



**Barcelona
Supercomputing
Center**

Centro Nacional de Supercomputación



EXCELENCIA
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Seasonal prediction of fire danger using ECMWF's SEAS5 prediction system

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Earth Sciences Department



The 2017 fire season in California WAS the costliest on record, with 18 Billion US\$ in damages, and deadliest with 43 casualties on record.

2018 wildfire season was even worse...



- The European countries most affected by wildfires are in the Mediterranean basin, with summer fires occurring during periods of drought.
- 2017 was a particularly extreme year for wildfires fire season with many deaths in Portugal and record-breaking wildfires in California.
- The 2018 wildfire season in California has been even worse, with many tragic deaths.
- In light of this, seasonal prediction of wildfire danger appears as a priority for health, safety and economic welfare.
- While several short-term (up to 10 days in advance) fire danger systems are in place, there is currently no operational seasonal wildfire forecasting system for Europe and only a few for other continents



Fire Danger Ratings give you an indication of the consequences of a fire, if one was to start. The higher the fire danger, the more dangerous the conditions.

Fire Danger Ratings should be used as a trigger to take action to prevent or control a possible fire

Alexander, M.E.; De Groot, W.J. 1988. Fire behavior in jack pine stands as related to the Canadian Forest Fire Weather Index System. Canadian Forest Service, Northern Forestry Centre, Edmonton, AB. Poster with text.

Quintilio, D.; Fahnestock, G.R.; Dubé, D.E. 1977. Fire behavior in upland jack pine: the Darwin Lake Project. Canadian Forest Service, Northern Forestry Centre, Edmonton, AB. Information Report NOR-X-174.

Source : Francesca Di Giuseppe (ECMWF)

<https://cpo.noaa.gov/Portals/0/Docs/MAPP/Pdfs/DiGiuseppe.pdf>

EFFIS 10-day FWI forecast



COPERNICUS

Emergency Management Service



European Commission > JRC EU Science Hub > DRM > Copernicus EMS > EFFIS > Applications > Current Situation Viewer

