Multiwavelength Refraction Modeling Improvements for Laser Ranging Observations

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14th International Workshop on Laser Ranging

June 7-11, 2004, San Fernando, Spain

Introduction

- UMBC/JCET is PI for AIRS instrument on NASA's AQUA spacecraft of EOS program
- When the mission is declared operational (real soon!!!), it will provide quick access to global fields of temperature, water vapor, and other geophysical environmental parameters daily in rapid mode
- Such data can be used for improved atmospheric delay modeling (e.g. gradients)

AIRS on AQUA

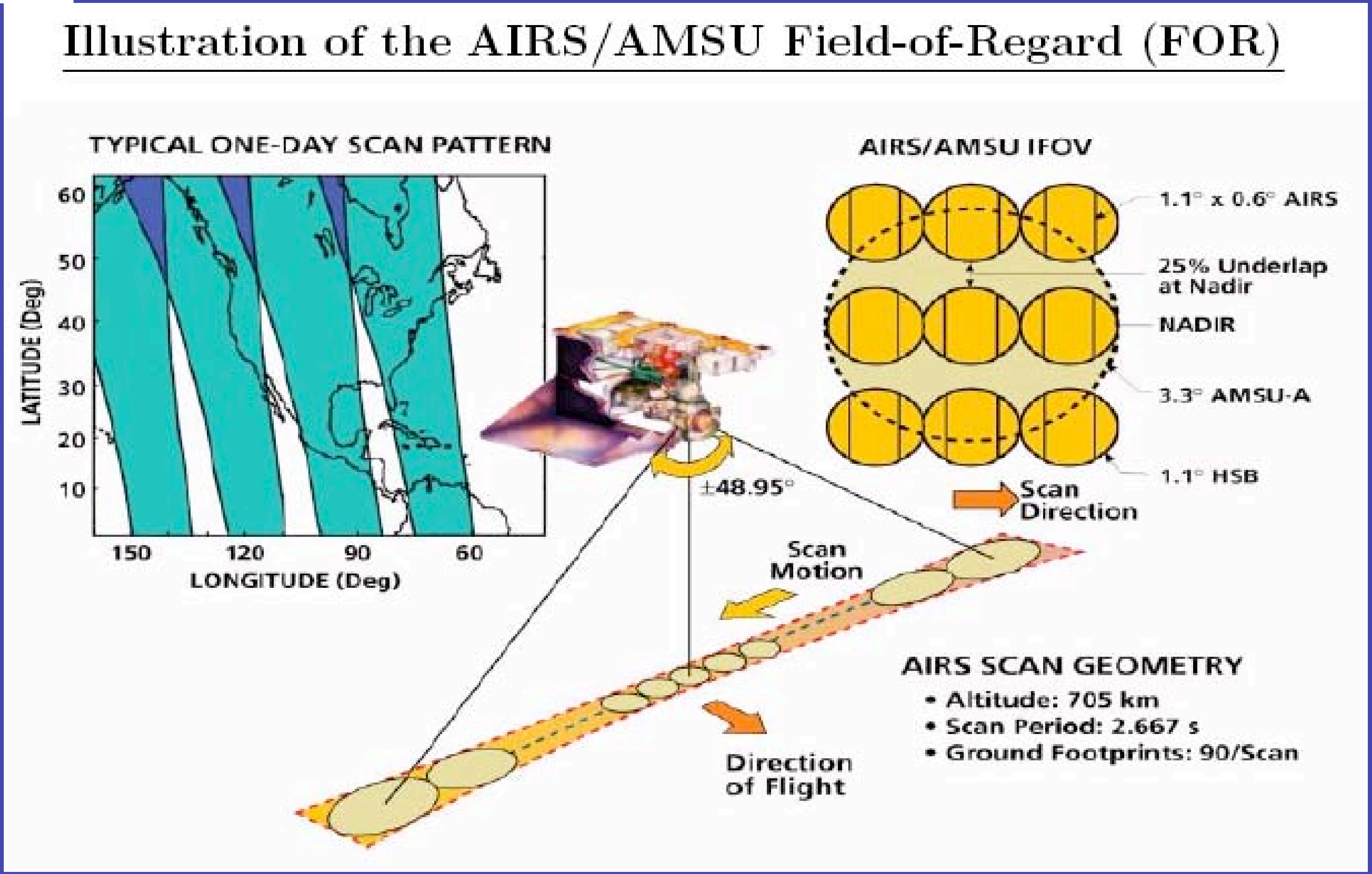
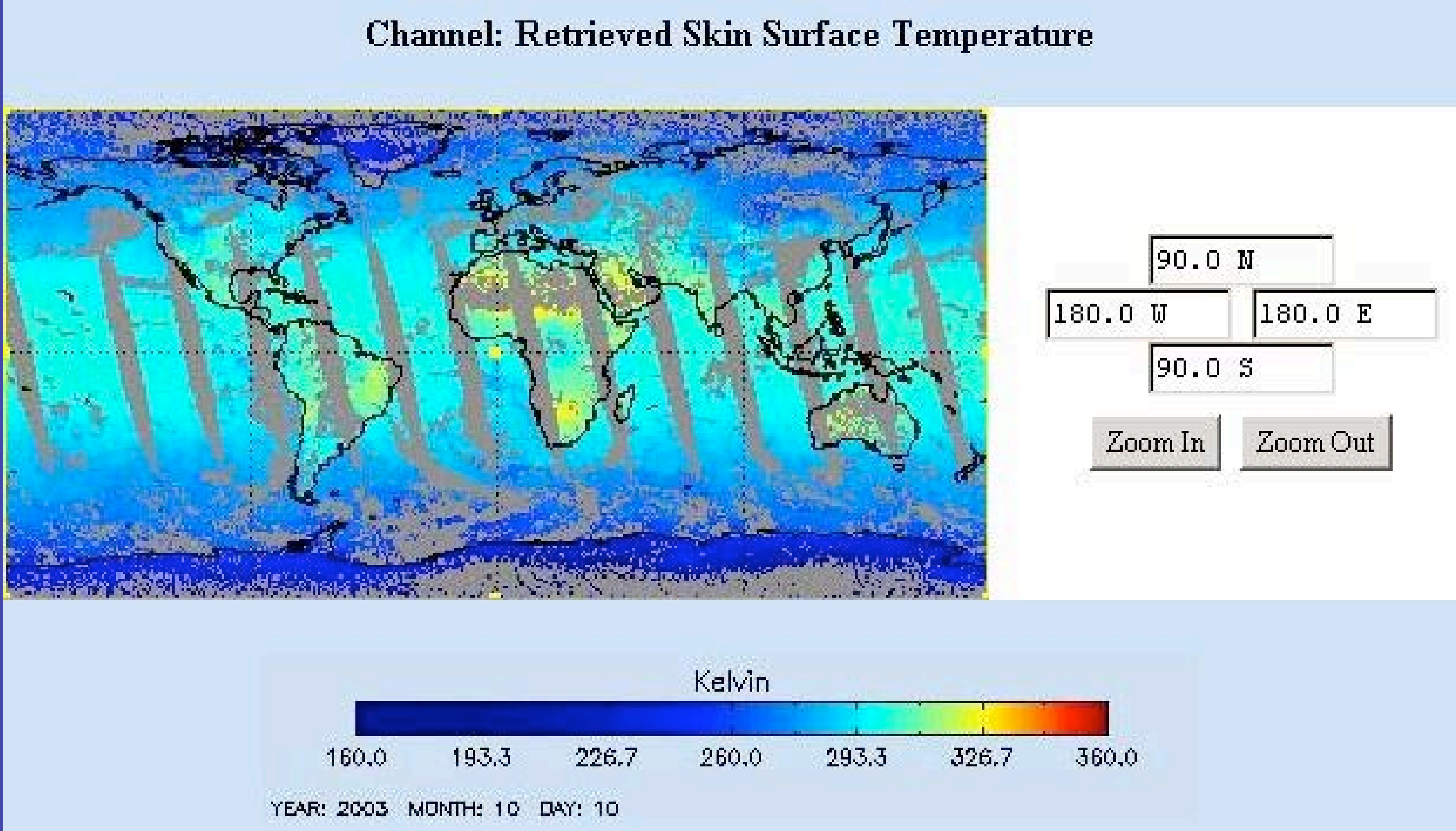


