

Modelling of Atmospheric Clouds

Sylwester Arabas

Faculty of Mathematics and Computer Science, Jagiellonian University

lecture+lab 1
Feb. 24 2020

zanim zaczniemy...

Does everybody in the audience understand English?

about me / the “ego” slide

- ▶ 2002–2015: MSc,PhD,postdoc @ Dept. of Physics, U. Warsaw
- 2015–2017: quant dev @ Chatham Financial in Kraków
- 2017–2018: data analyst @ AETHON Engineering in Athens
- 2018–2020: postdoc @ WMil UJ

about me / the “ego” slide

- ▶ 2002–2015: MSc,PhD,postdoc @ Dept. of Physics, U. Warsaw
2015–2017: quant dev @ Chatham Financial in Kraków
2017–2018: data analyst @ AETHON Engineering in Athens
2018–2020: postdoc @ WMil UJ
- ▶ scope of work:
 - modelling aerosol-cloud-precipitation interactions
 - research software engineering

about me / the “ego” slide

- ▶ 2002–2015: MSc,PhD,postdoc @ Dept. of Physics, U. Warsaw
2015–2017: quant dev @ Chatham Financial in Kraków
2017–2018: data analyst @ AETHON Engineering in Athens
2018–2020: postdoc @ WMil UJ
- ▶ scope of work:
 - modelling aerosol-cloud-precipitation interactions
 - research software engineering

about me / the “ego” slide

- ▶ 2002–2015: MSc,PhD,postdoc @ Dept. of Physics, U. Warsaw
2015–2017: quant dev @ Chatham Financial in Kraków
2017–2018: data analyst @ AETHON Engineering in Athens
2018–2020: postdoc @ WMil UJ
- ▶ scope of work:
 - modelling aerosol-cloud-precipitation interactions
 - research software engineering
- ▶ more about me:
<http://www.ii.uj.edu.pl/~arabas/>
- ▶ team & projects:
<http://github.com/atmos-cloud-sim-uj/>

about you?

course logistics:

- ▶ contact: Sylwester.Arabas@uj.edu.pl; room 2151
- ▶ materials++:
<https://github.com/atmos-cloud-sim-uj/MoAC-2020>

course logistics:

- ▶ contact: Sylwester.Arabas@uj.edu.pl; room 2151
- ▶ materials++:
<https://github.com/atmos-cloud-sim-uj/MoAC-2020>
- ▶ attendance: default (i.e., 2 unexcused absences \rightsquigarrow NZAL)

course logistics:

- ▶ contact: Sylwester.Arabas@uj.edu.pl; room 2151
- ▶ materials++:
<https://github.com/atmos-cloud-sim-uj/MoAC-2020>
- ▶ attendance: default (i.e., 2 unexcused absences \rightsquigarrow NZAL)
- ▶ project (four grades averaged):
 - ▶ pitch (week of March 30)
 - ▶ demo (week of April 27)
 - ▶ code (week of May 25)
 - ▶ revision (optional, default: same grade as for code)

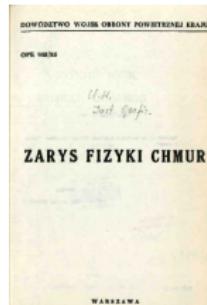
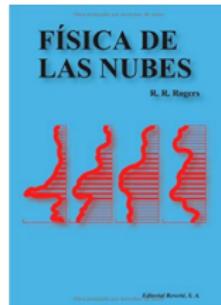
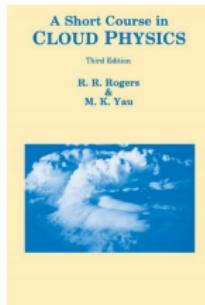
course logistics:

- ▶ contact: Sylwester.Arabas@uj.edu.pl; room 2151
- ▶ materials++:
<https://github.com/atmos-cloud-sim-uj/MoAC-2020>
- ▶ attendance: default (i.e., 2 unexcused absences \leadsto NZAL)
- ▶ project (four grades averaged):
 - ▶ pitch (week of March 30)
 - ▶ demo (week of April 27)
 - ▶ code (week of May 25)
 - ▶ revision (optional, default: same grade as for code)
- ▶ project: Jupyter notebook reproducing a (non-trivial) result from cloud modelling literature (suggestions will be provided)

course logistics:

- ▶ contact: Sylwester.Arabas@uj.edu.pl; room 2151
- ▶ materials++:
<https://github.com/atmos-cloud-sim-uj/MoAC-2020>
- ▶ attendance: default (i.e., 2 unexcused absences \rightsquigarrow NZAL)
- ▶ project (four grades averaged):
 - ▶ pitch (week of March 30)
 - ▶ demo (week of April 27)
 - ▶ code (week of May 25)
 - ▶ revision (optional, default: same grade as for code)
- ▶ project: Jupyter notebook reproducing a (non-trivial) result from cloud modelling literature (suggestions will be provided)
- ▶ exam: material from slides and notebooks

literature & lecture scope (cloud physics)



short course in cloud physics

zawierające frazę w ▾ całym opisie ▾

Wybrane 0 2 (liczba wyników)

