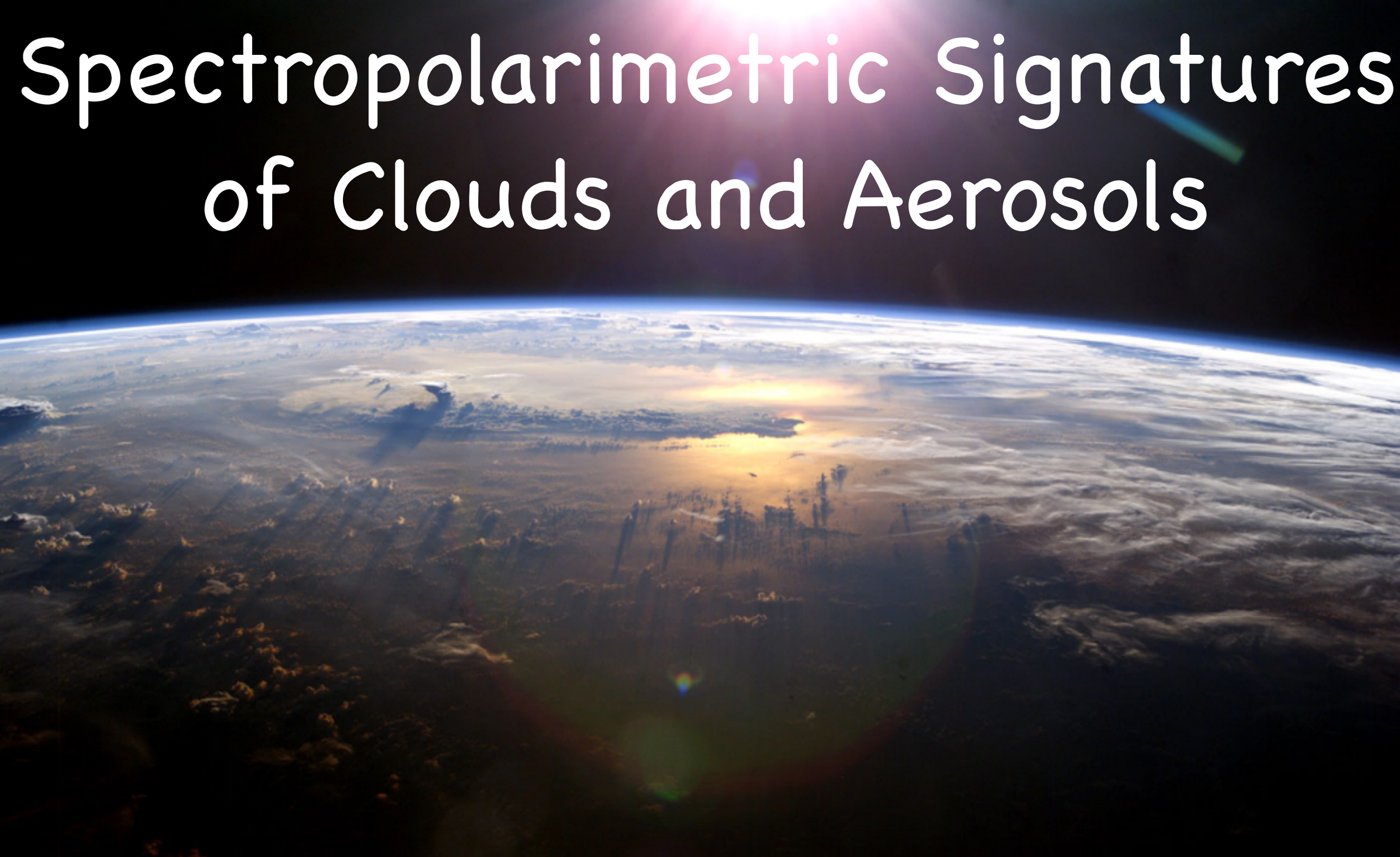
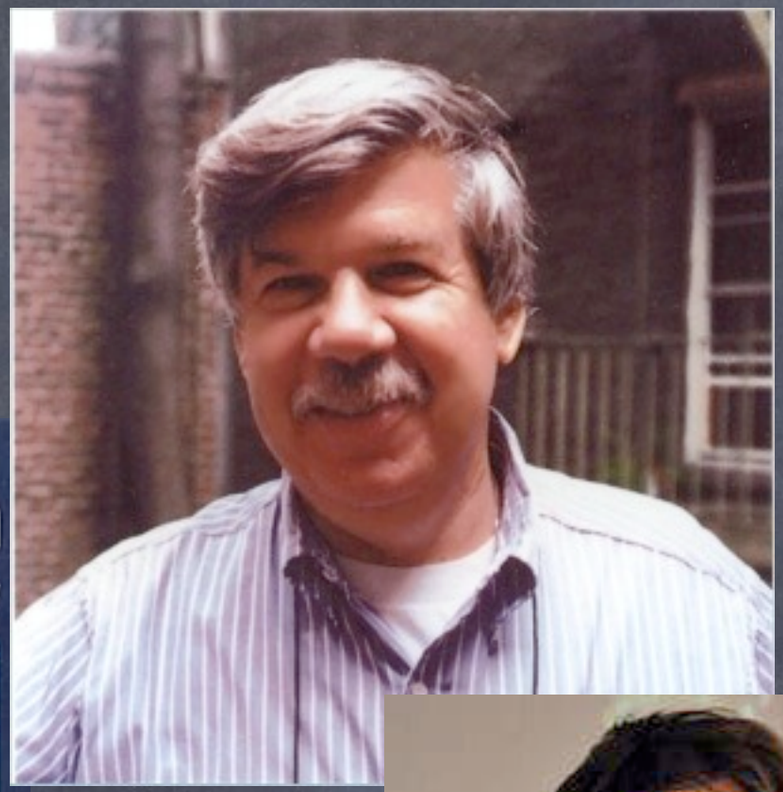
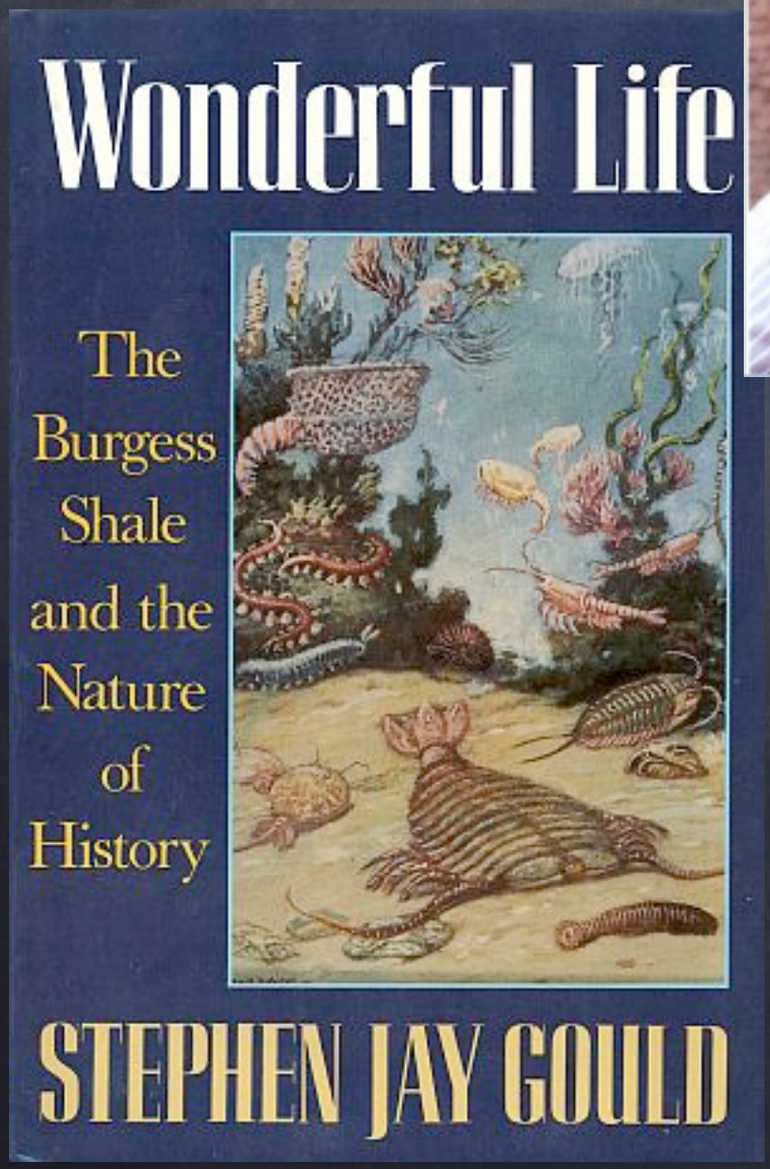
Spectropolarimetric Signatures of Clouds and Aerosols

