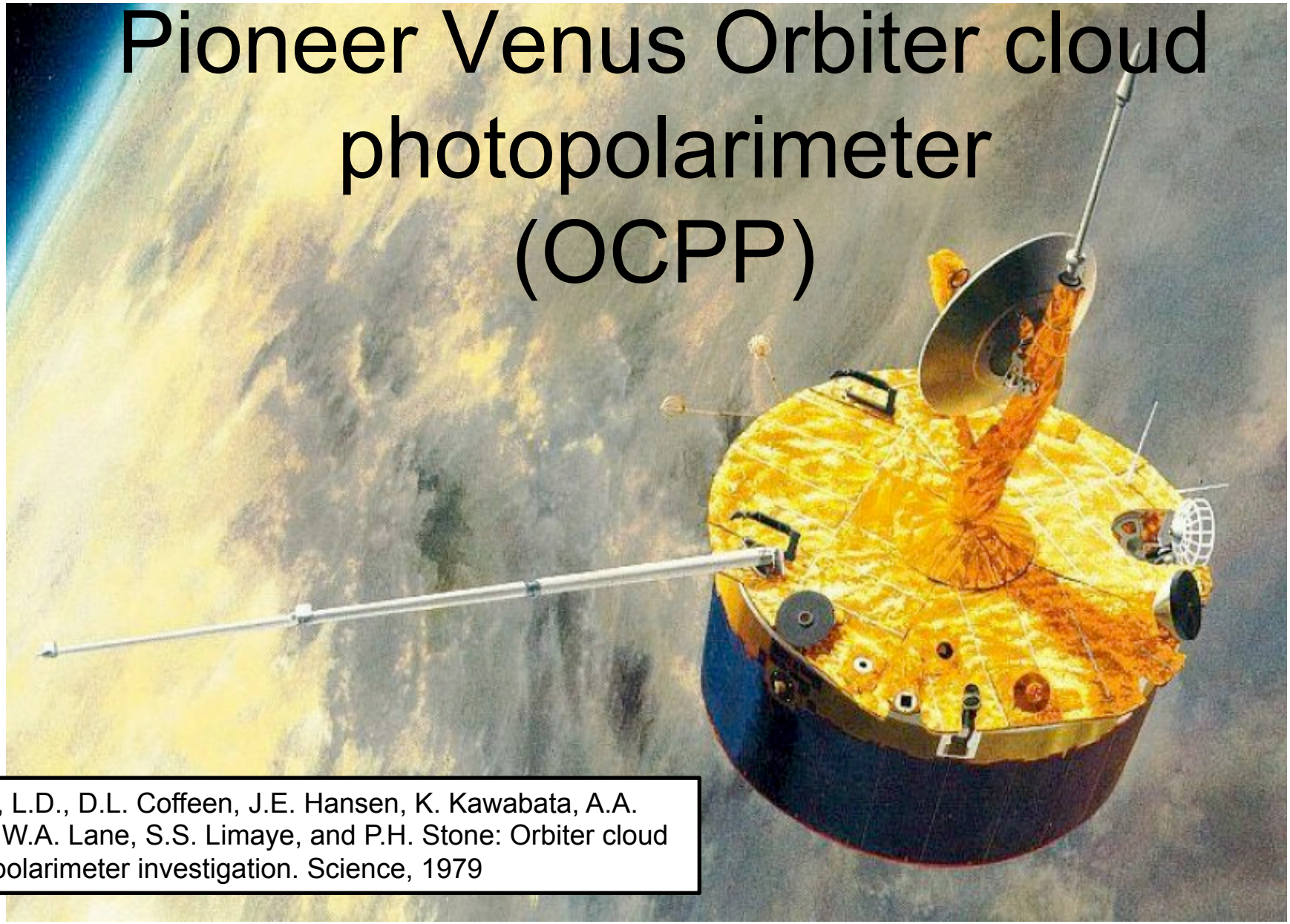
The Research Scanning Polarimeter (RSP)

Heritage, measurement concept, and application to aerosol and cloud property retrievals

RSP Team: Brian Cairns, Bastiaan van Diedenhoven, Jacek Chowdhary, Mikhail Alexandrov, Matteo Ottaviani, Andrzej Wasilewski

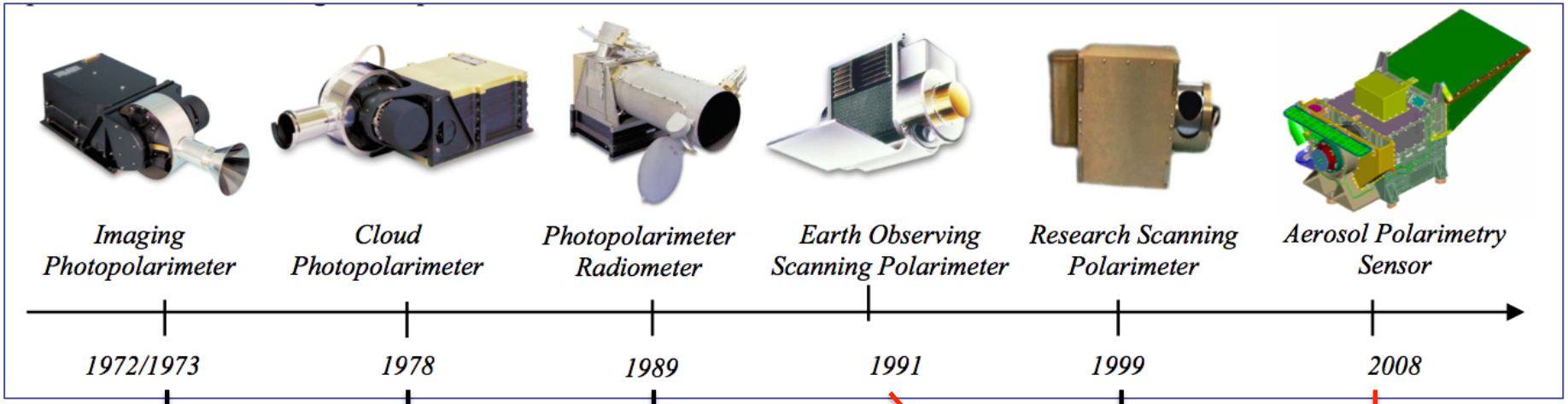
Polarimetry at NASA GISS:

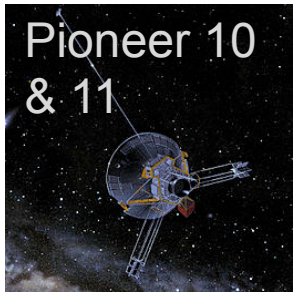
Pioneer Venus Orbiter cloud photopolarimeter (OCPP)

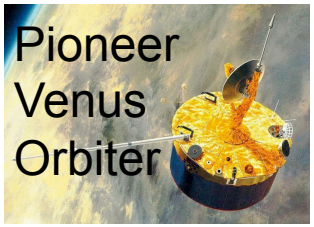


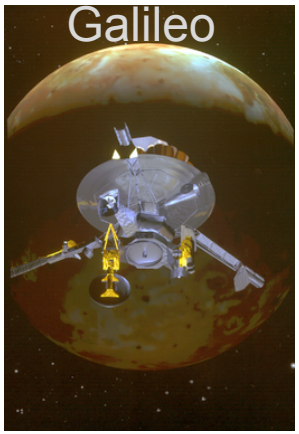
Travis, L.D., D.L. Coffeen, J.E. Hansen, K. Kawabata, A.A. Lacis, W.A. Lane, S.S. Limaye, and P.H. Stone: Orbiter cloud photopolarimeter investigation. Science, 1979

