Fishing Bans in Chinese Waters: Effectiveness and Spillovers

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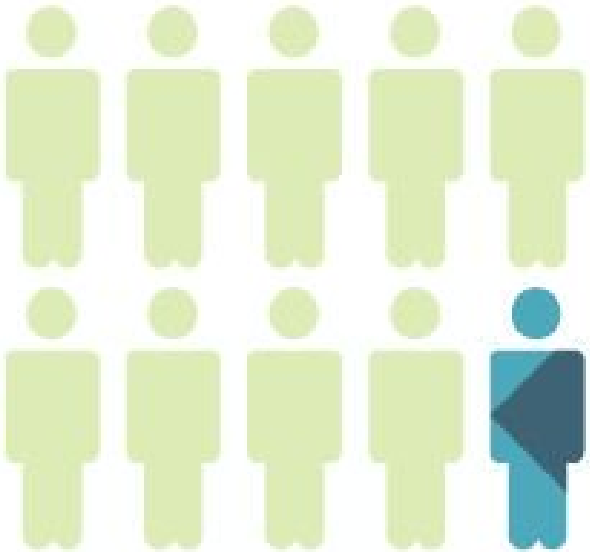
Fisheries & Aquaculture

Approximately

1 in 10

PEOPLE

rely on fisheries and aquaculture for their livelihoods.

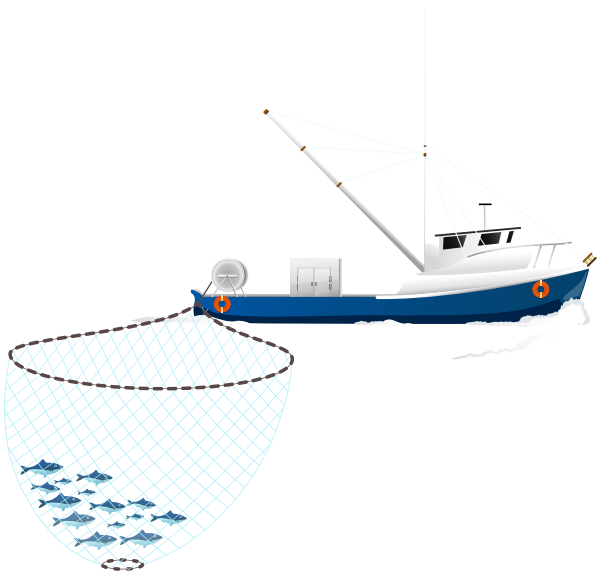


Food and Agriculture Organization of the United Nations

FISH STOCKS

71% of the commercially important marine fish stocks monitored by FAO are fished within biologically sustainable levels (2011)

10% Under-fished	61% Fully fished	29% Over-fished



Regulating Fishery:

- Large number of small-scale fishing vessels
- Vast ocean, hard to patrol
- Inter-jurisdictional spillover

In This Paper

- China's Seasonal Fishing Bans:
  - China is by far the largest country in fisheries
  - Implemented the first large-scale seasonal fishing ban
- Questions:
  - Does the fishing ban work?
  - Scope for international policy coordination?
- Empirical Challenges:
  - Measurement
  - Causal Identification

How?

- Main Data: Remote Sensing Imageries
  - Boat detections at night
  - Near global coverage
  - High frequency: nightly
- Empirical Approaches:
  - RD in Time
  - Spatial RD in Density
  - Diff-in-diff
- Other Data:
  - Global Fishing Watch: Data derived from AIS signals
  - NASA Ocean color: oceanographic conditions

Related Literature

- Remote sensing data
  - Chen & Nordhaus (2011); Henderson, Storeygard, and Weil (2012); Hodler & Raschky (2014); Donaldson & Soreygard (2013); Axbard (2016); Marx, Stoker, and Suri (2017); Burgess, Costa, and Olken (2017); etc.
- Fisheries & Piracy
  - Besley, Fetzer, and Mueller (2015); Flückiger & Ludwig (2015); Axbard (2016); Kroodsma et al. (2018)
- My contributions:
  - Use novel data from the new generation weather satellite program to look at China's seasonal fishing ban: effectiveness & spillovers

Main Results

- Effectiveness:
  - 72% reduction in boat detections within China's EEZ during bans
  - Sharp increase post-ban
  - Compliance weakens over time
  - Areas with favorable fishing conditions show higher non-compliance
- Spillovers:
  - Decline in boat detections in neighboring EEZs during China's bans
  - Evidence of Chinese boats operating abroad and foreign boats in China's EEZ

Exclusive Economic Zone (EEZ)

- 200 nautical mile (≈ 370 km) from baseline
- A coastal state has sovereign rights below the surface of the sea, including marine resources.
- GIS Data of EEZ boundaries:
  - MarineRegions.org
  - World EEZ v8
- Disputed areas are excluded in this study.

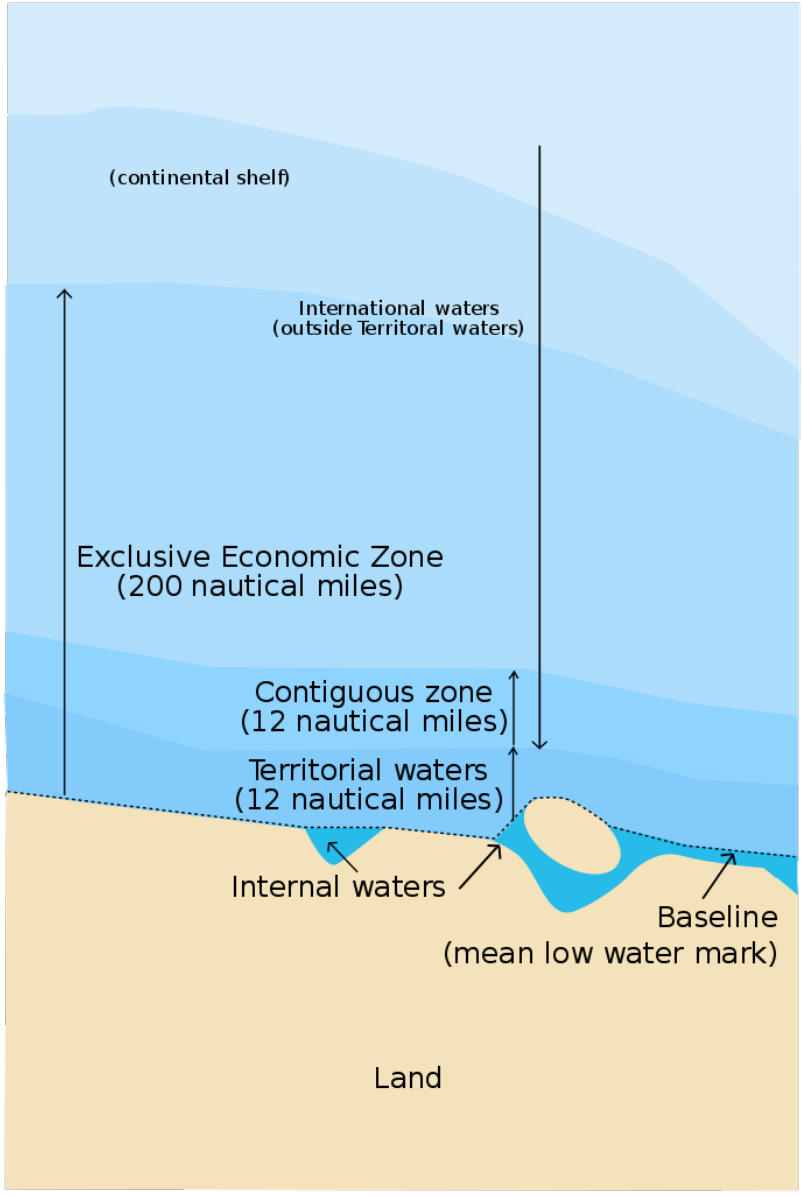
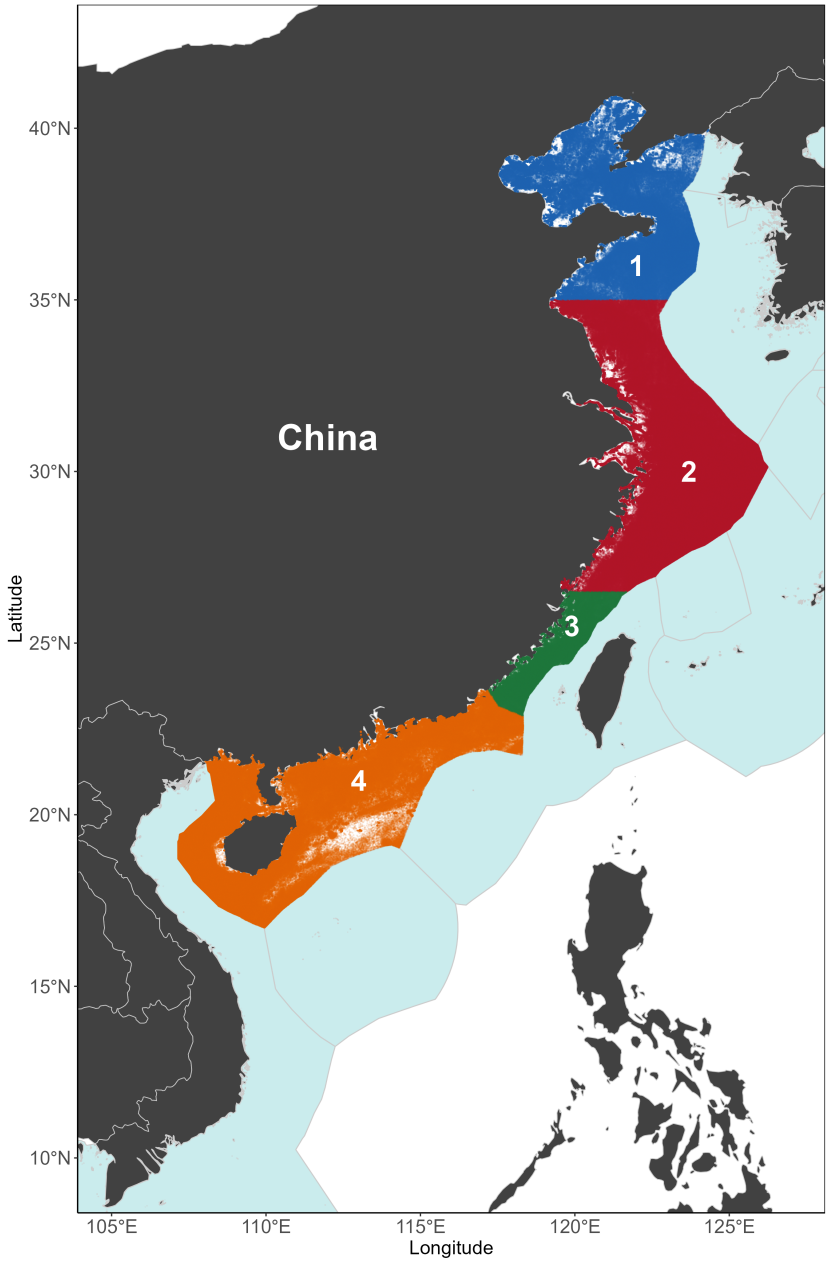


Figure: MJSmith (Wikipedia)


Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth
Imagery Date: 12/14/2015 22°16'13.55" N 128°42'11.86" E elev -5139 m eye alt 7259.72 km

Zones of Fishing Ban



Duration of Fishing Bans

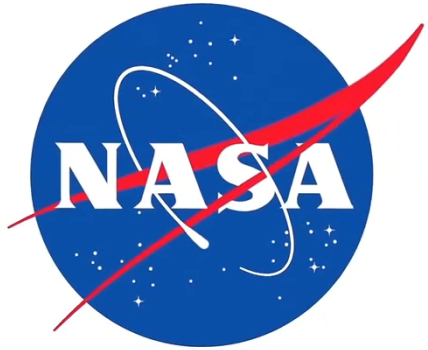
#	Zone Description	2009 – 2016		2017 – 2018	
		Start	End	Start	End
1	Northern Yellow Sea	June 1	Sep. 1	May 1	Sep. 1
2	Southern Yellow Sea & Northen East China Sea	June 1	Sep. 16	May 1	Sep. 16
3	Southern East China Sea	May 16	Aug. 1	May 1	Aug. 16
4	Taiwan Strait & South China Sea	May 16 May 16	Aug. 1 Aug. 1	May 1 May 1	Aug. 16 Aug. 16

Number of Seafaring Fishing Vessels by Size

	Number		Tonnage	
Less than 12 meter	186,781	68.6%	882,361	10.0%
12 meter to 24 meter	49,697	18.2%	1,919,347	21.8%
24 meter or longer	35,844	13.2%	5,989,801	68.1%
Total	272,322	100%	13.838,949	100%

Suomi National Polar-Orbiting Partnership Satellite

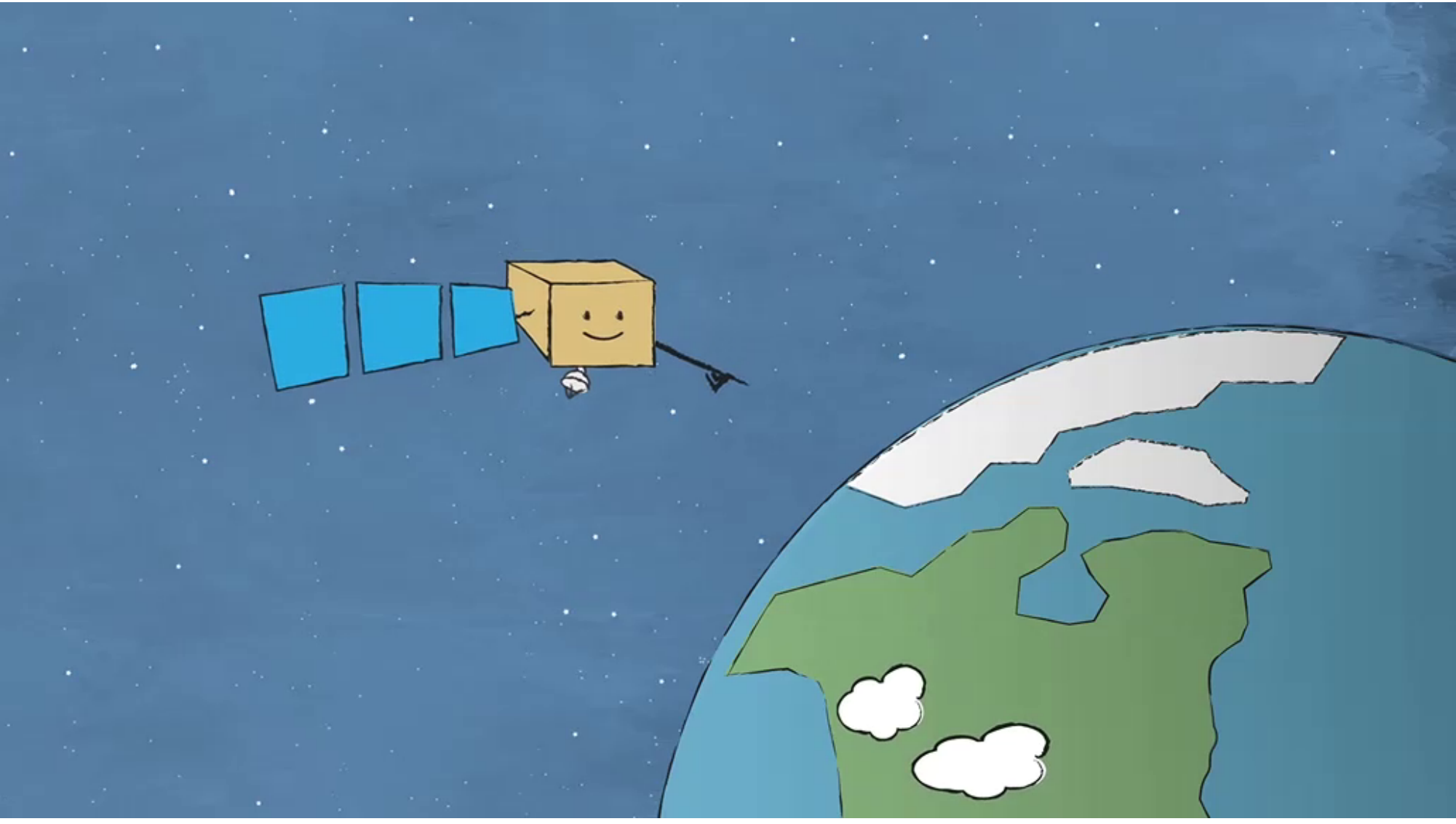
- New generation weather satellite launched on October 28, 2011
- Polar-Orbiting
- Better sensors: VIIRS



National Oceanic and Atmospheric Administration

U.S. Department of Commerce

Suomi National Polar-Orbiting Partnership Satellite



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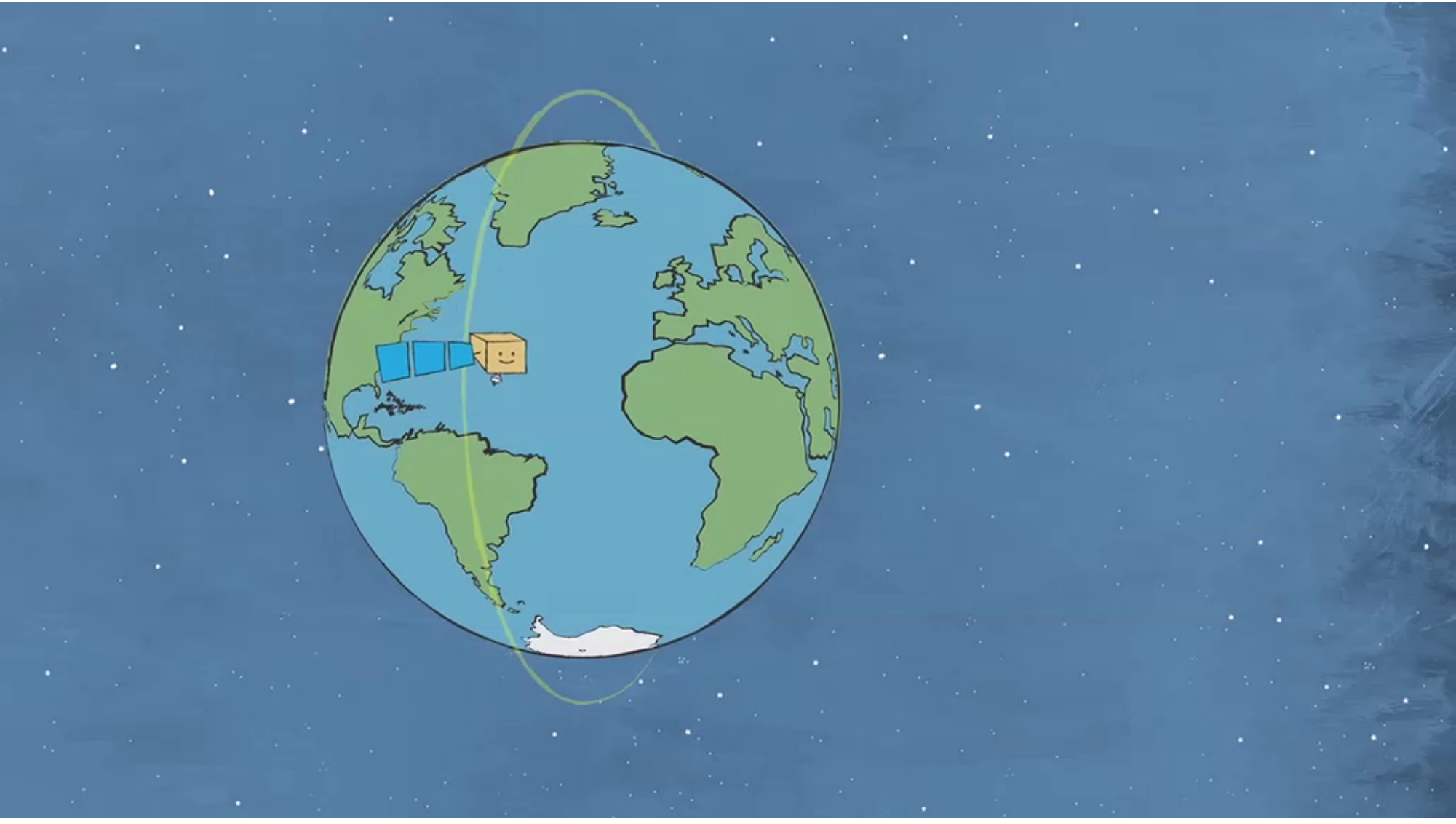

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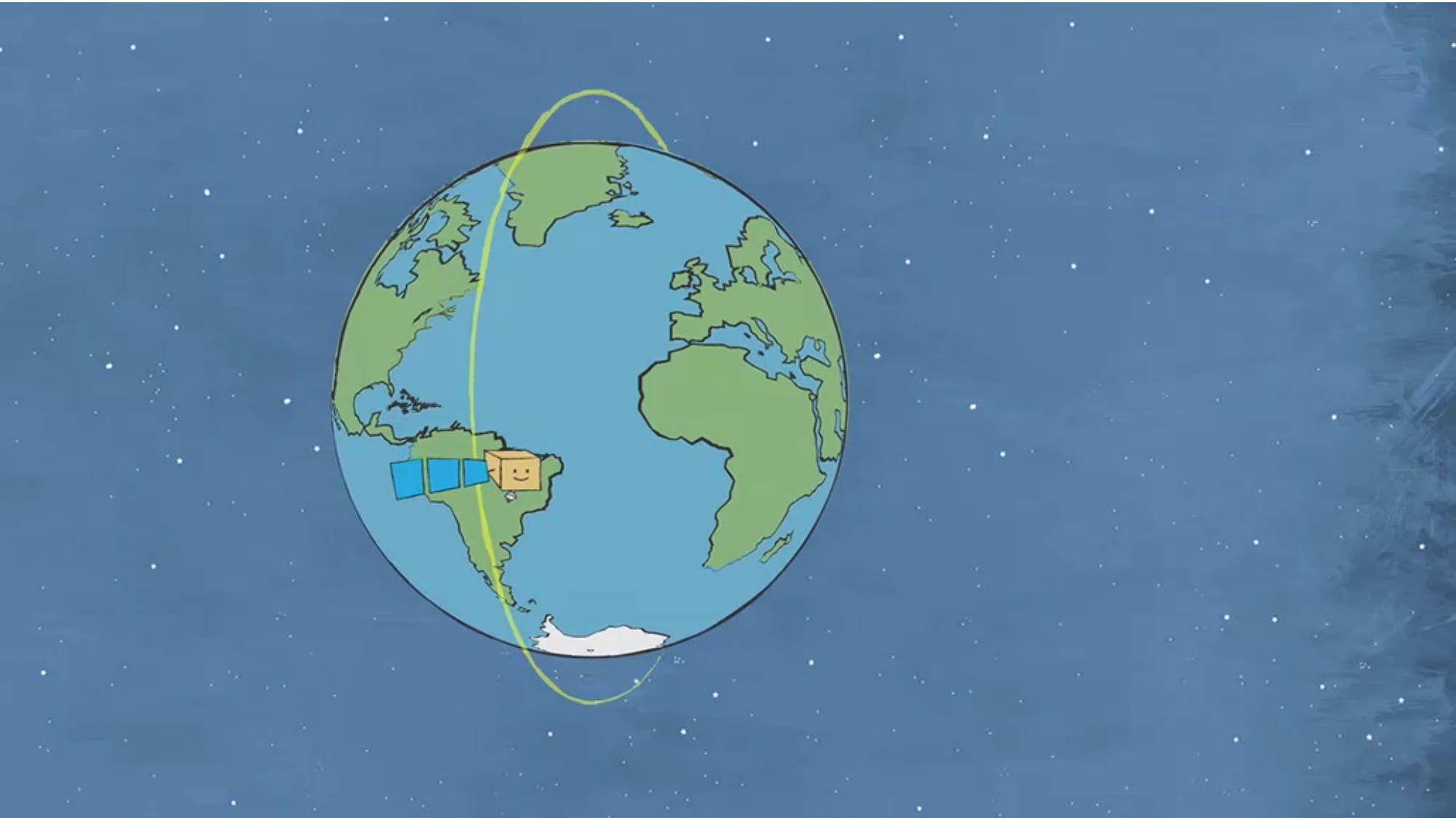

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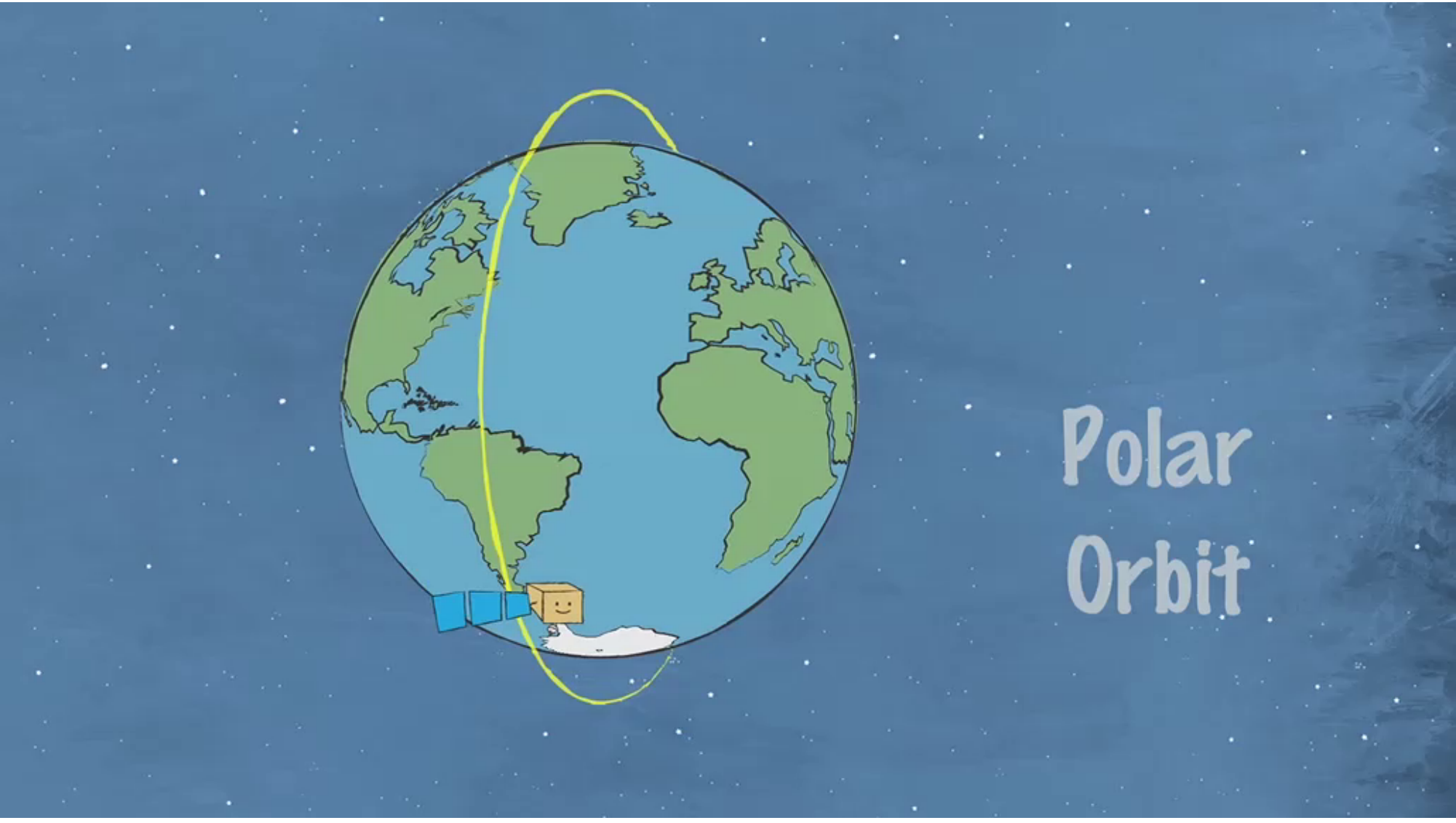

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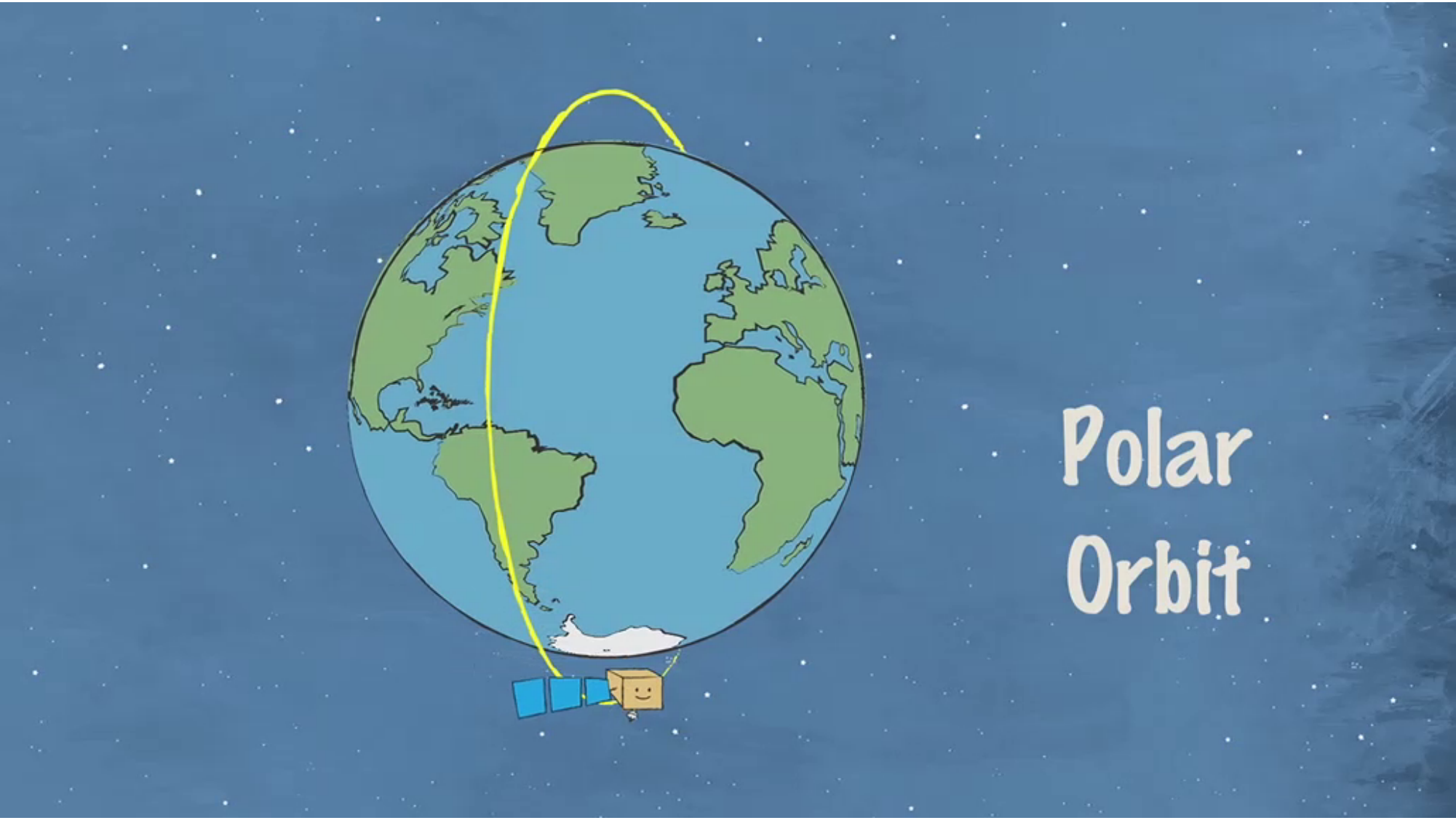

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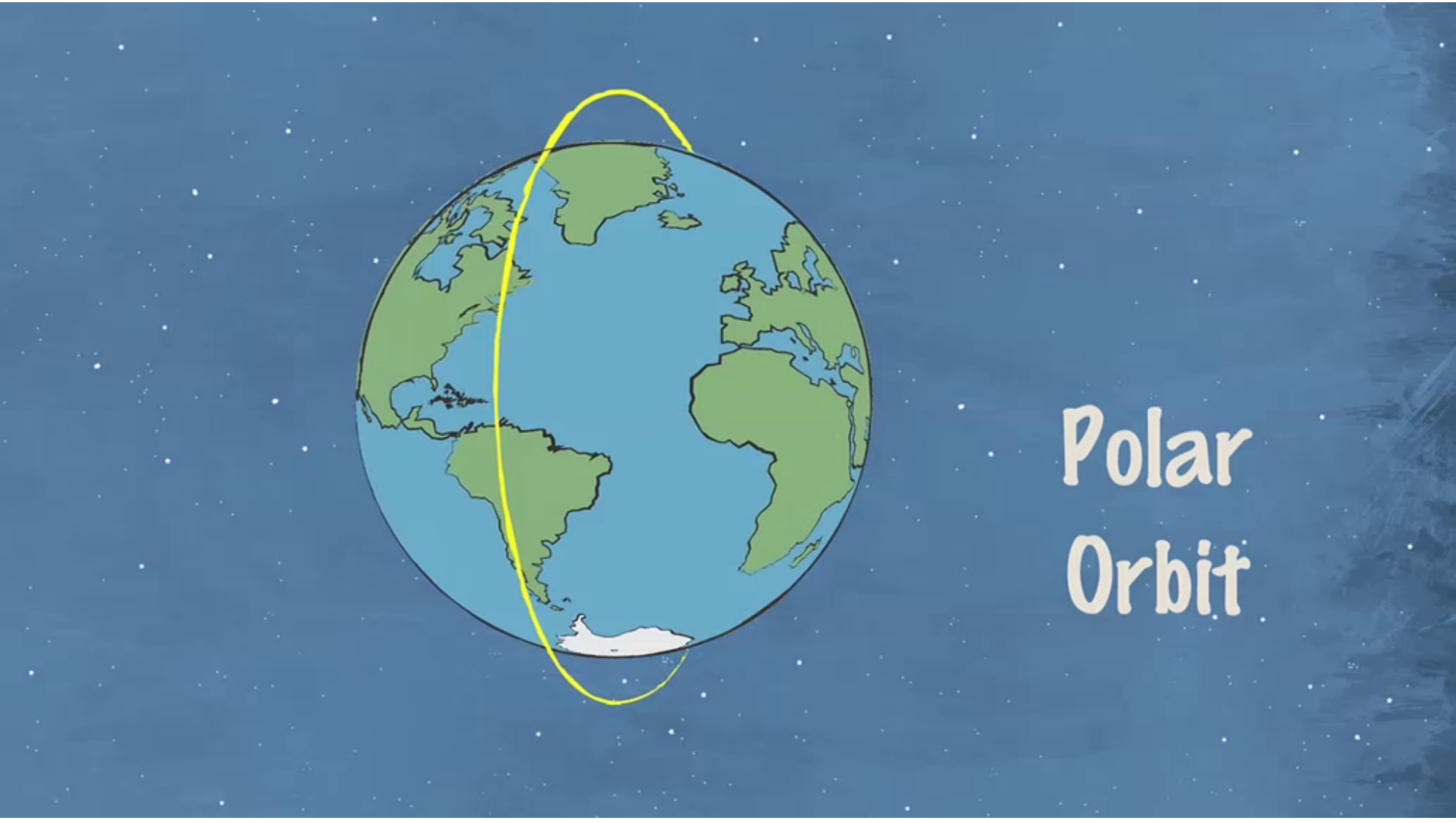

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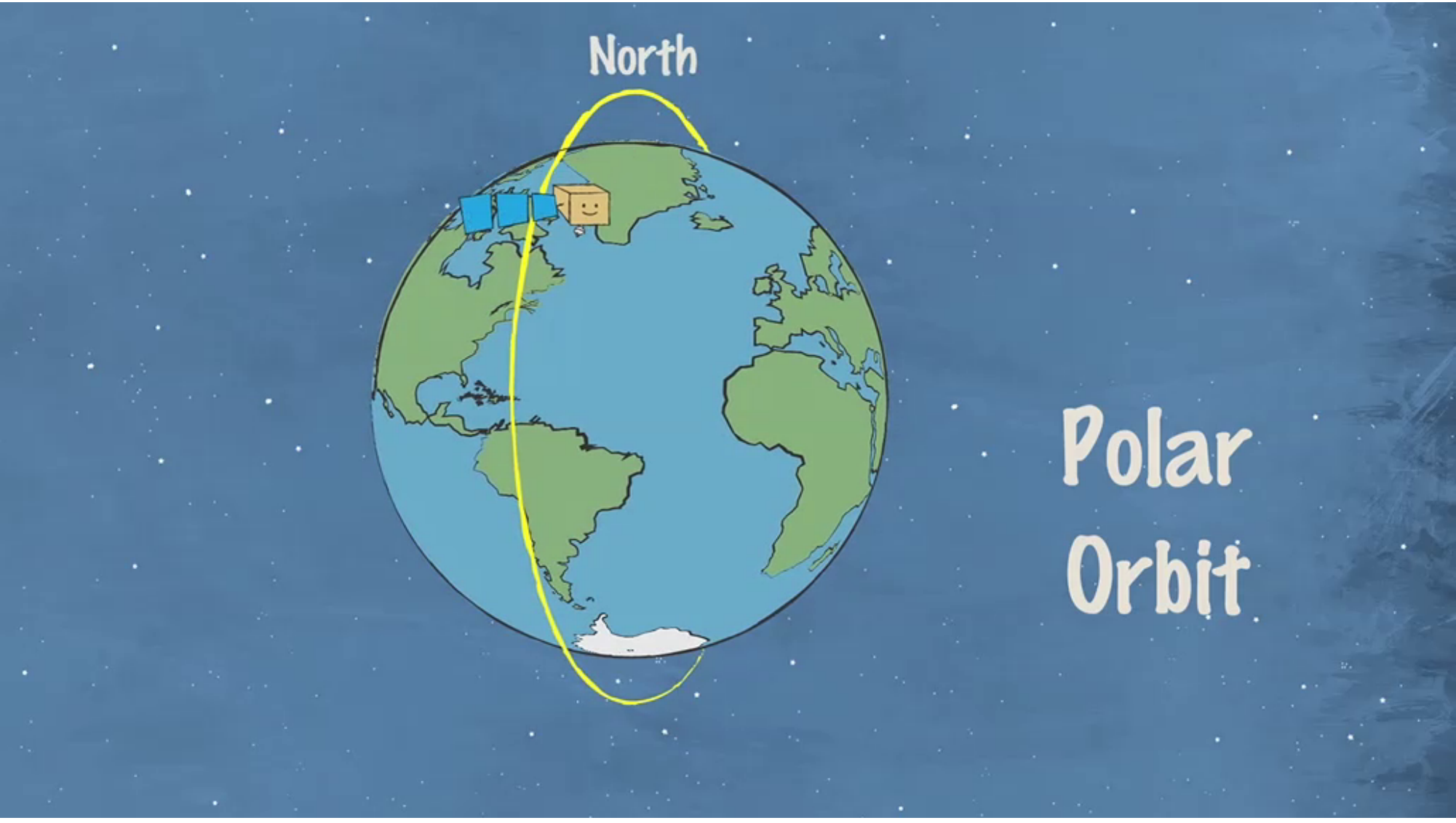

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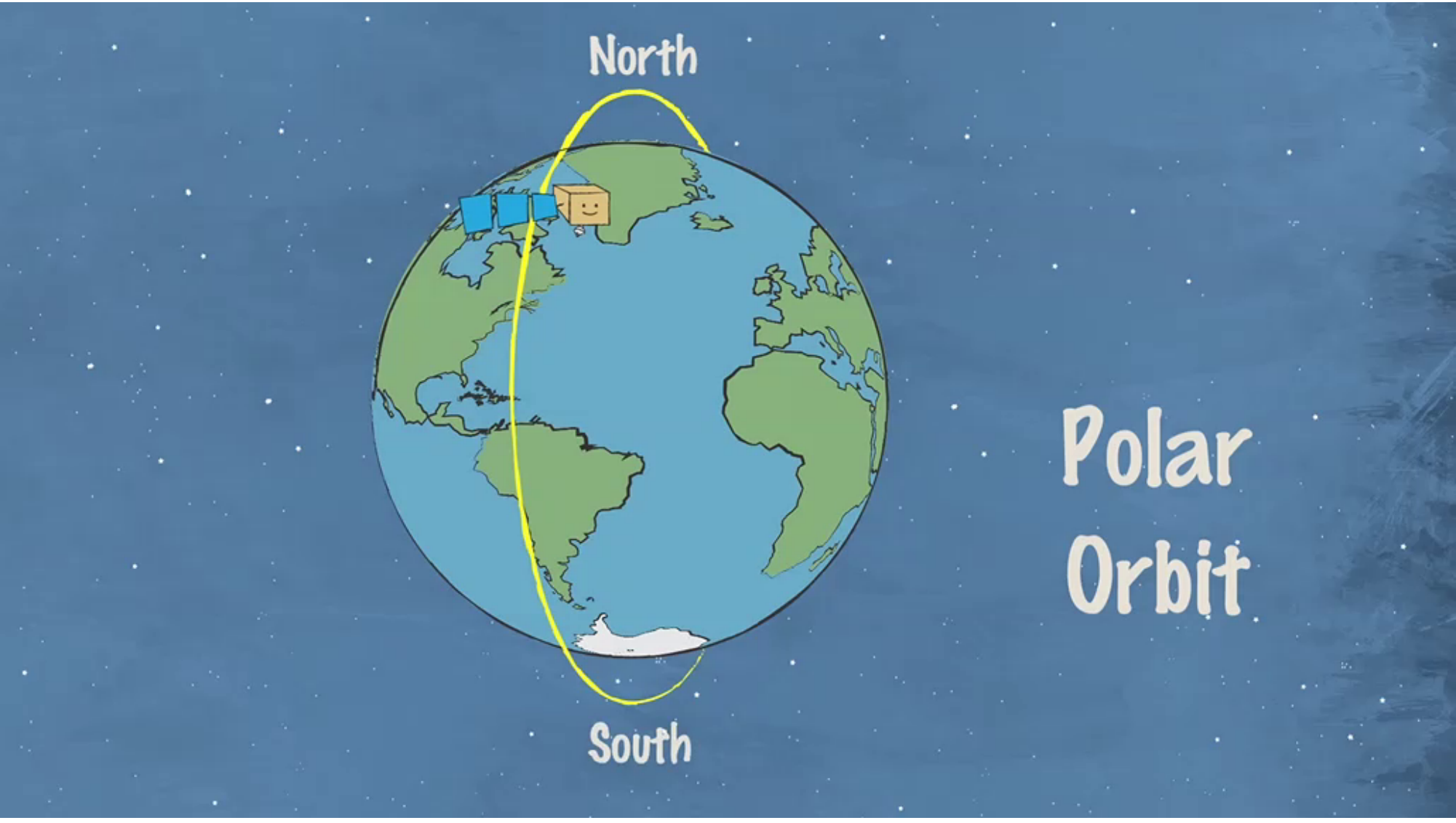

