GFAS-CLIM :
A Climate Data Record for ECV ‘fire disturbances’

MAX PLANCK INSTITUTE
FOR CHEMISTRY

DLR Symposium: Neue Perspektiven der Erdbeobachtung

25 - 27 June 2018, Köln

Gefördert durch:

Bundesministerium
für Wirtschaft
und Technologie

aufgrund eines Beschlusses
des Deutschen Bundestages

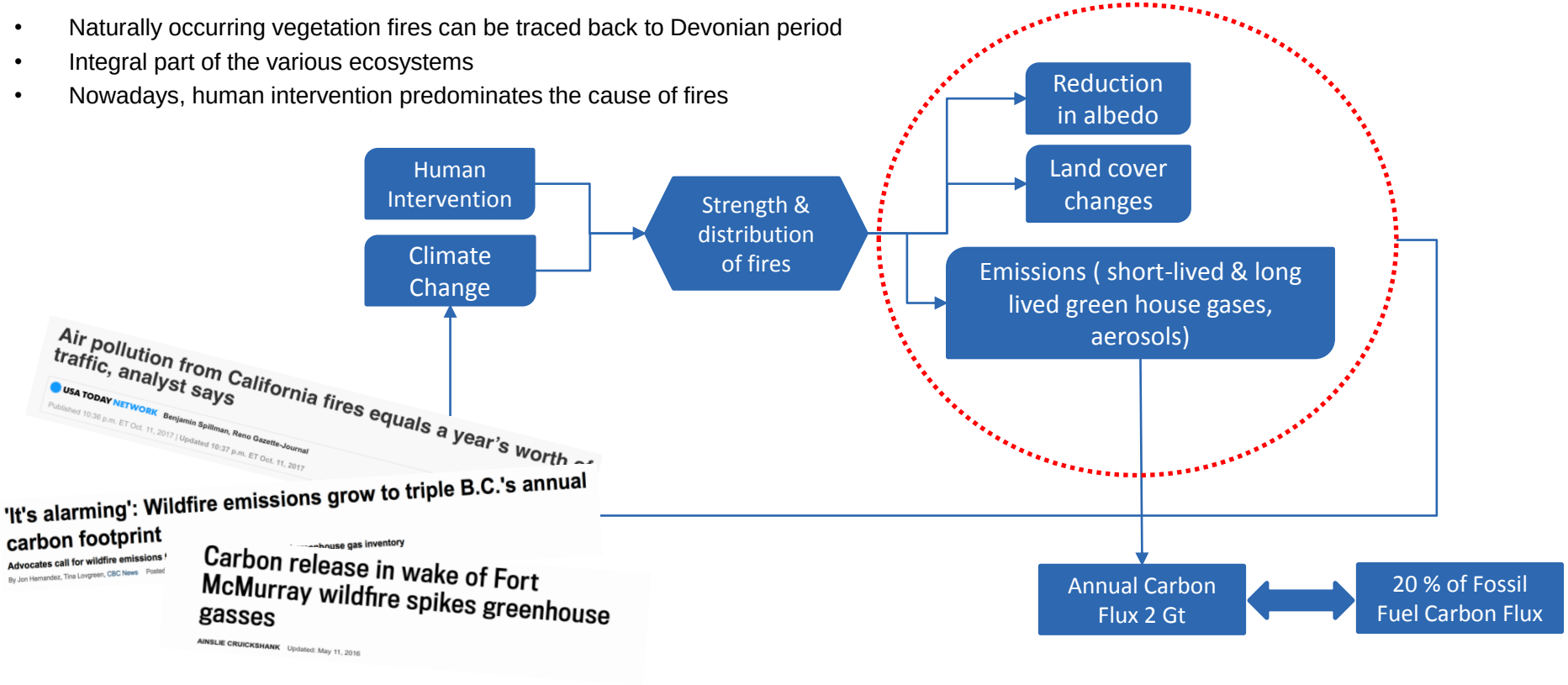
Inderpreet Kaur, J. W. Kaiser
Max Planck Institute for Chemistry,
Mainz

Vegetation Fires

(forest fires, agricultural residual burning, peat fires)

