# Rapid Estimation of Maximum Storm Surges Induced by Hurricanes Katrina and Rita in 2005

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**Abstract.** Storm surges generated by Hurricanes Katrina and Rita inundated much of coastal Louisiana as revealed by Landsat imagery. A simplified equation for estimating maximum surge height is provided. Estimated heights are shown to be in reasonable agreement with preliminary water mark measurements. An application of the equation for a different geographical setting is described.

At the end of August 2005, Hurricane Katrina made landfall near the Louisiana / Mississippi border (Fig. 1). Less than one month later, Hurricane Rita struck near the Louisiana / Texas border (Fig. 2). Both of these storms produced catastrophic damage, and areas of the Louisiana and Mississippi coasts were devastated. According to the National Hurricane Center (Knabb et al., 2005a and 2005b), precise measurements of the maximum storm surges associated with these storms were complicated due to incomplete or failed gauge records and, in some areas, the complete destruction of coastal structures which otherwise might have been left with residual high water marks. Nevertheless, extensive surveys were conducted by the Interagency Performance Evaluation Taskforce (IPET) and by the Federal Emergency Management Agency (FEMA). Results of these surveys are still being compiled and verified; however preliminary findings combined with existing gauge records and modeled surge elevations indicate that the maximum surge induced by Hurricane Katrina was between 26 - 28 feet over the western coast of Mississippi, and by Hurricane Rita, between 16 - 18 feet over coastal areas of Cameron Parish in southwestern Louisiana. Figures 3 and 4 illustrate the effects of widespread flooding, saltwater intrusion and land loss generated by these storms by contrasting vegetation cover as observed by Landsat.

The maximum storm surge ($S_p$) may be estimated rapidly by modifying Jelesnianski's method (1972) as proposed by Hsu (2004) that

$$S_p \;(in\;\; m) = \left(0.070\, \Delta P\right) F_S F_M \tag{1}$$

where

$$\Delta P = \left(1010 - P_0\right) \tag{2}$$

and $P_0$ is the minimum sea level pressure in mb, $F_S$ is the shoaling factor (obtained from the nomogram in Fig. 5), and $F_M$ is the correction factor for storm motion (from the nomogram in Fig. 6).

Our inputs and results are shown in Table 1. For Katrina, landfall was between Grand Isle and Gulfport, and from Fig. 5, $F_S = 1.5$. The track was nearly perpendicular (90˚, see Fig. 1) to the coast and forward speed approximately 15 mph, hence $F_M = 1.0$ from Fig. 6. For Rita, landfall was near Sabine Pass, therefore $F_S = 1.1$. From Fig. 2, the track was about 60˚ to the coast and forward speed 12 mph; $F_M = 0.9$. Computed $S_p$ are in very good agreement with the estimated maximum surges produced by Katrina and Rita, therefore Eqs. (1) and (2) are recommended for rapid maximum surge estimation as a first approximation for emergency preparedness applications. Note that Eqs. (1) and (2) are used only for the estimation of the maximum surge which occurs near the radius of maximum wind (R) on the right-hand side of the storm; the surge height diminishes with distance from R.

This analytical estimate is not intended to replace any official numerical models, such as SLOSH. On the other hand, it is notable that a Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM 2006) Expert Team on Wind Waves and Storm Surges survey on storm surge data sources and forecasting systems revealed that 75% of the responding countries had operational / pre-operational models, and 75% reported regular sea level observations and /or historical records. In many Caribbean countries, the TAOS/L model has been applied to understand storm hazards and assess the risks to coastal areas from surges, waves and high winds, however it was not designed as a storm forecasting tool (OAS, 2001 and 2004). Thus the rapid estimation technique presented here can be of great value to those areas with limited access to real-time model data, and can be adapted for a specific location.

As an example, since $S_p$ can be estimated through high water mark measurements, the shoaling factor $F_S$ may be fixed for a certain location for forecasting purposes. According to Avila (2001), Hurricane Iris in 2001 was a small but severe Category Four hurricane that devastated southern Belize. The minimum sea-level pressure was 948 mb and the maximum storm surge reached 15 feet near Monkey River Town. According to Hsu (2004) the mean speed of hurricane movement is about 12 mph which is not much different from 15 mph so that we may set $F_M = 1.0$ for the maximum effect (i.e., perpendicular to the coast). Now, substituting $P_0 = 948$ mb, $S_p \simeq 15$ ft or 4.57 m, and $F_M = 1.0$ into Eqs. (1) and (2), $F_S = 4.57\ [(0.07 * (1010 - 948)] \simeq 1.0$. Therefore for the Belize coast, the forecasters may use the following equation for the rapid estimation of maximum storm surge such that

$$S_p\ (in\ feet) = 0.23\left(1010 - P_0\right) \qquad \textbf{(3)}$$

where $P_0$ is in mb.

