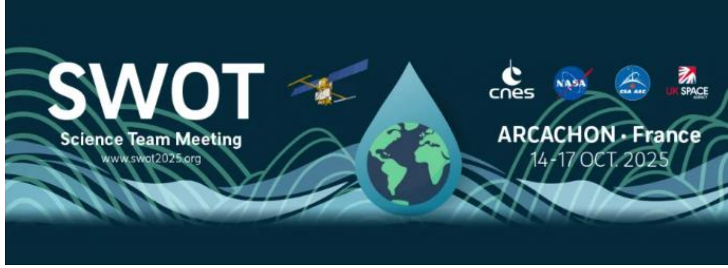
ADVANCING MARINE GRAVITY FIELD RECOVERY IN THE BAY OF BENGAL USING SWOT ALTIMETRY DATA



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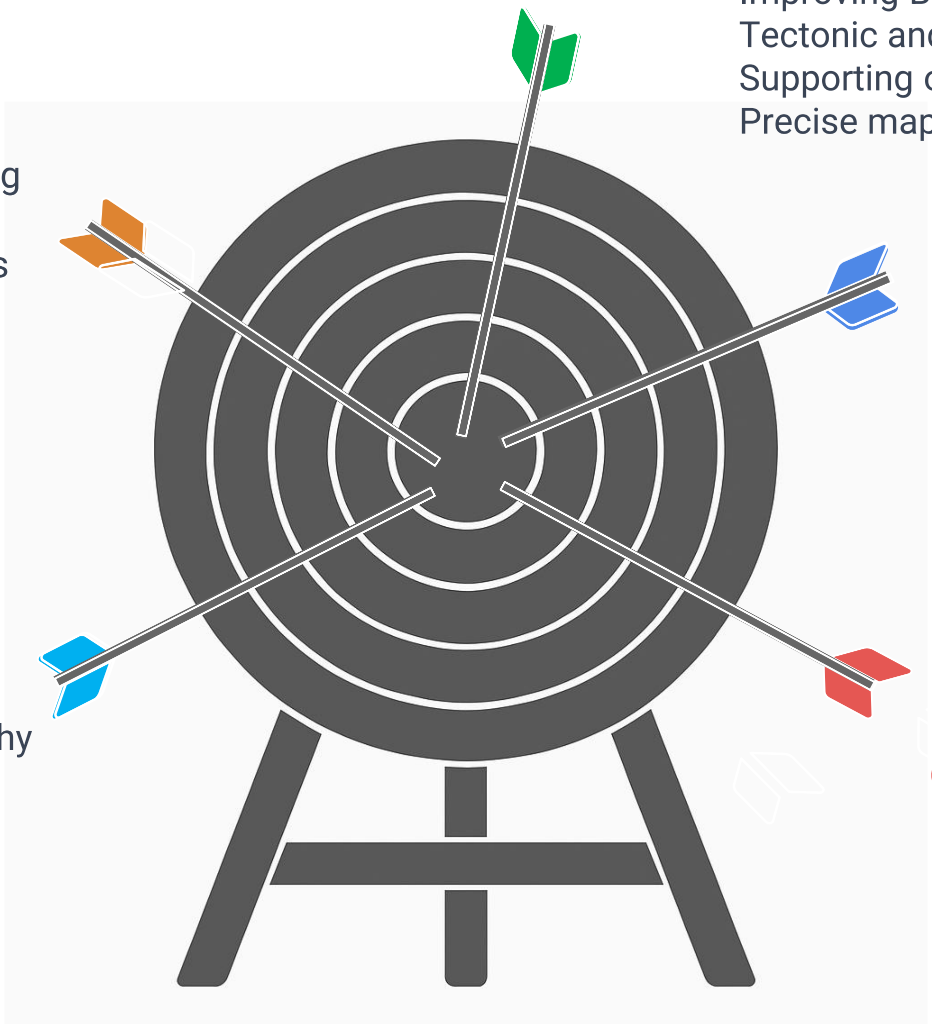
Applications of Gravity Data

Geodetic and Mapping

Global and Regional Geoid Models
Improving Bathymetry
Tectonic and Subduction Zones
Supporting other gravimetric Missions
Precise mapping of water bodies

Other Benefits

Resource Exploration
Cable and Pipeline Routing
Marine Navigation Safety
Military and Defense Uses
Tsunami Modeling



Hydrology

Ground water Exploration
Aquifer Characterization
Water Storage Monitoring
Mapping Water Subsurface
Water Resource Management

