ON THE MECHANICS OF THE TYPHOON MORAKOT

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1.Introduction:

Correlation of convective heat and moisture fluxes from the ocean to the atmosphere is traditionally based on the simple concept of Newton. In this model, the convective transfer process is diffusively limited by a thin sub-layer of the ocean's surface within which resides most of the driving temperature and moisture gradients. Consequently, the *vertical* water-vapor flux is proportional to the sea-air humidity difference and wind-speed. However, for *high* wind-speeds no consistent results exist. Under increasing sea-states micro water droplets produced by breaking waves contribute more to the overall evaporation process than the sea surface does. Consequently, the variables of momentum, temperature, humidity, and micro water droplets are strongly coupled in a highly complex manner. Because the basic bulk-transport equations for momentum, heat, and mass do not allow cross-coupling, the experimentally derived bulk exchange coefficients based on these bulk-equations all show such large standard deviations from their respective means that they preclude any probabilistic confidence in their values. After successfully considering cross-coupling mechanics, Ling (1993) determined a functionally more correct expression for water-vapor flux, which is applicable to a wide range of sea states:

$$F_v = 6.54 \times 10^{-4} \left(e_{10s} - e_{10}\right) U_{10}^2 + 5.58 \times 10^{-4} \left(e_{ws} - e_{10}\right) U_{10}, \qquad (1)$$

where F_v is the net vertical water-vapor flux in g/m^{2}s, e is vapor pressure in millibars, and U is wind speed in m/s. Subscript 10 is the variable evaluated at 10 m above sea level. Subscripts 10s and ws are saturated vapor pressure of water droplets at 10 m and at the sea surface, respectively.

It is this paper's objective to discover if the analytical mechanics derived for smaller sea states can still be functionally applied to a Class 5 sea state, such as experienced in the recent typhoon Morakot (August 2009). By applying this new function to Morakot's data, the *world-record* rainfall and flooding to the watershed of southern Taiwan is a naturally accountable event.

2.The Mechanics of a Hurricane/Typhoon

For this study, we must first recognize the thermal capacity of the ocean's *mixed* layer is more than 2,000 times greater than the atmosphere's. It is the thermal capacity of this mixed layer that regulates planet temperature from excessive variation. When the ocean's mixed layer gets too warm, it will generate an intense storm to cool quickly. From the comprehensive International 1978 JASIN experiments, Ling (1993) obtained considerable knowledge concerning the mechanics of the sea-air interface up to a Class 2 sea state. As shown by Equation 1, we can determine the cooling mechanics of the ocean's mixed layer along a storm track and the amount of seawater evaporated.

Any two-dimensional relative motion in a fluid medium will produce a two-dimensional vortex flow due to the system's *least stress* effect (Ling & Pao 2002). Thus, any air motion on the Earth's surface will first form into a counter-clockwise vortex in the northern hemisphere. A powerful updraft will be produced due to the concentration of lighter humid air into the eye rim of the storm vortex. The downdraft of cold and dry stratospheric air lifts the moist air to the top of the troposphere (altitude 10 km for a low category storm) creating a clear cloudless eye, which can be seen from space (Fig. 1).

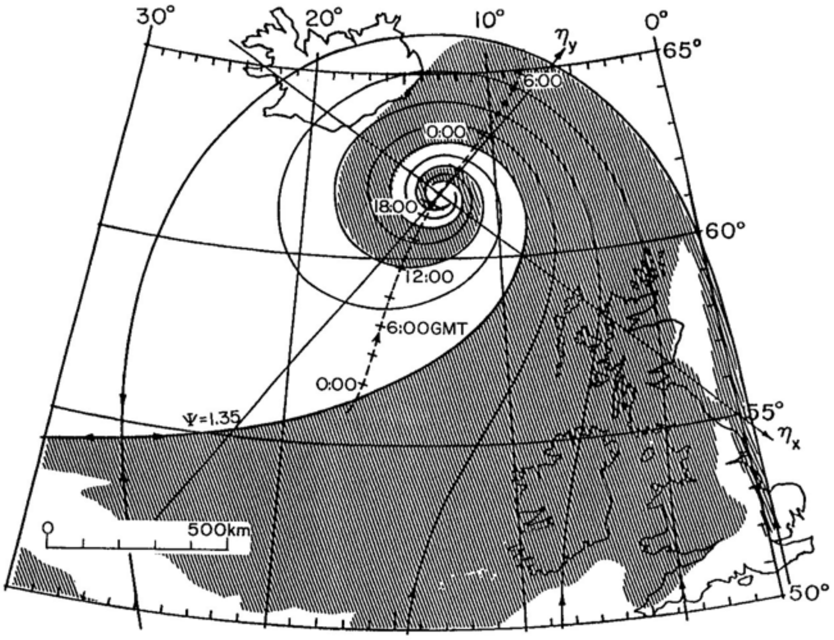

Figure 1. Cloud cover at 19:00 GMT for August 21, 1978, North Atlantic storm.

