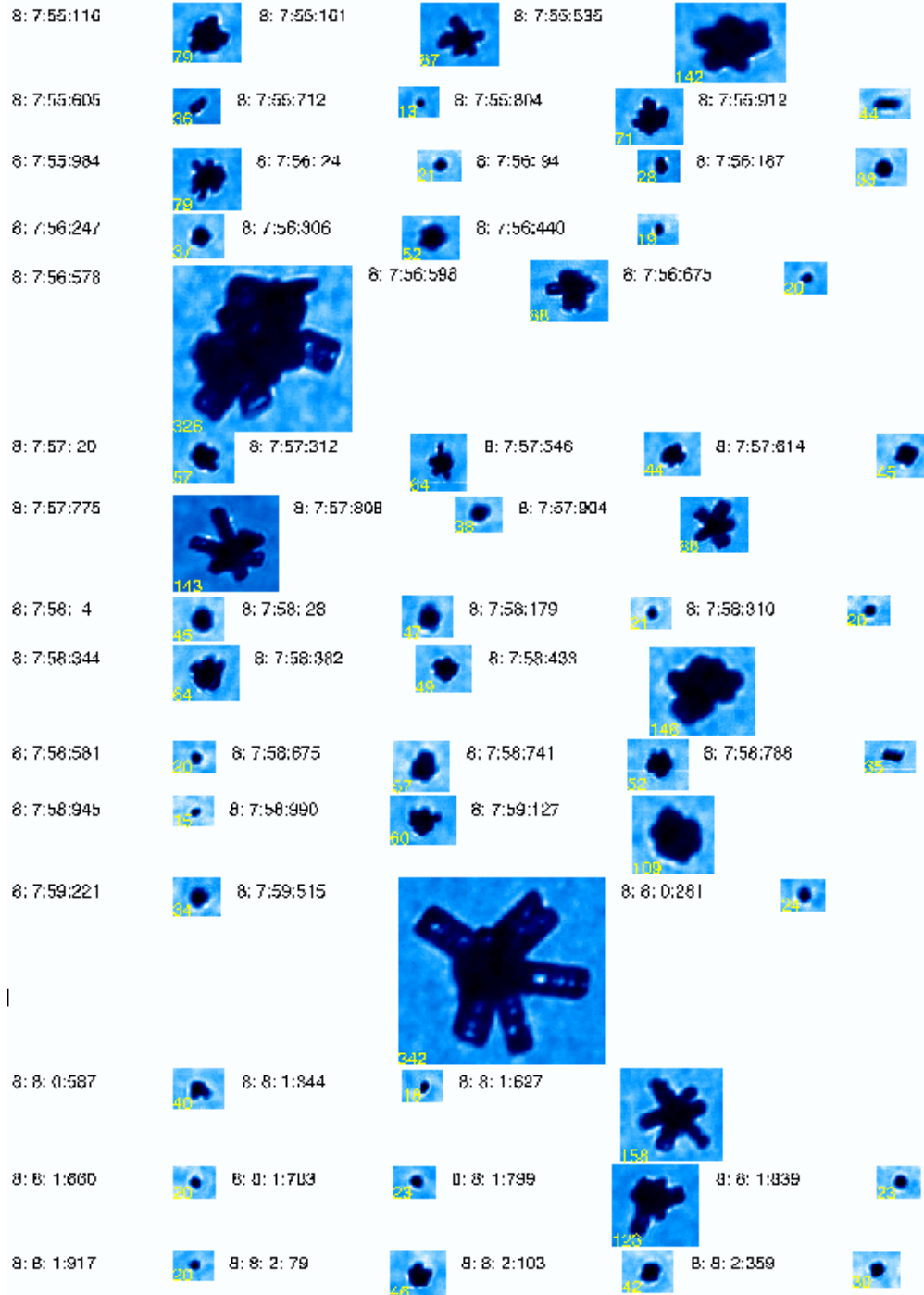


Cloud Spectrometer and Impactor (29 Jan case)

- Cloud Water Content from the CSI instrument = 21.22 mg/m^3
- Start time (hh:mm:ss): 8:07:52 UTC
- End time: 8:09:56 UTC



