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Published in:
BuildSIM-Nordic 2020 Selected papers

Publication date:
2020

Document Version
Publisher's PDF, also known as Version of record

Simplified Tool for Pre-Designing Ventilation Air Flow in Greenland

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Abstract

Few inhabitants in Greenland results in few small consulting companies, and they do not invest in building thermal simulation programs since they are too expensive and the use will be very limited. The aim of the paper is to describe a simplified thermal calculating design tool TCD2 for pre-designing ventilation air flow in Greenland, and thereby improving the level of calculation of the thermal indoor climate in Greenlandic buildings. In this phase, it has never been the intention to make a full validation of TCD2; however, this will take place during the next phase. The preliminary results show that the proposed design ventilation air volumes by TCD2 for annual simulations in BSim and IDA ICE meet the typical Danish/Greenlandic requirements, which are a given number of hours above 26 ºC and 27 ºC in the working hours, thus indicating that TCD2 is an alternative on the safe side to more advanced programs.

Introduction

Background

The development of TCD2 – Thermal Calculation by Design was originally done for teaching purposes, so it could be used for ventilations courses at Technical University of Denmark. Joan Ferris Gimeno and Jørgen Erik Christensen developed the program. It is easy to calculate the ventilation that maintains an acceptable atmospheric indoor climate according to DS_EN 16798-1:2019 (2019) that includes building emissions and CO2 emissions. The challenge is to estimate the necessary ventilation for thermal comfort. In order to calculate the thermal comfort, it is necessary to apply dynamic building simulation programs like BSim and IDA ICE. However, it has been a problem that students with no knowledge of these types of programs should spend a disproportionate amount of time familiarizing themselves with these programs. In addition the students never reach the necessary user level to make proper simulations. Instead this knowledge will be taught in other courses, where the focus is only on BSim or IDA ICE. Since the focus of the ventilation courses must be on ventilation, the decision was made to drop these more complex programs and instead develop a simplified program in Excel for calculating the thermal indoor climate.

In connection with the ventilation courses, two programs have been developed. They can fulfil different requirements in a fast and clear way in order to give the student a broader practical experience of sizing ventilation systems: TCD2 – Thermal indoor climate design and TCD Vent – Design of the overall ventilation system.

For a specific location to simulate the indoor air temperature and ventilation need, the program TCD2 applies a design day, which is a warm day with clear skies. The purpose of the program is mainly the development of a simplified thermal calculating design tool. During the early design phase, exact airflow is not required; but rather an estimate of the total ventilation air volume and the design pressure loss to the critical diffuser in order to be able to design the aggregate unit.

Greenland

Greenland has approximately 57,000 inhabitants. The average monthly temperature in Greenland is between -9 and +7 °C. The low temperatures have led to the false conclusion that overheating problems in Greenland are almost non-existent. In general, there is hardly no verification of the thermal indoor climate, only a basic calculation to prove that the requirements for a satisfactory atmospheric indoor climate are fulfilled. According to the Greenlandic Building regulation's (Bygningsreglement, 2006) chapter 11.5, the user must ensure that appropriate temperature conditions are achieved; but this is usually not normal practise. This is the main reason for this paper, since major problems could arise in Greenland from not performing thermal indoor climate validation.

This paper deals specifically with overheating problems in Nuuk. Greenland is situated between latitude 59° N and 82° N, which means most cities have 24 hours of sunlight in the summertime. In addition, the solar radiation hits the vertical windows at a very low angle, resulting in maximum transmission of direct solar radiation through the windows. The consequence is a significant amount of transmitted solar radiation into the buildings through the windows. Even when the outside air temperature in the summertime is low, it will not cool the building due to the low U-values of the external construction in new-built buildings. The minimum ventilation air temperature can only be around 16 ºC to avoid undercooling and if the ventilation system has been designed according to the atmospheric indoor climate, this will result in a limited cooling effect in the ventilation system.

Because there are so few inhabitants in Greenland, the consulting companies are few and small and do not invest in building thermal simulation programs like BSim, IDA ICE, IES-VE, etc. since they are too expensive and the use will be very limited. This means that no competencies will be achieved. To deal with the challenge, the simple Excel

based program TCD2 can be used for analysing the overheating problems in buildings.

Ventilation airflow

When analysing the indoor climate, there are many factors to contemplate. It is therefore not possible to use standard solutions in all cases. There will be a need to consider the activities and processes that will occur in the actual building.

In many cases, it is required during the early design phase to make calculations of air volumes in order to get an estimate of the size of the overall ventilation system: Ducts, valves, air handling units, etc. These components need to be sized to satisfy the indoor thermal comfort.

At this stage, only limited resources are available for this estimate, and there is no money for calculations with building thermal simulation programs such as BSim, ICE-ICE, IES-VE, etc. There is a need to use methods that are very user-friendly and can produce results in a short time.

To achieve sufficient ventilation, it is necessary to provide an acceptable indoor climate for both the atmospheric and the thermal indoor climate. Three requirements are applied to determine the size of the ventilation: 1) authority regulations (minimum requirements), 2) atmospheric indoor climate, 3) thermal indoor climate.

The largest value is applied for sizing, which in most cases will be the value for dimensioning the thermal indoor climate. The designer must always ensure to fulfil the atmospheric indoor climate. Calculating the thermal indoor climate is the focus of this paper, further elaboration of the first two items will not be included. In most cases, the thermal indoor climate has the highest value for ventilation air, hence the dimensionally highest value. Various methods can be applied in order to calculate the required amount of ventilation air:

1. Maximum hourly average indoor temperature
2. Daily average indoor temperature
3. Simulation on an hourly basis using building thermal simulation programs

The first two methods are older methods before the invention of the computer, when the use of hand calculations was common. The two methods give an overview of the influence of the different parameters. If the project is in an initial phase, when only a need to estimate for the size of the ventilation system is required, the two first methods are applied in practice.

Focusing on the hour with the highest external and internal loads, Method 1 'Maximum hourly average indoor temperature' will result in very oversized systems, increasing the cost of the overall project, along with having a system that does not run optimally in normal operating mode. Applying Method 2 'Daytime average temperature' for a warm day with clear skies will result in lower ventilation air volumes than method 1. However, both methods are associated with great uncertainty.

The use of dynamic thermal simulation programs is therefore the most widely applied method, Method 3. Nevertheless, attention must be drawn to the fact that several of the large simulation programs are very complex, and incorrect use can easily lead to completely misleading results. Program results never get better than their users. Here, TCD2 can be advantageous since using it provides an extra control of results from the complex programs and helps detect errors. In addition, TCD2 is a much simpler tool to apply.

Methods

The thermal indoor climate and energy consumption of a room is the result of a complicated interaction between the design of the building, the thermal loads, the ventilations system, and the outdoor climate. To account for this, it is necessary to calculate a heat balance for the room. For a room the supplied heat flow must be equal to the heat flow carried away, considering the heat effect supplied or emitted from heat accumulating in building parts.

Thermal loads. The thermal loads matter a great deal in the heat balance and it is therefore important to determine them as accurately as possible. However, during the early stage of planning when the user makes decisions, uncertainty is high, since only limited knowledge of the building is available. For this reason a simplified method can be used since only limited data is available and there is no need for a detailed simulation.

The thermal loads transmit heat to the room air and/or room surfaces. It is important to distinguish between these two types of heat transfer because heat transfer to the room air will temporarily give a different temperature course than heat transfer to the surfaces. There will be a greater rise in temperature if most of the energy is transmitted directly to the room air rather than to the surrounding surfaces. The exterior gain is solar radiation, applied as radiation only to the surfaces contrary to the ventilation air, which applies directly to the room air. However, given the other uncertain assumptions, it is accurate enough to apply according to estimates. For most low-temperature heat sources, such as persons, it is a good estimate to apply half of what is emitted as convection heat and the other half as radiant heat.

Outdoor temperature. The outdoor temperature used in TCD2 simplifies to a cosine function around the air's daily average temperature plus/minus the amplitude of the outdoor air temperature with a maximum at a specific time.

The simulation model

The foundation of the simulation model in TCD2 is a simplified model for the heat balance and was originally developed by Bo Adamson (Adamson, 1968) and Bo Andersen (Becher, 1971) and described by Jørgen Erik Christensen in (Hansen et al., 1988). The model was applied in tsbi 2.1 (Johnsen, 1985), which is the precursor of the calculation model tsbi5 in the BSim program.

The most important thermal climate factors are the indoor air temperature and the internal surface temperature. In order to calculate them at different times, it is necessary to establish heat balance equations for the room air, for the surfaces and for the instantaneous heat conduction through the adjacent walls.

The foundations of the simplifications of the model are that all internal surface temperatures are equal and that the calculation of the instantaneous heat conduction in the walls is solved by introducing fictitious, infinitely thin heat accumulating layers with the same temperature. These layers describe the room's heat capacity. Consequently, it will only be necessary to establish three heat balance equations: The heat balance of the room air, the heat balance of the surfaces and the heat balance of the heat accumulating layers. These balances have three unknown temperatures: The room indoor air temperature, internal surface temperatures, and the temperature of the heat-accumulating layer. In (Hansen et al., 1988) a description of the simulation model can be found.

Internal Heat Loads. The internal heat gains of a room are divided into heat gains from equipment, occupants, and lighting. In TCD2 these values are based on predesigned values from (Christensen, 2017) and guidelines written by (Vorre et al., 2017).

Model for the solar radiation through glass panes – Reference year

William Kristian Krogh Vergo and Jørgen Erik Christensen created the method for developing the weather data. The first step in the process of creating weather data for TCD2 is using BSim to create a fictitious reference year. The result of this process shall be a reference year consisting of perfect cloudless days on two selected dates, the 6th and the 21st, of each month. All other dates are of no interest. To create this, it is necessary to find cloudless days during the reference year for Nuuk, which has the coordinates 64.17 N, 51.87 W and the time zone UTC-3.

Most of the cloudless days are from observed data in the reference year that have gone through a manual screening process in BSim. The selected data are transferred to Excel and processed.

If the day has a few hours with some cloud cover, an empirically weighted formula for adjustment will be used. The direct radiation is adjusted up and the diffuse radiation is adjusted down. The adjustment is designed so that the changed values will not exceed a natural cloudless hour from the weather data set during the same period of the year.

The solar radiation is evenly distributed throughout the day. Symmetry is formed around 12 a.m. true solar time since the sun is at the highest point in the sky. In addition to this, symmetry is formed around 21 June by "adding" days. This means that if there is a cloudless day on 12 June (minus nine days), then it is assumed that the same day will occur on 30 June (plus nine days). This resulting in a mirrored duplicate for each cloudless day around 21 June. The reason for this is that it is difficult to find perfect cloudless days in the northernmost climates, since there is always some haze and light clouds that require compensation. Some cloudless days are required to be able to perform the next step, where a regression analysis of the direct and diffuse solar incidence is performed throughout the year. The regression analysis is done in Excel and formed for Nuuk, Greenland, a second-degree polynomial formula, see Figure 1 and formula 1 for the direct normal radiation and formula 2 for the diffuse radiation.

Direct normal radiation:

$$y = -0{,}7014x^2 + 241{,}27x - 10391,\ R^2 = 0.9605 \quad (1)$$

Diffuse radiation:

$$y = -0{,}0804x^2 + 27{,}655x - 30{,}846;\ R^2 = 0{,}766 \quad (2)$$

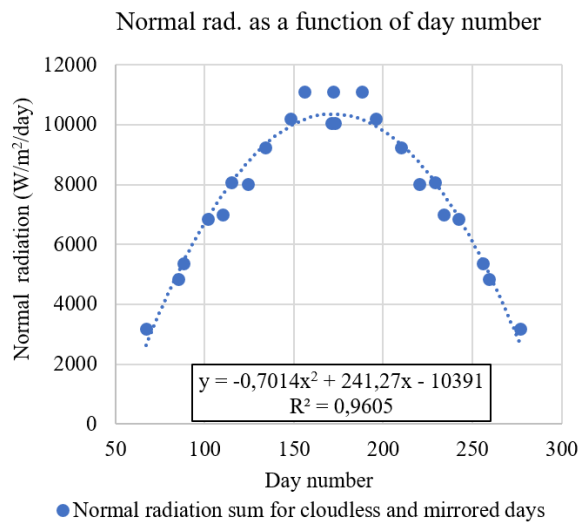

Figure 1: Direct normal radiation as function of the day number.

The formulas are applied to find the diffuse radiation as well as the normal radiation estimated on the desired date for TCD2 for the 6th and 21st of each month. Thereafter, the solar radiation was distributed throughout the day based on a distribution pattern from a "real cloudless day" that was resembling the date. Then the days were eventually corrected for sunrise and sunset on the desired days, which of course have different times than the original days due to the date difference. This means that if the sun rose before 7 a.m. on a truly clear skies day, but did not do it on the desired day, then the sunrise before 7 a.m. was instead distributed over the remaining hours of the day. Then the solar data are ready to be deployed in BSim again. Here they are applied both to create data for use in TCD2 and for direct simulation use in BSim, in order to be able to compare with TCD2 in single days.

Model for the solar radiation through glass panes – TCD2 weather data

TCD2 applies an Excel data file for the transmitted solar radiation through a standard doubled-glazed reference pane with two 4-mm layers of glass and an air gap of 12 mm with a g-value of 0.76 and a U value of 2.8 W /m^{2}K. TCD2 requires the following three parameters on an hourly basis: Direct transmitted solar radiation, diffuse transmitted solar radiation, and ground-reflected transmitted solar radiation. BSim is not able to provide these data directly and for that reason, BSim needs three simulations with two kinds of weather data:

1. Standard weather data – Results of total transmitted solar radiation (ground reflectance = 0,25)
2. Standard weather data – Results of transmitted solar radiation, excluding ground-reflected radiation (ground reflectance = 0)
3. Diffuse weather data, direct solar radiation = 0 – Results of transmitted diffuse solar radiation, excluding direct and ground reflected radiation (ground reflectance = 0)

Based on the three BSim simulations it is possible through simple equations to calculate the values for the transmitted solar radiation for the three necessary components for the TCD2 weather file (a standard reference pane):

- Direct transmitted solar radiation
- Diffuse transmitted solar radiation
- Ground-reflected transmitted solar radiation.

The performance of the weather data is estimated for the seven slopes: 90º (vertical), 75º, 60º, 45º, 30º, 15º, 0º (horizontal), and for the eight orientations: North, northeast, east, southeast, south, southwest, west, northwest. The data are created in BSim with 49 zones (6 slopes · 8 orientations + 1 slope · a fictive direction = 49 zones). The results for the 49 zones from BSim are transferred to an Excel sheet for further calculations.

The selected dates for the weather file are the 6th and 21st of each month. If the user chooses other dates or directions than the ones in the TCD2 weather file, TCD2 makes a linear interpolation. The seven slopes are fixed. All these calculations in the creation of the weather file creates restrictions for the user in terms of choosing different slopes and weather data for other locations. The results for other dates or directions also create some uncertainty in the results.

Model description

The model used is a medium heavy single office with the interior dimensions of 3 m x 4 m x 2.6 m, area 12 m^2 and a volume of 31.2 m^3. The model description is based on (Wittchen et al., 2011) and (Treldal et al., 2011).

The internal load is set to 122 W and consist of 7 W (Working lamp), 25 W (PC screen), 30 W (PC) and general lighting 60 W, (Christensen, 2017) and (Vorre et al., 2017). The occupant has a metabolic rate of 1.2, which emits approximately 100 W as dry heat to the room. The internal load schedules state that the light and equipment are on from 8-16 on weekdays, off at the weekends. The same goes for occupants in the office, except for when they leave for lunch during the period from 12-13 when the load is only half.

The office has a single facade facing the outside, whereas the other five surfaces face a similar room with the same temperature conditions: two sidewalls, back wall, floor, and ceiling. The office is analysed for the four main orientations north, east, south and west. The exterior wall has an area of 10.6 m^2, a U-value 0.13 W/m^{2}K and consists of a medium heavy construction of lightweight concrete and mineral wool insulation, Table 1. The office meets the minimum requirements of the Building Regulations for climate screen (Bygningsreglement, 2018).

Table 1: Structure of the exterior wall with the U-value 0.13 W/m^{2}K – From inside out.

Material	Thick-ness (m)	Thermal Conductivity (W/mK)	R-Value (m^{2}K/W)
Light concrete	0.1	0.17	0.59
Mineral wool	0.25	0.037	6.75
Brick cladding	0.115	0.17	0.68

There is one window in the office and in the standard office (S, 22 % window area of the interior area in the office) with an opening area of 2.6 m^2 (1.98 m^2 glass) and a thermal bridge around the edge of the window set to 0.06 W/m·K. The recess value is set 0 m in BSim and IDA ICE (very low app. 0.1 mm for program reason in BSim). The U-value of the window depends on the type of simulations. In the annual simulations three window areas have been studied: S 22 %, M 30 % and L 55 % window area in relation to the inside area.

A window with a U-value for the glass 2.8 W/m^{2}K, frame 1.4 W/m^{2}K, g-value of 0.76, and light transmission being 0.82 was used for the first simulations with a comparison of solar radiation through the window and the corresponding temperatures. A window with a U-value for the glass 1.1 W/m^{2}K, frame 1.1 W/m^{2}K, g-value of 0.43, and light transmission being 0.71 was used for the last simulations with a comparison of temperatures in the room for the reference years using BSim and IDA ICE.

Results

The results of this paragraph include many different comparisons. The following shows a small part of this work. The results do not give the full picture of the comparison. A more detailed investigation is needed for that. The following simulations are only the first step in the validation of TCD2 in order to create a simplified thermal calculating design tool for pre-designing of airflow for ventilation in Greenland. The purpose has not been to make a full validation of TCD2 for Greenlandic conditions.

Comparison of solar radiation into the room

TCD2 directly applies the solar radiation through a double-glazed standard pane with a g-value of 0.76, as described in the *"Model for the solar radiation through glass panes – TCD2 weather data"*. Therefore, at this initial stage, it will be natural to compare the solar incident between TCD2, BSim, and IDA ICE for this pane.

TCD2 focuses on the date of 21 June and 21 August, both of which are during the summer season. 21 June shows results for the sun being highest in the sky and the most hours above the horizon. On the other hand, this results in the sun hitting the pane with the greatest angle of view, thus giving a smaller solar incident at 12 a.m. on a south-

facing facade. 21 August results in a lower angle of view on the pane, this resulting in a greater solar incident on a south facing pane at 12 a.m. and can therefore become the design factor even if the sun is above the horizon fewer hours than on 21 June.

Without solar shading

The results of the analysis of data without solar shading show that 21 June is dimensioning for east and north, and that 21 August is dimensioning for south.

Table 2 and Figure 2 show a comparison of transmitted solar radiation through a standard double-glazed window with a g-value of 0.76 for TCD2, BSim, and IDA ICE on 21 August for south, east, and north in Nuuk, Greenland, using the weather data developed. The table and Figure show very fine agreement between TCD2 and BSim for both days and directions, except for a small difference for north on 21 June with 4,5 %. The similar results for IDA ICE show relative fine agreement for south, however for east the difference is around 26 % and for north between 39 % and 43 %. In general, the values for IDA ICE are much higher than for TCD2 and BSim.

Table 2: Daily solar sum difference from TCD2 of the transmitted solar radiation for BSim and IDA ICE.

	% Daily solar sum difference from TCD2			
	21st June		**21st August**	
Direction	BSim (%)	IDA ICE (%)	BSim (%)	IDA ICE (%)
South	0.1	7,6	0.4	3.7
East	0.1	26.4	0,3	26.2
North	4.5	38.7	-0,7	43.1

The TCD2 solar data is derived from BSim for the same weather data; hence, the expectation for the comparisons will be relatively fine.

IDA ICE applies the Perez diffuse radiation distribution model as default. Originally, creation of solar data for TCD2 derived from BSim applied with the Munier solar radiation model. IDA ICE does not include this model. The Perez model generally shows higher results for the diffuse radiation distribution. This can be noticed especially for the north and east orientated curves, where the IDA ICE results are higher than the others are. This can explain the relatively large difference between BSim/TCD2 and IDA ICE.

With solar shading

In Figure 3 is shown comparisons of solar radiation in W/m^2 for the same window with outside solar shading for TCD2, BSim, and IDA ICE for 21 August for south in Nuuk. The results show fine agreement between TCD2, BSim, and IDA ICE. Larger differences have been measured only in the hours just before and after the use of the outside solar shading

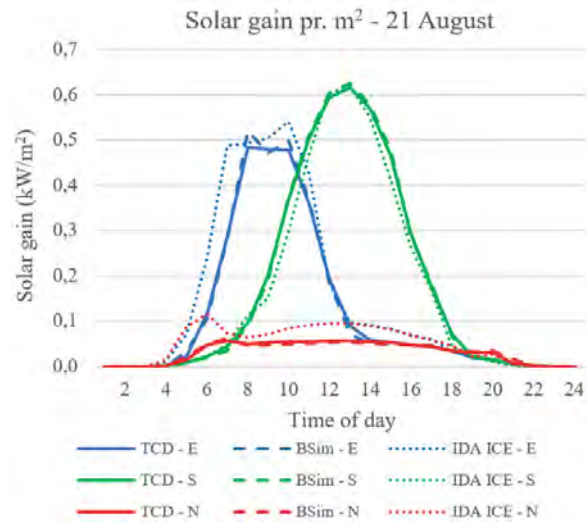

Figure 2: Comparison of solar radiation through a double-glazed window for TCD2, BSim, and IDA ICE for 21 August for south, east, and north.

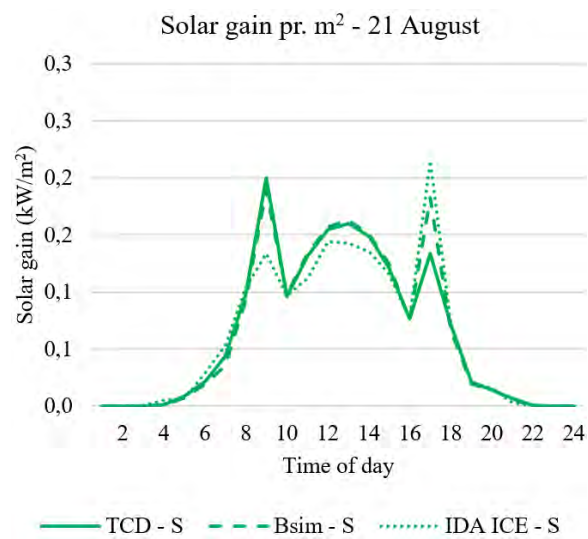

Figure 3: Comparison of solar radiation through a double-glazed window with outside solar shading for TCD2, BSim, and IDA ICE for 21 August for south.

At 9 a.m. and 5 p.m. IDA ICE differs a lot from TCD2 and BSim. This is due to differences in the control strategies of the programs.

Comparison of temperatures in the room for design days

In the first comparisons a standard double-glazed window with a U-value for the glass/frame 2.8 W/m^{2}K was used. To use this window now will not be relevant in practice in Greenland since the U-value is so poor; however, it has only been used to compare results in the first phase. All analyses are for Nuuk, Greenland. The applied weather data are the ones particularly developed for TCD2 for the specially selected design dates with clear skies for the 6th and 21st of each month. These data are applied to create

weather files for BSim and IDA ICE. The weather file for BSim has already been created in the process of producing weather data for TCD2. The outdoor temperature applied to evaluate the initial data has been derived from warm days around the 21 June and 21 August.

No solar shading

In Figure 4, the standard office (S, 22 % window area of the interior area in the office) with no solar shading for south has been analysed for 21 August. The results for the temperatures are fluctuate extremely for the south-facing façade: TCD2 45 ºC – 52.6 ºC, BSim 41.2 ºC – 48.6 ºC, and IDA ICE 39.2 ºC – 48.1 ºC. All together, the temperatures in TCD are around 4 ºC higher than BSim and IDA ICE. This is a relatively big difference even in an extreme situation with very high temperatures. The higher results will be on the safe side for TCD2 compared with the more advanced programs. The reason for the high temperatures in TCD2 is that the program continues to simulate until the heat loss and heat gain during the 24 hours are the same, resulting in a very high asymptotic final temperature. In actual situations, there will be ventilation, solar shading, etc., which will result in much more realistic results – see next section with solar shading.

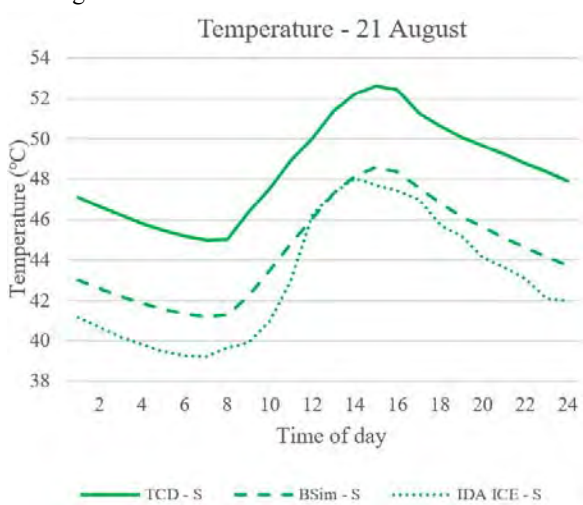

Figure 4: Comparison of temperatures on 21 August between TCD2, BSim, and IDA ICE in the room facing south with a double-glazed window and no solar shading

With outside solar shading

The following example is a study of temperatures with an outside solar shading, Figure 5. Everything else is the same as in the previous paragraph. The temperature results for the south-facing façade are: TCD2 28 ºC – 31.6 ºC, BSim 26.3 ºC – 29.7 ºC and IDA ICE 29.1 ºC – 34.4 ºC. As opposed to the results without solar shading, TCD2 now is 1.1 ºC to 2.8 ºC lower than IDA ICE and 1.7 ºC to 1.9 ºC higher than BSim. It is a little bit surprising that the temperatures are higher in IDA ICE since the daily sum for the solar radiation in TCD2 is lower.

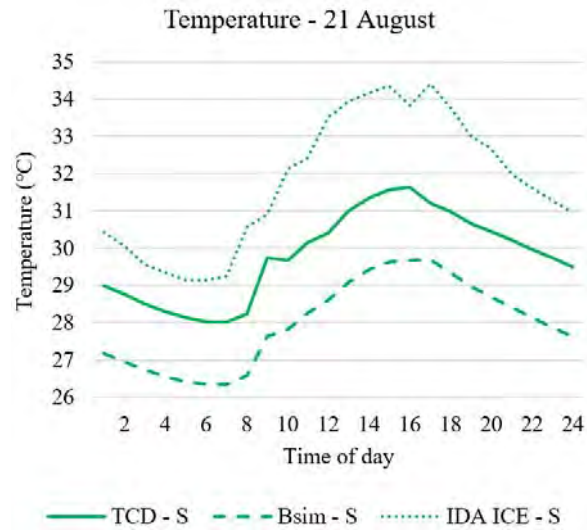

Figure 5: Comparison of temperatures on 21 August between TCD2, BSim, and IDA ICE in the room facing south with a double-glazed window and exterior solar shading.

Comparison of temperatures in the room for reference year

The last comparison of TCD2 (applying a design day with clear skies) is with BSim and IDA ICE (applying the reference year). Analysing with TCD2 includes two design days: 21 June and 21 August. For these two days the results indicate the temperature distribution during a day. Determining the necessary ventilation air volumes is the day with the highest temperature distribution.

The design day is analysed and ventilation air volumes and other factors adjusted so the highest temperature during the day will be between 27 °C and 28 °C. The selected ventilation air volumes are transferred to BSim and IDA ICE and the data implemented. Then the two programs simulate with the reference year to find the number of hours above 26 ° C and 27 °C. According to The Danish building code BR18 (Bygningsreglement, 2018), this limit is recommended to be a maximum of 100 hours above 26 °C and 25 hours above 27 °C during working hours.

Since TCD2 is a simplified program, the intension is that the results from BSim and IDA ICE for the number of hours above 26 °C and 27 °C are significantly lower than the limits of 100 hours and 25 hours respectively using similar data.

In these simulations, the data for the window is a U-value for the glass 1.1 W/m^{2}K, frame 1.1 W/m^{2}K, g-value of 0.43, and light transmission is 0.71.

Using exterior sunshades is a problem due to the harsh weather conditions in Greenland. It is only possible to obtain limited effect of internal sun protection when using modern windows with low U-value. This means that the shading factor will only be approximately 75 %. Hence, it is much more problematic to limit high solar incidence in Greenland than in Denmark, since it is not possible to use

an external solar shade with a shading factor of e.g. ca. 25 %.

Based on these observations an inside screen is used. The inside white/white screen has the data 15 % absorptance, 19 % transmittance, and 66 % reflectance. The calculated shading factor for this window is 71 %.

Three cases have been studied: S 22 %, M 30 % and L 55 % window areas in relation to the inside area. Figure 6 illustrates the estimated temperature distribution for south office S 22 % during 21 August when the objective has been to keep the maximum temperature below approximately 28 °C. Table 3 shows the corresponding values on an annual basis for BSim and IDA ICE.

The results show that the calculated values in TCD2 are within the safe limits for overheating, when compared to the annual simulations in BSim and IDA ICE. However, the number of hours in IDA ICE exceeds the limit of 25 hours for 27 °C for case S 22 %, M 30 % with 11 and 4 hours respectively.

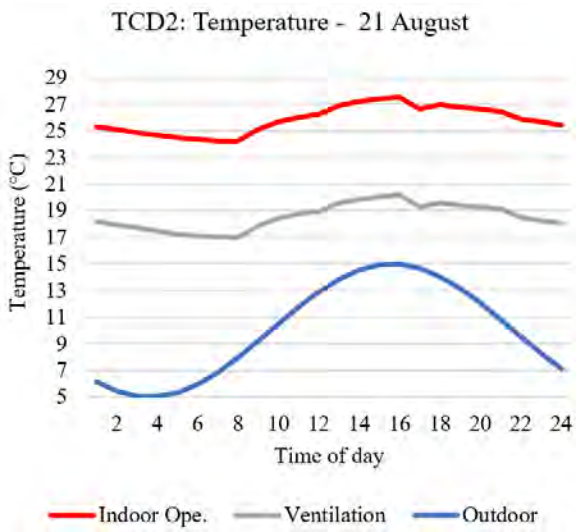

Figure 6: Temperature distribution in TCD2 for 21 August for south in Nuuk. (Ventilation: Ventilation air temperature)

Table 3: Numbers of hours above 26 °C and 27 °C in the working hours for the reference year.

Window % of interior area		Venti-lation air ref.	Numbers of hours above specific temperatures in working hours			
			BSim		IDA ICE	
			26 °C	27 °C	26 °C	27 °C
	Hours limit:		100 h	25 h	100 h	25 h
	(%)	(%)	(h)	(h)	(h)	(h)
S	22	100	4	0	71	36
M	30	160	7	0	68	29
L	55	480	6	0	57	13

Discussion

The purpose of the paper was to develop a simplified thermal calculating design tool for pre-designing of airflow for ventilation in Greenland based on the experience of using TCD2 in Denmark. Part of that work is to make a validation of TCD2 up against BSim and IDA ICE. It has never been the intention at this stage to make a full validation of TCD2. The work is only the first step in the process of validation of TCD2. Comparisons made for Danish conditions for hot sunny periods show fine results compared to BSim.

Why IDA ICE differs in solar radiation

In IDA ICE the default diffuse radiation distribution model was developed by Perez. The Munier model used originally in BSim (and the data for TCD) has not been implemented in IDA ICE. Munier states relative constant values for the diffuse for all directions. The Perez model generally states higher results for the diffuse distribution. It is especially obvious from the north orientated curves that the IDA ICE results are higher than the others are. The Perez model also depends more on the direction than Munier.

In general, the temperatures in TCD2 are higher than in BSim, which is on the safe side. The temperature distribution is very similar in TCD2, BSim, and IDA ICE. The difference between TCD2 and BSim is reduced when the temperature level is lower. The comparison between TCD2 and IDA ICE shows no similar clear results, which is due to the difference in solar models between TCD2/BSim and IDA ICE.

Comparison of temperatures in the room for reference years

Comparisons of TCD2 for the dimensional design day with BSim and IDA ICE applying the reference year is the most interesting. The intention is to use TCD2 for pre-designing airflow for ventilation in Greenland instead of the more complicated dynamic building simulation programs like BSim and IDA ICE. The work shows that the use of data from TCD2 indicates a number of hours above 26 ° C and 27 °C, using BSim and IDA ICE for the reference year. The results are on the safe side, since the number of hours in general are lower than the recommendation from BR18 (Bygningsreglement, 2018) setting the maximum during working hours to 100 hours above 26 °C and 25 hours above 27 °C. In two of the cases IDA ICE exceeds the limit for 27 °C for case S 22 %, M 30 % with 11 and 4 hours respectively.

In order to give a better recommendation of how to apply TCD2 on Greenlandic conditions more work will be necessary.

Conclusion

It is a fact that Greenland is dealing with overheating problems. The location between latitude 59 ° N to 82 ° N means the solar radiation hits the vertical windows at a very low angle, resulting in maximum transmission of direct solar radiation through the windows. In addition,

there is sunlight 24 hours per day in the summertime. The consequences are that more solar radiation is transmitted through the windows into the buildings than on more southern locations like Denmark.

The few and small consulting companies in Greenland do not invest in building simulation programs. However, there is a need for a simple inexpensive program for analysing overheating problems in buildings. One possibility could be the use of TCD2, and showing pre-validation of this method is the purpose for this paper.

The preliminary results for comparing TCD2 for design days with annual simulations with the reference year for BSim and IDA ICE show more work is necessary in the future.

Acknowledgement

Kathrine Breinstrup Butler and Natacha Hajj for basic work on model development and validation, DTU.

Thomas Raahauge Andersen for development of the 49 zones model for BSim, DTU.

Charlotte Kira Treschow for the development of TCD Vent

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