Satellite Water Temperature Indicator for Chesapeake Bay

Indicator Development and Cross-comparison with Chesapeake Bay Program Monitoring Data

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CBP Climate Resiliency Workgroup Meeting

June 15, 2020

Climate Change and Chesapeake Bay

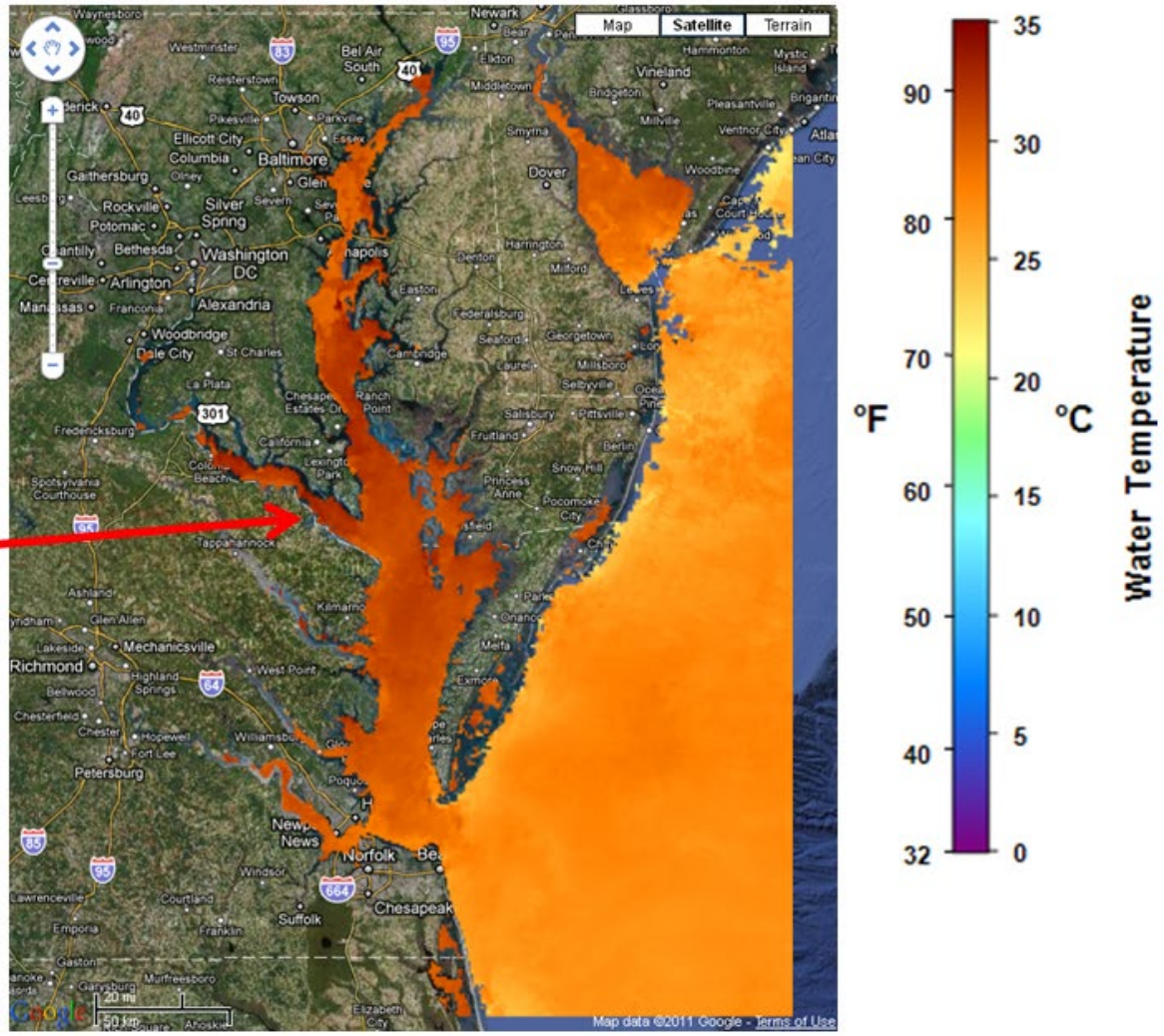
Public Interest: Are water temperatures rising? How fast?

Satellites give a synoptic spatial view of water temperature

NOAA Satellite
Water Temperature
from AVHRR

July 23, 2011

Mid-Chesapeake Bay and Potomac River at 90+ °F (up to 34 °C)



Outline

- Project Background
- Data Description & Indicator Development
- Data Cross-comparison Study with In-situ Data
- Indicator Web Display
- Next Steps

Project Background

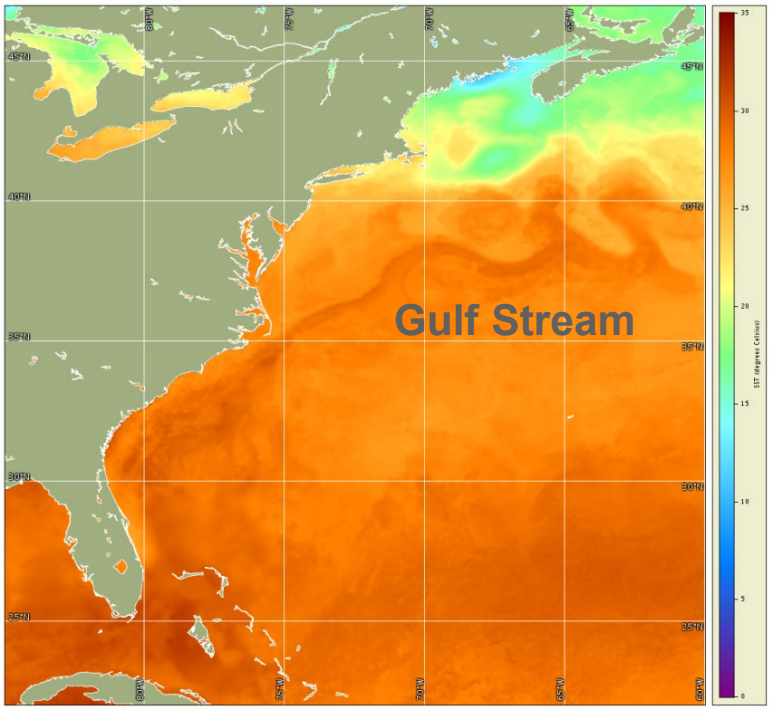
- Initiated by EPA National Estuary Program
  - Goal: To develop water temperature indicators for U.S. estuaries using satellite data, *because most U.S. estuaries do not have monitoring programs*
  - Discussions between EPA, NASA, NOAA on satellite data sources, selection of data sets, implementation plan
  - NOAA CoastWatch is developing the nationwide indicator, currently in Phase 2
- Chesapeake Bay added by NOAA to EPA NEP's initial pilot estuaries
- Feedback obtained from NEP estuarine managers for the pilot estuaries
- Evaluated as potential Chesapeake Bay Water Temperature Indicator by CBP
  - CBP-contracted ERG Indicators Study, 2017
  - CBP Indicators Implementation Plan, 2018

Satellite Sea Surface Temperature (SST)

Long Data Series:
'Multiscale Ultrahigh Resolution (MUR) SST'

