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Christopher Hain
NASA Marshall Space Flight Center, christopher.hain@nasa.gov

Martha C. Anderson
USDA-ARS Hydrology and Remote Sensing Lab, martha.anderson@ars.usda.gov

Mitch Schull
University of Maryland at College Park

Christopher M.U. Neale
University of Nebraska- Lincoln, cneale@nebraska.edu

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Demonstration of a Daily High-Resolution (375-m) ALEXI Evapotranspiration Product for the NENA Region

Christopher R. Hain[1], Martha C. Anderson[2], Mitch Schull[3], Christopher Neale[4]

Marshall Space Flight Center, Earth Science Office, Huntsville, AL[1]
USDA-ARS Hydrology and Remote Sensing Lab, Beltsville, Maryland[2]
Earth System Science Interdisciplinary Center, University of Maryland, College Park, Maryland[3]
Daugherty Water for Food Institute, University of Nebraska, Lincoln, NE[4]

Contact Information:
christopher.hain@nasa.gov

Atmosphere-Land-Exchange-Inversion Model (ALEXI)

ALEXI is a two-source energy balance model which was initially developed to address issues dealing with the monitoring of surface fluxes, including actual evapotranspiration (ET), from a satellite-based platform (Anderson et al., 1997; Fig.1). Flux partitioning within ALEXI is driven by time changes in land surface temperature (LST): the amplitude of the diurnal surface temperature wave has been found to be a good indicator of surface flux partitioning, and using a time-differential measurement significantly reduces model sensitivity to errors in LST retrieval. Model evaluation through disaggregation over flux sites in the US and other regions indicate accuracy on the order of 10% at daily time steps(e.g., Cammalleri et al, 2013, 2014; Fig 2).

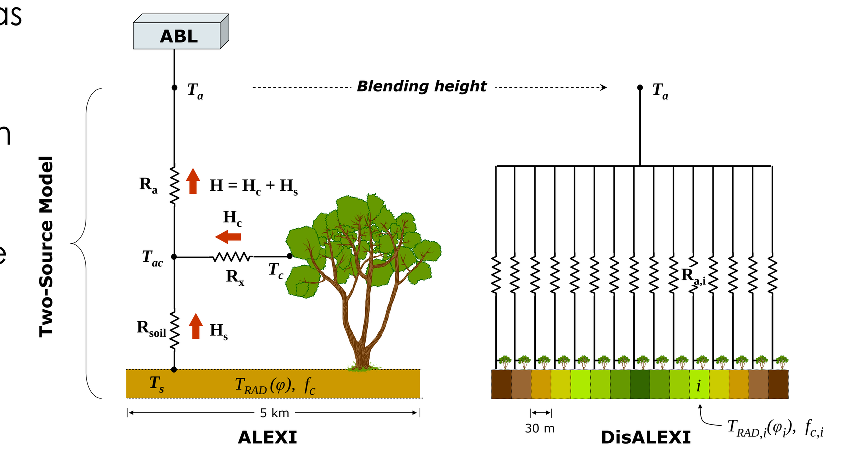


Figure 1. Multi-scale modeling framework: (left) ALEXI system, using morning surface temperature rise from geostationary (GEO) satellites; (right) flux dsaggregation using LST from Landsat, MODIS, aircraft, etc.

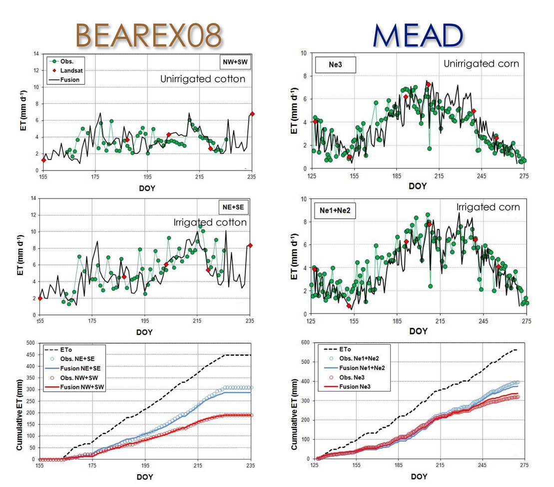


Figure 2. ET evaluation over rainfed and irrigated crops in semiarid (BEAREX08; Bushland TX) and temperate (Mead, NE) conditions.

