Ionosphere Scintillation Mapping using a Kriging Algorithm

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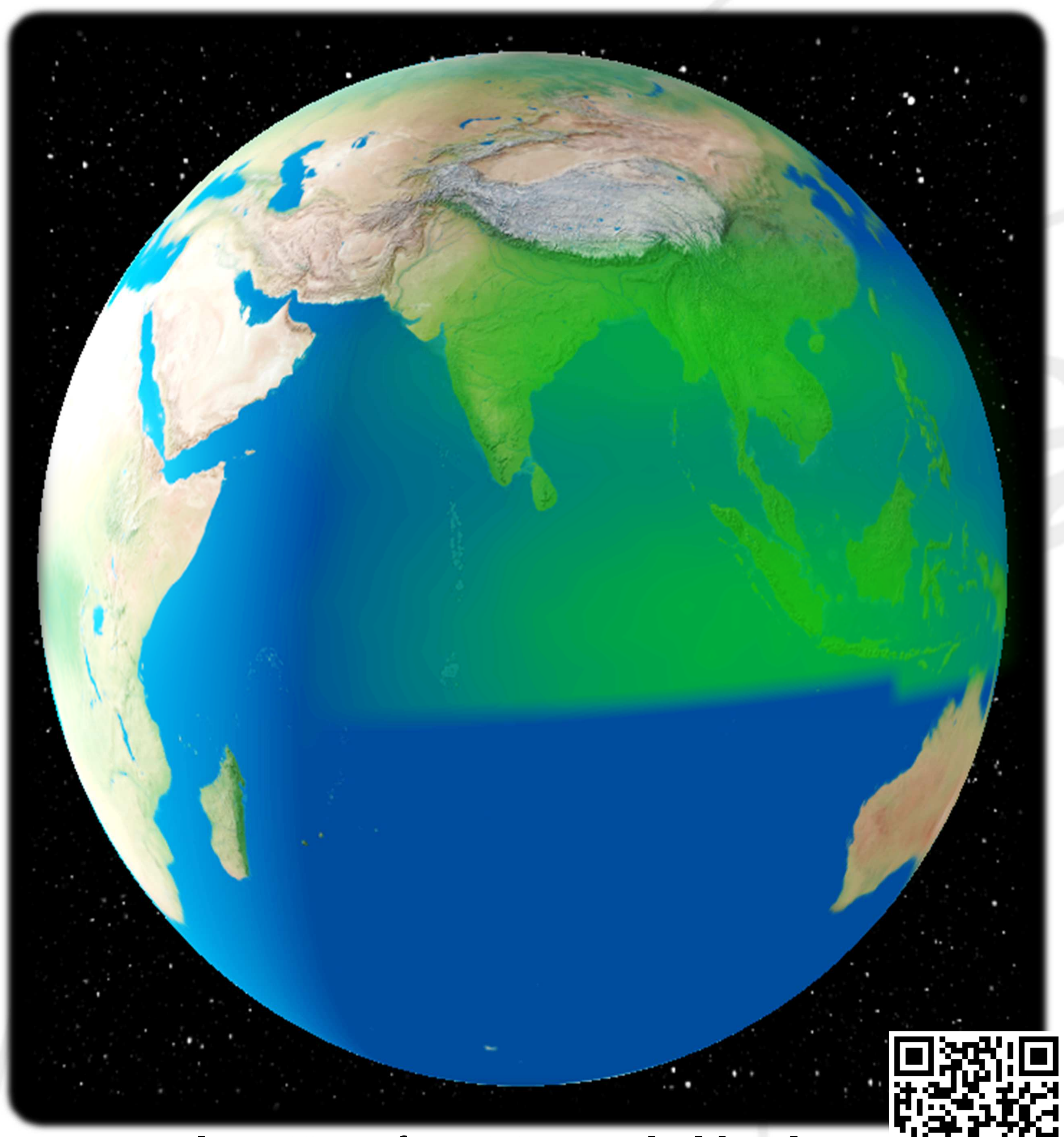
Introduction

The scintillation mapping aims to give a planar view at the Ionosphere Peak Point (IPP) altitude (usually set to 350 km) of the bubbles extent. A climatological scintillation model such as GISM (Béniguel 2011) fails to accurately produce ionosphere scintillation maps as the medium is described in terms of statistical parameters which may depart from current observations.

The algorithm presented is based on a Kriging technique. It uses real or near real time data recorded by receivers. The Kriging technique can be seen as a data assimilation technique. The accuracy of the results is related to the accuracy and quantity of the measurements. The GISM model is used as a background tool to fill the gaps between the measurement data points.

