# Dissecting effects of orbital drift of polar-orbiting satellites on accuracy and trends of cloud fraction climate data records

Jędrzej (Jed) Bojanowski and Jan Musiał
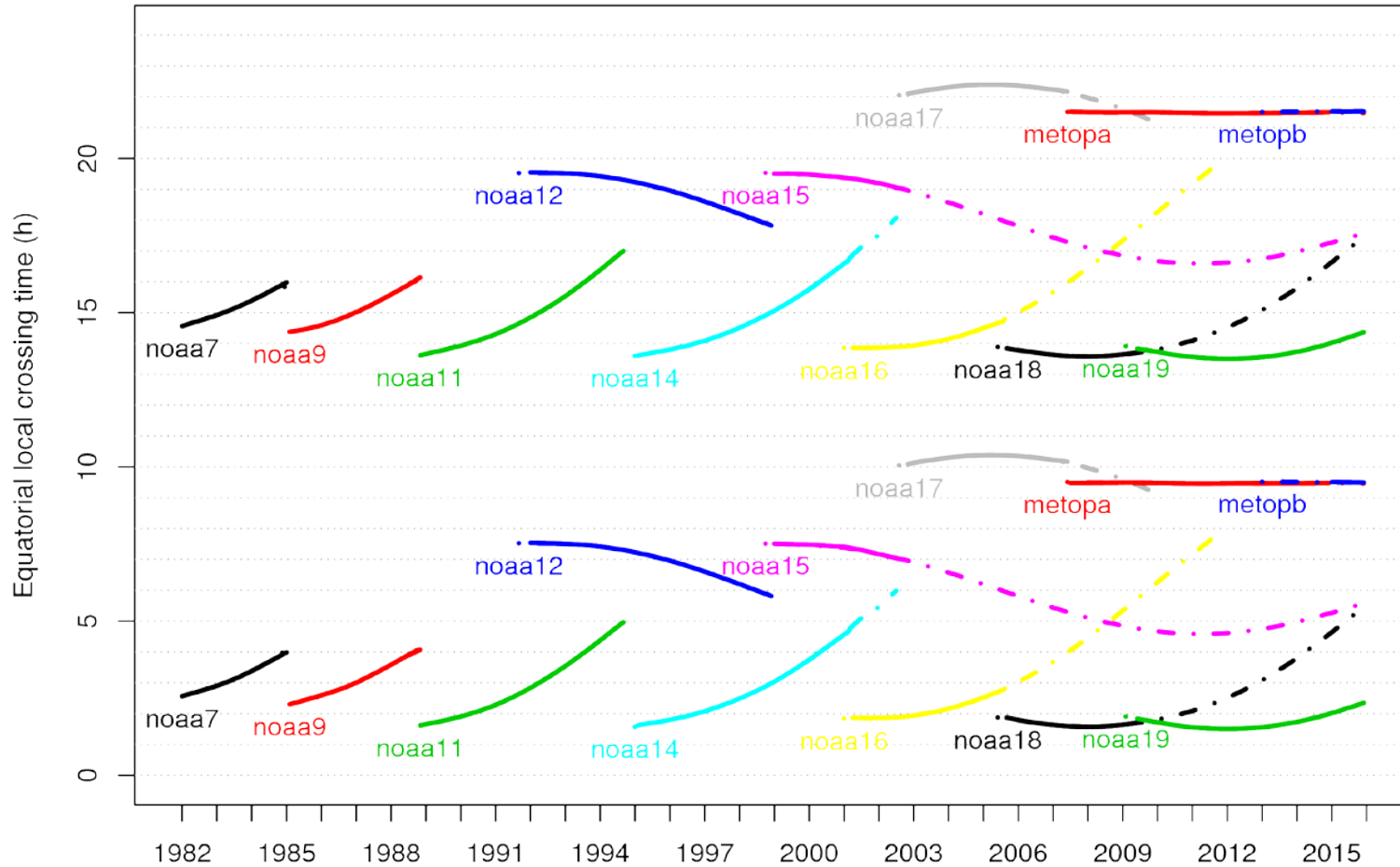
Remote Sensing Centre, Institute of Geodesy and Cartography, Warsaw, Poland
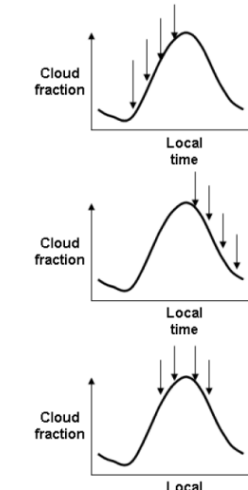
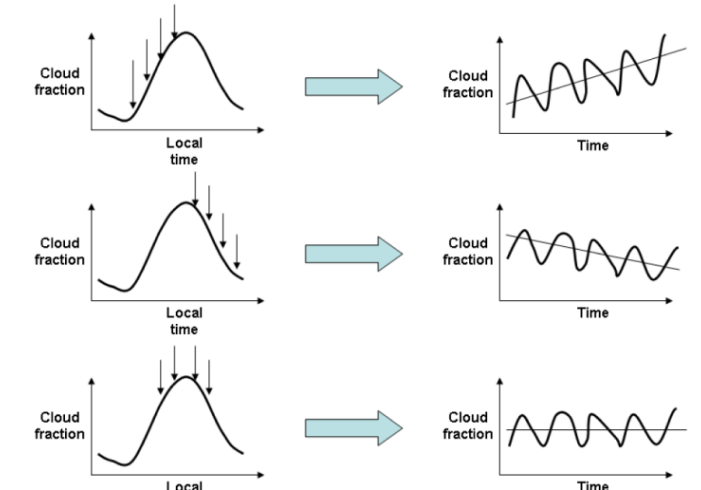NATIONAL SCIENCE CENTRE
POLAND

# Orbital drift & overlapping satellites



L2 → L3 aggregation
- Orbital drift
- Changing numer of observations
- AMs / PMs separately
- Overlapping satellites



(Devasthale et al, 2012)

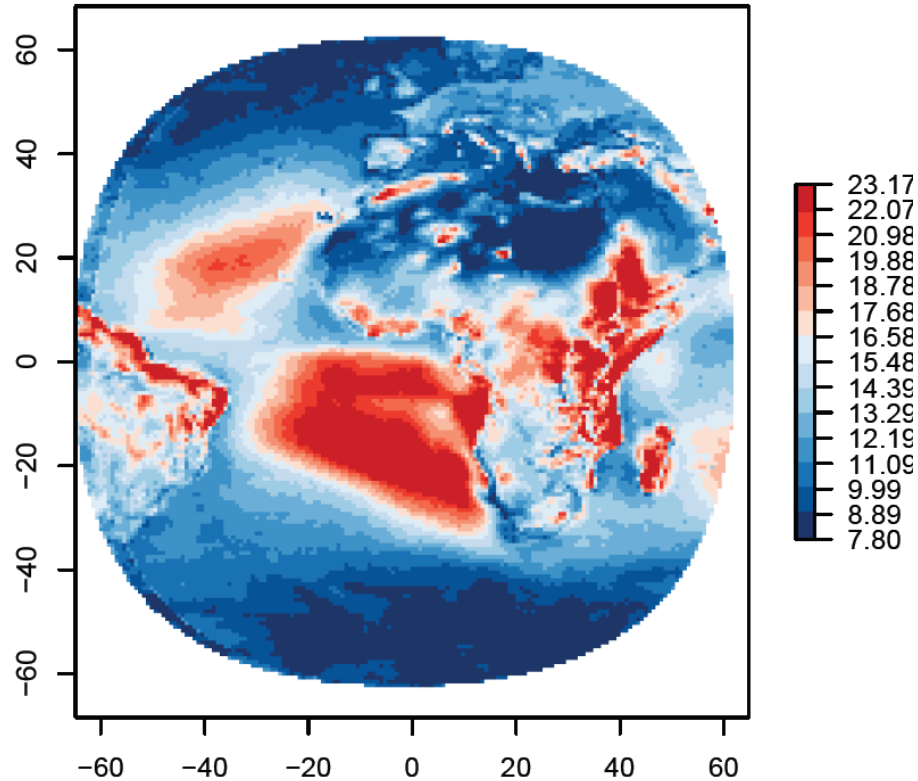CGMS International Cloud Working Group (ICWG-2), Madison, 1 November 2018
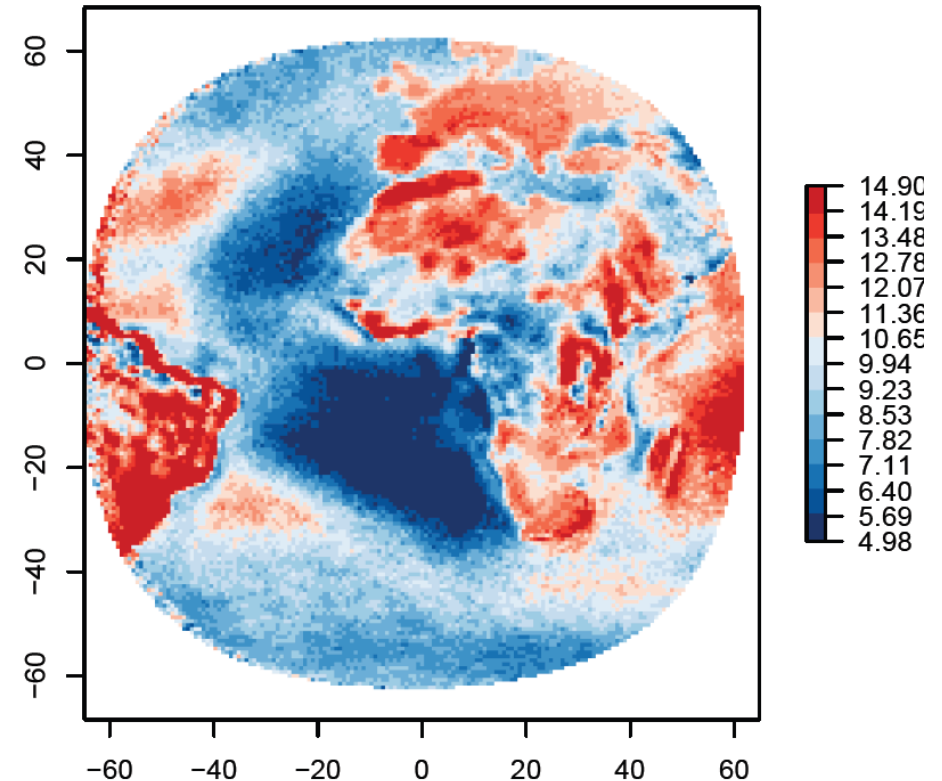Jędrzej Bojanowski

