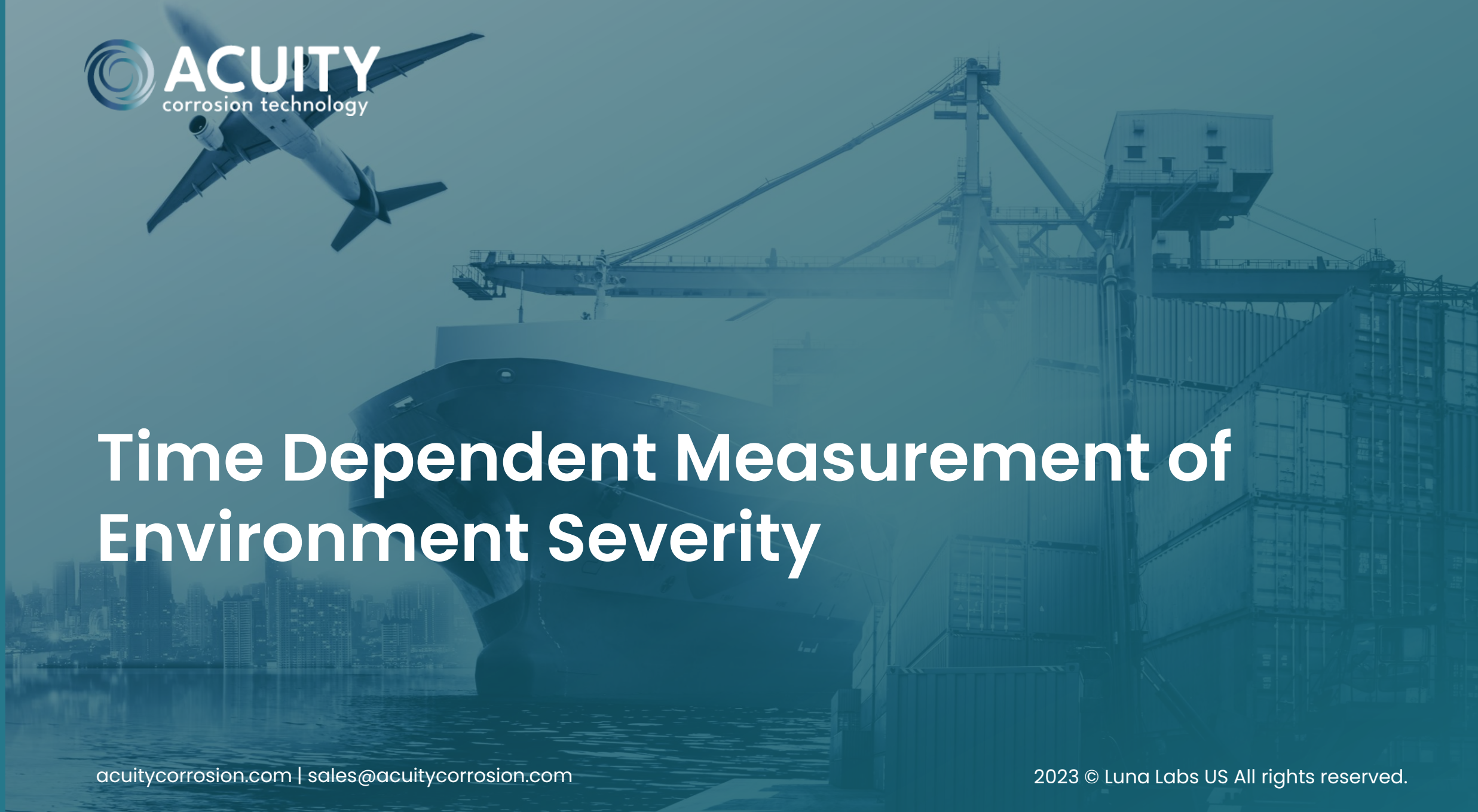

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Time Dependent Measurement of Environment Severity

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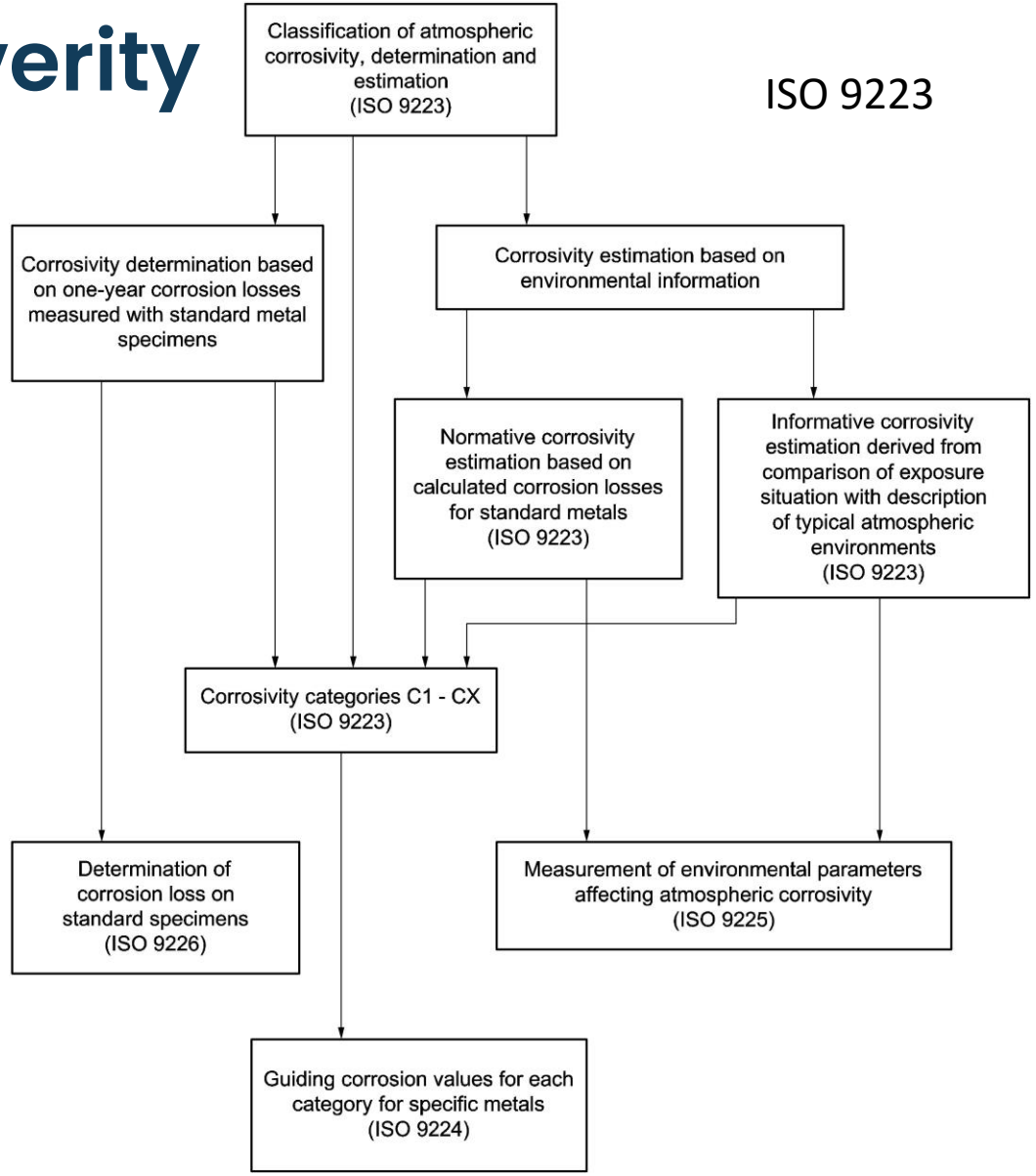
Environment and Corrosion Severity

