Assimilation of VIIRS Aerosol Optical Depth (AOD) within the Copernicus Atmosphere Monitoring Service (CAMS) data assimilation (DA) system

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3: MetOffice, Exeter, UK
4: EUMETSAT

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CAMS AOD forecast bias against AERONET

1d forecast with DA

4d forecast with DA

forecast without DA

Positive impact on AOD
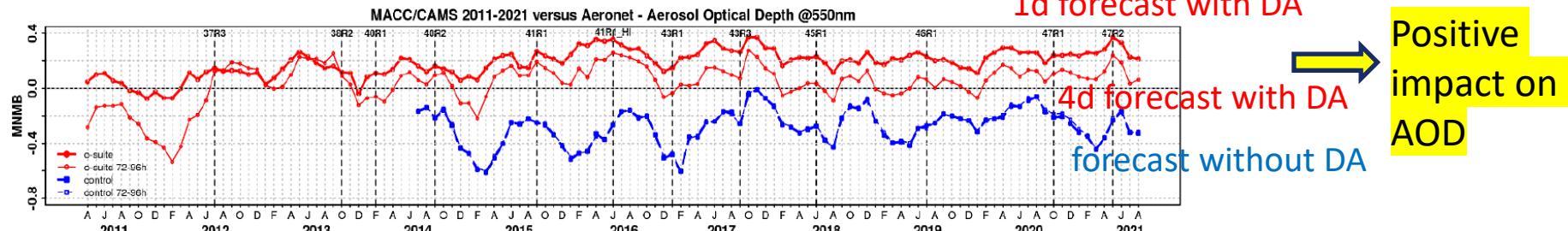
AMS PM2.5 forecast compared to EMEP and IMPROVE ground observations

forecast with DA

observations

forecast without DA

Mixed result for PM2.5
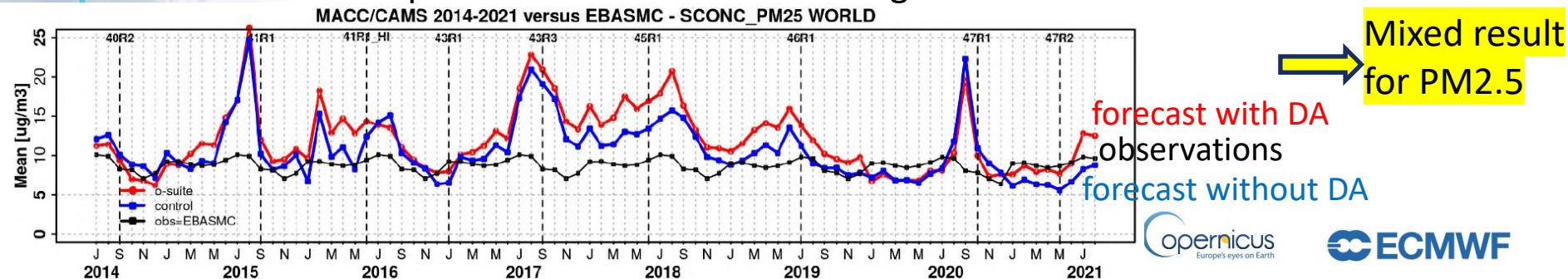
Credit: CAMS validation report (CAMS84_2018SC3_D1.1.1_JJA2021)

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Satellite AOD
MODIS (AQUA, TERRA)
PMAp (METOP A,B,C)

Produce best optimal initial conditions
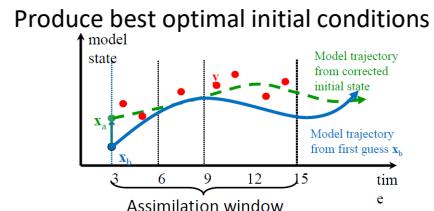
4D VAR data assimilation

Integrated Forecasting Sytem (IFS)
➢ **Atmos. model**
• Semi-Lagrangian advection model
• 137 atm levels, ~40 km horizontal resolution

➢ **CB05 chemistry model (**Flemming et al., 2015**;** Huijnen et al, 2019**)**

➢ **Aerosol model (**Remy et al., 2019,2022**)**:
• Bulk-bin scheme
• Species: sea salt, dust, organic matter, black carbon, sulfate, nitrate, amomium

Emission sources:
• satellite-based biomass burning (GFAS)
• emission inventories (anthropogenic, biogenic)

- 5 day forecast,
- CAMS reanalysis

AOD,
PM2.5,
PM10

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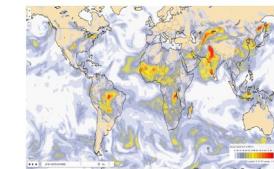
Summer 2020 atmospheric composition events
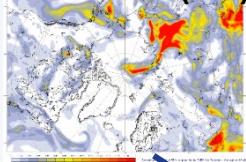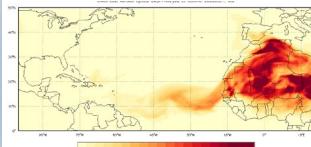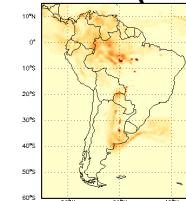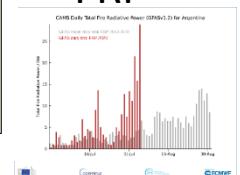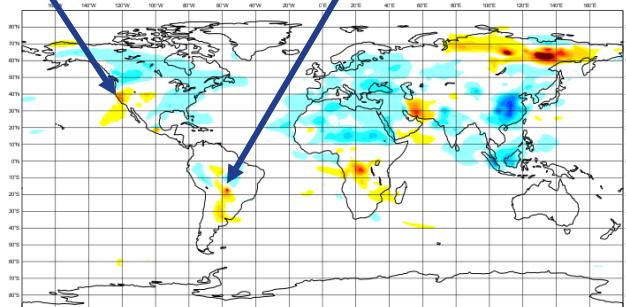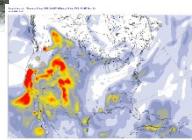
Credit: Mark Parrington (CAMS weather room, June-Sept 2020)

