

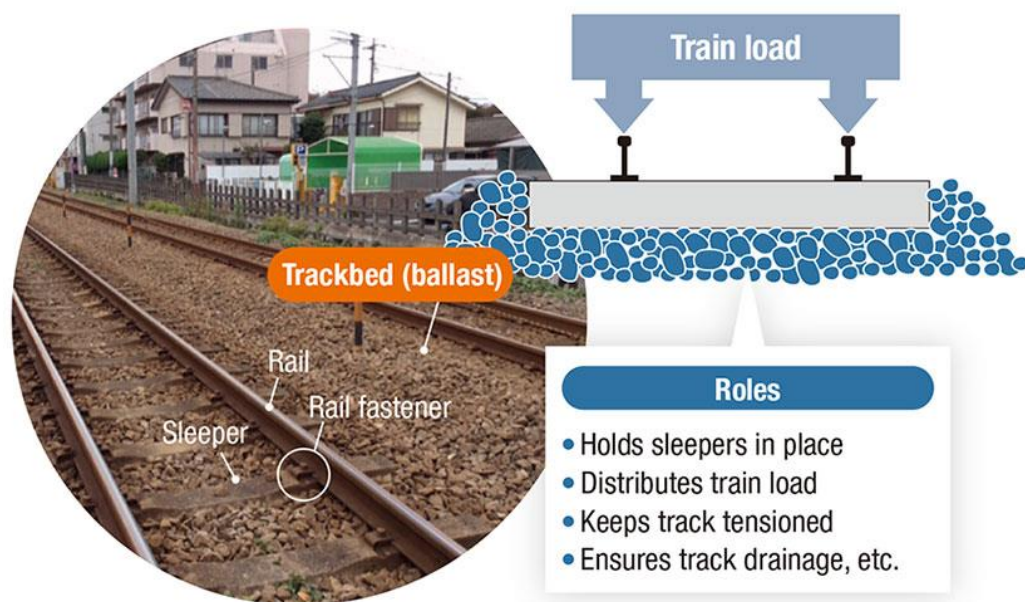
Atmospheric Corrosion Assessment in Railway Infrastructure and Rolling Stock Components

Wanida Pongsaksawad, Ph.D.

Failure Analysis and Corrosion Technology Research Team
National Metal and Materials Technology Center

11 July 2019

Infrastructure



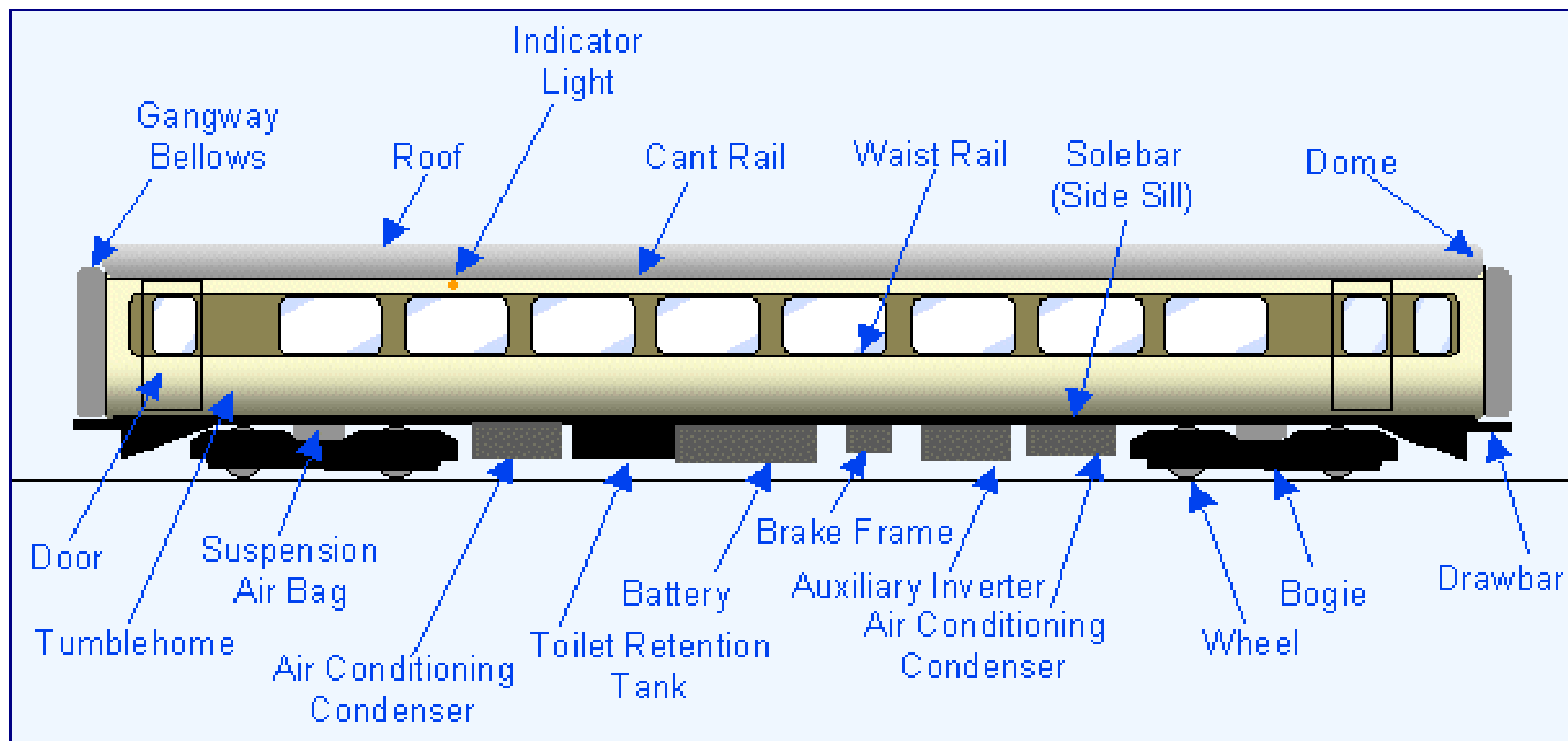
<https://www.hitachi.com>



Figure 2 End view of the bridge



Rolling Stock Components



Comparative appearance of the foot portion of rails near the rail fastenings after three years and seven months of in-track service in a coastal environment.



SECTIONAL THINNING AND perforation in conventional 90 UTS rail.



LESS SECTIONAL THINNING on weathering Cu-Mo rail.

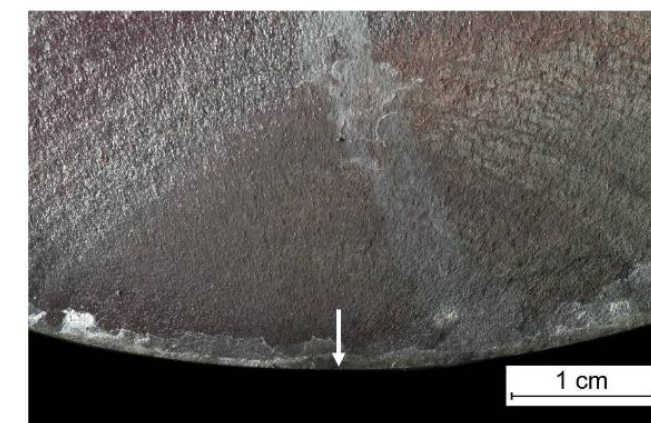
frontline.thehindu.com



structuralintegrity.eu

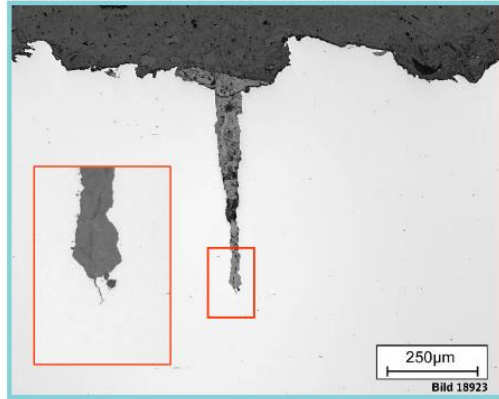


nsers.org

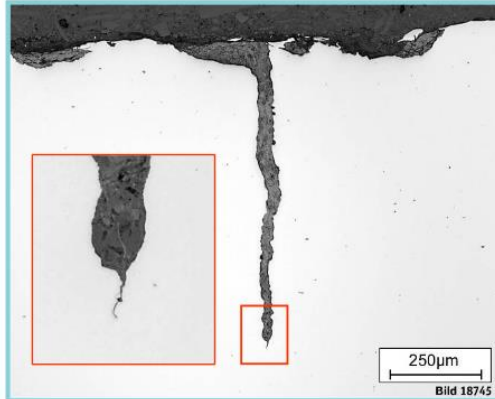


Corroded fatigue fracture surface with beach marks

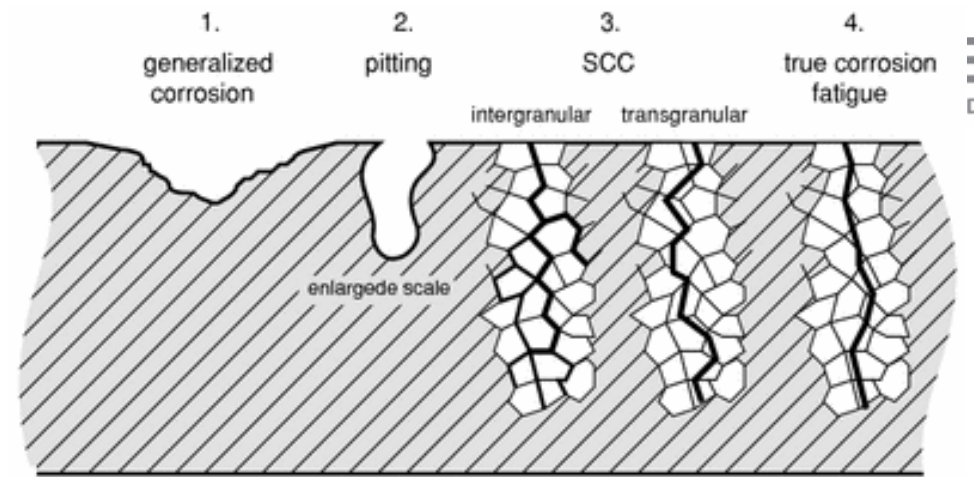
A – Near fracture position



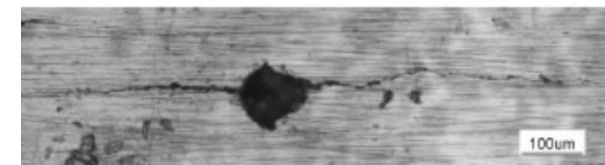
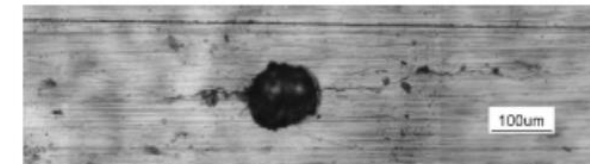
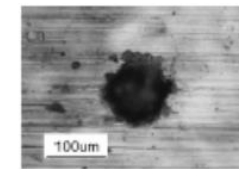
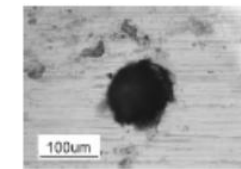
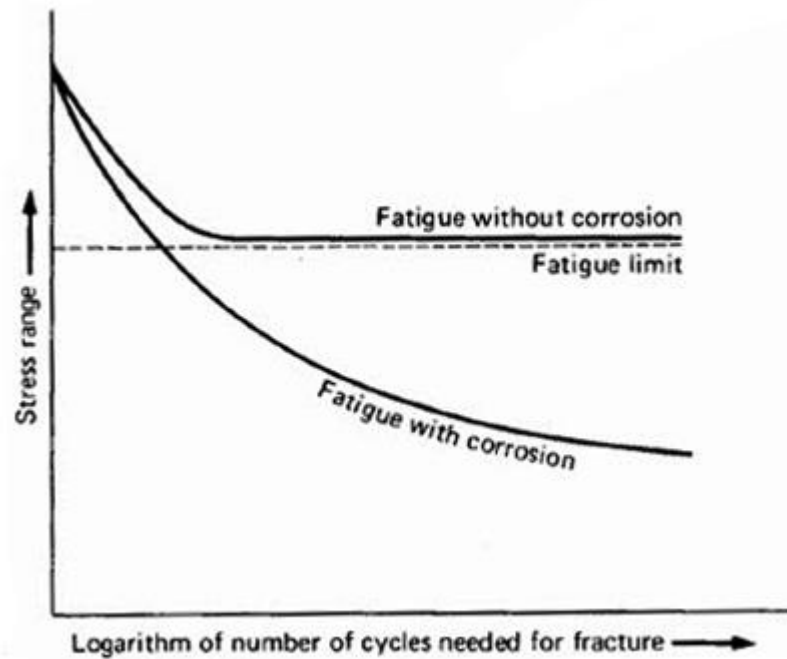
B – Crack cluster



