
National Aeronautics and
Space Administration
NASA
Global climate change research utilizing BusanSat, an ultra-small ocean observation satellite
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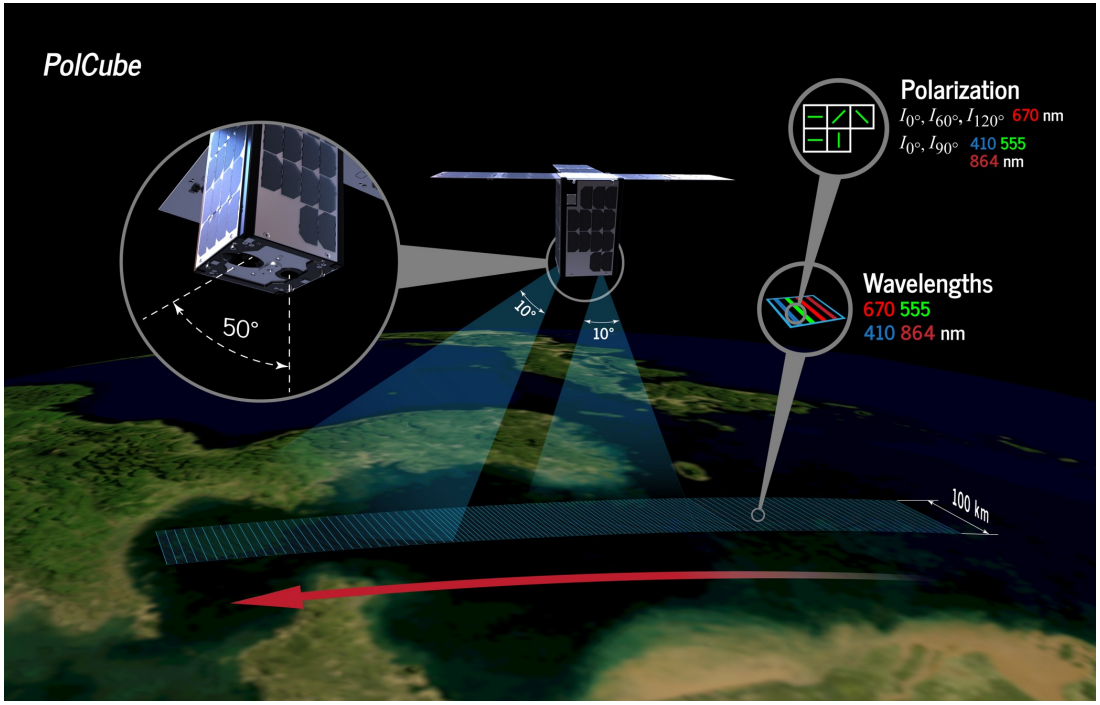
1

Polarimetry: the future of **passive** remote sensing of aerosols, clouds, oceans, and lands (UV-VIS-NIR-SWIR)

- Polarimeters can retrieve significantly more information about aerosol properties than radiometers
- Liquid water and ice cloud properties and ocean/land properties
- Polarimetry has very high synergy with collocated lidar measurements

Polarimeters:

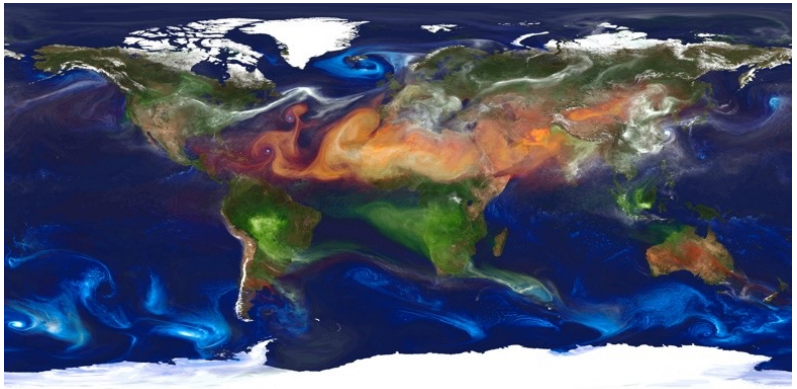
- NASA Research Scanning Polarimeter (1999-present)
- PARASOL/POLDER-3 (2004-2013)
- PACE/SPEXone, PACE/HARP2 (2024-)
- MAIA (2024-)
- KASA/NASA BusanSat/PolCube (2025-)
- AOS (2029-)



