Testing enviromental disturbances in precision accelerometry onboard low Earth orbiters

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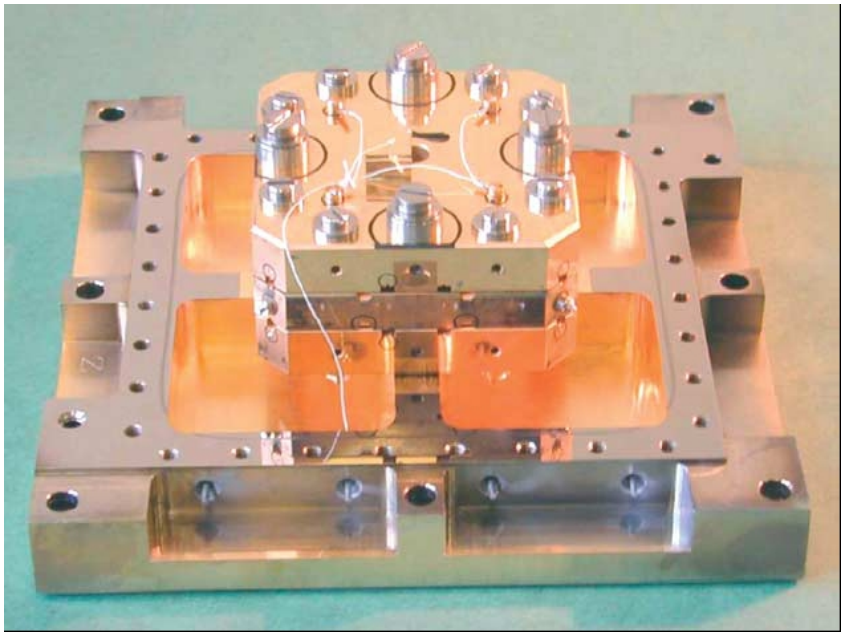

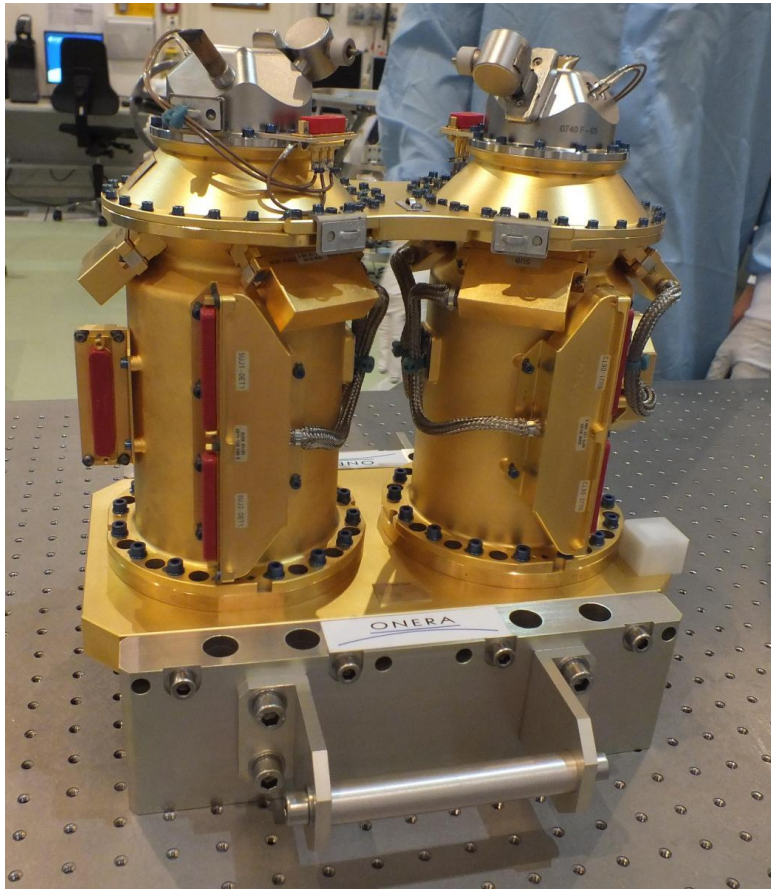

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geo

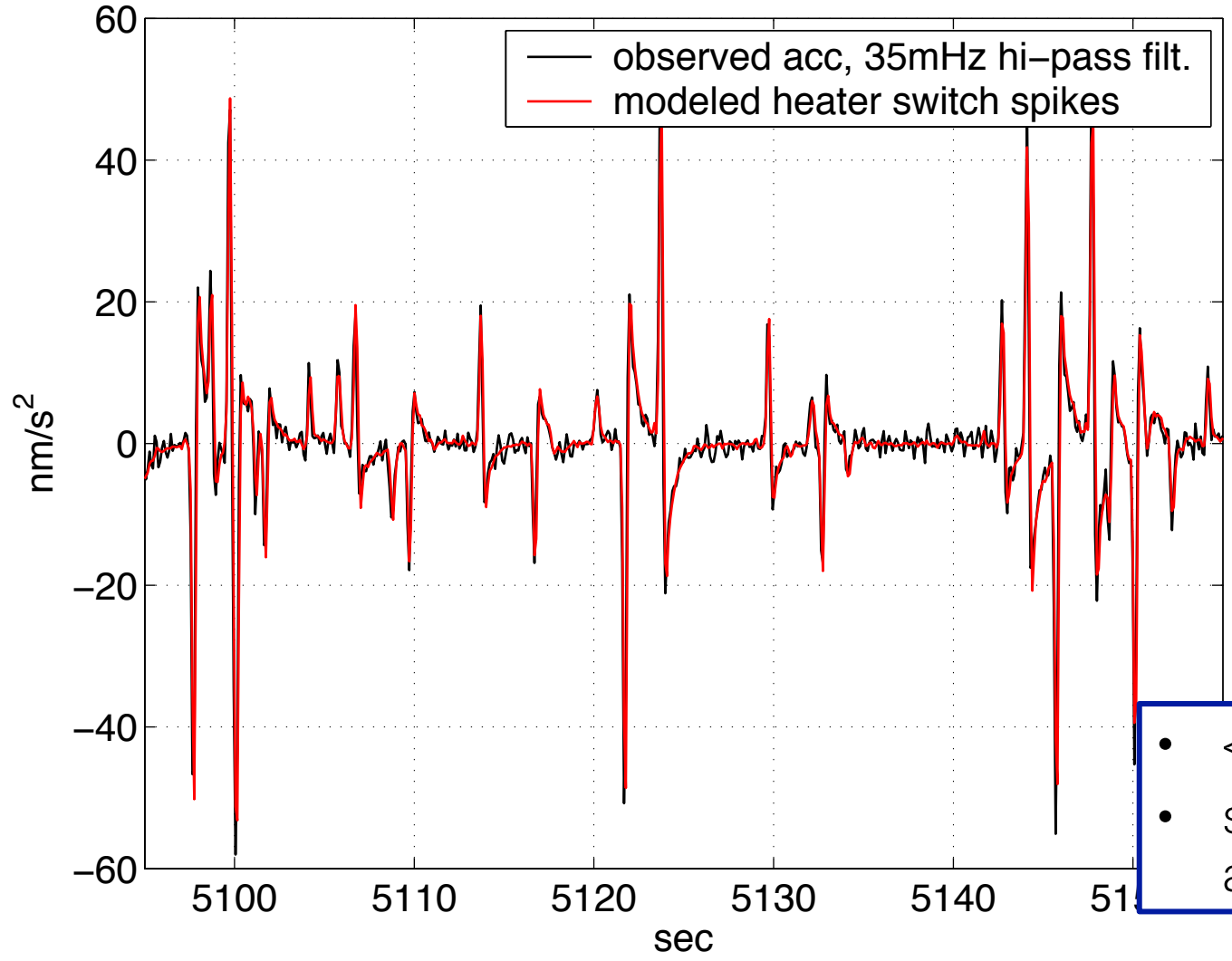
Environmental disturbances

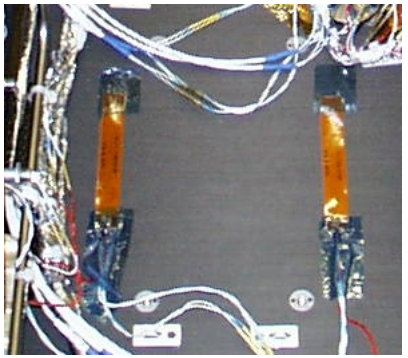
- all previous precision accelerometry missions in Earth orbit affected
- sensitivity of accelerometry to environmental conditions
- coupling of ionosphere?
- disturbances affect:
  - gravity results
  - calibration
  - performance assessment
  - aeronomy results
- will they effect EP results?