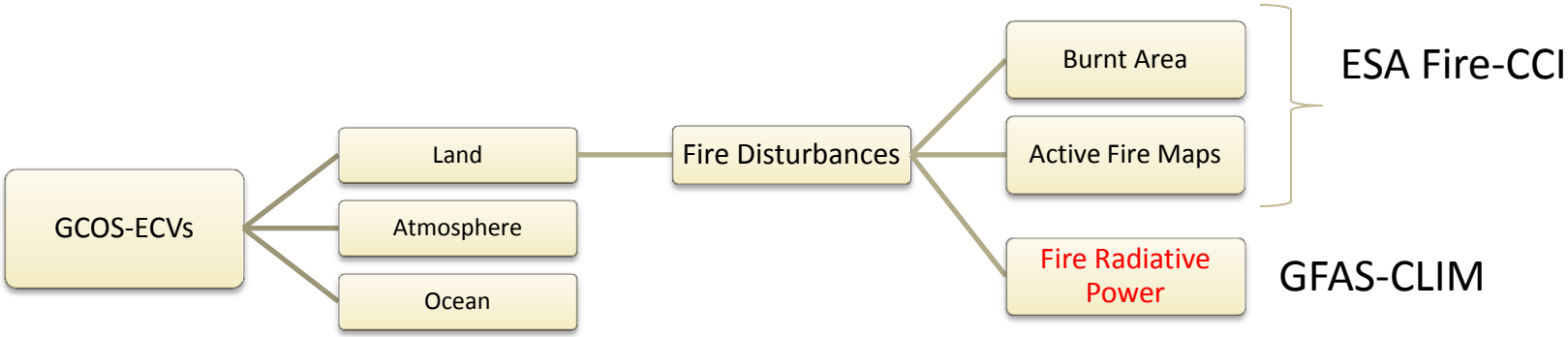
MAX PLANCK INSTITUTE FOR CHEMISTRY

- Naturally occurring vegetation fires can be traced back to Devonian period
- Integral part of the various ecosystems
- Nowadays, human intervention predominates the cause of fires



Global Climate Observing System : GCOS

Global Climate Observing System (GCOS) aims to provide:
- access to the climate observations, data records and information
- to assess the climate related issues.
- define 54 Essential Climate Variables (ECVs)



Fire radiative power (FRP)

- The **Fire Radiative Power** (FRP) measures the rate of radiant heat output from a fire.

- FRP of a fire is related to the rate at which fuel is being consumed *(Wooster et al., 2005)* and smoke emissions.

- FRP measurements are used to assess the contribution of biomass burning to local and global carbon budgets.

Active Fire Detections → Fire radiative power (FRP) → Biomass burnt → Emission estimates

Development of the **Global Fire Assimilating System – GFAS**

- Operated at ECMWF
- Input data for the atmospheric chemistry model at CAMS
- Open to external users

Global Fire Assimilation System - GFAS

MAX PLANCK INSTITUTE FOR CHEMISTRY

Current Operational Version :

MODIS (Aqua/Terra) FRP-based

FRP assimilation with Kalman filter

- Fire persistence based assumption
- observations gaps
- partial cloud cover

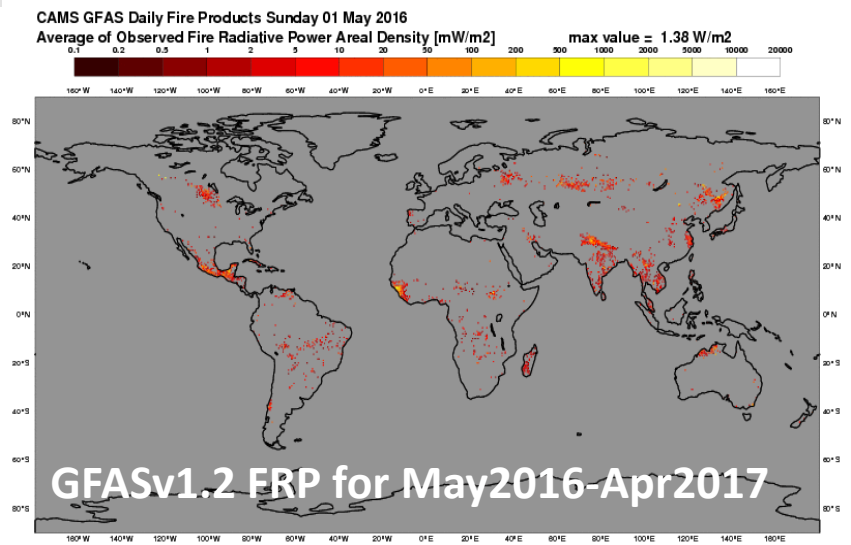
spurious signal mask

- volcanoes
- gas flares / industry

emission fluxes

- 40 smoke constituents
- 0.1° (≈10km)