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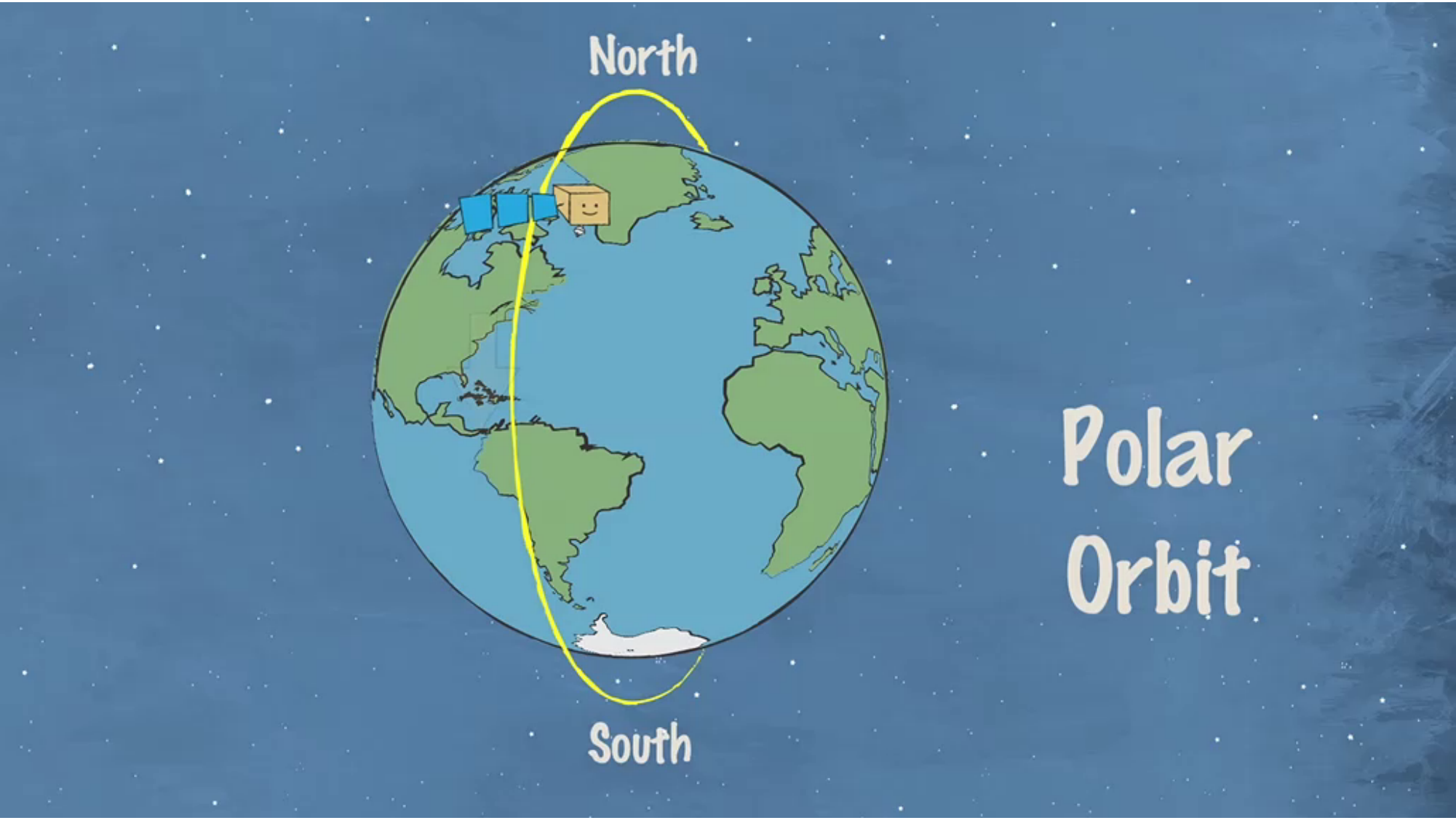

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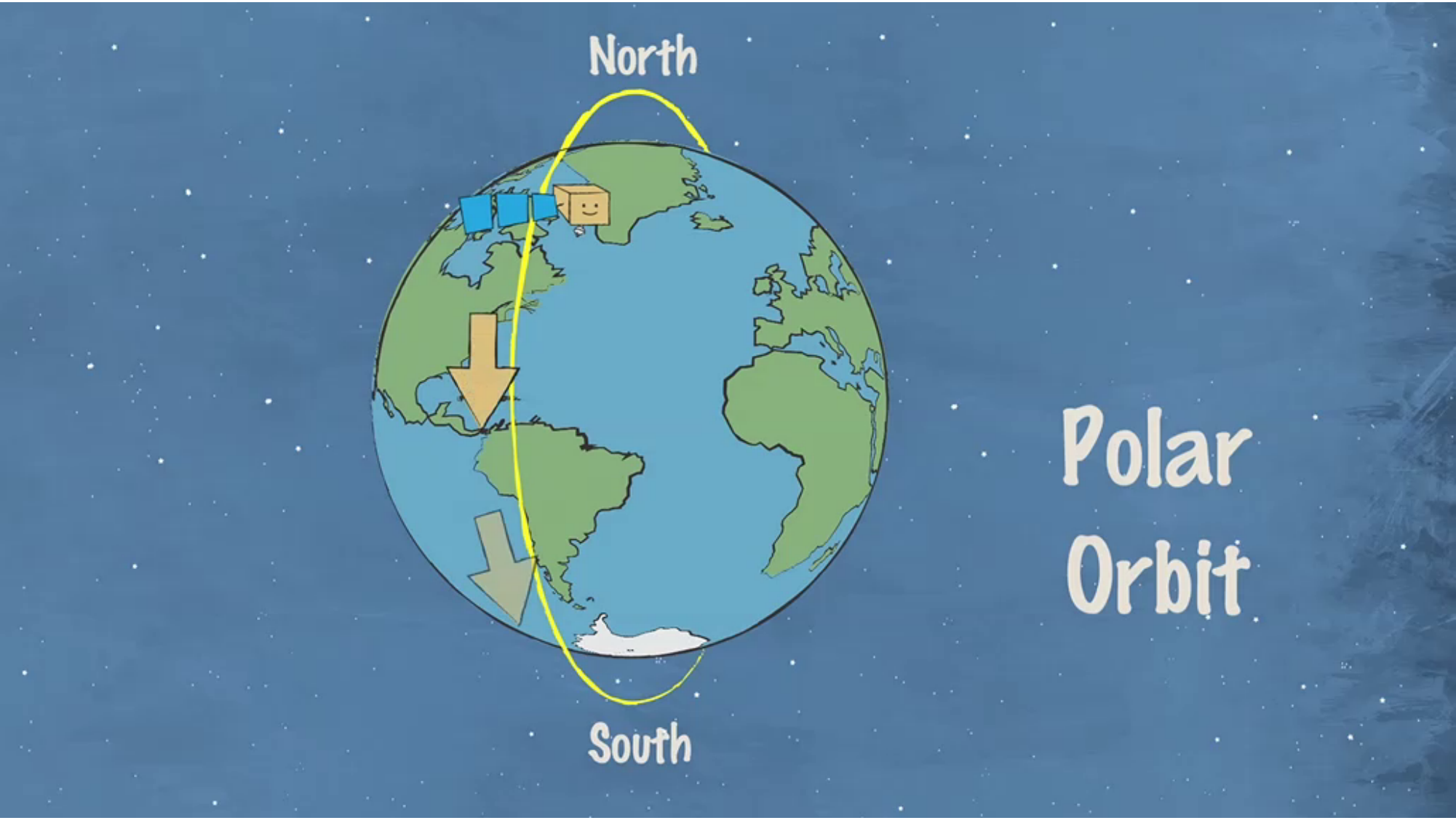

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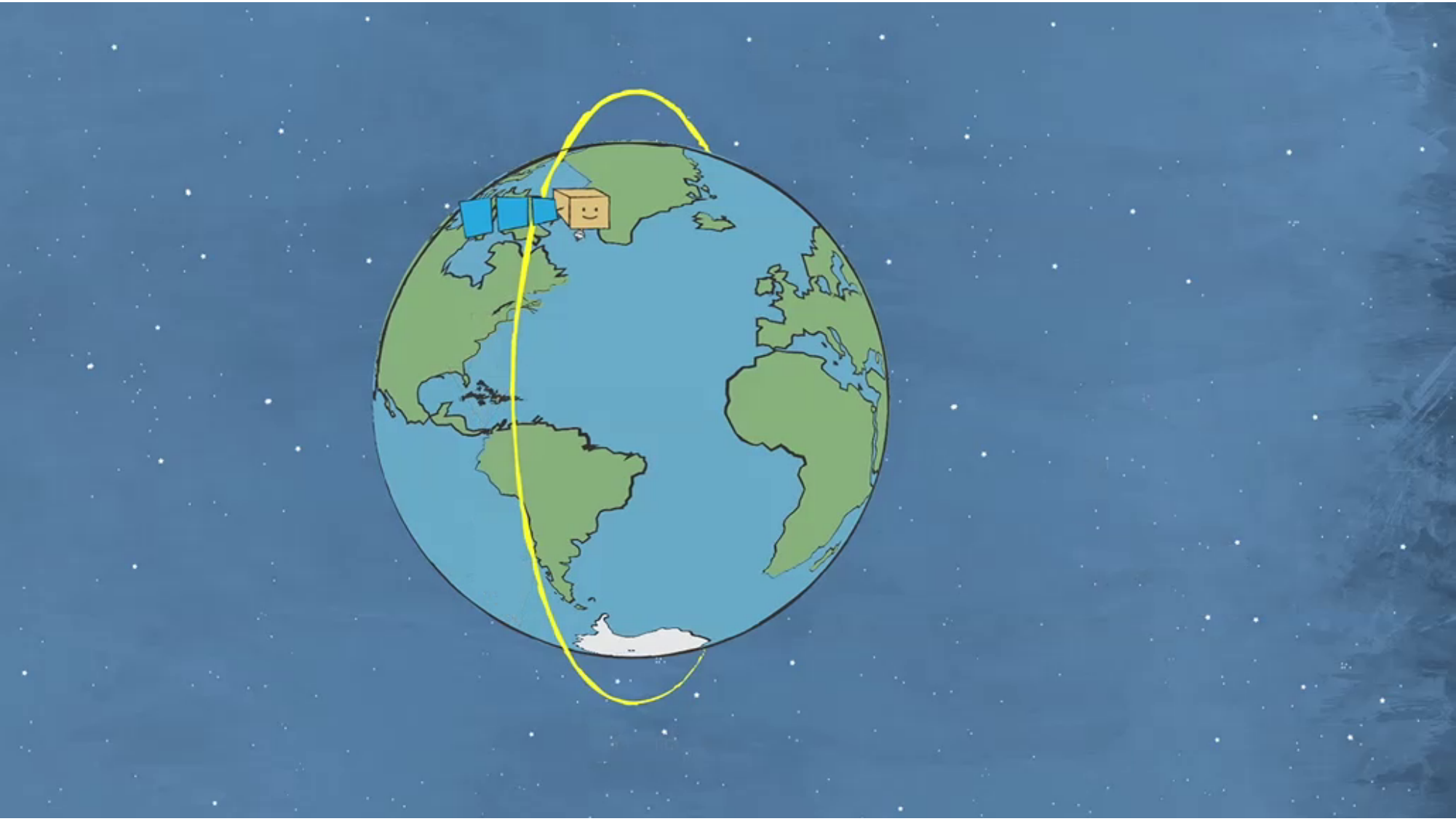

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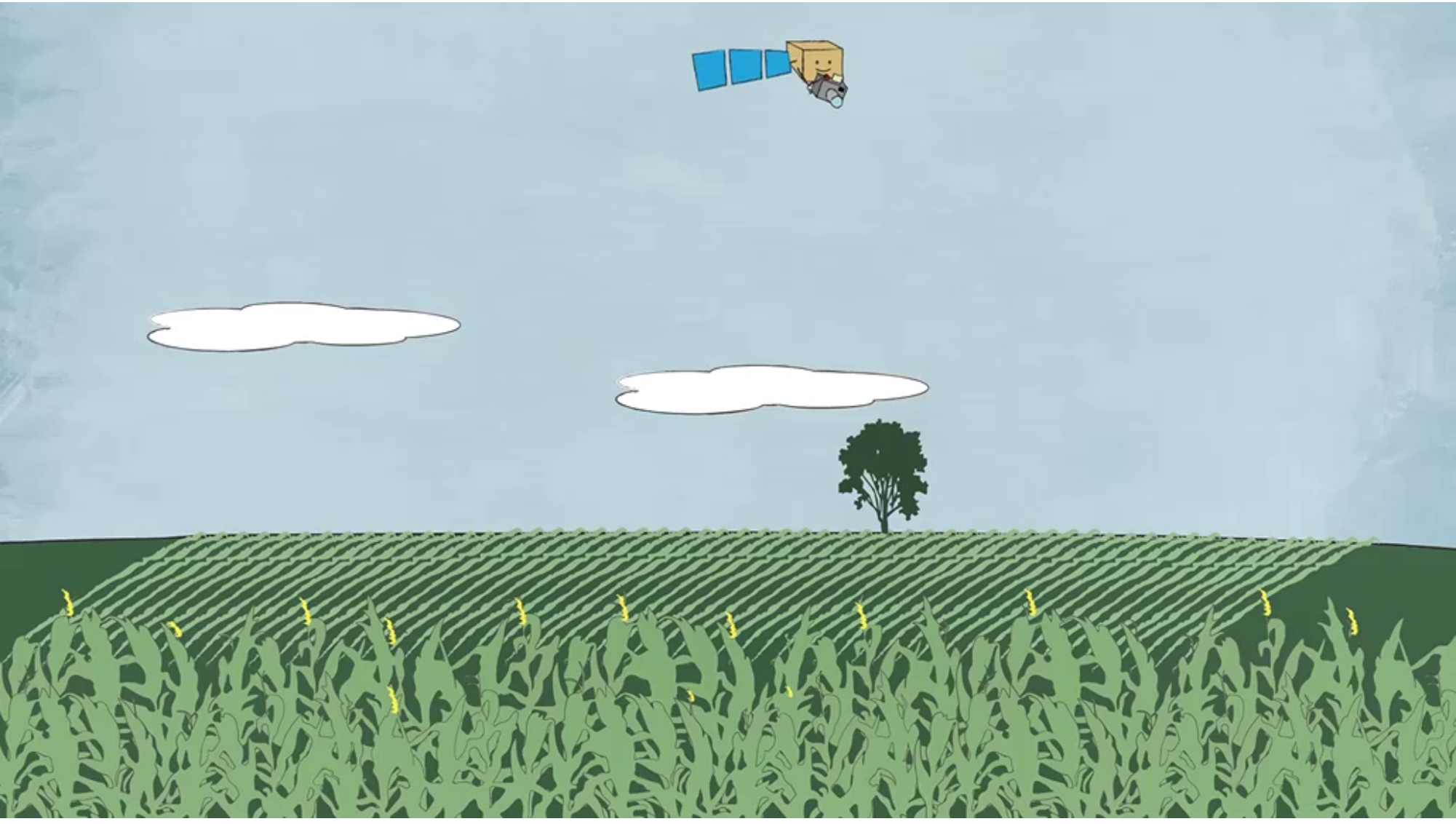

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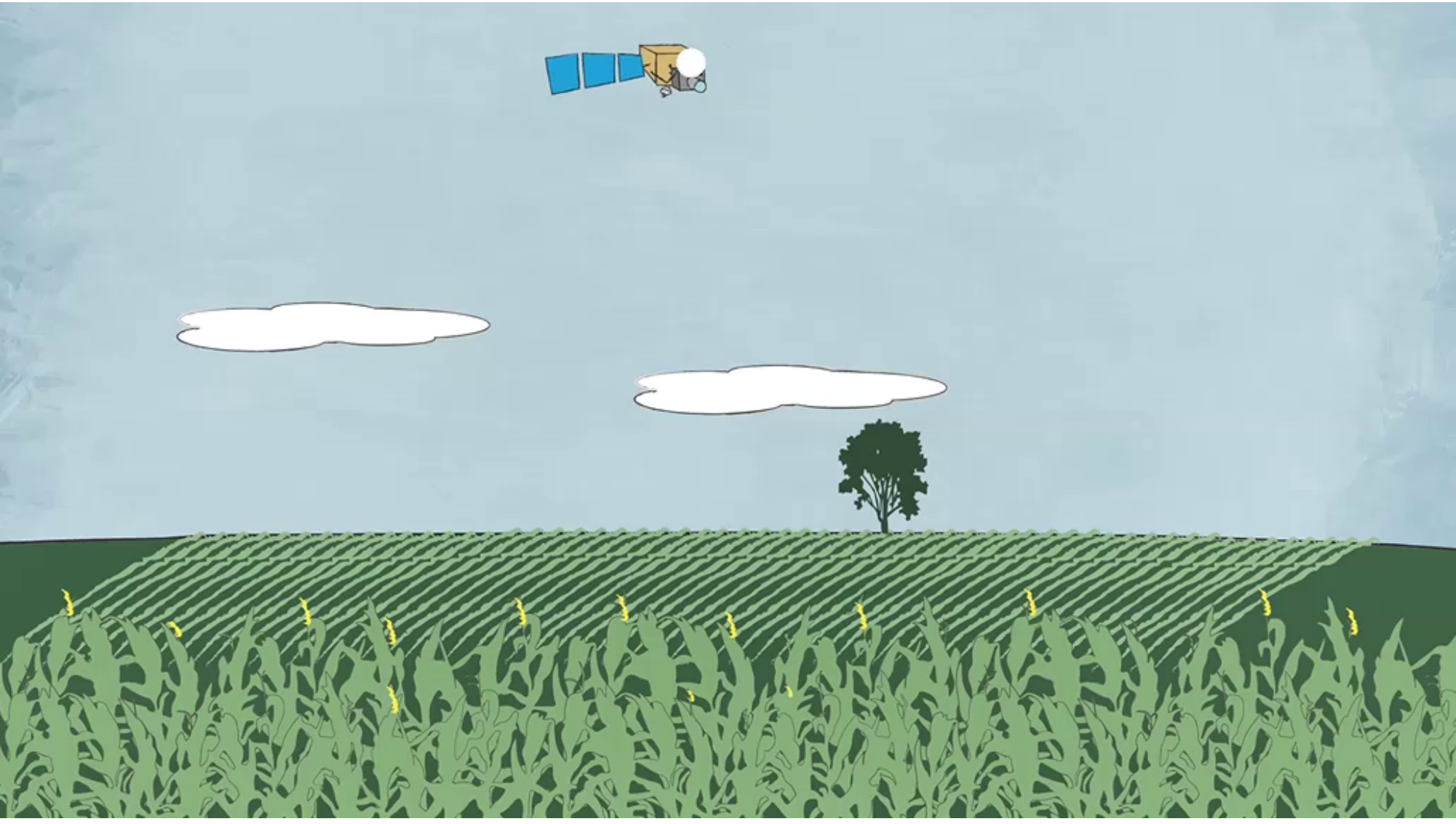

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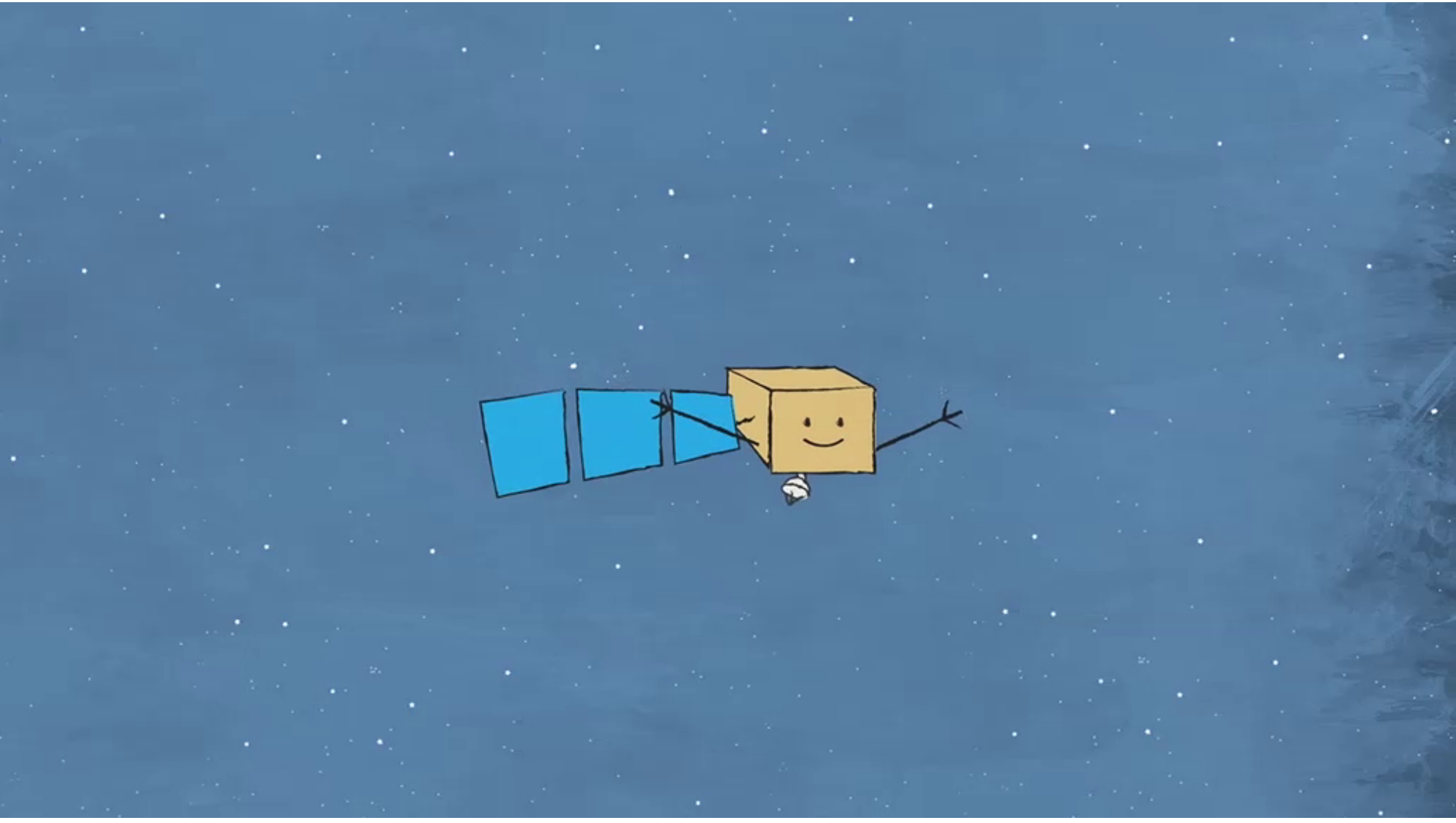

