Drift Characteristics of Paroscientific pressure sensors

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- PIES + current meter & CPIES arrays
- Paroscientific Digiquartz sensors
- 4 arrays, 7 settings
- leveling / dedrifting method
- Characterizing the observed drifts

Drift Characteristics of Paroscientific pressure sensors

- Aim to show…
  - (exponential+linear) curve is well suited to represent the drift
  - Geostrophic leveling & drift detection is reliable to ~0.01 dbar
    - new drift curves differ from previous method that used just P data, although both use (exp + lin) fit
  - Averaging records from two or more ‘same-site’ sensors produces an average drift, but not zero drift
  - Pre-stressing reduces |drift|

CPIES:
current and pressure recording inverted echo sounder

Measures bottom current.
(50 m off bottom)

Emits 12kHz sound pulses.
Measures round trip travel times of acoustic pulses to sea surface and back.

Measures bottom pressure (and temperature).

(includes acoustic release + relocation radio+strobe light)

A CPIES array yields daily maps of upper and deep circulation.

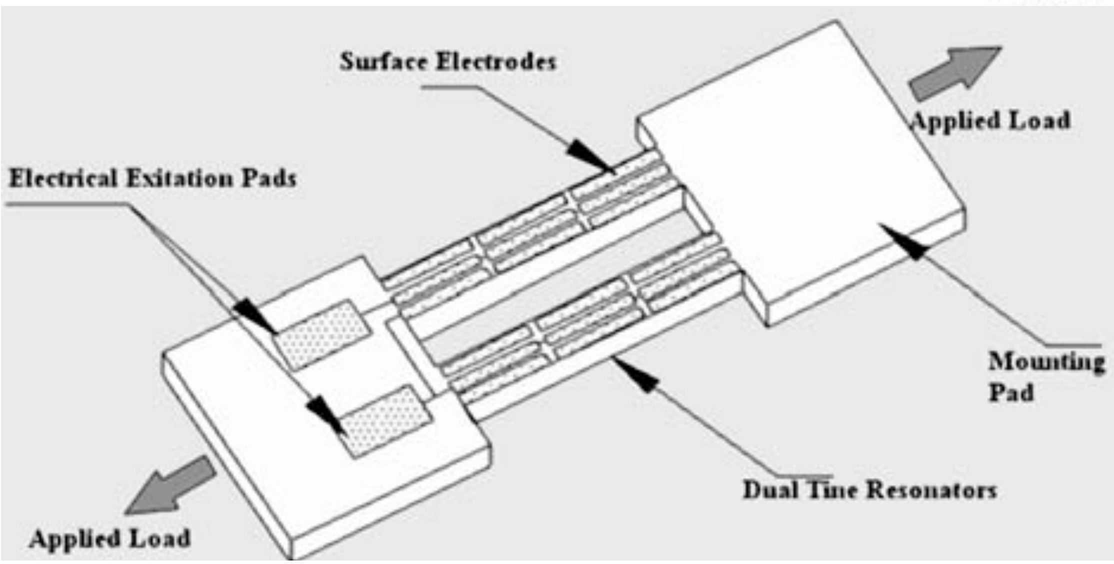
Look-up tables interpret acoustic travel times as geopotential height (0 referenced to 5000 dbar).

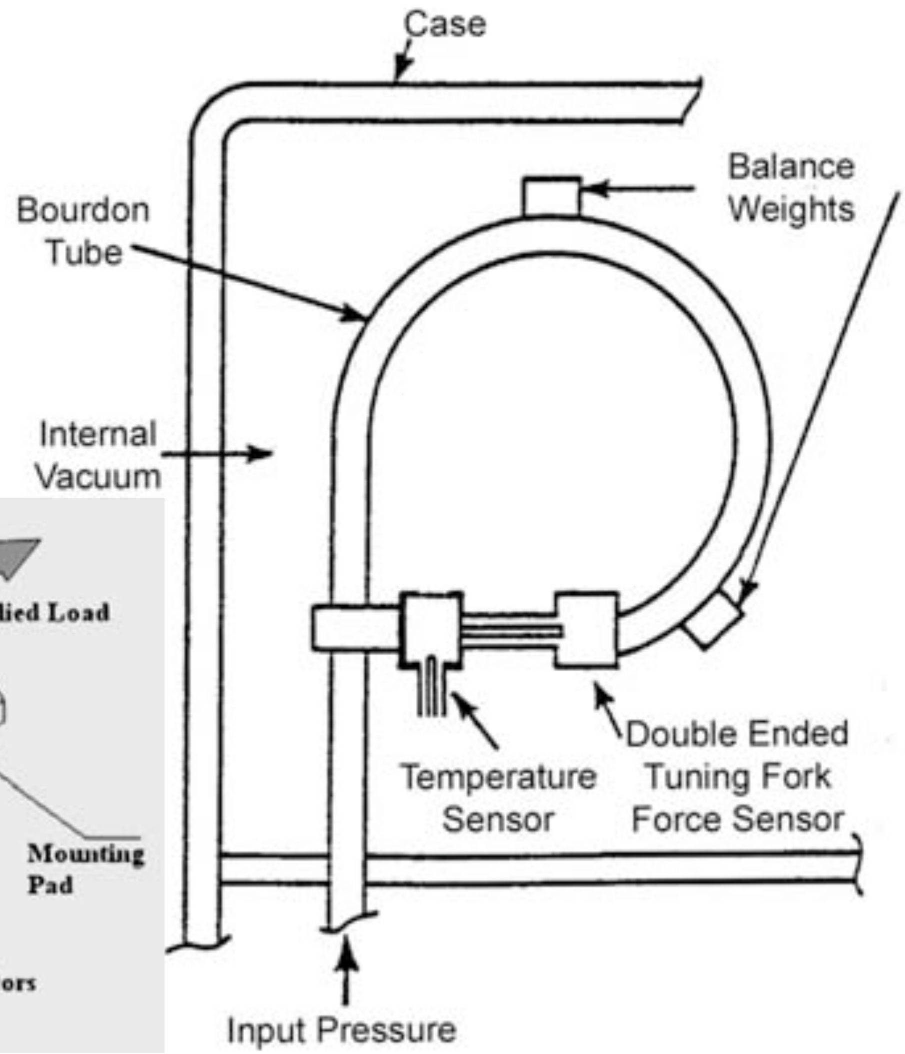
2-D arrays of CPIES estimate horizontal gradients of geopotential to calculate geostrophic velocities.

Velocity profiles are referenced by measured near-bottom currents.

Bottom pressures are leveled using near-bottom currents to map the geostrophic streamfunction.

Digiquartz sensor
- Paroscientific website



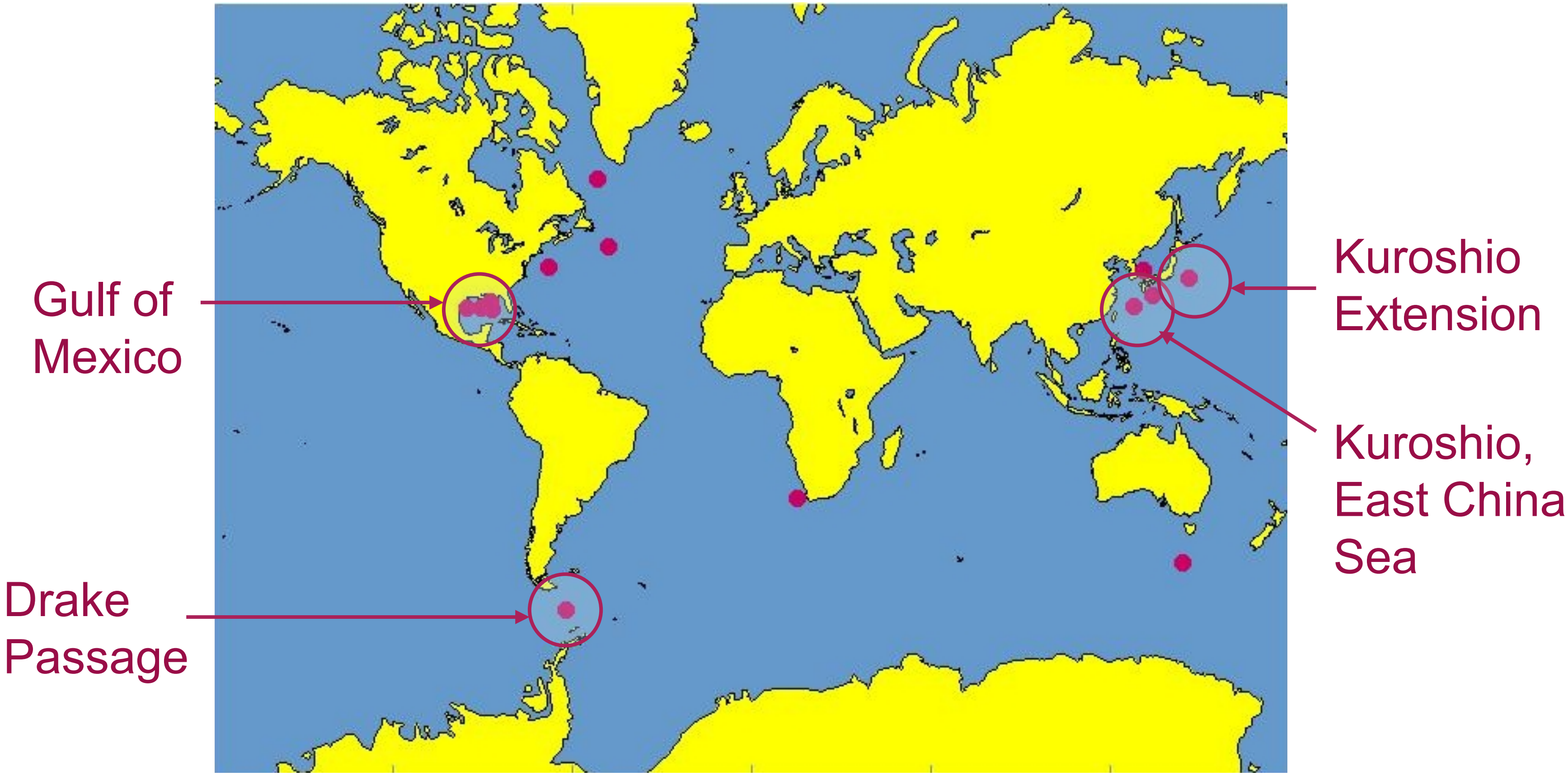


- Digiquartz frequency increases with pressure-applied load:
  - Accuracy 100 ppm; drift ~ 10 ppm; stability & resolution ~ <1-2 ppm
- PIES measures frequency with 4MHz temperature-compensated crystal
  - freq. spec: 10 ppb accuracy to serve as a stable reference