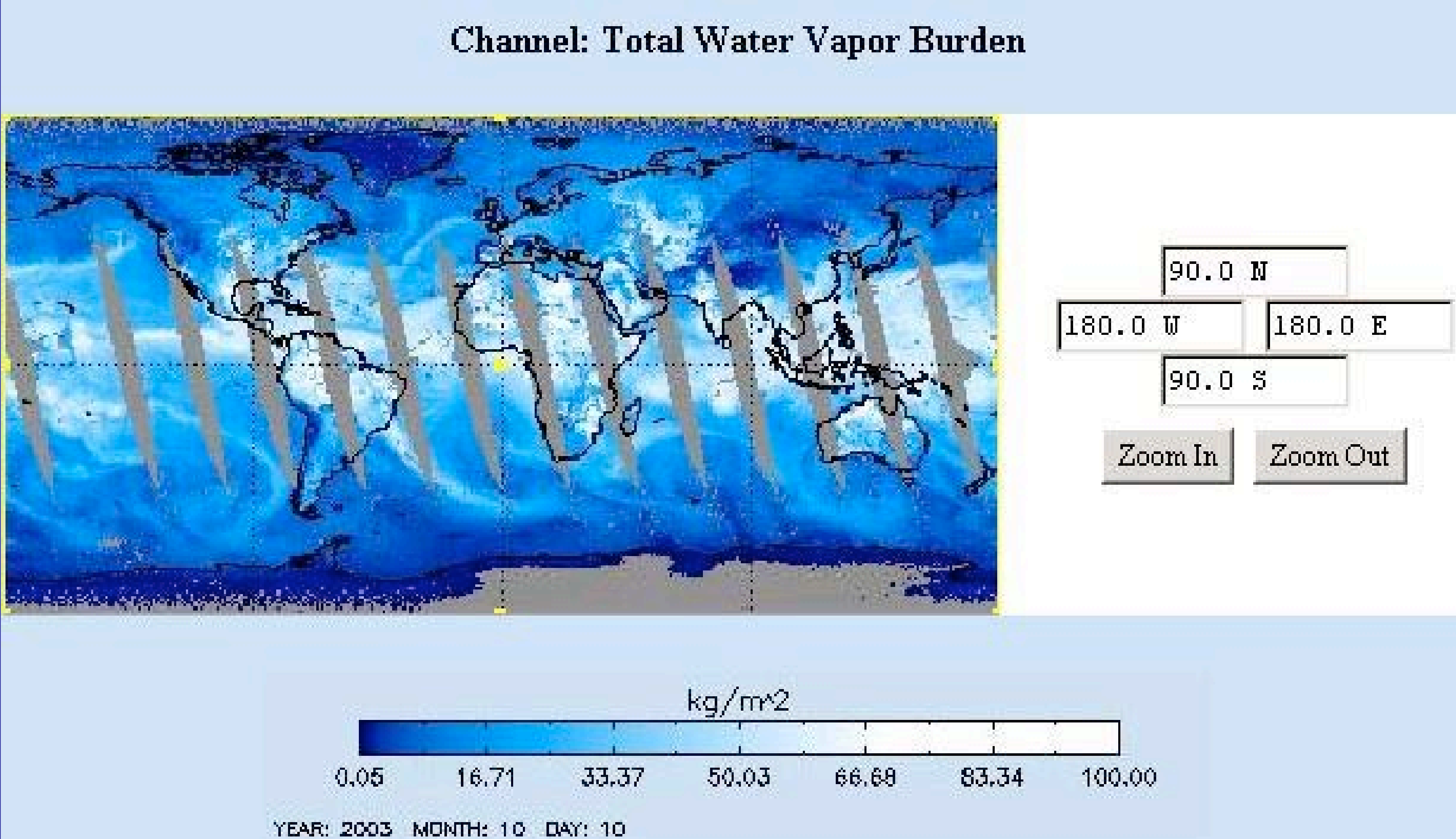
Illustration of the AIRS/AMSU Field-of-Regard (FOR)
TYPICAL ONE-DAY SCAN PATTERN
LATITUDE (Deg)
60
50
40
30
20
10
150
120
90
60
LONGITUDE (Deg)
AIRS/AMSU IFOV
1.1° x 0.6° AIRS
25% Underlap at Nadir
NADIR
3.3° AMSU-A
1.1° HSB
Scan Direction
±48.95°
Scan Motion
Direction of Flight
AIRS SCAN GEOMETRY
• Altitude: 705 km
• Scan Period: 2.667 s
• Ground Footprints: 90/Scan