1/29/2006 Max Size. <----->200microns focus gt 25 and cutoff lt 6



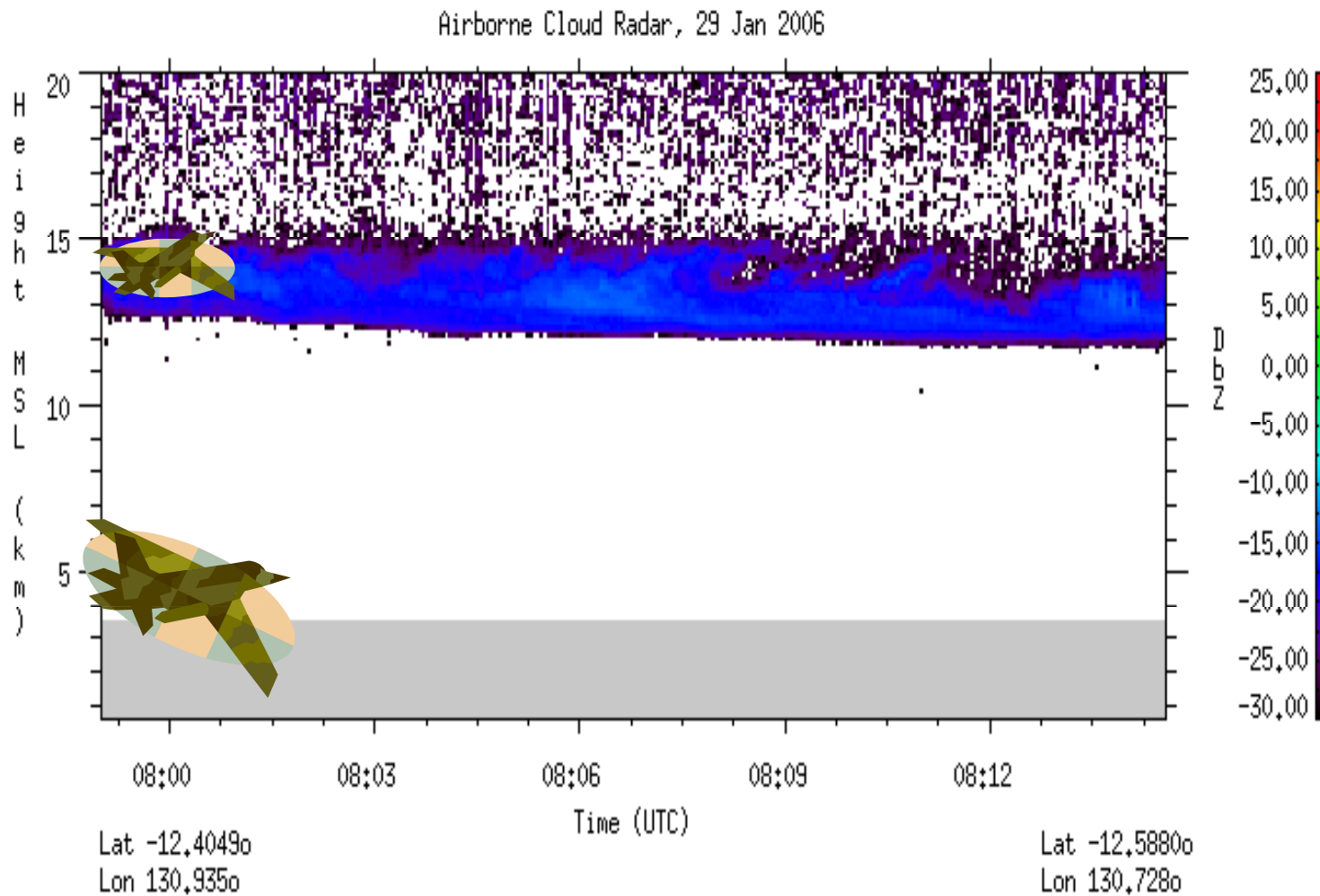
Cirrus Ice Crystals
↔ = 200 microns

One second of Cloud Particle Imager data while flying through the persistent cirrus.

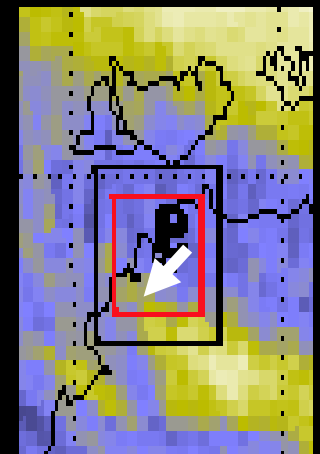
Notice the small spheroids and the bullet rosettes.

Airborne Cloud Radar on Twin Otter Aircraft

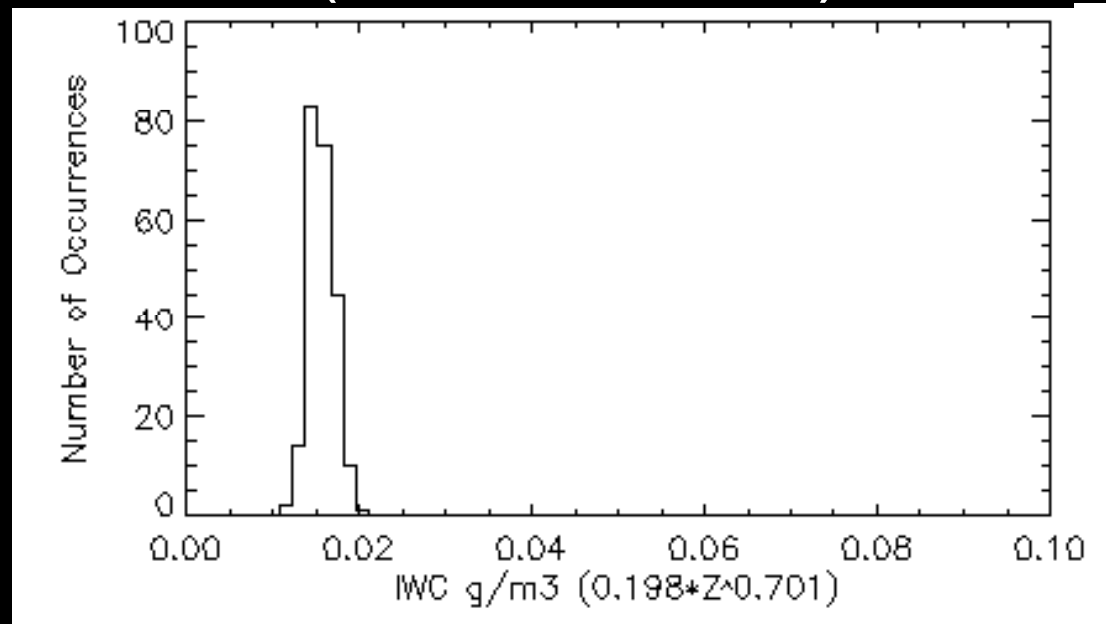
Purpose: To determine Ice Water Content from Z (Liu, Illingworth, 2000)
(29 Jan case)



