Princeton Sensible Heat Flux 0.5 degree, hourly global product

The files in the Data_files directory are the sensible heat flux files for our baseline product. These binary files can be read in GrADS using the control file SH_processed_final_WZ_ERAInt_16.ctl. The sensible heat flux is stored in $W/m^2$, at hourly, 0.5° resolution from 1979-2009. We calculate the sensible heat flux ($H$) at the surface within the atmospheric boundary layer (ABL) according to Brutsaert (2005) as follows:

$$H = -\rho C_p C_h u_z \Delta \bar{\theta}$$

in which $\rho$ is the air density, $C_p$ is the specific heat capacity of air at constant pressure, $C_h$ is the coefficient of heat transfer, $u_z$ is the mean wind speed at a reference height, and $\Delta \bar{\theta}$ is the difference between the potential temperatures at two different reference heights. By grouping the $C_h$ and $u_z$ into the aerodynamic resistance ($r_a$) as follows

$$r_a = \frac{1}{C_h u_z}$$

we parameterize the surface sensible heat flux using land surface temperature (LST), air temperature, and aerodynamic resistance as follows (Monteith 1973)

$$H = \rho C_p (T_s - T_a)$$

$\rho$ (kg m$^{-3}$) is calculated from the CFSR air pressure (Pa) at the 2-meter air temperature (°K), $C_p$ is held constant at 1004.6 J kg$^{-1}$ K$^{-1}$, $T_s$ is the physical LST calculated using a High Resolution Infrared Radiation Sounder (HIRS) -consistent LST (°K) (see Coccia et al., 2015 and Siemann et al. 2016) and the MODIS emissivity (because the HIRS-consistent LST assumes an emissivity of 1), $T_a$ is the potential air temperature calculated using a 2-meter air temperature, and $r_a$ is calculated with units of sm$^{-1}$.

We use six 0.5° resolution, hourly, global 2-meter air temperature datasets from 1979-2009 to calculate six sensible heat products corresponding with each of the air temperatures. The product provided here is our baseline product using the air temperature based on ECMWF Interim Re-Analysis (ERA-Interim) developed by Wang and Zeng (2013). Wang and Zeng bias corrected the ERA-Interim air temperature by monthly mean minimum and maximum surface air
temperature using Climate Research Unit Time Series 3.10 monthly gridded data (Wang and Zeng 2013). We choose this air temperature for our baseline product because it produces the highest Pearson correlation coefficient and lowest RMSE when validated against the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information Integrated Surface Database (ISD) observations for air temperature (Smith, Lott and Vose 2011) at 13,545 stations, globally.

For the calculation of $r_a$, we use the parameterization of $C_h$ used in the offline Noah land surface model (LSM) version 3.4.1, described in (Ek, et al. 2003), which solves for the $C_h$ using the following formulation based on Janjic (1994)

$$C_h = \frac{u_\kappa k}{\ln \left( \frac{z + z_{0m}}{z_{0h}} \right) + \psi_h \left( \frac{z + z_{0m}}{L} \right) - \psi_h \left( \frac{z_{0h}}{L} \right)}$$

in which $u_\kappa$ is the friction velocity (m/s), $k$ is the von Karman constant, $z$ is the reference height (m), and $z_{0h}$ and $z_{0m}$ are the roughness lengths for heat and momentum (m). $L$ in the equation for $C_h$ is the Obukhov length which is described by the following equation (Monin and Obukhov 1954)

$$L = -\frac{u_\kappa^3 \bar{\theta}_v}{kgw'\theta_v'}$$

in which $g$ is gravitational acceleration (m/s$^2$), $\bar{\theta}_v$ is the virtual potential temperature (K), and $w'\theta_v'$ is the virtual potential temperature flux at the surface (K/(m$^2$s)). The heat stability correction function, $\psi_h$, is based on Paulson (1970) for unstable boundary layer conditions and based on Holtslag and de Bruin (1988) for stable boundary layer conditions. In addition to Beljaars’ correction for $u_\kappa$ (1995) to account for instances of vanishing wind speed due to free convection, this parameterization also applies the following relationship between $z_{0h}$ and $z_{0m}$ to account for the difference between the radiative skin temperature (used as the LST) and the near-surface air temperature

$$\frac{z_{0m}}{z_{0h}} = \exp(kC_{zil} \sqrt{Re^*})$$

where $C_{zil}$ is the Zilinkitevich empirical constant (Zilitinkevich 1995) and $Re^*$ is the roughness Reynolds number. Instead of holding $C_{zil}$ constant at 0.1, we use estimates calibrated at 85
FLUXNET eddy covariance locations, which are extended globally to 1km spatial resolution using objective analysis based on climate and land cover covariates (Chaney, et al. in review).

We use the roughness length for momentum, $z_{0m}$, from the UMD land cover type dataset (Defries, et al. 2000) for 14 land cover types upscaled from ~1km to 0.5° resolution (see Hansen et al., (2000) for detailed description of each type). To calculate the total sensible heat flux for each grid cell, we run the algorithm for each land cover type present in that grid cell. We compute a weighted average total sensible heat flux value for each cell based on the fractional green vegetation coverage over each land cover type within the cell (derived from Gutman and Ignatov (1998)), which is then added to the sensible heat flux calculated for the bare soil fraction.

For evergreen broadleaf forest and bare soil, the solver for aerodynamic resistance may not converge with 50 iterations, or the $C_h$ may be large, causing a very large sensible heat flux. We check for sensible heat fluxes over 1000.0 W/m2, under -1000.0 W/m2, or for which the aerodynamic resistance doesn’t converge within 50 iterations, and in these cases, we use an average $C_h$ for the respective vegetation type. If an average $C_h$ isn’t available for the grid cell, we use an overall global average $C_h$. For each time step, we store a flag of 1.0 for a sensible heat flux estimate adjusted with an overall global average $C_h$ and a flag of 2.0 for a sensible heat flux estimate adjusted with the overall average $C_h$ for that specific grid cell. The vegetation fraction or bare soil fraction is stored when an estimate is adjusted. If the total sensible heat flux weighted average remains greater than or equal to 1000.0 W/m2 or less than or equal to -1000.0 W/m2, then the estimate is made undefined and the additional flag is set to 1.0 or 2.0, respectively. The order of the flags is specified within the GrADS control file SH_flag_file_WZ_ERAInt_16.ctl, and the flag files are stored in the Flag_files directory.

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References:


