Generation of one minute data

New models and comparison

24.10.2016

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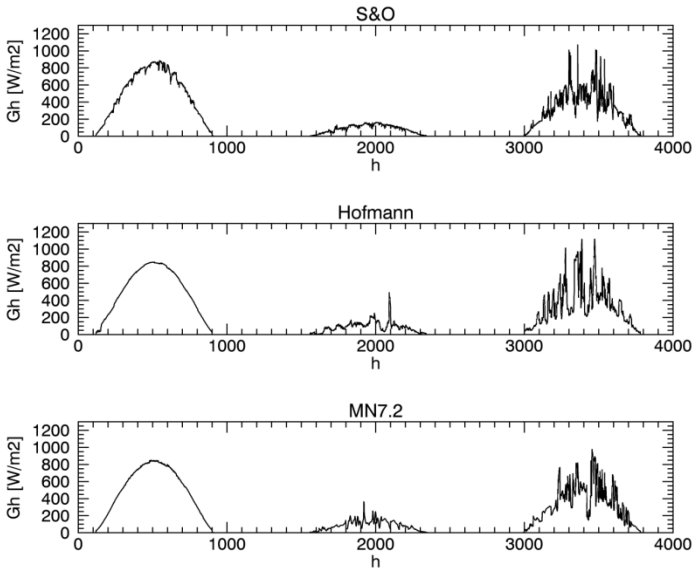


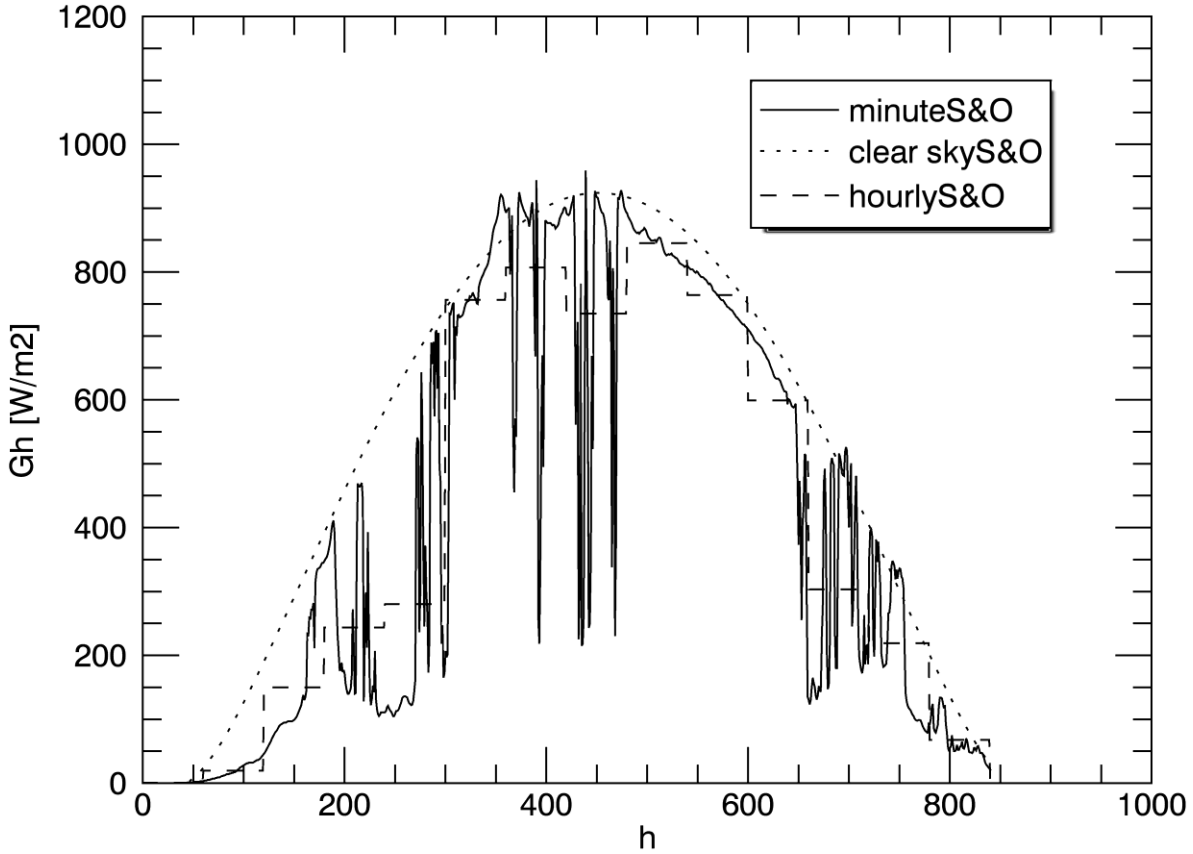
«All models are wrong – some are useful»

Scope

- One minute data gets important for accurate modelling of:
  - bigger PV plants
  - smaller PV plants including
    - storage (batteries),
    - self consumption or
    - Peak shaving
- One minute data has a different distribution as one hour data
- Measured data is only scarcely available (no satellite data)
  → models are needed
- In Meteonorm 6.x and 7.x:
  - TAG and Skartveit&Olseth models included
    - Not «good enough»
  - Two new models tested: «Hofmann» and «MN7.2»