Satellite Image and Flight Track



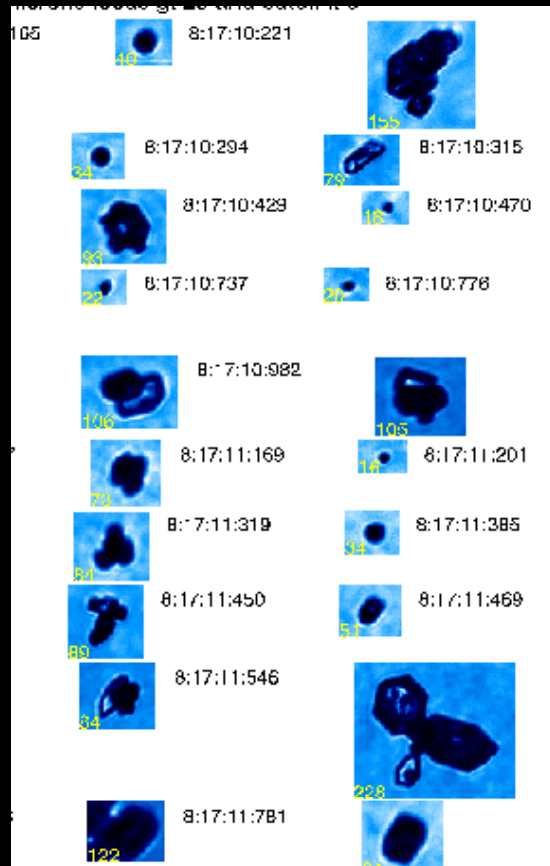
Ice Water Content From Radar Z (29 Jan Case)



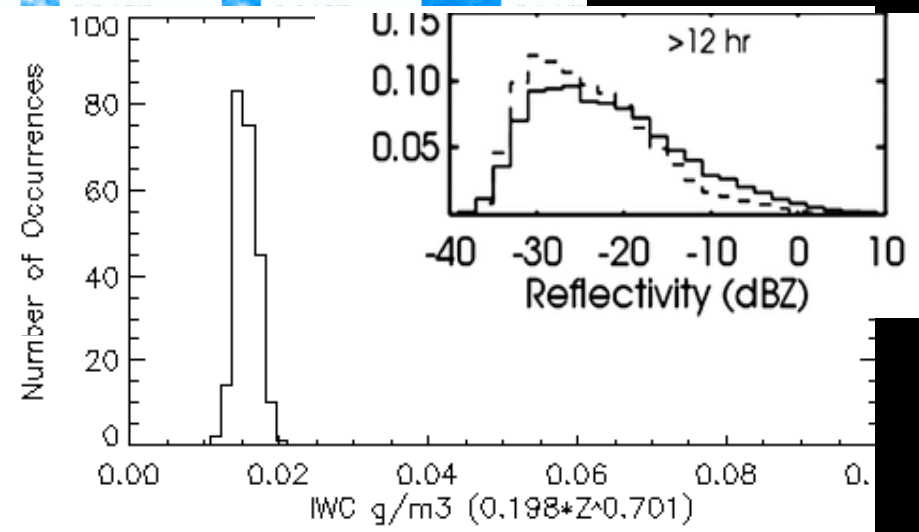
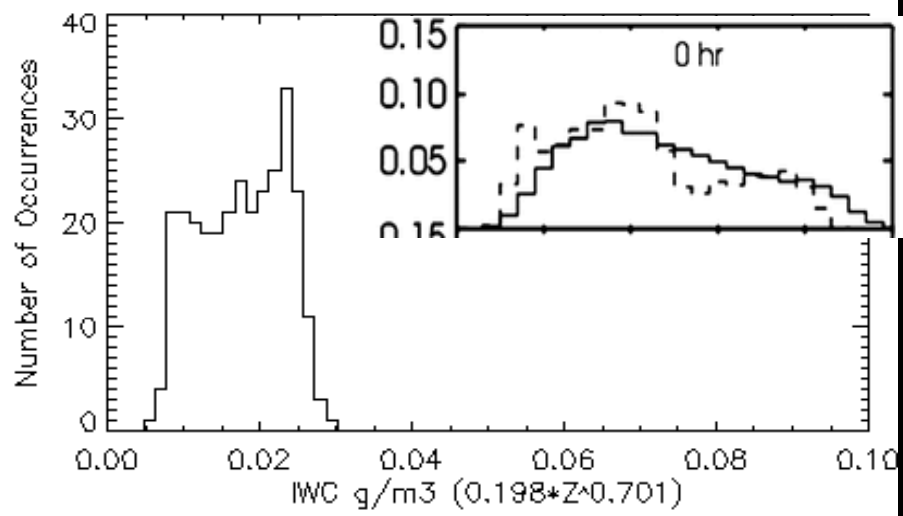
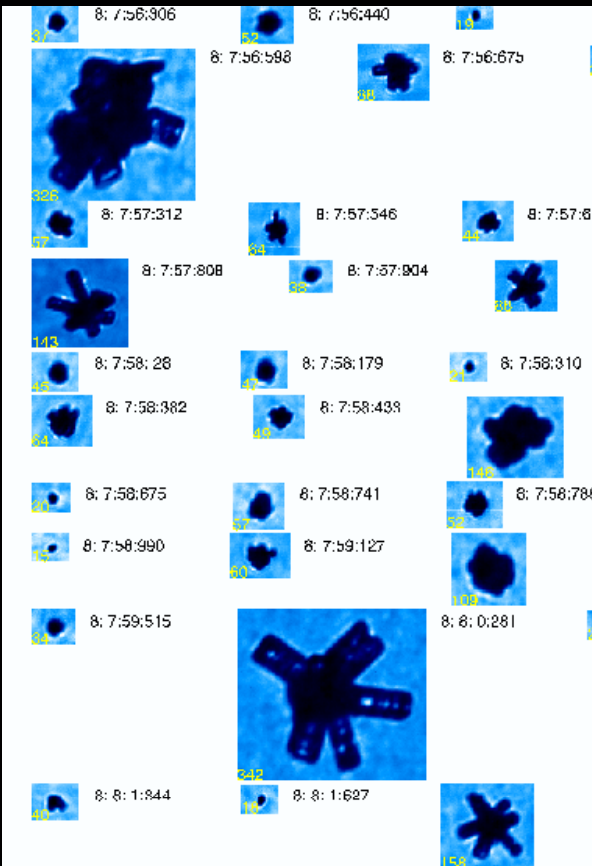
- Mean IWC = 13.4 mg/m³
- Standard Dev. IWC: 1.6 mg/m³
- Data Fraction: 1.0
- Proteus Altitude: 13.0 km

