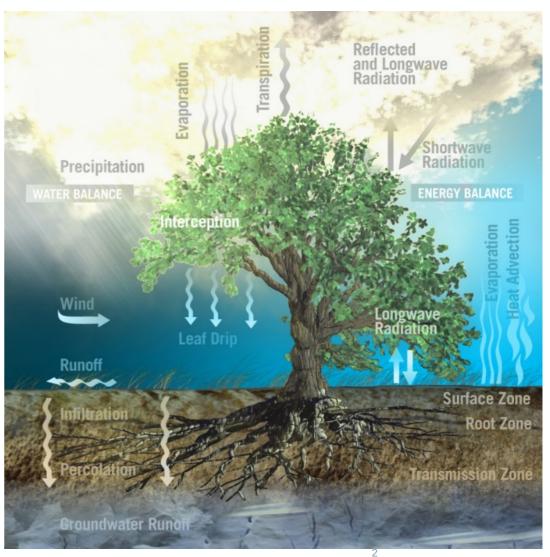


#### NOT possilbe to directly estimate ET with RS



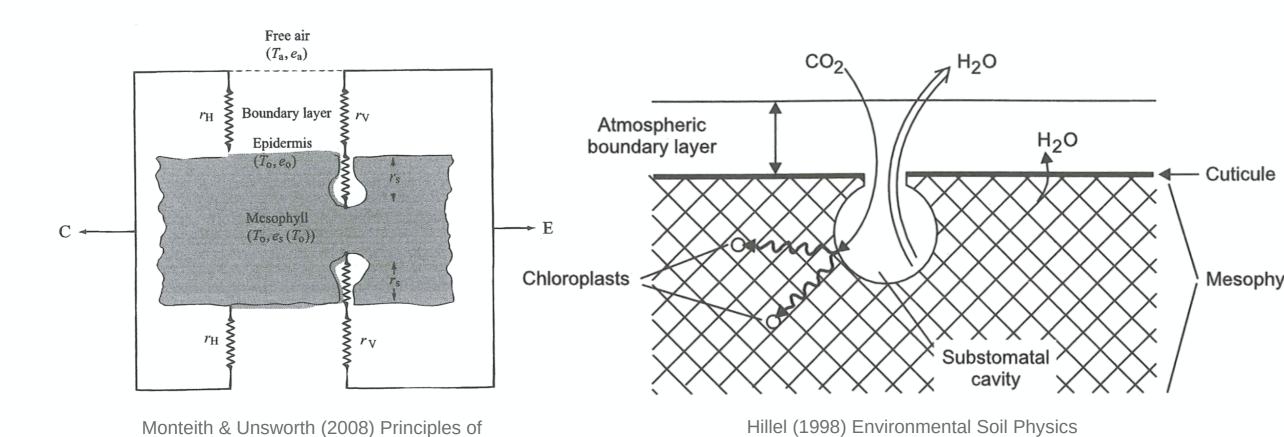
- With Remote Sensing we basically measure electromagnetic radiation
- ET therefore must be estimated indirectly
  - Water Balance
  - **Energy Balance**



