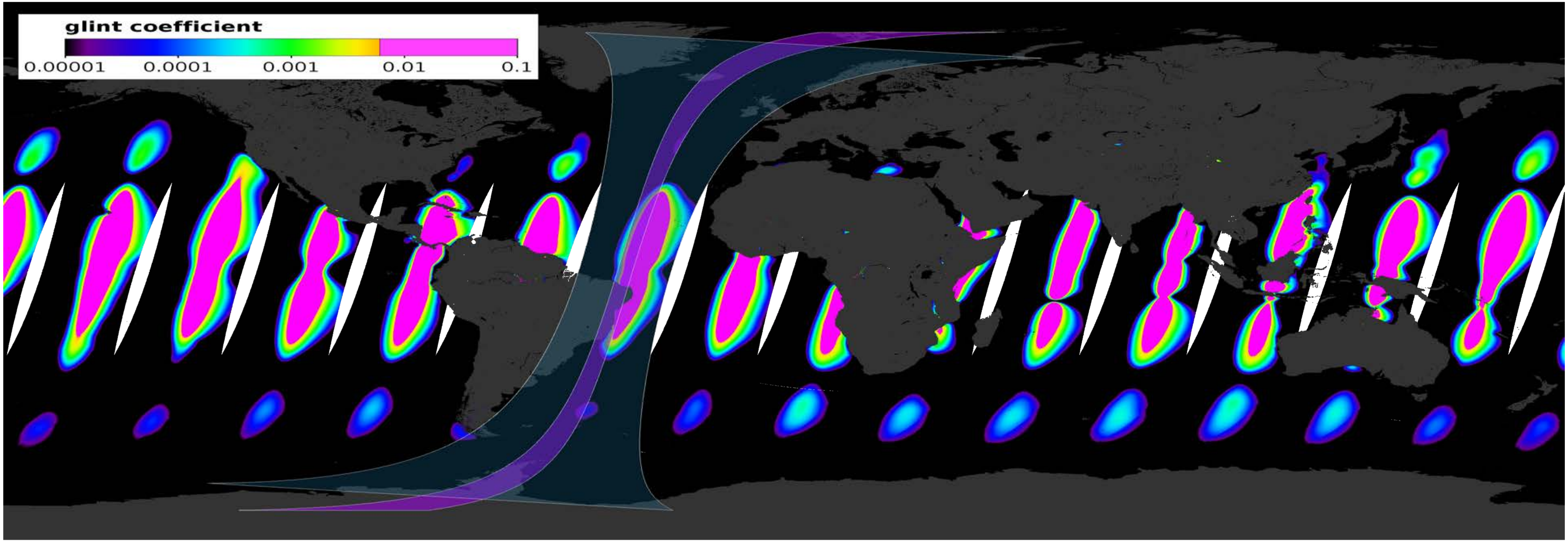
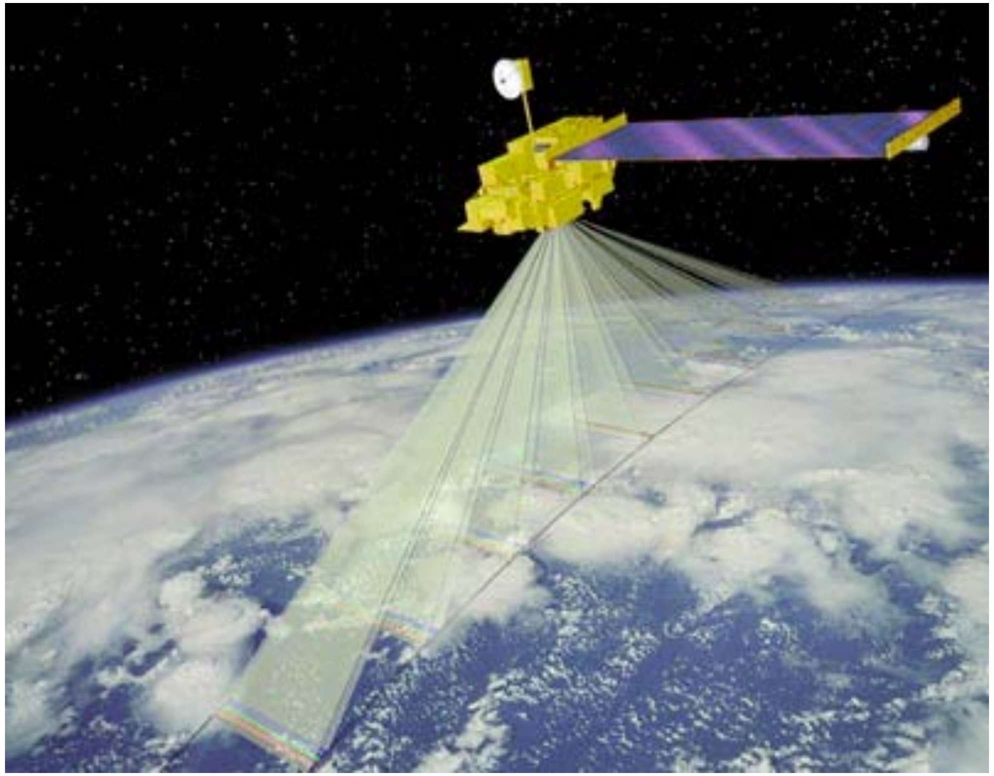
Joint MISR/MODIS Ocean Color Atmospheric Correction with a New Algorithm that Utilizes Reflected Sun Glint

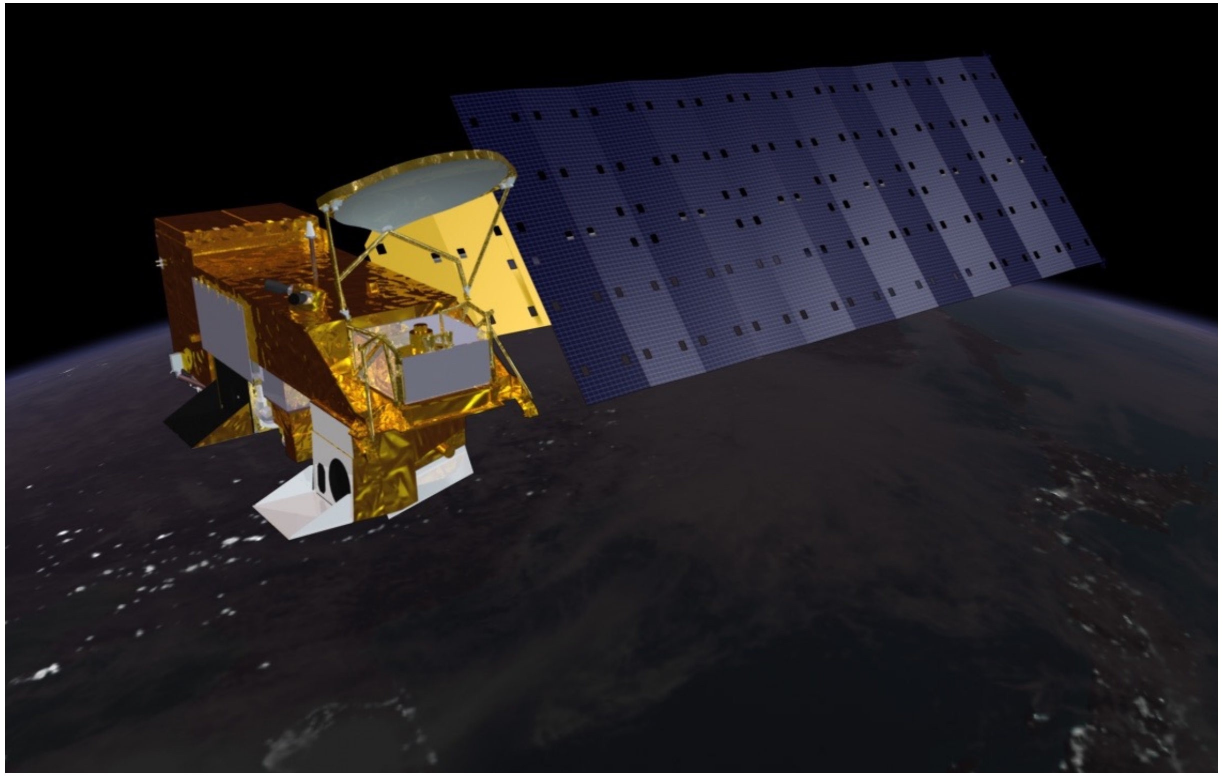
Kirk Knobelspiesse, Amir Ibrahim, Zia Ahmad, Sean Bailey, Bryan Franz, Joel Gales, Michael Garay, Robert Levy, Olga Kalashnikova

GSFC & JPL



In a nutshell





MISR

multi-angle + glint observations: atmospheric correction

MODIS

Ocean Color algorithms

As proposed

Coincident MISR data will be used to benefit MODIS-Terra atmospheric correction by:

1. Improving aerosol model selection in the NIR with multi-angle observations
2. Refining reflected sun glint characterization with direct observations, and
3. identification of aerosol absorption with multi-angle glint observation.