RSP-MAPP polarimeter algorithm

Microphysical **A**erosol **P**roperties from **P**olarimetry (**MAPP**) is the operational polarimeter algorithm for the NASA **R**esearch **S**canning **P**olarimeter (**RSP**)

- Goal: retrieve accurate aerosol optical and microphysical properties and ocean properties using optimal estimation
- Use a ***coupled*** atmosphere-ocean vector radiative transfer (VRT) model
- Use accurate but fast Lorenz-Mie and T-matrix aerosol IOP LUTs



Aerosol VIS-NIR-SWIR properties:
fine mode (absorbing), sea salt, and dust

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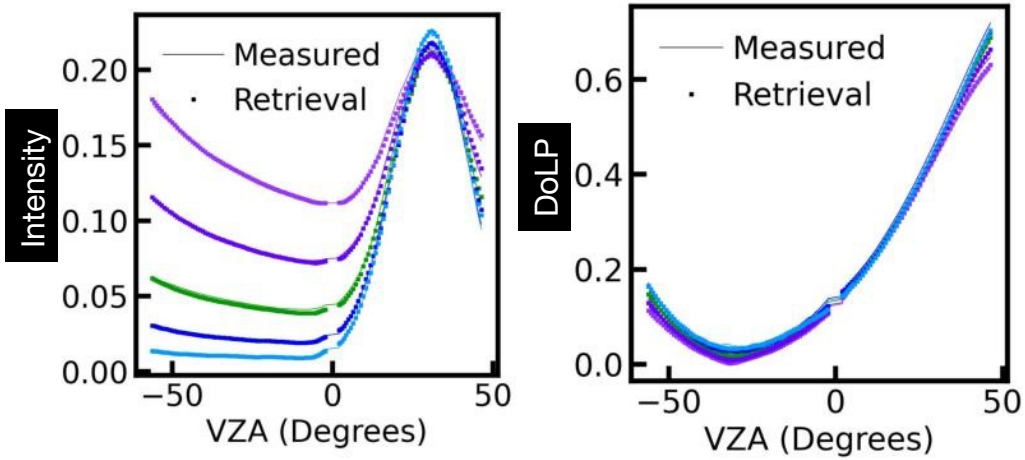
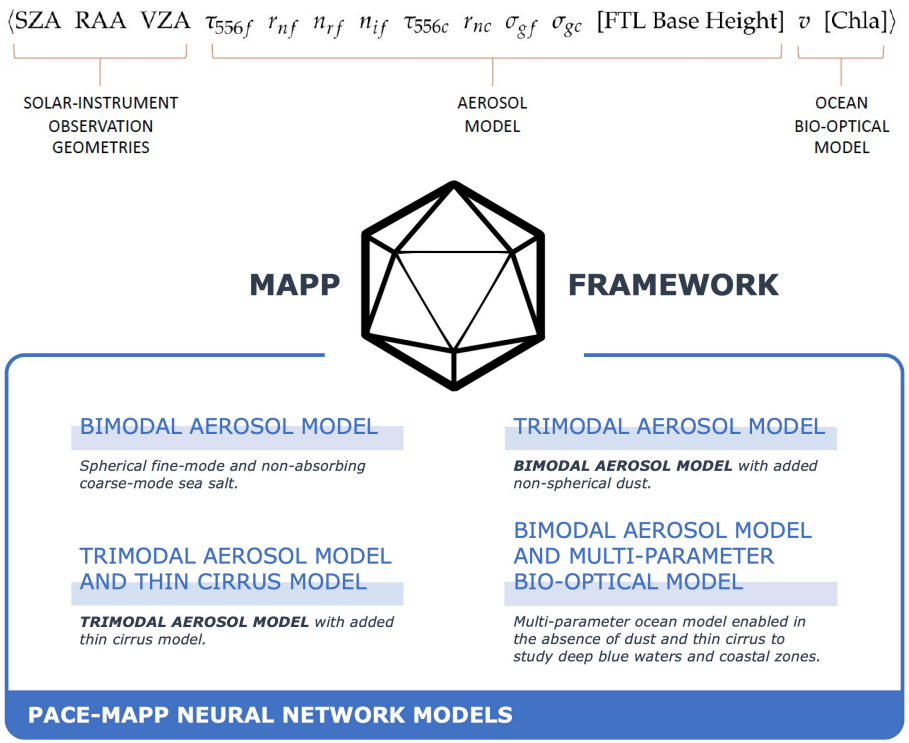


