Machine learning-based identification and classification of ocean eddies

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EDDY

UNIVERSITÄT BONN

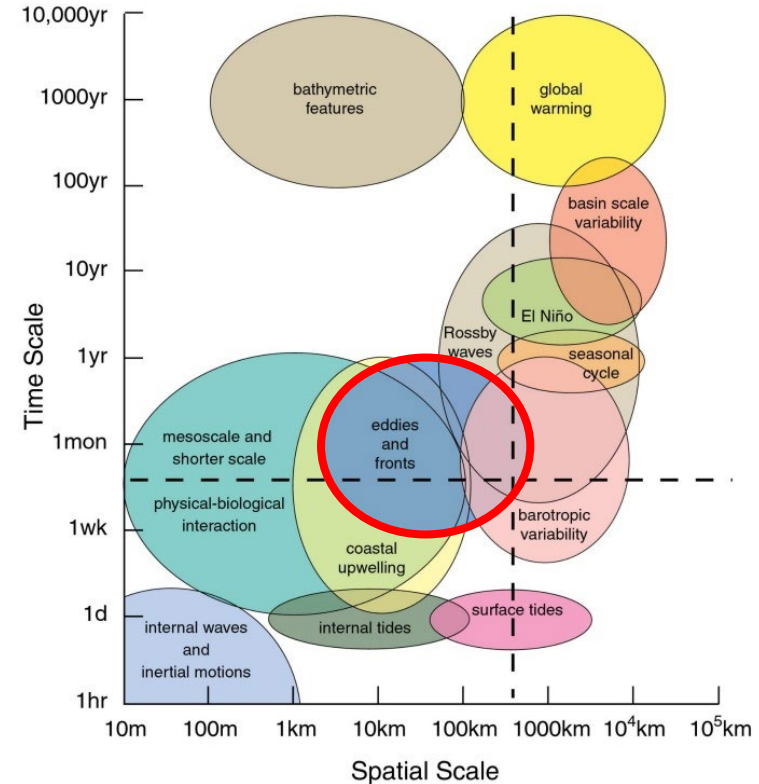# Mesoscale Eddies - The Weather of the Ocean

- Gyrating circular motion of **ocean currents**

- Scales:
  - Spatial: 10 km to 500 km
  - Time: weeks to a month

- Results in mass transport
  - Horizontal **heat transport**
  - Vertical heat and **carbon transfer**

- Relevant in hydrology, marine biology, fishery, ...

False Color Image, https://www.gfdl.noaa.gov/ocean-mesoscale-eddies/
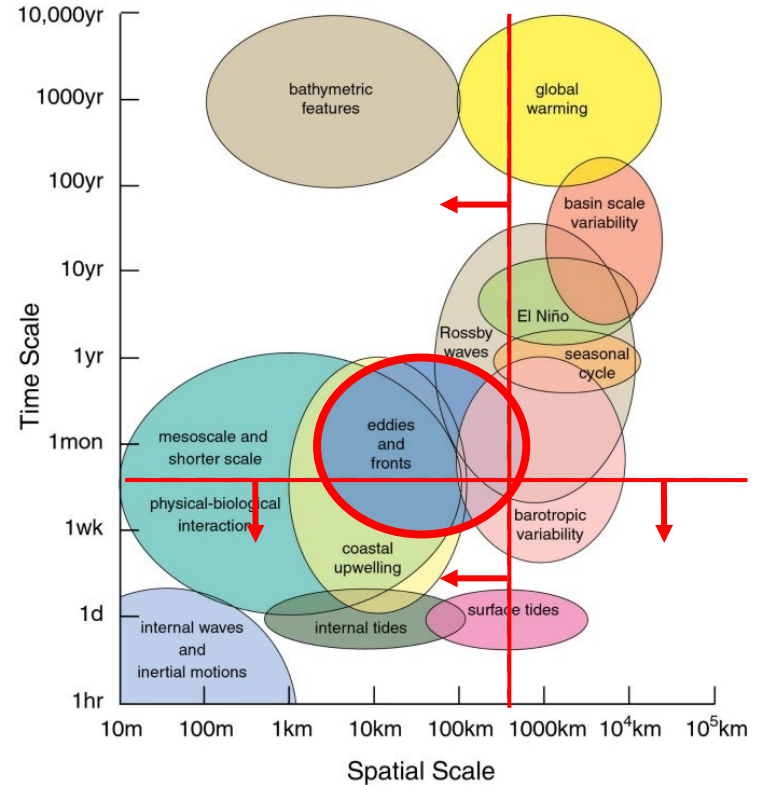
How to Detect Eddies?