# **Energy, Water and Carbon in the plant**

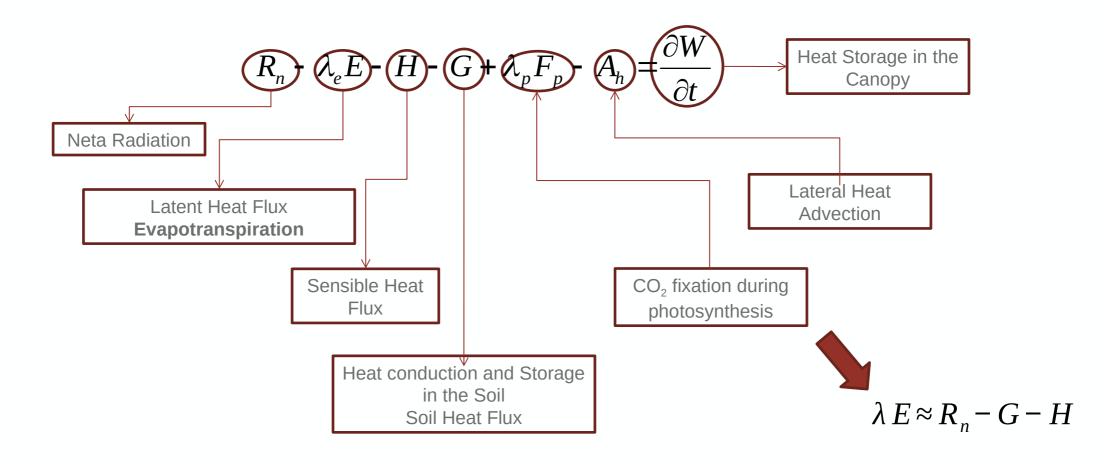
**Environmental Physics** 





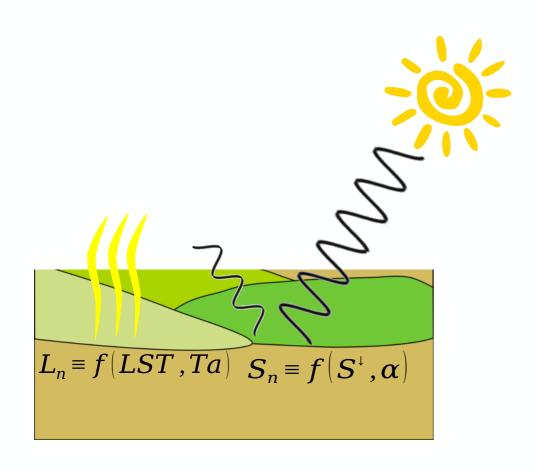
# The Surface Energy Balance





## Net Radiation and Soil Heat Flux





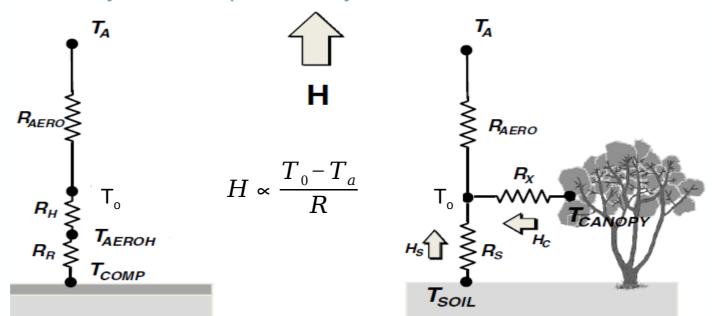
- Leaf biochemistry (pigments) and canopy density/structure characterize absorbed shortwave(solar) radiation
  - LAI/fAPAR
  - leaf/surface albedo
  - }
- Surface Temperature & Emisivity characterize absorbed/emitted longwave radiation
- Soil Heat Flux of smaller magnitude
  - Usually estimated as a fraction of Rn
  - Other methods available

Available Energy  $\approx$  (Absorbed radiation – Emitted radiation) – Soil Heat Flux

#### Sensible Heat Flux



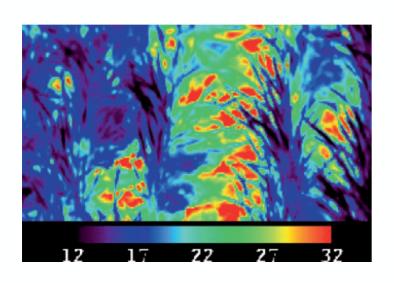
- Vertical transport/exchange of heat
  - Driven by a gradient of temperatures (aerodynamic vs. air)
  - Do not confuse aerodynamic temperature with surface temperature
- Wint-Surface interaction enhances/inhibits this transport
  - We "simplify" this interaction by the concept of aerodynamic resistances

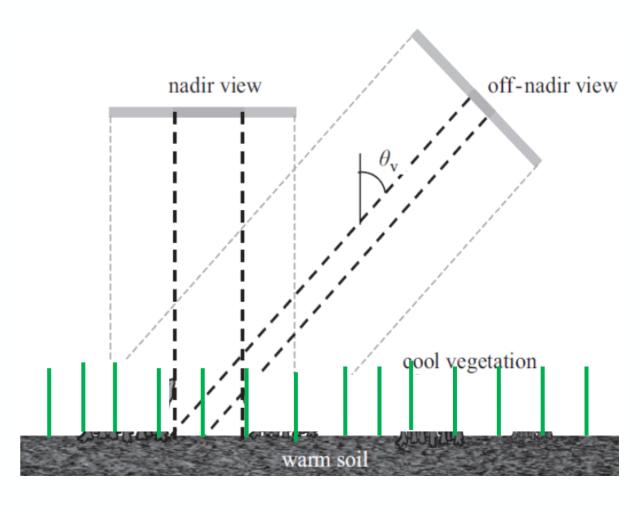


## Interpretation of Surface Temperature



- LST is a mixture of soil, leaf (...) temperatures
  - Depends on vegetation density and observation angle







