Surface PM2.5 and AOD Data assimilation Status update from the Global CAMS system

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European Commission

Atmosphere Monitoring

WHAT IS THE SCOPE OF CAMS?

CAMS provides consistent and quality-controlled information related to air pollution and health, solar energy, greenhouse gases and climate forcing, everywhere in the world.

Air quality

Policy tools

Solar energy

Ozone layer and UV radiation

Emissions and surface Fluxes

Climate forcing

http://atmosphere.copernicus.eu

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Global and Regional CAMS systems

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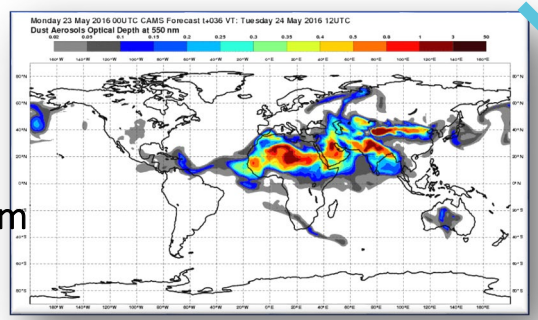
Global CAMS Emissions

GFAS wild fire emissions

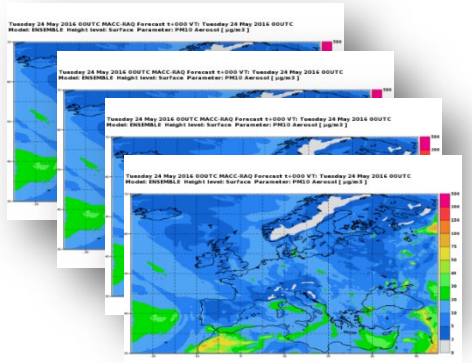
European CAMS Emissions

ECMWF IFS global, 40x40 km

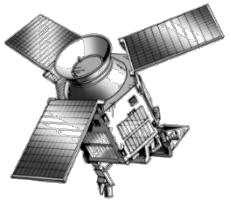


BC

11 regional CTMs over Europe, 10x10 km



Data assimilation



Satellite Observations (AOD, O_3, CO, NO_2, SO_2)

Surface AQ observations

Data assimilation

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Global CAMS operational forecast system

- ECWMF's Integrated Forecasting System (IFS) with modules for data assimilation and simulation of aerosols and reactive gases
  - 00 and 12 UTC forecast over 5 days at 40 km resolution (TL511l137)
  - Data assimilation of satellite retrievals for AOD, CO, Ozone and NO_2
  - Anthropogenic and biogenic emissions inventories (CAMS-GLOB)
  - NRT fire emissions from GFAS
- 48r1 update of CAMS o-suite (27th of June 2023)
  - Full stratospheric chemistry (BASCOE)
  - New secondary organic aerosols (biogenic and anthropogenic)
- Control forecast (00 only) without DA of atmospheric condition
  - AC IC are taken from the previous day
- CAMS aerosol model has 16 aerosol variables :
  - sea-salt (3 bin), desert dust (3 bin), OM (2), BC (2), SO4, NO3(2 bins), NH3, SOA (2)
  - Coupled to the CB05/BASCOE chemistry scheme

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Aerosol Data assimilation

- Assimilated observations of AOD at 550 nm
  - **MODIS &VIIRS** over ocean and land
  - PMAp (Metop-BC) over ocean only
  - SLSTR from Sentinel 3A/B passively monitored
- 4D-VAR with prescribed background error statistics (NMC)
- Variational Bias Correction (VarBC) for MODIS, VIIRS(SNPP) and PMAp – VIIRS (NOAA-20) is anchor
- Control variable is formulated in terms of the total aerosol and fractional contribution of each aerosol type is maintained in analysis increments
- Challenges of AOD DA:
  - Lack of vertical information in AOD retrieval
  - Lack of aerosol speciation information in AOD retrieval
  - Multi-instrument biases
  - Precision and accuracy of AOD retrieval (clouds, surface albedo, optical porperties …)

Analysis departures (an-obs) 202309

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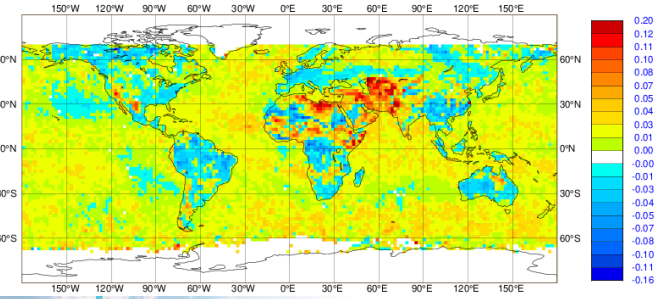
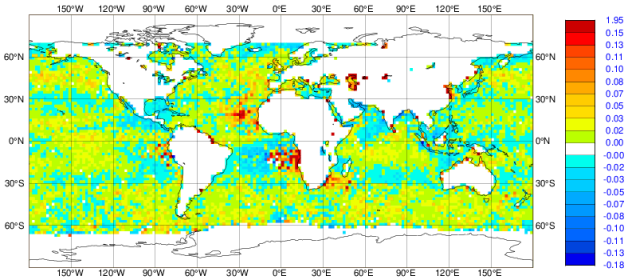
https://atmosphere.copernicus.eu/charts/packages/cams_monitoring

