Environmental Fluid Dynamics: Sub-mesoscale processes in coastal regions

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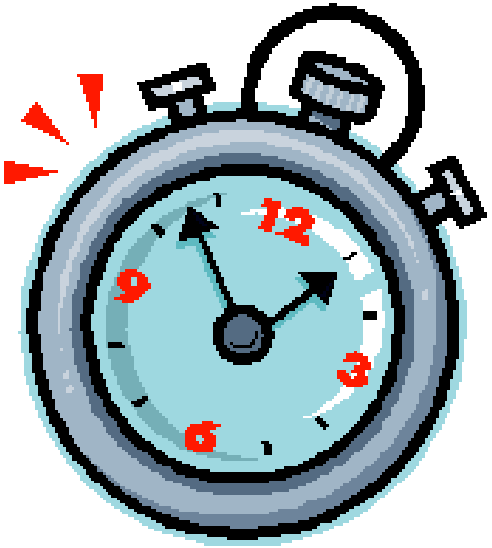
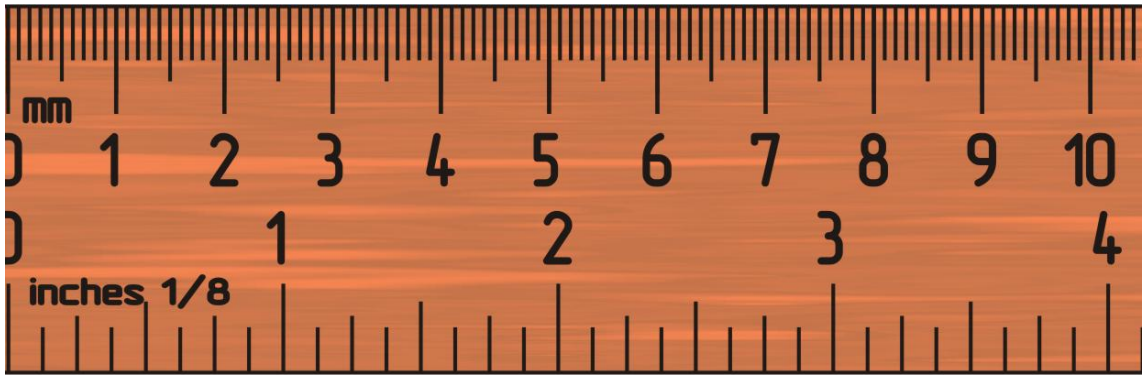
Definition of scales



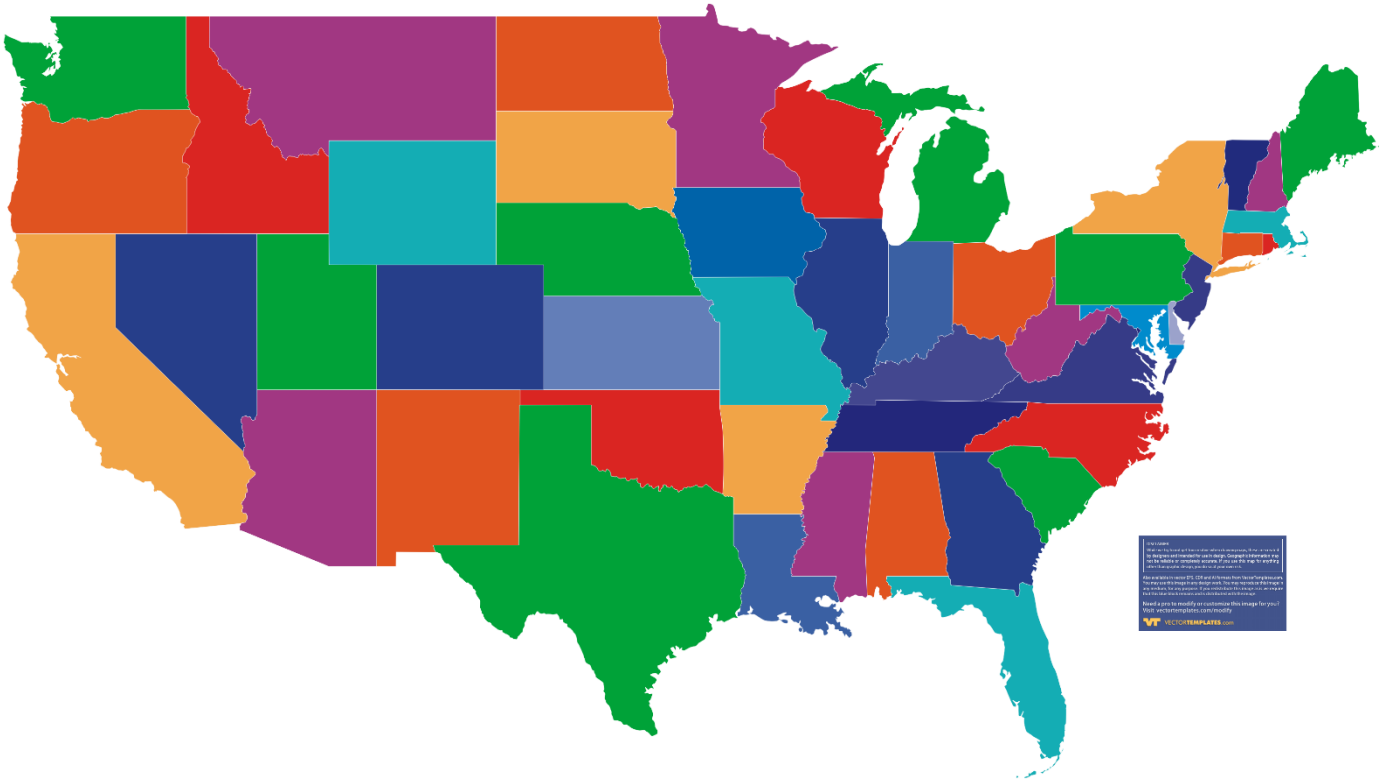
Scales can be defined
in time and space..



Temporal scales

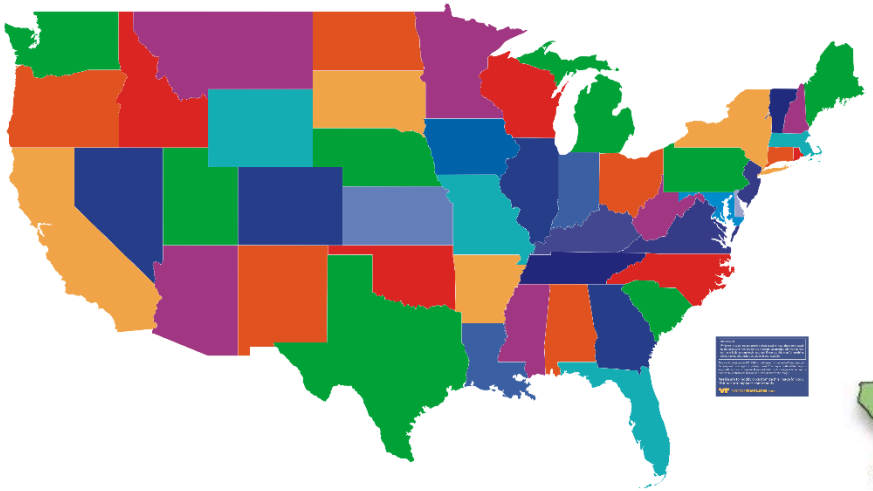
Near the coast, shoaling waves typically have ☐☐ seconds period and land-sea breezes change their directions at every ☐☐☐.

