# Altimeter Detection of Coastal-Trapped Wave Responses to Winds on the US West Coast

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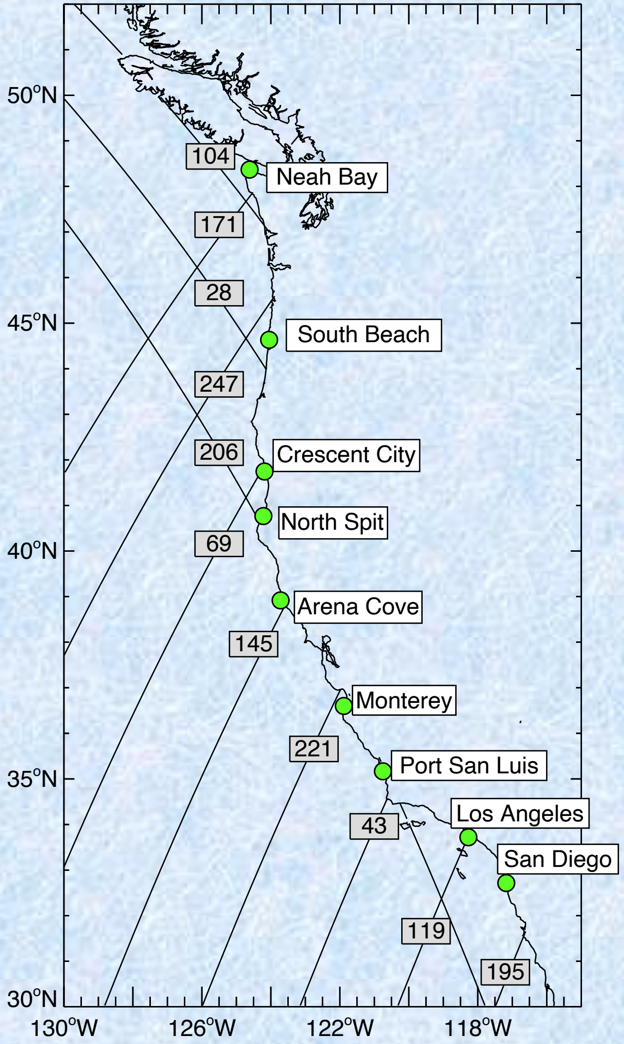



Along the US west coast (USWC), a primary source of sea level anomalies and along-coast geostrophic velocity variations is poleward-propagating coastal-trapped waves (CTWs). Although altimeter repeat times are too infrequent to resolve CTWs, we are compositing multiple CTW events, based on an index of wind reversals from equatorward (upwelling-favorable) to relaxed or poleward. For each wind-reversal, we collect the alongtrack altimeter data on each ground track in daily bins stretching from -5 to +5 days around the event for all ground tracks intersecting the USWC between 34-48 °N. The altimeter overpass at each track occurs at different time lags relative to the start time of each wind relaxation and CTW event. By compositing along-track data from wind events during a period (June-August, March-August, all year), we build up a composite picture of sea level along the tracks and compare to the local tide gauges.

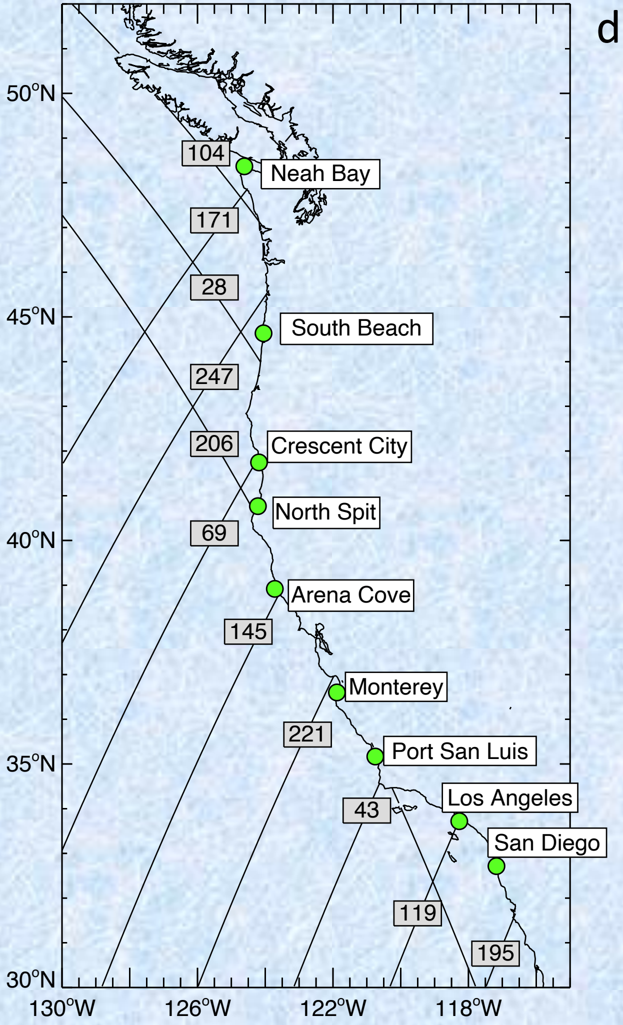
**Objectives:**

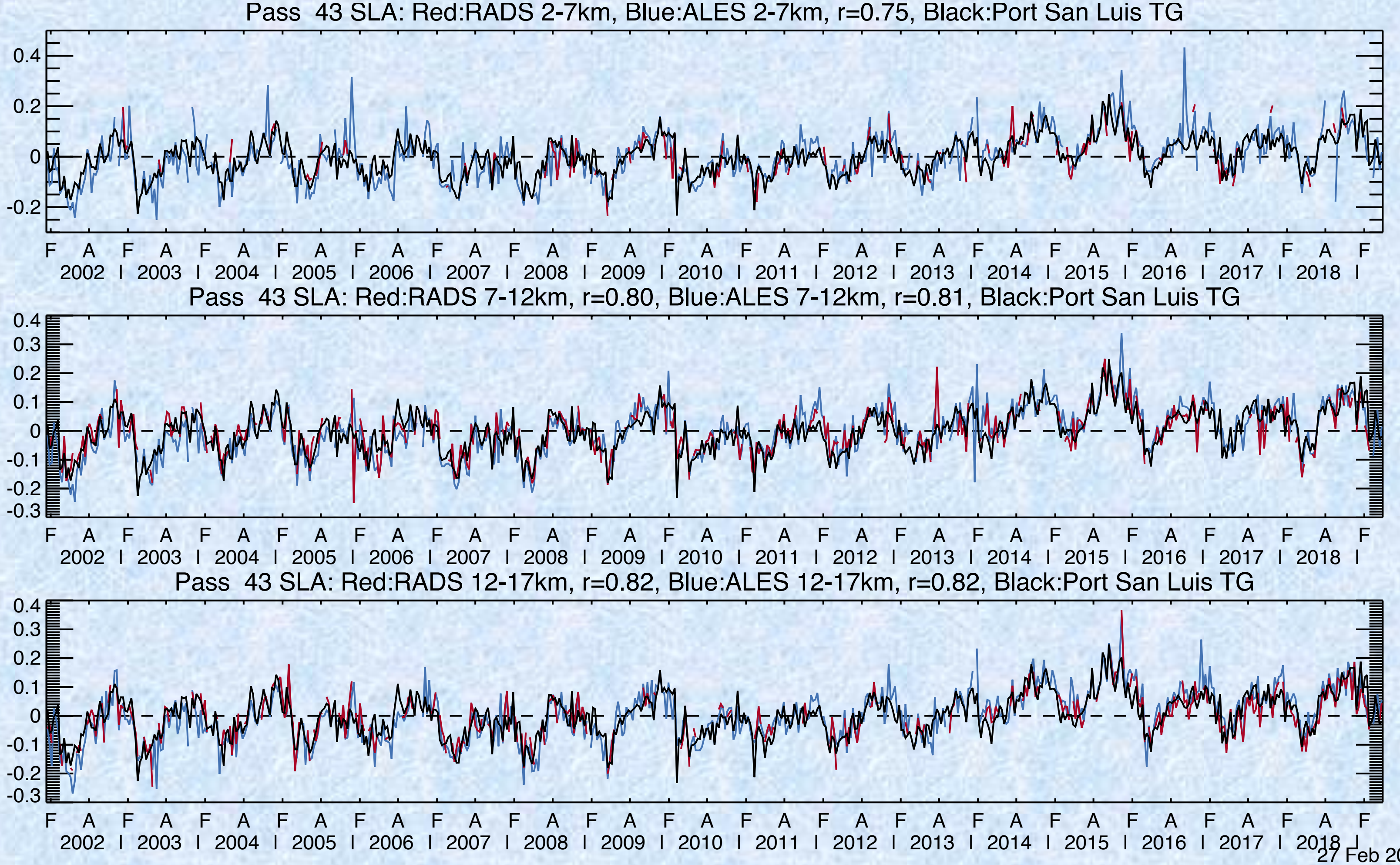
1) Test whether the ALES or RADS alongtrack data set is better at retrieving the equivalent of the tide gauge data during and after the wind relaxations;
2) Test whether either alongtrack data set can resolve the alongtrack (cross-shore) profile of heights associated with the passage of the CTW.

# How well do the ALES and RADS alongtrack data in the nearshore bins reproduce the coastal tide gauge data? (Example at Port San Luis)

Initial Tests: Below is sea level data at the PSL Tide Gauge (35N) compared to track 043 alongtrack SLA, using data in three alongtrack bins: 2-7km, 7-12km, & 12-17km. The mean of the TG data is removed for the same times as for altimeter data in each case. There is more data for ALES near the coast.

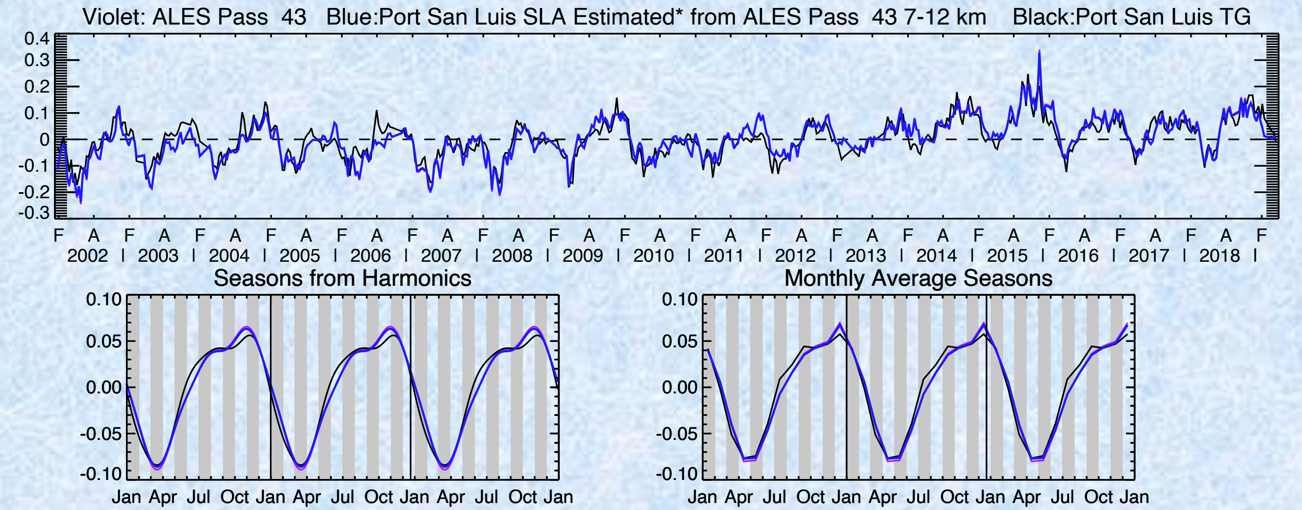
**Tide Gauges (green dots) and Altimeter Tracks (numbered)**