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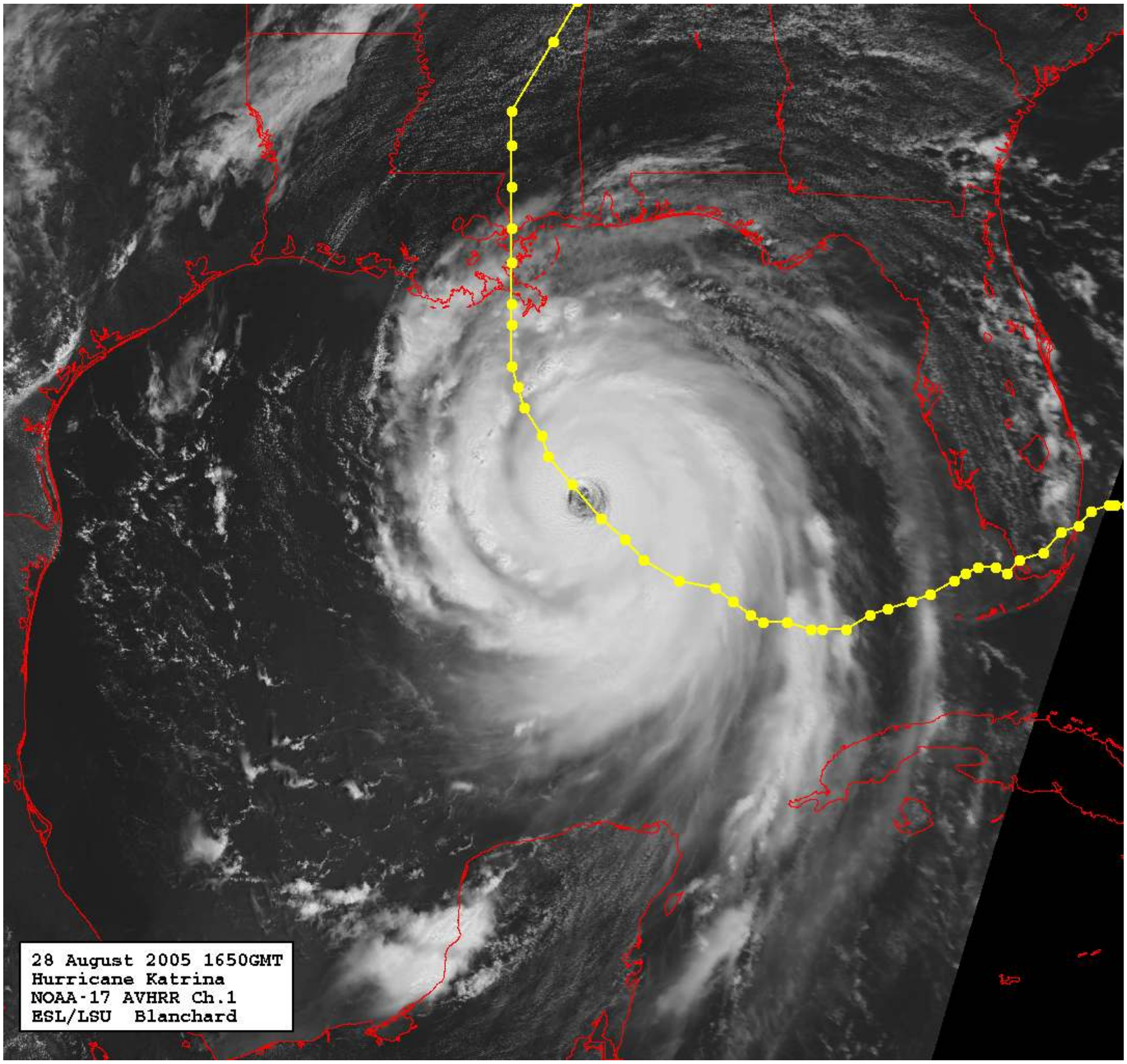


Figure 1. The track of Hurricane Katrina from 1700 UTC 25 August 2005 to 0000 UTC 30 August 2005. Final landfall occurred at1445 UTC 29 August 2005 near the mouth of the Pearl River at the Louisiana / Mississippi border; maximum surge was observed along the western Mississippi coast.