Radar Data provided courtesy Steve Denardo and Richard Austin
Analysis by Jay Mace

Fresh Anvil



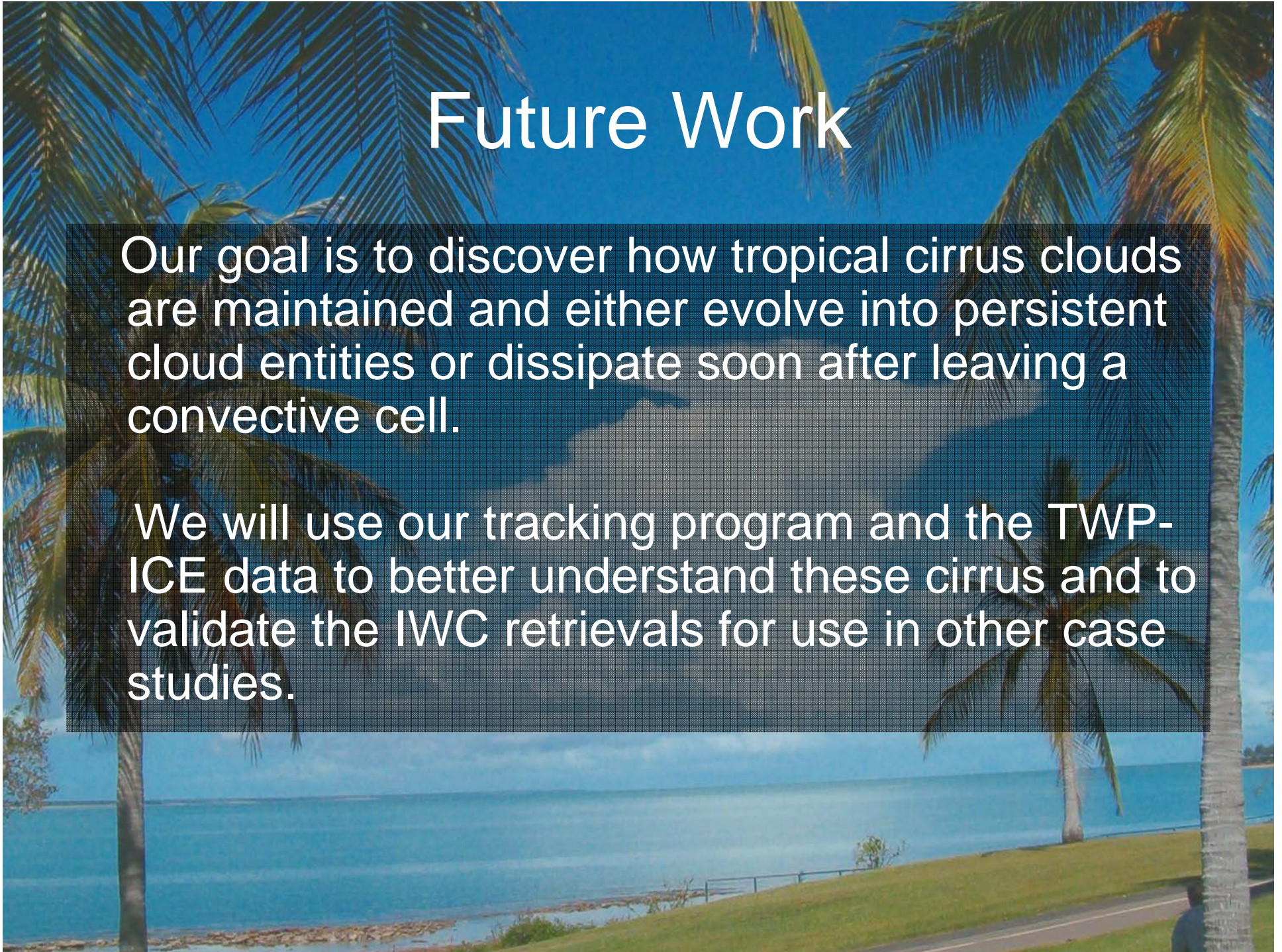
Aged Cirrus



Future Work

Our goal is to discover how tropical cirrus clouds are maintained and either evolve into persistent cloud entities or dissipate soon after leaving a convective cell.

We will use our tracking program and the TWP-ICE data to better understand these cirrus and to validate the IWC retrievals for use in other case studies.



Credits:

- Airborne Cloud Radar Data courtesy Richard Austin and Steve Dinardo.
