Global Observation of Tropospheric Turbulence Inferred from Radio Occultation

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Outline

Objectives

Global scintillation maps derived from COSMIC RO

- **COSMIC signal amplitudes**
- **Global scintillation estimates**
- **Power spectra of CT amplitudes**
- **Index of refraction structure parameter**

Wave propagation modeling

- **Multiple phase screen model (MPS)**
- **Scintillation index from simulations**

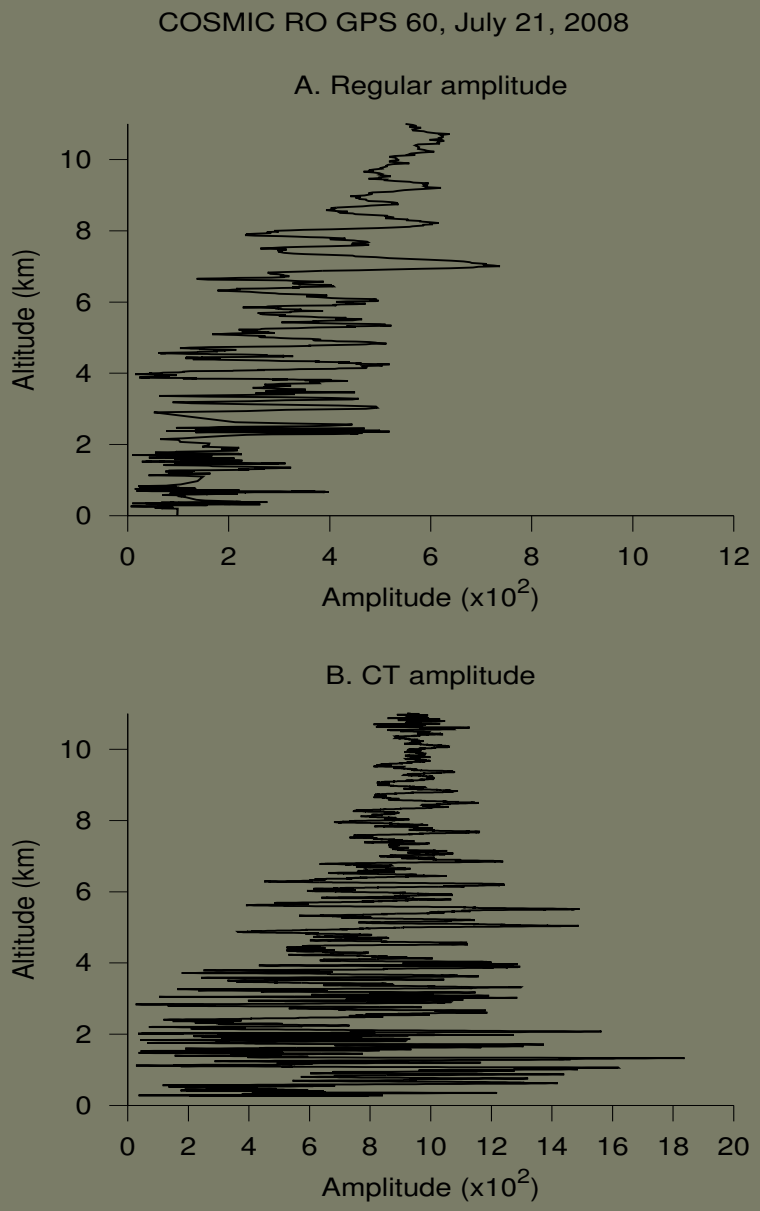
Summary and conclusions

Objectives

- **Global estimates of tropospheric turbulence strength (scintillation) inferred from COSMIC RO measurements.**

- **MPS model simulation to investigate the effects of tropospheric turbulence on signals received in a GPS to a LEO satellites radio links.**