Polarimetry at NASA

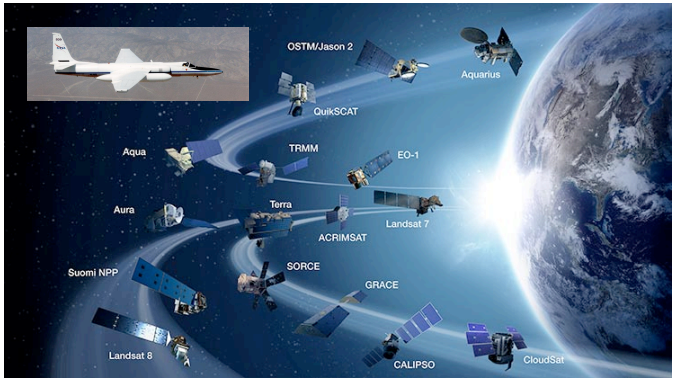


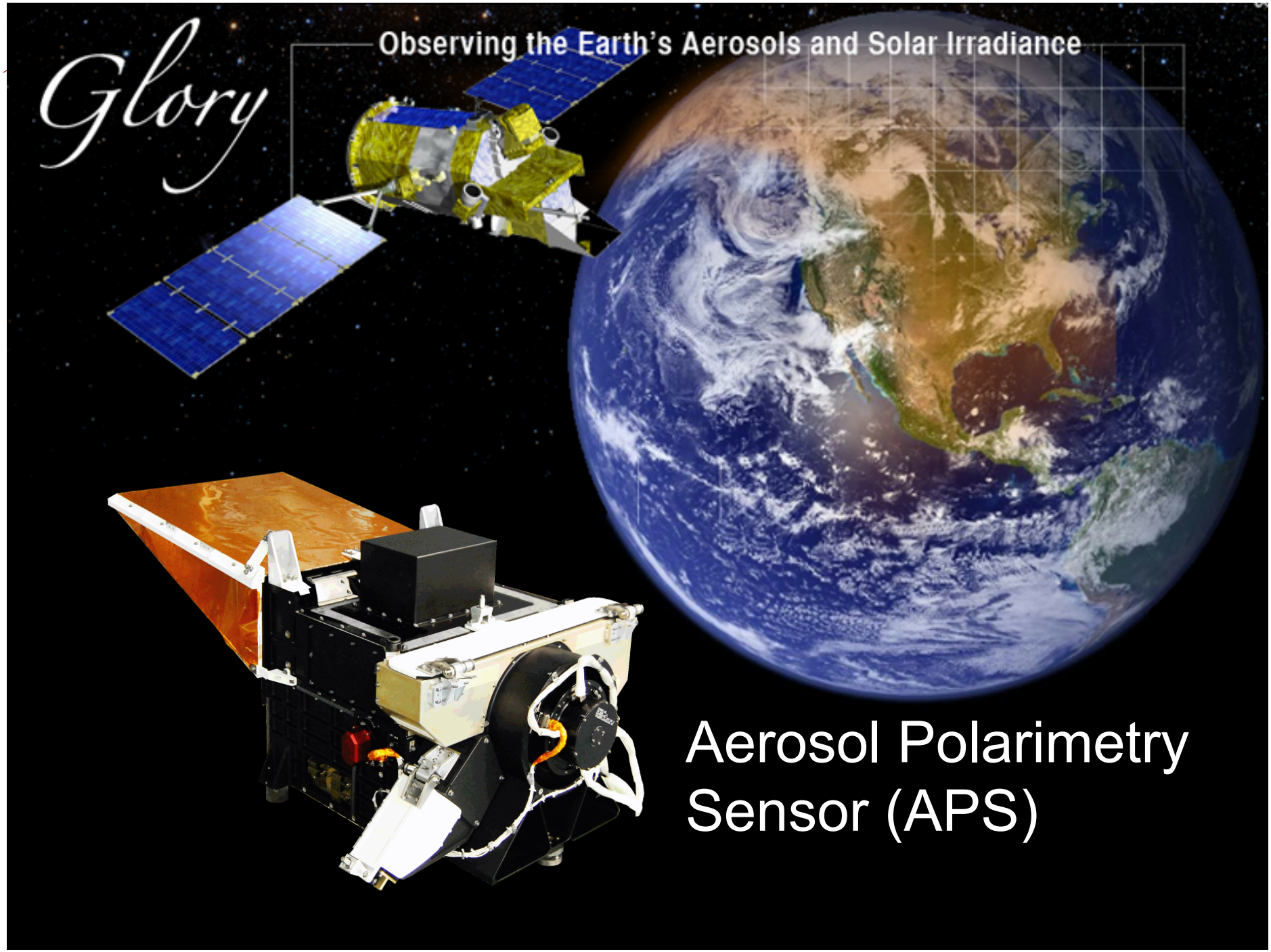




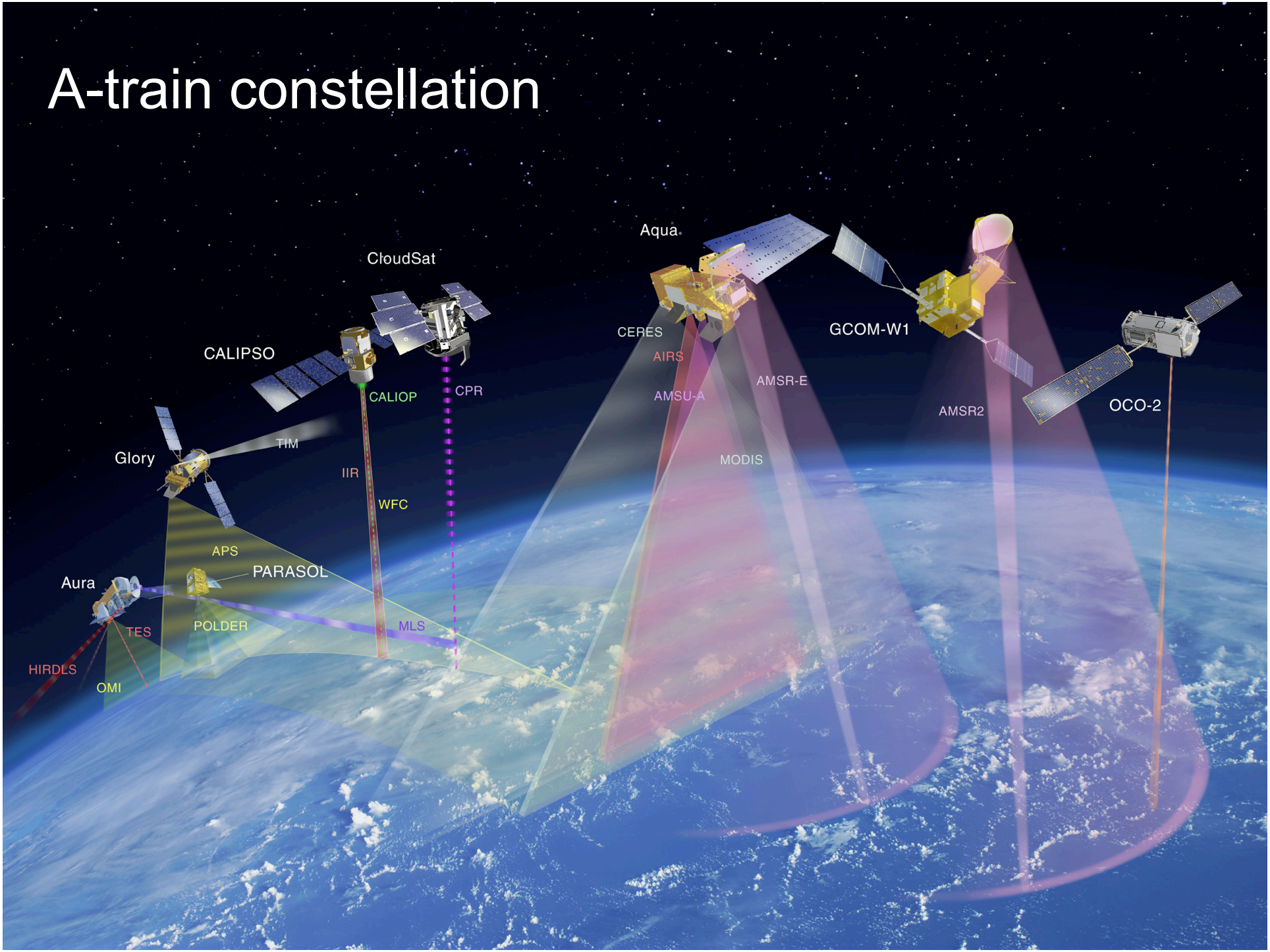


Earth Observing System (EOS)




Glory
Observing the Earth's Aerosols and Solar Irradiance
Aerosol Polarimetry
Sensor (APS)

A-train constellation



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4 March 2011 Last updated at 13:24

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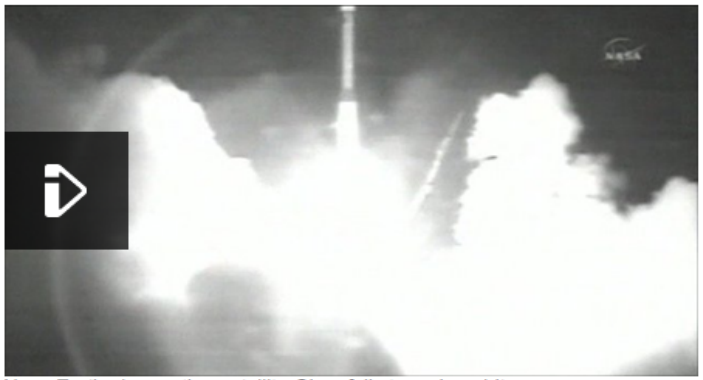
Nasa Glory mission ends in failure

By Jonathan Amos
Science correspondent, BBC News



Nasa Earth observation satellite Glory fails to make orbit

The US space agency's (Nasa) attempt to launch its latest Earth observation mission has ended in failure.

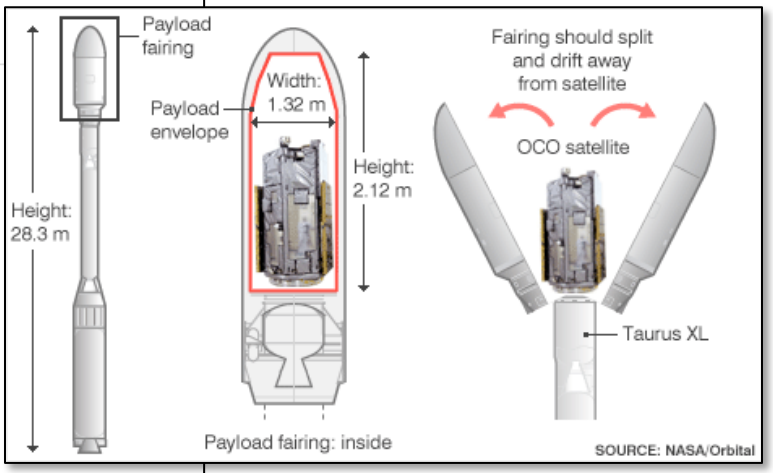
The Glory satellite lifted off from California on a quest to gather new data on factors that influence the climate.

But about three minutes into the flight, telemetry indicated a problem.

It appears the fairing - the part of the rocket which covers the satellite on top of the launcher - did not separate properly.

This would have made the rocket too heavy and therefore too slow to achieve its intended 700km orbit.

"All indications are that the satellite and the rocket are in the Southern Pacific Ocean somewhere," said launch director Omar Baez.

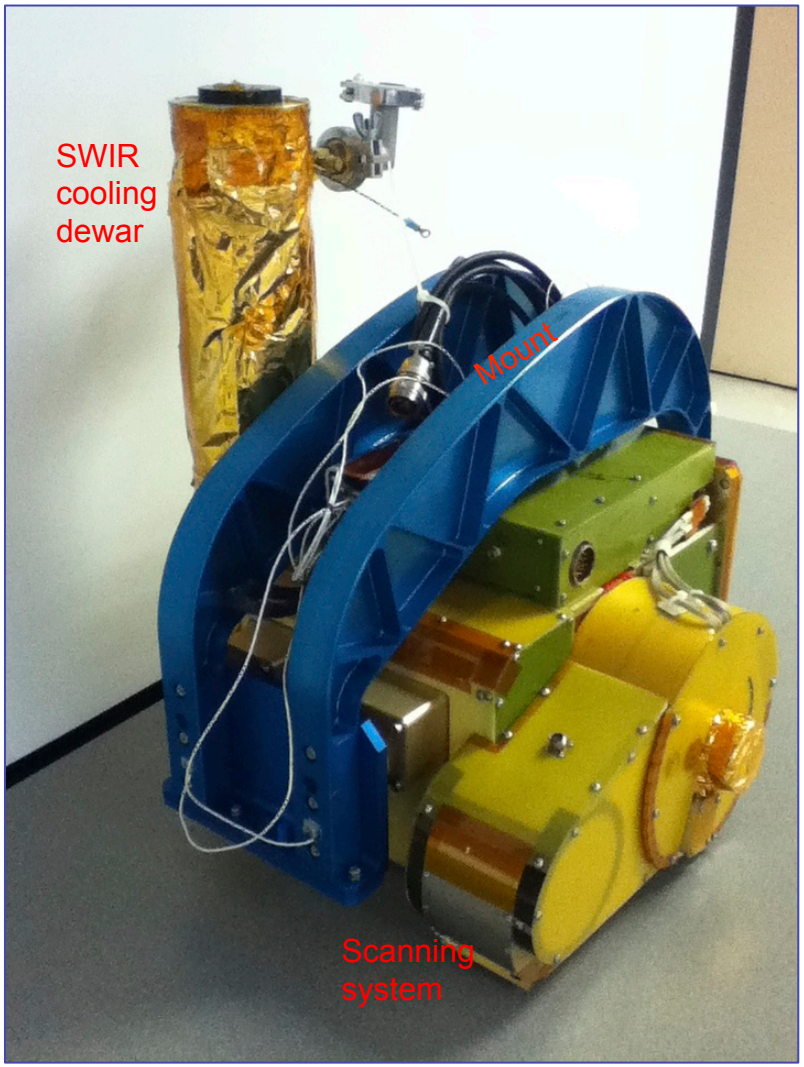


Related Stories

- Failure hits Nasa's 'CO2 hunter'
- Euro space laser gets go ahead
- Climate change glossary: A-B

