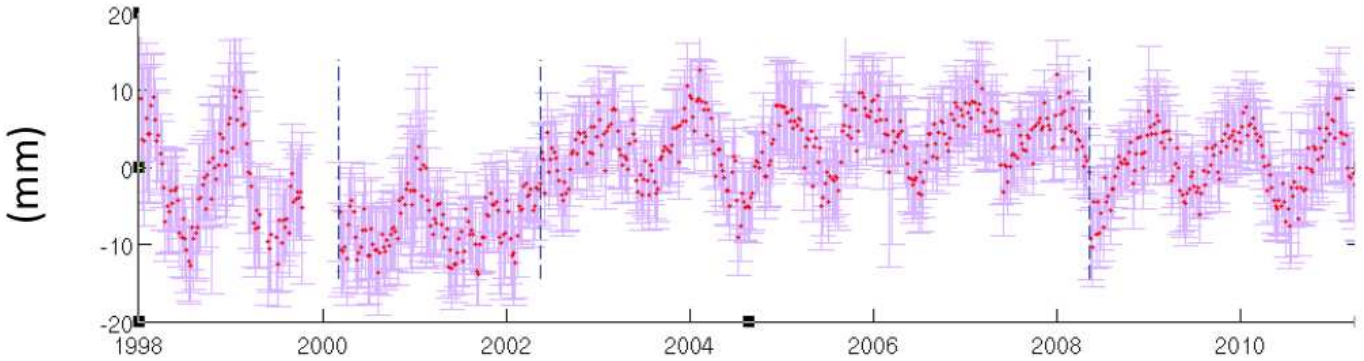
Analysis effects in IGS station motion time series

P. Rebischung, X. Collilieux, T. van Dam, J. Ray, Z. Altamimi

Background: expected signals

- **IGS station position time series mainly consist of:**
  - **Trends + discontinuities**



Ex: YAR2 (Australia) height time series

  - **Seasonal variations, including:**
    - Displacements due to mass transfers at the Earth's surface (loading)
    - Thermal expansion of ground and monuments
    - Other local deformations
    - **Artificial variations due to, e.g.,**
      - Mis-modeling (orbits, troposphere...)
      - Observation data & data quality variations
      - Local multipath variations

Background: GPS draconitic year

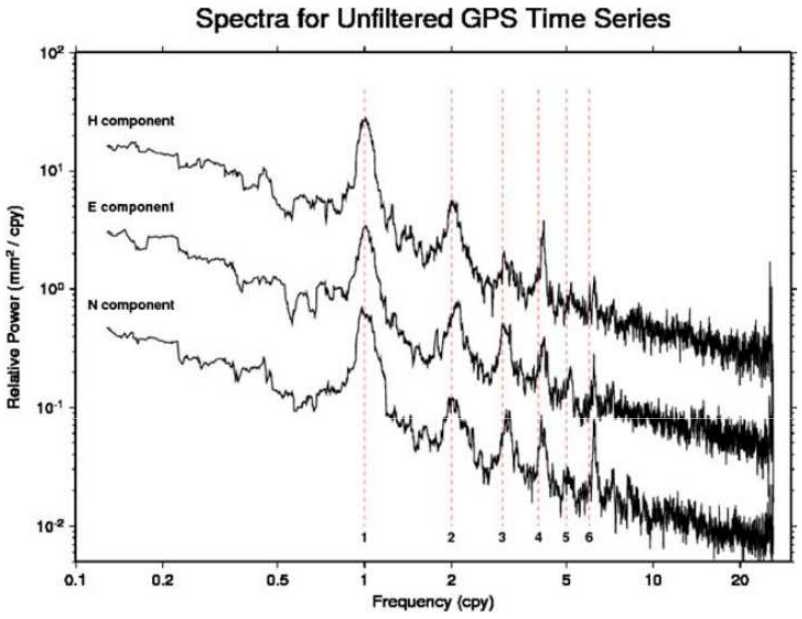
- **Period at which the GPS/sun orientation repeats**

$$\dot{\Omega} = -3\pi \frac{J_2}{T}\left(\frac{R_e}{a}\right)^2 \cdot \cos i = -14.1°/\text{year}$$

Schmid et al., (2007)

$$T_R = \frac{2\pi}{2\pi - \dot{\Omega}_{\text{GPS}} \cdot 1\ \text{year}} \cdot 365.25\ \text{days} \approx 351.5\ \text{days}$$

  - **Detected by *Ray (2006)* in IGS position time series**
  - **Visible in nearly all IGS products**



  - **Possible origins:**
    - Aliasing of local site effects (multipath, antenna mis-calibration…)
    - Orbit errors (e.g. due to errors in IERS subdaily ERP tide model, *Griffiths & Ray, 2011*)

Outline

Goal: Investigate systematic errors in IGS station positions

1) Load-corrected IGS combined station positions

- What is the contribution of draconitic errors?

2) Inter-AC discrepancies

- Are there systematic AC-specific analysis artifacts?
- How large are they compared to the IGS-load residuals?

IGS positions & loading model: Data

- **GPS position time series:**
  - (Special) combination of AC repro1/operational weekly SINEX solutions
  - Time series segmentation
  - Corrections for offsets, velocities & apparent geocenter motion

- **Non-tidal loading model:**
  - Green's function approach
  - Earth model: Gutenberg-Bullen
  - Reference Frame: Center of Figure (CF) of the Earth *(Blewitt, 2003)*

ECCO + **NCEP** + **GLDAS version 1**

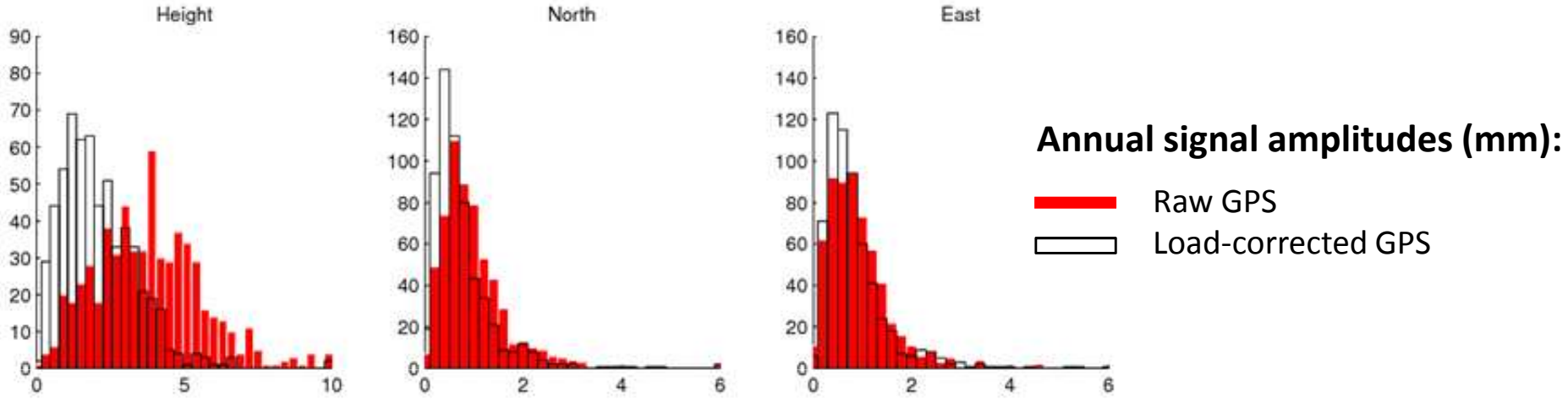
12h
1° x 1°

6 h
2,5° x 2,5 °

1 month
1° x 1°

IGS positions & loading model: Comparison

- **Conclusions from *Collilieux et al., 2011* and *Ray et al., 2011*:**
  - **Load corrections reduce WRMS for most stations, even in horizontal.**
    (Mostly due to reduction of annual signals.)

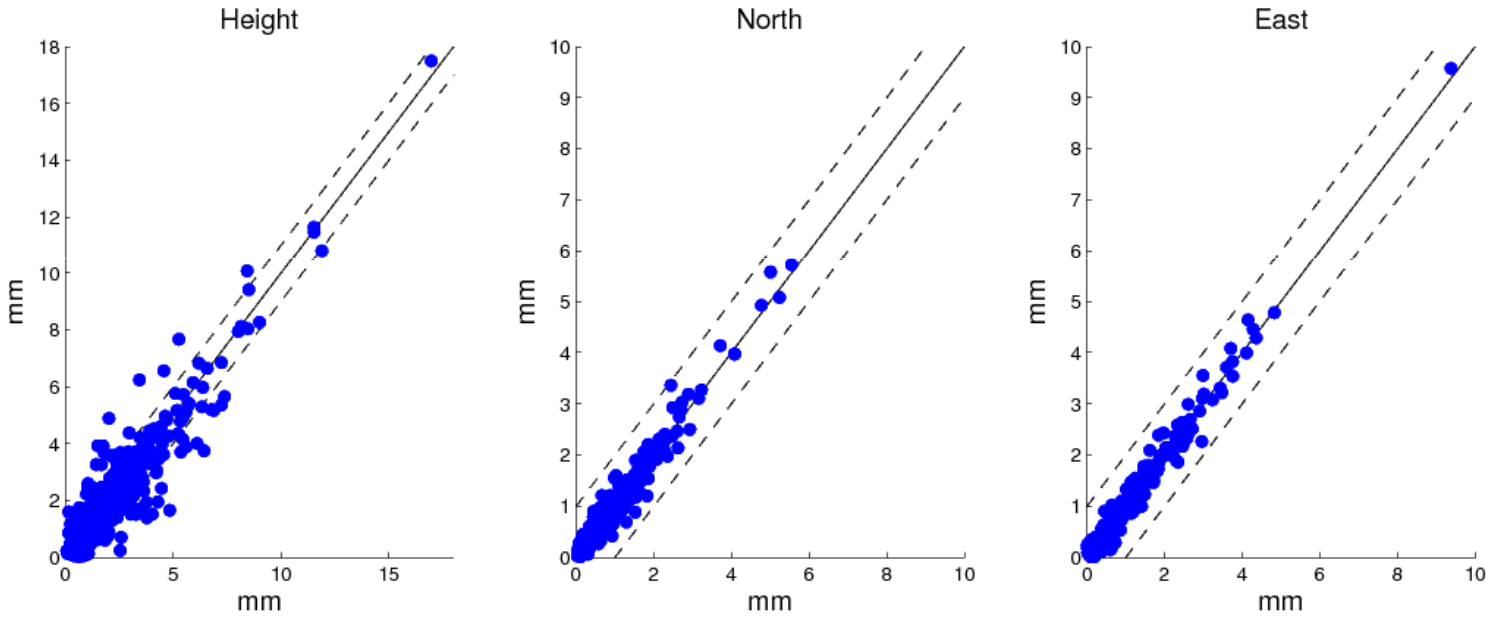


  - **But most residual signal remains, especially in horizontal.**
    - Inaccuracy of loading models
    - Thermal + local deformations
    - GPS errors
  - **Draconitic errors must contribute to remaining annual signals, but magnitude is unknown.**

Load-corrected IGS positions: annual or draconitic?

- **Simultaneous estimation of annual & draconitic:**
  - Possible with long enough time series (beat period ≈ 25 years)
    cf. *Watson et al., UGGI 2011* & *Haines et al., AGU 2011*
  - But hypothesis of time-variable annual signal plausible as well.

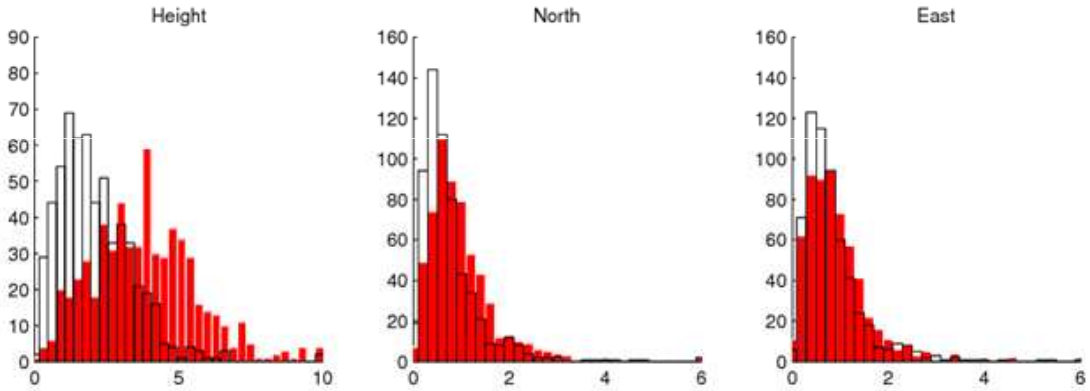
Draconitic amplitudes: load-corrected GPS series vs. raw GPS series
(records longer than 3 years)



- **Estimated draconitic signals seem reliable.**

Load-corrected IGS positions: annual or draconitic?