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✓ **AOD retrieval assimilated in CAMS**:

    ✓ Used in **operational forecast**:
- MODIS (TERRA, AQUA; C6.1, DT+DB)
- PMAp (Metop-A,B; v2.1; ocean only)

    ✓ **Tested product**: VIIRS
- NOAA EPS product
- S-NPP, NOAA20
- 0.750 km spatial resolution=>superobbing at ~40 km resolution
- v2r1

✓ **Simulation period**: 02 June 2020- 30 November 2020
(evaluation on JJA and SON periods)

✓ **Experiments: impact of assimilating VIIRS**
- **MODIS+PMAp versus MODIS+PMAp+VIIRS**
- **MODIS only versus VIIRS only**

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Satellite AOD latitude transect (ocean and land)

Temporal average
June-August 2020

Dust outbreak: VIIRS<MODIS

North America and Siberia fires
VIIRS>MODIS
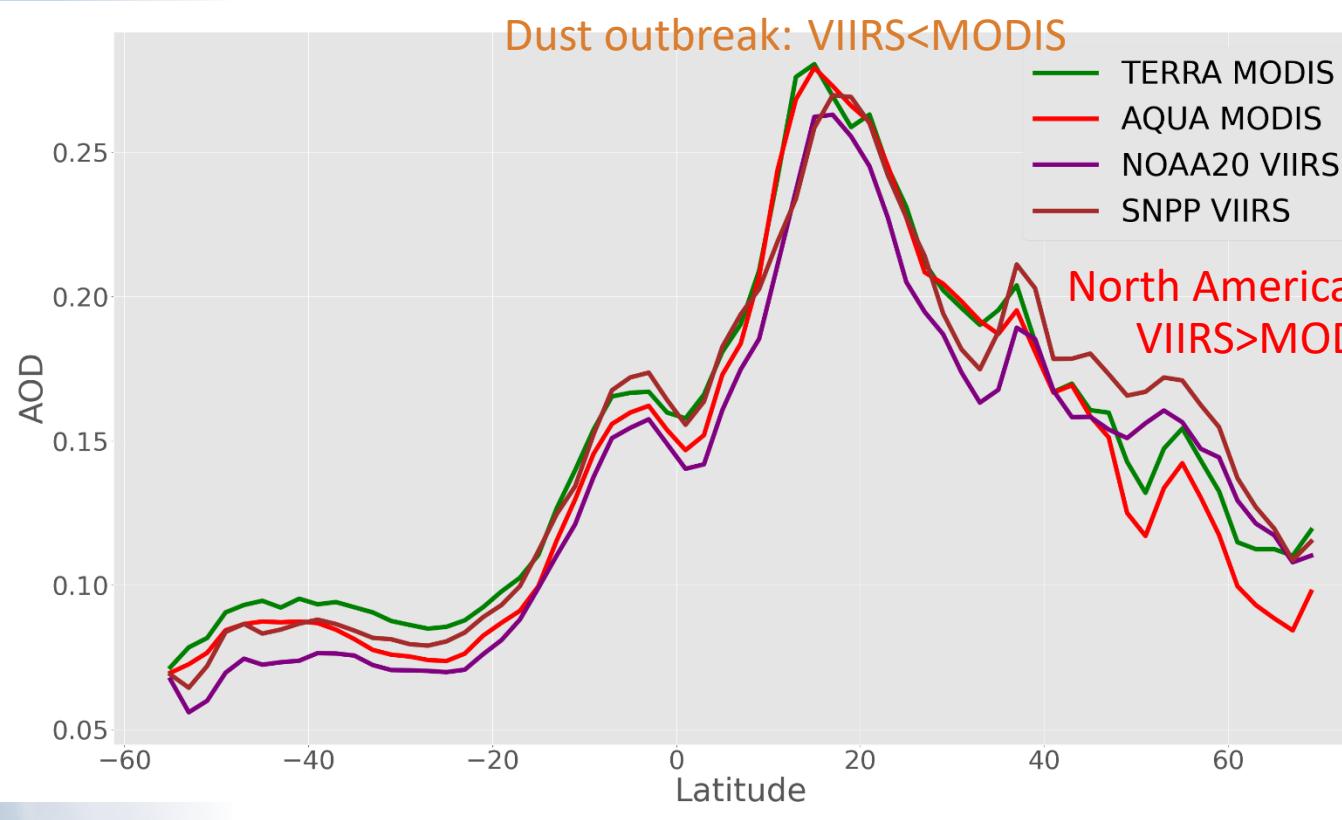


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First guess departure (satellite-model)

