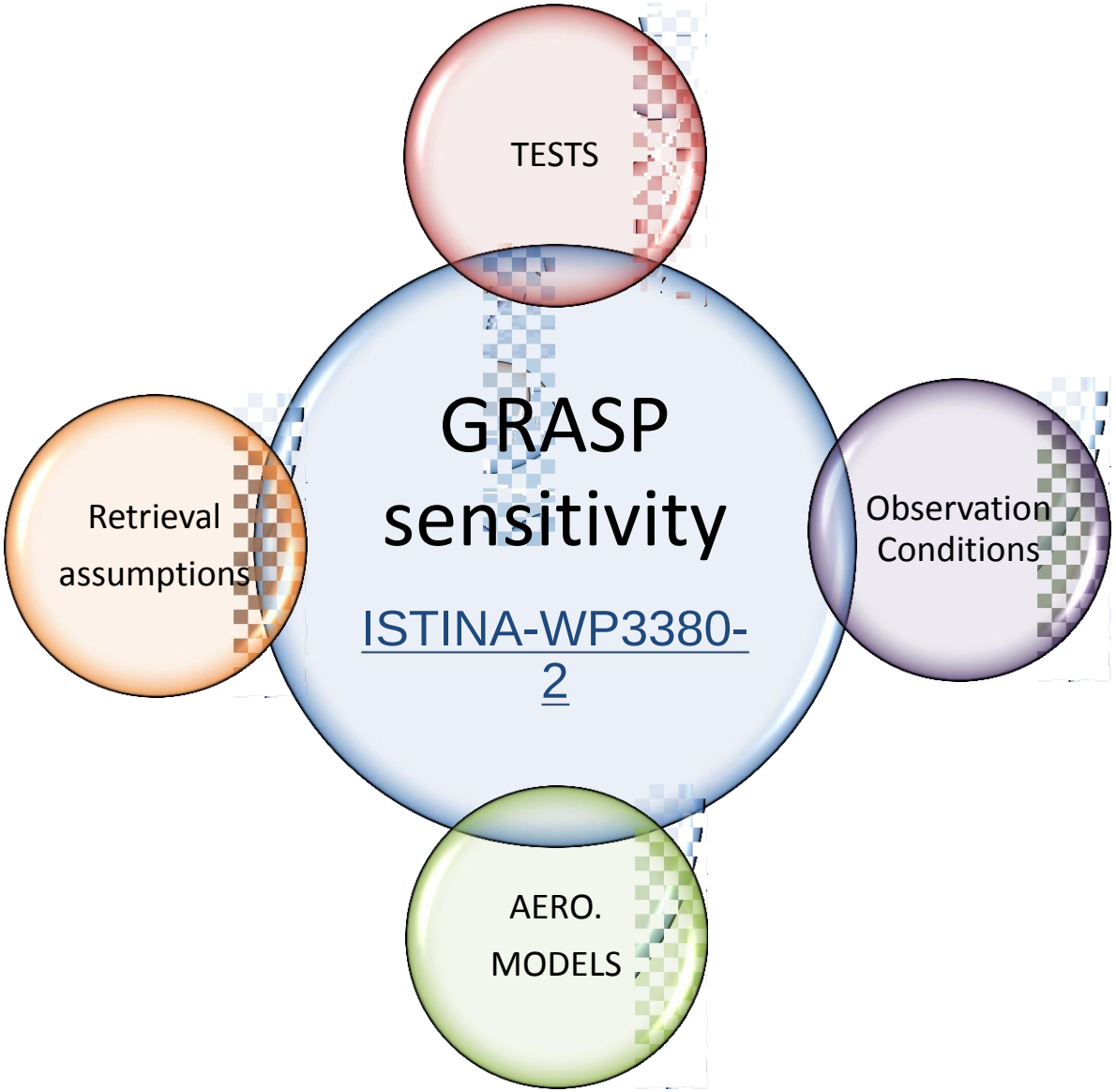


B. Torres, O. Dubovik and D. Fuertes

GRASP

Introduction

Scope of ISTINA-WP3380-2

- To establish **fundamental limits** for the different types of aerosol remote sensing approaches:
  - Up and down looking.
  - Active and passive.
- Variability of **retrieval accuracy** limits for observations with **different set ups**:
  - Spectral coverage.
  - Multi-Angularity.
  - Polarimetric capabilities.
- **Potential of synergy**.

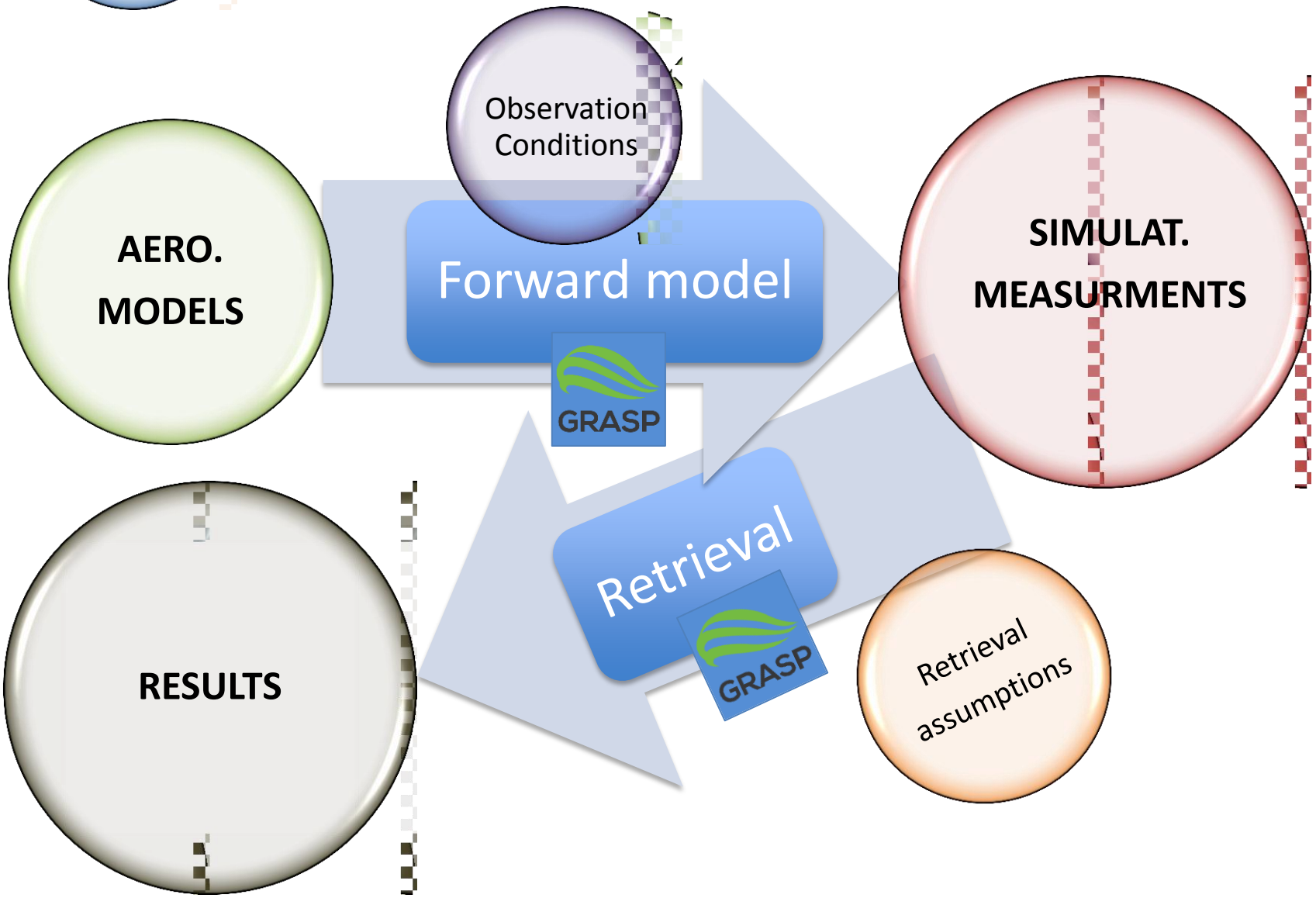
Introduction

Key questions:

- What is the best approximation for modelling size distribution?
  - Bi-modal log-normal.
  - Binned distributions size.
- Can the composition (or refractive index) of fine and coarse modes be distinguished and using which observations?
- How some inevitable assumptions may limit retrieval accuracy even from highly accurate observations?
- What are the limitations of surface reflectance parametric models of land and water surfaces?

ISTINA-WP2

Sensitivity Tests



ISTINA - WP3380-2:

Assessments of Sensitivity Tendencies in Aerosol Remote Sensing Experimental data. ("Single Scattering")

ISTINA – WP3380-4 (Ext):

Practical recommendations for aerosol retrieval of real remote sensing observations ("Multiple Scattering")

WP3380-2: Focus on "Single scattering"

Why?

- Aerosol remote sensing algorithms rely on the manifestation of angular and spectral features in aerosol scattering **which are mostly determined by aerosol single scattering properties** such as phase matrix, extinction and absorption.

- We expect **to clarify some fundamental tendencies and limitations** in information content, and benefit from them in the follow-on more complex studies (WP3380-4) for outlining and establishing clear limits in the retrieval capacities.

... having in mind the limitations of real ground-based and satellites observations.

Type of tests

1.- Only extinction values

- ***Objective: Information of SD and fine/coarse mode separation.***
- ✧ ***Main interest: moon photometers, cloudy sites, etc***

2.- Scattering measurements

a.- Extinction is not part of the measurements.

- ***Objective: Retrieval of extinction values and SSA.***
  - Only $P_{11}(\Theta)$ measurements.
  - Adding polarization: $-P_{12}(\Theta)/P_{11}(\Theta)$.
- ✧ ***Main interest: Relevant to AOD-SSA satellite retrieval.***

b.- Extinction is part of the measurements.

