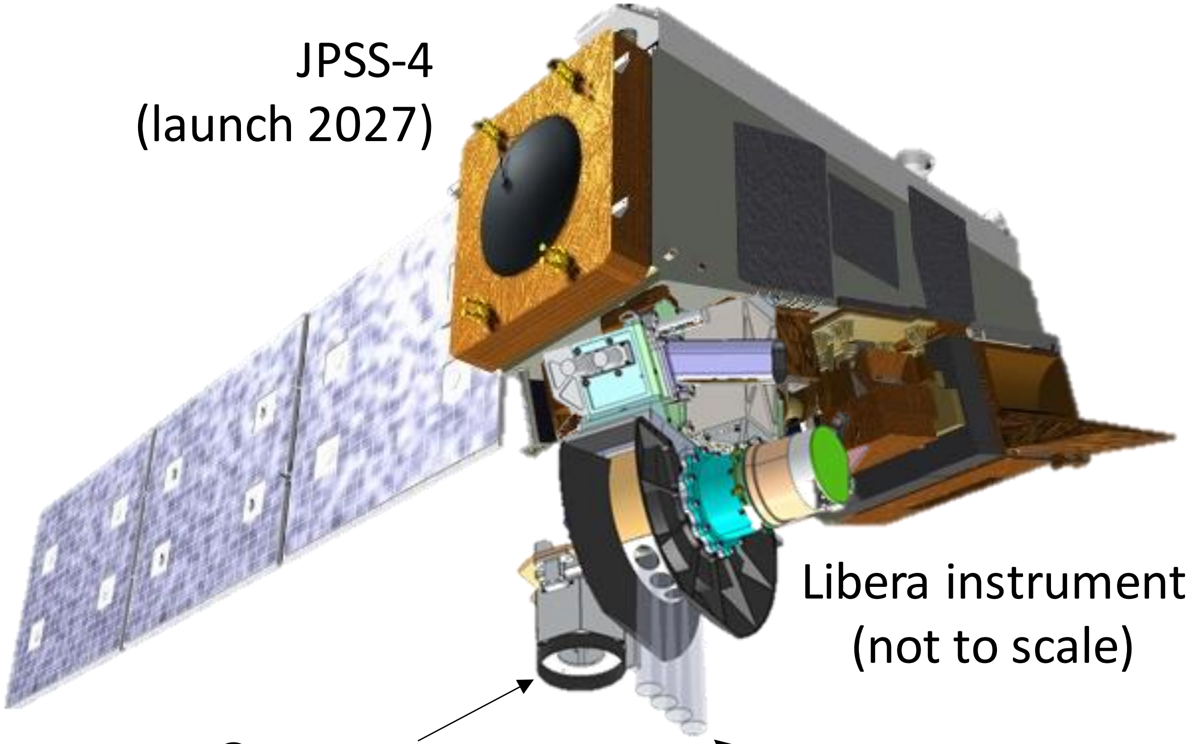
Exploring the angular dimension of ERB with the Libera camera



Jake J. Gristey[1,2,3], K. Sebastian Schmidt[3,4], and the Libera Science Team

[1]CIRES, CU Boulder [2]NOAA CSL [3]LASP, CU Boulder [4]ATOC, CU Boulder

 Jake.J.Gristey@noaa.gov

Outline

- Libera camera characteristics
- Example application 1: Split-solar angular distribution model generation
- Example application 2: Testing of proposed alternate split-solar radiance-to-irradiance conversion
- Example application 3: Stereo cloud detection in challenging environments

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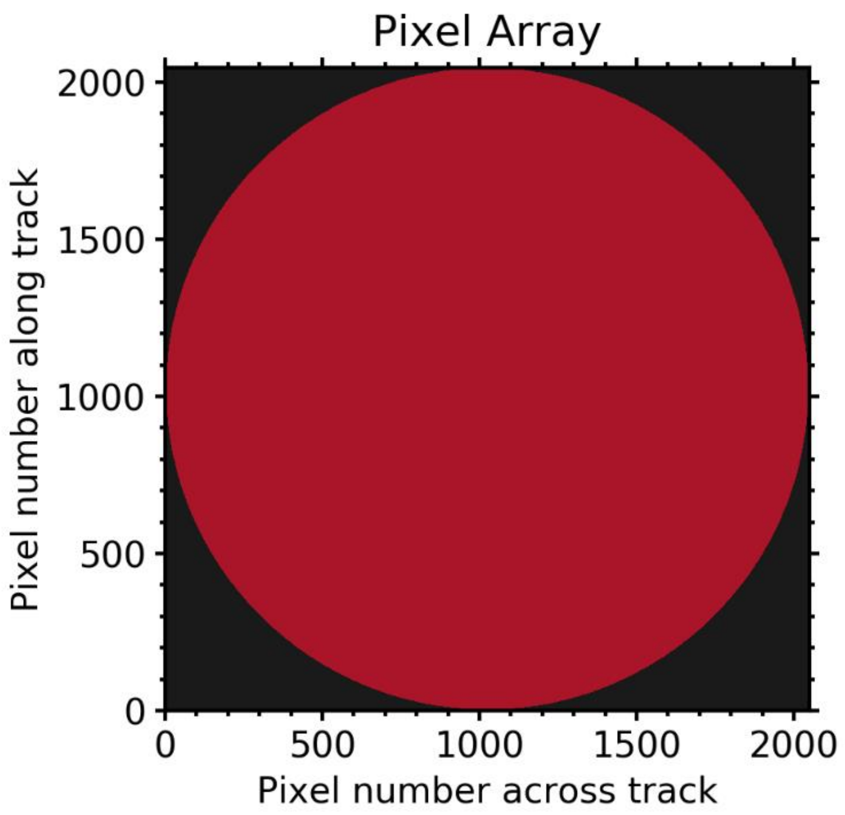
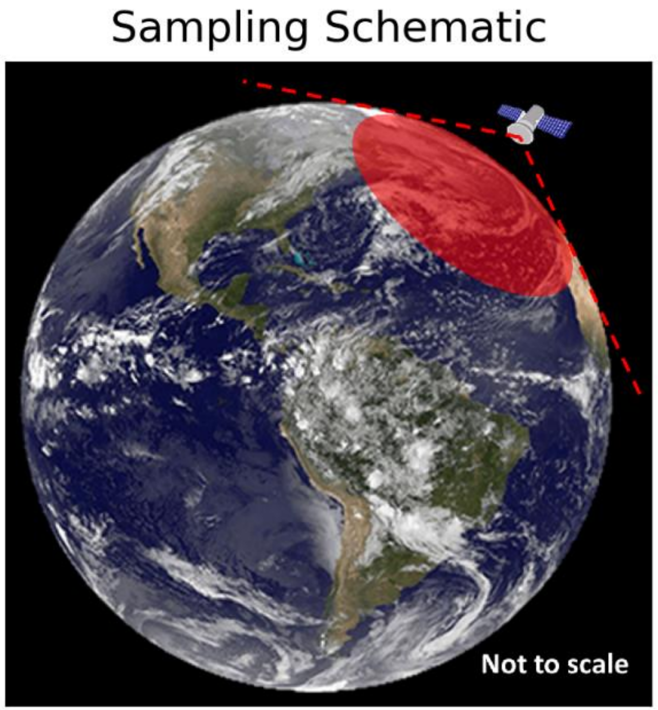
Libera wide-field-of-view (WFOV) camera overview

- 2048 × 2048 pixel array samples entire Earth disk subtended from the satellite





Gristey et al., AMT [2023]

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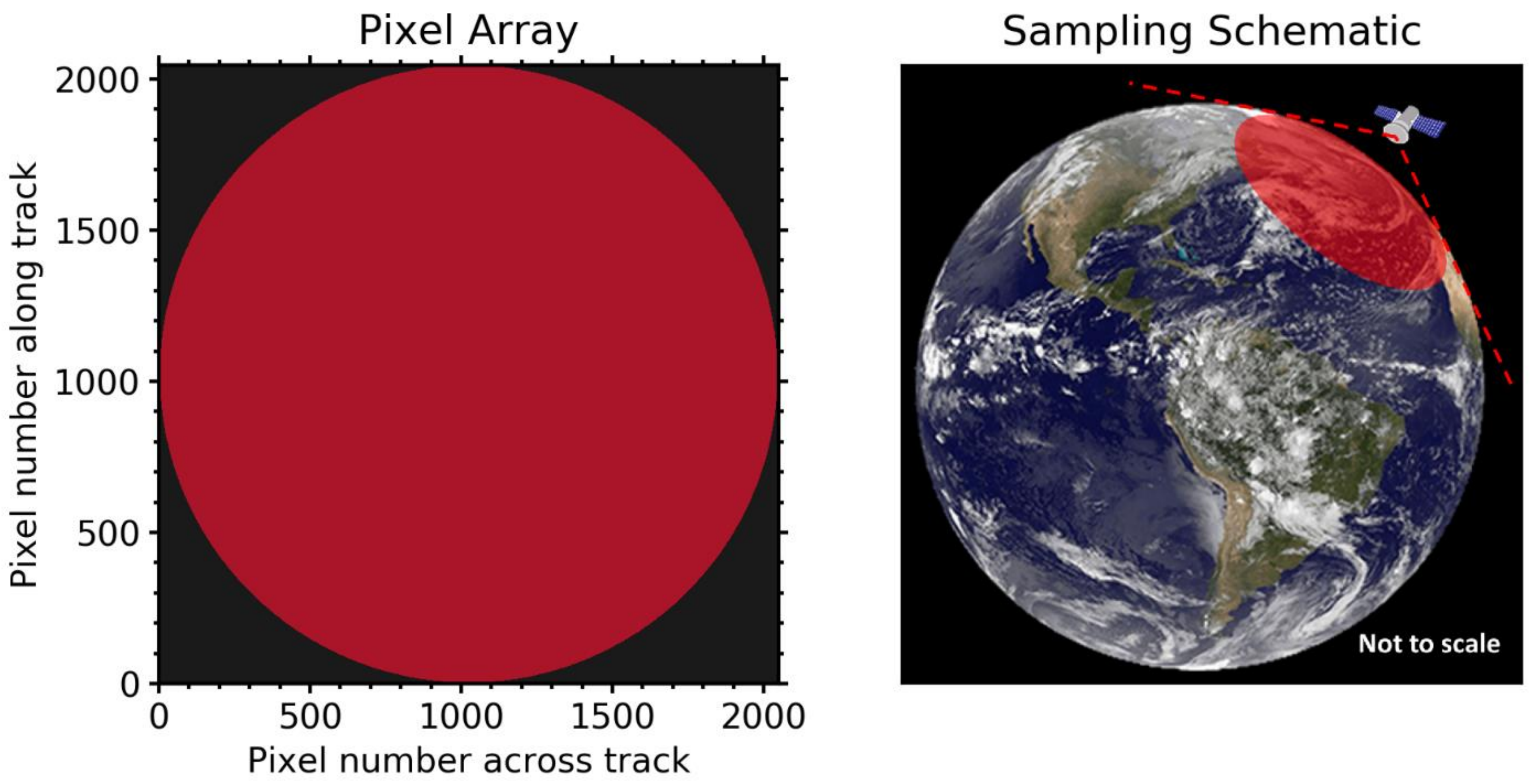

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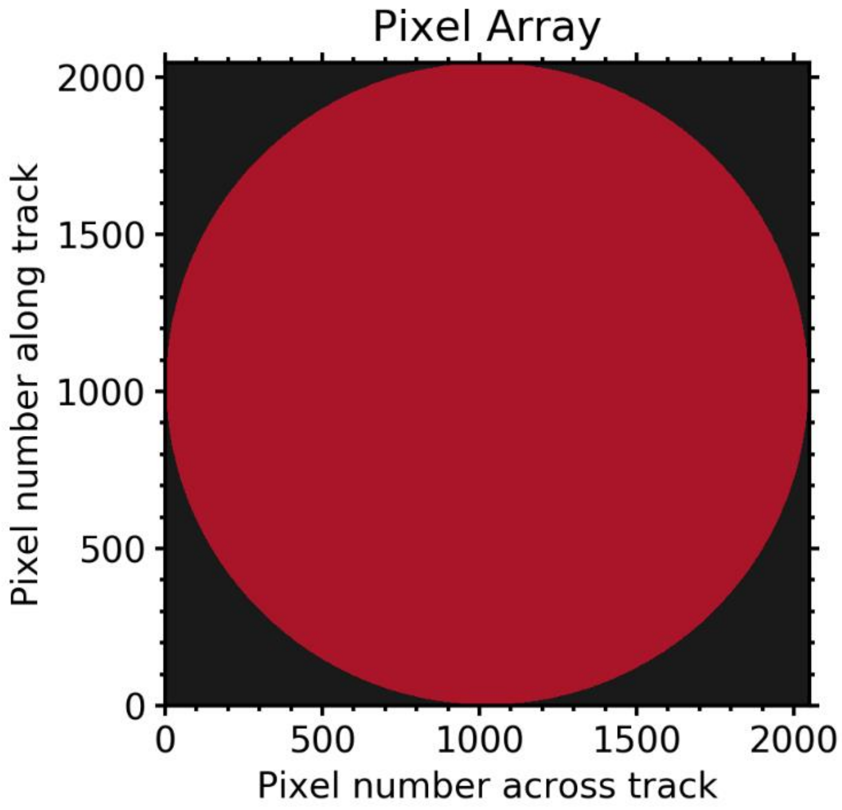

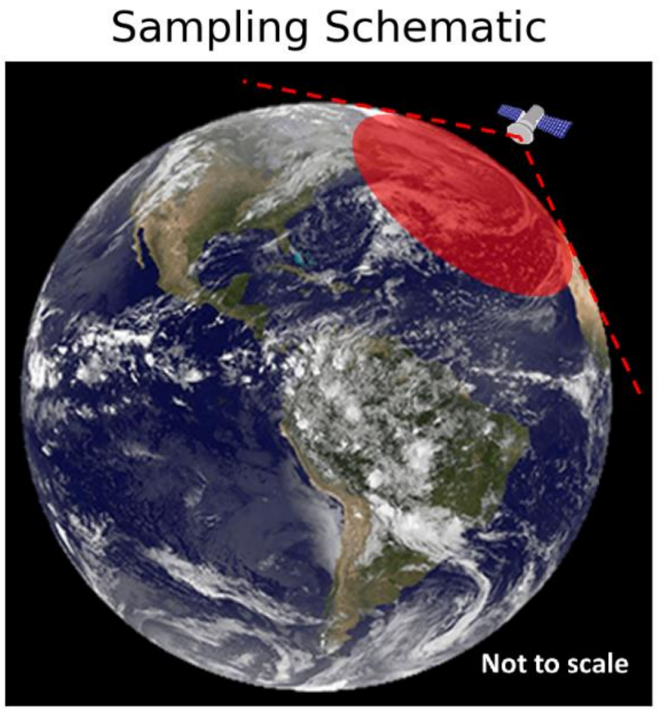

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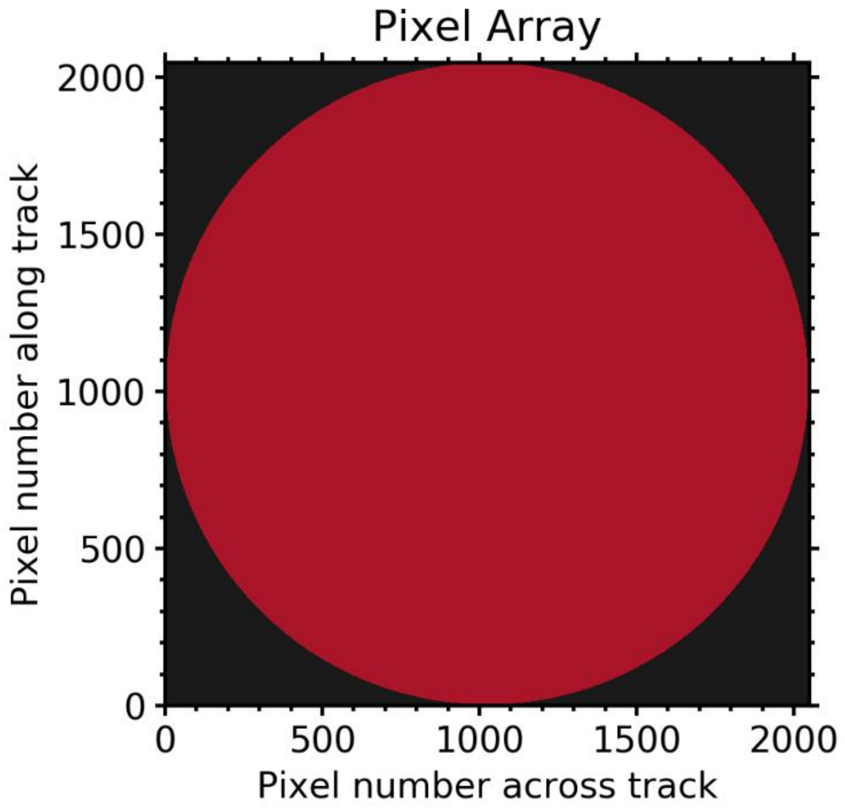