Deutsche Bahn AG, Katrin Mädler, T.TVI53, 4 March 2011

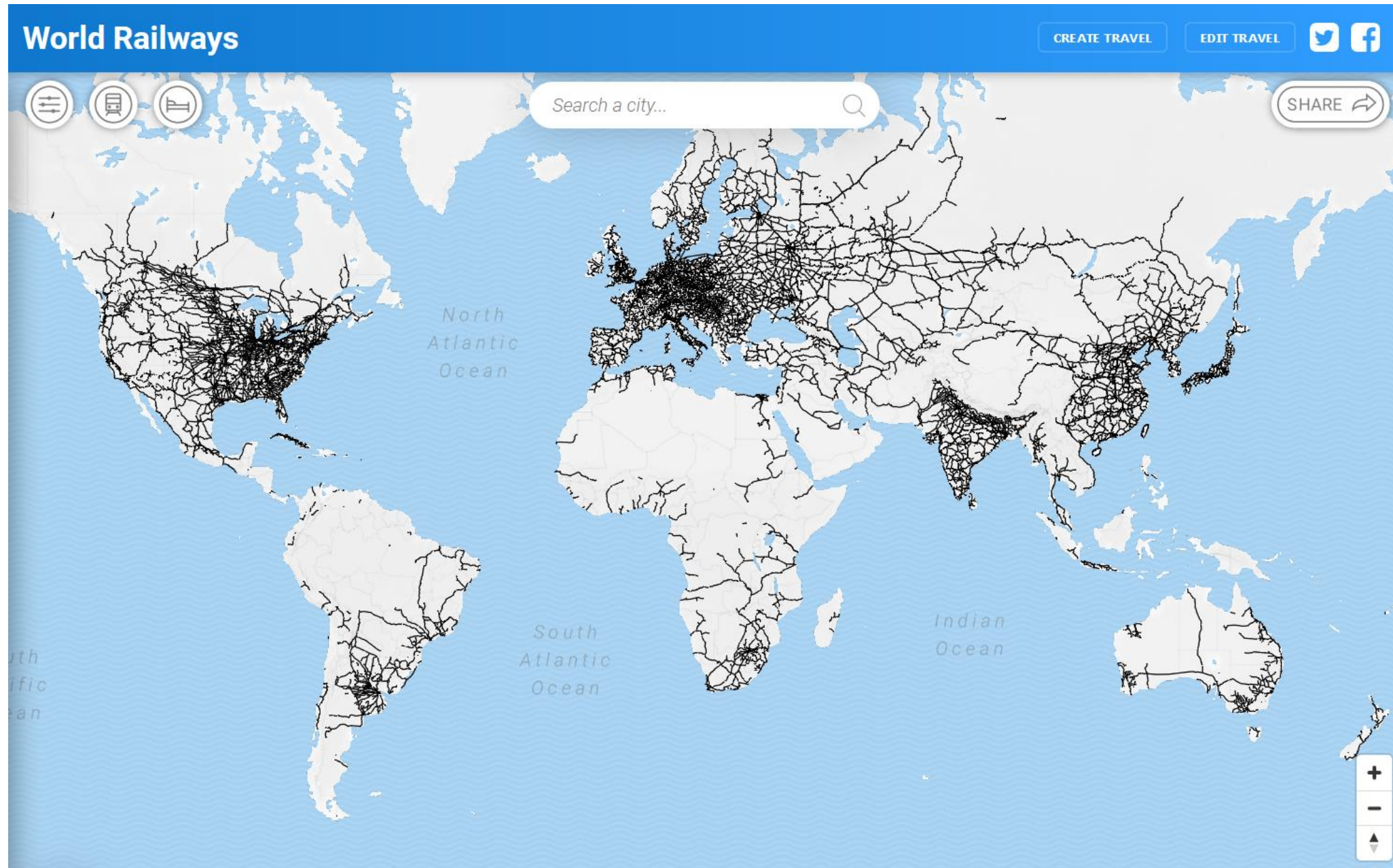


Milella P.P. (2013) Corrosion Fatigue



S. Beretta – Corrosion –fatigue of axle steels

https://traveler.sharemap.org/World_Railways



FUTURE SOUTHEAST ASIA

CURRENT AND PROPOSED RAILWAYS IN SOUTHEAST ASIA

FUTURE SOUTHEAST ASIA MAP

This map is a combination of current and proposed railways across mainland and maritime Southeast Asia. The proposed lines consist of railways under construction, lines announced as election promises, undergoing a feasibility study, or approved lines waiting for funding. Details of the proposed railways can be found at:

www.nomadicnotes.com/travel-blog/southeast-asia-rail-map/

ABOUT THE MAP

This is a subway-style map that represents how to travel between destinations rather than portraying geographical accuracy. Train routes and borders have been straightened, and stations have been realigned to fit the style of the map. Most of the lines are current or have been proposed at some point. Some "Nomadic Notes Recommendations" have been added to fill in missing gaps.

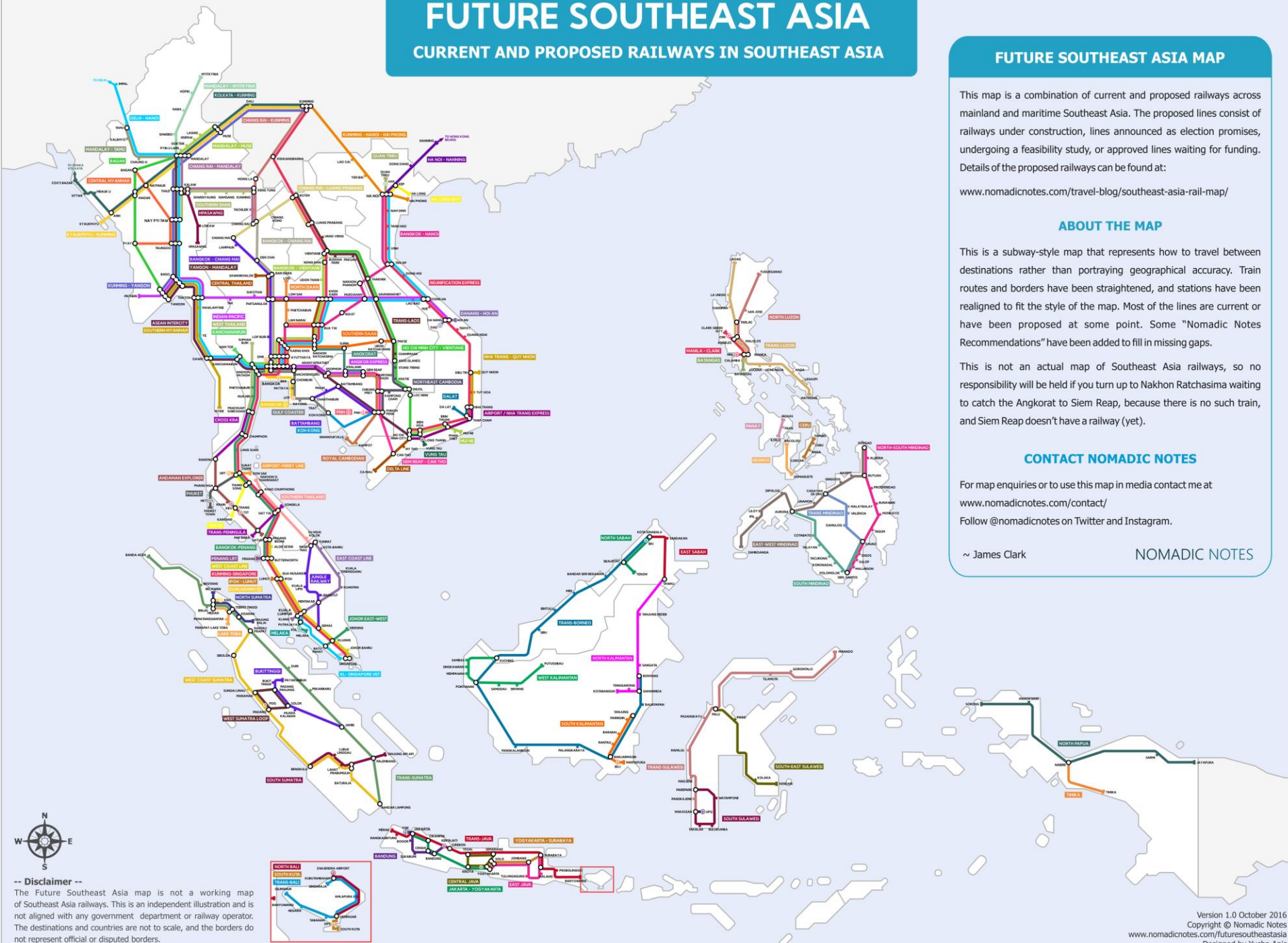
This is not an actual map of Southeast Asia railways, so no responsibility will be held if you turn up to Nakhon Ratchasima waiting to catch the Angkorat to Siem Reap, because there is no such train, and Siem Reap doesn't have a railway (yet).

CONTACT NOMADIC NOTES

For map enquiries or to use this map in media contact me at www.nomadicnotes.com/contact/
Follow @nomadicnotes on Twitter and Instagram.

~ James Clark

NOMADIC NOTES

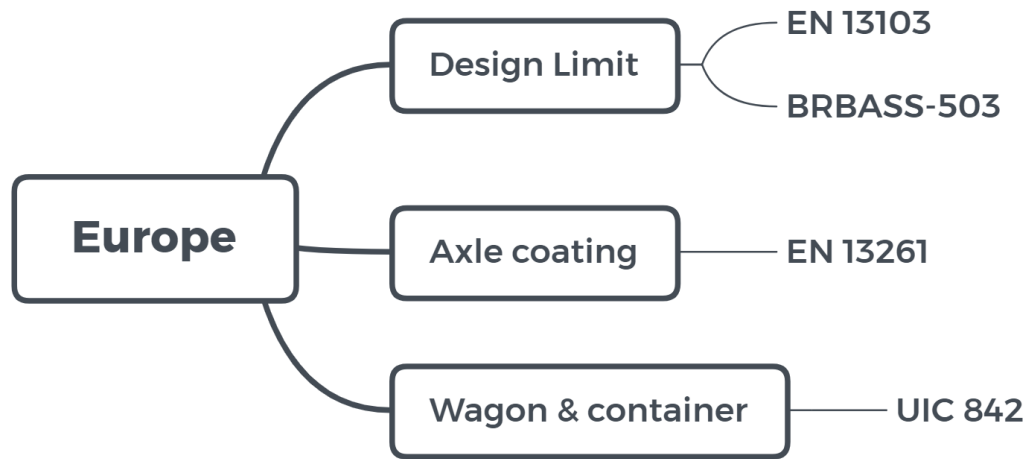


-- Disclaimer --

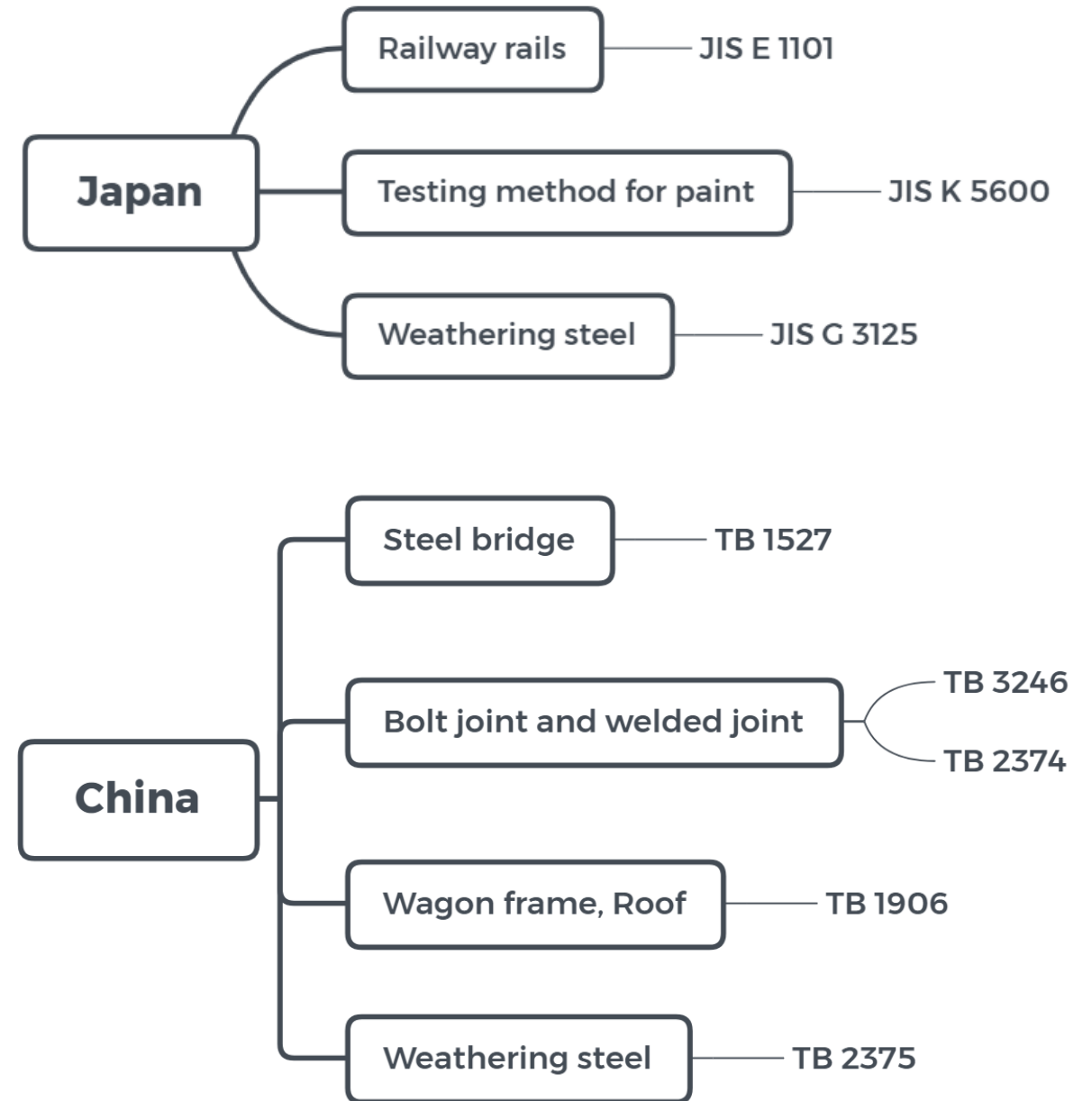
The Future Southeast Asia map is not a working map of Southeast Asia railways. This is an independent illustration and is not aligned with any government department or railway operator. The destinations and countries are not to scale, and the borders do not represent official or disputed borders.



