Development of Forward Cloud Optical Model in Support of GIFTS/IOMI MURI Project

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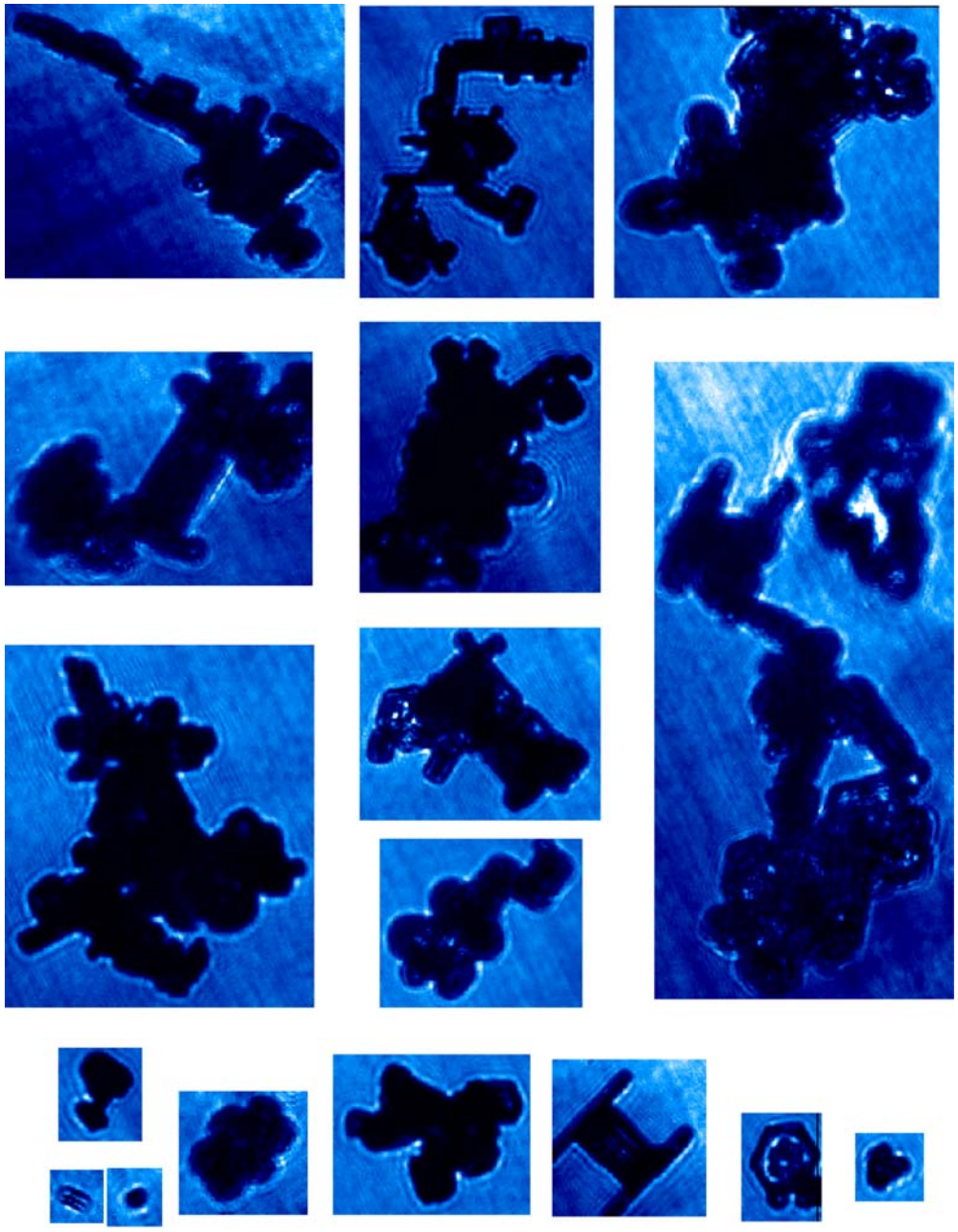
- Background
- Delivered Products
- Plan for Next Year

Objective

- Calculate cloud optical properties based on cloud microphysical data :
  - Ice/Liquid Water Content
  - Effective (mean) Particle Size
  - Cloud Thickness
- Sensitivity of infrared hyperspectral radiance to cloud properties (e.g., optical thickness and particle size)
- Explore a practical cloud retrieval algorithm