RSP-MAPP uses neural networks to become 1000x faster
(7 channels from 410-2264 nm are simulated at all viewing angles)

S. Stamnes et al., "Simultaneous polarimeter retrievals of microphysical aerosol and ocean color parameters from the “MAPP” algorithm with comparison to high-spectral-resolution lidar aerosol and ocean products," Appl. Opt. 57, 2394-2413 (2018)

PACE-MAPP polarimeter algorithm



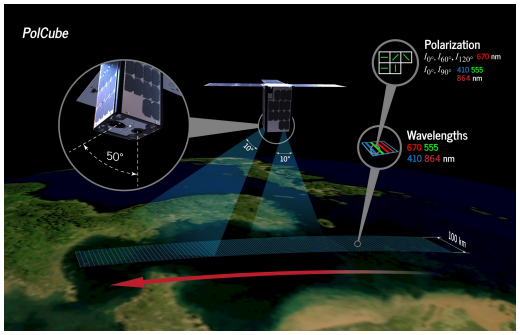
- PACE-MAPP is a fully adaptable, 100% Python framework that supports different retrieval parameters, processing pipelines, and neural network forward models via a simple config file
- Supports bimodal and trimodal aerosol models
- Tested using synthetic PACE data and airborne RSP polarimeter data
- Support for PACE Level-1C (L1C) data
- Combined SPEXone + HARP2 retrieval speed using 11 channels and all available viewing zenith angles: ~5 sec/core
- MAPP is the only planned operational algorithm for both polarimeters on PACE

S. Stamnes, et al., "The PACE-MAPP algorithm: Simultaneous aerosol and ocean polarimeter products using coupled atmosphere-ocean vector radiative transfer." Frontiers in Remote Sensing. (2023)

BusanSat/PolCube-MAPP

	Symbol	Range	PolCube forward-looking mode (1σ)
PolCube aerosol products			
Total AOD_{555}	τ	0–0.9	0.068
Fine-mode AOD_{555}	τ_f	0–0.5	0.078
Sea-salt AOD_{555}	τ_c	0–0.2	0.039
Dust AOD_{555}	τ_d	0–0.2	0.038
Fine-mode effective radius	$r_{eff,f}$	0.1–0.4 μm	0.059 μm
Sea-salt mode effective radius	$r_{eff,c}$	1.0–3.5 μm	1.3 μm
Dust mode effective radius	$r_{eff,d}$	1.0–4.0 μm	1.2 μm
Fine-mode SSA	SSA	0.8–1.0	0.036
Fine-mode real refractive index	n_{rf}	1.36–1.65	0.074
Aerosol top height	h_f	1.1–5 km	1.4 km
PolCube ocean products[a]			
Ocean surface windspeed	v	0.02–11.5 m/s	1.1 m/s
Ocean chlorophyll-a concentration	[Chla]	0.025–9.9 mg/m^3	2.4 mg/m^3

