Advanced Geostationary Sounders

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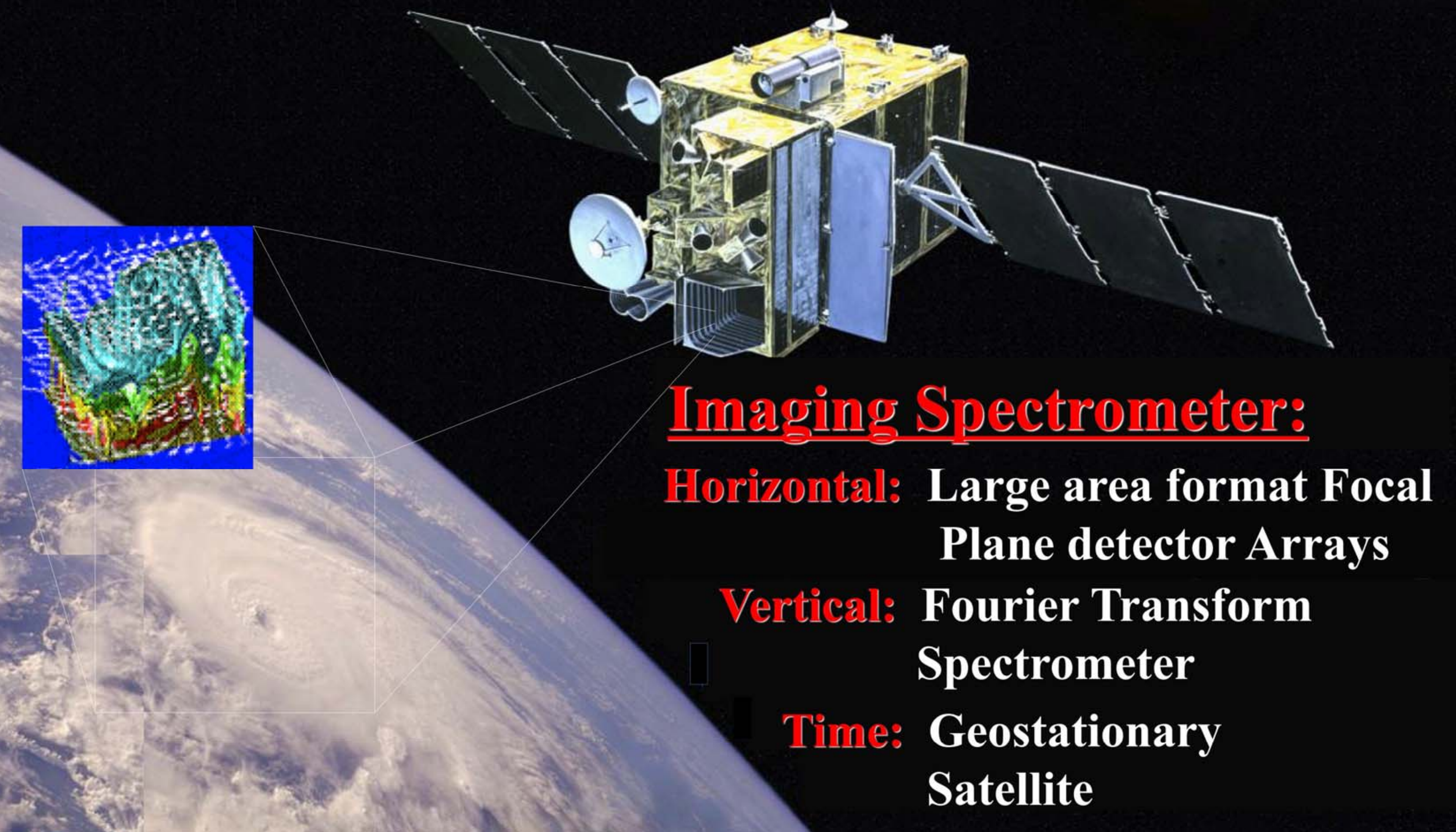
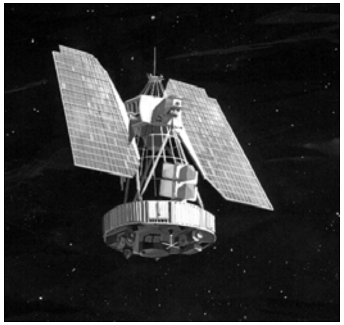


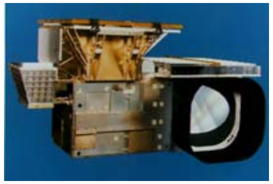
Geostationary Atmospheric Sounder Evolution

Nimbus 3 & 4
IRIS/SIRS
(1969-1972)



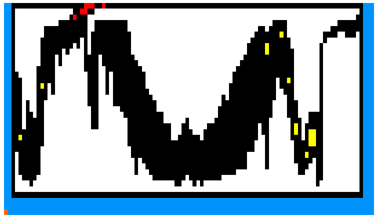
First Satellite Sounder Spectrometers

Nimbus 5/*ITPR*
ITOS/VTPR
Nimbus 6/NOAA *HIRS*
GOES/VAS & HIRS
(1972-2010)



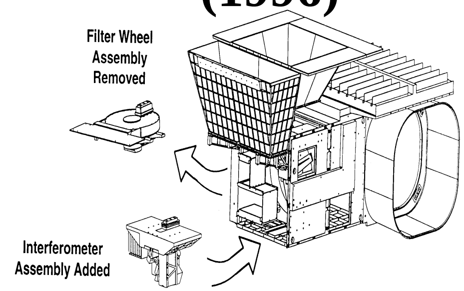
High Horizontal Resolution

High Resolution Interferometer Sounder (*HIS*)
(1985-)



Adv.Geo-Sounder A/C Demonstrator

GOES-HIS (GHIS)
Replaced Filter Wheel with FTS
(1996)

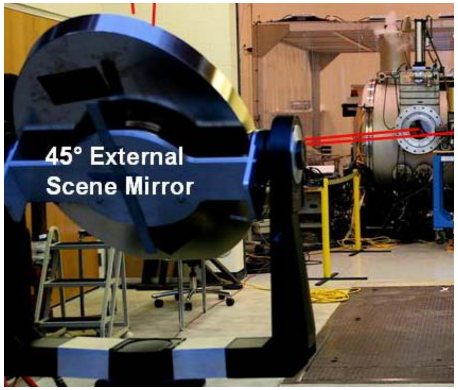


Lab. Demonstration of Concept

NAST-I / SHIS
(1998 -)

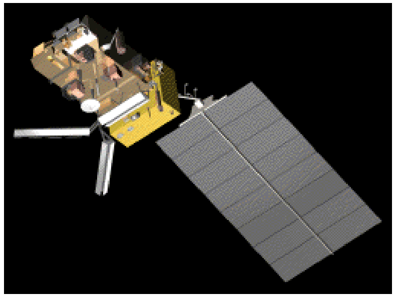
Aircraft 3-d FTS Sounding Demonstration

GIFTS-EDU (2006)



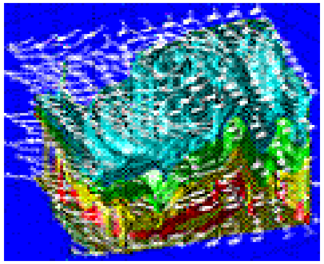
1st Groundbased 4-d Imaging FTS Demonstration

METOP-*IASI*
(2006) [LEO]



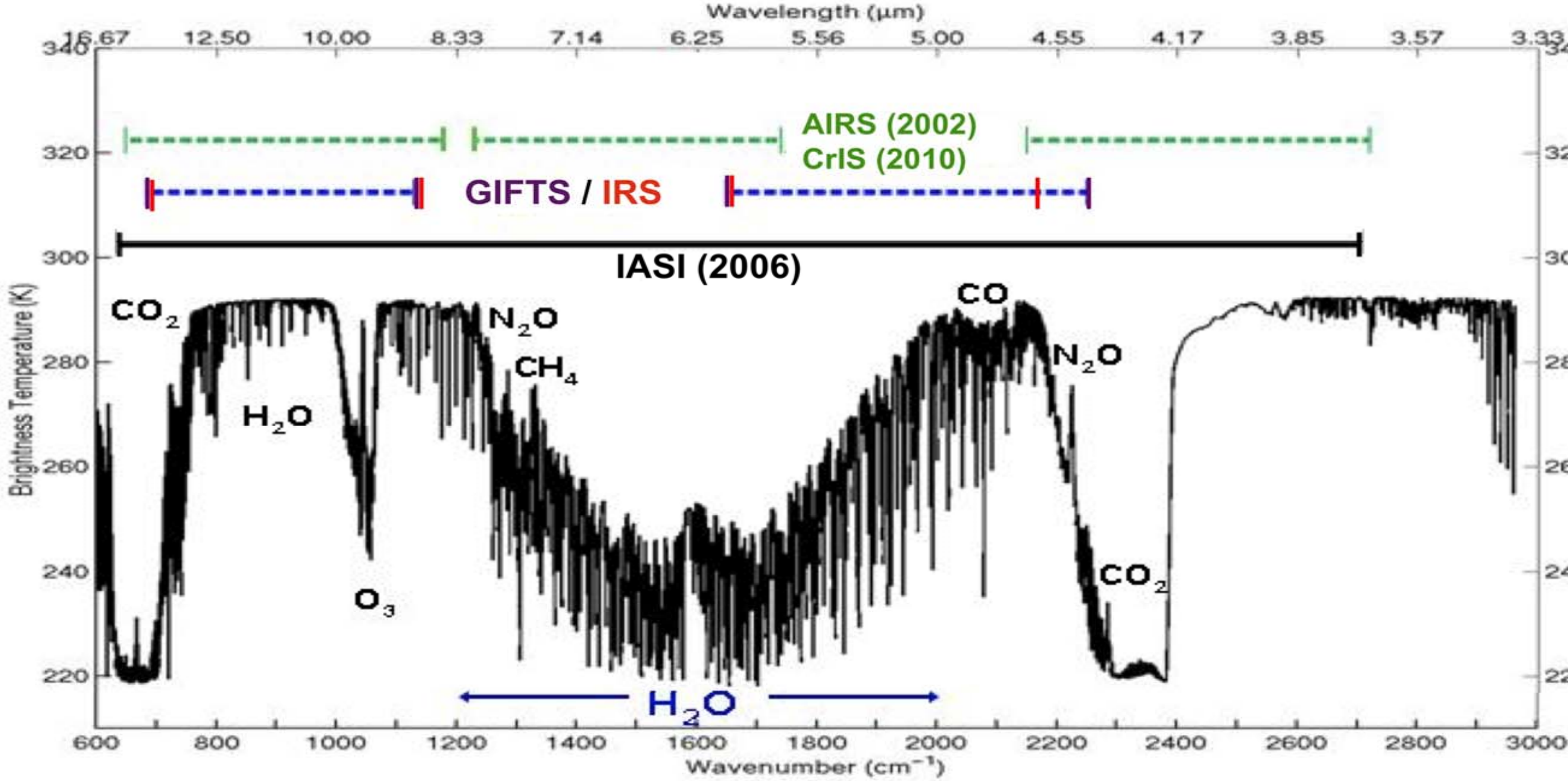
1st Operational Satellite 3-d FTS Sounder

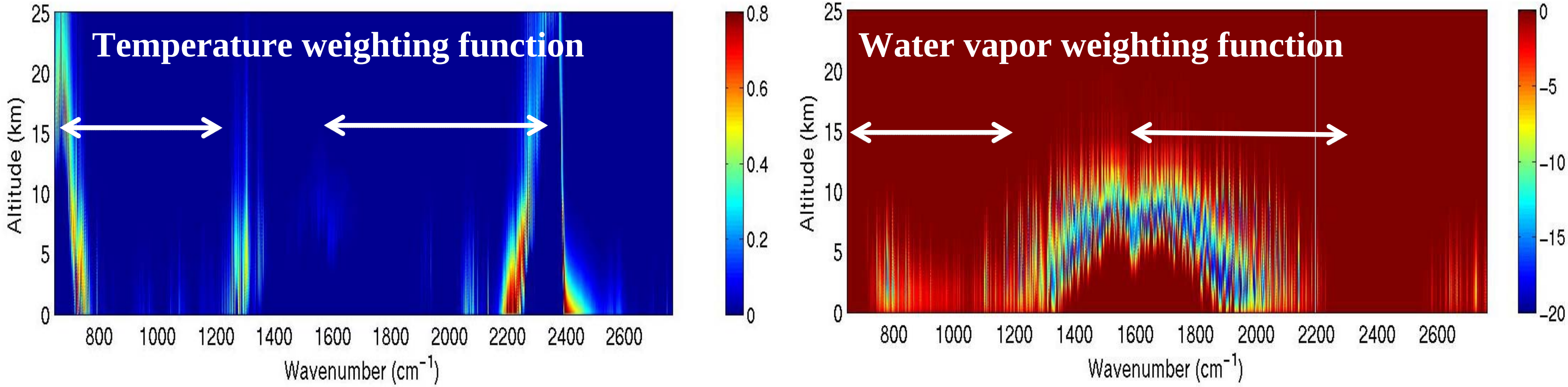
GIFTS?
MTG-IRS, others



Geostationary 4-d Imaging FTS Sounder

Satellite Ultra-spectral Sounders





Importance of Geo-Imaging FTS

Improved Weather Forecasting

- Convective Storms/Tornadoes
- Hurricane Landfall Location and Time
- Global Numerical Weather Prediction (Temperature, Water Vapor & Wind Profiles)

Atmospheric Gas Transport

- Pollutant Gases (CO & O_3)
- Greenhouse Gases (H_2O, CO_2, O_3, CH_4)

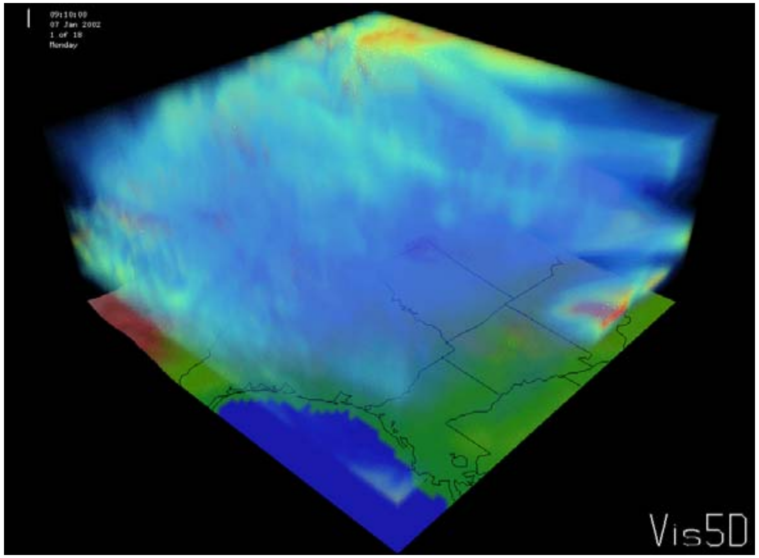
Monitor Climate Dynamics

- Cloud Properties (Height, Particle Size, Optical Depth)
- El Nino / La Nina (Ocean Temp & Winds)

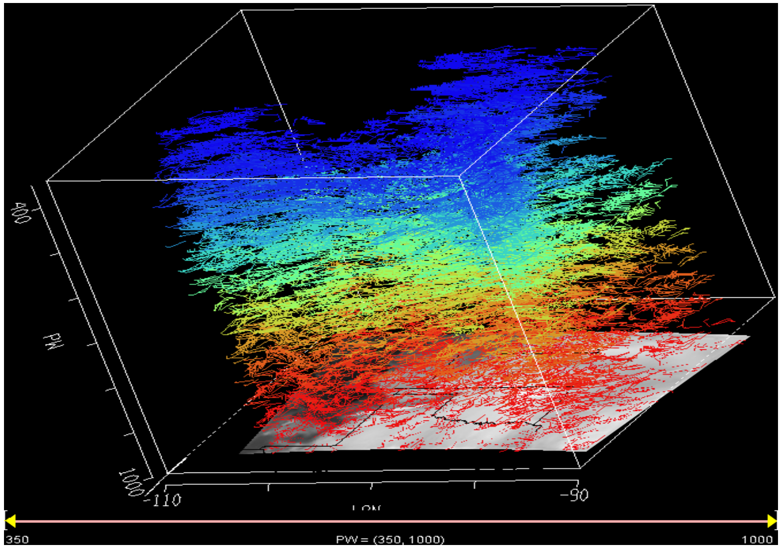
Geostationary Imaging FTS measurement capability is key to improving the quality and timeliness of forecasts for severe weather, pollution, global weather, and climate

Observation of Atmospheric Dynamics

Three Dimensional Moisture Flux & Wind Observations

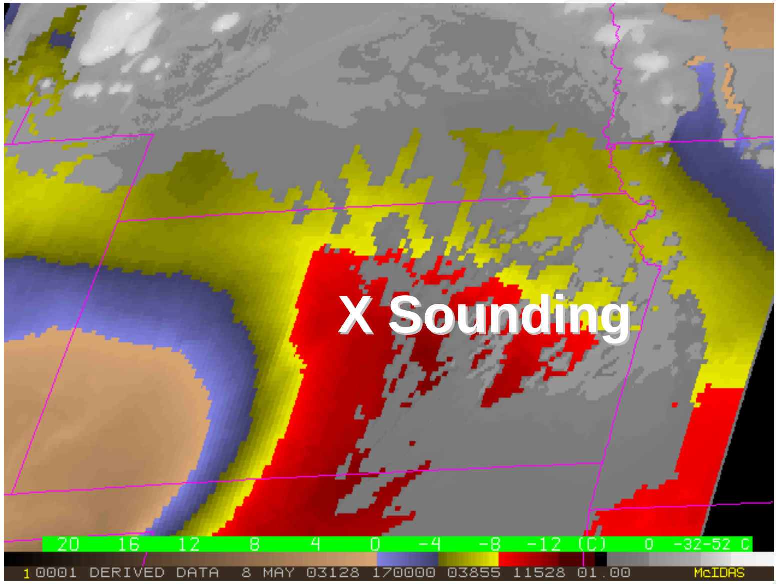


4-d Water Vapor Imaging Geo-FTS

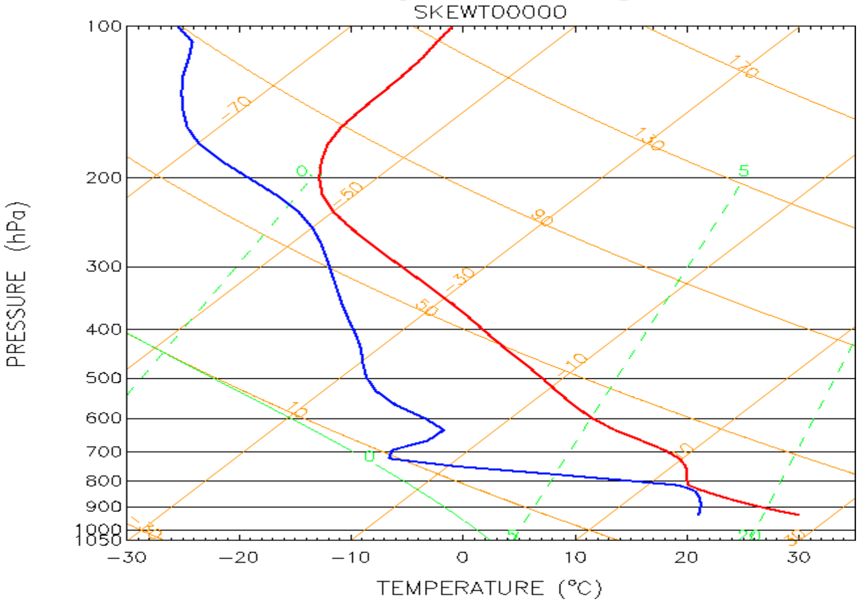


3-d Wind Vector Distribution

Atmospheric Thermodynamic Stability Change



Thermodynamic Stabilty (LI)



Atmospheric Sounding Dynamics(LI)

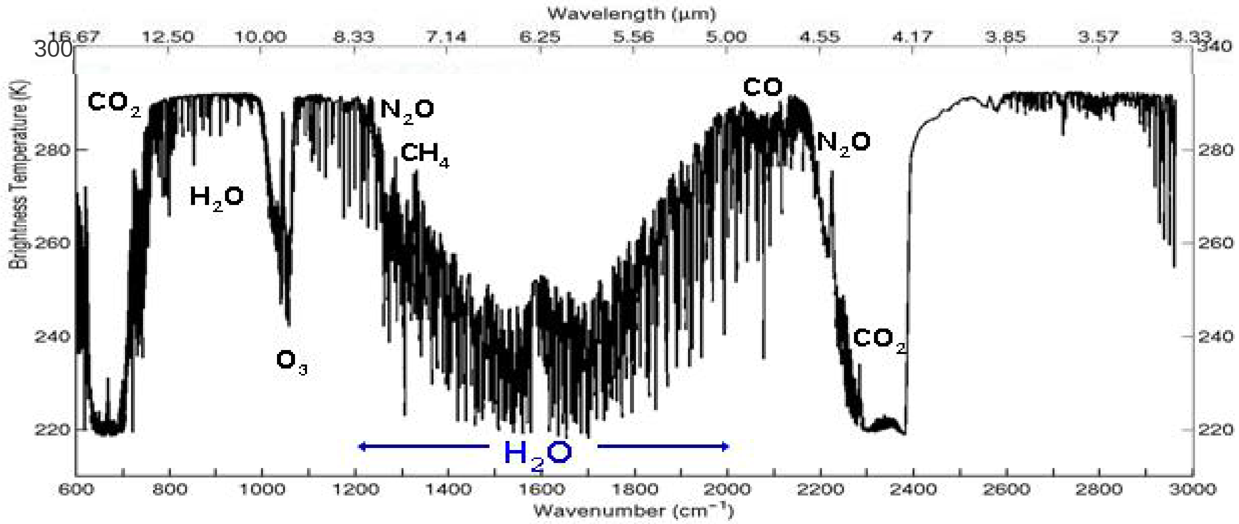
High Vertical Resolution Sounding Concept

High spectral resolution and broad spectral coverage enables high system S/N for providing accurate de-convolution of vertically smeared thermal radiance signals

High Vertical Resolution Provided by Ultraspectral Resolution Radiance Spectra

- Spectrum

Several thousand spectral channels are observed to profile the atmosphere with high vertical resolution



PC Statistical Retrieval

Initial Profile PC Regression Retrieval:

a(T,Rh) = **G**(A,R) **r**(T,Rh,T_s,ε_s, gases,,)

– **a** is a vector of atmospheric state pc scores
– **G(A,R)** is a regression matrix relating atmospheric profiles (A) to LBLRTM calculated IASI radiance spectra (R) for a statistically representative set of surface and atmospheric profile conditions
– **r** is a vector of radiance pc scores

R = R*^{T}r$_\nu$

– **R*** is a matrix of radiance spectra PCs, R*^{T} being the transpose of R*
– **r$_\nu$** is a vector of radiances (i.e., an individual radiance spectrum)

T/Rh = a(T,Rh) **A***

– **T/Rh** is a vector of the temperature (T) and humidity (Rh) profile values, plus sfc T, sfc emissivity PC scores, etc.
– **A*** is a matrix of atmospheric state PCs

LBLRTM IASI simulated radiance and atmospheric statistics defined from statistical sample of radiosondes *10 randomly selected surface temperature/emissivity conditions per radiosonde sounding

PC Physical Retrieval

1-d Variational Physical PC-score Retrieval:

Given: $R = aR^* \cdot r_\nu$

$T/Rh = aA^*$

The Physical Solution is:

$$a_{n+1} = a_0 + (K_n^T S_{\varepsilon(R)}^{-1} K_n + \lambda S_a^{-1})^{-1} K_n^T S_{\varepsilon(R)}^{-1} [R_m - R(a_n) + K_n(a_n - a_0)]$$

Where:

$S_{\varepsilon(R)} = R^{*T} E(r_\nu)$

$S_a = A^{*T} S(T,Rh)$ (with T/Rh covariances set = 0)

$K_n = [\delta R(a)/\delta a]_n$

λ=Lagrangian multiplier

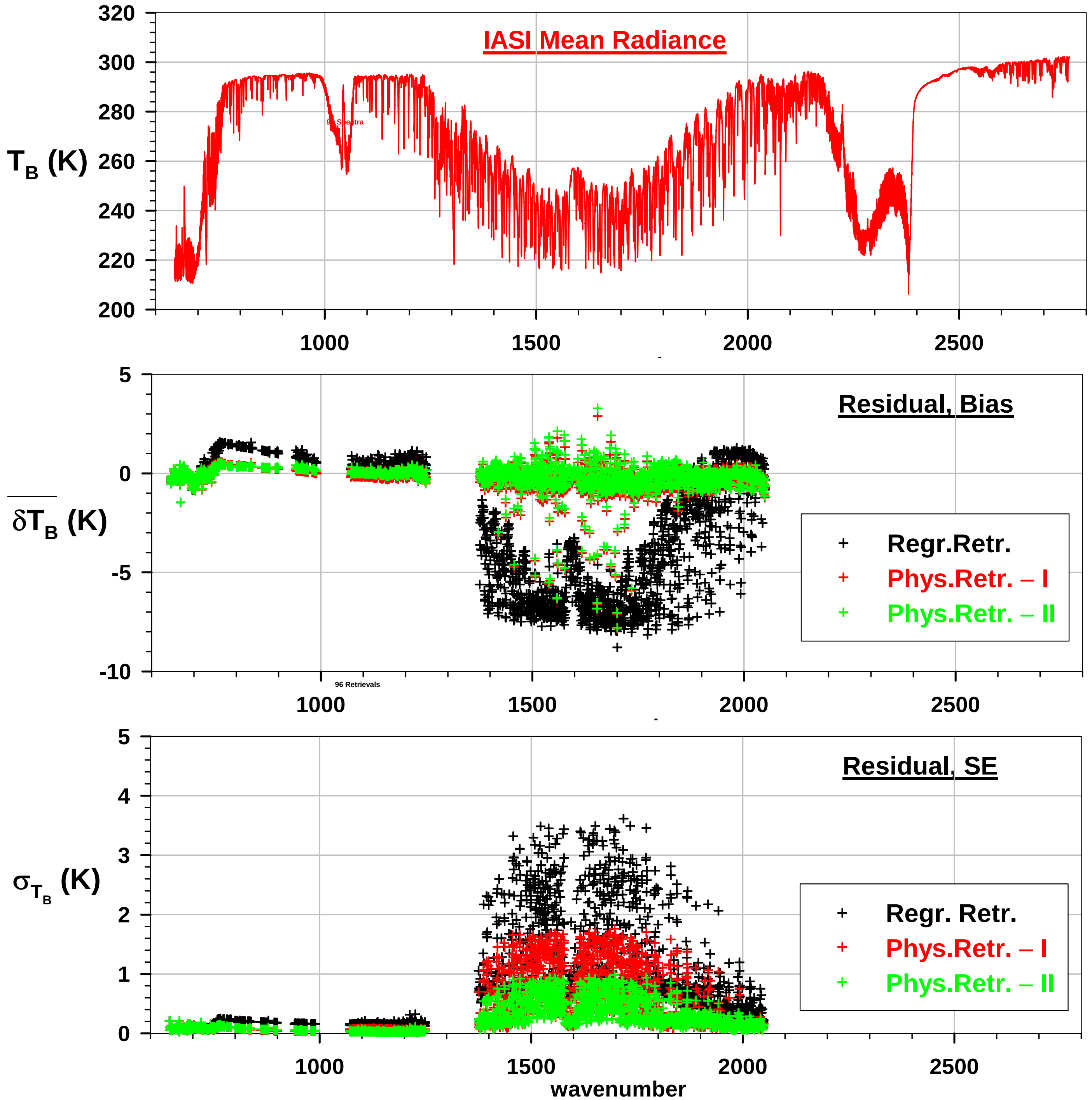
<u>Two step physical retrieval</u>:

(1) solve for an improved relative humidity profile, assuming all the temperature profile PC score Jacobians are zero (i.e. temperature fixed to initial regression solution)

(2) simultaneous solution for the final T and Rh PC scores.