AIRS Products - Temperature

October 10, 2003



AIRS Products - Water Vapor
October 10, 2003



AIRS Products - Coverage

October 10, 2003

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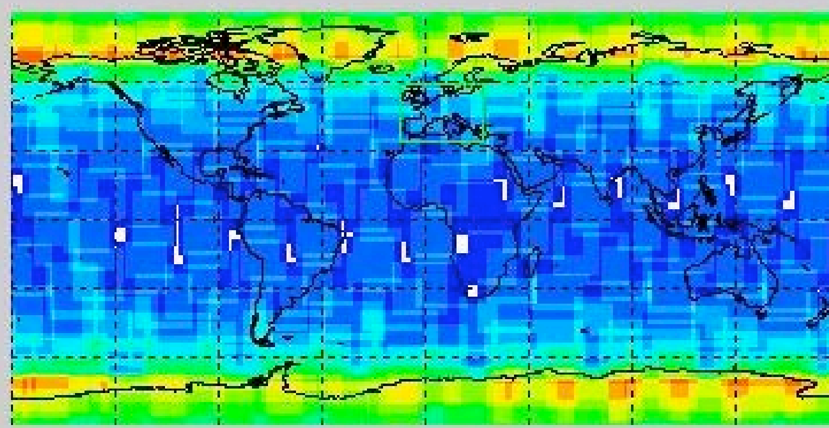