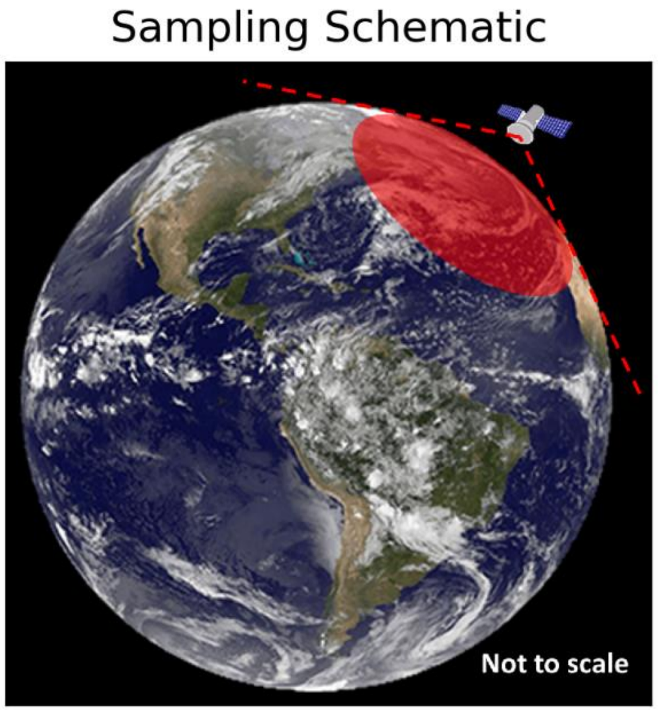

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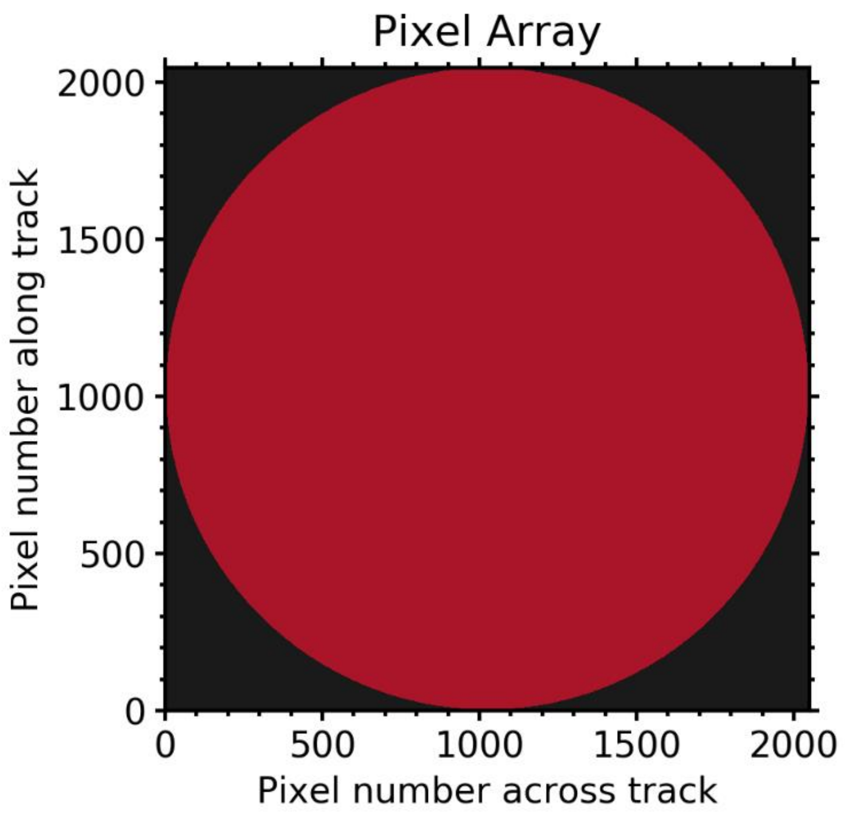

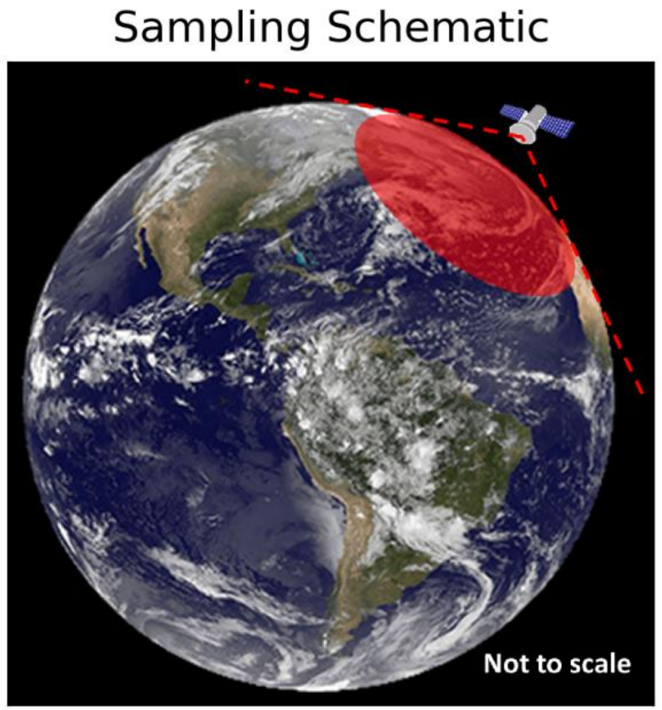

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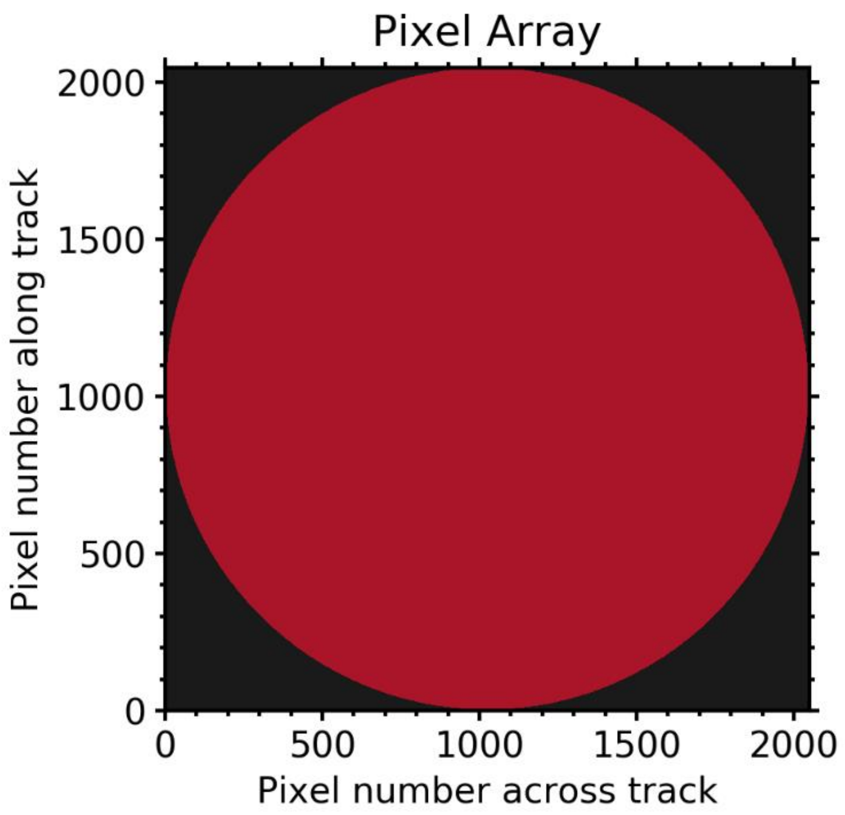

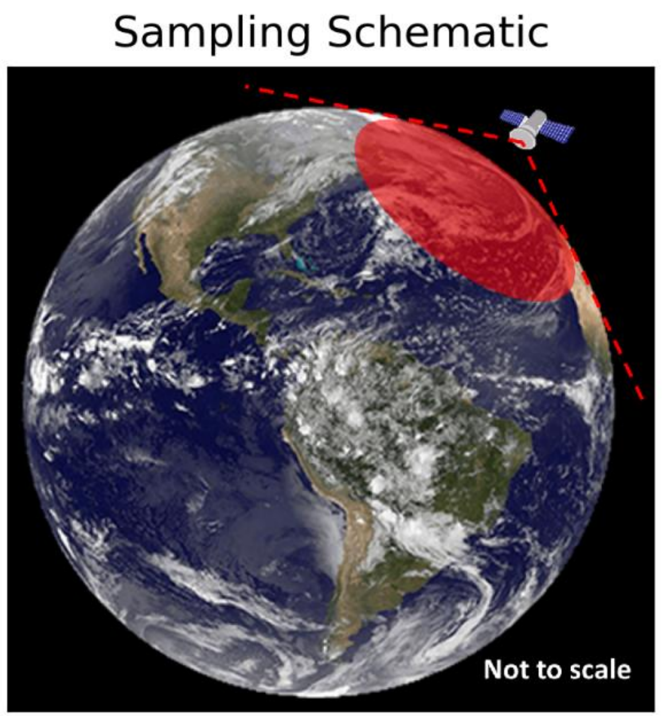

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- Photograph every 5 secs
- 1.5% uniformity, 5% absolute accuracy

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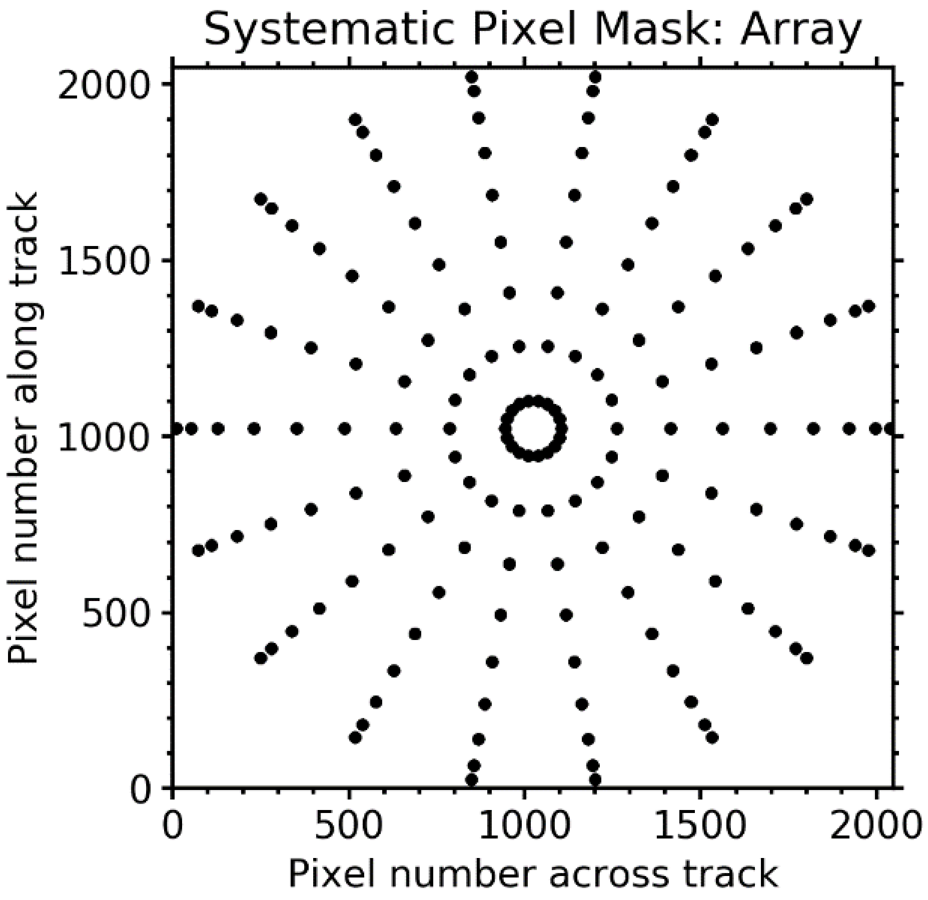
Camera ADM samples will be sent to the ground



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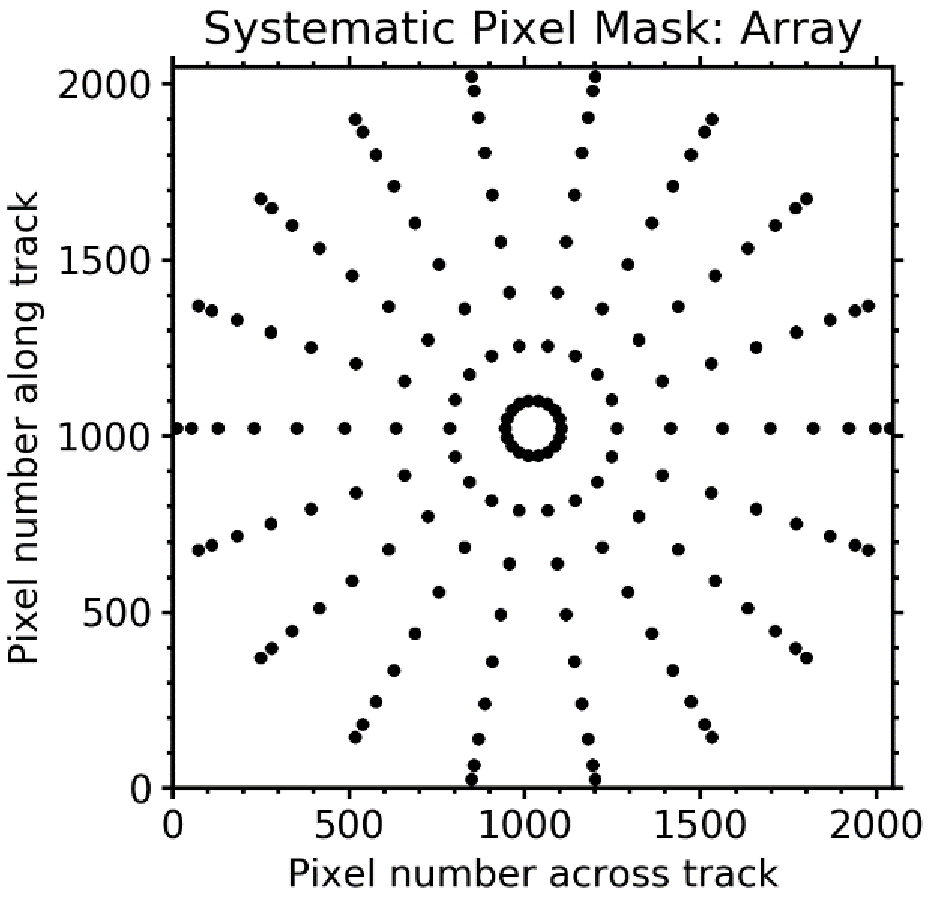

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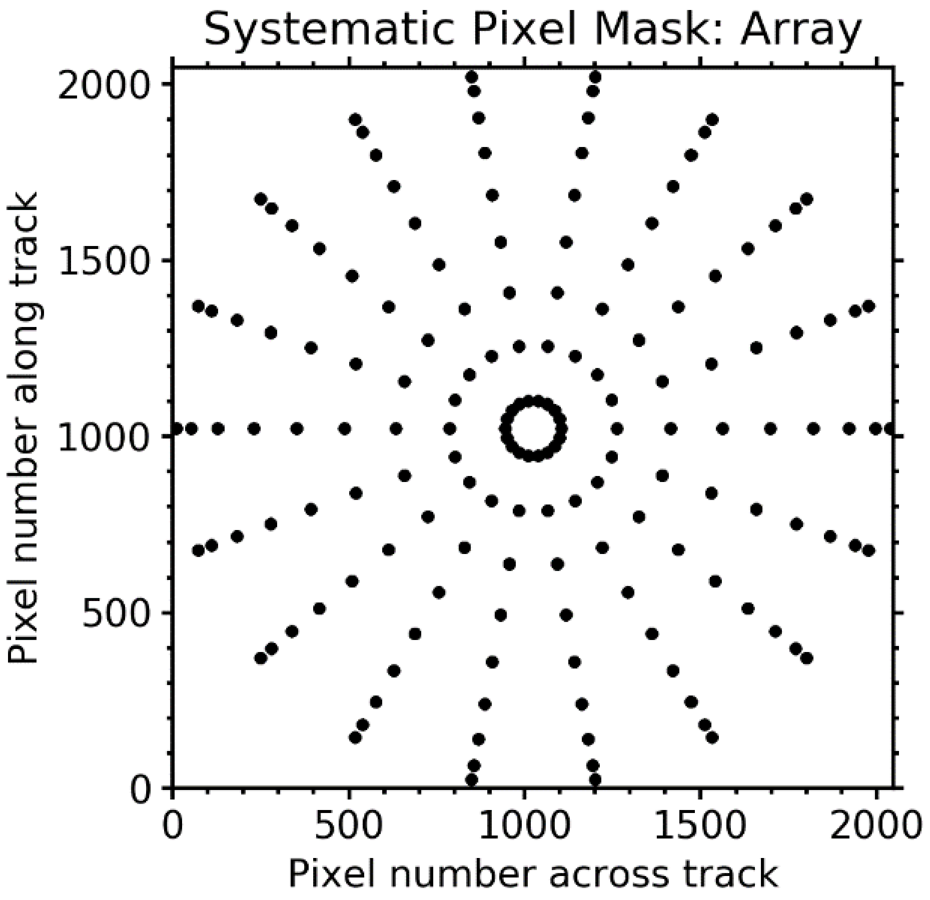

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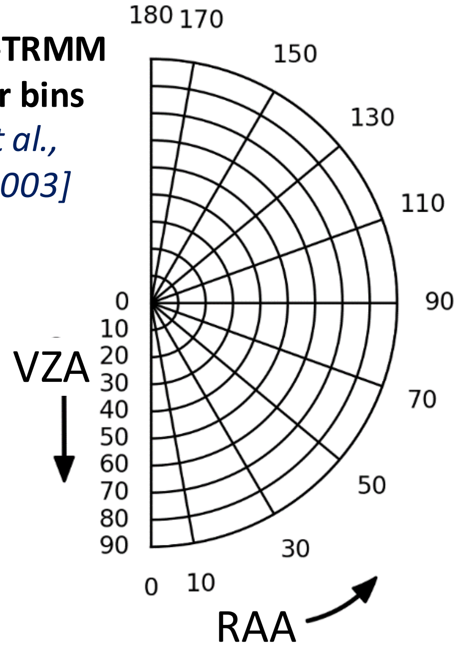
CERES-TRMM angular bins
Loeb et al., JAM [2003]



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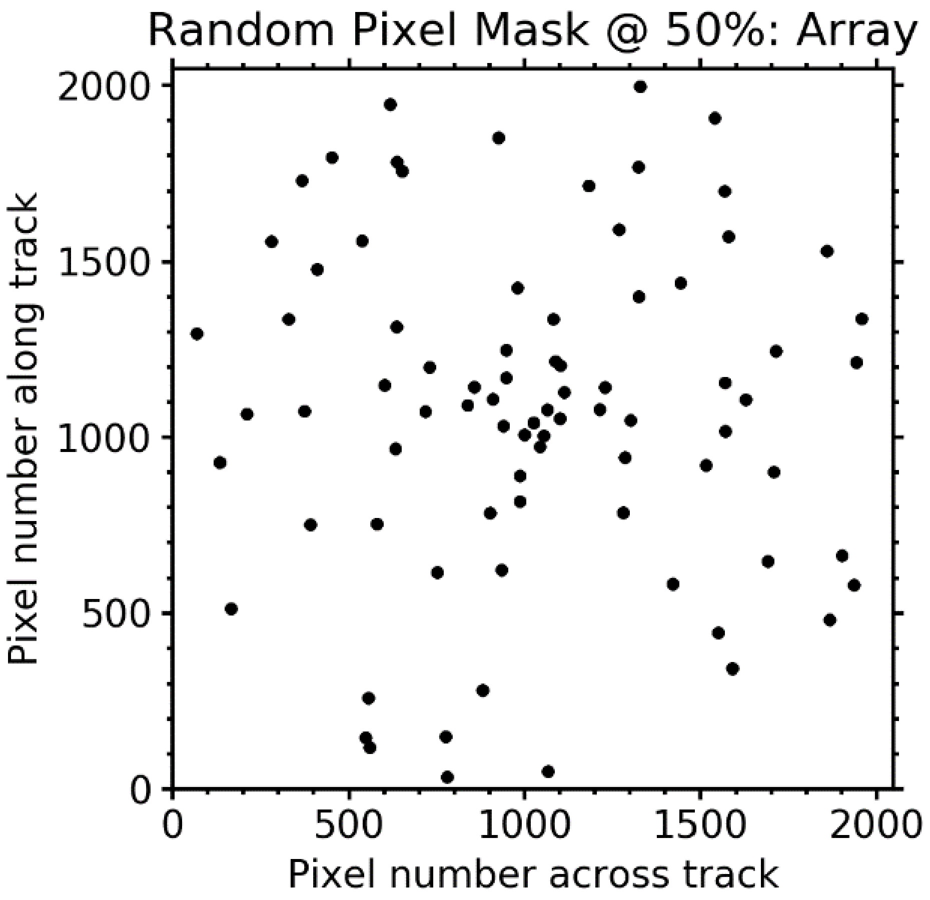

