Assimilation of multiple satellite Aerosol Optical Depth (AOD) in the CAMS global system

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OUTLINES

1. Introduction
2. Evaluation of MODIS and VIIRS within the CAMS global system
3. Assimilation of MODIS and VIIRS
4. Conclusion

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CAMS AEROSOL DATA ASSIMILATION SCHEME

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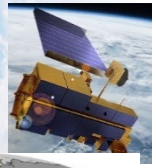
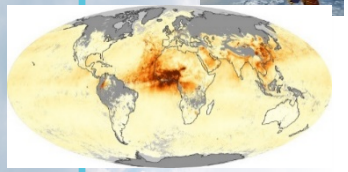
Satellite AOD

MODIS (AQUA, TERRA)

PMAp (METOP A,B,C)





4D VAR data assimilation

Integrated Forecasting Sytem (IFS)

Atmosp. model

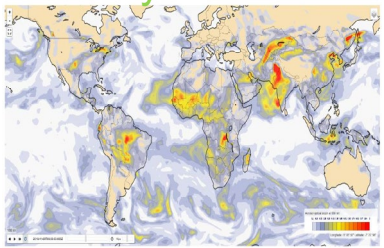
- Semi-Lagrangian advection model
- 137 atm levels
- 40 km horizontal resolution

AER model:

- Bulk-bin scheme
- Species: sea salt, dust, organic matter, black carbon, sulfate, nitrate, amomium
- Emission sources: biomass burning (GFAS), CAMS_GLOB dataset

Remy et al., 2019 GMD

5 day forecast, reanalysis



AOD, aerosol concentration, PM2.5, PM10

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Rationales

➢ Needs for new observational data streams

- ✓ **More accurate observations**.
- ✓ **Enhanced spatial and temporal coverage**.
- ✓ **Increased resilience to instrument failure**

➢ Implementation of a new satellite product

- ✓ **Passive monitoring**
  - **Consistency with the other AOD products**
  - **Evaluation of observation – model departure**
- ✓ **Assimilation test**
  - **Observation error**
  - **Bias correction and choice of an anchor**
  - **Impact**
    - **Analysis increment**
    - **Forecast performances (AOD: evaluation against AERONET)**

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SATELLITE AOD USED IN CAMS

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Products used in operational assimilation

- **MODIS**
  - AQUA, TERRA
  - C6
  - DB+DT product
  - 10 km
  - Land and ocean
  - Thinning

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

Monitored product

- **SLSTR**
  - S3a and S3b
  - V2 (released Aug 2020)
  - 9.5 km
  - Ocean only
  - No thinning

- **NOAA-EPS VIIRS**
  - NOAA-20 and S-NPP
  - V2r1
  - 0.750m
  - Land and ocean
  - Superobbing

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Methodology

Experiment design (dec 2019-jan 2020)

Experiment	MODIS (Land & Ocean)	PMAp (ocean)	VIIRS (Land & Ocean)
Exp_{CTL}	X (anchor)	X	NO
$Exp_{VIIRS,MODIS}$	X	X	X (anchor)
$Exp_{VIIRS\ only}$	NO	X	X (anchor)

Evaluation metrics

- Temporal average over the experiment period
- Observation: global and regional maps
- First guess departure : Observation – short range forecast

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Observation – global maps

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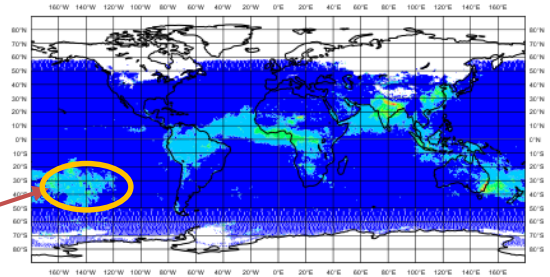
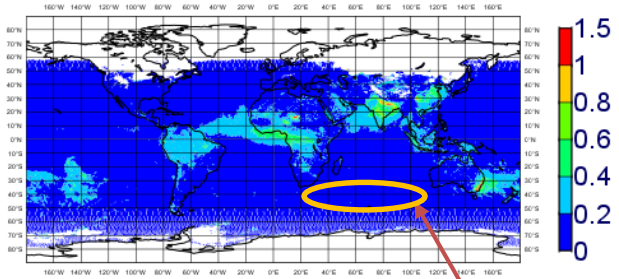
VIIRS/SNPP obs