- From NASA Jet Propulsion Lab / Physical Oceanography Distributed Active Archive Center
- 2002 – present
- Daily, global, cloud-free
  - Data from all available satellites (infrared, microwave) blended together
  - Data assimilated with global in-situ SST data from NOAA iQuam database to account for differences in the source data sets
  - New data added on a daily basis
- 1 km spatial resolution
- Surface water temperature only

July 30, 2015

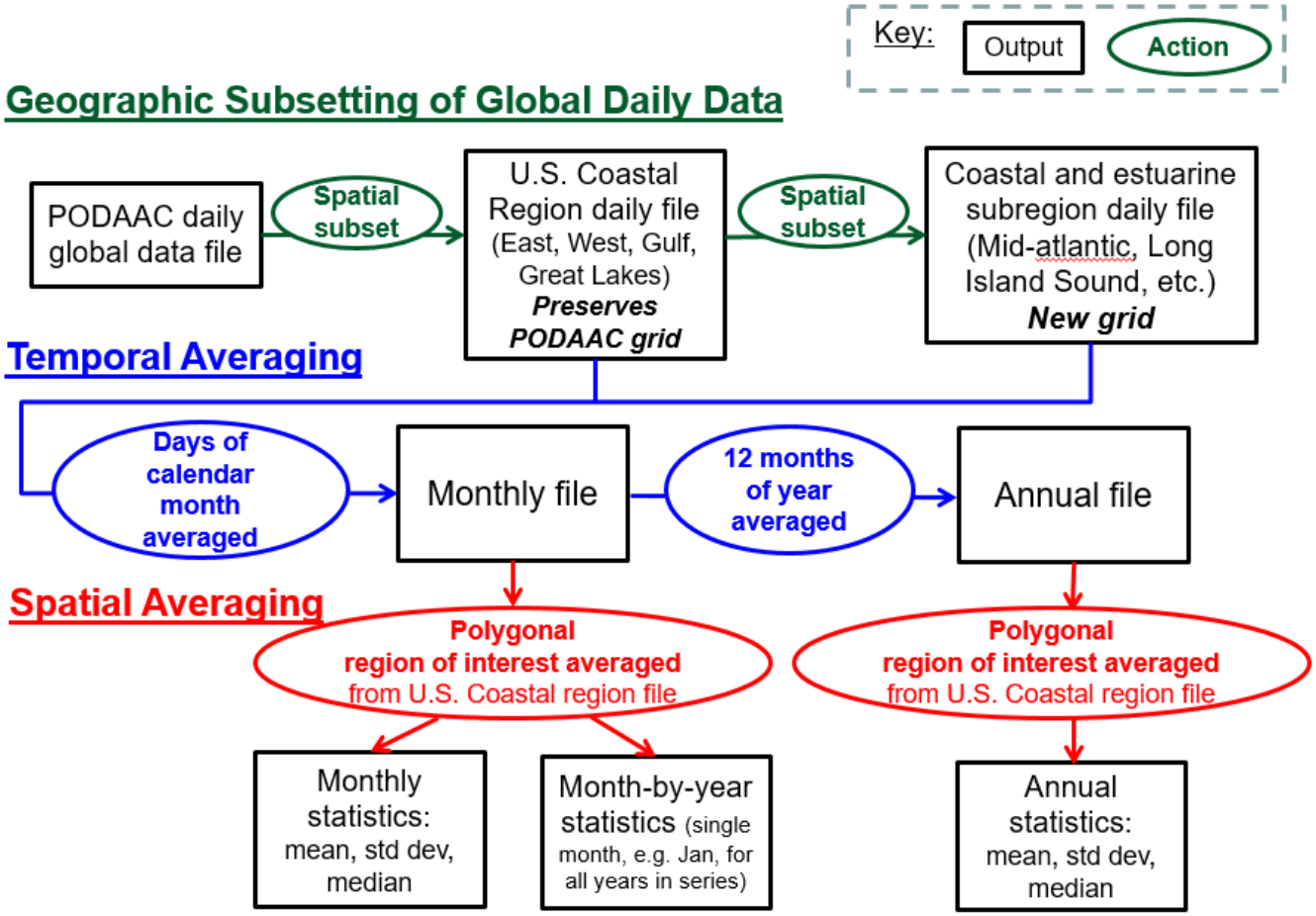


Satellite Sea Surface Temperature (SST)

Long Data Series:
'Multiscale Ultrahigh Resolution (MUR) SST'

- **Advantages** as an indicator
  - Data points at 1km grid spacing, resolution adequate for most estuaries
  - Capitalizes on spatial coverage (global & cloud-free) and spatial resolution (1km) compared to in-situ data (ship-based or buoy/mooring)
  - On-going, new data available daily
  - Daily data is better temporal resolution than ship-based data but not as frequent as buoy/mooring data
  - Automated processes calculate monthly & annual statistics for web display
- **Disadvantages**
  - Surface water only
  - Only available back in time to 2002
  - Nighttime temperature estimation – need to take diurnal bias into account when comparing with daytime or day-night combined data sets

Temperature Climate Indicator Methodology



Methodology follows CBP STAC 2008 climate change report:

Pyke et al., 2008, Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations, Chesapeake Bay Program Science and Technical Advisory Committee (STAC), Annapolis, MD.

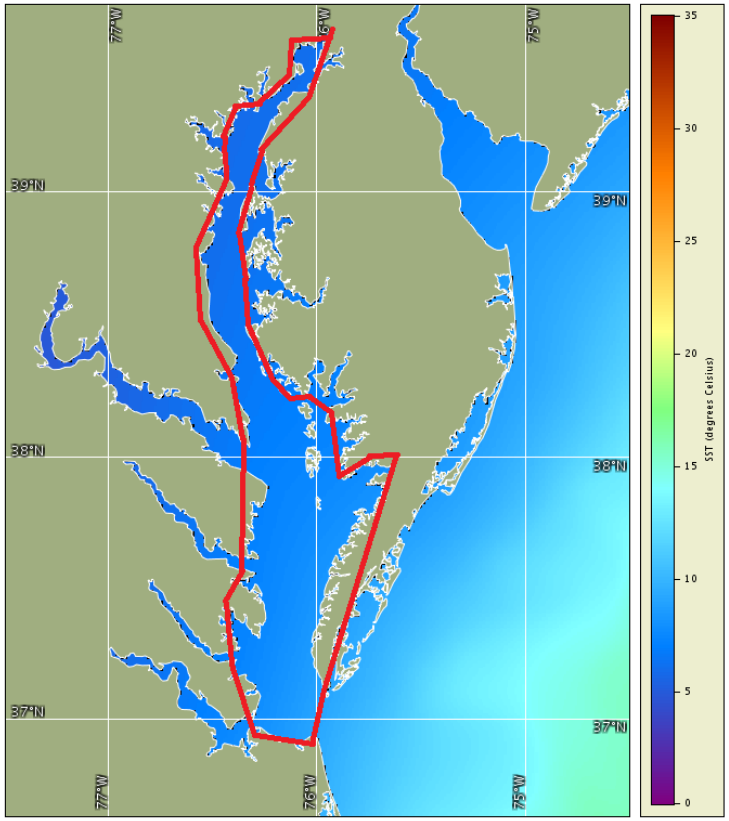
How good is satellite MUR SST data?

