Developing a parameterization of 3-D radiative effects for CRMs

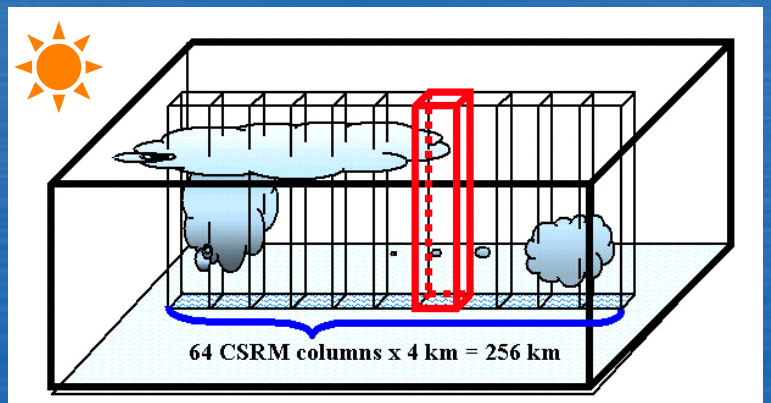
Tamás Várnai[1] and Jerry Y. Harrington[2]

[1]University of Maryland Baltimore County and NASA Goddard Space Flight Center
[2]Penn State University

Parameterization and analysis of 3-D solar radiative transfer in clouds

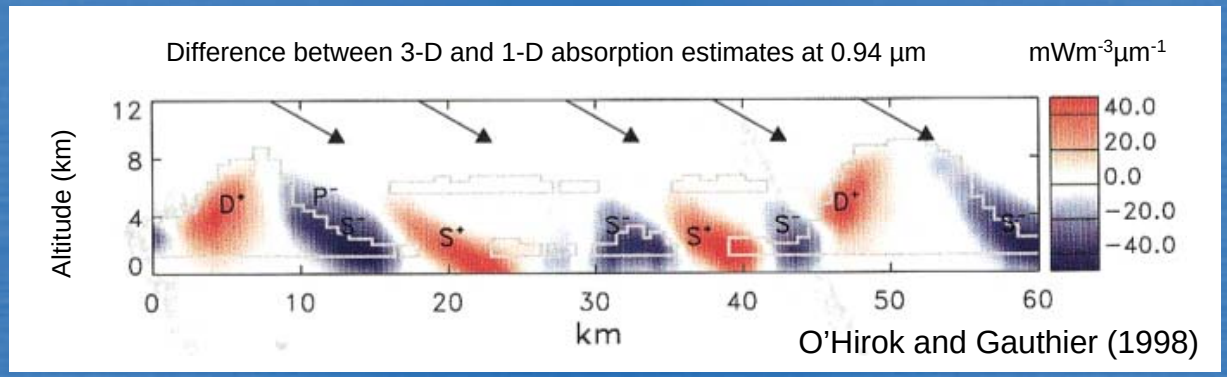
Goals:

- Develop 3-D radiative parameterization for CRMs
- Examine 3-D radiative effects on cloud development

