Representing irrigation in the ISBA model

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CNRM – Meteo-France

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Context

- **« WHAT IF » questions related to the adaptation to climate warming**
  - Impact of changes in land cover / agricultural practices on
    - local climate and meteorological conditions
      - air temperature
      - cloudiness, precipitation
      - ...
    - carbon storage
    - water scarcity, water resources
    - disasters
    - …

- **Model improvement needs**
  - Reduce uncertainties on simulated fluxes over land
    - Link terrestrial energy, water and carbon cycles
    - Spatial resolution
    - Anthropogenic effects (e.g. agricultural practices)
    - **Integration of remote sensing observations**

Modelling irrigation: heritage

➔ IRRITEL: « bulletin de l'irrigant » on Minitel

- Irrigation triggered by a soil water deficit
- Decreasing thresholds of soil water deficit
- Bonnemort et al. 1996, https://doi.org/10.4267/2042/51182

➔ PhD thesis of Sophie Voirin-Morel (2003) on Adour-Garonne basin hydrology

- IRRITEL (Météo-France) + MODERATO (INRAE)
- MODERATO uses phenological stages (degree days)
- Decreasing thresholds of SWI (0.70, 0.55, 0.40, 0.25, 0.25, …) with constant rooting depth
- Irrigation stopped after intense precipitation

➔ Simplified version in ISBA-A-gs

- Only C4 crops
- ISBA-2L, NIT (interactive vegetation)
- Decreasing thresholds of SWI (0.70, 0.55, 0.40, 0.25, 0.25, …) with constant rooting depth
- Prescribed emergence dates (LAI = LAImin before emergence)
- No harvest date
- Available in SURFEX v8
- Calvet et al. 2008, https://doi.org/10.5194/acp-8-397-2008

Modelling irrigation: heritage

CoCO2 Prototype system for a Copernicus CO_2 service

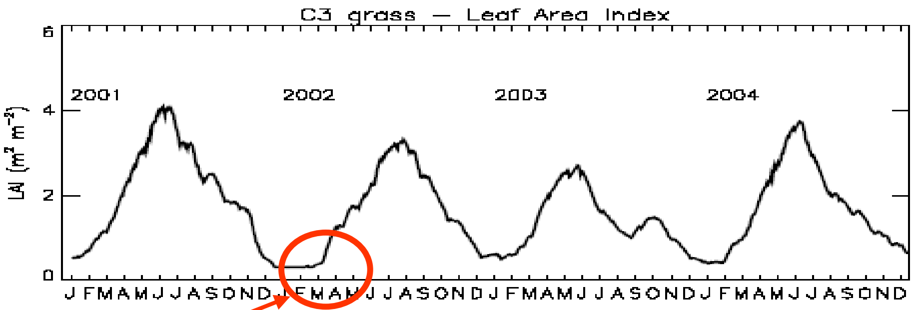
➔ Plant growth simulation in ISBA (NIT and NCB options)

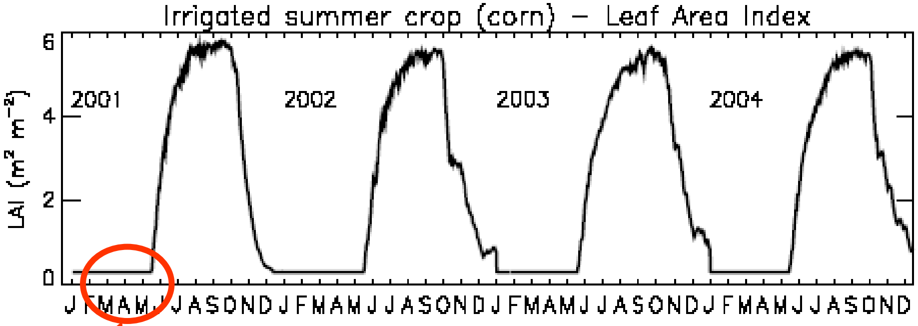
$$dB = \frac{M_c}{P_c M_{CO_2}} \times A_{nI} dt - B d(t/\tau)$$

(https://doi.org/10.1016/S0168-1923(98)00091-4)

Photosynthesis-driven phenology

- LAI is linearly related to the **active biomass** (parameters = **SLA**, derived from leaf nitrogen concentration and 2 plasticity parameters)
- A minimum value of LAI, **LAI_{min}**, is prescribed (e.g. 0.3 for annual vegetation), permitting a self restart of the vegetation when photosynthesis becomes active
- Possibility to cut the vegetation or to maintain LAI at its minimum value, for agricultural applications