Validation comparison study with in-situ data

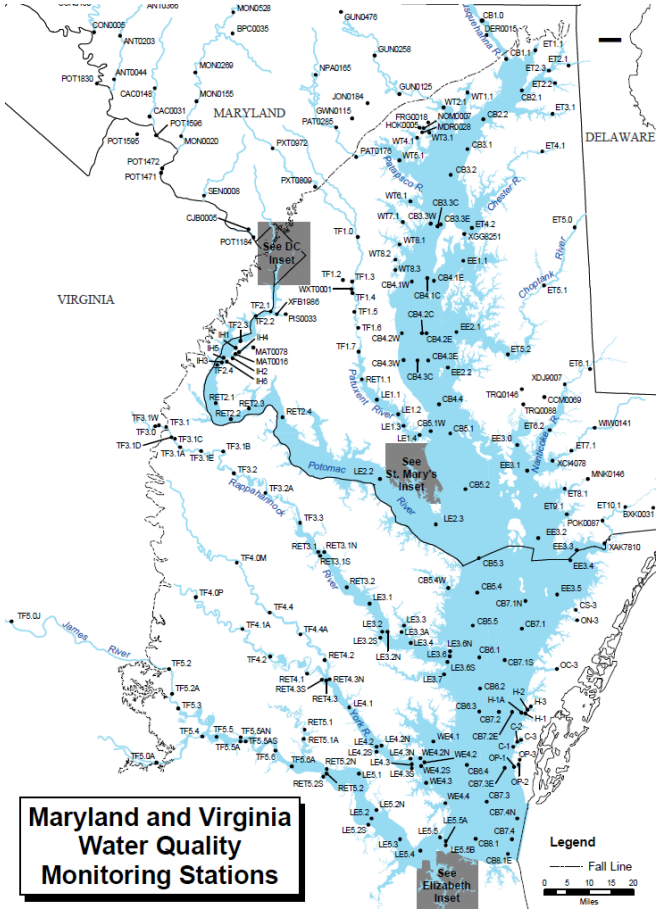
Study Area: Chesapeake Bay

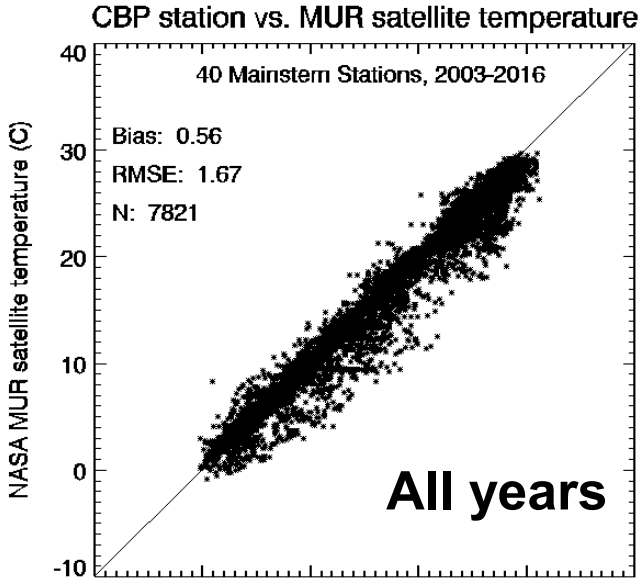
Satellite MUR region averaged:

Main bay only, no tributaries



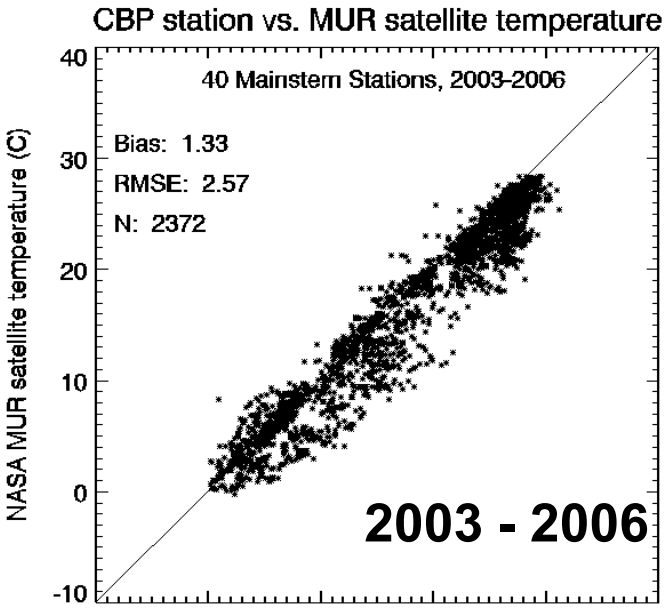
Chesapeake Bay Program water quality monitoring stations: used 40 monthly or bi-monthly stations