# Spatial variation of CFC diurnal cycle

Based on CMSAF COMET,
Bojanowski & Musial, 2018

**Mean diurnal amplitude (0-100%)**    **Time of maximum CFC [phase] (0-24h)**

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# **Objectives**

- Dissect effects on performance and trends in L3 CFC data:
    - of **orbital drift** separately for each NOAA/MetOp satellite and each node
    - of **diurnal cycle sampling** by changing number of satellites in orbit and their different time of image acquisition

- Create an auxiliary information for interpretation of CFC CDR derived from NOAA/MetOp

- Thoroughly analyse and understand these effects to build a background for optimal orbital drift and sampling correction

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# Methods - data

**NOAA/MetOp AVHRR acqusition times**

➢ AVHRR per-pixel acqusition times based on CM SAF CLARA-A2

- 1982-2015 (NOAA-7 to MetOp B)
- Aggregated to 0.25 degree by circular median

**Reference CFC data with resolved diurnal cycle**

➢ The CM SAF ClOud Fractional Cover dataset from METeosat First and Second Generation - Edition 1 (COMET)

- MVIRI+SEVIRI: 1991-2015
- Bayesian-based CFC for each 0.05 deg pixel → aggregated to 0.25 deg
- Mean monthly diurnal cycle (1 hour resolution) smoothed with splines
- *Missing years (1982-1990) were replaced by 2007-2015*
- *Daily diurnal cycle is stable for each day during a month*

# COMET evaluation: CFC & diurnal cycle

Bojanowski & Musial, 2018

| | N | Amplitude (%) | | Phase (h) | |
|---|---|---|---|---|---|
| | | MBE | bcRMSE | MBE | bcRMSE |
| Overall | 33195 | -2.66 | 8.35 | 0.33 | 5.25 |
| MFG | 18648 | -3.07 | 8.61 | 0.34 | 5.46 |
| MSG | 14547 | -2.13 | 8.00 | 0.32 | 4.97 |

## Accuracy and precision

| temporal aggregation | N | mean Meteosat | mean SYNOP | MBE | bcRMSE |
|---|---|---|---|---|---|
| daily | 2141165 | 51.74 | 51.90 | -0.17 | 16.53 |
| monthly | 71040 | 51.77 | 51.91 | -0.14 | 7.04 |

## Temporal stability



(a) Trend of bias: –0.99 % per decade (p < 0.05)

## Amplitude



(b) Trend of bias: 0.72 % per decade (p < 0.05) — SNHT T(k)

## Phase



(c) Trend of bias: 0.02 % per decade (not signif.) — SNHT T(k)

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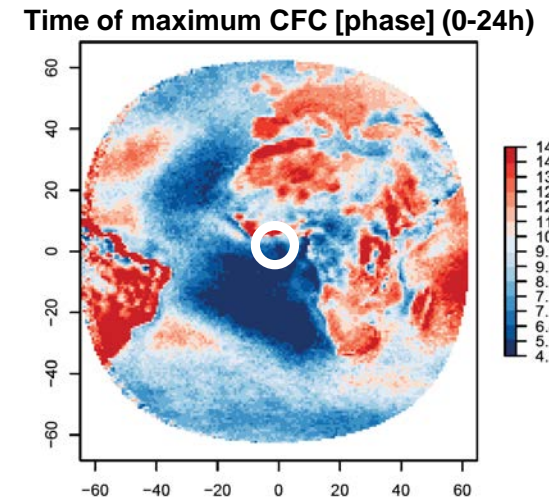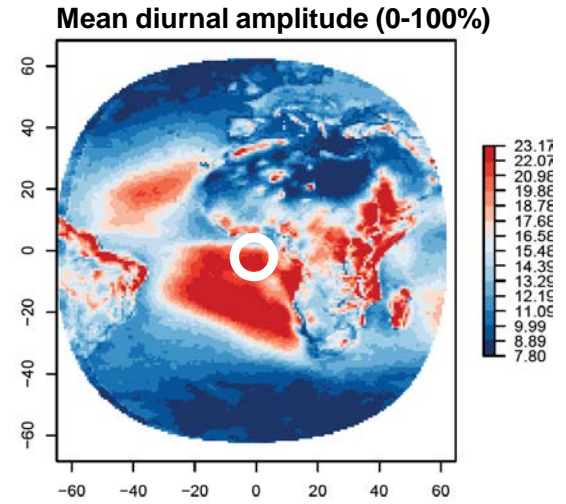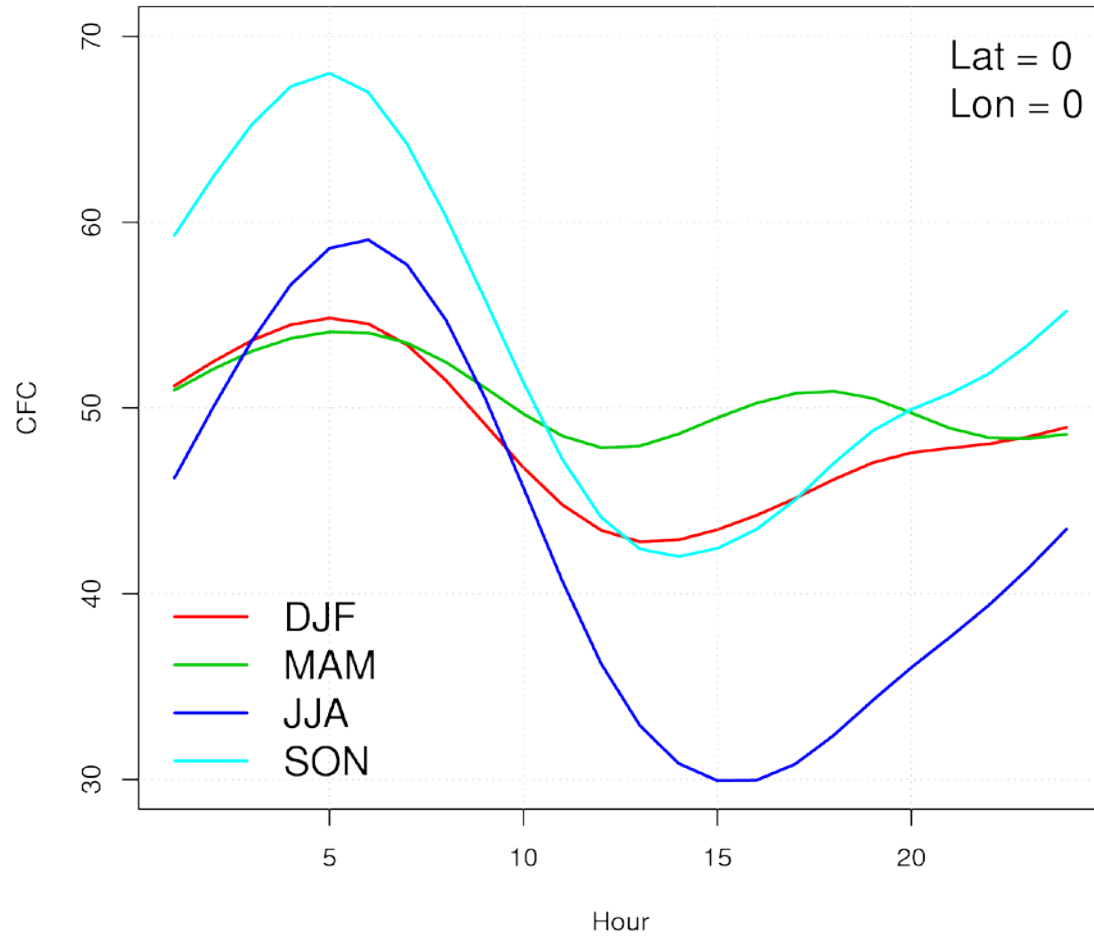
# Methods - sampling

**For each 0.25° grid in 1982-2015:**

1. Sampling reference COMET CFC data with AVHRR observation times
    - → COMET-like L2 AVHRR time series

2. Aggregation of reference COMET and COMET-like AVHRR to CFC monthly means
    - → COMET-like L3 AVHRR time series
    - → reference COMET L3 time series

3. Calculation of errors in COMET-like AVHRR against reference COMET
    - → bias and bias-corrected RMSE

4. Calculation of bias time series bewteen COMET-like AVHRR and reference COMET
    - → (false) trends (Theil-Sen) in AVHRR time series