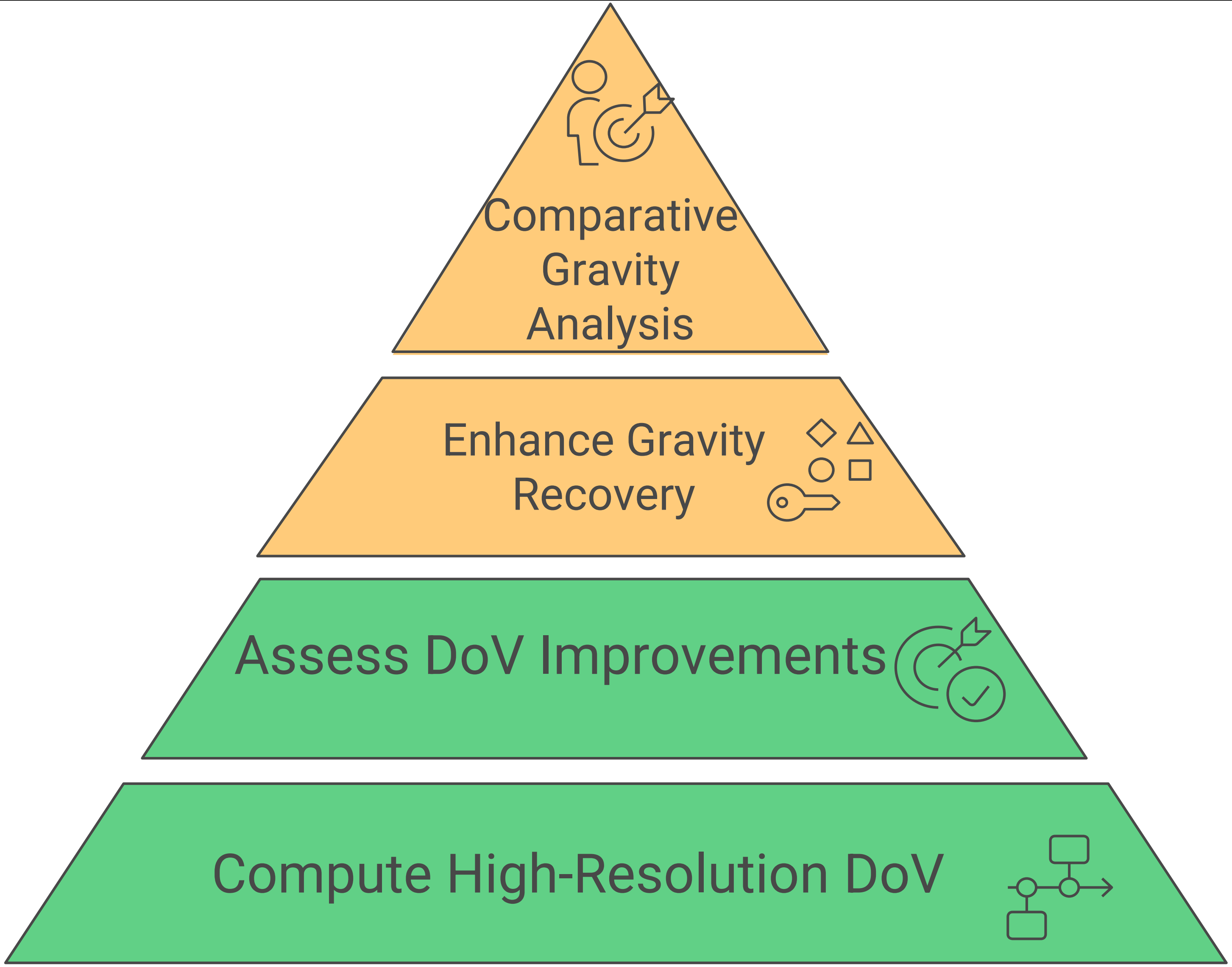
Oceanography

Mapping Ocean Currents
Improving Dynamic Topography
Subsurface Ocean Features
Supporting Ocean Tide Model
Understanding Ocean Mass Redistribution

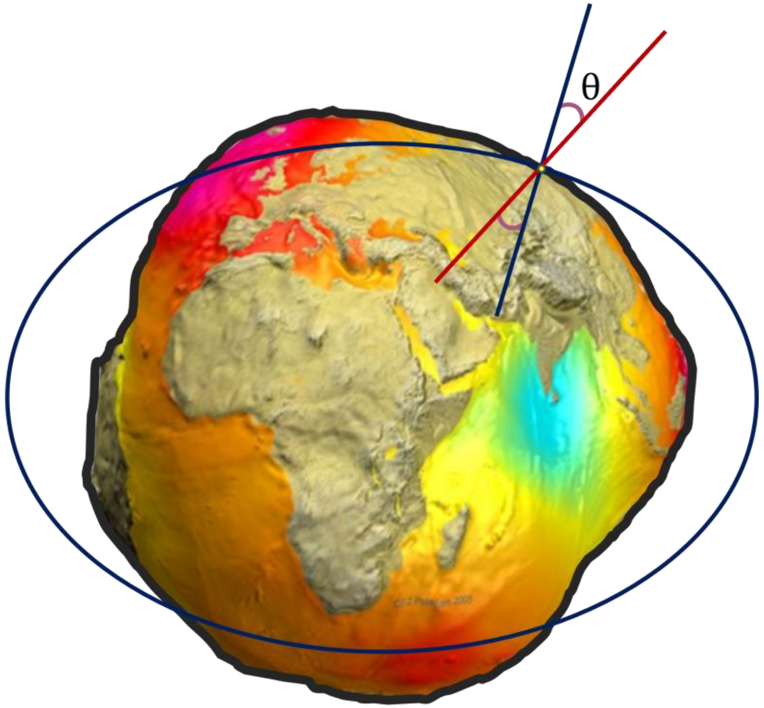
Climate Monitoring

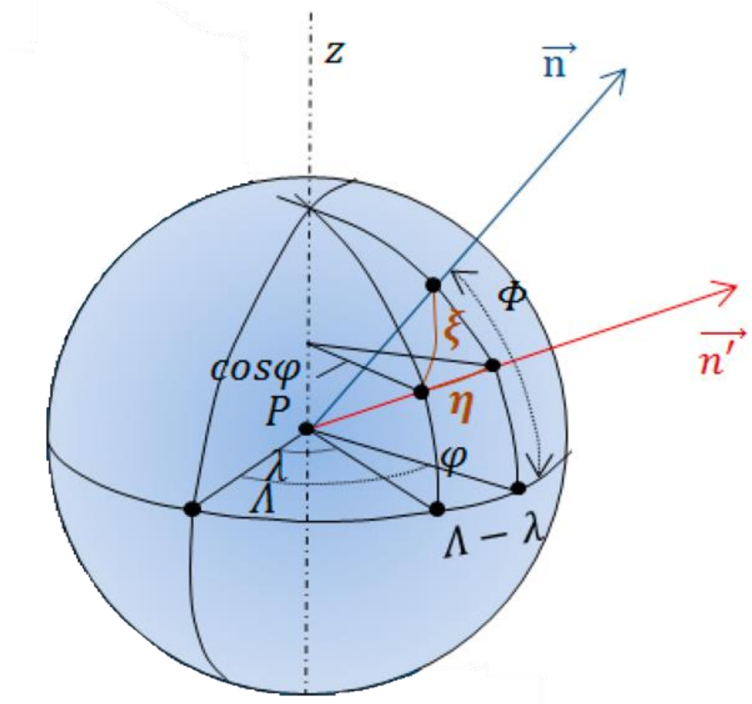
Detecting Sea Level Change
Monitoring Ocean Heat Content
Understanding Ice Mass Loss
Supporting Climate Models
Detecting Vertical Land Motion