URI PIES & CPIES deployment sites

- 4 recent arrays with current meters; 7 settings

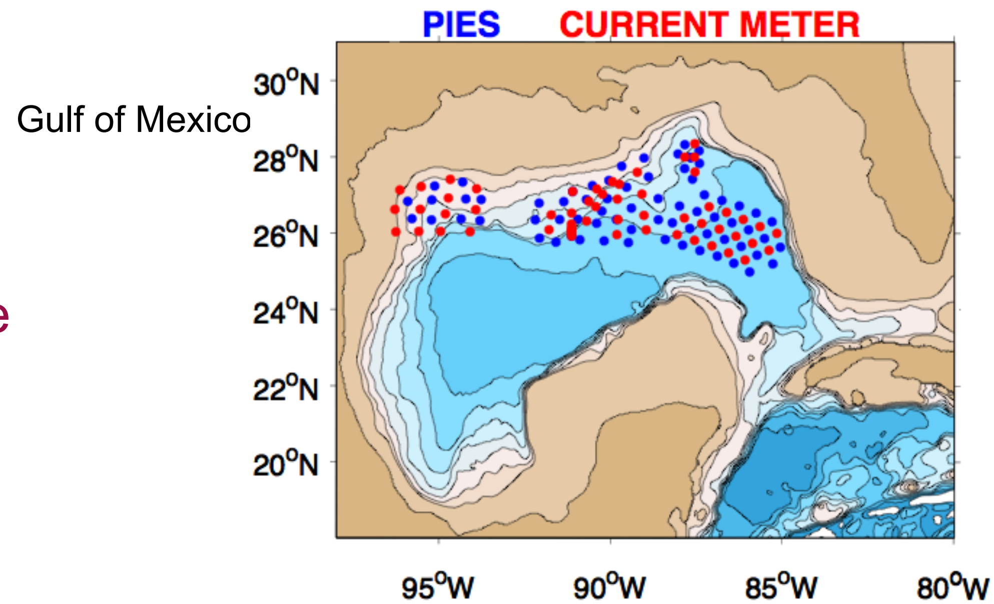
URI PIES & CPIES deployment sites

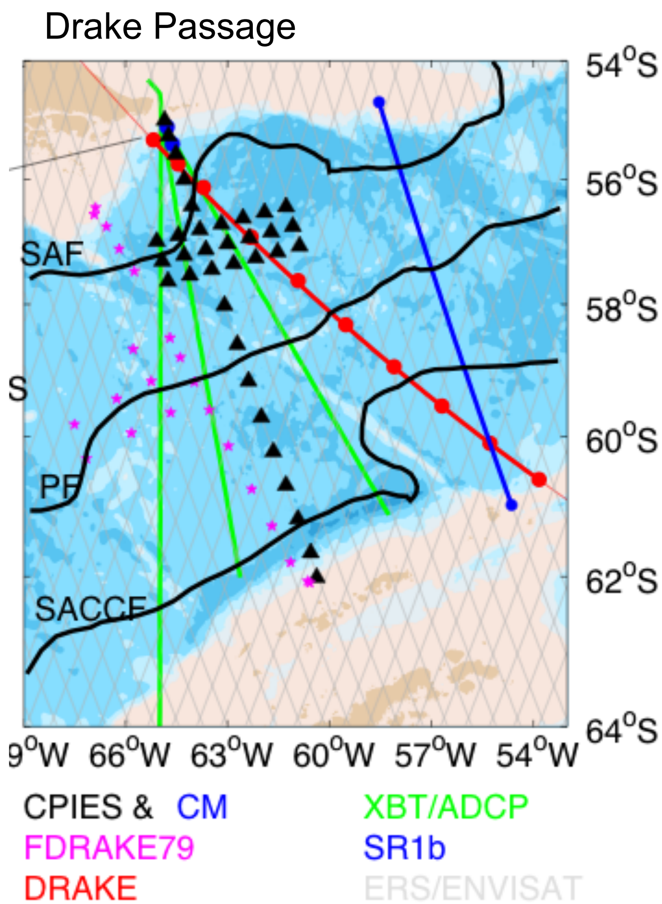


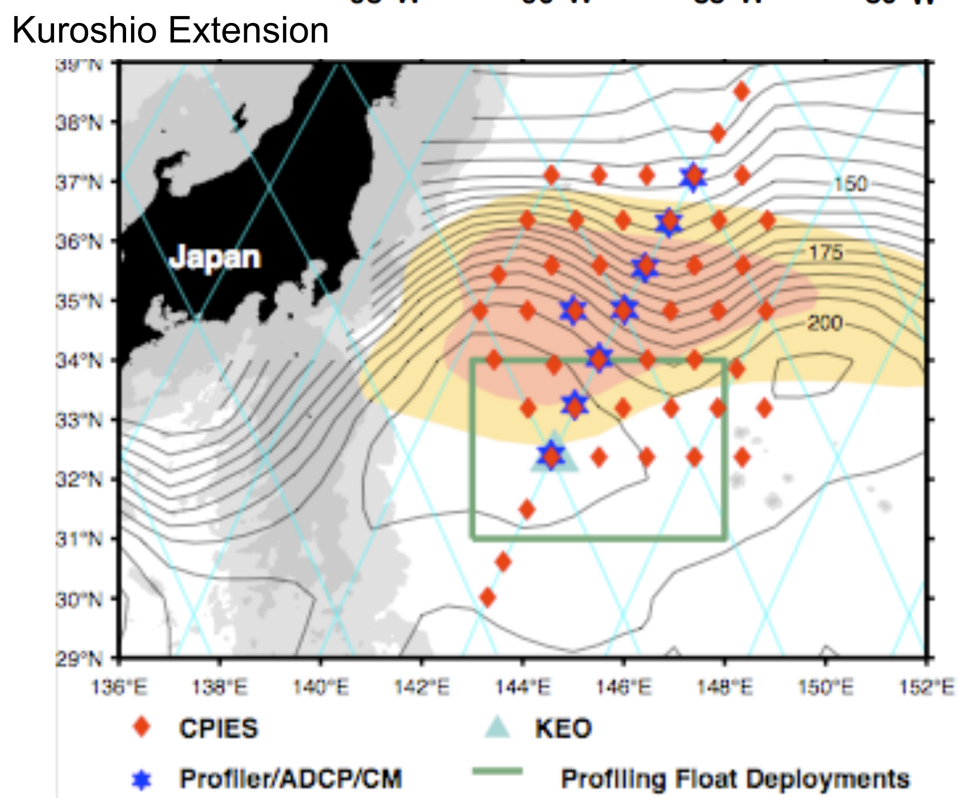
- 4 recent arrays with current meters; 7 settings

arrays of PIES & CMs

… combined to level the pressure sensors geostrophically







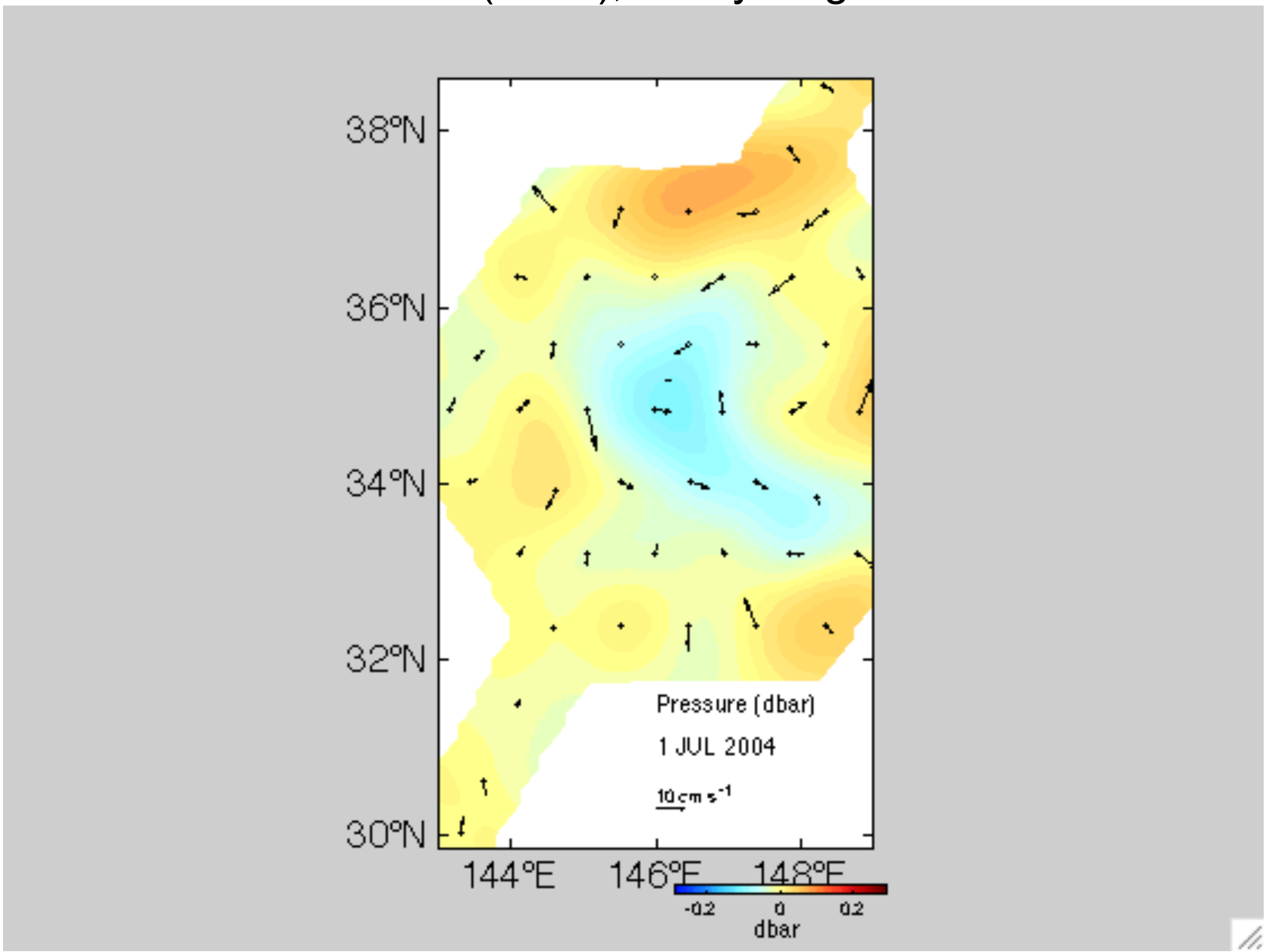
detide

Tidal response analysis (Munk and Cartwright, 1977) determines the tidal constituents for each instrument.

Tides are then removed from the pressure records.

Kuroshio Extension deep streamfunction maps

LP filter (1-mo); July-Aug 2004



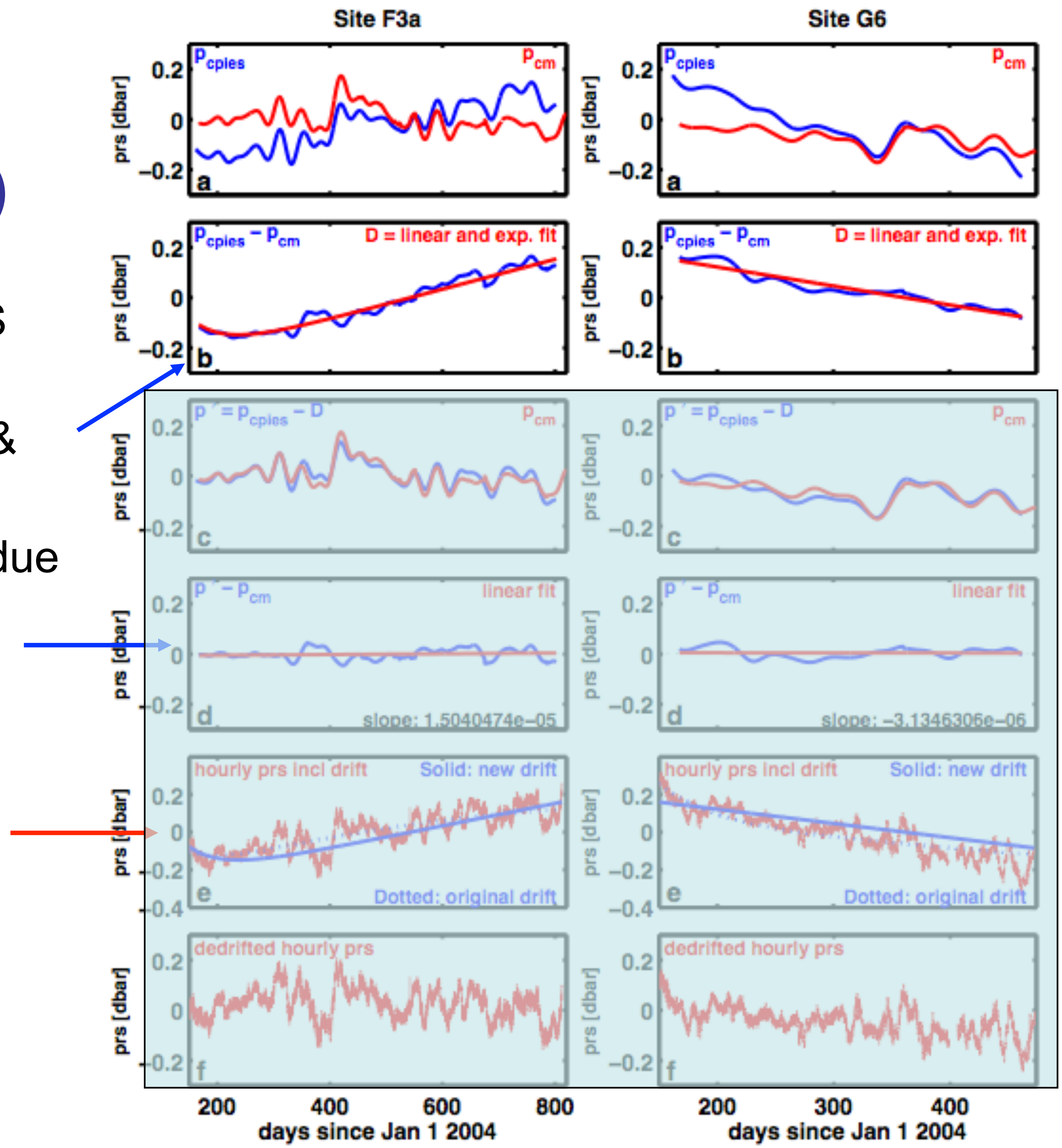
These are used to level and dedrift the P(t) records as follows.

Leveling (and drift)

- The streamfunction from CMs and the pressure from PIES measure the same geostrophic pressure field.
  - The two fields should only differ by a site-dependent leveling constant.

drift-curve fit to P(t) - P_{cm}(t)

- Examples from KESS sites
- 31-d lowpass filter p & p_{cm}
- Difference ($p-p_{cm}$) is due to mapping-error and drift



drift-curve fit to $P(t) - P_{cm}(t)$

- Examples from KESS sites
- 31-d lowpass filter p & p_{cm}
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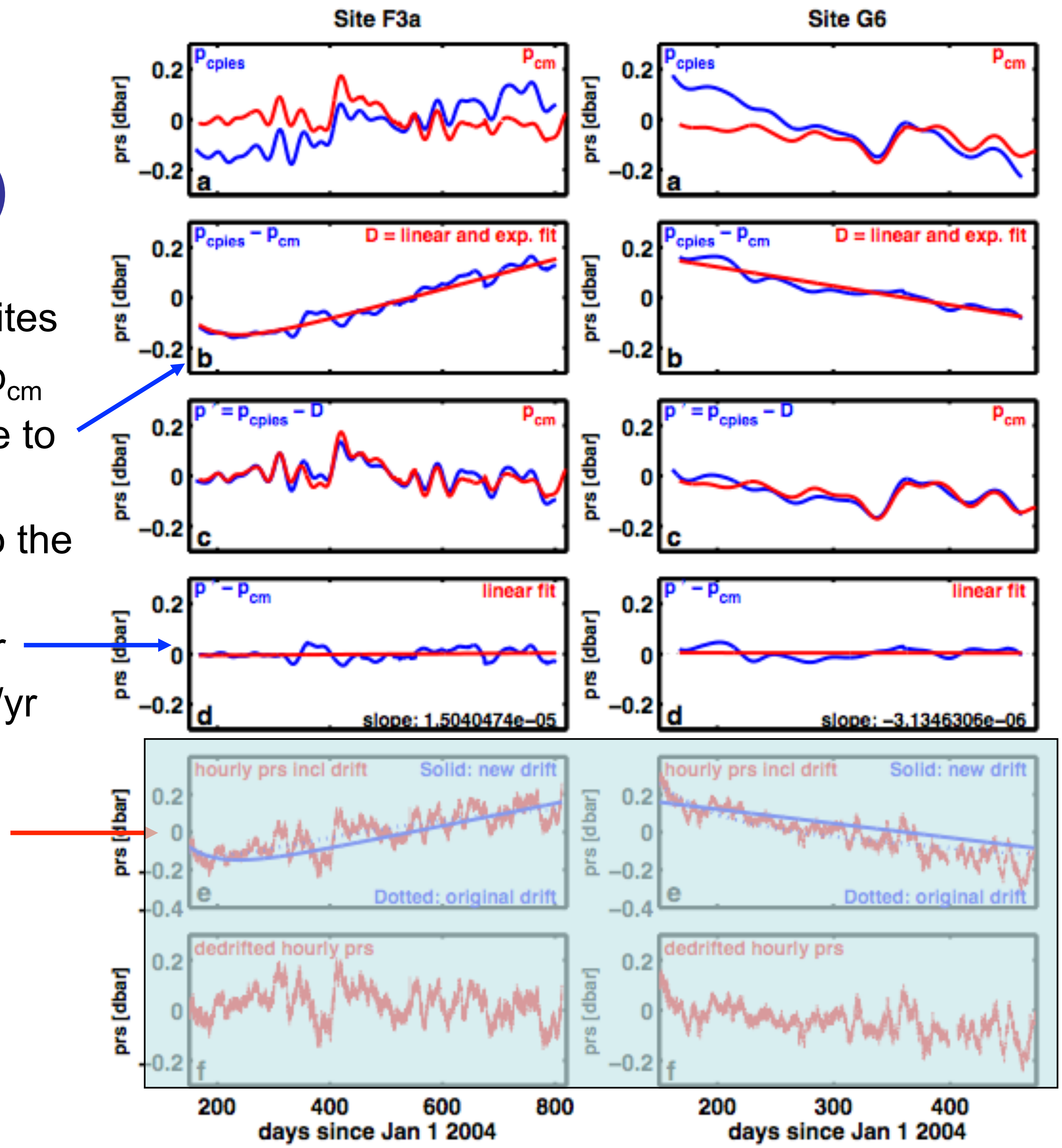
- Fit exponential+linear to the difference
- Residual rms<0.01 dbar
- Resid slope<0.005dbar/yr



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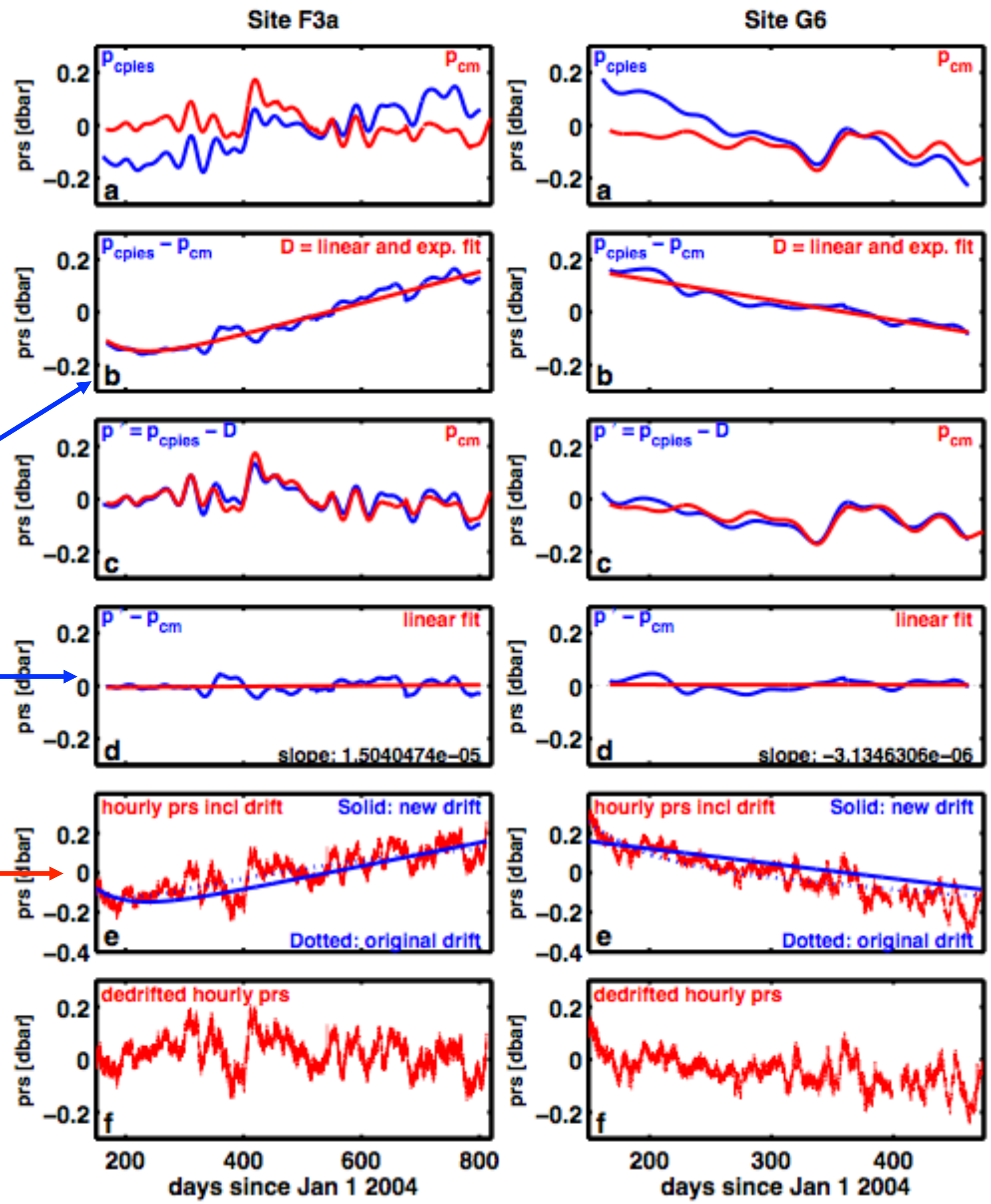
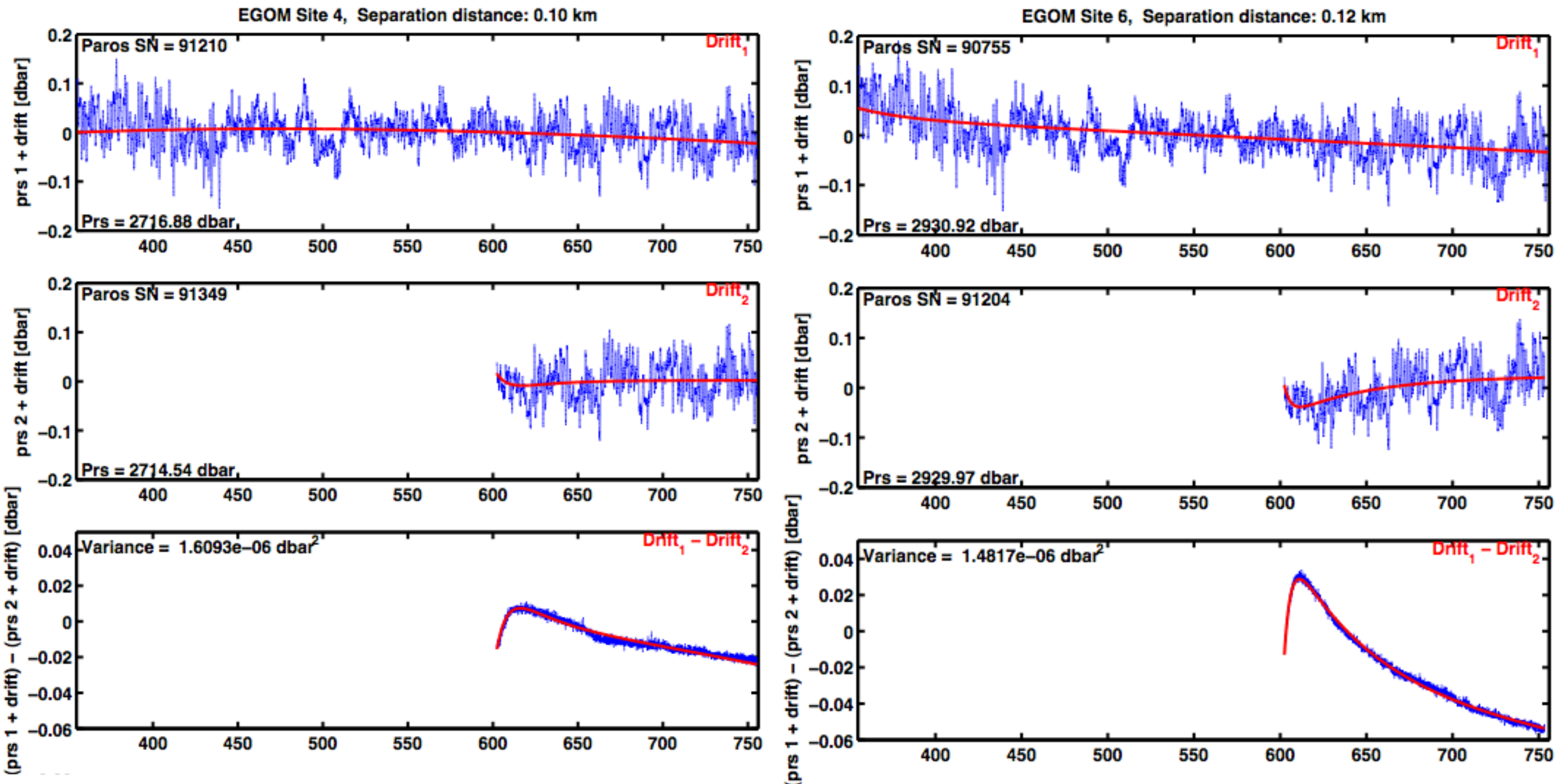
- Old method fit (exp+lin) to hourly data (dotted line), w/o geostrophic leveling could differ by 0.03-0.05 dbar



Digiquartz Pressure Drift (1)

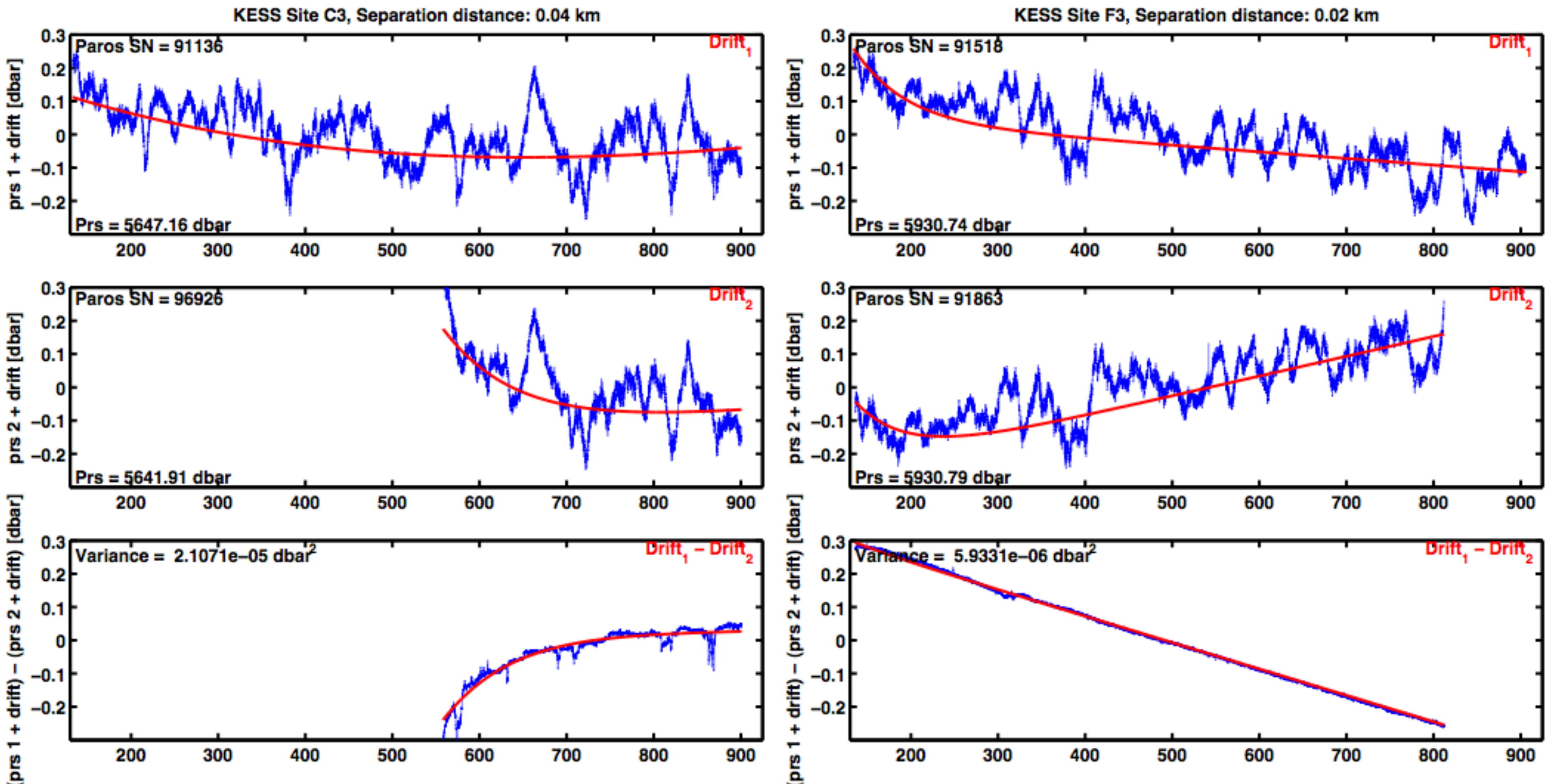
- How well-suited is the (exponential + linear) curve-fit to the ‘processes’ causing observed drifts?
  - Test by comparing ‘same-site’ differences of raw records against the sum of fitted drift curves
  - Note ‘same-site’ pairs could be 0.1 to 0.4 km apart

Consistency of method at 'same-site' pairs in GoMex



- (rows 1, 2) sites with two PIES each, separately dedrifted
- (row 3) The difference between raw records (blue) agrees with difference between drift curves (red); rms <0.0013 dbar (model 46K's)

Consistency of (exp+lin) at 'same-site' pairs in Kuroshio

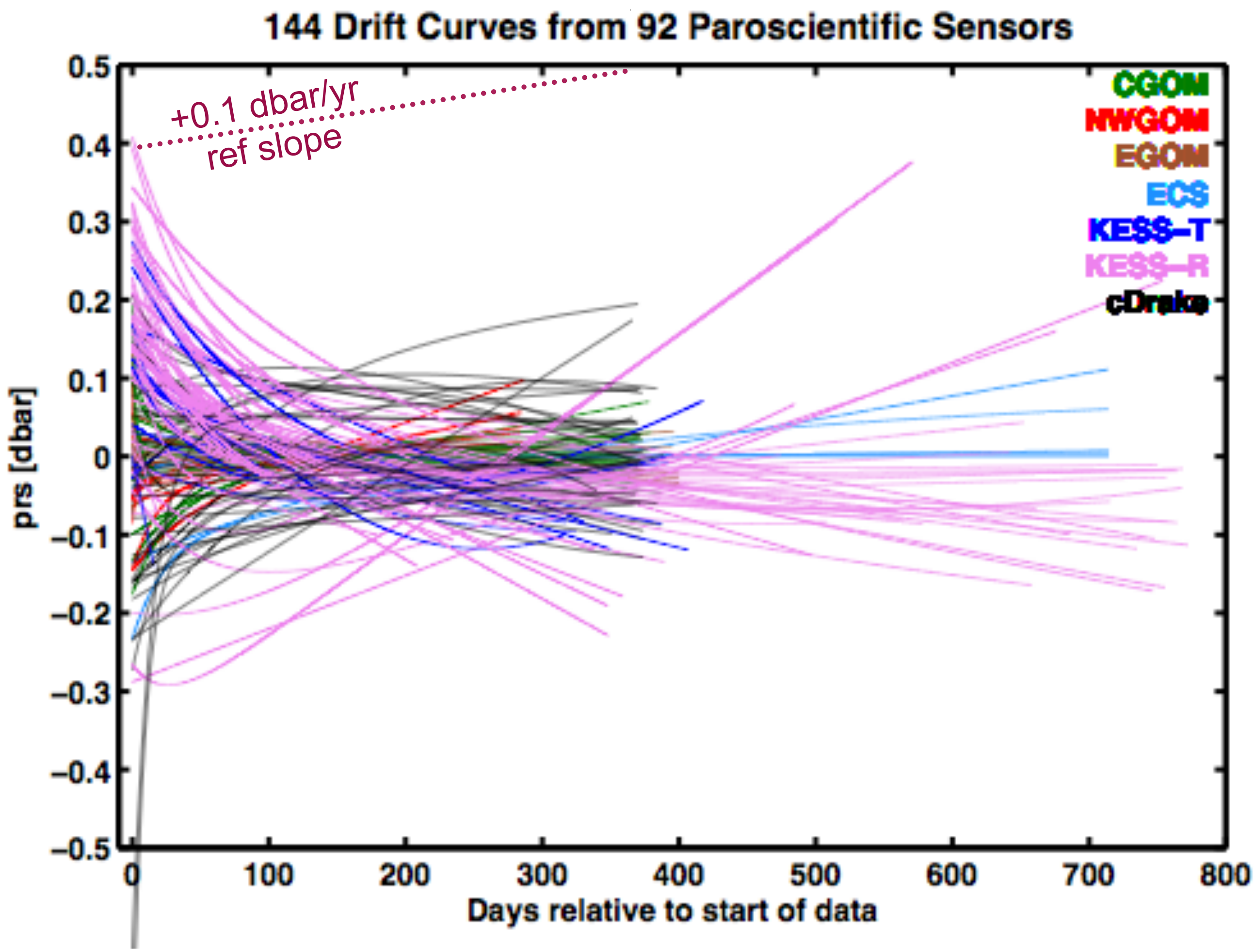


- (rows 1, 2) Two sites with two PIES each, separately dedrifted
- (row 3) The difference between raw records (blue) agrees with difference between drift curves (red); rms=0.004, 0.002 dbar (model 410K's)