- Limited **temporal and spatial** scales observable with satellite altimetry

- Visible through **advancement** in satellite oceanography and detecting algorithms

Chelton, D. B., 2001b: Report of the high-resolution ocean topography science working group meeting. http://www-po.coas.oregonstate.edu/research/po/research/hotswg/HOTSWG_report.html
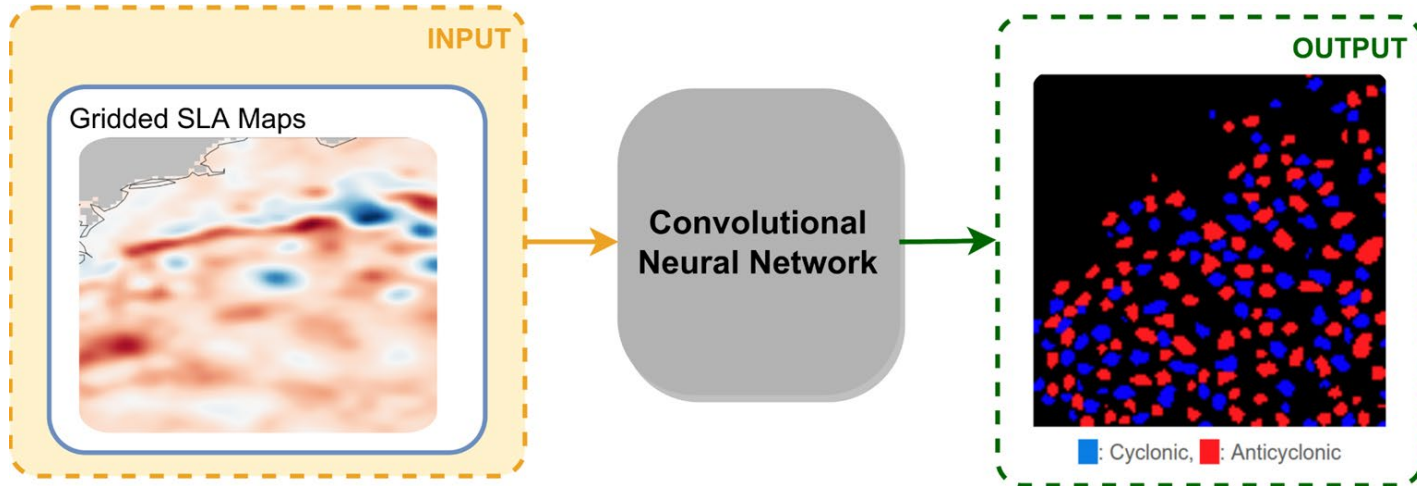
How to Detect Eddies?

- Limited **temporal and spatial** scales observable with satellite altimetry

- Visible through **advancement** in satellite oceanography and detecting algorithms

- How do we **push** the boundaries?