Mean: 0.144 RMSE: 0.167



VIIRS/NOAA20 obs

Mean: 0.132 RMSE: 0.158

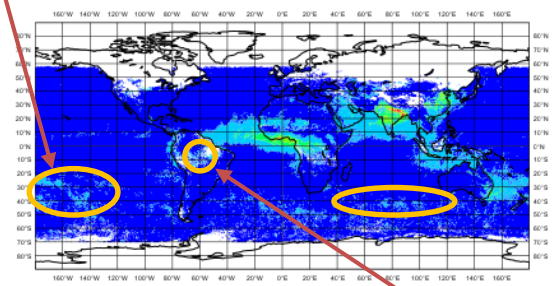


Australian fire plume not fully resolved by MODIS

VIIRS: less noisy over South ocean compared to MODIS

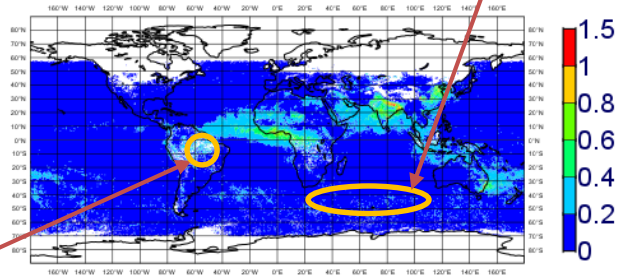
MODIS/TERRA obs

Mean: 0.146 RMSE: 0.166



MODIS/AQUA obs

Mean: 0.138 RMSE: 0.160



MODIS: larger gaps

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Observation – regional maps

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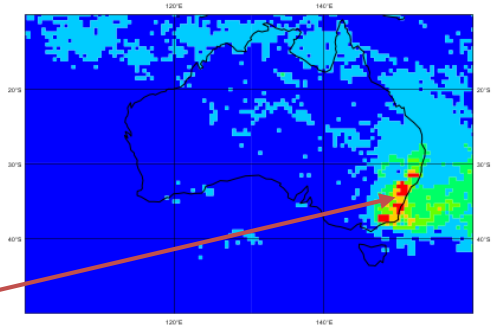
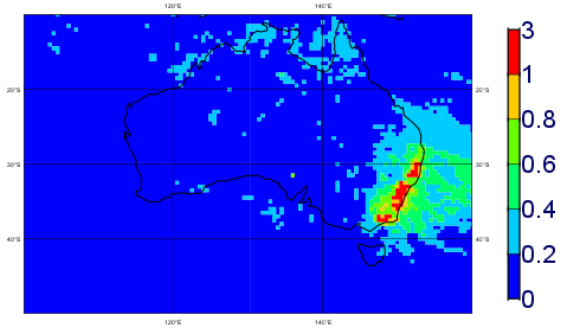
VIIRS/SNPP obs