[a]*Ocean product uncertainties for AOD_{555} < 0.3.*



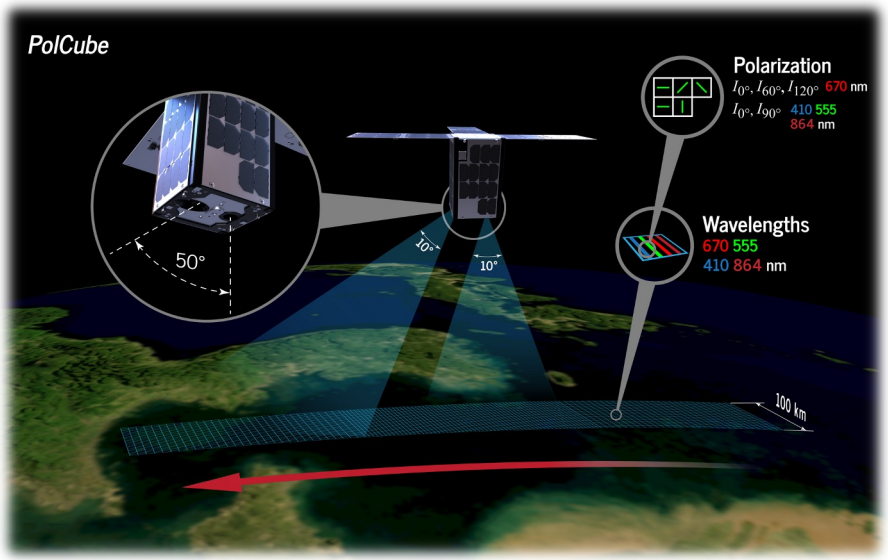
- *Stamnes et al., 2021, Simultaneous aerosol and ocean properties from the PolCube CubeSat polarimeter. Frontiers in Remote Sensing, 2, p.709040.*
- *Briggs, Causey, Cawdery, Entner et al., 2022, Use of Satellite Polarimeter Observations in Air Quality Monitoring (University of Virginia Capstone paper).*

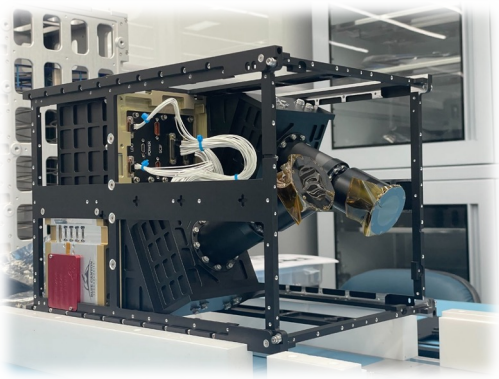
BusanSat/PolCube Overview

Collaboration between NASA and the Korea AeroSpace Administration (KASA)

BusanSat/PolCube will:

- Pave the way to **quantify and monitor floating plastics in our oceans from space**
- Generate **air quality** measurements (PM 2.5) over the Republic of Korea
- BusanSat/PolCube data and algorithms **are directly relevant to current and future NASA missions** with a polarimeter (PACE, AOS)





BusanSat/PolCube is built on heritage from the PolCam polarimeter on the KPLO lunar mission (NASA/KASA)

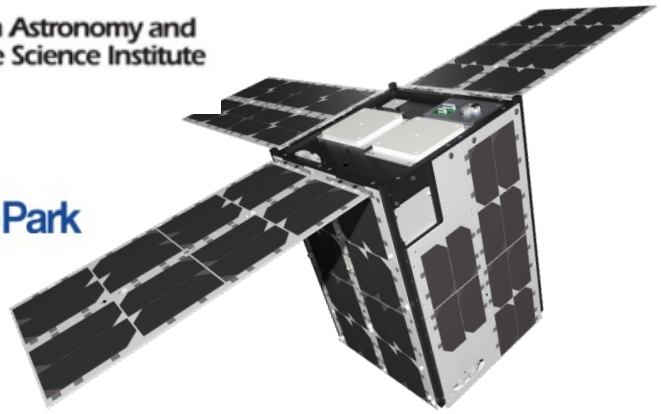
BusanSat/PolCube Partners

- Republic of Korea Partners
  - Korea AeroSpace Administration (KASA)
  - Korea Astronomy and Space Science Institute
  - Busan Metropolitan City
  - Busan TechnoPark
  - Nara Space Technology
  - Pukyong National University
- NASA Langley Research Center