- The (*exp* + *lin*) curve suits the drift process well

- Next simply characterize the drift of each of many records by its (*exp* + *lin*) curve…

144 drift curves from 92 sensors

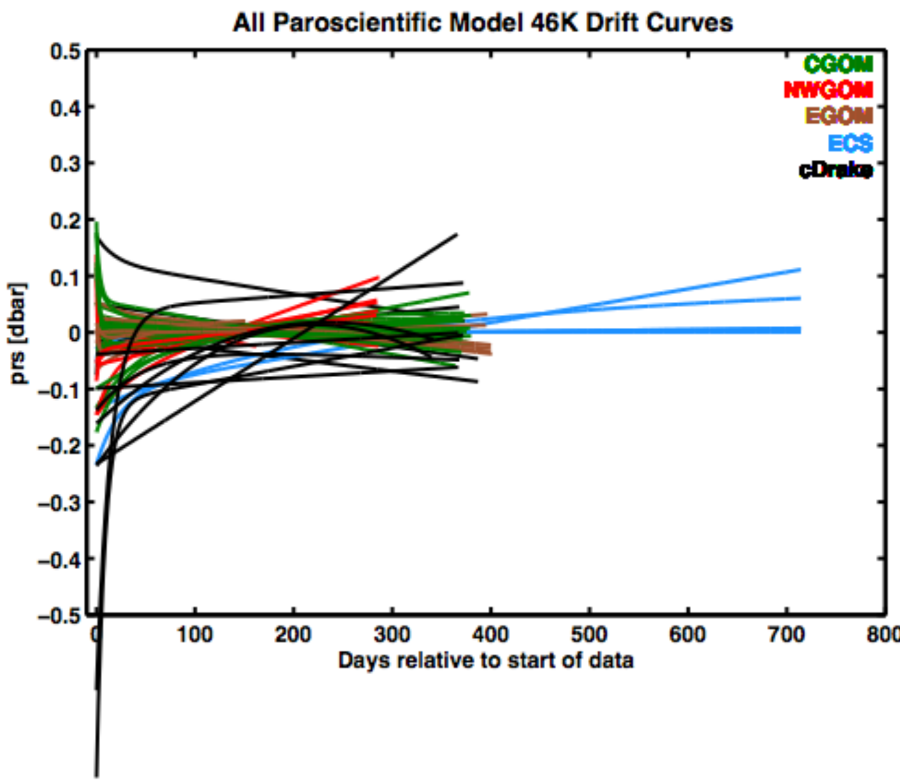


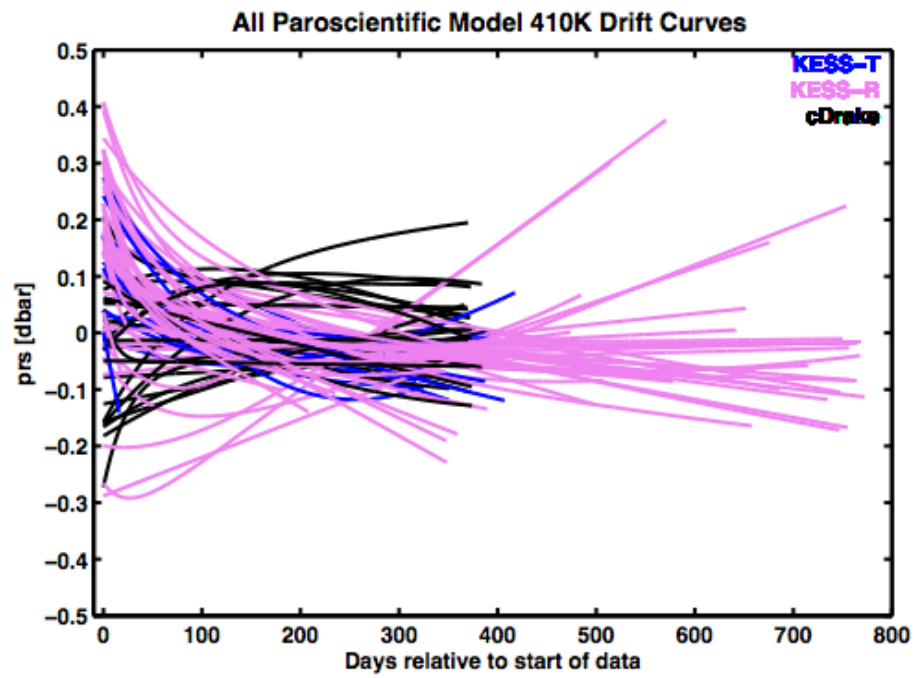
Digiquartz Pressure Drift (2)

- 6000 psi ~ 4000 dbar sensors, model 46K
- 10000 psi ~ 6800 dbar sensors, model 410K

- Do drifts scale with FS range?
- What sign and magnitude of drift?

Model 46K and 410K sensor drift

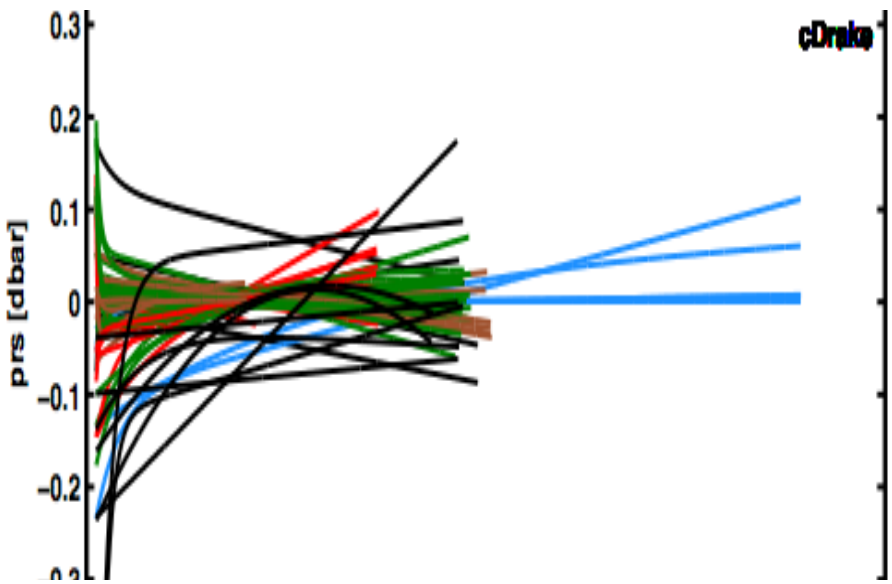


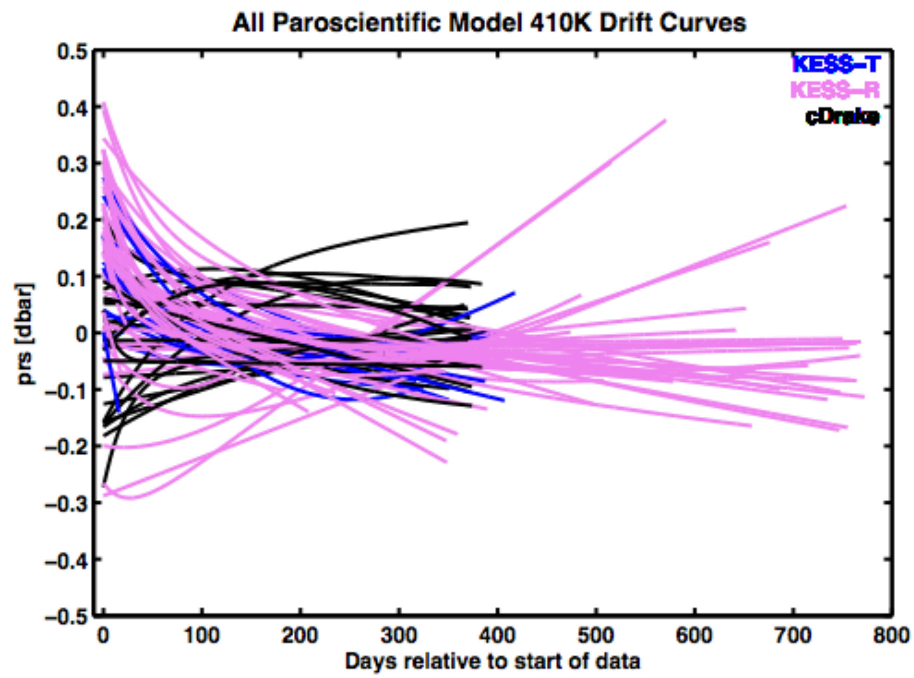


46K's - *all* pre-stressed

410K's - *mixed* pre-stressing

Model 46K (stretched) and 410K sensor drift





46K's, vertical scale X (10/6)

-Slightly less drift, but the improvement may have arisen from pre-stressing

46K's - all pre-stressed

410K's - mixed pre-stressing

- Typical |drift| ~ 0.4 dbar
- Upward and downward drifts would arise from two different processes
- Exponential and linear drifts would arise from different processes
- So there must be at least 3-4 substantial contributions to drift
- Yeow!

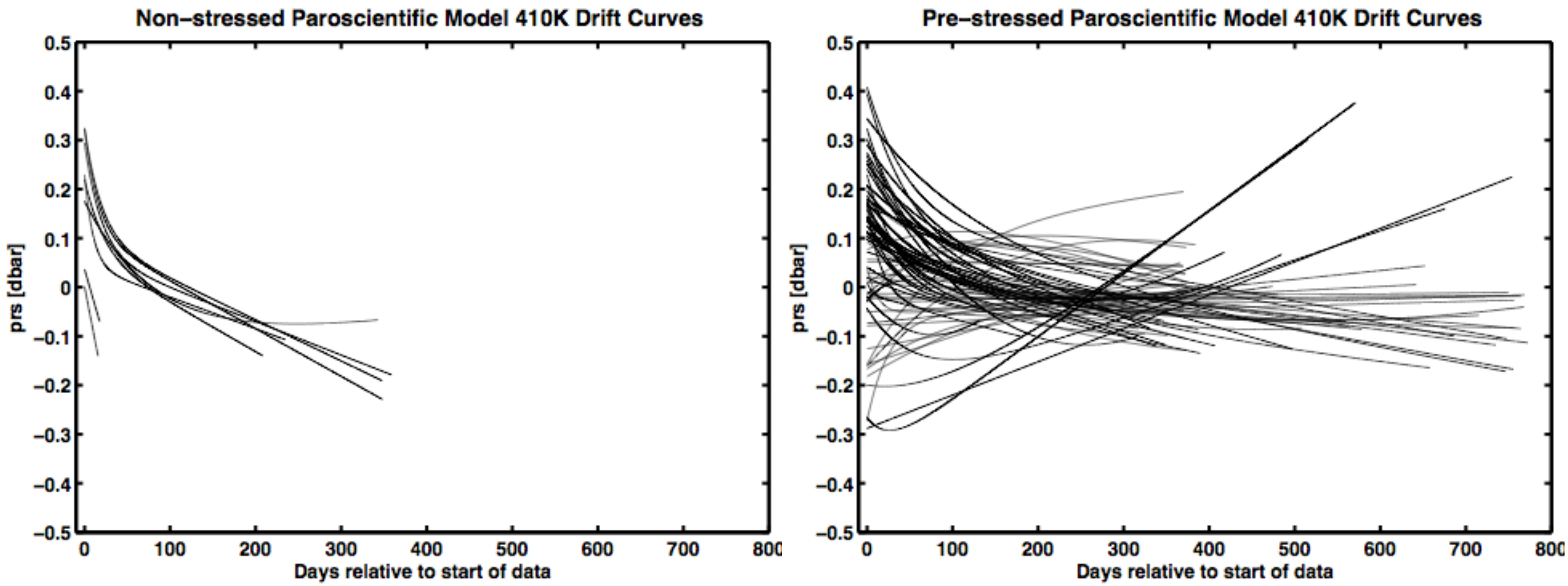
Digiquartz Pressure Drift (3)

- Since the largest part of the drift decays exponentially with time, can pre-stressing the sensors decrease subsequent drift?
  - We usually pre-stress for many weeks or months
  - 4000 psi for 6000 psi FS (~2800 dbar for ~4000 dbar FS)
  - 6000 psi for 10000 psi FS (~4100 dbar for ~6800 dbar FS)

- How much might it help to pre-stress at nearly the *same* pressure as the subsequent deployment?

- Does sensor improve with age?

