Impact of Solar Intensity Variations on ACE Tropospheric Retrievals

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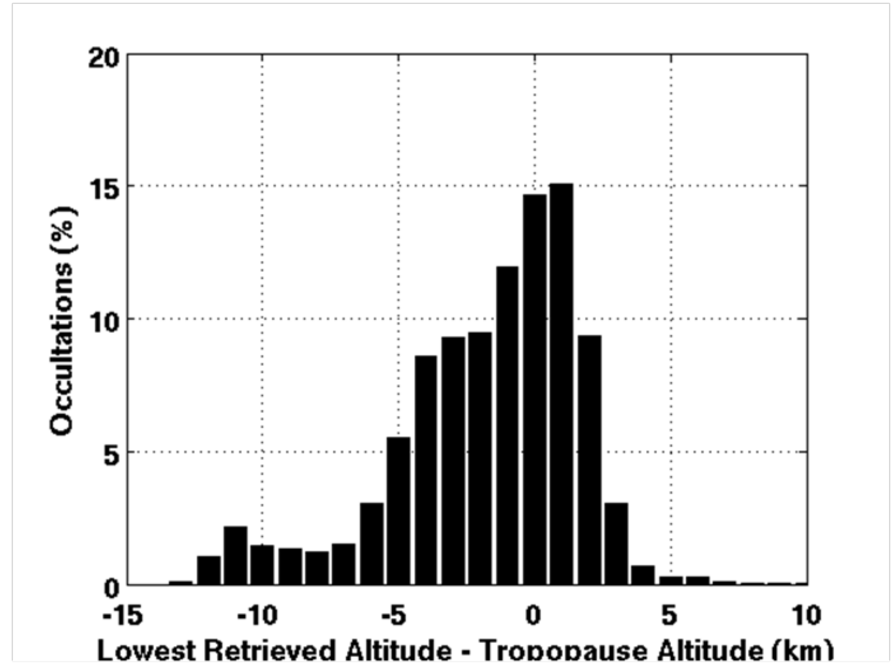
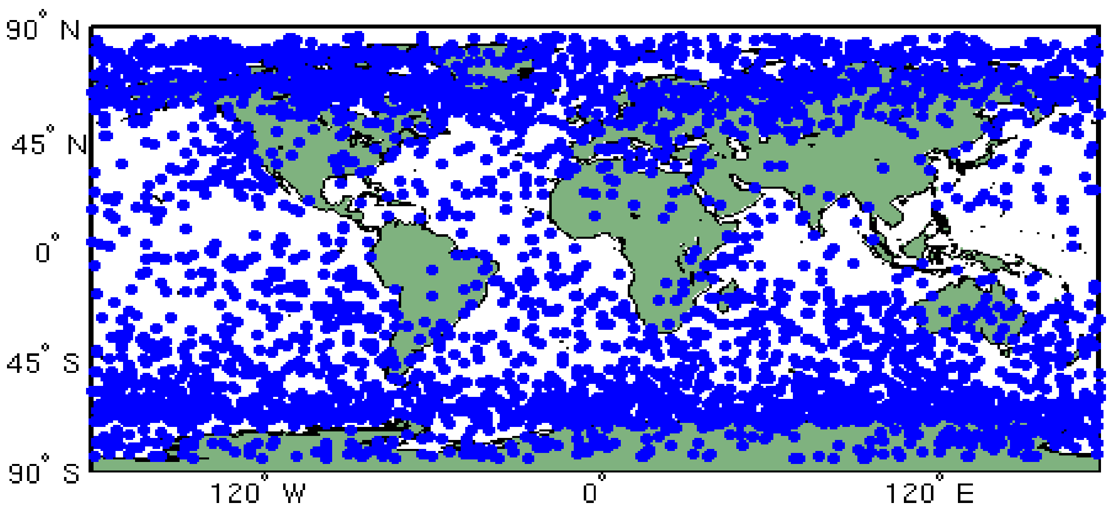
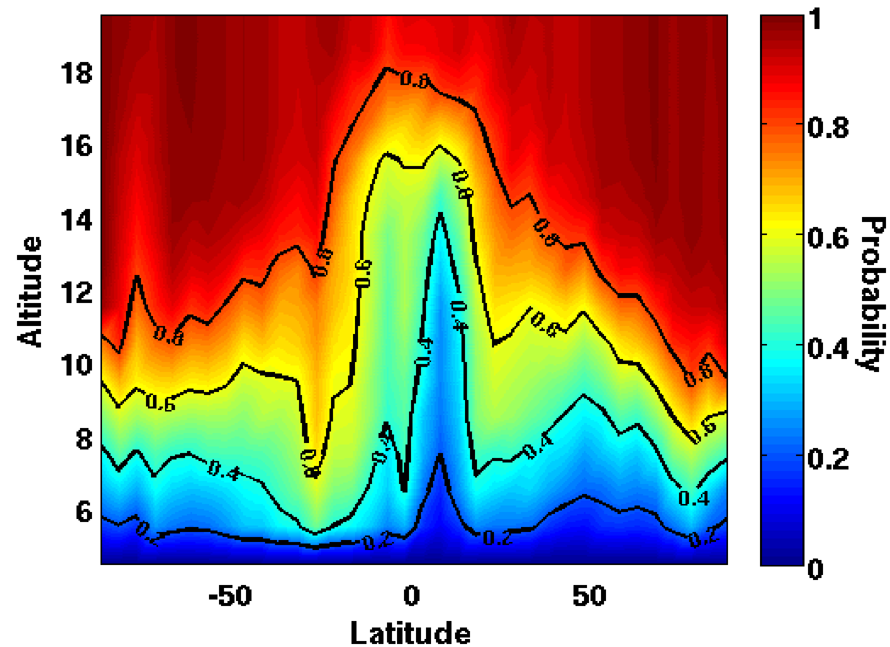
Introduction

- ACE-FTS mission was optimized for stratospheric retrievals
- Current ACE-FTS v2.2 profiles do not reach as deep into the troposphere as they could





Location of ACE occultations for which the lowest tangent altitude is <=6 km



Why Try to Retrieve Deeper into the Troposphere?

- ACE-FTS has great potential for the troposphere
  - Large number of retrieved gases
  - Long timeseries
  - Refraction slows down sunrise/sets; more spectra obtained
- Improved tropospheric retrievals could help better answer questions related to
  - Carbon cycle science (sources/sinks of CO_2)
  - Greenhouse gas emissions (international treaty verification)
  - Pollutant emissions (CO, H_2CO, PAN, HNO_3)
  - Satellite validation (NASA Aura – TES, AIRS, MLS, OMI; GOSAT; SCIAMACHY)

Obstacles to Retrieving Deeper into the Troposphere

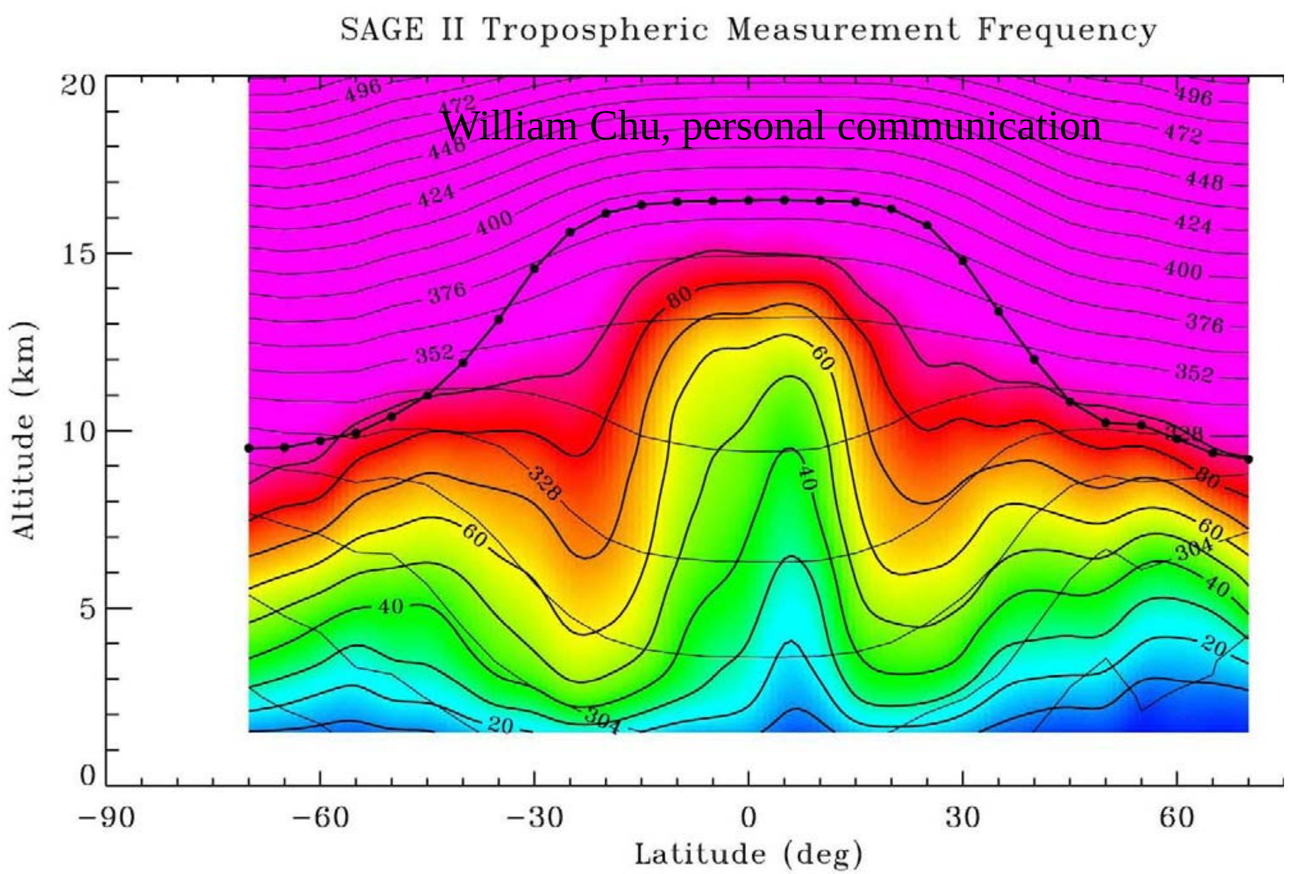
1. Lack of weak T-insensitive CO_2 lines for tangent height determination
2. Impact of FOV on strong H_2O lines
3. Suntracker glitches/jumps
4. Solar intensity variations due to clouds/aerosol