We will produce an improved MODIS-Terra atmospheric correction in the MISR footprint that is more successful, in a wider range of conditions, than the operational algorithm.

Leveraging combined atmospheric (GSFC, JPL), instrument (GSFC MODIS, JPL MISR) and ocean color (GSFC) experience, and utilize the infrastructure of the GSFC OBPG.

Research algorithm for Section 2.2 of TASNPP call "Algorithms – New Data products" as part of the Ocean Biology and Biogeochemistry Measurements Science Team

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1. Improving aerosol model selection in the NIR with multi-angle observations

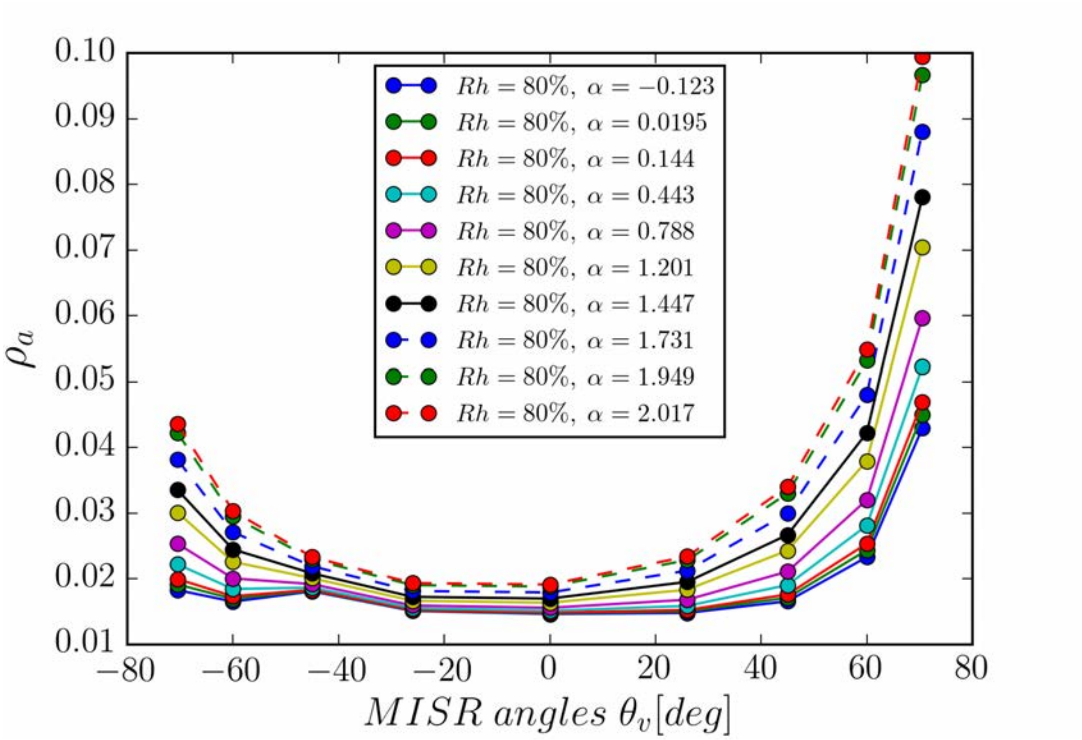

Figure 5 Aerosol reflectance contribution to the TOA reflectance at 865 nm for solar zenith angle = 32˚, relative azimuth angle= 40˚/140˚ for relative humidity=80% and 10 aerosol types. Aerosol optical depth (AOD) for this simulation is 0.15.

This shows that an aerosol model can be determined with a single wavelength if there are multi-angle observations

*Table 1 MODIS and MISR characteristics. *note listed MODIS channels are high signal-to-noise (SNR) "ocean color" channels only. Other channels could also be incorporated in the AC process, but their lower SNR must be considered.*

Instrument	**Channels (nm)**	**View zenith angles** (& labels)	**Swath width (km)**
MODIS	412, 443, 488, 531, 547, 555, 667, 678, 748, 869*	Nadir	2330
MISR	447, 558, 672, 866	Da: -70.5˚, Ca: -60˚, Ba: -45.6˚, Aa: -26.1˚, An: 0.0˚, Af: 26.1˚, Bf: 45.6˚, Cf: 60˚, Df: 70.5˚	360

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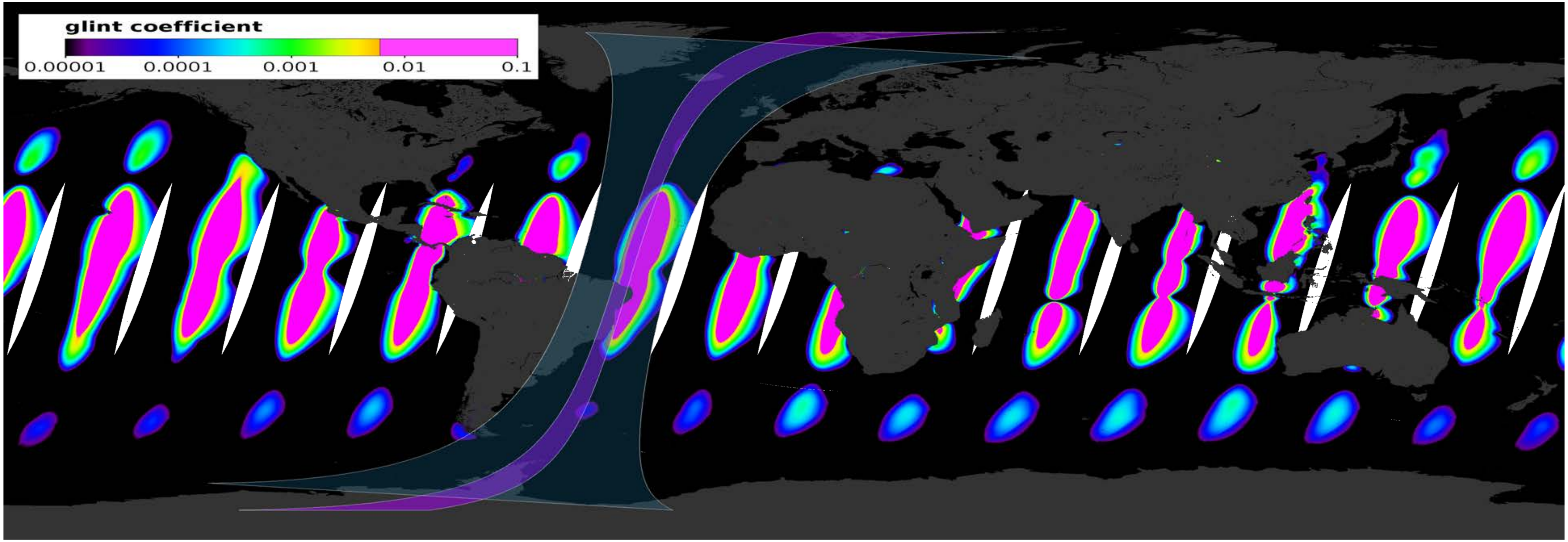
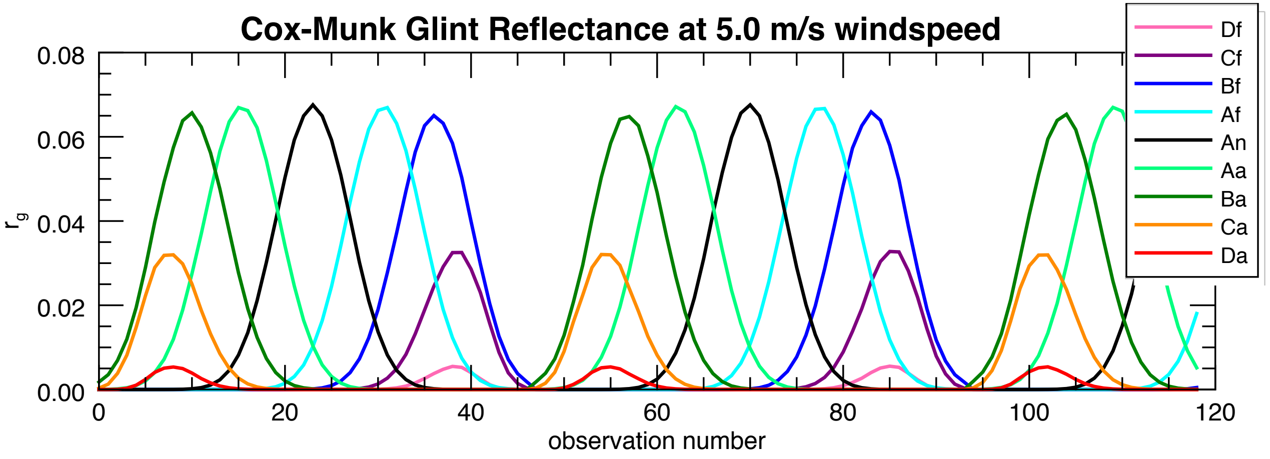
2. Refining reflected sun glint characterization with direct observations



