An Empirical Angular Distribution Model for the Calculation of Top-of-Atmosphere Radiative Fluxes in the Presence of Biomass Burning Aerosols

Preliminary Ph.D. Research Proposal

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Background

- The impact of global biomass burning on the Earth's climate is relatively uncertain.
- Biomass burning causes direct and indirect impacts on climate that yield a net radiative cooling, but the magnitude and impact varies widely.

  Direct: Increased SW reflectance

  Indirect: Aerosol / cloud interaction precipitates cloud formation and persistence
- The magnitude of the cooling associated with direct and indirect anthropogenic aerosols may offset the magnitude of global warming due to the presence of CO_2 (Houghton, et.al. 1990)
- The uncertainty in aerosol radiative forcing is considered to be one of the largest uncertainties in modeling climate change (Hansen, et.al. 1990; IPCC, 1995).

Current Research

- Few studies address the radiative forcing effect of biomass burning aerosols at the TOA.
- Sundar Christopher notes "*a concerted effort is needed to develop ADM's for aerosols that reduce uncertainties in direct radiative forcing estimates*", 1998.
- Radiative fluxes are currently calculated using ERBE-like ADM's to account for radiative anisotropy. (Smith, et.al., 1986).
- In most cases biomass burning aerosols are misclassified as partly cloudy or mostly cloudy, thereby resulting in errors in TOA fluxes. LW flux errors are small, but SW flux errors are near 14% (Dieckman, et.al., 1989).
- Since instantaneous radiance uncertainties are 1% for LW and 2-3% for SW observations (Barkstrom, et.al., 1989), ADM's account for a large portion of the uncertainty.

Research Objectives

Research Goal:

Improve the measurement accuracy of Earth reflected and emitted radiation in the presence of biomass burning aerosols.

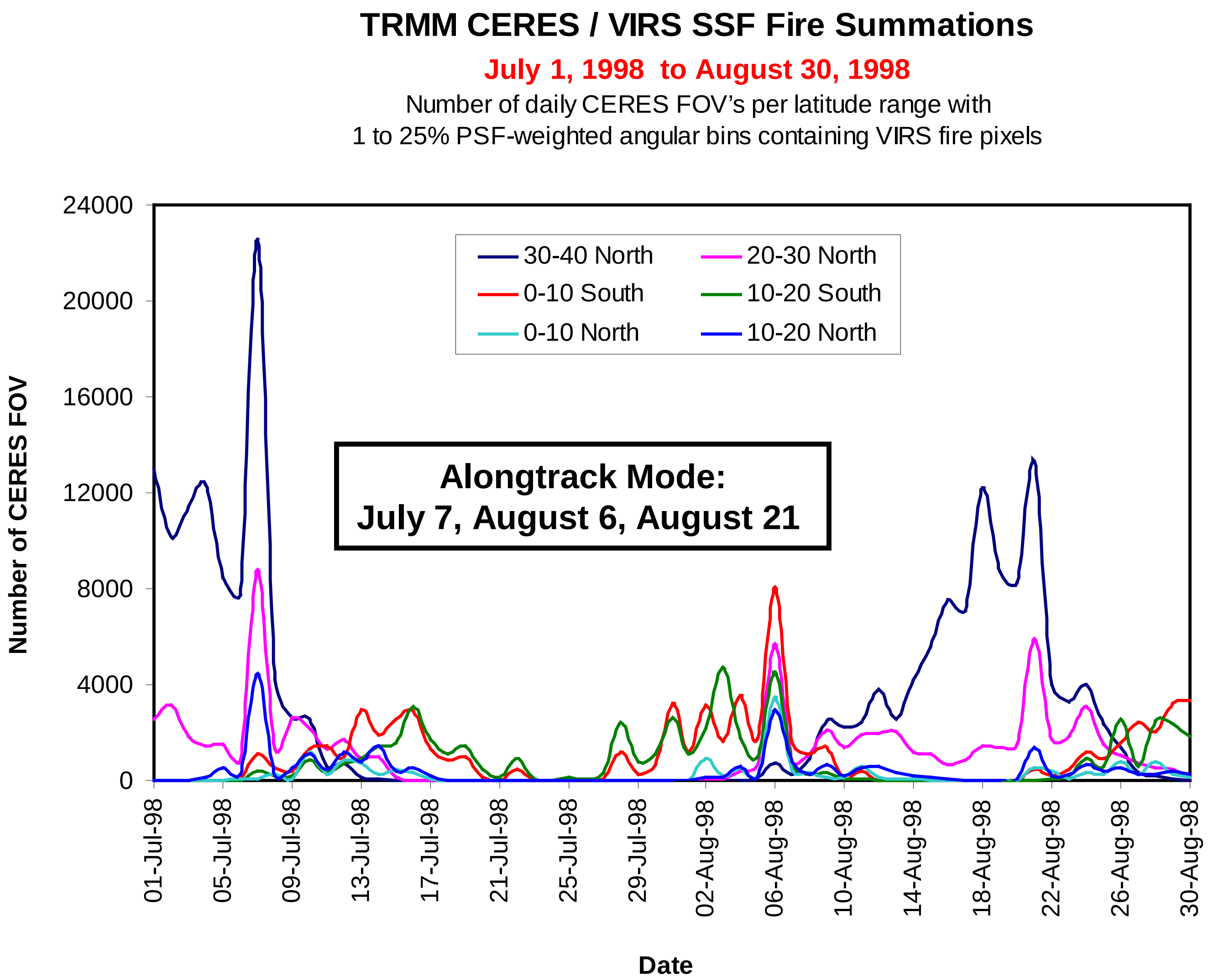
Primary Research Tasks:

- Fire Scene Identification
- Radiative Transfer Parametric Studies
- Empirical Angular Distribution Model Development
- Regional Net Radiative Forcing

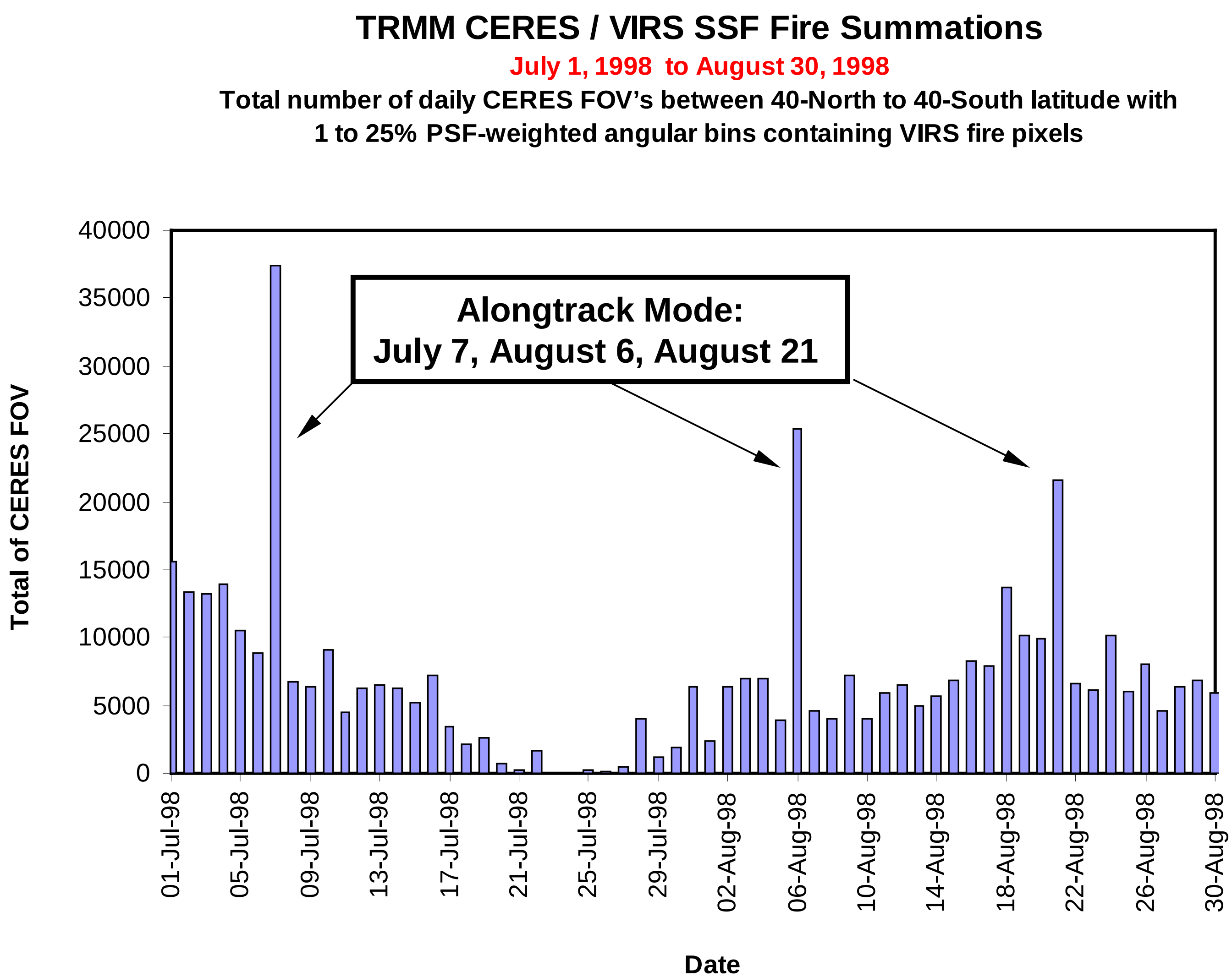
Fire Scene Identification

- Use TRMM SSF data to identify CERES and VIRS collocated footprints with smoke aerosols.
- Develop a statistical database of TRMM data to summarize fires, smoke, and mixed scenes of cloud and smoke over the 8-month operation period (January through August 1998).
- Perform literature and internet search to positively identify fires for correlation with TRMM data.
  - Levine, Minnis, Christopher, Trepte, EOS Fire webpage
  - Africa, South America, Central America, China, Indonesia, China, Boreal Forests
- Identify potential ground measurements (AERONET, etc.) for smoke property correlation.
- Develop FORTRAN model to sample TRMM data for critical radiative parameters in the presence of smoke aerosols.