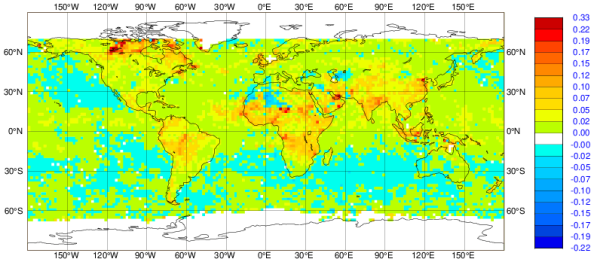
MODIS/AQUA



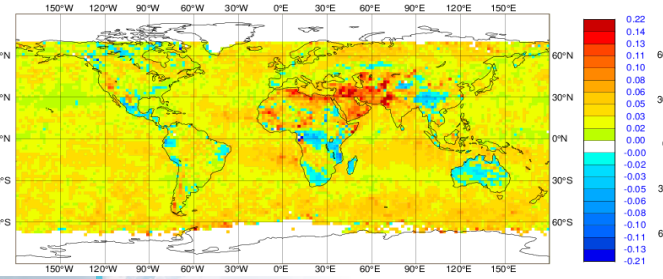
PMAP/B



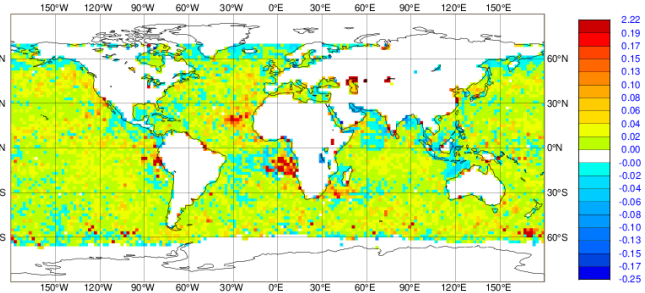
VIIRS/NOAA22



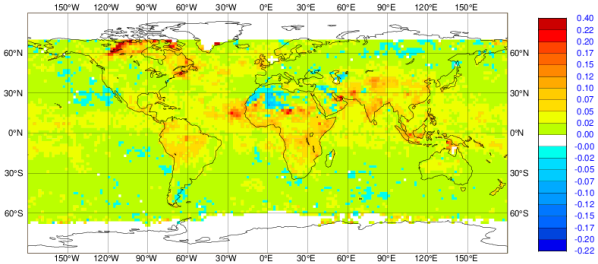
MODIS/TERRA



PMAP/C



VIIRS/SNPP



Assimilated observations only

Note the different colour ranges, esp. for PMAP

AOD retrievals show significant inter-instrument biases

30 day Mean

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AOD evaluation against AERONET (JJA 2023)

