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# OCEANIC SUBMESOSCALE SAMPLING WITH WIDE-SWATH ALTIMETRY

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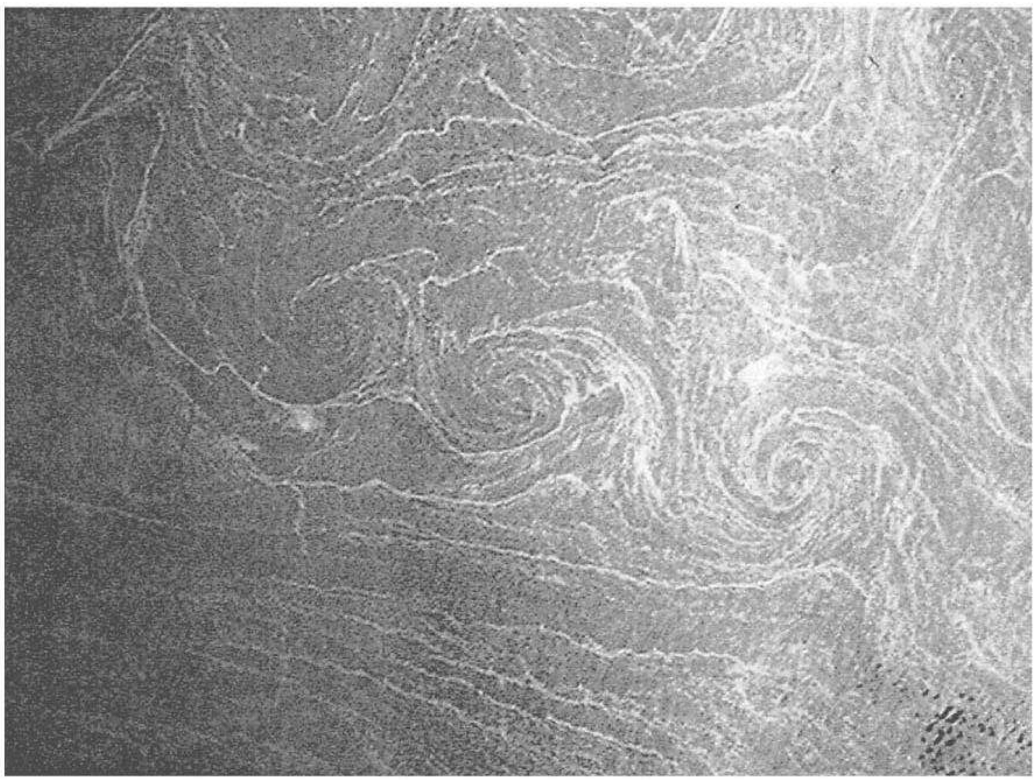
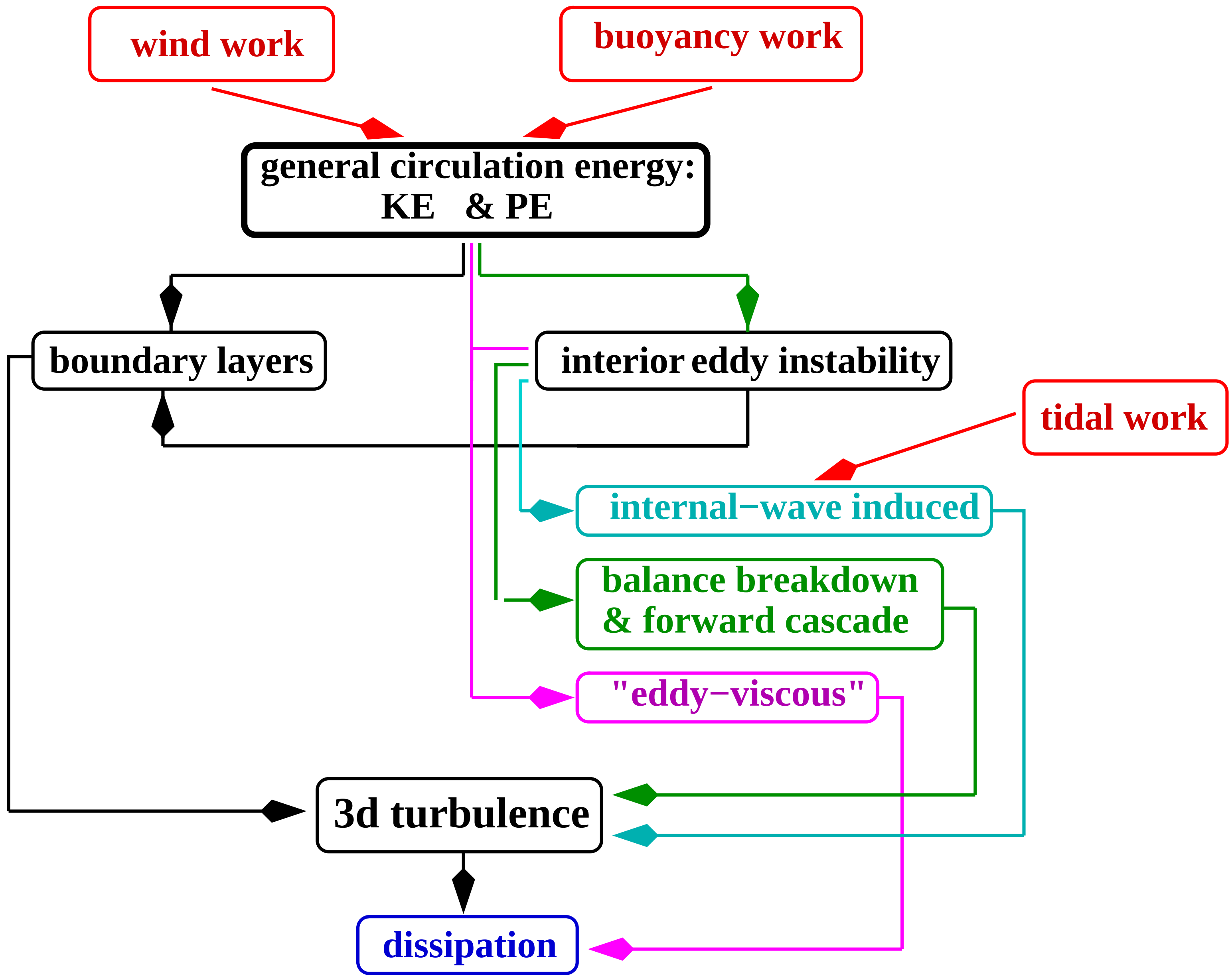
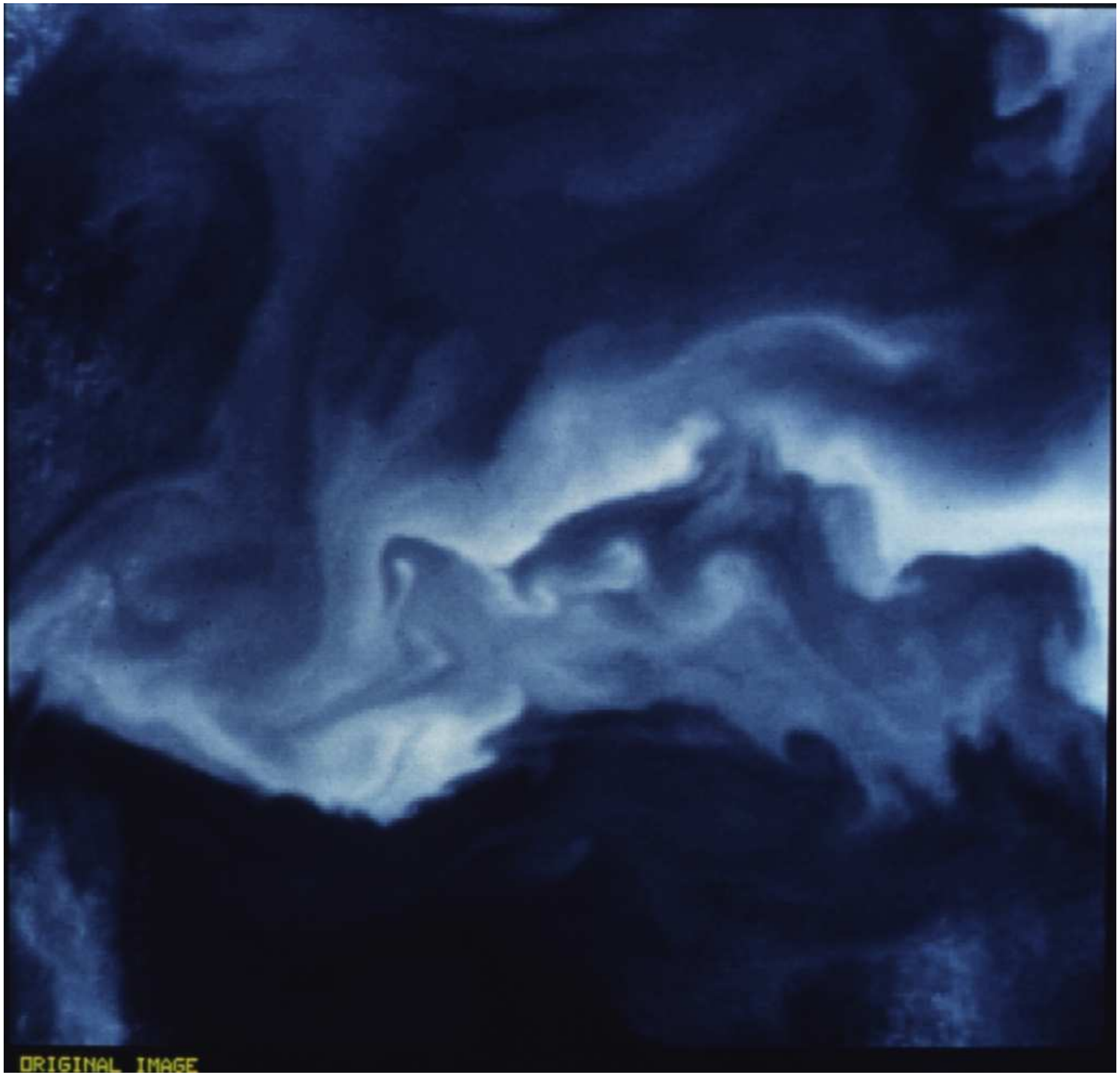