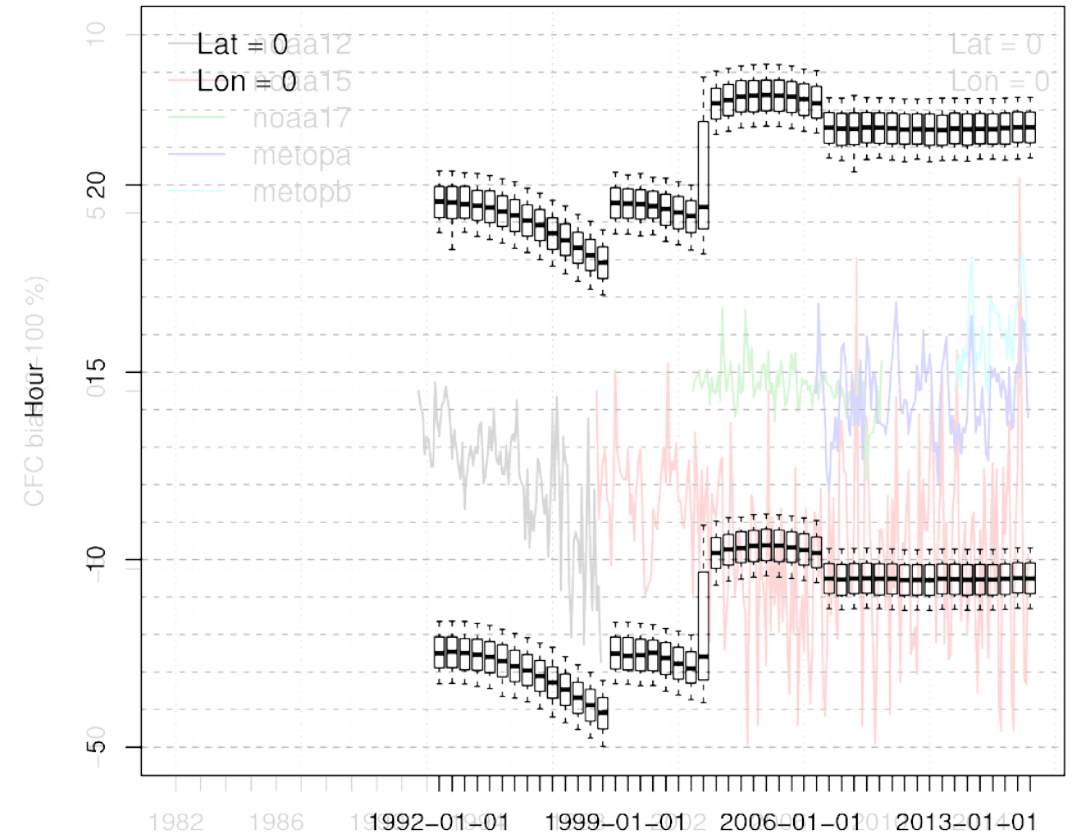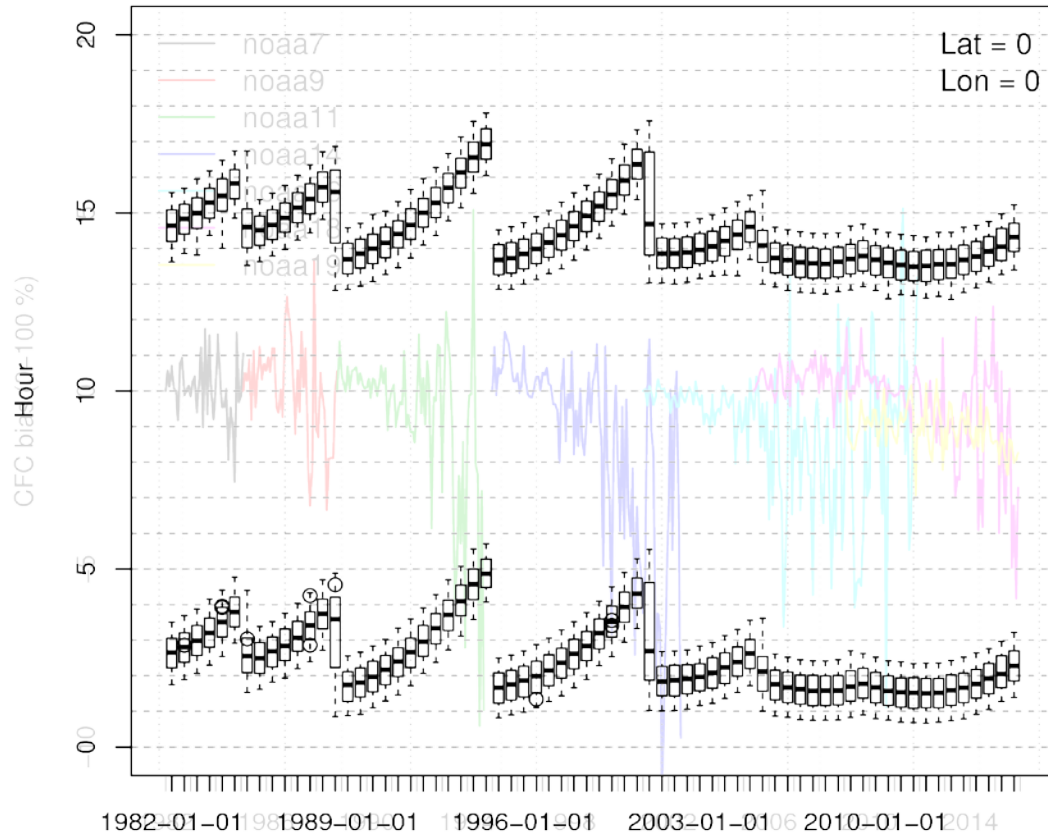**No AVHRR-derived CFC used & COMET CFC retrieval error not relevant**
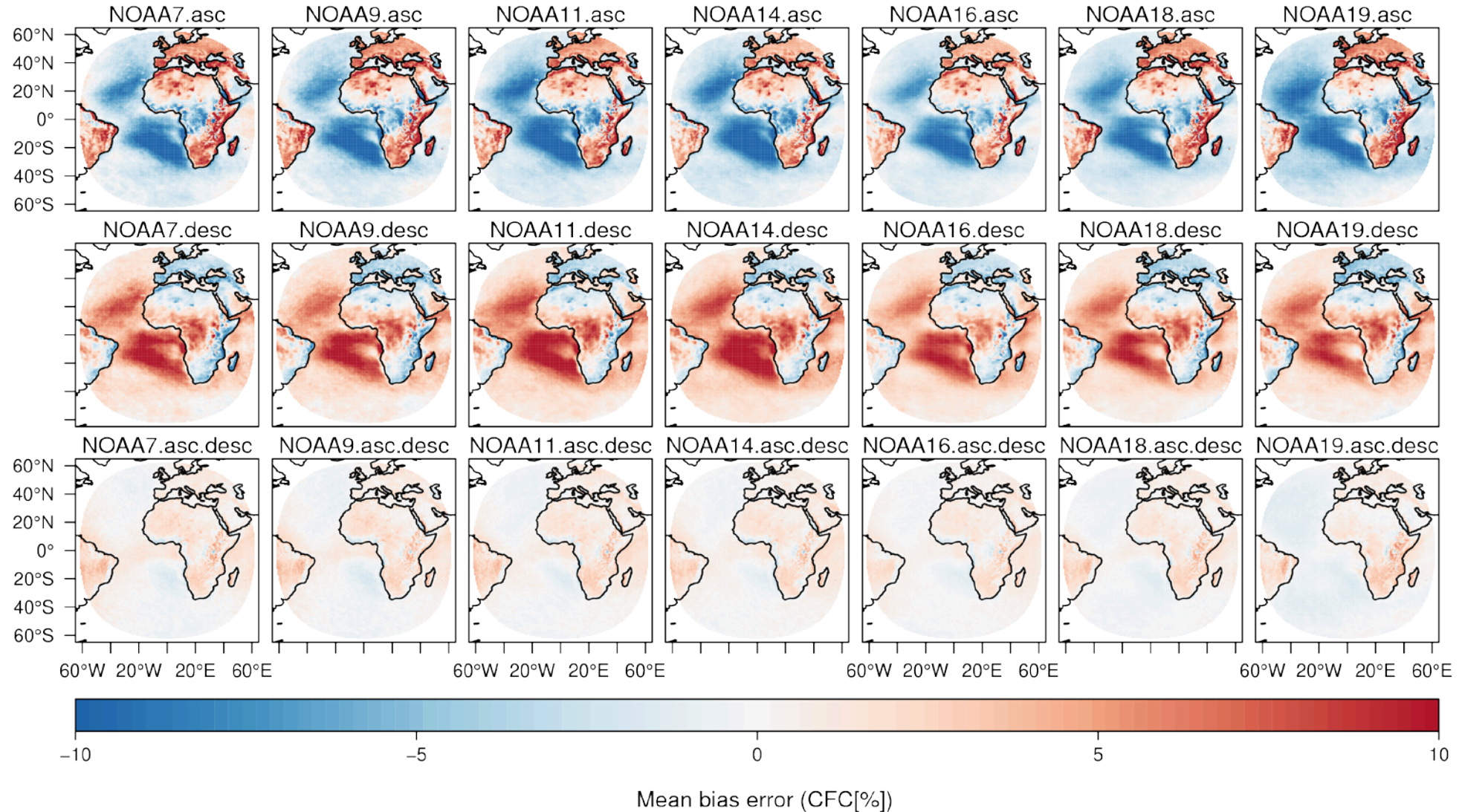
# One grid example: Lon=0, Lat=0

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# Drift-only effect

# Mean bias NOAA-PM

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# Bias-corrected RMSE, NOAA-PM

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# False trends, NOAA-PM



False trend in CFC (%/dec)