The LST inputs to ALEXI are a valuable diagnostic of biospheric stress resulting from soil moisture deficiencies. Soil surface temperature increases with decreasing water content, while moisture depletion in the plant root zone leads to stomatal closure, reduced transpiration, and elevated canopy temperatures that can be effectively detected from space.

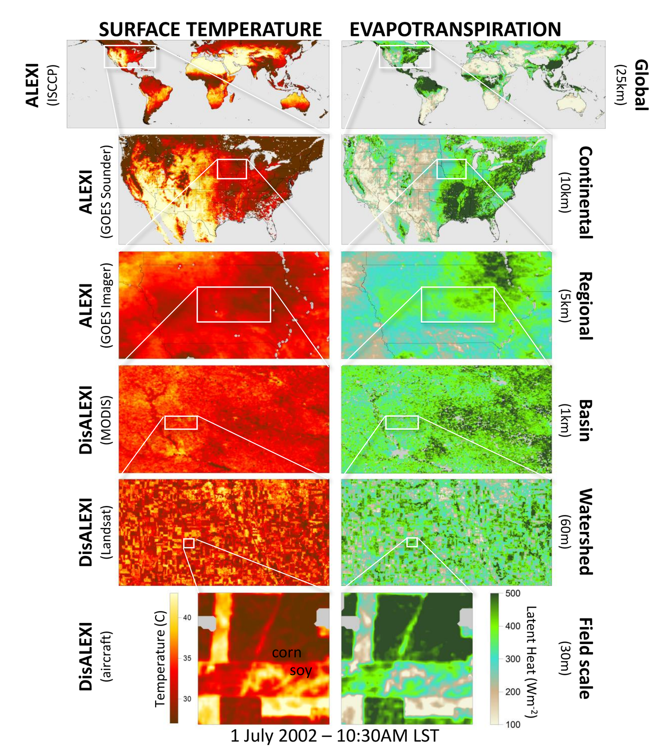


Figure 3. Multi-scale ET maps for 1 July 2002 produced with ALEXI/DisALEXI using LST data from aircraft (30-m resolution), Landsat (60-m), MODIS (1-km), GOES Imager (5-km) and GOES Sounder (10-km).

Because ET in ALEXI is computed based on energy balance rather than water balance, precipitation is not a required input to the modeling system. The LST inputs to ALEXI inherently capture non-precipitation related moisture signals (such as irrigation; vegetation rooted to groundwater; lateral flows) that need to be modeled a priori in prognostic LSM schemes (Yilmaz et al, 2014; Hain et al, 2015). Techniques are being developed to integrate LST retrieved using thermal and microwave data from multiple sensors to provide improved spatiotemporal sampling over a broad scale range (Fig. 3)

Project Overview

Food and water security over the MENA (Middle East / North Africa) region is of increased importance as diminishing water supplies and a growing population continues to put strain on countries to provide adequate agriculture production. Satellite remote sensing of consumptive water use provides a mechanism to observe how efficiently, or in many cases inefficiently, local farmers are using water.

In this project, we aim to produce near-real-time (latency less than 5 days) daily 375-m evapotranspiration estimates from VIIRS towards improvement monitoring of agricultural water use and as the primary input into Landsat-based DisALEXI simulations (~30-m resolution) over several targeted agricultural regions in the study domain.

