Zonal jets in the Madagascar plankton bloom

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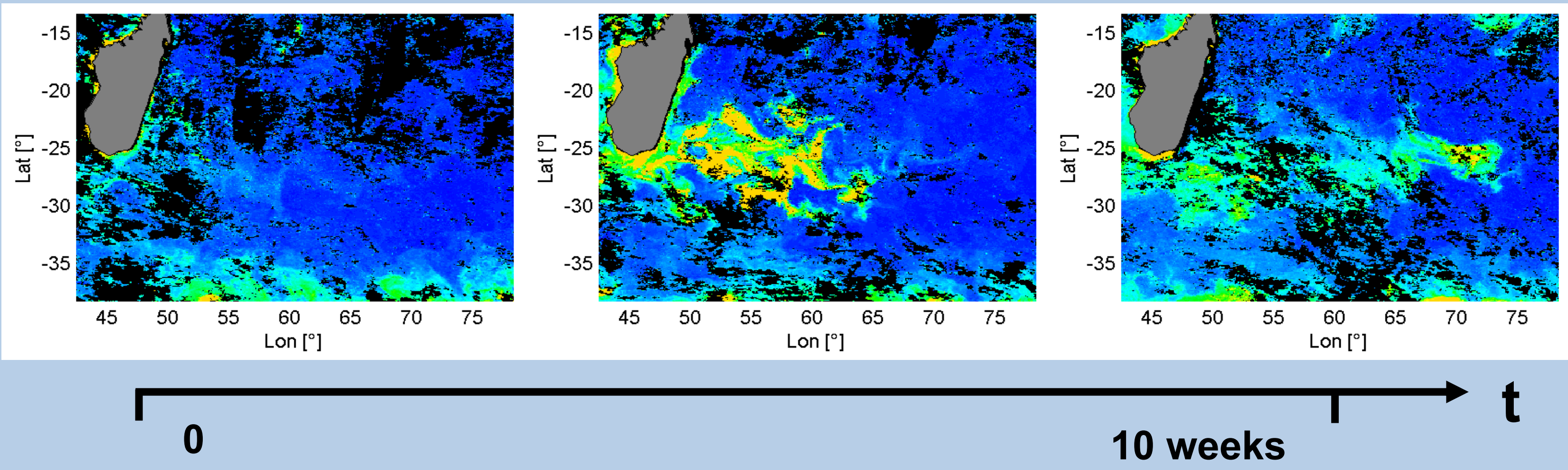
Madagascar plankton bloom



The Madagascar plankton bloom is one of the largest, most pronounced dendroid plankton blooms in the oceans. It often shows an explosive propagation over 2000 km to the east in few weeks from its origin south of Madagascar. Typically in February or March the plankton bloom reaches its largest extent, but it also exhibits a strong interanual variability. The temporal evolution of the plankton bloom and its filamentary shape suggest that advection by horizontal mesoscale circulation is a key process. In particular, the recently discovered South Indian Ocean Countercurrent (SICC) runs along ~25ºS, the latitude where the plankton bloom develops, and has so far not been linked to the Madagascar plankton bloom.

Question: What is the impact of advective transport on the plankton bloom? Does the plankton bloom go with the flow?

Compare chlorophyll patterns with patterns of Lagrangian passive transport in the horizontal mesoscale flow

Data and methods

Lagrangian quantities are computed from trajectories of particles initialized on a fine grid. They are advected for 12 weeks in the geostrophic velocity field in Lon/Lat coordinates (λ,θ) following the equations of motion

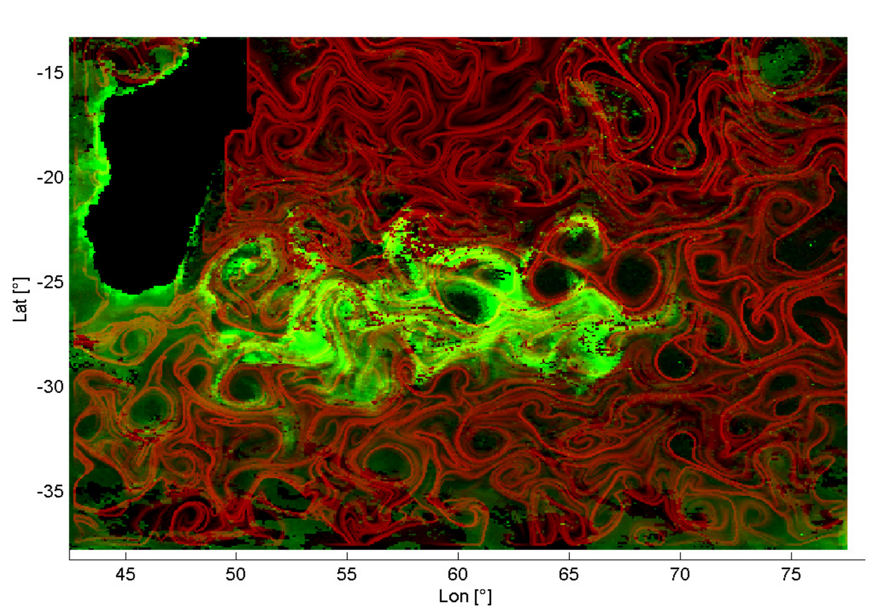
$$\dot{\lambda} = -\frac{g}{R^2 f(\theta)\cos\theta}\partial_\theta \eta(\lambda,\theta,t),$$
$$\dot{\theta} = +\frac{g}{R^2 f(\theta)\cos\theta}\partial_\lambda \eta(\lambda,\theta,t).$$

