Remotely Sensed Soil Moisture and Landslide Hazards

UNIVERSITY of NEW HAMPSHIRE

SMAP Applications Workshop, Silver Spring, Maryland, September 9-10, 2009

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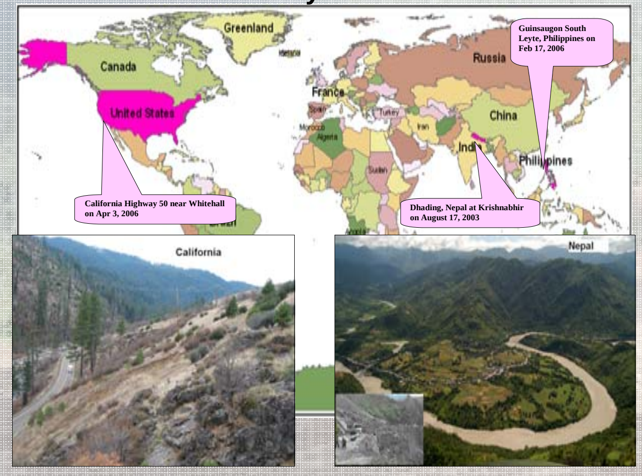
Overview

- Landslide are natural disasters that cause enormous loss of physical property and human lives, are becoming more prevalent in mountainous region of many countries.
- Remote sensing data have been used to detect and identify, actively monitor and assess hazards using Synthetic Aperture Radar (SAR), Differential SAR Interferometry (DInSAR), Light Detection and Ranging (LIDAR), IKONOS, Tropical rainfall Measuring Mission (TRMM), Landsat, and SPOT instruments.
- Groundwater and soil moisture play a critical role in triggering slope failure. Microwave remote remote sensing (e.g., SMAP, SSM/I, and AMSR-E) can measure surface soil moisture. Here, we show two examples of microwave soil moisture applications to landslide prone hillslope:
  - TRMM rainfall, AMSR-E soil moisture and landslide events at three study regions; Cleveland Corral, CA, US, South Leyte Philippines and Dhading Nepal.
  - AMSR-E soil moisture and the variable infiltration capacity (VIC-3L) model's soil moisture for landslide susceptibility mapping in California, US.

Study Areas



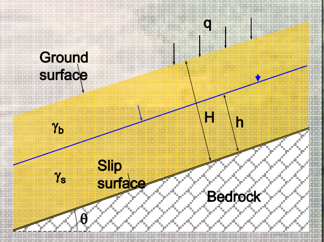
Slope Stability Model

- Slope stability depends on soil moisture and groundwater elevation as given by the safety factor FS.

$$FS = \frac{C_s + C_r}{H\,\gamma_s \sin\theta} + \left[\left(1 - m\frac{\gamma_w}{\gamma_s}\right)\right]\frac{\tan\varphi}{\tan\theta}$$

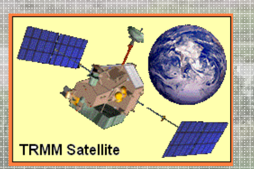
$$m = \frac{h + (H-h) * \dfrac{\theta_s}{\eta}}{H}$$

Safety Factor	Slope Stability
FS > 1.5	Stable
1.25 < FS < 1.5	Moderately Stable
1 < FS < 1.25	Quasi Stable
FS < 1	Unstable

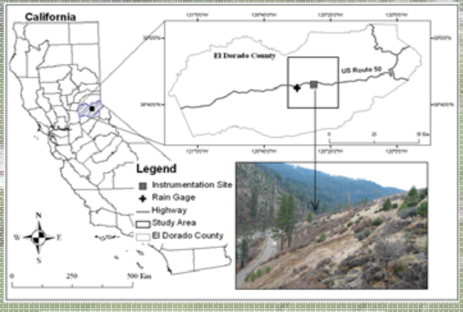


Data

Remotely Sensed Data
Daily Tropical Rainfall Measuring Mission (TRMM) precipitation data and AMSR-E soil moisture data from Jan. 1, 2005 to Dec. 31, 2006.