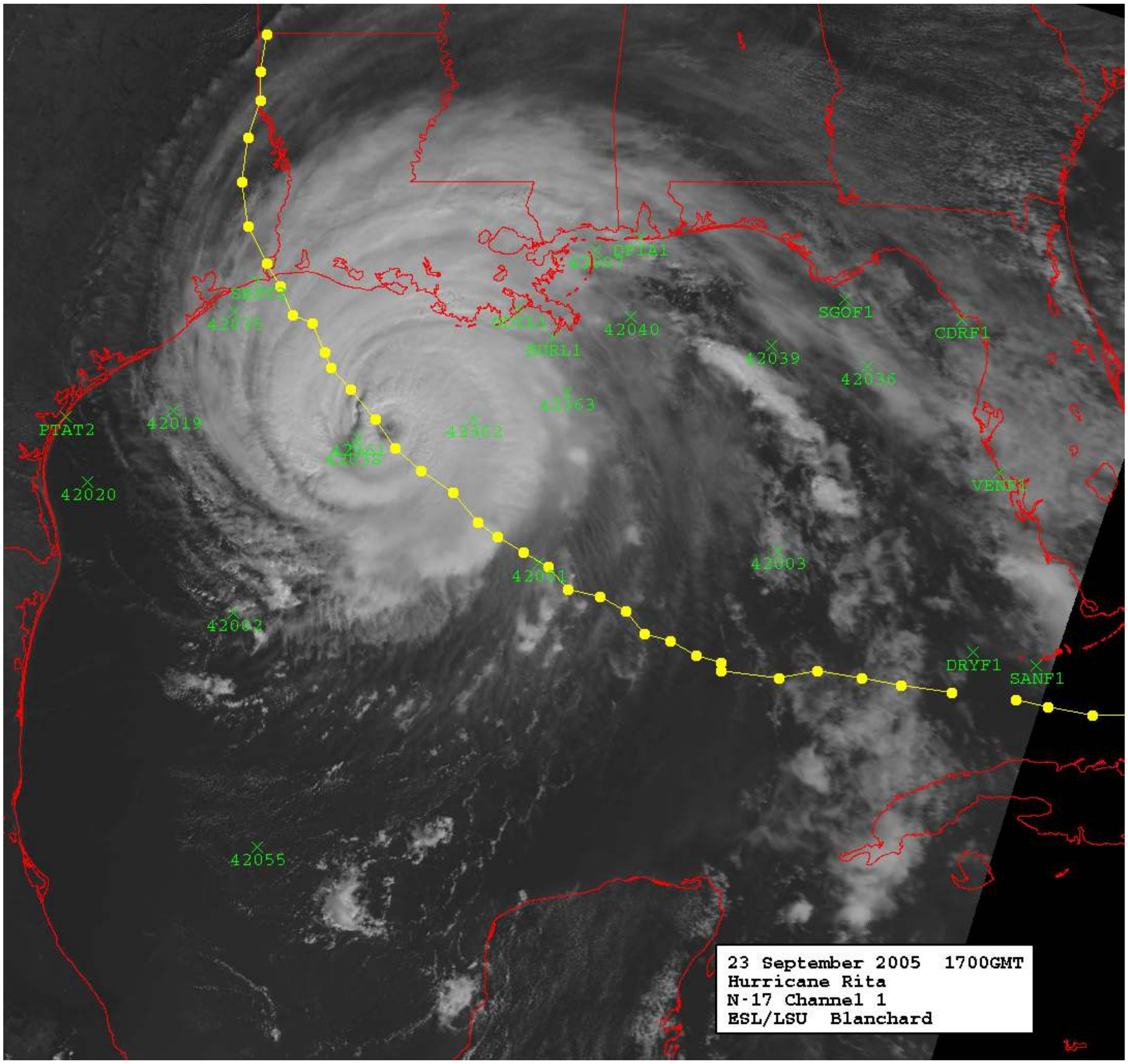


Figure 2. The track of Hurricane Rita from 1500 UTC 20 September 2005 to 0300 UTC 25 September 2005. Final landfall occurred at 0740 UTC 24 September 2005 between Johnson's Bayou, Louisiana and Sabine Pass. Maximum surge occurred along the coast of Cameron Parish in southwestern Louisiana.

