Multi-Scale Characterization of Saltwater Intrusion in Heterogeneous Volcanic Aquifers with Airborne Electromagnetics

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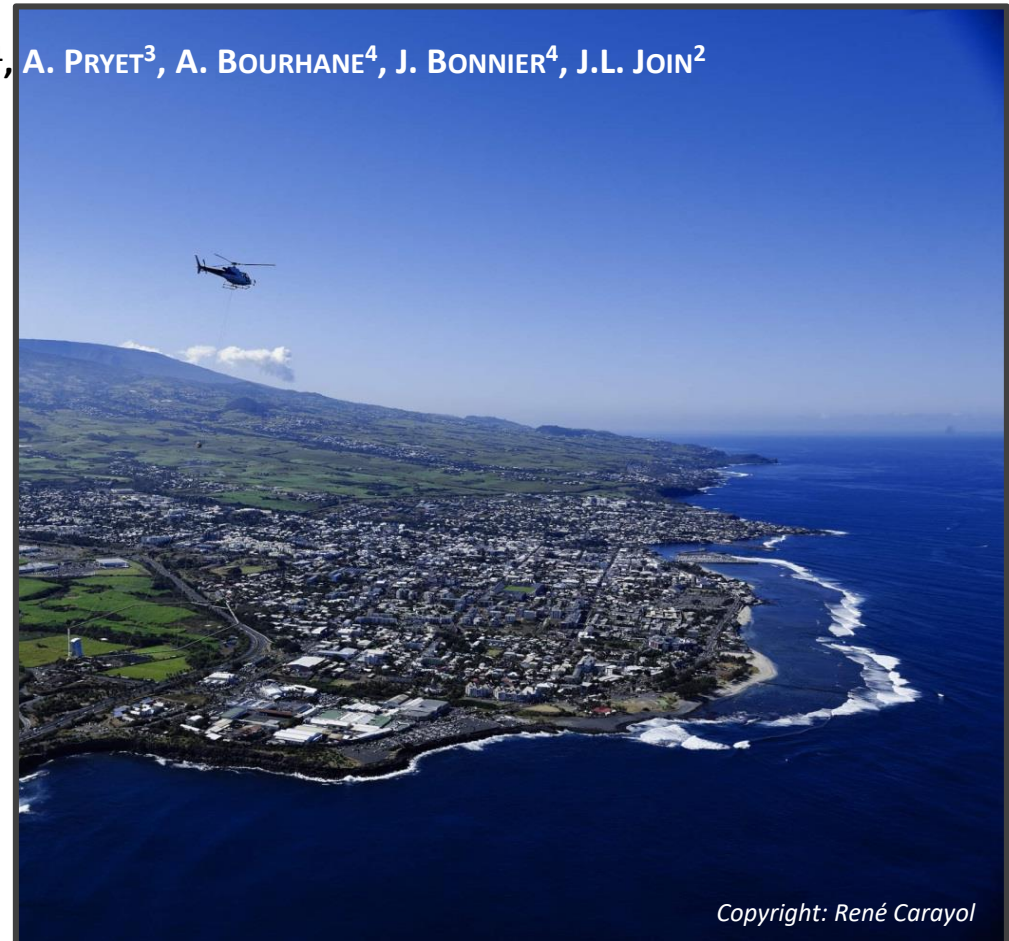

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SCOPES AND ISSUES OF THE STUDY

Airborne **E**lectro**M**agnetic [**AEM**] campaign:

> regional resistivity mapping (inland & offshore)

> effective characterization of **S**alt**W**ater **I**ntrusion [SWI]

Problematic :

> Provide efficient and reliable SWI mapping in heterogeneous & complex environments.

> Evaluate the impact of parameters governing SWI in coastal volcanic aquifers.

> Which interpretations can provide AEM results ?

CASE STUDY

Reunion Island in the Indian Ocean

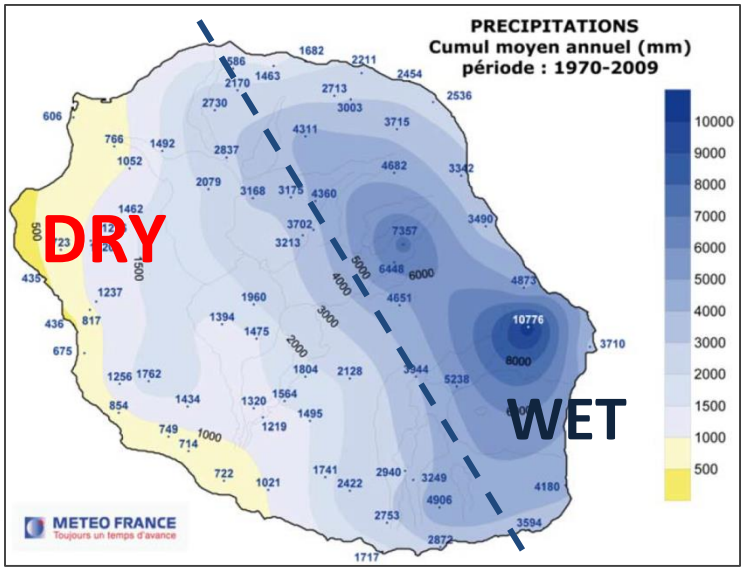
> **Windward/leeward climatic variation**
Rainfall from 10 m/years (windward) to 0.5 m/years (leeward)

