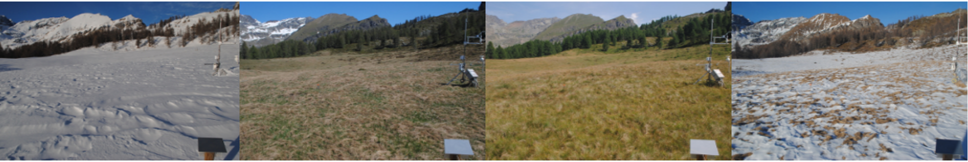
Programme Interreg V-A France Italie ALCOTRA 2014-2020
Projet n°427 TourScience

Heat wave beats green wave: the effect of a climate extreme on alpine grassland phenology as seen by phenocams

E. Cremonese[1], G. Filippa[1], M. Migliavacca[2], C. Siniscalco[3], L. Oddi[3], M. Galvagno[1]

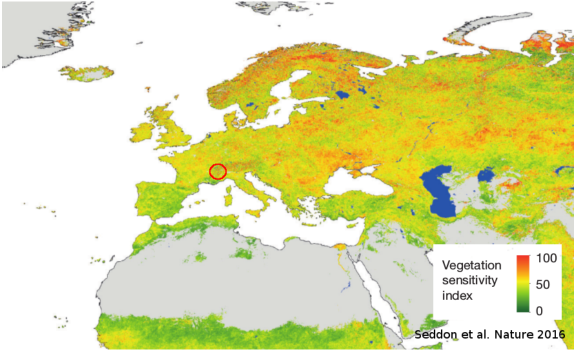
[1]Environmental Protection Agency of Aosta Valley, Italy
[2]Max Planck Institute for Biogeochemistry, Jena, Germany
[3]Dept. of Life Sciences and Systems Biology University of Torino, Italy



EGU-18 Apr 2016

Climate extremes in the Alps

- ✓ Impact of 2015 heatwave on the phenology of an alpine grassland in the Northwestern Alps (Torgnon, 2100 m asl)
- ✓ "Alpine regions are ecologically sensitive regions with amplified responses to climate variability" (Seddon *et al*, 2016 Nature)

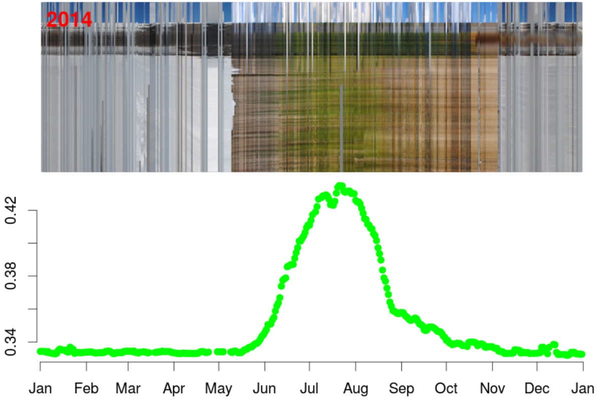


Climate extremes impact on phenology

- ✓ **green wave** or green-up is the spring onset of photosynthesis (Schwartz 1998 Nature)
- ✓ **green wave** as the greenness seasonal course seen by **phenocam**

Climate extremes impact on phenology

- ✓ **green wave** or green-up is the spring onset of photosynthesis (Schwartz 1998 Nature)
- ✓ **green wave** as the greenness seasonal course seen by **phenocam**

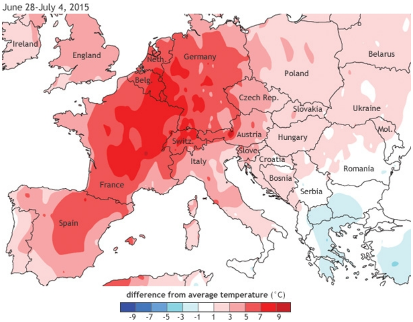


2015 heat wave

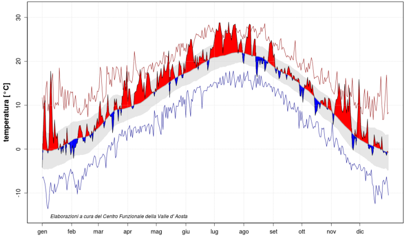
✓ 2015 breaks heat records (Nature 2016)