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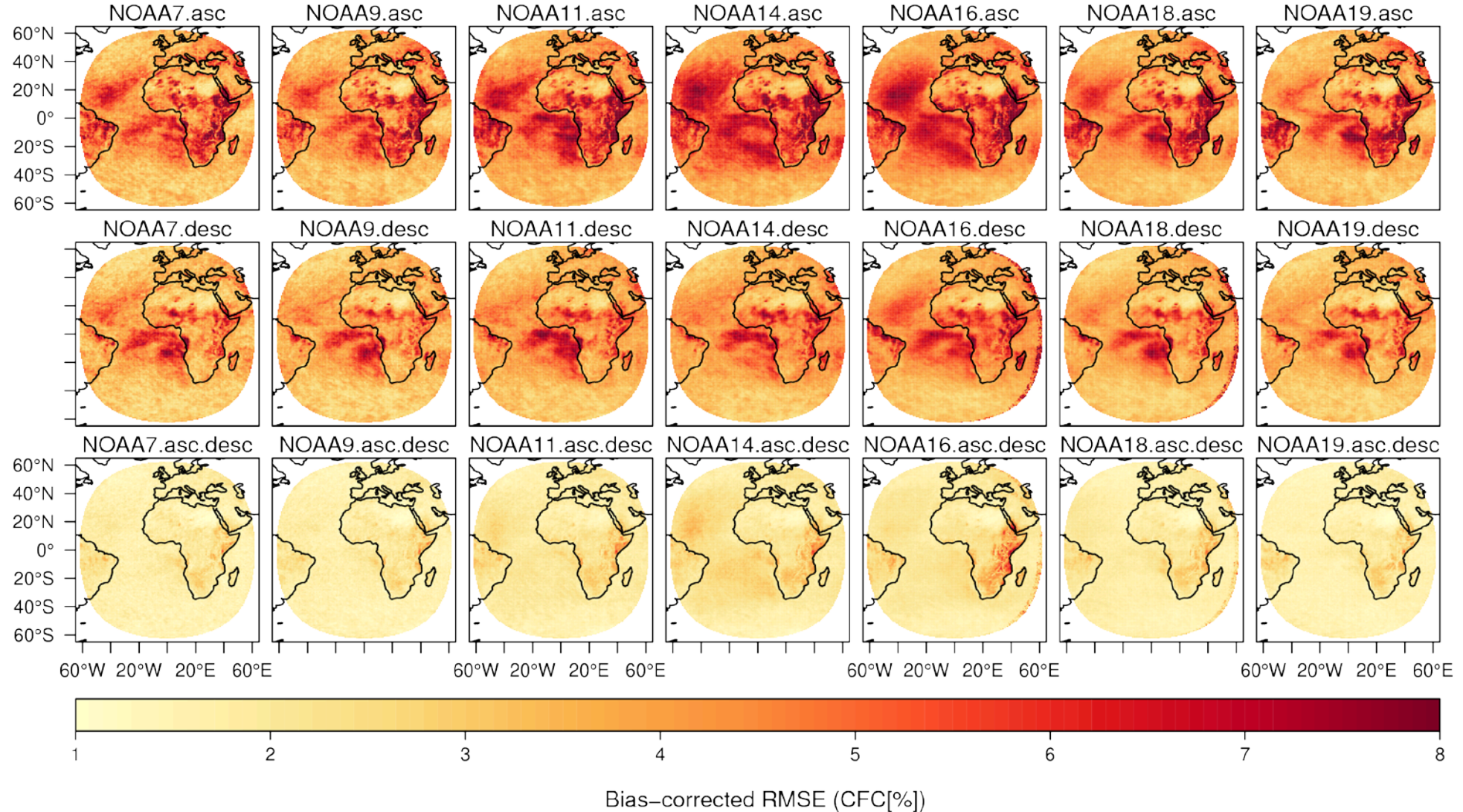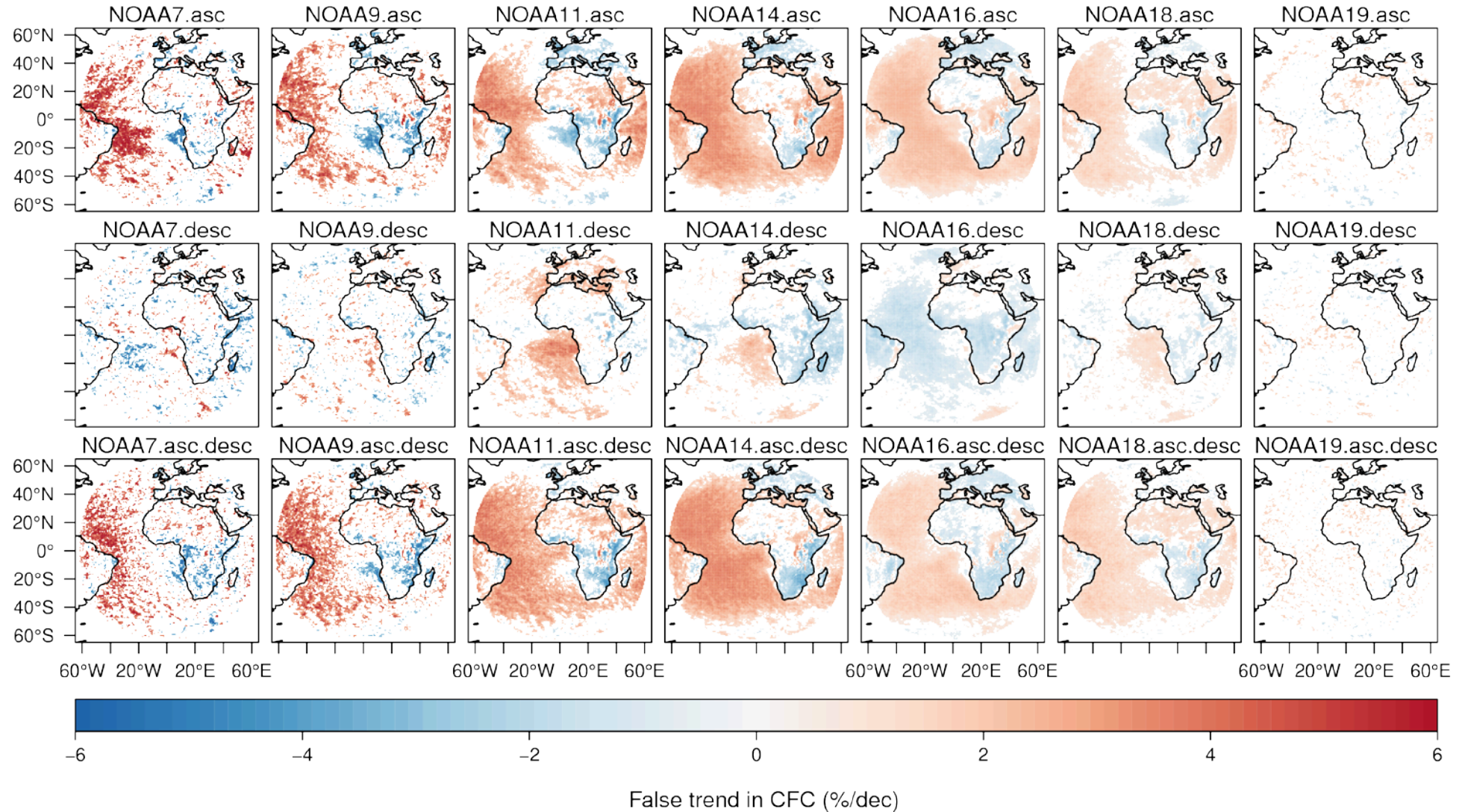
**AVHRR CDR**
**bias**
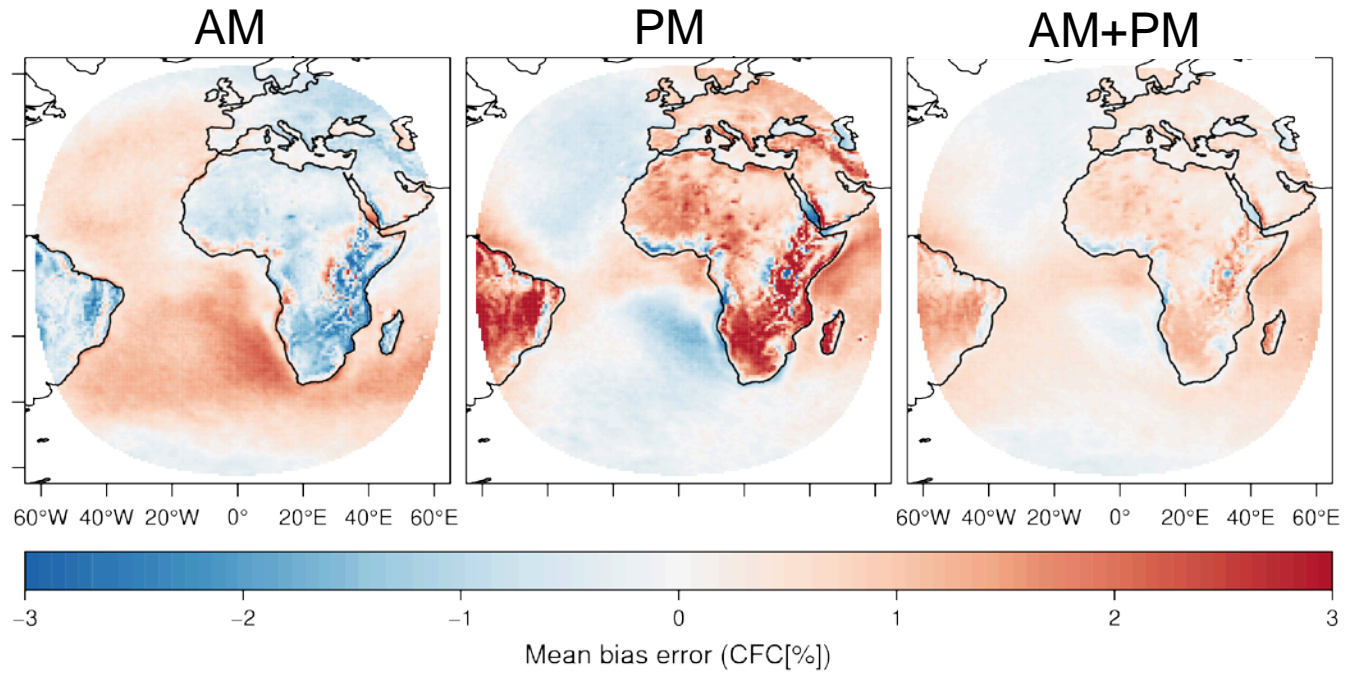
**CLARA-A2** / **AVHRR CDR**
**observed trends** / **false trends**
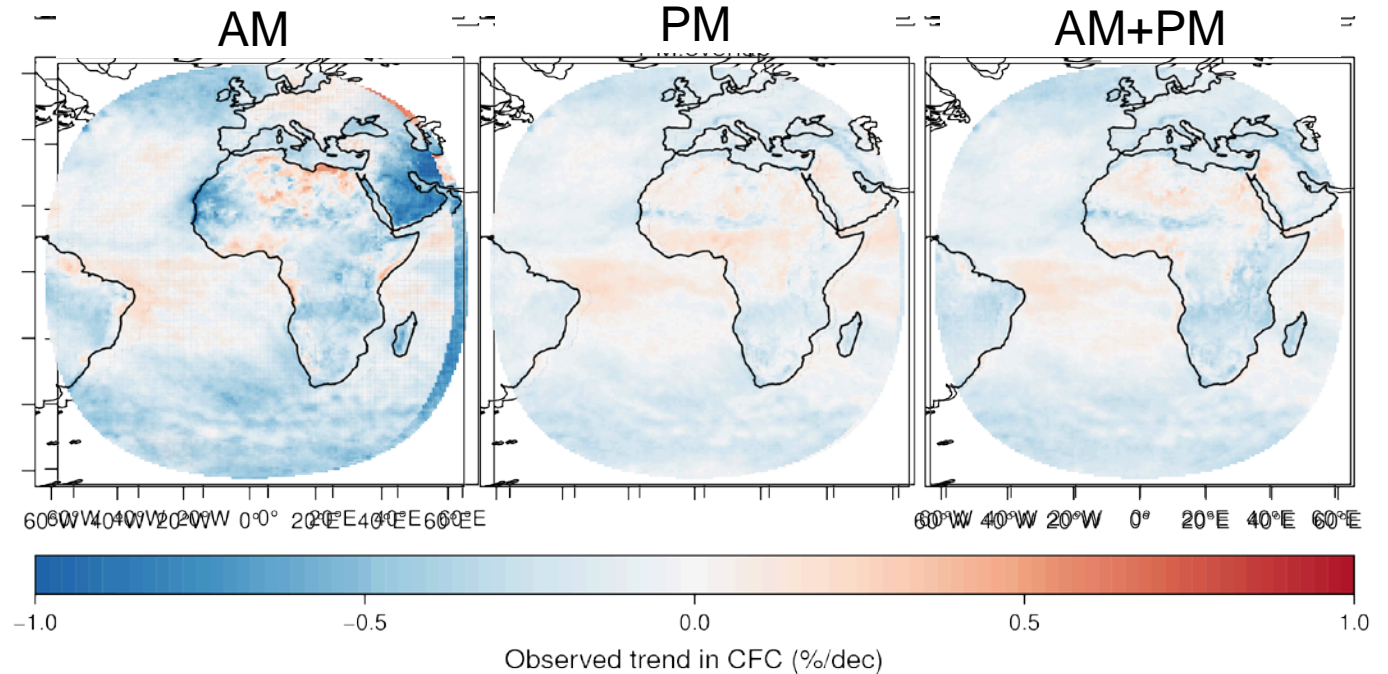
# Temporal stability