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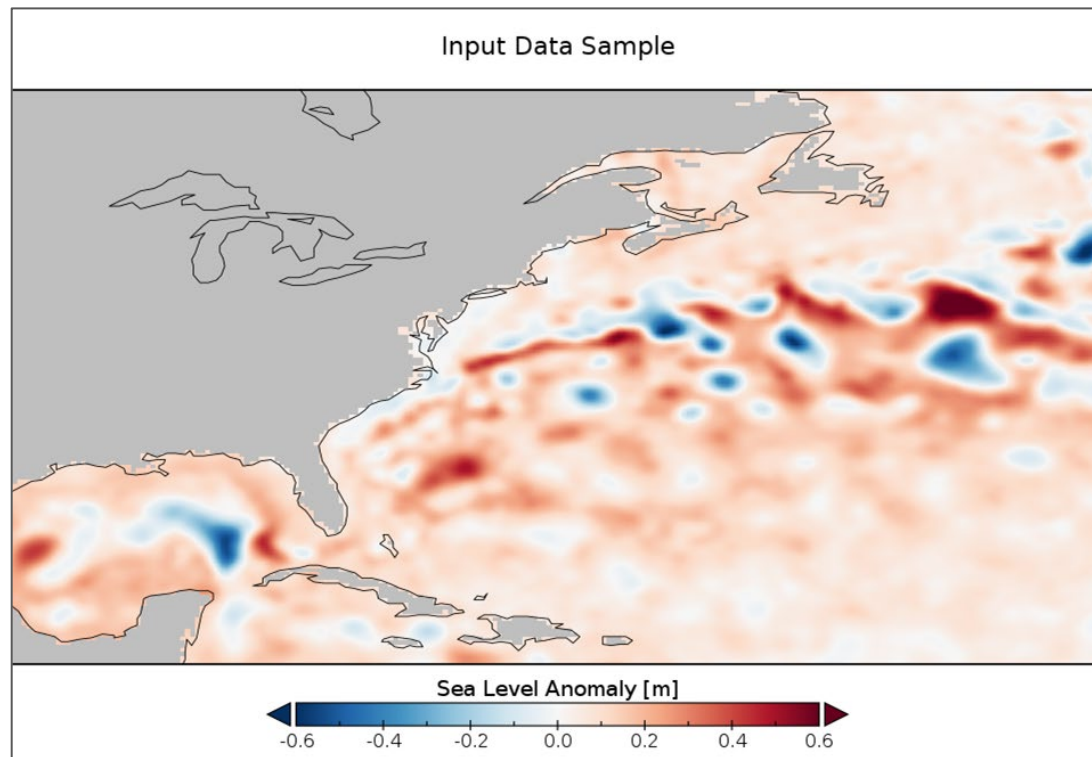
State of the Art

- Convolutional Neural Network for Semantic Segmentation (Classifying each pixel/datapoint on a picture/grid map)
  - Input: 2D Sea Level Anomaly grid maps
 - Output: Segmentation map of cyclonic and anticyclonic eddies

EddyNet: R. Lguensat et al, "Eddynet: A deep neural network for pixel-wise classification of oceanic eddies (2017)

Data

- Daily gridded (Level 4) Sea Level Anomaly Data from multiple missions from CMEMS

- Resolution:
  - Daily
  - 0.25° x 0.25°

- 01.01.2017 - 31.12.2017

Input Data Sample

Sea Level Anomaly [m]

py-eddy-tracker: https://py-eddy-tracker.readthedocs.io/

Data

- Reference data of Eddies can be acquired by **detecting algorithms**

- Processed reference data of eddies using the **py-eddy-tracker**

- Manual cleaning necessary

- Labeled classes: cyclonic and anticyclonic eddies

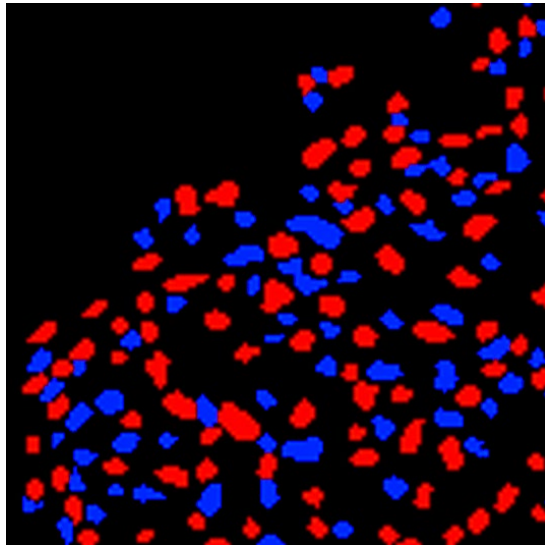Reference data of eddies superimposed on SLA grid map
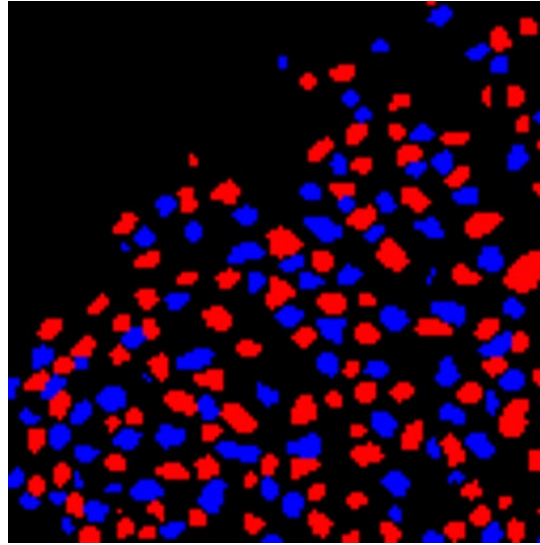