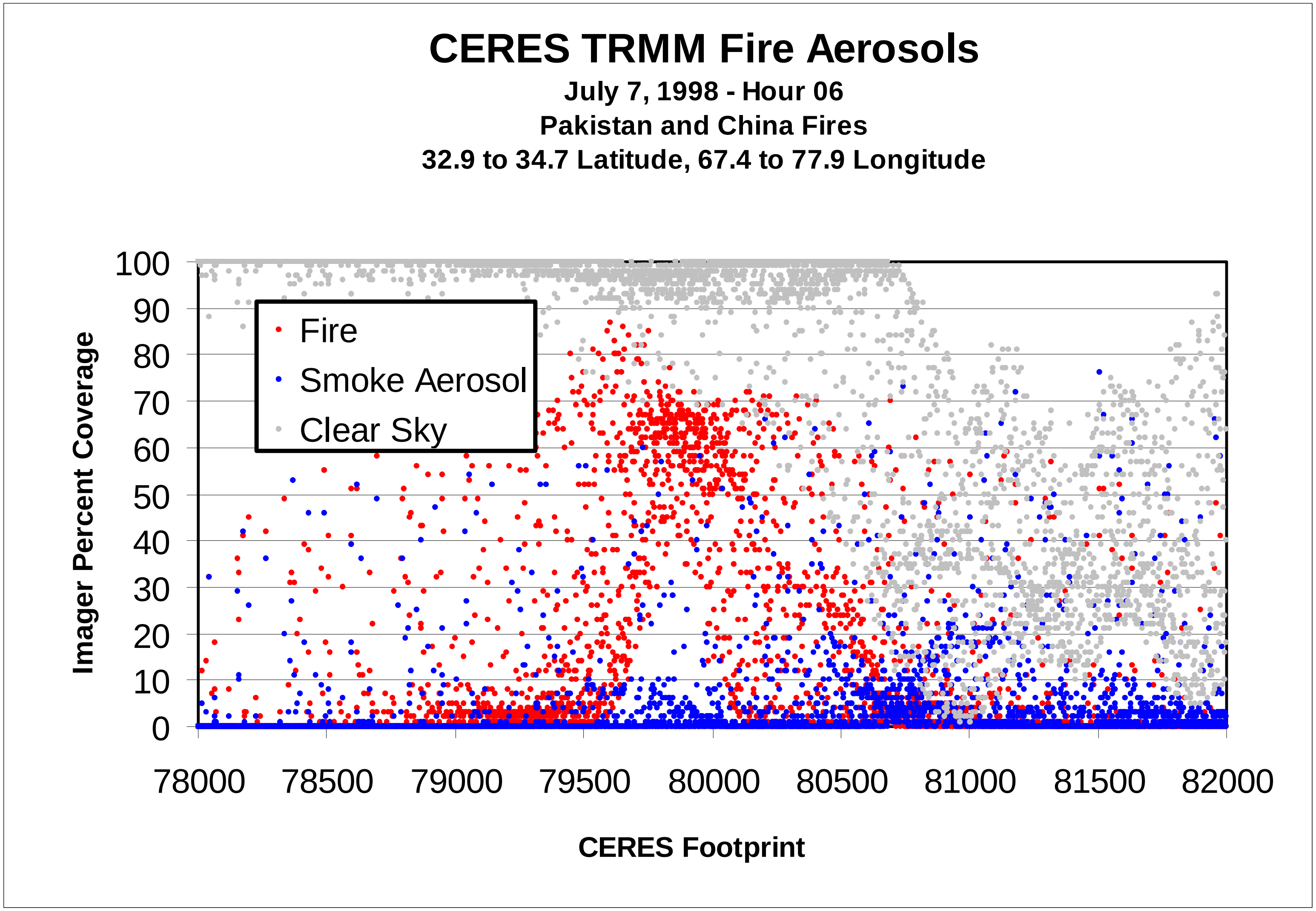
Example TRMM Fire Statistics



Example TRMM Fire Statistics