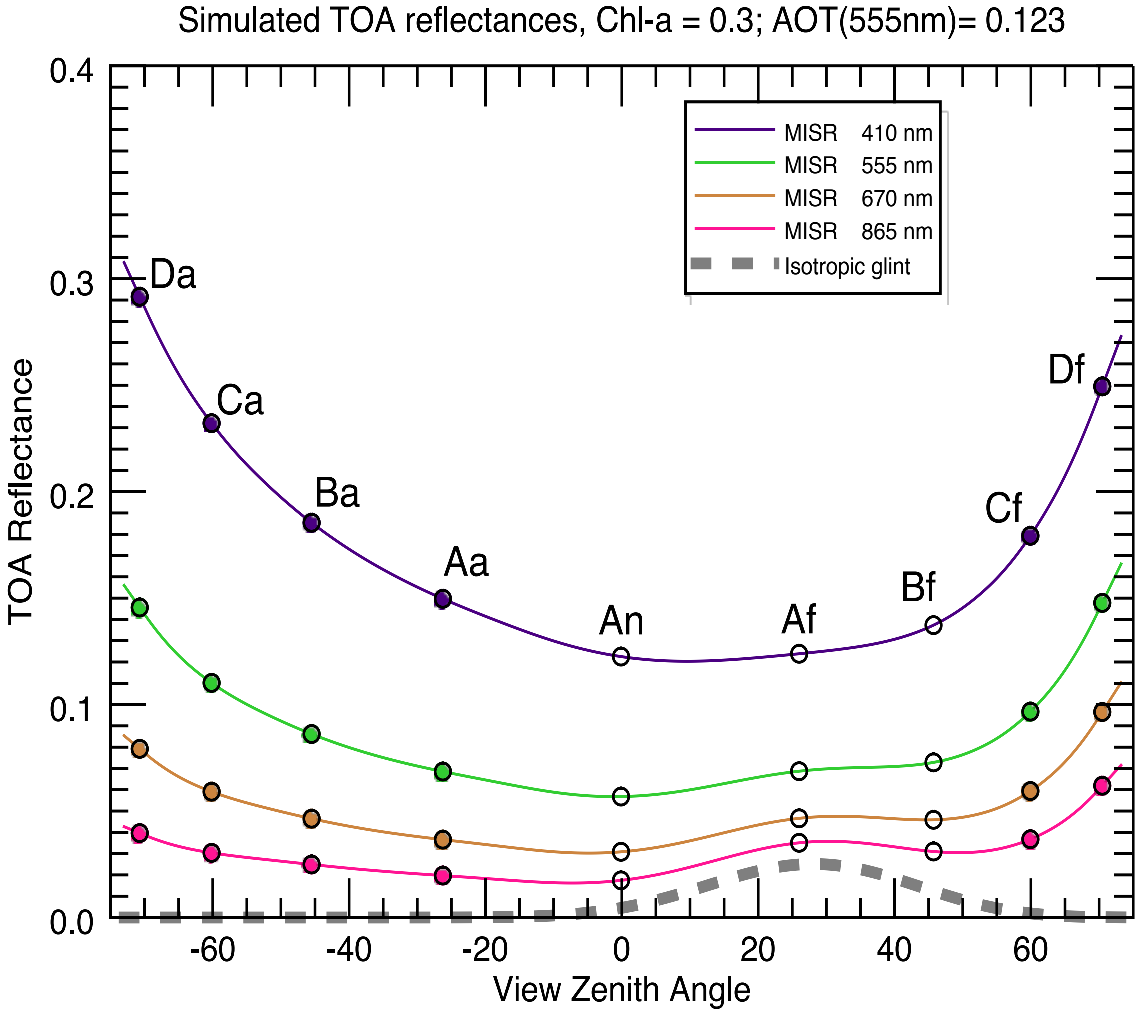
Simulated glint coefficient map for a day, with overlay of a single orbit for MODIS (dark grey) and MISR (purple) ground observations. Magenta indicates regions whose geometry and wind speed information would generate 'glint contaminated' flag in standard MODIS processing, while other colors indicate glint reflectance that must be incorporated into an atmospheric correction. These values are only as accurate as the underlying wind speed data, but demonstrate the spatial extent of glint within observation swaths.

2. Refining reflected sun glint characterization with direct observations

Glint affects 3+ MISR cameras for most scenes. Rather than ingesting ancillary wind data and screening to remove glint ‘contamination,’ we use it as part of our retrieval process



Cox-Munk predicted surface glint reflectance for 2.5 MISR orbits. Colors correspond to specific MISR camera angles. “Observation number” refers to a specific point within the simulated Terra orbital geometry.



Simulated TOA MISR reflectance. Camera angles are indicated by circles, those unaffected by reflected sun glint are filled. At surface sun glint reflectance is indicated by a dashed line.

