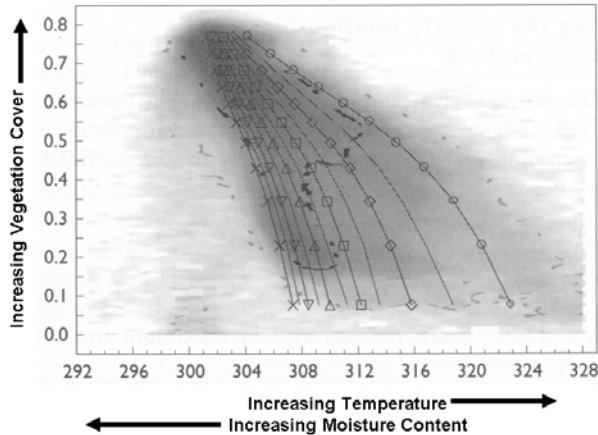


REMOTE SENSING AND GIS ANALYSIS OF SOIL MOISTURE AND OTHER GEOLOGIC FACTORS INFLUENCING MOSQUITO-BORNE DISEASE POTENTIAL IN THE RIO GRANDE DELTA, U.S.-MEXICO BORDER AREA.

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Introduction: A small dengue fever outbreak near Matamoros, Mexico, south of Brownsville, Texas exploded into an epidemic during the Summer, 2005 with nearly 200 reported cases during one week [1]. This epidemic was caused by increased flooding and mosquito activity following heavy rainfall from Hurricane Emily and Tropical Storm Gert within just four days of one another in late July, 2005. Mosquito vectors carrying diseases such as dengue, malaria and west-nile virus all require standing water continuously available during the time it takes for them to complete their life cycle of breeding, ovipositing and larval development. This typically range from a week to ten days for most species under suitable environmental temperature and humidity conditions [2]. Because stagnant water in flood-prone areas imply higher values of soil moisture, an index was developed for use with multispectral remote sensing datasets covering parts of the visible, near-infrared, and thermal infrared (TIR) regions of the spectrum [3].

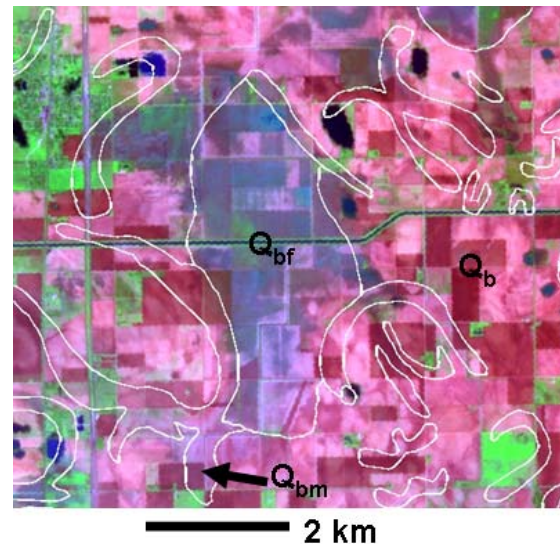
Figure 1 (modified after [4])



Methods: Standard normalized difference vegetation index (NDVI) images combined with surface radiant or kinetic temperature images can be used to model soil moisture availability (Mo) by applying the “triangle method” as depicted in figure 1, which is constrained by a fourth-order polynomial equation developed by Capehart [5]. For example, vegetation cover is directly scaled from NDVI values ranging between fully vegetated pixels and bare soils, while surface temperatures are similarly scaled between pixels representing the cold and warm bases of the triangular-shaped scatterplot.

Both Landsat and ASTER have visible and near-infrared bands useful for deriving NDVI. Soil surface temperatures can either be derived from atmospherically corrected and radiometrically calibrated Landsat band 6 TIR radiance by inversion of the Plancks equation [6], or by using the standard ASTER surface kinetic temperature product derived using an automated temperature-emissivity separation algorithm [7]. The resulting Mo map is an index representing the relative amounts of “field gravimetric obtainable” moisture in soils, which are not directly available for evapotranspiration by vegetation [4].

Figure 2 (geology shown in white after [8])



Preliminary Results: The triangle method was tested using an ASTER scene acquired 25 November 2003 during a particularly wet and rainy period as indicated by historic archived National Weather Service (NWS) rainfall data for various stations throughout South Texas. This image subset (fig. 2) is a false-color composite of ASTER bands 6, 3, and 1 displayed as red, green and blue respectively, which covers parts of the Late Pleistocene Beaumont Formation near the town of Lyford, TX. The Beaumont Formation was deposited by ancestral coalescing deltas, that extend throughout the Texas Gulf Coastal Plain [9]. Beaumont facies Qbf and Qbm are comprised of clay and mud paleo-floodplain and channel deposits with low permeability, poor drainage and high water-holding capacity [8,9]. Qb areas are comprised of clayey-sands and loamy- (or silty-) sands with moderate per-

meability and drainage character [8,9]. The ASTER 6-3-1 false color composite illustrates that the Qbf mapped areas appear darker-colored than the Qb areas, which is expected for wet, poorly drained soils exhibiting low spectral contrast [10].