Lagrangian Coherent Structures (LCS) are organizing centers for Lagrangian patterns in the time-dependent flow. As material lines they are transport barriers and mark the locally strongest attraction, repulsion or shearing in the flow. LCS can be estimated as ridges in fields of the Finite-time Lyapunov Exponent (FTLE).

Satellite data sets

1) Plankton: chlorophyll concentration, 8-day composite maps from the SeaWiFSensor

2) Flow field: weekly geostrophic velocity field from AVISO multi-satellite altimetric SSH maps



Chlorophyll concentration (green) and attracting Lagrangian Coherent Structures (red)

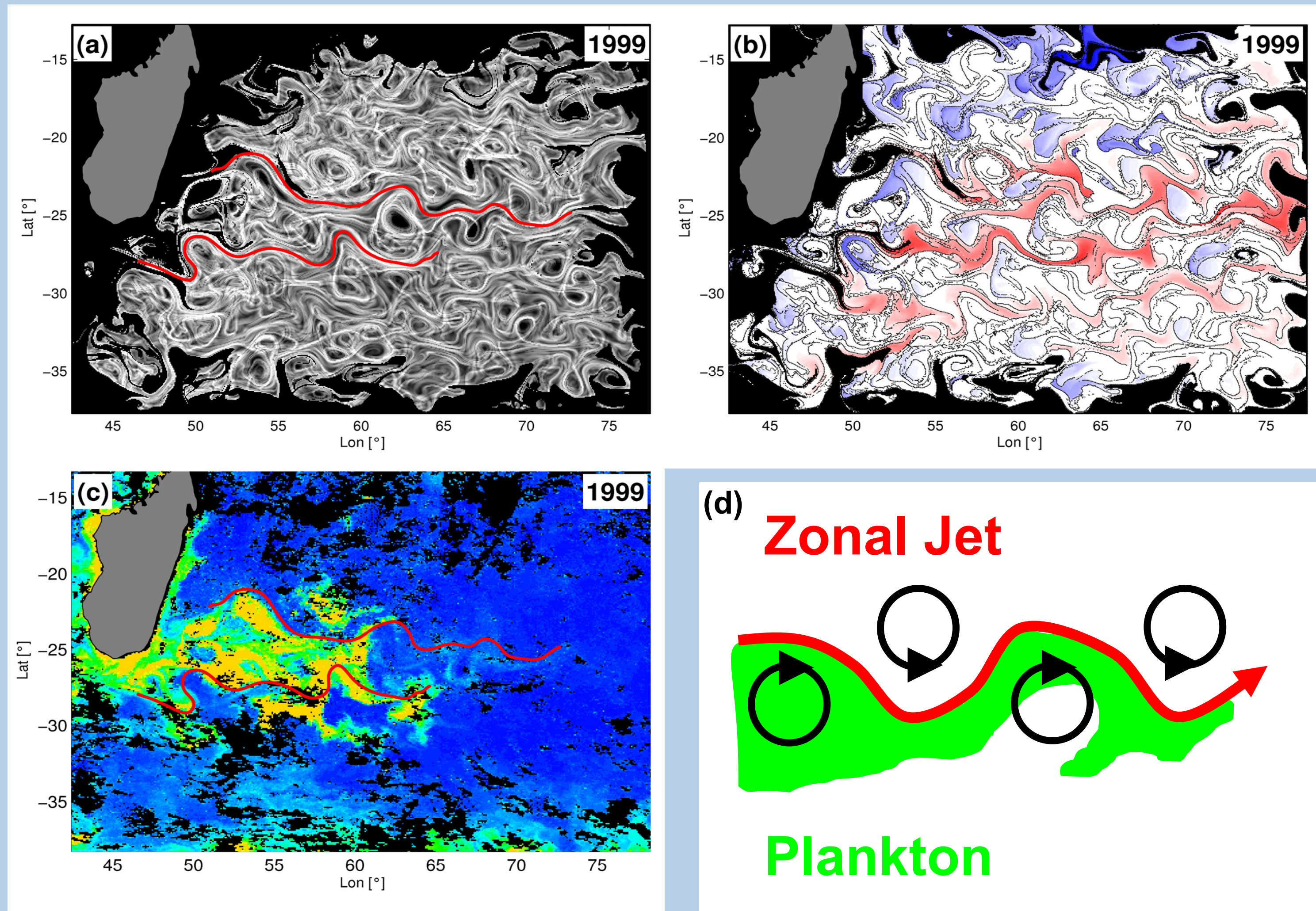
Lagrangian transport patterns

a) Map of the FTLE with highlighted jet-like LCS (red) that act as barriers to meridional transport.