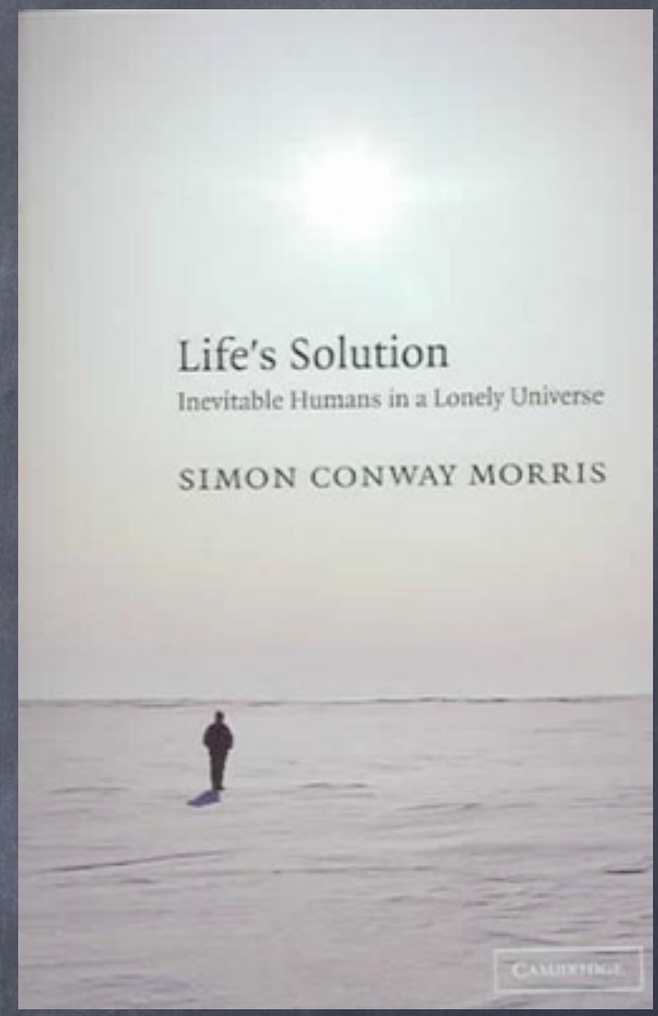


Michael Sterzik, European Southern Observatory
Stefano Bagnulo, Armagh Observatory
Claudia Emde, Meteorological Institute, LMU, Munich

