THE FLORIDA STATE UNIVERSITY

Center for Ocean-Atmospheric Prediction Studies

Influence of sea surface temperature gradient and roughness changes due to a slick on the motion of surface oil: A simple idealized study

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1. Motivations

Catastrophes caused by the Deepwater Horizon oil spill in April 2010 alert us that we need a more accurate oil track forecast model system. Most oil track forecast models generally use virtual particles (passive tracers) without considering the feedback of surface oil presence to atmospheric and oceanic boundary processes. For example, there exists a strong SST front in the boundary zone between surface oil and water owing to different capability in absorbing solar radiation that have an important influence upon atmospheric boundary conditions. Significant roughness changes between the two media due to damping of ocean surface waves by surface oil also play a role in modifying atmospheric boundary properties that in turn affect the surface oil movement (direction and magnitude). Preliminary analysis from an idealized study may be beneficial to the improvement of oil track forecast model.

2. UWPBL Model 4.0

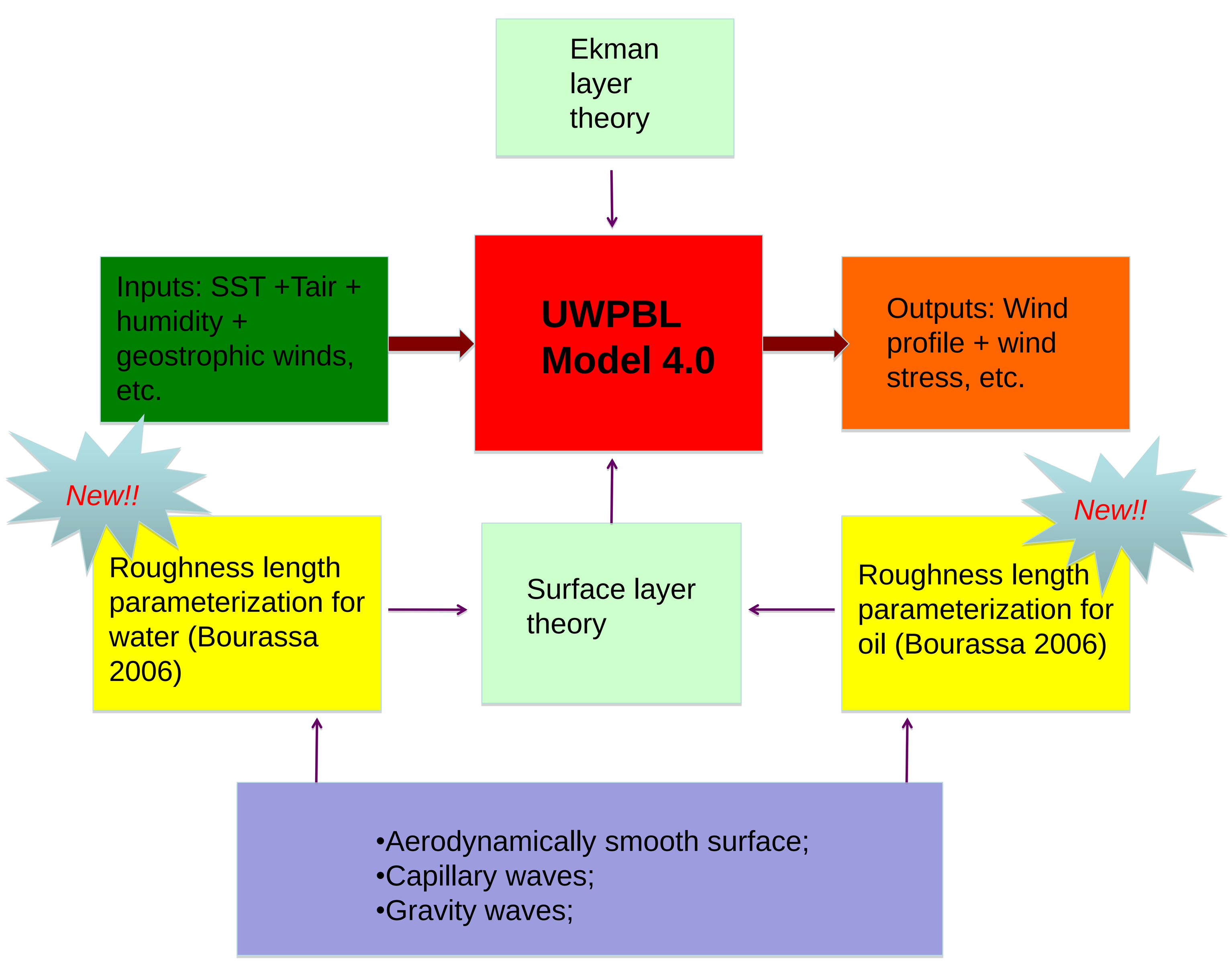

Fig. 1. Schematic of UWPBL model 4.0 flow

3. Experimental design

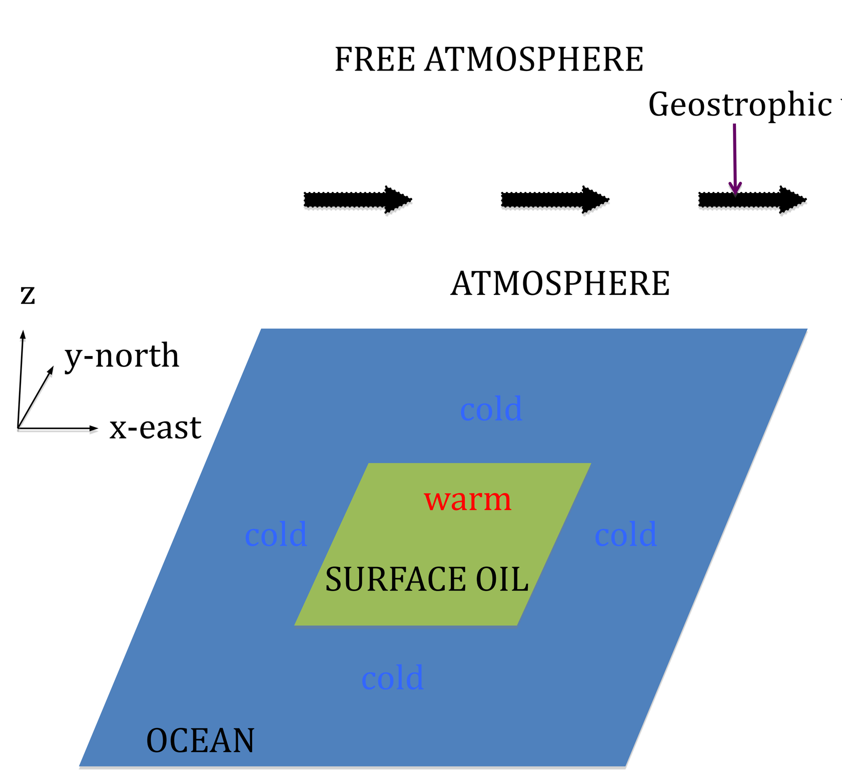

Fig. 2. Schematic of experimental design

Model resolution and input variables:

•Model domain: 90°W-87°W, 27°N-30°N
•Oil domain: 89°W-88°W, 28°N-29°N
•Resolution: deltaX by deltaY = 0.04° X 0.04°

•Ugeo is about 8 m/s
•Air humidity = 0.02 kg/kg
•SST = 25°C for water;
= 25°C + deltaT for oil
•Tair = 24.5°C for water;
= 24.5°C + deltaT for oil
•deltaT = 0.001, 0.002, …, 0.04°C
•Temperature gradient = deltaT/deltaX in unit of °C per 0.04°.