Mean: 0.174 RMSE: 0.208



VIIRS/NOAA20 obs

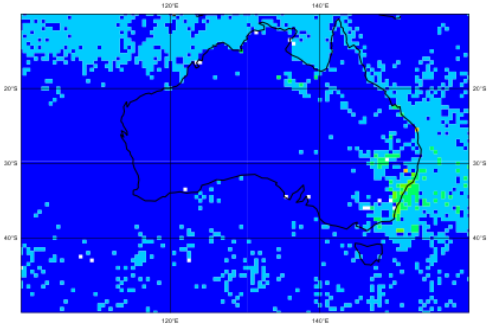
Mean: 0.150 RMSE: 0.192



VIIRS: higher AOD for biomass burning plume

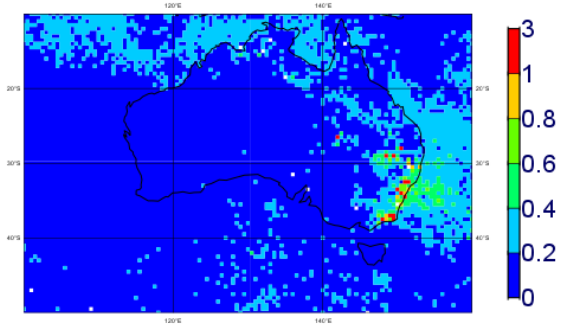
MODIS/TERRA obs

Mean: 0.151 RMSE: 0.170



MODIS/AQUA obs

Mean: 0.154 RMSE: 0.182



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Observation – scatterplots

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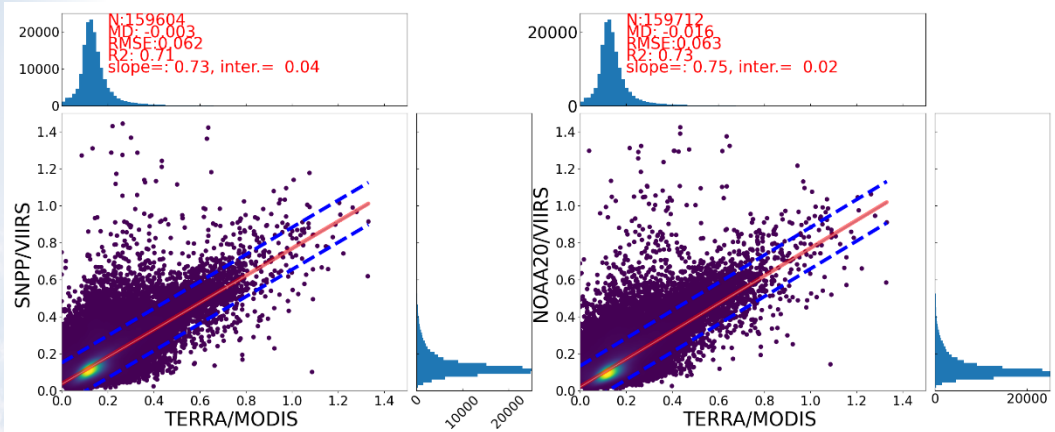
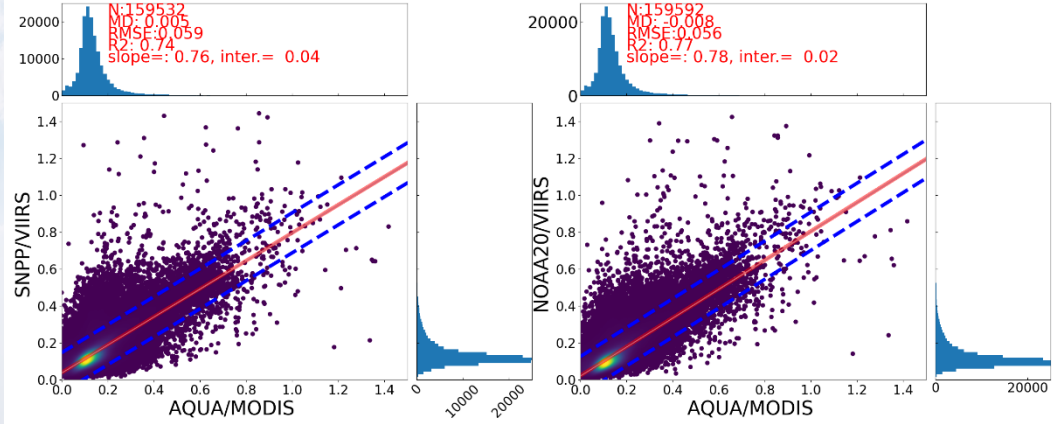
VIIRS vs MODIS/TERRA