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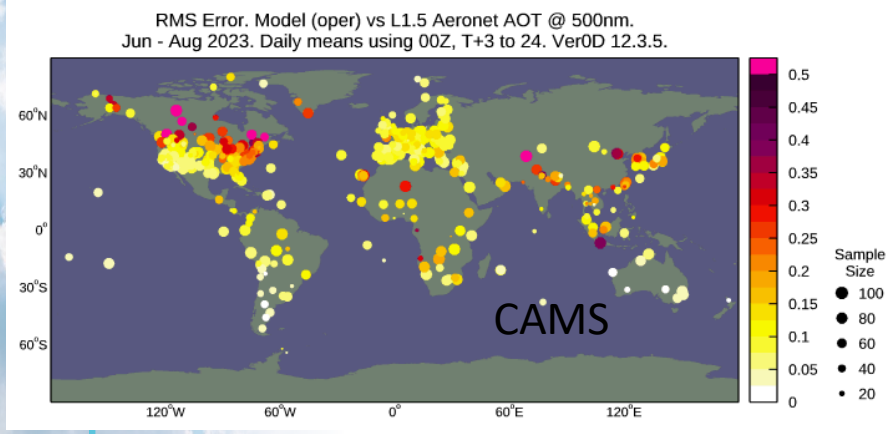
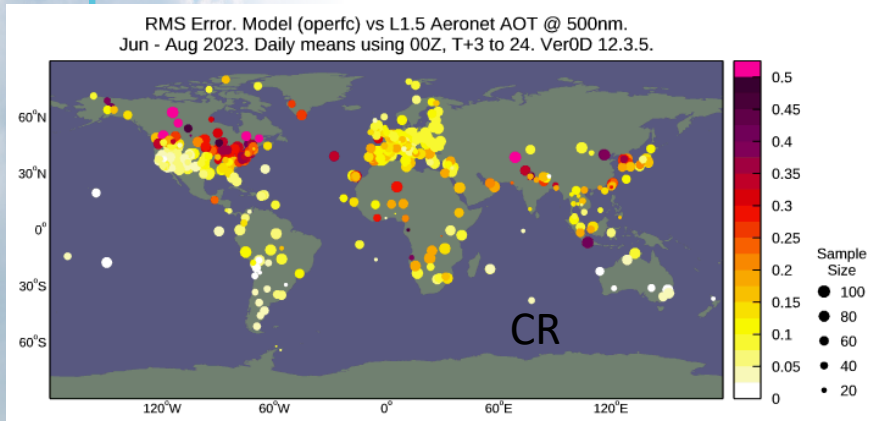
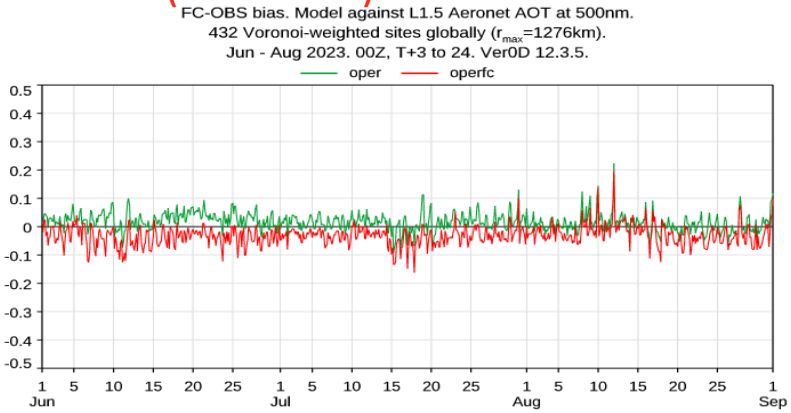
RMSE

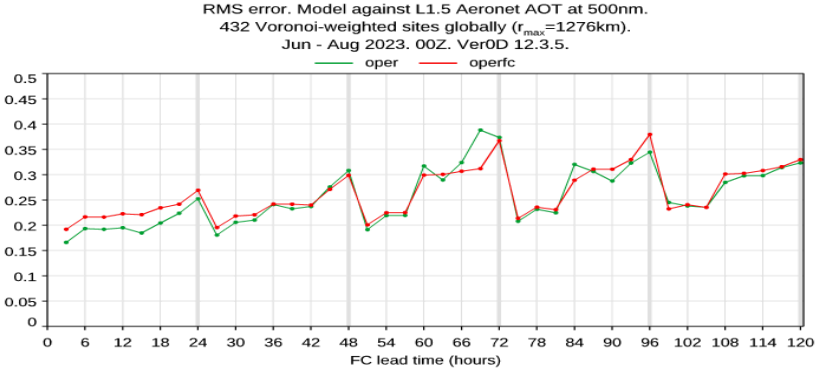




CAMS forecast (AOD DA)

Control (no AC DA)