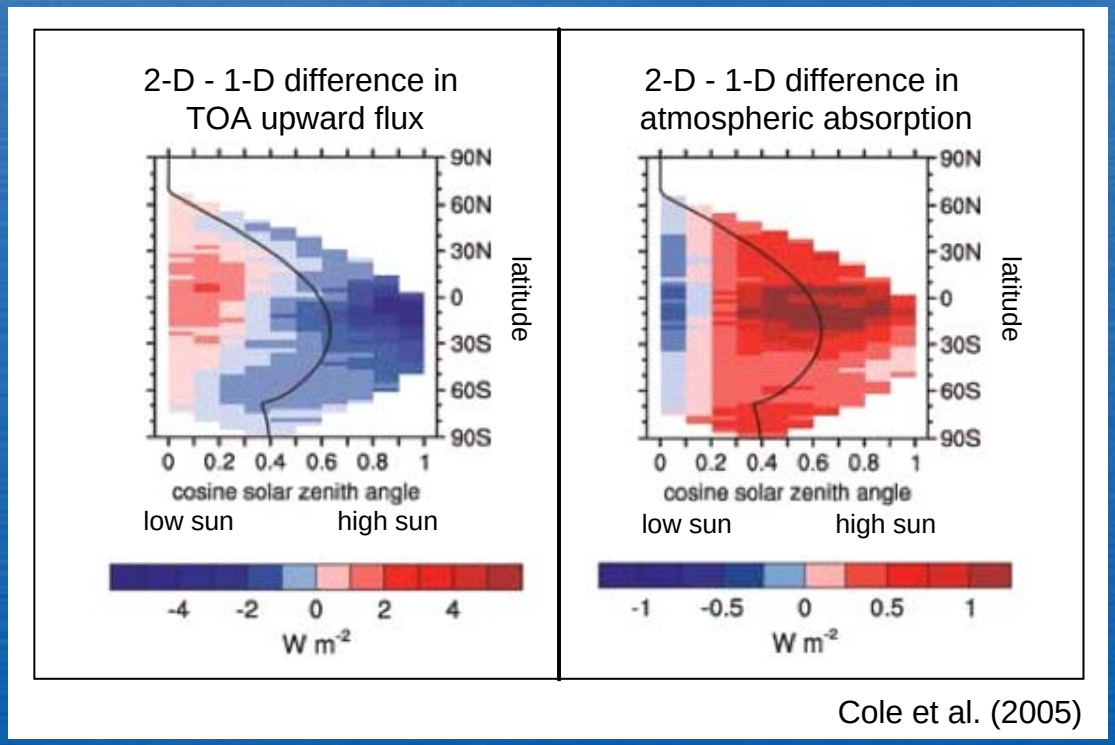


Picture from ARM website

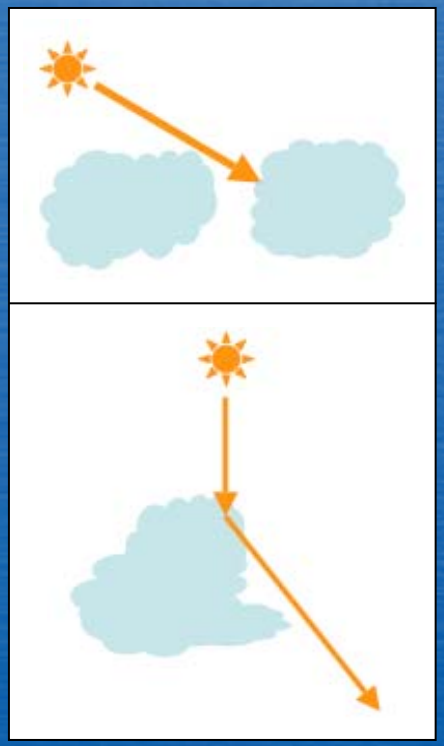
Motivation



O'Hirok and Gauthier (1998)



Cole et al. (2005)

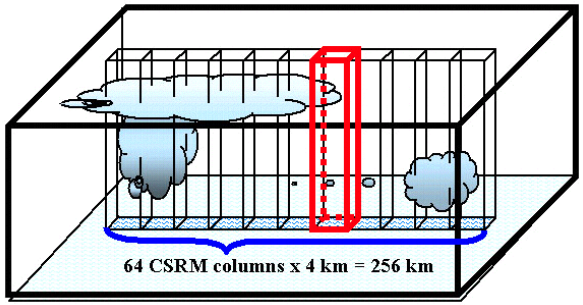


Challenges and approach

Cloud structure not fully known

- 2-D only
- Coarse resolution

3-D radiative calculations slow



Step 1. Create dataset of 3-D cloud structures & simulated radiative fluxes F_{1D}, F_{3D}

Step 2. Use dataset to develop parameterization

$$C = \frac{F_{3D}}{F_{1D}}$$

Neural net: 3-D cloud variability $\Rightarrow C$

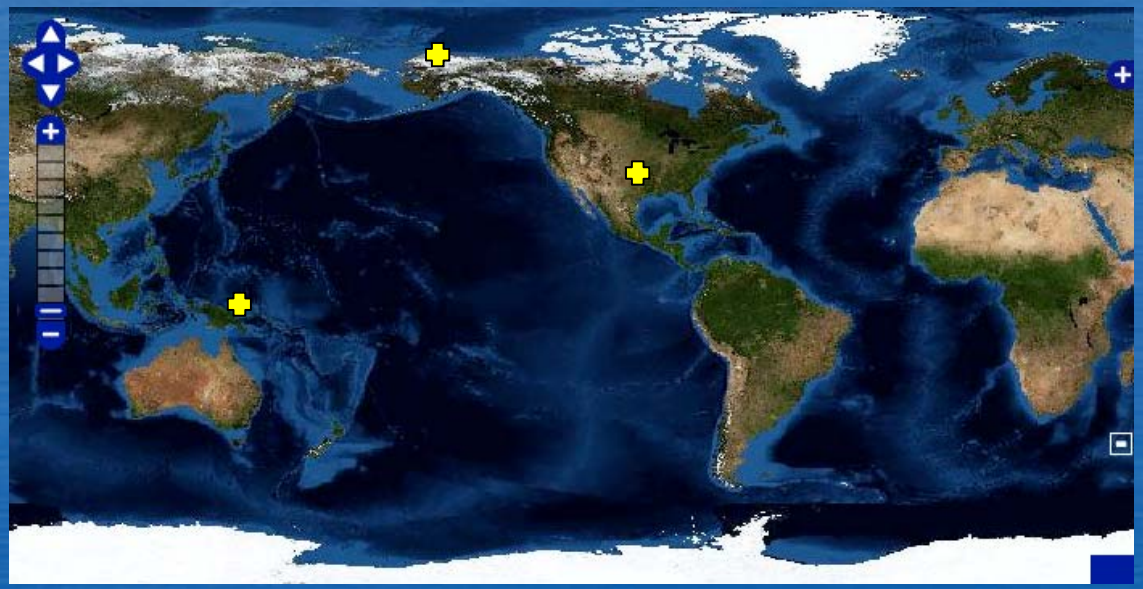
$$F_{3D} = F_{1D} \cdot C$$

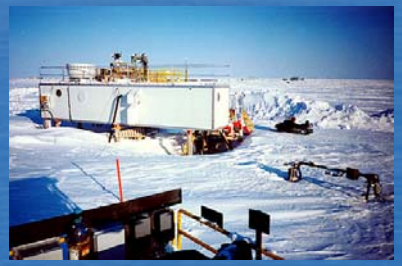
Step 3. Examine influence of 3-D radiation on cloud development

