1st Glory Science Team Meeting, August 10-11, 2011
Goddard Institute for Space Studies, New York (NY)

Disentangling Aerosols and Clouds in APS's Footprints using its Multi-Angle Multi-Spectral Polarimetry-Diverse Data

Anthony B. Davis

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The Problem …

Project Team

PI: *Anthony B. Davis*, JPL/CalTech
Co-PI: *Alexander Marshak*, NASA – GSFC
Co-I: *Michael J. Garay*, JPL/Raytheon

Collaborators:
Brian Cairns, NASA – GISS
Bernhard Mayer, DLR – Oberpfaffenhoffen
Pengwang Zhai, NASA – LaRC

Mayer, B. (2009). Radiative transfer in the cloudy atmosphere. *European Physical Journal Conferences* **1**, 75-99.

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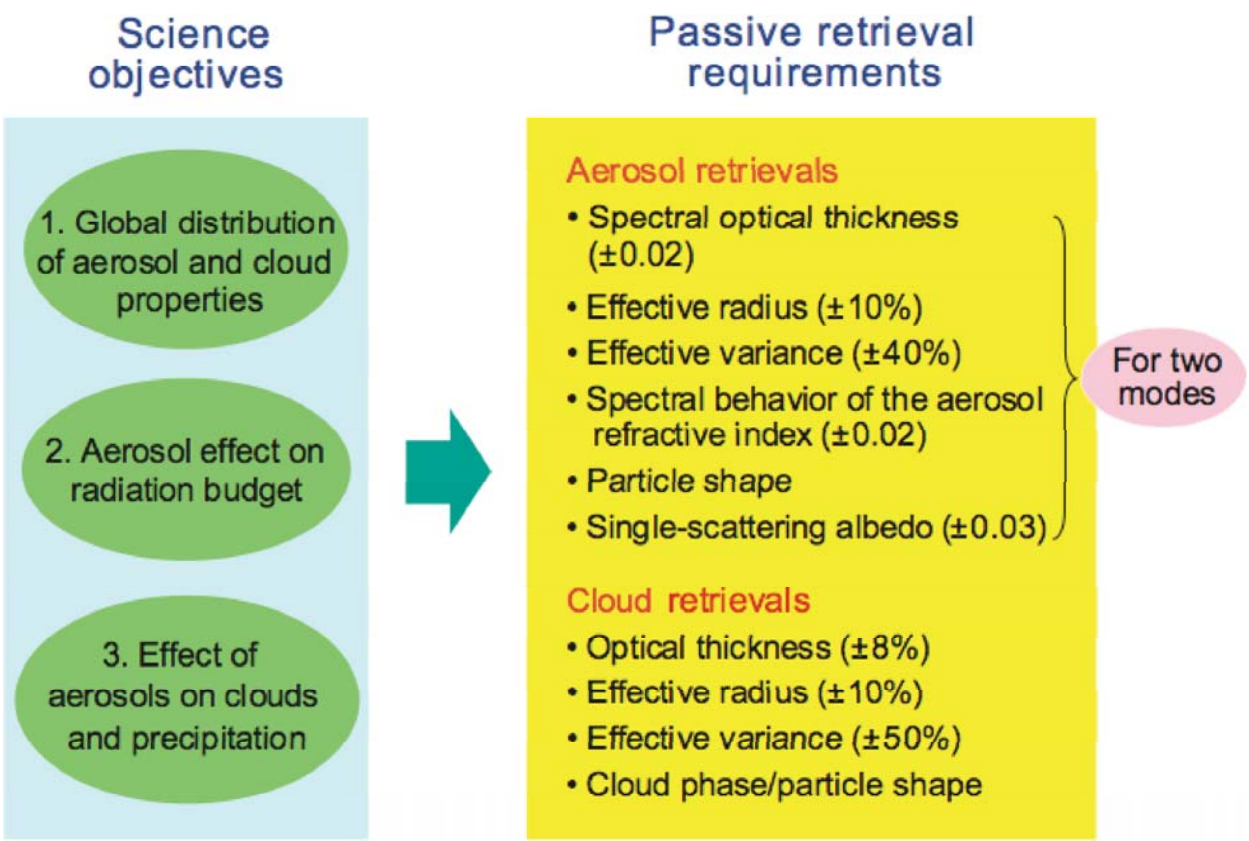
Claudia Emde, Ludwig Maximilians Universität, München
Pengwang Zhai, NASA – LaRC

Emde, C., R. Buras, B. Mayer, and M. Blumthaler (2010). The impact of aerosols on polarized sky radiance: Model development, validation, and applications. *Atmos. Chem. Phys.* **10**, 383-396.

Glory Goals



Science objectives and retrieval requirements for APS instrument, assuming a cloud-free scene, from Mishchenko et al. [2007]

Our Goals

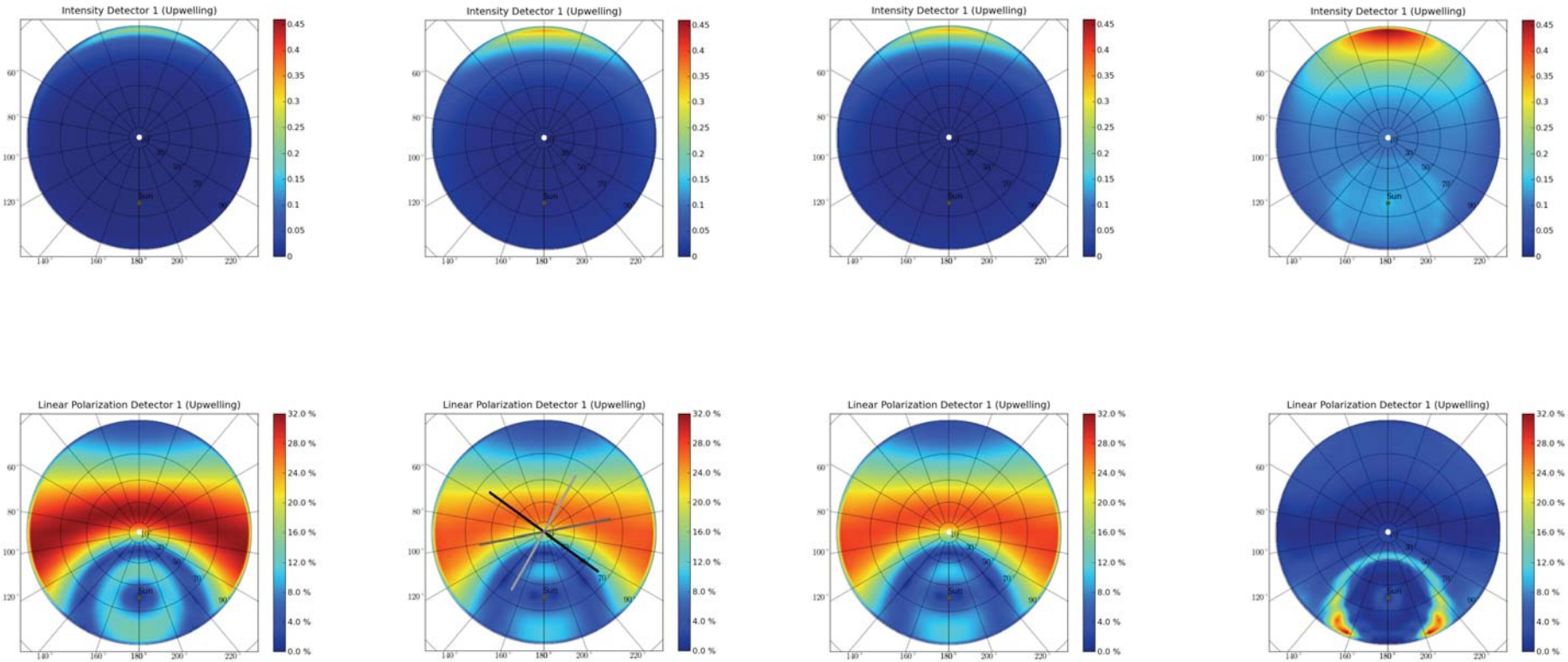
- **Learn how to use Cloud Cameras (CCs) to detect partial cloudiness and estimate gross cloud properties using Independent Pixel Approximation (IPA) think:**
  - Fractional cloud coverage, in the APS footprint
  - PDF of cloud optical depth, in the APS footprint
- **Simple mixture model:**
  Independent *Sub*-Pixel Approximation
  - Leads to a 1st-order correction for cloud contamination
  - Leads back to standard aerosol property retrieval
- **Evaluate and predict forward vRT model error:**
  - Unresolved cloud adjacency effects
  - Inform aerosol property retrieval about this bias

Our *Alternative* Goals

- **Learn how to use Cloud Cameras (CCs) to detect partial cloudiness and estimate gross cloud properties using Independent Pixel Approximation (IPA) think:**
  - Fractional cloud coverage, in the APS footprint
  - PDF of cloud optical depth, in the APS footprint
- **Simple mixture model:**
  Independent *Sub*-Pixel Approximation
  - Leads to a 1st-order correction for aerosol contamination
  - Leads back to standard cloud property retrieval
- **Evaluate and predict forward vRT model error:**
  - Unresolved aerosol adjacency effects
  - Inform cloud property retrieval about this bias