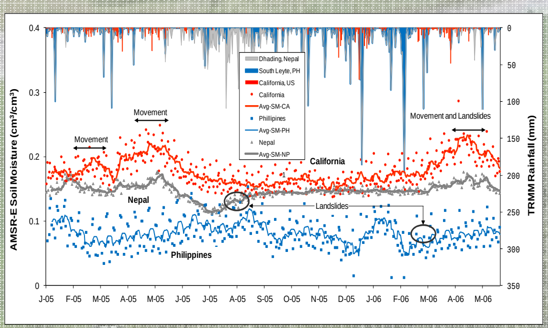
In Situ Data and Measurements
Soil: STATSGO soil maps and parameters
Vegetation: University of Maryland/GIS land cover
Climatic data: National Climatic Data Center (NCDC)/Daily
Slope: SRTM 90 m DEM
Parameters: Soil shear strength and root cohesion from the literature



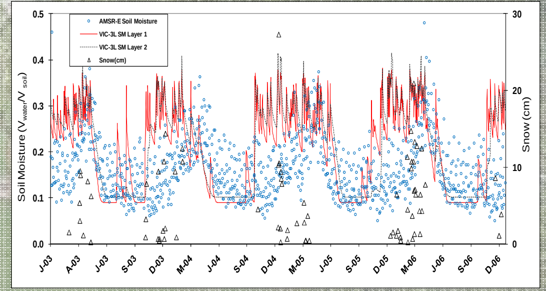
The California study area and landslide locations

Results

Figures below show AMSR-E's ability to capture California's wet spring season, Nepal's monsoon season and the Philippines's wet winter and late summer. All the slope movements and landslides coincide with wet periods and indicate that AMSR-E soil moisture data are viable for landslide studies.



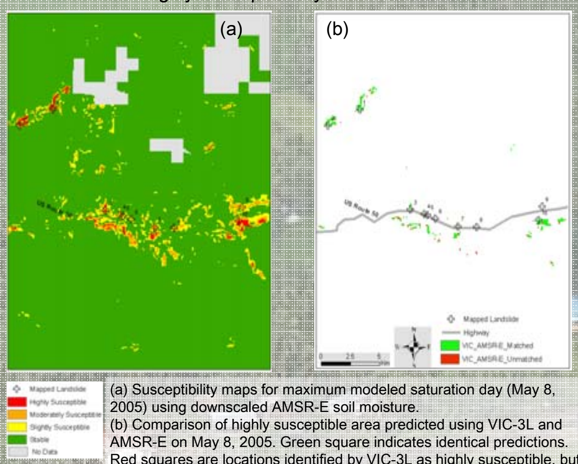
A comparison of soil moisture, rainfall and landslides in the three study regions



Observed scaled (0.05-0.48 cm³/cm³) AMSR-E soil moisture, VIC-3L soil moisture, and snow values at Cleveland Corral, California, US

Results (cont.)

Under the maximum modeled saturation scenario, both VIC-3L and AMSR-E vadose zone soil moisture identified the same hazard zones as highly, moderately and slightly susceptible. Small differences occur in the predicted susceptible areas. 83.2% of highly susceptible locations predicted using VIC-3L vadose zone soil moisture were also identified as highly susceptible by AMSR-E.



(a) Susceptibility maps for maximum modeled saturation day (May 8, 2005) using downscaled AMSR-E soil moisture.
(b) Comparison of highly susceptible area predicted using VIC-3L and AMSR-E on May 8, 2005. Green square indicates identical predictions. Red squares are locations identified by VIC-3L as highly susceptible, but not by AMSR-E.

References

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2. Ray, R.L., Jacobs, J.M., and de Alba, P. (In Review). Impact of vadose zone soil moisture and groundwater on slope instability, Journal of Geotechnical and Geoenvironmental Engineering, August, 2009
3. Ray, R.L., Jacobs, J.M., and Douglas, E.M. (In Review). Modeling landslide susceptibility using dynamic soil moisture profiles, Journal of Hydrology, August, 2009.
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5. Ray, R.L., Jacobs, J.M., and Ballestero, T.P. Regional landslide susceptibility: Statistical distribution in space and time, anticipated submission, September, 2009.

Acknowledgement: This work was supported by NASA Headquarters under the Earth System Science Fellowship Grant NNG05GP66H.