- Satellite data courtesy Pat Minnis.
- This study is based on techniques introduced by Brian Soden.

Thank you!



Outline

- Goals
- Dissipating Anvil
- Persistent Cirrus
- Methodology
 - Tracking using Satellite Data
 - Flights
 - Radar Reflectivity
 - Cloud Particle Imager (CPI)
 - Cloud Spectrometer and Impactor (CSI)
- Future Work

Track Path (29 Jan case)

Start time: Airplane
“P” intersects the
Cirrus “C”.

Next time: -1 hour

Watch the C (cirrus).

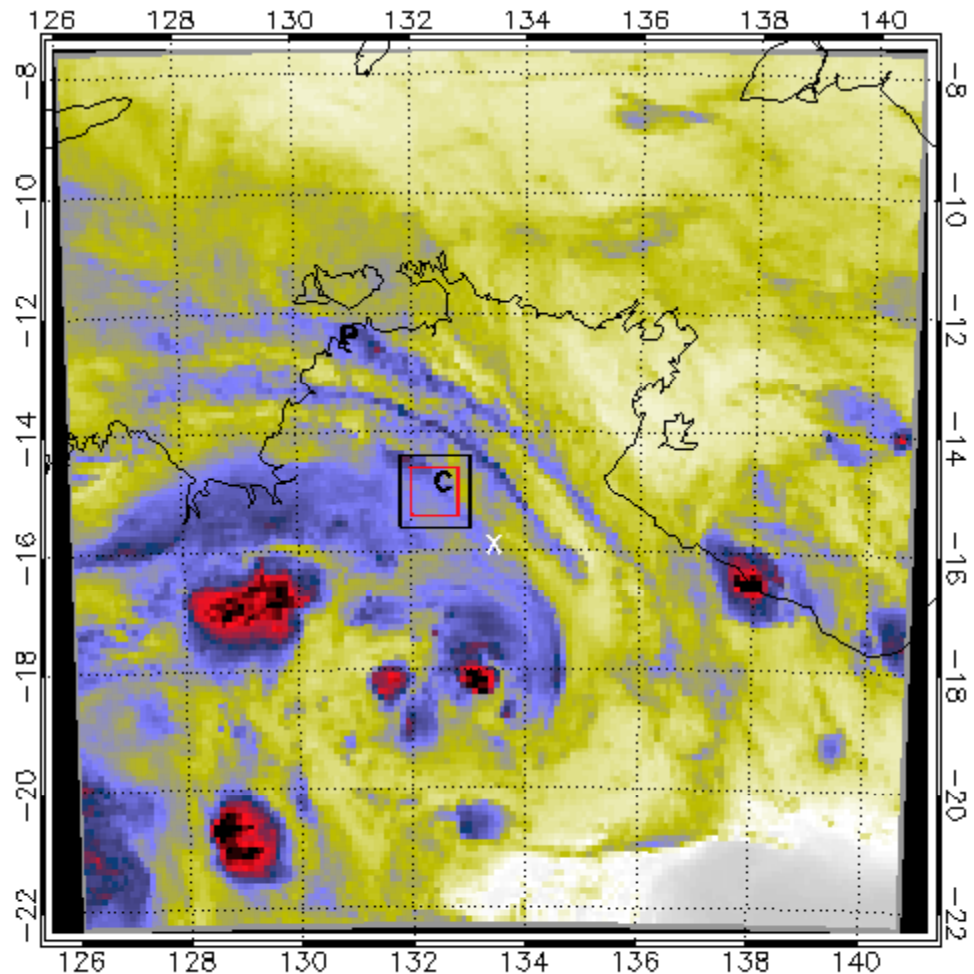
The airplane “P” flew
through the cirrus that
has evolved from
convection 3 hours
ago.