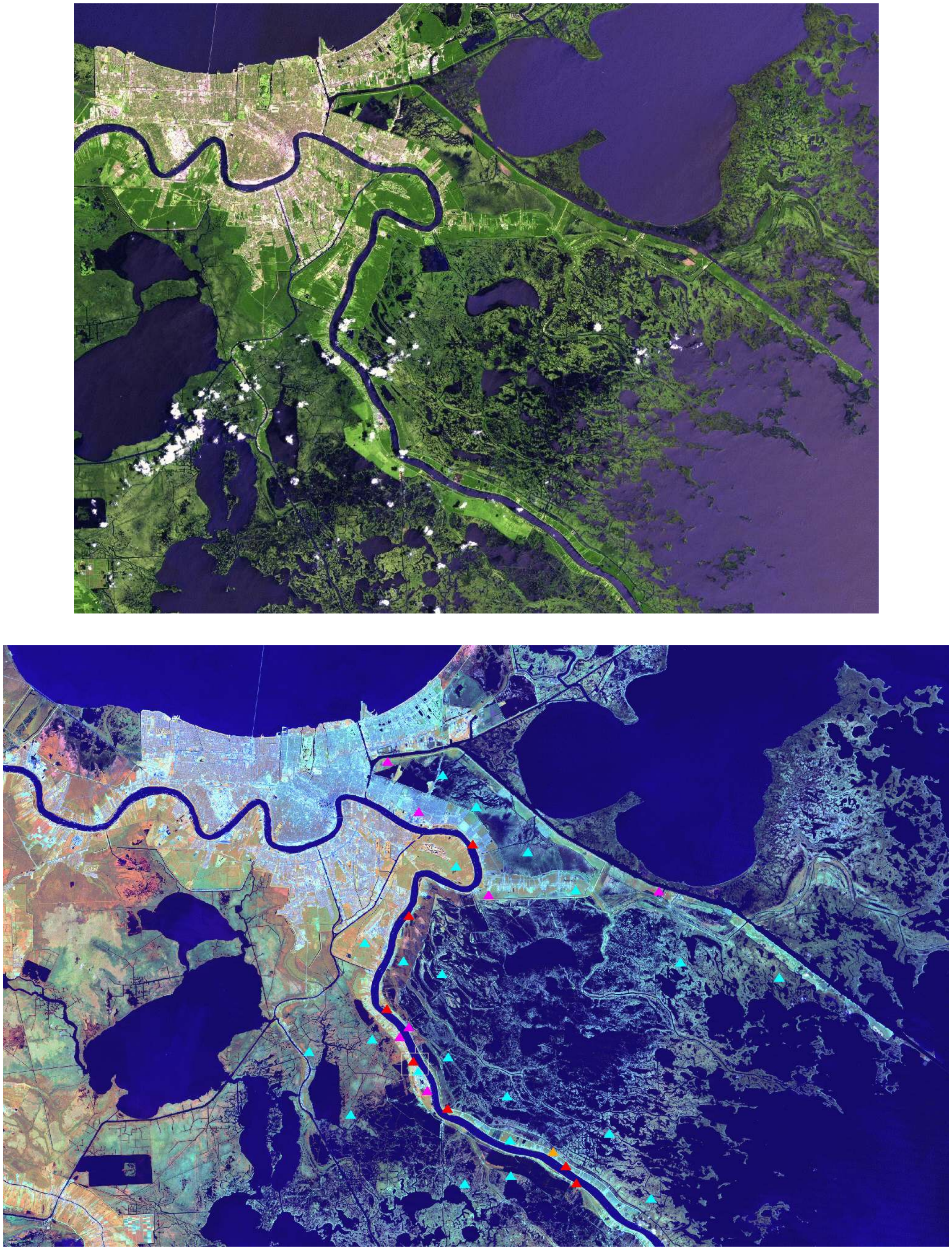

Figure 3. The effect of storm surge from Katrina (before in June 2005, top image, and after in September 2005, bottom image) based on Landsat imagery. Spot terrain elevations (above MSL) are provided in the bottom image with cyan, magenta, orange, and red triangles representing less than 5 feet, between 5 and 10 feet, between 10 and 15 feet, and greater than 15 feet, respectively.