One of the operational real time services of CAMS
Link : https://atmosphere.copernicus.eu



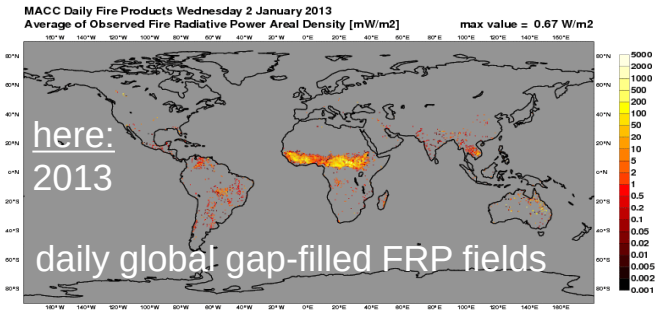
http://atmosphere.copernicus.eu/fire
[Kaiser et al. BG 2012]

Next GFAS version – updates:

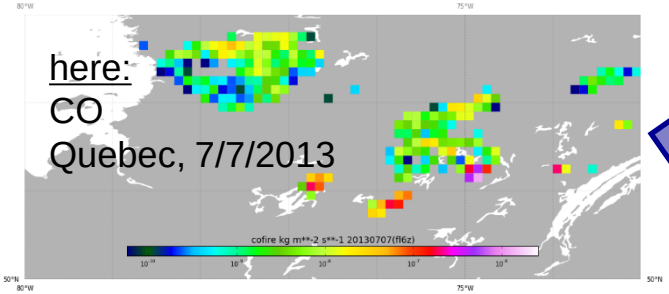
- improved FRP uncertainty representation
- more satellite products: SEVIRI,VIIRS, GOES, Himwari-8
- Temporal resolution 24h → 1h
- dynamic emission factors
- Diurnal cycle parametrisation
- emission forecasting

GFAS in Copernicus Atmosphere Monitoring Service (CAMS)

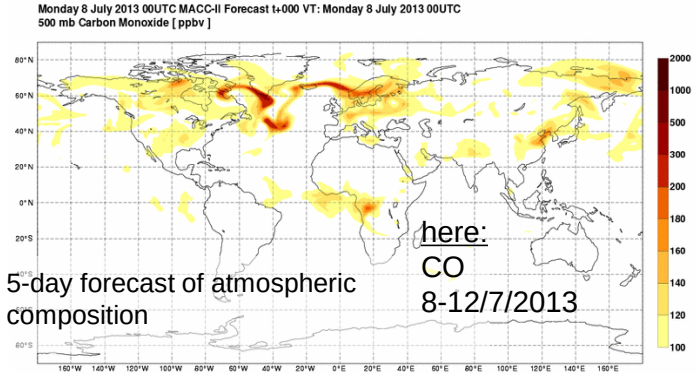
MAX PLANCK INSTITUTE FOR CHEMISTRY



0.1º fluxes of 40 smoke constituents



air quality forecasts



- Only real time operations
- Can we get better FRP estimates?
- Are there any new requirements?