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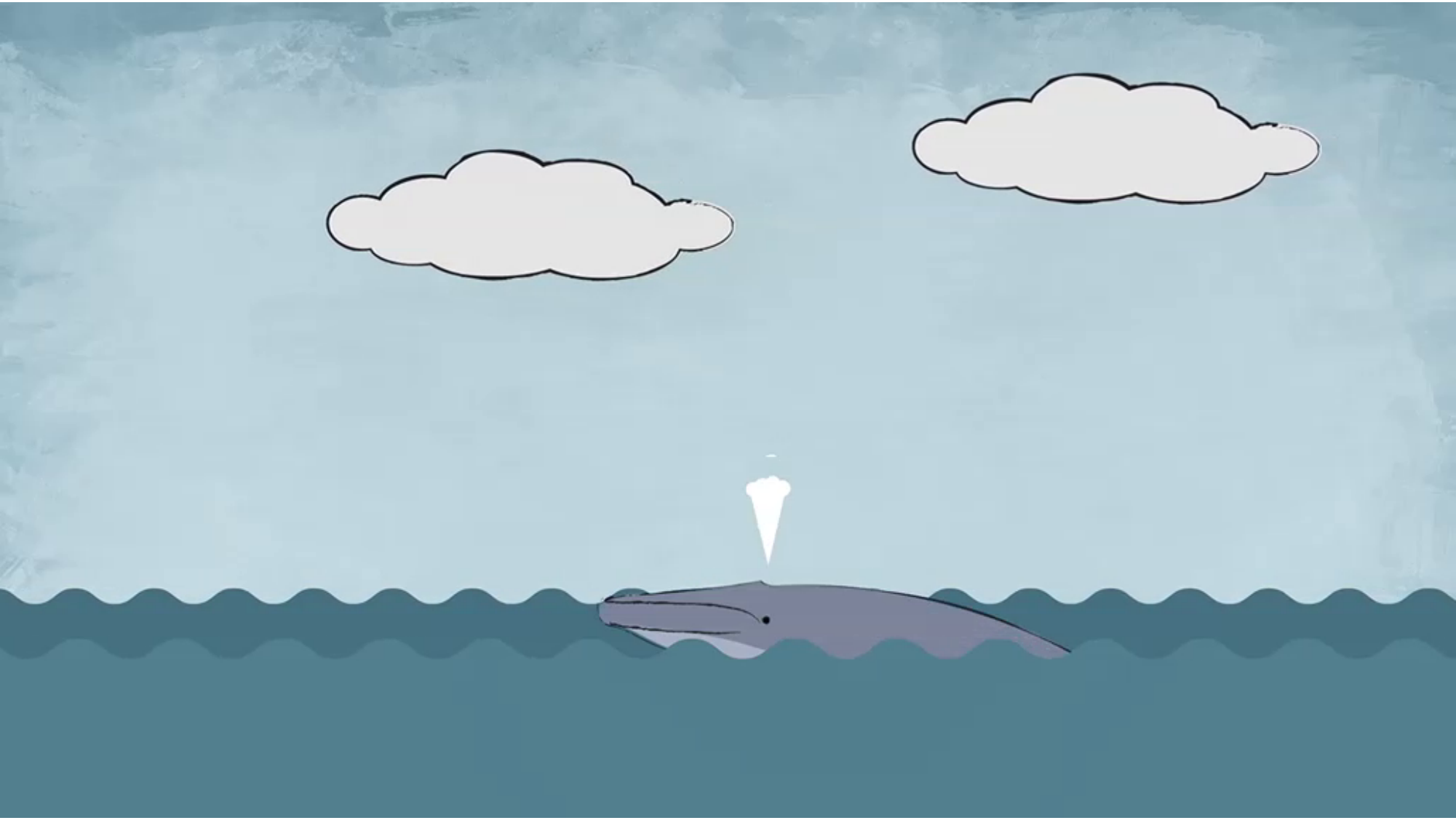


Defense Meteorological Satellite Program (DMSP)

Operational Linescan System (OLS)

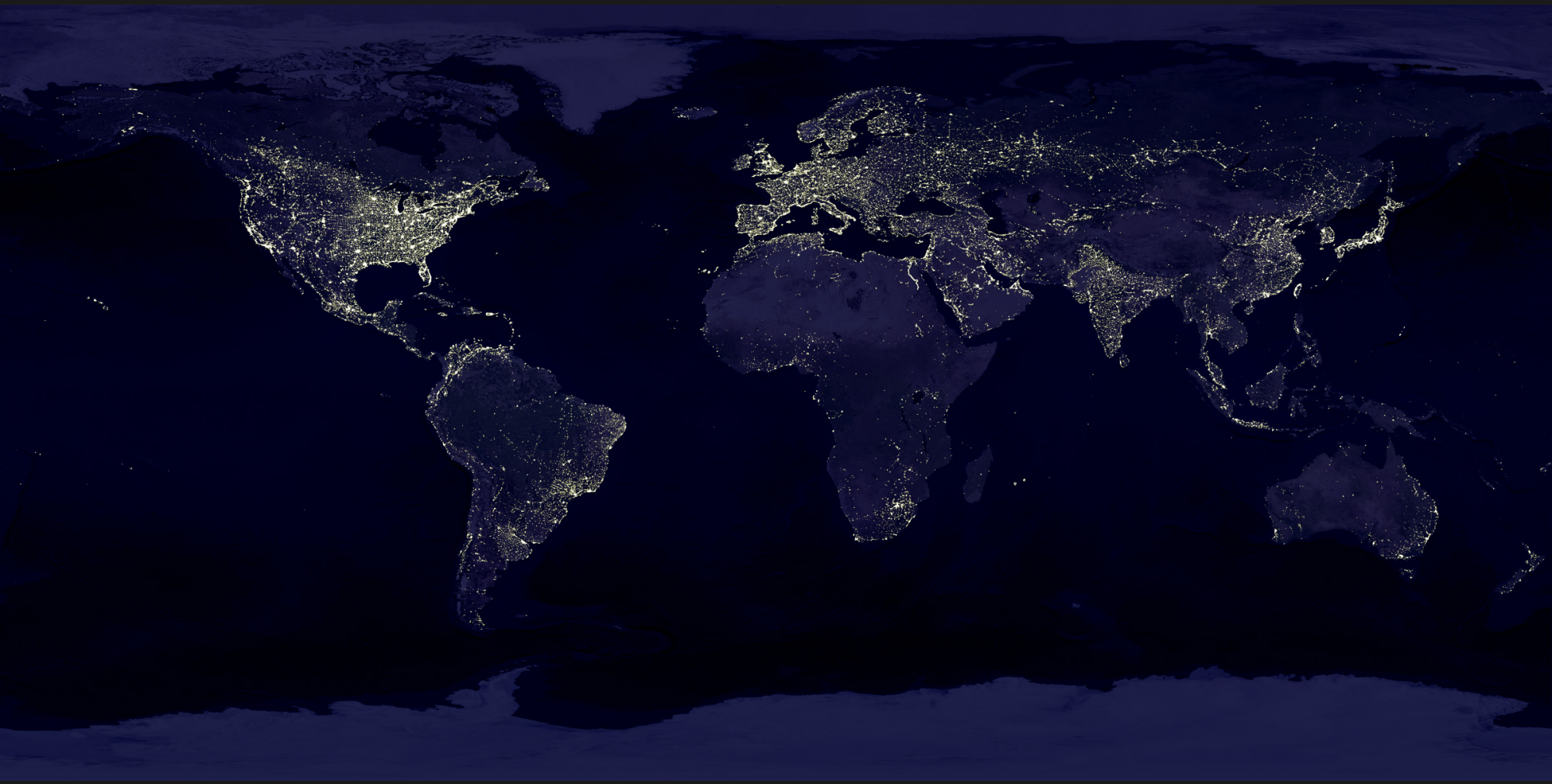


Photo Source: NASA

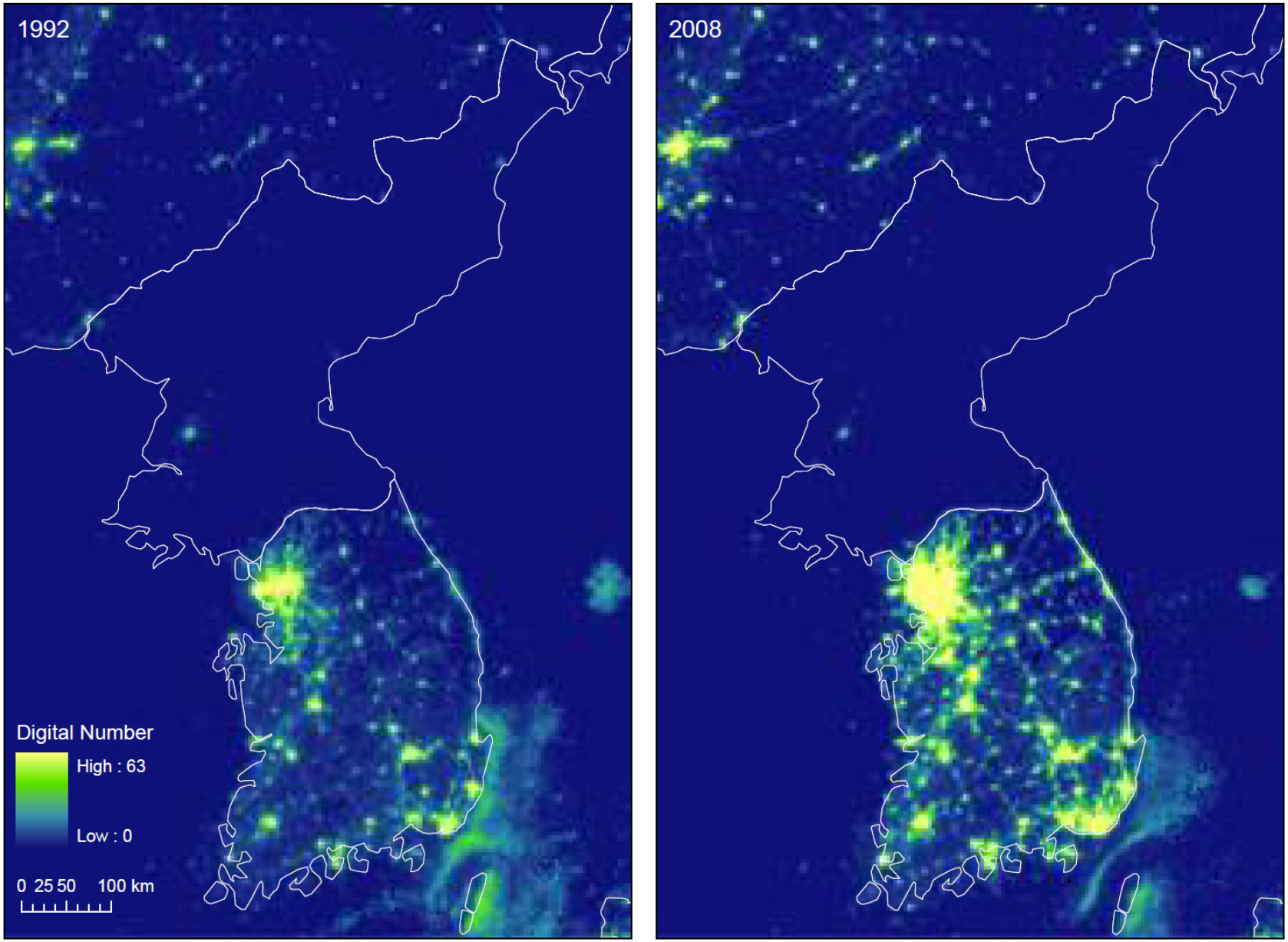


FIGURE 2. LONG-TERM GROWTH: KOREAN PENINSULA

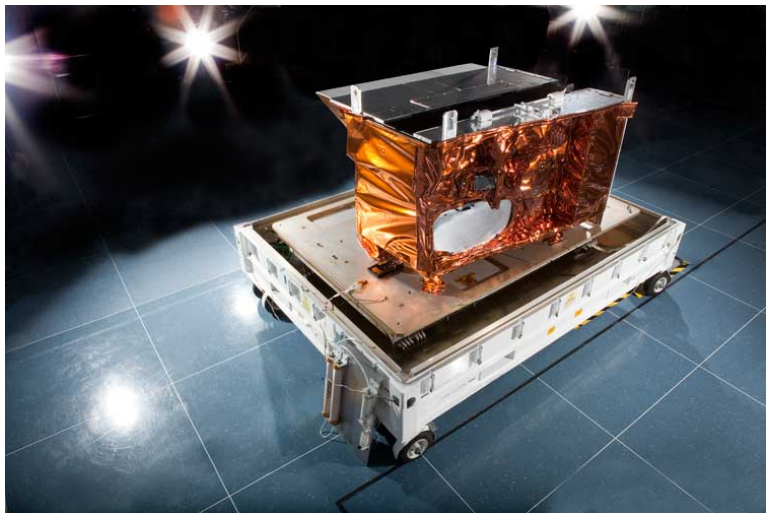
Henderson, Storeygard, and Weil (2012)

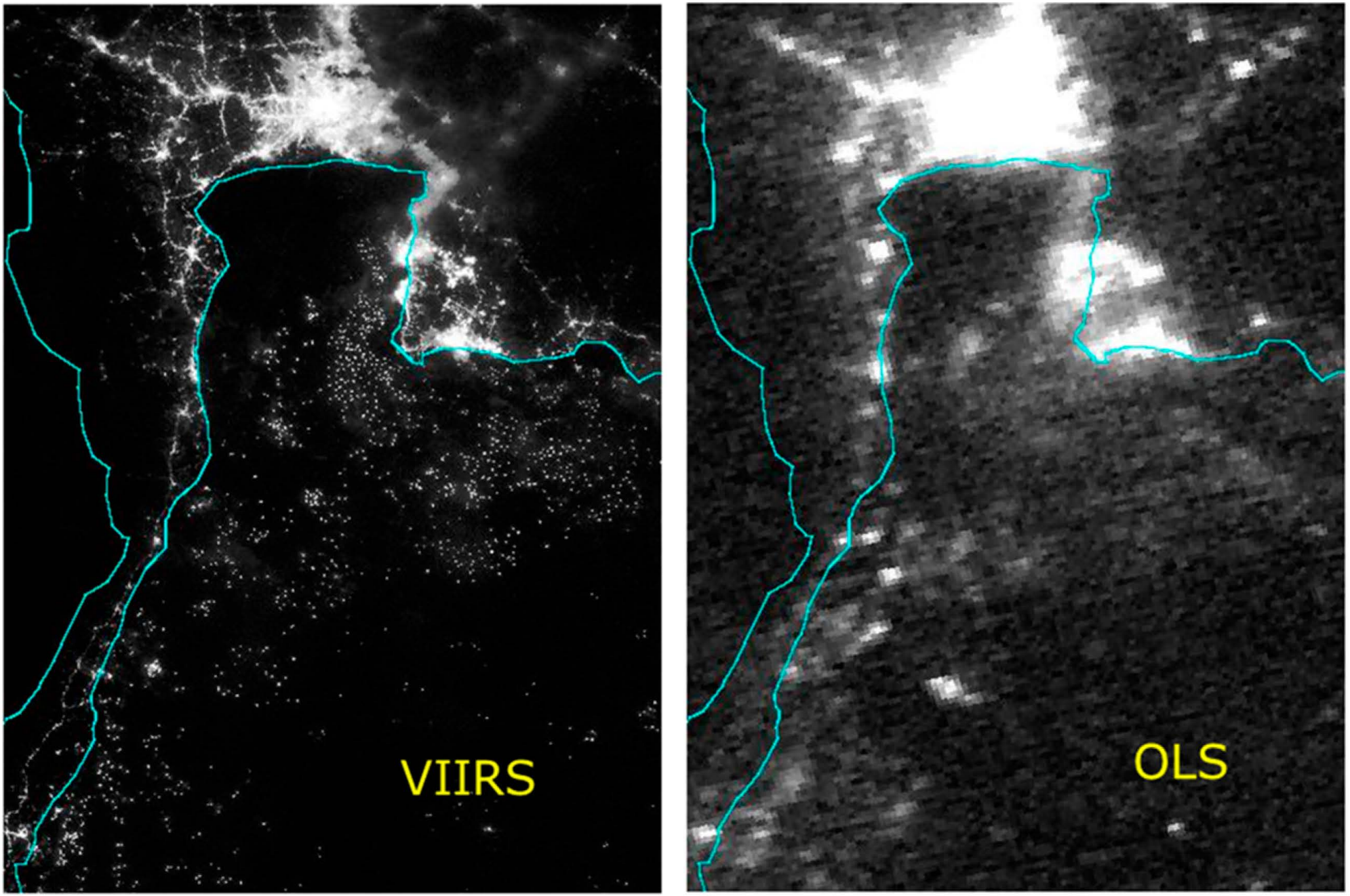
Suomi NPP Satellite - VIIRS

VIIRS Day/Night Band

- 742m footprint: 45 times smaller than DMSP-OLS
- Lower detection limits: dimmer lighting detectable
- Multispectral, dynamic range, in-flight calibration, better quantization, etc.

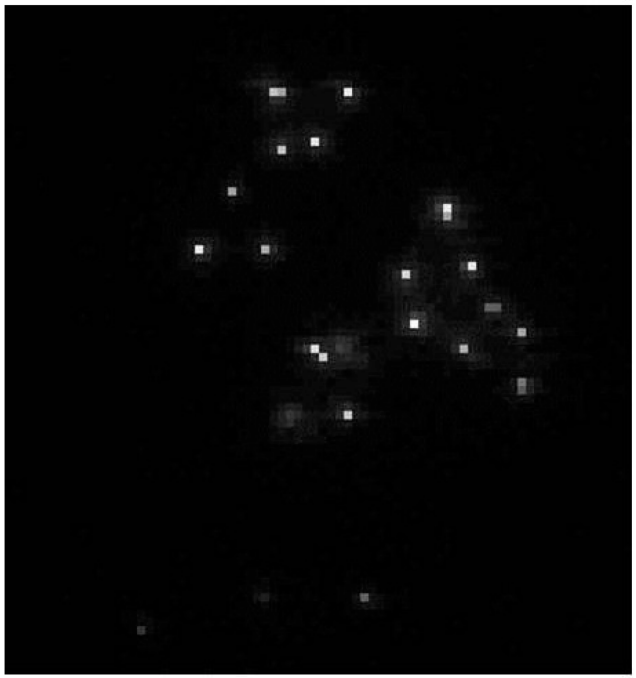
Visible Infrared Imaging Radiometer Suite (VIIRS)

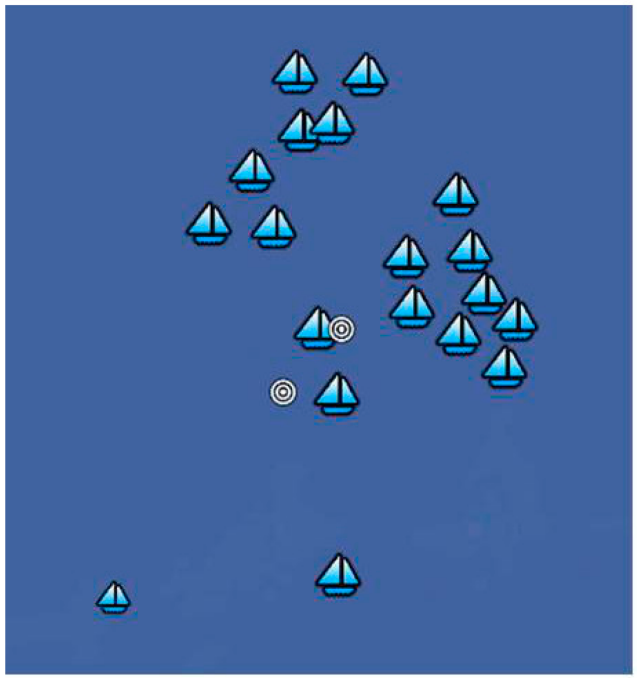


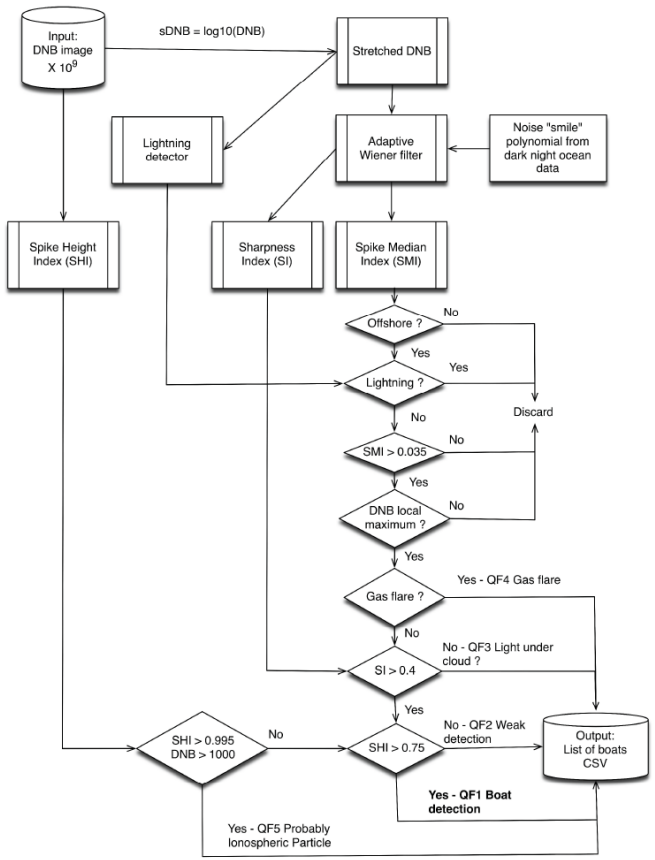


Elvidge et al., (2015)