Airborne RSP: Instrument and Overview

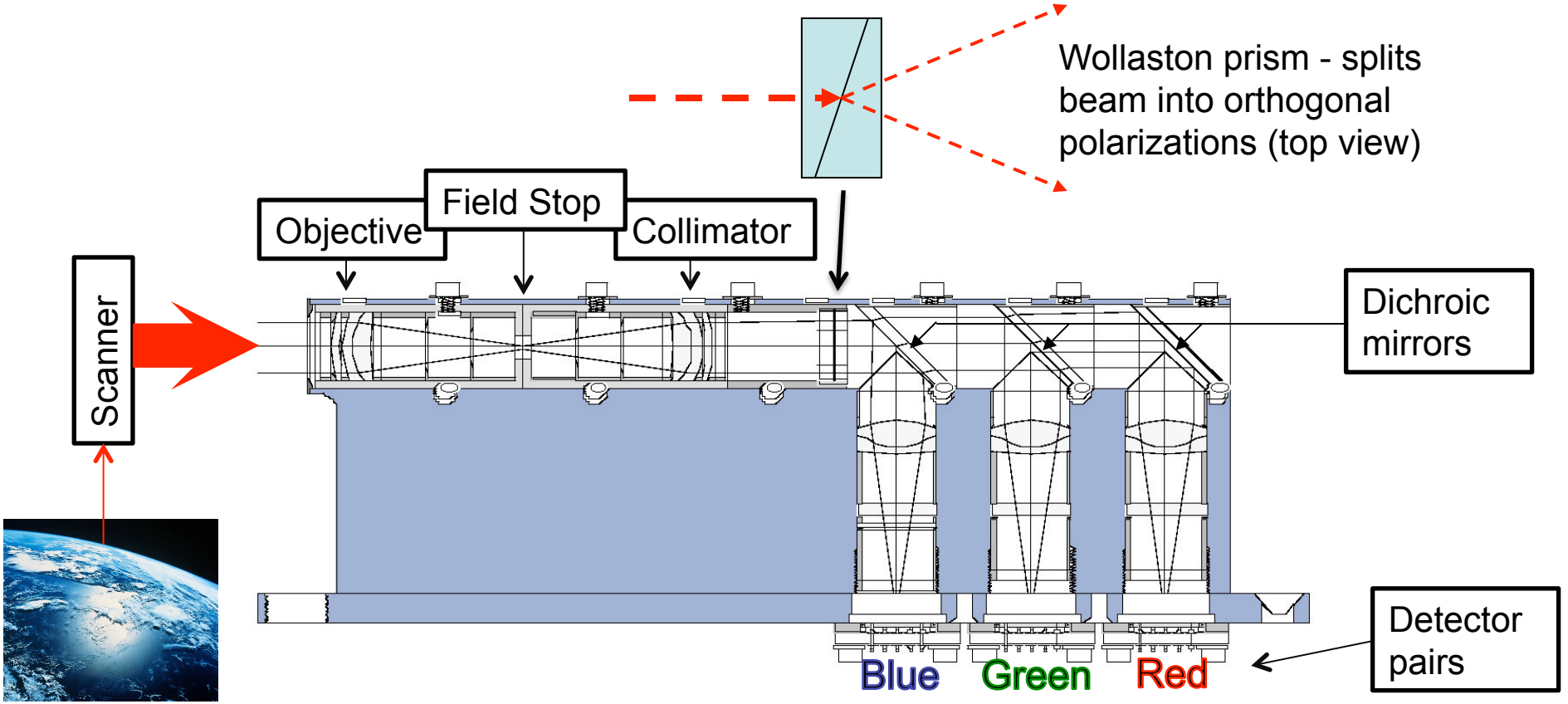
- Prototype for APS on Glory
- Two versions built in 1999 and 2001
- 152 viewing angles per scene + dark reference and unpolarized calibrator views on every scan
- 9 bands in visible and shortwave infrared:
  - 410, 470, 555, 670, 864, 960, 1593, 1880, 2263 nm for aerosols and clouds
  - 960 nm for column water vapor
  - 1880 nm for cirrus (lower atmosphere screened by water vapor absorption)
- 14 mrad Field of view
- Accuracy: polarimetric <0.5%, radiometric <5%



Instrument Description – APS/RSP

The APS/RSP measurement approach:

- A Wollaston prism is used to measure orthogonal polarization states simultaneously
- In APS/RSP one telescope measures I and Q in three spectral bands and a second telescope measures I and U in the same spectral bands.
- In total 6 telescopes are used for I, Q and U in 9 bands

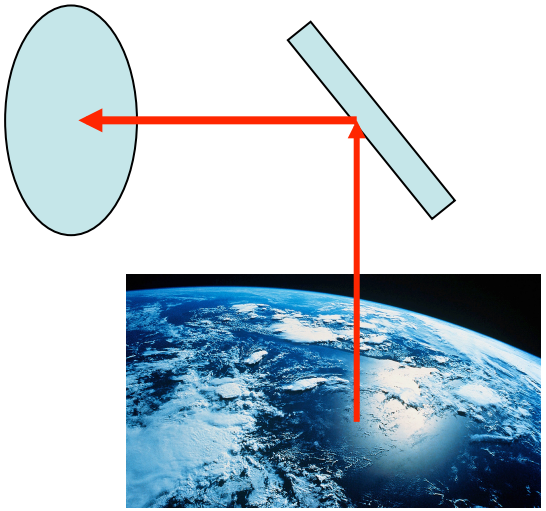


Instrument Description – APS/RSP

APS/RSP Scanning

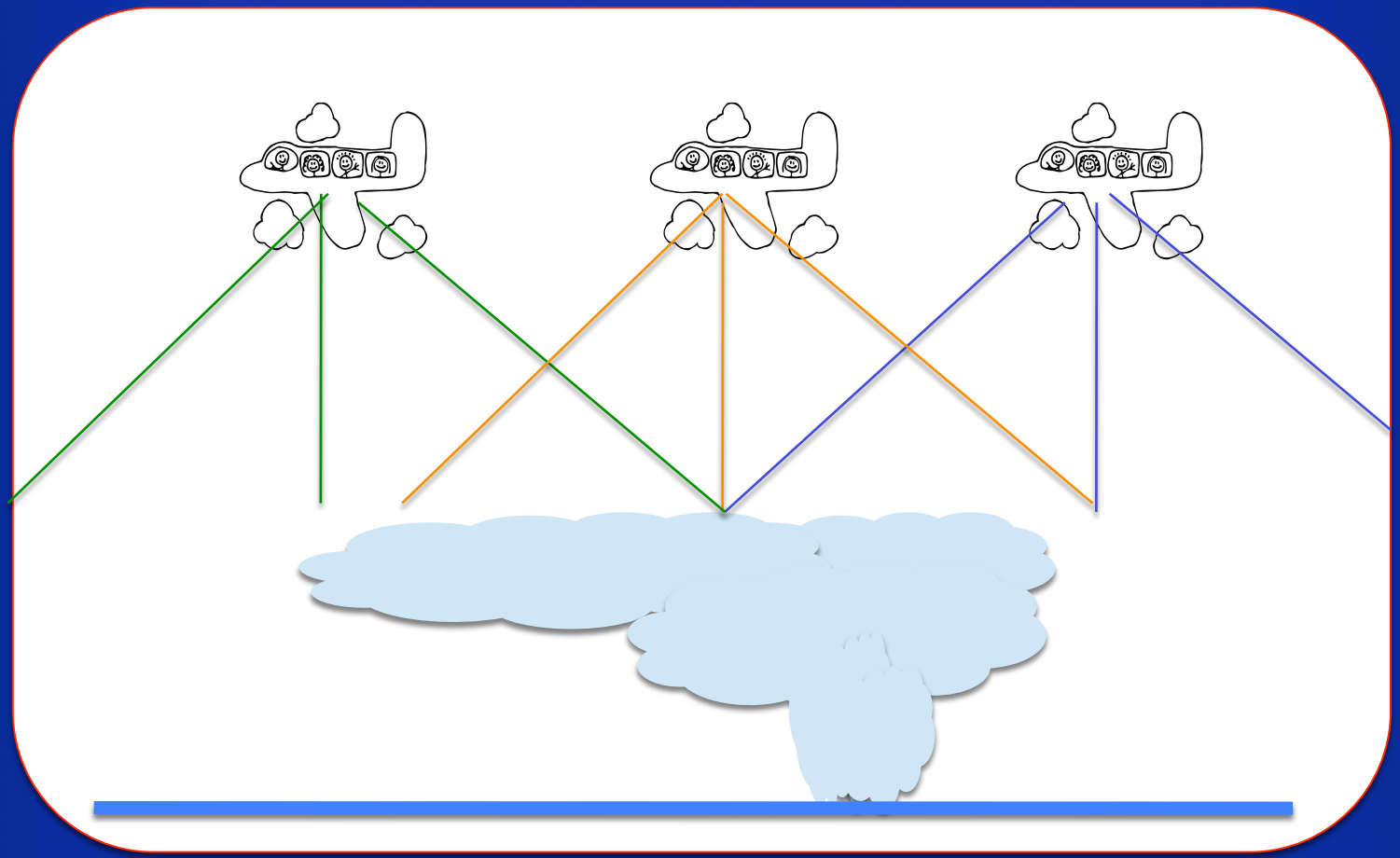
- APS/RSP scans along flight track to get multiple viewing angles, but has no imager capabilities.
- Identical crossed mirrors are used that introduce no polarization
- Polarization induced by scan mirror assembly of RSP was not measurable <<0.1%.
- A dark reference and unpolarized calibrator is also viewed at each scan. (APS included polarized calibration source too.)