Tracking Box on 6.7 Micron Brightness Temperatures 28 Jan 2006 20 UTC

193 205 218 231 243 256 269 281 294 307 320

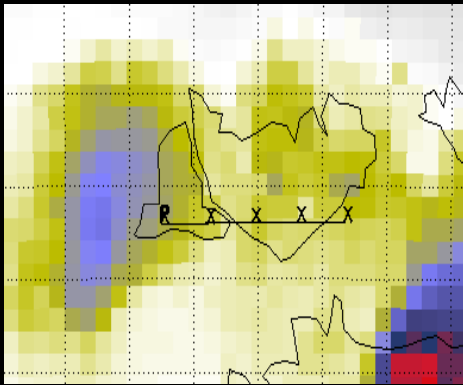


The tracked points Cor Lat: -14.9667 Cor Lon: 132.428

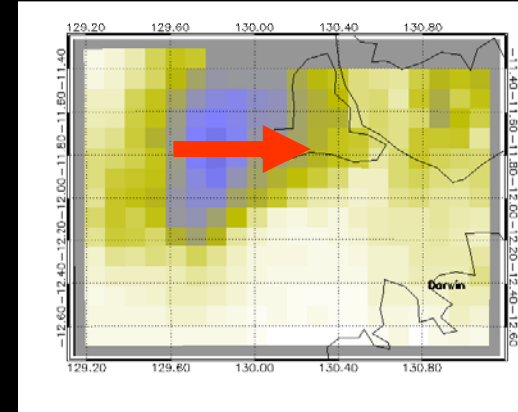


Data Sources for Cloud Information

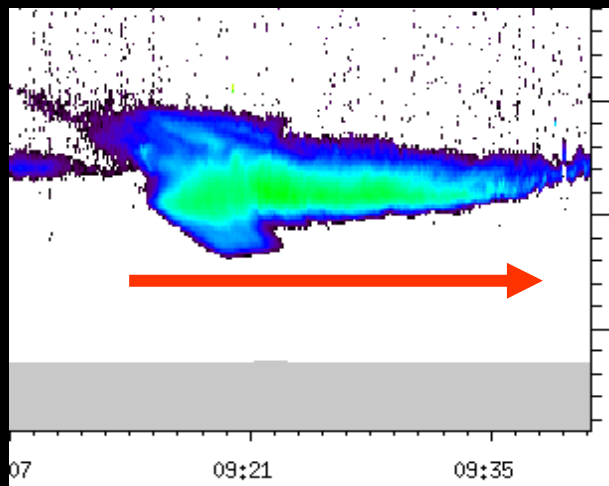
Satellite Tracking



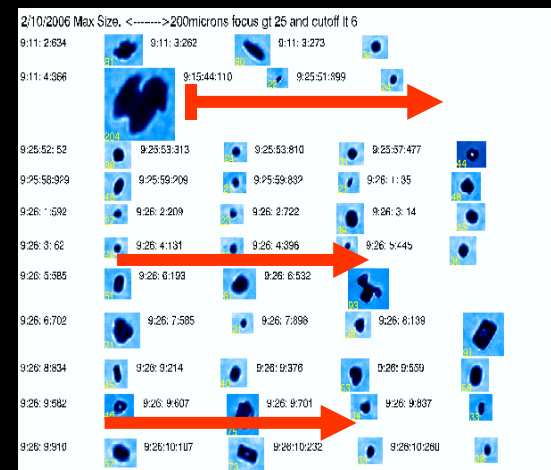
Aircraft Flight Path on Satellite Image



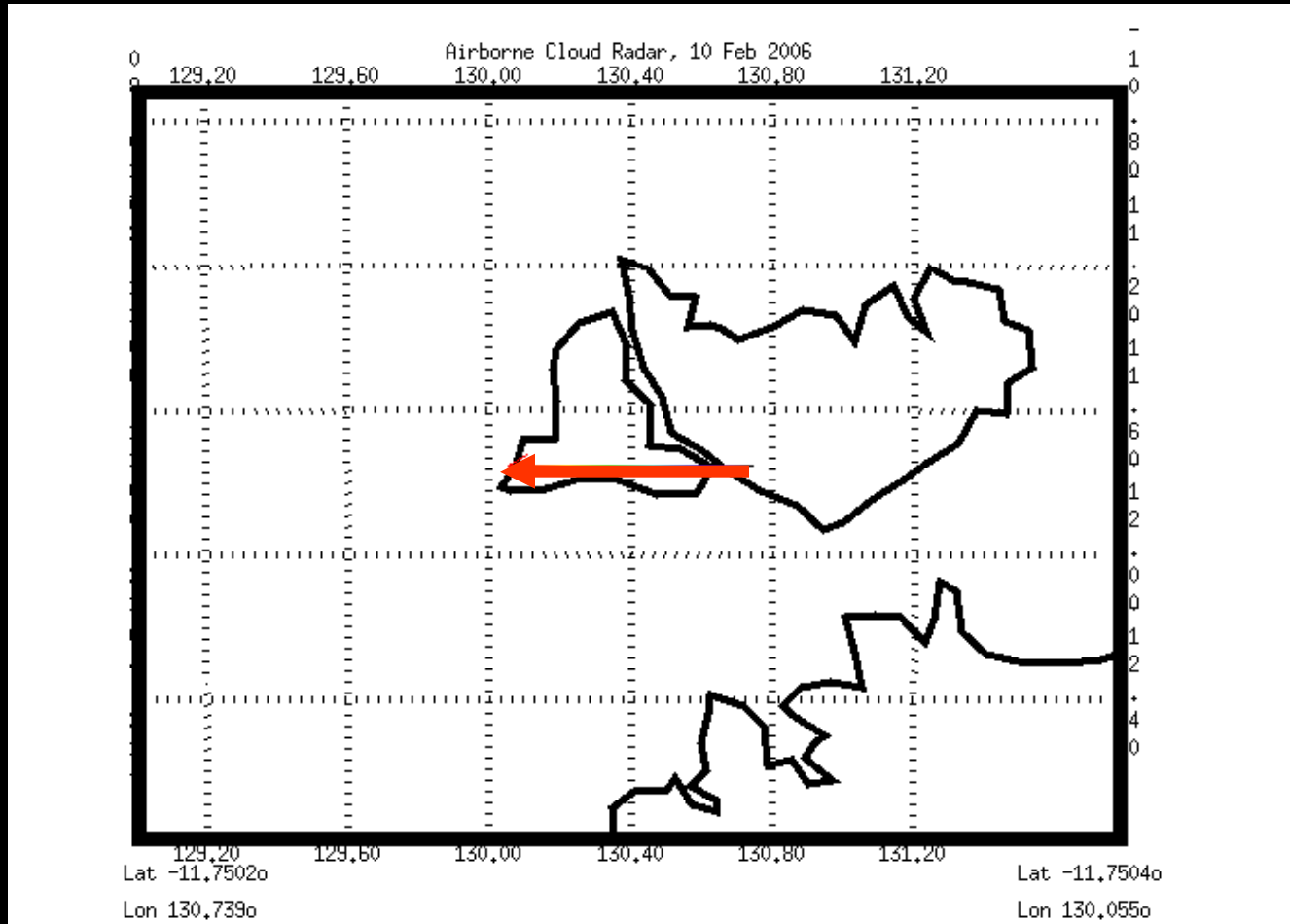
