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Ocean Surface Currents from Space

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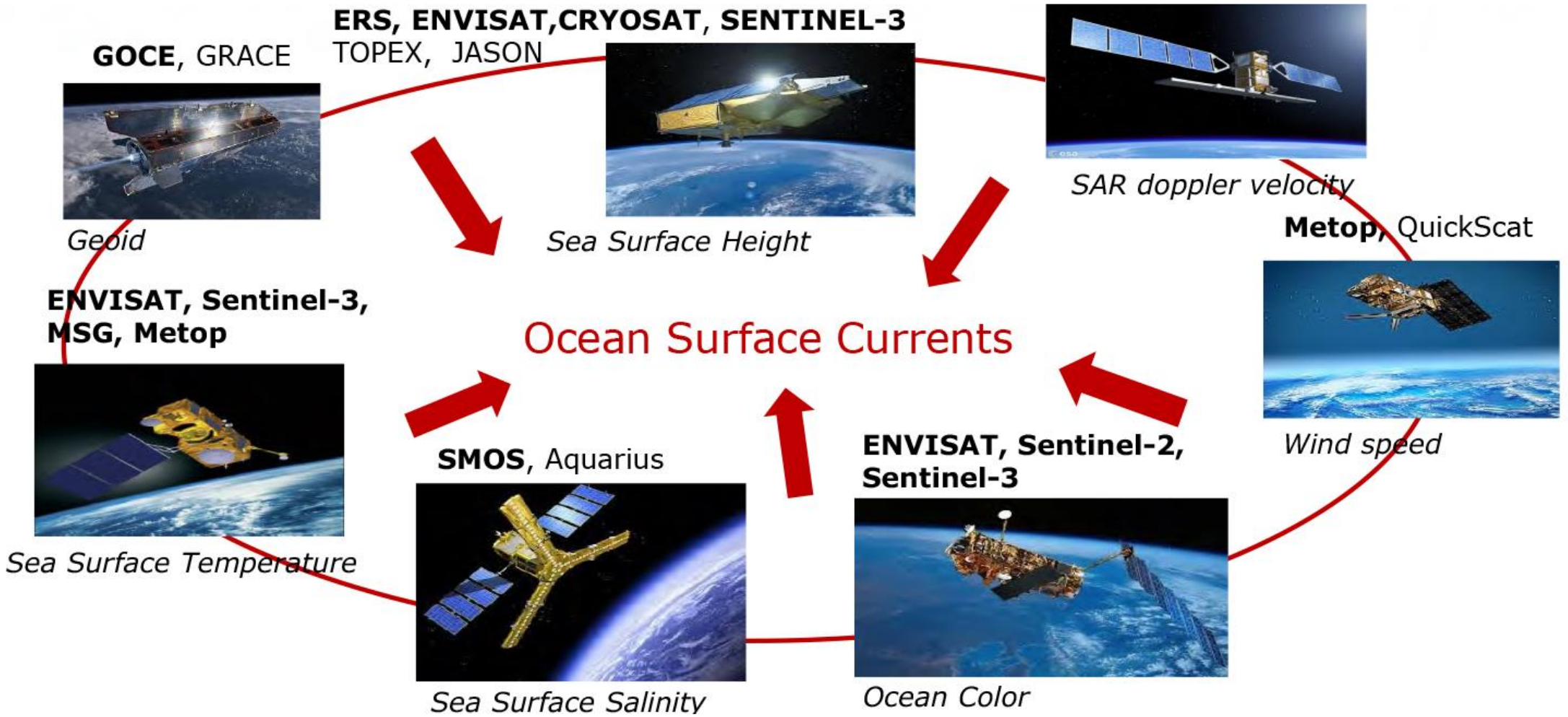
How measure surface currents from space?

NO direct measurement of ocean surface currents from space BUT…



How measure surface currents from space?

Sensor	Measured variable	Method	Surface current component retrieved	Spatio-temporal resolution
Altimeter + Gravimeter	Sea level above reference ellipsoid Geoid above reference ellipsoid	Optimally interpolated gridded field + Geostrophic approximation	Geostrophic current	100-400km 10-30 days
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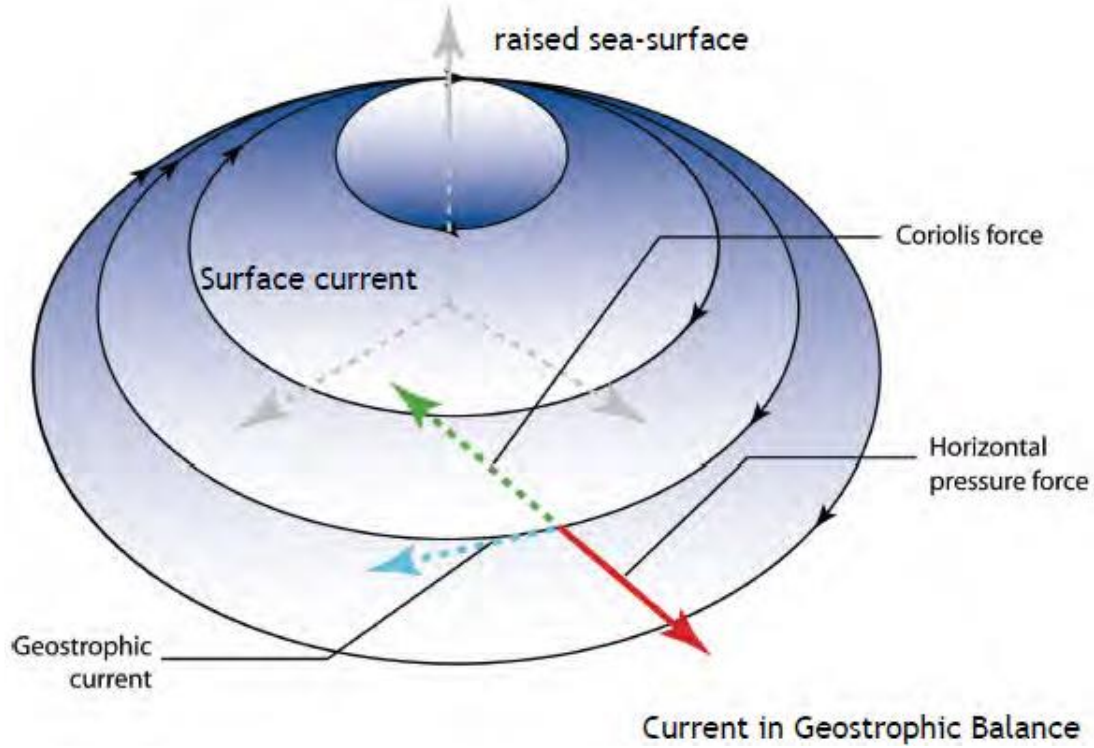
The geostrophic circulation

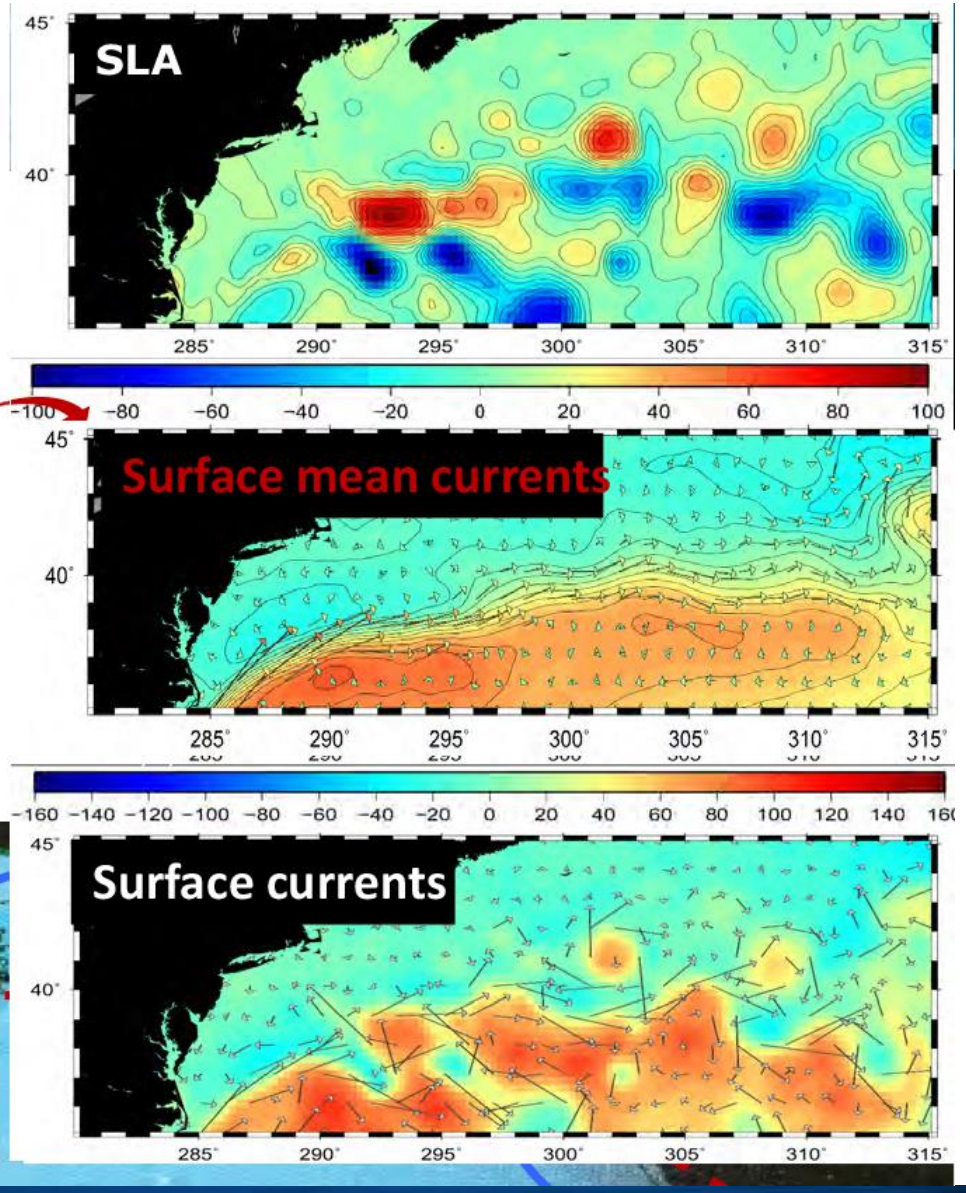
Away from the boundary layers and away from the equator, over large (>50-100km) spatial and long (>2-10days) temporal scales ocean is to the first order in geostrophic balance.



The ocean surface velocity field (u,v) can be readily obtained from the gradients of h, the sea level above the geoid h.

