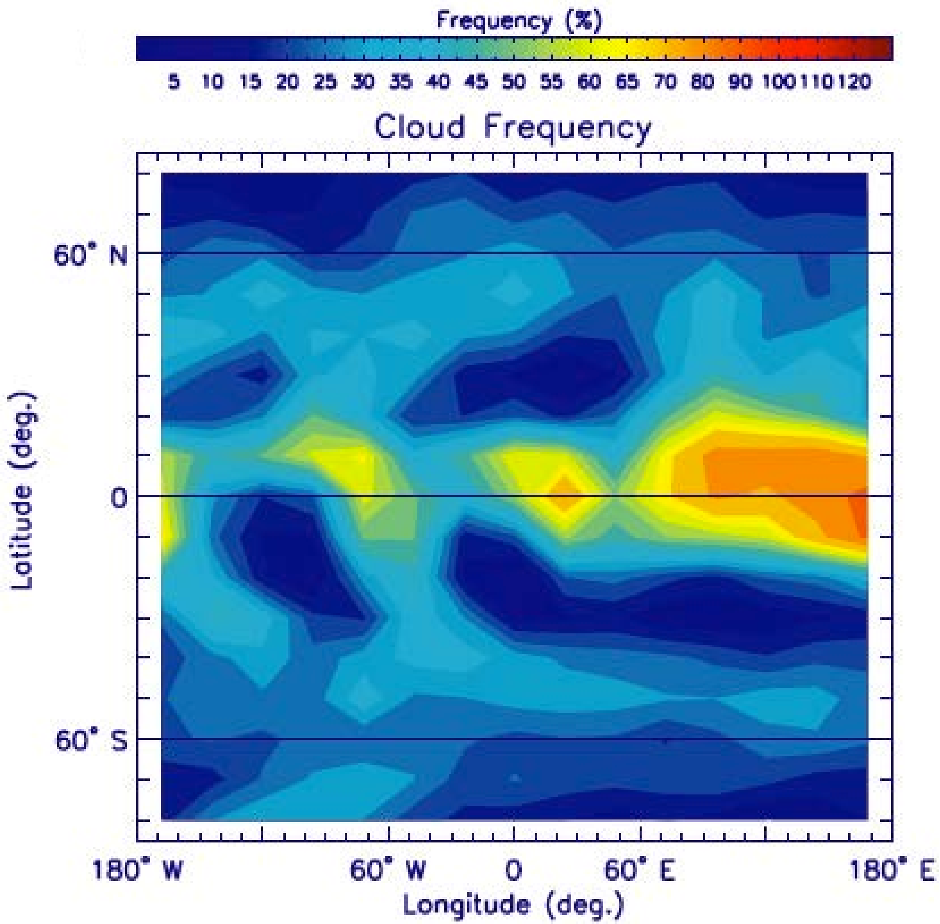
A New Limb RT Model for the Investigation of TTL Cirrus Cloud Properties

Vijay Natraj (JPL/Caltech)
Rob Spurr (RT Solutions, Inc.)
Jochen Stutz, Fedele Colosimo (UCLA)

March 4, 2016
Yuk Lunch Seminar

Cirrus Clouds are Everywhere!



Nazaryan et al., 2008

Why Study Cirrus Clouds?

- Cover large part of the Earth
- Reflect solar radiation (albedo effect)
- Trap thermal radiation (greenhouse effect)
- Balance between these effects determines sign of forcing
- Regulate strat-trop exchange
- Impact chemical composition of atmosphere by facilitating multiphase chemistry