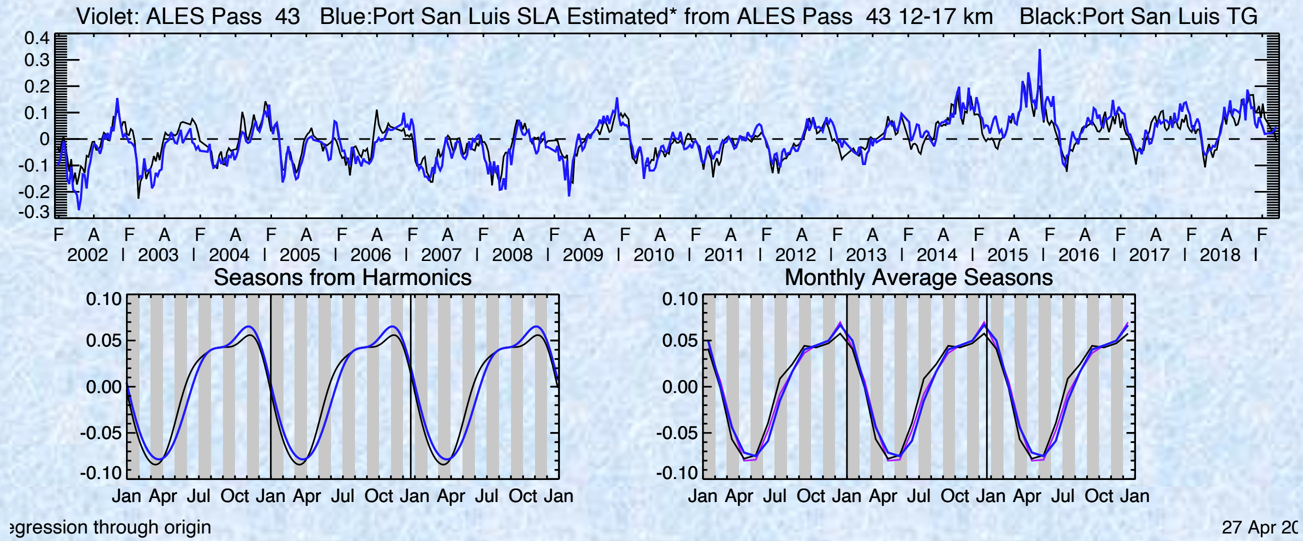


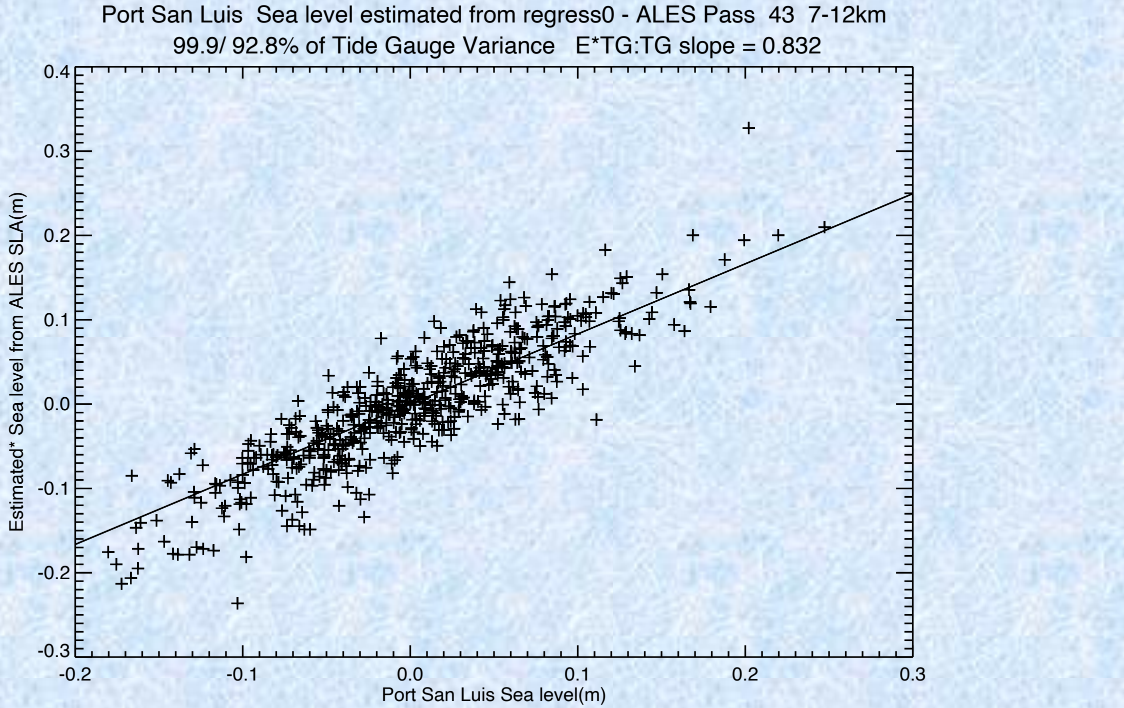



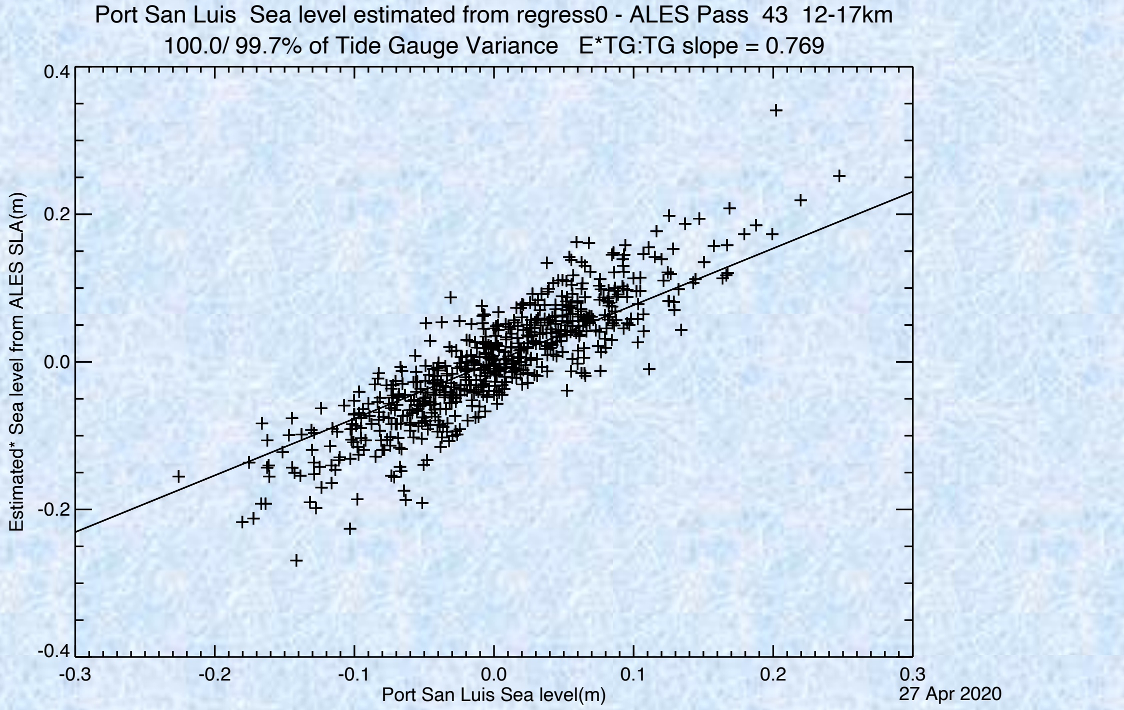

27 Feb 2020

Regressions test the ability of the ALES altimeter data from different nearshore bins to reproduce the tide gauge data. Example of individual estimates of PSL sea level from Track 43 alongtrack data in the 7-12 km bin and 12-17 km bin. ALES data does slightly better than RADS data. Both do relatively well.

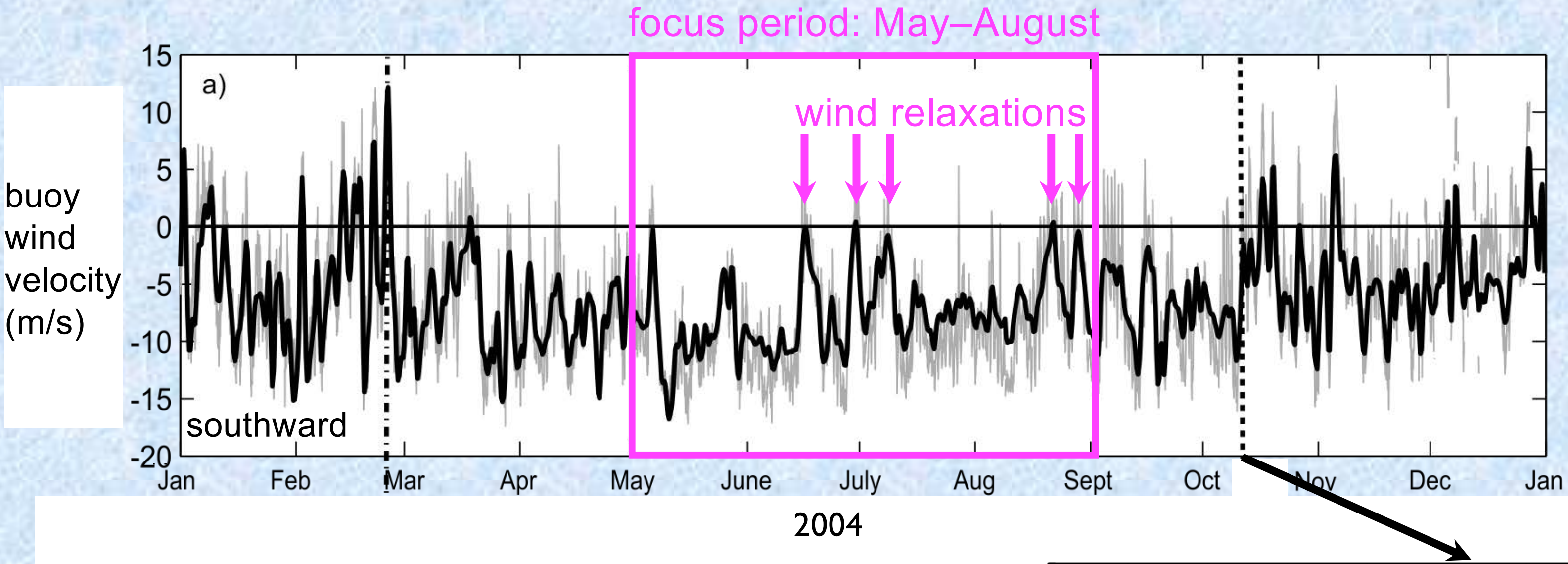


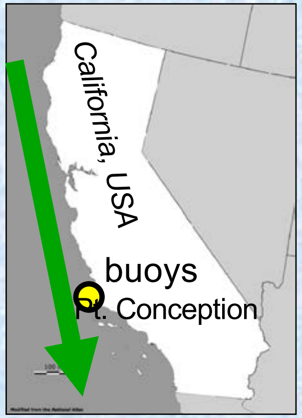



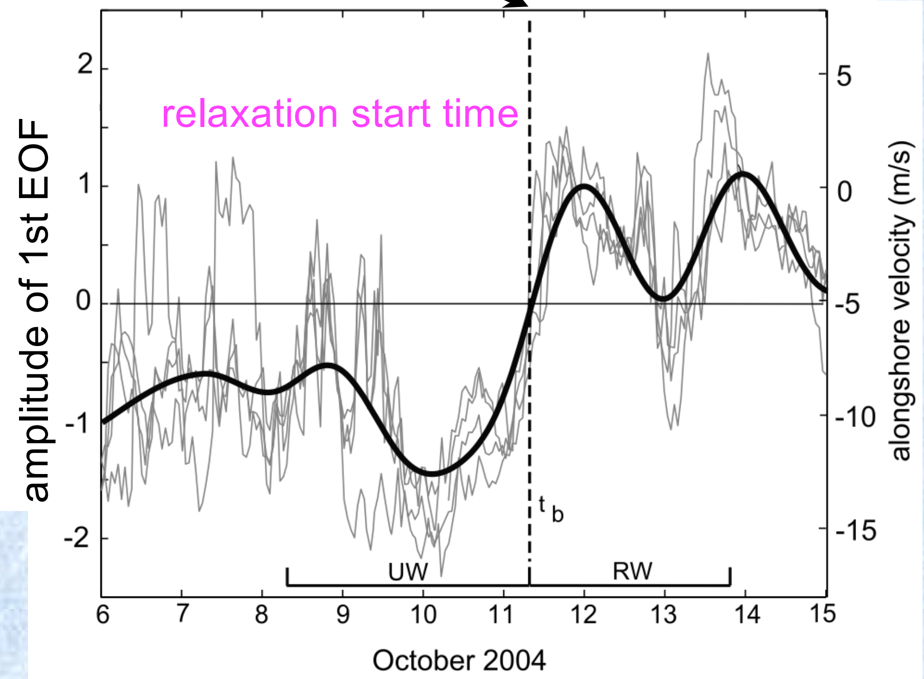



**Main Analyses:** We identify wind relaxation times at Pt. Conception using buoy data, then select satellite data before, during, and after each relaxation.