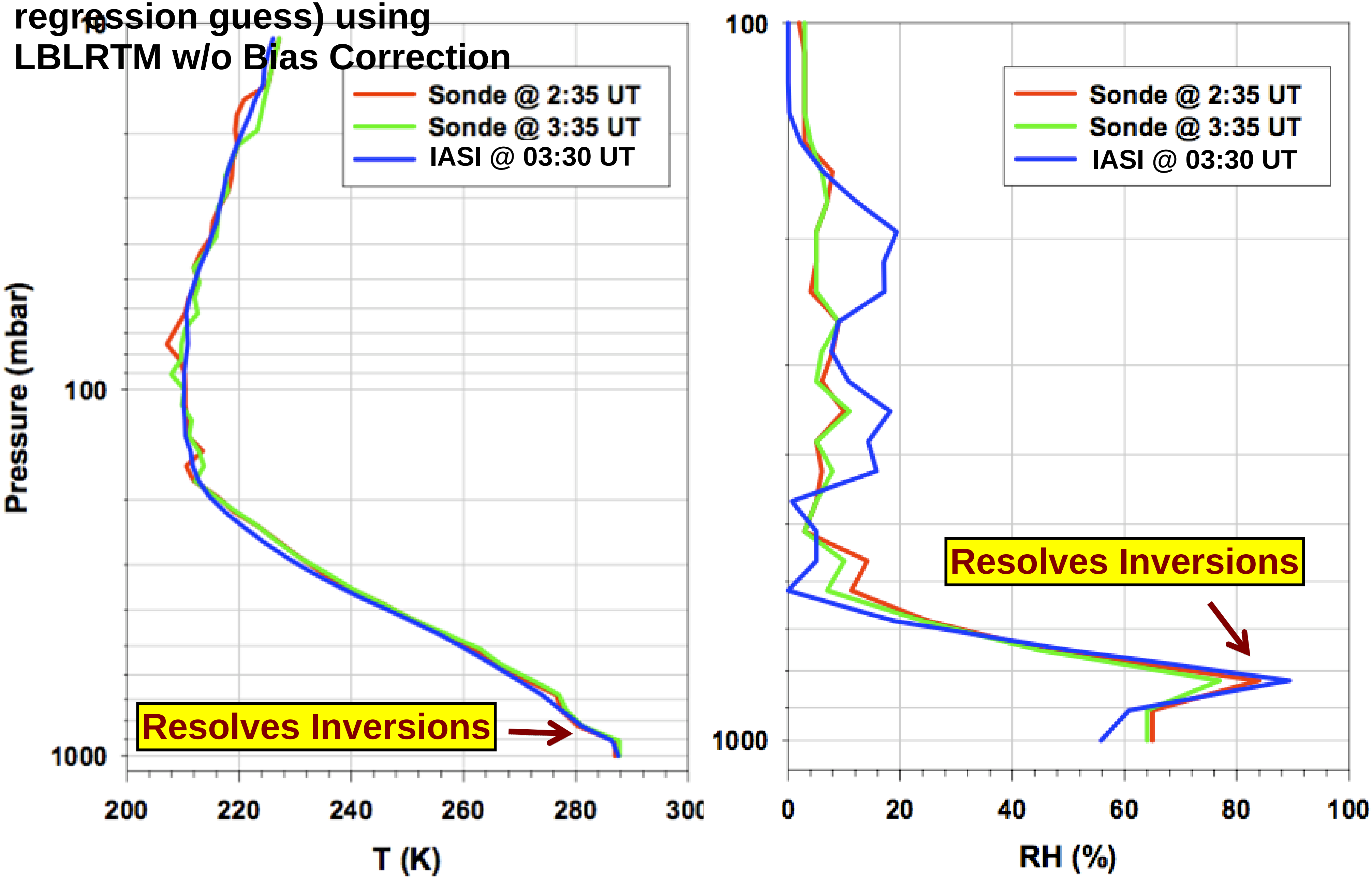
- LBLRTM used for background radiance and Jacobian calculation
- ~ 4000 spectral channels (0.5 cm^{-1} spacing)
- No Bias Correction

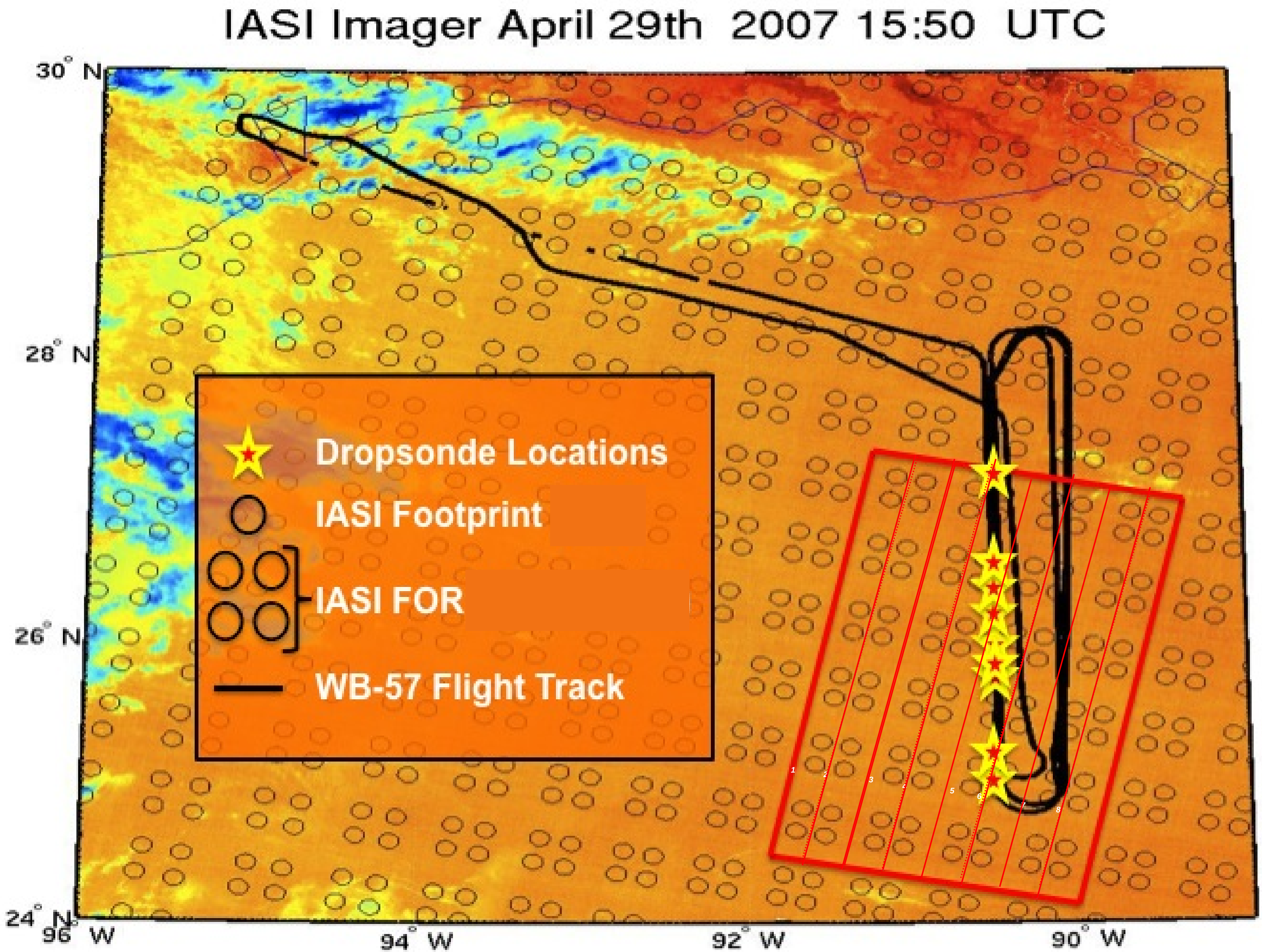
Radiance Residual Mean and Standard Deviation (96 Retrievals)



IASI Retrievals at CART site (19 April

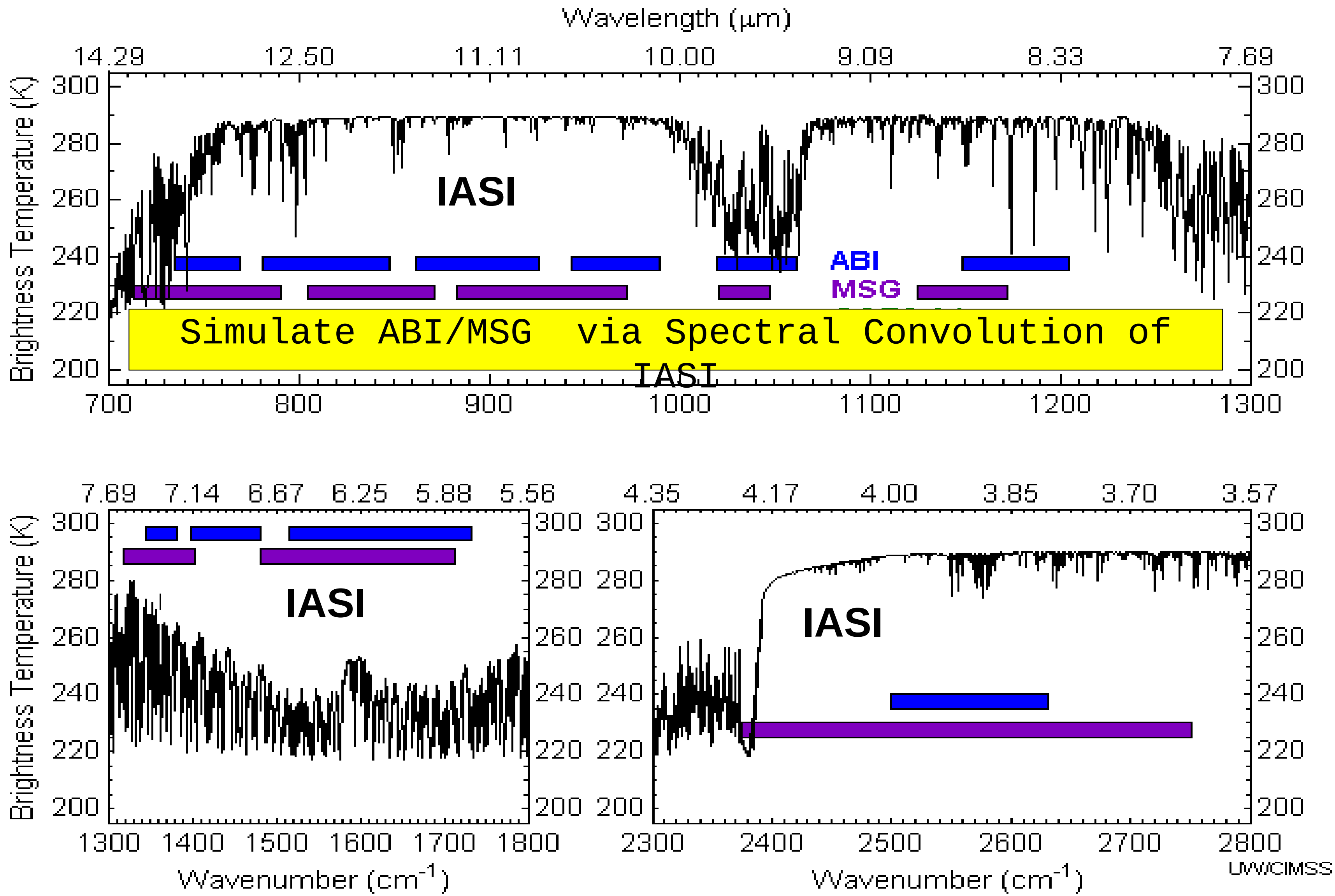
Variational Solution (EOF regression guess) using LBLRTM w/o Bias Correction

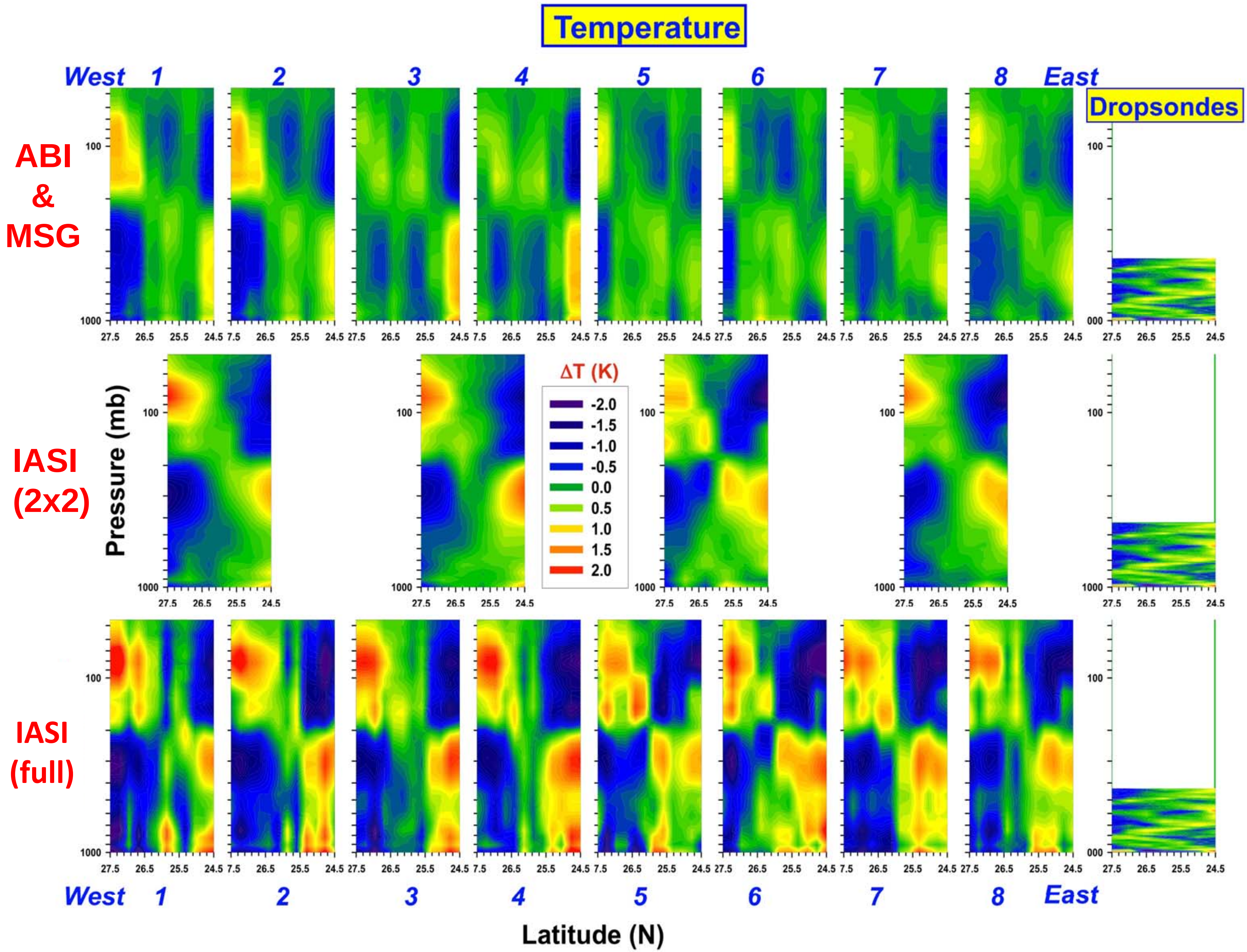




IASI Imager April 29th 2007 15:50 UTC
30° N
28° N
26° N
24° N
96° W
94° W
92° W
90° W
Dropsonde Locations
IASI Footprint
IASI FOR
WB-57 Flight Track

Imaging Ultra-spectral FTS Vs Multi-spectral IR





Temperature
West
1
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3
4
5
6
7
8
East
Dropsondes
ABI & MSG
IASI (2x2)
IASI (full)
Pressure (mb)
ΔT (K)
-2.0
-1.5
-1.0
-0.5
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0.5
1.0
1.5
2.0
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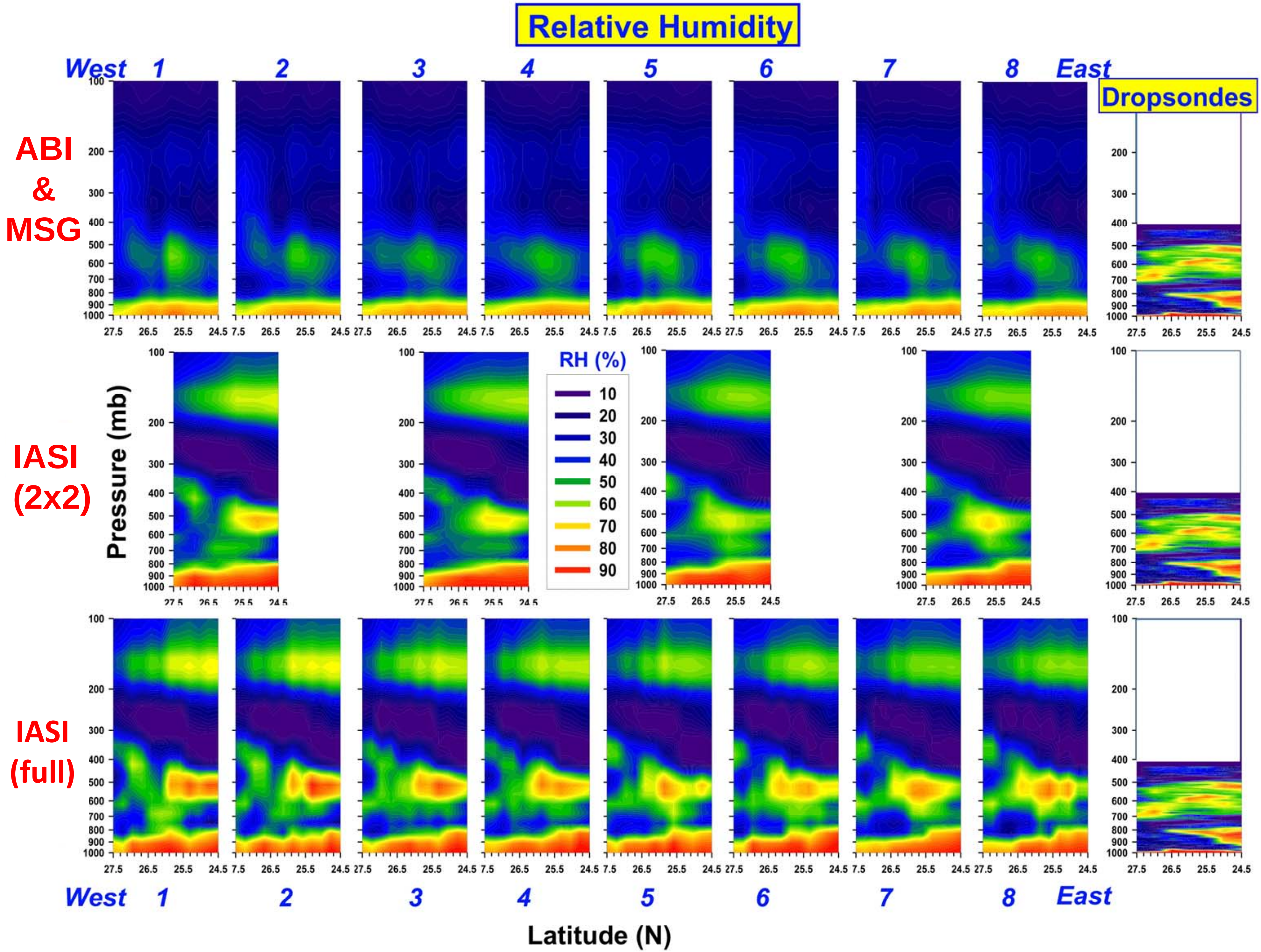
1000
27.5
26.5
25.5
24.5
Latitude (N)



Relative Humidity
West
1
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7
8
East
Dropsondes
ABI & MSG
IASI (2x2)
IASI (full)
Pressure (mb)
RH (%)
10
20
30
40
50
60
70
80
90
Latitude (N)

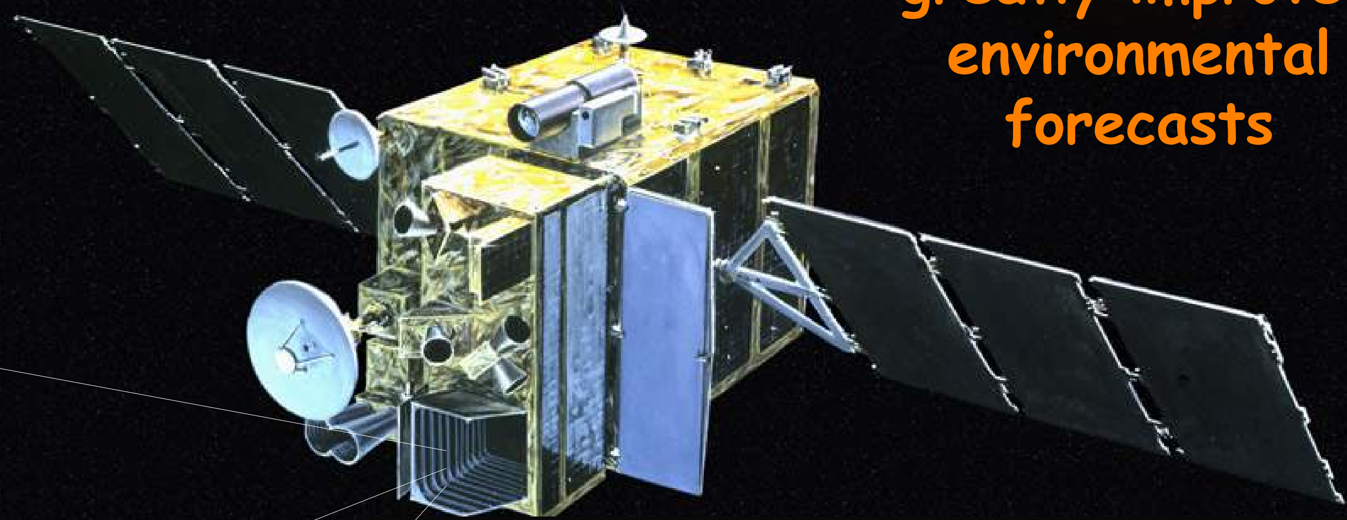
Geostationary Imaging Fourier Transform Spectrometer

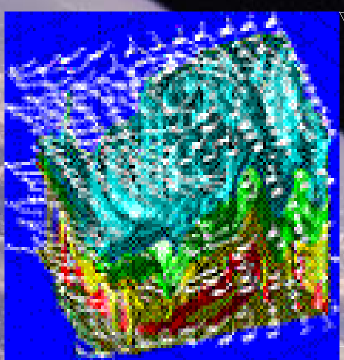
Ultraspectral Instrument for Atmospheric Temperature, Moisture, Chemistry, & *Winds*

Provides ~ 80,000 Atmospheric Soundings every minute

The opportunity for greatly improved environmental forecasts

"GIFTS"





4-d Digital Camera:

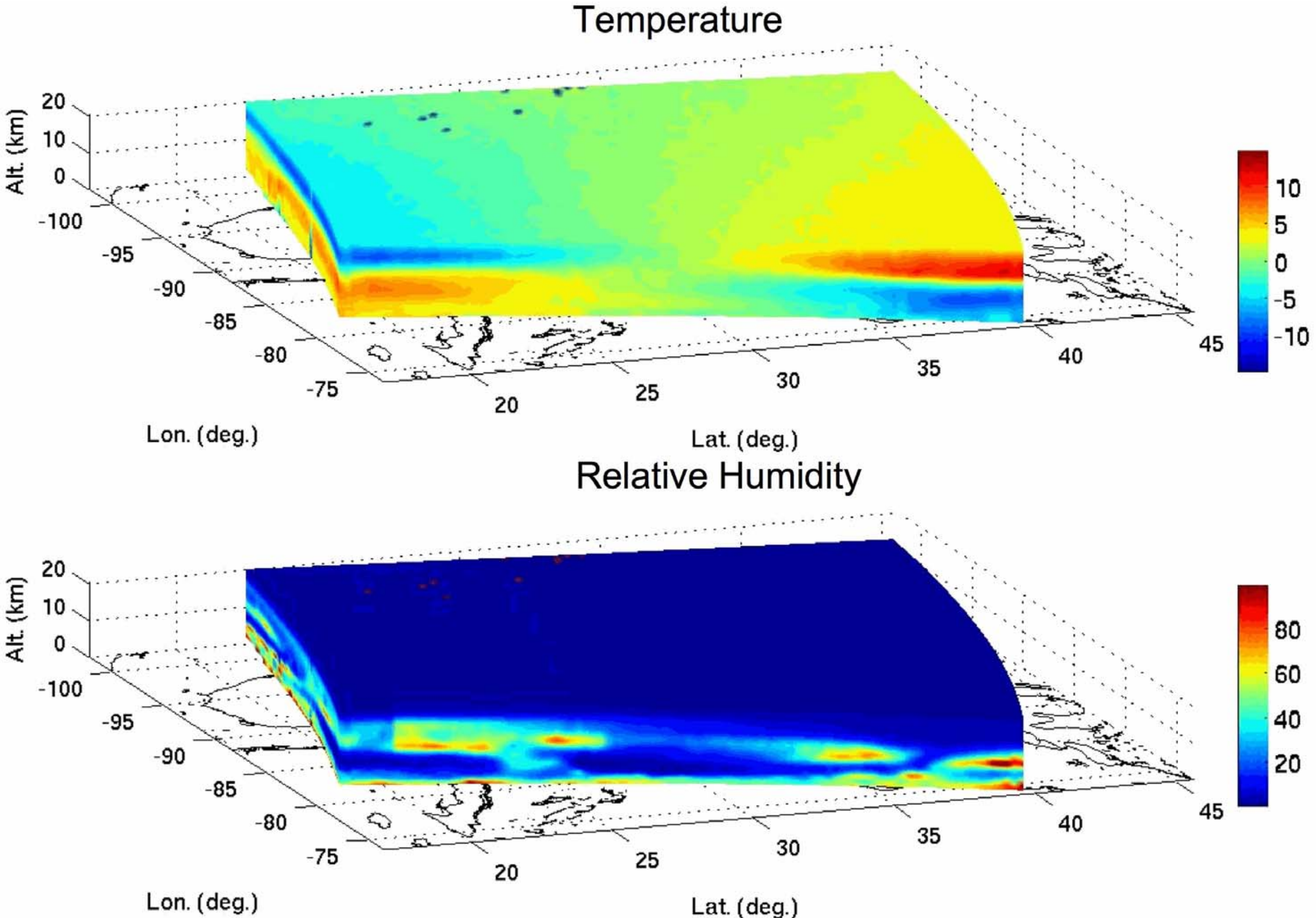
Horizontal: Large area format Focal Plane detector Arrays

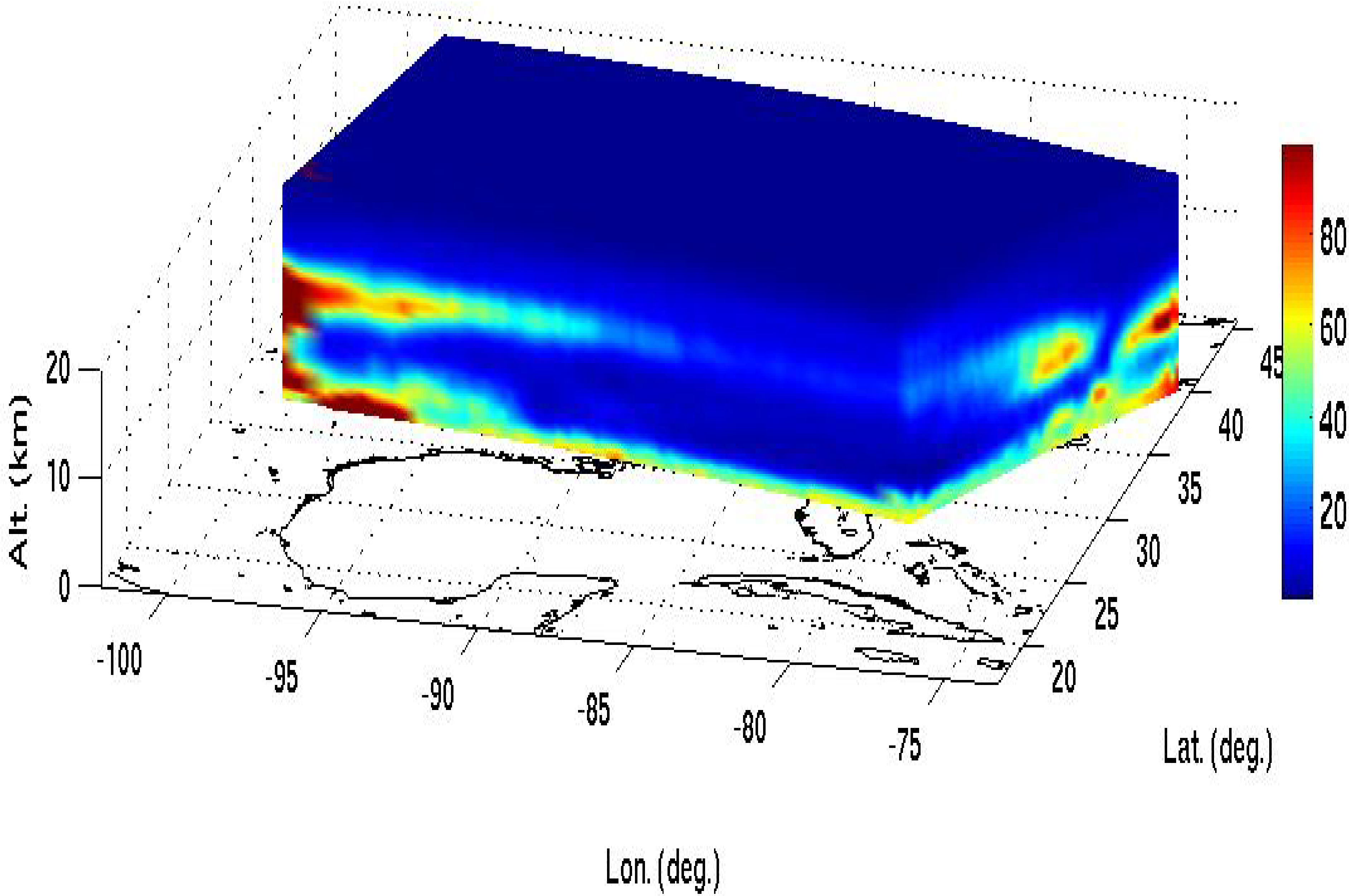
Vertical: Fourier Transform Spectrometer

Time: Geostationary Satellite

IASI Demonstrates Ultraspectral Capability to Observe 3-D H_2O Structure

(US on April 29, 2007)

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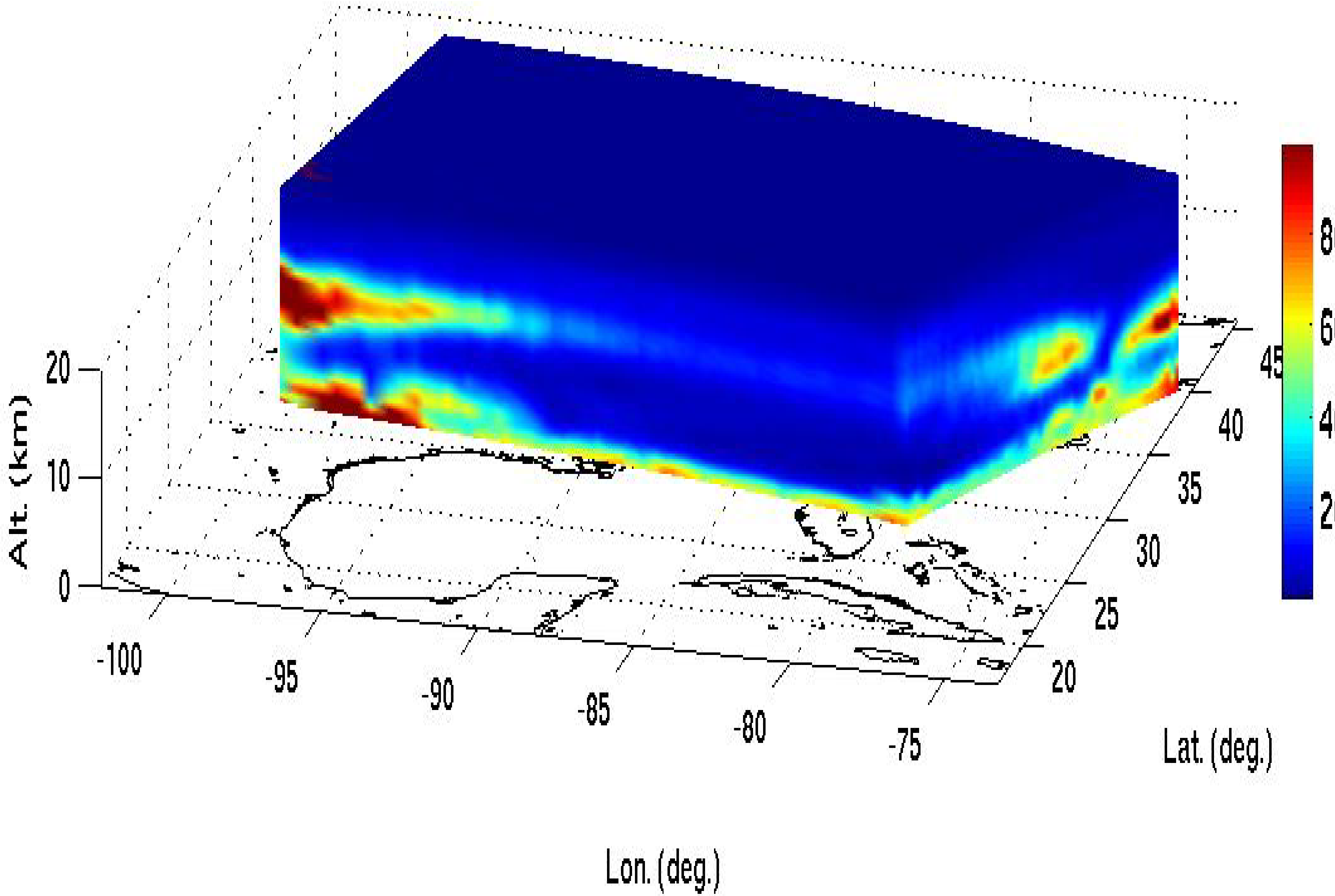