One minute data

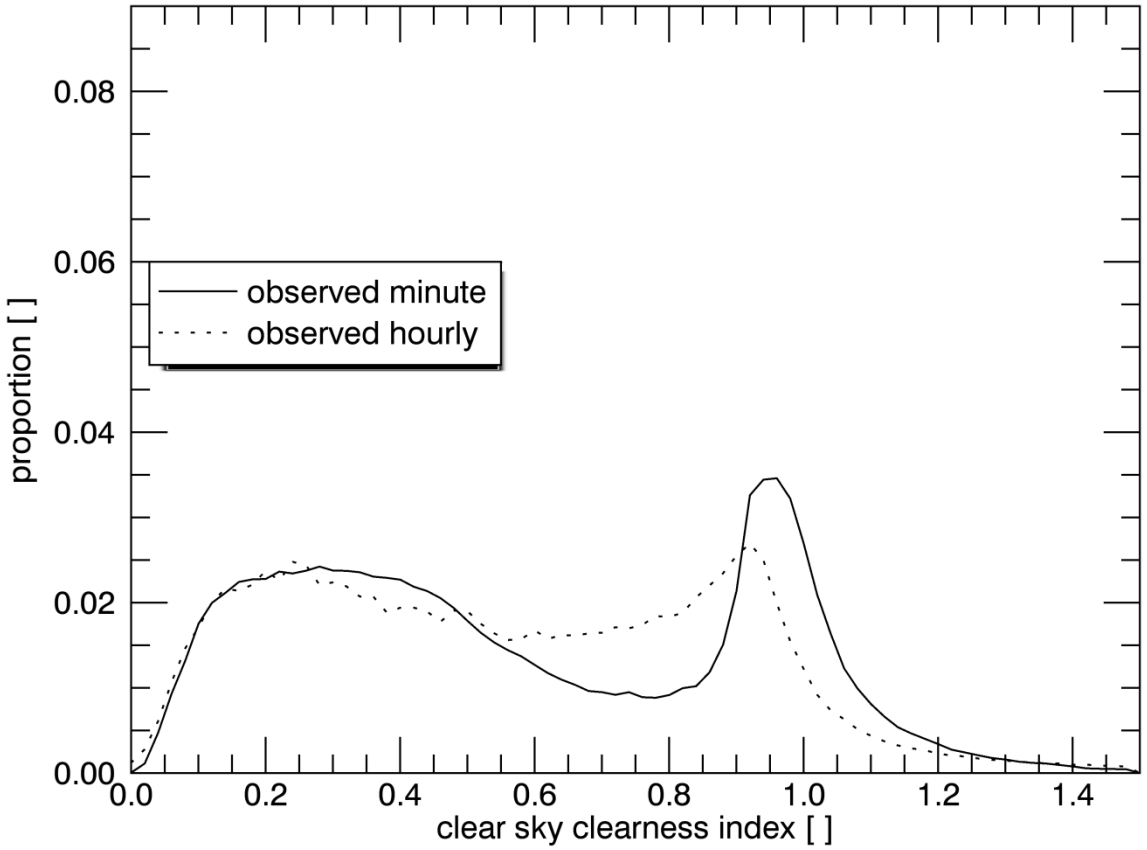
- Variations much higher than for hourly averages
- Over-shootings often



One minute Gh values for Payerne (BSRN), 15.04.2008

One minute data

- Distributions different
- Shifted towards lower and higher values (cloud / no cloud)



Distribution of one minute and hourly Gh values for Camborne (BSRN), 2004-2005

Existing (examined) models

Model	Source	Used in	Type of model
Skartveit & Olseth (S&O)	Skartveit, A. and J.A. Olseth (1992): The probability density and autocorrelation of short-term global and beam irradiance. Solar Energy Volume 49, No. 6, pp 477-487.	Meteonorm 7.0 -7.1	Auto-correlation (1. order)
Aguiar & Collares-Pereira (TAG)	Aguiar, R. and M. Collares-Pereira (1992): TAG: A time-dependent auto-regressive, Gaussian model. Solar Energy, Vol. 49, No.3, pp. 167-174.	Meteonorm 6.1 -7.1	Autoregressive model (AR1)
Hofmann	Hofmann, M., Riechelmann, S., Crisosto, C., Mubarak, R., & Seckmeyer, G. (2014). Improved Synthesis of Global Irradiance with One-Minute Resolution for PV System Simulations. International Journal of Photoenergy, 2014.	PVSol (Valentin)	Markov chain model

Hofman model

- Included in PVSol
- Based on Markov chain model (similar to Aguiar&Collares-Pereira, 1988)S
  - Conditional probabilities of previous hour/minute

	$k_{t,l}$ 0	0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08	0,09	0,1
$k_{t,l+1}$ 0	0	0	0	0	0	0	0	0	0	0	0
0,01	0	0,8293	0,1707	0	0	0	0	0	0	0	0
0,02	0	0,1034	0,7241	0,1724	0	0	0	0	0	0	0
0,03	0	0	0,0941	0,7529	0,1412	0	0,0118	0	0	0	0
0,04	0	0	0,0101	0,1111	0,7475	0,1111	0,0202	0	0	0	0
0,05	0	0	0	0	0,0592	0,8092	0,1118	0,0132	0,0066	0	0
0,06	0	0	0	0	0,0171	0,1453	0,6496	0,1453	0,0256	0,0085	0,0085
0,07	0	0	0	0	0	0,0115	0,2184	0,4943	0,2529	0,0230	0
0,08	0	0	0	0	0,0148	0	0,0370	0,1407	0,6074	0,1481	0,0296
0,09	0	0	0	0	0	0	0	0,0550	0,1835	0,4954	0,2018
0,1	0	0	0	0	0	0	0	0	0,0233	0,2016	0,5271