- **Annual estimated alone:**

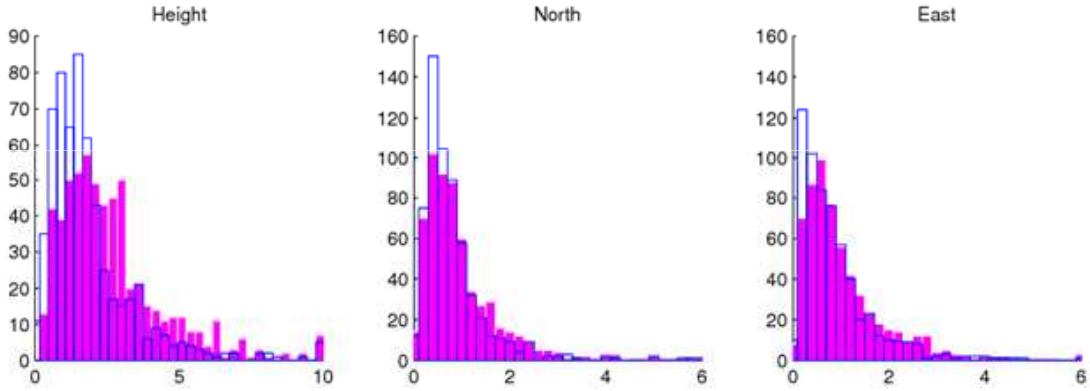


Amplitudes (mm):

Annual in raw GPS

Annual in load-corrected GPS

- **Annual & draconitic estimated simultaneously:**



Amplitudes (mm):

Annual in load-corrected GPS

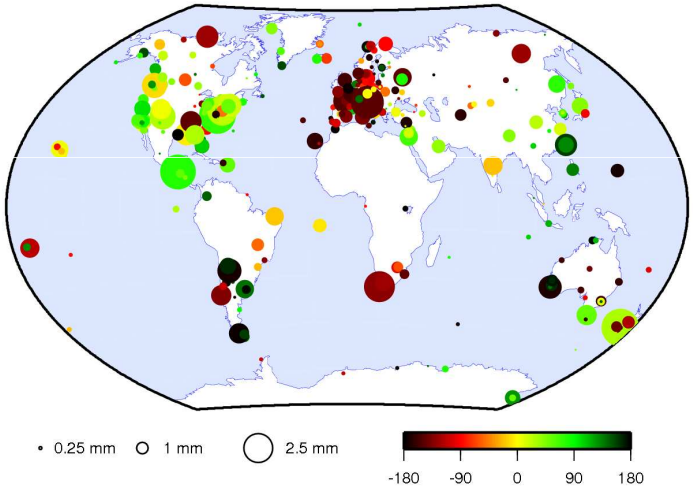
Draconitic in load-corrected GPS

→ **Simultaneous estimation of annual & draconitic does not significantly improve the agreement between GPS and loading models at the annual frequency.**

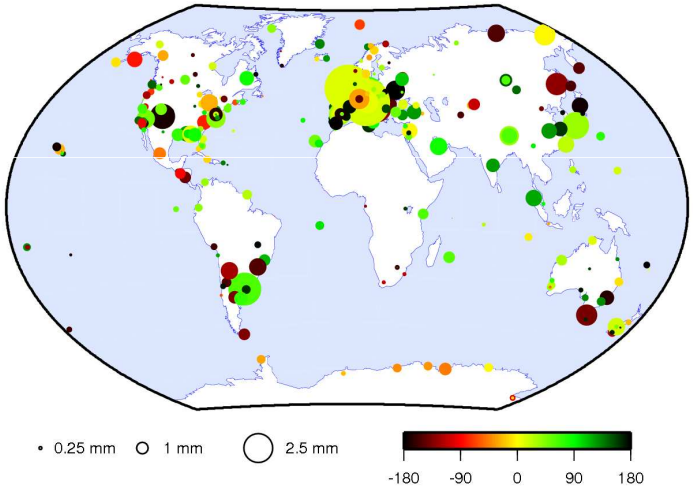
→ **Residual annual & draconitic signals have similar magnitudes.**

Load-corrected IGS positions: annual/draconitic

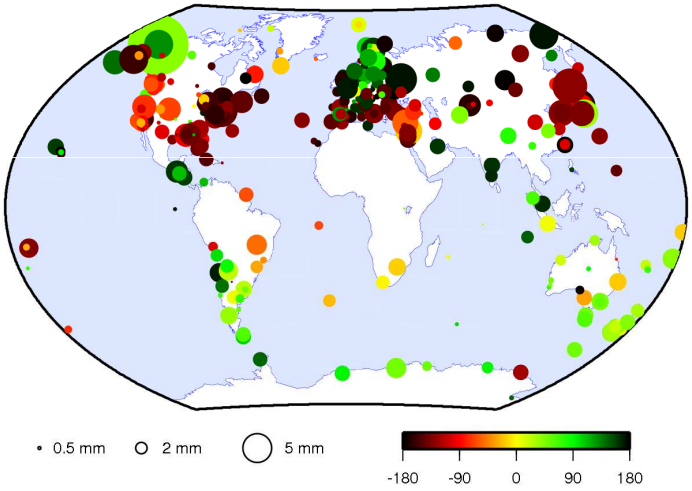
Annual – East



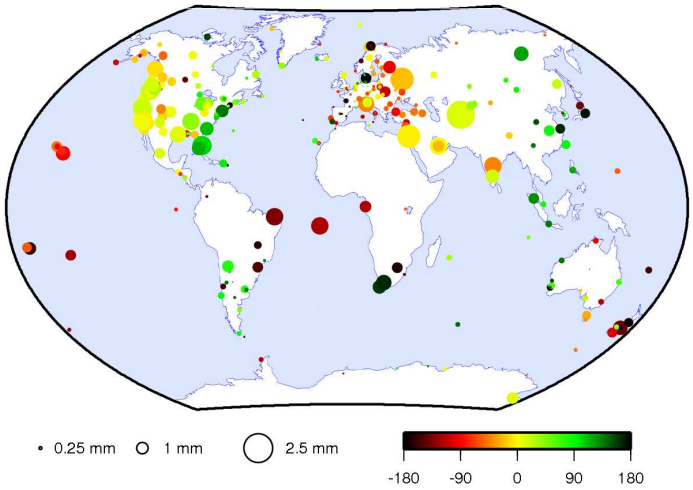
Annual – North



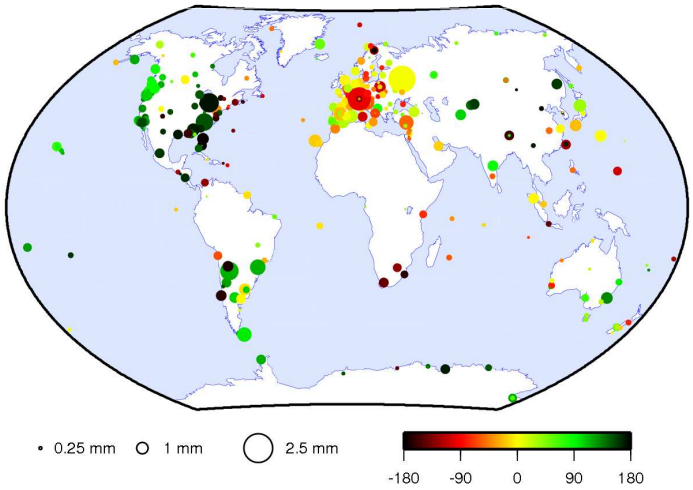
Annual – Up



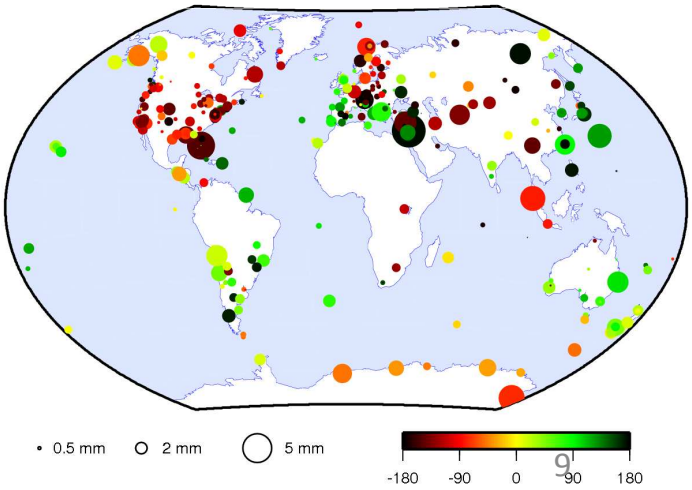
Draconitic – East



Draconitic – North

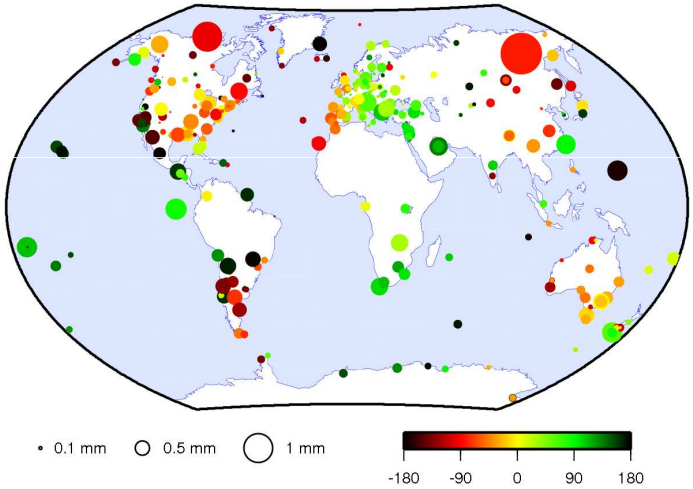


Draconitic – Up

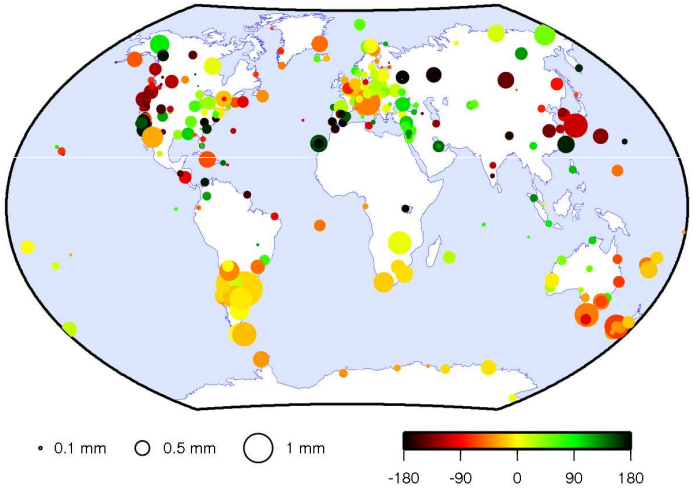


Load-corrected IGS positions: semi-annual/2nd draconitic

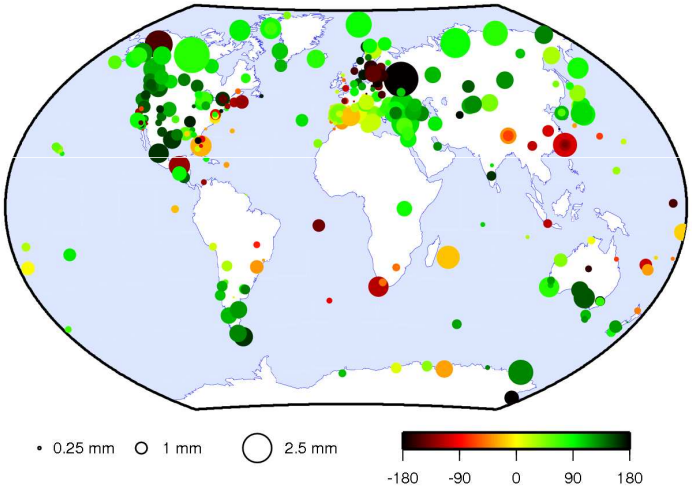
Semi-annual – East



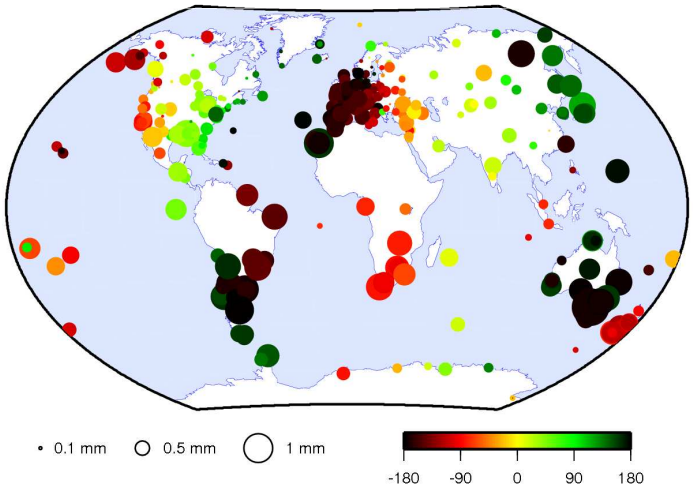
Semi-annual – North



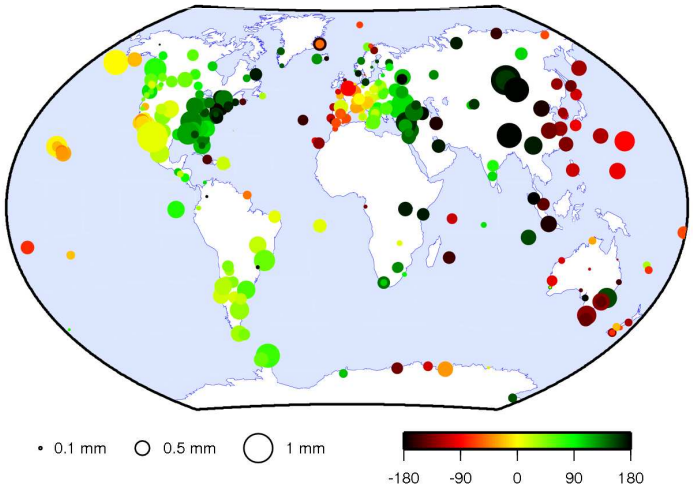
Semi-annual – Up



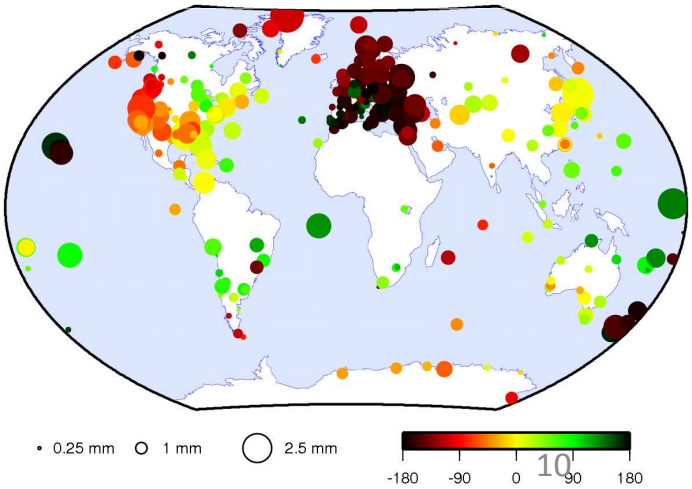
2nd draconitic – East



2nd draconitic – North



2nd draconitic – Up

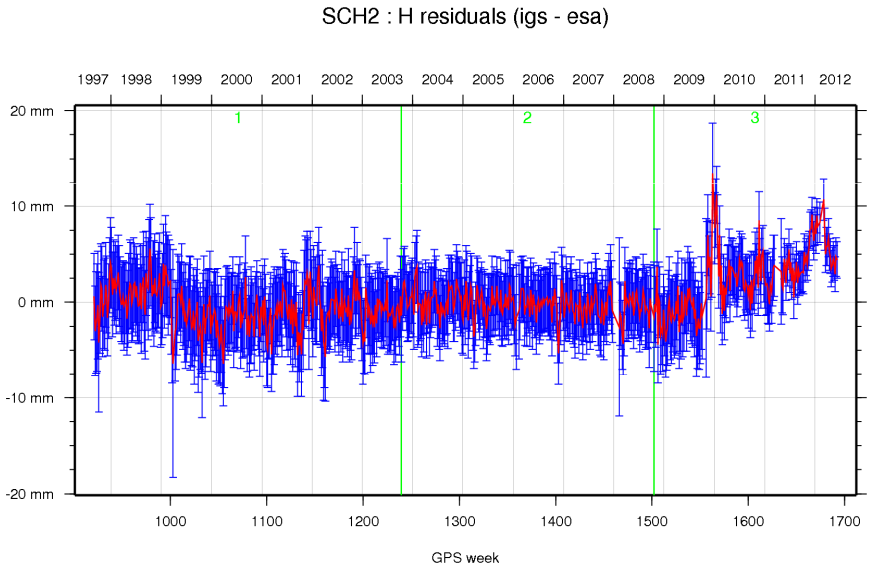


Inter-AC discrepancies

- **Are there systematic AC-specific analysis artifacts?**
- **How large are they compared to the IGS-load residuals?**