1D vRT model: *Zhai et al. [2009]*

$\tau_a = 0.05$ $\tau_a = 0.2$ $\tau_a = 0.16$ $\tau_c = 30.$



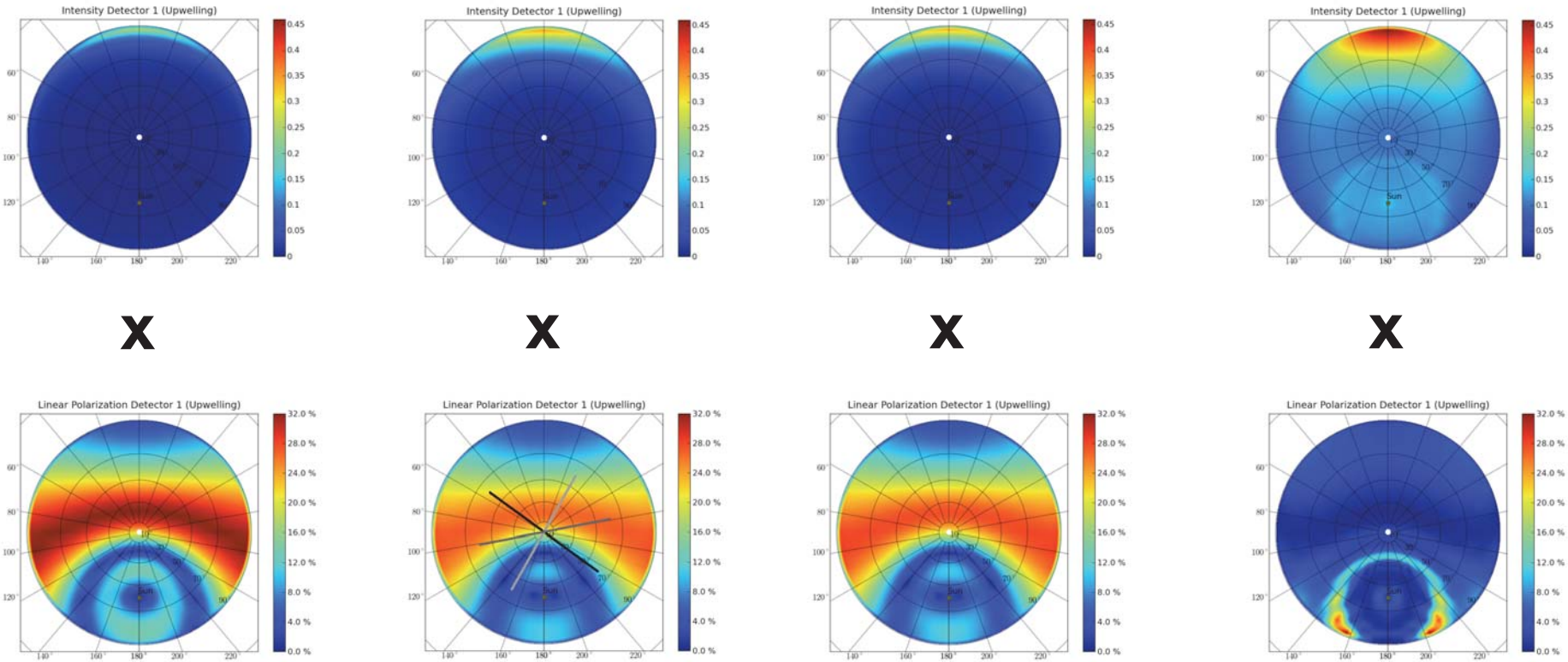
Aerosol cases

TOA radiances (for a black surface)

Cloudy case

IPA model based on 1D vRT: I_{pol}

$\tau_a = 0.05$ | $\tau_a = 0.2$ | $\tau_a = 0.16$ | + | $\tau_c = 30.$



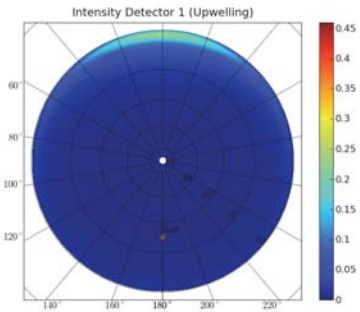
x | x | x | x

or | or

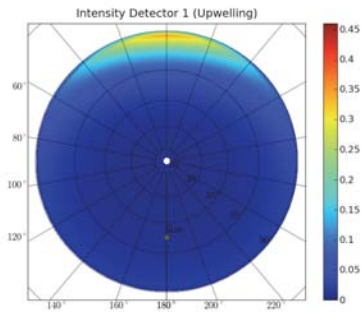
x $(1-f_c)$ | x f_c

IPA model based on 1D vRT: *I*

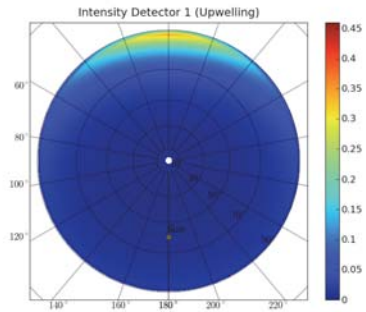
$\tau_a = 0.05$



$\tau_a = 0.2$

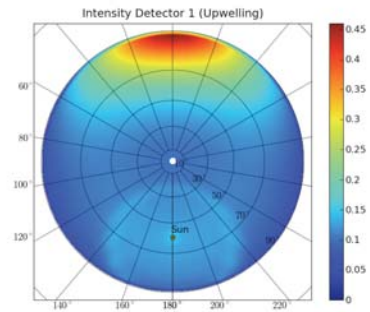


$\tau_a = 0.16$



+

$\tau_c = 30.$



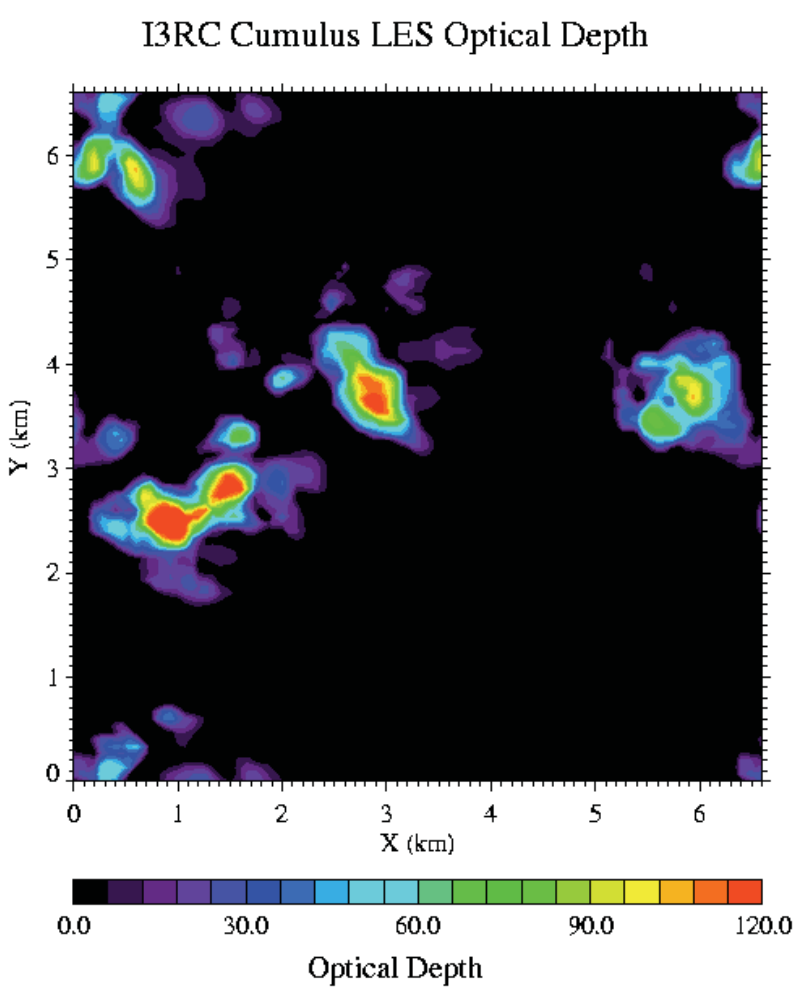
or **or**

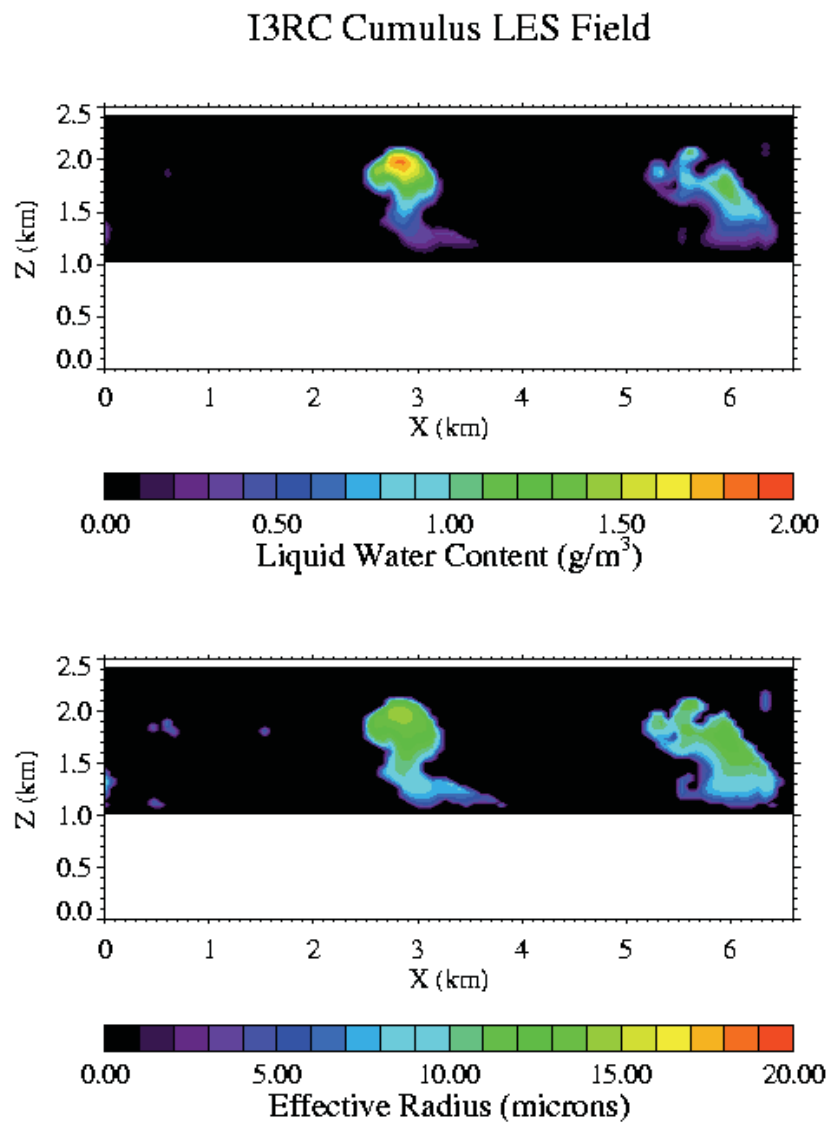
x (1–f_c) **x f_c**

Approach

- **Build simulation framework for APS and CC observations using high-fidelity 3D vector RT**
  - Control background 1D aerosol of interest
  - Control 3D clouds
- **Bring probabilistic cloud modeling to bear**
  - 1-point stats, a.k.a. PDFs or histograms
  - 2-point stats, a.k.a. wavenumber spectra of auto-correlation functions/structure functions
- **Bring Markovian stochastic 3D (v)RT to bear**
  - Uses CF and cloud aspect ratio
  - Equivalently, layer thickness and mean cloud size