[Inness et al. 2009, Flemming et al. 2014, Morcrette et al. 2009, Benedetti et al. 2009]

CORE-CLIMAX CDR maturity matrix – *reach initial operations capabilities*

MAX PLANCK INSTITUTE FOR CHEMISTRY

- CORE-CLIMAX defines a system maturity matrix for CDRs
- allow assessment of status of CDR generation systems

Software Readiness	Metadata	User Documentation	Uncertainty Characterization
•PEP-8 python coding standard •submission for security review	• netCDF - CF compliant	• validation report • user guide	• FRP uncertainty in FRP units (Wm^{-2})

In synergy with CAMS-GFAS

GCOS requirements for CDR:

MAX PLANCK INSTITUTE FOR CHEMISTRY

GCOS requirement

- 6 hours (1 from geostationary satellite)
- 0.25-1 km

GFAS-CLIM target

- 1 hour
- 0.05°, approx. 5 km

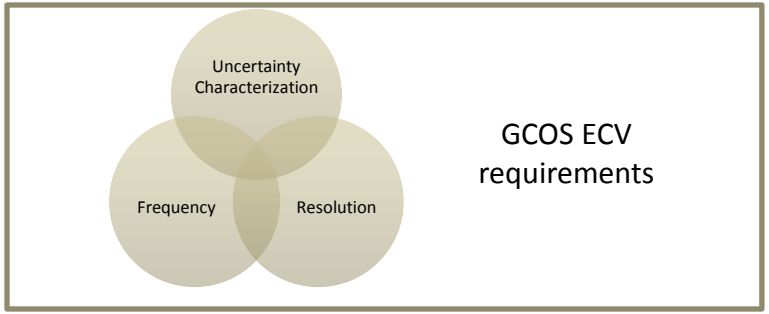
Dataset	GFAS-CLIM v1.4
Time Period	2005 – 2011 (available) ; to be done: 2003 - present
Input Satellite Data	MOD14 MODIS FRP observations
Format	Grib/ netCDF
Frequency / Resolution	Hourly/ 0.05 deg
Area	Global

GFAS-CLIM Overview

MAX PLANCK INSTITUTE FOR CHEMISTRY

Aim : provide the world-wide best CDR for the *FRP* element of the ECV *fire disturbance*

Optimize GFAS



Approach:

- exploit opportunity of retrospective production, as opposed to **real time** service in CAMS (Kalman Filter → Kalman Smoother)
- Improve spatial and temporal resolution
- prepare using Copernicus Sentinel-3 (data to be available after autumn?)

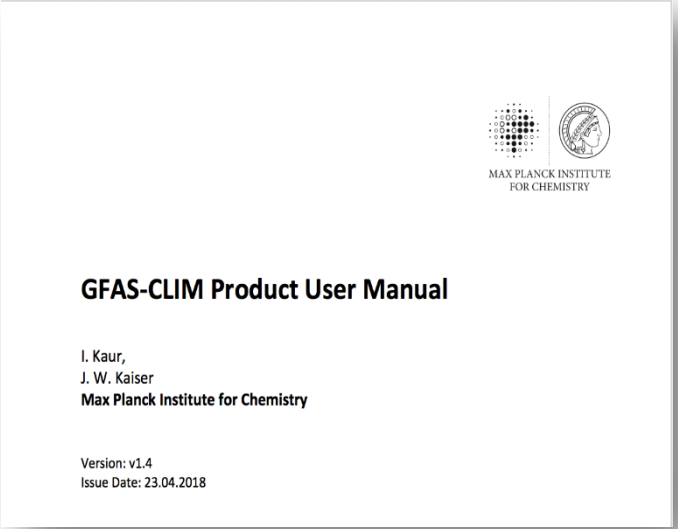
disseminate through GEIA portal http://eccad.sedoo.fr

GFAS-CLIM Status

MAX PLANCK INSTITUTE FOR CHEMISTRY

Achieved:

- Spatial resolution : 0.05 deg
- Temporal resolution : 1 hour
- Data format : netCDF – CF compliant
- PEP-8 python code standard
- Product User Manual (will be updated over time)