West Longitude -11.0 | South Latitude 34.0

East Longitude 25.0 | North Latitude 59.0

ShiftMap

The total number of granules: 241

Color area	blue	cyan	green	yellow	red
Number of granules per area	1	4	7	10	14

AIRS Products

Summary of Geophysical Products

$T(p)$	vertical temperature profile
$q(p)$	vertical water vapor profile ($\approx$ 8 g/kg @ surface)
$L(p)$	vertical liquid water profile (f/ AMSU/HSB)
$O_3(p)$	vertical ozone profile ($\approx$ 8 ppmv @ 6 mb)
T_s	surface temperature
$\epsilon(\nu)$	spectral surface emissivity, (*e.g.*, 0.95 @ 800 cm^{-1})
$\rho_{\odot}(\nu)$	spectral surface reflectivity of solar radiation
P_{cld}	cloud top pressure for $\leq$ 2 cloud levels
$\alpha_{cld,fov}$	cloud fraction for $\leq$ 2 cloud levels and 9 FOV's
CO_2	total column carbon dioxide ($\approx$ 363 ppmv)
$CH_4(p)$	methane profile ($\approx$ 1.65 ppmv)
$CO(p)$	carbon monoxide profile ($\approx$ 0.11 ppmv)

Ancillary Information Needed for Retrieval

P_s	surface pressure (f/ forecast)
θ	satellite zenith angle
$\theta_{\odot}$	solar zenith angle
$\epsilon_{cld,\nu}$	spectral cloud emissivity for $\leq$ 2 cloud levels

New Zenith Delay Model

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GEOPHYSICAL RESEARCH LETTERS, VOL. ???, XXXX, DOI:10.1029/,

High-Accuracy Zenith Delay Prediction at Optical Wavelengths

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A major limitation in accuracy in modern satellite laser ranging is the modeling of atmospheric refraction. Recent improvements in this area include the development of mapping functions to project the atmospheric delay experienced in the zenith direction to a given elevation angle. In this paper, we derive zenith delay models from revised equations for the computation of the refractive index of the atmosphere, valid for a wide spectrum of optical wavelengths. The zenith total delay predicted with these models were tested against ray tracing through radiosonde data from a full year of data, for 180 stations distributed worldwide, and showed sub-millimeter accuracy for wavelengths ranging from 0.355 μm to 1.064 μm.