 **KSIAŻKA**
A short course in cloud physics / by R. R. Rogers and M. K. Yau.
Rogers, Roddy Rhodes.; Yau, Man Kong.
Burlington : Butterworth-Heinemann; 1996
Dostępny w BIBLIOTEKA NAUK PRZYRODNICZYCH BIBL. NAUK PRZYR. - Lectorium (36129 34044) i
inne lokalizacje >

 **KSIAŻKA**
A short course in cloud physics / by R. R. Rogers and M. K. Yau.
Rogers, Roddy Rhodes.; Yau, Man Kong.
Oxford etc. : Pergamon Press; 1989
Dostępny w BIBLIOTEKA NAUK PRZYRODNICZYCH BIBL. NAUK PRZYR. - zb. IGI GP (II 6112 A 10373) >

<https://scholar.google.com/scholar?cites=10100188685602707044>

cloud evolution: conceptual picture

cloud evolution: conceptual picture



background image: vitsly.ru / Hokusai

cloud evolution: conceptual picture



cloud evolution: conceptual picture

- aerosol particles of natural and anthropogenic origin act as condensation nuclei



cloud evolution: conceptual picture

- aerosol particles of natural and anthropogenic origin act as condensation nuclei
- cloud droplets grow by water vapour condensation



cloud evolution: conceptual picture

- aerosol particles of natural and anthropogenic origin act as condensation nuclei
- cloud droplets grow by water vapour condensation
- rain drops form through collisions of cloud droplets



cloud evolution: conceptual picture

- aerosol particles of natural and anthropogenic origin act as condensation nuclei
- cloud droplets grow by water vapour condensation
- rain drops form through collisions of cloud droplets
- aqueous chemical reactions irreversibly modify the drop composition



cloud evolution: conceptual picture

- aerosol particles of natural and anthropogenic origin act as condensation nuclei
- cloud droplets grow by water vapour condensation
- rain drops form through collisions of cloud droplets
- aqueous chemical reactions irreversibly modify the drop composition
- rain drops precipitate washing out aerosol

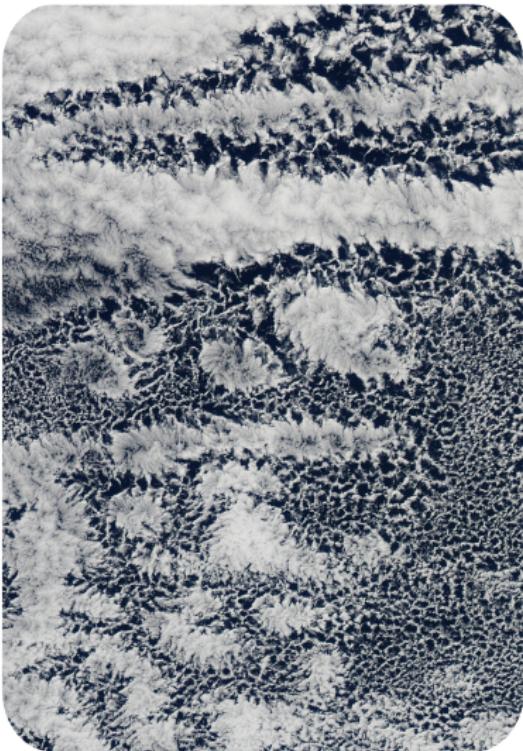
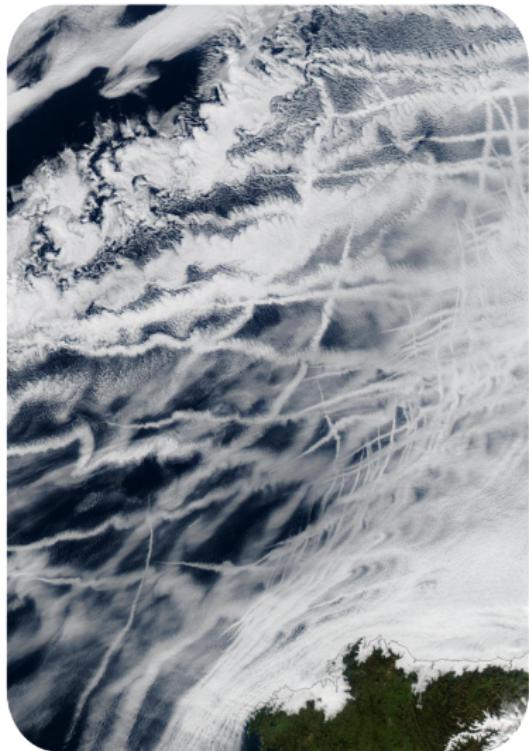


cloud evolution: conceptual picture

- aerosol particles of natural and anthropogenic origin act as condensation nuclei
- cloud droplets grow by water vapour condensation
- rain drops form through collisions of cloud droplets
- aqueous chemical reactions irreversibly modify the drop composition
- rain drops precipitate washing out aerosol
- rain drops evaporate into aerosol particles of potentially altered size and/or composition (collisions, chemistry)



cloud evolution: as seen from space



NASA/MODIS (27 Jan 2003 – Bay of Biscay; 17 Apr 2010 – off the coast of Peru)
<http://visibleearth.nasa.gov/view.php?id=64992>
<http://earthobservatory.nasa.gov/IOTD/view.php?id=43795>

