



OPAC-1 Workshop

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Sensitivity of GNSS Occultation Profiles to Horizontal Variability in the Troposphere

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Sensitivity of GNSS Occultation Profiles to Horizontal Variability in the Troposphere

Outline



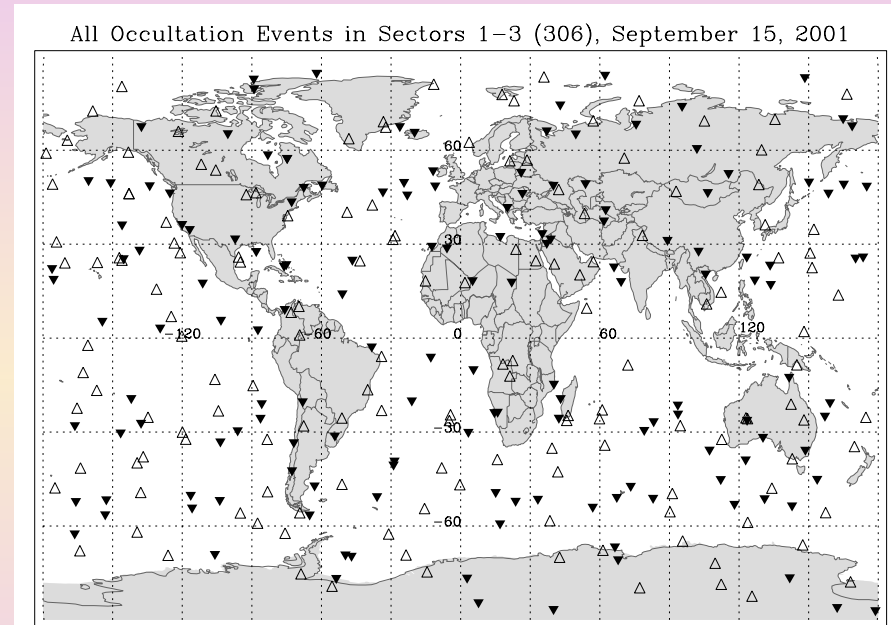
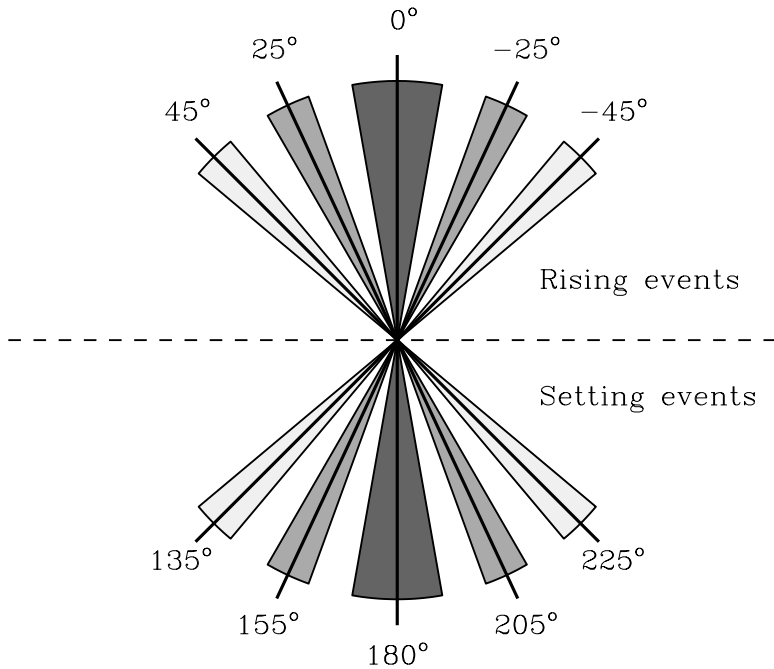
- **Experimental Setup**
 - Overview on Setup and Simulations
 - Azimuth Sectors and Event Distribution
 - Model Atmosphere
- **Sensitivity to Horizontal Variability Errors**
 - Temperature Errors as Example
 - Parameter Inter-Comparison
 - Relevance of Tangent Point Trajectory
- **Sensitivity to the Angle-of-Incidence**
 - Temperature Errors as Example
 - Parameter Inter-Comparison
 - Selected Dry Temperature Profiles
- **Summary, Conclusions and Outlook**



Overview on Setup and Simulations



- **Geometry**
 - Full nominal constellation of 24 GPS satellites
 - GRAS receiver onboard METOP assumed (altitude ~ 830 km)
 - Three azimuth sectors ($\pm 10^\circ$, $\pm 20^\circ$ to $\pm 30^\circ$, $\pm 40^\circ$ to $\pm 50^\circ$)
- **Event Distribution**
 - \sim Uniform distribution over latitude in each azimuth sector
 - \sim Equal density over oceans and over land in each sector
 - ~ 100 events in each azimuth sector – 306 in total (during 24h)
- **Generation of simulated data**
 - Ray-tracing through high-resolution ECMWF analysis fields at 10 Hz
 - Realistic errors superimposed (GRAS-type standard errors)
 - Geometric optics retrieval with statistical optimization
 - “Dry air” retrieval
- **Reference profiles**
 - “True” ECMWF vertical profiles at mean tangent point (~ 12 – 15 km height)
 - “True” profiles along the actual 3D tangent point trajectory