→ **Investigate residuals of the weekly SINEX combinations**

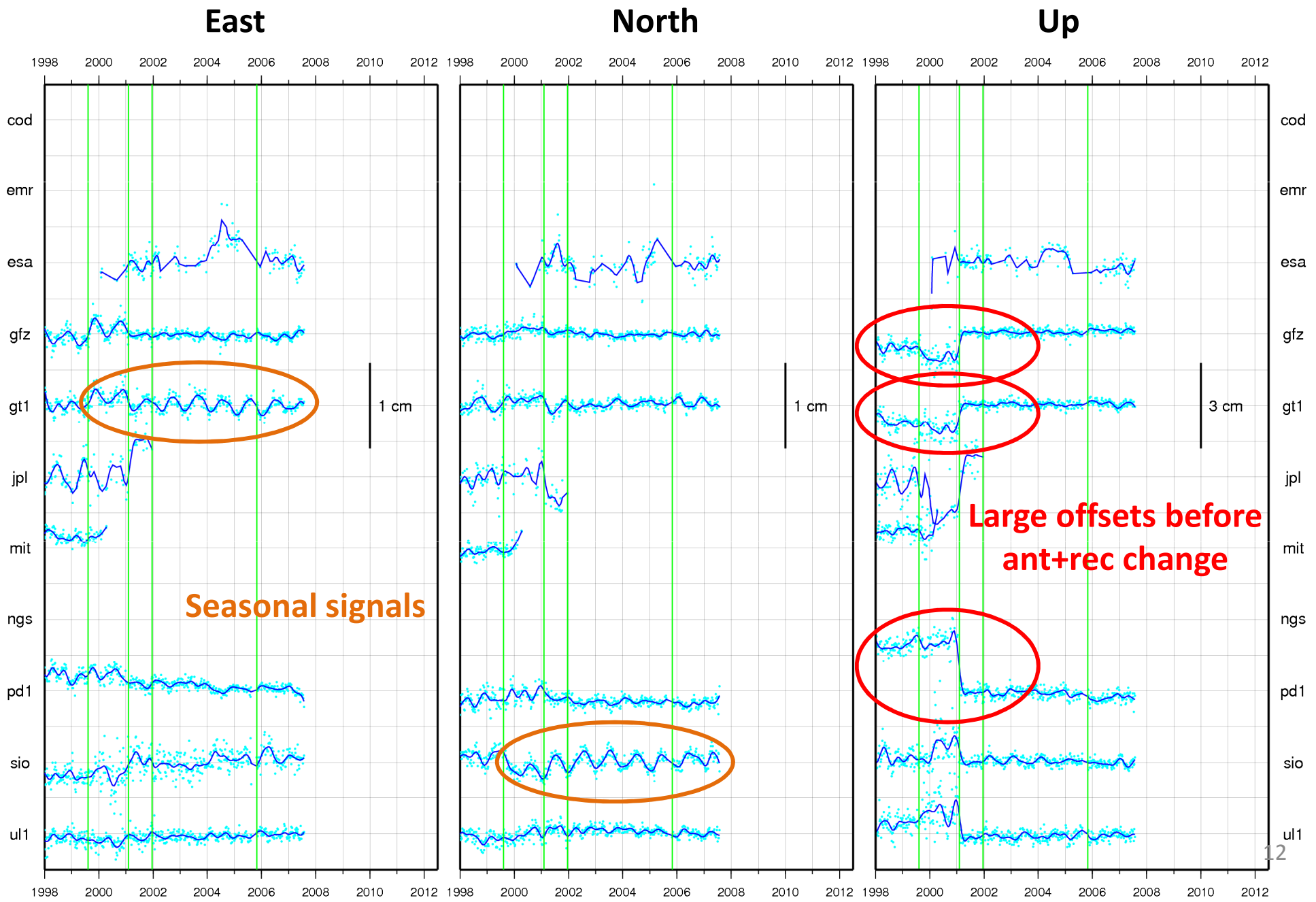
= differences between AC and IGS weekly station positions



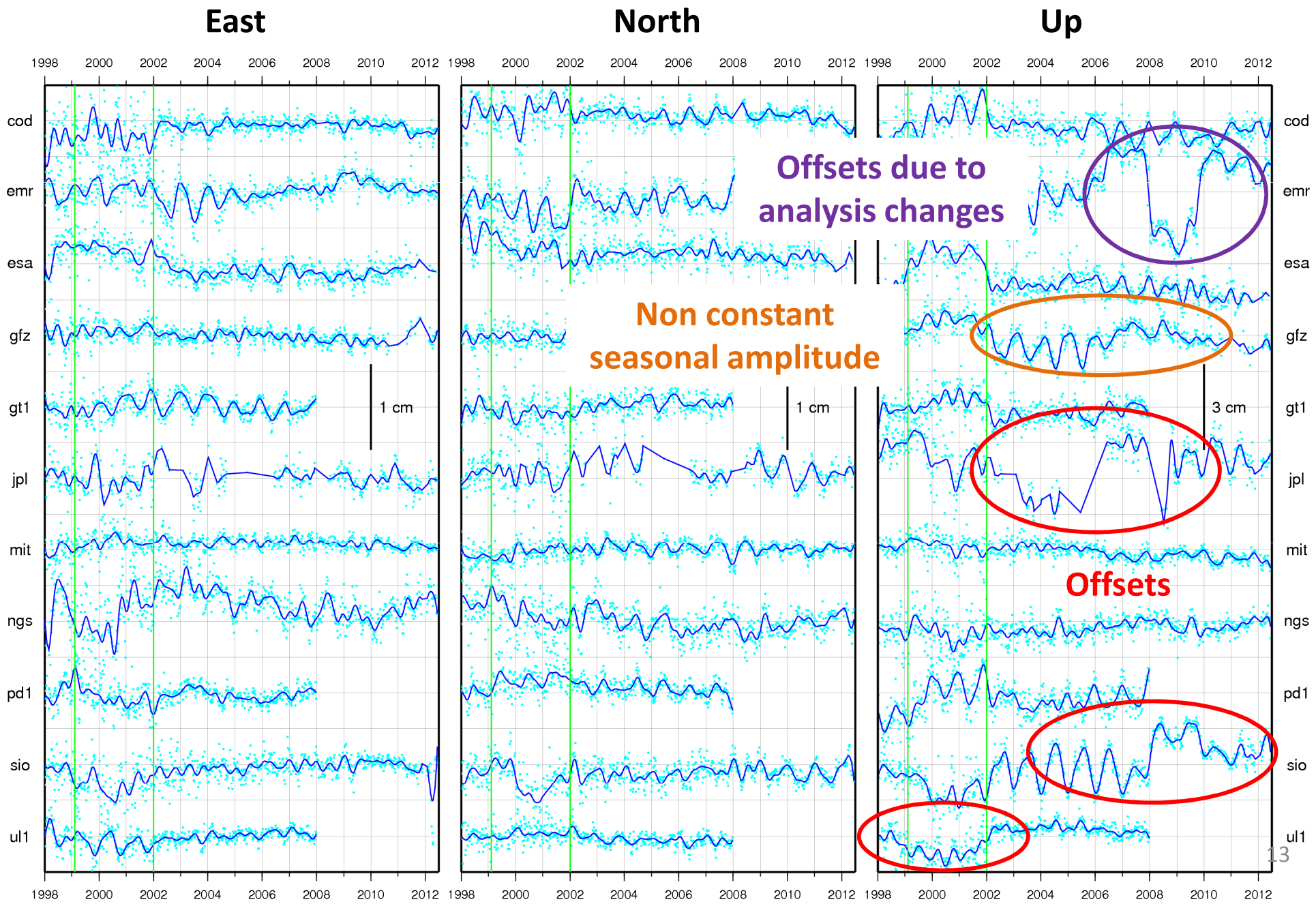
Geophysical signals should cancel out, leaving analysis related effects:

- Differences in data modeling/selection/weighting
- Metadata errors
- Different impacts of common modeling errors (e.g. antenna mis-calibrations, sub-daily EOPs)

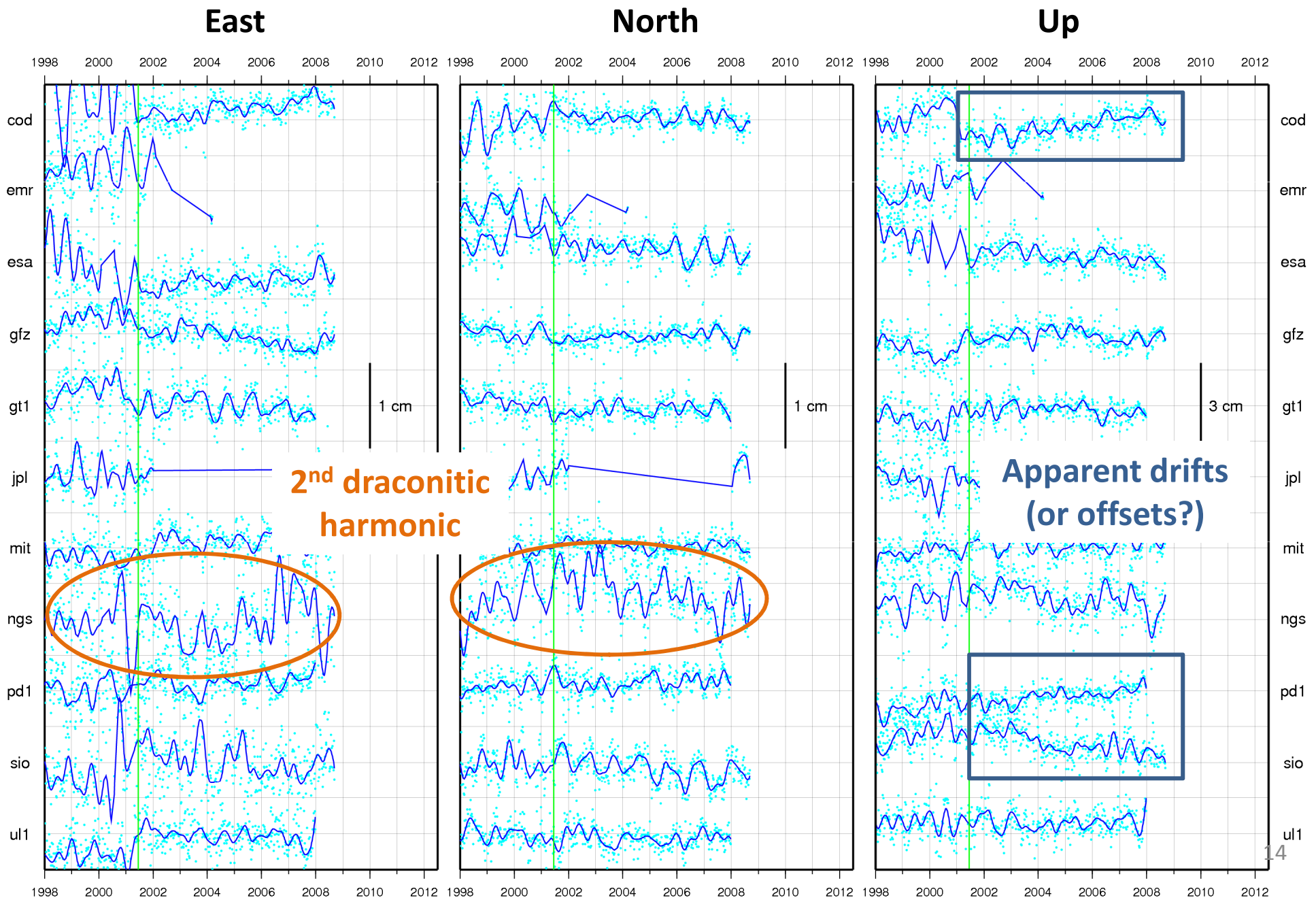
Inter-AC discrepancies: VENE



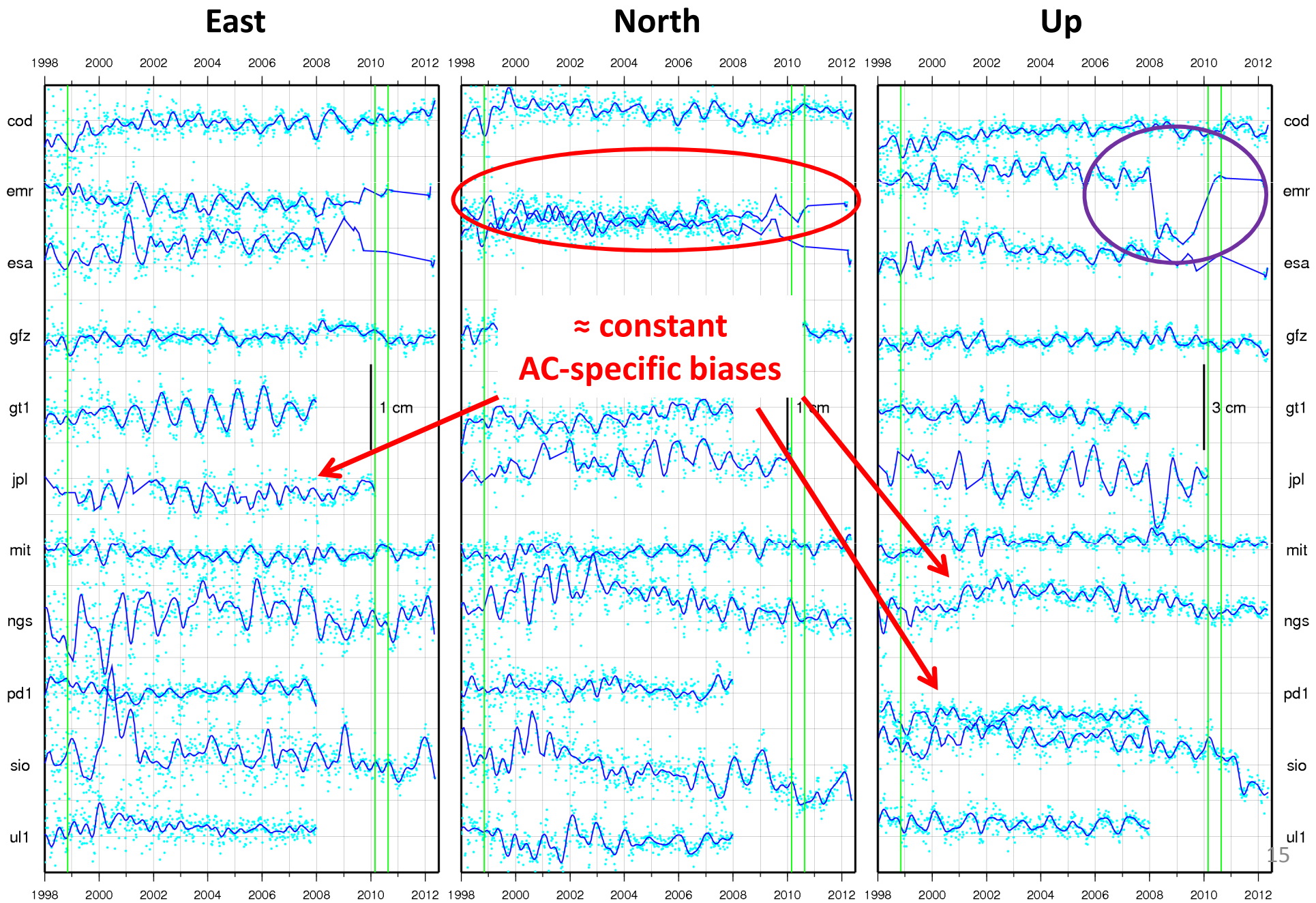
Inter-AC discrepancies: MCM4



Inter-AC discrepancies: MALI



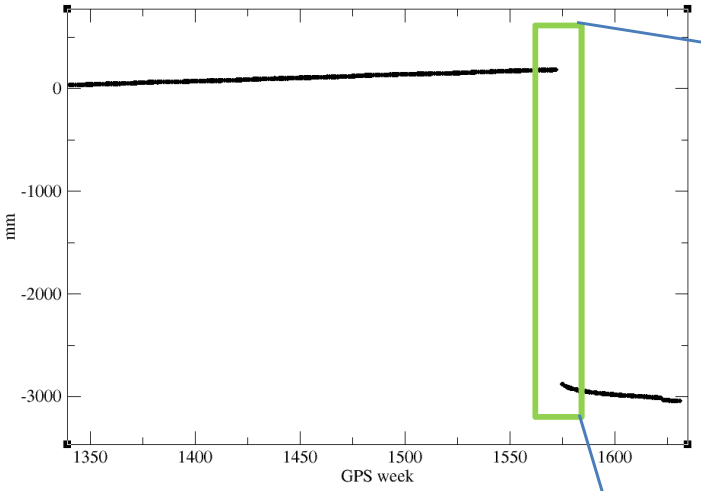
Inter-AC discrepancies: SANT (co-located)