New model «MN7.2»

- Based on 15 BSRN locations worldwide, 2 years of one minute data
- Sites = ['CAR','PAY','CAM','CAB','LIN','TAT','LAU','MAN','REG','CLH','ASP‘ ,'BER','BIL','SBO','TAM']

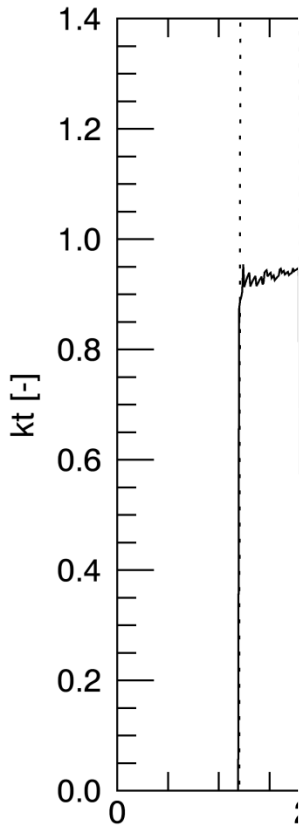
also used for tests

New model: «MN7.2»

- Look-up database of measured timeseries in one minute time resolution in blocks of one hour
  - Model is based on 20 measured timeseries per weather class
  - Classes depend on:
    - Clearsky clearness index (10 classes at 0.1 width)
    - Elevation of sun (5 classes at 18° width)
    - Wind speed (3 classes: < 2 m/s, < 6 m/s, ≥ 6 m/s)
    - Totally: 150 classes
    - One fits all (→ one table, no separation by climate zone)
    - 84% of the classes include measurements
  - Measured timeseries (1 of 20) is chosen stochastically
  - Extra criterion: if timeseries is stable, gap between hours is limited
  - Generation model is computationally very quick

New model: «MN7.2»

- 60-minute sequences are added to each other
- Values in clearsky clearness index

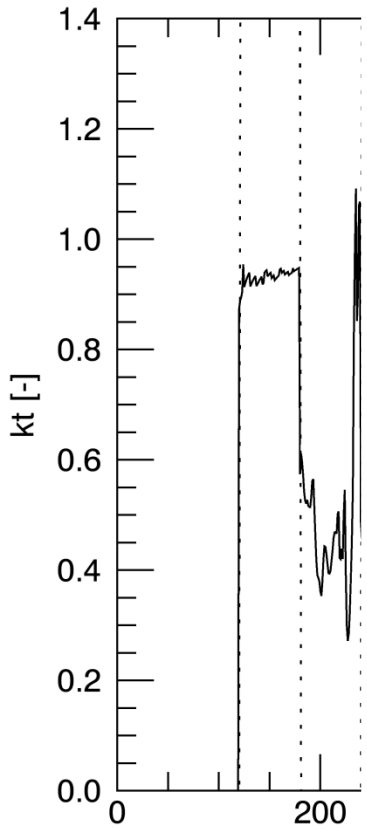


First hour

Billings

New model: «MN7.2»

- 60-minute sequences are added to each other
- Values in clearsky clearness index