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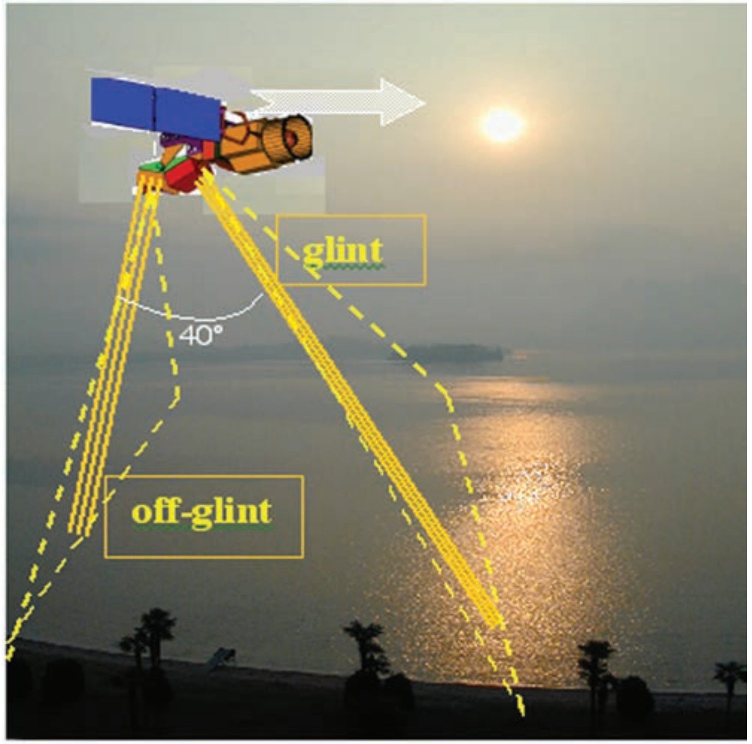
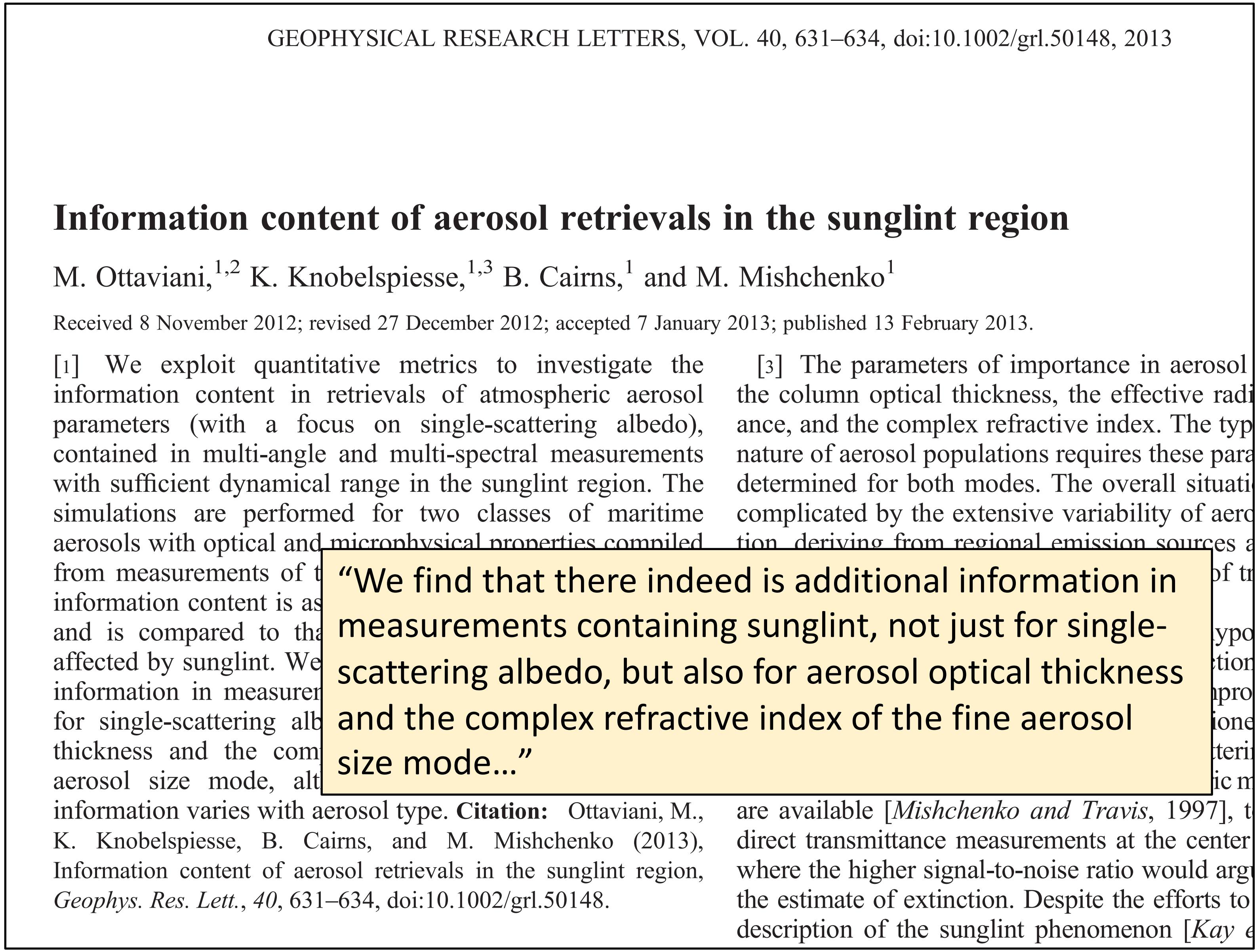


Figure 2. Solar glint over Lago Maggiore, Italy, June 27, 2001. The haze is urban pollution (optical thickness ~1) plus dust from the Sahara [*Gobbi et al.*, 2000]. A hypothetical spaceborne mission to measure aerosol absorption over the ocean consists of two pushbroom instruments that scan across-track as the spacecraft moves along track: one through the glint and one 40° off-glint.

From Kaufman, Y. J., Martins, J. V., Remer, L. A., Schoeberl, M. R., & Yamasoe, M. A. (2002). Satellite retrieval of aerosol absorption over the oceans using sunglint. *Geophysical Research Letters*, *29*(19).



GEOPHYSICAL RESEARCH LETTERS, VOL. 40, 631–634, doi:10.1002/grl.50148, 2013

Information content of aerosol retrievals in the sunglint region

M. Ottaviani,[1,2] K. Knobelspiesse,[1,3] B. Cairns,[1] and M. Mishchenko[1]

Received 8 November 2012; revised 27 December 2012; accepted 7 January 2013; published 13 February 2013.

[1] We exploit quantitative metrics to investigate the information content in retrievals of atmospheric aerosol parameters (with a focus on single-scattering albedo), contained in multi-angle and multi-spectral measurements with sufficient dynamical range in the sunglint region. The simulations are performed for two classes of maritime aerosols with optical and microphysical properties compiled
from measurements of t
information content is as
and is compared to tha
affected by sunglint. We
information in measurem
for single-scattering alb
thickness and the com
aerosol size mode, alt
information varies with aerosol type. **Citation:** Ottaviani, M., K. Knobelspiesse, B. Cairns, and M. Mishchenko (2013), Information content of aerosol retrievals in the sunglint region, *Geophys. Res. Lett.*, *40*, 631–634, doi:10.1002/grl.50148.

[3] The parameters of importance in aerosol
the column optical thickness, the effective radi
ance, and the complex refractive index. The typ
nature of aerosol populations requires these para
determined for both modes. The overall situati
complicated by the extensive variability of aero
tion, deriving from regional emission sources a
of tr
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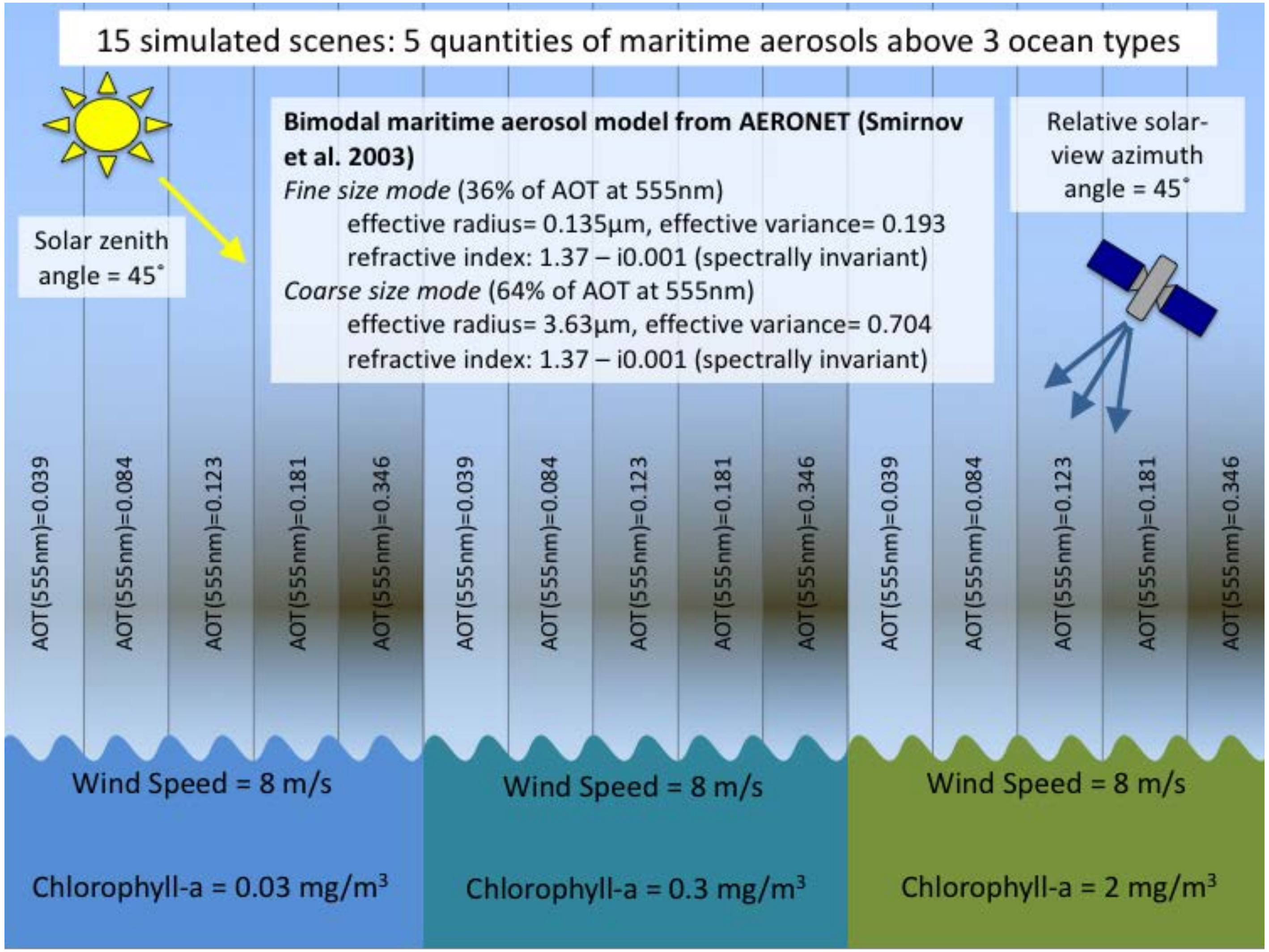
npro
ione
teri
ic m
are available [*Mishchenko and Travis*, 1997], t
direct transmittance measurements at the center
where the higher signal-to-noise ratio would arg
the estimate of extinction. Despite the efforts to
description of the sunglint phenomenon [*Kay e*

