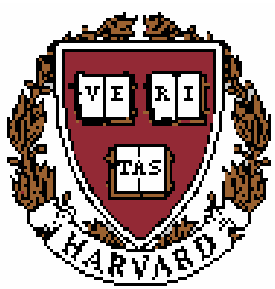
Multi-Scale Processes and Dynamics for the Monterey Bay Region Circulation

X. San Liang

New York University
Courant Institute of Mathematical Sciences
Center for Atmosphere Ocean Science

Allan R. Robinson

Harvard University
Division of Engineering and Applied Sciences
Department of Earth and Planetary Sciences



Multi-Scale Energy and Vorticity Analysis

- **MS-EVA utilizes multiple scale window decomposition in space and time for the investigation of processes which are multi-scale interactive, nonlinear, intermittent in space and episodic in time**

- **Through exploring pattern generation and energy and enstrophy transfers transports, and conversions**

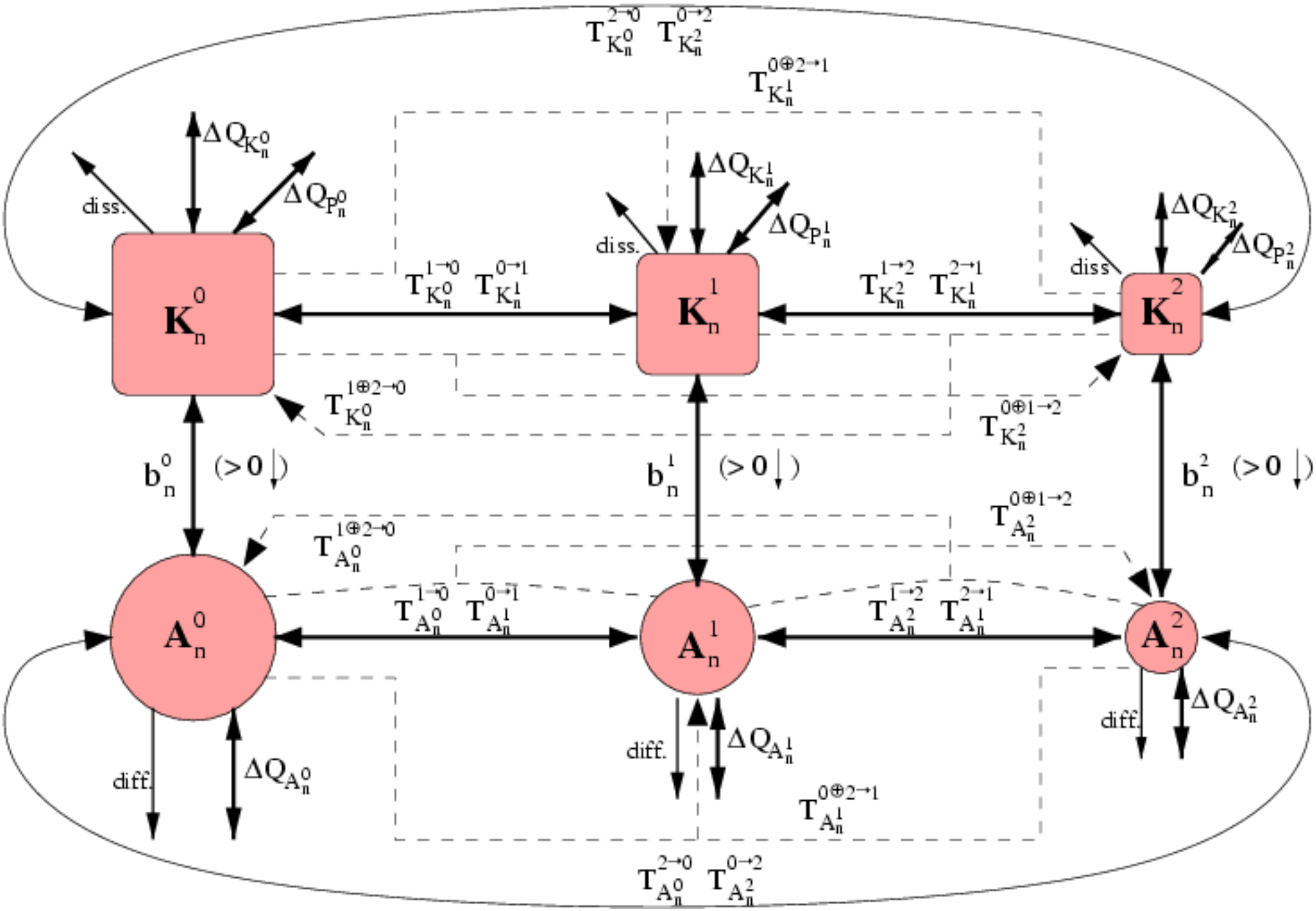
- **MS-EVA helps unravel the intricate relationships between events on different scales and locations in phase and physical space.**

Multi-Scale Energy and Vorticity Analysis

Symbols for multiscale energetics (time step n, scale window ϖ).

Kinetic energy (KE)		Available potential energy (APE)	
$\dot{K}_n^{\varpi}$	Time rate of change of KE	$\dot{A}_n^{\varpi}$	Time rate of change of APE
$\Delta Q_{K_n^{\varpi}}$	KE advective working rate	$\Delta Q_{A_n^{\varpi}}$	APE advective working rate
$T_{K_n^{\varpi}}$	Total KE transfer	$T_{A_n^{\varpi}}$	Total APE transfer
$\Delta Q_{P_n^{\varpi}}$	Pressure working rate	b_n^{ϖ}	Rate of buoyancy conversion
$F_{K_n^{\varpi},z}$	Rate of vertical dissipation	$F_{A_n^{\varpi},z}$	Rate of vertical diffusion

Multi-Scale Energy and Vorticity Analysis



Multi-Scale Energy and Vorticity Analysis

Window-Window Interactions:
MS-EVA-based Localized Instability Theory

Perfect transfer:

A process that exchanges energy among distinct scale windows which does not create nor destroy energy as a whole.

In the MS-EVA framework, the perfect transfers are represented as field-like variables. They are of particular use for real ocean processes which in nature are non-linear and intermittent in space and time.

Localized instability theory:

BC: Total perfect transfer of APE from large-scale window to meso-scale window.

BT: Total perfect transfer of KE from large-scale window to meso-scale window.

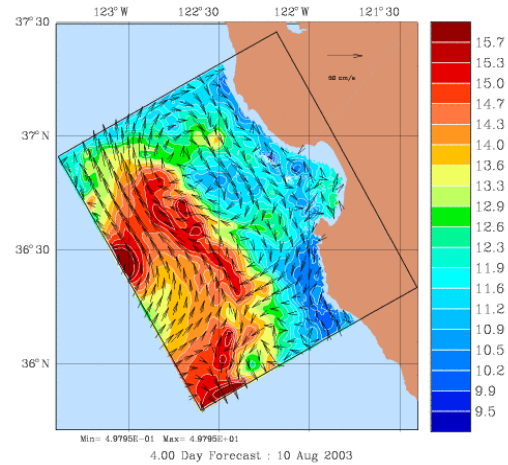
$BT + BC > 0$ => system locally unstable; otherwise stable

If $BT + BC > 0$, and

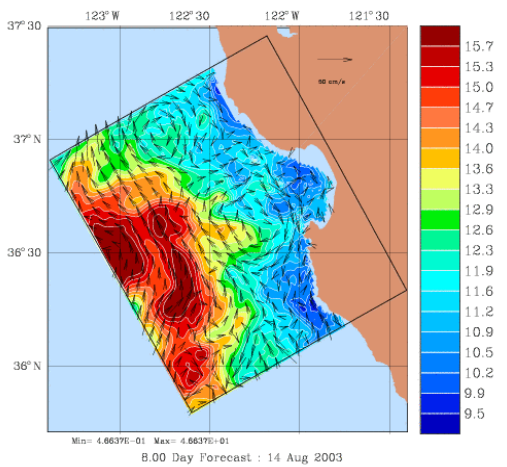
- $BC \leq 0$ => barotropic instability;
- $BT \leq 0$ => baroclinic instability;
- $BT > 0$ and $BC > 0$ => mixed instability

Harvard Ocean Prediction System AOSN-II Fields

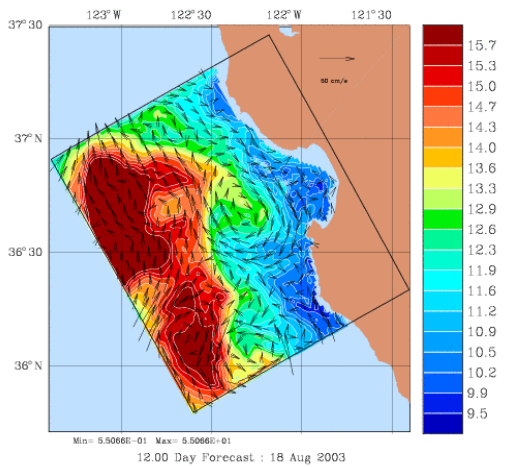
30m Temperature: 10 - 30 August (4 day intervals)



10 Aug



14 Aug



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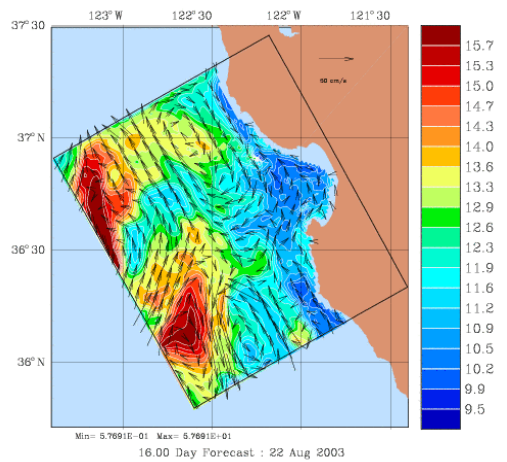

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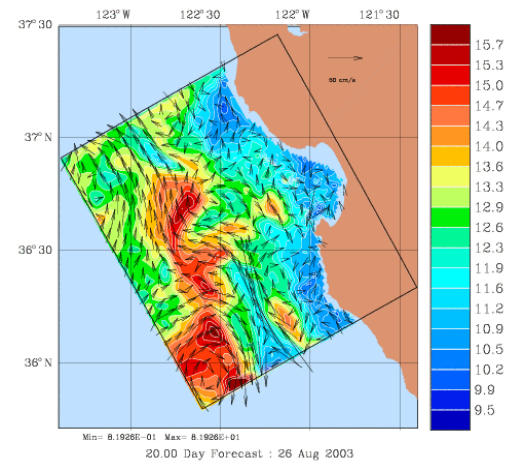
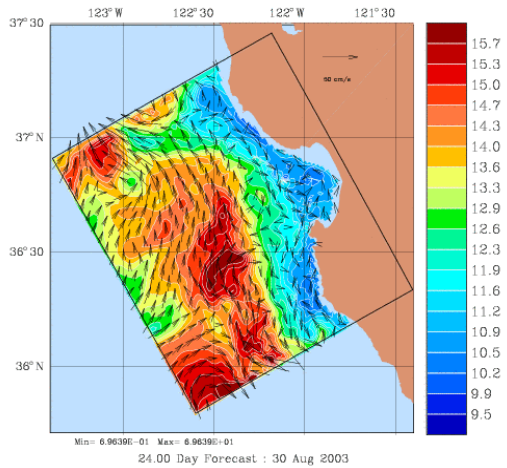


26 Aug



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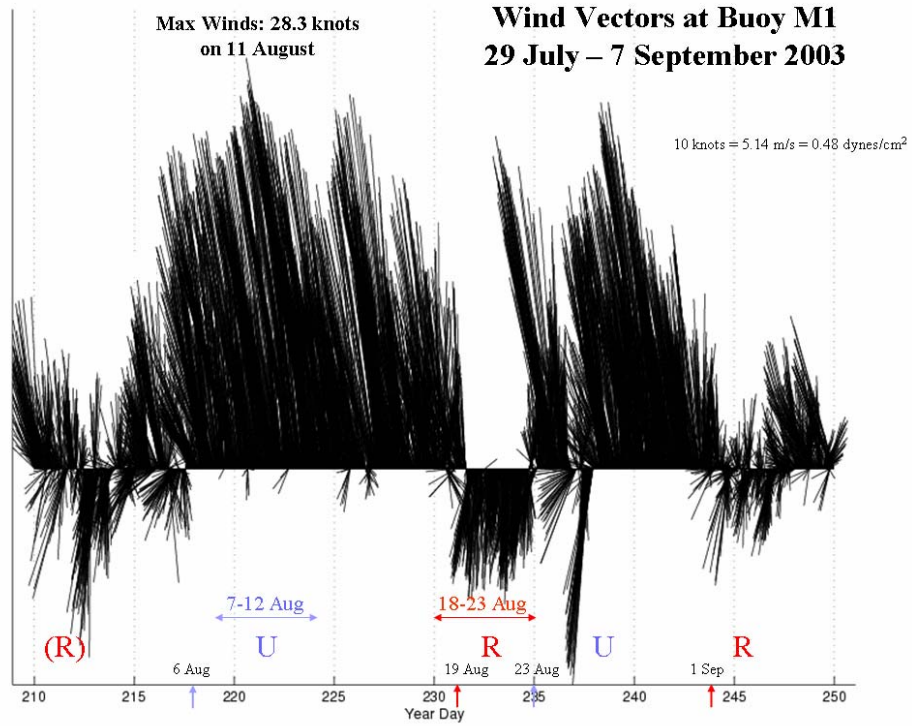
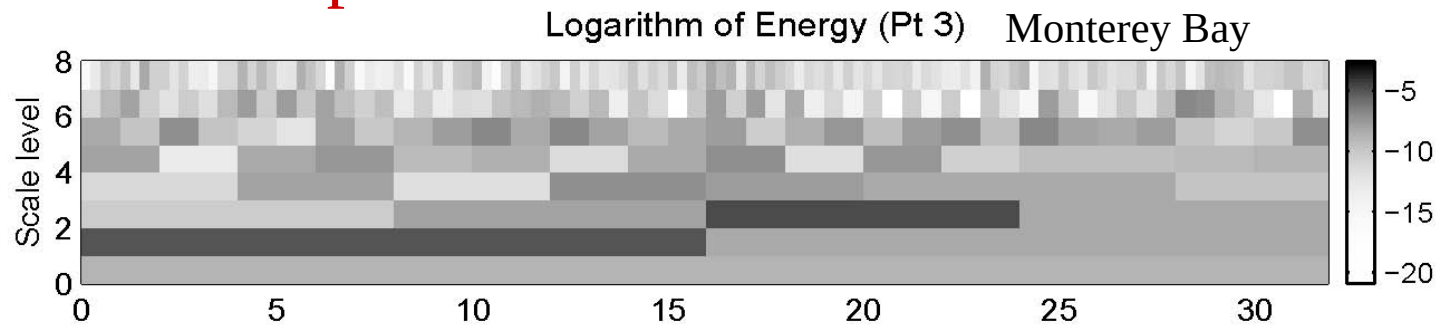
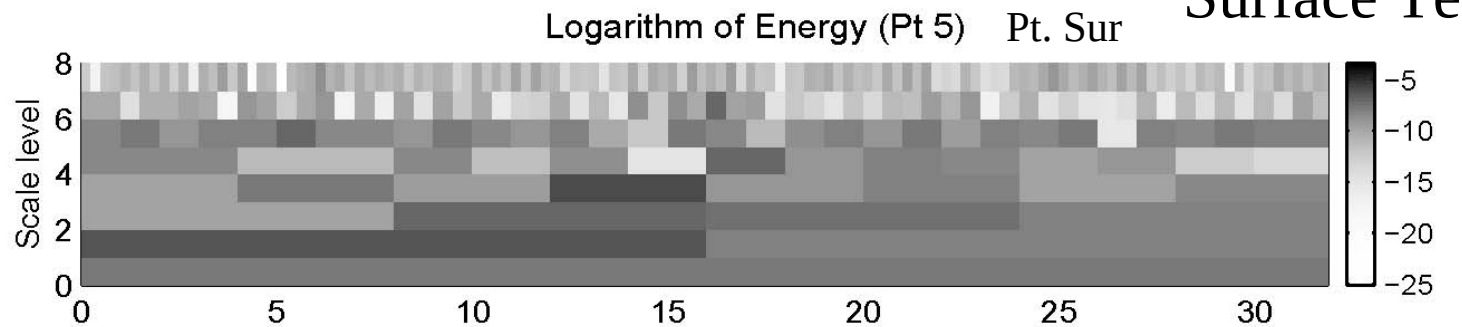
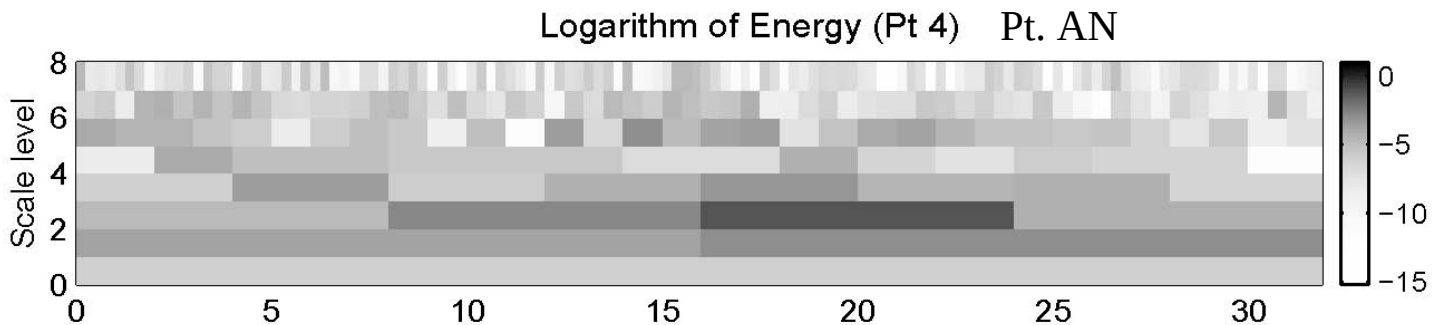


Wavelet Spectra

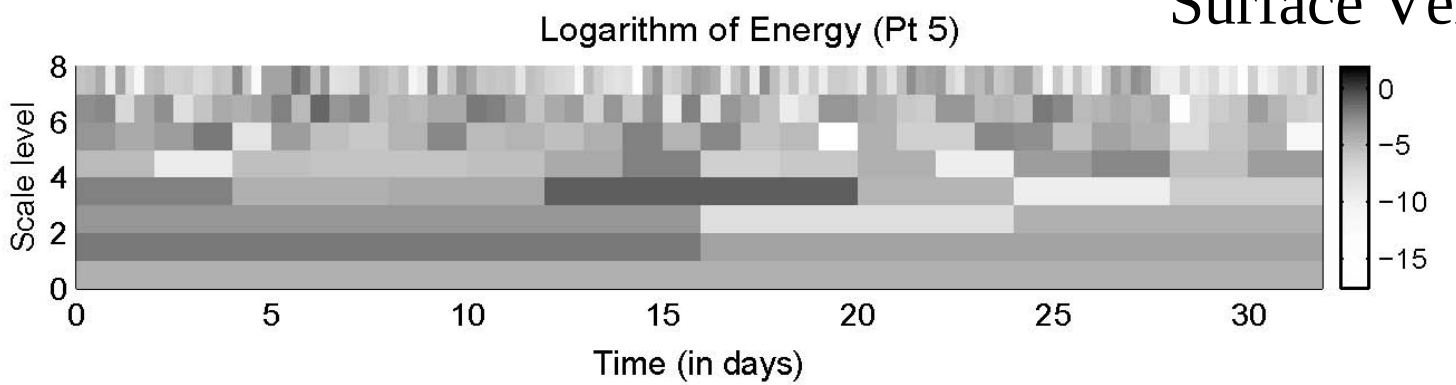


Surface Temperature



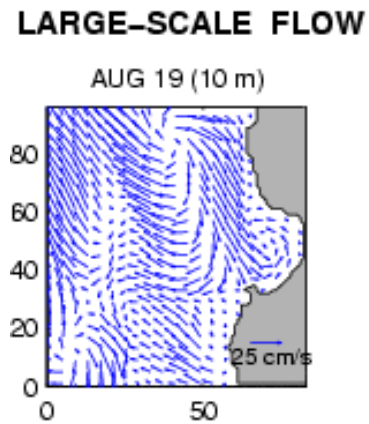


Surface Velocity

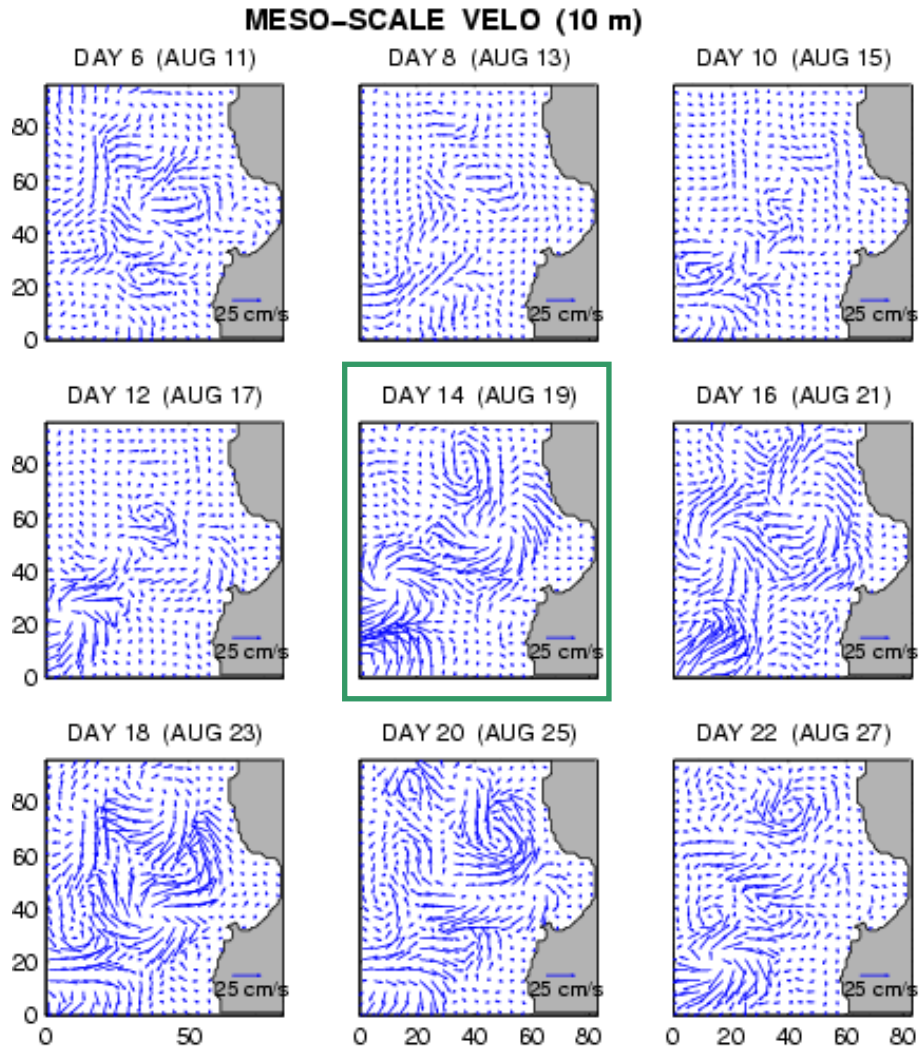


Multi-Scale Energy and Vorticity Analysis

Multi-Scale Window Decomposition in AOSN-II Reanalysis



The reconstructed large-scale and meso-scale fields are filtered in the horizontal with features < 5km removed.



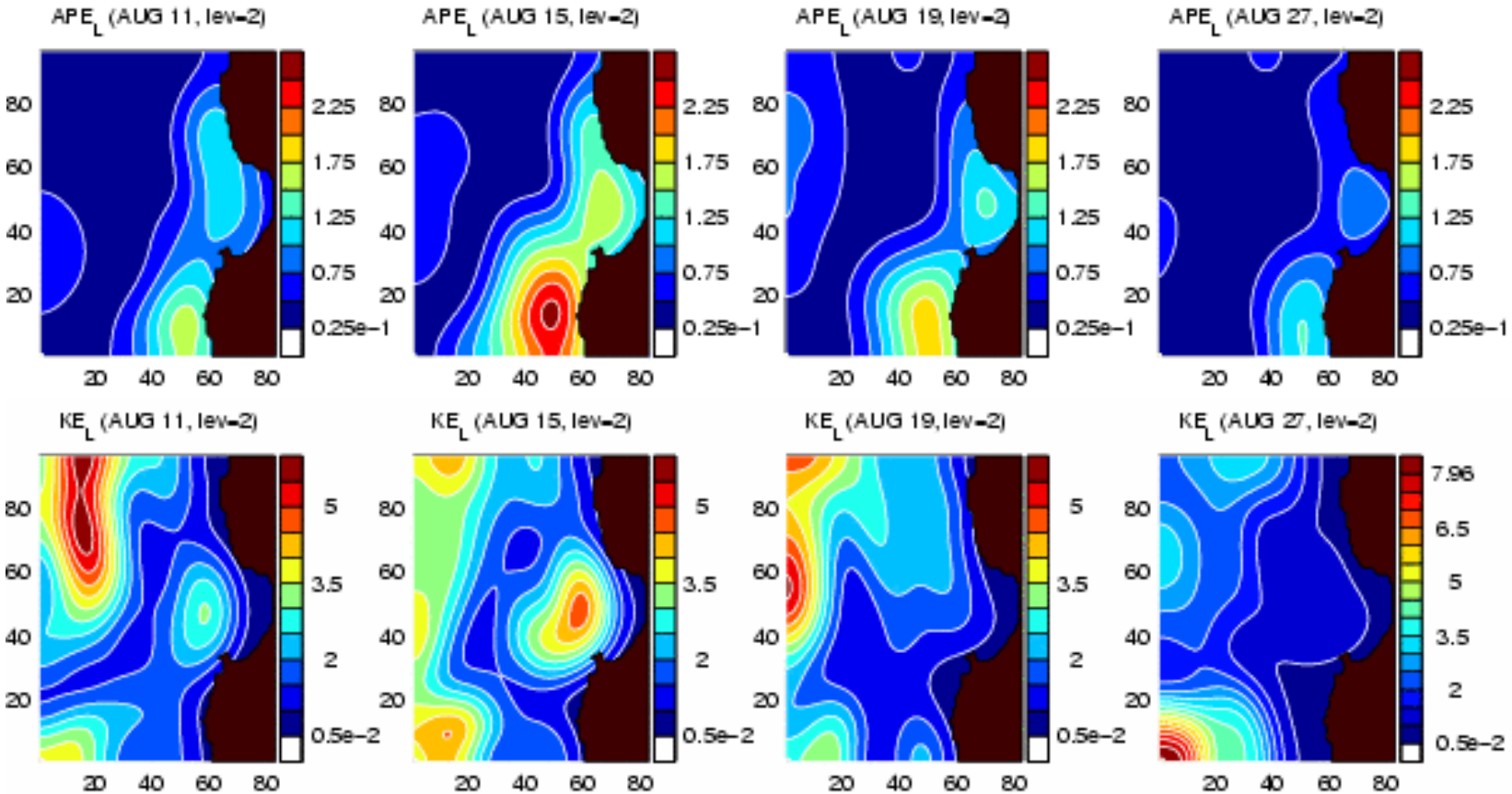
Time windows
Large scale: > 8 days
Meso-scale: 0.5-8 days
Sub-mesoscale: < 0.5 day

Question: How does the large-scale flow lose stability to generate the meso-scale structures?

Multi-Scale Energy and Vorticity Analysis

- Decomposition in space and time (wavelet-based) of energy/vorticity eqns.

Large-scale Available Potential Energy (APE)



Large-scale Kinetic Energy (KE)

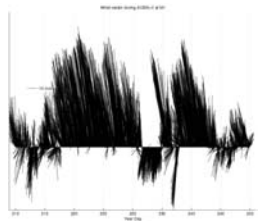
- Both APE and KE decrease during the relaxation period
- Transfer from large-scale window to mesoscale window occurs to account for decrease in large-scale energies (as confirmed by transfer and mesoscale terms)

Windows: Large-scale (>= 8days; > 30km), mesoscale (0.5-8 days), and sub-mesoscale (< 0.5 days)

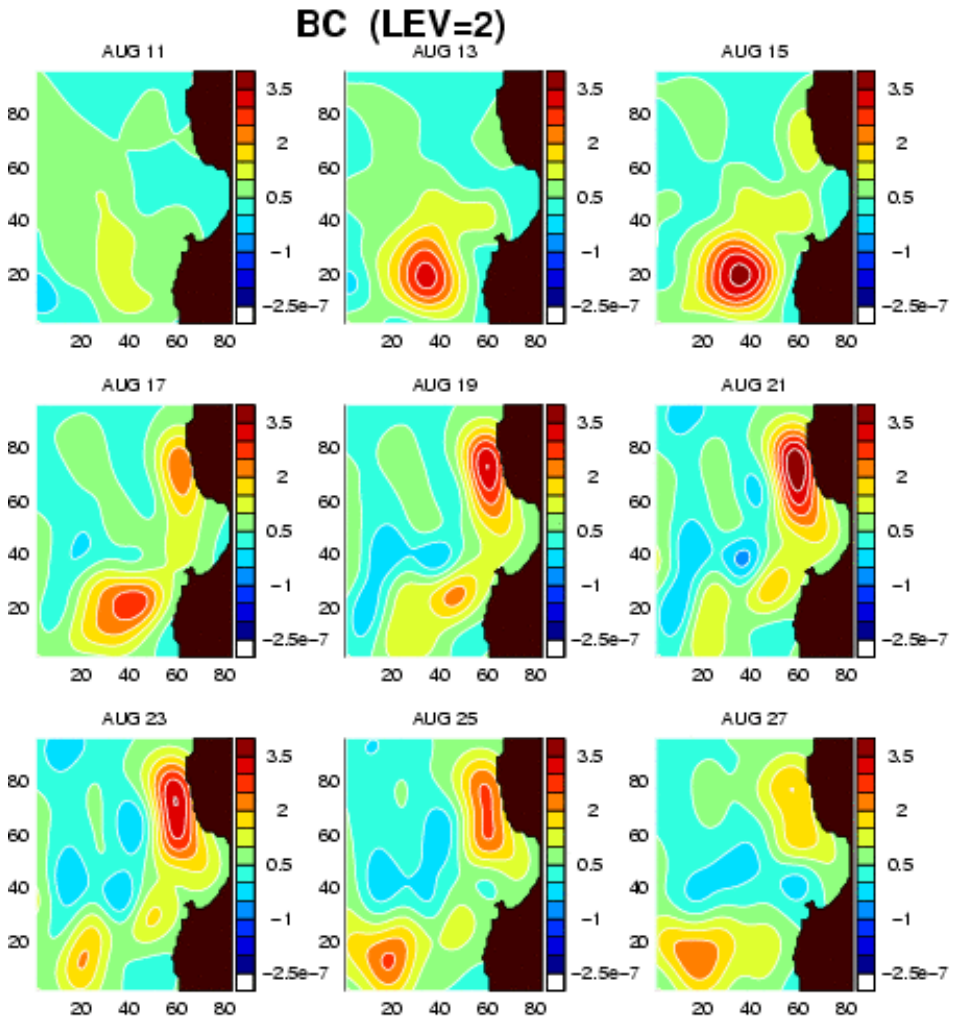
Dr. X. San Liang

Multi-Scale Energy and Vorticity Analysis