Kwajalein, Marshall Islands

August 22, 1999

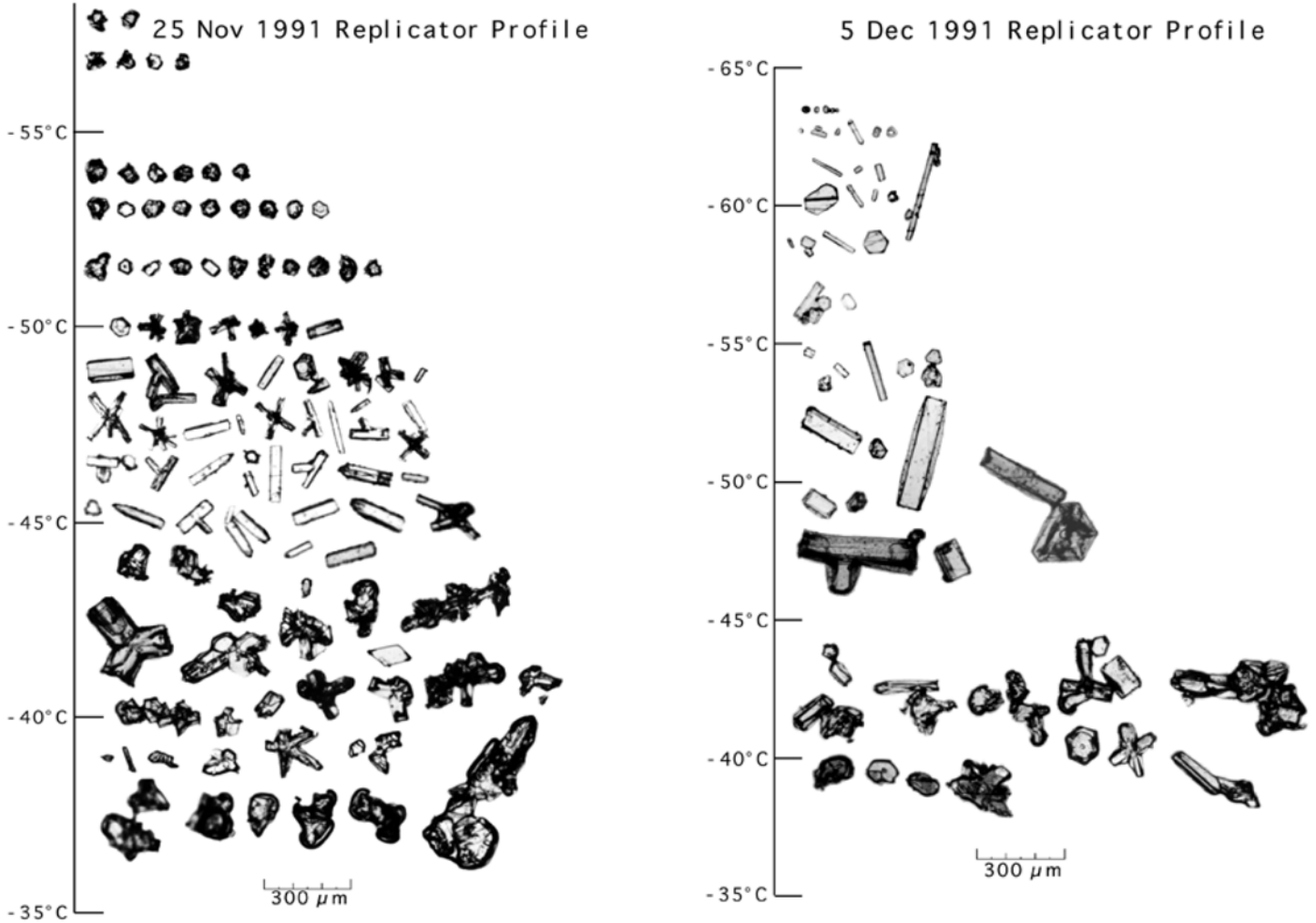
2122 - 2124 UTC

T = -46^{o}C to -48^{o}C

Data Courtesy of
Andrew Heymsfield, NCAR

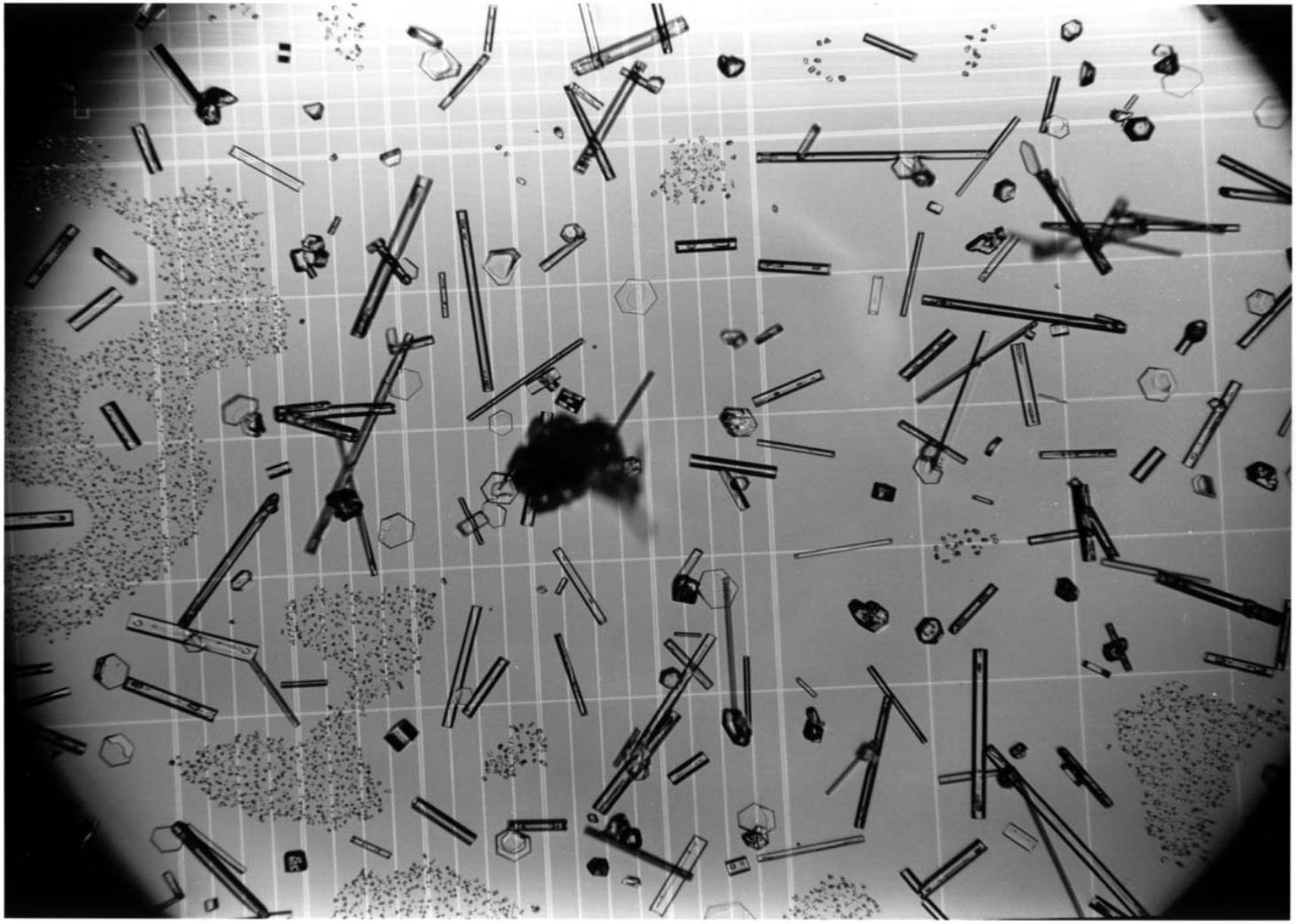
Replicator Ice Crystal Profiles for FIRE Cirrus II Campaign

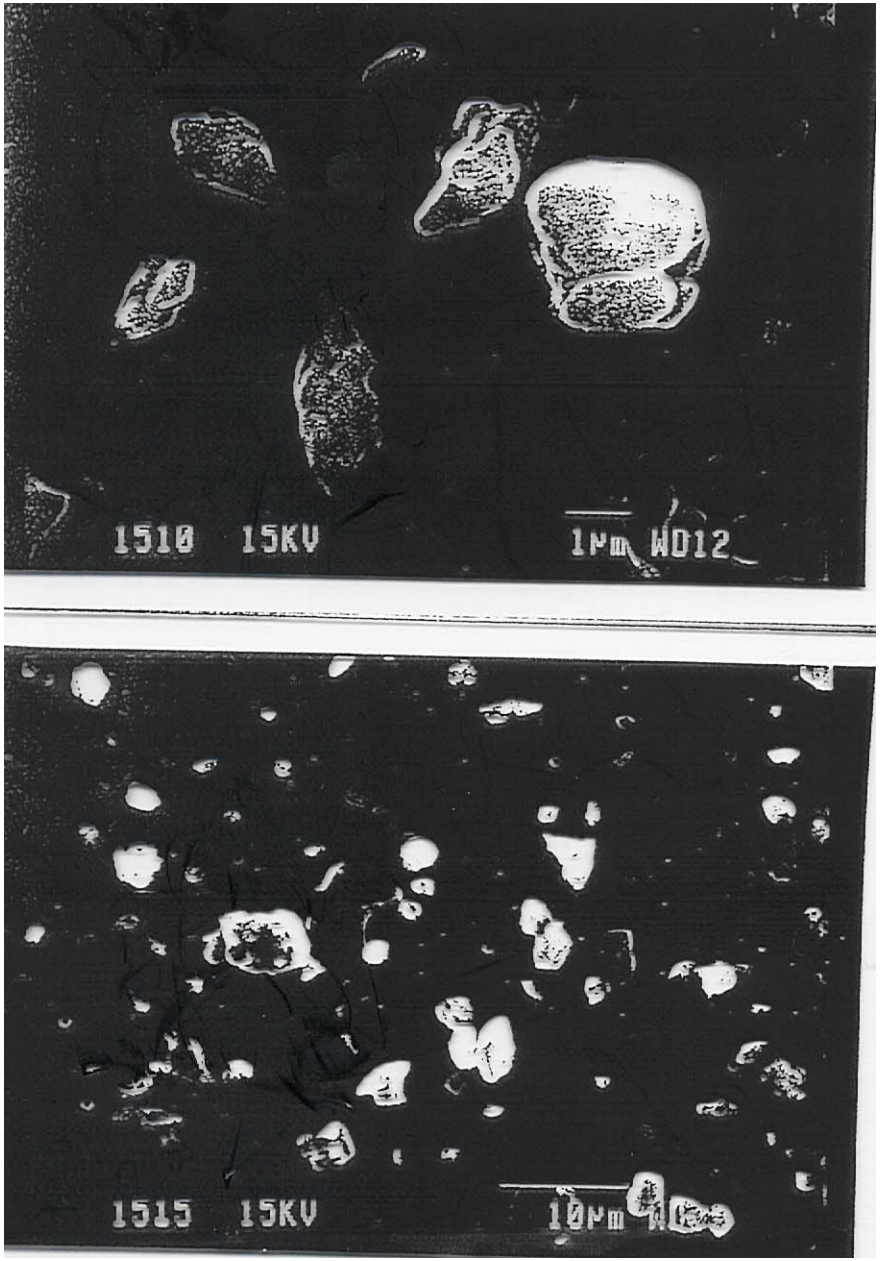
(Data courtesy of A. Heymsfield, L. Miloshevich, S. Aulenbach, NCAR)