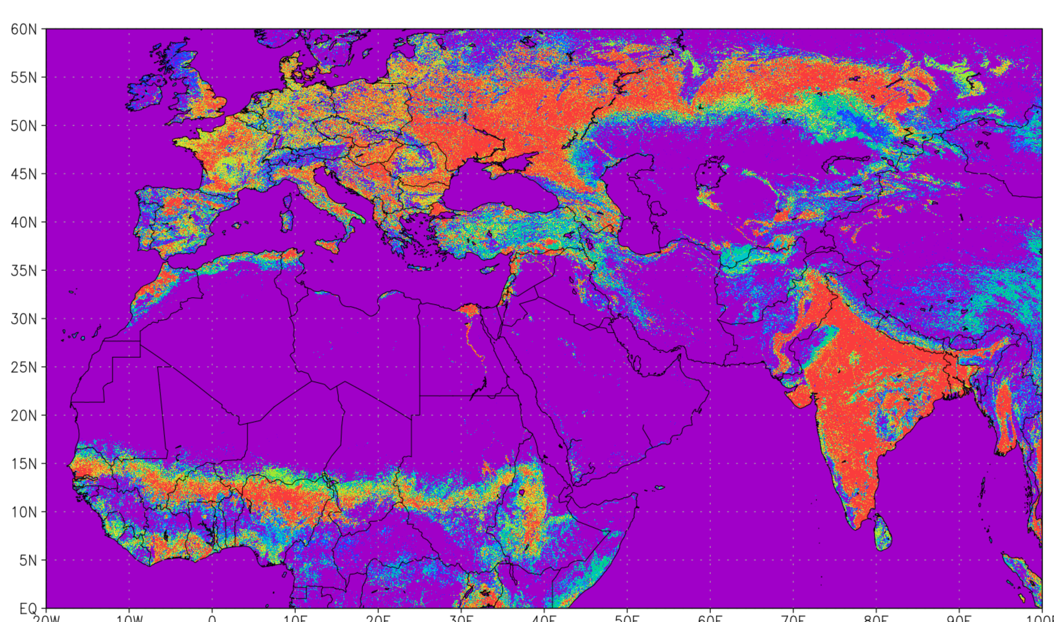


Figure 8. Study domain for the MENA 375-m VIIRS ET product. Shading shows the percentage of each pixel which has been classified as cropland.

Training a Regression Model to Estimate Mid-morning LST rise from Day/Night MODIS/VIIRS Observations

While the current constellation of geostationary sensors provides near-global coverage (60N to 60S) – it requires merging data from 7 satellites [resolving time differences; view angles; atmospheric correction]. Polar orbiting sensors such as MODIS and VIIRS provide daily global coverage of LST at higher resolutions than GEO sensors but at only two times per day.

A technique has been developed and evaluated using GOES data to train a regression model to use day-night LST differences from MODIS to predict the morning LST (DTRAD) rise needed by ALEXI (Fig. 5). The regression model can provide reasonable estimates of the mid-morning rise in LST (RMSE ~ 5 to 8%; Fig. 6) from the twice daily MODIS or VIIRS LST observations.

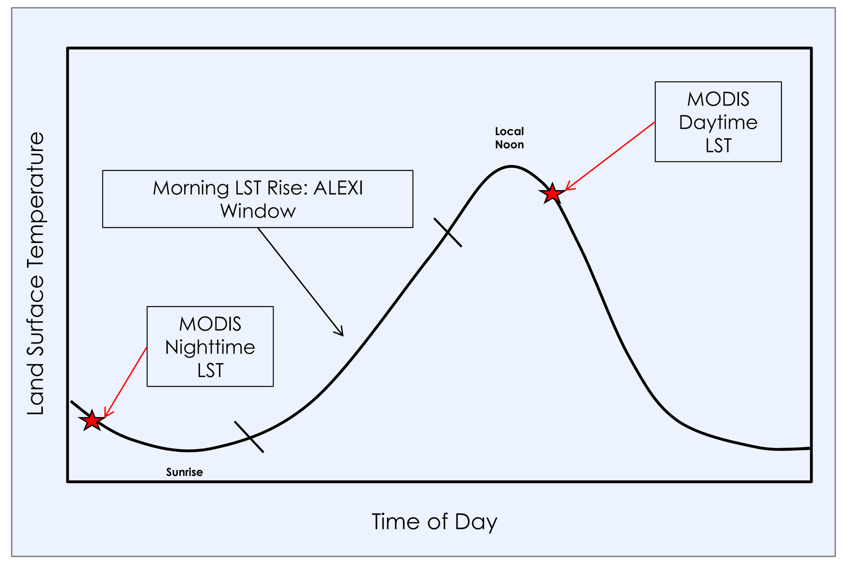


Figure 5. Schematic showing the typical diurnal cycle of LST with the morning LST required by ALEXI and typical MODIS LST observation times (1:30 am/pm).