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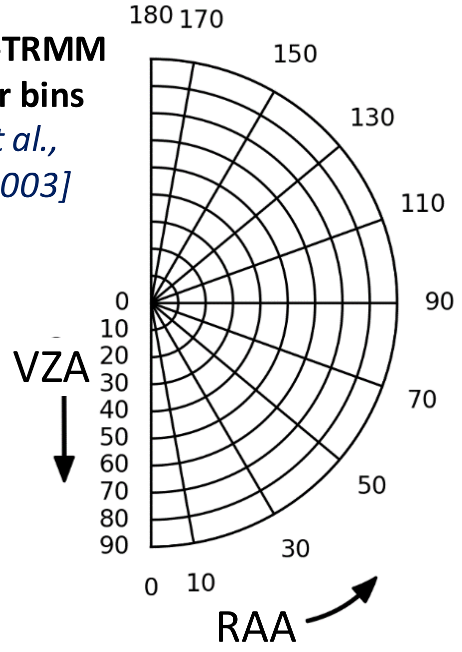
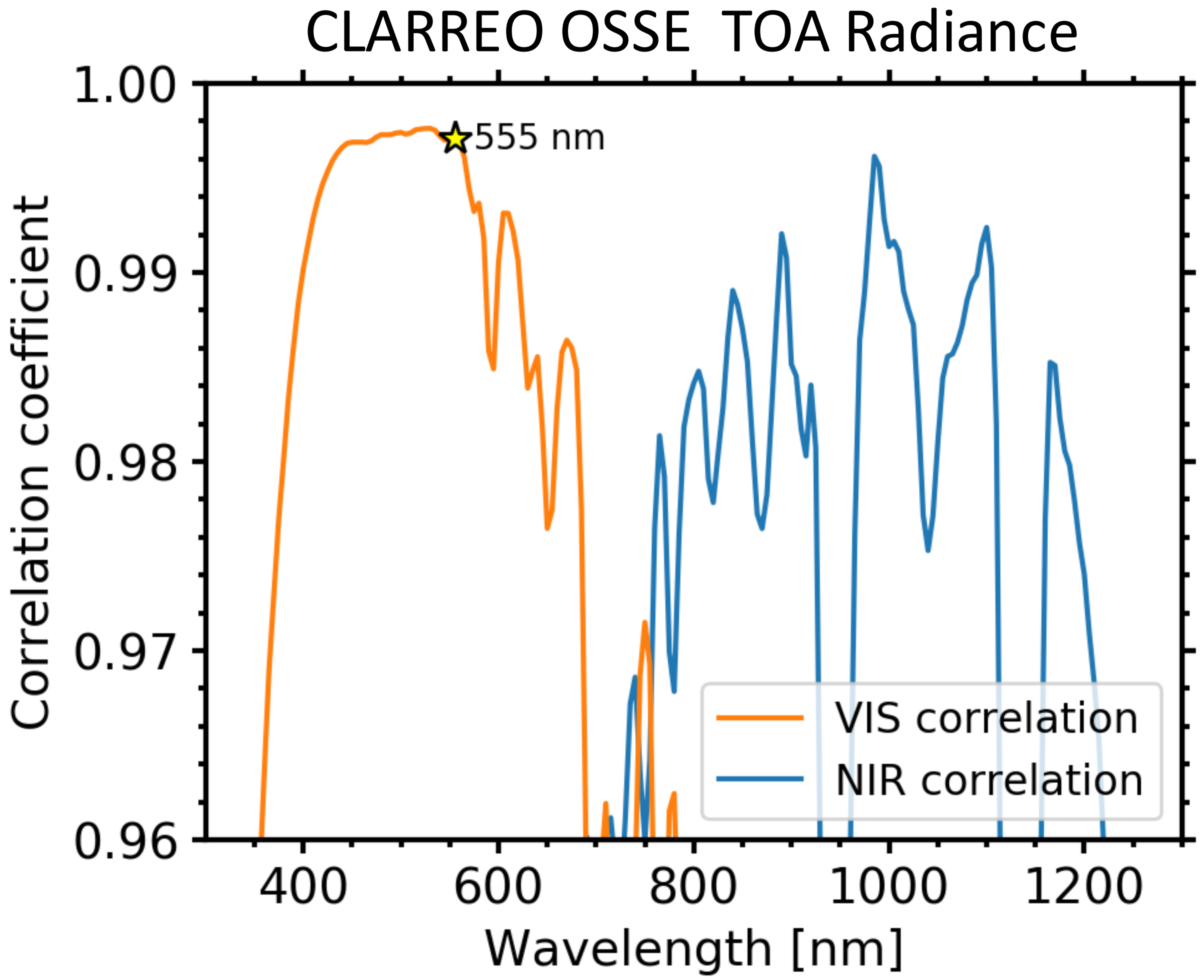
- Select "ADM samples": groups of pixels encompassing Libera point spread function (PSF)
- Randomization (or "systematic shift") within angular bins from one exposure to the next
  - 39,609/4,194,304 pixels (**0.94%**)

CERES-TRMM angular bins
Loeb et al., JAM [2003]



555 nm provides optimal proxy for split-solar

- CLARREO OSSE data (*Feldman et al., JGR [2011]*) suggests mid-visible wavelength is optimal for Libera VIS sub-band



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- Consistent with:
    - SCIAMACHY *Gottwald and Bovensmann [2011]*
    - SCIAMACHY-like simulations *Gristey et al., J. Climate [2019]*
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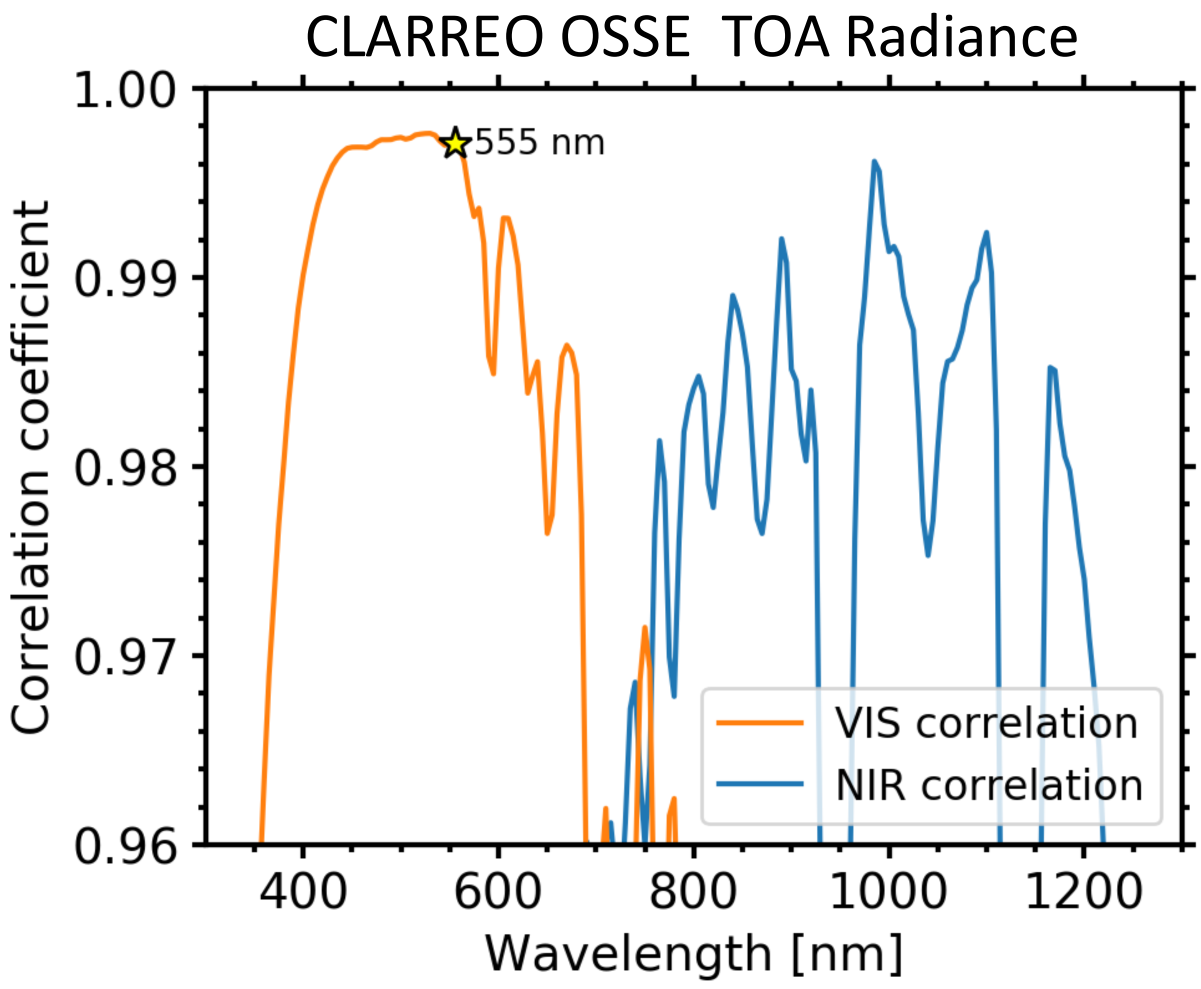

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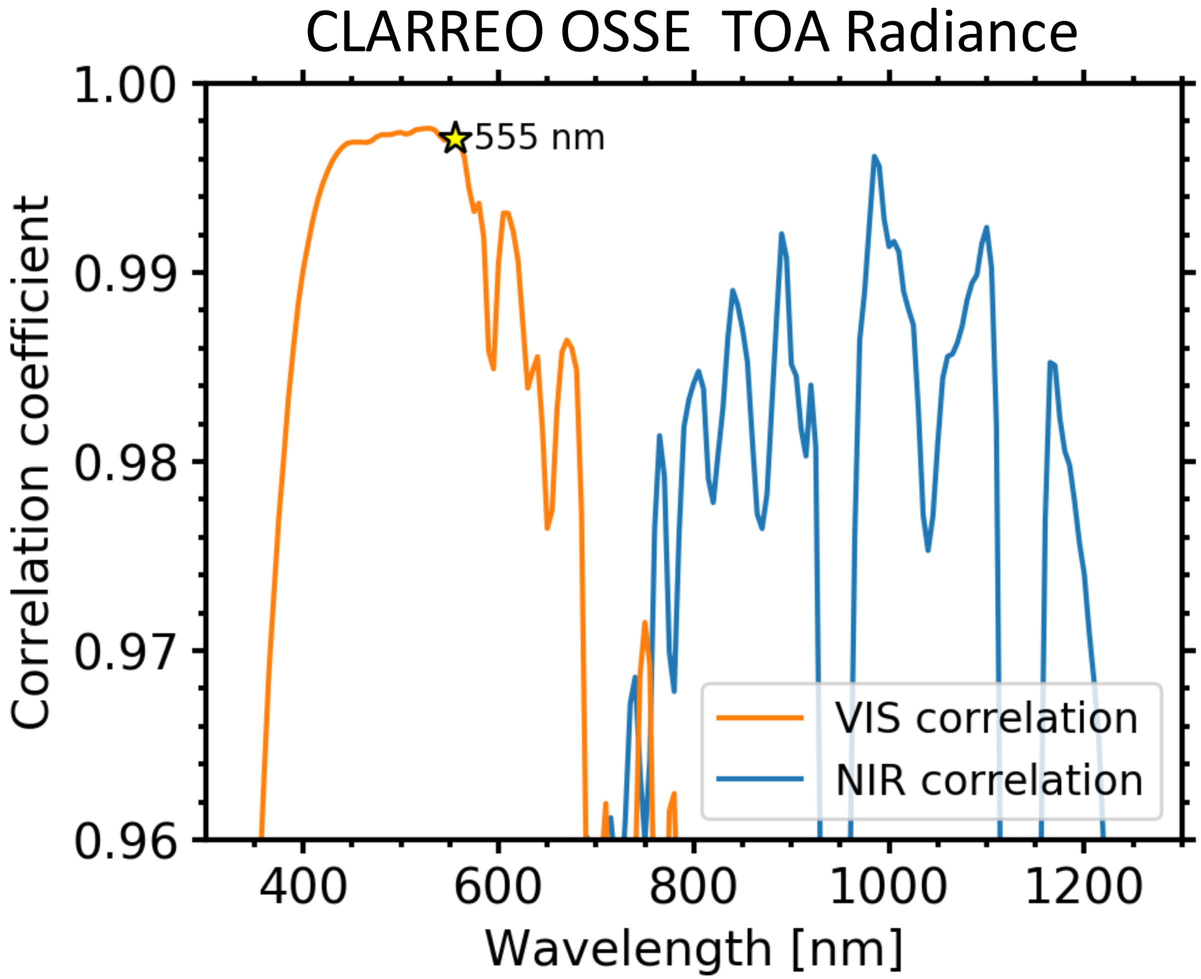
- 555 nm has several operational advantages
  - ➢ Matches VIIRS M4 band (flat-fielding)
  - ➢ Less optical degradation



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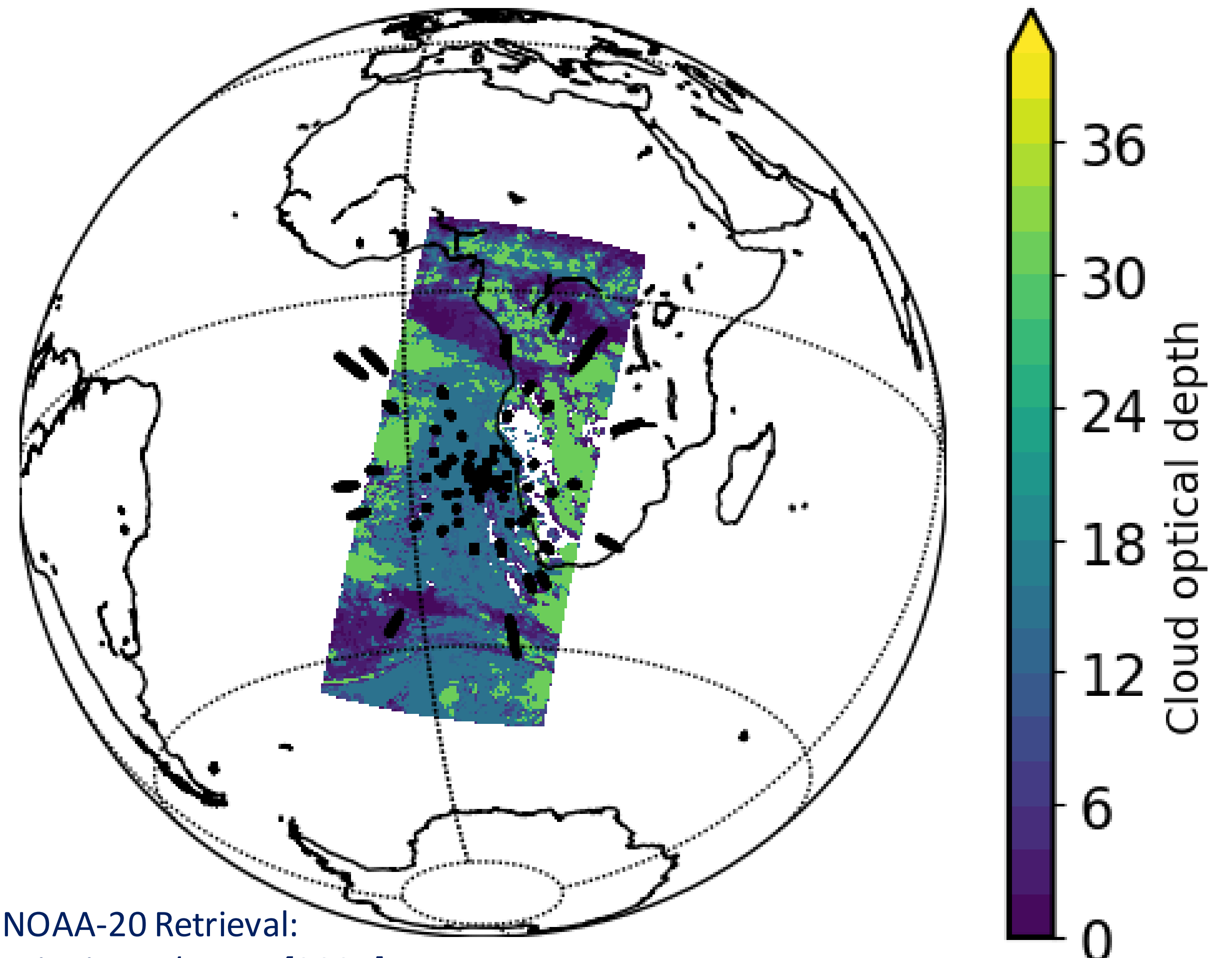
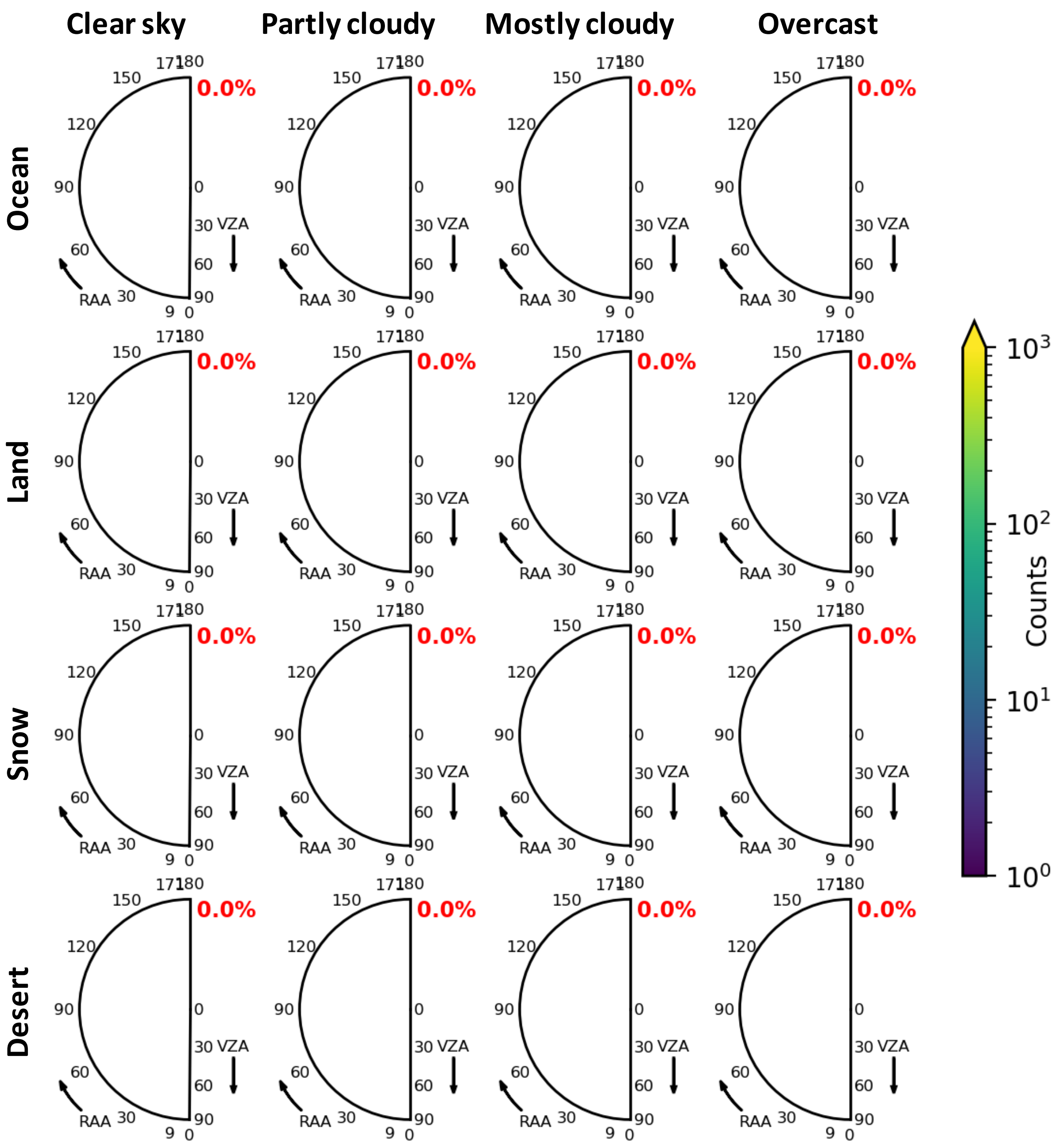
2021-10-01 00:30 UTC