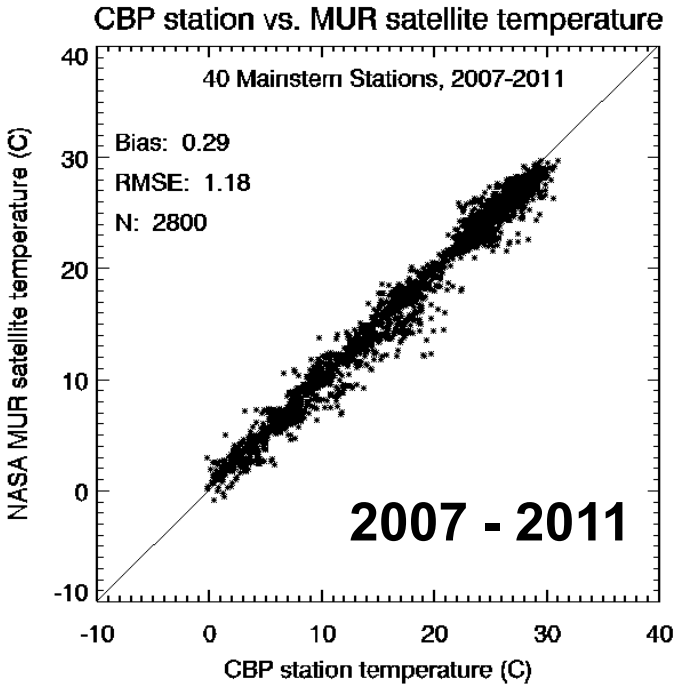




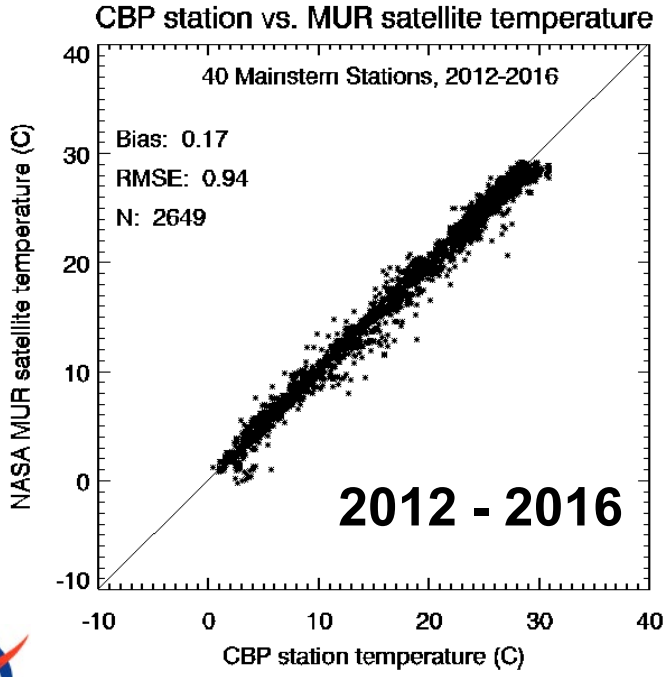
Scatter plots of CBP vs MUR temp

By year





2012-2016:
Lowest bias
Lowest RMSE

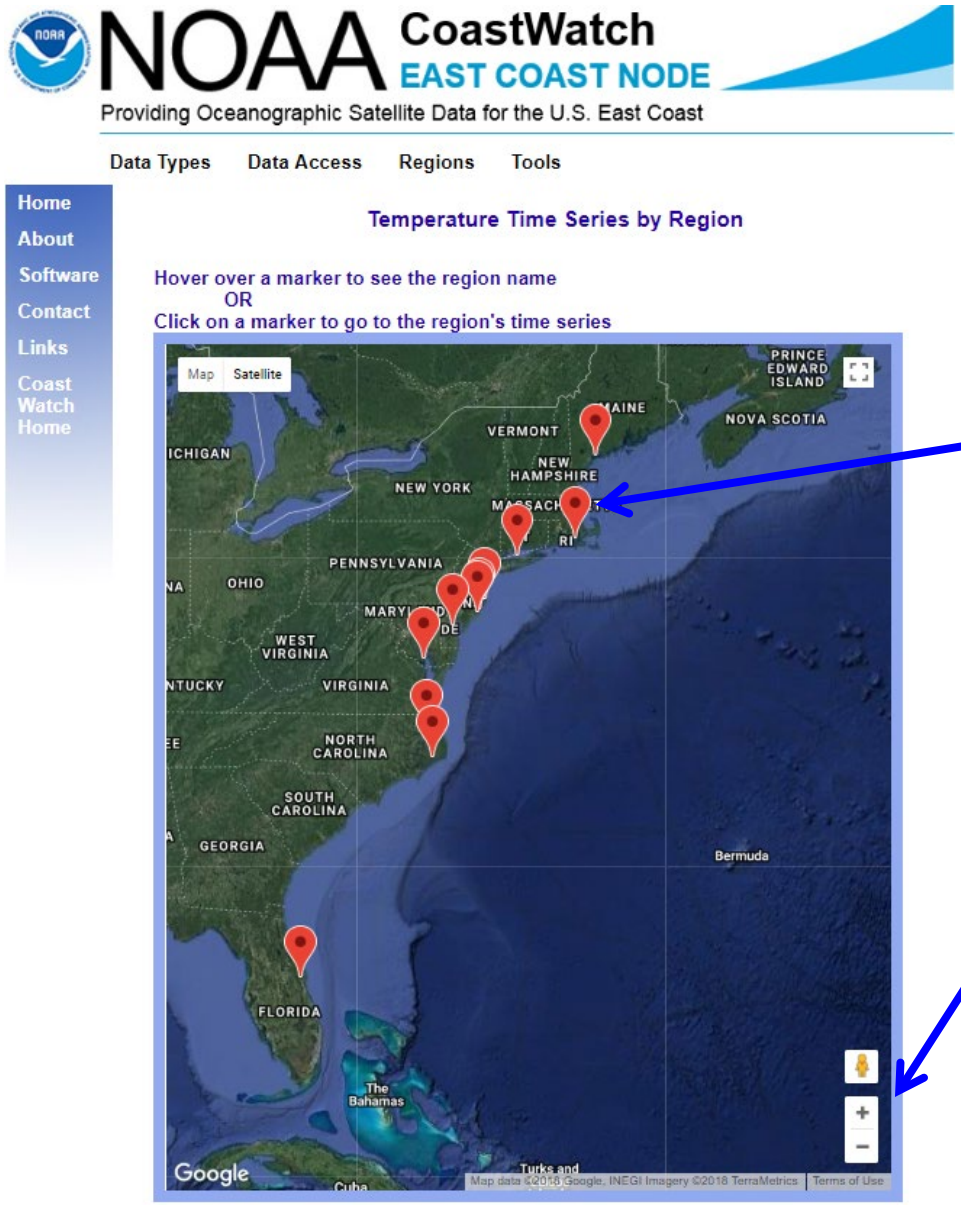


Validation Comparison Result

- Bias and variability for Chesapeake Bay are higher in the satellite data for earlier time periods (satellite underestimates)
- In discussion with NASA/JPL dataset PI:
  - Earlier period (2002-2006) has errors because it uses older versions of two of the input satellite data sets
  - NASA will reprocess the earlier period to correct the errors
- As a result, only data from 2007–present are used in the indicator, to exclude earlier high-variability data
- When the corrected data is available from NASA, the climate indicator will be updated to extend back to 2002

Climate Indicator Web Display:

https://eastcoast.coastwatch.noaa.gov/time_series_sst_regions.php



Climate Indicator Web Display:

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NOAA CoastWatch
EAST COAST NODE
Providing Oceanographic Satellite Data for the U.S. East Coast

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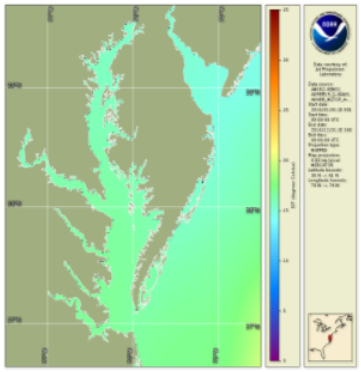
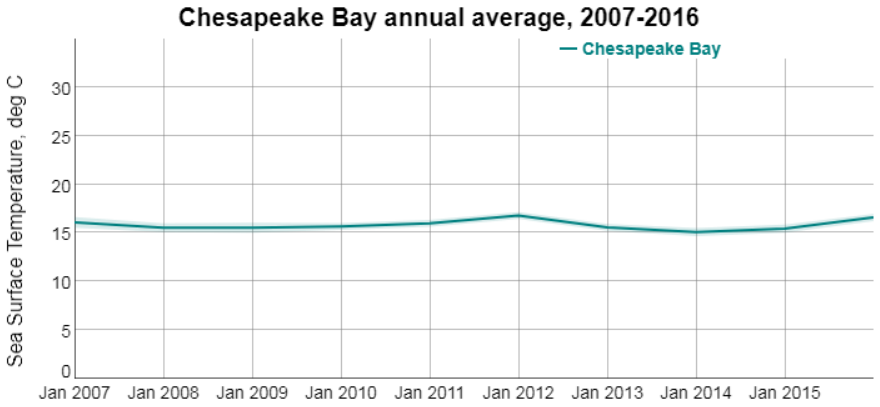
Chesapeake Bay Temperature Time Series 2007-2016