Categorization of severity can be done by measuring

1. environmental parameters (ISO 9225)
2. corrosion of reference materials (ISO 9226)

Corrosion severity is important for:

- Select materials
- Estimate service life
- Make commercial decisions (warrantee)
- Plan maintenance



ISO 9223

Severity Categories & Classification

Methods for determining corrosion severity are well established (ISO 9223)

- These dose response methods use annual average measurements of temperature, relative humidity, contaminant deposition, or mass loss

Methods for time resolved assessment of environment and corrosivity are less common

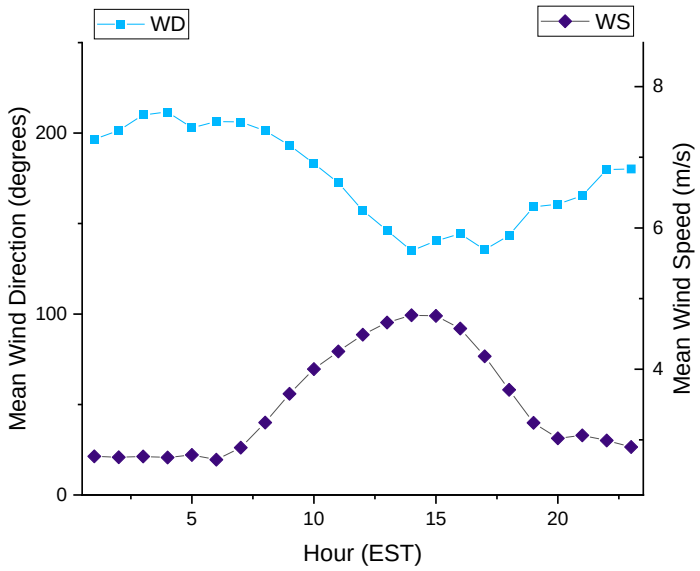
- May be more appropriate for mobile assets that experience a wider range of conditions and dynamic processes associated with operation

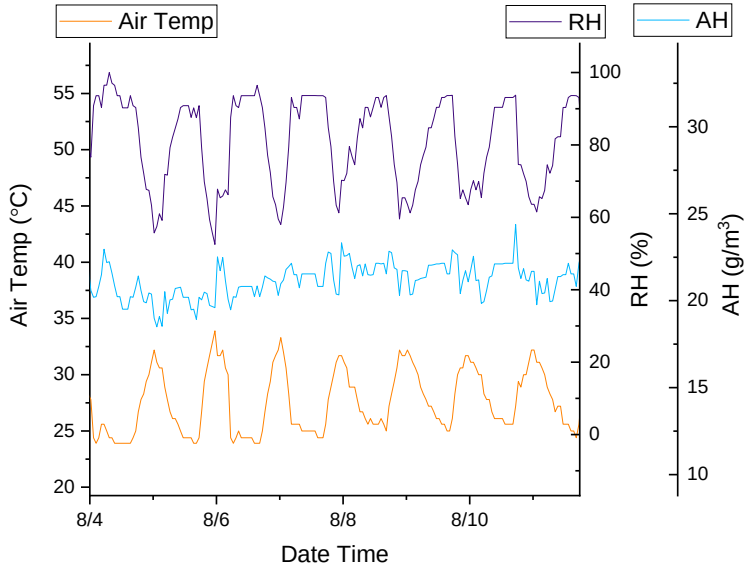
Time Dependence of Environment Severity

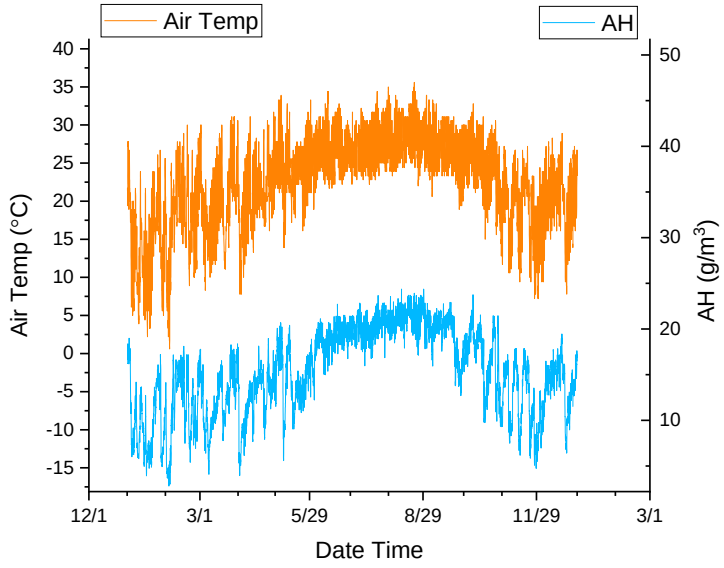
A broad range of time scales are significant to the environment severity and corrosion

Operation and use • Weather events • Diurnal cycle • Seasonal variation • Climate change

Daytona Beach Florida (NOAA)







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Continuous Monitoring of Environment and Corrosivity

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Continuous Environment and Corrosion Monitoring

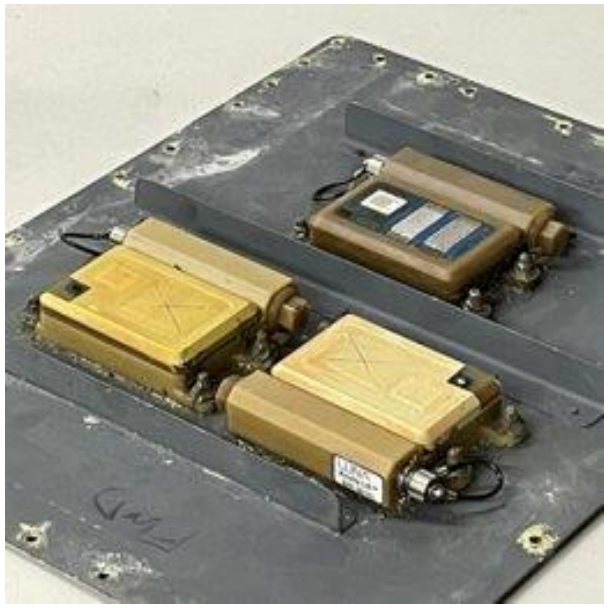
Goal of current work is to obtain environment spectra and corrosion measurements of time-varying processes to assess local severity and support model development

- Utilize measurements that can be applied to laboratory testing, outdoor exposure, and on-asset monitoring

Laboratory Testing

Outdoor Exposure

On Asset



Outdoor Testing

Environment and corrosion data have been obtained at multiple locations to assess severity