Precision space accelerometry

- Cactus
- CHAMP
- GRACE
- GOCE
- Swarm
- Microscope
- GRACE Follow-On
- ...

GRACE heater switching spikes

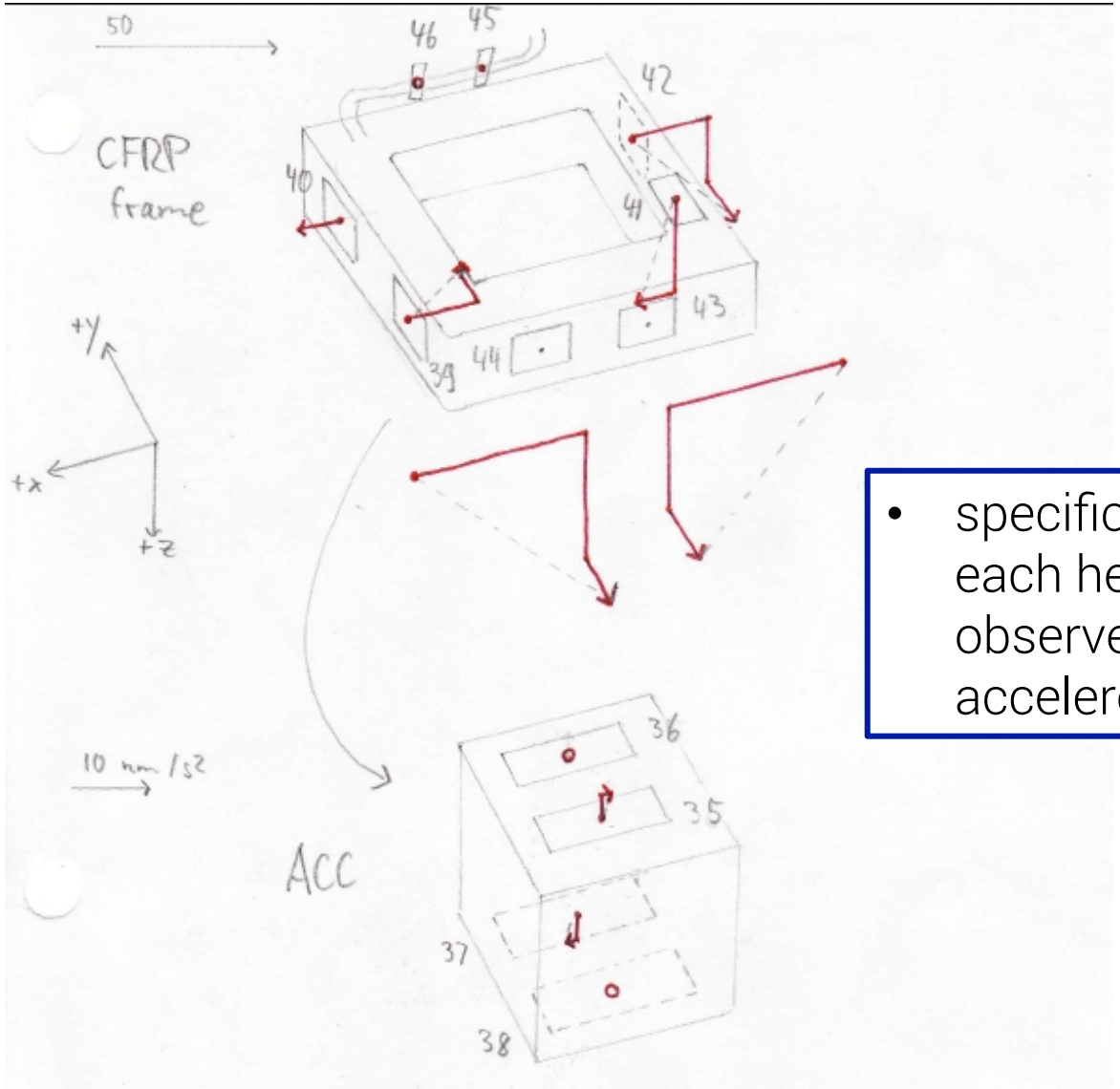




GRACE heater foils

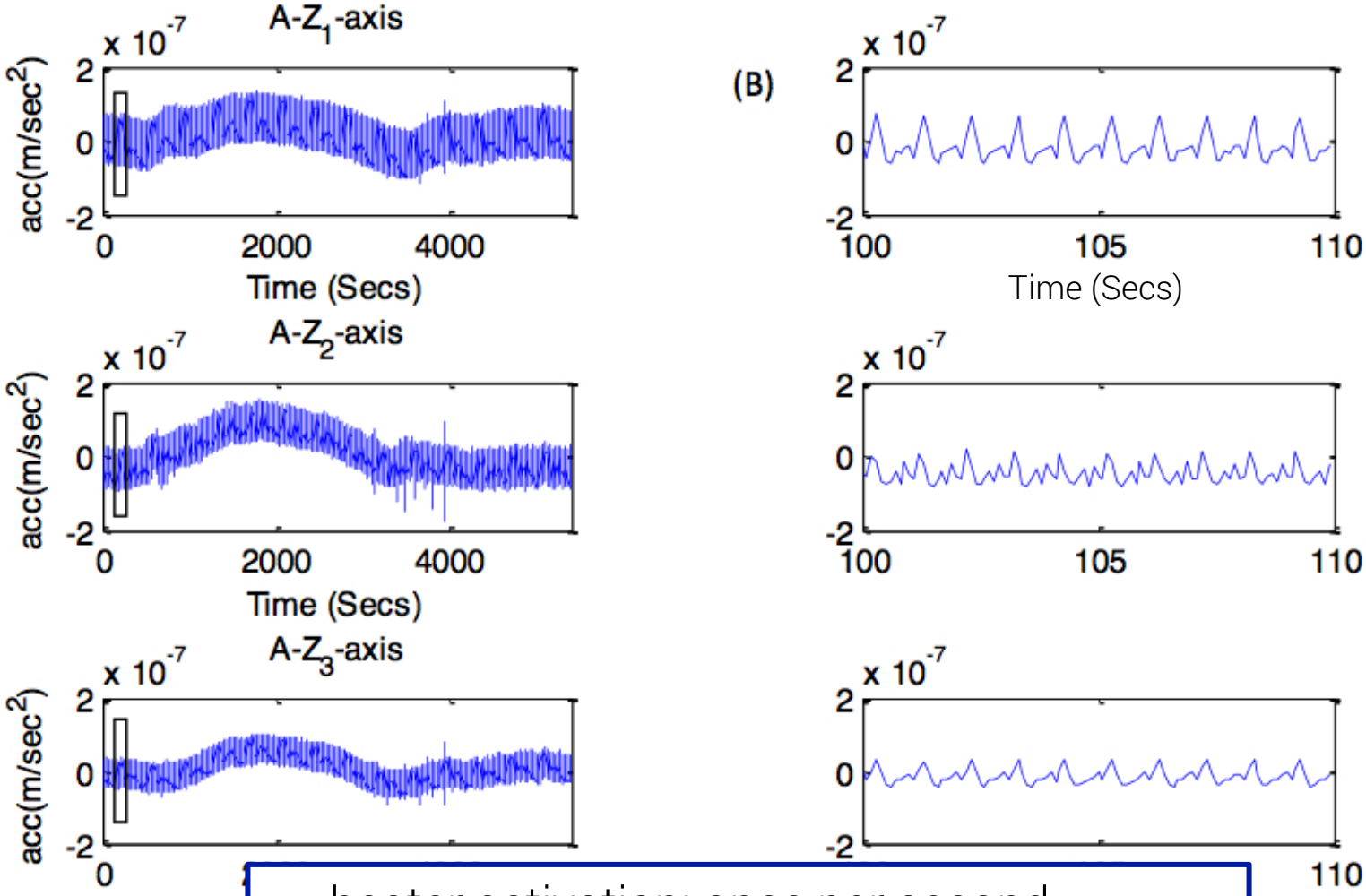
- < 0.5 sec duration
- symmetry due to *on* and *off* switches