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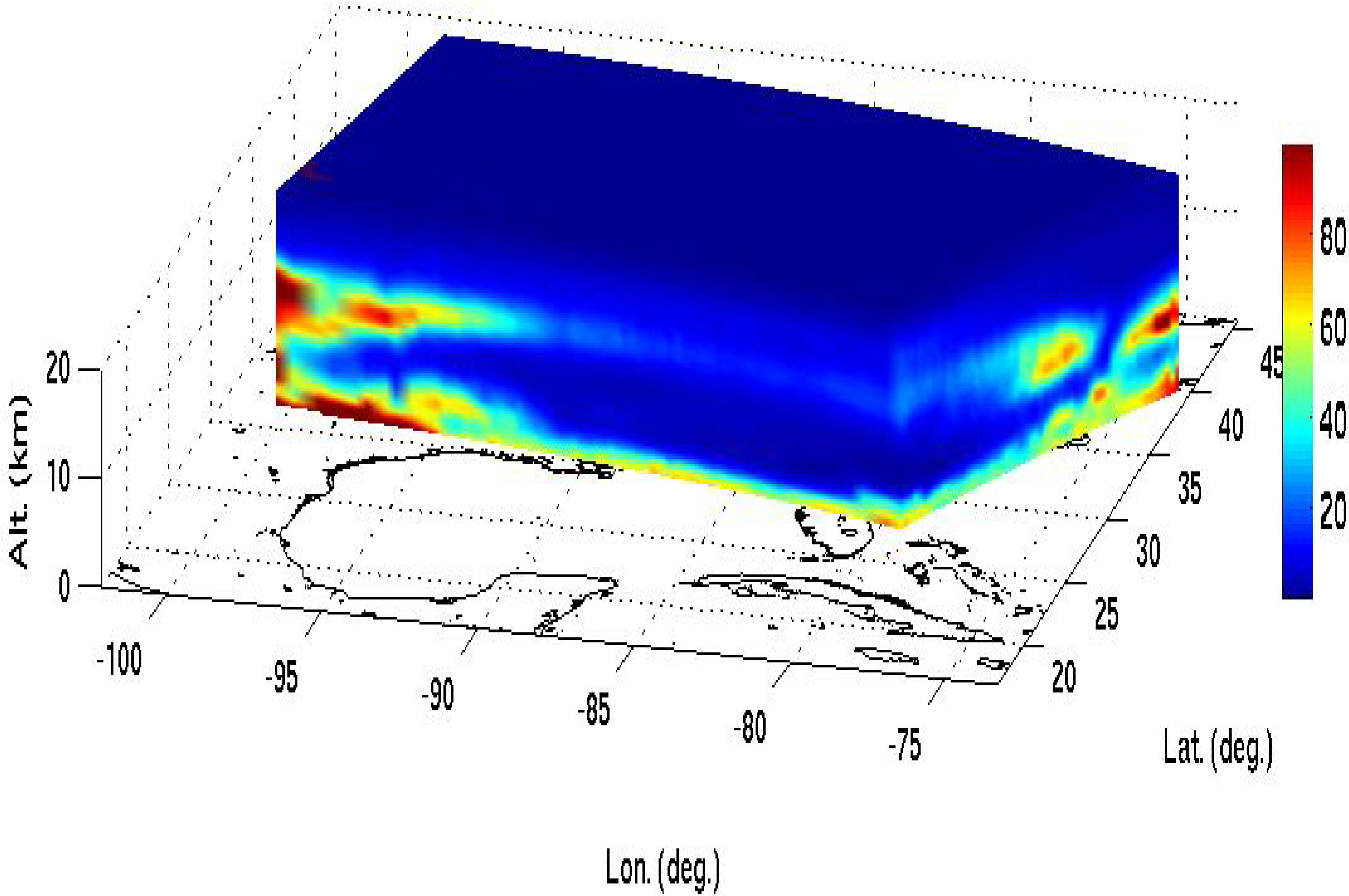

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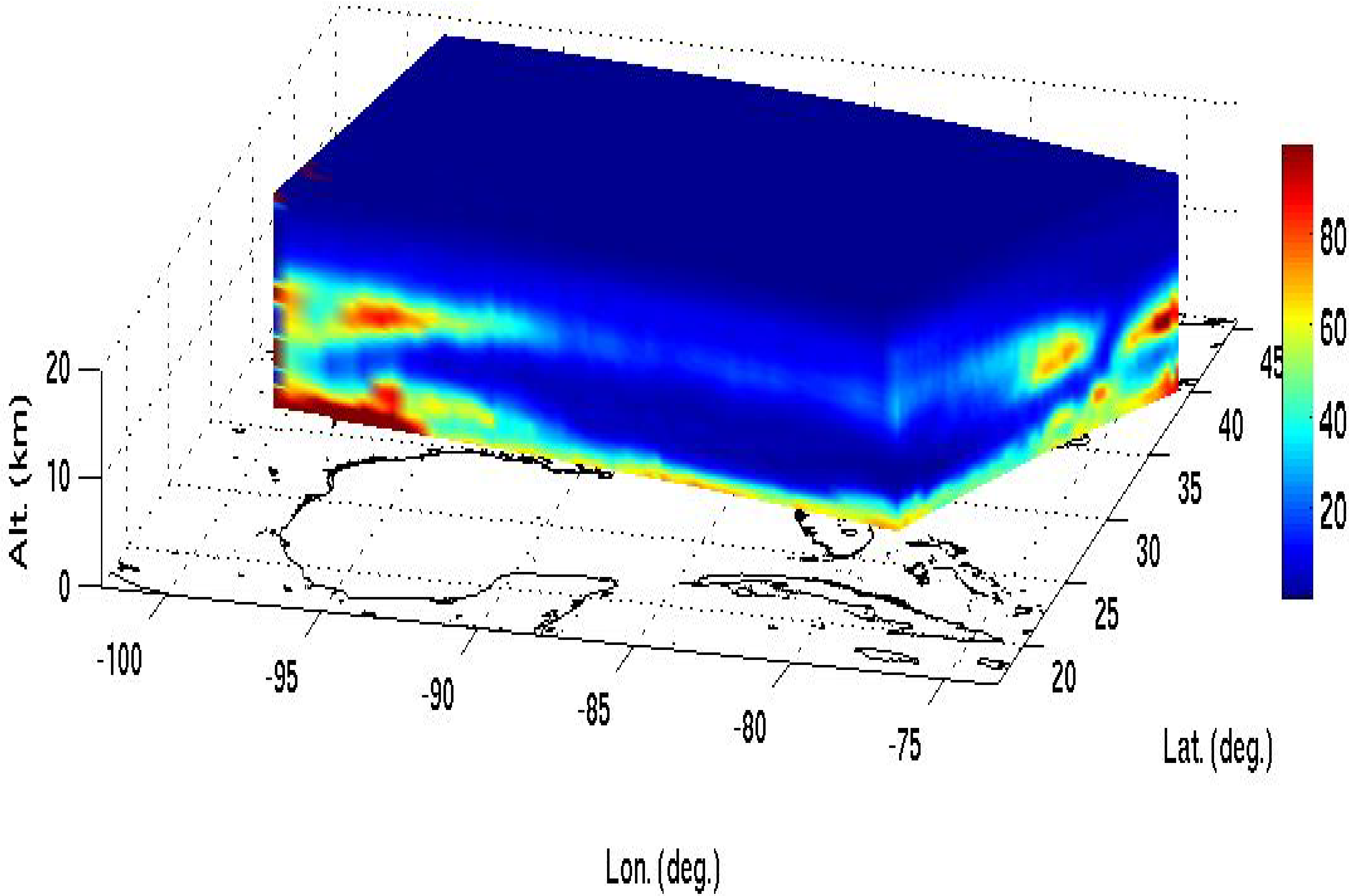

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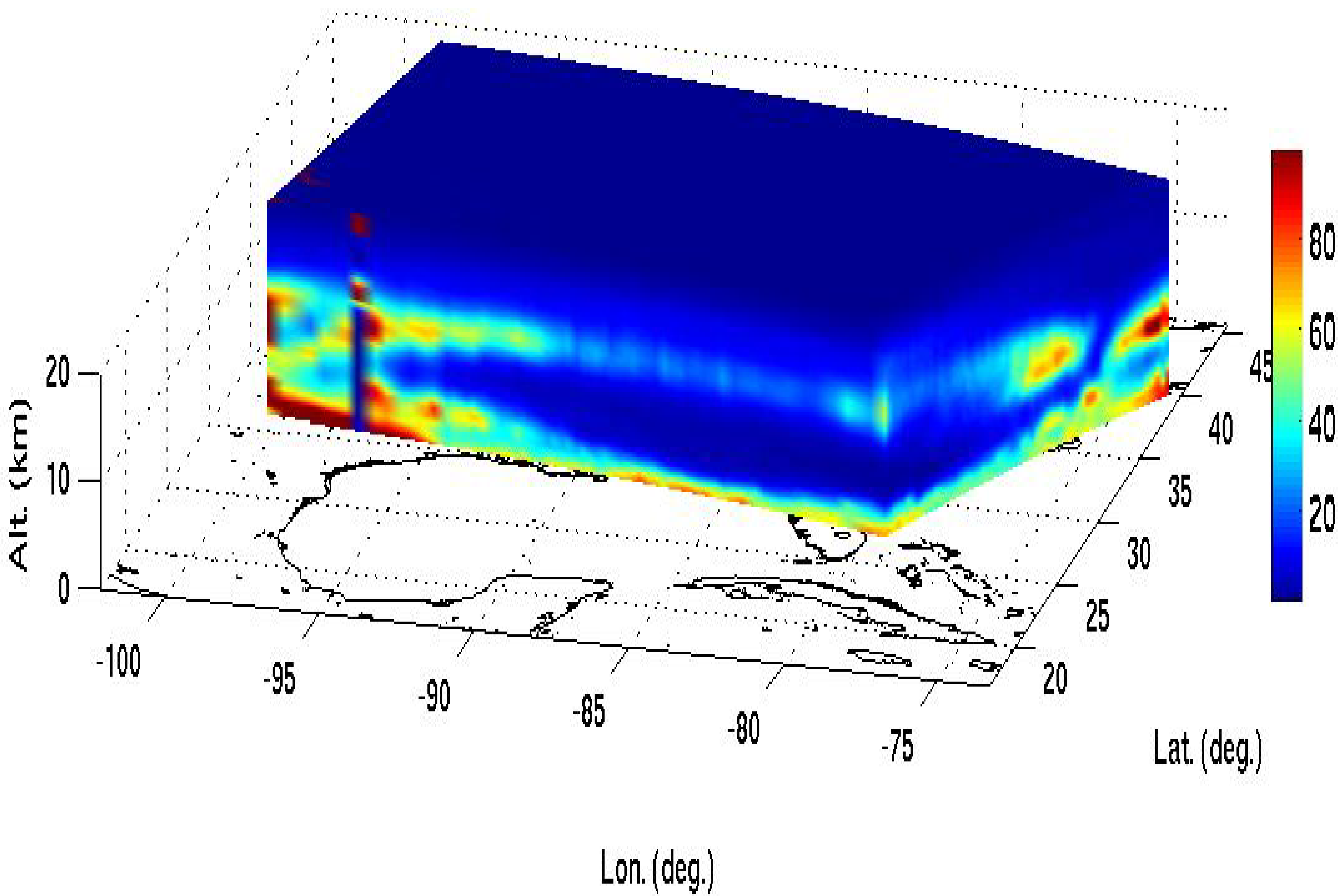

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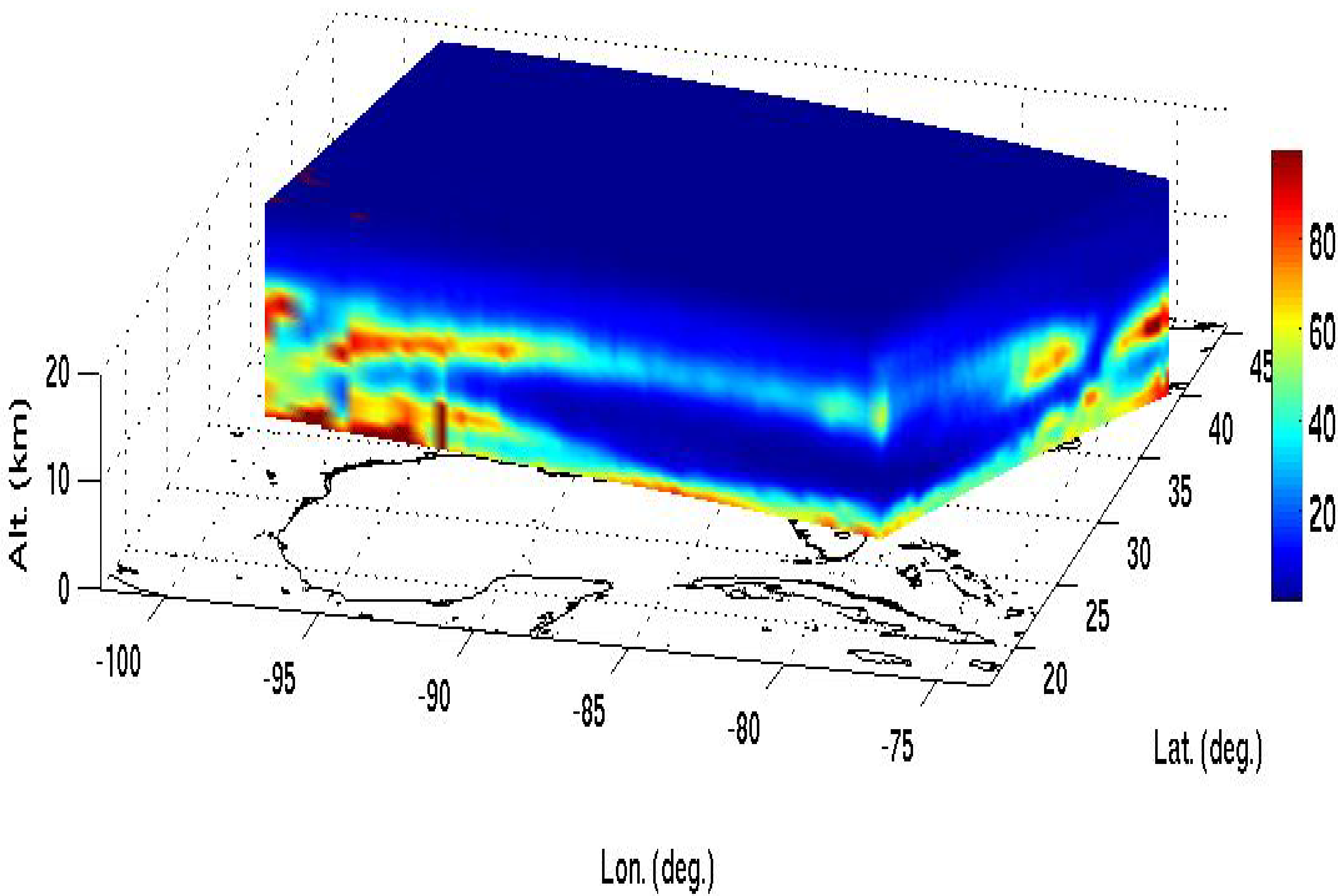

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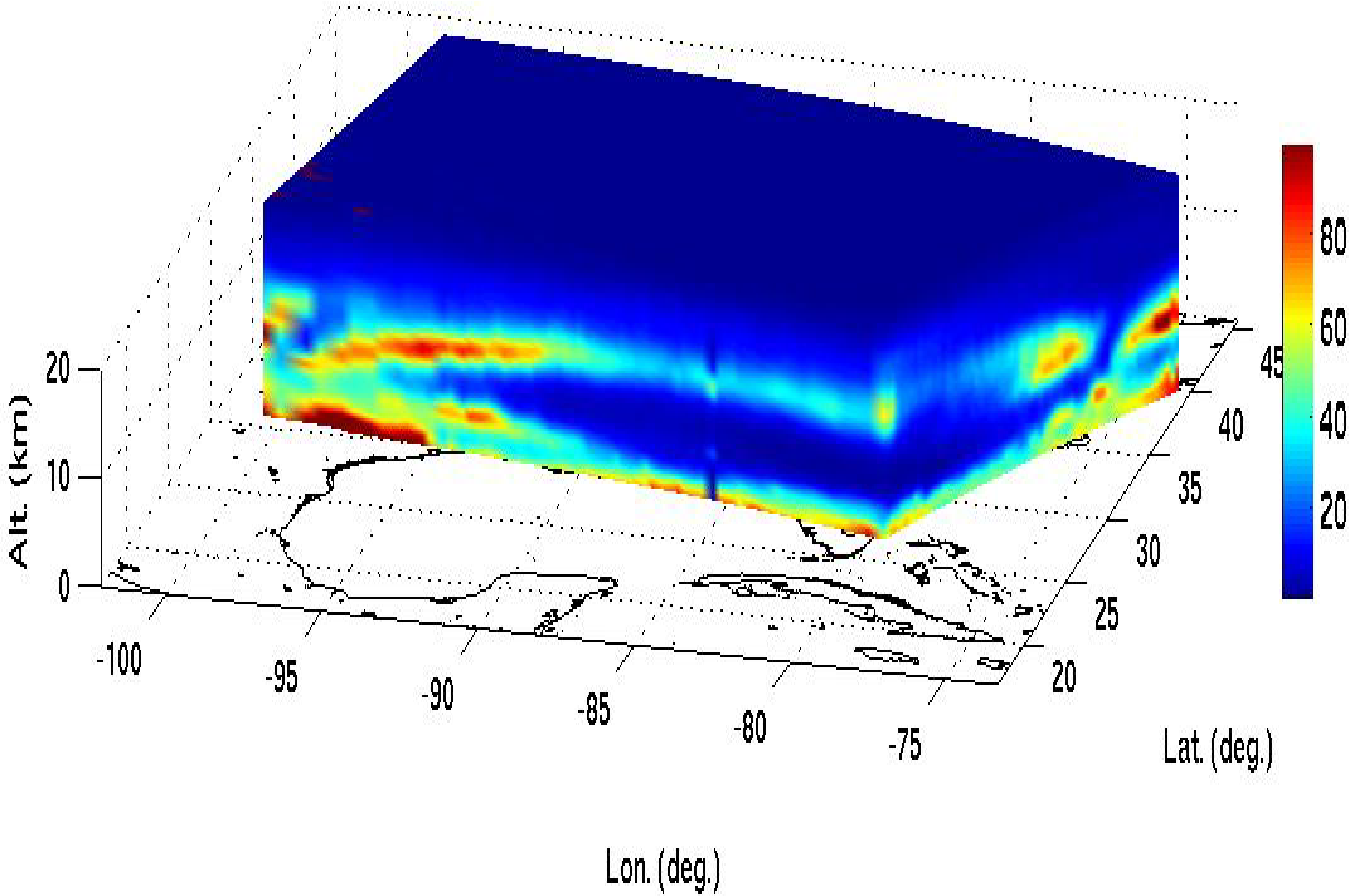

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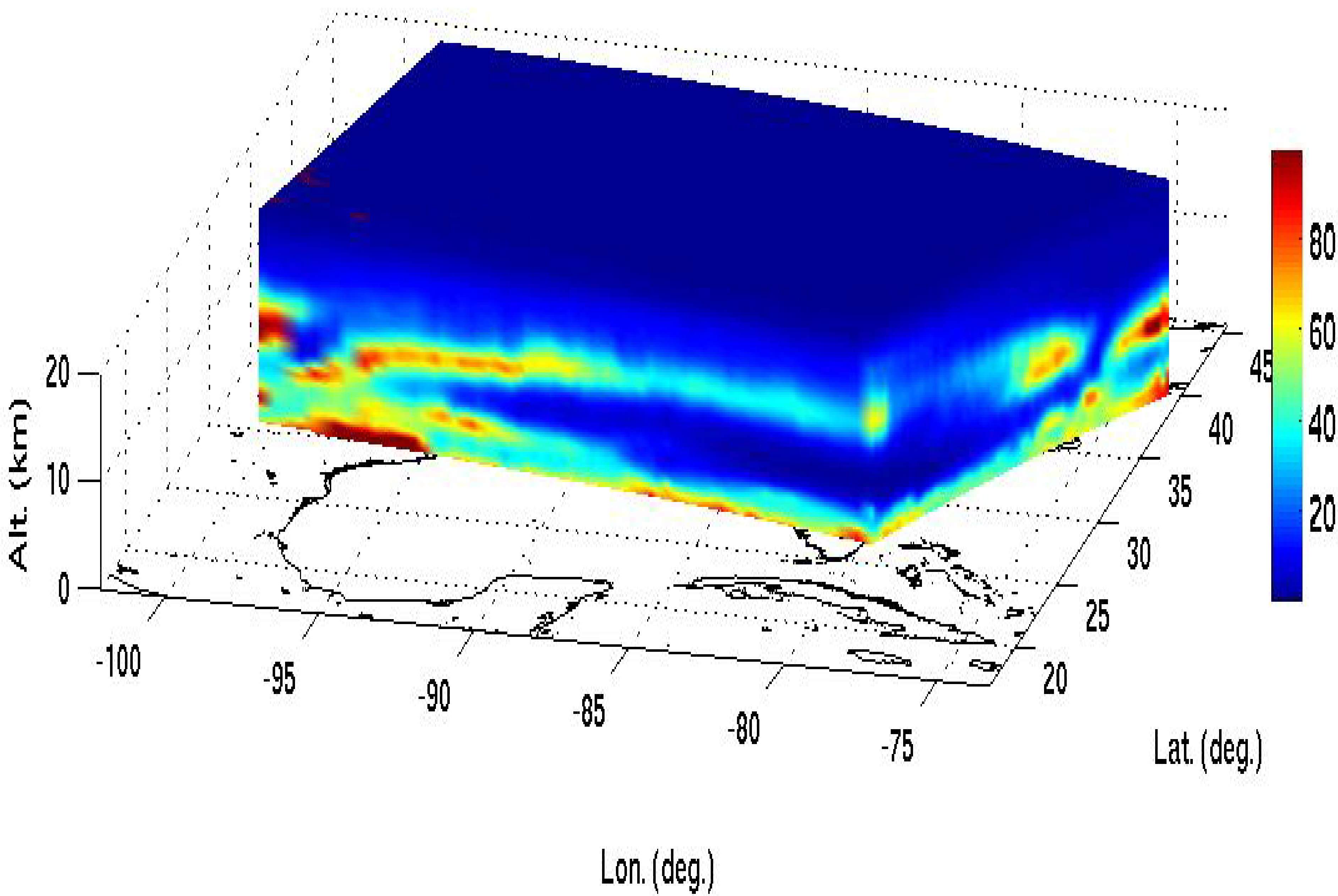

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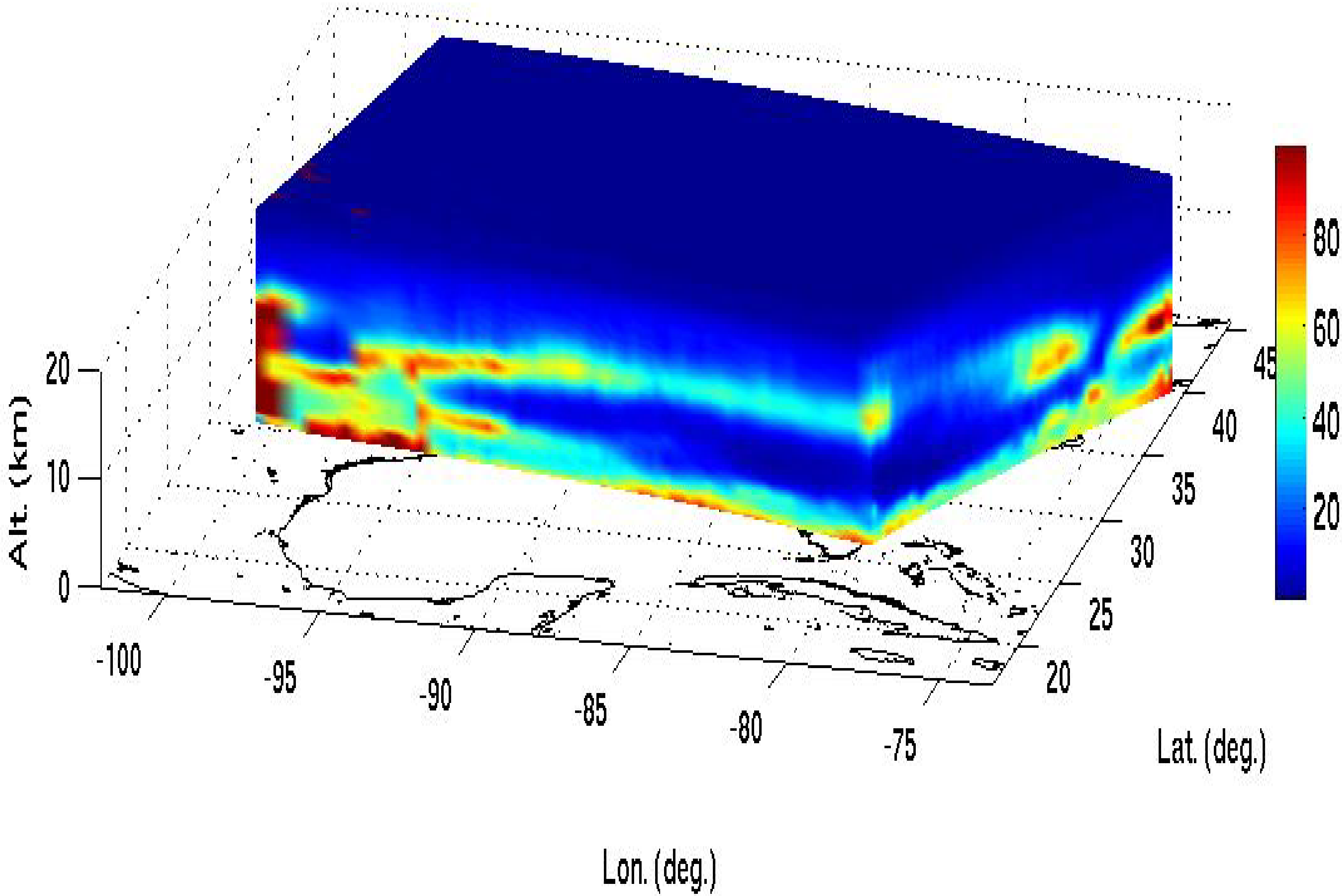