Locations

Battelle FMRF, Ponce Inlet, FL USA

- Ocean site
- Intracoastal site

El Segundo, CA USA

Materials

Galvanic corrosion couples

- A286/AA7075
- CFRP/AA7075
- Ti-6-4/AA7075

Free corrosion

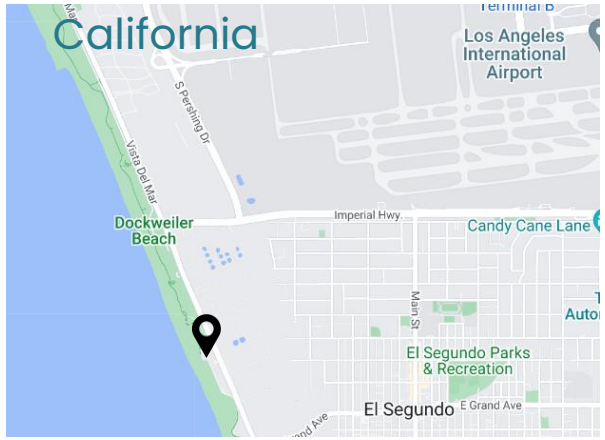
- AA7075

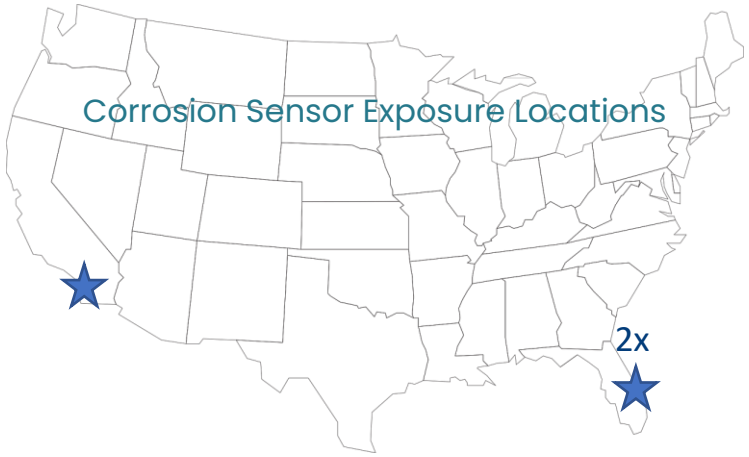
Details

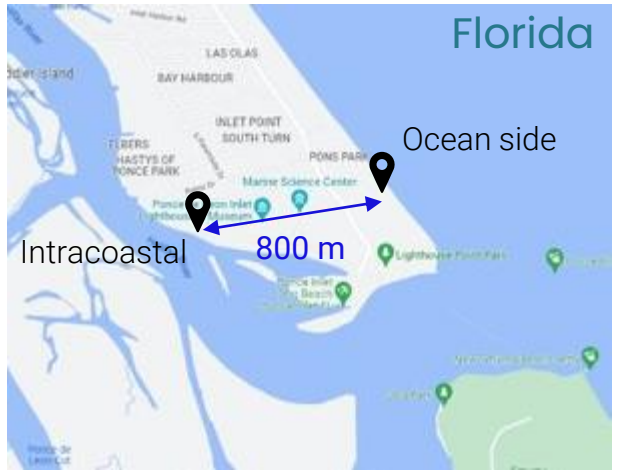
Six measurement devices at each site

- Six replicate environment parameters
- Three replicate corrosion measurements

Wet candle chloride measurements at both Battelle Florida sites

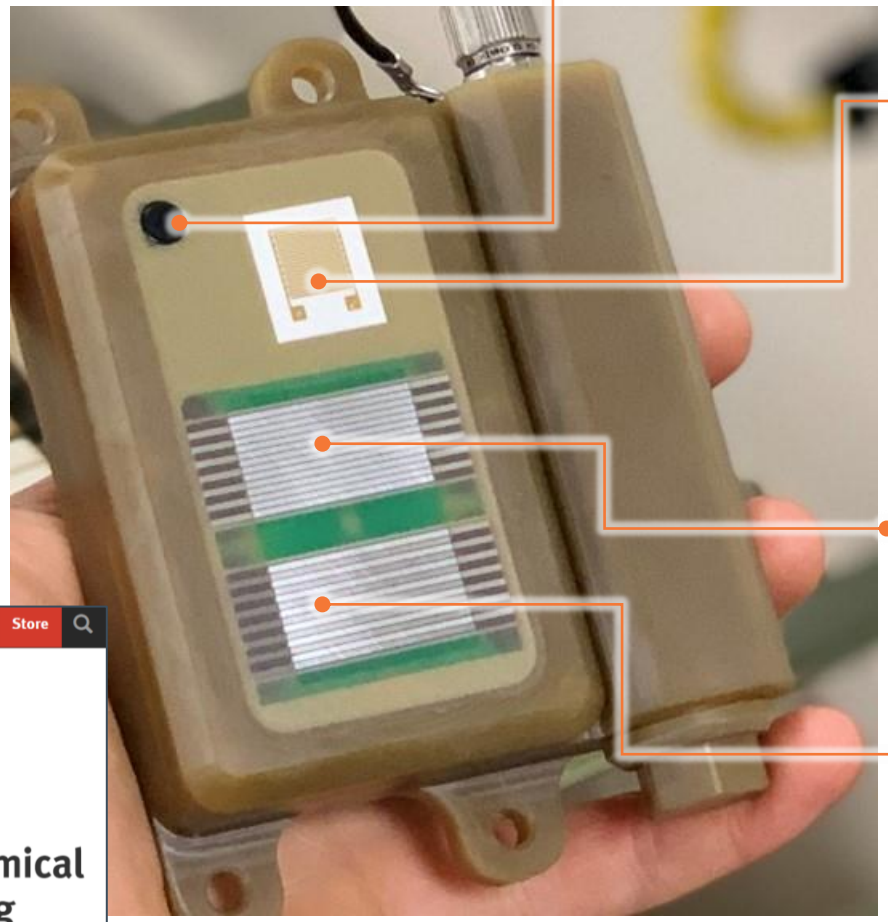






Continuous Measurements

Autonomous measurements of environment spectra and corrosivity



Environment

Temperature & relative humidity

Conductance (RH & salt deposition)

- Gold interdigitated electrode (IDE)
  20 mV peak-to-peak 25 kHz

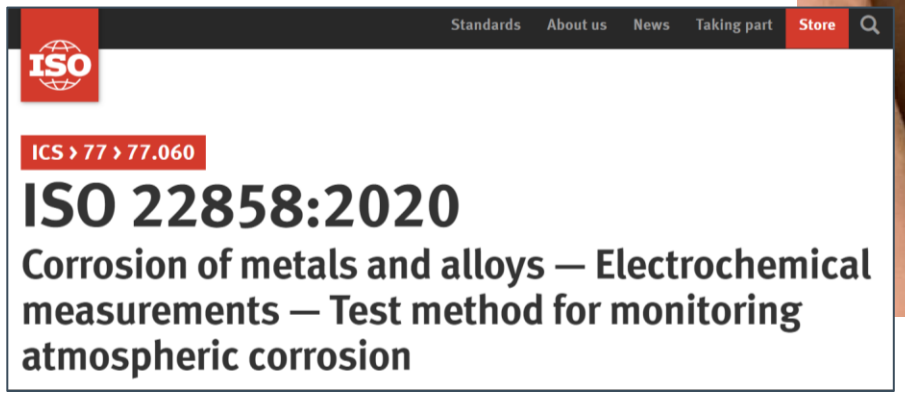
Corrosivity

Free corrosion rate

- Single engineering alloy
- Low frequency impedance measurement;
  20 mV peak-to-peak, 0.5 Hz