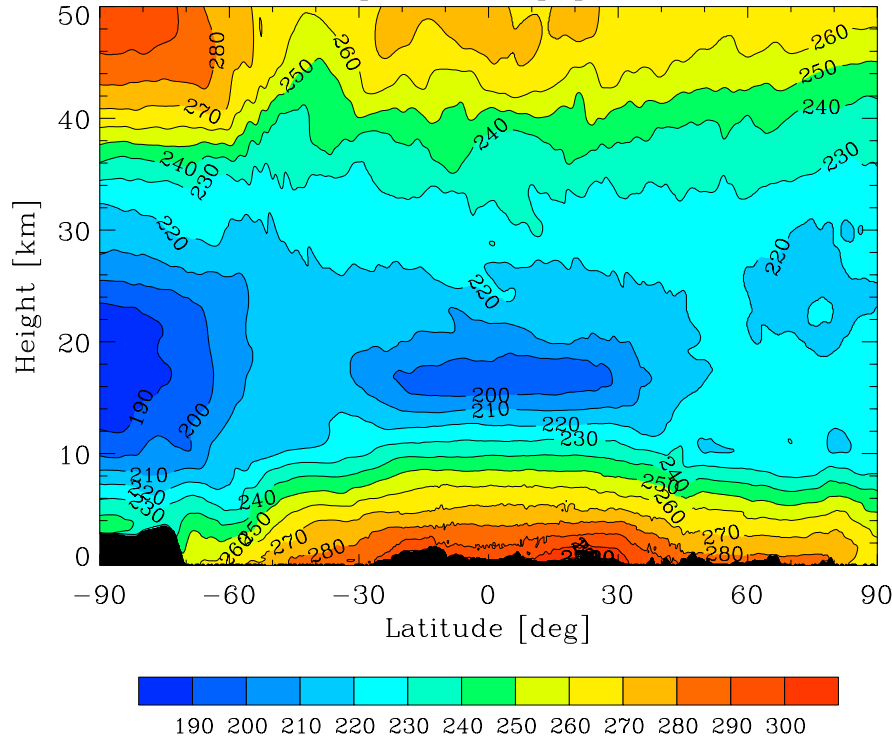
Azimuth Sectors

- **Sector 1:** $0^\circ < |\text{Azimuth}| < 10^\circ$
- **Sector 2:** $20^\circ < |\text{Azimuth}| < 30^\circ$
- **Sector 3:** $40^\circ < |\text{Azimuth}| < 50^\circ$