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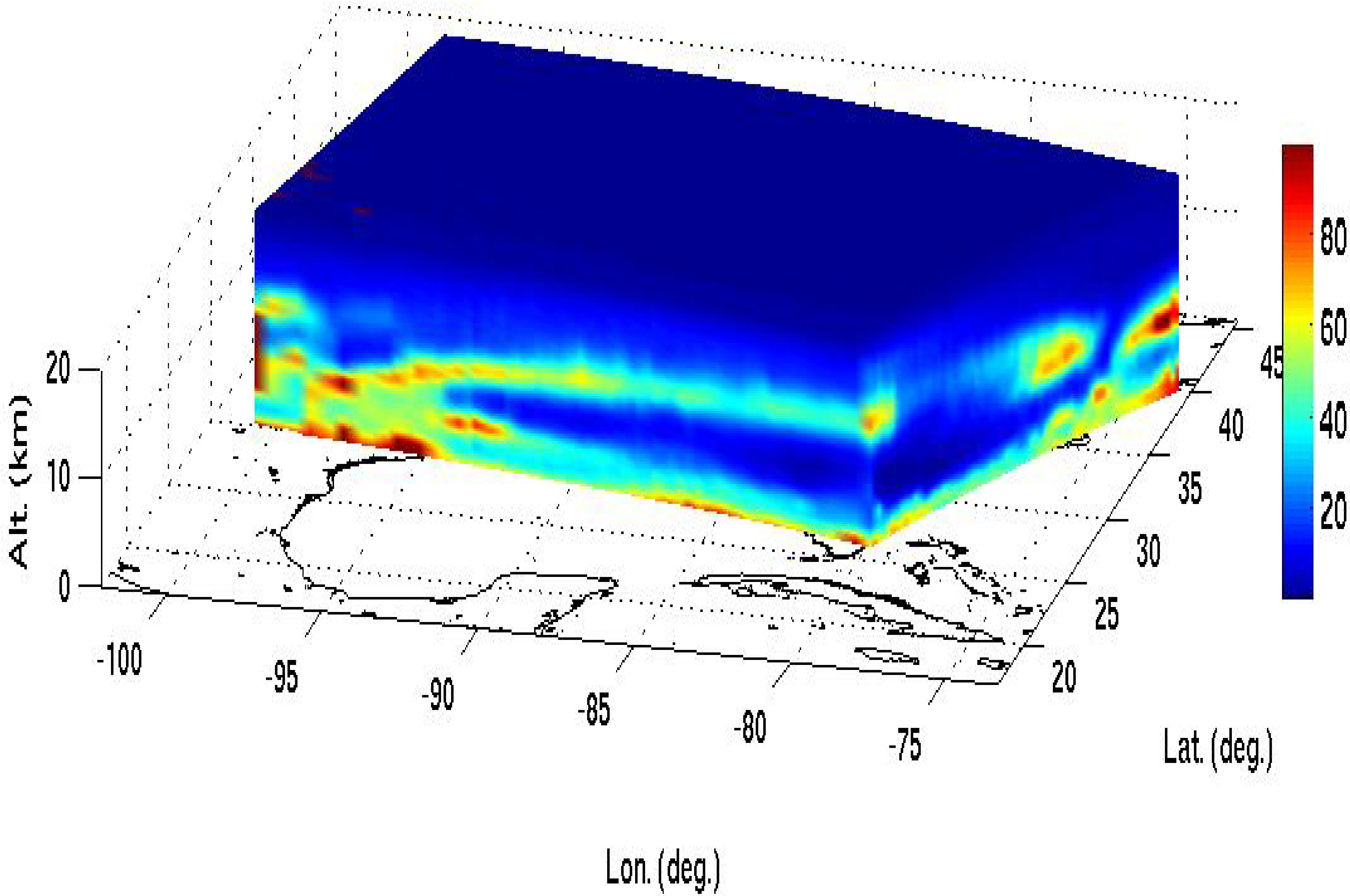
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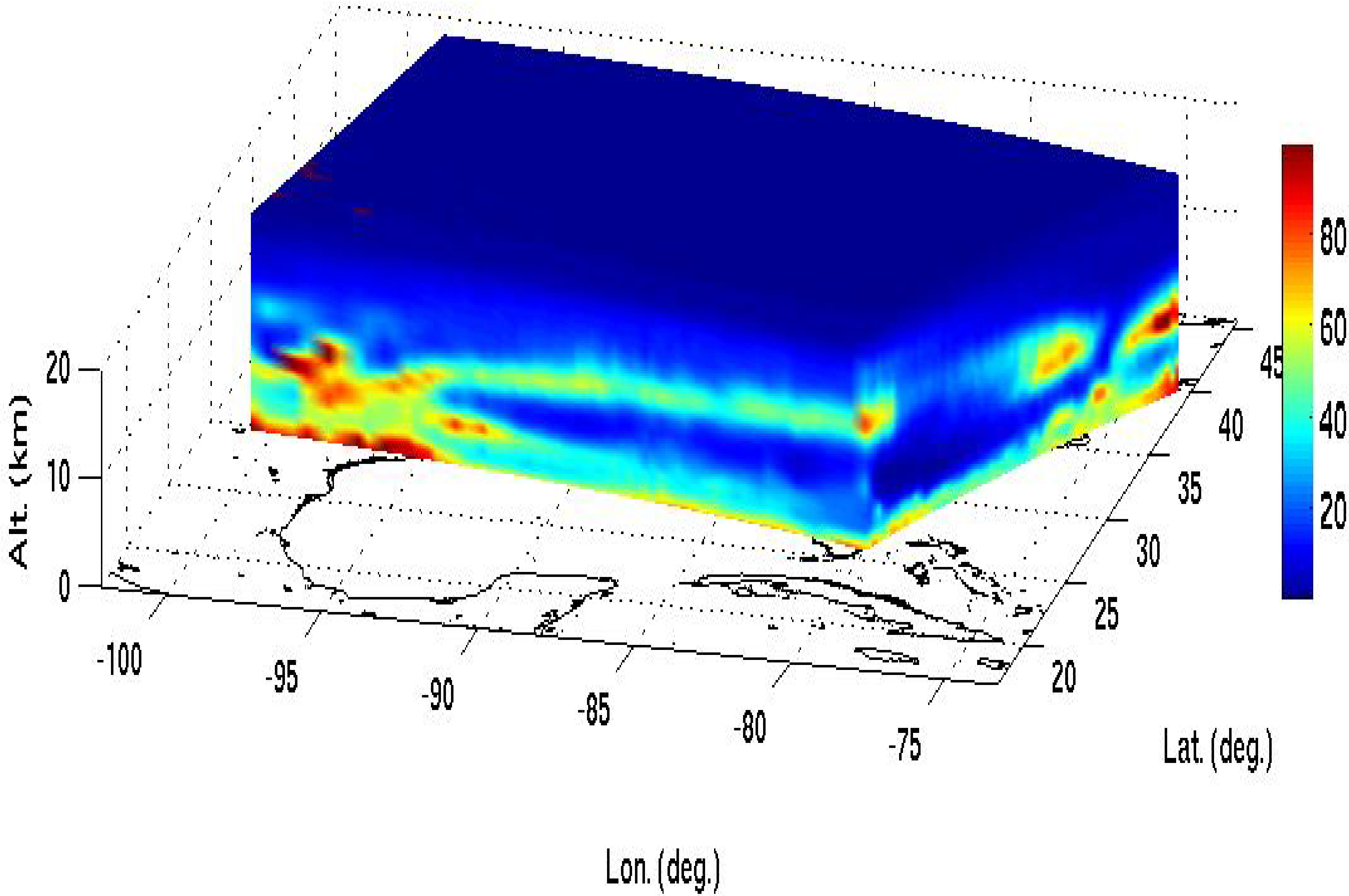

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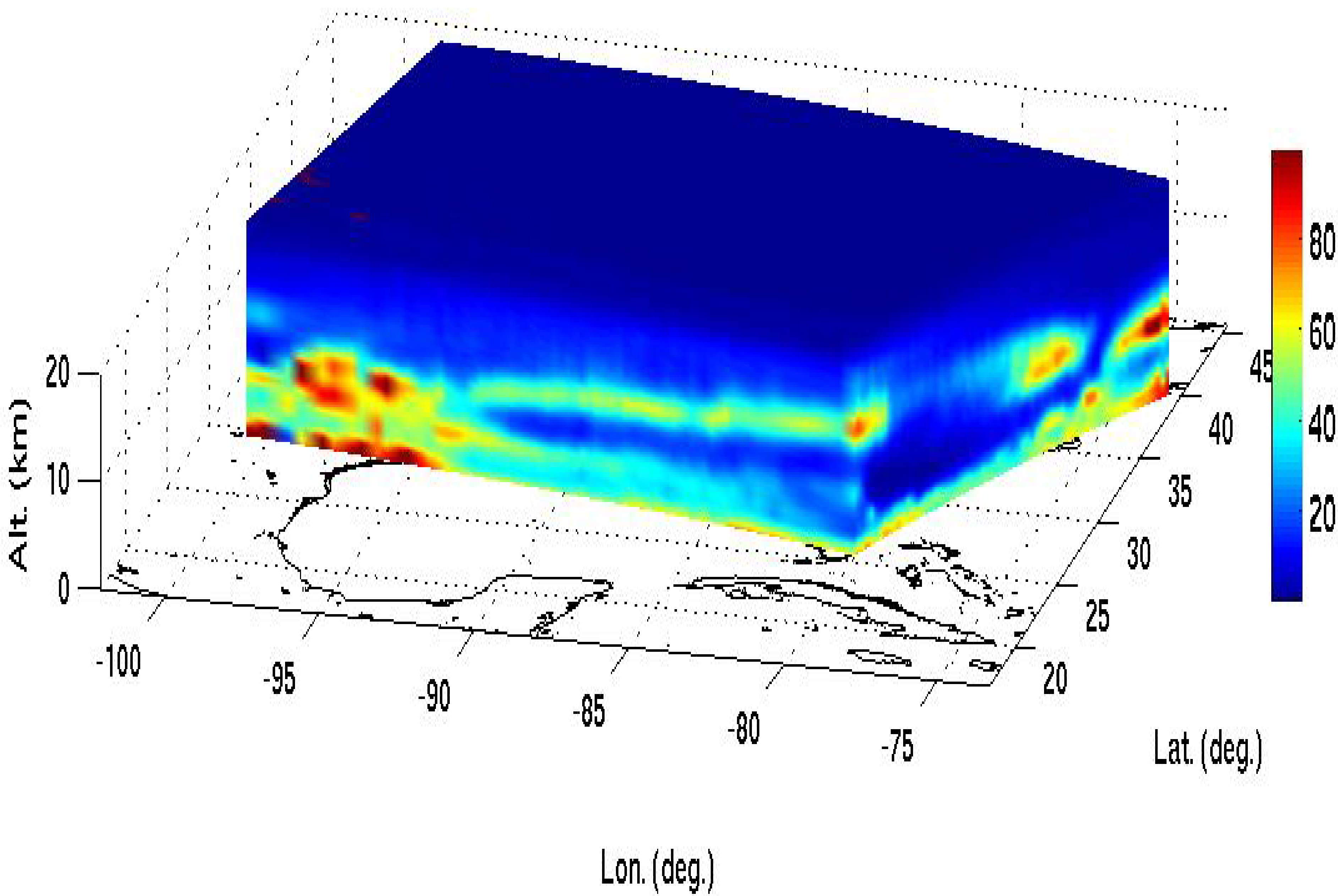

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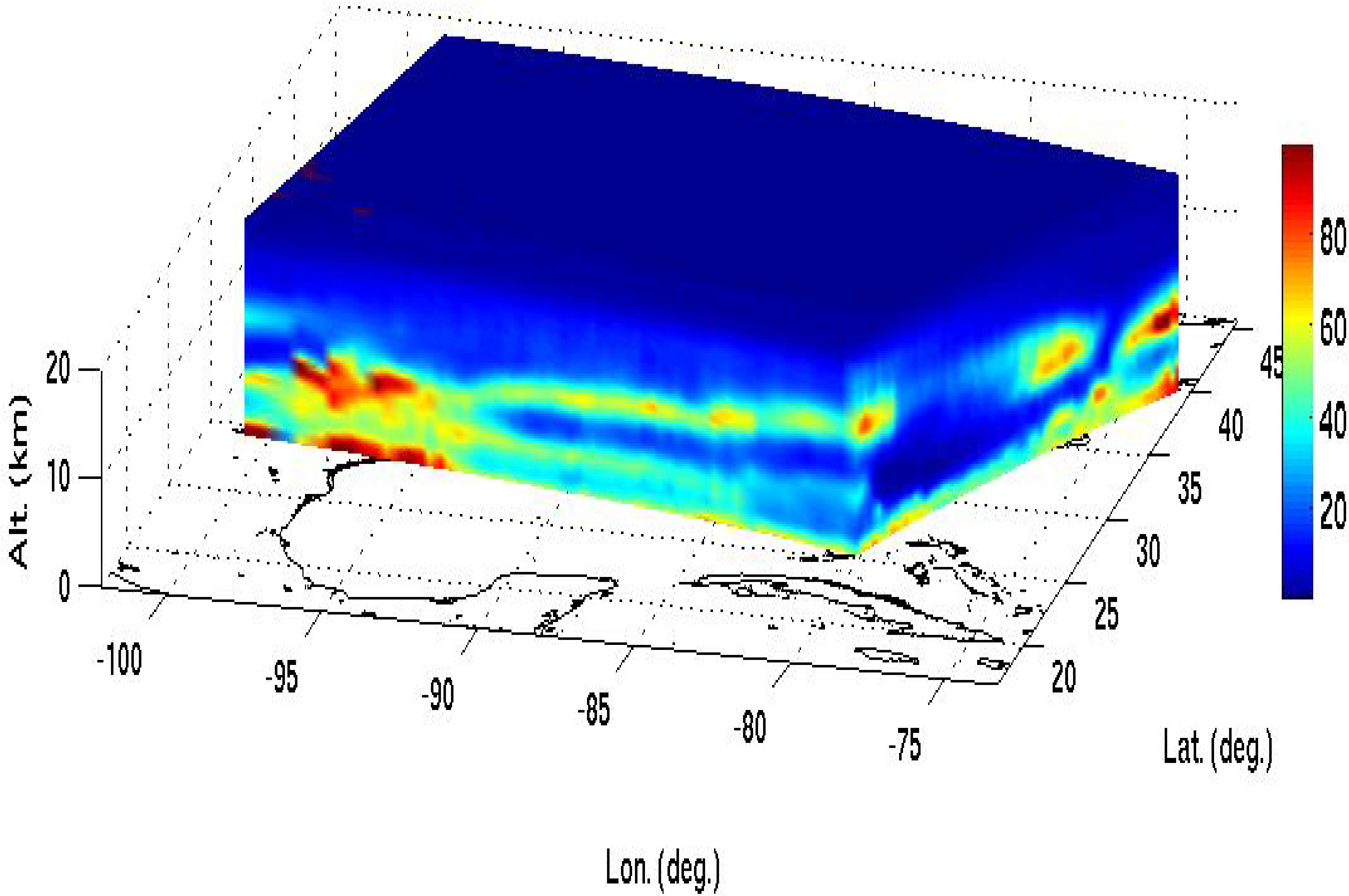

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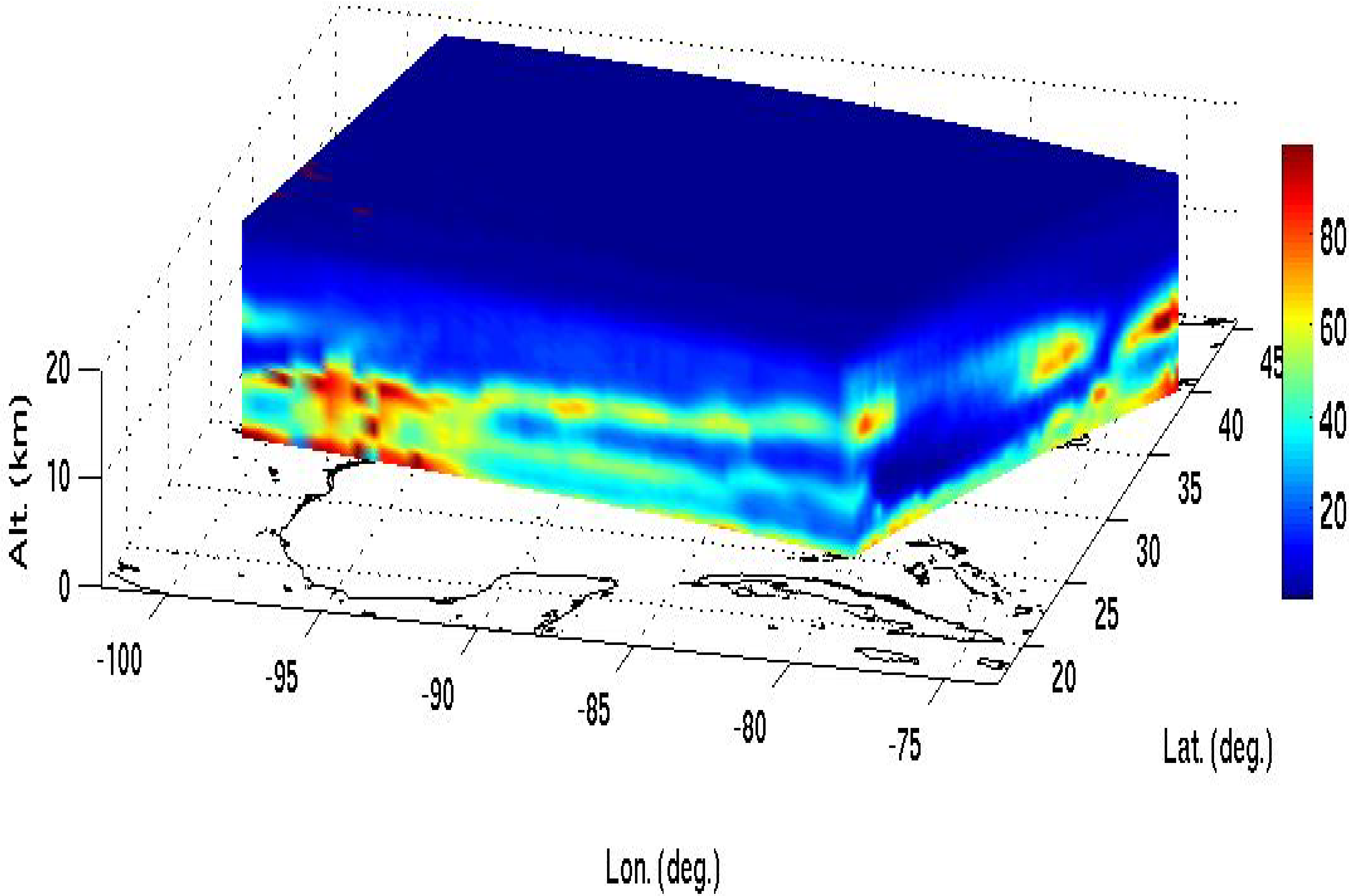
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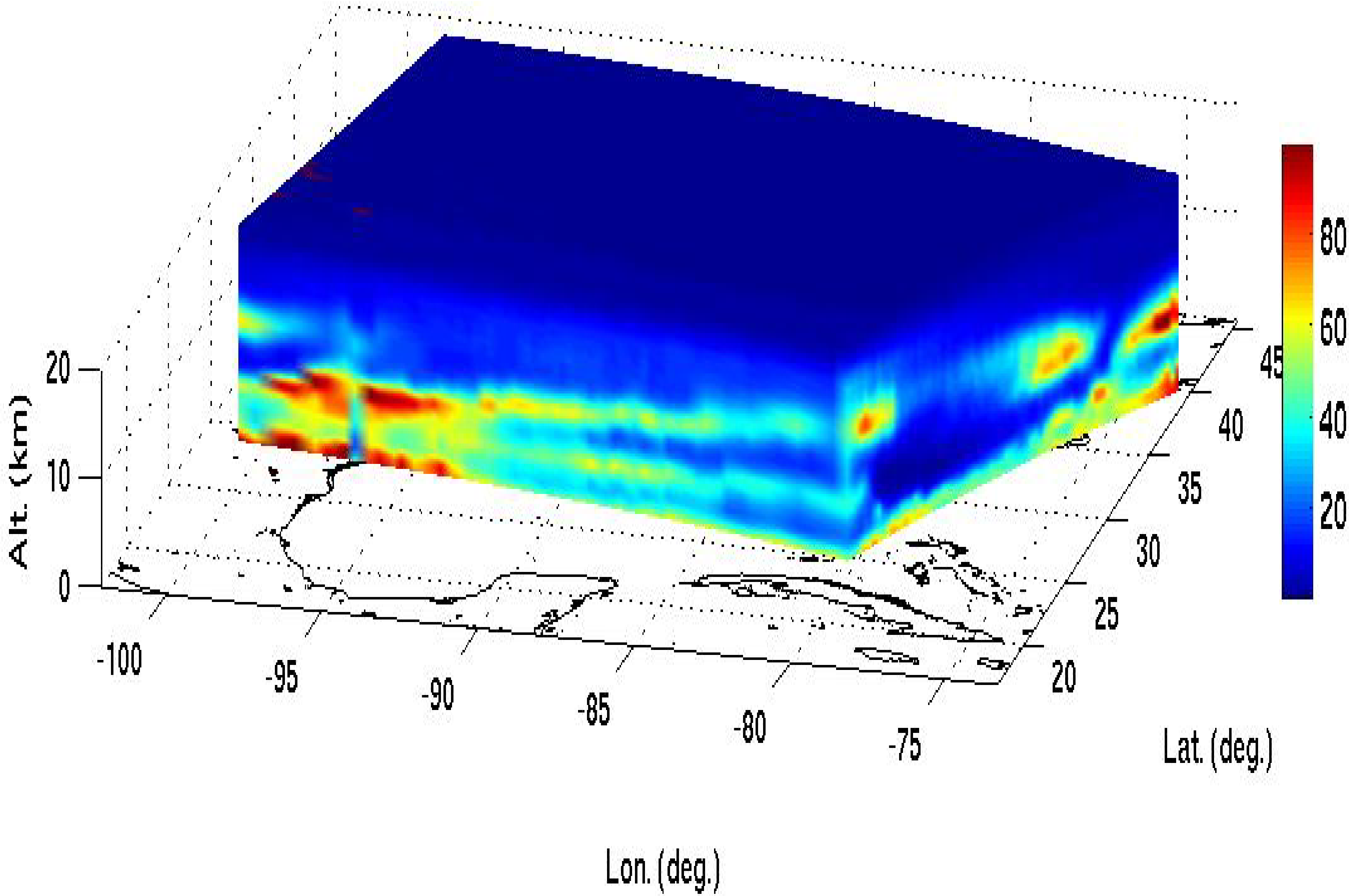

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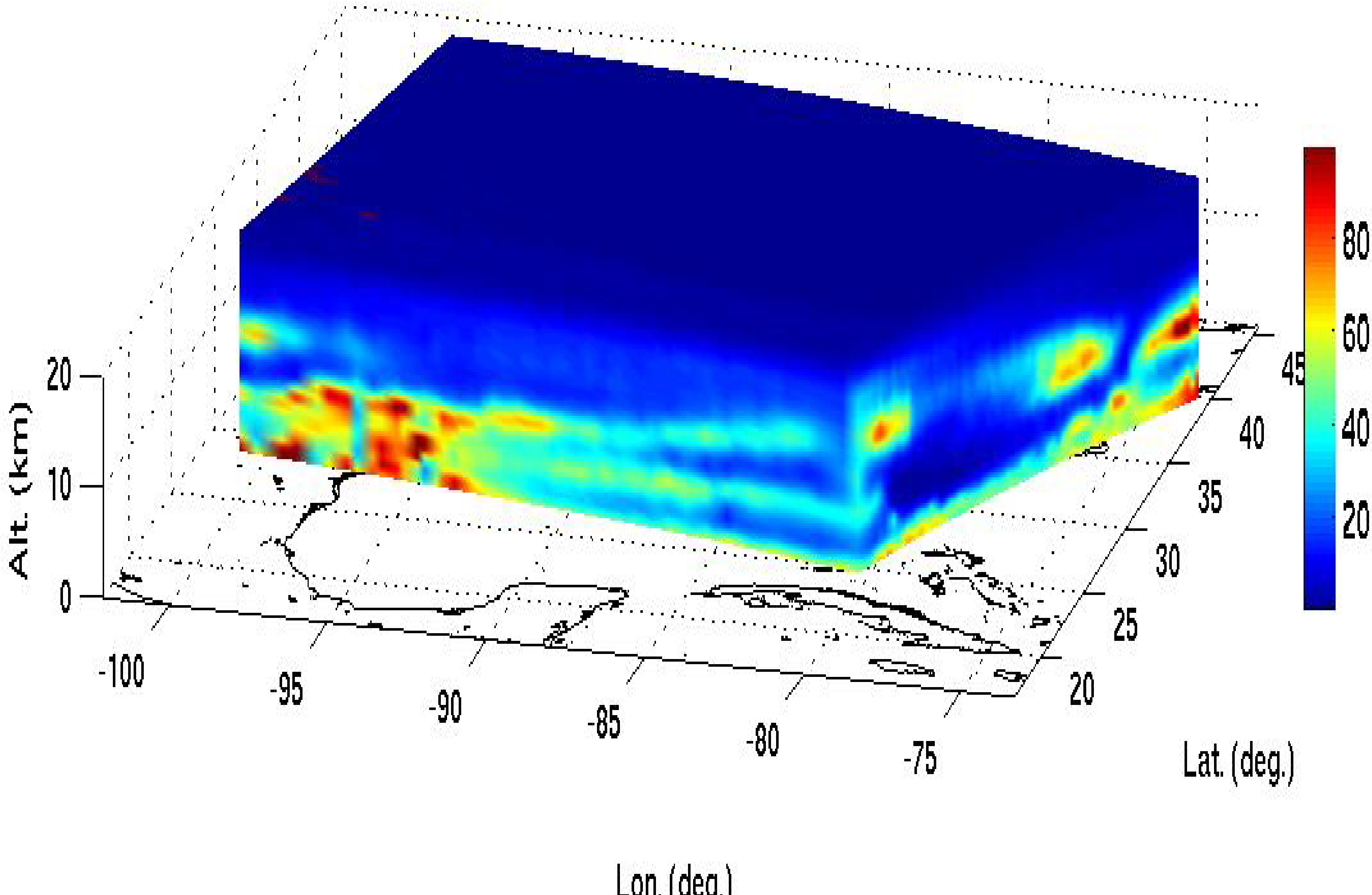

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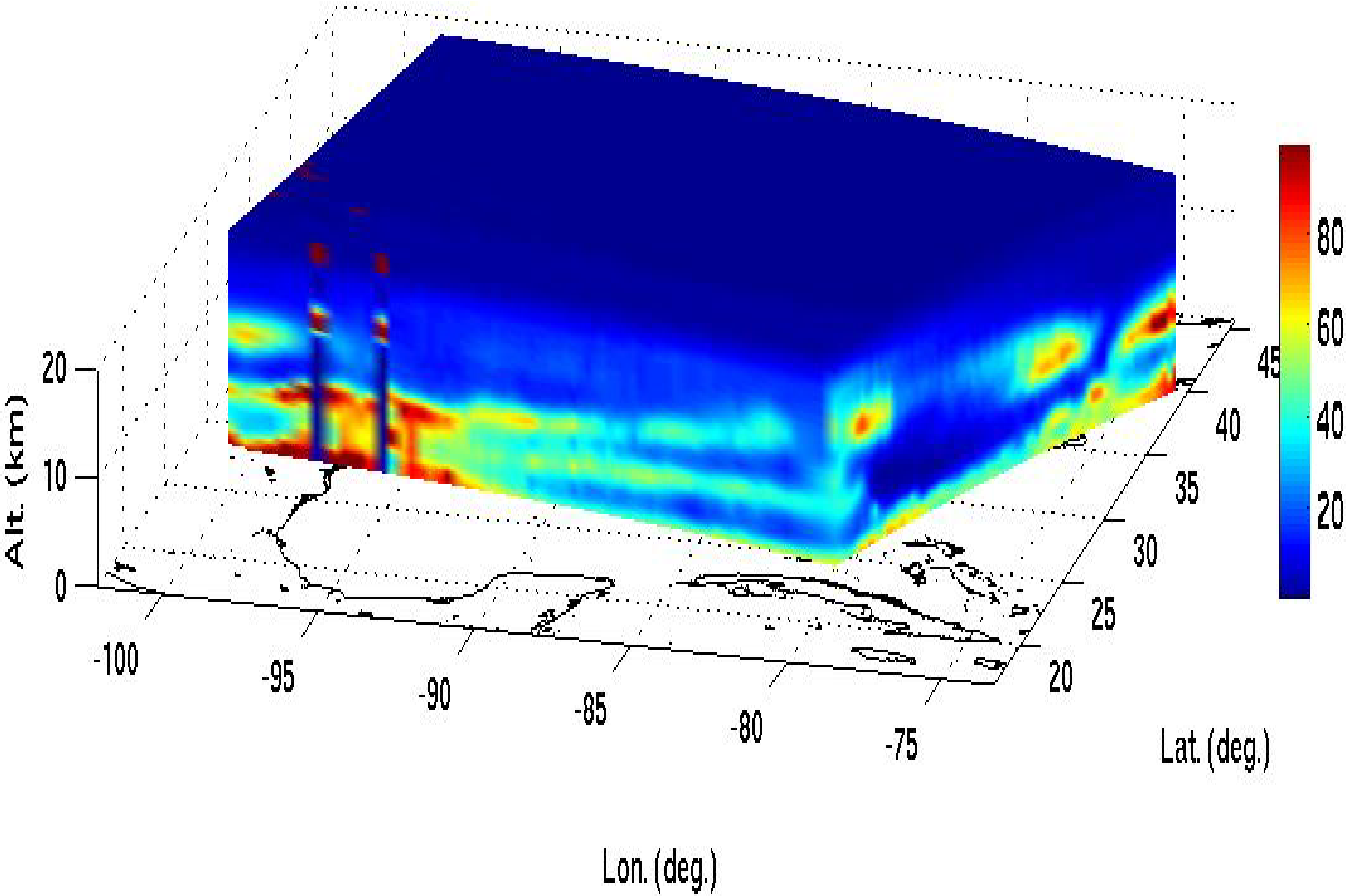
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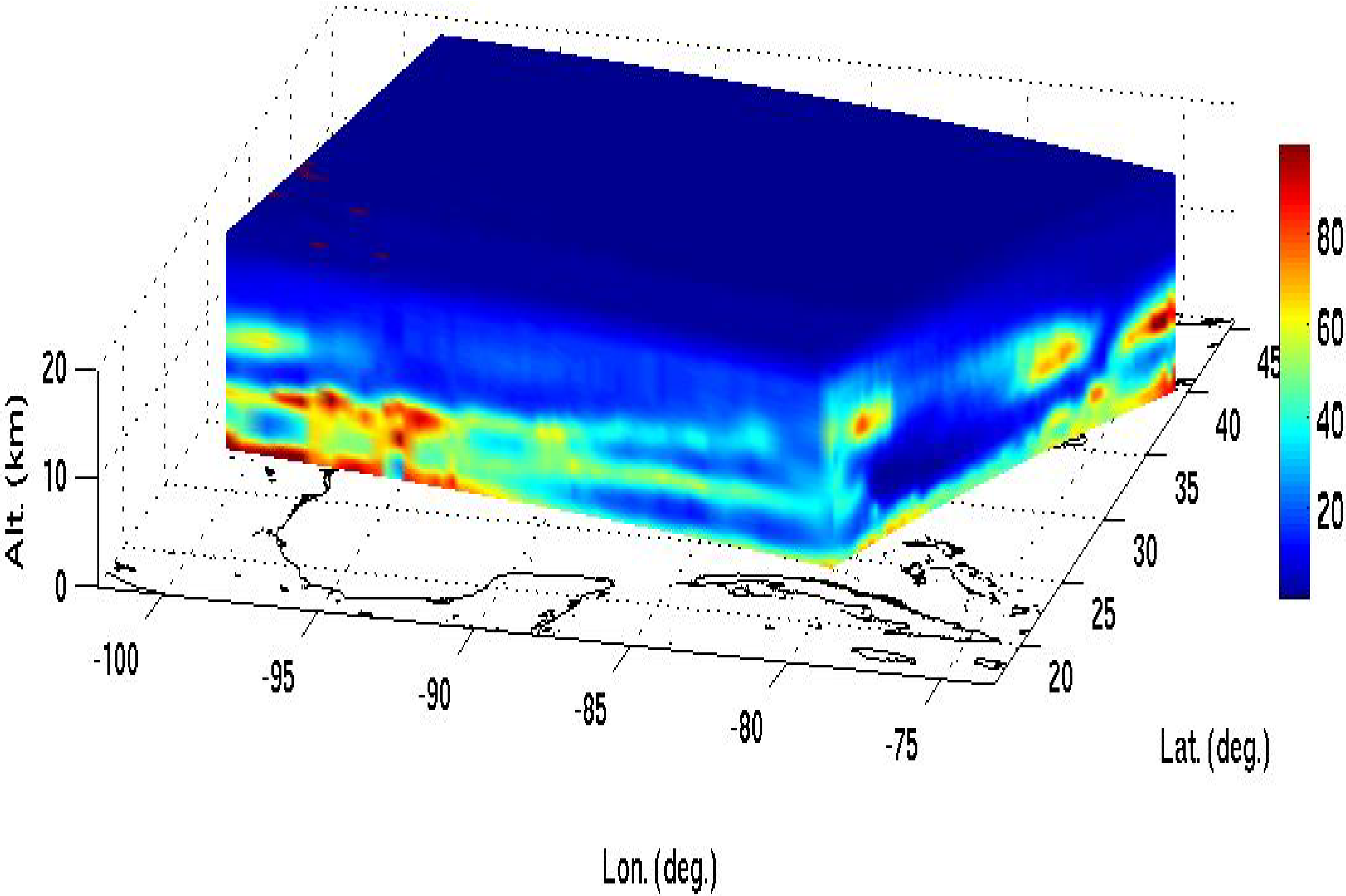
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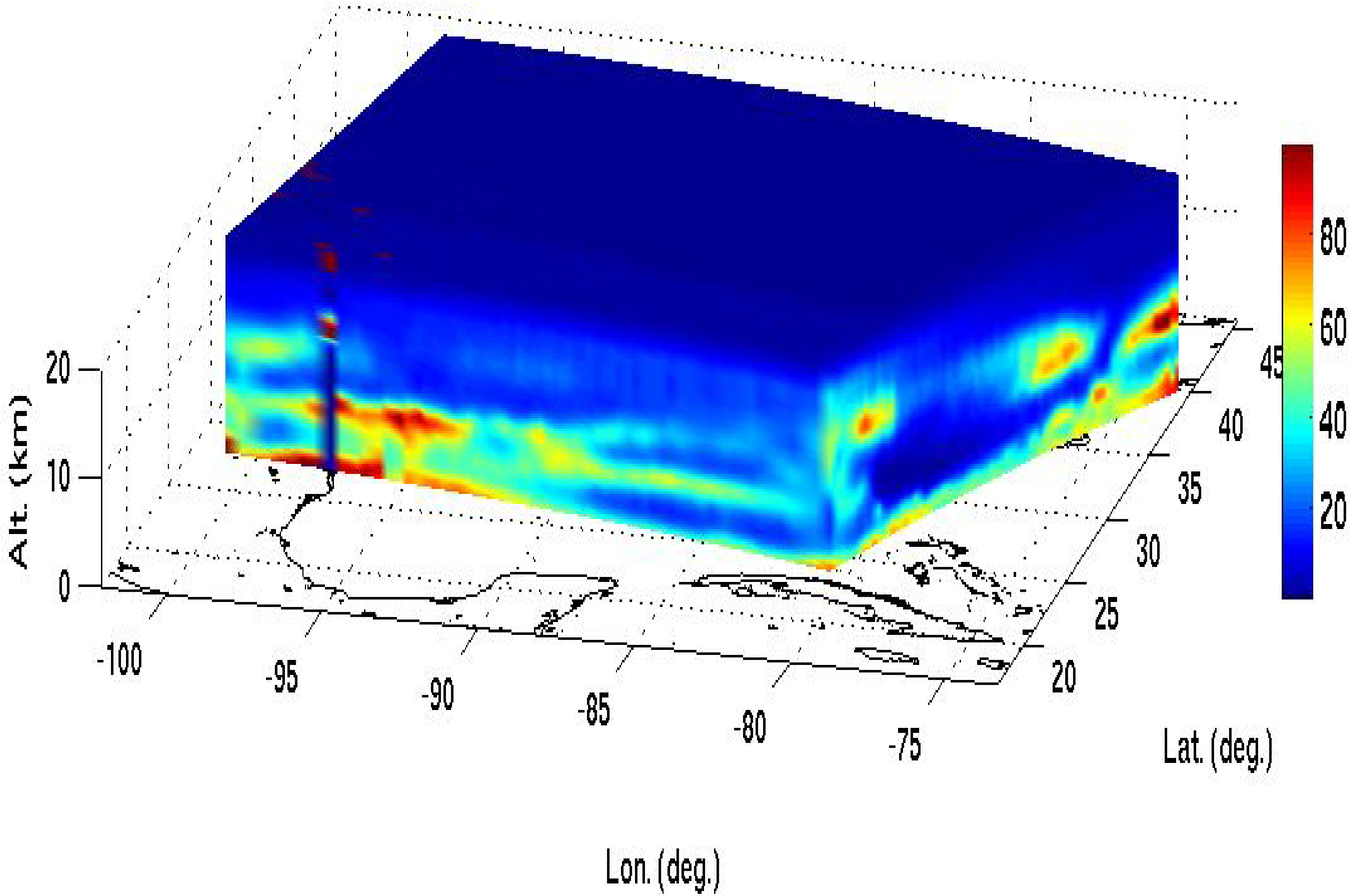

