Monitoring daily evapotranspiration in the Alps exploiting Sentinel-2 and meteorological data

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Motivation

- Key role of evapotranspiration (ET) in the global bio-geo-chemical cycling – it is an important indicator for monitoring drought conditions;
- Increasing frequency of summer droughts in the Alps, and expected fast temperature increase;
- Monitoring ET to assist policy makers in the development of strategies to reduce the vulnerability of agriculture and forestry to climate change;
- We tested the energy balance model **TSEB ALEXI/DisALEXI** in the study area, and found limitations in the spatial and temporal resolution of available thermal satellite data;
- We want to implement a simple method based on water balance and EO, and explore the possibility to fuse the two approaches.

ALEXI/DisALEXI simulations in Trentino-Alto Adige driven by **MODIS LST**

Evaporative stress from **MODIS LST** and climate model data

\[ f_{PET} = \frac{ET}{f_{PET}} \]

*Castelli et al., 2018, Remote Sensing of Environment*
Modelling ET with optical remote sensing

**Method:** FAO dual crop coefficient approach based on water balance

\[ ET = ETo(K_s K_{cb} + K_e) \]

- Penman-Monteith potential ET
- Water stress from water balance of the root zone
- Basal crop coeff. from landcover and vegetation density
- Evaporation coeff. from water balance of the soil surface

**Generalized approach** for remote sensing data

And large areas

(project Sentinel Alpine Observatory
http://sao.eurac.edu/)

**Eto:** FAO Penman-Monteith equation:

\[ ETo_{FAO\_PM} = \frac{0.408 \times Ss \times NR + \frac{\gamma \times 900}{(T+273) \times W \times (es-ea)}}{Ss + \gamma \times (1+0.34 \times W)} \]  \[ [mm\ day^{-1}] \]

NR = average daily net radiation; 
T = daily mean air temperature; 
W = daily mean wind speed; 
Ss = slope of the saturation vapour pressure-temperature curve; 
(es – ea) = vapour pressure deficit in the air; 
\( \gamma \) = psychrometric constant.

(Maselli et al., 2014, *Rem. Sen. of Environment*)

Average evaporation coefficient
\[
ET = ETo\left[F_cK_{c\text{ veg}}C_{\text{ws}} + (1 - F_c)K_{c\text{ soil}}A_W\right]
\]
KED air temperature

Covariates: altitude from 250 m DEM

Kriging error from cross-validation, average for all the stations for summer 2016

Kriging accuracy decreases when the distance from the measurement point increases

RMSE | MEAN RES
---|---
1.76 | 0.003
KED air humidity

Covariates: altitude, slope, aspect, roughness from 250 m DEM

Kriging error from cross-validation, average for all the stations for summer 2016

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Covariates: altitude, slope, aspect, roughness from 250 m DEM

Mean prediction error for daily mean AIR HUMIDITY (%)
Kriging error from cross-validation, average for all the stations for summer 2016

RMSE  MEAN RES
1.43  0.002
KED monthly cumulated rain

Covariates: altitude, slope, aspect, roughness from 250 m DEM

Kriging error from cross-validation

RMSE | MEAN RES
-----|-------
28.3 | -0.035
KED Net Radiation

Covariates: altitude, slope, aspect, roughness from 250 m DEM

Original maps derived from MSG SEVIRI based albedo, emissivity, short- and long-wave incoming radiation
Spatial resolution: 3km
Potential Evapotranspiration [mm day\(^{-1}\)]

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Water stress coefficient (Cws)

\[ AW = \frac{\sum_{\text{month}} \text{rain}}{\sum_{\text{month}} \text{ET}_{0}} \]

\[ Cws = 0.5 + 0.5AW \]
The level 1C Sentinel-2A data are calibrated and atmospherically corrected by the sen2cor processor. Snow areas and clouds are masked based on the quality snow/cloud confidence layers. This product covers all vegetated land surfaces as defined by the CORINE 2012 land cover classification.
High resolution of Sentinel-2

Actual ET [mm day\(^{-1}\)] 28.07.2016

Caldaro lake area
Conclusions:

- The NDVI-Cws method is promising for operational monitoring of ET for water resources management;
- We cannot obtain daily ET only with Sentinel-2 optical data, because its temporal resolution is reduced by cloudiness;
- KED helps for downscaling meteorological fields, and reanalyses datasets (e.g. ERA5, hor. res. 31 km) could be added as covariates to constrain the meteo variables.

Next steps:

- Validate ET maps against eddy covariance measurements (in meadow, pasture, forest, and apple orchard sites) in South Tyrol;
- Fusion of MODIS and Sentinel-2 NDVI to obtain daily maps at 20 m resolution;
- Exploit Sentinel-2 NDVI for downscaling Sentinel-3 LST for energy balance modelling of ET in mountainous regions, and explore the possibility to exploit Sentinel-1 backscattering.