Ling (1993) noted clouds on the southwest side of the eye had condensed out as rain due to the cold temperature of Iceland below. In contrast, the cloud for Morakot lifted to the top of the stratosphere (altitude 20 km). These high-level clouds, which were expanding clockwise due to the Earth's rotation, obscured the storm's eye. There was record rainfall within a 500 km long track on the southwest side of the eye. We would expect the expression derived for the vertical water-vapor flux under weaker hurricane conditions to still be valid for an extreme sea state because the mechanics of intensive sea-air interaction should still be related to the second power of the reference-mean U_{10} wind. For the 1978 JASIN storm, we have a complete set of field measurements to calculate and verify the cooling contour for the mixed layer of the North Atlantic Ocean (Fig. 2).

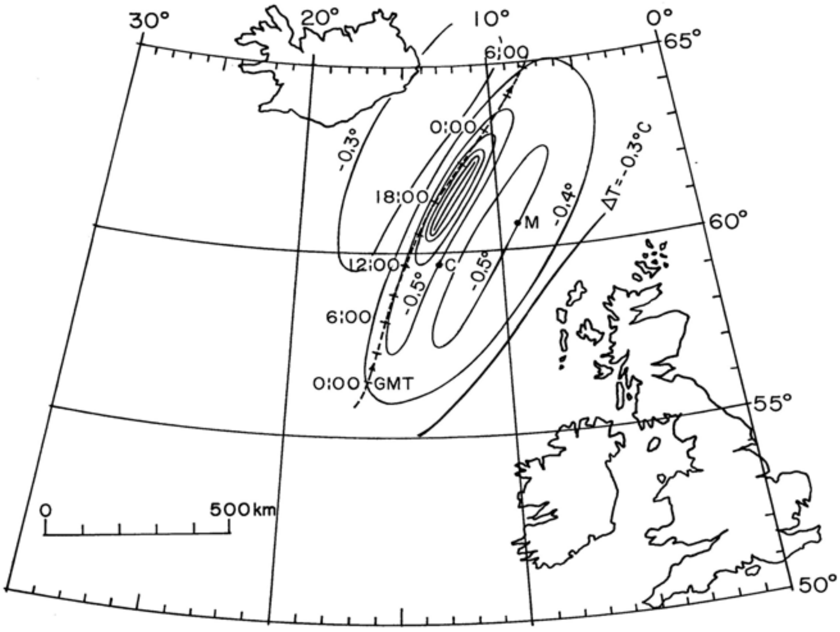

Figure 2. Path of August 20-21, 1978 North Atlantic storm and the simulated cooling of the ocean's mixed layer. The cooling contours are shown in ΔT = - 0.1°C intervals.

These measurements show a vast area of the storm track had cooled an average of 0.5°C along a storm track 600 km wide by 1,000 km long; and a 2.5 cm layer of water had evaporated. As a first order estimate, one would expect Morakot's respective values would be increased by the ratio of the reference U_{10} winds squared [(39 m/s Morakot / 14.6 m/s JASIN)^2 = 7.3 times]. This ratio gives an expected cooling of 3.7°C, which matches the field cooling measurement of 3.7°C (30.7°C – 27.0°C). This data was taken at a distance of 150 km from the maximum cooling track to represent the mean of cooling. A 20 cm depth of water along Morakot's vast storm track area evaporated into the atmosphere. Only a small percentage of this water returned as a world-record 1.4 m rainfall into the valley of southern Taiwan. The remainder transported halfway around the world until all the water vapor's remaining latent heat was emitted at a limited rate into cosmic space and returned as rain back to the ocean. The maximum cooling contour for the 1978 JASIN storm is shown as a parallel line 40 km to the east of the storm track (Fig. 2) with a value of ΔT_{JASIN} = 0.9°C. For Morakot we would expect the maximum cooling contour to be $\Delta T_{JASIN} \times 7.3$ = 6.6°C. Field measurement near the NE tip of Taiwan showed $\Delta T_{Morakot}$= 7°C. Based on this good functional fit, there is no doubt that Eq. (1) can be universally applicable to all sea states.

3.Conclusion

We now have a simple tool *based on the engineering mechanics* to provide a more reliable warning of severe weather, and future planning of water supply and flood control systems.

Acknowledgement

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