Review of

Subvisible cirrus clouds – a dynamical system approach

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The paper presents a new, straightforward theoretical approach to explain the formation mechanism and development of subvisible cirrus clouds (SVCs). Due to their climate feedback mechanisms and high frequency of occurance this is of importance, especially since this approach has the potential to be implemeted in large-scale models where a realistic representation of ice clouds is still problematic. Thus, the topic of the paper is of interest and the method is convincing. Its structure is clear and it is mostly well written. Altogether, the manuscript is a nice piece of work and I recommend it for publication in NPG.

Of course I have some suggestions that I think could improve the paper. The amount of comments lead to my rating of the paper as 'major revisions', though I have no major criticism. In complement to the other referees, who concentrated on the theoretical work, my comments focus on the SVCs itself. In this context,

a) I like to encourage the authors, reversely to the comment of RC2:

'*Reduce the discussion of SVCs, and put more emphasis on the major point of the paper, i.e. a conceptual model using the ideas of Nonlinear Dynamics, ...*'

to extend the discussion of SVCs. More detailed recommendations are given in the specific comments below.

b) I also like to know how realistic the modelsimulations are ? Specifically,

- will the two states develop in case of a previous heterogeneous ice nucleation event, which most probabaly occurs in the atmosphere?
- Also, will the two states develop in the presence of temperature fluctuations? Especially at low vertical velocities, temperature fluctuations can influence the development of cirrus clouds.

Specific comments:

1) Abstract: in its present form, I think the abstract might not highly attract the attention of potential readers. It could be written in a more clear way and give some more information about the results and impact of the study:

   (i) for example:

   '*We found two different states for the long-term behaviour of subvisible cirrus clouds, i.e. an attractor case and a limit cycle scenario. The transition between the states constitutes a Hopf bifurcation...*'

   Please say here that the attractor case is a damped and that the limit cycle scenario an undamped oscillation of the cirrus properties. Also, it would be more clear to say that the two states differ by the microphysical properties of the developing cirrus (attractor regime: stable cirrus at higher T with in general fewer and larger ice crystals, limit cycle regime: unstable cirrus at lower T with in general more and smaller crystals) and are separated in the temparature – vertical velocity parameter space by a Hopf bifurcation.

(ii) it should be noted in the abstract that the study is valid for vertical velocities < 5 cm/s.

(iii) I also would recommend to include a sentence on the impact of the study to investigate 'structure formation' and also on the 'potential for large-scale models' – both points are now only mentioned at the end of the conclusions.

2) First part of Introduction: the word 'usually' appears quite often …

3) Introduction:
(i) the reference Hoose and Möhler (2012) is used for heterogeneous ice nucleation , but this process is already known much earlier. Isn't there a more basic reference?
(ii) line 36: you might also cite the articles of Immler et al. (2008), ACP, one study on mid-latitude and the other on tropical cirrus.

4) Page 9: (i) 2.5 '*Additional settings*' maybe better '*Boundary conditions*' ?

(ii) I would recommend to provide a header to points 1. and 2., so that the reader has an immediate idea about the major settings. E.g. :

1. *Langrangian coordinates*: *Instead of an Eularian ….*

2. *Constant air parcel volume at cloud top and w < 5cm/s*: *In our study, we will exclusively consider very low vertical velocities or vertical changes with limited amplitude.*
→ please also tell the reader here the reason to choose only very low vertical velocities – I think I know ;-) .

5) Page 10, first paragraph: '*… meaning that after twelve hours the temperature difference would be about 8 K.*' Would be good to note the magnitude of the change of Nc due to a density change caused by cooling by 8K is.

6) Page 11, first paragraph: ODE is not defined.

7) Page 12, end of second paragraph:
'*In fact, sedimentation is the key process, which leads to different states in the cloud evolution. The system exhibits two qualitatively distinct behaviours, depending on the parameter values of w and T.*'
Where is the link between the two sentences ?

8) Page 12, lines 340 and 353: *State 1: …* and *State 2: …*
It would be helpful and more clear for the reader if the definitions are more specific (here and throughtout the manuscript)

State 1 (attractor regime, damped oscillations): …
State 2 (limit cycle regime, undamped oscillations): …

9) Page 12, line 340: '…, *the three competing microphysical processes …*'
Please define the processes, I guess you mean
' … , the three competing microphysical processes -nucleation, growth, sedimentation- *…*'

10) Page 12, lines 343-344: '*… resulting in a damped oscillation in all three variables,*

finally asymptotically reaching an equilibrium ...'
better
'... resulting in a damped oscillation in all three variables Nc, qc, RHi, which finally asymptotically reaches an equilibrium ..'

11) Page 14, second paragraph: Here I miss a more detailed discussion of Figure 5.

What I see is that the higher the temperature, the higher w must be to switch the system from the damped attractor to the undamped limit cycle regime. That means that damped attractor cases are more frequent at higher temperatures and undamped limit cycle cases at lower temperatures, yes ? Please discuss.

12) Page 14, line 424 and 425:
'*correspond to state 1 (attractor regime, damped),...*'
'*... for state 2 (limit cycle regime, undamped);*'

13) Paragraph page 14-15: Also Figure 6 could be discussed in more detail.

In this Figure it can be seen that most warmer cirrus are in the stable damped attractor regime, with few, large crystals. At colder temperatures there is a tendency to more variable cirrus with more, smaller crystals at higher w (limit cycle regime).

A further consideration could be if the cirrus in the limit cycle regime are still SVCs? Immler et al. (2008), ACP, provided relations between OD, IWP, Nc and Rc. Using these relations it should be possible to see which of the simulated cirrus are SVCs and which are thin cirrus – maybe only attractor regime cirrus are SVC?

A last thought to Figure 6: a third panel showing the mean size would be informative.

14) Page 15, lines 433 – 436: 'I*n the double logarithmic representation in figure 6, the number concentrations Nc(w) at x0 appear as straight lines. For different temperature regimes, there seems to be a constant shift between the curves Nc(w) (i.e. a constant factor c(T)), leading to parallel lines in the double logarithmic representation.*'

Here you mean the attractor regime, yes ? Please state.

15) Page 17, first paragraph: you use '*damped oscillations*' (line 500) together with '*limit cycle*' (line 504). To ease the undertanding of the manuscript, I recommend to always use 'attractor case (damped, state1)' together with 'limit cycle (undamped, state 2).

16) Page 19, line 568:
'*The microphysical properties of the cloud in both states are similar ...*'
I wouldn't say that they are similar, see comment 13 !
Same comment for lines 586-587.

Comments to the Figures:

Figure 1, caption: '*Here, a scenario in state 1 (damping) …*'
better 'Here, a scenario in state 1 (attractor regime, damping) …'

Figure 2, caption: '*Positive attractor for state 2 (limit cycle) …*'
better 'Positive attractor for state 2 (limit cycle, no damping) …'

Figure 5: A suggestion

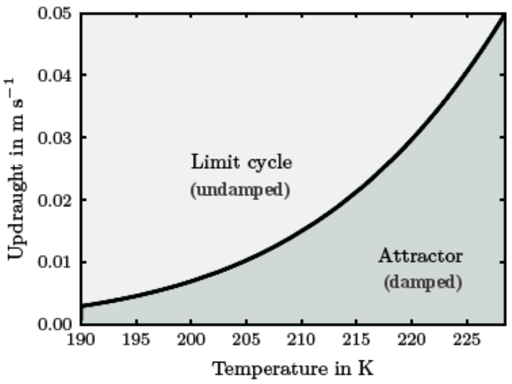

Figure 6:

- On the right axis, it would be very helpful if the values of Nc in 1/L and qc in g/m3 which are noted in the text would be marked.
- Caption: '*Solid lines are for parameter combinations (w, T) in the attractor regime (state 1), dashed lines are for the limit cycle regime (state 2).*'

better 'Solid lines are for parameter combinations (w, T) in the attractor regime (damped, state 1), dashed lines are medians of the the limit cycle regime (undamped, state 2), see also Fig. 7.'

- I would find it informative to also see a panel showing mean sizes.

Figure 7, caption: '*The solid line represents values at the critical point x0 of the attractor regime.*', *yes ?*

Figure 8:

- Wouldn't it be worth to note in the text that the median state of the limit cycle regime is nearly identical with the attractor regime (this is also seen in Figure 7 ….)?
- Caption: '*For the critical point x0 of the attractor regime …* ', yes ?