MAX PLANCK INSTITUTE FOR CHEMISTRY

GFAS-CLIM Product User Manual

I. Kaur,
J. W. Kaiser
Max Planck Institute for Chemistry

Version: v1.4
Issue Date: 23.04.2018

https://www.mpic.de/uploads/media/User_Guide_GFAS-CLIM_20180423.pdf

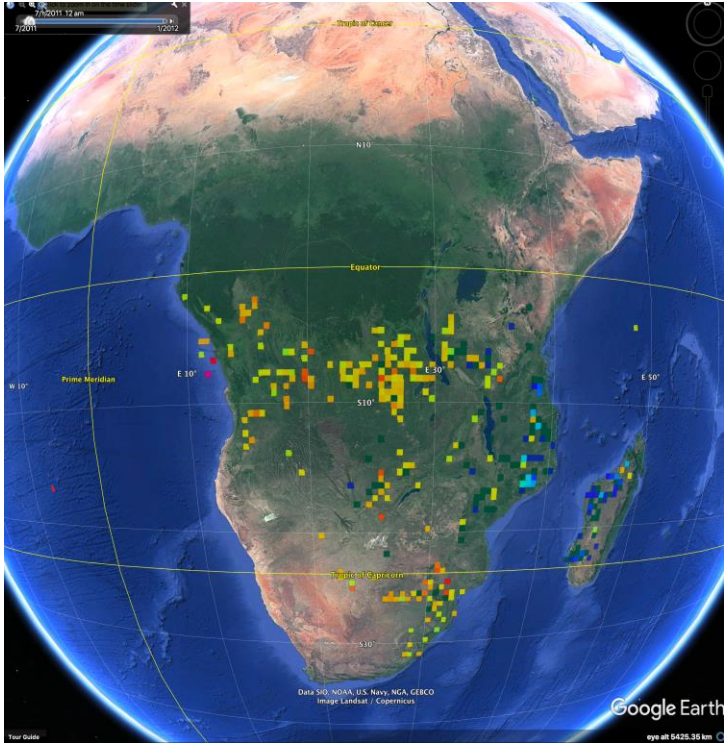
Ongoing:

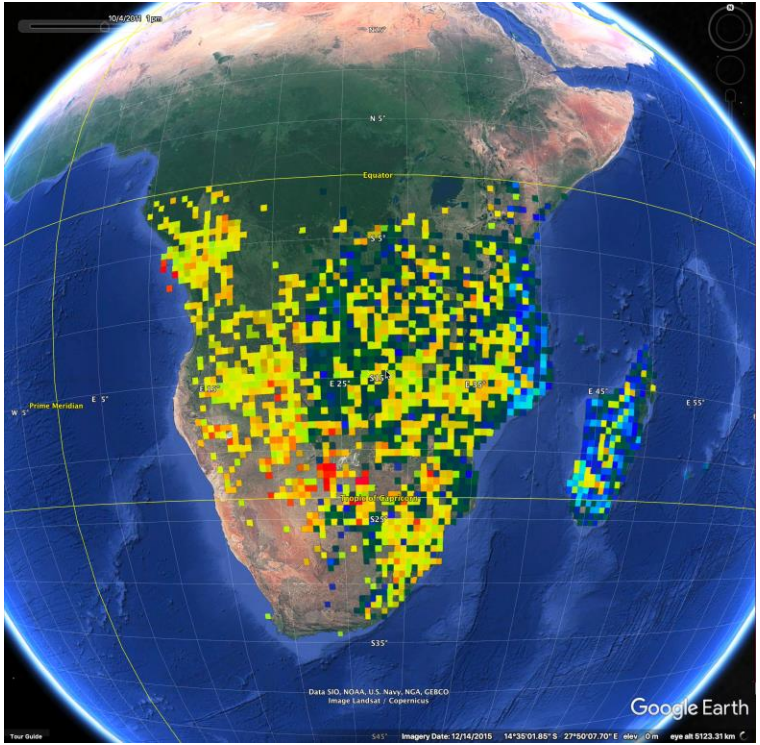
- Kalman Smoother
- Validation report

Improved temporal and spatial resolution

MAX PLANCK INSTITUTE
FOR CHEMISTRY

http://satfire.de/GFAS-CLIM.kml





Kalman Smoother

The Kalman Smoother utilizes future measurements for the state estimation and this method can be exploited only in the retrospective analysis. The Kalman smoother is implemented in three steps:

- **Forward Pass** : Kalman Filter in forward direction

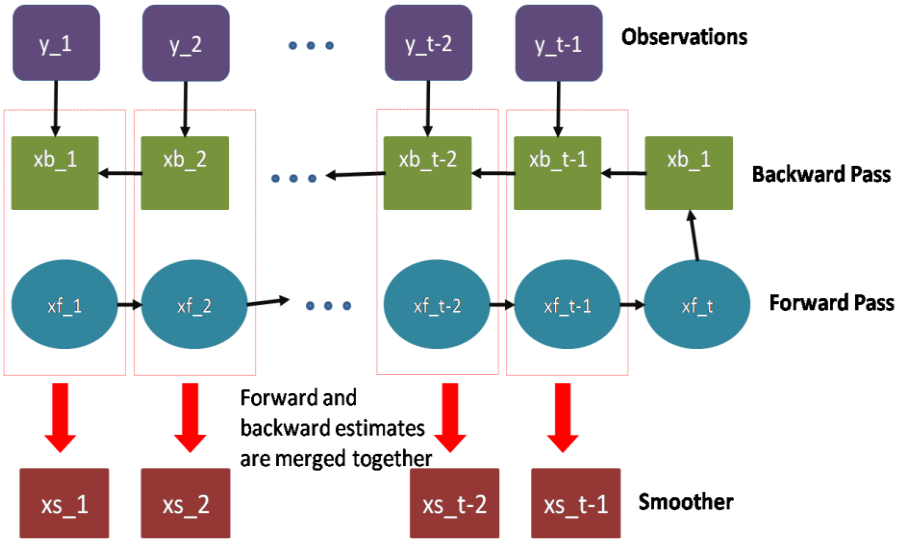
$$\hat{x}^f_{k+1} = F_k \hat{x}^b_k$$

- **Backward Pass** : Kalman Filter in backward direction

$$\hat{x}^b_k = F^{-1}_{k+1} \hat{x}^b_{k+1}$$

- **Merging two Estimates** : The backward pass is stopped at the time step before the point of interest and a prediction step is performed. The two estimates are merged through optimal interpolation:

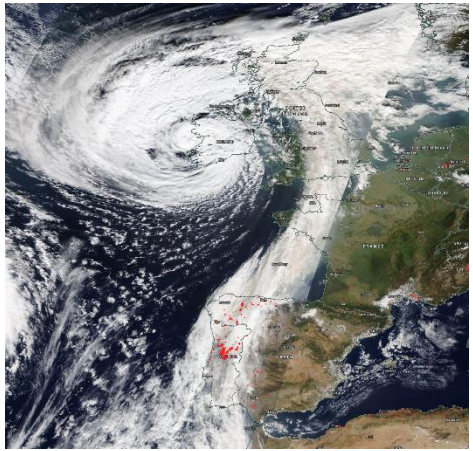
$$\hat{x}^s_k = \sigma^s_k [\sigma_f^{-1} \hat{x}^f_k + \sigma_b^{-1} \hat{x}^b_k]$$