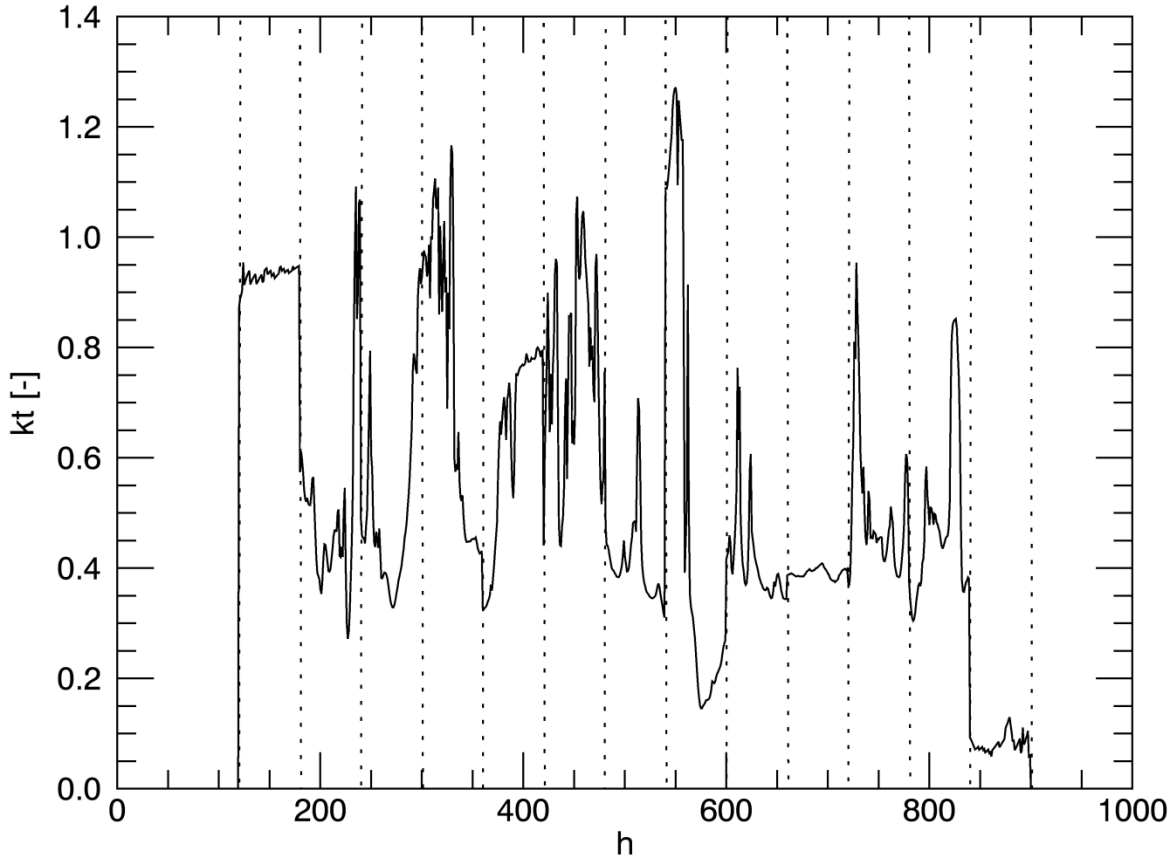


Second hour

Billings

New model: «MN7.2»

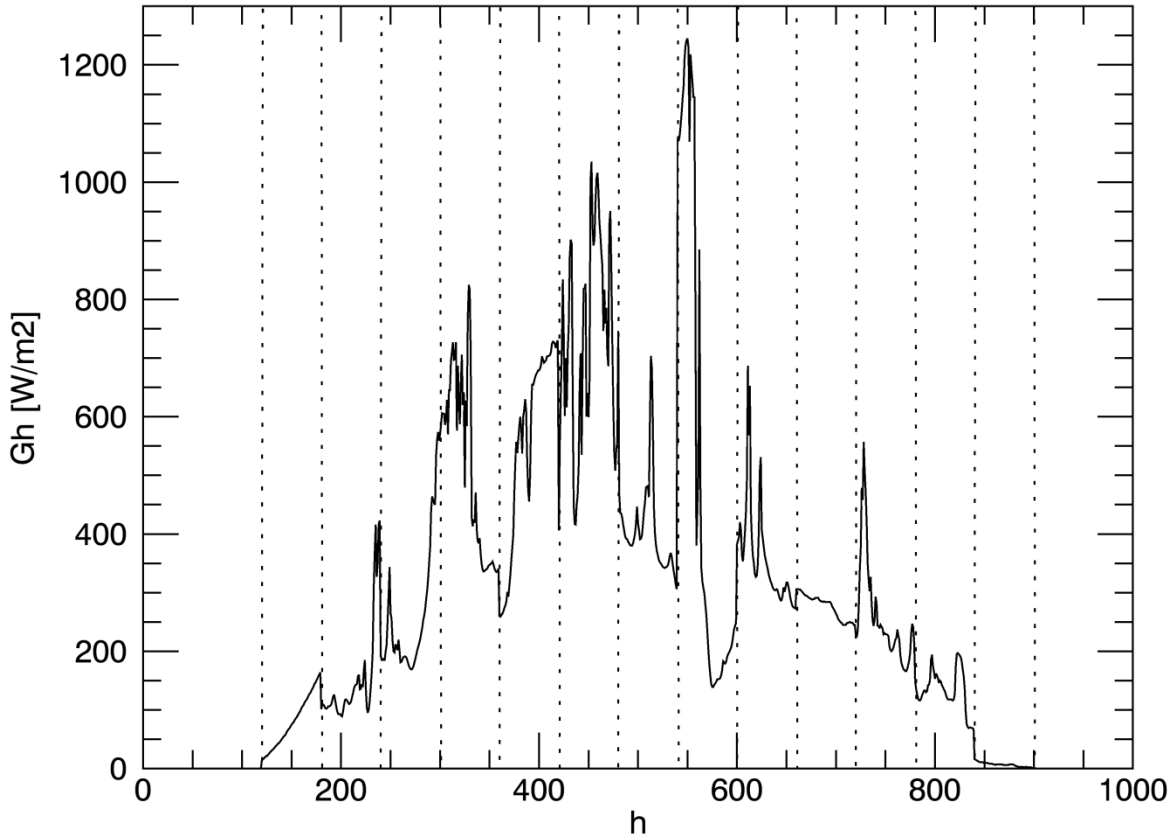
- 60-minute sequences are added to each other
- Values in clearsky clearness index



Billings

New model: «MN7.2»

- 60-minute sequences are added to each other
- Same day in global radiation (Gh)