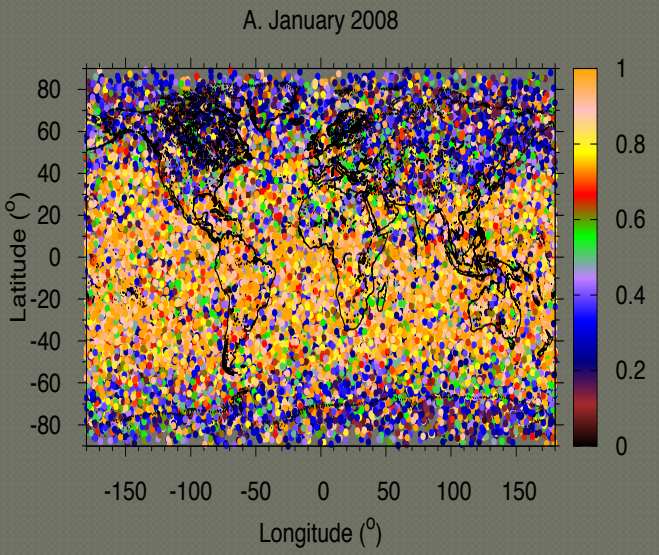
Regular and CT amplitude: Examples

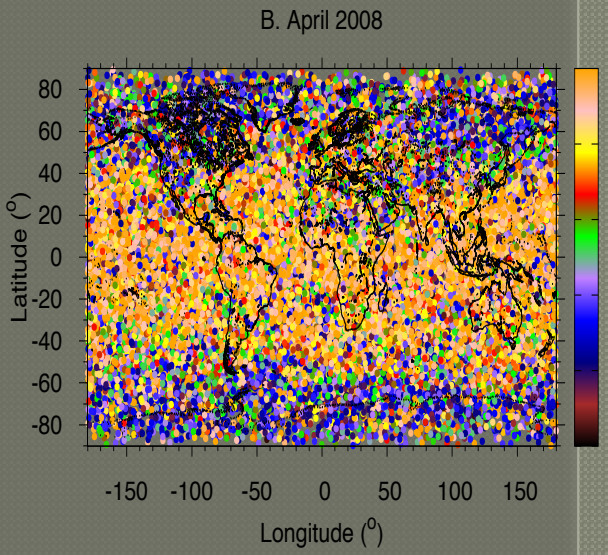


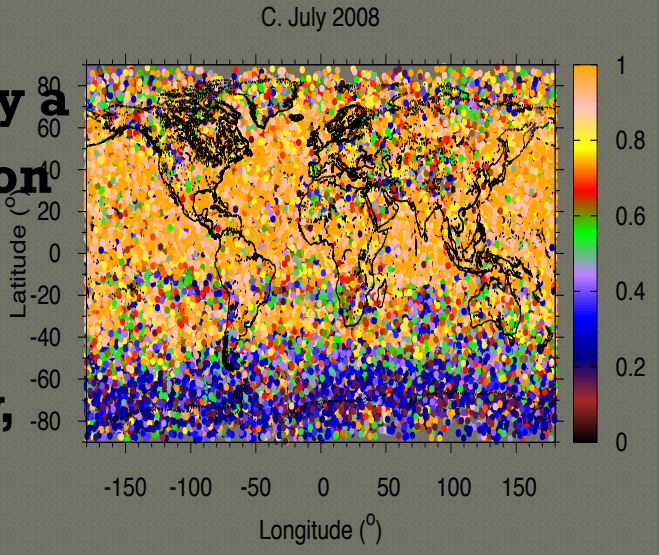
- **As the radio signal propagates through the troposphere, the amplitude of the regular signal suffers from the effects of defocusing, multipath propagation, and diffraction effects.**
- **To suppress amplitude fluctuations due to these effects, the canonical transform (CT) has been applied on the received complex signal.**
- **In the process of undoing the defocusing effects, the magnitude of the CT amplitude is amplified with larger fluctuations compared to the regular signal amplitude.**

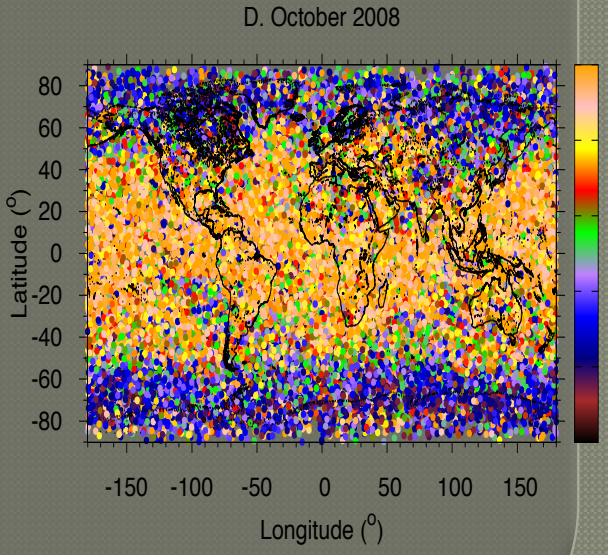
Global scintillation map

- **S4 index inferred from CT amplitudes (1-4 km alt).**
- **Strong seasonal dependence.**
- **NH summer exhibits relatively large turbulent activities compared to the SH.**
- **Tropical regions are generally characterized by a relatively large scintillation index.**
- **Land-sea contrast.**
- **Correlation with humidity, precipitation, and CAPE.**