Recall the long-standing mystery of "spirals on the sea" (Munk *et al.*, 2000) seen in slick patterns and SAR images on a scale of kilometers — (top) near Catalina Island; (bottom) in the Mediterranean (Scully-Power, 1986) — but never measured *in situ* nor even remotely in $\mathbf{u}$, $\eta$, or $T$.

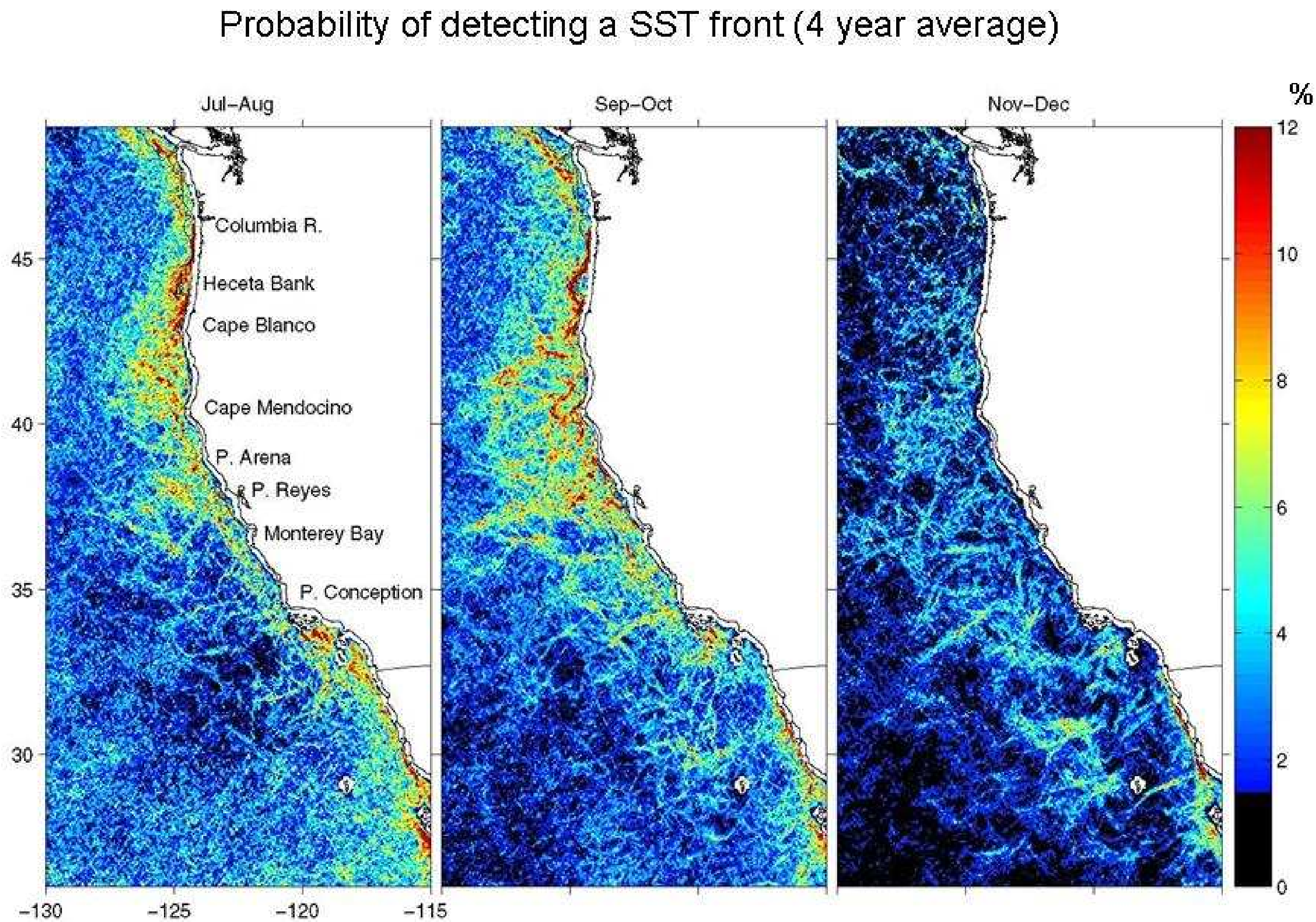
| **mesoscale currents:** | **submesoscale currents:** |
| --- | --- |
| $\sim$ 40 km horizontally, 1 km vertically, & 1 week temporally | $\sim$ 4 km horizontally, 100 m vertically, & 1 day temporally |
| arising from instabilities of the general circulation | arising by frontogenesis from the messocale |
| dominance of horizontal velocity spectrum and isopycnal eddy fluxes | dominance of near-surface vertical velocity spectrum and diapycnal eddy fluxes |
| $\approx$ energetically conservative and adiabatic in interior | energetically dissipative and diabatic |
| statistically well sampled by Jason/TOPEX/Poseidon altimetry | an opportune target for wide-swath altimetry |
| relatively well understood | a scientific frontier |

