Land SAF LSA-SAF
Evapotranspiration (ET) Product

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• The ET process
• Factors affecting the ET process
• The LSA-SAF ET product
• Possible applications of the ET product
• Data access
The water cycle

- Precipitations
- Condensation
- Infiltration
- Evapotranspiration
Evapotranspiration (ET)

What is ET and why it matters?

ET = Evaporation + Transpiration

- **Evaporation**: Process where liquid water is converted to water vapor (from soil surface, open water,..)

- **Transpiration**: Vaporization of liquid water in plant tissues and vapor removal to the atmosphere (from vegetation canopy)
The transpiration process

• Plant “Breathing” and the Transpiration Process

1. Root-zone water

For transpiration to occur, there must be water available!

Hygroscopic water

Capillary water

Gravitational water

Water taken to leaves through roots
Light is necessary

2. Root water uptake

3. Exchange plant-atmosphere

Water vapour is released into the air through leaves stomata
Evapotranspiration means loss of water

Plants do transpire

Credit: Ming Kei College, Hong Kong
Evapotranspiration means loss of water.

- On land, ET returns 58% of precipitation!

- Evaporation of intercepted water: 16%
- Evaporation from soil: 36%
- Transpiration: 48%
What amount of water can a large oak tree transpire during one year?
A) 1000 liters
B) 100000 liters
C) 150000 liters

And what amount for a 100 m x 100 m maize field in one day at ET rate of 1 mm/day?
A) 1000 liters
B) 10000 liters
C) 20000 liters
Water and energy cycles

**Energy balance:** \((1 - \alpha) \cdot S + \varepsilon \cdot (L - \sigma) \cdot T_k^4 + H + LE - G = 0\)

**Catchment Water balance:** \(P - Q - ET - Dw - OF = 0\)

- \(P\): Precipitation
- \(Q\): Discharge
- \(Dw\): stock variation
- \(OF\): flow at the outlet

**Diagram notes:**
- Incoming Solar Radiation: 100%
- Lost to Space: 30%
- IR Lost to Space: 70%
- Absorbed in the Atmosphere: 19%
- Absorbed at Surface: 51%
- IR from surface: 21%
- Latent Heat Flux: 23%
- Sensible Heat Flux: 7%

**Definitions:**
- **Evapotranspiration** = transpiration + evaporation
  - Transpiration: trees, grass
  - Evaporation: runoff

**Groundwater recharge**
Evapotranspiration – some definitions

• **Potential Evapotranspiration (PET):** Maximum value of ET for a given climate depending on the available energy and dynamic features of the atmosphere (enough water to meet the evaporative demand)

• **Actual Evapotranspiration (AET):** Effective water vapor loss suffered by a canopy/soil system. Less than the PET due to resistance to the flow of water (soil-plant) and the diffusion of water vapor (leafy atmosphere)

• **Reference Evapotranspiration (ET\text{ref}/ET\text{0}):** ET rate from a reference vegetative surface, actively growing, not short of water (The FAO Penman-Monteith method is recommended as the standard method for calculating ET\text{0})

• **Crop Evapotranspiration (Etc):** Is the evapotranspiration from disease-free, well-fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions.
Reference evapotranspiration

\[ ET_0 \approx a_M f(T) DSSF_{Daily} \]

ET rate from reference surface it is essentially determined by solar irradiance

\[ ET_C = K_c ET_0 \]

Crop evaporation or crop water need
Reference evapotranspiration

Important in irrigation management, allowing an effective use of soil water reserves on agricultural production.
Main factors affecting evapotranspiration
Qu’est-ce qui influence l’évapotranspiration (ET)?

Les facteurs météorologiques suivants peuvent influencer l’évapotranspiration:

- Solar radiation
- Air température (Ta)
- Air humidité (Ha)
- Wind speed (Ua)
Type and characteristics of vegetation

- type and variety
  - Height, stomatal control, ground cover, roots depth
  - Stage of development

Grassland

Broadleaf forest

Crops
Management practices

Irrigation management and methods

Diseases control and prevention
Environmental conditions

- Soil type and texture, water content, water-holding capacity

Soil depth, fertility, exposure
Estimating ET at different scales

- ~1 m
  - Lysimeter
  - Profile method
  - Soil
- ~10^2 m
  - Eddy covariance
- ~10^2 m
  - Scintillometry
- ~1 km
  - Eddy covariance from aircraft
- ~10 km
  - Geodetical spaceborne measurements
- ~10^3 km
  - Altitude

- ~10^-1 m
  - Atmospheric surface layer
- ~1-10 m
  - Airborne
- ~100 m
  - Spaceborne
LSA-SAF products

- Surface Radiation
- Surface Water Balance
- Evapotranspiration
- Vegetation
- Wild fires

- Increased level of maturity
The LSA-SAF ET model

MSG pixel

Tiles:
% Bare soil
% Forest
% Crops
% Grassland
• …
The LSA-SAF ET model

The tile approach: The energy exchanges between the surface and the atmosphere is modelled using a resistance scheme. Each pixel in the image is divided into ‘tiles’ of homogeneous vegetation types.
The LSA-SAF ET model

MSG SEVIRI pixel Tiles:
- Bare soil
- Forest
- Crops
- Grassland
- ...