> **2 shield volcanoes**
Piton des Neiges: activity from 3 Ma to 30 ka
Piton de la Fournaise: active since 450 ka

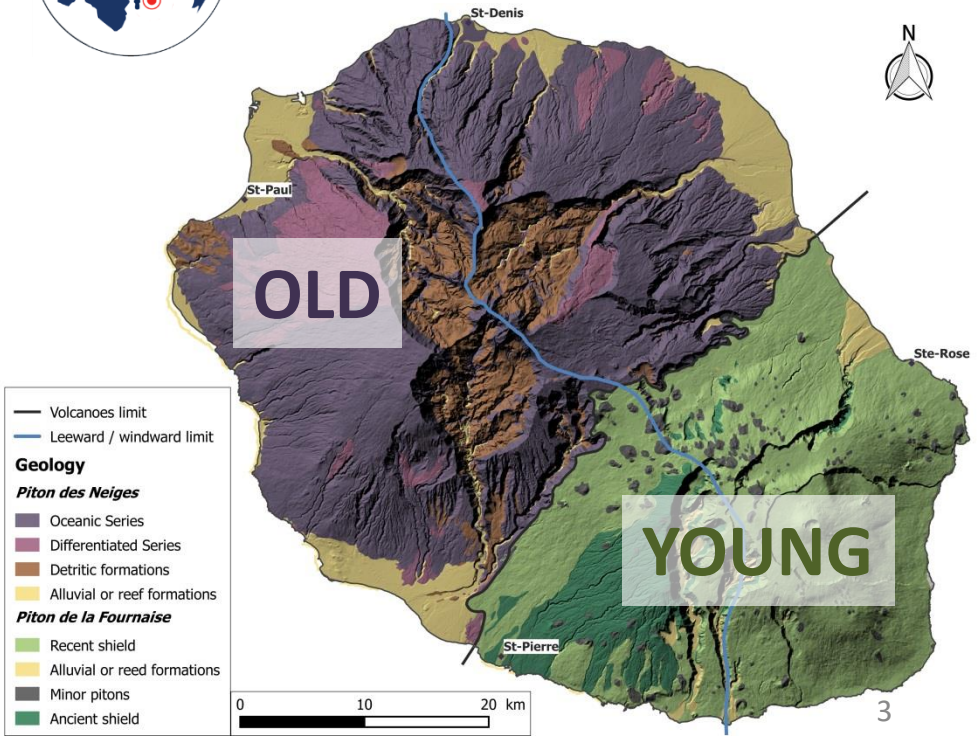
> **Intense weathering and erosive process**
[Oehler et al., 2008]

> **Steep morphology**

How SWI impacts groundwater resources ?
How this complexity control SWI ?



Rainfall map (Meteo France)
and geological map of Reunion Island



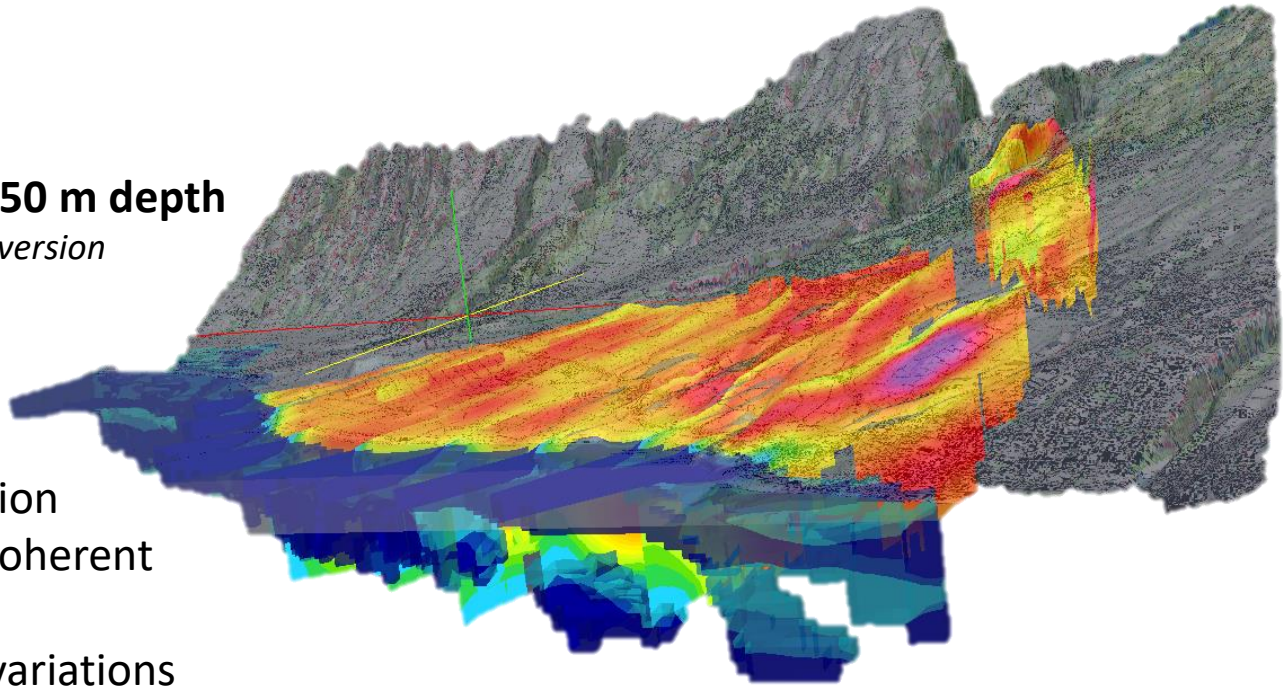
RESISTIVITY MODEL

AEM campaign [April – July 2014 – **Dry season**]