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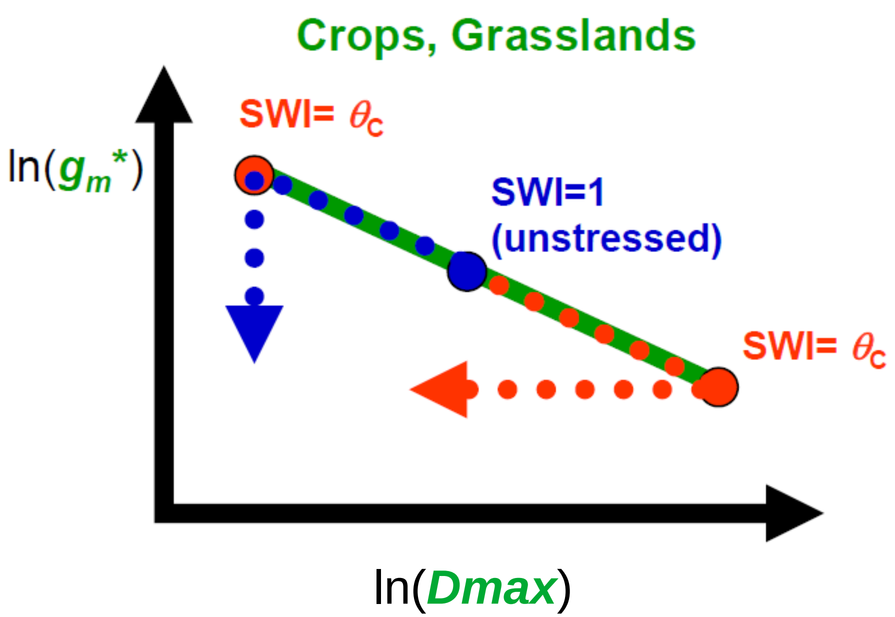
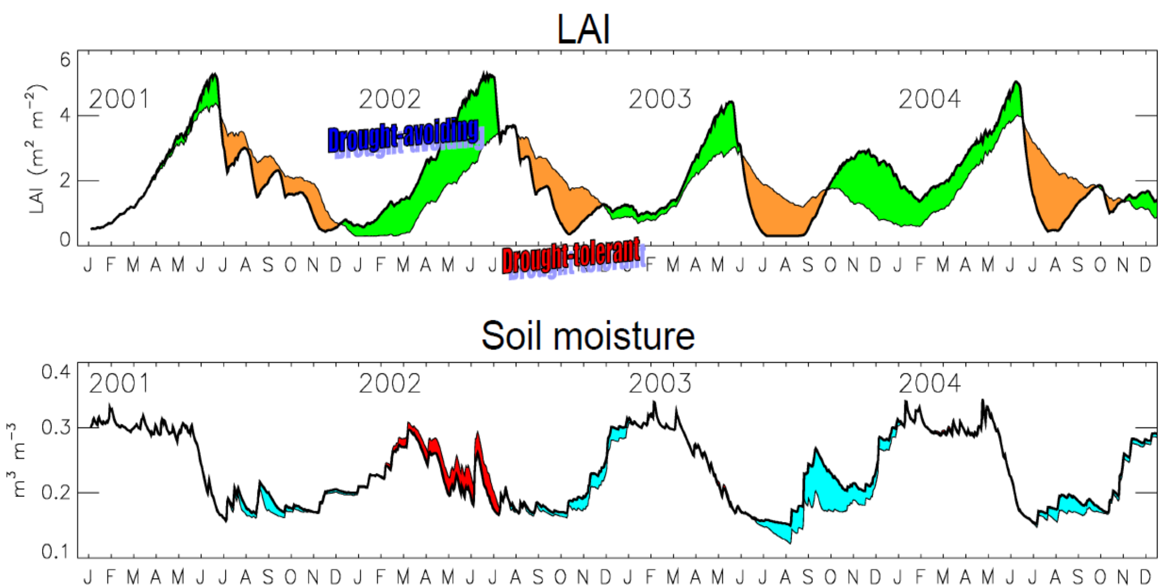
CoCO2 Prototype system for a Copernicus CO_2 service

➔ Enhanced representation of drought effects (AST, NIT and NCB options)

- **Key parameters of the photosynthesis model are affected by drought: the well-watered value are adjusted by using the Soil Wetness Index (SWI)**
- **Two possible strategies: drought-avoiding / drought-tolerant**
  (https://doi.org/10.1016/S0168-1923(98)00091-4)
- **Important parameter: θ_c critical extractable soil moisture content, below which severe soil moisture stress is observed**





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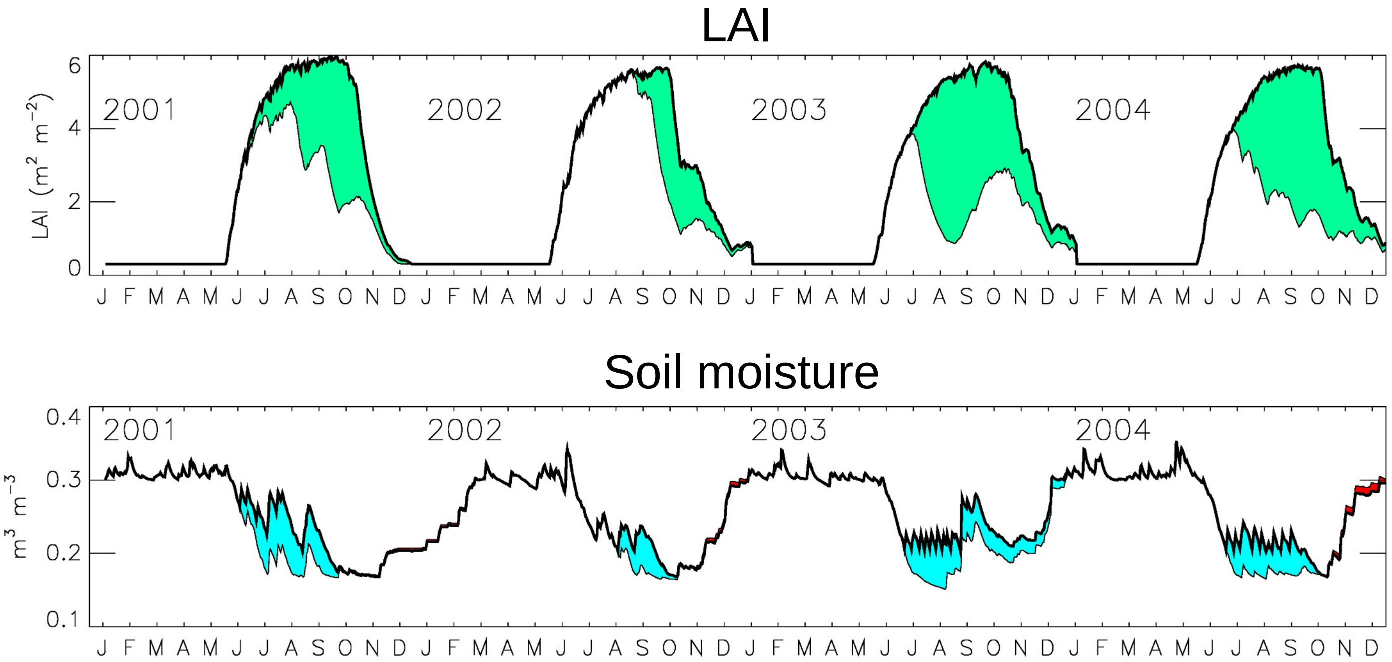
➔ Representation of irrigation in southwestern France (corn, Haute-Garonne)