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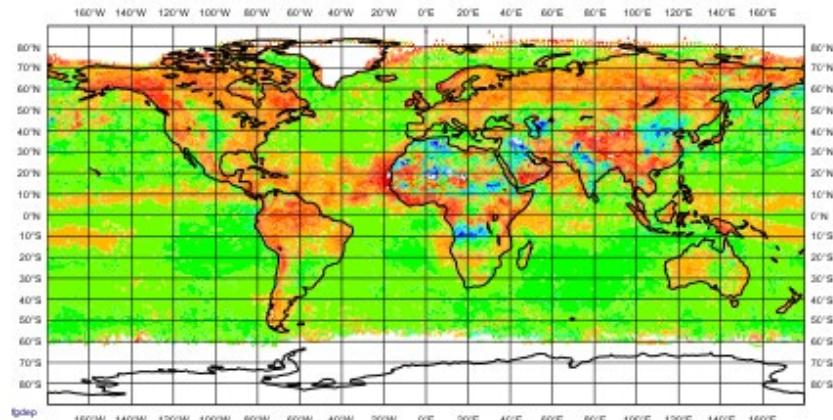
VIIRS

MODIS
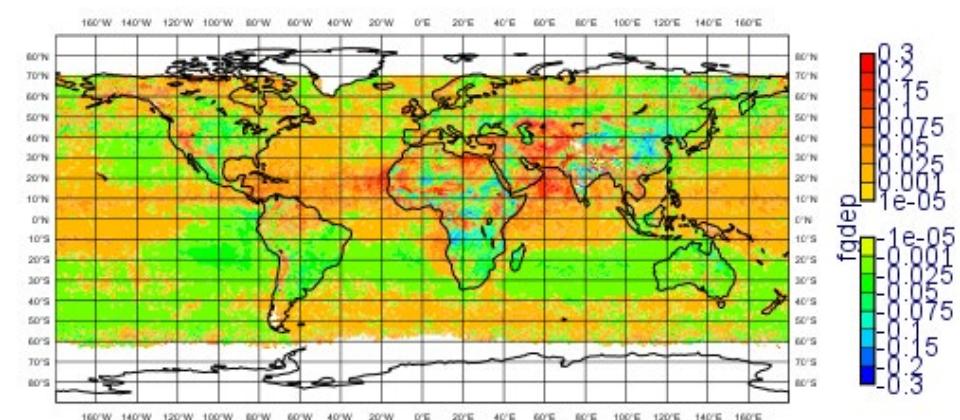
Temporal average
June-August 2020

Ocean: VIIRS <model, MODIS > Model

Temporal average
June-August 2020

Land: VIIRS > model over dust source and biomass burning regions

Atmosphere
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00z
3pm to 3am

12z
3am to 3pm

00z VIIRS only (anchor noaa20)

Mean: 4.65e-03 SDD: 2.13e-02

00z MODIS only (anchor AQUA)

Mean: 5.76e-03 SDD: 1.45e-02

Increments (an-fg)

12z VIIRS only (anchor noaa20)

Mean: 5.11e-03 SDD: 2.50e-02

12z MODIS only (anchor AQUA)

Mean: 5.92e-03 SDD: 1.79e-02
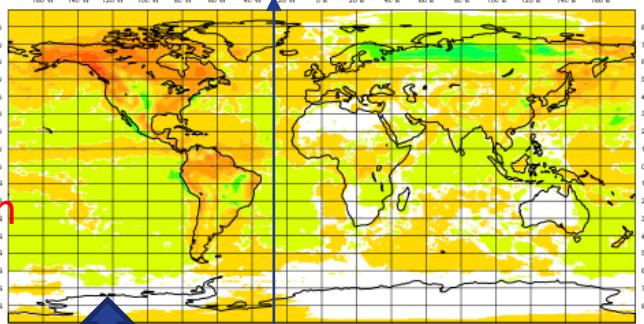
Impact of VIIRS
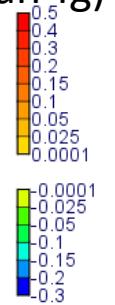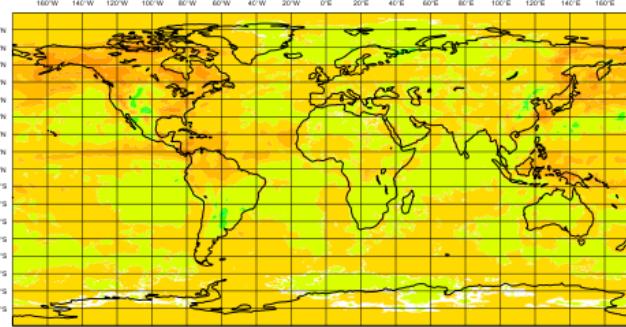
Impact of VIIRS