Estimating ocean surface currents from space

Altimetry + Gravimetry



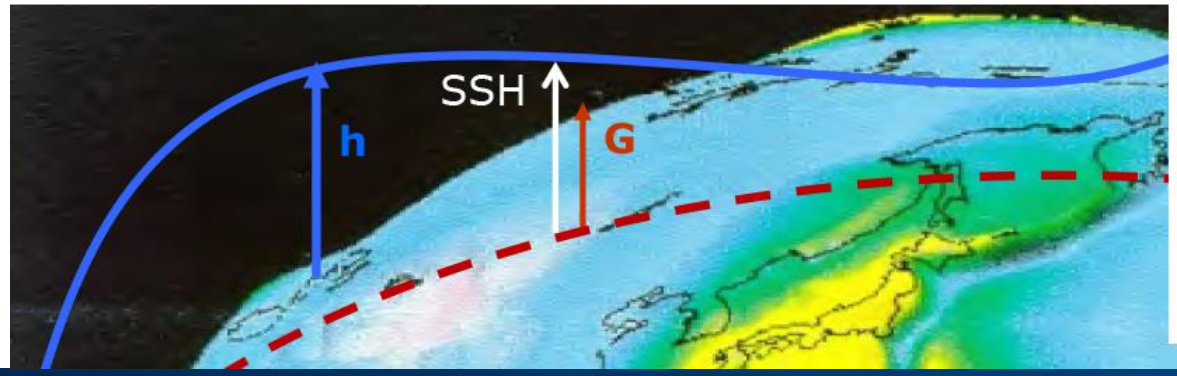
Some very simple equations

SSH=h+G ↔ h=SSH-G

MSSH=MDT+G ↔ MDT=MSSH-G

SSH-MSSH=h-MDT=SLA

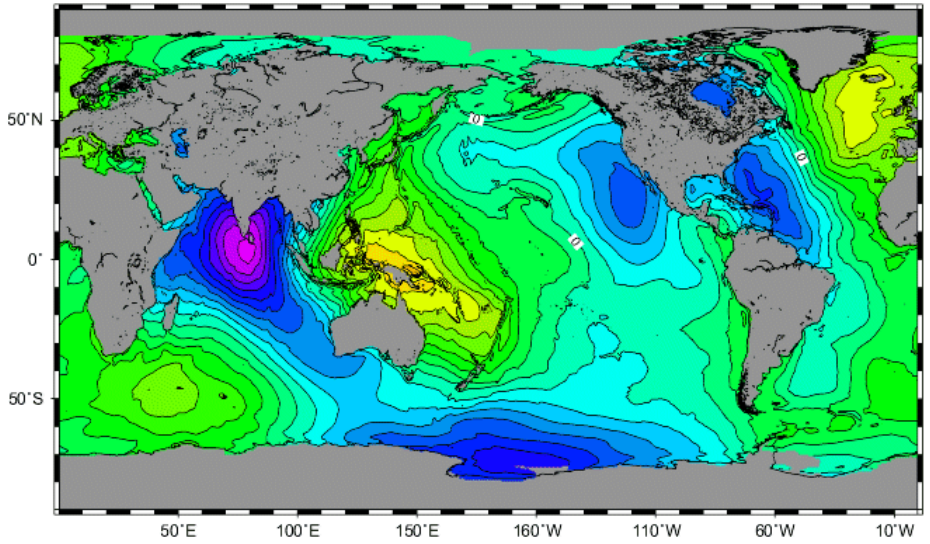
h=SLA+MDT



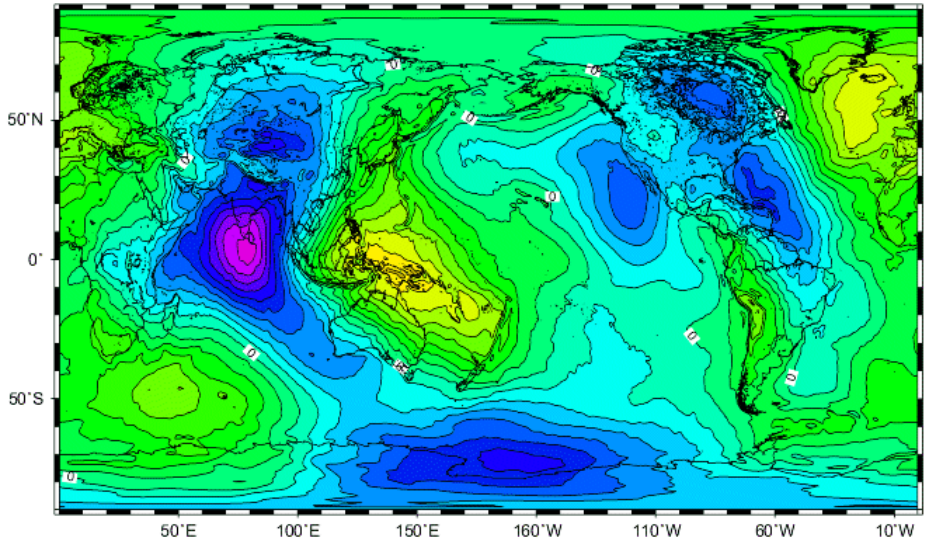
Estimating ocean surface currents from space

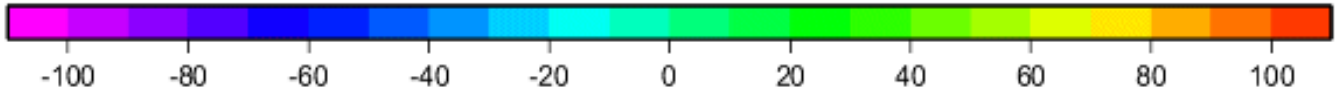
MDT = MSSH – GEOID

MSSH



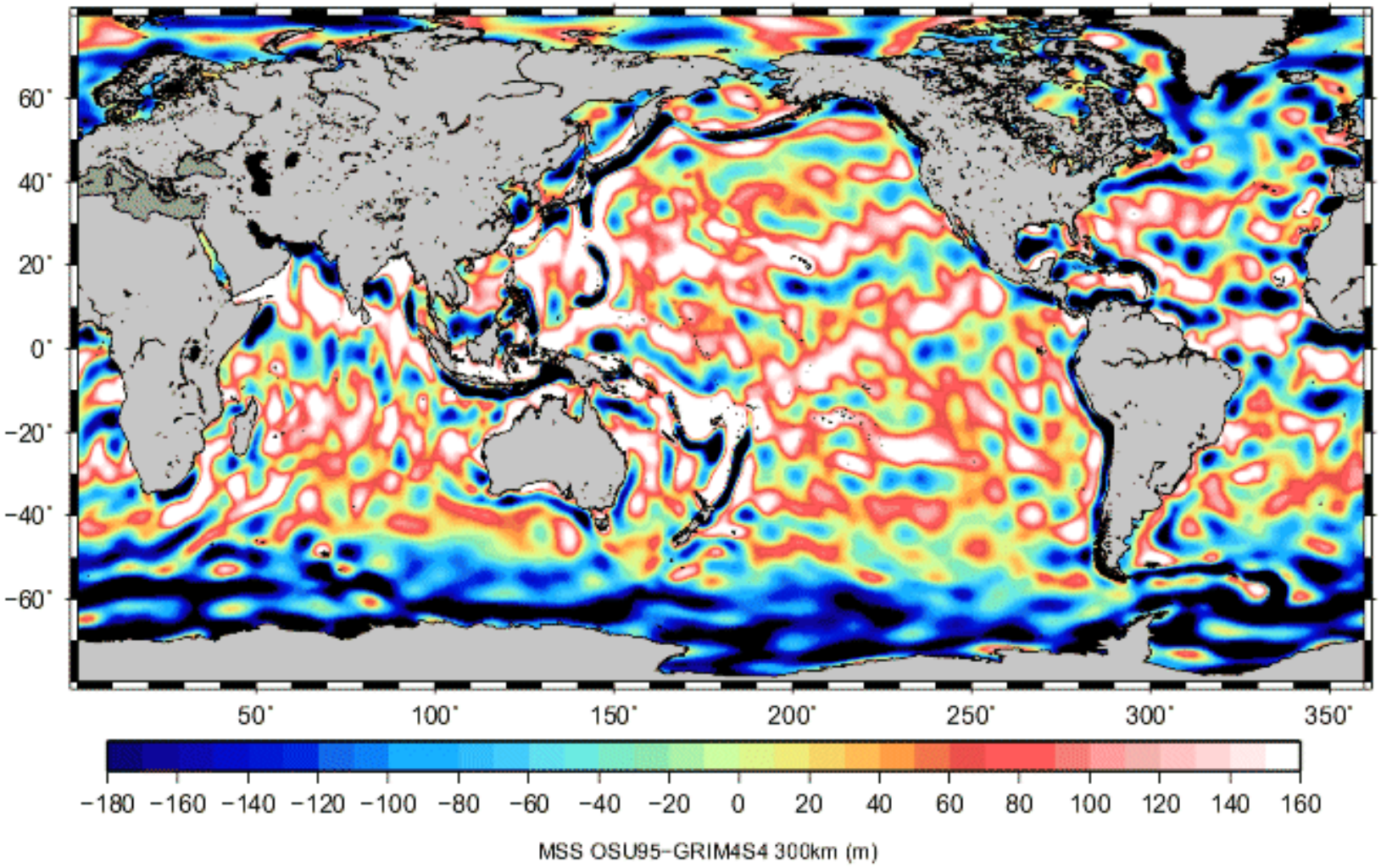
GEOID





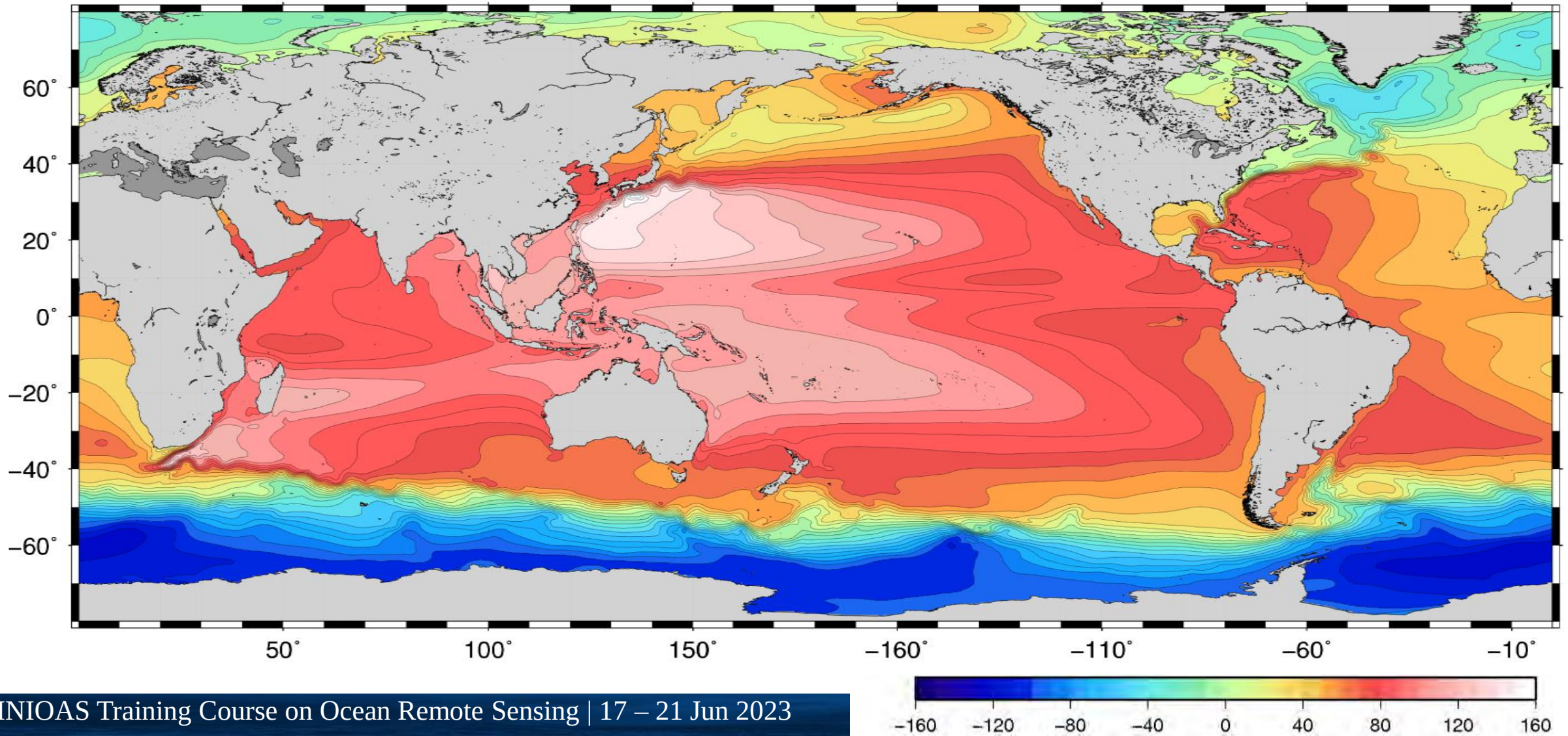
Estimating ocean surface currents from space

