Center for Western Weather and Water Extremes

Coastal sea surface temperature variability in Northern California during landfalling atmospheric rivers

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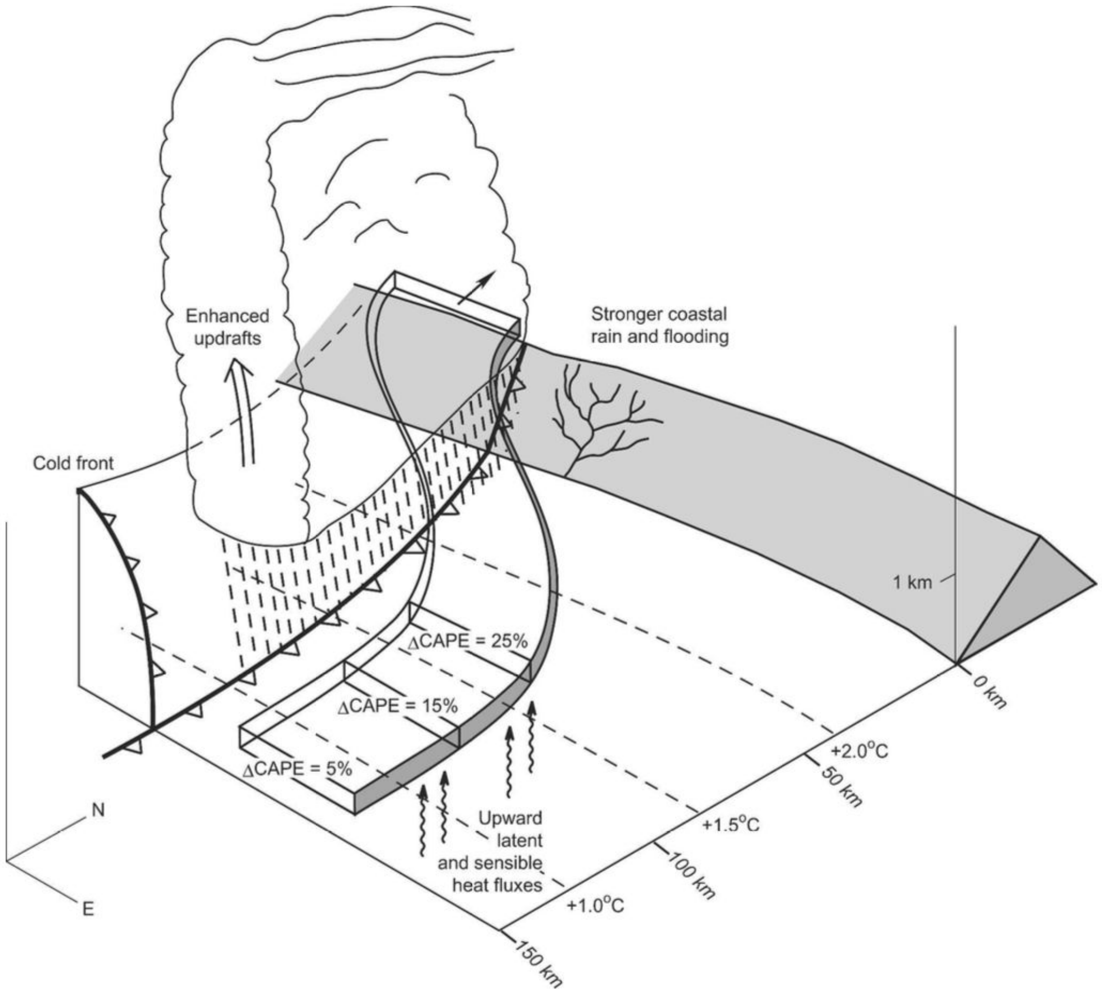
AR Dynamics II – IARC 2018

June 27, 2018

UC San Diego

Motivation:

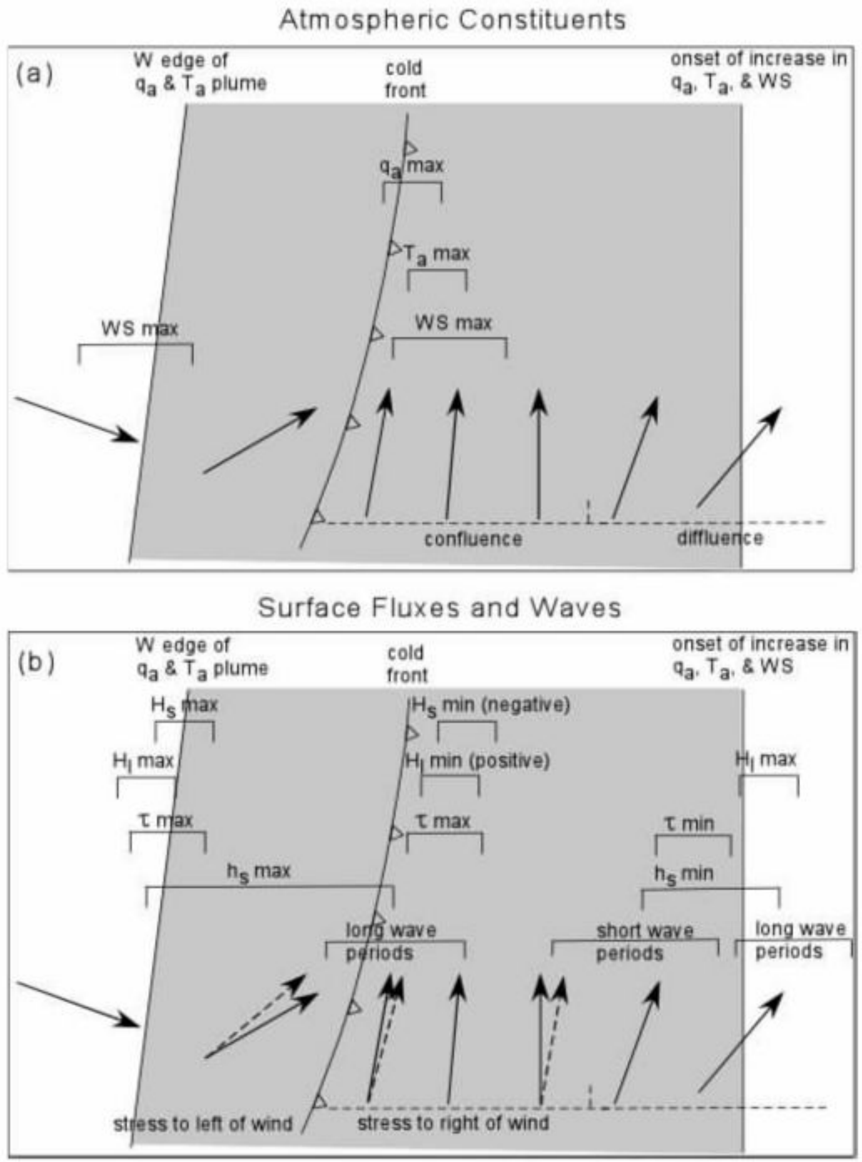
- Sea surface temperatures (SST) can **regulate** precipitation, AR **intensity** and duration
- Local **SST variability** can cause an increase in convective potential and lead to **higher precipitation totals**
- In the CA Bight, **warmer SSTs** contributed to **destabilization** of the boundary layer, inducing **convection** and contributing to flooding in Southern CA



Persson et al., 2005

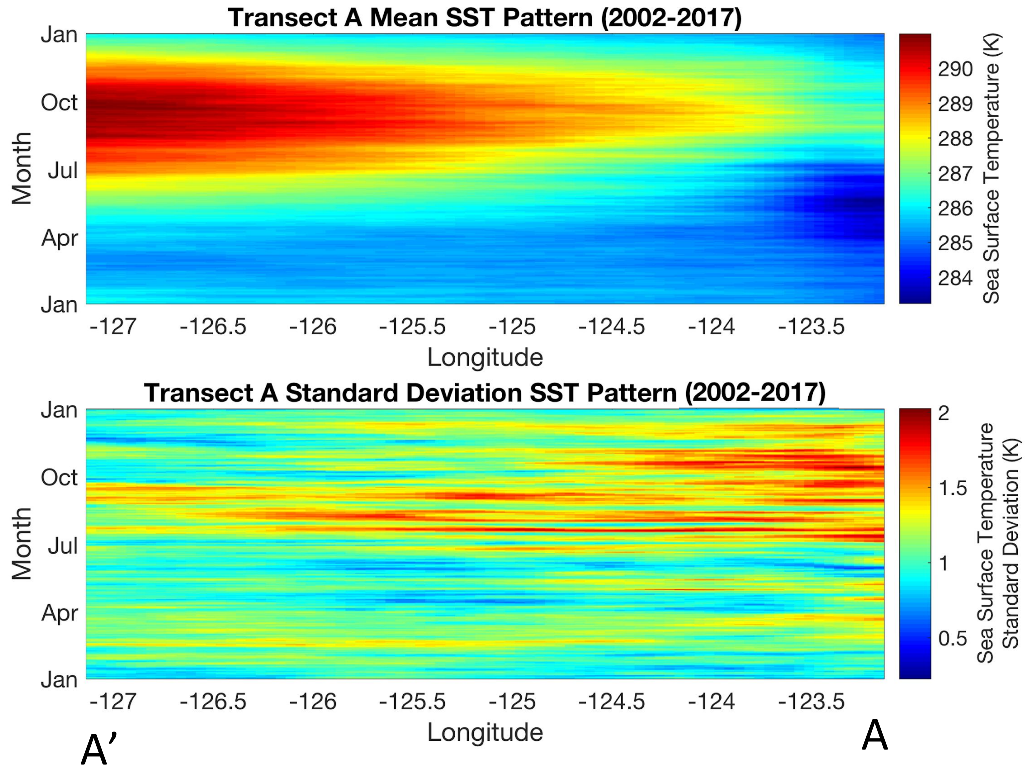
Motivation:

- **Varying spatial scales** with maximum and minimum heat and momentum fluxes
- Identify SST and planetary boundary layer (PBL) **processes**, such as latent and sensible heat fluxes, that might be important for **AR development and forecasting**
- Determine whether regional NWP (WRF) model and offshore observations (i.e., buoys) **captures** these physical processes

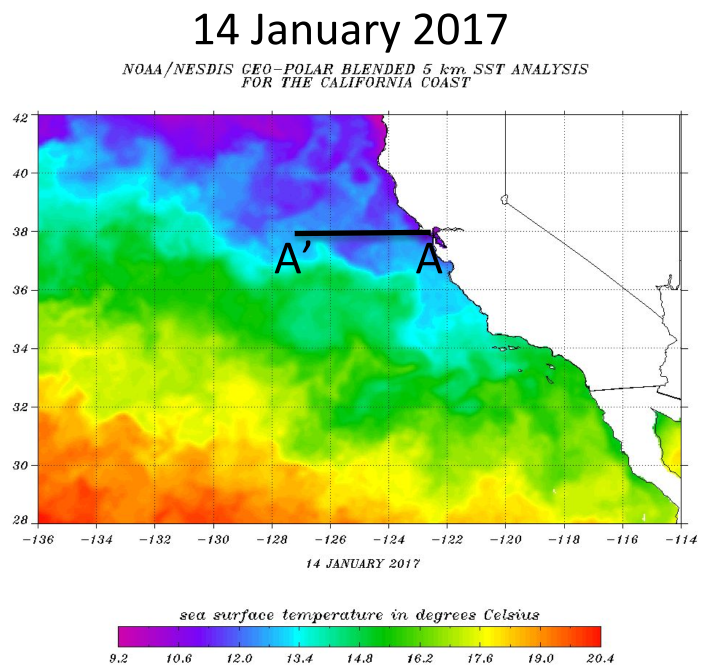


Persson, et al. Impact of Air-Sea Interaction on Extra-Tropical Cyclones, *ECMWF Workshop On Ocean-Atmospheric Interactions, 10-12 Nov. 2008*