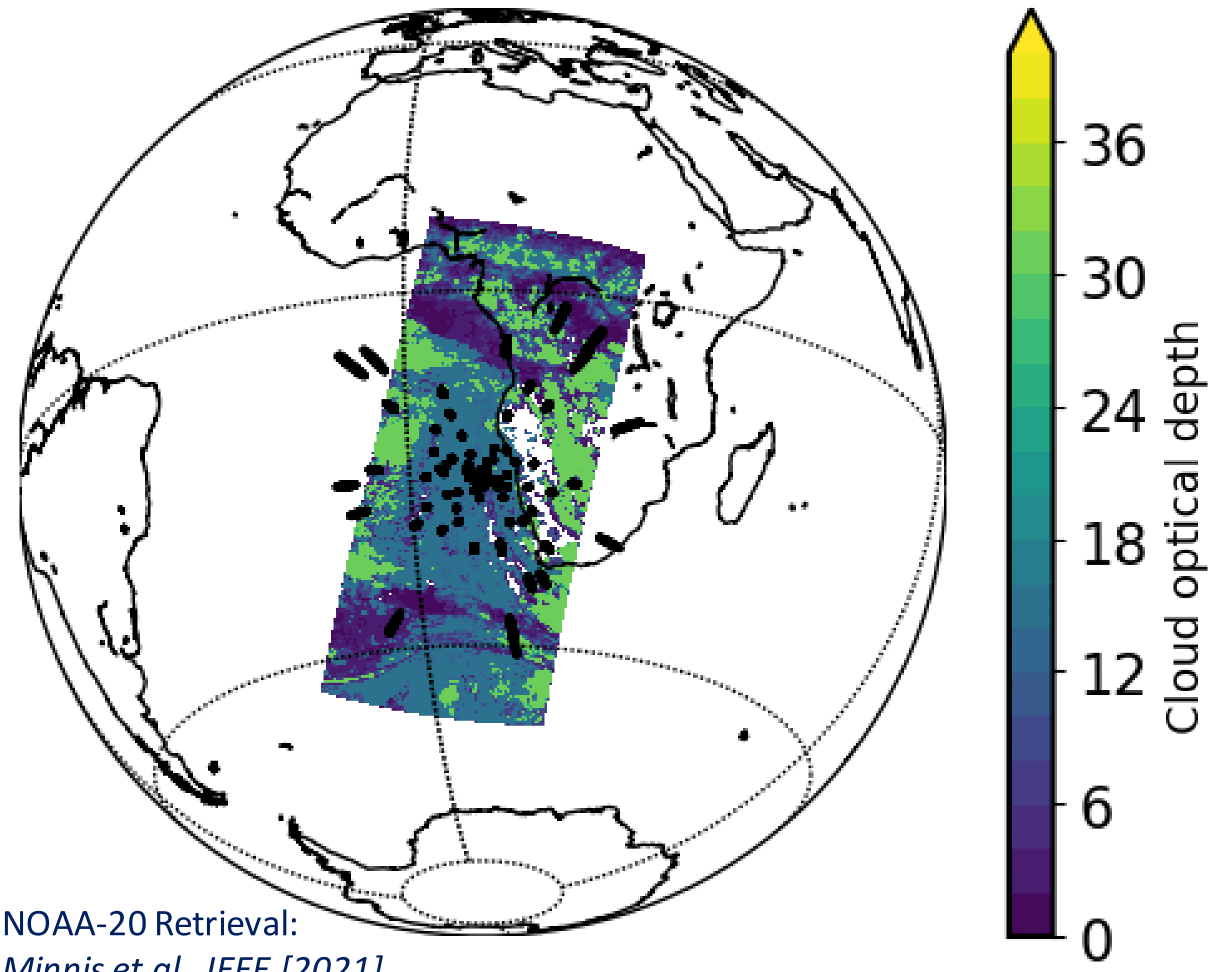
NOAA-20 Retrieval:
Minnis et al., IEEE [2021]



Gristey et al., AMT [2023]

Key
- Night ADM sample
- Day ADM sample, outside VIIRS swath
- Day ADM sample, added to count

2021-10-01 00:30 UTC



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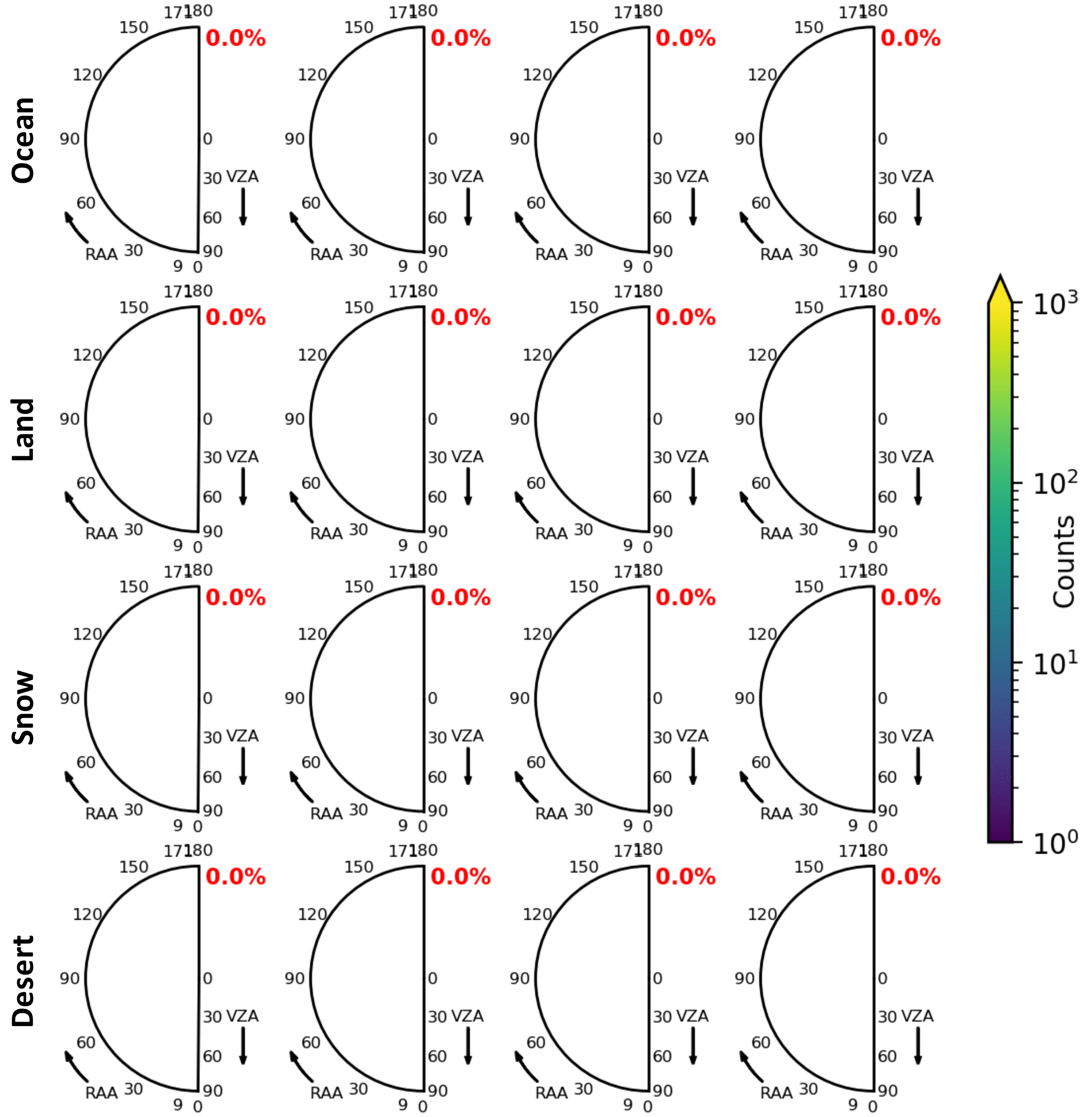

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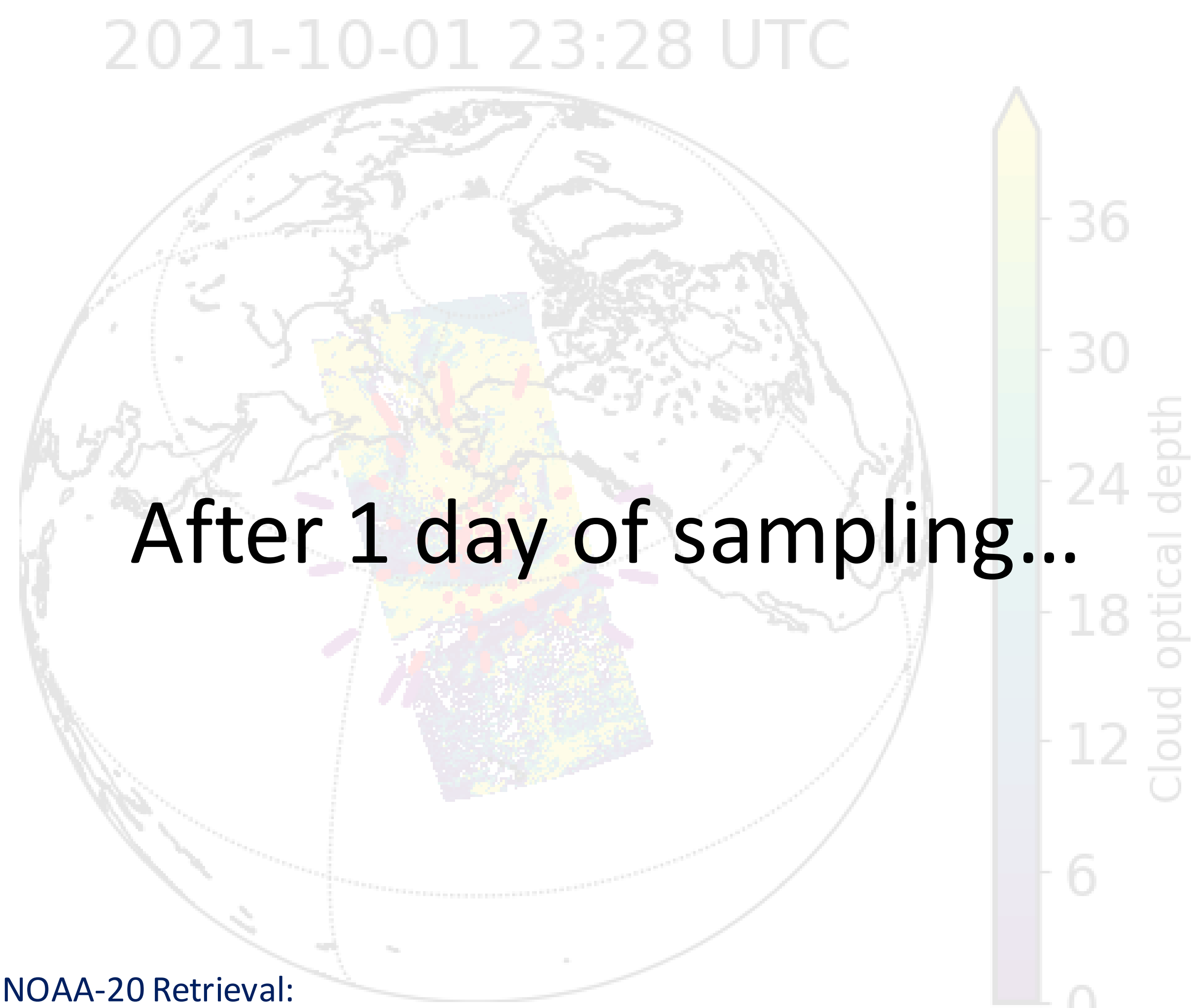

After 1 day of sampling…

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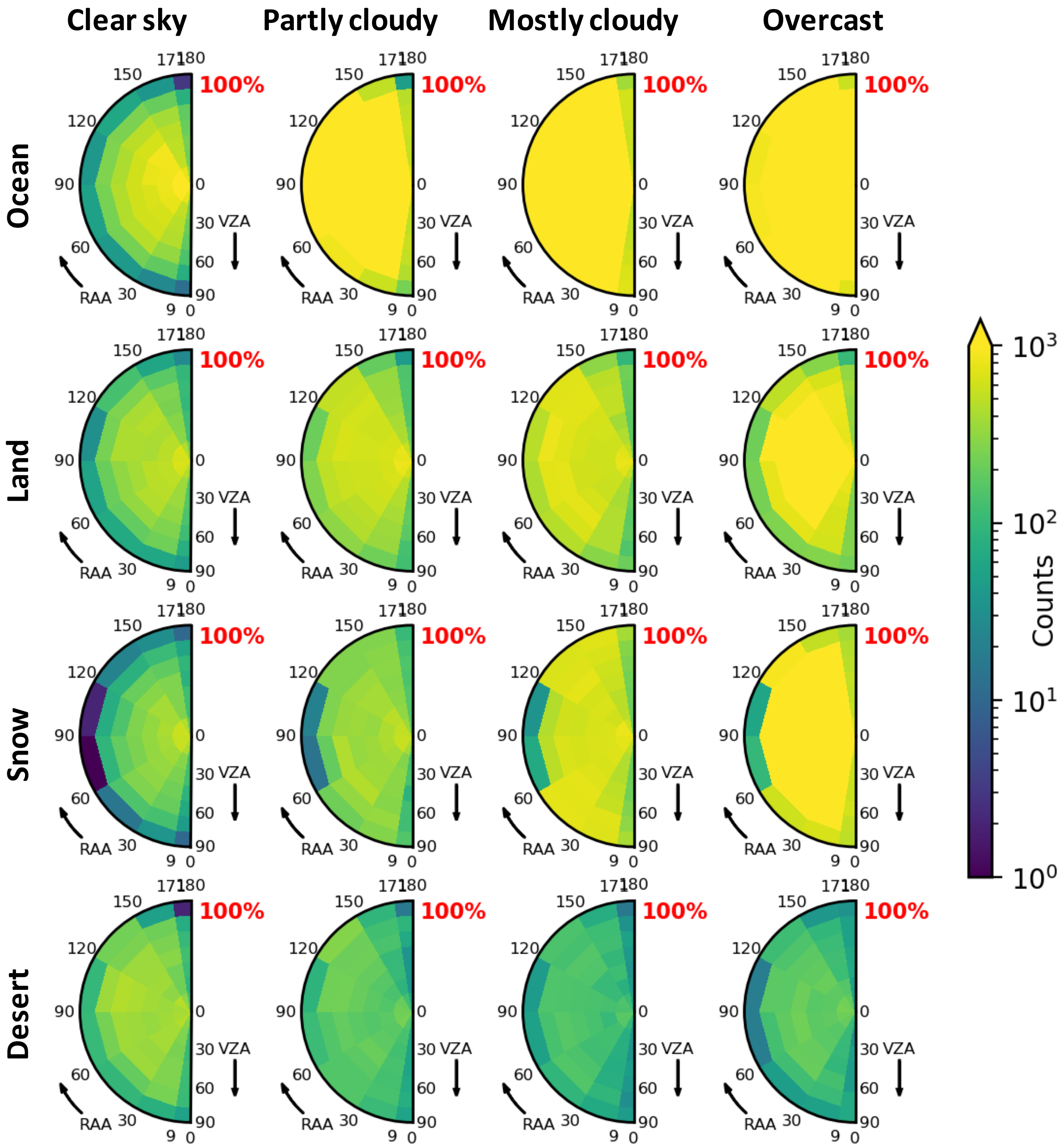

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Alternate approach for split-solar irradiance

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    1. Pre-launch: Run radiative transfer for a variety of scenes to calculate multi-spectral and broadband radiances and irradiances, providing a “lookup table”

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observed *retrieved*

F : irradiance (or flux)
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- One key concern: information about the split-solar angular distribution is entirely based on theory
  - ➢ The Libera camera could provide a useful observational test here…

