What Are Missing in the AVISO SSH Dataset:
Mesoscale vs. Submesoscale Variability along the STCC Band

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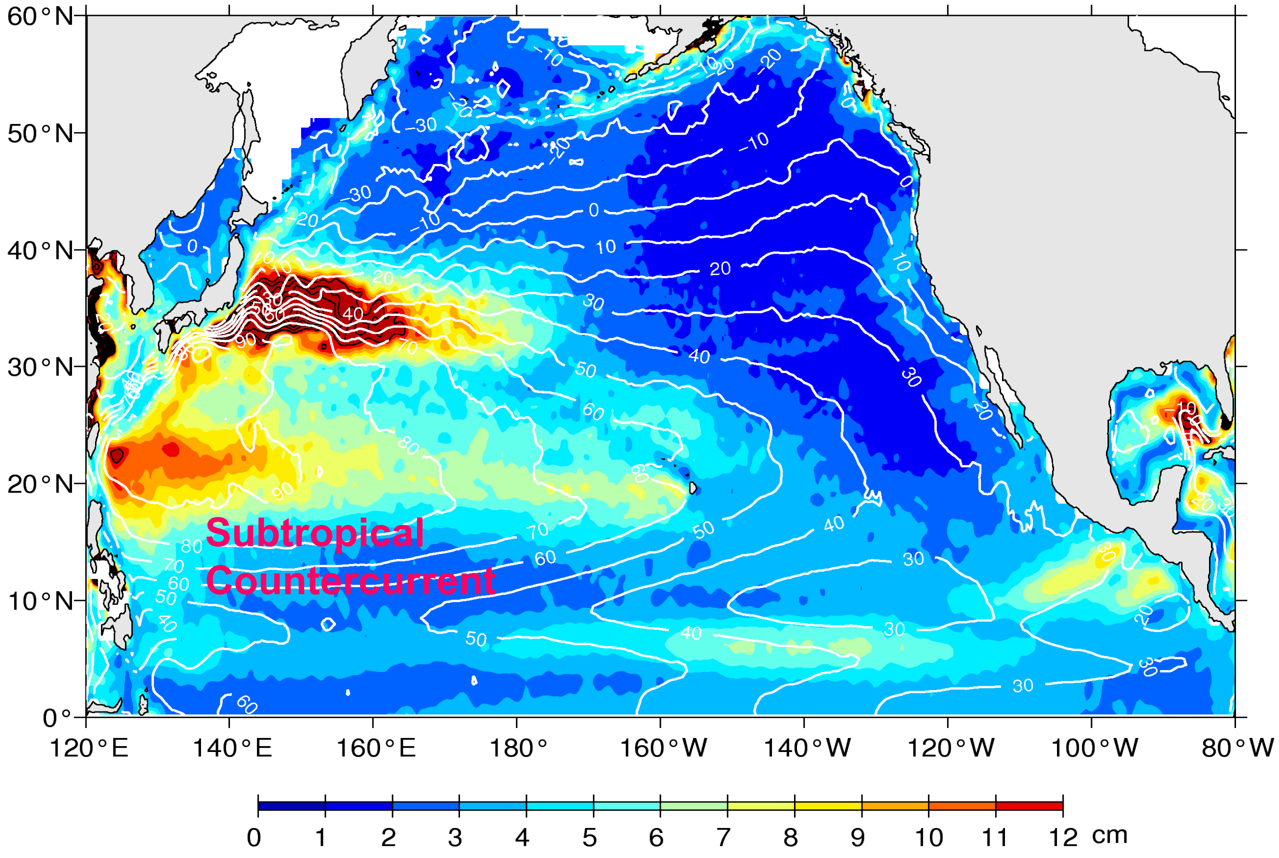
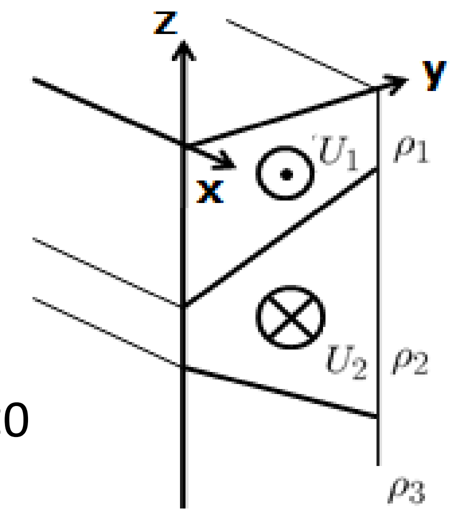
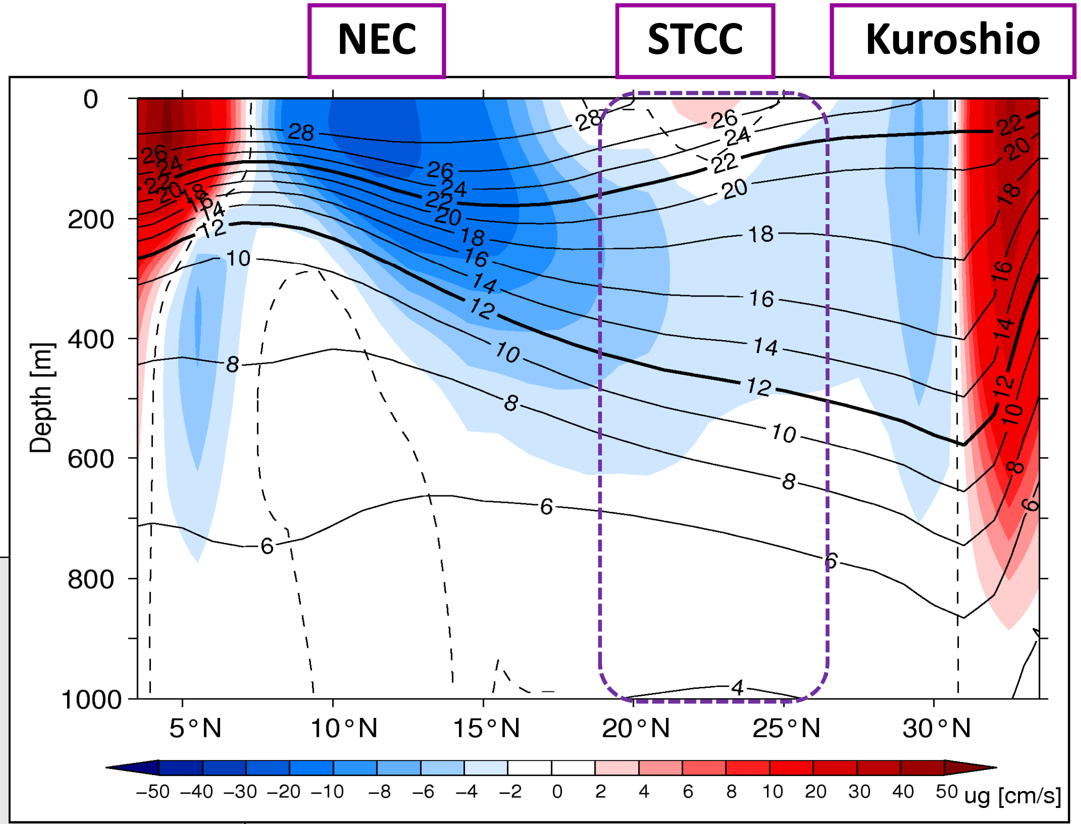


New Frontiers of Altimetry
Lake Constance, Germany
27-31 October 2014

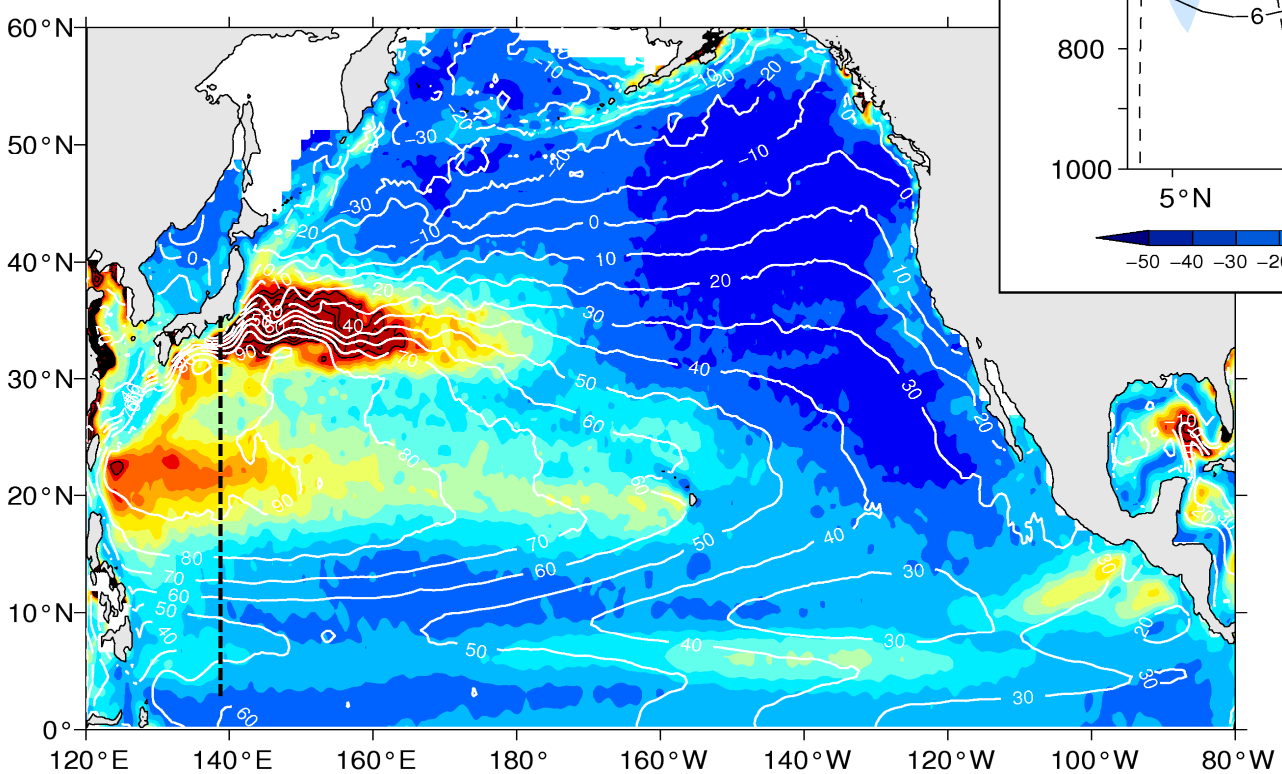
Enhanced eddy variability along STCC due to baroclinic instability



$\Pi_{1y}\Pi_{2y}<0$

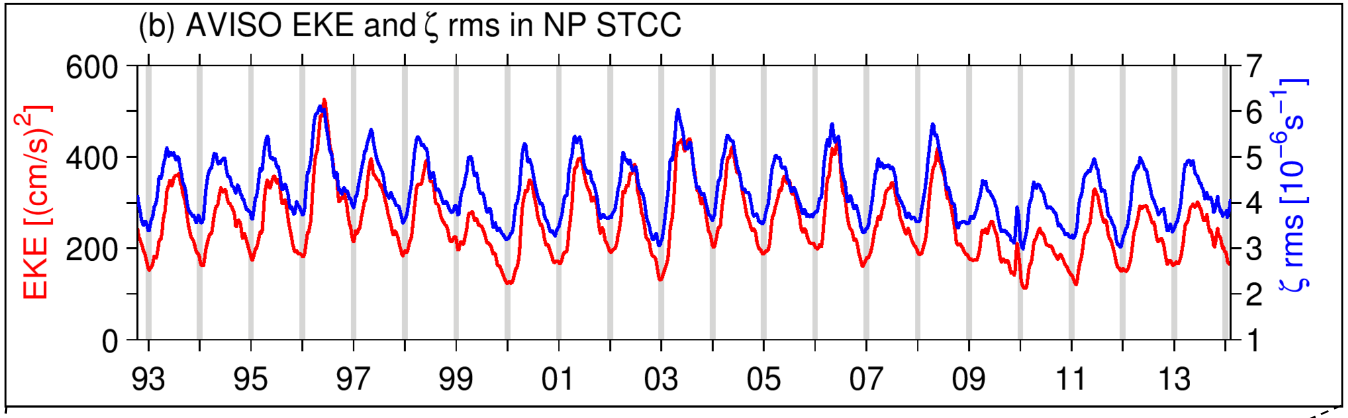


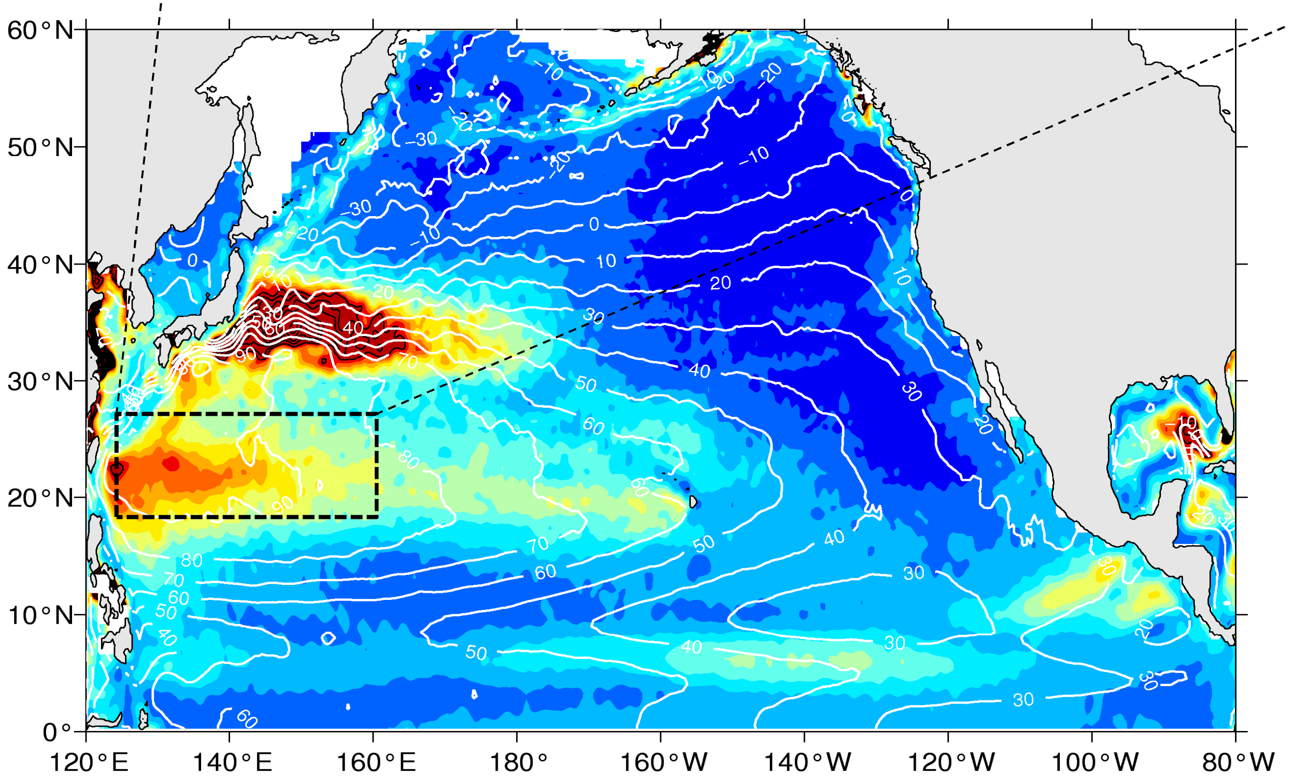
JMA temperature and Ug section along 137°E (1993-2008 mean)

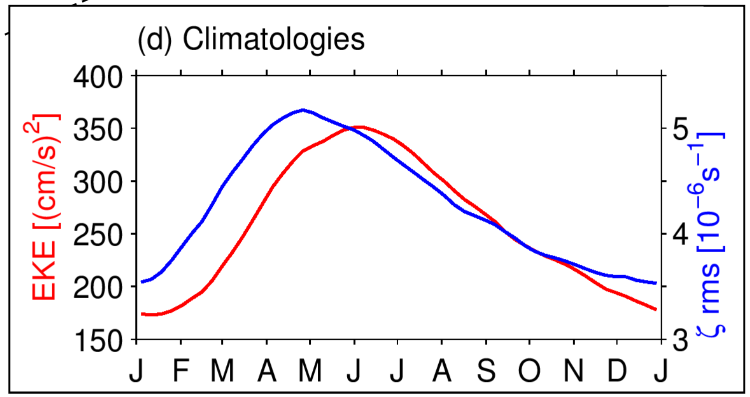


AVISO rms SSH variability in N Pacific

AVISO EKE and rms ζ time series in the STCC band: 18°-28°N, 135°-160°E





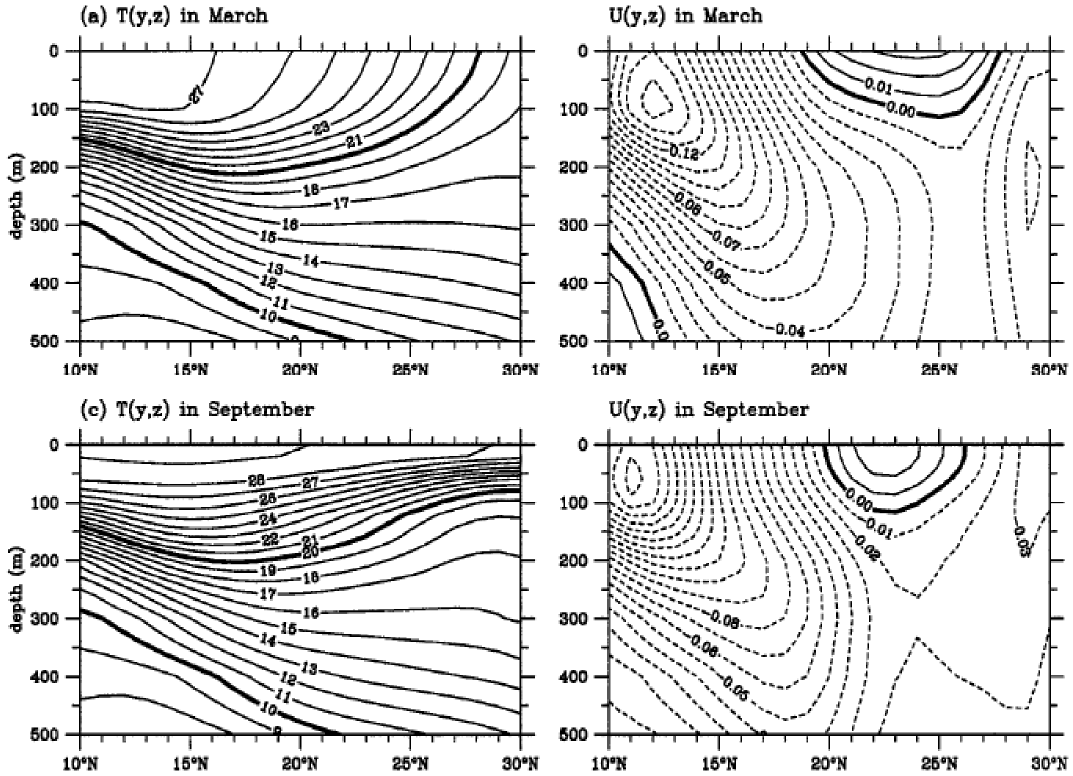


- **well-defined annual cycles**

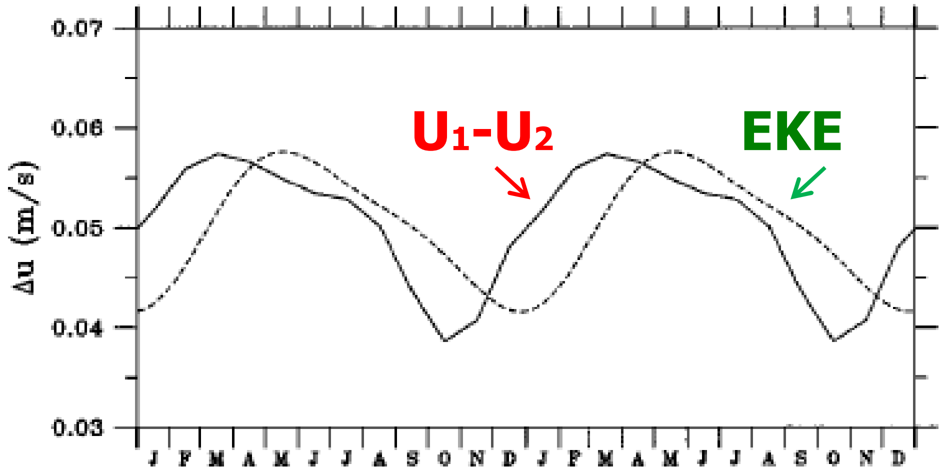
EKE: May max, Dec min

ζ_{rms}: April max, Dec min

T(y,z) & U(y,z) in March vs. September

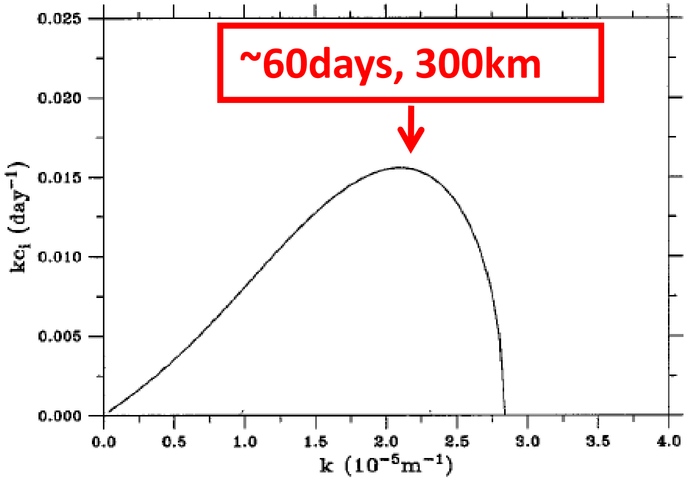


Annual cycle of U_1-U_2 vs EKE



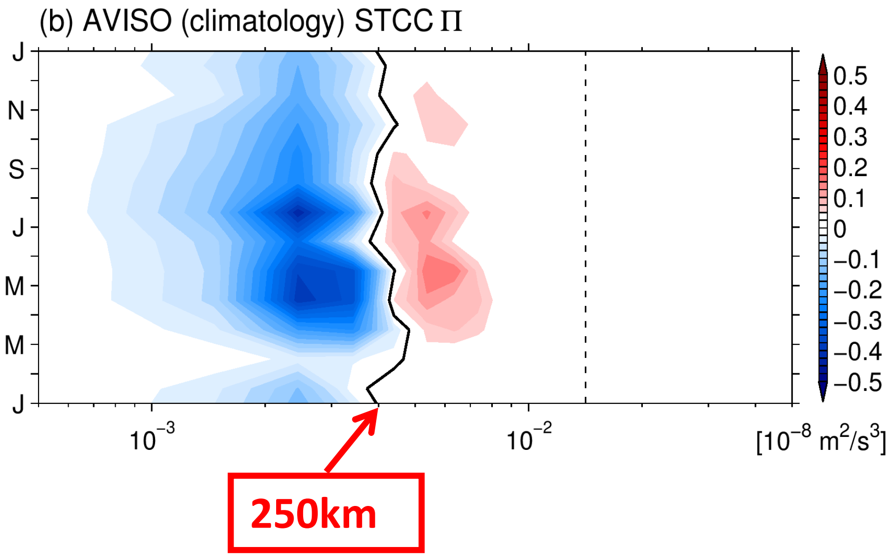
- March: stronger STCC/NEC shear + weaker surface N^2
- 2.5-layer model predicts an e-folding growth scale of ~60 days, explaining EKE delay behind U_1-U_2

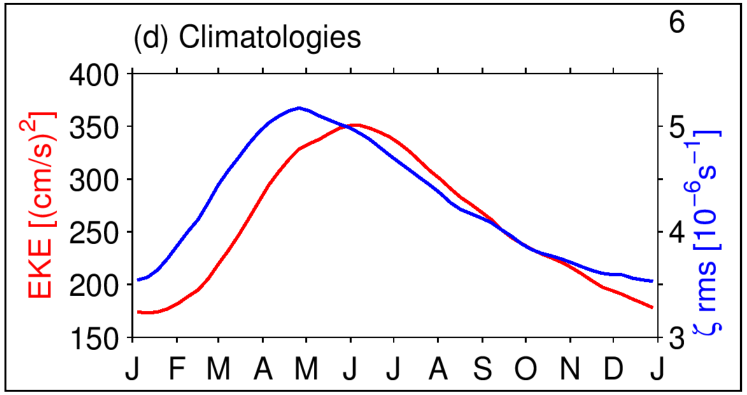
Growth rate in March



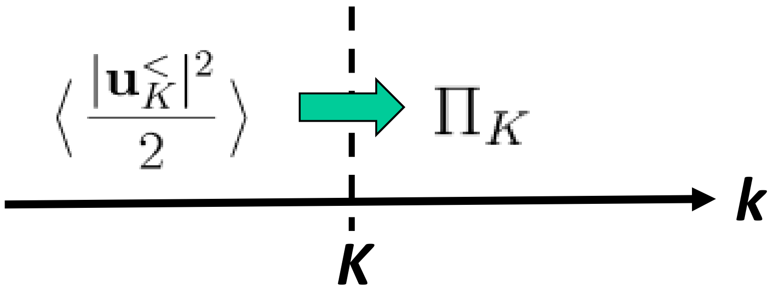
Qiu (1999, JPO)

Spectral kinetic energy flux in the STCC band





$$\Pi_K \equiv \langle\, \mathbf{u}_K^< \cdot (\mathbf{u}_K^< \cdot \nabla \mathbf{u}_K^>)\,\rangle + \langle\, \mathbf{u}_K^< \cdot (\mathbf{u}_K^> \cdot \nabla \mathbf{u}_K^>)\,\rangle$$

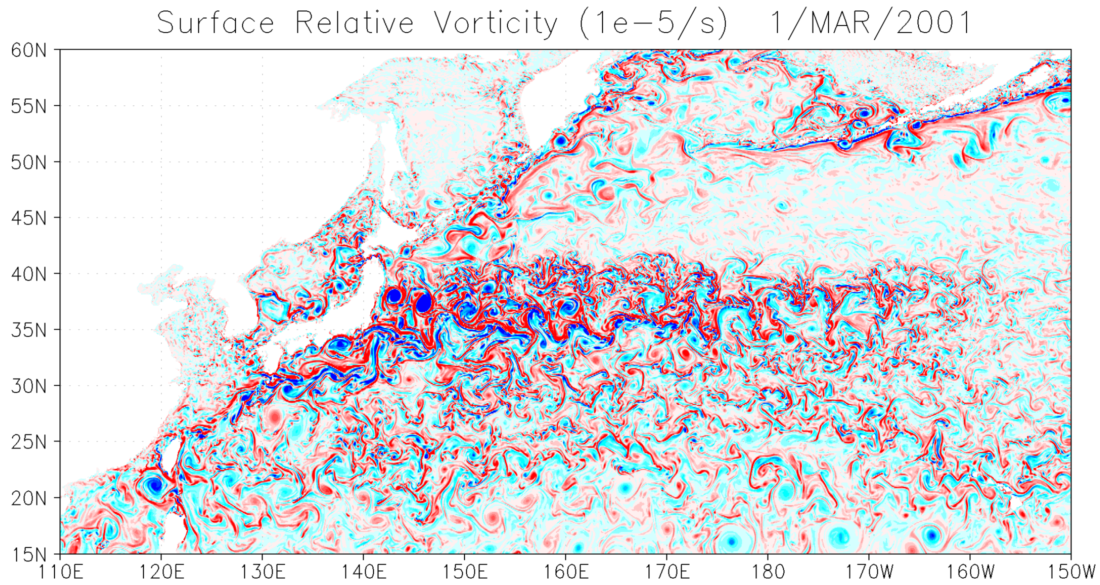


Π_K = **spectral kinetic energy flux** from k < K to k > K through nonlinear interactions

- **March: stronger STCC/NEC shear + weaker surface N^2**
- **2.5-layer model predicts an e-folding growth scale of ~60 days, explaining EKE delay behind U_1-U_2**
- **rms ζ leads EKE due to inverse cascade**

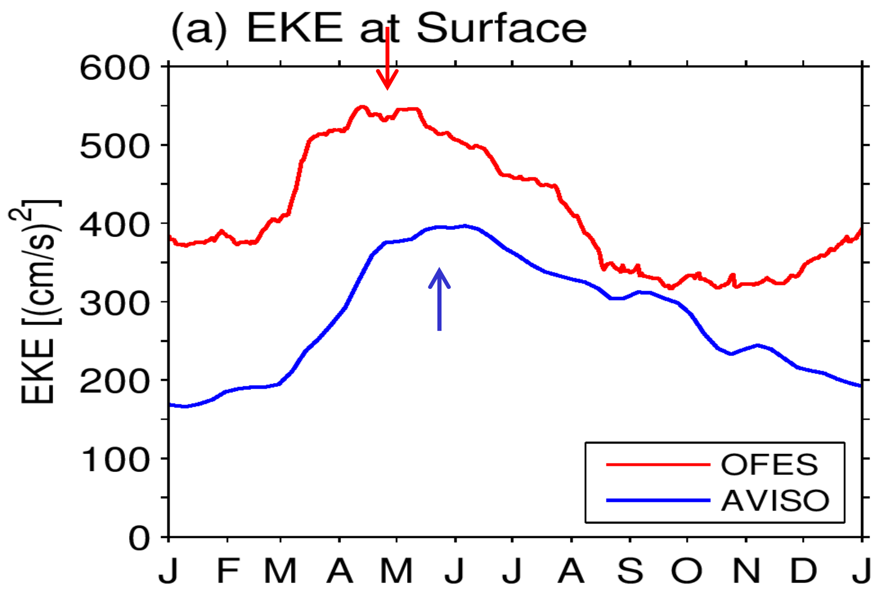
OFES 1/30° N Pacific OGCM Simulation:

- SWOT-equivalent 3-km horizontal grid resolution; 100 vertical levels (60 in upper 500 m)
- Model domain 100°E-70°W, 20°S-66°N
- Initialized with T/S from output of the 1/10° North Pacific hindcast simulation on 1 January 2010
- Forced by JRA-25 6-hourly reanalysis data (1° resolution)



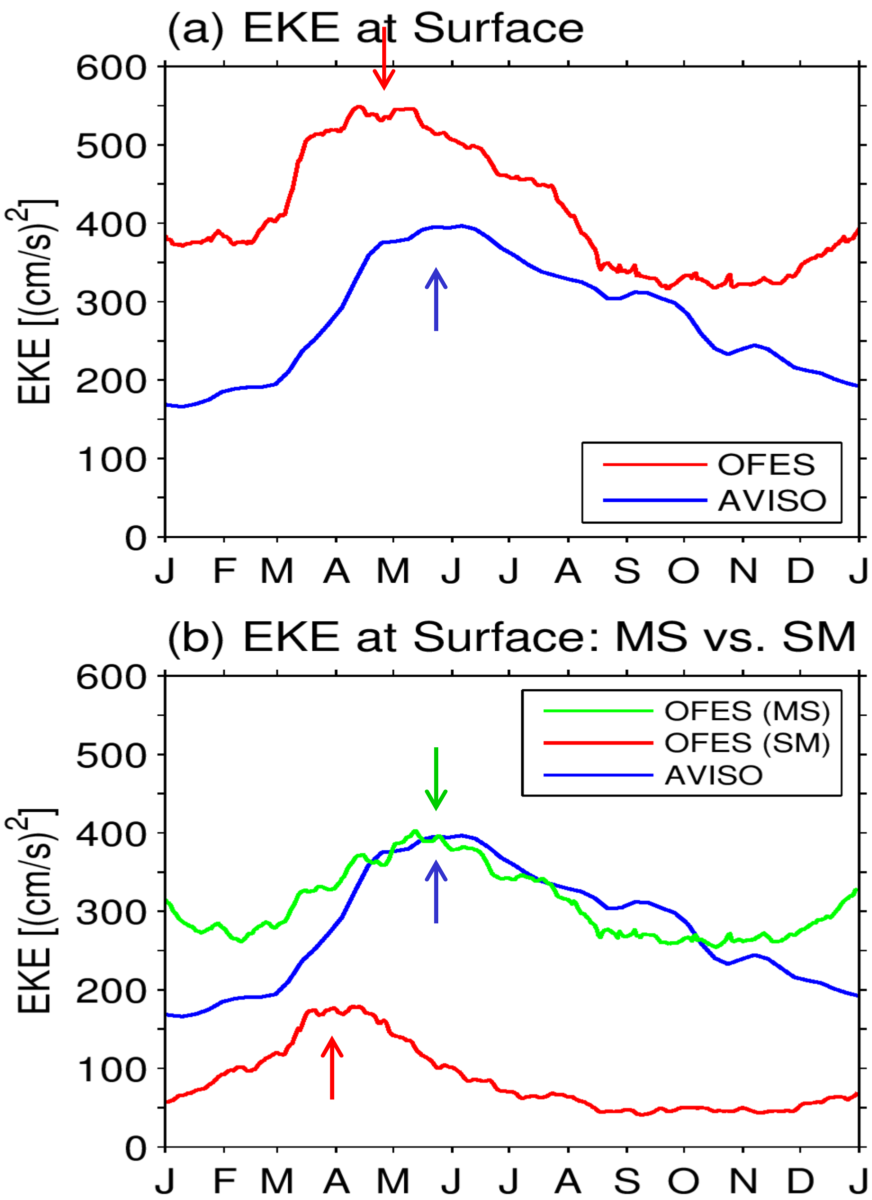
Sasaki and Klein (2012, JPO)

AVISO vs. OFES30 EKE time series in the STCC band: 18°-25°N, 135°-160°E



- **Aside from the energy level, modeled EKE peak precedes the AVISO peak by ~1 month**

AVISO vs. OFES30 EKE time series in the STCC band: 18°-25°N, 135°-160°E



- **Aside from the energy level, modeled EKE peak precedes the AVISO peak by ~1 month**

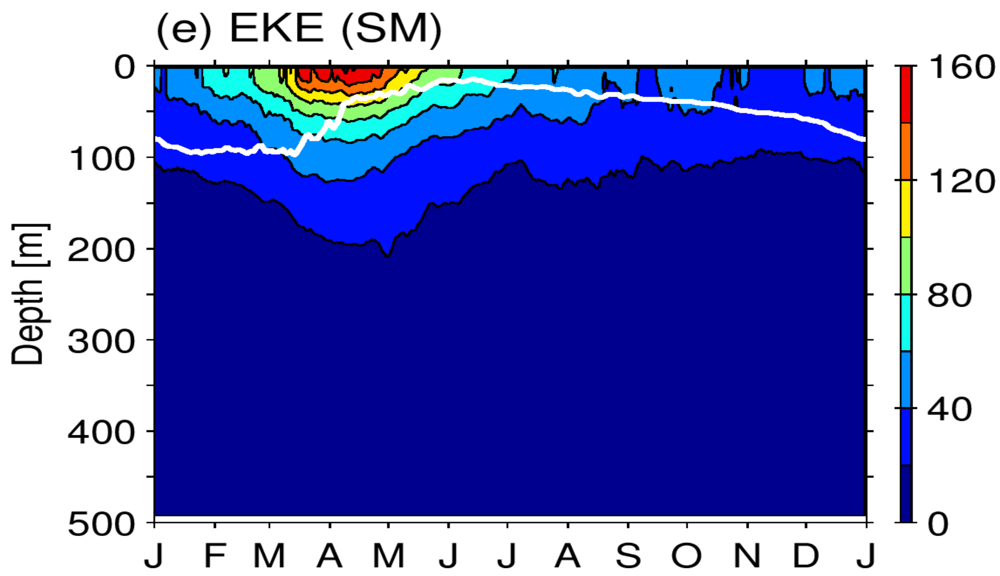
$$\eta' = \eta'_{MS} + \eta'_{SS}$$

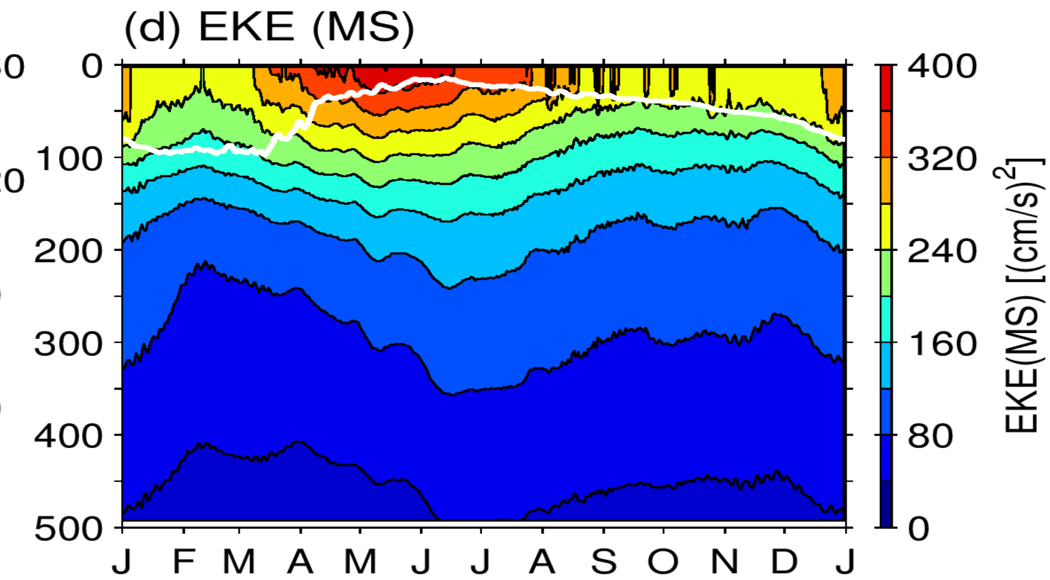
η'_{MS} : **mesoscale SSH signals resolved by AVISO; $2\pi/K > 150$ km**

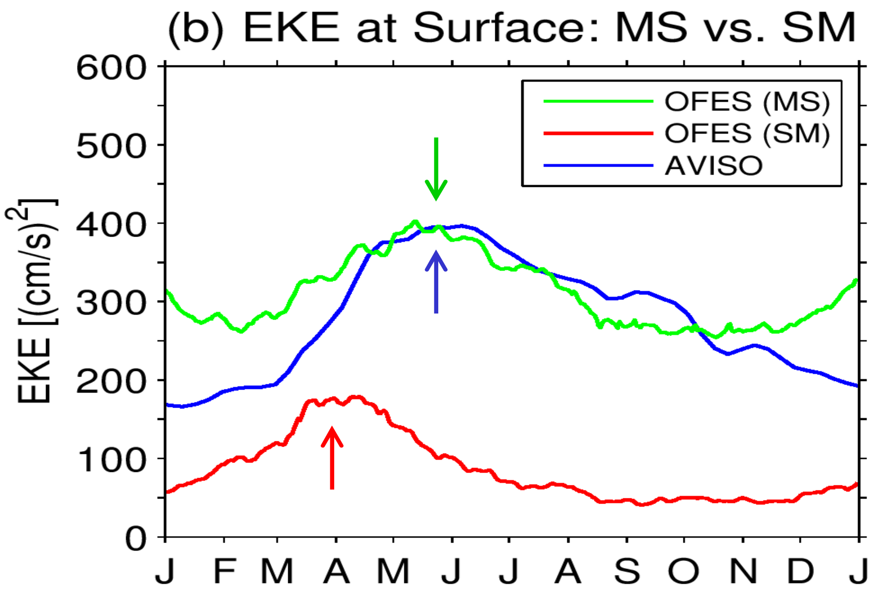
η'_{SS} : **submesoscale SSH signals unresolved by AVISO; $2\pi/K < 150$ km**

- **OFES EKE seasonal amplitude & phase are similar to AVISO**
- **Submesoscale EKE peaks in late March**

OFES30 vertical EKE time series in the STCC band: 18°-25°N, 135°-160°E

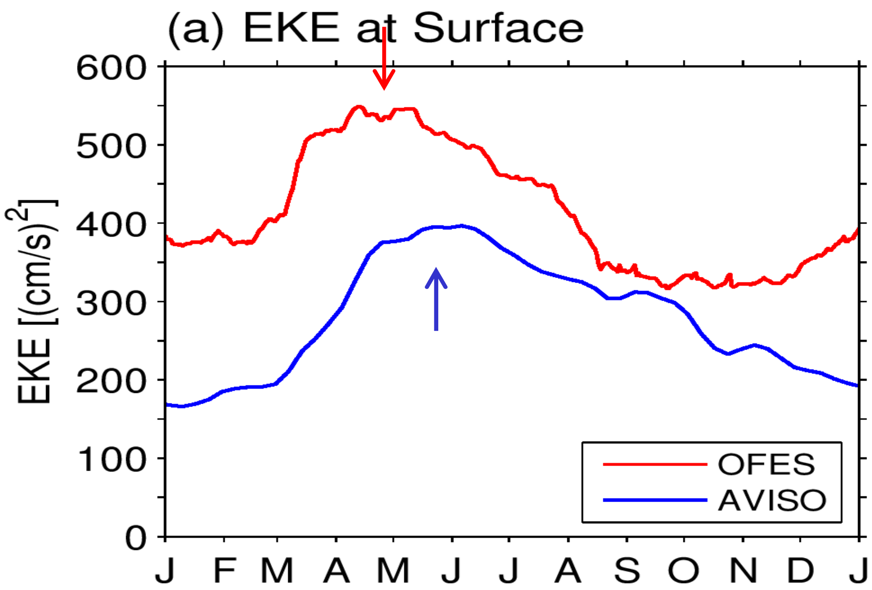




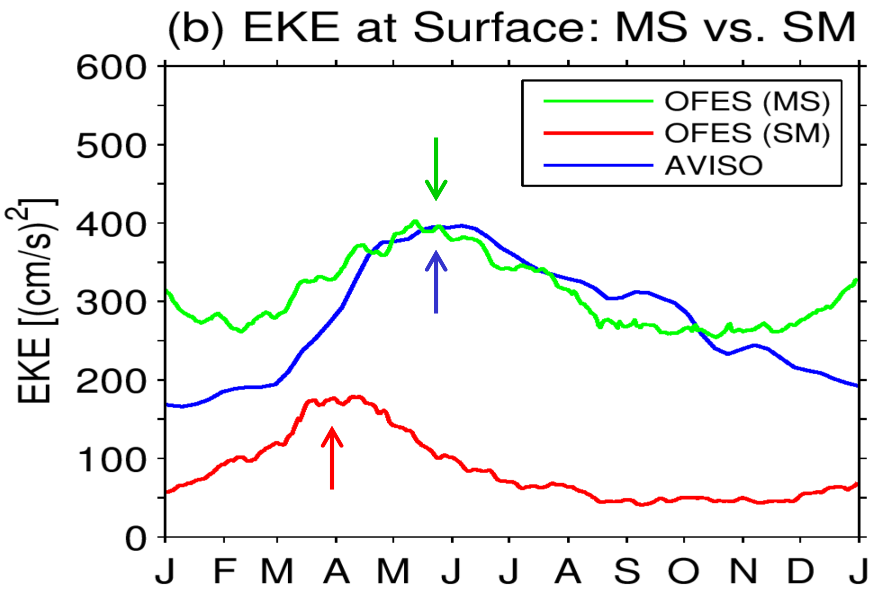


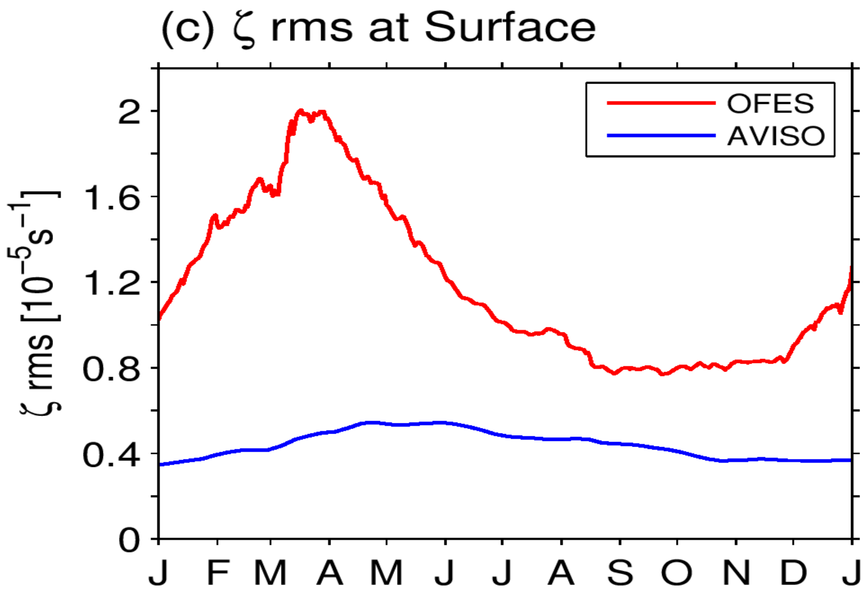
- **Vertically, submesoscale EKE is largely trapped within the surface ML (white curve)**
- **Mesoscale EKE has deeper expressions and its seasonal peak lags with increasing depth**

AVISO vs. OFES30 rms ζ time series in the STCC band: 18°-25°N, 135°-160°E

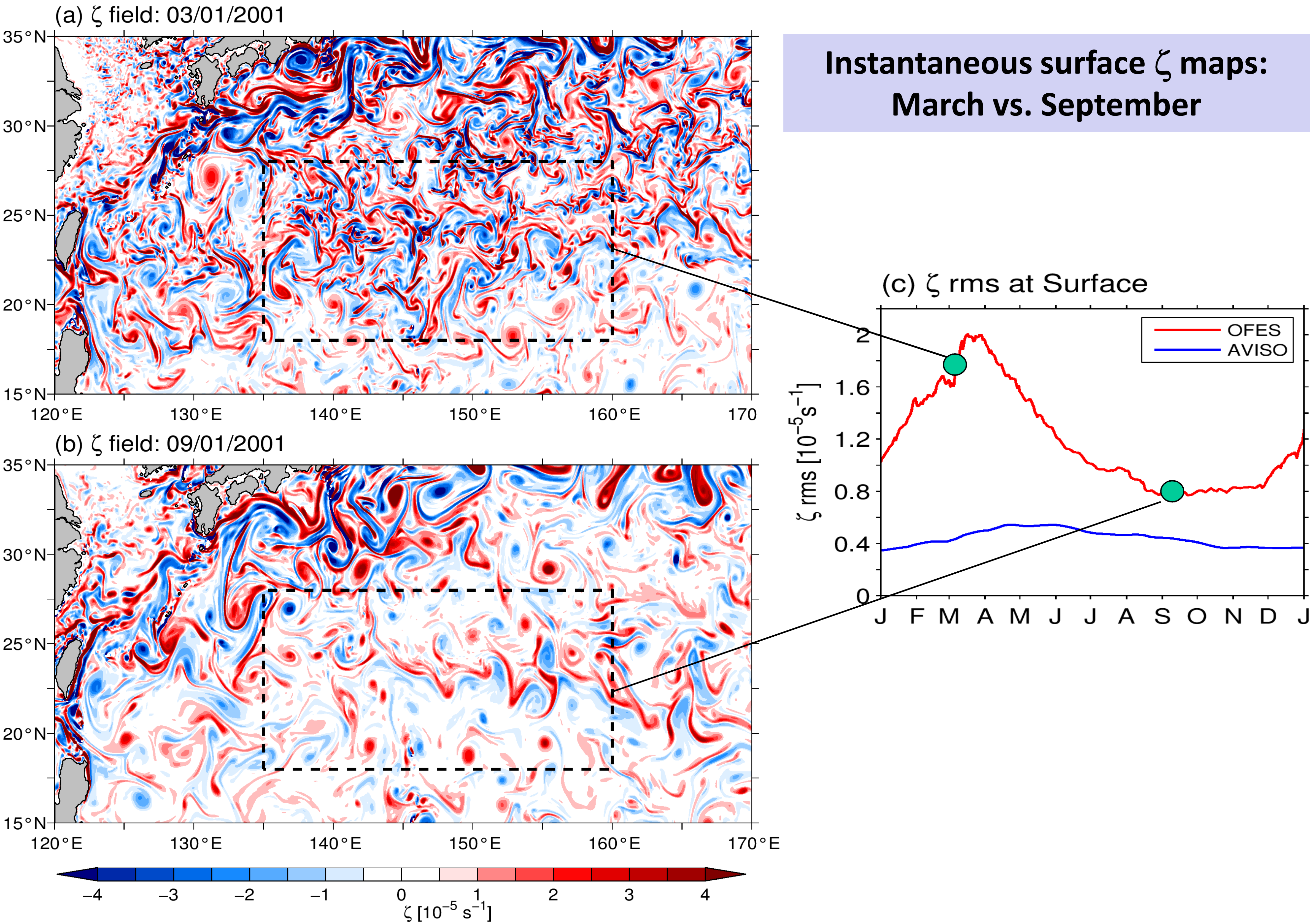


- **Though small in EKE level, submesoscales dominate rms ζ signals**
- **AVISO captures a very weak rms ζ seasonality**

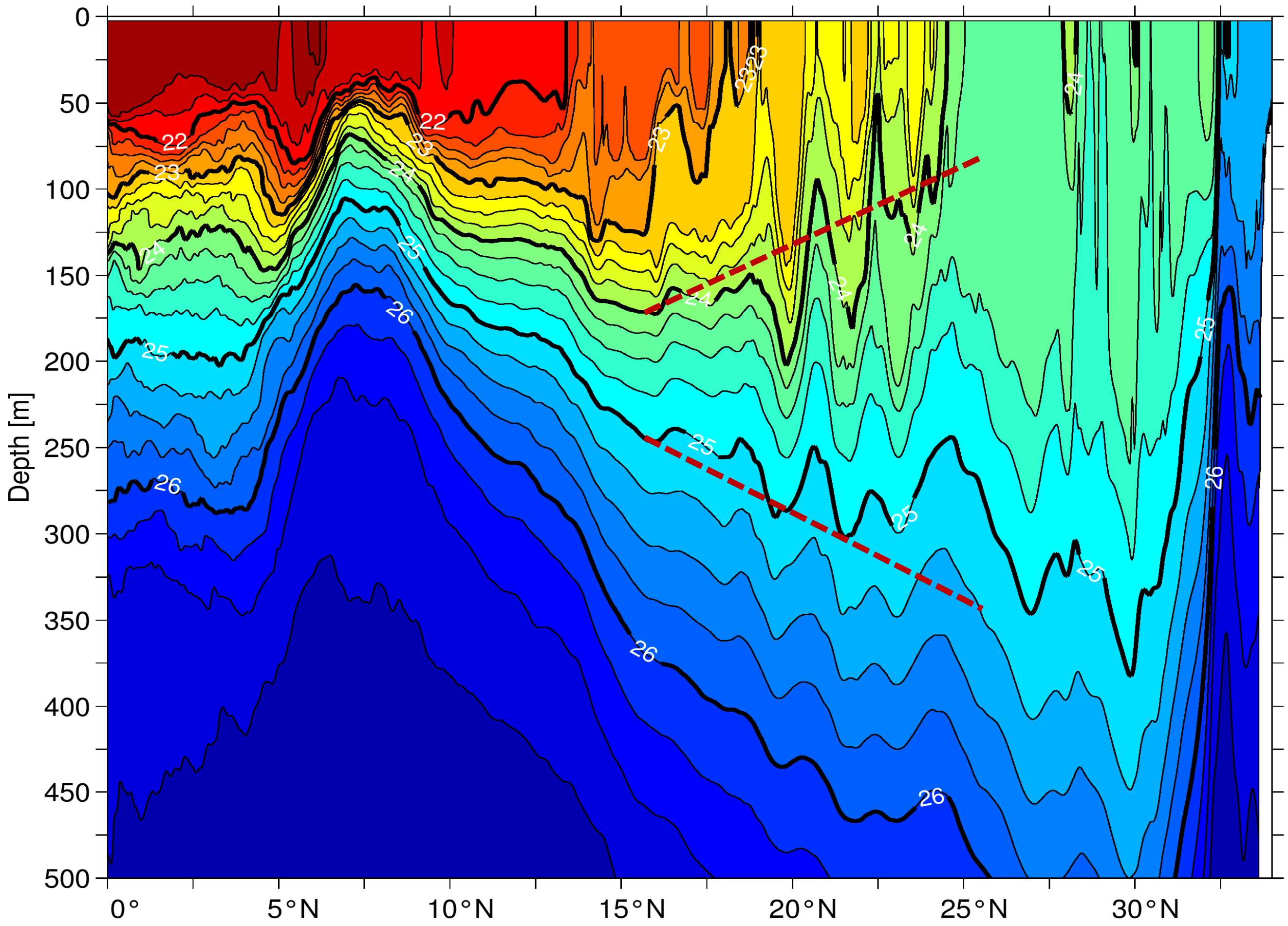


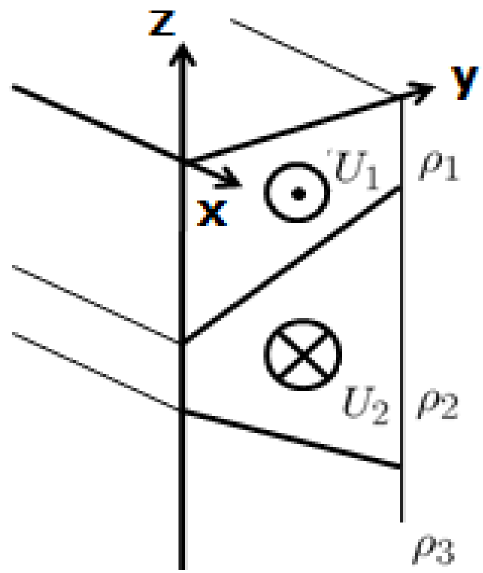


Instantaneous surface ζ maps: March vs. September



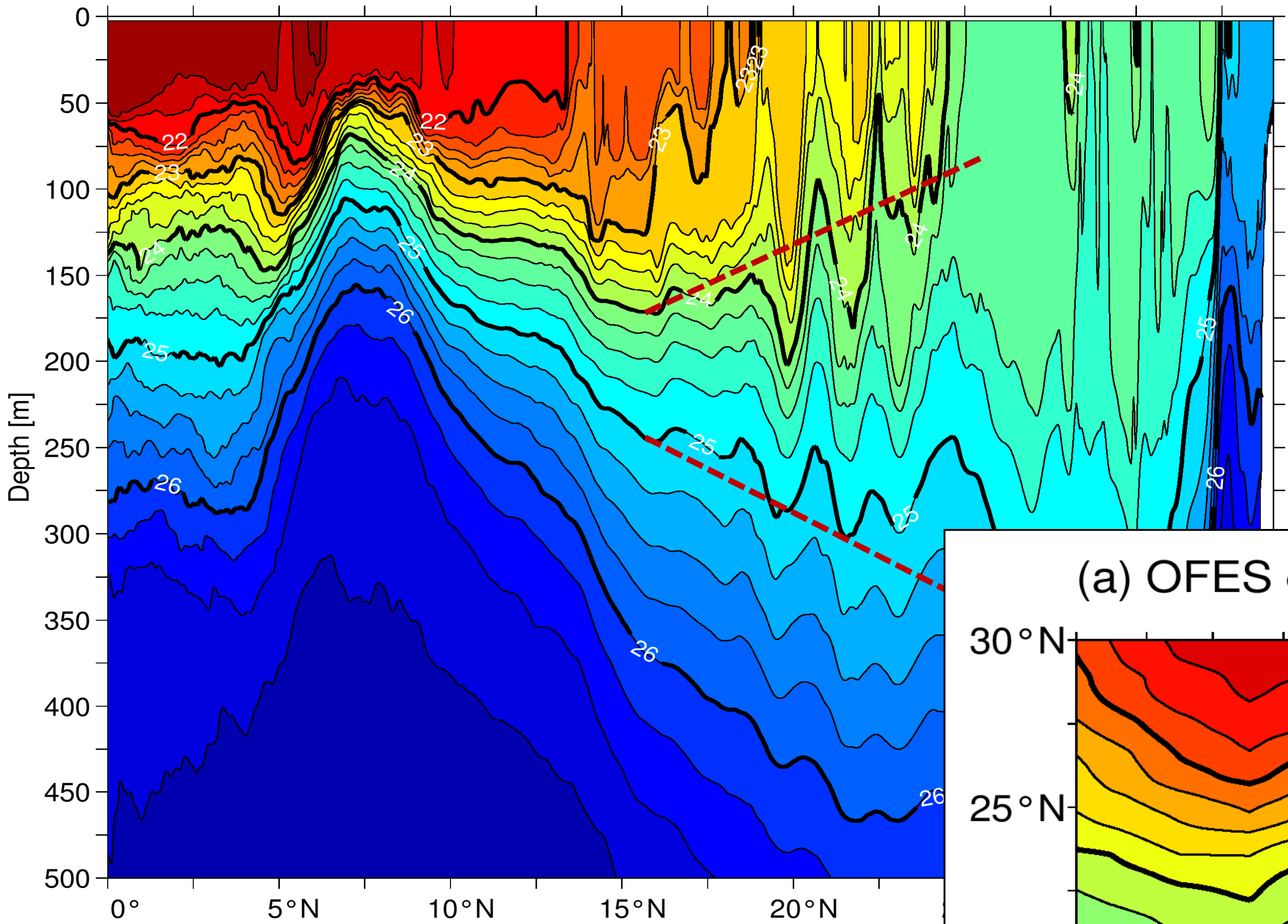
OFES30 σ_θ(y,z) section along 135°E on 1 March 2002



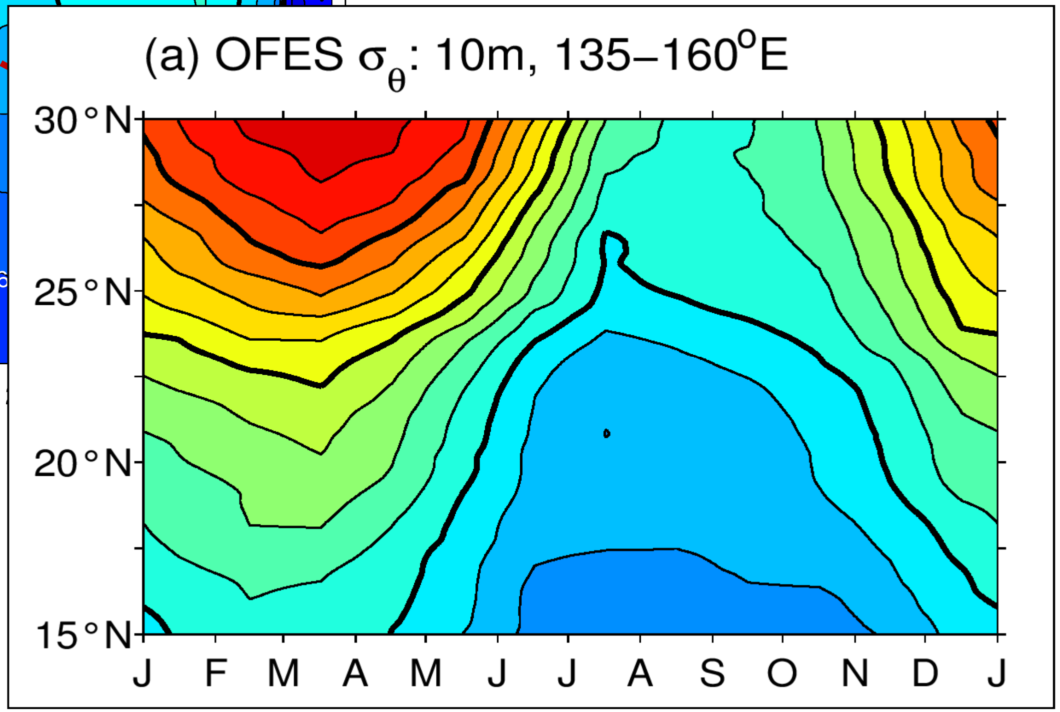


- In addition to the vertical STCC/NEC shear that generates **interior baroclinic instability**, steep density gradients in the mixed layer lead to **submesoscale ML instability**

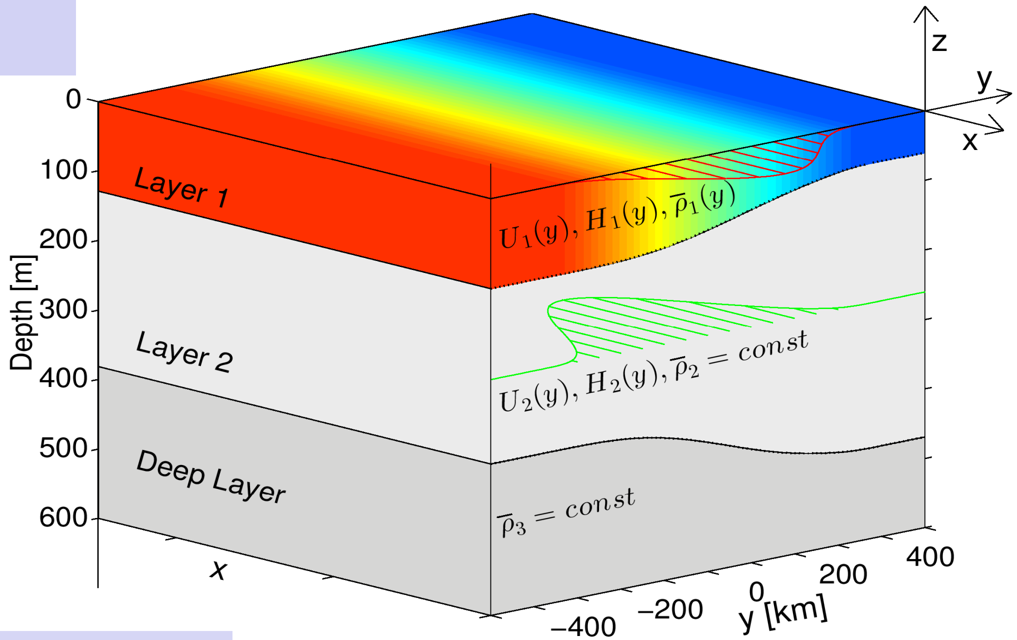
OFES30 $\sigma_\theta(y,z)$ section along 135°E on 1 March 2002



- **The surface STCC front is a function of season; its intensity peaks in March**



An extended 2.5-layer RG model with a density front embedded in upper layer



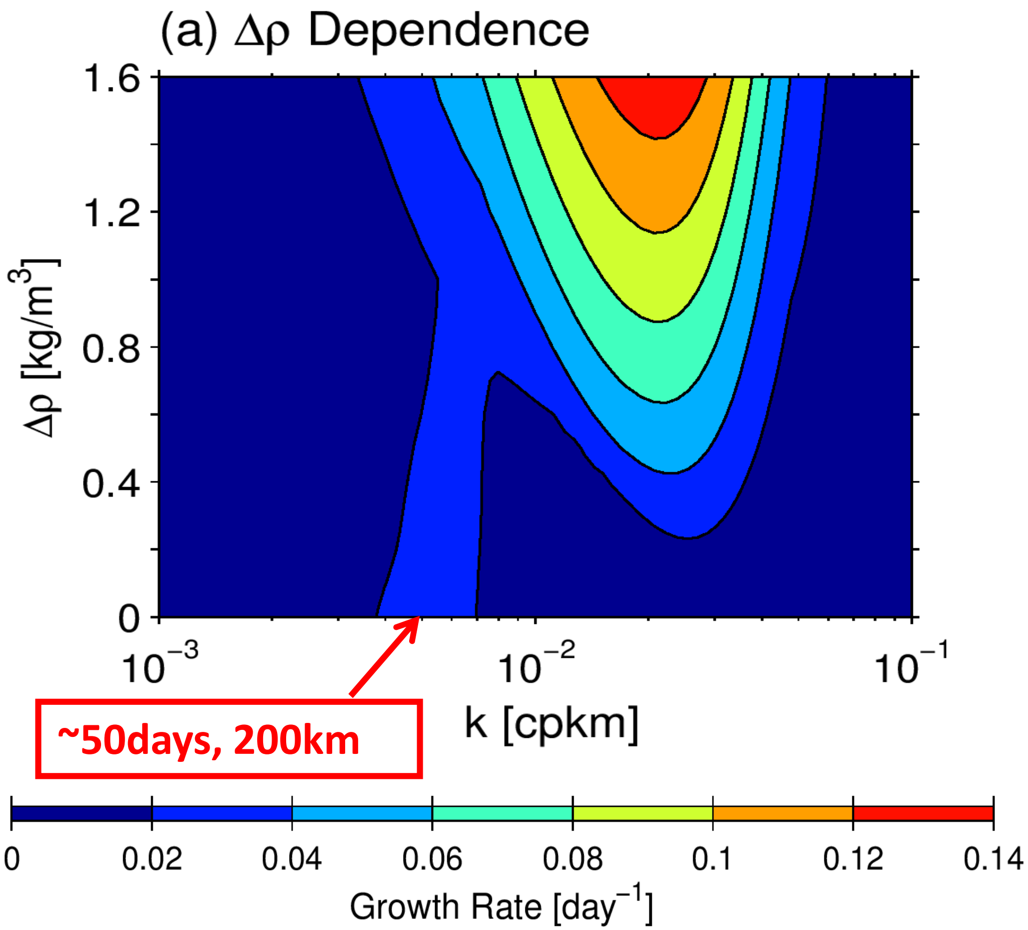
Idealized U-profiles for STCC, NEC, and ML density:

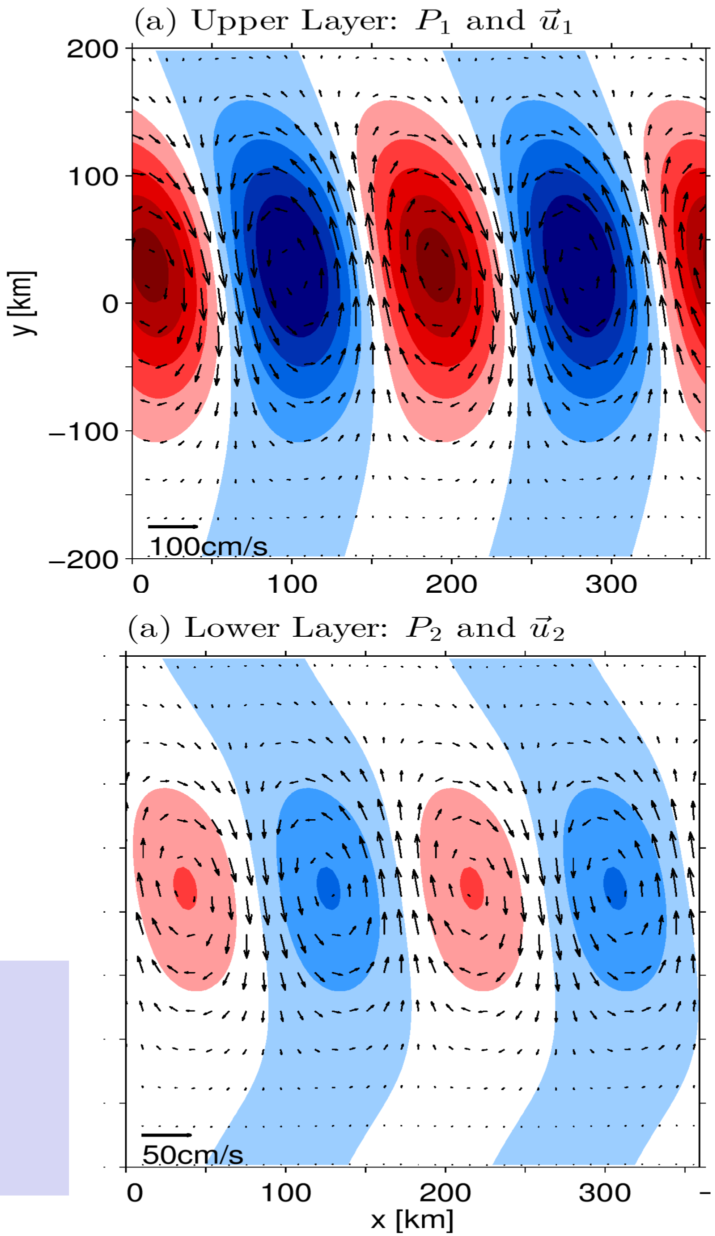
$$U_i(y) = \begin{cases} \frac{1}{2} A_i \left[1 + \cos \frac{2\pi(y-y_0)}{L} \right], & |y-y_0| \leq L/2 \\ 0, & \text{otherwise} \end{cases}$$

$$\overline{\rho}_1(y) = \begin{cases} \overline{\rho}_{10} - \Delta\rho/2, & y - y_0 < -L/2 \\ \overline{\rho}_{10} + (y-y_0)\Delta\rho/L, & |y-y_0| \leq L/2 \\ \overline{\rho}_{10} + \Delta\rho/2, & y - y_0 > L/2, \end{cases}$$

Δρ sets the strength of STCC front

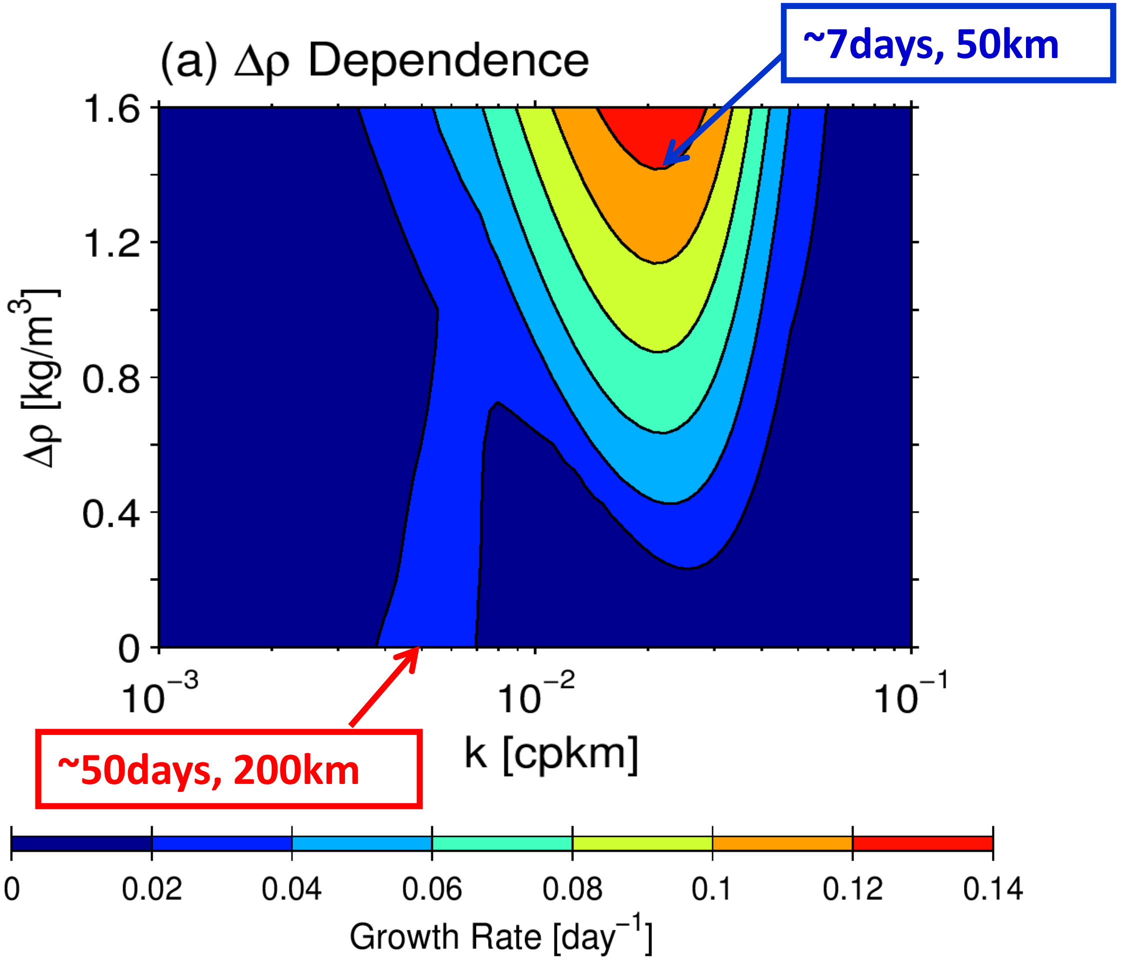
Interior baroclinic instability vs. submesoscale ML instability

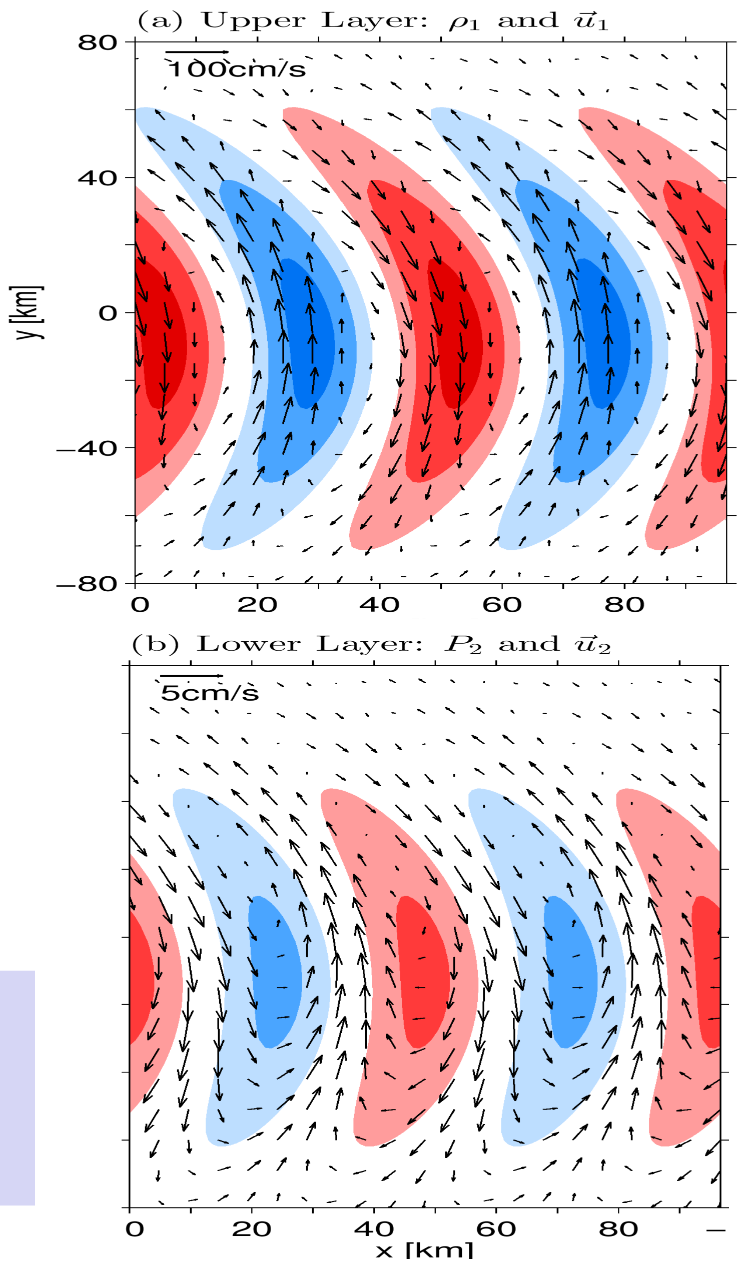




- When Δρ=0, recovers the interior QG instability
- Vertical anomalies tilted again the mean STCC/ NEC shear; layer anomalies have similar amplitudes

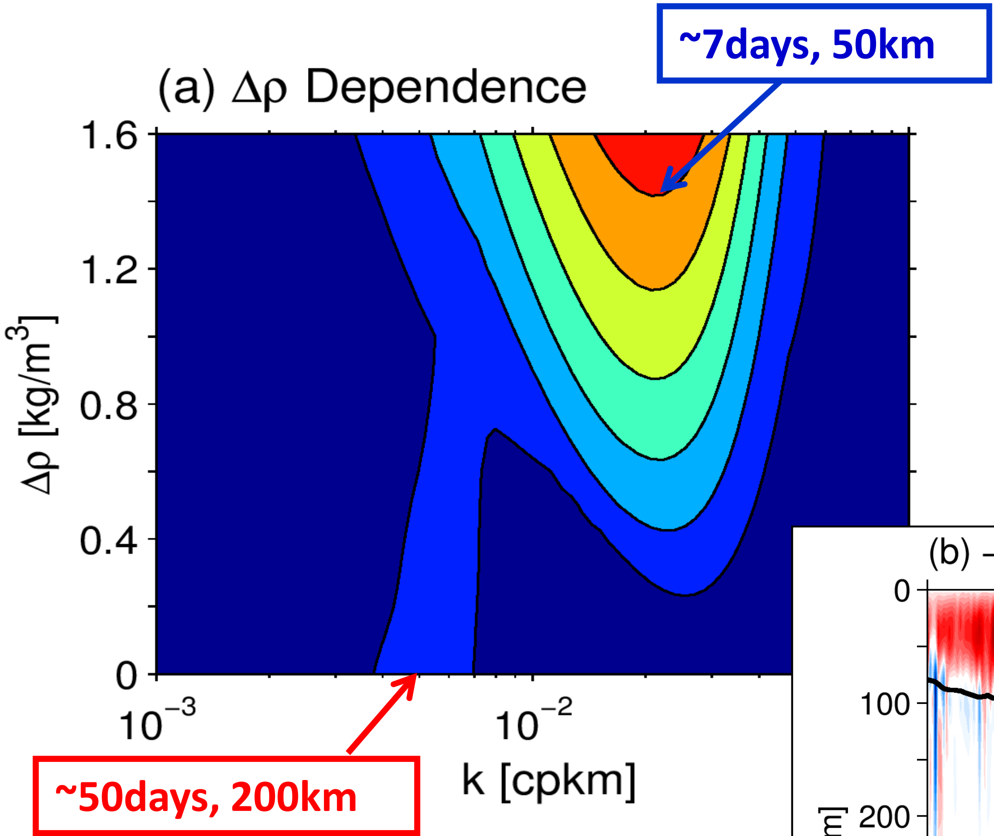
Interior baroclinic instability vs. submesoscale ML instability

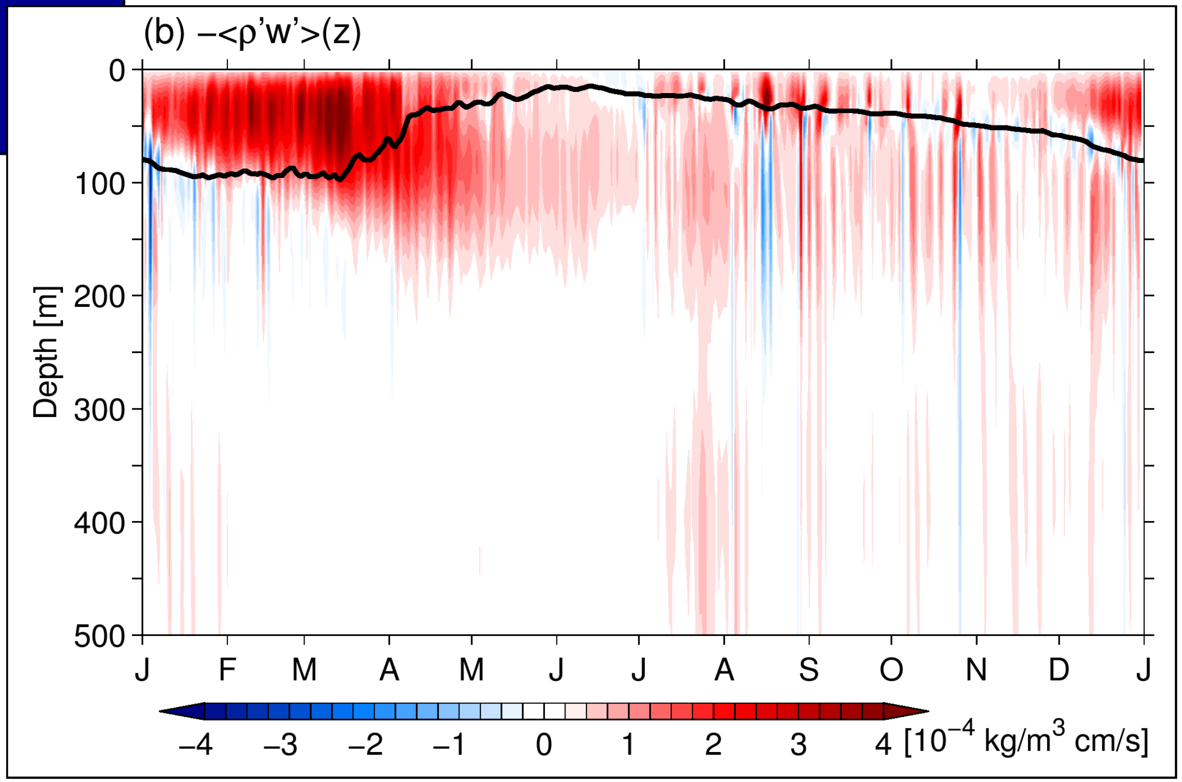




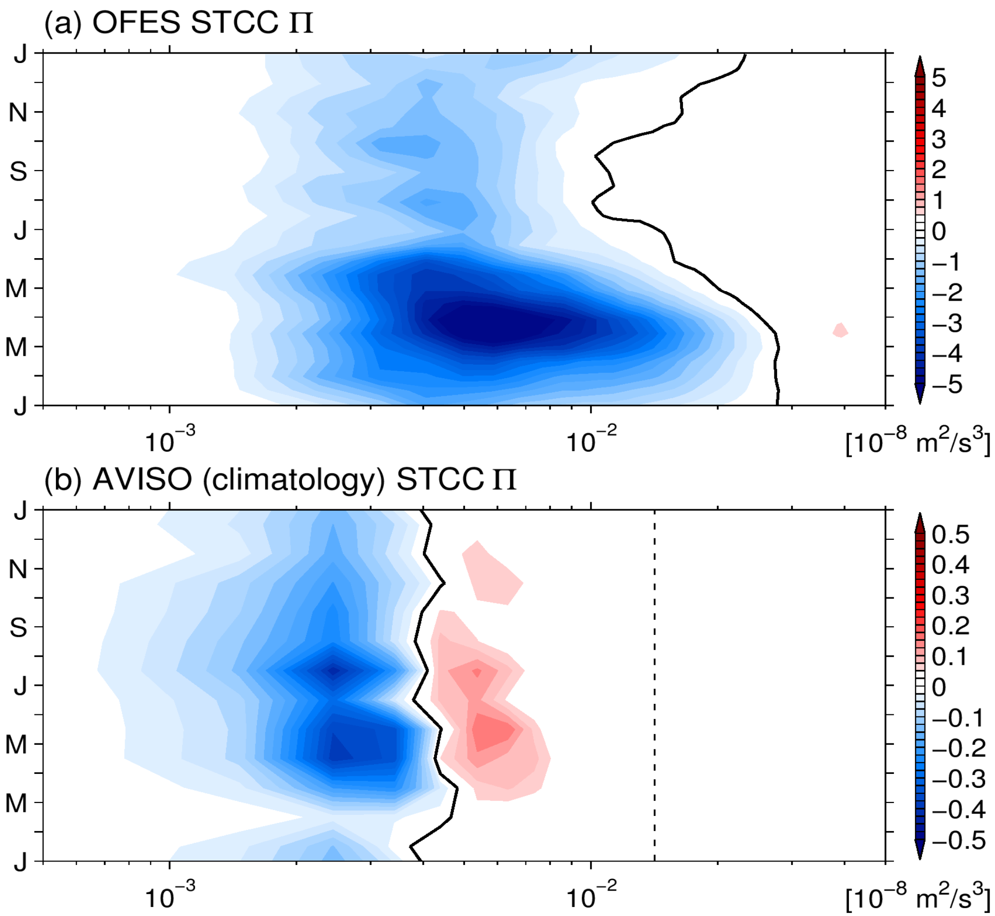
- **When Δρ≠0, ML frontal instability occurs**
- **Anomalies surface trapped, release of upper layer meridional T gradient (or APE)**

- **– <ρ'w'> is confined to ML during winter relating to ML instability**
- **It extends vertically into the main thermocline after April relating to interior baroclinic instability**





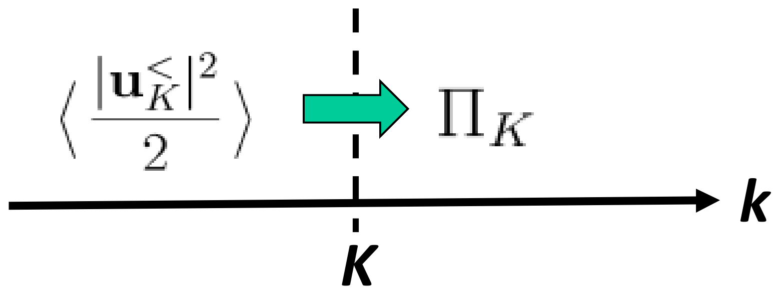
Diagnosing the conversion from APE to EKE: – <ρ'w'> in the STCC region



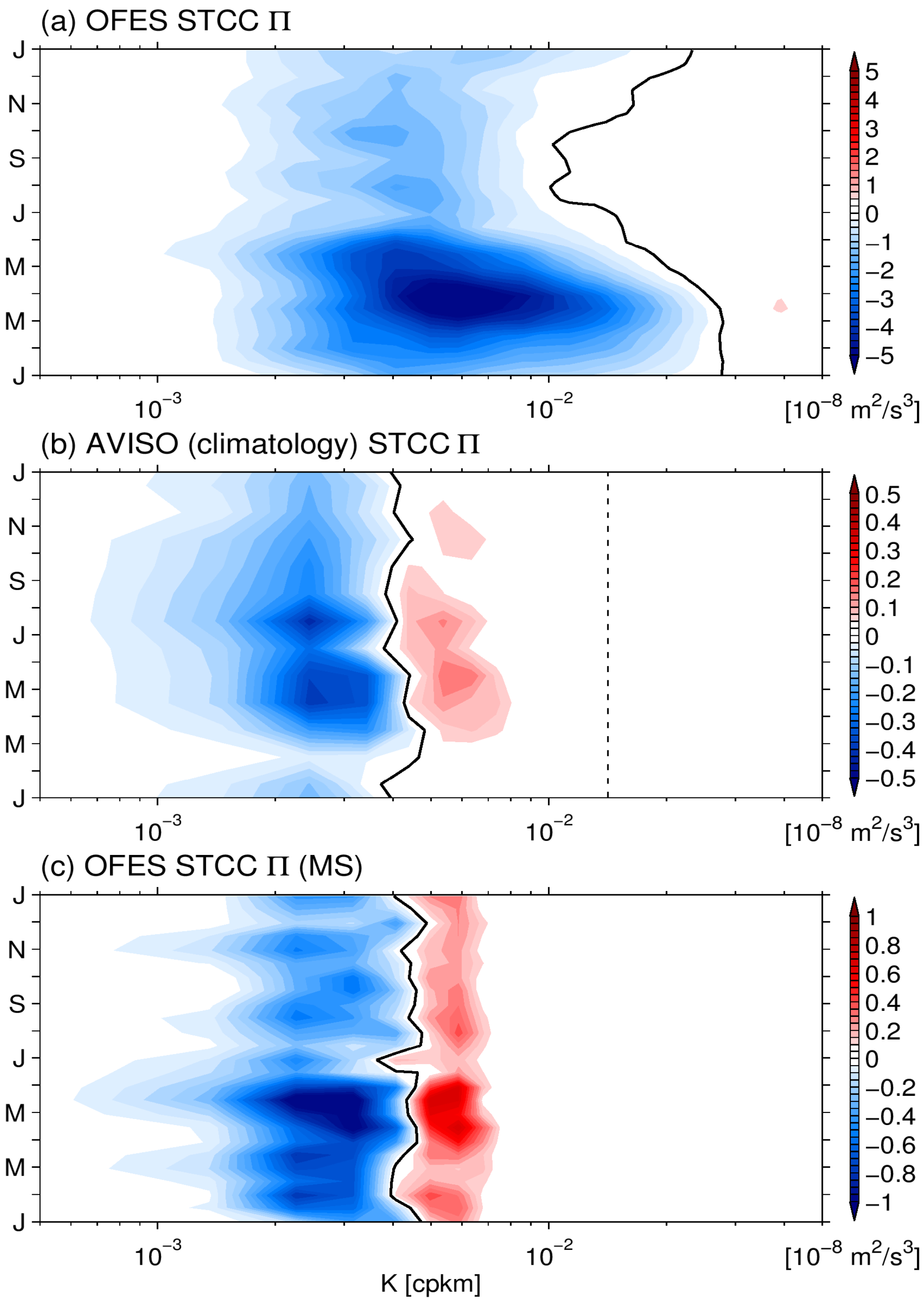
OFES30 vs AVISO spectral kinetic energy flux in the STCC band as a function of season

- **Inverse KE cascade is maximum in March/April (peak of ML instability) with scales as small as 30~40 km < L_R = 60 km.**

- **AVISO result shows the cascade scale separation at ~250km, an order of magnitude larger.**
- **Max inverse cascade is in May, not March-April.**



Π_K = **spectral kinetic energy flux** from k < K to k > K through eddy-eddy interactions



OFES30 vs AVISO spectral kinetic energy flux in the STCC band as a function of season

- Inverse KE cascade is maximum in March/April (peak of ML instability) with scales as small as 30~40 km < L_R = 60 km.