b) Map of the zonal eastward drift of particles clearly visualizing the regions of fast eastward transport in the South Indian Ocean Countercurrent that coincide with the jet-like LCS

c) Chlorophyll concentration with highlighted jet-like LCS. The extracted transport barrires agree with large parts of the boundary of the plankton bloom.

d) Simplified and idealized sketch of the transport pattern: plankton is transported eastwards along the zonal jet. The coherent transport barrier impedes meridional transport and confines the plankton bloom to the north.

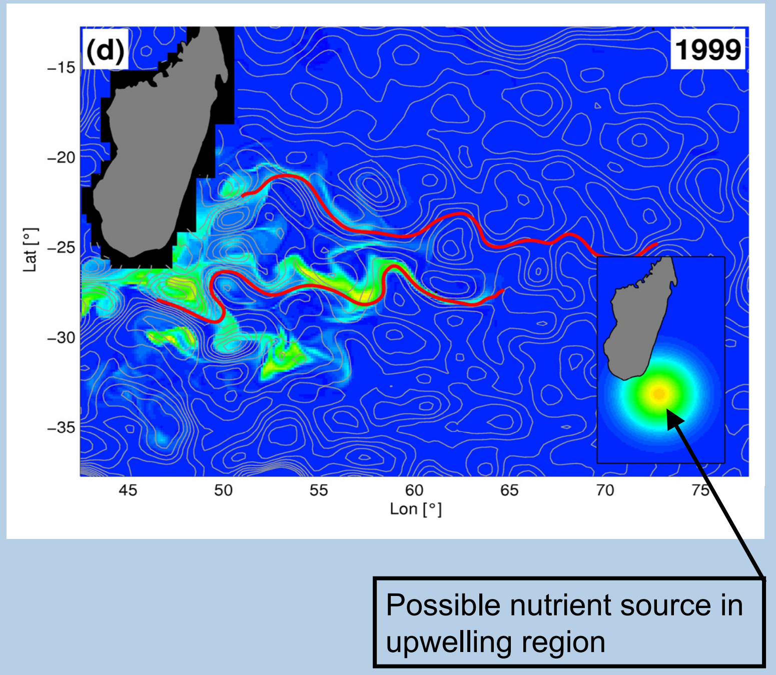


Zonal jets transport plankton

Jet-like LCS shape boundaries of the plankton bloom

Passive tracer

The distribution of a passive tracer released at the proposed origin of the plankton bloom at the south tip of Madagascar resembles the observed chlorophyll pattern above. Two tracer filaments extend to the east along the two existing zonal jets.



Front velocity

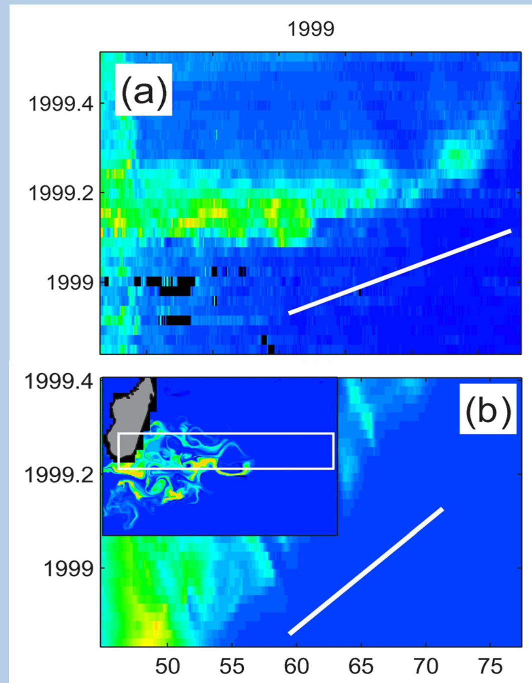
Space-time Hovmöller plots of front propagation.

a) Plankton (chlorophyll)

Plankton front: ~0.25 m/s

b) Passive tracer

Tracer front: ~0.14 m/s
Particles: ~0.14 m/s



Plankton front faster than pure flow

Conclusions

Zonal jets in the SICC provide fast persistent eastward transport for plankton bloom

Jet-like LCS associated with zonal jets act as barriers to meridional transport

Hypothesis of origin at south tip of Madagascar supported

References

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