New ZD Model Performance

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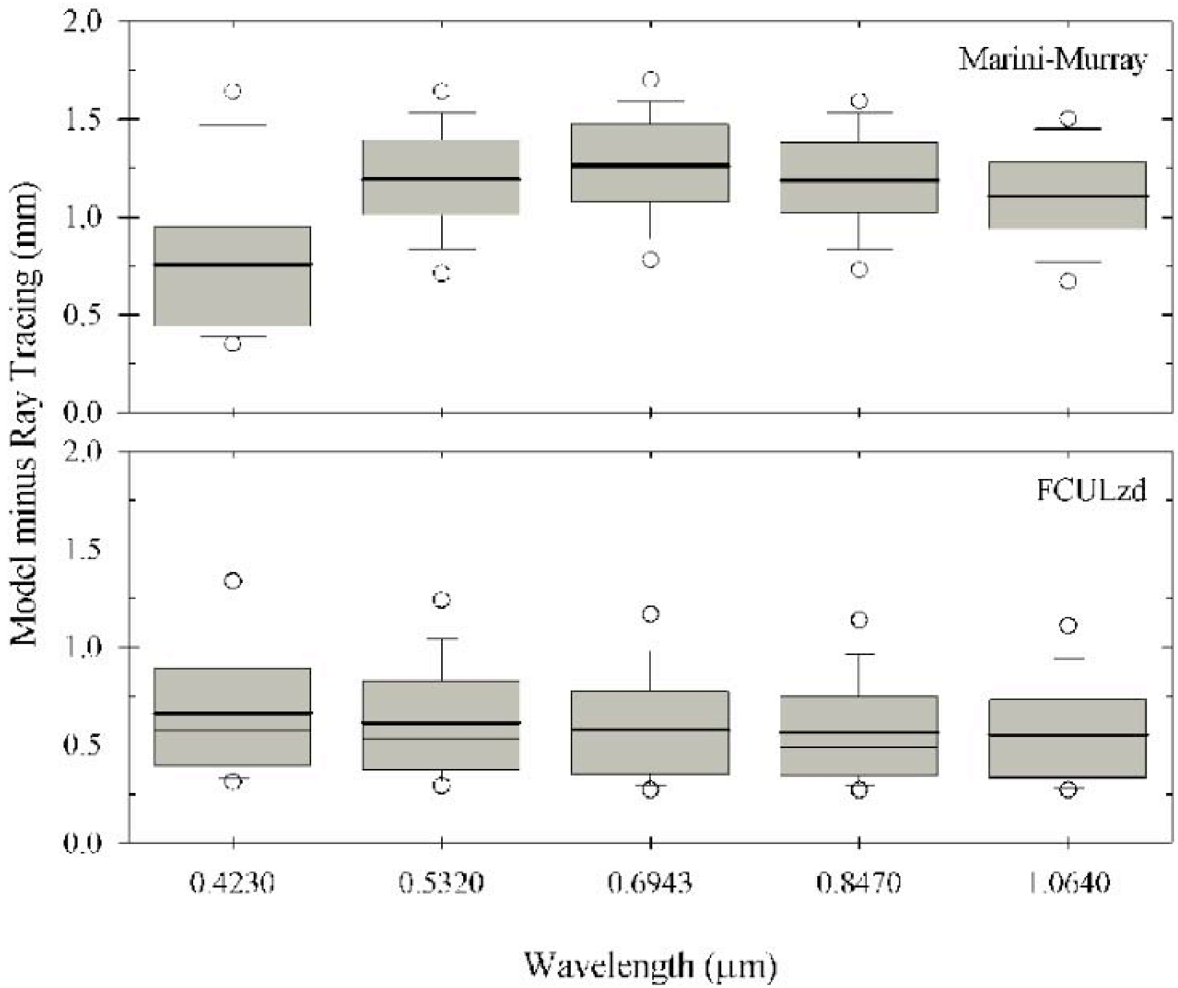
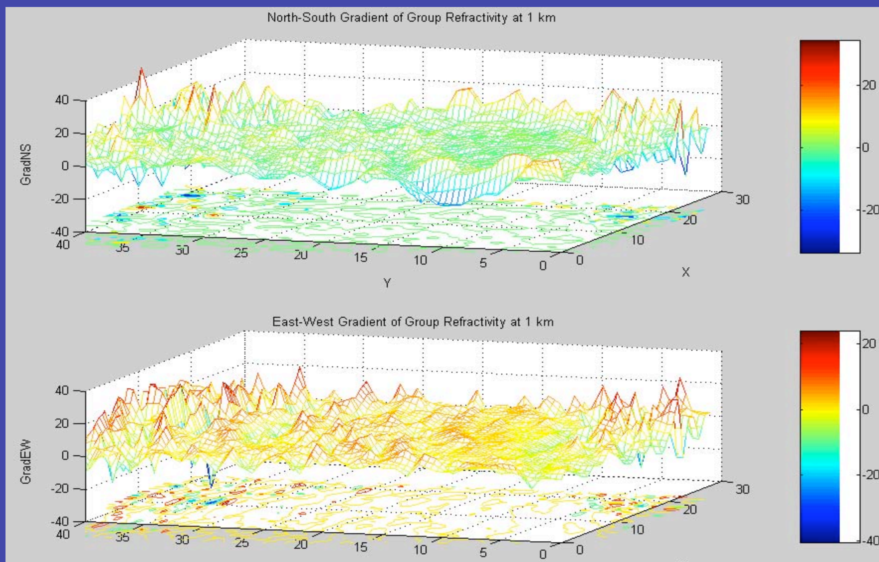
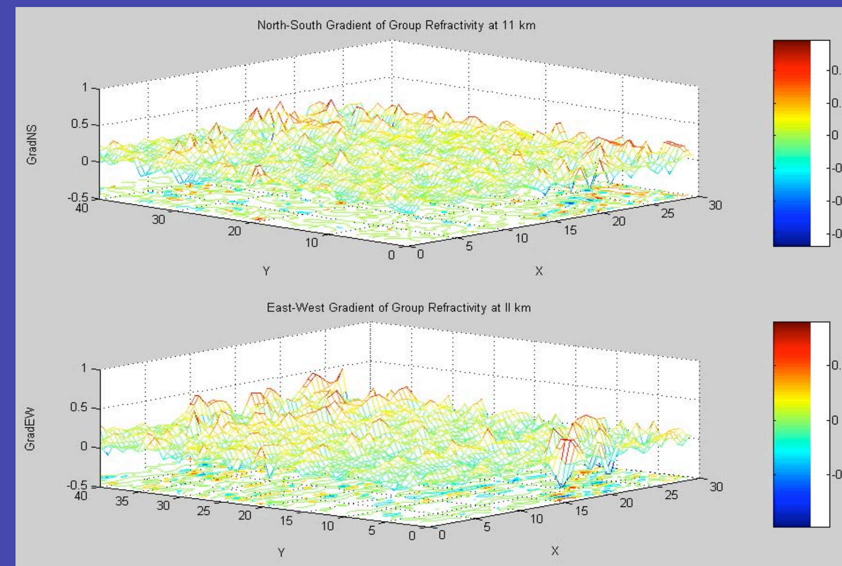