Map Options

COUNTRY BOUNDARIES ⓘ

Fire Danger Forecast

FIRE DANGER FORECAST ⓘ

Source: ECMWF (16 km res.) ▾

Index: Fire Weather Index (FWI) ▾

Date: 19 Apr 2018

Rapid Damage Assessment

Select a date-range

From: 12 Apr 2018 To: 19 Apr 2018

ACTIVE FIRES ⓘ

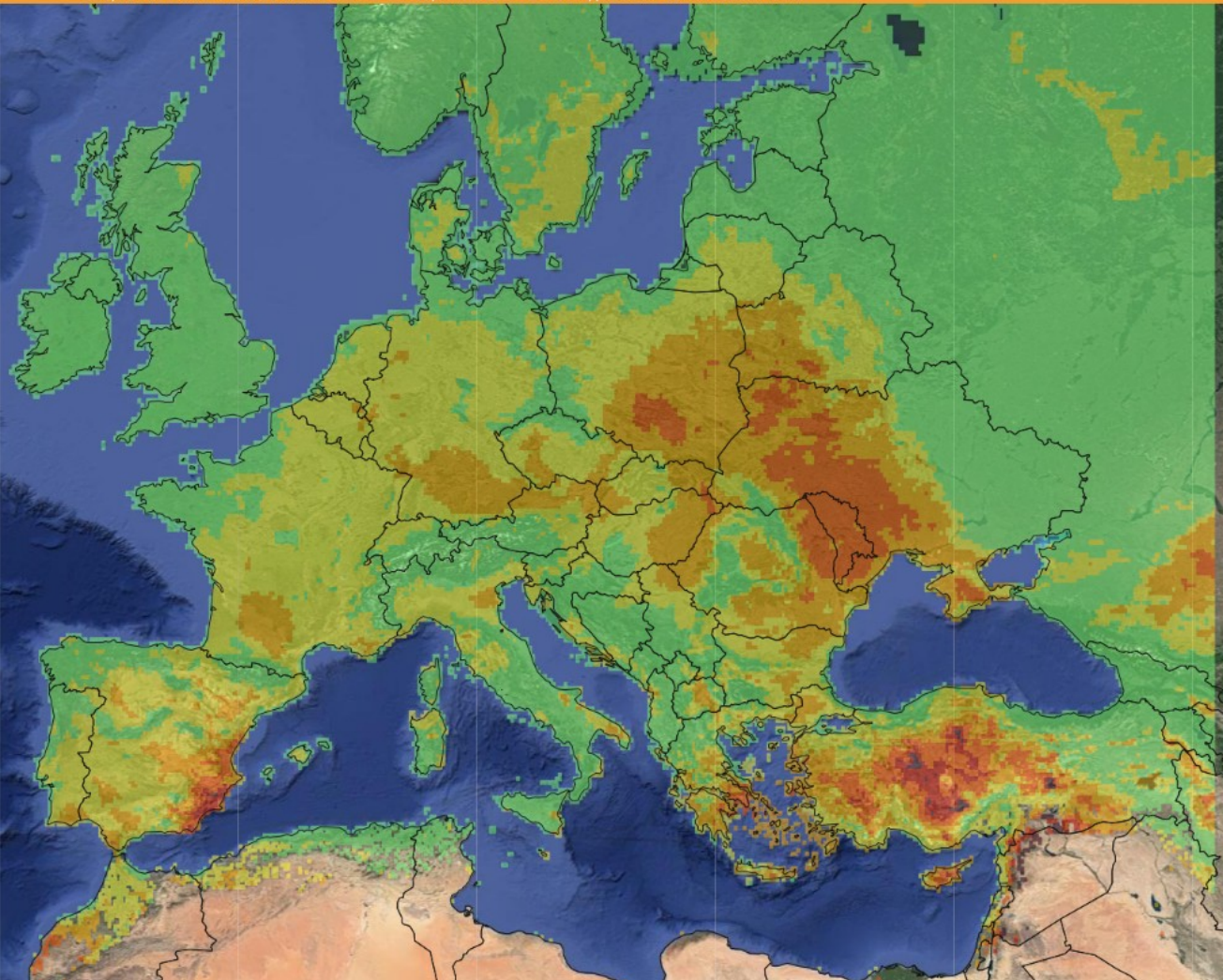
MODIS VIIRS

BURNT AREAS ⓘ

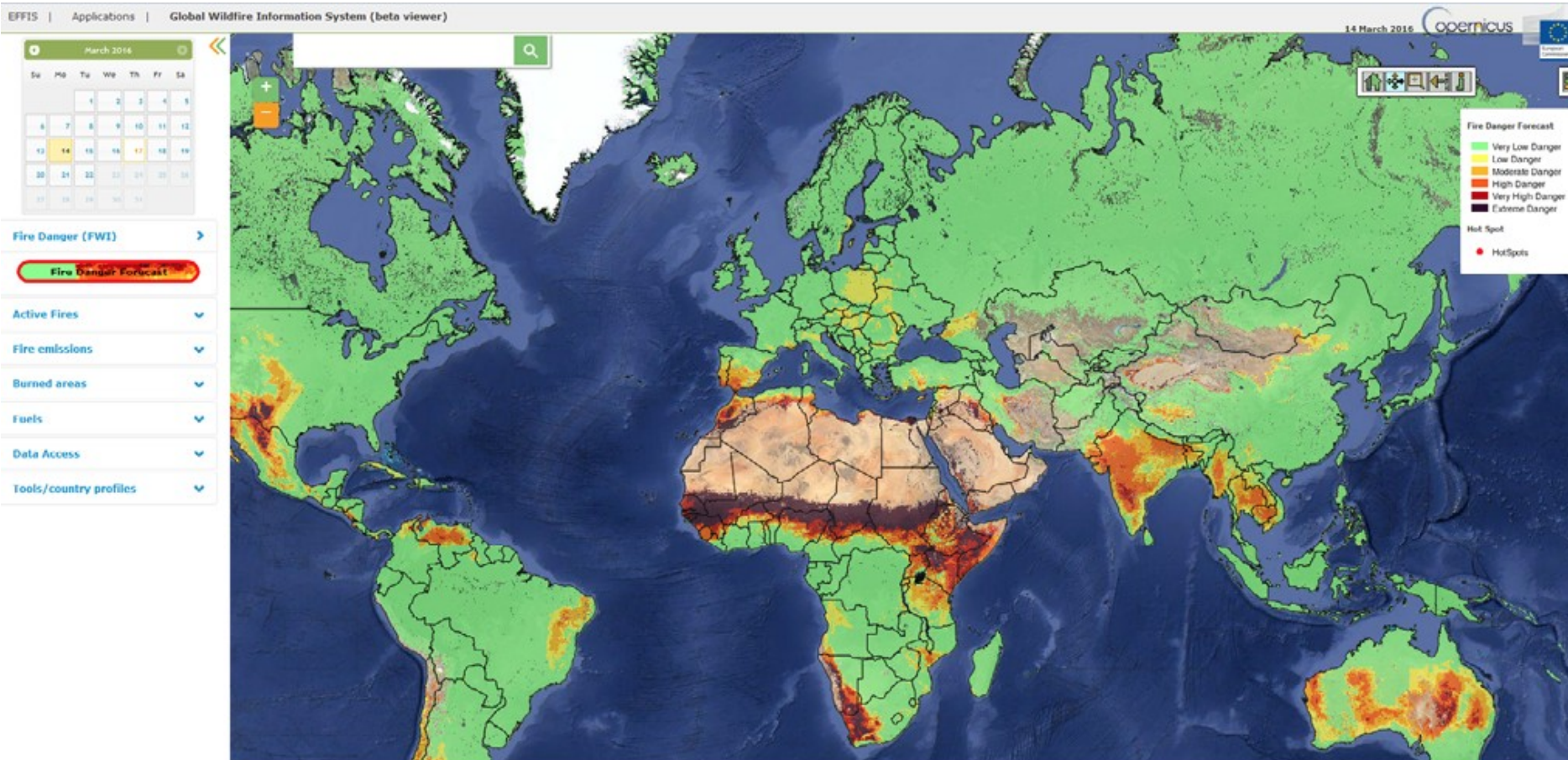
MODIS VIIRS

Fire Severity

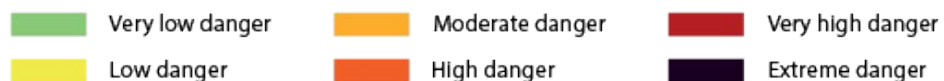
Analysis Tools



GWIS 10-day FWI forecast



Fire danger forecast

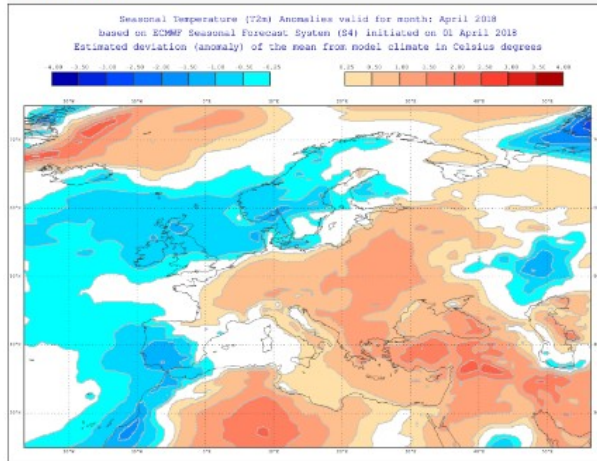


Hotspot



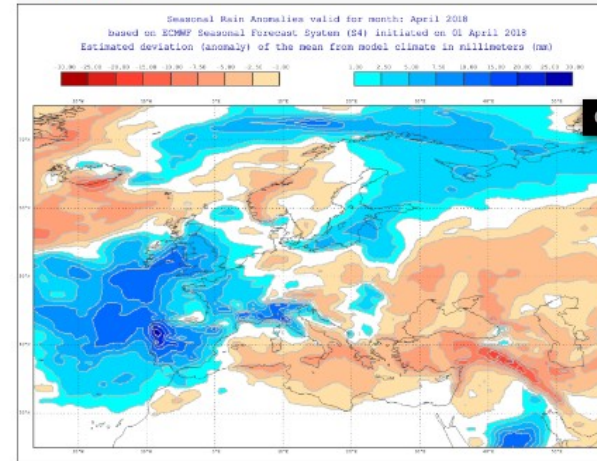
Temperature anomalies

APRIL 2018



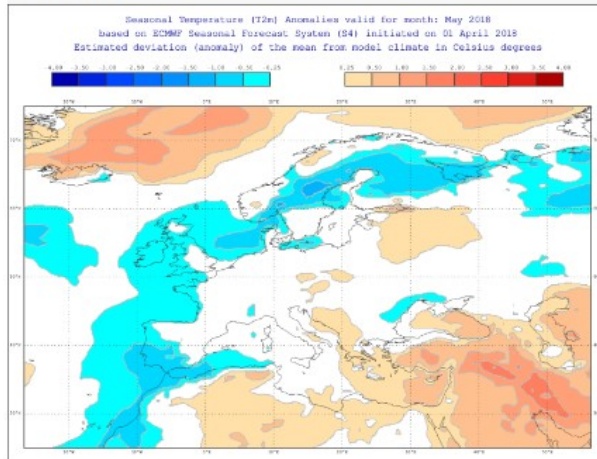
Rain anomalies

APRIL 2018



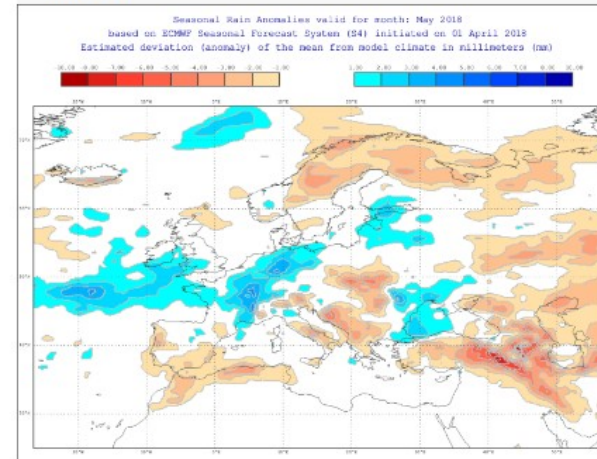
Temperature anomalies

MAY 2018



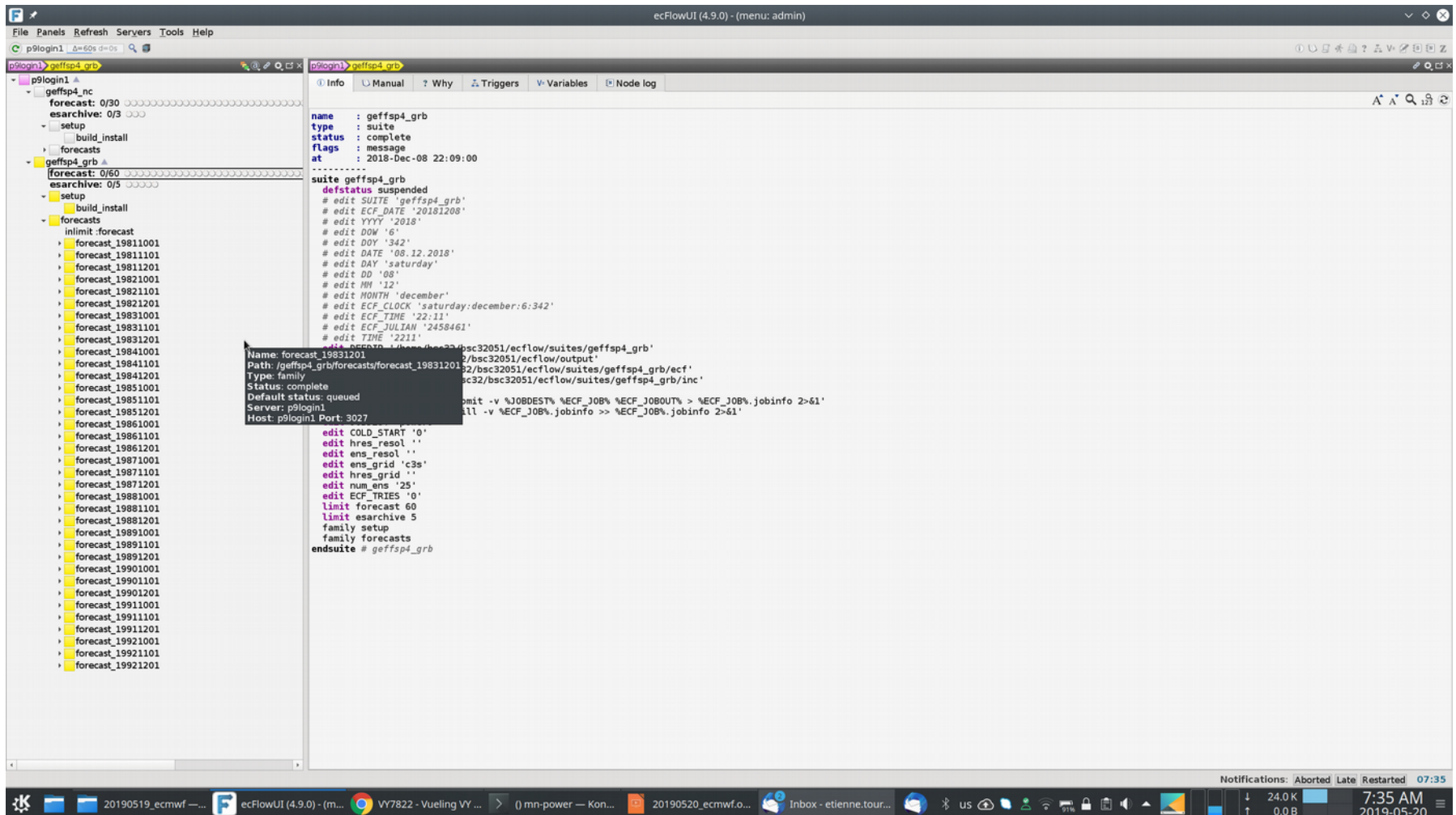
Rain anomalies

MAY 2018



- Seasonal Prediction of Fire danger using Statistical and Dynamical models (SPFireSD) is a MSCA Individual Fellowship
- Other approaches not discussed here:
 - Statistical approach: fire danger predictions using linear regression models
 - Dynamical approach: ensemble dynamical predictions using Earth System Models
 - Decadal prediction of fire danger using SPI/SPEI
- **Fire danger indices approach:** simple fire danger indices computed from seasonal dynamical climate prediction systems
 - Adapt existing ECMWF infrastructure for operational short-term wildfire predictions (GEFF-RT ecfw) to use seasonal predictions
 - ECMWF SEAS5 hindcasts (C3S 1degree grid) from 1981-2017 used as input for FWI computations, compared to FWI computed from ERA-Interim
 - Adapted the ecfw suite to run on BSC cluster
 - FWI prediction from daily predictions of precipitation, max. temperature, minimum relative humidity and wind

GEFF-SP running on BSC power cluster

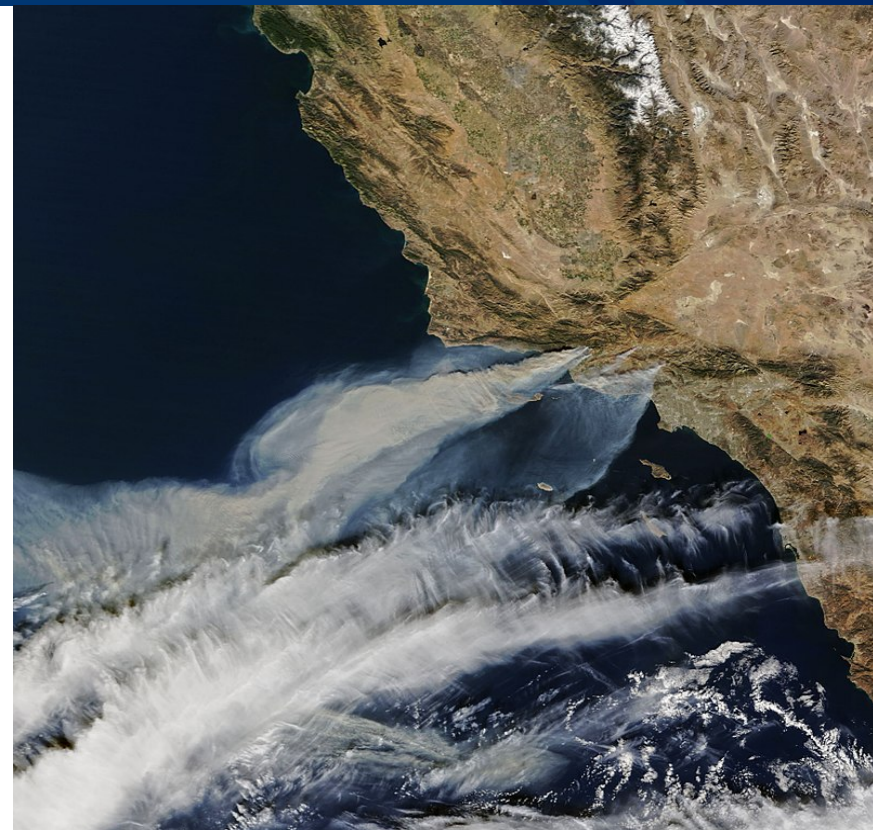


The screenshot displays the ecFlowUI (4.9.0) interface. On the left, a tree view shows the job hierarchy: 'p9login1' > 'geffsp4_nc' > 'forecast: 0/30' > 'esarchive: 0/3' > 'setup' > 'build_install' > 'forecasts' > 'geffsp4_grb' > 'forecast: 0/60' > 'esarchive: 0/5' > 'setup' > 'build_install' > 'forecasts' > 'inlimit_forecast' > 'forecast_19811001' through 'forecast_19921201'. The main panel shows the configuration for the selected job 'forecast_19831201'.

```
name      : geffsp4_grb
type      : suite
status    : complete
flags     : message
at        : 2018-Dec-08 22:09:00
-----
suite geffsp4_grb
defstatus suspended
# edit SUITE 'geffsp4_grb'
# edit ECF_DATE '20181208'
# edit YYYY '2018'
# edit DOY '6'
# edit DOY '342'
# edit DATE '08.12.2018'
# edit DAY 'saturday'
# edit DD '08'
# edit MM '12'
# edit MONTH 'december'
# edit ECF_CLOCK 'saturday:december:6:342'
# edit ECF_TIME '22:11'
# edit ECF_JULIAN '2458461'
# edit TIME '2211'
# edit ECF_PATH '2/bsc32051/ecflow/suites/geffsp4_grb'
Name: forecast_19831201
Path: /geffsp4_grb/forecasts/forecast_19831201
Type: family
Status: complete
Default status: queued
Server: p9login1
Host: p9login1 Port: 3027
# edit COLD_START '0'
# edit hres_resol ''
# edit ens_resol ''
# edit ens_grid 'c3s'
# edit hres_grid ''
# edit num_ens '25'
# edit ECF_TRIES '0'
limit forecast 60
limit esarchive 5
family setup
family forecasts
endsuite # geffsp4_grb
```



In October, around the Napa valley in Northern California, the Tubbs fire was the most destructive in US history. Warm temperatures and strong winds are thought to be responsible for the severity of these wildfires.



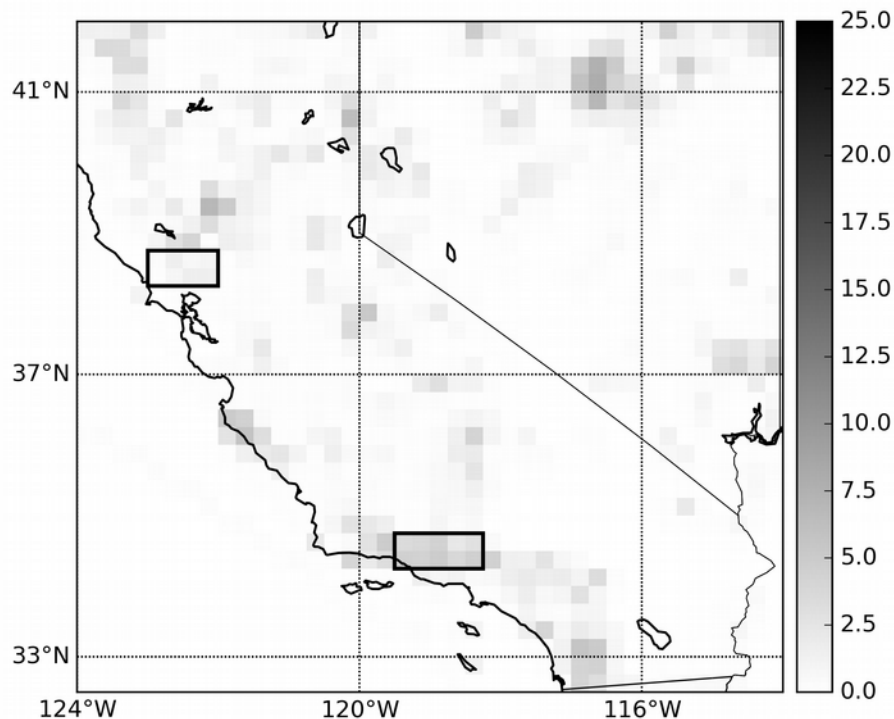
In December, Southern California was plagued by severe wildfires and the Thomas fire near Los Angeles became the largest in California history. It was thought to be fueled by severe Santa Ana winds and warmer than average temperatures.

was 2017 extreme?

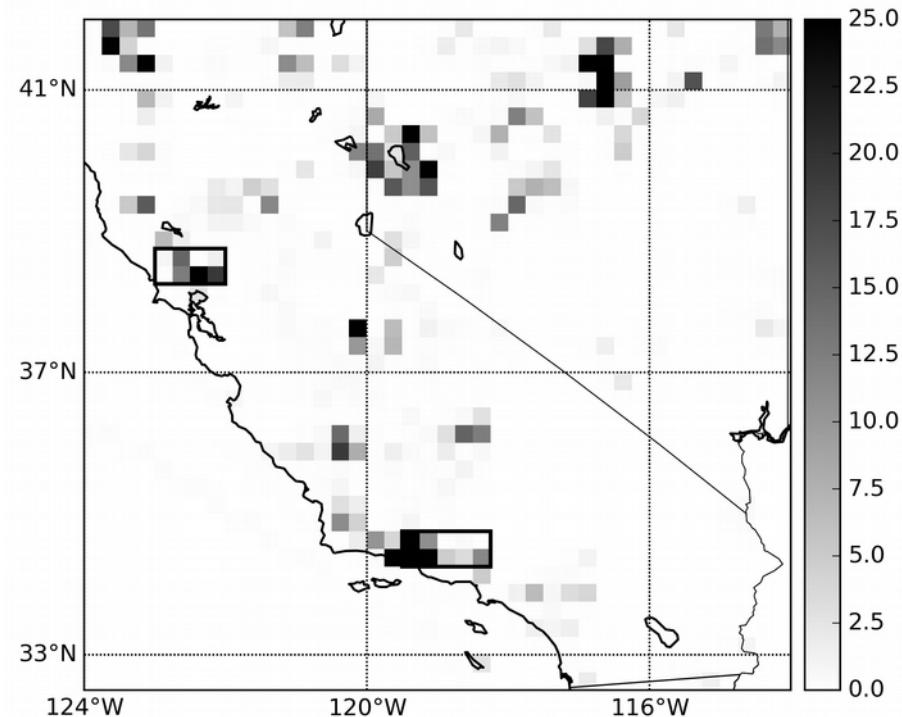
Observed burned areas in 2017 were indeed much higher than climatological averages.

In fact many areas had not been previously burned in the entire MODIS observation period (2000-2017).

burnt fraction (%) / clim



burnt fraction (%) / 2017



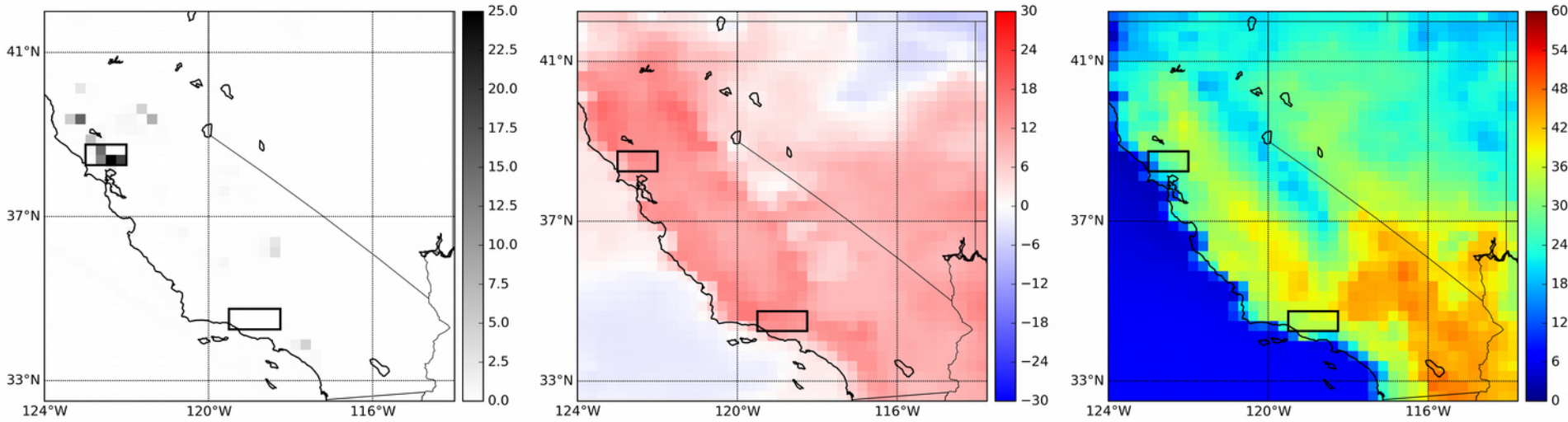
FWI in October-December 2017

Widespread positive FWI anomalies in Oct and Dec created conditions which favoured the extreme wildfires in northern and southern California.

burnt fraction (%) / 2017-10

Fire Weather Index anomaly / 2017-10

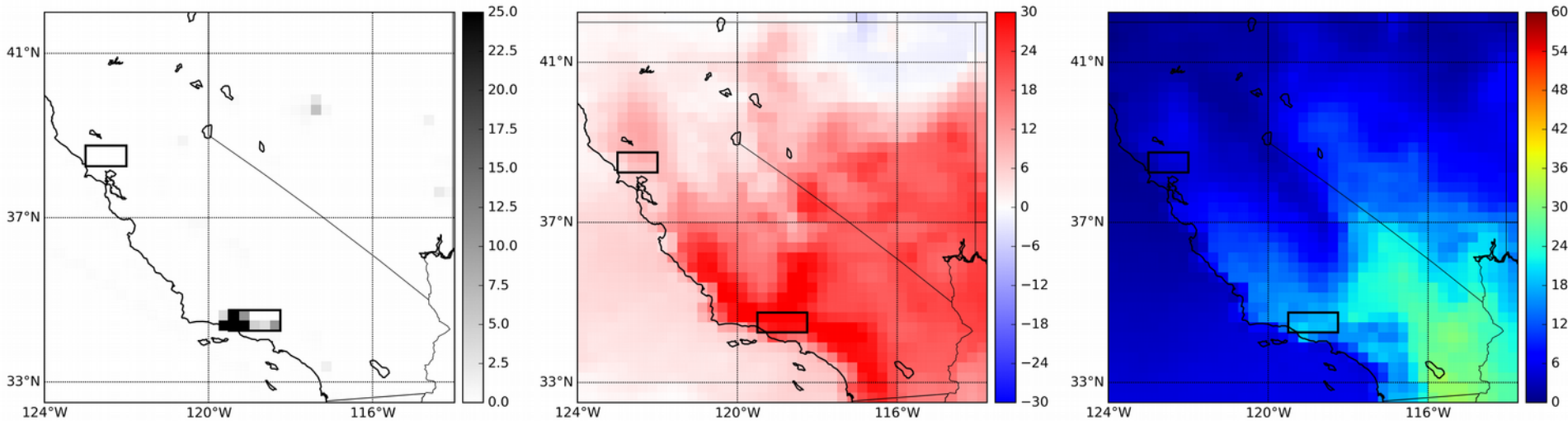
Fire Weather Index / clim-10



burnt fraction (%) / 2017-12

Fire Weather Index anomaly / 2017-12

Fire Weather Index / clim-12



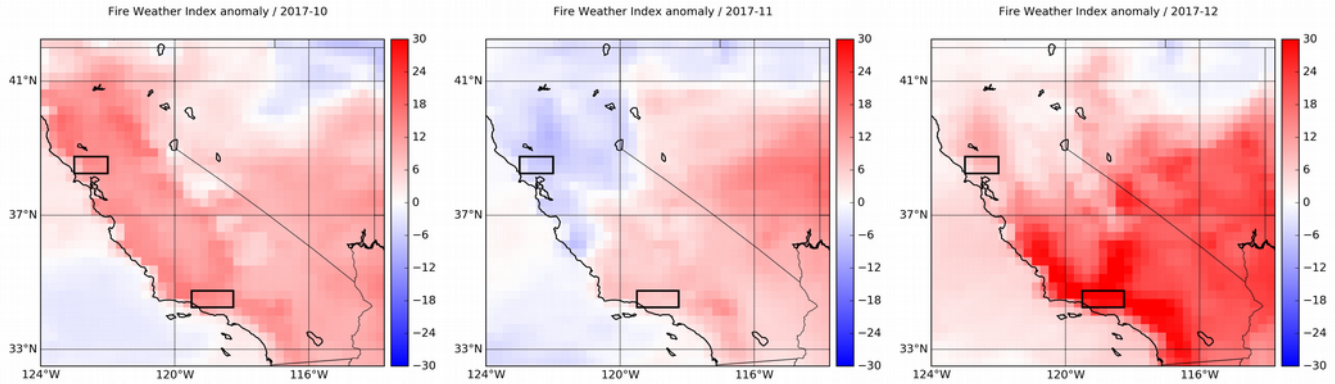
FWI anomaly in OCT-DEC 2017

October

November

December

FWI

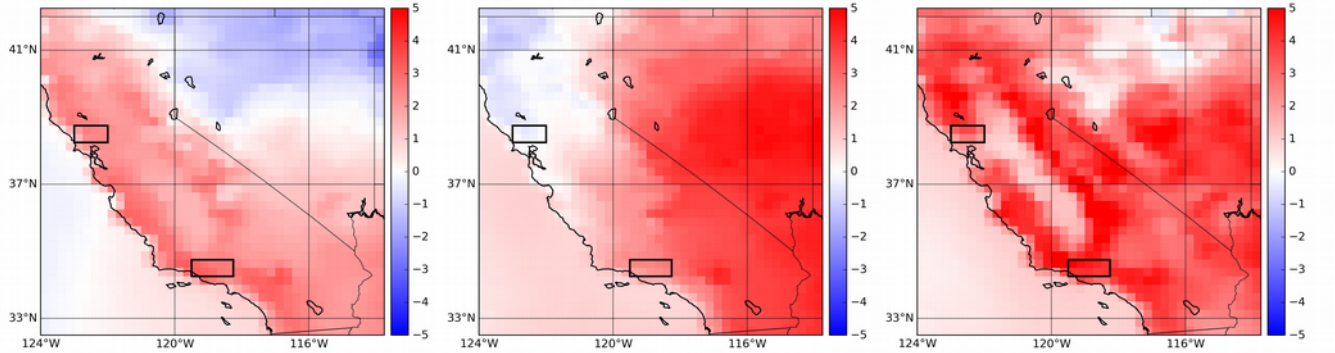


2m temperature max. anomaly (degC) / 2017-10

2m temperature max. anomaly (degC) / 2017-11

2m temperature max. anomaly (degC) / 2017-12

Temperature

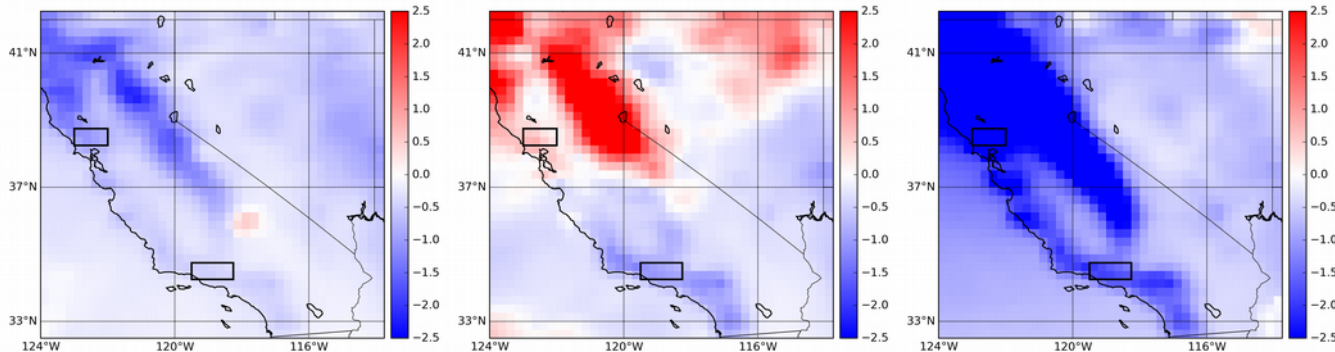


precipitation anomaly (mm/day) / 2017-10

precipitation anomaly (mm/day) / 2017-11

precipitation anomaly (mm/day) / 2017-12

Precipitation

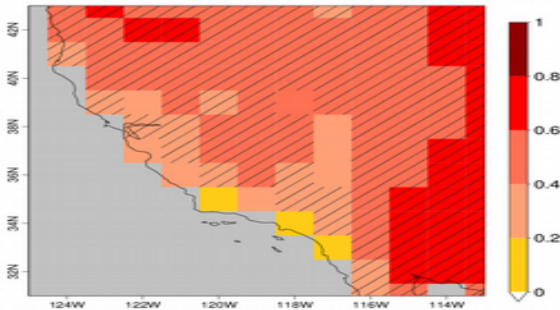


Anomaly Correlation Coefficient (ACC) of FWI from SEAS5 predictions (**monthly, ensemble means**) vs. ERA-Interim over California, initialized in August.

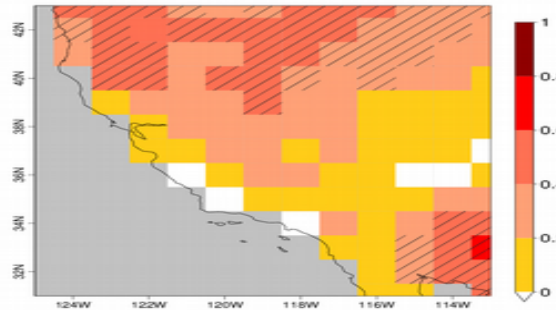
Shows potential skill in Lead month 0 (August) and 2 (October), but not near the coast

After 3 months skill drops rapidly.