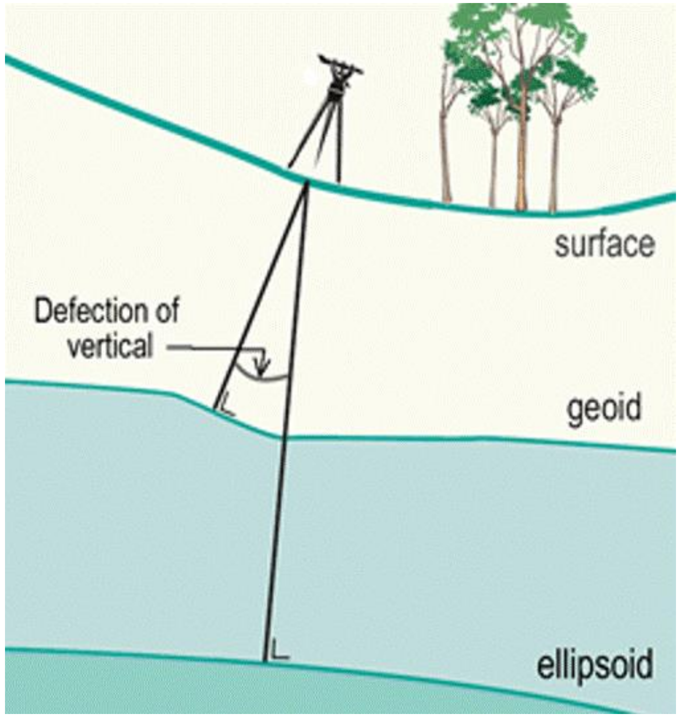
What to expect?



Deflection of Vertical (DoV)