Galvanic corrosion rate

- Two dissimilar materials
- Zero resistance ammeter



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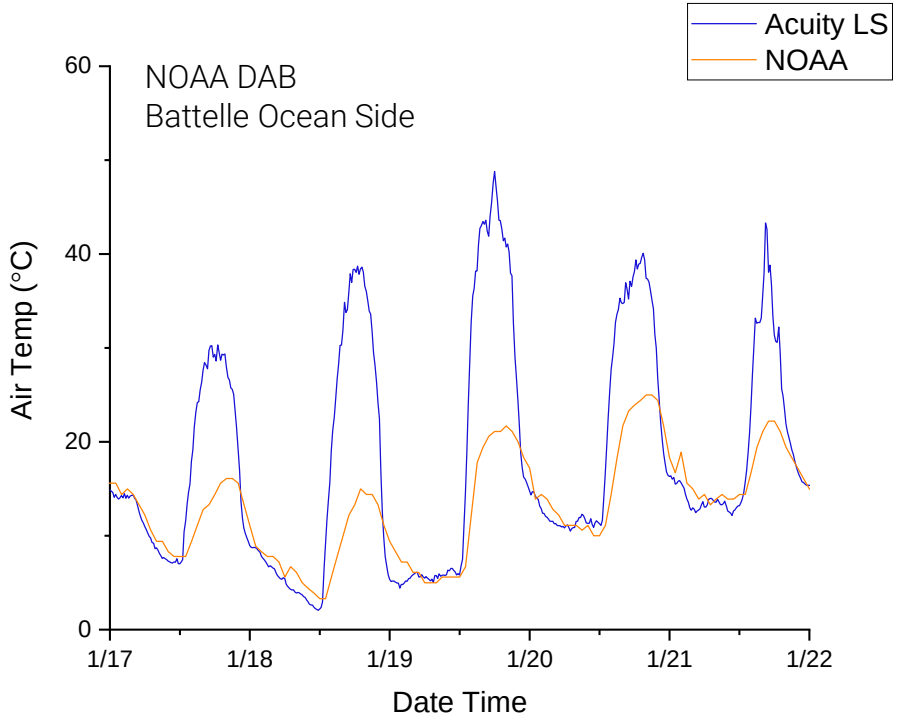
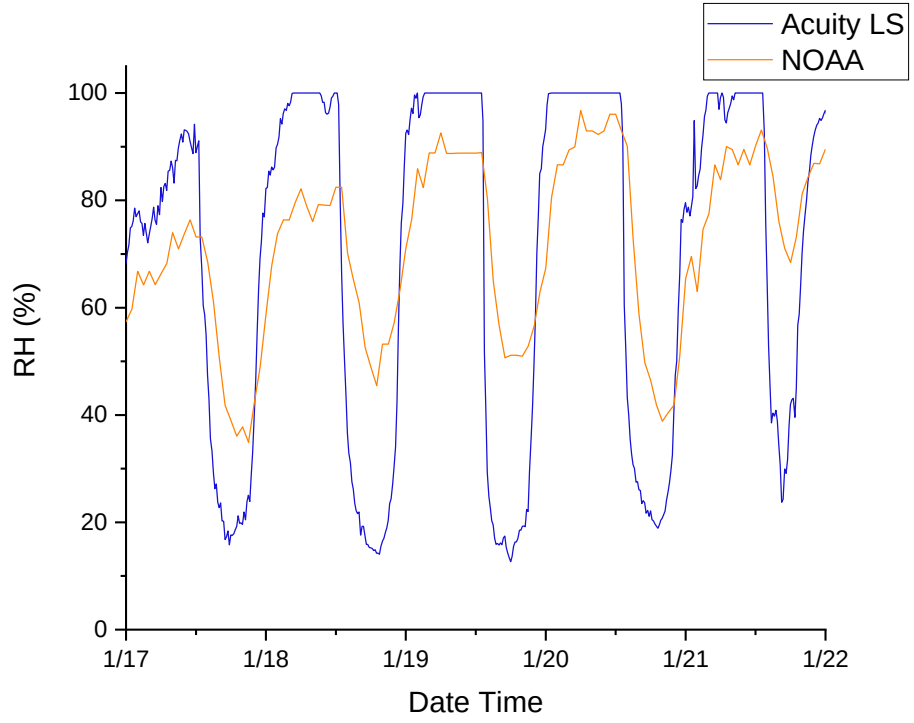
Environmental Measurements

Environmental Parameters – Temperature and Humidity

Relative humidity and temperature affect surface electrolyte properties: thickness, concentration, and conductivity

Weather station temperature and humidity differ substantially from local surface conditions





Salt Deposition – Conductance

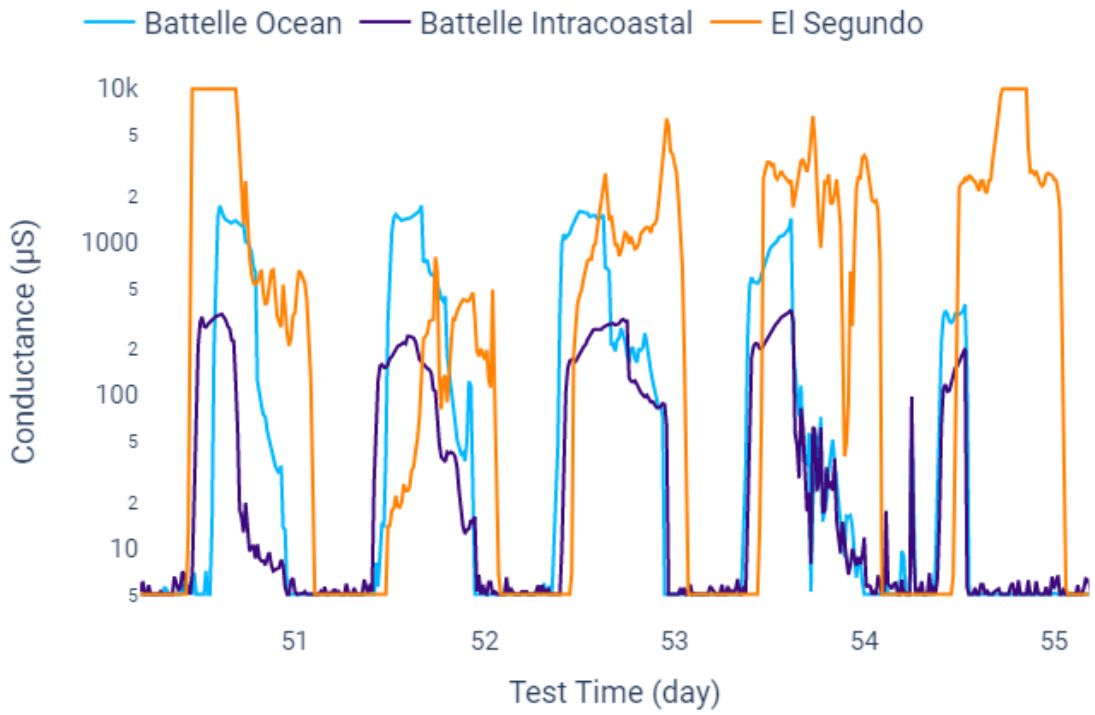
Conductance sensor measurements respond to surface electrolyte:

- Thickness
- Conductivity
- Electrolyte coverage

These same parameters affect galvanic corrosion rate and damage distribution

- Film thickness affects oxygen diffusion rates
- Thickness, conductivity, and coverage affects IR dro and the 'throwing power' of a couple

Segment of conductance data



The conductance sensor responds to diurnal changes in relative humidity (electrolyte volume and conductivity)