# ENERGY BUDGET FOR THE OCEANIC GENERAL CIRCULATION

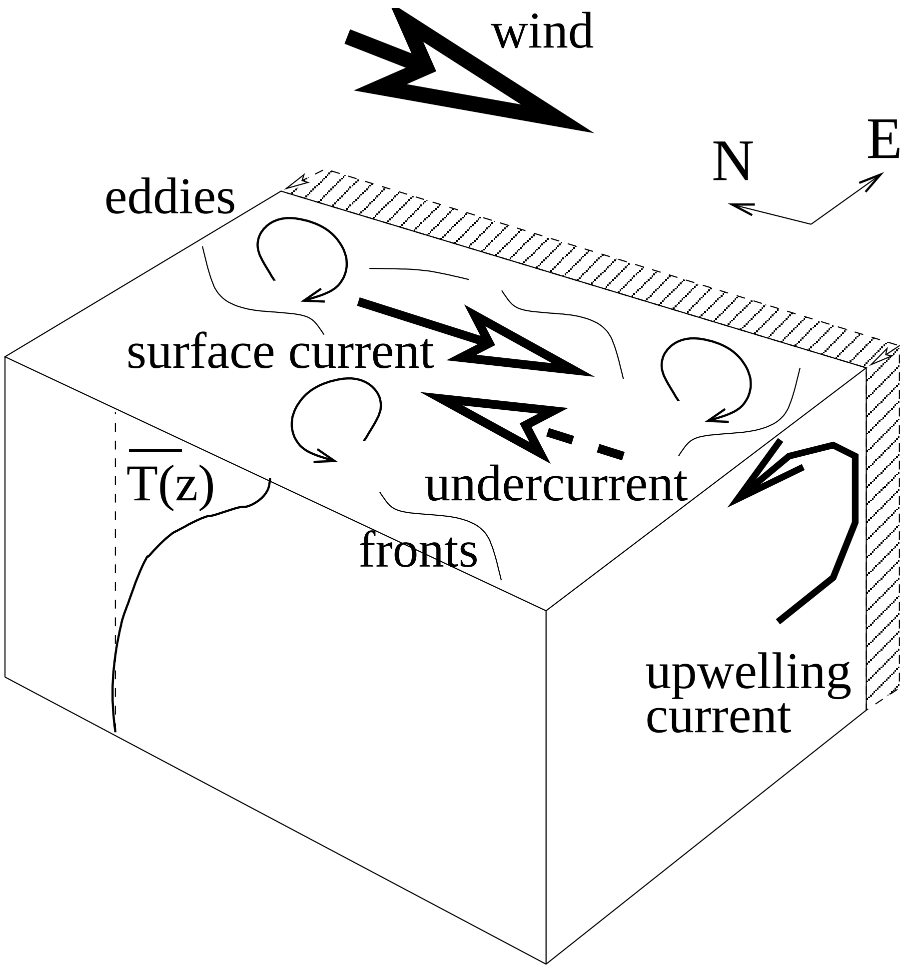





SST image in (250 km)$^2$ off California with associated measurements *in situ*.
Notice fronts and frontal instabilities (Flament *et al.*, 1985).




Criterion: large $\Delta T$ over $\Delta x = 5$ km (Castelao *et al.*, 2006).