> "We find that there indeed is additional information in measurements containing sunglint, not just for single-scattering albedo, but also for aerosol optical thickness and the complex refractive index of the fine aerosol size mode…"

3. identification of aerosol absorption with multi-angle glint observation.

Information content assessment for simultaneous atmosphere + ocean retrieval



15 simulated scenes: 5 quantities of maritime aerosols above 3 ocean types

Bimodal maritime aerosol model from AERONET (Smirnov et al. 2003)

Fine size mode (36% of AOT at 555nm)

effective radius= 0.135μm, effective variance= 0.193

refractive index: 1.37 – i0.001 (spectrally invariant)

Coarse size mode (64% of AOT at 555nm)

effective radius= 3.63μm, effective variance= 0.704

refractive index: 1.37 – i0.001 (spectrally invariant)

Solar zenith angle = 45˚

Relative solar-view azimuth angle = 45˚

Wind Speed = 8 m/s

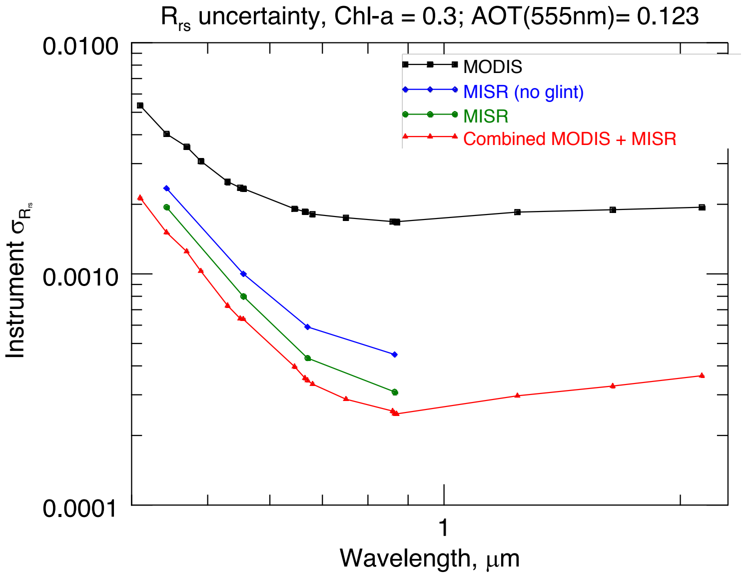
Chlorophyll-a = 0.03 mg/m^3

Wind Speed = 8 m/s

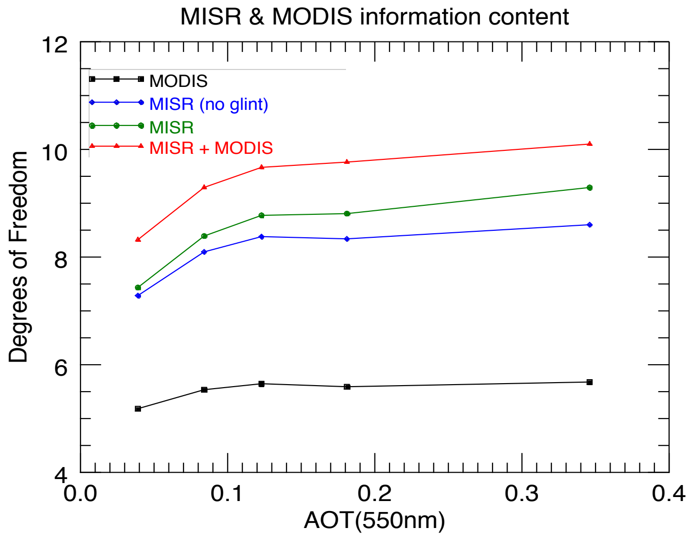
Chlorophyll-a = 0.3 mg/m^3

Wind Speed = 8 m/s

Chlorophyll-a = 2 mg/m^3

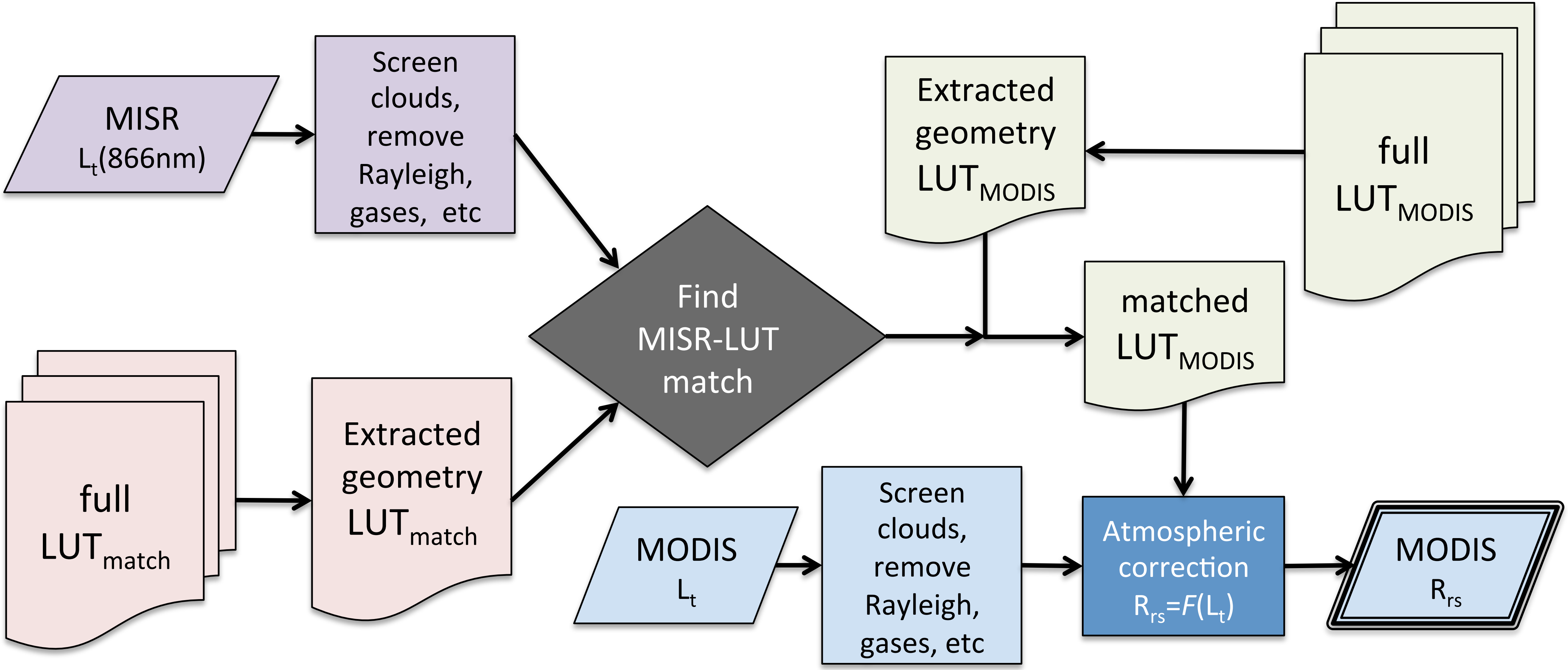


Remote sensing reflectance uncertainty



Total degrees of freedom

Preliminary algorithm flowchart



MISR L_t(866nm)