Figure 3 ASTER-derived Mo values

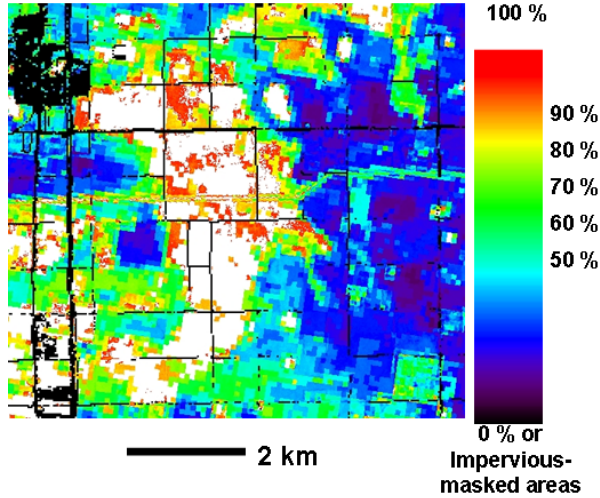


Figure 3 shows the distribution of Mo values derived for the area shown in figure 2 using the triangle method. Similar to the results obtained in a previous study focusing on the Nile River delta area in Egypt [3], Mo values below 50% and approaching 0% (fig. 3) correlate well with dry, permeable sandy soils (fig. 2), while those approaching 100% (fig. 3) represent impermeable muds, water-saturated floodplains, wetlands, irrigation canals and perennial bodies of water (fig. 2). Note that non-soil and non-vegetation urban and built areas have all been excluded (fig. 3).

The clay mineralogy of soils sampled throughout the area in both 2004 and 2007, is quite variable with mixtures of quartz and calcite dominating the larger size fractions, while mixtures of illite, smectite and kaolinite dominate the clay-sized fractions. Mineral maps produced using drought period ASTER imagery acquired 15 March 2001 and X-ray diffraction and laboratory spectral analysis results from area soil samples collected from Pleistocene Beaumont deposits and Holocene Rio Grande floodplain and delta deposits indicate that the wetter, impermeable mud areas within both geologic units contain higher smectite abundances than the surrounding sandier, more permeable facies. In contrast, the sandier, more permeable soils of the Pleistocene Beaumont Formation contain the most abundant amounts of illite, while equivalent facies within the Holocene Rio Grande floodplain and delta contain greater amounts of kaolinite.

Continuing Work and Concluding Remarks:

We are currently analyzing ten cloud-free Landsat-7 ETM scenes acquired during representative wet and

drought periods throughout 2002. These scenes cover the entire Rio Grande delta, spanning both sides of the U. S. – Mexico border. In particular, Landsat-7 ETM has a 185-km swath width which is better for regional landscape-scale mapping than ASTER and a 60 m/pixel resolution TIR band which is better than the 90m/pixel ASTER TIR bands. Unfortunately, Landsat provides continuous temporal coverage only every 16 days, which is still not optimal for monitoring changing soil moisture conditions within the life cycle of a mosquito.

Ancillary GIS data such LIDAR coverage over the entire U. S. side of the Holocene Rio Grande floodplain and delta, and portions of the Beaumont deposits, provide additional information about the topographic and geomorphic characteristics of impermeable mud areas, most of which are low-lying and/or preserve the remnants of ancient floodplains or abandoned meanders (ie. resacas). SSURGO and STATSGO GIS layers distributed by the NRCS provides additional validating information such as soil field textures, drainage properties, and permeabilities for the U. S. side of the border. Bi-national landuse/cover maps provide up-to-date information on urban and built-up areas, as well as colonias which are most at risk for infectious disease.

The 2002 Landsat imagery plus ancillary GIS data on the U. S. side will allow us to extend our mapping of impermeable mud areas, with persistently high soil moisture values and greatest potential for disease-carrying mosquito habitats, across both sides of the border. The resulting maps and multi-temporal satellite derived soil moisture data could be useful for both targeted mosquito control measures in the area, as well as better management of scarce water resources.

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- U.S.-Mexico border news, 09/14/05, fnsnews@nmsu.edu. [2] Matheson (1966) *Handbook of the Mosquitoes of North America*. [3] Crombie et al. (1999) *Photogr. Eng. Rem. Sens.*, 65(12), 1401–1409. [4] Quattrochi and Luvall (2000): *Thermal Remote Sensing in Land Surface Processes*, Chapter 5. [5] Capehart (1996): PhD dissertation, Penn State U. [6] Barsi et al. (2003) *Proceedings of IGARSS*. [7] Gillespie et al. (1998) *IEEE Trans. Geosc. Rem. Sens.* 36, 1113–1126. [8] Geologic Atlas of Texas (1976), Mc-Allen-Brownsville sheet, 1:250,000 scale. [9] Brown et al. (1980) *Environmental Geologic Atlas of the Texas Coastal Zone- Brownville-Harlingen Area*. [10] Ben-Dor et al. (1999) *Soil Reflectance*. In: *Manual of Remote Sensing* (Rencz, ed.), Chapter 3.

Additional Information: See the following web-sites: <http://borderhealth.cr.usgs.gov/> and <http://health.usgs.gov/>.