Ice crystals observed over south pole

(Data courtesy of Pro. S. Warren, U. of Washington)





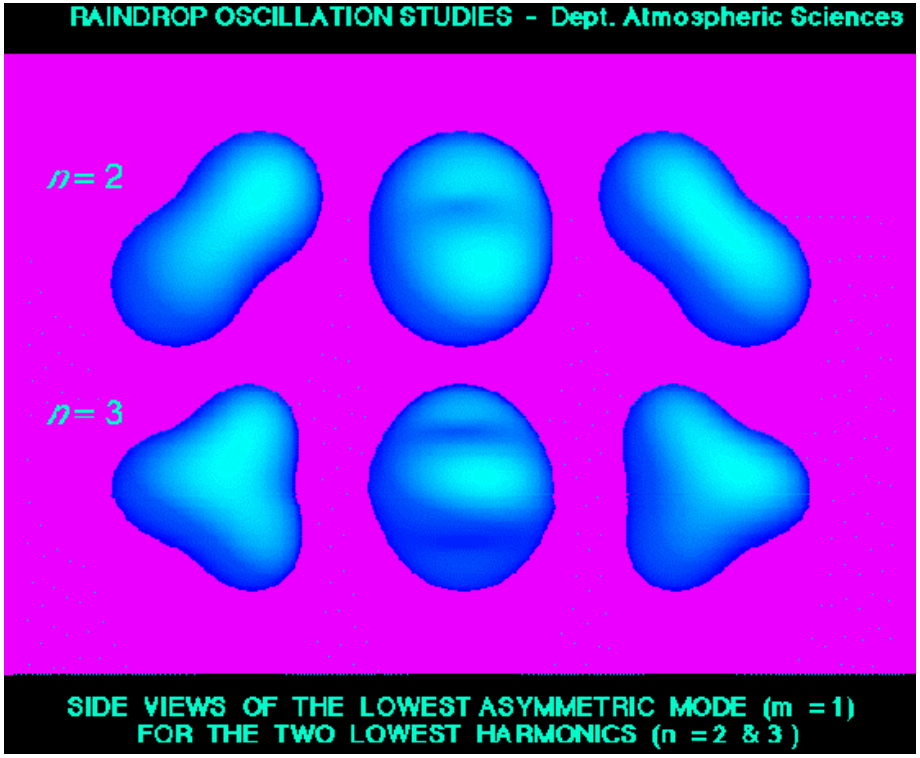
Microsized dust particles from Sahara desert

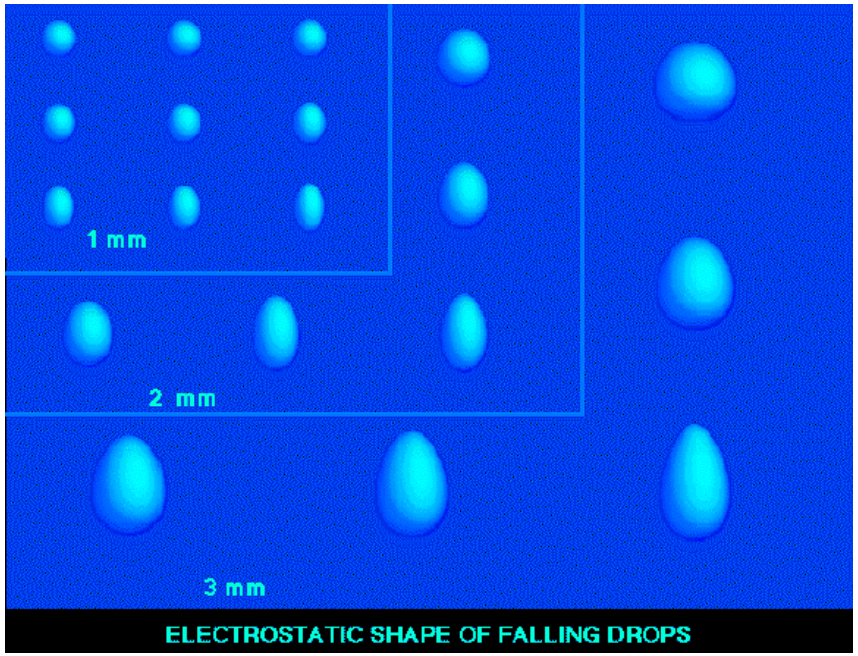
(Courtesy of Dr. Yoram Kaufman, NASA/GSFC)

Large rain drops

Data source:

Prof. Ken Beard, UIUC





Nonsphericity Effect

- Nonsphericity effect can affect the retrieval of ice clouds by a factor that exceeds 2.