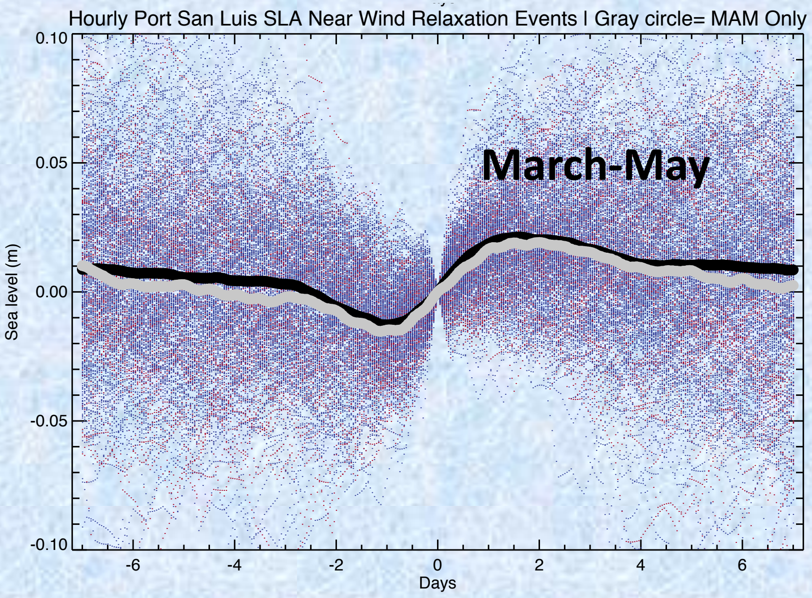



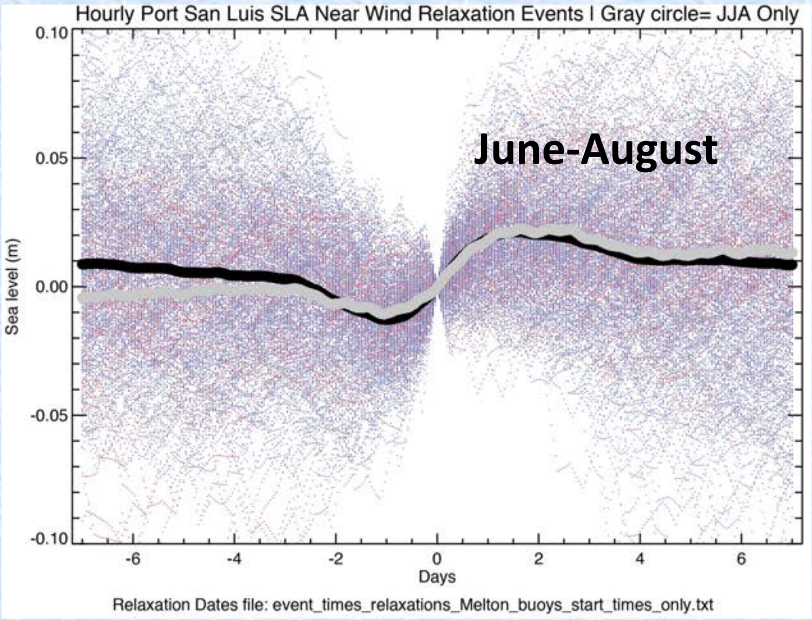

- We identify wind relaxation start times following Melton et al. (2009) as the times of zero crossings of the 1st EOF of wind velocity at 4 NOAA buoys near Pt. Conception, CA

- We can identify start times for relaxations in 1982-present but here use just the 2002-2018 ALES period. We also use data from different monthly periods.

figures based on Melton et al. 2009

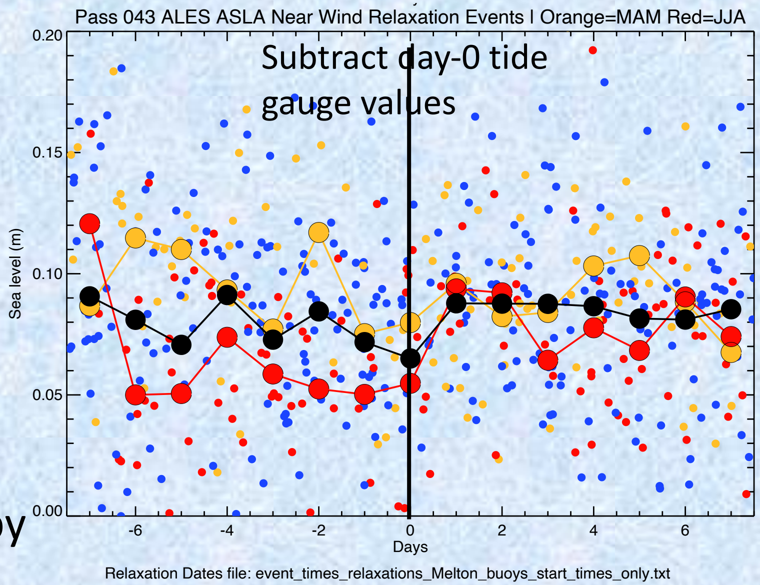
# Initial Tests: Composite Tide Gauge & altimeter data around the Wind Relaxation Events

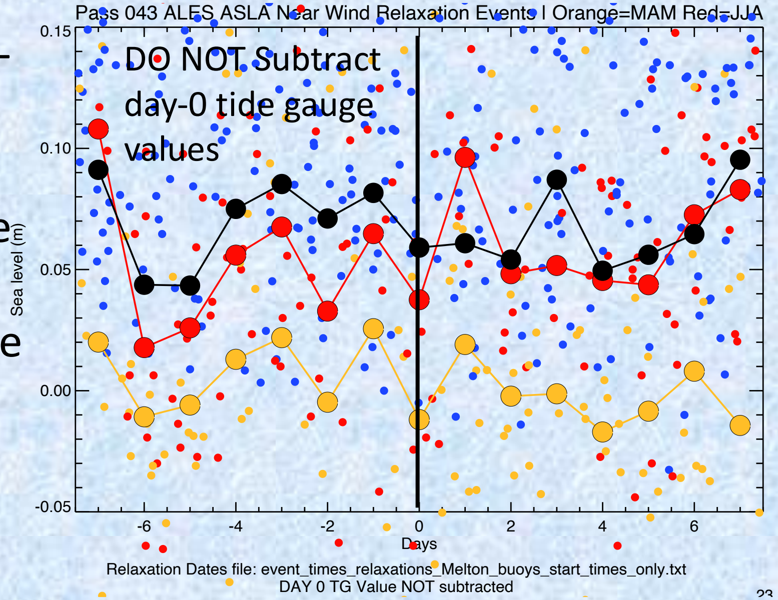


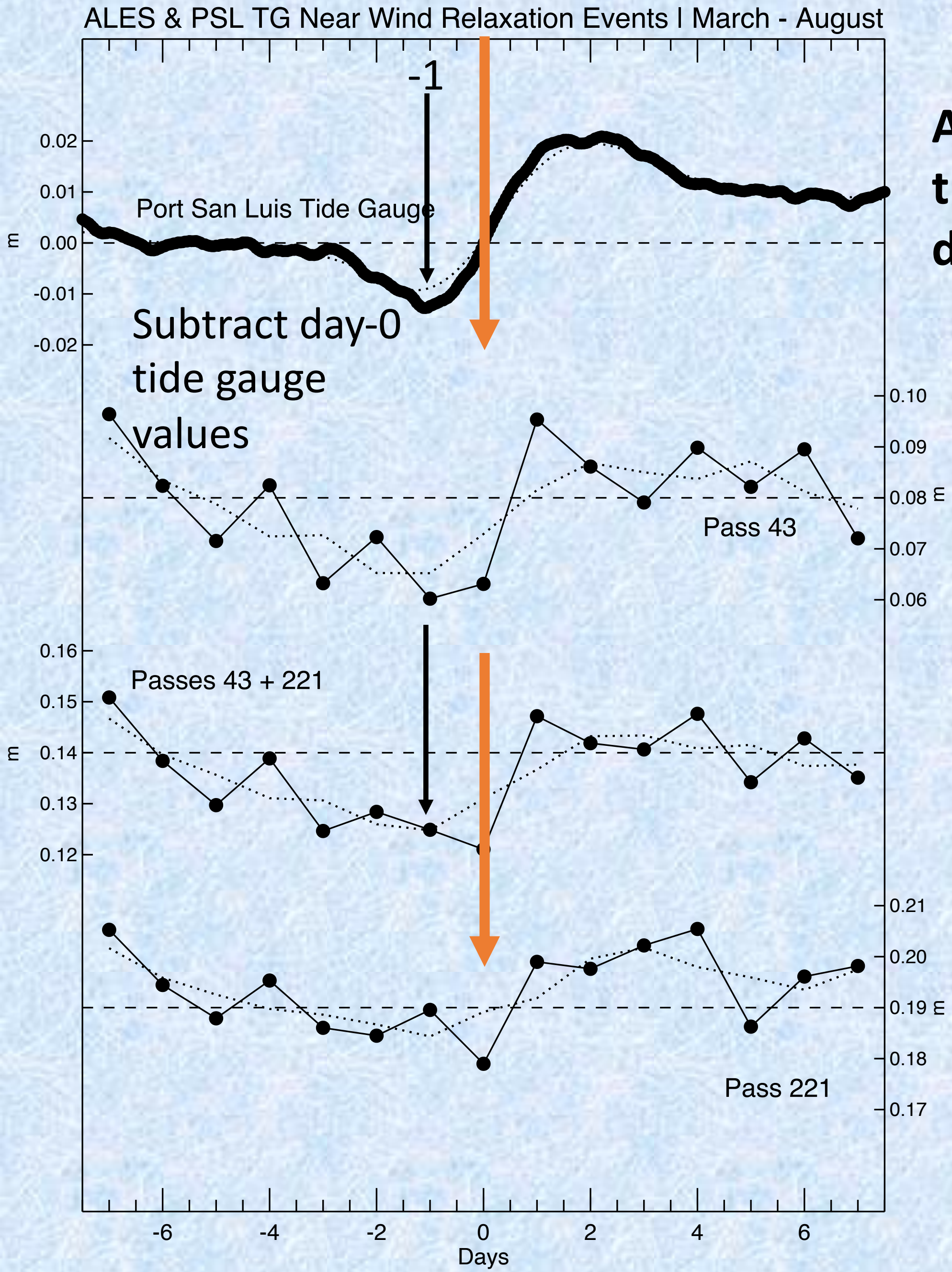




**(Left):** Hourly TG (PSL) SLA relative to day-0 following wind events in March-May (top) and June-August (bottom). For each event the TG value on day-0 is subtracted from the time series for that event. The large amount of scatter is evident in the tide gauge data, presenting the challenge for the small number of altimeter samples. The gray line is for the specified months. The black line is for all months.