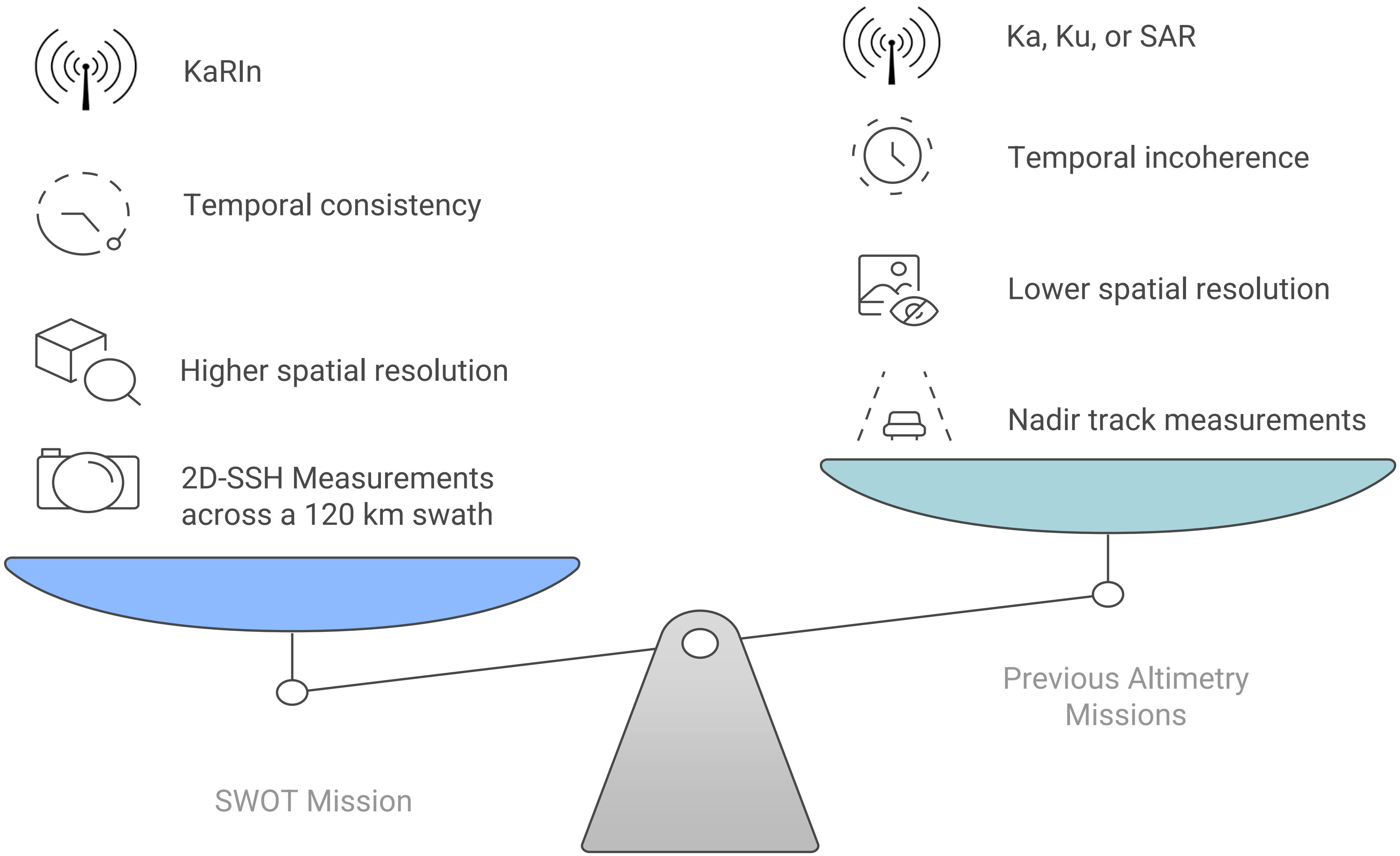




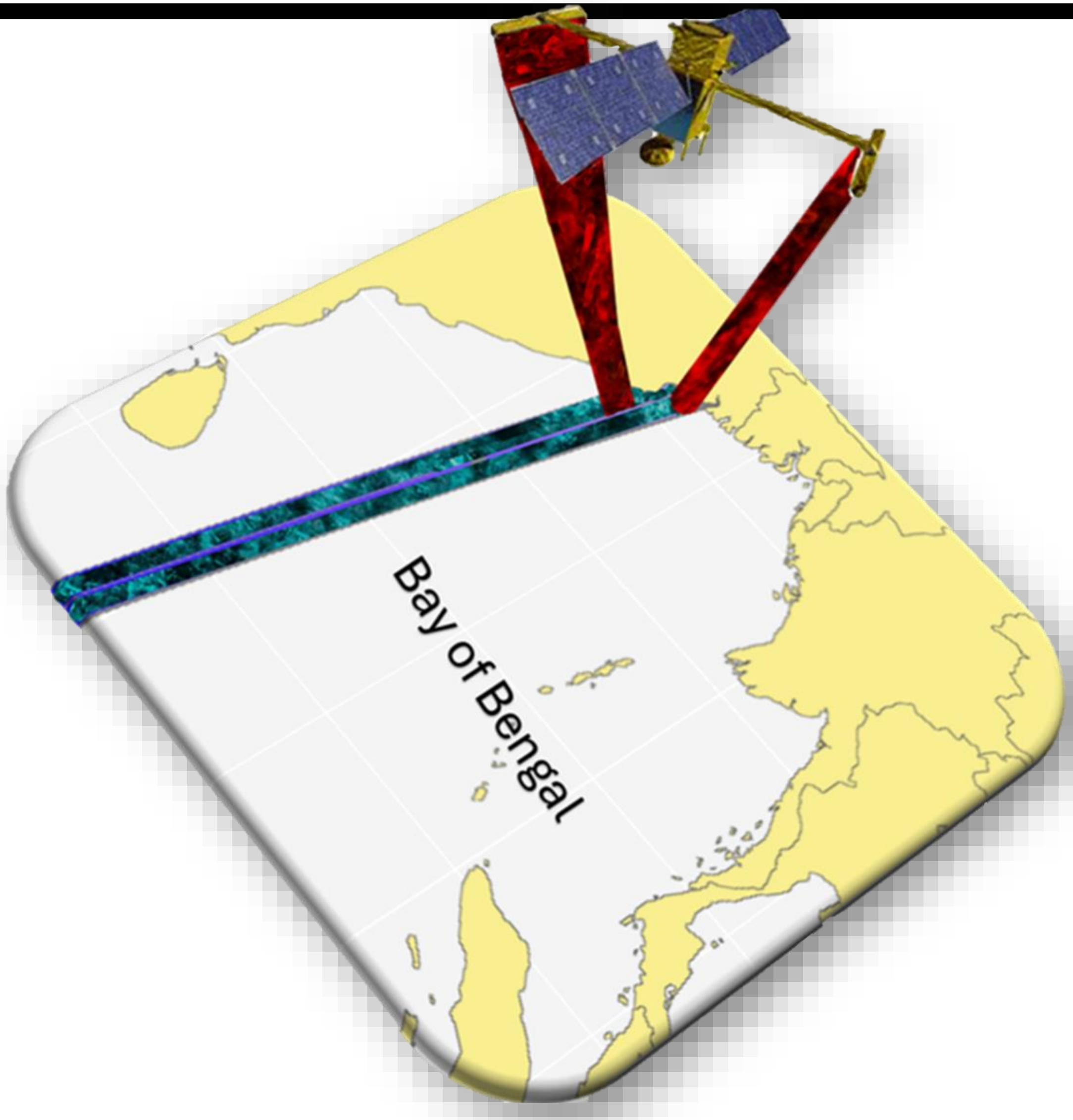


Angular difference between true direction of gravity and the ellipsoidal normal
Is there an imbalance or anisotropy which limits the geoid modelling?

SWOT's Advancements Over Previous Altimetry Missions



GUIDING QUESTIONS?



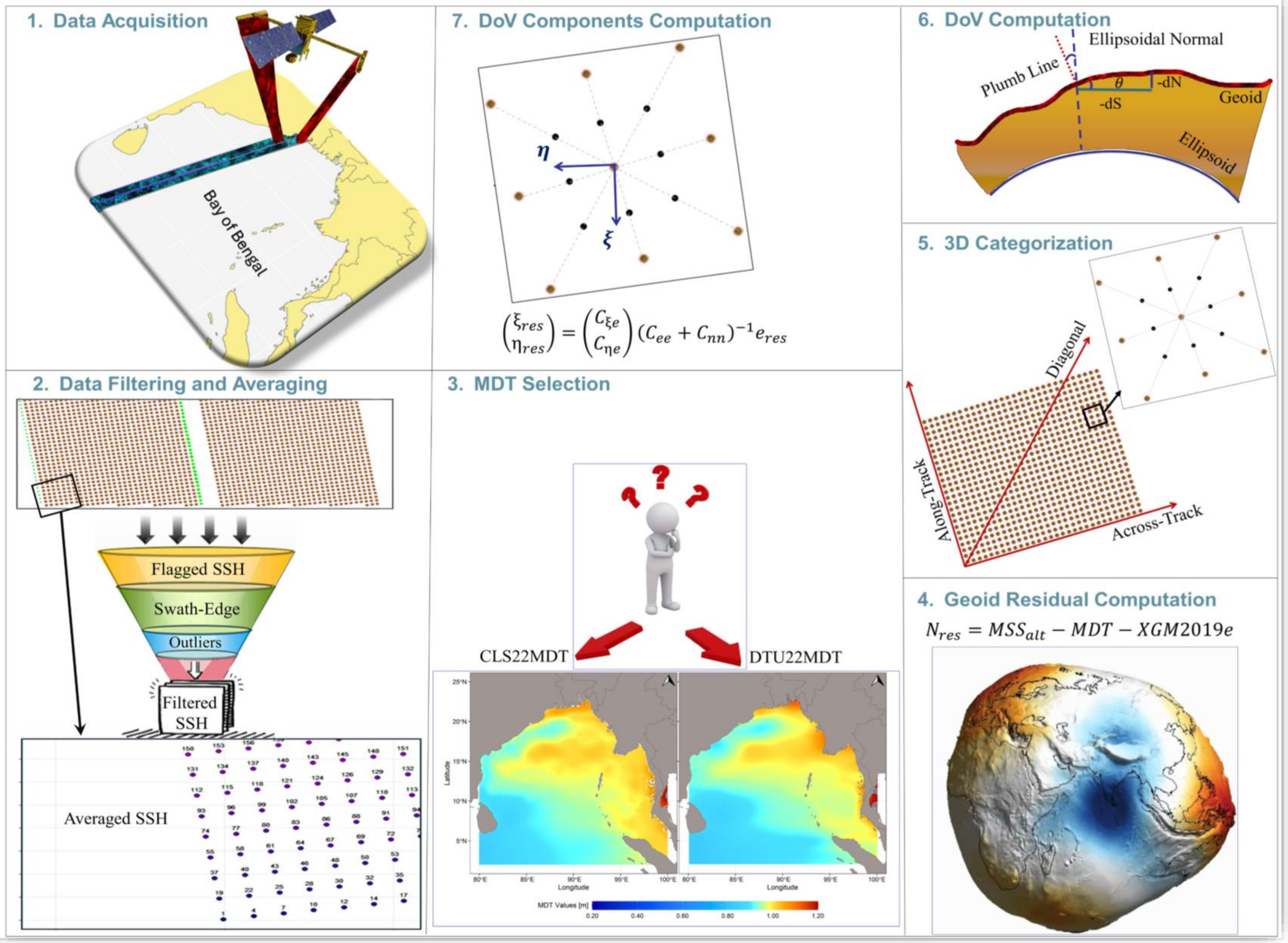
Study focuses on 80°E–100°E, 2°N–25°N, characterized by complex ocean dynamics, strong monsoonal forcing, and significant tectonic structures from Bengal Fan and Andaman-Nicobar subduction zone.