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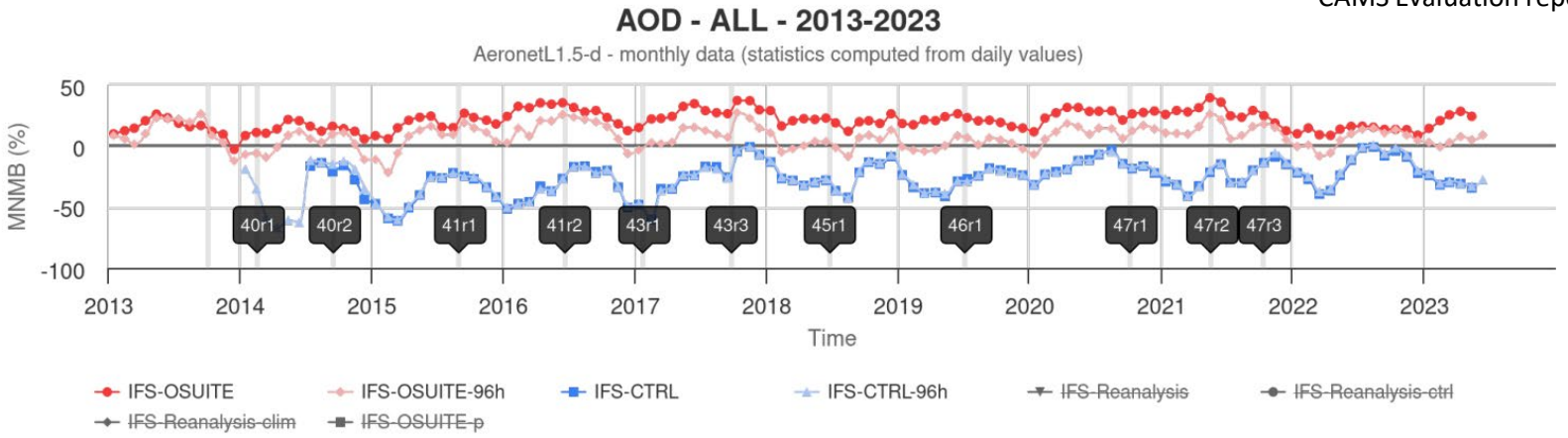
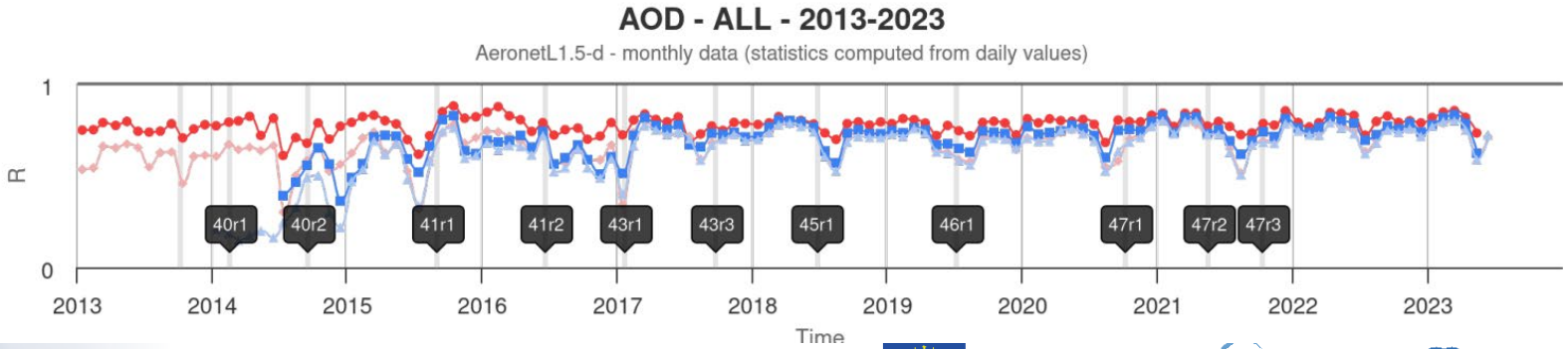
Long term performance AOD CAMS

https://atmosphere.copernicus.eu/node/1058
CAMS Evaluation report





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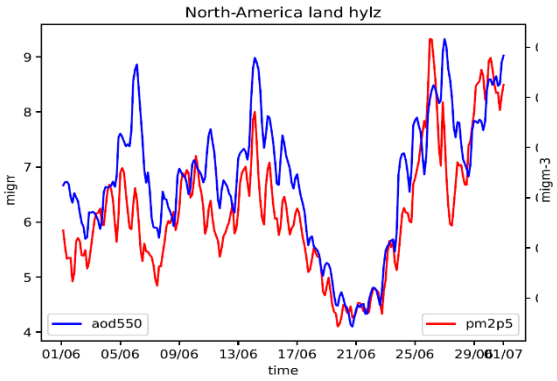
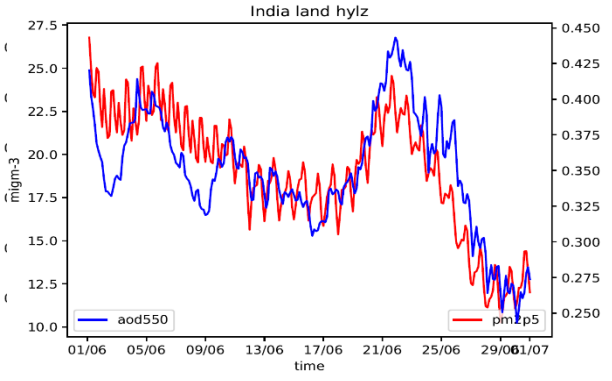
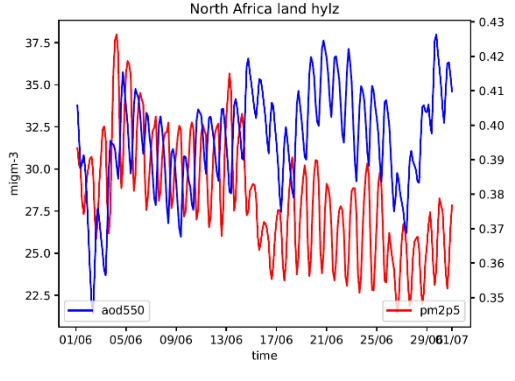
Area mean AOD-PM2.5 temporal corelation