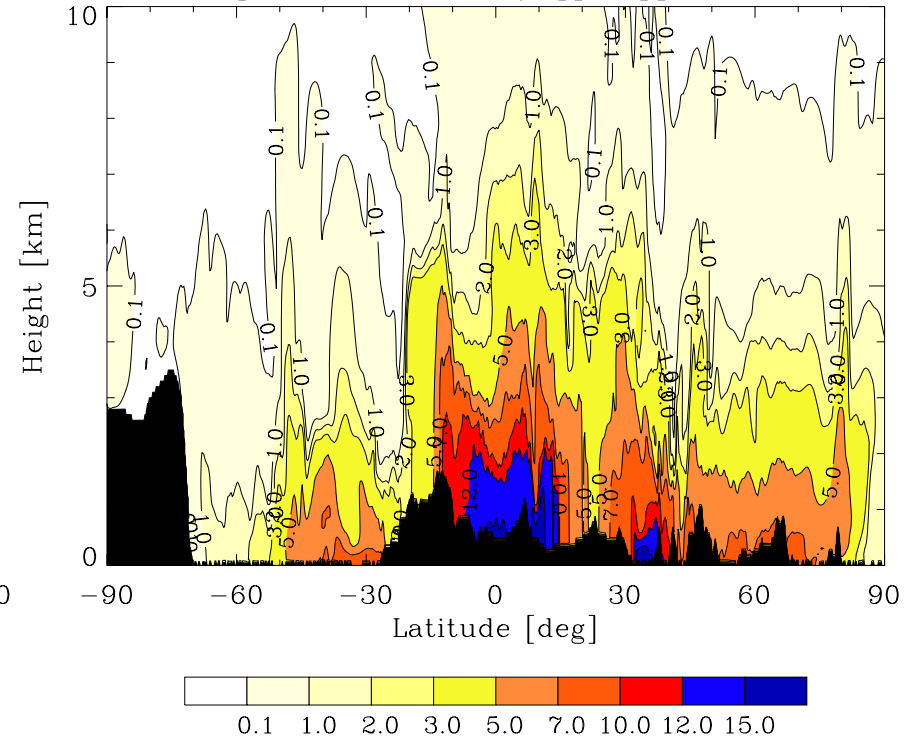
Distribution of Occultation Events

- Sample of ~ 100 events in each sector, 306 in total

Temperature [K], 15°E



Specific Humidity [g/kg], 15°E



ECMWF analysis field: Temperature slice

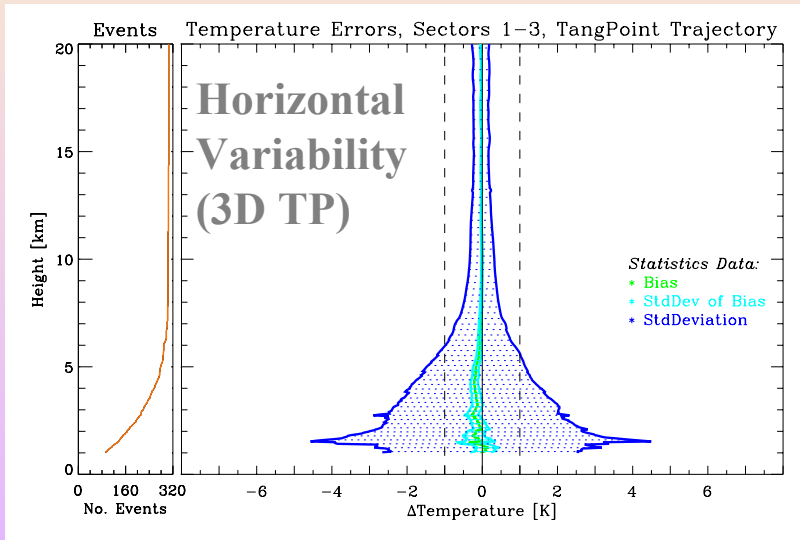
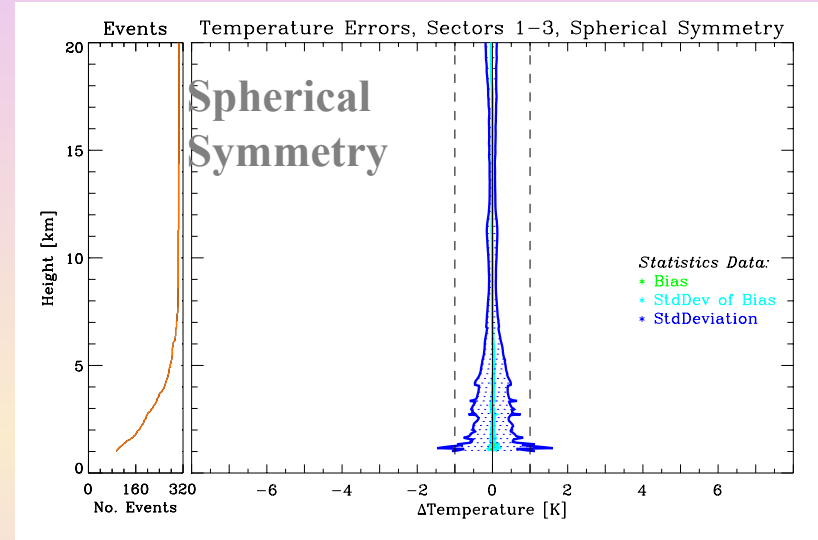
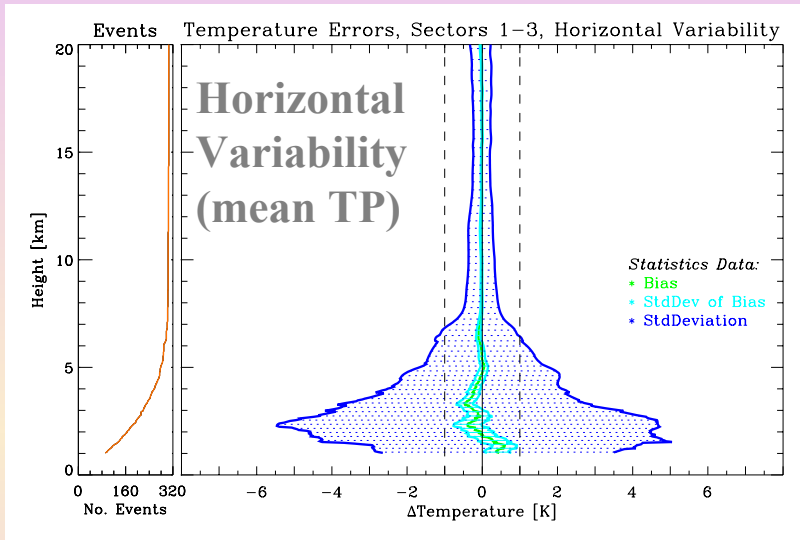
- T511L60 field, September 15, 2001, 12 UT
- 1024 lon x 512 lat points
- Height range shown: **0 – 50 km**