Scanner uses matched mirrors illuminated at 45° with reflection planes at 90° to one another

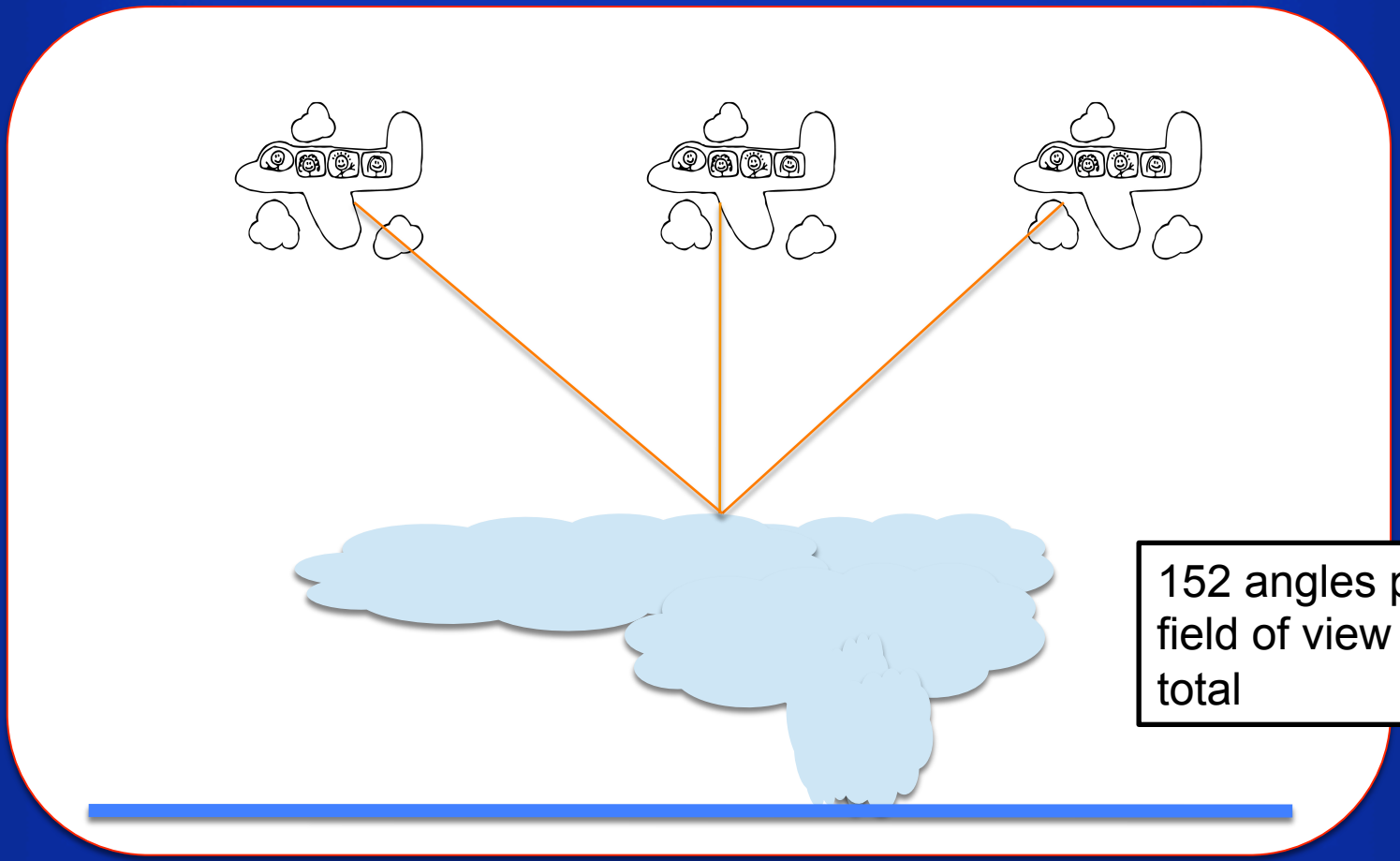


RSP mirror alignment setup

RSP multi-angle measurements



RSP multi-angle measurements



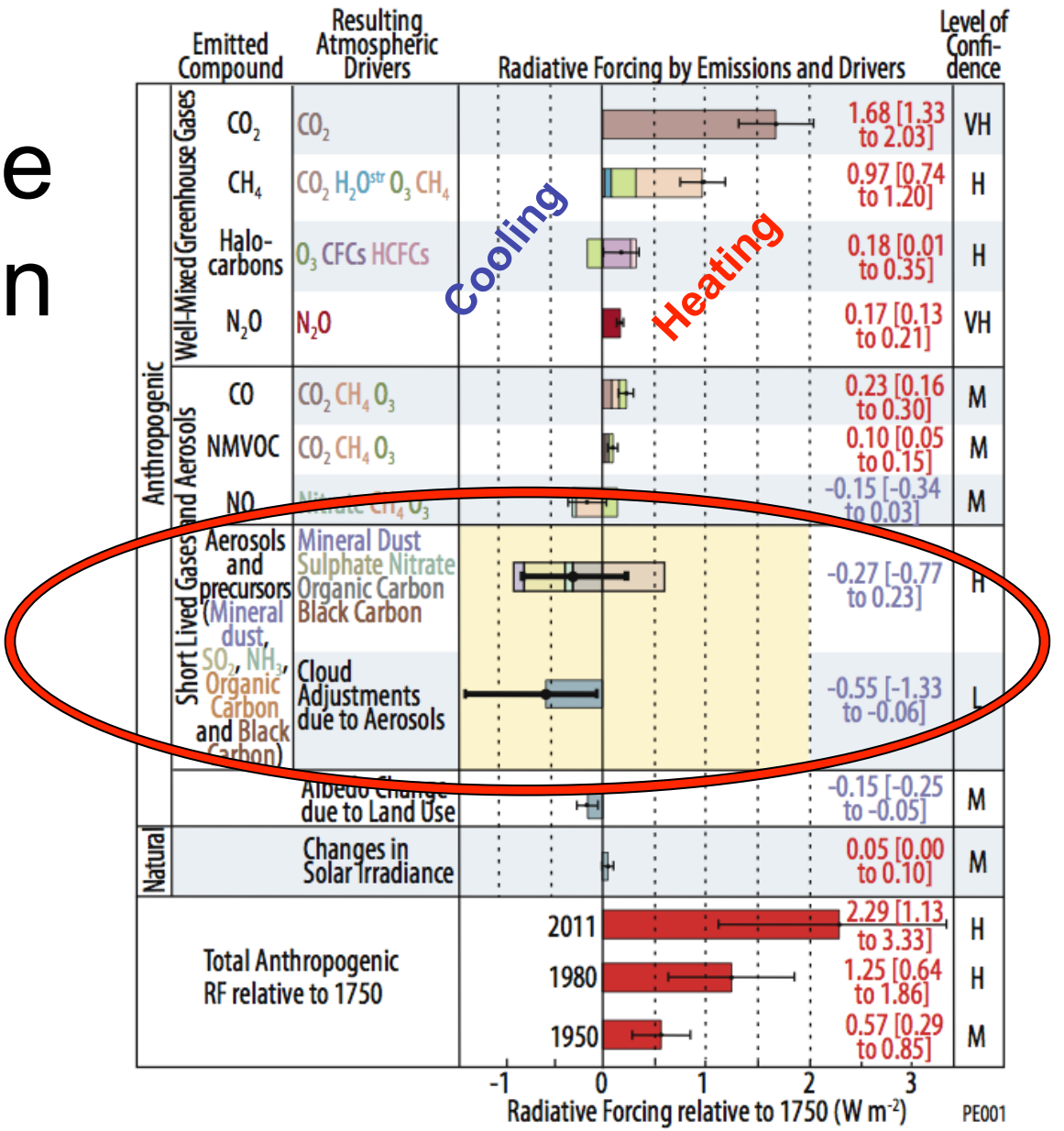
152 angles per field of view in total

RSP campaigns (incomplete)

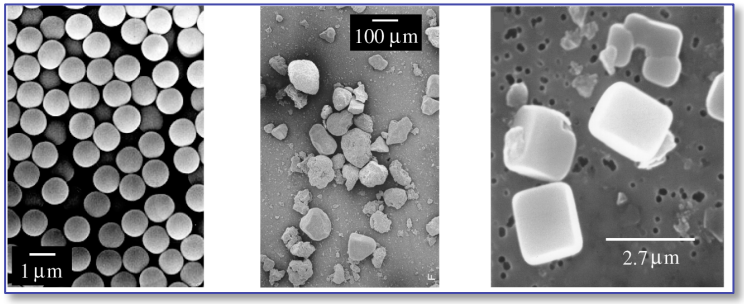
Campaign	Year	Aircraft
CLAMS, CSTRIPE	2001	Cessna
IHOP, CRYSTAL-FACE	2002	Proteus (18 km)
ALIVE, MILAGRO	2005, 2006	J31
ARCTAS	2008	B200
RACORO, CALNEX, CARES, COCOA	2009, 2010	B200
DEVOTE	2011	UC12
TCAP	2012	B200
PODEX, SEAC4RS	2013	ER-2 (20 km)

Providing crucial climate information on aerosol and clouds

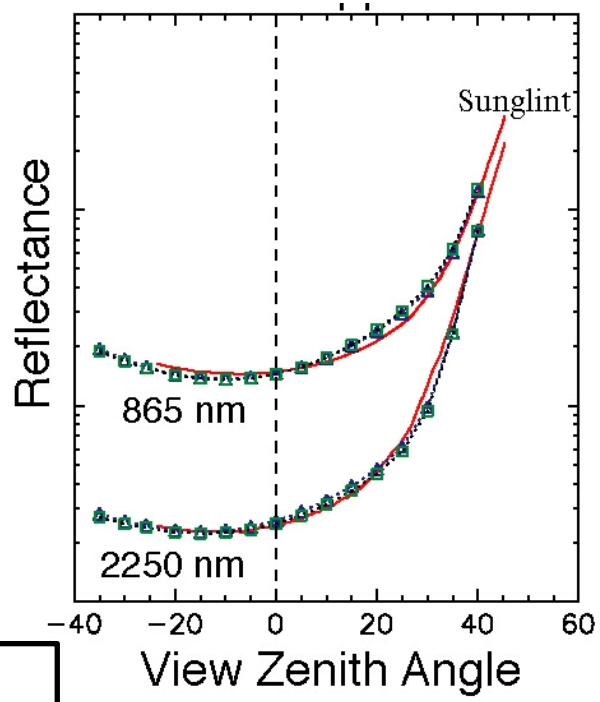
International Panel on Climate Change 2013