- ✓ How much improvement does SWOT offer compared to conventional altimetry?
- ✓ Are SWOT grid-based inversions consistent with crossover-based estimates?
- ✓ Do any spectral distortions or smoothing artifacts occur?
- ✓ Can crossover derived DoV serve as a benchmark for validating gridded estimates?

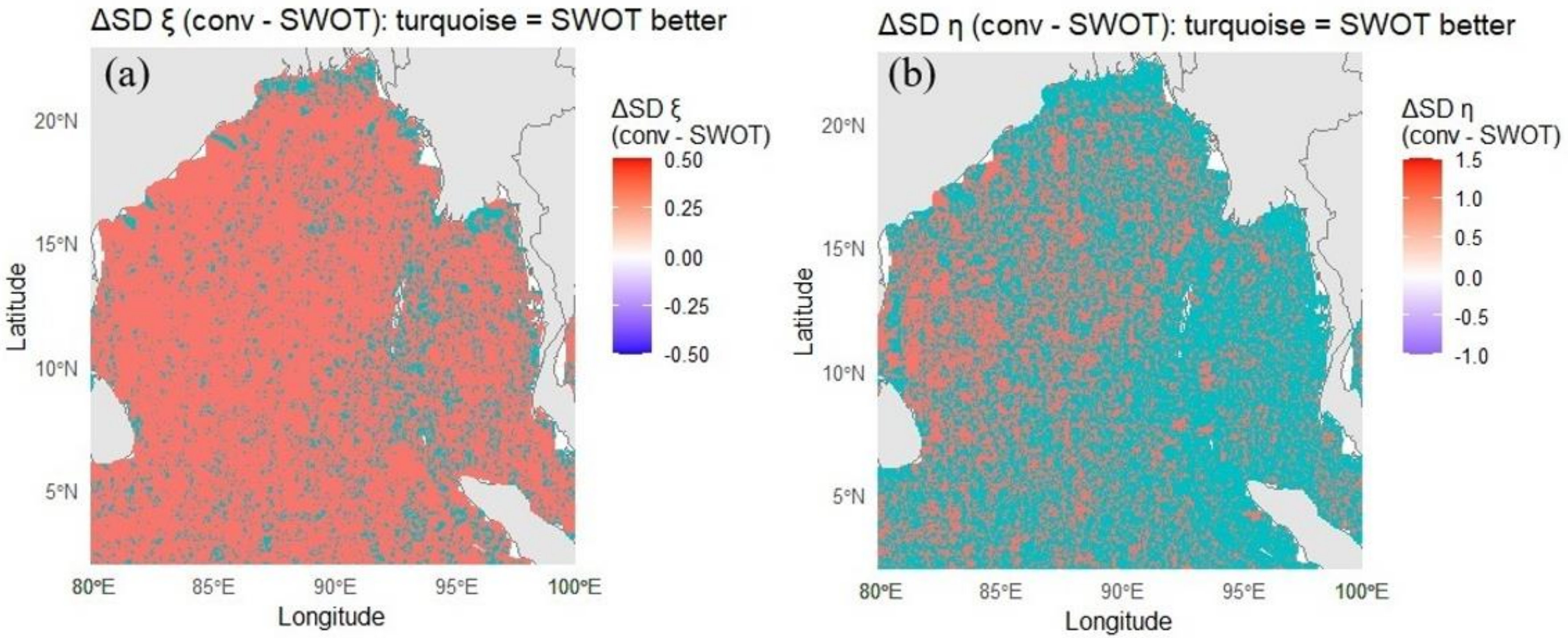
Evaluate three approaches: conventional nadir altimetry, grid-based SWOT inversion, and crossover-based estimation

Methodology

- SWOT: L2 KaRIn SSH (19 cycles)
- Conventional Altimeters: Jason-1 GM, SARAL, CryoSat-2 & Combined
- SIO: V32.1-DoV Model
- MDT: CLS22
- GGMs: EGM08 XGM2019e-2159 (for validation)