VIIRS vs MODIS/AQUA





- ✓ Good agreement between VIIRS and MODIS AOD
- ✓ VIIRS/NOAA 20 < MODIS

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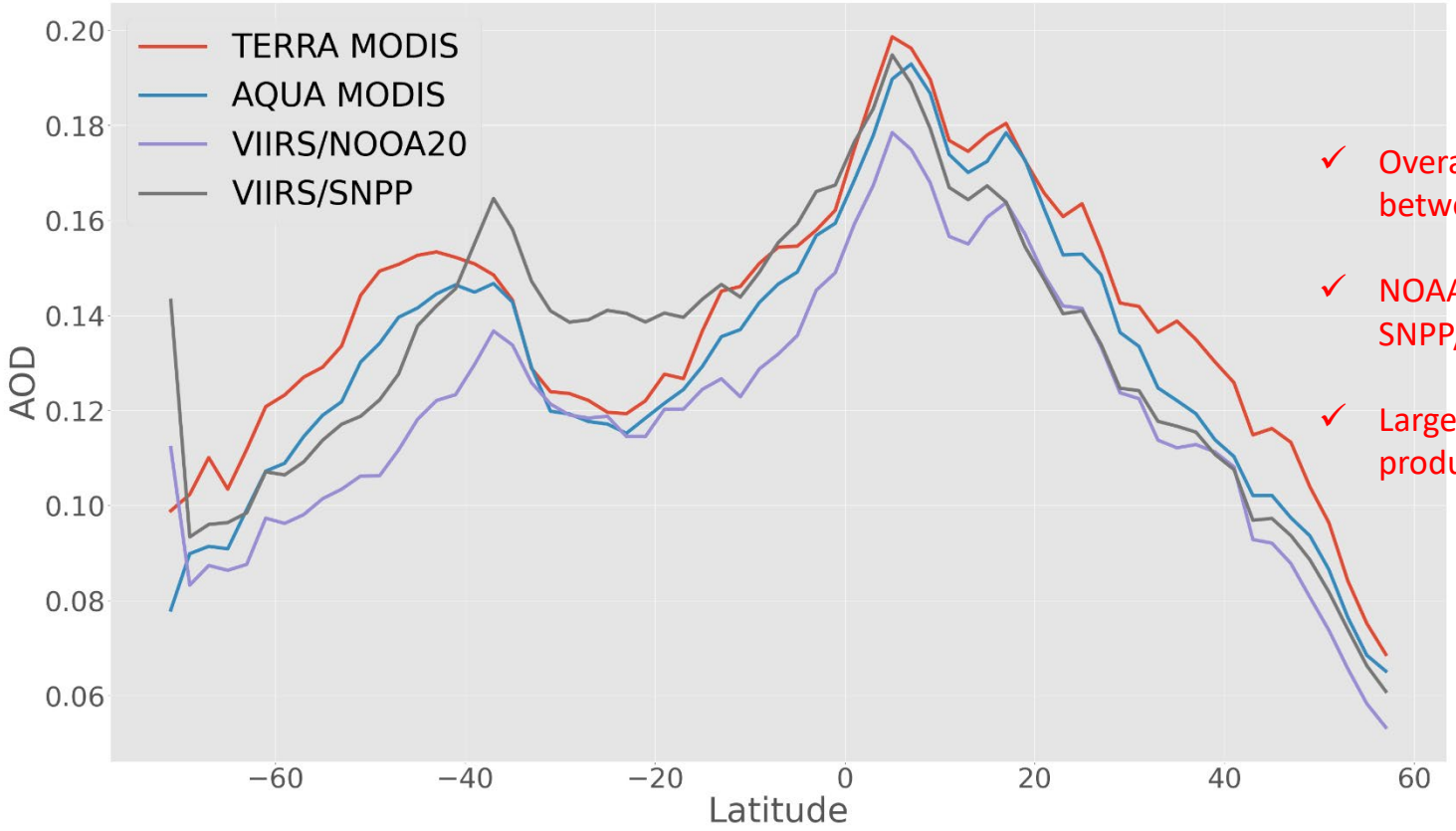
Observation – latitude cross section over land and ocean



- ✓ Overall good agreement between VIIRS and MODIS
- ✓ NOAA 20/VIIRS lower than SNPP/VIIRS for SH
- ✓ Larger diversity between products in SH

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First guess departure (Observation-Model)

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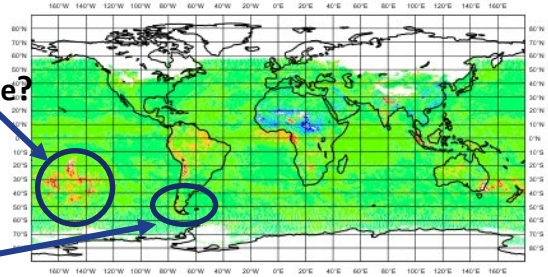
VIIRS/SNPP fgdepar uncorr

Mean: 0.001 RMSE: 0.053

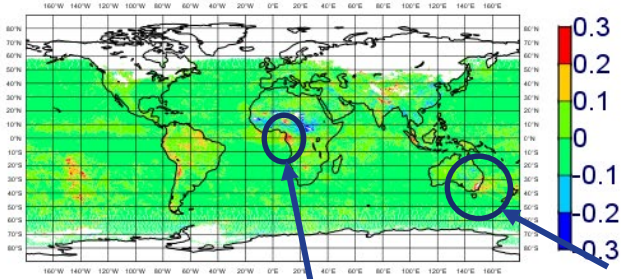


Australian fire plume?

Volcanic activity ?