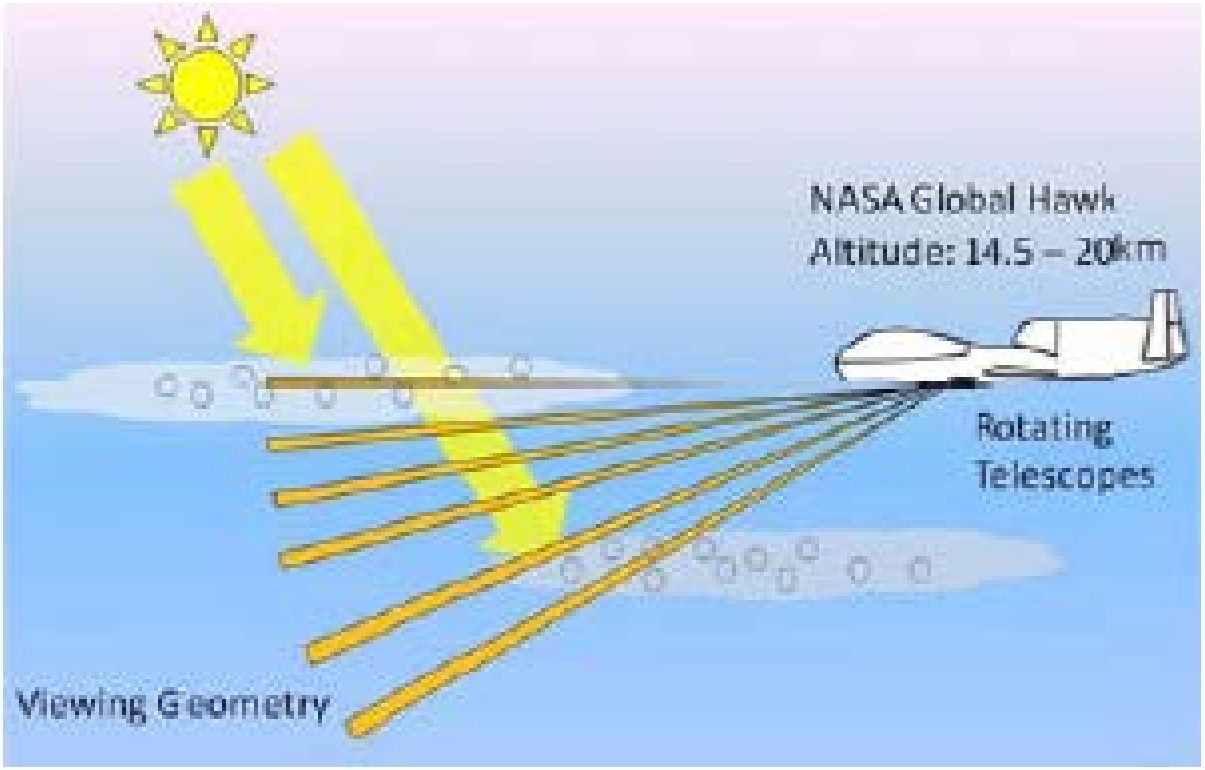
Motivation for this Work

- In order to quantify radiative effects of cirrus, we need:
  - ✓ Microphysical properties (ice crystal size distribution and shape)
  - ✓ Structural properties (height and spatial extent)
  - ✓ Optical properties (optical thickness)
- Optically thin cirrus clouds have weak signature in space-based measurements
- Airborne experiments sparse because of location of cirrus clouds
- Understanding of cirrus clouds, especially optically thin ones, remains weak
- Need to develop methods to better understand cirrus properties