Example TRMM Fire Scene Data



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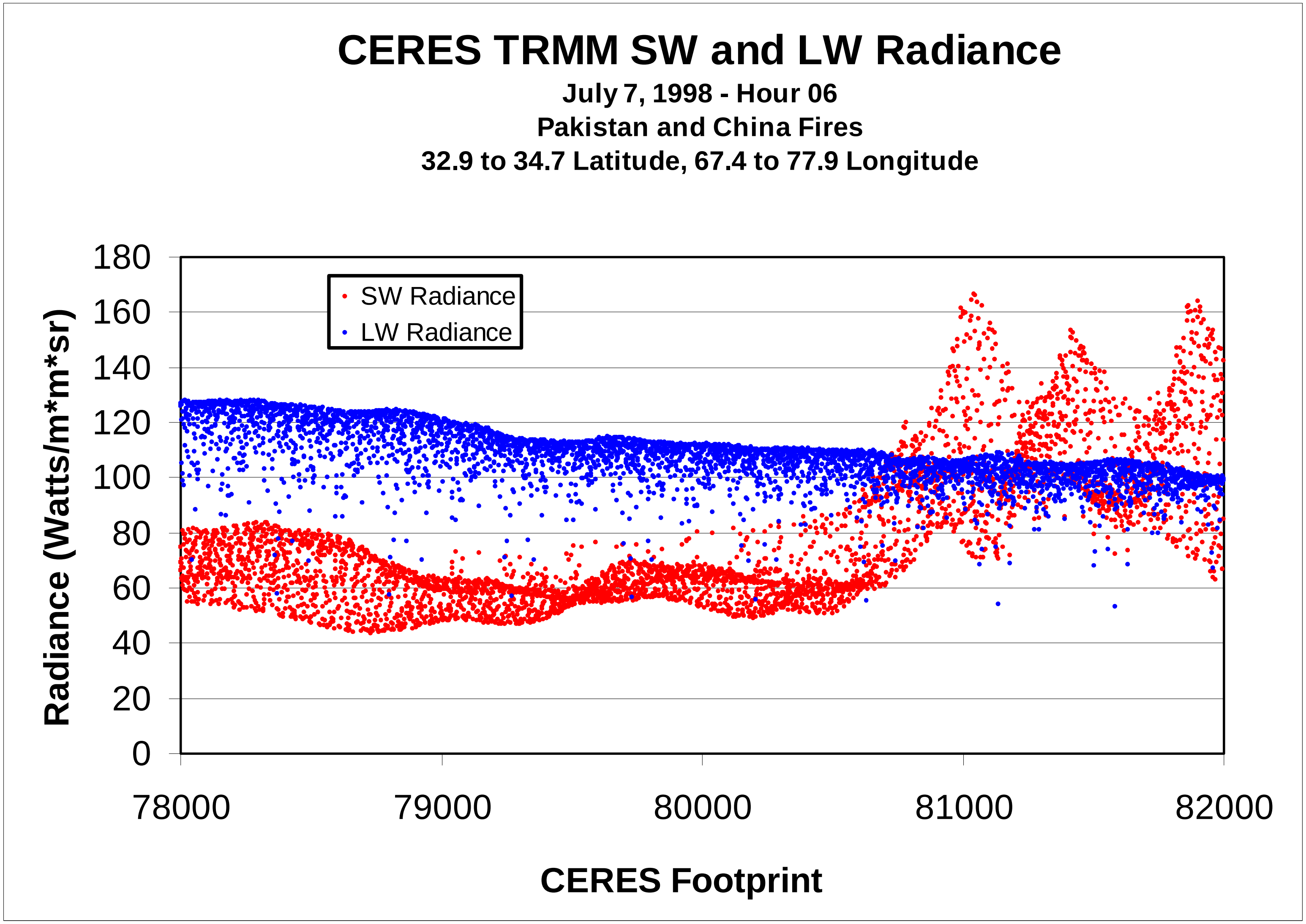