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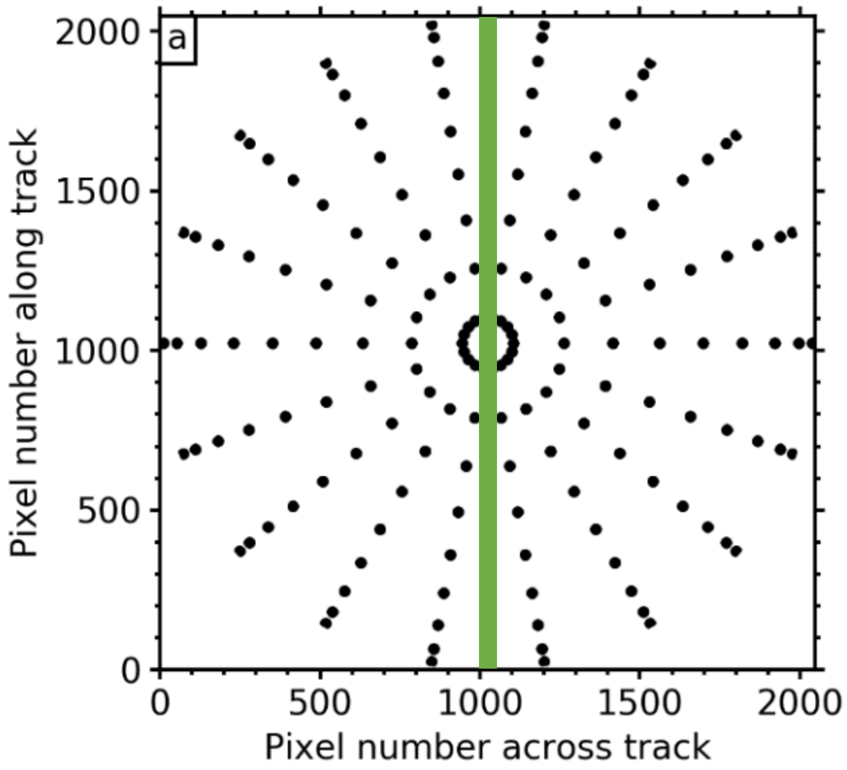
Hyper-angular sampling as an observational test



- Along track "stripe" - also downlinked

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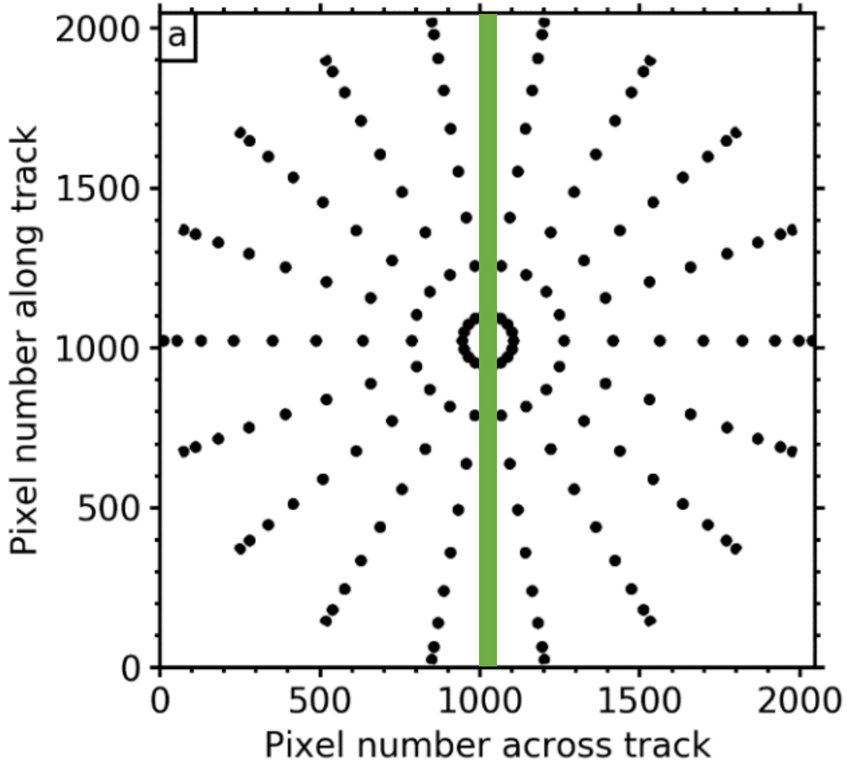

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- In the 16 minutes to pass through the camera WFOV, an exposure every 5 seconds provides 192 angular radiances

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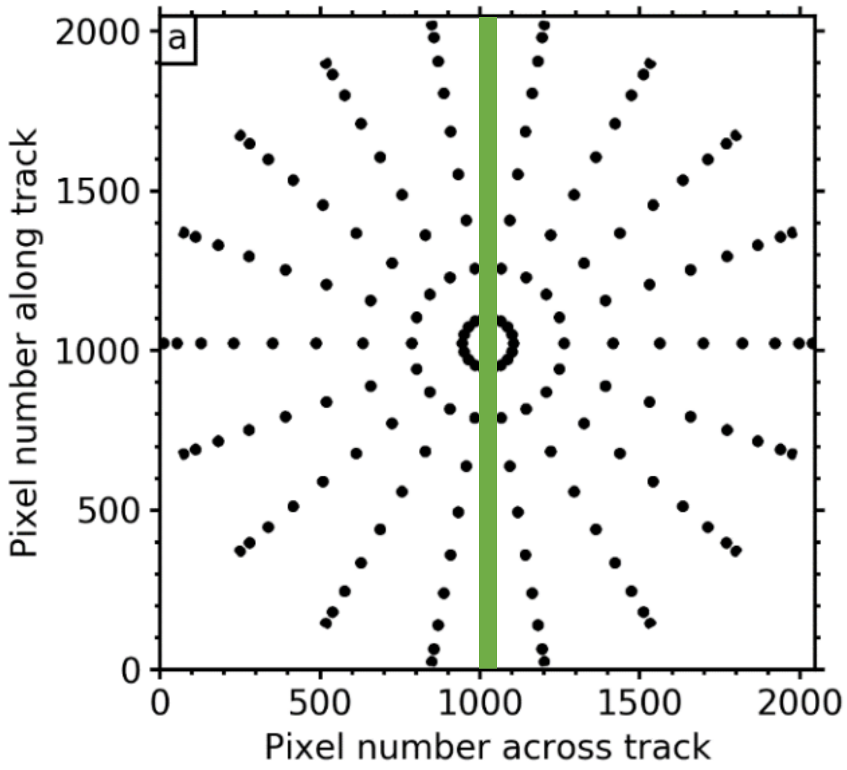

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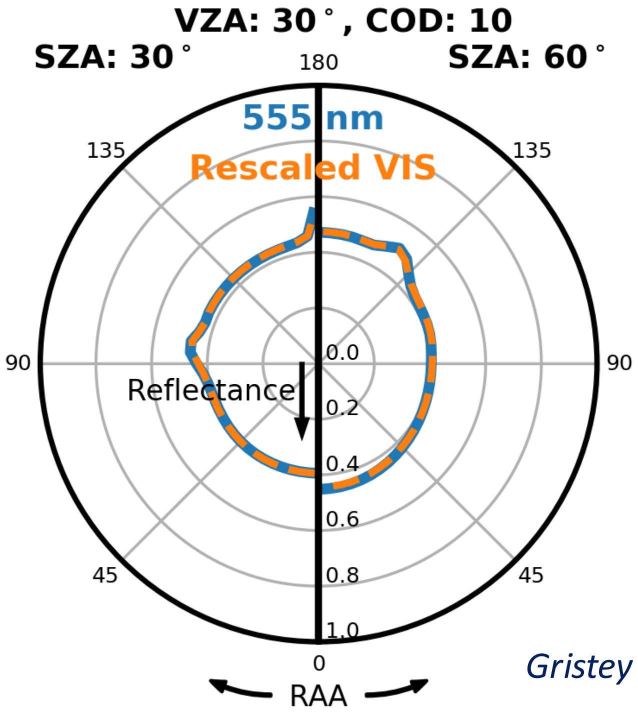

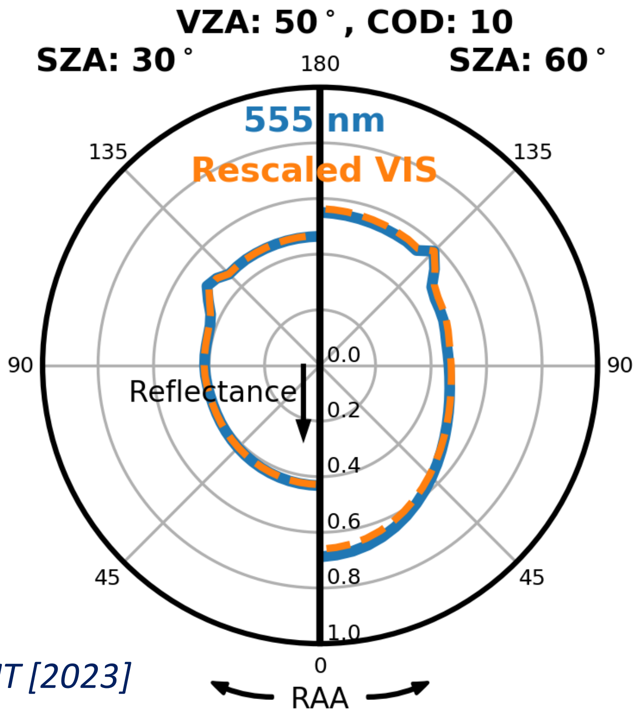

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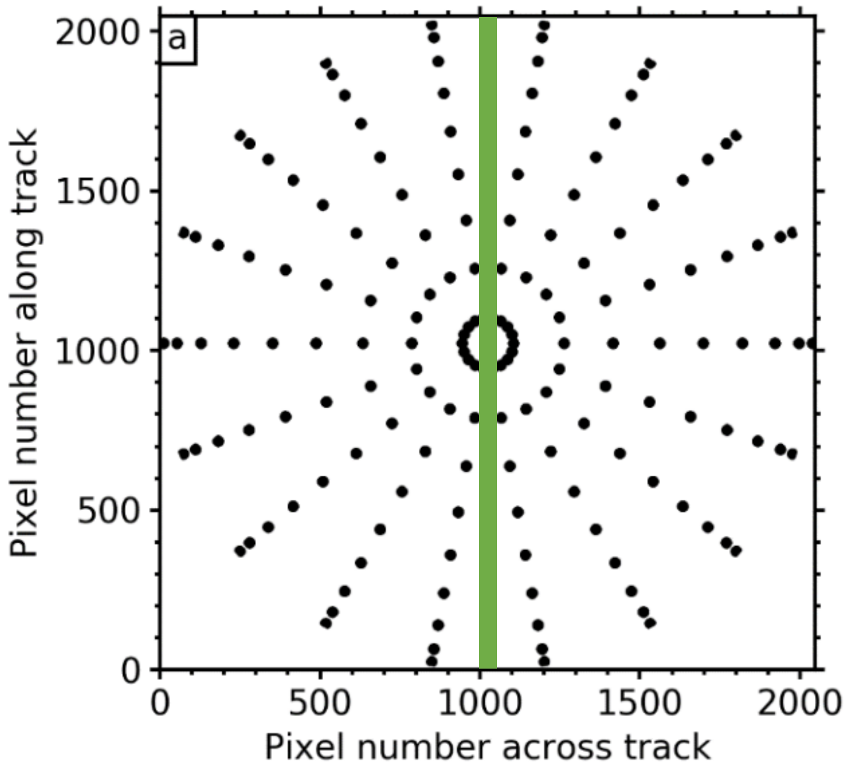

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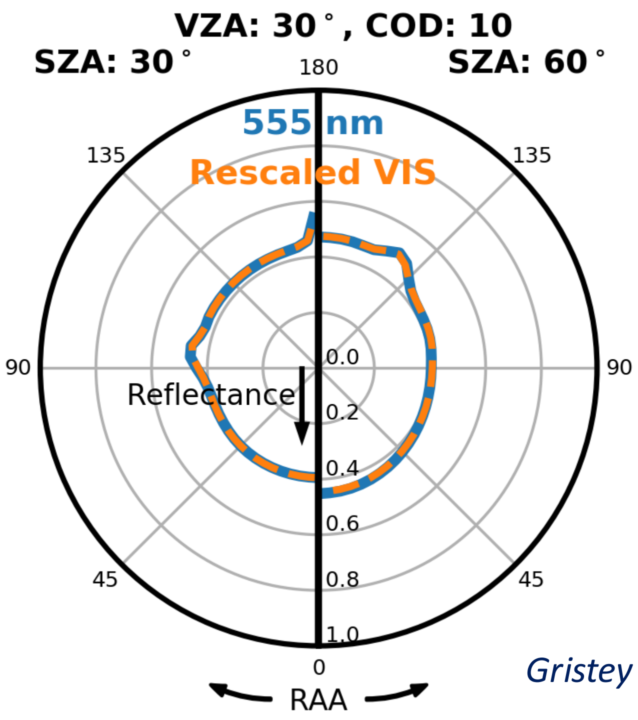

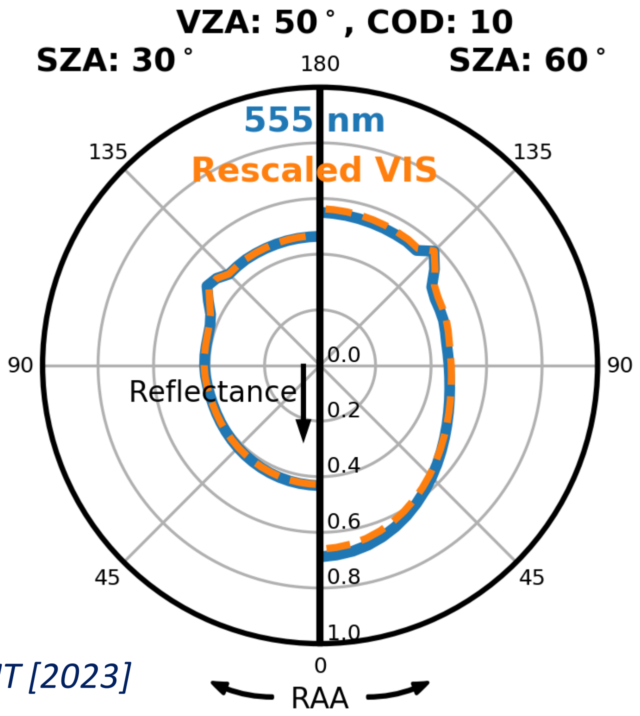

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- Note: currently exploring expansion beyond just along track

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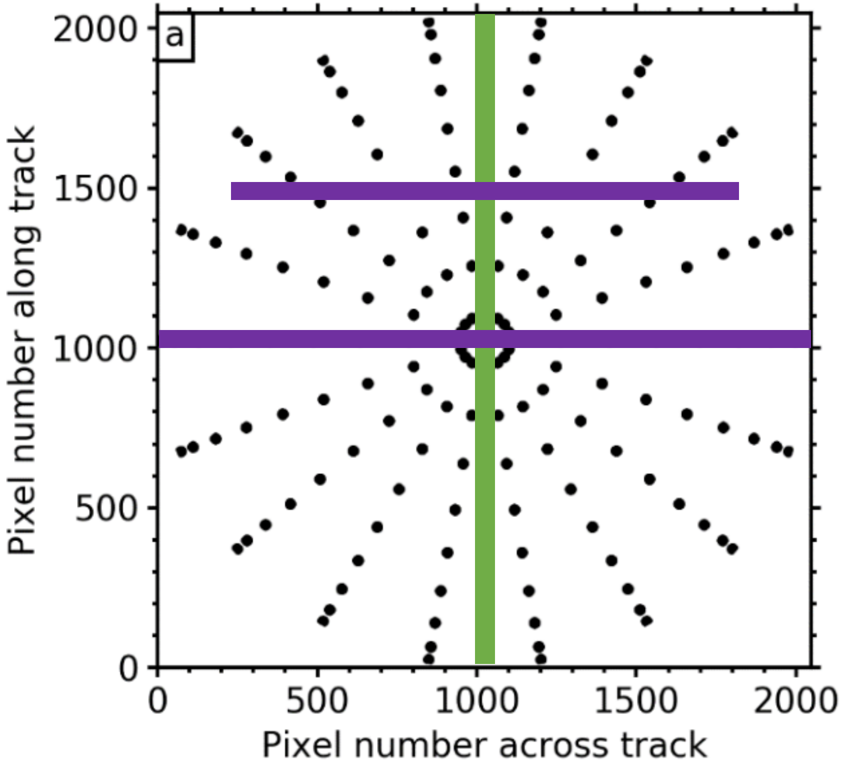
Cross-track imagery provides scene context



- Cross-track and fwd "stripes" - also downlinked
  - Provides scene context for radiometer footprint