✓ July 2015 warmer and drier than July 2003

June July heat wave in Europe



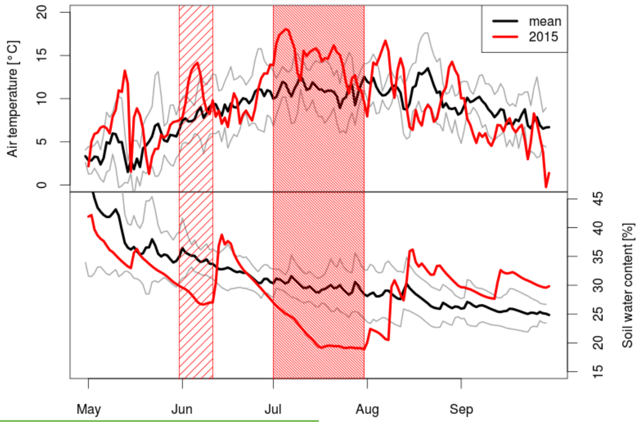
temperature anomaly in the Alps



2015 heat wave

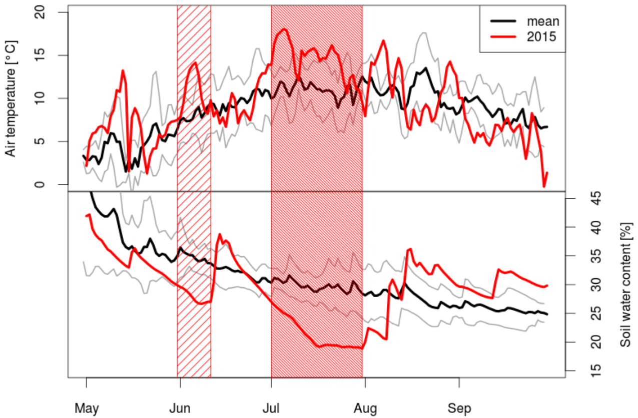
✓ June July heat wave at Torgnon grassland: co-occurrence of **high temperature** and **drought**

✓ "... when heatwaves coincided with drought, the plants showed clear signs of stress, resulting in vegetation browning and reduced phytomass production" (De Boeck *et al.* 2015)