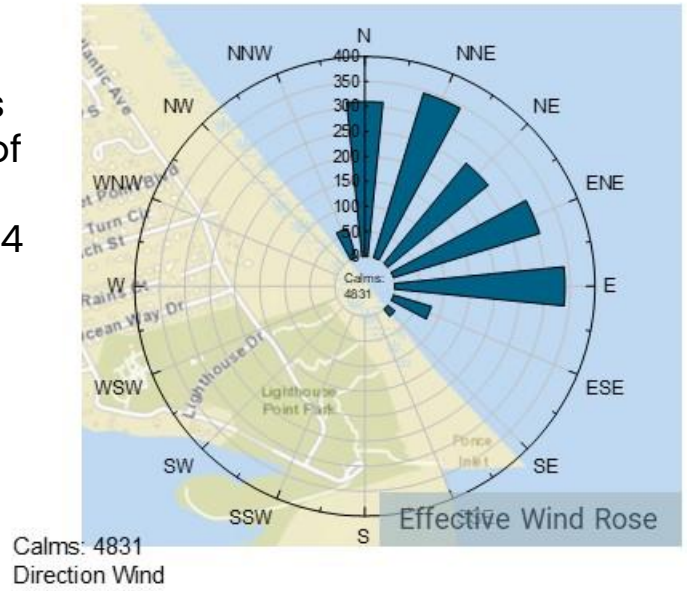
Salt Deposition – Wind and Conductance

Wind is the primary means of delivery of marine salt contaminants

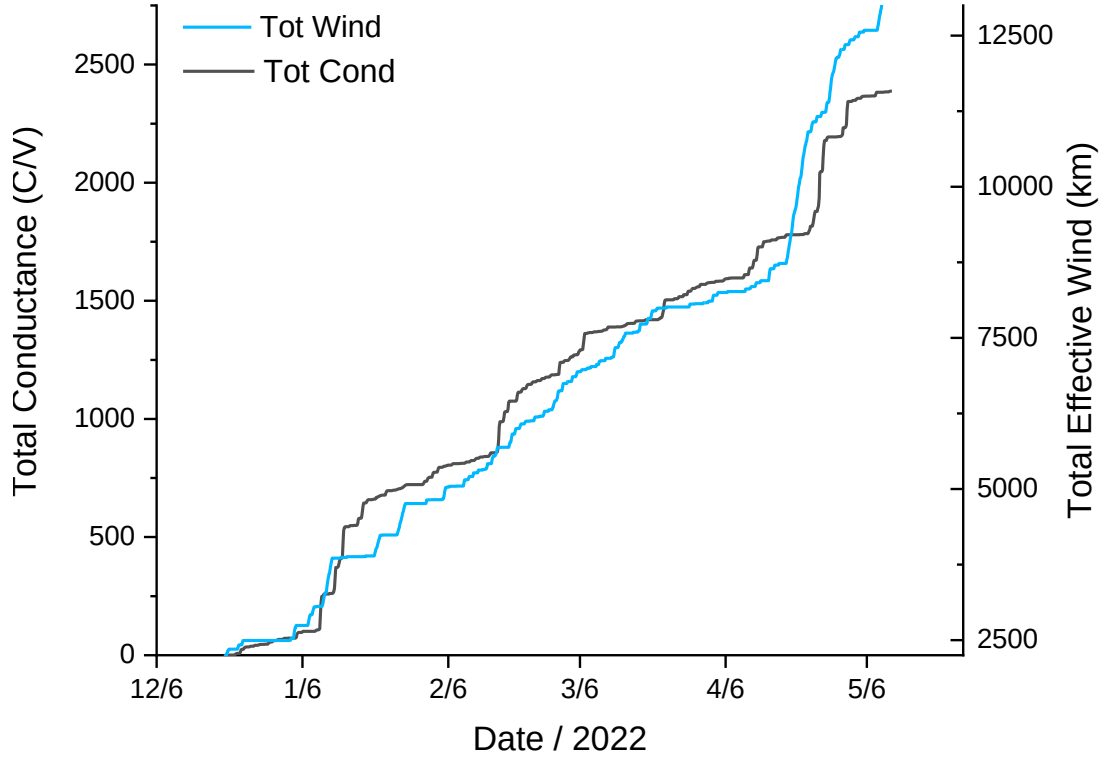
The conductance sensor is expected to respond to salt deposition (wind) and contaminant removal by rain or condensation runoff

The total conductance tracks with total effective wind

Effective wind is defined as the on-shore component of wind speed, for a wind speed that is greater than 4 m/s



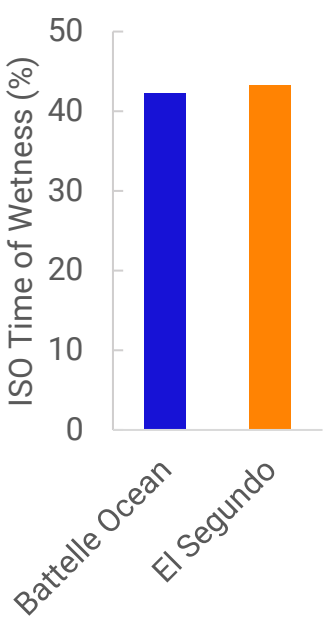
Battelle ocean side and DAB wind data

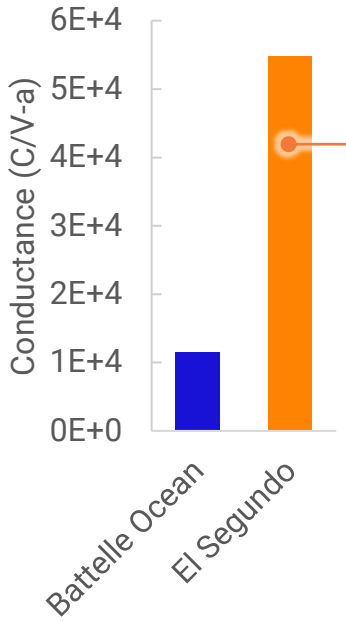


Location Dependent Salt Deposition

Time of wetness is similar between Battelle and El Segundo, but there is a significant difference in total annual conductance

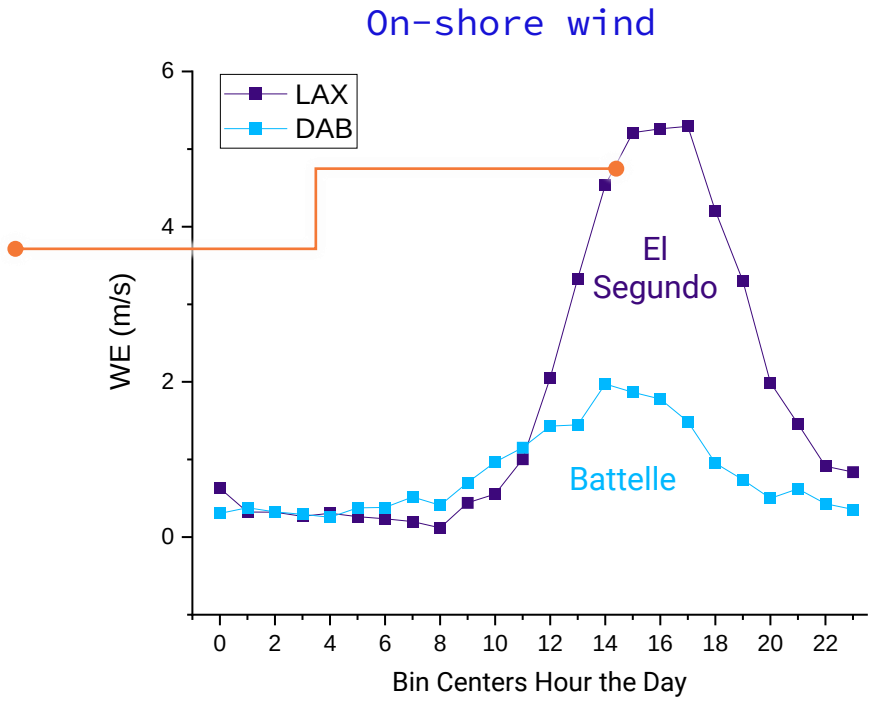
Differences in on-shore winds are consistent with higher salt deposition and conductance at El Segundo