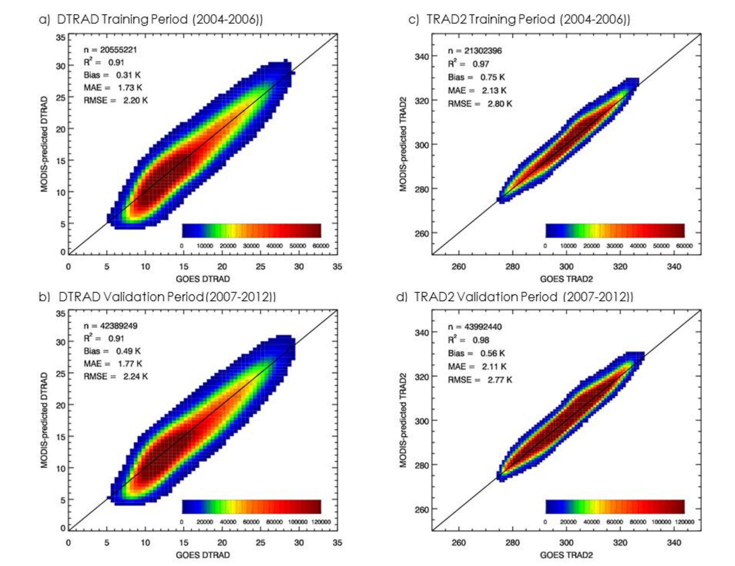


Figure 6. Validation of estimated DTRAD and TRAD2 (LST at ALEXI time 2) from MODIS for the training period (a. and c.; 2004-2006) and the validation period (b. and d.; 2007-2012).

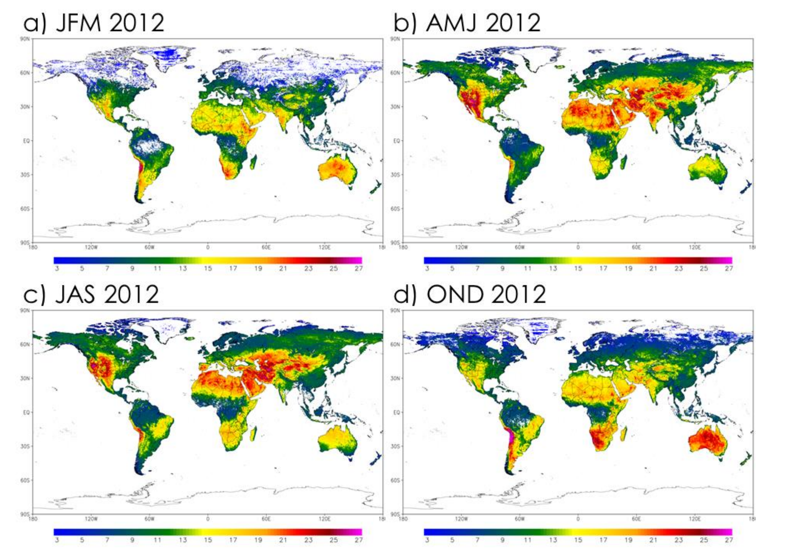


Figure 7. 3-month DTRAD composites estimated from MODIS for (a) JFM 2012, (b) AMJ 2012, (c) JAS 2012 and (d) OND 2012.