Rewind the Tape of Life

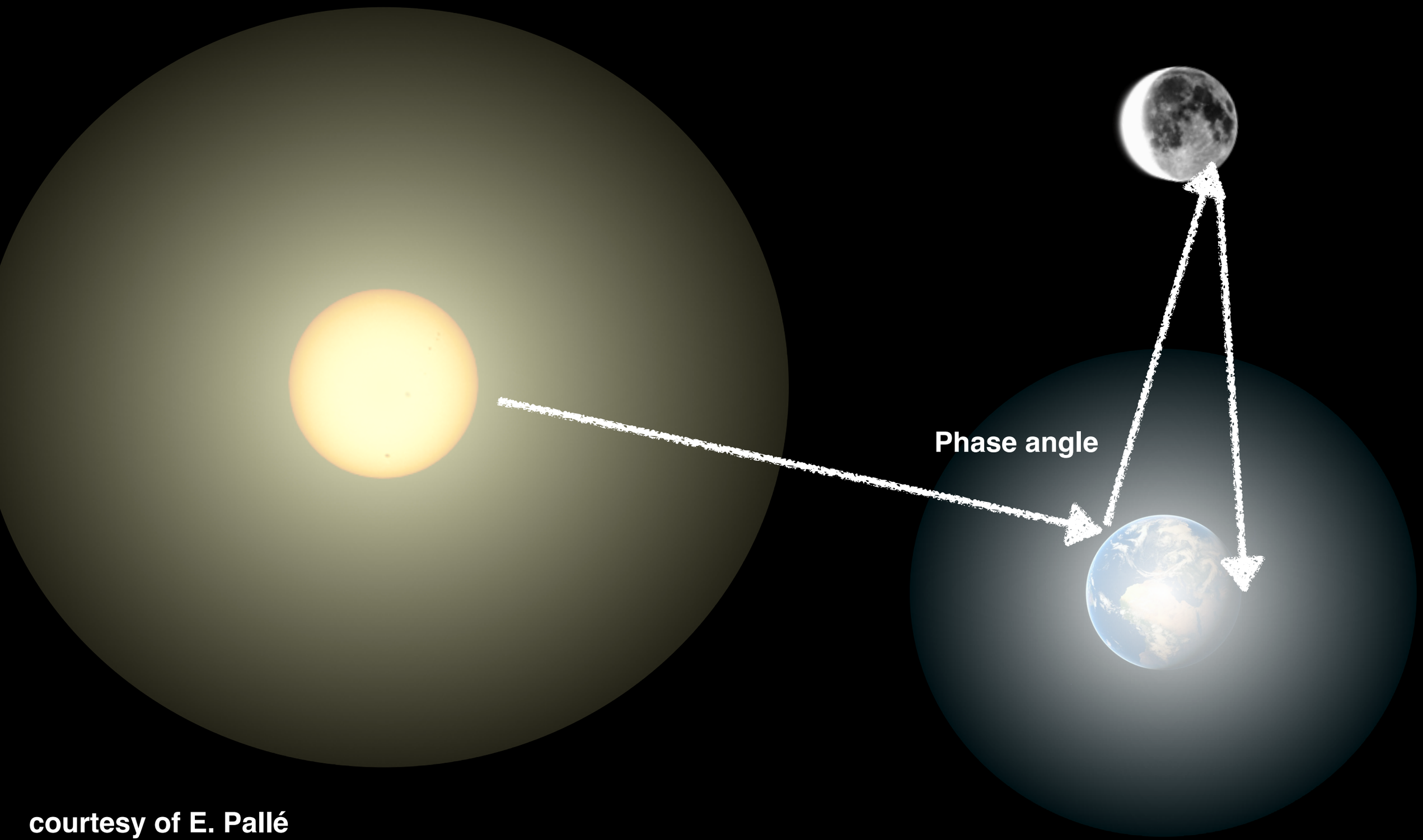






cp. day 1, Yaroslav Isopolatov

Earthshine

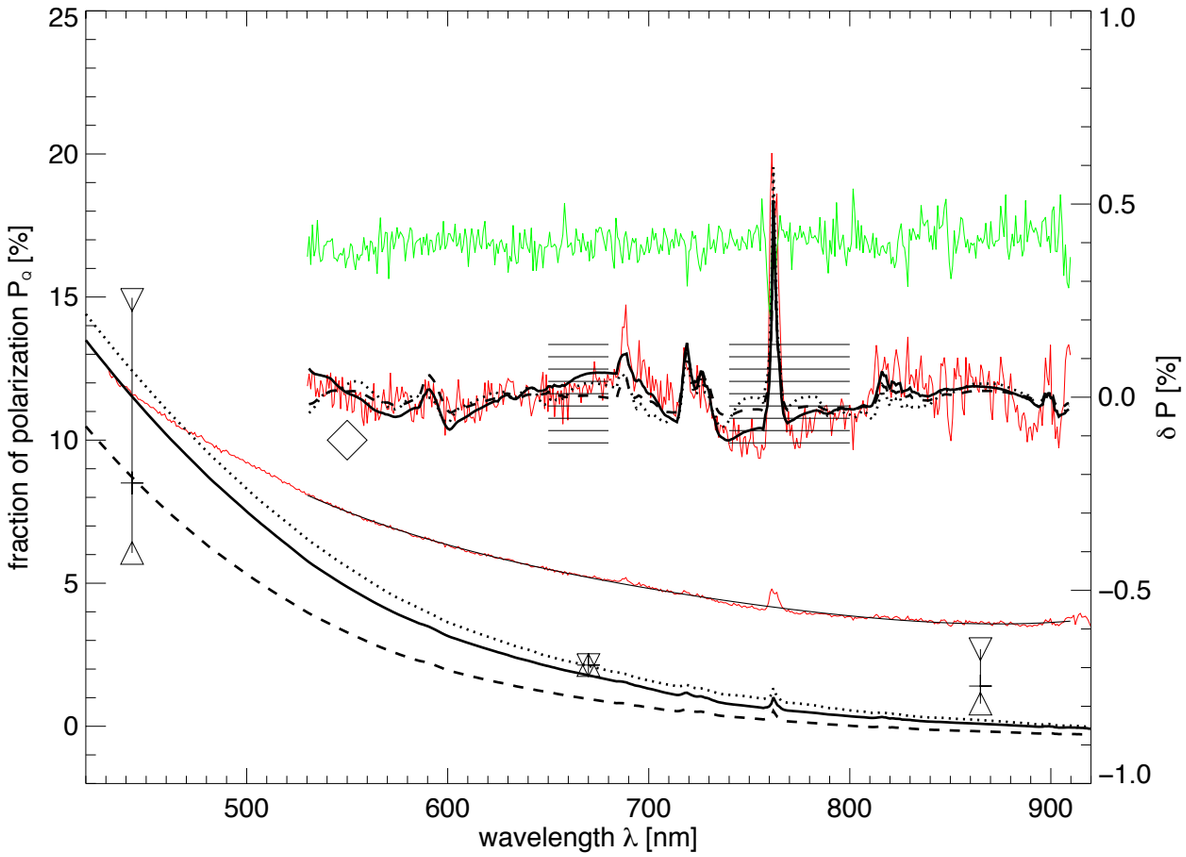


courtesy of E. Pallé

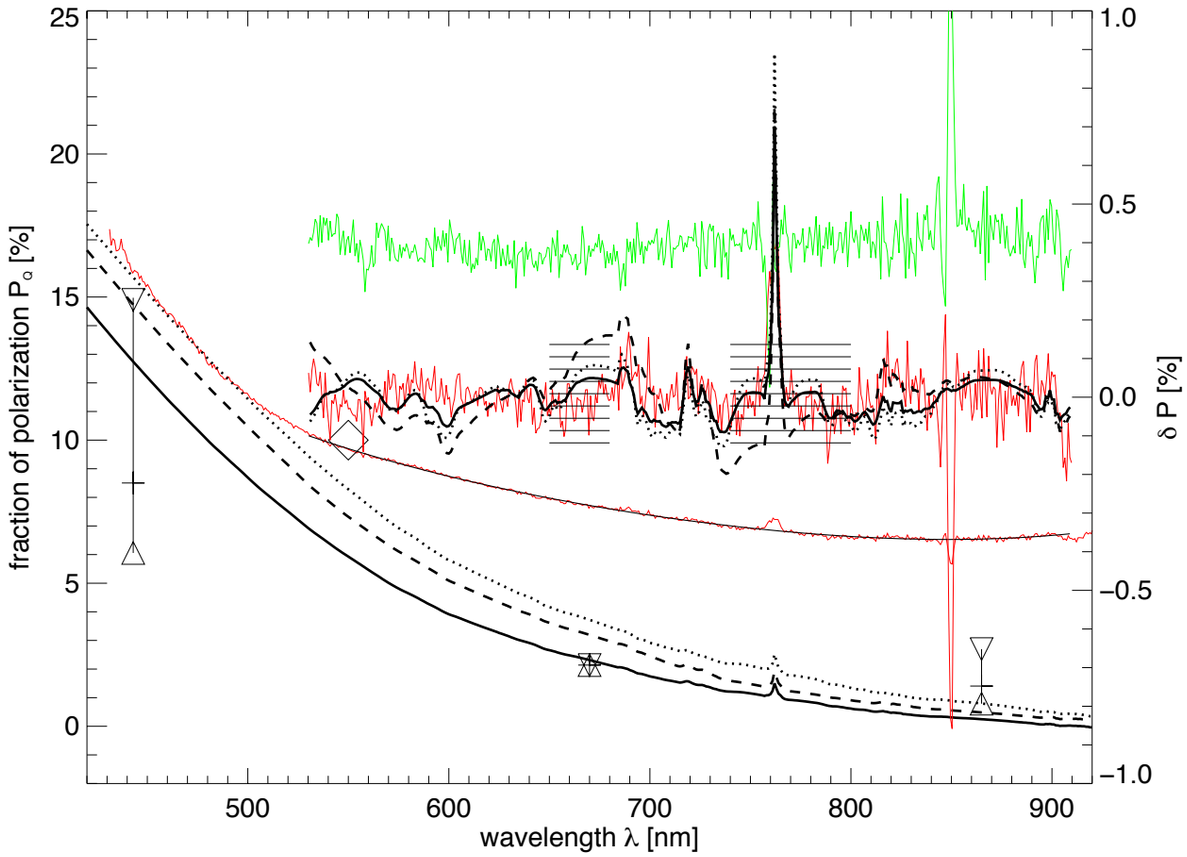
Spectropolarimetry of ES:

Observing Date	25-Apr-2011:UT09	10-Jun-2011:UT01
View of Earth as seen from the Moon		
Sun-Earth-Moon phase	87 deg	162 deg
ocean fraction in Earthshine	18%	46%
vegetation fraction in Earthshine	7%	3%
tundra, shrub, ice and desert fraction in Earthshine	3%	1%
total cloud fraction in Earthshine	72%	50%
cloud fraction t > 6	42%	27%

25-Apr-2011:UT09



10-Jun-2011:UT01

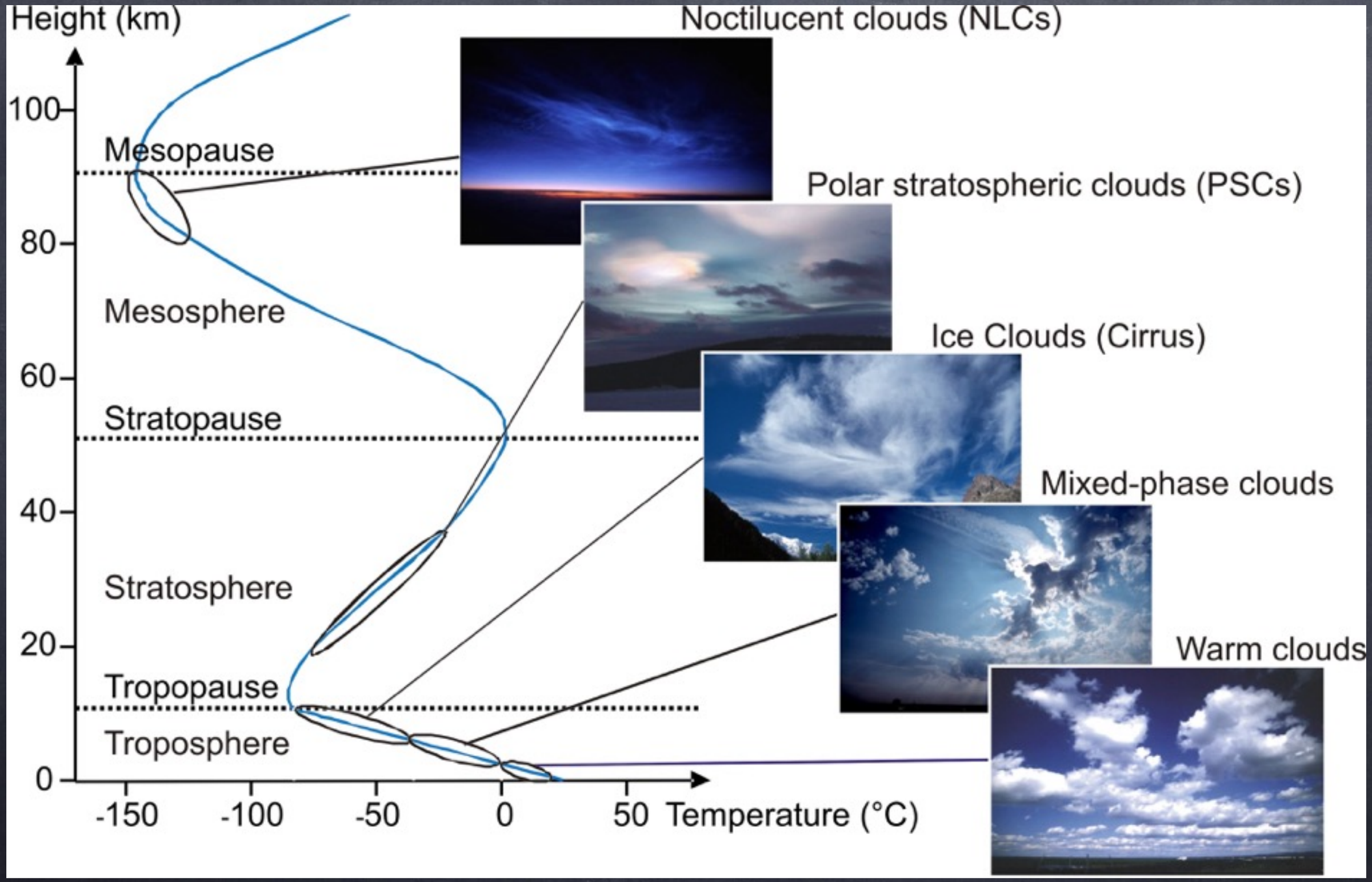


SP of ES allows recovery of cloud fraction, surface properties, and TOC height

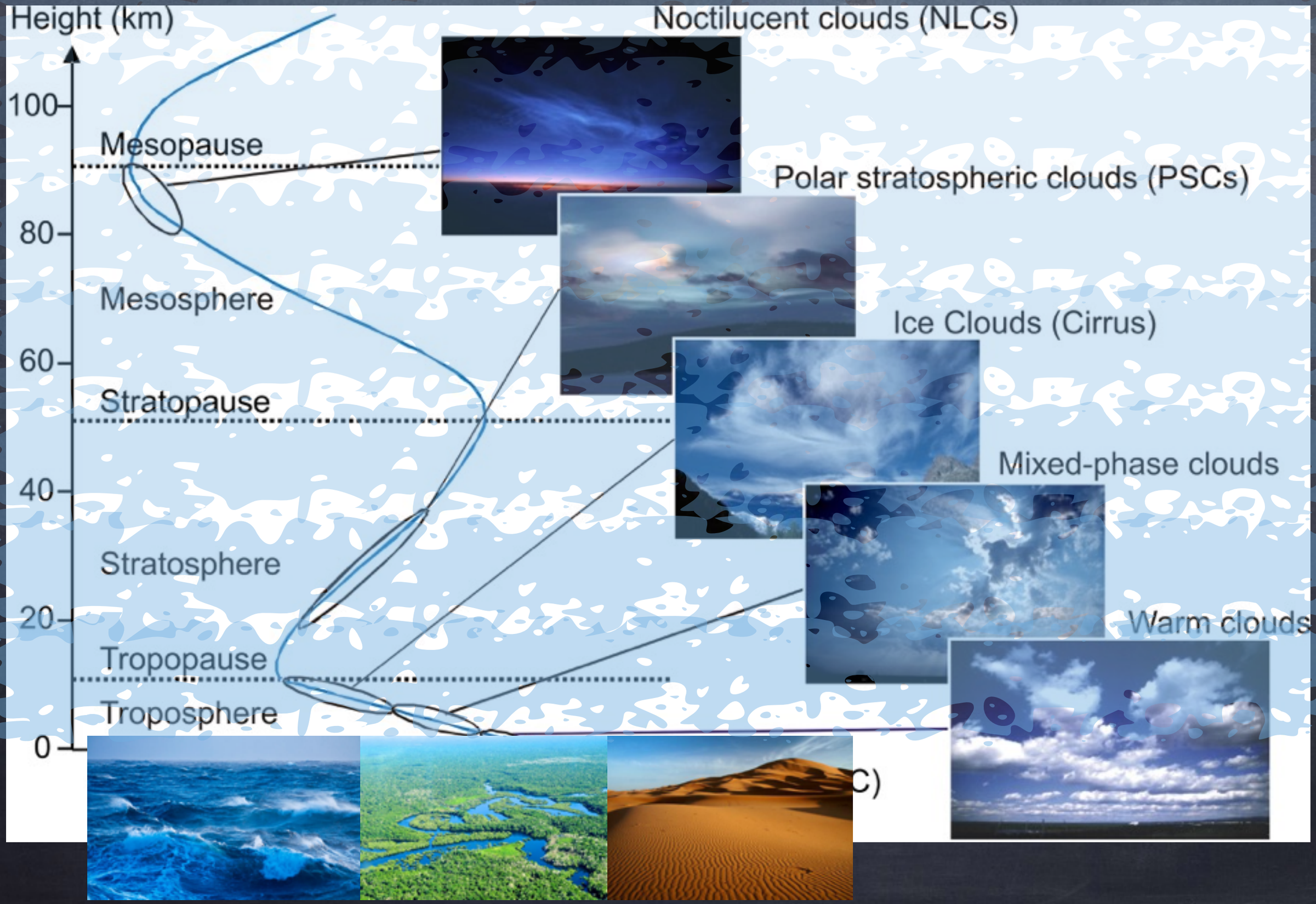
ocean clear: 45%	75%
cloud cover: 45%	25%
top of cloud: 800 hPa	
surface vegetation (NDVI/VRE): 10%	<10%

Sterzik, M. F., Bagnulo, S. & Pallé, E. Biosignatures as revealed by spectropolarimetry of Earthshine. Nature 483, 64–66 (2012).

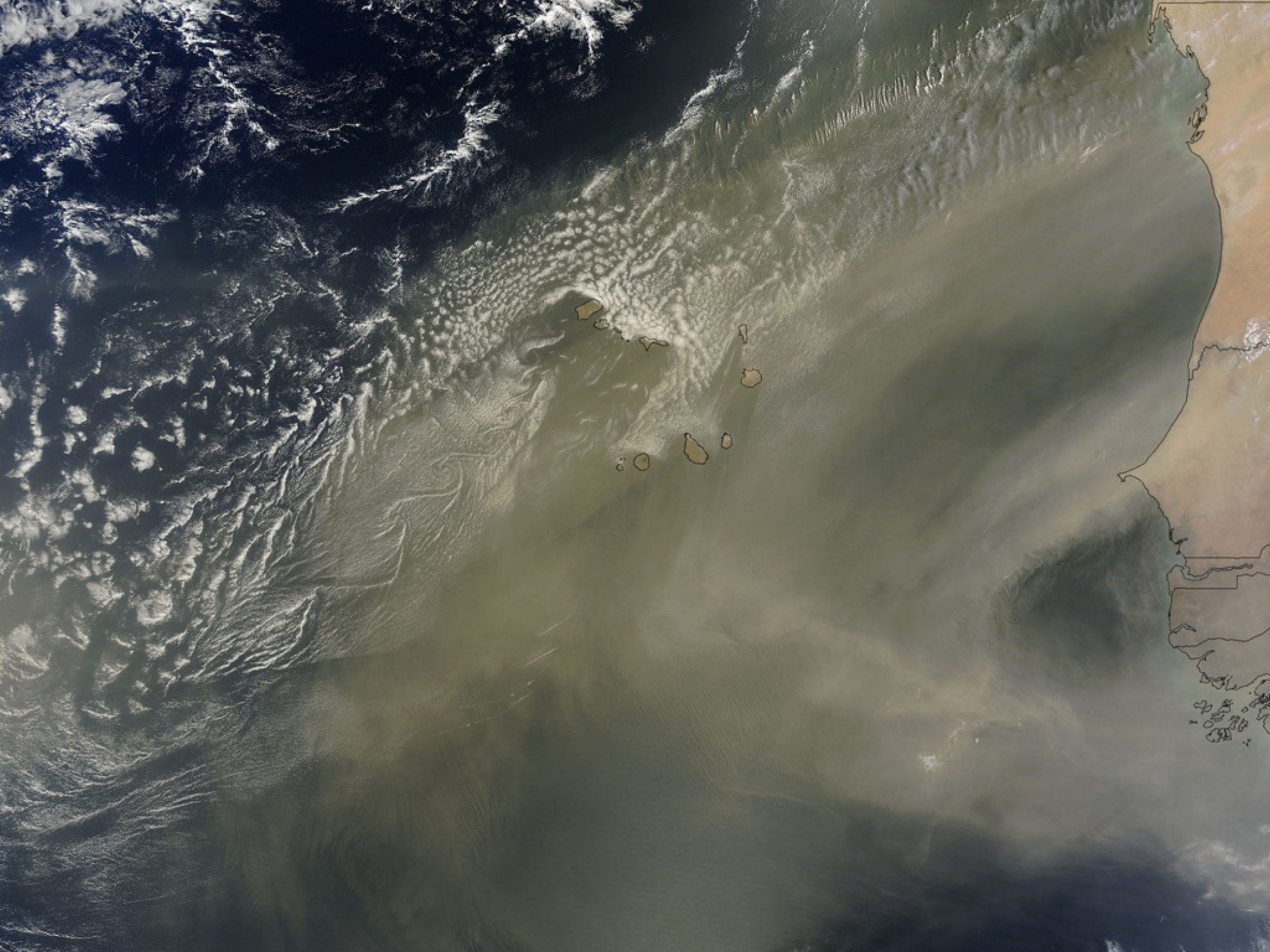
Earth Cloud Systems



Earth Cloud Systems



Variety of Aerosols



Sea Spray Aerosols (SSA)