Standards



- Atmospheric corrosion test
- Cyclic corrosion test
- Design of corrosion protection

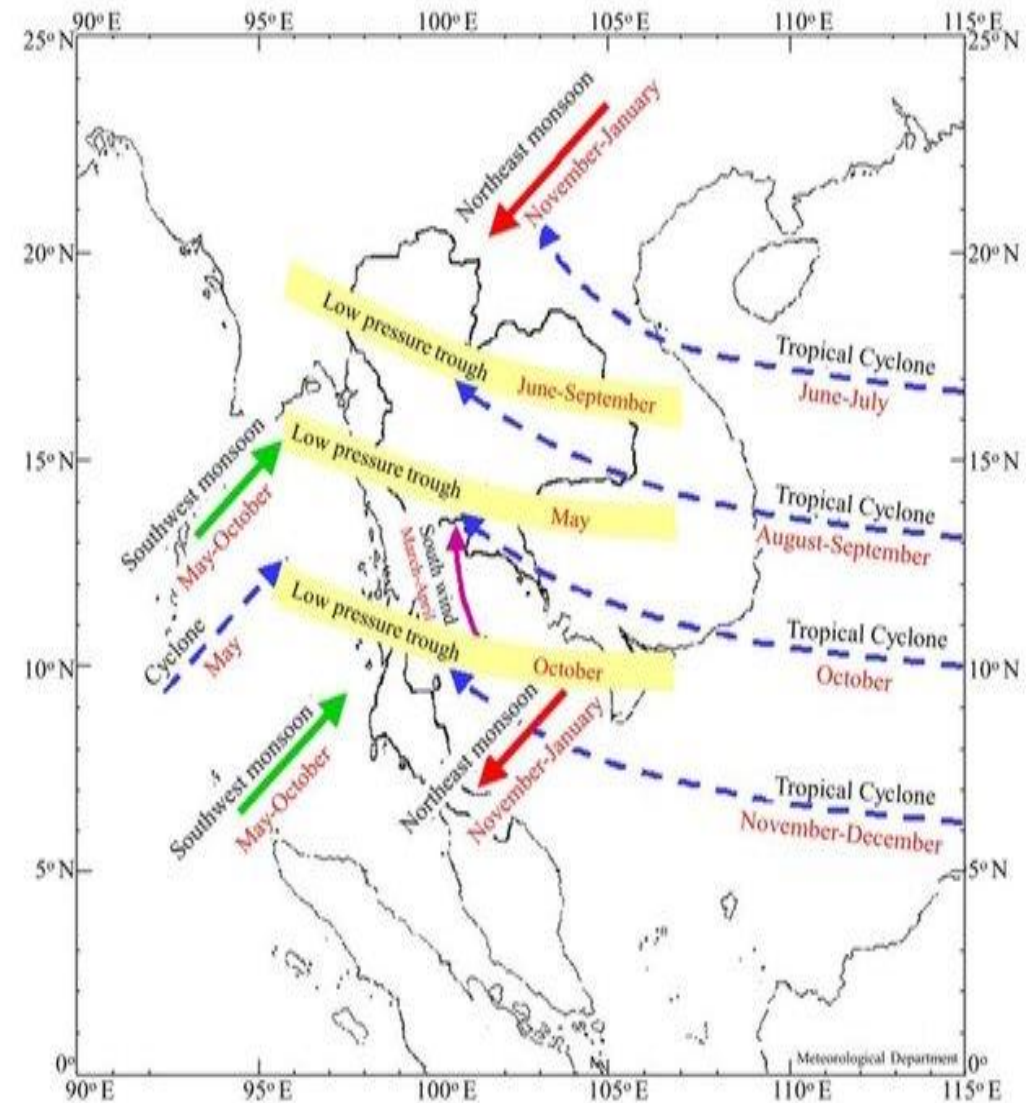


THAILAND CONNECTIVITY PLANS BY 2022



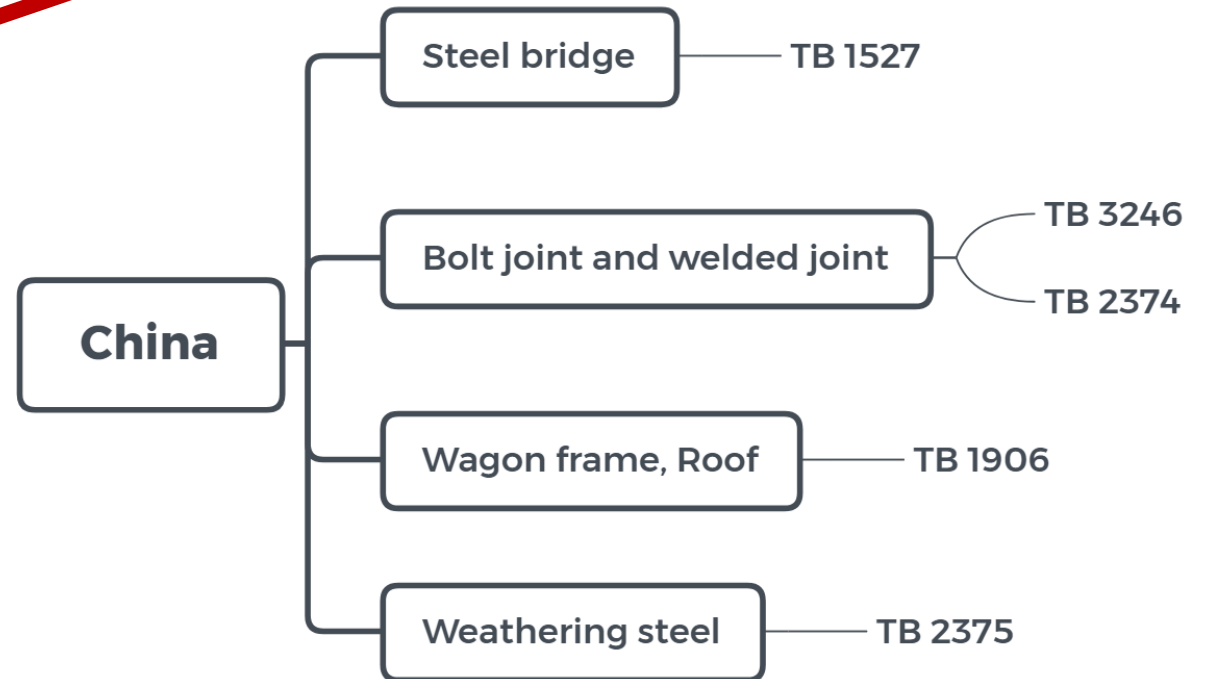
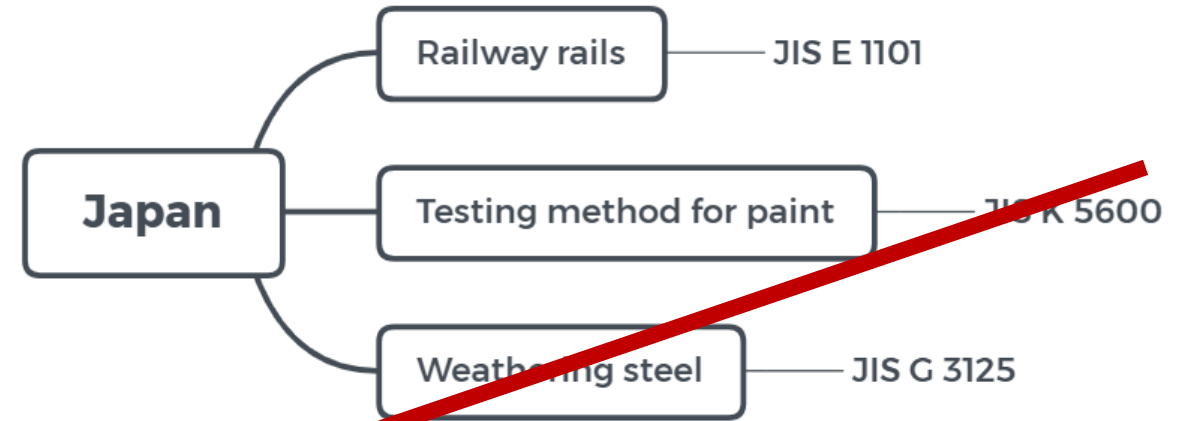
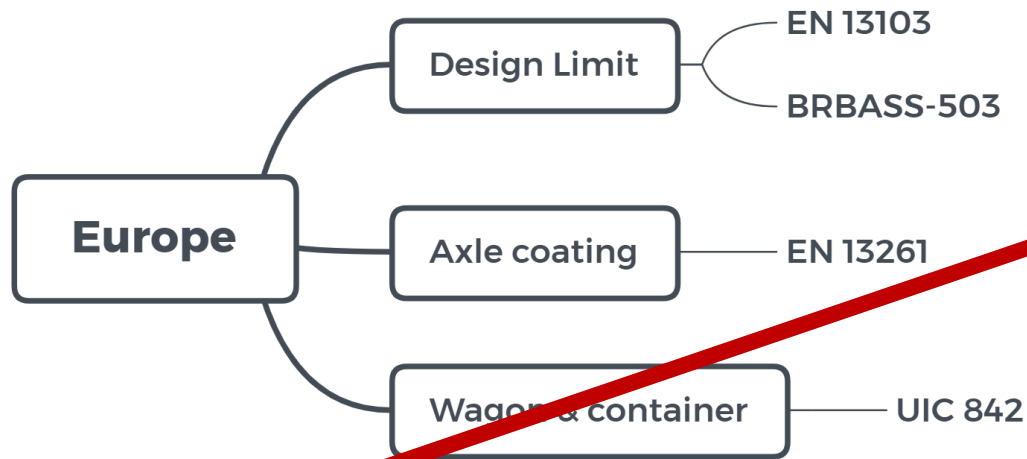
POSTgraphics

Tropical Monsoon Climate



Source: "The Rainfall of Thailand", A Study by Lawrence Sternstein, supported by The U.S. Army Quartermaster Corps, Research and Engineering Command, Project No. 7-83-01-006.

Standards



- Atmospheric corrosion test
- Cyclic corrosion test
- Design of corrosion protection

Thailand Atmospheric Corrosion Data

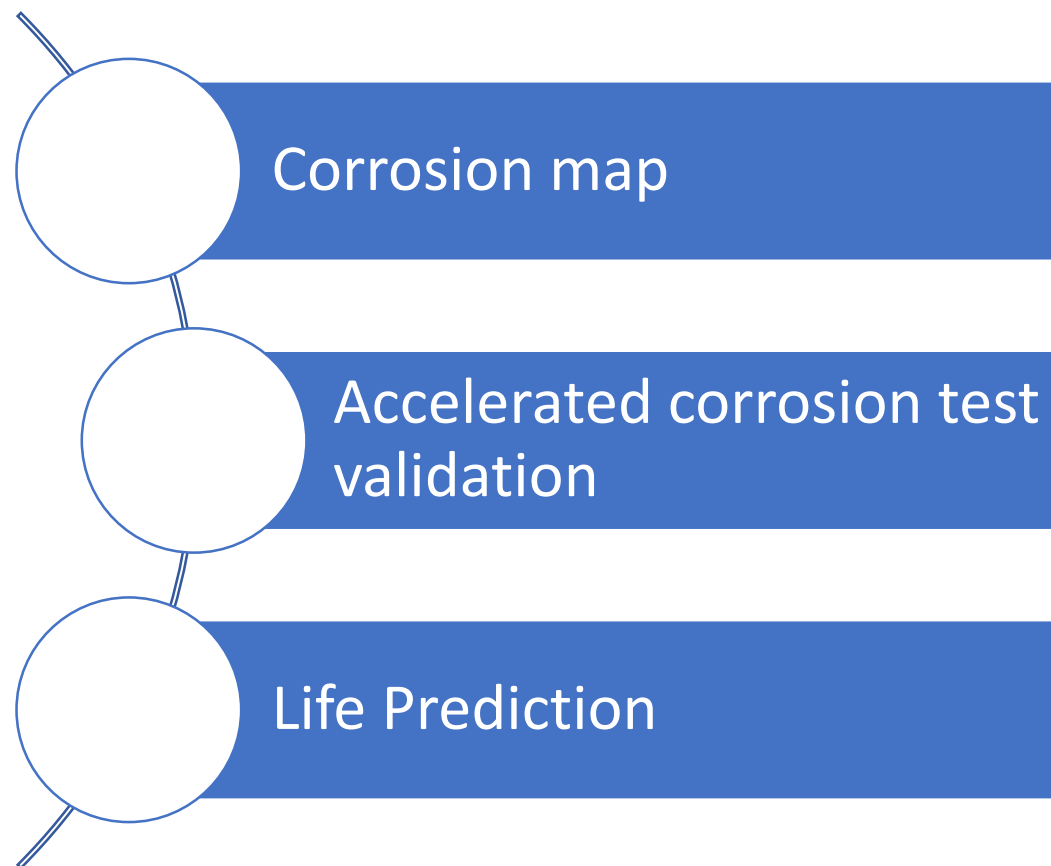
2007 - 2012

2013-2018

2018-2023

4 stations - Central and eastern area near the Gulf of Thailand	7 stations - North, Northeast - Central and eastern area near the Gulf of Thailand - Andaman coast	5 stations + 3 more - Northeast - Central and eastern area near the Gulf of Thailand - Andaman coast - Lower and upper southern area along the Gulf of Thailand
SS 400, stainless steels	SS400, Corten, GI, GL	+ Al alloy, Painted steels, Zn-Al-Mg coated steel + etc.
T, RH, TOW	T, RH, TOW, Cl ⁻ , SO ₂	T, RH, TOW, Cl ⁻ distribution, SO ₂