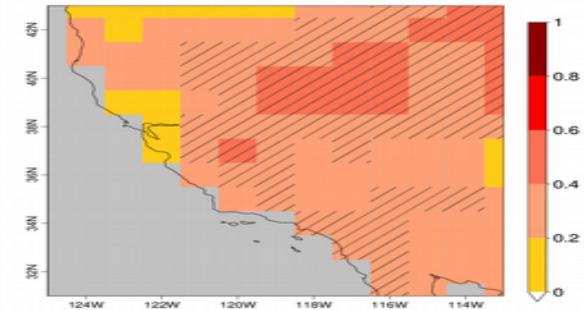
August



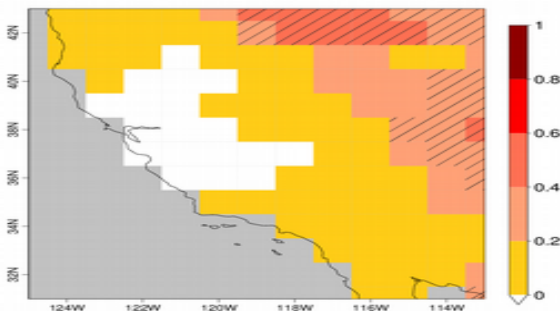
September



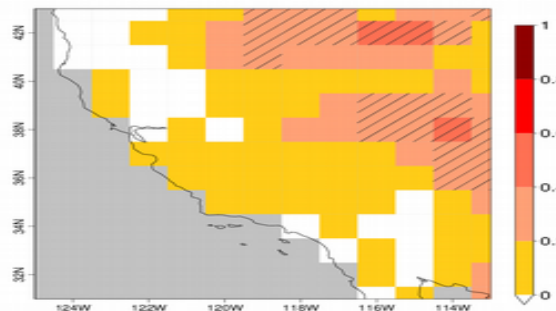
October



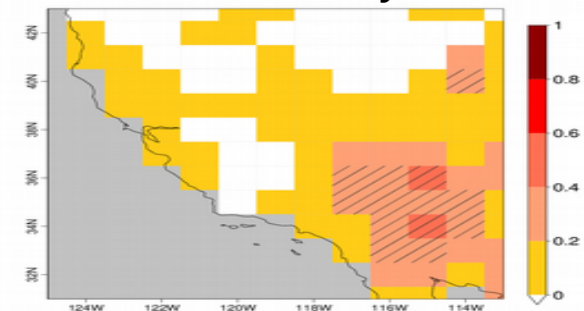
November



December



January

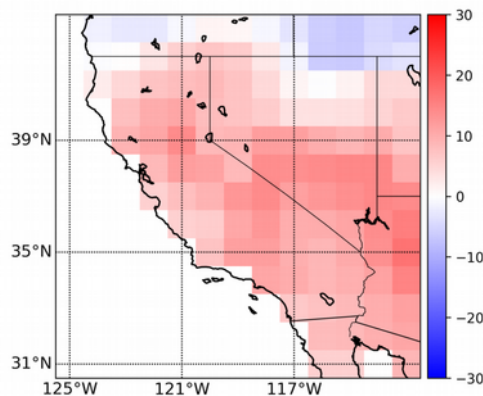


Seasonal prediction – August 2017

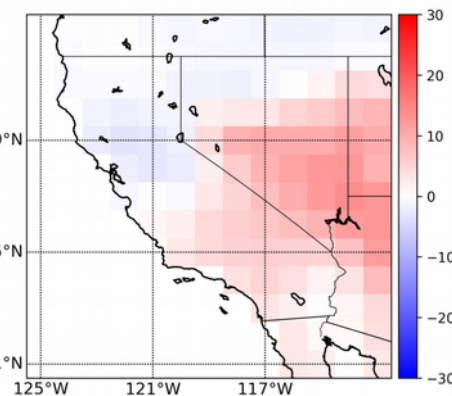
FWI computed from August predictions – results are quite dissapointing...

This is due to poor skill after 2+ months

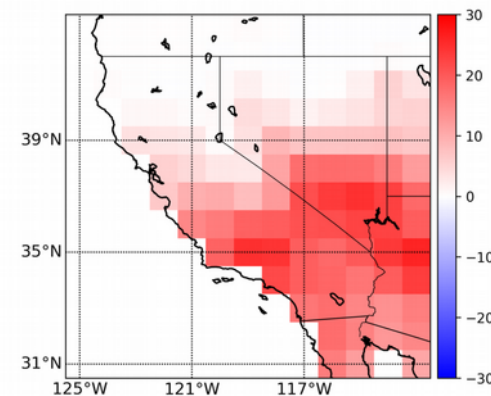
ERA-Interim



October



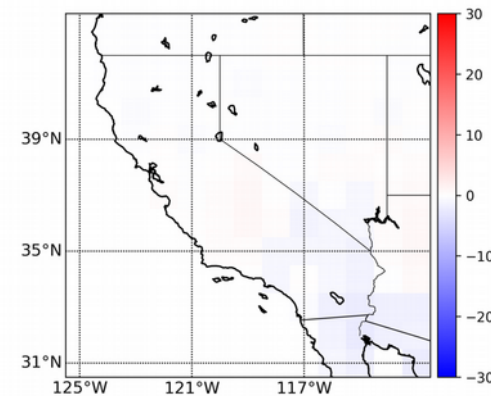
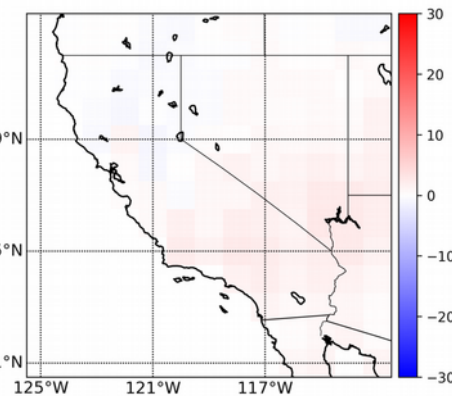
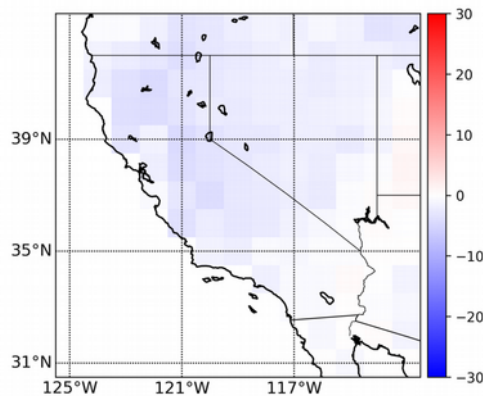
November



December

FWI

SEAS5



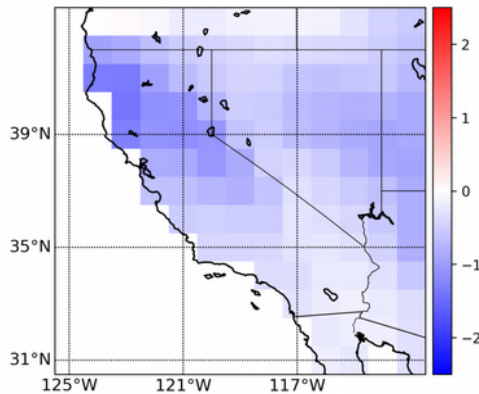
Seasonal prediction – August 2017

FWI computed from August predictions – results are quite dissapointing...

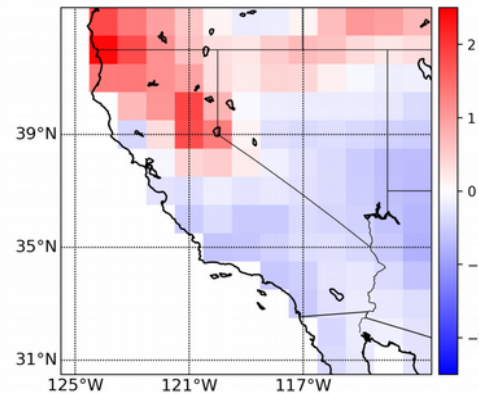
Precipitation is not well predicted 2+ months ahead!

Must run hindcasts at later start dates

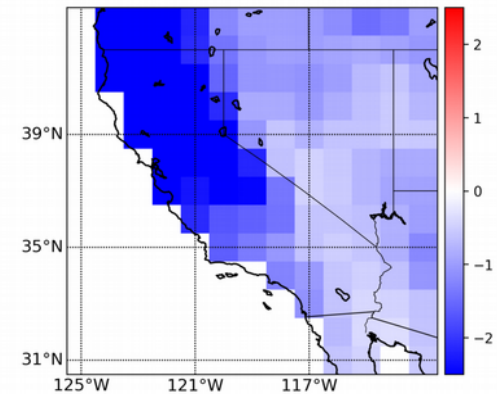
ERA-Interim



October



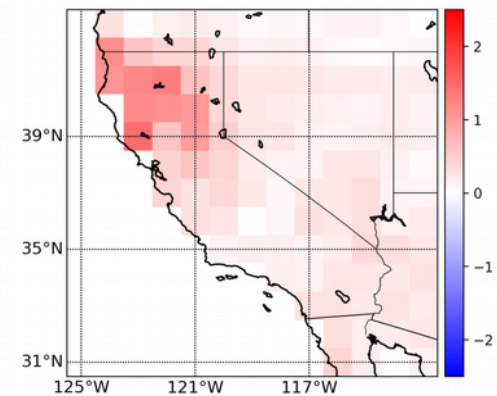
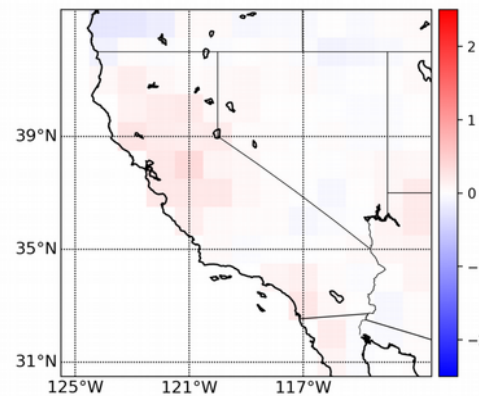
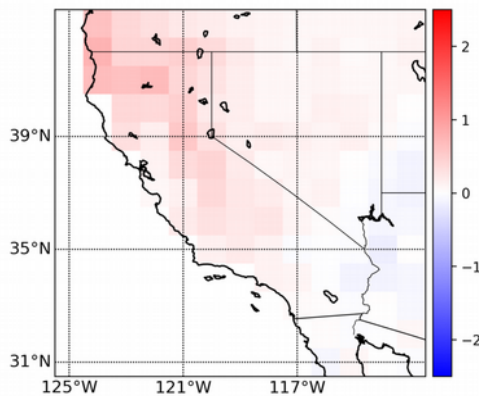
November



December

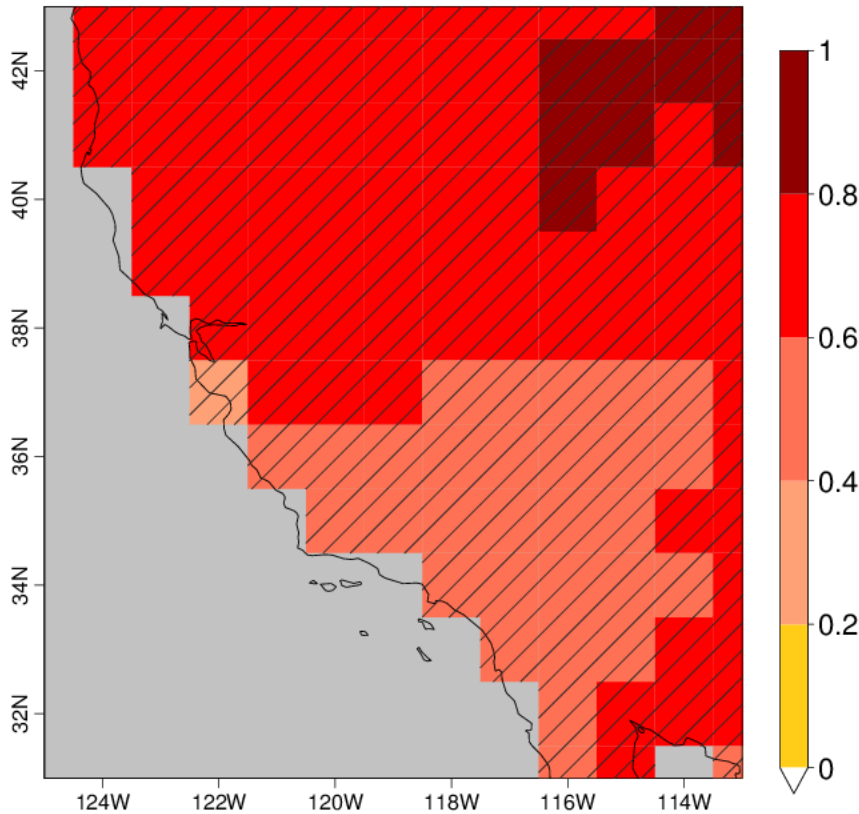
Precip.