The MDT from altimetry and gravity data, Raw difference



Estimating ocean surface currents from space

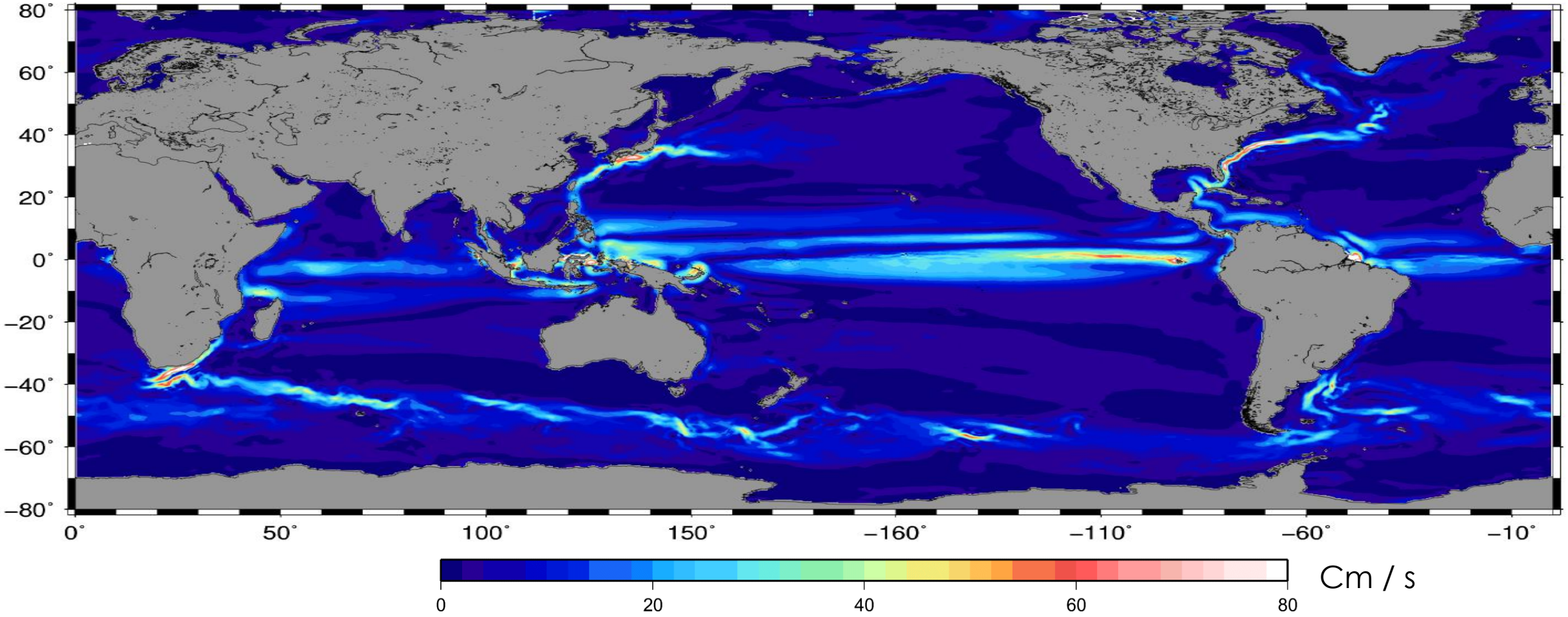
The MDT from altimetry and gravity data, Optimally filtered (cm)



Estimating ocean surface currents from space

Mean geostrophic currents speed: GOCE

GOCE (Gravity field and steady-state Ocean Circulation Experiment) mission, launched in 2009



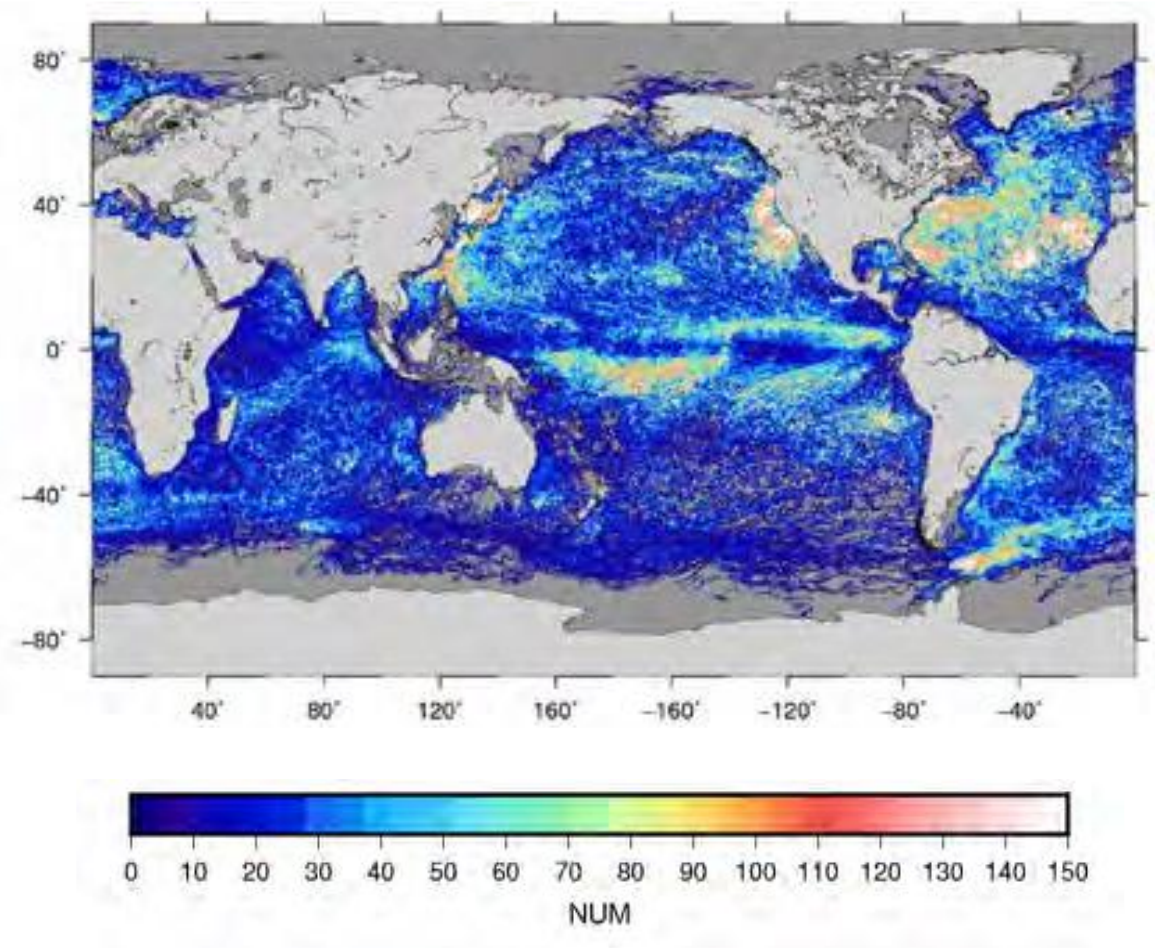
Estimating ocean surface currents from space

In-Situ measurements: drifting buoys

SVP (Surface Velocity Program) type

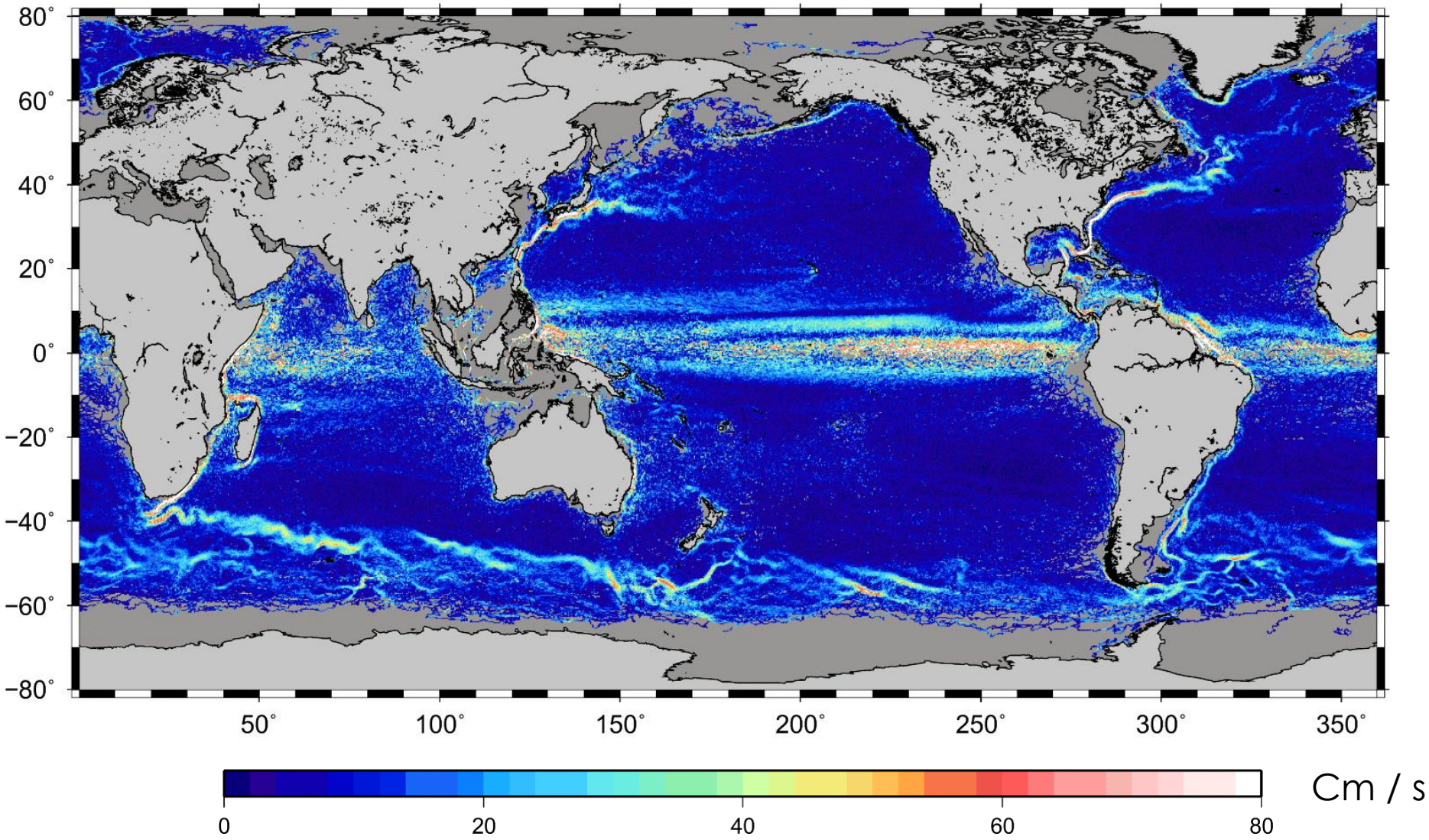
- Buoy position localized by Argos/Iridium
- Have been designed to minimize the direct winds lippage (less than 0.7 cm/s in 10 m/s winds)
- Forecast loss detection sensor
- After quality control and position processing, regularly sampled velocities are estimated along the buoy trajectory.
  - Time sampling: 1hour, 6hours
  - Lifetime: ~400 days