Use of exposure test data

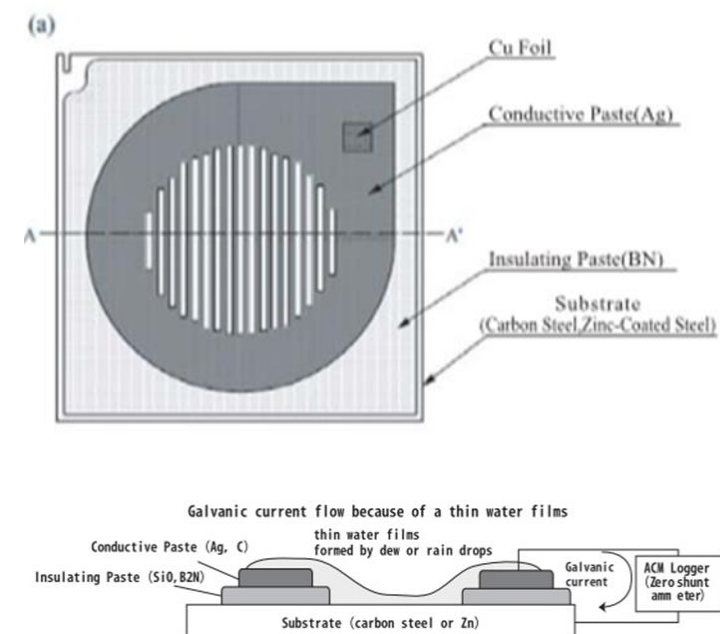


Exposure Test

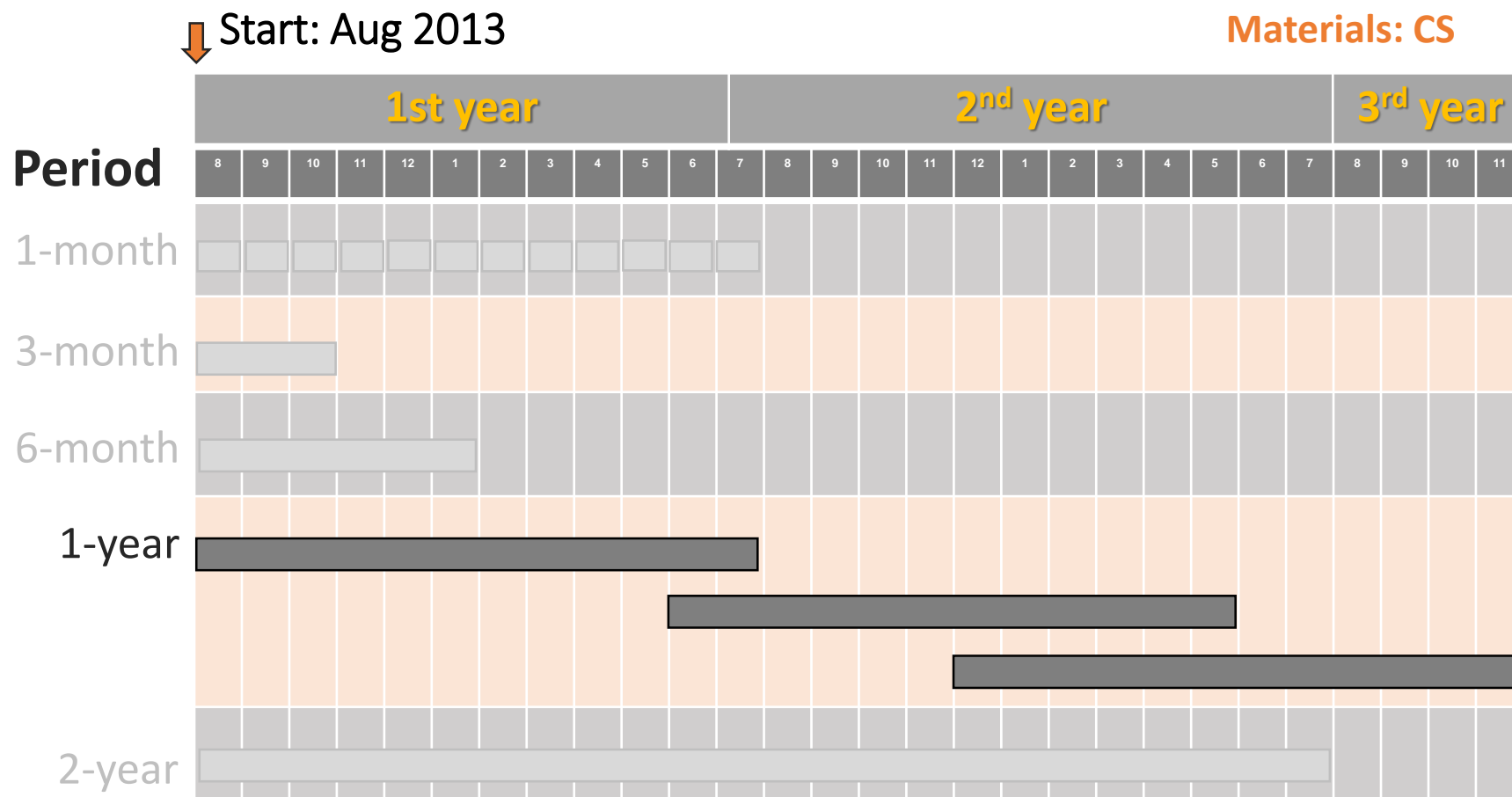
Exposure test

Weather data

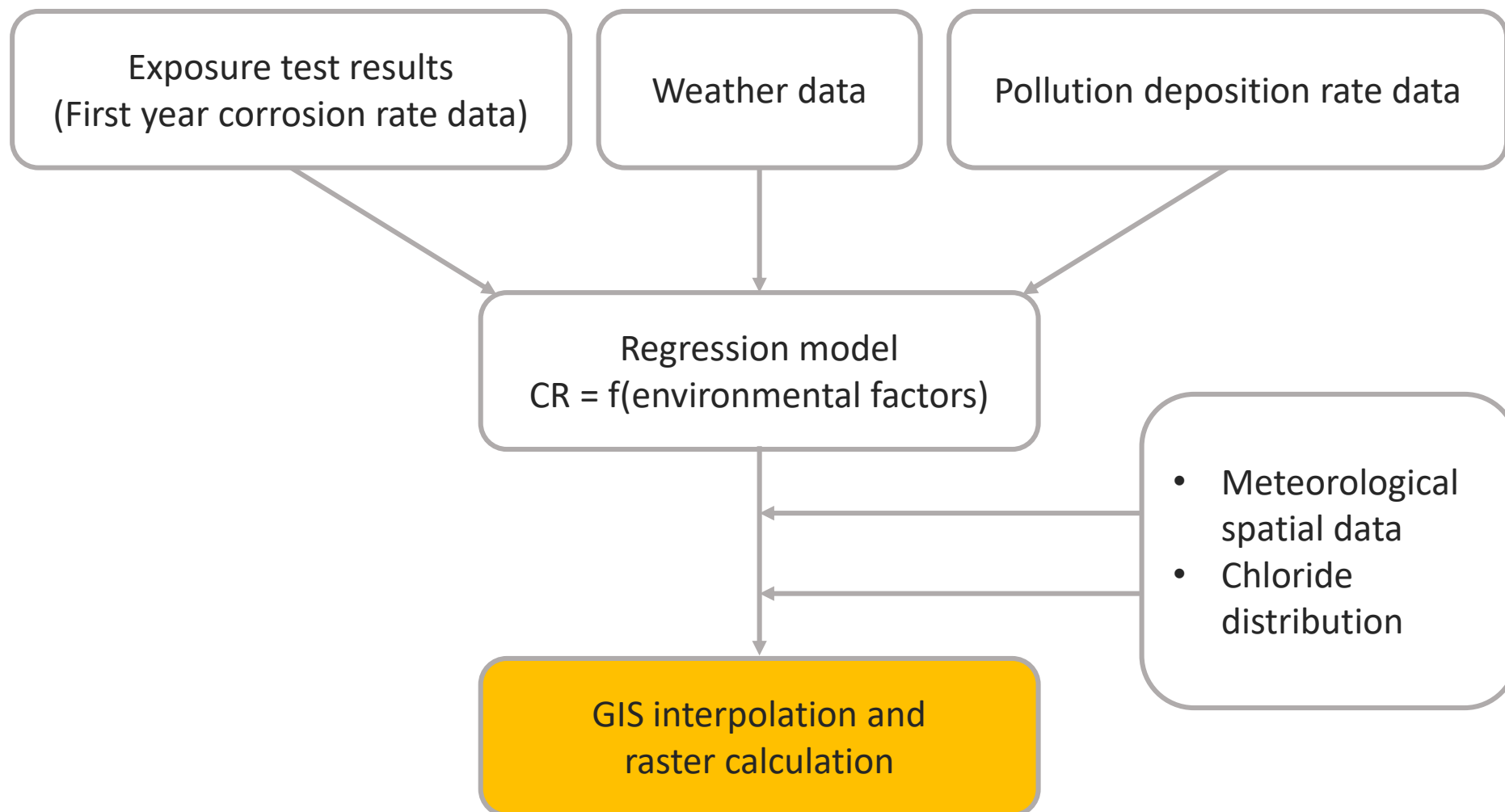
Pollution deposition rate data



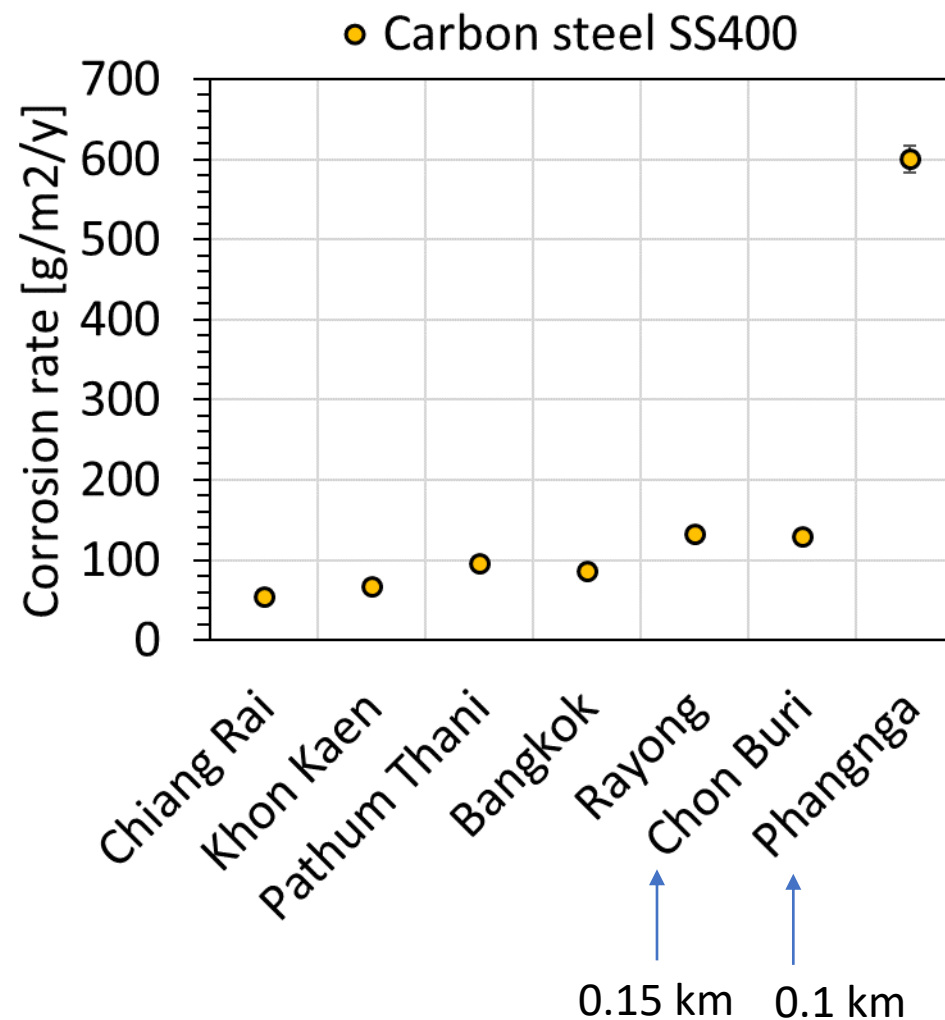
Exposure Test Period



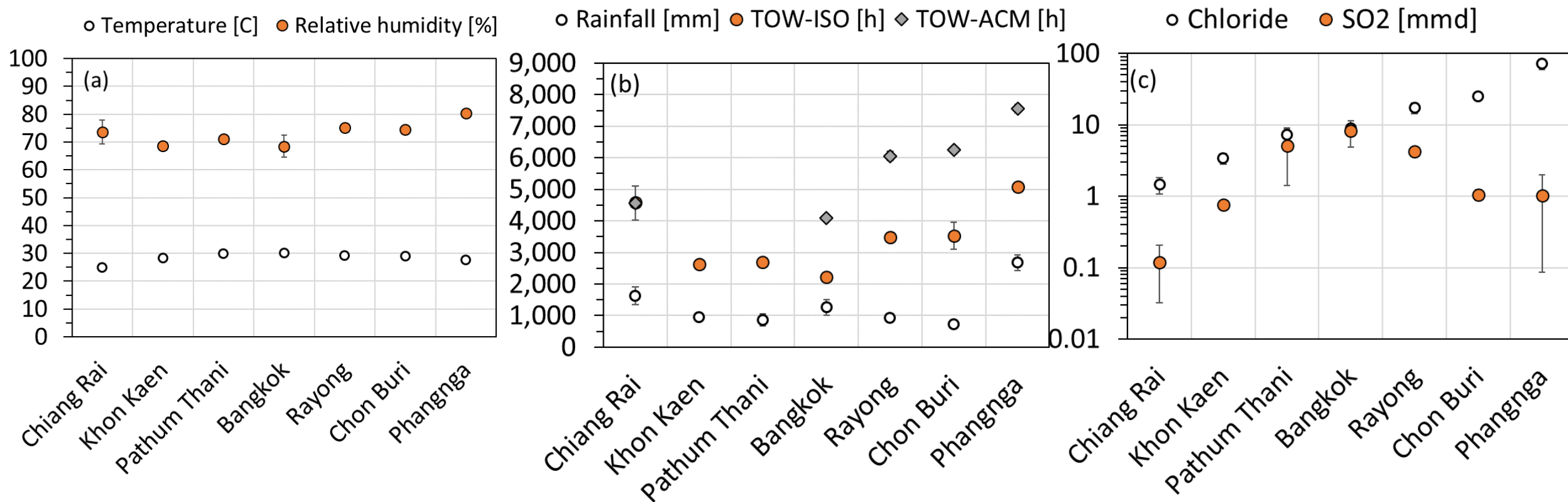
Current Corrosion Rate Prediction Model



First year corrosion rate



Environmental Parameters

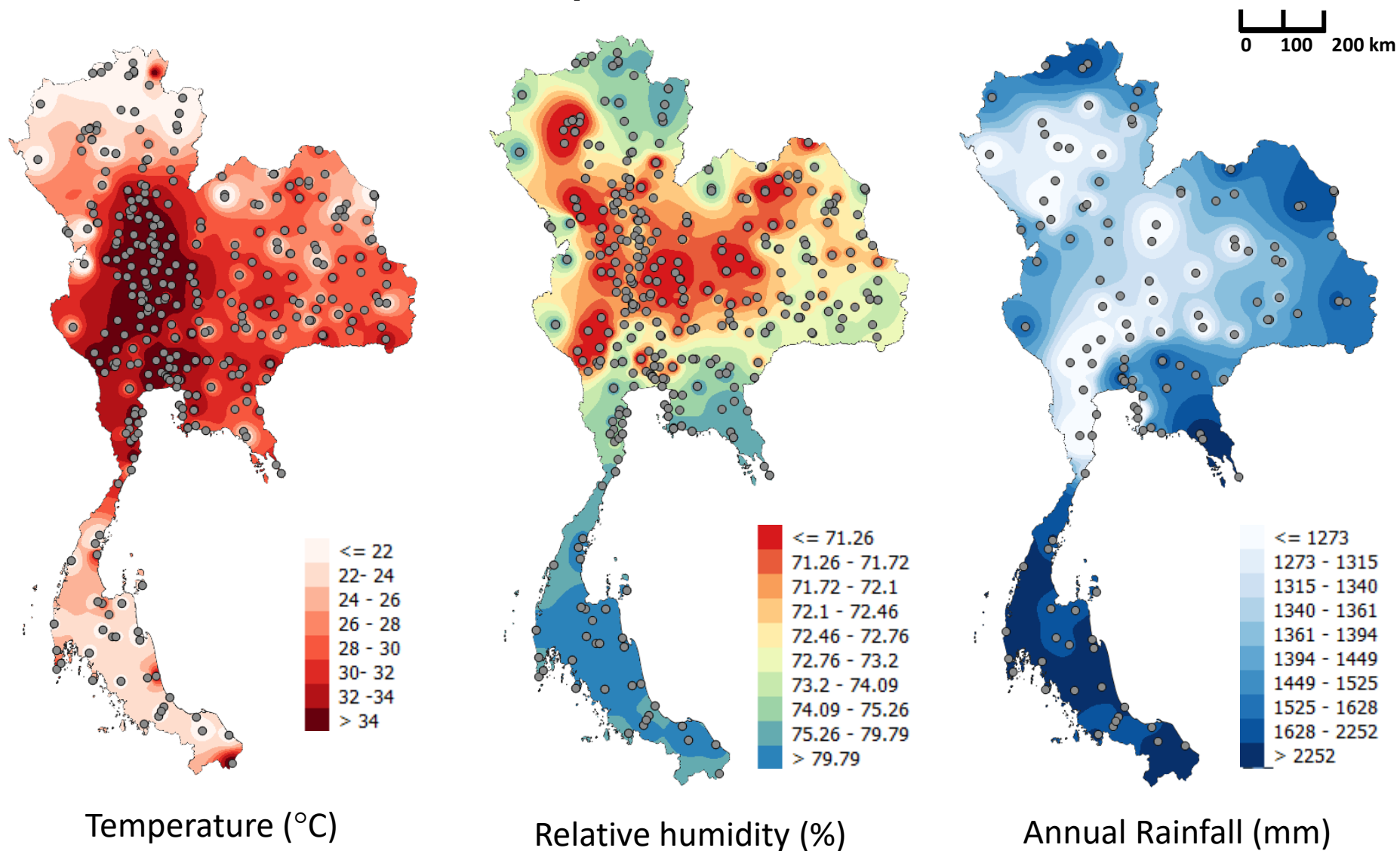


Regression model

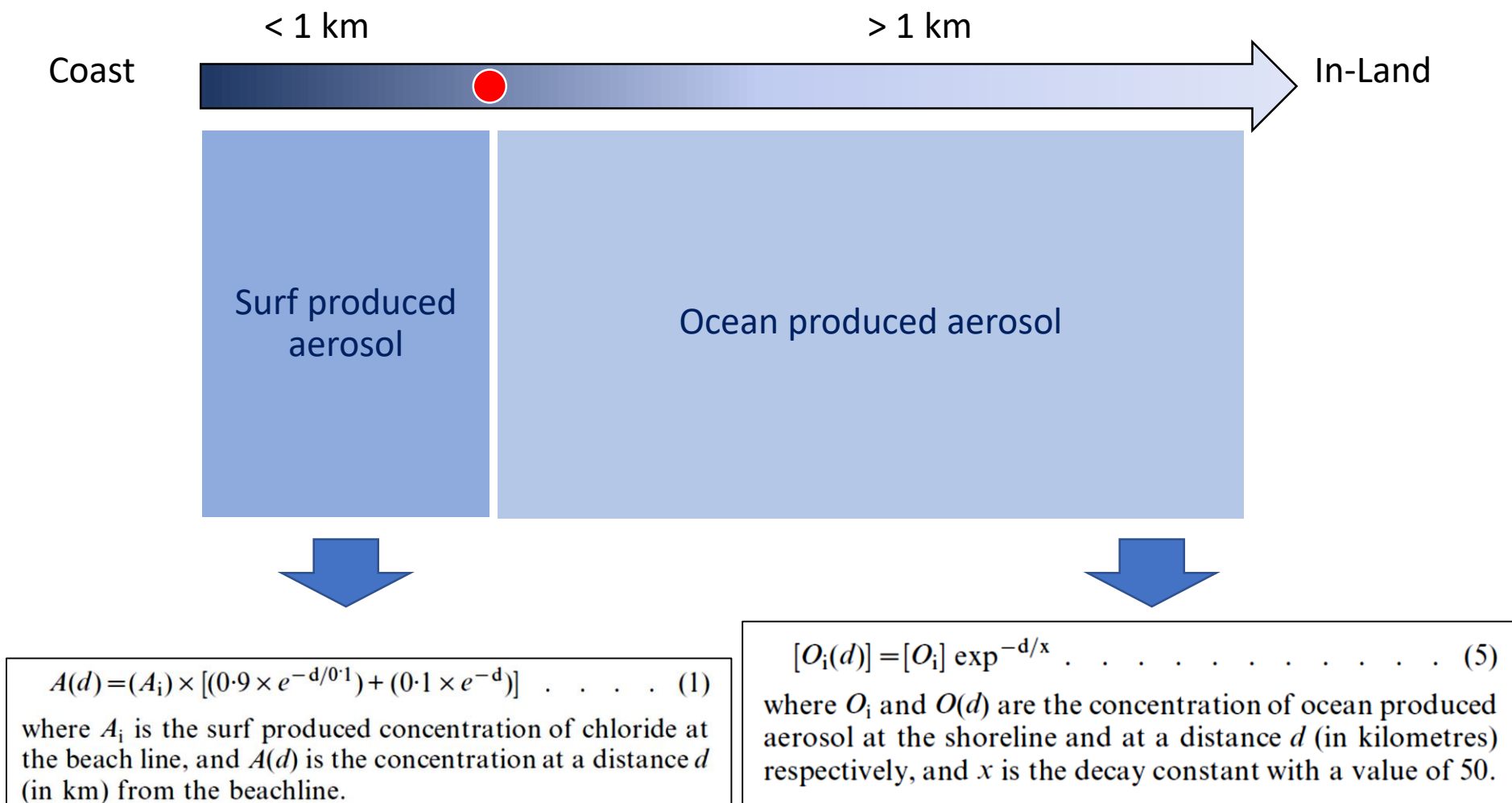
CR \rightarrow f (T, RH, RF, Cl⁻, SO₂)

Equation	R ²	Adjusted R ²	P-value	
			Variable 1	Variable 2
CR = -639.99 + 12.97T + 5.03RH	0.7303	0.6943	6.01x10 ⁻⁵	9.07x10 ⁻⁴
CR = -51.94 + 0.10RF + 12.09Cl ⁻	0.9395	0.9309	6.03x10 ⁻³	6.45x10 ⁻⁵