- ***Objective: Detailed aerosol properties characterization.***
- ***Main interest: Sun photometer retrieval.***

Test 1: Only extinction values

"Advanced characterization of aerosol properties from measurements of spectral optical thickness of the atmosphere." (Torres et al. 2016)

➔ *Operational inversion code!*

INPUT

- 8 AOD measurements between 340-1640 nm
- We assume optical properties (refr. ind. 16 parameters) & 1 sphericity

OUTPUT

- Size distribution:
  - We started with 22-bins approximation
    - Extremely sensitive to errors
    - Stability problems (only solved with string smoothness constraints)
  - Bi-lognormal approximation (6 parameters): R_{Vf} , σ_{Vf} , C_{Vf} +R_{Vc} , σ_{Vc} , C_{Vc}

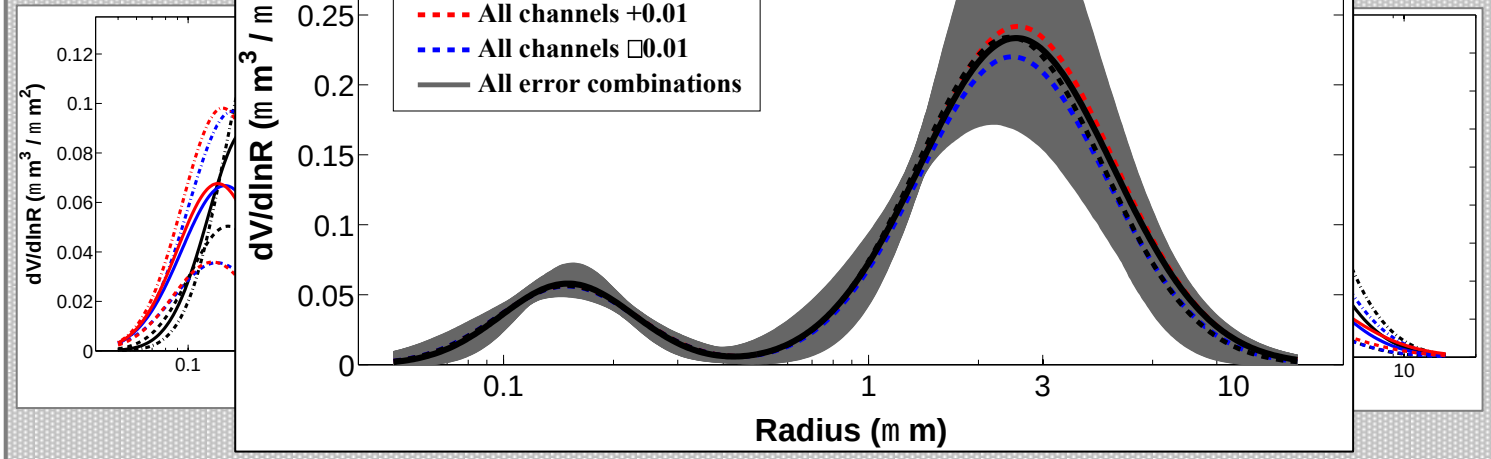
Test 1: Only extinction values

a) Sensitivity tests

- Self
- Initi

rs.

e index



17 aerosol cases

+100000 retrievals

b) Validations with AERONET

- 650 AOD inversions vs 150 almucantar inversions (daily averages).

Test 1: Only extinction values

Conclusions

- Spectral AOD measurements are sufficient for a **reliable characterization of aerosol fine mode** optical properties;
- **The discrimination between the extinction of fine and coarse modes of aerosol is not dependent on any assumption**, while the retrieval of parameters such as (R_{Vf} , σ_{Vf} and C_{Vf}) depends on available information about the real part of refractive index and the quality of the measurements.
- The characterization of the **coarse mode** using only AOD measurements **is less accurate**, but can be significantly improved using moderate a priori assumptions.

Test 2a: Scattering measurements

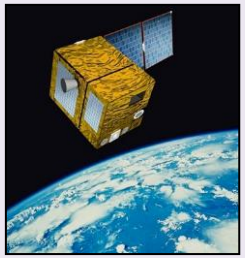
Observation Conditions

- Scattering angular range

Sun-Photometer

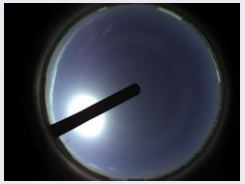
Θ=(3° – 180°)
Θ=(3° – 120°)
Θ=(3° – 90°)
Θ=(3° – 45°)
Θ=(3° – 10°)

Satellite



Θ=(60° – 180°)
Θ=(100° – 180°)
Θ=(140° – 180°)
Θ=(120°)

Sky- Camera



Θ=(20° – 120°)

- Spectral coverage

[340, 380, 440, 500, 670, 870, 1020, 1640] – AERONET extended, 3MI.

[440, 670, 870, 1020] – AERONET standard, Parasol, MODIS.

[440, 670, 870] – Meris.

Retrieval Assumptions

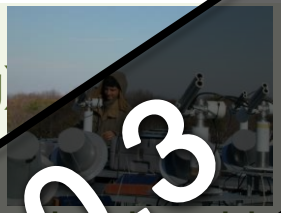
- *Side distribution - Binned*
  - *22 bins (like in AERONET retrieval).*
  - *Refractive index spectrally dependent (1-2 aerosol).*
- *Side distribution - Bi-lognormal*
  - *6 parameters: R_{Vf}, σ_{Vf}, C_{Vf} - R_{Vc}, σ_{Vc}, C_{Vc}*
  - *Refractive index spectrally dependent (1-2 aerosol).*

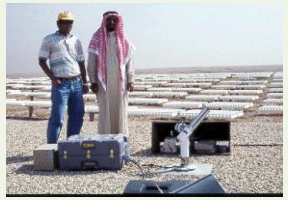
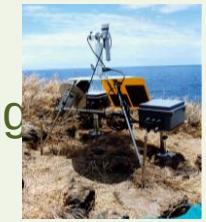
- Standard aerosol models for regular tests.
- Volcanic: Three modes for size distribution.
  - ➔Effect of considering bi-lognormal?
- Mixed: Two refractive index: fine/coarse.
  - ➔Effect of considering only one in the retrieval.
  - ➔Can they be **distinguished**? In which conditions?

Aerosol models

- GSFC - Urban (Fine mode non absorbing)
- ZAMB - Biomass burning (Fine mode absorbing)
- SOLV - Desert dust (Coarse mode non absorbing)
- LANA - Marine (Coarse mode non absorbing)
- Mixed: Biomass burning + Desert dust
  - MIXT - 1:1 -
  - MASH - 3:1 -
- Three modes: Volcanic + Urban

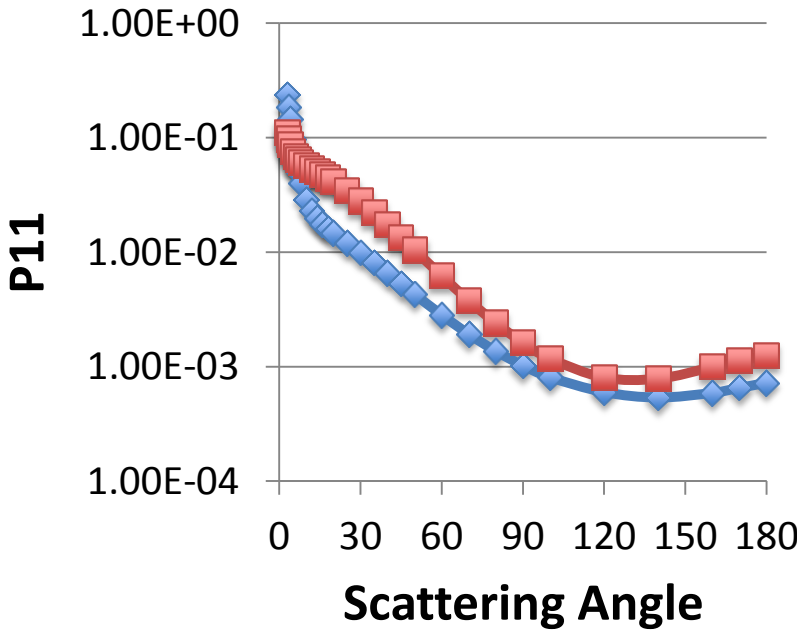
All with $\tau_{440} = 0.3$

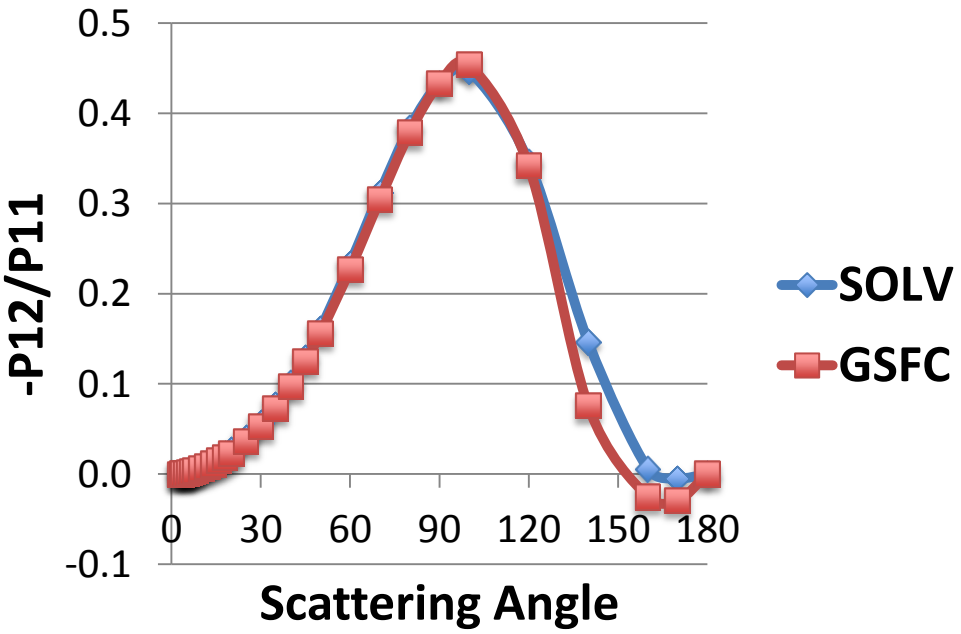


- Regular tests:

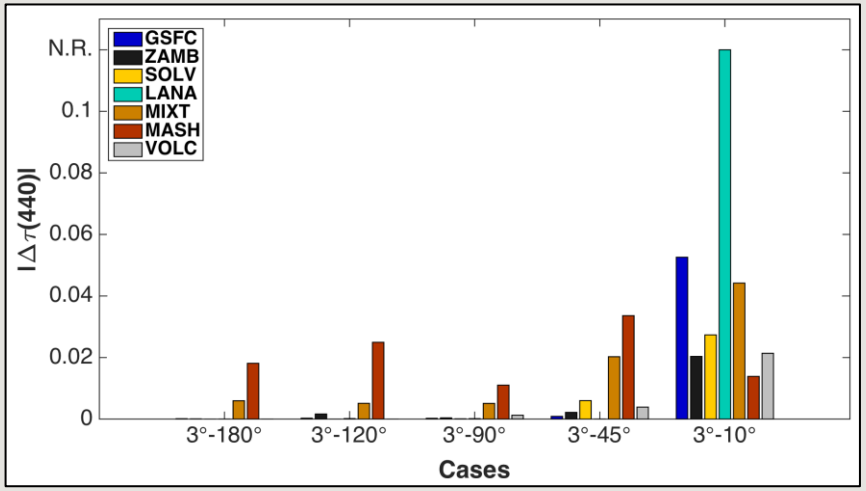
➔ AOD retrieval from P_{11} (and $-P_{12}/P_{11}$)



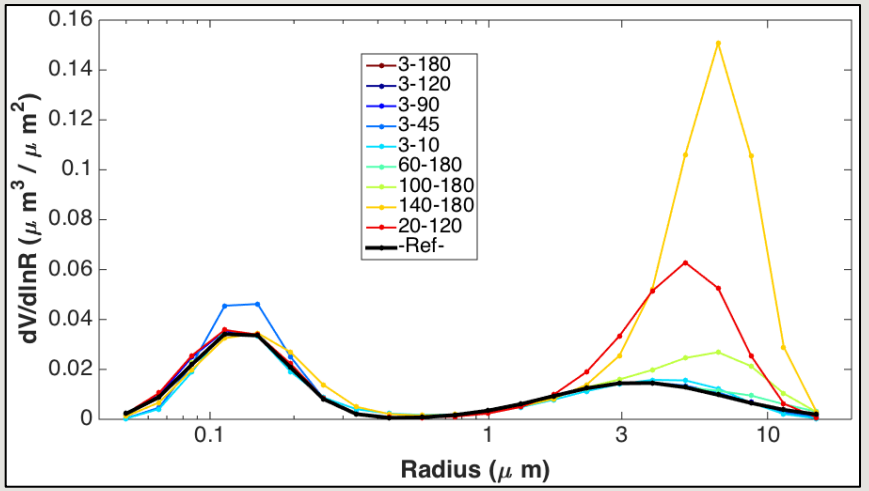


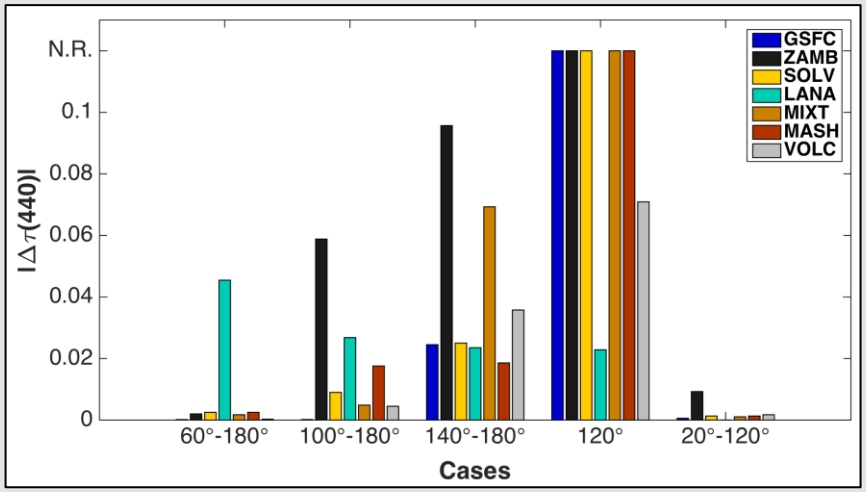
Regular tests: 22 bins – 4 wv

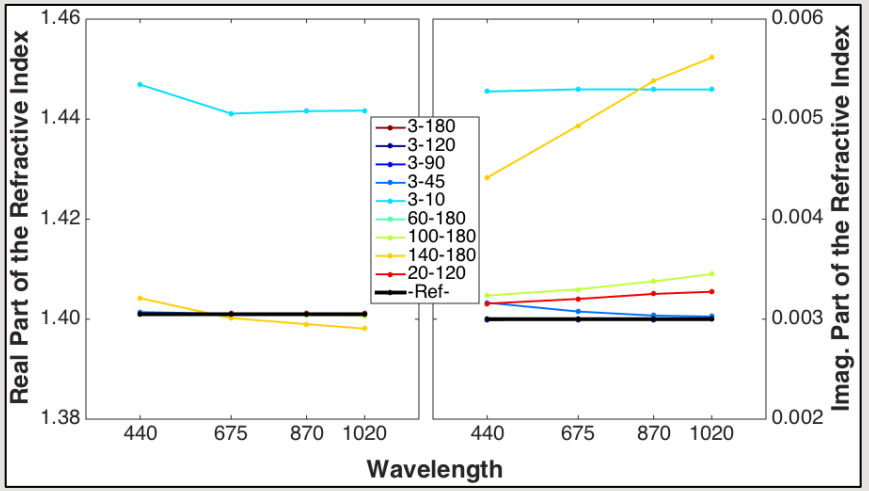
22 Bins: 4 wv - P_{11}



Ex. Zambia

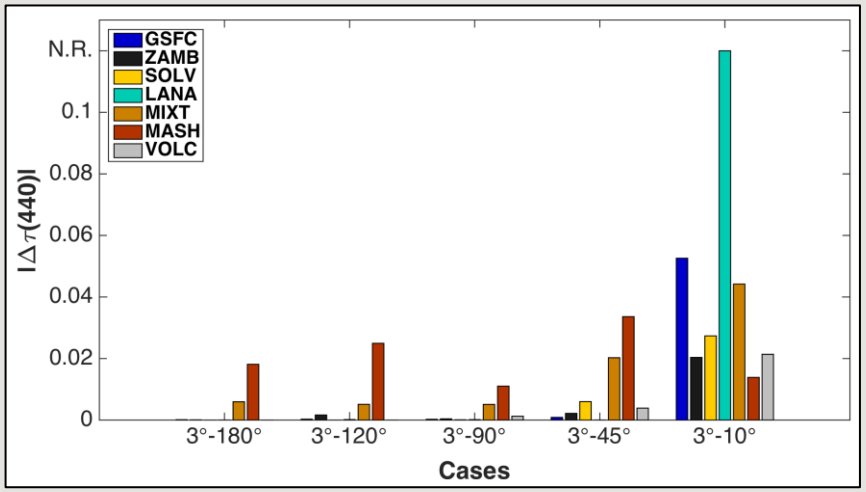


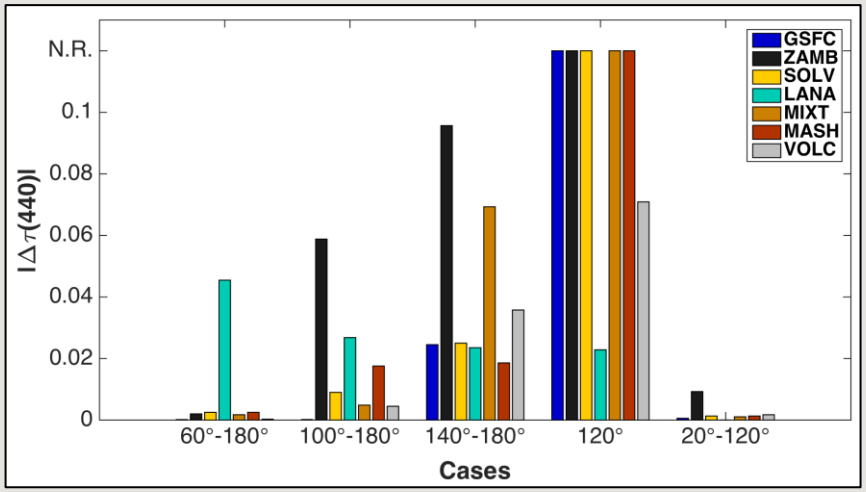




Regular tests: 22 bins – 4 wv

22 Bins: 4 wv - P_{11}

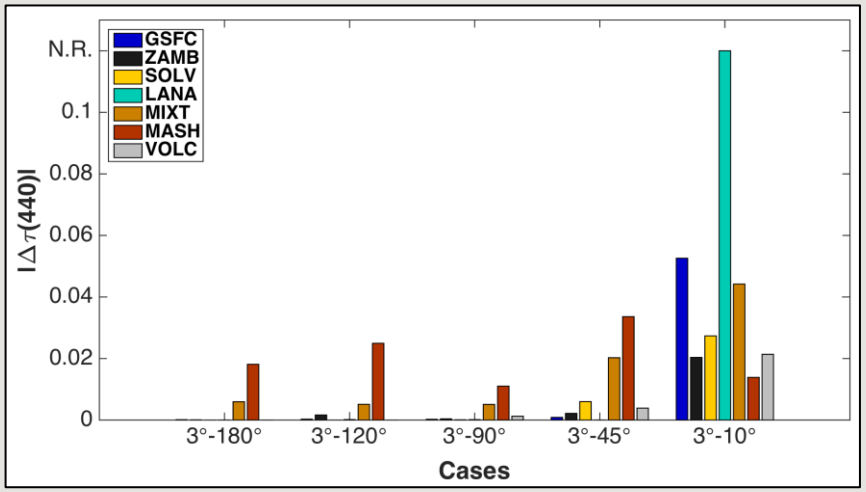


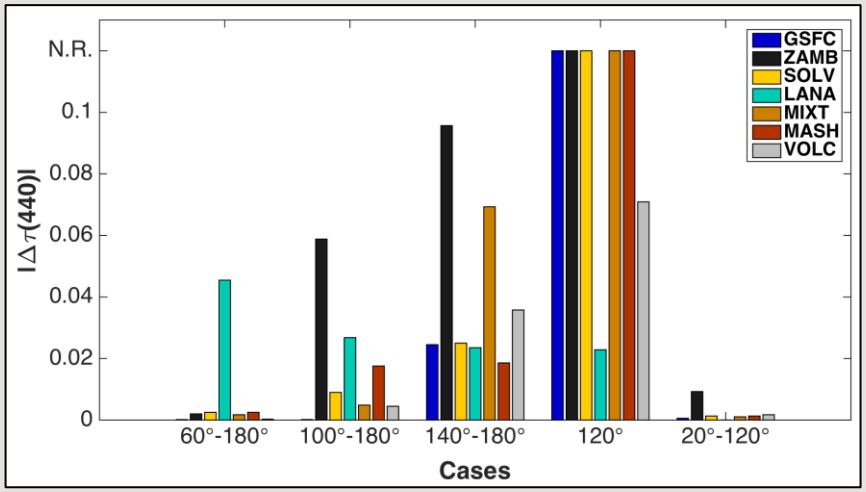


- Differences under 5% for most of the cases.
- Largest differences for:
  - [3º-10º]
  - [100º-180º]
  - [140º-180º]
  - [120º] → No retrieval.
- Improvement for 8wv (not shown).
- Improvement with polarization (not shown).
- **Uncertainties related to retrieval of optical properties.**
- Improvement with bimodal lognormal approach.