> 10 400 km of flight lines
> 240 000 inverted soundings

Resistivity model

25 layers smooth from **0 to 350 m depth**
with quasi 3D spatially constrained inversion
[SCI – Viezzoli et al., 2008]

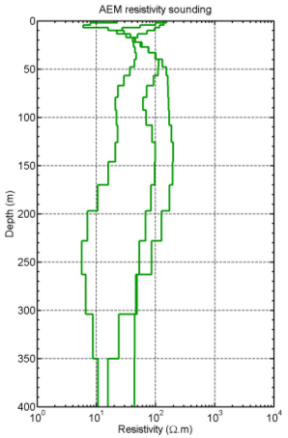


AEM 3D resistivity model

⊕ regional geophysical inversion
resistivity model spatially coherent

⊖ smooth vertical resistivity variations
hard to handle 3D geophysical variations

STATISTICAL TREATMENT



Clustering of AEM dataset

> AHC - **A**gglomerative **H**ierarchical **C**lustering algorithm allow gathering statistically similar EM soundings in clusters
(Dumont et al., 2015)

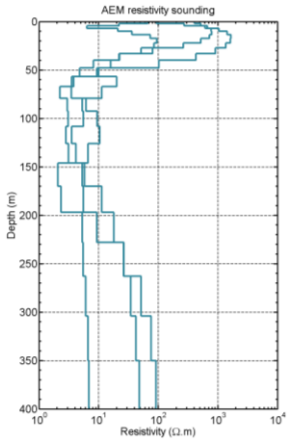
> Summarize 3D geophysical information in 2D mapping

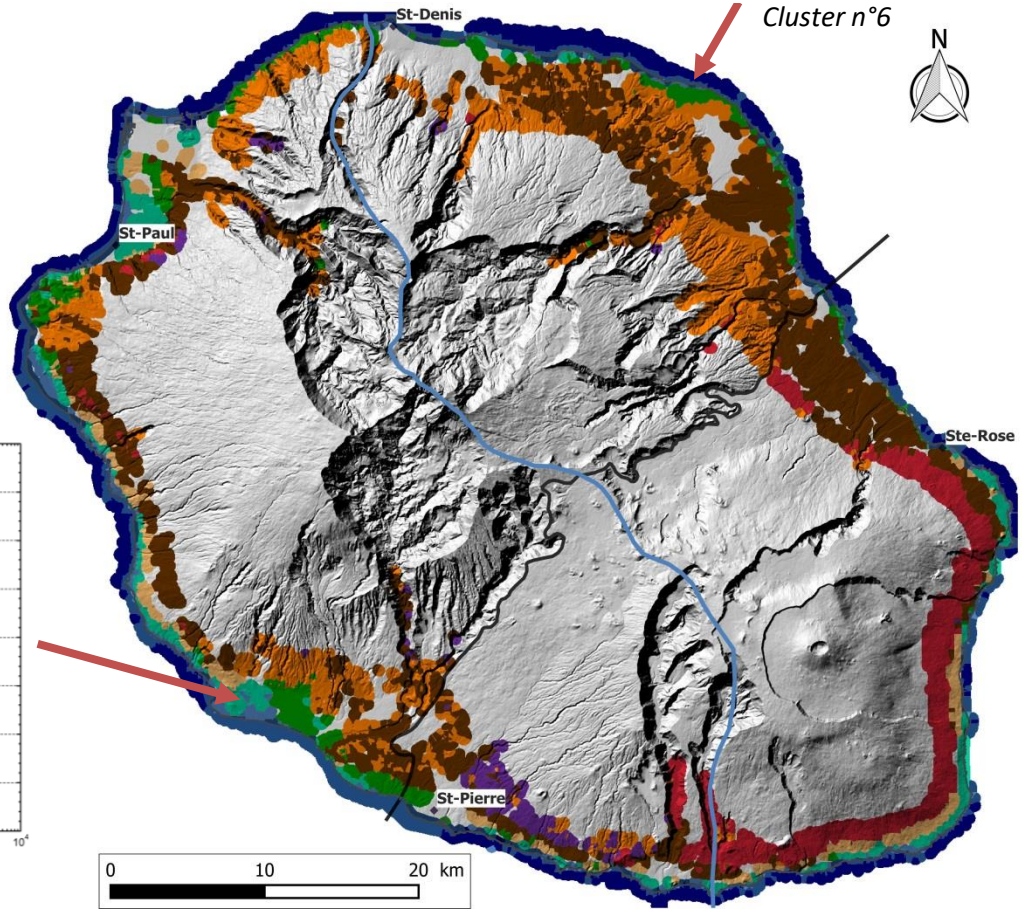
> Delineate area with similar Geophysical response