Korea Astronomy and Space Science Institute

Foundation BusanTechnoPark

NARASPACE TECHNOLOGY

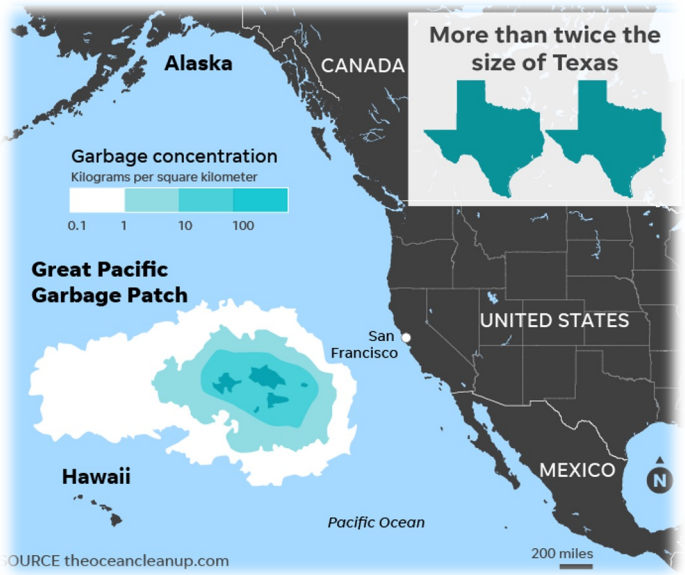


BusanSat/PolCube Ocean Applications

- **BusanSat/PolCube will help NASA quantify and monitor plastics in our oceans**
- Ocean Applications

  Plastic Zone Management - With its fine spatial resolution data products, BusanSat/PolCube will have the potential to provide key inputs for supporting ocean plastic cleanup operations

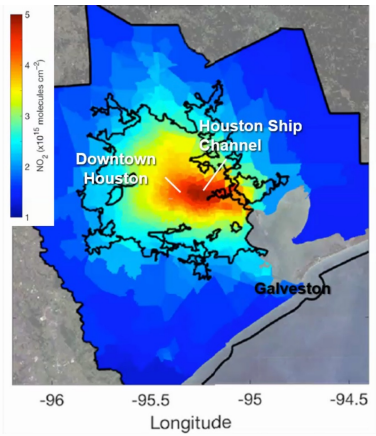
  Marine Wildlife and Fisheries - Fisheries operations can benefit from remote sensing data that measures physical properties of the ocean that can help determine plastics in marine organisms and impact of plastics to fish habitat and migration
- Potential Users - The Ocean Cleanup, Global Partnership on Marine Litter, NOAA

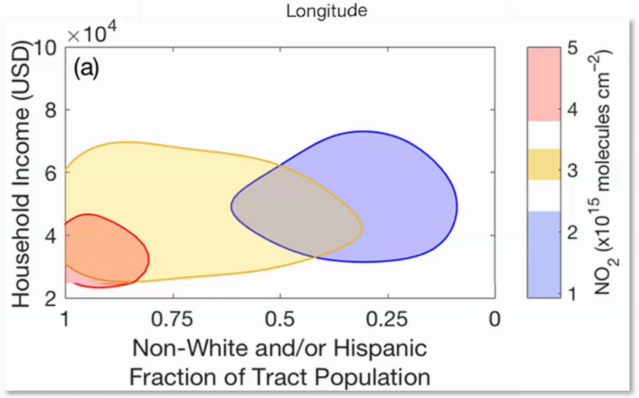


BusanSat/PolCube Air Quality Applications

- BusanSat/PolCube's fine spatial resolution data products enable PM 2.5 monitoring of Busan Metropolitan City, Republic of Korea
- **Environmental Health Applications**

  BusanSat/PolCube data can help determine impacts to human health from environmental pollutants and extreme weather events (wildfires, dust storms)
- Potential Users - Busan Metropolitan City and the Republic of Korea's Ministry of Environment



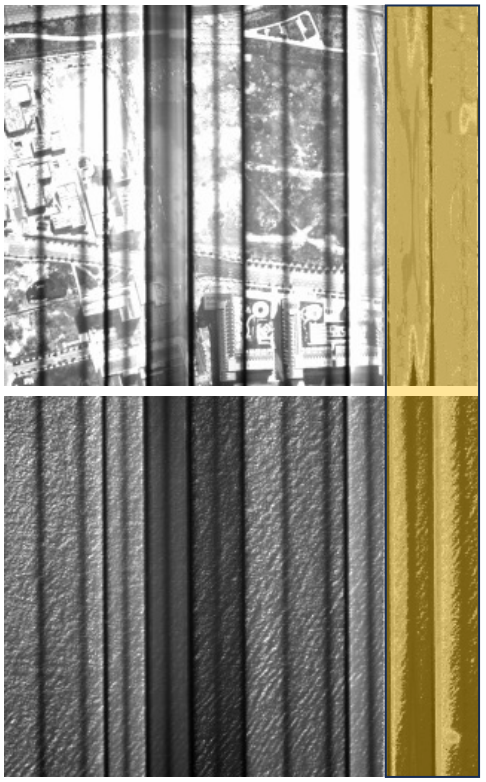


Demetillo**, M. A. G., Navarro, A., Knowles, K. K., Fields, K. P., Geddes, J. A., et al (2020). Observing nitrogen dioxide air pollution inequality using high-spatial-resolution remote sensing measurements in Houston, Texas. *Environmental Science & Technology 54*(16), 9882–9895. https://doi.org/10.1021/acs.est.0c01864 **FINESST proposal

BusanSat/PolCube Airborne Experiment

- Flight path (May 8-10, 2024)
  - Yellow Sea (May 8, May 9)
  - Busan Port area (May 10)
  - Altitude: 3 km above sea level
- PolCube Airborne
  - Made with BusanSat/PolCube EQM
  - Single camera with polarization filter

Busan Port area



Yellow Sea

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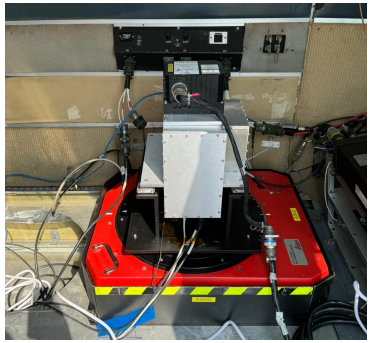

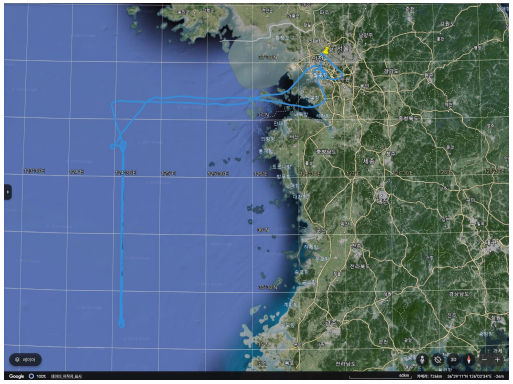

BusanSat/PolCube Impact and Path Forward

- Impact
  - BusanSat/PolCube will help **pave the way** to quantify and monitor **floating ocean plastics** using satellite data
  - BusanSat/PolCube data and algorithms directly relevant to NASA missions with a polarimeter (present PACE and future AOS)
- Path Forward
  - Launch planned for 2025 (fund-permitting)
  - 1 year of operations

Thank You and References

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