Number of obs (1993-2016)



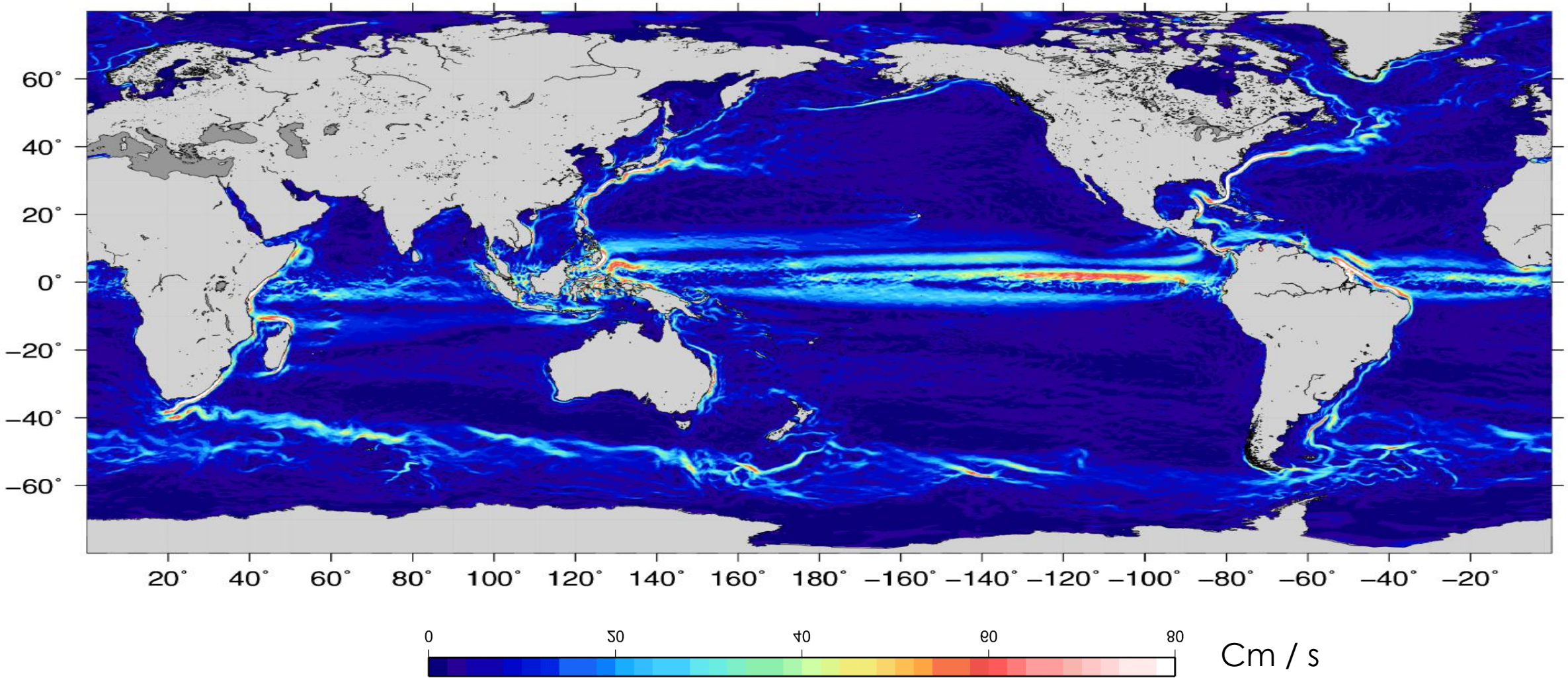
Estimating ocean surface currents from space

Mean geostrophic currents speed from in-situ measurements



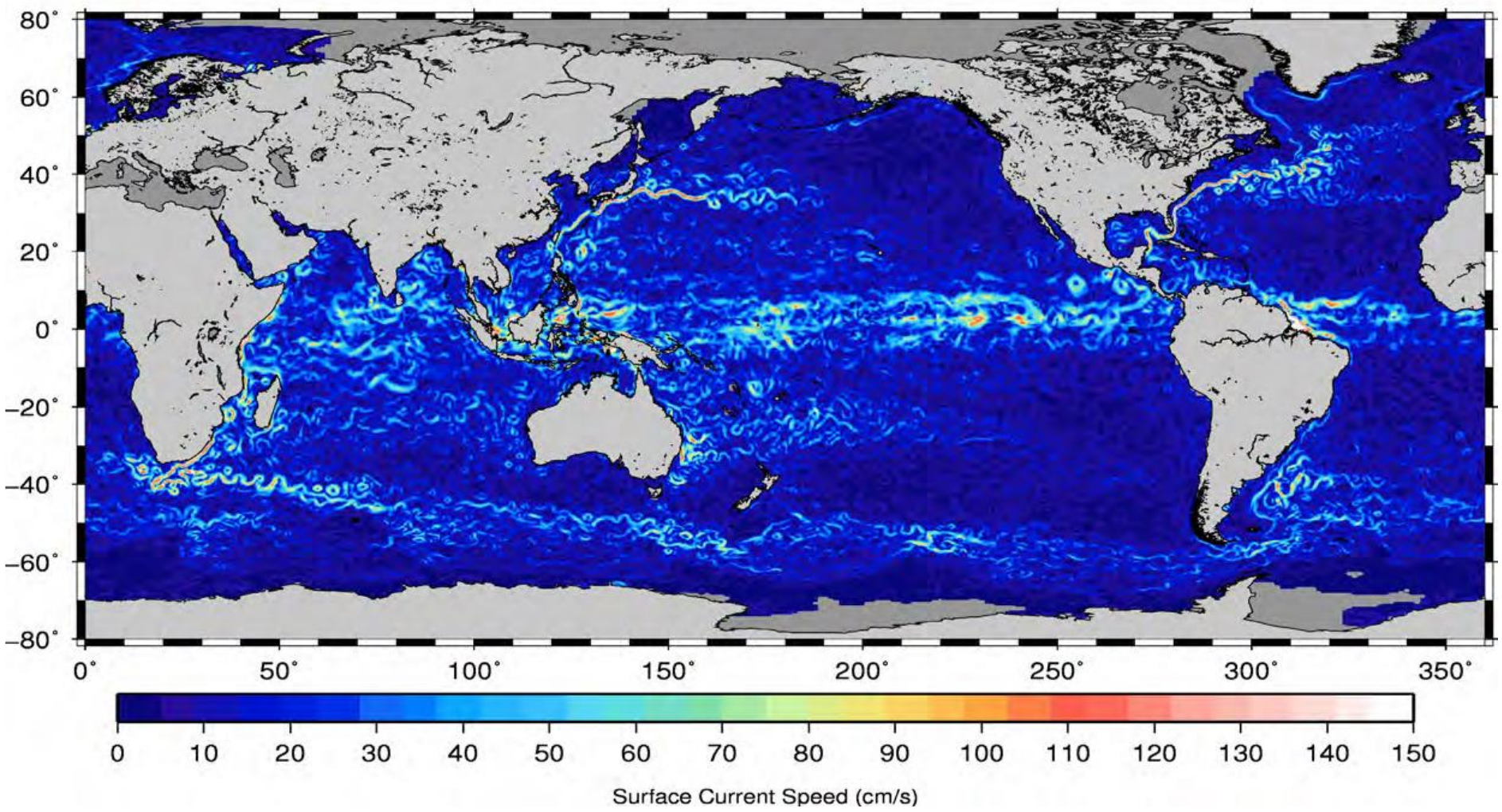
Estimating ocean surface currents from space

Mean geostrophic currents speed from Altimetry + GOCE + in-situ measurements



Estimating ocean surface currents from space

24 years of geostrophic currents speed from Altimetry + GOCE + in-situ measurements



Estimating ocean surface currents from space: Altimetry+ Gravimetry

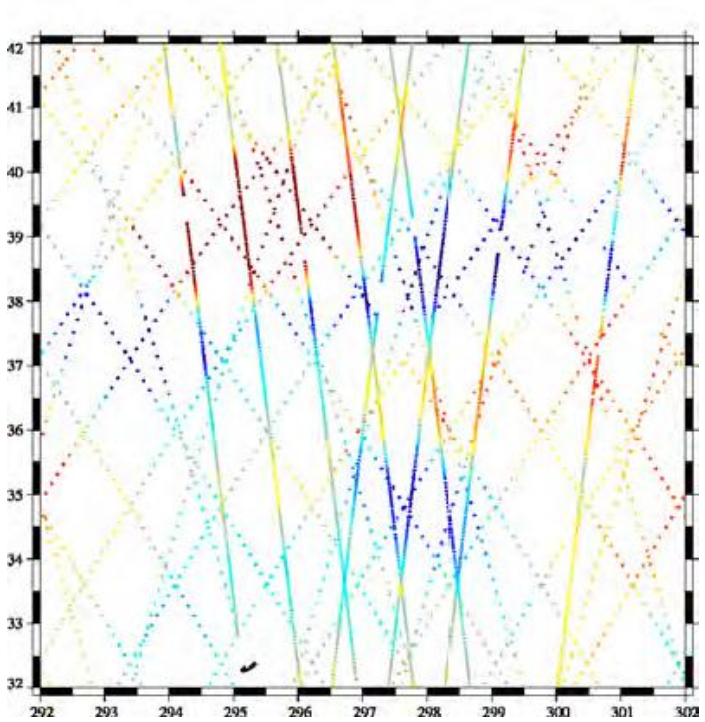
25 years of geostrophic currents from gravity + altimetry, (+ near real time and real time products):

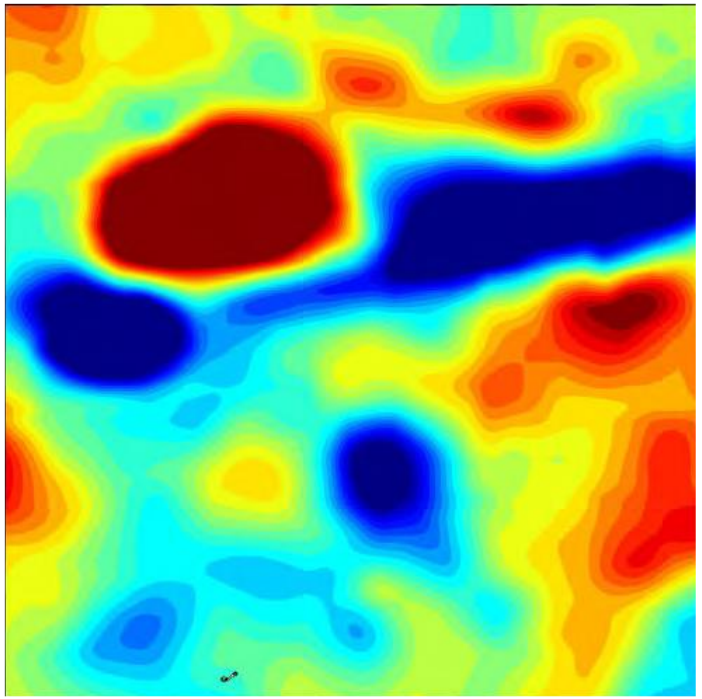
Only the **geostrophic component of the surface current** is obtained