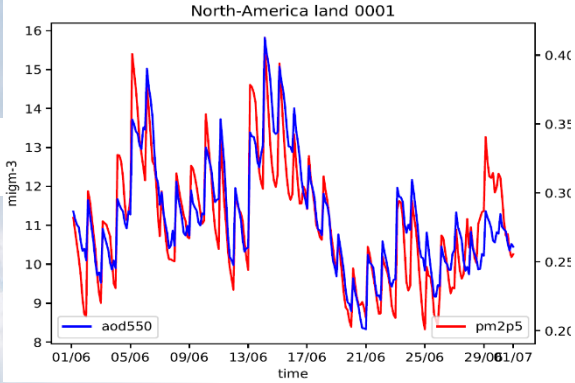
Control

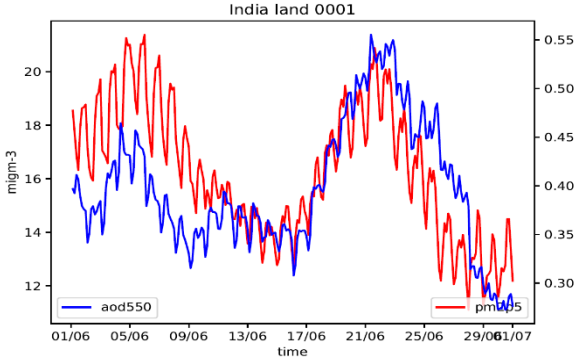
CAMS

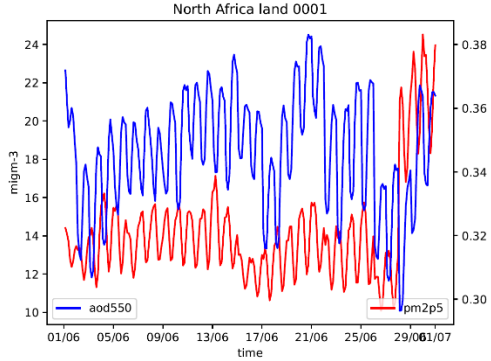












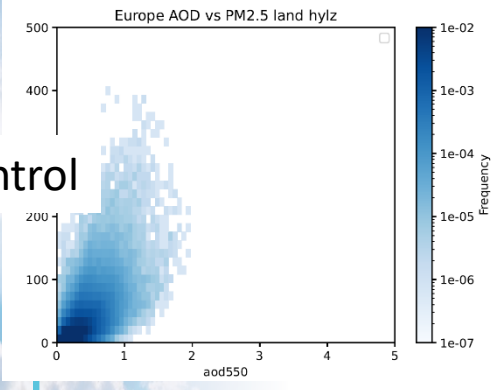
June 23

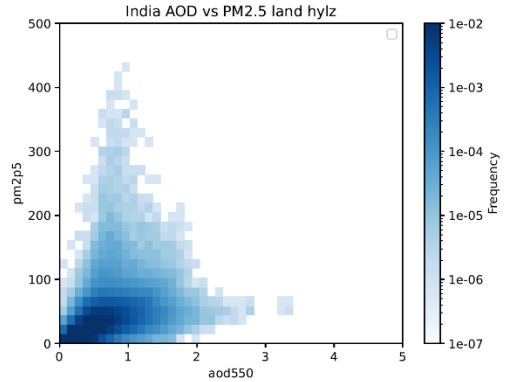
Large scale AOD and PM2.5 variability is often well correlated