Automatic Boat Identification System



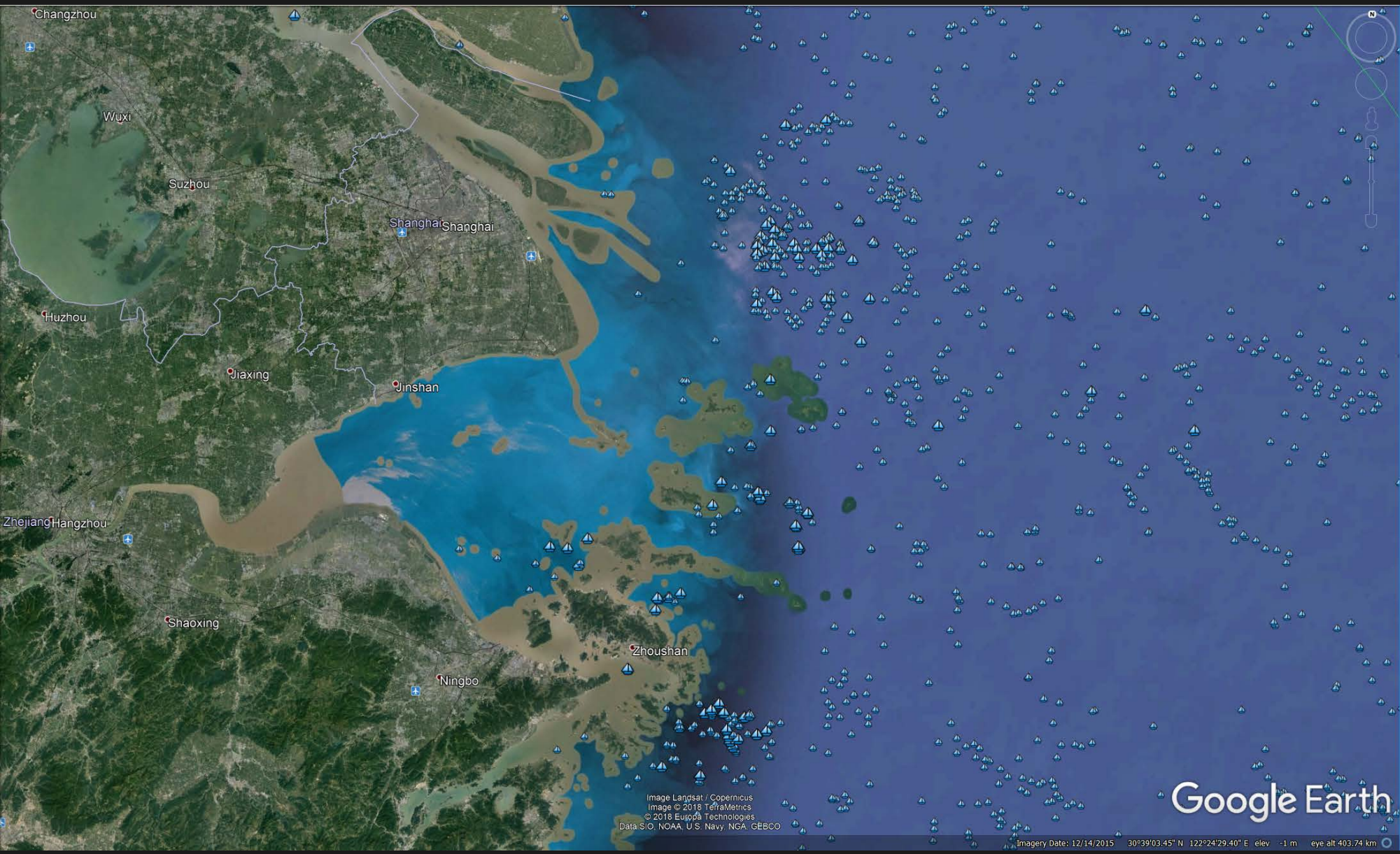




Elvidge et al., (2015) at *Remote Sensing*

Exclusive Economic Zones

Melbourne on May 31, 2018



Shanghai on April 15, 2018

Shanghai on May 15, 2018

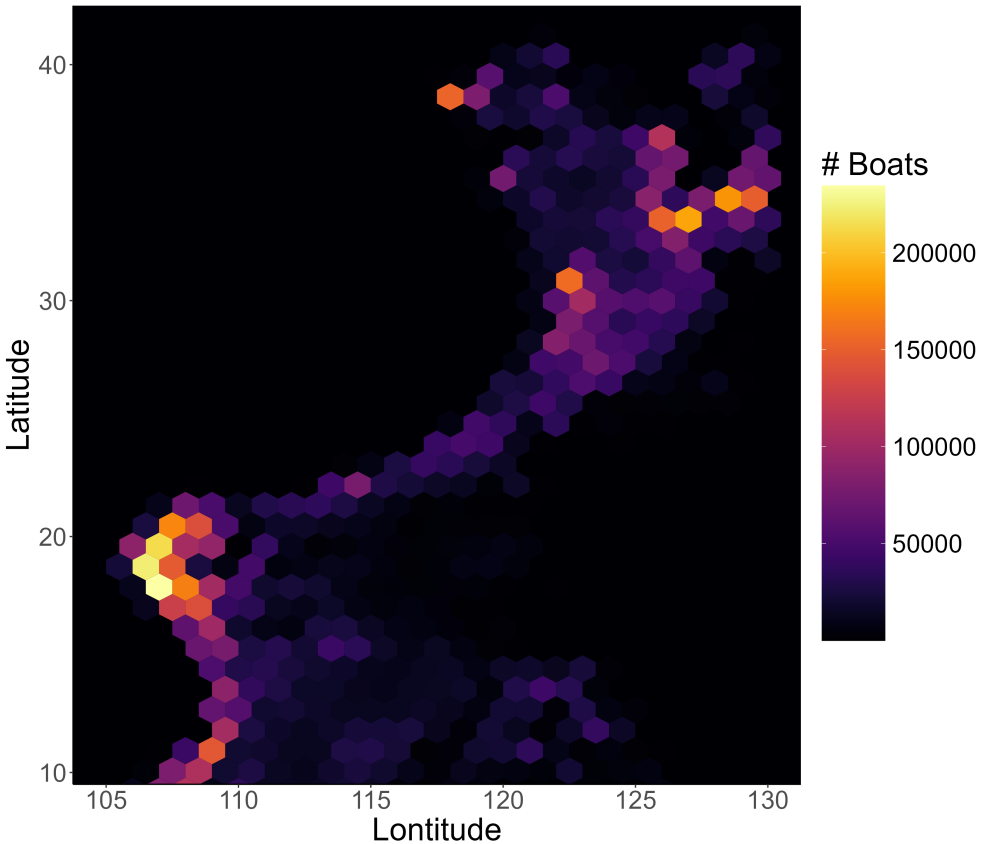
Fishing Vessels at Sanya Harbor during Ban Period in 2016

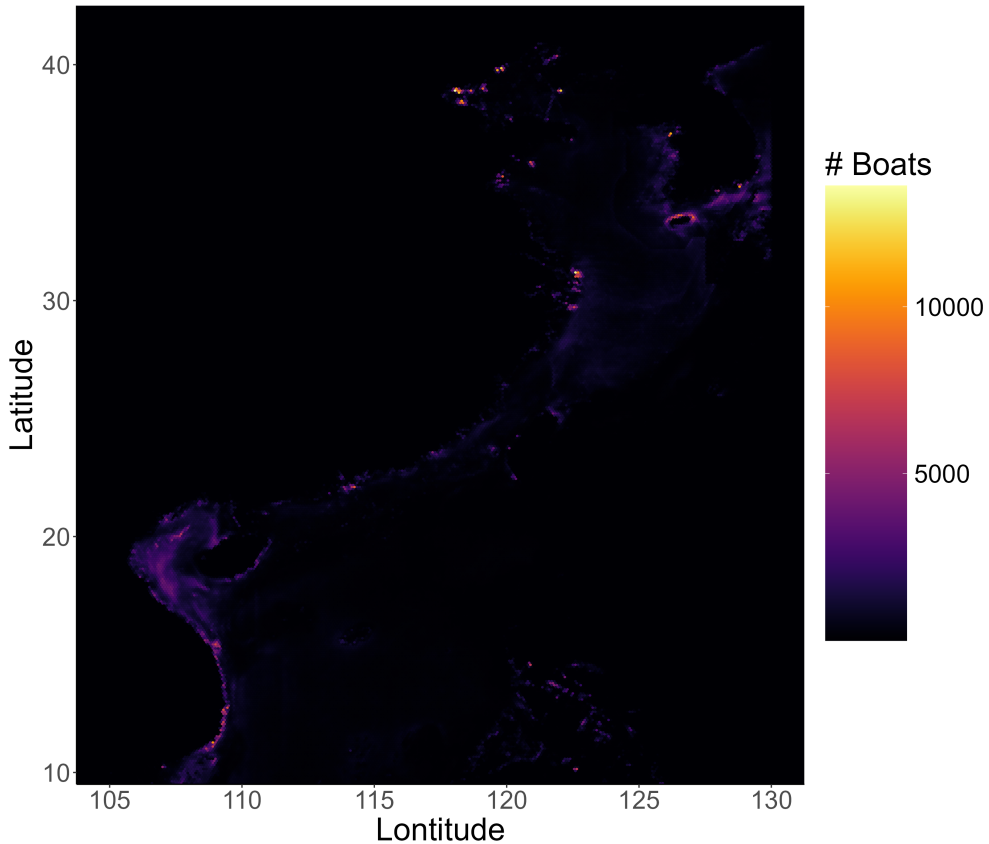
Photo: National Geographic

Boat Detection

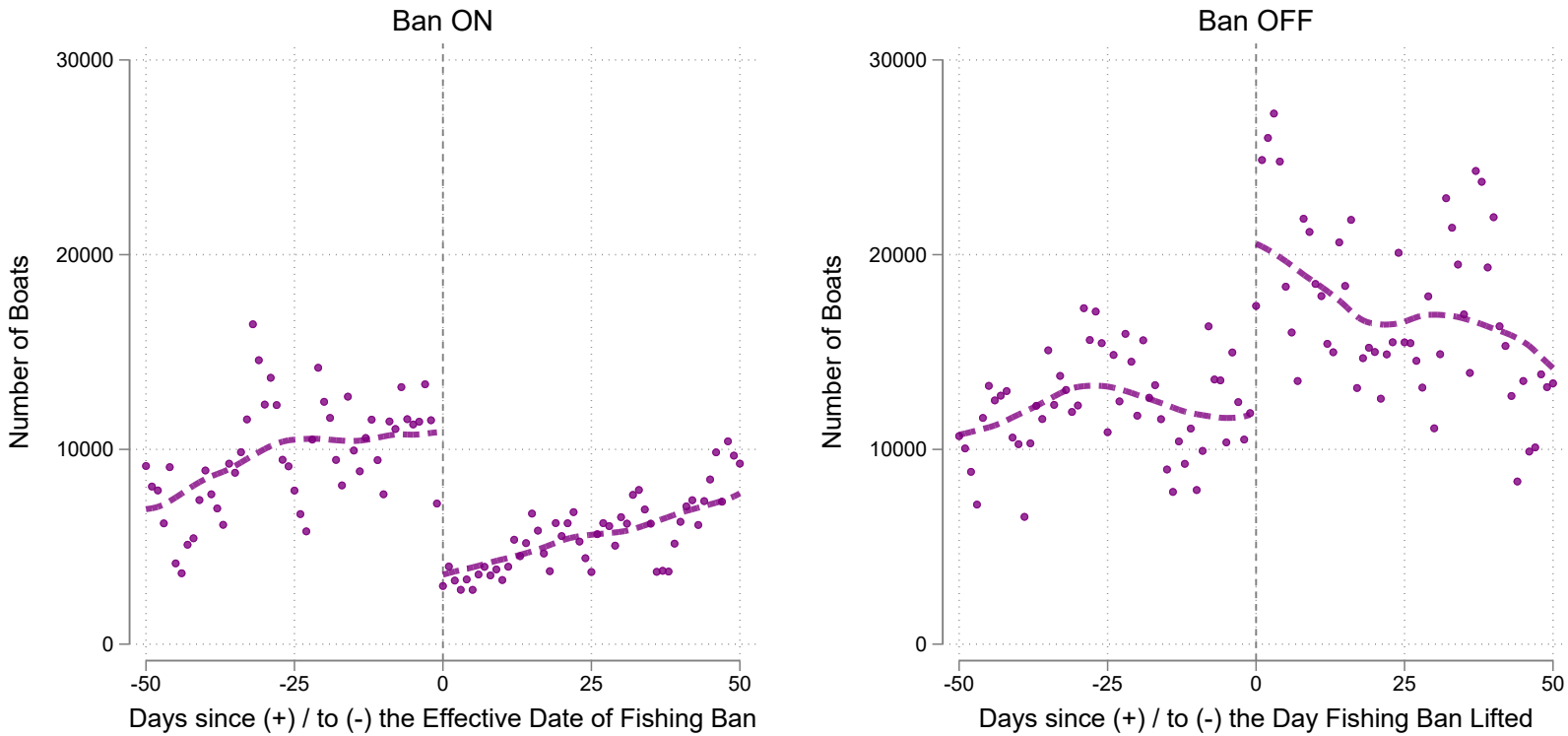
- Sample Period
  - April 2012 to May 2018
- Spatial Coverage
  - Coast of East Asia & Southeast Asia
  - $105^\circ \leq$ Longitude $\leq 130^\circ$
  - $4^\circ \leq$ Latitude $\leq 41^\circ$

Spatial Distribution of Boat Detections





Boats Detected at Night around the Imposition and Lifting of Fishing Bans



Fishing Ban and Boat Detections (RDiT)

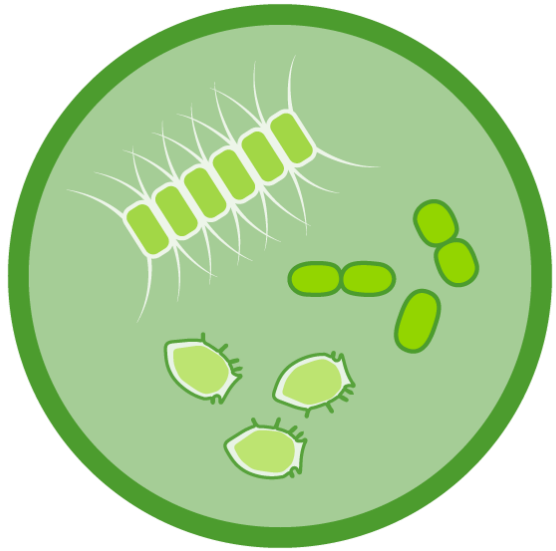
	Ban ON		Ban OFF	
	(1)	(2)	(3)	(4)
Fishing Ban Effective	-0.911***	-0.644***	-0.687***	-0.451***
	(0.162)	(0.113)	(0.133)	(0.111)
Observations	4791	4791	5053	5053
Sample	Days before lifting ban		Days after effective ban	
Day of Year	Quadratic	Quadratic	Quadratic	Quadratic
Day of Week F.E.	-	X	-	X
Day of Lunar Month F.E.	-	X	-	X
Cloud Cover	-	X	-	X

Notes: All specifications include regulatory zone fixed effects.
Newey-West standard errors (max lag = 35) are in parentheses.
*** $p<0.01$; ** $p<0.05$; * $p<0.10$.

Robustness & Validity

- Randomization inference
- Nonparametric RD
- Donut hole RD
- Continuity tests with oceanographic variables
  - sea surface temperature
  - chlorophyll-a concentration
- Difference-in-differences

Chlorophyll-a

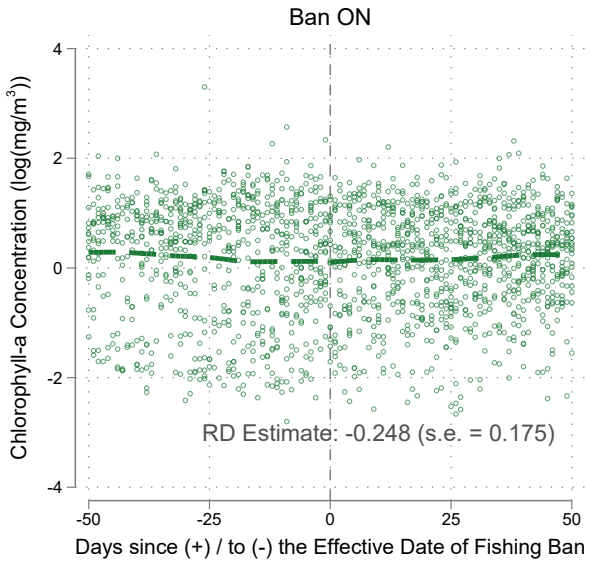


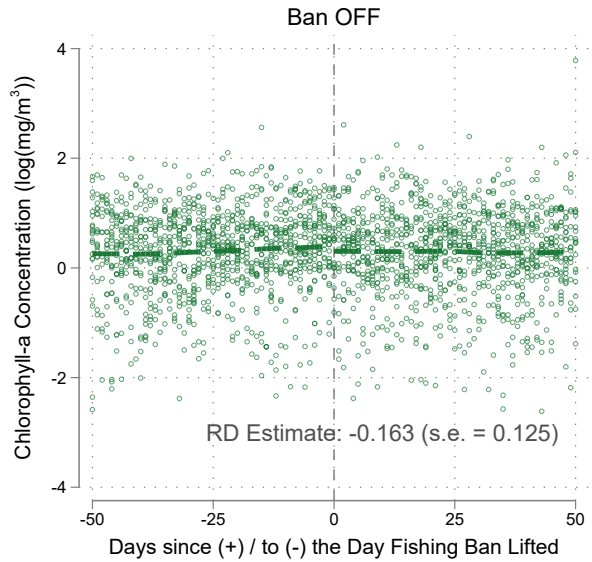
- Phytoplankton are microscopic marine plants that produce nearly half of Earth's oxygen
- Chlorophyll a is a green pigment used by phytoplankton to absorb sunlight for photosynthesis
- Chlorophyll a concentration serves as a proxy for estimating phytoplankton abundance in oceans

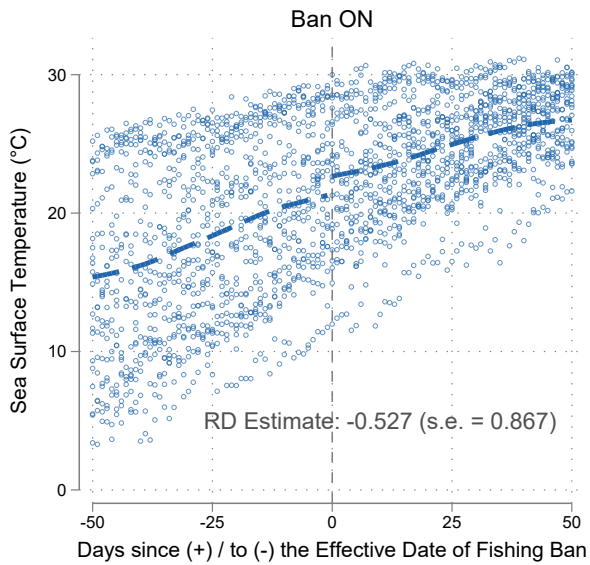
Ocean Color

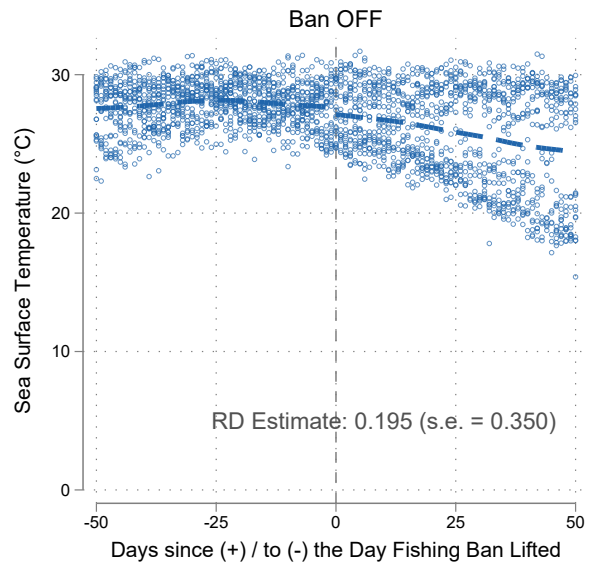
- Satellite sensors measure ocean color to calculate chlorophyll a concentrations in surface waters
- Blue water indicates low chlorophyll levels, while green water indicates high chlorophyll levels

Continuity of Oceanographic Variables

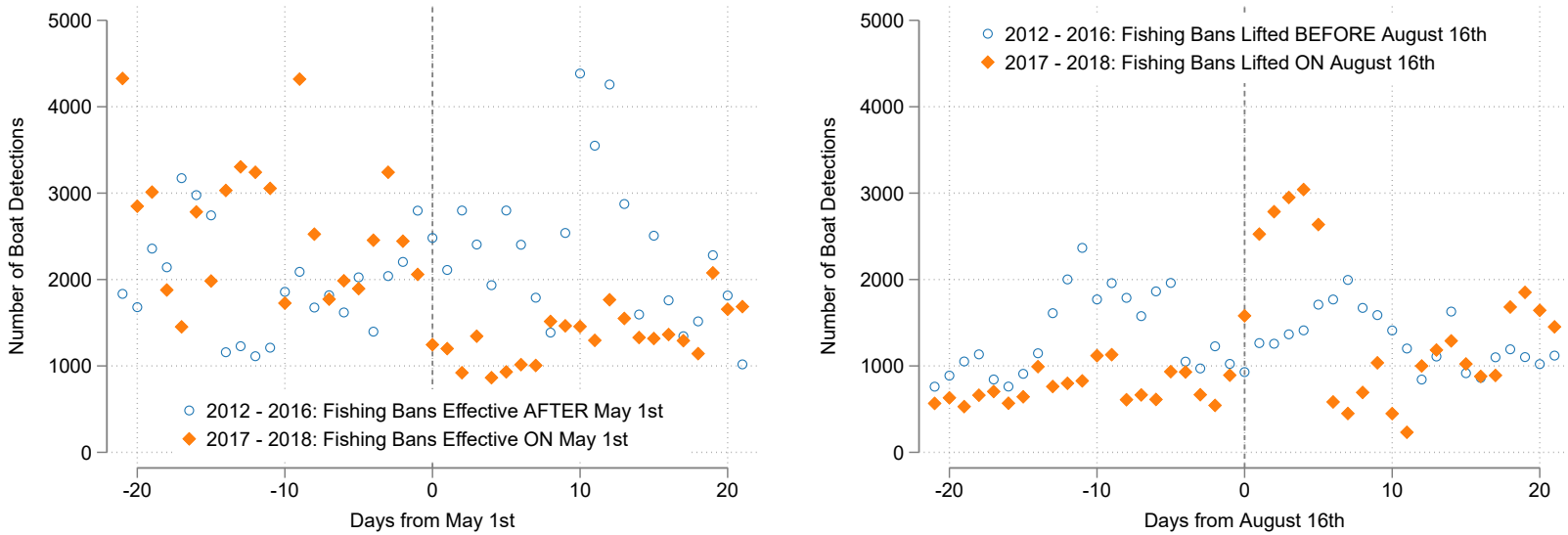








Placebo RDiT due to Shifting Start and End Dates of Fishing Ban



Left panel: May 1st in 2017 (previously June 1st for Zones 1-2 and May 16th for Zones 3-4). Right panel: extension of ban end dates to August 16th in 2017 for Zones 3-4 (previously August 1st).