Inter-AC discrepancies: Earthquakes

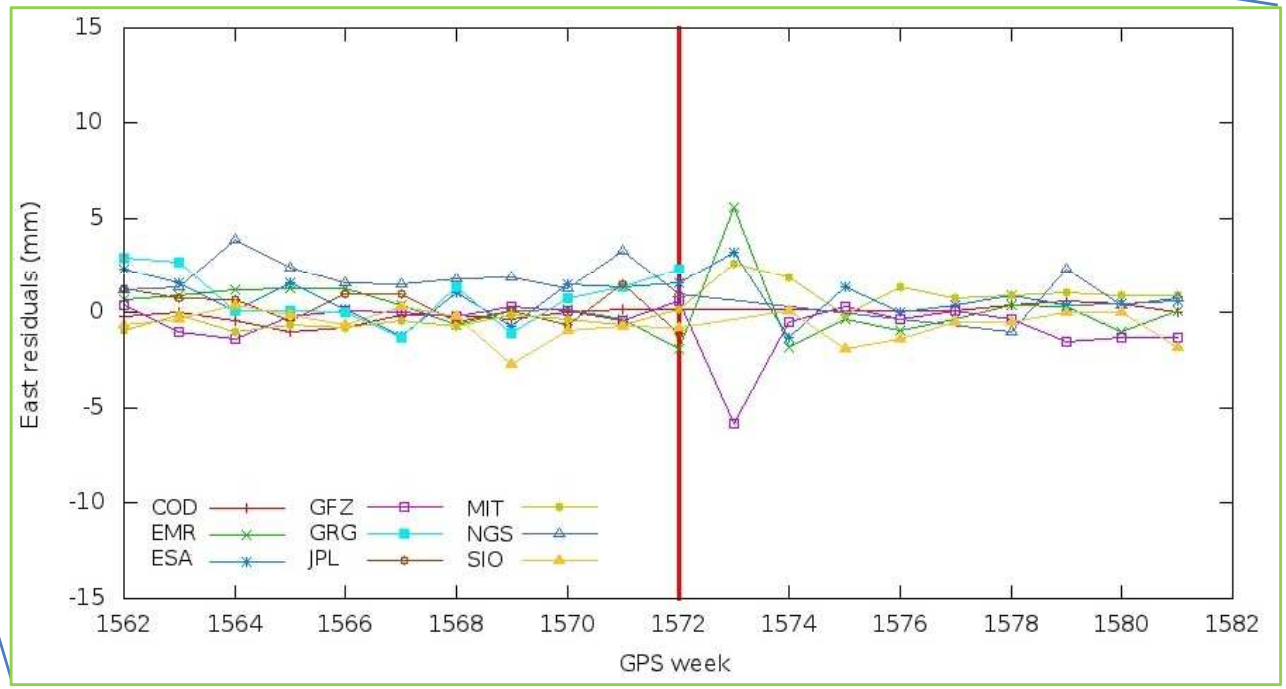
Are there differences between AC co-seismic offset estimates?

CONZ: IGS weekly combined positions



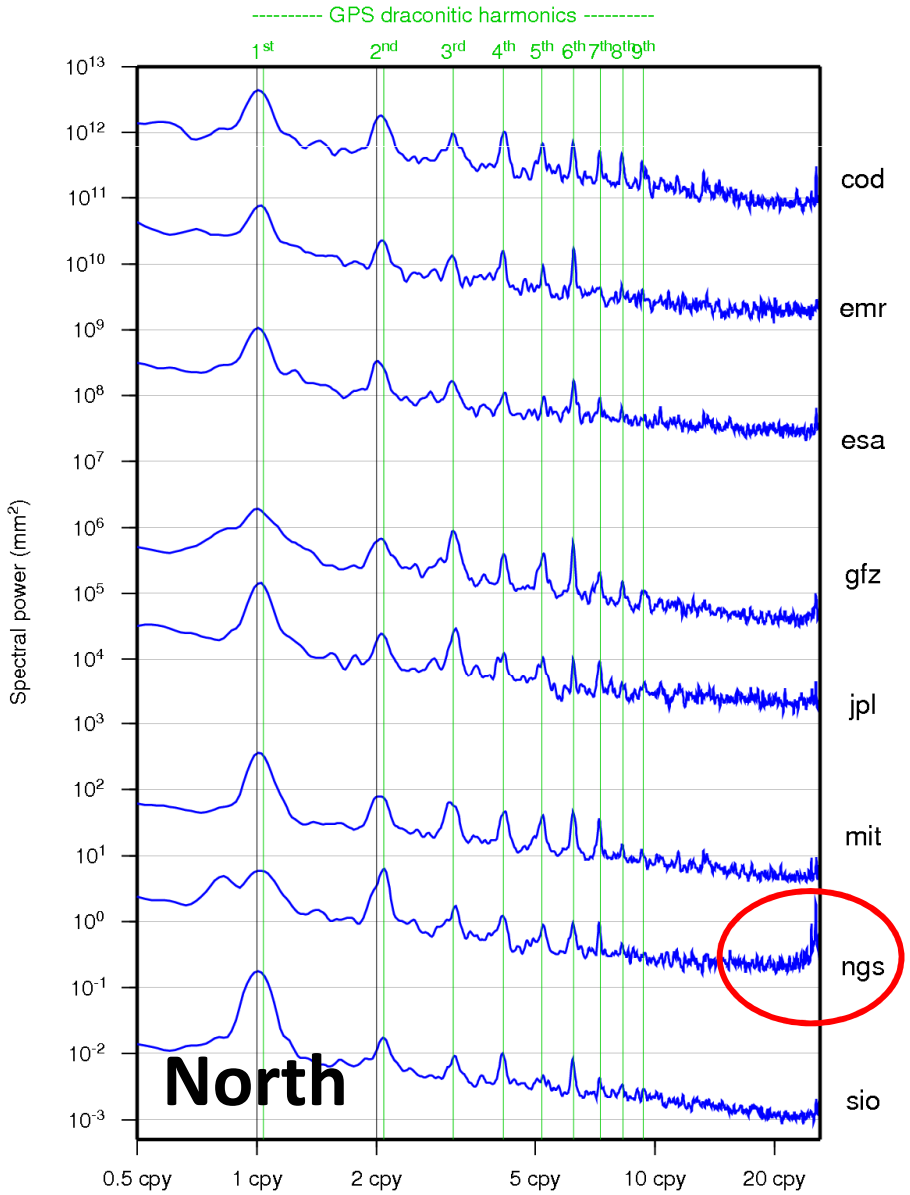
→ See poster by Lercier et al.

CONZ: weekly combination residuals (AC – igs)

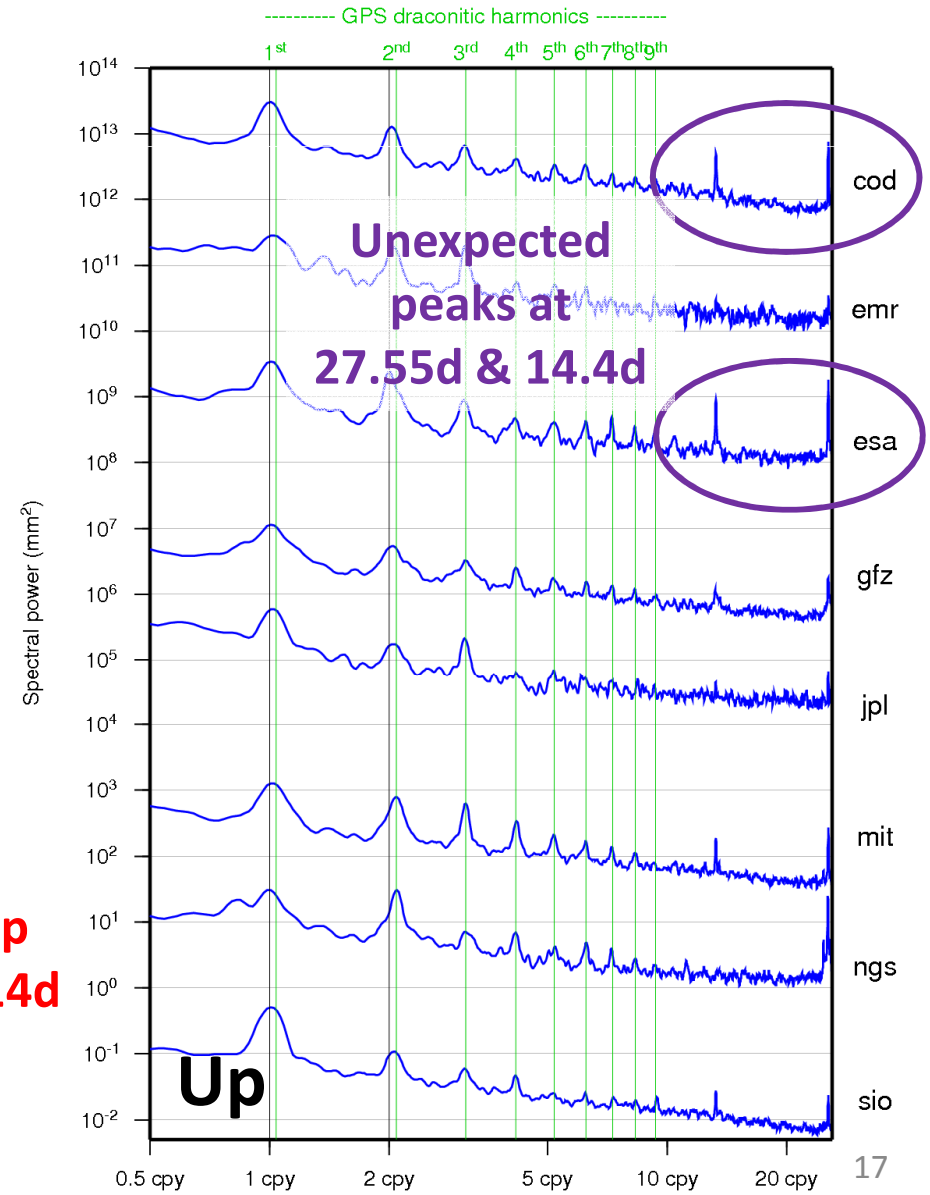


Inter-AC discrepancies: Spectra

Stacked periodograms (stations present more than 75% over 2000.0 – 2012.5)



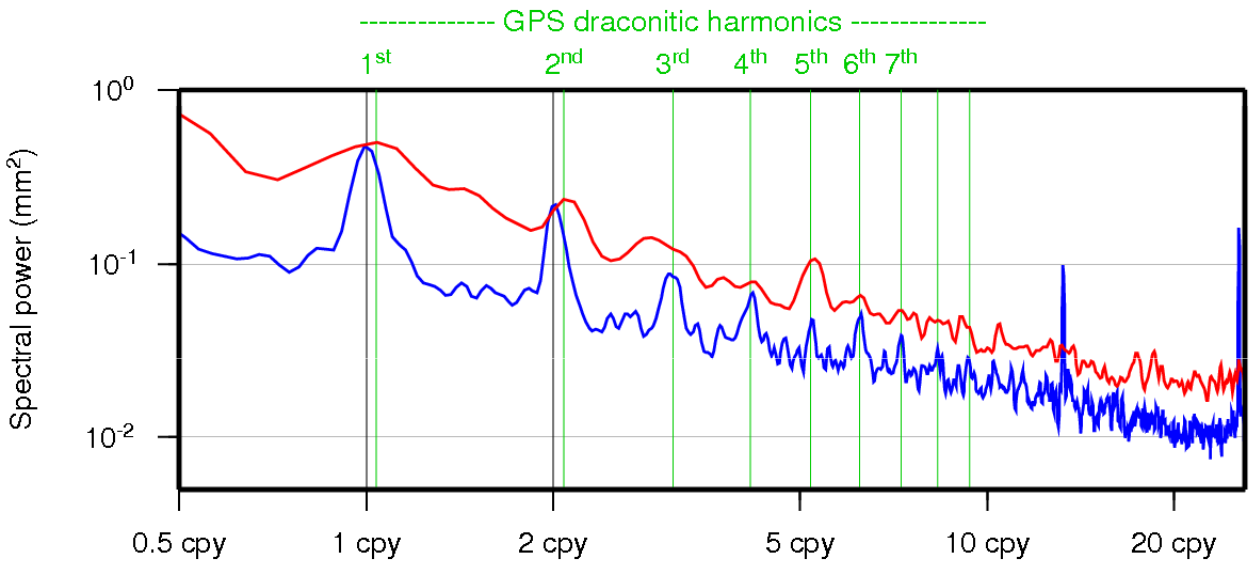
Bump near 14d



Inter-AC discrepancies: Ocean tidal loading

- **Peaks at 27.55d & 14.4d probably explained by an error in the version of hardisp.f distributed in 2006 *(Agnew, 2008)***