SEAS5

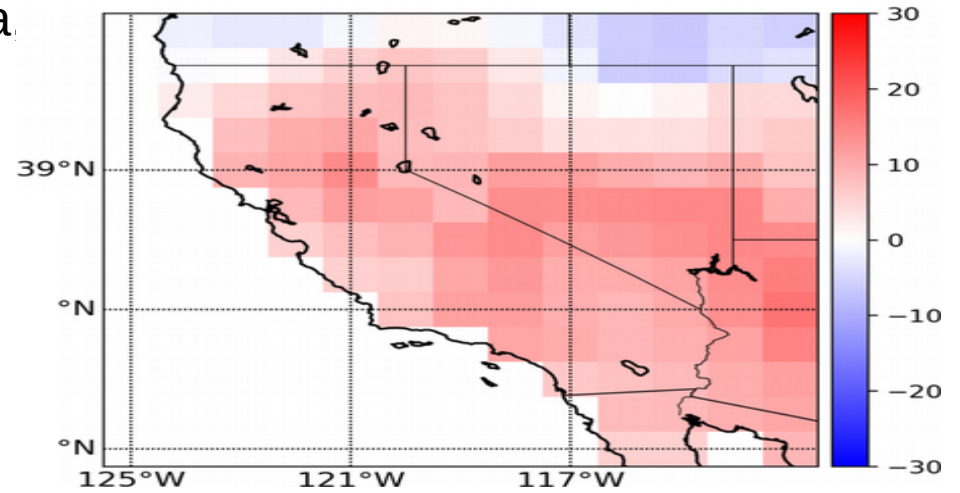


Anomaly Correlation Coefficient (ACC) of SEAS5 FWI predictions over California, initialized in October – much better!!!

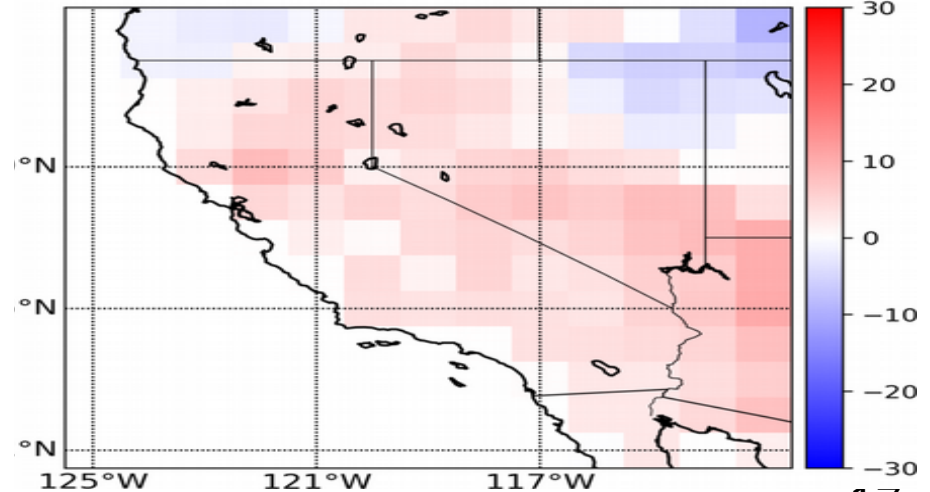
Ens-corr monthly fwi seas5-eraint Oct startdate-lead 0



ERA-Interim Oct. 2017 FWI anomaly

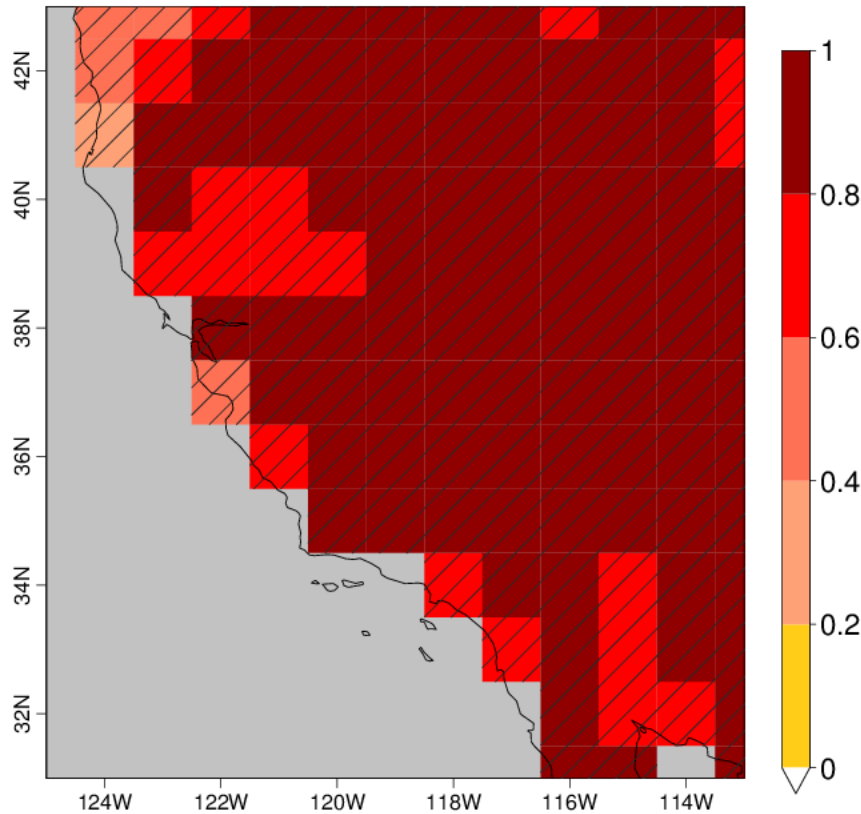


SEAS5 Oct. 2017 FWI anomaly

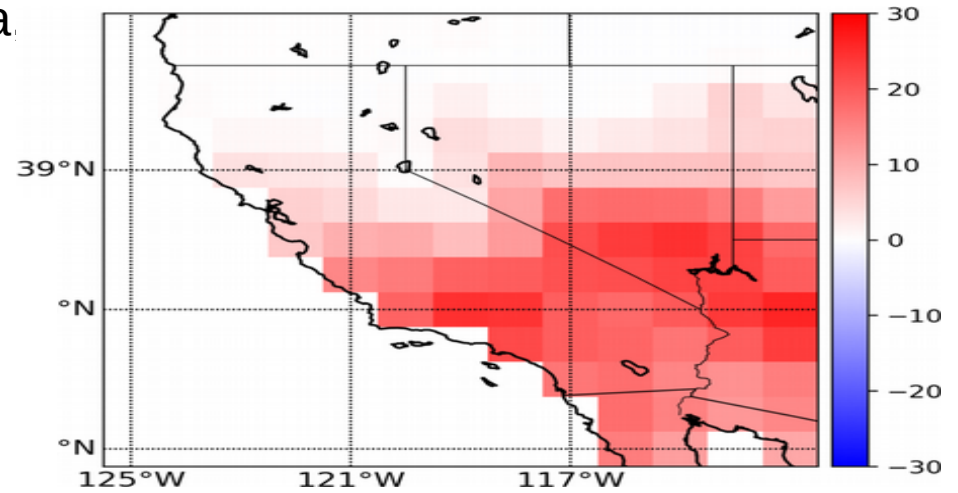


Anomaly Correlation Coefficient (ACC)
of SEAS5 FWI predictions over California,
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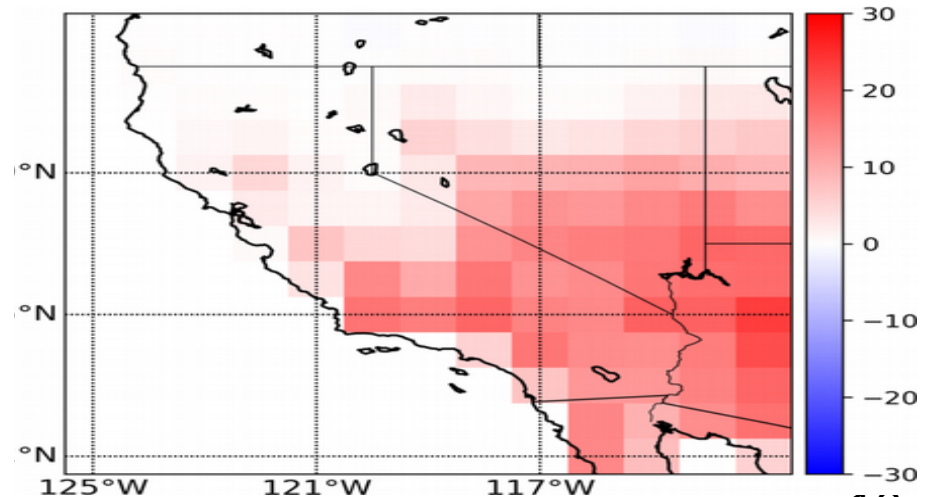
Ens-corr monthly fwi seas5-eraint Dec startdate-lead 0



ERA-Interim Dec. 2017 FWI anomaly



SEAS5 Dec. 2017 FWI anomaly





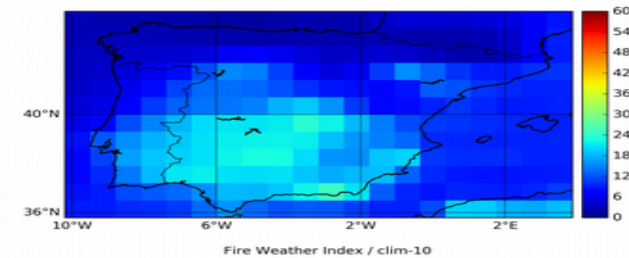
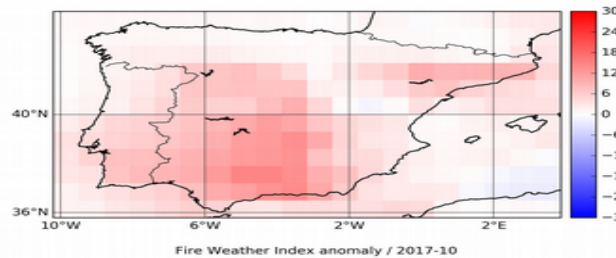
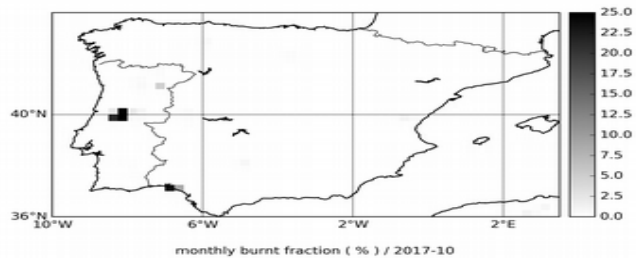
In June 2017, the infamous “Pedrogão Grande” wildfires (in central Portugal) killed 62 people trapped in their cars as they fled the intense wildfires.

During the “Pedrogão Grande” wildfires in Portugal in June 2017, positive FWI anomalies were observed, but not so strong over the area of interest.

Burned Area

FWI anomaly

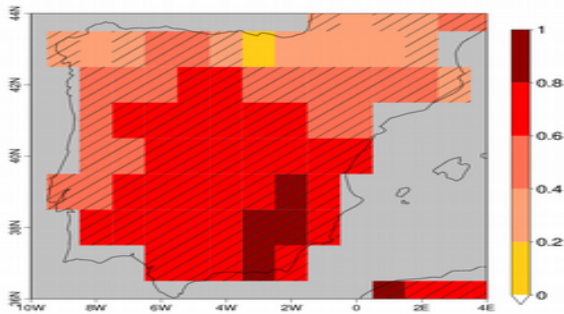
FWI climatology



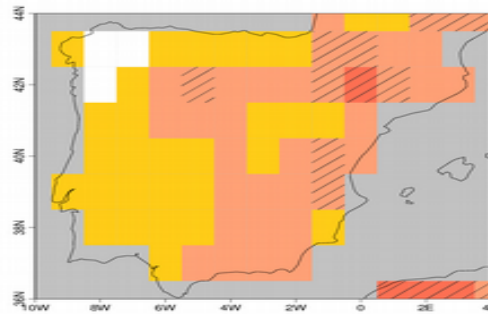
Anomaly Correlation Coefficient (ACC) of SEAS5 FWI predictions over Iberia, initialized in May.

Shows potential skill in Lead month 0 (May), patchy skill later.