MODIS less impacted by assimilation window
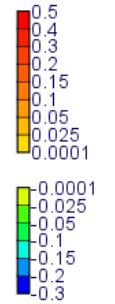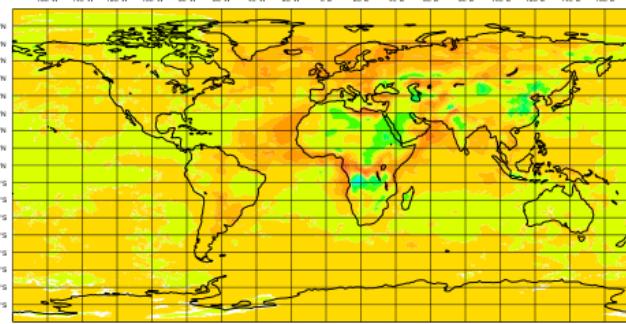
Land
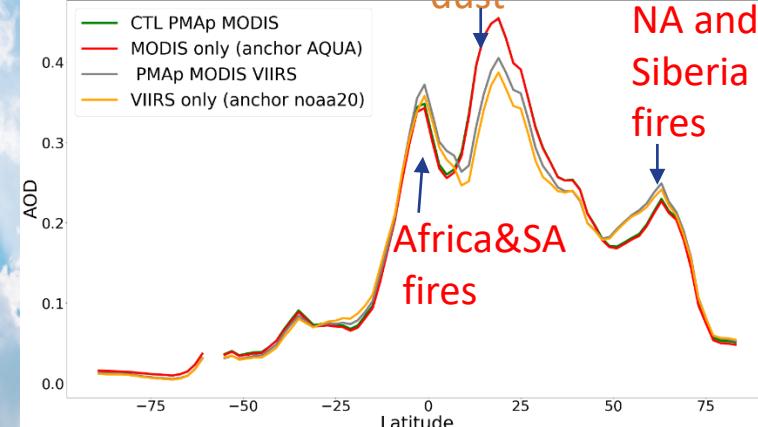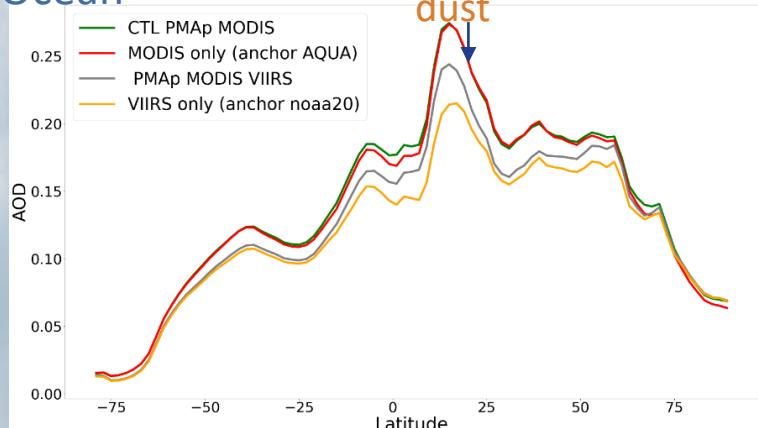
Ocean

VIIRS Only – MODIS Only analysis

AOD increases over biomass burning regions
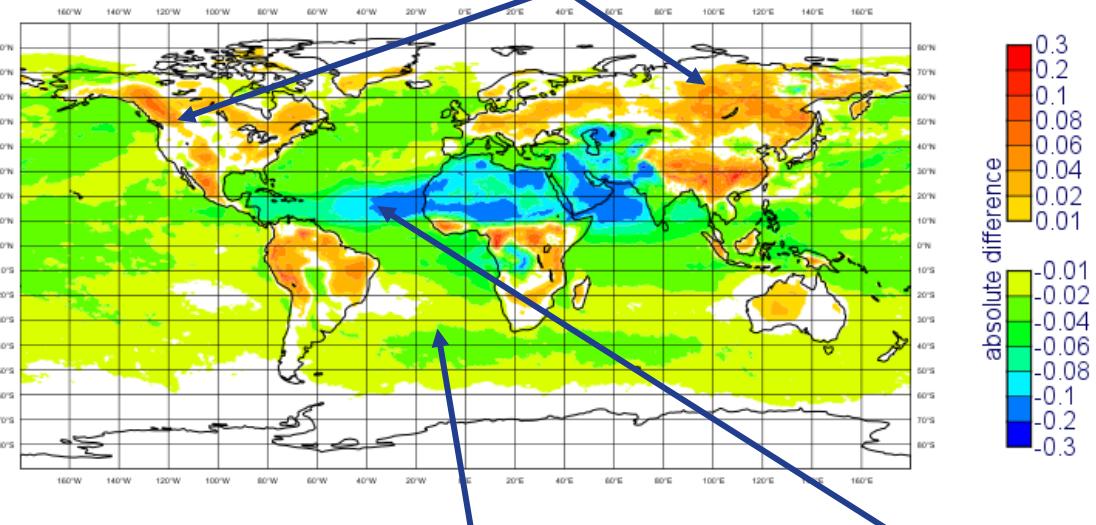
AOD decreases over ocean background and dust

Temporal average
June-August 2020

Atmosphere
Monitoring

Global bias
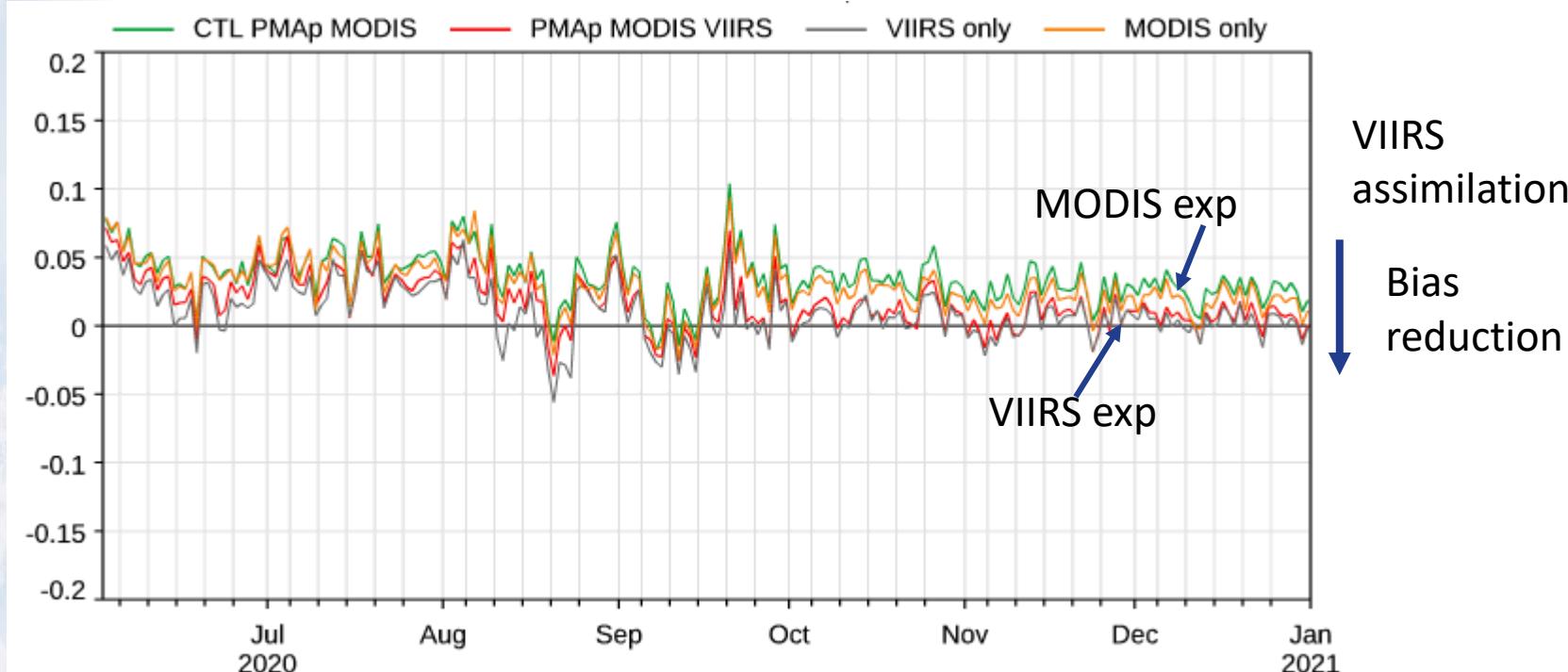
Legend: CTL PMAp MODIS — PMAp MODIS VIIRS — VIIRS only — MODIS only

VIIRS assimilation

MODIS exp

Bias reduction

VIIRS exp

EXP$_{CTL}$: MODIS, PMAp
EXP$_{PMV}$: MODIS, PMAp, VIIRS
EXP$_{V}$: VIIRS only (anchor SNPP)
EXP$_{M}$: MODIS only (anchor AQUA)

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Atmosphere
Monitoring
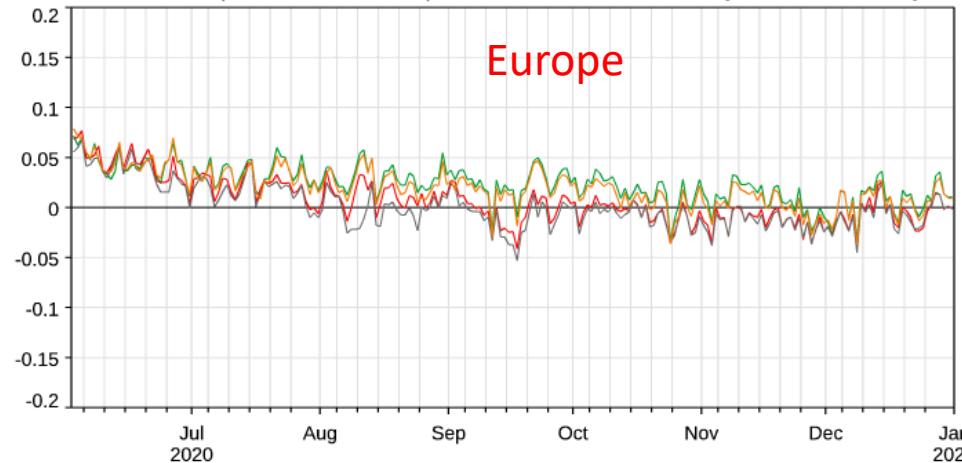
bias

Europe

VIIRS
assimilation

Bias
reduction

bias
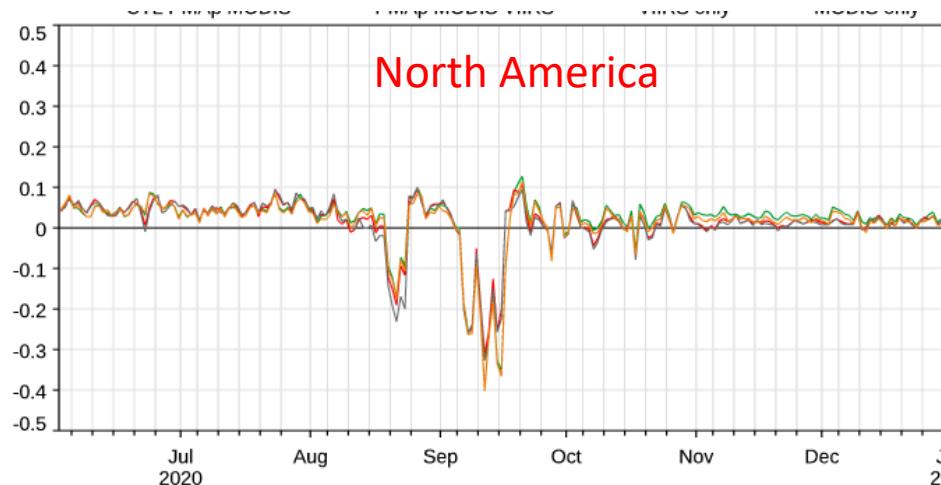
North America

VIIRS
assimilation:
No
significant
impact

EXP$_{CTL}$: MODIS, PMAp
EXP$_{PMV}$: MODIS, PMAp, VIIRS
EXP$_V$: VIIRS only (anchor SNPP)
EXP$_M$: MODIS only (anchor AQUA)

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Atmosphere
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Desert sites
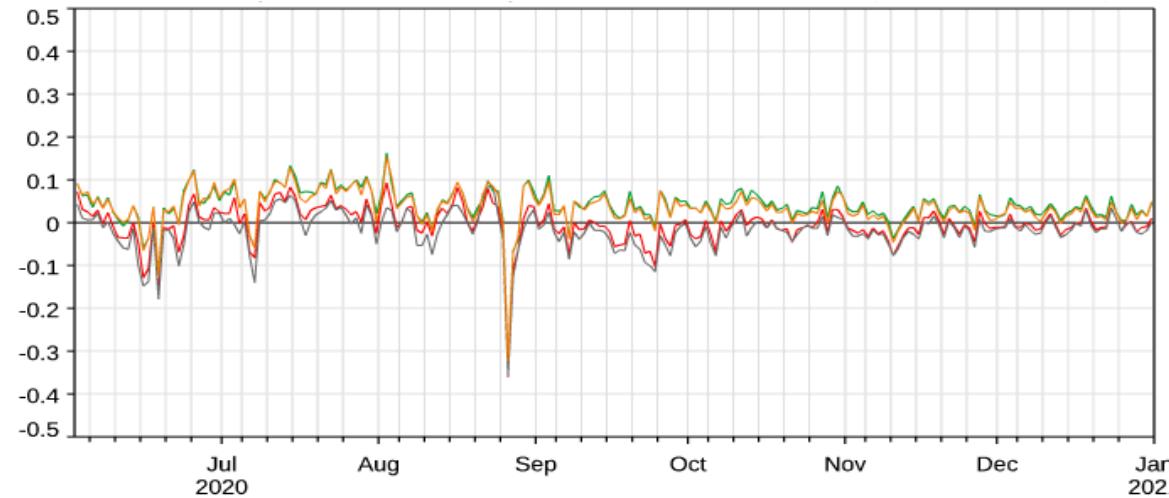
VIIRS
assimilation
Bias
reduction

Oceanic sites
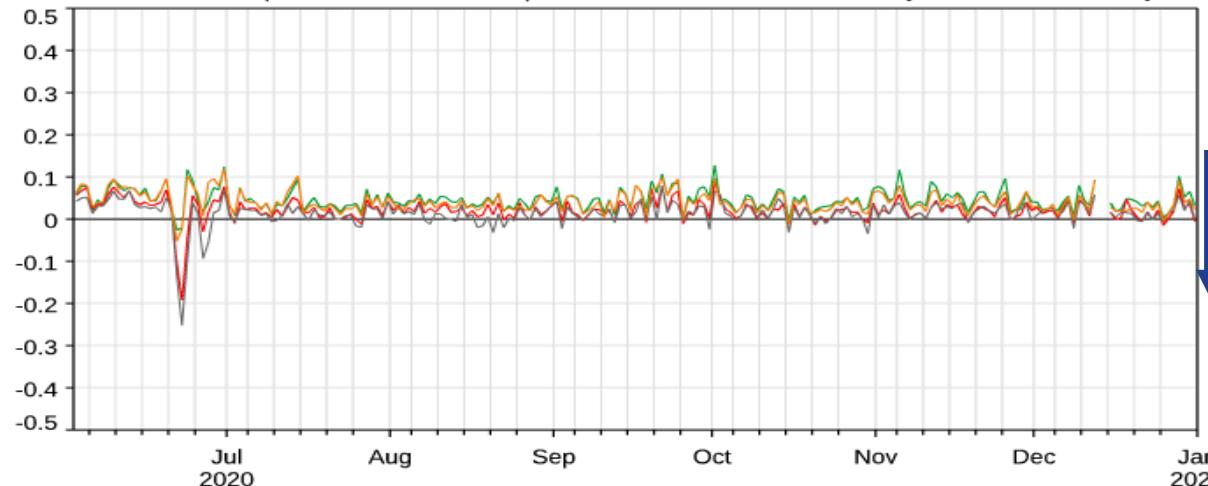
Slight bias
reduction

EXP$_{CTL}$: MODIS, PMAp
EXP$_{PMV}$: MODIS, PMAp, VIIRS
EXP$_{V}$: VIIRS only (anchor SNP
EXP$_{M}$: MODIS only (anchor A
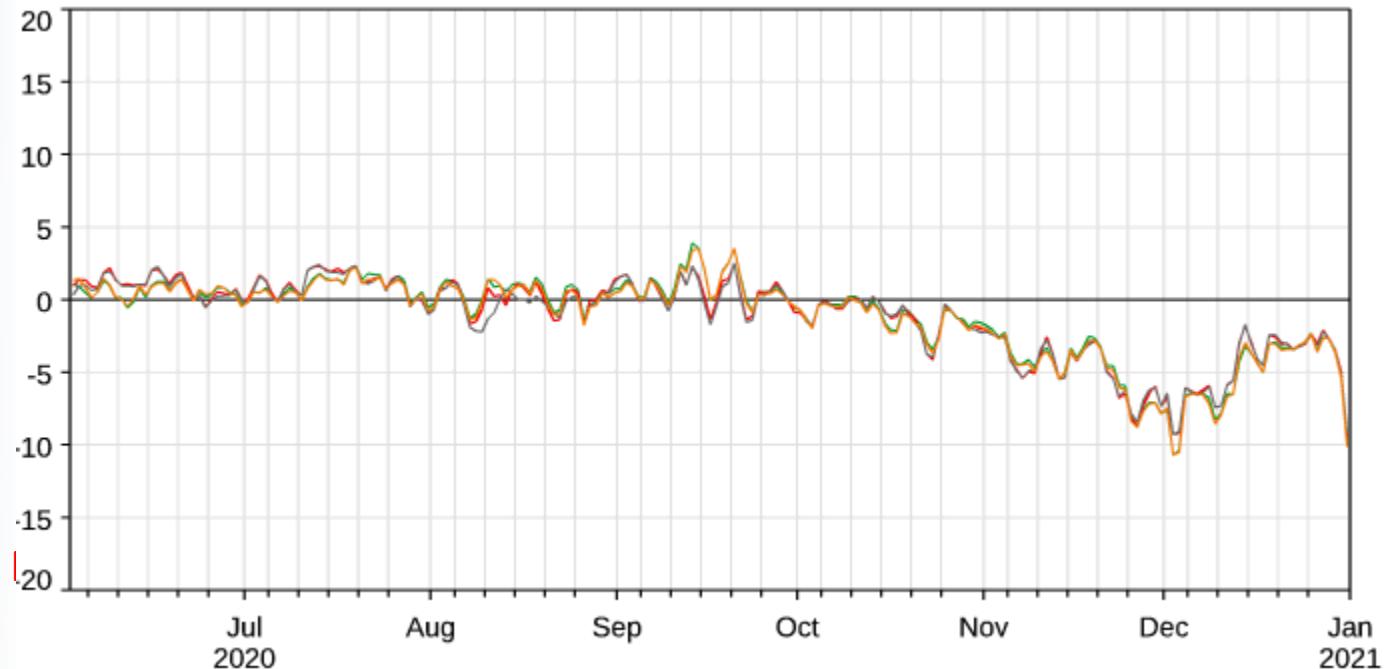
∧WF

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PM2.5 bias

EXP_CTL : MODIS, PMAp
EXP_PMV : MODIS, PMAp, VIIRS
EXP_V : VIIRS only (anchor SNPP)
EXP_M : MODIS only (anchor AQUA)

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Atmosphere
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1. Introduc

2. What is

3. Conclusions

Atmosphere Monitoring

✓ **VIIRS versus MODIS AOD within CAMS**
  - Overall good consistency between VIIRS and MODIS
  - VIIRS < MODIS over ocean background and dust outbreak in the Atlantic
  - VIIRS>MODIS over biomass burning regions

✓ **Impact of assimilating VIIRS**
  - **Lower increment over ocean** and mid-Atlantic dust outbreak
  - **Higher increment over biomass burning regions**

✓ **Impact on the forecast**
  - Positive impact on AOD forecast: reduction of bias, particularly for Europe and desert sites
  - Mixed results for PM2.5
    - US, China: low impact
    - Europe: mixed results

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- ADDITIONAL SLIDES

Atmosphere
Monitoring

Products used in operational assimilation

➢ **MODIS**
- AQUA, TERRA
- C6
- DB+DT product
- 10 km
- Land and ocean
- Thinning
- Spatially constant obs error

➢ **PMAp**
- METOP-A,B,C
- From GOME-2+IASI+AVHRR
- V2.1
- 40*10 km
- Assimilated over ocean only
- Thinning
- Pixel-level observation error +inflation

Monitored/tested new product

➢ **NOAA-EPS VIIRS**
- NOAA-20 and S-NPP
- V2r1
- 0.750m
- Land and ocean
- Superobbing
- Pixel-level observation error

| Experiments	Model	MODIS	VIIRS	PMAp
PMAp, MODIS - 47r3	47r3	Anchor: TERRA and AQUA	No	Bias Corrected
PMAp, MODIS, VIIRS-47r3	47r3	Bias Corrected	Bias Correction : SNPP, Anchor: NOAA20	Bias Corrected
VIIRS only-47r3	47r3	NO	Bias Correction : SNPP, Anchor: NOAA20	No
MODIS Only-47r3	47r3	Bias Corrected : TERRA, Anchor: AQUA	No	No
PMAp, MODIS-48r1	48r1	Anchor: TERRA and AQUA	No	Bias Corrected
PMAp, MODIS, VIIRS – 48r1	48r1	BC	Bias Correction : SNPP, Anchor: NOAA20	Bias Corrected

Atmosphere
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PM2.5

PM2.5 (ug/m3) FC-OBS bias. Model versus China AQ.
1497 sites globally. 2 Jun - 15 Aug 2020. FC start hrs=00,12Z. T+3 to 12.

— hotq_china_aq   — hohg_china_aq   — ho9h_china_aq   — ho9l_china_aq
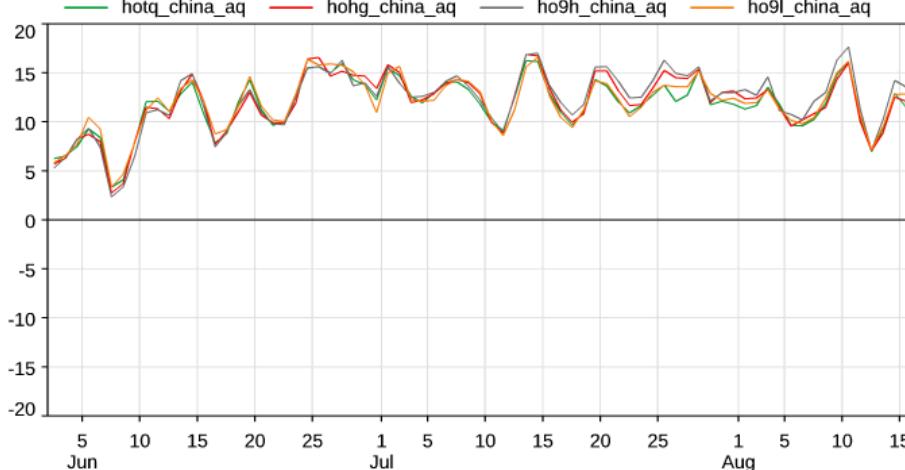

PM10

PM10 (ug/m3) Mean. Model versus China AQ.
1498 sites globally. 2 Jun - 15 Aug 2020. FC start hrs=00,12Z. T+3 to 12.