How effective is pre-stressing? (410K's)

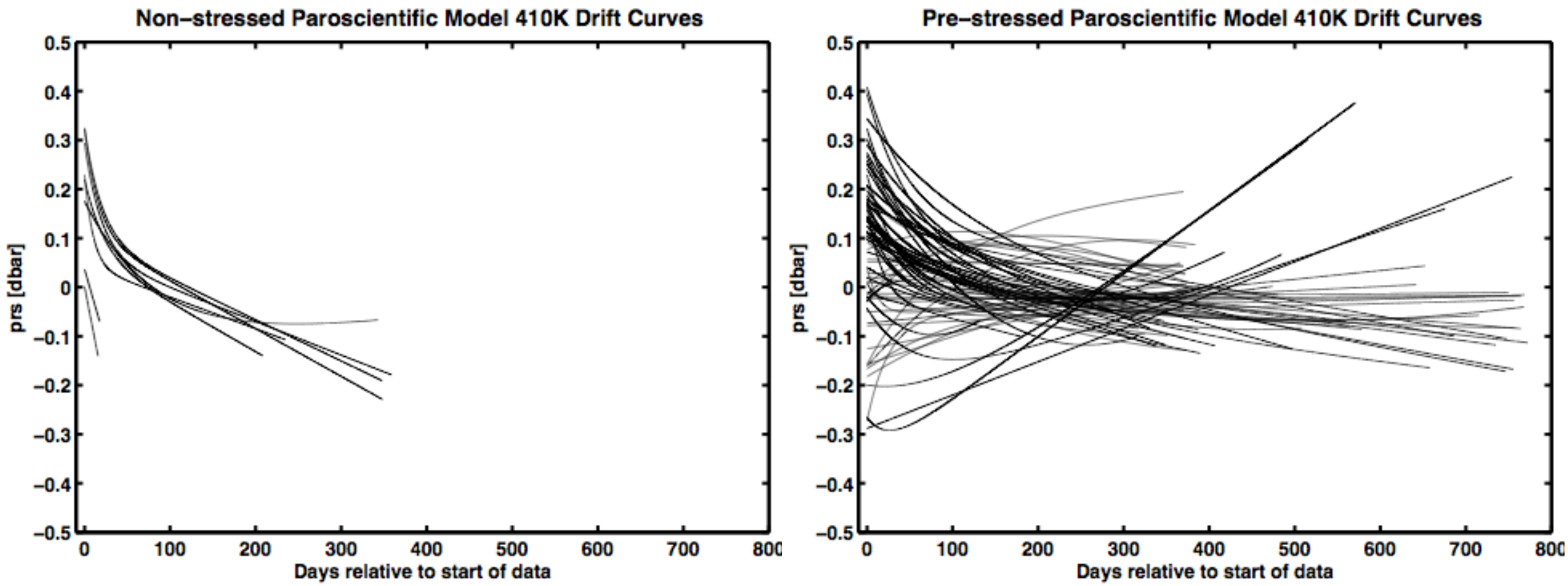


- Without pre-stressing, all six |drifts| ~ -.4 dbar in a year

- With pre-stressing many |drifts| <0.1 dbar (+/-) in a year, but many others drifted up or down ~0.4 dbar in 1-2 yrs

- pre-stressing seems highly advisable, but does not guarantee small drift

How effective is pre-stressing? (410K's)



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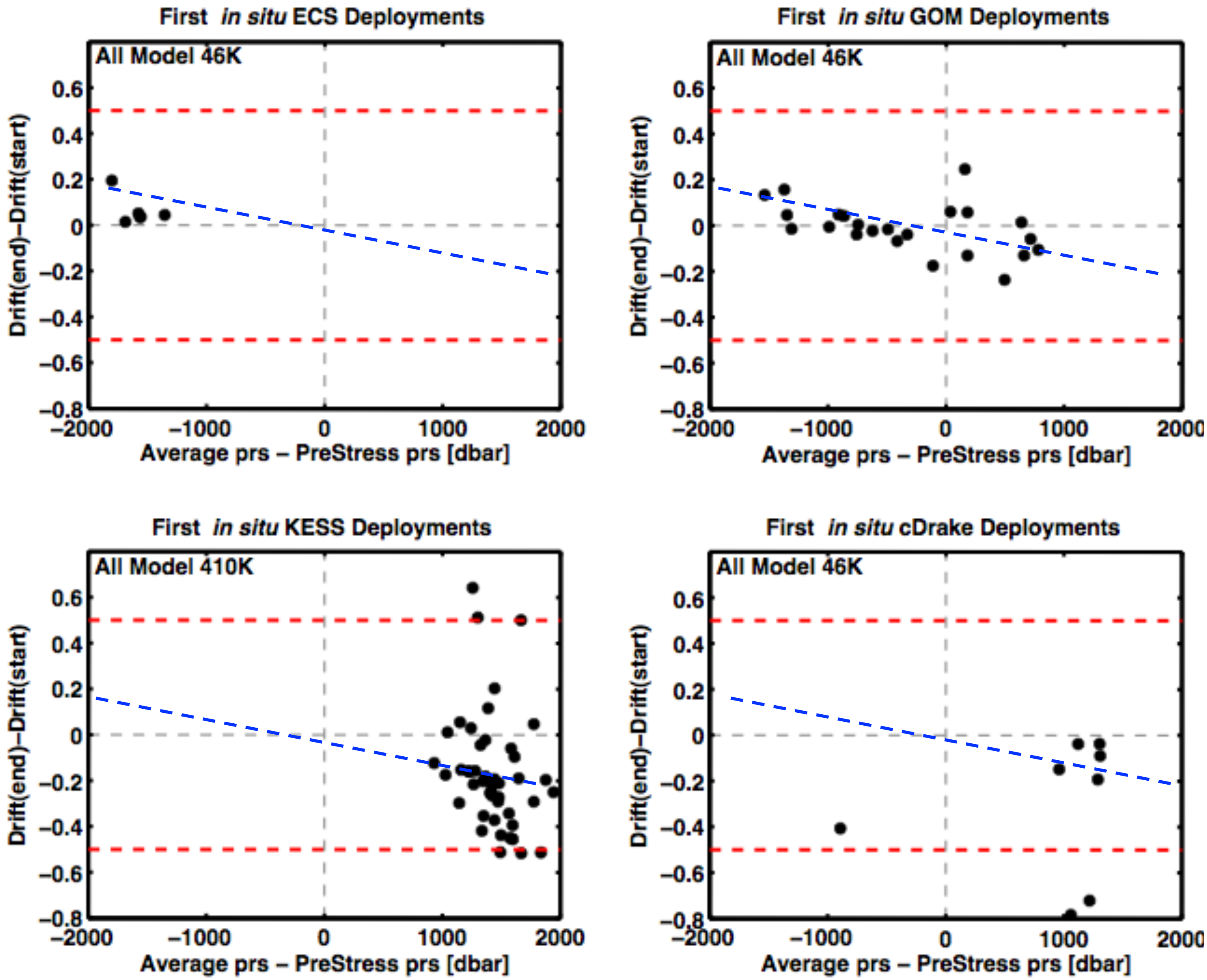
Next represent drift as (end-start)…

Does it help to pre-stress at ~ deployment P?

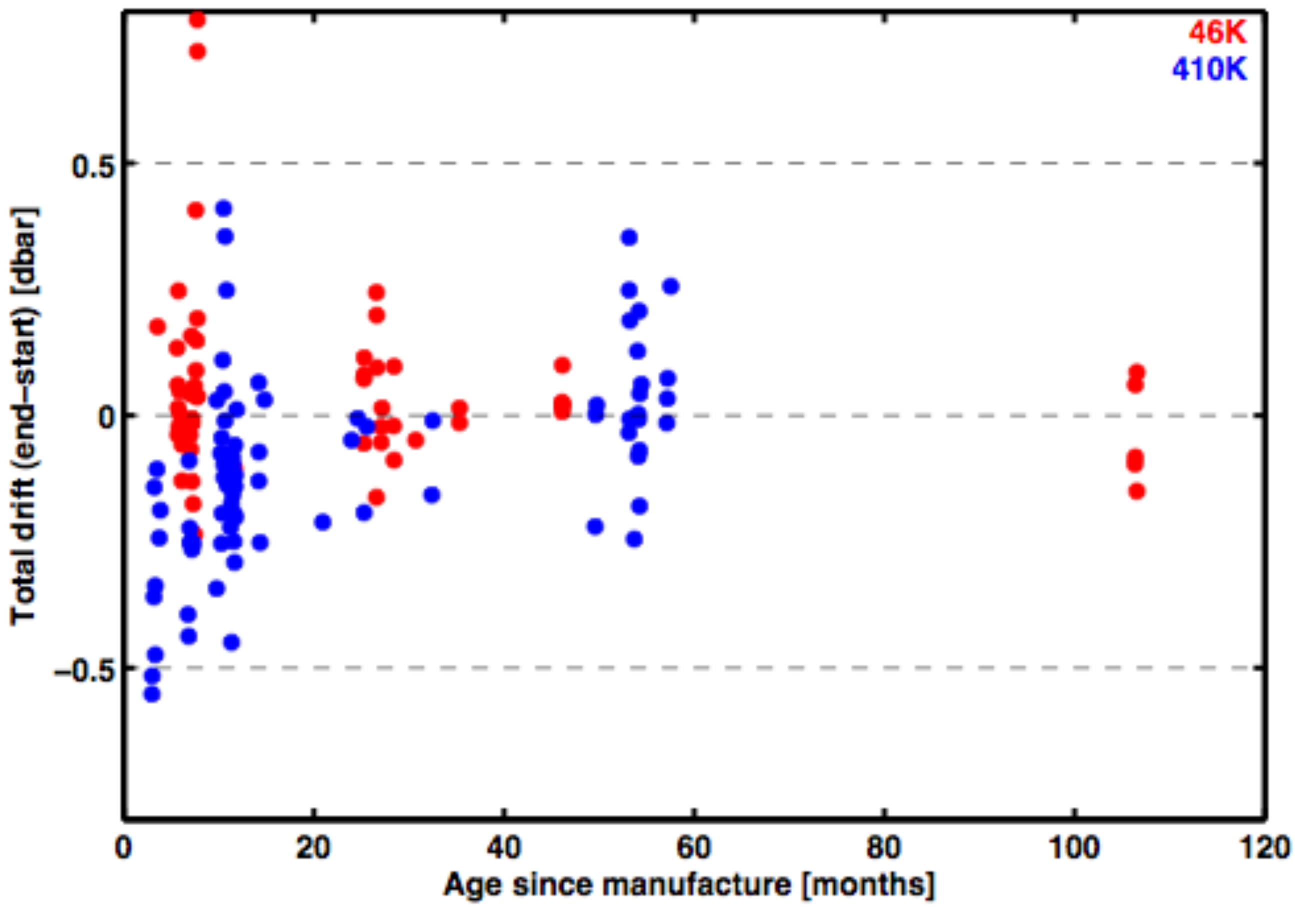


Answer *maybe*… excepting outliers

Does drift depend on prior deployment depth? difference (P_{new} - P_{prior})

- Answer is similarly murky…
- Slightly less drift with `same’ new and old deployment depths.

Does age of sensor reduce drift rate?



- (1-year) total drift *vs.* age

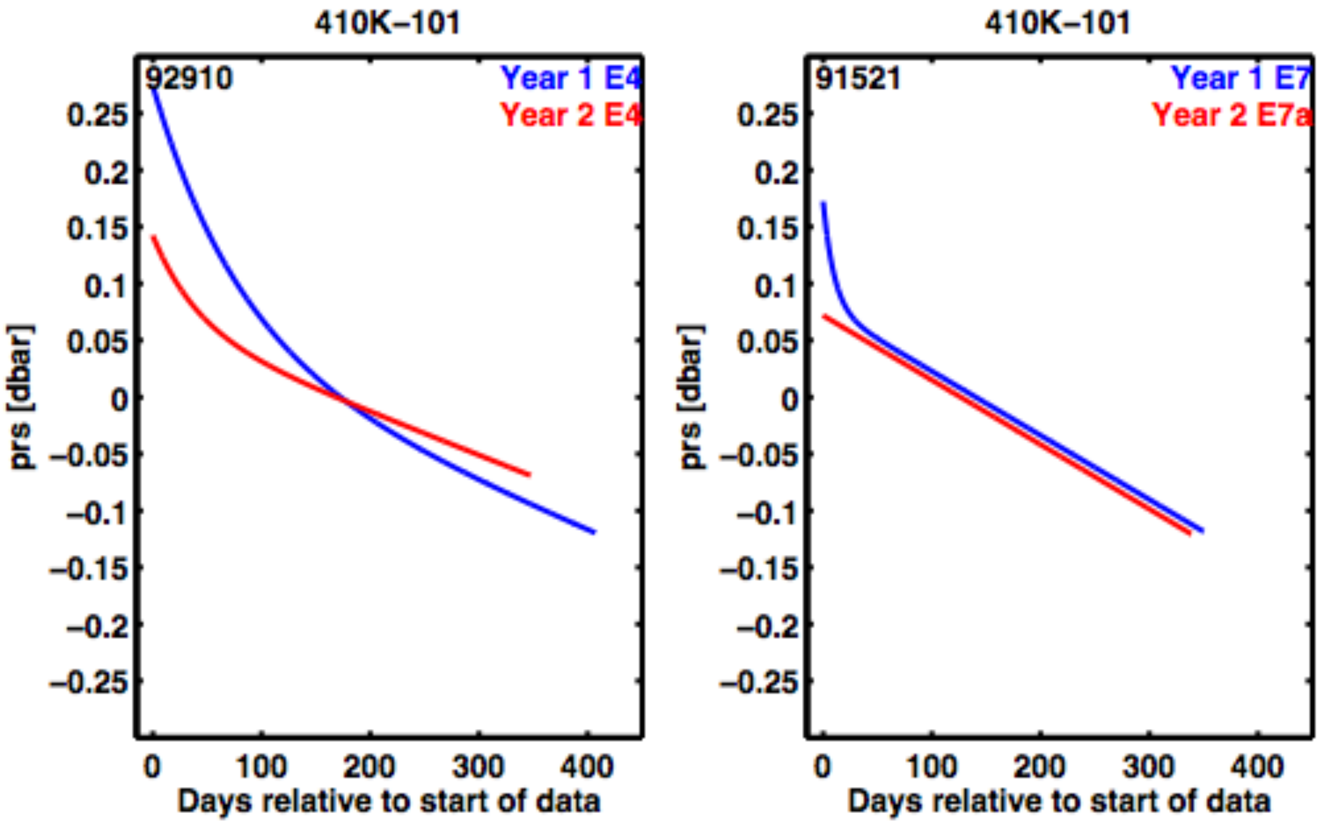
Digiquartz Pressure Drift (4)

- Does a given sensor drift ‘predictably’ from one deployment to the next?

Digiquartz Pressure Drift (4)

- Does a given sensor drift ‘predictably’ from one deployment to the next?