- GCOS-200: 1%/dec temporal stability



(a)

> 6 obs per day

Trend of bias: –0.42 % per decade (p < 0.05)
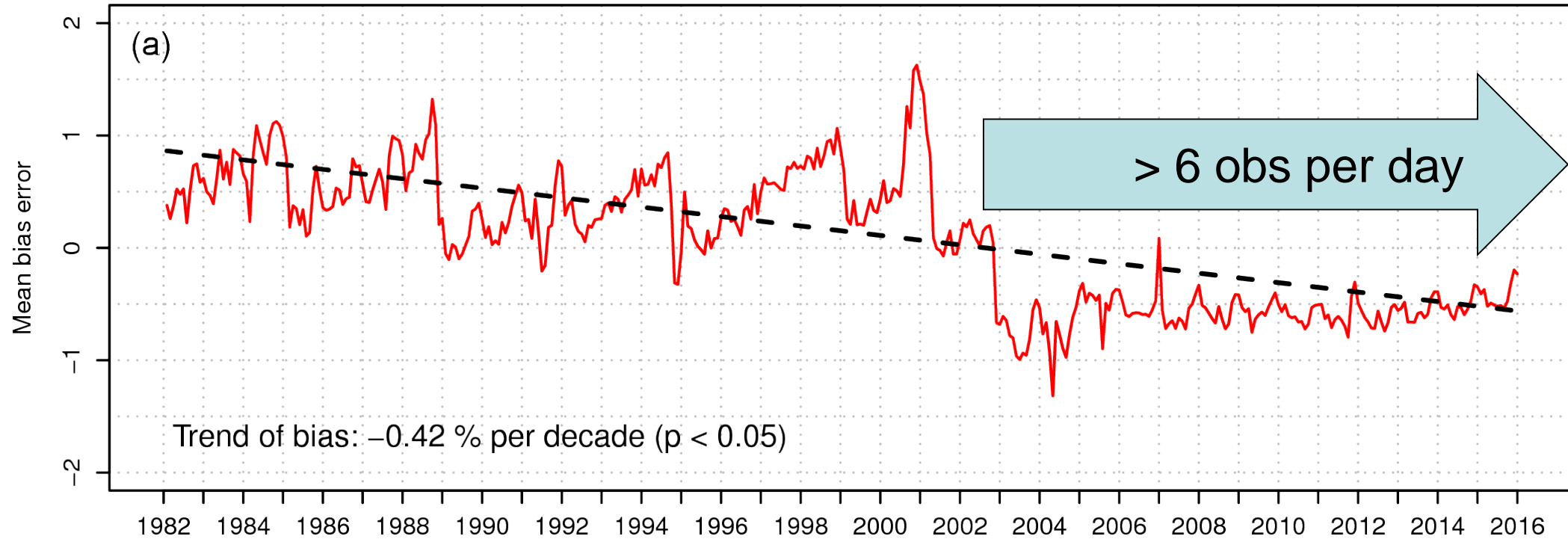
# Summary & outlook

- **Orbital drift and sampling errors: ±10% bias, <8% bcRMSE**
- **False trends: ±6% per decade (±1 for merged satellites, -0.42 averaged over Met disc)**
- **Without diurnal cycle correction, L3 data before <u>2003</u> don't comply with GCOS requirements**
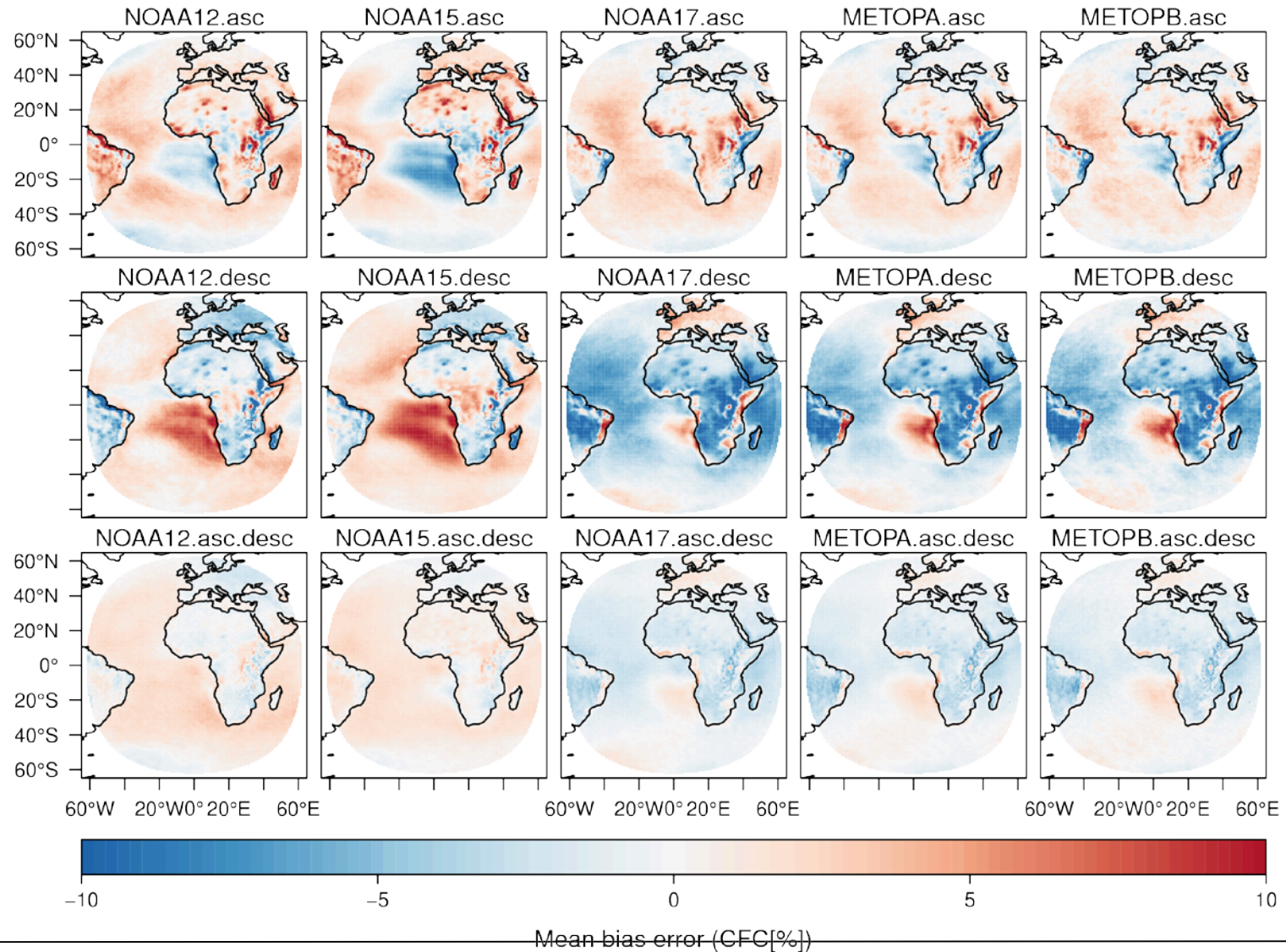
- Aggregated PM-satellites reveal lower false trend than AMs
- No big difference between overlapping and non-overlapping satellites aggregation
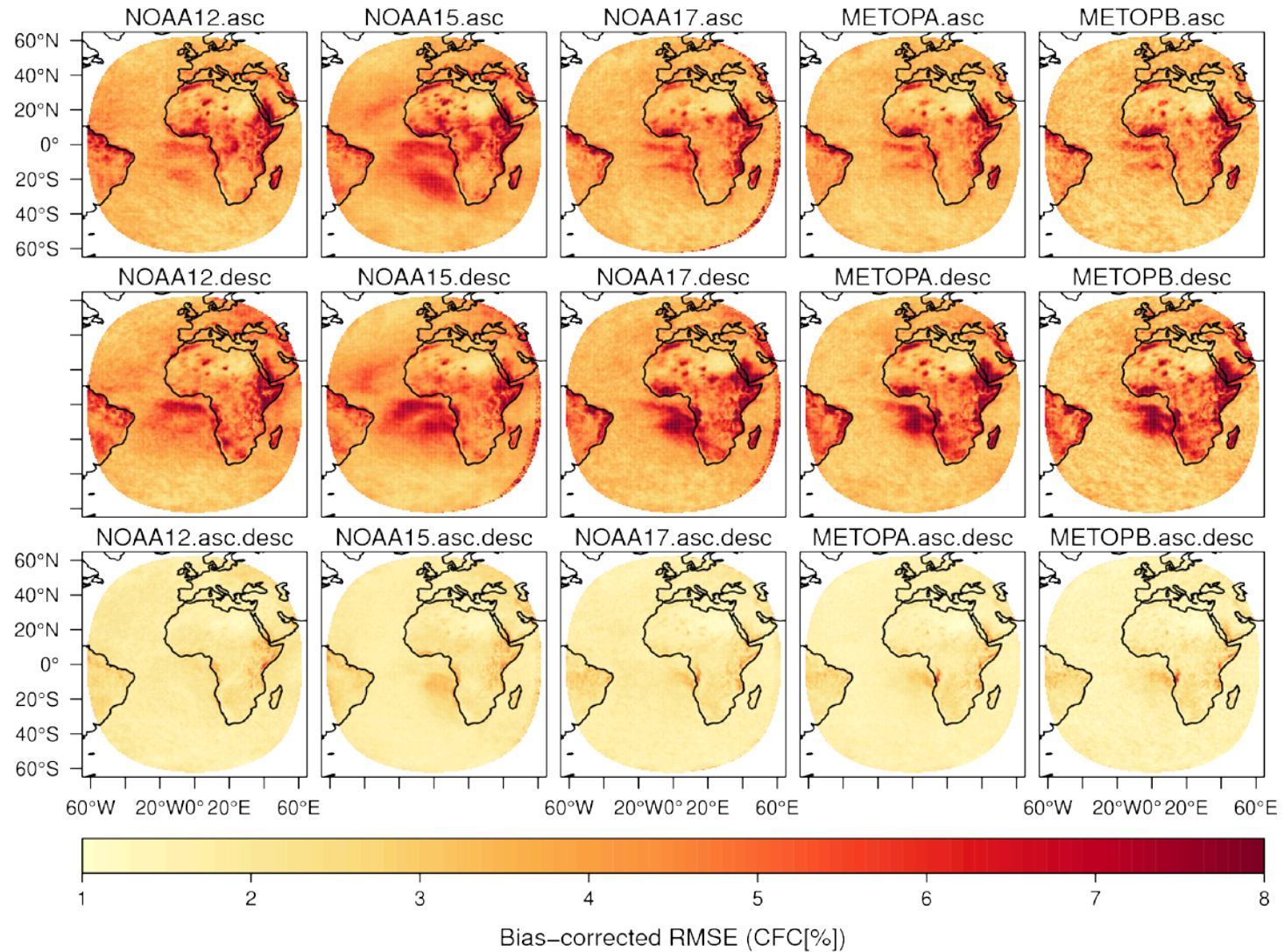- Low correlation bewteen false and observed trends… (why?)