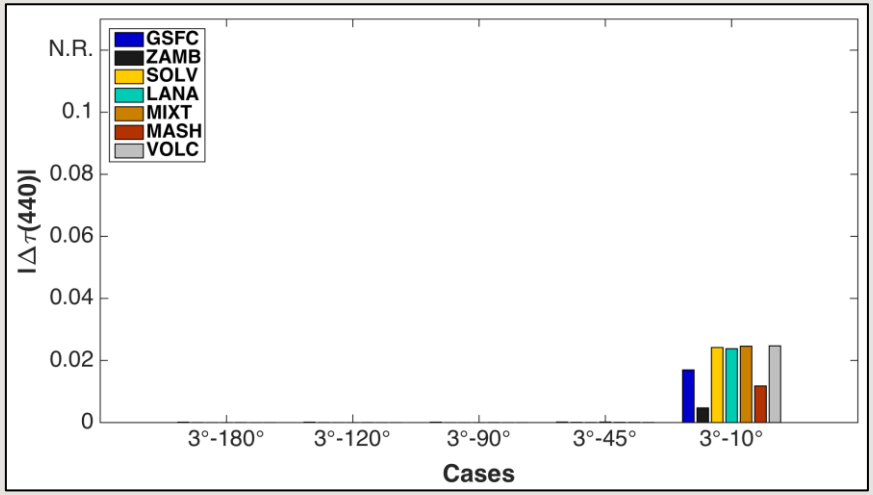
Regular tests: 22 bins – 4 wv

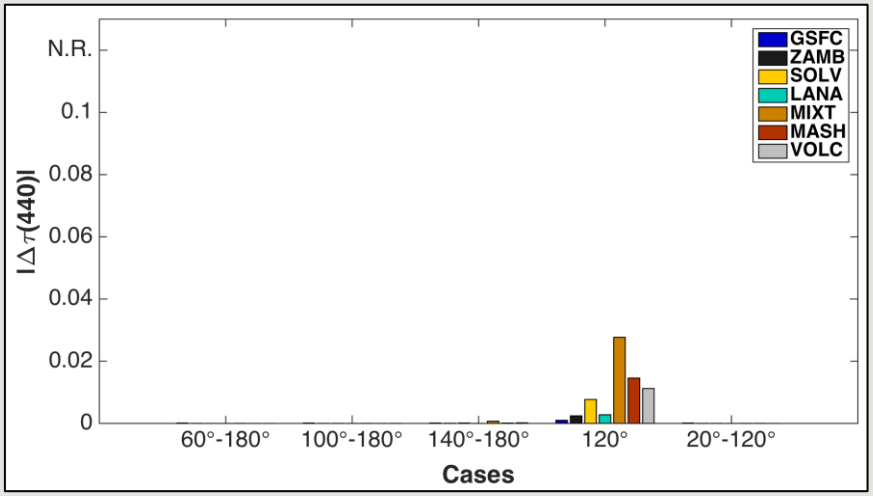
22 Bins: 4 wv - P_{11}





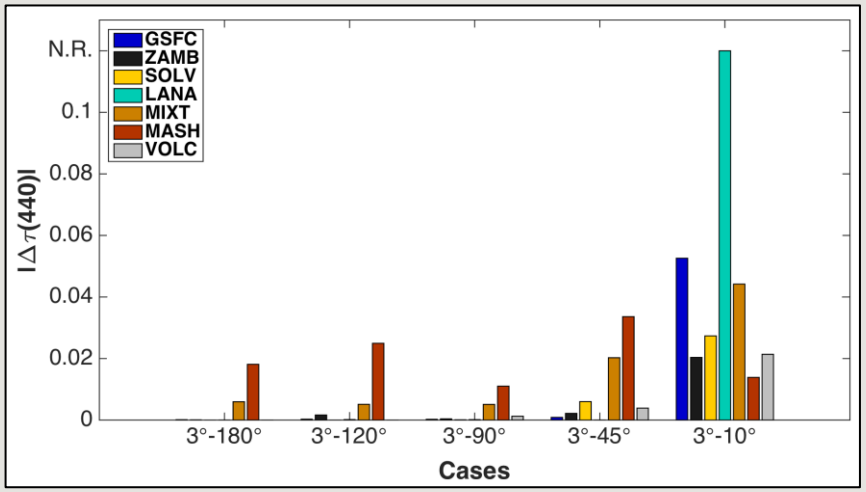
Refractive index – known -

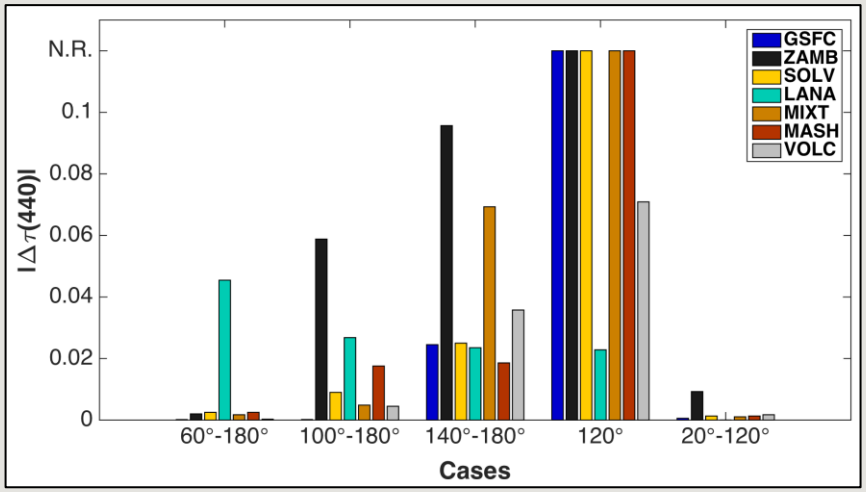




Regular tests: 22 bins – 4 wv

22 Bins: 4 wv - P_{11}





- Differences under 5% for most of the cases.
- Largest differences for:
  - [3º-10º]
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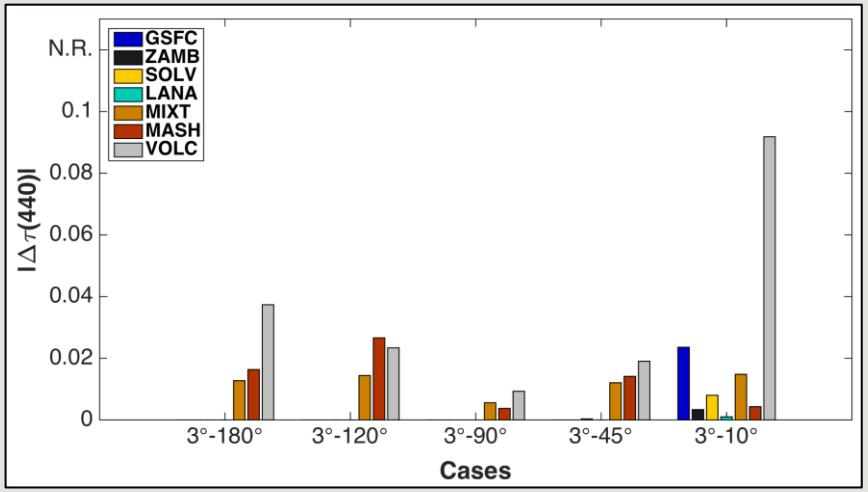
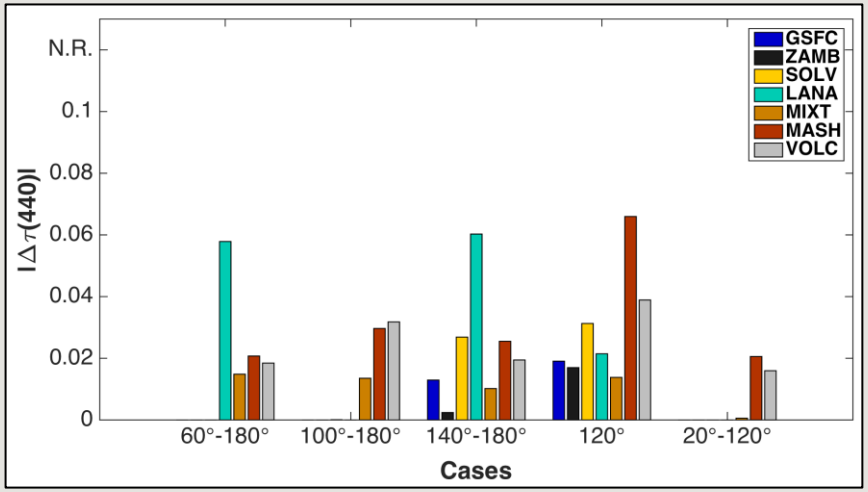
  - [140º-180º]
  - [120º] → No retrieval.
- Improvement for 8wv (not shown).
- Improvement with polarization (not shown).
- Uncertainties related to retrieval of optical properties.
- **Improvement with bimodal lognormal approach.**