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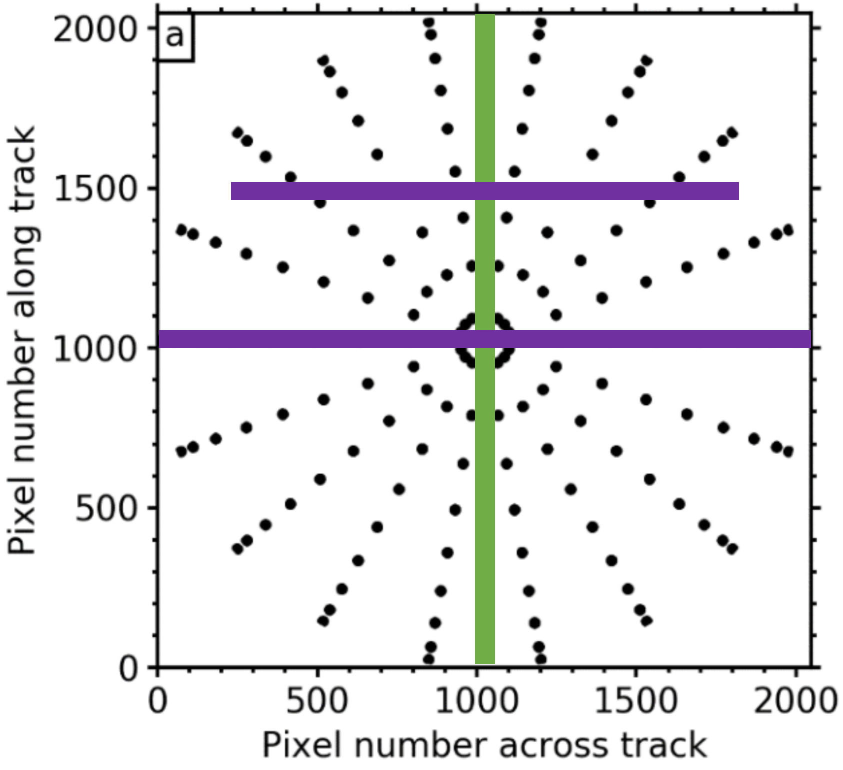
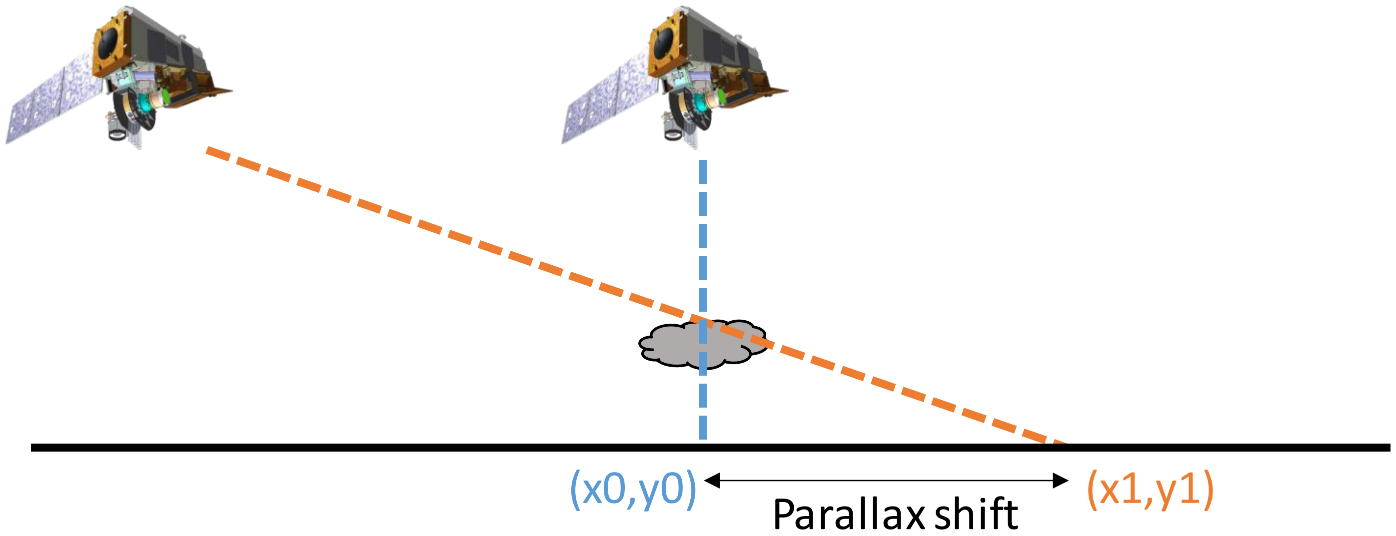
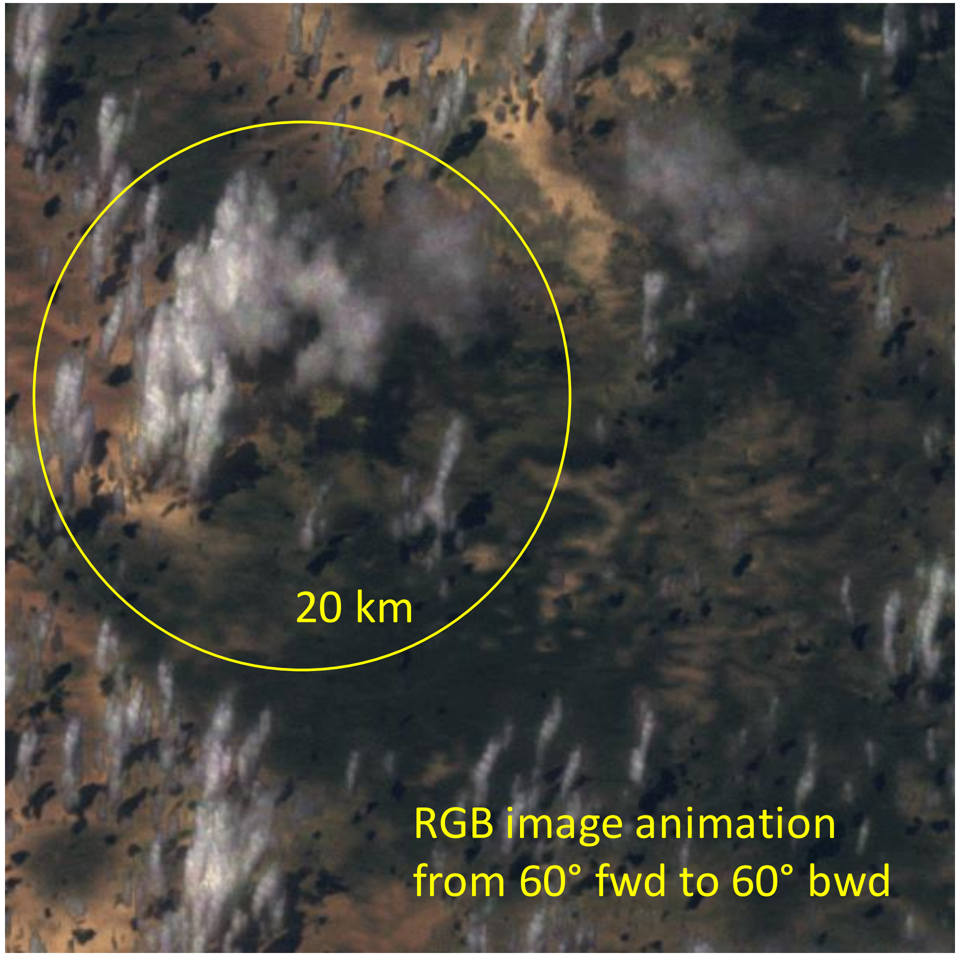


- Cross-track and fwd "stripes" - also downlinked
  - ➢ Provides scene context for radiometer footprint
- Camera cloud detection sometimes challenging (multi-spectral imagers too)
  - ➢ Cloud parallax: the apparent horizontal shift of a cloud relative to the surface with view-angle *e.g., Zhao & Di Girolamo, JAM [2004]*



Angular contrast can help to identify clouds

3D radiative transfer: EaR^{3}T *Chen et al., AMT [2023]*



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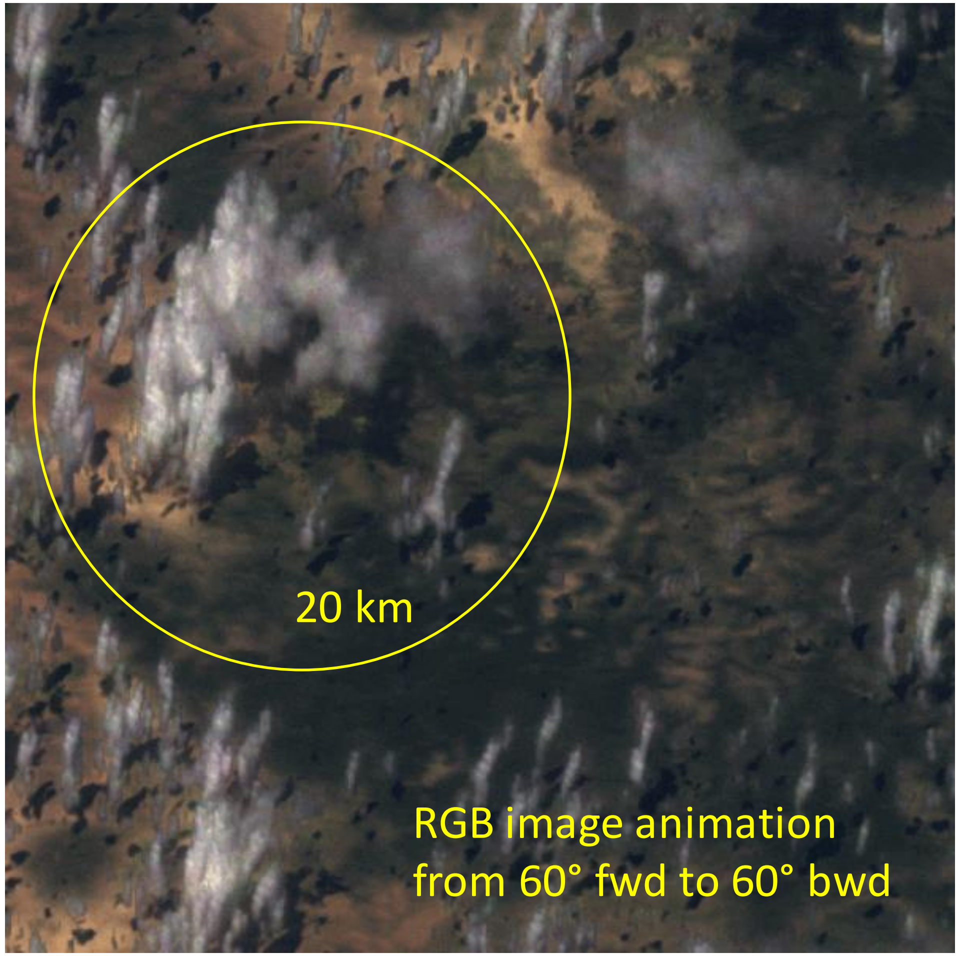

Monochromatic
555 nm image → R
@ 30° fwd

Monochromatic
555 nm image → G
@ nadir

Monochromatic
555 nm image → B
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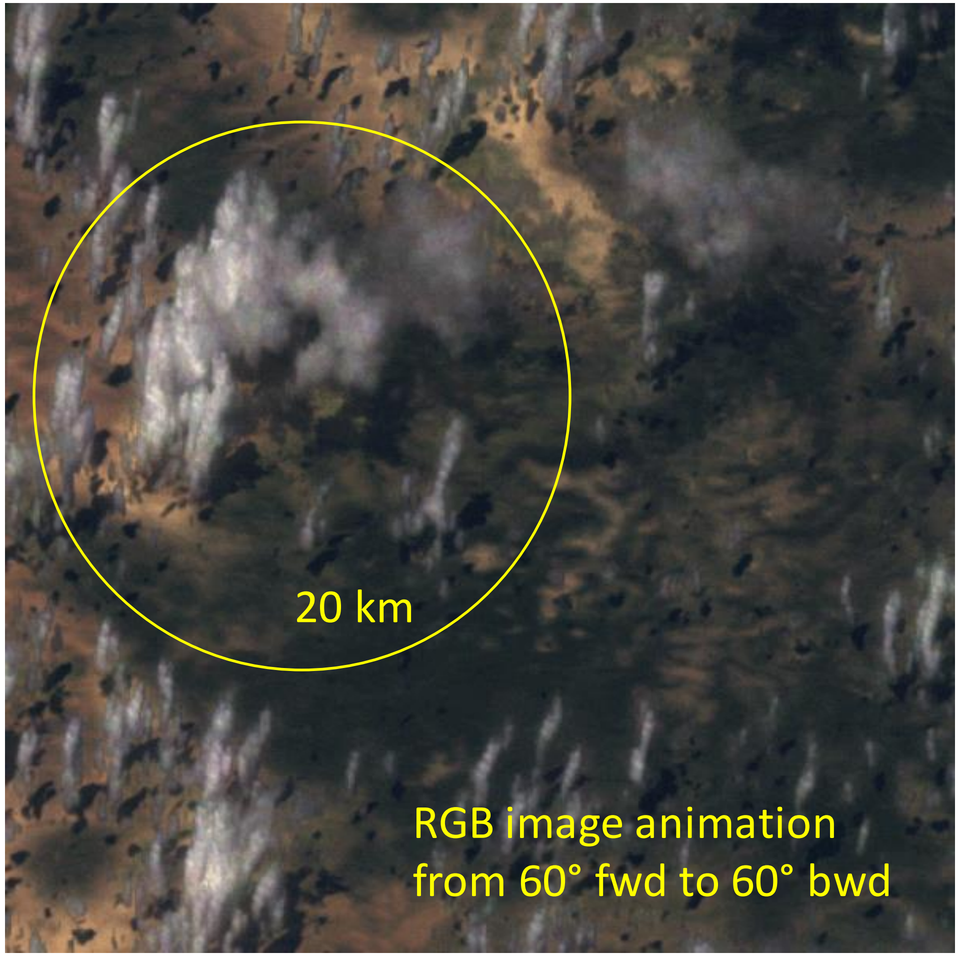

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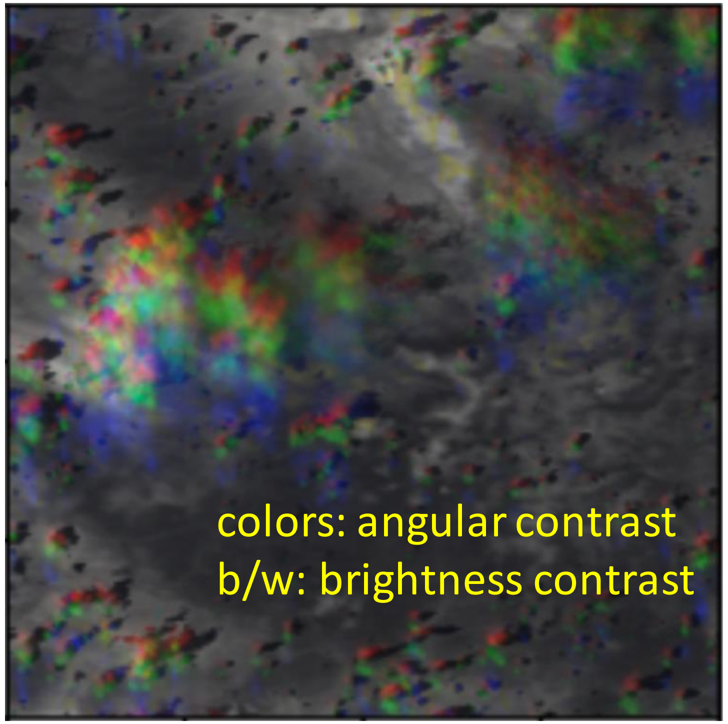

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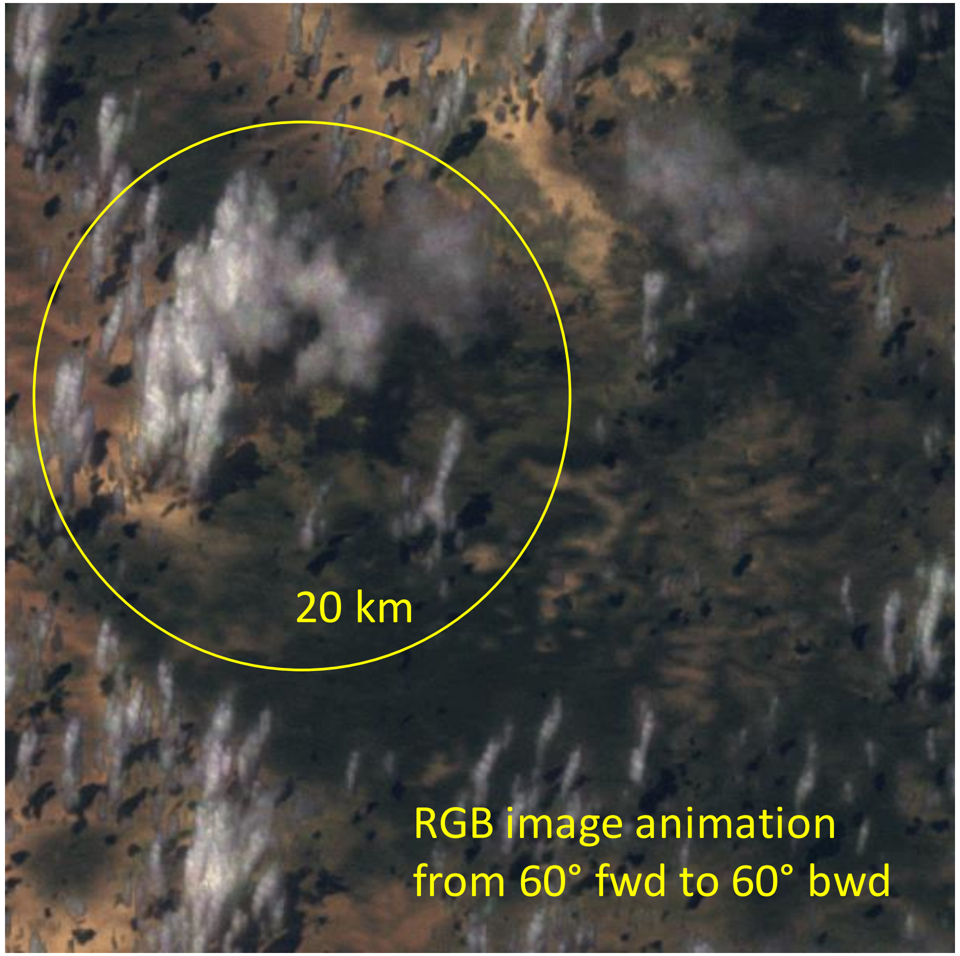

Monochromatic 555 nm image @ 30° fwd → R

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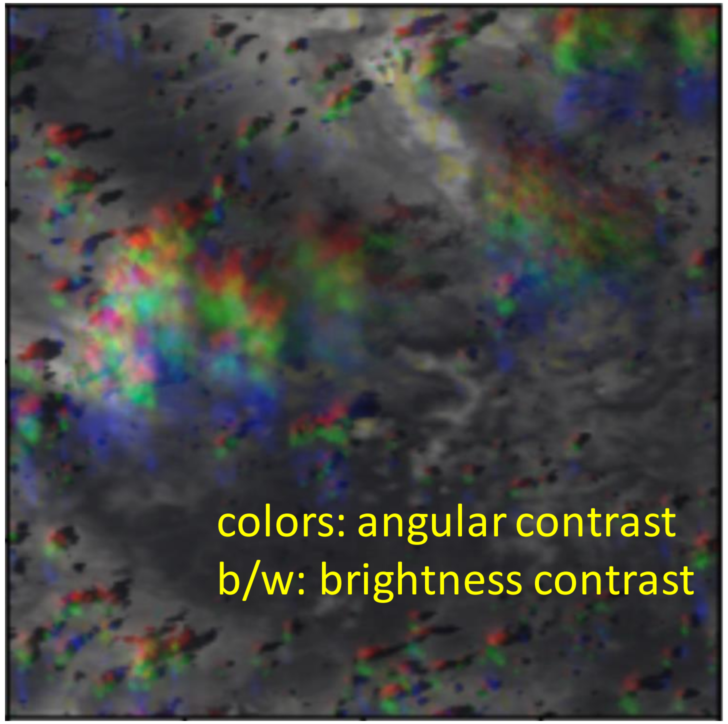
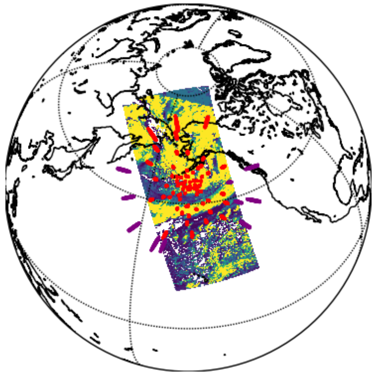
Monochromatic 555 nm image @ 30° bwd → B