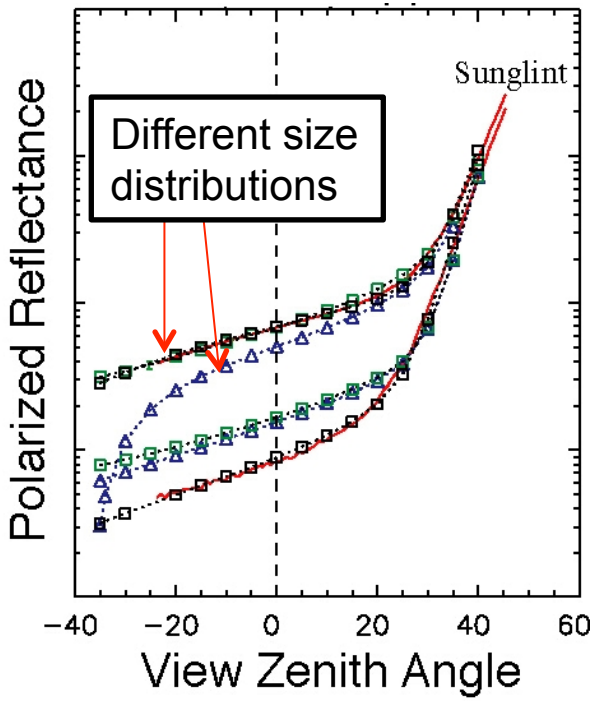


Advantage of multi-directional polarization



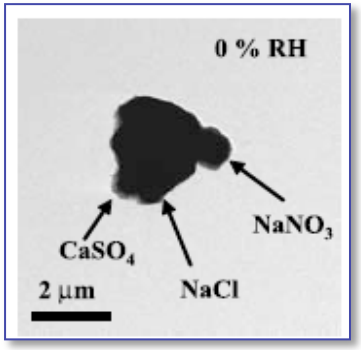
- Multi-angle polarization provides better constraints on aerosol **size**



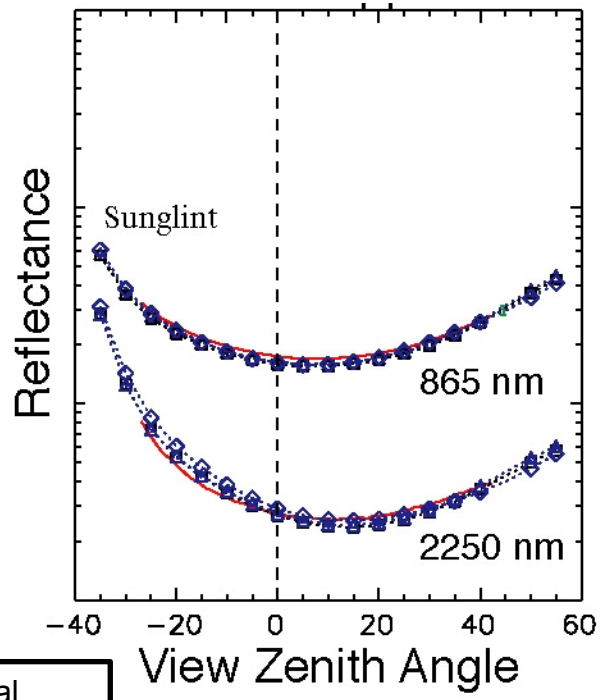


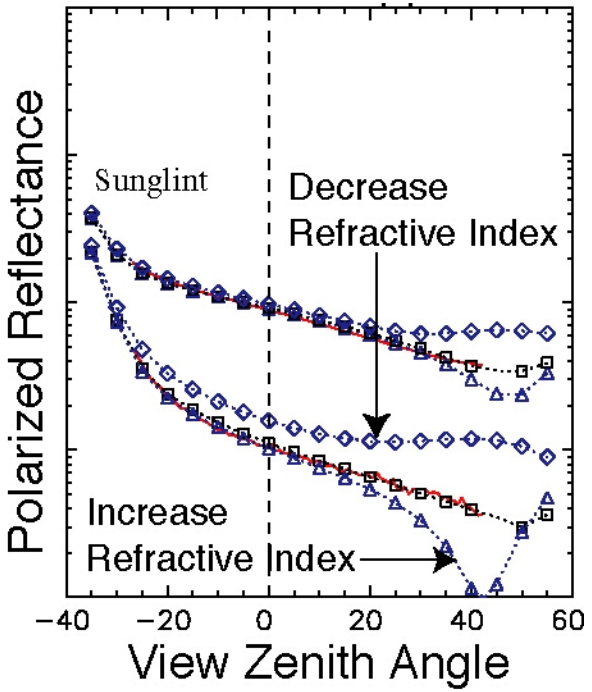
Chowdhary et al., GRL 2001

Advantage of multi-directional polarization



- Multi-angle polarization provides better constraints on aerosol **composition**

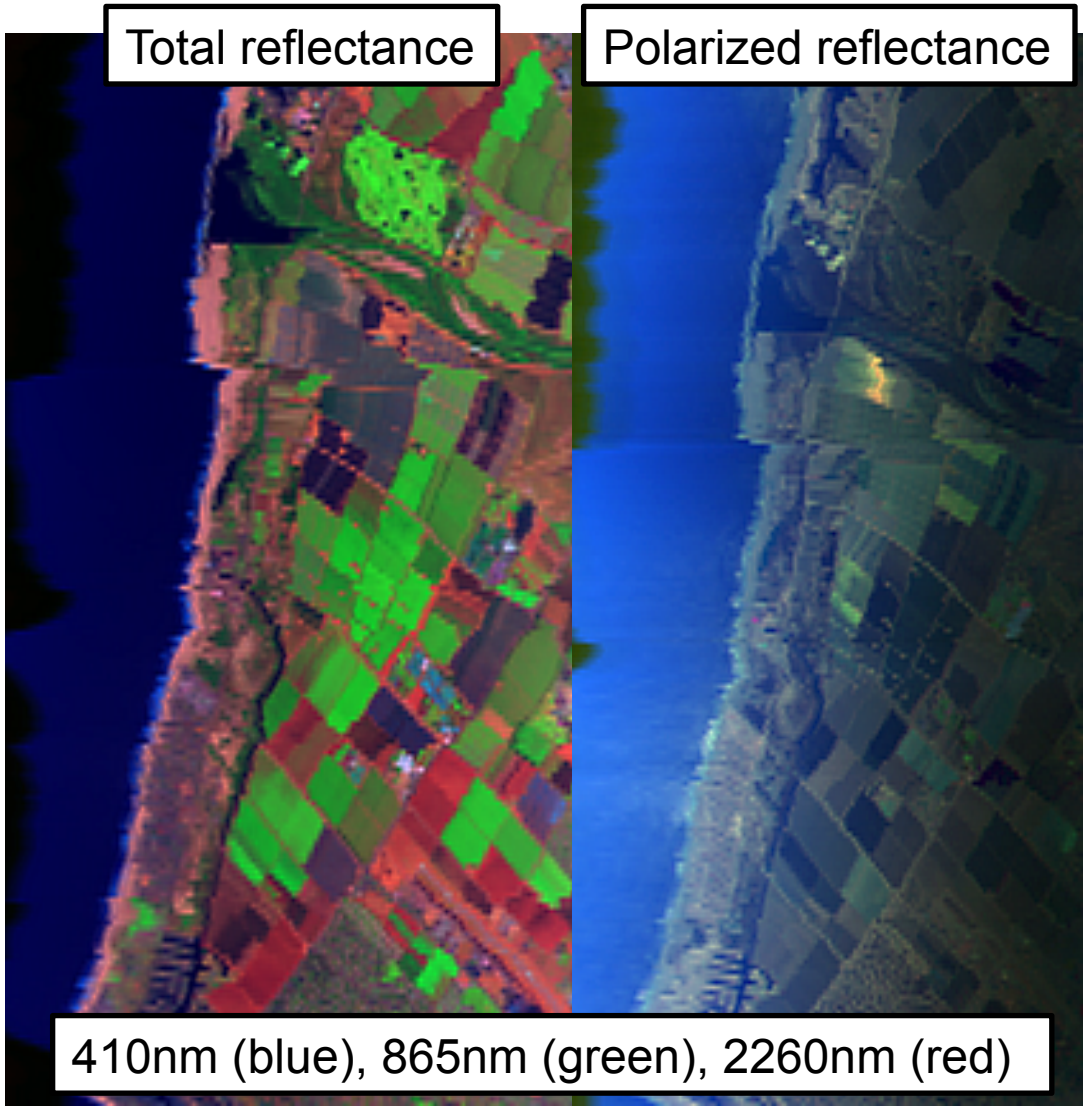




Chowdhary et al., GRL 2001

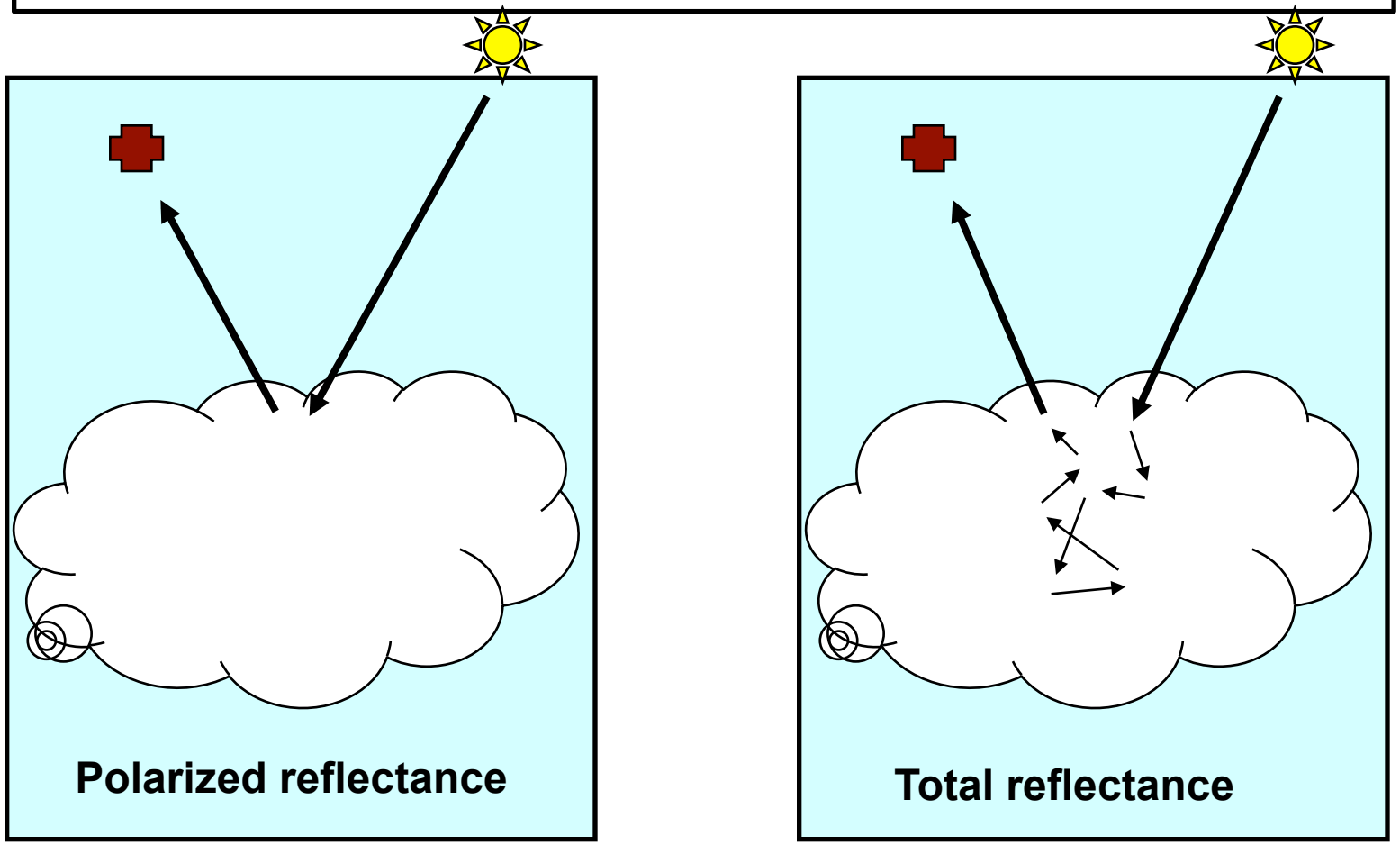
Advantage of multi-directional polarization