Coastal SST seasonal variability

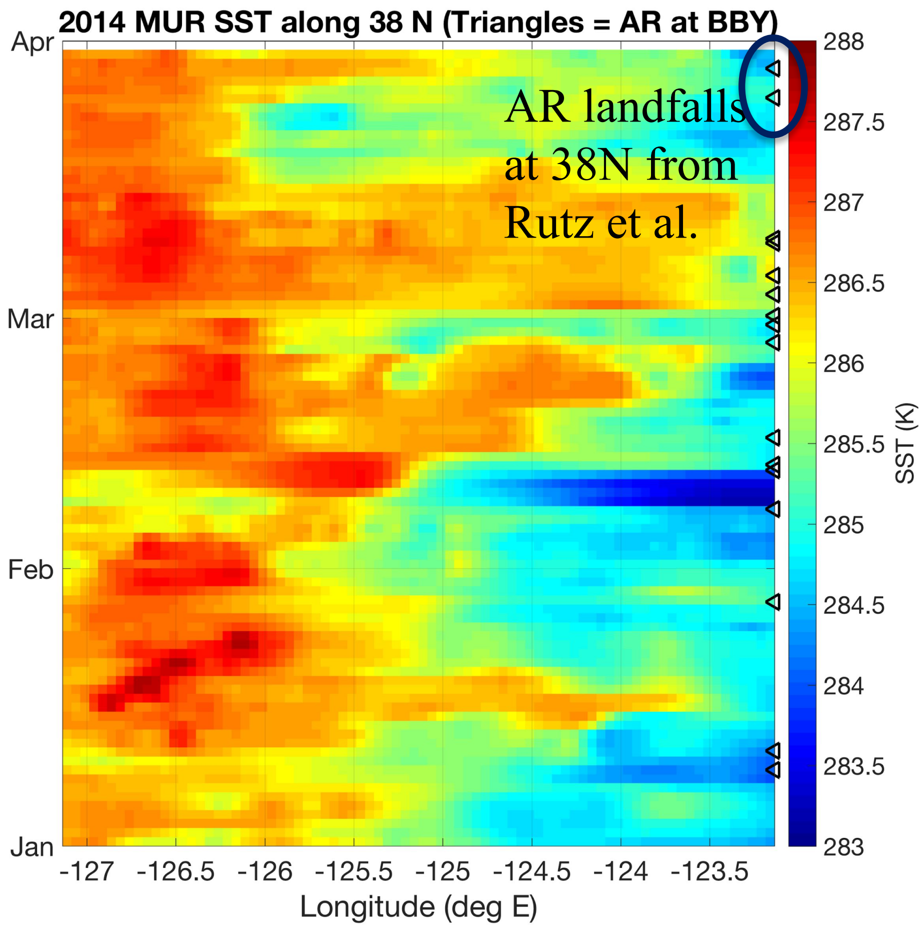


Multi-scale Ultra-High Resolution SST; NASA PO-DAAC

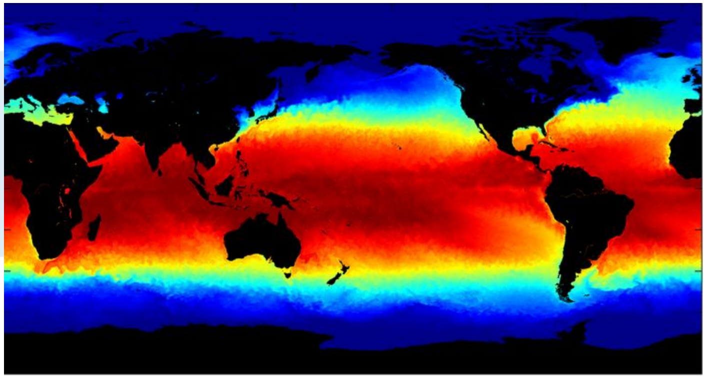


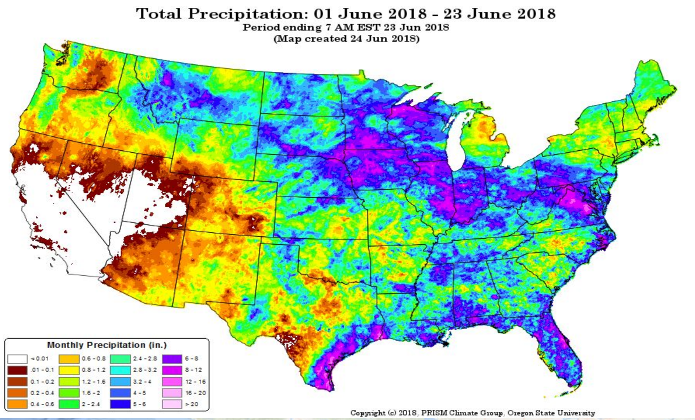
- Mean SST coastal variability dominated by summertime upwelling
- Large variance in SST during early cool season (> 1° C on average) especially during spring/fall transition period

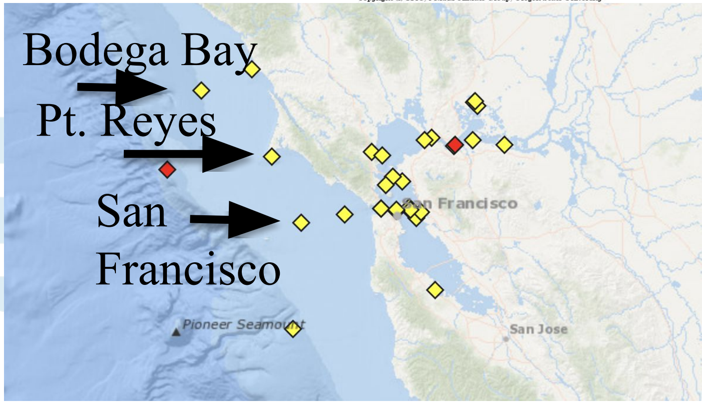
Coastal SST variability



- Change in SST (~1-2 K) during or after AR
- If SST variations due to post-cold front heat flux loss, what are time scales of SST "rebound"?
- Could heat flux loss affect next storm? What spatial scales and magnitude would affect the AR?







Data Used:

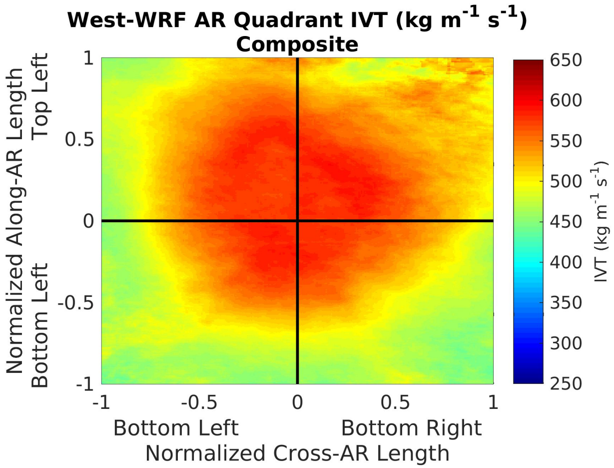
- Weather Research and Forecasting (WRF) model
  - West-WRF: configuration optimized to simulate West Coast weather including ARs (Martin et al., 2018)
  - Outer domain: 9 km, inner domain: 3 km
- Multi-Scale Ultra-High Resolution (MUR) SST analysis
  - Starts June 1, 2002 through present
  - Global daily data at roughly 1 km resolution
- PRISM High-Resolution Spatial Climate Data for the United States
  - Resolution: 4 km
  - Weighted regression scheme accounts for orography and rain shadows
- National Data Buoy Center
  - Point Reyes, Bodega Bay, and San Francisco, CA buoys: SST and air temperature
  - 2011 – 2017
- Rutz et al. (2014) AR detection catalog
  - Based on MERRA-2 reanalysis, 1980 – 2017
  - 250 kg m^{-1} s^{-1} IVT; length: <= 2000 km

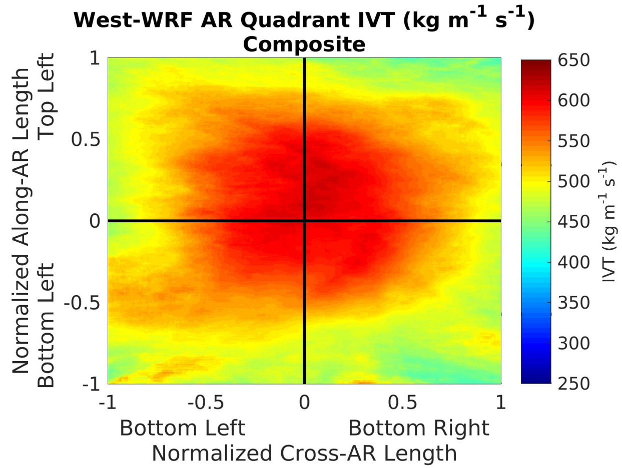
West-WRF AR Composites

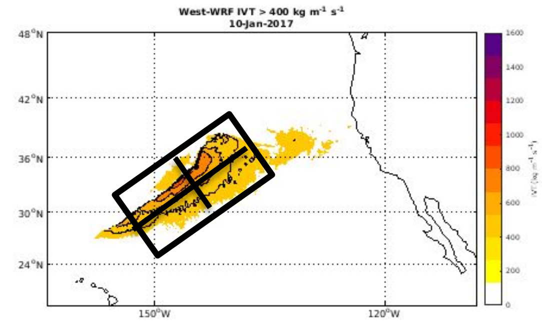
WY2017

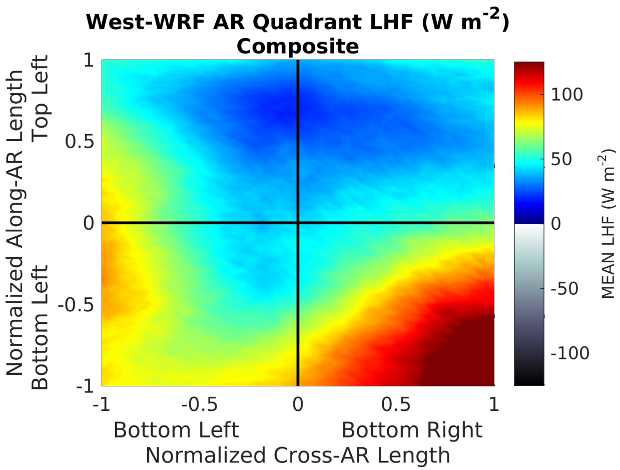
WY2018

Quadrant orientation

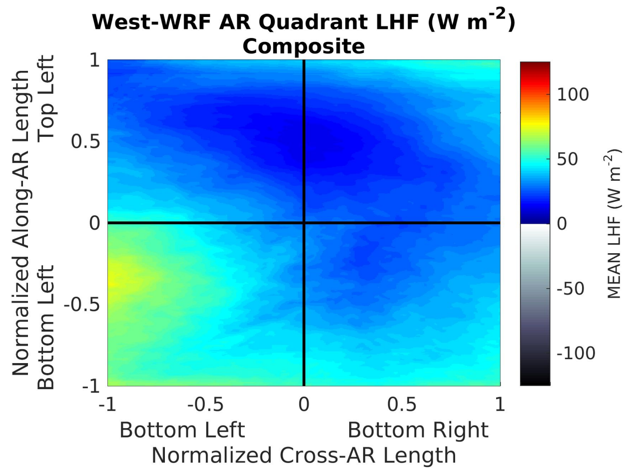








WY2017 E Pac Mean LHF = 100.31 Wm^{-2}



WY2018 E Pac Mean LHF = 90.53 Wm^{-2}

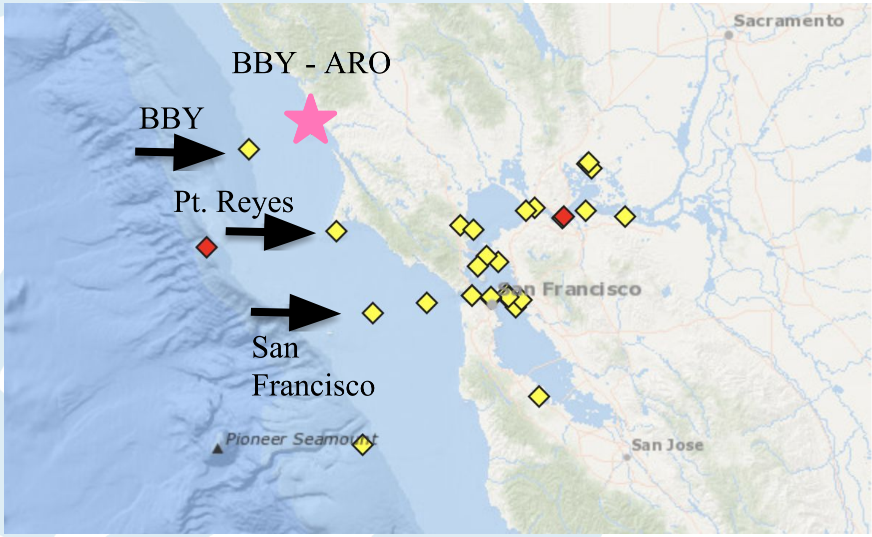
Number of samples:
WY2017 = 155 objects
WY2018 = 107 objects

Now, because West-WRF was able to capture the minima and magnitude of latent heat flux within an AR, let’s consider some case studies were coastal SST variability could be impactful:

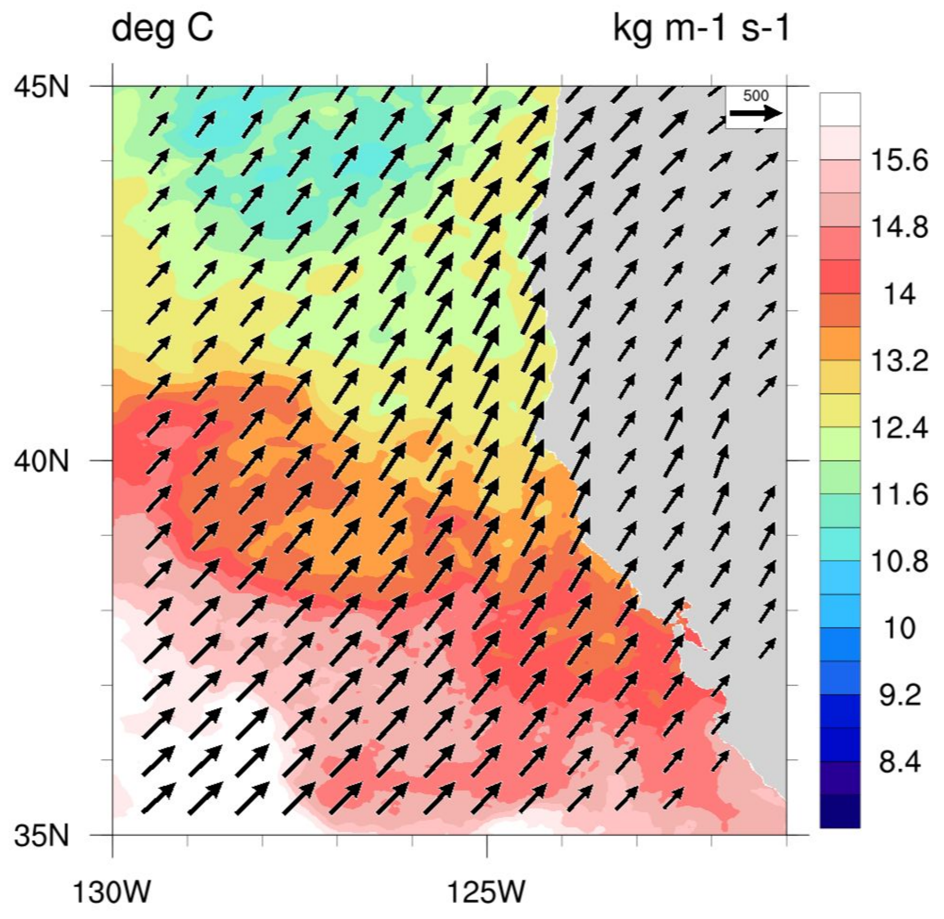
Case Study #1: February 5 – 10, 2015
Case Study #2: January 4 – 10, 2017
Case Study #3: February 15 – 21, 2017

Case Study #1: February 5-10, 2015

Case study average of IVT (vectors) and SST (color shaded) from February 5-10, 2015.



Map of Northern CA, showing ocean buoy locations of Bodega Bay (BBY), Point Reyes and San Francisco.



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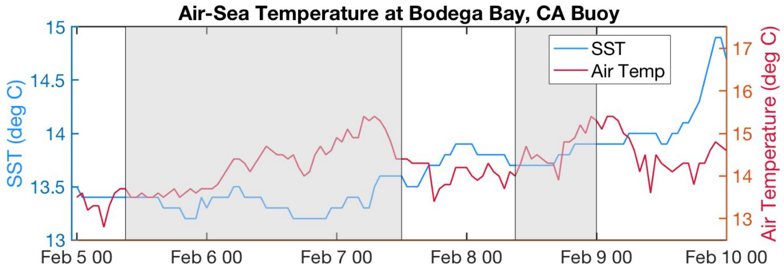

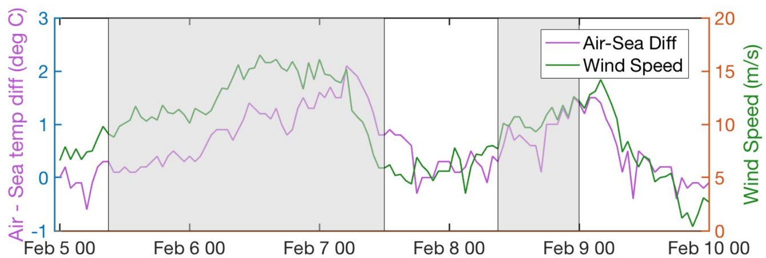

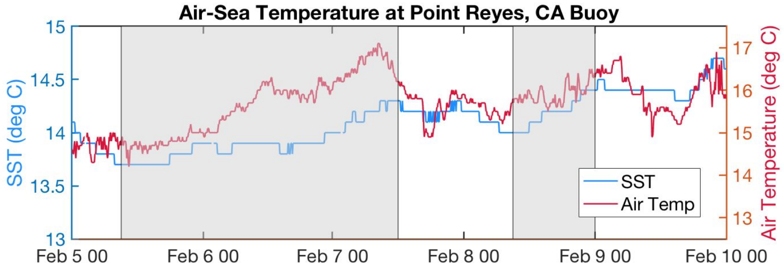

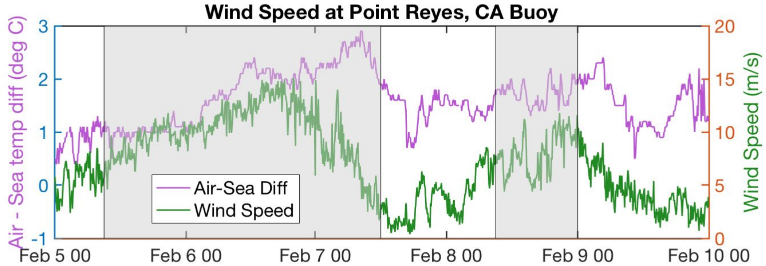

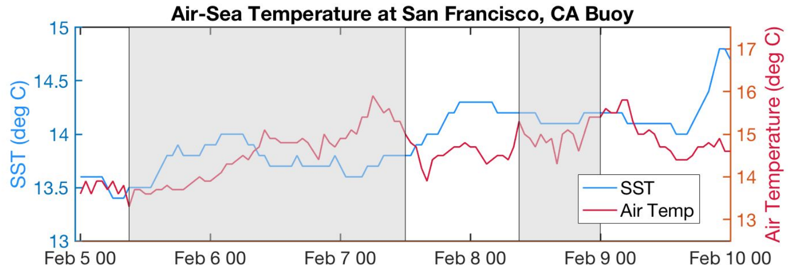

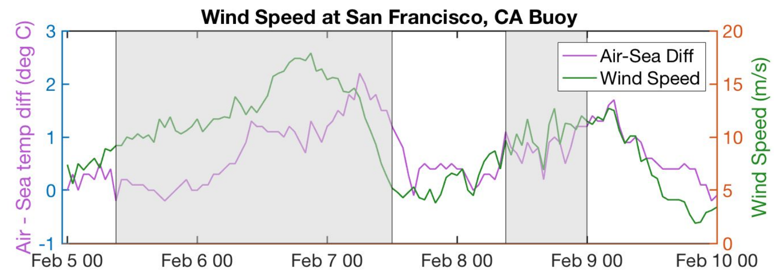

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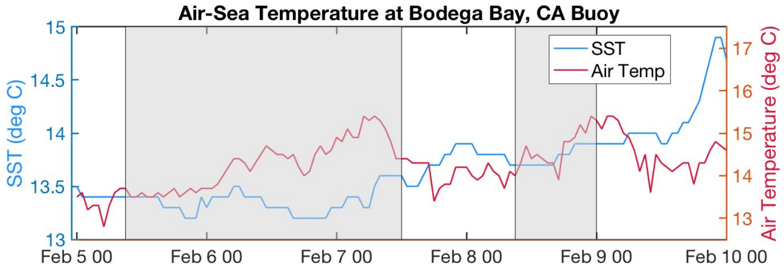

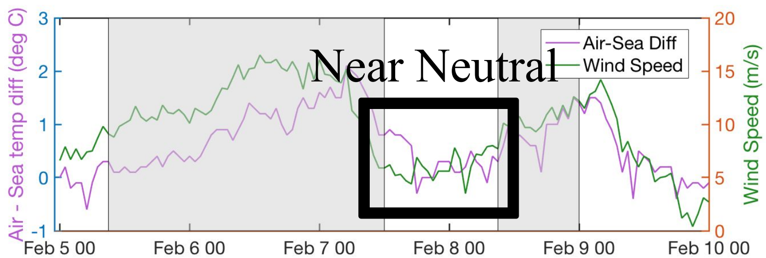

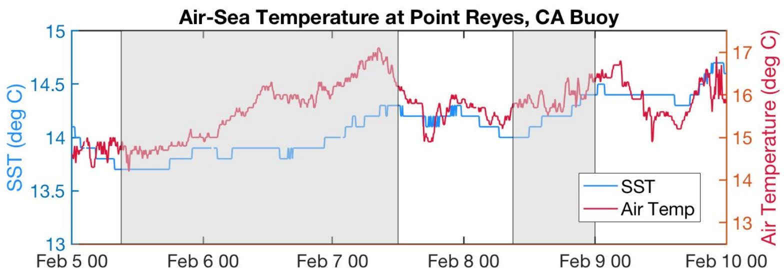

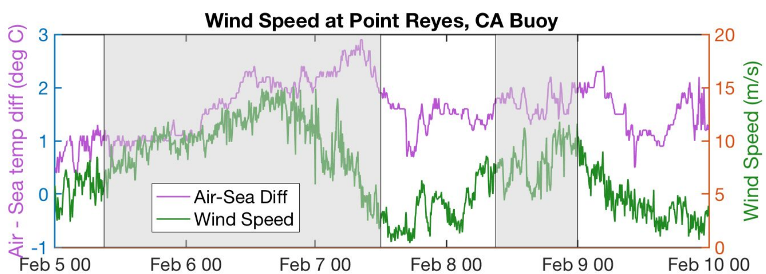

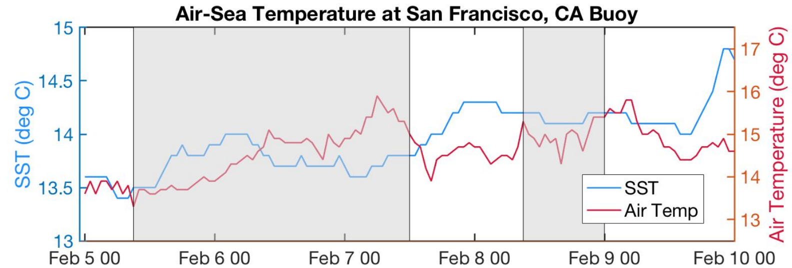

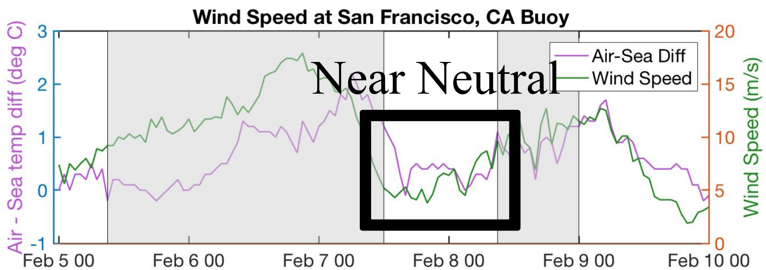

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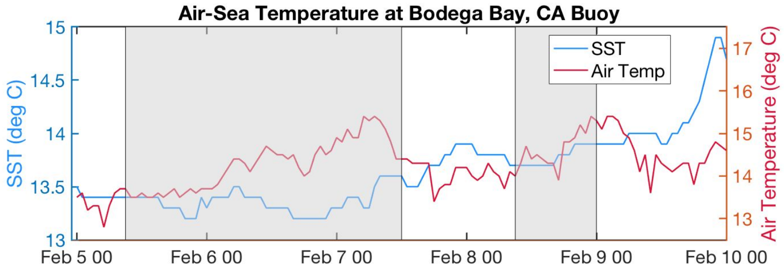