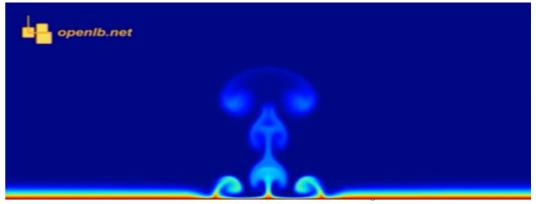
Wind is a flud

water transport

- ... usually under a turbulent regime
  - Mechanical turbulence driven by surface roughness
  - Thermal turbulence driven by convection (gradient of temperatures)
- This turublence produces eddies:
  - ↑ vertical transportl ↓ lower resistance ↑ H

$$H \propto \frac{T_0 - T_a}{R}$$





























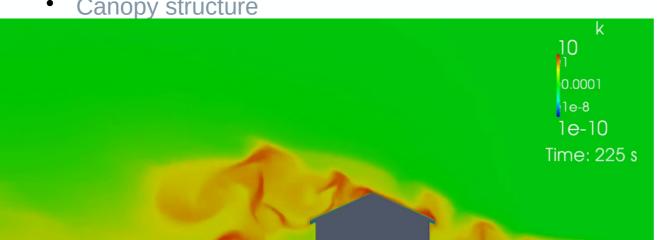


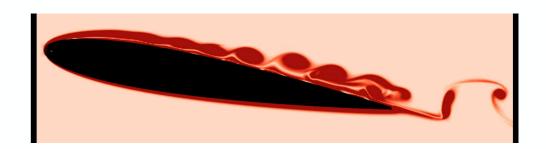
### **Aerodynamic roughness**

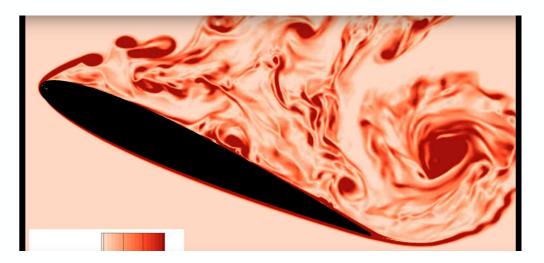


- Depends on
  - Obstacles height
    - Canopy height
  - Canopy density
    - Leaf Area Index
  - Horizontal and vertical heterogeneity

Canopy structure



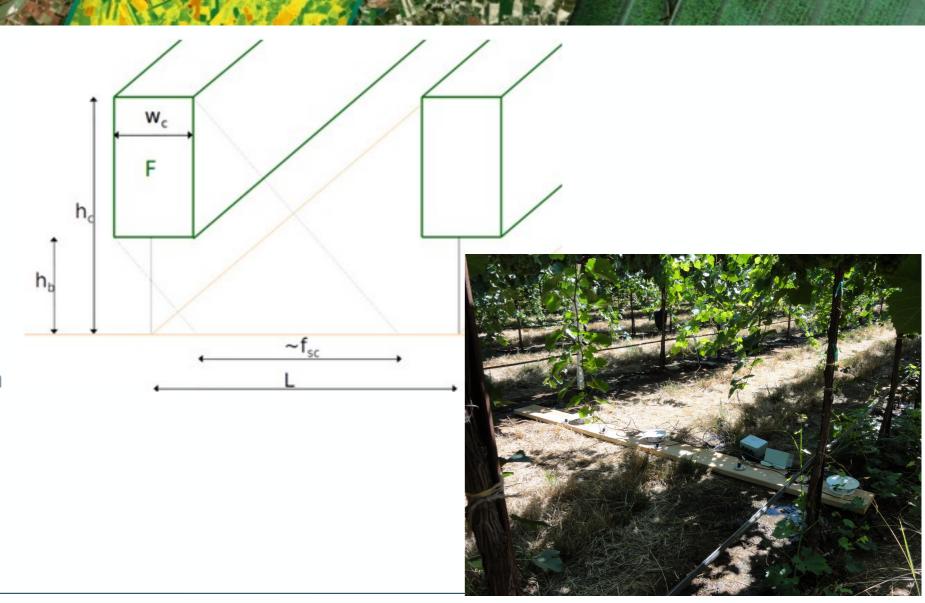




#### Radiation transmission in row crops



- LAI
- Canopy height
- Canopy shape
- Row width
- Row orientation
- Solar position
- Cloudiness/diffuse radiation
- Leaf and soil albedo































