Reconstructing Ionospheric TEC: The VISTA Algorithm and VISTA Dataset

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January 29, 2023

Outline

1 VISTA Database

Database Pipeline

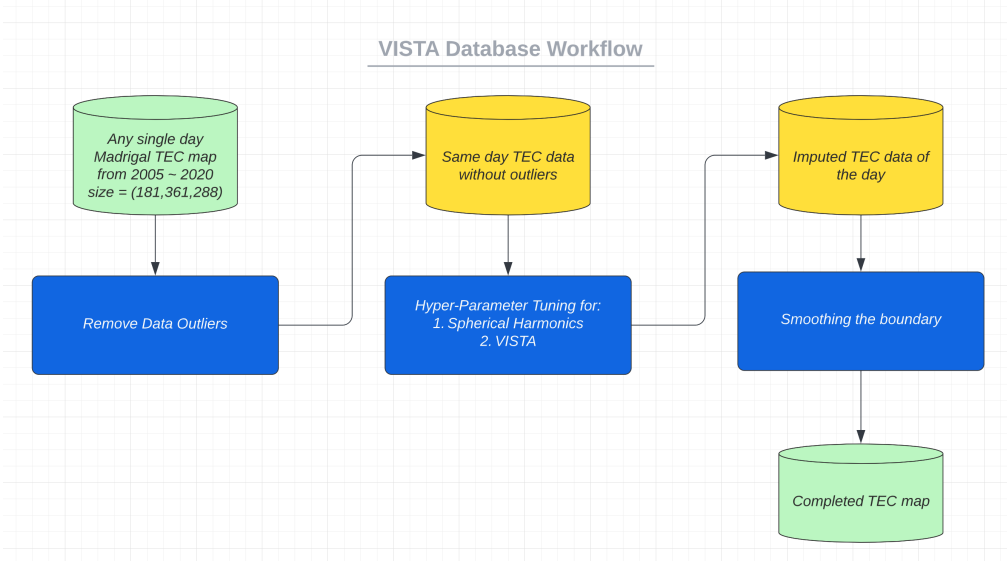

Figure: Database Workflow

TEC Outlier Removal

There are outliers within the Madrigal TEC database:

- due to the malfunctioning ground-based receivers (**Hardware Outlier**)
- or due to having very high TEC values compared to the rest of the data in the same day (**Distribution Outlier**)
- or due to domain experts' visual diagnosis (**Patch Outlier**)

TEC Outlier Removal

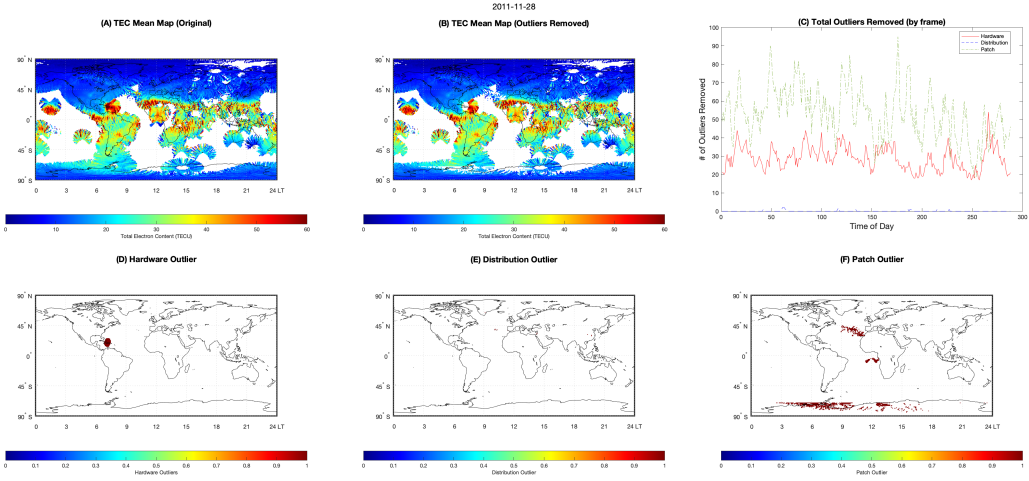

Figure: Outlier Example on Nov 28, 2011

Hyper-Parameter Tuning

Parameter tuning is conducted over two selected months of data, i.e. 2009-Apr and 2015-Sept, on these two sets of parameters:

Category	Notation	Description
VISTA	r	rank of the imputed map
	λ_1	control soft penalty on $A_{1:T}, B_{1:T}$ norms for sparsity of imputed maps
	λ_2	control temporal smoothness of the imputed maps
	λ_3	control learning rate from the auxiliary data
Auxiliary Data	l_{max}	maximum order of spherical harmonics basis function
	ν	control penalty on the spherical harmonics coefficients for sparsity

Table 1. Description of tuning Parameters of the VISTA method. All of the parameters are included as metadata in each data file of the database.

Hyper-Parameter Tuning

To tune the parameters, we:

- randomly split the available pixels into a train set and a validation set ($80\% - 20\%$ division)
- fit the model on the train set, validate the performance using Mean-Squared Error and Relative-Squared Error on the validation set
- tune one parameter at a time, keeping all others fixed