Clustering result map

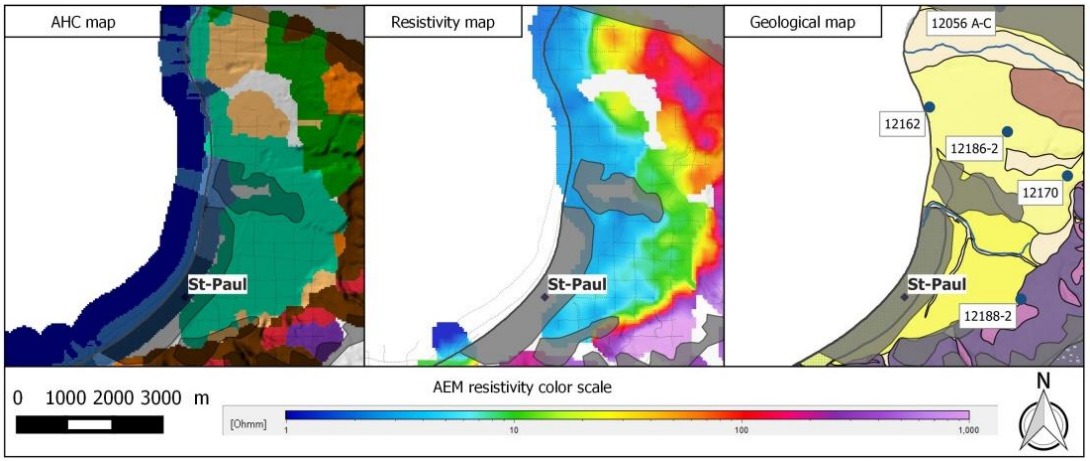
Cluster n°6

Cluster n°7



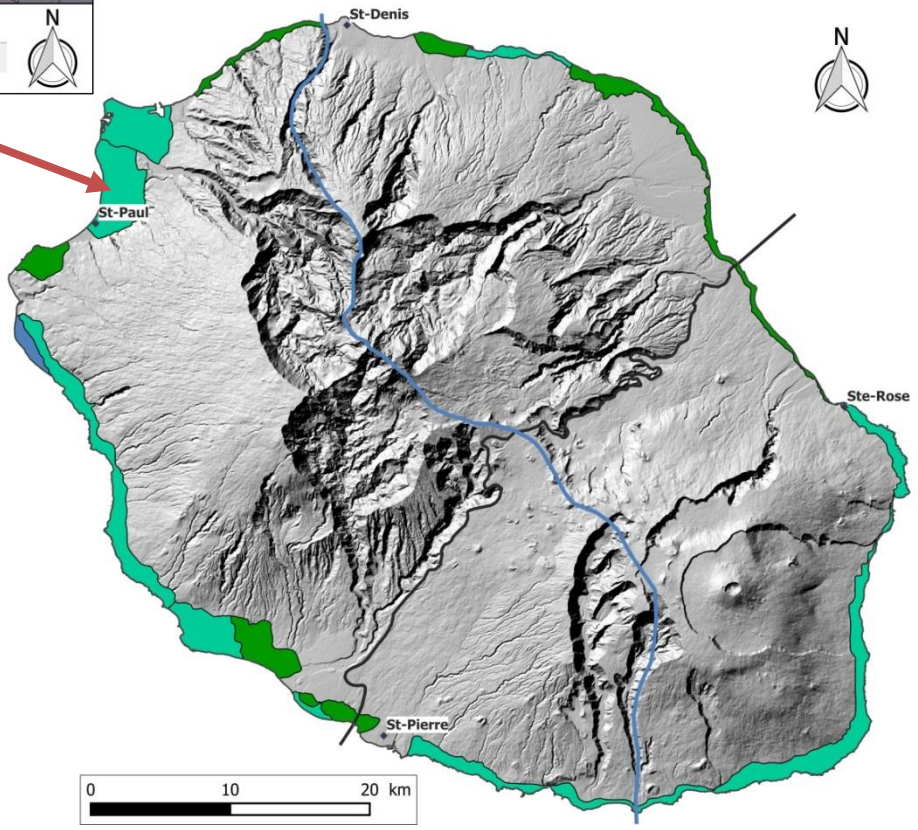


SWI AREAS



3 maps used for SWI mapping

Geophysical SWI mapping



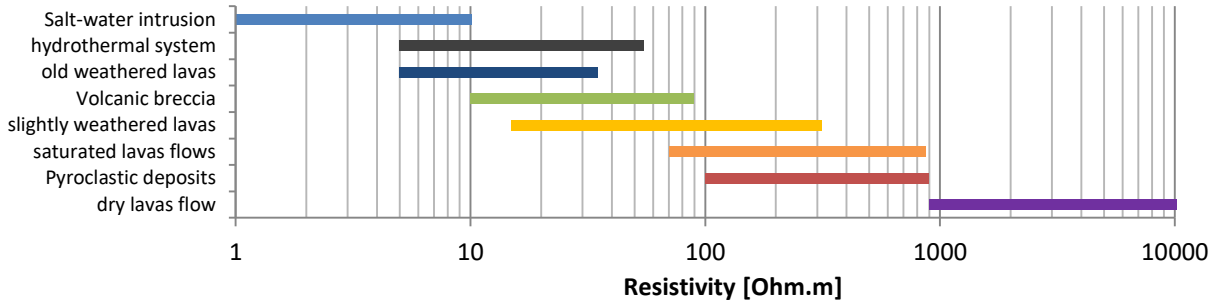
Delineate SWI areas

from "homogeneous" geophysical areas to hydrogeological domains:
> mapping aquifers invaded or vulnerable by SWI