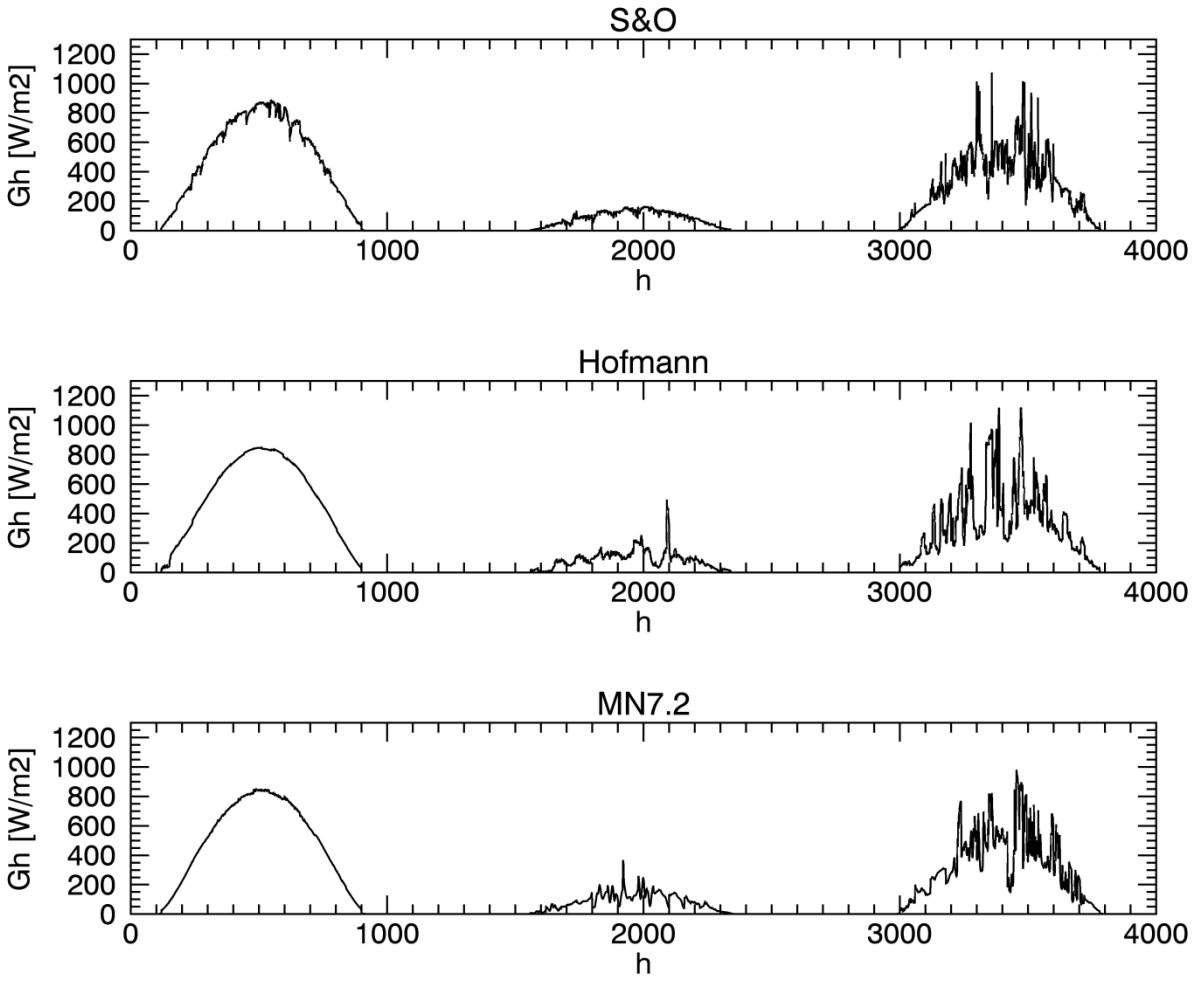
Billings

Validation

- Comparison of four models with BSRN data at 4 locations
  - Camborne, Carpentras, Payerne, Billings
- Tests:
  - Visual comparison
  - Distribution tests (KSI over)
  - Comparison of autocorrelation (KSI test)
  - Comparison of standard deviation (KSI test)
  - Ranks

Validation

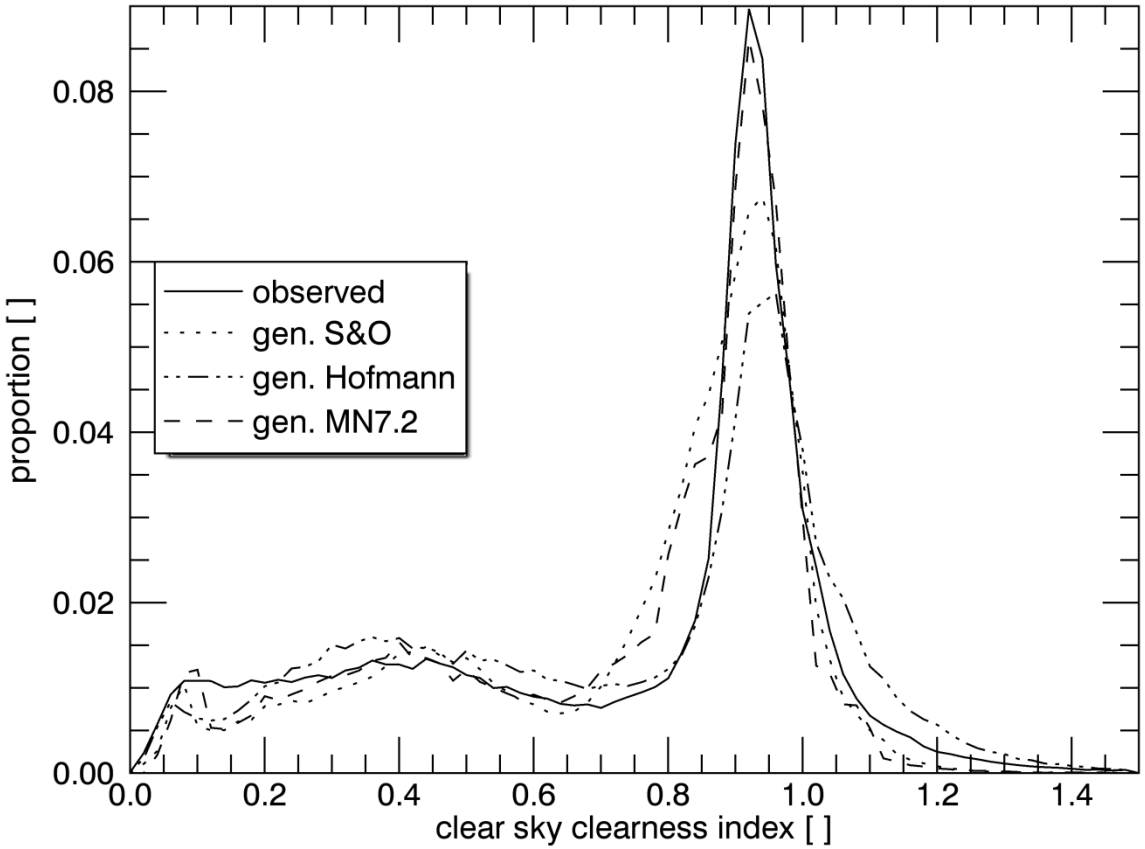
- Visual comparison: generated timeseries