GRACE heater switching spikes



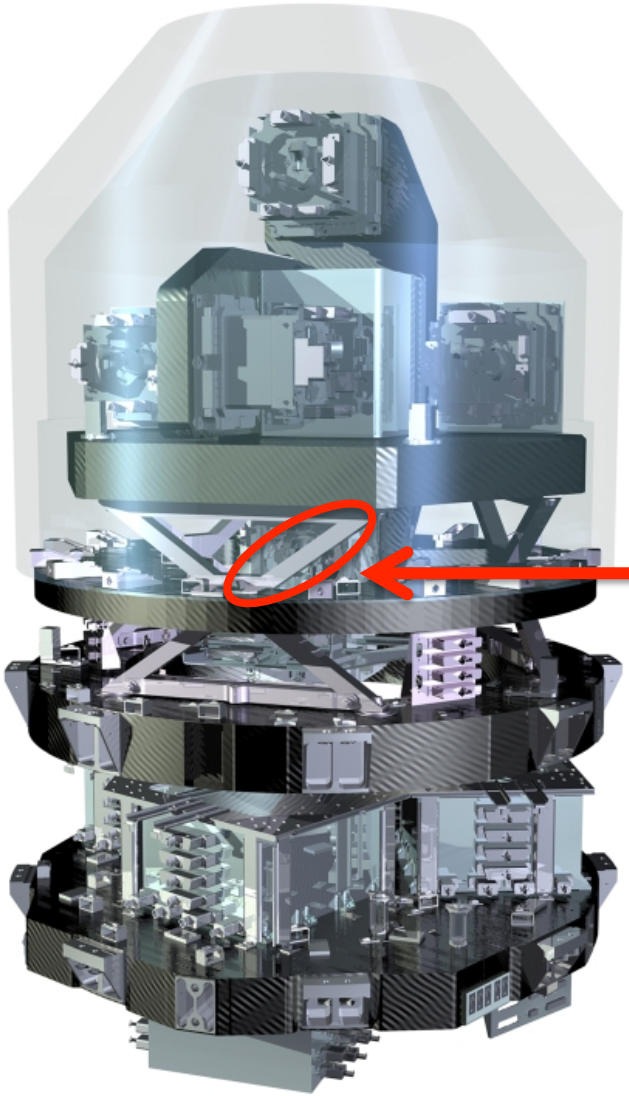
- specific directions for each heater element, observed from 3 axes accelerometers

GOCE heater switching spikes



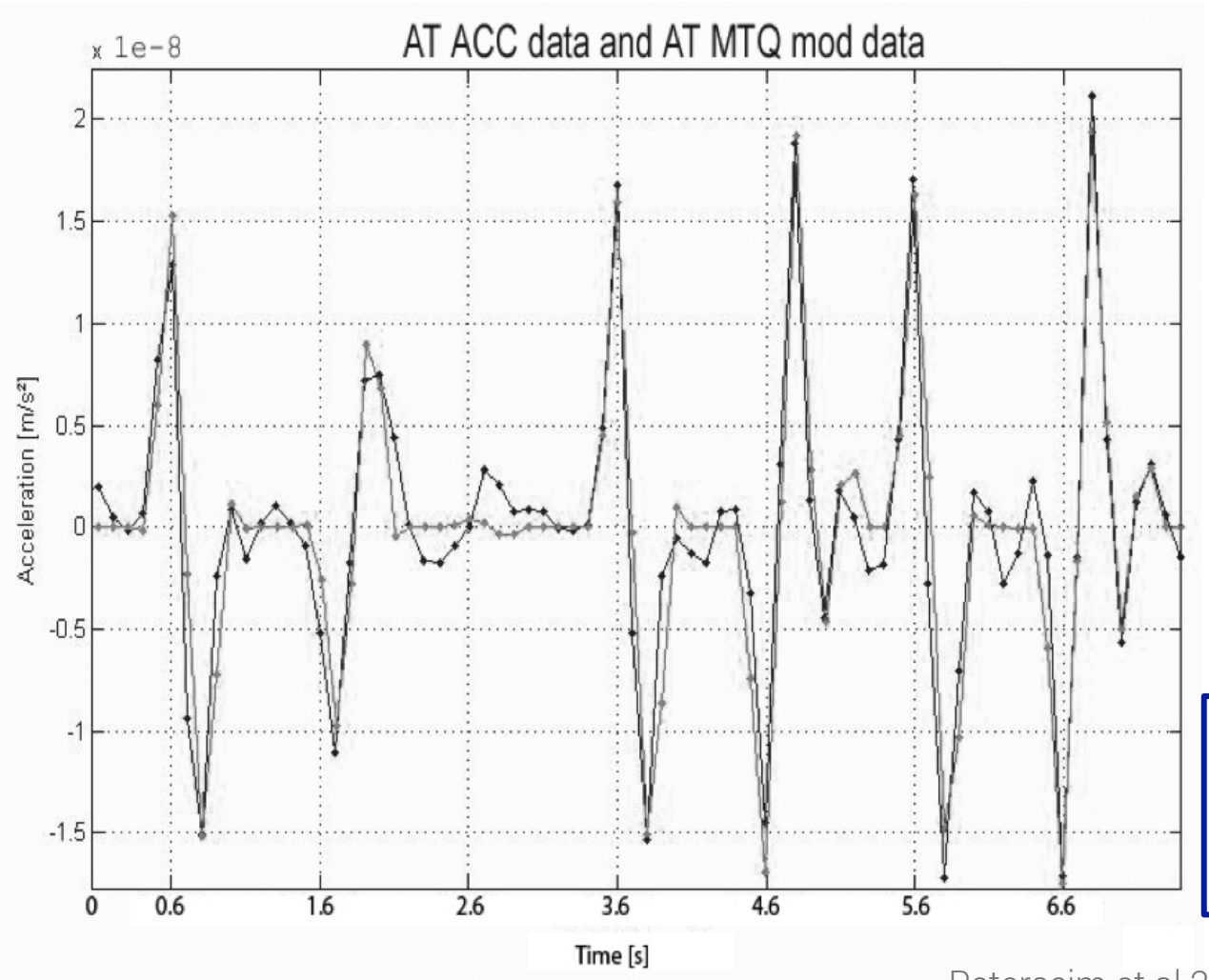
- heater activation: once per second
- DFACS data: acceleration spikes in all 6 accelerometers
- science data: 1 Hz resolution only

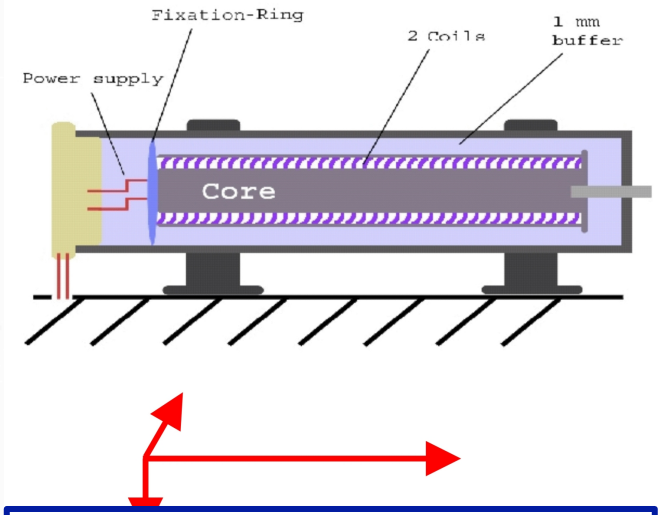
GOCE heater switching spikes



- for some heaters, mechanical effects suggested (nm- scale rotations of gradiometer support)
- no mechanical explanation for other heaters
- separation challenging