AIRS Data I

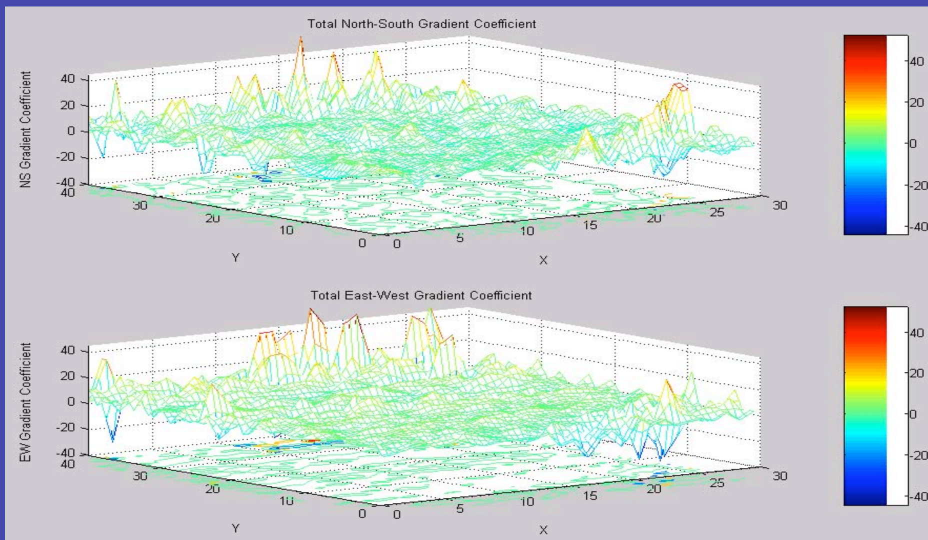


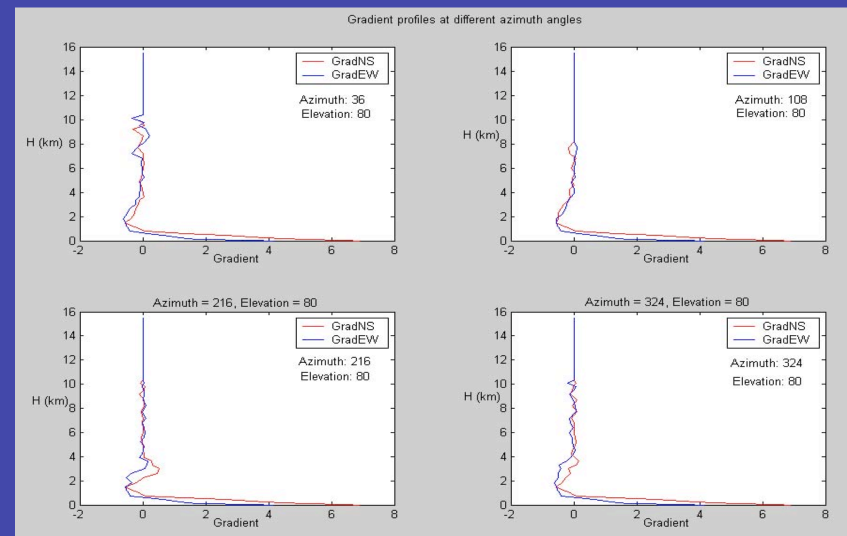


N-S and E-W Refractivity Gradients at altitude

For each AIRS "granule" these fields are generated and processed at a maximum of 28 levels. The contribution from levels above the 10 km altitude can be neglected at the moment.