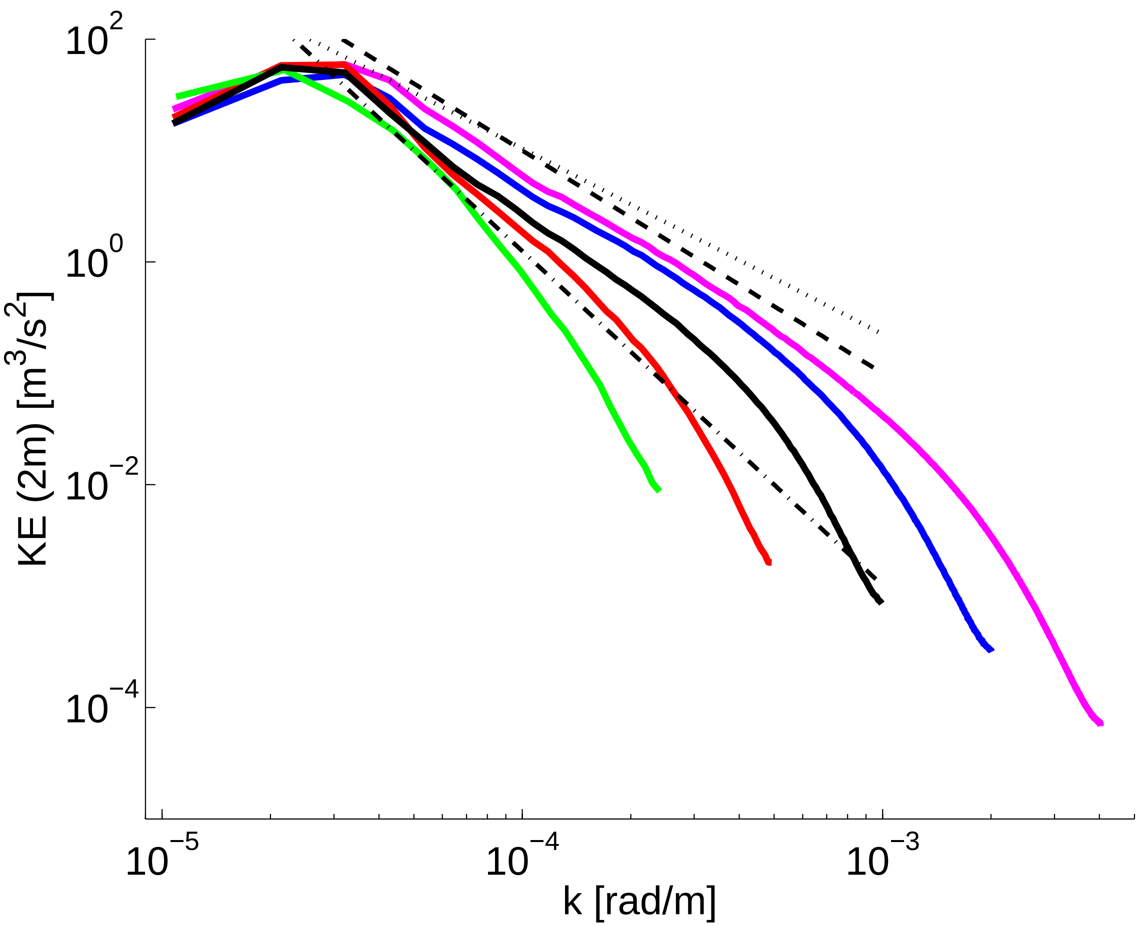



EASTERN BOUNDARY CURRENT

## Computational Simulations:

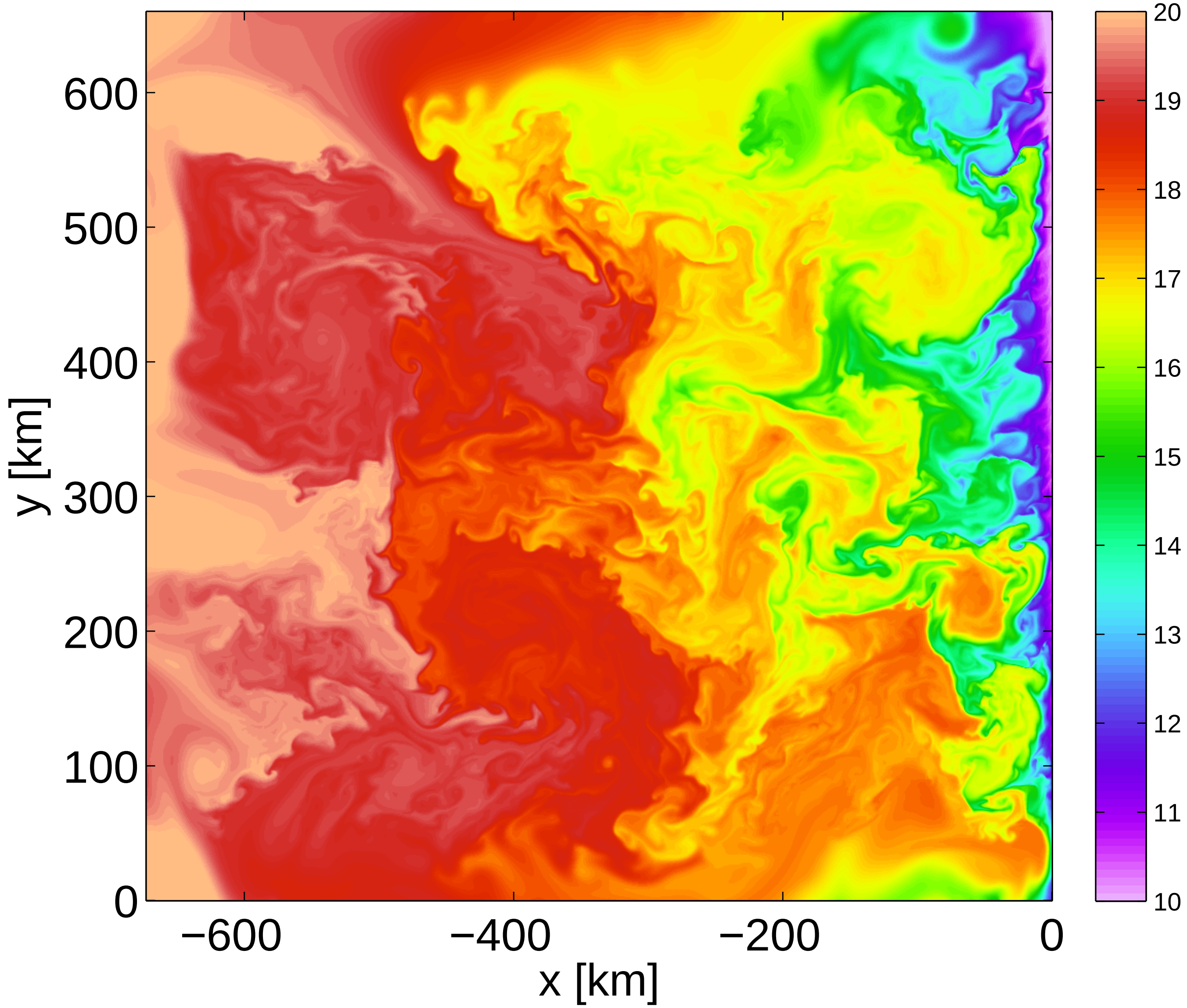
(Capet *et al.*, 2006)

- steady $\boldsymbol{\tau}$, $Q$, $F$
- flat bottom & straight coast
- embedded in equilibrium EBC domain with $\Delta x = 12$ km
- interior domain: $(750\,km)^2$ with $\Delta x = 12 \rightarrow 0.75$ km grid sizes [spanning the submesoscale transition]
- ROMS code (Shchepetkin & McWilliams, 2005)