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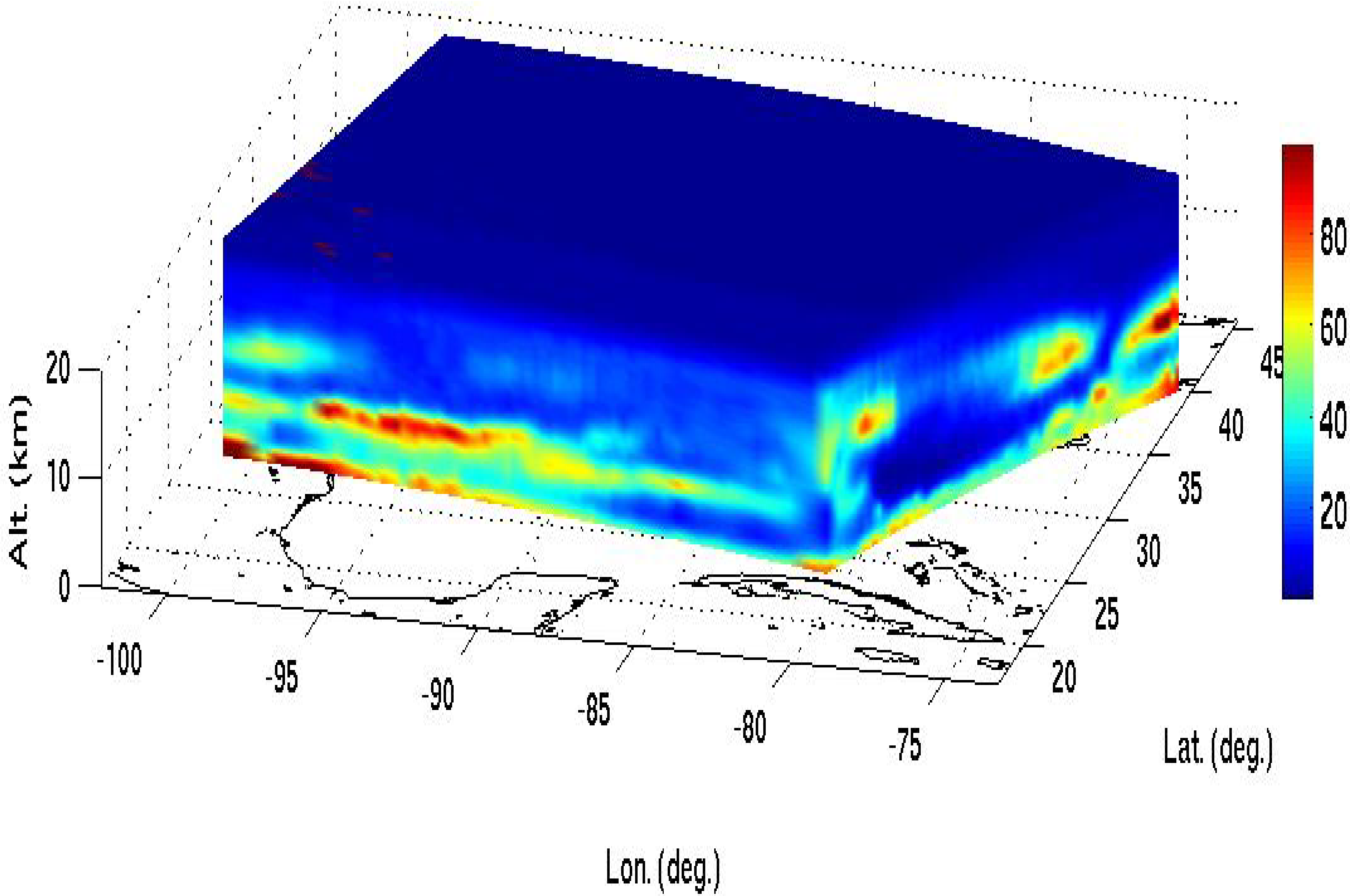

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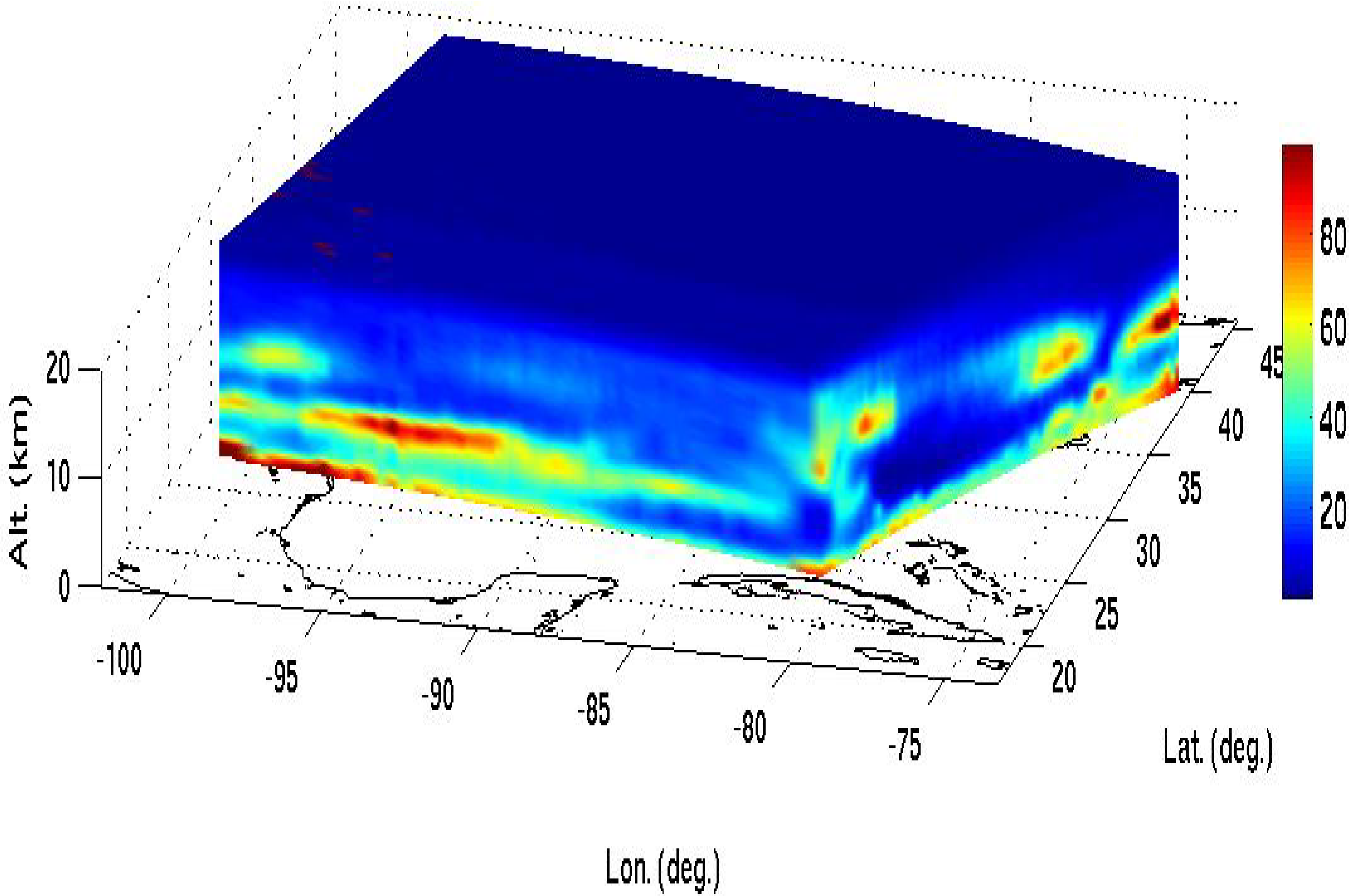
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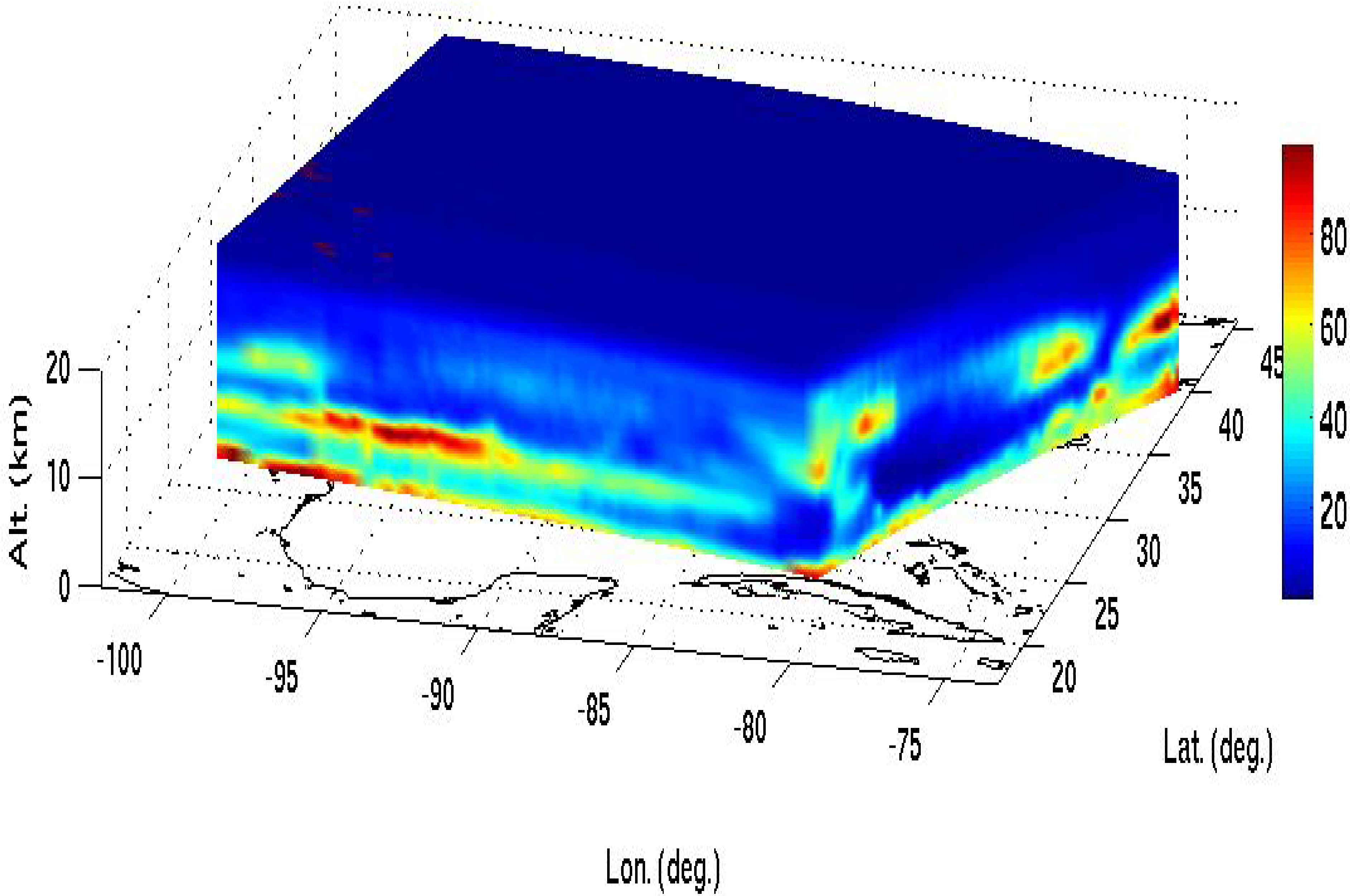

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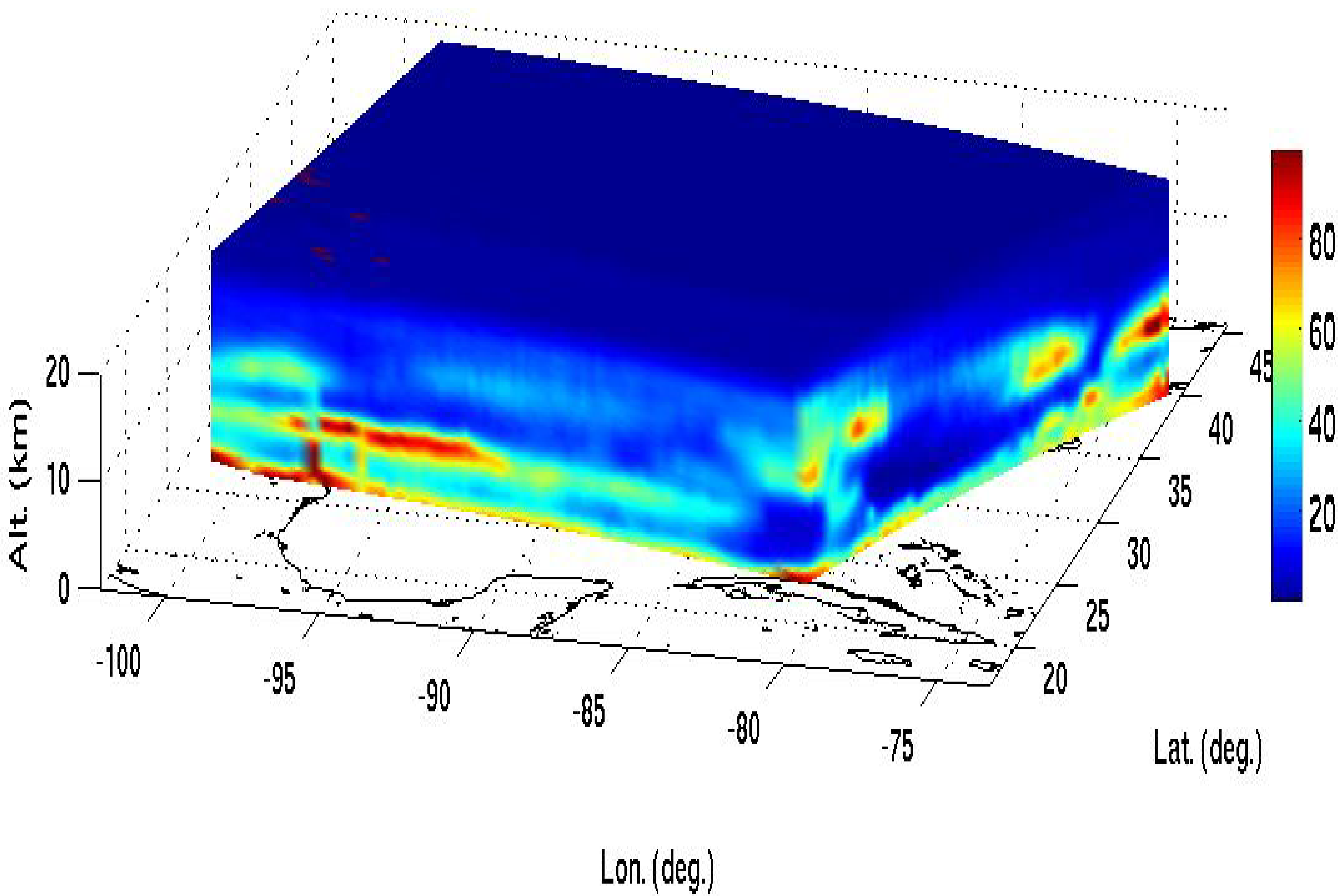
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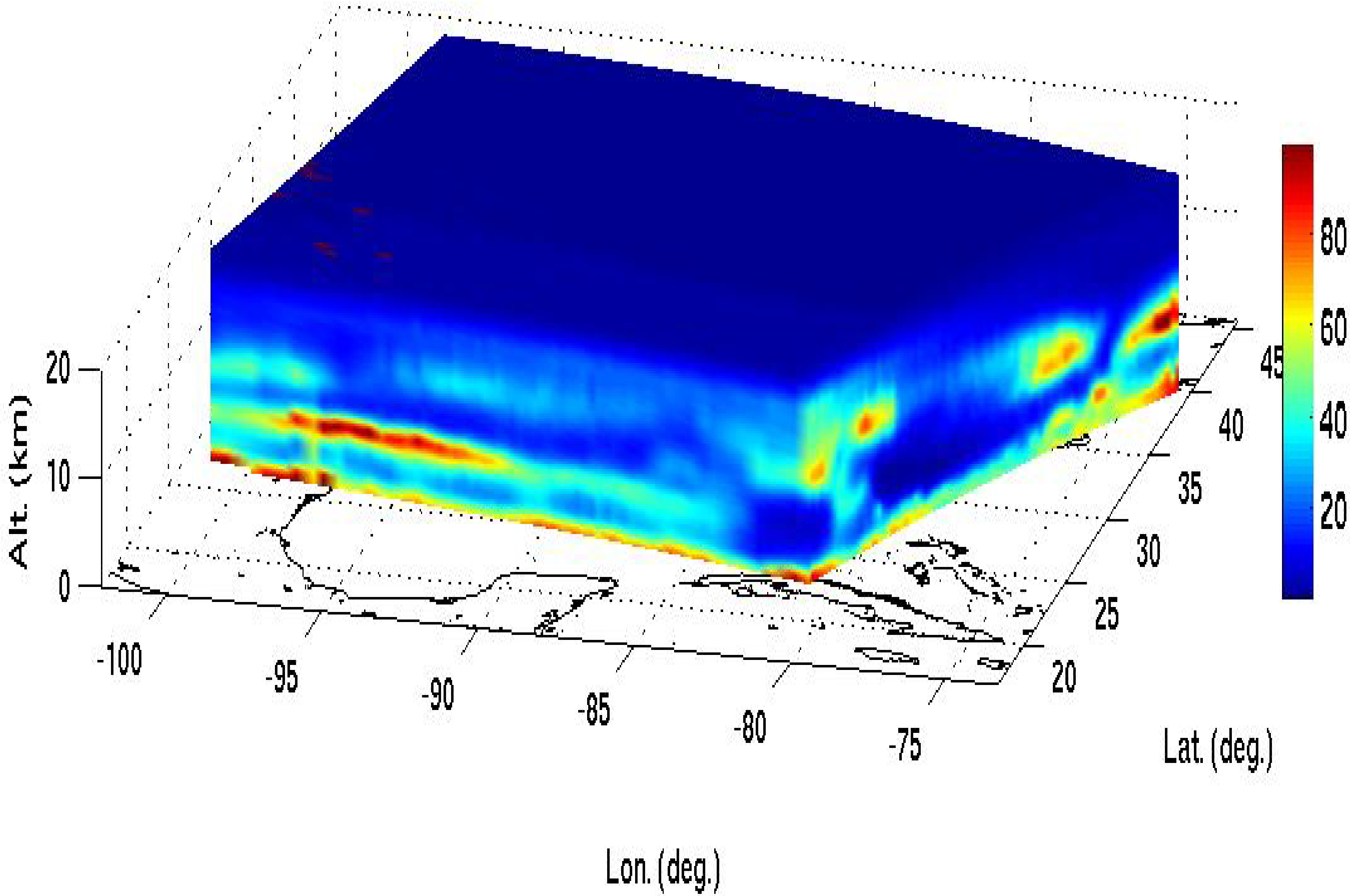

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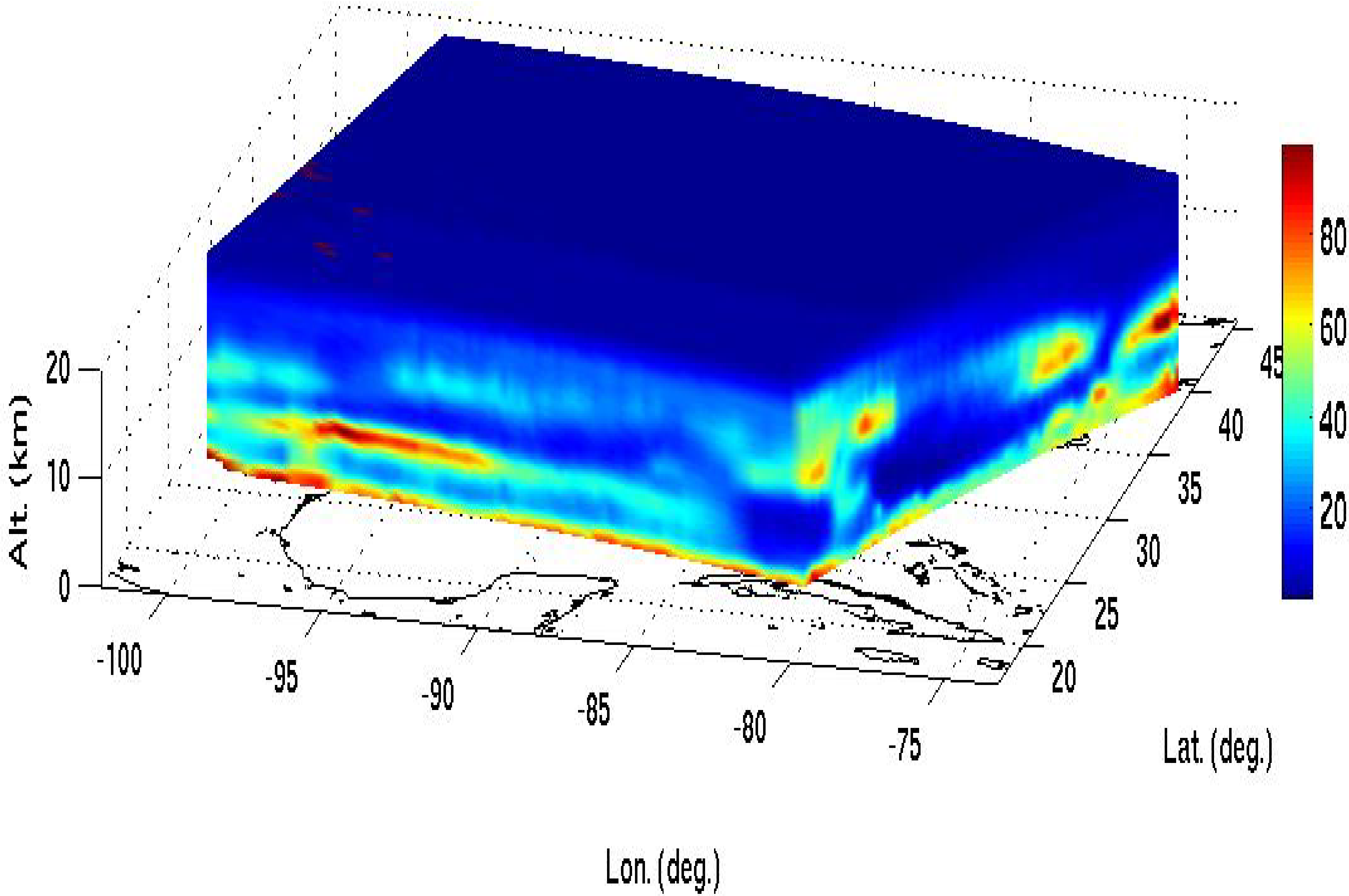
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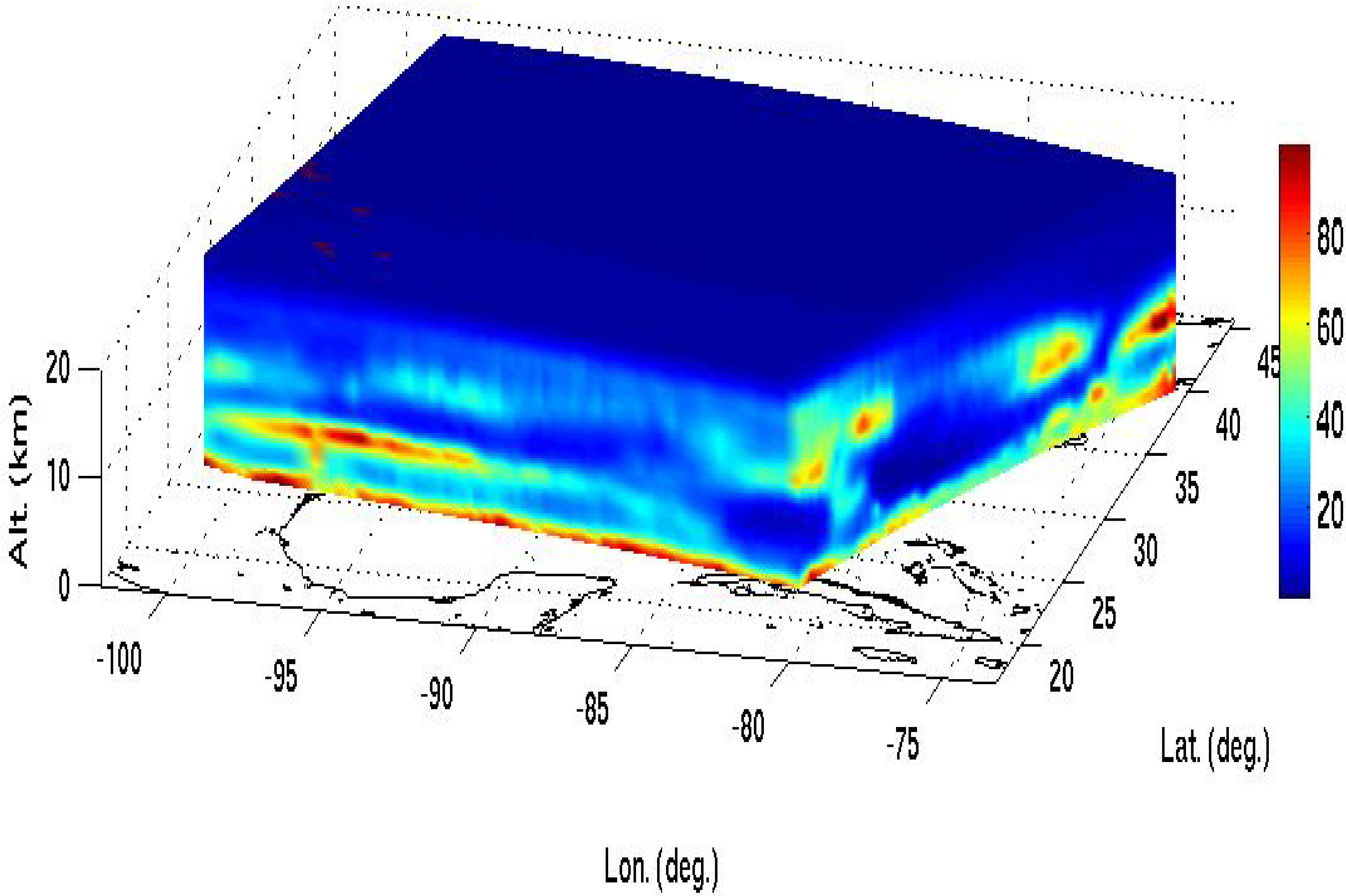