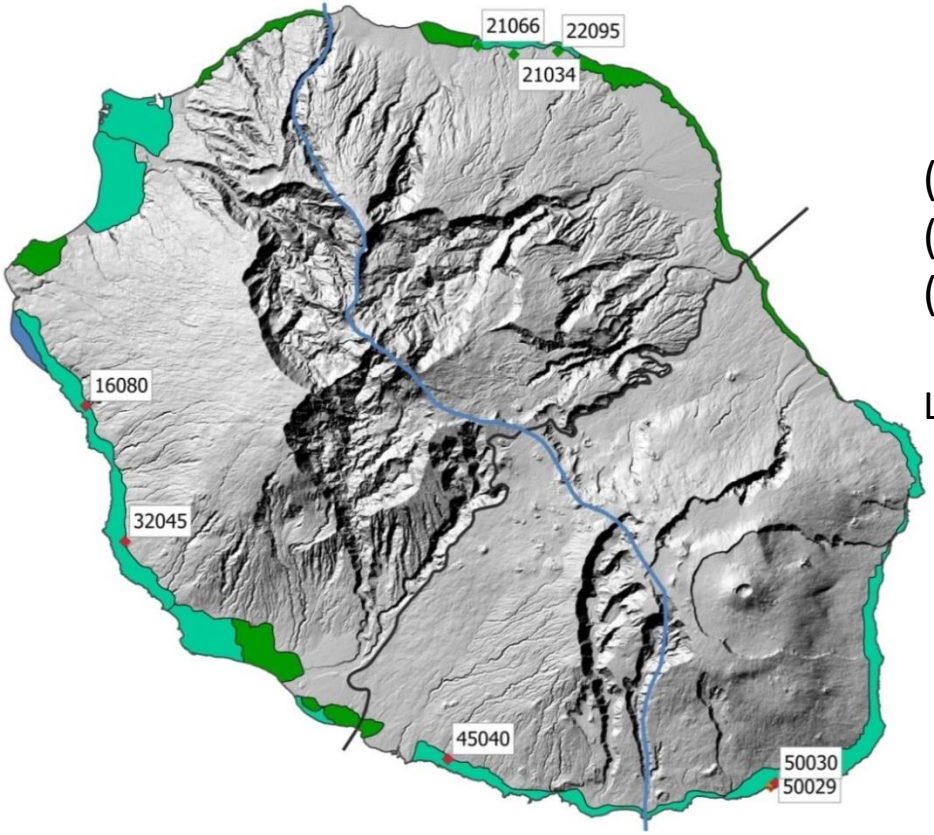
> local interpretation to confront AEM results to EC and geological logs

BASALTIC COAST

Local validation > Resistivity equifinality problem



Volcanic formations resistivity from bibliography



(i) confront AEM resistivity with EC log
(ii) validate AEM geometry
(iii) estimate qualitative hydraulics parameters

Local validation is presented only for basaltic coast

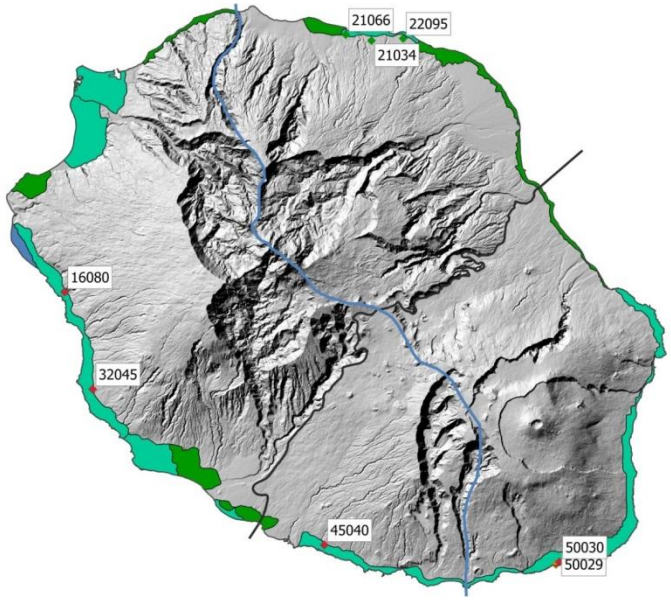
EC log have been measured by Reunion water office, CISE and ImaGeau companies