GISM

The Global Ionospheric Scintillation Model allows obtaining both mean errors and scintillations due to propagation through ionosphere. This model has been accepted by the International Telecommunications Union (ITU) as a reference code for scintillation evaluations.



http://ieea.fr/en/gism-webgl.html

Kriging algorithm

Main advantages:

- It is an exact interpolator
- It is well suited to interpolate multivariate random data
- It provides an estimation of the interpolation error

To apply the Kriging algorithm it has to be assumed that the random variable depends on:

$$Y(x) = \underbrace{\boxed{\sum p_i . f_i\,(x)}}_{\text{Linear summation of deterministic model (Regression model)}} + \boxed{\omega(x)}$$

Random variable with $< \omega >= 0$

Based on the measurements, 2 parameters have to be optimized:

- law of the random variable ω, based on the variogram
- weight coefficient p_i of the regression model

From the law of the random variable, covariance matrices C are calculated. From the regression model, regression matrices R are calculated.

$$C_e = C(x_e, x_s) \qquad C_s = C(x_s) \qquad R_e = R(x_e) \qquad R_s = R(x_s)$$

The estimation Y_e of the variable Y at the locations x_e depends on the measured value Y_s at the location x_s:

$$Y_e = R_e A Y_s + C_e C_s^{-1}(I_d - R_s A) Y_s$$

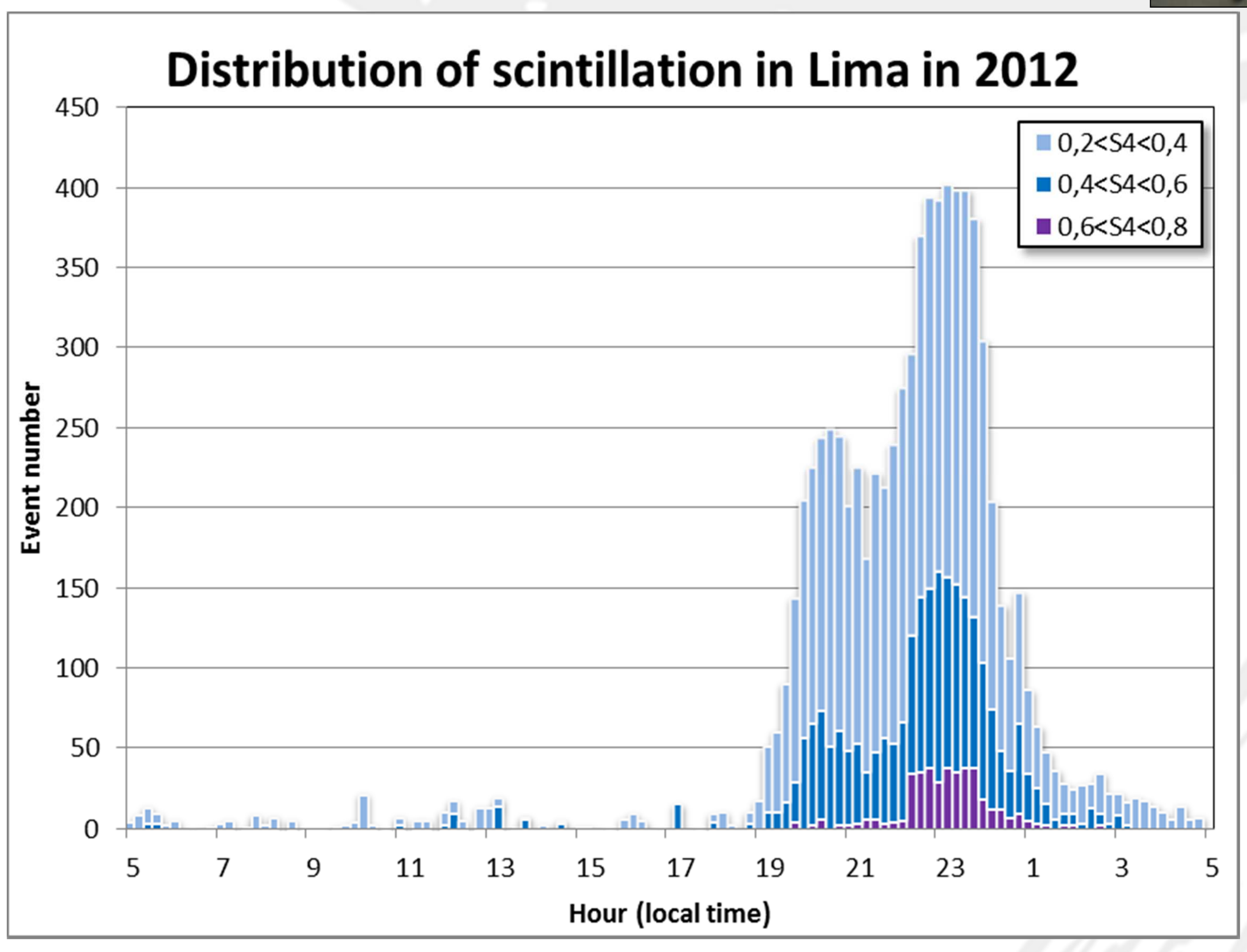
$$A = (R_s^t C_{s\omega}^{-1} R_s)^{-1} R_s^t C_{s\omega}^{-1}$$

Measurement Campaign

Over the last decade, data have been collected:

- PRIS (ESA)
- Monitor 1 – 2 (ESA)
- Sagaie (CNES – TAS – ASECNA)
- LISN (Boston College - Space Environment Corporation)

Based on these data an algorithm has been developed to perform scintillation maps.



Results

Estimation of the σ_ϕ index over South America, on 11/10/2013: