

**NAVAL AVIATION ENVIRONMENTAL SEVERITY CORRELATION:
COMPARATIVE 17 SITE ASSESSMENT**

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ABSTRACT

Naval Research Laboratory (NRL)-Key West is a state-of-the-art testing facility for atmospheric and marine corrosion. The site naturally has elevated Ultraviolet (UV) intensity, similar to operational areas for the Navy. Recently, testing capabilities were expanded to include the ability to rinse samples with clear water (to mimic preventative maintenance washing), to shelter samples within a protective aircraft cover (to mimic preventative maintenance storage), and to spray samples with sea water (to increase the severity of the exposure). It is hypothesized that the Key West site can be tuned so as to mimic the exposure conditions of other sites of relevance to Navy operations.

A 2-Phase, multi-year site severity assessment was conducted to compare sixteen sites to Key West. Two standard Navy coatings (chrome and chrome-replacement) were exposed in addition to steel and silver corrosion coupons. This evaluation will update the relative ranking of these sites in terms of environmental severity index (ESI) and Total Corrosion Risk (TCR). Data presented will include steel mass loss, galvanostatic reduction of silver, and evaluation of the coated samples. In addition, select sites also received environmental dataloggers which will be compared against the exposure samples and nearby publicly available weather data in a follow up study. An understanding of how different local environments impact site-specific corrosion is developed and although many of the 16 test site environments are very different from the ambient conditions in Key West, there is an opportunity to simulate the environments of various bases at this one location. This can be achieved by altering the Key West environment through sea water application and sample sheltering or by adjusting the location and duration of exposure to match the base of interest.

Key words: atmospheric corrosion, environment, marine environments

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INTRODUCTION

The exposure environment of an engineering material quite often has a large impact on how that material behaves over time. Environments are distinguished by differences in meteorological patterns, geography, salinity, Ultraviolet (UV) radiation, etc¹⁻³. Thus, the degradation of various materials scales proportionately to the characteristics of the exposure site, with more severe sites leading to worse degradation. Developing an understanding of how the local environment impacts the corrosion rates of metals and the deterioration of anti-corrosion coatings is critical for informing asset maintenance schedules and lifetime predictions⁴.

The Naval Research Laboratory (NRL) Key West facility (**Figure 1**) is a rigorously characterized atmospheric corrosion test site. It offers a platform for elucidating the effects of the environment on the atmospheric corrosion of engineering materials. The NRL Center for Corrosion and Atmospheric Structural Testing (C-CoAST) includes the capability to mechanically fatigue test components in an outdoor, environmentally relevant location. Furthermore, it is possible that the local Key West environment can be “tuned” in order to replicate a variety of service conditions. This is accomplished by the combination of sea water spray, clear water rinsing, static or dynamic loading, covering/sheltering, etc. However, to be able to fine-tune the Key West environment, the relationship between environmental parameters, corrosion rates, and coating degradation must be known. In order to understand how results obtained from this new capability will compare to Navy and Marine Corps bases, an update to the historical Environmental Severity Index (ESI) is needed.

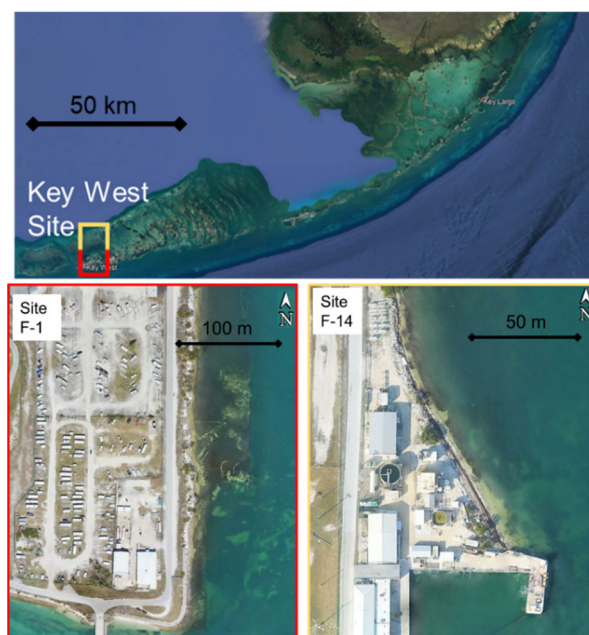


Figure 1. Overview of the NRL Key West exposure site showing the location of F-1 and F-14.