ECMWF analysis field: Specific Humidity

- T511L60 field, September 15, 2001, 12 UT
- 1024 lon x 512 lat points
- Height range shown: **0 – 10 km**

Sensitivity to Horizontal Variability (1)

Temperature Errors as Example

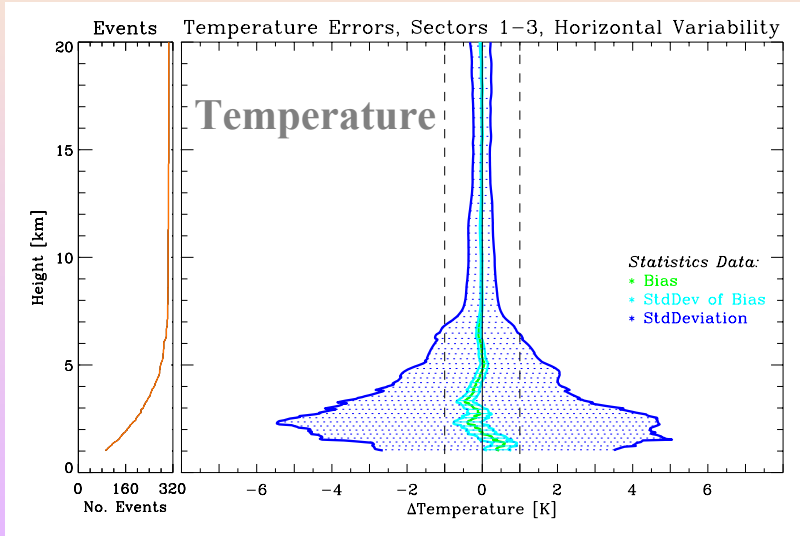
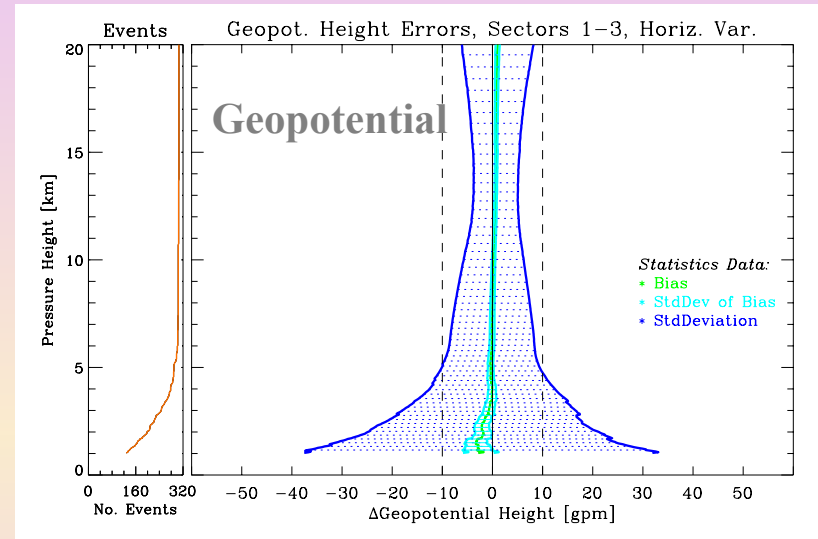
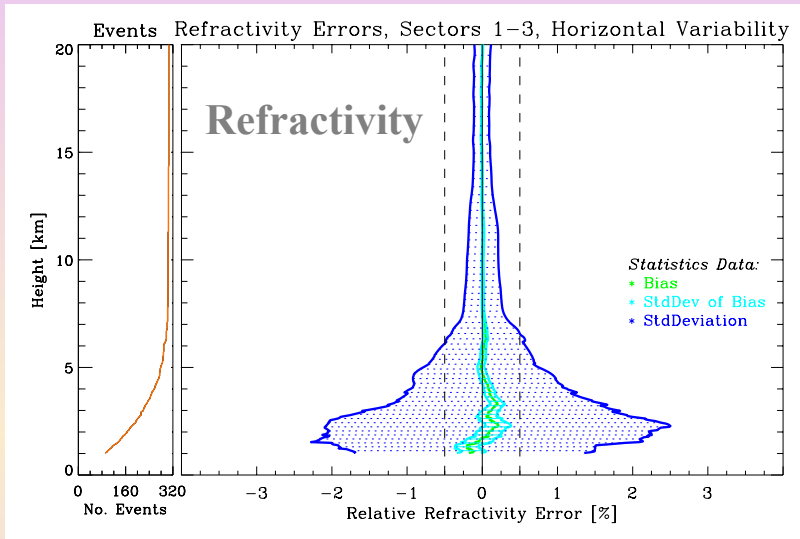