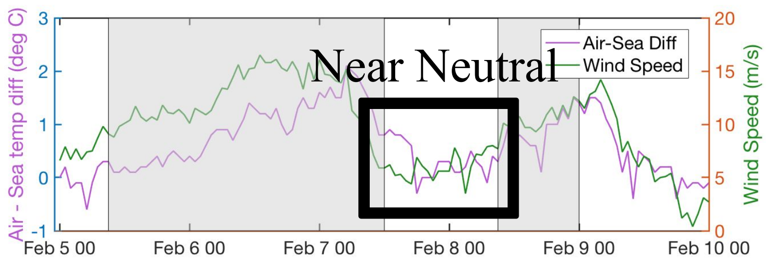

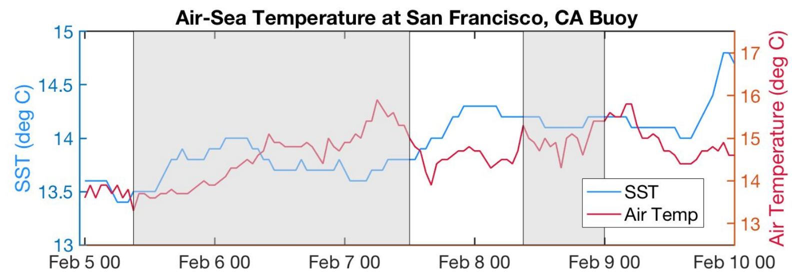

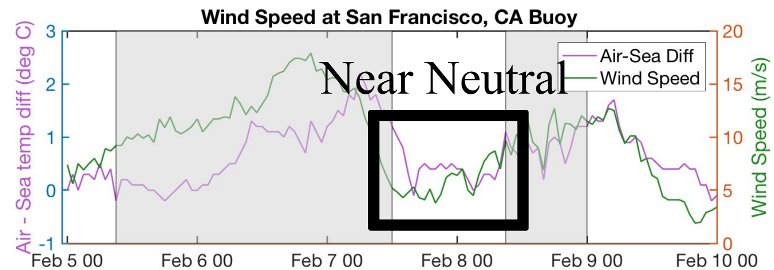

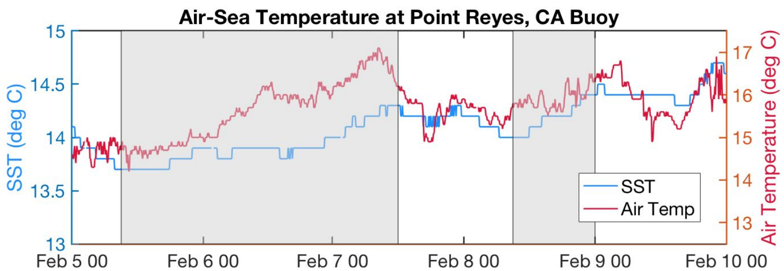

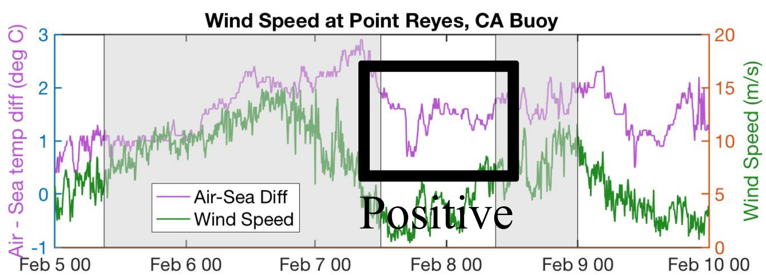

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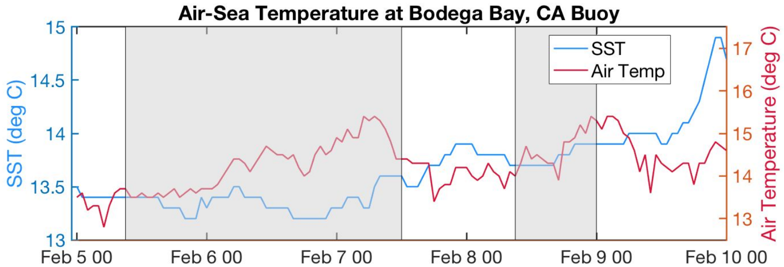

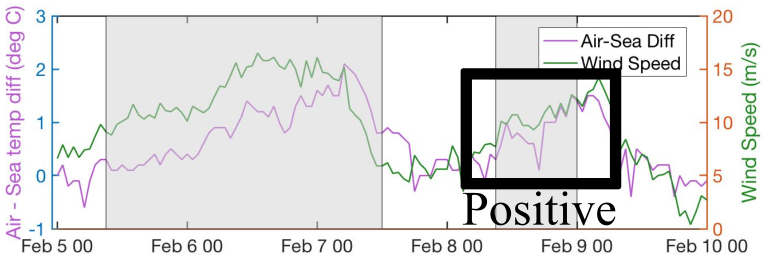

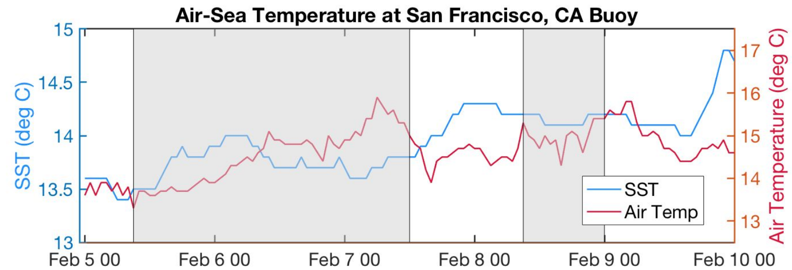

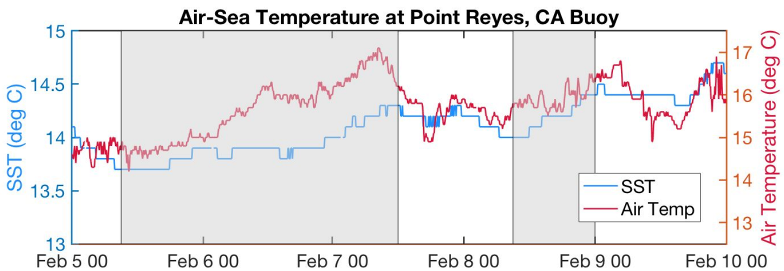

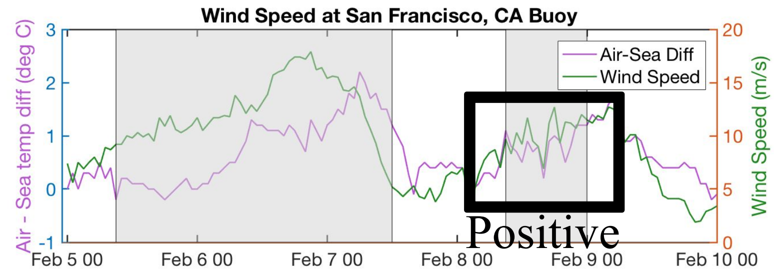

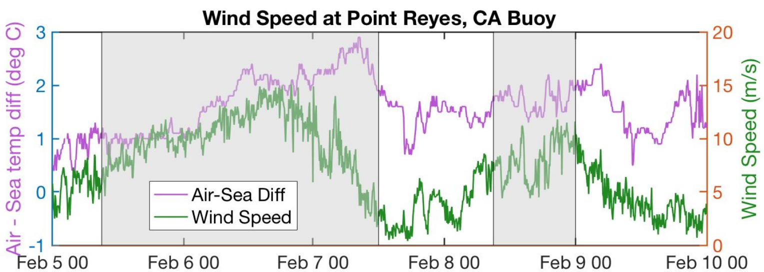

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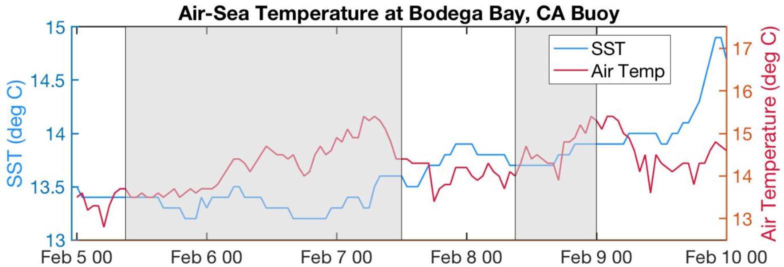
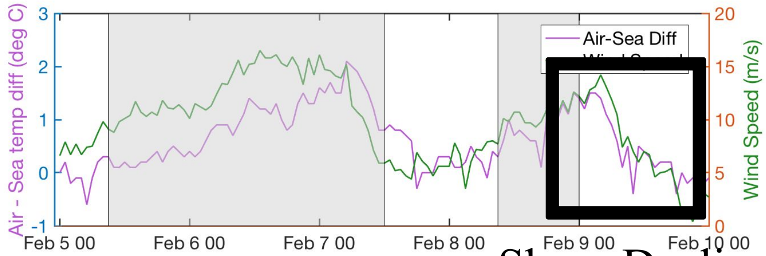
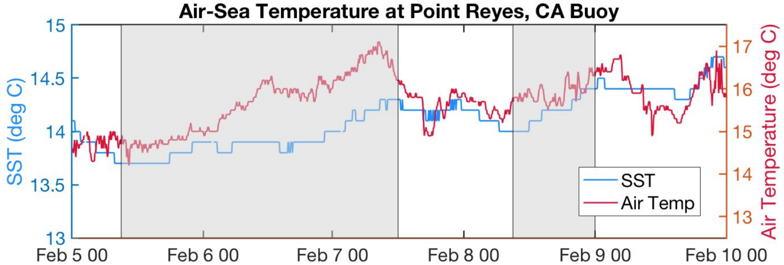
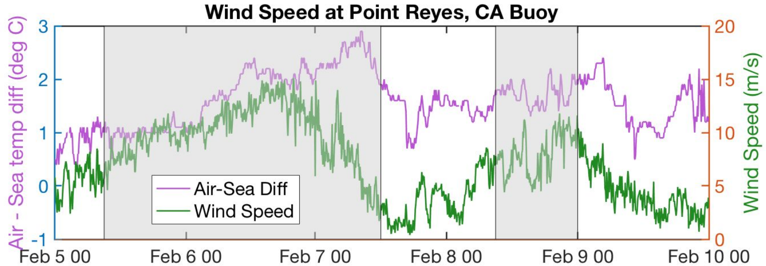
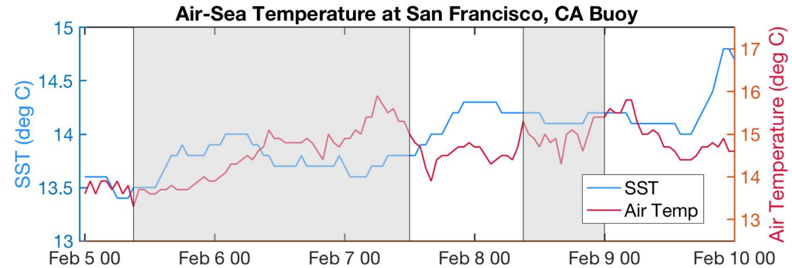


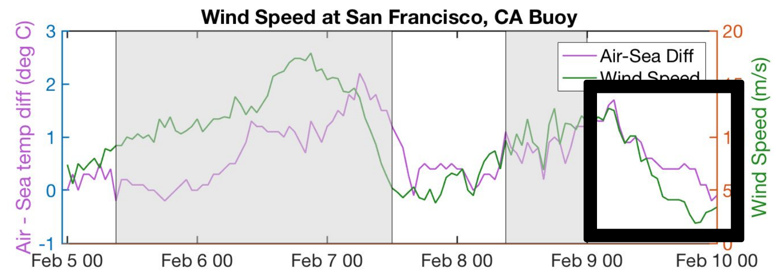


Sharp Decline









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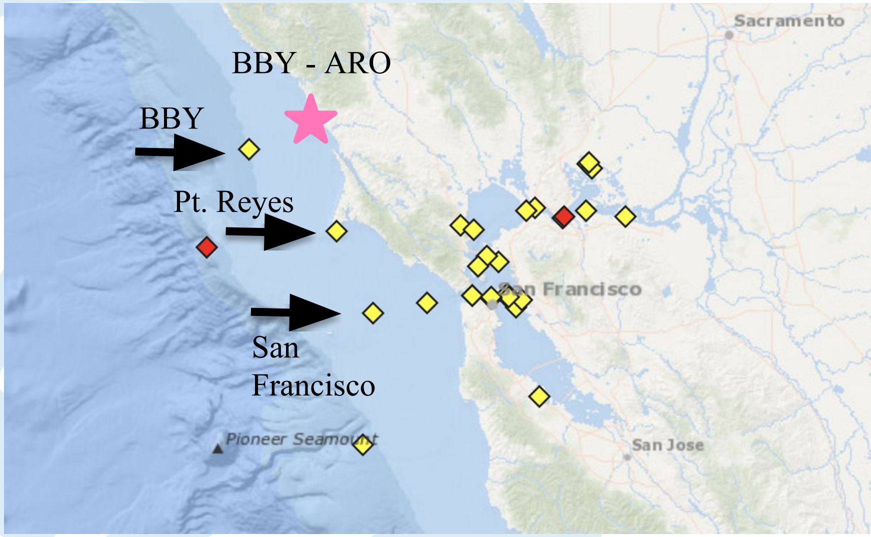