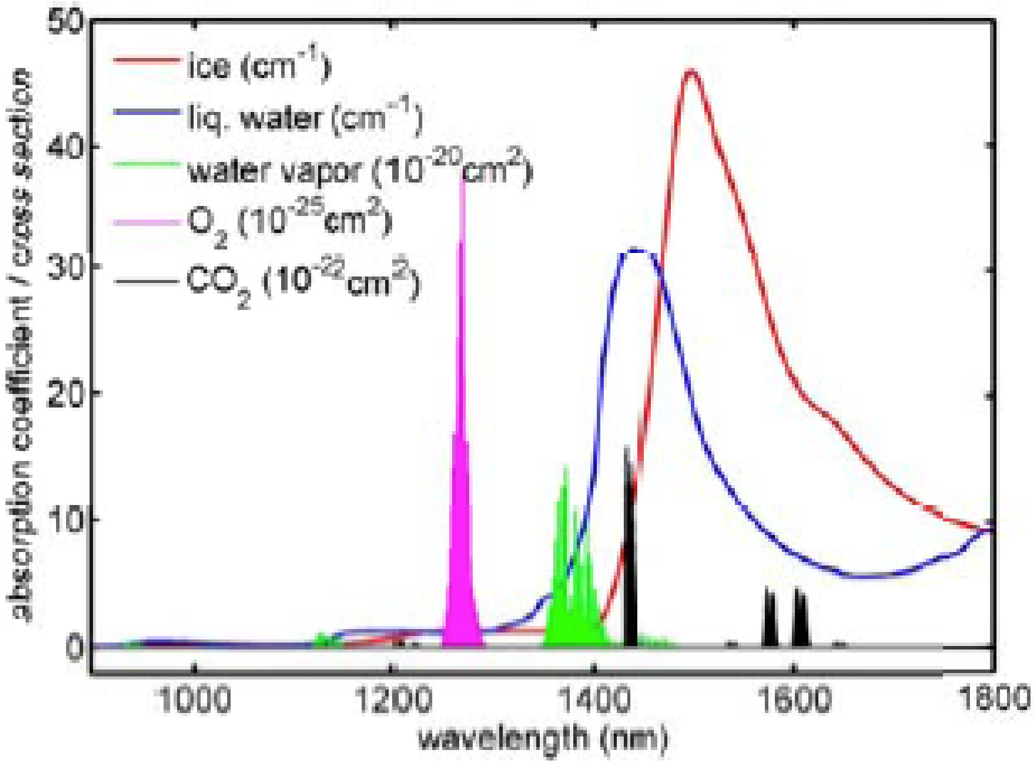
Proposal

- Use limb-scanning near-IR measurements onboard Global Hawk during ATTREX project
- Similar physical principles as satellite observations (observation of ice absorption signature in scattered/reflected sunlight)
- Limb geometry significantly increases sampling distance
- For very thin cirrus, path enhancement close to geometric (vertical extent of cirrus clouds vs. view along cirrus cloud for hundreds of kilometers)
- Enhanced sensitivity will yield new insights into structure and properties of cirrus clouds and also allow comparisons with satellite observations of the thinnest clouds

Mini-DOAS Limb Scanning Strategy



Ice Absorption



FOMS-LIMB RT Model

- **Based on the widely used VLIDORT model**
- **Assumes a spherical shell atmosphere, with a series of optically uniform layers extending from surface to TOA, and no horizontal dependency**