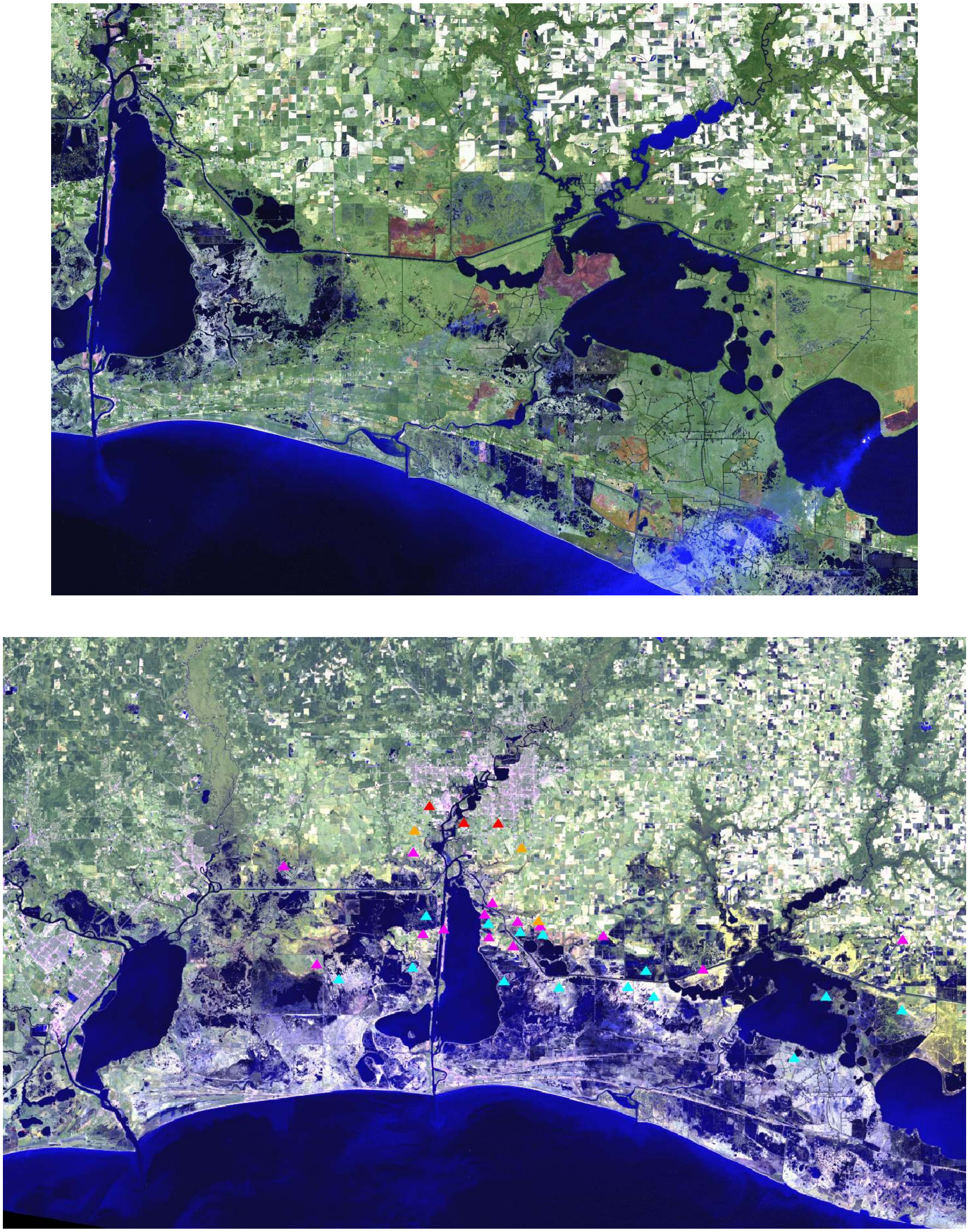

Figure 4. Same as Fig. 3 but for surge due to Rita (before in September 2005, top image, and after in October 2005, bottom image).

