Resolving Tropical Storm Inner Core Temperatures with a Three-Meter Geostationary Scanning Microwave Sounder

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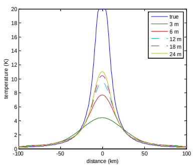
Donald Chu | Norman Grody | Michael Madden

Swales Aerospace, Inc. | 5050 Powder Mill Road | Beltsville MD 20705 USA

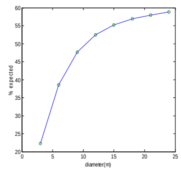
Measuring Core Temperatures

- Inner Core
  - temperature reflects storm strength
  - measured at 250 mb (10 km)
  - typically 20 km in diameter
- Instrument
  - 60/118 GHz temperature sounding
  - maximum filled aperture ~ 3 m
  - instantaneous resolution ~ 100 km
- The Problem
  - Even large antennas don't capture entire temperature rise from GEO



Three Approaches

1. Use visible observations …
   - to determine inner core location and size
   - Scale observed temperature peak
2. Parameterize inner core profile …
   - in terms of location, size, and amplitude
   - Choose parameters to fit observations
3. Trade sensitivity for resolution …
   - because it's easier to improve sensitivity
   - Deconvolve to recover the profile



Proposed Algorithms

- Method 1 – Scaling
  - Divide by expected fraction

$$\Delta T = \Delta T_{obs} / f$$

- Method 2 – Parameter Estimation
  - Estimate Holland model parameters

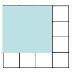
$$T = T_0 + \Delta T \cdot \left(1 - e^{-r_0^2/r^2}\right)$$

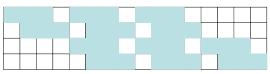
- Method 3 – Deconvolution
  - Solve for temperature field

$$\vec{x} = \vec{x}_0 + \left(S_0 + G^T W G\right)^{-1} G^T W \left(\vec{y} - \vec{g}\right)$$

Convolution

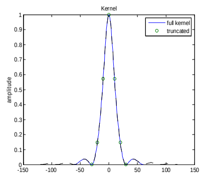
- The image is the 2D convolution of the antenna pattern with the warm core brightness temperature.
- The valid convolution keeps the antenna pattern within the bounds of the original temperature field.
- If the columns of the warm core object are concatenated, the convolution operator is a band diagonal matrix.





Antenna Patterns

- Actual
  - 3-meter diameter (60 GHz)
  - Filled aperture
- HiFi Observations
  - 1 kilometer resolution
  - Truncated at 2nd null
- LoFi Predictions
  - Resolved to ground sample distance
  - Truncated at 1st null

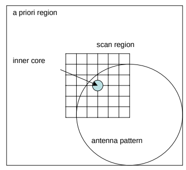


Coverage

- Sensitivity depends on
  - System temperature (1000K)
  - Bandwidth (100 MHz)
  - Integration time (1 sec)

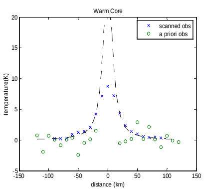
$$\sigma_T = T_s \big/ \sqrt{B\tau}$$

- Coverage depends on
  - Ground sample distance (20 km)
  - Feature size (20 km)
  - Antenna beamwidth (100 km)
- Result
  - 0.1 K sensitivity
  - 6-by-6 sample scan
  - 36+ seconds



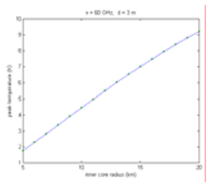
Observations

- Warm Core Profile
  - 20 K peak
  - 10 km radius
- Scanned Observations
  - 0.1 K noise
  - ground sample distance
- A Priori Observations
  - 1 K noise
  - No a priori near core



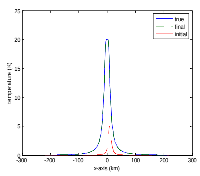
Method 1 – Scaling

- Pros
  - Scaling works if the warm core radius is known
  - Simple but more subject to error than the later methods
- Cons
  - Noise multiplied by same factor as observed peak temperature
  - A 5 km radius error can change the scaling by 100%



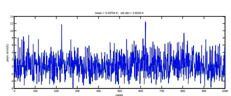
Method 2 – Four Parameter Error

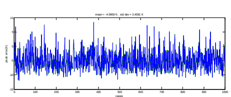
- Pros
  - Accurate to better than 1 K
  - Converges even from a poor initial guess
- Cons
  - Search takes a long time
  - Depends on model fidelity



Method 3 – Deconvolution

- Pros
  - Model-independent
  - Peak recovery:
    - 75% @ 60 GHz
    - 95% at 118 GHz
- Cons
  - Processing increases noise
  - 3 K noise standard deviation





Conclusions

- Simulations suggest that inner core temperature profiles can be recovered with 3-meter antenna at GEO.
- Requirements
  - Known antenna pattern
  - 0.1 K temperature sensitivity
- Performance
  - Accuracy up to 1 K
  - Coverage in as little as 1 minute

NOAA NESDIS Office of Satellite Operations, Hurricane Inner Core, http://www.oso.noaa.gov/goes/