Final report
PT RC2 - revised cloud radiation coupling

Ulrich Blahak (DWD)

Status of PT RC2 work packages

➔ Priority Task (RC)2 (2014 – 2015)

green: done; orange: in progress; red: not yet started

- ➔ **UB (Ulrich Blahak), PK (Pavel Khain), HM (Harel Muskatel)**
- ➔ **We had a 1-week workshop in Offenbach from 12.1. – 16.1. to coordinate the work**
- ➔ Upgrade test code to the newest COSMO version 5.1_beta **(➔ UB)**
- ➔ Getting familiar with the COSMO radiation scheme and with UB‘s test code together with the changes/ extentions contained herein **(➔ PK, HM)**
- ➔ Further revision of optical properties of ice hydrometeors (single scat. alb., asym. param.) based on a new parameterization of Fu et al. (2007) **(➔ HM, UB)**
- ➔ Review/ revise treatment of subgrid scale clouds in radiation **(➔ PK, HM)**
  - ➔ E.g., decoupling of CLC diagnostic and radiation tuning; SGS clouds consistent to turbulence scheme?

Status of PT RC2 work packages

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- ➔ Reduce number of tuning parameters **(➔ PK, HM, UB)**
  - ➔ 1) Find insensitive parameters by case studies and set to constant values.
  - ➔ 2) Physically based closures. Examples:
    - ➔ Replace parameter *cloud_num* (number conc. of cloud drops) by a climatology. UB has developed a method for a similar parameter in the microphysics, based on Tegen et al. (1997) and Segal & Khain (2006), but not implemented in the radiation so far. Now it has been implemented also in the radiation.
    - ➔ Replace *radqc_fact* by a PDF-based closure. Would be a new development and not clear if possible.
- ➔ Case studies for different weather situations and different climates
- ➔ Consultation / Collaboration with LMU Munich, group of Prof. Bernhard Mayer initiated

Achievements PT RC2

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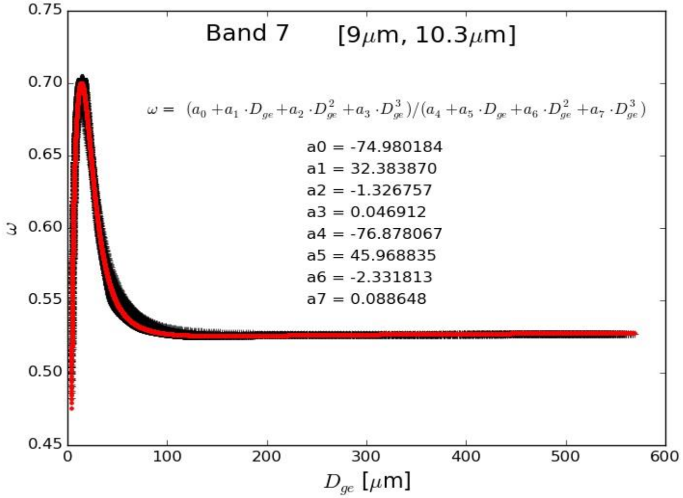
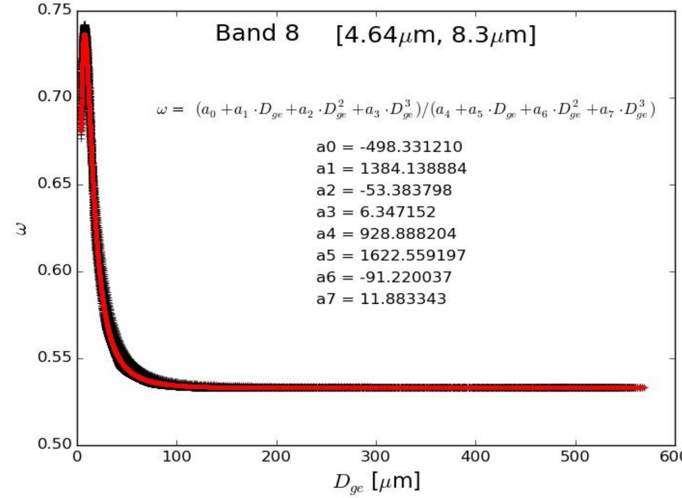
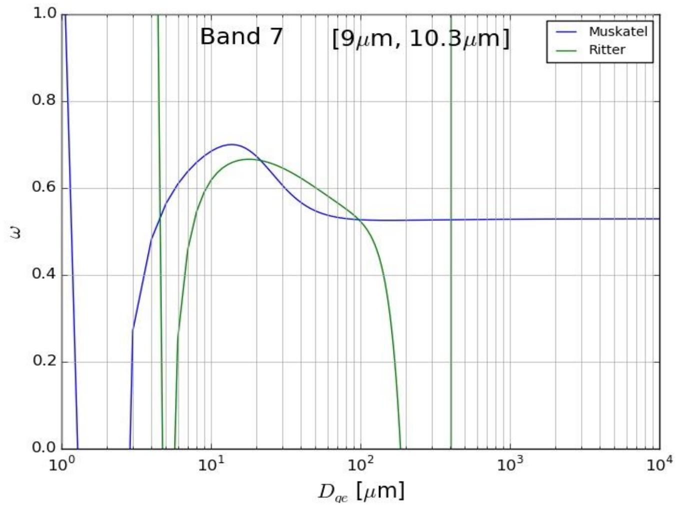
- Porting of our test code to COSMO version 5.1_beta
- New ice particle optical properties for the 8 RG92 wavelength bands by size-distribution-integration of single-particle single-wavelength scattering data (provided by Quiang Fu from University of Washington), with subsequent wavelength band averaging:
  - Extended validity range of fits out to D_{ge} = 600 µm (before: 140 µm), now suitable for snow, graupel
  - New parameterization of g based on mean axis ratio AR instead of D_{ge} (Fu, 2007)
- Idealized sensitivity study for different typical cloud types (cirrus, low stratus, mixed-phase stratus, SGS stratocumulus, convective anvil)
- Real-case sensitivity studies over 7-day periods (only preliminary results yet)
- We have some preliminary ranking of the various new tuning parameters, but not definite yet.
- Continuation of open tasks and some extentions in a new PP $T^2(RC)^2$

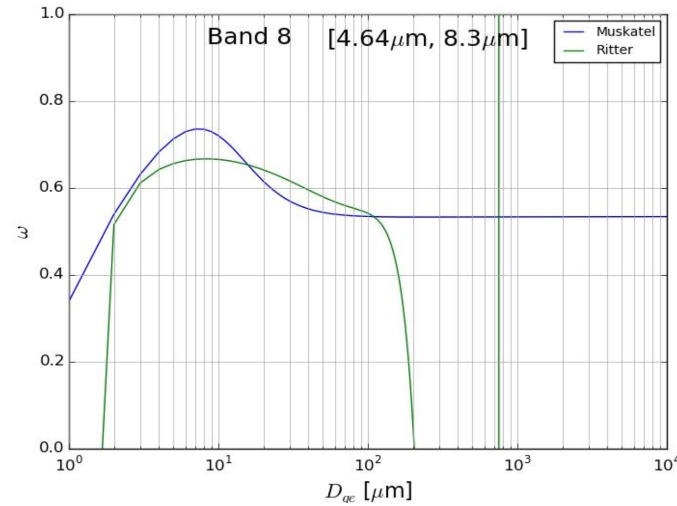
New optical properties of ice hydrometeors

➔ Example: single scattering albedo for 2 infrared bands, function of D_{ge}



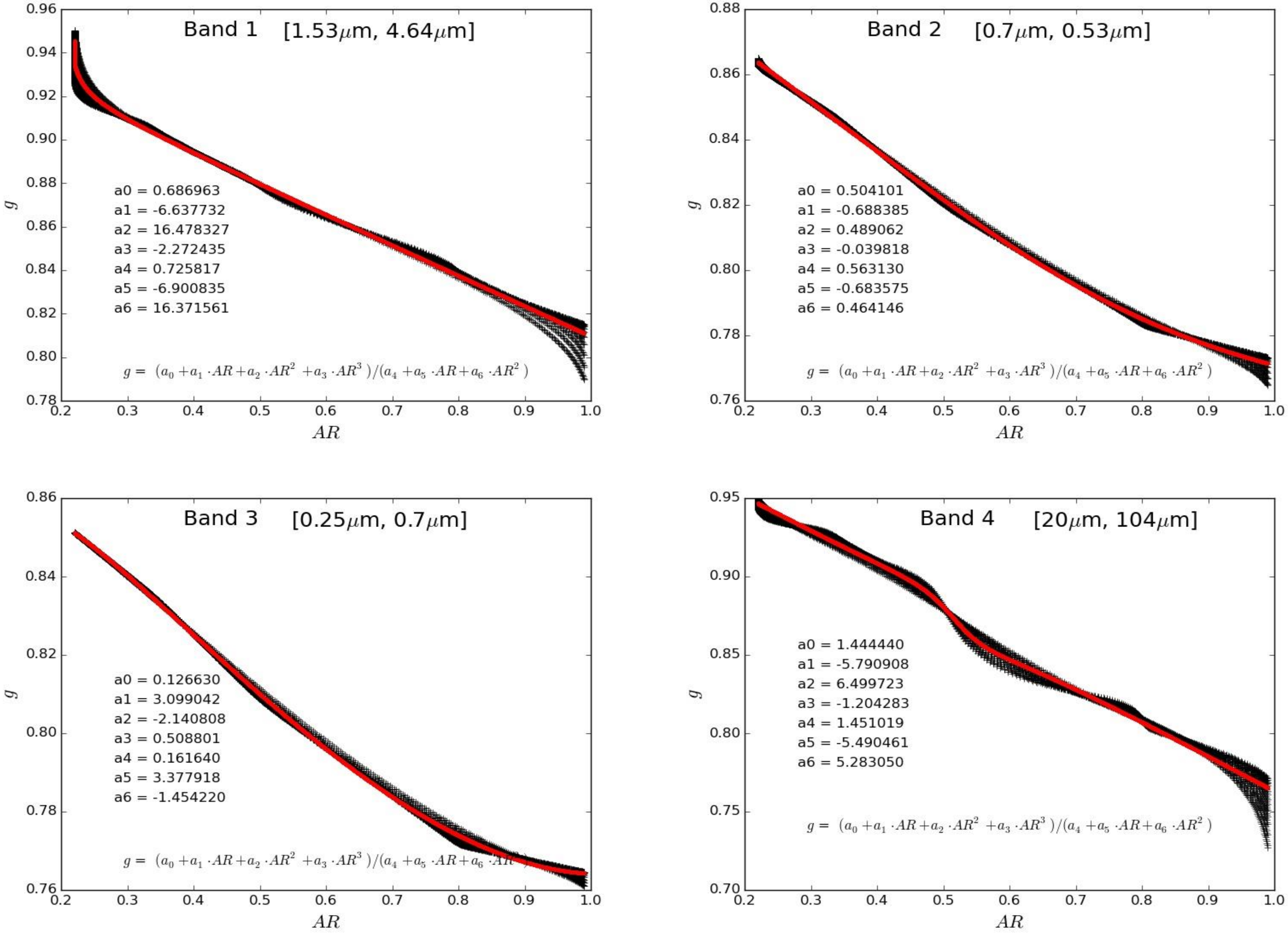






New optical properties of ice hydrometeors

➔ Example: g for 3 visible bands („1“-“3“) and 1 infrared band („4“), function of AR



Idealized sensitivity studies

Problem: New radiation scheme – 32 new parameters. Which of them are most important?

1. lrad_incl_qrqsqg
2. iradpar_cloud
3. lrad_use_largesizeapprox
4. itype_aerosol
5. icloud_num_type_rad
6. radqcfact
7. radqifact
8. rad_arearat_ls_i
9. rad_arearat_ls_s
10. rad_arearat_ls_g
11. rad_arearat_ls_h
12. rhobulk_ls_ini_i
13. reff_ini_c
14. reff_ini_i
15. cloud_num_rad
16. zref_cloud_num_rad
17. dz_oe_cloud_num_rad
18. tqc_thresh_rad
19. tqi_thresh_rad
20. tqs_thresh_rad
21. rhos_n0shigh_rad
22. rhos_n0slow_rad
23. n0s_low_rad
24. rhoc_nchigh_rad
25. rhoc_nclow_rad
26. ncfact_low_rad
27. rhoi_nihigh_rad
28. rhoi_nilow_rad
29. nifact_low_rad
30. qvsatfact_sgscl_rad

Difficult to answer... it depends on cloud type.

Solution:

1. Use ***idealized*** COSMO framework to create different cloud types
2. Decide which parameters are the most important for each cloud type

For example, we (preliminary) found out that:

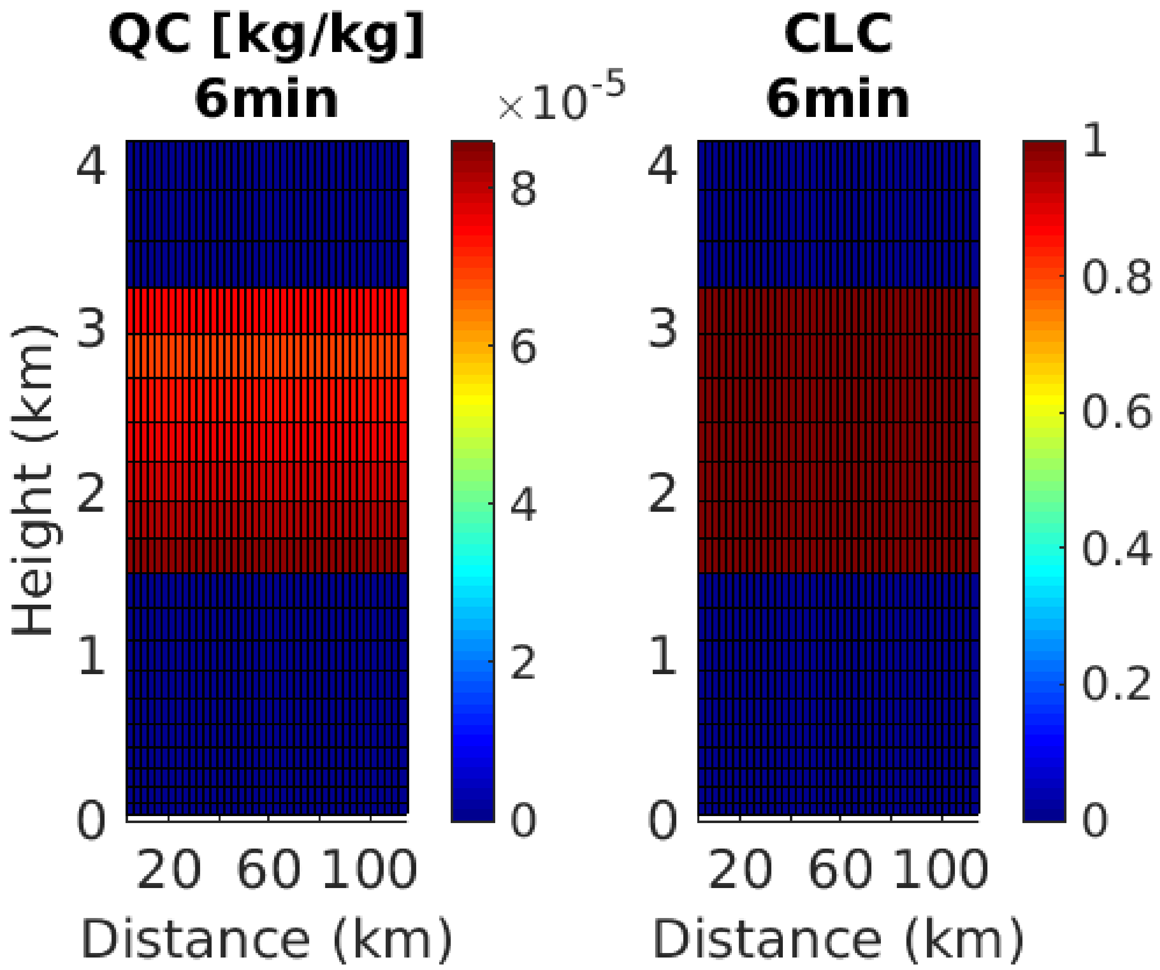
Anvil of Cumulonimbus	Shallow convective cumulus	SGS Strato-cumulus	Mixed phase	Stratus	Cirrus
p1,p2,p3,p4,p5,p7,p8,p9,p12, p14,p21,p22,p23,p27,p28, p29, p30	p2,p4,p5,p6,p13,p15, p16,p17, p30	p2,p4,p5,p6,p13,p15, p16,p17,p30	p1,p2,p3,p4,p5, p6,p7,p8,p9,p12, p13,p14,p15,p16, p17,p21,p22,p23, p24,p25,p26,p27, p28,p29, p30	p1,p2,p4, p6,p13,p15, p16,p17,p24, p25, p26, p30	p1,p2,p3,p4, p5,p7,p8,p9, p12,p14,p21, p22,p23,p27, p28,p29,p30

p6,p7,p13,p18,p19,p20,p30 – new tuning namelist parameters in the future version

All the others – predefine in the code

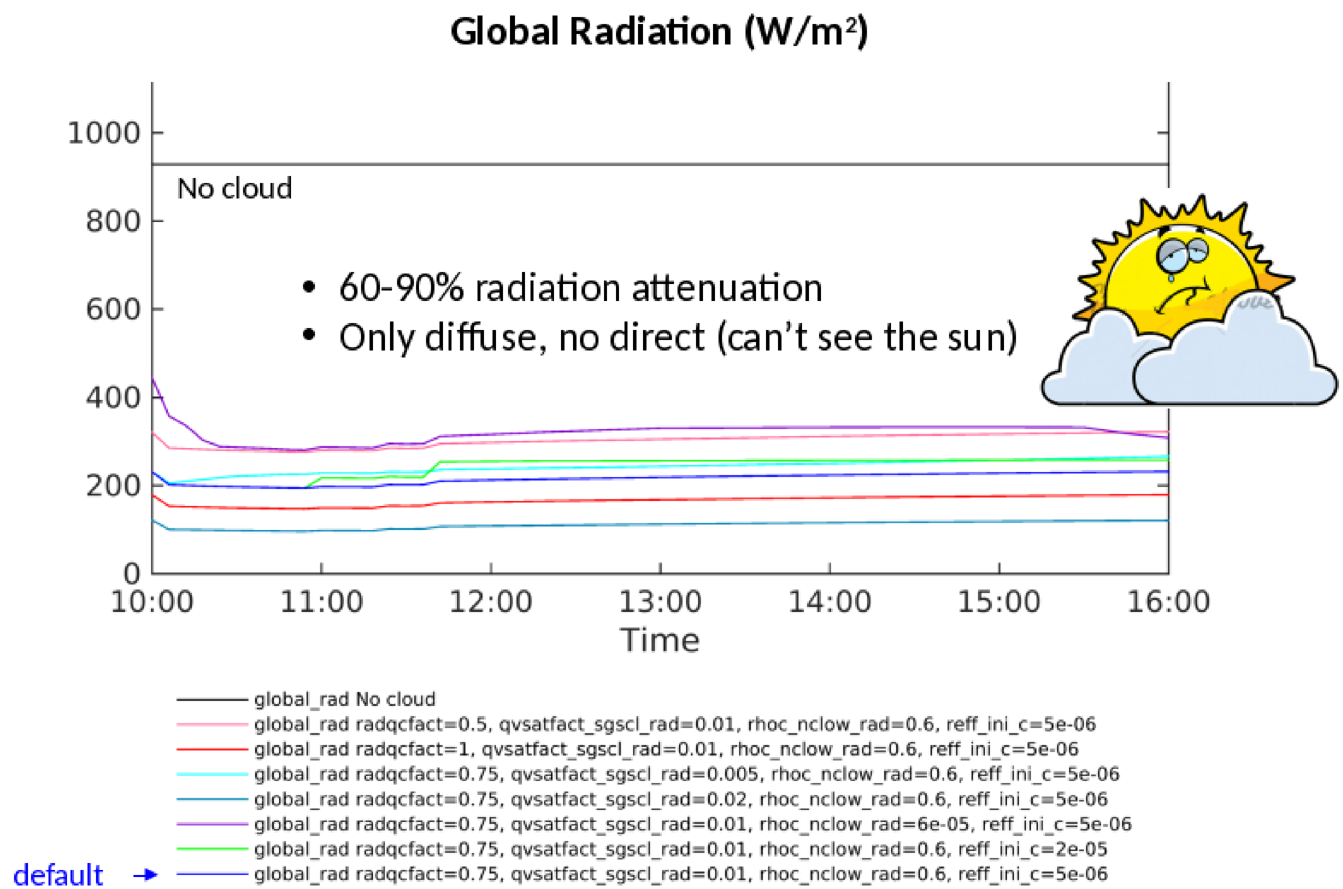
Idealized sensitivity studies: example

➔ Idealized simulation of a low stratus cloud:



Idealized sensitivity studies: example

1b. Idealized simulation of stratus cloud



Idealized sensitivity studies: Method to quantify „sensitivity“ for ranking of param.