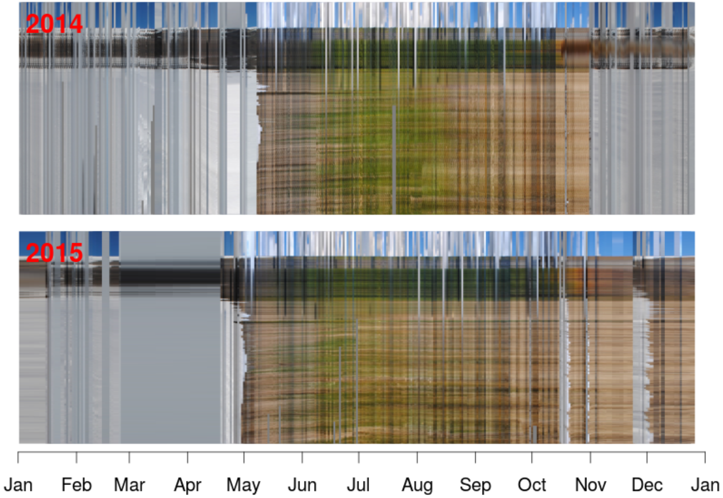


2015 heat wave

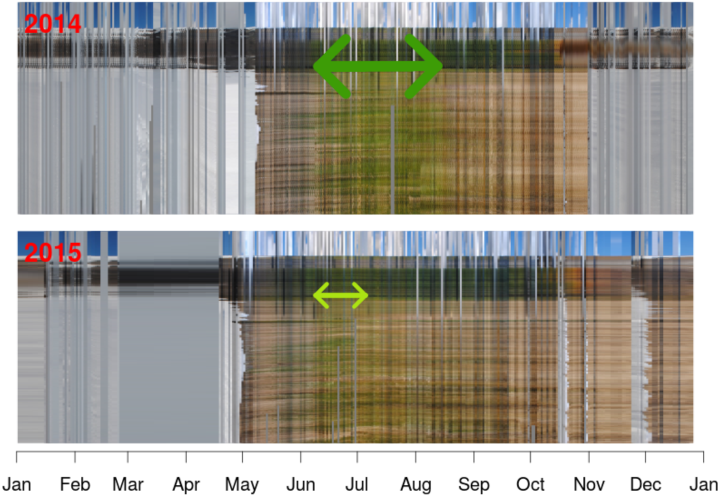
- ✓ June July heat wave at Torgnon grassland: co-occurrence of **high temperature** and **drought**
- ✓ "... when heatwaves coincided with drought, the plants showed clear signs of stress, resulting in vegetation browning and reduced phytomass production" (De Boeck *et al.* 2015)



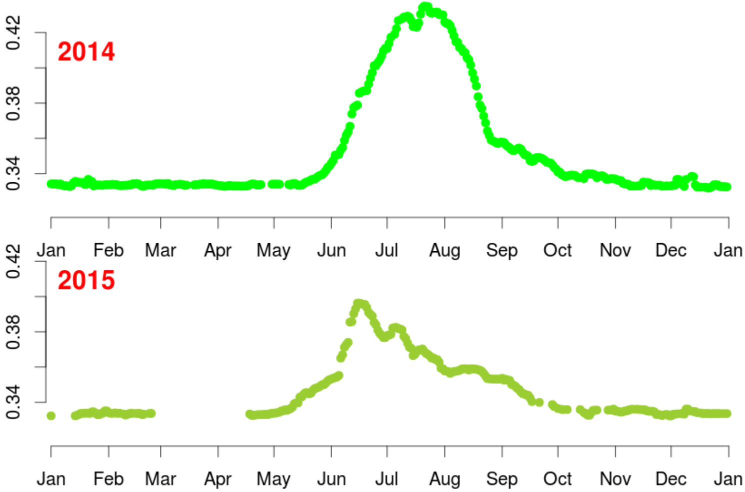
heat wave impact on green wave



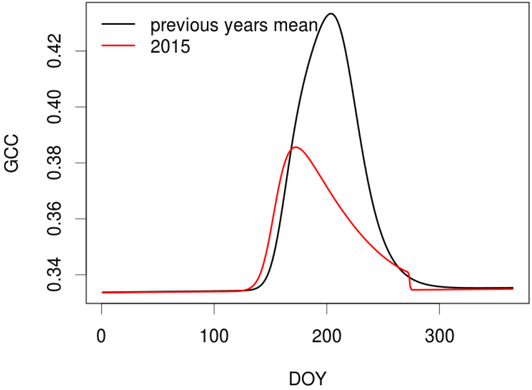
heat wave impact on green wave



heat wave impact on green wave



heat wave impact on green wave

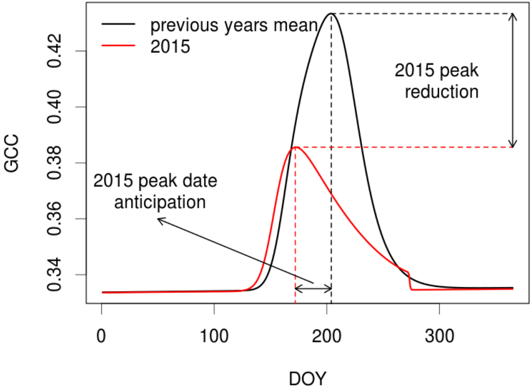


✓ earlier start of senescence (i.e. peak anticipation)

✓ lower greenness (i.e. peak reduction)

✓ lower senescence rate

heat wave impact on green wave



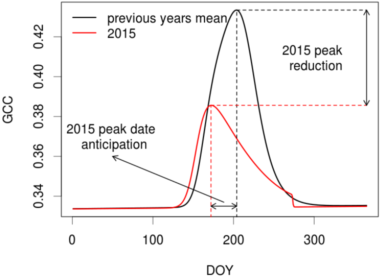
- ✓ earlier start of senescence (i.e. peak anticipation)
- ✓ lower greenness (i.e. peak reduction)
- ✓ lower senescence rate