Ice clouds

Mixed phase clouds

Organic-enriched film drops

Jet drop

Microlayer

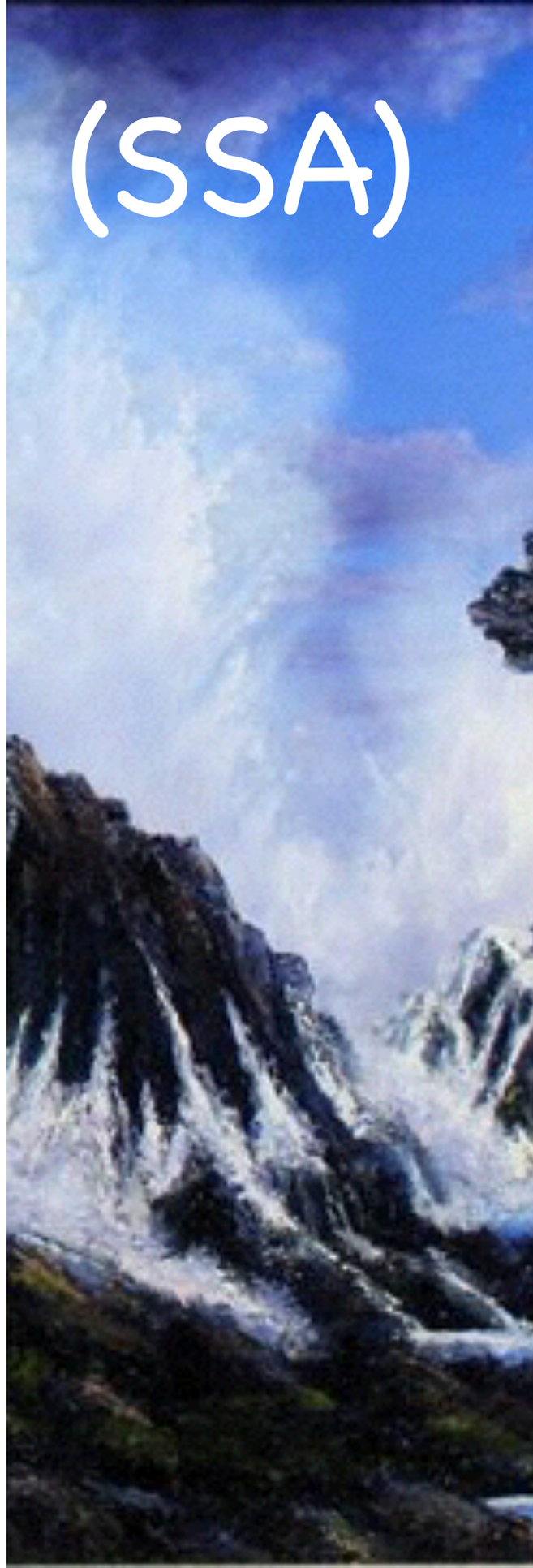
Wave breaking

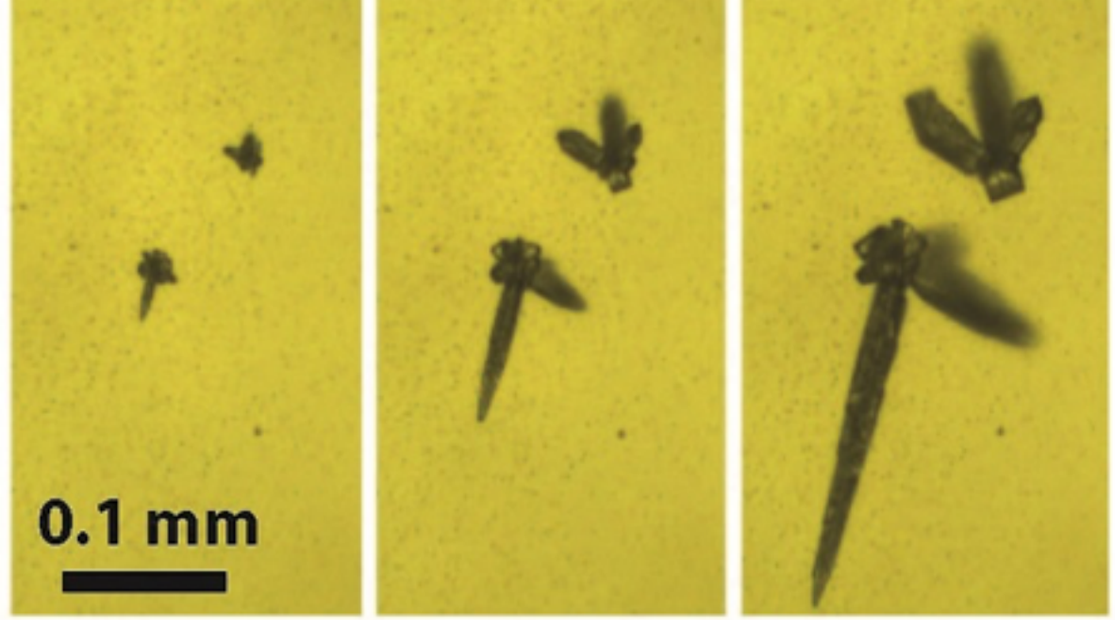
Bubble bursting

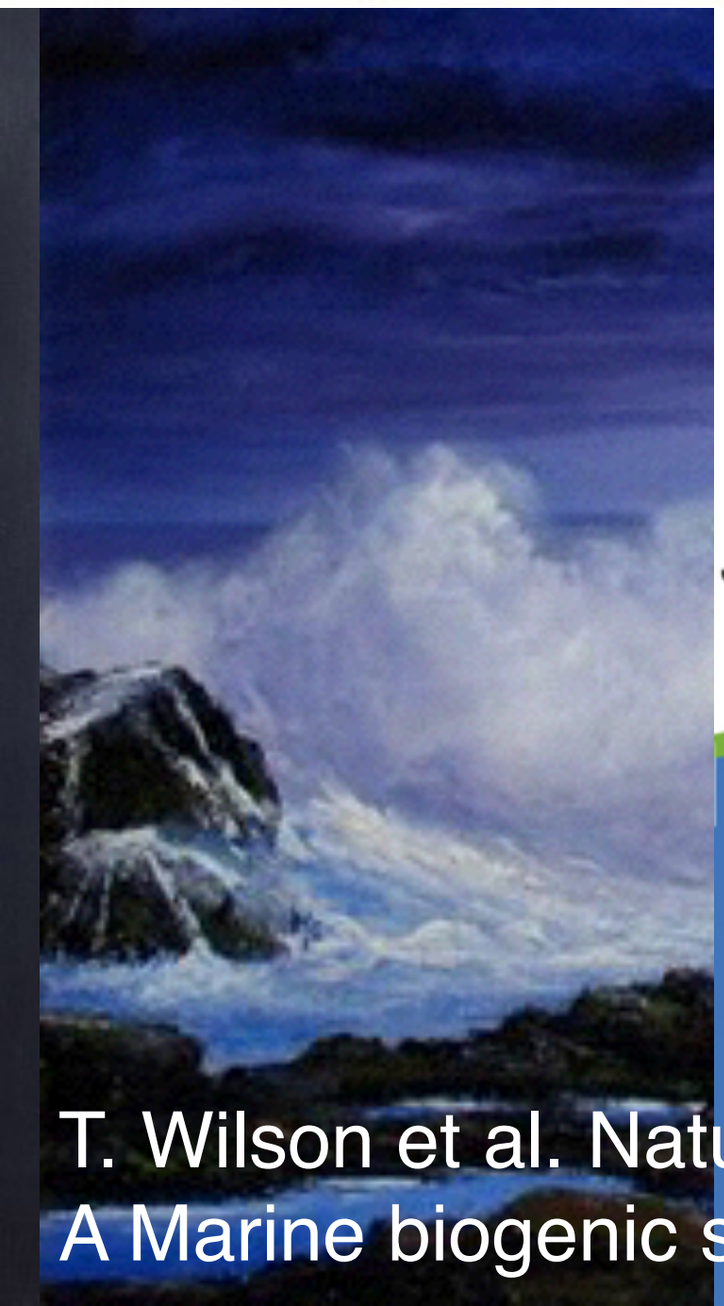
Scavenging of biogenic organics

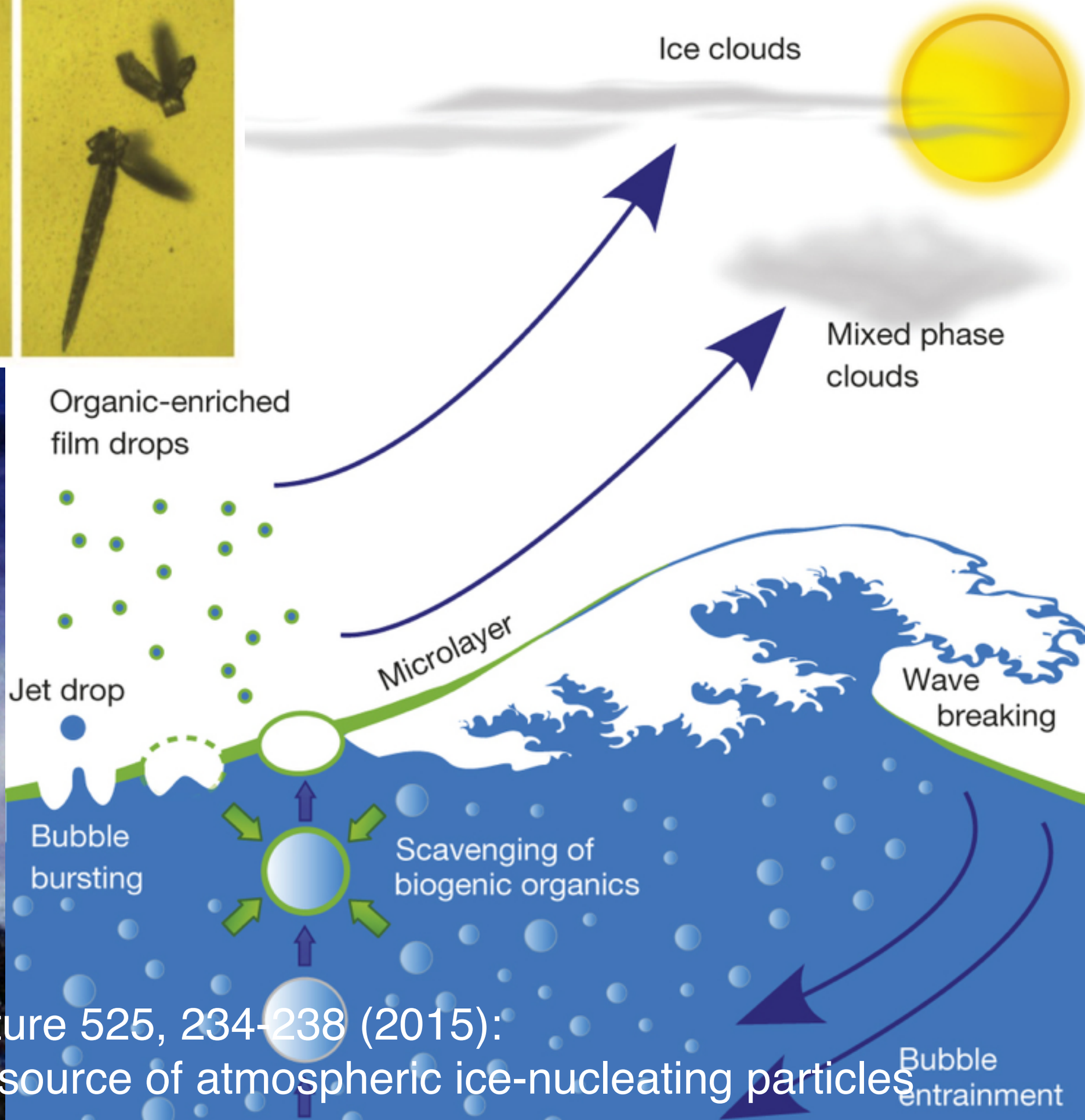
Bubble entrainment

(SSA)