2. Method: How to define sensitivity to model parameters ?

For given time step t:

- Perform idealized COSMO simulations for many parameters combinations
- Replace the radiation dependency on the model parameters by an analytic function or a Meta-Model (MM):

$$\tilde{R}(\tilde{x}_1,\tilde{x}_2,\tilde{x}_3,\tilde{x}_4) \cong \sum_{p=1}^{4} \frac{a_{p,1} + a_{p,2}\tilde{x}_p + a_{p,3}\tilde{x}_p^{\,2}}{a_{p,4} + a_{p,5}\tilde{x}_p + a_{p,6}\tilde{x}_p^{\,2}} + \frac{1}{2}\sum_{p=1}^{4}\sum_{i\neq p} b_{p,i}\tilde{x}_p\tilde{x}_i$$

Attenuation of global radiation (%)

$$100 \text{ X } \frac{R_{no\ cloud} - R(\tilde{x}_1,\tilde{x}_2,\tilde{x}_3,\tilde{x}_4)}{R_{no\ cloud}}$$

“Effective” parameter

$$\frac{f_p(x_p) - f_p(x_{p,def})}{MAX\{f_p(x_p)\} - MIN\{f_p(x_p)\}}$$

More about on the next slide…

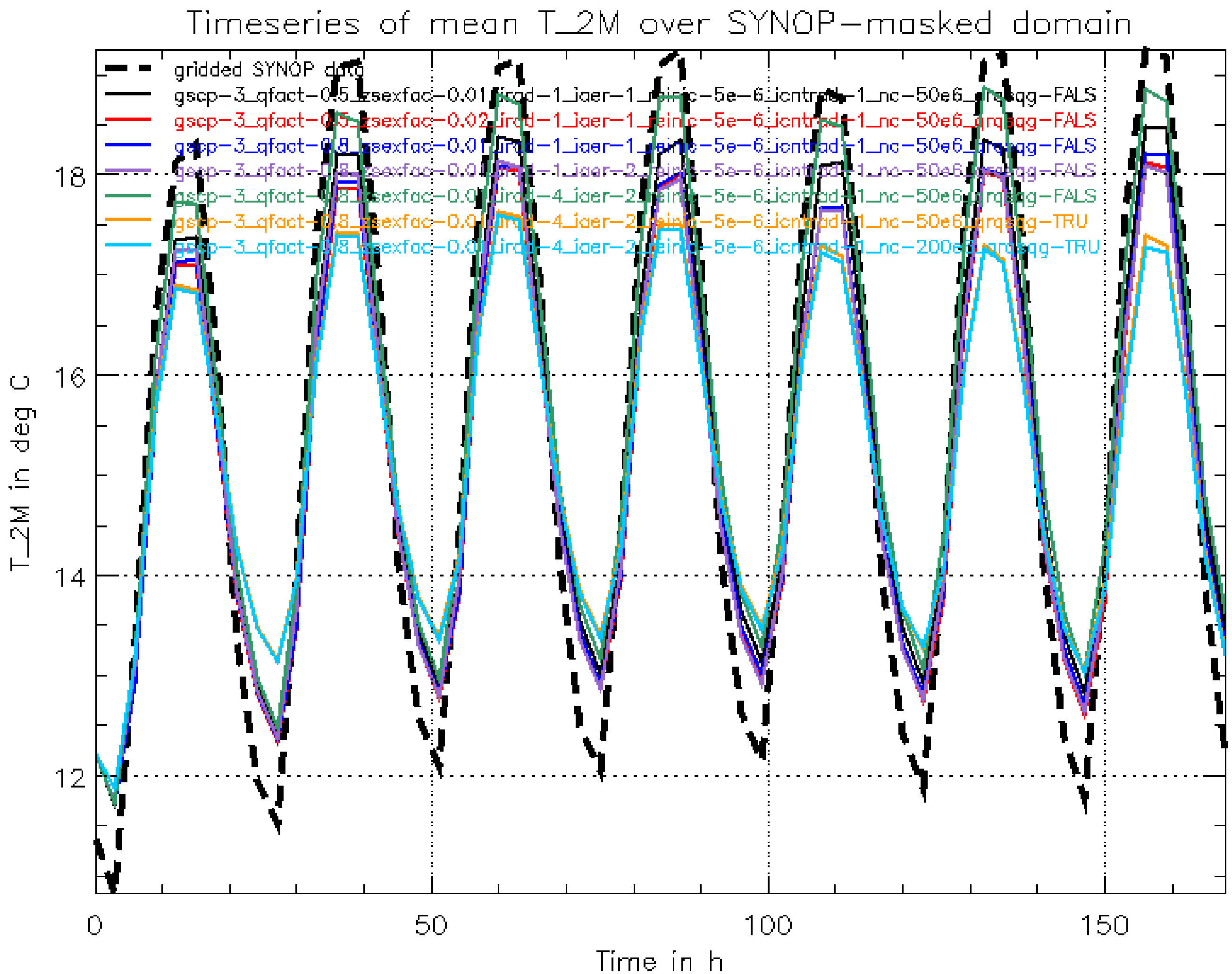
$x_1 \equiv radqcfact$
$x_2 \equiv qvsatfact\_sgscl\_rad$
$x_3 \equiv rhoc\_nclow\_rad$
$x_4 \equiv reff\_ini\_c$

chosen to get ***smoothed*** dependence on

$f_1(x_1) \equiv x_1$
$f_2(x_2) \equiv x_2$
$f_3(x_3) \equiv -1/(x_3 - q_0)$
$f_4(x_4) \equiv x_4$

$$\frac{\partial \tilde{R}}{\partial \tilde{x}_p} = \text{Sensitivity to parameter } \tilde{x}_p$$

Case study: 28.5. – 4.6.2013 (C-EU) closer look at sensitivities (1)



Synop Data - - - - - - -

Control

+ SGS factor from 0.01 to 0.02

+ back to 0.01, but incr. k to 0.08

+ Tegen aerosols

+ new optical properties

+ add qs, qr, qg

+ nc_0 from 50 to 200 cm^{-3}

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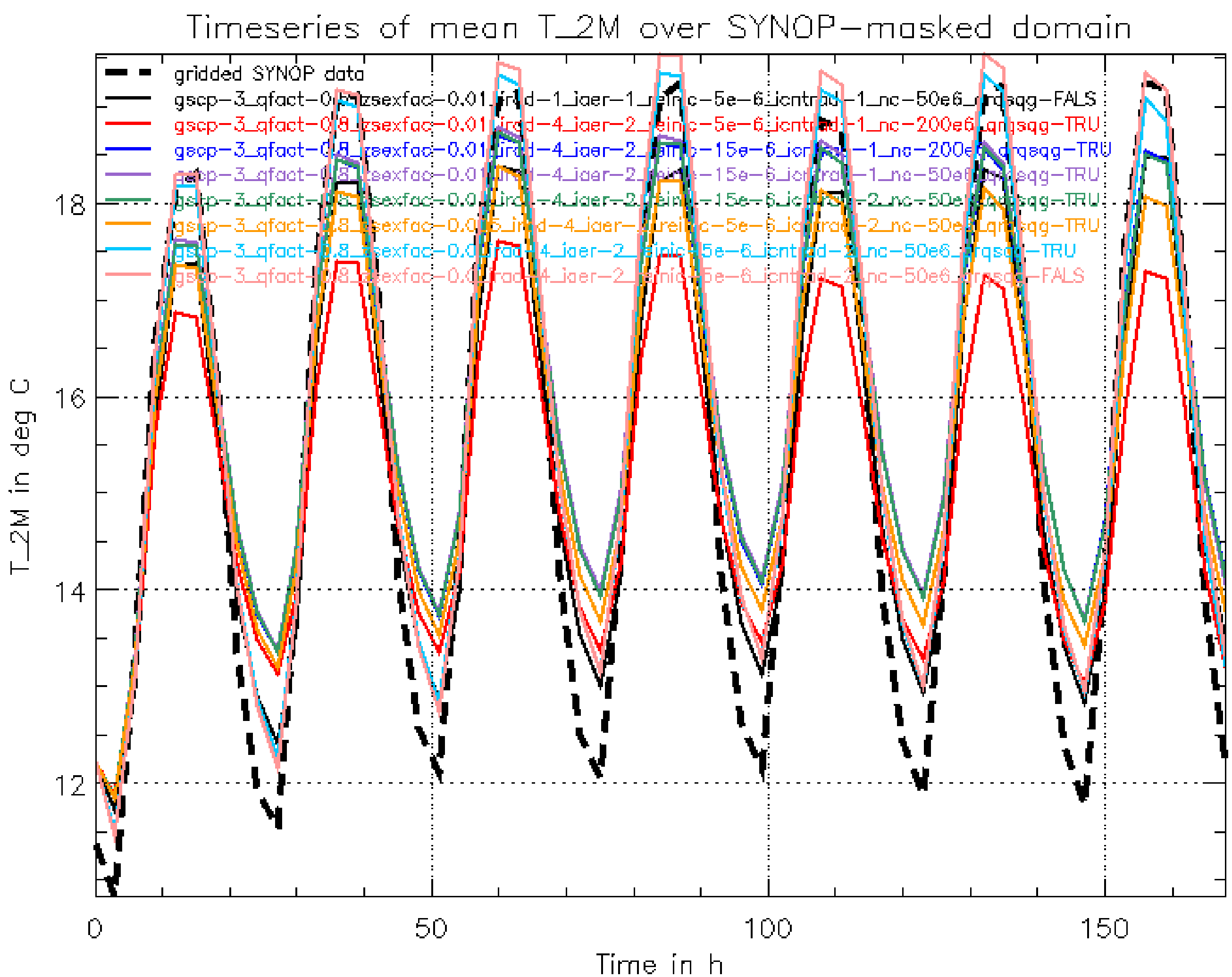

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+ incr. Re for SGS water clouds to 15 µm

+ decr. n_{c0} to 50e6

+ Tegen-based n_{c0}

+ Re SGS water clouds back to 5 µm and qvsatfact red. to 0.005

+ set qvsatfact = 0.0 (no SGS clouds at all)

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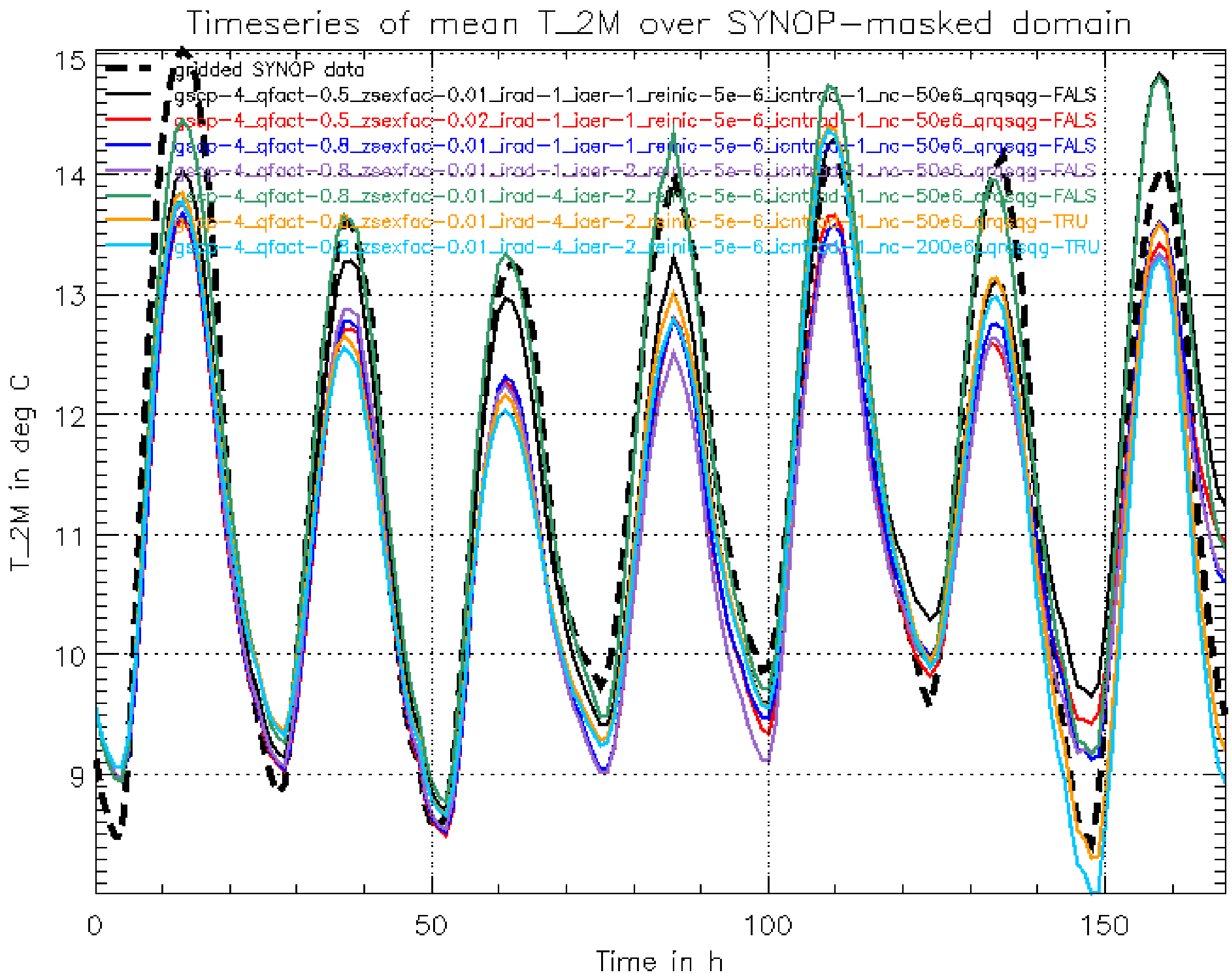

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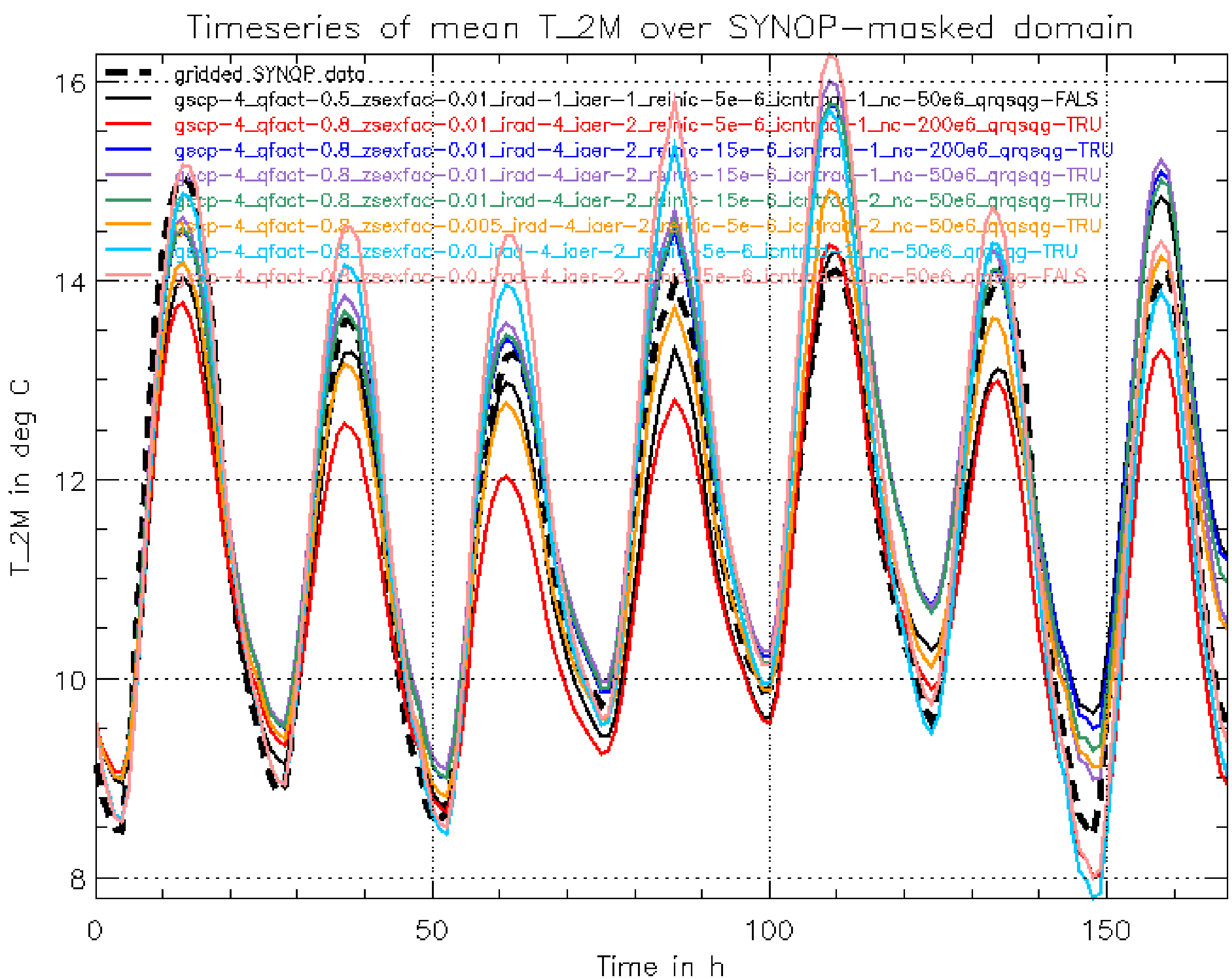

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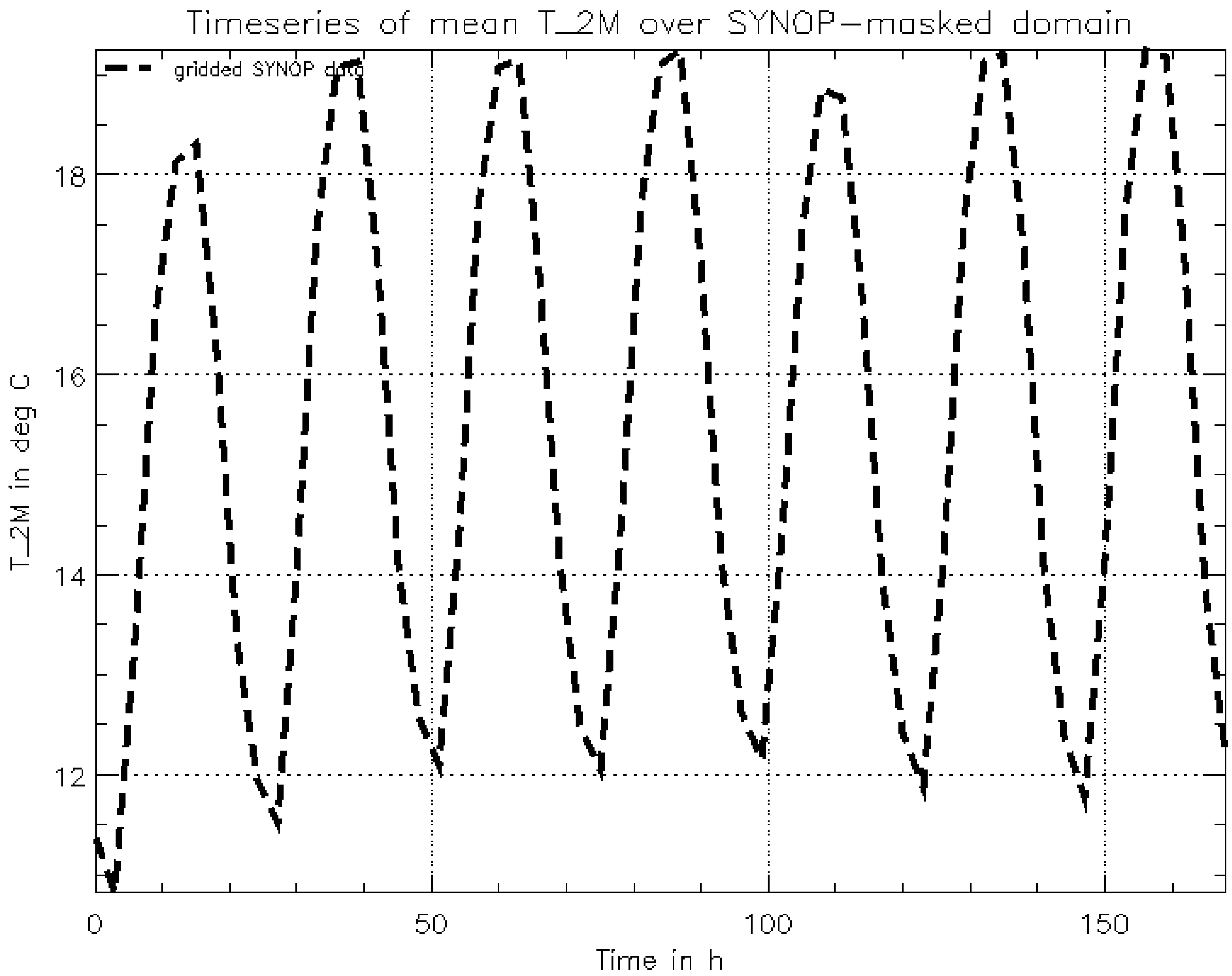