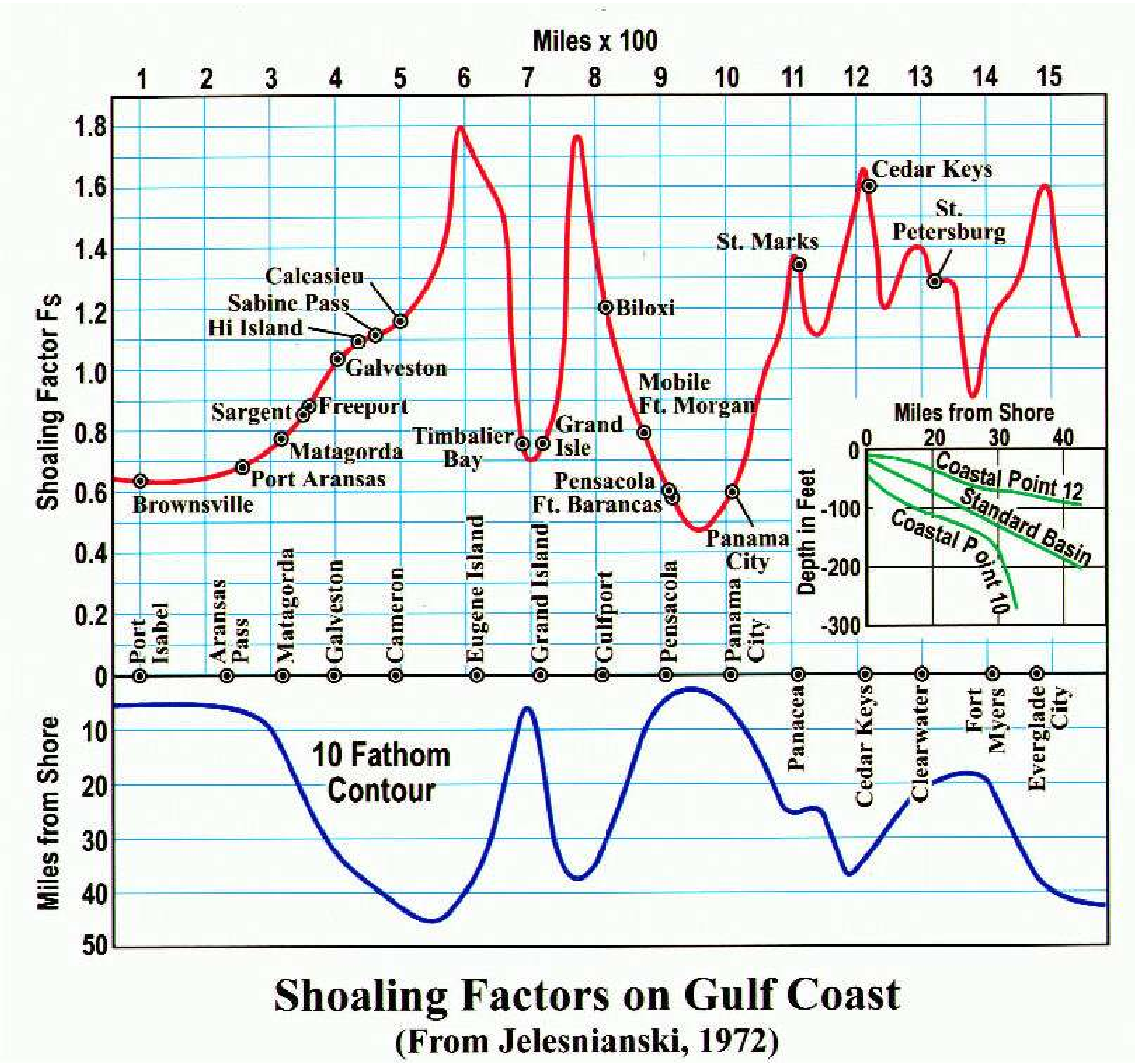


Figure 5. Shoaling factors on the Gulf coast.