VIIRS/NOAA20 fgdepar uncorr

Mean: -0.012 RMSE: 0.054

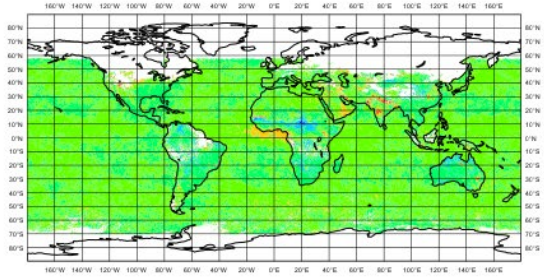


Australian fire plume

Higher aod over tropical fires

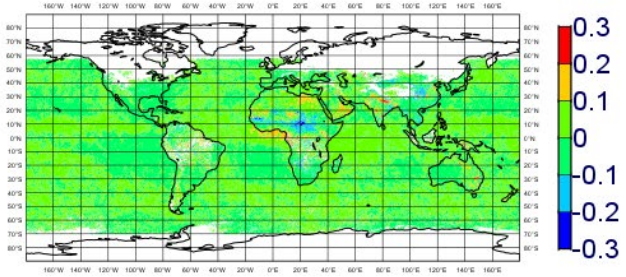
MODIS/TERRA fgdepar uncorr

Mean: 0.008 RMSE: 0.045



MODIS/AQUA fgdepar uncorr

Mean: -0.002 RMSE: 0.041



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OUTLINES

1. Introduction
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Global increments (analysis- first guess)

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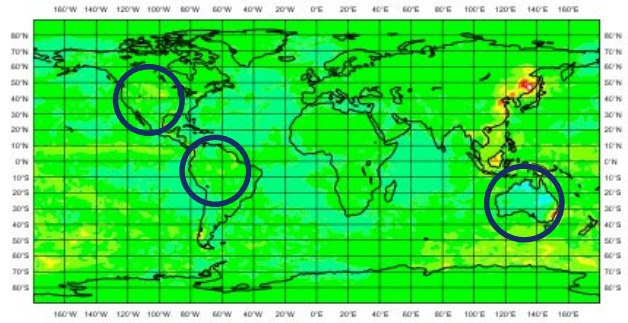
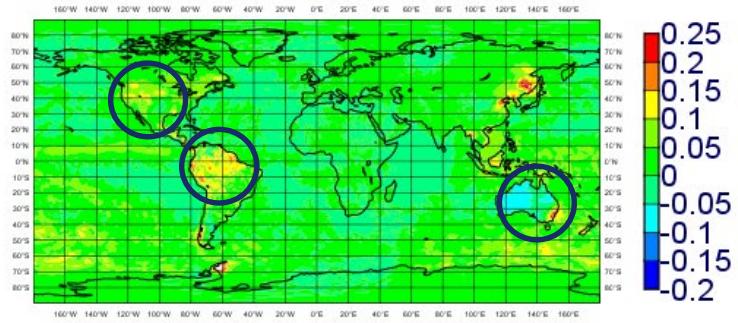
Exp_{CTL}: **MODIS (Anchor), PMAp**

Mean: 0.016 RMSE: 0.032



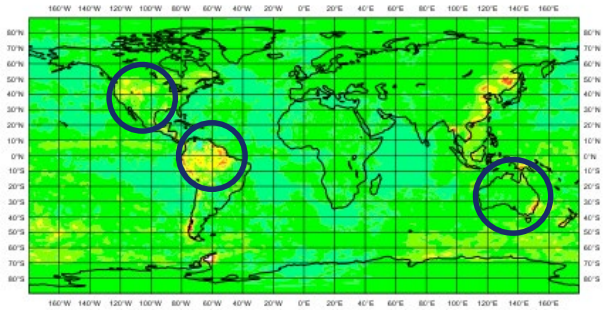
$Exp_{VIIRS+MODIS}$ **VIIRS (Anchor) , MODIS, PMAp**

Mean: 0.017 RMSE: 0.035



$Exp_{VIIRS\ only}$ **VIIRS (anchor), PMAp**

Mean: 0.017 RMSE: 0.034



Assimilation of VIIRS:

- Reduced increment over ocean
- Larger increment over North and South America

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Regional increments

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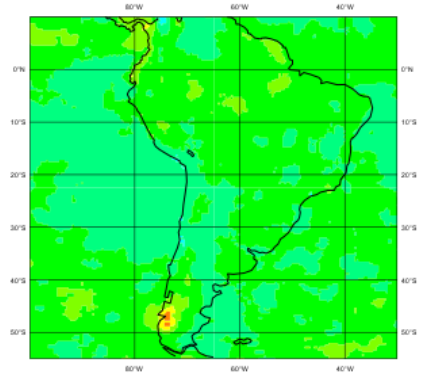
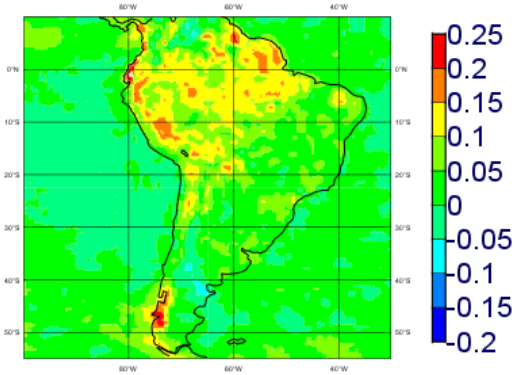
Exp_{CTL}: MODIS (Anchor), PMAp