Airborne Cloud Radar



Cloud Particle Imager



Twin Otter Flight Path 10 February



UAV CSI Files

- CSI (Cloud Spectrometer and Impactor) probe flown in the ARM-UAV TWP-ICE campaign. The files contain the condensed water content (CWC) measured by the probe.

Instruments:

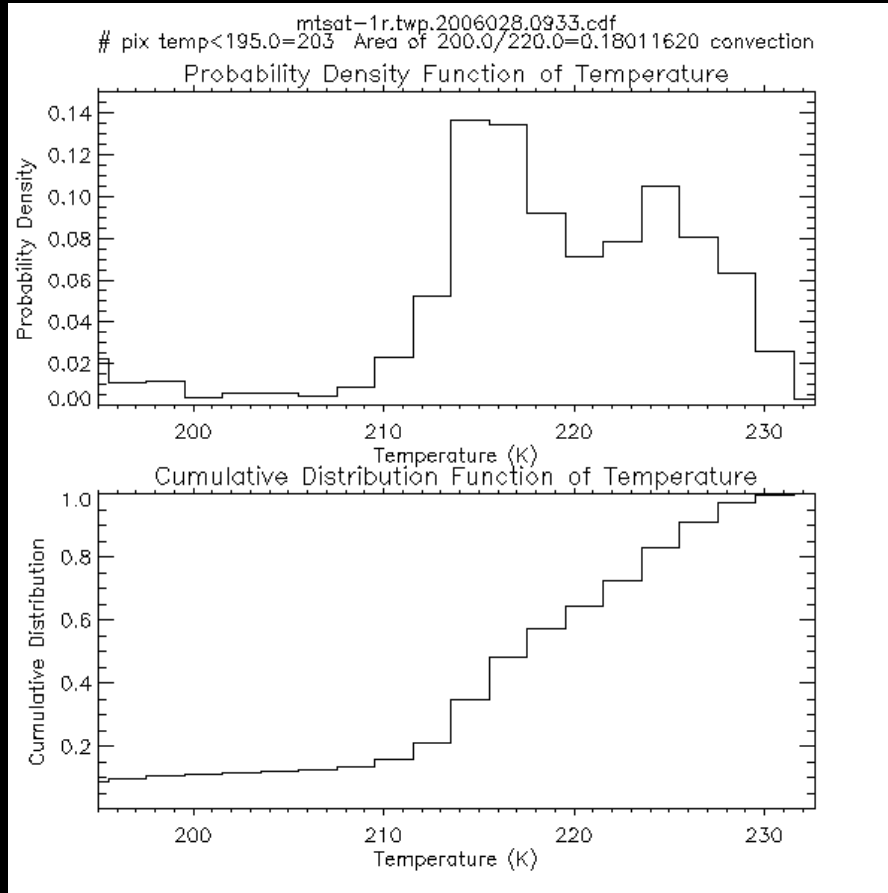
The CSI probe has a counter-flow virtual impactor (CVI) which incorporates a tunable diode laser (TDL) to detect condensed water vapor from 0.001 to 5 g/m³.