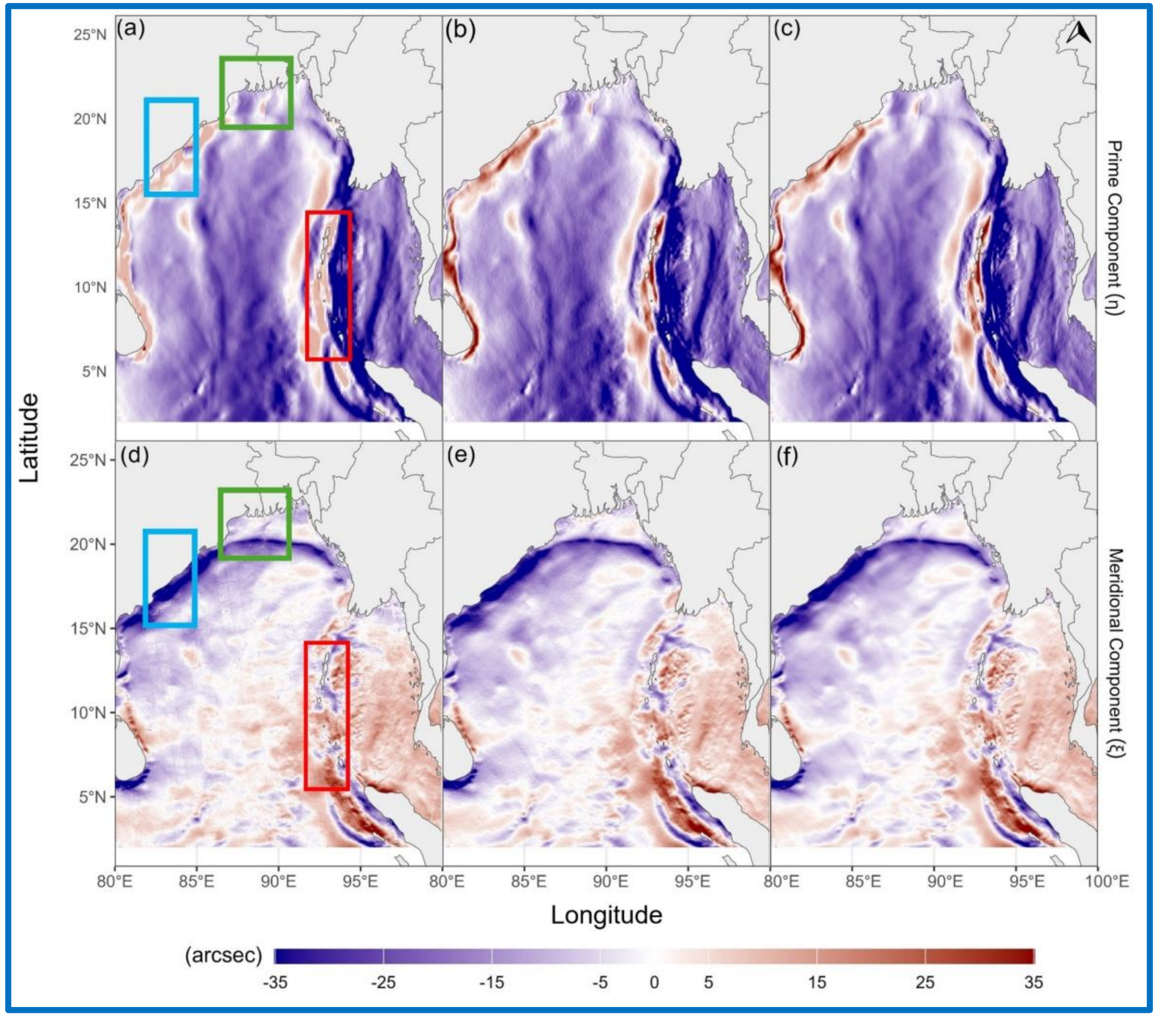


Workflow for inverting DoV components from SWOT data. The diagram summarizes the steps described above: (a) data acquisition; (b) KaRIn L2 SSH preprocessing and MSS formation; (c) MDT subtraction; (d) GGM remove–restore to form ; (e) directional gradient computation by centred differences along azimuth; (f) conversion to DoV; (g) radial–transverse decomposition and LSC inversion with covariance modelling



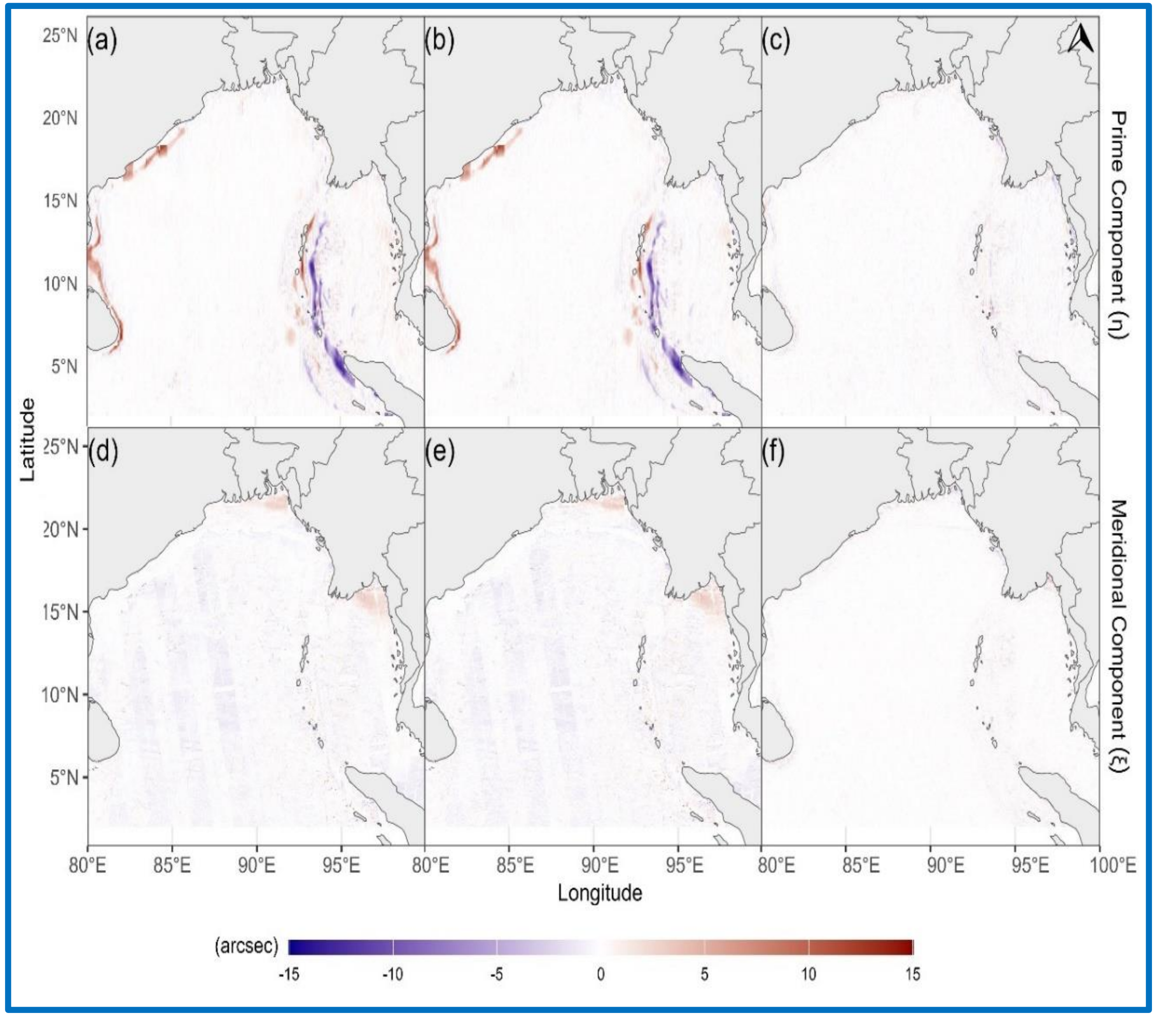
Maps of the difference in standard deviation (ΔSD) between SWOT and conventional altimetry on a $2\ arcmintues$ grid for (a) ξ and (b) η components. Turquoise shades indicate regions where SWOT reduces variability ($\Delta SD\ >\ 0$). SWOT improvements are widespread for η but more localized for ξ.