AIRS Data II

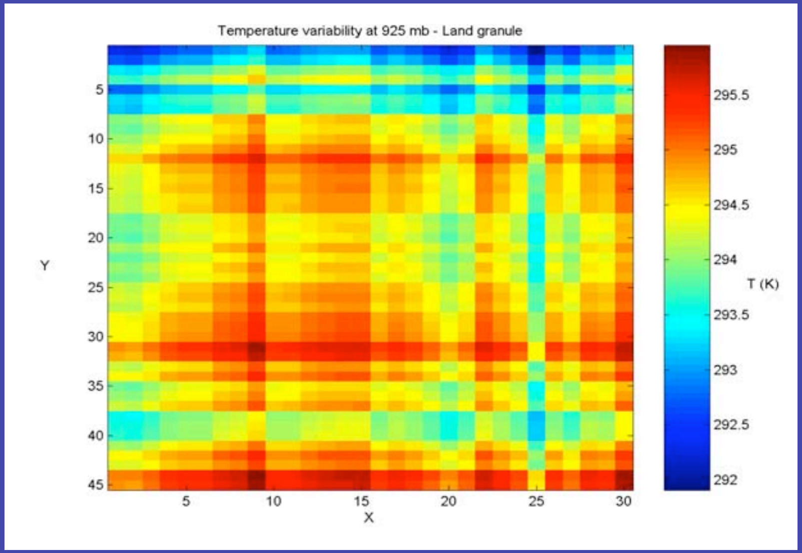


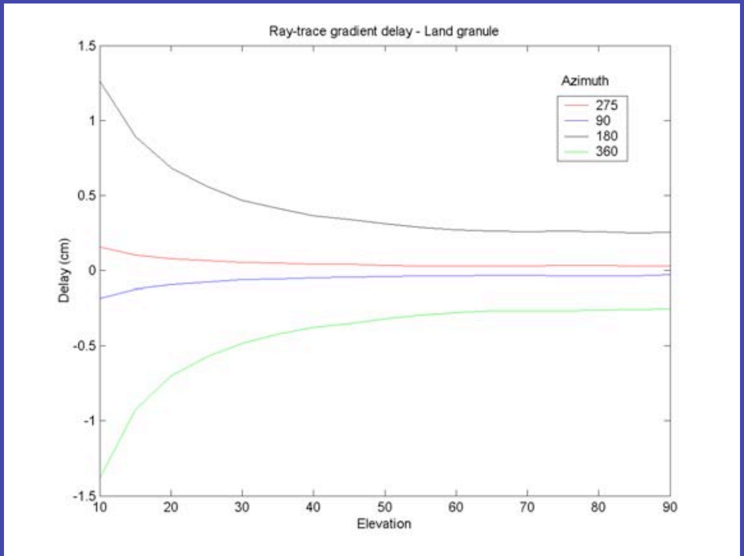


Total Horizontal Delay

Total East-West and North-South gradient coefficients are integrated through all layers of data to produce a quantitative picture of the total effect (left). Gradient profiles at four different azimuth angles and for an 80° elevation direction.

AIRS Data III

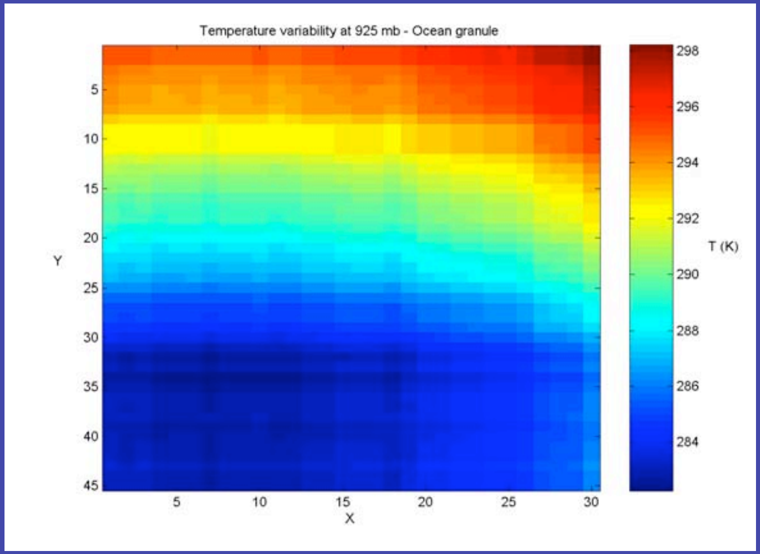


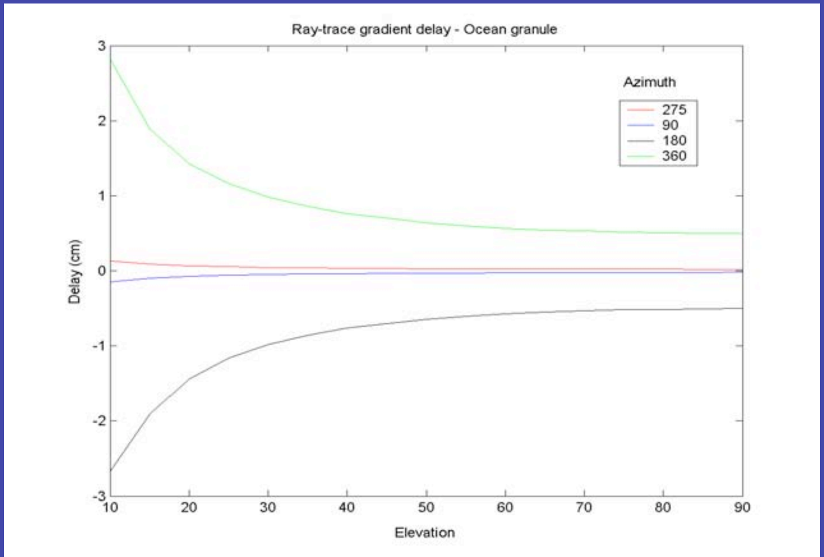


Land Granule Case

Ignoring horizontal gradients is most likely the largest error in ray-tracing techniques at low elevation angles, but they also correct a small bias for near-zenith directions. We can see from the figures on the right, that the delay is greatest in the north-south direction (azimuths 180° and 360°).

AIRS Data VI





Ocean Granule Case

The increase of the delay at low elevations is mainly due to a decrease in temperature from the equator to the poles as can be seen in left figures. In this "ocean" case, the temperature gradients are greatest over the ocean where the latitude of the granule runs from -38° to -17° . Notice the doubling of the errors at 10° elevation between the "land" and the "ocean" example cases.

H - Gradient Computation

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- The system that we are developing in place retrieves the AIRS and ancillary data, several times a day around ILRS sites
- The data are preprocessed and converted to quantities useful in the derivation of the local gradients' functions (G_{NS} and G_{EW})
- The gradient formulation to be adopted is under investigation, including the possibility of an altogether brand new one.