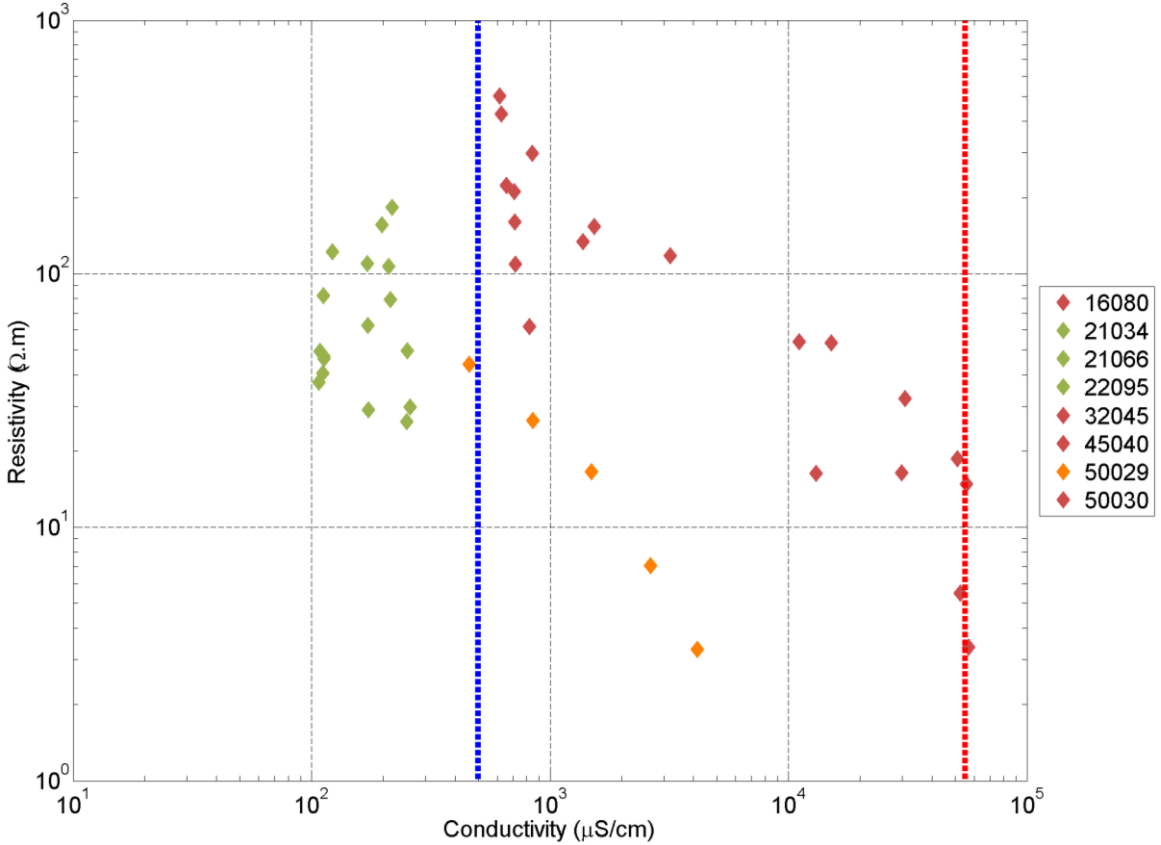
imaGeau instrumentation du sous-sol
CISE RÉUNION
OFFICE DE L'EAU RÉUNION

BASALTIC COAST

AEM resistivity and EC log confrontation

> 2 main behaviors





Groundwater EC log versus AEM inverted resistivity.

Blue line [500 µS/cm]*: freshwater usual threshold at Reunion island*
Red line [55 00 µS/cm]*: 100 % saltwater conductivity*

Red dot: wells in basaltic coast impacted by SWI
Green dot: wells in basaltic coast **not** impact by SWI

Orange dot: wells in basaltic coast close to coast lines. Regional AEM inversion is not reliable.

BASALTIC COAST

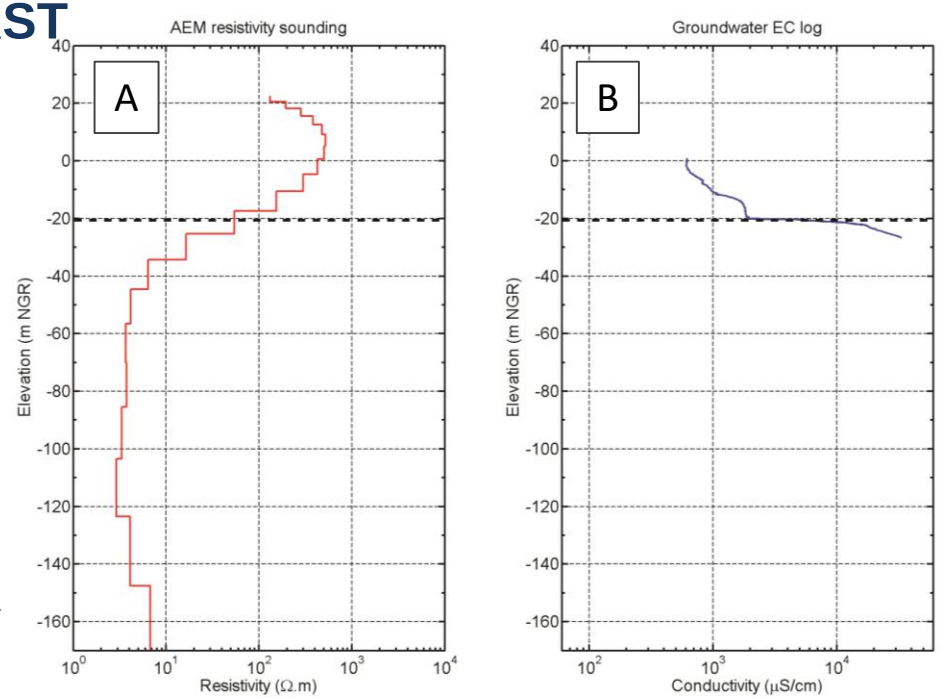
Geophysical contrasts coherent with EC logs in basalt coast

Qualitative estimation of hydraulic conductivity with Glover analytic solution (Glover 1959):