4. Surface wind speed and vectors

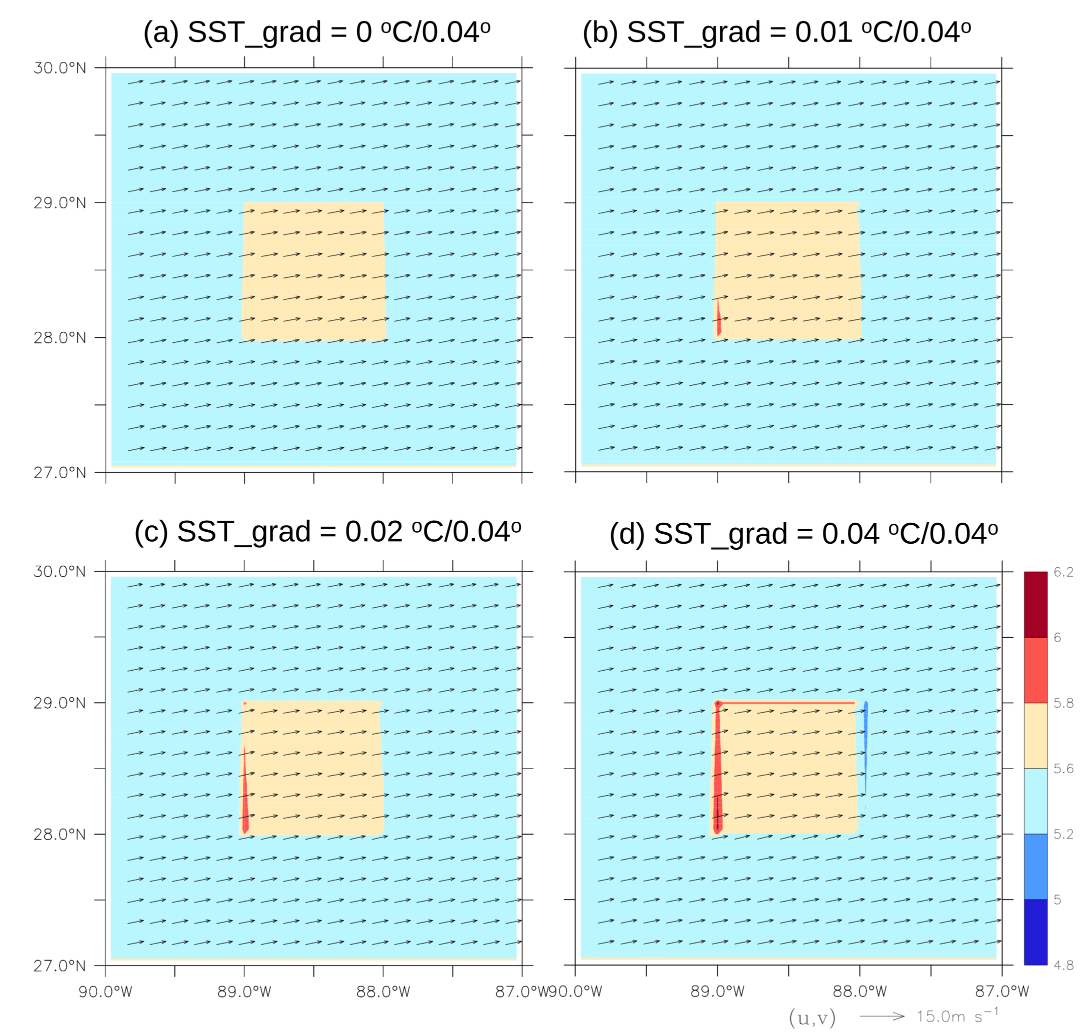

Fig. 3. Surface winds as well wind speed evidently change cross the boundary zones between water and surface oil.