🟦: Cyclonic, 🟥: Anticyclonic

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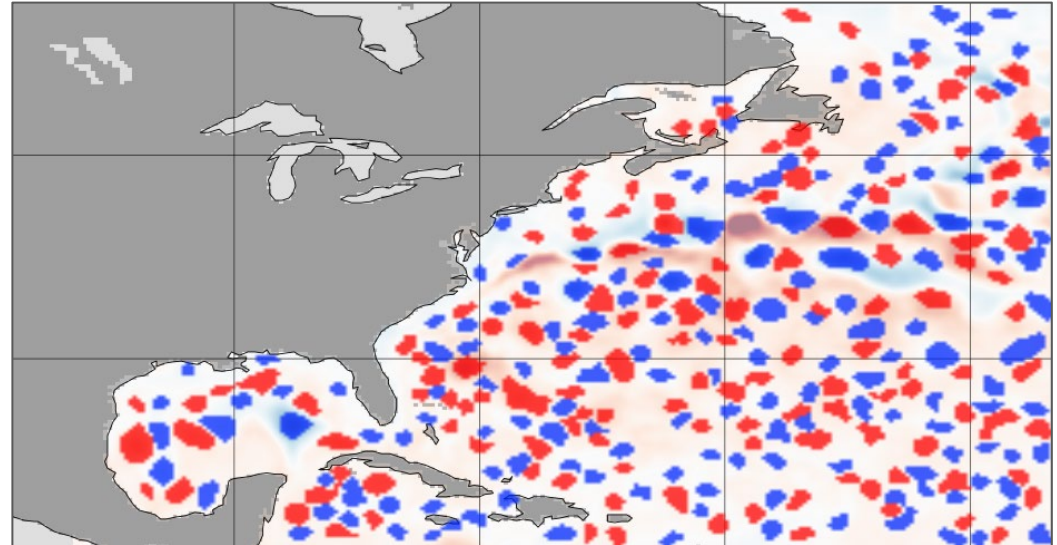
State of the Art