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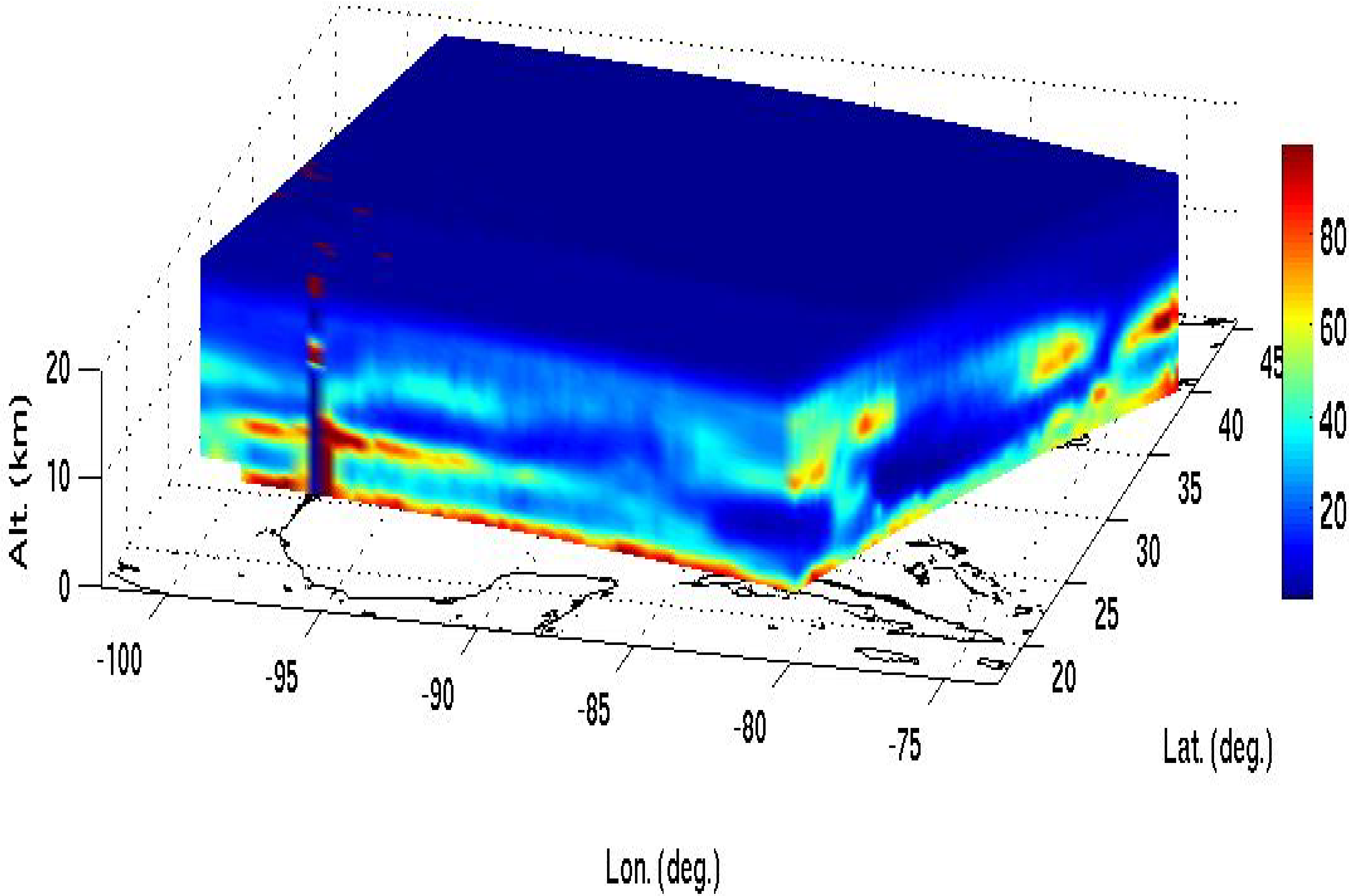

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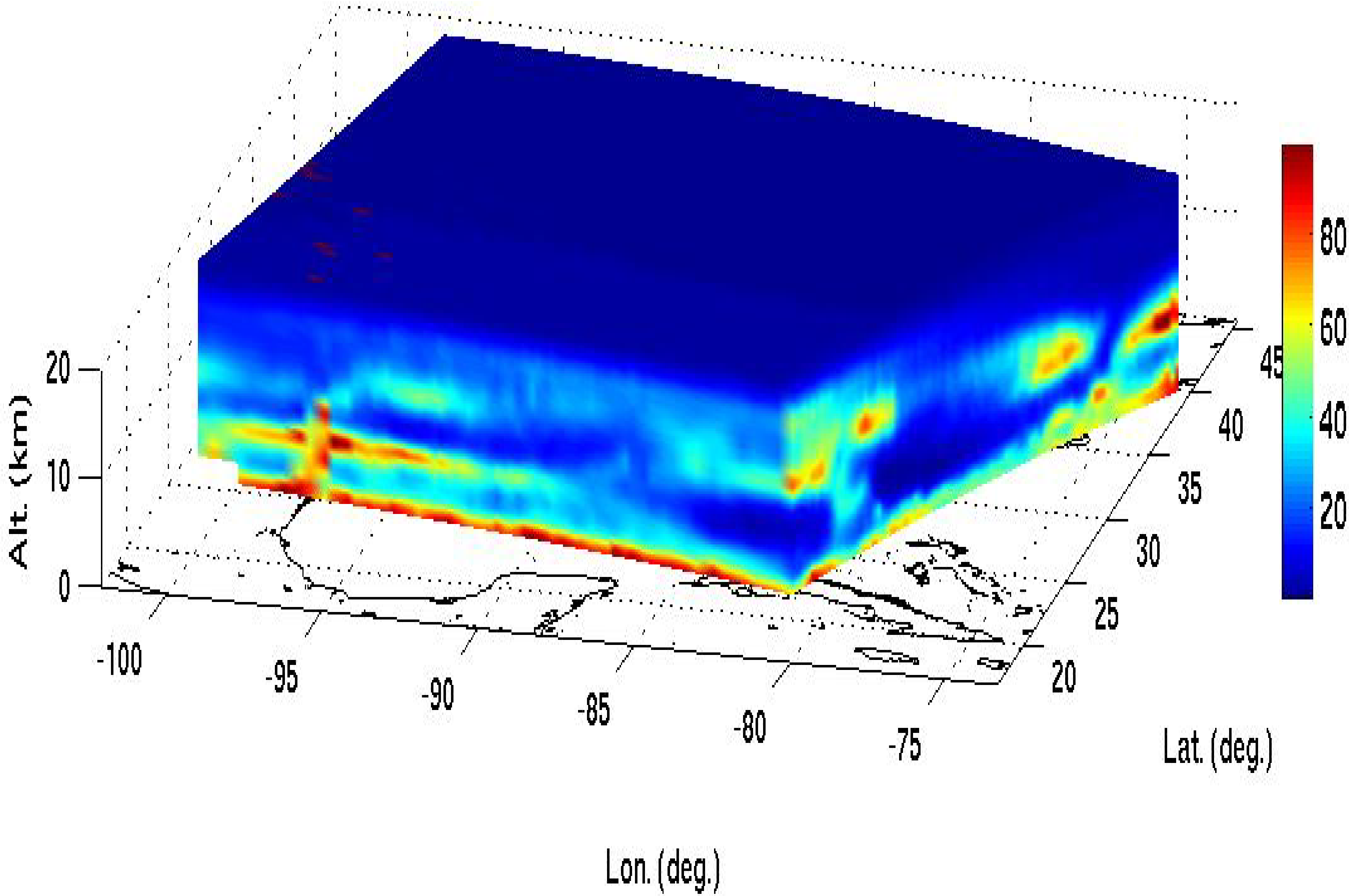

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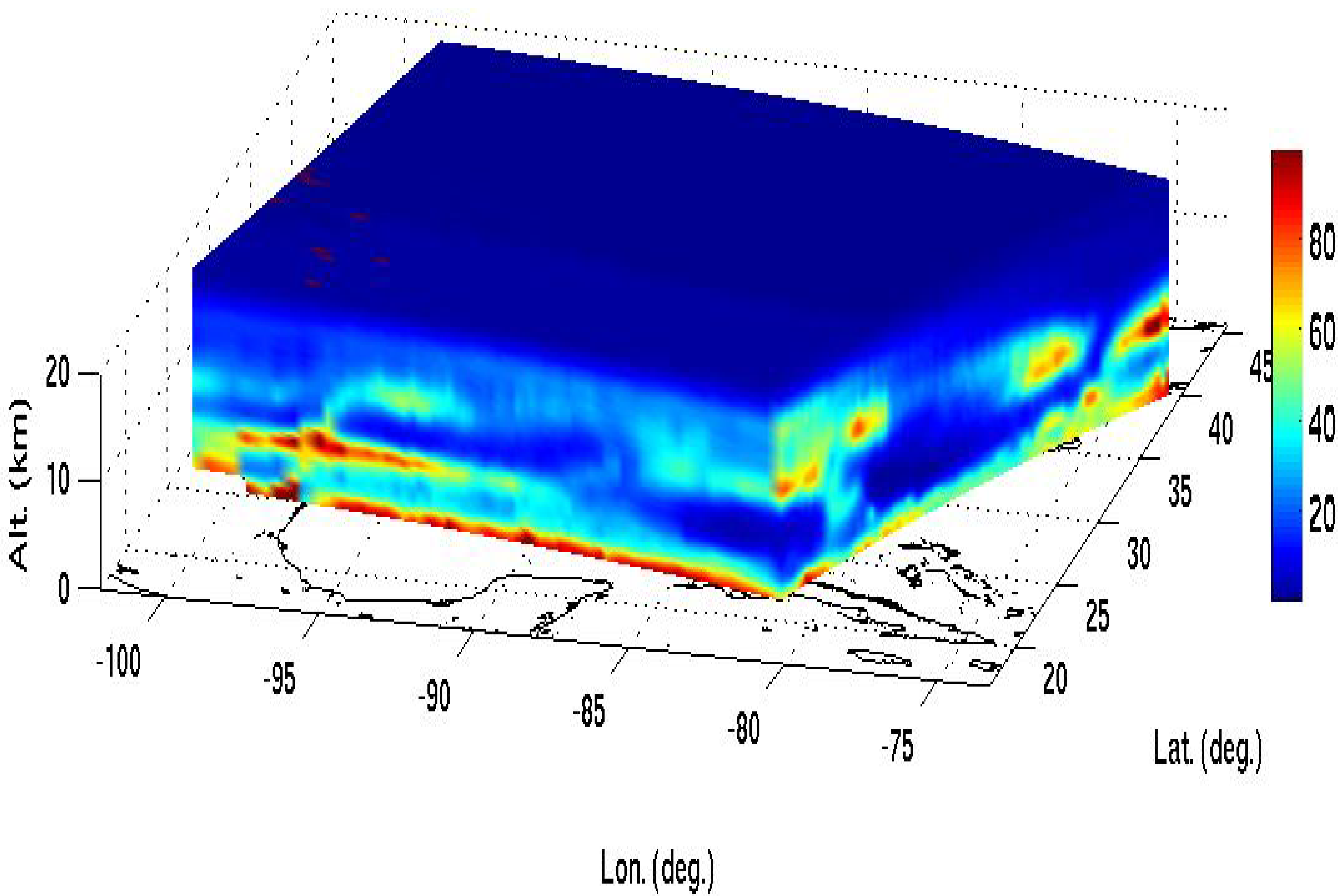

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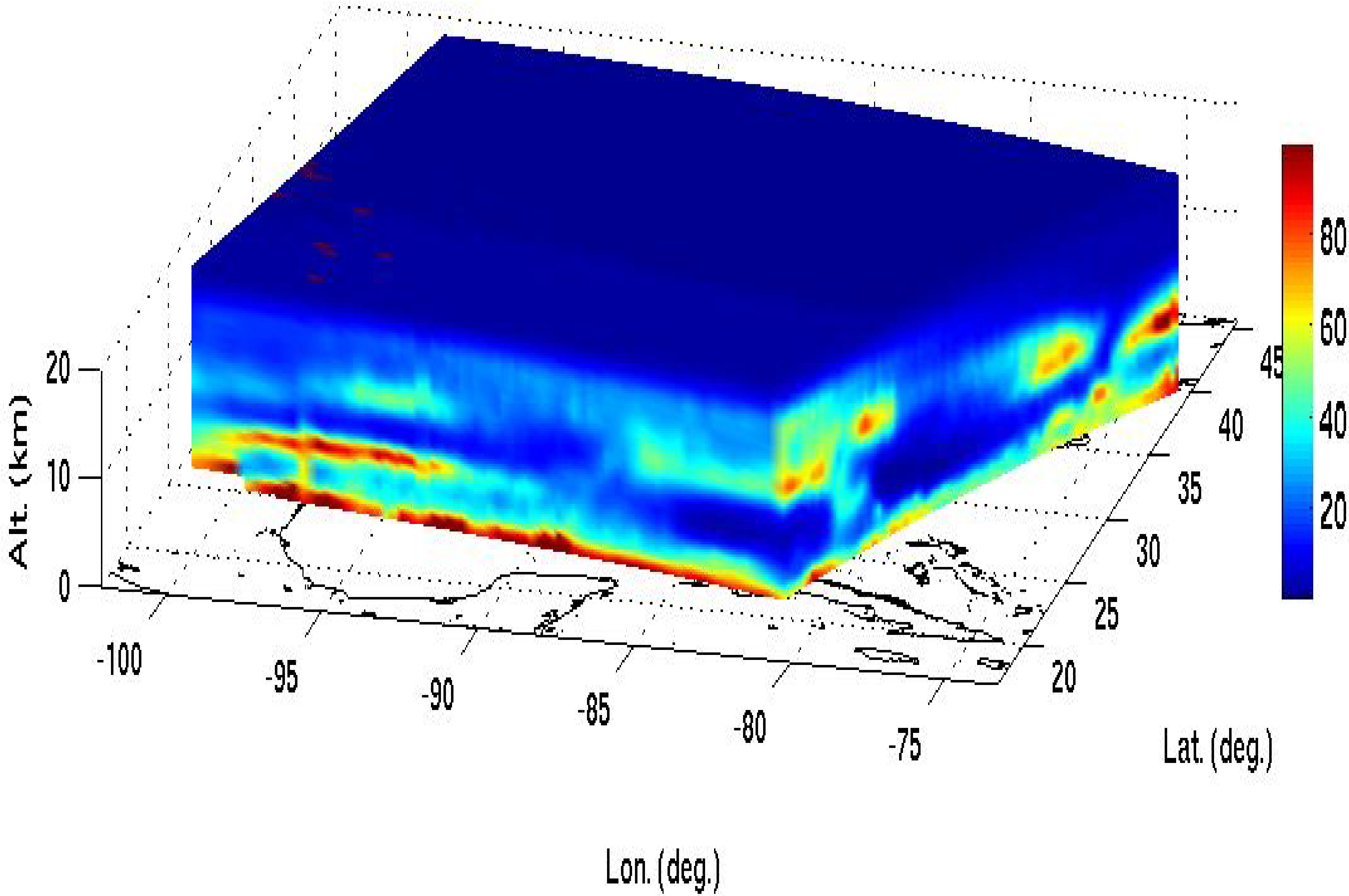

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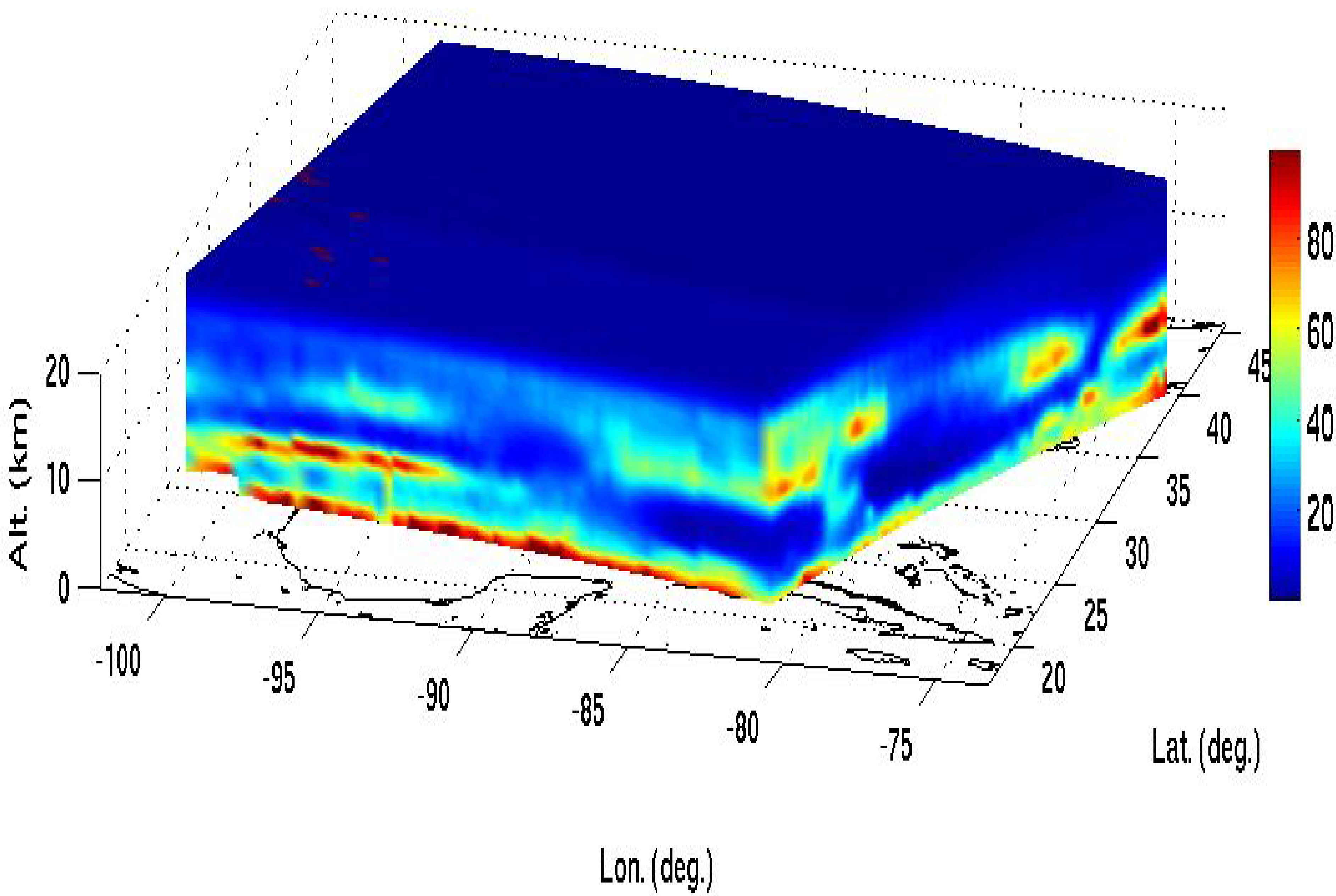

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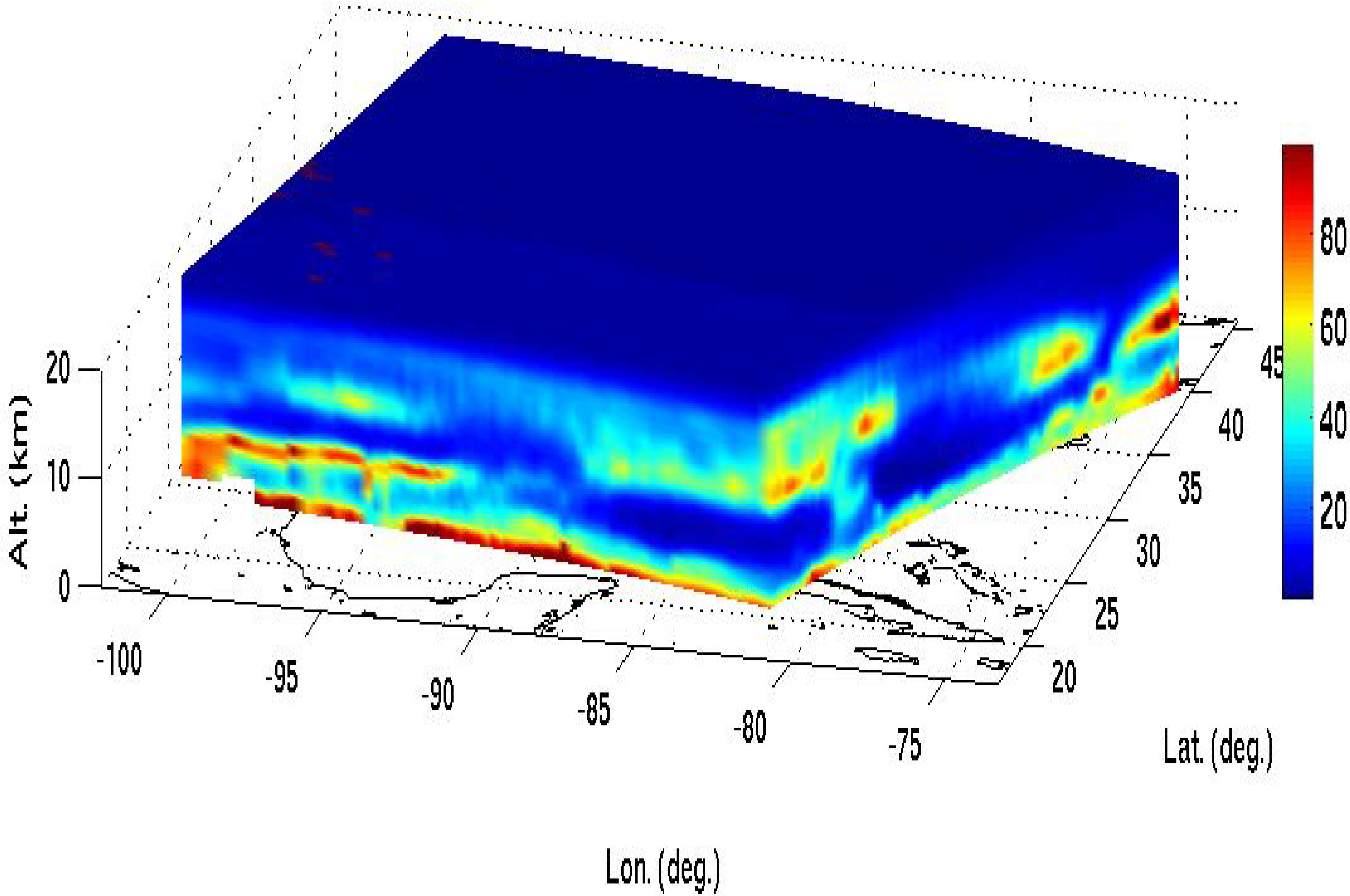
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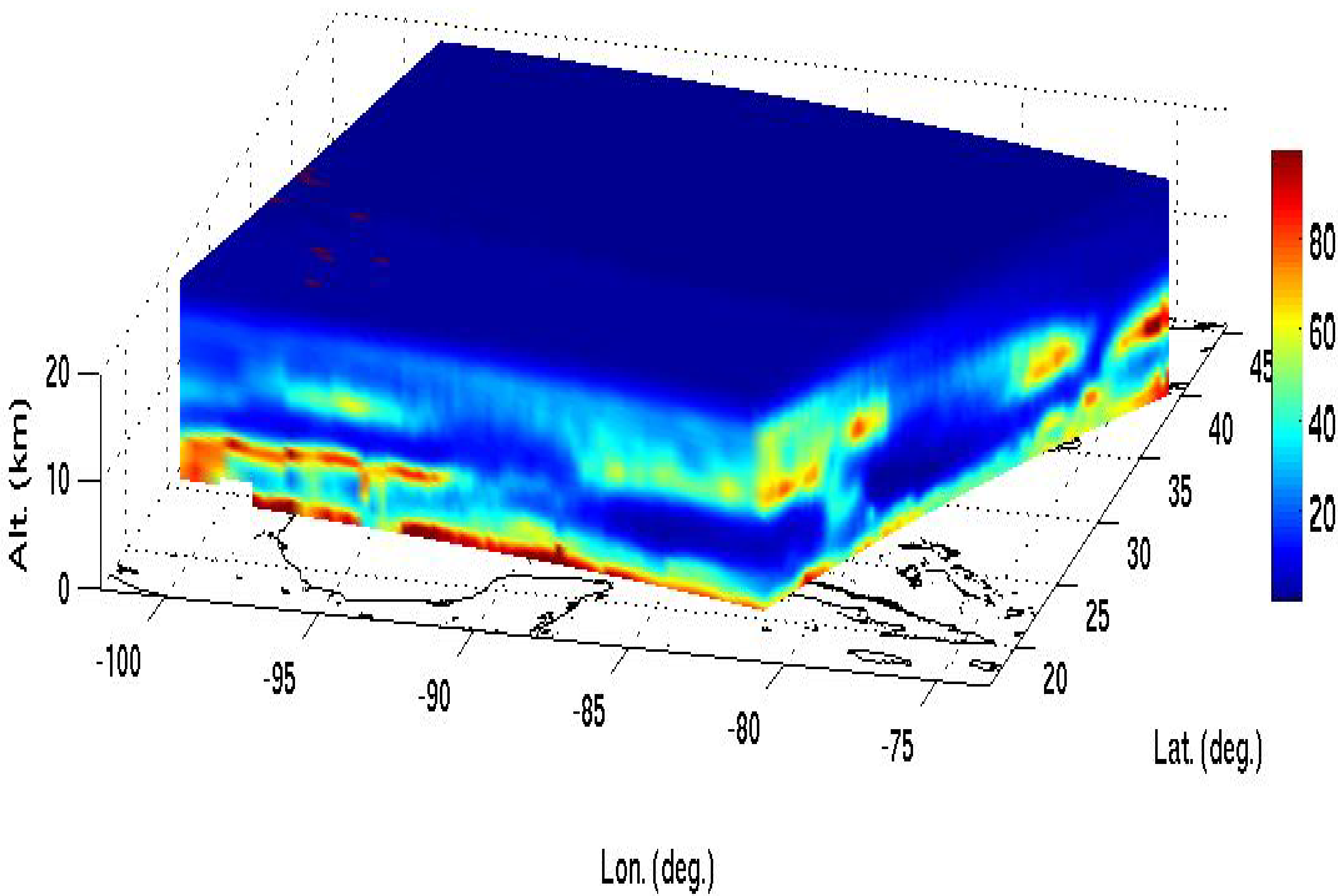