Chesapeake Bay Temperature, 2016 Annual Average

Select a Time-Averaging Interval: Annual ▾

Generate Time Series



Annual Average map, current year

<u>Drop-down list:</u> select annual or month of interest

Annual Average series, all years

Link to statistics ASCII text files

Climate Indicator Web Display:

https://eastcoast.coastwatch.noaa.gov/time_series_sst_regions.php

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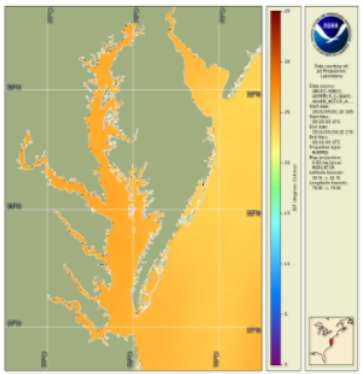
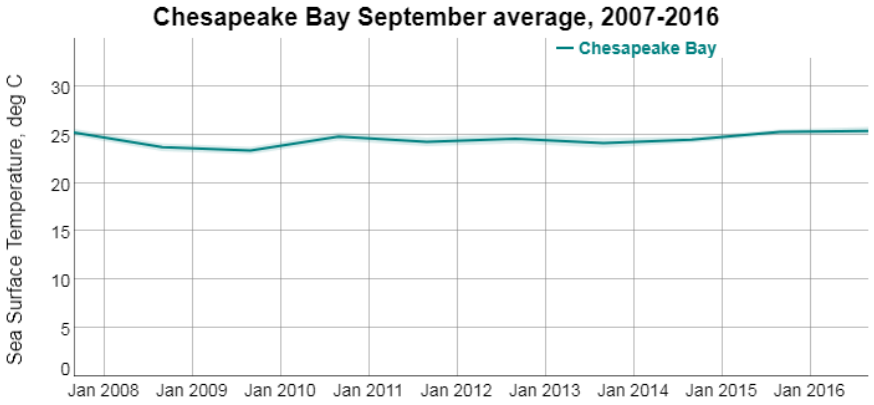
Chesapeake Bay Temperature Time Series
2007-2016



Chesapeake Bay Temperature, September 2016 Monthly Average

Select a Time-Averaging Interval: Annual ▾
Generate Time Series



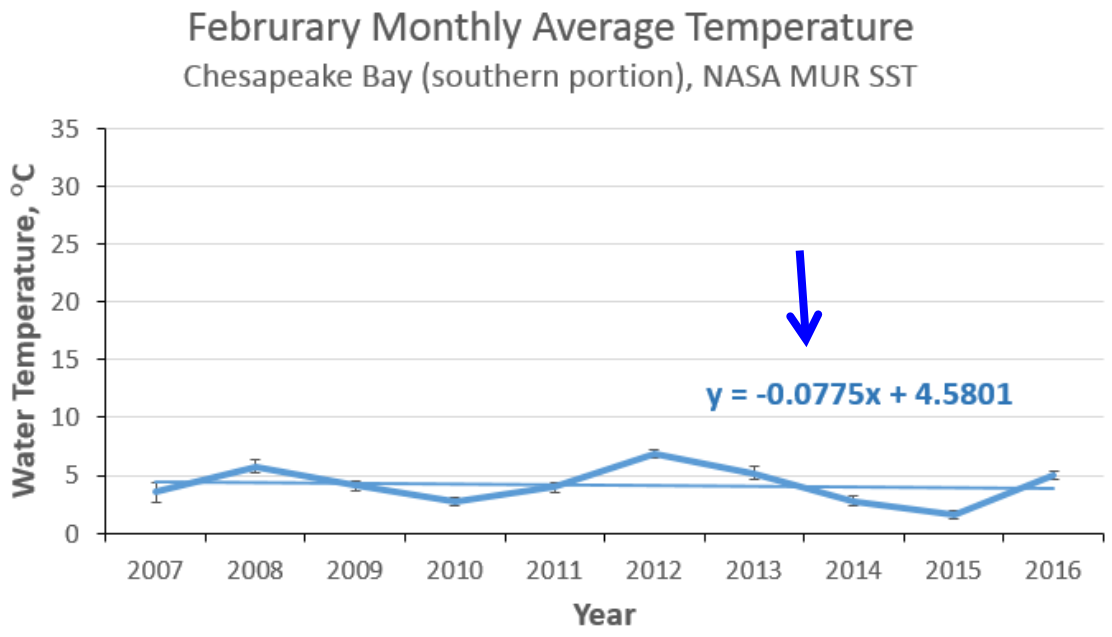
September Average map, current year

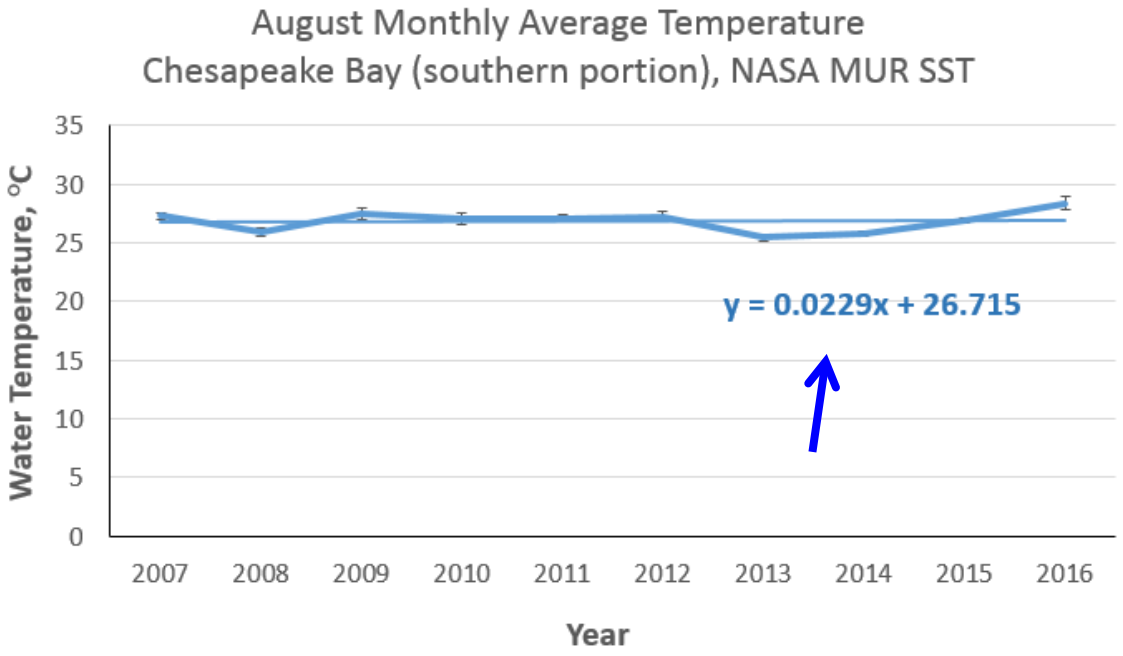
September Average series, all years

Link to statistics ASCII text files

What are the seasonal differences?

Is there more change in a particular season?