Payerne

Validation

- Distribution

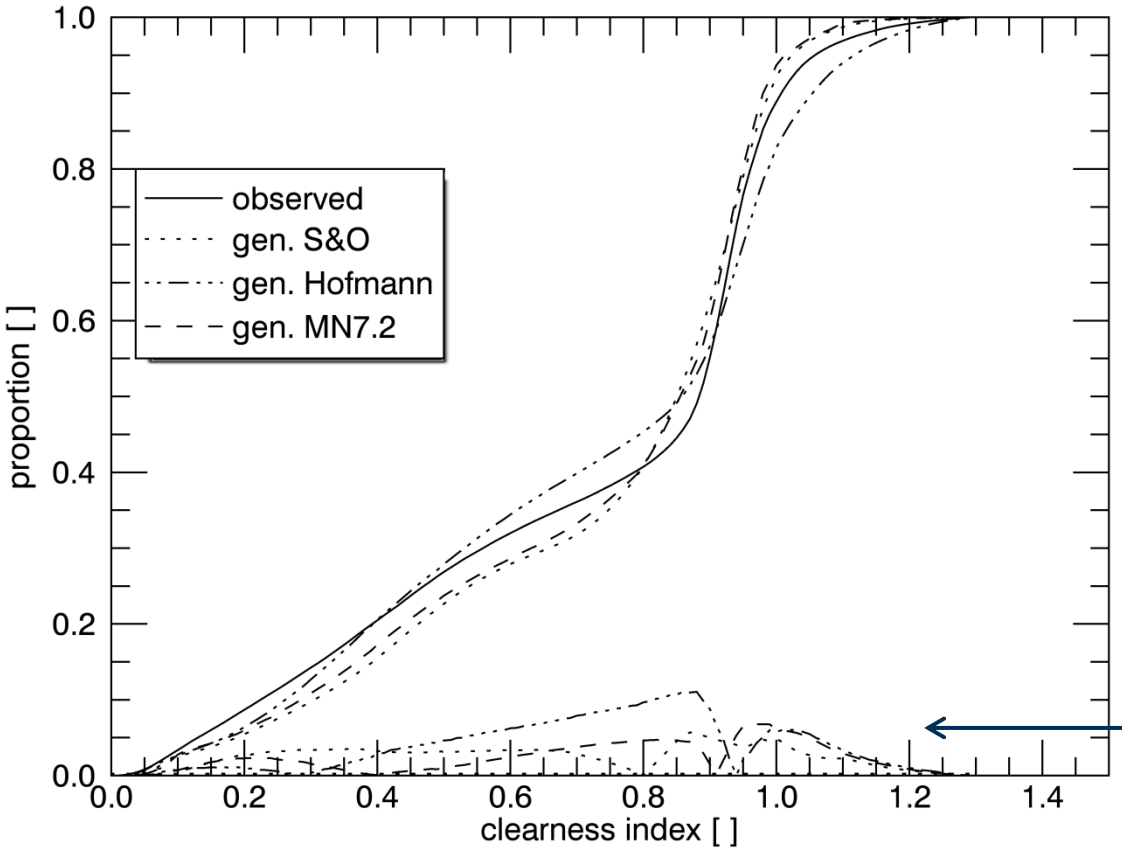


Carpentras

gen. = generated

Validation

- Distribution test (KSI over)*



Carpentras

gen. = generated

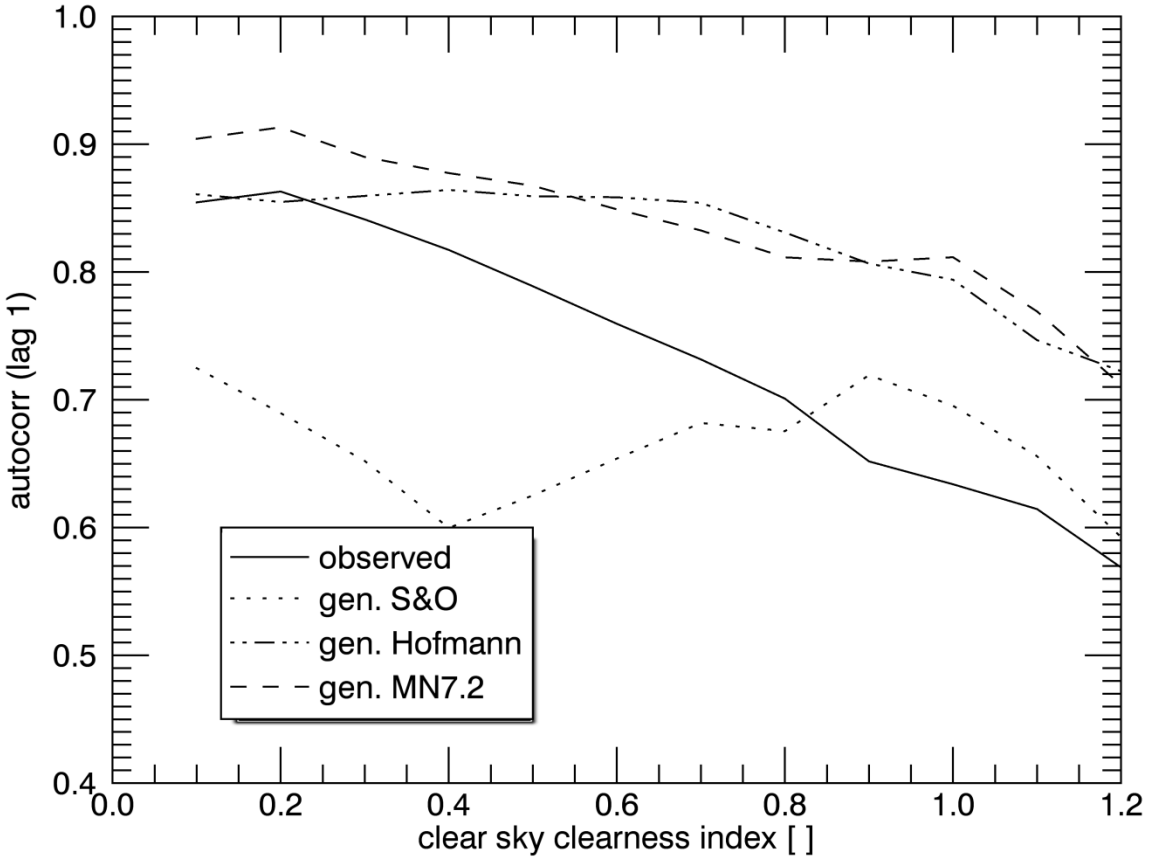
Difference of cumulative distributions

KSI over = area above critical level (99%)

*Espinar, B. et al. (2009): *Solar Energy*, *83*(1), 118–125. http://doi.org/10.1016/j.solener.2008.07.009