Missing a geostrophic components include:

- Ekman currents
- Stokes drift
- Inertial oscillations
- Tidal currents

The **spatial and temporal** resolution depend on the altimeter constellation





Estimating ocean surface currents from space

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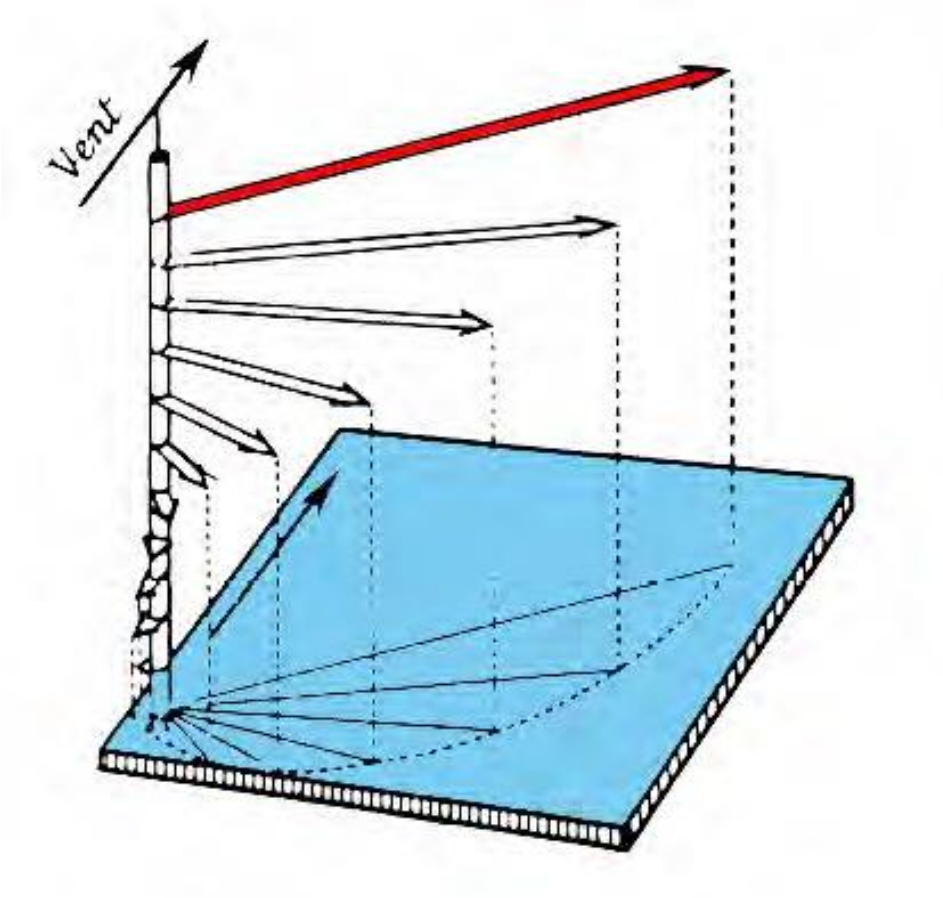
Estimating ocean surface currents from space: Wind, Ekman Model

Wind-driven Ekman

- **Ekman currents** are ocean currents that are generated by wind blowing over the surface of the ocean.
- Wind creates a drag force that causes the water to move in a circular motion.
- The direction of this motion is influenced by the Coriolis effect.
- The Ekman current is the results from the combined effect of the wind and the Coriolis effect.
- These currents are typically found in the upper 100 to 200 meters of the ocean.
- Ekman currents have a significant impact on ocean circulation.



Estimating ocean surface currents from space: Wind, Ekman Model

The Ekman currents

$$\vec{u}_e = \beta \vec{\tau} e^{i\theta}$$

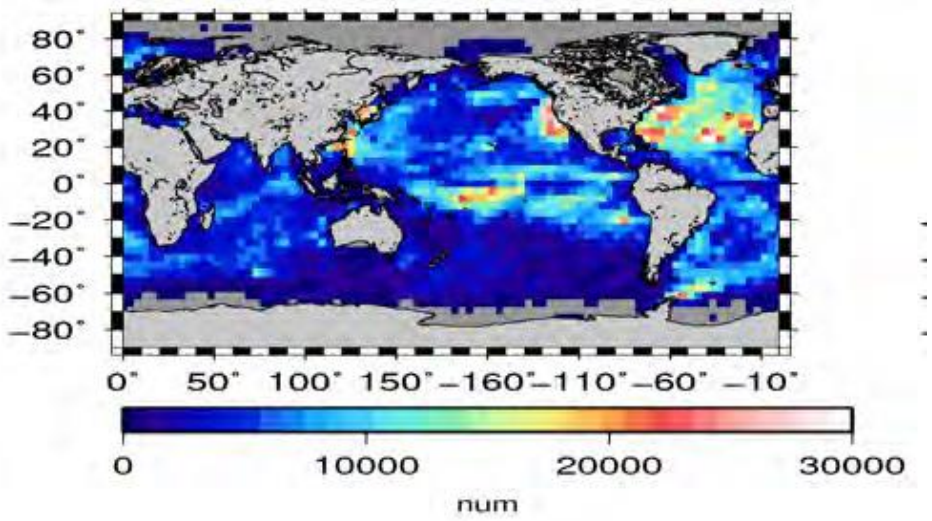
$\vec{u}_{buoy} - \vec{u}_{alti}$

Wind stress (ERA-INTERIM from ECMWF)