Water Temperature Indicator Next Steps

- For EPA NEP / NOAA:
  - expand indicator to 28+ estuaries in NEP
  - expand to NOAA's National Estuarine Research Reserves
  - eventually expand to all U.S. estuaries
- For Chesapeake Bay: work with CBP & partners on a multi-dataset water temperature climate indicator
  - A multi-dataset temperature indicator leverages the advantages of different data sets:
    - Satellite temperature adds excellent spatial resolution, excellent spatial coverage, and good temporal resolution
    - CBP's monthly monitoring data adds excellent temporal coverage (back in time) and temperature by water depth
- Add data back to 2002 when quality improved by NASA
  - OR switch to NOAA satellite climate record back to 1980's ***whichever is available first***

Access the Indicator

- NOAA CoastWatch/OceanWatch:

  provides oceanographic satellite data for understanding and managing our oceans and coasts

  https://coastwatch.noaa.gov

- Temperature Indicator

https://eastcoast.coastwatch.noaa.gov/time_series_sst_regions.php

Contacts

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- Shelly Tomlinson Michelle.Tomlinson@noaa.gov

Backup Slides

Validation Comparison Data Sets

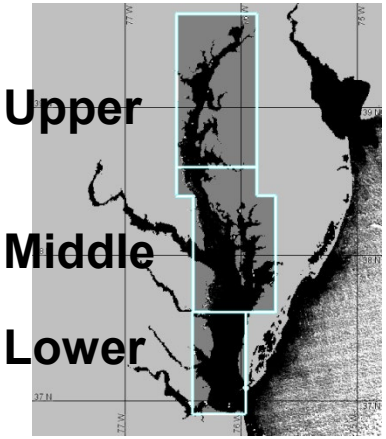
- MUR Satellite Sea Surface Temperature (SST)
  - Daily coverage, multi-satellite blended, cloud-free, 1-km spatial resolution
  - Blending process assimilates in-situ SST measurements to reconcile differences in the satellite inputs
  - Night time SST estimation
  - Surface ‘bulk’ estimation, i.e. ~ top 1 m
- CBP in-situ water quality monitoring program
  - Monthly or bi-monthly water sample collection at multiple depths, including surface (0.5m – 1m).
    - Only surface measurement used in this comparison.
  - 40 of 49 mainstem stations used in this comparison, i.e. all stations except those without data collection Nov-Feb to avoid over-biasing summertime measurements
    - 9 stations not used: CB3.3E,W; CB4.1E,W; CB4.2E,W; CB4.3E,W; 5.4W

Validation Comparison Method

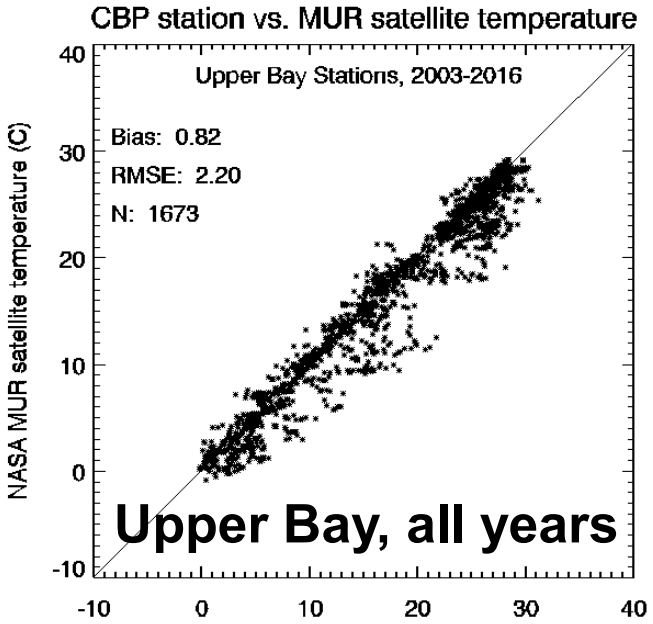
- Study time period: 2003 - 2016
- Match-up: at each CBP station location, MUR 3x3 grid-cell average calculated for day of CBP sample collection (only CBP surface measurement is used)
- Scatter plots of daily CBP temperature vs. daily MUR temperature
  - Histograms of daily CBP-MUR temperature difference also available
- Annual average time series: annual avg calculated the same as CBP STAC 2008 report: monthly avg, then yearly avg, then spatial avg of all stations or grid-cells
  - CBP stations missing a month of data collection are gap-filled using average of all existing mainstem station values for that month (i.e. monthly Bay-wide CBP avg is used to fill missing station-months)