Spatial scales

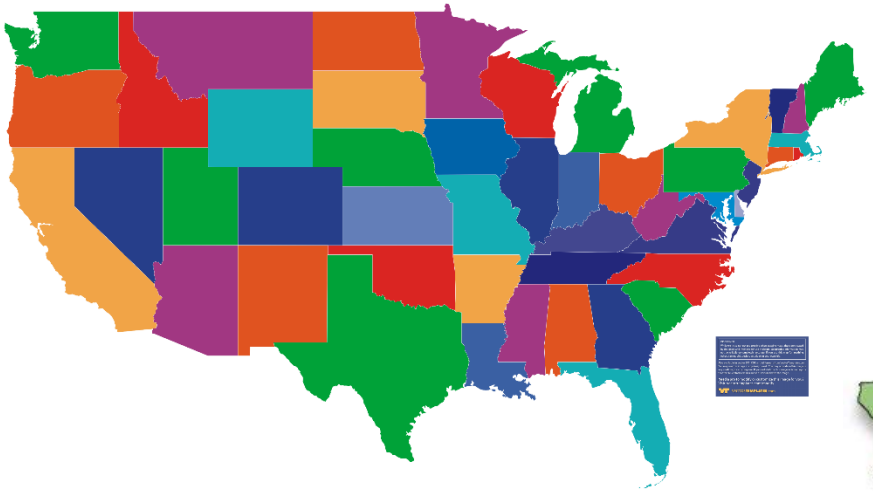


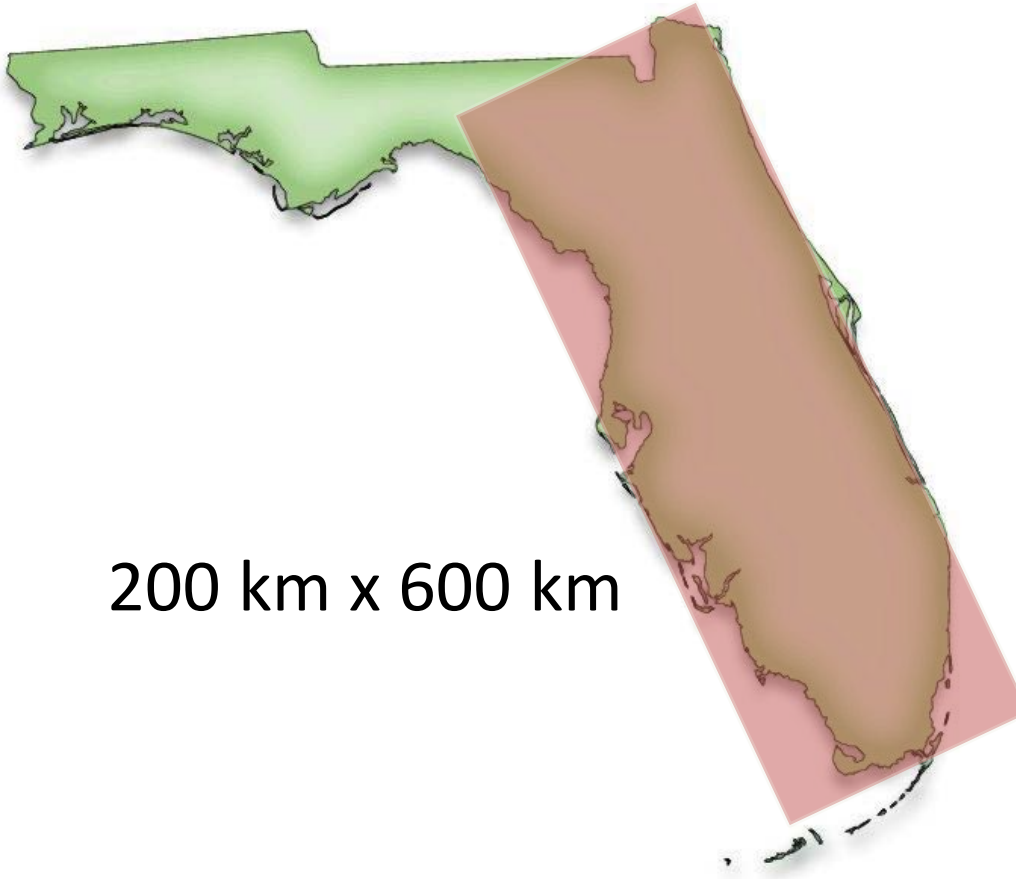
can be used as a nature-driven-ruler…..

Spatial scales



Spatial scales





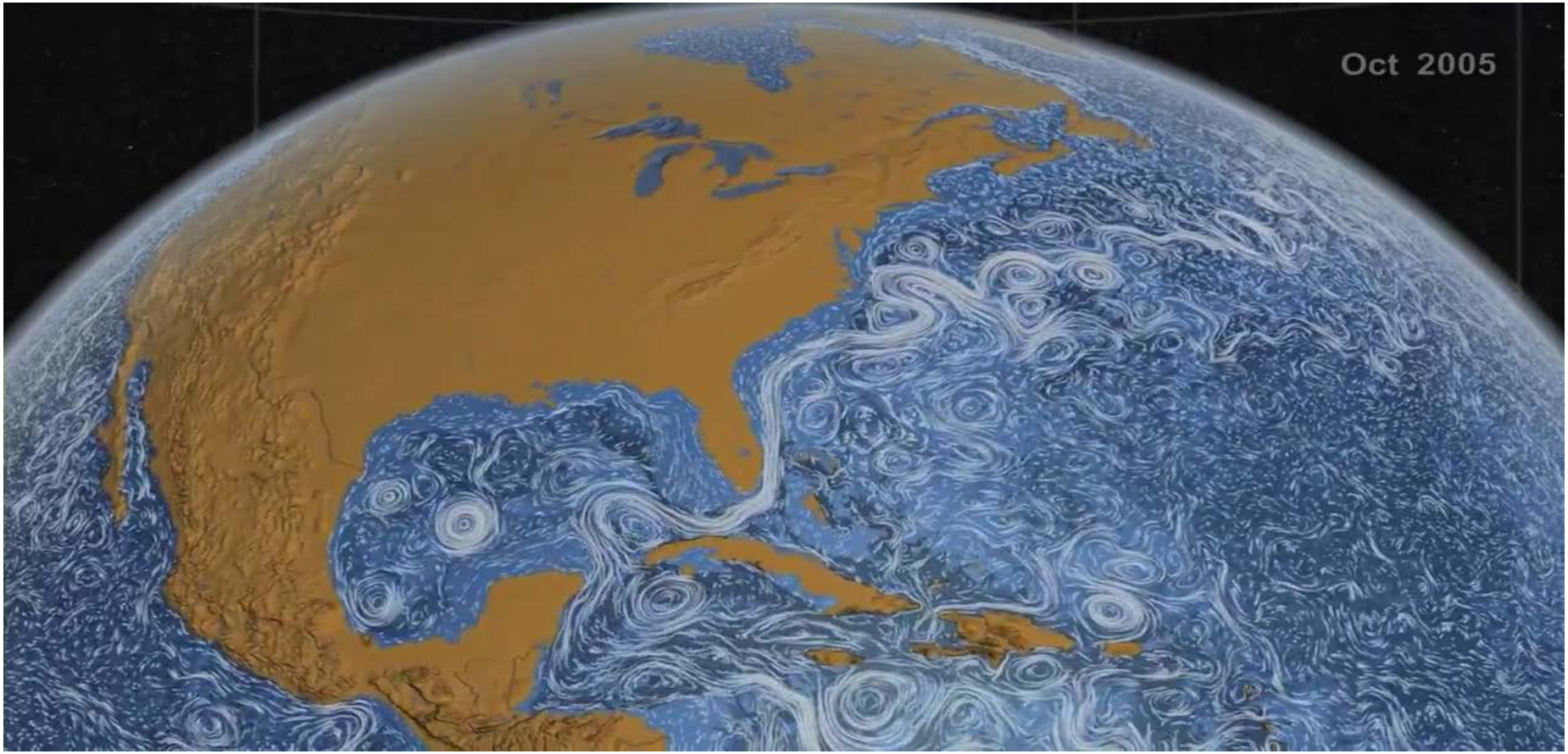
200 km x 600 km

Spatial scales - Mesoscale

How big are the eddies?

Spatial scales - Mesoscale

Influence of earth rotation (a moving object on a rotating frame) becomes dominant compared with rotational tendency (relative vorticity) of an object.



Spatial scales - Mesoscale

Influence of earth rotation (a moving object on a rotating frame) becomes dominant compared with rotational tendency (relative vorticity) of an object.

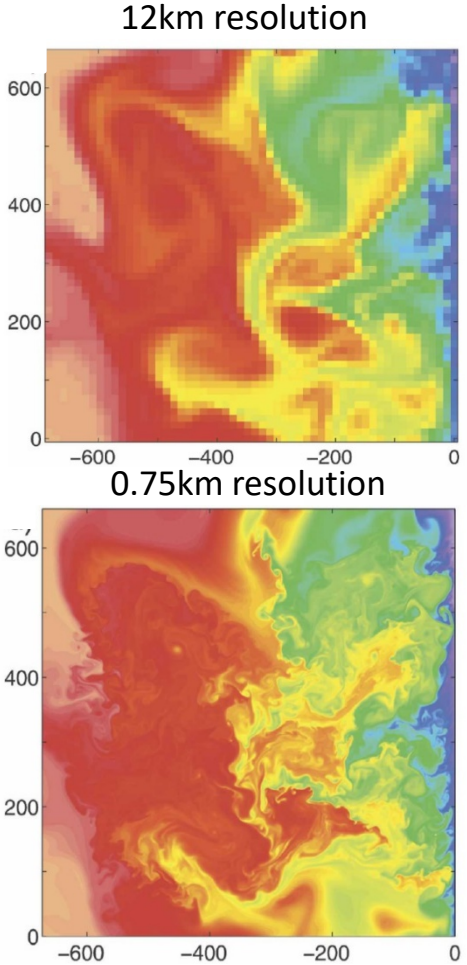
Spatial scales - Submesoscale

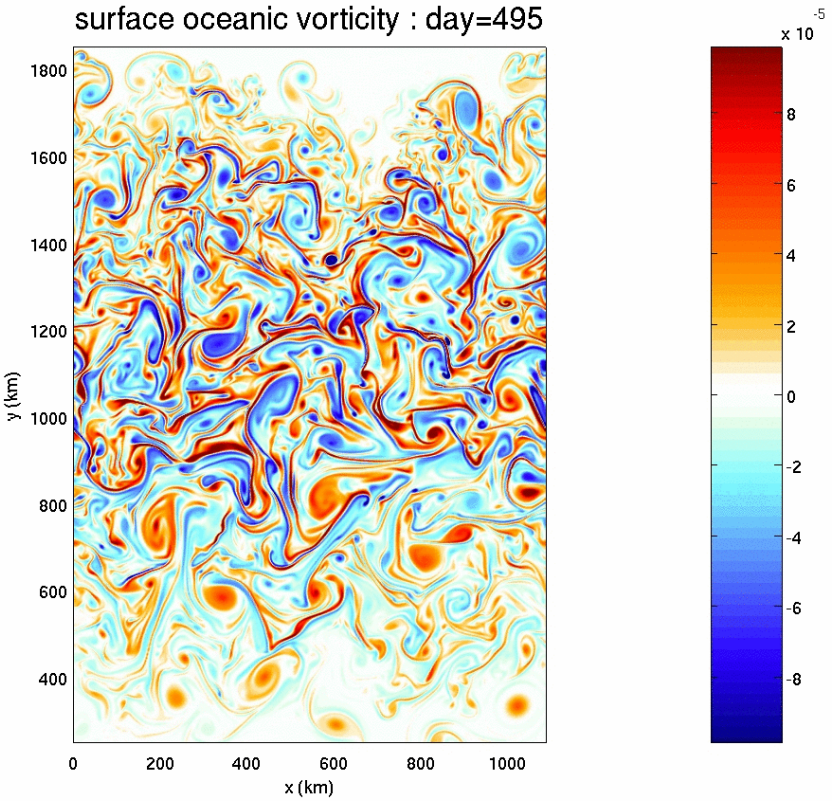
Influence of earth rotation (a moving object on a rotating frame) becomes equal or small compared with rotational tendency (relative vorticity) of an object.

Submesoscale processes

- O(1) Rossby number [Ro = ζ/f]
- A horizontal scale smaller than the first baroclinic Rossby deformation radius; O(1-10) km
- Frequently observed as fronts, eddies, and filaments

Simulations on mesoscale and submesoscale grids (SST)

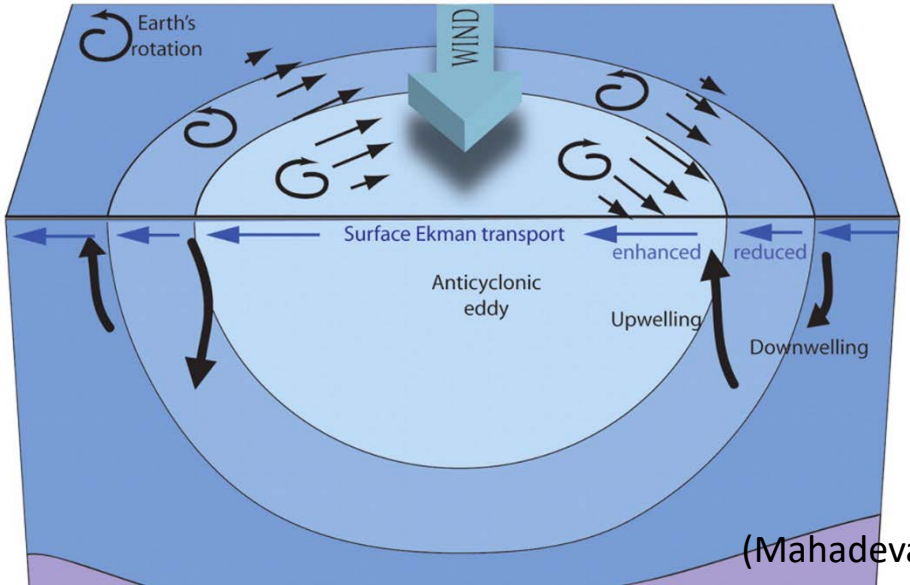




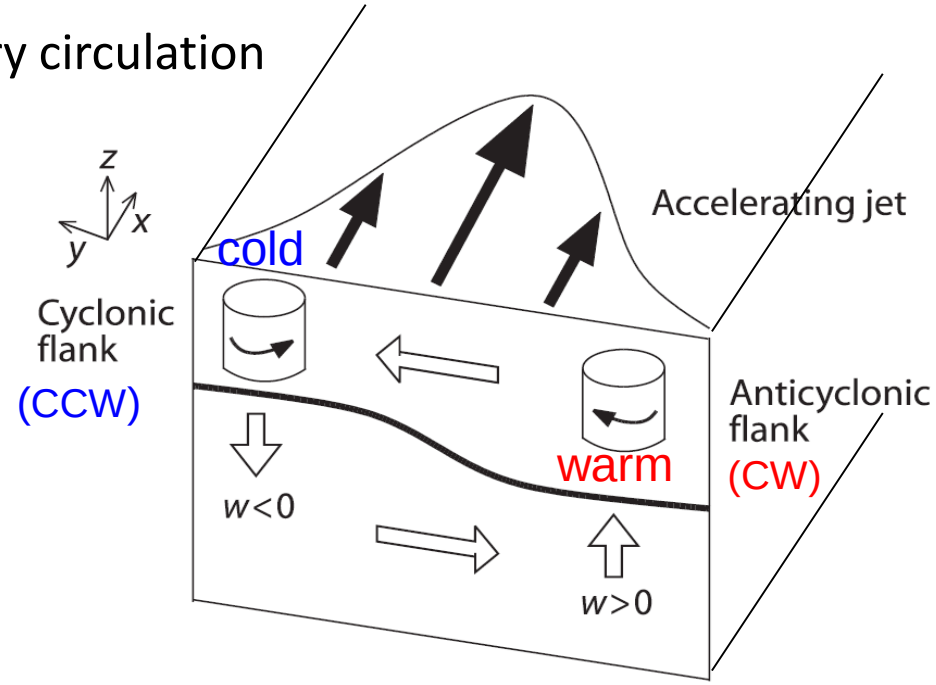
(Courtesy of X. Capet and P. Klein)

Submesoscale processes

- O(1) Rossby number [Ro = ζ/f]
- A horizontal scale smaller than the first baroclinic Rossby deformation radius; O(1-10) km
- Frequently observed as fronts, eddies, and filaments
- Contribute to the vertical transport of oceanic tracers, mass, and buoyancy and rectify the mixed-layer structure and upper-ocean stratification
  - e.g., vertical frontal scale secondary circulation



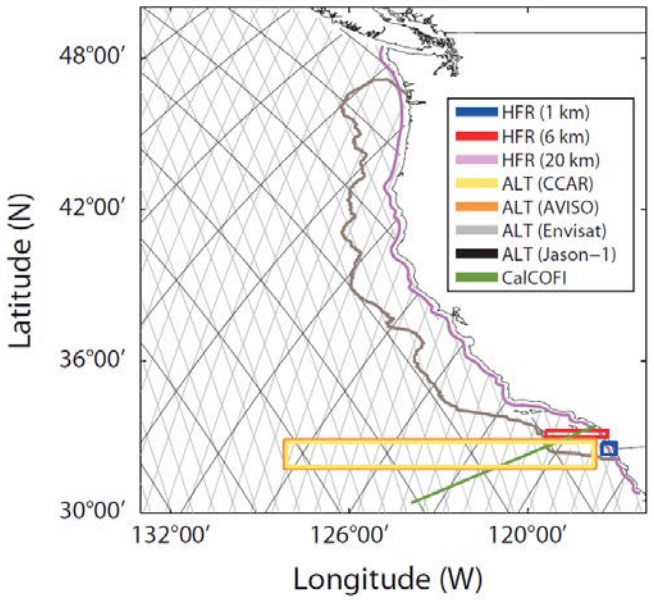
(Mahadevan et al, Science, 2008)



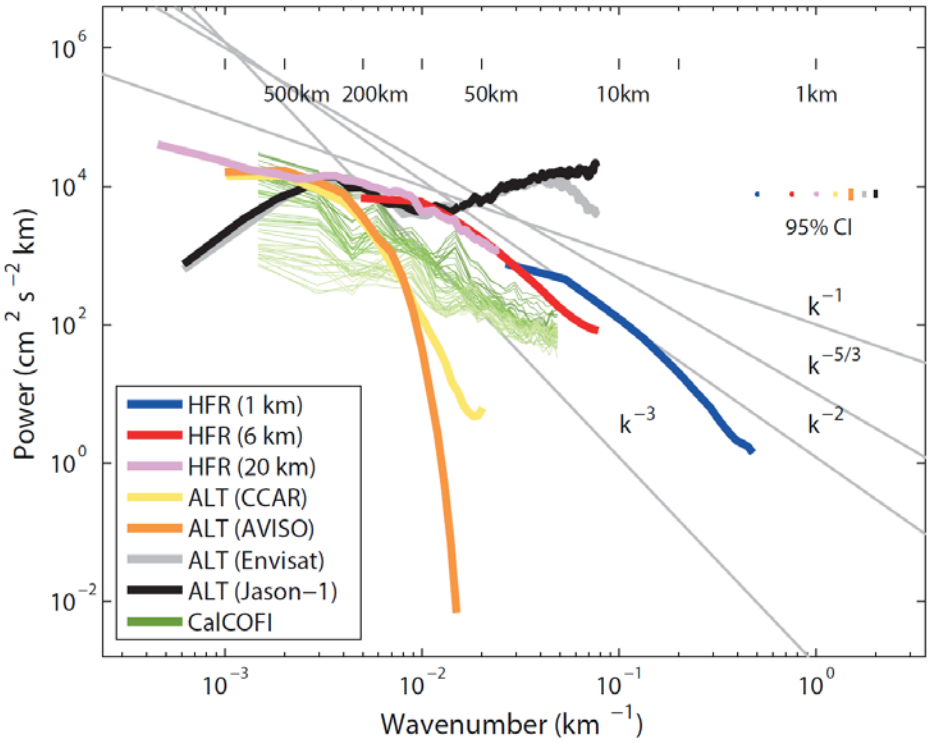
(Williams and Follows, 2003)

Submesoscale processes

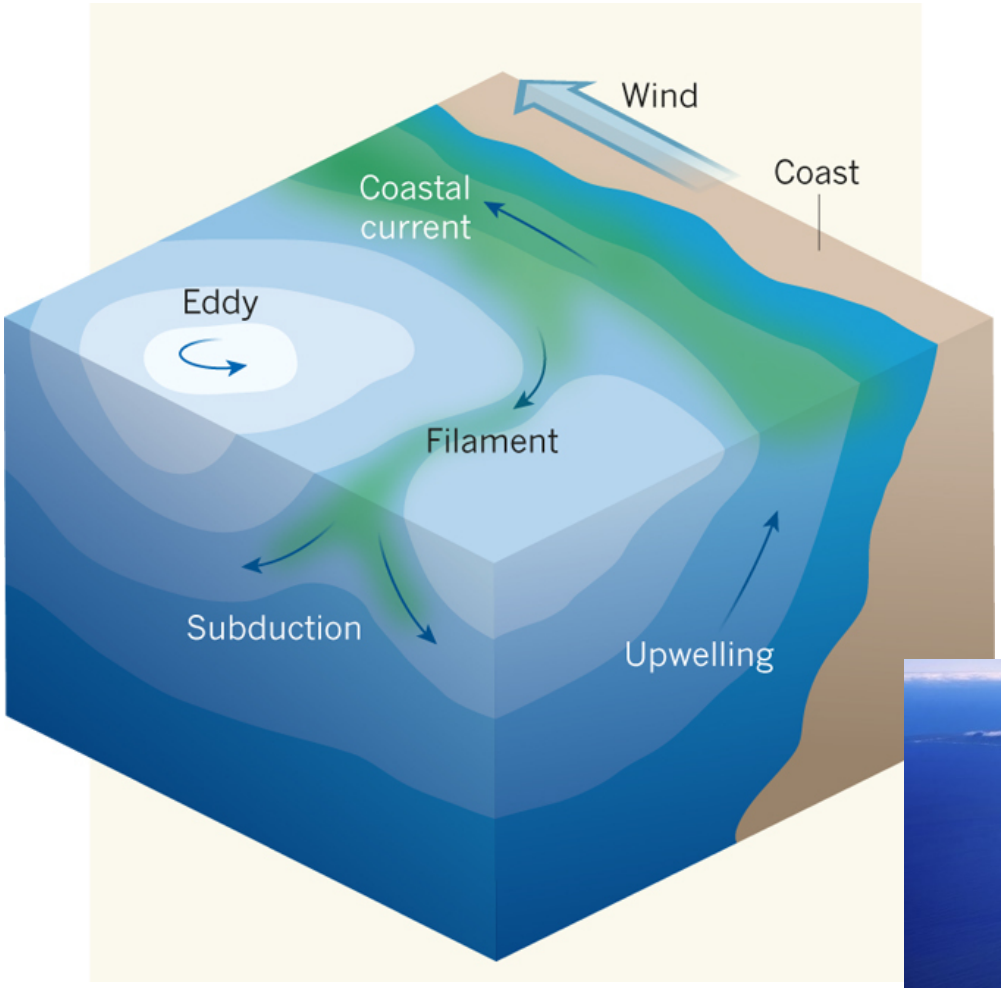
- O(1) Rossby number [Ro = ζ/f]
- A horizontal scale smaller than the first baroclinic Rossby deformation radius; O(1-10) km
- Frequently observed as fronts, eddies, and filaments
- Energy spectra with a slope of k^{-2} at *O*(1) km scale
  - Quasi Geostrophic theory (QG;k^{-3})
  - Surface QG (sQG; $k^{-5/3}$)
  - Semi-geostrophic theory (SG; $k^{-8/3}$)



(Extended from Kim et al, JGRC 2011)



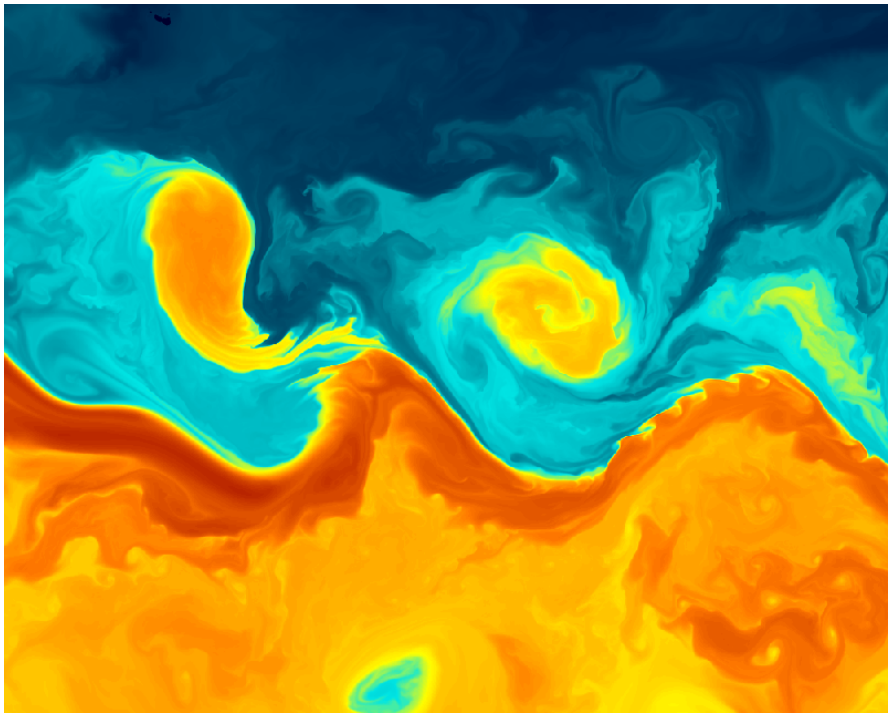
Boundary layer flows: At air-sea-land interfaces