Magnetotorquer activation spikes

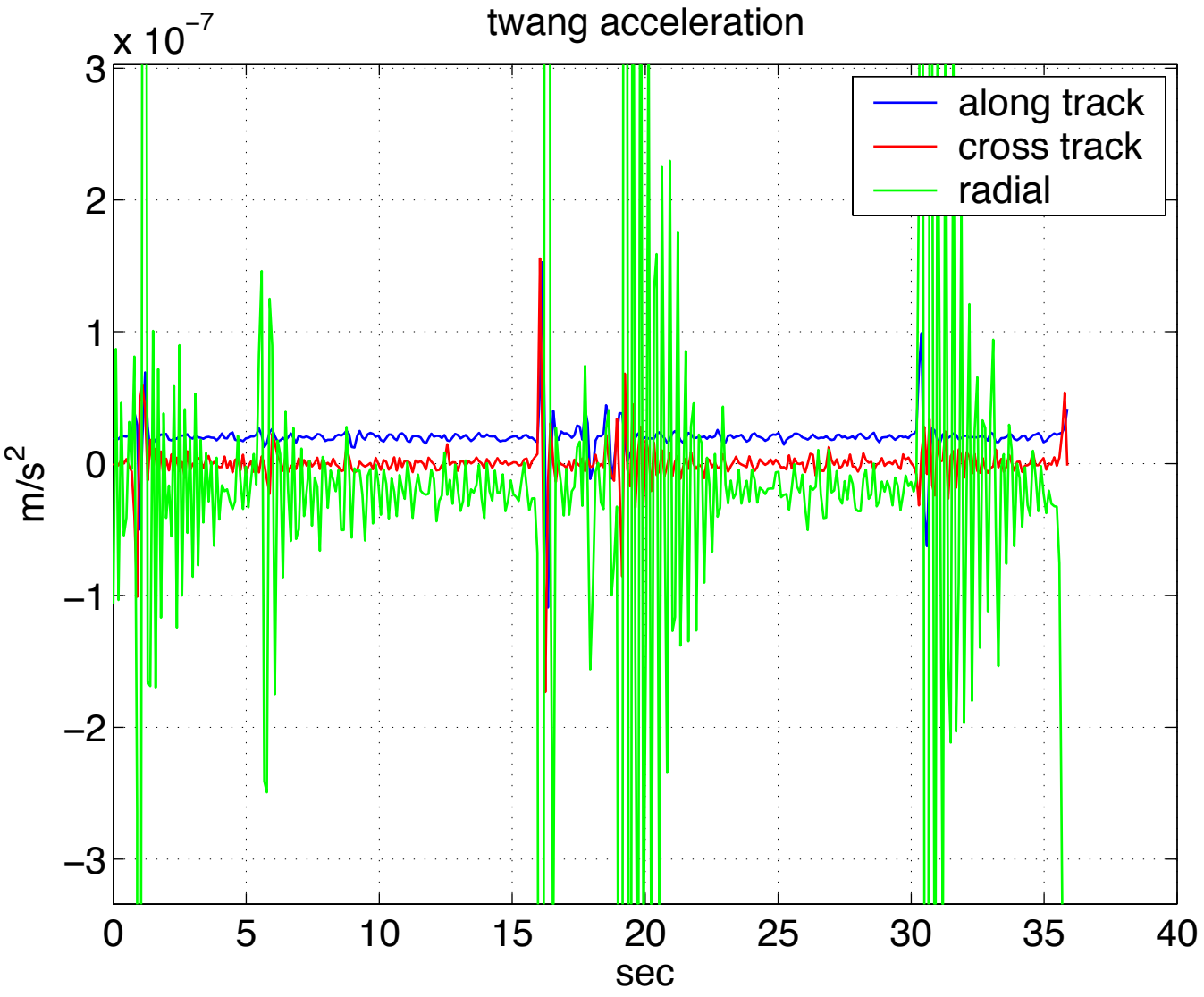




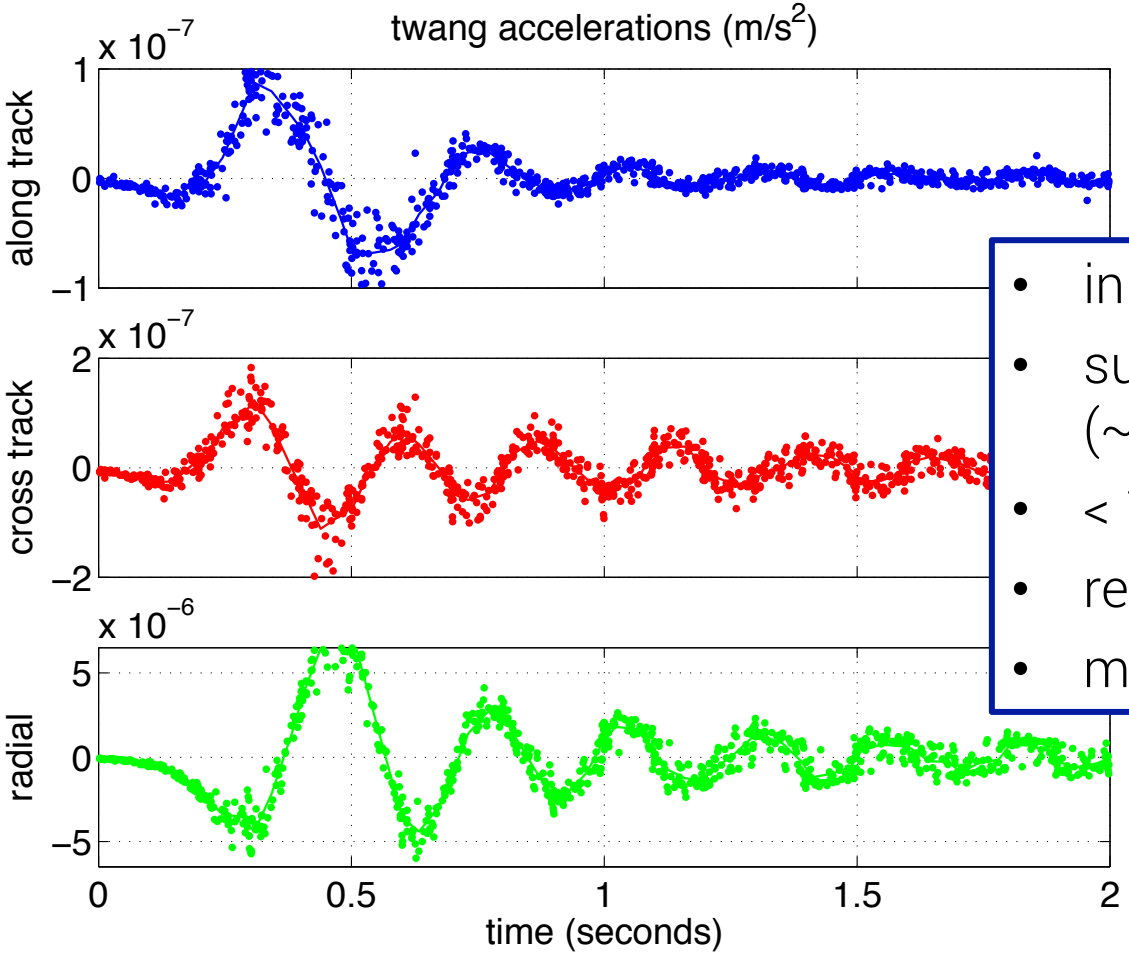
- < 0.5 sec duration
- simulaneous with fast current changes