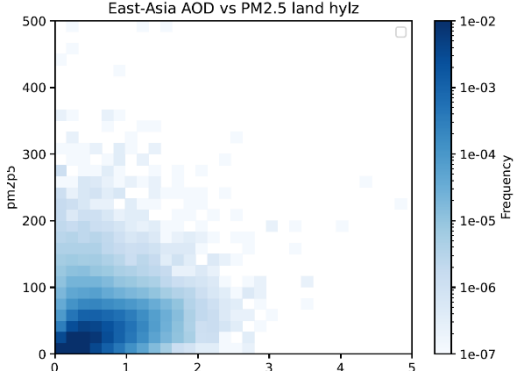
AOD PM2.5 correlation- pixel by pixel

Atmosphere M

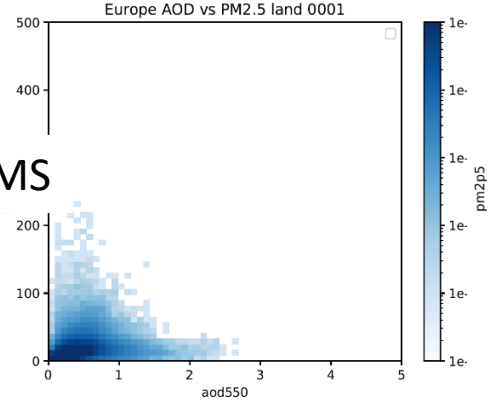
Control

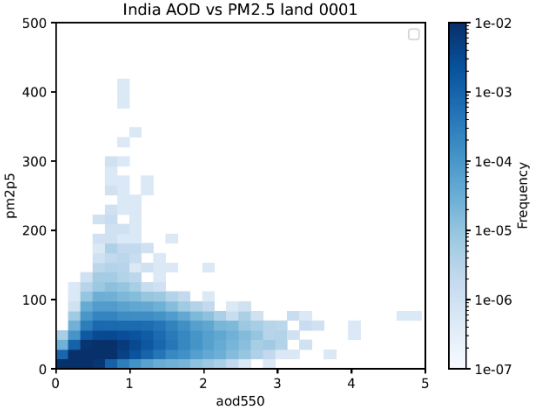


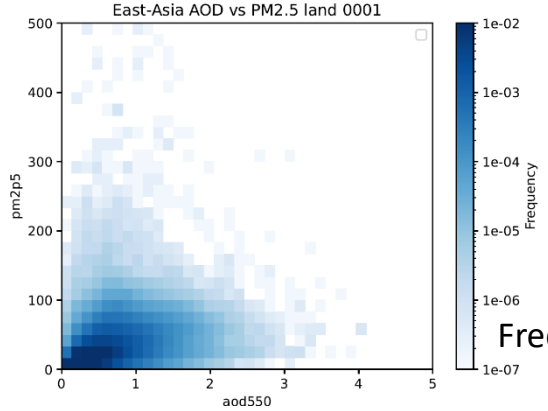




CAMS







AOD and PM2.5 differ because of

- **Vertical profiles – lofted plumes**
- **Deposition and emissions**
- Different sensitivity to hygroscopic growth

Frequency in log-scale

PM evaluation with AQ Obs. (7-9/2023)

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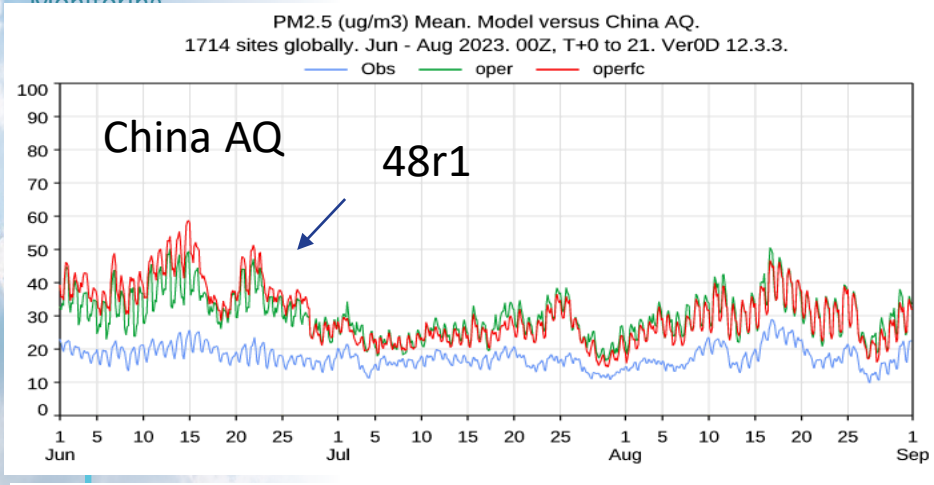