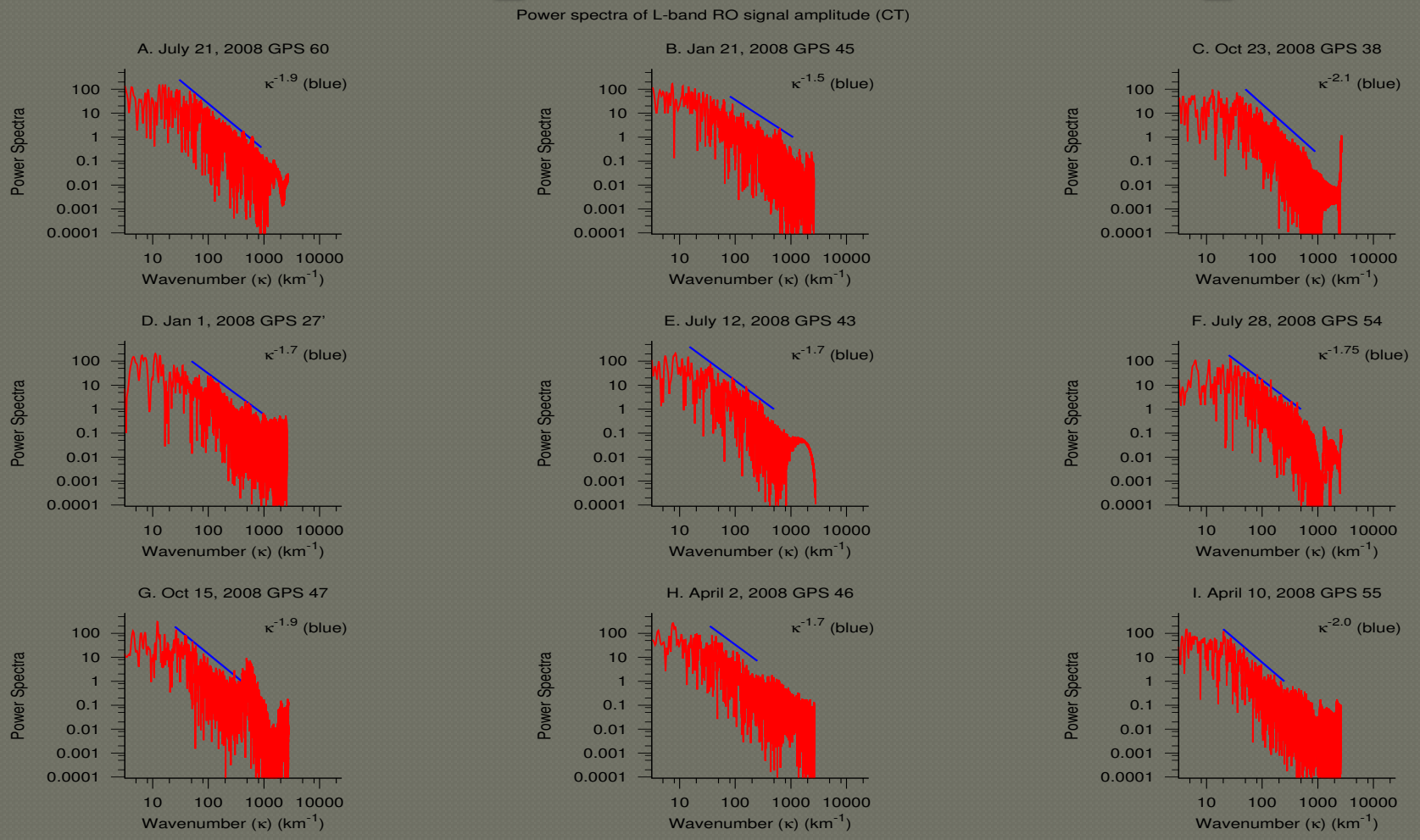








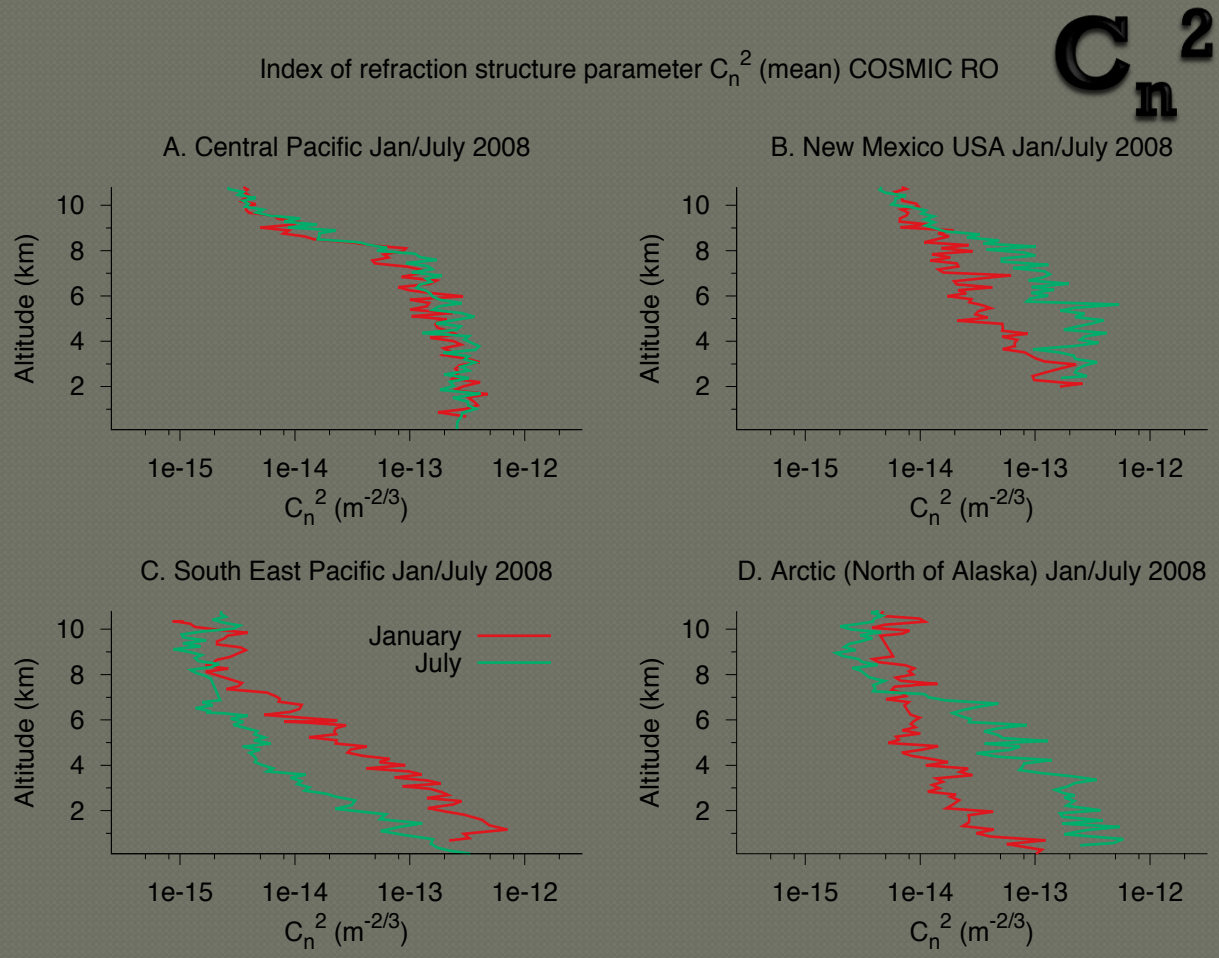
Power spectra of CT amplitude



- **The power spectra follow a power law k^{-s}, k is a vertical wavenumber. The index s ranges from about 1.5 to 2.1**
- **The spectral slopes are consistent with 1D Kolmogorov spectra $k^{-5/3}$**
- **Energy may have be injected around (100 to 700 m) and cascaded to small scales to be dissipated by viscosity ~10 m**