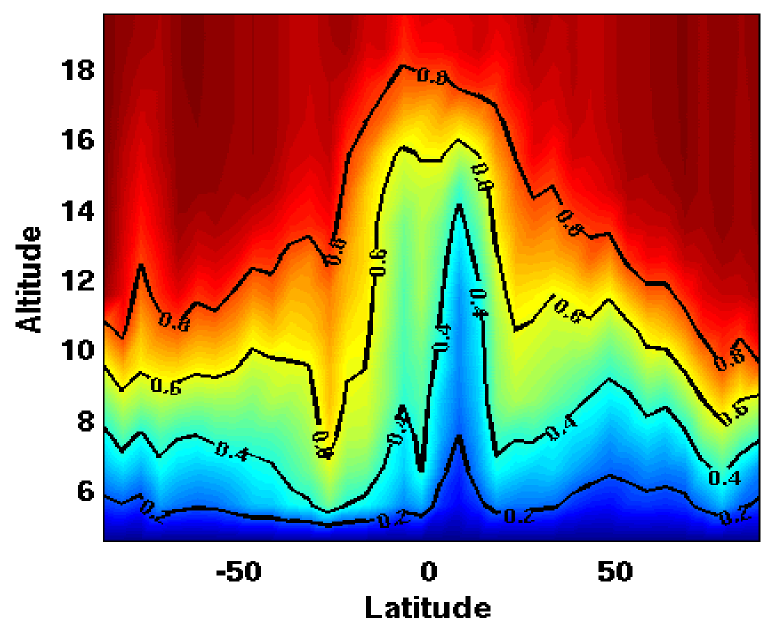
This presentation focuses on 4.

- Is it worth the trouble?
  - To retrieve tropospheric species and hence emissions, we need
    - Retrievals that reach as close to the surface as possible
    - The best possible accuracy for those retrievals
- How much deeper is ACE likely to get if all the above are fixed?

SAGE II Retrievals

- SAGE II has similar (high-inclination) orbit, and measures in solar occultation
- ACE-FTS operates at longer wavelengths, and therefore should see deeper into the atmosphere than SAGE II
- SAGE II retrievals reach ~3-4 km lower than the ACE-FTS retrievals

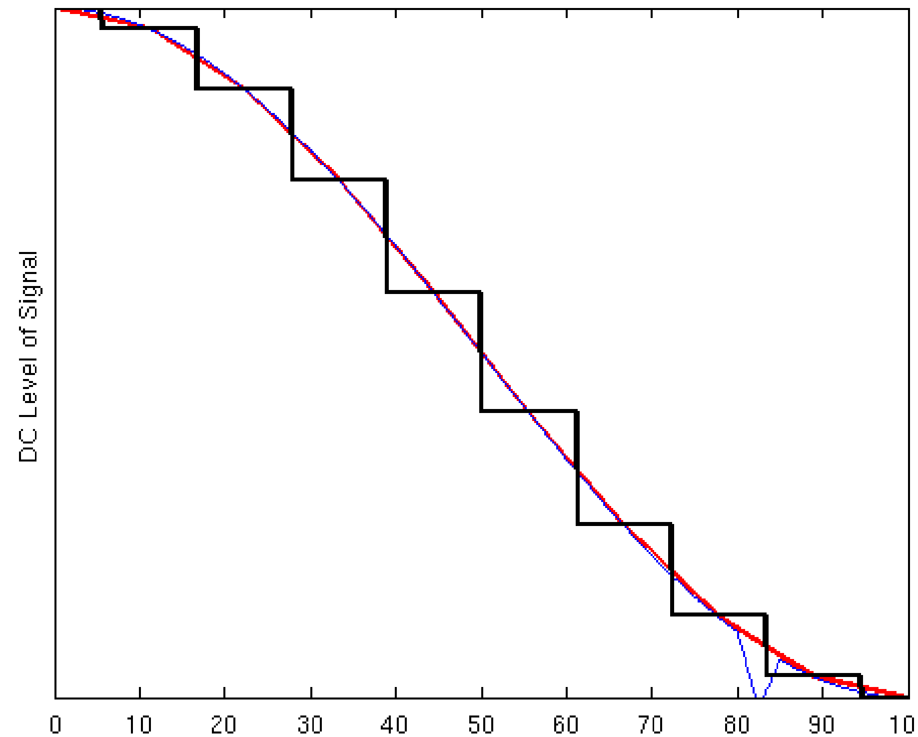




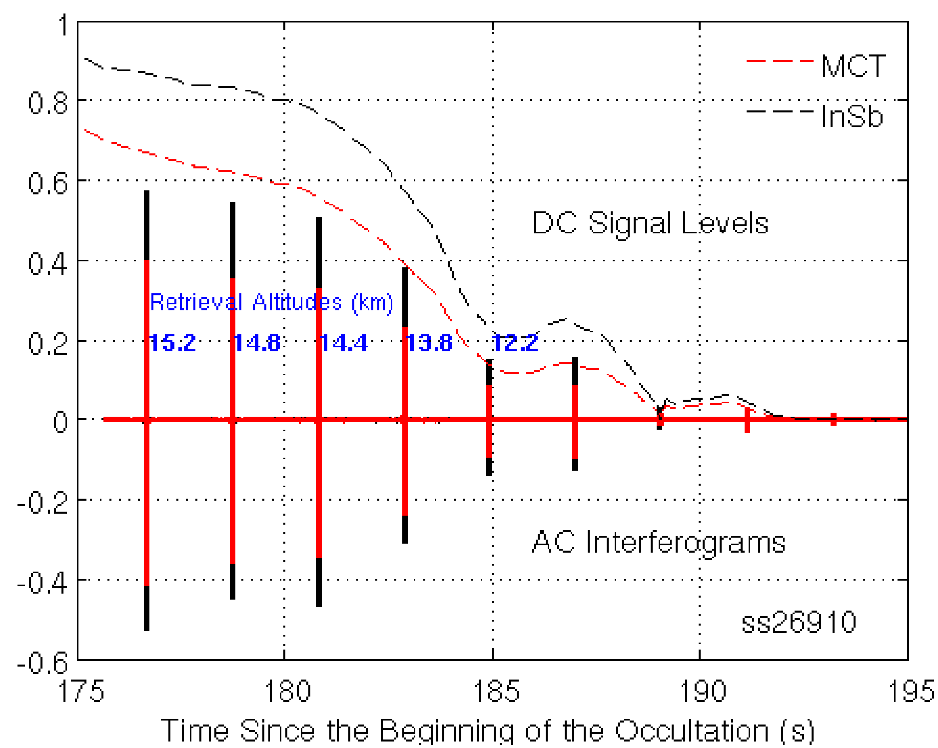
Changing solar intensity during an occultation