- Polarized surface reflectance generally darker and greyer

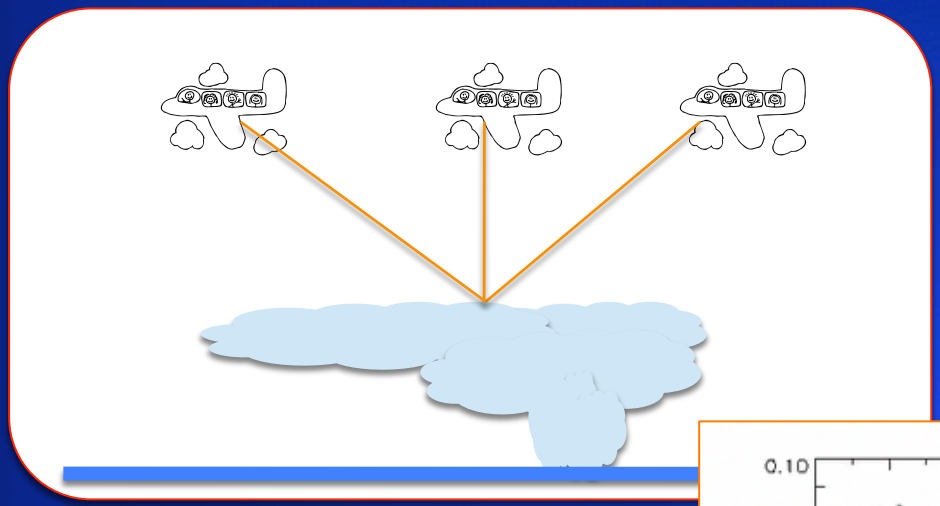


Advantage of multi-directional polarization: Clouds

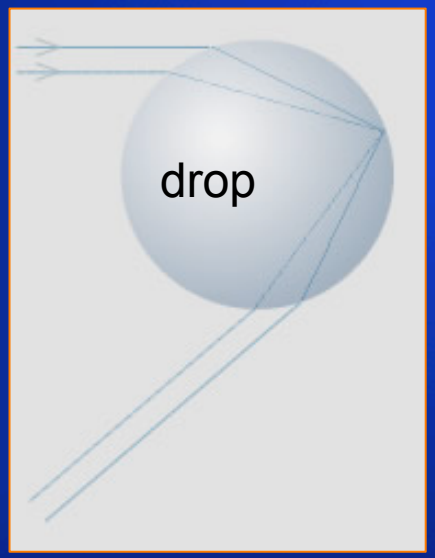
Polarization probes single scattering features of cloud particles

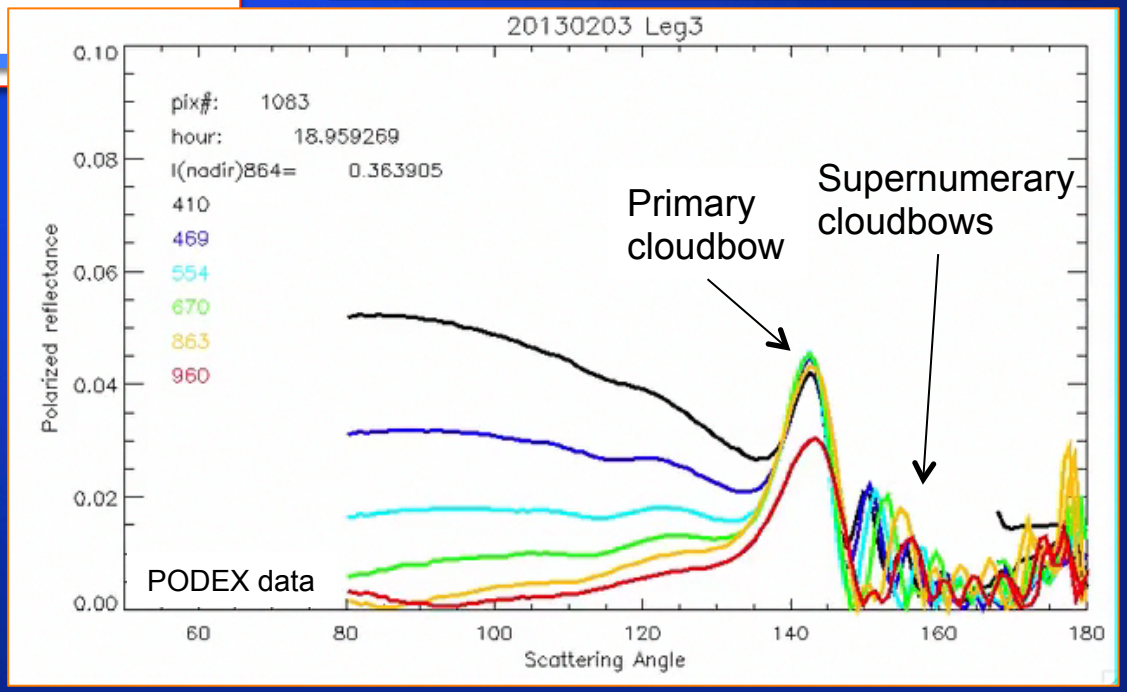


RSP example: liquid clouds



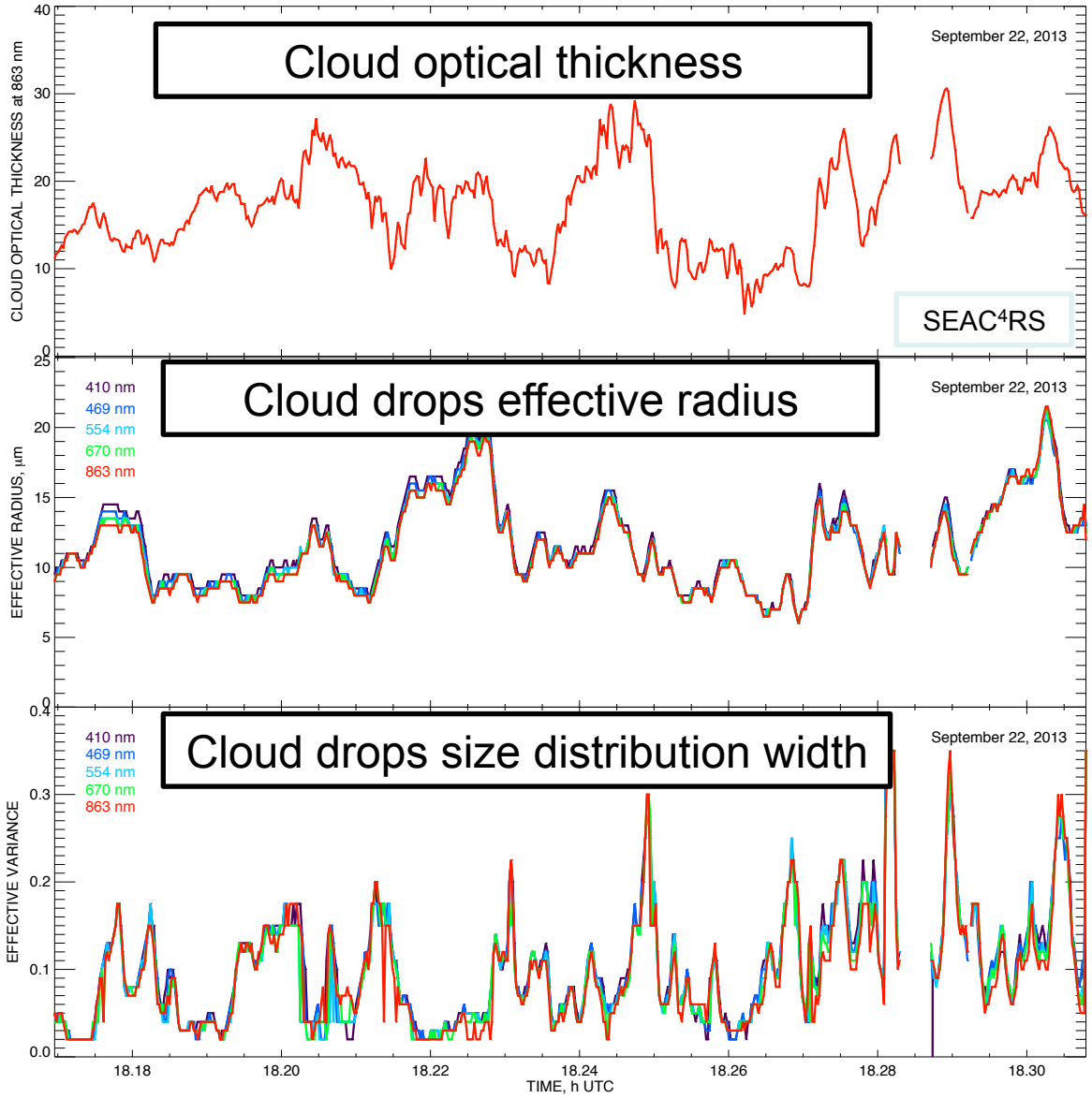
Every frame in the movie represents an RSP measurement at a different location on the cloud