**(Right)** Alongtrack SLA on Track 43 is binned by day relative to the wind event for all months (blue & black), March-May (orange) and June-August. (red). Small dots are indivudual events, large dots are daily averages.
For each event the altimeter does not provide a complete time series so we cannot subtract day-0 values. The top right figure subtracts the day-0 TG value for each event. The bottom right figure does not. The rise in sea level is roughly captured when the TG day-0 value is subtracted to eliminate some SLA variability.





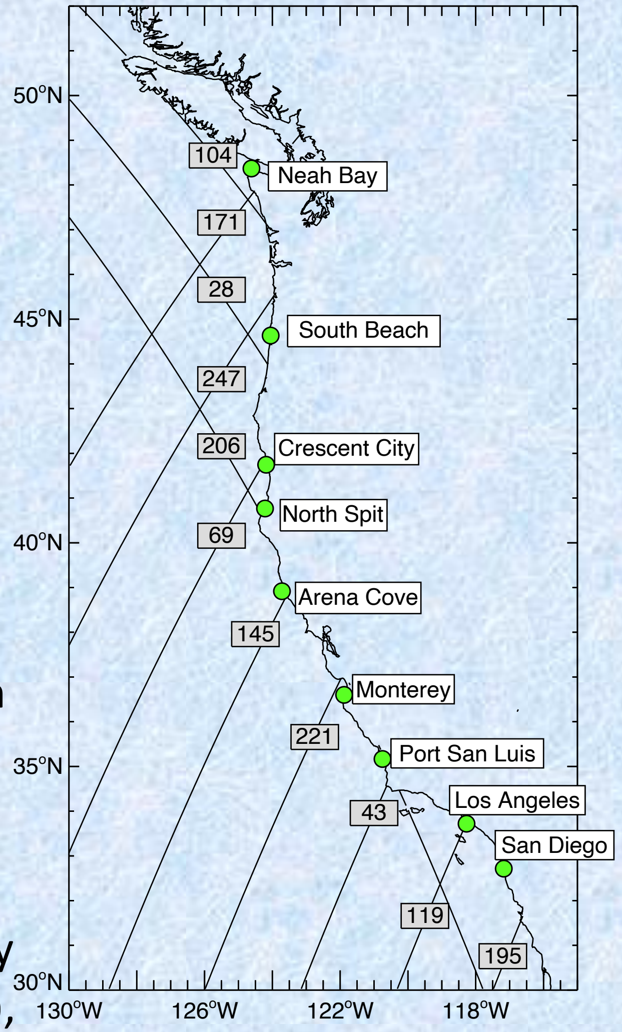

Relaxation Dates file: event_times_relaxations_Melton_buoys_start_times_only.txt
Day 0 TG Values have been subtracted

# Main Results

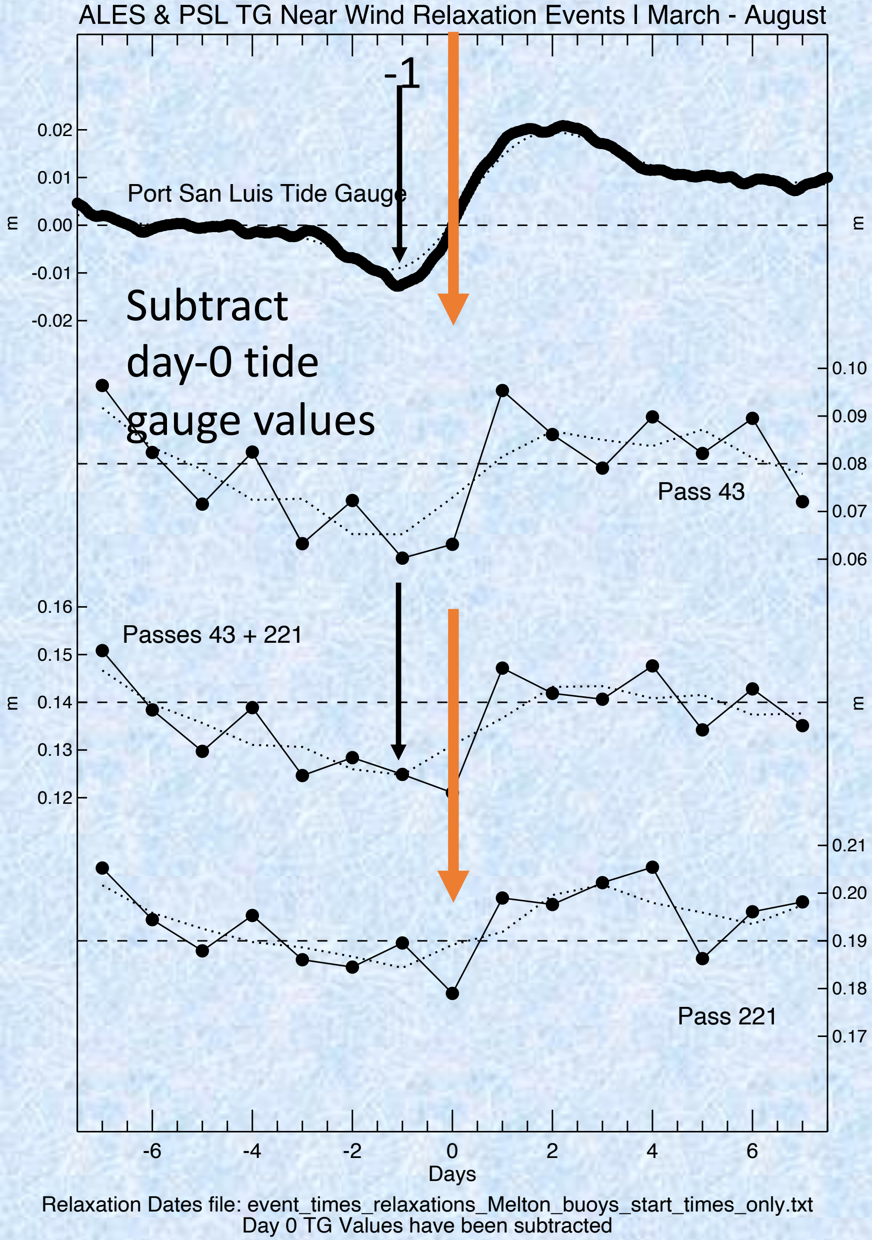
**ALES data provide more data points in regions closer to the coast than RADS, reducing the noise and increasing agreement with TG data. We show ALES data results in the remaining figures.**

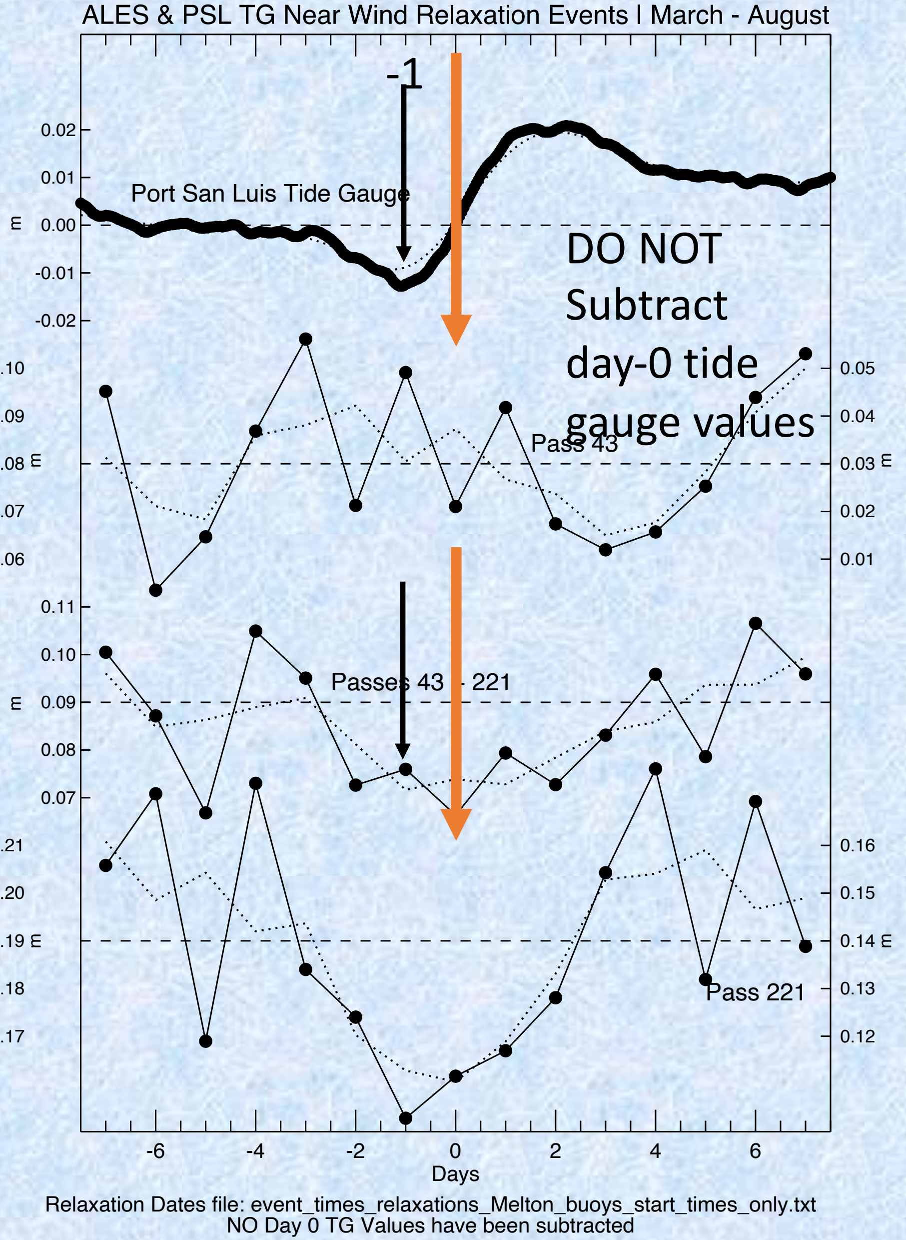
In each of the following plots we show the daily binned TG SLA (top) and alongtrack SLA in the ~10-30km next to the coast (below), binned and averaged by day relative to day 0 (solid line), with a 3-day running mean (dotted line). Two altimeter tracks are shown separately (top and bottom altimeter plots) and averaged (middle). Orange arrows show day 0 on all plots; black arrows show minimum TG SLA for that TG. On the LEFT we subtract the day-0 value from the closest TG. On the slides below, we also show the results when we DO NOT subtract the day-0 TG value (on the RIGHT). Here we show results for tracks 43 and 221.

The Crescent City TG and track 69 are poorly correlated. We use tracks in pairs: (43, 221), (145, 206), and (247, 28).