October 14-17 2017, Portugal: An intersection of extreme events

MAX PLANCK INSTITUTE FOR CHEMISTRY

Ex-hurricane “Ophelia” fanned wildfire in Portugal and spread smoke over Europe



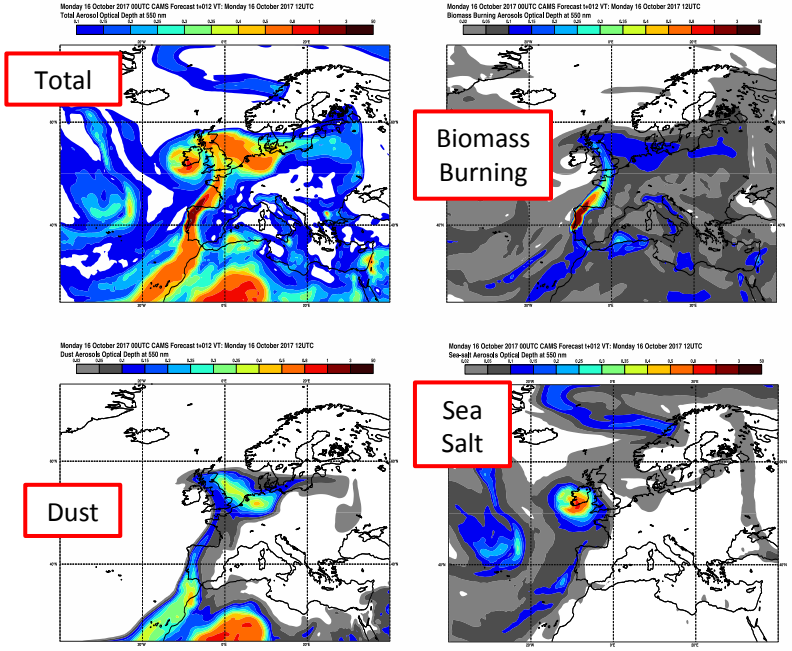
NASA worldview 16-10-2017

Strong winds from Ex-Hurricane Ophelia fanned large scale fires in Portugal and Spain between 15-16 October 2017. This intersection of two extreme events lead to a huge transport of the smoke from the wildfires and dust from Sahara desert to Europe.

15-10-2017
GFAS 1h (MODIS) analysis – mean daily FRP
Fires and Thermal Anomalies MODIS + VIIRS

Chemistry Transport Models require accurate estimates of fire emission fluxes

Model forecasts from the Copernicus Atmosphere Monitoring System (CAMS) simulated the aerosols track towards the UK

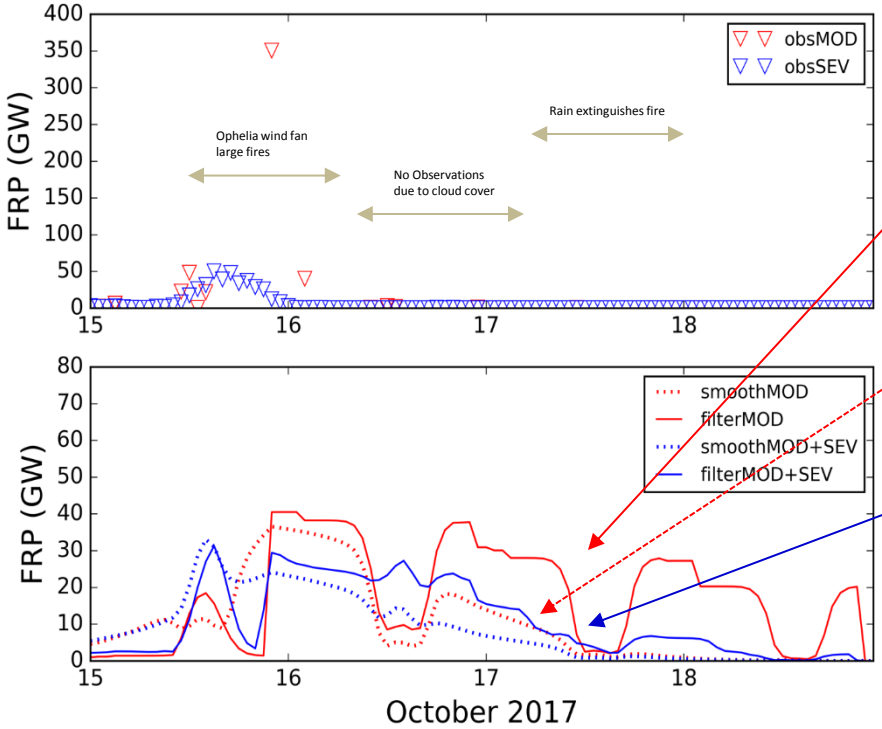


Slide courtesy, I. Hüser, MPIC

Results : Kalman Smoother

MAX PLANCK INSTITUTE FOR CHEMISTRY

We applied the Kalman Smoother to GFAS data from 14-30 October 2017 to evaluate its performance on the FRP fields over Portugal and Spain.



Artefacts in diurnal cycle due to Kalman Filter persistence assumption

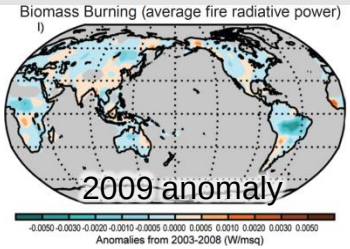
Kalman smoother removes these ambiguous values

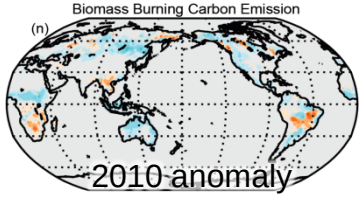
Similar effect is observed when SEVIRI observations are also assimilated