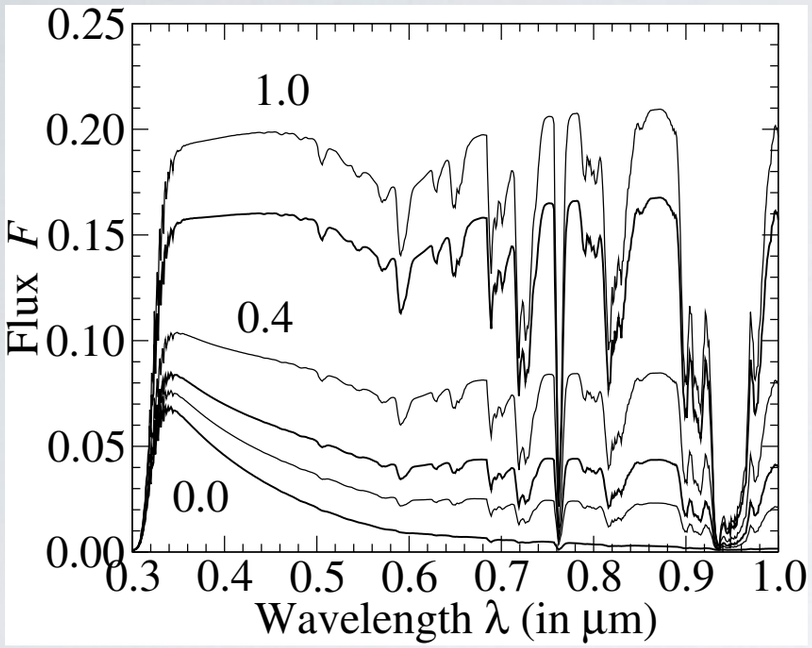


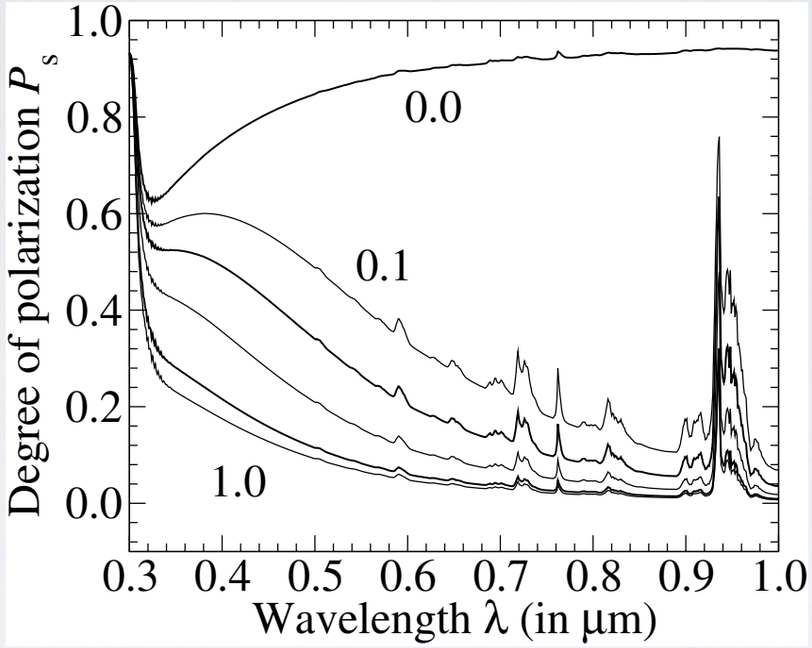




T. Wilson et al. Nature 525, 234-238 (2015):
A Marine biogenic source of atmospheric ice-nucleating particles

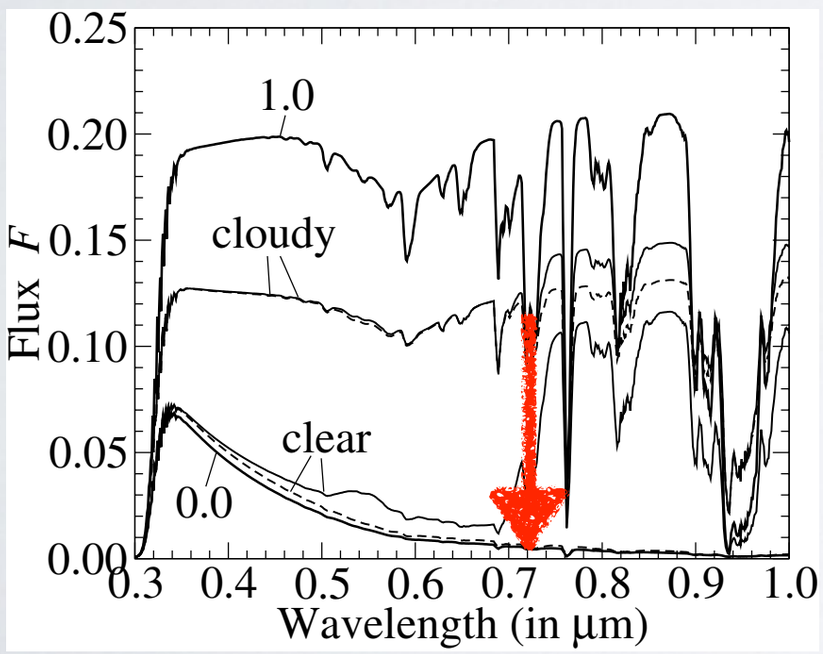
Models of the Earth's Polarization

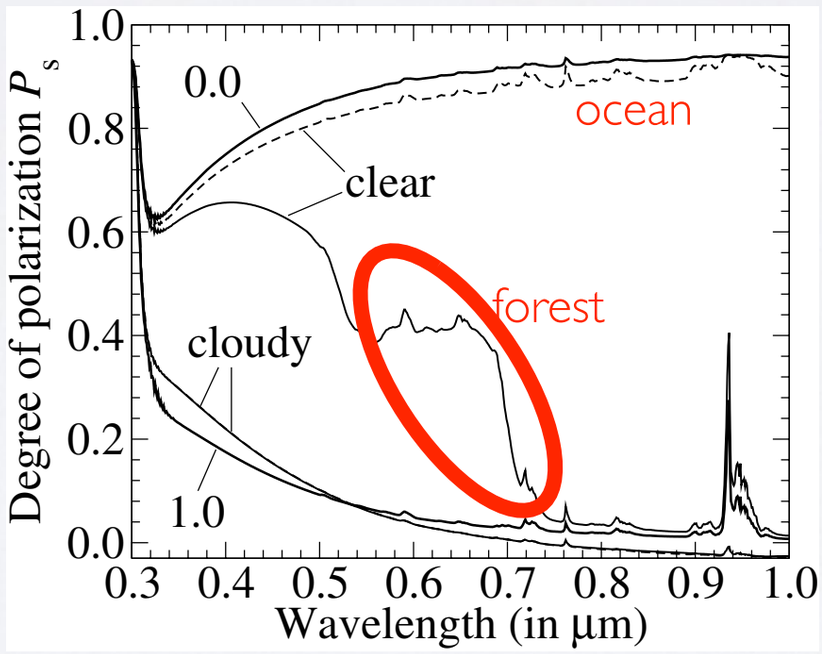




VRT calc. include

atmosphere
geometry
surfaces





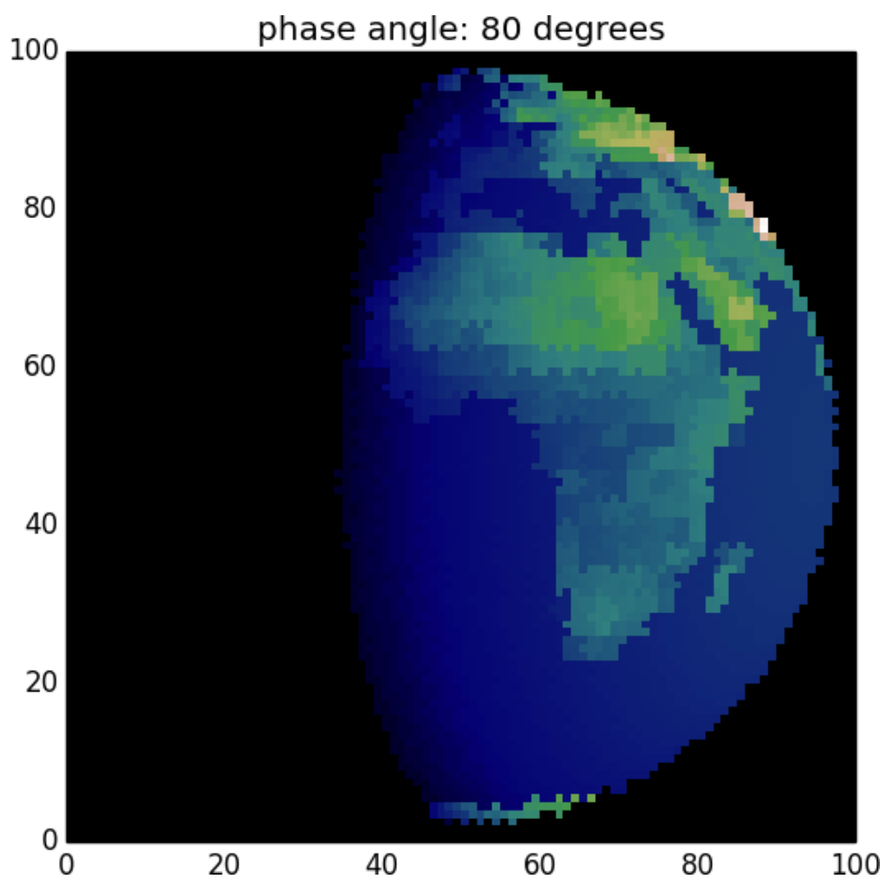