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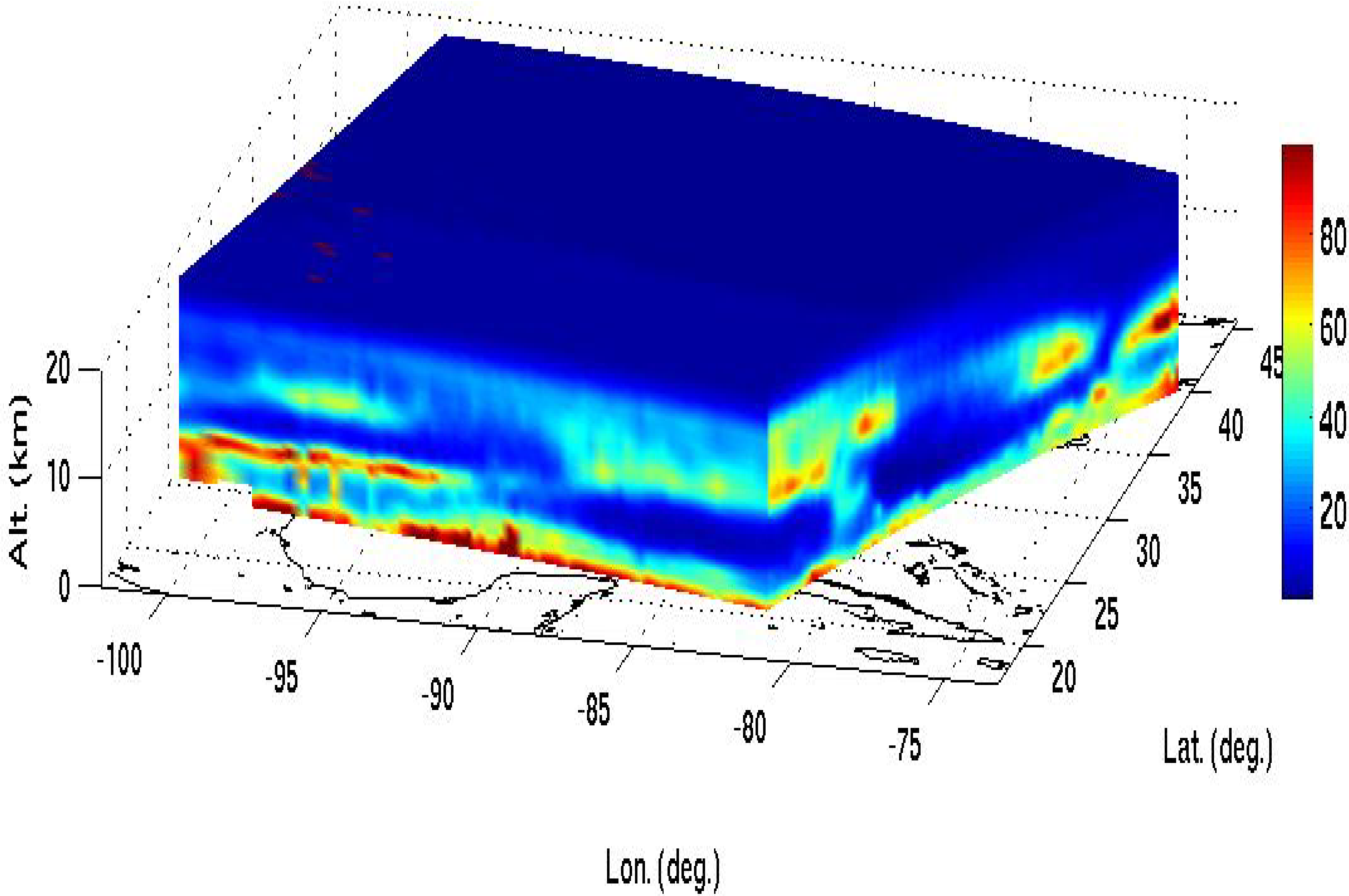
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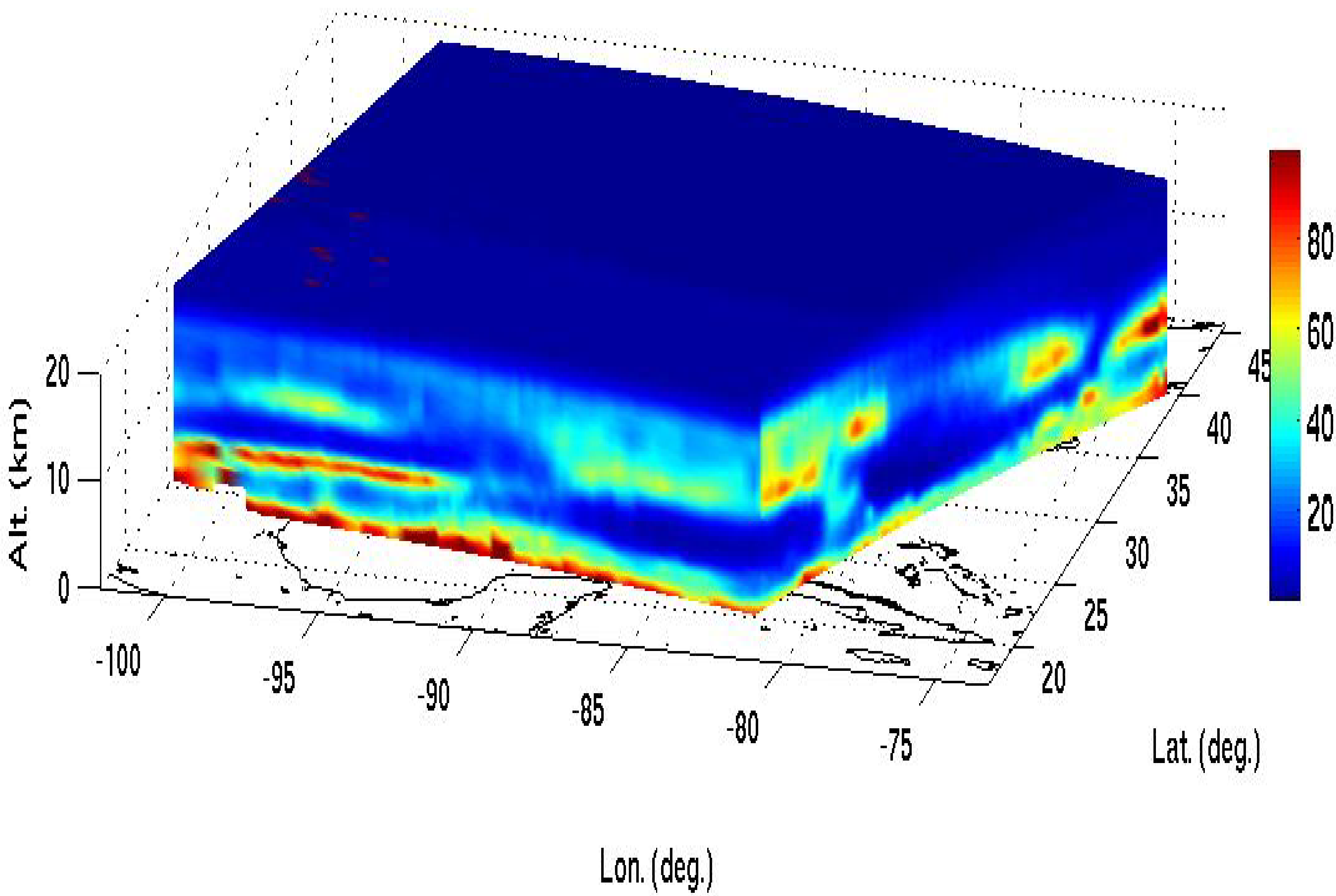

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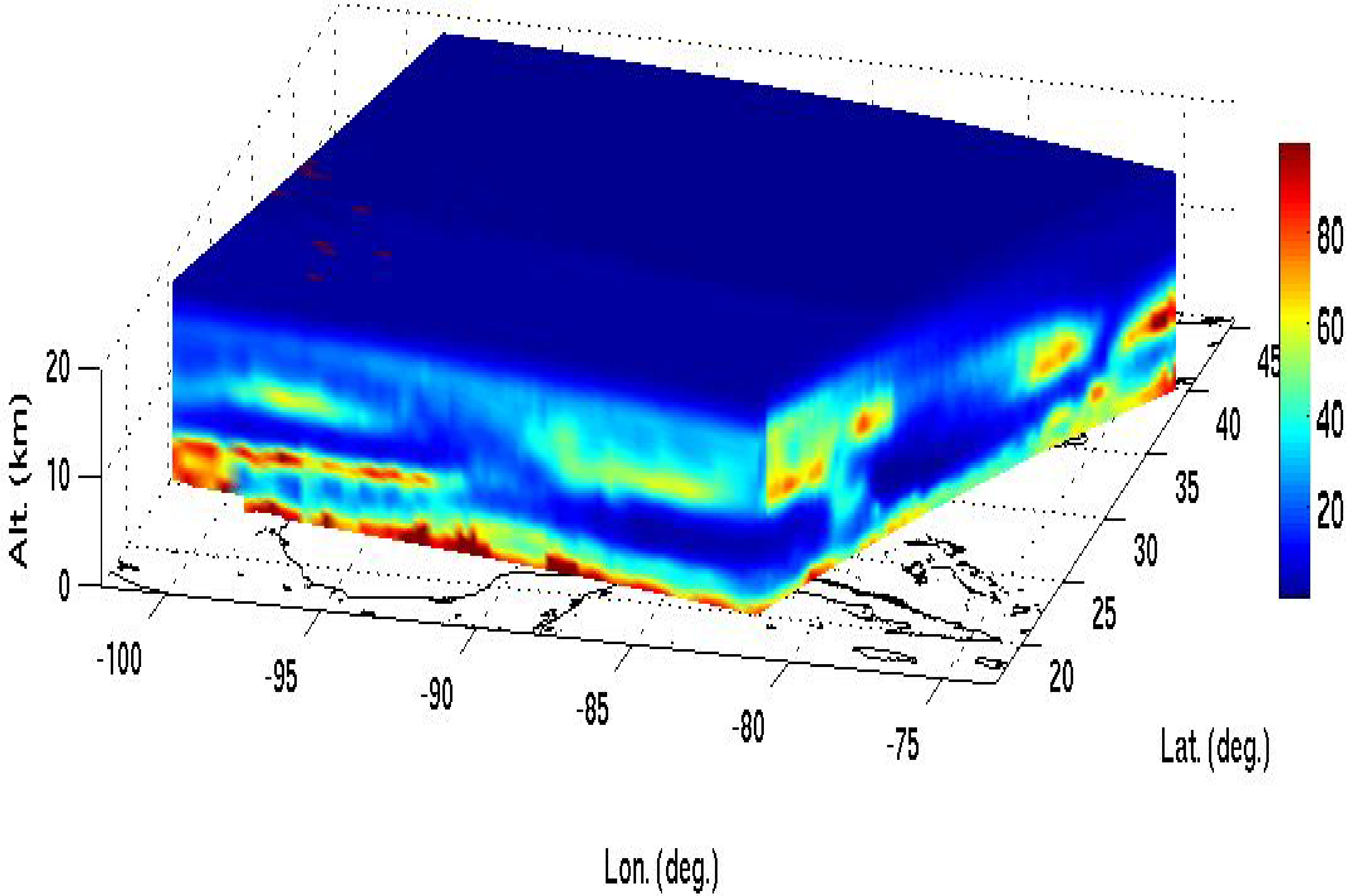
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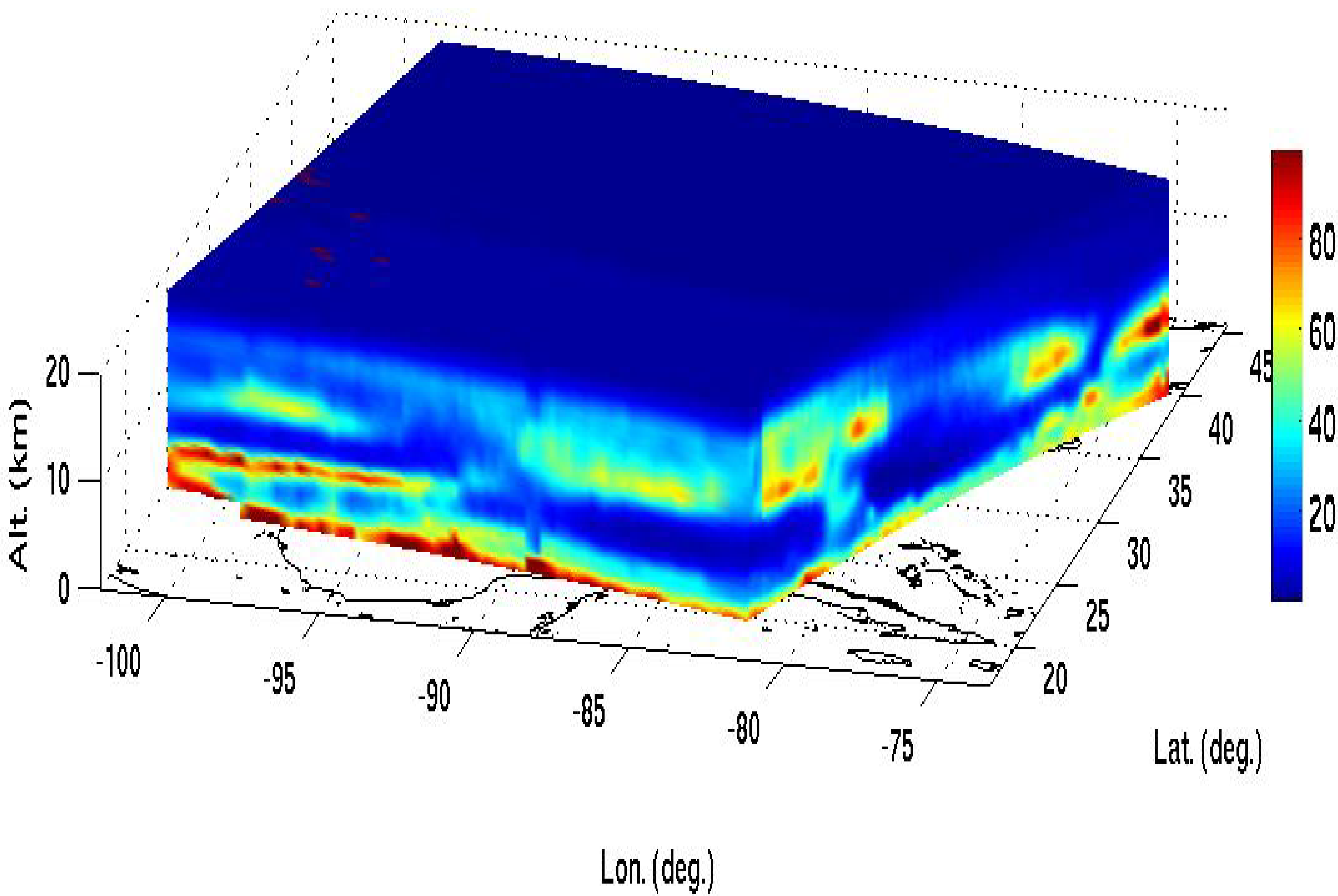

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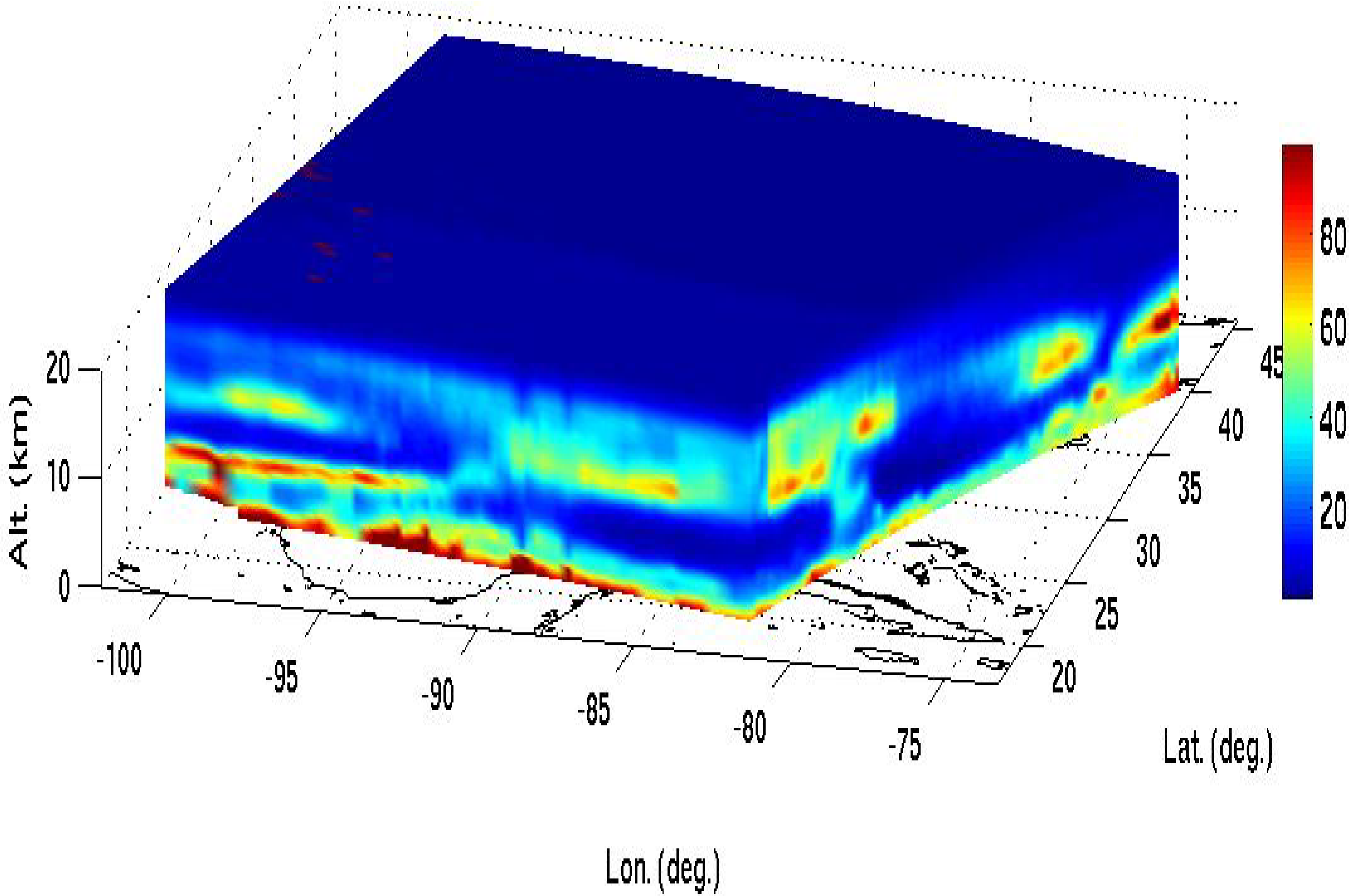

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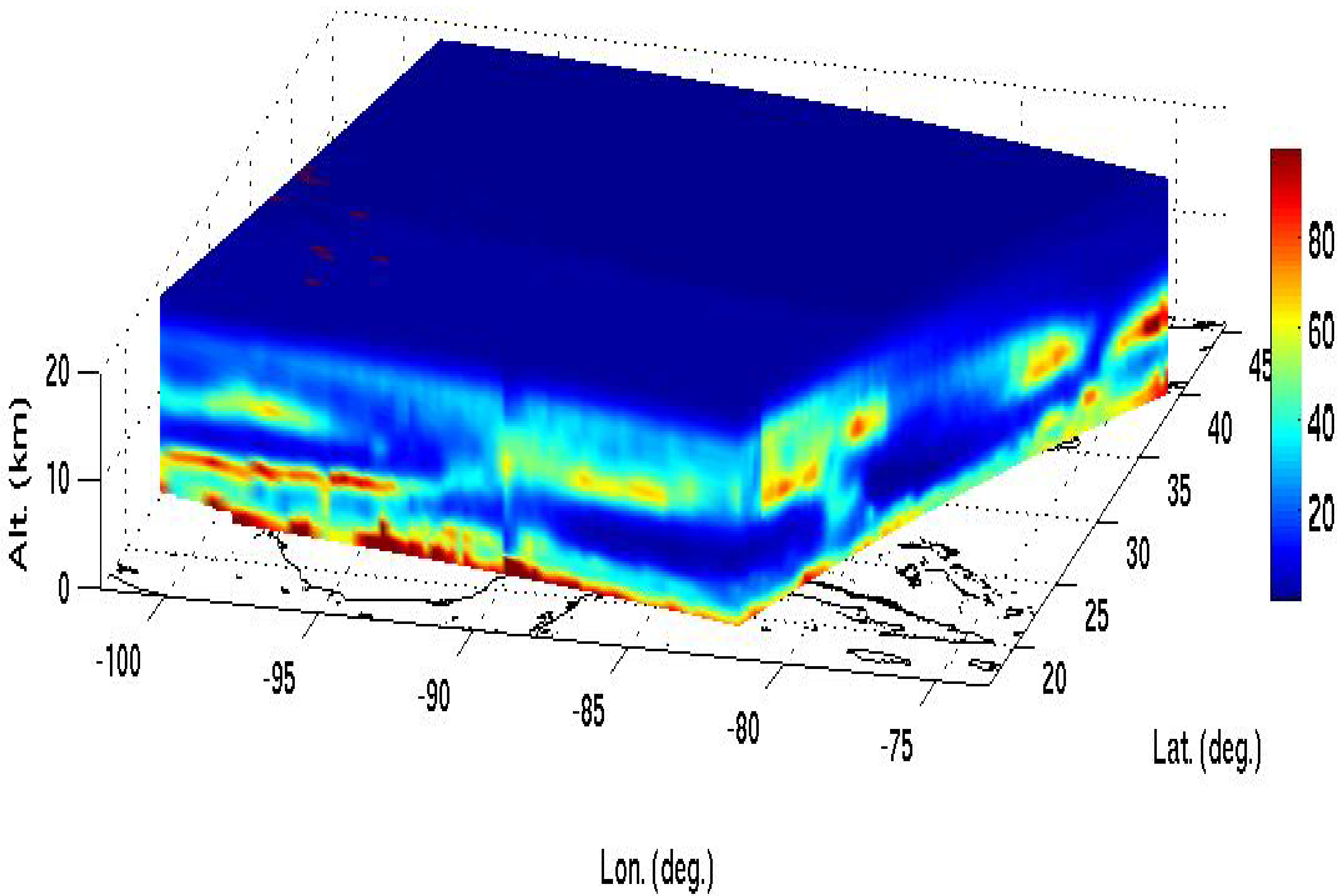

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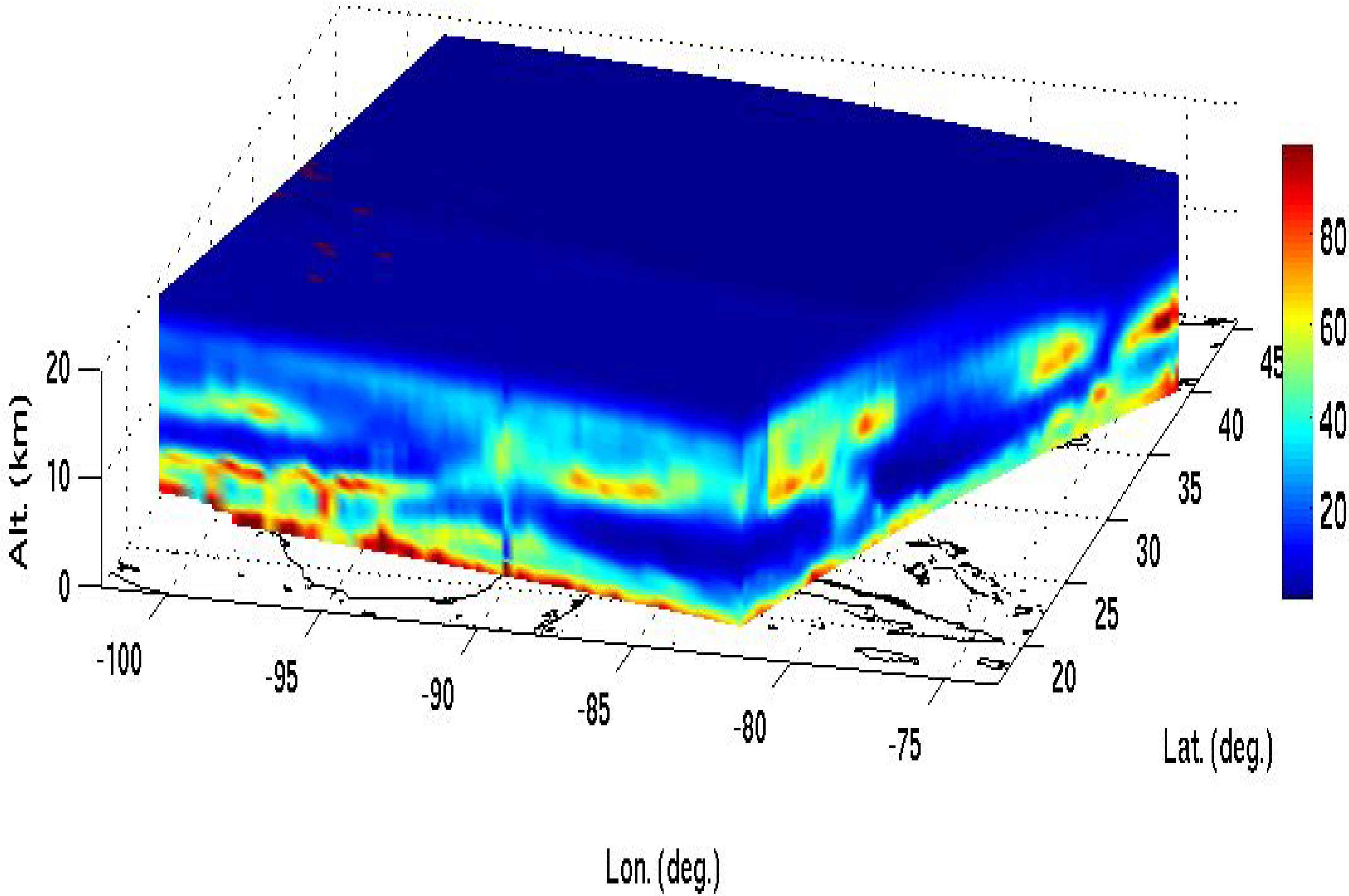

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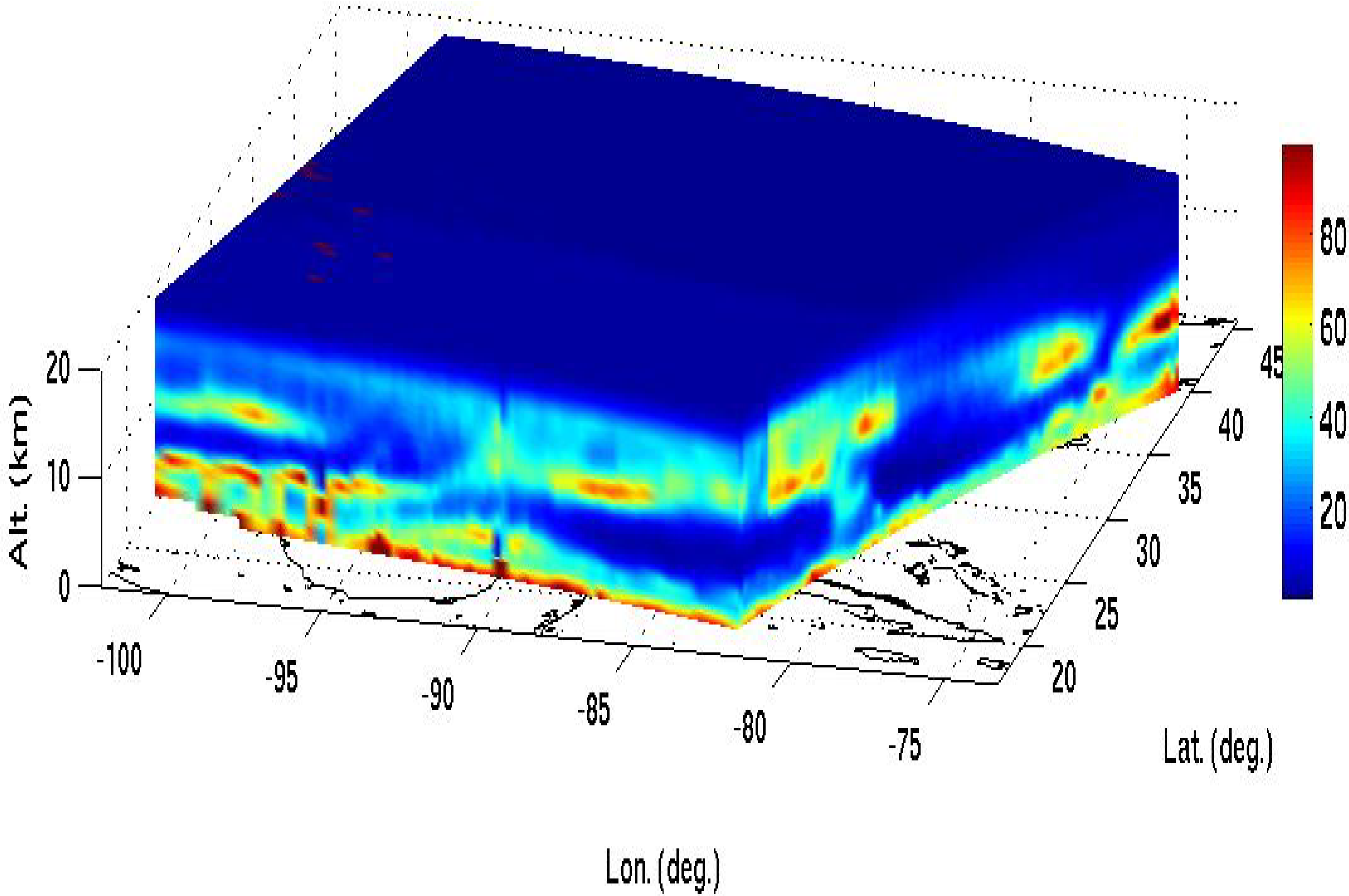