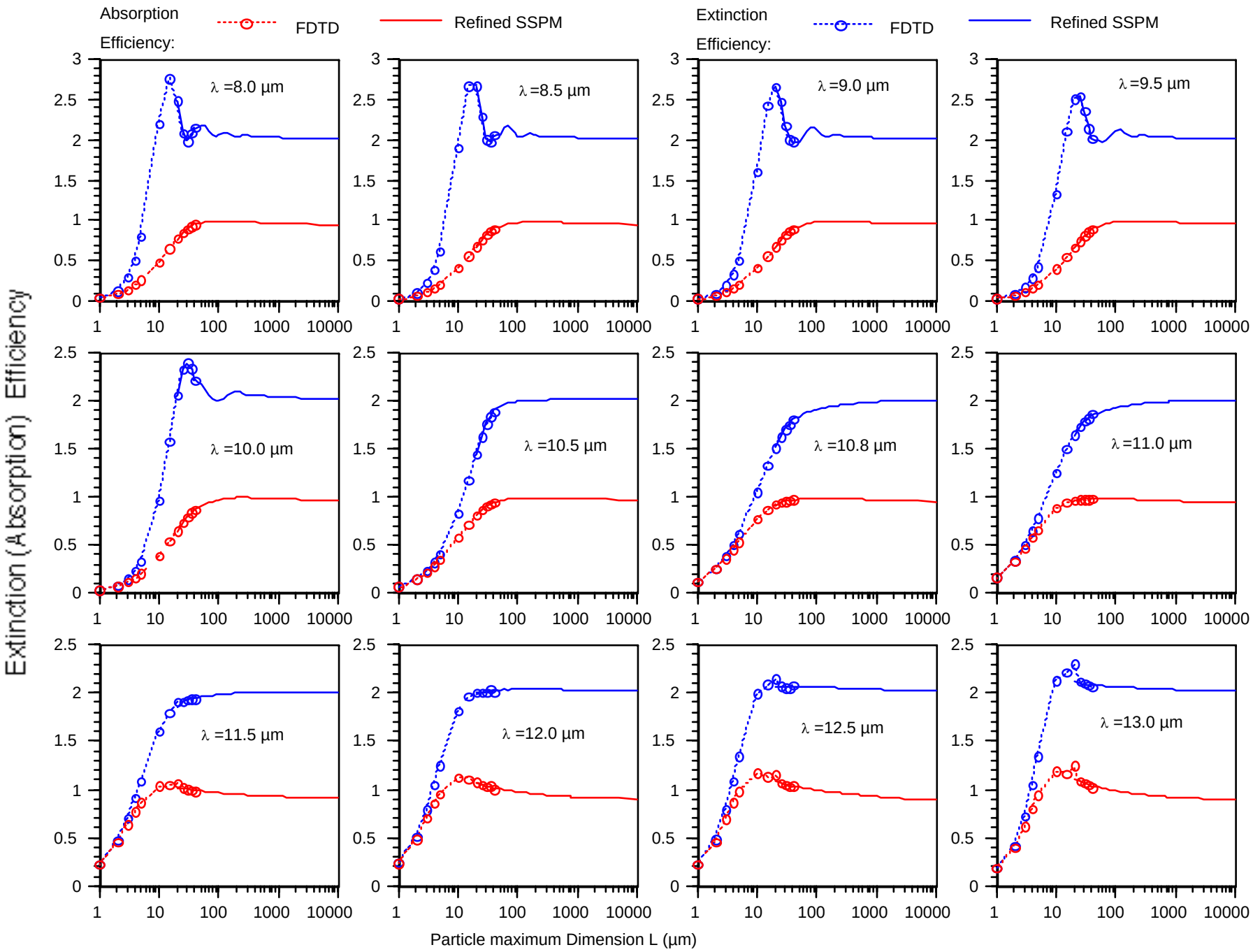
- Nonsphericity effect has also been found important for dust-like aerosols

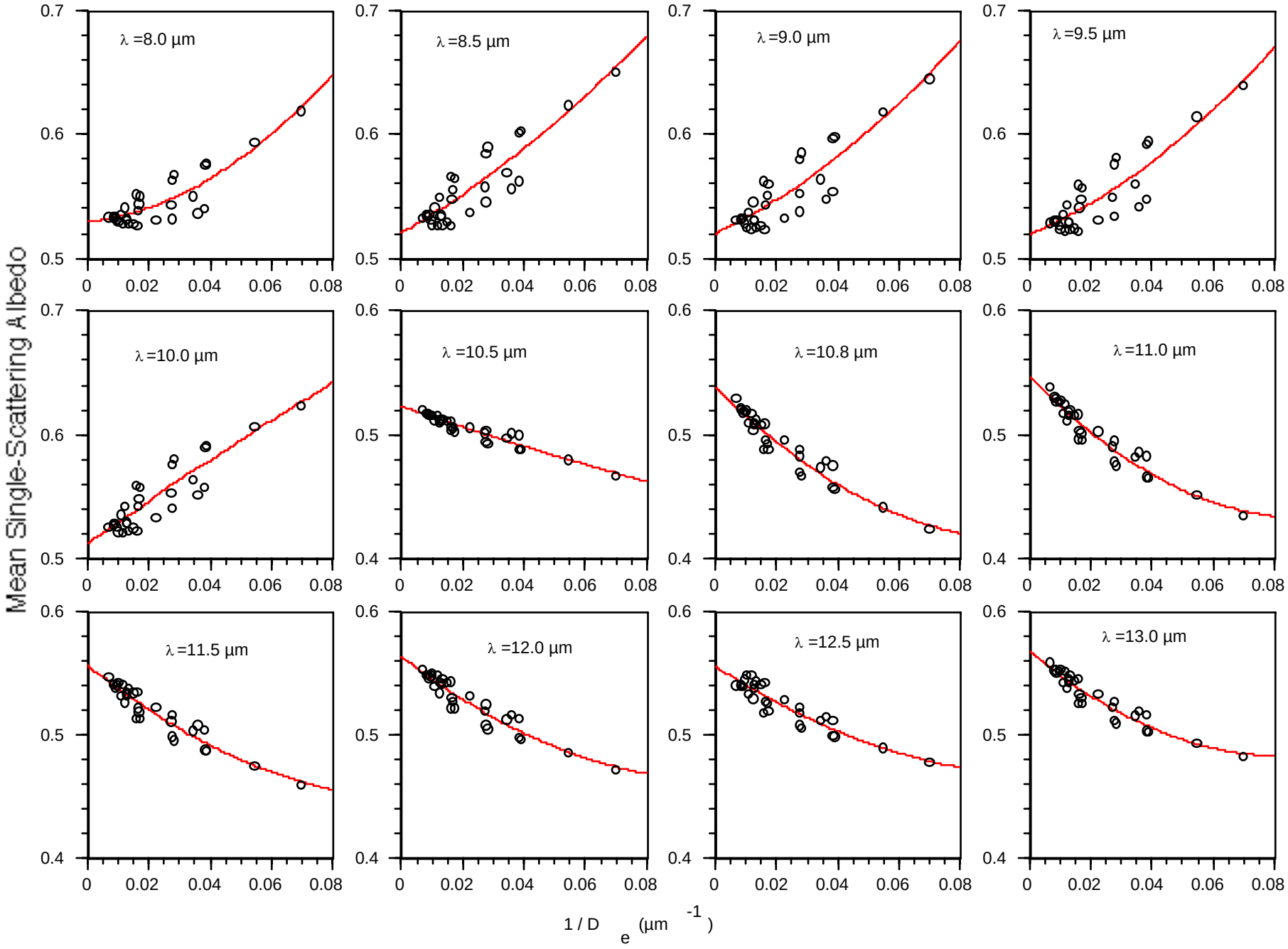
Slow Pace From Spheres to Nonspherical Particles

- Sphere (Mie 1908); Numerical Stable Schemes (1970s, 1980s)
- T-matrix method for axially symmetric particles (M.I.Mishchenko, 1992) limited to size parameters smaller than 200 numerically.
- Numerical Methods for Nonspherical Ice Crystals and Aerosols (Yang and Liou, 1996,1998,Yang et al. 1999,2000,2001)

Light Scattering Models

- Improved geometric optics method (applicable to visible and near-infrared wavelengths)
- Infrared computational package including the finite-difference time domain (FDTD) method, stretched scattering potential method (SSPM), and asymptotic method (applicable to infrared wavelengths)


Absorption Efficiency:
FDTD
Refined SSPM
Extinction Efficiency:
FDTD
Refined SSPM
λ =8.0 μm
λ =8.5 μm
λ =9.0 μm
λ =9.5 μm
λ =10.0 μm
λ =10.5 μm
λ =10.8 μm
λ =11.0 μm
λ =11.5 μm
λ =12.0 μm
λ =12.5 μm
λ =13.0 μm
Extinction (Absorption) Efficiency
Particle maximum Dimension L (μm)


Mean Single-Scattering Albedo
λ =8.0 μm
λ =8.5 μm
λ =9.0 μm
λ =9.5 μm
λ =10.0 μm
λ =10.5 μm
λ =10.8 μm
λ =11.0 μm
λ =11.5 μm
λ =12.0 μm
λ =12.5 μm
λ =13.0 μm
1 / D e (μm -1)

Optical properties of Water Clouds in spectral regions of 685-1130 and 1650-2250 cm^{-1}

(Delivery Date: 6/20/2001)

- Extensive computations based on the standard Mie code and Gamma size distribution were carried out for the bulk optical properties of liquid droplets with various effective (mean) sizes
- User-friendly interface between the database and applications.

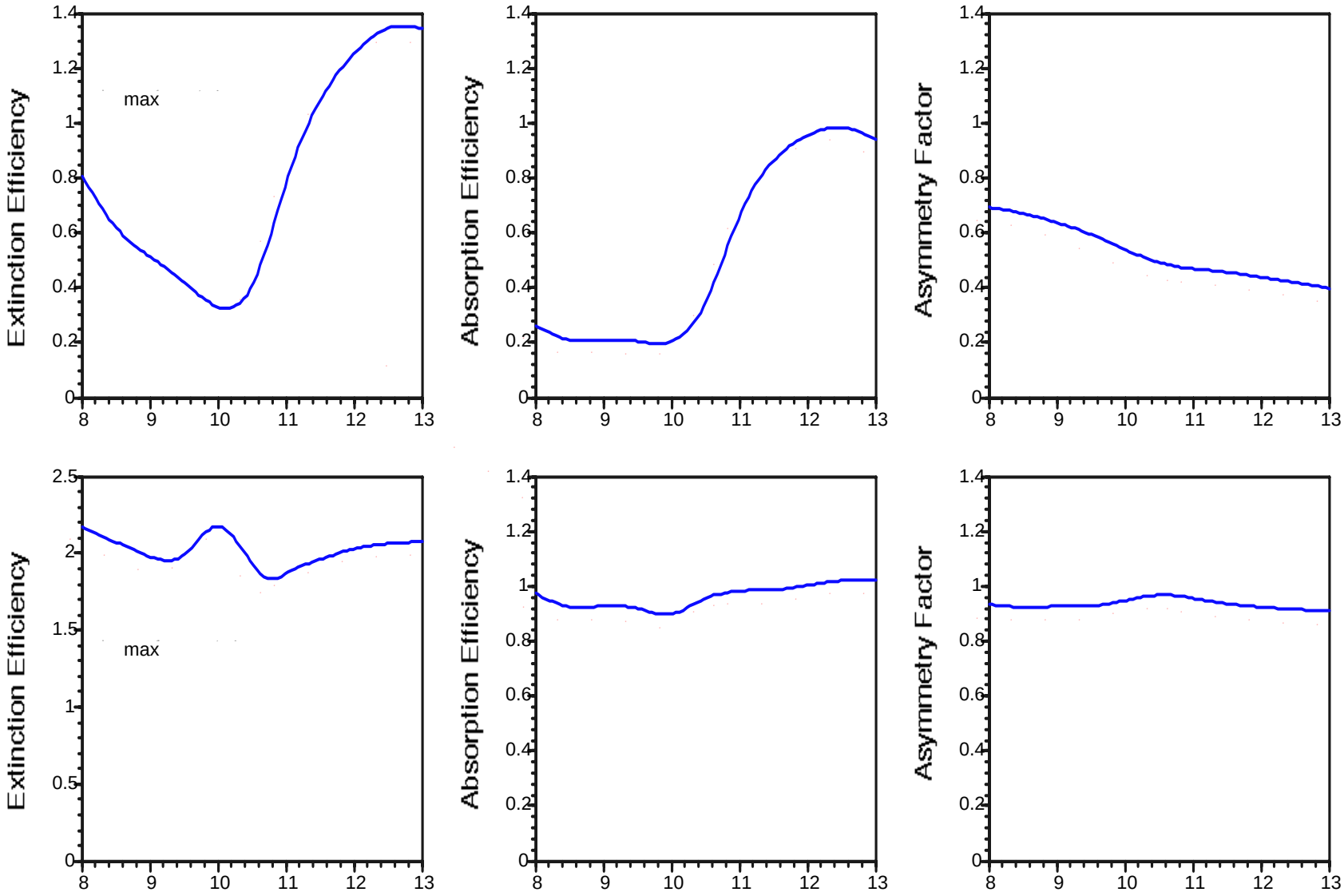
  FORTRAN code has been delivered, which allows a high-level user to obtain the cloud optical properties by supplying liquid water content (LWC), cloud physical thickness, and the mean size of cloud droplets.

Optical Properties of Ice clouds in Terrestrial Window (8-13 μm) region

(Delivery Date: 10/20/2001)

- Integration of various scattering computational models (e.g., FDTD, SSPM, IGOM) developed by Yang and his colleagues for light scattering computation in the infrared spectral region involved in GIFTS/IOMI MURI project

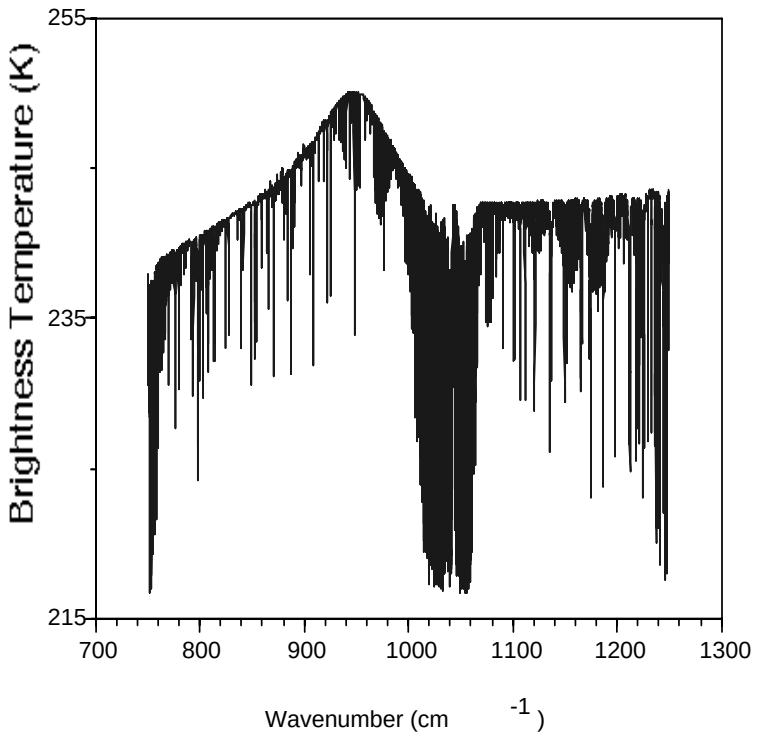
- Assume pristine ice crystal geometry (hexagonal columns)


Extinction Efficiency
max
Absorption Efficiency
Asymmetry Factor
Extinction Efficiency
max
Absorption Efficiency
Asymmetry Factor