Difference-in-Differences Estimates

	(1)	(2)	(3)
Fishing Ban Effective	-0.272	-0.311	-0.420
	(0.139)*	(0.139)**	(0.125)***
	[0.111]**	[0.122]**	[0.114]***
Fixed Effects			
Year	X		
EEZ × Year		X	X
EEZ × Month	X	X	
EEZ × Month × Day			X
# EEZ Clusters	147	147	147
# Day Clusters	2,644	2,644	2,644
# Obs.	111,977	111,977	111,977

Two-way cluster by EEZs & dates S.E. in parentheses

Conley (1999) S.E. in brackets (1,000 km & 35 nights)

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

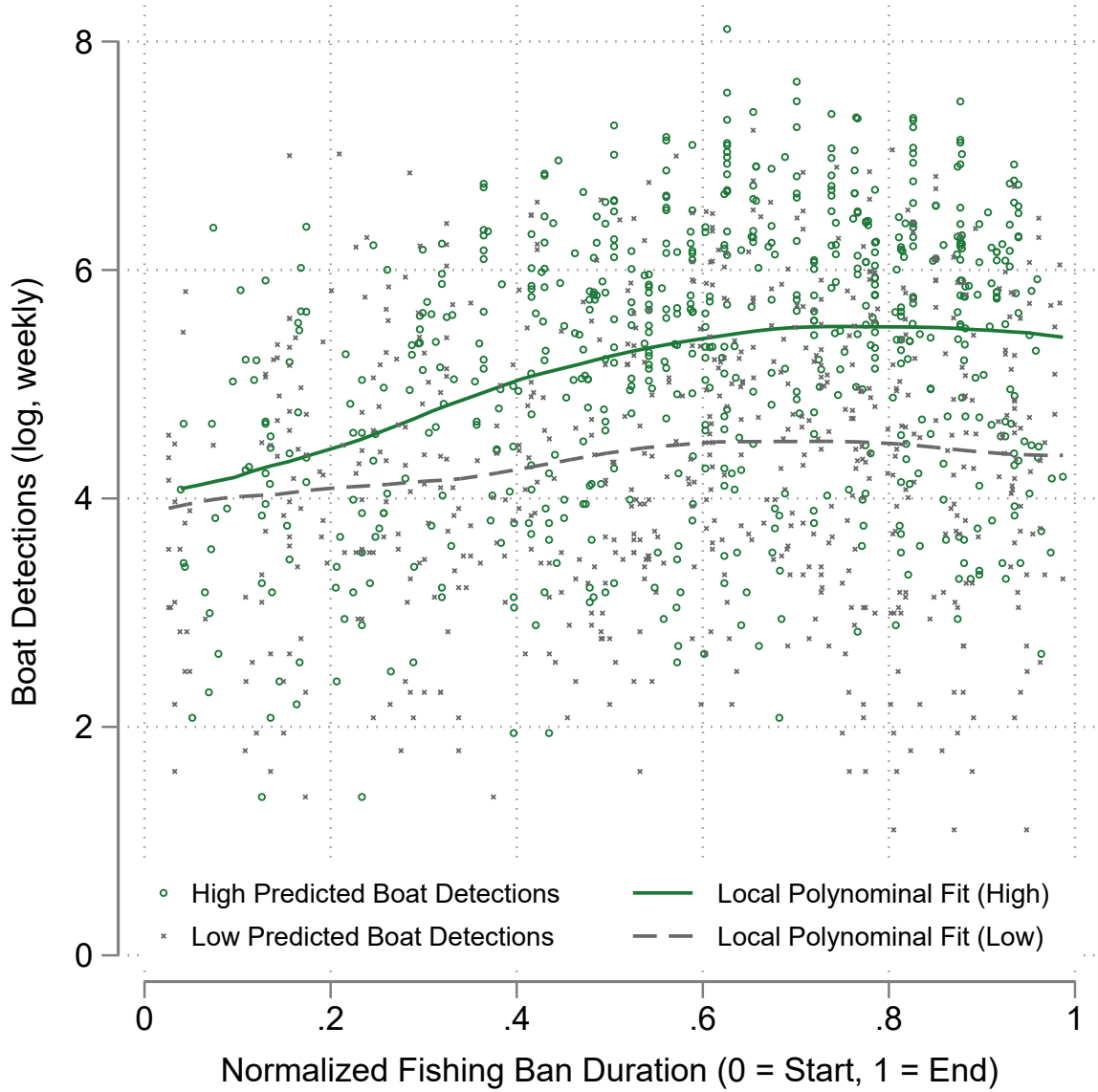
Boat Detections during Fishing Ban

by Oceanographic Conditions

- Plots boat detections during fishing bans vs. normalized ban duration (0-1 scale)
- Areas classified as high/low fishing opportunity based on LASSO predictions using oceanographic data
- LASSO model uses temperature, chlorophyll-a, and interaction terms from non-ban periods (2012-2017)
- High-opportunity areas show substantially larger increases in detections during bans
- Effects intensify as ban progresses, suggesting oceanographic conditions influence illegal fishing

Boat Detections during Fishing Ban

by Oceanographic Conditions



Boat Detections During Fishing Ban

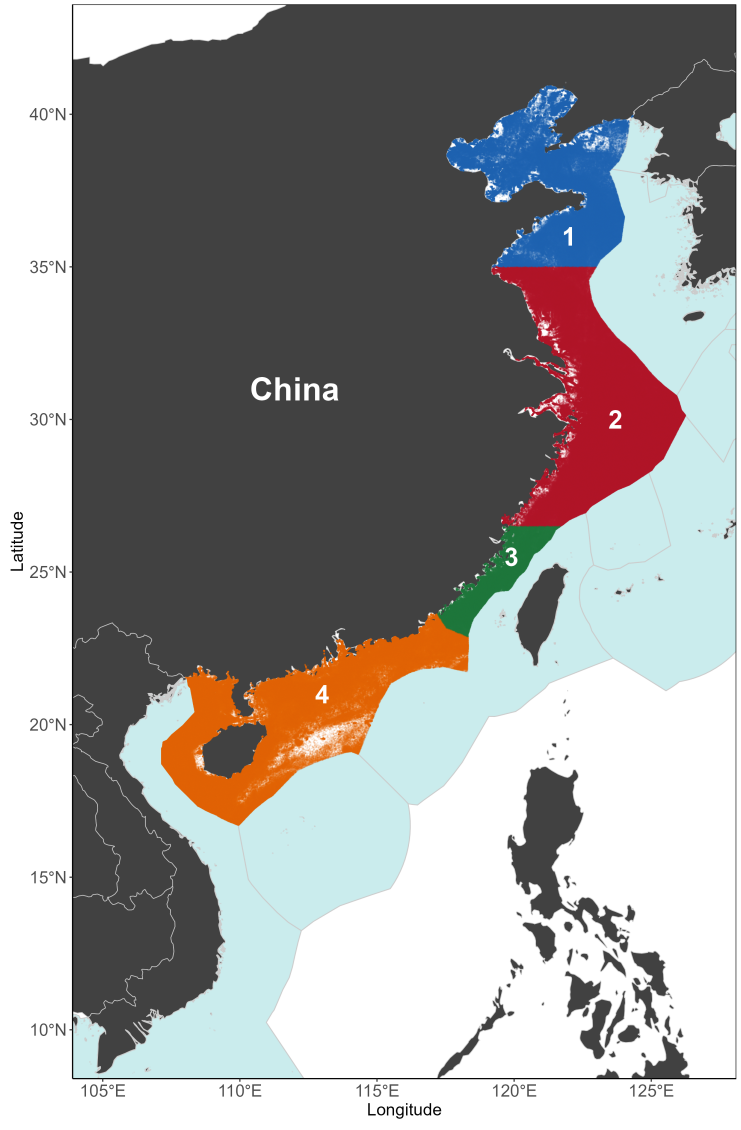
by Oceanographic-based Prediction

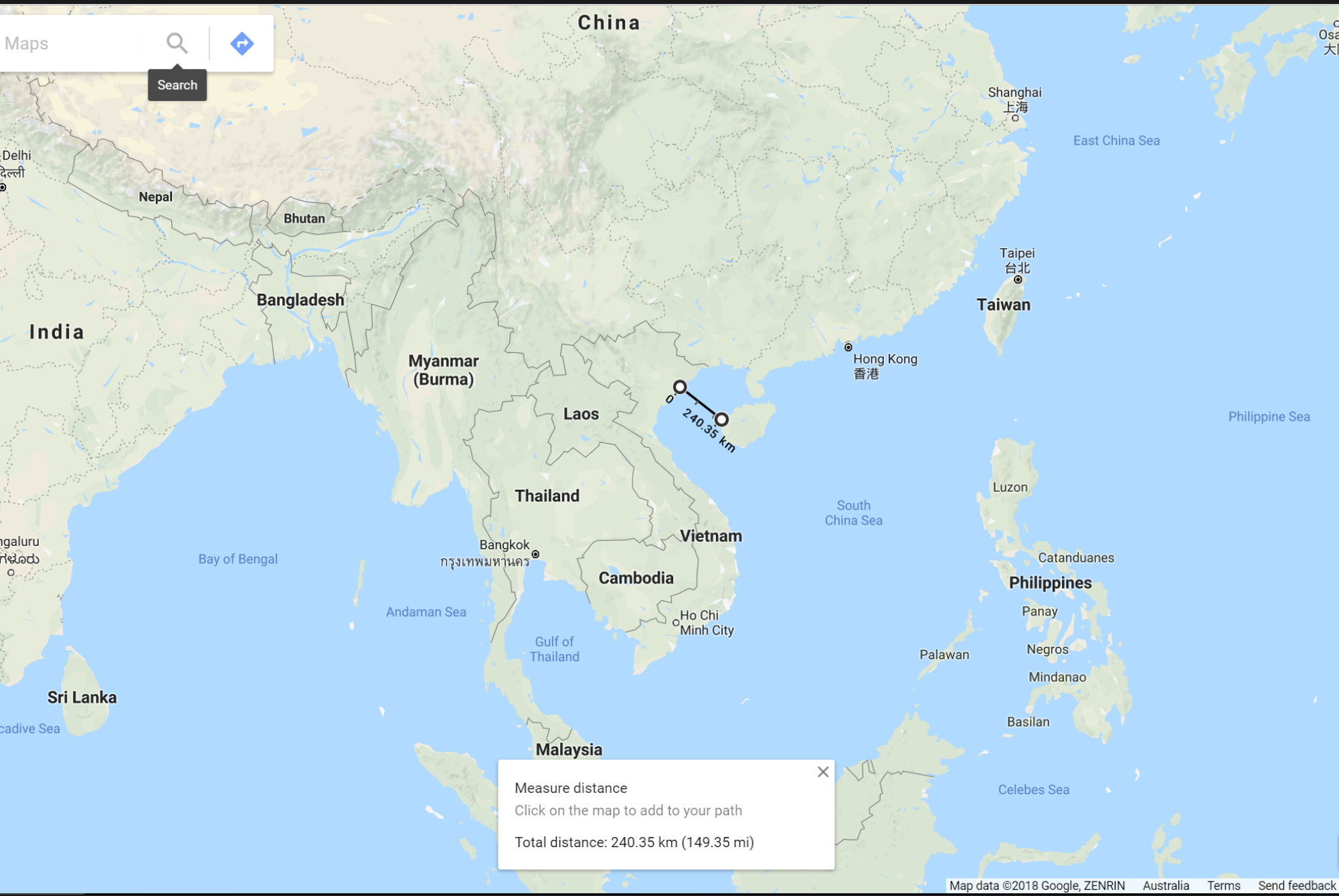
	Boat Detections (log)			
	(1)	(2)	(3)	(4)
Favorable	0.626***	0.781**	0.379	0.454
	(0.228)	(0.311)	(0.294)	(0.337)
2nd Half of Ban	0.436***	0.293**		
	(0.162)	(0.125)		
2nd Half of Ban × Favorable	0.324	0.426**		
	(0.219)	(0.199)		
Normalized Duration			0.716**	0.347
			(0.302)	(0.238)
Normalized Duration × Favorable			0.768*	1.074***
			(0.415)	(0.390)
1° × 1° Grid Cell Fixed Effects	No	Yes	No	Yes
R^2	0.156	0.446	0.153	0.443
# Obs.	1316	1316	1316	1316

Robust standard errors, clustered by 1° × 1° grid cell, are in parentheses.
* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Spillovers?

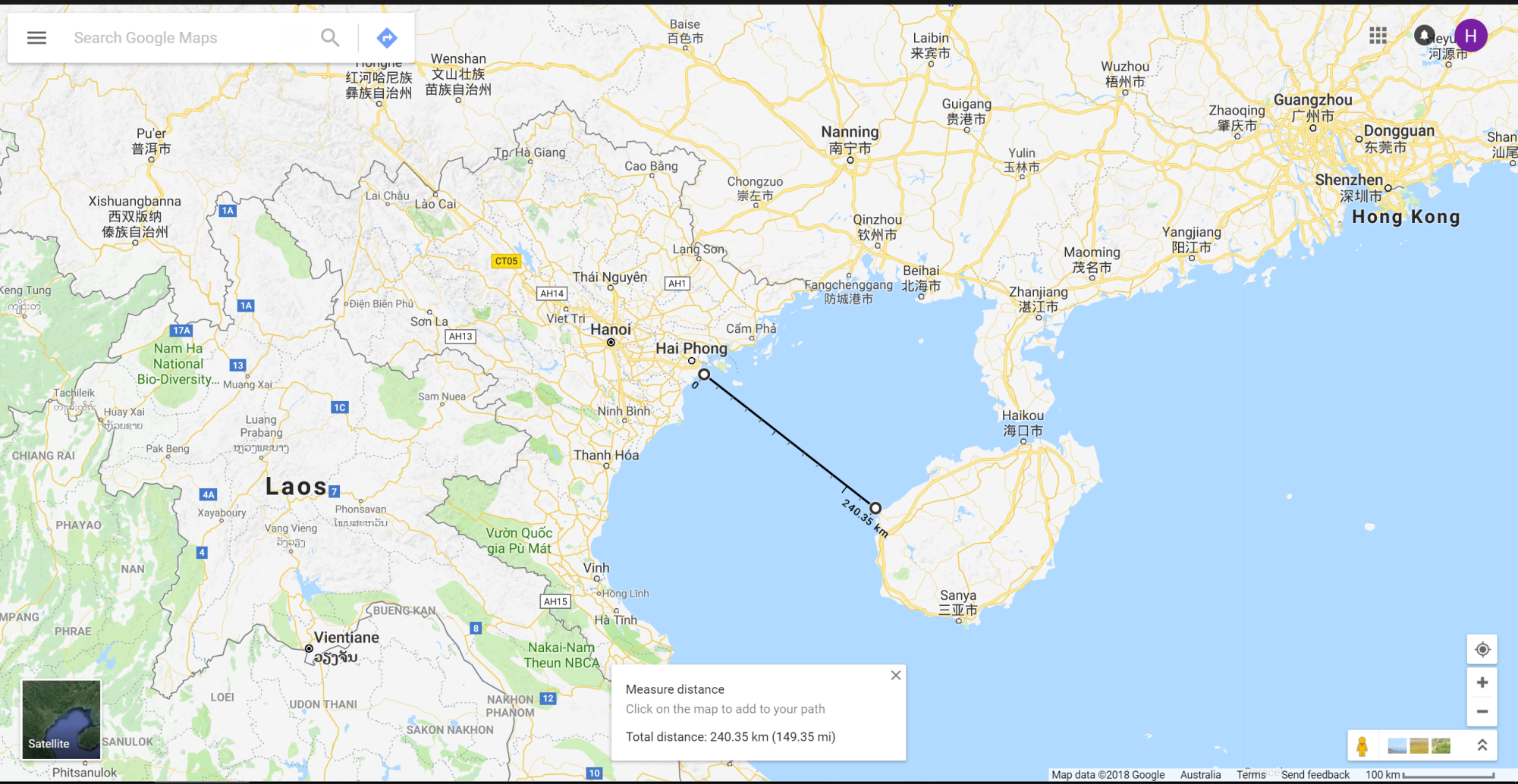
- Inter-jurisdiction spillovers across EEZs?
  - Density discontinuity at EEZ borders?
  - RDiT in neighboring EEZs?
- Across regulatory zones within Chinese EEZ?