# Tracks 43 and 221: Port San Luis & Monterey 35-37N



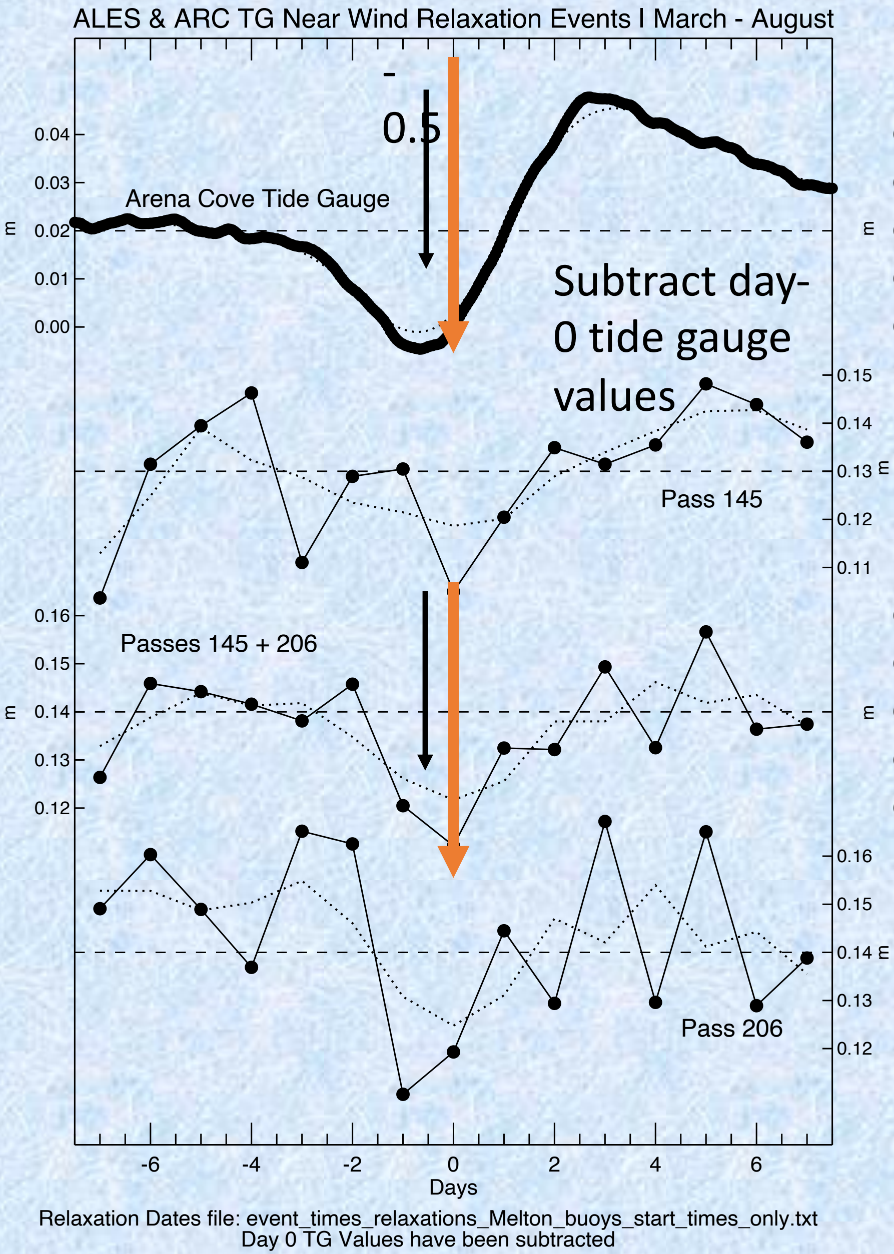



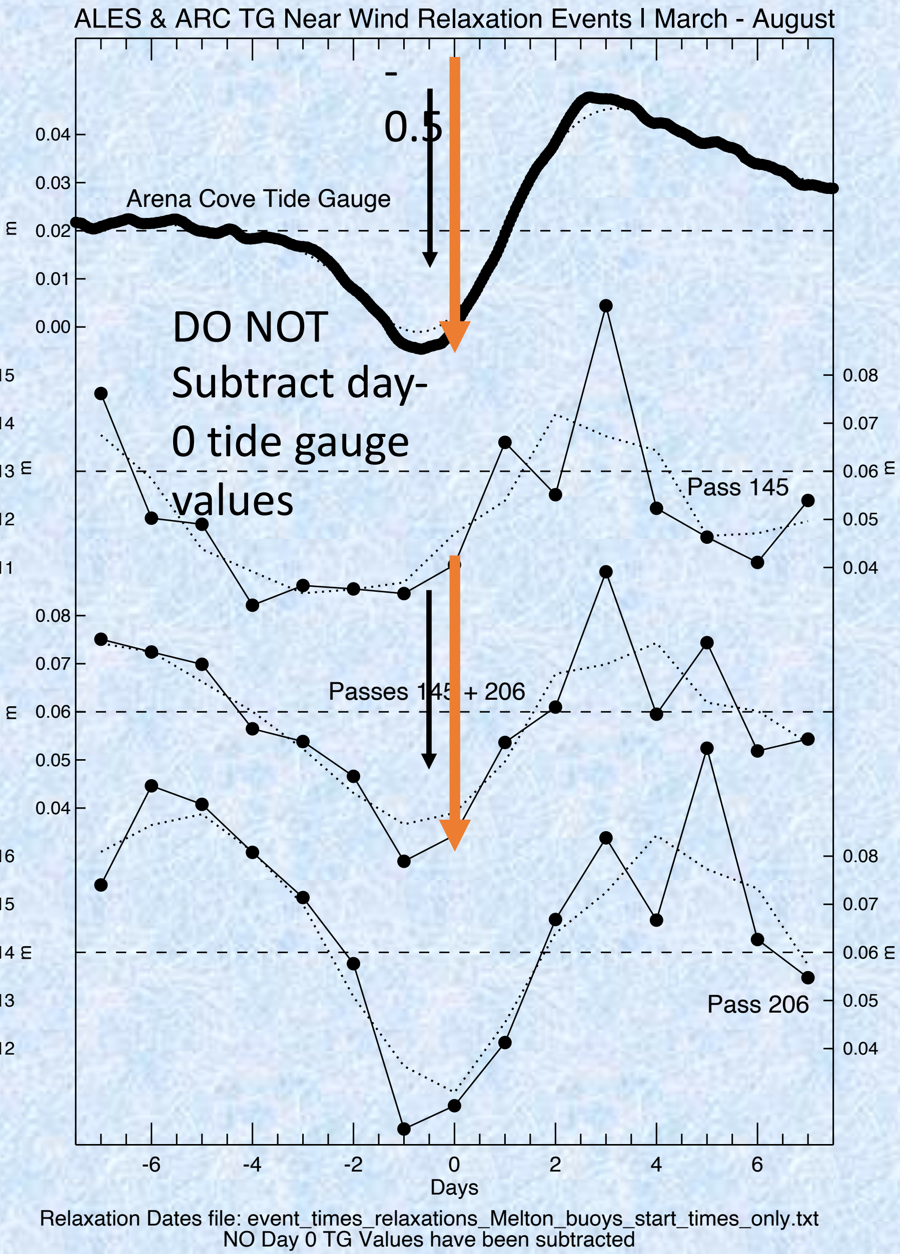

Daily binned TG SLA (top) and alongtrack SLA in the ~10-30km next to the coast, binned by day relative to day 0. Pass 43 (top) and 221 (bottom) and their average (middle). Dotted line is a 3-day centered mean. Orange arrows are day-0, black arrows show minimum TG SLA.