Step 1: 3-D clouds & simulated radiative fluxes

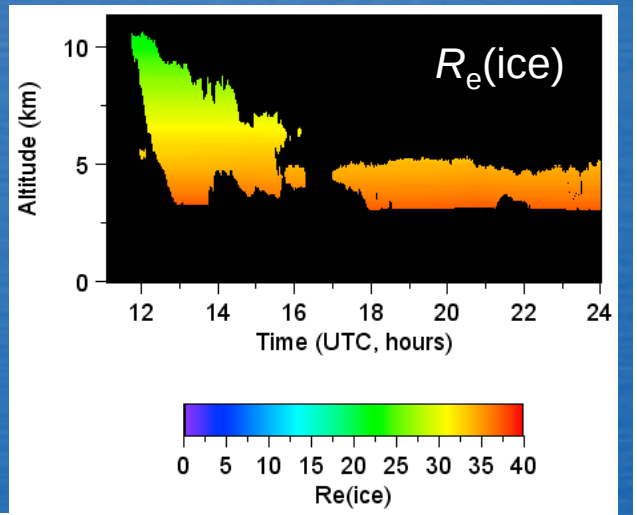
ARM data is well-suited for training parameterization:

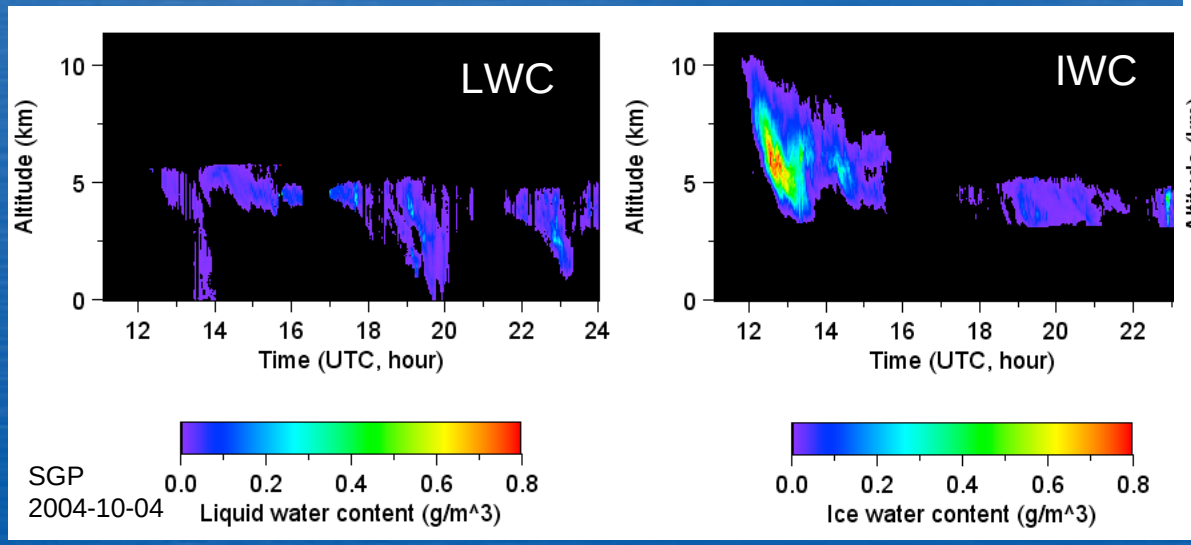
- Detailed, high-resolution cloud structures
- Full annual cycle at three climates