Credit: K. S. Schmidt & K. Dong



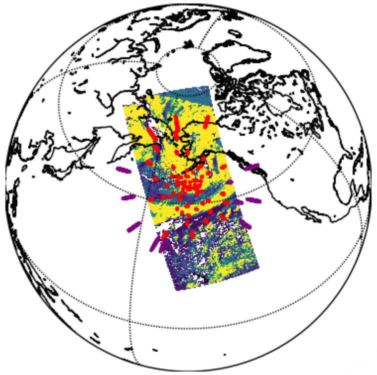
- Concept also applies to traditionally challenging conditions e.g., low clouds in the Arctic

Summary and conclusions



- Simulation experiments show that the Libera camera can aid rapid VIS ADM development

Summary and conclusions



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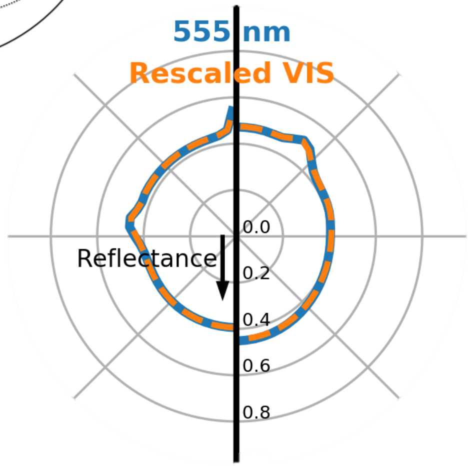
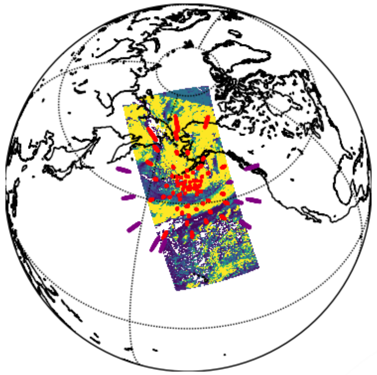


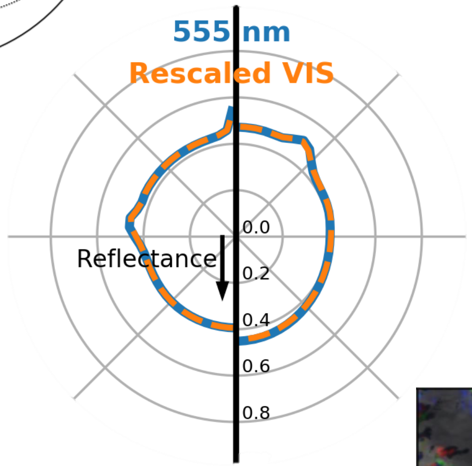
- “Hyper-angular” data could serve as a powerful observational test of an alternate radiance-to-irradiance approach

Jake.J.Gristey@noaa.gov

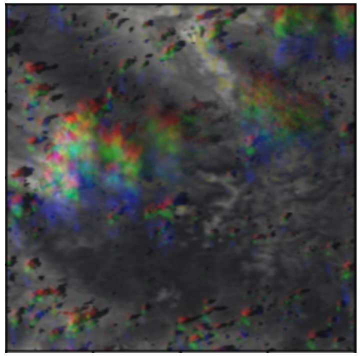
Summary and conclusions



➢ Simulation experiments show that the Libera camera can aid rapid VIS ADM development



➢ "Hyper-angular" data could serve as a powerful observational test of an alternate radiance-to-irradiance approach

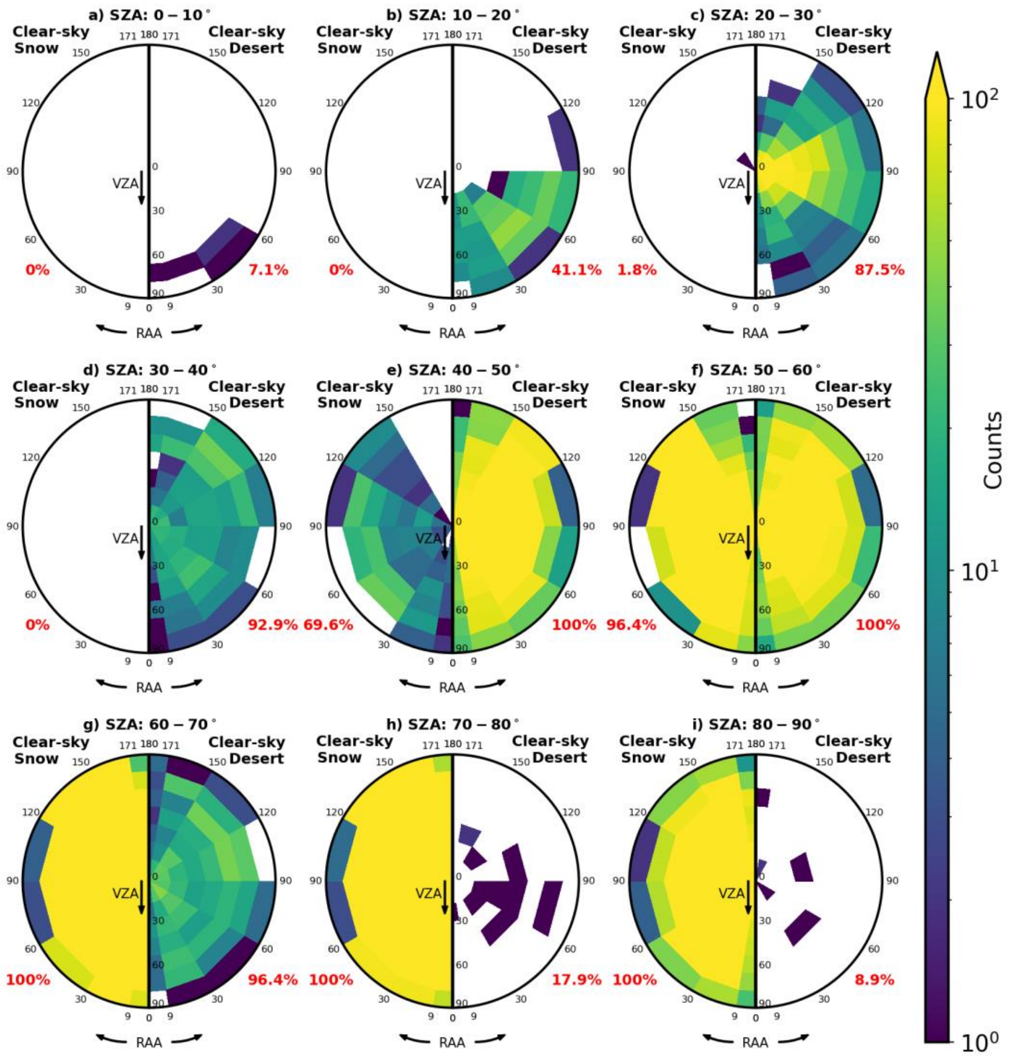


➢ Stereo imagery shows promise for assisting cloud detection in challenging environments