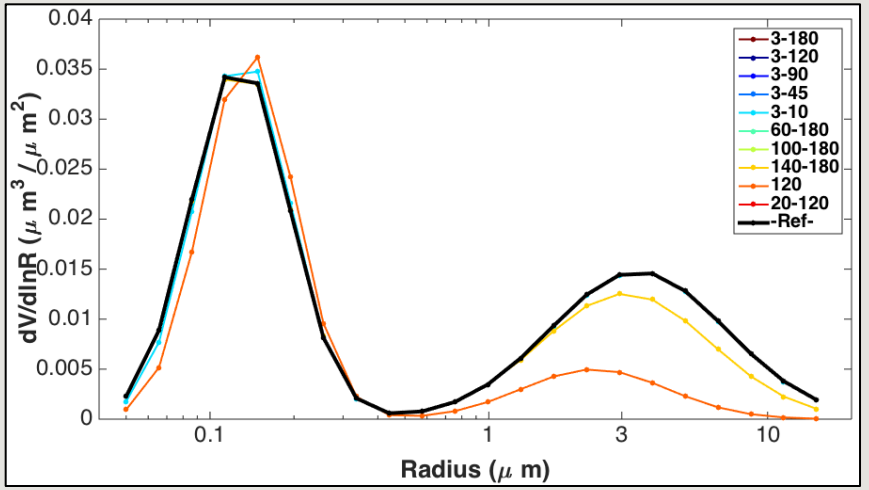
Regular tests: bimodal log-normal.

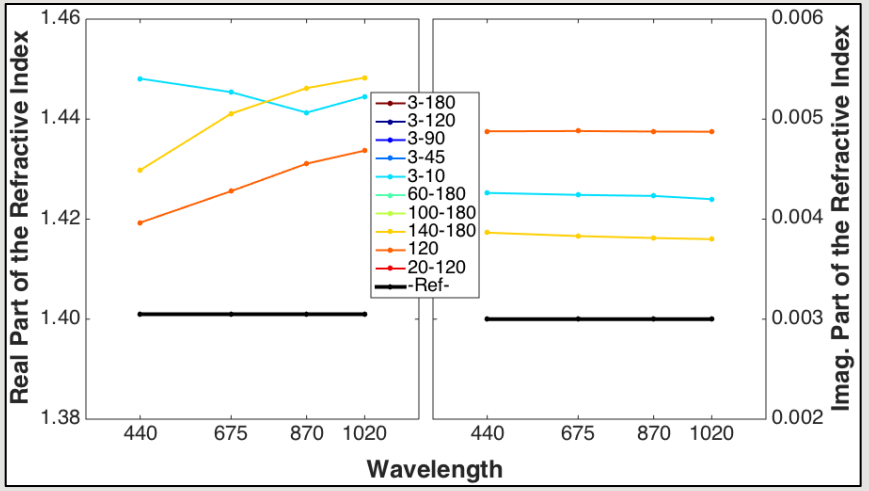
Bi-log: 4 wv - P_{11}





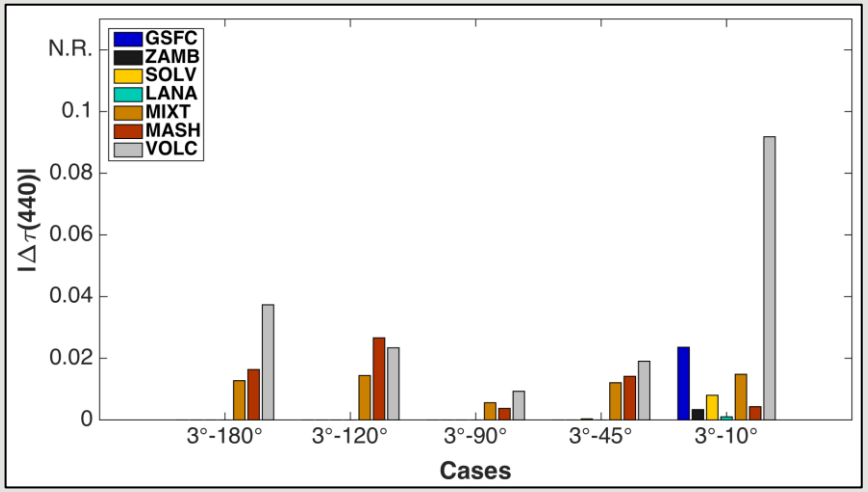
Ex. Zambia



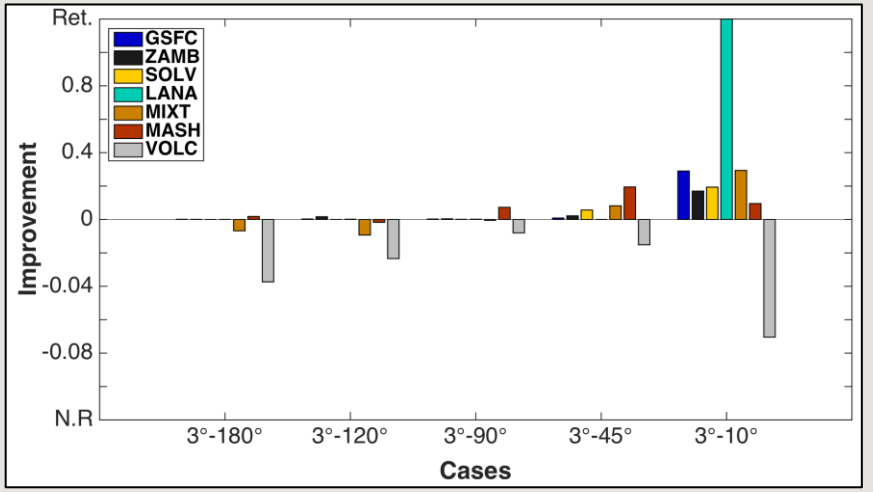


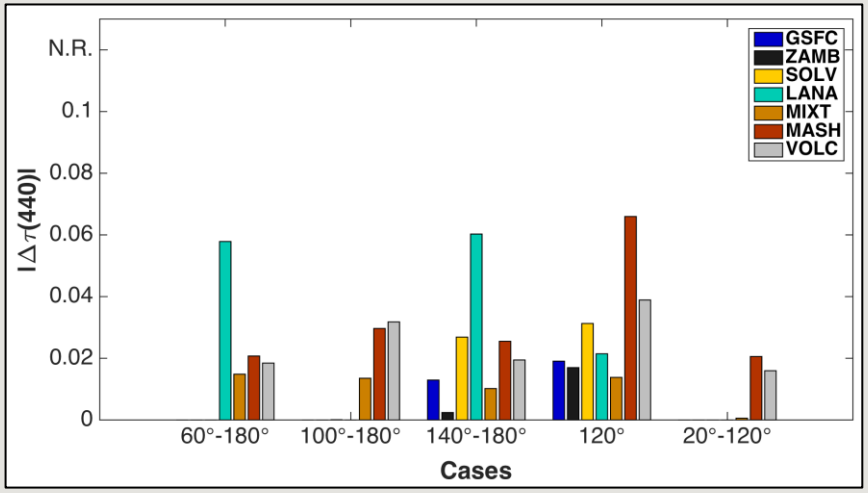
Regular tests: bimodal log-normal.

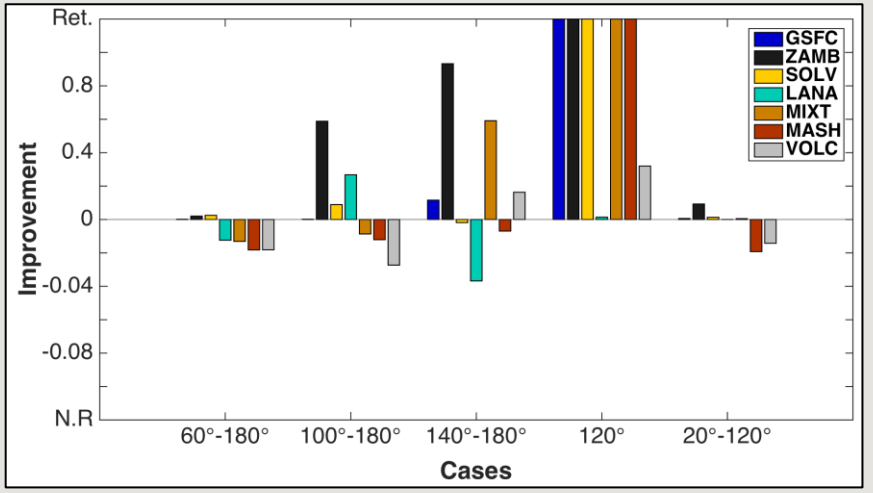
Bi-log: 4 wv - P_{11}



Improvement



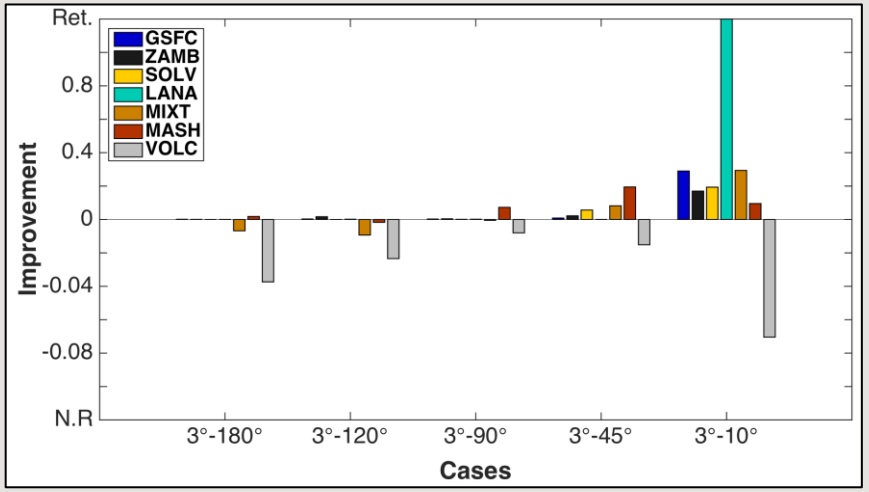


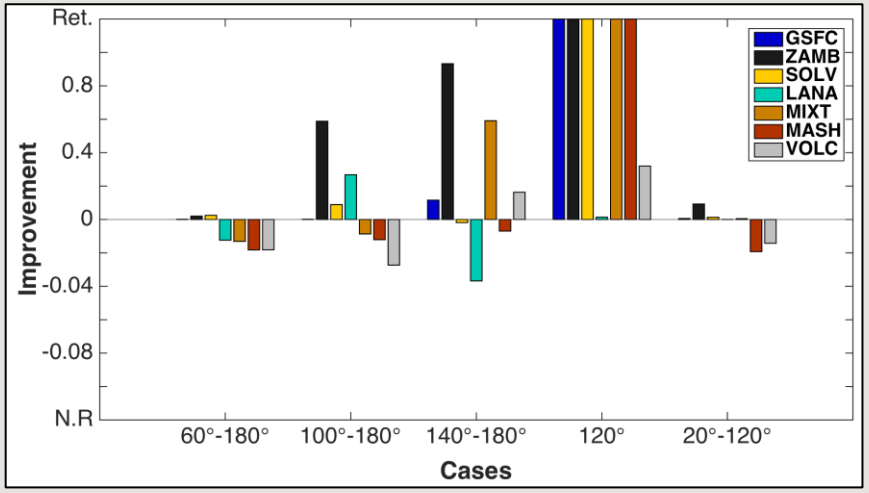


Regular tests: bimodal log-normal.