Resulting 2D CNN predictions of a random sample

Reference

Prediction

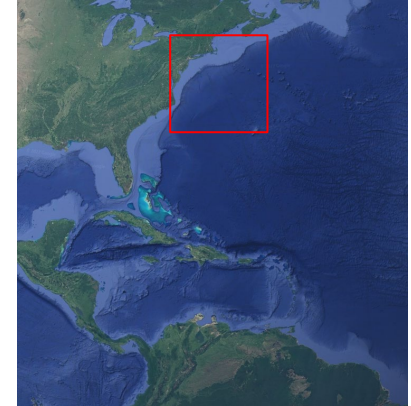■: Cyclonic, ■: Anticyclonic

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Dice Scores

No Eddy	Cyclonic Eddies	Anticyclonic Eddies	Average
95.09%	77.84%	79.11%	84.01%

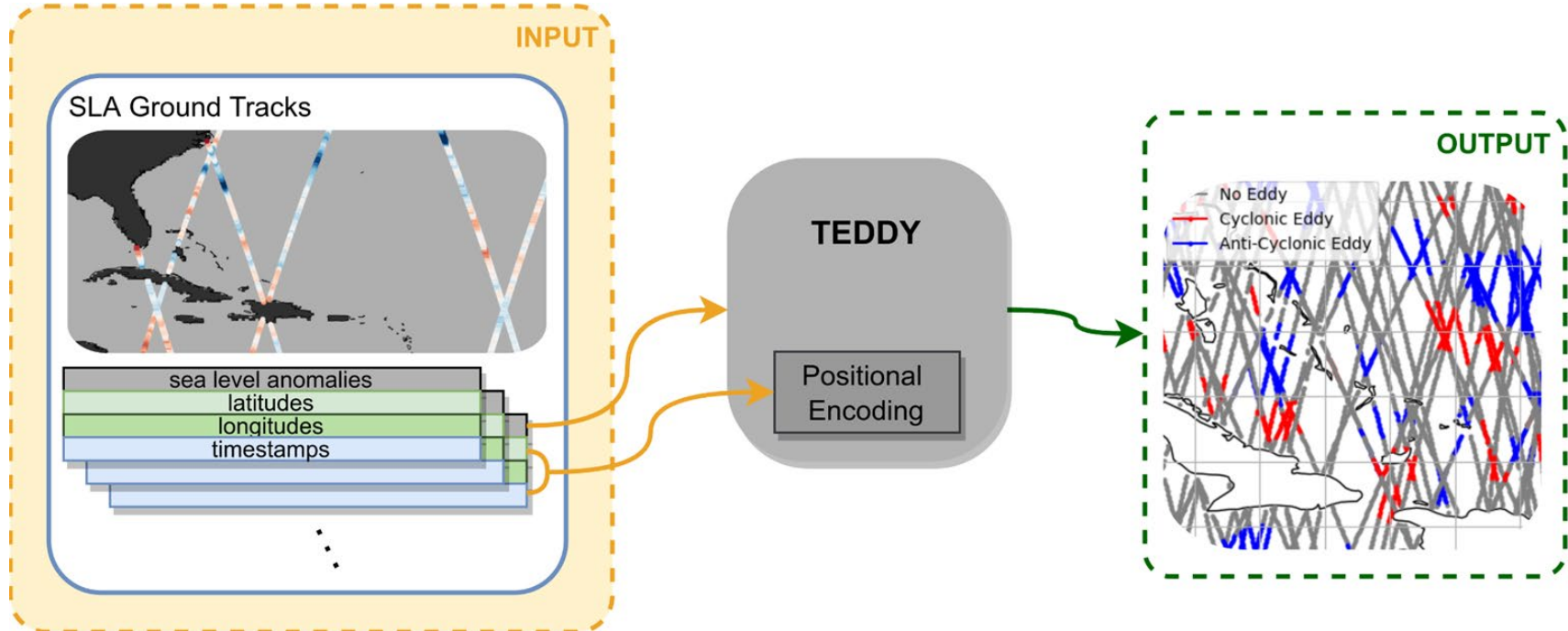# From Grid Maps to Ground Tracks

Research question:

How can we base **automated eddy identification and classification** on **ground track data** using sophisticated deep learning techniques?

Our Approach:

Transformer Architecture

- Utilizes data and its **spatiotemporal** context
 (Ground track coordinates & time of measurement)

From Grid Maps to Ground Tracks - TEDDY

From Grid Maps to Ground Tracks - TEDDY - Data

- Sea Level Anomaly ground tracks (Level 3) from multiple missions from CMEMS

- 01.01.2017 - 31.12.2017

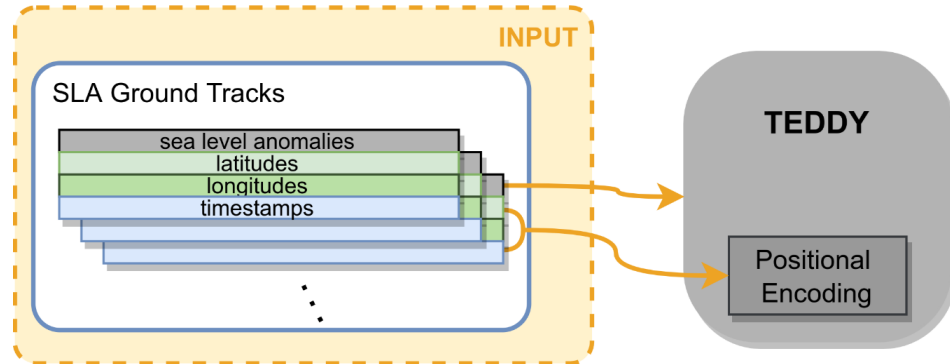- Processed reference data of eddies using the product of 2D grid data