Screen clouds, remove Rayleigh, gases, etc

full LUT_{match}

Extracted geometry LUT_{match}

Find MISR-LUT match

Extracted geometry LUT_{MODIS}

full LUT_{MODIS}

matched LUT_{MODIS}

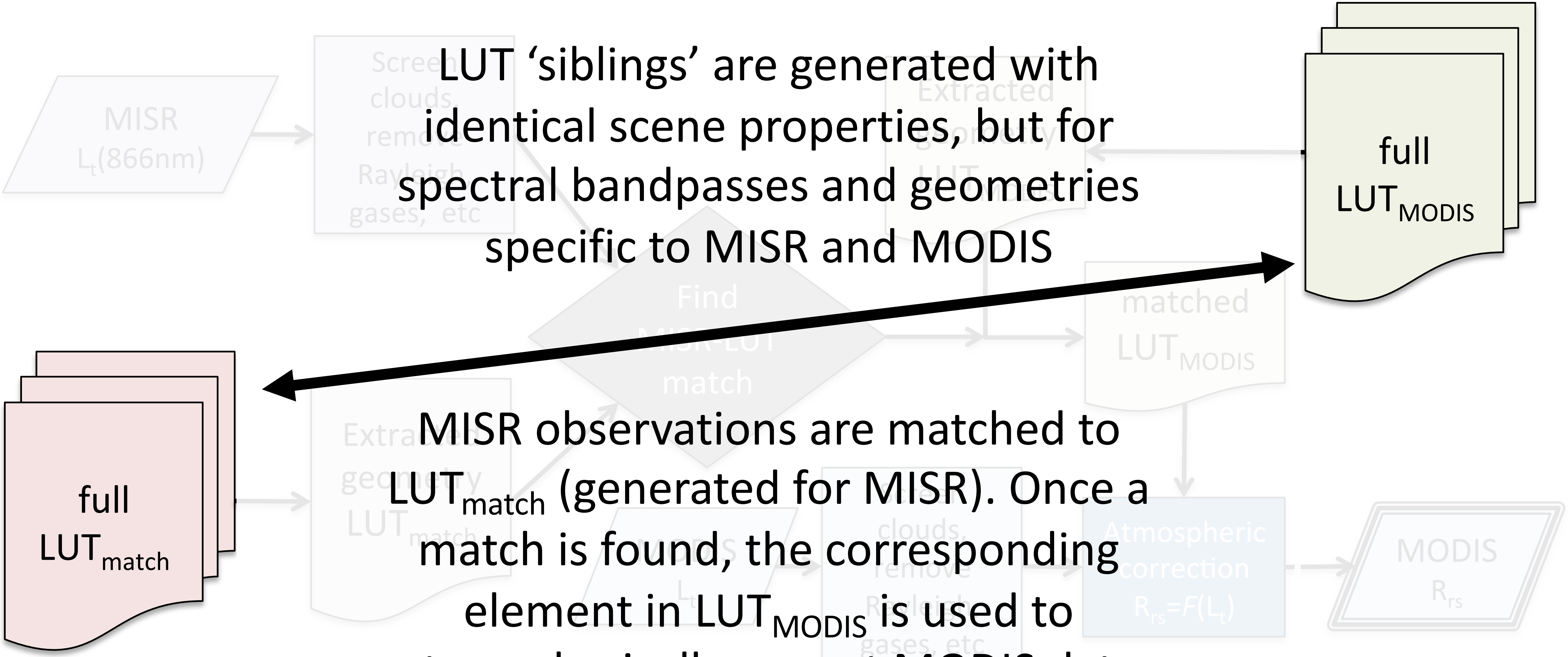
MODIS L_t

Screen clouds, remove Rayleigh, gases, etc

Atmospheric correction $R_{rs}=F(L_t)$

MODIS R_{rs}

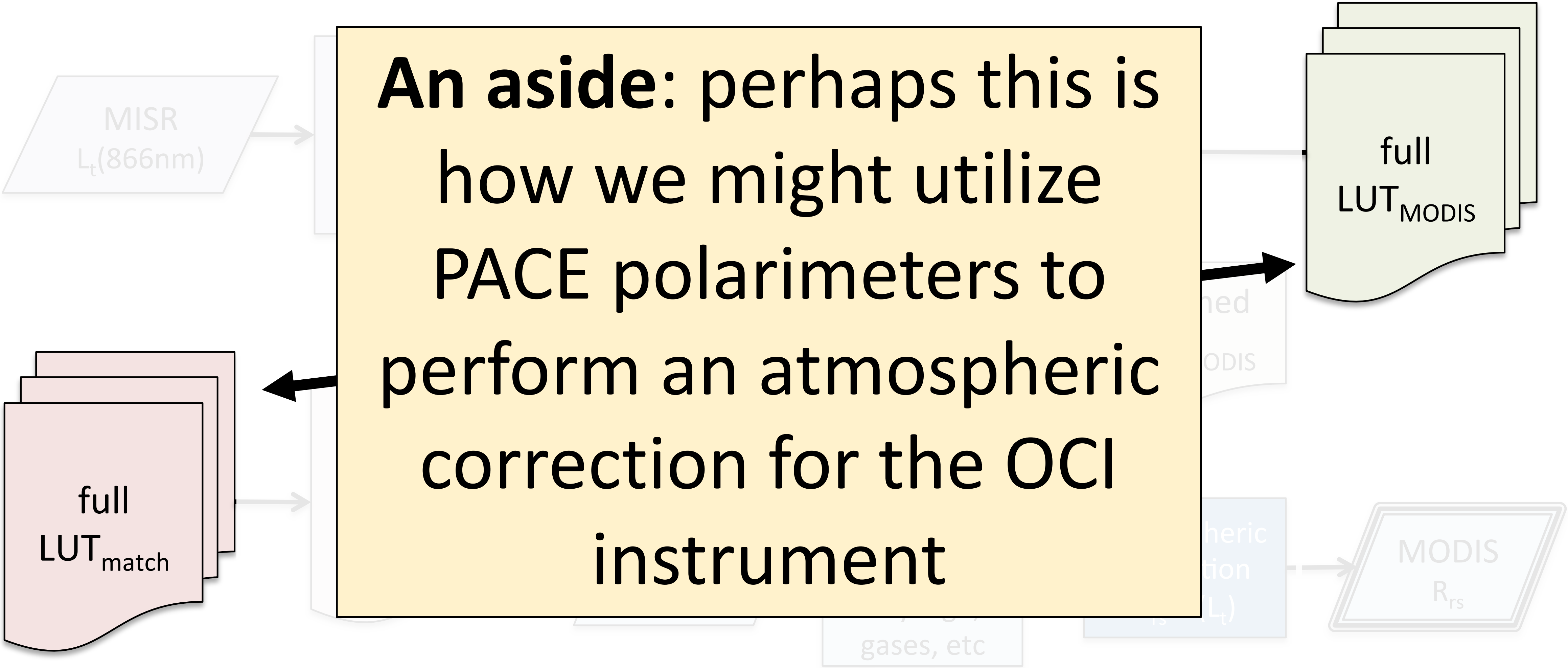
Preliminary algorithm flowchart



LUT ‘siblings’ are generated with identical scene properties, but for spectral bandpasses and geometries specific to MISR and MODIS