**Left:** the day-0 closest TG value for an event is subtracted from all altimeter height values for that event.

**Right:** the day-0 TG value is not subtracted.

# Tracks 145 and 206: Arena Cove and North Spit: 39-41N



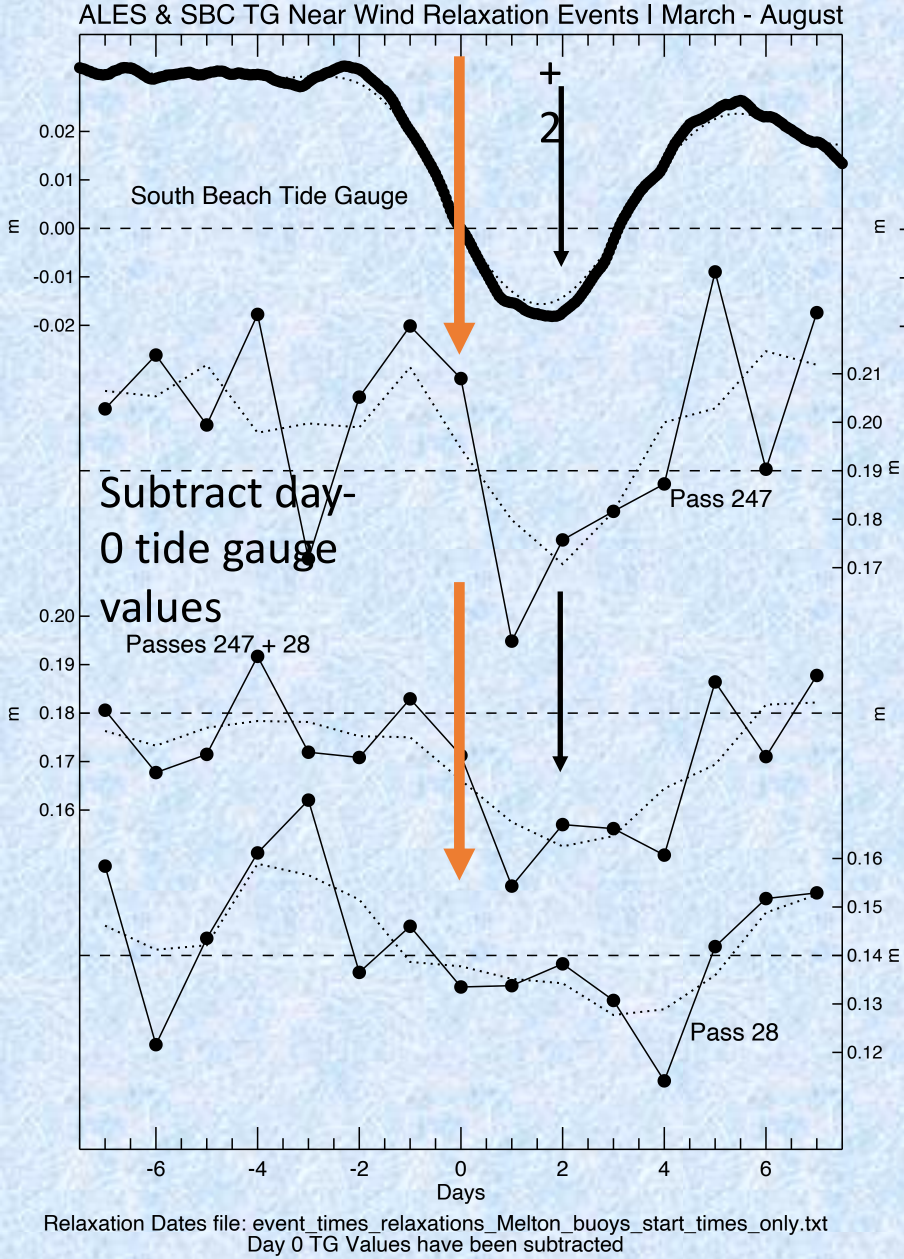



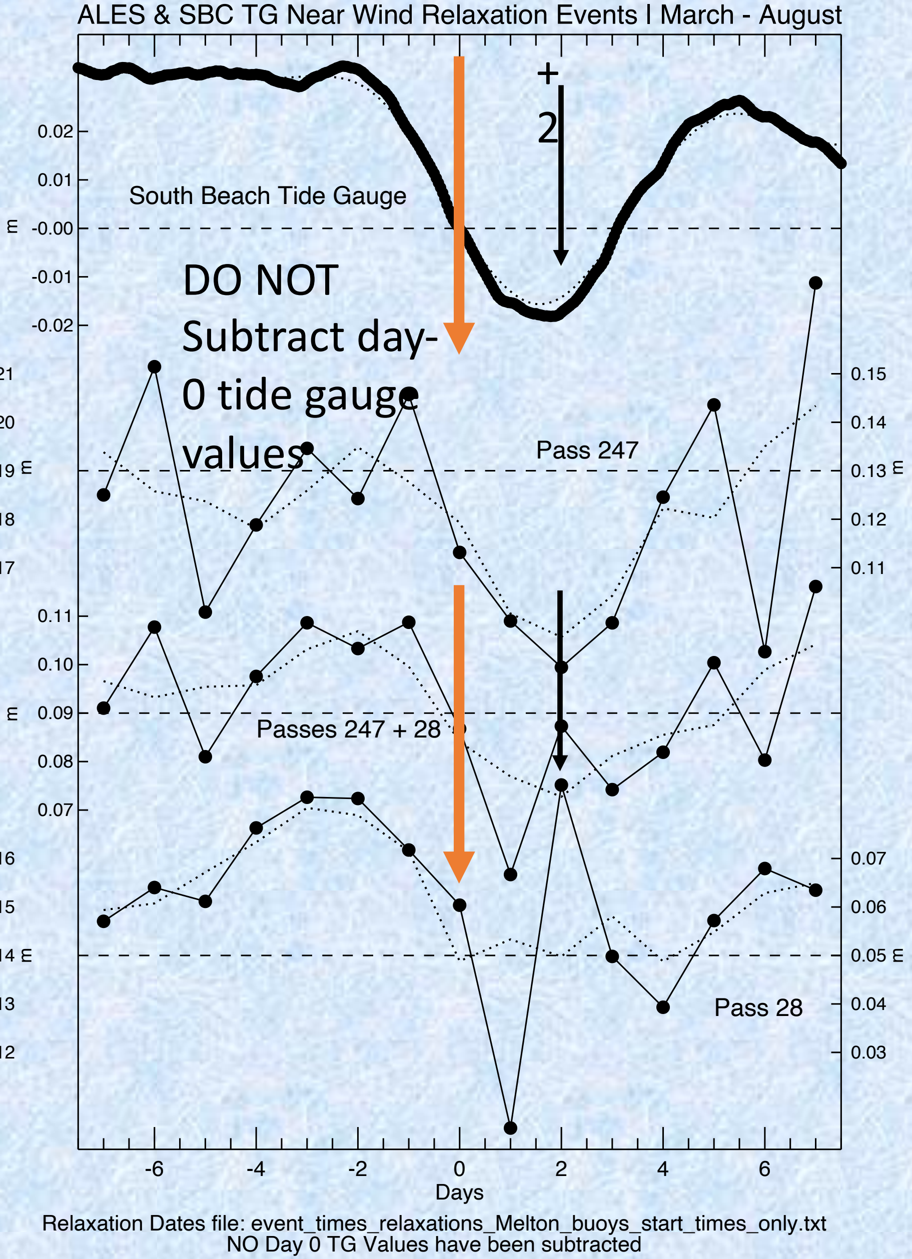

Daily binned TG SLA (top) and alongtrack SLA in the ~10-30km next to the coast, binned by day relative to day 0. Pass 145 (top) and 206 (bottom) and their average (middle). Dotted line is a 3-day centered mean. Orange arrows are day 0, black arrows show minimum TG SLA.

**Left:** the day-0 closest TG value for an event is subtracted from all Altimeter height values for that event.

**Right:** the day-0 TG value is not subtracted.

# Tracks 247 and 28: South Beach, North and South: 44-46N

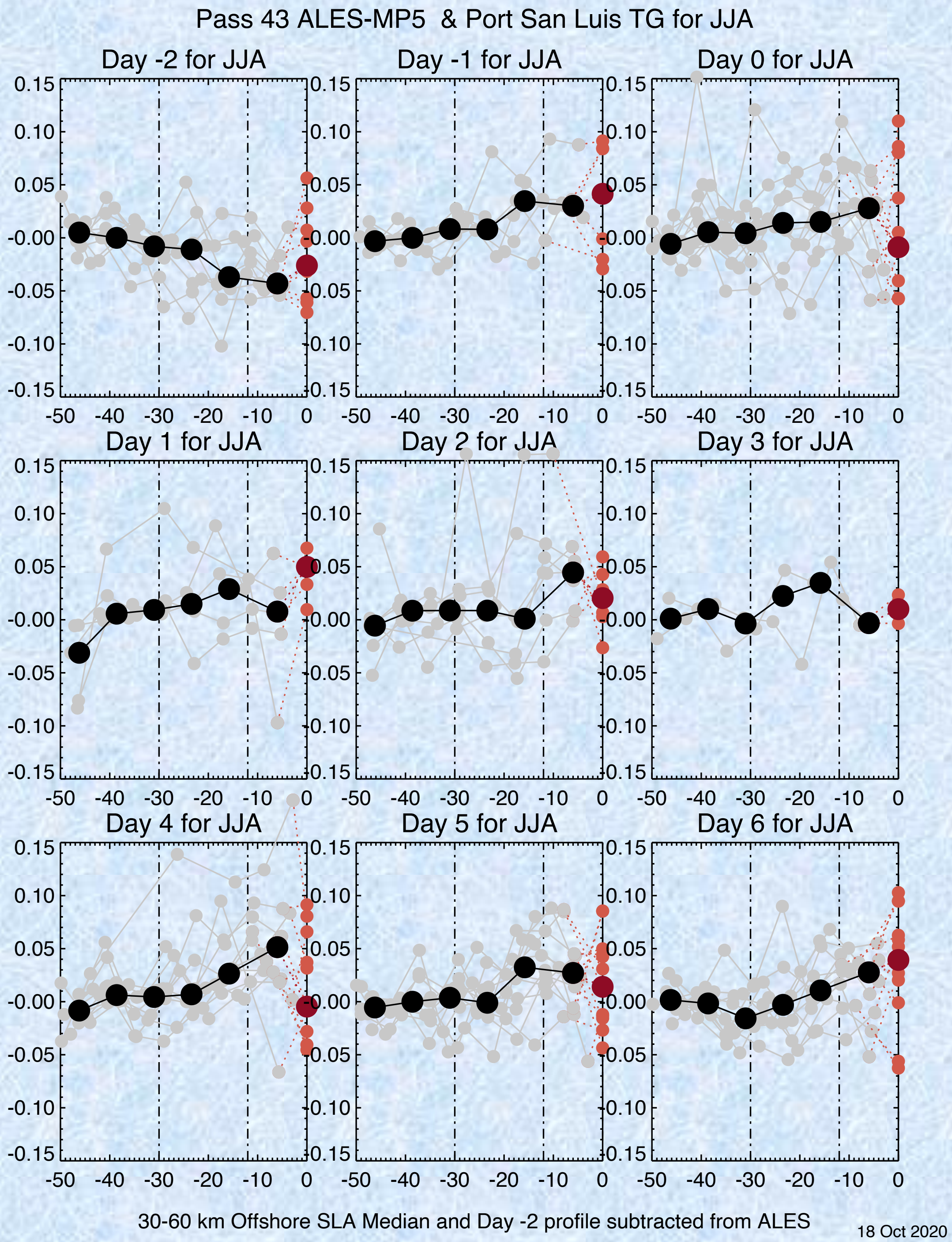



Daily binned TG SLA (top) and alongtrack SLA in the ~10-30km next to the coast, binned by day relative to day 0. Pass 247 (top) and 28 (bottom) and their average (middle). Dotted line is a 3-day centered mean. Orange arrows are day 0, black arrows show minimum TG SLA.

**Left**: the day-0 closest TG value for an event is subtracted from all Altimeter height values for that event.

**Right**: the day-0 TG value is not subtracted.



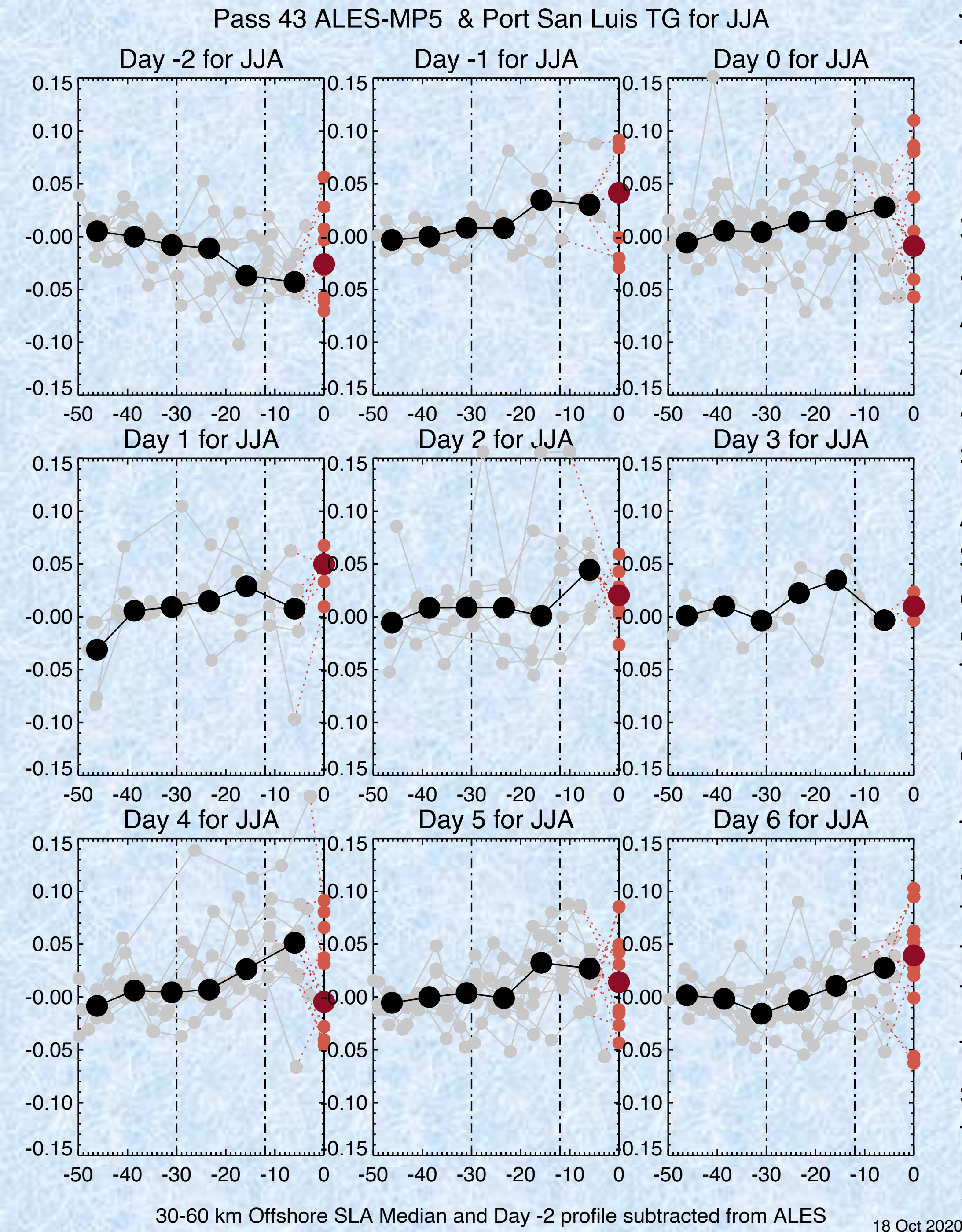

# Retrieval of Alongtrack Profiles for the Same Days as Used for the Above Time Series

In the slides that follow we show the composited profiles for the alongtrack SLA using the same events and daily bins as above. In the previous slides we were showing the average of the data between 10-30 km. Here we show the **median value of the profile data during each lagged day to form the profiles,** after some aligning. ALES SLA provides more data than RADS and is shown. Medians remove slightly more noise than the averages, due to the small number of samples. June-August produces slightly stronger profiles but fewer points and noiser data.