5. Surface wind divergence (x 10^5 s^{-1})

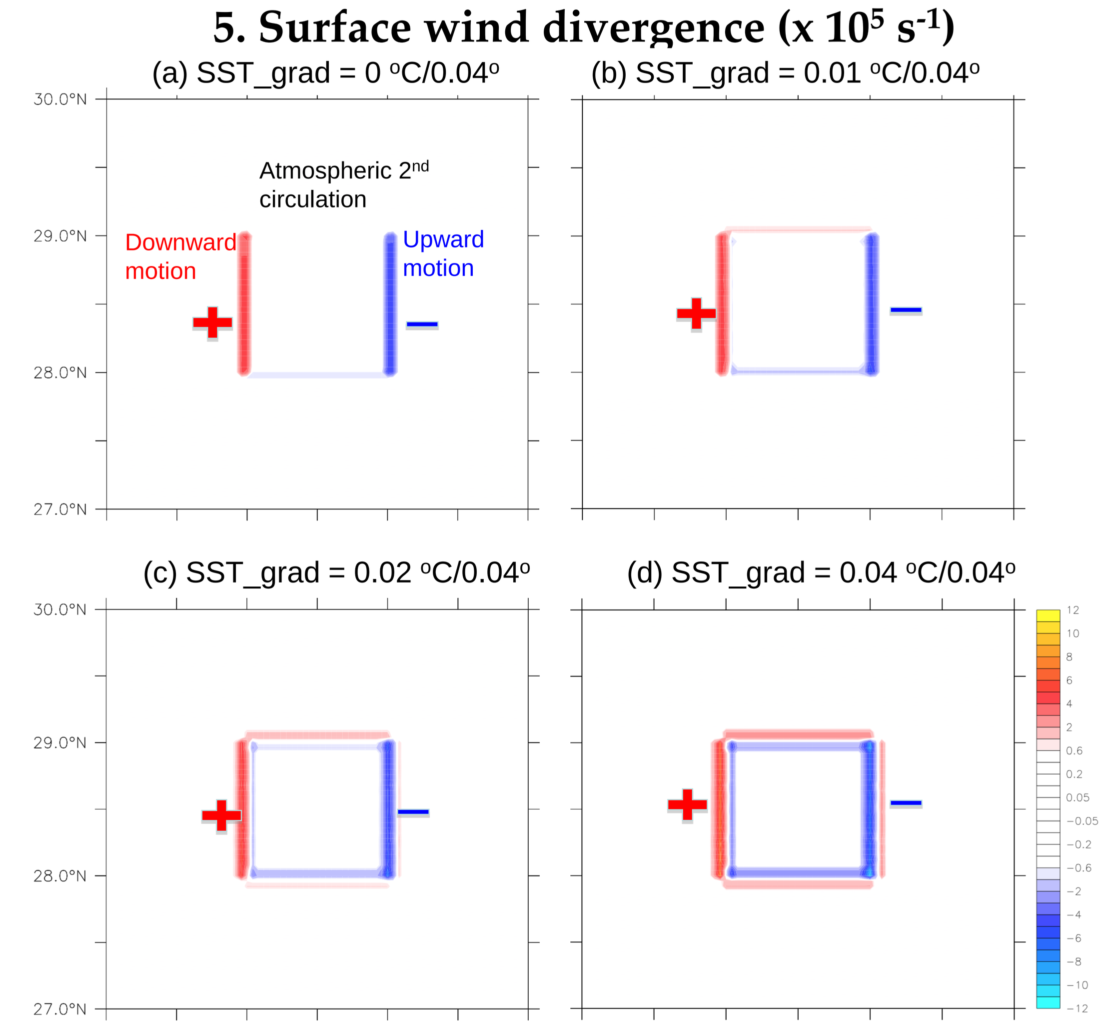

Fig. 4. There are significant changes in surface wind divergence in the boundary zones between water and surface oil, which induce an atmospheric secondary circulation. This, in turn, influences the movement of underneath surface oil.

6. Wind stress curl (x 10^7 N m^{-3})

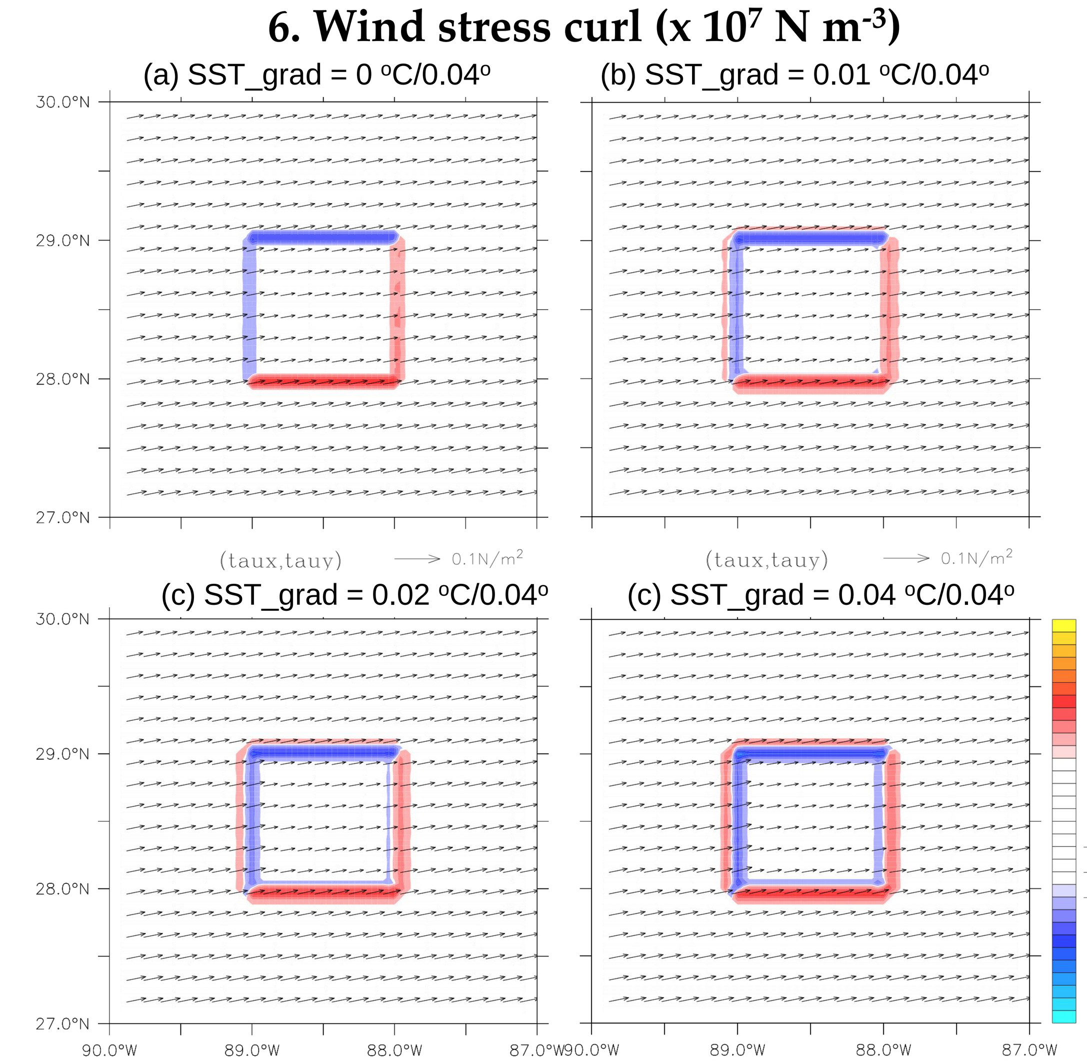

Fig. 5. There are evident changes to wind stress curl in the boundary zones between water and surface oil, which cause anomalous Ekman transport that affects the motion of surface oil.