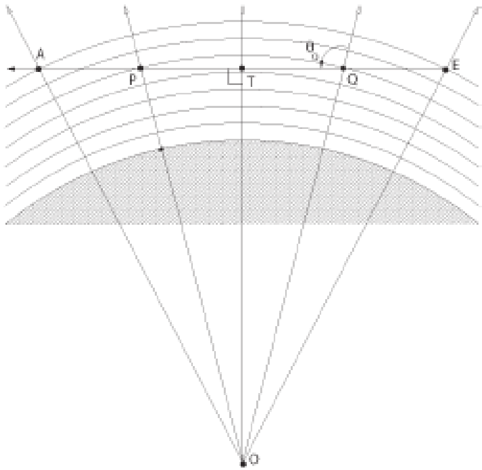
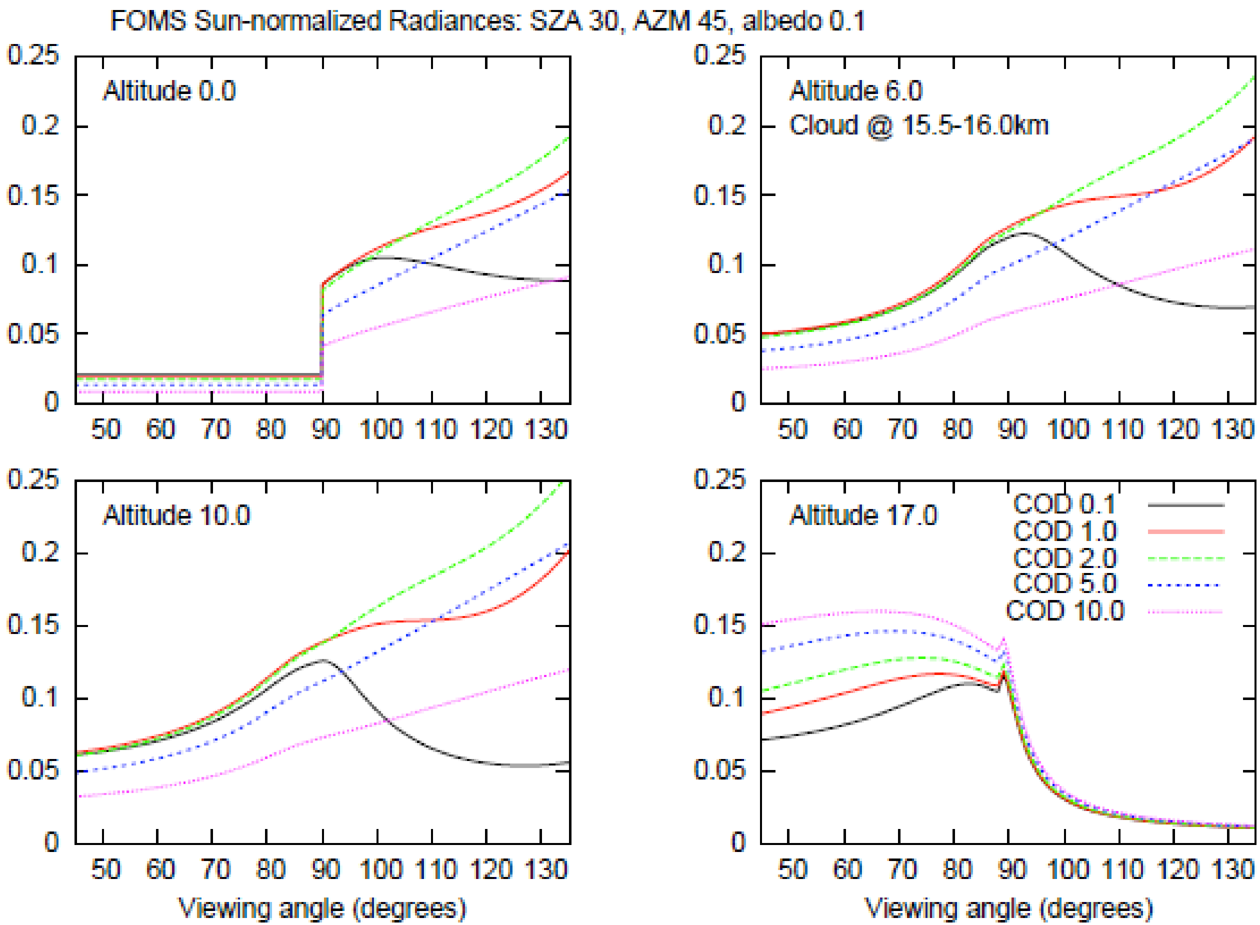


Figure 2. Illustration of the LS geometry. The radiation travels along the LS LOS from the TOA at point E downward to the tangent point T, then upward to the TOA at A. Zeniths originate at the center of the spherical Earth O and radiate outward through the atmosphere (from Fig. 9 of Loughman et al., 2004).