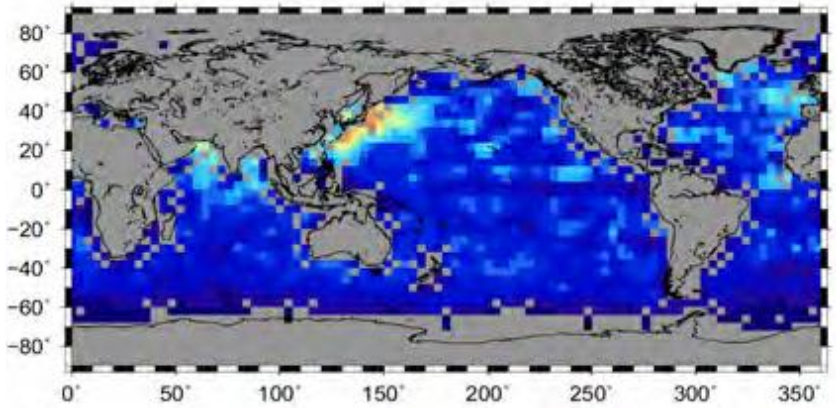
Model

Rio et al, 2003, 2014

Number of buoy velocities at15m depth
Period: 1993-2014

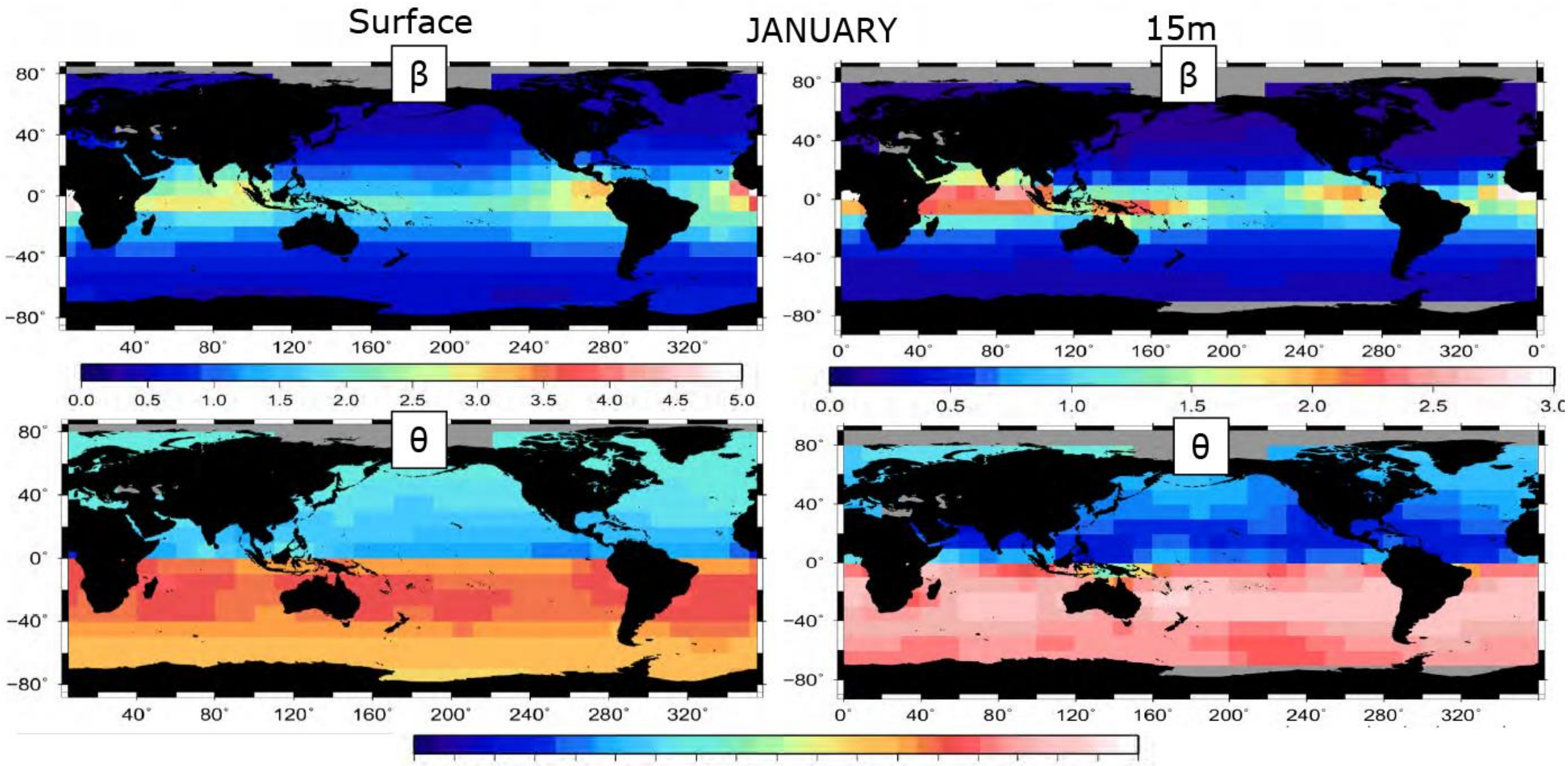


Number of Argo float surface velocities
Period: 1997-2014



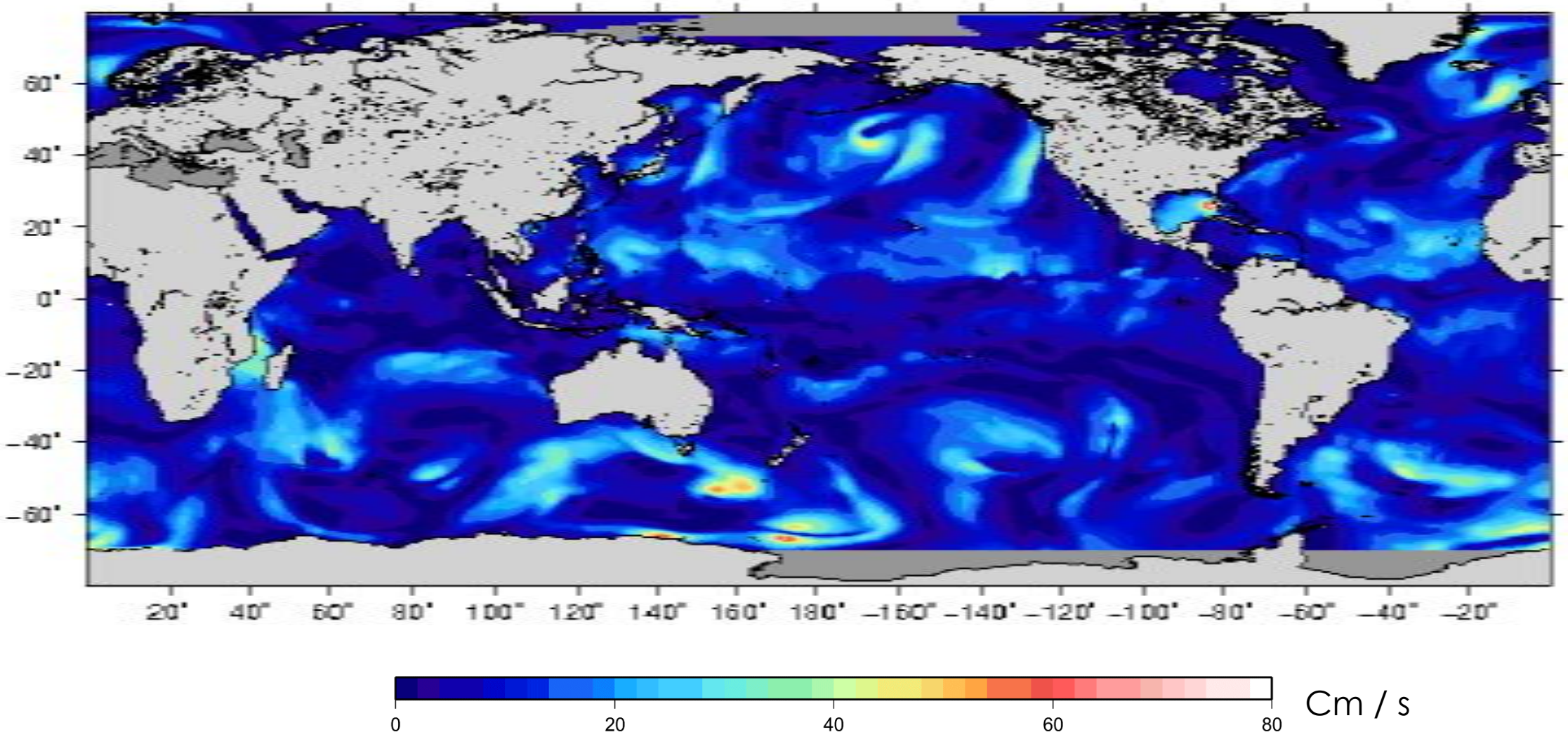
B and θ are estimated through least square fit

Estimating ocean surface currents from space: Wind, Ekman Model



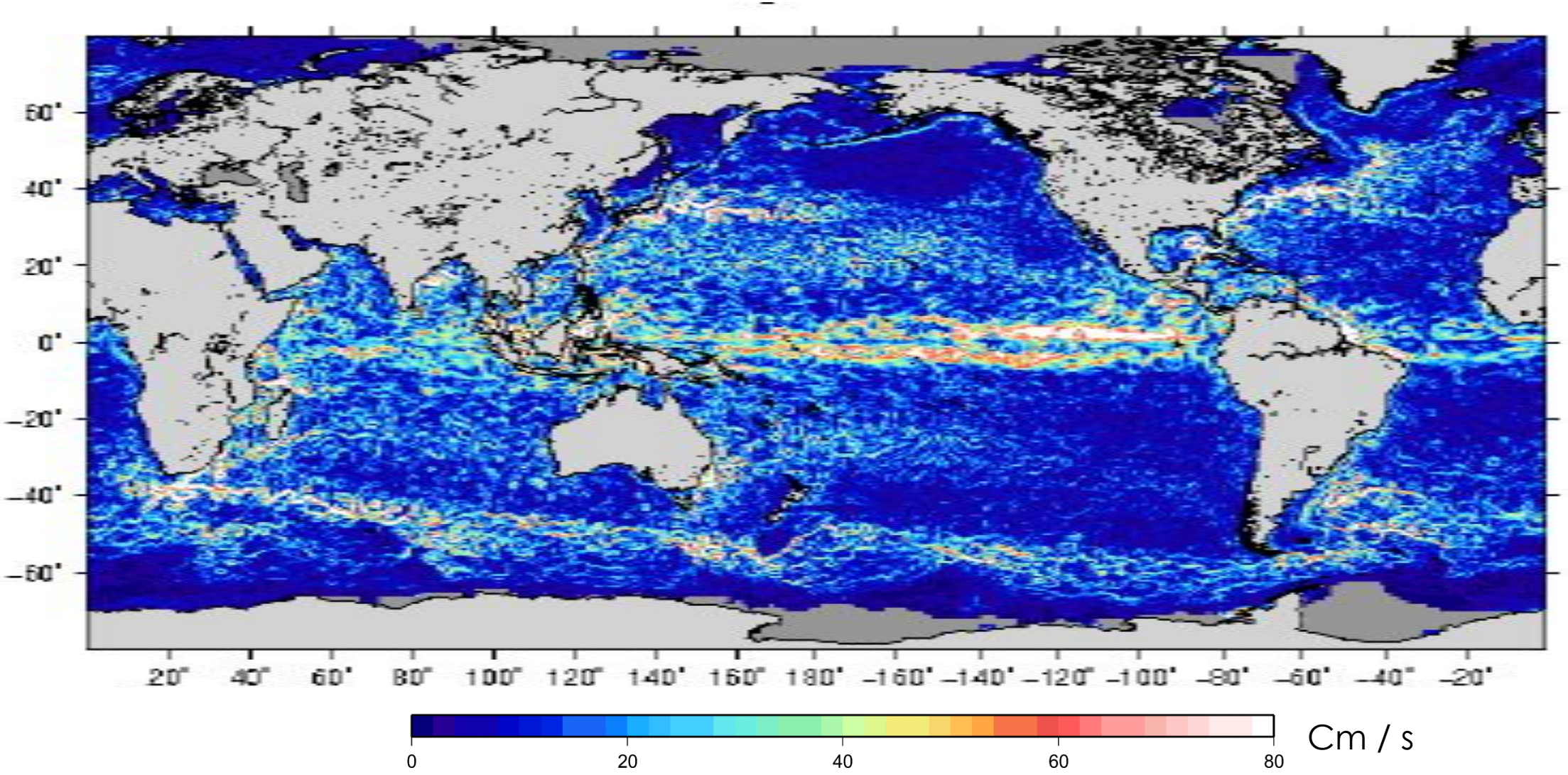
Estimating ocean surface currents from space: Wind, Ekman Model