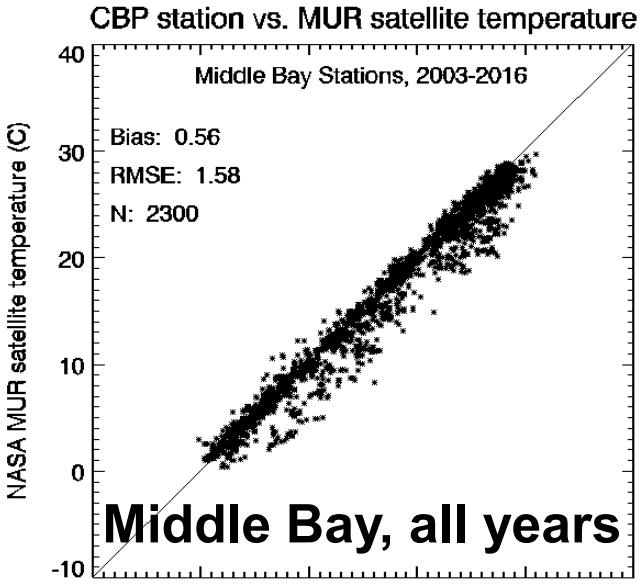
Scatter plots of CBP vs MUR temp

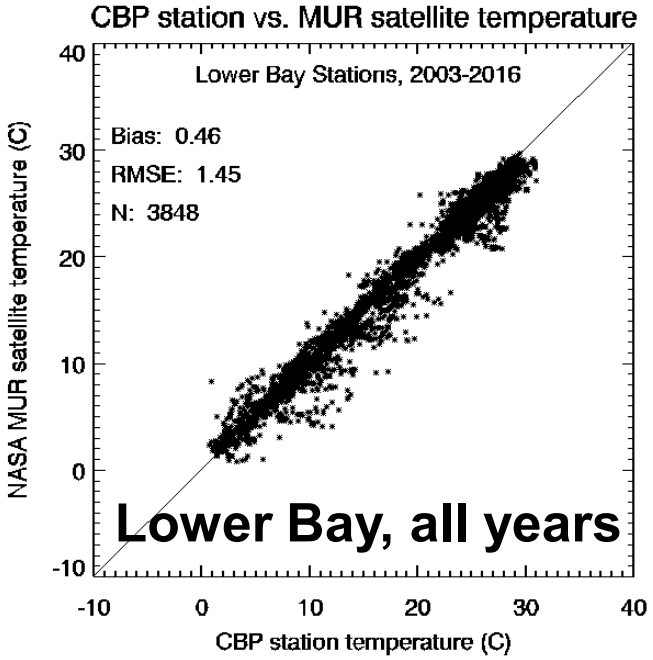
By Region

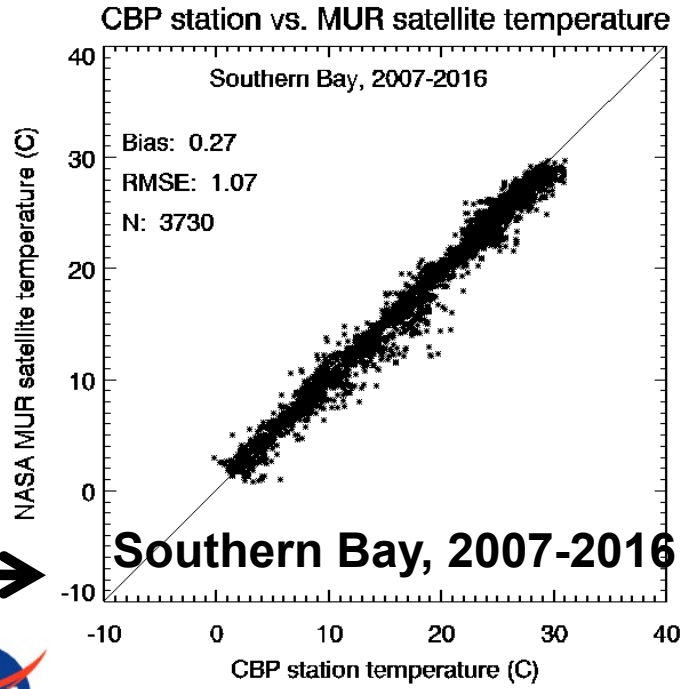


Southern Bay for 2007-2016 shows lowest bias and RMSE



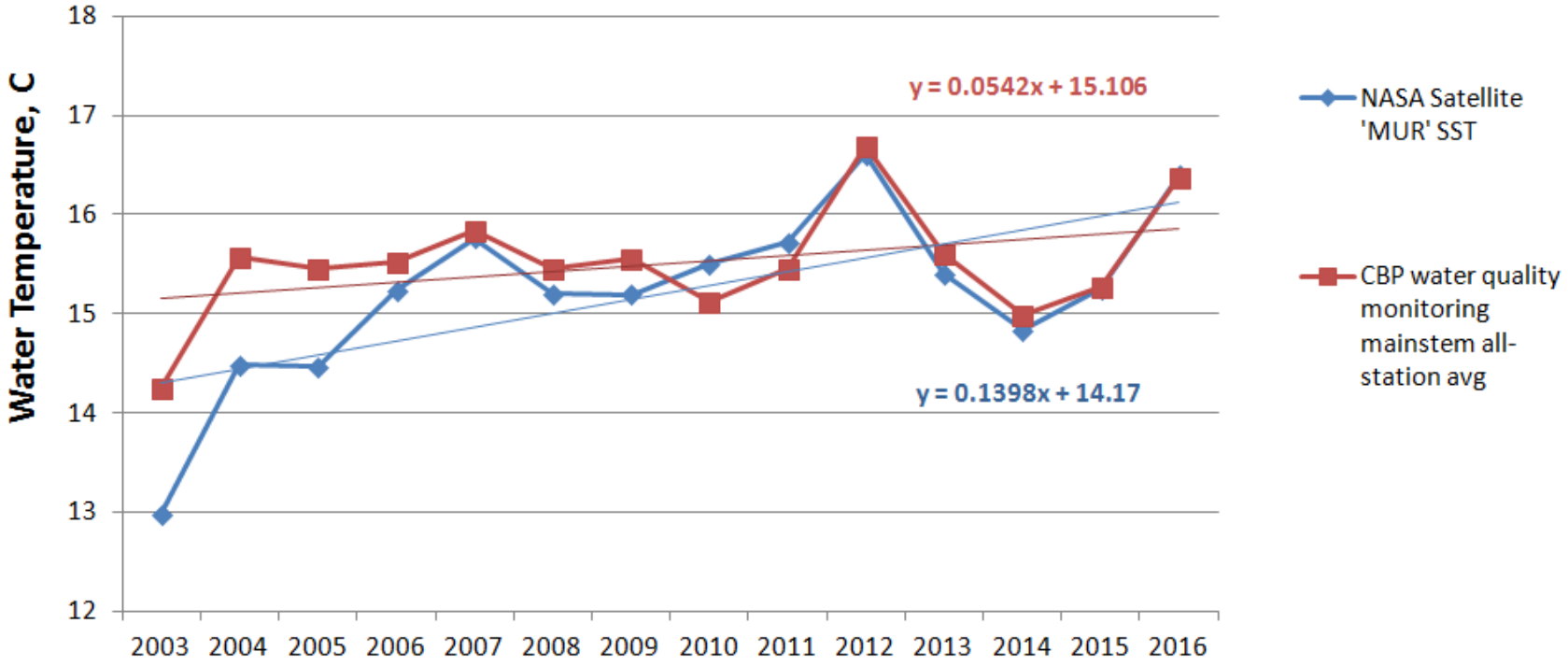






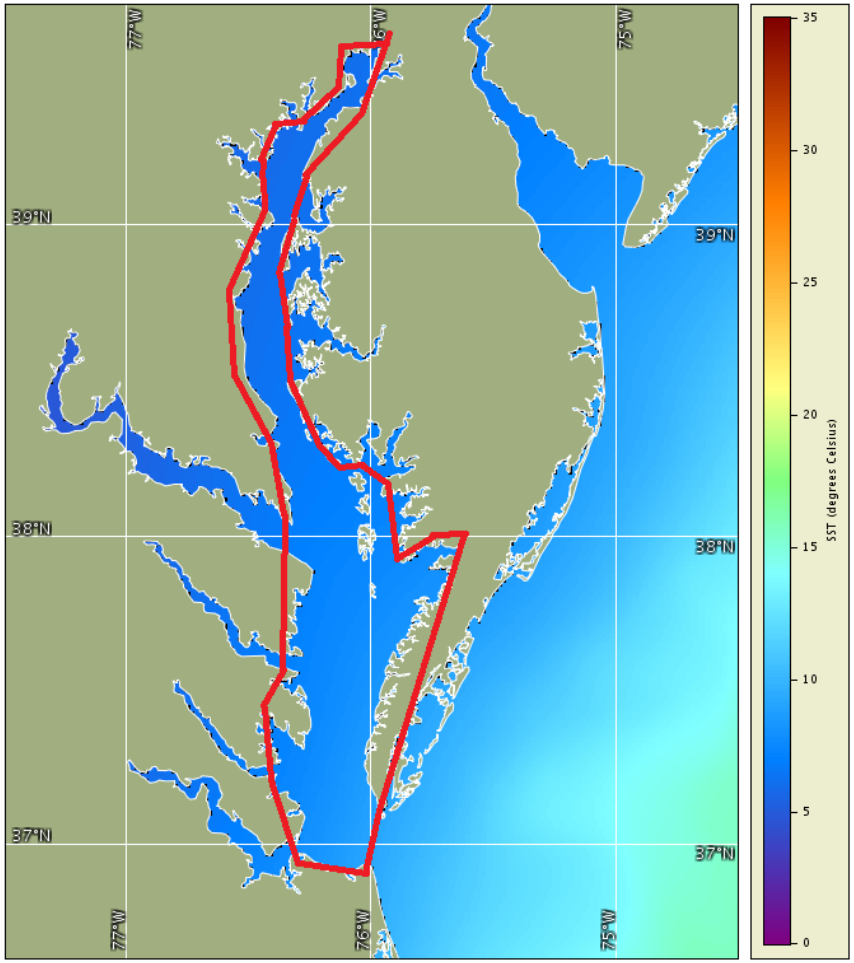
Rate of temperature change from MUR SST Chesapeake Bay, **before** validation study