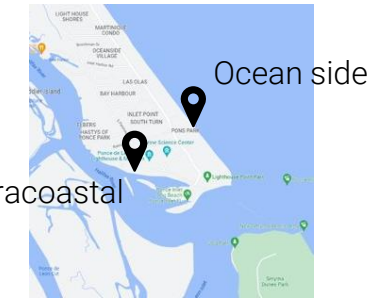


Higher annual conductance indicates higher salt deposition

Higher daily on-shore wind speeds at El Segundo



Location Dependent Chloride Deposition

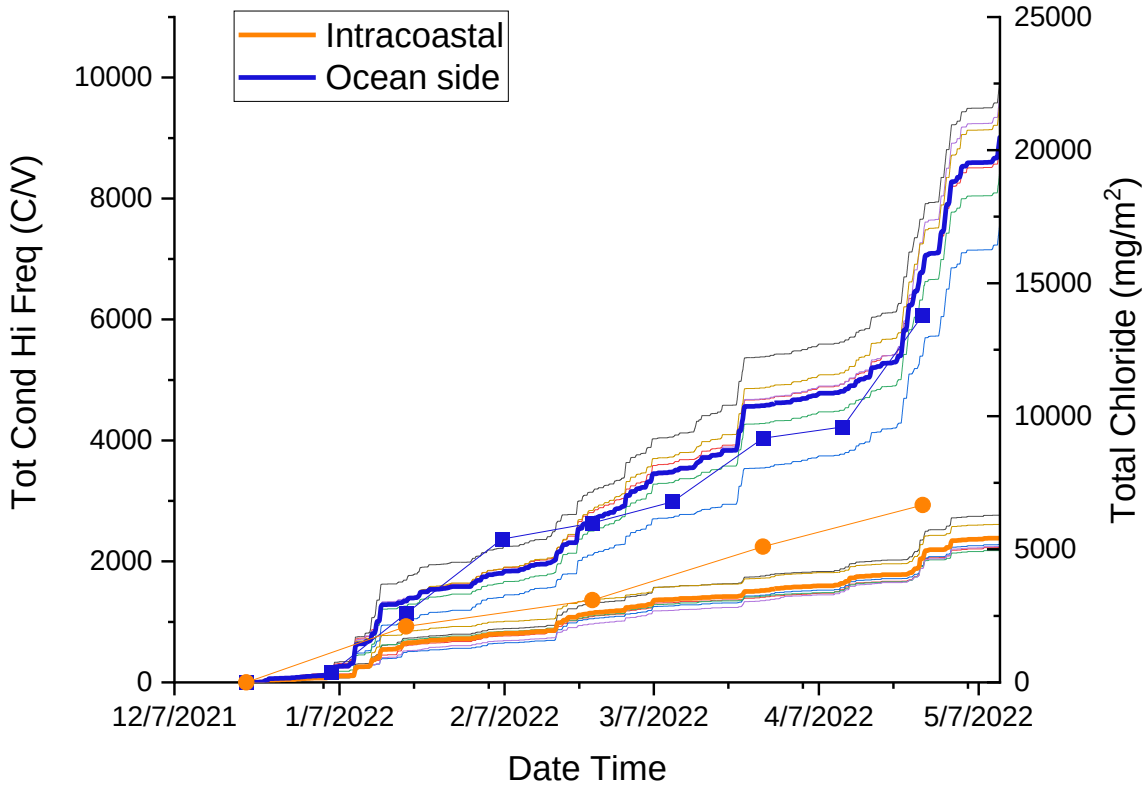


The wind-deposited salt decreases with distance from shoreline

Relative ranking of conductance and wet candle chloride measurements are similar between the two Battelle test sites

Conductance and chloride wet candle measurements have similar trends with time

Wet candle measurements only measure deposition and do not account for chloride removal



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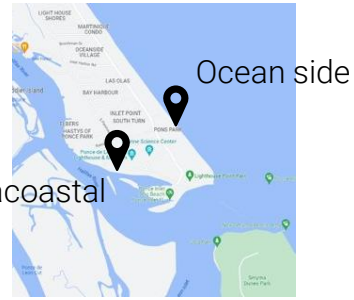
Corrosion Measurements

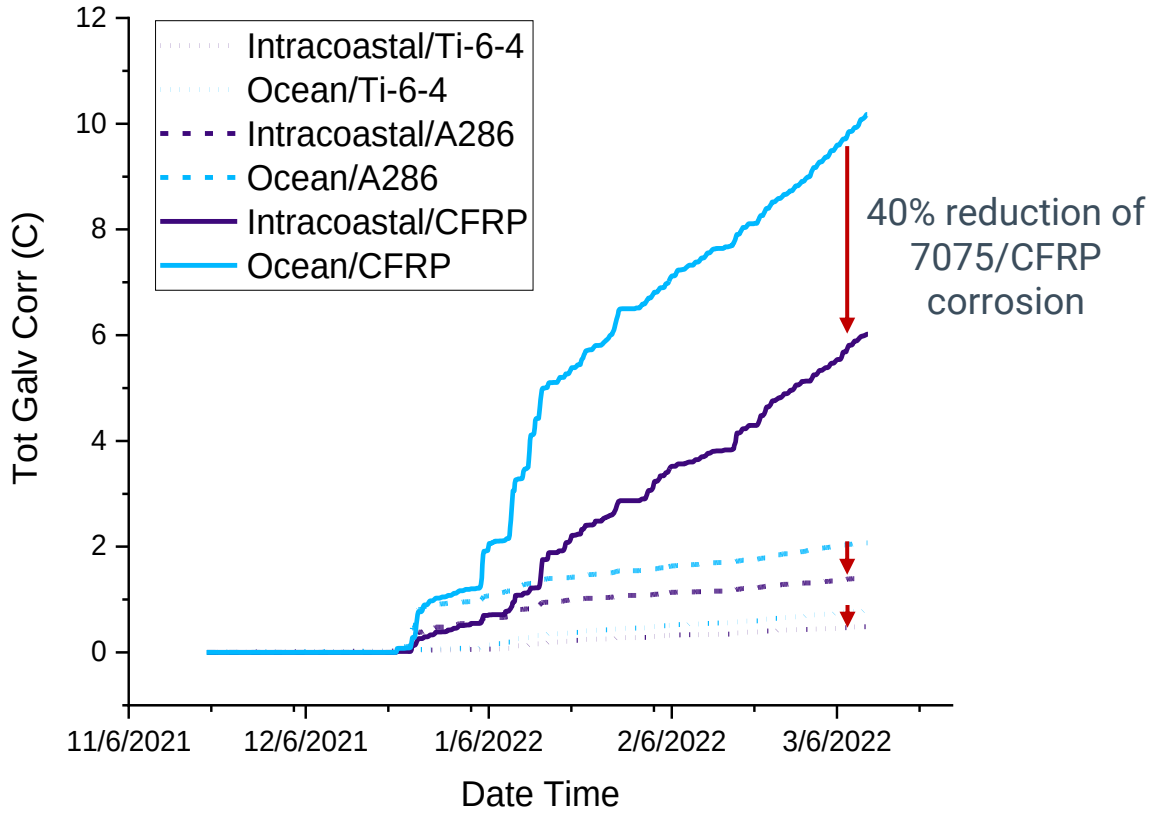
Location Dependent Galvanic Corrosion

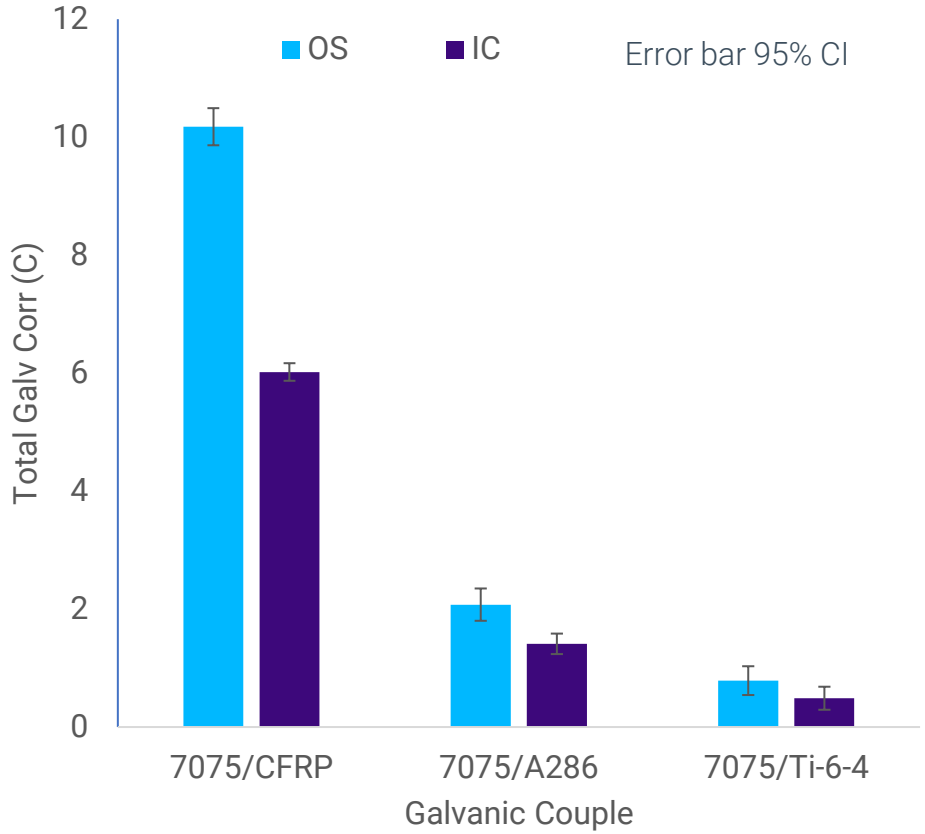
Rank order of the galvanic couples and site severity are consistent