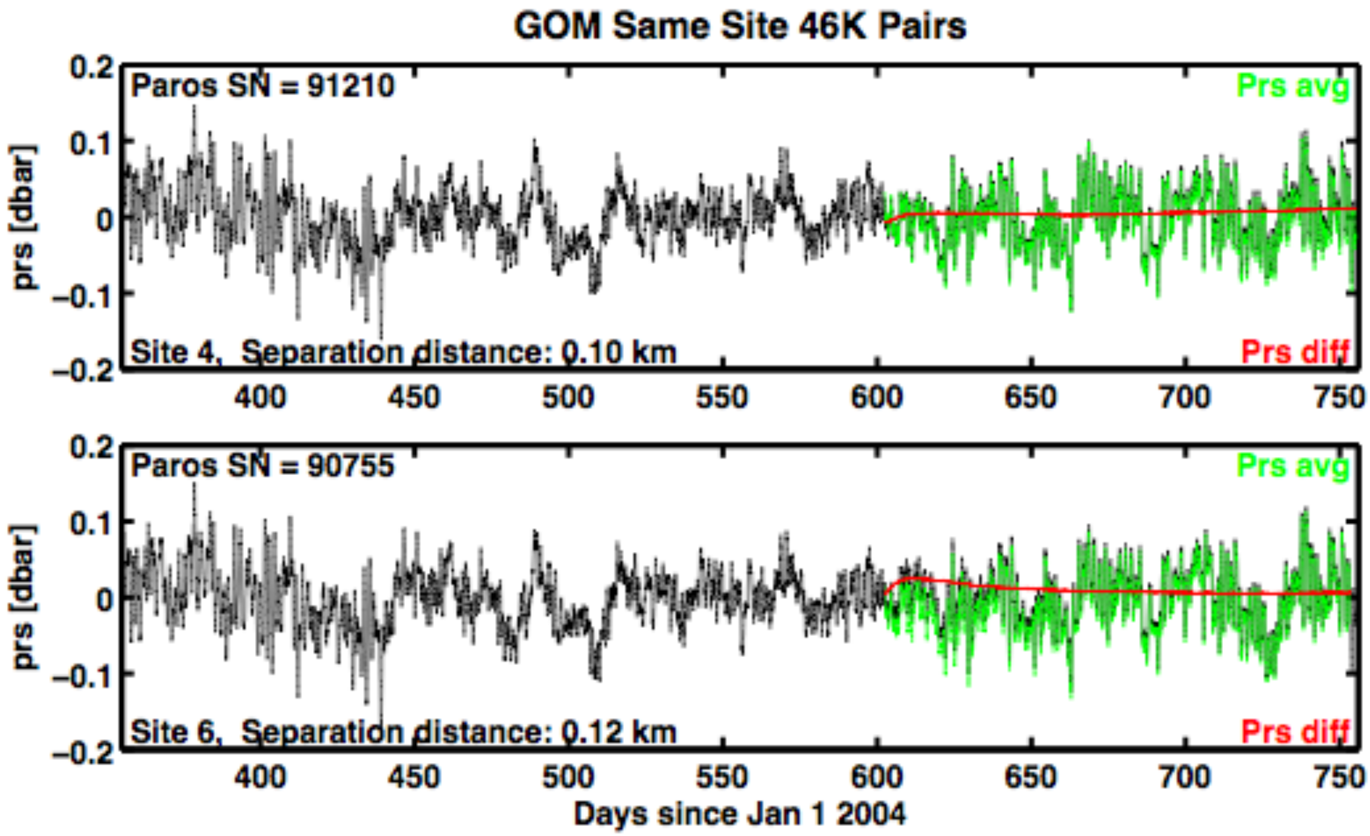
- Answer… the drift is not necessarily replicated in magnitude or direction! But we had many variables, and have not yet sorted out all effects.
- A few sensors DID replicate drift.



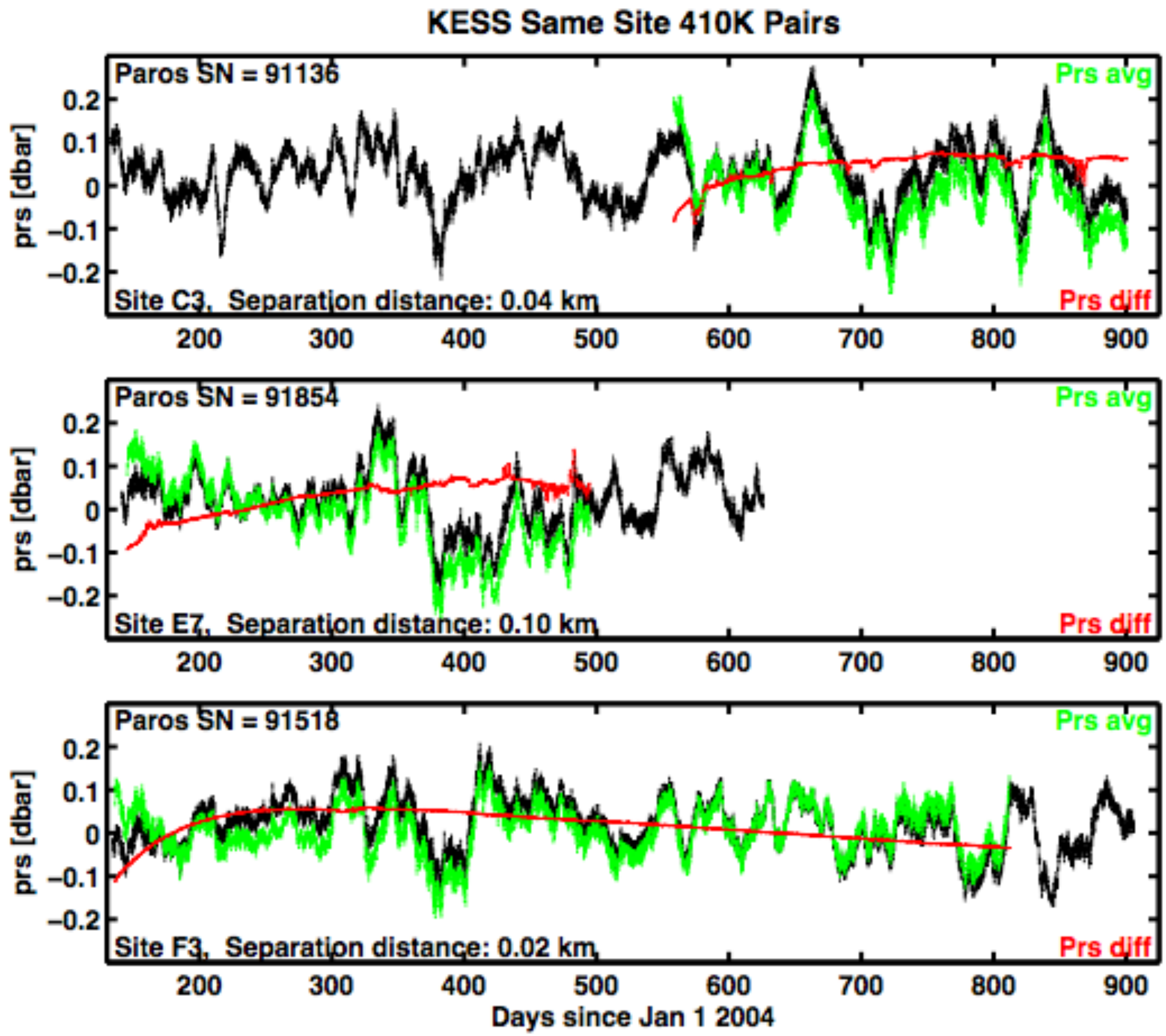
410K−101
92910
Year 1 E4
Year 2 E4
prs [dbar]
0.25
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
−0.25
0
100
200
300
400
Days relative to start of data
410K−101
91521
Year 1 E7
Year 2 E7a
prs [dbar]
Days relative to start of data

Digiquartz Pressure Drift (5)

- If you average two “same-site” pressure records, how well can this approximate a drift-free record?
  - Test by comparing near-neighbor averages of raw records against the accurately dedrifted curves
    - Near-neighbors could be 0.1 to 0.4km apart



- These 46K sites average very well because they had small drifts that fortuitously opposed each other.



- These 410K site-pairs did not average to small drift.

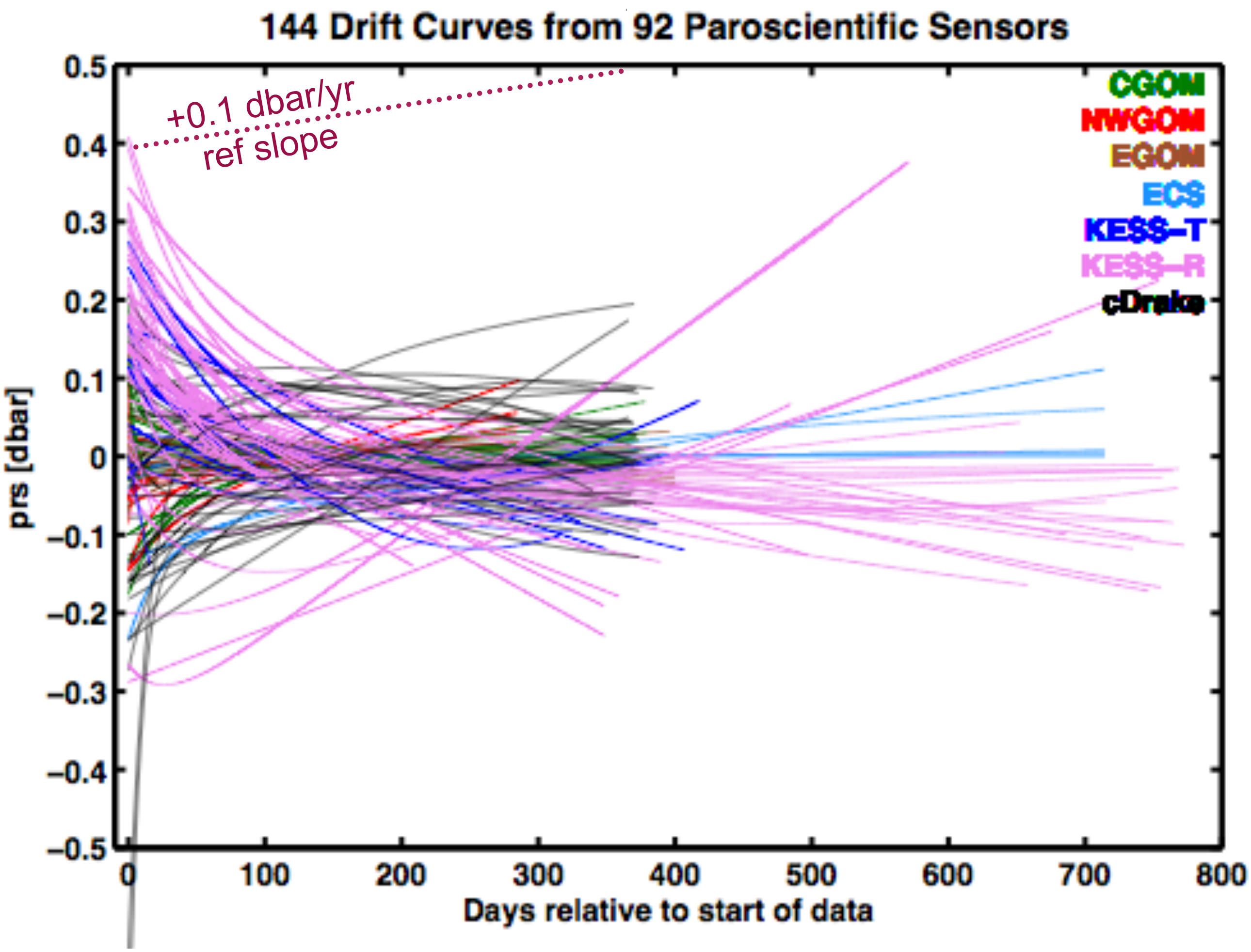
Drift Characteristics of Paroscientific pressure sensors

- Summary …
  - (exponential+linear) fitted curve is well suited to represent the drift, to which 3 or more processes contribute
  - Geostrophic leveling & drift detection is reliable to ~0.01 dbar
    - New drift curves differ from previous method of fitting data, although both use (exp + lin) fit
  - Averaging records from two or more ‘same-site’ sensors produces an average drift, but not zero drift
  - Pre-stressing reduces |drift| (usually) < 0.10 dbar / yr
    - Small net drift helps reduce uncertainty in fitted drift curve
  - Aged sensors improve like good wine
  - Drift of a given sensor is not predictable from one deployment to the next
    - Choose a low range sensor (when possible) to achieve smaller drift

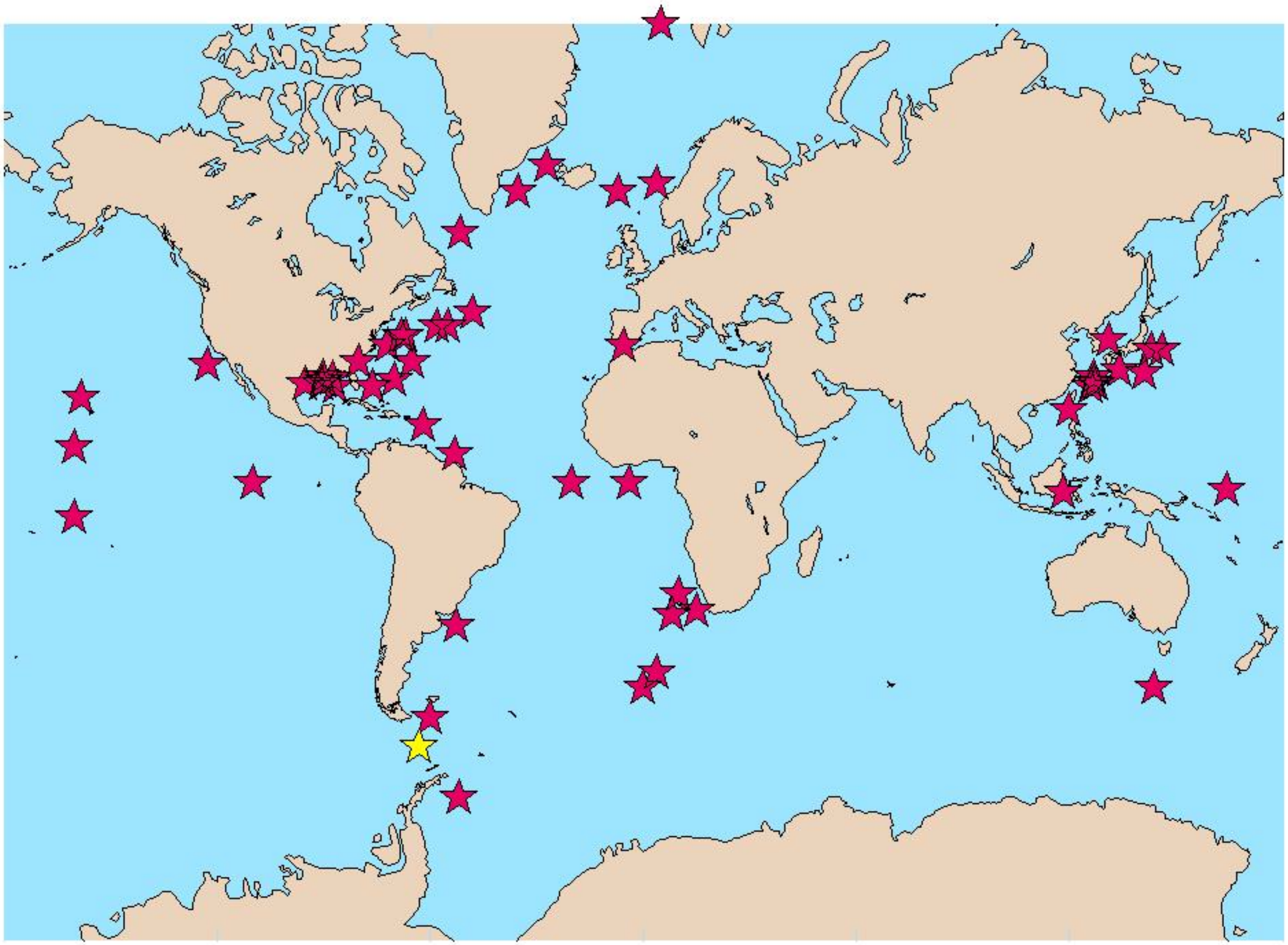
FINI

- Might add histogram of decay time scale

144 drift curves from 92 sensors



IES deployment sites



A CPIES array yields daily maps of upper and deep circulation.