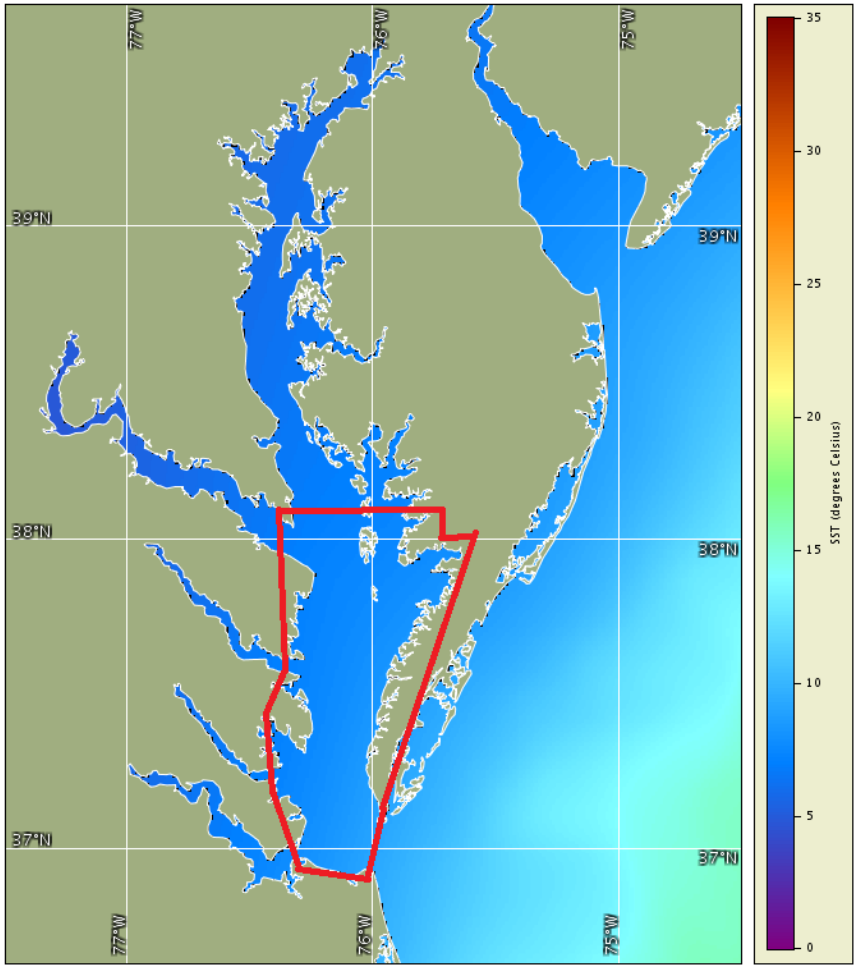
MUR SST vs. Chesapeake Bay Program in-situ water quality monitoring data
Annual average surface temperature comparison



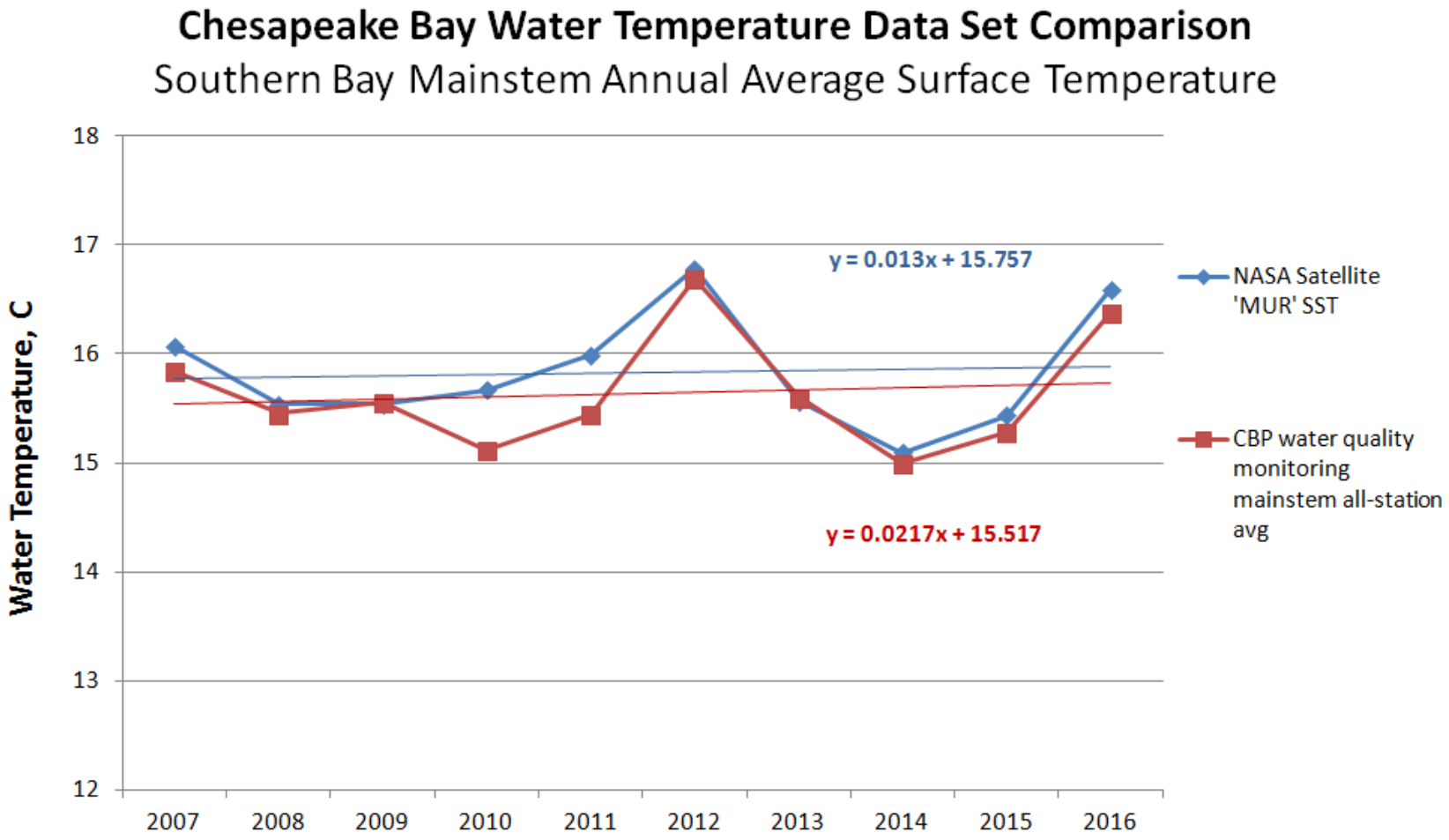
MUR rate of change **2.5x** that of CBP in-situ data

New polygon for Southern Bay to recalculate the rate of change for the less-biased time period and less-biased subregion





MUR satellite SST comparison with CBP monitoring data **recalculated** for Southern Bay mainstem & 2007-2016



Using only Southern Bay region and time period beginning 2007 gives a rate of change closer to CBP in-situ measurements

This is implemented in the indicator web display