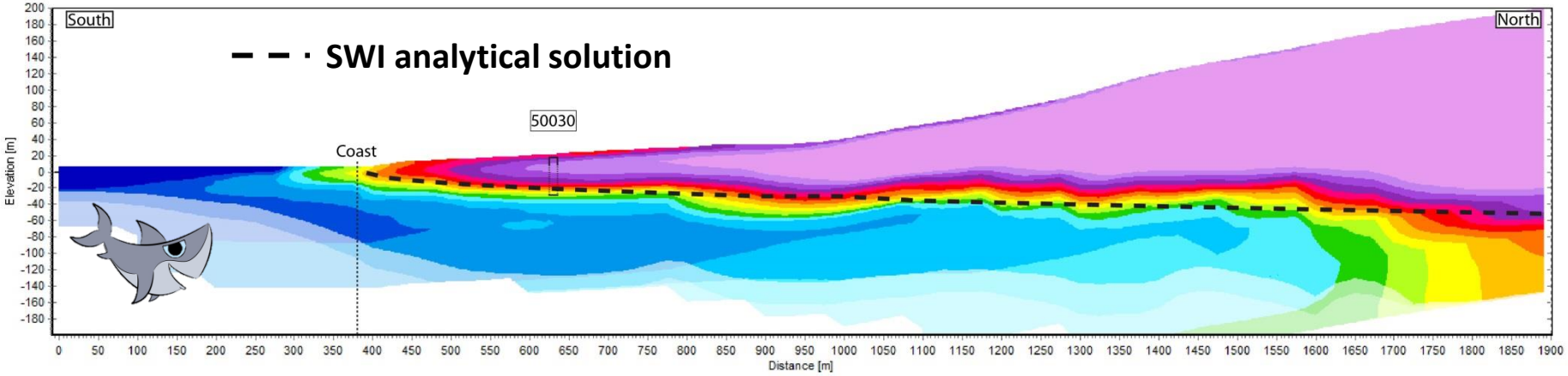
$$\xi = \sqrt{\frac{2.q.x}{\Delta s.K} + \frac{q^2}{\Delta s^2.K^2}}$$

q: freshwater outflow rate per unit length of coastline
K: hydraulic conductivity
Δs = 0.025 : difference between seawater and freshwater specific gravity
X: coast distance

q has been estimated from water budget model (Bessière & Allier 2011)



[A] *In red resistivity vertical sounding close to 50030 well*
[B] *In blue groundwater EC log measured at 50030 well*