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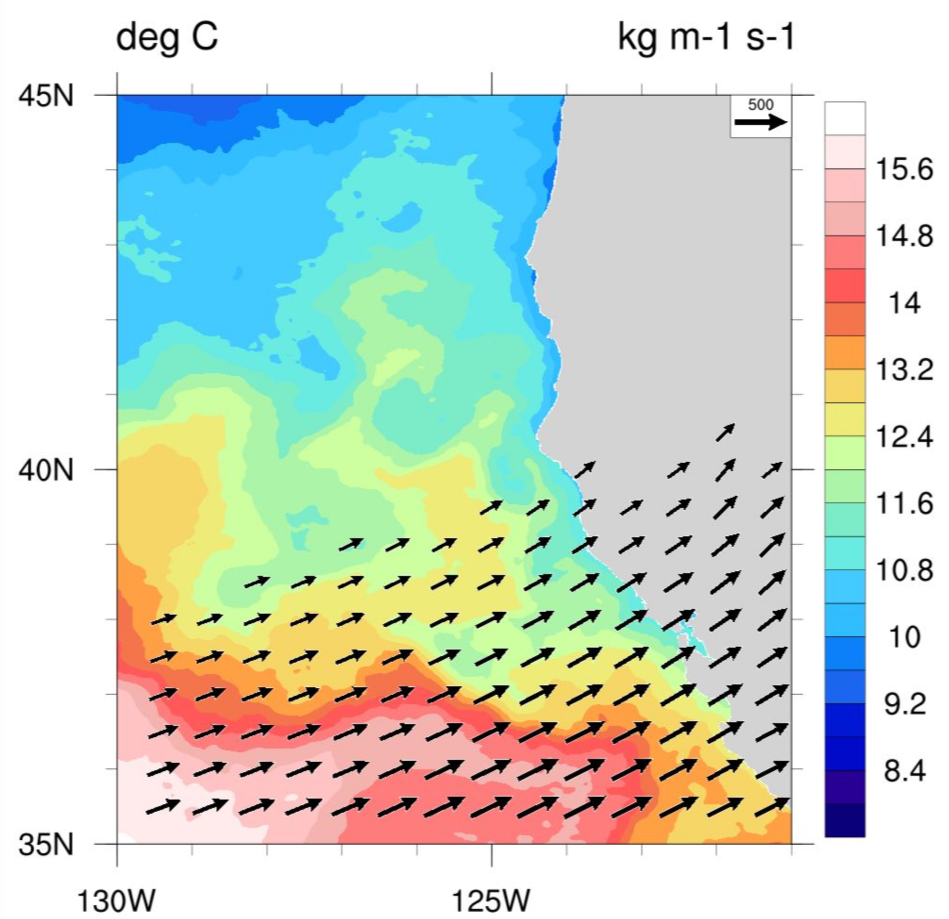

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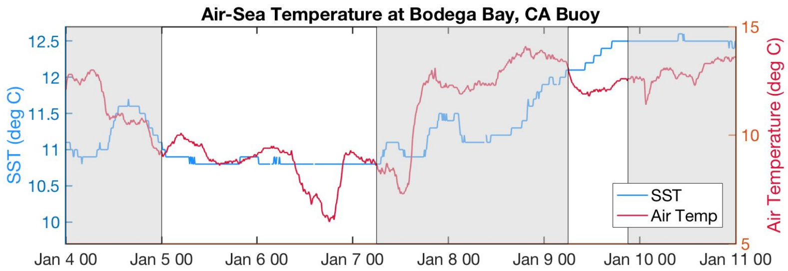

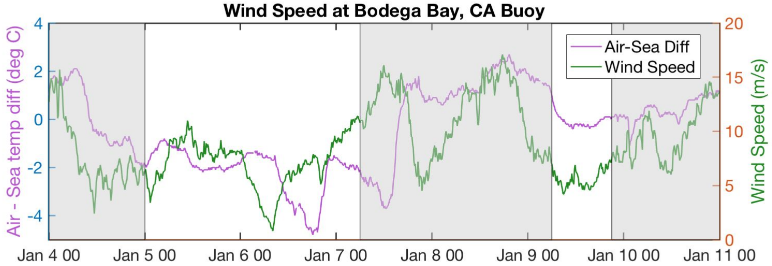

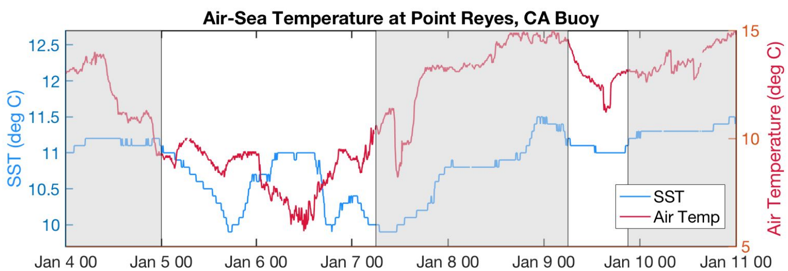

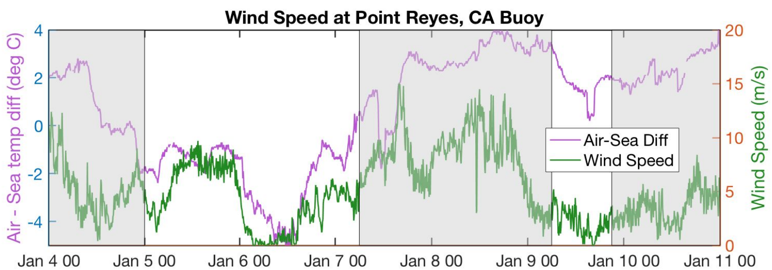

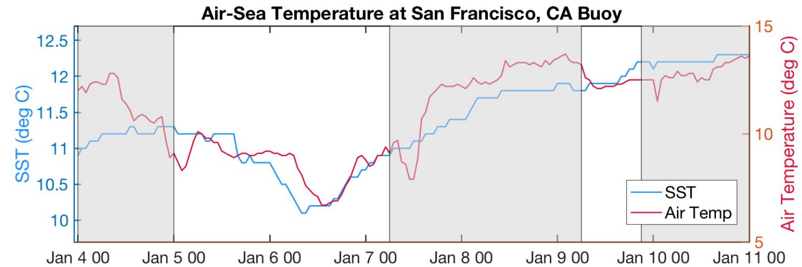

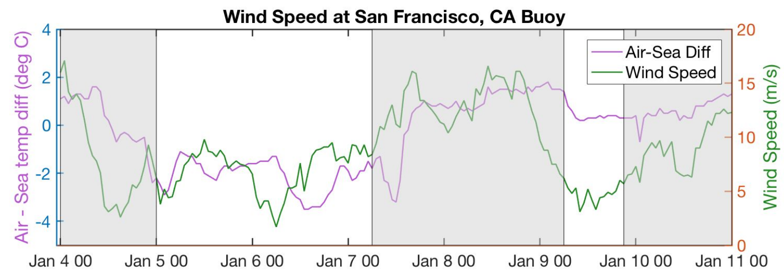

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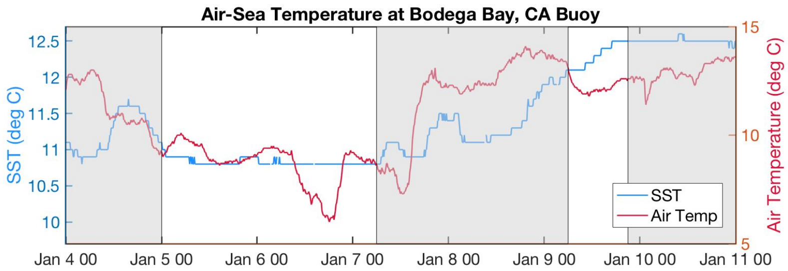

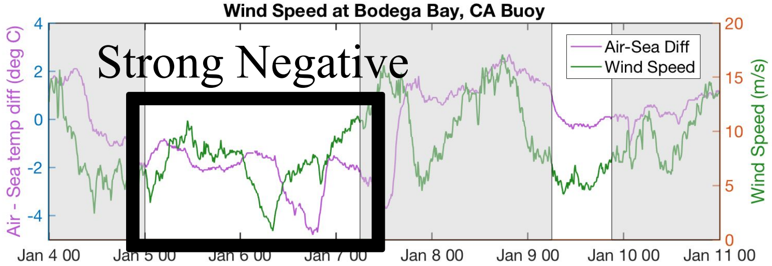

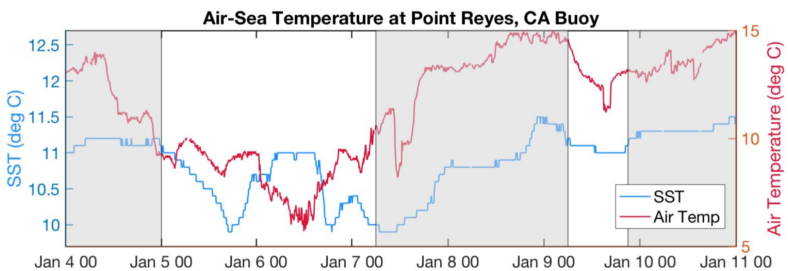

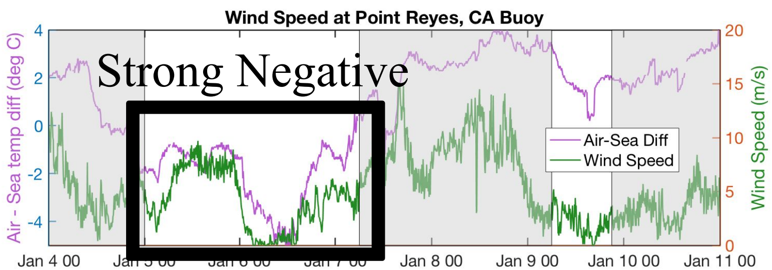

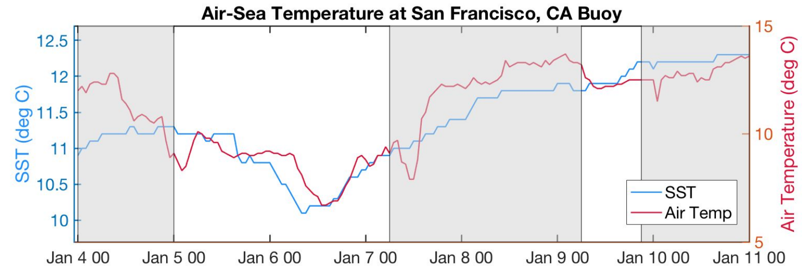

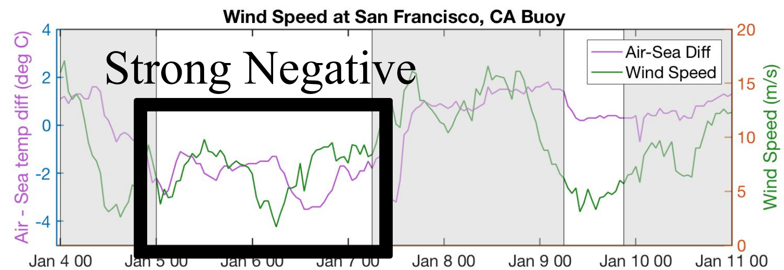

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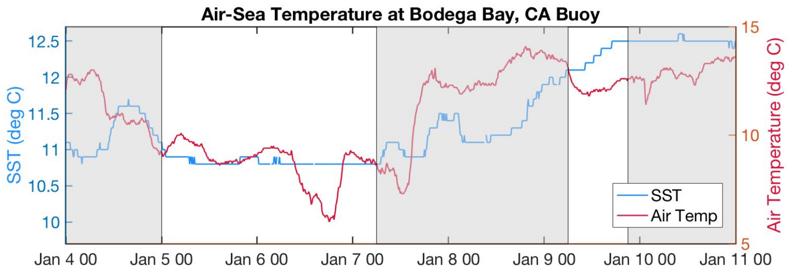
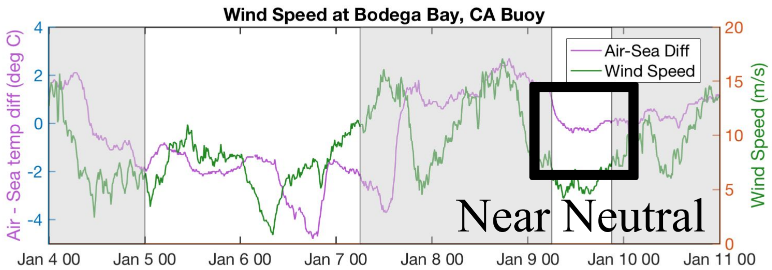
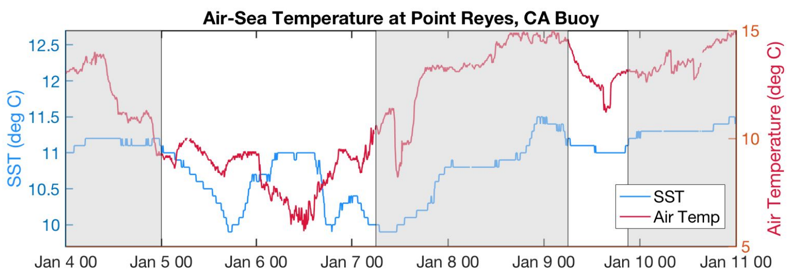
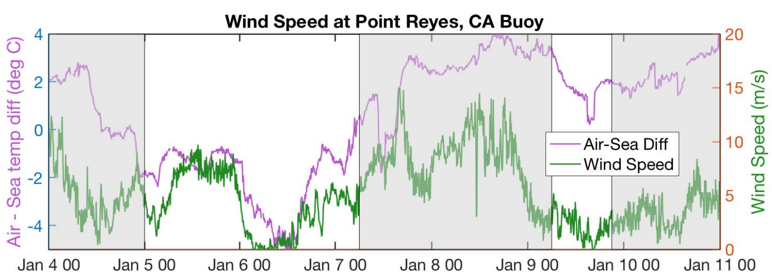
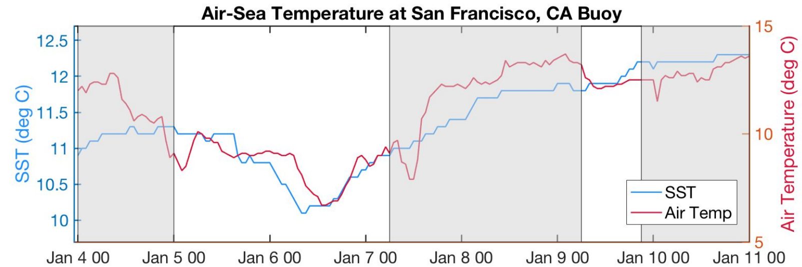
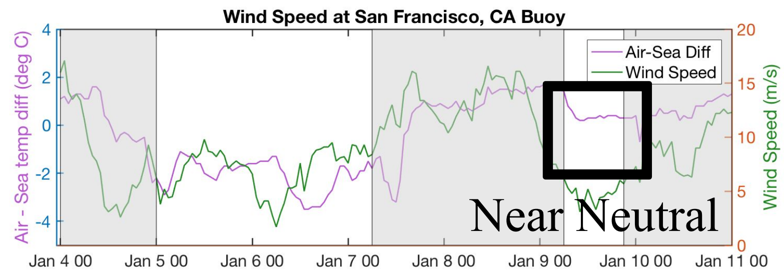