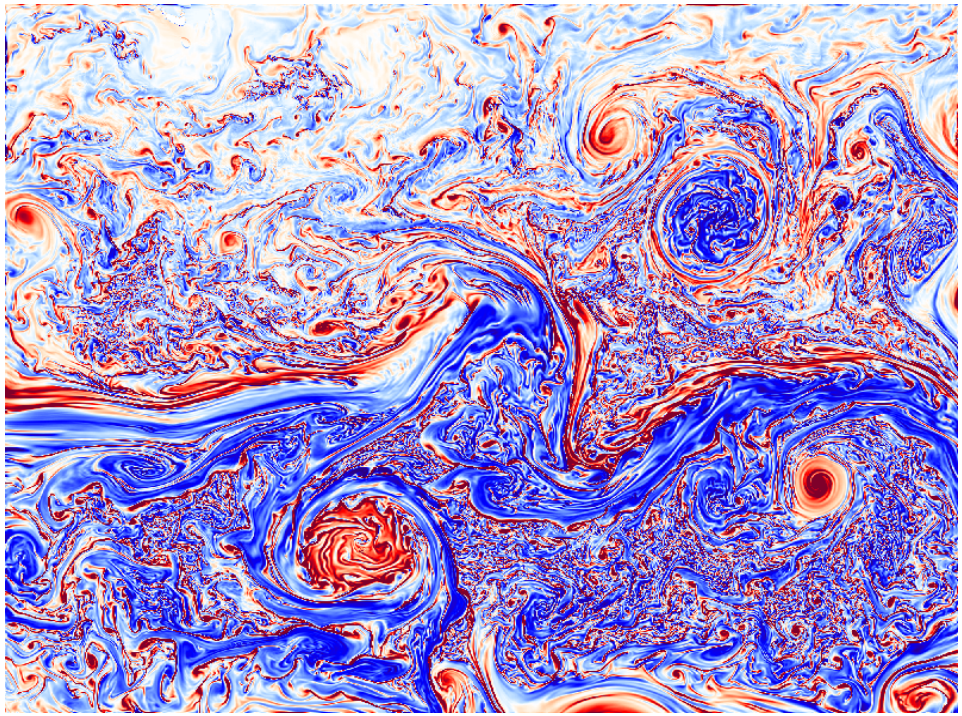


(A. Mahadevan, Nature 2014)

(An aerial image of red tide)

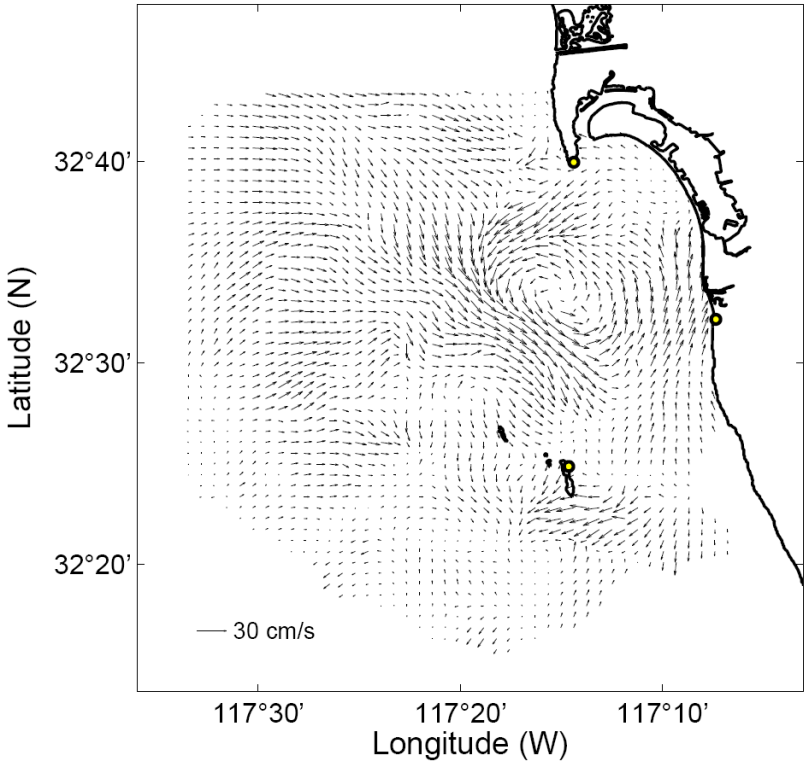
Boundary layer flows: Numerical simulations