— Obs   — hotq_china_aq   — hohg_china_aq   — ho9h_china_aq
— ho9l_china_aq
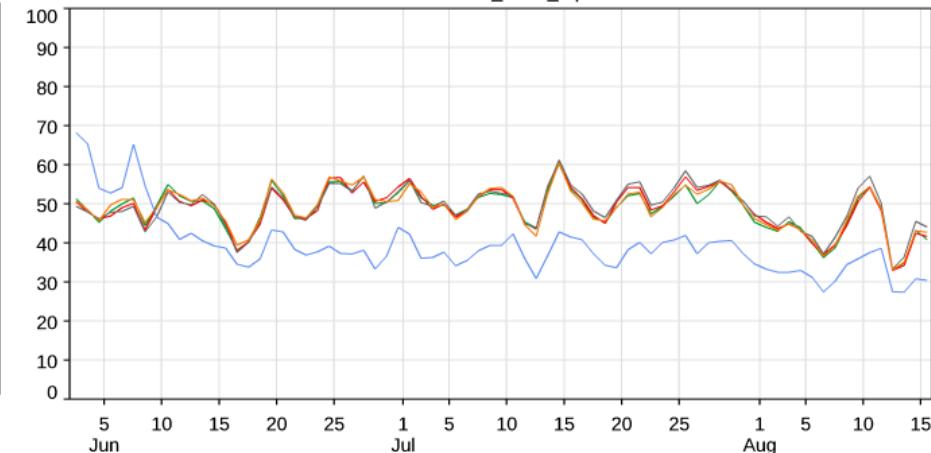
No significant differences between experiments
No significant impact of VIIRS assimilation

— EXP_{CTL} : MODIS, PMAp
— EXP_{PMV} : MODIS, PMAp, VIIRS
— EXP_V : VIIRS only (anchor SNPP)
— EXP_M : MODIS only (anchor AQUA)

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PM2.5 bias
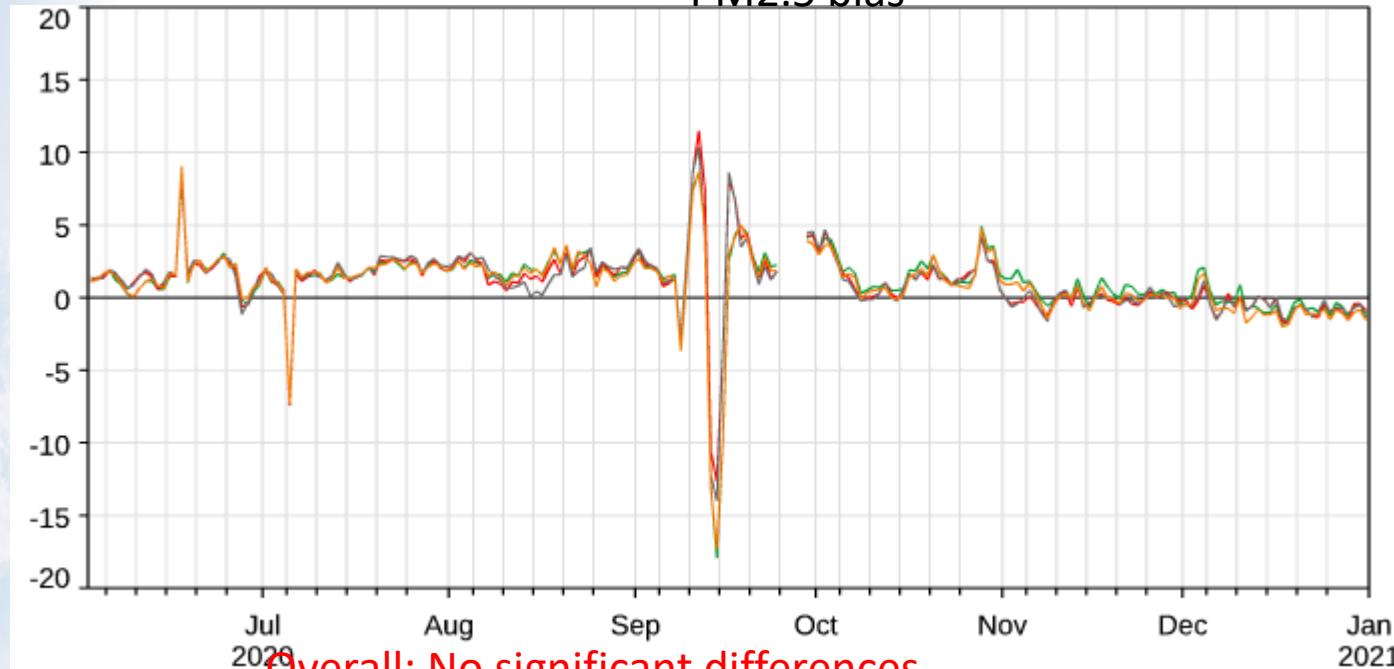
Overall: No significant differences

Mid-August: reduction of bias for the California fire season

— EXP$_{CTL}$: MODIS, PMAp
— EXP$_{PMV}$: MODIS, PMAp, VIIRS
— EXP$_V$: VIIRS only (anchor SNPP)
— EXP$_M$: MODIS only (anchor AQUA)

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