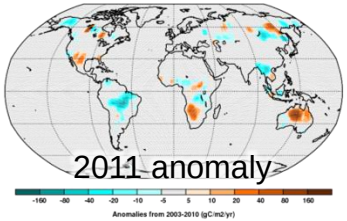
Contribution to State of the Climate (SotC)

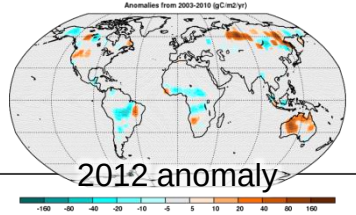
MAX PLANCK INSTITUTE FOR CHEMISTRY

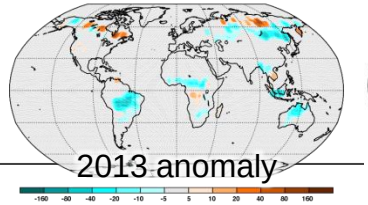
From NOAA *"State of the Climate"* reports:
[Kaiser, Goldammer, van der Werf, Heil, BAMS 2010-2018] graphics courtesy Kate Willett & Robert Dunn











Stronger than usual fire activity in N. America

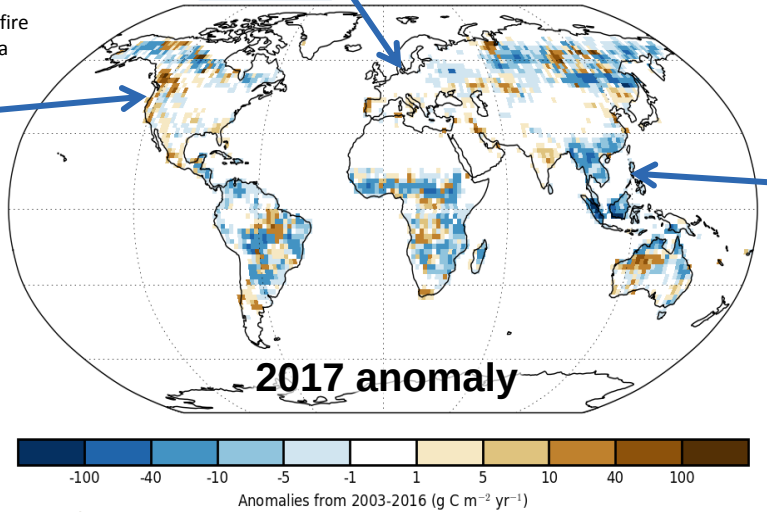
+36%

+22%

Exceptionally long burning seasons in Portugal and Galicia (Spain)

High rainfall rates

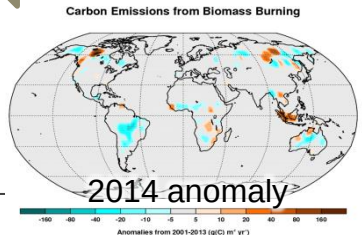
-84%

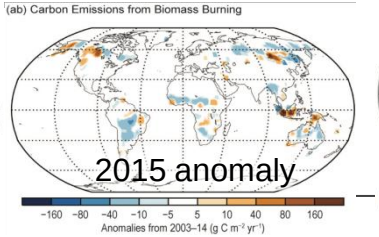


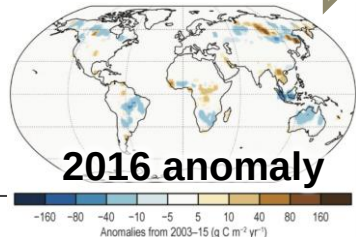
CAMS-GFAS contributed to SotC till 2015, but since 2016 GFAS-CLIM datasets have been used.

GFAS

GFAS-CLIM







Summary

MAX PLANCK INSTITUTE FOR CHEMISTRY

- GFAS provides emission estimates on real time for use in European air quality forecasts and global atmospheric composition.
- GFAS-CLIM is a version which aims at climate applications.
- GFAS-CLIM provide the world-wide best CDR for the *FRP* element of the ECV *fire disturbance.*
- Dataset adheres to CORE-CLIMAX system maturity matrix atleast in initial operations.
- Offers retrospective analysis, use of kalman smoother