**Outlook:**

- Global analysis using ERA-5 as a reference
- Comparison of correction methods: Foster and Heidinger, 2013, rotated empirical orthogonal function (EOF, Devasthale et al.. 2012), singular spectrum analysis (SSA, under investigation)
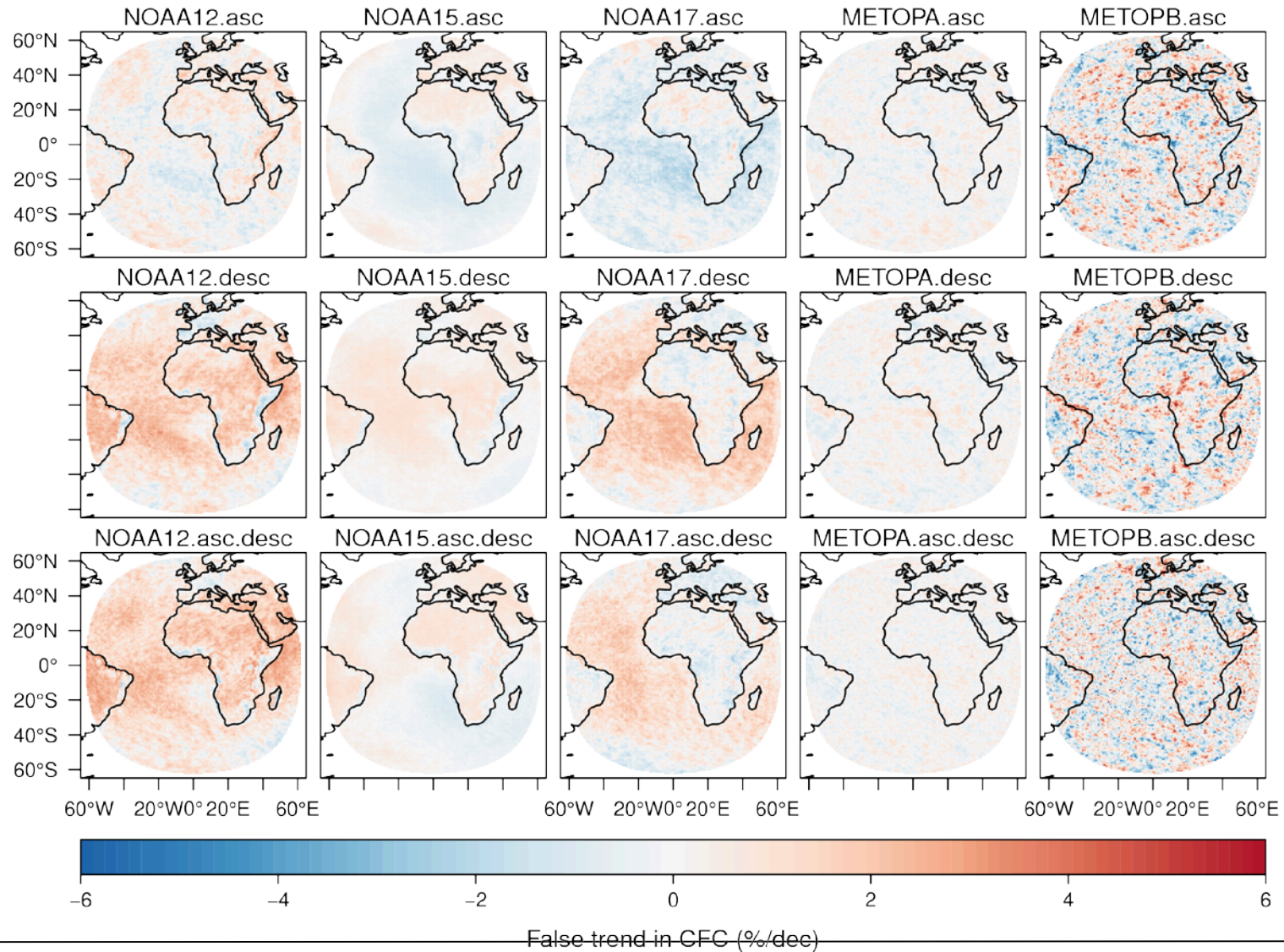- Similar study for cloud properties (e.g. based on CMSAF CLAAS as a reference)
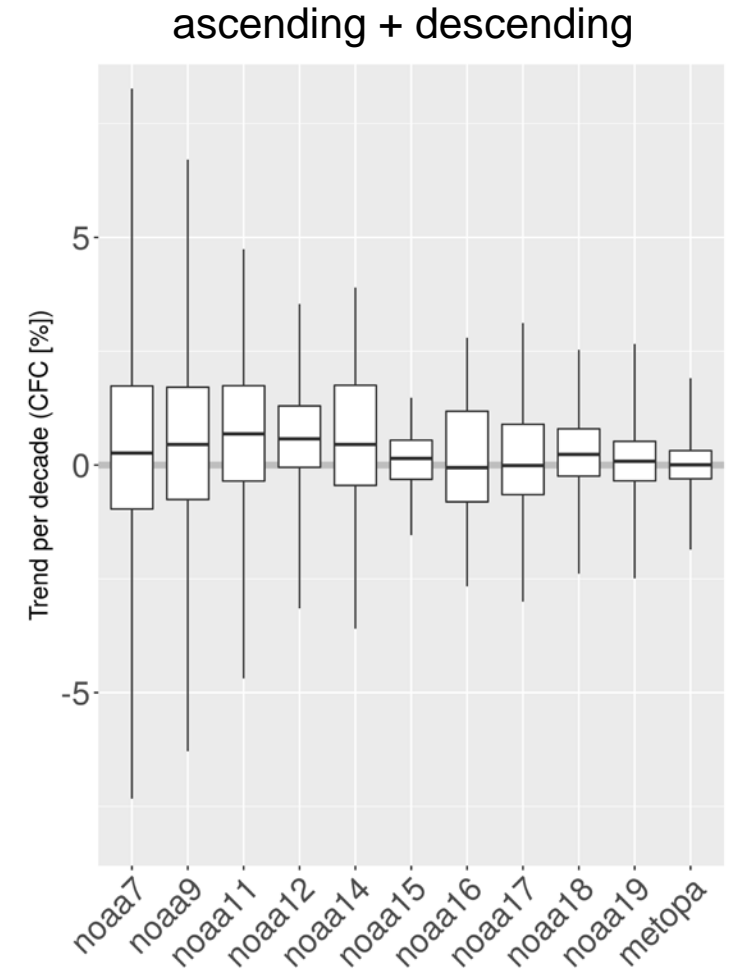
# Mean bias NOAA-AM



Mean bias error (CFC[%])

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# Bias-corrected RMSE, NOAA-AM