- Calvet et al. 2008 (https://doi.org/10.5194/acp-8-397-2008) … in SURFEX v8



Optimal Irrigation : 120mm 60mm 270mm 240mm

Modelling irrigation: SURFEX v9

Druel et al. 2022 (GMD, https://doi.org/10.5194/gmd-15-8453-2022): case study over Nebraska

→ Improved irrigation mapping

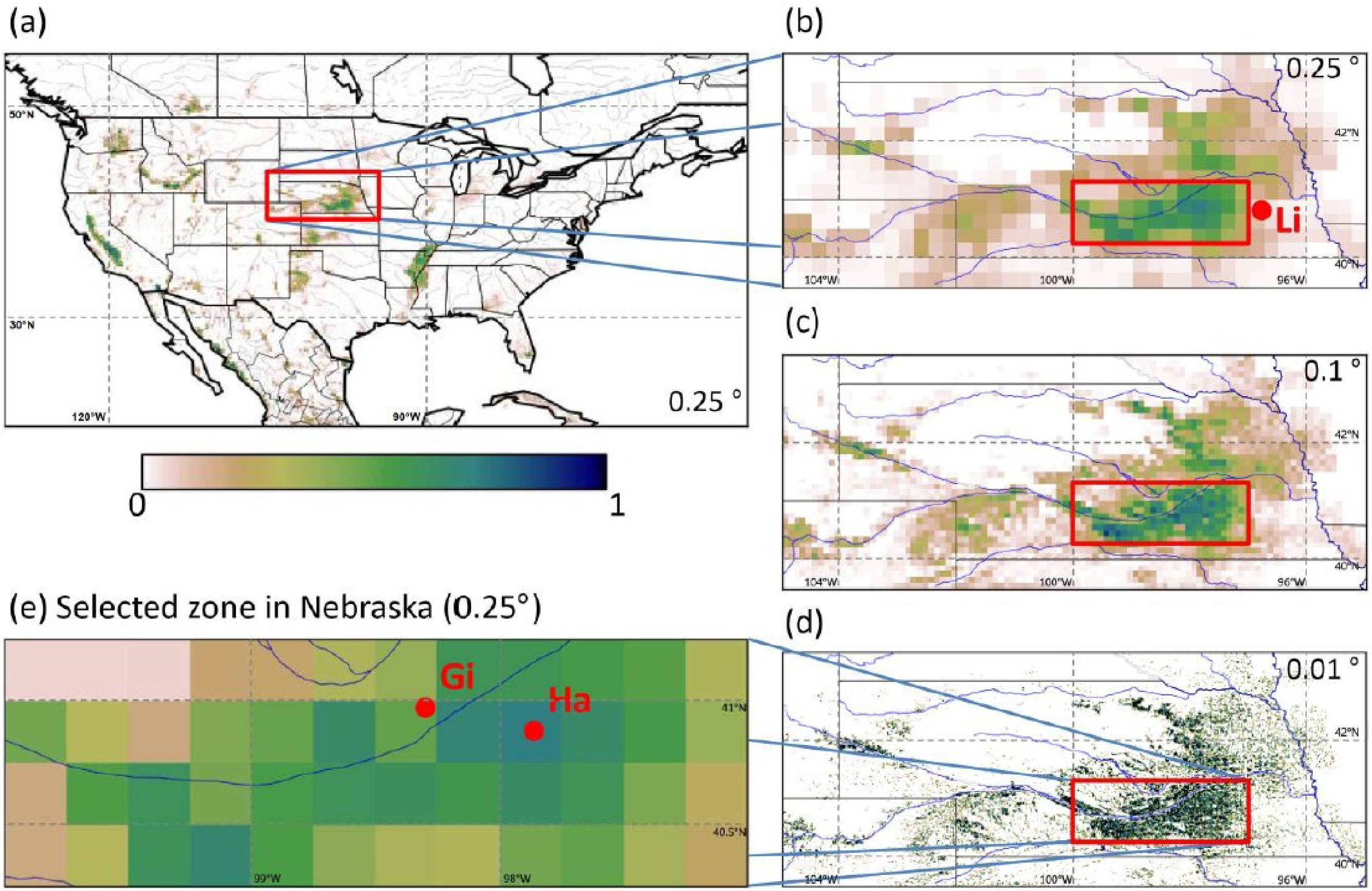
- Global map of irrigated areas 1 km x 1 km (Meier et al. 2018)
- ECOCLIMAP-SG
- Aggregation of rainfed and irrigated crops (patches)