Validation

- Autocorrelation (1 minute time lag) in dependence on clearsky clearness index

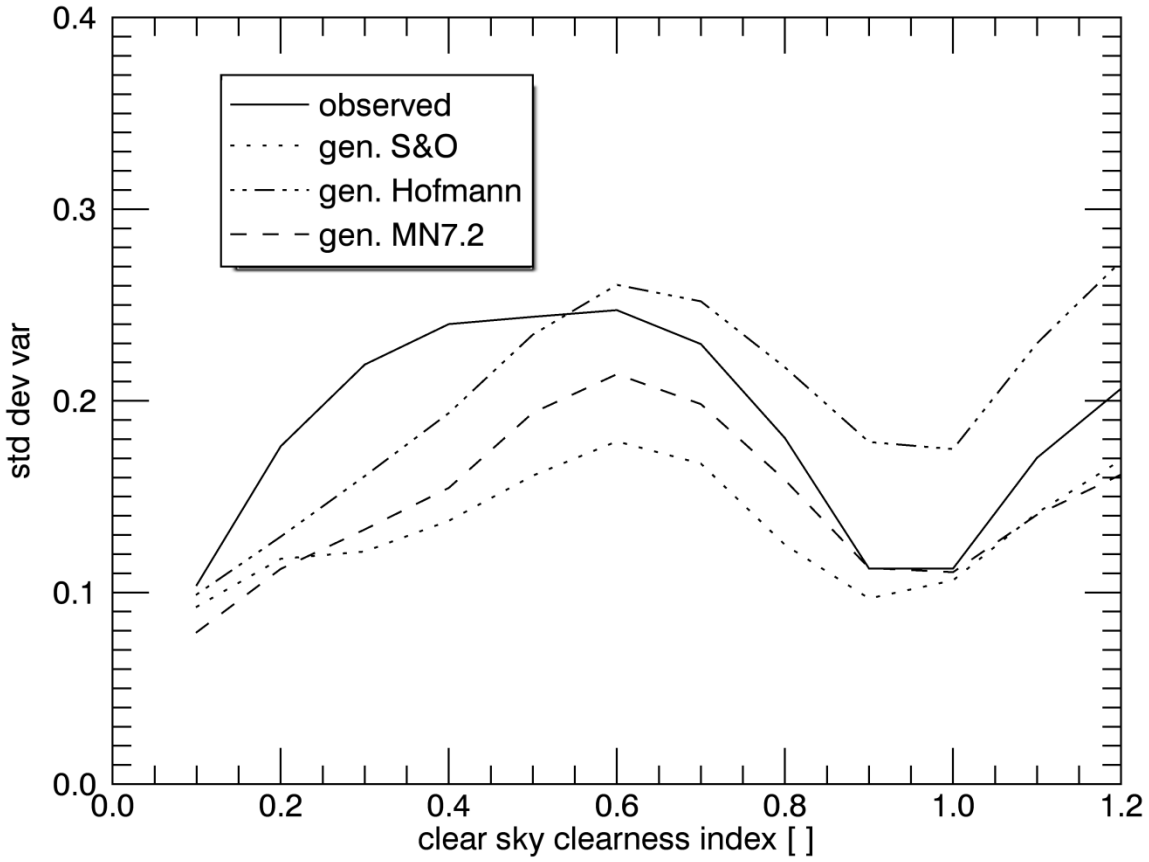


Camborne

gen. = generated

Validation

- Standard deviation in dependence on clearsky clearness index



Billings

gen. = generated

Validation results

- Averages of KSI over% value

	S&O	TAG	Hofmann	MN7.2
Distribution	1289	1417	1356	1249
Autocorrelation	21.2	14.6	15.3	14.2
Standard dev.	87.3	118.2	2.94	10.5
Avg. Weighted	1.29	1.37	0.67	0.67
Rank	3	4	2	1

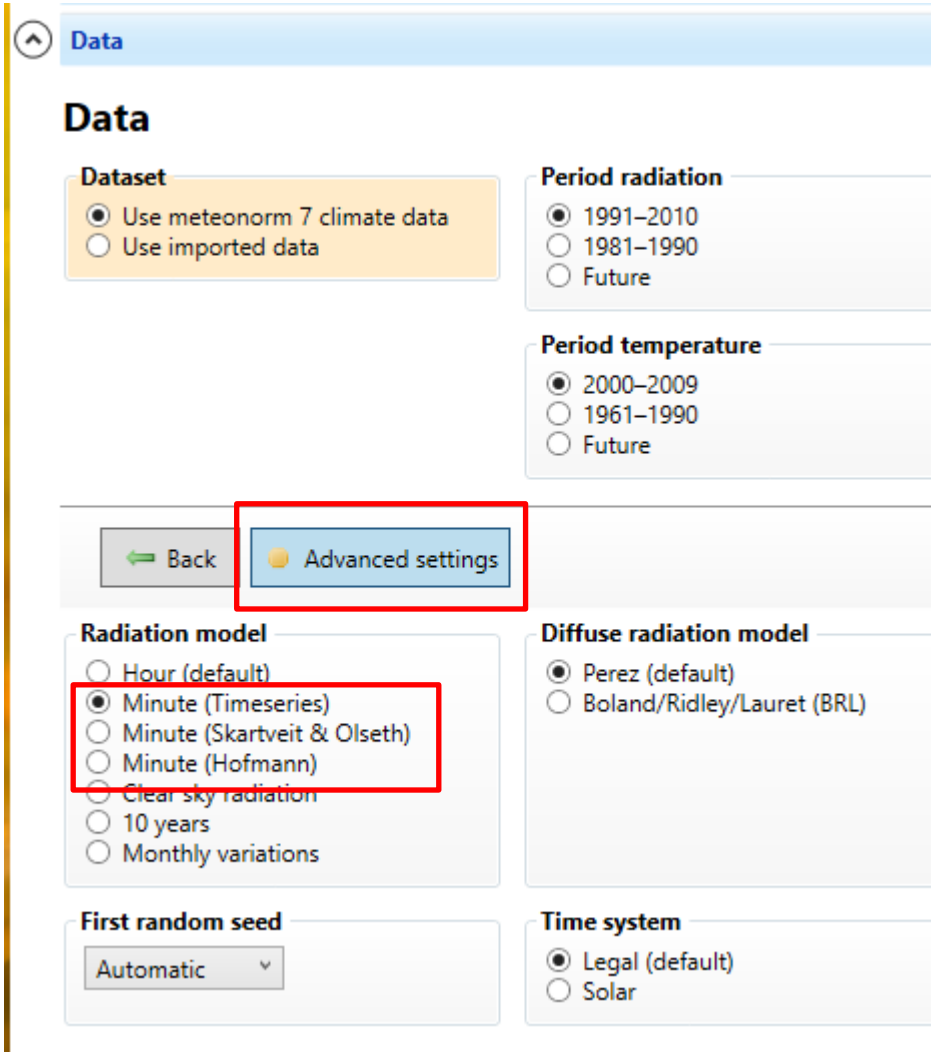
- S&O: 2nd for distribution, bad at autocorrelation and standard deviation
- TAG: 2nd for autocorrelation, bad at standard deviation
- Hofmann: First at standard deviation, third at autocorrelation
- MN7.2: First at autocorrelation and distribution

Conclusions

- New models show much better results
  - However still “models” (which approximate the reality)
- TAG will be excluded in version Meteonorm 7.2 (www.meteonorm.com)
- S&O will be kept together with
  - MN7.2 (timeseries based model)
  - Hofmann (Valentin/PVSol-model)

Conclusions

- New version 7.2 foreseen for mid January 2017
  - Can be used to enhance resolution of satellite timeseries or TMY's
  - Available also in plugins/dll
  - Available in web service (15 minute data)
- Additional major update:
  - New turbidity climatology



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Questions & suggestions?

Meteotest

www.meteotest.ch