Changes are small in the stratosphere, but large in the troposphere (cloud layers), causing 3 main problems:

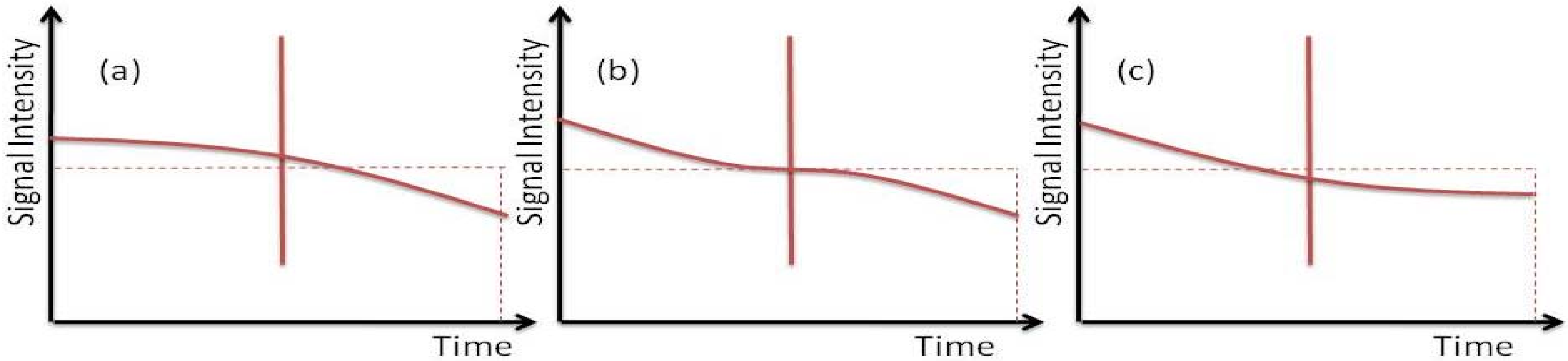
1. Reduced SNR
2. Interferogram fringe modulation
3. Suntracker jumps/glitches



- Top panel shows theoretical sunset and the assumed altitudes attributed to each interferogram
- Bottom panel shows actual ACE-FTS interferograms and the corresponding DC levels, recorded in the housekeeping stream
- These DC changes will cause spectral distortions.



Slow solar intensity variations



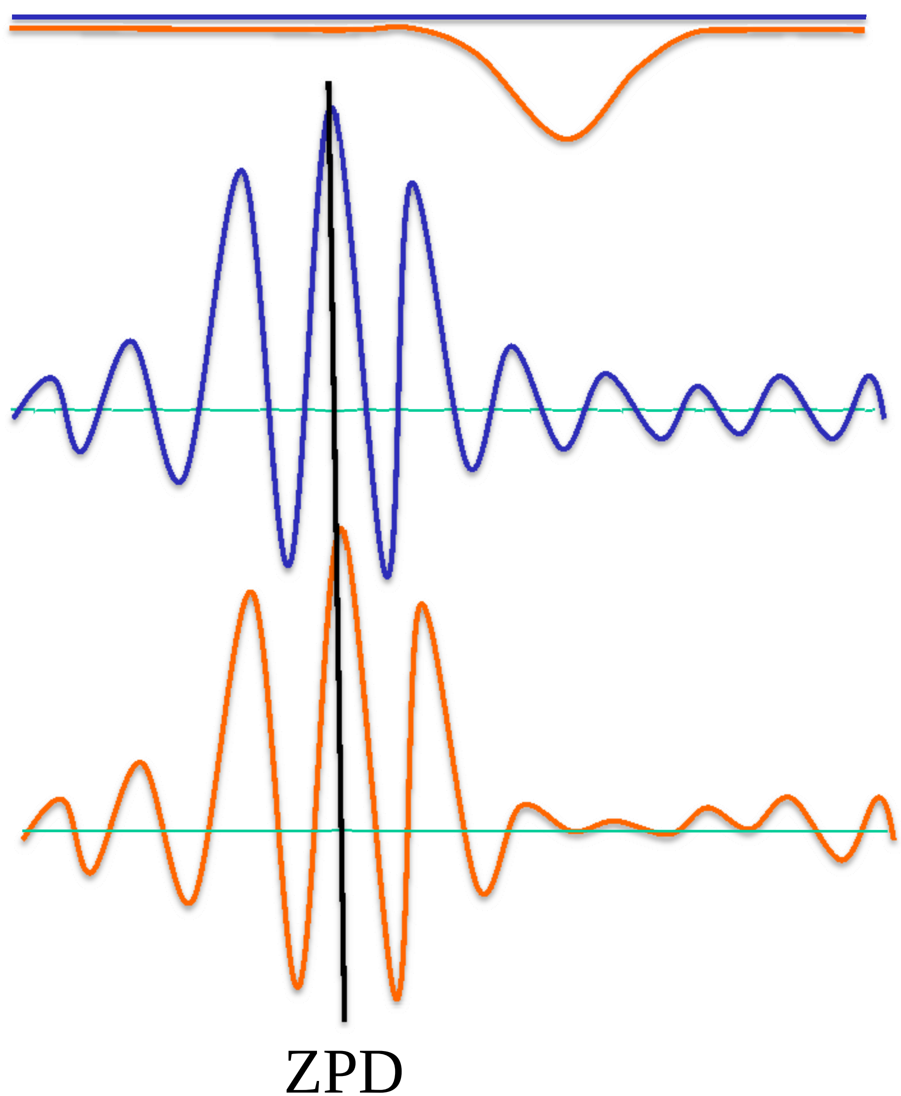
- DC levels (red), vertical line representing time of ZPD crossing
- Dashed horizontal line represents the interferogram-average signal intensity
  a) Interferogram signal intensity in the ZPD region exceeds the interferogram-average signal by ~5%.
     - Results in an underestimate in the amplitude of sharp spectral features with respect to broad spectral features (i.e. continuum).