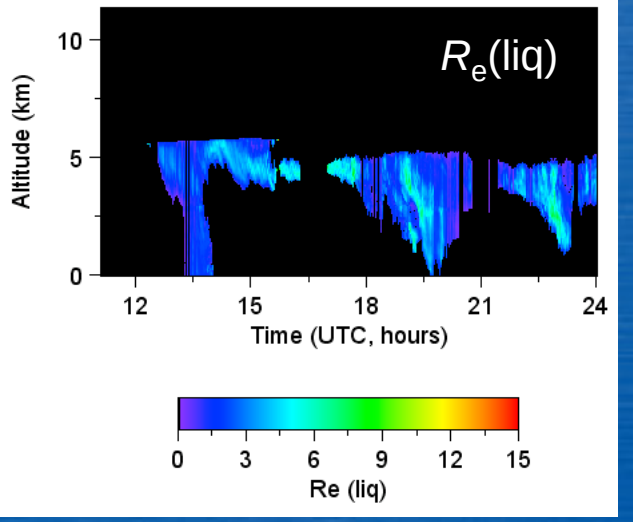




Microbase VAP



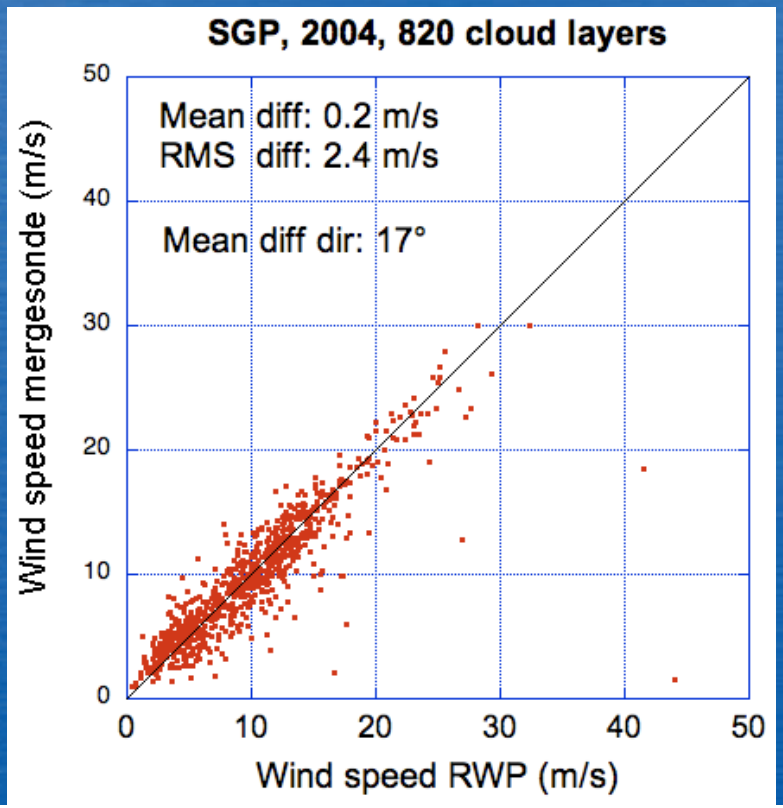




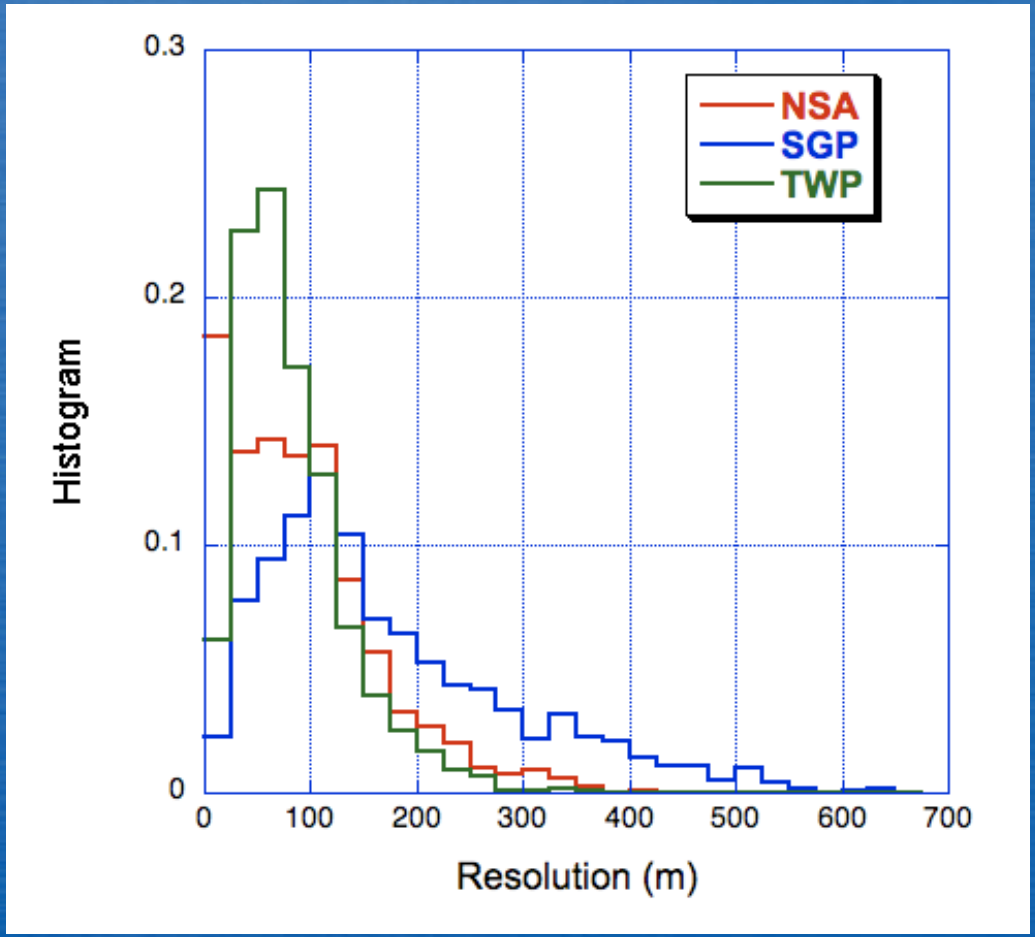
Converting time to horizontal distance

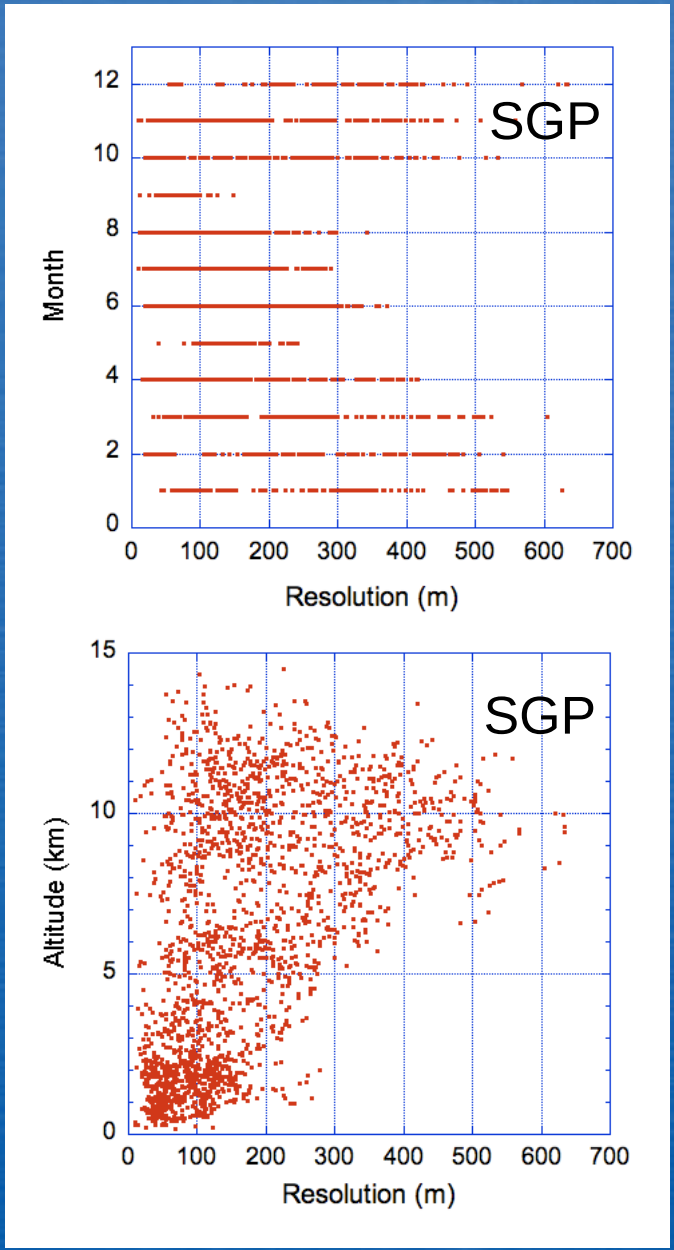
Wind speed, direction

- 915 MHz radar wind profiler
- Mergesonde VAP

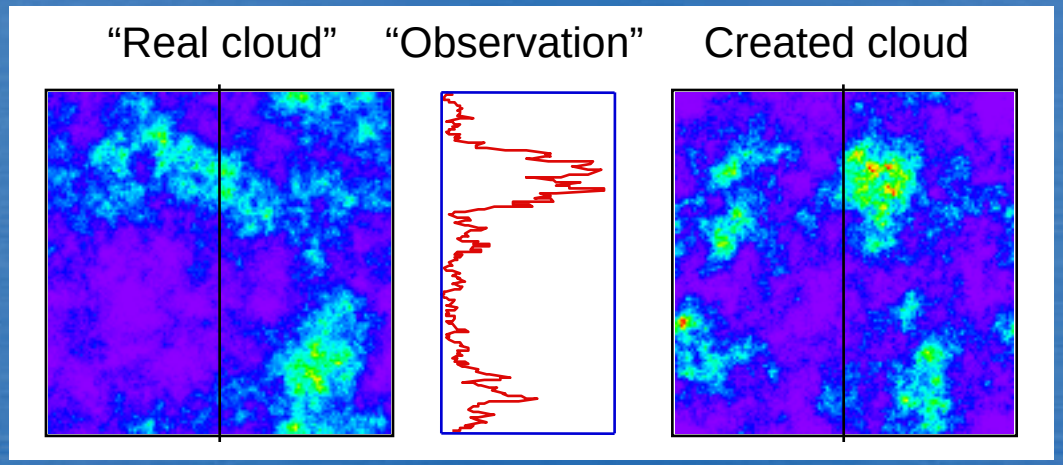


Horizontal resolution of cloud fields