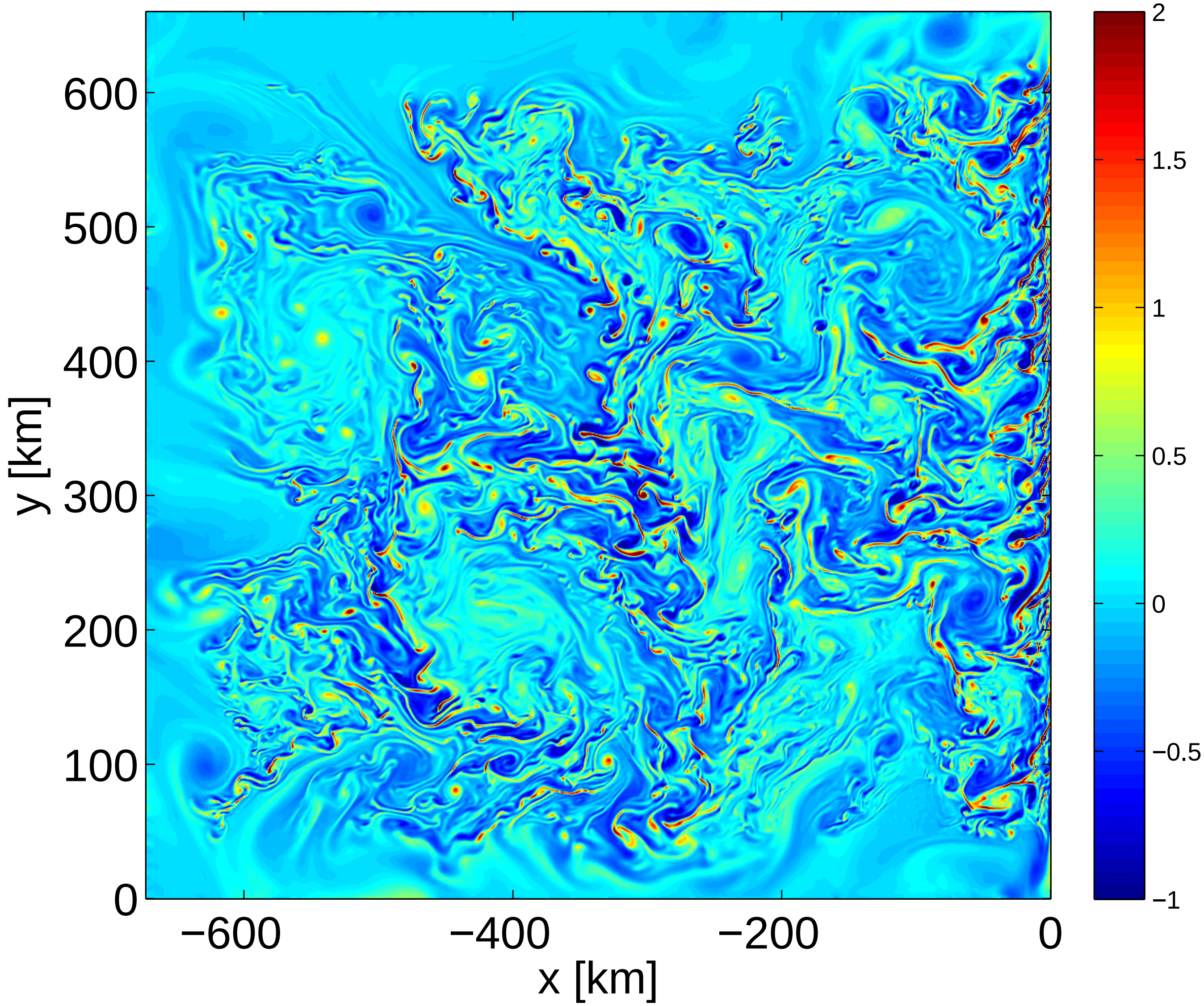



Horizontal velocity $\mathbf{u}_\perp$ spectrum at the surface with $\Delta x = 12 \rightarrow 0.75$ km grid sizes:

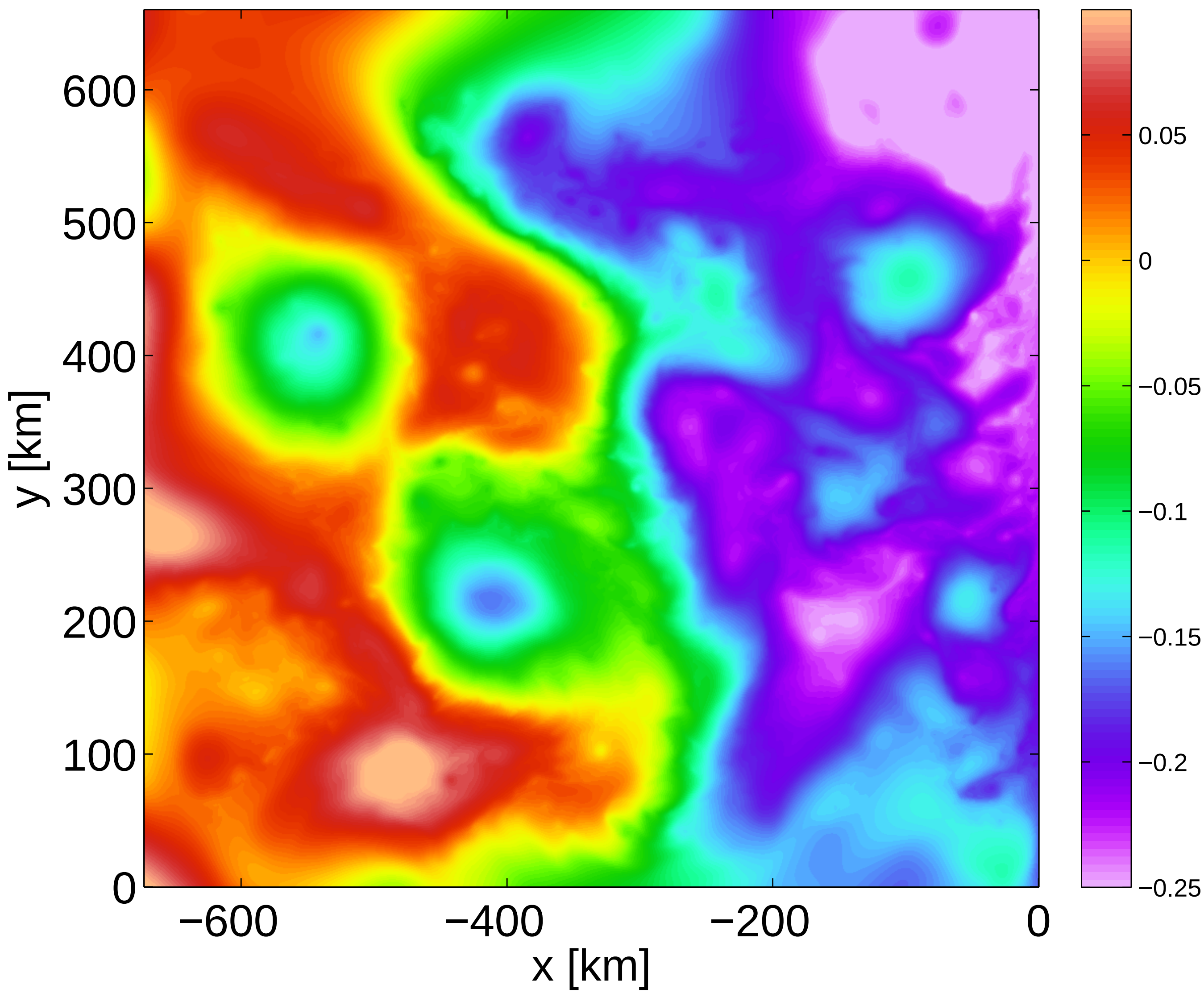
- convergent shape $\sim k^{-2}$ in submesoscale range (dashed; *cf.*, Stammer, 1997)
- currents are mostly geostrophic
- not enstrophy cascade of geostrophic turbulence, $k^{-3}$ (dot-dashed)
- not kinetic energy inertial-range cascade, $k^{-5/3}$ (dotted)




Simulated SST [C] with mesoscale eddies and submesoscale fronts and frontal instabilities.