Prototype VIIRS ET Results – Spatial Resolution Improvements with VIIRS

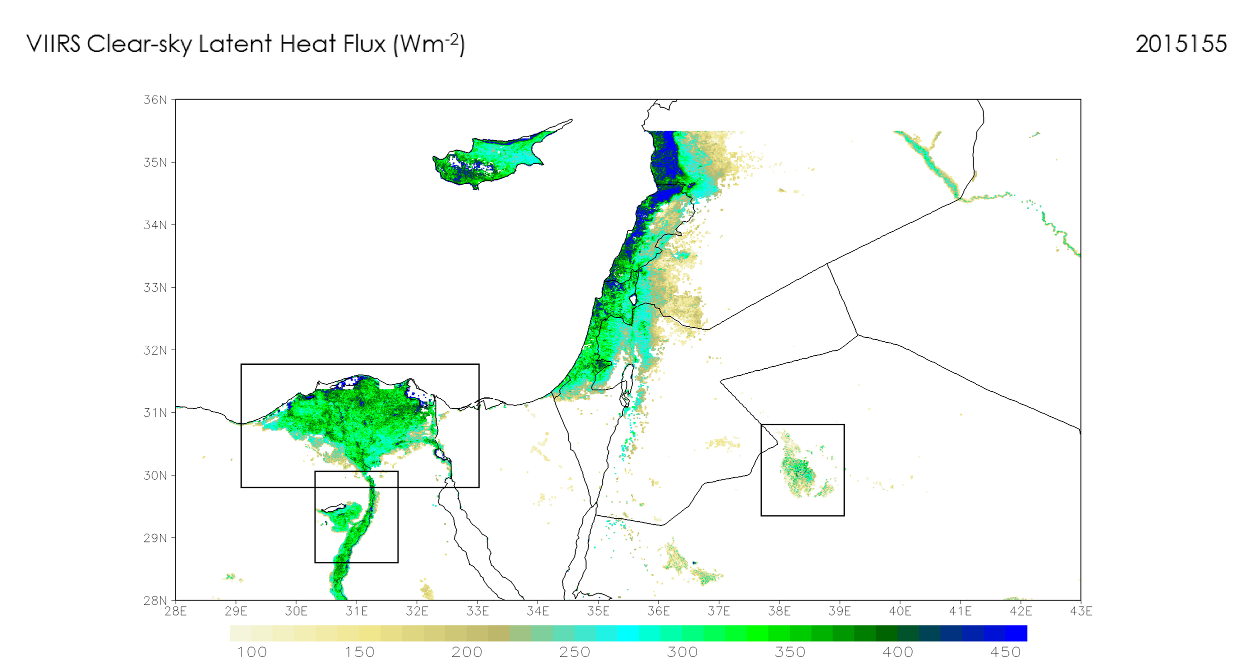
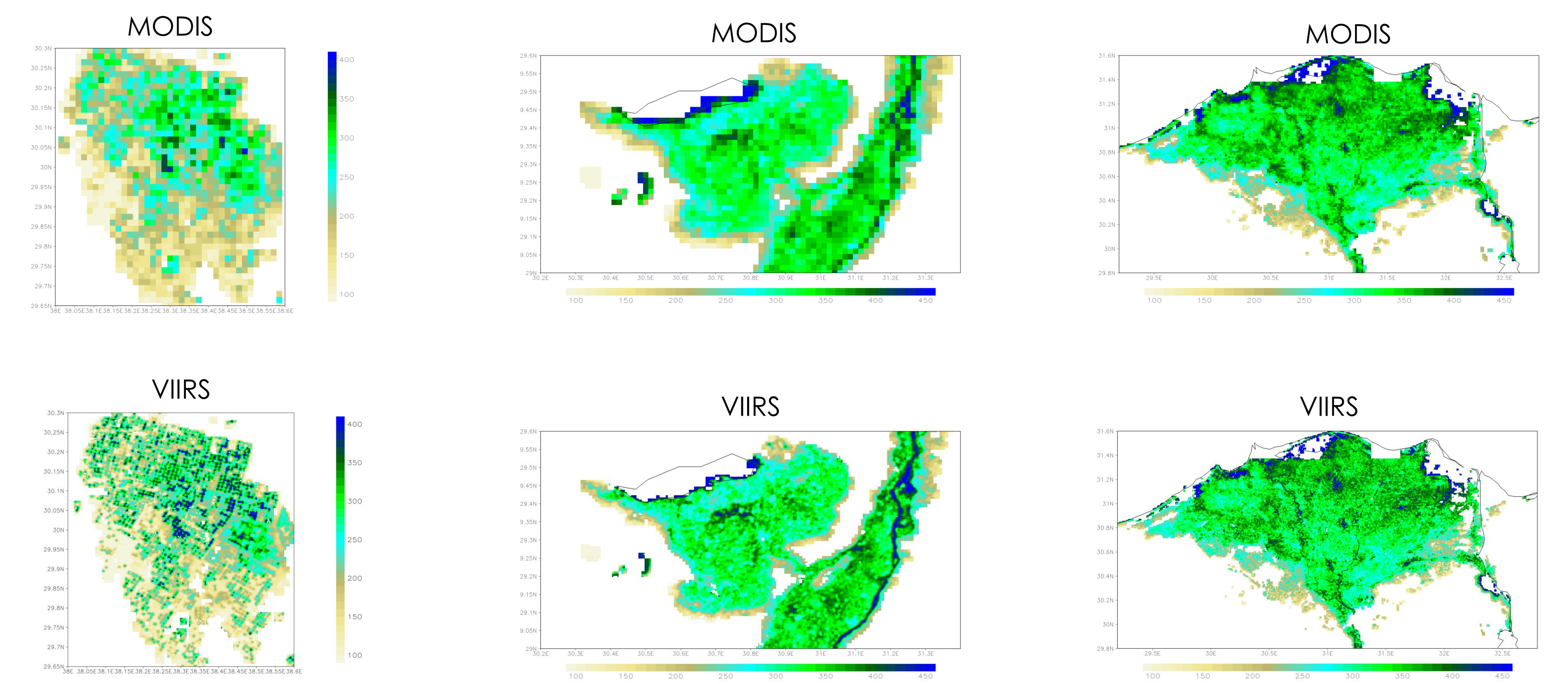