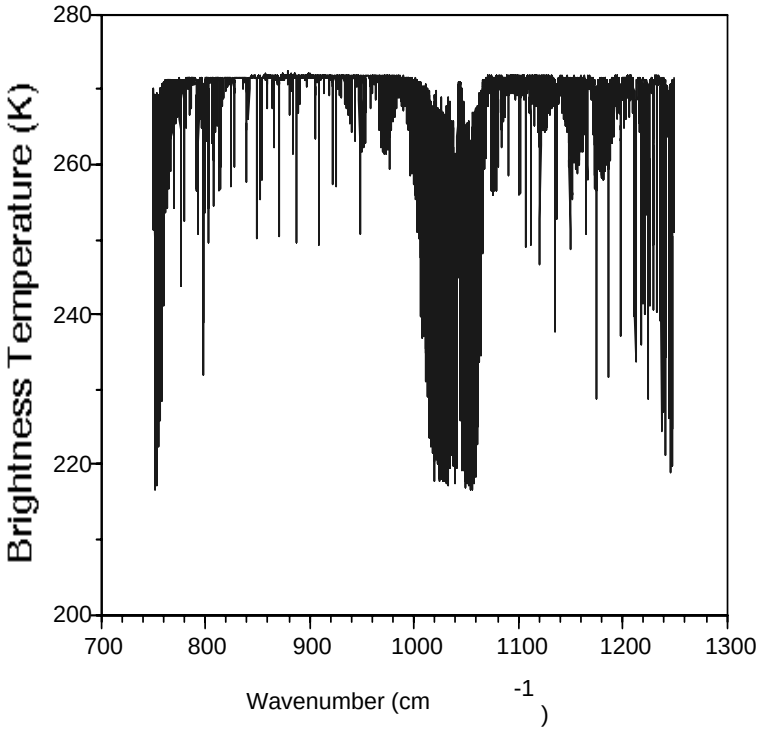
Optical Properties of Ice clouds in 1667-2500 cm^{-1} spectral region

(Delivery Date: 4/29/2002)

- Similar to the previous delivery
- A finer spectral resolution used in the light scattering calculation: 20 wavenumbers between 1667-2500 cm^{-1} were selected for scattering computation

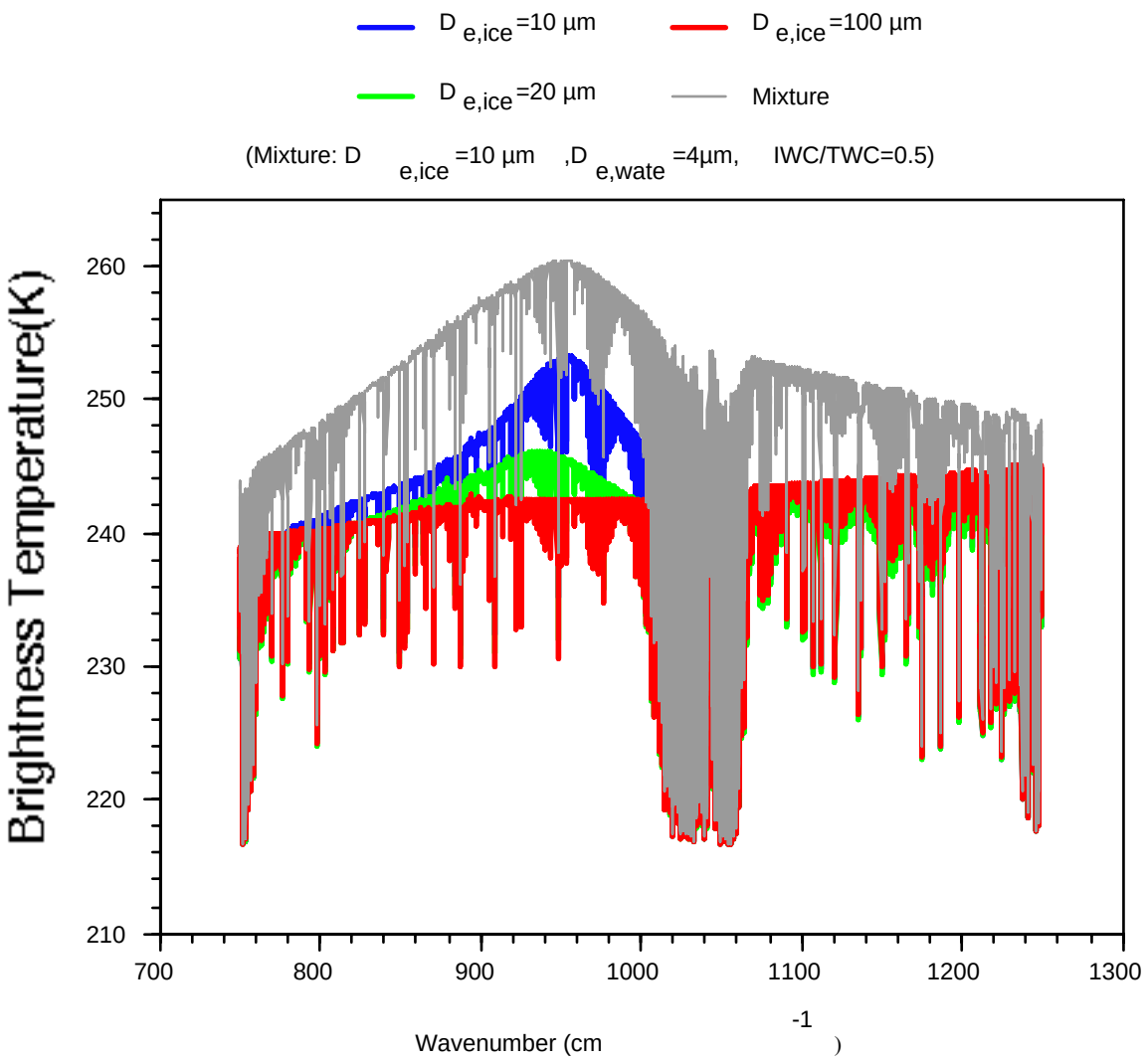

Brightness Temperature (K)
255
235
215
700
800
900
1000
1100
1200
1300
Wavenumber (cm -1)

e,ice


Brightness Temperature (K)
280
260
240
220
200
700
800
900
1000
1100
1200
1300
Wavenumber (cm -1)