→ Improved irrigation model

- All vegetation types can be irrigated
- ISBA-DIF can be used
- Harvest date can be prescribed (LAI = LAImin after harvest)
- Minimum time interval between
  - two irrigation events
  - the last irrigation event and the harvest
- Several irrigation types (sprinkler, flood, and drip irrigation)

Example of Nebraska

CoCO2
Prototype system for a Copernicus CO_2 service



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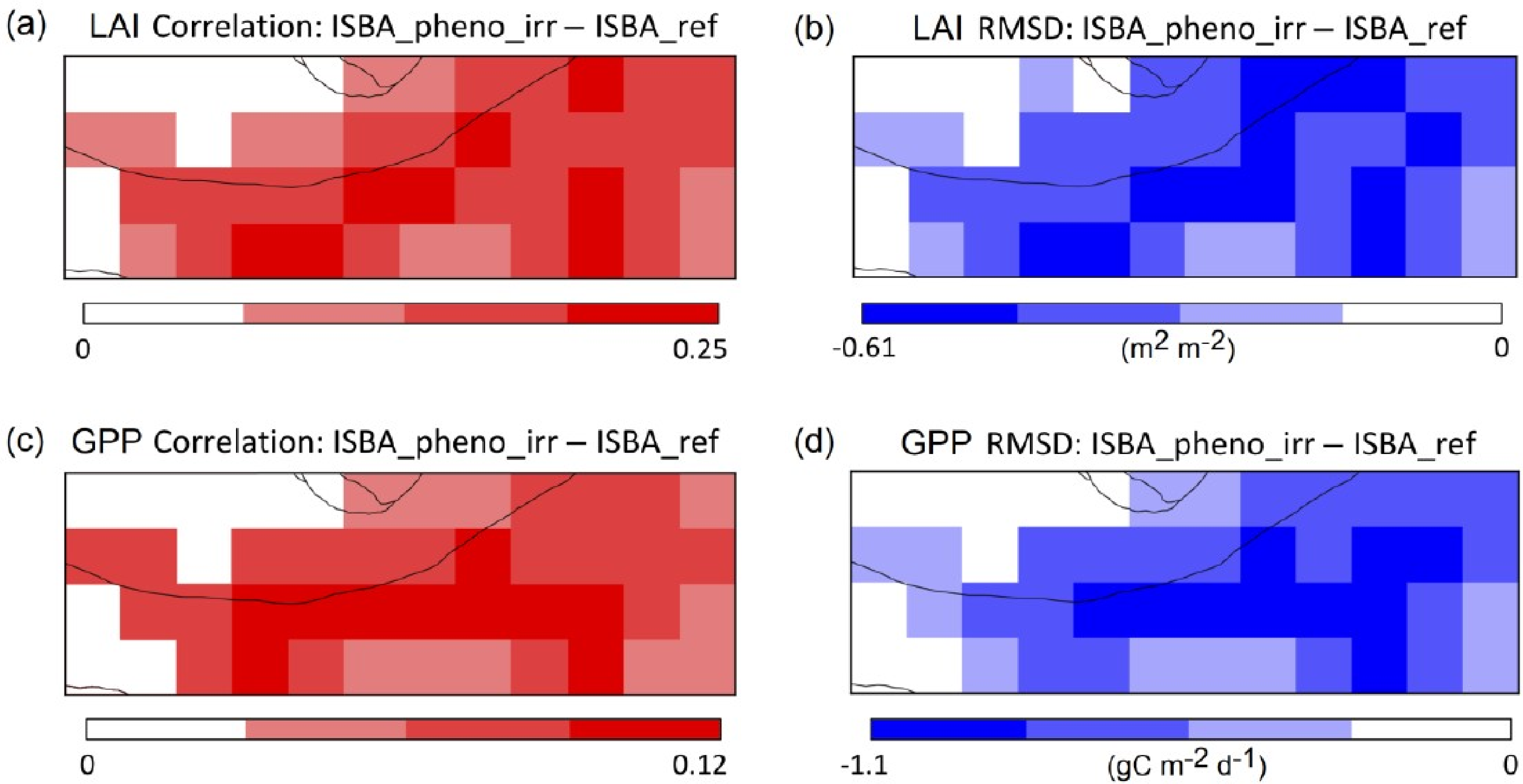
Example of Nebraska