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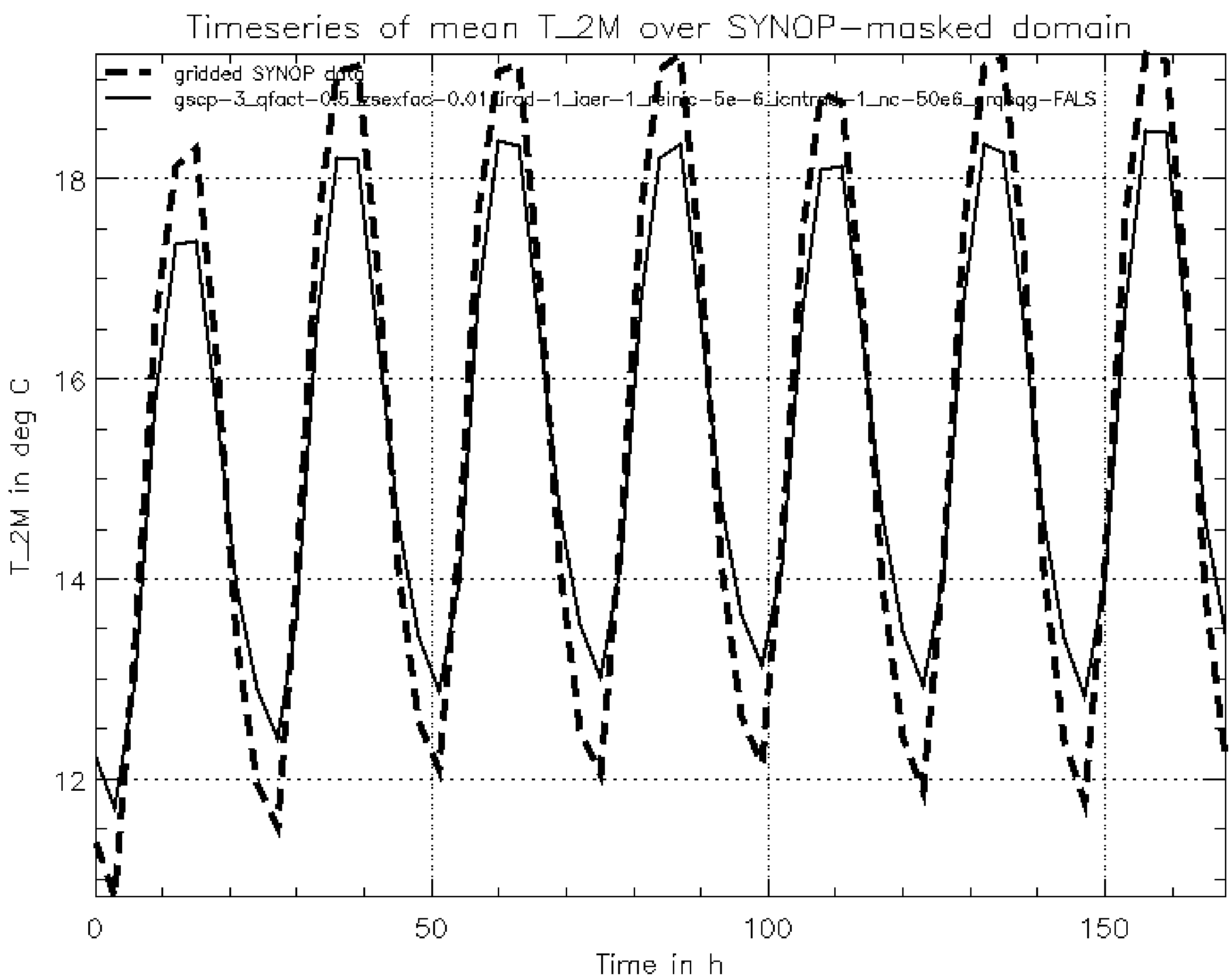

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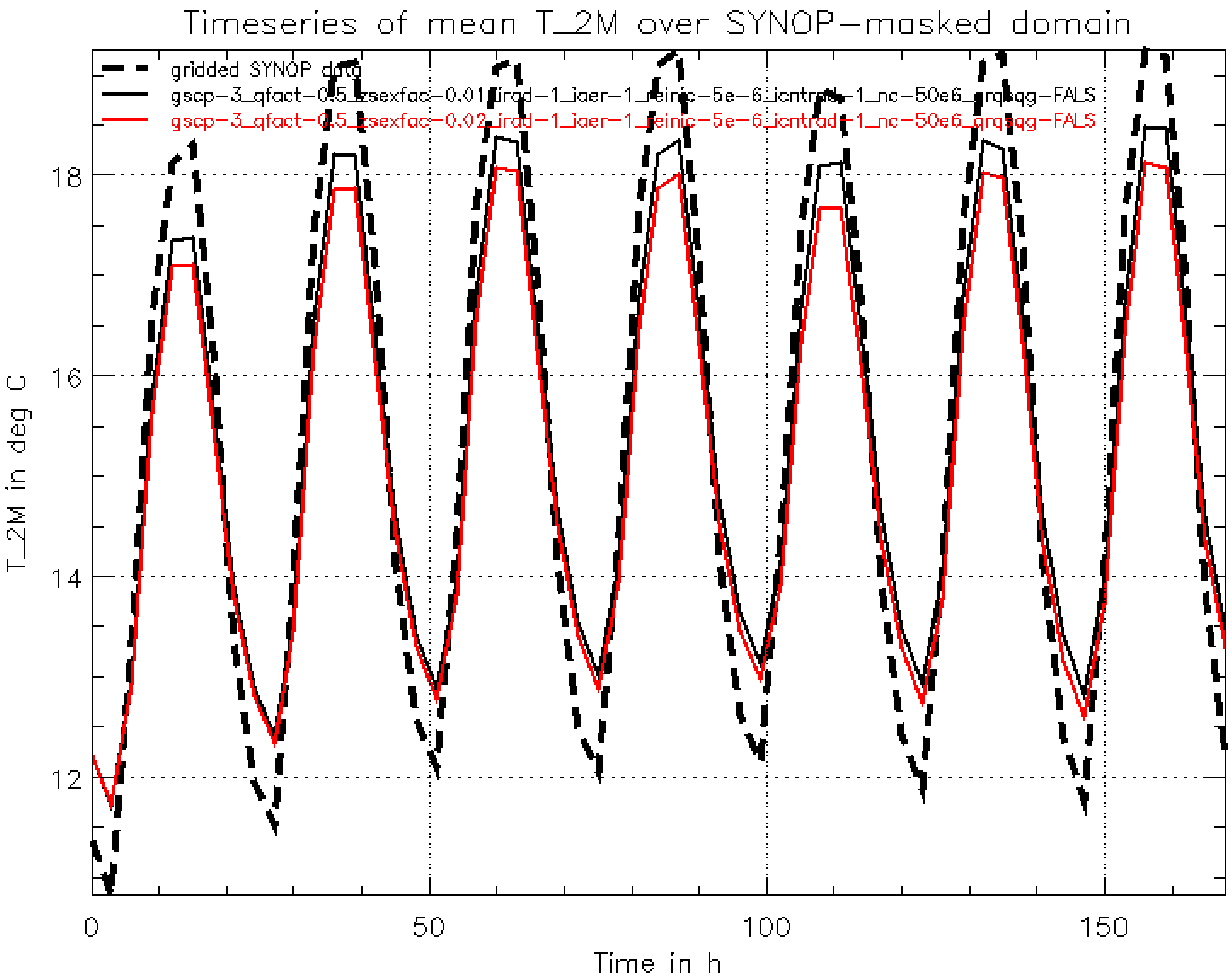

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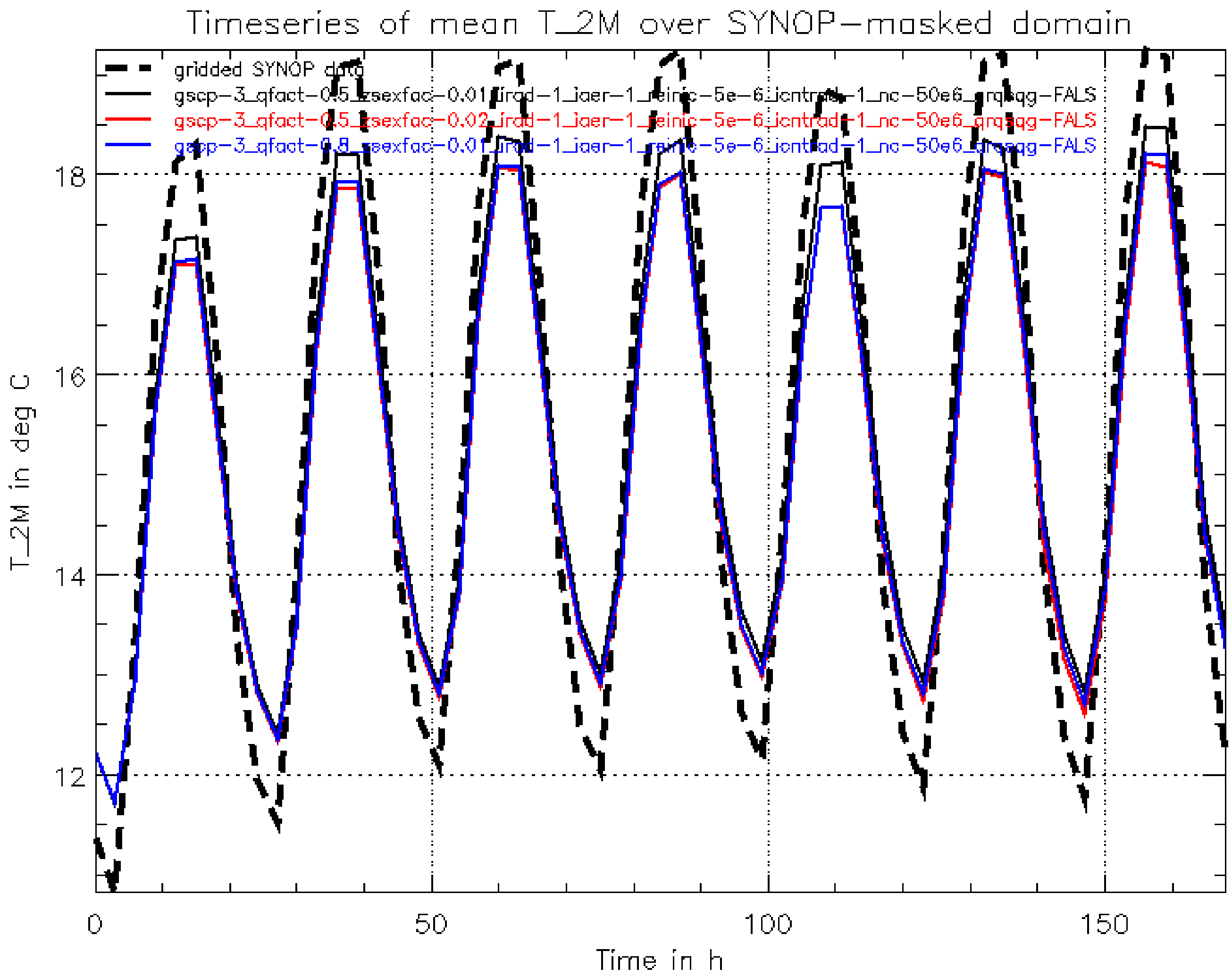

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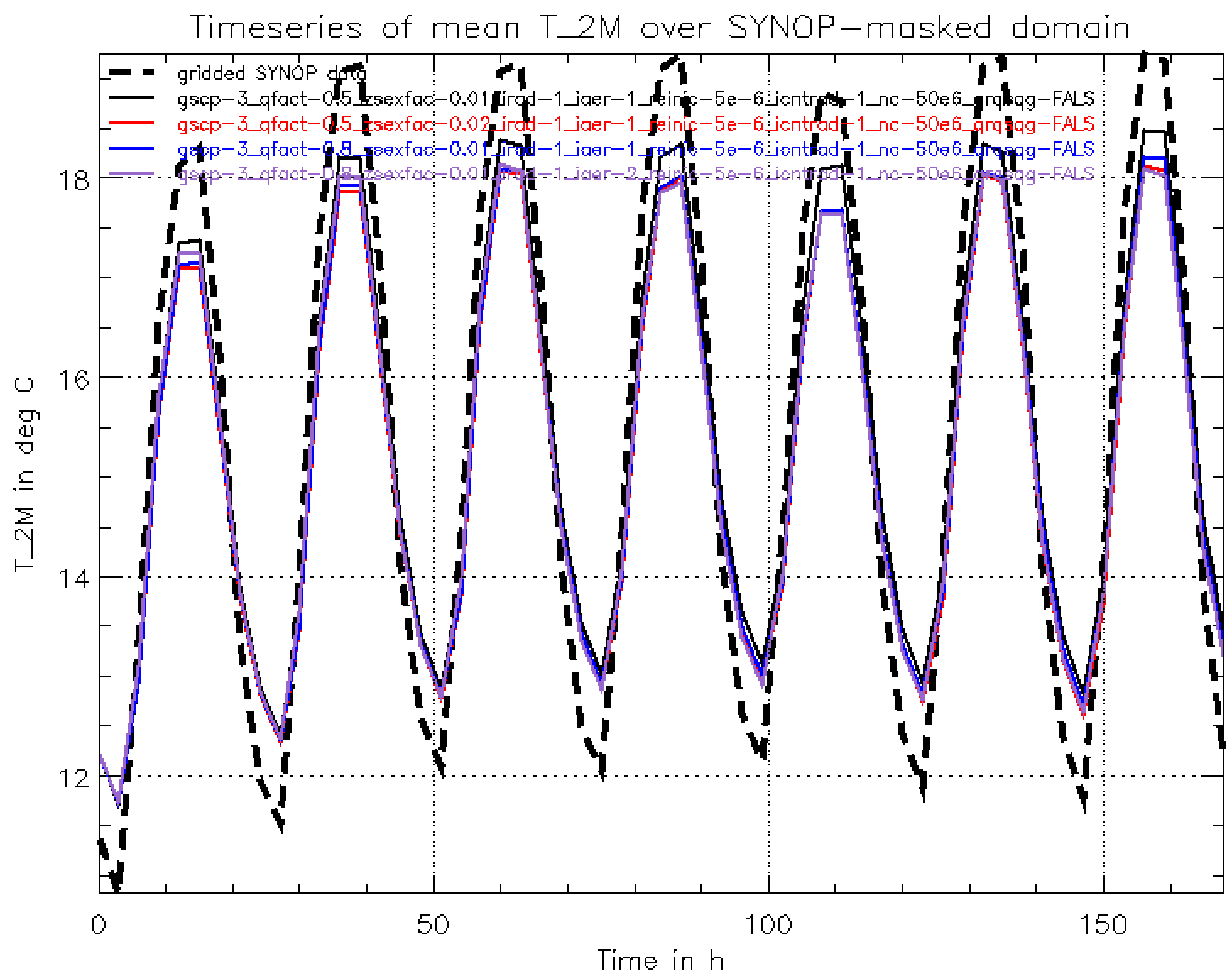

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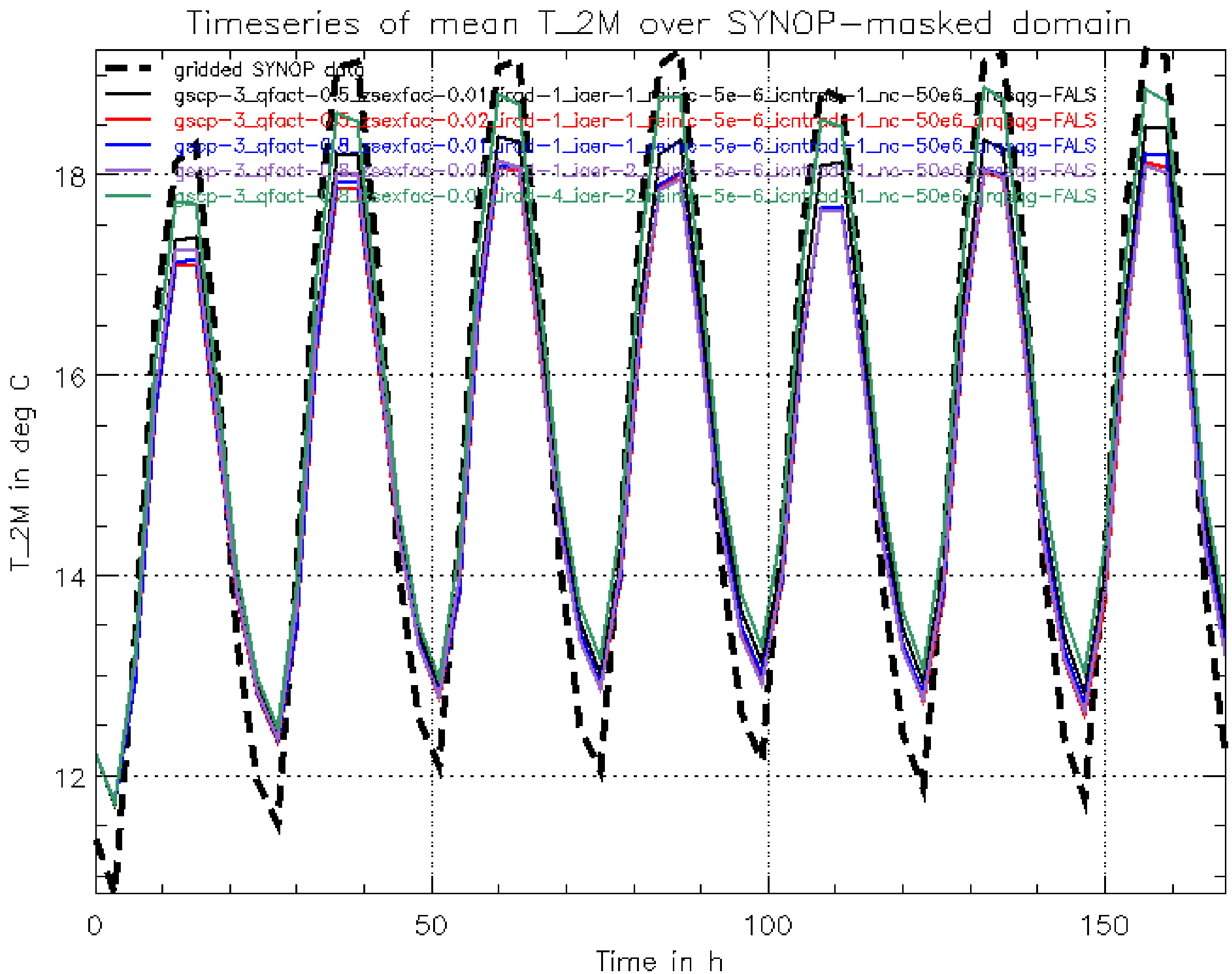

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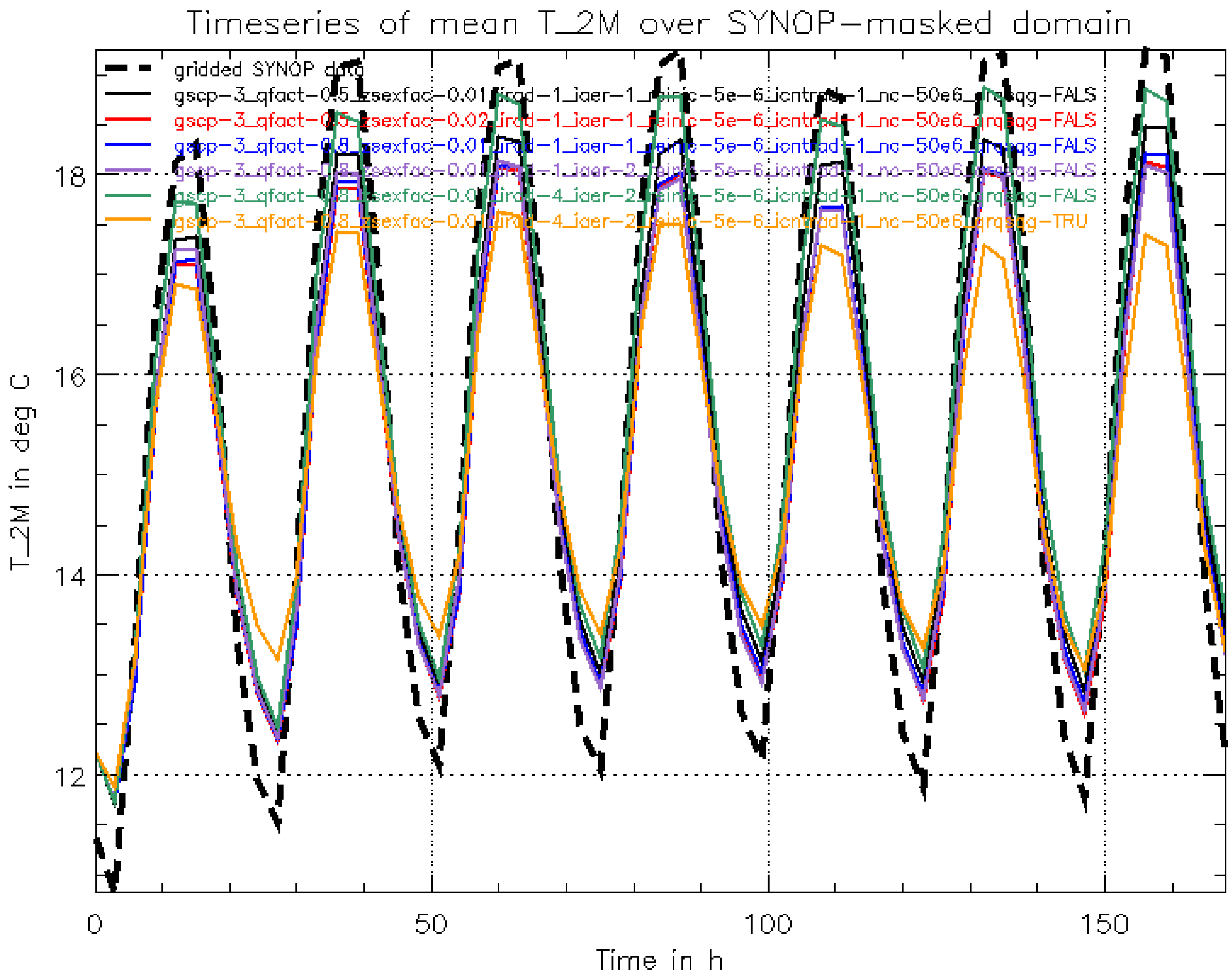