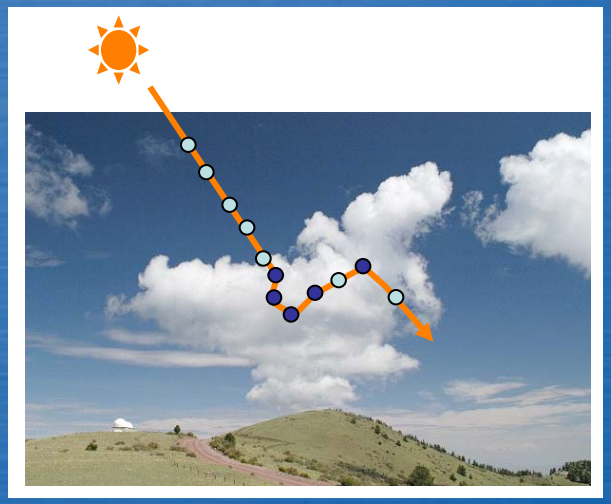




Extension to cross-wind direction



3-D radiative transfer simulations

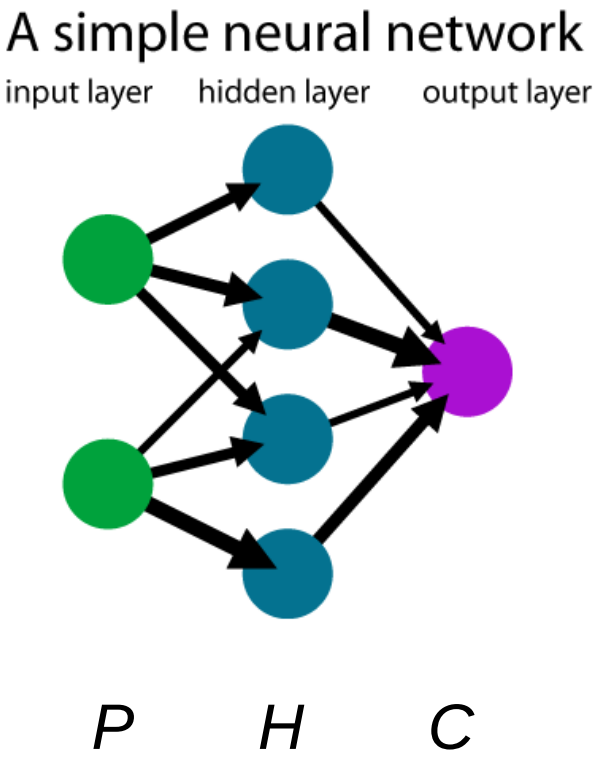


Broadband Monte Carlo simulations

$$F_{3D}, F_{1D}$$

$$C = \frac{F_{3D}}{F_{1D}}$$

Step 2: Parameterization using neural net



$$H_j = f\left[\sum_i W_{ij} P_i\right]$$

$$C_k = f\left[\sum_j W'_{jk} H_j\right]$$

$$f(z) = (1 + e^{-z})^{-1}$$