  b) No bias since the solar intensity variations are entirely anti-symmetric about ZPD and therefore completely cancel.

  c) Narrow spectral features would be over-estimated relative to the broad spectral features

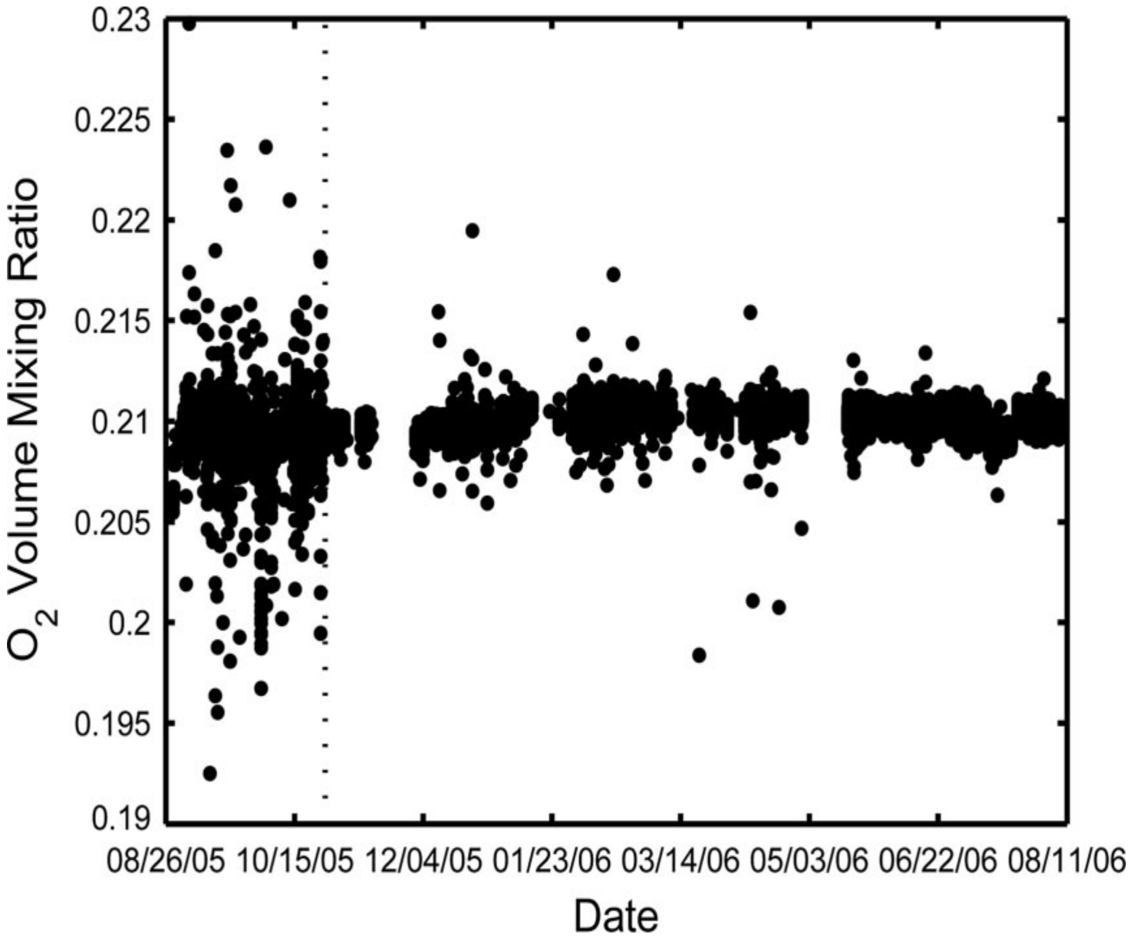
Fast solar intensity variations cause spectral distortions

- Interferogram fringes are modulated by cloud- and aerosol-induced variations in the solar intensity
- In FTS, low frequency spectral structure (from ZPD) are not recorded simultaneously with the high frequency spectral structure
- This will cause spectral distortions which lead to errors in the retrieved VMR profiles
- The fast and slow variations can both be fixed with knowledge of the DC solar intensity by ratioing (e.g. TCCON)
- ACE-FTS records the DC solar intensity in its housekeeping data stream