Jake.J.Gristey@noaa.gov

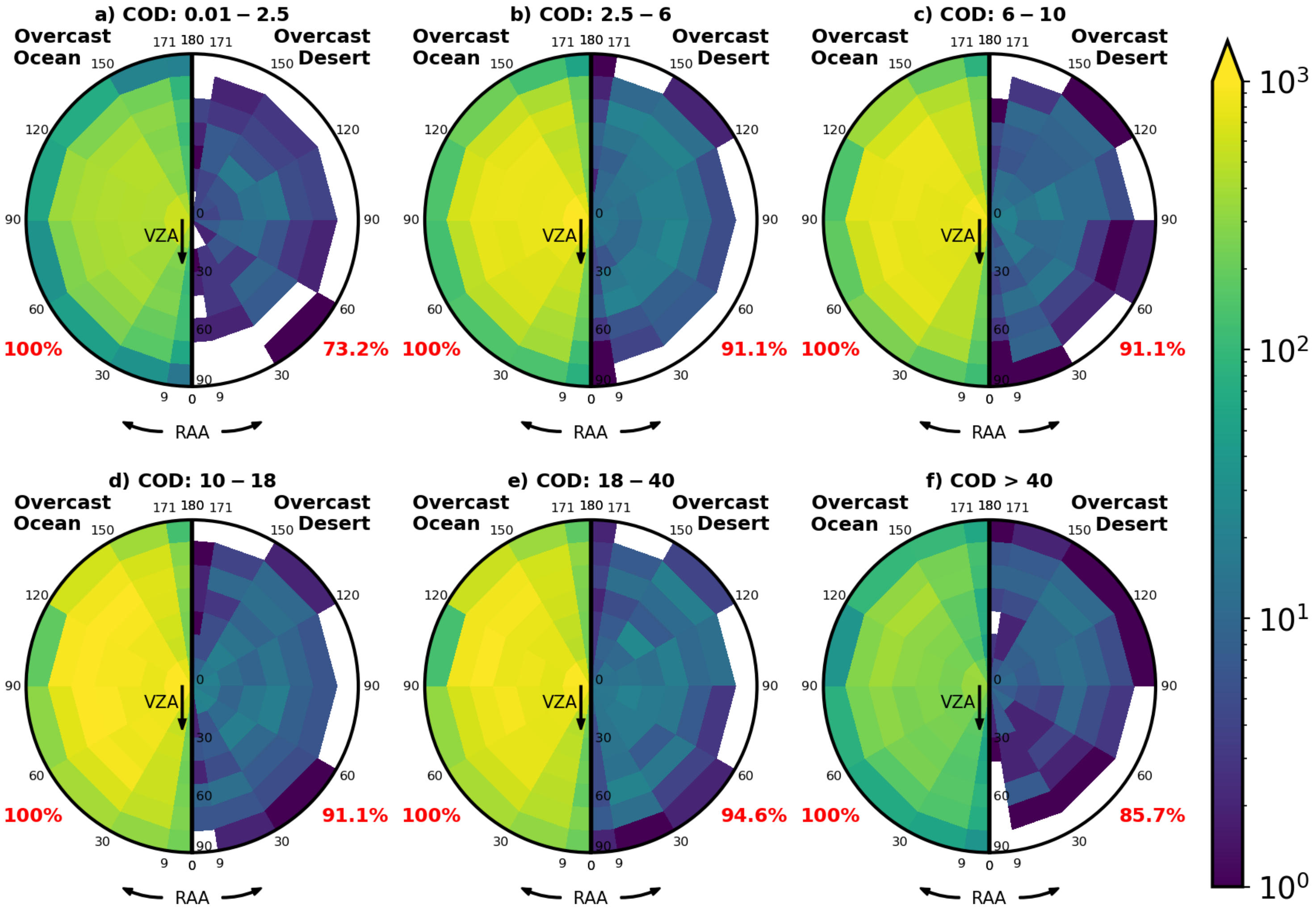
Counts: SZA dependence

extra



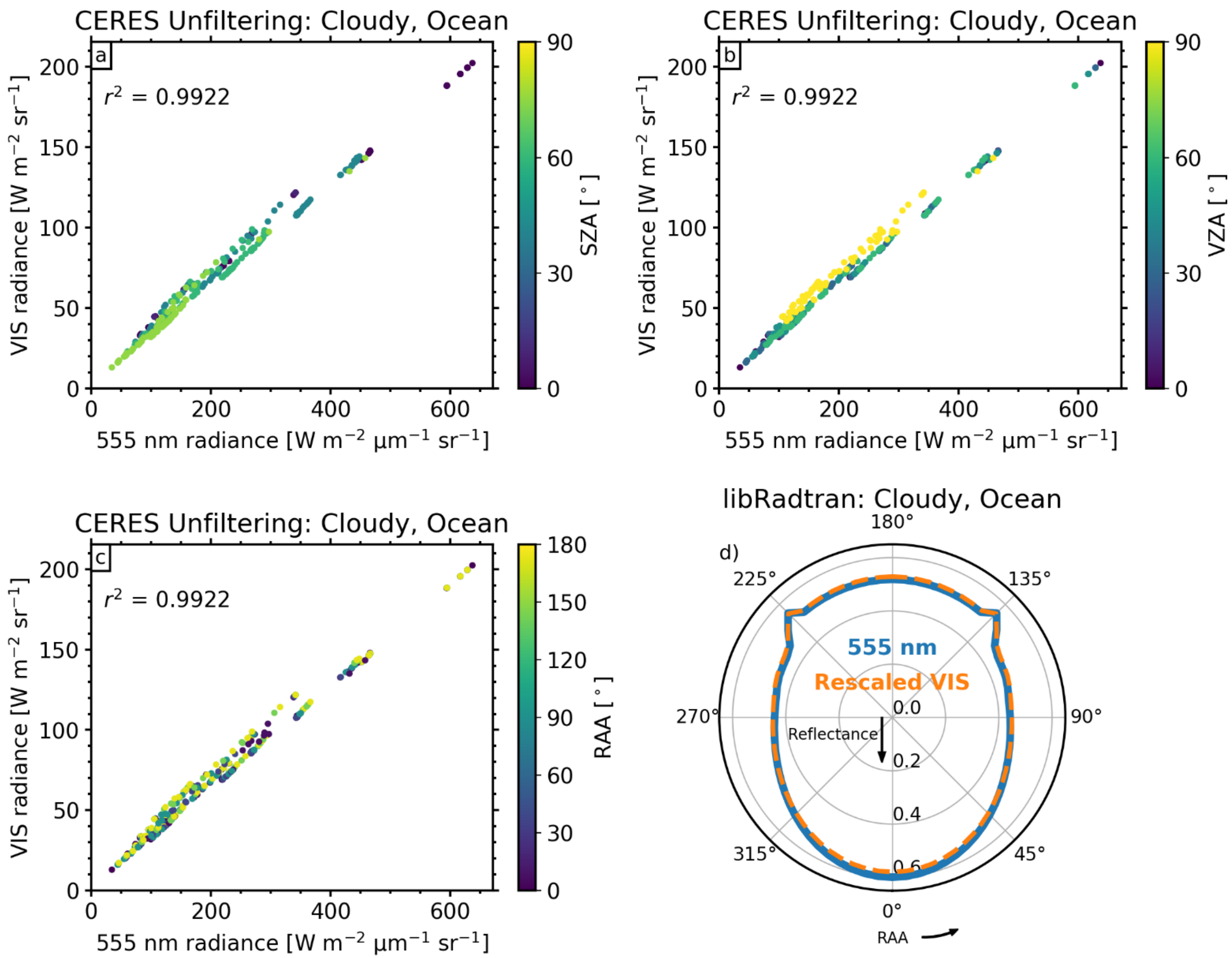
Counts: Cloud optical depth dependence

extra



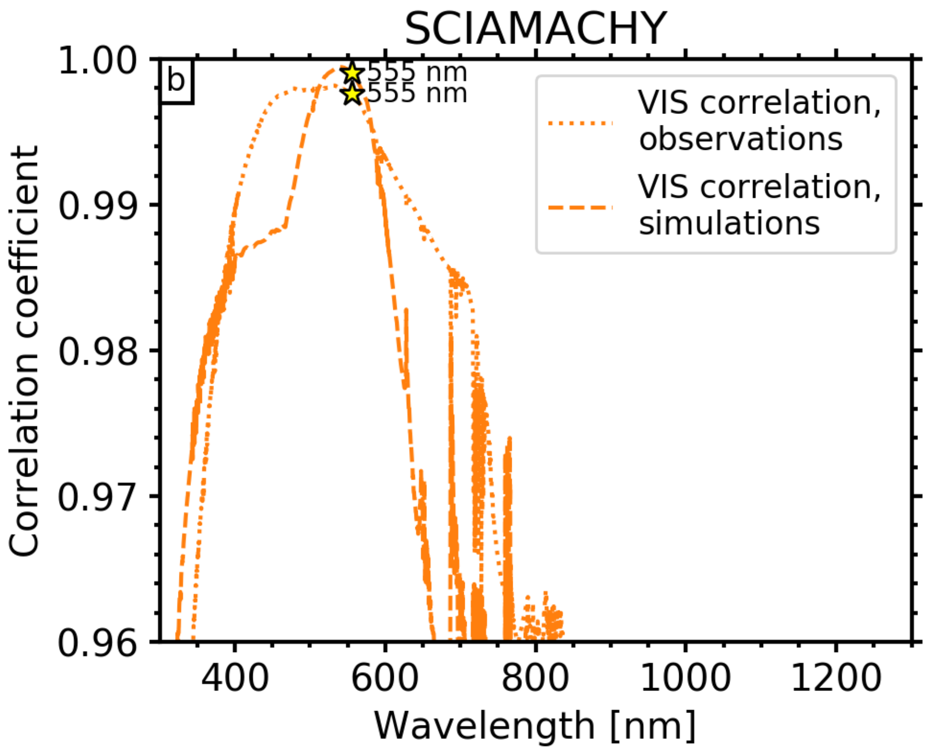
Spectral relationship vs. angle

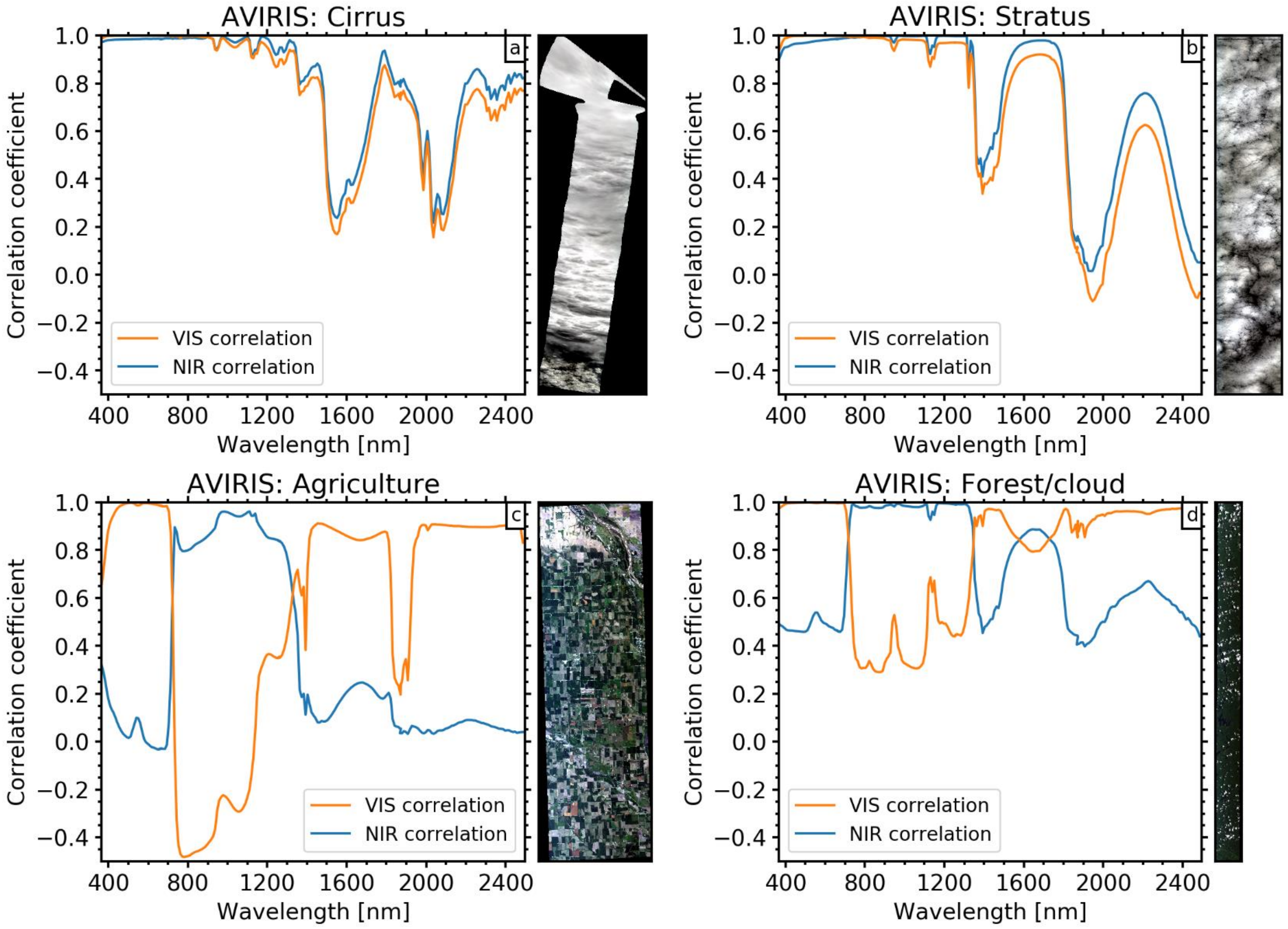
extra



Spectral relationship: SCIAMACHY/AVIRIS

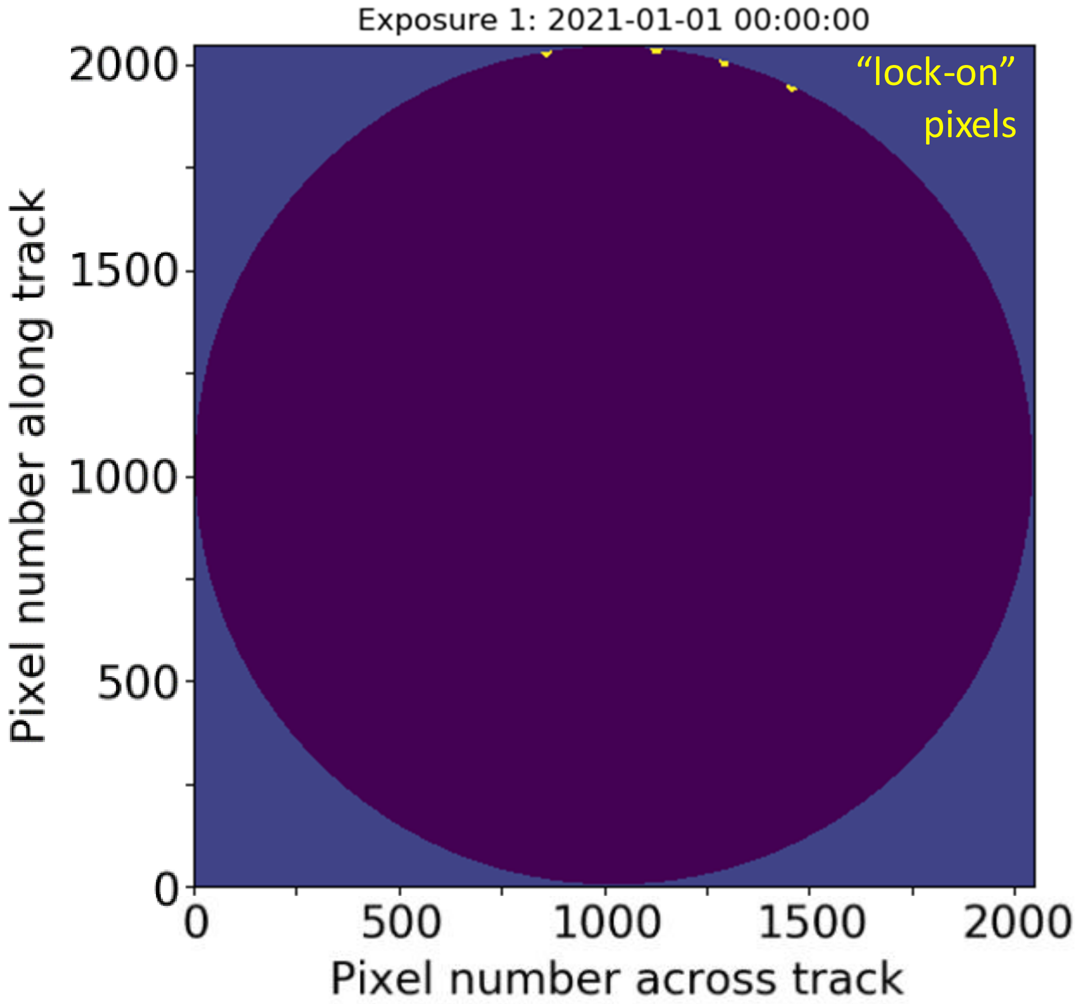
extra

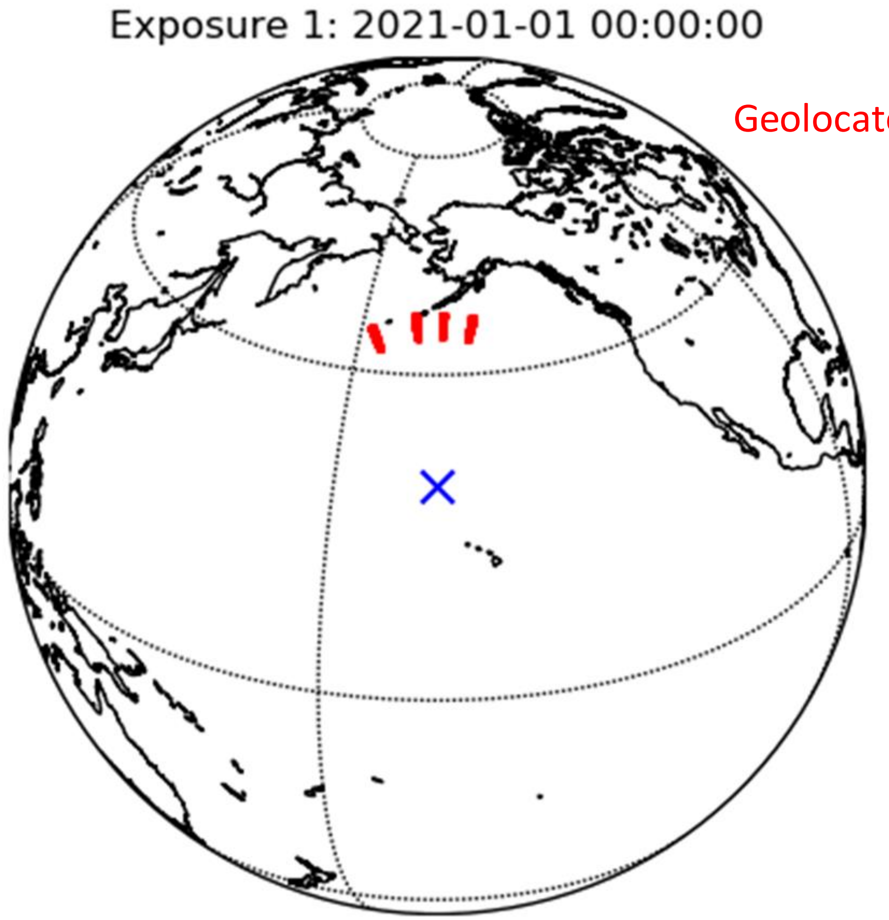




Expanding beyond along-track

extra

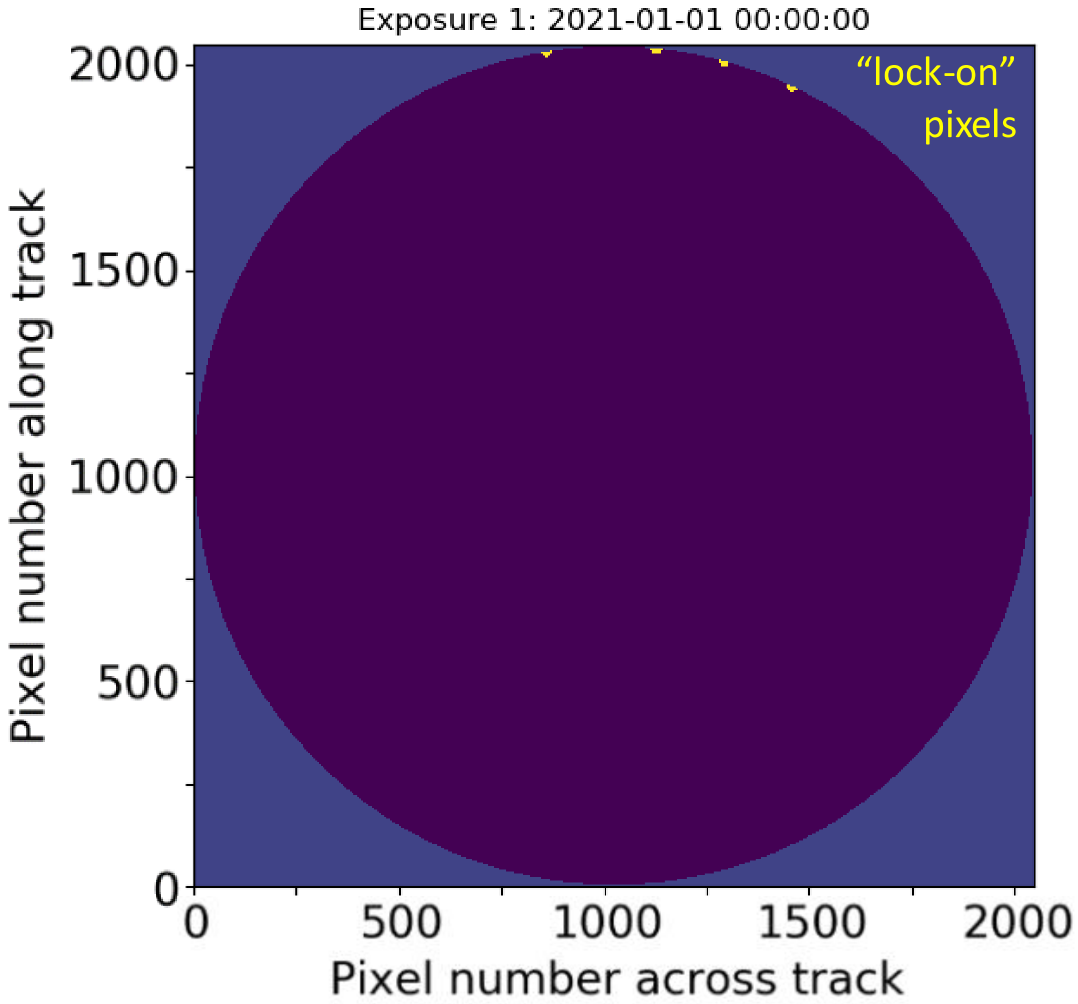


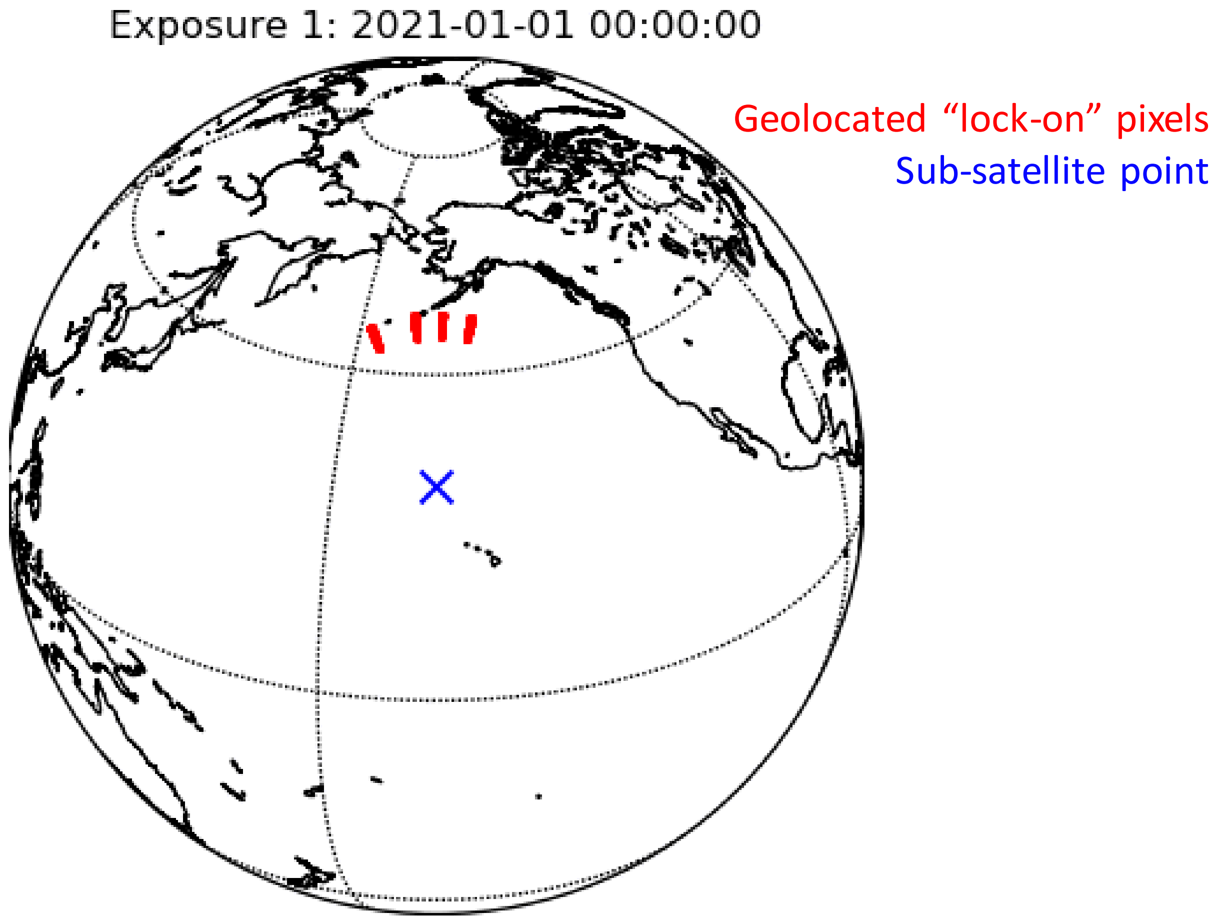


Geolocated "lock-on" pixels
Sub-satellite point

Expanding beyond along-track

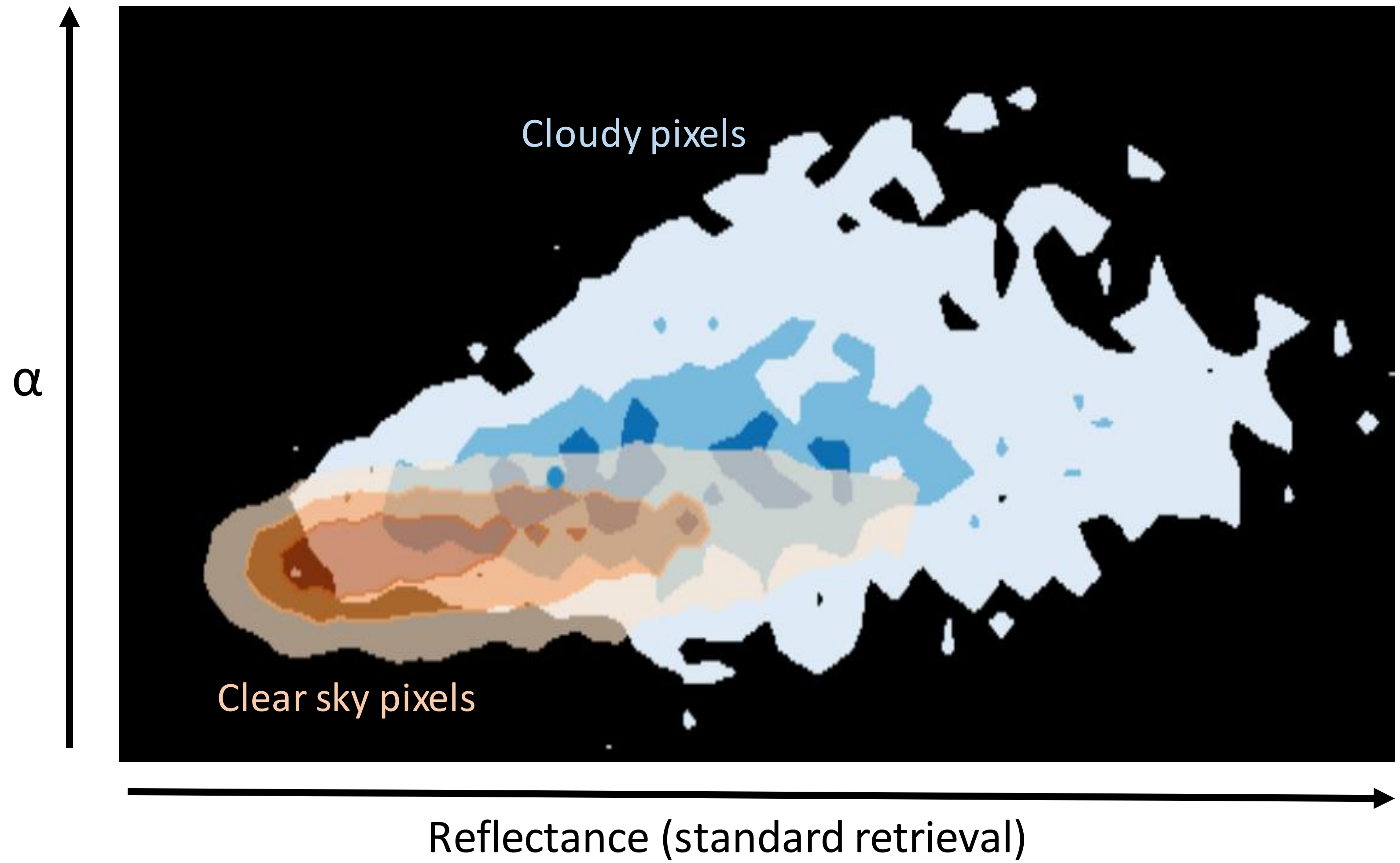
extra





Angular index as an additional dimension

extra



Angular index:
α = (fwd – bwd) / nadir

Example of cloud over frozen surface

extra

Same cloud scene over a frozen surface