Temperature Error Statistics

- Ensemble of all 306 occultation events
- Atmosphere with horizontal variability (vertical profile at mean tangent point as reference)
- Atmosphere with spherical symmetry applied
- Atmosphere with horizontal variability (profile along 3D tangent point trajectory as reference)

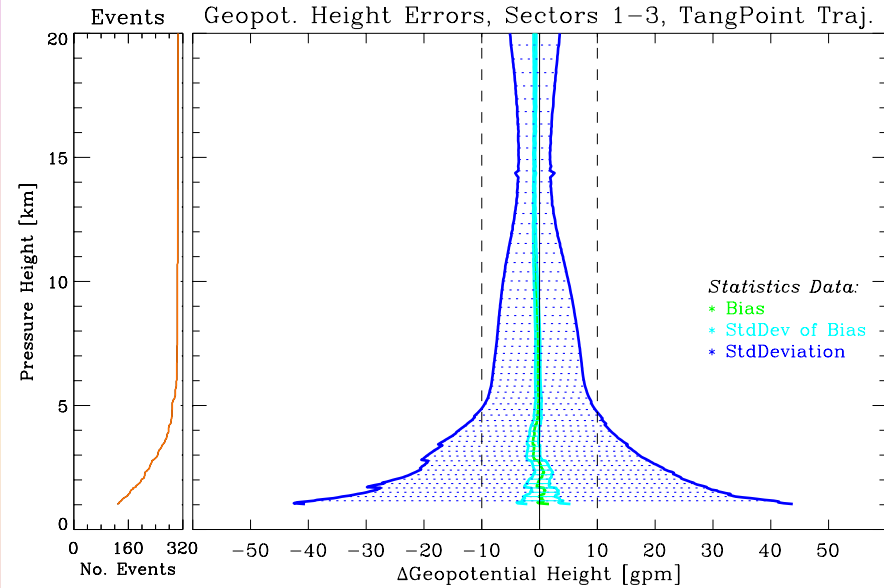
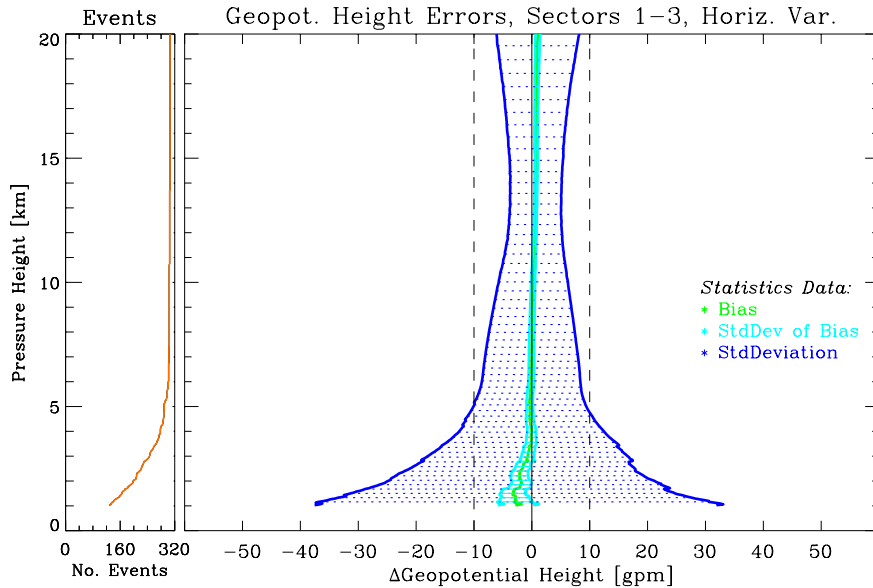
Sensitivity to Horizontal Variability (2)

Parameter Inter-Comparison



Parameter Inter-Comparison

- Ensemble of all 306 occultation events
- Atmosphere with **horizontal variability** (vertical profile at mean tangent point as reference)
- **Relative Refractivity** errors
- **Absolute Geopotential Height and Temperature** errors