Retrieval of cloud drop size distributions

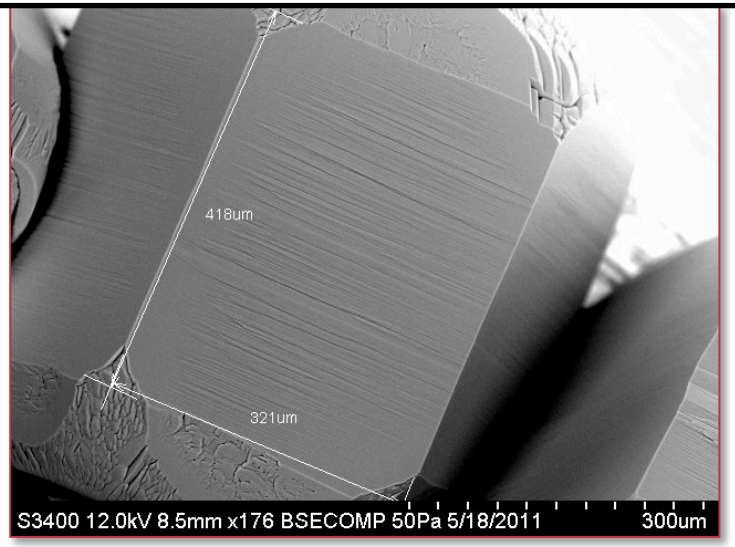
- RSP Provides unique retrievals of cloud drop size distributions
- Crucial for studies on aerosol effects on clouds



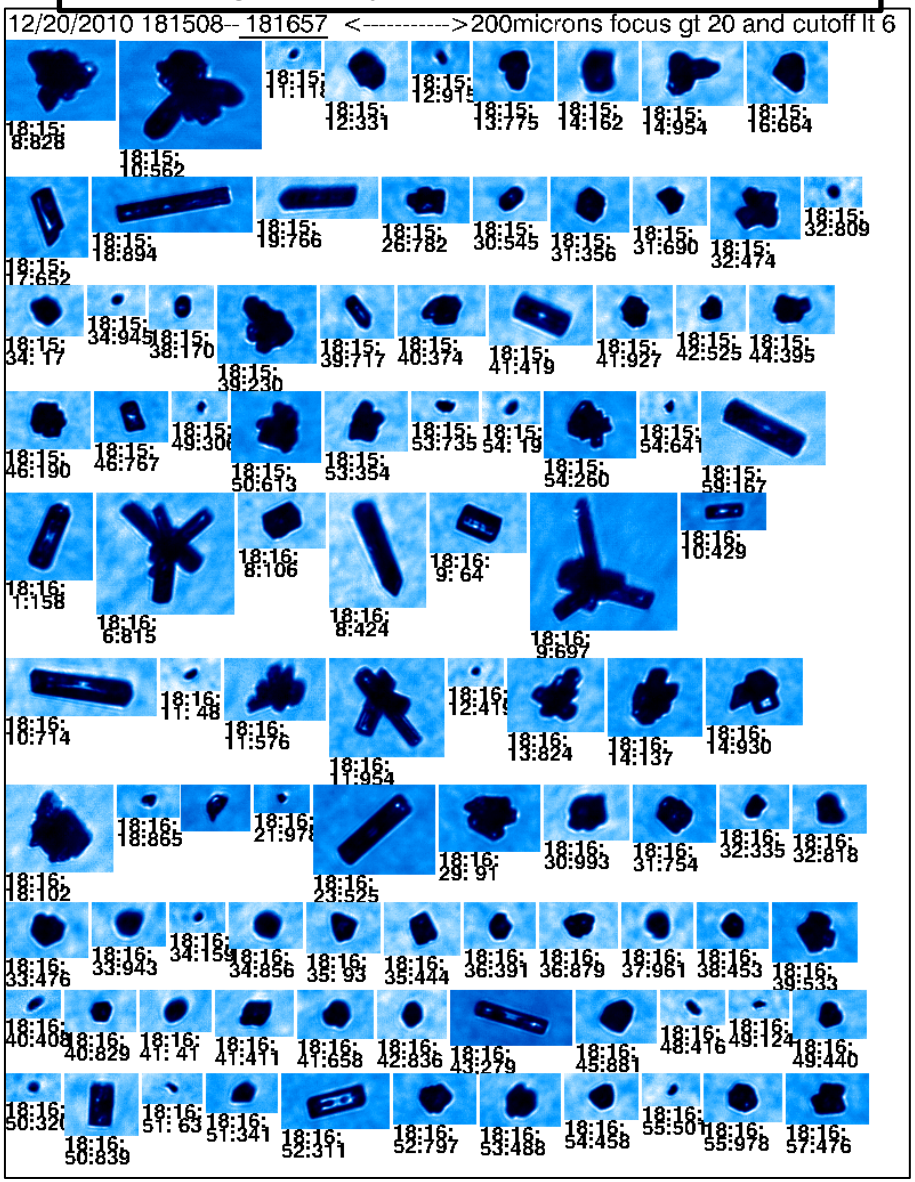
Alexandrov et al., 2014

Retrieval of ice cloud properties

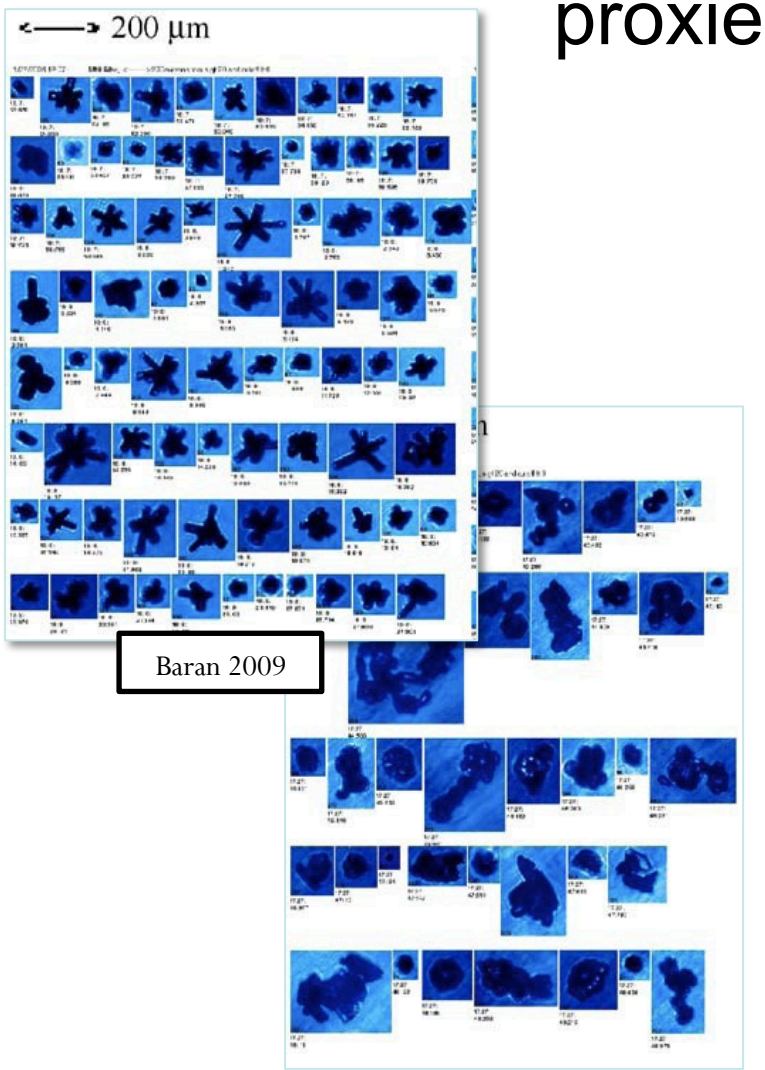
Scanning electron microscope images revealing rough/distorted crystals
From Steven Neshyba



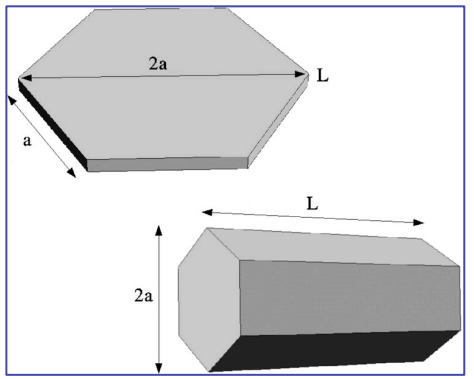
Cloud probe images of ice crystals revealing variety of shapes and sizes

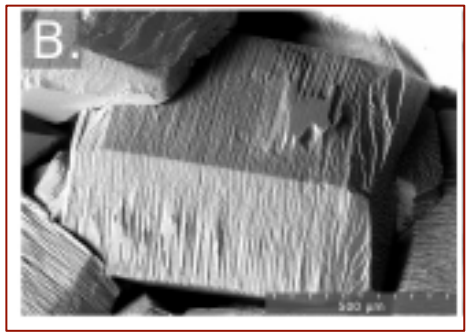


Using single hexagonal columns and plates with varying aspect ratio and distortion as radiative proxies of complex ice