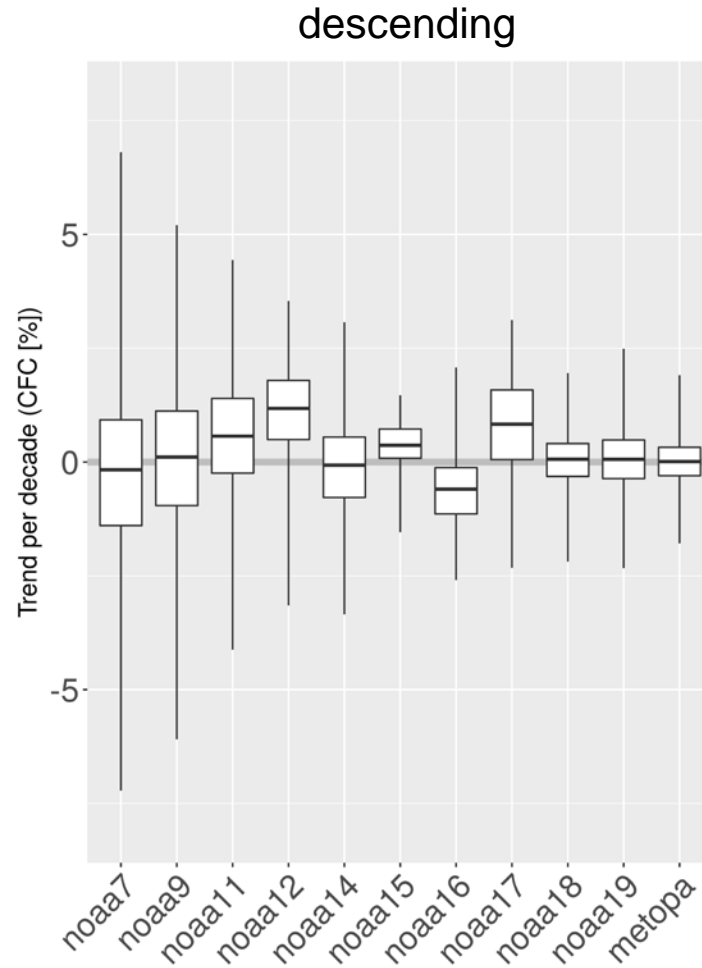CGMS International Cloud Working Group (ICWG-2), Madison, 1 November 2018
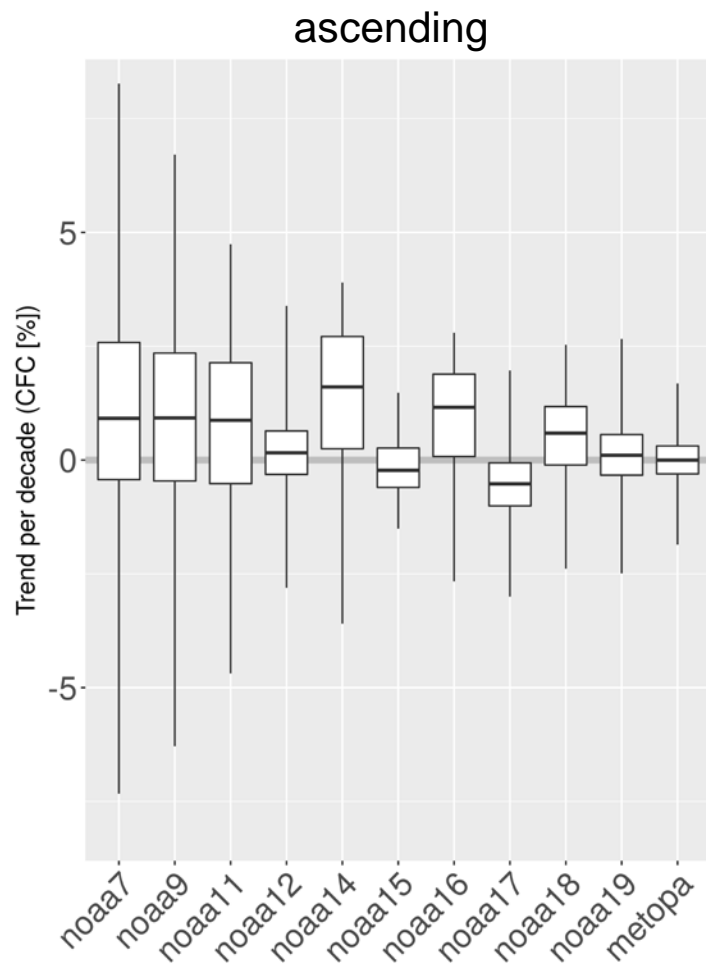Jędrzej Bojanowski

# False trends, NOAA-AM

# False trends by NOAA & node

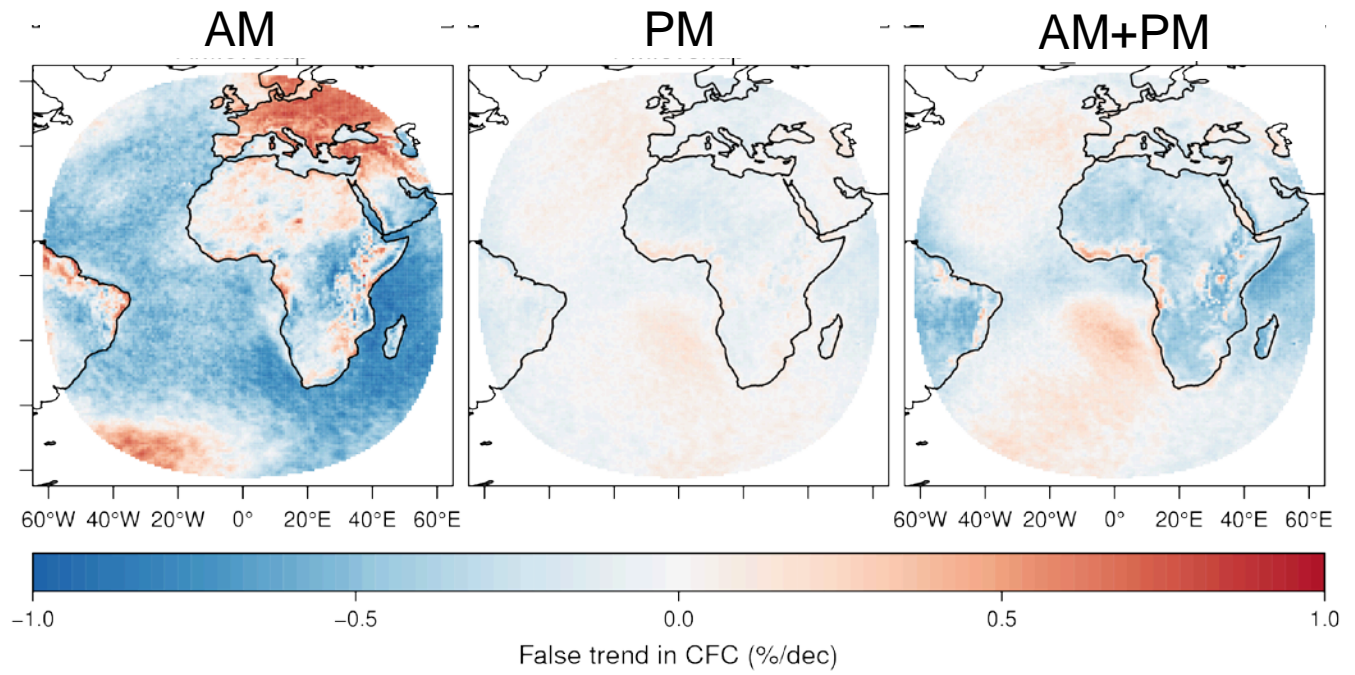# Bias-corrected RMSE, AVHRR CDR

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# AVHRR CDR
## false trends



AM   PM   AM+PM

60°W 40°W 20°W 0° 20°E 40°E 60°E          60°W 40°W 20°W 0° 20°E 40°E 60°E

-1.0          -0.5          0.0          0.5          1.0

False trend in CFC (%/dec)
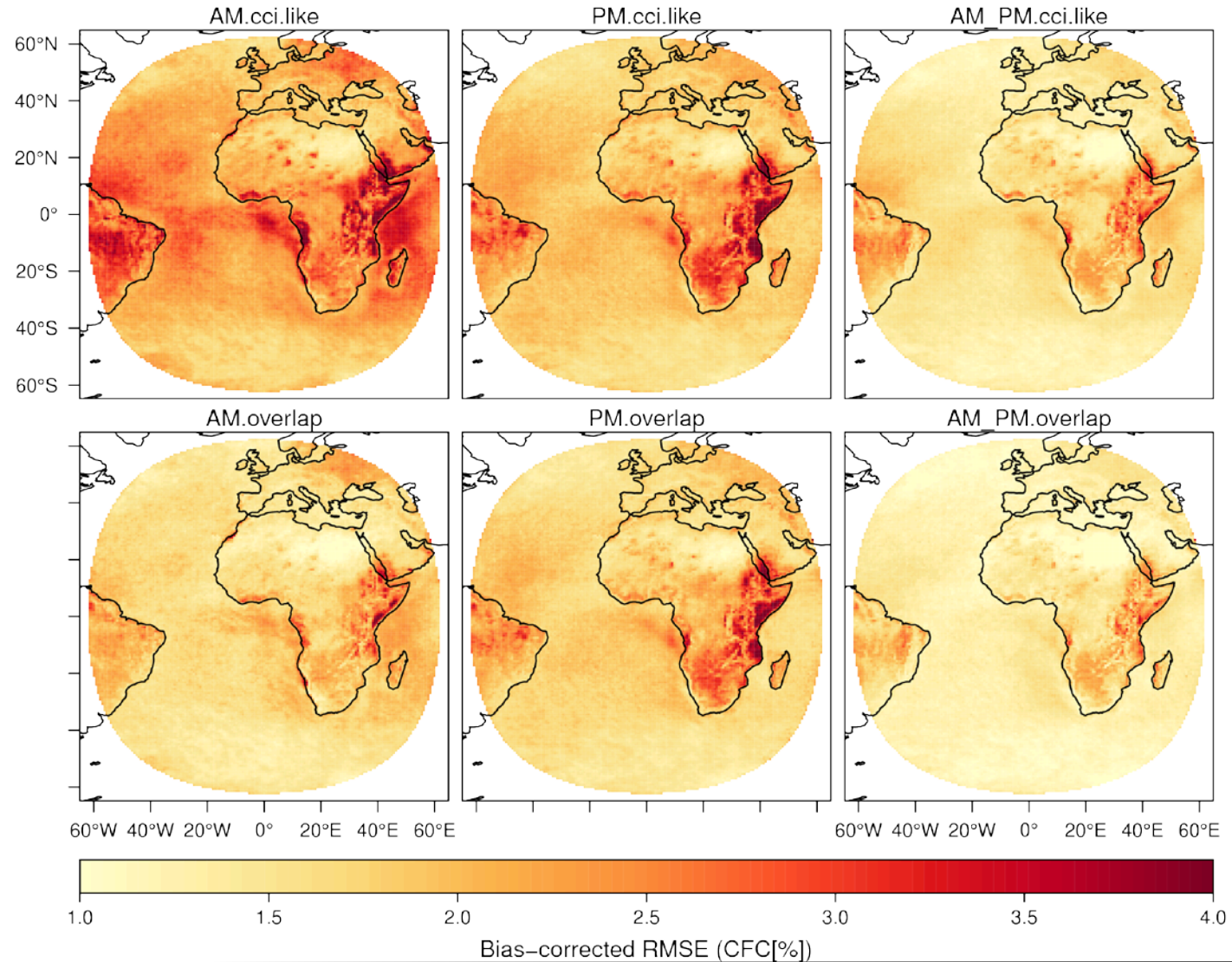
# CLARA-A2
## <u>observed</u> trends