Hyper-Parameter Tuning

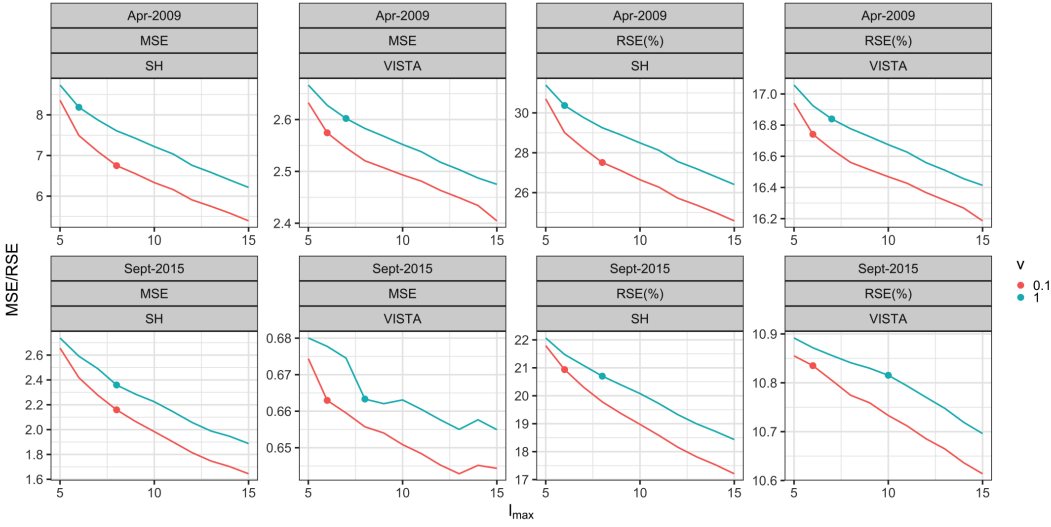

Figure: Spherical Harmonics Tuning (Validation set result)

Hyper-Parameter Tuning

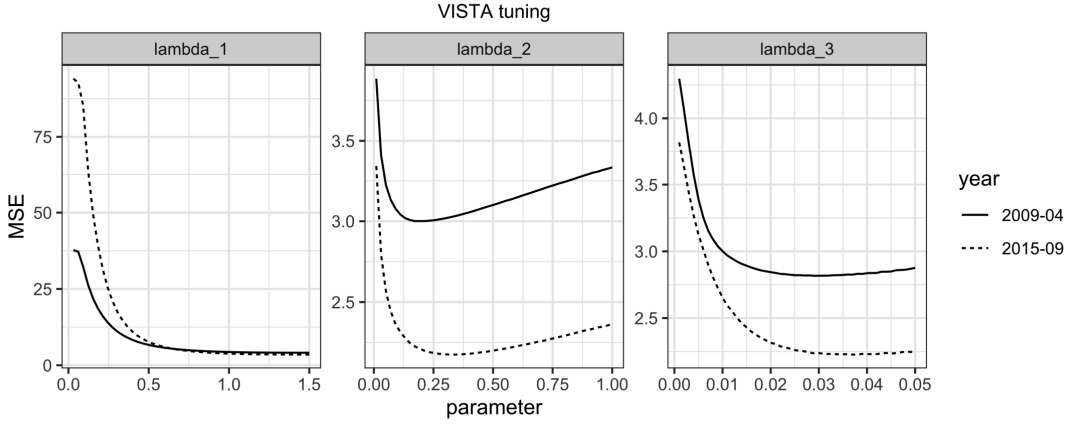

Figure: VISTA Tuning (Validation set result)

Example of VISTA Database 1.0

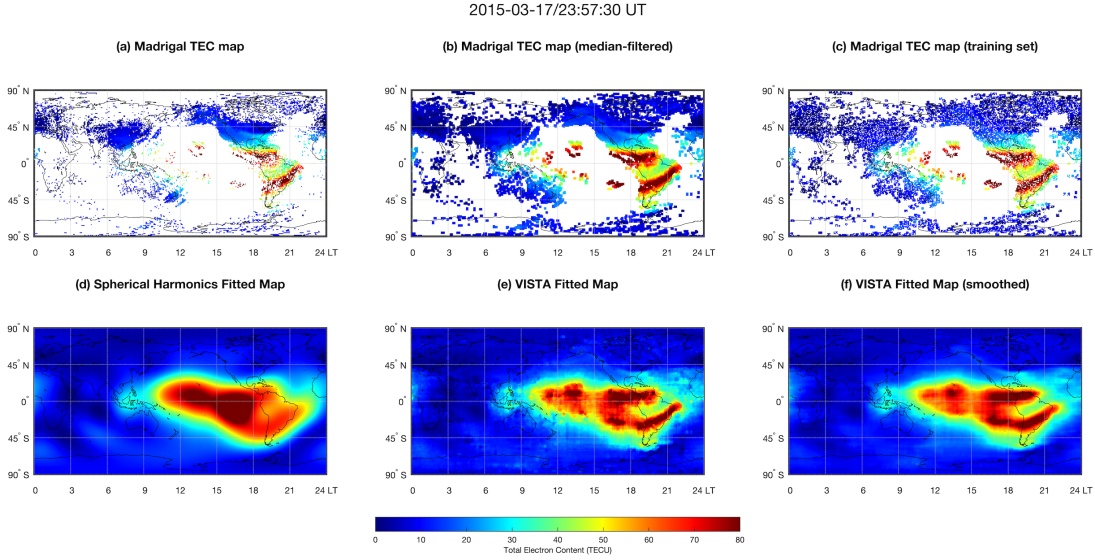

Figure: Example of the VISTA database, sample from the last frame (23:57:30 UT) of March 17, 2015.

Conclusion

- We propose a new imputation method (VISTA), combining matrix completion with soft rank constraint, temporal smoothing and spherical harmonics in a unified framework, to impute Total Electron Content (TEC) maps with over 50% data missing.

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- VISTA can reveal global and large-scale TEC structures and preserve the observed Meso-scale structures, such as plasma patch and equatorial bubbles.

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- VISTA can reveal global and large-scale TEC structures and preserve the observed Meso-scale structures, such as plasma patch and equatorial bubbles.
- A dataset covering 16 years (2005-2020) with fine-tuned VISTA algorithm is generated to facilitate TEC map related research.