DoV: SWOT vs. Global Models on 1 arcminute resolution



Spatial patterns of the DoV components, (panels a–c) and (panels d–f), over the Bay of Bengal at resolution. Panels (a) and (d) show results derived from SWOT data,
panels (b) and (e) correspond to the EGM2008 model, and panels (c) and (f) represent the SIO-V32.1 model.

- ✓ **Blue rectangle:** Anomalies along the eastern Indian continental margin coincide with the shelf–slope
- ✓ **Red rectangle:** elongated high-magnitude and signals along mark the Andaman–Nicobar subduction zone ;
- ✓ **Green rectangle:** moderate η anomalies (±5–7) are observed in the northern Bay near , coinciding with the Ganges–Brahmaputra–Meghna delta front



The differences in the and of the DoV between different models (SWOT, EGM2008, and SIO-V32.1) in the Bay of Bengal region.

The difference between EGM2008 and SWOT:
(a) $\Delta\eta = \eta^{\mathrm{EGM}} - \eta^{\mathrm{SWOT}}$ and (d) $\Delta\xi = \xi^{\mathrm{EGM}} - \xi^{\mathrm{SWOT}}$,

The difference between SIO and SWOT:
(b) $\Delta\eta = \eta^{\mathrm{SIO}} - \eta^{\mathrm{SWOT}}$ and (e) $\Delta\xi = \xi^{\mathrm{SIO}} - \xi^{\mathrm{SWOT}}$, and

The difference between EGM2008 and SIO models:
(c) $\Delta\eta = \eta^{\mathrm{EGM}} - \eta^{\mathrm{SIO}}$and (f) $\Delta\xi = \xi^{\mathrm{EGM}} - \xi^{\mathrm{SIO}}$.

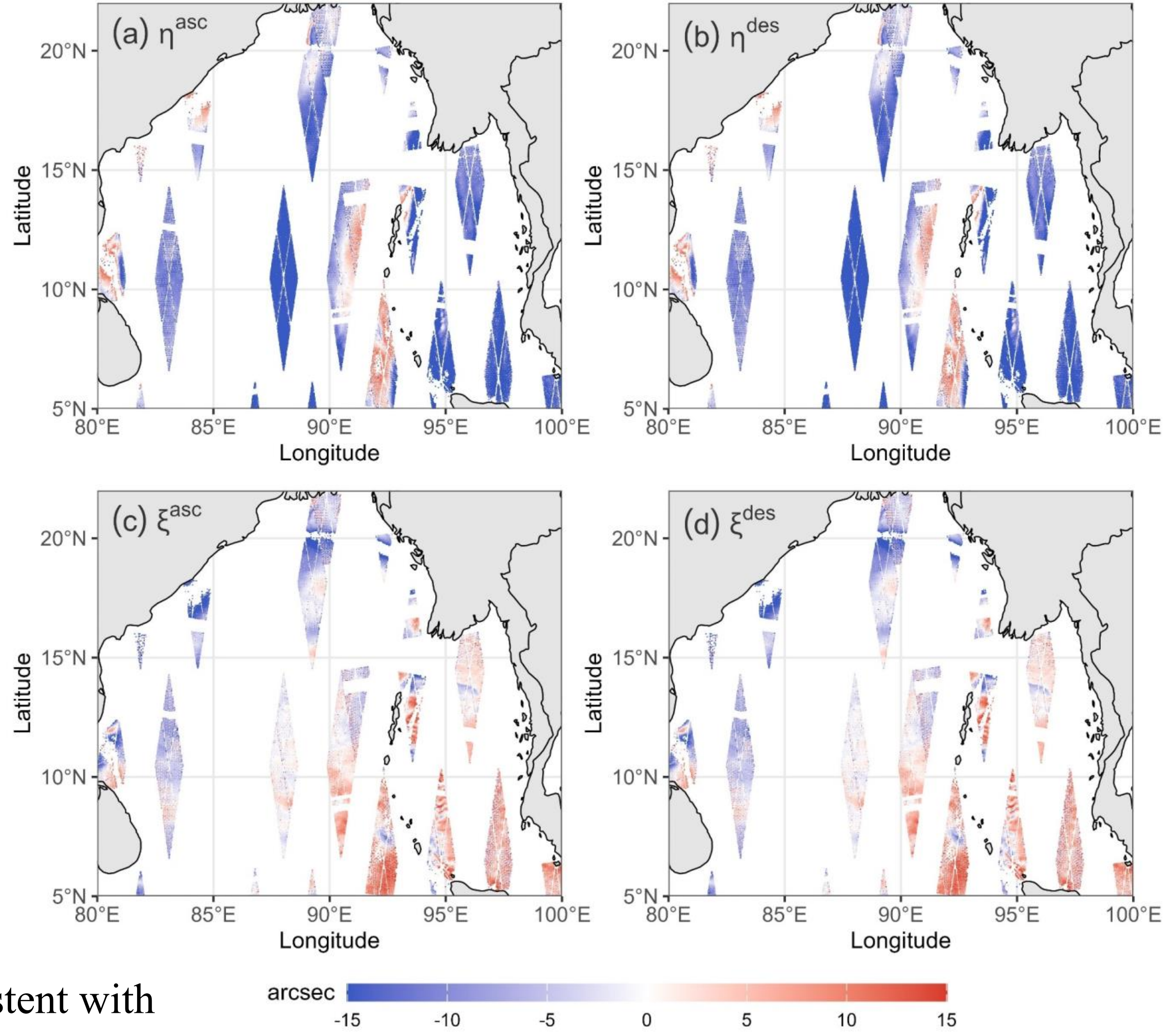
Results: SWOT vs Other missions

- SWOT showed:
  - Lower Standard Deviation
  - Lower RMS values than Jason-1, SARAL, CryoSat-2
- RMS improvements:
  - η: $\sim 28 - 41\%$
  - ξ: $\sim 7 - 15\%$
- SWOT excels in η, traditionally weaker in past missions