- General improvement. Specially for the ranges:
  - [3º-10º]
  - [100º-180º]
  - [140º-180º]
  - [120º] → Now retrieval!
- Worse retrieval for 3-mode case (specially, when we have information).

Improvement





What happens with 3-mode case with the appox. of bimodal log-normal?

Can we distinguish two Ref. Ind.?

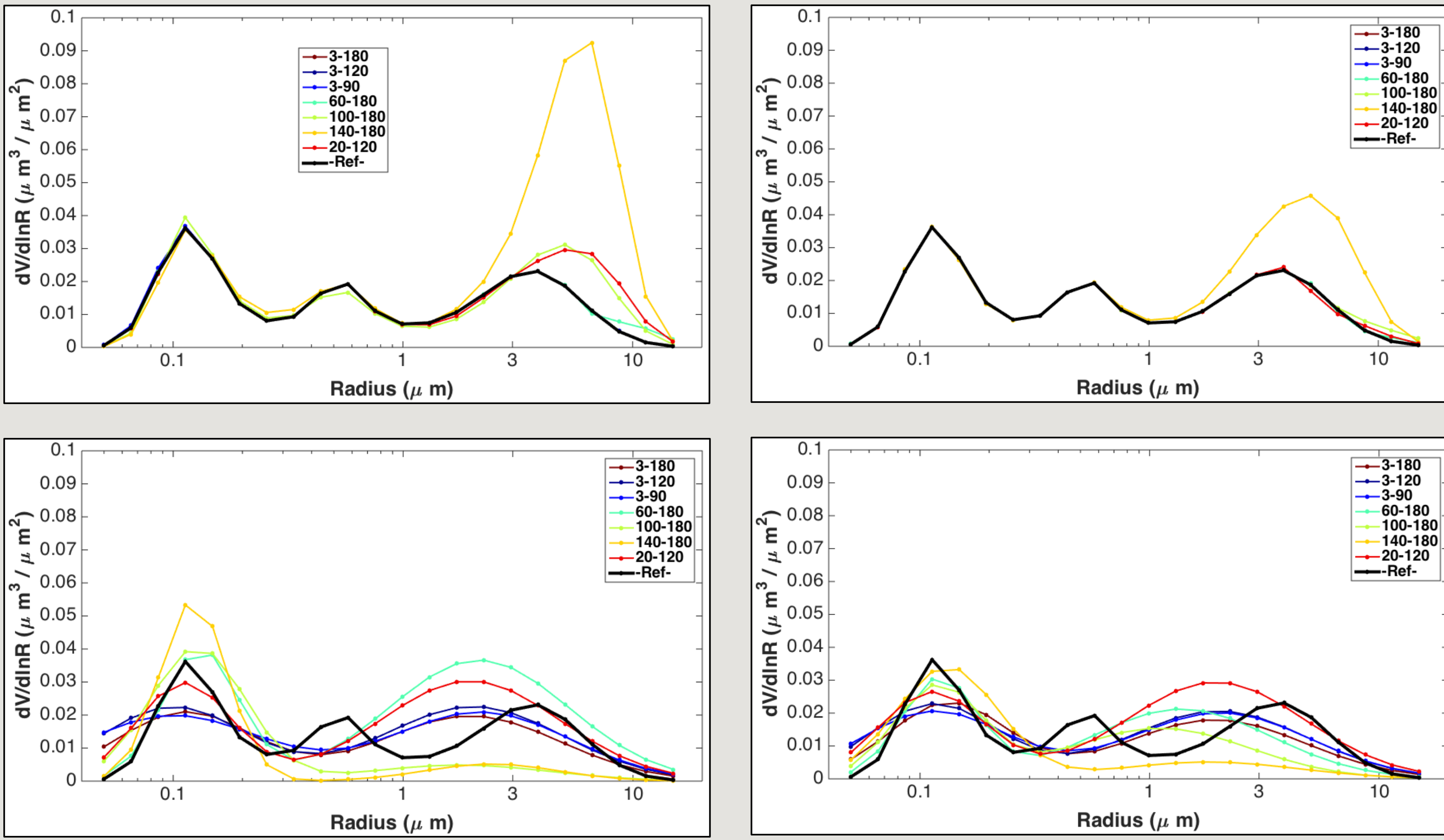
Three modes: 22 bins vs bi-lognormal

Without polarization

With polarization

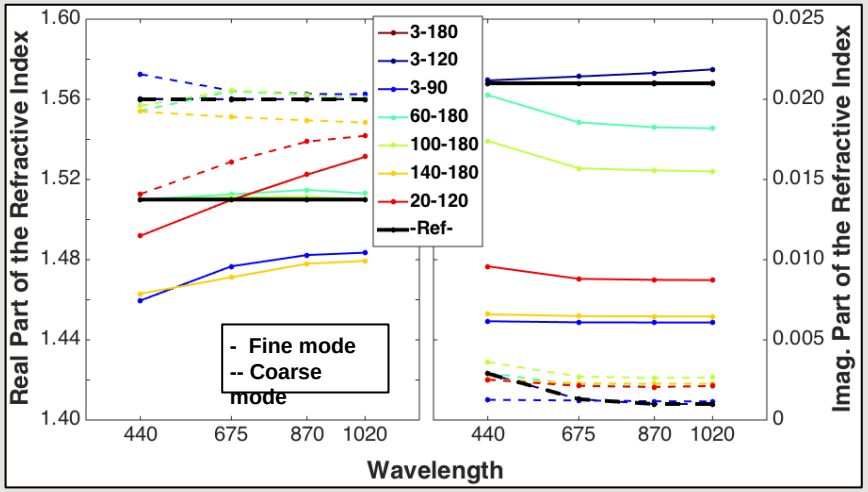
22 bins

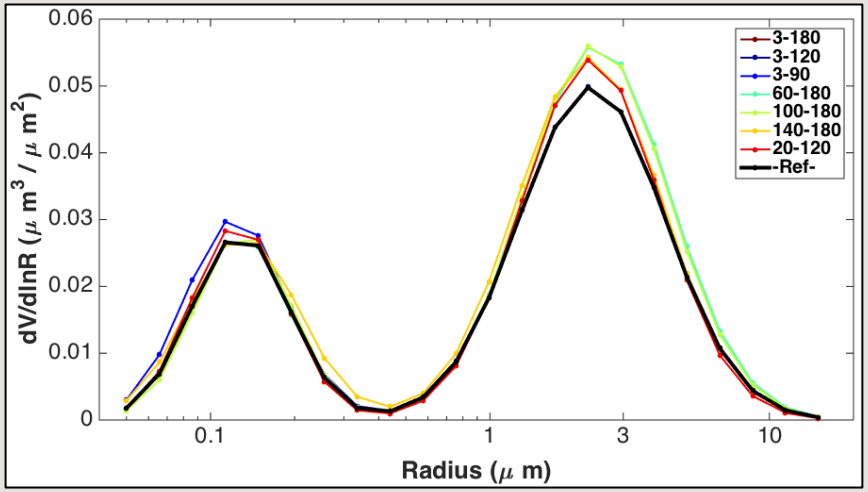
Bi-lognormal



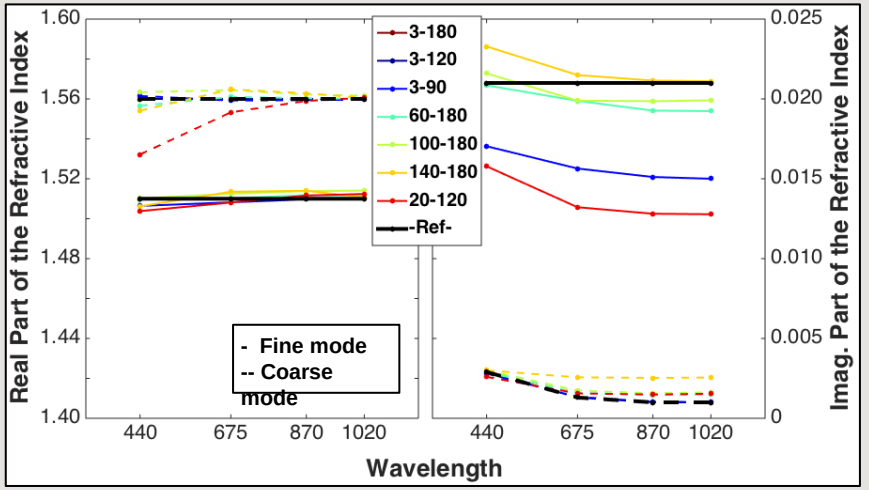
Can we separate the modes? -Mash-

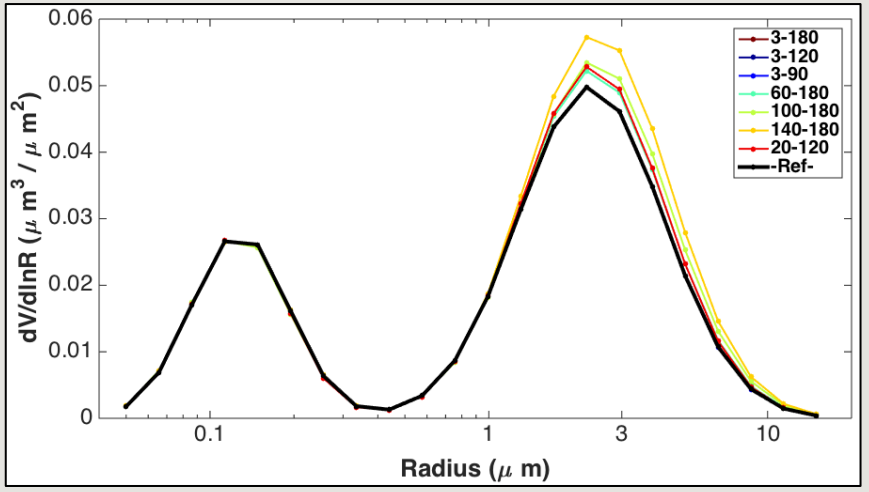
Without polarization





With polarization





Progress…

Step 1: *"Advanced characterization of aerosol properties from measurements of spectral optical thickness of the atmosp…"* *(Torres et al. 2016)*

+100000 retrievals

Step 2: Retrievals from single scattering measurements.

- Retrieval of extinction values from P11 measurements.
- Addition of polarimetric information -P12/P11.
- Full retrieval with extinction as input.

1680 retrievals

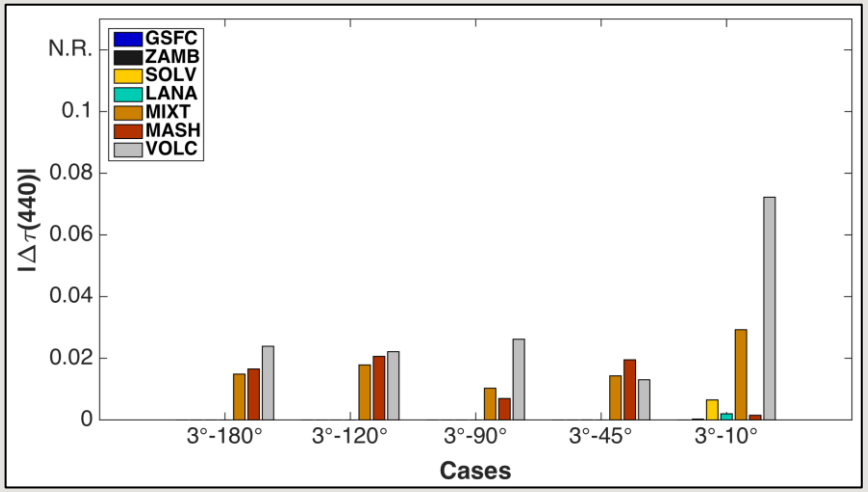
"…" (Torres et al. 2016)

Step 3: Up looking (sun-photometry)

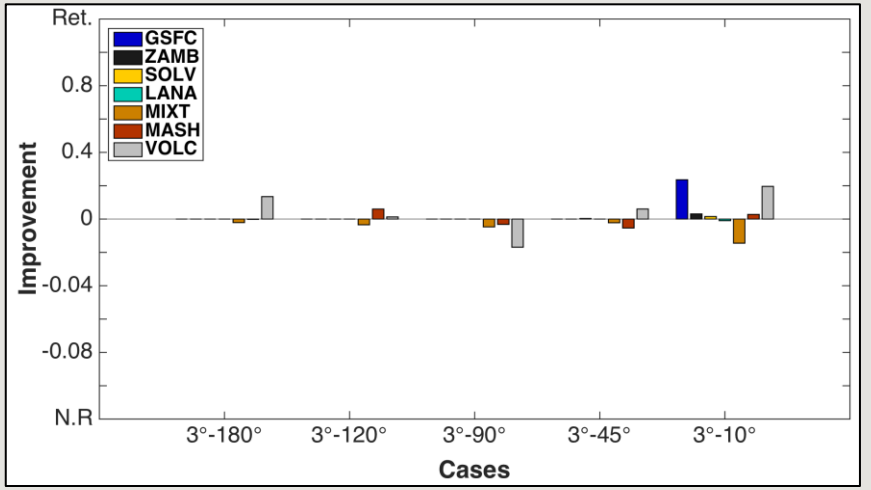
Step 4: Down looking (satellite retrievals)

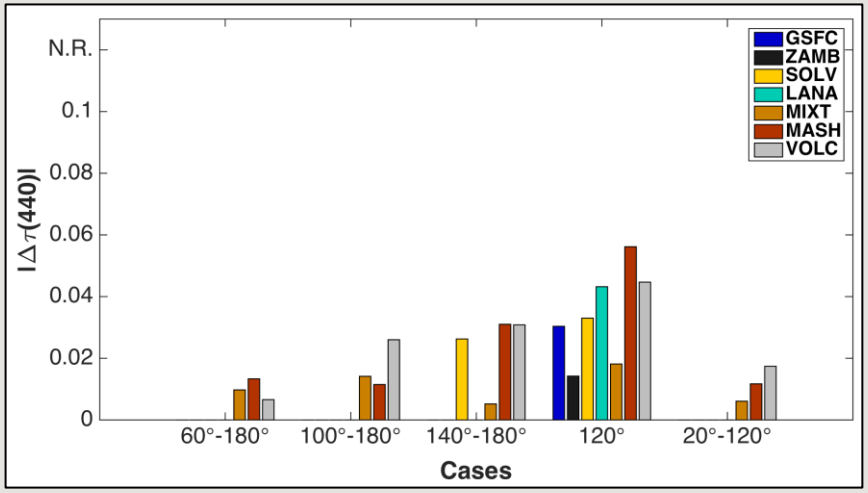
Adding wavelength (not shown)

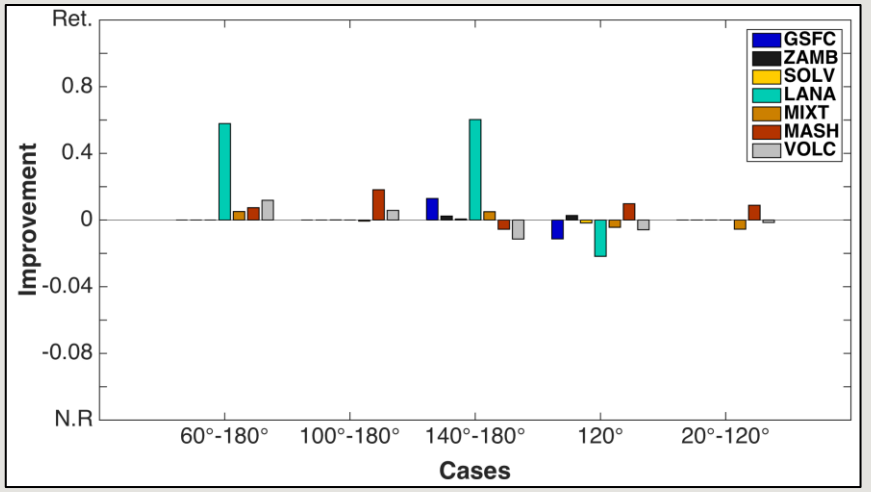
Bi-log: 8 wv - P_{11}



Improvement from just 4 wv

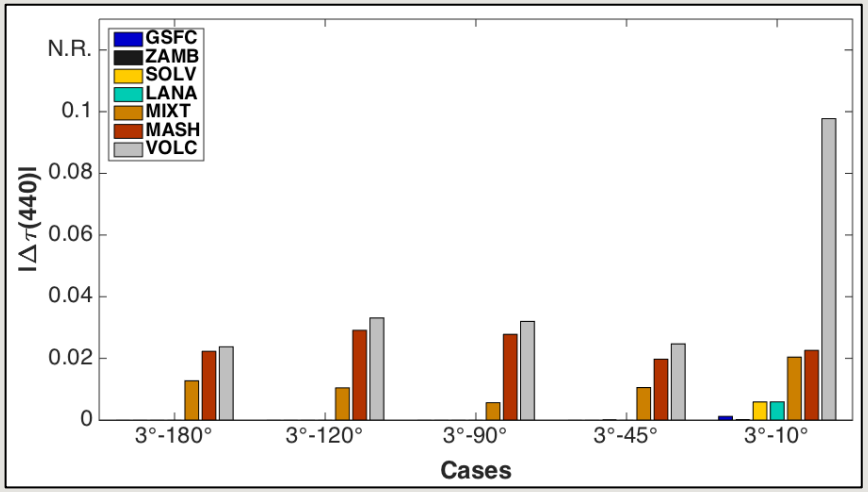




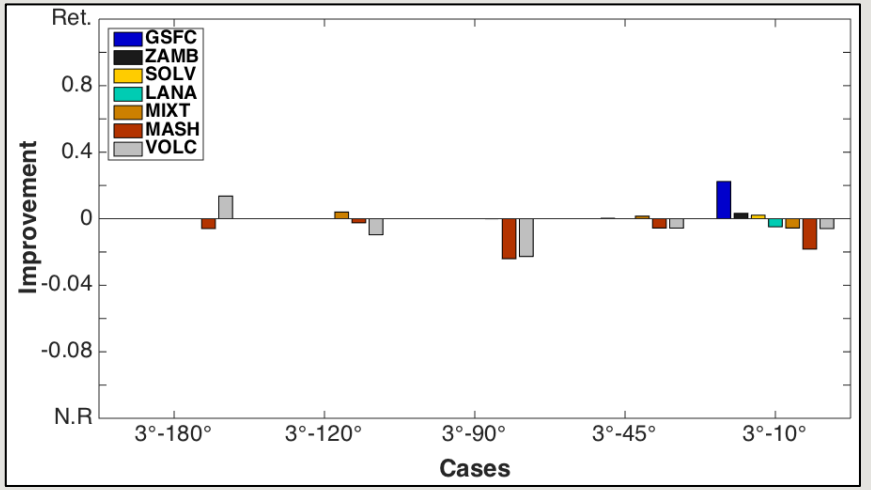


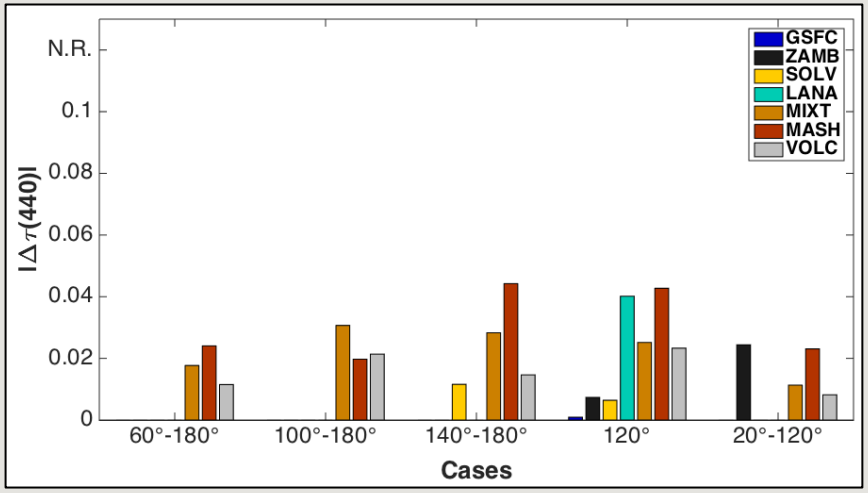
Adding polarization (not shown)

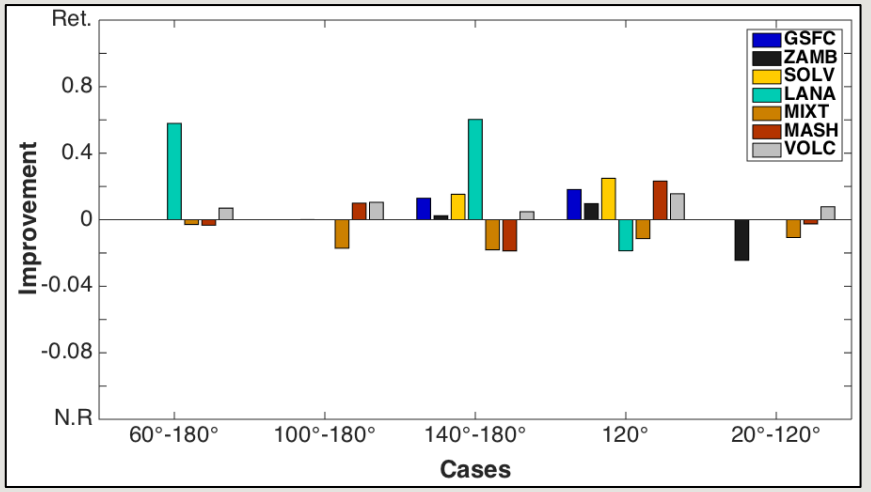
Bi-log: 4 wv - P_{11} & -(P_{12}/P_{11})



Improvement from just P_{11}

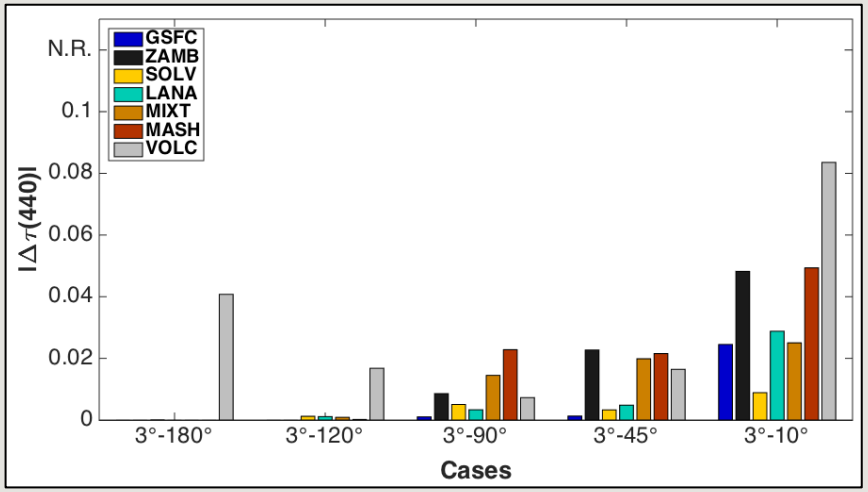




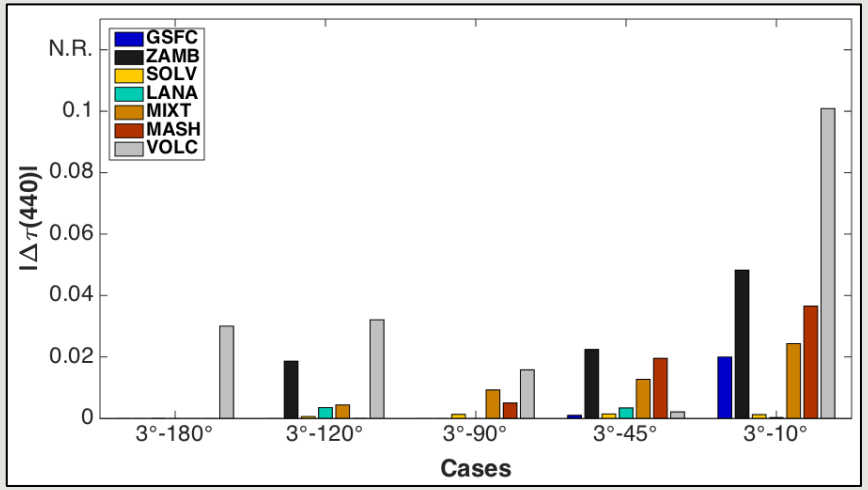


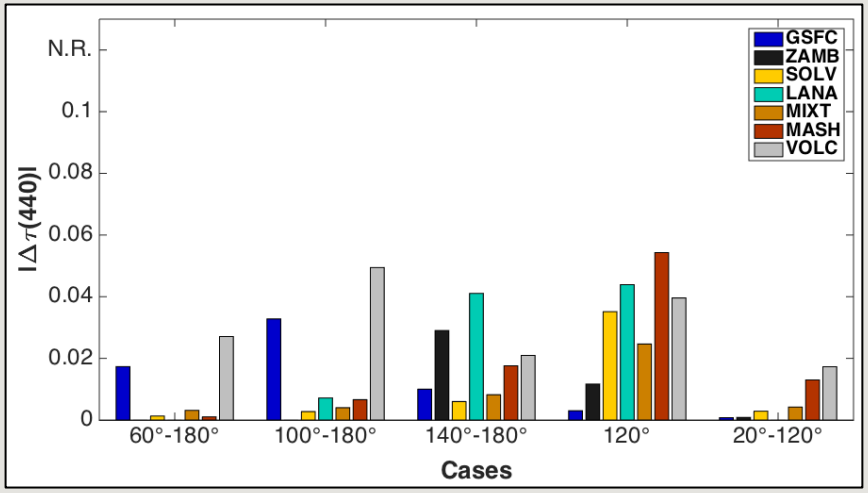
Bi-lognormal with 2 refractive index.

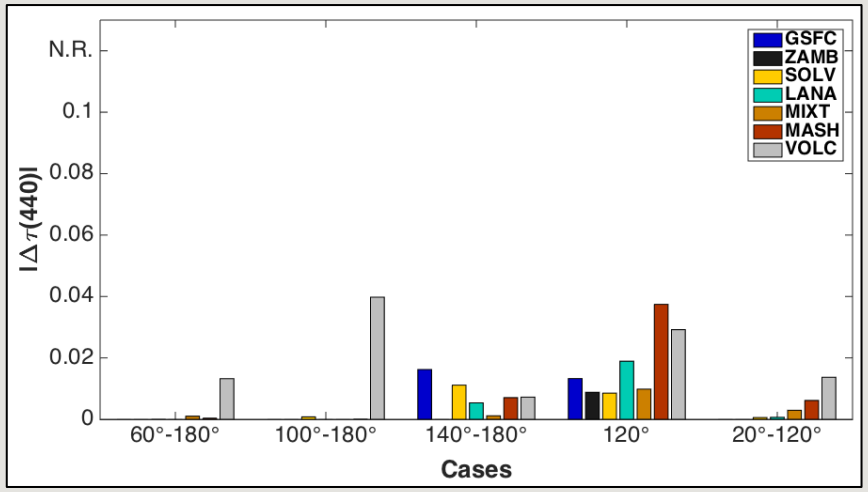
Bi-log: 4 wv - P_{11}



Bi-log: 4 wv - P_{11} & $-(P_{12}/P_{11})$

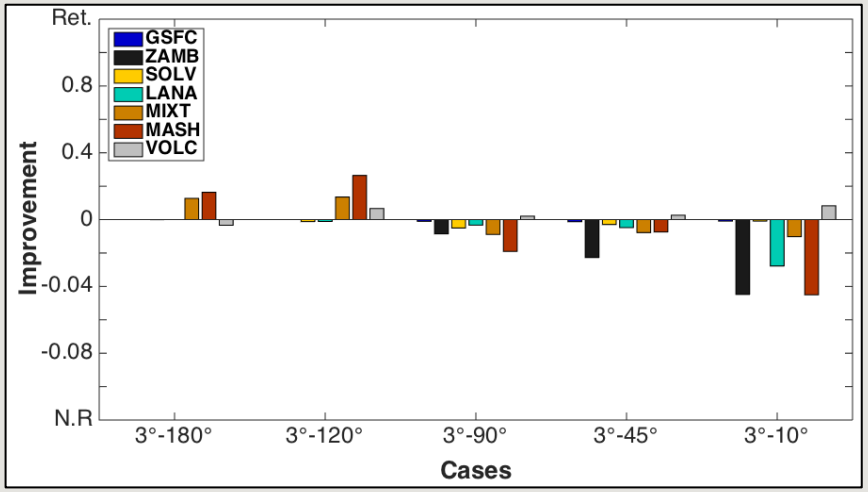






Bi-lognormal with 2 refractive index.

Improv. without polarization



Improv. with polarization