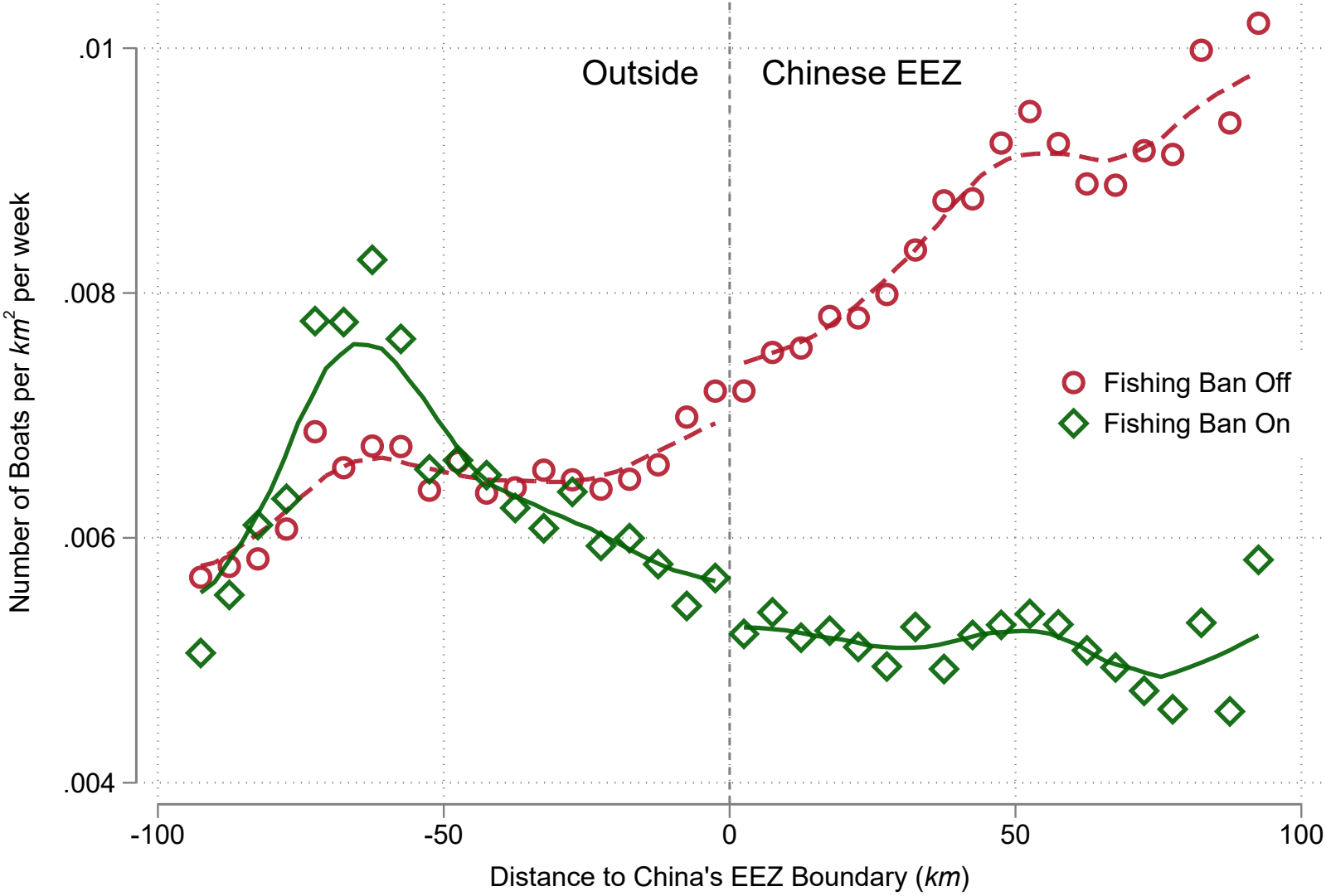


Gulf of Tonkin

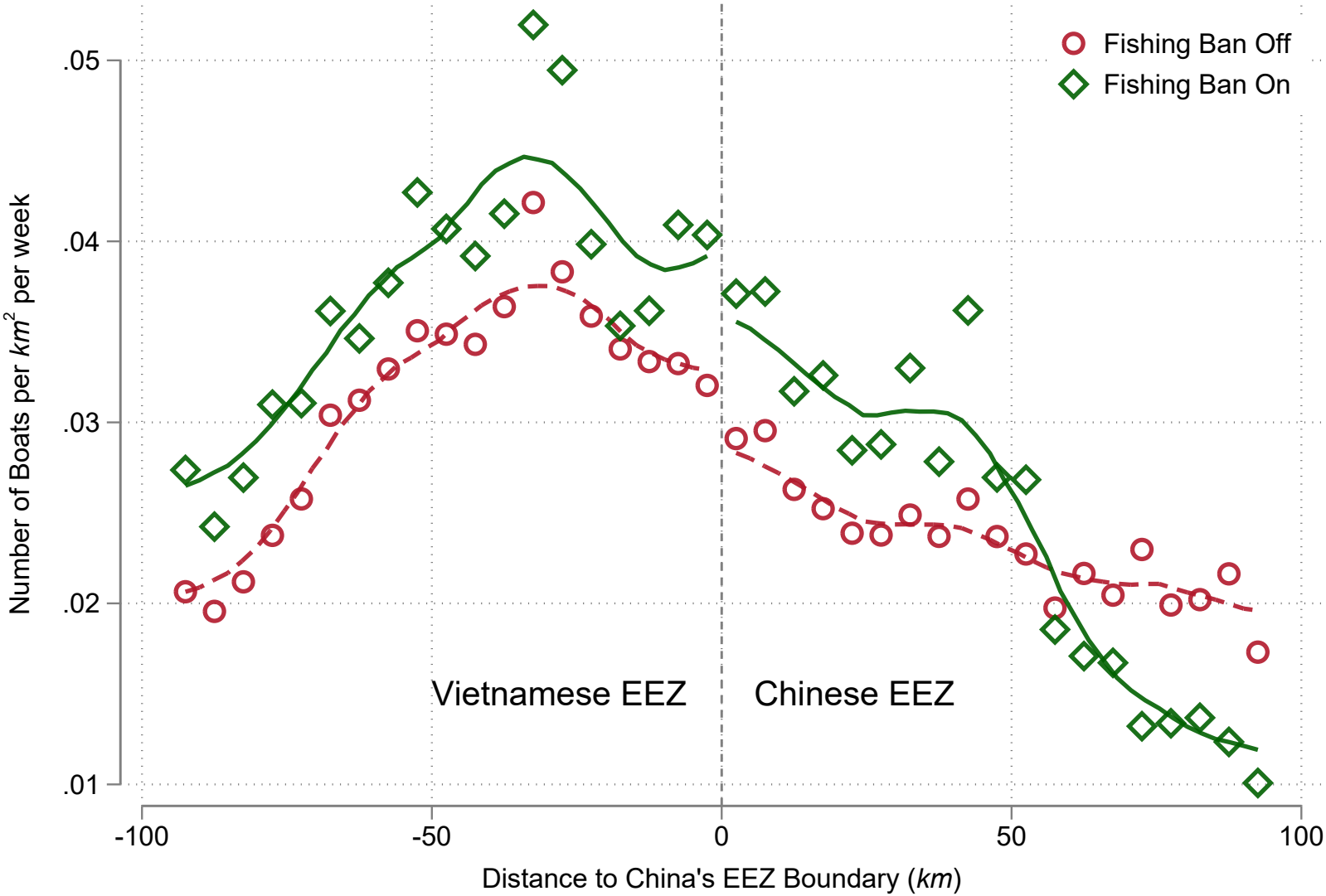
Gulf of Tonkin



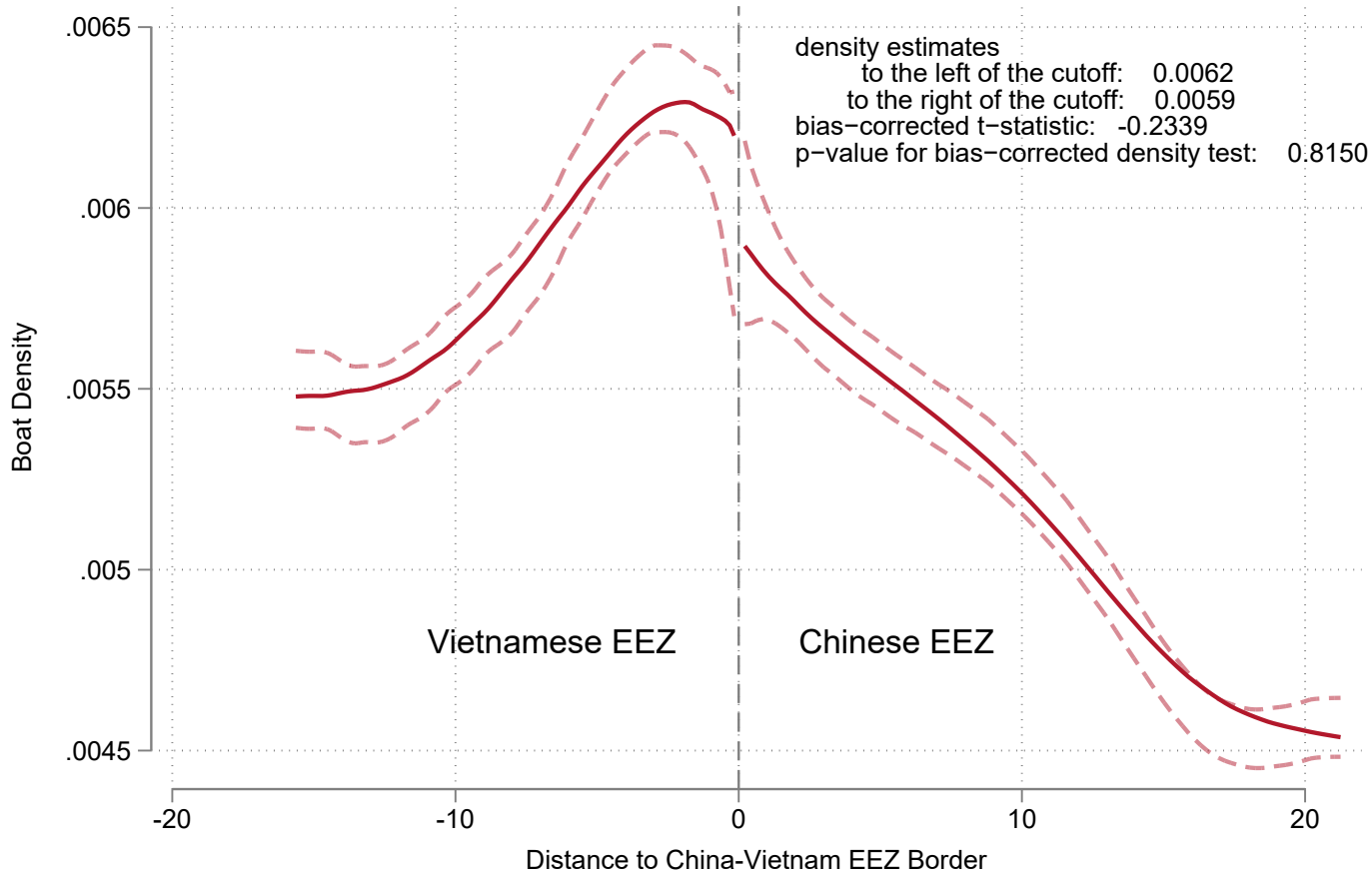
Boat Density at China's EEZ Boundaries (Excluding China-Vietnam Border)



Boat Density around the China-Vietnam EEZ Boundary



Density Discontinuity Test around the China-Vietnam EEZ Boundary



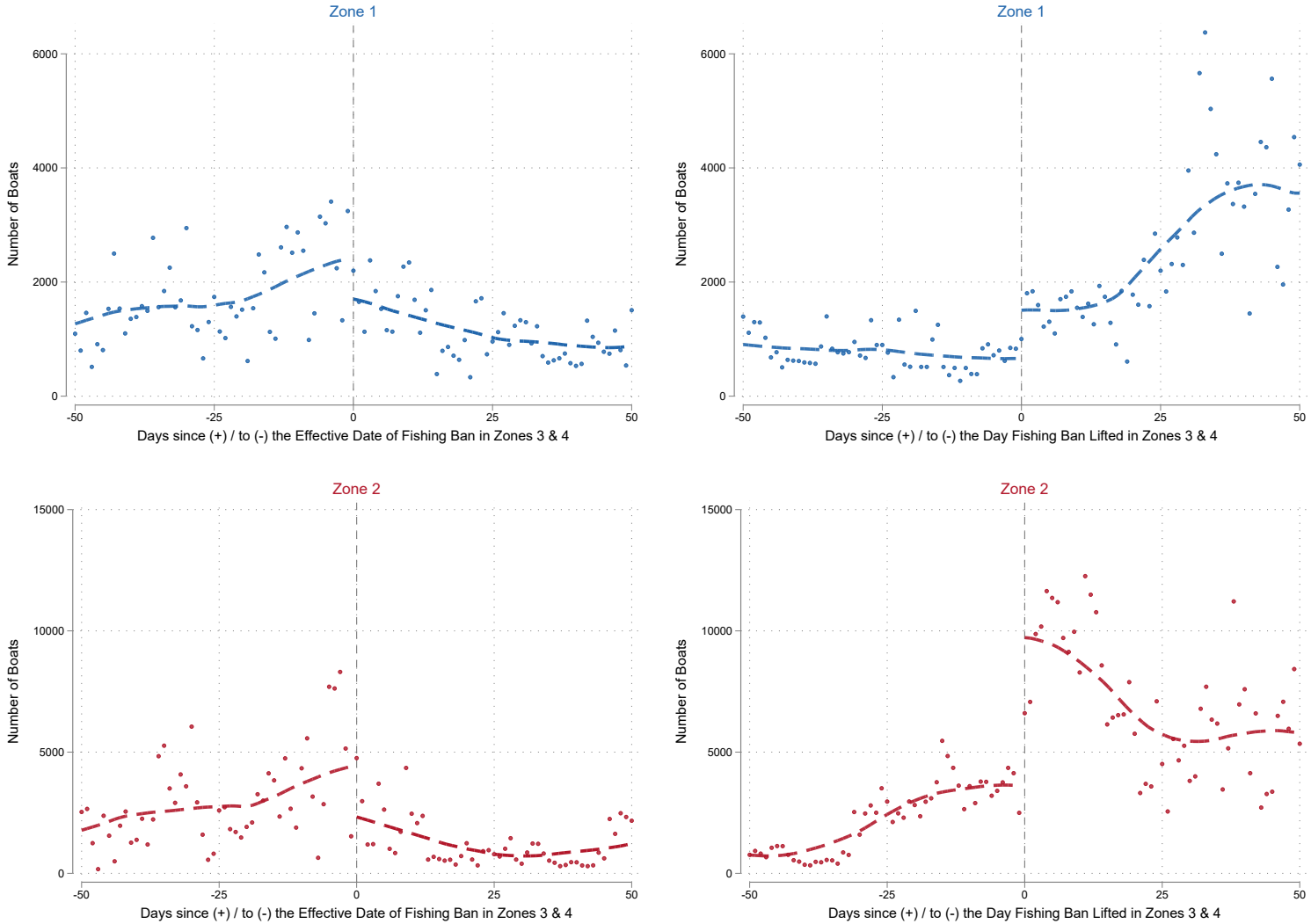
Cattaneo et al. (2020) simple local polynomial density estimator.

Boat Detections in Neighboring EEZs

Spillover across Regulatory Zones?

#	Zone Description	2009 – 2016		2017 – 2018	
		Start	End	Start	End
1	Northern Yellow Sea	June 1	Sep. 1	May 1	Sep. 1
2	Southern Yellow Sea & Northen East China Sea	June 1	Sep. 16	May 1	Sep. 16
3	Southern East China Sea	May 16	Aug. 1	May 1	Aug. 16
4	Taiwan Strait & South China Sea	May 16 May 16	Aug. 1 Aug. 1	May 1 May 1	Aug. 16 Aug. 16

Spillover from Zones 3 & 4 to Zones 1 & 2



RD plots apply the start and ending dates in Zones 3 & 4 to Zones 1 & 2. Left subplots: starts; Right: ends. Rows 1 = Zone 1.

Limitations of Boat Detections

Nature of spillovers?

- Reduced profitability affecting Vietnamese waters as enforcement preventing Chinese vessels from operating in Vietnamese waters? or
- Vietnamese vessels opportunistically entering Chinese EEZ?

Limitations of Boat Detections:

- Vessel's flag state?
- Fishing intensity?

Automatic Identification System (AIS)

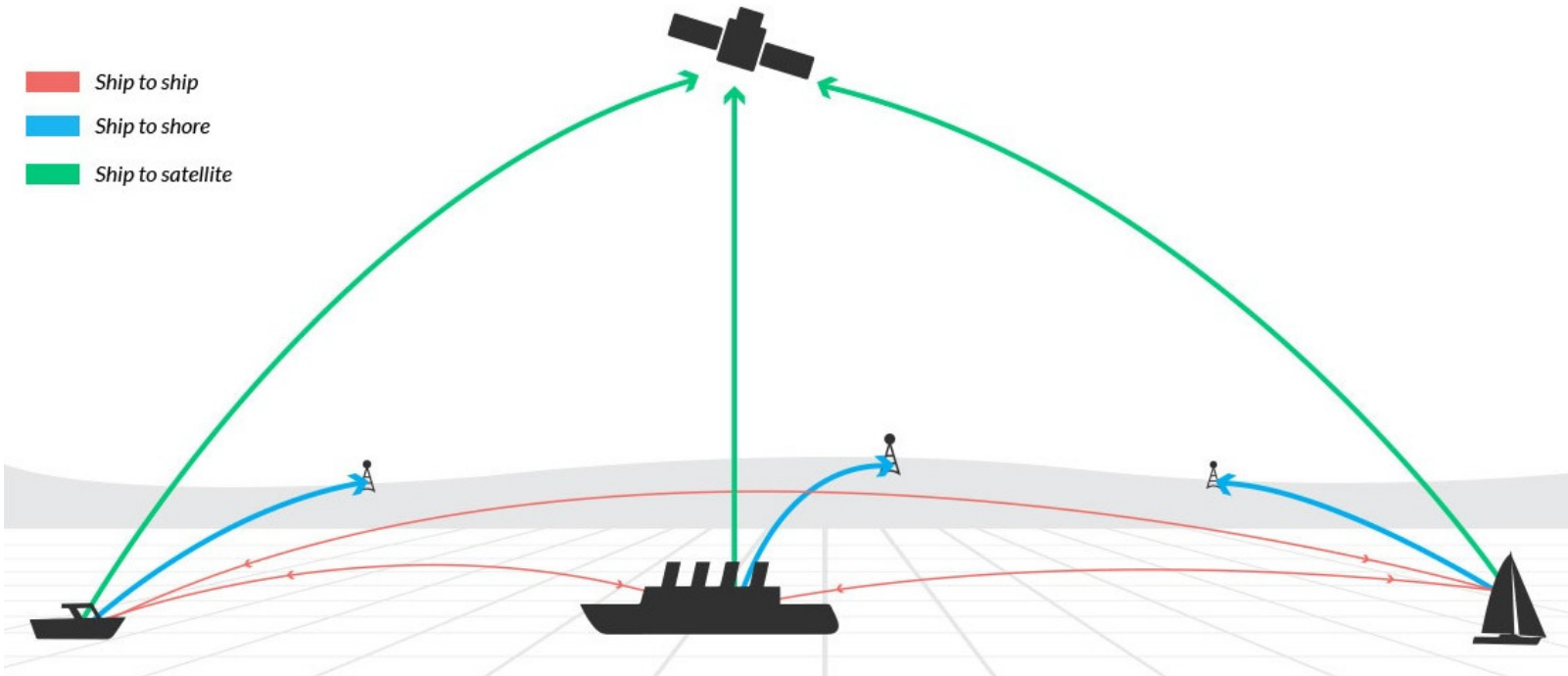


Figure: NATO Shipping

Automatic Identification System (AIS)

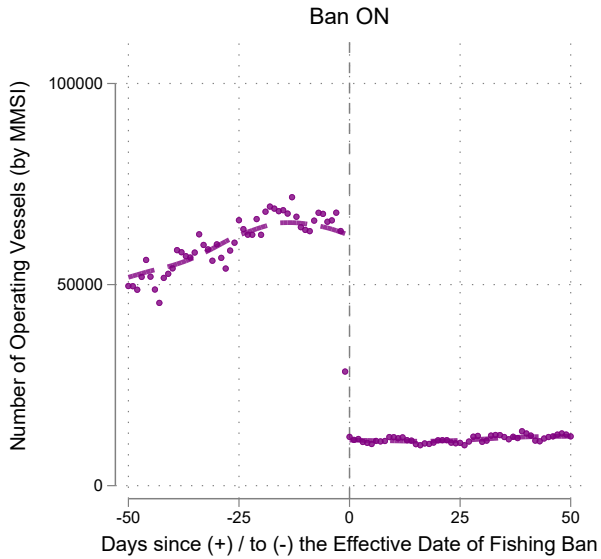
Automatic Identification System (AIS):

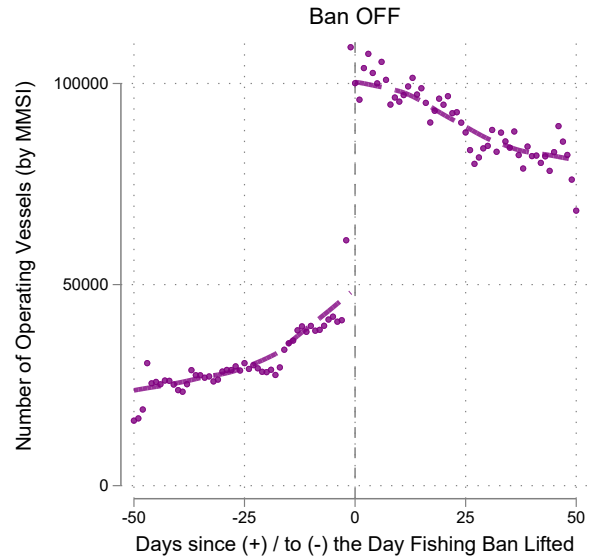
- Enhances maritime navigation safety.
- Provides vessel identification and tracking.
- Supports collision avoidance and traffic management.

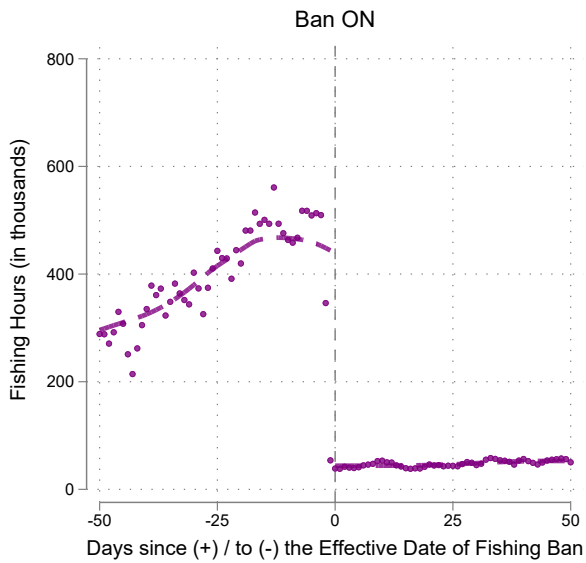
Fishing activities from AIS signals:

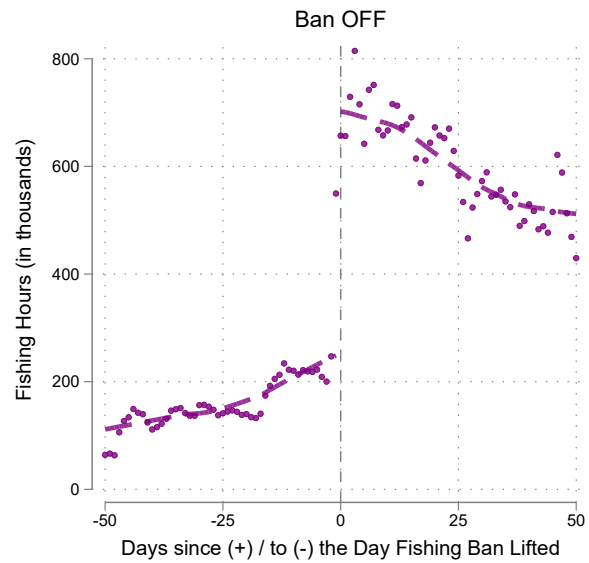
- ML algorithms (2 CNNs) by Kroodsma et al. (2018)
- from Global Fishing Watch

Fishing Effort based on AIS Signals









Foreign Fleets in Chinese Waters

- Chinese fleets dominates the fishing operation in Chinese EEZs ($\approx$ 99%).
- Chinese vessels also fish in neighboring EEZs.
- However, Vietnamese-flagged vessel count and fishing hours in Zone 4 of Chinese EEZ increased by about 280% during the ban periods.