H - Gradient Formulation

A possible (currently used) model for adoption is one similar to what was used in prior studies with VLBI data:

$$m_{az}(\varepsilon) = \frac{1}{\sin(\varepsilon) \cdot \tan(\varepsilon) + 0.0032}$$

$$L_{ns} = 10^{-6} \int_{0}^{H} N_{ns} \cdot h \cdot dh$$

$$L_{ew} = 10^{-6} \int_{0}^{H} N_{ew} \cdot h \cdot dh$$

$$L_{az} = L_{ns} \cdot m_{az}(\varepsilon) \cdot \cos(\alpha) + L_{ew} \cdot m_{az}(\varepsilon) \cdot \sin(\alpha)$$

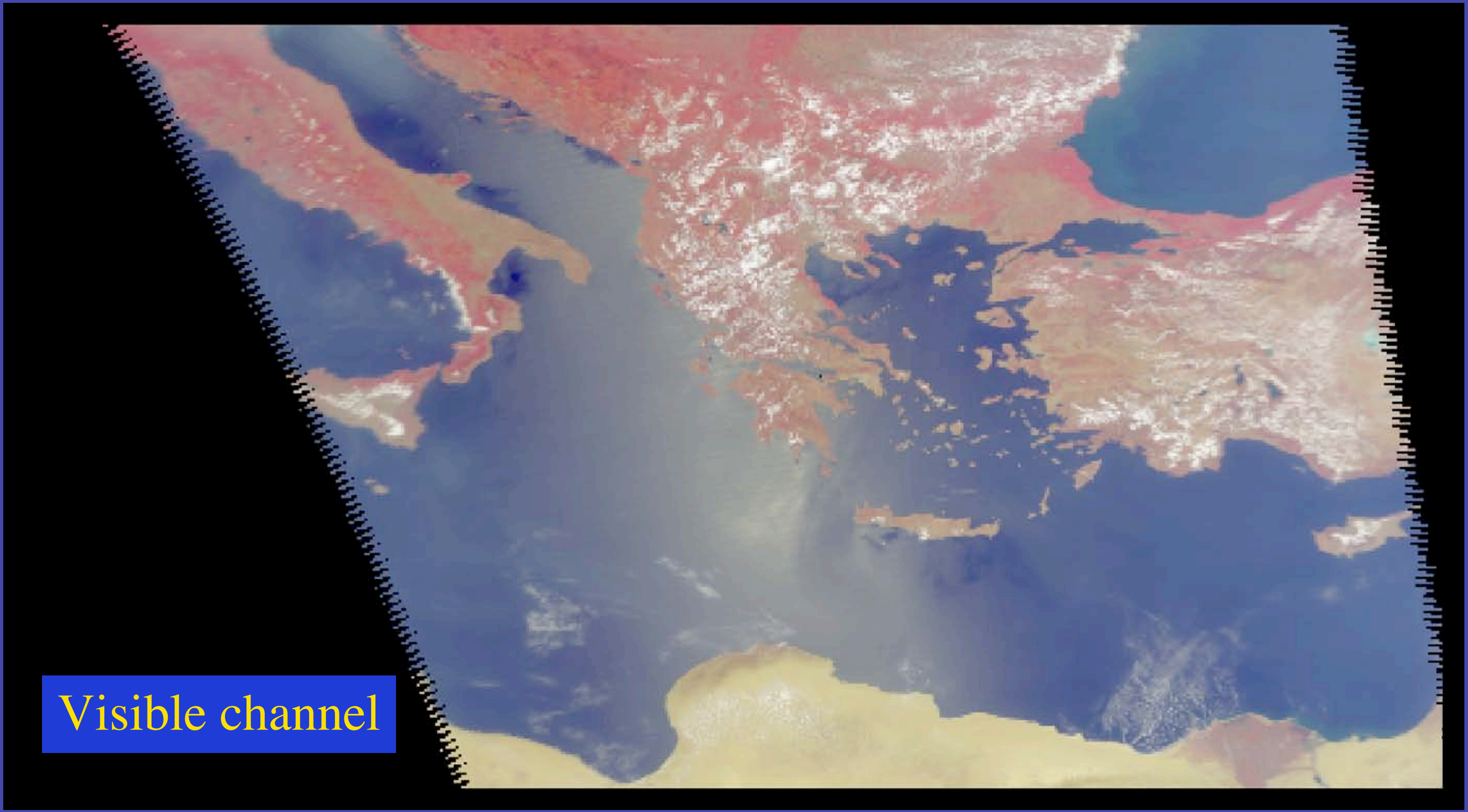
but other approaches are being examined and in the computations we adopted the [*Mendes and Pavlis, 2004*] refractivity formula.

Summary

- We are able to utilize existent AIRS data to generate fields with delays due to horizontal gradients.
- JCET is developing an automated procedure to generate these fields for all ILRS sites on an operational basis.
- We are investigating 3-D ray-tracing algorithms using these fields to compute directly the total delay, thus avoiding the use of mapping functions entirely.

AIRS on AQUA

“First Light over the Med”



AIRS on AQUA
"First Light over the Med"