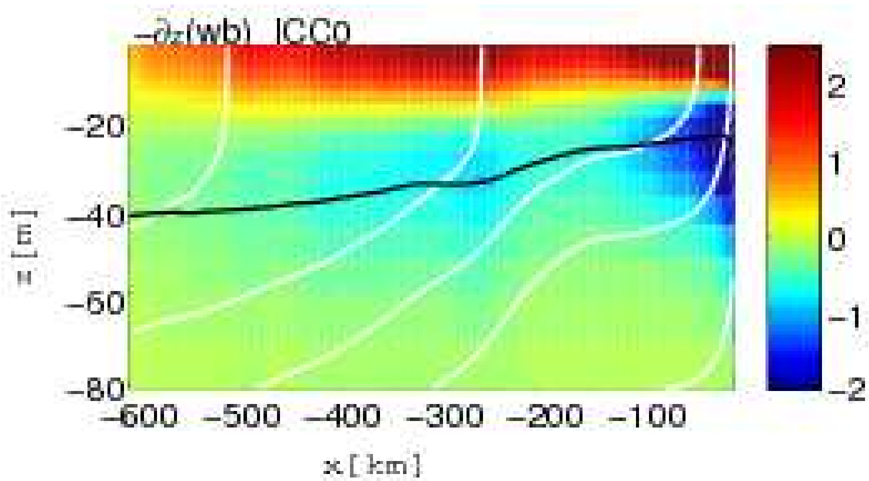

Simulated vertical vorticity normalized by $f$: submesoscale is most active between mesoscale eddies.

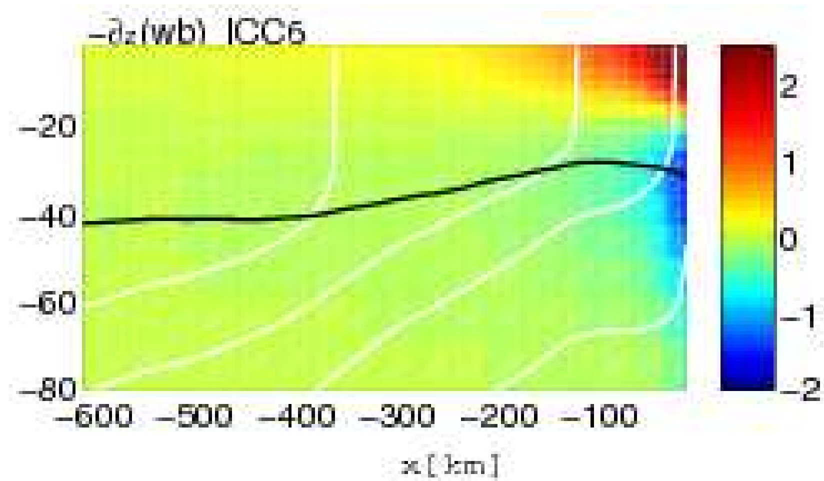



Simulated sea-surface height [m]: submesoscale is subtle finestructure.

# Submesoscale Restratification Flux

. $\Delta x = 0.75$ km | $\Delta x = 6$ km



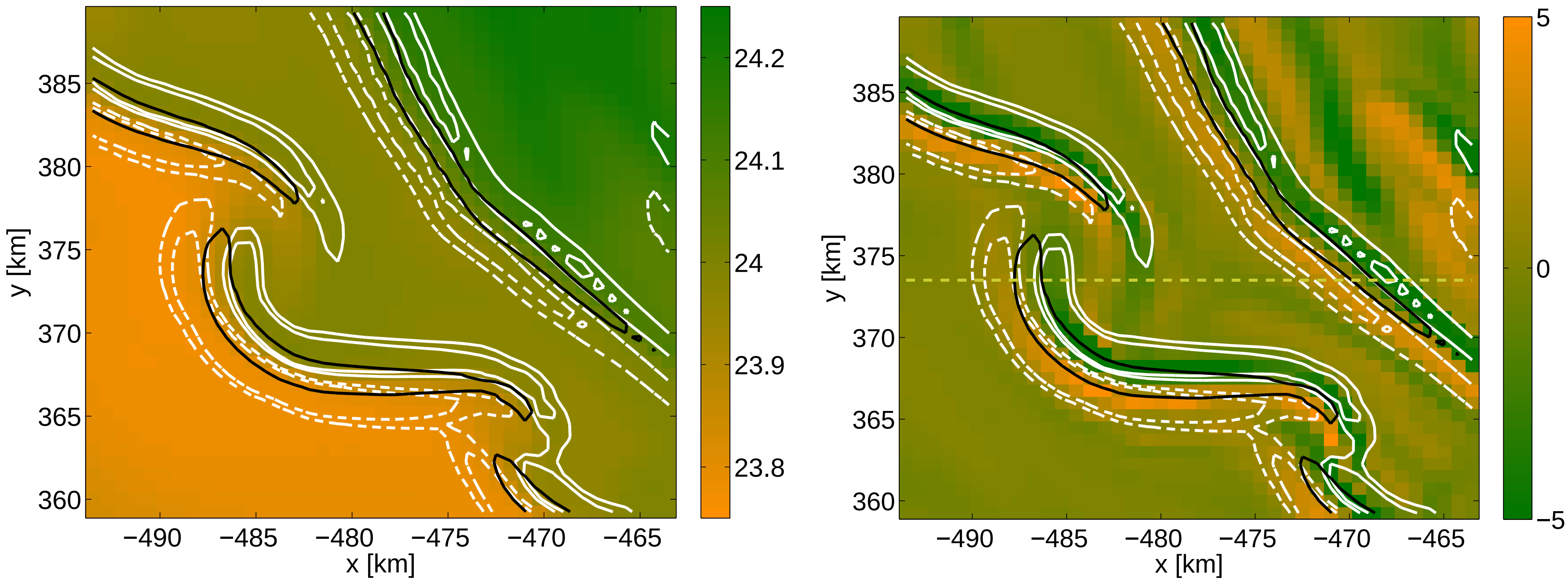

Equilibrium buoyancy balance, $b = g(\alpha T - \beta S)$:

$$\partial_t \overline{b} \;=\; -\boldsymbol{\nabla}_\perp \cdot (\overline{\mathbf{u}_\perp b}) \quad - \; \partial_z(\overline{wb}) \quad + \; \partial_z(\overline{\kappa \partial_z b})$$

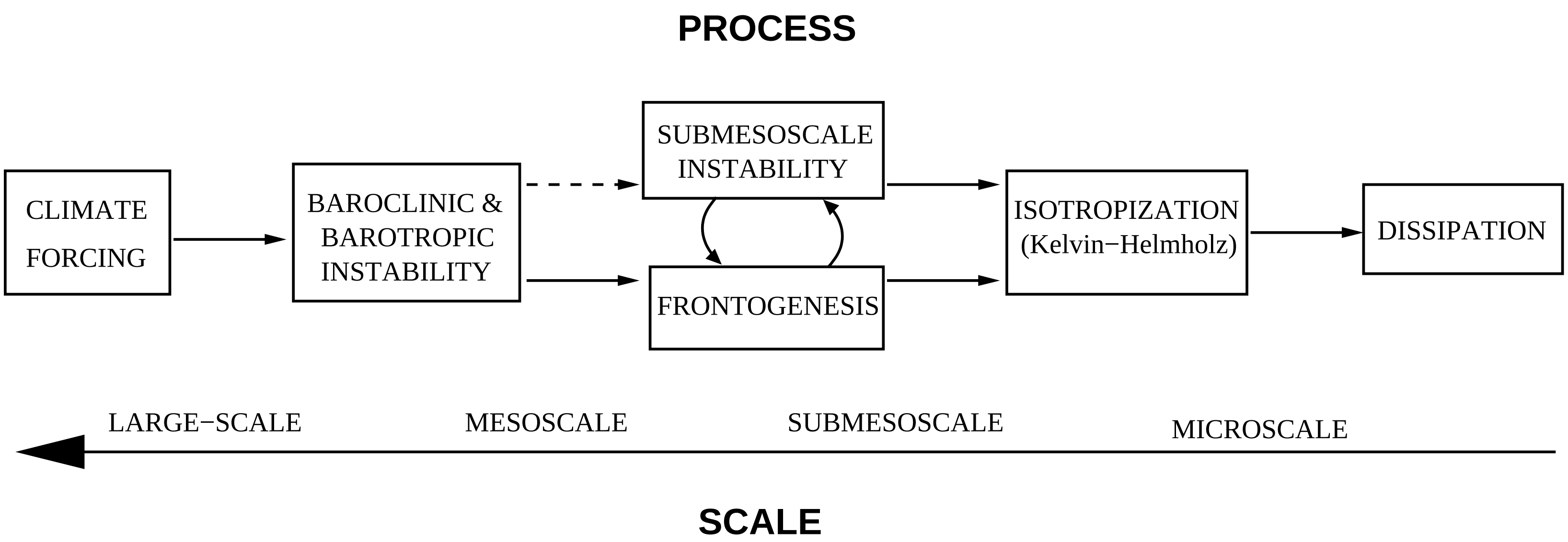
. $\approx$ 0 mesoscale boundary-layer

. submeoscale $[\boldsymbol{\tau},\ Q,\ F]$

Submesoscale vertical restratification flux is $\mathcal{O}(100)$ W m$^{-2}$, largely balanced by boundary-layer turbulent flux.




Horizontal pattern for two adjacent fronts: $b$ (left) & $w$ (right).
One is evidently stable and the other actively unstable.




The submeoscale range connects the mesoscale to the microscale by downscale energy transfers, both potential and kinetic.

It is an inherently different dynamical regime — neither mesoscale ($Ro = V/fL \ll 1$) nor microscale ($Ro \gg 1$).

Its primary effects are restratification, interior − boundary-layer material exchange (ecosystems), frontogenesis, frontal instabilty & breakdown, partial geostrophic imbalance, and forward energy cascade toward dissipation.

# Submesoscale Altimetric Measurements

There are few measurements *in situ* because of difficult sampling requirements.

Computational simulations are new but will proliferate.
[OSSEs are possible.]

Principle altimetric objective is documenting global variety, especially in regions with small $\Delta SST$ where surface fronts are obscure and with differing mesoscale activity levels.

Wide-swath sampling limit (Fu): $\delta\eta = 1$ cm over $\Delta x = 1$ km (*cf.*, 2 cm over 7 km now) $\Rightarrow$ partial coverage of submesoscale range down to 4 km radian scale based on $k^{-2}$ $\mathbf{u}_g$ spectrum, with sparse temporal sampling.

Issue of confusion with internal tide and other inertia-gravity waves.
[Pattern discrimination is likely to work well.]

Desirability of burst sampling at higher $(\mathbf{x}, t)$-resolution, if feasible (Alsdorf).

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## Summary

Wide-swath altimetry is a great opportunity for exploratory measurements of submesoscale (geostrophic) currents that are probably important for their roles in oceanic general circulation and biological productivity...

...as well, of course, for its utility for mesoscale currents.