The Ekman current May, 5th 2016

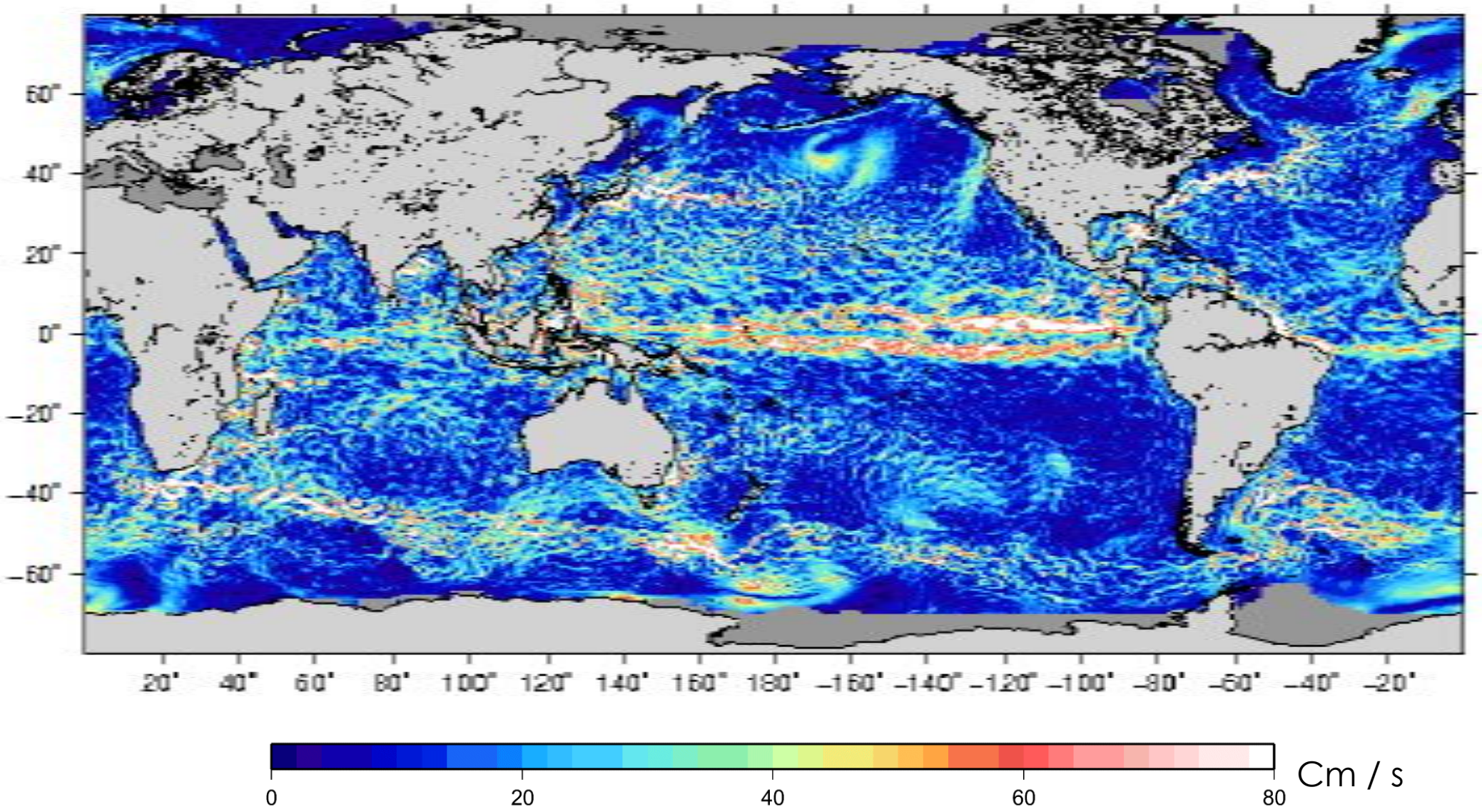


Estimating ocean surface currents from space: Wind, Ekman Model

The Geostrophic current May, 5th 2016



Estimating Ocean Surface Current from Gravity + Altimetry + Wind



Estimating ocean surface currents from space

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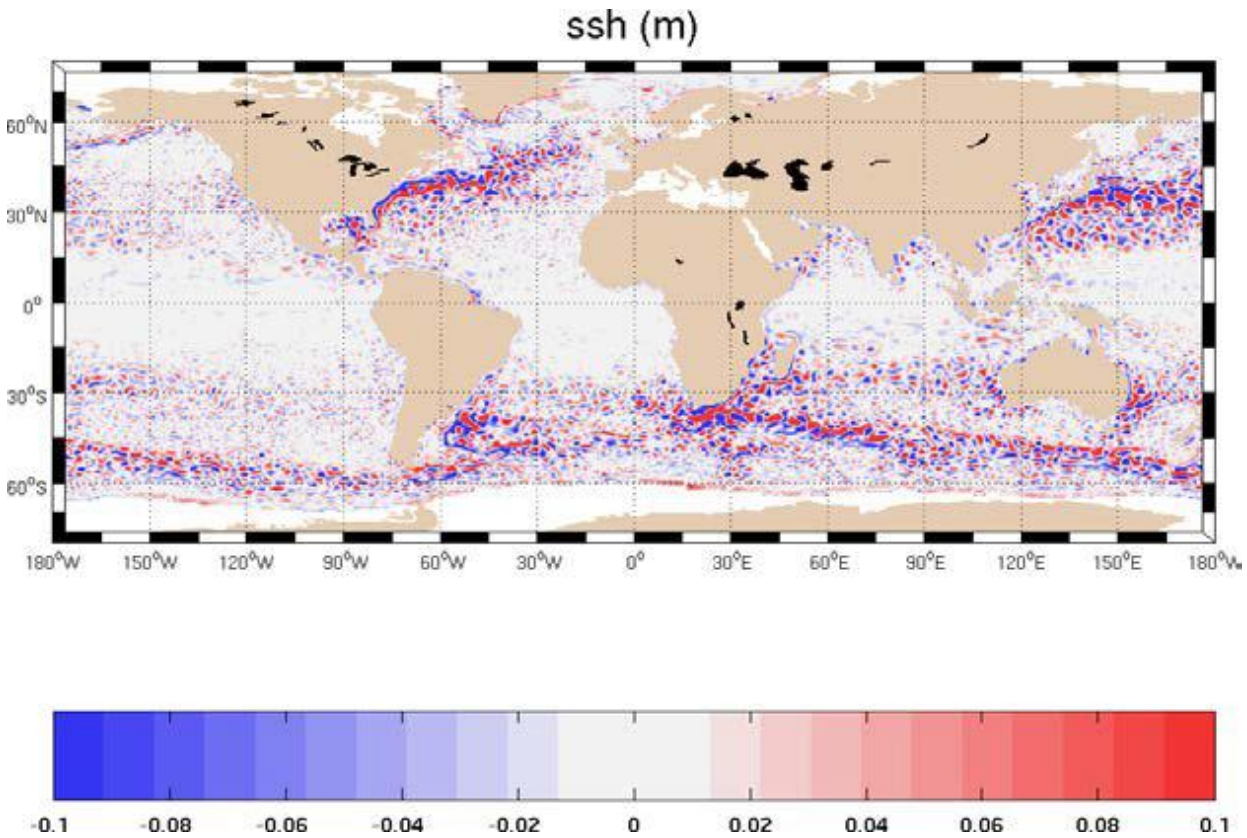
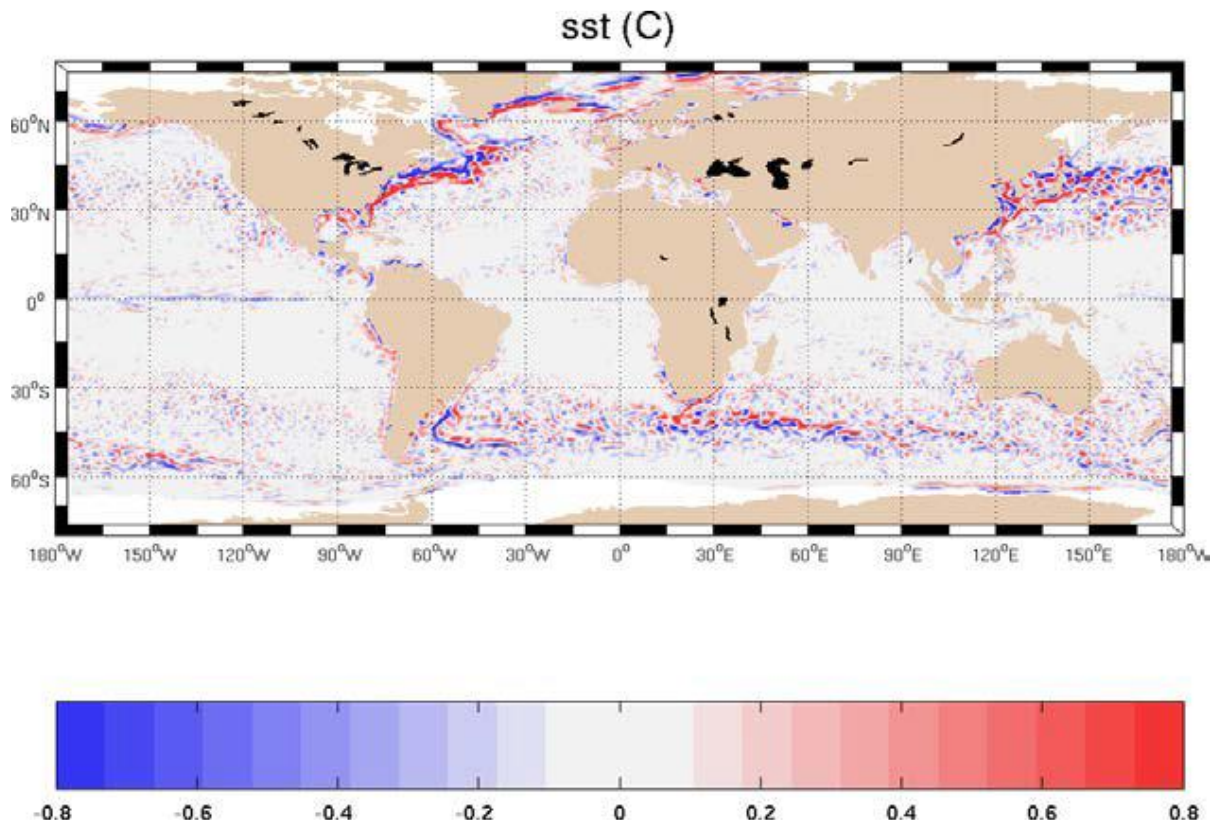
Estimating ocean surface currents from space: Wind, Ekman Model

Deriving surface currents from tracer information

- In cases when the upper ocean is well mixed, as for instance during winter, the geostrophic motions can be constrained by the SST and SSH anomalies.



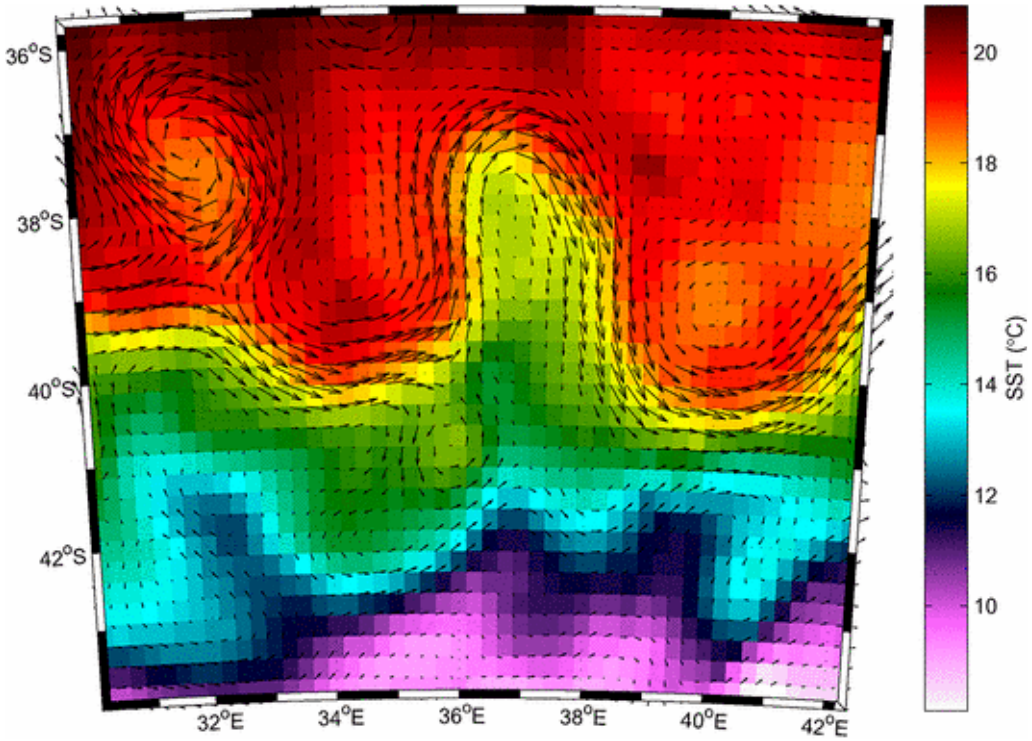


Estimating ocean surface currents from space

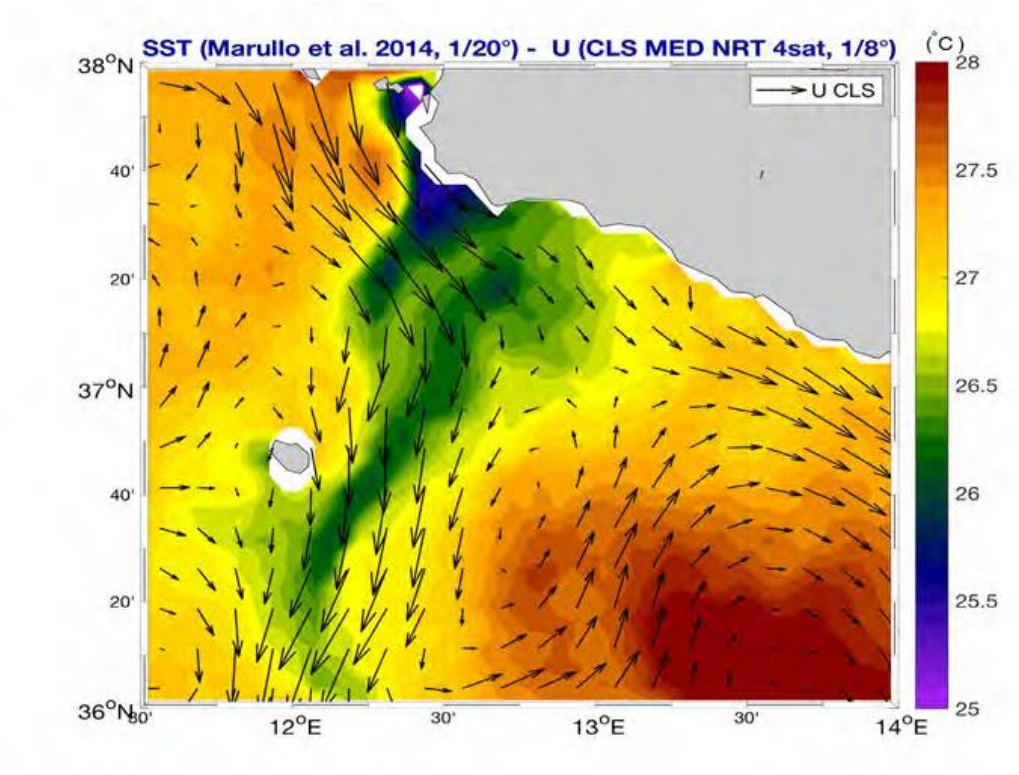
- The emerging and rich mesoscale circulation from SSH measurements, apparently stirs the large-scale SST fields.
- SST (a proxy of the upper layer density) can indeed become an active tracer coupled to the dynamics, leading to strong correlations with SSH fields.
- A qualitative inspection of the filtered SSH and SST global fields does not contradict such an assumption.
- The local relationships between SST, SSH, possibly SSS and the derived surface currents from satellite-based routine observations