Objectives

- ✓ **Obj1**: GCC is able to detect the heatwave impact on functional or structural canopy properties
- ✓ **Obj2**: GCC decrease is driven by a combined effect of high temperature and drought

Objectives

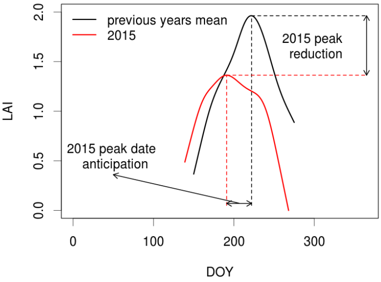
obj1: GCC is able to detect the heatwave impact on functional or structural canopy properties



- ✓ canopy photosynthesis (GPP, LUE, Amax), radiometric indexes (NDVI, PRI, Fapar), structural canopy properties (LAI, Biomass)
- ✓ heatwave impact metrics (e.g. peak reduction, anticipation) computed on all the variables

Objectives

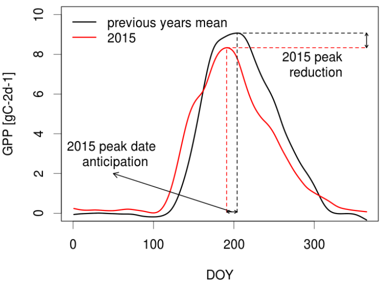
obj1: GCC is able to detect the heatwave impact on functional or structural canopy properties



- ✓ canopy photosynthesis (GPP, LUE, Amax), radiometric indexes (NDVI, PRI, Fapar), structural canopy properties (LAI, Biomass)
- ✓ heatwave impact metrics (e.g. peak reduction, anticipation) computed on all the variables

Objectives

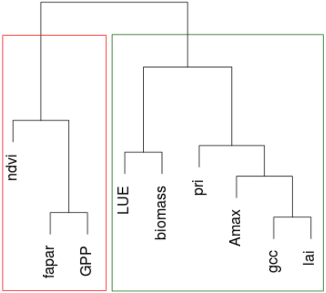
obj1: GCC is able to detect the heatwave impact on functional or structural canopy properties

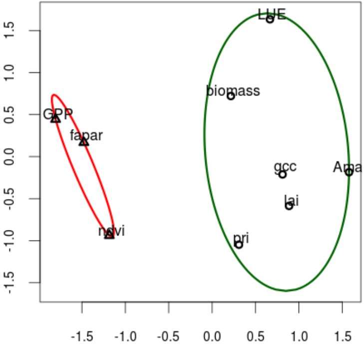


- ✓ canopy photosynthesis (GPP, LUE, Amax), radiometric indexes (NDVI, PRI, Fapar), structural canopy properties (LAI, Biomass)
- ✓ heatwave impact metrics (e.g. peak reduction, anticipation) computed on all the variables

heatwave impact metrics

variables grouping (hierarchical and pam clustering)





2015 summer heatwave impact

- ✓ Like GCC, all functional and structural variables showed an anticipation of peak dates (i.e. earlier senescence onset) and a reduction of peak values
- ✓ Cluster analysis reveals that heatwave impact on GCC is similar to the impact observed on LUE and Amax (parameters of photosynthesis light response curve), PRI (vegetation indexes related to chlorophyll content) and LAI and green biomass (canopy structure)

⇓

- ✓ GCC inter annual variability (IAV) can be used to track functional/structural canopy properties IAV

2015 summer heatwave impact

- ✓ Like GCC, all functional and structural variables showed an anticipation of peak dates (i.e. earlier senescence onset) and a reduction of peak values
- ✓ Cluster analysis reveals that heatwave impact on GCC is similar to the impact observed on LUE and Amax (parameters of photosynthesis light response curve), PRI (vegetation indexes related to chlorophyll content) and LAI and green biomass (canopy structure)

⇓

- ✓ GCC inter annual variability (IAV) can be used to track functional/structural canopy properties IAV