Battelle ocean side > Battelle intracoastal

CFRP > A286 > Ti 6-4







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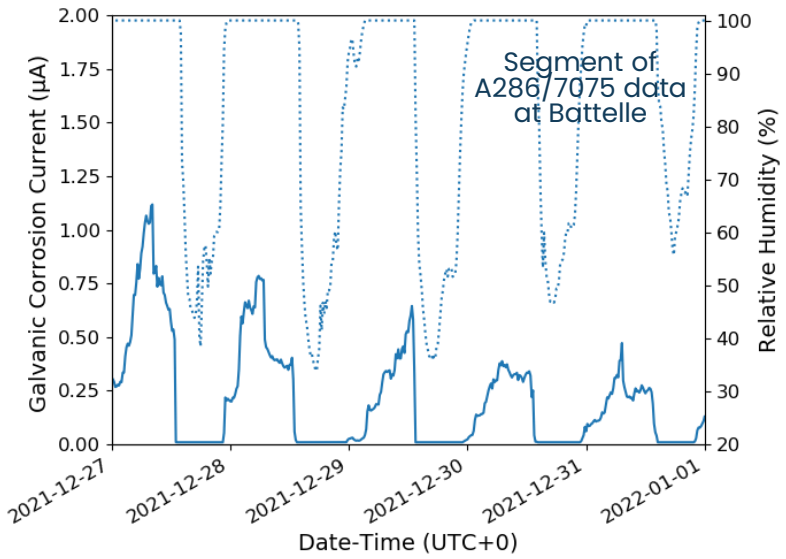
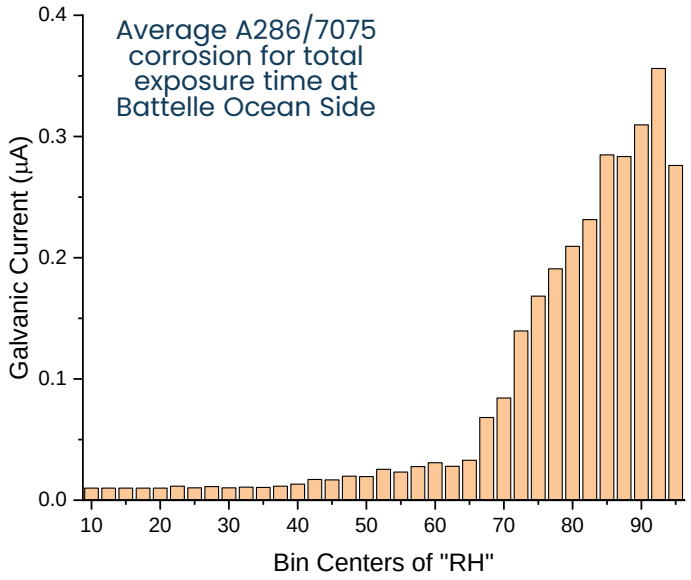
Environment Spectra and Corrosion

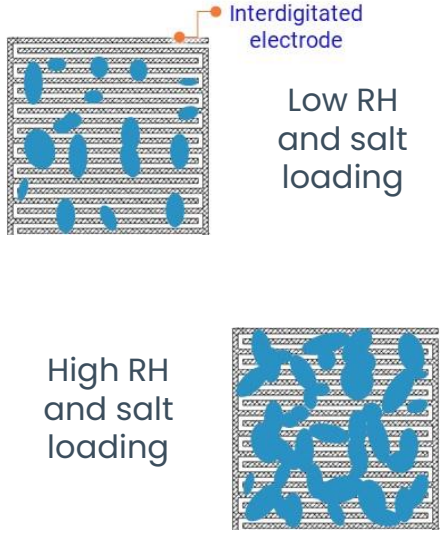
Environment and Galvanic Corrosion

Galvanic corrosion rate generally increases with RH for these marine environments

- The galvanic corrosion rates are typically not as high as immersion tests
  - These results are consistent with incomplete or discontinuous electrolyte film coverage