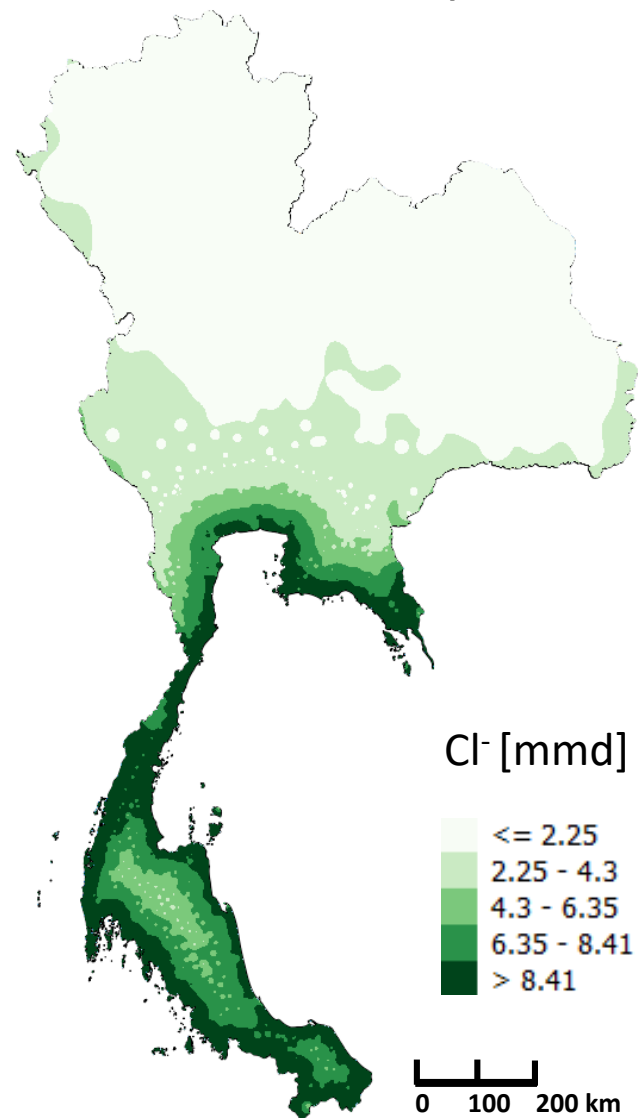
GIS: Climate data layer



GIS: Chloride data layer



GIS: Chloride data layer



Non-marine ($\text{Cl}^- < 3$ mmd)

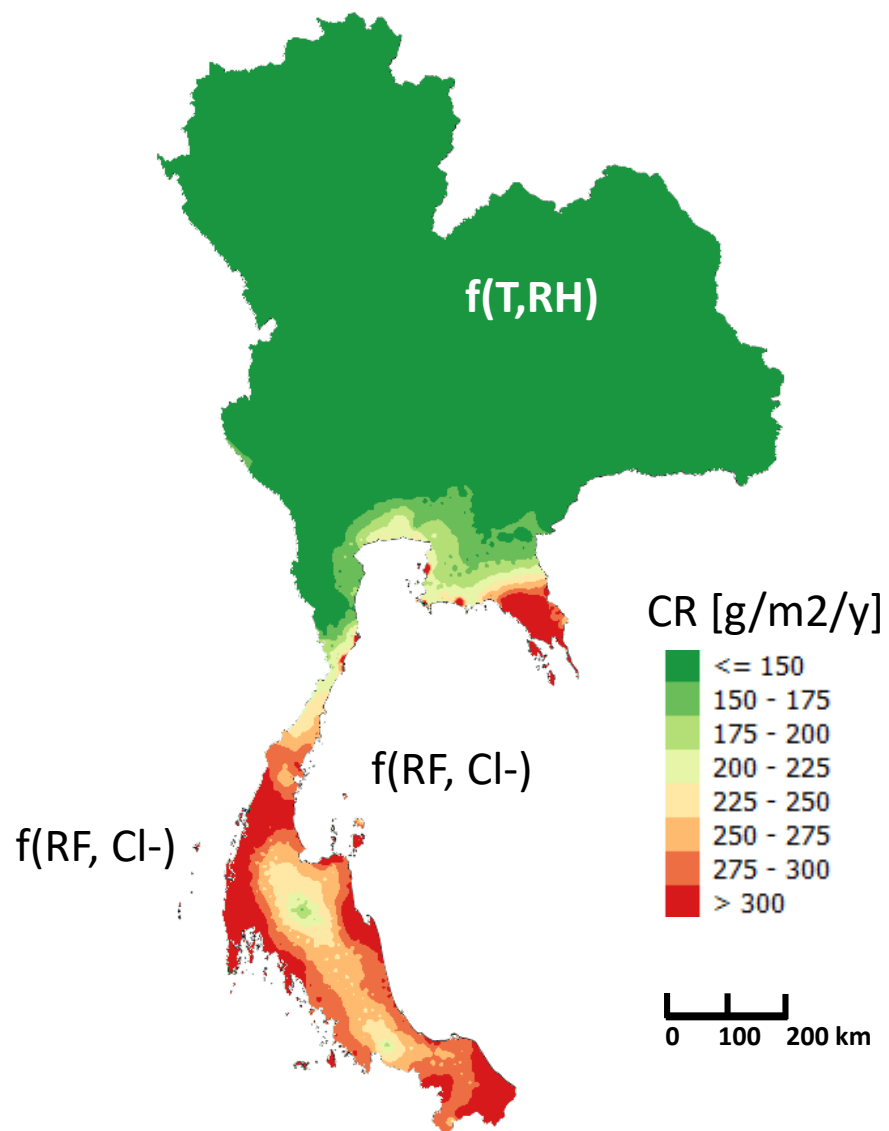
☐ $\text{CR} = f(\text{T}, \text{RH})$

Marine ($\text{Cl}^- \geq 3$ mmd)

☐ $\text{CR} = f(\text{RF}, \text{Cl})$

B. Chico, D. Fuente, I. Díaz, J. Simancas and M. Morcillo, Materials, 10(2017), 601.

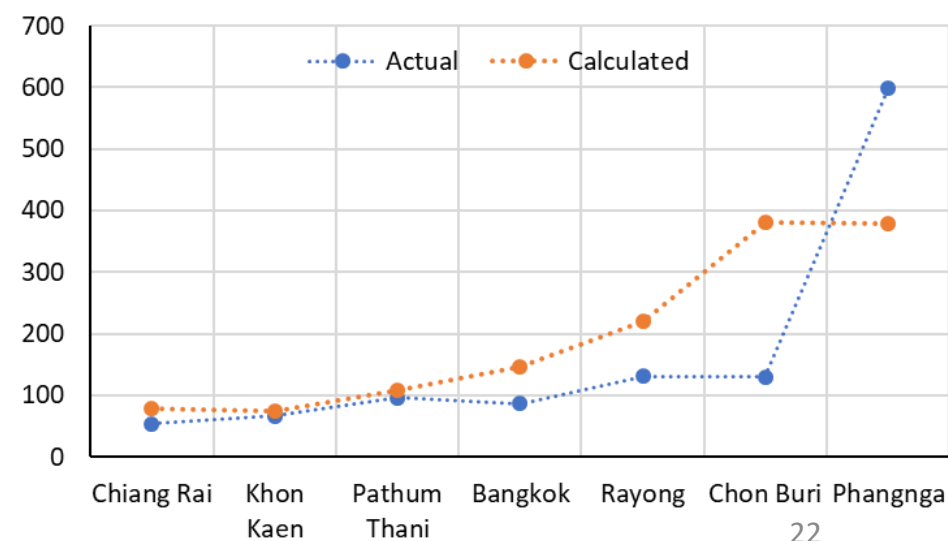
GIS: Corrosion rate data layer



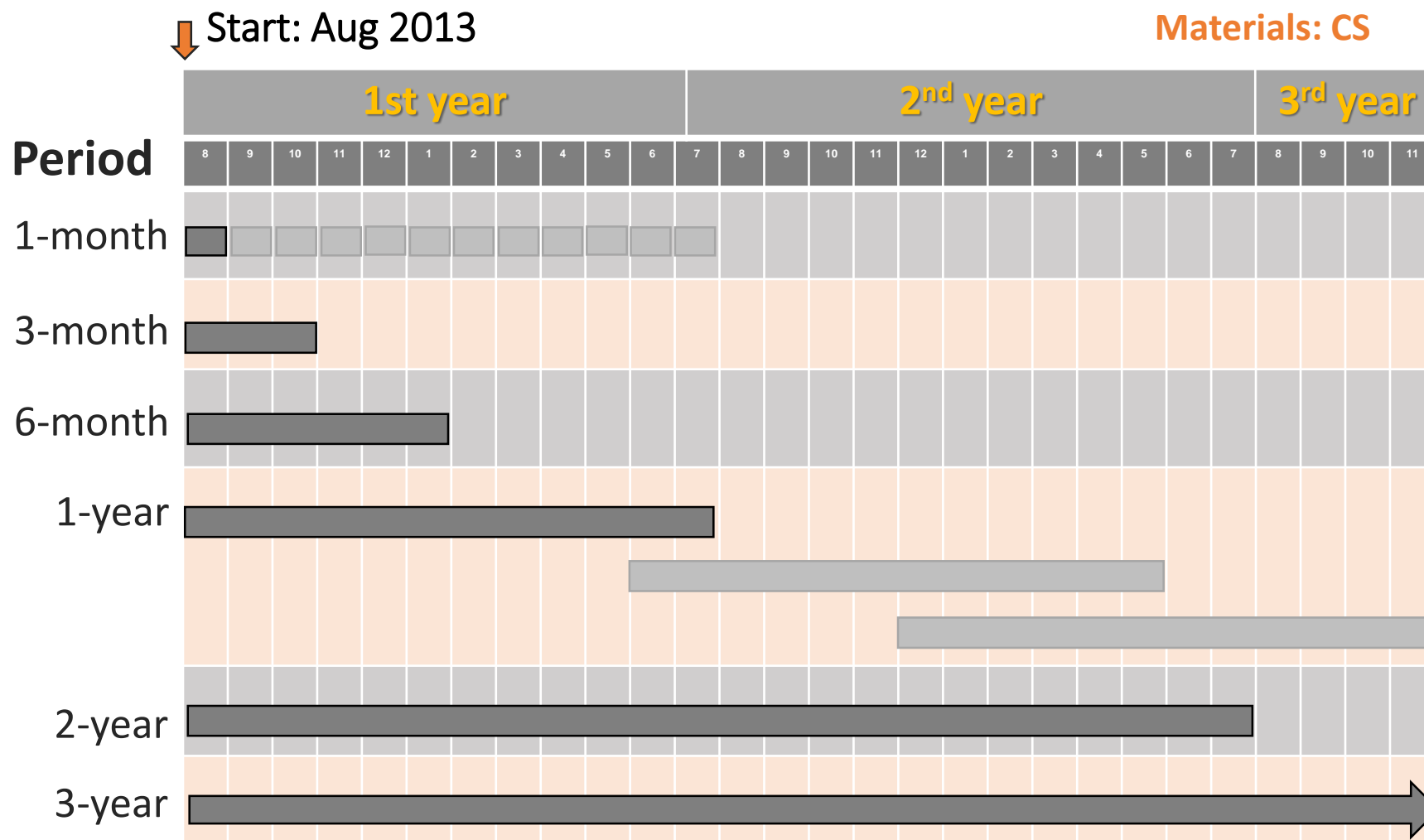
Corrosion rate of carbon steel in Thailand

- Non-marine, CR < 150 g/m²/y
- Marine, CR = 150 – 900 g/m²/y

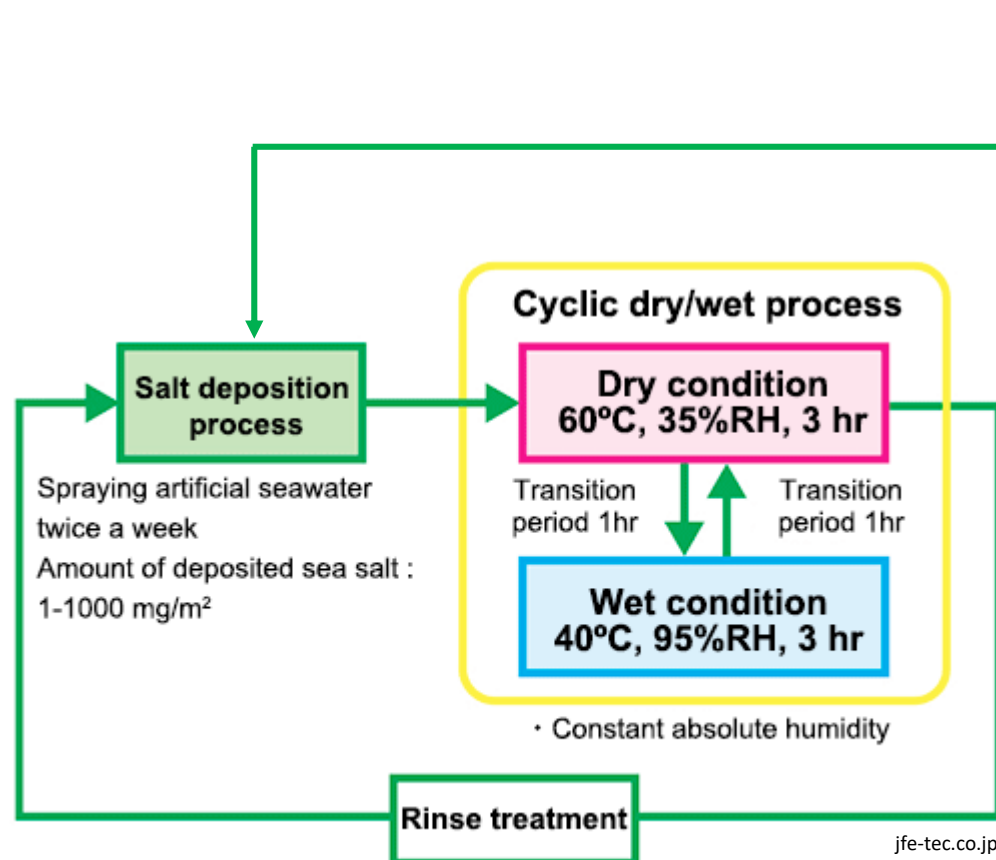
Corrosion rate [g/m²/y]



Exposure Test Period



Design an Accelerated Corrosion Test Method

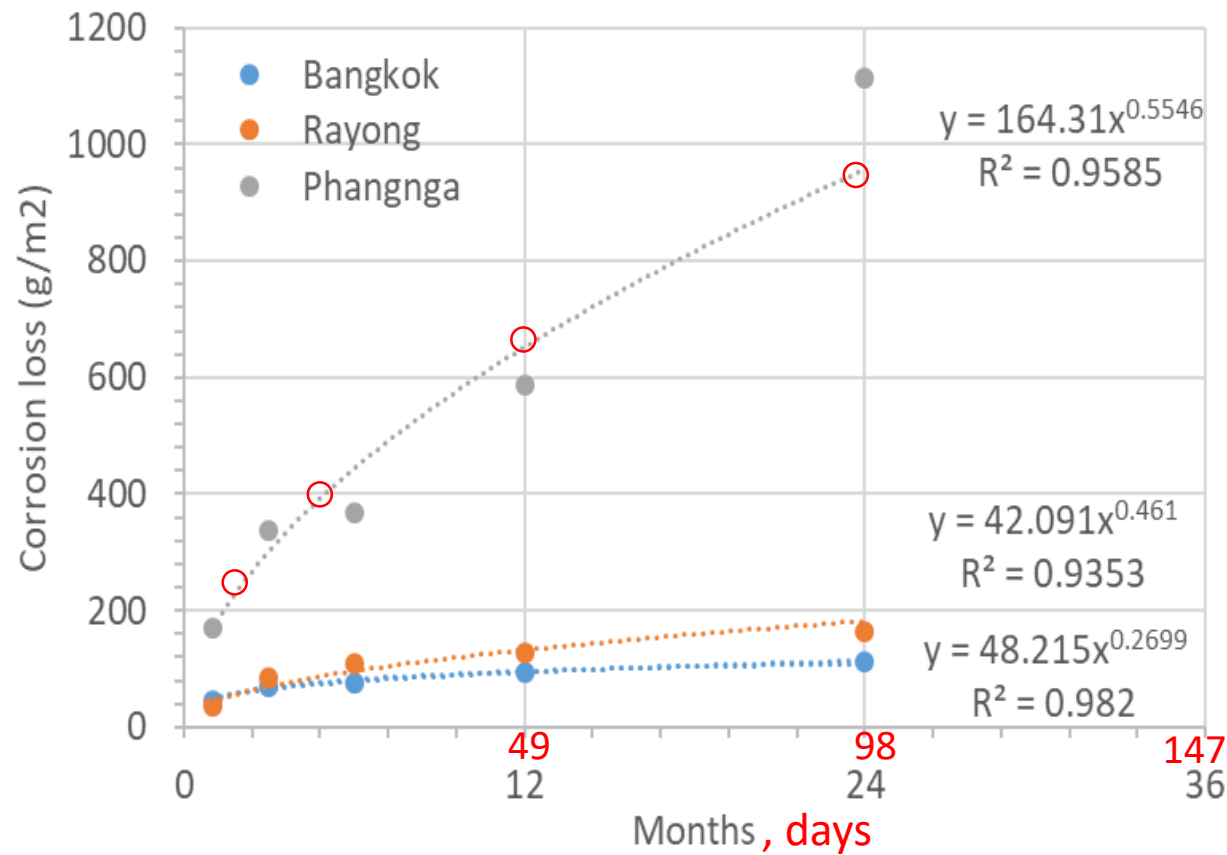


Condition of ACTE™ Test (ISO 16539 Method B)

ACTE™ is a registered trademark of JFE Steel Corporation in Japan.

Design an Accelerated Corrosion Test Method

Amount of salt in the spray solution to get similar trend of corrosion loss vs. number of cycles.

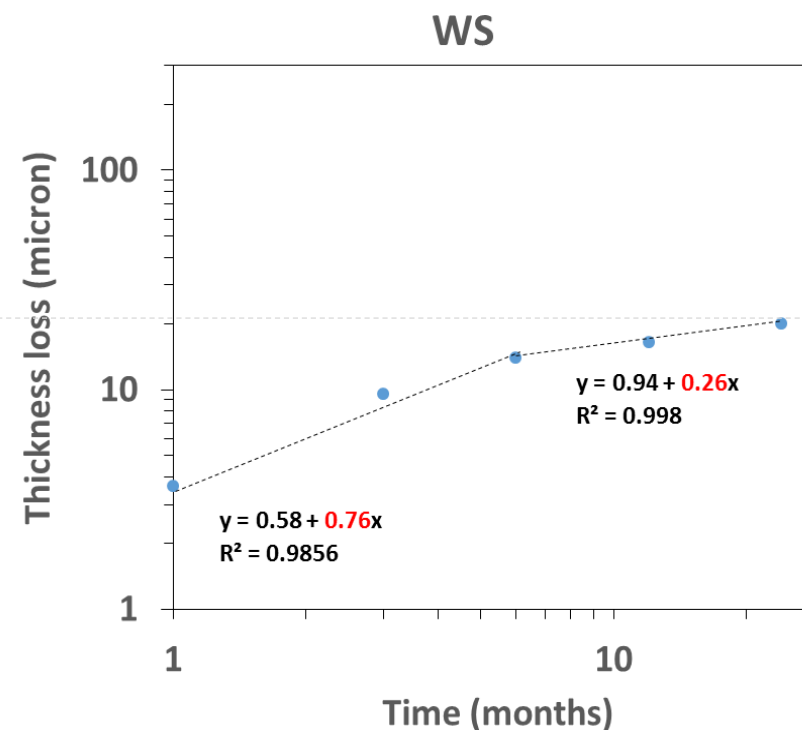
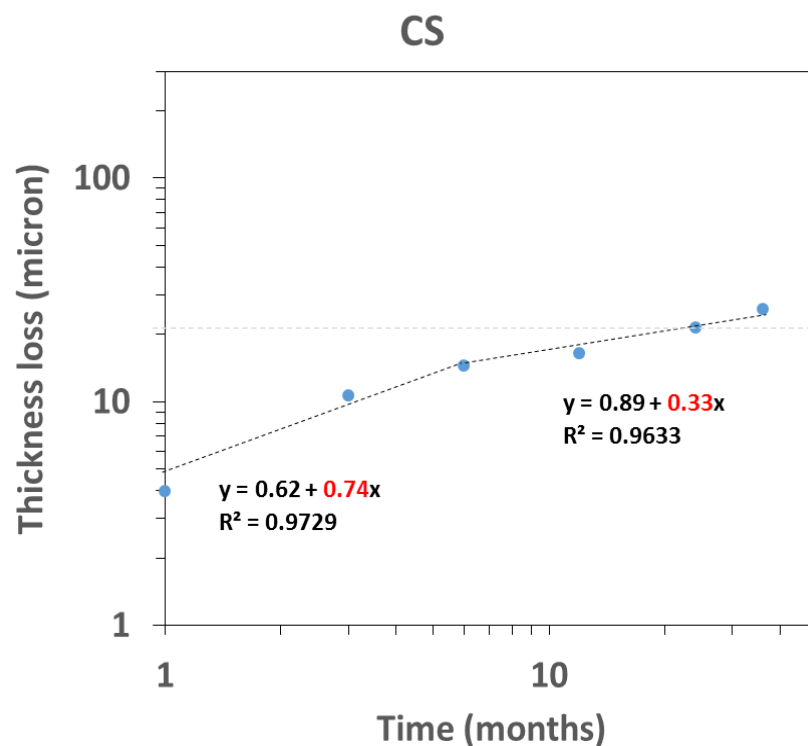


Life Prediction

$$D = At^n$$

$$\log D = \log A + n \log t$$

$n > 0.5$: non-protective corrosion product
 $n < 0.5$: protective corrosion product



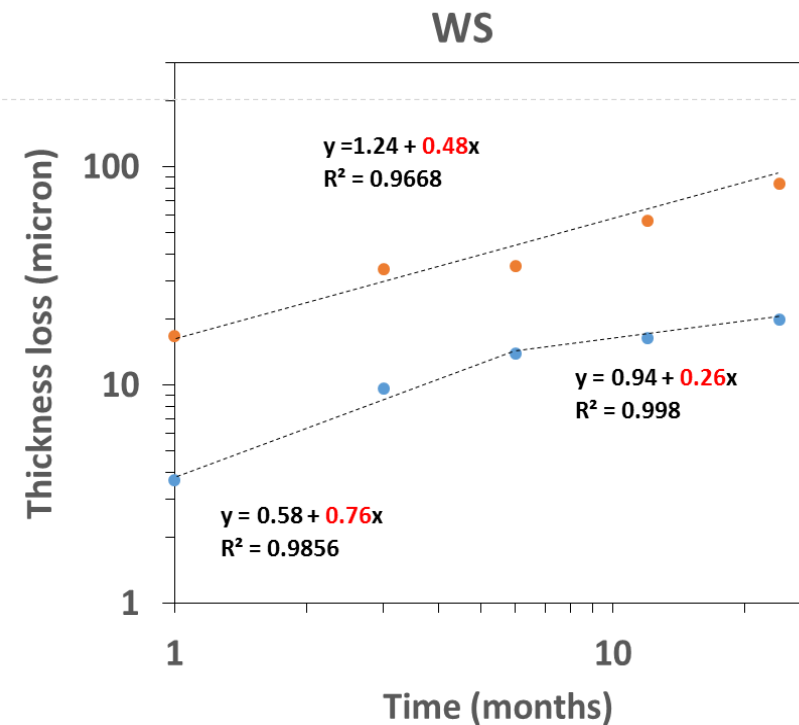
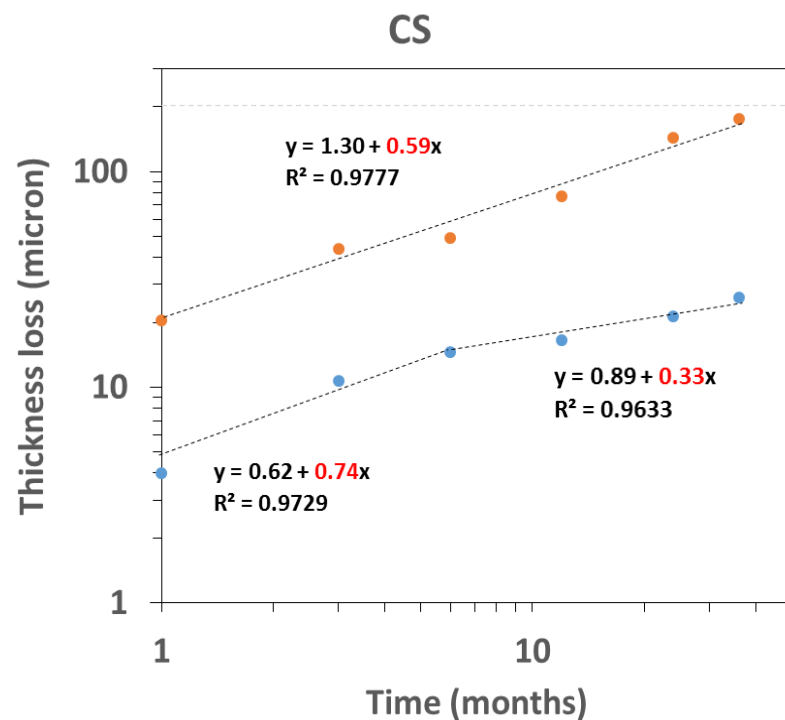
Marine (Gulf of Thailand)		Marine (Andaman)
$n_1 > 0.5$	$n_2 < 0.5$	

Life Prediction

$$D = At^n$$

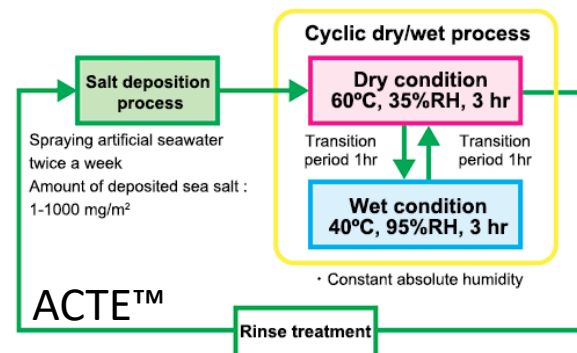
$$\log D = \log A + n \log t$$

$n > 0.5$: non-protective corrosion product
 $n < 0.5$: protective corrosion product

