

# Validation of the block Radiation\_on\_Inclined\_Surface

## TABLE OF CONTENTS

---

1	Software versions .....	2
2	Description of the model .....	2
2.1	Block.....	2
2.2	Model File .....	5
2.3	Incidence angles.....	6
3	Results.....	7
3.1	Annual Solar Radiation .....	7
3.2	Incidence angles.....	8
4	Literature.....	8

### Author

Bernd Hafner, Viessmann Werke, Germany

### Complete path of the block in the Carnot Library

Carnot/weather/radiation\_on\_inclinded surface

### Changes in the document

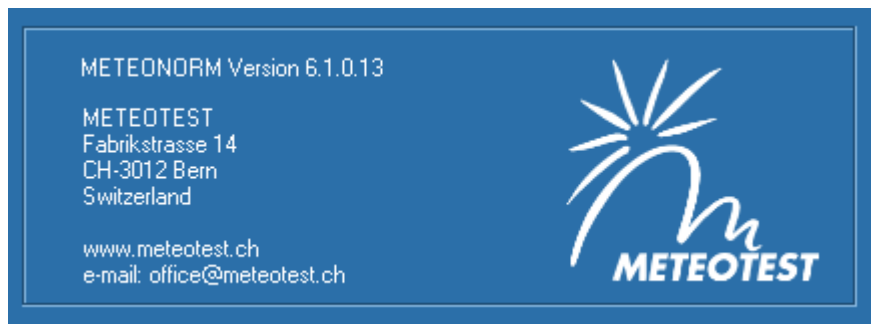
11/04/2012 created

19/04/2012 added incidence angles verification

Document	Project	Revision 1.1	Hafner
Validation_Report_inclined_surface.docx	-	Date: 19/04/19	Page 1 / 8

## 1 Software versions

Meteonorm Version 6.1



### Version of Model, Carnot, Matlab and Operation system

surfrad.c (V 5.1.0), Carnot 5.2, Matlab R2010b, Windows XP

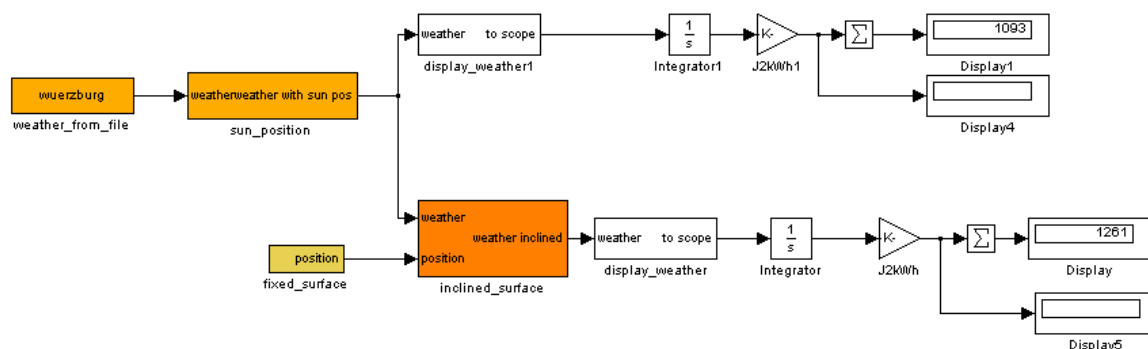
surfrad.c V 7.0 , Carnot 7.0, Matlab R2018b, Windows 10

## 2 Description of the model

### 2.1 Block

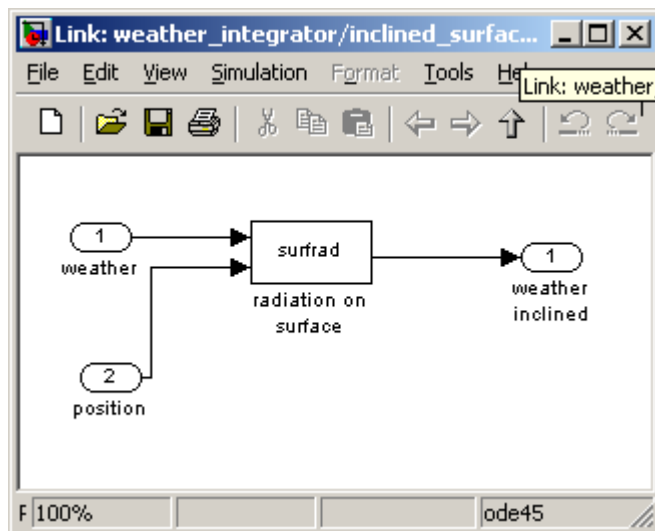
Detailed description of the equations is given by Duffie (2006).

Model for the comparison:

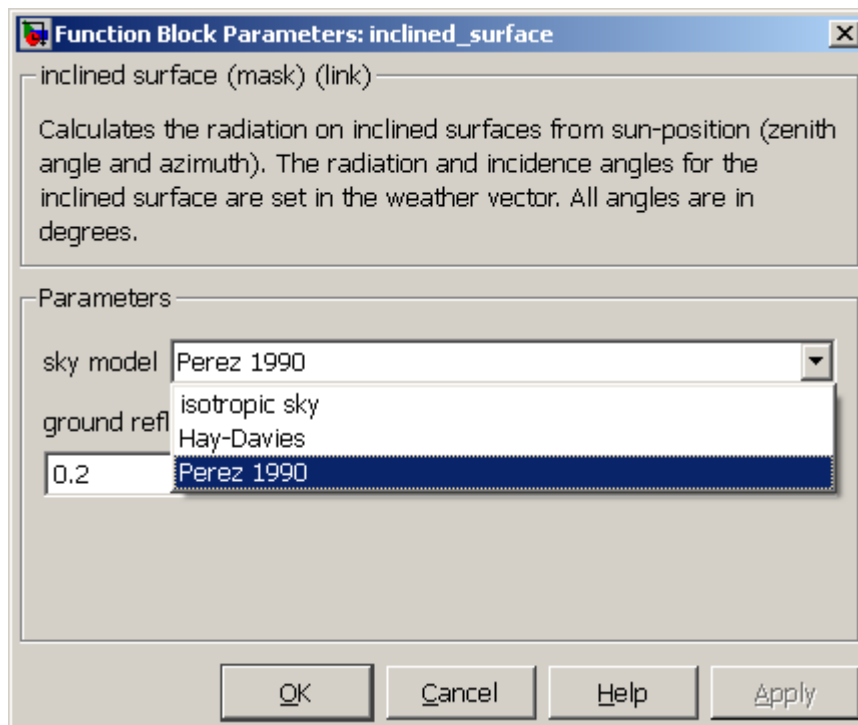


Document	Project	Revision 1.1	Hafner
Validation_Report_inclined_surface.docx	-	Date: 19/04/19	Page 2 / 8

“Look under Mask” of the Block:

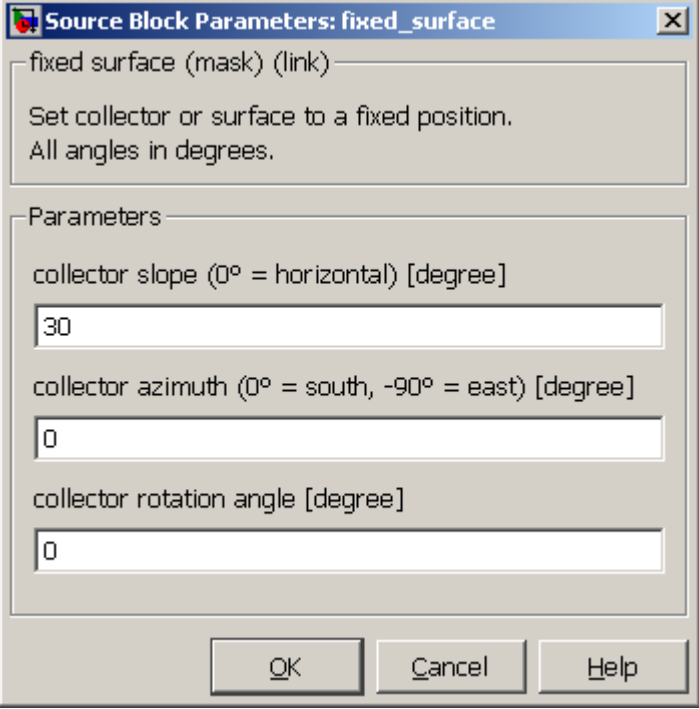


Block parameters:



Document	Project	Revision 1.1	Hafner
Validation_Report_inclined_surface.docx	-	Date: 19/04/19	Page 3 / 8

The Position is varied:



Source Block Parameters: fixed\_surface

fixed surface (mask) (link)

Set collector or surface to a fixed position.  
All angles in degrees.

Parameters

collector slope (0° = horizontal) [degree]  
30

collector azimuth (0° = south, -90° = east) [degree]  
0

collector rotation angle [degree]  
0

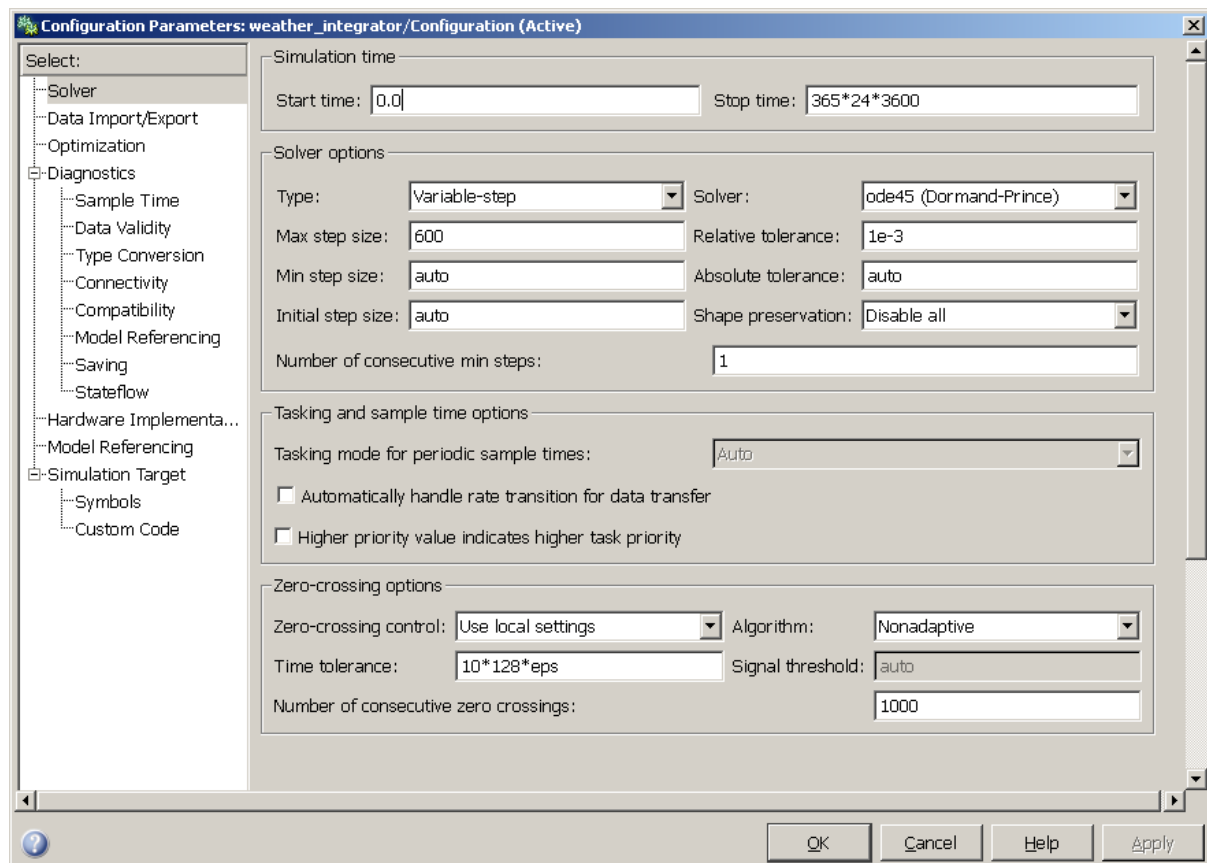
OK Cancel Help

Document	Project	Revision 1.1	Hafner
Validation_Report_inclined_surface.docx	-	Date: 19/04/19	Page 4 / 8

## 2.2 Model File

Comparison of horizontal and inclined solar radiation for the location Wuerzburg (Germany), results of Meteonorm and Carnot are compared. The input for Carnot is the Meteonorm weather data file generated for the same location using the 5.x Carnot weather data format (including direct normal radiation).

Solver parameters:



Document	Project	Revision 1.1	Hafner
Validation_Report_inclined_surface.docx	-	Date: 19/04/19	Page 5 / 8

## 2.3 Incidence angles

According to ISO 9806:2017 the longitudinal and transversal incidence angles are:

$$\theta_L(\theta, \gamma) = \tan^{-1} \left( \frac{\sin(\theta) \cos(\gamma)}{\cos(\theta)} \right)$$

$$\theta_T(\theta, \gamma) = \tan^{-1} \left( \frac{\sin(\theta) \sin(\gamma)}{\cos(\theta)} \right)$$

With

$\gamma$	Solarazimutwinkel	°
$\theta$	Einfallswinkel	°

The calculation of the incidence angle  $\theta$  can be taken from literature (e.g. Duffie, Beckmann: Solar Engineering of Thermal Processes, 2006).

The validation was done with the calculation results of Meteonorm.

Document	Project	Revision 1.1	Hafner
Validation_Report_inclined_surface.docx	-	Date: 19/04/19	Page 6 / 8

### 3 Results

#### 3.1 Annual Solar Radiation

Annual sum of solar radiation in kWh/m<sup>2</sup>

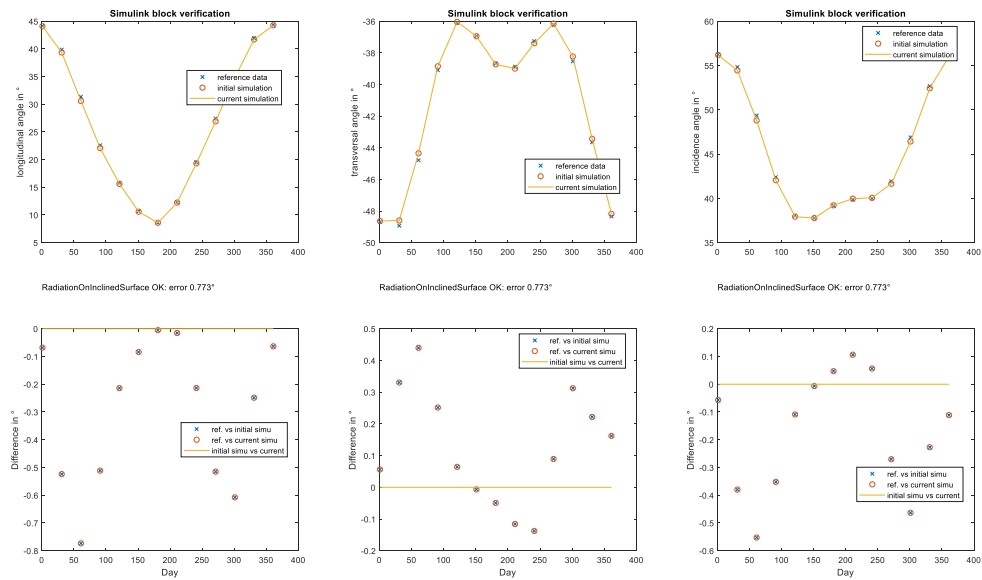
Perez Sky Model, ground reflectance 0.2

Azimut	Inclination	<b>Meteonorm</b> Global	CARNOT Global	<b>Meteonorm</b> Diffuse	CARNOT Diffuse
0	0	<b>1093</b>	1092	<b>594</b>	593
0	30	<b>1257</b>	1255	<b>628</b>	629
0	60	<b>1178</b>	1178	<b>583</b>	585
0	90	<b>882</b>	883	<b>471</b>	474
45	30	<b>1192</b>	1190	<b>614</b>	614
45	60	<b>1102</b>	1101	<b>565</b>	567
45	90	<b>846</b>	846	<b>461</b>	464
-90	30	<b>1041</b>	1044	<b>574</b>	576
-90	60	<b>906</b>	912	<b>511</b>	516
-90	90	<b>699</b>	707	<b>421</b>	427
120	30	<b>903</b>	901	<b>545</b>	544
120	60	<b>715</b>	715	<b>470</b>	471
120	90	<b>547</b>	548	<b>388</b>	391
-180	30	<b>775</b>	774	<b>512</b>	512
-180	60	<b>484</b>	486	<b>414</b>	415
-180	90	<b>373</b>	376	<b>350</b>	351

Document	Project	Revision 1.1	Hafner
Validation_Report_inclined_surface.docx	-	Date: 19/04/19	Page 7 / 8

## 3.2 Incidence angles

### Results of verify\_RadiationInclinedSurface



## 4 Literature

Duffie, J., Beckman, W.: Solar Engineering of thermal processes, John Wiley & Sons Inc, 2006

ISO 9806:2017 Solar energy – Solar thermal collectors – Test methods (ISO 9806:2017)

Document	Project	Revision 1.1	Hafner
Validation_Report_inclined_surface.docx	-	Date: 19/04/19	Page 8 / 8