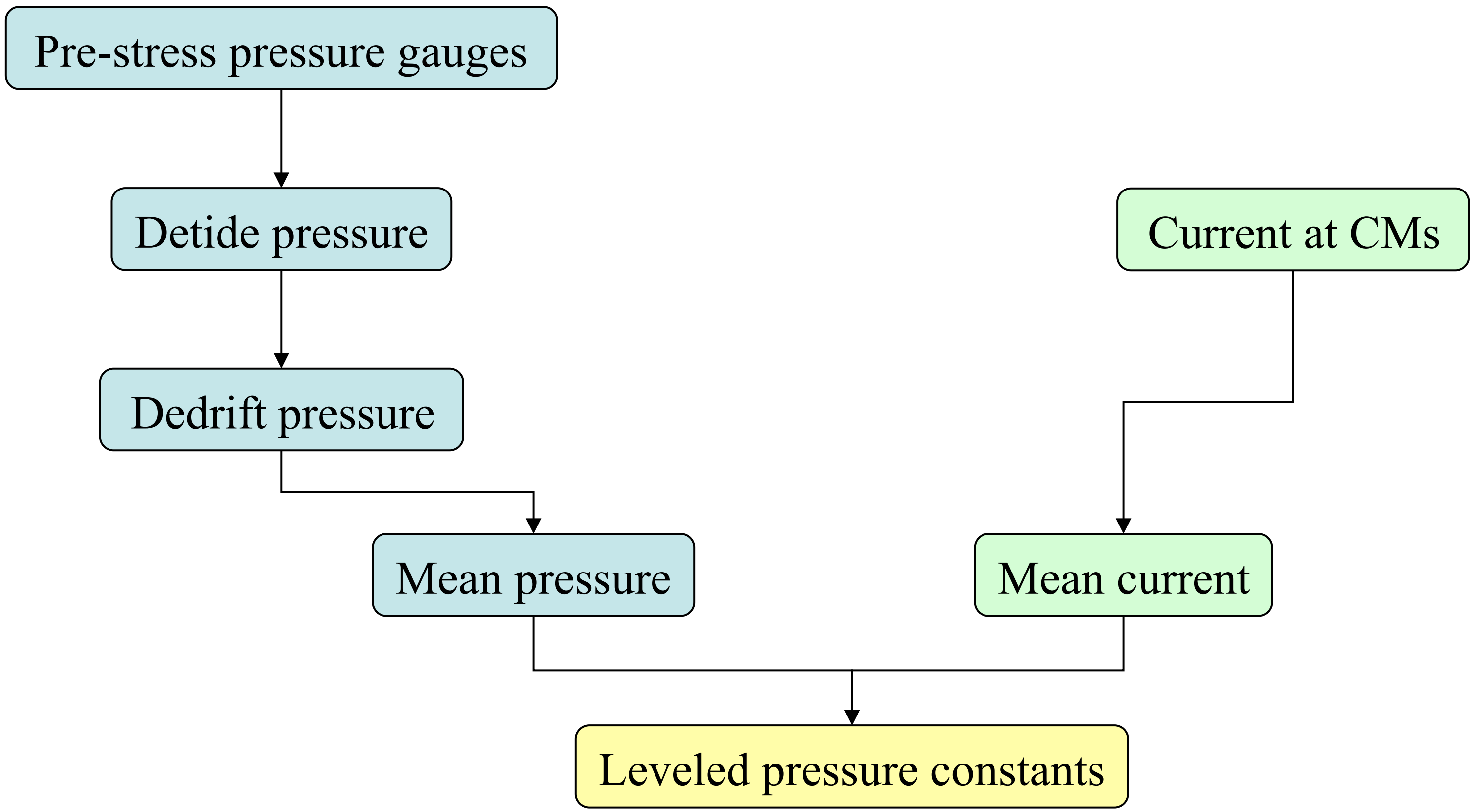
Look-up tables interpret acoustic travel times as geopotential height (0 referenced to 5000 dbar).

2-D arrays of CPIES estimate horizontal gradients of geopotential to calculate geostrophic velocities.

Velocity profiles are referenced by measured near-bottom currents.

Bottom pressures are leveled using near-bottom currents to map the geostrophic streamfunction.

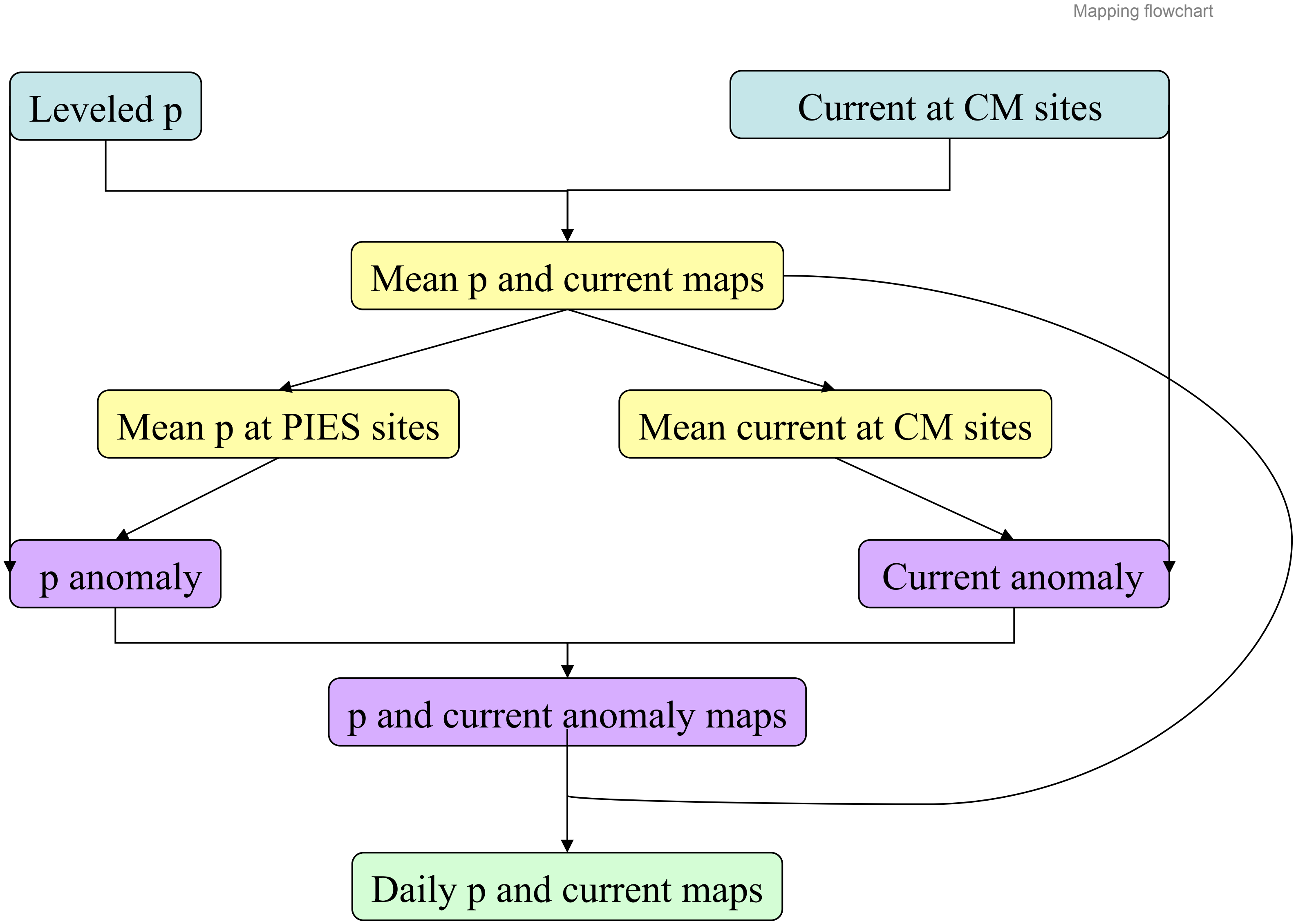
LEVELING PRESSURE GAUGE WITH DEEP CURRENT METERS



Pre-stress gauges

Experience has shown that pressure drift is greatly reduced by preconditioning.

Sensors are subjected to pressures of 3000 dbar for 1-2 months in the lab.


Mapping flowchart
Leveled p
Current at CM sites
Mean p and current maps
Mean p at PIES sites
Mean current at CM sites
p anomaly
Current anomaly
p and current anomaly maps
Daily p and current maps

Leveling (and drift)

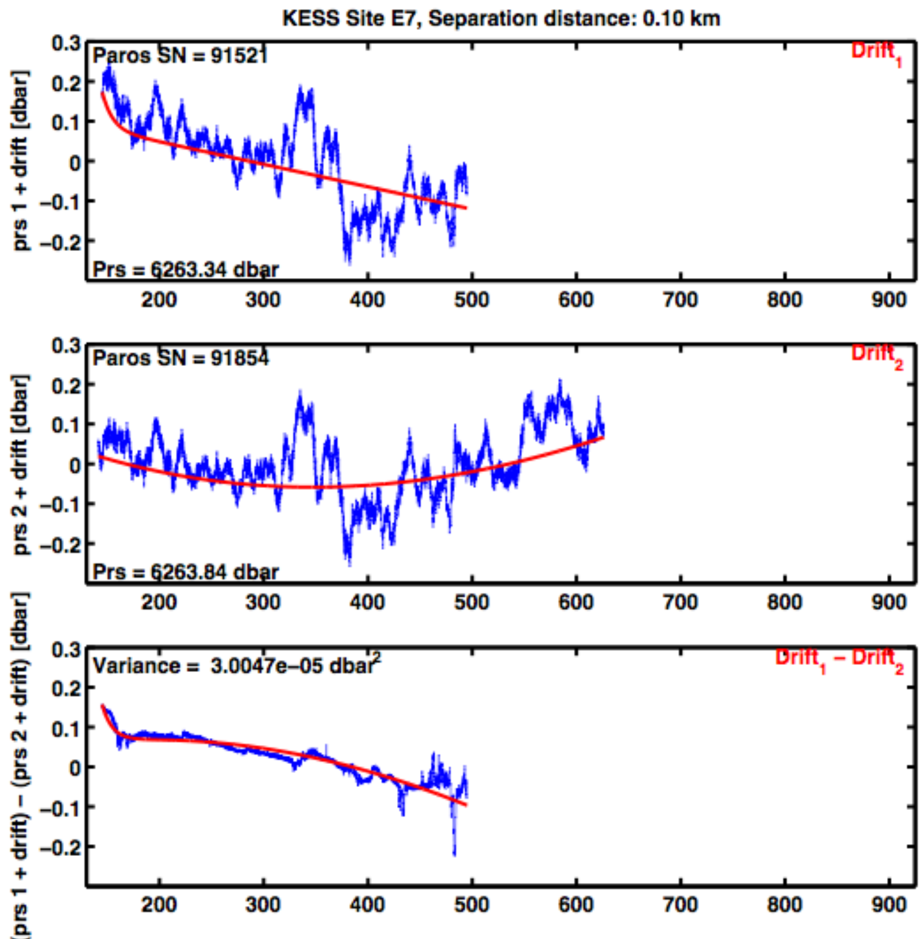
- The streamfunction from CMs and the pressure from PIES measure the same geostrophic pressure field.
  - The two fields should only differ by a site-dependent leveling constant.

- Other differences arise from error in OI mapped streamfunction and drift in the pressure sensor.

- The sensor drift is detected by the difference from the temporal record of geostrophic pressures

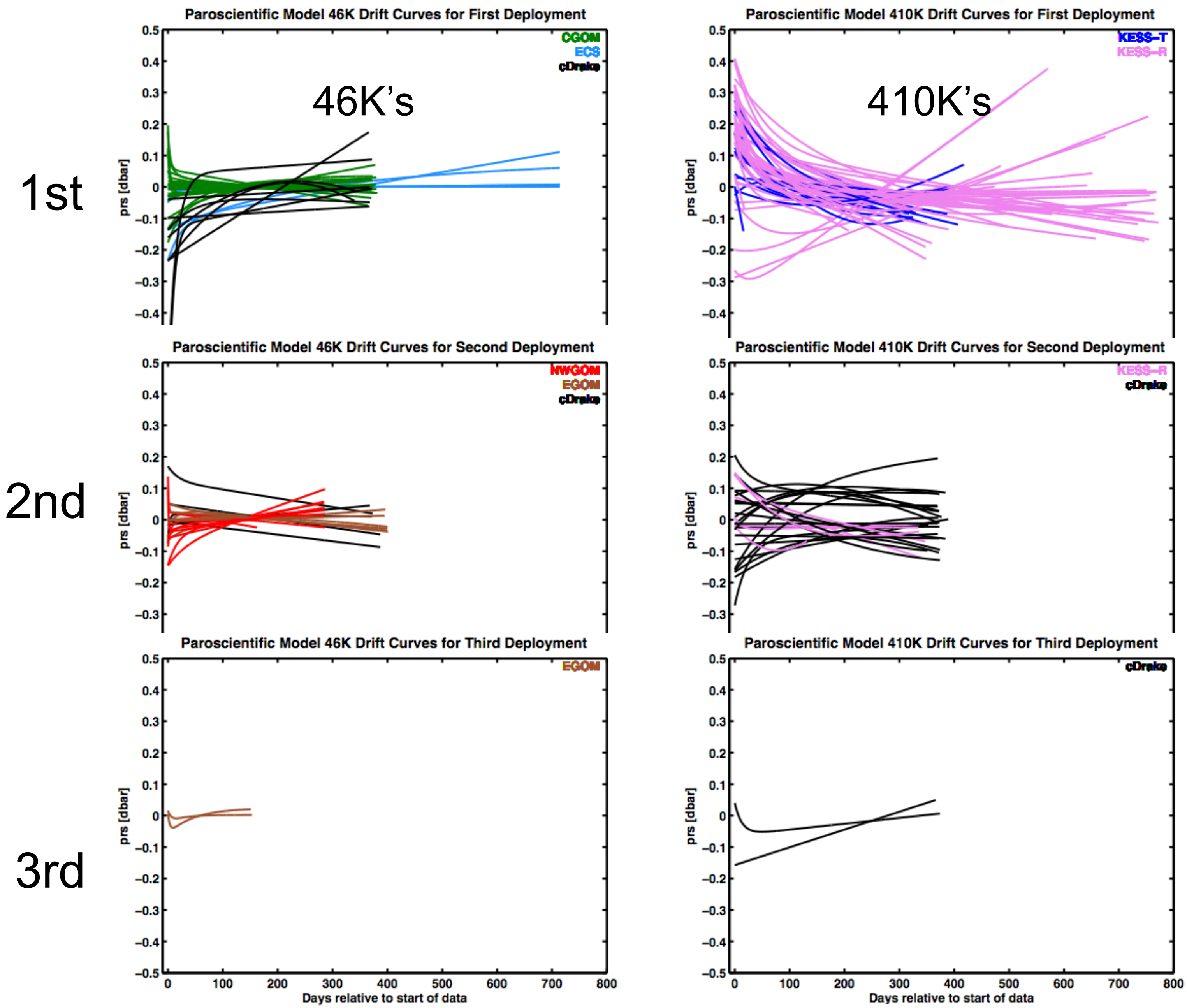
- The drift is represented by a decaying exponential plus linear curve, least-squares fitted to this difference

