Report from the Venus climate working group 3rd meeting 18-19 May 2009

Participants

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1. Observational aspect

1.1 Present status of the Venus Express mission & ESLAB Meeting (Svedhem, Titov)

The Venus Express mission continues the successful collection of a wide range of scientific data, which provide valuable information of the Venusian atmosphere and clouds.

- *Atmospheric structure*: The observations (from radio-occultation measurements) show neutral conditions (temperature follows dry adiabatic lapse rate) below 60 km (only as it appears minor latitudinal variations in the height of the tropopause) and stable stratification above the cloud top for the layer 60-80 km. A temperature inversion is apparent at the cloud top at polar latitudes. Convective regime persists within the clouds, which, however, seems to disappear below the clouds (except for high latitudes).
- *Atmospheric composition*: Measurements in the lower atmosphere from VIRTIS show CO, H_2O, COS and SO_2. The clouds between 45 -65 km consists of H_2SO_4.
- *Venus airglow emission*: The mission provides significant information concerning the airglow emission of the planet. These emissions are centred at the night side of the planet (anti-solar point) and come from NO and O_2. NO airglow is displaced in respect from O_2, probably because they come from different layers and altitudes.
- *Cloud and hazes morphology observations*: The cloud-top is found in lower altitude in the polar areas (65km instead of around 75km in the rest of the planet).
- *Atmospheric dynamics*: New data have been presented related to the planetary super-rotation and a possible dynamical transport barrier at 50-60°.

Venus express will probably extend until end of 2012. More news on that after the meeting of the financial committee (1st & 2nd October 2009).

A report on the successful outcome of the Earth-Venus-Mars ESLAB meeting at ESTEC was presented by Håkan Svedhem.

1.2 Report on the Japanese mission (Yamamoto)

The Japan's Venus climate mission is proceeding as planned. The final integration test will be on June 2009 and the launch will be held after one year (June 2010). The observation period is of 2 years.

1.3 Report on the status of US planned missions (Grinspoon)

The plan for the NASA Flagship mission to Venus was given. The mission has a budget envelope of the order of 3-4G$. It will include one orbiter, 2 drifting balloons, and 2 landers. The launch is foreseen between 2020-2025.

This mission focuses on the comparison between Venus and Earth climate and more precisely, intends to answer the following questions:

• **What does the Venus greenhouse tell us about climate change?**
– How do clouds and chemical cycles affect atmospheric energy balance?
– What drives the atmospheric superrotation?
– Is there evidence for climate change?

• **How active is Venus?**
– Is Venus geologically active and what is it's geologic history?
– How do surface/atmosphere interactions affect rock mineralogy and climate?
– What is structure of the interior, and what are its dynamics?

• **When and where did the water go?**
– How did the early atmosphere evolve?
– Did Venus have an ocean and if so, when was it lost?
– Is there continent-like crust on Venus?

• **Why is Venus so different from Earth?**

David Grinspoon highlighted further the importance that modelling is an integrated part of the mission. A new planetary modelling centre from NASA is under-way but preliminary only for Mars. Later after 1-2 years it is expected to also include Venus.

2. Modeling efforts

2.1 U.S. (Limaye)

The UCLA Venus Atmosphere Model is based on the NCAR Community Atmosphere Model (CAM). This has been modified (removed routines associated with Earth-specific processes) to produce a new GCM of Venus atmosphere. It has a comparatively high horizontal resolution of 0.9°x1.25° (lat/lon) and 50 hybrid sigma-pressure vertical levels (up to 95Km altitude). For radiative transfer, the model uses a simple solar forcing with Newtonian cooling, but an improved version will be added soon. The model does not yet include the effect of the topography or daily variations. A control simulation has been performed for around 200 Earth years (625 Venus solar days). The model reproduces the super-rotation (although significantly underestimates). However, a puzzling and unrealistic 10-year cycle is found which presently is being investigated.

2.2 Japan (Yamamoto)

The present status of the Japanese Venus GCM based on the CCSR/NIES GCM was reported. This is a T21 spectral-transform model. The model has 52 vertical levels in a sigma coordinate system. The results of a control run of 2 Venus days (after 360 Venus days) have been presented.

Super-rotation of 16-18m/s is formed in the cloud layer in the case of only a latitudinal temperature difference. Sensitivity simulations examining the influence of surface drag, topography, hyper-diffusion, on the zonal wind speed have been also conducted.