Peterseim et al 2012

GRACE twangs

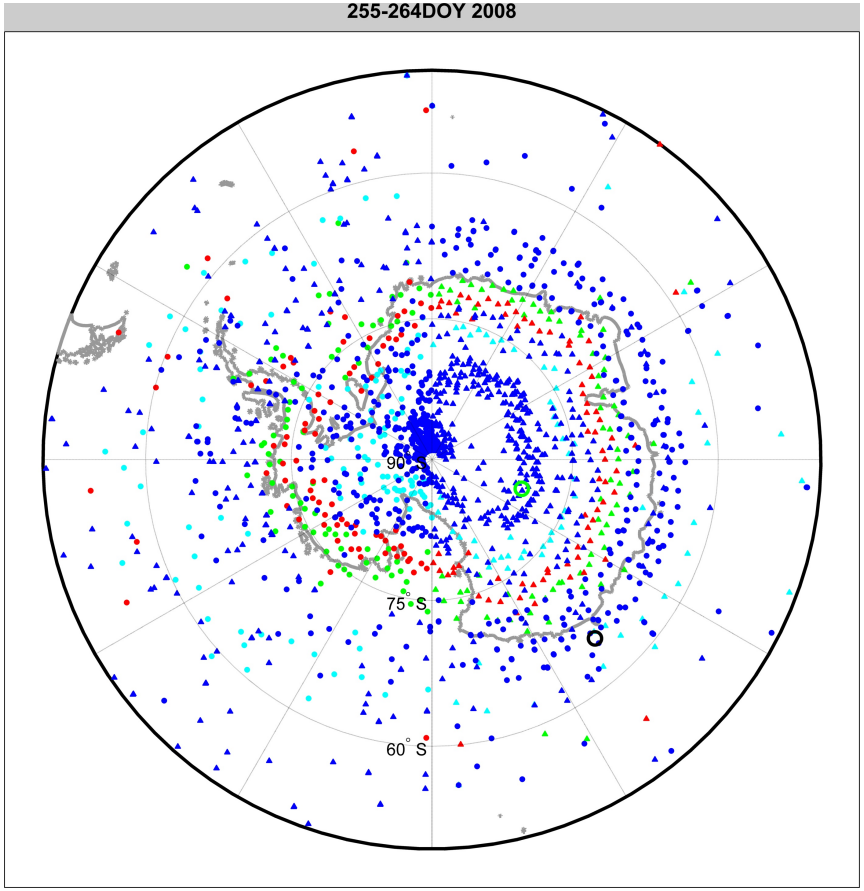


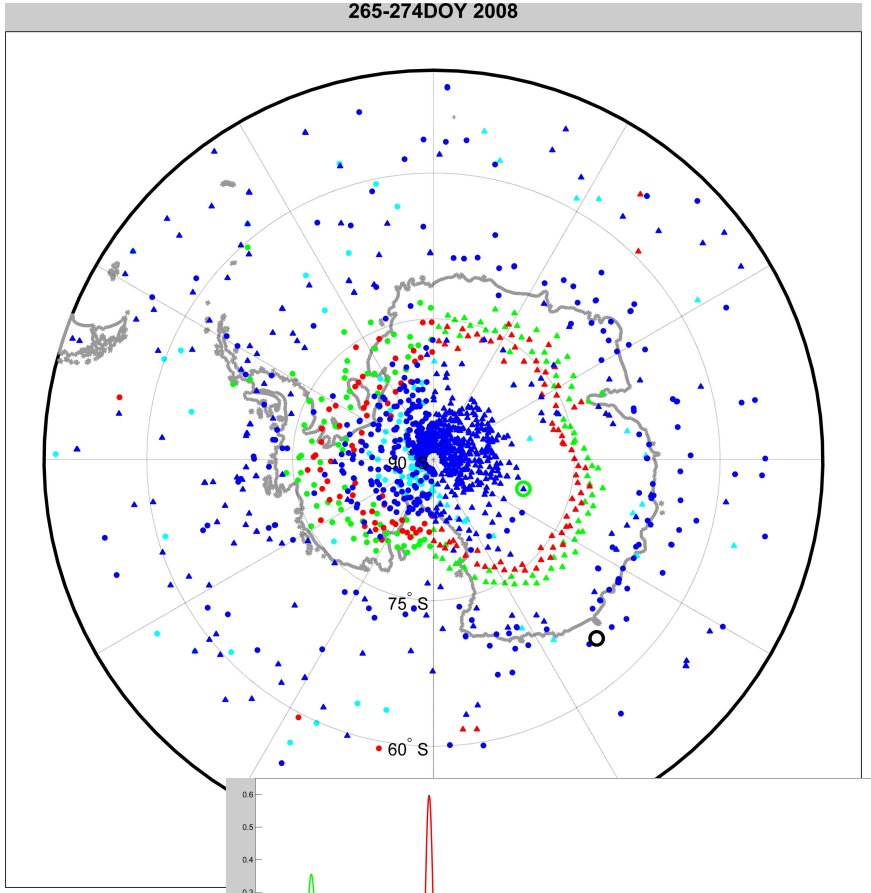
Twangs

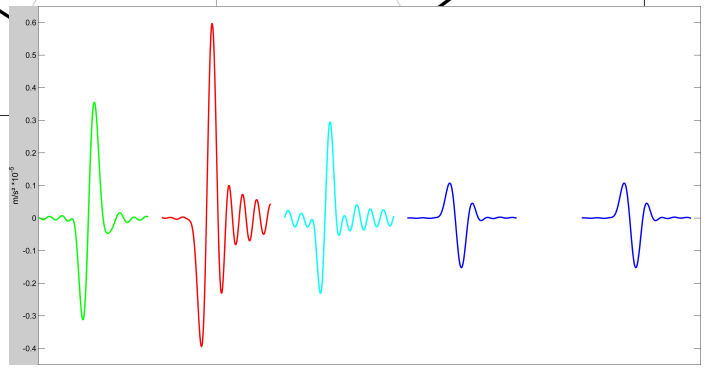


- initial spike
- subsequent oscillation (~0.2 sec period)
- < 10 sec duration
- regular shape
- many sub-species