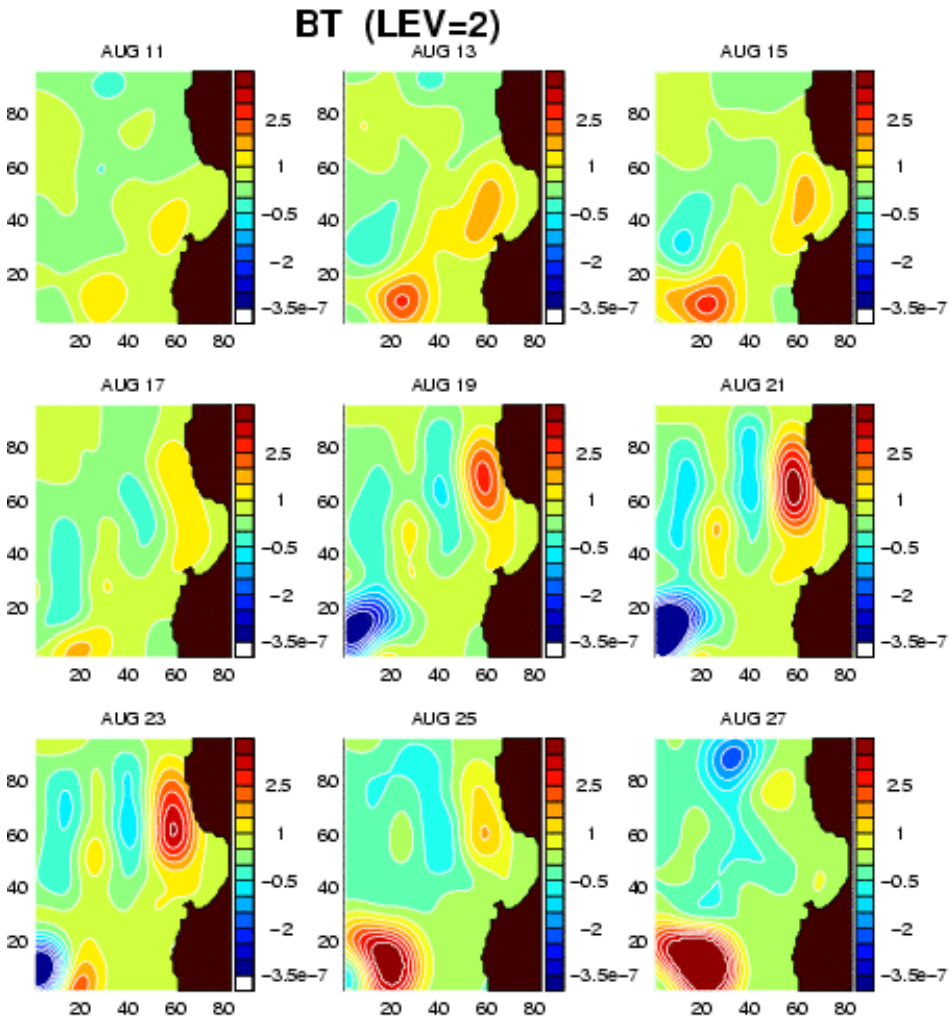
MS-EVA Analysis: 11-27 August 2003



Transfer of APE from large-scale to meso-scale

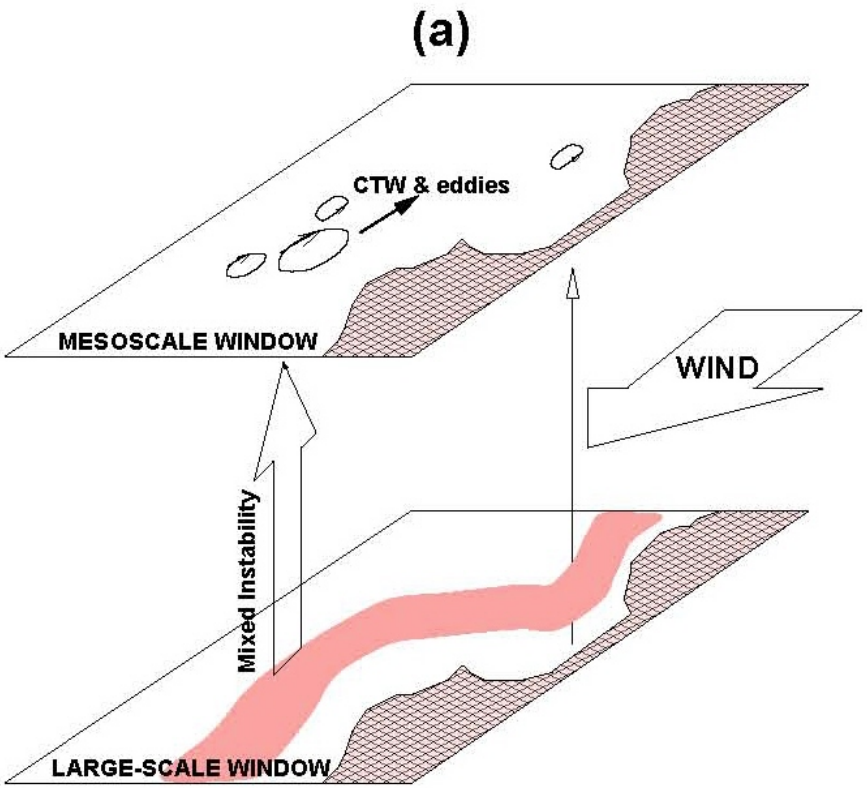


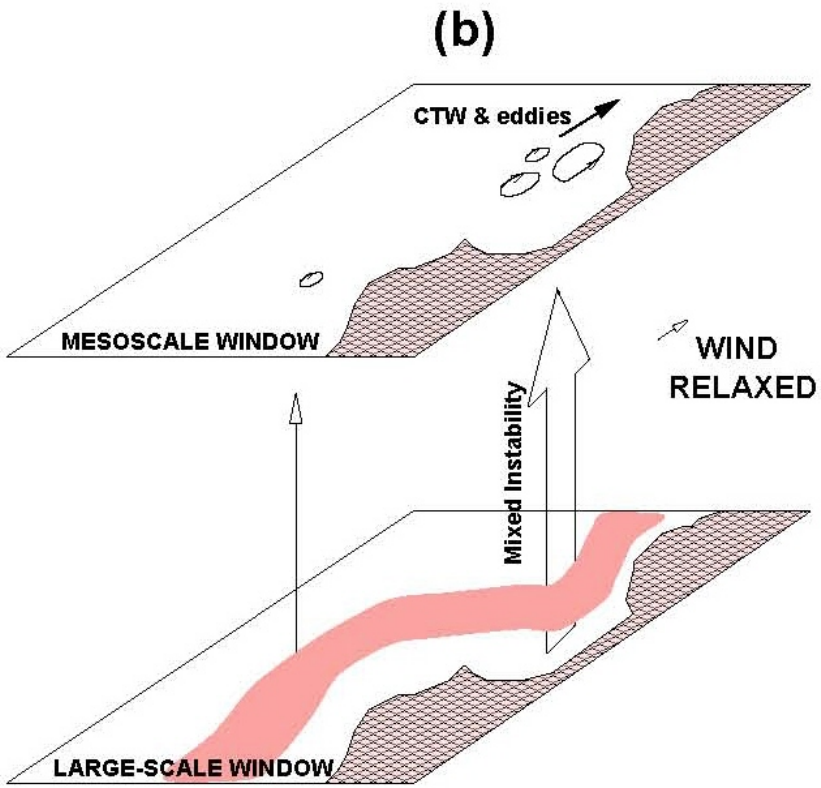
Transfer of KE from large-scale to meso-scale



Multi-Scale Energy and Vorticity Analysis

Process Schematic

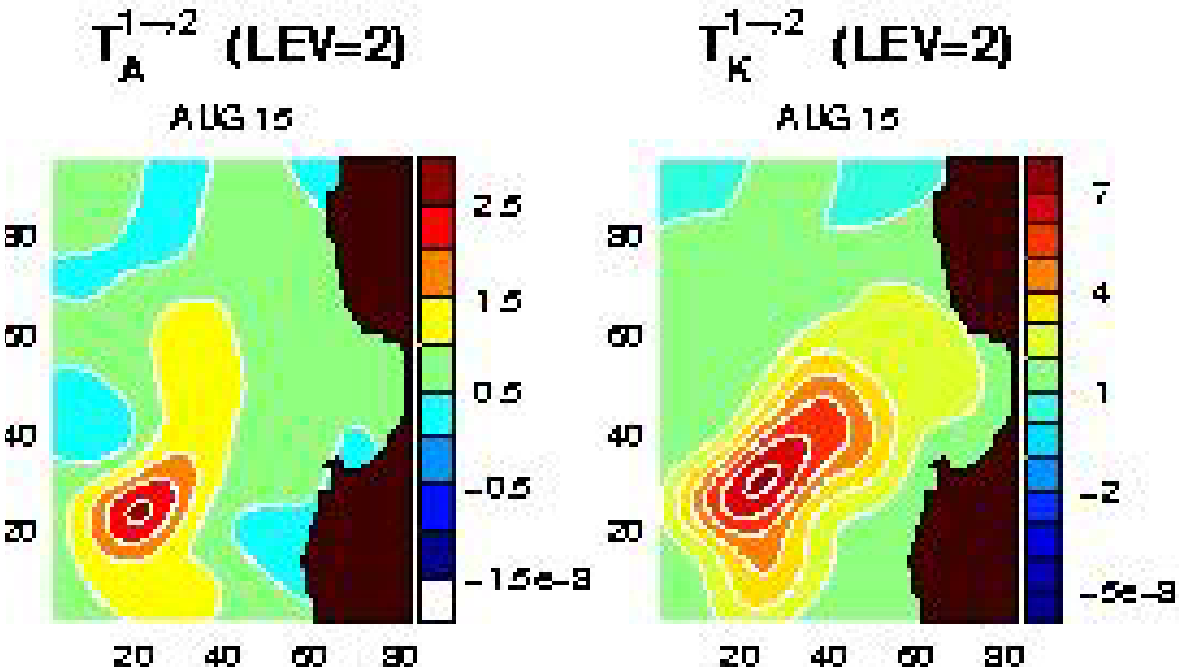




Multi-Scale Energy and Vorticity Analysis

Multi-Scale Dynamics

Sub-mesoscale processes and their role in the overall large, mesoscale, sub-mesoscale dynamics are under study.



Energy transfer from meso-scale window to sub-mesoscale window.

Multi-Scale Energy and Vorticity Analysis

Monterey Bay and California Current Region Processes

- Two distinct centers of instability: both of mixed type but different in cause.
- Center west of Pt. Sur: winds destabilize the ocean directly during upwelling.
- Center near the Bay: winds enter the balance on the large-scale window and release energy to the mesoscale window during relaxation.
- Monterey Bay is source region of perturbation and when the wind is relaxed, the generated mesoscale structures propagate northward along the coastline in a surface-intensified free mode of coastal trapped waves.

MS-EVA utilizes multiple scale window decomposition in space and time to investigate multi-scale interactive, nonlinear, intermittent , episodic processes through exploring pattern generation and energy and enstrophy transfers, transports, and conversions

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