Figure 8. 7-day clear-sky latent heat flux (W m-2) on day ending 2015155. Figures to the left show several regions of interest with examples of the current MODIS (~1 km) and VIIRS (~375 m) fields.



Prototype VIIRS ET Results – 2015 Annual Evapotranspiration (mm)

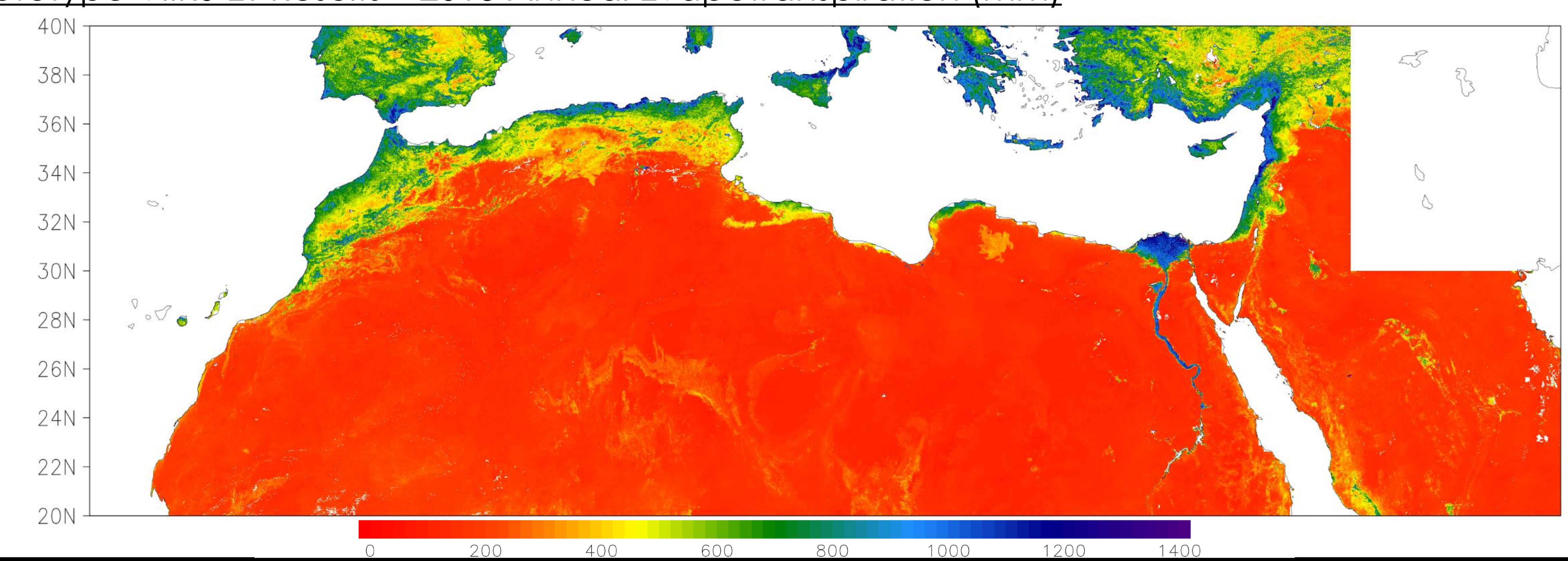


Figure 9. Annual 375-m VIIRS evapotranspiration (mm) for 2015.