Refractive index structure parameter C_n^2

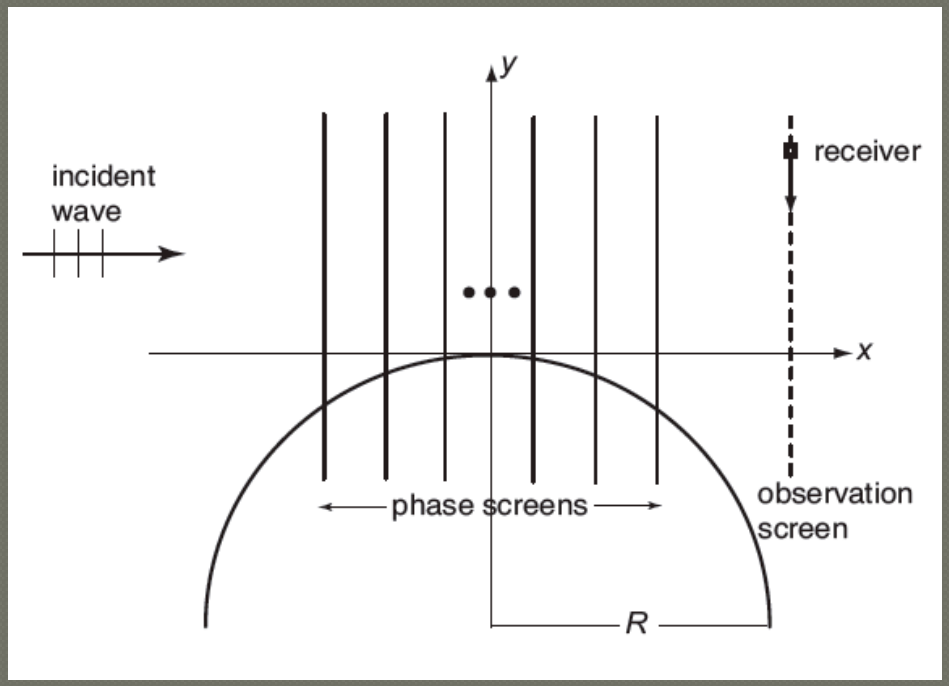
- C_n^2 is calculated using the Rytov relation assuming weak scintillation: $S_4^2 = 1.23 C_n^2 k^{7/6} L^{11/6}$
- L is an effective signal propagation length. In the troposphere, L=650 km, estimated from MPS model simulation.



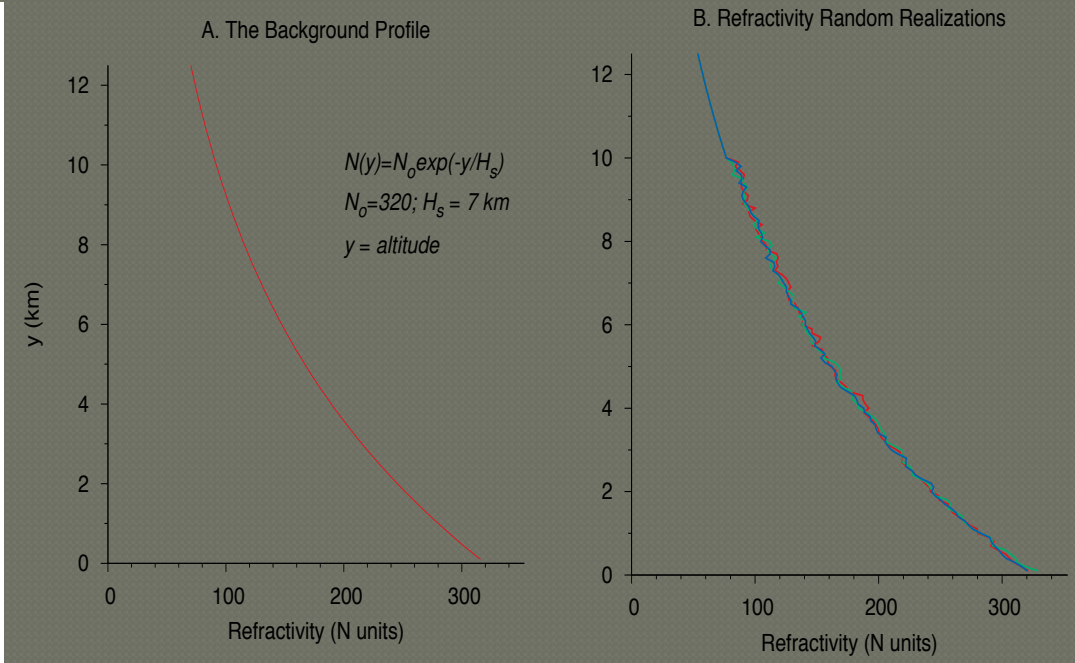
- L varies slowly with altitude. The estimated L represents an average value for the C_n^2 estimations.
- COSMIC RO C_n^2 profiles are in general agreement with the C_n^2 profiles inferred from radiosonde profiles.