Mean: 0.009 RMSE: 0.025



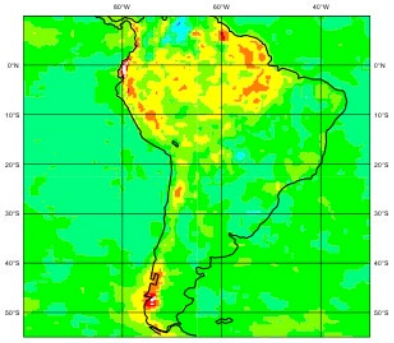
$Exp_{VIIRS+MODIS}$ VIIRS (Anchor) , MODIS, PMAp

Mean: 0.031 RMSE: 0.054



$Exp_{VIIRS\ only}$ VIIRS (anchor), PMAp

Mean: 0.027 RMSE: 0.053



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AERONET (1.5v3) EVALUATION

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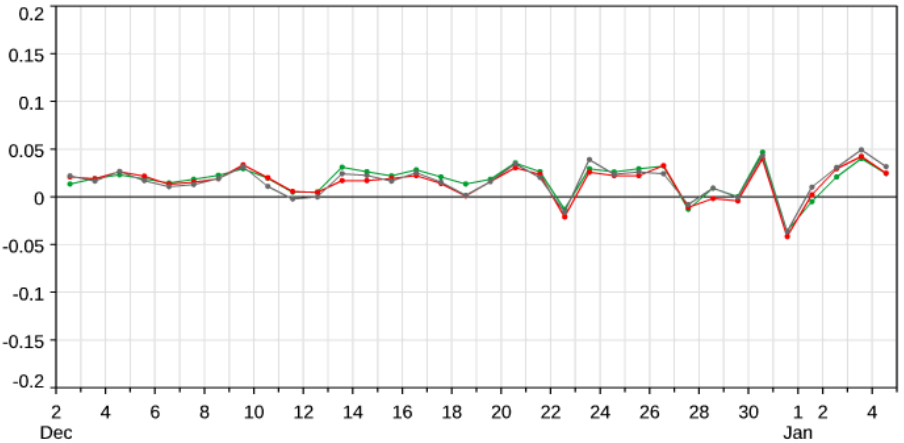
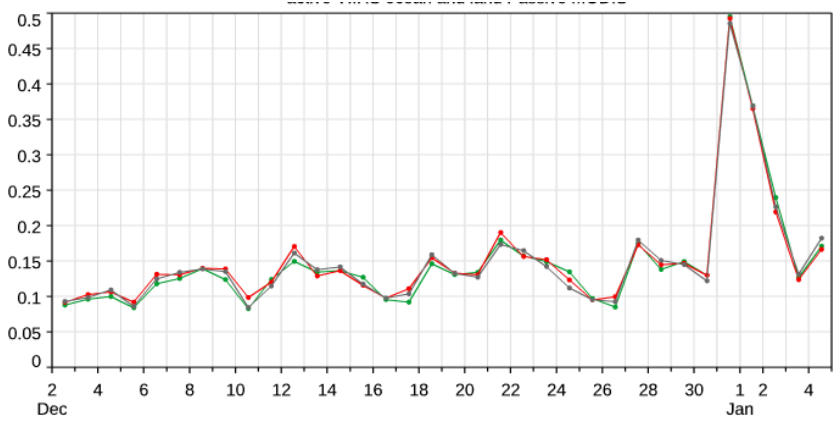
global

bias



rmse



EXP_{CTL} : MODIS, PMAp

$EXP_{VIIRS, MODIS}$: VIIRS, MODIS, PMAp

$EXP_{VIIRS\ only}$: VIIRS, PMAp

- ✓ Low global impact
- ✓ Bias slightly reduced when assimilating VIIRS

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Conclusions

- ✓ Intercomparison of MODIS and VIIRS in CAMS
  - Overall good agreement
  - Finer spatial details resolved by VIIRS
  - Larger diversity in SH: departure between NOAA20 and SNPP

- ✓ Assimilation of VIIRS
  - Ocean: Reduction of increments which was too high related to MODIS/TERRA
  - Land: Higher increments over North and South America
  - No substantial changes in forecast performances of AOD

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ADDITIONAL SLIDES

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Global increments (analysis - first guess)

