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PARAMETERIZATION OF SITE-SPECIFIC SHORT-TERM IRRADIANCE VARIABILITY

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ABSTRACT

This article presents a set of empirical models capable of extracting metrics quantifying the short-term variability of the solar resource based upon site/time specific satellite-derived hourly irradiance data. The model is derived from over 92,000 experimental hourly data points at twenty four sites in the United States. The model returns four metrics characterizing intra-hourly variability, including the standard deviation of the global irradiance **clear sky** index, and the mean index change from one time interval to the next, as well as the maximum and standard deviation of the latter. The variability time scales addressed in this paper are 20 seconds, one-minute, 5 minutes and 15 minutes. The trends underlying the models are robust and show little site dependency.

INTRODUCTION

The output of a small, single solar power system can vary from almost full power to no power in a matter of seconds. As a result, the short-term variability of solar resource is an issue of high relevance to large scale solar generation deployment.

In a previous study, Hoff and Perez (2010) introduced a parameter called the Dispersion Factor. The Dispersion Factor is a parameter that incorporates the layout of a fleet of PV systems, the time scales of concern, and the motion of cloud interferences over the PV fleet. Hoff and Perez demonstrated that relative output variability resulting from the deployment of multiple plants decreased quasi-exponentially as a function of the generating resource's Dispersion Factor. That is, the more a given capacity of PV is spread out, the lower the variability.

The previous study had two important limitations. First, it focused on relative output variability rather than absolute output variability. Second, it based results on a simplistic PV fleet configuration.

This current study addresses the first limitation by quantifying absolute output variability for a single location. A subsequent study will address the second limitation by extending the results to a general PV fleet configuration.

This current study investigates how well sub-hourly, absolute variability can be quantified using hourly insolation data from satellite-based products such as SolarAnywhere (2010), SolarGis (2010) or the NSRDB (1998-2005). If output variability can be accurately quantified, a product such as SolarAnywhere is valuable not only because it is useful for planning (using the product's historical data) but it is also useful utility system operations (using the product's current and forecasted data).

Previous studies (Skartveit and Olseth, 1992, Tovar et al., 2001) have indicated that it is possible to model sub-hourly variability from hourly irradiance time series. This research uses a systematic approach using a similar philosophy. The approach differs in that it is geared to quantify the variability metrics that are of particular concern to utilities, and to exploiting the information contained in gridded satellite-derived irradiance data sets.

METHODS

The objective of this work is to provide a model to characterize the short term variability at an arbitrary location, based on the time/site specific information available for that location from hourly satellite-derived insolation data. The known input to the model consists of the hourly satellite data and is used to parameterize insolation conditions. The unknown output of the model consists of a set of metrics that characterize the short term variability of the site's insolation.

Model Input -- Parameterization of insolation conditions

Two fundamental parameters that are used to characterize solar conditions are hourly global horizontal insolation (GHI) and direct normal insolation (DNI). These quantities are readily available from typical meteorological year (TMY) and satellite-derived solar resource data sets.

It is practical to use normalized indices for both components, which has the advantage of eliminating most of the effects of solar geometry1. The hourly global horizontal (Kt*) and direct normal (Kb*) clear sky indices are calculated by taking the ratio of the actual insolation to the clear-sky insolation.

$$Kt^* = \frac{GHI}{GHI_{clear}} \quad (1)$$

$$Kb^* = \frac{DNI}{DNI_{clear}} \quad (2)$$

GHI_{clear} and DNI_{clear} represent respectively the clear-sky global and direct insolation for the considered hour/location (e.g., obtained from Ineichen (2009) or Gueymard (1989)).

An additional piece of information relevant to short-term variability can be extracted from hourly site/time specific satellite data. This information is the spatial variability of the solar resource at any given hour in the region immediately surrounding the considered location.

Let σ_{space} represent the hourly spatial variability. It is calculated as follows:

1 We note that the range of the global index is somewhat reduced as the sun's elevation decreases, because the relative weight of diffuse irradiance increases during clear sky conditions. The direct index is not affected, hence the usefulness of the two-index approach. However, in the context of the present parameterization designed to exploit satellite-derived data, Kt* constitutes the very information that is remote sensed by the satellite.

$$\sigma_{space} = \left(\frac{1}{N}\right)\sqrt{\sum_{i=1}^{N^2}(Kt^{*\,i} - \overline{Kt^*})^2} \quad (3)$$

Where N is an odd number greater or equal to 3 and $Kt^{*\,i}$ is the clear sky index for one of the N^2 pixels including and surrounding the considered location, and $\overline{Kt^*}$ is the mean index across the extended area. For the present model, N equals 3 and the considered pixels are 0.1 degrees latitude-longitude in size (approximately 10 km by 10 km).

In summary, insolation conditions are parameterized by the satellite-derived hourly Kt*, Kb*, and σ_{space} parameters.

Model Output -- Site-specific short-term variability metrics

Hoff and Perez (2010) quantified the variability of a fleet of solar generators as:

$$\sigma_{\Delta t}^{\sum N} = \left(\frac{1}{C^{Fleet}}\right)\sqrt{Var[\sum_{n=1}^{N}\Delta \boldsymbol{P}_{\Delta t}^{\boldsymbol{n}}]} \quad (4)$$

Where C^{Fleet} is the total installed peak power of the fleet and $\Delta \boldsymbol{P}_{\Delta t}^{\boldsymbol{n}}$ is a random variable that represents the time series of changes in power at the n^{th} PV installation using a sampling time interval of Δt.

The random variable $\Delta \boldsymbol{P}_{\Delta t}$ quantifies the site-specific variability of one single system that is the focus of the present analysis.

The metrics used here to quantify short term variability are related to the Hoff and Perez parameter, but are dimensionless quantities that remove information pertaining to solar geometry and to the size of the considered solar generator, conserving only the information describing variability. This information is contained in the random variable $\Delta Kt_{\Delta t}^{*}$ denoting the time series of changes in the GHI index over a given hour at the considered location for a sampling interval of Δt. Specifically, we consider the three following ΔKt*-based metrics:

1. The mean absolute value of the GHI index changes over a given hour: $|\Delta K^*_{t\,\Delta t}|$
2. The standard deviation of the same for that hour: $\sigma|\Delta K^*_{t\,\Delta t}|$
3. The maximum absolute GHI index change occurring within the hour: max$|\Delta K^*_{t\,\Delta t}|$

The first metric, $|\Delta K^*_{t\,\Delta t}|$, provides a pragmatic measure of short term variability: the mean expected change in resource likely to occur from one sampling interval to the next. The second metric, $\sigma|\Delta K^*_{t\,\Delta t}|$provides a measure of the size distribution of such short term changes within an hourly interval answering the question whether all changes are comparable in size or not. The third metric quantifies the highest short-term change to be expected within an hour. It is relevant to the utility industry because it provides an upper limit of the perceived short term variability problem.

In addition to the three ΔKt*-based metrics, we also retained a fourth metric based on the time series of changes of the GHI index per se (not on the series of changes). This fourth metric is the standard deviation of the index over the considered hour, $\sigma K^*_{t\Delta t}$. It was retained as one of the quantifiers because it has been central to earlier modelizations of short-term variability. In particular, the Skartveit and Olseth high frequency time series generator (1992) models $\sigma K^*_{t\Delta t}$ as the probabilistic envelope from which a high frequency time series is generated.

Model Derivation and Structure

The model is built empirically from high-frequency experimental measurements at several climatically distinct locations and from time-coincident hourly satellite-derived irradiances at the same locations.

The model consists of 3-dimensional lookup tables defined by Kt*, Kb* an σ_{space}, returning all four variability metrics for a selected Δt. Lookup table bins are given in Table 1. Distinct sets of lookup tables are produced for Δt respectively equal to 20 seconds, 1 minute, 5 minutes and 15 minutes. The present modeling approach, including a robust insolation condition parameterization and empirically-derived look-up conversion tables, has proven effective in several solar radiation models previously developed by the authors (e.g., Perez et al., 1990).

Experimental Data

Two sets of experimental data are used. The first set, SolarAnywhere (2010), consists of the satellite data used to operationally parameterize insolation conditions. The second set consists of the high frequency measurements used to develop the model. This second data set includes more than one year of experimental observations at 24 measurement stations, 17 of which are part of the ARM central and extended facility network (Stokes and Schwartz, 1994) acquiring DNI and GHI at a Δt rate of 20 seconds. The seven other stations are part of the SURFRAD network (SURFRAD, 2010) and measure irradiances at a Δt rate of one minute. The experimental data are further detailed in Table 2.

RESULTS

Short Term Variability as a Function of Insolation Conditions

We first look at the influence of insolation conditions (as parameterized by the overlaying satellite data) upon the short-term variability quantified by the four selected metrics. We focus this first observational analysis on the one-minute Δt rate, since this is the shortest time frame common to all experimental data. Figures 1, 2, 3 and 4 present the trends obtained for each metric at all sites as a function of the selected insolation condition parameters -- Kt* and Kb* and σ_{space}. Figure 5 reports the number of hourly observations analyzed at each site for each insolation condition bin.

The trends observed at each individual site are consistent across the board. The clearest site -- e.g., Desert Rock – exhibit slightly less variability than the mean, and the sites with the highest tendency for convective cloud formation – e.g., Goodwin Creek – exhibit slightly more variability, but they do not depart substantially from the average trend, suggesting that the proposed parameterization is robust. The secondary peak occurring at very low Kt* for the low σ_{space} conditions represents only a small number of occurrences (Fig. 5) and occurs at a time of very low irradiance, hence its significance is marginal. The trends observed for low and high σ_{space} are visibly different; in the latter case the variability as quantified by all metrics is higher and is almost linearly proportional to Kt*. This difference indicates that the choice of σ_{space} as an additional insolation conditions describer is effective at better delineating variability.

Short-Term variability as a Function of Sampling Rate

Here we look at the influence of the sampling rate upon short term variability. In other words we investigate whether short term fluctuations characterized by the change from one sampling time interval to the next are dependent upon this sampling time and if yes by how much. Figures 6, 7, 8 and 9 are analogous to Figures 1, 2, 3, 4, but present only the mean trends for all sites obtained for Δt rates respectively equal to 20 seconds, 1 minute, 5 minutes and 15 minutes.

These trends show that variability as quantified by the clear sky index standard deviation ($\sigma K^*_{t\Delta t}$) and by the maximum clear sky index change (max$|\Delta K^*_{t\ \Delta t}|$) increases with the considered frequency -- noting that the differences observed between 20 seconds and one-minute are small. The trend is reversed when considering the mean clear sky index change (mean $|\Delta K^*_{t\ \Delta t}|$)metric. This indicates that, while the magnitude and the spread of individual short-term fluctuations increase inversely to Δt, their frequency relative to the selected Δt period increases with Δt.

The Δt trends are summarized in Fig. 10 where the mean variability across all insolation conditions and all sites has been plotted as a function of Δt.

Figures 11 and 12 provide a qualitative illustration of variability on all selected time scales for a sample partly cloudy day in one of the extended facility ARM stations. Figure 11 reports measured GHI while figure 12 reports the clear sky index change metric, $|\Delta K^*_{t\,\Delta t}|$.

Comparison with Earlier Work

Figure 13 compares the trends observed for $\sigma K^*_{t\Delta t}$ and mean $|\Delta K^*_{t\,\Delta t}|$ to the trends derived using the high frequency time series generator proposed by Skartveit & Olseth (S&O, 1992). The S&O generator was applied with the same hourly input data used in the present analysis (i.e., GHI and DNI from SolarAnywhere) and a Δt of 5 minutes – because the S&O model had been developed and tested using this time interval.

Although the trends are qualitatively consistent with present observations, the S&O generator produces more variability than observed during intermediate conditions for both $\sigma K^*_{t\Delta t}$ and mean $|\Delta K^*_{t\,\Delta t}|$ metrics. The overestimation is most pronounced for the mean $|\Delta K^*_{t\,\Delta t}|$ metric, indicating that the generator may have a tendency to produce more "on-off" type output than observed. Measured observations show that "on-off" events are intermingled with periods with less change resulting in a lower mean $|\Delta K^*_{t\,\Delta t}|$ metrics

Formulation of a Model to Predict Short-Term Variability from Gridded Satellite-Derived irradiances

The ~92,000 hourly data point spanning 16 months from the 24 sites are used to build a set of lookup tables that can be interfaced with hourly satellite-derived irradiance data to quantify short-term variability at any given location/time. Satellite derived DNI and GHI from which Kt* and Kb* can be derived and the knowledge of GHI at neighboring satellite pixels, from which σ_{space} can be derived can thus be used to infer the short-term variability of any hourly point at time scales ranging from seconds to several minutes.

