DLR Symposium: Neue Perspektiven der Erdbeobachtung
25 - 27 June 2018, Köln

Inderpreet Kaur, J. W. Kaiser
Max Planck Institute for Chemistry,
Mainz
Vegetation Fires
(vegetation fires, agricultural residual burning, peat fires)

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

Diagram:
- Human Intervention
- Climate Change
- Strength & distribution of fires
- Reduction in albedo
- Land cover changes
- Emissions (short-lived & long-lived greenhouse gases, aerosols)

- Annual Carbon Flux 2 Gt
- 20% of Fossil Fuel Carbon Flux

Air pollution from California fires equals a year’s worth of traffic, analyst says.

It’s alarming: Wildfire emissions grow to triple B.C.’s annual carbon footprint.

Carbon release in wake of Fort McMurray wildfire spikes greenhouse gases.
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.

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

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

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

http://atmosphere.copernicus.eu/fire
[Kaiser et al. BG 2012]
GFAS in Copernicus Atmosphere Monitoring Service (CAMS)

Daily global gap-filled FRP fields

0.1° fluxes of 40 smoke constituents

5-day forecast of atmospheric composition

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

CORE-CLIMAX CDR maturity matrix — reach initial operations capabilities

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

<table>
<thead>
<tr>
<th>Software Readiness</th>
<th>Metadata</th>
<th>User Documentation</th>
<th>Uncertainty Characterization</th>
</tr>
</thead>
<tbody>
<tr>
<td>• PEP-8 python coding standard • submission for security review</td>
<td>• netCDF - CF compliant</td>
<td>• validation report • user guide</td>
<td>• FRP uncertainty in FRP units (Wm⁻²)</td>
</tr>
</tbody>
</table>

In synergy with CAMS-GFAS
GCOS requirements for CDR:

<table>
<thead>
<tr>
<th>GCOS requirement</th>
<th>GFAS-CLIM target</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 6 hours (1 from geostationary satellite)</td>
<td>• 1 hour</td>
</tr>
<tr>
<td>• 0.25-1 km</td>
<td>• 0.05°, approx. 5 km</td>
</tr>
</tbody>
</table>

**Dataset GFAS-CLIM v1.4**

<table>
<thead>
<tr>
<th>Dataset</th>
<th>GFAS-CLIM v1.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Period</td>
<td>2005 – 2011 (available); to be done: 2003 - present</td>
</tr>
<tr>
<td>Input Satellite Data</td>
<td>MOD14 MODIS FRP observations</td>
</tr>
<tr>
<td>Format</td>
<td>Grib/ netCDF</td>
</tr>
<tr>
<td>Frequency / Resolution</td>
<td>Hourly/ 0.05 deg</td>
</tr>
<tr>
<td>Area</td>
<td>Global</td>
</tr>
</tbody>
</table>
Aim: provide the world-wide best CDR for the FRP element of the ECV fire disturbance

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

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)

Ongoing:
• Kalman Smoother
• Validation report
Improved temporal and spatial resolution

http://satfire.de/GFAS-CLIM.kml
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
  \[
  \hat{x}_{k+1}^f = F_k \hat{x}_k^b
  \]

- **Backward Pass**: Kalman Filter in backward direction
  \[
  \hat{x}_k^b = F_{k+1}^{-1} \hat{x}_{k+1}^b
  \]

- **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:
  \[
  \hat{x}_k^s = \sigma_k^s \left[ \sigma_k^f \hat{x}_k^f + \sigma_k^b \hat{x}_k^b \right]
  \]
October 14-17 2017, Portugal: An intersection of extreme events

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

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

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

Chemistry Transport Models require accurate estimates of fire emission fluxes

Dust
Biomass Burning
Sea Salt

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.

Slide courtesy, I. Hüser, MPIC
Results: Kalman Smoother

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.
Contribution to State of the Climate (SotC)

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

- Exceptionally long burning seasons in Portugal and Galicia (Spain)
- High rainfall rates
- Stronger than usual fire activity in N. America
- +22% (2017 anomaly)
- +36% (2016 anomaly)
- -84% (2015 anomaly)

CAMS-GFAS contributed to SotC till 2015, but since 2016 GFAS-CLIM datasets have been used.
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 at least in initial operations.

Offers retrospective analysis, use of kalman smoother.