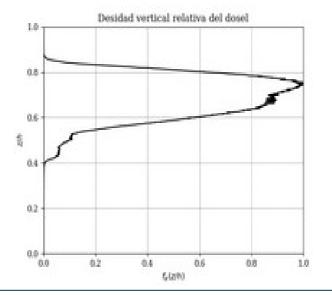
#### Turbulence in row crops

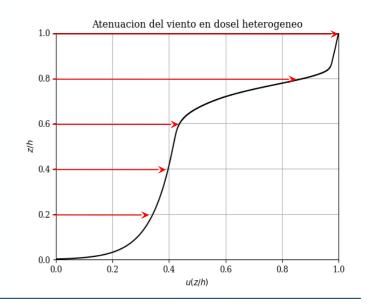


- ≠ aerydynamic roughness according to wind direction
- ≠ canopy wind attenuation depending on vertical canopy density
- Effect on heat and water exchange between canopy-soil-atmphosphere







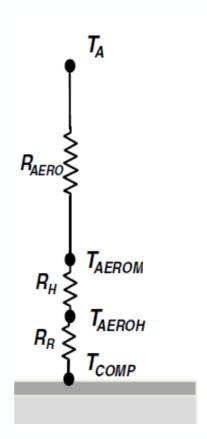


## Remote Sensing ET models

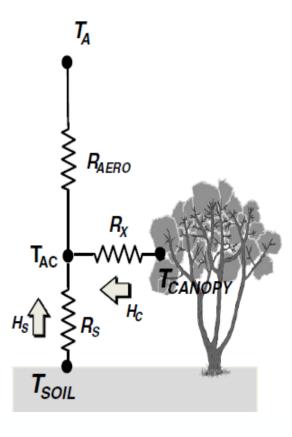


- One-Source Energy Balance
  - SEBS: <a href="https://github.com/jvdkwast/PySEBS">https://github.com/jvdkwast/PySEBS</a>
  - STIC: kaniska.mallick@list.lu / tian.hu@list.lu
  - 3 SEBAL
  - }
- Two-Source Energy Balance
  - ETLook:
    - https://bitbucket.org/cioapps/wapor-et-look/
  - TSEB: <a href="https://github.com/hectornieto/pyTSEB">https://github.com/hectornieto/pyTSEB</a>
  - ALEXI/Dis-ALEXI
  - 3SEB: <a href="https://github.com/VicenteBurchard/3SEB">https://github.com/VicenteBurchard/3SEB</a>

}







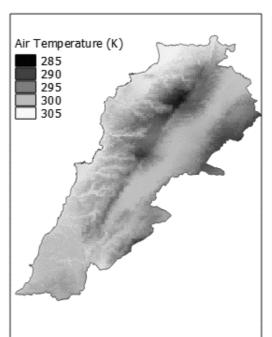
## ET models with Copernicus

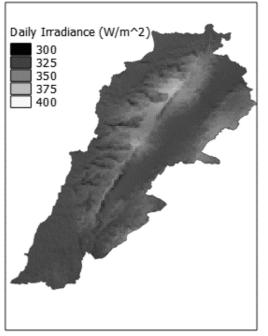


#### Sentinels

Satellite	Sentinel-2	Sentinel-3
Spatial Resolution	10 m - 60 m	300 m – 1000 m
Revisit time	5 (10) days	Daily
Spectral coverage	VIS-SWIR	VIS-SWIR & TIR

- Copernicus Climate Data Store
  - Air temperature & humidity
  - Solar and thermal irradiance
  - Wind speed
  - 3 Atmospheric pressure

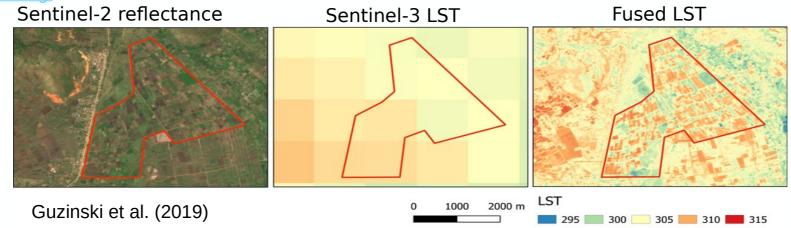




#### **Challenge with Copernicus**



- Lack of high/moderate spatial resolution TIR mission
- Sharpening methods
  - https://github.com/radosuav/pyDMS
  - SEN-ET SNAP plugin
  - https://www.esa-sen4et.org/



- Use other missions
  - **Landsat**
  - **ECOSTRESS** 
    - European Ecostress Hub <a href="https://foodsecurity-tep.net/ecostress-hub">https://foodsecurity-tep.net/ecostress-hub</a>