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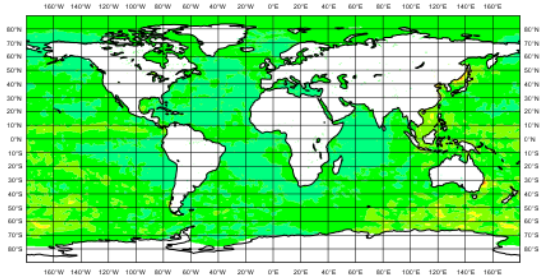
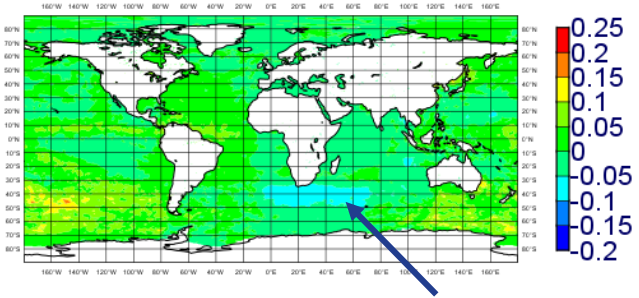
Exp_{CTL}: MODIS (Anchor), PMAp

Mean: 0.017 RMSE: 0.031



Exp_{SLSTR} MODIS (Anchor) , PMAp, SLSTR

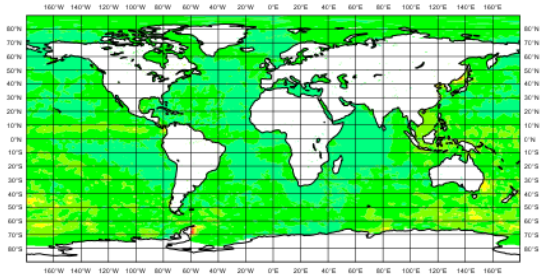
Mean: 0.009 RMSE: 0.034



Spurious increment reduction , can be due to observation errors

Exp_{VIIRS} MODIS , PMAp, VIIRS (anchor)

Mean: 0.015 RMSE: 0.030



- The assimilation of SLSTR leads to large reduced increments over ocean

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First guess departure (Observation-Model)

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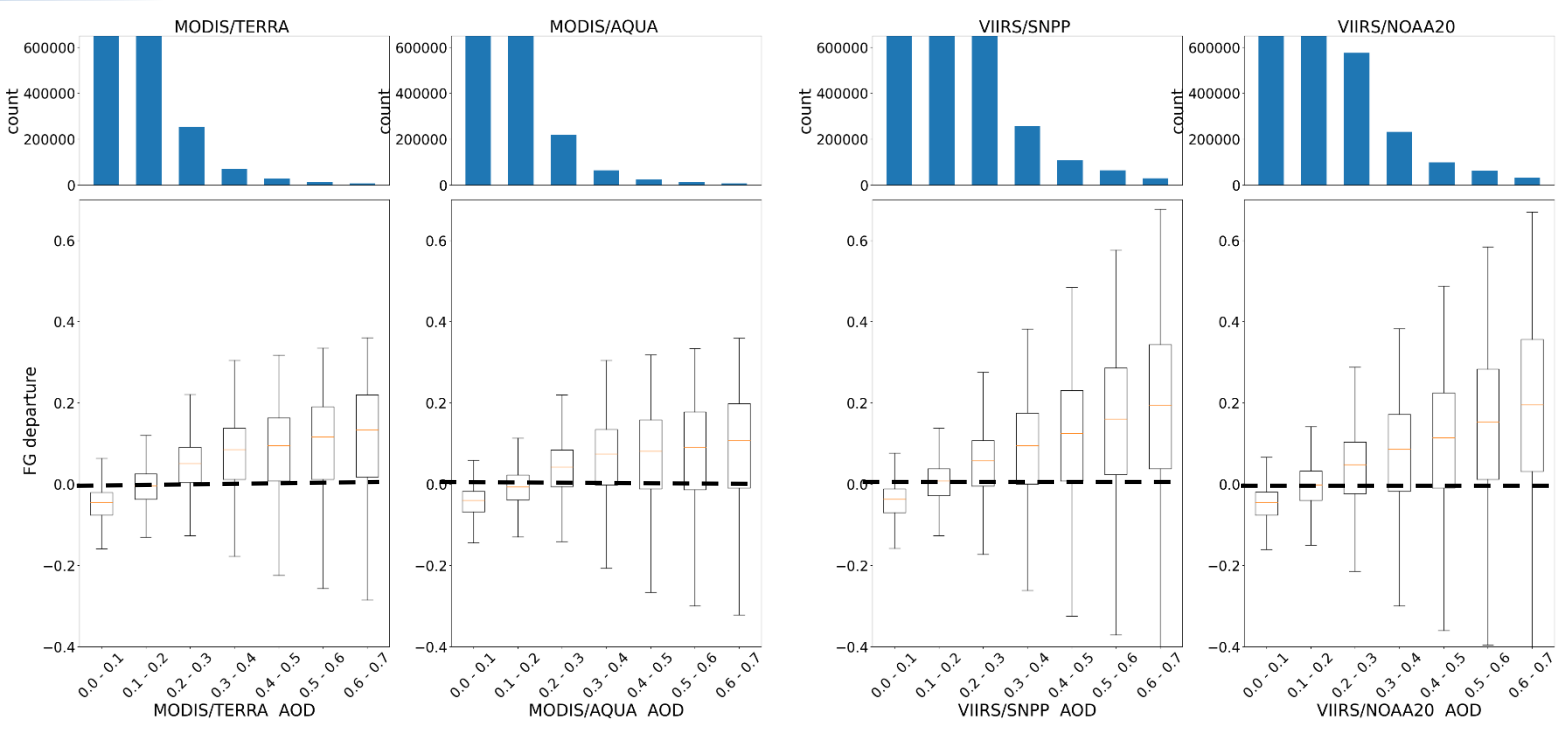