missing

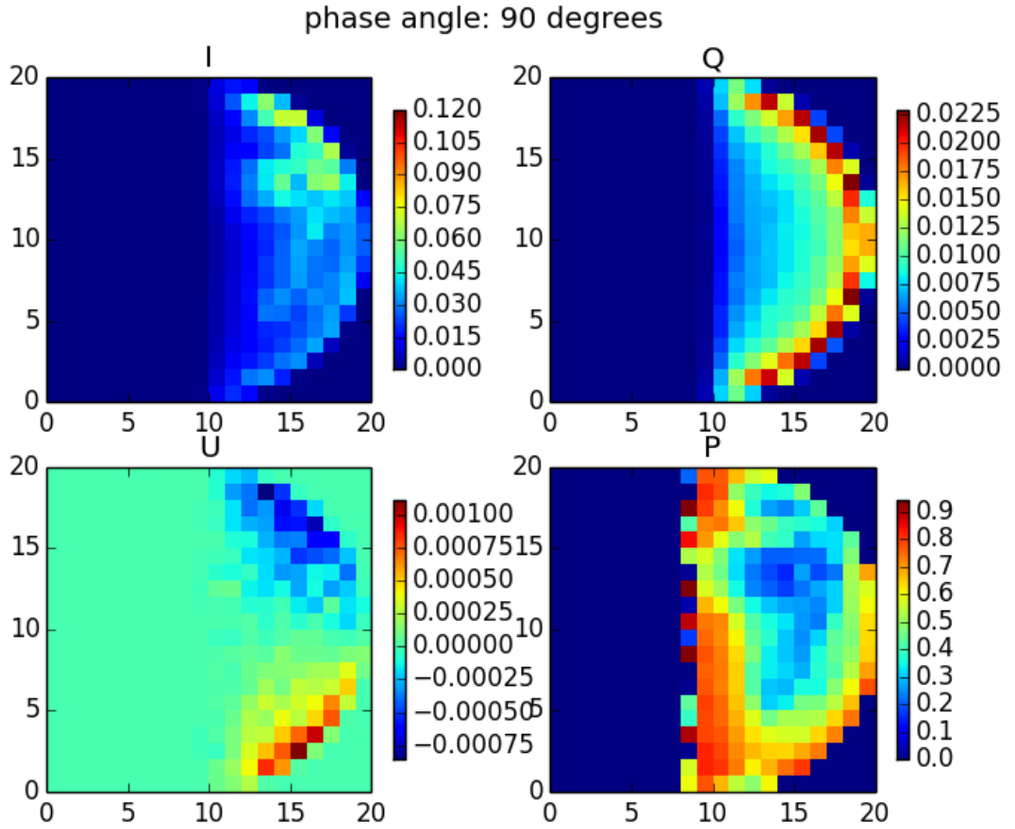
inhomogenities
realistic clouds
aerosols/haze
realistic surfaces

Stam, D. M. Spectropolarimetric signatures of Earth-like extrasolar planets. *A&A* **482**, 989–1007 (2008)

MYSTIC 3D-vec. rad. transfer

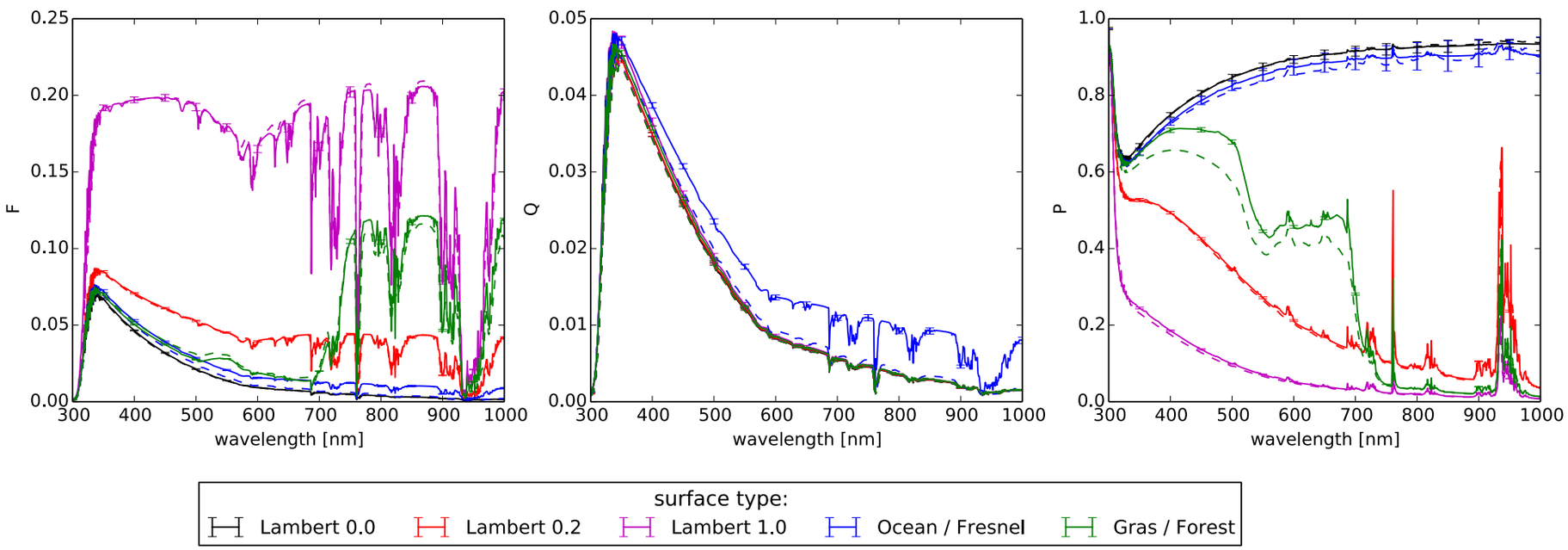
w/ C. Emde (Monte Carlo code for the phYSically correct Tracing of photons In Cloudy atmospheres)