Estimating ocean surface currents from space

Deriving surface currents from tracer information



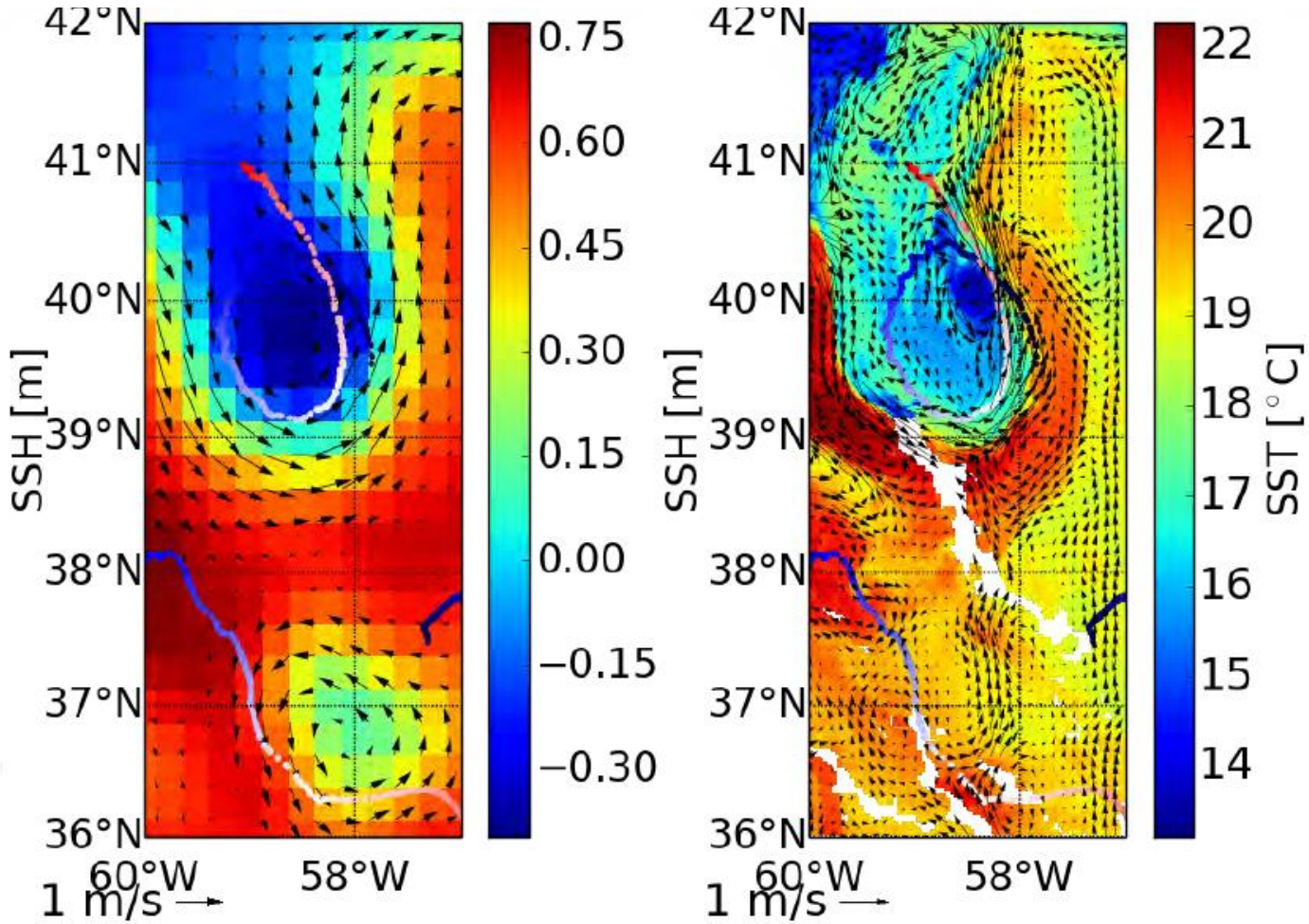
Microwave SST product
Altimeter geostrophic velocities



Microwave+ Infrared SST product
Altimeter geostrophic velocities

Estimating ocean surface currents from space

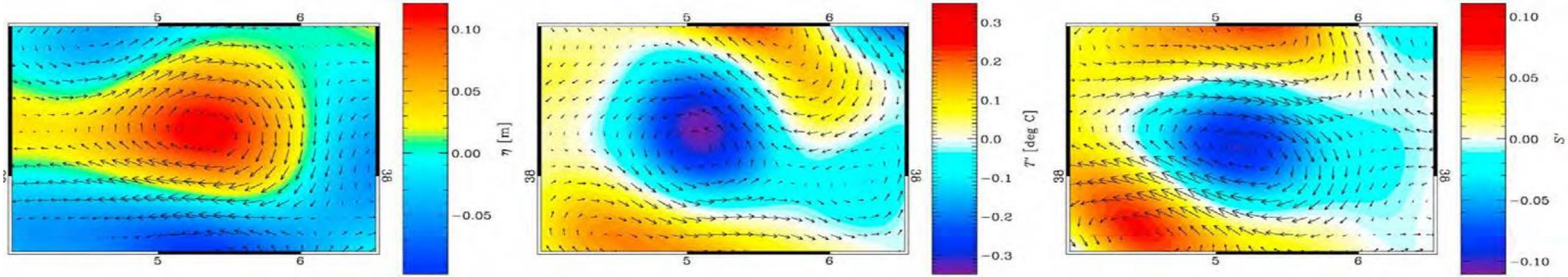
Surface currents are described by Combination of the phase of SST measurements and the amplitude of SSH measurements.



Estimating ocean surface currents from space

Limitation of Deriving surface currents from tracer information

- Limited to **the retrieval of mesoscale (30-300km),** not the large scale currents
- This is valid in baroclinic instabilities areas, and **strong gradients areas**
- In addition, the validity of this approximation is limited to cases when the SST is a good proxy of the density anomaly at the base of the mixed layer.



(left) SSH anomaly with the geostrophic velocities overplotted, (middle) SST anomaly with the velocities derived from SST, and (right) SSS anomaly with the velocities derived from SSS.

Estimating ocean surface currents from space

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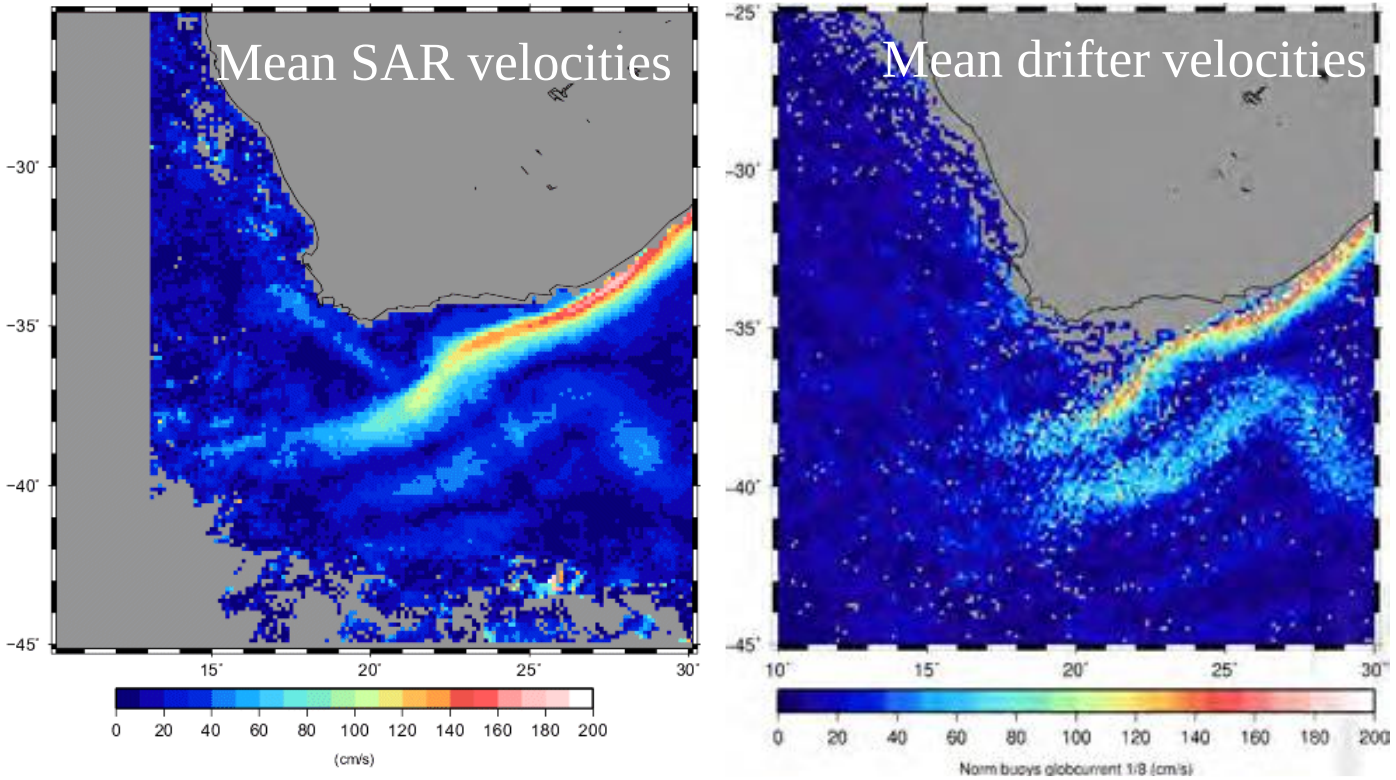
Estimating ocean surface currents from space

Surface velocities from SAR measurements

A Doppler shift is measured between the Signal emitted by the instrument and the signal **backscattered** by the sea surface and **measured** by the SAR antenna.

Sea surface current, with10 km pixel size that contains the contributions, **projected on to the range direction**, of the **geostrophic currents, the tidal currents**

SAR Doppler shift provides range velocities only. Altimeter velocity or SST front direction information can be used to recover the two components velocity.

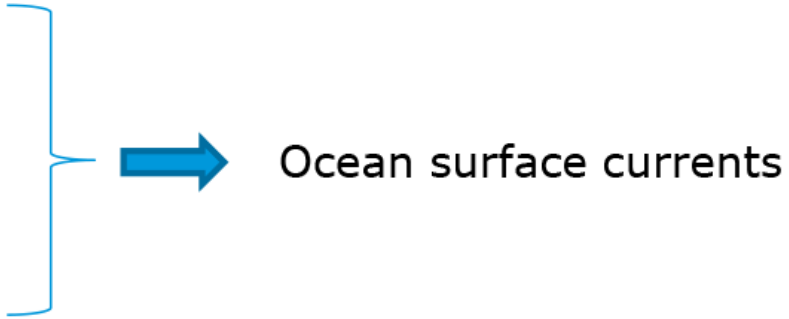


Estimating ocean surface currents from space

Conclusions

At the present time, **no direct measurement** of ocean surface currents from space
High number of space-borne sensors measuring different ocean variables from which ocean surface currents can be indirectly inferred.

SENSORS	VARIABLES	METHODS
Altimeter	altimetry	geostrophy
Radiometer	SST, SSS	MCC, e-SQG
Spectrometer	OC	Optical flow
SAR	rugosity	Doppler shift
Scatterometer	Wind	Ekman model



Each method has benefits and drawbacks in term of physical content, spatial and temporal coverage, accuracy

For optimal exploitation of space data and best estimation of ocean surface currents, **Ocean Data Lab and in-situ measurements needed**

Thank You