2.3 France (Lebonnois)

The Laboratoire de Météorologie Dynamique (LMD) has developed a 3-dimensional GCM of theVenus atmosphere. The current version of the model is based on a 48x32 grid, with 50 levels from surface to roughly 95 km altitude. Simulations with and without topography and using different parameterizations of the boundary layer and upper conditions have been conducted. The model reproduces the super-rotation (although significantly underestimates). The model has been run either using the full radiative transfer scheme or with Newtonian cooling. The later shows two distinct states that alternate periodically. The causes of that have not yet been clarified. Further development of the model includes the implementation of orographic and non-orographic gravity waves parameterization.

2.4 UK (Read)

The Oxford Venus GCM (OPUS-V) uses the dynamical core of UKMO Unified Model. The model has a 5°x5° grid resolution and 31 vertical levels from surface to around 80 km. It uses a simplified radiative forcing scheme and also includes boundary layer friction/mixing (linear relaxation drag or bulk coefficient turbulence model), surface topography (from Magellan maps) and H_2SO_4 clouds and vapour transport. The model experiment uses Newtonian cooling but takes also into account the diurnal variations in temperature. The meridional circulation is dominated by global Hadley cells and it has a realistic superrotation, albeit too weak. The cloud features are mimicked by passive transport of H_2SO_4 aerosol. The model also simulates a possible transport barrier at around 60° poleward of the jet core. Experiments using the same radiative transfer scheme as the LMD GCM [*Eymet et al.*, 2009] has commenced.

3. Discussion

The presentations of this (and the previous) meeting are available on this password-protected web page:

http://www.issibern.ch/workshops/venusclimate/documents.html

A password will be send to you in a separate e-mail.

3.1 Future Team activities

It is evident from the Section 2 that the models show difficulties in producing a realistic representation of some of the main features of the Venusian atmosphere, e.g., the magnitude of superrotation. Sensitivity simulations presented at the workshop have demonstrated that the dynamics governing the atmosphere of Venus are extremely sensitive to small differences in e.g., initial and boundary conditions, model resolution, and the numerical techniques used in the dynamical core. It is therefore necessary that the dynamical cores of each model be validated using e.g., methods similar to the Held-Suarez test [*Held and Suarez*, 1994], but adapted to Venus conditions.

Large differences exist also in the behaviour of the different models. The different dynamical cores and physics parameterizations used between them, make it difficult or even impossible to decide which phenomena are caused by which model component. The objective is for each group to run their own dynamical core, subject to a forcing boundary condition protocol that is common to all groups.

The protocol to run the models should be defined and agreed among all modelling groups. Sebastien Lebonnois will take the lead for the model inter-comparison. The joint results from these simulations will be discussed on the following Venus working group, to be held at ISSI, on the 16-17 November 2009. The first half-day (16th November) is reserved for the modelling sub-group, to deliver a unified presentation/report/input.

3.2 Outline of the ISSI Scientific Report (book)

The title of the ISSI Scientific Report has been agreed from all participants to be the following:

Towards understanding the climate of Venus

- Application of terrestrial models to our sister planet -.

The authors should provide some draft material for the next meeting including how the chapter is thought to be arranged. The tentative structure of the book is as follows:

Contents

1. Foreword (Bonnet**)**

2. Preface/introduction (Bengtsson et al.)

3. What do we know about Venus?

3.1 History of Venus observations (Grinspoon/Svedhem, Bonnet)
3.2 General background. What do we know about Venus. Previous work in theory and modeling (Grinspoon et al.)
3.3 Atmospheric composition and clouds, atmospheric structure etc., surface interactions incl. volcanism (Titov,Grinspoon)
3.4 Atmospheric circulation and dynamics (Limaye)
3.5. Radiation balance of Venus (incl. solar forcing) (Titov et al.)
3.6. Remaining Scientific questions (jointly)

4. Modeling the atmospheric circulation of Venus (modeling subgroup)
4.1. Modeling and general background/the theoretical framework (Read)
4.2. International modeling efforts
4.3. Inter-comparison of model results (protocol description)
4.4. Comparison with Earth modeling (Schmidt et al.)

5. Comparison with Earth climate (past, present, future) (jointly, Pierrehumbert to take the lead)

6. Future prospects: Prospects, guidance for future missions (Grinspoon, Svedhem et al.)

4. References

Eymet, V., R. Fournier, J.-L. Dufresne, F. Hourdin, S. Lebonnois, M. A. Bullock, 2009. Net-Exchange parameterization of infrared radiative transfers in Venus' atmosphere. JGR, submitted.

Held, I. H., and M. J. Suarez, 1994: A proposal for the intercomparison of the dynamical cores of atmospheric general circulation models. Bull. Amer. Met. Soc.,75, 1825-1830.