Consistency of (exp+lin) at ‘same-site’ pair in Kuroshio(2)

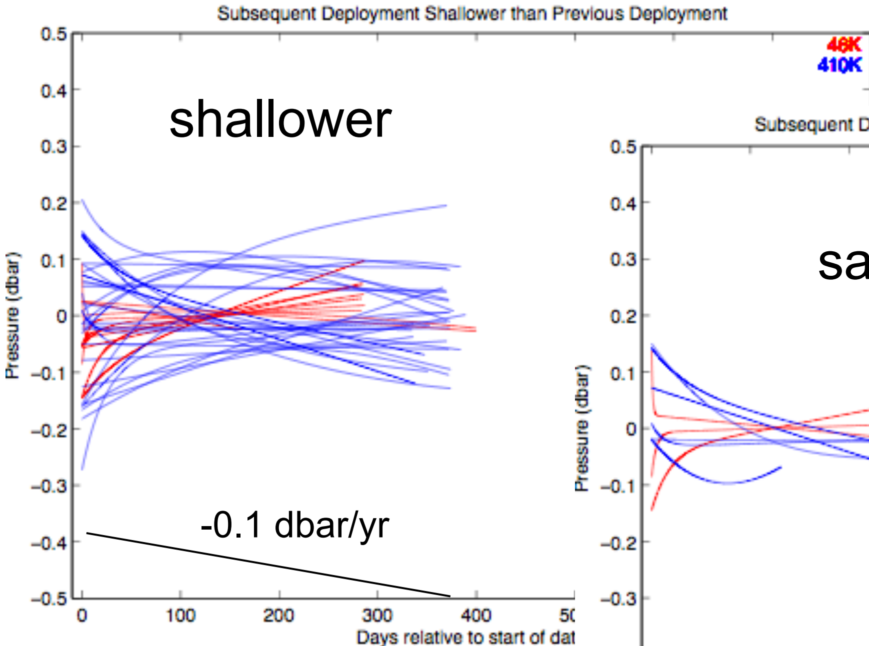


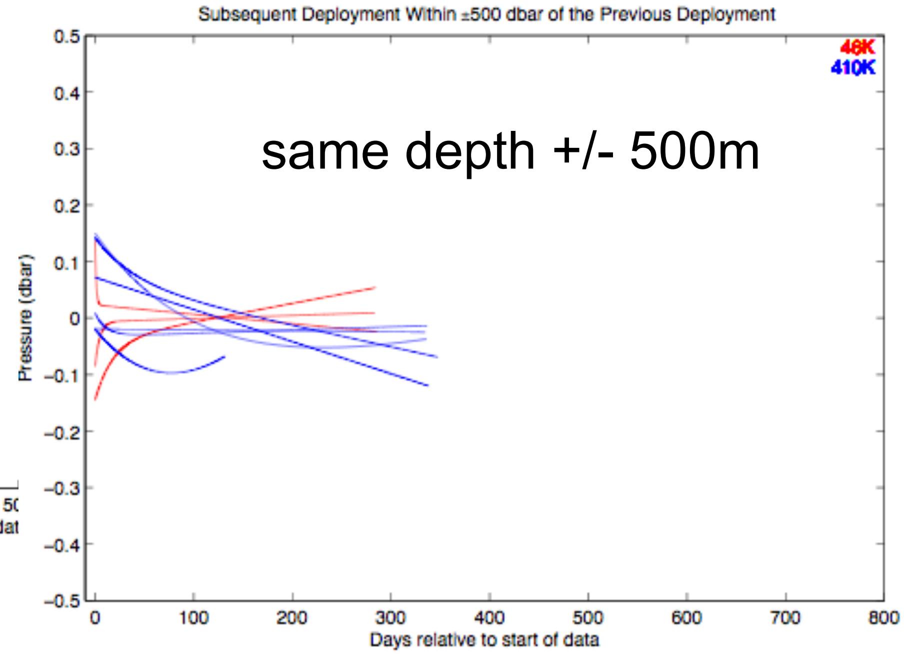
- (rows 1, 2) Another site with two PIES, separately dedrifted
- (row 3) The difference between raw records (blue) agrees with difference between drift curves (red); rms <0.005 dbar (model 410K)

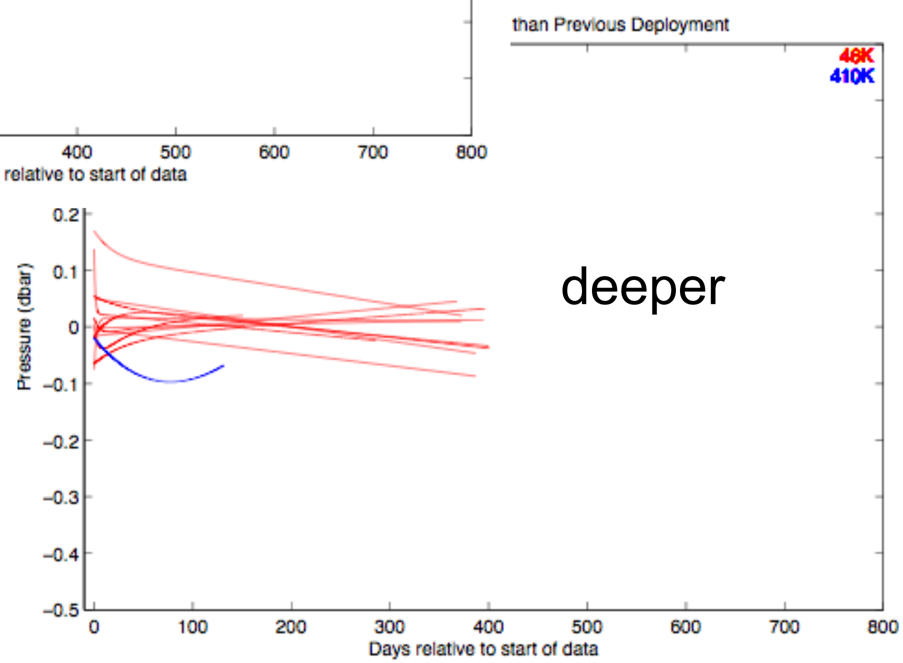
Is drift smaller in 2nd/3rd deployment?



Subsequent depth shallower/ same/ deeper

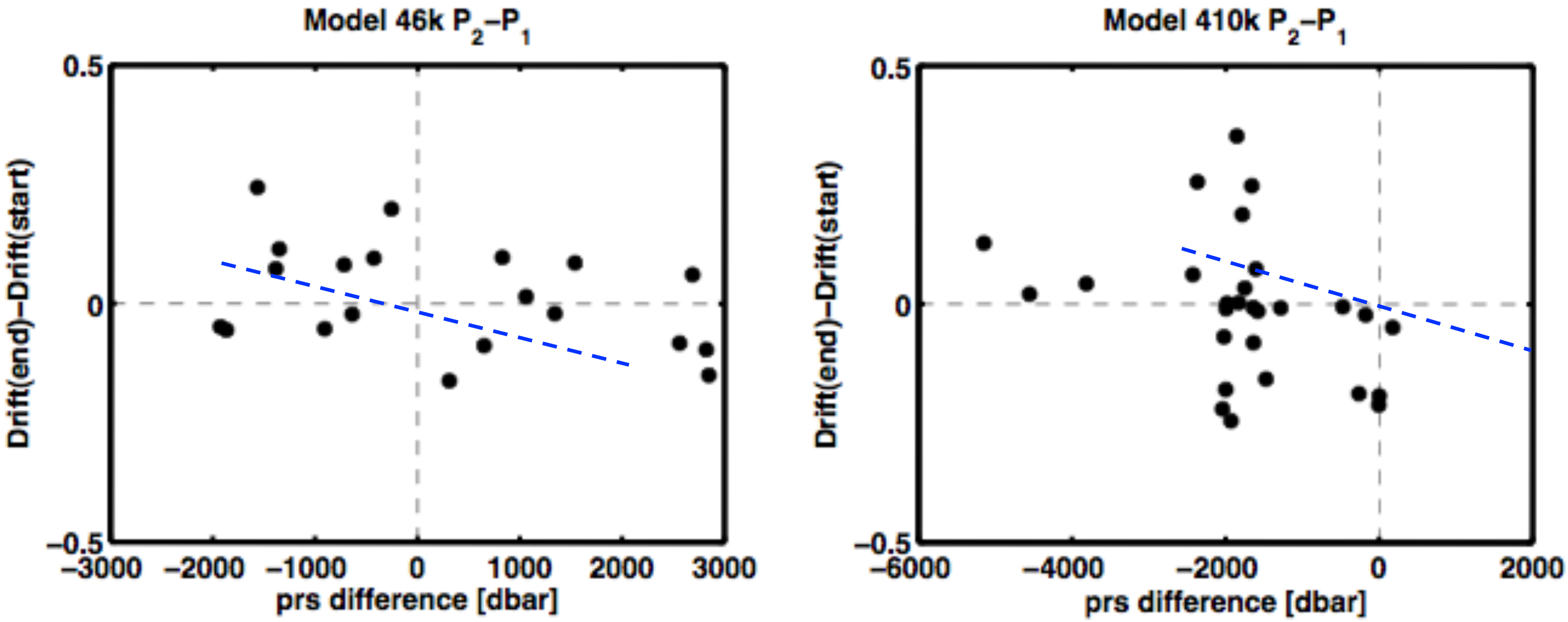




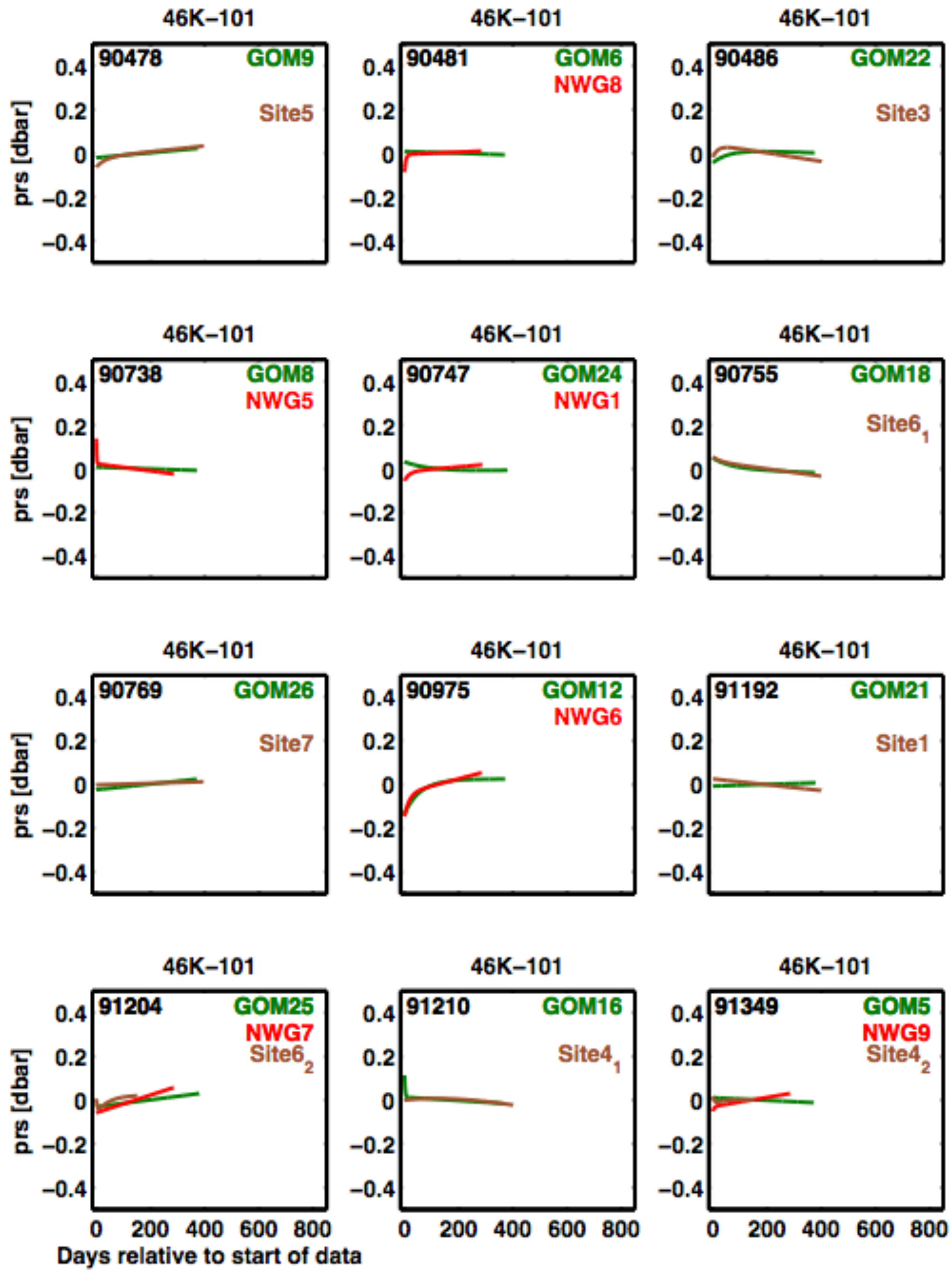


- 410K's drifts are mixed
- Shallower 46K's drift to higher P
  or "flat"
- Deeper 46K's drift to lower P
  or nearly "flat"
- Same-depth 46K's - slightly better?

Does drift depend on prior deployment depth? difference (P_{new} - P_{prior})



- Slightly less drift with `same' new and old deployment depths.



Repeatable drifts? 46K

Twelve representative repeats of 46K's having same Bliley and smallest depth differences between deployments.

The repeatability of 46K's looks promising.

However next look at 410K's - not as reproducible

Repeatable drifts? 410K

- These are 2nd deployments of 410K's.
- Not as reproducible as for the previous set.

- Other factors changed
  - Deployment depth
  - Time interval between