Baran 2009



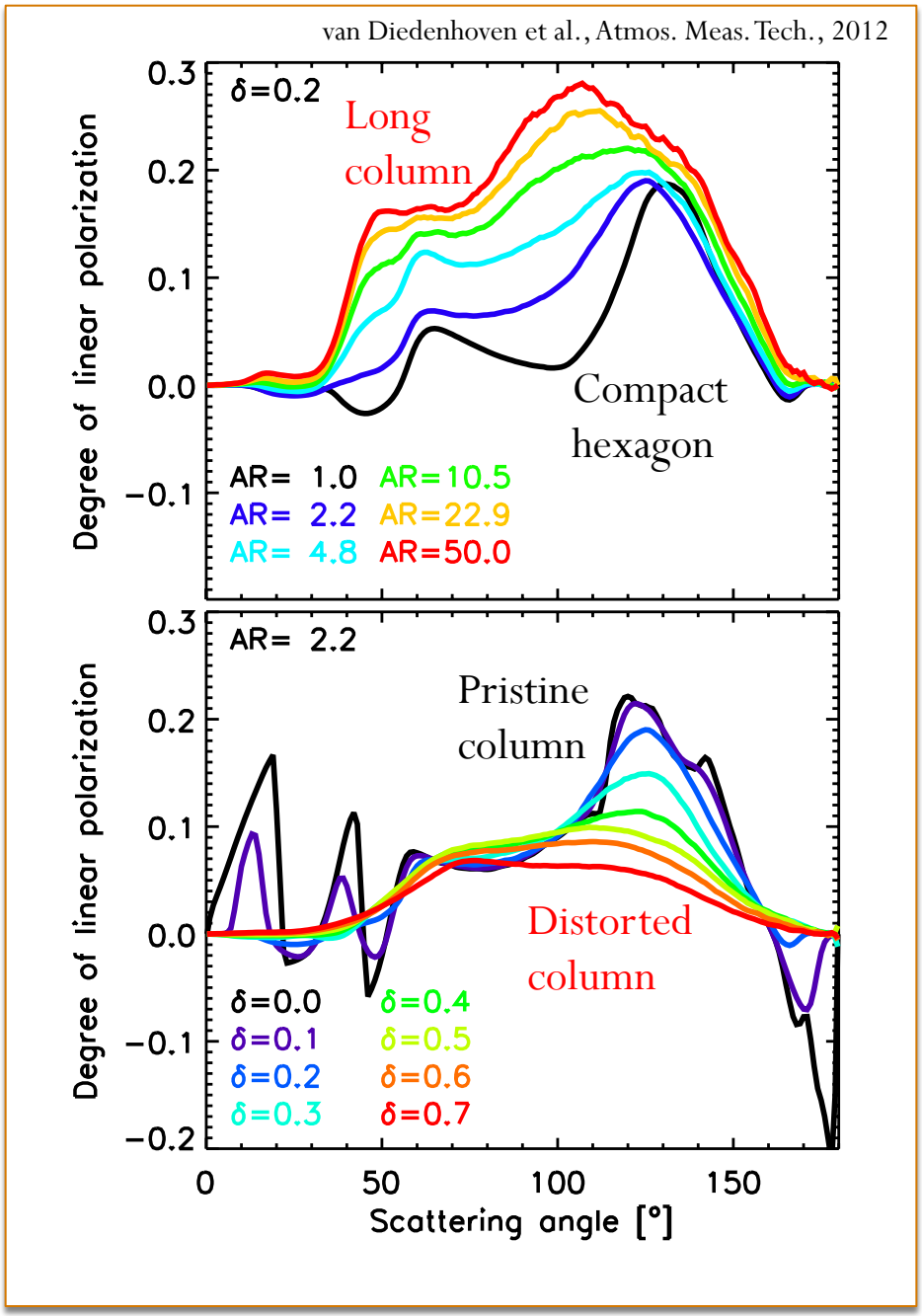


Retrieval of ice cloud properties

Polarization contains info about ice crystal

- Aspect ratio
- Distortion

Ice crystal shape crucial for radiative properties



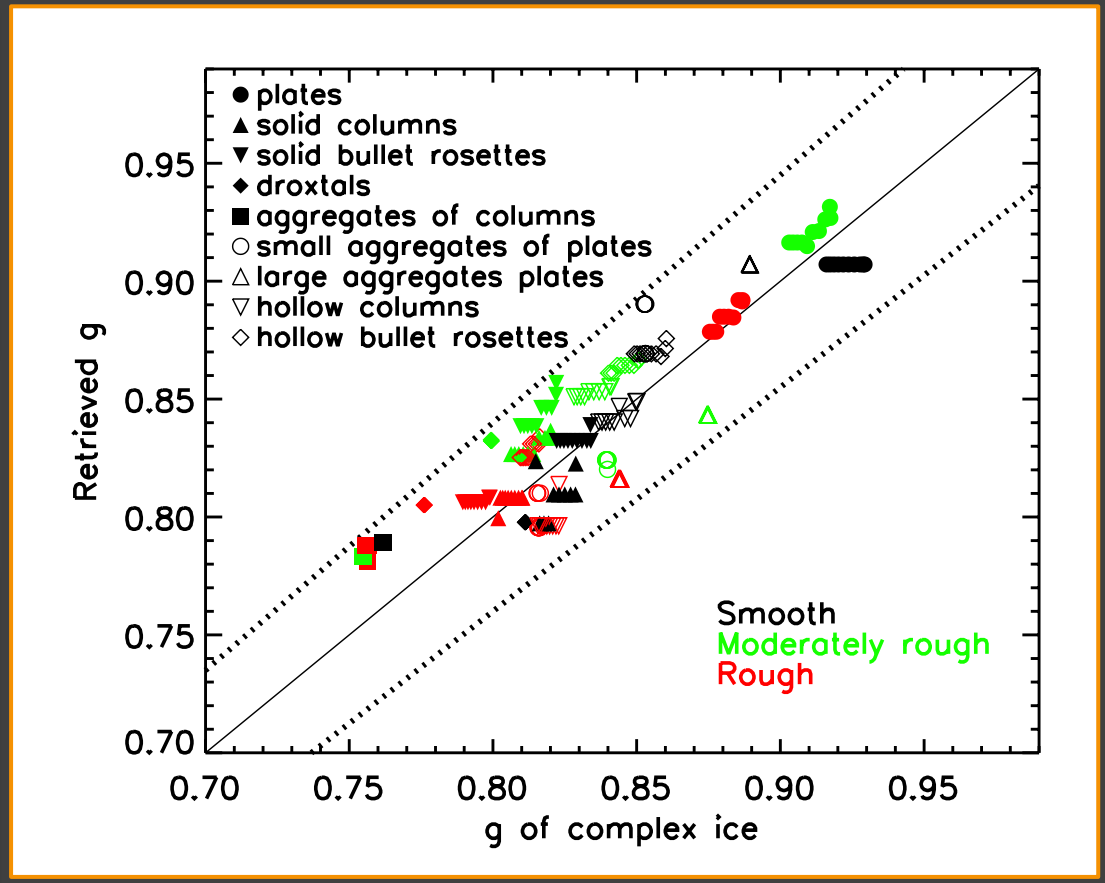
Simulated data test

Simulated data:

- Complex ice habits (Yang et al.)
- IGOM
- 3 roughness degrees
- 20 different size distributions

Retrieved asymmetry parameter

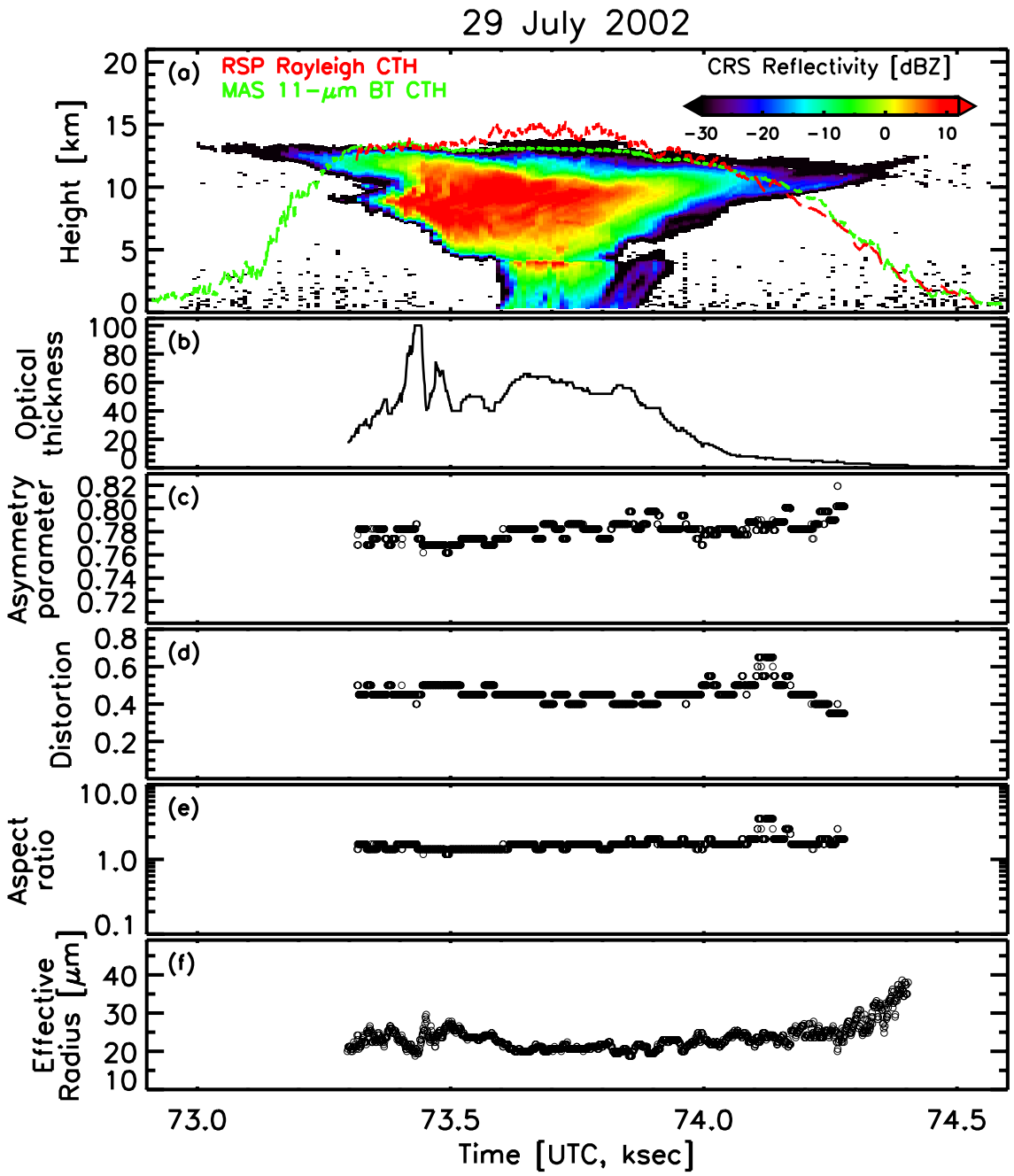
- Within 5% (0.04)
- Mean bias: 0.004
- Standard deviation: 0.02



van Diedenhoven et al.,
Atmos. Meas. Tech., 5, 2361–2374, 2012

CRYSTAL-FACE campaign Florida 2002

van Diedenhoven et al., Atmos. Chem. Phys., 13, 3185-3203, 2013



RSP products

Aerosol (2 modes)
Effective radius
Effective variance
Absorption
Refractive index (composition)
Shape (non-sphericity)
Optical thickness (total)
Aerosol info under and above clouds

Clouds
Top height
Optical thickness
Phase (liquid or ice)

Liquid clouds
Effective size
Size distribution shape
Super-cooled liquid detection

Ice clouds
Crystal aspect ratio and distortion
Ice crystal asymmetry parameter
Ice crystal size
Oriented ice detection


NASA
DRYDEN
FLIGHT RESEARCH CENTER
Thanks!
bastiaan.vandiedenhoven@nasa.gov