e,water

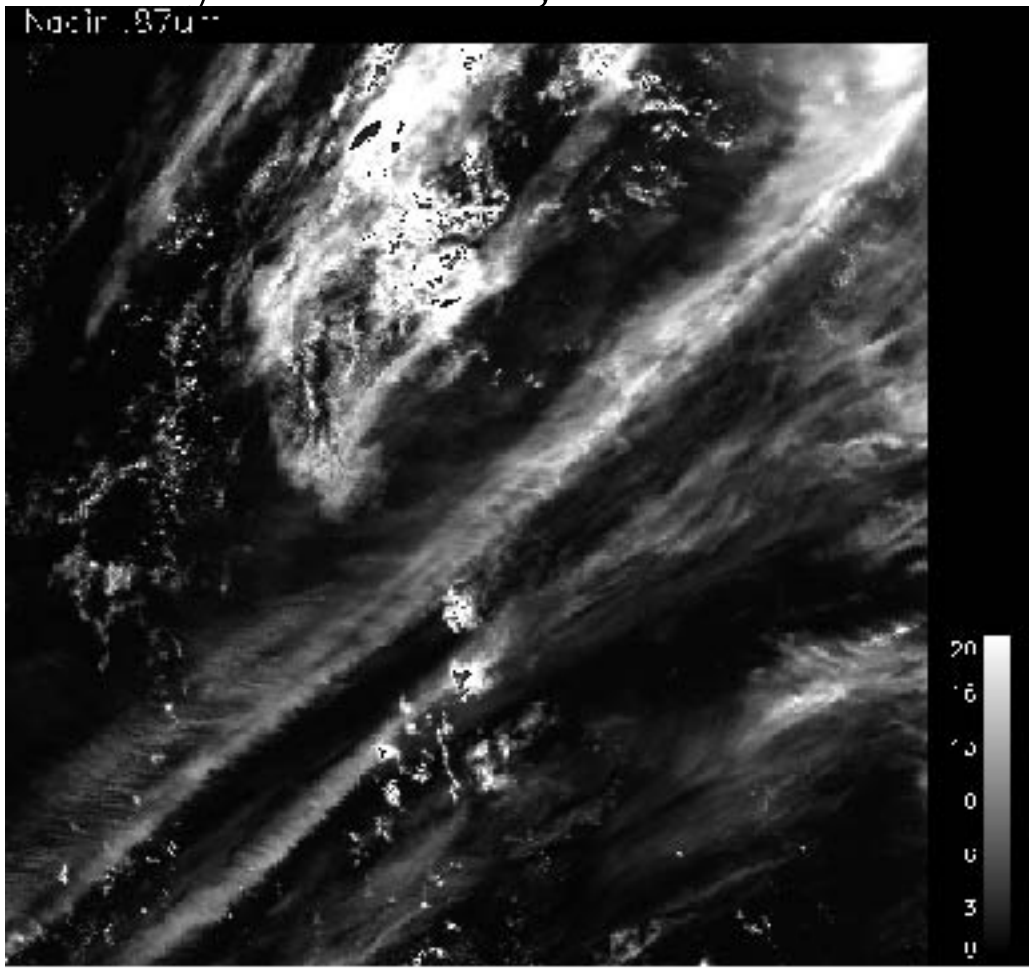
Sensitivity Study



Plan for Next Year

- Improve the optical model for cirrus clouds
- Aerosol scattering properties
- Continue the sensitivity study of infrared spectrum to cloud microphysical properties
- Explore cloud retrieval algorithm using IR window information

ATSR-2 Data at 0.65 μm
21 July, 1996; Latitude -32.5°; Longitude -95.9°
Courtesy of A. Baran, UK Met Office