Ground Track Sample from Saral/AltiKa Mission provided by CMEMS

Sea Level Anomaly Ground Tracks [m]
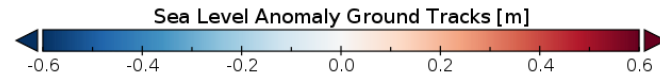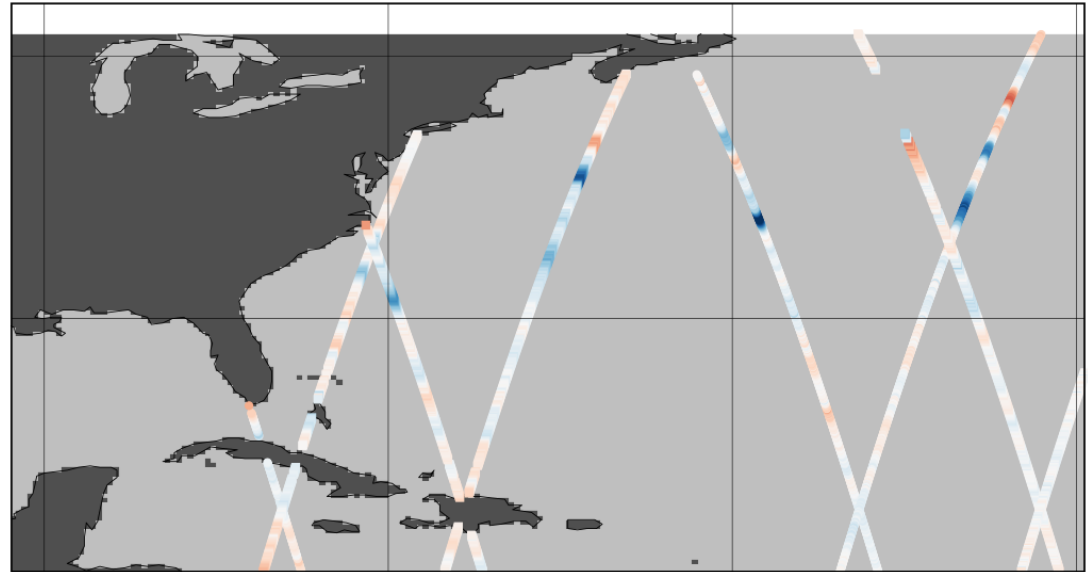
From Grid Maps to Ground Tracks - TEDDY

Positional Encoding:

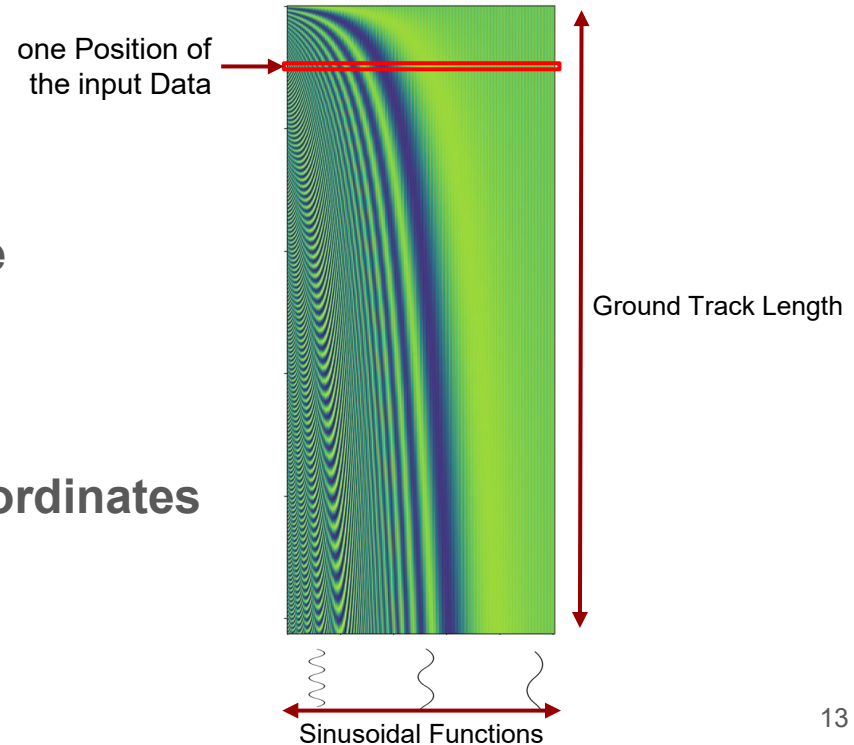- **Relative** Positional Encoding of the time