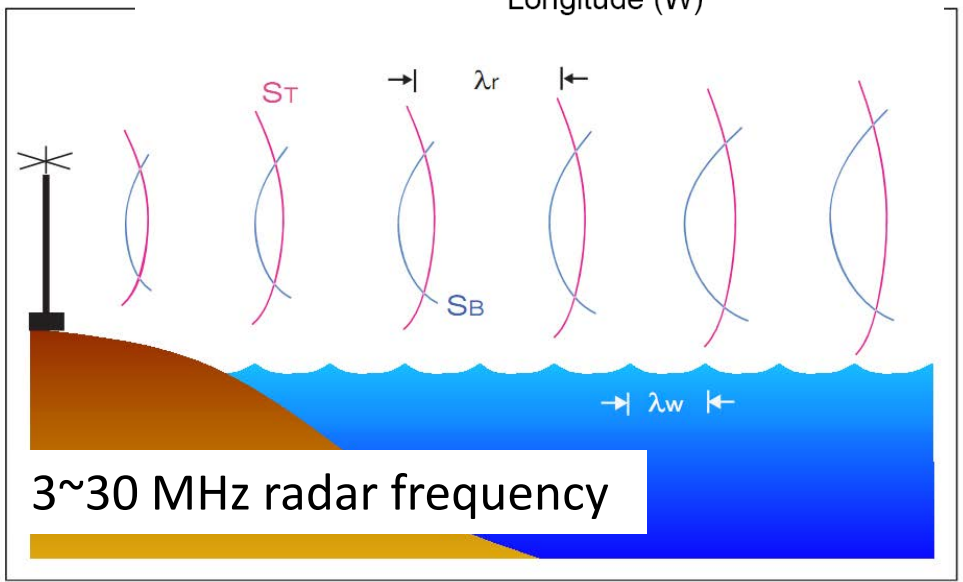


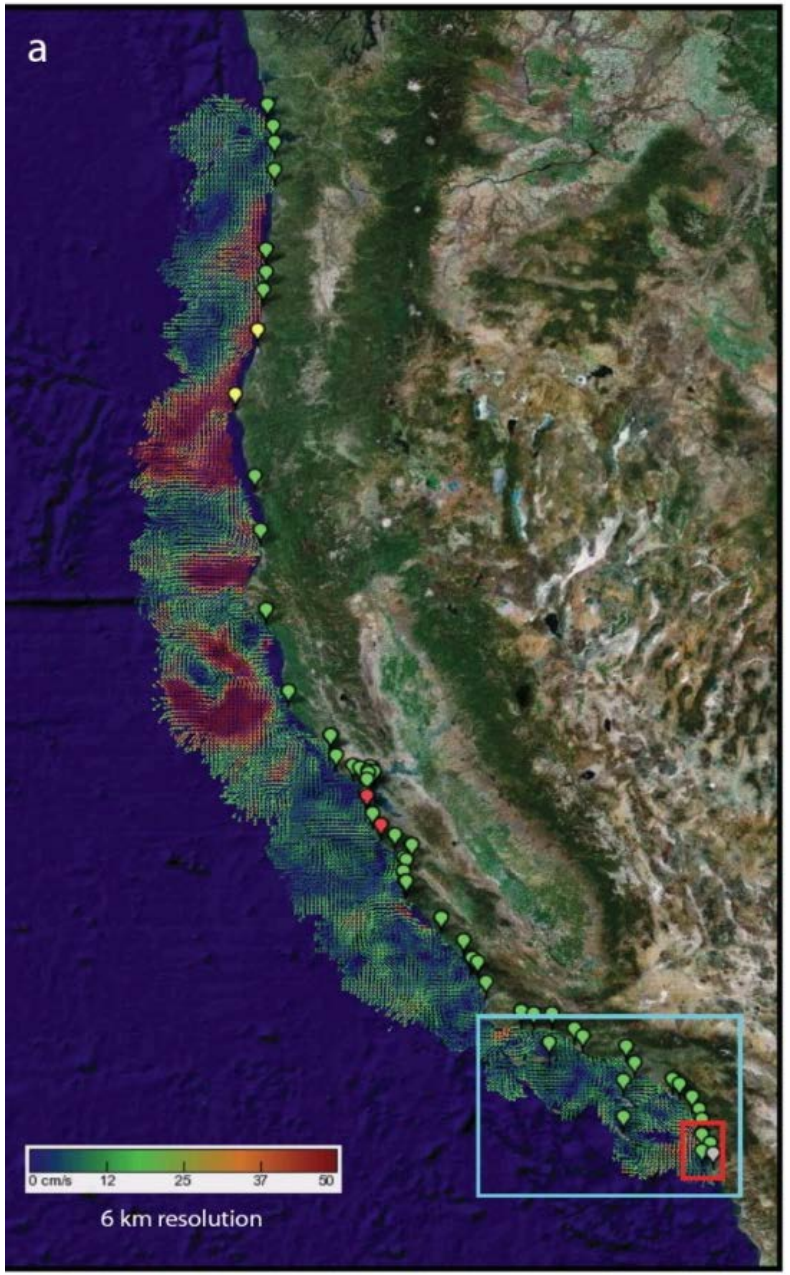


(J. Gula @ UCLA)