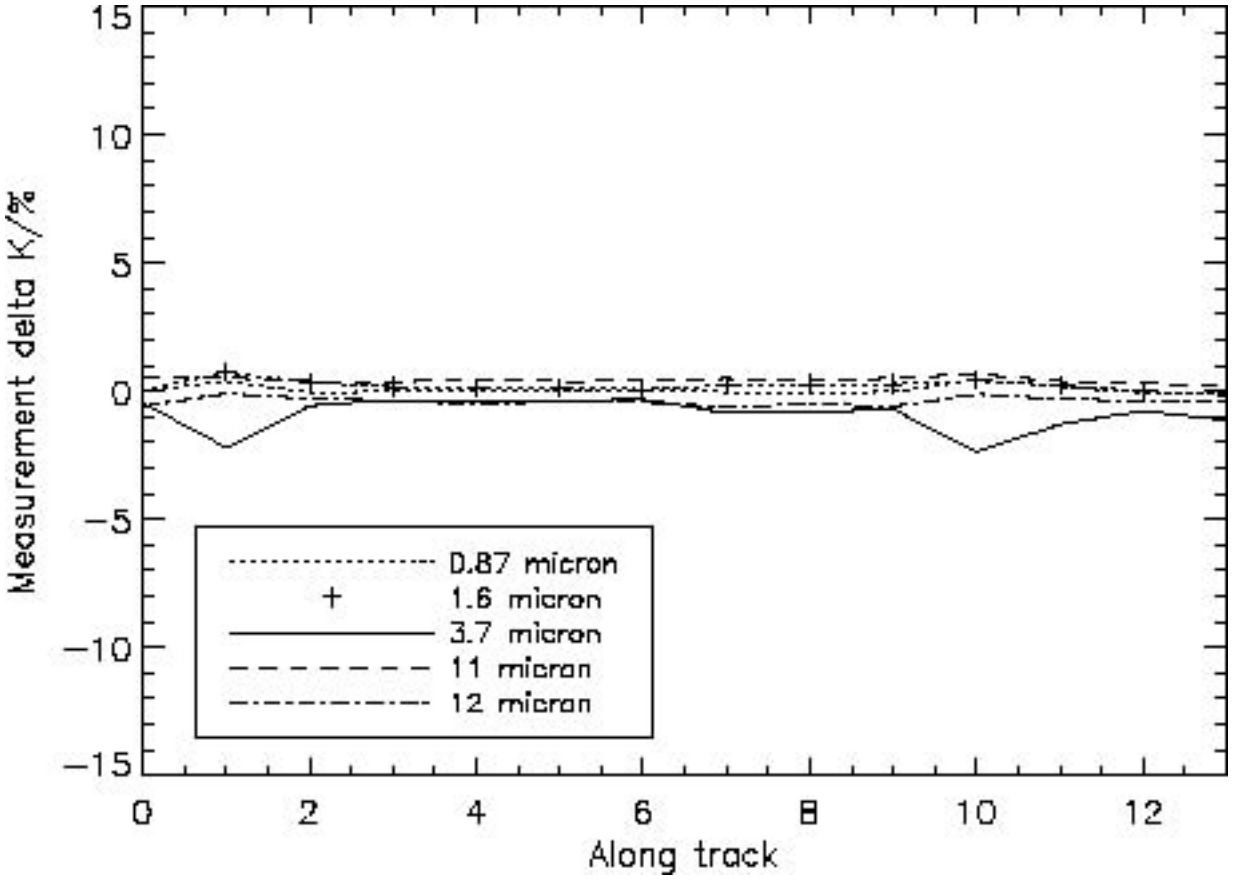


ATSR-2 Cirrus Results

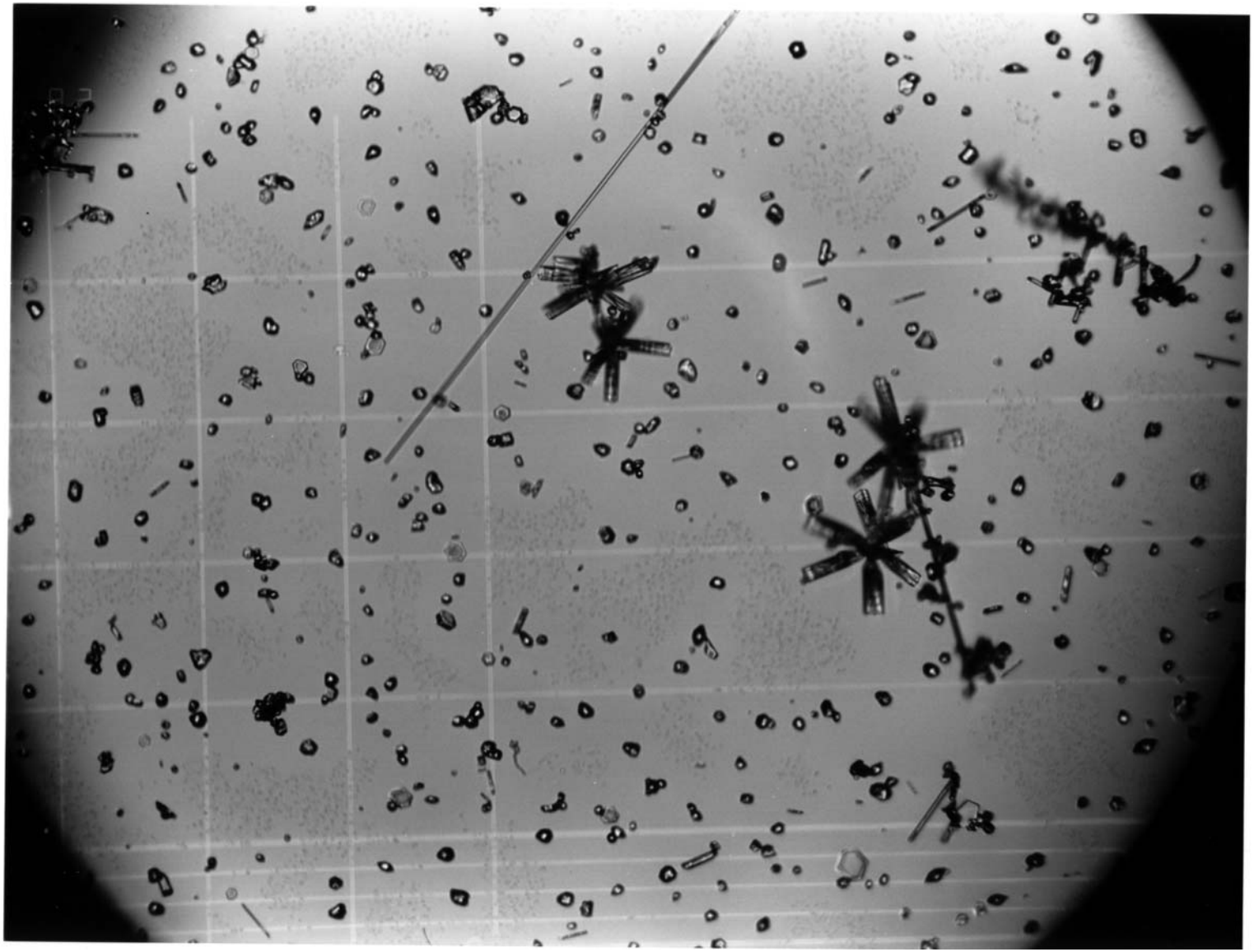
21 July, 1996;

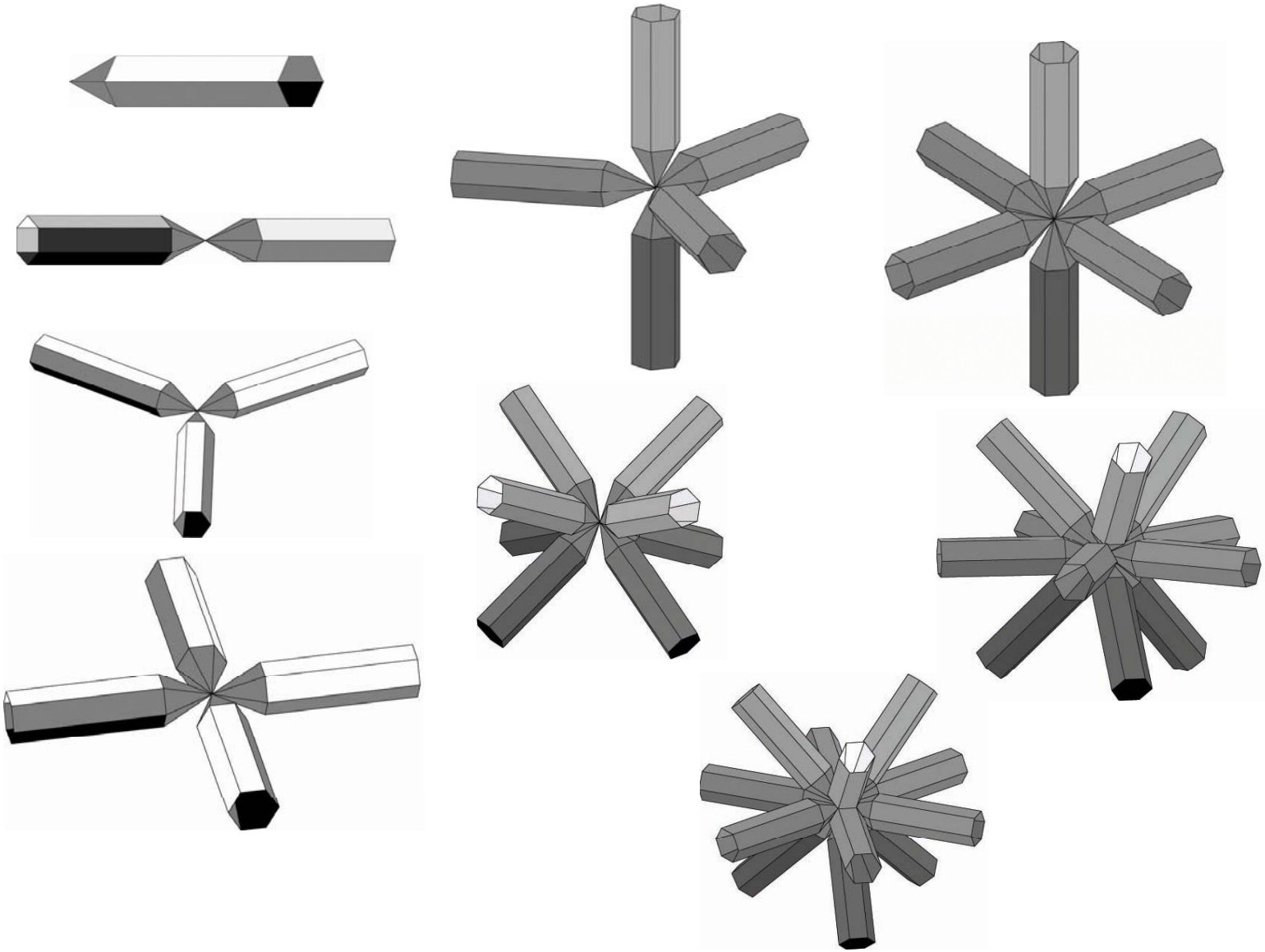
Latitude -32.5°; Longitude -95.9°; Scattering angle: 118.9° (nadir)

Courtesy of A. Baran, UK Met Office



Courtesy of Pro. S. Warren, U. of Washington





Priorities for Coming Year

- Ice (or cirrus) clouds

  Development of new IR scattering property code for bullet rosettes

  IR scattering database consistent with that used by MODIS and other team

- Aerosol scattering properties

  both spherical and spheroidal shapes

  refractive index effect

- Infrared radiative transfer

  Shape effect and vertical inhomogeneous

- Development of an IR retrieval algorithm