- **Corrected version used at CODE since week 1529:**



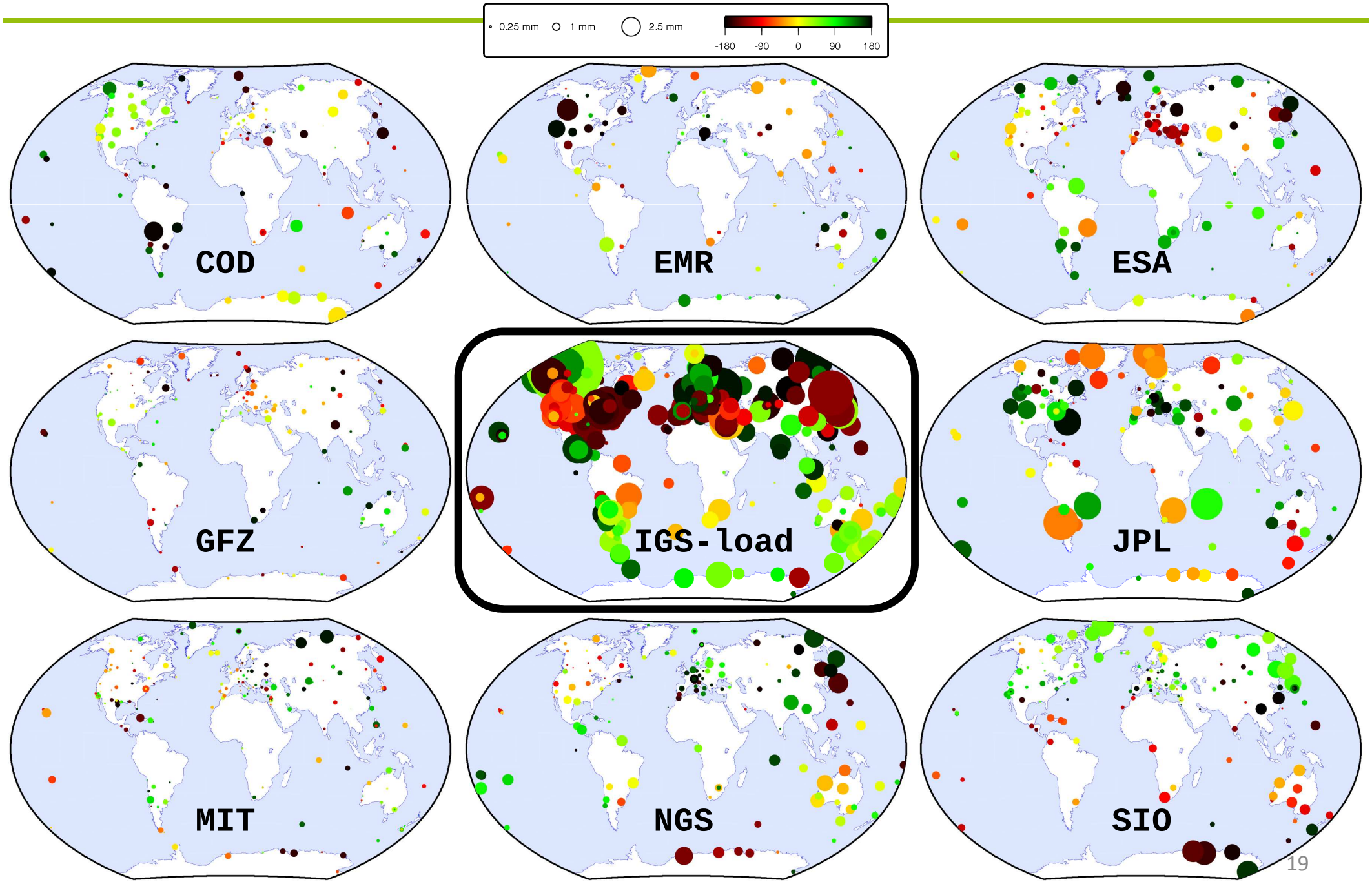
Stacked periodograms of CODE Up residuals:

— before week 1529

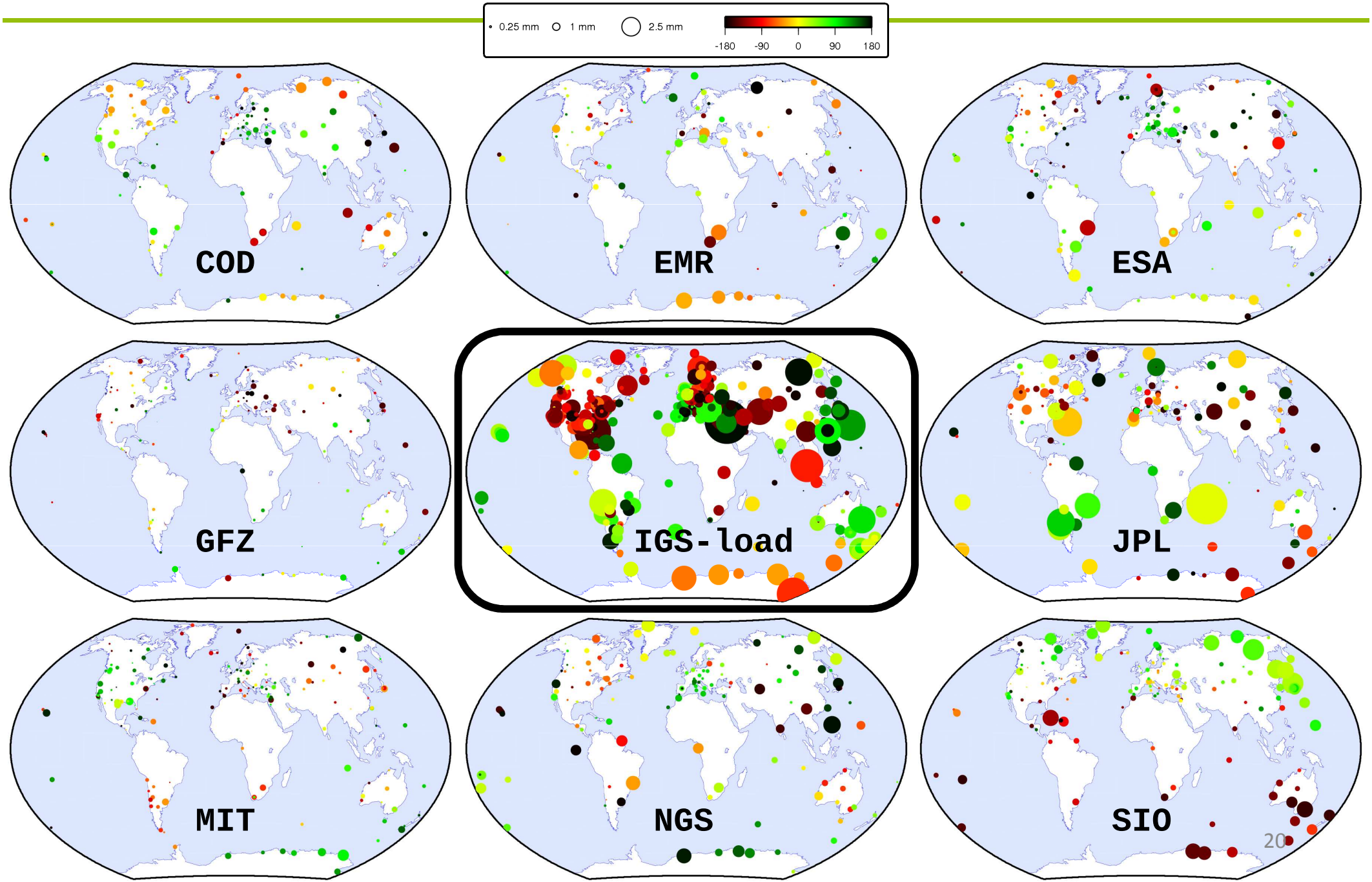
— after week 1529

- **Older version still in use at ESA?**

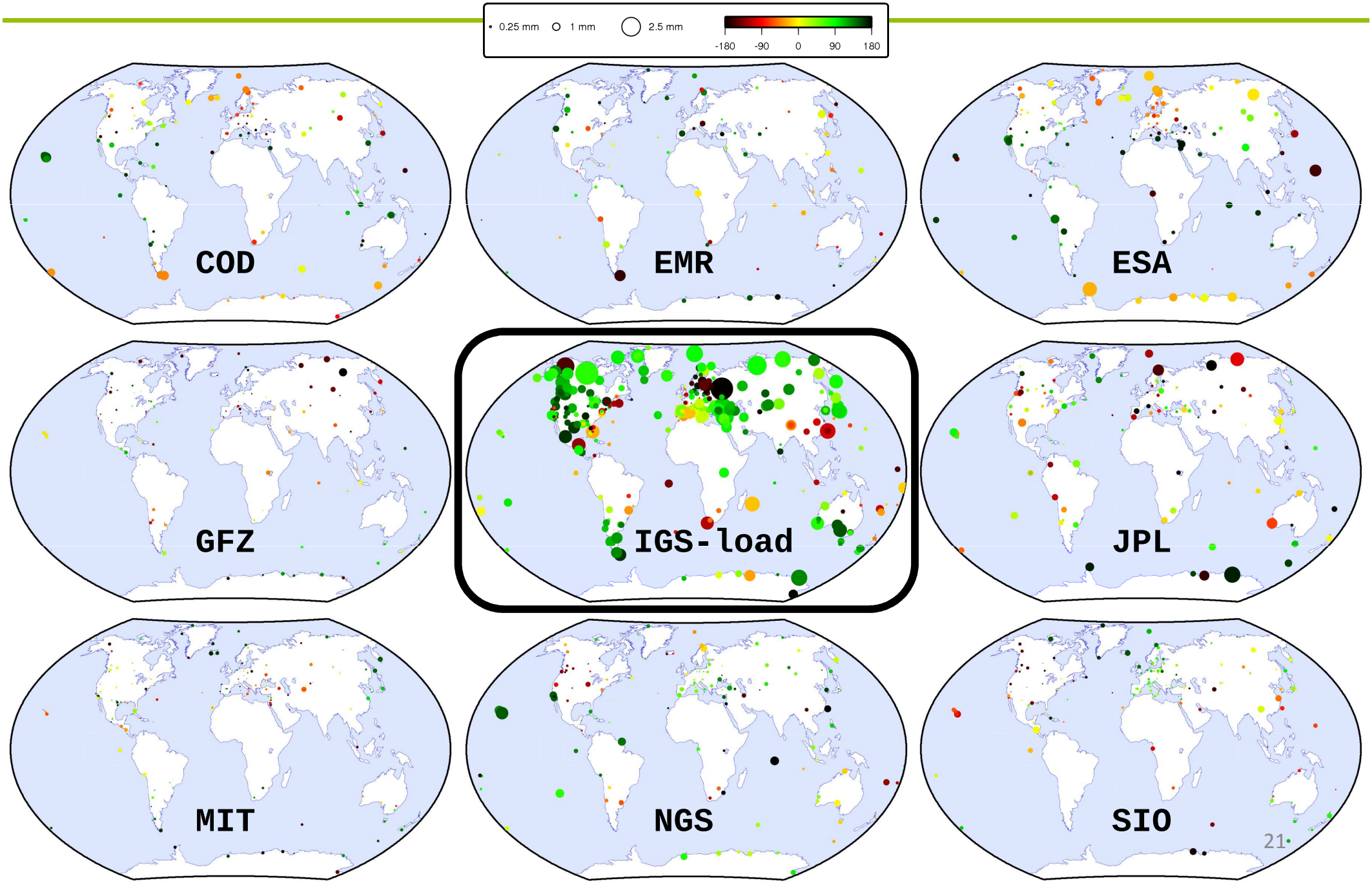
Inter-AC discrepancies: Annual - Up



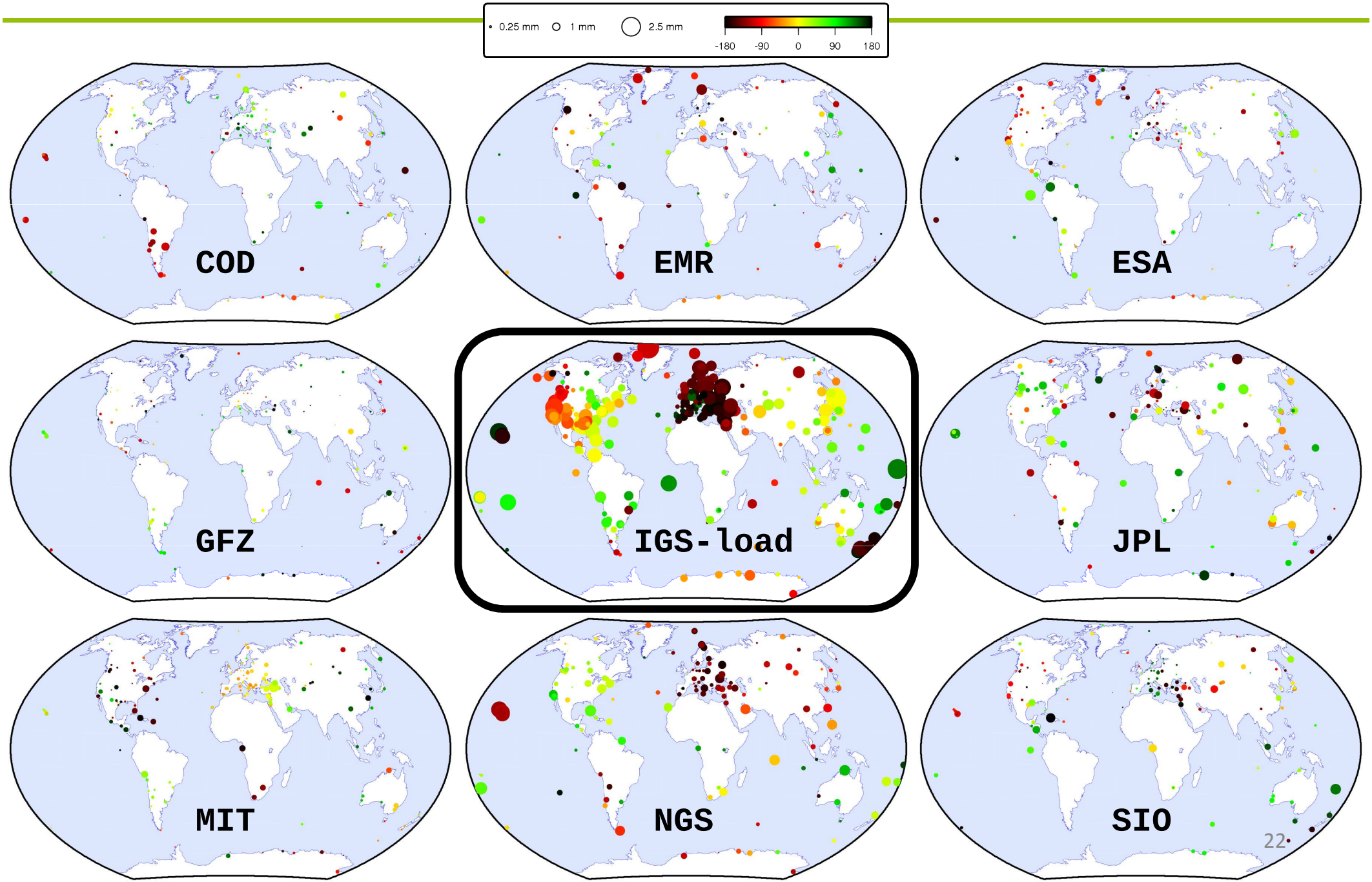
Inter-AC discrepancies: 1st draconitic - Up



Inter-AC discrepancies: Semi-annual - Up



Inter-AC discrepancies: 2nd draconitic - Up



Conclusions (1/2)

- **Load-corrected IGS positions:**
  - Simultaneous estimation of annual & draconitic does not significantly improve the agreement between GPS and loading model at the annual frequency.
  - Residual annual & draconitic signals have similar magnitudes.
  - Spatial coherence of draconitic errors suggests major orbit-related source. (e.g., due to errors in IERS subdaily ERP tide model)

- **Inter-AC discrepancies:**
  - A lot can be learnt from the weekly combination residual time series.
  - Deeper investigation needed to understand biases and offsets, especially at co-location sites!
  - Two-step combination planned for repro2:
    1. Combination
    2. Investigation of residual time series; Exclusion of aberrant AC positions; 2nd combination

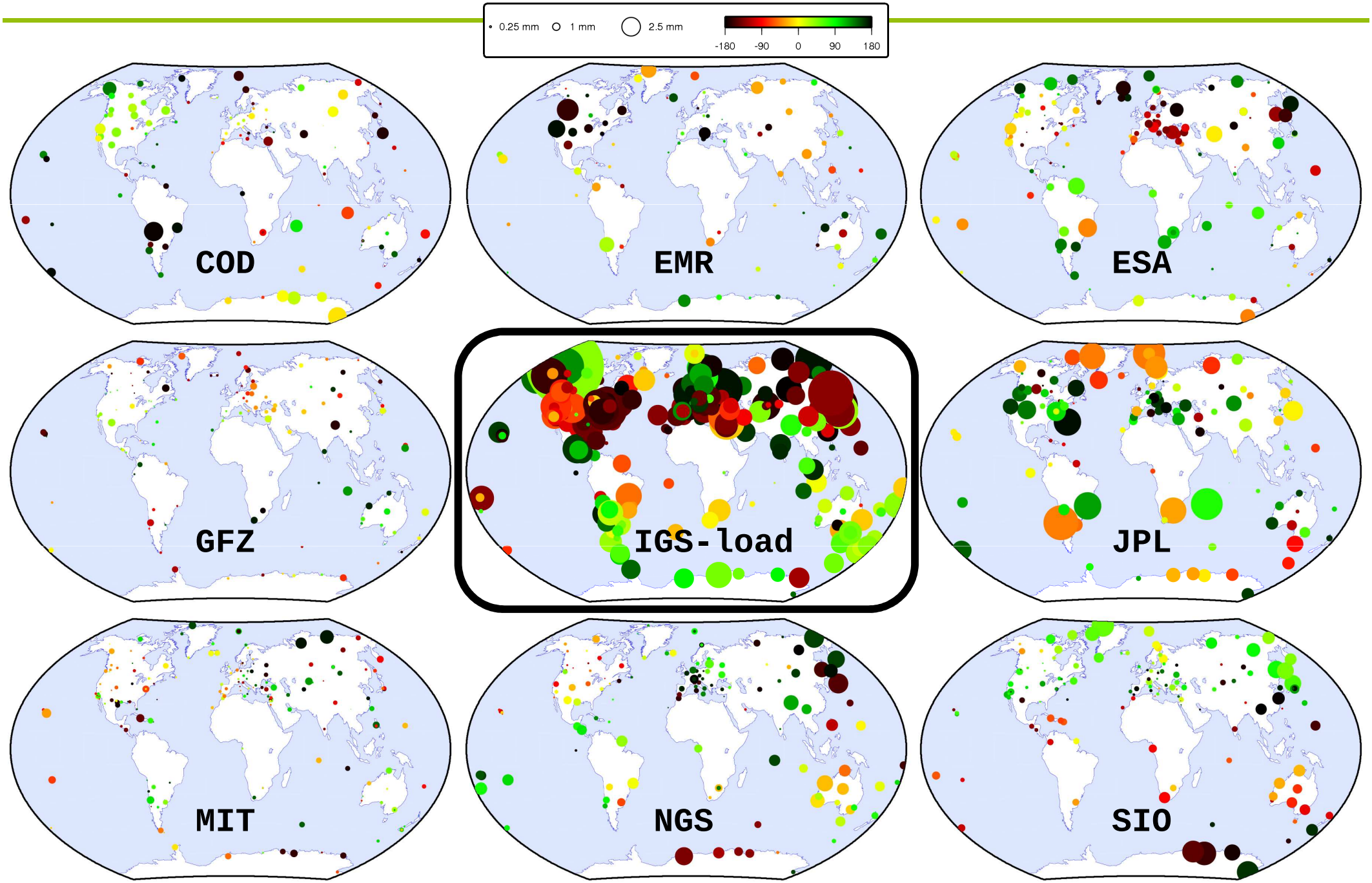
Conclusions (2/2)

- **Inter-AC discrepancies (continued):**
  - Spectral analysis reveals AC specificities:
    - hardisp.f problem
    - Large 2nd draconitic signals in NGS residuals, with strong spatial coherence (?)
    - JPL residuals often the largest at other frequencies, with less spatial coherence. (modeling difference at the station level?)
  - Inter-AC discrepancies globally smaller than IGS-load residuals, at all frequencies.

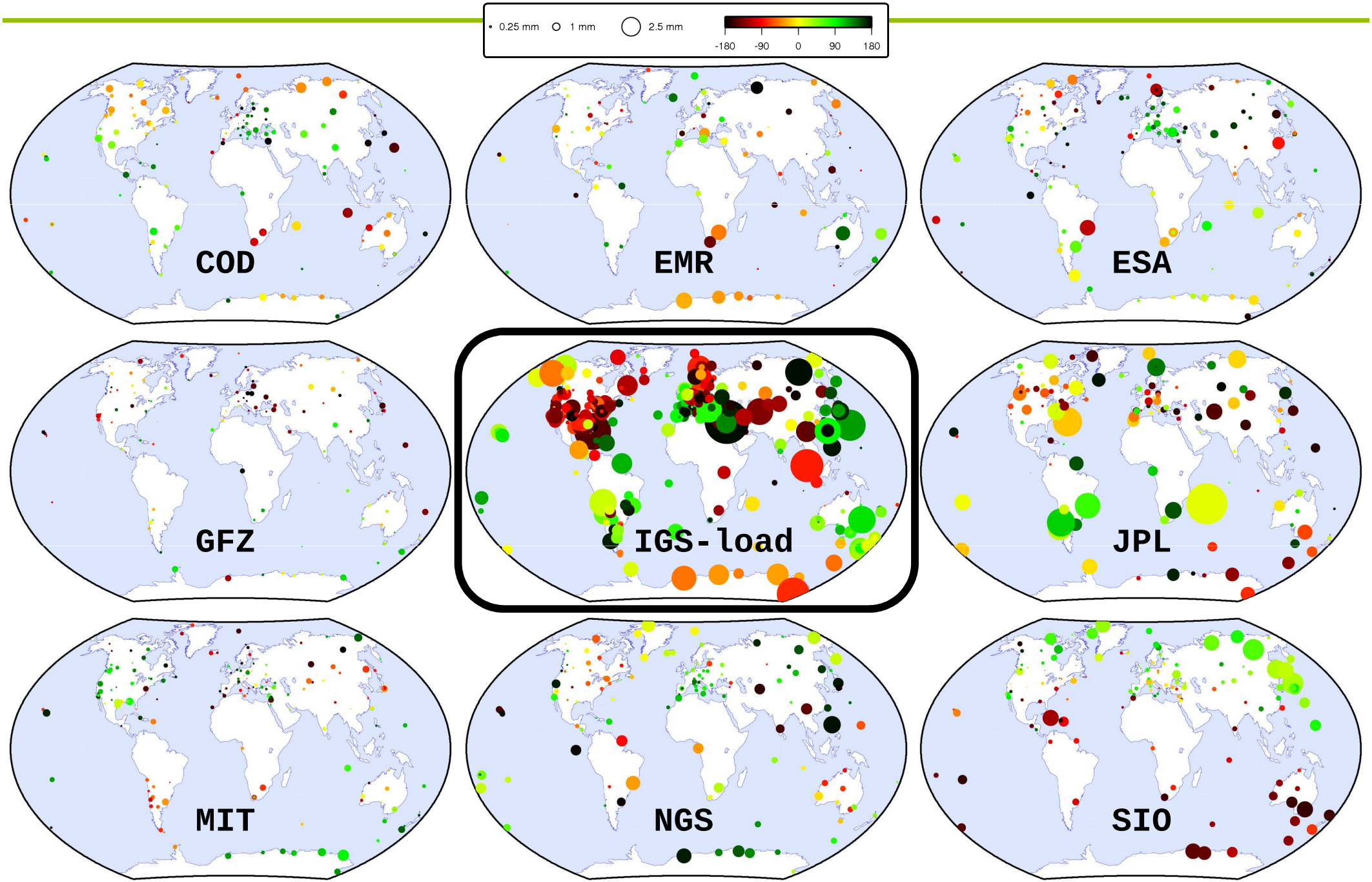
→ Common modeling errors (and/or loading model errors) predominant over AC specificities.

Additional slides

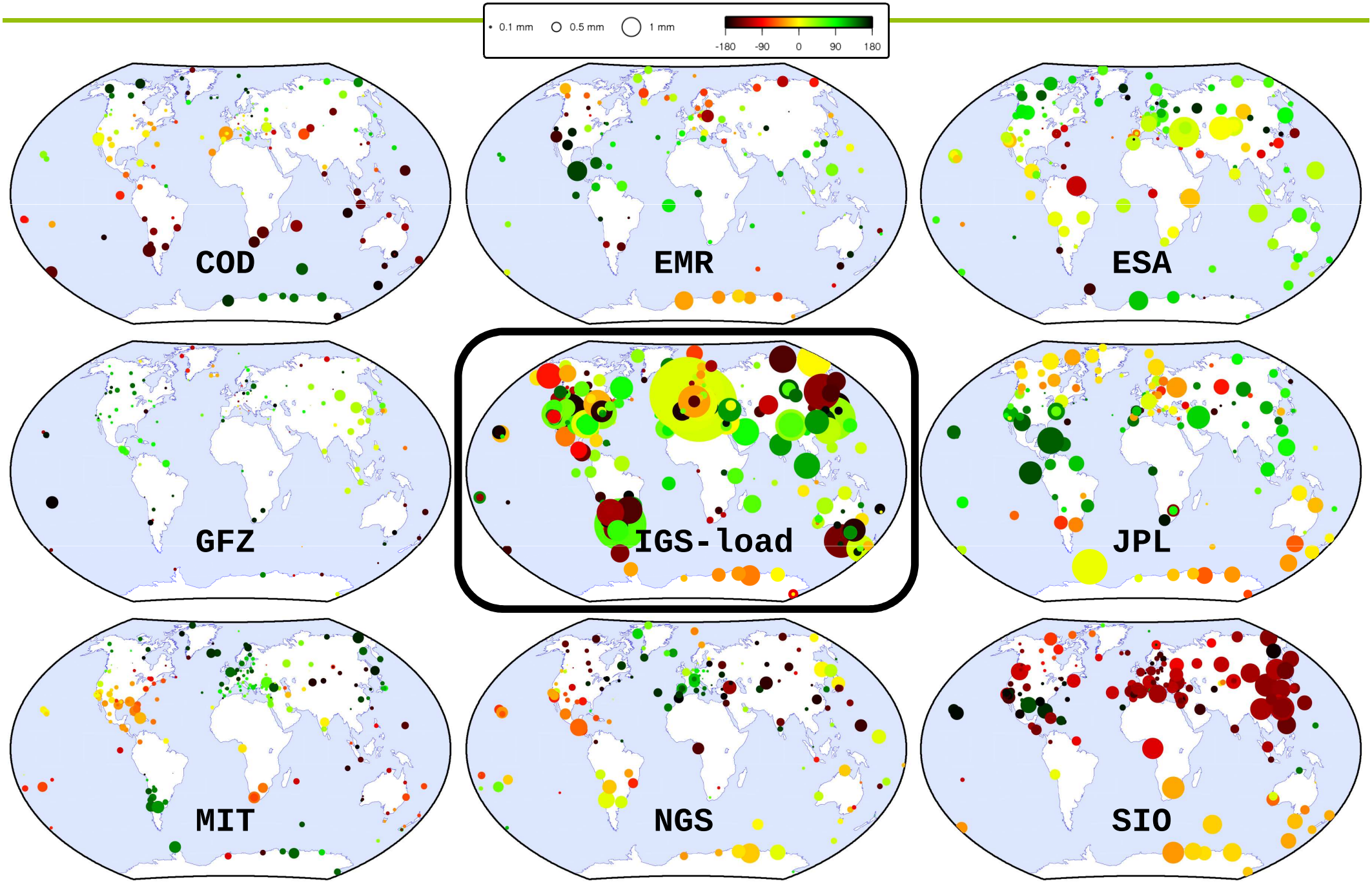
Inter-AC discrepancies: Annual - Up



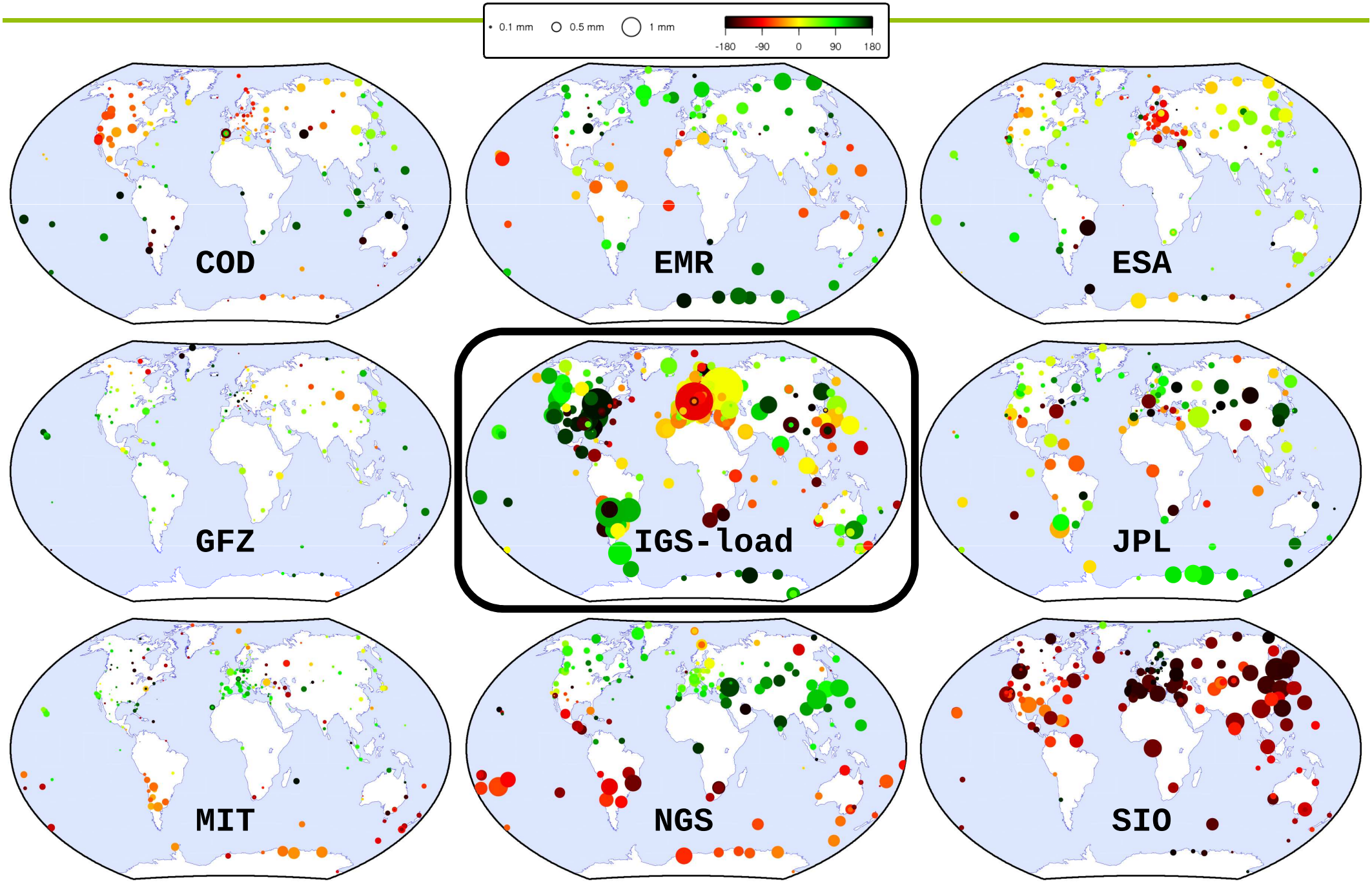
Inter-AC discrepancies: 1st draconitic - Up



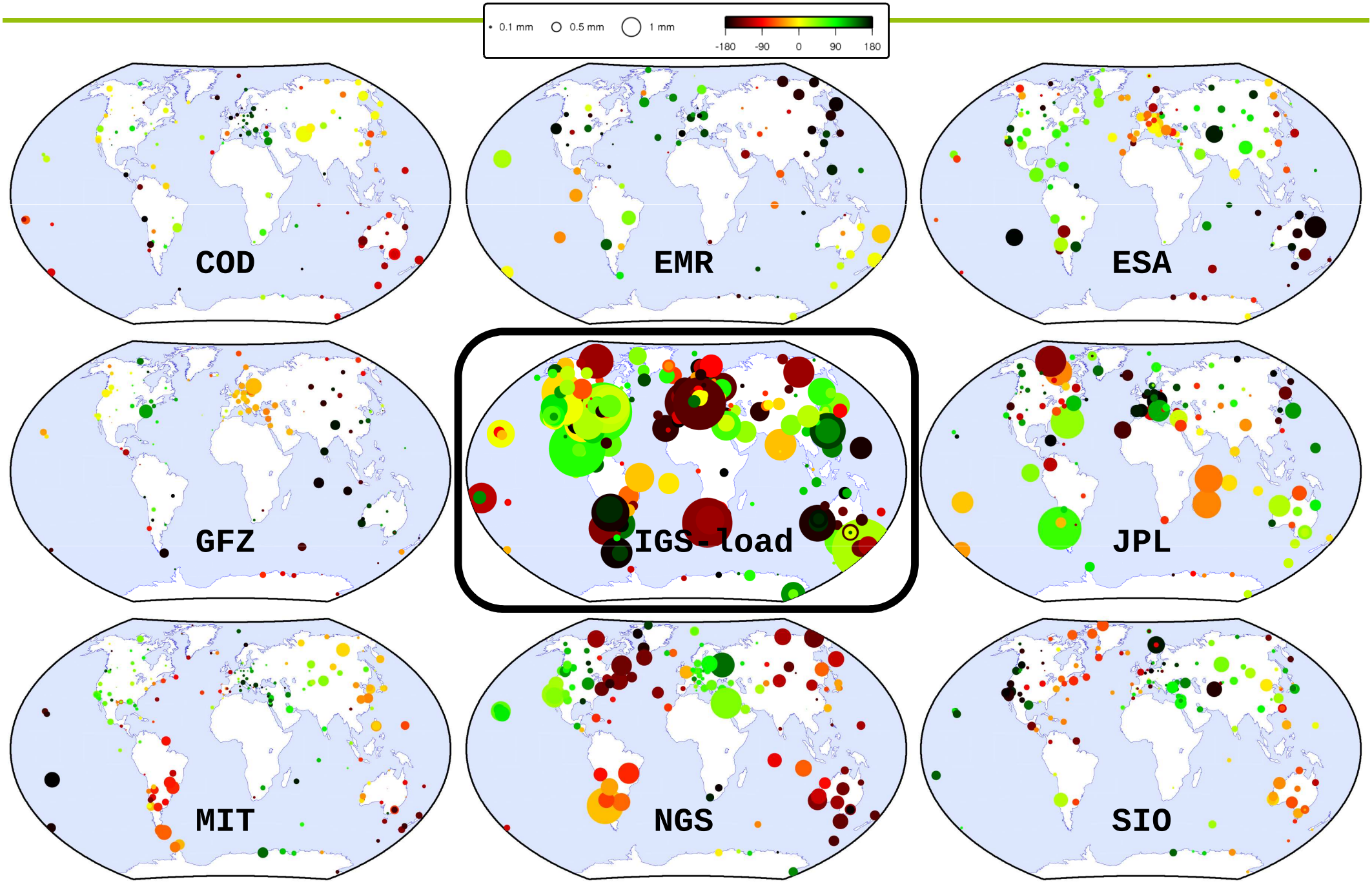
Inter-AC discrepancies: Annual - North



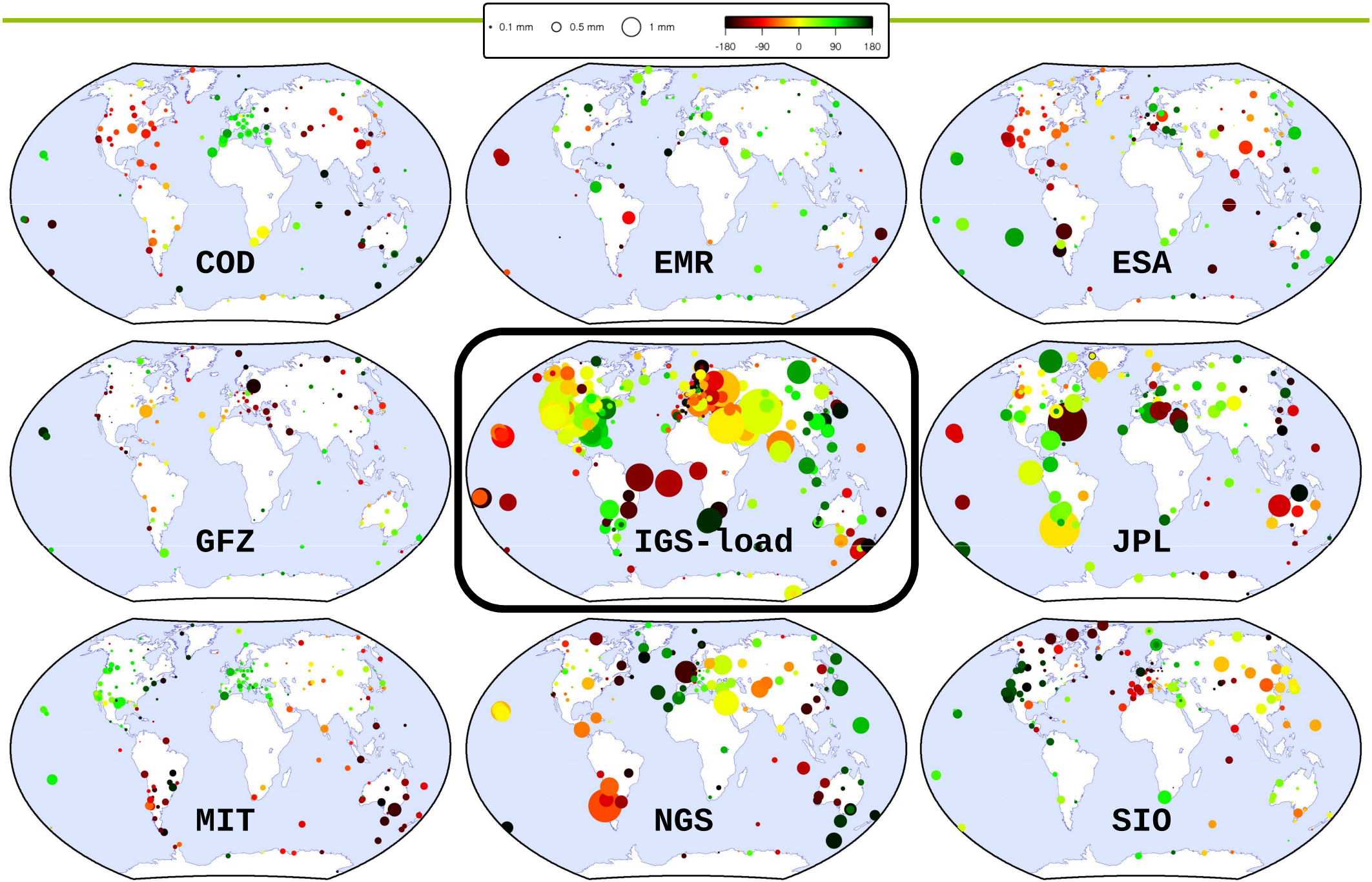
Inter-AC discrepancies: 1st draconitic - North