This understanding is developed through comparison of the Key West test site with other exposure test sites via witness coupon corrosion and aerospace coating deterioration measurements. In Phase I of this program, Naval Air Station (NAS) Whidbey Island and Marine Air Corpse Station (MCAS) Kaneohe Bay were used as alternate test sites because they report high corrosion rates but are environmentally distinct from one another and from Key West. This offered the ability to explore the effect different environmental parameters have on anti-corrosion coating performance. Phase I also provided an important proving ground for developing the experimental framework for the larger Phase II initiative. In Phase II, a total of 17 different sites were assessed as listed in **Table 1**. Sites were selected from aviation-relevant Department of Defense (DoD) installations across the United States and Japan, as shown in **Figure 2**. This offered practical utility to the DoD since operationally relevant sites were being examined. It also provided a large parameter space for testing a range of variables.

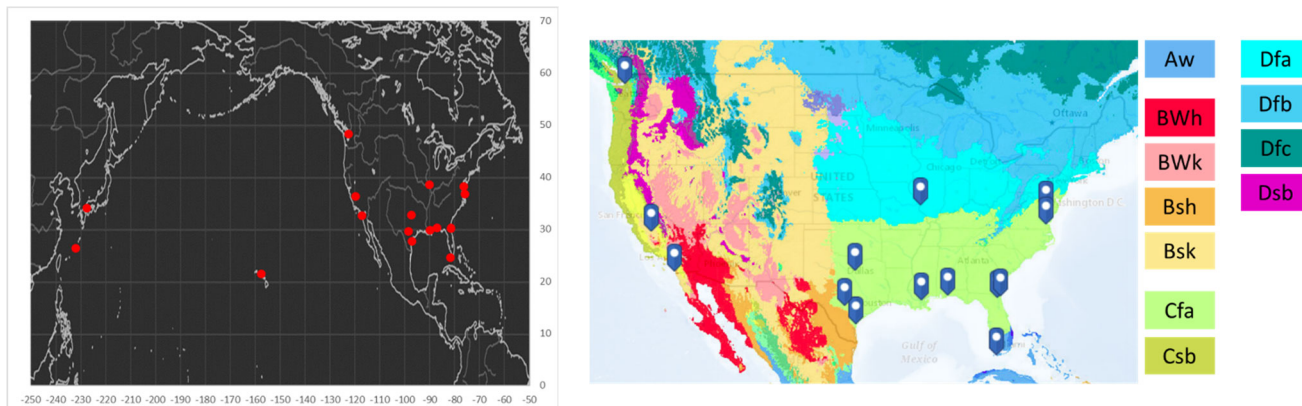


Figure 2. Global overview (left) of the NAESC Phase II sites. Location of the continental US (right) sites overlaid on a Köppen Climate Map (ArcGIS). The climate zones are color coded to highlight the diversity of sites analyzed in this study. A=Tropical, B=Arid, C=Temperate, D=Cold, a=Hot Summer, b=Warm Summer, c=Cold Summer, f=No Dry Season, h=Hot, k=Cold, s=Dry Summer, W=Desert.

If the NRL Key West site can be successfully modified to mimic the conditions of other sites then it will confirm that a proper understanding of the effect of environmental conditions on atmospheric corrosion has been achieved. This understanding can be used to inform engineering modification for testing in the future. Furthermore, with this understanding, the NRL Key West site can be modified to mimic other service conditions of interest, greatly increasing the applicability and versatility of Key West. Even if the site cannot be completely adjusted to perfectly mimic other sites, a similar effect can be achieved by adjusting the resulting data using a scaling factor. For any useful comparison to happen, the morphology and mechanism of corrosion should be similar between the sites. Finally, the wide variety of sites assessed in this phase of the program offers a chance to improve our current understanding of how the local environment influences atmospheric corrosion. The climatic/meteorological character of all the sites is diverse, as shown in **Figure 2**. Locations, Köppen codes, and exposure start dates for each site are listed in **Table 1**³.

Table 1. List of the 17 sites tested in Phase I and II of the Naval Aviation Environmental Severity Correlation.