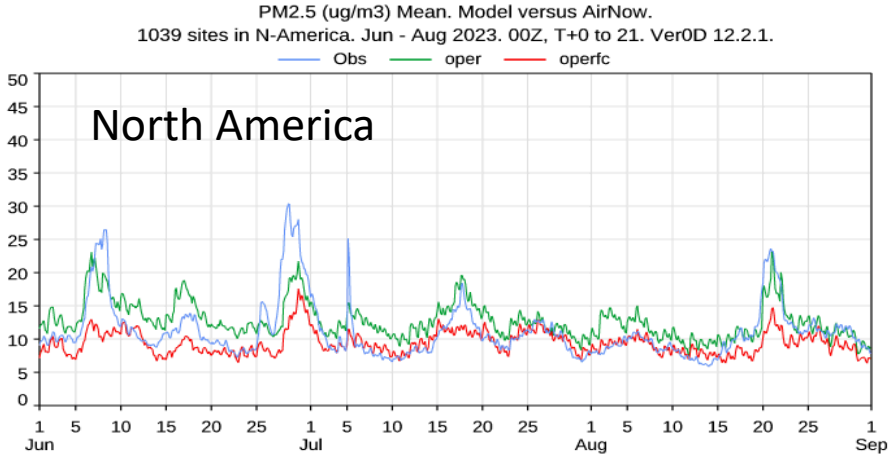

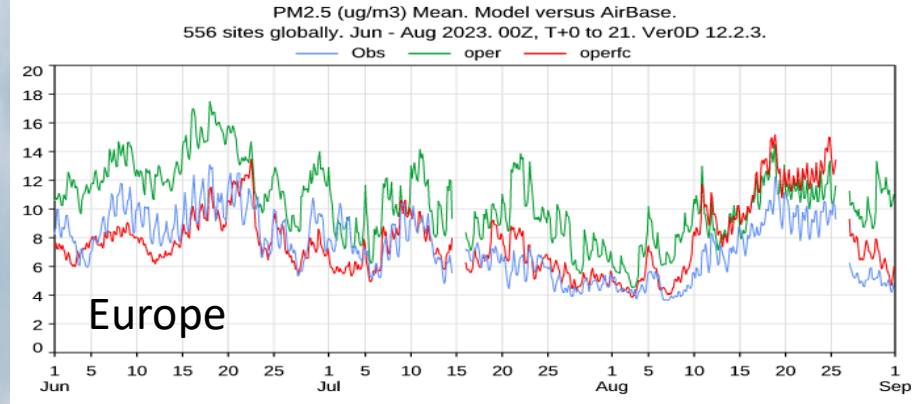

CAMS forecast (AOD DA)

Control (no AC DA)

Observations from National/Regional AQ networks

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Operational AQF intercomparisons

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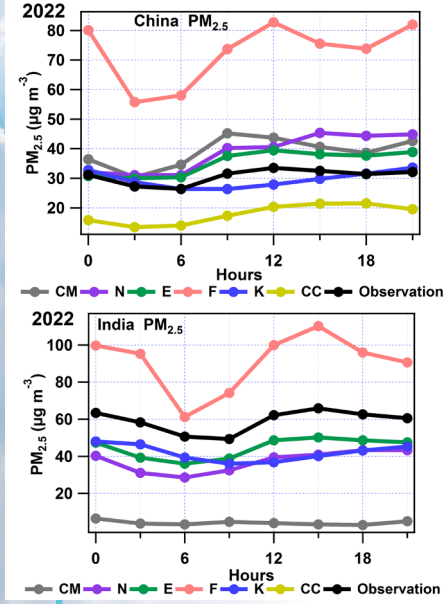
CMA- AQF Asia Intercomparison



Bihui Zhang - CMA

ECCC- AQF North America Intercomparison

Multi Model Air Quality Performance Indices (AQPI)

Domain: NAQFC–RAQDPS intersection (Southern Canada and cont. US)

Agency	System	O_3			NO_2			$PM_{2.5}$		
		Apr	May	Jun	Apr	May	Jun	Apr	May	Jun
ECCC	RAQDPS	81	87	87	66	**71**	**70**	50	41	29
ECCC	RAQDPS-FW	81	87	**89**	66	**71**	**70**	51	59	70
NOAA	NAQFC	**88**	**90**	**89**	-	-	-	58	**72**	60
ECMWF	IFS-CAMS	85	87	88	64	65	64	**59**	65	**75**
NASA	GEOS-CF	82	84	84	**67**	61	59	38	48	64
FMI	IFS-SILAM	86	86	86	**67**	68	66	55	57	54

Legend	AQPI (%)
Excellent	[90, 100]
Very Good	[80, 89]
Good	[70, 79]
Acceptable	[60, 69]
Poor	[50, 59]
Very Poor	≤ 49

$$AQPI[O_3, NO_2, PM_{2.5}] = 100 \cdot avg[\,FAC2, R, 1 - |MFB/2|\,]$$

3

Patrick Manseau - ECCC

- **GAW-WMO GAFIS** aims to promote best practices of air quality forecasting
- GAFIS AQF inter-comparison efforts for Asia and North-America
- Comparing different system with and without AOD DA