***The day -2 profile shows the actual SLA values. The following days all subtract the day -2 values to show the change since day -2. We are looking for the change in 'shape', i.e., the rise in SLA in the ~30km next to the coast.***

The red dot is the TG data, processed like the altimeter data.

The SLA average value between30-60km SLA is subtracted from each profile to eliminate large-scale sea level fluctuations.



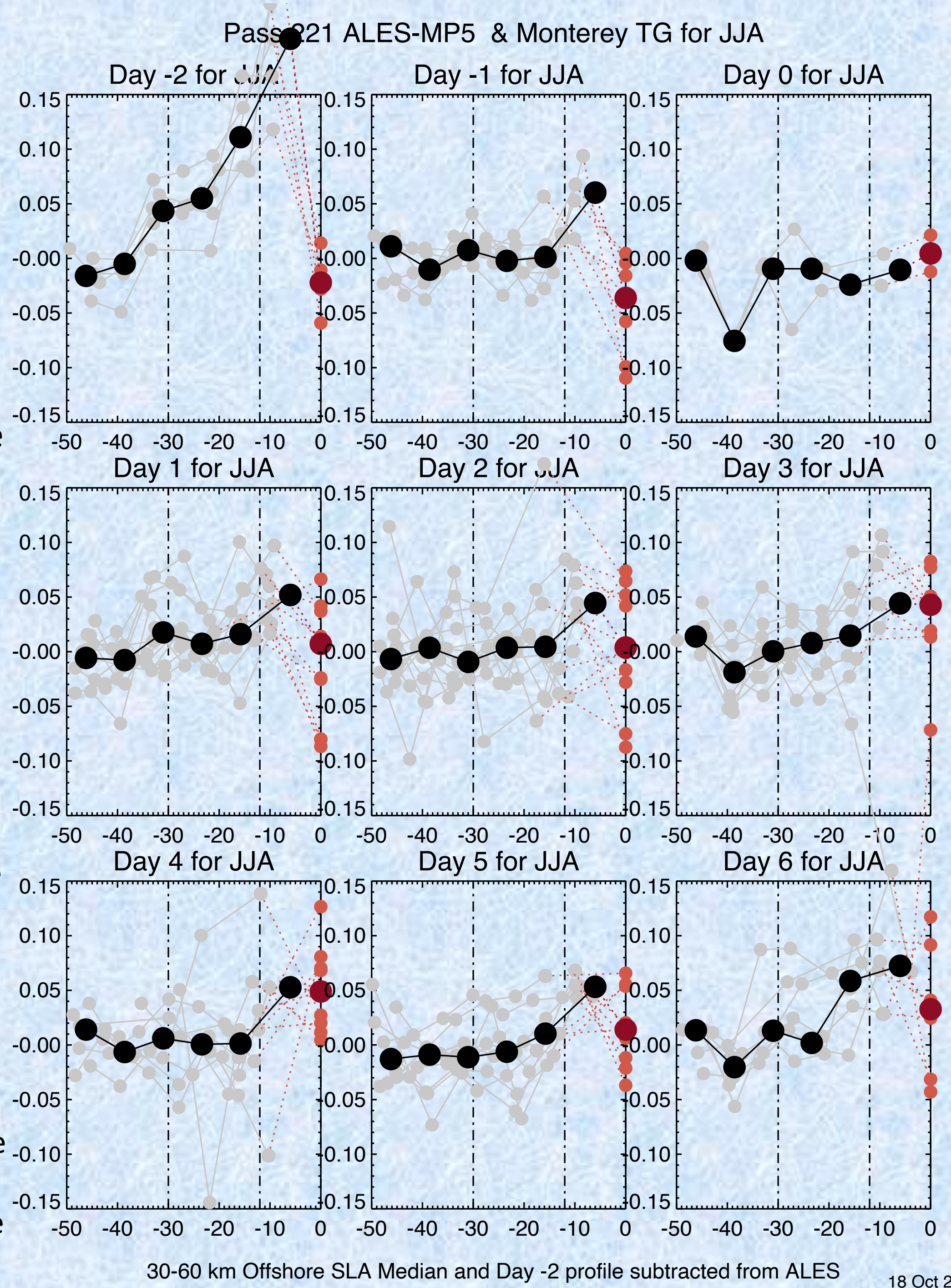

# June-August Tracks 43 & 221 Port San Luis & Monterey

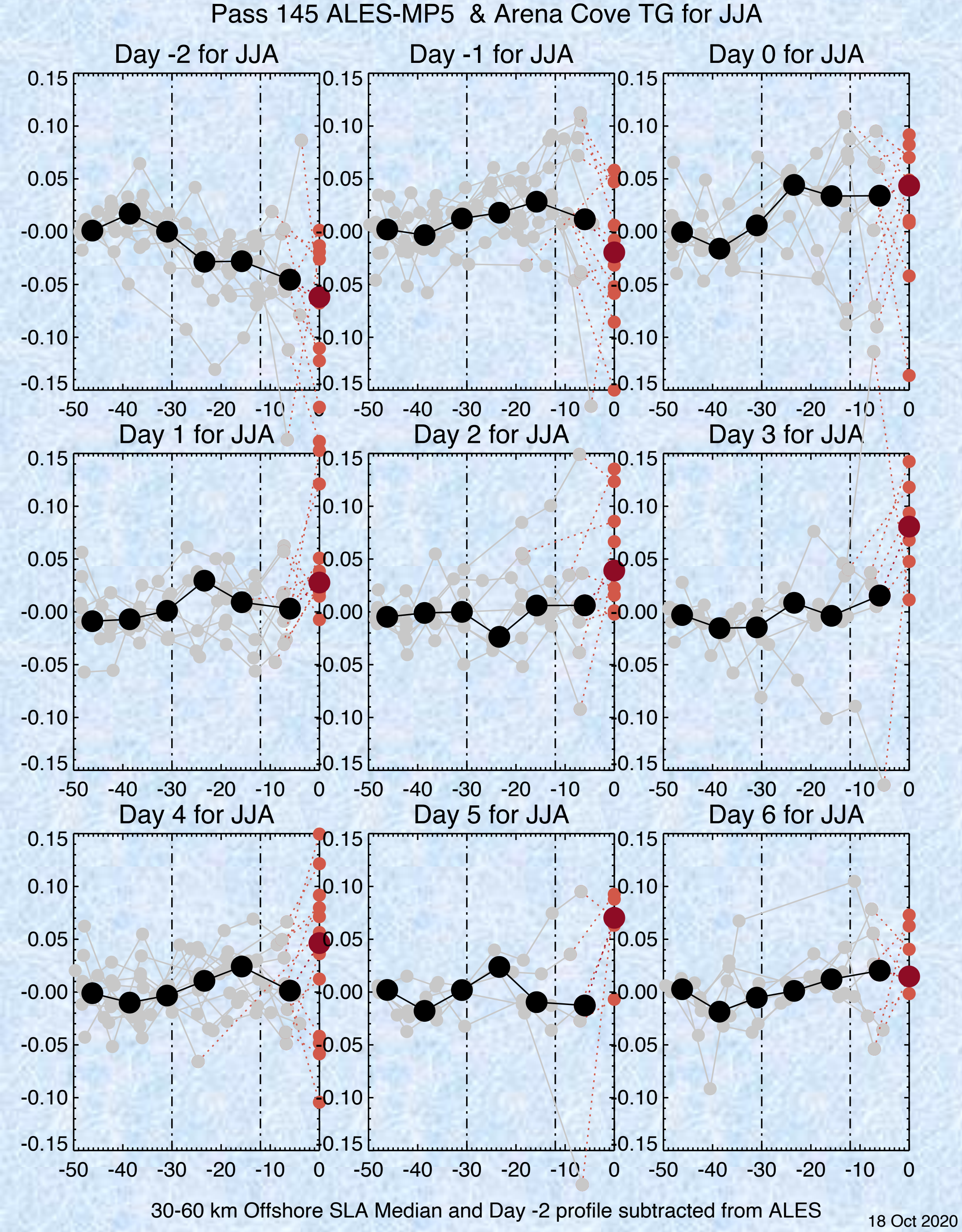
Slightly stronger slopes are found during June-August (vs March-August), but the noise also increases due to the small number of points.

Alongtrack profiles of ALES SLA for composited data in daily bins surrounding day 0 of the events: June-August. The red dot is the TG data, processed like the altimeter data.

The day -2 profile shows the actual SLA values. The following days all subtract the day -2 values to show the change since day -2.

The 30-60km SLA average is subtracted from each profile to eliminate large-scale sea level fluctuations (the shape is what matters).