Geopotential Height Error Statistics

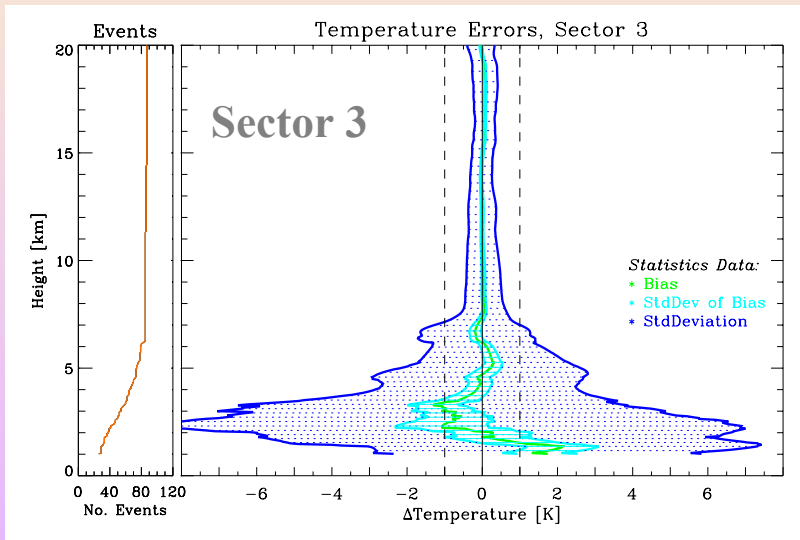
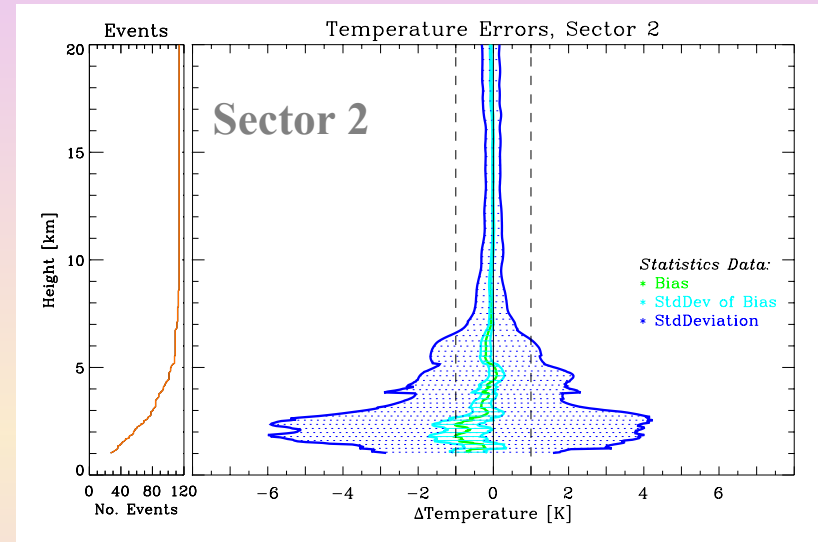
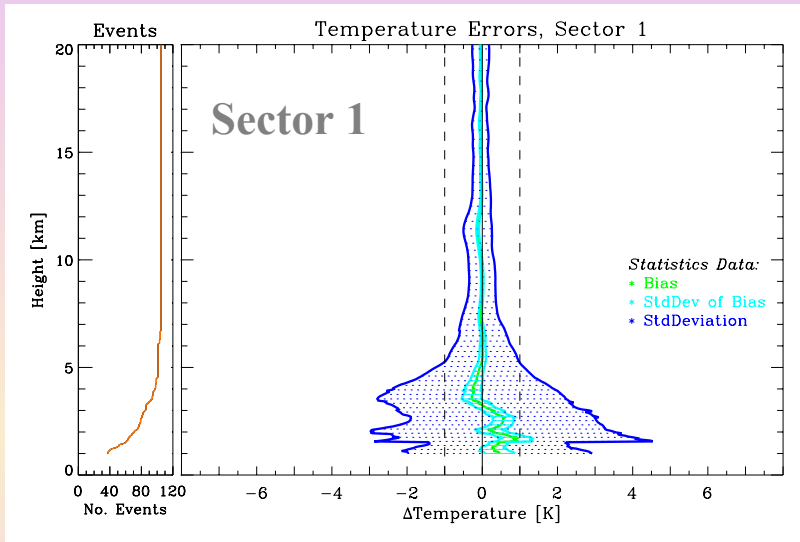
- Ensemble of all 306 occultation events
- Atmosphere with horizontal variability (vertical profile at mean tangent point as reference)

Geopotential Height Error Statistics

- Ensemble of all 306 occultation events
- Difference vertical profile at mean tangent point-minus-along 3D tangent point trajectory