Usage The data in these files are useful for determining the condensed water content along the aircraft's flight path.

ARM UAV CPI Image Files

- **Instrument:** The CPI was developed by the Stratton Park Engineering Research Company (SPEC Inc.). The CPI provides high-resolution (2.3 micrometers) two-dimensional images of ice crystals as particles pass through a sample volume. The CPI uses a particle detection system that consists of two continuous wave laser diodes, the intersection of which forms the sample volume of the instrument. When a particle passes through the sample volume, a 60-W imaging laser is pulsed and the image of the particle is cast on the charge-coupled device (CCD) of a digital camera, giving the high-resolution images included here. The images have been generated by CPIview software developed by SPEC Inc. with the ice particle acceptance criteria of the focus greater than 25% and cutoff less than 6%.

What defines convection?

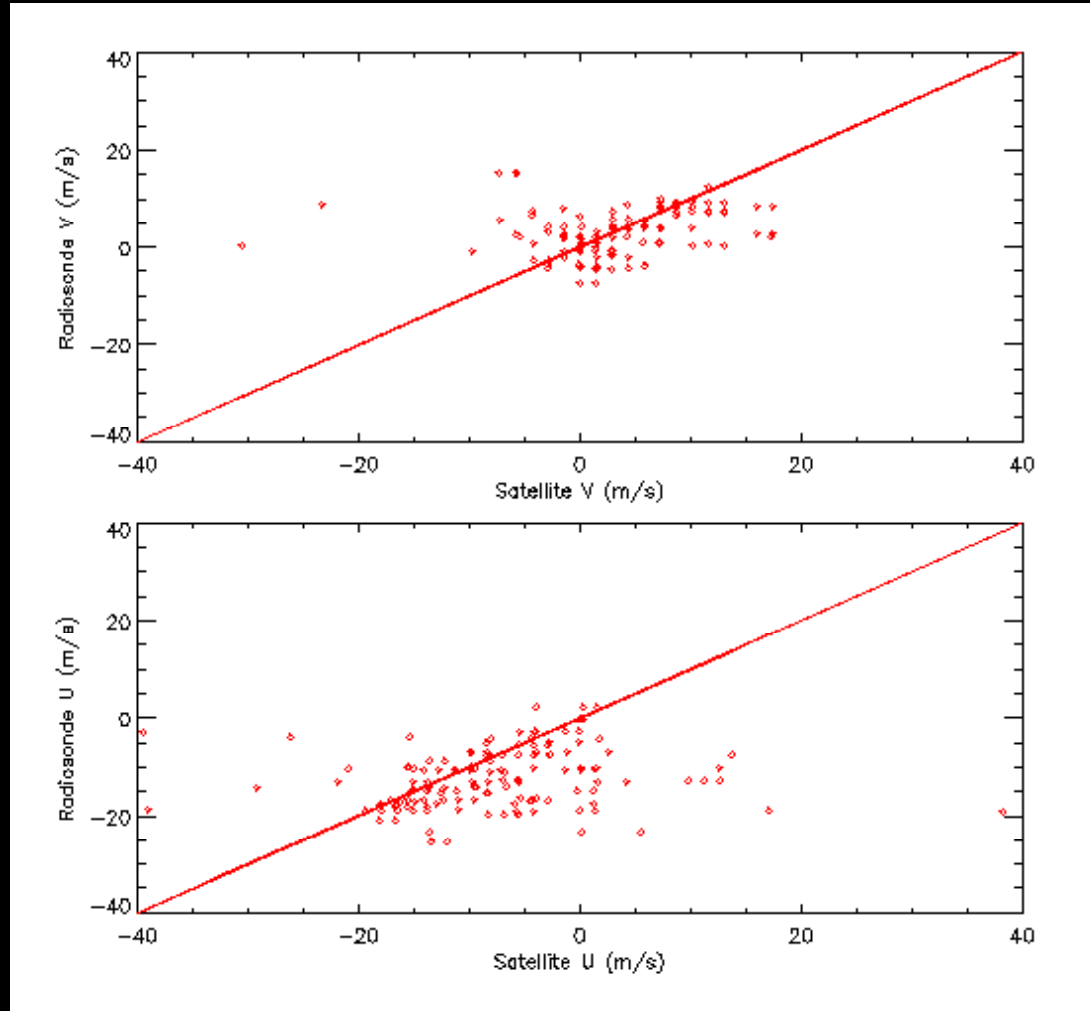


- FILL THIS IN

Min Deng, 2006

CPI data from Jan 29 case

What are the challenges?



Wind shear and new convection are challenges in the tracking validation.

Why study in Darwin, Australia?



- The Australian monsoon, is traditionally strong in Darwin during January and February. The monsoon convection generates cirrus clouds.
- The ARM twp site is located in Darwin, Australia.