7. Relative Ekman mass transport (kg/ms)

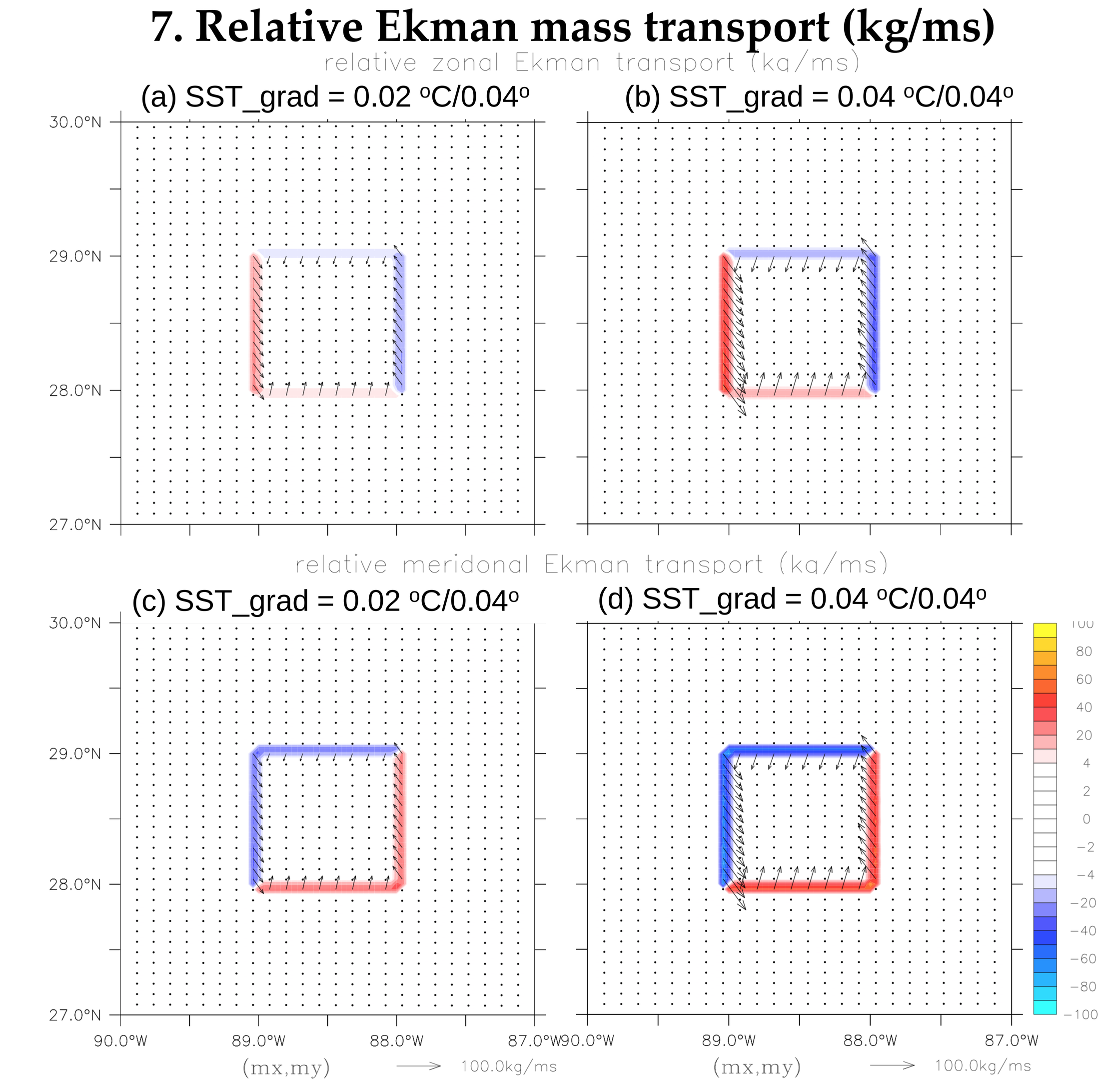

Fig. 6. A net convergence of Ekman mass transport owing to the presence of SST gradient and roughness changes in the transpition zones, which tends to push the oil downward to the subsurface. The orientation of Ekman transport tends to spin the surface oil and deform the surface oil.