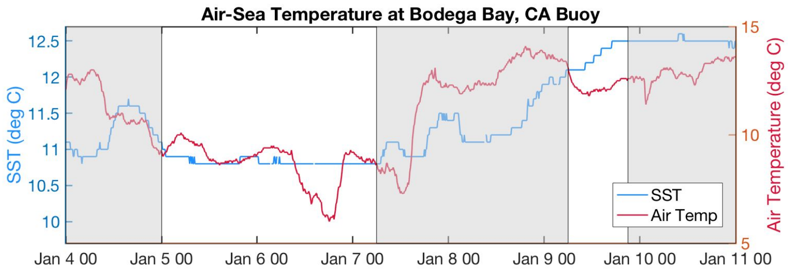


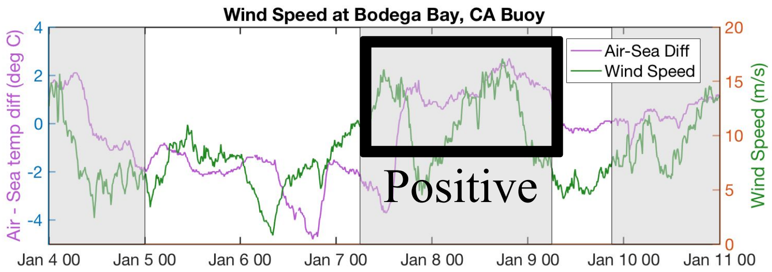


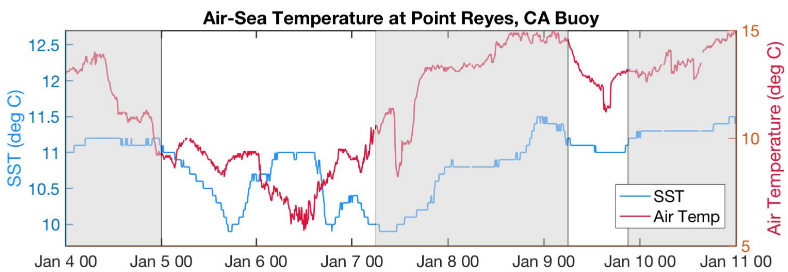


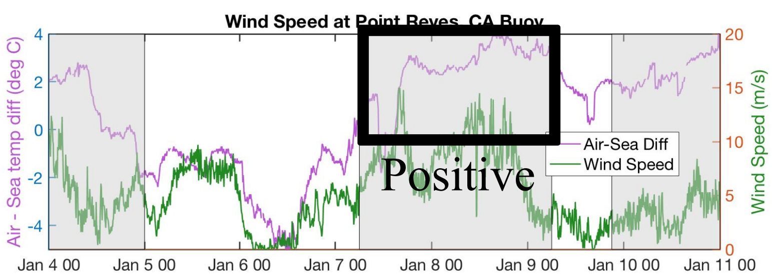
Top. SST (blue, deg C) and air temperature (red, deg C) from 00 UTC February 5-10, 2015.
Below. Wind speed (green, m/s) from 00 UTC February 5-10, 2015.
Gray shading indicates AR periods.

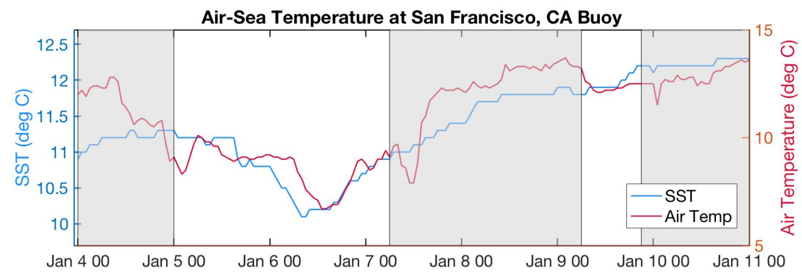
<u>Case Study #2:</u> January 4-11, 2015

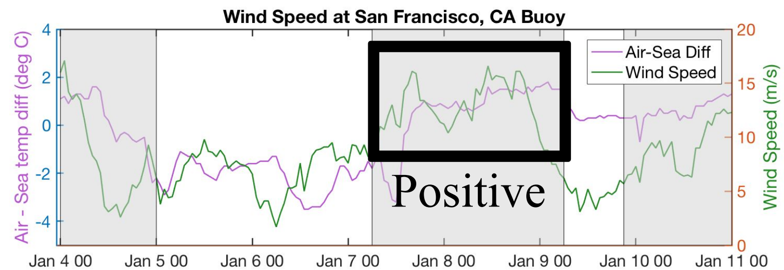












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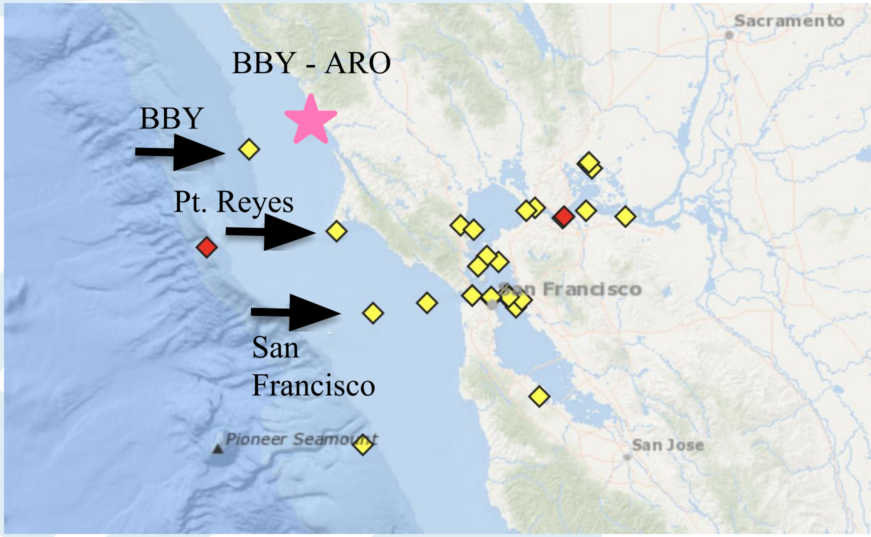
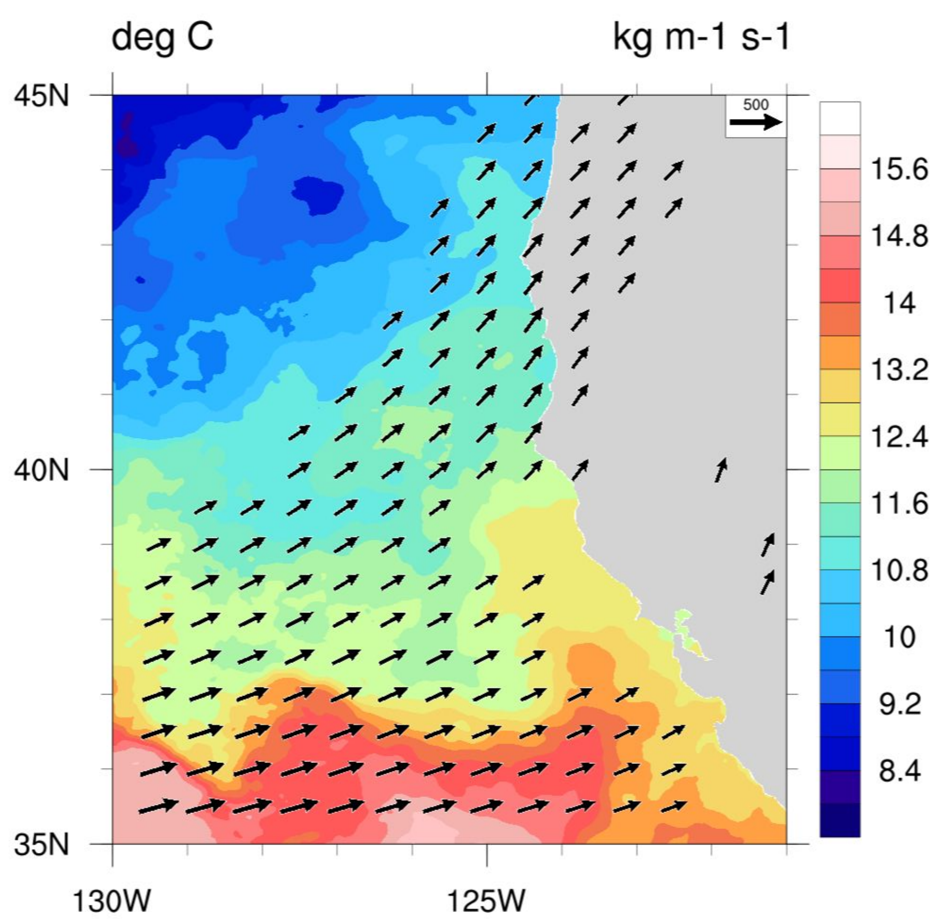
Case Study #3: February 15-21, 2017

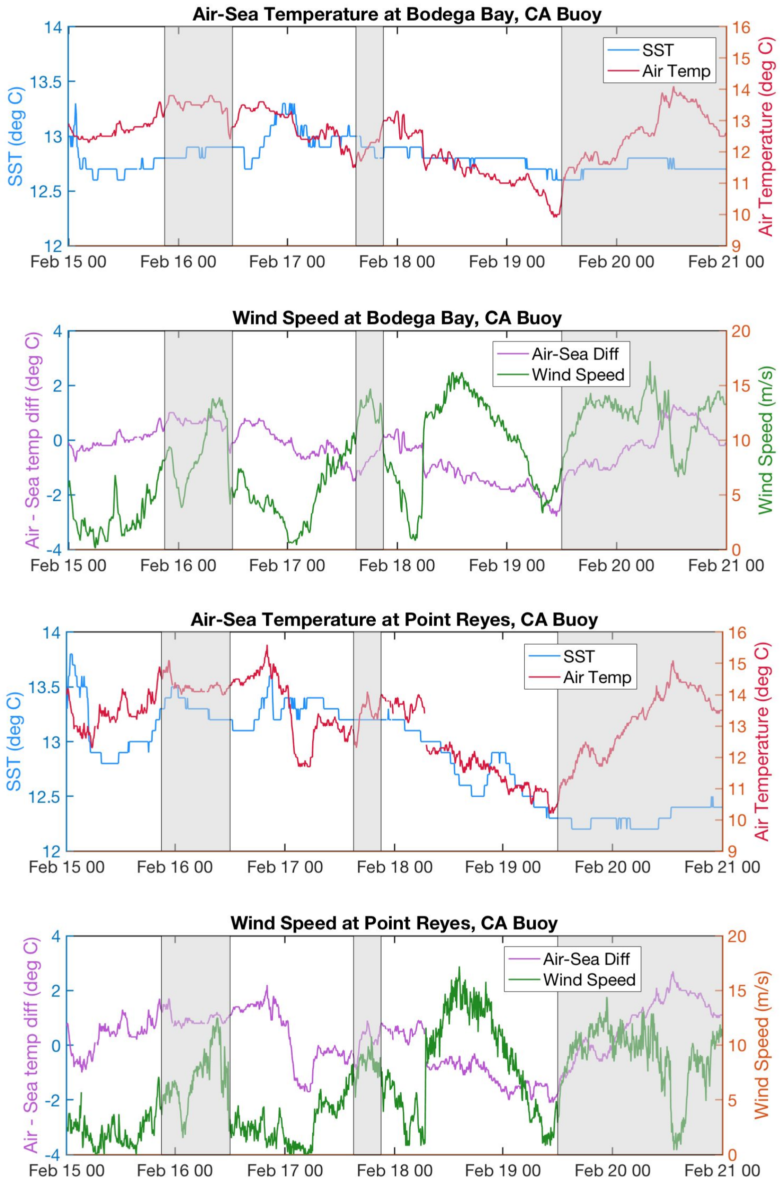


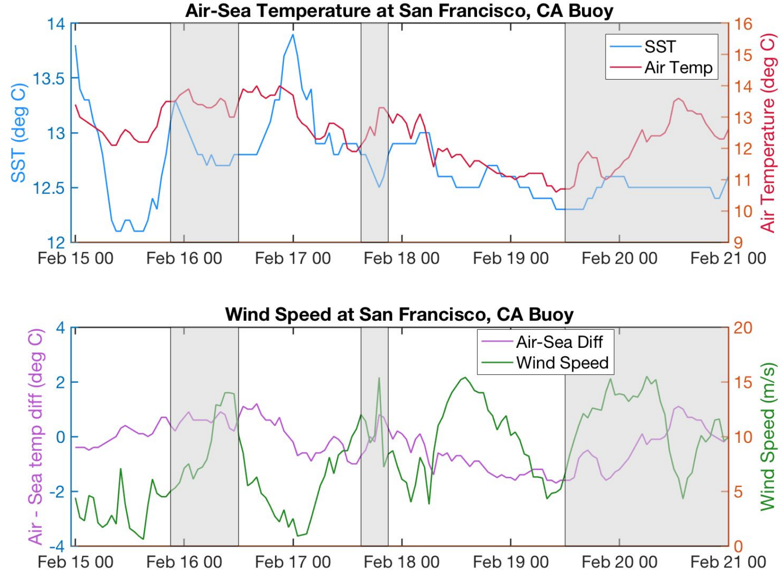
Map of Northern CA, showing ocean buoy locations of Bodega Bay (BBY), Point Reyes and San Francisco.

Case study average of IVT (vectors) and SST (color shaded) from February 15-21, 2017.



Case Study #3: February 15-21, 2017





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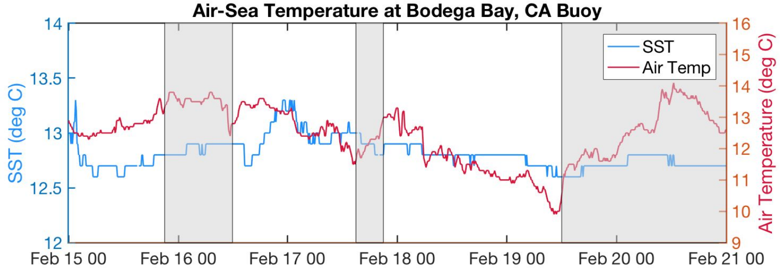

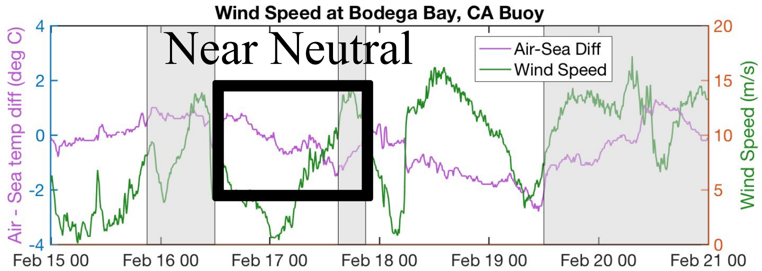

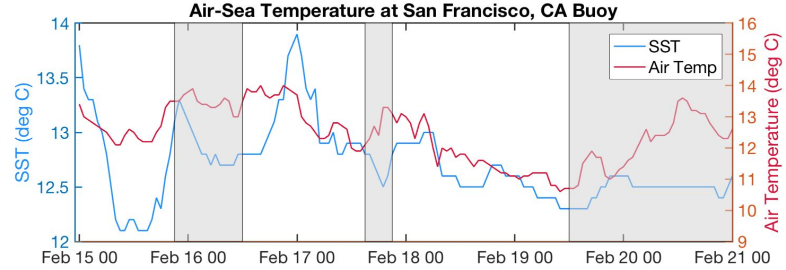

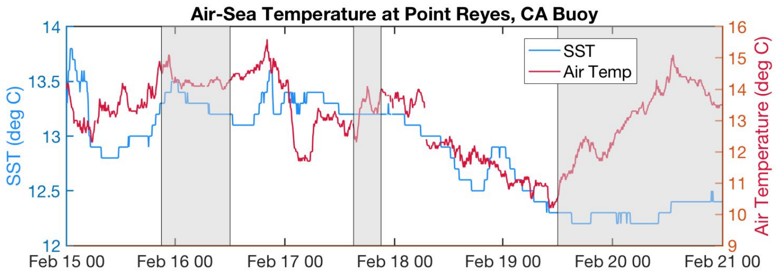

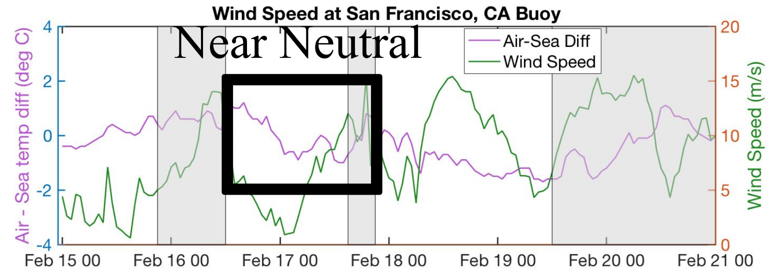

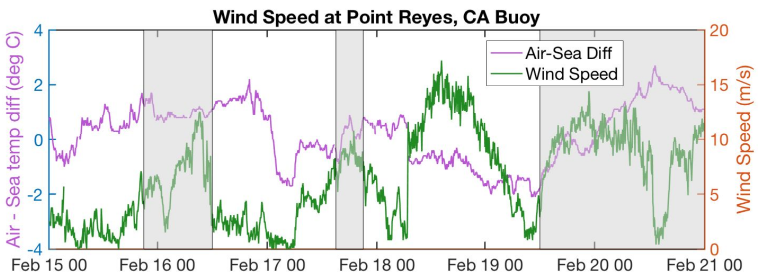

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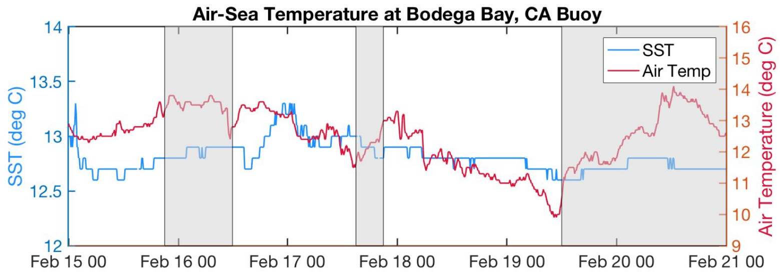

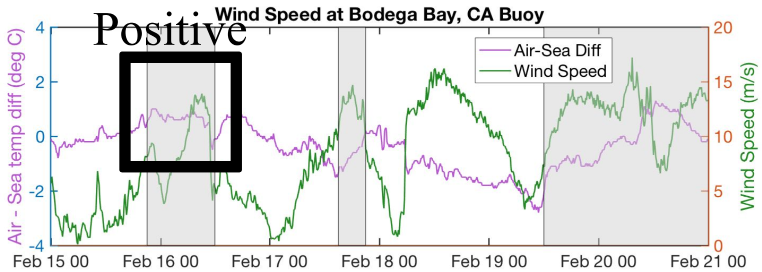

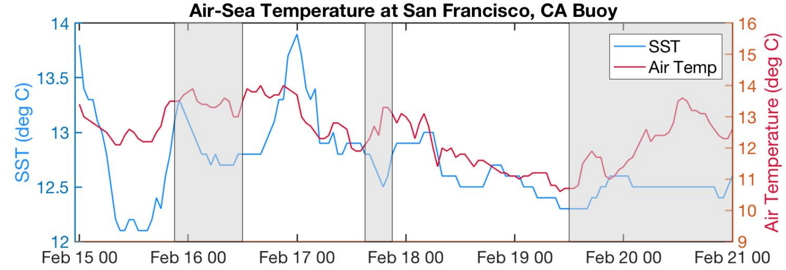

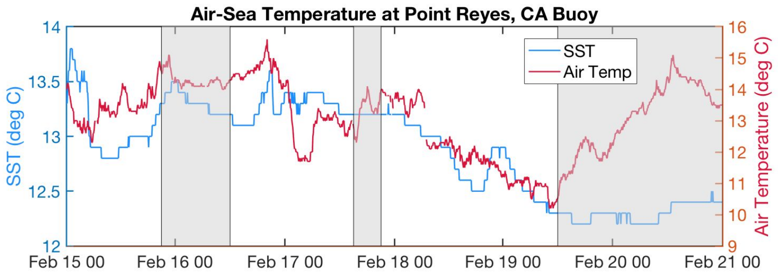

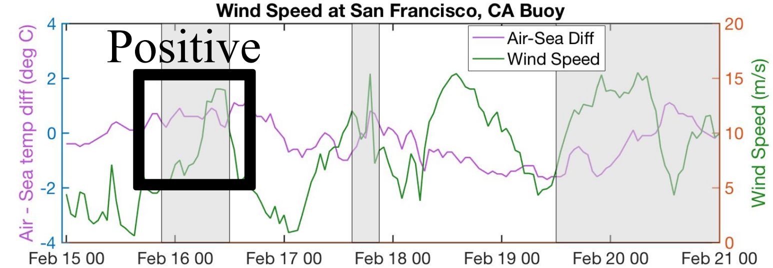

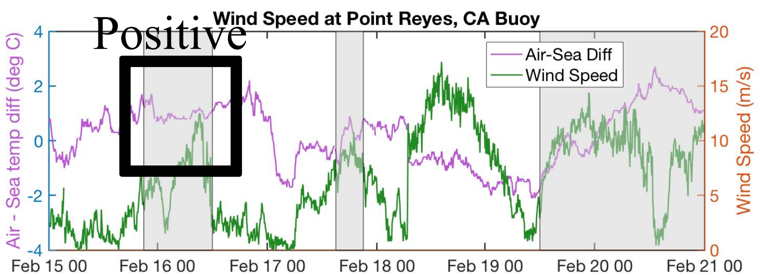

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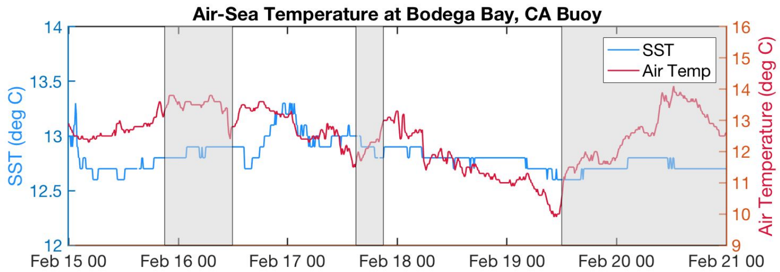