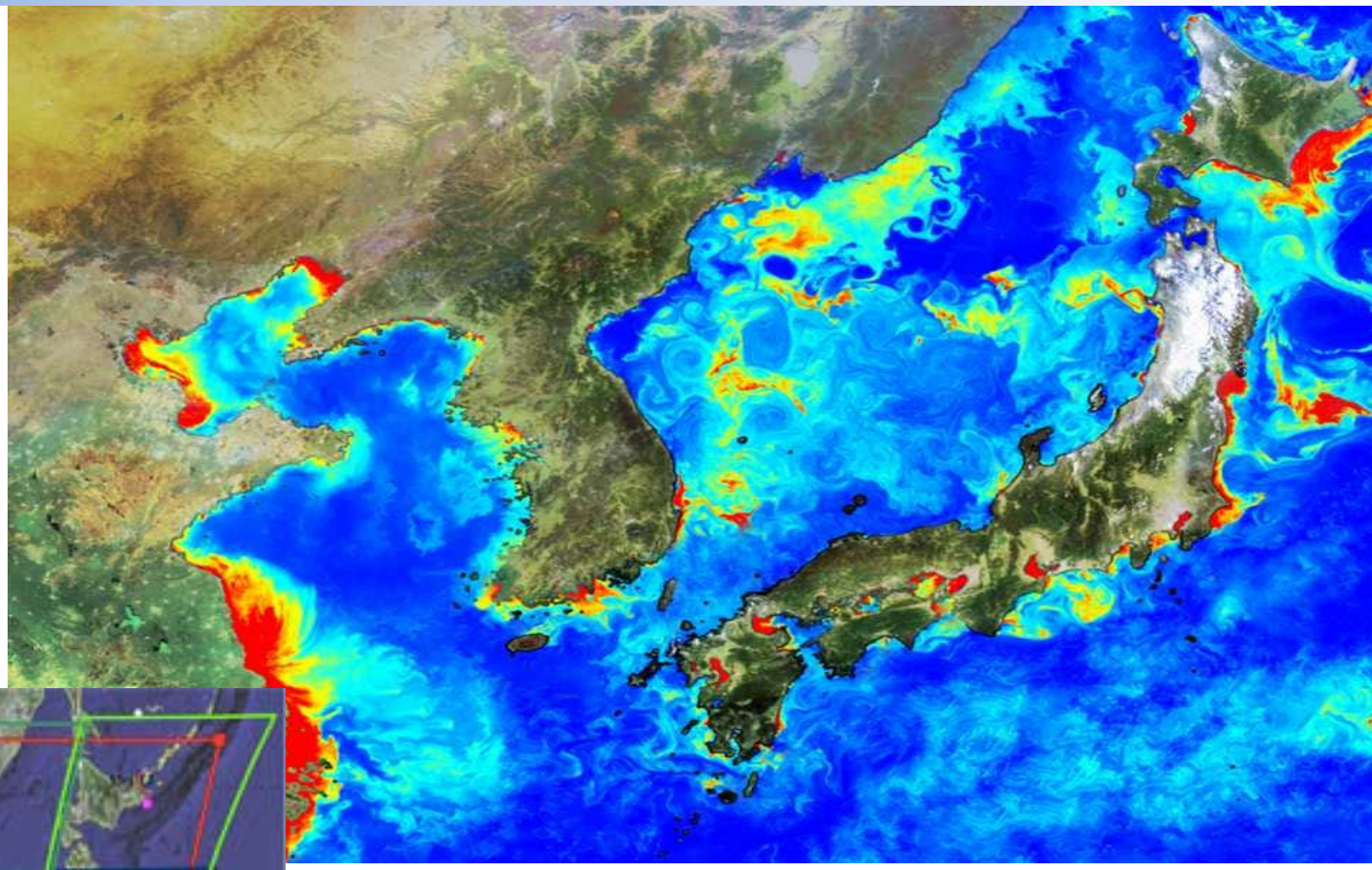
Remote sensing – High-frequency radars

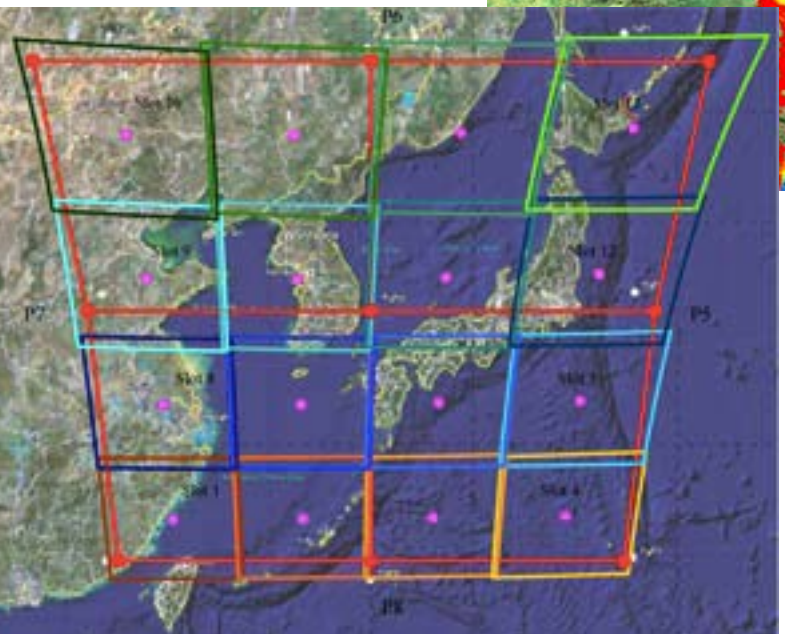






Remote sensing – Geostationary Ocean Color Imagery

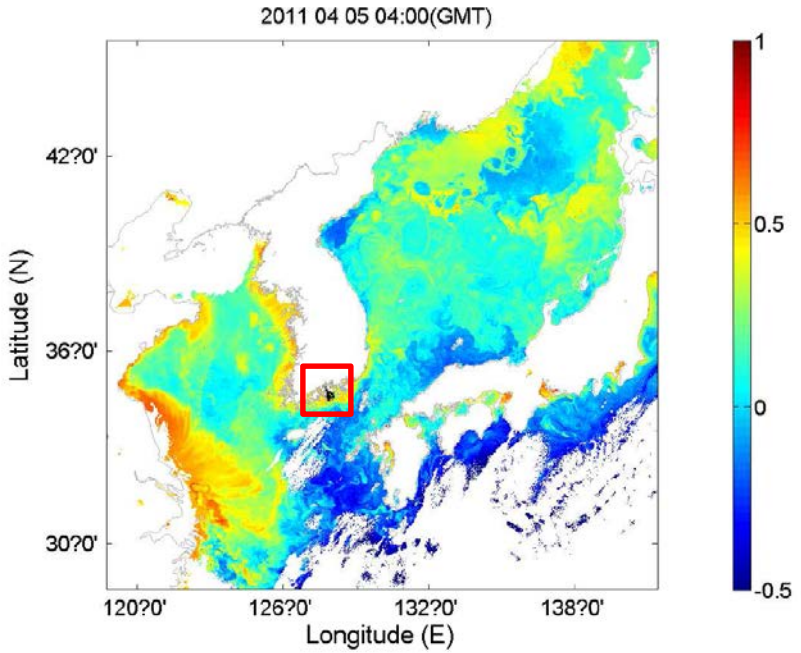


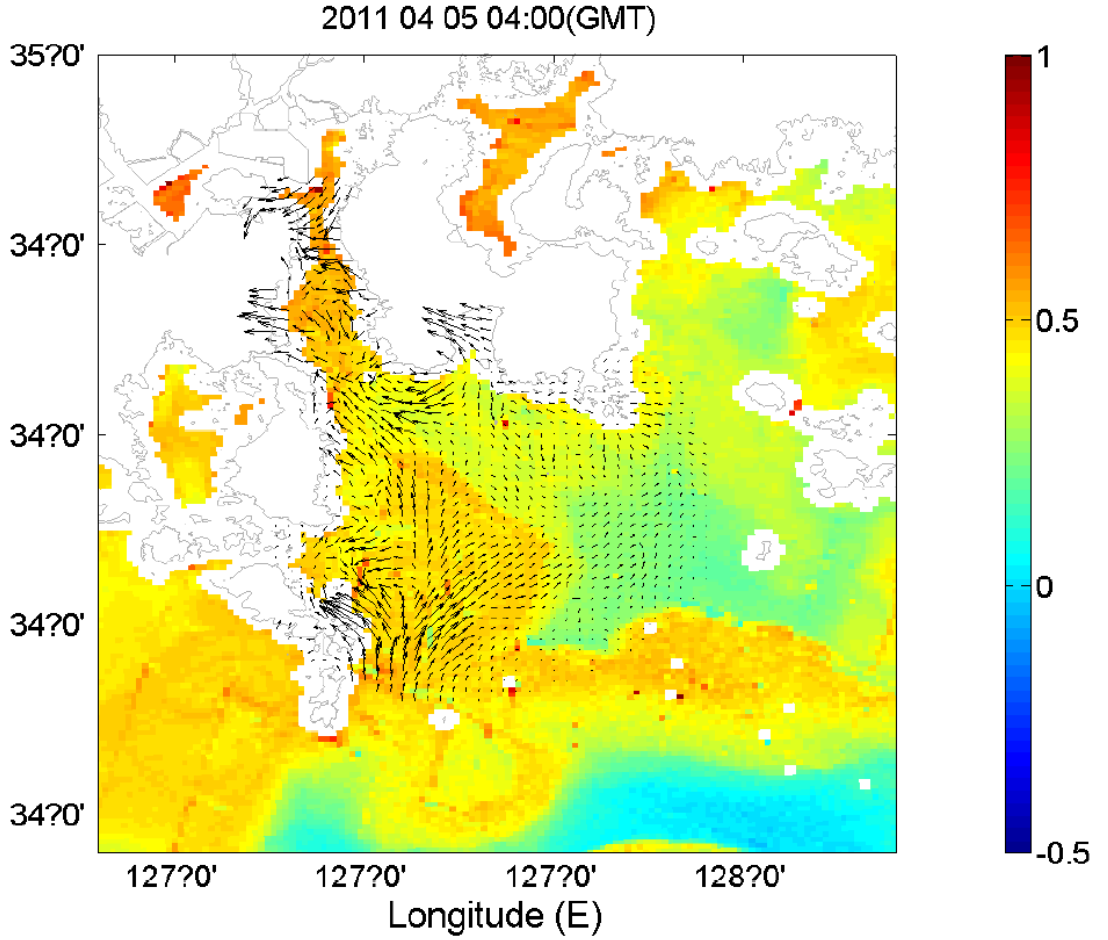


(0.5 km and hourly; GOCI @ KOSC)

Submesoscale process studies

- have benefited from primarily idealized numerical models and theoretical frameworks because they require the use of high-resolution observations of less than one hour in time and O(1-10) km in space.





On-going research topics

- Tracking of water-borne materials at submesoscale
  - Pollutants; red tides; oil spills; larvae transports
  - Particle trajectory model
  - Estimates of diffusion coefficients using 1D/2D advection-diffusion equations
- Bio-physical interactions at submesoscale
  - Finite-size/Finite-time Lyapunov Exponents (FSLE/FTLE) using current field (AVIOS; HFR; model)
  - Comparison with concentration maps (e.g., CHL/CDOM)
- Fontal instability s at submesoscale
  - Upwelling fronts; Submesoscale eddies and fronts
  - Reynolds flux estimates
  - Instability due to horizontal density gradients; feature extractions and energy spectra