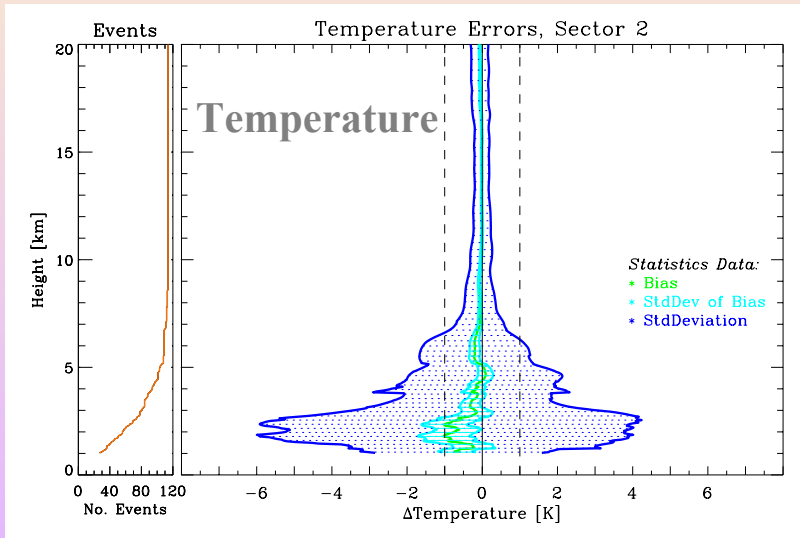
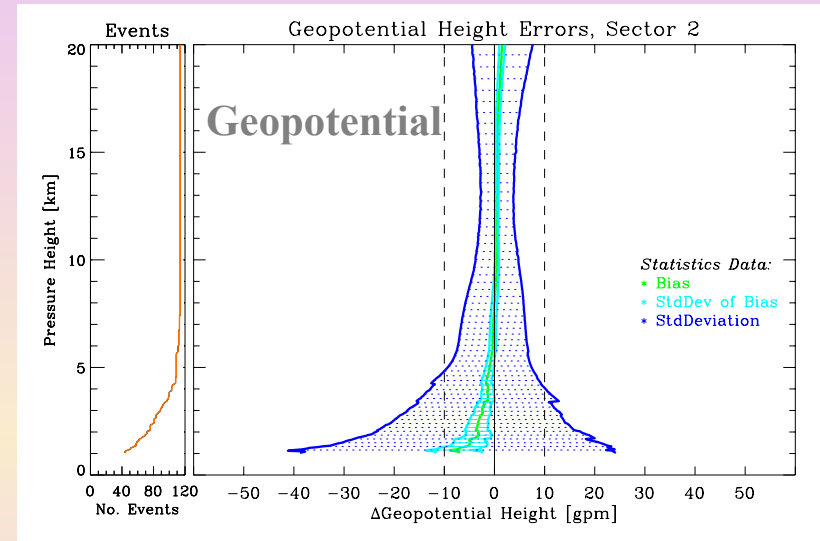
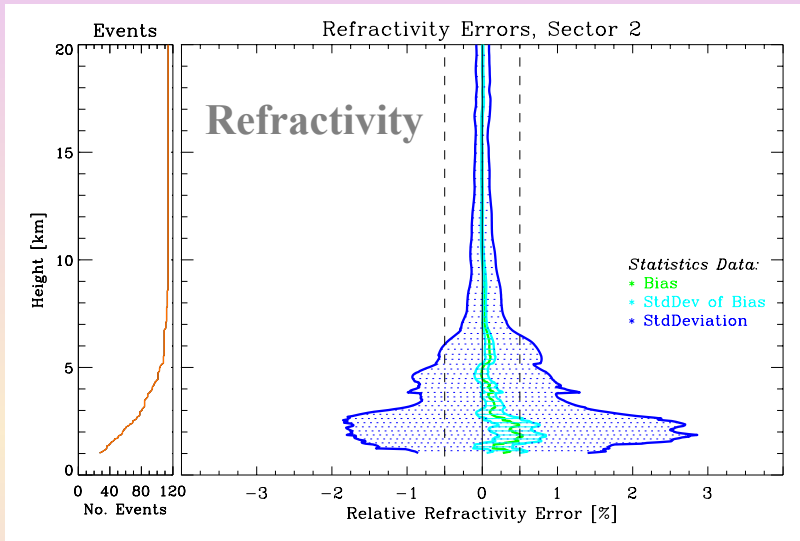
Sensitivity to the Angle-of-Incidence (1)

Temperature Errors as Example



Temperature Error Statistics

- Sector 1: $0^\circ < |Az| < 10^\circ$ **105** events
- Sector 2: $20^\circ < |Az| < 30^\circ$ **114** events
- Sector 3: $40^\circ < |Az| < 50^\circ$ **87** events