Link between LE and ET:

\[ LE = L_v \ ET \]

**LE**: latent heat flux \([W \ m^{-2}]\)

**ET**: evapotranspiration \([kg \ m^{-2} \ s^{-1}]\)

**L_v**: latent heat of vaporisation

- At tile level

\[
(1-\alpha)S_\downarrow + \varepsilon(L_\downarrow - \sigma T_{sk,i}^4) + H_i + LE_i - G_i = 0
\]

\[
LE_i = \frac{L_v P_a}{r_a + r_c} [q_{sat}(T_{sk,i}) - q_a(T_a)]
\]

\[
H_i = \frac{P_a}{r_a} \left[ c_p (T_{sk,i} - T_a) - g z_a \right]
\]

\[
G_i = \beta_i Rn_i \quad \text{with} \quad \beta_i = f(LAI_i)
\]

- Pixel value

Evapotranspiration \([mm \ h^{-1}]\)

\[ ET = 3600 \]

\[ LE/L_v \]

For each pixel of day \(d\)

Evapotranspiration \([mm \ d^{-1}]\)

\[ ET_d = \Sigma ET_k \]
The LSA-SAF ET model (input data)

**From satellite MSG-II**
- AL - Surface ALbedo -
- DSSF - Shortwave flux at surface
- DSLF - Longwave flux at surface
- LAI - Leaf Area Index -
- FVC - Fractional Vegetation Cover -
- LST - Land Surface Temperature -

**From database (ECOCLIMAP)**
- Ti - Tiles in pixel -
- FV_i - Fraction of tiles -
- Rs_i - Tile minimum stomatal resistance
- LAI_i - Tile Leaf Area Index -
- FVC_i - Tile fractional vegetation cover
- AL_M - Monthly pixel Albedo

**From NWP (ECMWF)**
- Ta - Air temperature -
- U - Wind speed -
- Pa - Air pressure -
- Td - Dew-point temperature -
- ST - Soil Temperature -
- SM - Soil Moisture -

MODEL FORMULATION

**MET**

**QF**

1 included in last version (2012)
2 future versions (2013)
The LSA-SAF ET Algorithm output

Two images are generated: the first one contains instantaneous ET estimates in mm/h while the second one is the quality flag image, provides information on the quality of estimates pixel by pixel.

ET (mm/h) for 2010/10/29 at 12:00 UTC

Associated quality flag (-)
The LSA-SAF ET Algorithm output

Instantaneous ET (mm/h) over the MSG disk For 2010/10/29
Daily evapotranspiration product (DMET)

\[ DMET = \sum_{t1=1}^{t2=48} MET_i \]

- Daily evapotranspiration product (DMET): temporal integration of instantaneous (MET\textsubscript{i}) product.
- MET\textsubscript{i}: instantaneous evapotranspiration for i time-step between 00:30 UTC and 24:00 UTC.
- In optimal conditions (no missing slots) 48 images are integrated for a given day.
Daily evapotranspiration product output

a) DMET (mm/day) every pixel

b) Percent of missing values for
Daily evapotranspiration product output

Daily cumulated ET for the 15th of Each month, over MSG FOV for the year 2016
Products validation

Validation Approaches

a) Comparison to in-situ measured/computed fluxes (LE, ET)

b) Comparison to models generating fluxes at large scale (region, continent)
Products validation (instantaneous ET)

Cabauw (NL) - grassland

Wetzstein (GE) - coniferous forest

March – Nov 2007

Tojal (PT) - grassland

Vielsalm (BE) - mixed forest
Products validation (daily ET)

Cabauw (NL) - grassland

Tojal (PT) - grassland

Wetzstein (GE) - coniferous forest

Vielsalm (BE) - mixed forest

March – Nov 2007
Products validation

Compare the output of the operational model to in-situ observations at predefined locations.
Products validation (Models intercomparison)

Cumulated (12:00 to 18:00 UTC) Evapotranspiration from LSA-SAFT ET, ECMWF and GLDAS for the day 15.08.2007
Comparison at 3 hours at 1°x1° (06/07/2007 from 9-12 UTC)
Differences between models are due mainly to used radiative forcing and soil humidity
Potential applications

- Hydrology
- Drought monitoring and desertification
- Water management
- Crop modelling
- Climate change studies
Applications in hydrology

Generate Monthly/seasonal/yearly averages and cumulated ET at regional and continental scales
Applications in hydrology

Generate Monthly/seasonal/yearly average and cumulated ET over hydrological basins

West Africa basin

South Atlantic coast basin

Nile basin

Congo basin

Cumulated ET over selected hydrological basins in Africa November 2009
Applications in hydrology

Month by month daily average ET over the Nile river basin for 2010
Applications in hydrology

- Monthly cumulated evapotranspiration over the Danube River Basin for the year 2016
Applications in drought monitoring

Evapotranspiration monitoring is essential for drought detection.
Applications in drought monitoring

From Julia Stoyanova (Bulgarian National Institute of Meteorology and Hydrology)
Applications in drought monitoring

- Rhin river basin
- Danube river basin
Summary

- ET is key component of the water cycle important to determine water requirements

- Most direct methods have limited practical application

- Many factors affect ET (Weather, Crop type, Management, environmental conditions)

- The LSA SAF ET Product suitable for applications in:
  - Hydrology
  - Drought monitoring
  - Crop modelling
  - Water management
  - Climate studies

- The LSA SAF ET Product free for registered users
LSA-SAF data & info

http://landsaf.ipma.pt

Publications
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