GRACE twangs

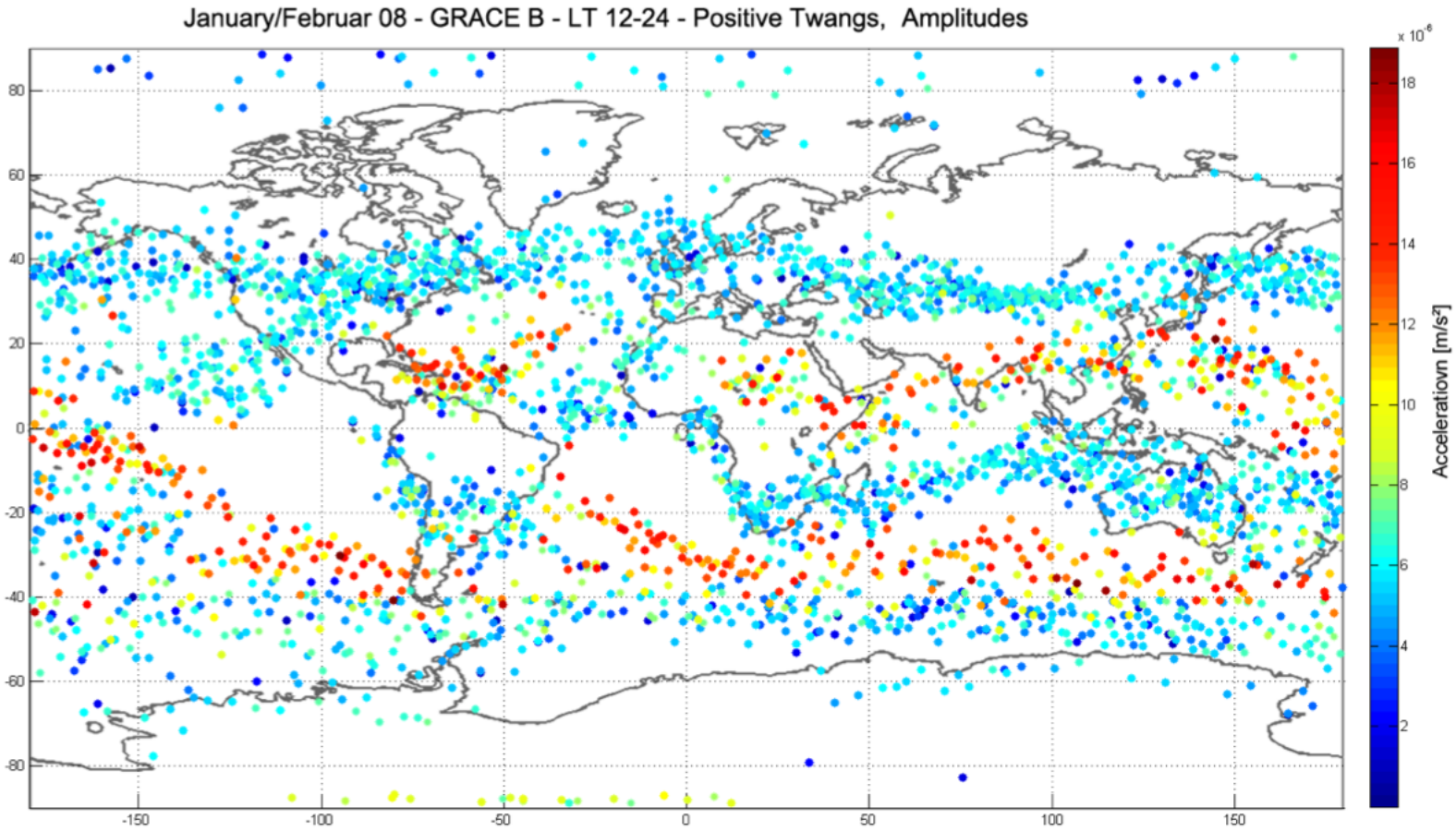






- polar circles of variable shape for some sub-species

GRACE twangs

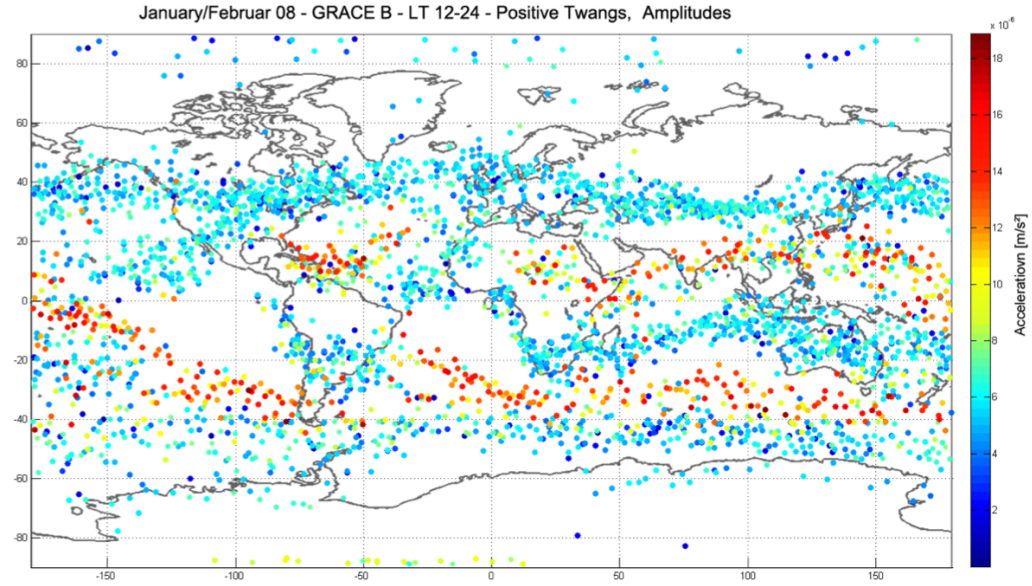


Peterseim 2014

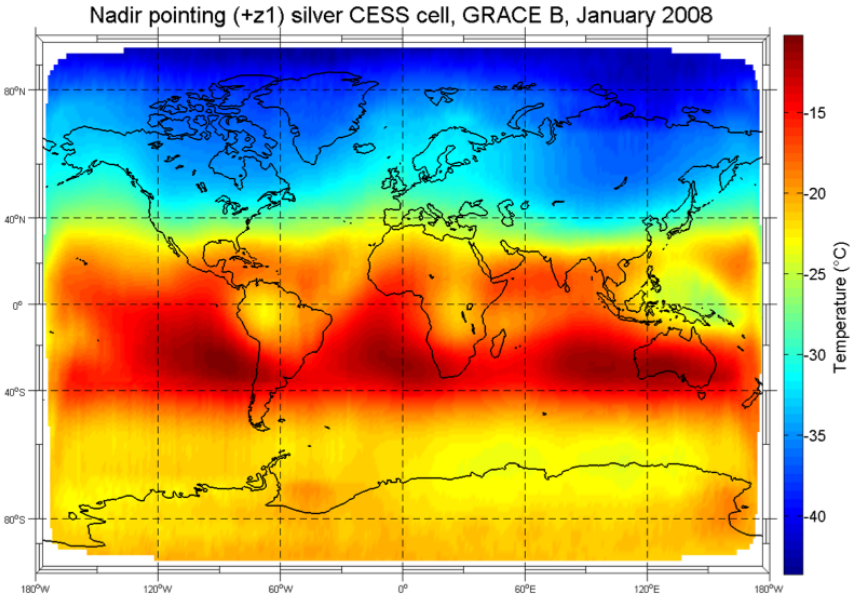
- latitudinal bands

Twangs

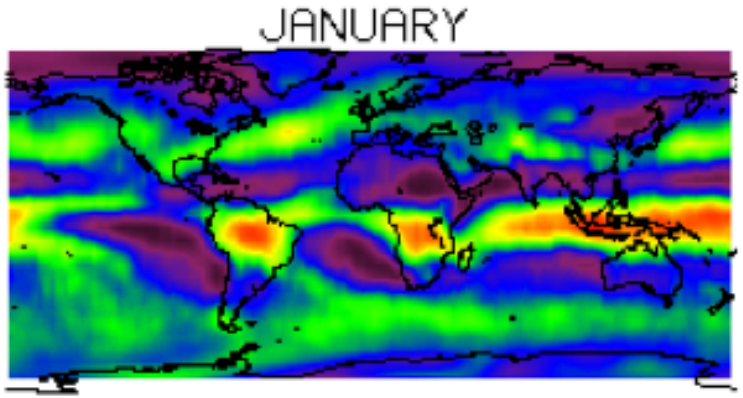
twang distribution, Jan/Feb 2008



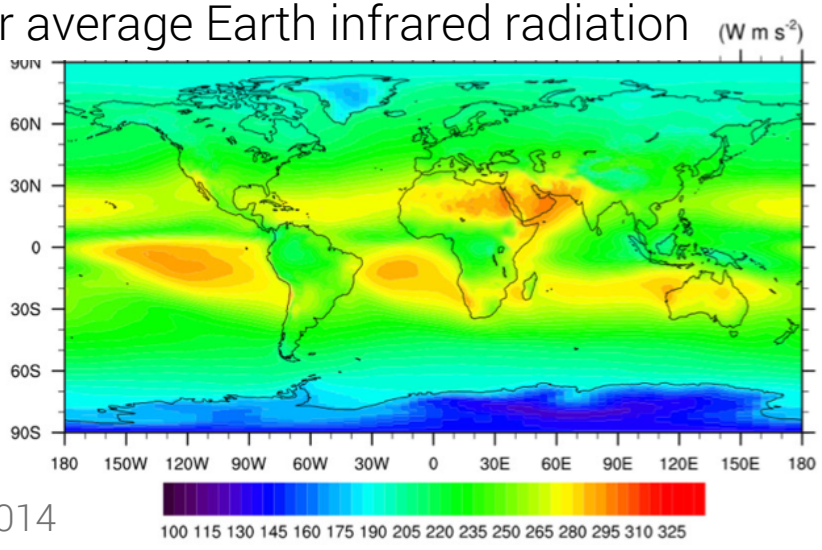
nadir side temperature, Jan 2008



average cloud cover



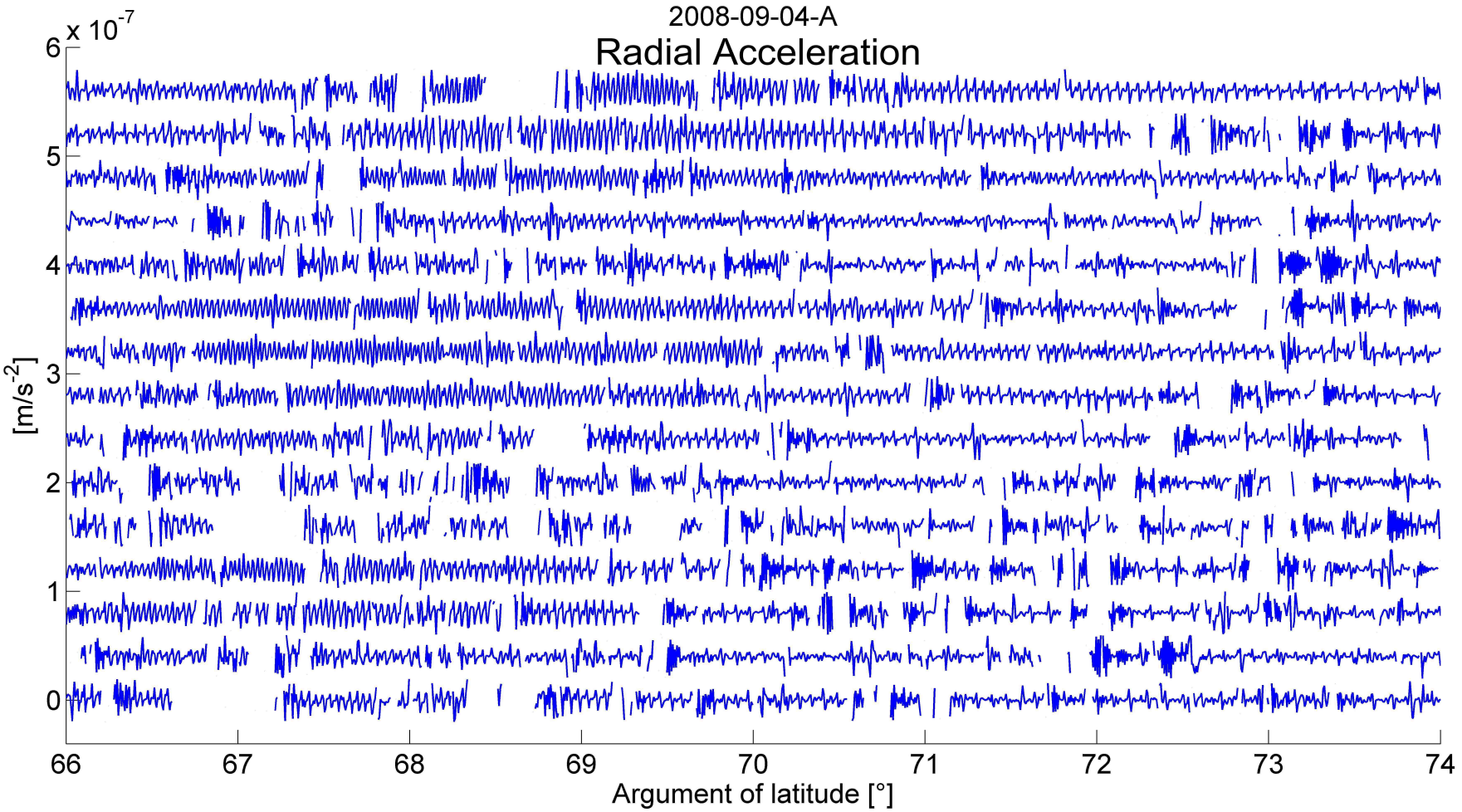
multi-year average Earth infrared radiation