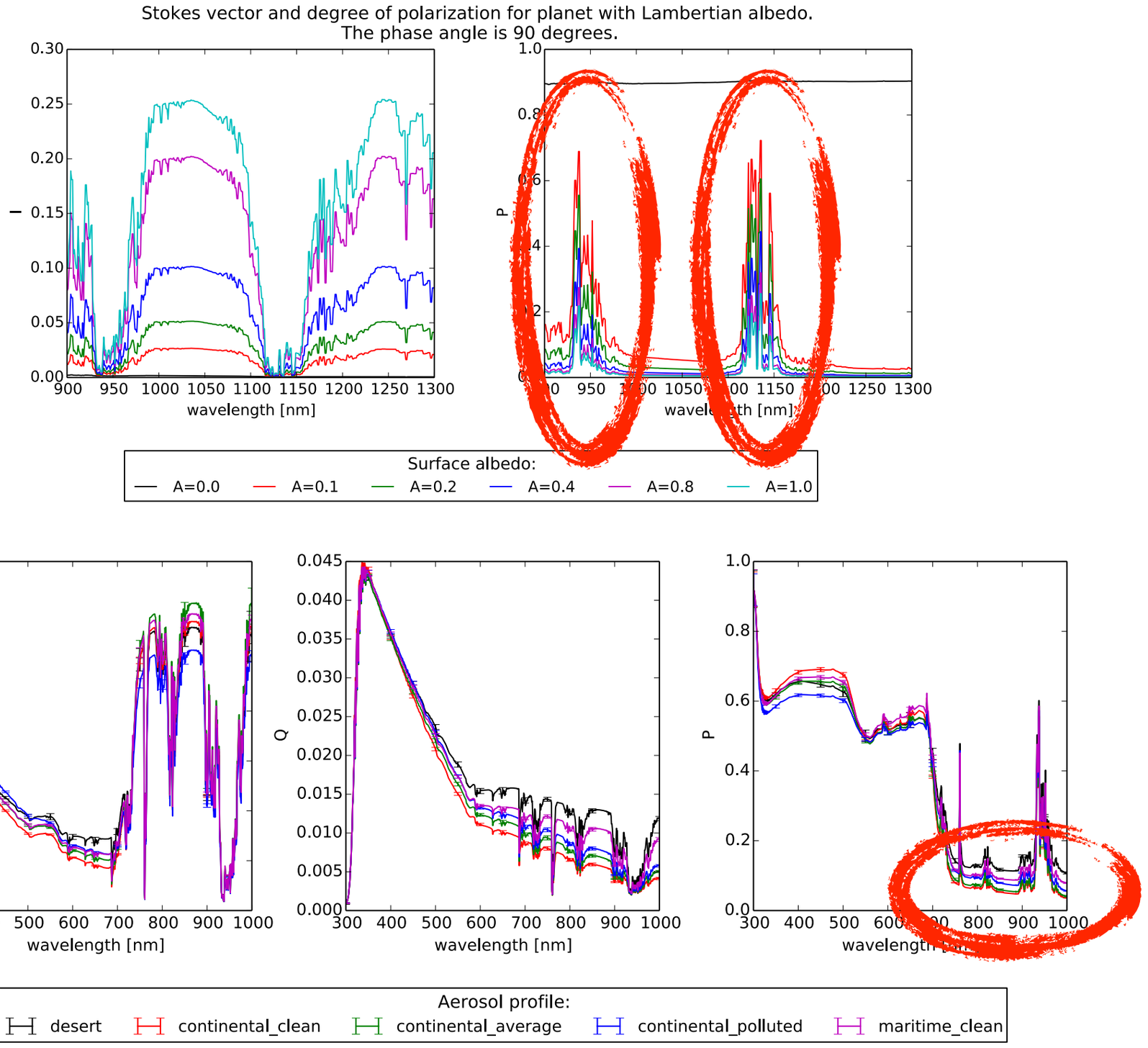


Emde, C., Buras, R., Mayer, B. & Blumthaler, M. The impact of aerosols on polarized sky radiance: **model development, validation, and applications**. *Atmos. Chem. Phys. 10*, 383–396–396 (2010).

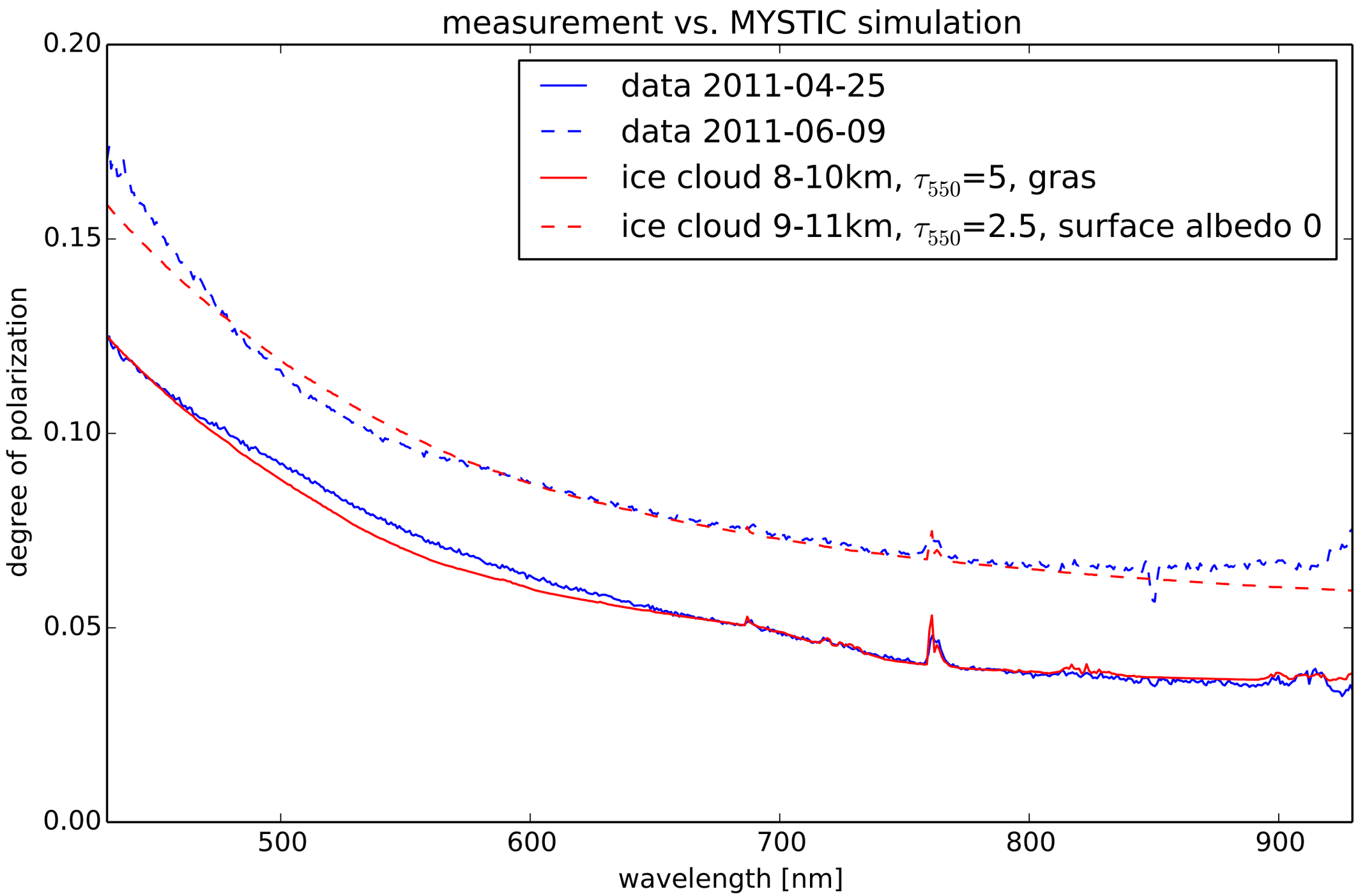
Emde, C., Buras, R. & Mayer, B. An efficient method to compute **high spectral resolution** polarized solar radiances using the **Monte Carlo** approach. *Journal of Quantitative Spectroscopy and Radiative Transfer* **112,** 1622–1631 (2011).



MYSTIC 3D-vec. rad. transfer



towards 3D-vec. rad. transfer



Spectro-Polarimetry of Planet Earth through Earthshine

- (+) robust tool to retrieve integrated surface and atmospheric properties
- (+) sensitive on biosignatures (VRE, O_2, H_2O)
- (-) restricted phase coverage
- (-) improve lunar depolarisation models
- (-) improve Earth VRT atmosphere/surface/haze modeling
- (-) long shot towards biosignatures on exo-planets...
- (+) SP of Planet Earth can constrain the design of future exo-Life machines