8. Linear relation with SST gradients

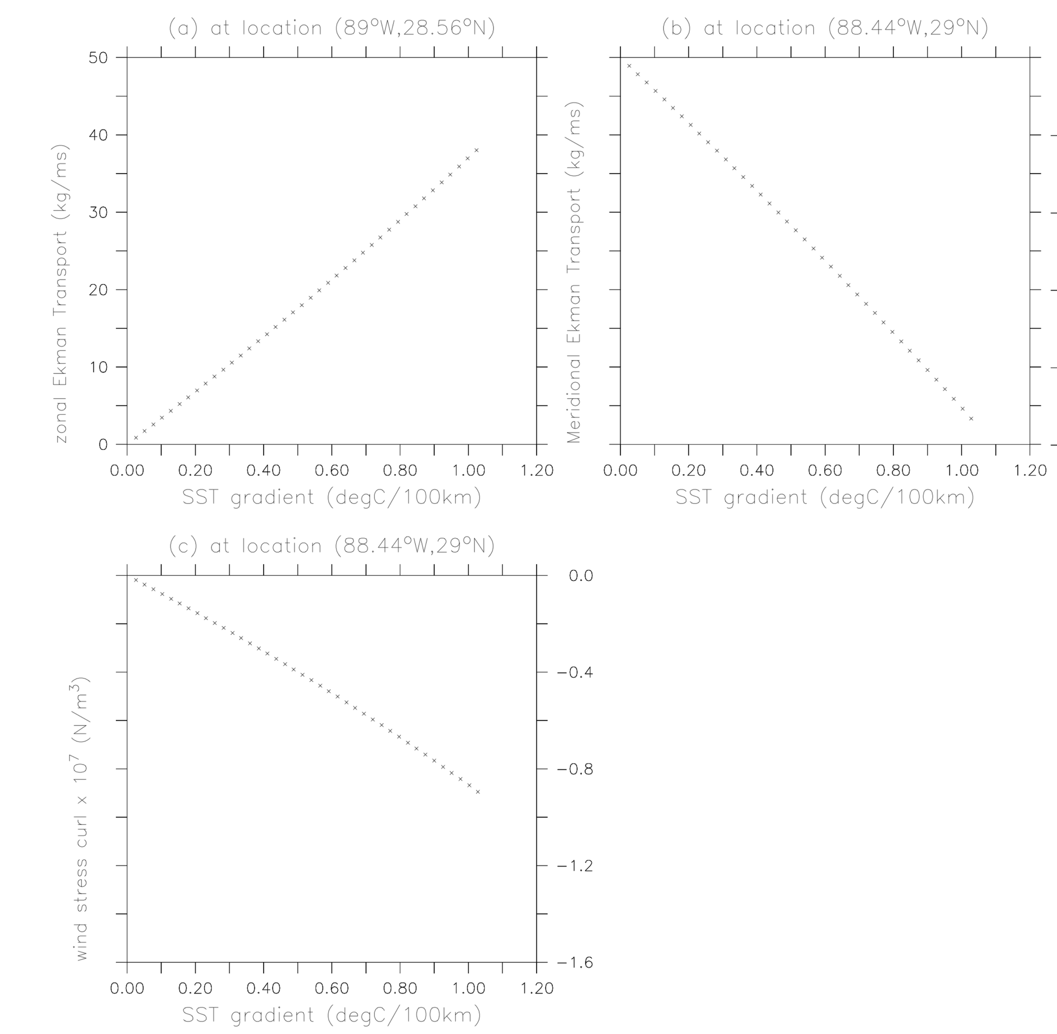

Fig. 7. Strength of Ekman transport and wind stress curl are almost in linear relationship with the strength of SST gradient.

9. Conclusions

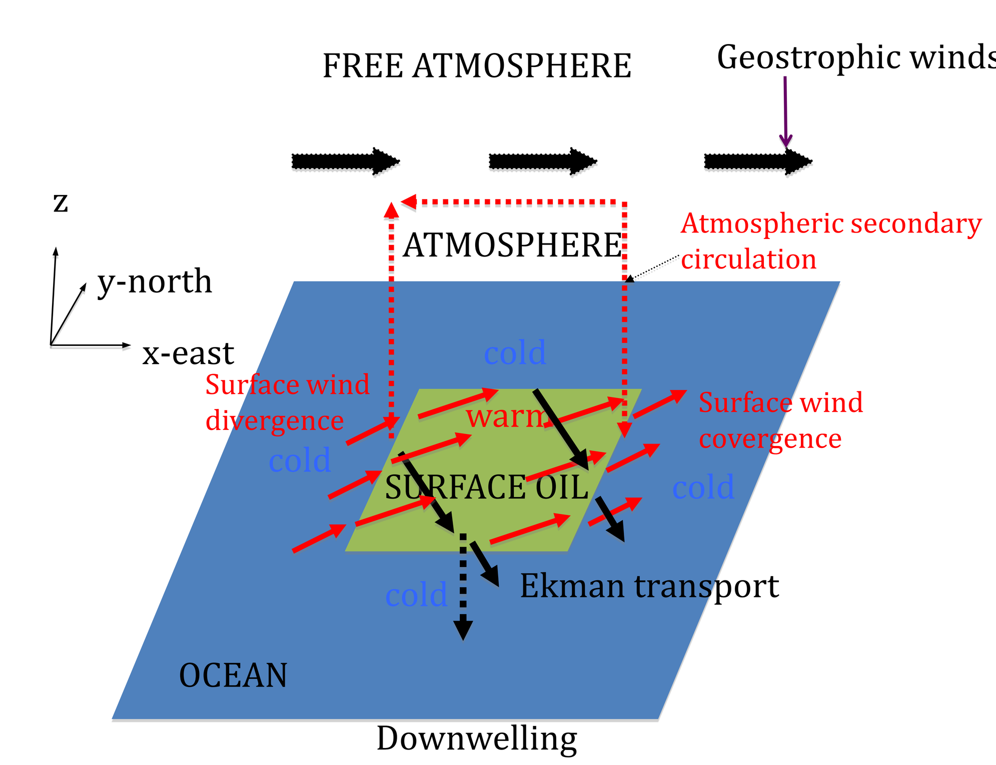

Fig. 8. A schematic diagram describing experimental results.

• There are apparent changes to surface winds and speed, wind stress curl and Ekman transport in the boundary zones between water and surface oil owing to the presence of strong SST gradient and roughness shift.

• Surface wind divergence (convergence) in the boundary zones induces an atmospheric second circulation, which in turn influences the movement of surface oil.

• Strength of Ekman transport and wind stress curl is almost in linear relationship with strength of SST gradient.

• A net convergence of Ekman transport produced by the remarkable changes in wind stress curl in the boundary zones tends to push the surface oil downward to the subsurface. The orientation of Ekman transport owing to strong SST gradient and roughness change tends to spin and deform the slick.

Acknowledgments

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