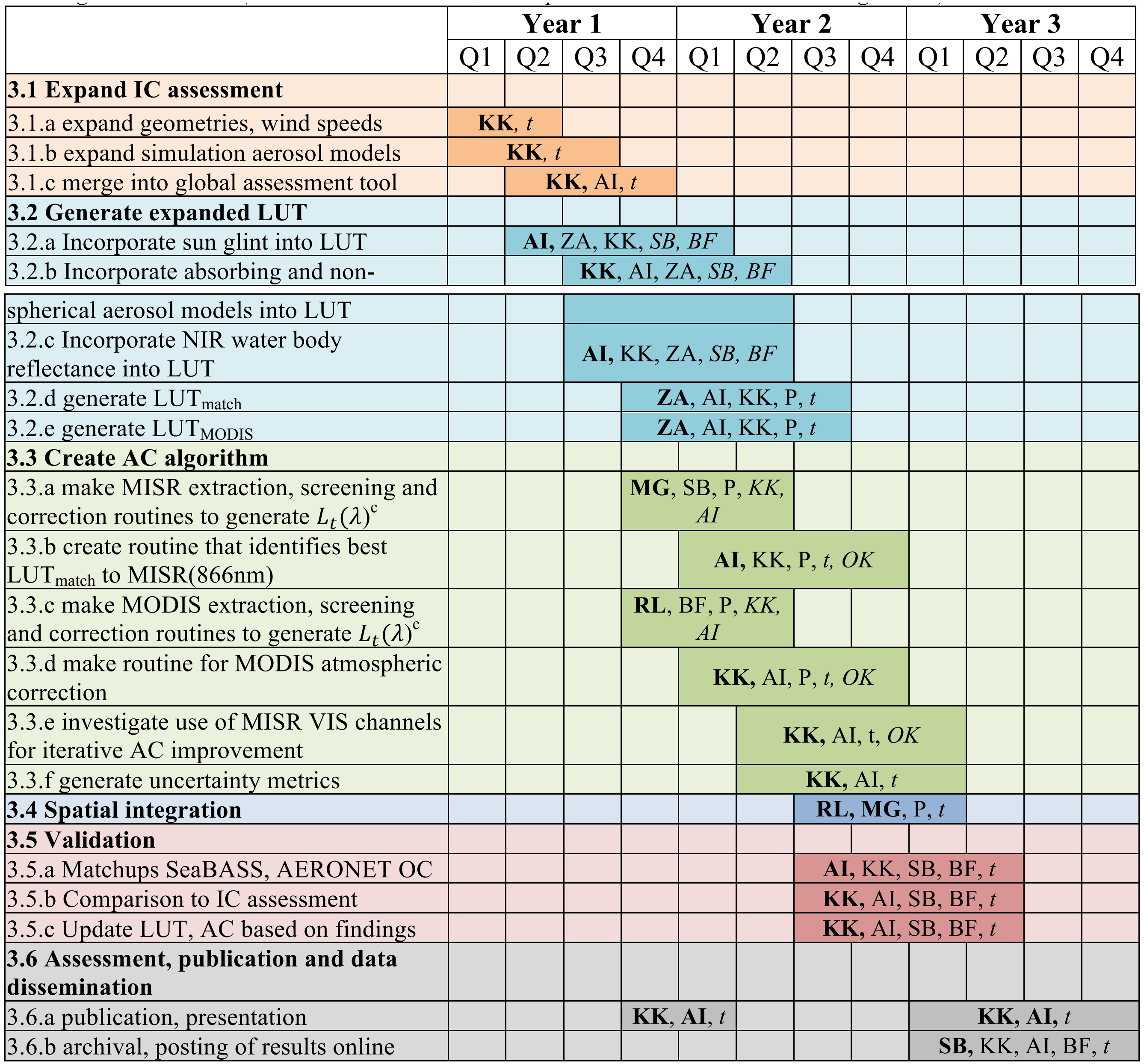
MISR observations are matched to LUT_{match} (generated for MISR). Once a match is found, the corresponding element in LUT_{MODIS} is used to atmospherically correct MODIS data

Preliminary algorithm flowchart



An aside: perhaps this is how we might utilize PACE polarimeters to perform an atmospheric correction for the OCI instrument

Schedule and team



	Year 1				Year 2				Year 3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
3.1 Expand IC assessment												
3.1.a expand geometries, wind speeds	**KK**, *t*											
3.1.b expand simulation aerosol models	**KK**, *t*											
3.1.c merge into global assessment tool		**KK**, AI, *t*										
3.2 Generate expanded LUT												
3.2.a Incorporate sun glint into LUT		**AI**, ZA, KK, *SB*, *BF*										
3.2.b Incorporate absorbing and non-spherical aerosol models into LUT			**KK**, AI, ZA, *SB*, *BF*									
3.2.c Incorporate NIR water body reflectance into LUT			**AI**, KK, ZA, *SB*, *BF*									
3.2.d generate LUT_{match}				**ZA**, AI, KK, P, *t*								
3.2.e generate LUT_{MODIS}				**ZA**, AI, KK, P, *t*								
3.3 Create AC algorithm												
3.3.a make MISR extraction, screening and correction routines to generate $L_t(\lambda)^c$				**MG**, SB, P, *KK*, *AI*								
3.3.b create routine that identifies best LUT_{match} to MISR(866nm)					**AI**, KK, P, *t*, *OK*							
3.3.c make MODIS extraction, screening and correction routines to generate $L_t(\lambda)^c$				**RL**, BF, P, *KK*, *AI*								
3.3.d make routine for MODIS atmospheric correction					**KK**, AI, P, *t*, *OK*							
3.3.e investigate use of MISR VIS channels for iterative AC improvement						**KK**, AI, t, *OK*						
3.3.f generate uncertainty metrics						**KK**, AI, *t*						
3.4 Spatial integration							**RL, MG**, P, *t*					
3.5 Validation												
3.5.a Matchups SeaBASS, AERONET OC							**AI**, KK, SB, BF, *t*					
3.5.b Comparison to IC assessment							**KK**, AI, SB, BF, *t*					
3.5.c Update LUT, AC based on findings							**KK**, AI, SB, BF, *t*					
3.6 Assessment, publication and data dissemination												
3.6.a publication, presentation				**KK**, **AI**, *t*					**KK**, **AI**, *t*			
3.6.b archival, posting of results online									**SB**, KK, AI, BF, *t*			

KK: **Kirk Knobelspiesse**, PI, NASA GSFC Ocean Ecology Laboratory

AI: **Amir Ibrahim**, co-I, NASA GSFC Ocean Ecology Laboratory

ZA: **Ziauddin Ahmad**, co-I, NASA GSFC Ocean Ecology Laboratory

SB: **Sean Bailey**, co-I, NASA GSFC Ocean Ecology Laboratory

BF: **Bryan Franz**, co-I, NASA GSFC Ocean Ecology Laboratory

MG: **Michael Garay**, co-I, JPL

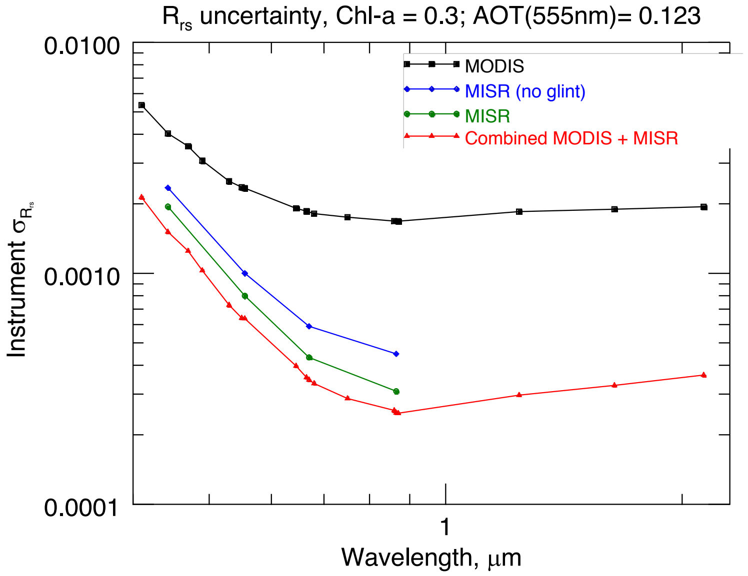
RL: **Robert Levy**, co-I, NASA GSFC Climate and Radiation Laboratory

P: programmer **Joel Gales**, NASA GSFC Ocean Ecology Laboratory

t: entire team

OK: **Olga Kalashnikova** collaborator, JPL

Progress so far…



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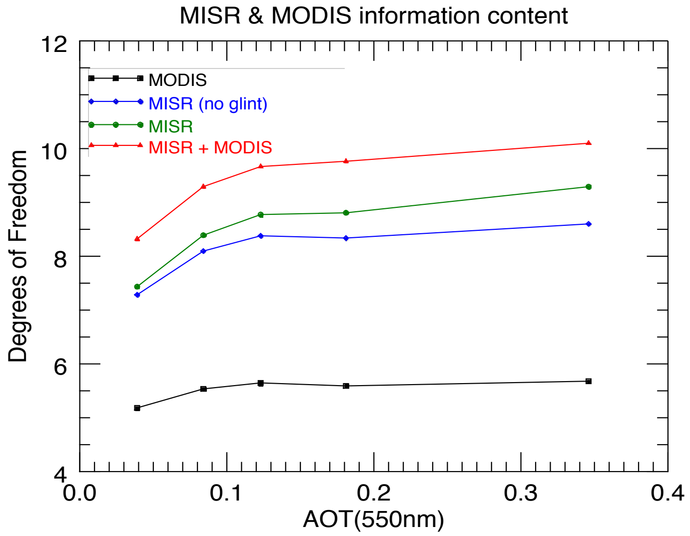