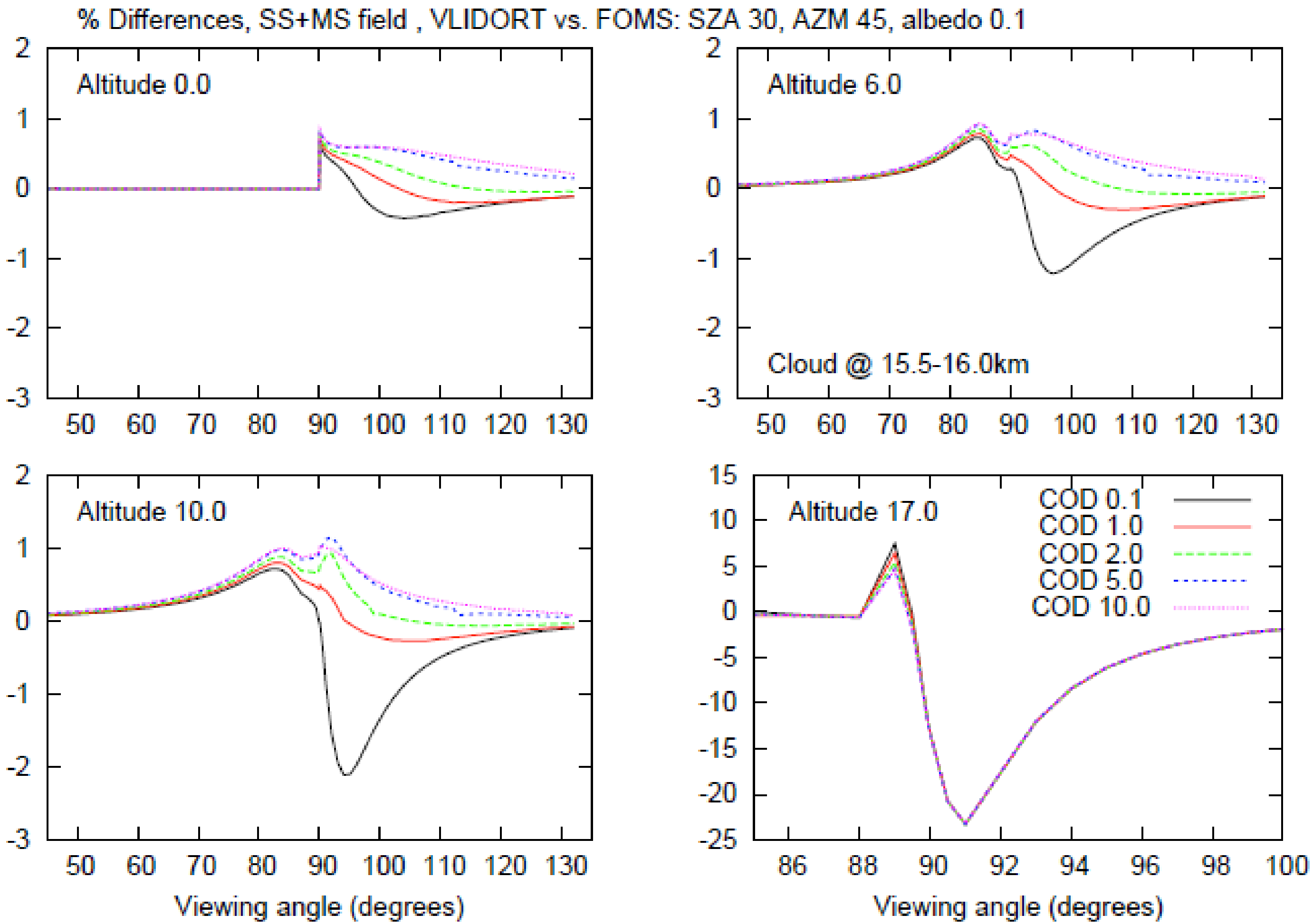
FOMS-LIMB RT Model

- For single scatter field, RTE solved accurately for a spherical atmosphere
- For multiple scatter field, quadrature solutions to RTE computed in plane-parallel framework, but post-processing (source function integration) done in full spherical geometry
- Source function integration proceeds by solving RTE in each segment of path for which the optical properties are unchanged.