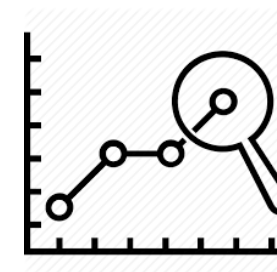


Marine (Gulf of Thailand)		Marine (Andaman)
$n_1 > 0.5$	$n_2 < 0.5$	$n_{CS} > 0.5$ $n_{WS} < 0.5$

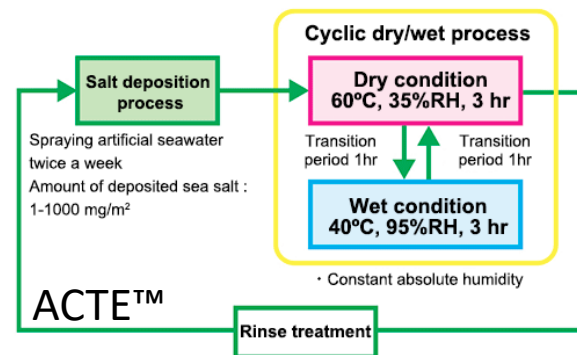
Infrastructure



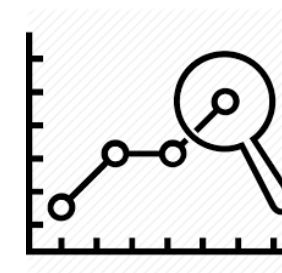
<http://www.hawaii corrosionlab.org/per/per.html>



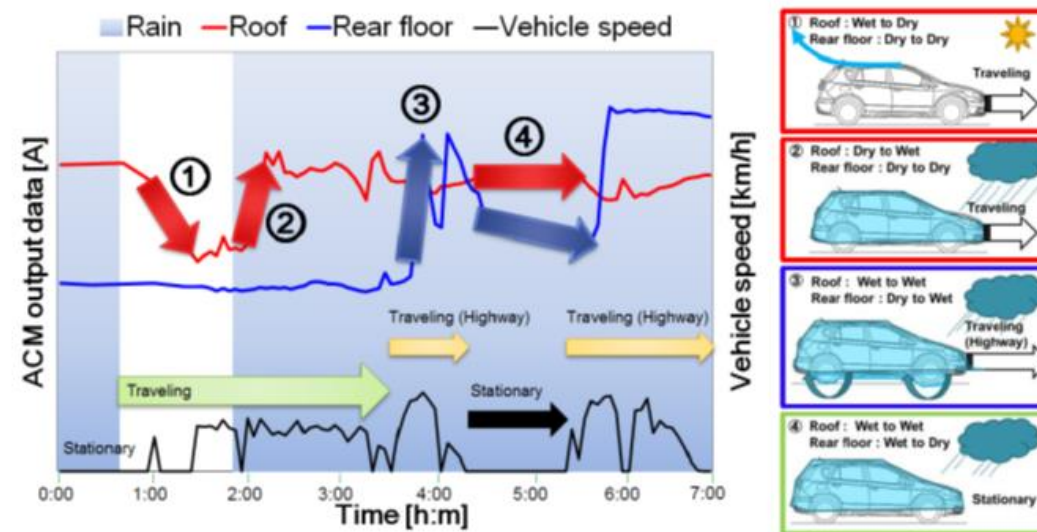
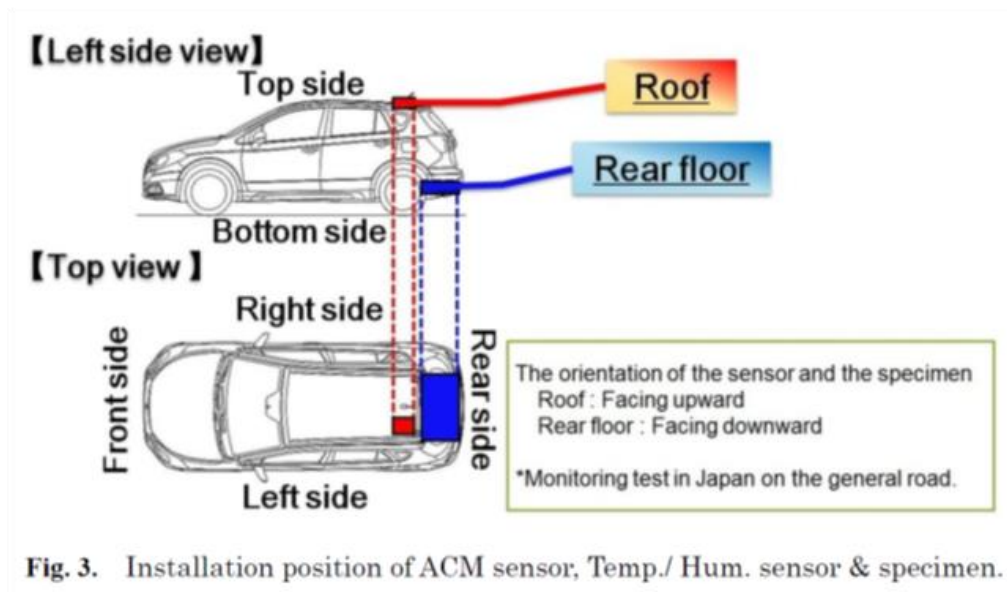
Rolling stock components



- 1. หลังคา A, C, D
- 2. โครงรถด้านใน A, B, C
- 3. ตัวถังด้านนอก A, C
- 4. ใต้ท้องรถ A, C

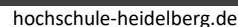
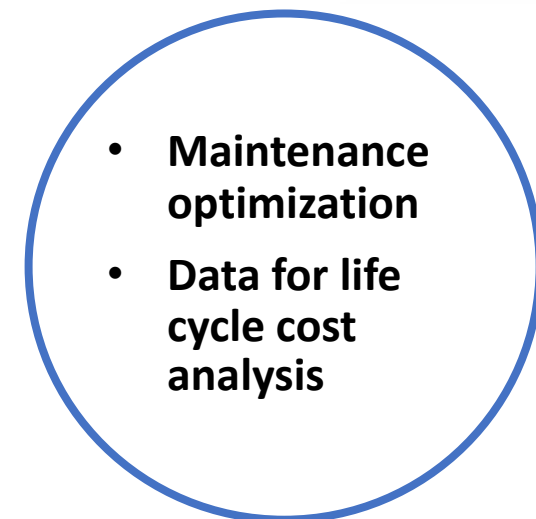


ACM sensor monitoring



H. Takahashi et al., Proc. 14th Int. Conf. on Global Research and Education, Inter-Academia, 2015.

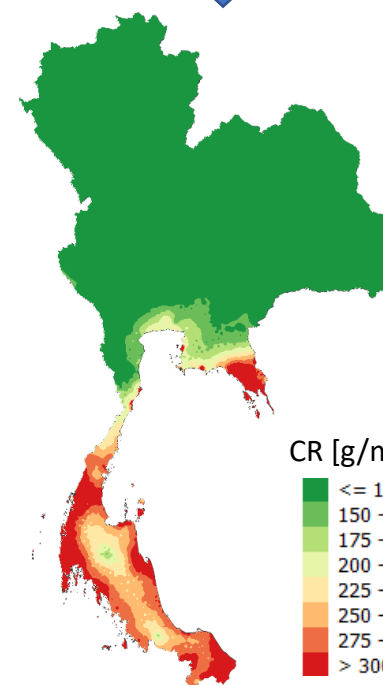
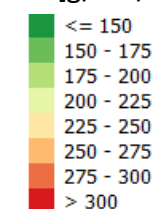
At high travelling speed, corrosion underneath the car is more severe.



materialsperformance.com



- performance ranking
- material/coating selection
- database generation

CR [g/m²/ y]

**Add more data
to
Thailand
corrosion map**

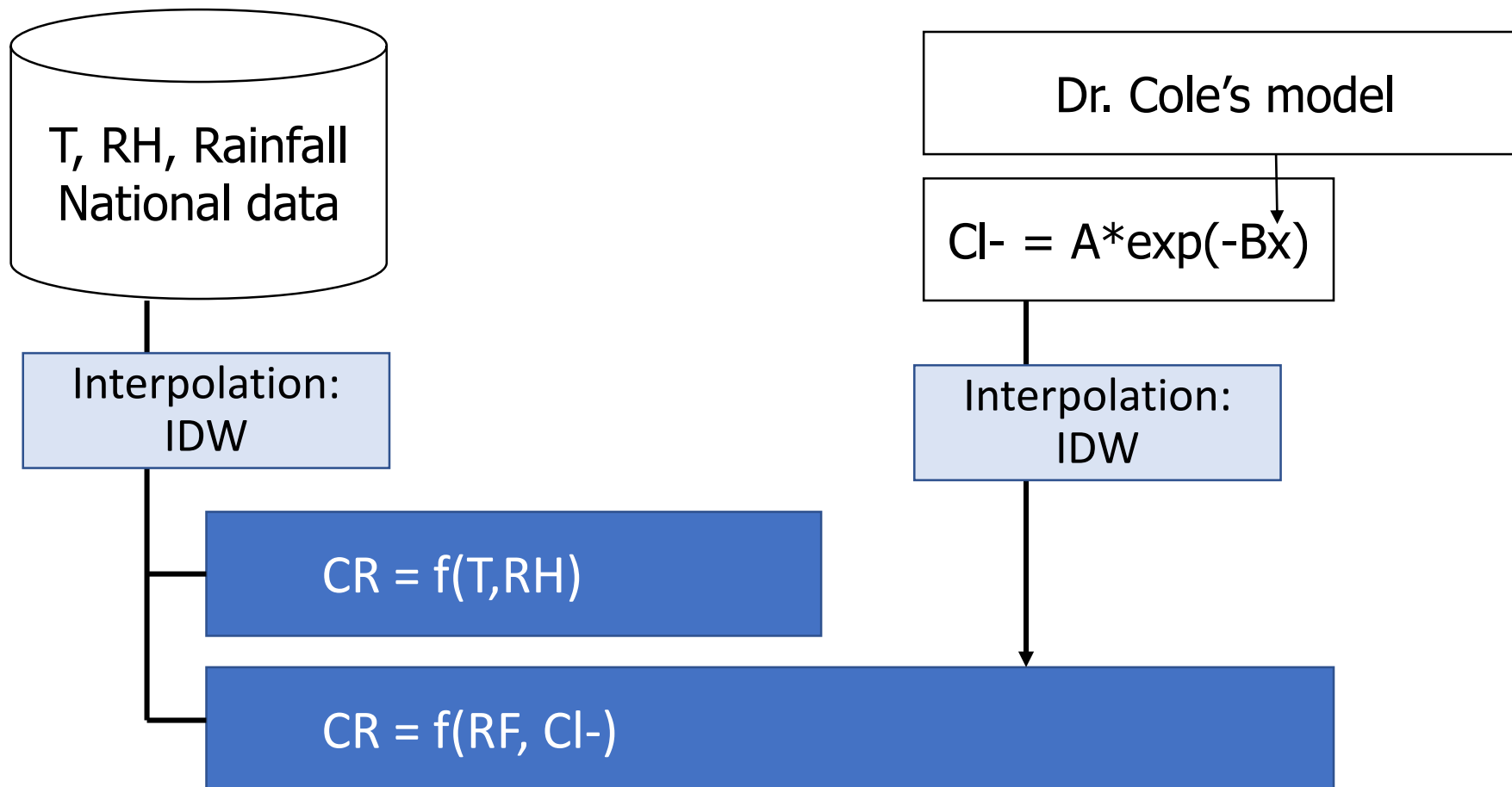
Acknowledgements

- National Metal and Materials Technology Center
- Thailand Meteorological Department
- National Hydroinformatics and Climate Data Center
- Geo-Informatics and Space Technology Development Agency
- NIMS, Japan
- IMS, Vietnam

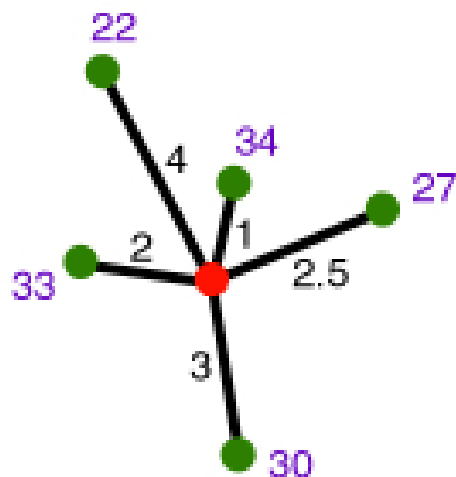
Thank you

Wanida Pongsaksawad, Ph.D.
wanidap@mtec.or.th

GIS: Corrosion rate



Inverse Distance Weighting Interpolation



$$Z(x) = \frac{\sum w_i z_i}{\sum w_i} = \frac{\frac{34}{1^2} + \frac{33}{2^2} + \frac{27}{2.5^2} + \frac{30}{3^2} + \frac{22}{4^2}}{\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{2.5^2} + \frac{1}{3^2} + \frac{1}{4^2}} = 32.38$$

An unknown value is calculated by inverse distance weight from the known value points.