  - ➢ Added to Attention Maps

From Grid Maps to Ground Tracks - TEDDY

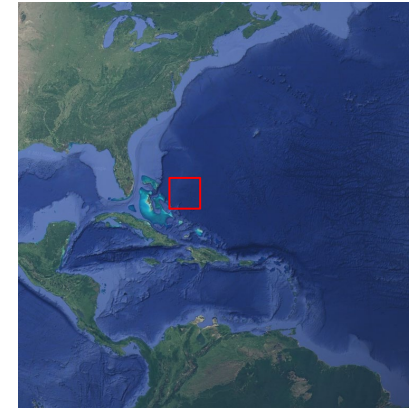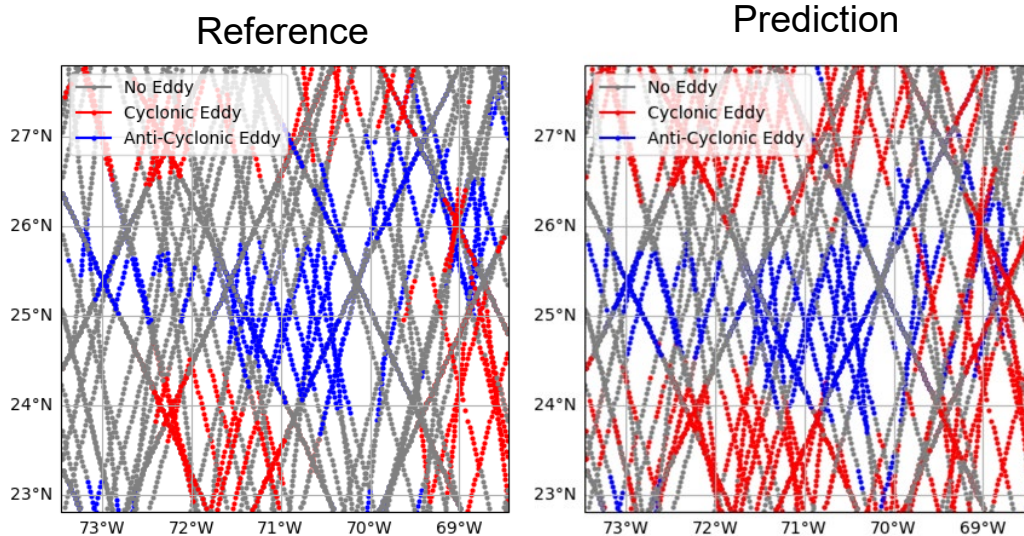**Absolute Positional Encoding**

Positional Encoding:

- **Relative** Positional Encoding of the **time**
  - ➢ Added to Attention Maps

- **Absolute** Positional Encoding of the **coordinates**
  - ➢ Added to the input data

one Position of the input Data

Ground Track Length

Sinusoidal Functions

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Vision Transformer: A. Dosovitskiy et al, An Image is Worth 16x16 Words: Transformers for Image Recognition at Scale (2020)

From Grid Maps to Ground Tracks - TEDDY

Resulting TEDDY predictions of a random sample

Reference

Prediction

Dice Scores

No Eddy	Cyclonic Eddies	Anticyclonic Eddies	Average
74.80%	47.06%	50.92%	57.59%

Outlook

How can multi-modal data be combined efficiently?

- Gridded data such as SLA or
  Sea Surface Temperature
  - Utilizing the strength of convolutions

- SLA Ground Track data
  - Considering spatiotemporal context
    with Transformers

-

64130	Eddy identification from along track altimeter data using deep learning: EDDY project
	Poster C1.06 Data assimilation and machine learning for the Earth system
Day 5 Friday	A. Abulaitijiang Speaker
	Bonn University, Germany

Thank you!

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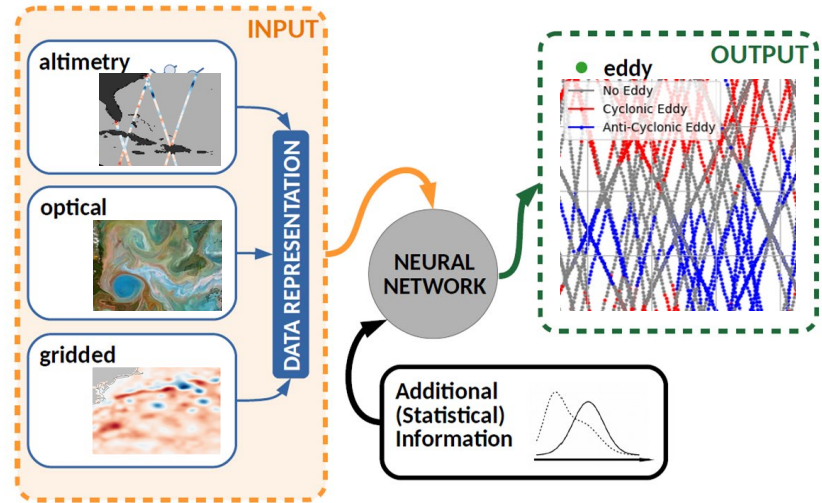 - Considering spatiotemporal context with Transformers

- 64130   Eddy identification from along track altimeter data using deep learning: EDDY project

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