Wave propagation simulation

MPS geometry



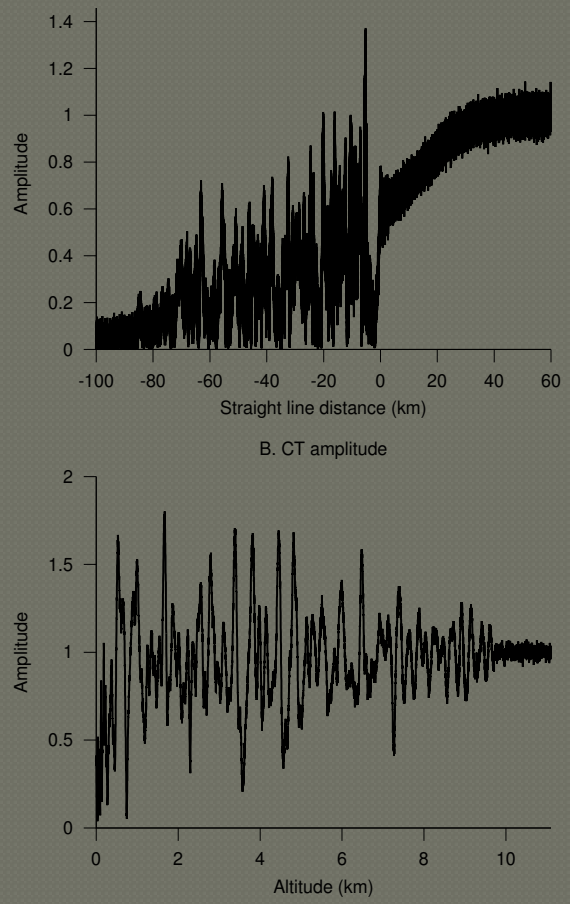
Refractivity profile inputs



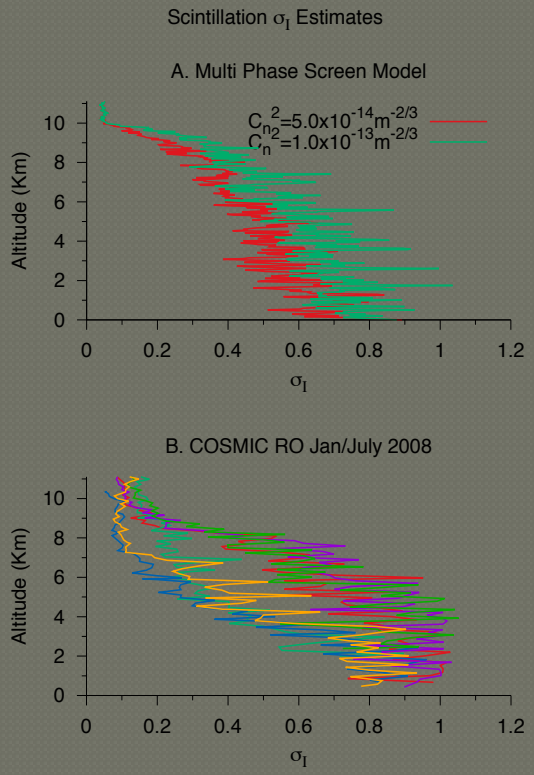
- **The refractivity profiles on the phase changing screens are specified by the characteristics of a Kolmogorov turbulence spectra**

Model results

Profile of the regular (top) and CT (bot) amplitude of radio signal (examples) calculated by the MPS simulation



Scintillation index profiles inferred from (top) MPS model runs, and (bot) COMSIC RO observations (regional averages).



The scintillation estimates are averages of 50 MPS model simulation random realizations

Summary and Conclusions

- **Radio occultation observations on board the COSMIC satellites, and MPS model calculations, have been utilized to investigate and quantify the effect of tropospheric turbulence on L-band signals**
- **Calculating global maps of scintillation measures were possible due to the availability of substantial number of COSMIC RO profiles covering the entire globe.**
- **We have presented seasonal, latitudinal and longitudinal characteristics of tropospheric turbulence.**
- **We have inferred realistic index of refraction structure parameter profiles estimated from COSMIC RO observations.**
- **Scintillation profiles inferred from the MPS simulations are in very good agreement with scintillation index profiles inferred from COMSIC RO measurements.**