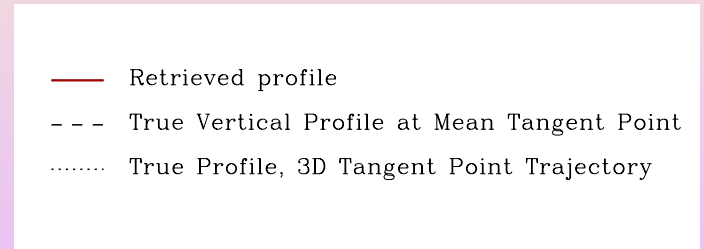
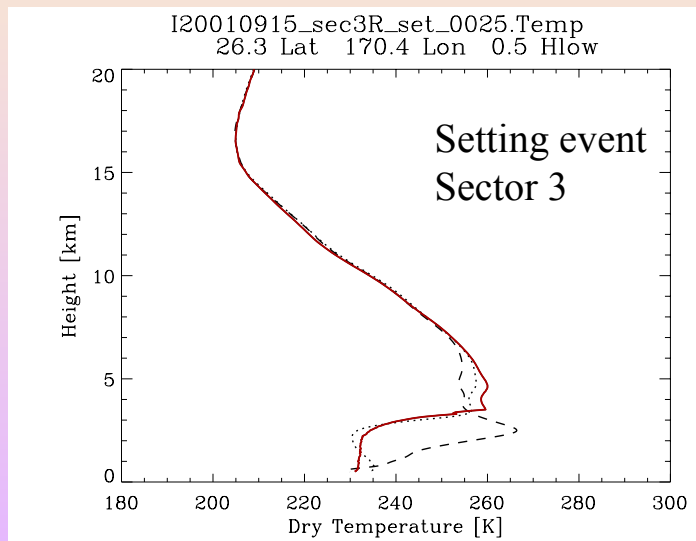
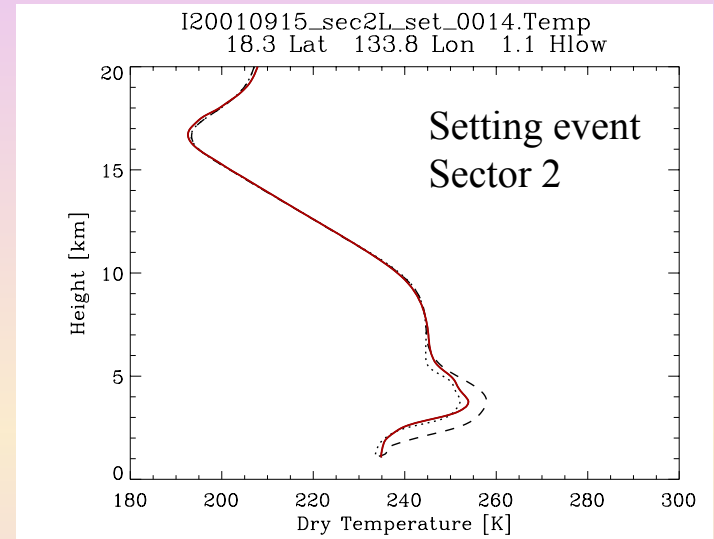
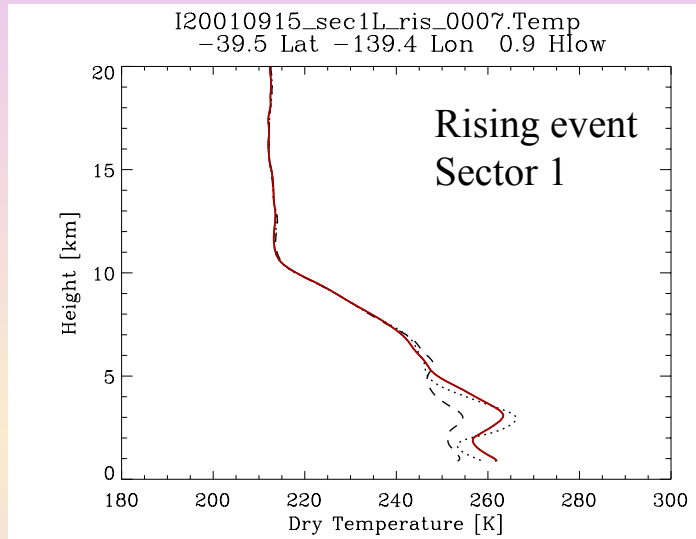
Parameter Inter-Comparison

- Ensemble of 114 occultation events
- **Sector 2** ($20^\circ < |\text{Azimuth}| < 30^\circ$)
- Atmosphere with **horizontal variability** (vertical profile at mean tangent point as reference)
- **Relative Refractivity errors**
- **Absolute Geopotential Height and Temperature errors**



Sensitivity to the Angle-of-Incidence (3)

Dry Temperature Profiles (horiz. var.)





Sensitivity of GNSS Radio Occultation Data to Horizontal Variability in the Troposphere

Summary, Conclusions, and Outlook



- **Sensitivity to horizontal variability**
 - Biases and standard deviations in a realistic atmosphere are considerably larger than under spherical symmetry, especially below ~ 7 km
 - Temperature profiles above ~ 7 km are essentially bias-free in both cases
 - A significant part of the total error below ~ 7 km can be attributed to adopting reference profiles vertically at mean tangent point
- **Sensitivity to angle-of-incidence**
 - Below ~ 7 km most errors increase with increasing angle of incidence
 - Temperature biases above ~ 7 km, however, do not increase with increasing angle of incidence, which is favorable for the climate utility of the data
- **Outlook**
 - Investigation of advantage to exploit data along 3D tangent point trajectories
 - Improved understanding and (hopefully) mitigation of residual tropospheric biases