Regional increments

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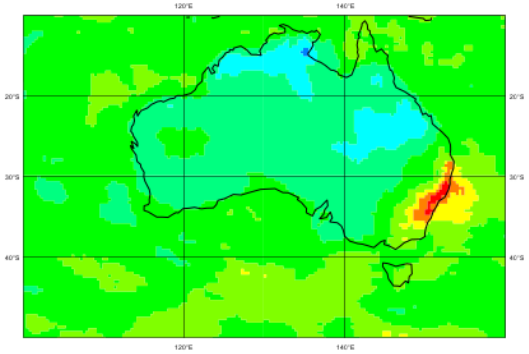
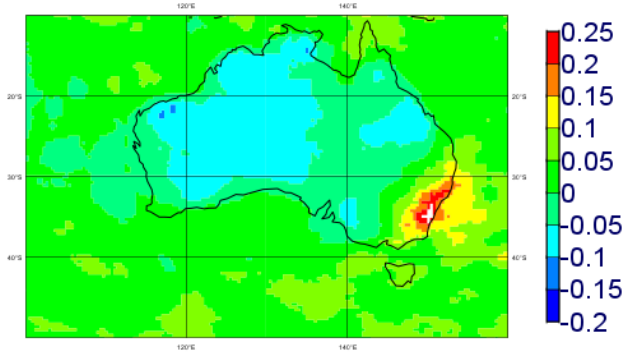
Exp_{CTL}: MODIS (Anchor), PMAp

Mean: 0.019 RMSE: 0.043



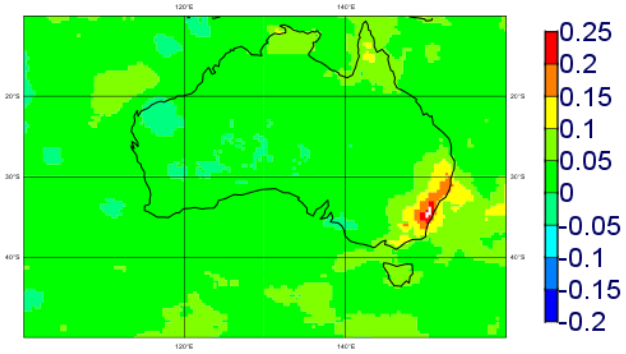
$Exp_{VIIRS+MODIS}$ VIIRS (Anchor) , MODIS, PMAp

Mean: 0.011 RMSE: 0.047



$Exp_{VIIRS\ only}$ VIIRS (anchor), PMAp

Mean: 0.029 RMSE: 0.039



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PM2.5 EVALUATION

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North America

bias

rmse

EXP_{CTL} : MODIS, PMAp

$EXP_{VIIRS, MODIS}$: VIIRS, MODIS, PMAp

$EXP_{VIIRS\ only}$: VIIRS, PMAp

- ✓ Low global impact
- ✓ Bias slightly reduced when assimilating VIIRS

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Observation – latitude cross section over ocean

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Observation – latitude cross section over land

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Global analysis (an)

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Exp_{CTL}: **MODIS (Anchor), PMAp**

$Exp_{VIIRS+MODIS}$ **VIIRS (Anchor) , MODIS, PMAp**

$Exp_{VIIRS\ only}$ **VIIRS (anchor), PMAp**

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