A well-documented test case …



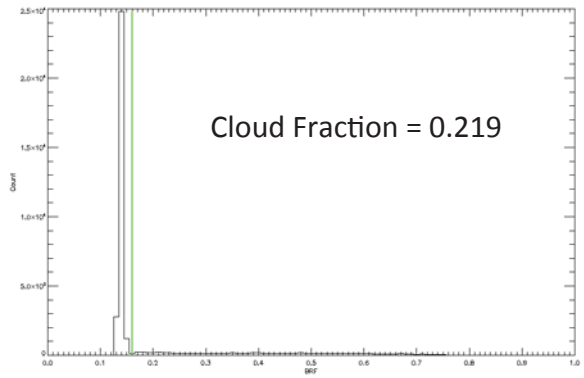


"True" Cloud Fraction (i.e., fraction of grid containing ANY cloud water) = 0.228

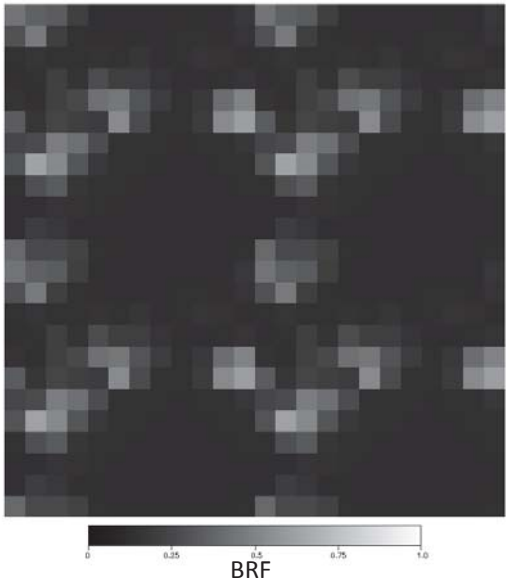
BRF Image

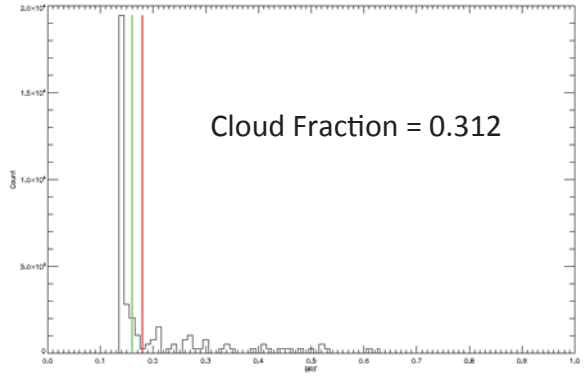
BRF Histogram

Binary Cloud Mask



33.3 m resolution





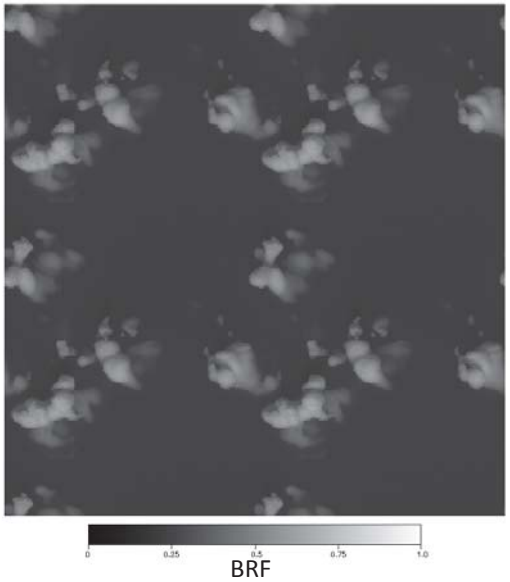
533.6 m resolution

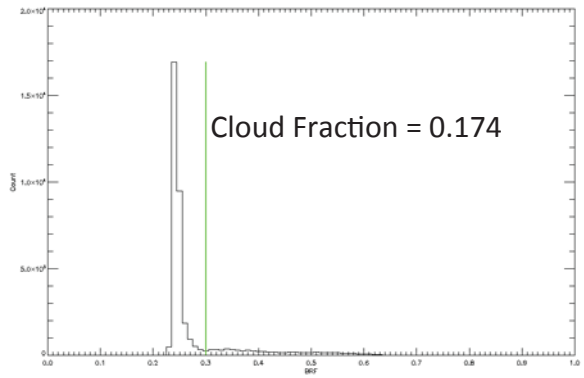
412 nm “Blue Band” Cloud Camera with aerosol (AOD at 550 nm = 0.16)

BRF Image

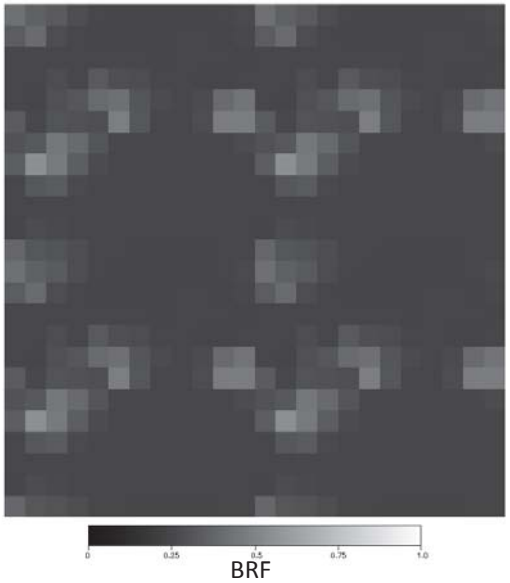
BRF Histogram

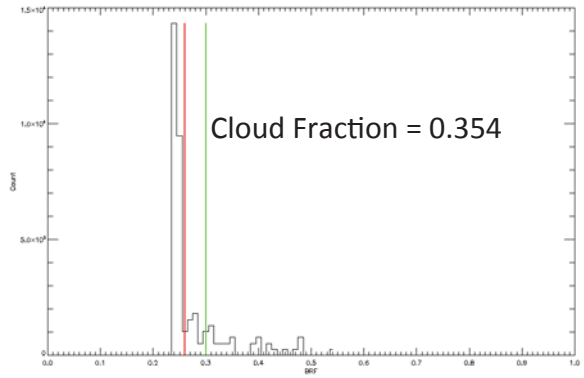
Binary Cloud Mask





33.3 m resolution



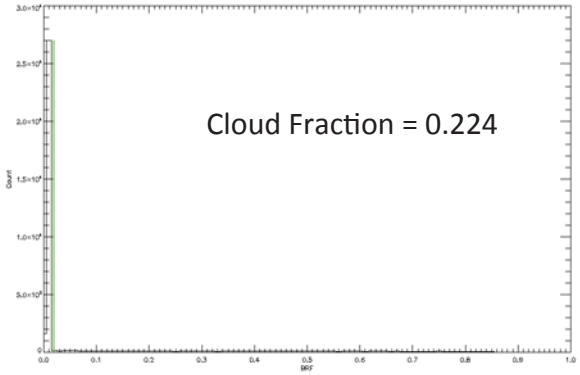


533.6 m resolution

412 nm “Blue Band” Cloud Camera with aerosol (AOD at 550 nm = 2.60)

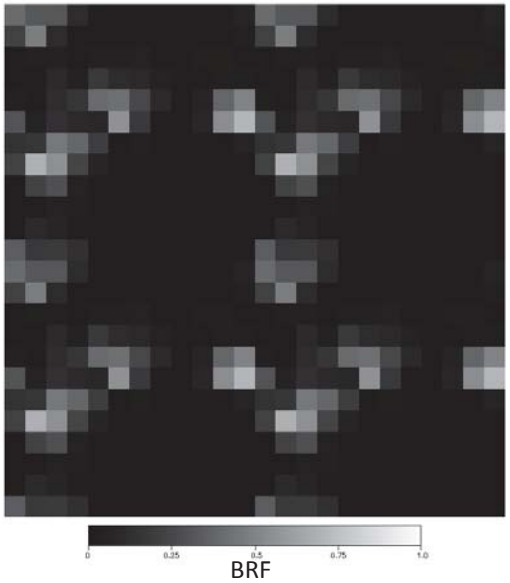
BRF Image

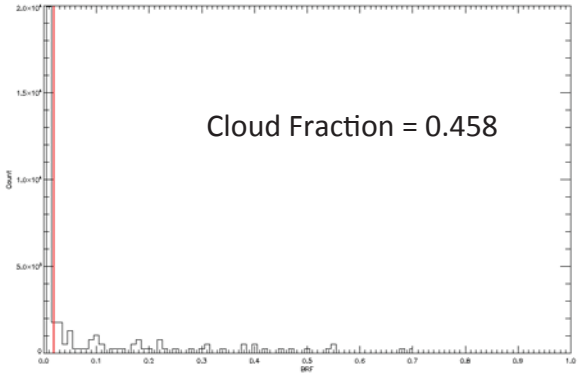
BRF Histogram



33.3 m resolution

Binary Cloud Mask



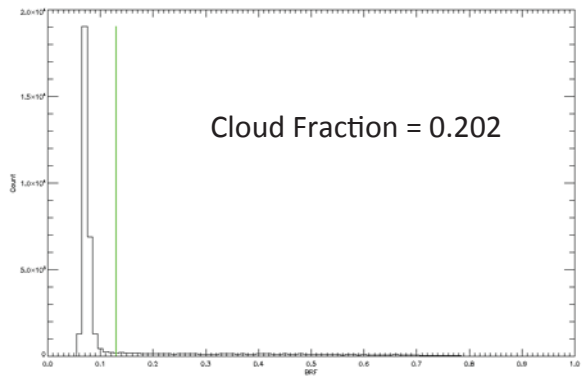


533.6 m resolution

865nm “NIR Band” Cloud Camera with aerosol (AOD at 550 nm = 0.16)