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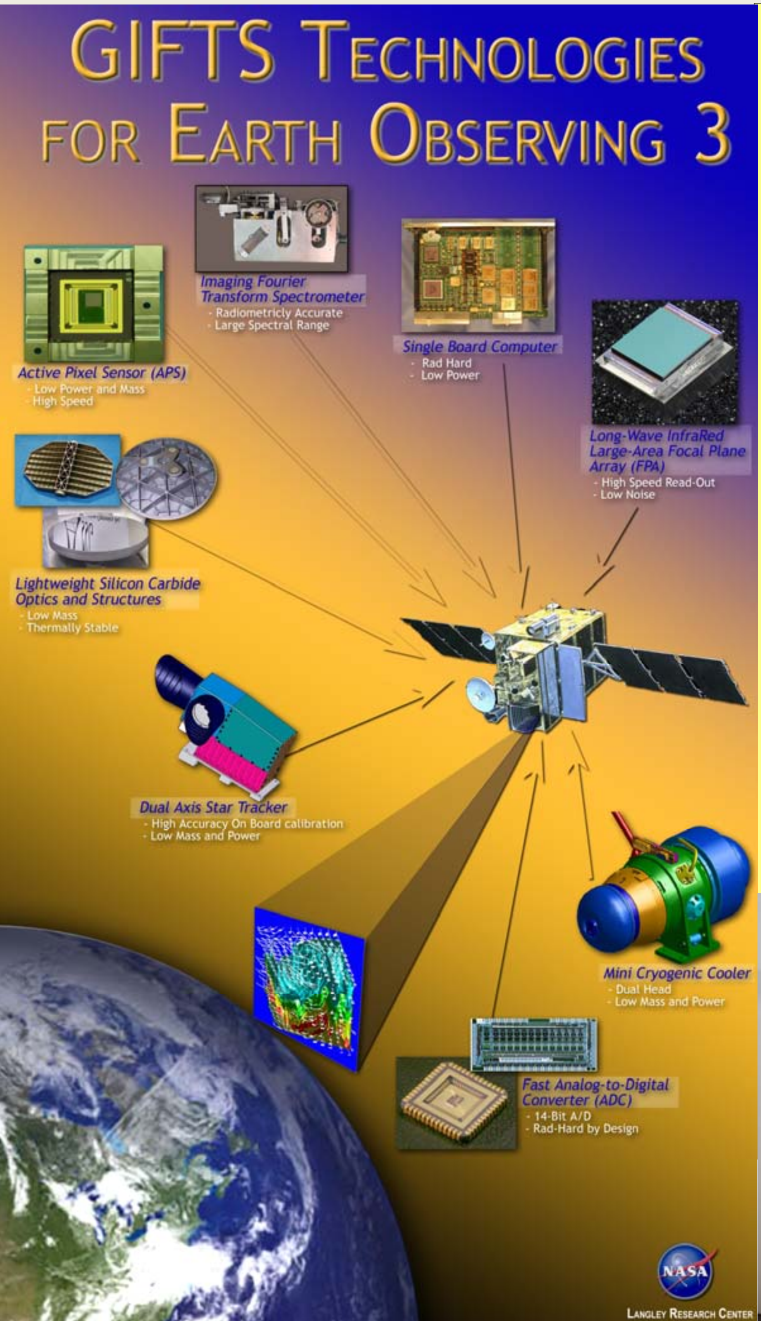
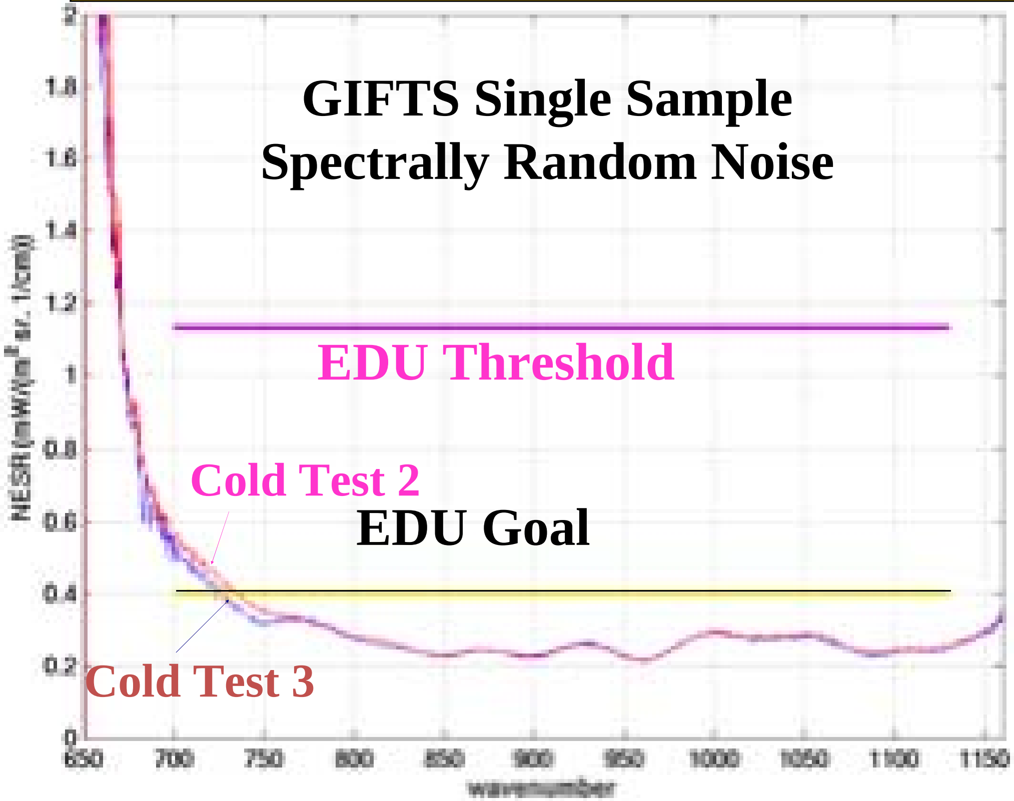
GIFTS Program Background

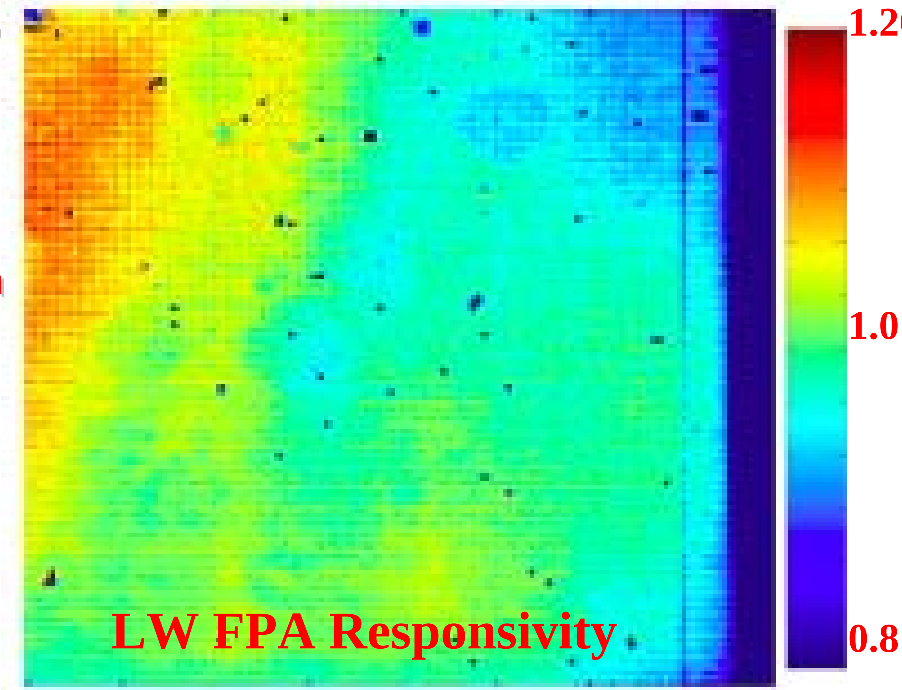


- 1999: GIFTS was selected from a competitive process for the NASA New Millennium Program (NMP) Earth Observing 3 (EO-3) mission.
  - GIFTS had significant programmatic risk related to technology development and to securing a geosynchronous spacecraft with limited funding. NASA partnered with the U.S. Navy to secure spacecraft.
- 2004: The GIFTS flight project was terminated as a result of a Navy budget shortfall and changing priorities.
- 2006: The GIFTS was completed as an EDU and successfully tested by upward viewing of the sky and the moon.

GIFTS T-V Tests Show That HES LW Band Measurements With Required S/N &High Operability Are Achievable



LW FPA Operability



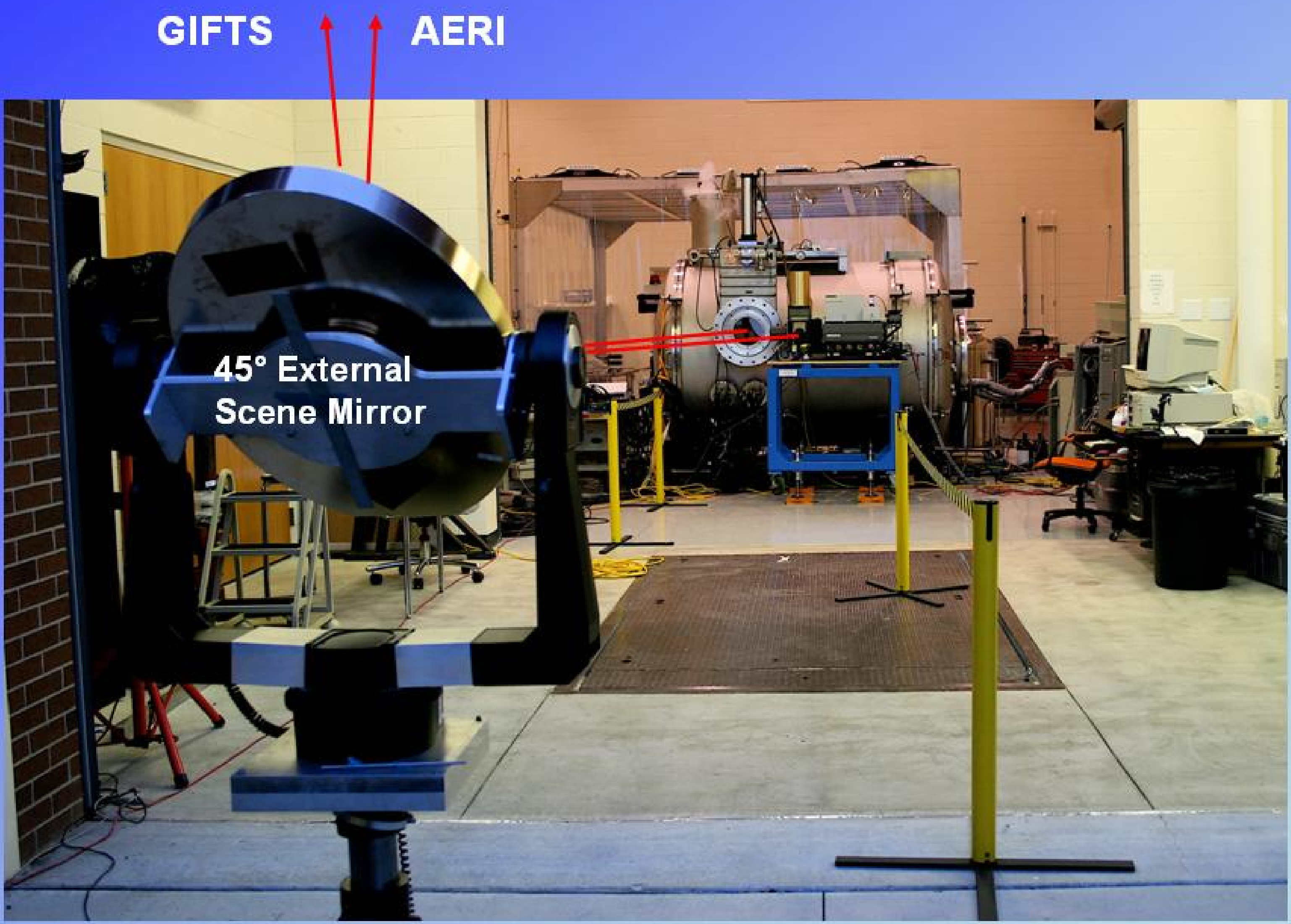
Pixels with responsivity in range 80%-120% of mean	98.2%
Pixels with noise less than 3X mean noise	96.3%
Active pixels (those that meet both responsivity & noise criteria)	95.9%

Significance:

- Can achieve IASI-like radiometric performance for 4 km spatial footprints covering 500x500 km field every 12 seconds.
- Coverage about 40 x faster than GOES, 5-6 times faster at full spectral resolution, all with spatial footprints that are 4 times smaller in area and contiguous.

THE UNIVERSITY of WISCONSIN MADISON

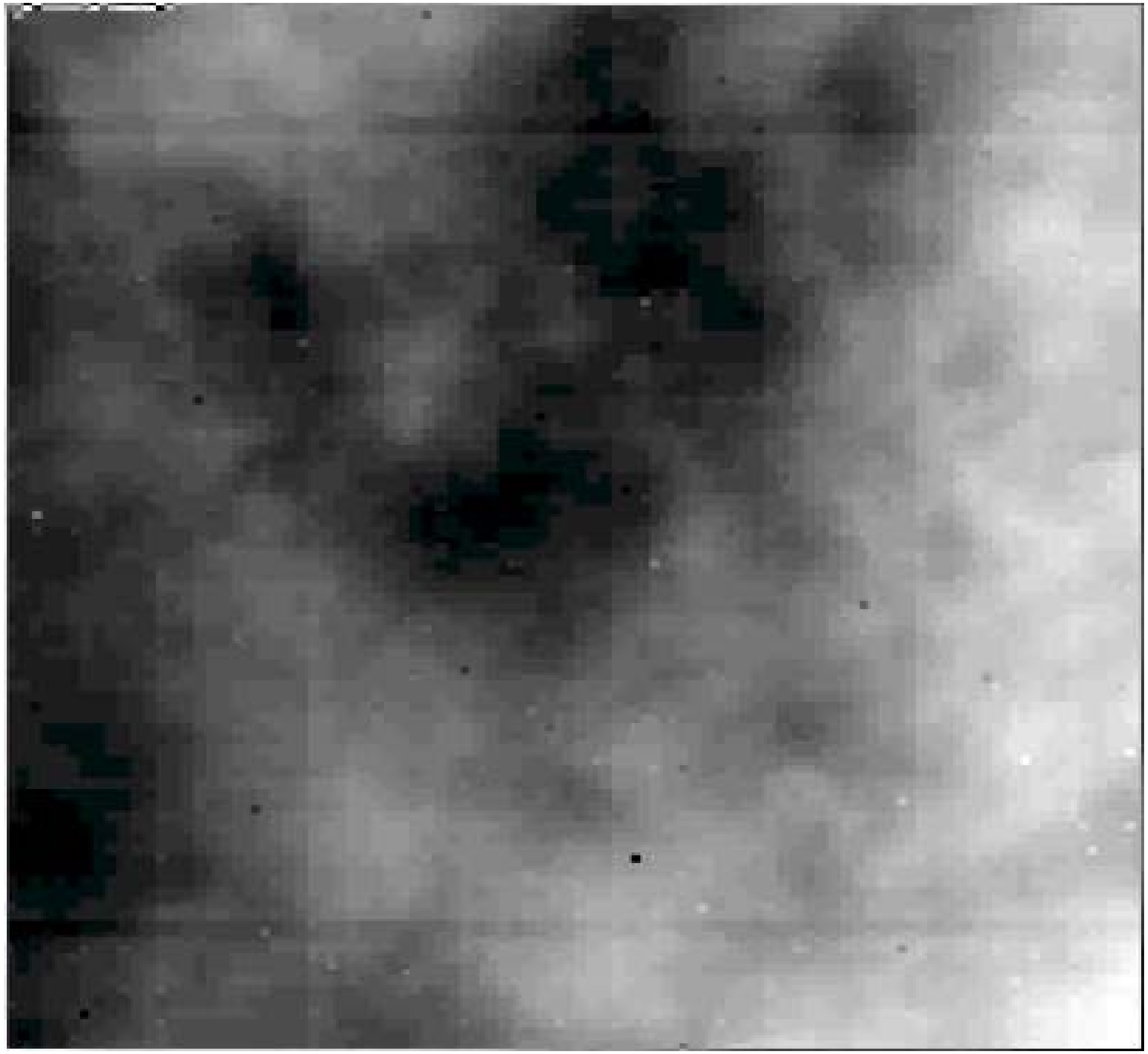
GIFTS and AERI Viewing Sky



Interferogram Scan Movie

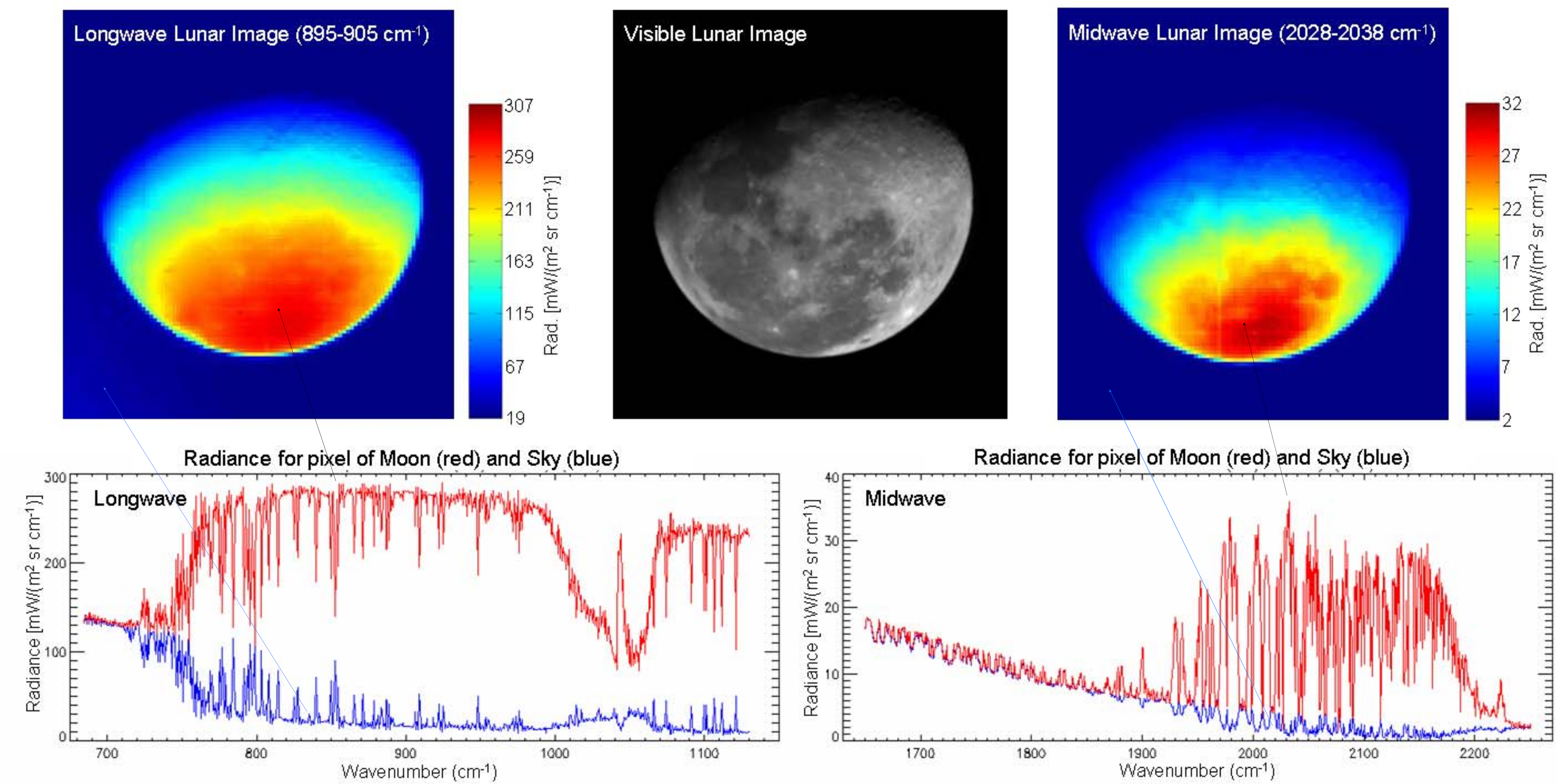
DC output of the LW detector array during one >10^9 sample (66,276 point /pixel) interferogram scan (11 sec)

Movie made from a sequence of every 50th Frame (1325 frames)

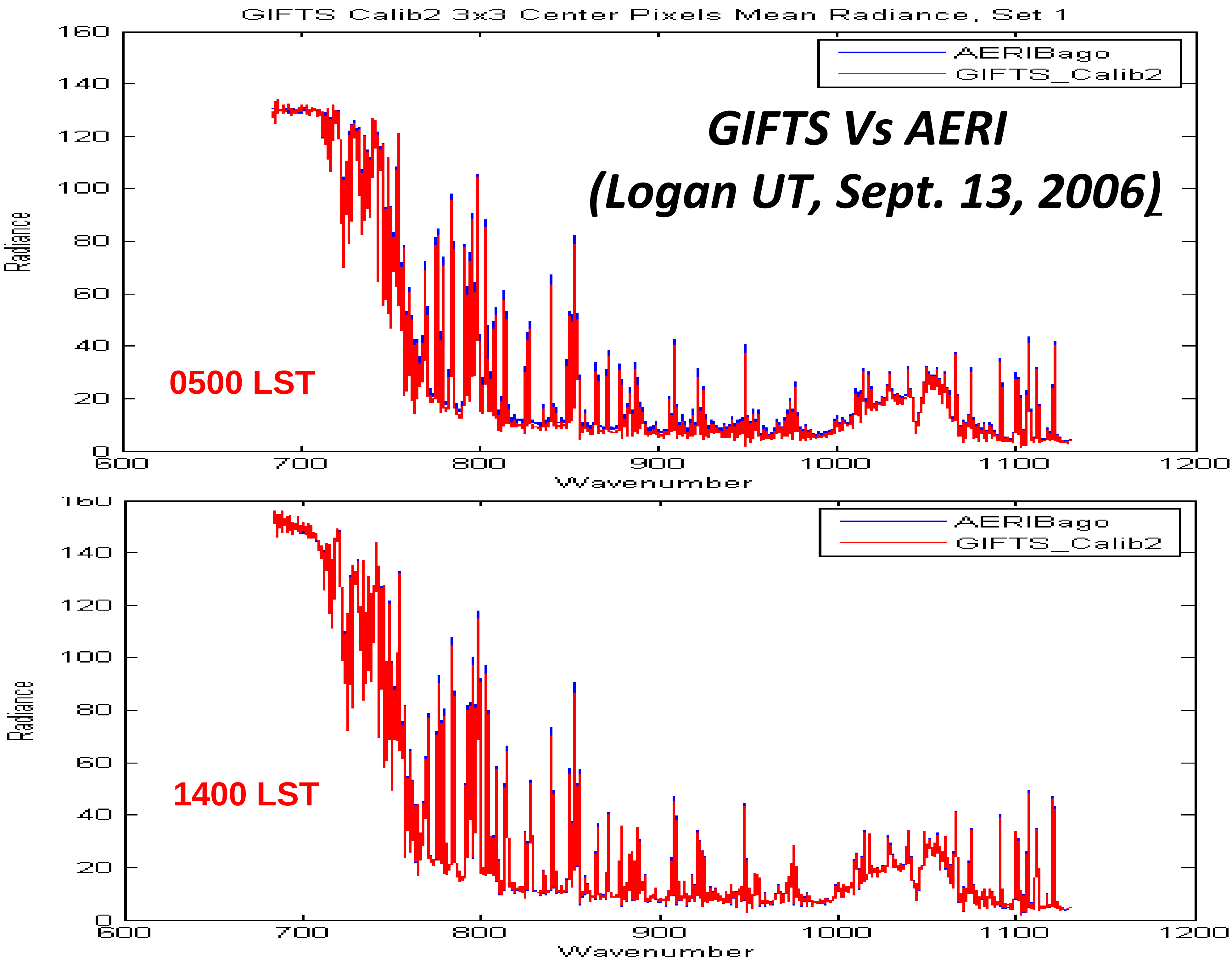


←135 meters @10 km altitude →

Moon Imaging Demonstration



Moon viewing/tracking demonstrates the GIFTS imaging spectrometer capability. Lunar and sky measurements are obtained with the GIFTS visible and two infrared spectral bands. Data recorded at 05:50 MST on 11 September 2006 in Logan, Utah.


GIFTS Calib2 3x3 Center Pixels Mean Radiance, Set 1
GIFTS Vs AERI
(Logan UT, Sept. 13, 2006)
AERIBago
GIFTS_Calib2
Radiance
Wavenumber
0500 LST
1400 LST
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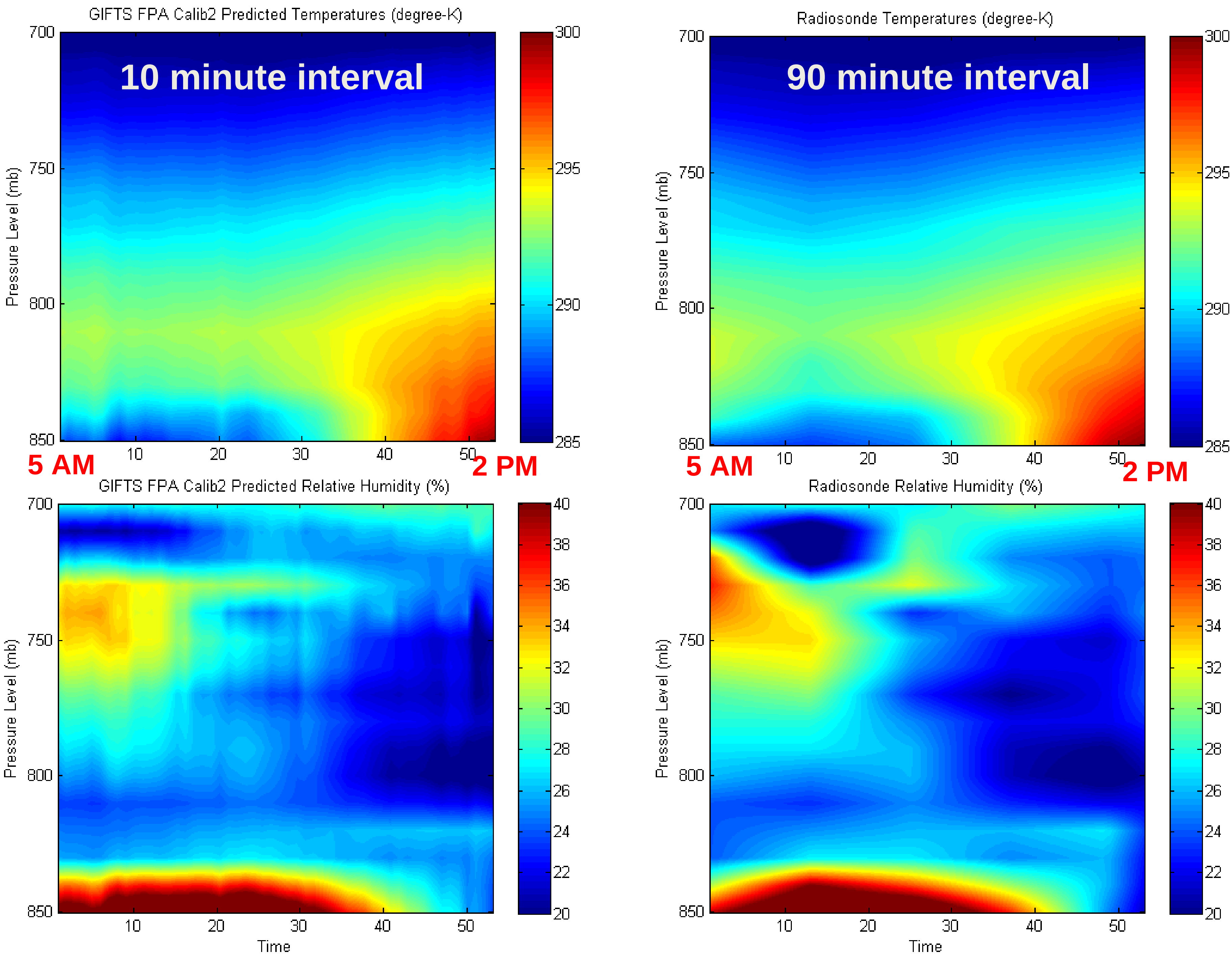
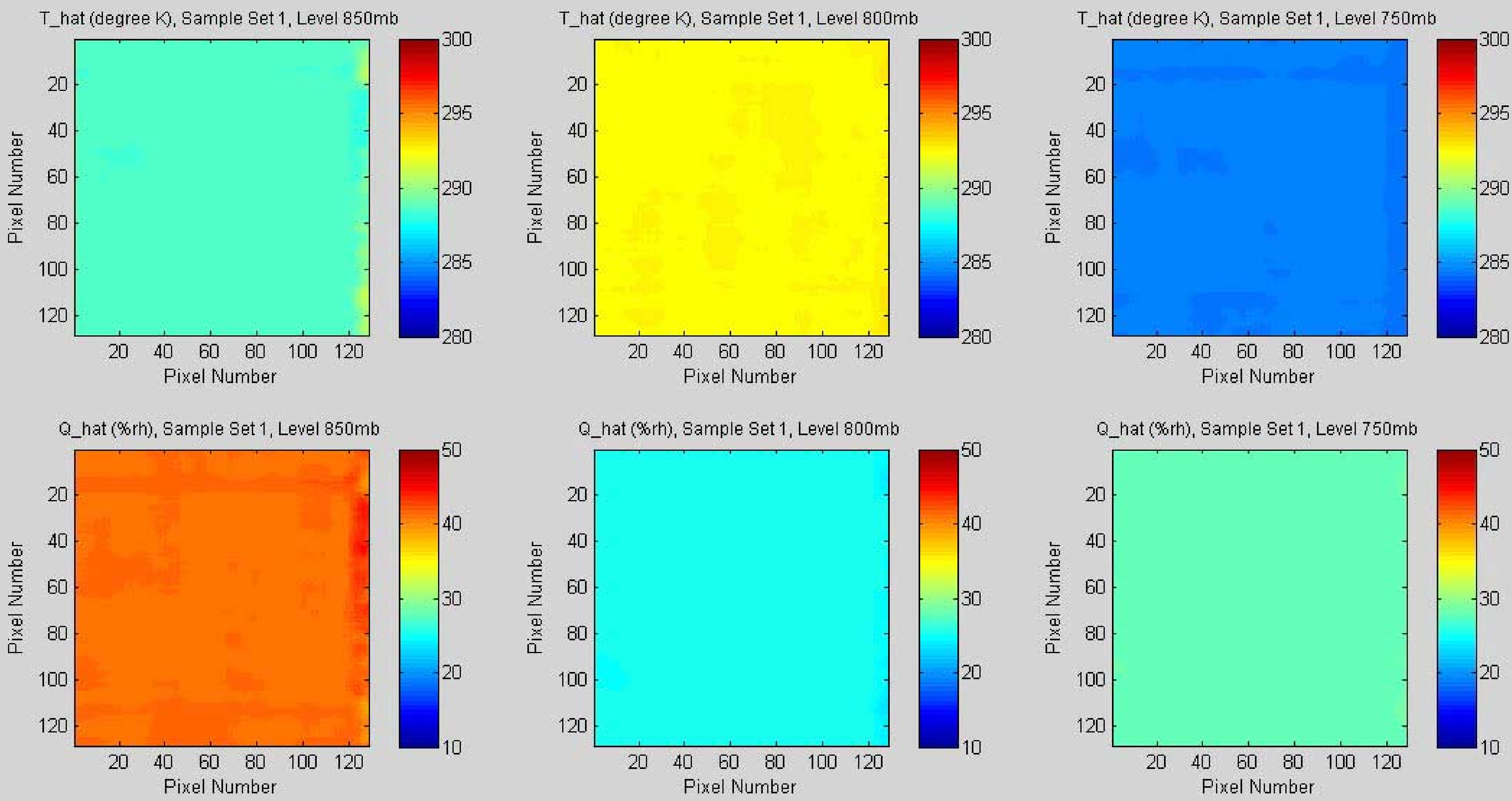
GIFTS Vs Radiosonde (Logan UT, Sept. 13, 2006)



Temperature & Humidity Images

September 13, 2006 (10 min. interval: 5 AM – 2 PM)



GIFTS- A Technical Success

- **All technologies successfully integrated to create a revolutionary Geostationary Satellite Imaging Spectrometer, fully tested and characterized in a space (T/V) chamber**

- **Accurate radiometric data demonstrated through direct comparisons with AERI**

- **High resolution temperature and moisture sounding capability demonstrated through ground-based sky viewing measurements**

Advanced Geostationary Sounders-Summary

- IR Imaging FTS Technology is now proven
- The ability to achieve the Geo science measurement objectives have been demonstrated with IASI
- Advanced geostationary sounding capability will greatly improve severe weather forecasts, thereby saving lives and property, as well as provide data useful for improving extended range, air quality, and climate predictions.
- Its time to get this proven technology and revolutionary measurement capability into orbit ASAP!