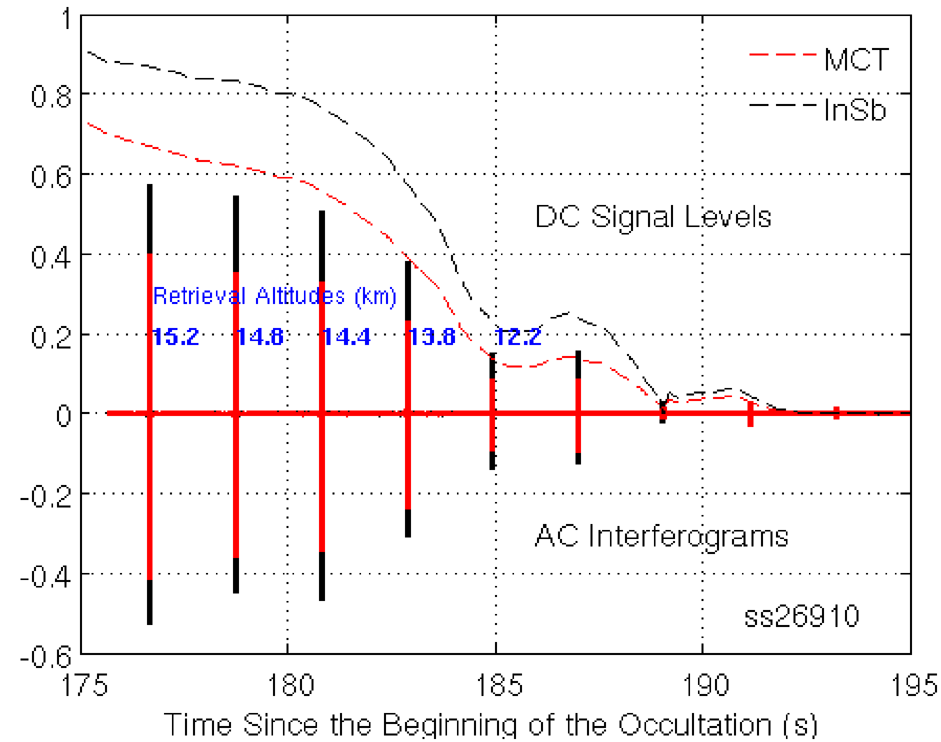
TCCON Solar Intensity Variation Correction

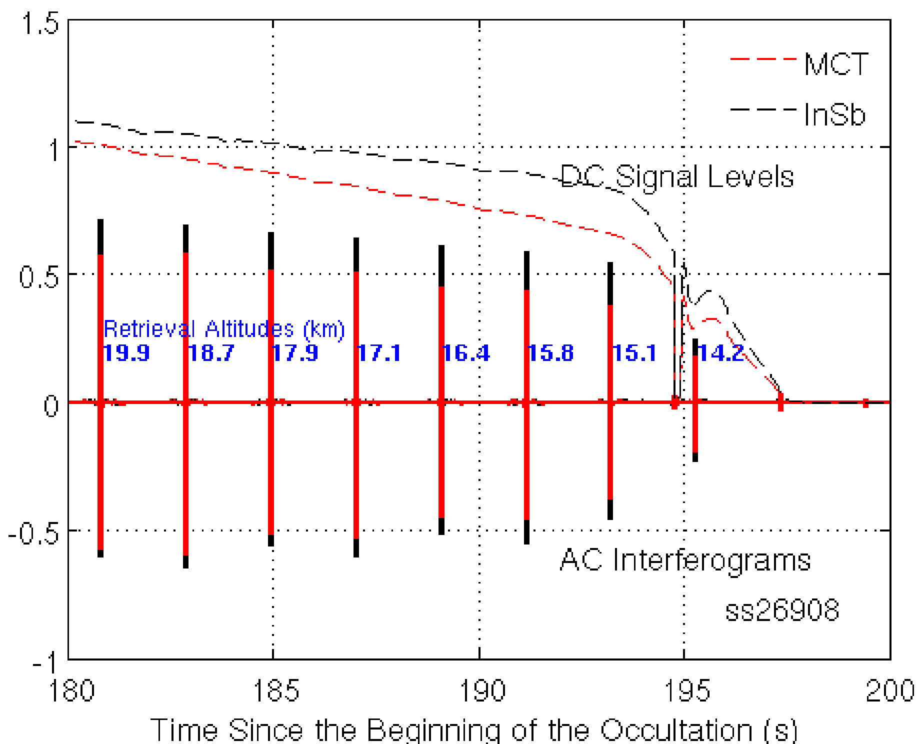
- TCCON (Total Carbon Column Observing Network) operationally employs a method of correcting the interferograms with DC signals
  - Keppel Aleks et al., 2007
- Interferograms are divided by the DC detector signal which restores the fringes to their correct amplitude
- This reduces the impact of solar intensity variations during a scan