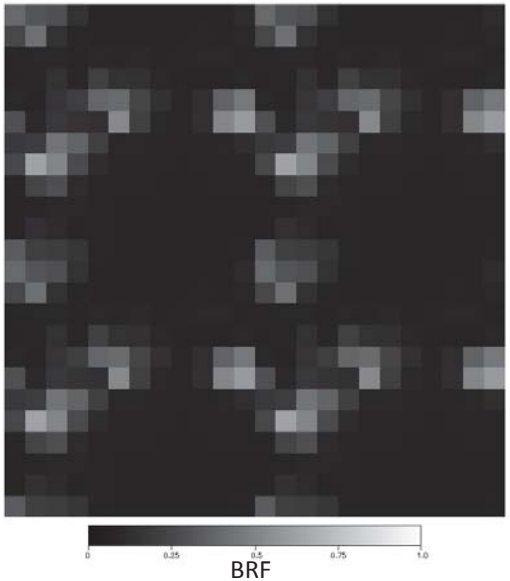
BRF Image

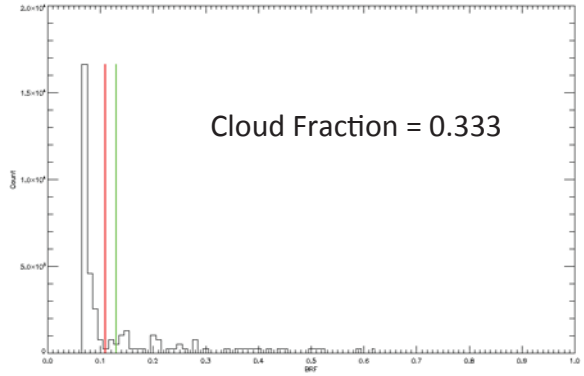
BRF Histogram



33.3 m resolution

Binary Cloud Mask





533.6 m resolution

865nm “NIR Band” Cloud Camera with aerosol (AOD at 550 nm = 2.60)

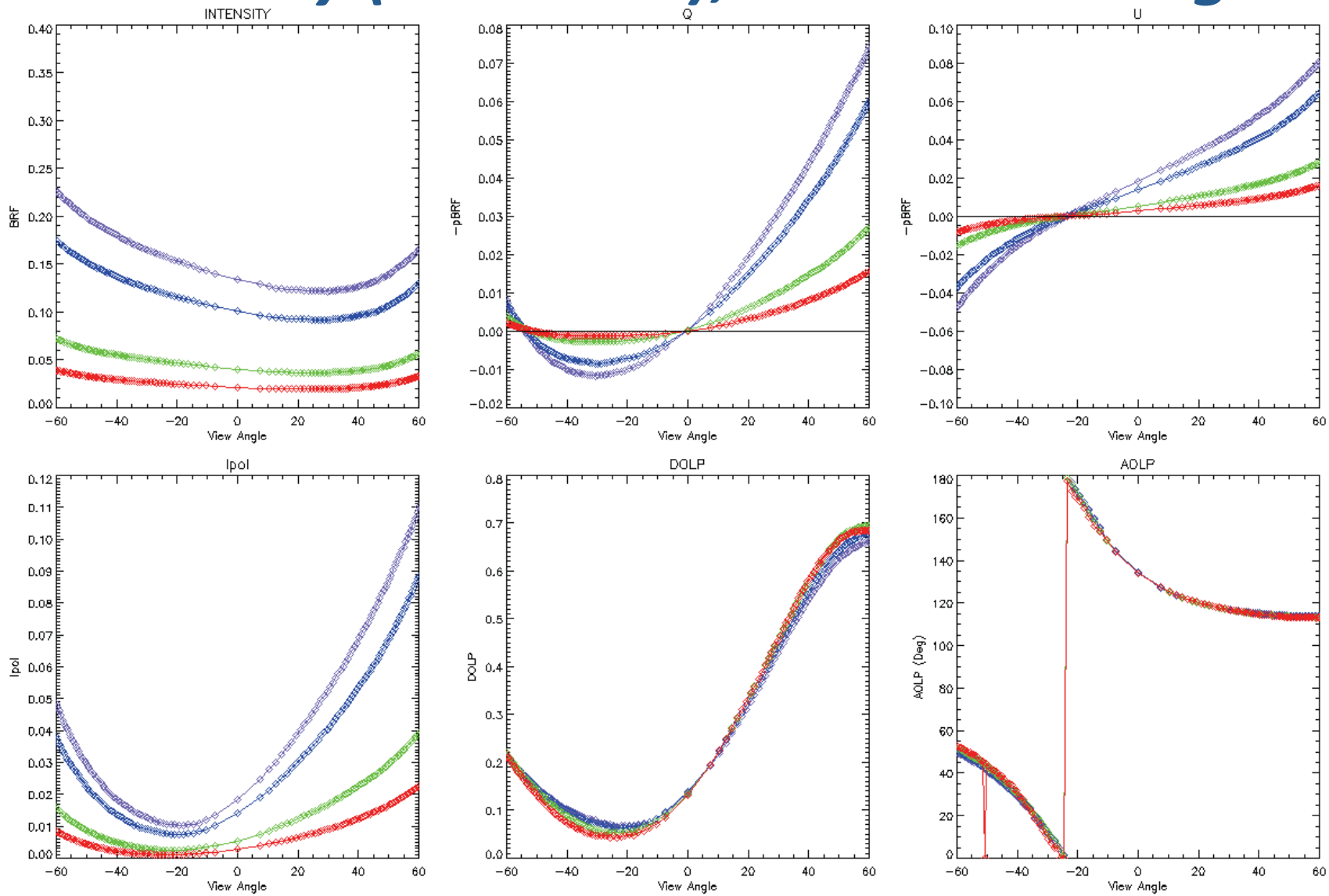
The theshold/scale CF problem

Cloud Camera Image	BRF Threshold Full Resolution	BRF Threshold Reduced Resolution	Cloud Fraction Full Resolution	Cloud Fraction Reduced Resolution
Blue Band – Base Aerosol	0.16	0.18	0.219	0.312
Blue Band – Heavy Aerosol	0.30	0.26	0.174	0.354
NIR Band – Base Aerosol	0.02	0.02	0.224	0.458
NIR Band – Heavy Aerosol	0.13	0.11	0.202	0.333
TRUTH			0.228	

Cf. many papers by Roger Davies, Larry Di Girolamo, and associates Ā

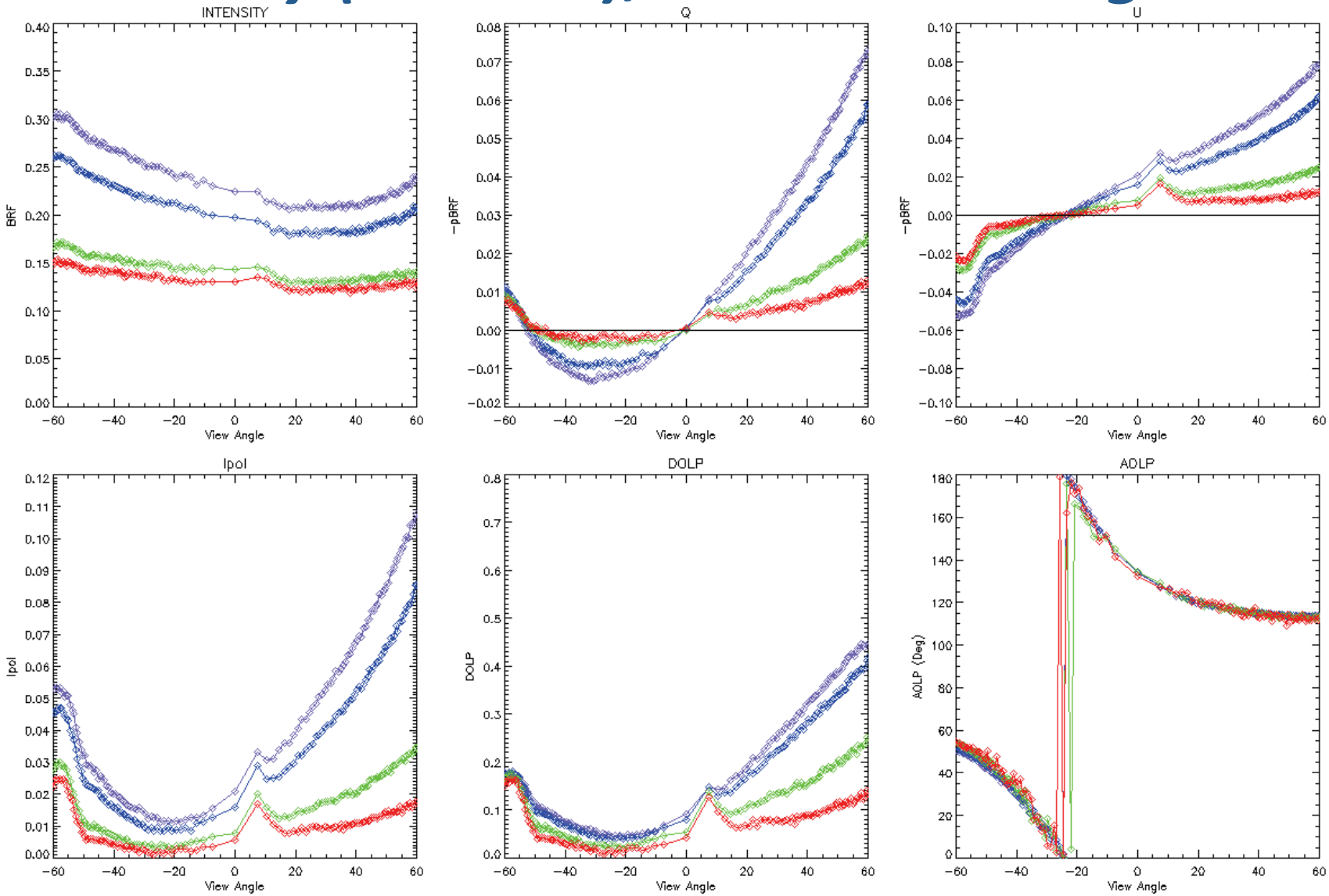
APS signals predicted with vMYSTIC:

Aerosol only (base case); short wavelengths



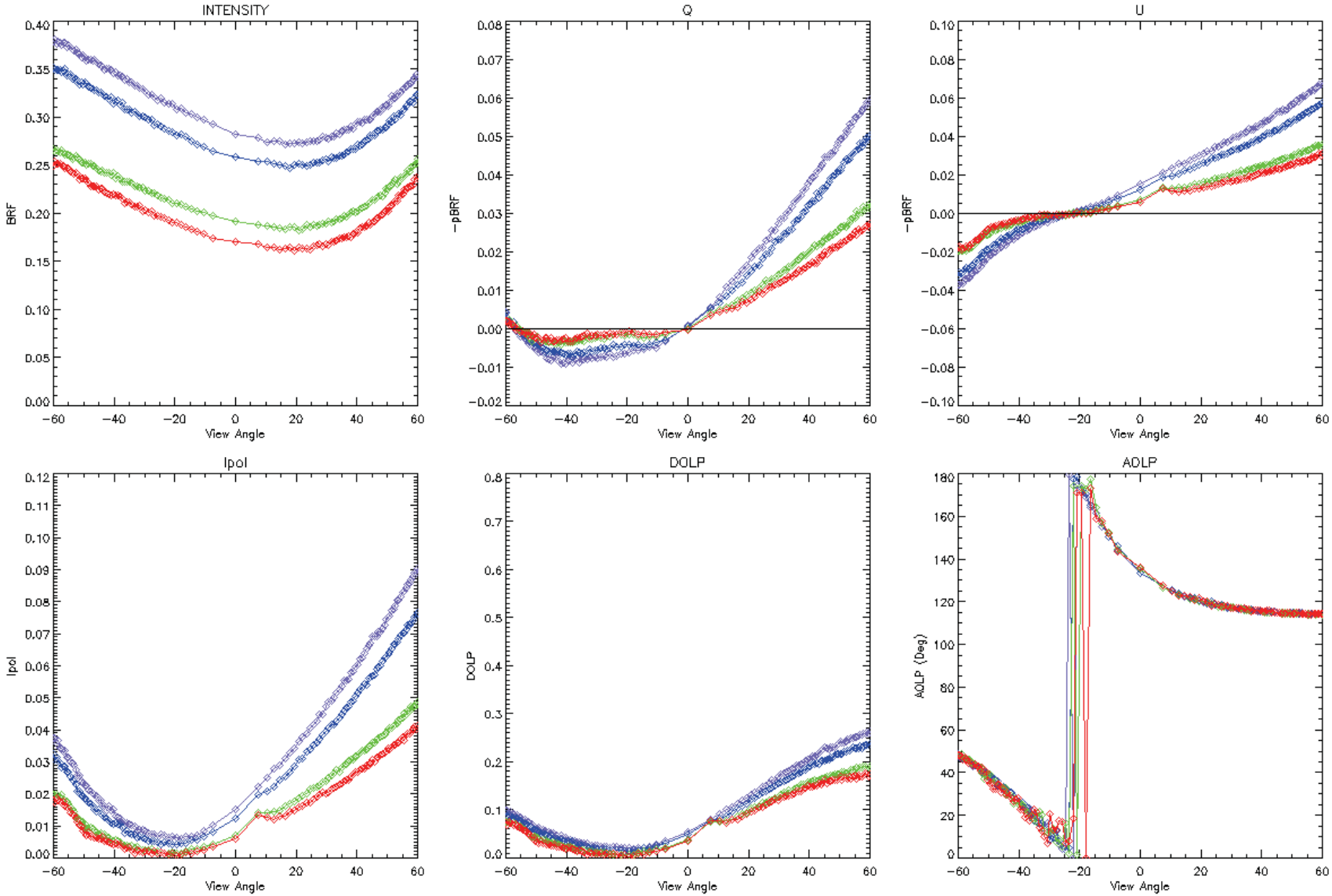
APS signals predicted with vMYSTIC:

Clouds only (IPA rule); short wavelengths



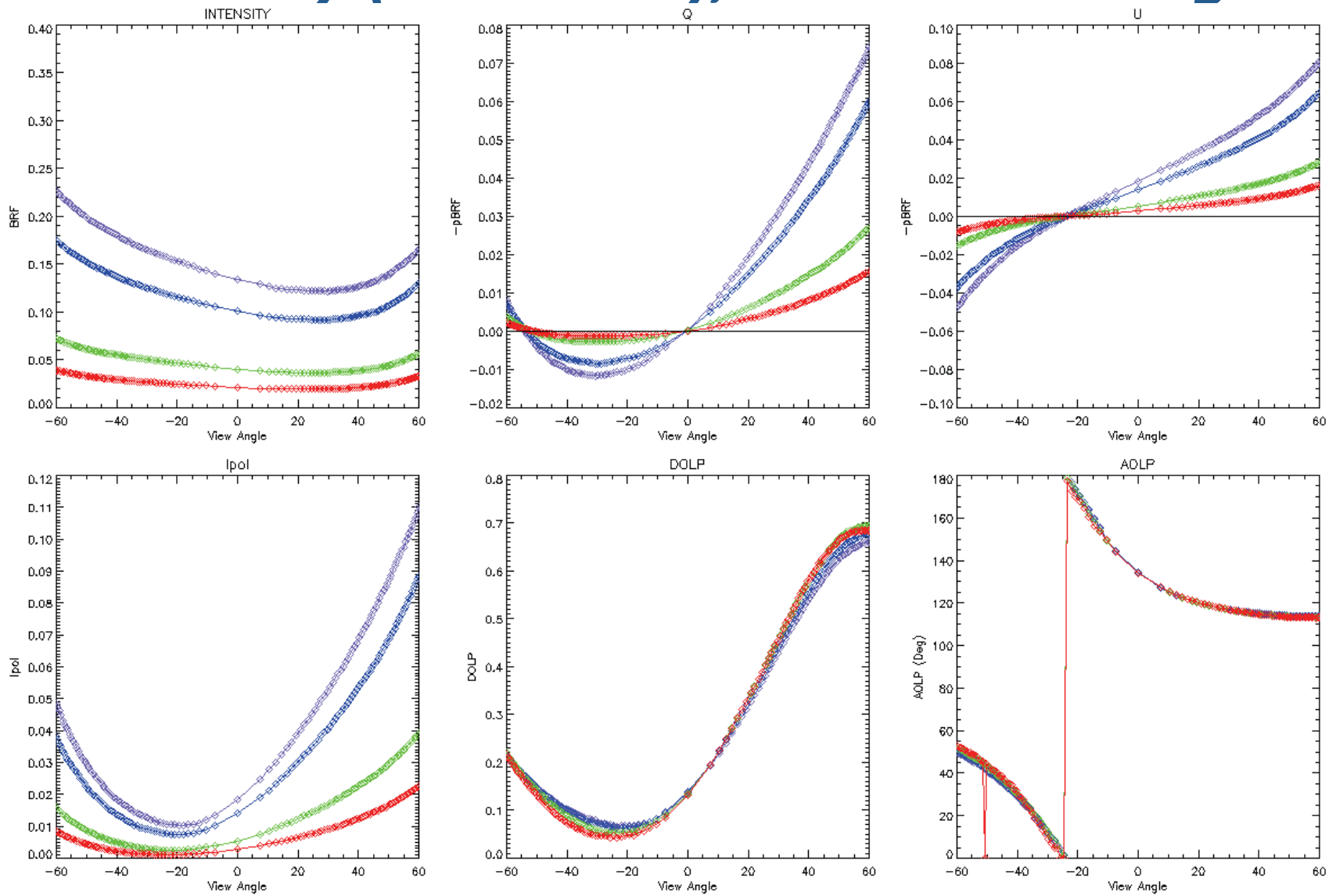
APS signals predicted with vMYSTIC:

Cloud-base aerosol mix; short wavelengths



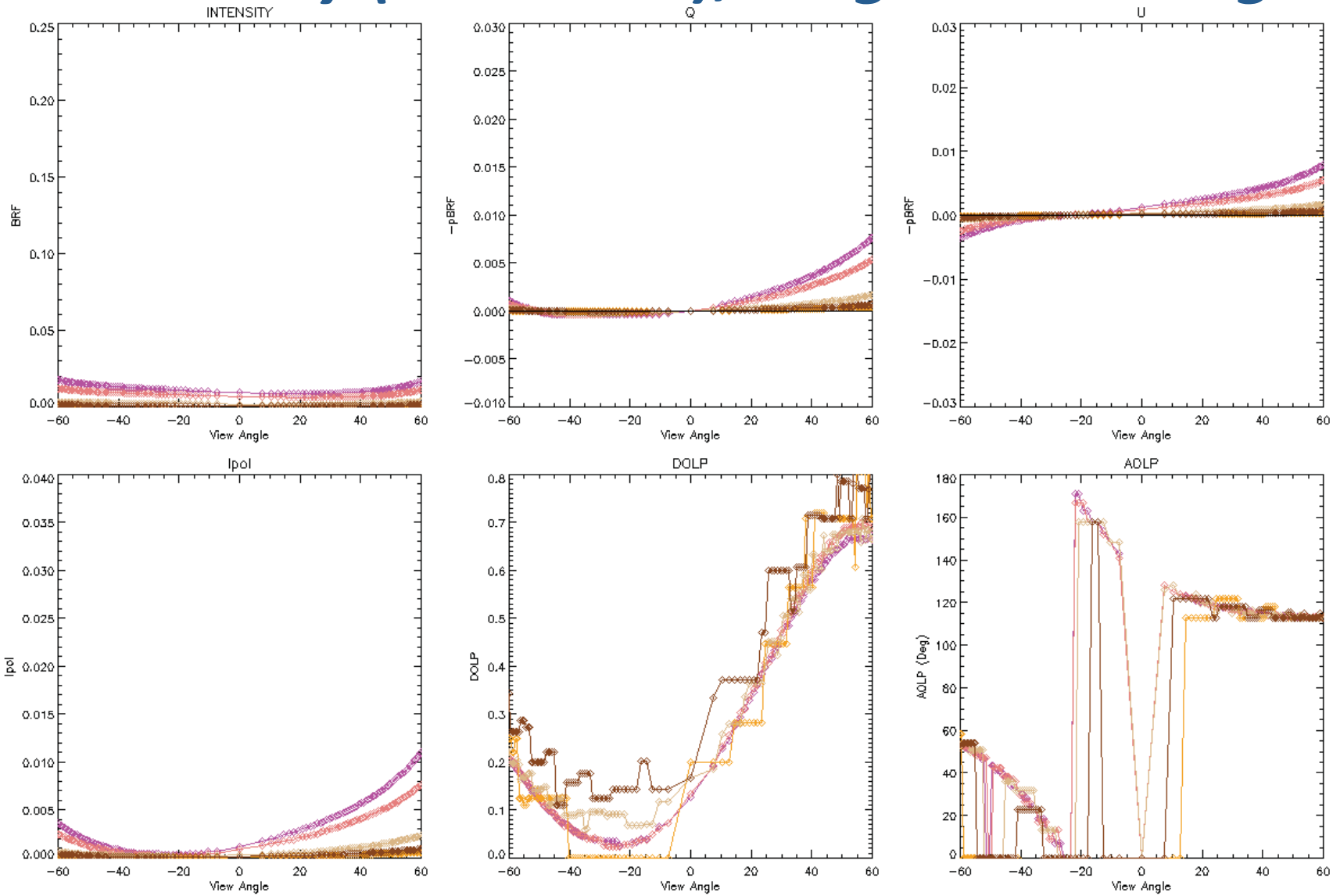
APS signals predicted with vMYSTIC:

Aerosol only (base case); short wavelengths



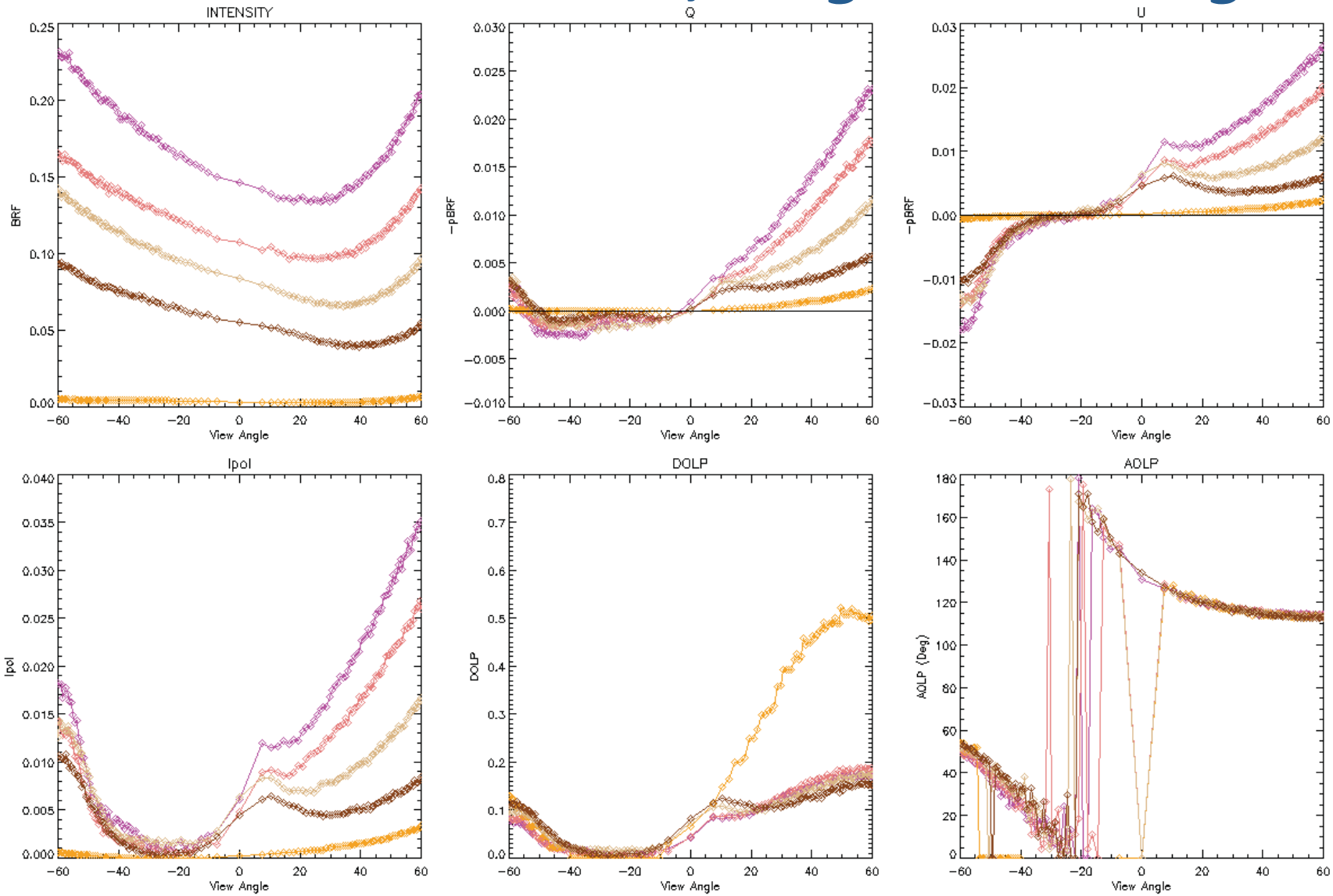
APS signals predicted with vMYSTIC:

Aerosol only (base case); longer wavelengths

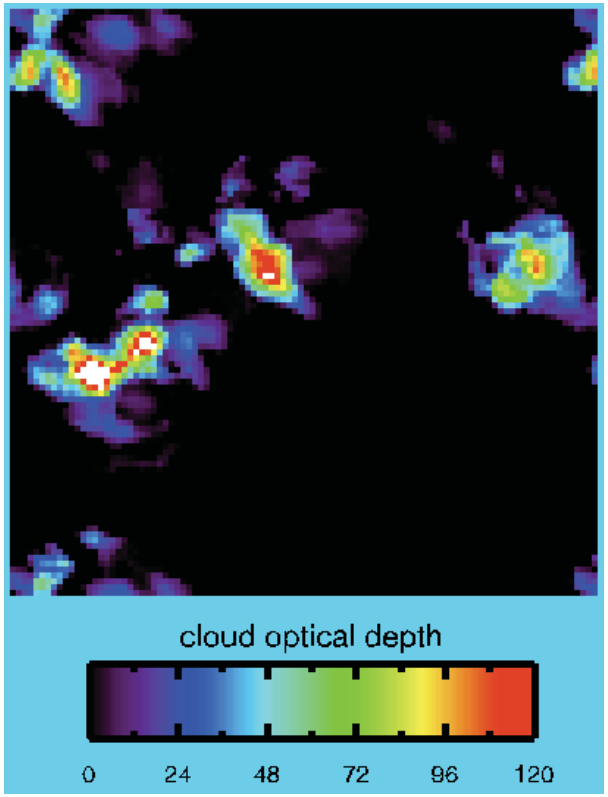


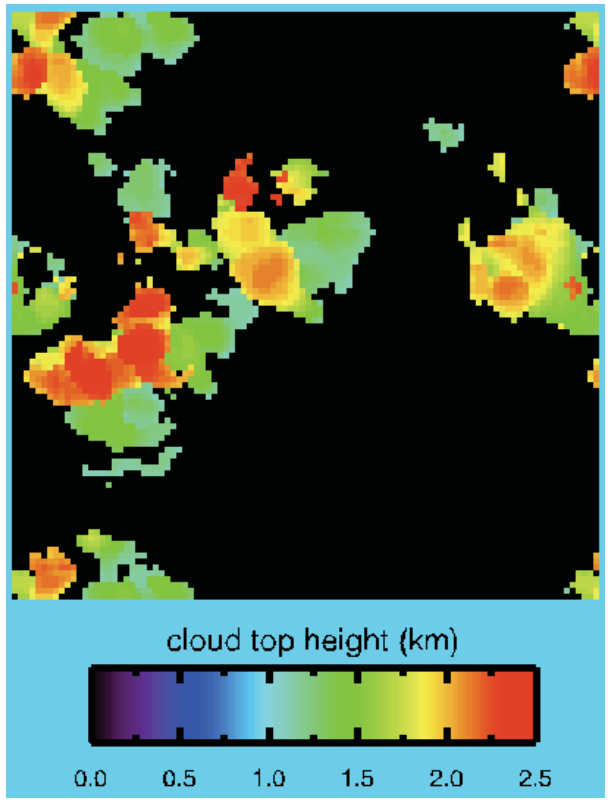
APS signals predicted with vMYSTIC:

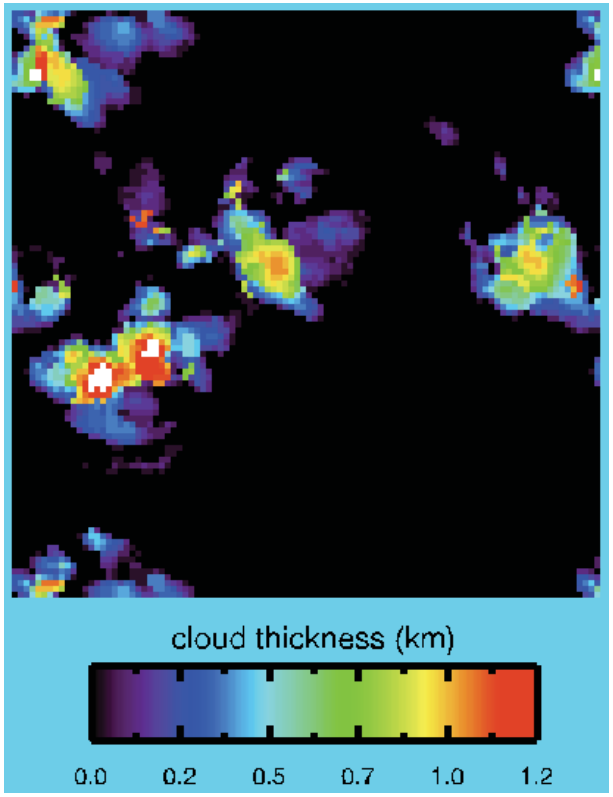
Cloud-base aerosol mix; longer wavelengths