Conclusion

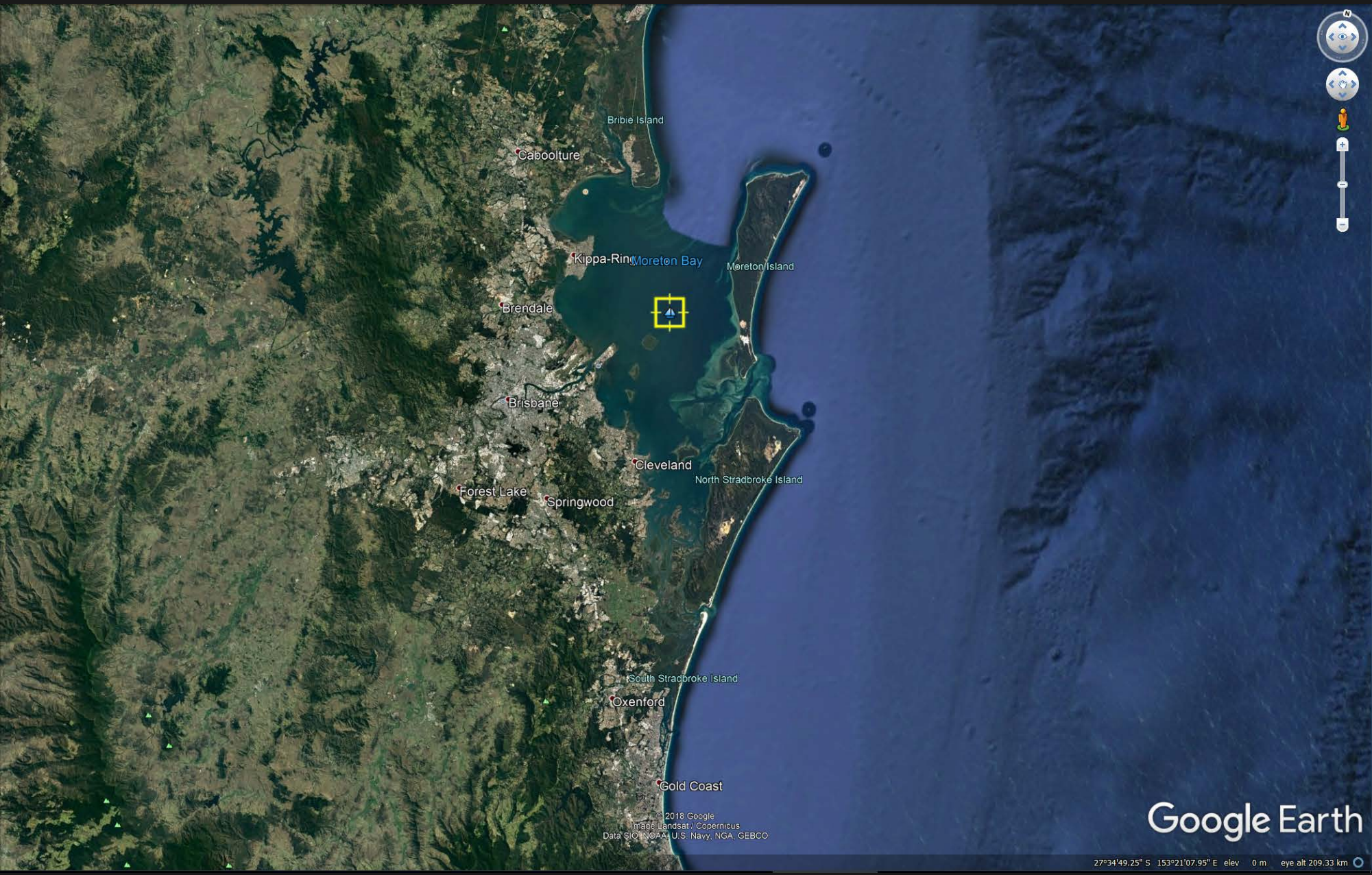
- Fishing bans significantly reduce activity, but compliance weakens over time.
- Spillovers affect neighboring countries / zones.
- Remote sensing data valuable for enforcement

Thanks!

Lists of Figures & Tables

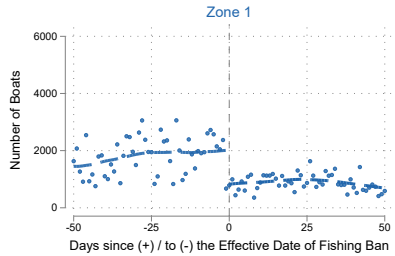
Working Paper
available at:

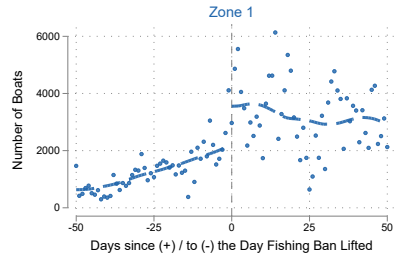
https://haishan-yuan.weebly.com/

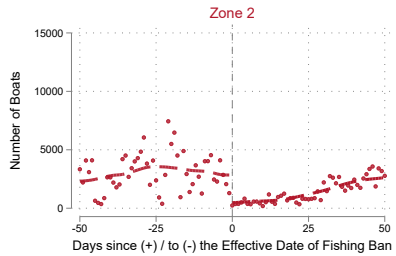


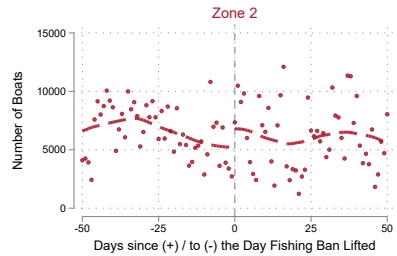
Brisbane on May 31, 2018

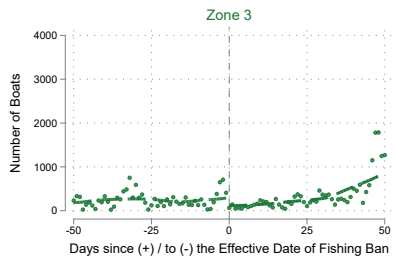
RD in Time by Zone

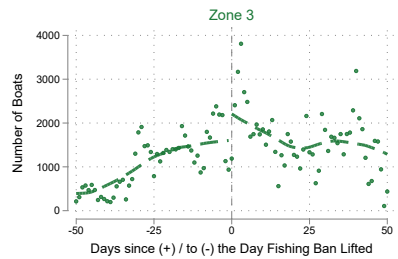


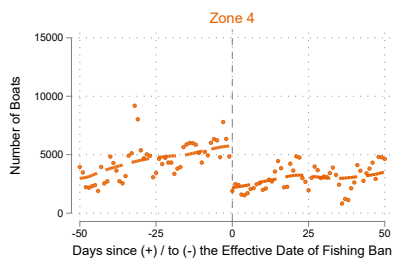


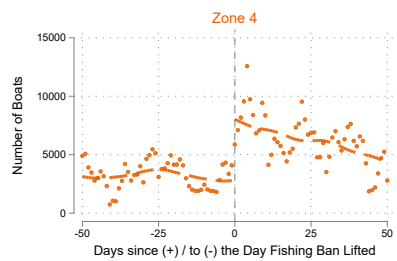




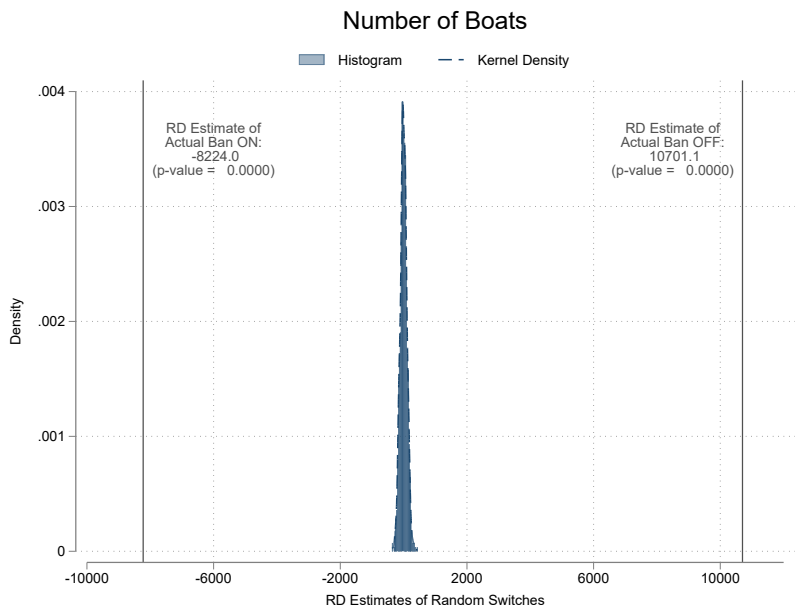


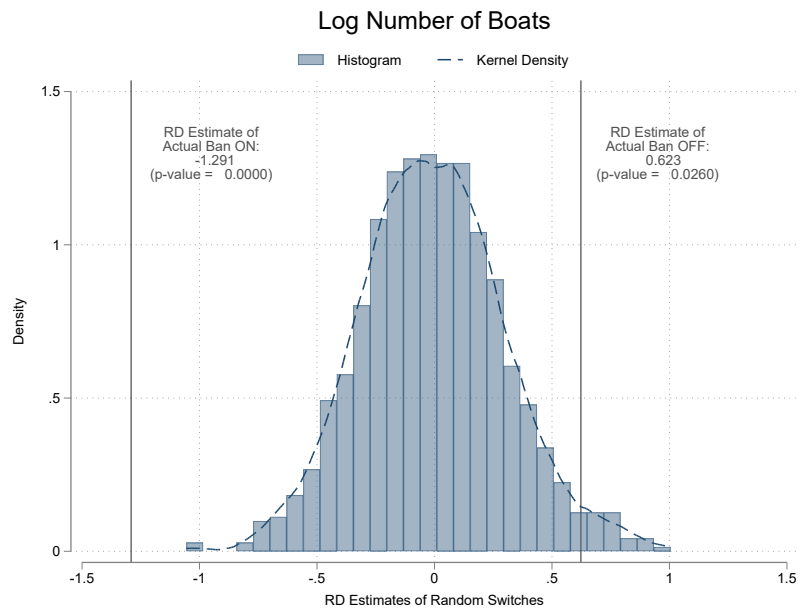




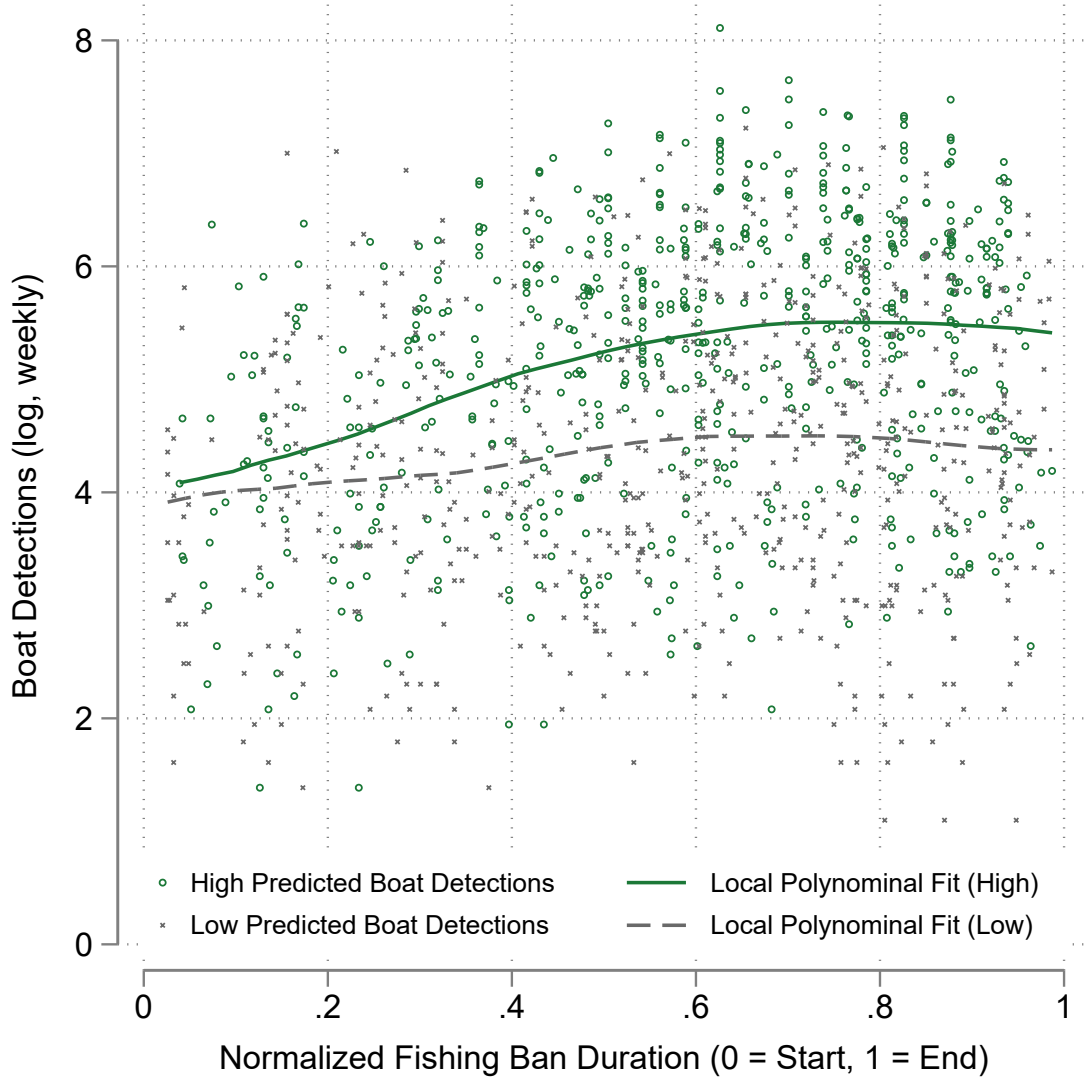


Randomization Inference

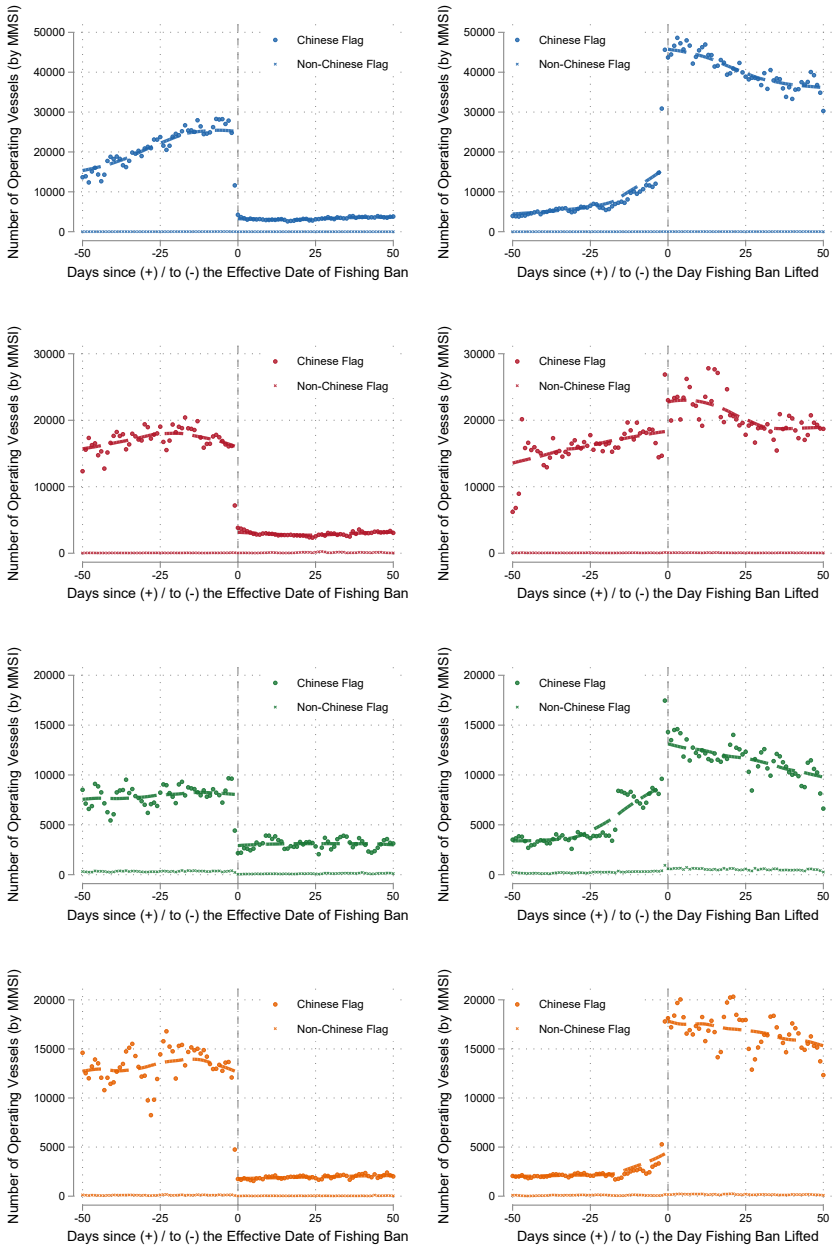




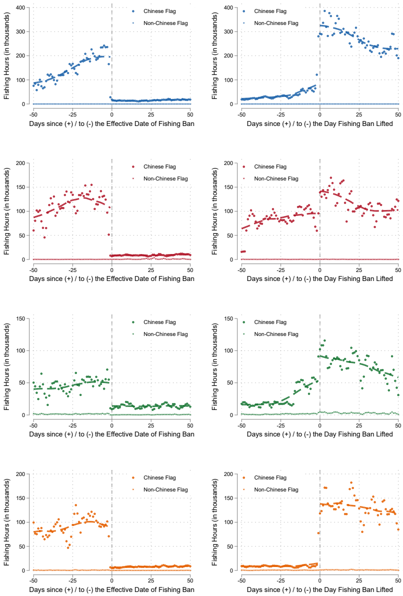
Boat Detections during Fishing Ban by Oceanographic Conditions



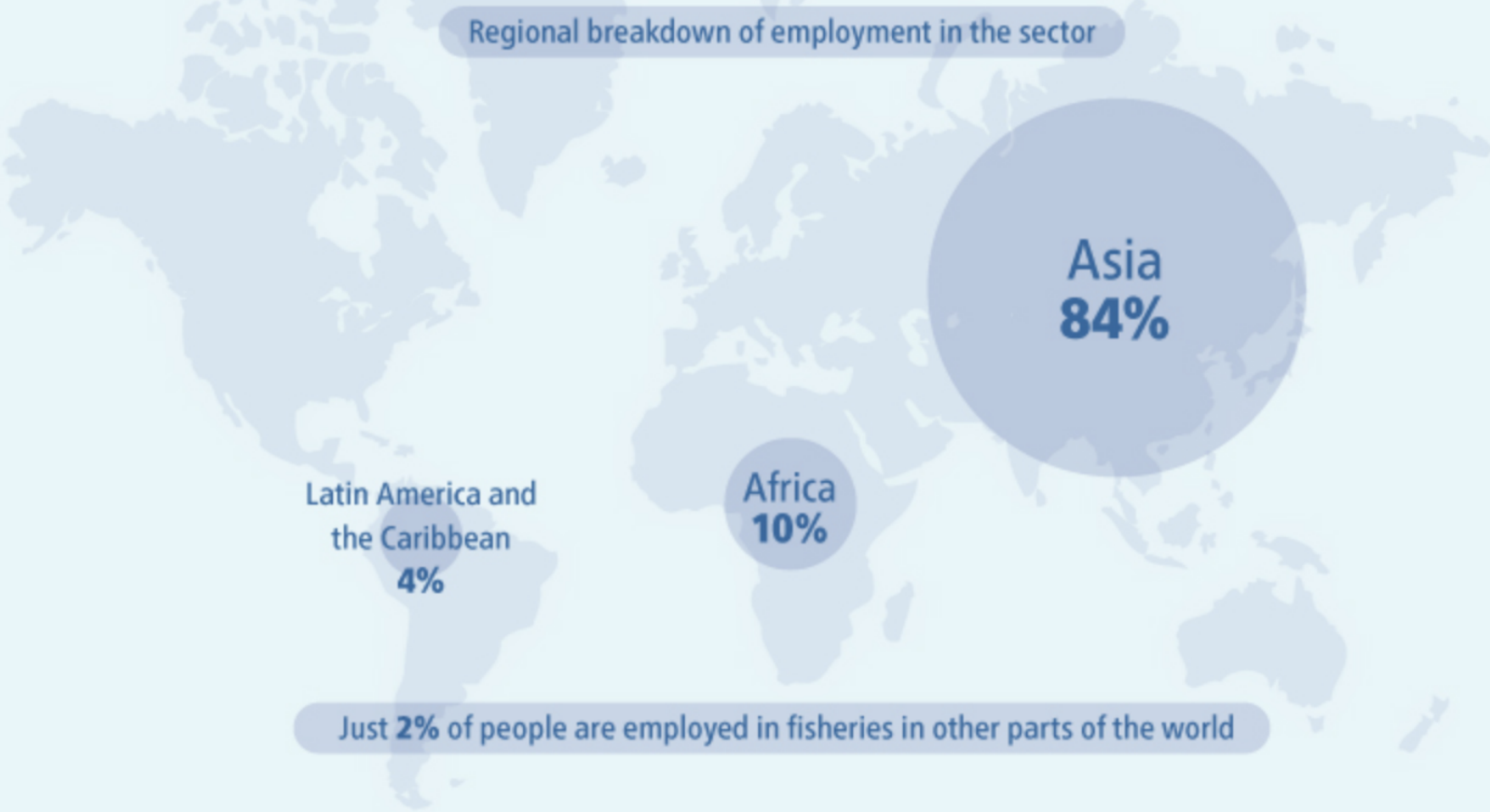
Vessel Counts based on AIS Signals



Fishing Hours based on AIS Signals



10-12% of the world's population depends on fisheries and aquaculture for their livelihoods



The total number of fishing vessels in the world was estimated to be about **4.7 million** in 2012