CoCO2 Prototype system for a Copernicus CO_2 service



Improved representation of LAI and GPP

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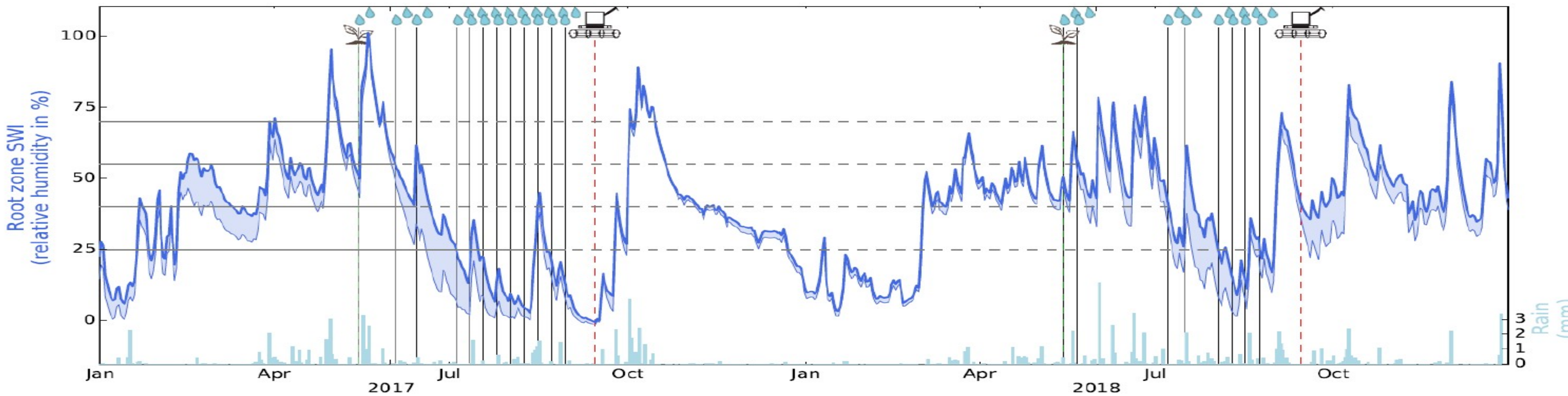
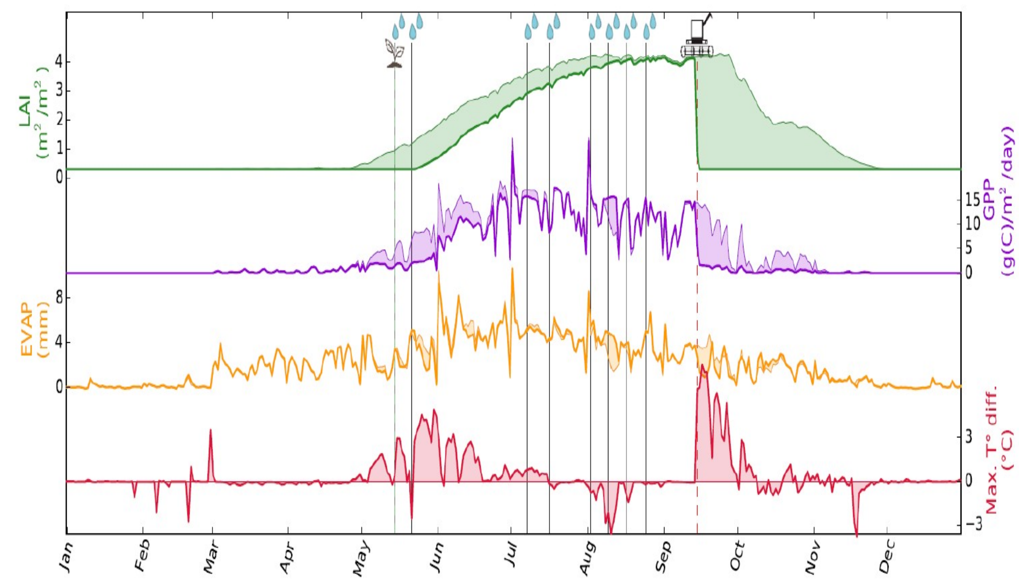
Example of Nebraska