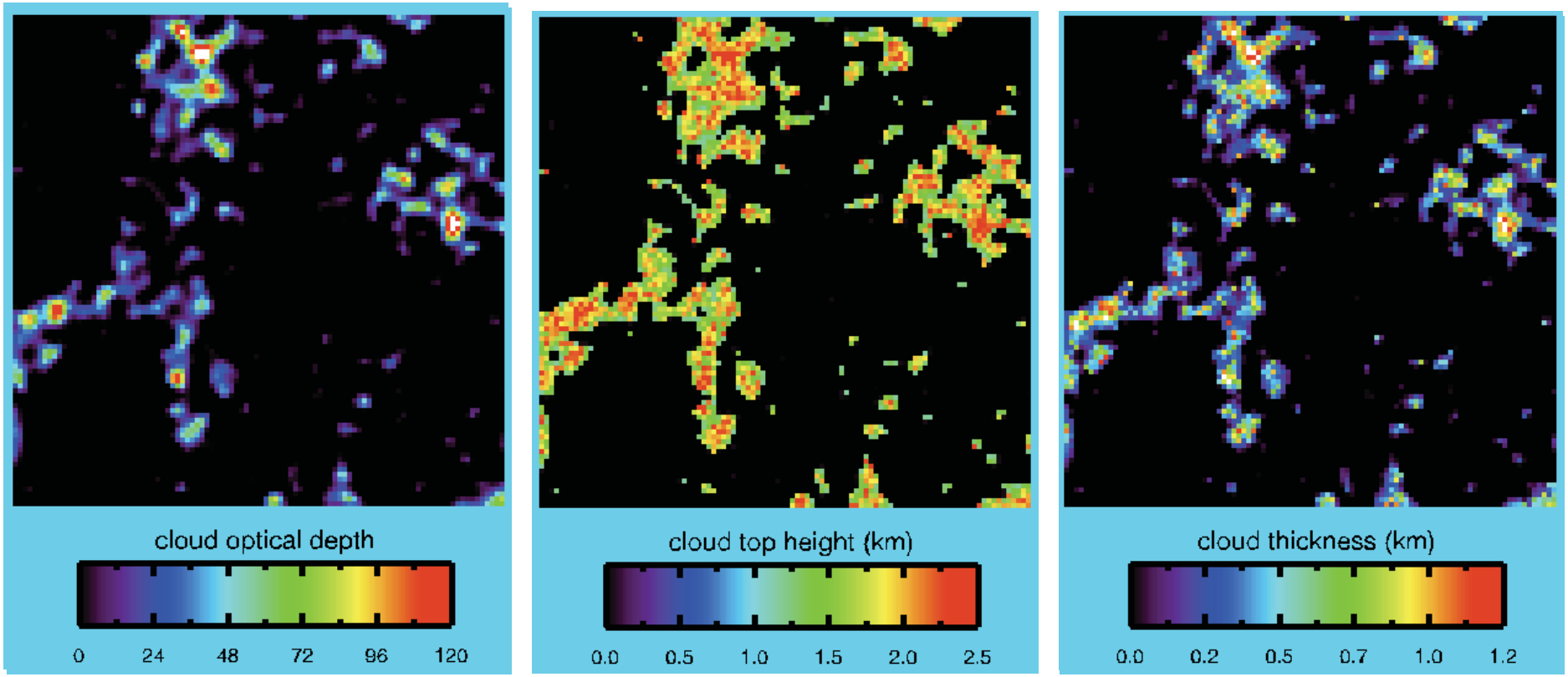
Original I3RC case





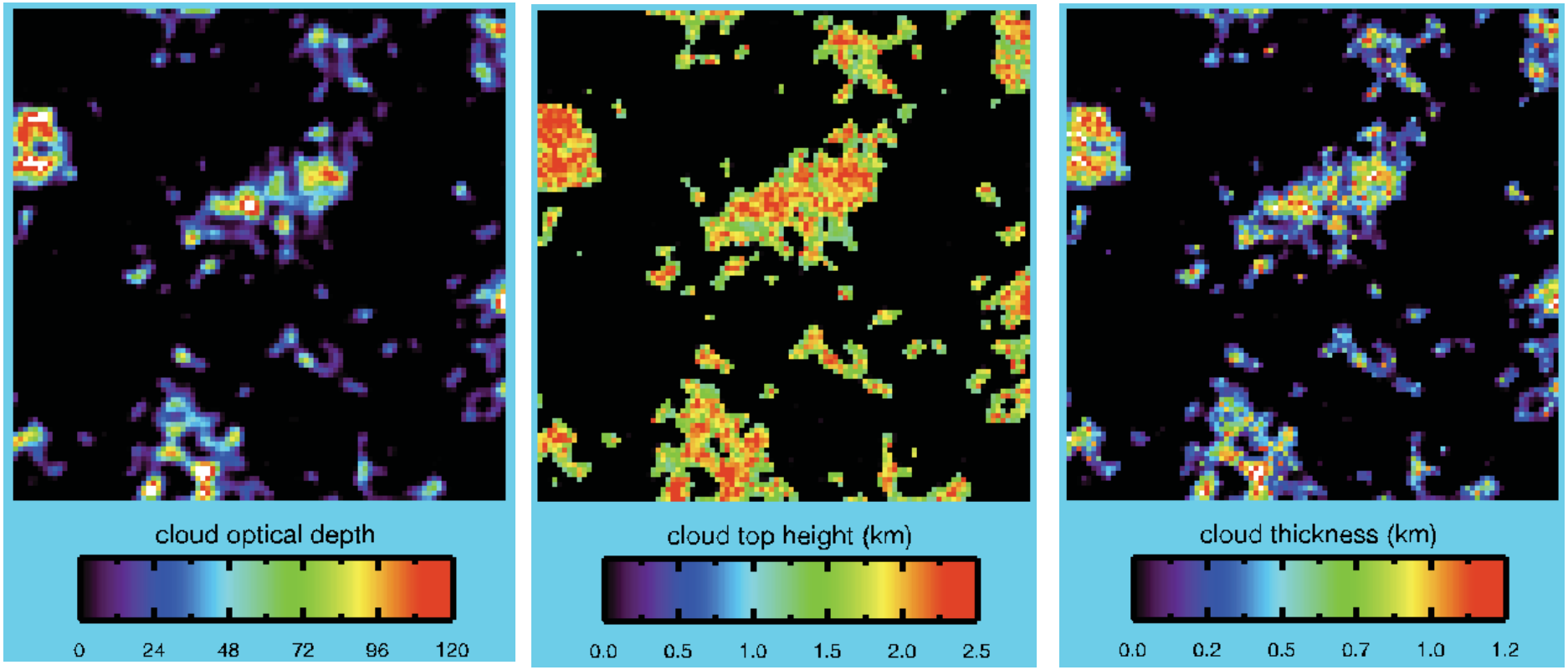


Simulation 1

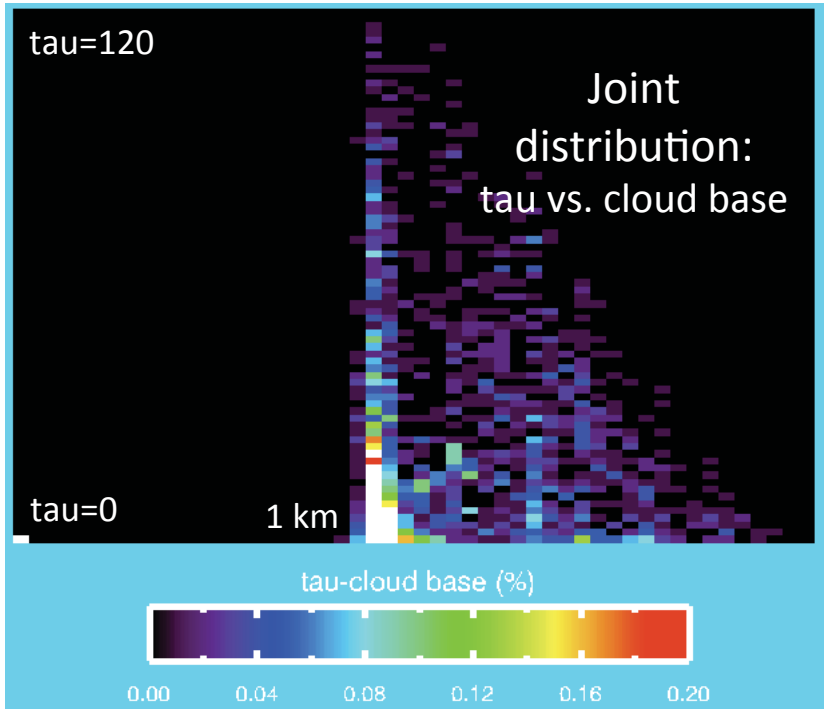


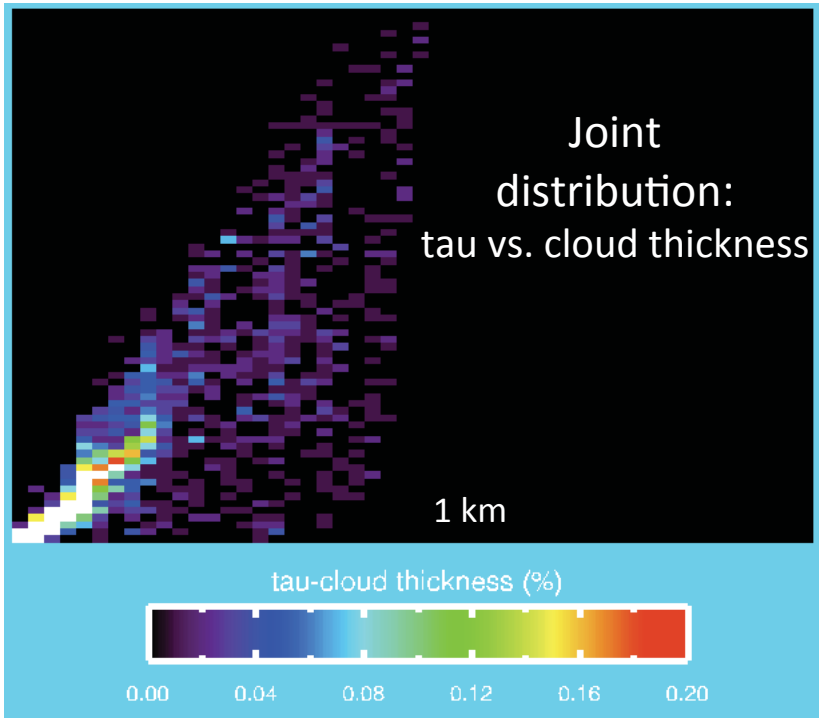
Ā based on Prigarin and Marshak (2009)

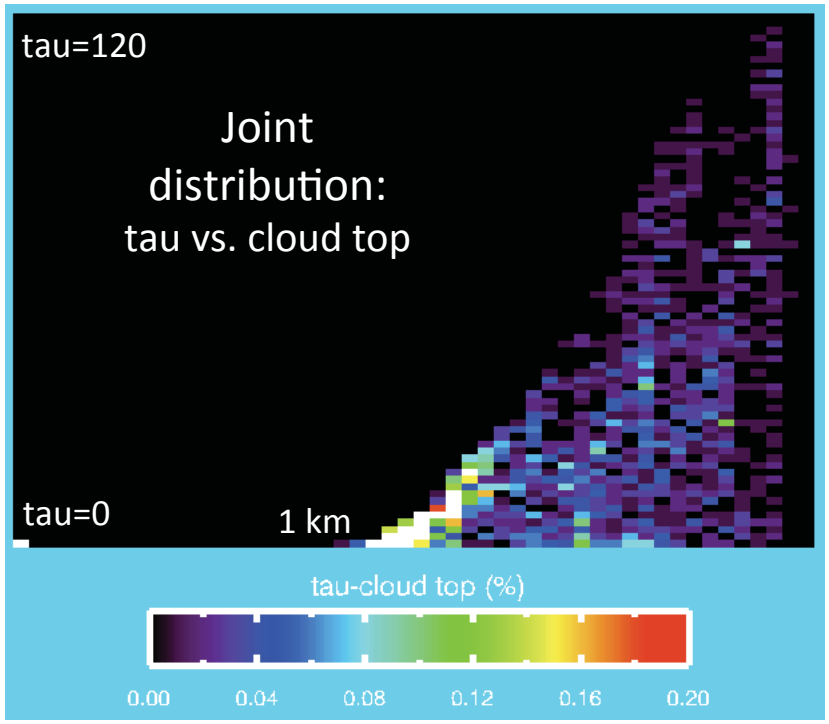
Simulation 2



Cloud top height (and geometrical thickness) is a bit noisy at small scales (it's a known feature of the model … sorry;). Can be smoothed if needed.



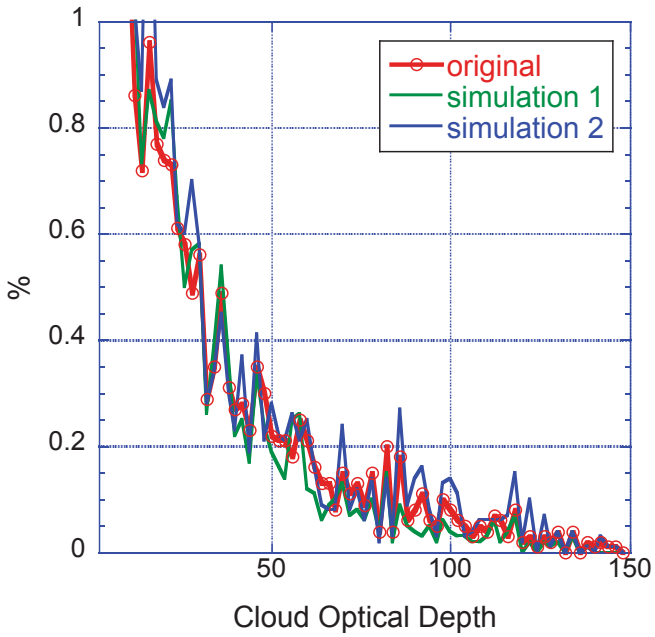




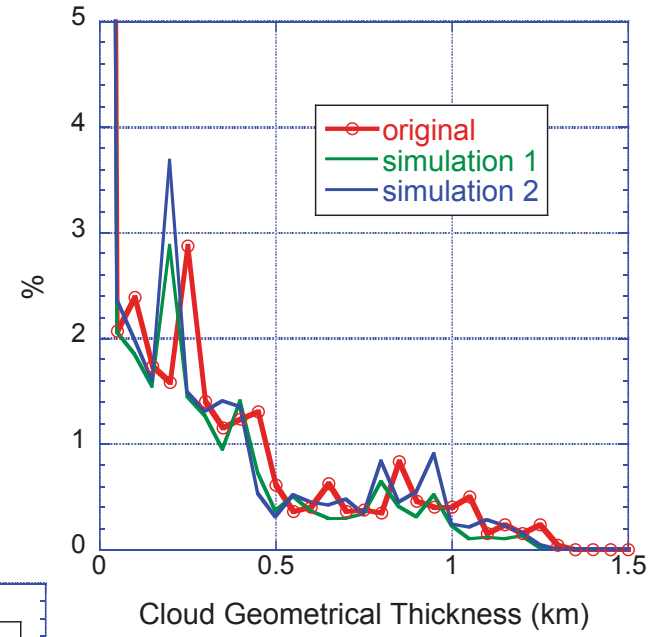
Vertical optical (tau): 0-120
Horizontal geometrical (base, top, thickness): 0-2.5 km

Joint Distributions

1D Statistics

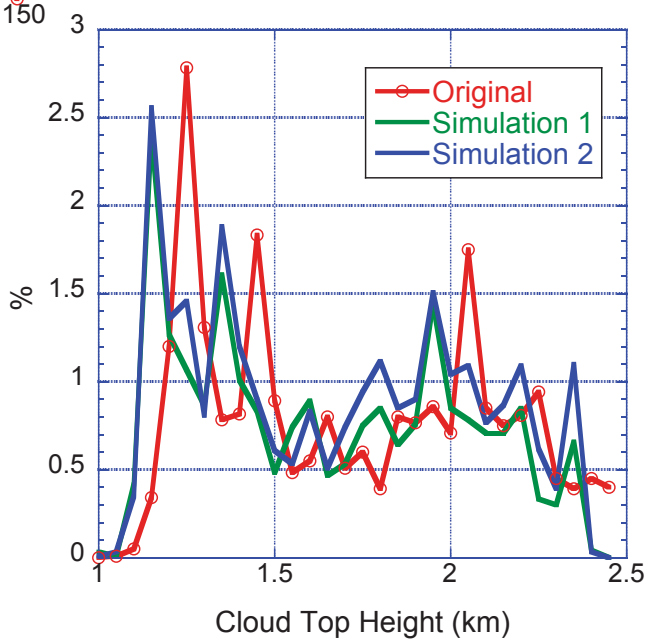


Cloud optical thickness



Cloud geometrical thickness

Cloud top height



Cloud top height histogram seems like shifted 100 m (shouldn't be; don't know why)

Conclusions

- 3D vRT effects are in the signal, not in the noise
- Computational tools are in place

Next Steps

- Master vMYSTIC input, not just output specs
- Assess robustness of APS signals w.r.t. a switch to statistically equivalent clouds
- Explore 3D RT damage mitigation strategy, using mean-field Markovian RT model

Thank you!

Questions?

Acknowledgment:

support from NASA/SMD/ESD/Radiation Sciences

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