Total degrees of freedom

Information content assessment using 'Rodgers' formalism, e.g.
Knobelspiesse, K., Cairns, B., Mishchenko, M., Chowdhary, J., Tsigaridis, K., van Diedenhoven, B., Martin, W., Ottaviani, M. and Alexandrov, M., 2012. Analysis of fine-mode aerosol retrieval capabilities by different passive remote sensing instrument designs. Optics express, 20(19), pp.21457-21484. https://doi.org/10.1364/OE.20.021457

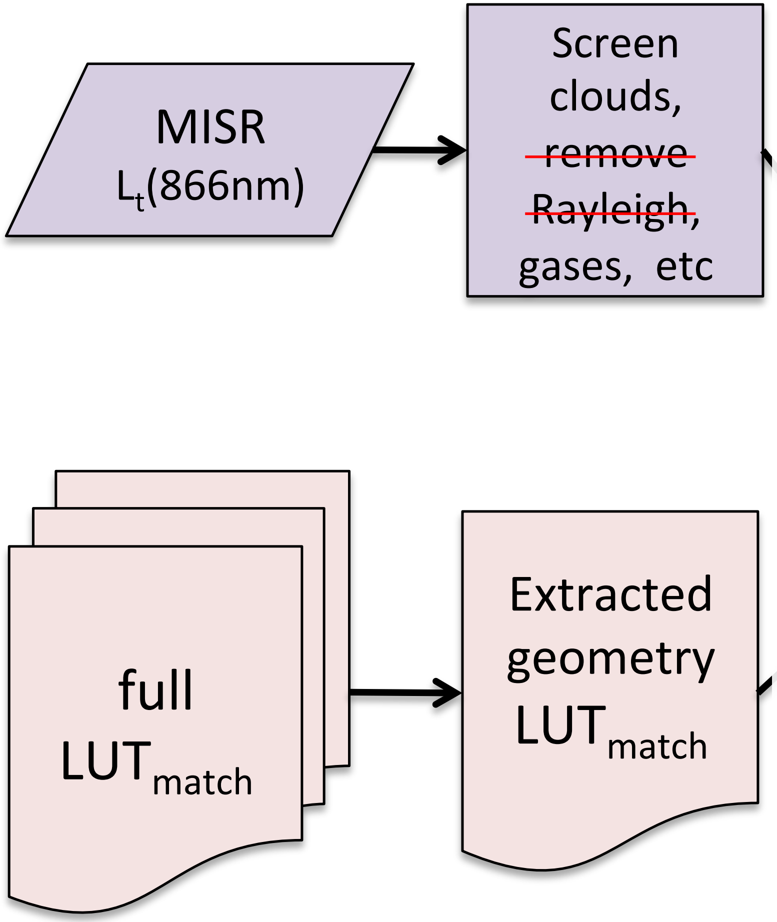
Need to expand to wider range of aerosol types (including dust, absorbing aerosols), turbid oceans and more realistic MISR geometries.

Also considering GEneralized Nonlinear Retrieval Analysis (GENRA) technique, e.g.
Coddington, O., Pilewskie, P. and Vukicevic, T., 2012. The Shannon information content of hyperspectral shortwave cloud albedo measurements: Quantification and practical applications. Journal of Geophysical Research: Atmospheres, 117(D4).

Progress so far…

Routines have been built to ingest MISR data into the NASA GSFC OBPG (Ocean Biology Processing Group) satellite processing software.

A preliminary LUTmatch has been built (one RH only at this point). Dimensions:



MISR L_t(866nm)

Screen clouds, ~~remove Rayleigh,~~ gases, etc

full LUT_{match}

Extracted geometry LUT_{match}

OUTPUT	Name	# view zenith angles (senz)	relative azimuth angle (phi)	# solar zenith angles (solz)	Aerosol Optical Depth (tau_aer)	Wavelengths (wave)	Wind speed (wind)
TOA I radiance	radiance	22: [2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62 66 70 74 78 82 87]	16: [0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180]	22: [2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62 66 70 74 78 82 87]	9: [0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.40 0.50]	4: [443, 557, 670, 865]	5: [1.87 4.21 7.49 11.70 16.85]
TOA Q radiance	qq	22: [2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62 66 70 74 78 82 87]	16: [0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180]	22: [2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62 66 70 74 78 82 87]	9: [0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.40 0.50]	4: [443, 557, 670, 865]	5: [1.87 4.21 7.49 11.70 16.85]
TOA U radiance	uu	22: [2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62 66 70 74 78 82 87]	16: [0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180]	22: [2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62 66 70 74 78 82 87]	9: [0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.40 0.50]	4: [443, 557, 670, 865]	5: [1.87 4.21 7.49 11.70 16.85]
Surface irradiance at 0+	es			22: [2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62 66 70 74 78 82 87]	9: [0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.40 0.50]	4: [443, 557, 670, 865]	5: [1.87 4.21 7.49 11.70 16.85]
Solar transmission	tsol			22: [2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62 66 70 74 78 82 87]	9: [0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.40 0.50]	4: [443, 557, 670, 865]	5: [1.87 4.21 7.49 11.70 16.85]
absorption coefficient	absp					4: [443, 557, 670, 865]	
scattering coefficient	scat					4: [443, 557, 670, 865]	
extinction coefficient	extc					4: [443, 557, 670, 865]	
rayleigh optical depth	taur					4: [443, 557, 670, 865]	

Currently for 10 aerosol models, one relative humidity. Future LUT will have a full range of relative humidity values to make 80 models

Things to investigate

What geometric grid in LUT is needed to fully capture glint patterns?

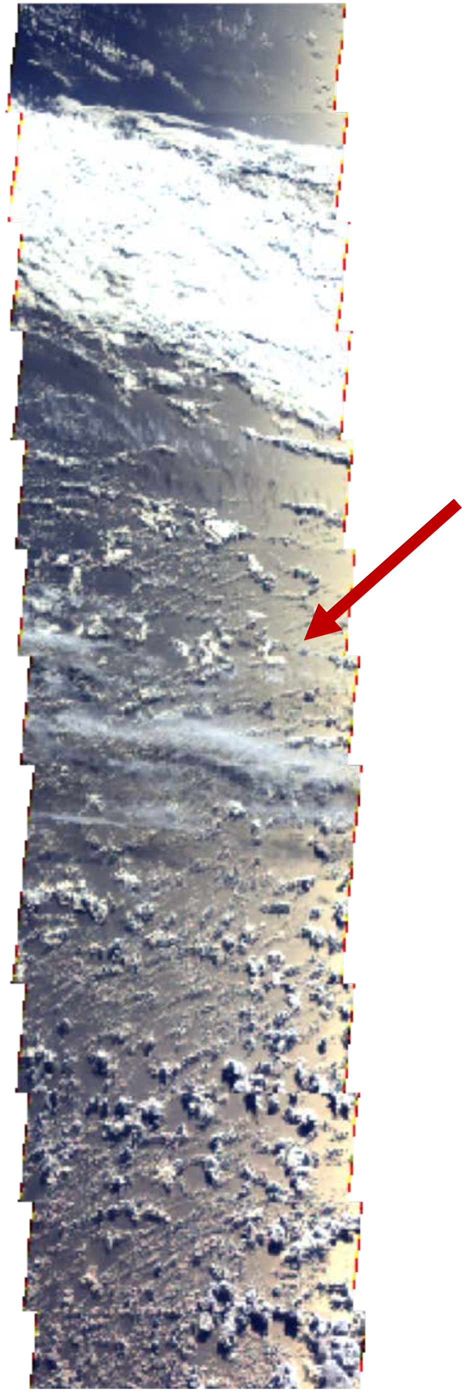
What parameter spacing in LUT is required?

How to best manage potential MISR calibration and other sources of uncertainty (such as ghosting)

Is MISR polarization sensitivity an issue for bright, polarized glint?

Are we sensitive to change in glint shape due to aerosol size and magnitude?

How useful is the glint to the overall retrieval?



Direct
Sun
Glint,
Camera:
DA

Thanks!

We’ve given ourselves a name:

MODIS **O**cean **C**olor with **M**ISR **A**tmospheric **C**orrection **MOCMAC**