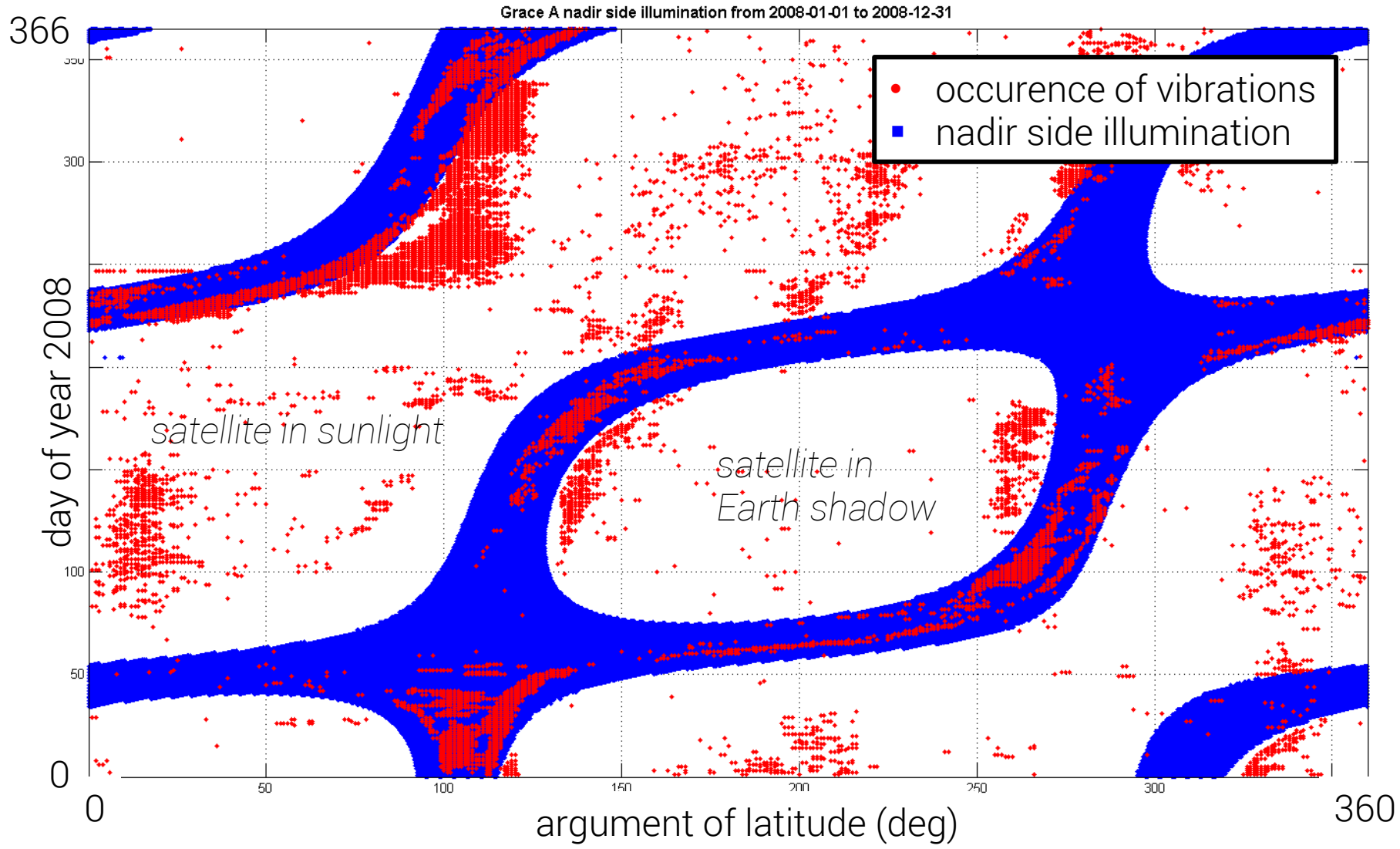
Twangs

- many sub-species
- number of twangs increasing with aging
- coupling of ionosphere into measurements?

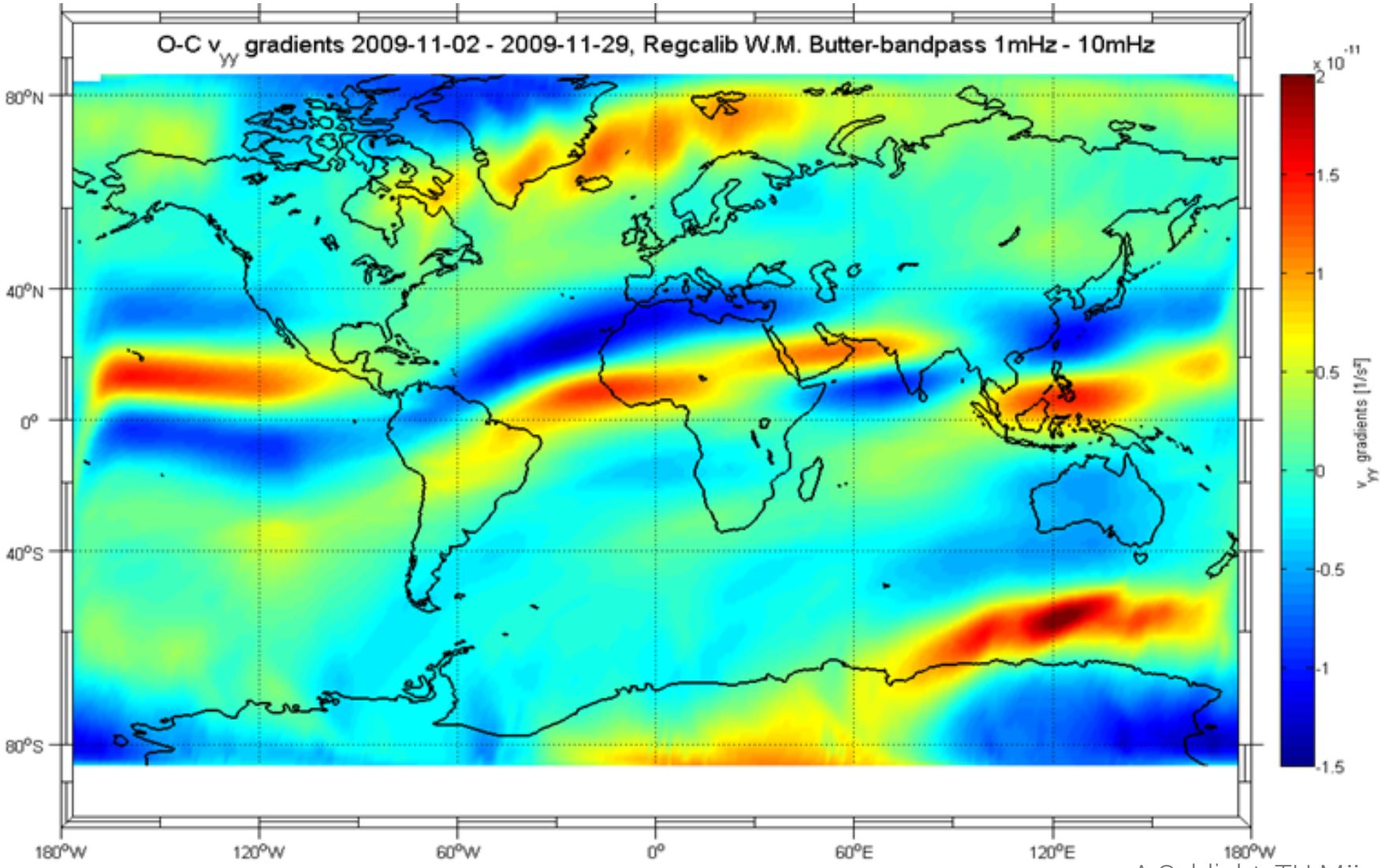
GRACE regular “vibrations”



GRACE “regular vibrations”