AM   PM   AM+PM

60°W 40°W 20°W 0° 20°E 40°E 60°E          60°W 40°W 20°W 0° 20°E 40°E 60°E

-1.0          -0.5          0.0          0.5          1.0

Observed trend in CFC (%/dec)

**AVHRR CDR bias**

AM   PM   AM+PM

Mean bias error (CFC[%])

**AVHRR CDR false trends**

AM   PM   AM+PM

False trend in CFC (%/dec)
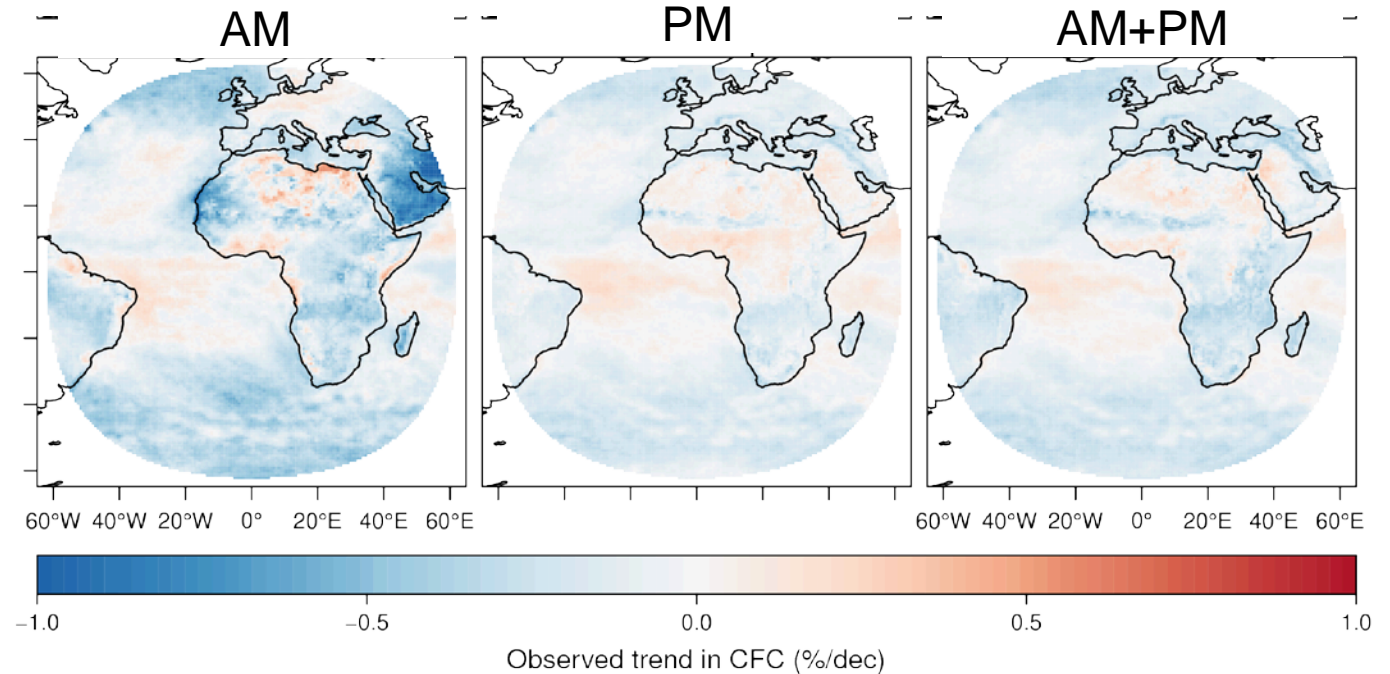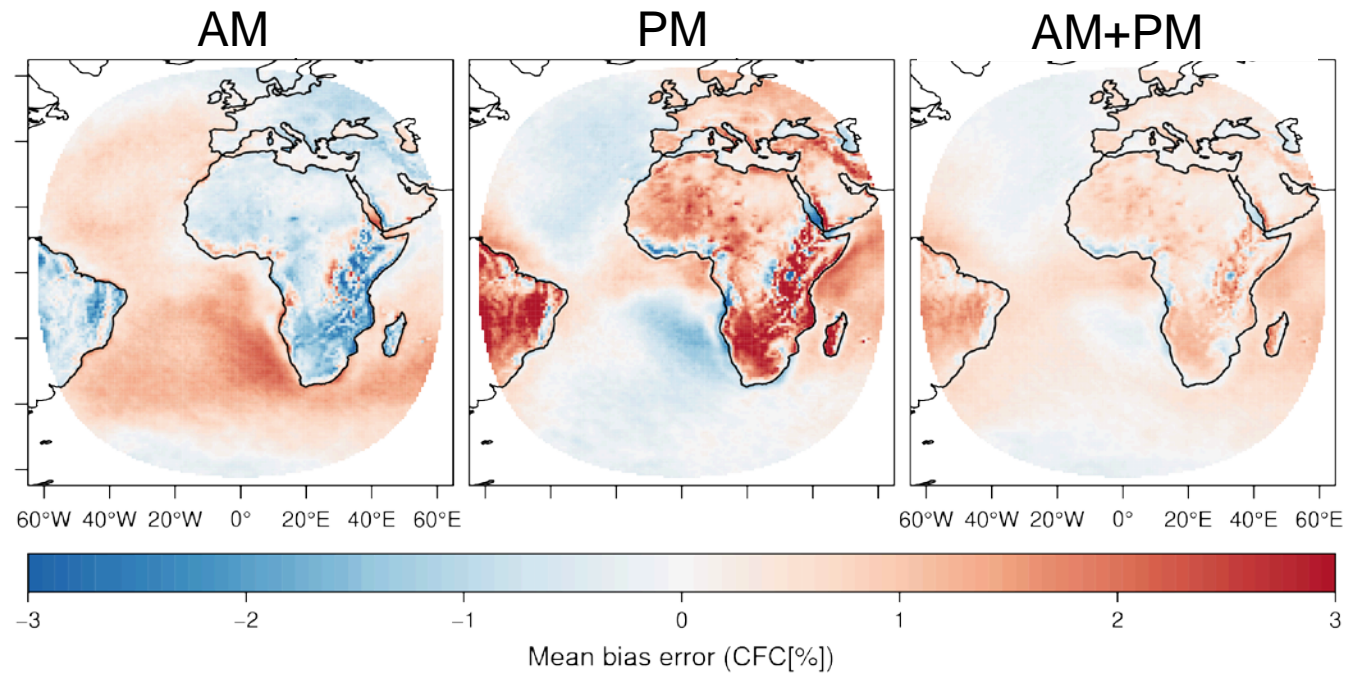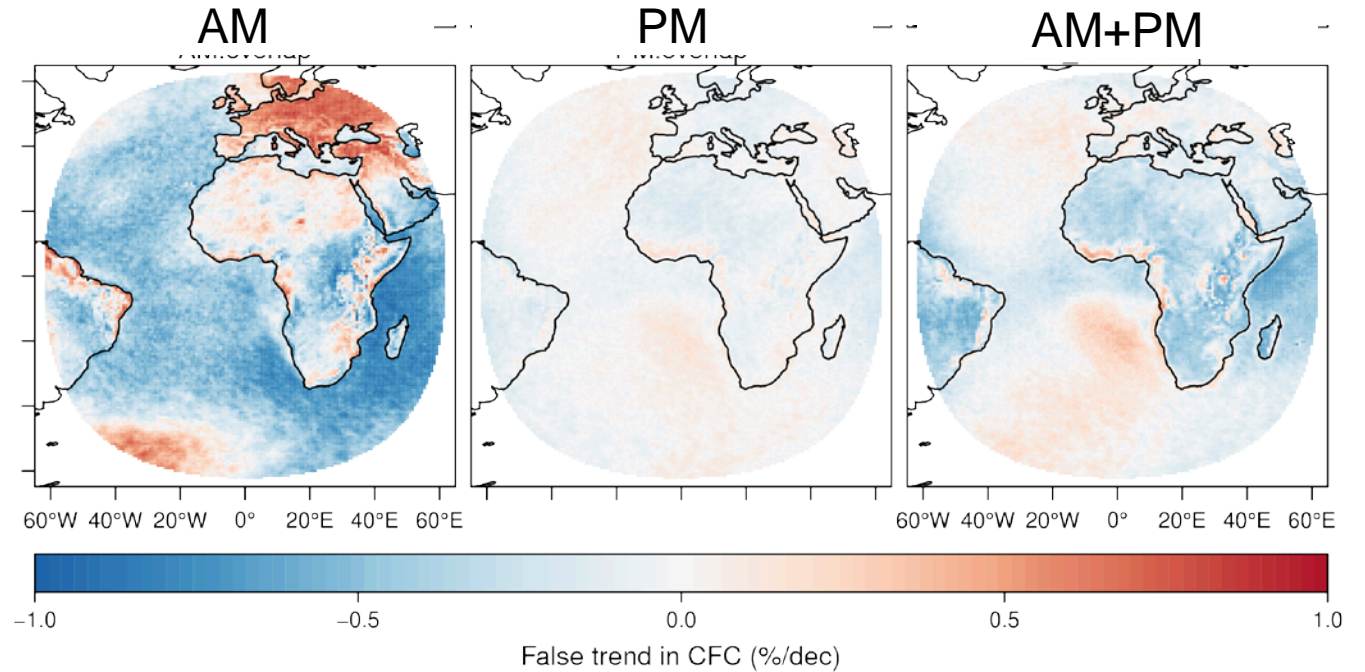
# Drift and sampling effect

# Drift and sampling effect



AM + PM

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