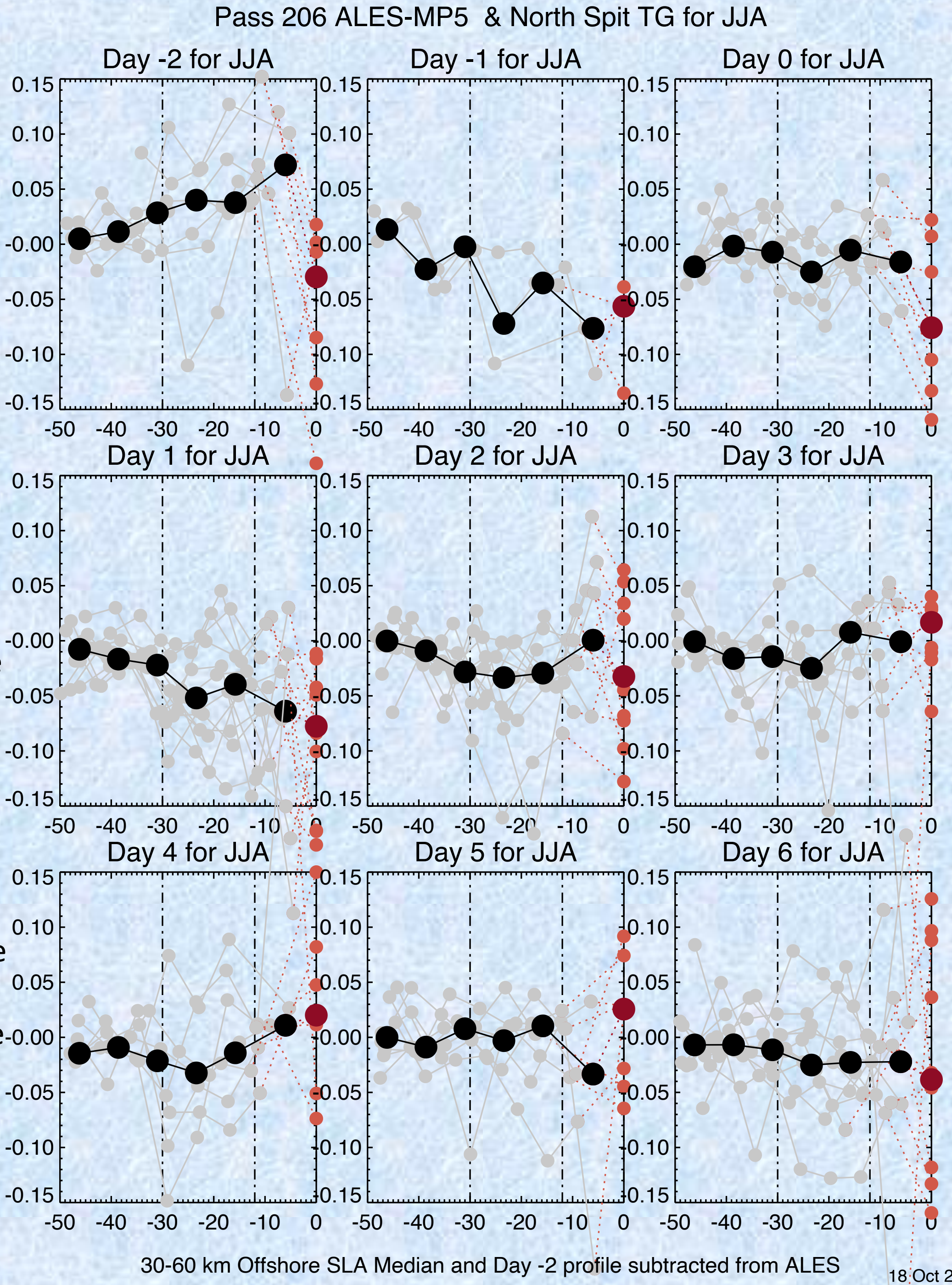


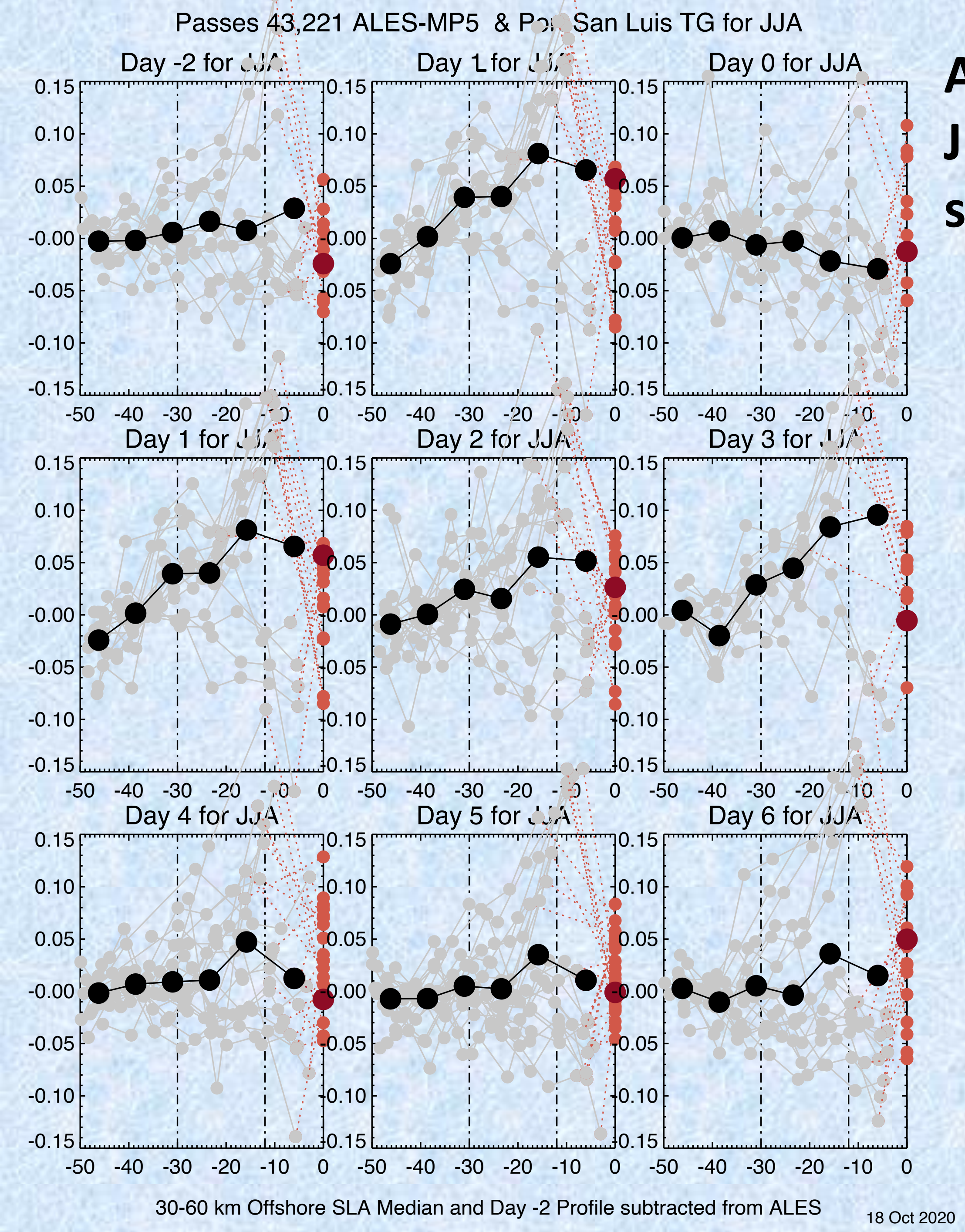

# June-August Tracks 145 & 206 Arena Cove & North Spit

As in the previous slides. Alongtrack profiles of ALES SLA for composited data in daily bins surrounding day 0 of the events: June-August. The red dot is the TG data, processed like the altimeter data.

The day -2 profile shows the actual SLA values. The following days all subtract the day -2 values to show the change since day -2.

The 30-60km SLA average is subtracted from each profile to eliminate large-scale sea level fluctuations (the shape is what matters).






# Averaged tracks 043 & 221 Port San Luis & Monterey June-Augusts. Averaging two tracks reduces noise, as seen in the time series above.

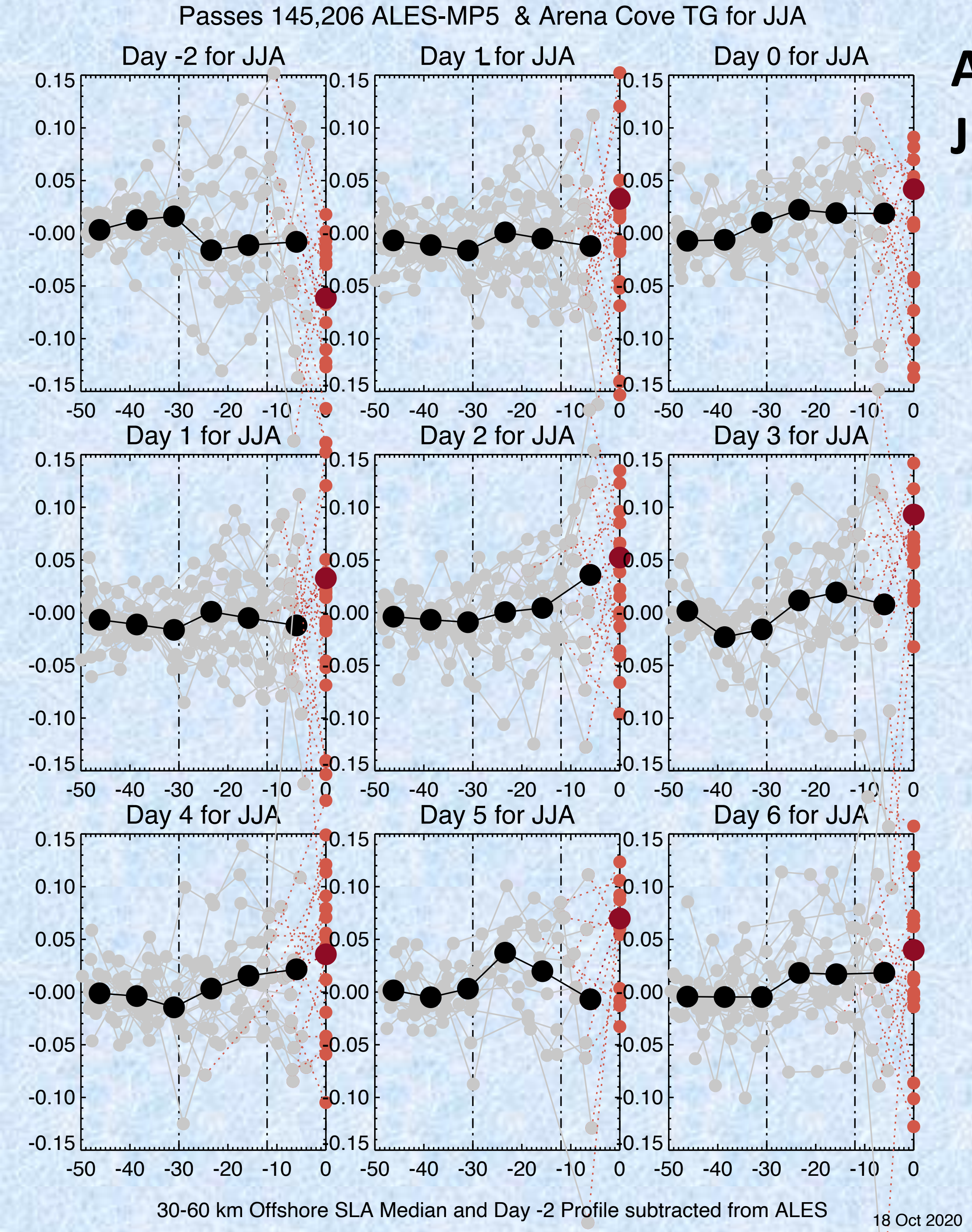
Averages of two tracks for alongtrack profiles of ALES SLA for composited data in daily bins surrounding day 0 of the events: June-August. The red dot is the TG data, processed like the altimeter data.

The day -2 profile shows the actual SLA values. The following days all subtract the day -2 values to show the change since day -2.

The 30-60km SLA average is subtracted from each profile to eliminate large-scale sea level fluctuations. (the shape is what matters).

**The averages of these two tracks, near the latitude of the wind event, show profiles with a rise toward the coast of 5-10 cm on days +1 through +3, inshore of 30-50km.**

**The time series above shows that days 1-3 are when the tide gauge and SLA rises to its peak values at these latitudes.**




# Averaged tracks 145 & 206 Arena Cove & North Spit June-August

Averages of two tracks for alongtrack profiles of ALES SLA for composited data in daily bins surrounding day 0 of the events: June-August. The red dot is the TG data, processed like the altimeter data.

The day -2 profile shows the actual SLA values. The following days all subtract the day -2 values to show the change since day -2.

The 30-60km SLA average is subtracted from each profile to eliminate large-scale sea level fluctuations. (the shape is what matters).

**The averages of these two tracks, 400-500 km north of the wind event, show profiles with a rise of 2-4 cm toward the coast on days +2 through +4, inshore of 30km.**

**The time series above shows that days +2 to +4 are when the tide gauge and SLA rises to its peak values at these latitudes.**

**At the higher latitudes near 45N, tracks 247 and 28 do not show a rise in sea level next to the coast on days +4 to +6, which is when the time series indicates a rise in sea level.**

# Conclusions:

**The ALES data set provides more data in the region closest to the coast along the tracks. Because there is a need to composite many events, the additional data allow the ALES data a better chance to average out the considerable 'noise' in the data. This noise is not due to errors in the instrument, but sea level variability other than the wind-driven responses we want to isolate. Note that the signal we are trying to isolate is small, 3-10 cm in the average tide-gauge data. The ability of the altimeter data to see this signal at all is a testament to the accuracy in the alongtrack altimeter data.**

**** By averaging the data in the 10-30 km next to the coast in the along-track data, a signal resembling the tide gauge signals is retrieved, showing the rise in the sea level after the wind relaxation, with an increasing delay as one moves north. The tide gauge signal is better at resolving the timing, which is approximately what one expects for a first baroclinic mode CTW with a phase velocity of ~200-300 km per day, understanding that there is wind forcing all along the coast, so these are not freely traveling waves. The composites that average two tracks in the vicinity of the tide gauge help to eliminate a bit more of the noise. A temporal average also helps.**

**** The attempt to retrieve the cross-shore profile of the SLA using the along-track data shows promise in detecting a rise in sea level within 30-50 km of the coast, though results are noisy.**

<u>**The small number of events at each of the daily lags creates a challenge due to significant noise in the data for both time series and profiles.**</u>

*We thank NASA for its support in our research.*