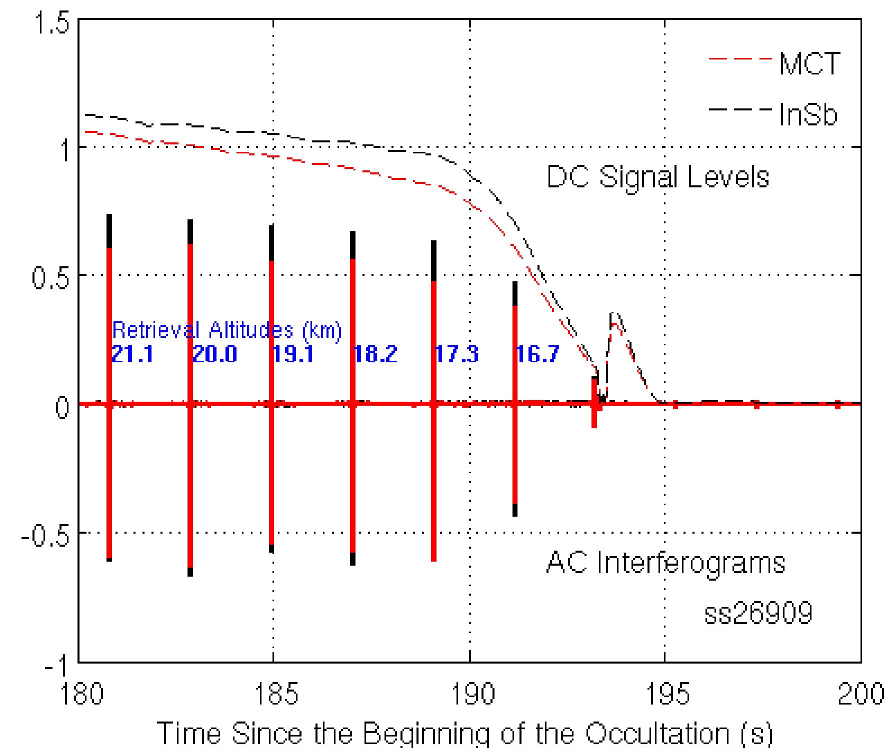


Gretchen Keppel-Aleks, Geoffrey C. Toon, Paul O. Wennberg, and Nicholas M. Deutscher, "Reducing the impact of source brightness fluctuations on spectra obtained by Fourier-transform spectrometry," Appl. Opt. 46, 4774-4779 (2007)

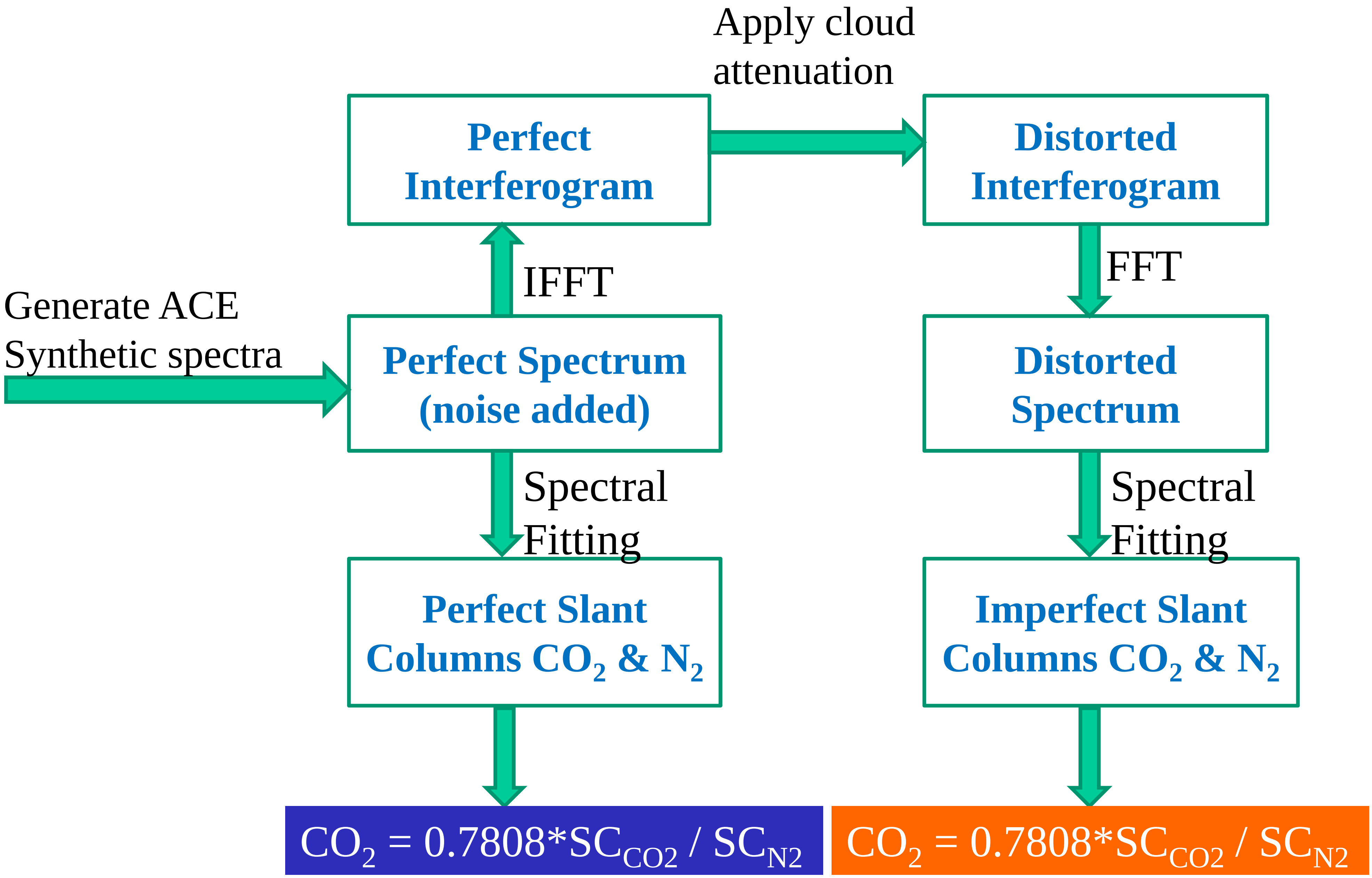
- Examples of ACE-FTS occultations
  - Suntracker glitches
  - Solar intensity variations
- By applying corrections
  - Additional interferograms should be suitable for VMR retrievals
  - The interferograms already used should have a higher quality





