Ionosphere Scintillation Mapping

Y. Béniguël, P. Hamel, IEEA, Paris, France
C. Sambou, M. Darces, M. Hélier, UPMC, Paris, France
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Calculation Technique

Kriging technique

• Well suited to random data processing

• Accuracy increases with the number of data

• Allows to produce a map and the corresponding error map
Input Data

50 Hz receivers → Monitor Project

1 Hz → IGS Data

Simulated → GISM
Scintillation indices at 50 Hz (top panel) vs 1 Hz (IGS data: bottom panel)
Modelling (GISM) MPS model

The model includes an orbit generator (GPS, Glonass, Galileo, ...)

Inputs

Geophysical Parameters
Scenario

Intermediate calculation: LOS, Ionisation along the LOS

Outputs

Time series, Scintillation indices, Correlation Distances
Scattering function

Modelling vs Measurements (Intensity)

Measurements

Samples with $S_4 < 0.2$ were ignored (noise level)

Modelling
Modelling vs Measurements (Phase)

Measurements

The phase RMS value is slightly lower than the S4 value. Some samples exhibit high values (both measurements and modelling) due to the phase jumps.

Modelling

Beacon Satellite Symposium, Bath, 8 – 12 July 2013
Comparison with Measurements
Year 2011 / Guiana / Novatel Measurements
Kriging Algorithm
Y the observable, \( f \) a vector of factors (location, ...)

Y is the sum of a mean value and a random part

\[
Y(f, \omega) = m(f) + \Gamma(f, \omega)
\]

\[
m(f) = \sum_{i=1}^{M} a_i \varphi_i(f)
\]

Covariance function

\[
c(f_i, f_j) = \left\langle \Gamma(f_i, \omega) \Gamma(f_j, \omega) \right\rangle = c(h)
\]
Covariance Function

- Many data points
  Computation of the experimental covariance

- Few data points
  Choice of the covariance function among known models.
Kriging Interpolation Technique

A linear estimator is built with all data points

\[ Y^* = \sum_{j=1}^{N} \lambda_j Y(f_j, \omega) \]

The outcome at \( f_0 \) is linear

\[ Y^*(f_0) = \sum_{j=1}^{N} \lambda_j (f_0, f_j, c) Y(f_j) \]

The estimator gives an exact value at the data points (Lagrange multipliers)
• Minimizing the variance \( \left| Y^* - Y_0 \right|^2 \)

• Taking the inverse of the covariance matrix

\[
Y^*(f_0) = w^T Y
\]

• It is an exact interpolator: no errors at data points

• Gives an estimate of the accuracy of the Kriged estimates

\[
\text{Min} \left\langle \left| Y^* - Y \right|^2 \right\rangle = \sigma_{\text{Min}}^2
\]
Variogram Estimation

\[ \gamma(h) = \left\{ \left| Y(\vec{r}_i) - Y(\vec{r}_j) \right|^2 \right\} \]

\[ h = \left| \vec{r}_i - \vec{r}_j \right| \]

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Experimental variograms based on GISM calculations

S4 variogram

$\sigma_\phi$ variogram
Covariance Function

\[ C(h) = T - \gamma(h) \quad \text{with} \quad T = 7.4 \times 10^{-4} \]
Results of S4 data kriging
Cut at Latitude 6°
Cut at Latitude - 3°
Cut at Latitude – 3°
Cut at Longitude - 44°
Cut at Longitude - 44°
Cut at Longitude - 36°
Cut at Longitude - 36°

Coupe de SigmaPhi pour une longitude de -36°
Kriging Over a Whole Year

The covariance function used was deduced from GISM calculations.

Lima 2012
Dip Lat. 0°65
Conclusion

Analysis of scintillations using the IGS network
  (Comparison to 50 Hz data)

Improve the calculation of the variogram
  (Time as an additionnal factor)

Produce the error maps
Thank you