- AVISO result shows the cascade scale separation at ~300km, an order of magnitude larger.

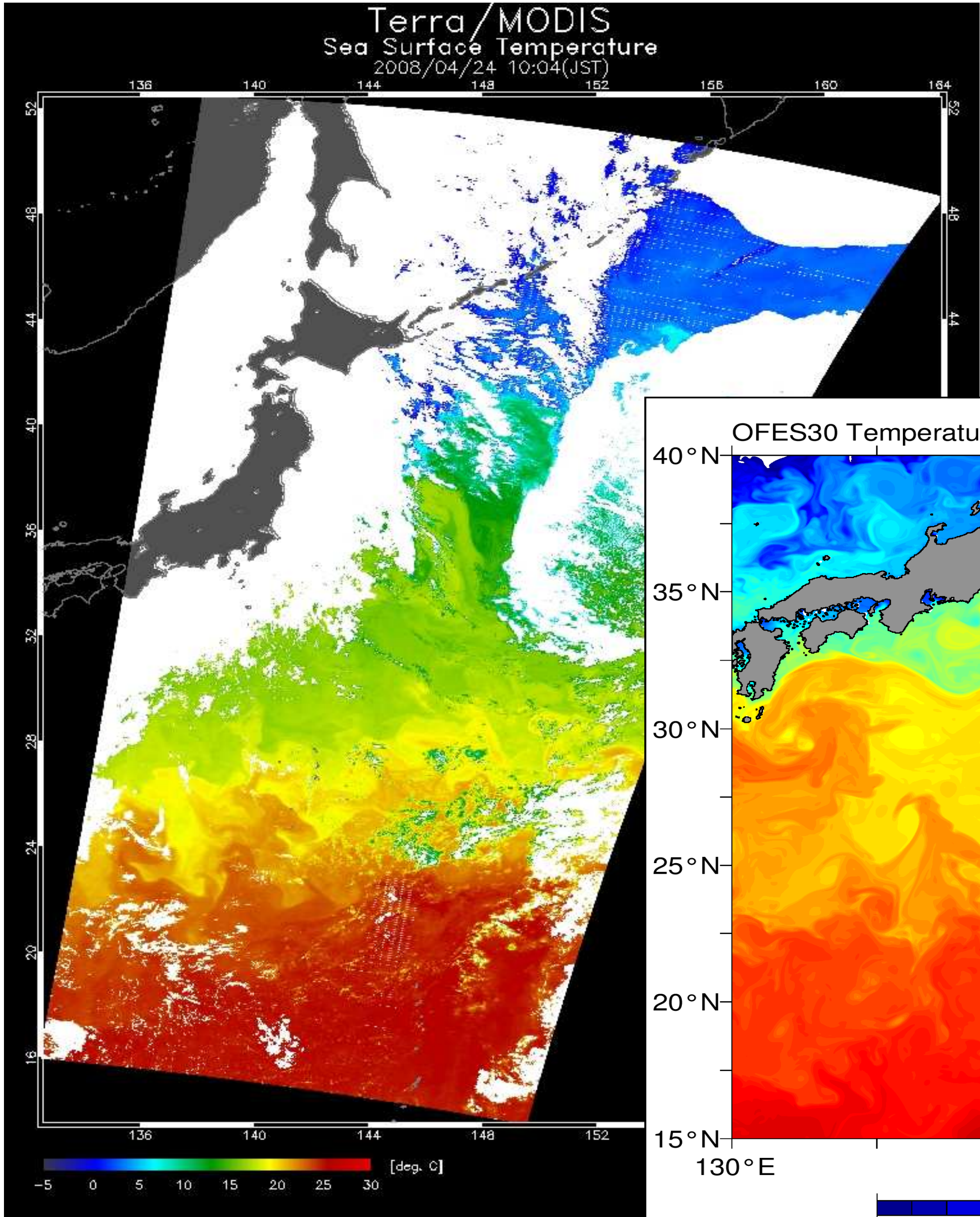
- Max inverse cascade is in May, not March-April.

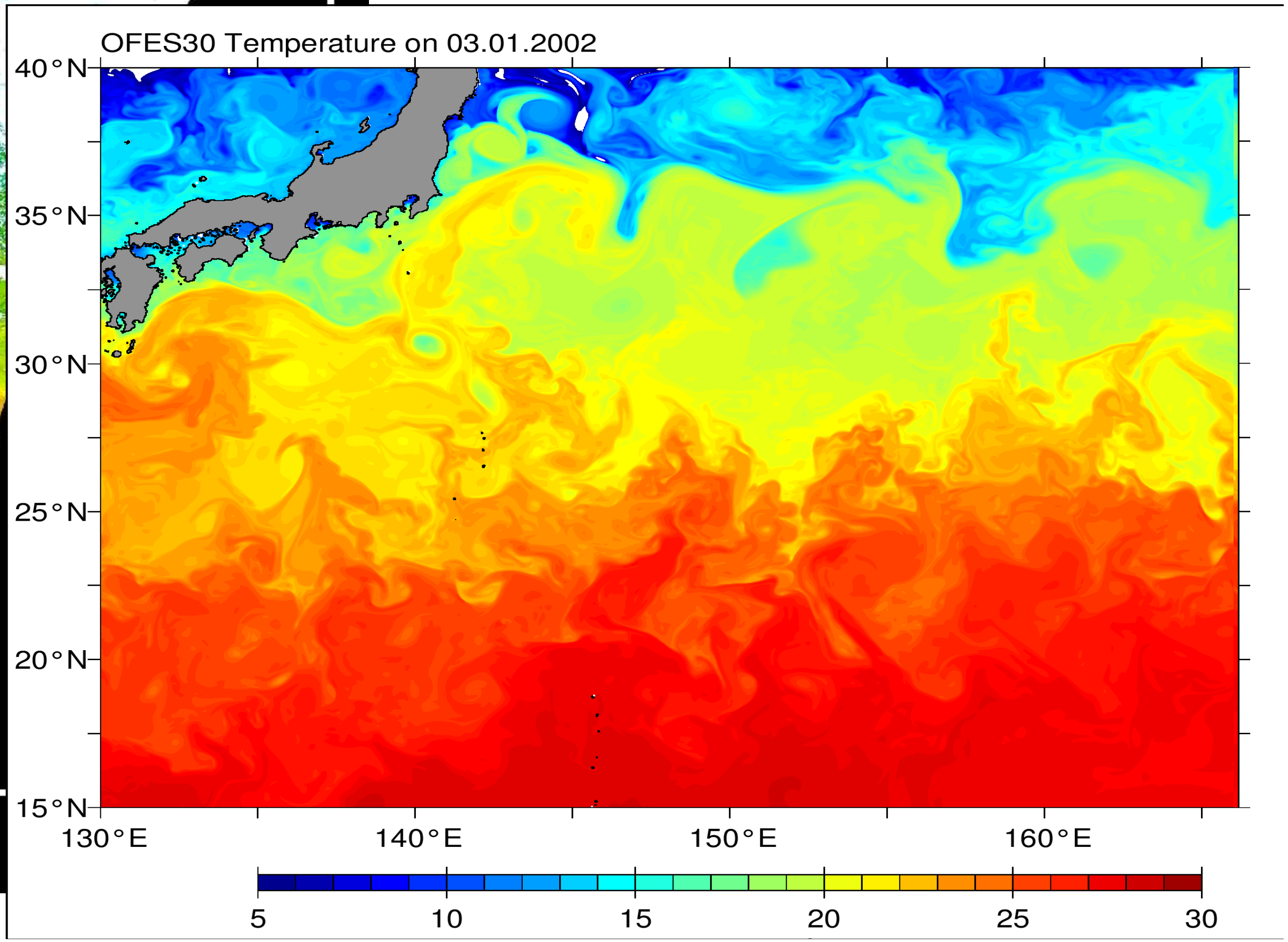
- When mesoscale OFES SSH data is used, energy cascade shows similar patterns as AVISO.

Concluding Remarks

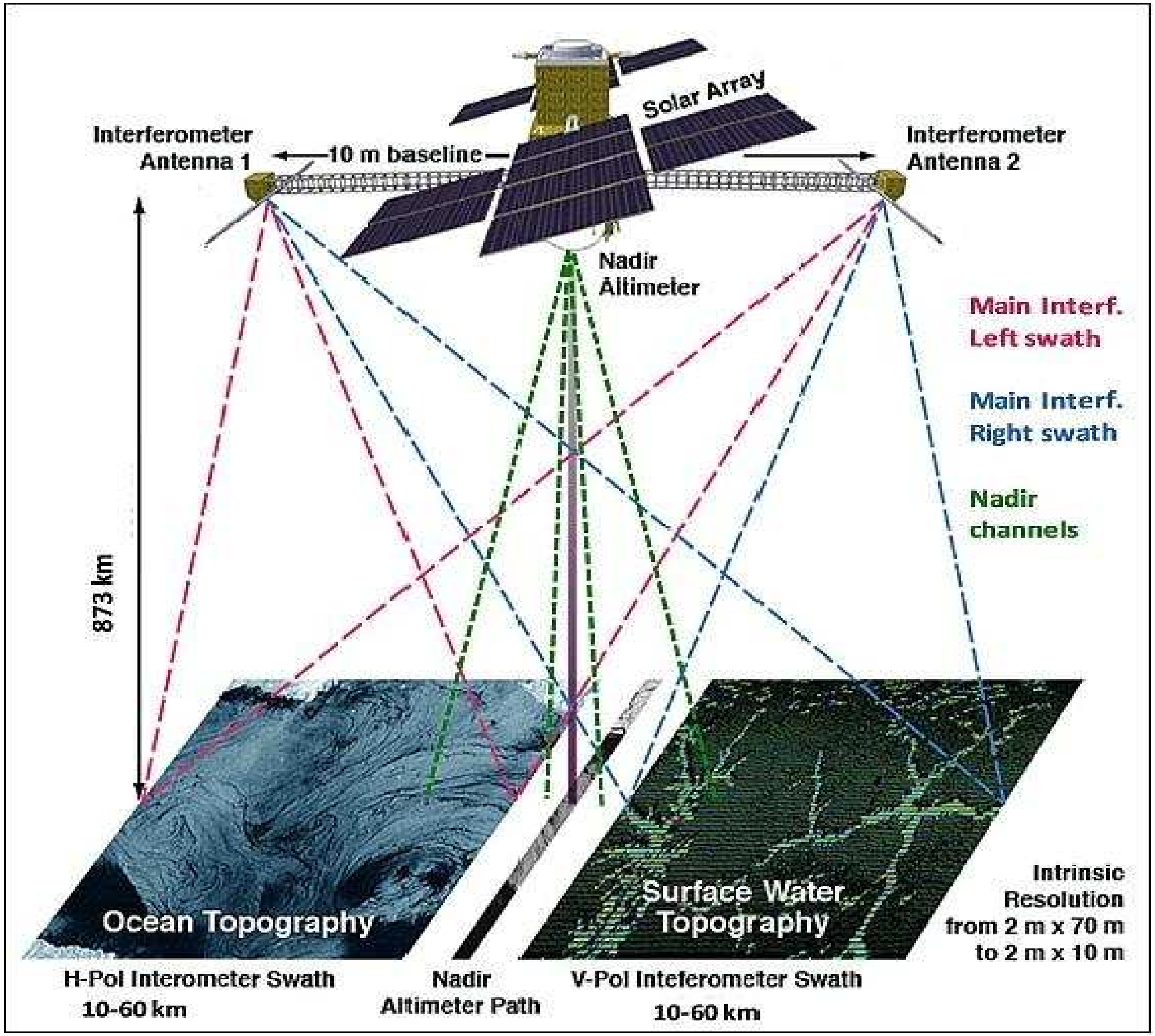
- AVISO product only captures the mesoscale features > 150km. Caution is needed in analyses involving EKE seasonal cycle, spectral fluxes & vorticity polarities.
- Interior and ML baroclinic instabilities occur concurrently along STCC. Interior instability is deep-reaching, slowly-growing and occurs year-round with a spring max. It contributes directly to mesoscale eddy variability.
- ML instability is confined to wintertime surface ML, fast-growing, and disappears after spring. It generates submesoscale variability and contributes to mesoscales through inverse cascade.
- It is important for future altimeter missions to capture submesoscale circulation features and verify their representations in high-res. OGCMs.

- **Wintertime submesoscale SST filaments along STCC seen both in observations and OFES30**





“Surface Water and Ocean Topography (SWOT)” Mission



www.jpl.nasa.gov/missions/surface-water-and-ocean-topography-swot/

- Point vs 200km-wide swath measurements
- O(100~150km) vs O(10km) resolution;

  cf. L_R = O(50km)
- Main mission: 21-day repeat with 10-day subcycle
- 1-day repeat for initial 90 days
- To be launched jointly by NASA-CNES in 2020