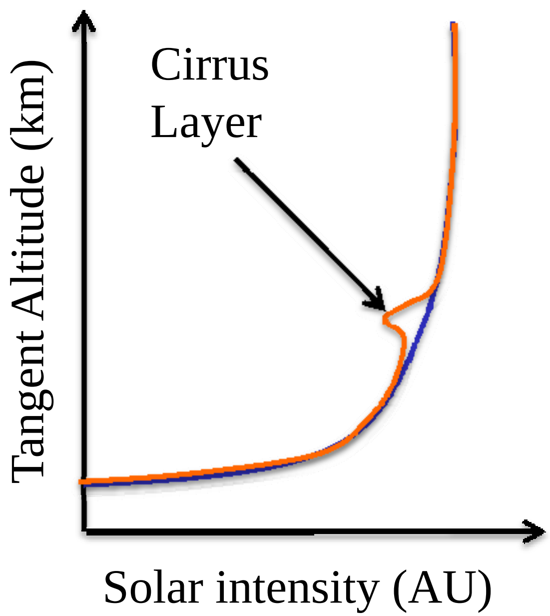


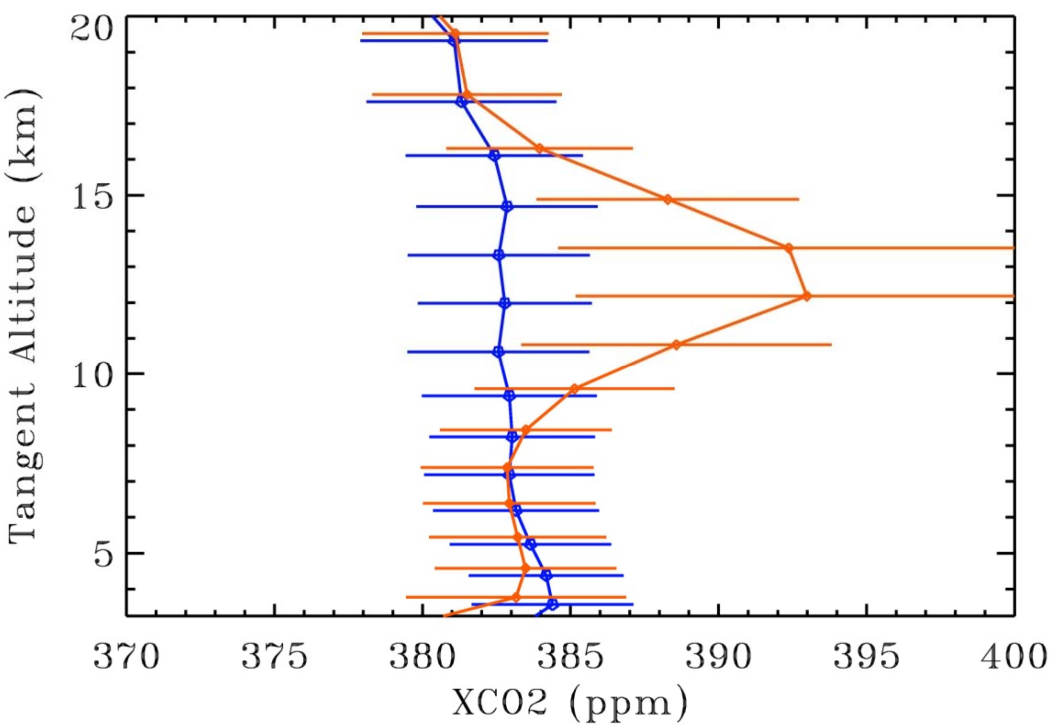
Simulation of cloud attenuation on CO_2/N_2



Simulated CO_2 Retrieval

- Retrieving CO_2 requires we retrieve tangent altitudes with N_2
- The N_2 CIA feature is broad (defined by the ZPD region of the interferogram)
- The CO_2 features are narrow (come from entire interferogram)
- Solar intensity variations during an occultation will affect CO_2 and N_2 differently





Blue: True CO_2 profile (simulation + noise)
Orange: CO_2 retrieved when high cirrus clouds between 13-14 km

Conclusions

Troposphere is becoming more important scientifically

There exists the potential to improve ACE tropospheric profiles:

- Extend profiles up to ~3 km deeper on average (based on SAGE II)
- Improved accuracy higher in troposphere (in the presence of thin clouds)

Benefits include:

- Better information on tropospheric pollution
- Extend profiles of GHGs (e.g. CO_2) closer to their surface source/sinks
- Improved validation of nadir sounders (e.g. AIRS, TES, SCIA, GOSAT) whose averaging kernels peak in the middle or lower troposphere.

Will require considerable work to achieve this:

- Correction of interferograms for solar intensity variations
    - Keppel-Aleks et al. approach with an ACE-tailored algorithm
- Repair of interferograms damaged by suntracker glitches
- Requires revisiting L0-L1 data processing
- Properly account for the finite FOV of ACE