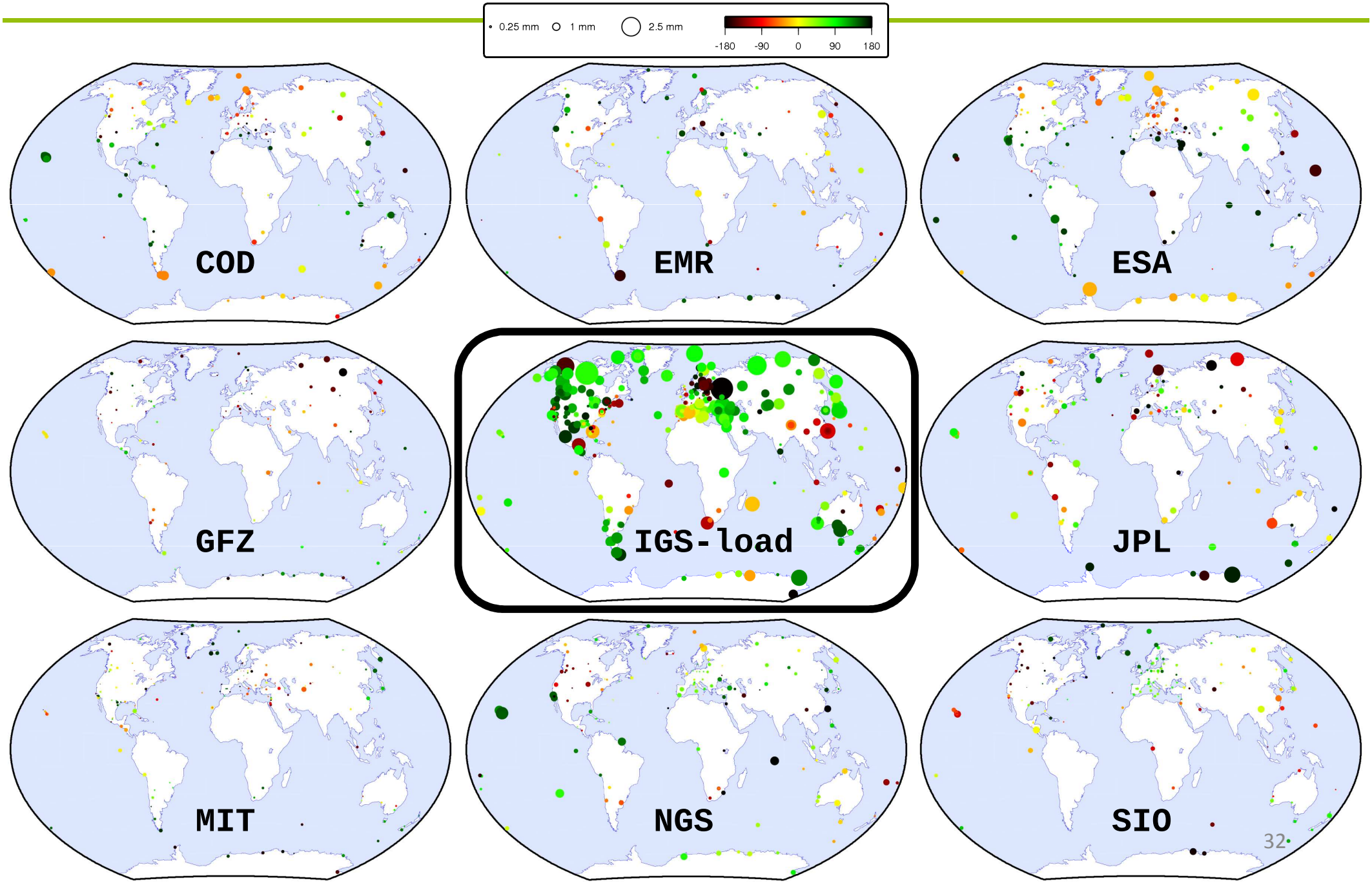
Inter-AC discrepancies: Annual - East



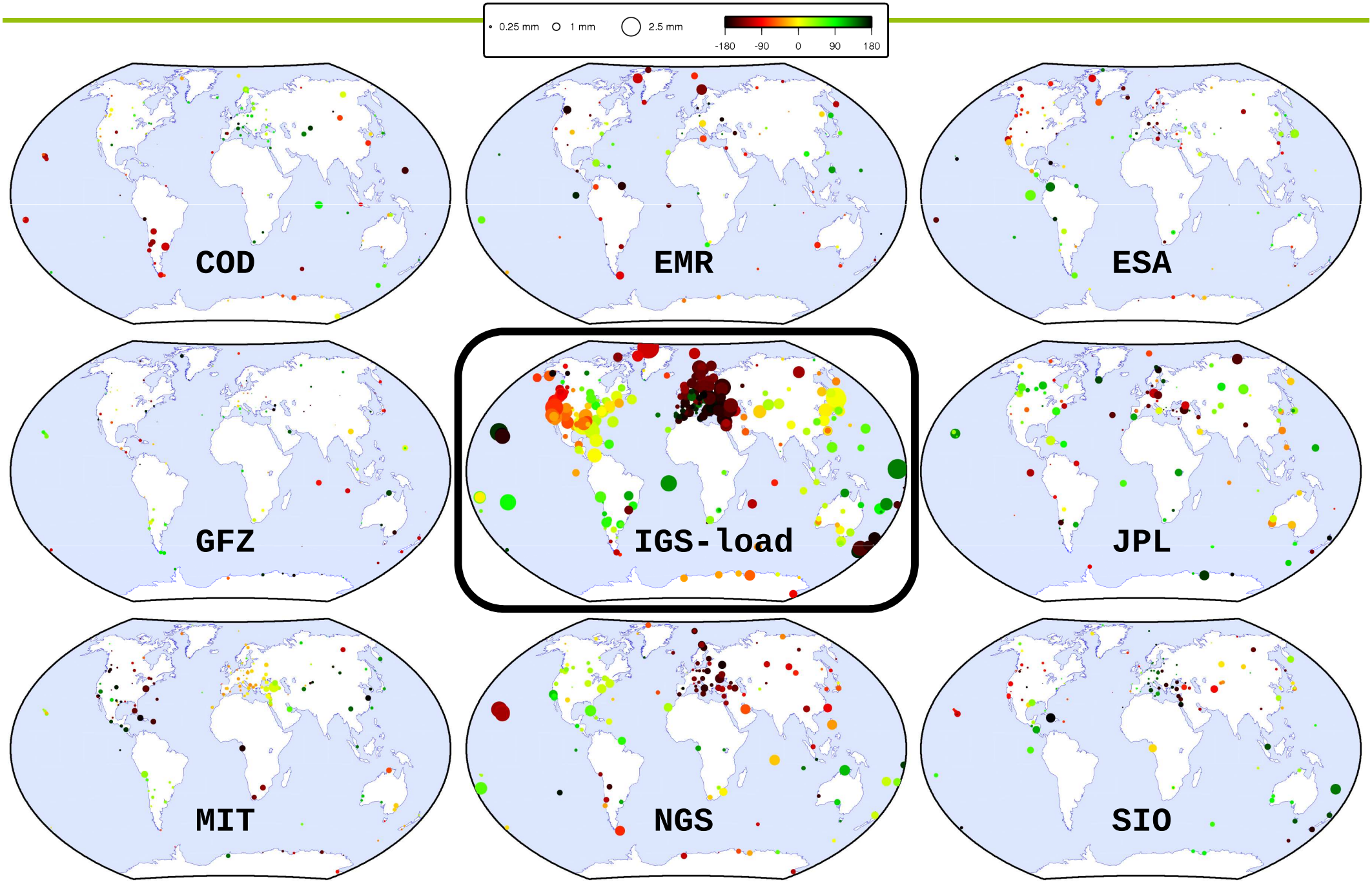
Inter-AC discrepancies: 1st draconitic - East



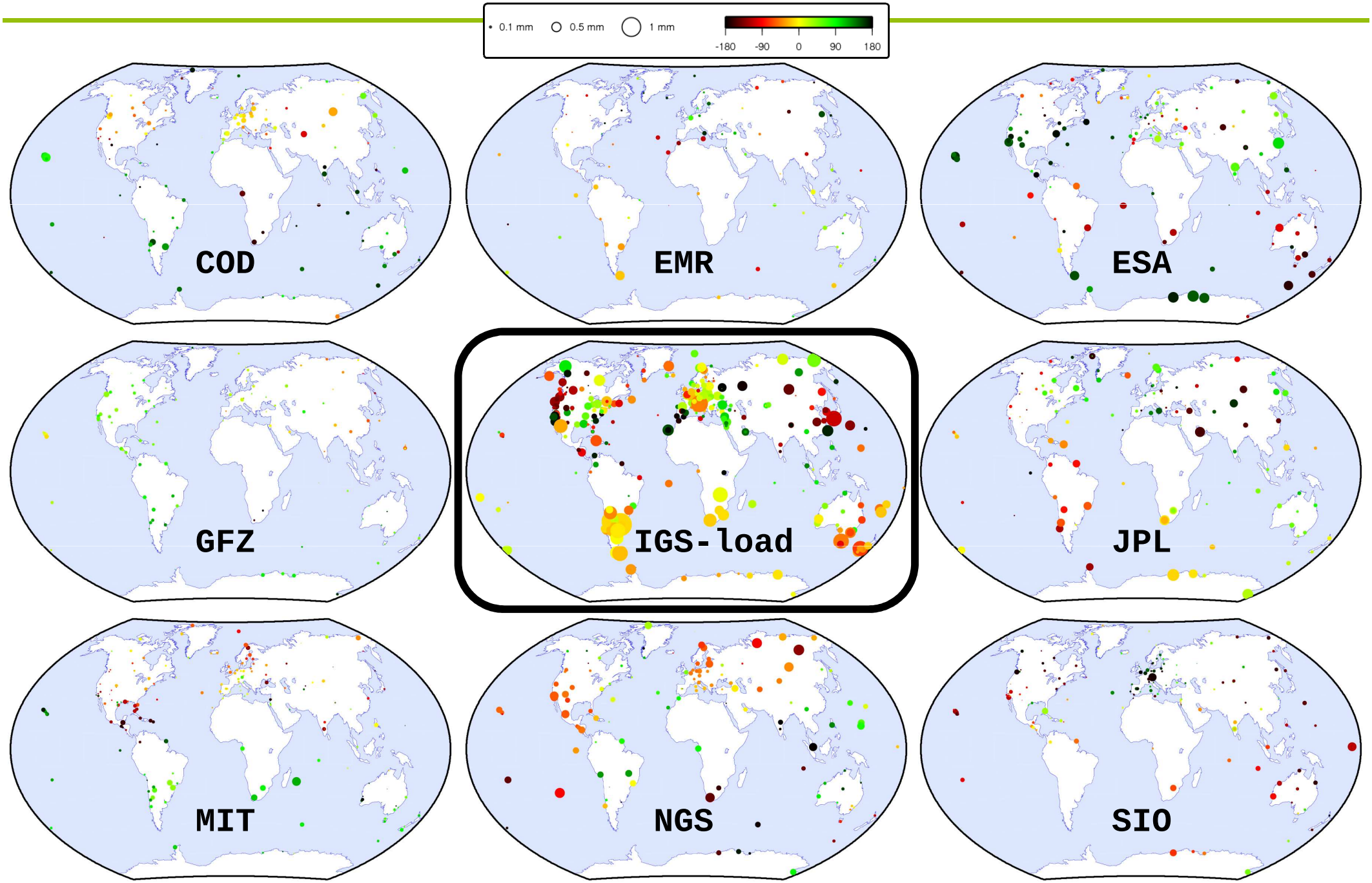
Inter-AC discrepancies: Semi-annual - Up



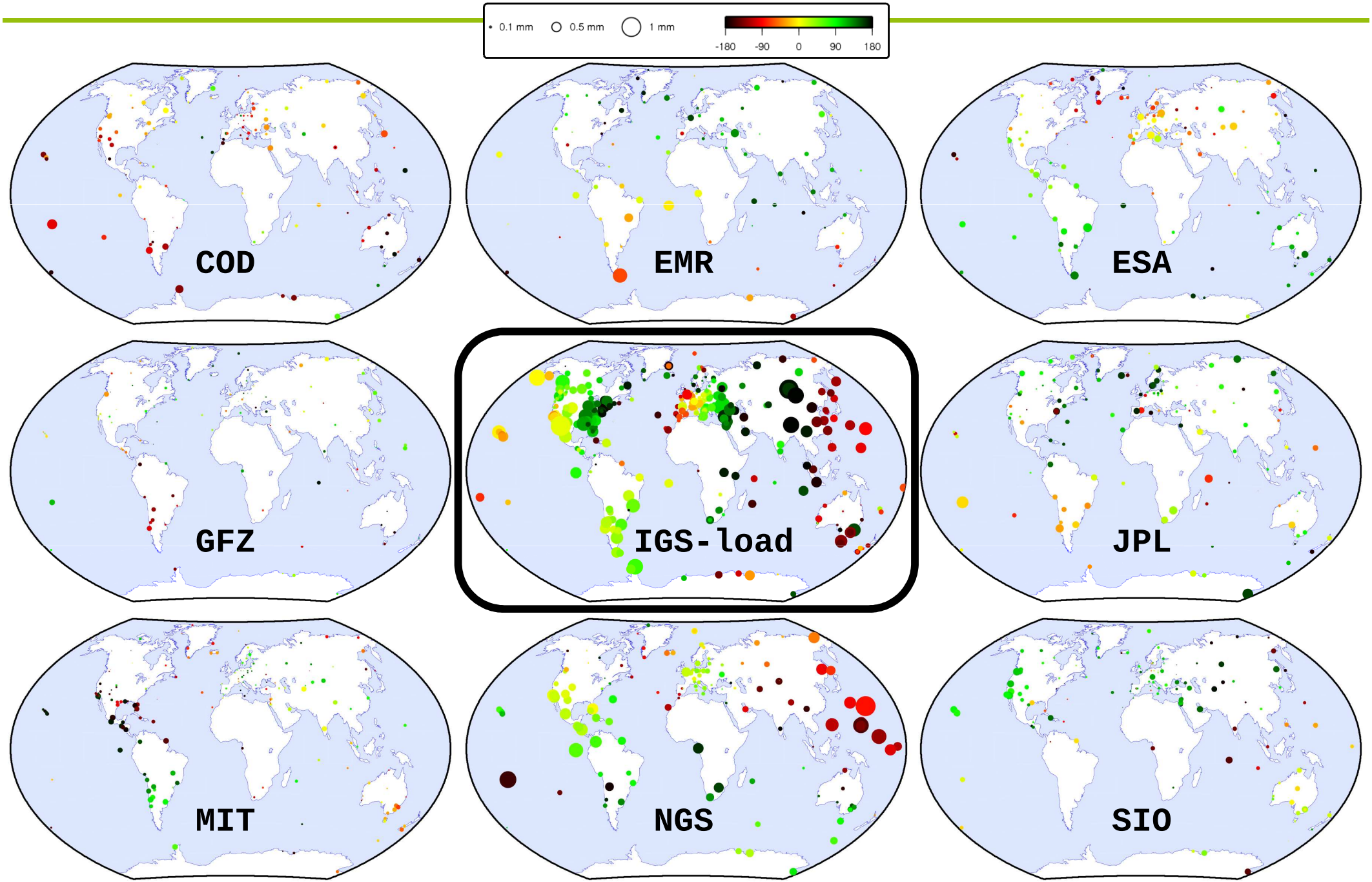
Inter-AC discrepancies: 2nd draconitic - Up



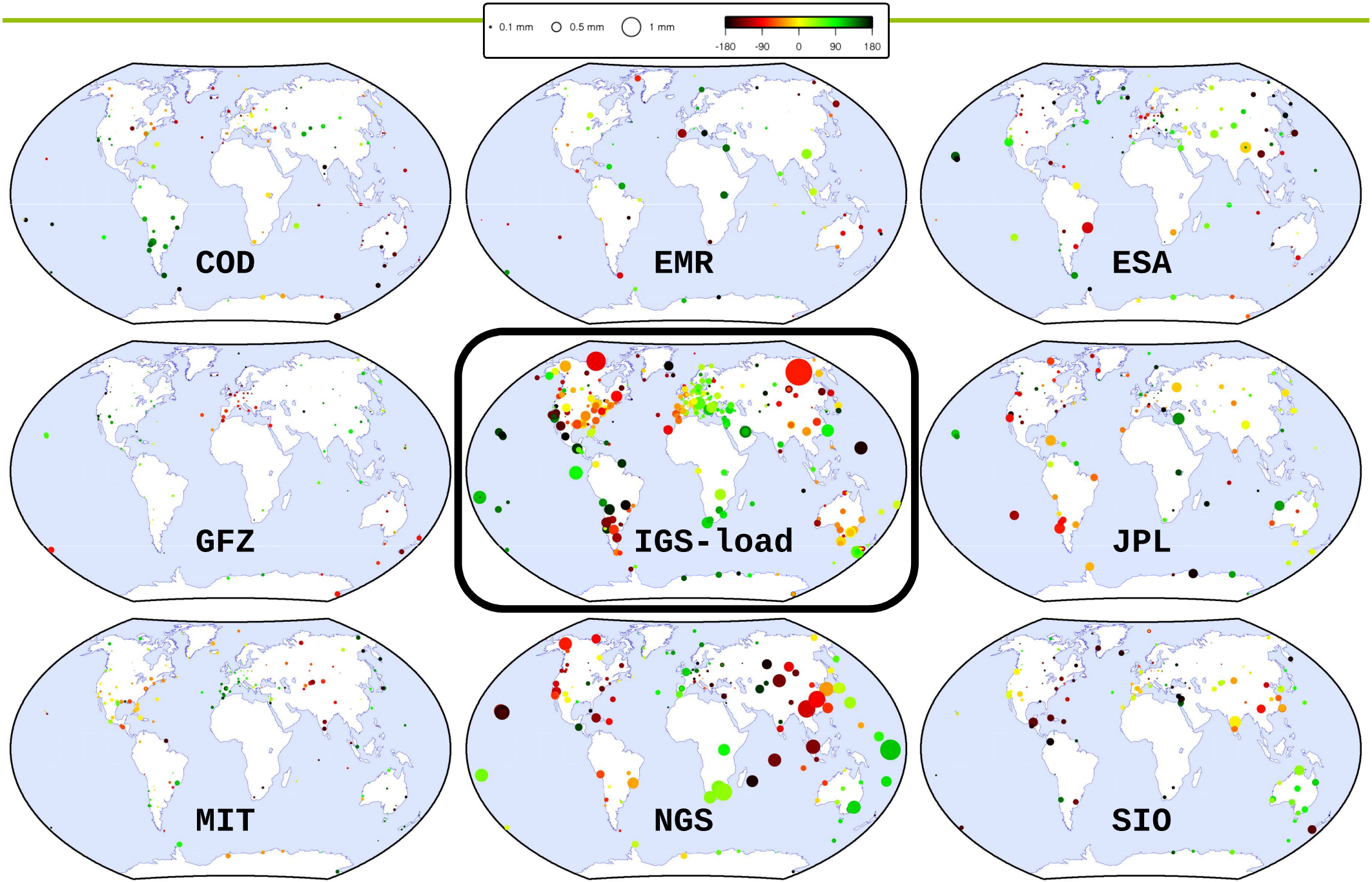
Inter-AC discrepancies: Semi-annual - North



Inter-AC discrepancies: 2nd draconitic - North



Inter-AC discrepancies: Semi-annual - East



Inter-AC discrepancies: 2nd draconitic - East