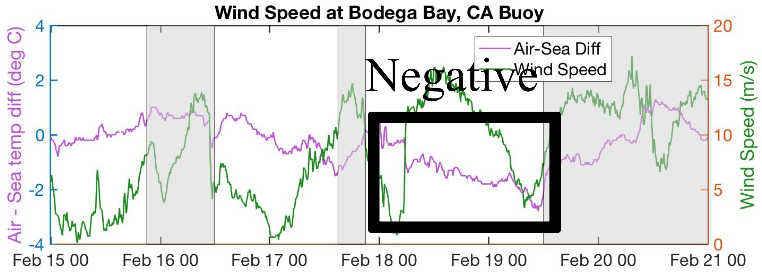

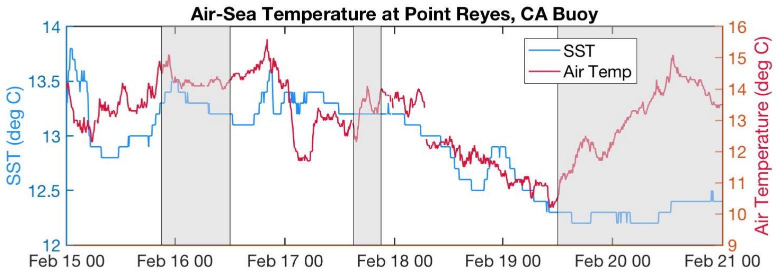

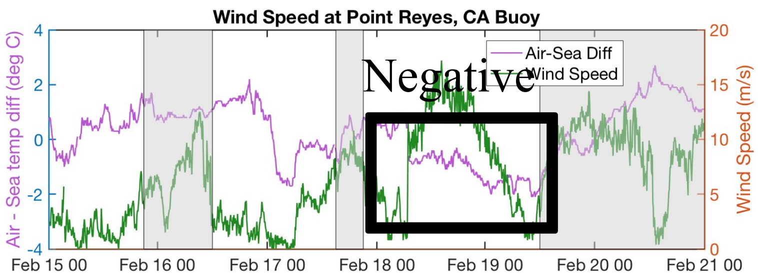

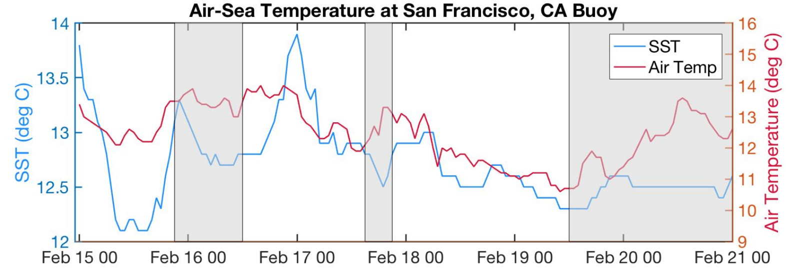

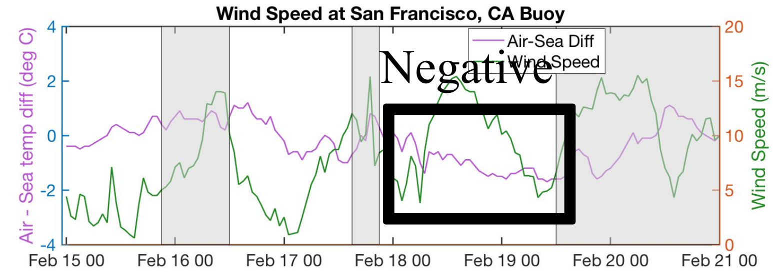

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Center for Western Weather and Water Extremes

UC San Diego

Northern CA spatial standard deviation

Region: 35 to 39N, -127.136 to -118.0 W

Top 10 2-day precipitation total dates	Standard deviation T	Standard deviation T-1 day	Standard deviation T-2 day	Standard deviation T-3 day
1/8/2017	0.3154	0.3250	0.3411	0.3701
12/31/2005	0.3557	0.3629	0.3769	0.4023
12/14/2002	0.3919	0.3785	0.3777	0.3780
1/4/2008	0.3109	0.3259	0.3216	0.3282
1/9/2017	0.2804	0.3154	0.3250	0.3411
11/30/2012	0.5193	0.5141	0.5066	0.4308
1/5/2008	0.2794	0.3109	0.3259	0.3126
10/24/2010	0.5003	0.5220	0.5301	0.5116
12/1/2012	0.5298	0.5193	0.5141	0.5066
11/8/2002	0.4727	0.4508	0.4162	0.4264

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12/14/2002	[illegible]	[illegible]	[illegible]	[illegible]0
1/4/2008	[illegible]	[illegible]	[illegible]	[illegible]2
1/9/2017	[illegible]	[illegible]	[illegible]	[illegible]1
11/30/2012	[illegible]	[illegible]	[illegible]	[illegible]
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AR = red

90% of top 2-day precipitation totals are from ARs

Northern CA spatial standard deviation

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11/8/2002	0.4727	0.4508	0.4162	0.4264

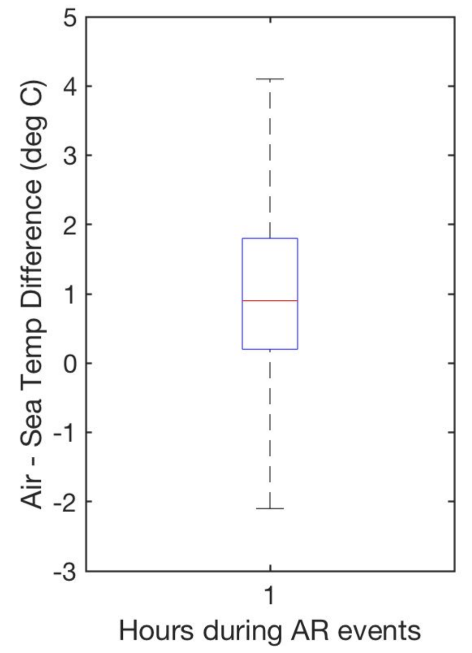
Northern CA spatial lag correlation

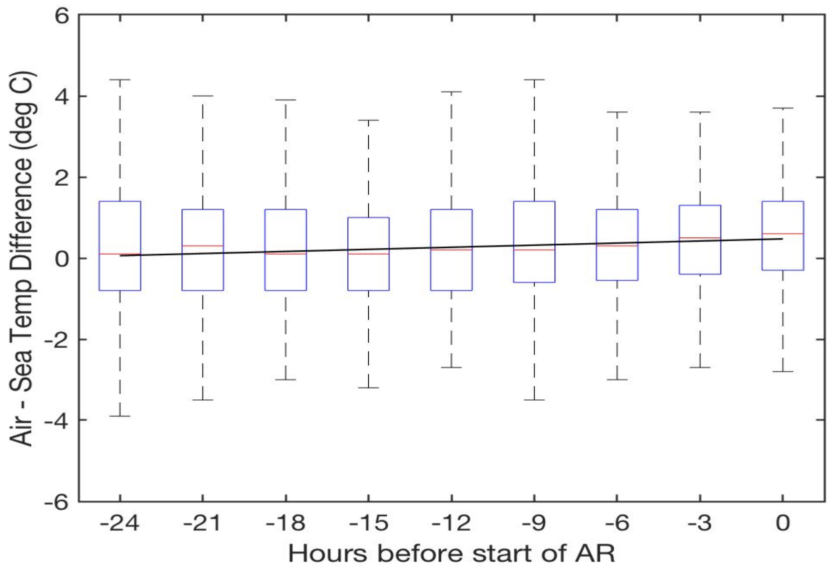
Region: 35 to 39N, -127.136 to -118.0 W

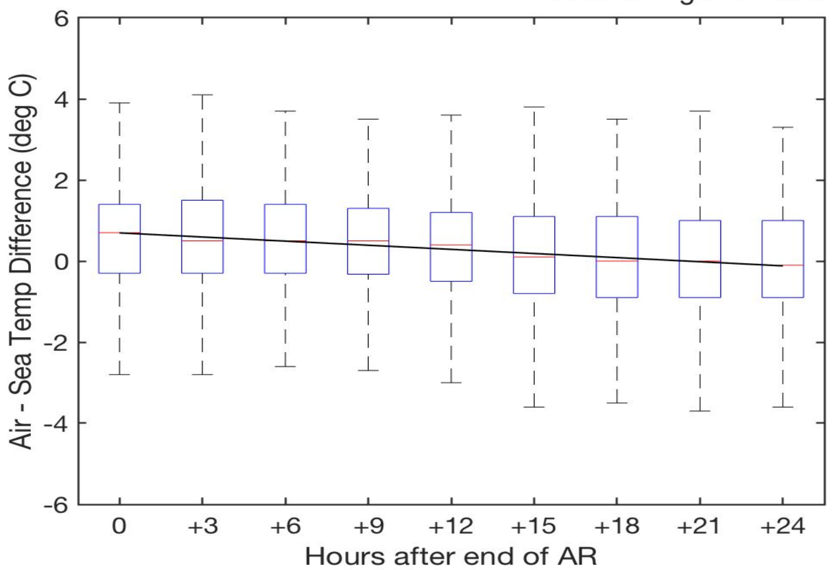
Top 10 2-day precipitation total dates	Correlation coefficient T	Correlation coefficient T-1 day	Correlation coefficient T-2 day	Correlation coefficient T-3 day
1/8/2017	1.0	0.99984	0.99986	0.99986
12/31/2005	1.0	0.99976	0.99992	0.99985
12/14/2002	1.0	0.99984	0.99993	0.99995
1/4/2008	1.0	0.99962	0.99954	0.99988
1/9/2017	1.0	0.99954	0.99984	0.99986
11/30/2012	1.0	0.99996	0.99993	0.99994
1/5/2008	1.0	0.99989	0.99962	0.99954
10/24/2010	1.0	0.99984	0.99994	0.99995
12/1/2012	1.0	0.99985	0.99996	0.99993
11/8/2002	1.0	0.99940	0.99976	0.99984

Point Reyes, CA Buoy
Air Sea Temperature Difference

- Median subtly increases prior to AR start; subtly decreases after AR ends
- During AR air sea temp difference is positive
- No consistent precursor changes to the AR, during the AR primarily positive air-sea differences, post AR slightly more pronounced decline consistent with post-frontal cooling

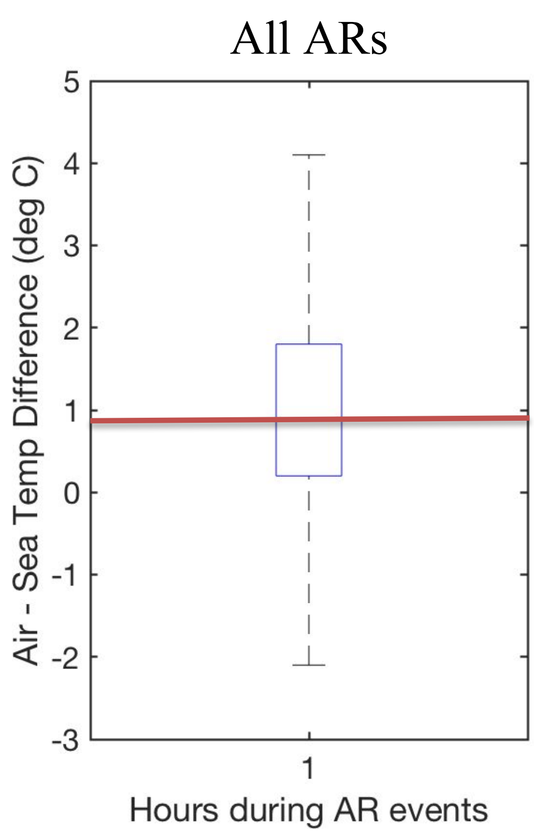


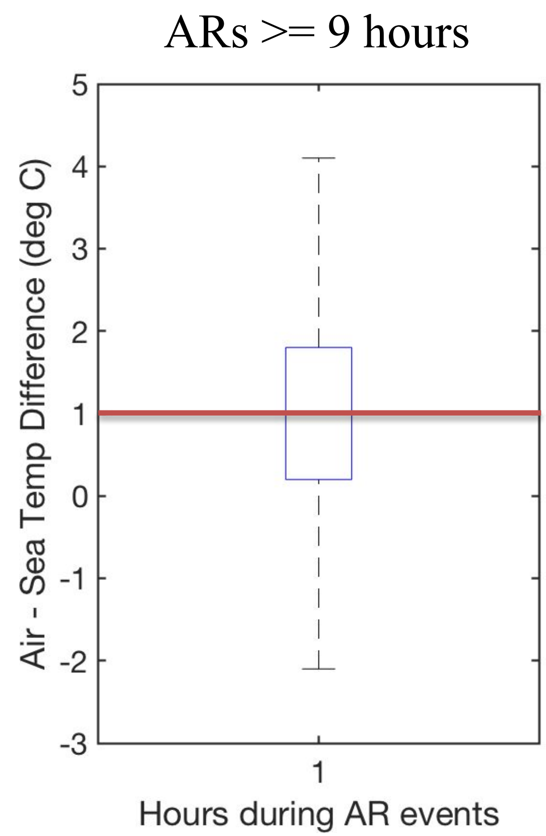




Point Reyes, CA Buoy
Air Sea Temperature Difference

- During AR hours the air-sea difference is greater than 1°C and doesn't change during longer duration ARs
- During the AR the range of air-sea flux is from -2 to +4 deg C
- Does this positive difference help to stabilize the atmosphere within the AR and hinder convection?





Conclusions:

- We are just at the tip of the iceberg beginning to understand the small scale variability of SST and its potential impact on ARs
- A case by case analysis of individual events would allow for further investigation into the physical processes
- West-WRF is able to capture the latent heat minima within the core of the AR
- Air sea temperature differences at these locations and the variability is also captured at these locations
- During ARs there is a positive air-sea flux
- The rebound time of SST is longer than the time scales of ARs
- The range of air-sea flux across these events was from -5 to +4 deg C

Future Work:

- Further buoy analysis at other coastal locations
  - Cape Mendocino, CA
  - Tanner Bank, CA
- Further work into understanding the comparison between West-WRF and observations
- Detect changes of the AR prior, during and after the event
- Determine which changes are significant and does the model capture many of these changes
- Evaluate outliers in the data to determine if accurate or if changes are due to QC issue