2015 summer heatwave impact

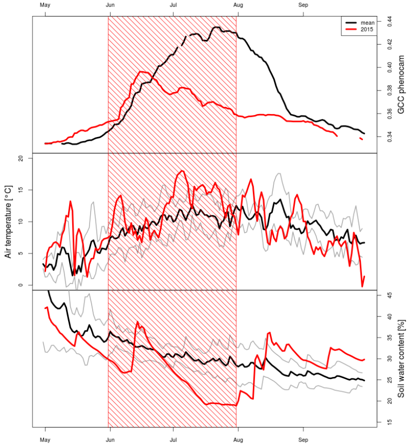
- ✓ Like GCC, all functional and structural variables showed an anticipation of peak dates (i.e. earlier senescence onset) and a reduction of peak values
- ✓ Cluster analysis reveals that heatwave impact on GCC is similar to the impact observed on LUE and Amax (parameters of photosynthesis light response curve), PRI (vegetation indexes related to chlorophyll content) and LAI and green biomass (canopy structure)

⇓

- ✓ GCC inter annual variability (IAV) can be used to track functional/structural canopy properties IAV

Objectives

obj2: GCC decrease is driven by a combined effect of high temperature and drought



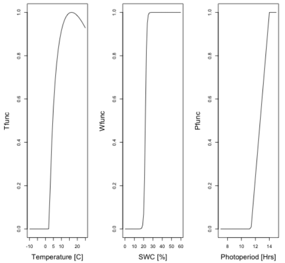
- ✓ **GSI model** (Jolly 2005 *et al.*, Stockli *et al.* 2011, Forkel *et al.* 2014)
- ✓ GSI is a bioclimatic index that predicts foliar phenology of vegetation driven by climate variables
- ✓ GCC modelling using GSI (Migliavacca *et al.* 2011)
  - snowmelt + temperature control on spring
  - photoperiod + temperature control on senescence

GSI model

new model formulation

- ✓ new optimum temperature limitation function (T_{opt})

- ✓ canopy development is limited by hot temperatures

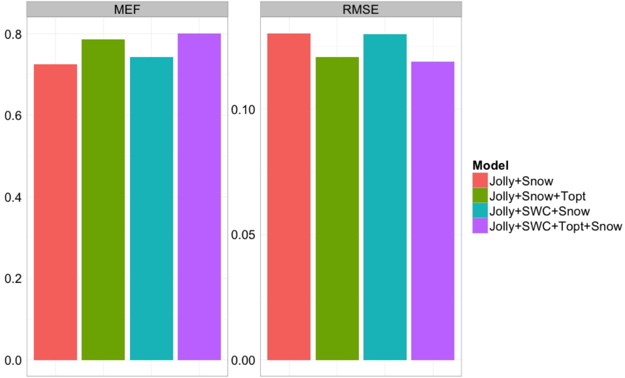


- ✓ 8 different GSI formulations including
  - temperature (T_{opt} and T_{step})
  - photoperiod
  - snow
  - VPD
  - SWC

- ✓ model parameters optimised for each model formulation (MCMC methods)

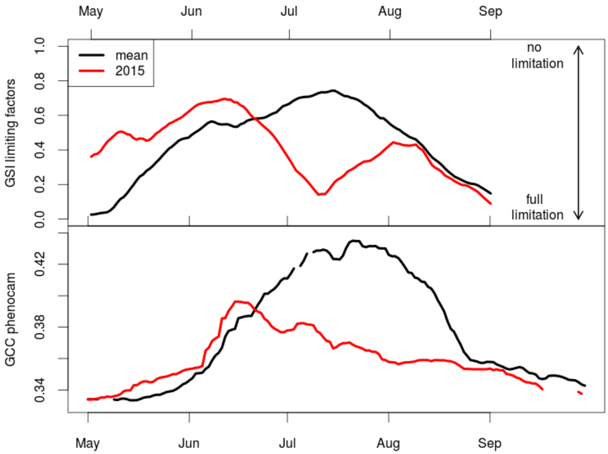
GSI model results

✓ GSI formulation including high temperature (T_{opt}) and soil water content limitation (SWC) gives the best results (MEF: 0.82, RMSE: 0.12)