Site (Alphabetical)	Site ID	Köppen Code	Exposure Start
NAS Corpus Christi	CC	Cfa	21DEC2020
NAS Ft. Worth	FW	Cfa	17DEC2020
MCAS Iwakuni	Iw	Cfa	01DEC2020
NAS Jacksonville	Ja	Cfa	17DEC2020
MCAS Kaneohe Bay	KB	Aw	15MAY2019 / 30NOV2020
NRL Key West	KW	Aw	23May2019 / 14DEC2020
NAS Lemoore	Le	BSk	23DEC2020
NS Mayport	Ma	Cfa	14DEC2020
NAS New Orleans	NO	Cfa	15DEC2020
NAS North Island	NI	Csa / BSk	04FEB2021
NAS Oceana	Oc	Cfa	17DEC2020
MCAS Futenma, Okinawa	Ok	Cfa	31DEC2020
NAS/NAVAIR Patuxent River	PAX	Cfa	16DEC2020
NAS Pensacola	Pe	Cfa	14JAN2021
Boeing, St. Louis	SL	Cfa	13JAN2021
JB San Antonio	SA	Cfa	17DEC2020
NAS Whidbey Island	WI	Csb	14 MAY2019 / 14DEC2020

EXPERIMENTAL PROCEDURE

Exposure

NRL Key West is a state-of-the-art testing facility located on Fleming Key within the Naval Air Station. The facility is equipped for structural testing, coating application, and outdoor exposure (both marine submersed and marine atmospheric). Its location at the end of the Florida Keys makes it an ideal test site for isolating atmospheric effects in the absence of influences from industrial or continental contaminants. Weather and water data is continuously collected to supplement a rich database of environmental parameters measured at the site with the goal of correlating the environment to material performance. There are principally two sites at the NRL Key West facility, F-1 and F-14. An overview of the facility is shown in **Figure 1**. The Key West facility serves as the ground-base or headquarters against which to compare all other sites for this investigation. The other 16 sites consisted of Navy/Marine installations around the United States and Japan (continental US sites shown in **Figure 2**). The two Japanese sites (Iwakuni and Okinawa) both have a Köppen Code of Cfa, by far the most common climate type sampled in this investigation. The complete list of sites is given in **Table 1**.

For Phase I, exposures were conducted from 23MAY2019 to 15MAY2020 at NRL Key West Test Facility (KW), 15MAY2019 to 18MAY2020 at MCAS Kaneohe Bay (KB), and 14MAY2019 to 21MAY2020 at NAS Whidbey Island (WI). For Phase II, exposures began over the course of 65 days around December 2020. Due to the dispersion of sites around the globe and travel restrictions associated with the COVID-19 pandemic, exact start times were staggered. Sample sets were targeted to be deployed at as close to the same time as logistically possible. Atmospheric corrosion is very sensitive to exposure start time, especially for shorter exposure durations. The effect of start time will be discussed further. The effect of the staggering start times across the sample set will be discussed herein and further explored in-depth by a later, more thorough analysis informed by meteorological data. **Table 1** shows the exposure schedule for all 17 sites. In each instance, samples were exposed at the best possible available location, as described by the joint NRL-Naval Air Systems Command (NAVAIR) Technical Action Guide for Atmospheric Exposure Testing (NRL internal Letter Report). At Key West, samples were exposed on a fence line in order to mimic the conditions used at the other sixteen sites. An example is shown in **Figure 3**, where the samples are attached to a chain-link fence in proximity to where aircraft are stored at a height of 4 ft off the ground and facing South (toward the equator for maximum solar impingement). Exposures were conducted in a cumulative fashion in which samples were deployed all at once and selectively retrieved at intervals of 1, 3, 6, 9, and 12 months.



Figure 3. Representative example of the fence line deployment set-up utilized in this study.

Meteorological Data

Meteorological data was collected on a historic basis (to give the climatic overview of each site) and also on a contemporary basis (to collect the actual weather each site experienced over the course of this investigation). Climate data was used to group the 17 sites in to sub-group based on climate classification. The Köppen classification system was used³, an example of which is seen in **Figure 2**. The Köppen codes for each site are listed in **Table 1**. Köppen classifications are determined from climatic weather trends as reported in **Table 2**³. When contemporary meteorological data was needed, public databases