Component	Mission	Min.	Max.	Mean	SD	RMS
ξ $(arcsec)$	Jason-1 GM	-8.06	7.38	-0.20	2.84	2.90
	SARAL	-8.75	8.03	-0.27	2.88	3.10
	Cryosat-2	-8.07	7.44	-0.26	2.82	2.91
	Combined	-8.12	7.50	-0.24	2.89	2.89
	SWOT	-8.74	8.34	-0.04	2.63	2.63
η $(arcsec)$	Jason-1 GM	-19.31	16.49	-0.84	4.00	4.11
	SARAL	-20.89	17.63	-0.90	4.43	4.62
	Cryosat-2	-19.68	16.50	-0.68	4.33	4.77
	Combined	-18.05	15.14	-0.57	3.86	4.25
	SWOT	-18.15	17.18	-0.42	2.77	2.80

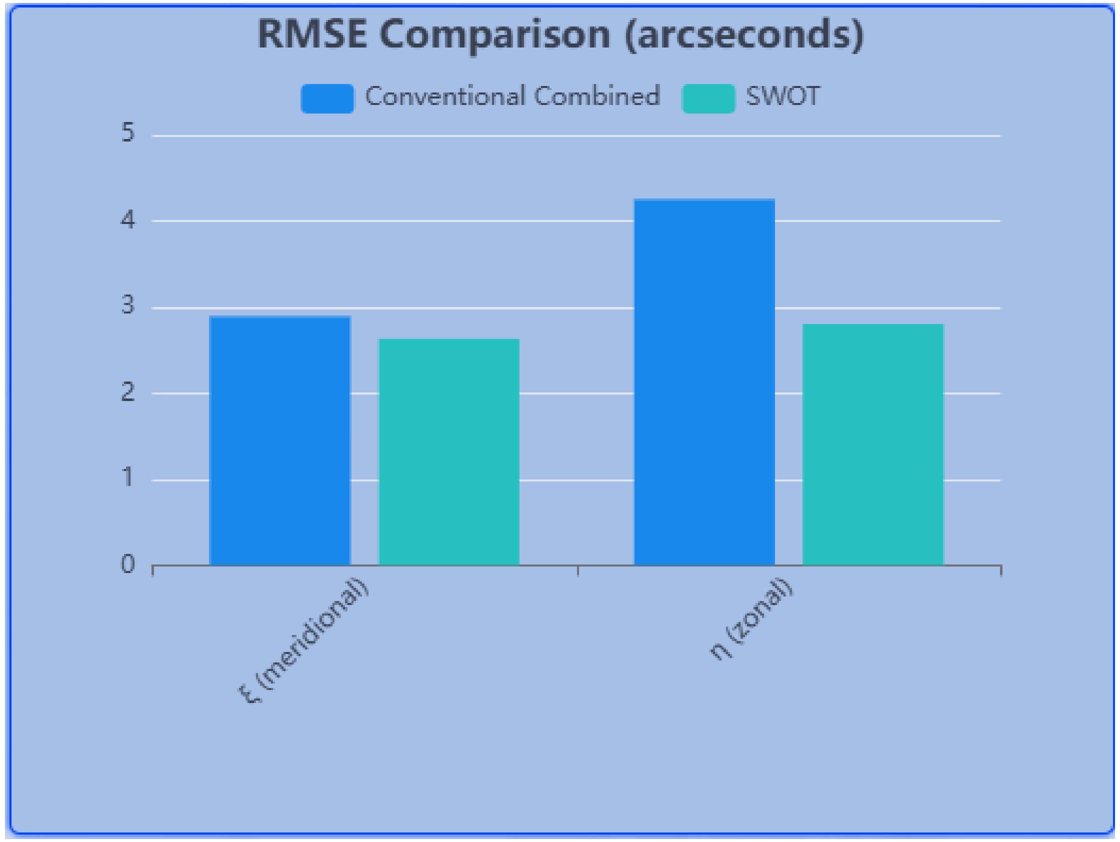
DoV: SWOT Crossovers

Spatial distribution of and DoV components at selected SWOT crossover locations.
A subset of crossovers is shown to highlight component variability without excessive visual clutter.
(33,800 crossovers across 19 science phase cycles)
- Sub arc second agreement for SWOT



Grid-based SWOT-DoV inversions are not only consistent with crossover estimates !

Key Performance DoV Results



SWOT Accuracy Gains

Achieves lowest regional variability with significant improvement in zonal component estimation, reducing east-west slope uncertainty dramatically compared to conventional missions.

Crossover Consistency

Sub-arcsecond agreement between ascending-descending passes confirms excellent observational stability with near-perfect correlations in grid-based validation.

Results: Global Models vs SWOT & Traditional Missions

Saral ✕ ✕ large discrepancies

Jason1GM: ✕ Poorer performance, especially in η (zonal)

CryoSat-2: ⚠ Better in ξ (meridional) but still poor in η(zonal)

Combined: ☑ Better than any single mission; close to SWOT

SWOT: ☑ ☑ Superior consistency in both ξ and η

RMSD Values	$\Delta\xi''$	$\Delta\eta''$
SIO – SWOT	0.42	0.97
SIO – Jason1GM	0.94	1.88
SIO – Saral	1.15	2.95
SIO – Cryosat2	0.53	2.28
SIO – Combined	0.43	1.02
EGM08 – SWOT	0.47	0.99
EGM08 – Jason1GM	0.98	1.89
EGM08 – Saral	1.18	2.96
EGM08 – Cryosat2	0.58	2.30
EGM08 - Combined	0.49	1.06

Major Scientific Achievements and Impact

59.2%	10-200 km	0.999	19
Grid Improvement	**Wavelength Coverage**	**Correlation Accuracy**	**Science Cycles**

Anisotropy Resolution

SWOT markedly reduces east-west slope uncertainty, closing long-standing anisotropy gap in deflection of vertical recovery.

Balanced ξ and η component estimation capability.

Multi-azimuthal sampling overcomes nadir-only geometry limitations.

Consistent performance across both meridional and zonal directions.

Spectral Preservation

Grid-based inversions preserve mesoscale variance at 10-200km wavelengths while maintaining spectral fidelity.

Slight damping below 20km reflects covariance smoothing.

Excellent agreement in 50-200km mesoscale range.

Crossover validation confirms minimal smoothing artifacts.

Geophysical Validation

DoV patterns align with known Bay of Bengal structures, confirming genuine geophysical signal detection.

Strong signals along Andaman-Nicobar subduction zone.

Smooth estimates across sediment-loaded Bengal Fan.

Localized anomalies match continental shelf breaks.

THANK YOU!

MERCI!