The lookup tables corresponding to each of the four metrics and time scales are provided in the appendix[2]. The one-minute mean **clear sky** index change data table is rendered visually in Figures 14 and 15 for low and high σ_{space} conditions, respectively, providing a full view of the combined Kb* and Kt* trends (which appear only as one-dimensional projections in Figs. 1-4 and 6-9).

Model application example: Considering the satellite-derived GHI scene presented in Fig. 16, let us consider the central pixel. Satellite-derived GHI is equal 391 W/m2 and DNI is 364 W/m2. GHI_{clear} and DNI_{clear} for that location and time are equal to 501 and 891 W/m2, respectively. kt* and kb* are thus respectively equal to 0.78 and 0.41. An analysis of the surrounding pixels reveals pronounced spatial variability with σ_{space} reaching 0.21. From this information, the model can produce a measure of variability for different time frames. For instance Table A4 indicates that this location/hour will experience a mean minute to minute clear sky index change of 0.09, with a maximum expected change of 0.42 ± 0.24.

CONCLUSIONS

We described and presented an empirical model capable of extracting metrics quantifying the short-term variability of the solar resource based upon site/time specific hourly irradiance data produced by satellite models. The model is derived from over 92,000 experimental hourly data points at twenty four sites. The model returns four metrics characterizing intra-hourly variability, including the standard deviation of the GHI index, the mean GHI index change from one time interval to the next, as well as the maximum expected, and standard deviation of the same. Four models are provided representing four time intervals, respectively 20 seconds, one-minute, 5 minutes and 15 minutes.

[2] An electronic copy of the lookup tables can also be downloaded from ftp://sunbay.asrc.cestm.albany.edu/pub/perez

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The trends underlying the models are robust as indicated by their similarities observed at all twenty four sites. Results are consistent with, but different from earlier work, particularly in the frequency of on-off fluctuations which had been modeled higher than currently observed.

The next step in this research will be to quantify the variability covariance of a pair of stations as a function of their distance. This next step will extend the current study (single point variability) with the objective of quantifying the findings of an earlier Hoff and Perez study (multi point variability and impact of dispersion factor) in terms of absolute distances and absolute variability of a fleet of solar generators.

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Table A7: Same as Table A1, but Δt = 15 minutes

Table A8: Same as Table A2, but Δt = 15 minutes

Table A9: distribution of hourly data points analyzed

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TABLE 1: Lookup Table Bins

Kt* Bins	Kb* Bins	σ_{space} Bins
0.0 – 0.1	0.0 – 0.1	0.0 – 0.1
0.1 – 0.2	0.1 – 0.2	> 0.1
0.2 – 0.3	0.2 – 0.3	--
0.3 – 0.4	0.3 – 0.4	--
0.4 – 0.5	0.4 – 0.5	--
0.5 – 0.6	0.5 – 0.6	--
0.6 – 0.7	0.6 – 0.7	--
0.7 – 0.8	0.7 – 0.8	--
0.8 – 0.9	0.8 – 0.9	--
0.9 – 1.0	0.9 – 1.0	--
> 1.0	> 1.0	--

TABLE 2: Experimental data

	Station	Latitude	Longitude	Elevation	Climate	Time Span
ARM NETWORK	ARM-E27	35.27	96.74	386 m	continental	1/09 - 4/10
	ARM-E19	35.56	98.02	421 m	continental	1/09 - 4/10
	ARM-E20	35.56	96.99	309 m	continental	1/09 - 4/10
	ARM-E21	35.62	96.07	240 m	continental	1/09 - 4/10
	ARM-E15	36.43	98.28	418 m	continental	1/09 - 4/10
	ARM-C1	36.61	97.49	318 m	continental	1/09 - 4/10
	ARM-E13	36.61	97.49	318 m	continental	1/09 - 4/10
	ARM-E12	36.84	96.43	331 m	continental	1/09 - 4/10
	ARM-E16	36.06	99.13	602 m	continental	1/09 - 4/10
	ARM-E11	36.88	98.29	360 m	continental	1/09 - 4/10
	ARM-E10	37.07	95.79	248 m	continental	1/09 - 4/10
	ARM-E9	37.13	97.27	386 m	continental	1/09 - 4/10
	ARM-E7	37.38	96.18	283 m	continental	1/09 - 4/10
	ARM-E6	37.84	97.02	409 m	continental	1/09 - 4/10
	ARM-E4	37.95	98.33	513 m	continental	1/09 - 4/10
	ARM-E1	38.20	99.32	632 m	continental	1/09 - 4/10
	ARM-E2	38.31	97.30	450 m	continental	1/09 - 4/10
SURFRAD NETWORK	Goodwin Creek	34.25	89.87	98 m	subtropical	1/09 - 4/10
	Desert Rock	36.63	116.02	1007 m	Arid	1/09 - 4/10
	Bondville	40.05	88.37	213 m	Continental	1/09 - 4/10
	Boulder	40.13	105.24	1689 m	Semi-arid	1/09 - 4/10
	Penn State	40.72	77.93	376 m	humid continental	1/09 - 4/10
	Sioux Falls	43.73	96.62	473 m	Continental	1/09 - 4/10
	Fort Peck	48.31	105.10	634 m	Continental	1/09 - 4/10

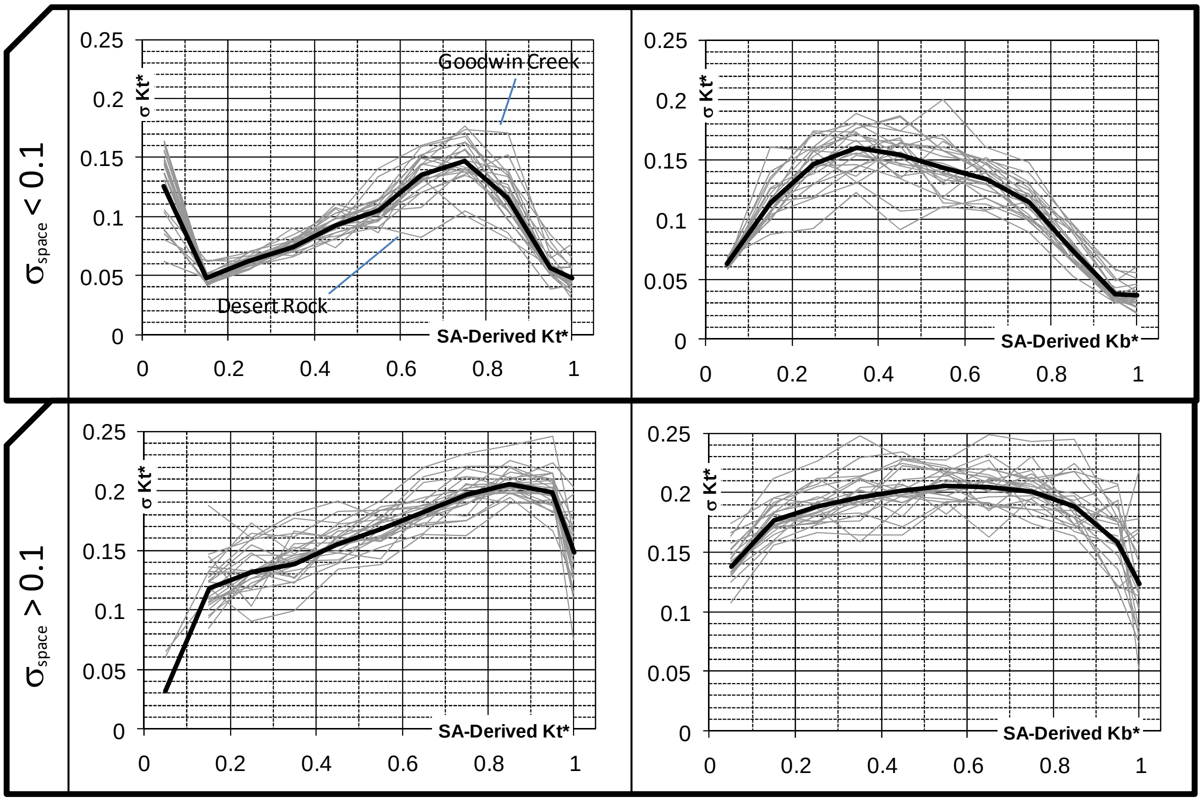

Figure 1: One-minute $\sigma K^{*}_{t\Delta t}$ metric trends as a function of Kt*, Kb* and σ_{space}. Each gray line represents an individual site. The bold black line represents the mean trend derived for all sites.

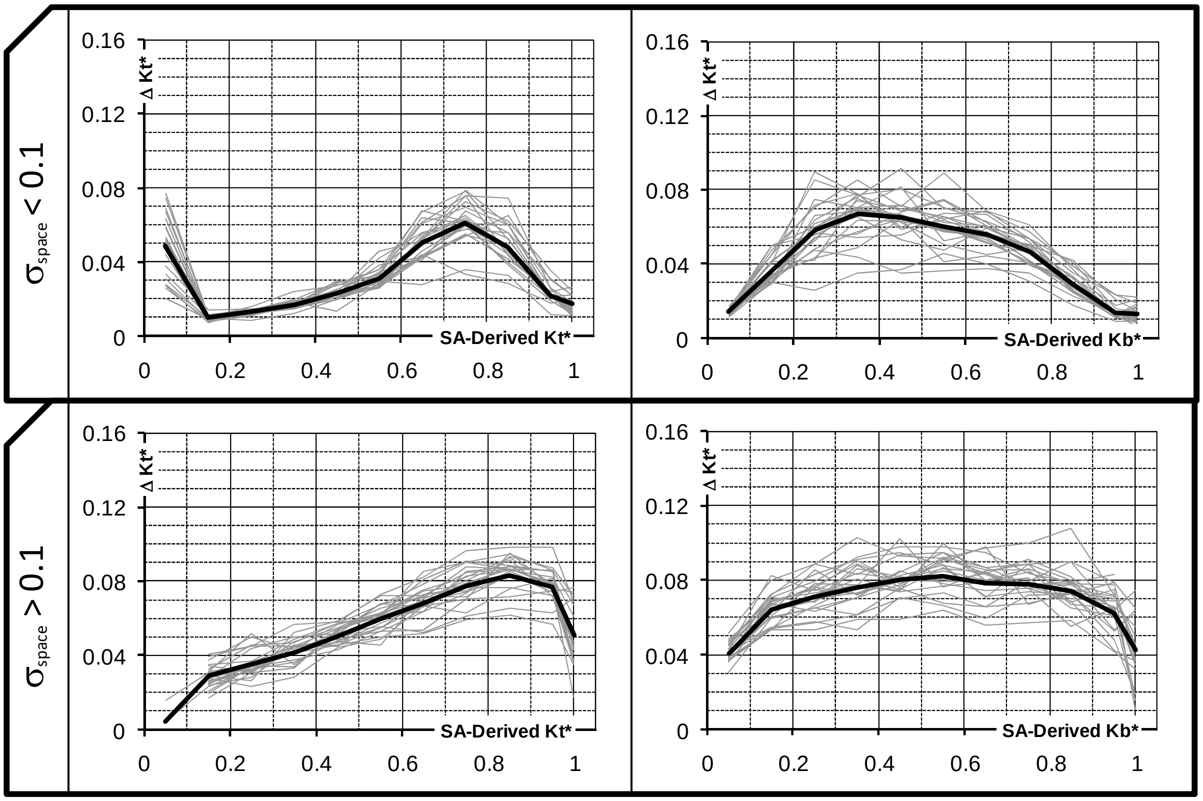

Figure 2: Same as Figure 1, but mean $|\Delta K^*_{t\,\Delta t}|$metric

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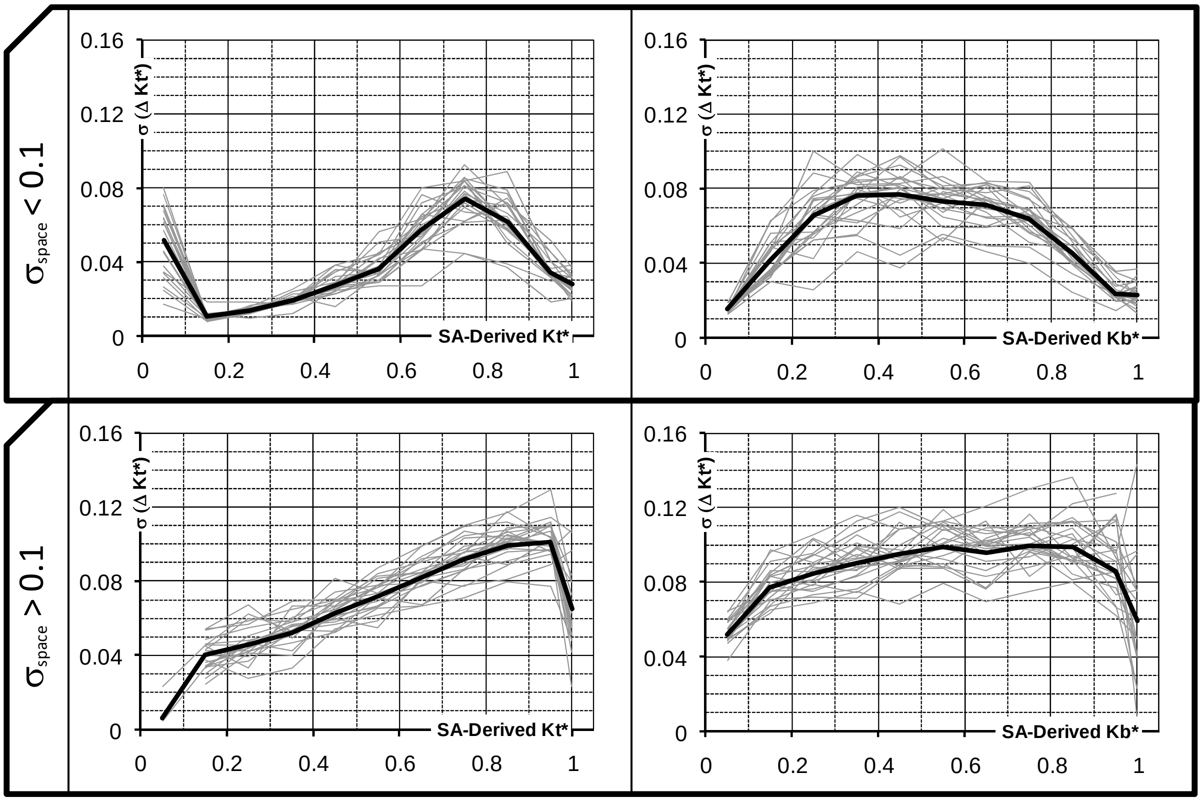

Figure 3: Same as Figure 1, but $\sigma|\Delta K^*_{t\,\Delta t}|$metric

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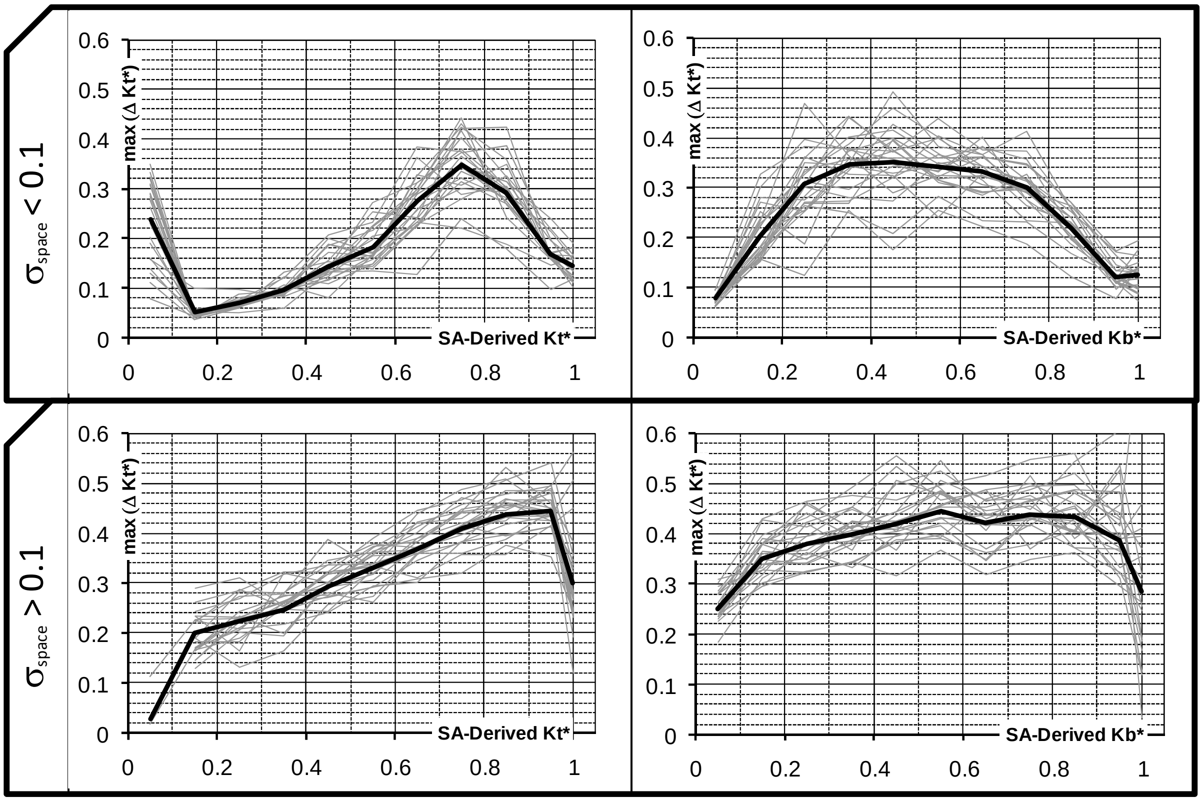

Figure 4: Same as Figure 1, but Max $|\Delta K^*_{t\,\Delta t}|$metric

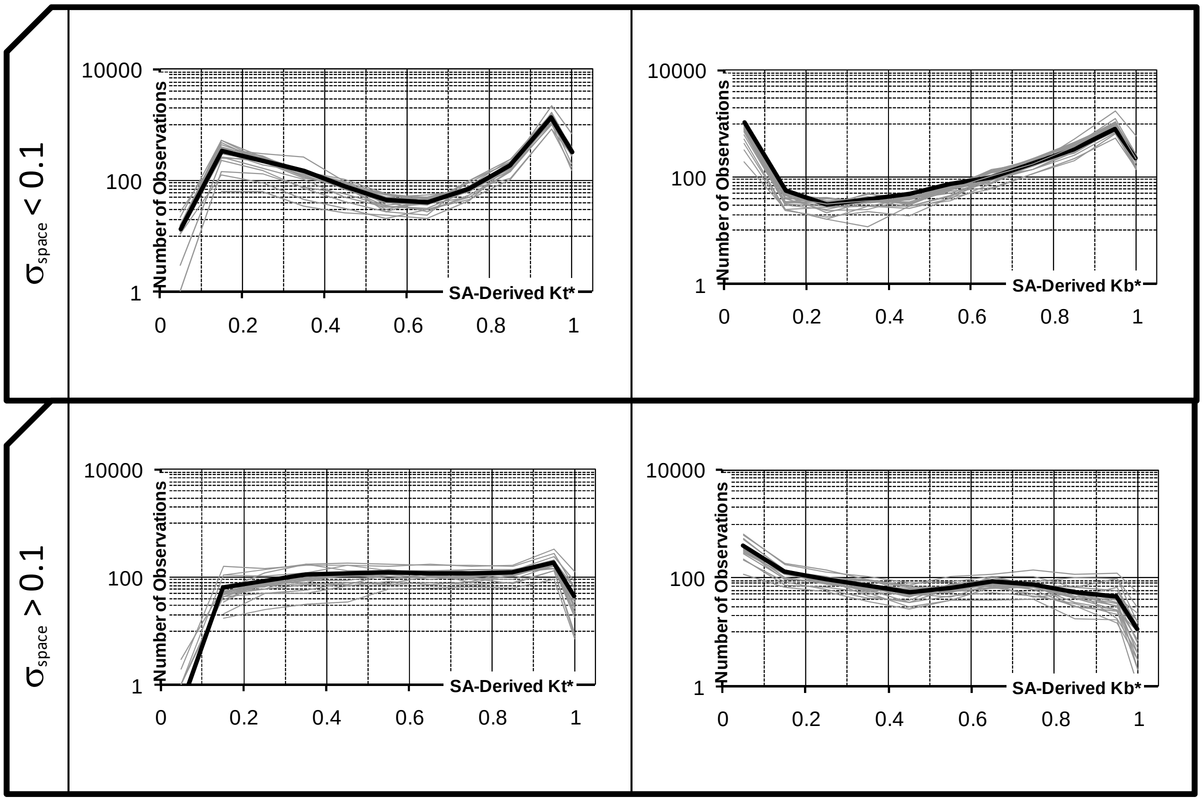

Figure 5: Number of data points analyzed as a function of Kt*, Kb* and σ_{space}. As in Figures 1-4, gray lines represent individual sites, and the bold black line represents the mean for all sites.

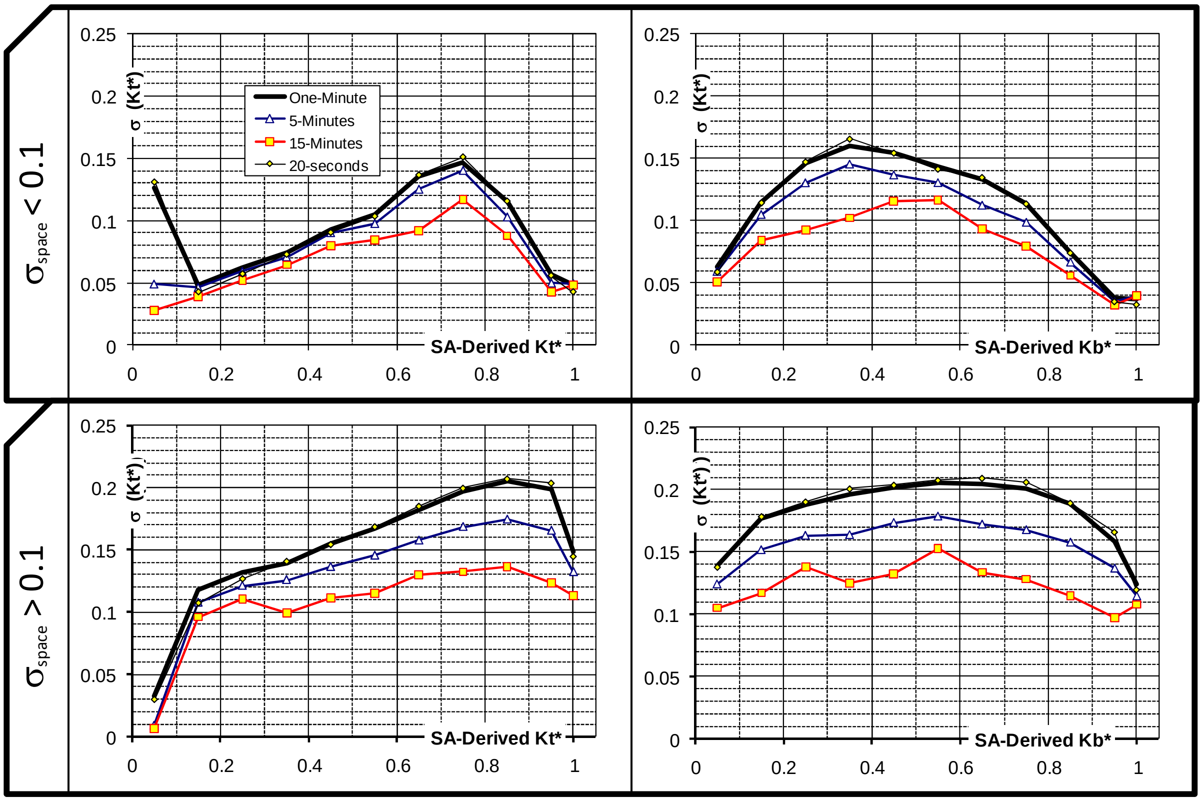

Figure 6: All-Site mean $\sigma K^{*}_{t\Delta t}$ metric trends as a function of Δt sampling interval

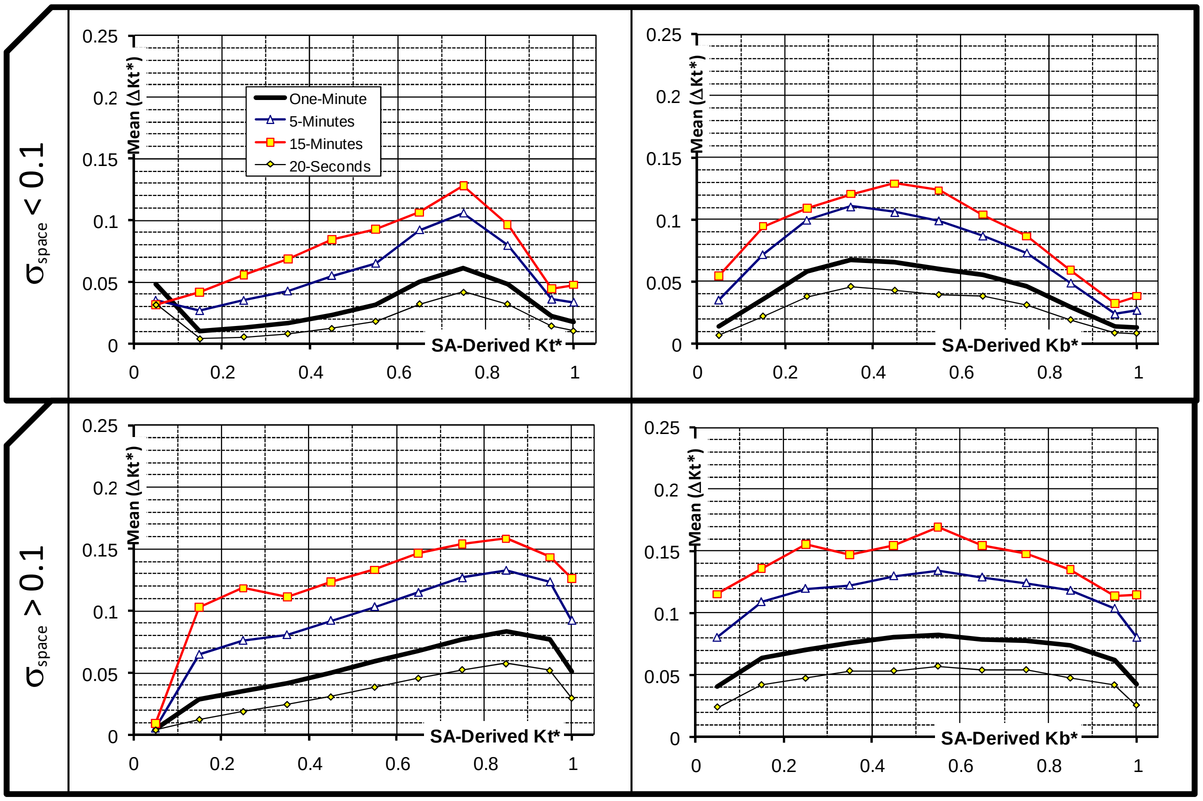

Figure 7: Same as Figure 6, but mean $|\Delta K^*_{t\,\Delta t}|$ metric

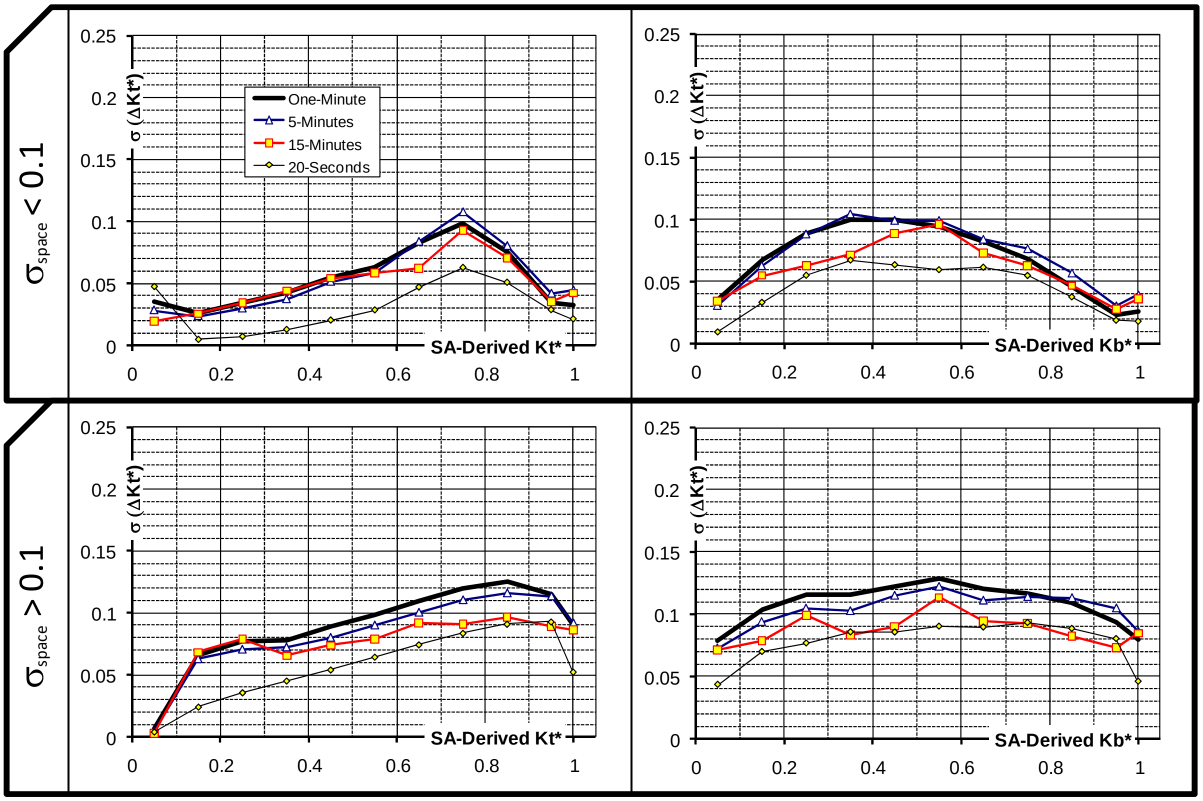

Figure 8: Same as Figure 6, but $\sigma|\Delta K^*_{t\,\Delta t}|$ metric

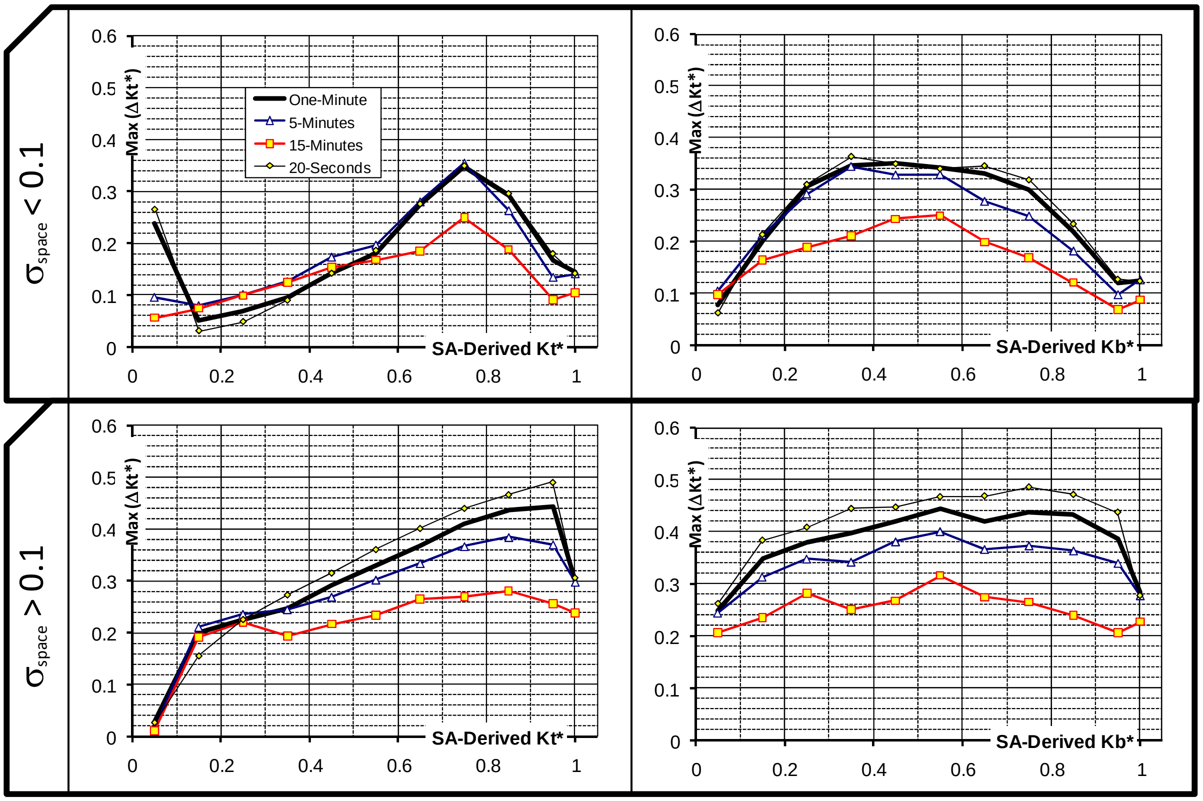

Figure 9: Same as Figure 6, but Max $|\Delta K_{t\,\Delta t}^{*}|$metric

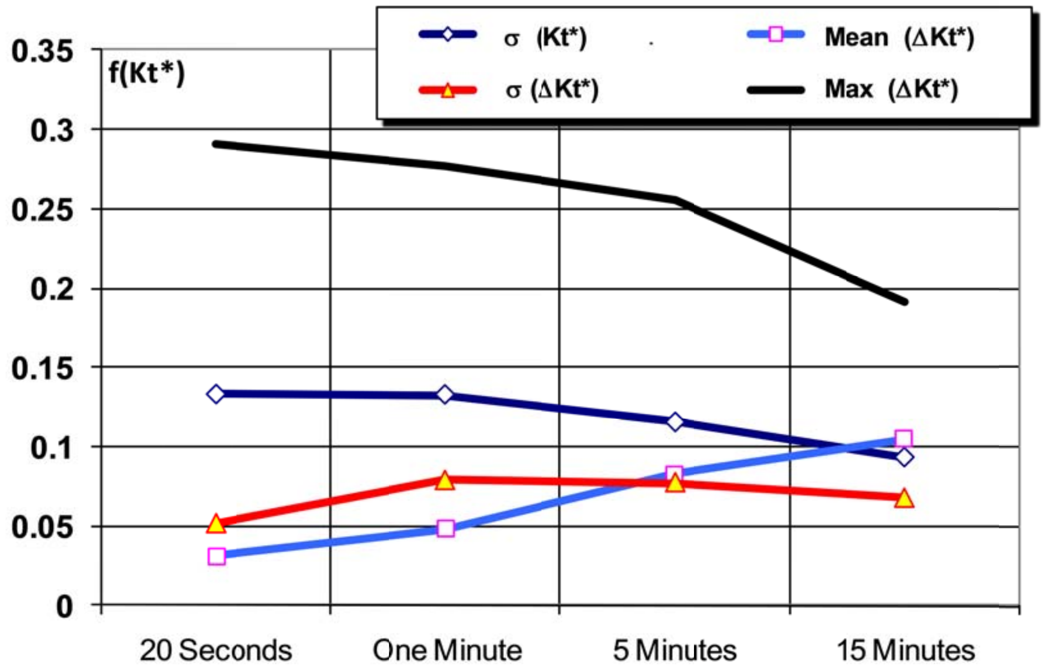

Figure 10: Comparing all-conditions mean variability metrics as a function of sampling rate Δt

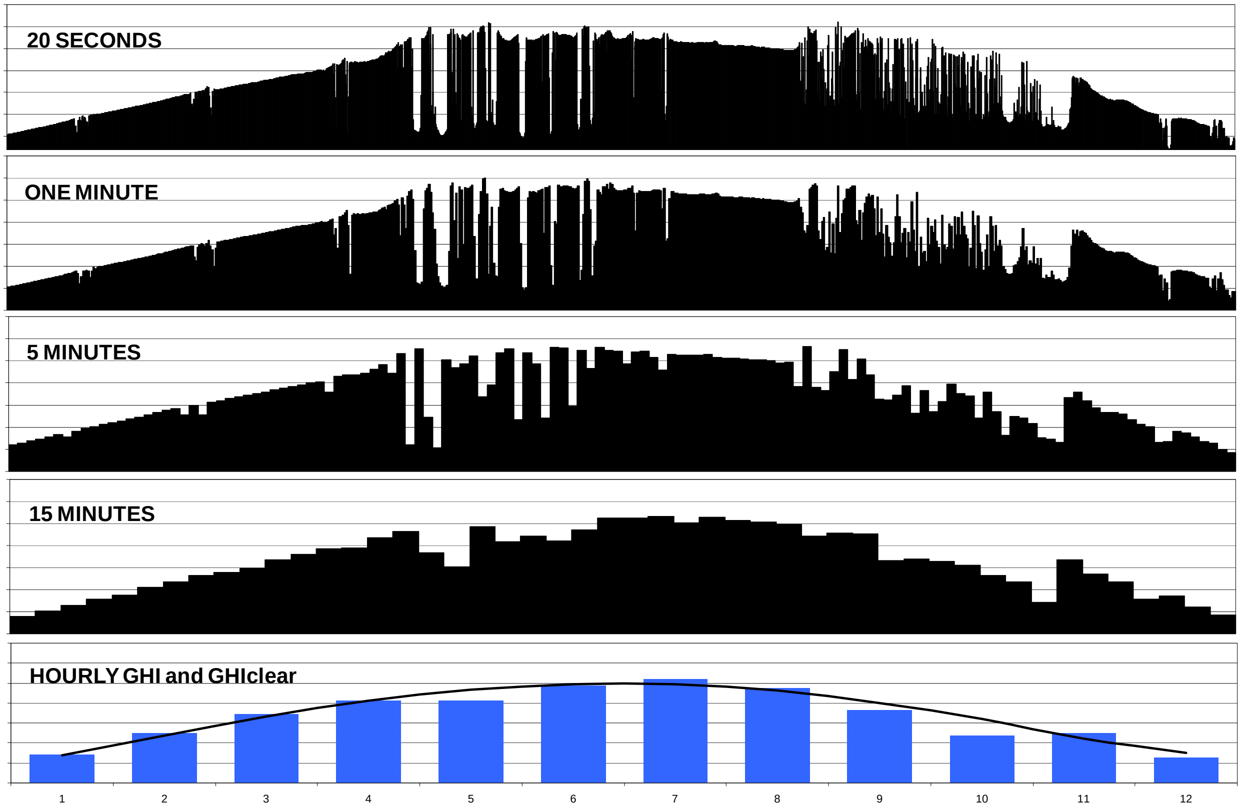

Figure 11: Comparing GHI for all selected Δt sampling rates for ARM site's central facility on May 25, 2001. The bottom plot reports hourly GHI model input and clear sky background.

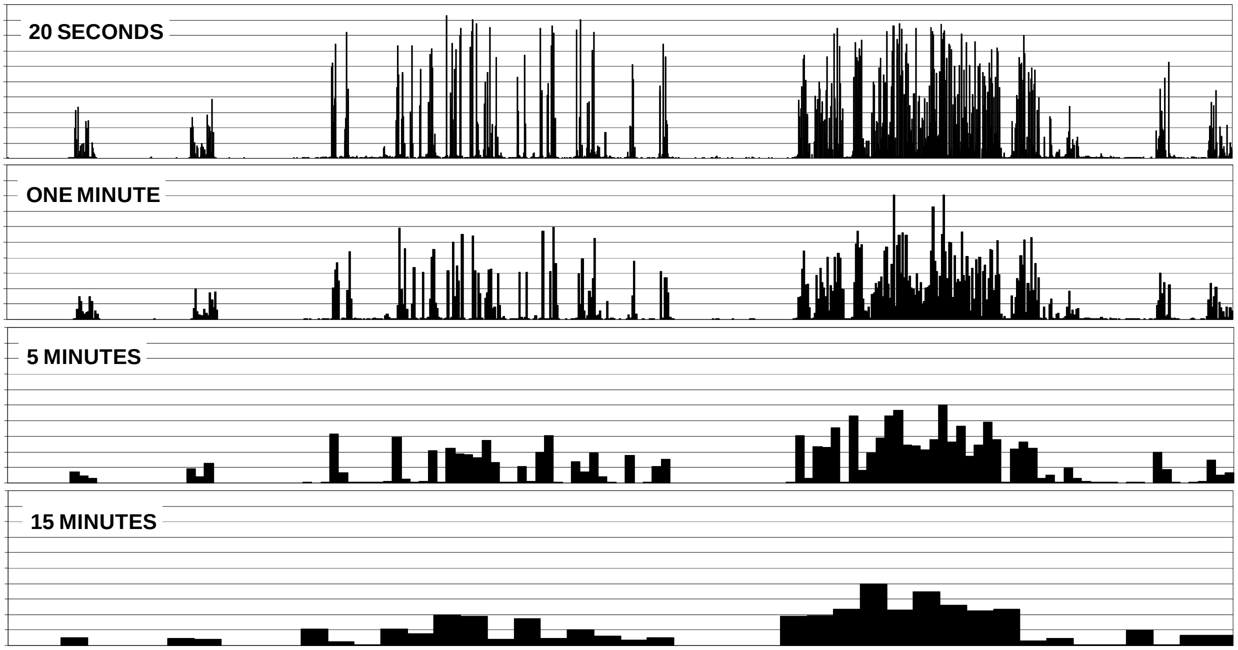

Figure 12: Comparing the $|\Delta K^{*}_{t\,\Delta t}|$ metric for all selected Δt sampling rates for the same site/day as figure 11.

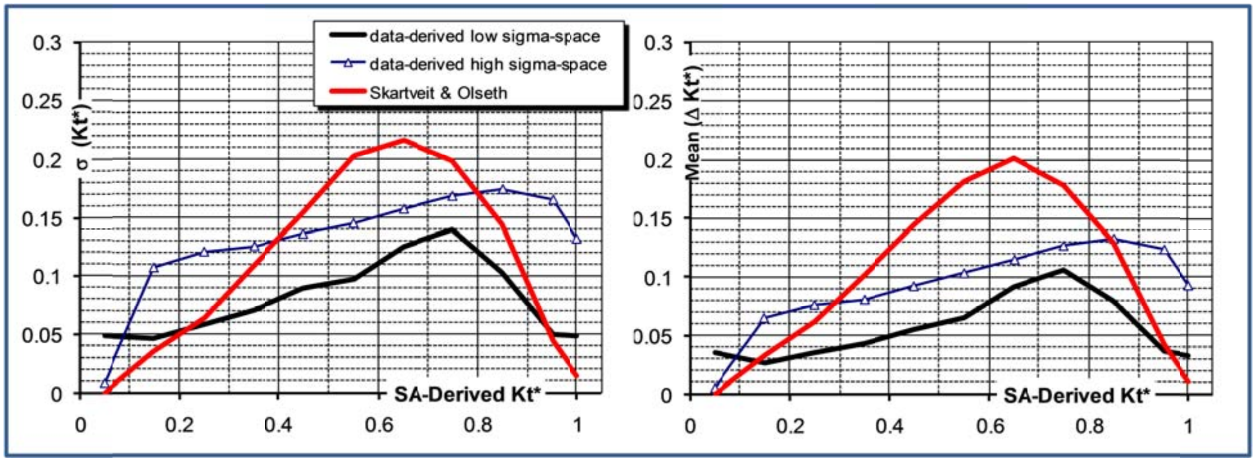

Figure 13: Comparing the observed 5-minutes Δt trends for $\sigma K^*_{t\Delta t}$ and mean $|\Delta K^*_{t\,\Delta t}|$ to that derived using the Skartveit and Olseth model (1992) with identical input data

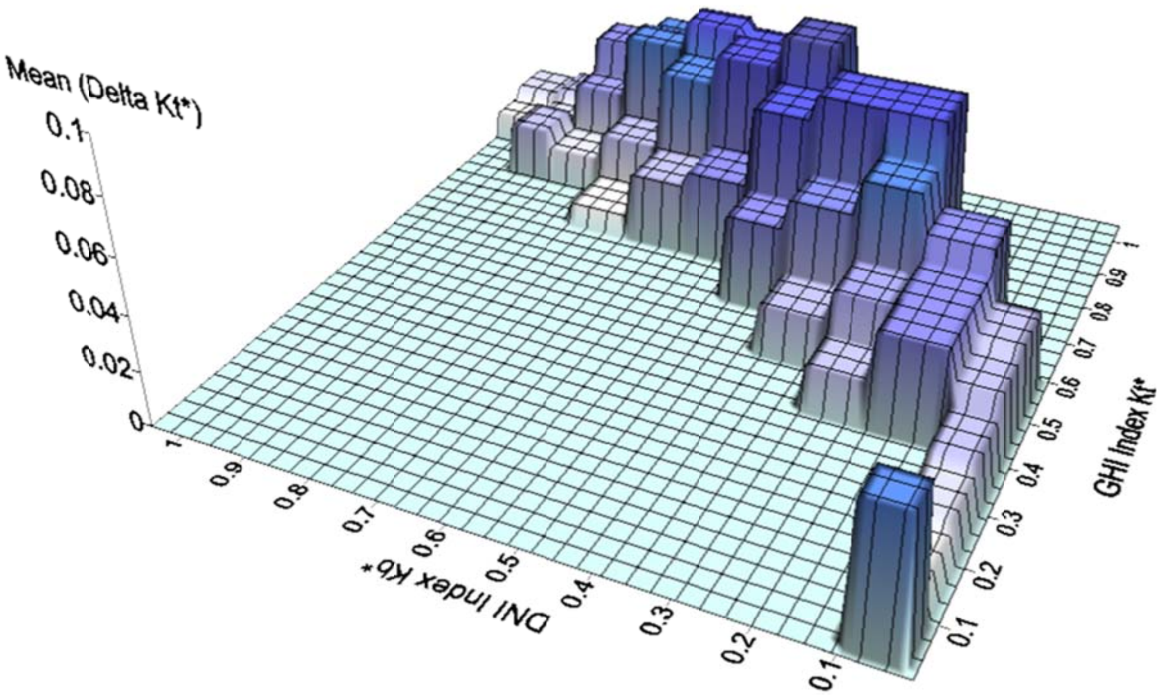

Figure 14: Mean $|\Delta K^*_{t\,\Delta t}|$model lookup table rendering for low σ_{space} conditions

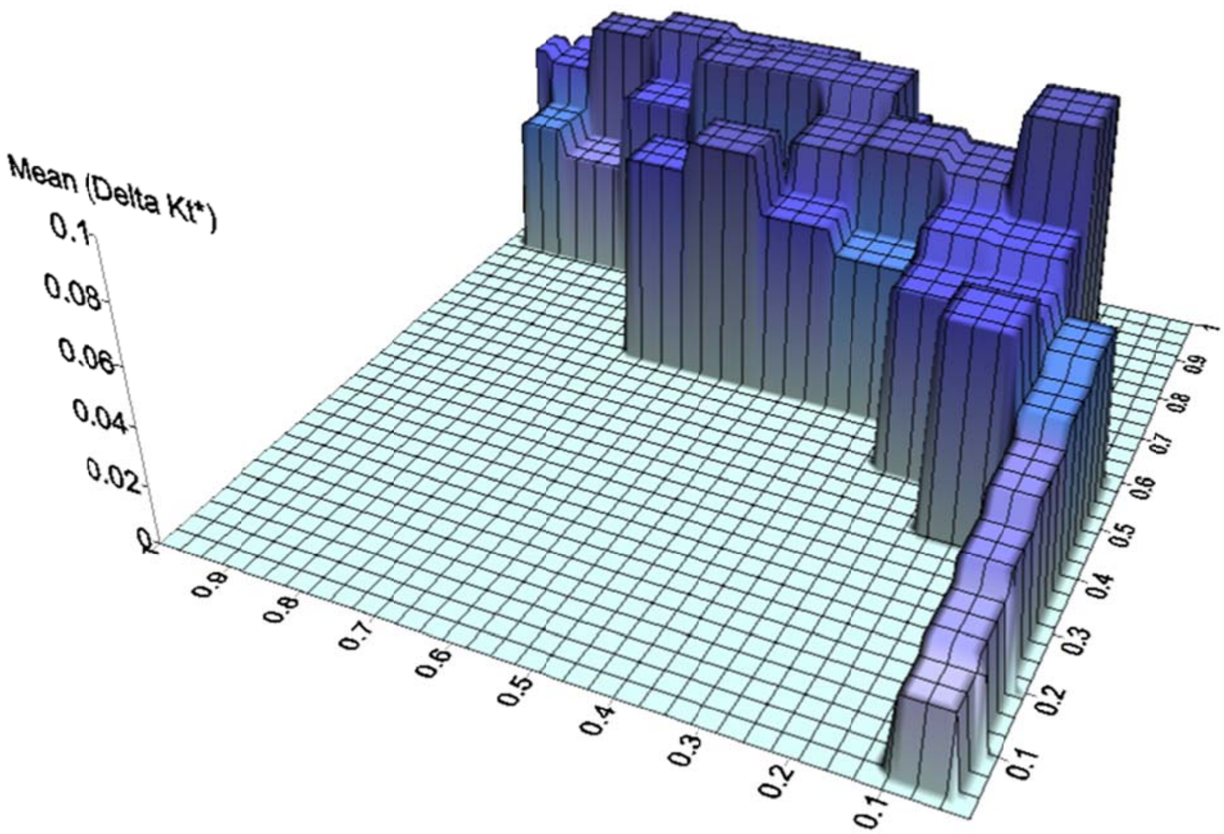

Figure 15: Same as figure 14, but high σ_{space} conditions

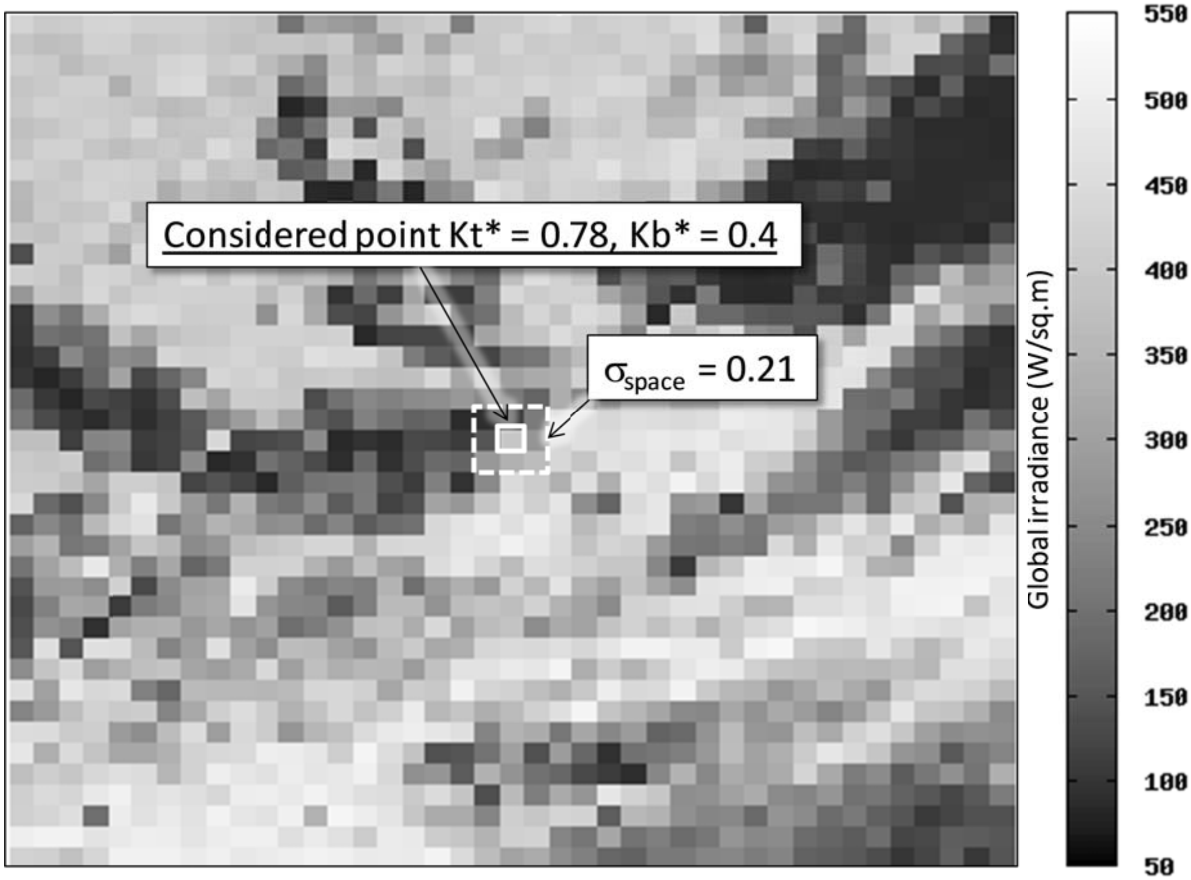

Figure 16: Example of present model application. Considering the above 4x4 degree satellite-derived irradiance scene at a given point in time, each pixel and its immediate surrounding area contains all the input information to derive each variability metric at time scales ranging from 20 seconds to 15 minutes.

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APPENDIX : Model Lookup Tables

Tables A1 to A8 reports variability metric values multiplied by 100 derived for all observations falling in a particular Kt*, Kb*, σ_{space} bin as well as the standard deviations around these means. The number of hourly observations in each bin is reported in Table A9. The number of observations should provide an indication of the robustness of any particular bin value.

Table A1 includes the lookup tables for the $\sigma K^*_{t\Delta t}$ and mean $|\Delta K^*_{t\ \Delta t}|$metrics with Δt = 20 seconds while

Table A2 includes the lookup tables for the $\sigma|\Delta K^*_{t\ \Delta t}|$and Max $|\Delta K^*_{t\ \Delta t}|$metrics for the same.

Tables A3 and A4 are identical to tables A1 and A2 but for the sampling rate Δt = 1 minute.

Tables A5 and A6, and A7 and A8, provide the same information for Δt = 5 minute and 15 minutes, respectively.

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TABLE A1

σ(Kt*) **20-Seconds**

	Kt*	Kb* <0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	14 +/- 8										
	0.1 - 0.2	5 +/- 5										
	0.2 - 0.3	6 +/- 5										
	0.3 - 0.4	8 +/- 6										
	0.4 - 0.5	9 +/- 6										
	0.5 - 0.6	10 +/- 6	11 +/- 7									
	0.6 - 0.7		13 +/- 8	14 +/- 8	13 +/- 8							
	0.7 - 0.8			18 +/- 8	18 +/- 9	15 +/- 9	11 +/- 8	7 +/- 6				
	0.8 - 0.9					19 +/- 9	16 +/- 9	14 +/- 10	8 +/- 8	6 +/- 6		
	0.9 - 0.99						18 +/- 10	18 +/- 9	14 +/- 10	8 +/- 9	4 +/- 7	3 +/- 7
	> 0.99							14 +/- 11	16 +/- 9	12 +/- 9	5 +/- 7	4 +/- 7
$\sigma_{space} > 0.1$	<0.1											
	0.1 - 0.2	12 +/- 10										
	0.2 - 0.3	14 +/- 10										
	0.3 - 0.4	15 +/- 10										
	0.4 - 0.5	16 +/- 10	21 +/- 11									
	0.5 - 0.6	16 +/- 10	18 +/- 10	19 +/- 12								
	0.6 - 0.7		20 +/- 10	20 +/- 10	17 +/- 11							
	0.7 - 0.8			22 +/- 9	22 +/- 10	20 +/- 10	15 +/- 9					
	0.8 - 0.9				18 +/- 10	23 +/- 9	23 +/- 9	23 +/- 10	18 +/- 11			
	0.9 - 0.99						23 +/- 9	23 +/- 10	23 +/- 10	22 +/- 11	17 +/- 12	
	> 0.99							17 +/- 11	19 +/- 11	20 +/- 11	20 +/- 12	14 +/- 11

Mean (ΔKt*) **20-Seconds**

	Kt*	Kb* <0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	3 +/- 3										
	0.1 - 0.2	0 +/- 1										
	0.2 - 0.3	1 +/- 1										
	0.3 - 0.4	1 +/- 1										
	0.4 - 0.5	1 +/- 2										
	0.5 - 0.6	2 +/- 2	2 +/- 2									
	0.6 - 0.7		3 +/- 3	4 +/- 4	3 +/- 4							
	0.7 - 0.8			5 +/- 4	5 +/- 4	4 +/- 4	2 +/- 2	1 +/- 1				
	0.8 - 0.9					5 +/- 5	5 +/- 4	4 +/- 4	2 +/- 2	1 +/- 1		
	0.9 - 0.99						4 +/- 4	5 +/- 4	4 +/- 4	2 +/- 3	1 +/- 2	1 +/- 2
	> 0.99							3 +/- 4	3 +/- 3	3 +/- 3	1 +/- 2	1 +/- 2
$\sigma_{space} > 0.1$	<0.1											
	0.1 - 0.2	2 +/- 2										
	0.2 - 0.3	2 +/- 3										
	0.3 - 0.4	3 +/- 3										
	0.4 - 0.5	3 +/- 4	4 +/- 4									
	0.5 - 0.6	3 +/- 4	4 +/- 4	4 +/- 4								
	0.6 - 0.7		5 +/- 4	5 +/- 4	4 +/- 5							
	0.7 - 0.8			5 +/- 4	6 +/- 5	5 +/- 5	3 +/- 3					
	0.8 - 0.9				2 +/- 2	6 +/- 4	6 +/- 5	6 +/- 5	5 +/- 5			
	0.9 - 0.99						5 +/- 4	6 +/- 4	6 +/- 5	6 +/- 4	4 +/- 4	
	> 0.99							2 +/- 3	4 +/- 4	5 +/- 5	5 +/- 4	3 +/- 4

TABLE A2

σ(ΔKt*) 20-Seconds

	Kt*	Kb*										
		<0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	5 +/- 5										
	0.1 - 0.2	1 +/- 1										
	0.2 - 0.3	1 +/- 2										
	0.3 - 0.4	1 +/- 2										
	0.4 - 0.5	2 +/- 3										
	0.5 - 0.6	2 +/- 3	3 +/- 4									
	0.6 - 0.7		4 +/- 4	5 +/- 5	4 +/- 5							
	0.7 - 0.8			7 +/- 6	8 +/- 6	6 +/- 5	3 +/- 3	3 +/- 3				
	0.8 - 0.9					8 +/- 6	7 +/- 6	6 +/- 6	3 +/- 3	2 +/- 2		
	0.9 - 0.99						7 +/- 5	8 +/- 6	7 +/- 6	4 +/- 5	2 +/- 4	2 +/- 4
	> 0.99							5 +/- 6	7 +/- 5	6 +/- 5	2 +/- 4	2 +/- 4
$\sigma_{space} > 0.1$	<0.1											
	0.1 - 0.2	3 +/- 4										
	0.2 - 0.3	4 +/- 5										
	0.3 - 0.4	5 +/- 5										
	0.4 - 0.5	5 +/- 6	8 +/- 6									
	0.5 - 0.6	6 +/- 6	7 +/- 6	7 +/- 6								
	0.6 - 0.7		7 +/- 6	8 +/- 7	6 +/- 7							
	0.7 - 0.8			8 +/- 6	9 +/- 6	8 +/- 6	4 +/- 3					
	0.8 - 0.9				4 +/- 4	9 +/- 6	10 +/- 7	10 +/- 6	7 +/- 6			
	0.9 - 0.99						9 +/- 5	9 +/- 6	11 +/- 7	10 +/- 7	8 +/- 7	
	> 0.99							4 +/- 4	6 +/- 6	8 +/- 6	8 +/- 6	6 +/- 7

Max (ΔKt*) 20-Seconds

	Kt*	Kb*										
		<0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	29 +/- 23										
	0.1 - 0.2	4 +/- 11										
	0.2 - 0.3	5 +/- 11										
	0.3 - 0.4	9 +/- 15										
	0.4 - 0.5	14 +/- 17										
	0.5 - 0.6	16 +/- 18	20 +/- 20									
	0.6 - 0.7		23 +/- 21	29 +/- 23	27 +/- 23							
	0.7 - 0.8			40 +/- 25	39 +/- 26	31 +/- 23	25 +/- 24	36 +/- 37				
	0.8 - 0.9					43 +/- 25	38 +/- 26	34 +/- 27	20 +/- 24	19 +/- 26		
	0.9 - 0.99						47 +/- 24	45 +/- 25	37 +/- 28	25 +/- 27	14 +/- 24	15 +/- 28
	> 0.99							34 +/- 33	39 +/- 26	34 +/- 27	15 +/- 22	14 +/- 23
$\sigma_{space} > 0.1$	<0.1											
	0.1 - 0.2	20 +/- 24										
	0.2 - 0.3	25 +/- 28										
	0.3 - 0.4	28 +/- 27										
	0.4 - 0.5	31 +/- 26	41 +/- 28									
	0.5 - 0.6	34 +/- 26	38 +/- 27	37 +/- 24								
	0.6 - 0.7		41 +/- 26	42 +/- 27	36 +/- 30							
	0.7 - 0.8			44 +/- 24	46 +/- 26	43 +/- 26	27 +/- 21					
	0.8 - 0.9				31 +/- 27	49 +/- 26	49 +/- 25	49 +/- 25	36 +/- 23			
	0.9 - 0.99						49 +/- 23	50 +/- 25	54 +/- 25	53 +/- 26	45 +/- 29	
	> 0.99							27 +/- 22	38 +/- 29	43 +/- 27	45 +/- 26	38 +/- 34

TABLE A3

σ(Kt*) **One - Minute**

	Kt*	Kb* <0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	13 +/- 8										
	0.1 - 0.2	5 +/- 5										
	0.2 - 0.3	6 +/- 5										
	0.3 - 0.4	7 +/- 5										
	0.4 - 0.5	9 +/- 6	13 +/- 6									
	0.5 - 0.6	10 +/- 6	11 +/- 6									
	0.6 - 0.7		13 +/- 7	14 +/- 7	12 +/- 7							
	0.7 - 0.8			17 +/- 8	16 +/- 8	14 +/- 8	9 +/- 8	8 +/- 8				
	0.8 - 0.9					18 +/- 8	15 +/- 9	12 +/- 9	6 +/- 7	4 +/- 6		
	0.9 - 0.99						19 +/- 10	16 +/- 8	13 +/- 9	7 +/- 8	4 +/- 6	3 +/- 6
	> 0.99							13 +/- 9	15 +/- 9	11 +/- 9	4 +/- 7	4 +/- 6
$\sigma_{space} > 0.1$	<0.1											
	0.1 - 0.2	12 +/- 10										
	0.2 - 0.3	13 +/- 10										
	0.3 - 0.4	14 +/- 10										
	0.4 - 0.5	15 +/- 10	20 +/- 10									
	0.5 - 0.6	16 +/- 9	17 +/- 9	18 +/- 11								
	0.6 - 0.7		19 +/- 9	18 +/- 9	15 +/- 10							
	0.7 - 0.8			21 +/- 9	20 +/- 9	19 +/- 10	14 +/- 9					
	0.8 - 0.9				19 +/- 10	22 +/- 8	21 +/- 9	20 +/- 9	17 +/- 10	11 +/- 10		
	0.9 - 0.99						23 +/- 9	22 +/- 9	21 +/- 9	19 +/- 10	16 +/- 11	21 +/- 12
	> 0.99							14 +/- 9	16 +/- 11	17 +/- 11	16 +/- 11	12 +/- 10

Mean (ΔKt*) **One - Minute**

	Kt*	Kb* <0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	5 +/- 4										
	0.1 - 0.2	1 +/- 1										
	0.2 - 0.3	1 +/- 1										
	0.3 - 0.4	2 +/- 2										
	0.4 - 0.5	2 +/- 2	3 +/- 2									
	0.5 - 0.6	3 +/- 2	3 +/- 3									
	0.6 - 0.7		4 +/- 3	6 +/- 5	4 +/- 4							
	0.7 - 0.8			7 +/- 5	7 +/- 5	6 +/- 5	3 +/- 3	2 +/- 3				
	0.8 - 0.9					8 +/- 5	6 +/- 5	5 +/- 5	2 +/- 3	1 +/- 2		
	0.9 - 0.99						6 +/- 5	6 +/- 5	5 +/- 5	3 +/- 4	1 +/- 3	1 +/- 2
	> 0.99							4 +/- 4	5 +/- 4	4 +/- 4	2 +/- 3	1 +/- 3
$\sigma_{space} > 0.1$	<0.1											
	0.1 - 0.2	3 +/- 3										
	0.2 - 0.3	4 +/- 4										
	0.3 - 0.4	4 +/- 4										
	0.4 - 0.5	5 +/- 4	7 +/- 5									
	0.5 - 0.6	5 +/- 5	6 +/- 5	6 +/- 5								
	0.6 - 0.7		7 +/- 5	7 +/- 5	5 +/- 5							
	0.7 - 0.8			8 +/- 5	8 +/- 5	8 +/- 6	5 +/- 4					
	0.8 - 0.9				5 +/- 4	9 +/- 5	9 +/- 6	8 +/- 6	7 +/- 5	4 +/- 5		
	0.9 - 0.99						8 +/- 5	8 +/- 5	8 +/- 5	8 +/- 5	6 +/- 5	7 +/- 4
	> 0.99							4 +/- 4	5 +/- 5	6 +/- 5	6 +/- 6	4 +/- 4

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TABLE A4

σ(ΔKt*) One - Minute

	Kt*	Kb* <0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
σ_{space} < 0.1	<0.1	5 +/- 4										
	0.1 - 0.2	1 +/- 2										
	0.2 - 0.3	1 +/- 2										
	0.3 - 0.4	2 +/- 2										
	0.4 - 0.5	3 +/- 3	4 +/- 3									
	0.5 - 0.6	3 +/- 3	4 +/- 4									
	0.6 - 0.7		5 +/- 5	6 +/- 5	5 +/- 6							
	0.7 - 0.8			8 +/- 6	8 +/- 6	7 +/- 7	5 +/- 7	8 +/- 11				
	0.8 - 0.9					9 +/- 6	8 +/- 6	7 +/- 6	4 +/- 6	3 +/- 7		
	0.9 - 0.99						9 +/- 7	8 +/- 6	7 +/- 6	4 +/- 6	2 +/- 5	2 +/- 4
	> 0.99							5 +/- 4	7 +/- 5	6 +/- 6	3 +/- 5	2 +/- 5
σ_{space} > 0.1	<0.1											
	0.1 - 0.2	4 +/- 5										
	0.2 - 0.3	5 +/- 5										
	0.3 - 0.4	5 +/- 5										
	0.4 - 0.5	6 +/- 5	9 +/- 6									
	0.5 - 0.6	7 +/- 6	7 +/- 6	8 +/- 7								
	0.6 - 0.7		8 +/- 6	8 +/- 6	7 +/- 6							
	0.7 - 0.8			9 +/- 6	9 +/- 6	9 +/- 6	7 +/- 7					
	0.8 - 0.9				7 +/- 5	10 +/- 6	10 +/- 6	10 +/- 6	8 +/- 6	6 +/- 7		
	0.9 - 0.99						11 +/- 7	10 +/- 6	11 +/- 6	10 +/- 6	9 +/- 7	11 +/- 8
	> 0.99							5 +/- 5	6 +/- 5	8 +/- 6	8 +/- 7	6 +/- 6

Max (ΔKt*) One - Minute

	Kt*	Kb* <0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
σ_{space} < 0.1	<0.1	24 +/- 19										
	0.1 - 0.2	5 +/- 9										
	0.2 - 0.3	7 +/- 11										
	0.3 - 0.4	10 +/- 13										
	0.4 - 0.5	14 +/- 17	20 +/- 15									
	0.5 - 0.6	17 +/- 20	18 +/- 20									
	0.6 - 0.7		25 +/- 29	29 +/- 26	27 +/- 33							
	0.7 - 0.8			38 +/- 28	35 +/- 29	33 +/- 34	32 +/- 50	54 +/- 72				
	0.8 - 0.9					41 +/- 31	34 +/- 27	30 +/- 30	20 +/- 37	20 +/- 46		
	0.9 - 0.99						46 +/- 39	38 +/- 27	33 +/- 28	22 +/- 30	12 +/- 25	11 +/- 23
	> 0.99							27 +/- 25	31 +/- 21	28 +/- 26	13 +/- 26	13 +/- 29
σ_{space} > 0.1	<0.1											
	0.1 - 0.2	20 +/- 24										
	0.2 - 0.3	22 +/- 23										
	0.3 - 0.4	25 +/- 23										
	0.4 - 0.5	28 +/- 26	39 +/- 25									
	0.5 - 0.6	31 +/- 25	33 +/- 25	41 +/- 39								
	0.6 - 0.7		38 +/- 26	37 +/- 25	31 +/- 25							
	0.7 - 0.8			42 +/- 27	42 +/- 24	40 +/- 28	37 +/- 41					
	0.8 - 0.9				30 +/- 20	45 +/- 22	45 +/- 26	44 +/- 25	41 +/- 36	32 +/- 46		
	0.9 - 0.99						51 +/- 36	44 +/- 24	46 +/- 24	45 +/- 25	39 +/- 29	59 +/- 52
	> 0.99							23 +/- 25	29 +/- 23	35 +/- 29	36 +/- 32	26 +/- 25

TABLE A5

σ(Kt*) **Five - Minute**

	Kt*	Kb* <0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	5 +/- 8										
	0.1 - 0.2	5 +/- 5										
	0.2 - 0.3	6 +/- 5										
	0.3 - 0.4	7 +/- 7										
	0.4 - 0.5	9 +/- 10	12 +/- 6									
	0.5 - 0.6	10 +/- 9	10 +/- 9									
	0.6 - 0.7		12 +/- 10	12 +/- 7	15 +/- 33							
	0.7 - 0.8			16 +/- 25	14 +/- 17	13 +/- 15	16 +/- 42	13 +/- 22				
	0.8 - 0.9					16 +/- 12	12 +/- 9	10 +/- 11	7 +/- 19	7 +/- 22		
	0.9 - 0.99						23 +/- 36	13 +/- 9	11 +/- 12	6 +/- 13	3 +/- 10	2 +/- 7
	> 0.99							12 +/- 9	12 +/- 8	9 +/- 10	4 +/- 15	4 +/- 16
$\sigma_{space} > 0.1$	<0.1	2 +/- 6										
	0.1 - 0.2	11 +/- 11										
	0.2 - 0.3	12 +/- 10										
	0.3 - 0.4	13 +/- 11										
	0.4 - 0.5	13 +/- 9	17 +/- 9									
	0.5 - 0.6	14 +/- 10	15 +/- 9	18 +/- 13								
	0.6 - 0.7		16 +/- 11	16 +/- 11	14 +/- 11							
	0.7 - 0.8			18 +/- 9	17 +/- 8	17 +/- 13	17 +/- 25					
	0.8 - 0.9				17 +/- 9	18 +/- 9	18 +/- 9	17 +/- 10	16 +/- 17	18 +/- 41		
	0.9 - 0.99						23 +/- 26	18 +/- 9	17 +/- 9	16 +/- 9	13 +/- 15	17 +/- 11
	> 0.99						12 +/- 19	12 +/- 9	14 +/- 10	16 +/- 23	14 +/- 17	11 +/- 13

Mean (ΔKt*) **Five - Minute**

	Kt*	Kb* <0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	3 +/- 6										
	0.1 - 0.2	3 +/- 3										
	0.2 - 0.3	3 +/- 3										
	0.3 - 0.4	4 +/- 4										
	0.4 - 0.5	5 +/- 6	7 +/- 4									
	0.5 - 0.6	6 +/- 6	7 +/- 6									
	0.6 - 0.7		8 +/- 6	9 +/- 6	11 +/- 24							
	0.7 - 0.8			13 +/- 18	11 +/- 9	10 +/- 8	9 +/- 19	9 +/- 17				
	0.8 - 0.9					12 +/- 9	10 +/- 7	8 +/- 9	5 +/- 13	5 +/- 15		
	0.9 - 0.99						16 +/- 26	10 +/- 7	8 +/- 8	5 +/- 9	2 +/- 6	2 +/- 5
	> 0.99							7 +/- 6	8 +/- 6	7 +/- 8	3 +/- 11	3 +/- 10
$\sigma_{space} > 0.1$	<0.1	1 +/- 3										
	0.1 - 0.2	6 +/- 7										
	0.2 - 0.3	8 +/- 7										
	0.3 - 0.4	8 +/- 7										
	0.4 - 0.5	9 +/- 7	12 +/- 7									
	0.5 - 0.6	10 +/- 7	10 +/- 8	12 +/- 10								
	0.6 - 0.7		12 +/- 7	12 +/- 8	9 +/- 7							
	0.7 - 0.8			13 +/- 8	13 +/- 7	13 +/- 10	12 +/- 18					
	0.8 - 0.9				10 +/- 6	14 +/- 7	13 +/- 8	13 +/- 8	12 +/- 12	10 +/- 18		
	0.9 - 0.99						16 +/- 18	13 +/- 7	13 +/- 8	12 +/- 8	10 +/- 9	12 +/- 8
	> 0.99						10 +/- 16	8 +/- 6	9 +/- 7	11 +/- 17	11 +/- 12	8 +/- 10

TABLE A6

σ(ΔKt*) Five - Minute

	Kt*	Kb* <0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	3 +/- 6										
	0.1 - 0.2	2 +/- 5										
	0.2 - 0.3	3 +/- 5										
	0.3 - 0.4	4 +/- 7										
	0.4 - 0.5	5 +/- 11	7 +/- 6									
	0.5 - 0.6	6 +/- 12	6 +/- 11									
	0.6 - 0.7		8 +/- 10	8 +/- 8	14 +/- 48							
	0.7 - 0.8			13 +/- 37	10 +/- 18	9 +/- 17	16 +/- 49	17 +/- 34				
	0.8 - 0.9					12 +/- 16	8 +/- 9	8 +/- 14	7 +/- 26	8 +/- 33		
	0.9 - 0.99						22 +/- 54	9 +/- 10	8 +/- 14	6 +/- 17	3 +/- 13	3 +/- 10
	> 0.99							8 +/- 11	8 +/- 5	7 +/- 12	4 +/- 21	4 +/- 21
$\sigma_{space} > 0.1$	<0.1	1 +/- 3										
	0.1 - 0.2	6 +/- 10										
	0.2 - 0.3	7 +/- 11										
	0.3 - 0.4	7 +/- 10										
	0.4 - 0.5	8 +/- 9	10 +/- 6									
	0.5 - 0.6	9 +/- 9	9 +/- 9	13 +/- 18								
	0.6 - 0.7		10 +/- 10	10 +/- 11	9 +/- 10							
	0.7 - 0.8			11 +/- 9	11 +/- 6	11 +/- 15	15 +/- 35					
	0.8 - 0.9				9 +/- 6	12 +/- 8	11 +/- 11	11 +/- 10	13 +/- 22	17 +/- 47		
	0.9 - 0.99						17 +/- 37	12 +/- 7	12 +/- 9	11 +/- 8	10 +/- 16	13 +/- 9
	> 0.99						16 +/- 29	7 +/- 6	8 +/- 6	11 +/- 32	11 +/- 21	8 +/- 17

Max (ΔKt*) Five - Minute

	Kt*	Kb* <0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	10 +/- 19										
	0.1 - 0.2	8 +/- 17										
	0.2 - 0.3	10 +/- 15										
	0.3 - 0.4	13 +/- 21										
	0.4 - 0.5	17 +/- 34	22 +/- 20									
	0.5 - 0.6	20 +/- 34	19 +/- 31									
	0.6 - 0.7		26 +/- 36	27 +/- 25	44 +/- 99							
	0.7 - 0.8			41 +/- 99	33 +/- 62	30 +/- 56	53 +/- 99	54 +/- 99				
	0.8 - 0.9					39 +/- 47	28 +/- 29	25 +/- 40	21 +/- 75	25 +/- 91		
	0.9 - 0.99						68 +/- 99	31 +/- 31	26 +/- 43	18 +/- 51	9 +/- 39	8 +/- 30
	> 0.99							28 +/- 36	25 +/- 17	22 +/- 33	13 +/- 59	14 +/- 62
$\sigma_{space} > 0.1$	<0.1	4 +/- 10										
	0.1 - 0.2	21 +/- 32										
	0.2 - 0.3	24 +/- 32										
	0.3 - 0.4	24 +/- 33										
	0.4 - 0.5	26 +/- 27	34 +/- 20									
	0.5 - 0.6	29 +/- 29	30 +/- 29	45 +/- 54								
	0.6 - 0.7		34 +/- 35	34 +/- 35	29 +/- 34							
	0.7 - 0.8			38 +/- 28	35 +/- 21	37 +/- 46	47 +/- 99					
	0.8 - 0.9				29 +/- 19	39 +/- 26	38 +/- 32	38 +/- 33	44 +/- 68	58 +/- 99		
	0.9 - 0.99						54 +/- 99	38 +/- 22	38 +/- 26	36 +/- 24	33 +/- 52	41 +/- 30
	> 0.99						50 +/- 89	24 +/- 22	28 +/- 21	35 +/- 88	35 +/- 67	27 +/- 50

TABLE A7

$\sigma(Kt^*)$ 15 - Minute

	Kt*	Kb* <0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	3 +/- 12										
	0.1 - 0.2	4 +/- 6										
	0.2 - 0.3	5 +/- 8										
	0.3 - 0.4	6 +/- 15										
	0.4 - 0.5	8 +/- 12	13 +/- 19									
	0.5 - 0.6	10 +/- 33	8 +/- 6									
	0.6 - 0.7		10 +/- 12	9 +/- 6	10 +/- 9							
	0.7 - 0.8			11 +/- 9	10 +/- 12	10 +/- 23	17 +/- 82	28 +/- 83				
	0.8 - 0.9					15 +/- 40	9 +/- 13	8 +/- 15	8 +/- 51	9 +/- 41		
	0.9 - 0.99						45 +/- 99	11 +/- 24	8 +/- 25	5 +/- 27	3 +/- 20	3 +/- 19
	> 0.99							16 +/- 32	9 +/- 7	7 +/- 7	5 +/- 41	4 +/- 23
$\sigma_{space} > 0.1$	<0.1											
	0.1 - 0.2	10 +/- 24										
	0.2 - 0.3	11 +/- 25										
	0.3 - 0.4	10 +/- 9										
	0.4 - 0.5	11 +/- 12	13 +/- 9									
	0.5 - 0.6	11 +/- 12	11 +/- 9	22 +/- 51								
	0.6 - 0.7		12 +/- 11	14 +/- 28	11 +/- 10							
	0.7 - 0.8			13 +/- 12	13 +/- 9	13 +/- 27	19 +/- 71					
	0.8 - 0.9				14 +/- 8	14 +/- 10	14 +/- 19	13 +/- 25	14 +/- 26	19 +/- 72		
	0.9 - 0.99						22 +/- 75	14 +/- 12	13 +/- 20	11 +/- 11	10 +/- 15	16 +/- 22
	> 0.99						34 +/- 79	11 +/- 14	11 +/- 8	11 +/- 9	10 +/- 19	10 +/- 30

Mean (ΔKt^*) 15 - Minute

	Kt*	Kb* <0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	3 +/- 10										
	0.1 - 0.2	4 +/- 5										
	0.2 - 0.3	6 +/- 7										
	0.3 - 0.4	7 +/- 12										
	0.4 - 0.5	8 +/- 10	13 +/- 15									
	0.5 - 0.6	10 +/- 25	9 +/- 6									
	0.6 - 0.7		11 +/- 11	11 +/- 6	11 +/- 9							
	0.7 - 0.8			13 +/- 9	12 +/- 11	11 +/- 19	15 +/- 64	23 +/- 66				
	0.8 - 0.9					16 +/- 31	11 +/- 12	9 +/- 13	7 +/- 39	8 +/- 32		
	0.9 - 0.99						39 +/- 99	12 +/- 20	9 +/- 20	6 +/- 21	3 +/- 16	3 +/- 15
	> 0.99							16 +/- 27	10 +/- 7	8 +/- 8	5 +/- 32	4 +/- 18
$\sigma_{space} > 0.1$	<0.1											
	0.1 - 0.2	10 +/- 19										
	0.2 - 0.3	12 +/- 21										
	0.3 - 0.4	11 +/- 9										
	0.4 - 0.5	12 +/- 11	15 +/- 9									
	0.5 - 0.6	13 +/- 11	13 +/- 10	21 +/- 40								
	0.6 - 0.7		14 +/- 11	15 +/- 23	12 +/- 10							
	0.7 - 0.8			16 +/- 12	15 +/- 10	15 +/- 22	18 +/- 55					
	0.8 - 0.9				17 +/- 11	16 +/- 11	16 +/- 17	15 +/- 21	16 +/- 22	18 +/- 55		
	0.9 - 0.99						22 +/- 57	16 +/- 12	15 +/- 17	13 +/- 12	11 +/- 14	19 +/- 20
	> 0.99						32 +/- 67	12 +/- 13	13 +/- 10	13 +/- 10	12 +/- 16	11 +/- 24

Forthcoming in Solar Energy 85 (2011) 1343–1353.

TABLE A8

$\sigma(\Delta Kt^*)$ 15 - Minute

	Kt*	Kb*										
		<0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	2 +/- 11										
	0.1 - 0.2	3 +/- 5										
	0.2 - 0.3	3 +/- 8										
	0.3 - 0.4	4 +/- 16										
	0.4 - 0.5	5 +/- 13	9 +/- 21									
	0.5 - 0.6	8 +/- 35	5 +/- 4									
	0.6 - 0.7		7 +/- 12	6 +/- 5	7 +/- 9							
	0.7 - 0.8			8 +/- 8	7 +/- 12	8 +/- 25	16 +/- 89	29 +/- 90				
	0.8 - 0.9					12 +/- 44	7 +/- 14	6 +/- 16	7 +/- 55	9 +/- 45		
	0.9 - 0.99						45 #####	8 +/- 26	6 +/- 28	4 +/- 29	2 +/- 21	3 +/- 20
	> 0.99							15 +/- 35	6 +/- 5	5 +/- 6	4 +/- 45	4 +/- 25
$\sigma_{space} > 0.1$	<0.1											
	0.1 - 0.2	7 +/- 25										
	0.2 - 0.3	8 +/- 27										
	0.3 - 0.4	7 +/- 8										
	0.4 - 0.5	7 +/- 12	9 +/- 8									
	0.5 - 0.6	8 +/- 12	8 +/- 8	19 +/- 56								
	0.6 - 0.7		8 +/- 11	10 +/- 29	7 +/- 10							
	0.7 - 0.8			9 +/- 11	8 +/- 8	9 +/- 29	16 +/- 76					
	0.8 - 0.9				10 +/- 6	9 +/- 10	10 +/- 20	10 +/- 27	11 +/- 28	18 +/- 79		
	0.9 - 0.99						18 +/- 81	10 +/- 12	9 +/- 21	8 +/- 11	7 +/- 16	13 +/- 24
	> 0.99						36 +/- 87	8 +/- 15	7 +/- 7	8 +/- 8	8 +/- 20	8 +/- 32

Max (ΔKt^*) 15 - Minute

	Kt*	Kb*										
		<0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	6 +/- 26										
	0.1 - 0.2	7 +/- 12										
	0.2 - 0.3	10 +/- 18										
	0.3 - 0.4	13 +/- 35										
	0.4 - 0.5	15 +/- 27	24 +/- 44									
	0.5 - 0.6	20 +/- 75	15 +/- 11									
	0.6 - 0.7		19 +/- 26	18 +/- 12	19 +/- 20							
	0.7 - 0.8			22 +/- 20	21 +/- 27	21 +/- 53	38 +/- 99	65 +/- 99				
	0.8 - 0.9					31 +/- 93	20 +/- 30	17 +/- 35	17 +/- 99	21 +/- 95		
	0.9 - 0.99						102 +/- 99	23 +/- 56	17 +/- 59	12 +/- 62	6 +/- 45	7 +/- 43
	> 0.99							36 +/- 76	18 +/- 14	14 +/- 15	11 +/- 96	9 +/- 54
$\sigma_{space} > 0.1$	<0.1											
	0.1 - 0.2	19 +/- 54										
	0.2 - 0.3	22 +/- 57										
	0.3 - 0.4	19 +/- 19										
	0.4 - 0.5	21 +/- 26	26 +/- 19									
	0.5 - 0.6	23 +/- 26	23 +/- 19	46 +/- 99								
	0.6 - 0.7		25 +/- 25	28 +/- 64	21 +/- 23							
	0.7 - 0.8			27 +/- 25	26 +/- 19	27 +/- 62	40 +/- 99					
	0.8 - 0.9				29 +/- 18	27 +/- 22	28 +/- 44	27 +/- 58	30 +/- 60	43 +/- 99		
	0.9 - 0.99						46 +/- 99	28 +/- 28	27 +/- 46	23 +/- 25	20 +/- 35	36 +/- 52
	> 0.99						82 +/- 99	23 +/- 33	22 +/- 18	23 +/- 20	22 +/- 43	22 +/- 70

TABLE A9

Mean (ΔKt*) **Number of hourly data points analyzed**

	Kt*	Kb* <0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 0.99	> 0.99
$\sigma_{space} < 0.1$	<0.1	-	-	-	-	-	-	-	-	-	-	-
	0.1 - 0.2	301	-	-	-	-	-	-	-	-	-	-
	0.2 - 0.3	7,789	-	-	-	-	-	-	-	-	-	-
	0.3 - 0.4	5,067	-	-	-	-	-	-	-	-	-	-
	0.4 - 0.5	3,377	-	-	-	-	-	-	-	-	-	-
	0.5 - 0.6	1,759	35	1	-	-	-	-	-	-	-	-
	0.6 - 0.7	345	645	10	1	-	-	-	-	-	-	-
	0.7 - 0.8	-	284	569	78	12	-	-	-	-	-	-
	0.8 - 0.9	1	-	130	722	565	176	49	3	-	-	-
	0.9 - 0.99	-	-	-	9	270	1,146	1,610	932	292	10	-
	> 0.99	1	-	-	-	1	49	709	3,036	7,689	19,523	1,141
$\sigma_{space} > 0.1$	<0.1	10	-	-	-	-	-	-	-	-	-	-
	0.1 - 0.2	1,492	-	-	-	-	-	-	-	-	-	-
	0.2 - 0.3	1,965	-	-	-	-	-	-	-	-	-	-
	0.3 - 0.4	2,621	-	-	-	-	-	-	-	-	-	-
	0.4 - 0.5	2,518	215	-	-	-	-	-	-	-	-	-
	0.5 - 0.6	723	2,065	63	-	-	-	-	-	-	-	-
	0.6 - 0.7	5	727	1,767	246	18	2	1	-	-	-	-
	0.7 - 0.8	2	2	342	1,417	741	133	9	-	-	-	-
	0.8 - 0.9	4	-	-	32	520	1,237	864	164	39	2	-
	0.9 - 0.99	8	-	-	-	8	127	945	1,374	1,035	828	22
	> 0.99	-	-	-	-	1	6	185	182	200	225	238