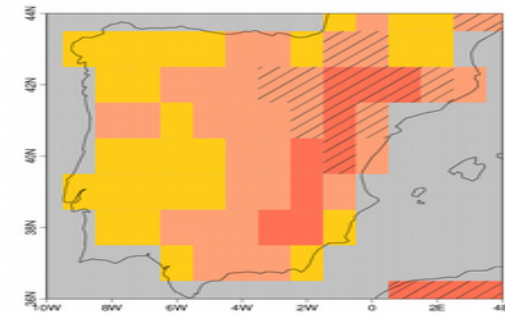
May



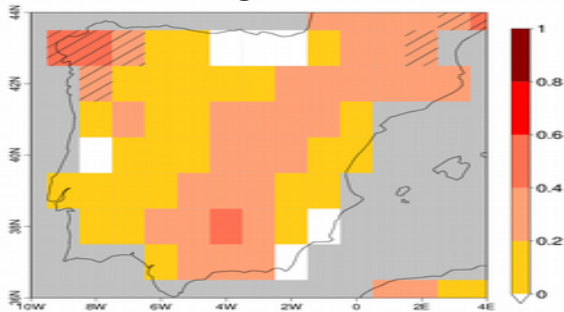
June



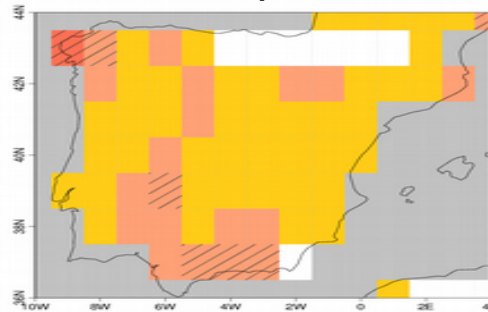
July



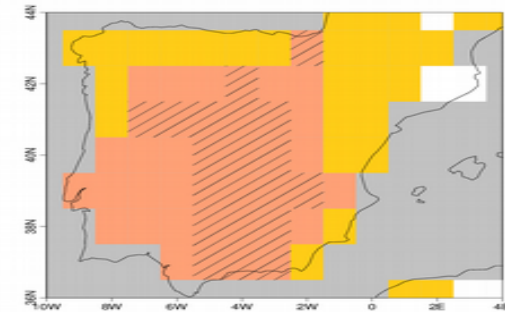
August



September



October

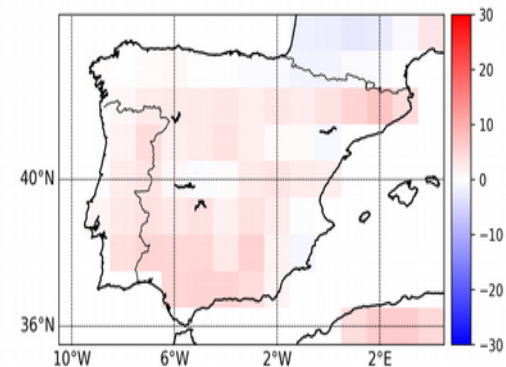
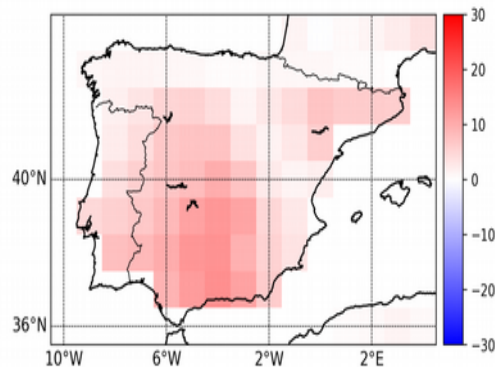
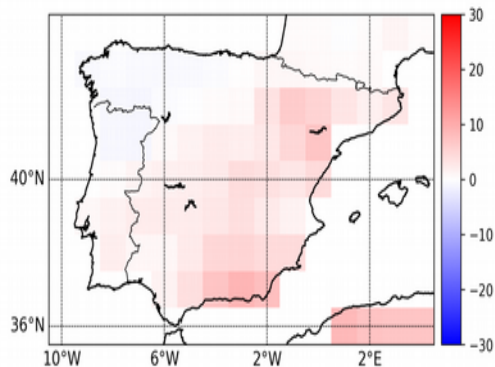


Seasonal prediction – May 2017

FWI computed from May predictions – results are not so bad!

Widespread positive FWI anomaly during the June wildfires.

ERA-Interim



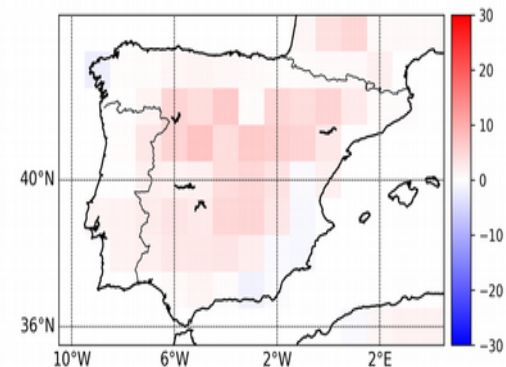
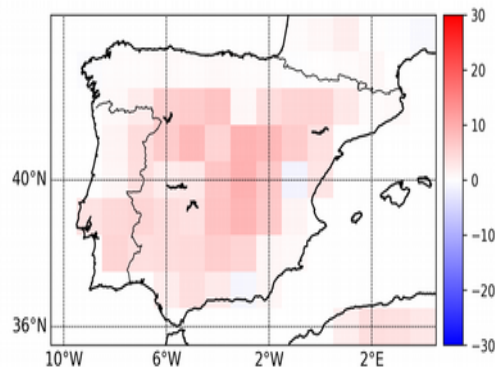
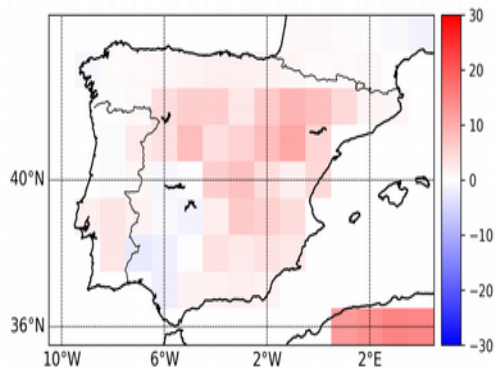
FWI

May

June

July

SEAS5





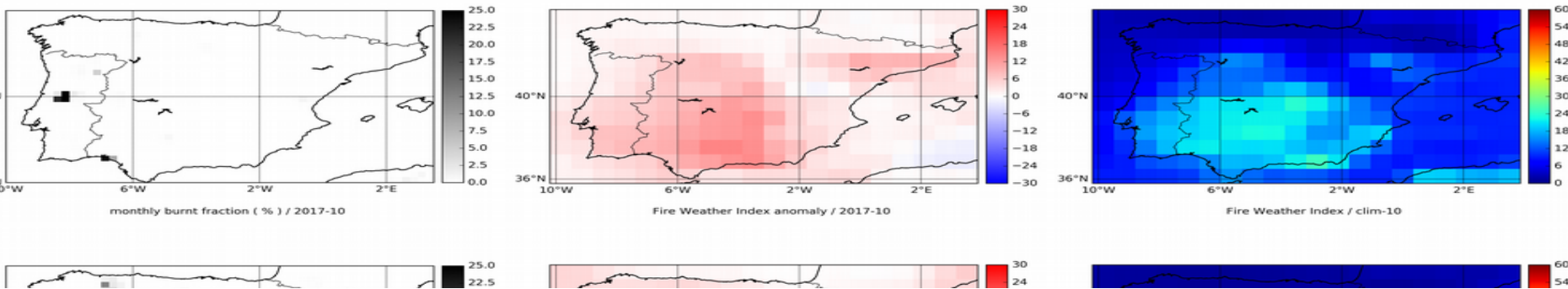
In October 2017, wildfires raged across northern Portugal and Galicia (Spain). The wildfires were made possible due to an intense drought and fueled by intense winds from Hurricane Ophelia. Arson is believed to be responsible for igniting many fires.

During the “Pedrogão Grande” wildfires in Portugal in June 2017, positive FWI anomalies were observed, but not so strong over the area of interest.

Burned Area

FWI anomaly

FWI climatology

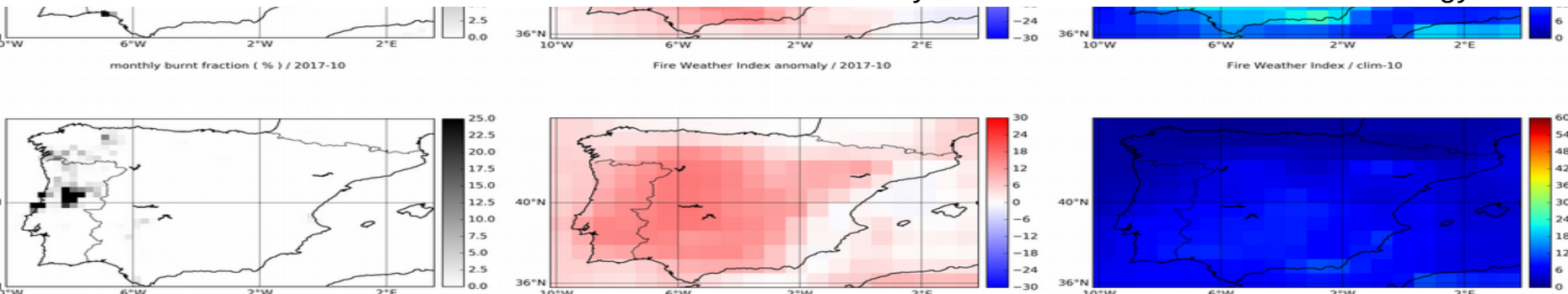


During the Galicia/Portugal wildfires in October 2017, widespread FWI anomalies were observed over most of the peninsula.

Burned Area

FWI anomaly

FWI climatology



Seasonal prediction skill – August init

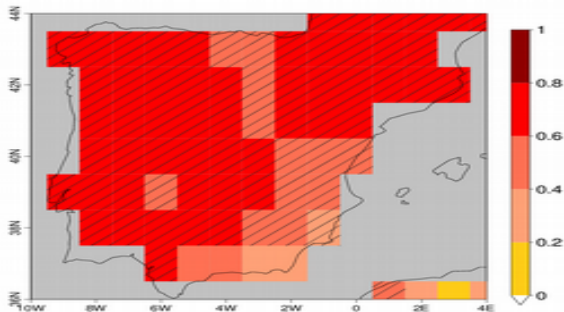


Anomaly Correlation Coefficient (ACC) of SEAS5 FWI predictions over Iberia, initialized in August.

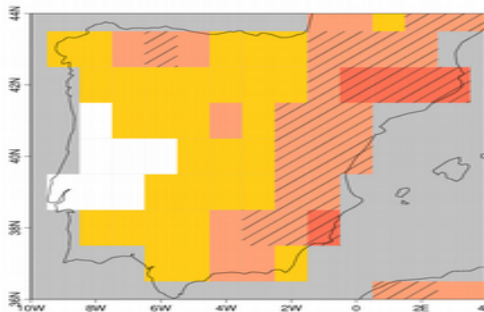
Shows potential skill in Lead month 0 (August), limited skill in Lead Month 1 (Sept.), some skill in northwest area of the peninsula in October.

After 2 months skill drops rapidly.

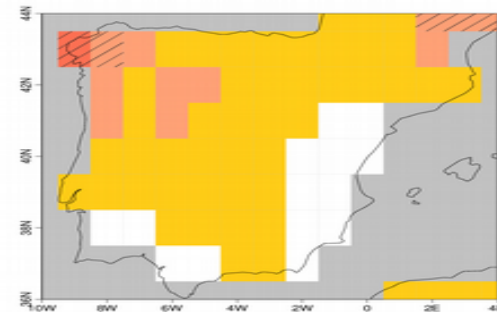
August



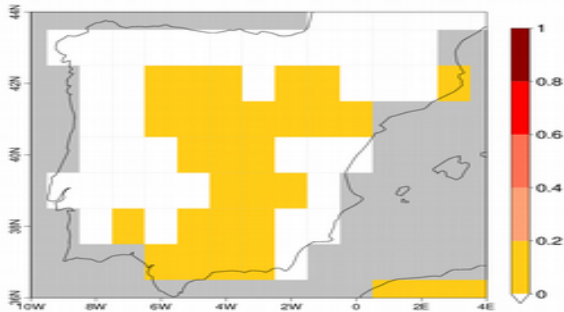
September



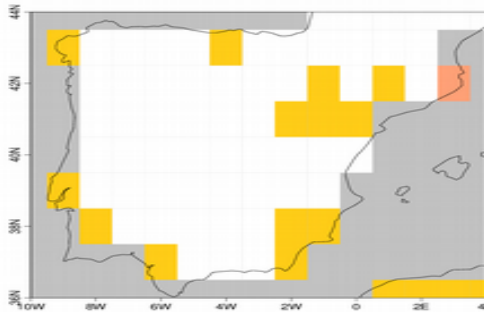
October



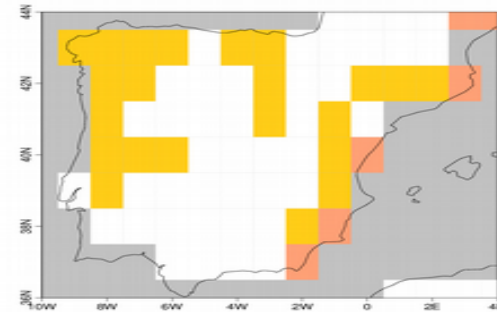
November



December



January

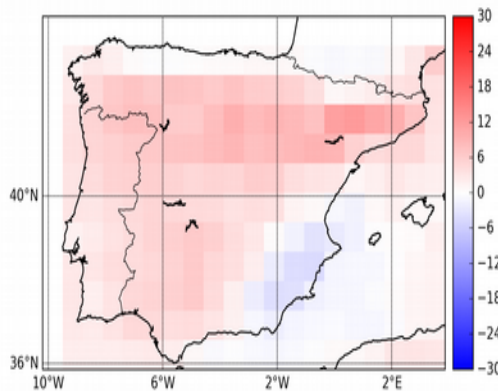


Seasonal prediction – August 2017

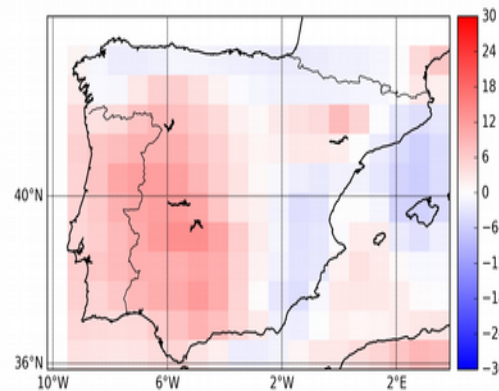
FWI computed from August predictions – results are mixed

Observed FWI anomaly during the October fires are stronger than predictions.

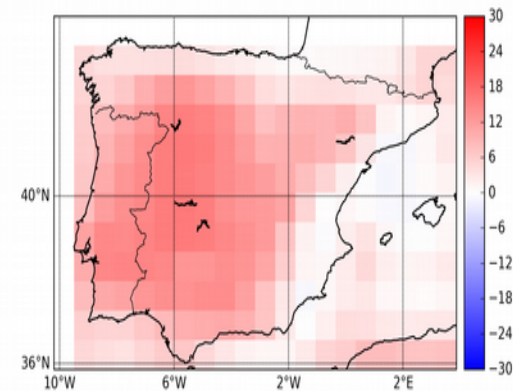
ERA-Interim



August

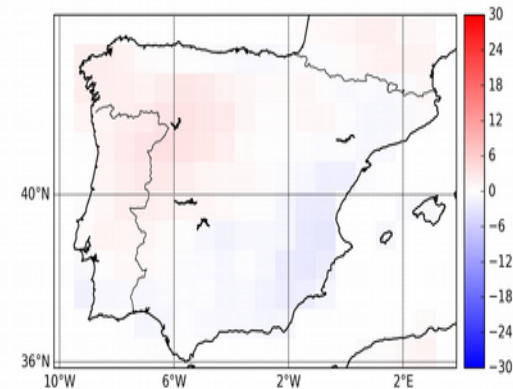
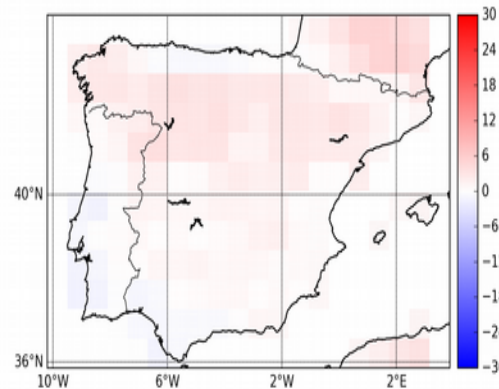
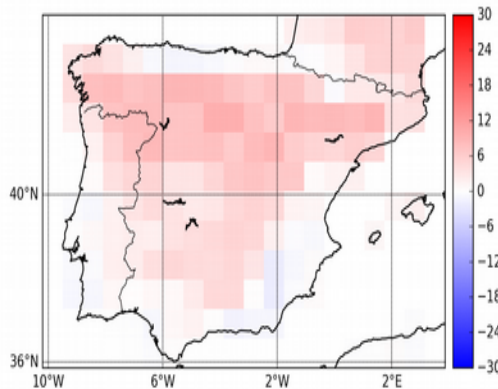


September



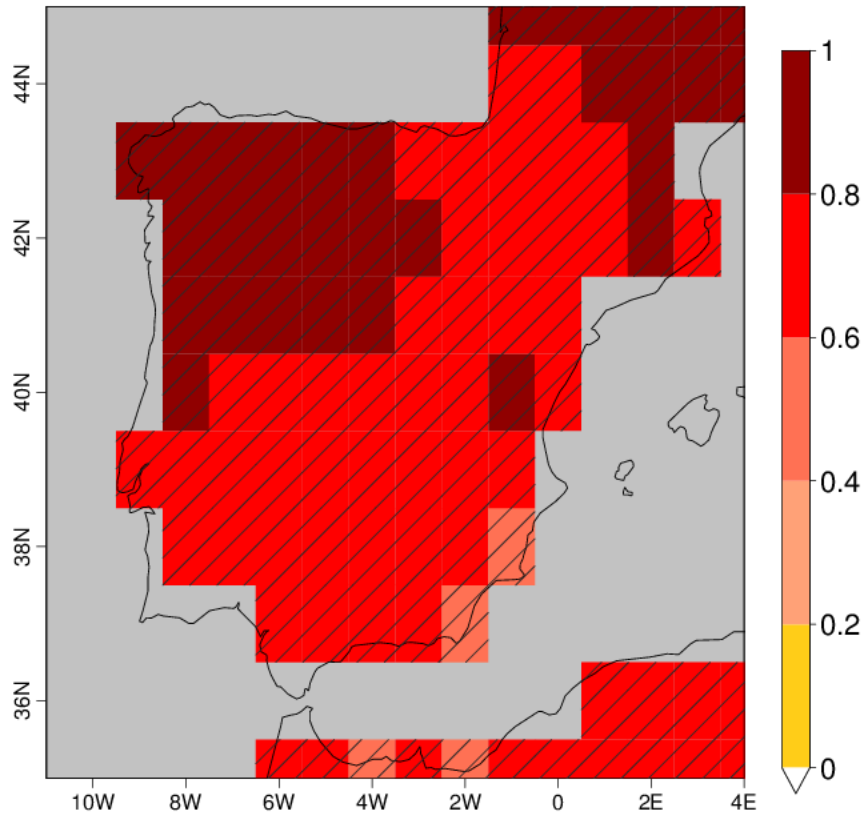
October

SEAS5 FWI

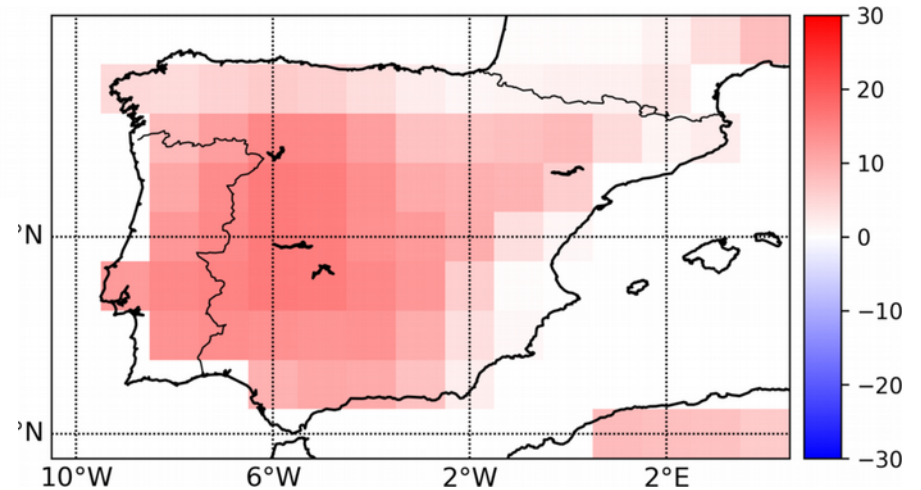


Anomaly Correlation Coefficient (ACC) of SEAS5 FWI predictions over Iberia, initialized in October – much better!!!

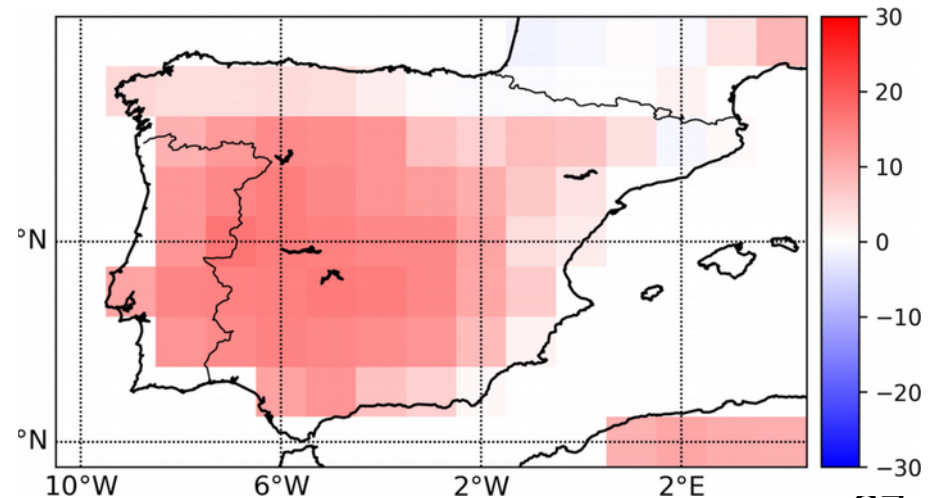
Ens-corr monthly fwi seas5-eraint Oct startdate-lead 0



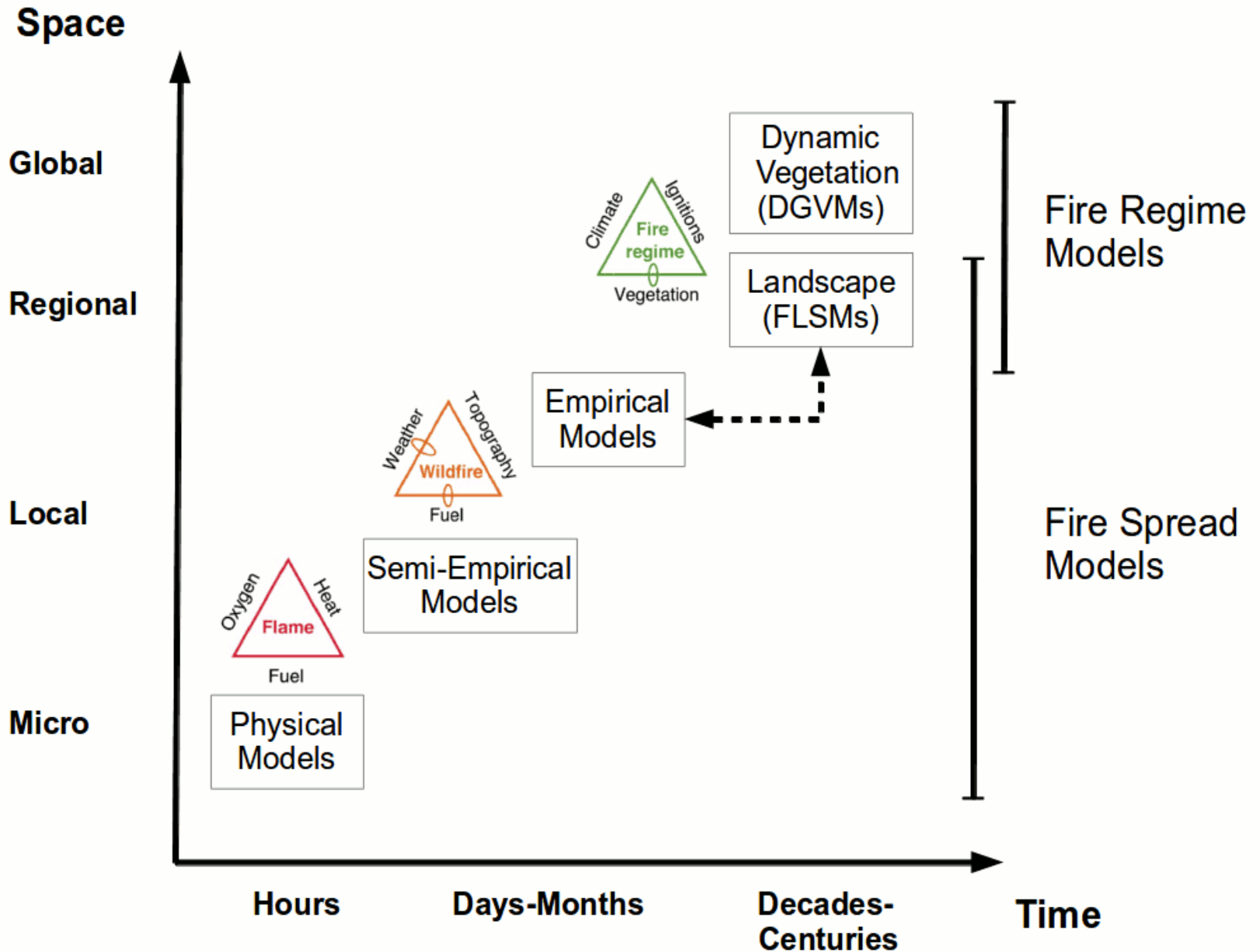
ERA-Interim October FWI anomaly



SEAS5 October FWI anomaly



Fire modeling across scales



Using SPI/SPEI indices (based on precipitation and temperature), multi-model ensembles of seasonal prediction systems can be used to predict Burned Area.

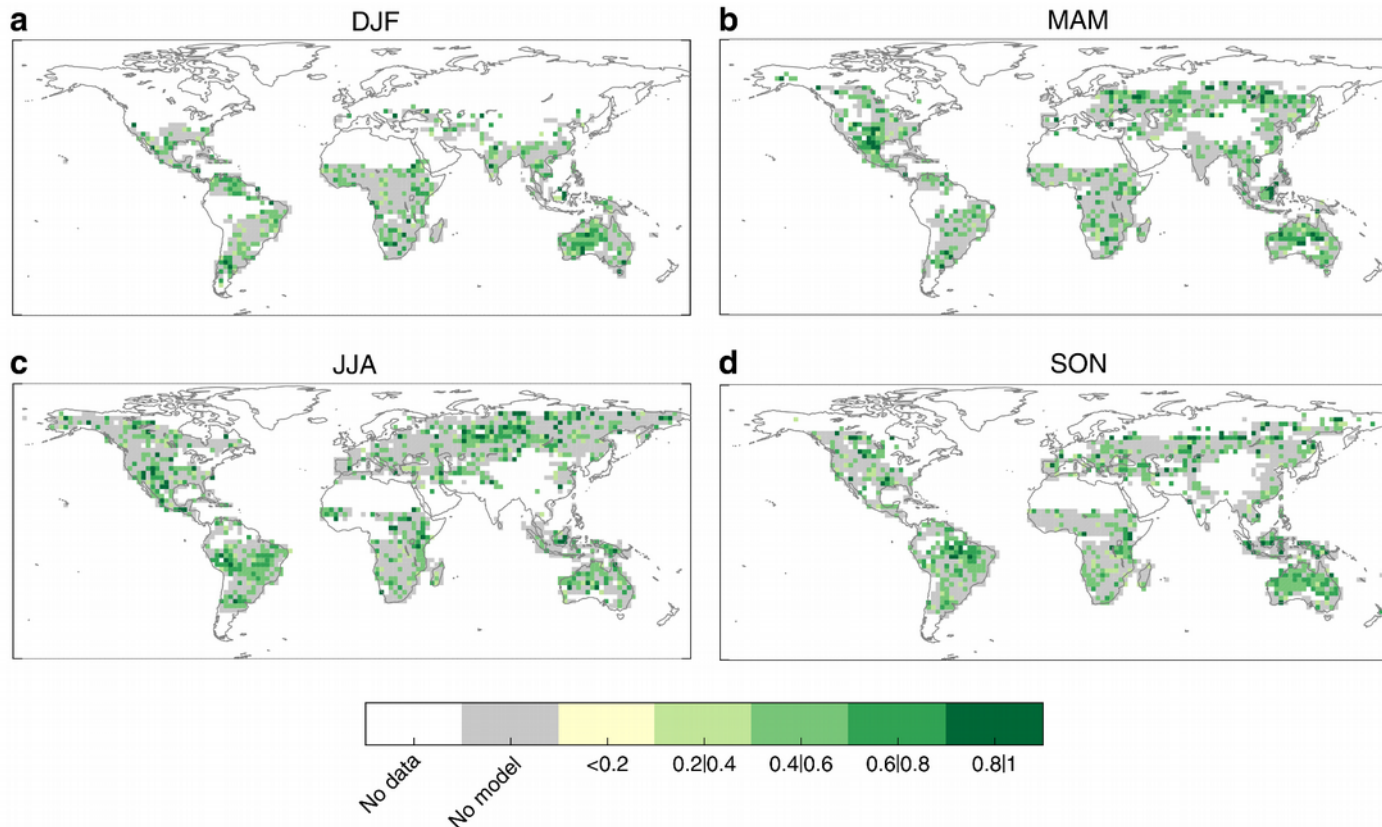
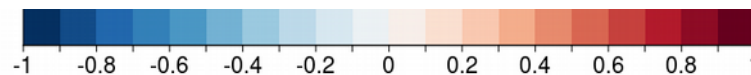
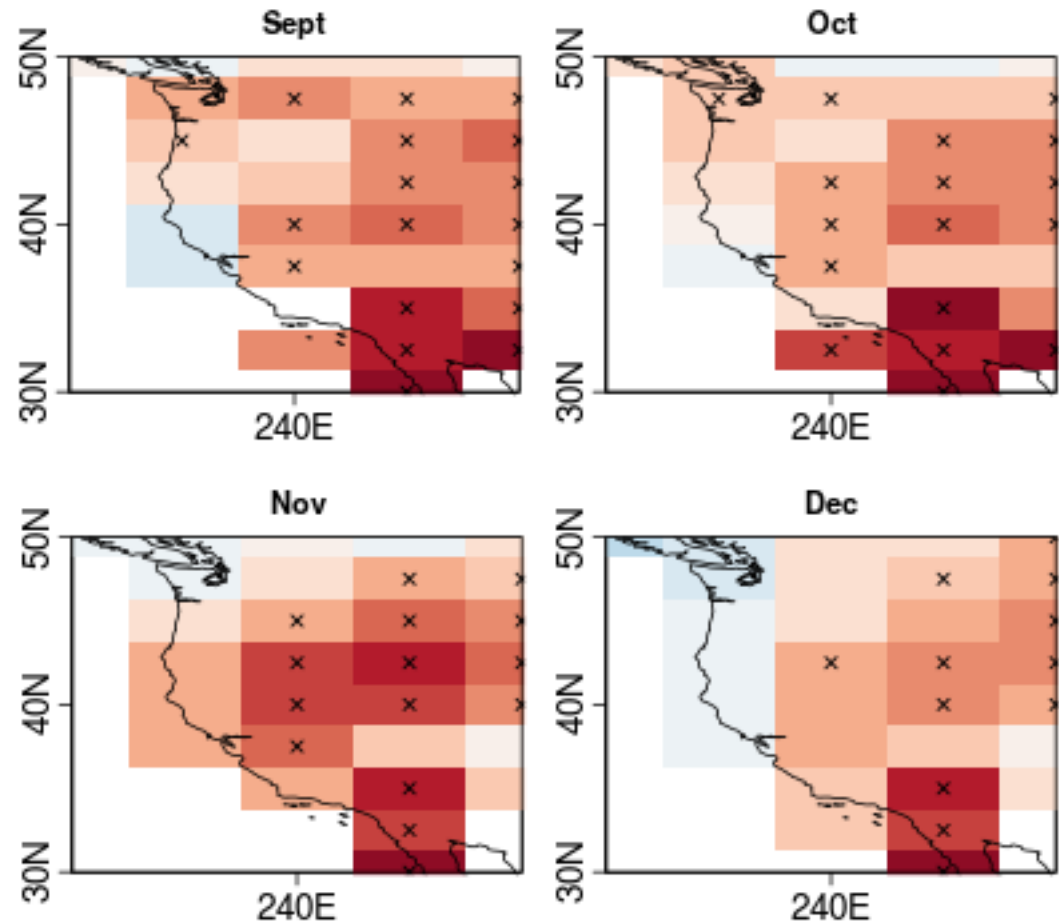


Fig. 5 Skill of burned area predictions obtained from the seasonal forecast ensemble BESTENS. Correlations of out-of-sample burned area (BA) predictions using the SPI-BA model fed with seasonal forecasts of SPI from the BESTENS for **a** December–January–February (DJF), **b** March–April–May (MAM), **c** June–July–August (JJA) and **d** September–October–November (SON). Only correlations that are significant (p -value < 0.05) are shown in green colours. Grey colour shadows the grid points with non-significant correlation values. White indicates areas where fires do not occur (e.g. sea) or have not been recorded

Long-term drought conditions can be estimated using the standardized precipitation evapotranspiration index over a 6 month temporal scale (SPEI6; Vicente-Serrano et al., 2010).

We show here the skill of a multi-model hindcast of drought conditions over the forecast years 2-5 over Western US.

Future work will evaluate the correspondance between Burned Area and SPEI6 and valuate the skill in predicting burned area from decadal forecasts.



A wildfire seasonal prediction system using ECMWF SEAS5 predictions and wildfire forecasting infrastructure has been tested.

- Preliminary results show some skill (1-2 months lead time) over California and Iberian peninsula
- However, FWI was not well predicted over California in 2017 with more than 2 months lead time, better results over the Iberian peninsula
- These results suggest that FWI is predictable at the sub-seasonal to seasonal timescale, not strictly seasonal timescale.
- Decadal prediction is a relatively new field in climate science, an interesting application is the prediction of fire danger and burned area by using simple drought indices.
- Future work:
 - Study potential in the tropical regions (e.g. Indonesia, South America)
 - Use thresholds / quantiles for forecasting fire danger classes instead of absolute FWI values
 - Use other seasonal prediction systems to make a multi-model forecast
 - Apply bias correction techniques (e.g. QQ mapping)
 - Decadal predictions using SPEI and Dynamic Vegetation Models!



Thank you!

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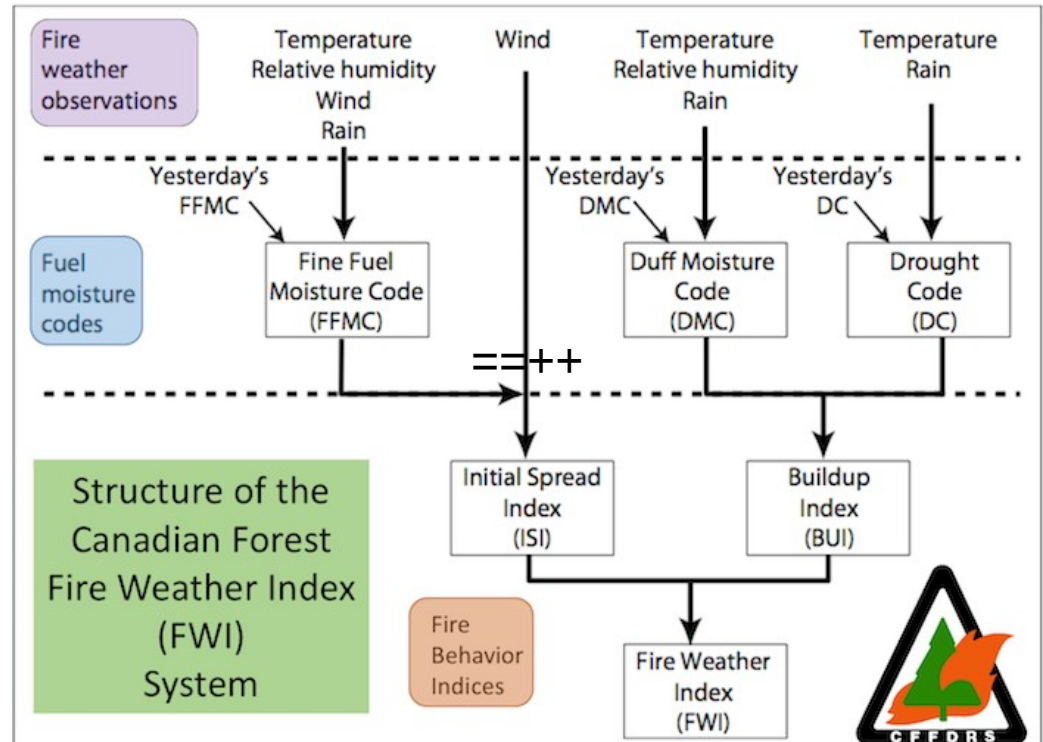
Canadian Fire Weather Index

The Canadian Fire Weather Index (FWI) is used operationally for short- and medium- term forecasting of fire danger in Canada.

It relies on daily observations of precipitation, temperature, wind and relative humidity at 12h local time.

It has been adopted by the (European Forest Fire Information System) EFFIS and Global Wildfire Information System (GWIS) for producing 10-day forecasts of fire danger in Europe.

However, these systems do not go beyond the 10-day short term forecast timeframe.



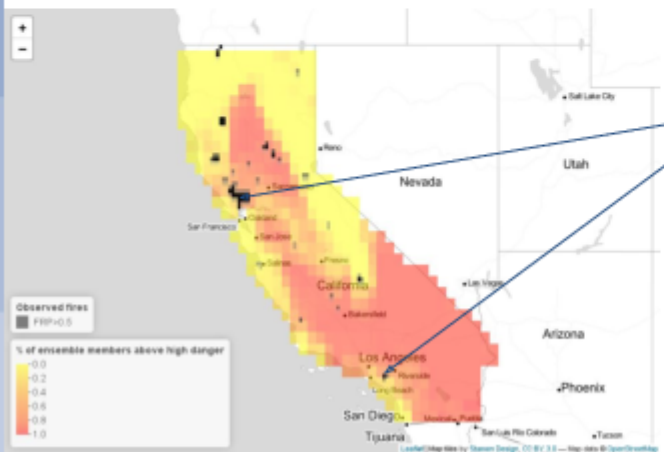
(source: <http://www.fbfrg.org/cffdrs/fire-weather-index-fwi-system>)

Another example: the California fire

California fire (8-11 October 2017)

The **2017 California wildfire season** was the most destructive wildfire season on record, which saw multiple wildfires burning across California. A total of 9,133 fires burned 1,381,405 acres (5,590.35 km²), according to the California Department of Forestry and Fire Protection, including five of the 20 most destructive wildland-urban interface fires in the state's history.

State data showed that the large wildfires killed 43 people – 41 civilians and 2 firefighters - higher than the previous 10 years combined



Observed fires

Probabilistic information provided by the fire forecast Ensemble prediction system

Long-term drought conditions can be estimated using the standardized precipitation evapotranspiration index over a 6 month temporal scale (SPEI6; Vicente-Serrano et al., 2010).

We show here the skill of the EC-Earth climate model at forecasting drought conditions over the forecast years 2-5 over Europe.