Optimal values of W_{ij}, W'_{jk} weights obtained iteratively during training phase

Examples of candidate *P*-values:

1-D parameters: θ_0, h, LWC, R_e, ...

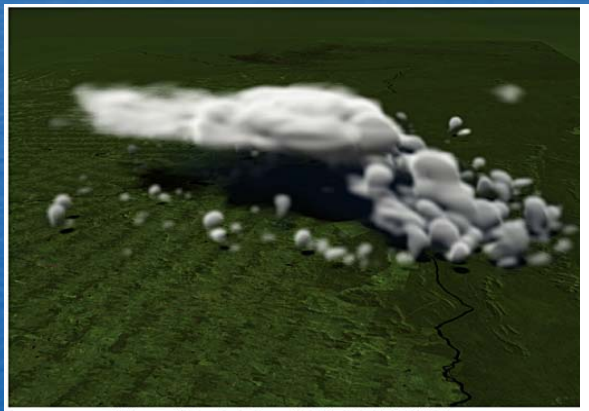
Horizontal gradients: ΔLWC(4 km), ΔIWC(1 km), ...

Optimal set selected using EOF analysis and testing performance.

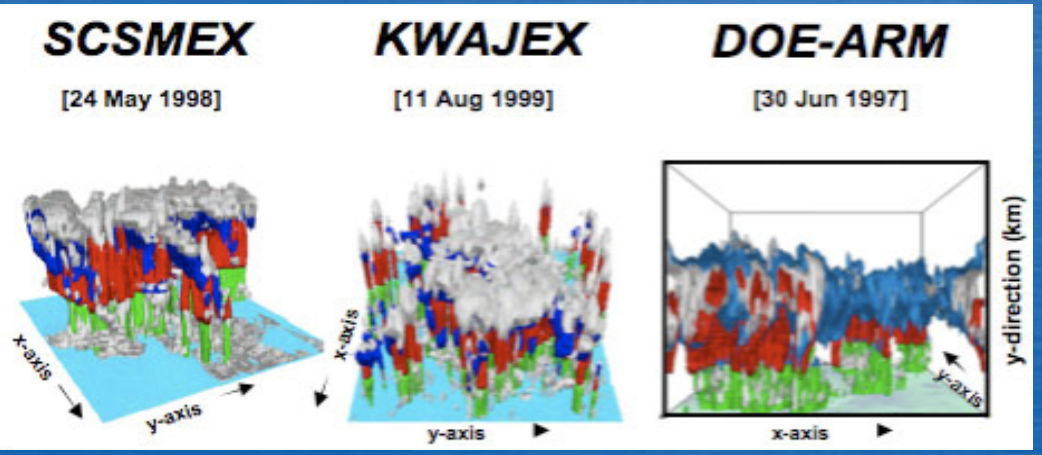
Testing parameterization

Accuracy:

- Calculate $F_{1\text{-}D}$, $F_{3\text{-}D}$ for fully 3-D cloud fields using Monte Carlo code
- Coarsen cloud fields to CRM resolution, cut out 2-D cross section, run parameterization
- Compare true and parameterized $F_{3\text{-}D}$ values



High resolution simulation of 23 Feb 1999 TRMM LBA case
Image by J. Williams (Scientific Visualization Studio)

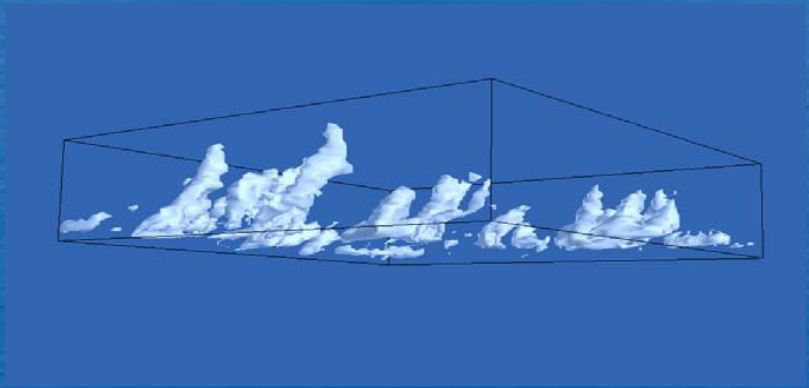


Speed and general performance: Jerry Harrington's version of RAMS model

Step 3: Examine influence of 3-D radiation on cloud development

Compare RAMS model runs that use 1-D and 3-D radiation

Examine: radiation, water content, precipitation, TKE, …



Summary of expected benefits

Fast parameterization that allows CRMs (and GCMs using CRMs) to consider shortwave 3-D radiative effects

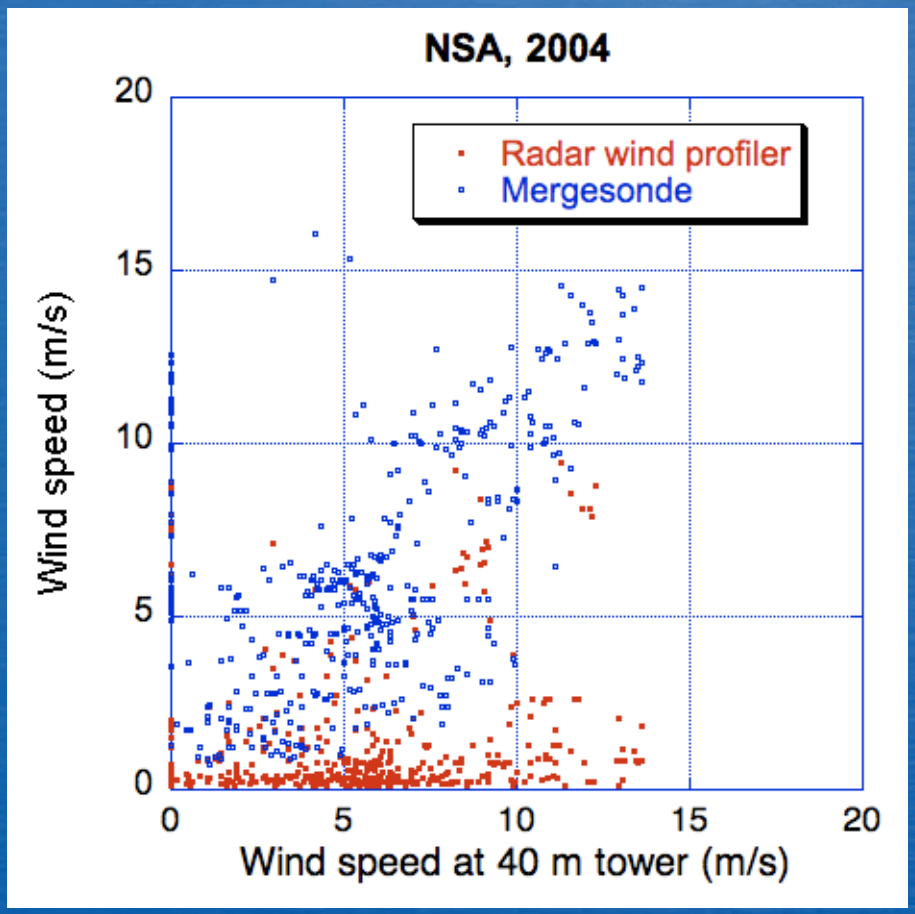
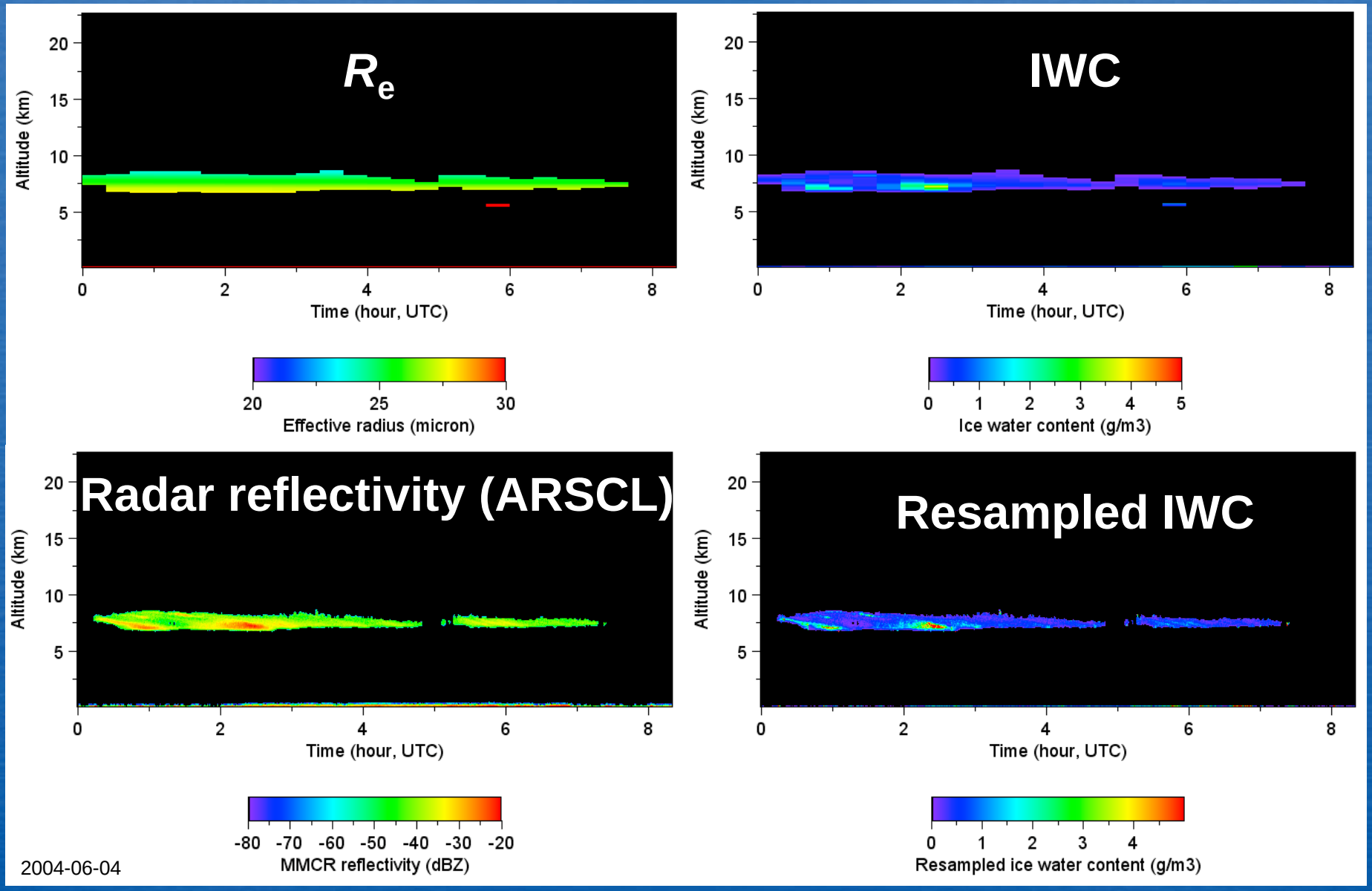
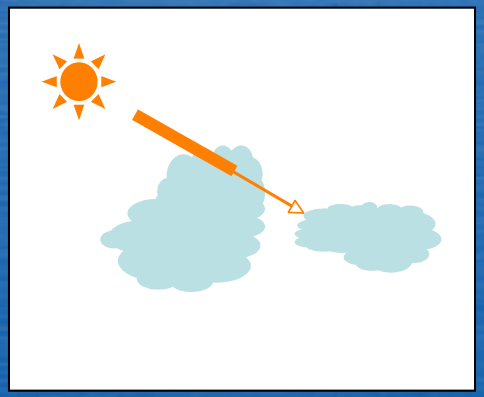
Better understanding of the influence 3-D radiation has on cloud development

Developing a parameterization of 3-D radiative effects for CRMs

Tamás Várnai[1] and Jerry Y. Harrington[2]

[1]University of Maryland Baltimore County and NASA Goddard Space Flight Center
[2]Penn State University

Low-altitude wind speed comparison



Resampling microbase IWC and LWC