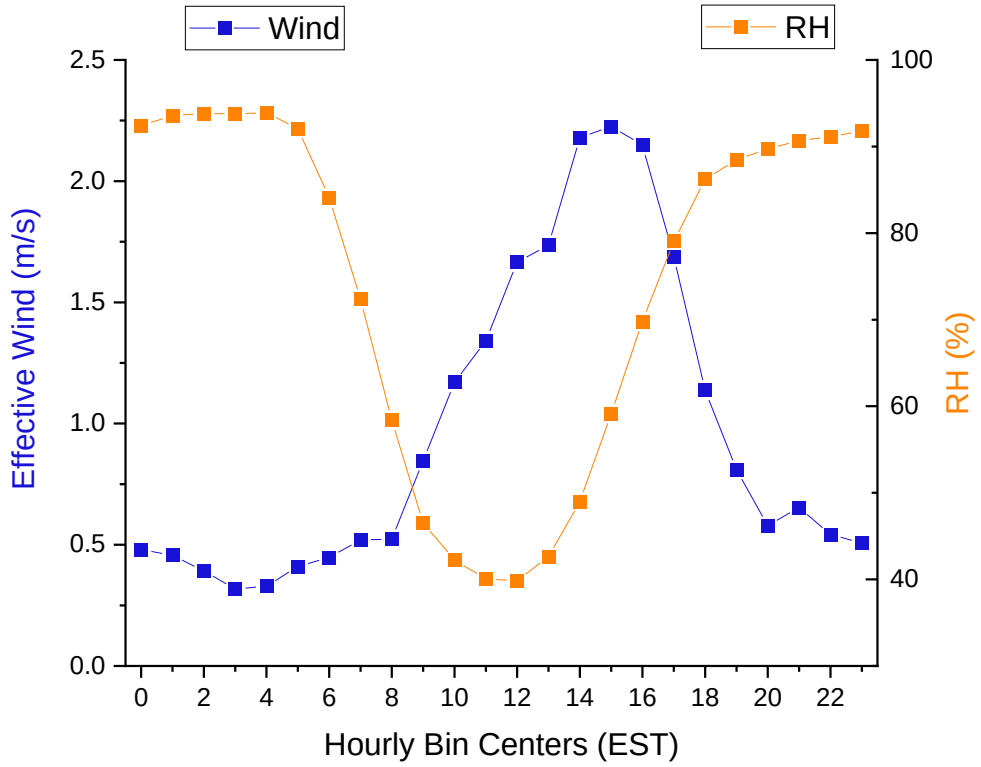


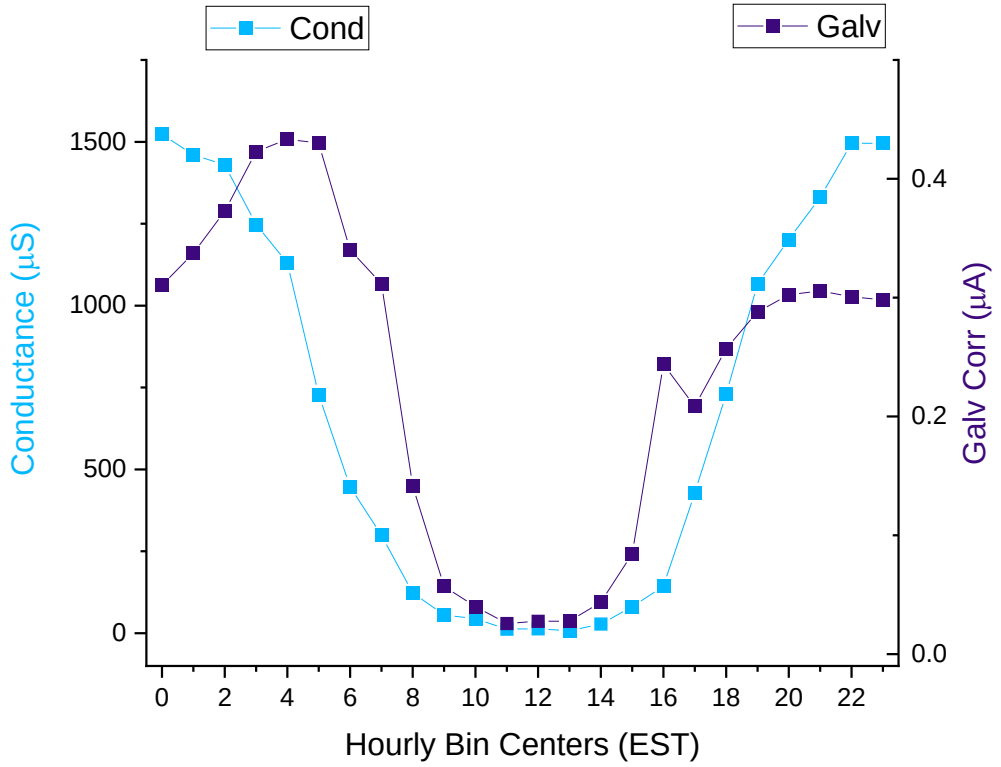




Diurnal Cycle for Environment and Corrosion

Maximum effective wind for salt deposition occurs during the afternoon, while maximum galvanic corrosion occurs early morning

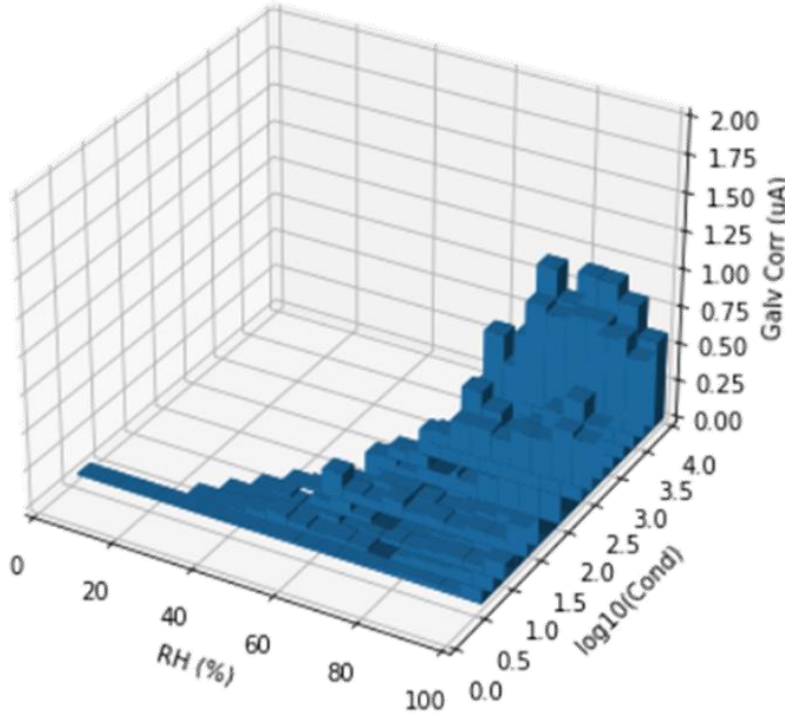




Relating Environmental Factors to Corrosion

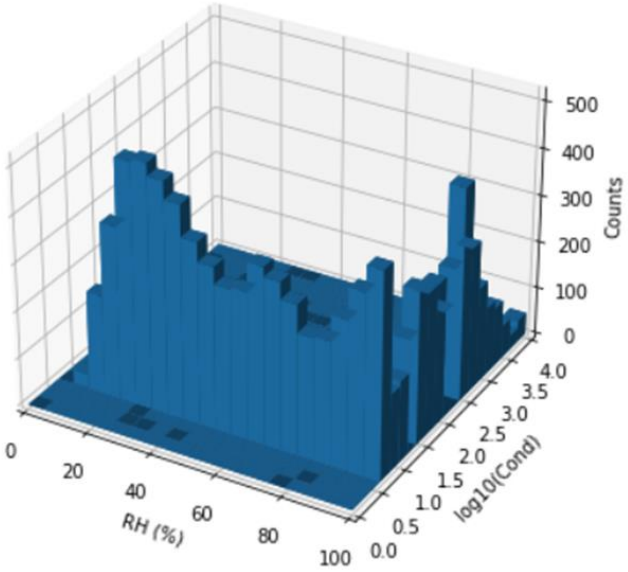
Galvanic corrosion response can be mapped relative to conductance and RH

A three dimensional histogram for a given location and time period may be used to determine residence time in different galvanic corrosion regimes

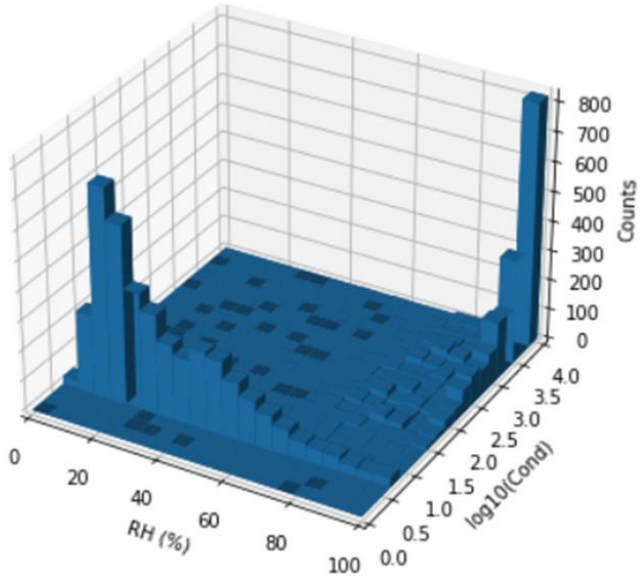


Histogram of environmental conditions

Sensor in FL



Sensor in CA



Each test site has a unique RH and conductance distribution, depending on the salt deposition and climate

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Summary

Summary of Environment and Corrosion Measurements

Environment spectra and corrosivity can be used to continuously quantify conditions that vary over short (hour) and long time scales (months)

Conductance measurements are consistent with other measures of contaminant and chloride deposition (effective wind and wet candle)

The conductance and corrosion sensors produced consistent results for rank ordering geographic location, salt deposition, and galvanic couple severity

Additional work is needed to:

- Validate and standardize the use of environment and corrosivity sensors for severity categorization
- Apply measurements to model development and validation

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Thank You

Questions?

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