Radiative Transfer Parametric Studies

- Identify radiative transfer code to perform parametric studies. Currently considering Nakajima Radiative Transfer Code.
- Study SW radiative anisotropy by varying scene parameters such as: optical depth, % coverage of aerosols and cloud, single scattering albedo, humidification, etc.
- Compare modeled radiance with TRMM measured radiance for similar scenes to understand variability.
- Evaluate radiative anisotropy using TRMM data sets for smoke scenes.

Empirical Angular Distribution Model (ADM)

- Assess variability in existing ADM’s for radiance to flux conversion over scenes with smoke aerosols.
- Develop empirical ADM’s for various scene types including biomass burning aerosols.
  - Data may be limited due to orbital and solar viewing geometry.
  - Empty empirical angular bins will be filled with calculated radiance.
- Assess empirical ADM’s against existing ERBE ADM’s for variations and expected accuracy improvement.
- Compare empirical ADM’s with theoretical radiative transfer calculations to evaluate variations and to complete empty empirical angular bins.

Regional Net Radiative Forcing

- Utilize empirical ADM's to calculate regional net radiative forcing in the presence of biomass burning aerosols for various TRMM fire scenes.
- Compare regional net radiative forcing values with current literature. For example:

(1) Christopher (1996) estimated net radiative forcing values of -36.9 W/m^2 for dense smoke and –16.9 W/m^2 for optically thin smoke over South America in 1985.

(2) Christopher (1998) estimated average net forcing values of –25.6 W/m^2 to –33.9 W/m^2 over the Amazon in 1985.

Net Radiative Forcing Calculation

$$Net\ Forcing = SWF + LWF = S_o(\alpha_{clear} - \alpha_{smoke}) + (LW_{clear} - LW_{smoke})$$

Net radiative forcing … negative value reflects cooling over smoke scenes

Shortwave Radiative Forcing = SWF

Longwave Radiative Forcing = LWF

Incoming solar flux = S_o

Clear sky albedo = α_{clear}

Albedo in the presence of smoke = α_{smoke}

Clear-sky LW radiance = LW_{clear}

Radiance in the presence of smoke = LW_{smoke}

Conclusions

- Research is in preliminary stage with intentions to complete an approved proposal by 2001.
- Current plan is to work with Dr. Norman Loeb and Dr. Paul Stackhouse at NASA LaRC. Dr. Joel Levine (NASA LaRC) is the primary research advisor.
- Suggestions and criticism concerning the proposed research and approach are desired.
- Suggestions for alternative radiative transfer codes are also desired.