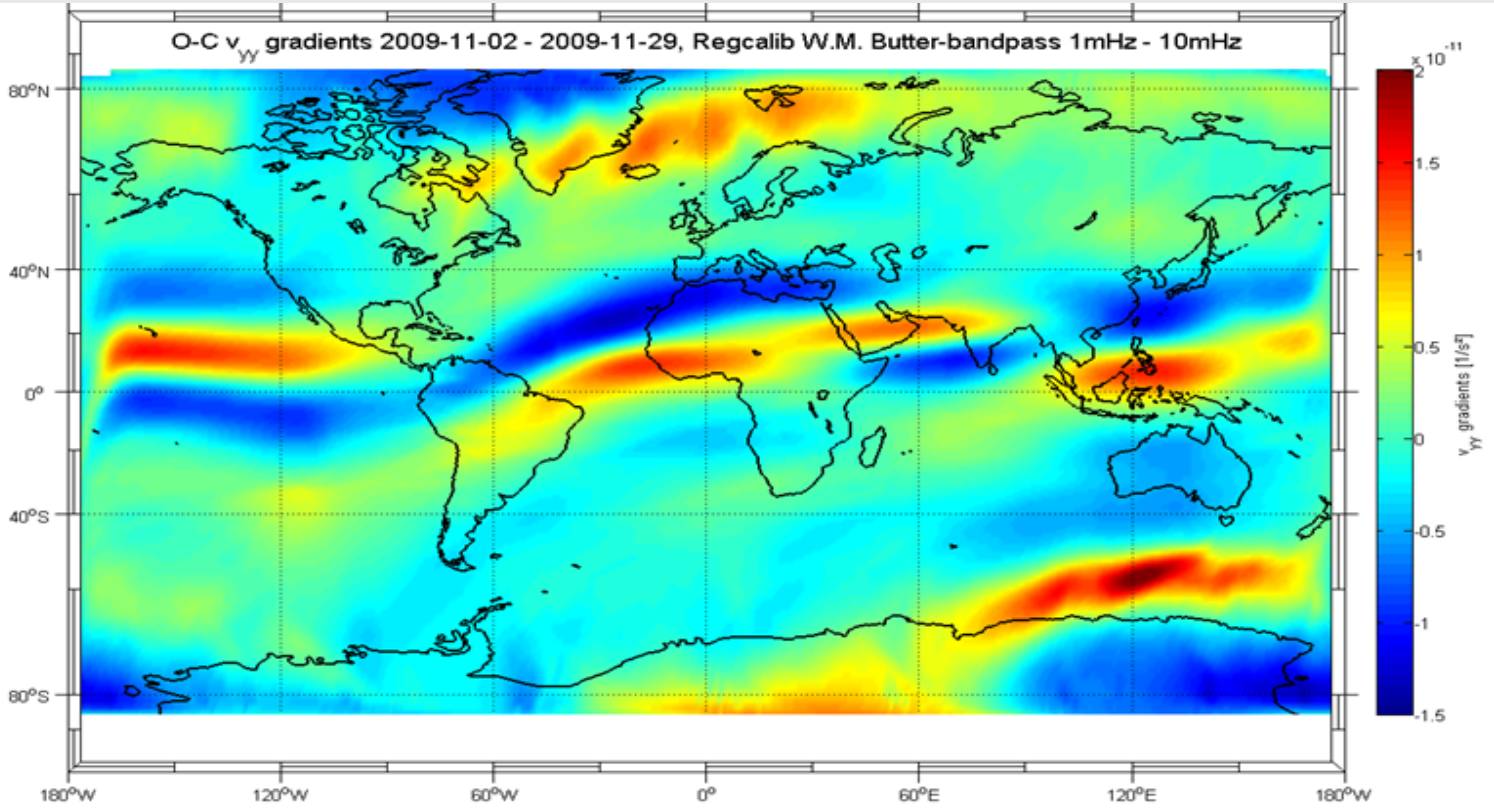


GOCE V_{yy} systematic errors



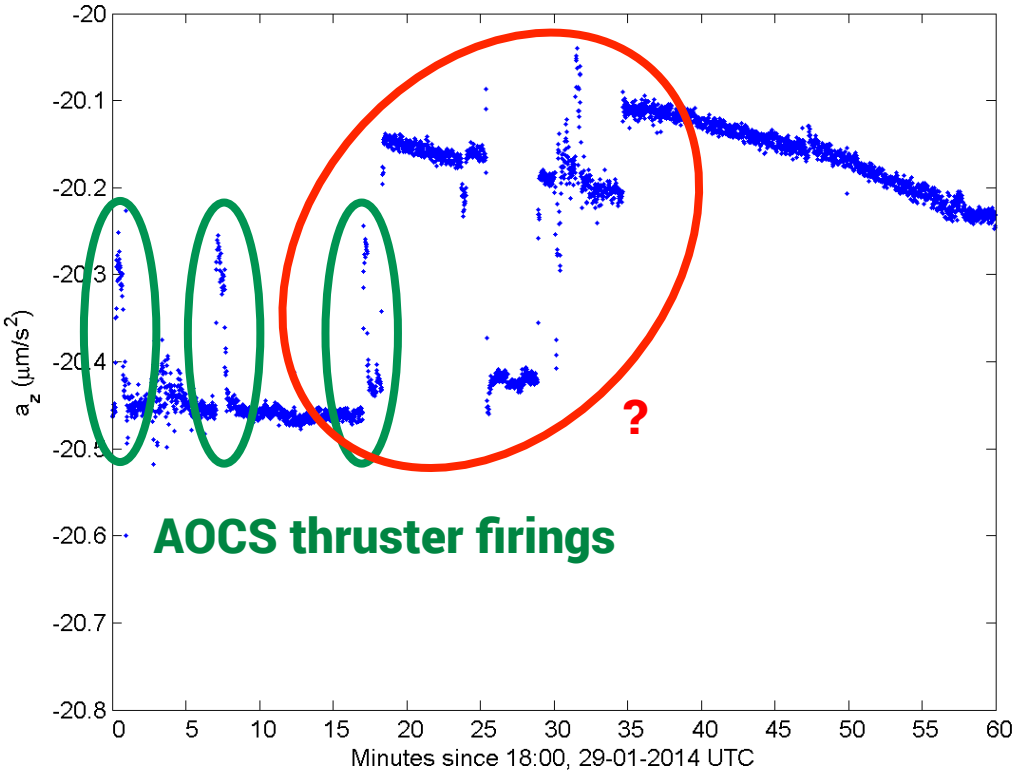
A Schlicht, TU München

GOCE V_{yy} systematic errors



- long (low frequency) and short (high frequency) disturbances: are they related? common source, e.g. EMC?
- for both, electromagnetic fields are involved
- does GOCE cross track anomaly exist, e.g., on GRACE?

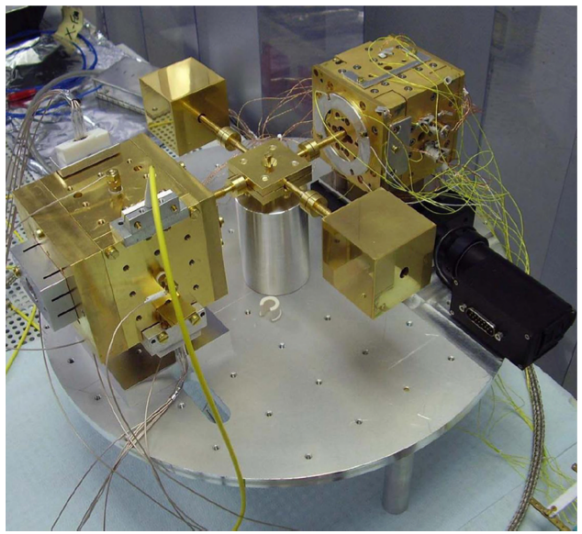
Swarm accelerometer data



C. Siemes / ESA

Testing options – switching spikes

- data analysis GRACE, GOCE
  - analysis of different configurations (computer switches, non-nominal AOCS modes, …)
  - comparison between missions
  - GOCE: MTQ spikes?
  - GOCE: separation of heaters through empirical modeling
  - inversion of transfer function
  - …
- drop tower tests?
  - with heater foils, …
- torsion balance tests?
  - better than pendulum?



Testing options – switching spikes

- dedicated in-orbit switching experiments
  - modification of voltage change, shape of transition (flanks, dV/dt)
  - modification of instrument sampling, built-in filtering
  - modification of testmass control, test mass position (procedures for experiments)
  - control of electric circuits
  - monitoring of electromagnetic compatibility (EMC)
- considering accelerometry missions as precision space laboratories
  - beyond thermal control

Cave-ats

- risk and cost of in-orbit experiments
- good case needed, including:
  - theoretical studies
  - simulations
  - test scenarios

Testing options – charge/discharge effects, twangs

- data analysis
  - addressed by *geo*-Q
  - comparing twangs in different configurations, radiation conditions, …
  - multi-mission analysis, e.g., for equatorial effects
- platform charge control
  - switch grounding (e.g., GRACE teflon foil)
  - other ways to influence charges on platform?
  - sensors for measuring electric charges on platform?

GRACE nadir side teflon foil

Testing options – charge/discharge effects, twangs

- dedicated rotational manoeuvers
  - for controlled change of environmental conditions, radiation, ionosphere, temperature of surfaces
  - GRACE: yaw turns
  - GOCE: was not prepared for significant rotational manoeuvers

GRACE nadir side teflon foil

Sampling with multiple accelerometers

- GOCE: 6 accelerometers, rich material, to be exploited
- science channels: sampling < 1 sec important
- Microscope: new insight expected from
  - dual material accelerometry
  - inertial pointing
  - …

Conclusions on environmental disturbances

- combination of science and engineering needed
- benefits of multi-mission approach
- separation of effects often successful
- many options for testing
  - experiments
  - modeling
- progress towards monitoring / controlling / understanding laboratory conditions in orbit