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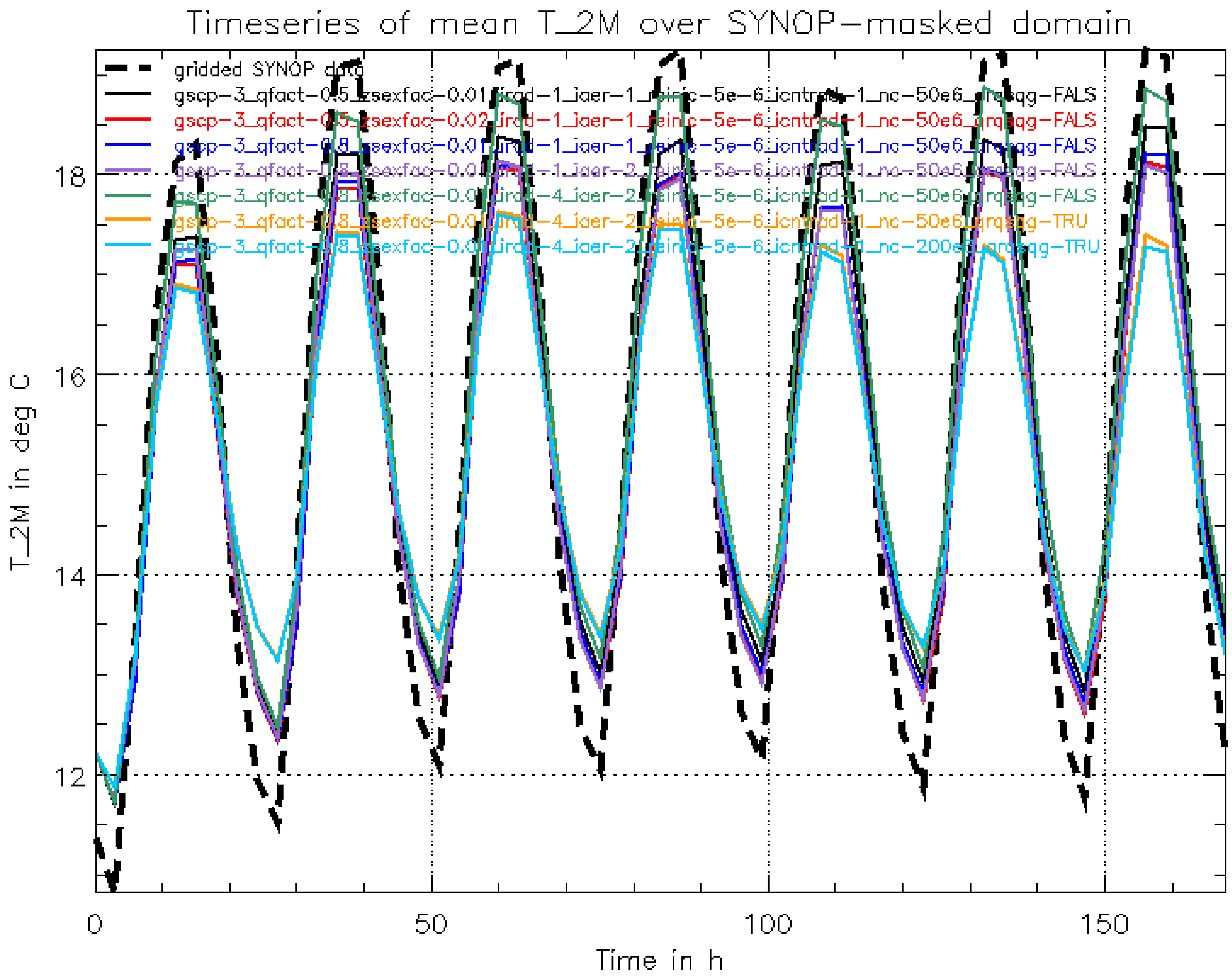

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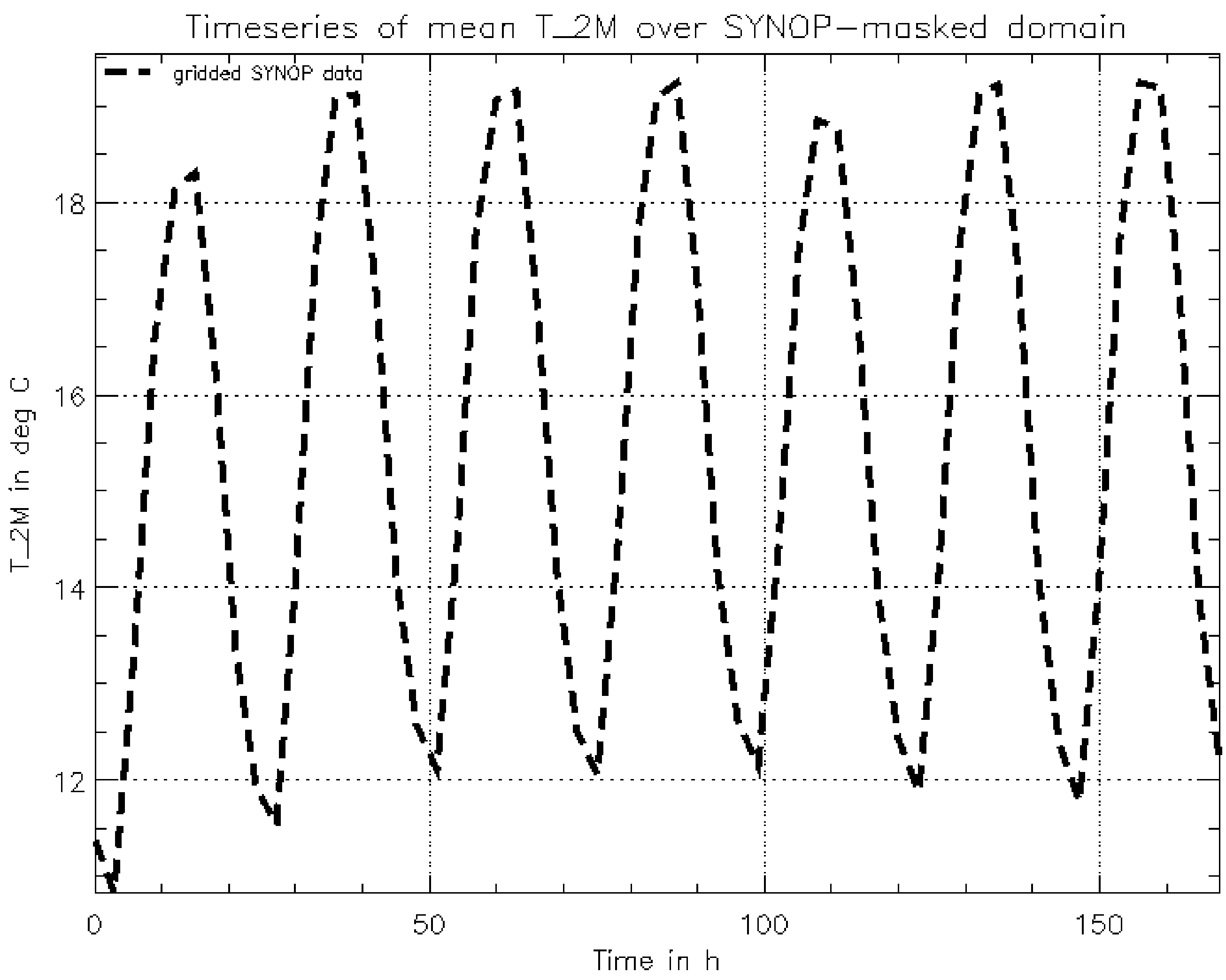

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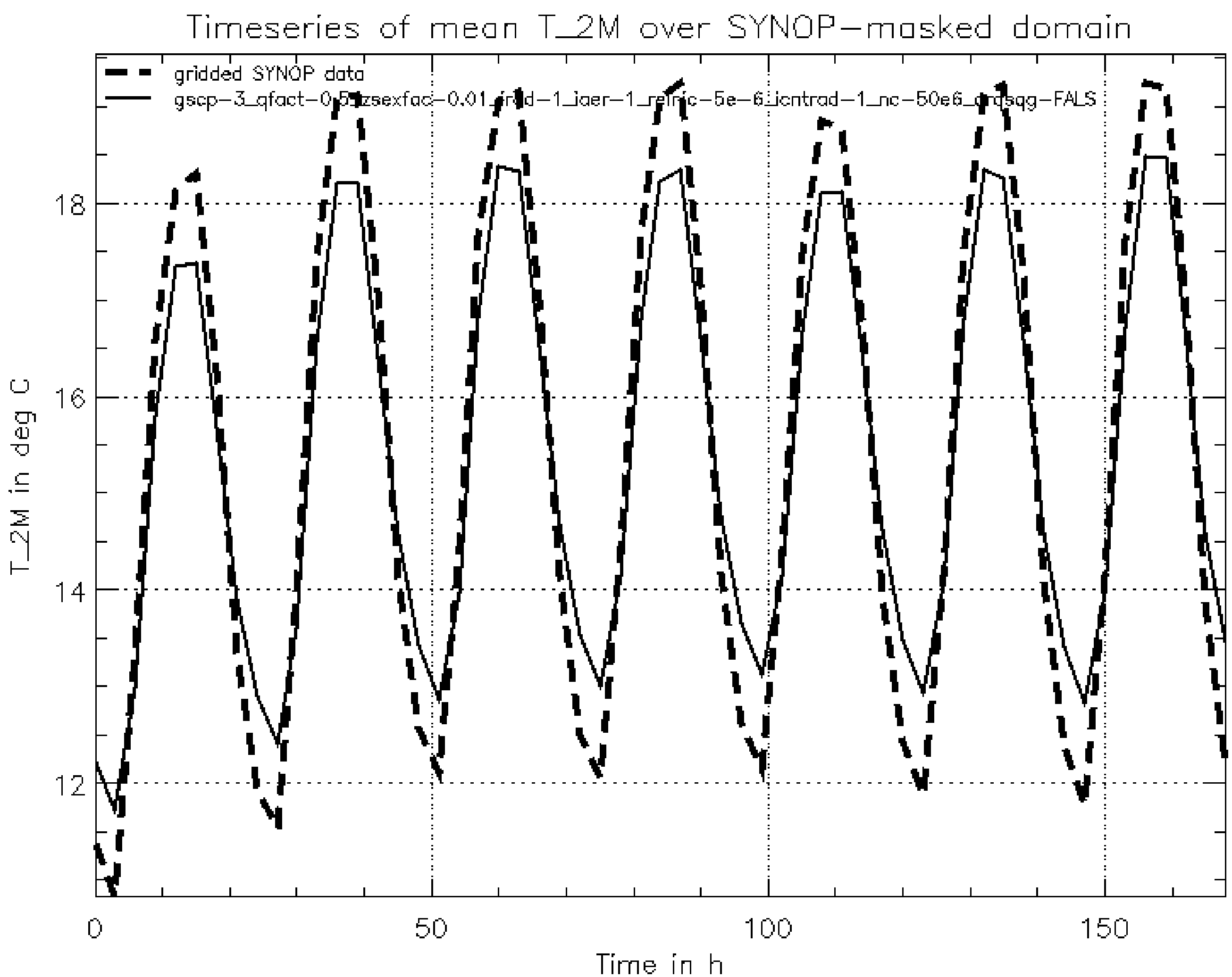

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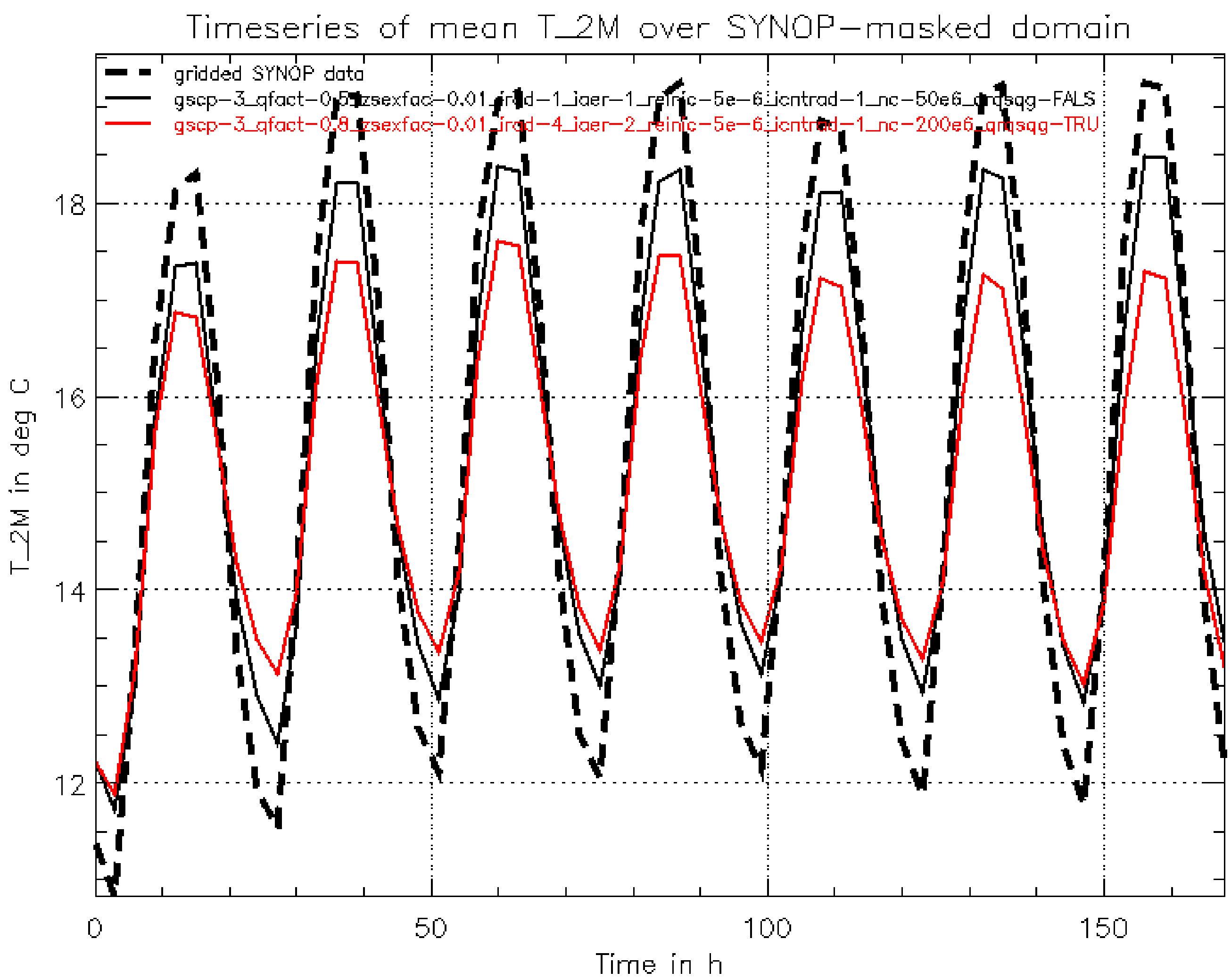

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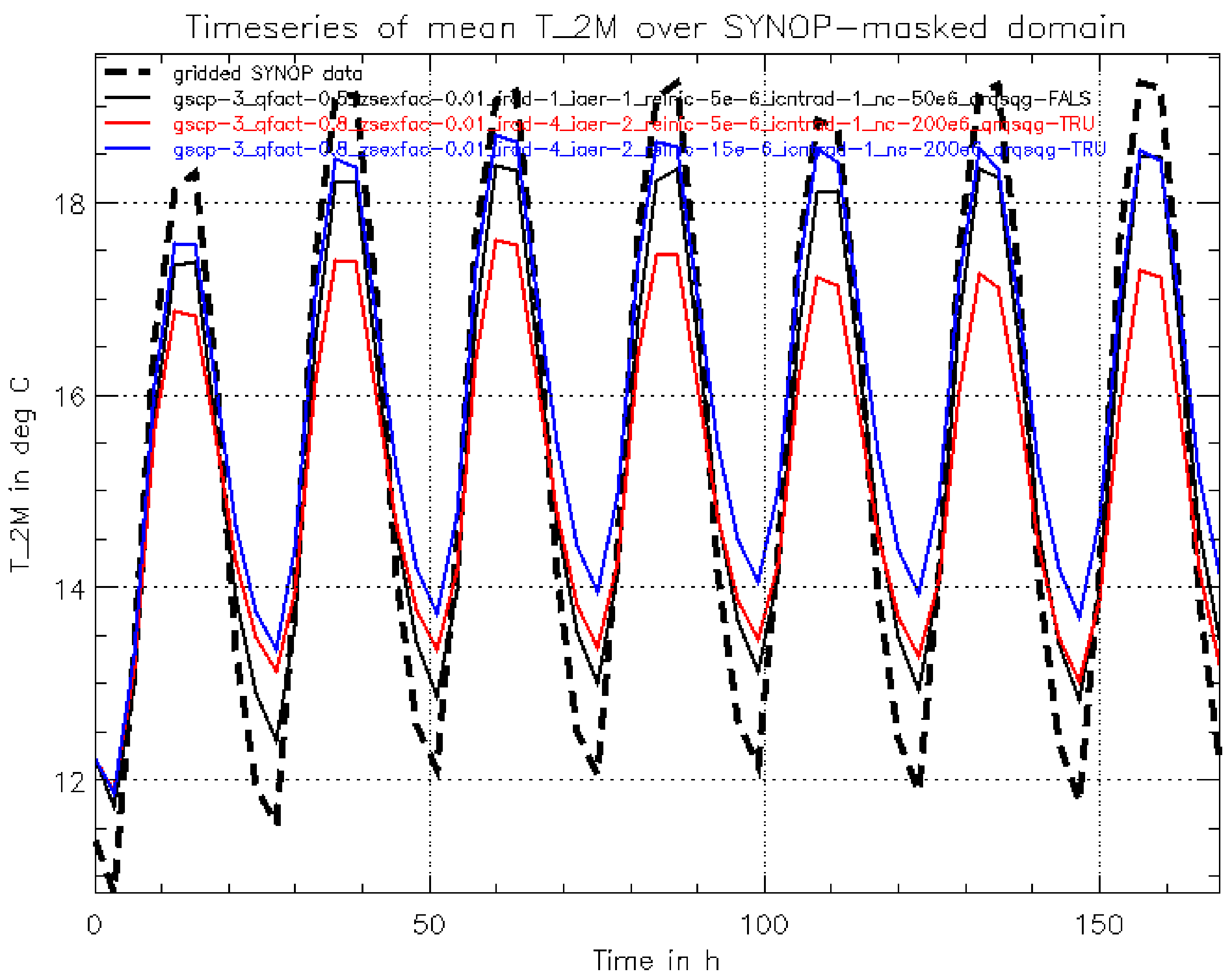

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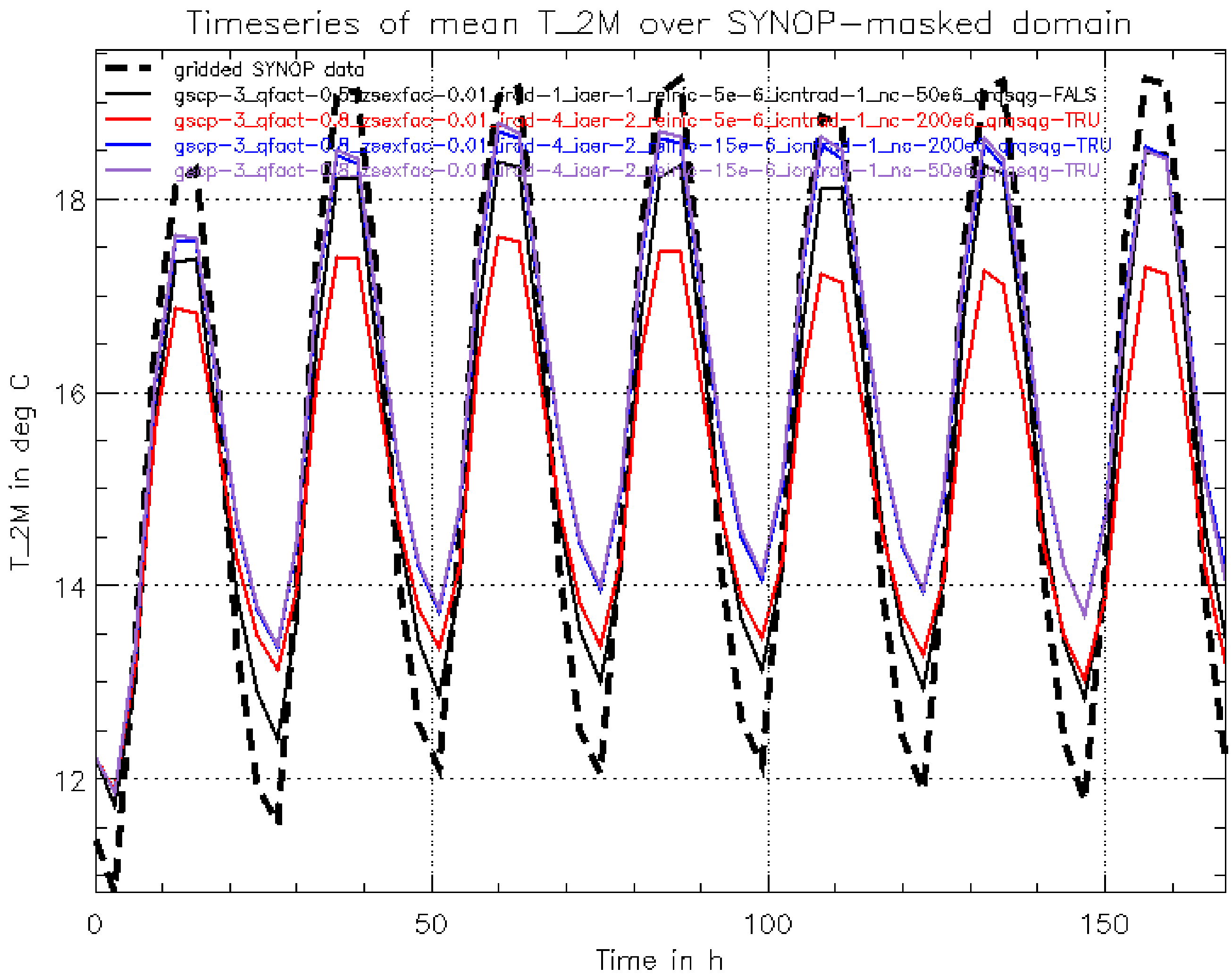

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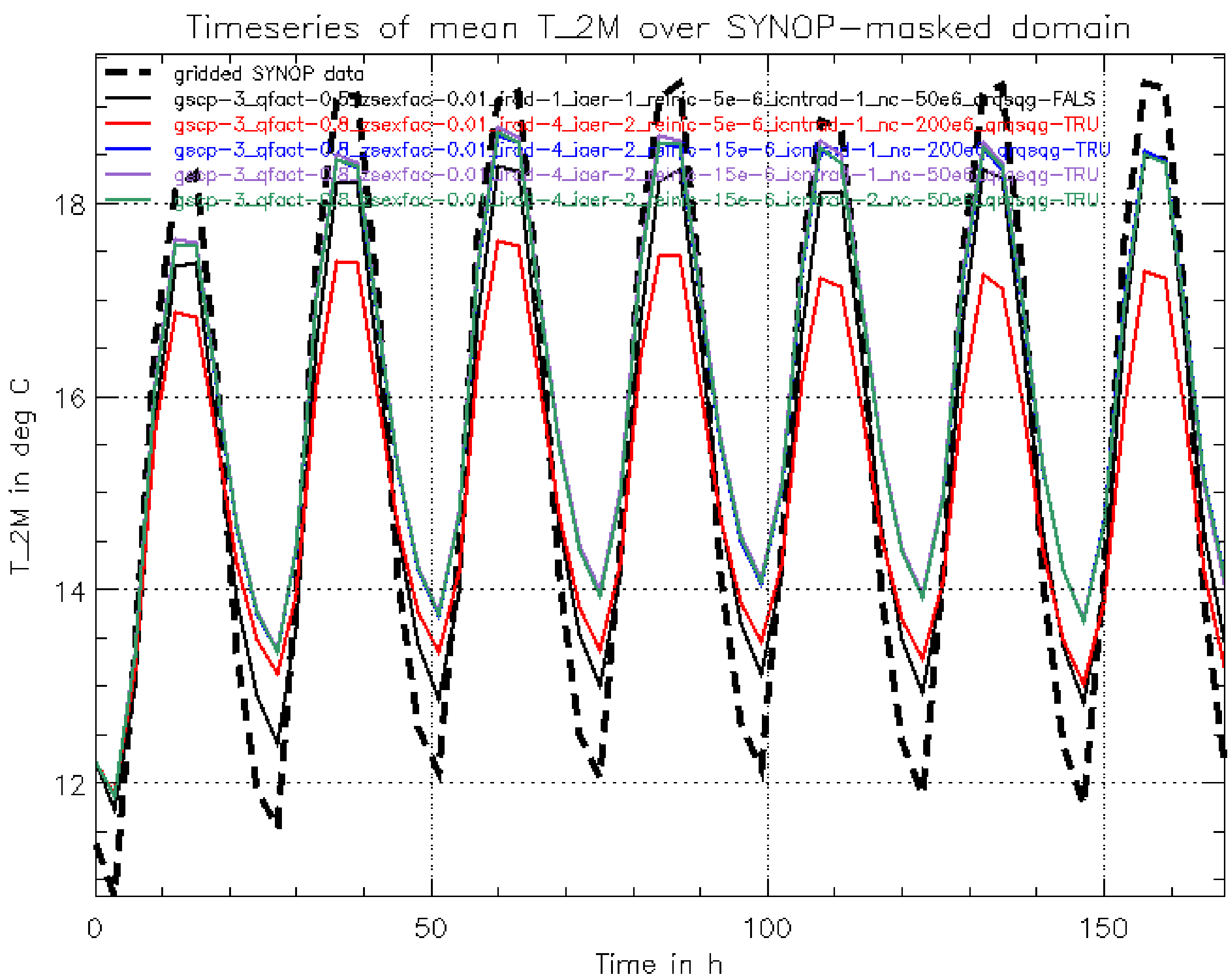

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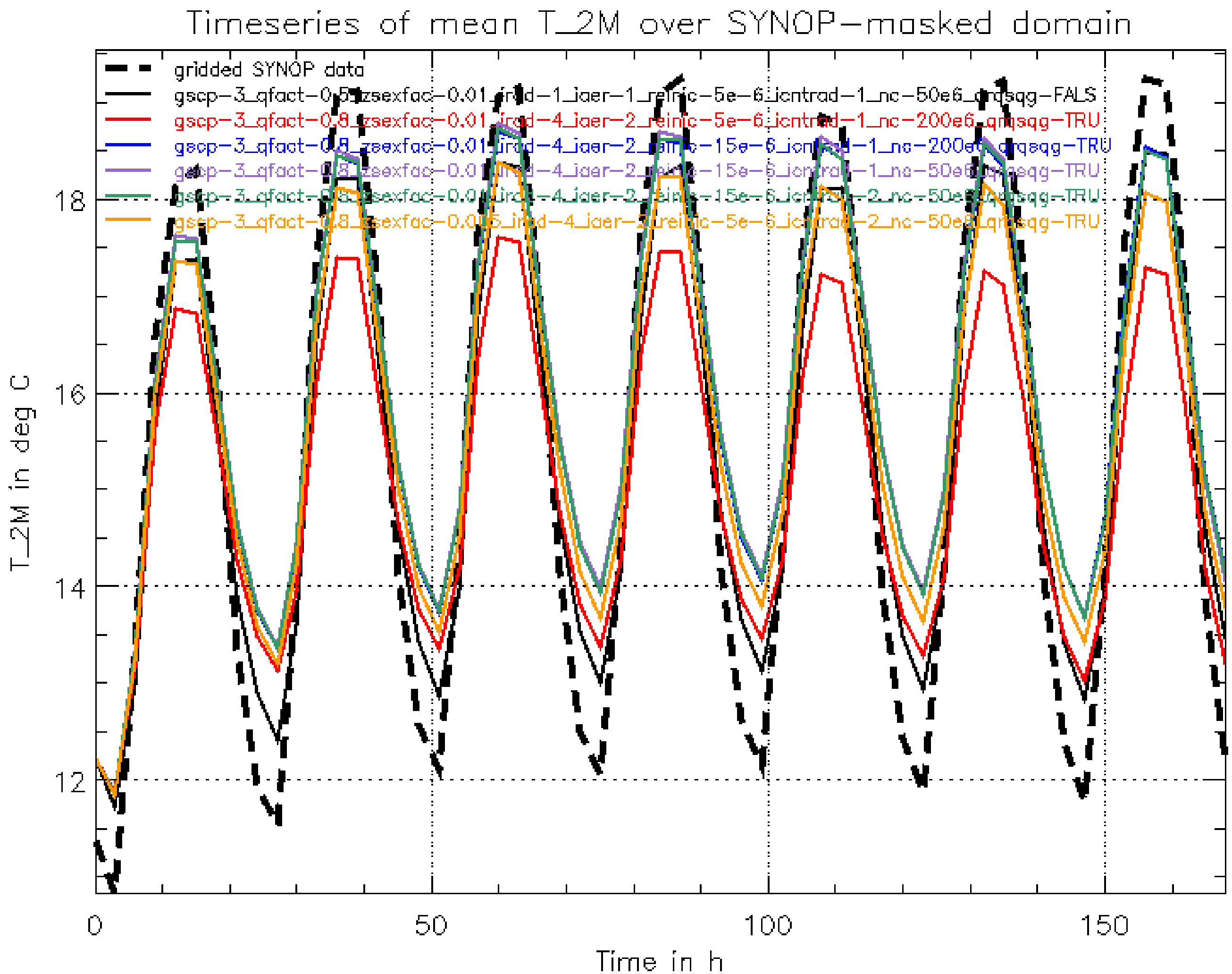

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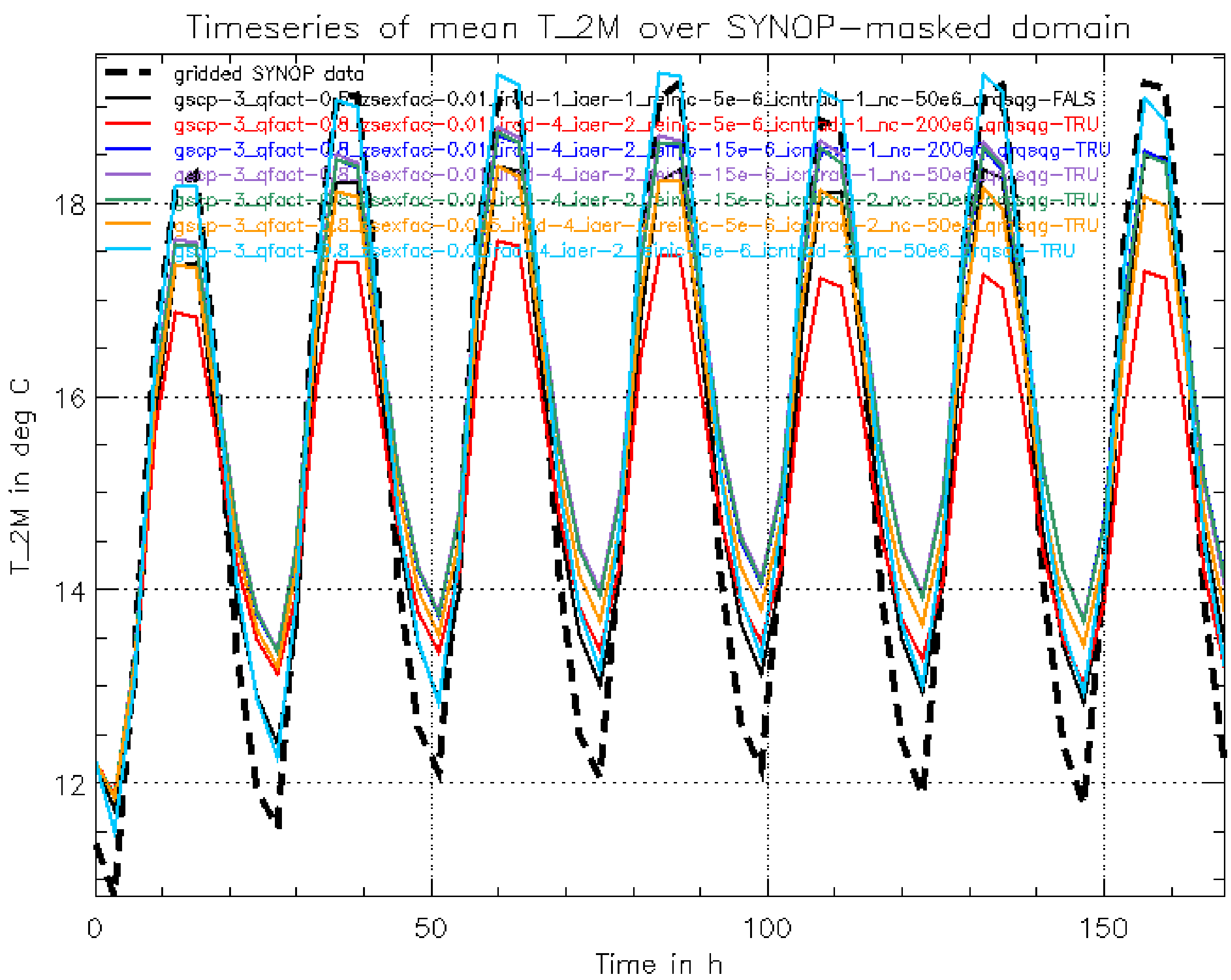

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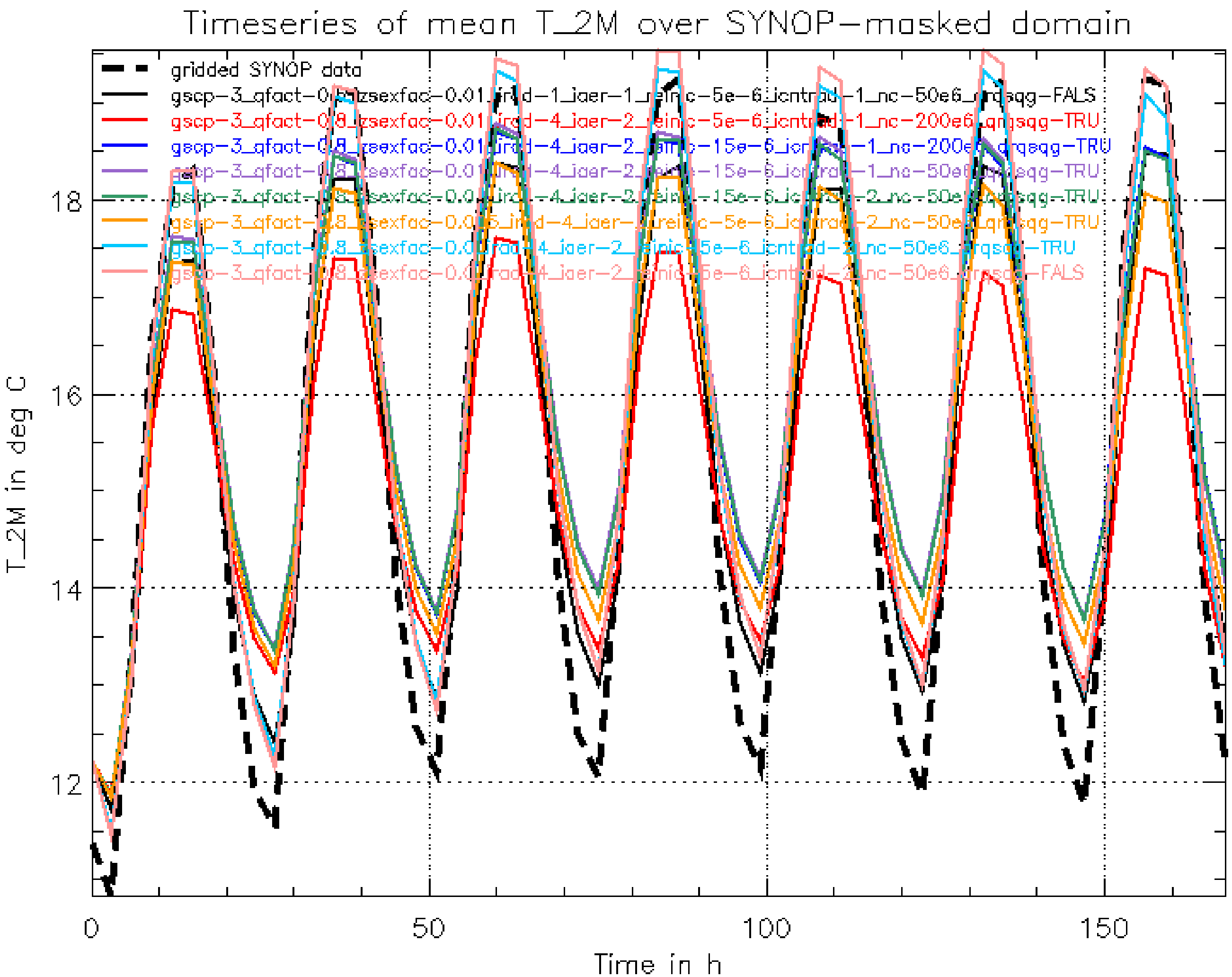

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Title

- Study with COSMO-DE (2.8 km)

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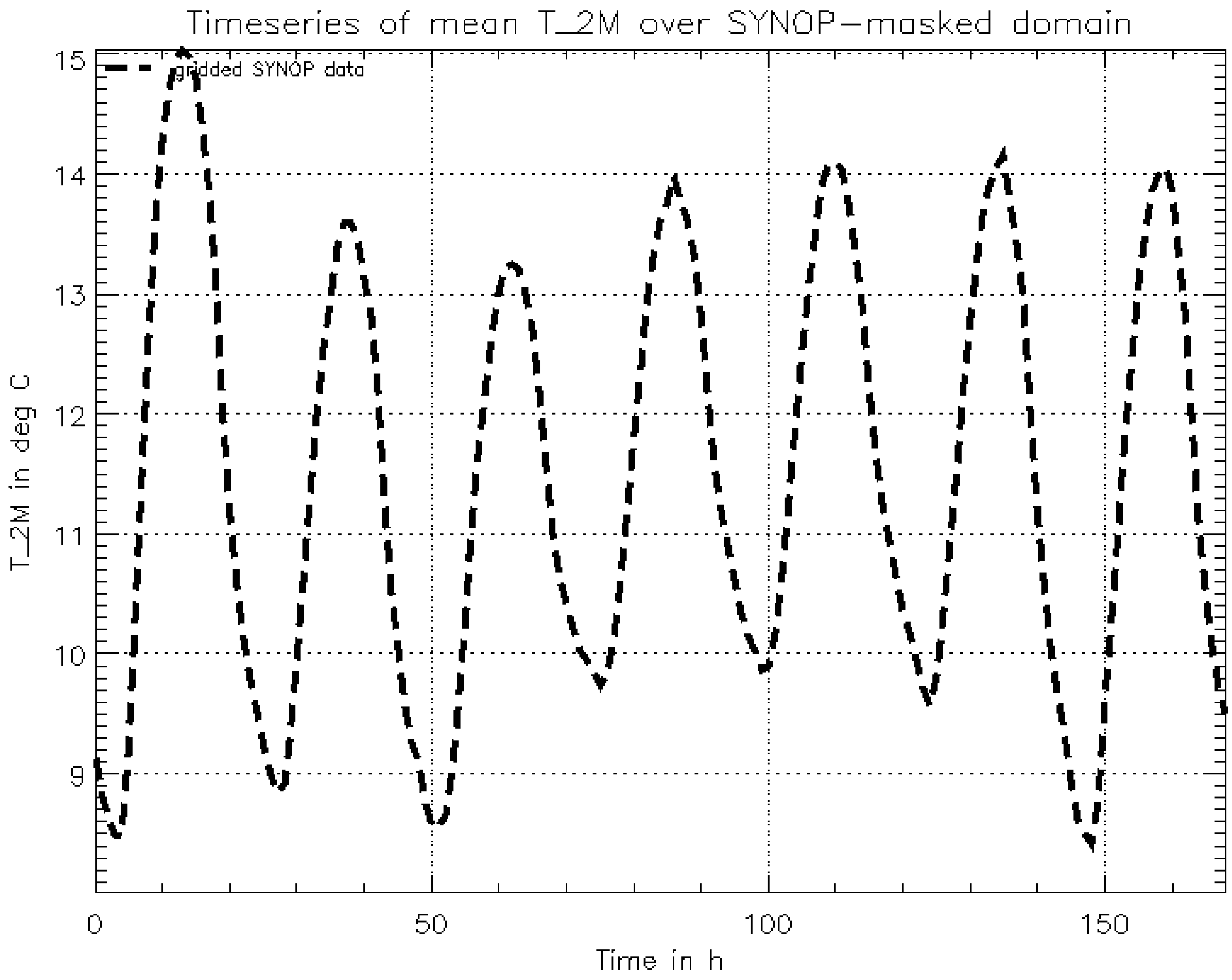
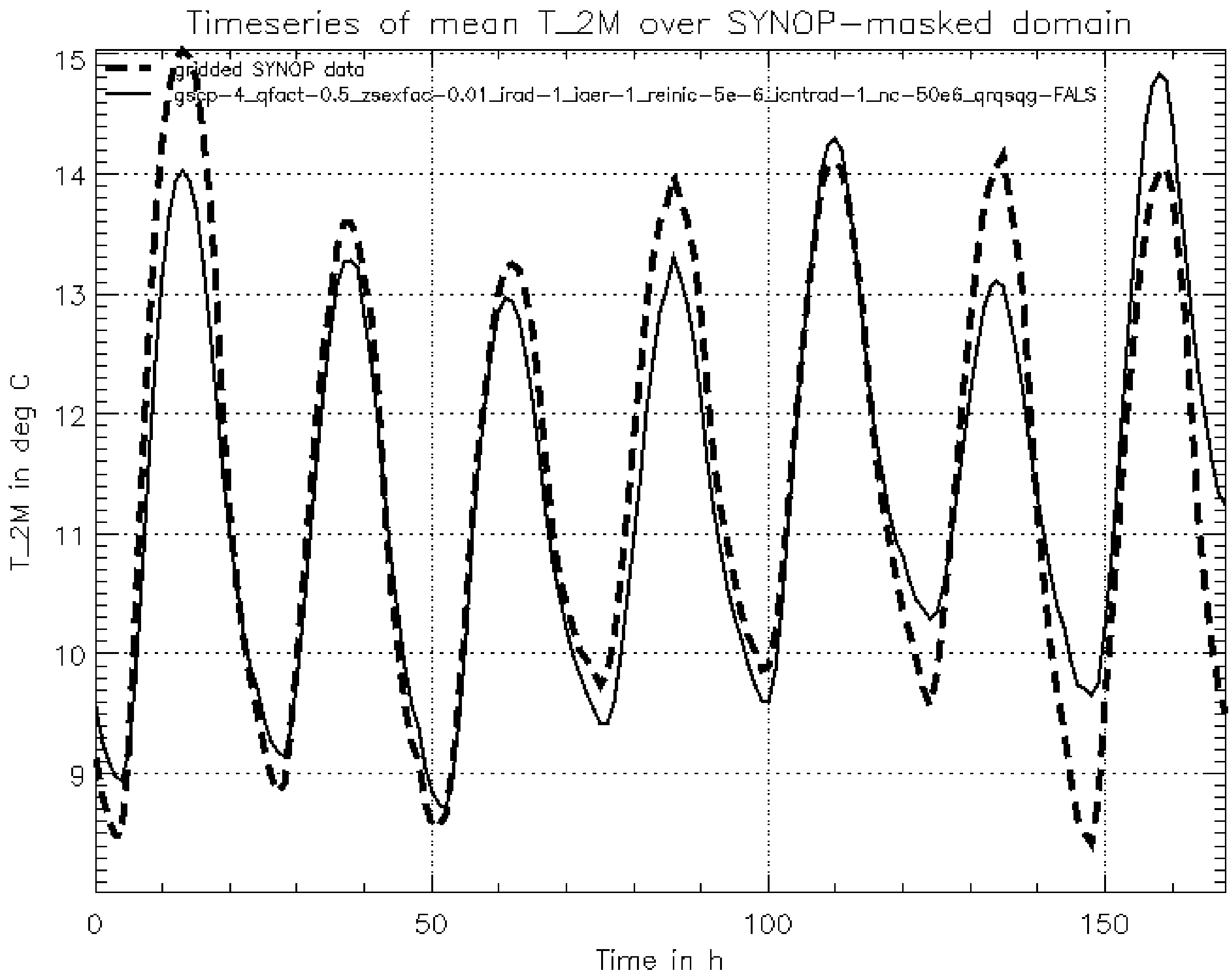


Synop Data - - - - - - -

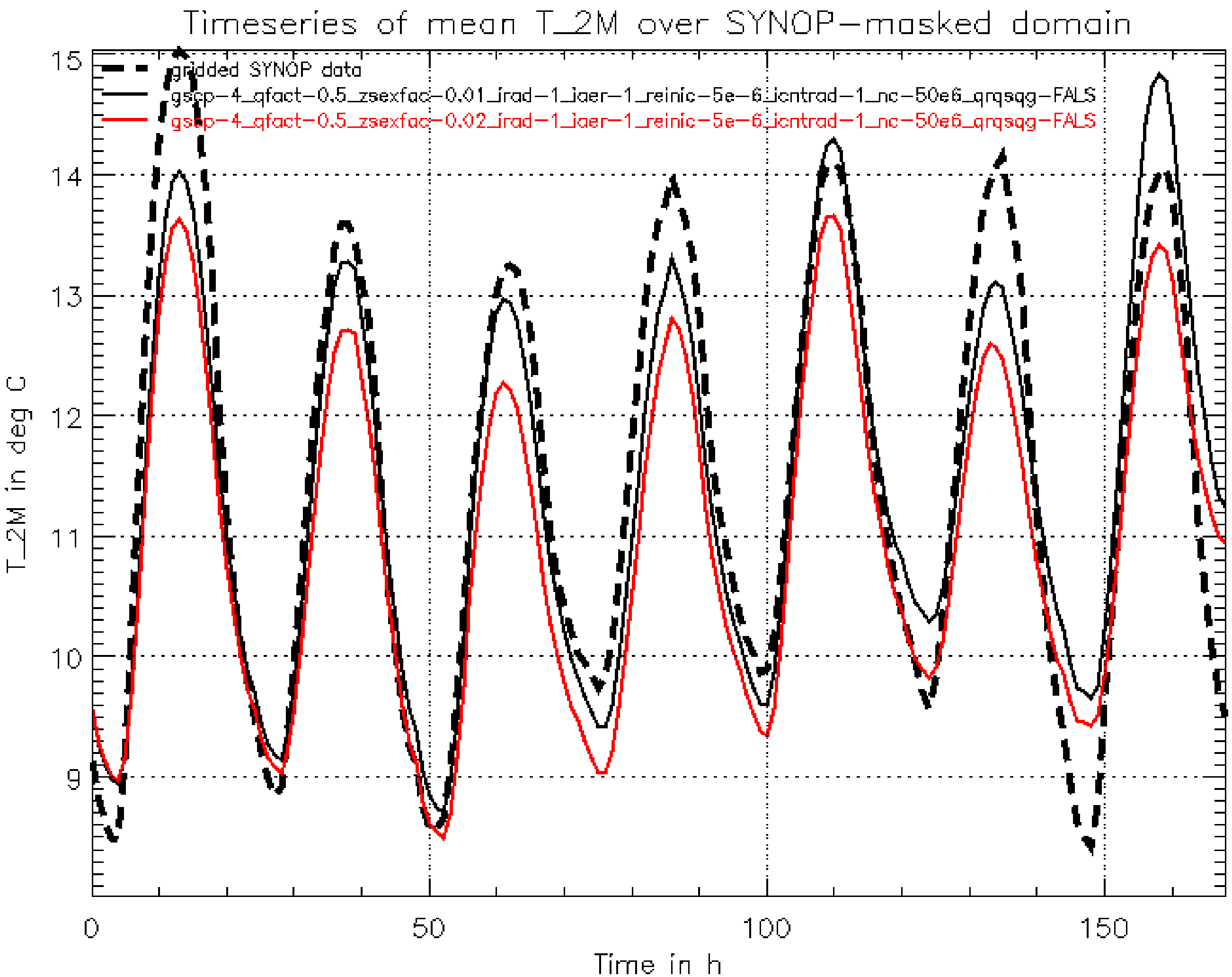
Case study: 28.5. – 4.6.2013 (C-DE)
closer look at sensitivities (1)



Synop Data - - - - - - -

Control

Case study: 28.5. – 4.6.2013 (C-DE) closer look at sensitivities (1)



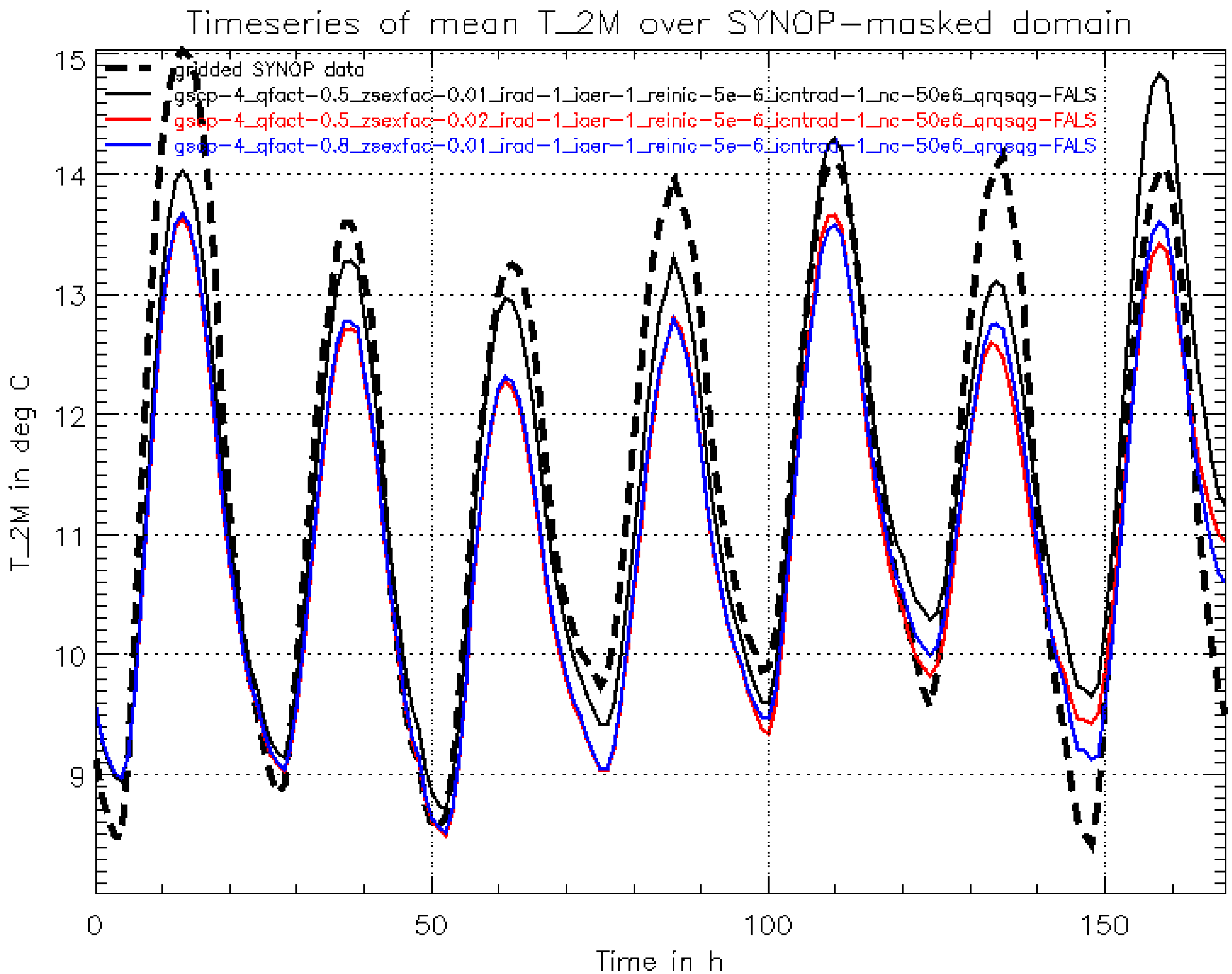
Synop Data - - - - - - -

Control

+ SGS factor from 0.01 to 0.02

Case study: 28.5. – 4.6.2013 (C-DE)
closer look at sensitivities (1)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



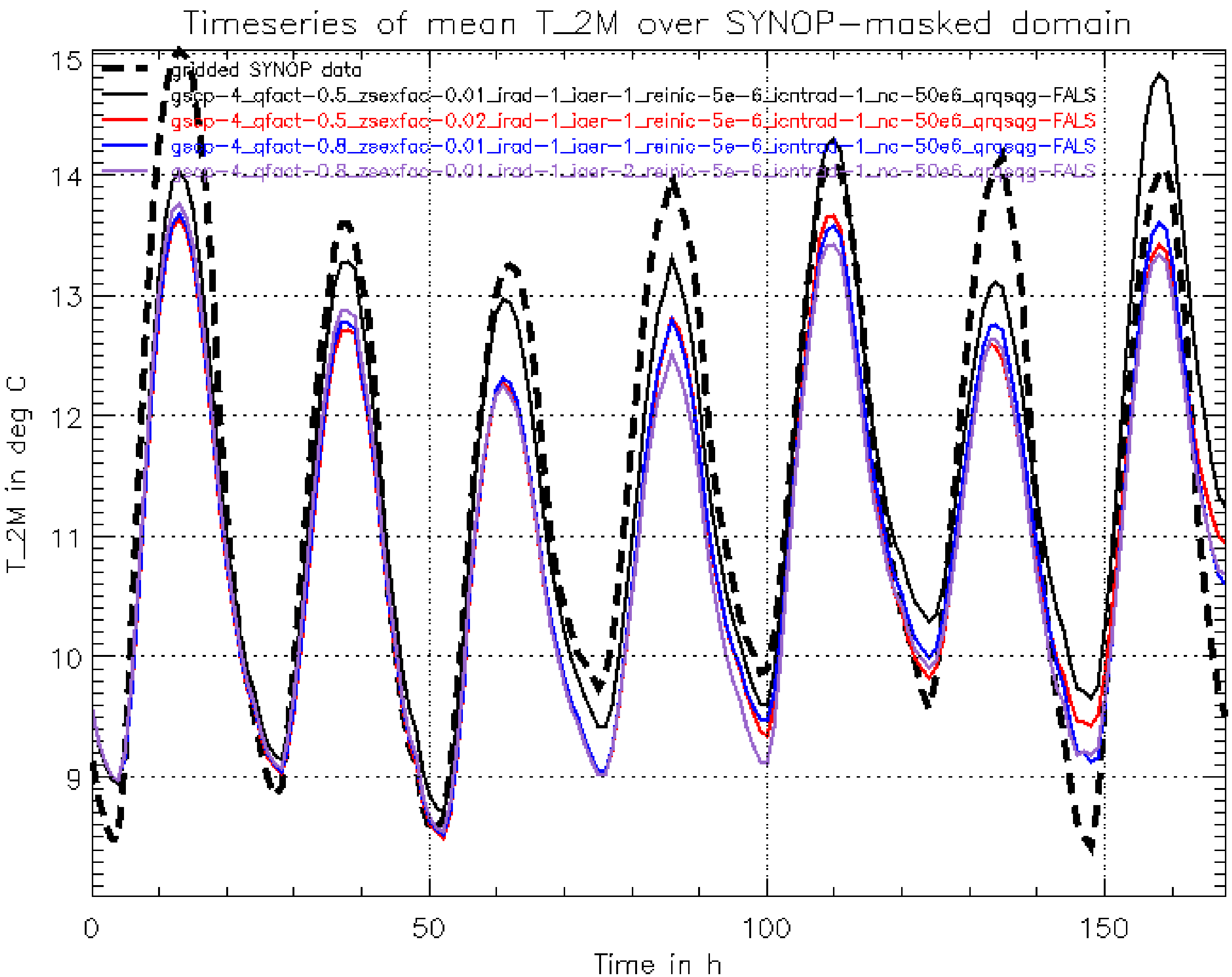
Synop Data - - - - - - -

Control

+ SGS factor from 0.01 to 0.02

+ back to 0.01, but incr. k to 0.08

Case study: 28.5. – 4.6.2013 (C-DE)
closer look at sensitivities (1)



Synop Data - - - - - - -

Control

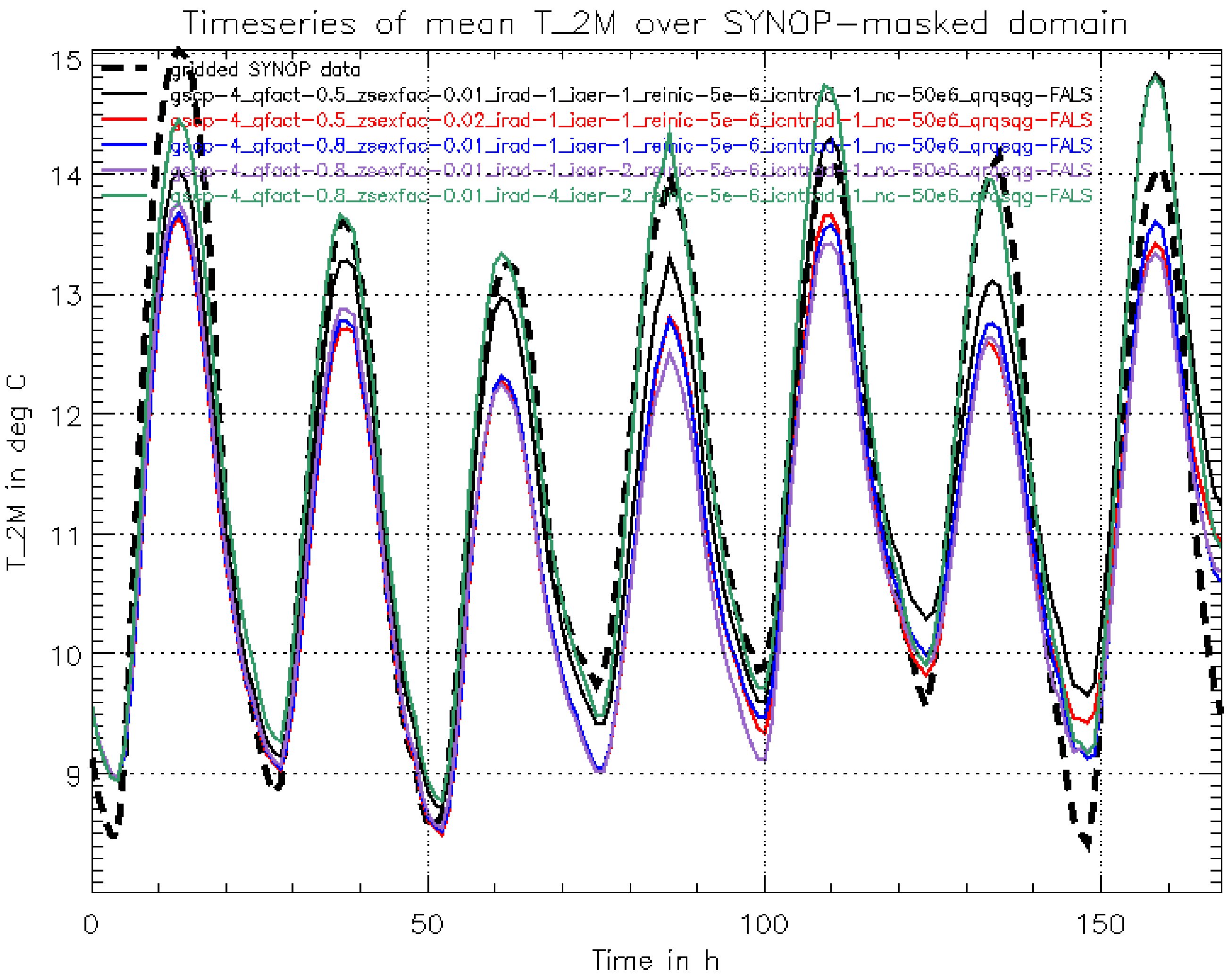
+ SGS factor from 0.01 to 0.02

+ back to 0.01, but incr. k to 0.08

+ Tegen aerosols

Case study: 28.5. – 4.6.2013 (C-DE)
closer look at sensitivities (1)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Synop Data - - - - - - -

Control

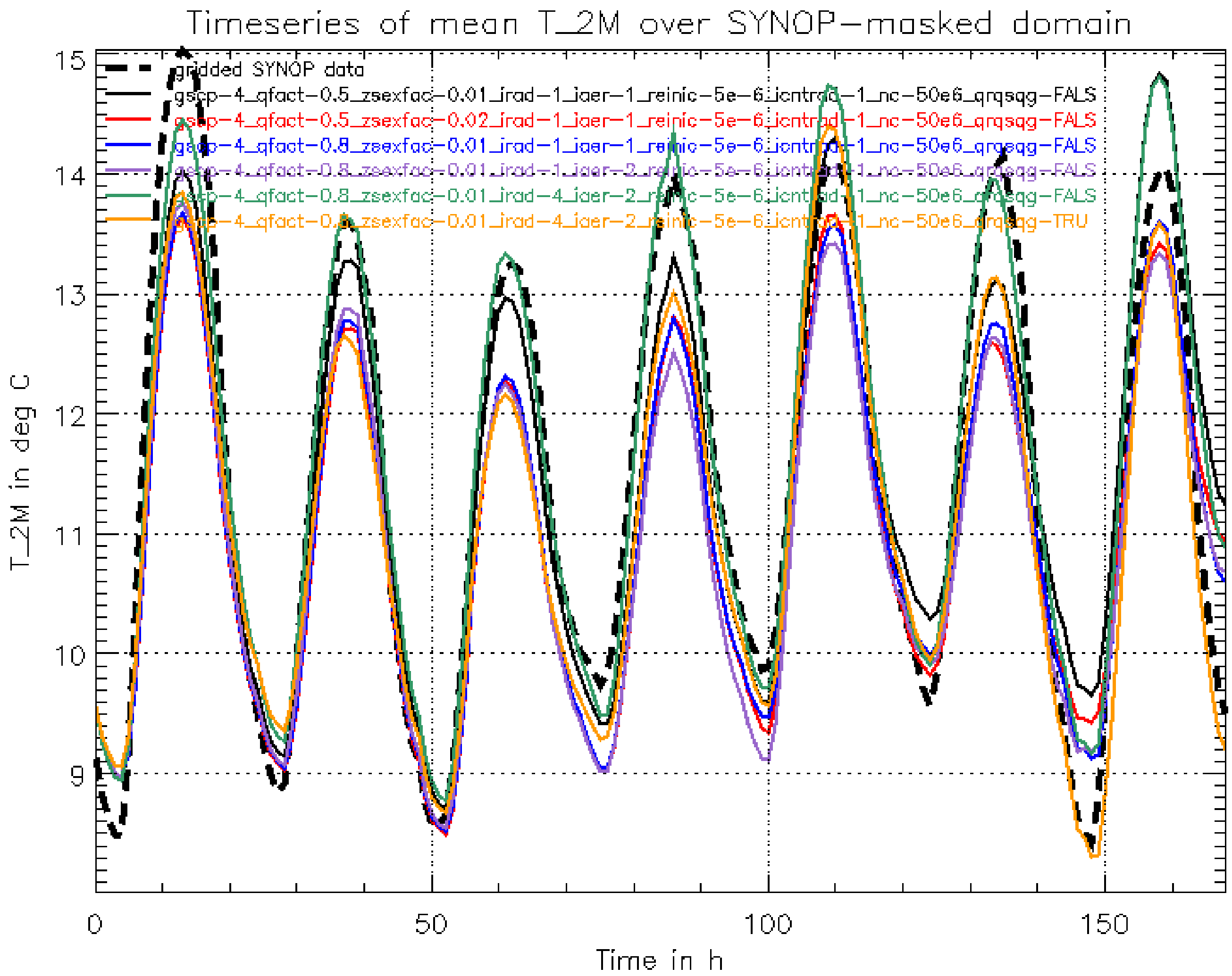
+ SGS factor from 0.01 to 0.02

+ back to 0.01, but incr. k to 0.08

+ Tegen aerosols

+ new optical properties

Case study: 28.5. – 4.6.2013 (C-DE)
closer look at sensitivities (1)



Synop Data - - - - - - -

Control

+ SGS factor from 0.01 to 0.02

+ back to 0.01, but incr. k to 0.08

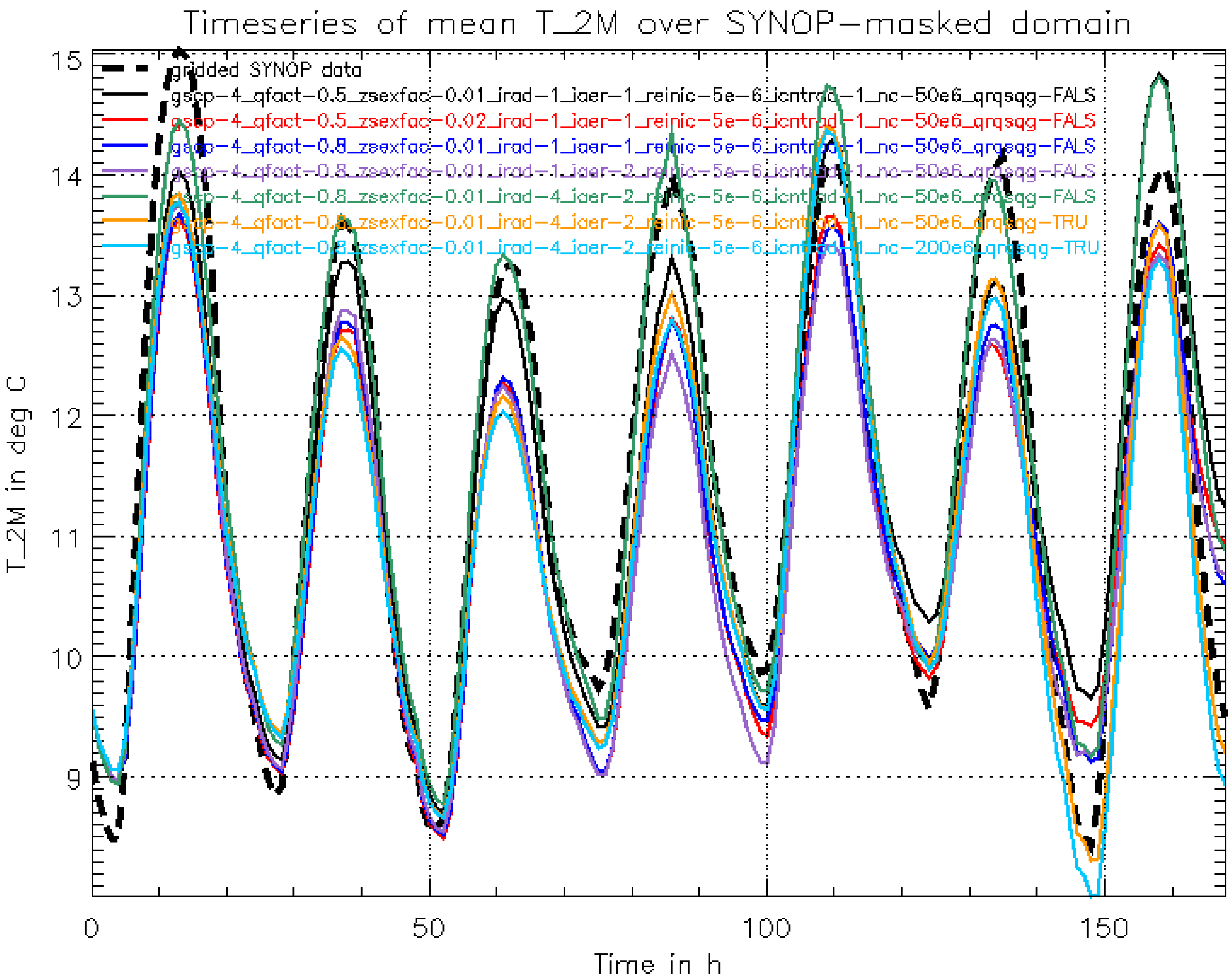
+ Tegen aerosols

+ new optical properties

+ add qs, qr, qg

Case study: 28.5. – 4.6.2013 (C-DE) closer look at sensitivities (1)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Synop Data - - - - - - -

Control

+ SGS factor from 0.01 to 0.02

+ back to 0.01, but incr. k to 0.08

+ Tegen aerosols

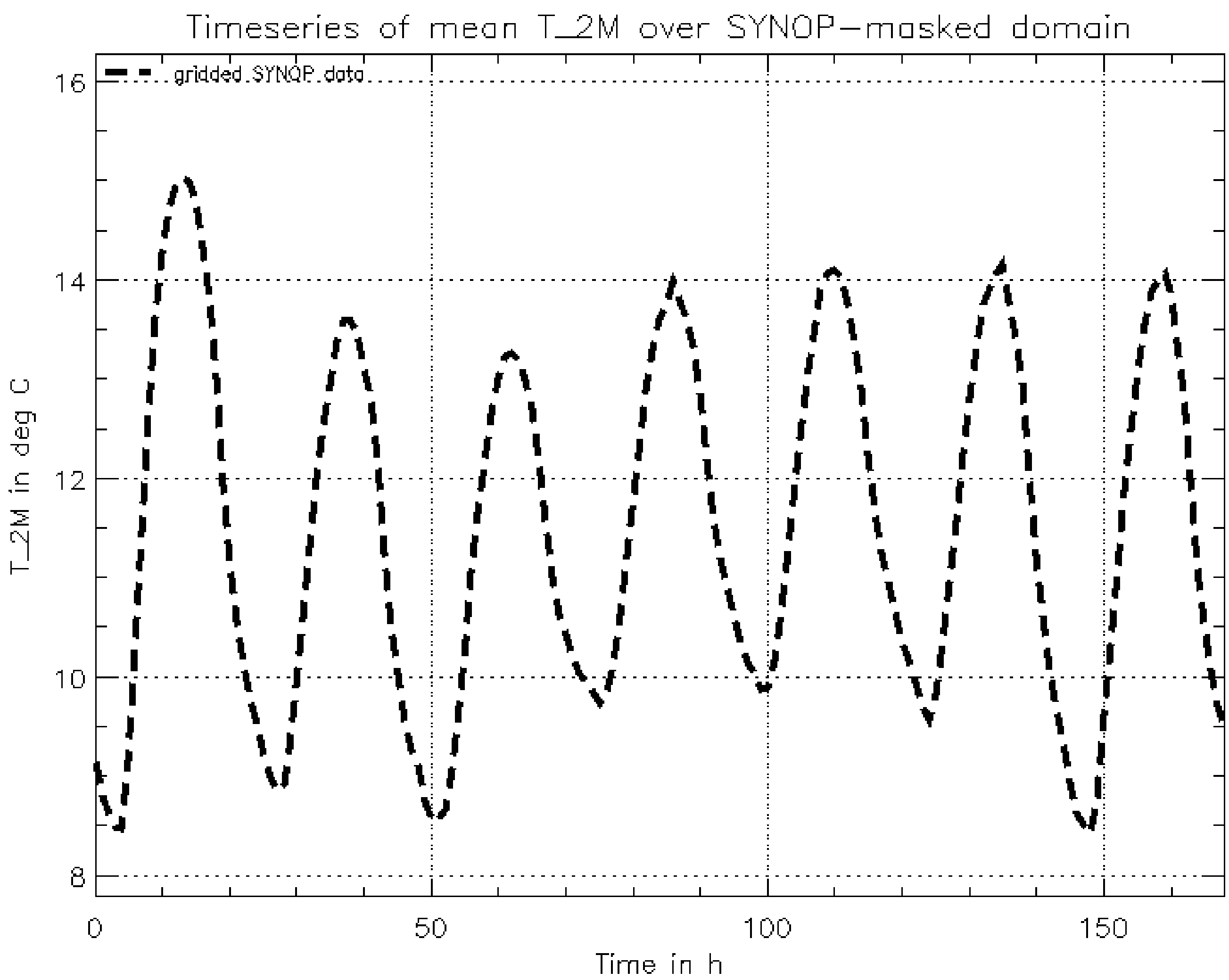
+ new optical properties

+ add qs, qr, qg

+ nc_0 from 50 to 200 cm^{-3}

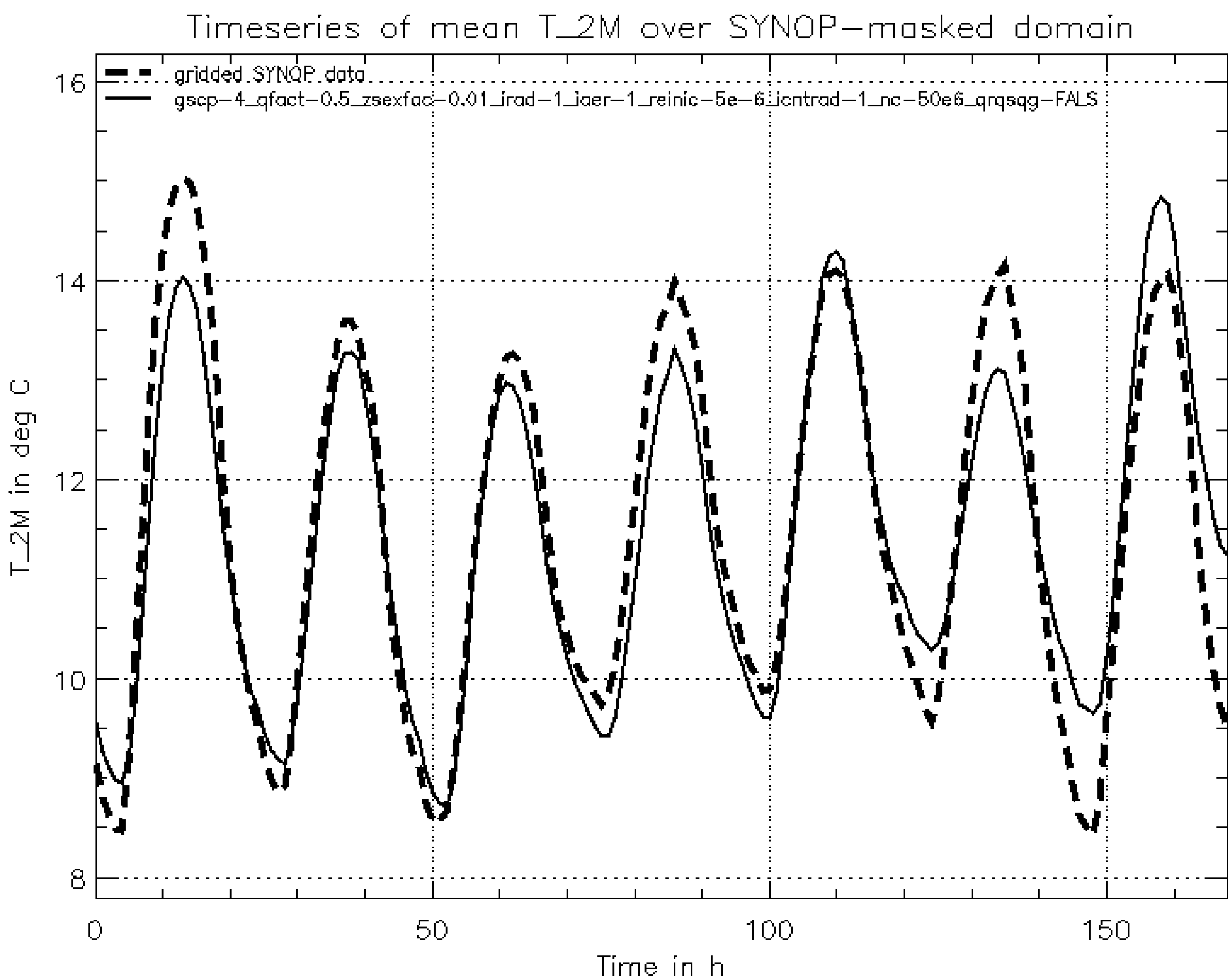
Case study: 28.5. – 4.6.2013 (C-DE) closer look at sensitivities (2)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Synop Data - - - - - - -

Case study: 28.5. – 4.6.2013 (C-DE) closer look at sensitivities (2)

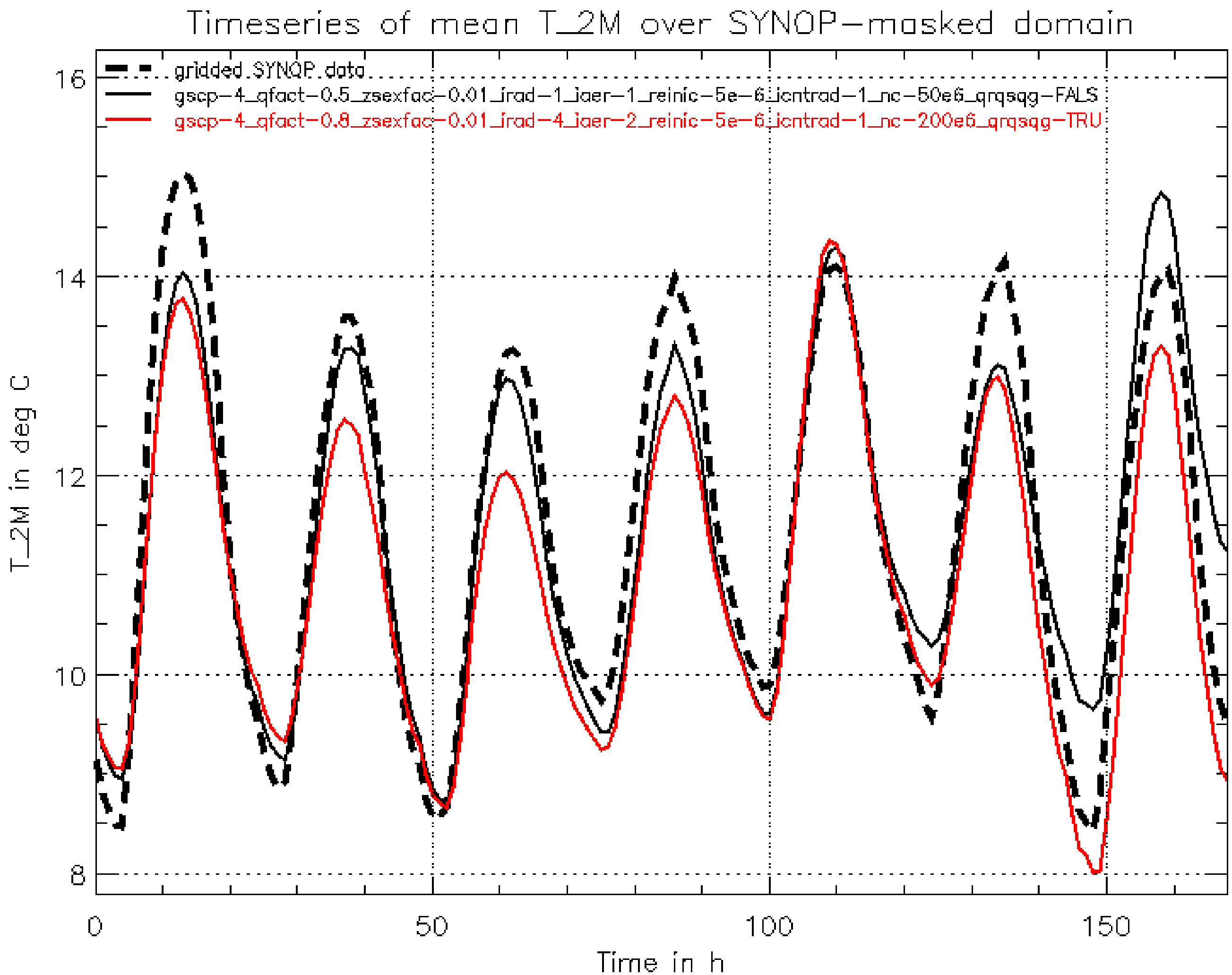


Synop Data - - - - - - -

Control

Case study: 28.5. – 4.6.2013 (C-DE) closer look at sensitivities (2)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

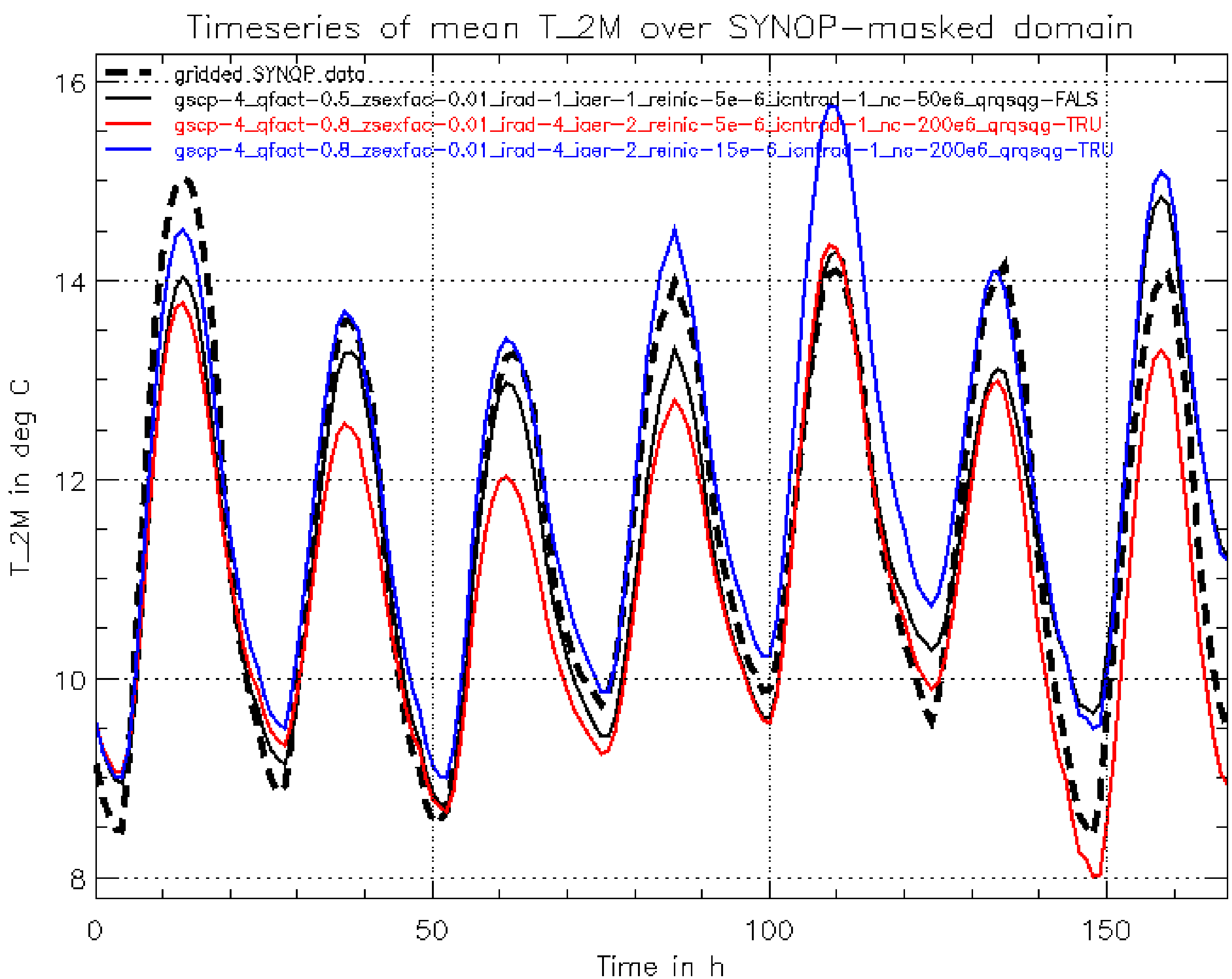


Synop Data - - - - - - -

Control

+ k = 0.8,
add qs, qr, qg,
n_{c0} = 200e6,
R_e for SGS water clouds = 5 µm,
new Tegen aerosols,
new optical properties

Case study: 28.5. – 4.6.2013 (C-DE) closer look at sensitivities (2)