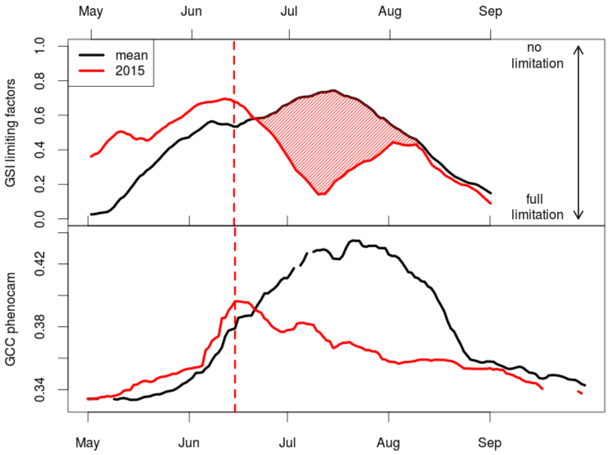
GSI model results

✓ high temperature and drought co-limitation



GSI model results

✓ high temperature and drought co-limitation



GSI model results

✓ snow + temperature control on **spring**

✓ temperature + photoperiod control on **senescence**

✓ T_{opt} improves model fitting statistics and GCC simulation

✓ results highlight the combined effect of **high temperature and drought** on GCC decrease during the heatwave

GSI model results

✓ snow + temperature control on **spring**

✓ temperature + photoperiod control on **senescence**

✓ $\mathbf{T}_{opt}$ improves model fitting statistics and GCC simulation

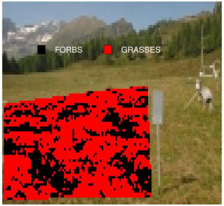
✓ results highlight the combined effect of **high temperature and drought** on GCC decrease during the heatwave

GSI model results

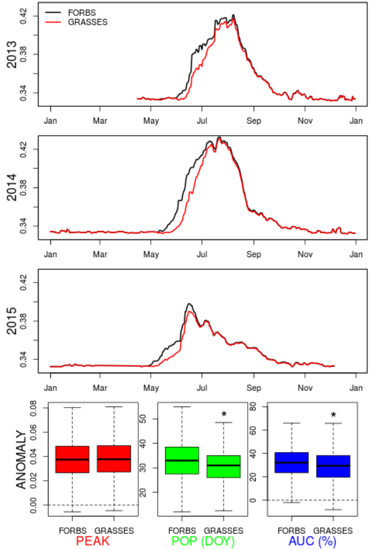
- ✓ snow + temperature control on **spring**
- ✓ temperature + photoperiod control on **senescence**
- ✓ $\mathbf{T}_{opt}$ improves model fitting statistics and GCC simulation
- ✓ results highlight the combined effect of **high temperature and drought** on GCC decrease during the heatwave

outlook: growth forms sensitivity to heatwave

- ✓ phenocam spatial analysis (**phenopix R package**, Filippa *et al.* 2015) can be used to infer the spatial distribution of phenologically different growth forms (i.e. grasses and forbs)



- ✓ both **grasses** and **forbs** are affected by the heatwave but **forbs** show a higher sensitivity: earlier peak and AUC reduction (t-test $p<0.05$)



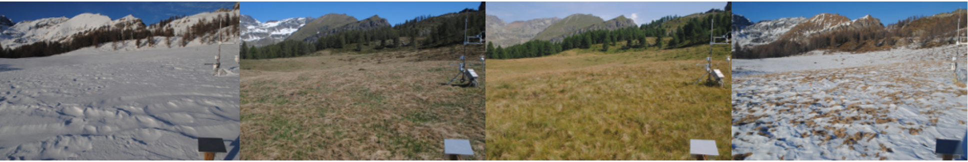
Conclusions

- ✓ GCC tracks not only phenology, but also **heatwave impact on functional and structural canopy properties**
- ✓ **High temperature** and **low soil water content** co-determine heatwave impact on GCC
- ✓ Whilst being both affected by the heatwave, **forbs** have been significantly more impacted than **grasses**

Thank you for the attention

e.cremonese@arpa.vda.it

www.arpa.vda.it/climate-change-impacts



variables grouping (hierarchical and pam clustering)

3 clusters