https://community.wmo.int/en/activity-areas/gaw/science-for-services/gafis

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Speciation and AOD DA

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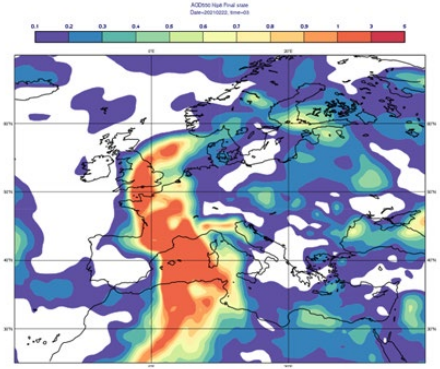
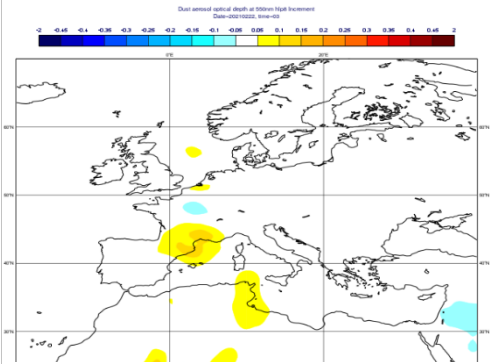
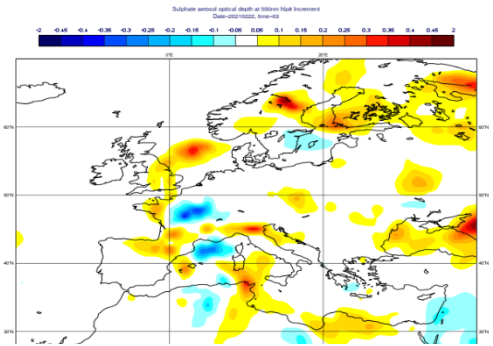
Credit: Melanie Ades

Dust Increments Sulphate

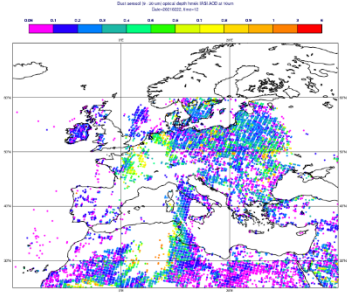


Total AOD at 550nm: 20210222 03hr

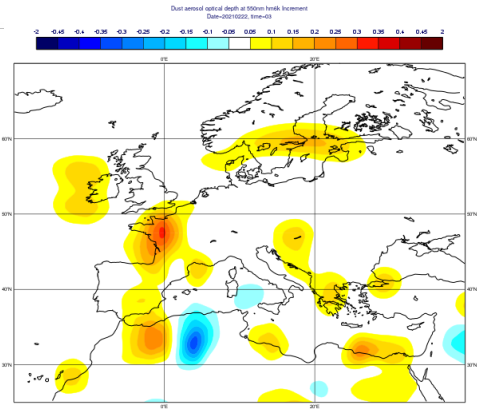


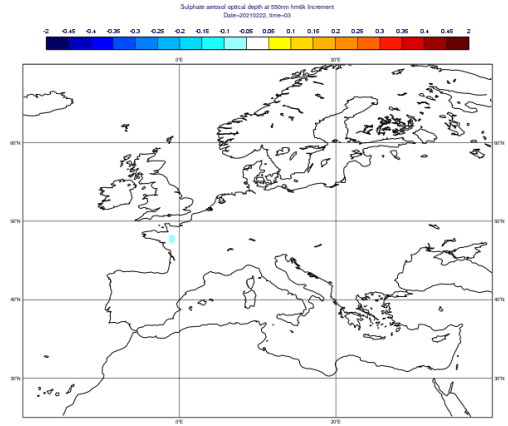


AOD DA



IASI Dust





AOD & DUAOD DA

Still in development

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Summary

- PM2.5 and AOD are often (temporally) well correlated at the large scale but there is considerable spread in a pixel-by-pixel comparison.
- Positive impact of DA AOD on analysis and forecast of AOD in CAMS
- Mixed impact of AOD DA on surface PM2.5 (and PM10) in CAMS (beneficial during BB events in North-America in JJA 23)
- Improvements by AOD DA have been reduced over time because of advances in aerosol modelling in CAMS
- GAW-WMO AQF intercomparisons show that modelling differences are main cause for performance differences of regional and global AQF systems
- Way forward:
  - Combined total and dust AOD assimilation is beneficial for aerosol speciation in analysis
  - Experimentation with vertical structure of background error statistics in 4D-VAR
  - Assimilation of AOD and other aerosol retrievals (AE, SSA, AIH) specifically adopted to CAMS aerosols (EU CAMEO project)
  - Preparation for DA for new aerosol satellite retrievals from 3MI and GEMS/TEMPO/S4 (EU CAMEO project) and aerosol lidar backscatter from the upcoming EarthCARE