Synop Data - - - - - - -

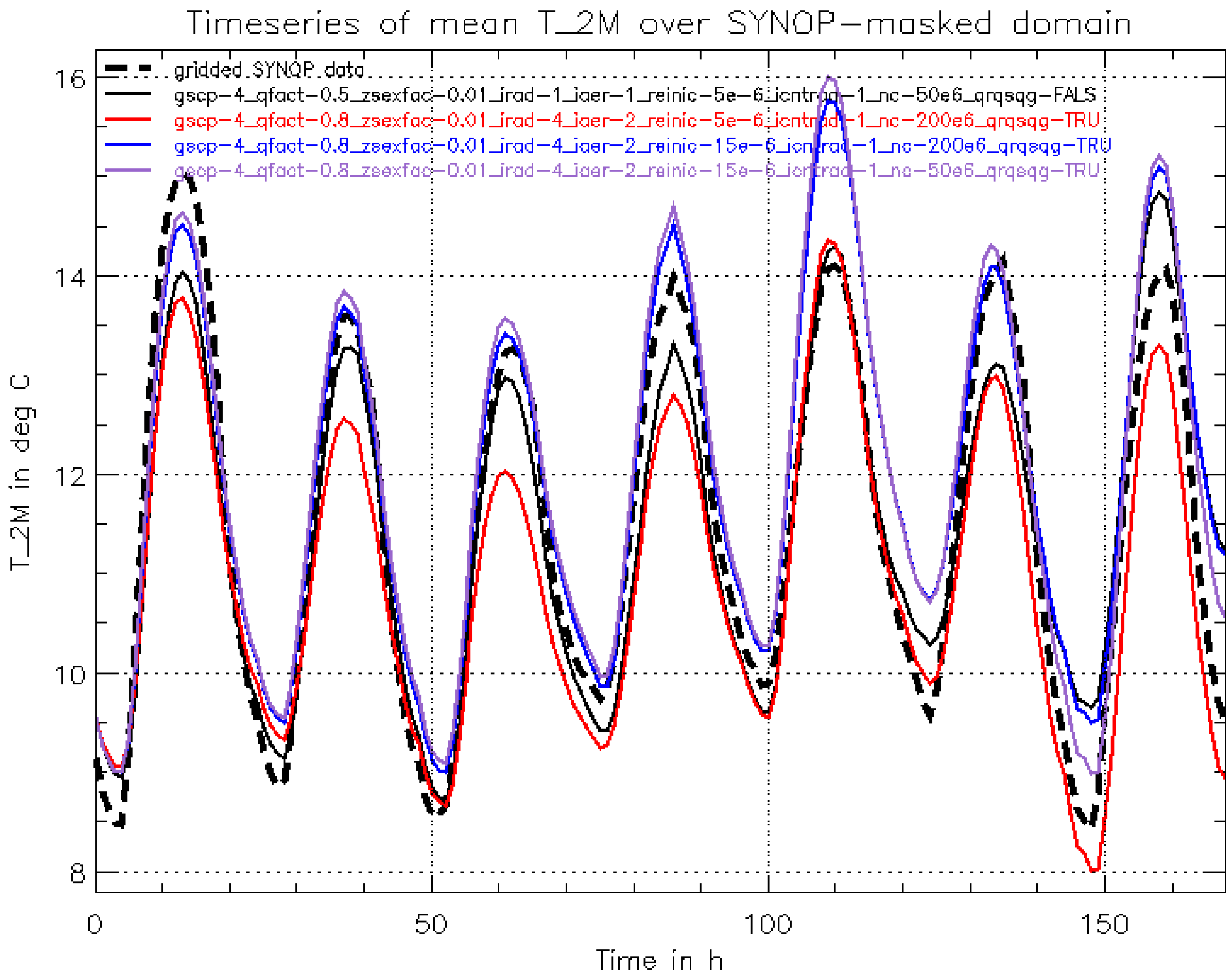
Control

+ k = 0.8,
add qs, qr, qg,
n_{c0} = 200e6,
R_e for SGS water clouds = 5 µm,
new Tegen aerosols,
new optical properties

+ incr. Re for SGS water clouds to 15 µm

Case study: 28.5. – 4.6.2013 (C-DE)
closer look at sensitivities (2)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Synop Data - - - - - - -

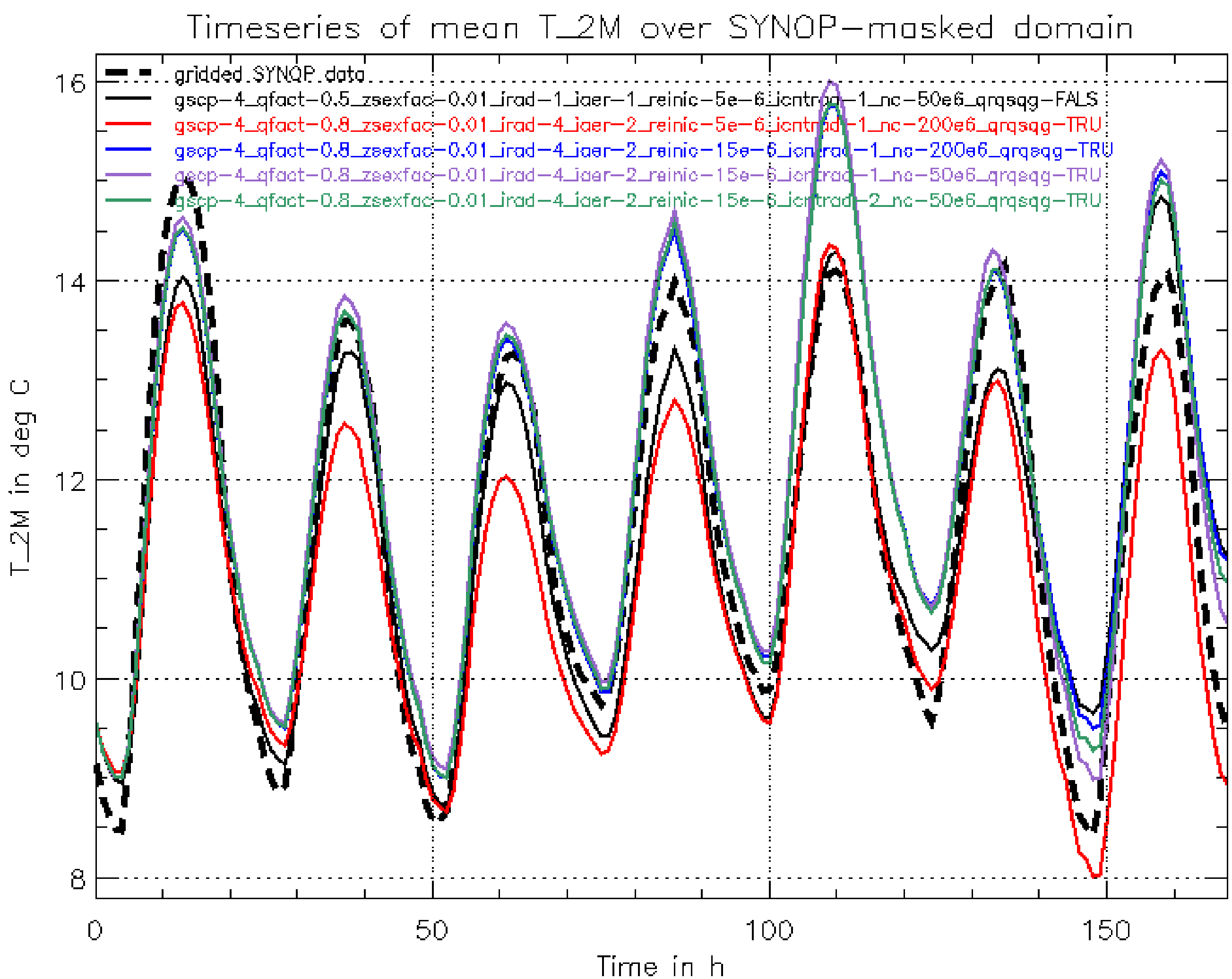
Control

+ k = 0.8,
add qs, qr, qg,
n_{c0} = 200e6,
R_e for SGS water clouds = 5 µm,
new Tegen aerosols,
new optical properties

+ incr. Re for SGS water clouds to 15 µm

+ decr. n_{c0} to 50e6

Case study: 28.5. – 4.6.2013 (C-DE) closer look at sensitivities (2)



Synop Data - - - - - - -

Control

+ k = 0.8,
add qs, qr, qg,
n_{c0} = 200e6,
R_e for SGS water clouds = 5 µm,
new Tegen aerosols,
new optical properties

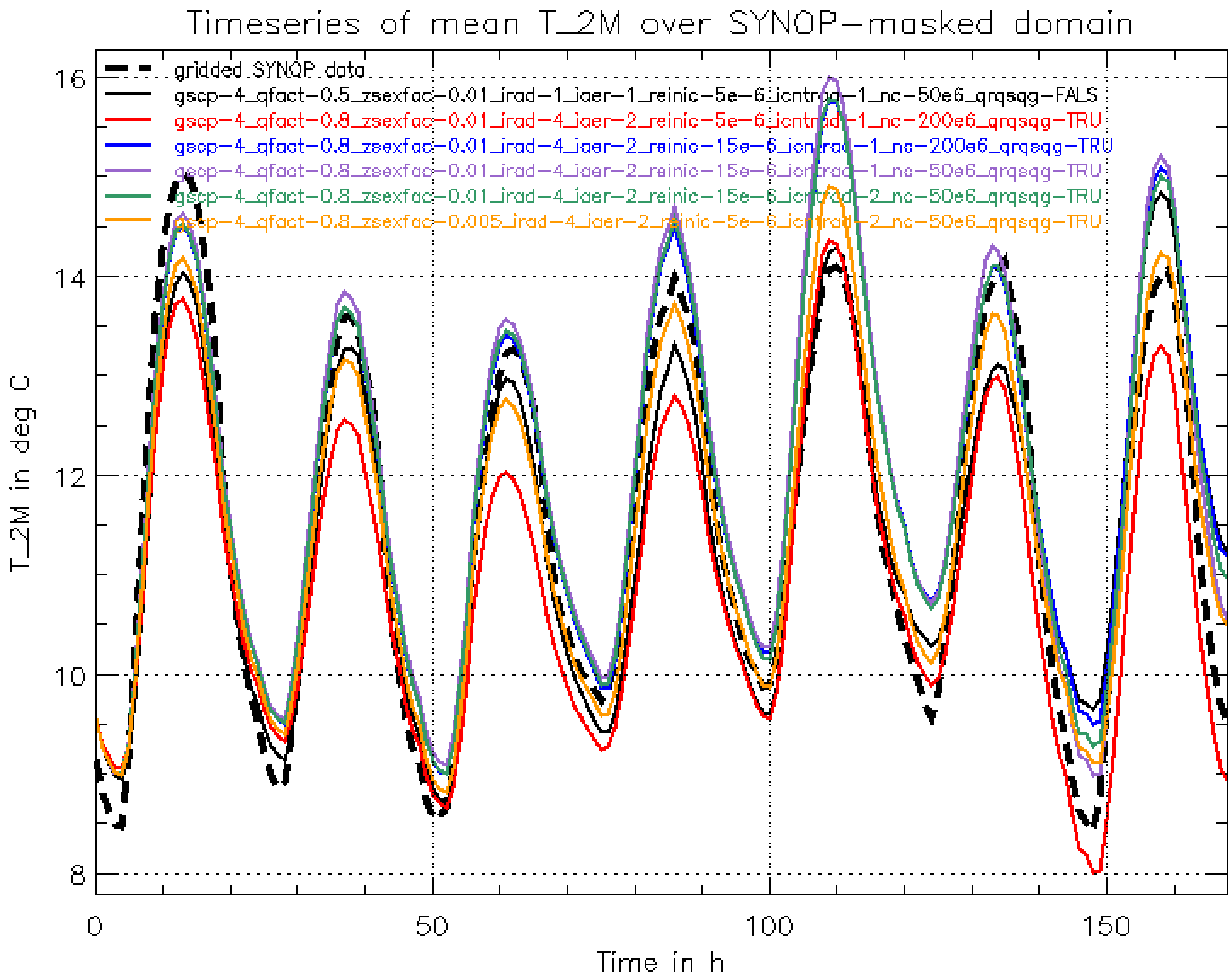
+ incr. Re for SGS water clouds to 15 µm

+ decr. n_{c0} to 50e6

+ Tegen-based n_{c0}

Case study: 28.5. – 4.6.2013 (C-DE)
closer look at sensitivities (2)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Synop Data - - - - - - -

Control

+ k = 0.8,
  add qs, qr, qg,
  n_{c0} = 200e6,
  R_e for SGS water clouds = 5 µm,
  new Tegen aerosols,
  new optical properties

+ incr. Re for SGS water clouds to 15 µm

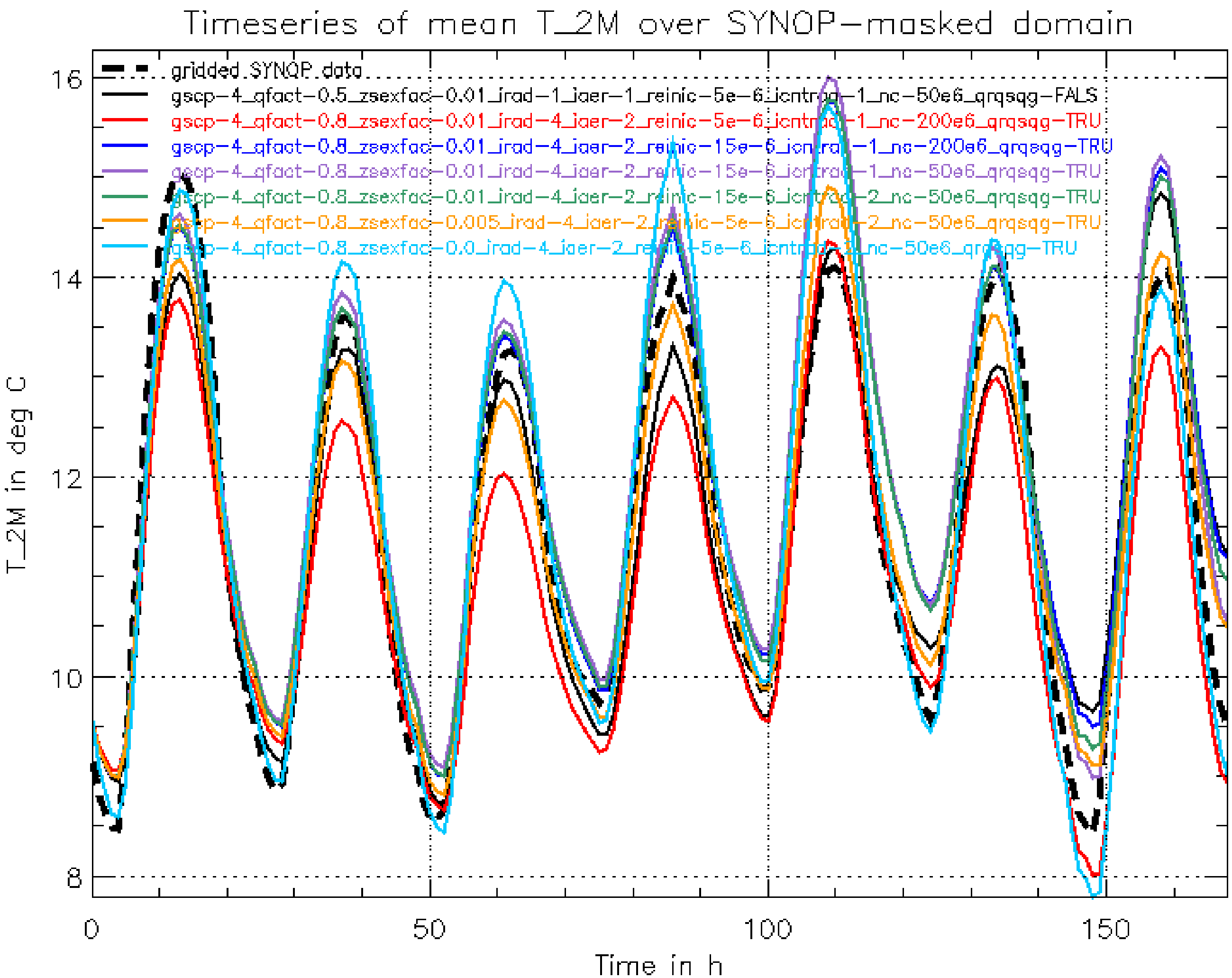
+ decr. n_{c0} to 50e6

+ Tegen-based n_{c0}

+ Re SGS water clouds back to 5 µm and SGS fact. red. to 0.005

Case study: 28.5. – 4.6.2013 (C-DE) closer look at sensitivities (2)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Synop Data - - - - - - -

Control

+ k = 0.8, add qs, qr, qg, n_{c0} = 200e6, R_e for SGS water clouds = 5 µm, new Tegen aerosols, new optical properties

+ incr. Re for SGS water clouds to 15 µm

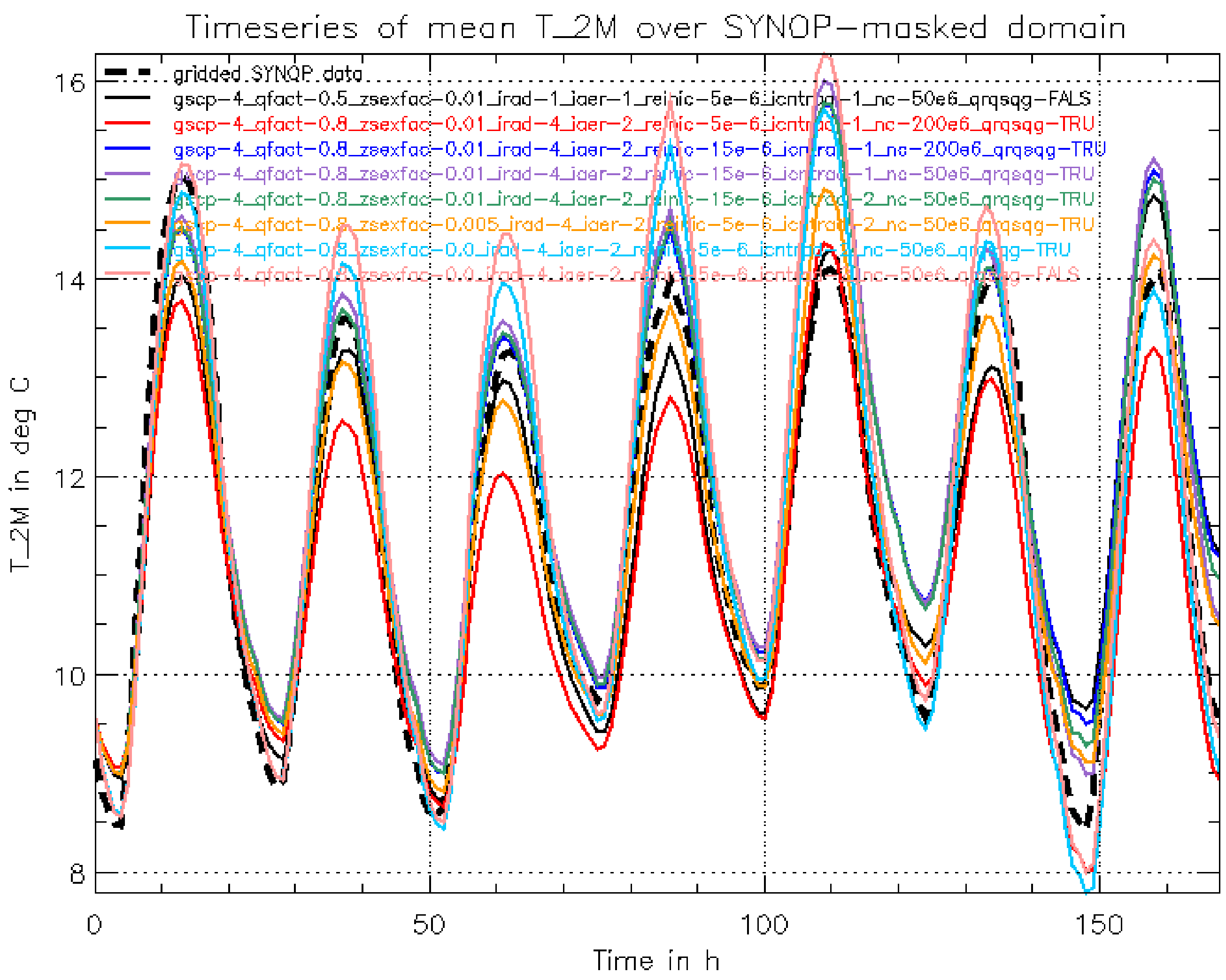
+ decr. n_{c0} to 50e6

+ Tegen-based n_{c0}

+ Re SGS water clouds back to 5 µm and SGS fact. red. to 0.005

+ set SGS fact. = 0.0 (no SGS clouds at all)

Case study: 28.5. – 4.6.2013 (C-DE) closer look at sensitivities (2)



Synop Data - - - - - - -

Control

+ k = 0.8, add qs, qr, qg, n_{c0} = 200e6, R_e for SGS water clouds = 5 µm, new Tegen aerosols, new optical properties

+ incr. Re for SGS water clouds to 15 µm

+ decr. n_{c0} to 50e6

+ Tegen-based n_{c0}

+ Re SGS water clouds back to 5 µm and SGS fact. red. to 0.005

+ set SGS fact. = 0.0 (no SGS clouds at all)

+ remove qs, qr, qg