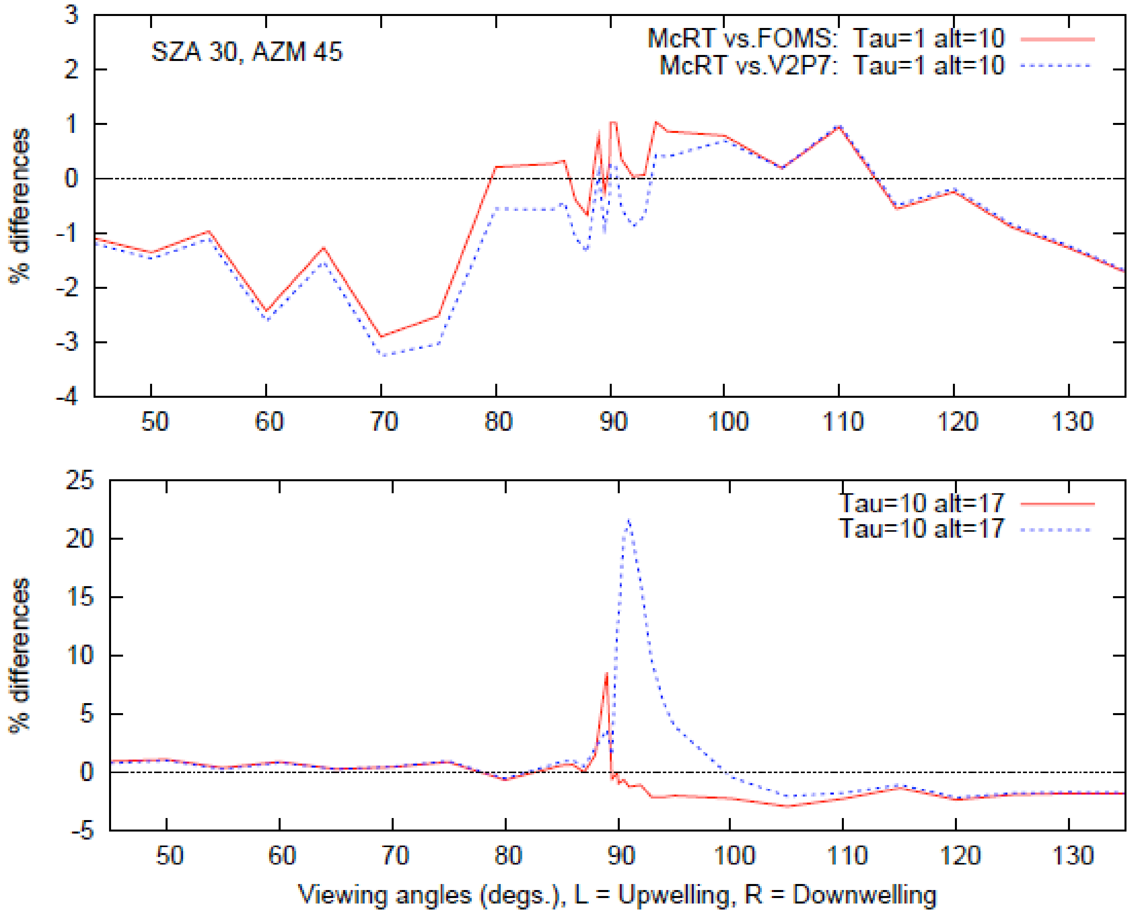
Radiance Variation with Viewing Angle



FOMS-LIMB Comparisons with VLIDORT



FOMS-LIMB Comparisons with McArtim



Ongoing/Next Steps

- **Validate against Monte Carlo models**
- **Use FOMS-LIMB in an optimal estimation framework to retrieve the physical and optical properties of cirrus clouds**
- **Validate retrievals using ATTREX in-situ data**
- **Use the cirrus cloud properties to get a better estimate of shortwave and longwave forcing due to thin and subvisible cirrus clouds**
- **Apply the knowledge gained on the physical properties of cirrus clouds to study the impact of ice surfaces on BrO and NO_2 chemistry in the TTL**