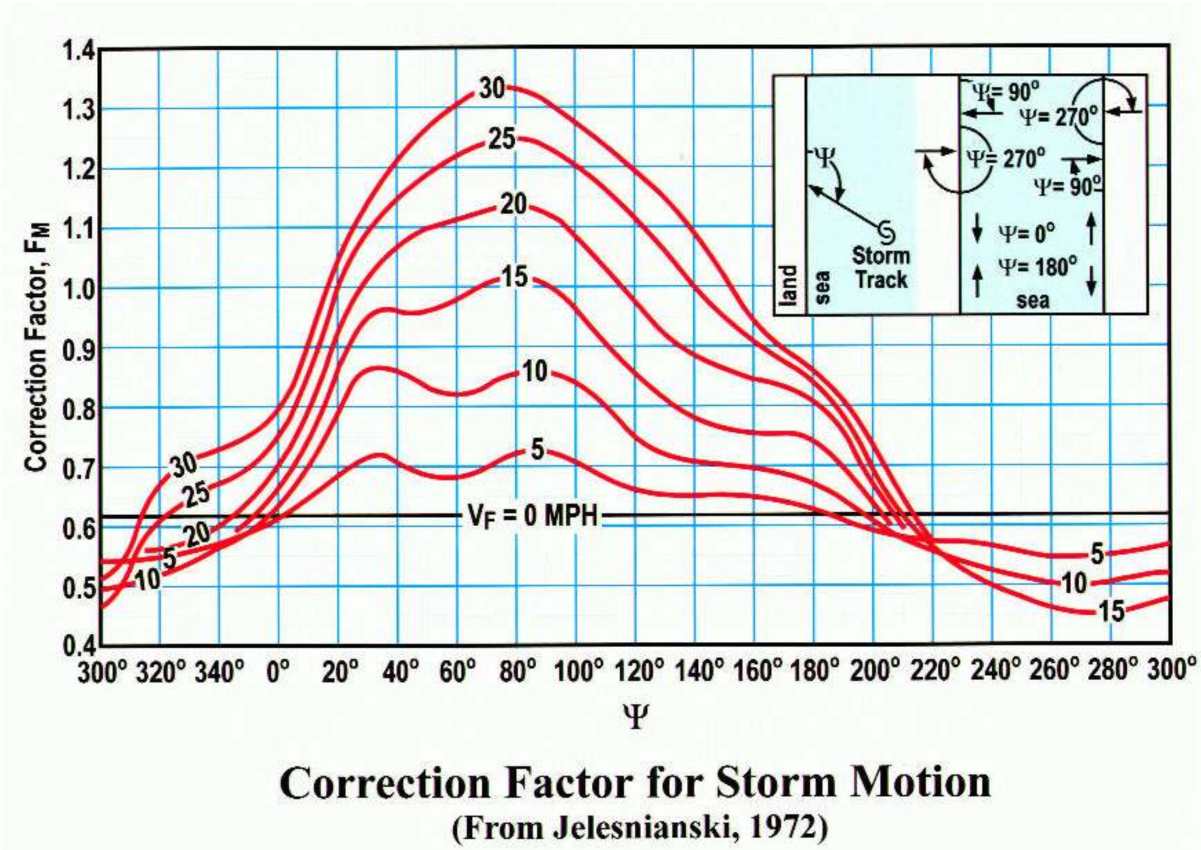


Figure 6. Correction factor for storm motion. Ψ, in degrees, is the orientation of the track of the storm relative to the coast.

Table 1. Rapid estimation of storm surges induced by Hurricanes Katrina and Rita and their comparison with the measurements (data sources: http://www.nhc.noaa.gov and http://www.fema.gov).

| Hurricane Katrina (2005) | Hurricane Rita (2005) |
|---|---|
| Landfall near LA/MS border | Landfall between Johnson's Bayou, LA and Sabine Pass |
| $P_0$ = 928 mb | $P_0$ = 937 mb |
| $V_F$ = 6.7 m/s (15 mph)* | $V_F$ = 5.4 m/s (12 mph)* |
| $F_M$ = 1.0 | $F_M$ = 0.9 |
| $F_S$ = 1.5 | $F_S$ = 1.1 |
| $\therefore S_p$ = 0.07 x (1010 - 928) x 1.0 x 1.5 | $\therefore S_p$ = 0.07 x (1010 - 937) x 1.1 x 0.9 |
| = 8.5 m (~28 feet) estimated | = 5.2 m (~17 feet) estimated |
| vs. 7.9 - 8.5 m (26 - 28 feet) measured | vs. 4.9 - 5.5 m (16 - 18) feet measured |

*$V_F$ is the forward speed of the storm estimated from Advisory positions.