AEM smooth resistivity profiles

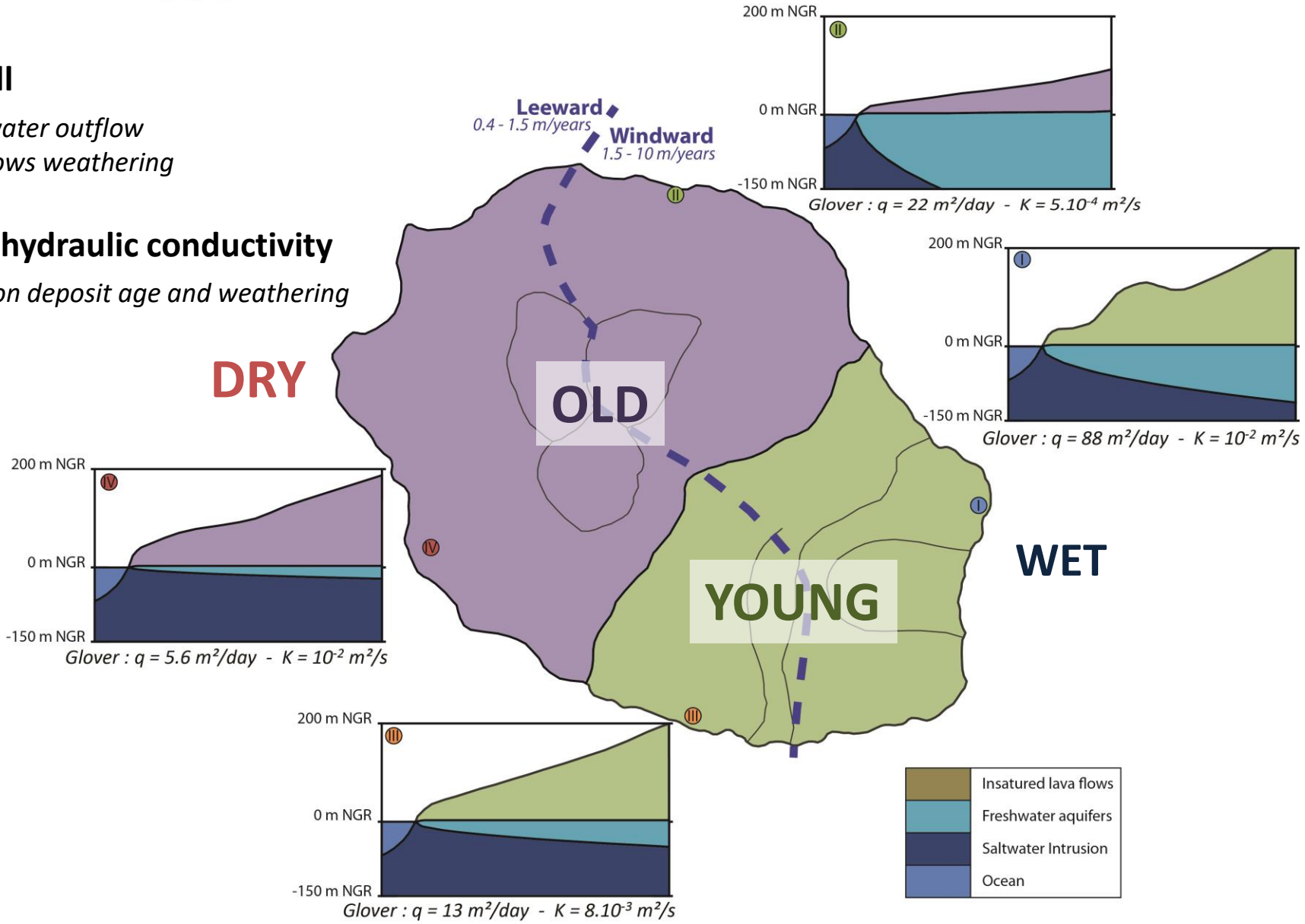
PARAMETERS GOVERNING SWI

Rainfall

> Freshwater outflow
> lava flows weathering

Basalt hydraulic conductivity

depend on deposit age and weathering



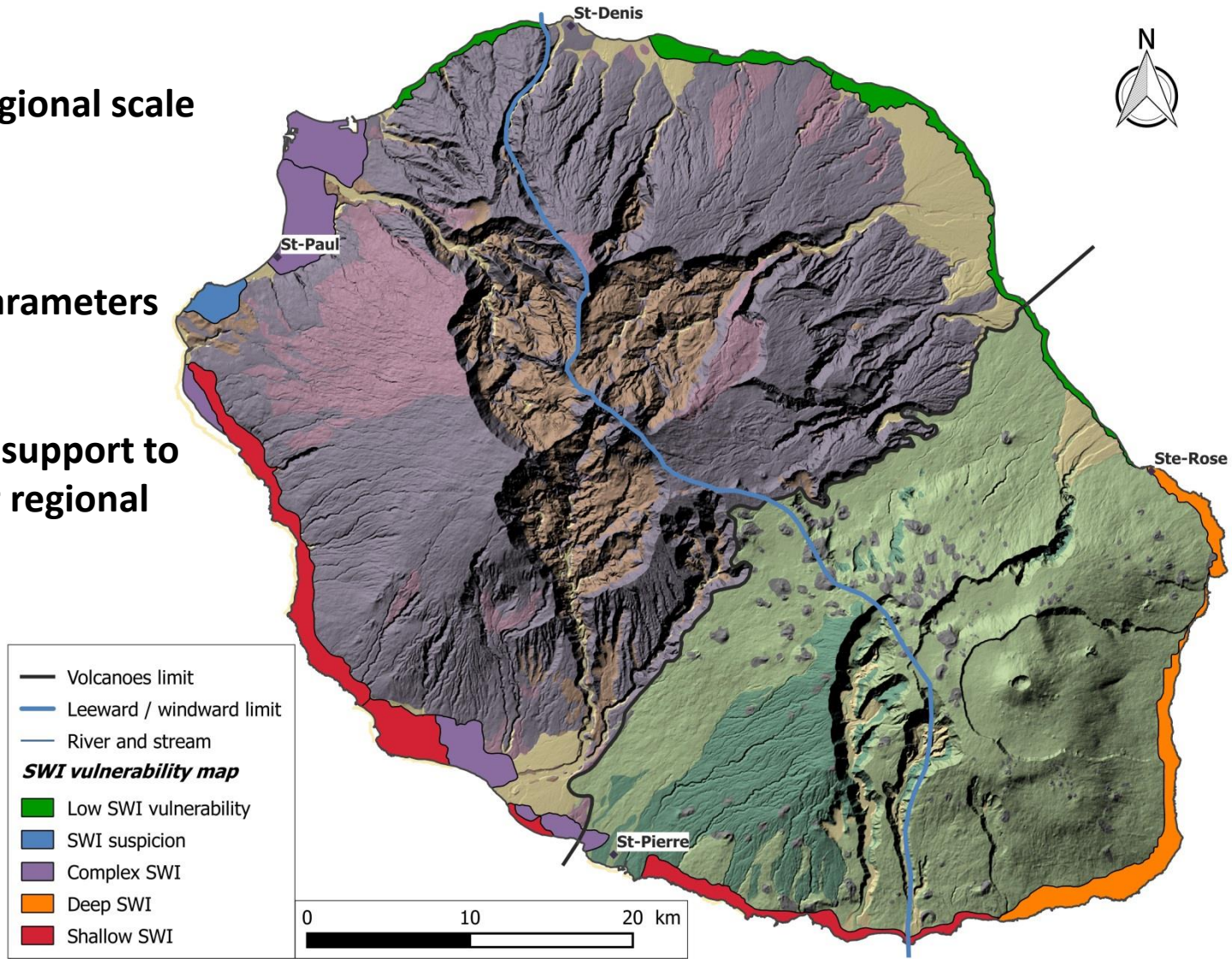
CONCLUSION

1. Mapping SWI at regional scale

2. Local validation

3. Impact of major parameters controlling SWI

4. Providing adapted support to SWI management for regional policymaker



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