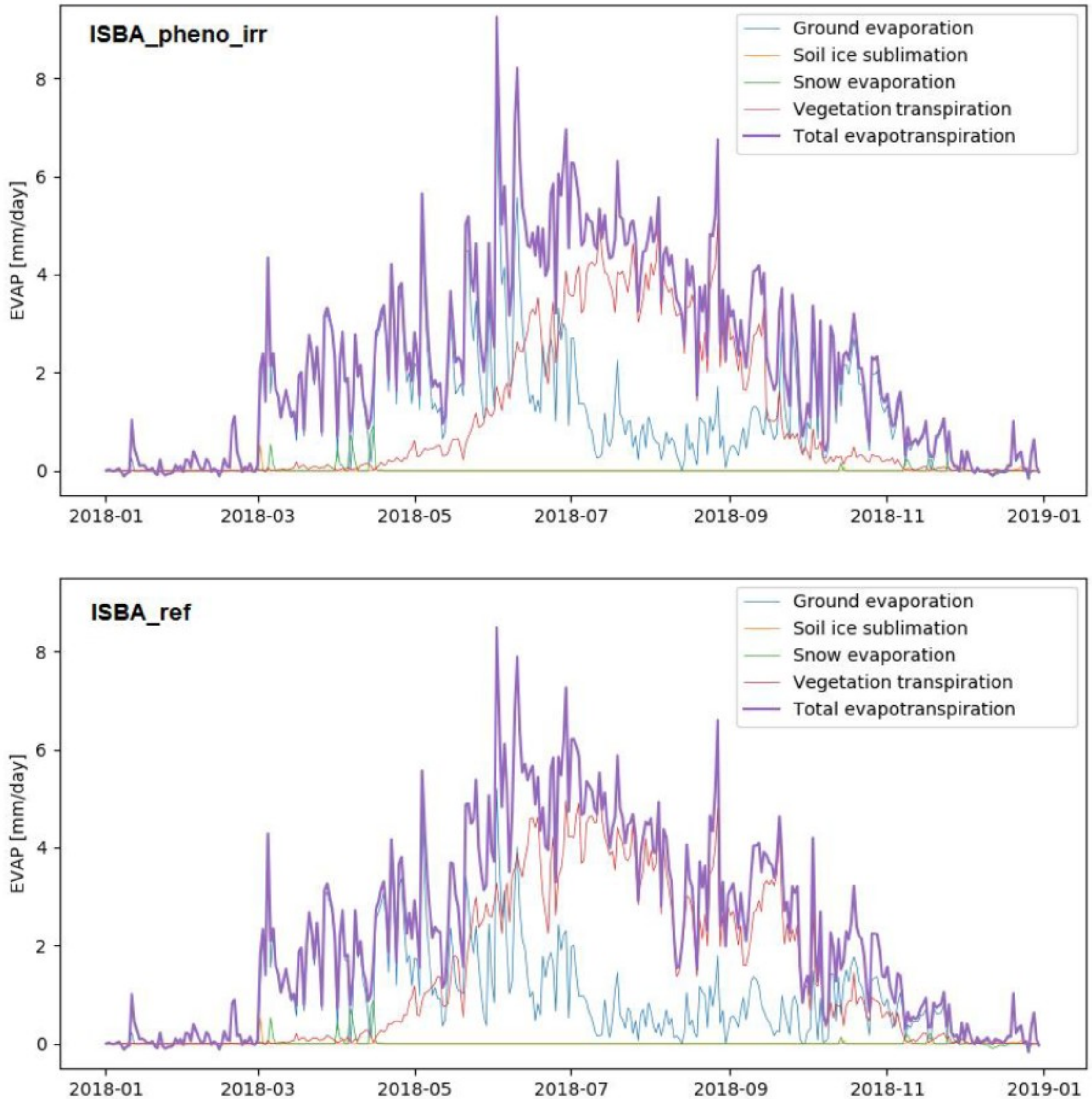


Hampton, NE:

Marked impact
of irrigation and crop phenology
on LAI an GPP
…
much less on evapotranspiration



Example of Nebraska



Hampton, NE:

Why is the impact of irrigation and crop phenology on evapotranspiration small?

Compensation between soil evaporation and leaf transpiration.

Modelled soil evaporation is too large.

In the real world, crop residues tend to limit evaporation.

Example of Nebraska

Suyker, A. E. and Verma, S. B.: Evapotranspiration of irrigated and rainfed maize–soybean cropping systems, Agric. For. Meteorol., 149, 443–452, https://doi.org/10.1016/j.agrformet.2008.09.010, 2009.

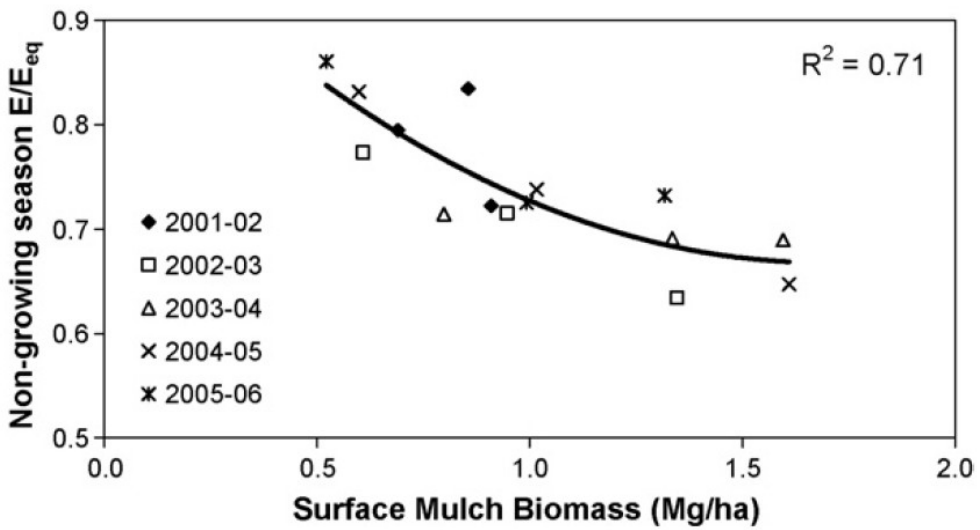


Fig. 8 – Non-growing season evaporation (E: integrated from 1 November to 1 May) normalized by equilibrium evaporation (E_{eq}) as a function of seasonal average surface mulch biomass.

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Example of Nebraska

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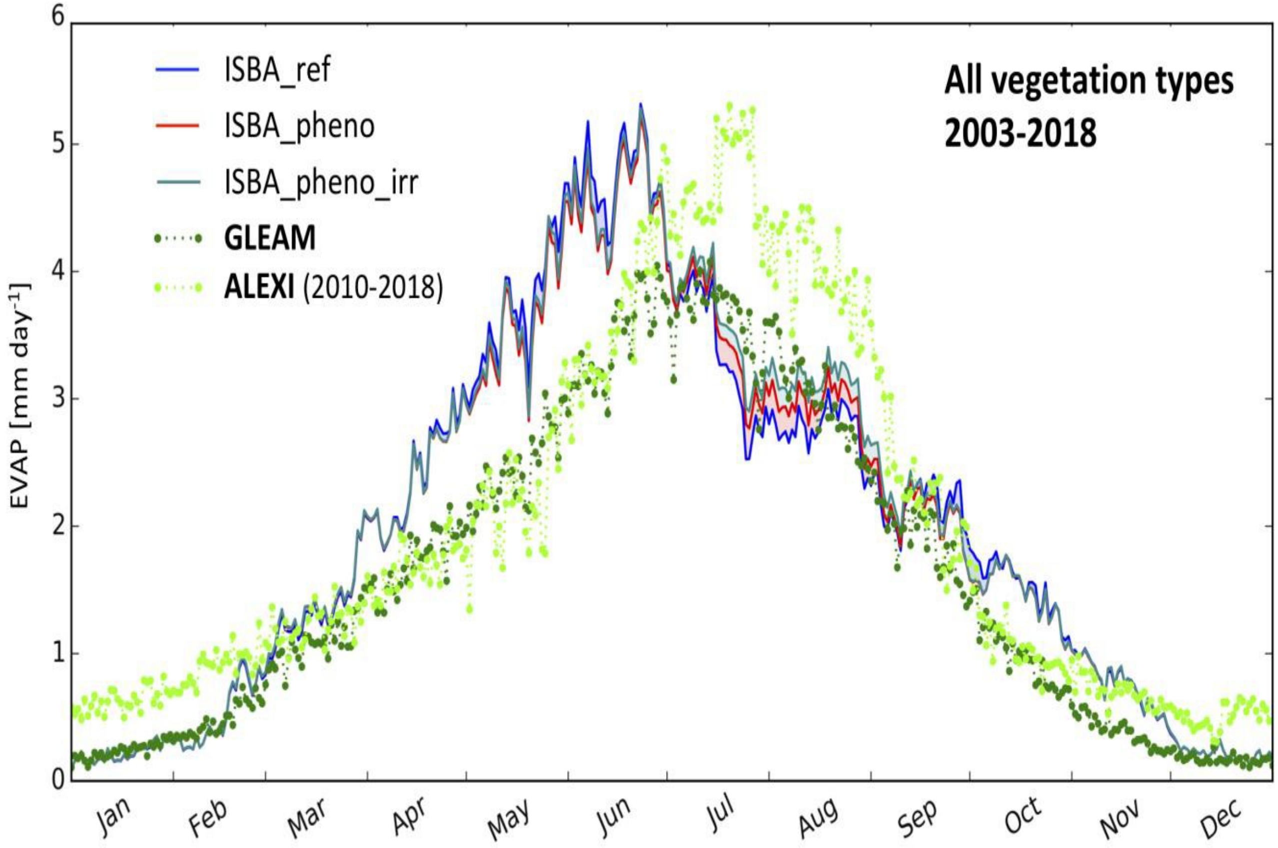
COMPARISON TO GLEAM AND ALEXI



April to June:

Overestimation of evapotranspiration?

- too large soil evaporation
- ERA5 precipitation bias in April

July - August:

ALEXI > GLEAM

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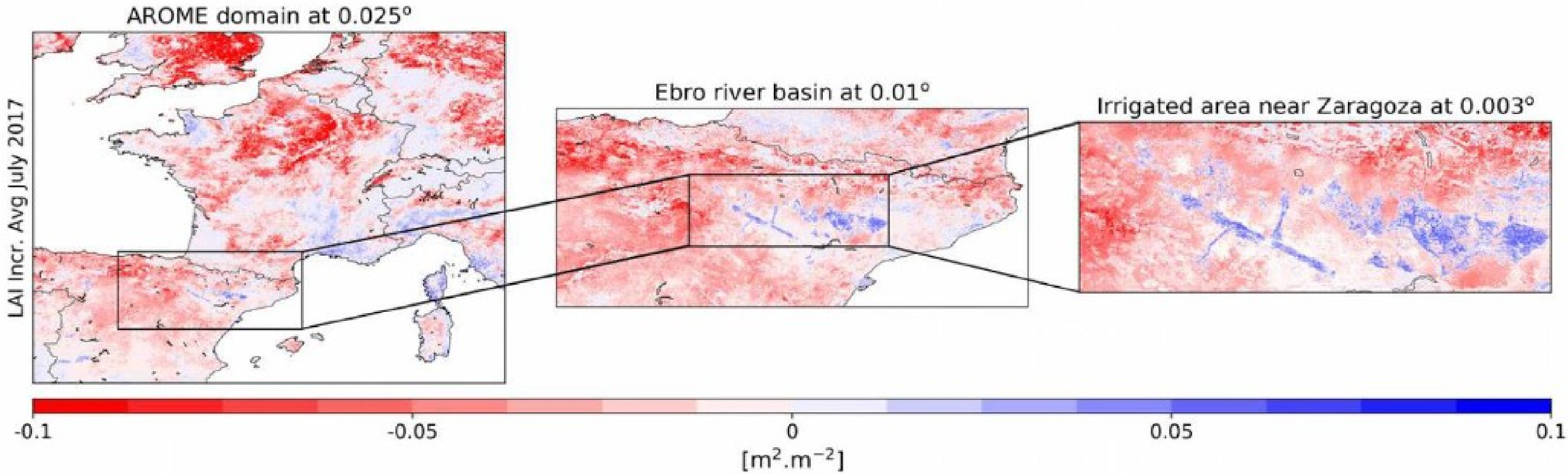
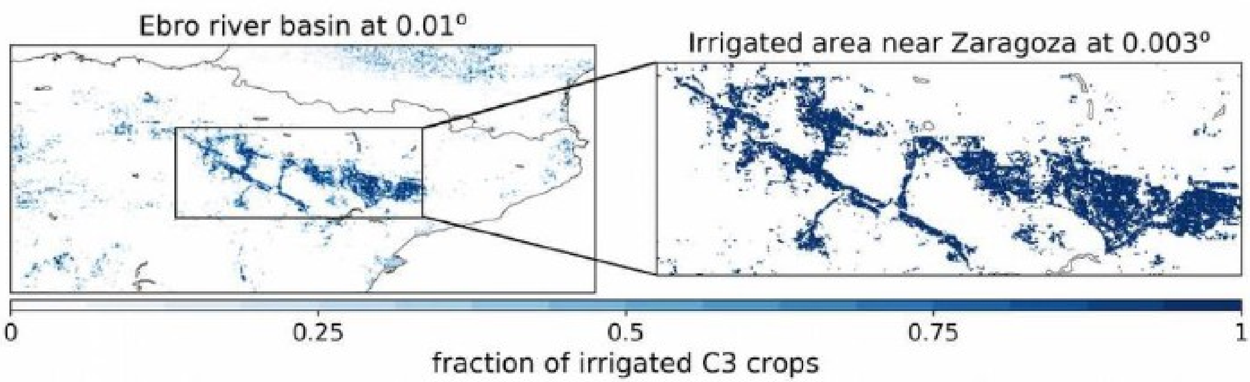
Integration of satellite data

- Using the LDAS-Monde tool (Albergel et al. 2017) : LAI analyses increments

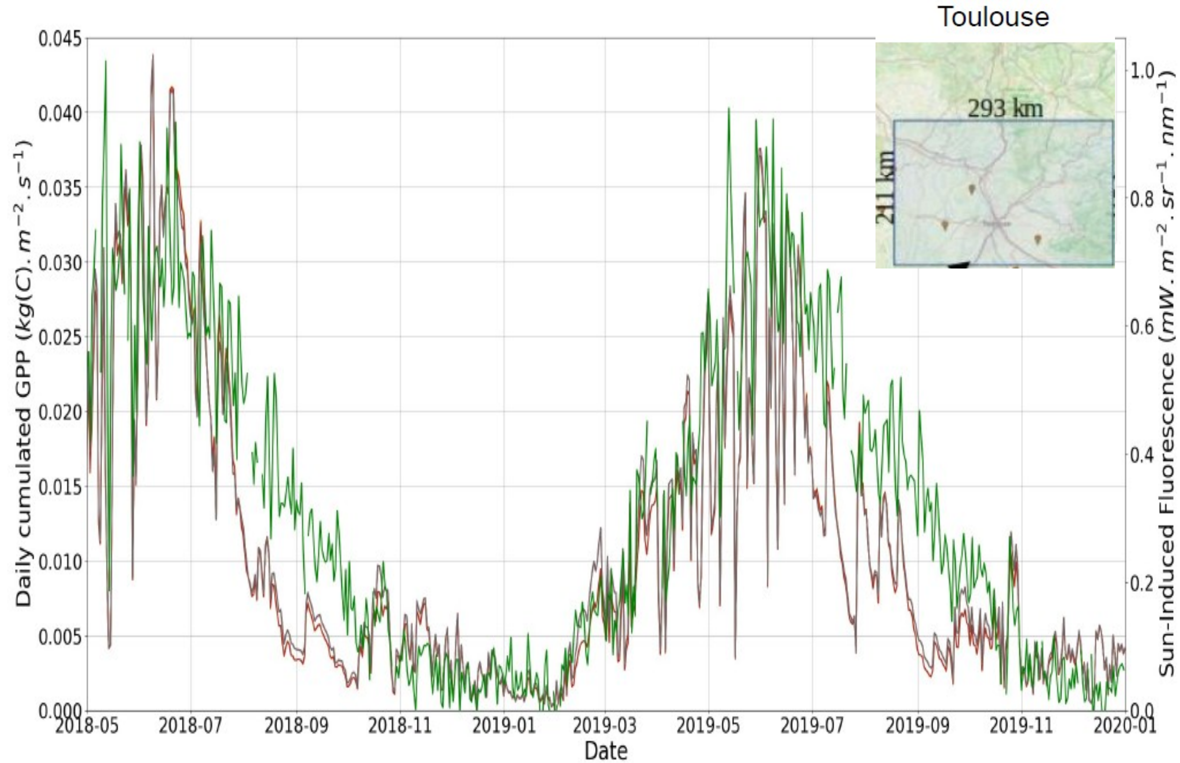


Positive increments match map of irrigated C_3 crop (wheat, …) as shown by figures



Integration of satellite data

- Solar-induced fluorescence (SIF)
  - **SIF is not GPP**
    - Linear relationship may disappear in very dry conditions
    - Disentangle instrumental noise from geophysical signal
  - **Assimilating SIF in ISBA?**
    - Comparison between daily TROPOSIF and daily GPP from ISBA
    - Use machine learning to build an observation operator in the Horizon Europe CORSO project (2023-2026)



SIF (in the 743-758 nm window) daily data available from 01/05/2018 to 31/12/2019, with 91% daily data for this period

Conclusions

➔ Photosynthesis-driven phenology in ISBA

- FLEXIBLE LAI
  - Emergence and harvest dates can easily be prescribed
  - LAI observations can be assimilated to analyse above-ground biomass and root-zone soil moisture
  - LAI analysis increments respond to irrigation

➔ Irrigation: full version (Druel et al.2022) in SURFEX v9

- Perturbing factors
  - Biases in the precipitation forcing
  - Uncertainties in soil evaporation modelling

➔ Next steps

- 1 km x 1 km simulations over LIAISE area for 2021
- Assimilation of SIF data (LIAISE airborne data, TROPOMI data)
- Assimilation of S1 sigma0 data (and comparison with LIAISE soil moisture observations)

Representing irrigation in the ISBA model

Thank you for your attention :)

Funding sources:

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