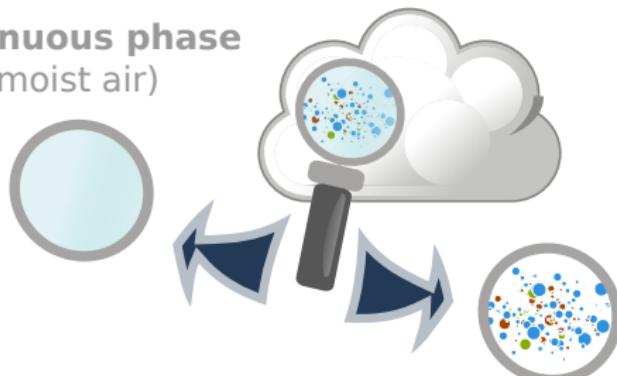
cloud evolution: modelling μ -physics



cloud evolution: modelling μ -physics

continuous phase

(moist air)



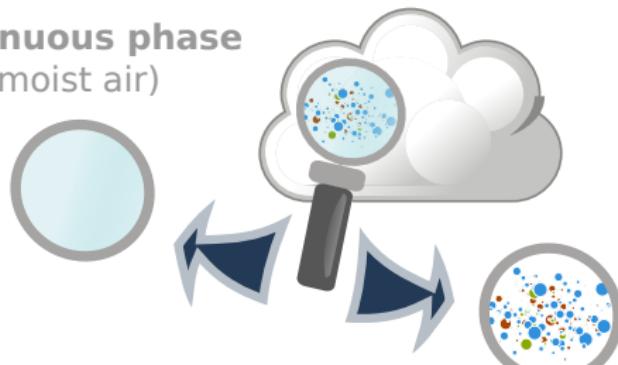
dispersed phase

(aerosol particles, cloud droplets, drizzle, rain, snow, ...)

cloud evolution: modelling μ -physics

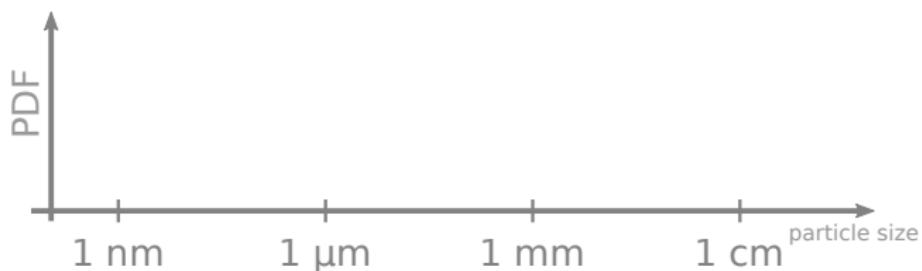
continuous phase

(moist air)



dispersed phase

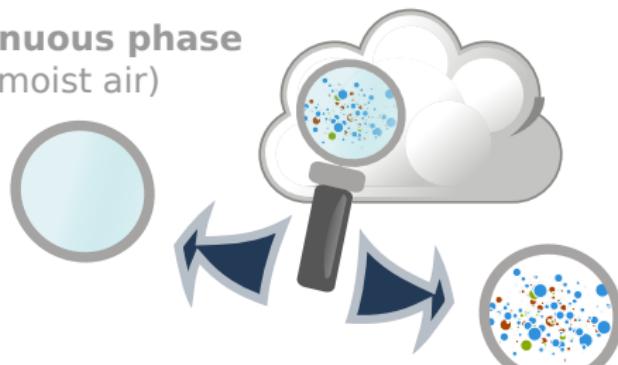
(aerosol particles, cloud droplets, drizzle, rain, snow, ...)



cloud evolution: modelling μ -physics

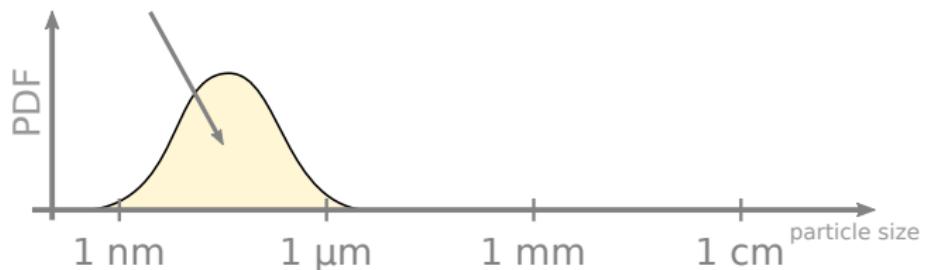
continuous phase

(moist air)



dispersed phase

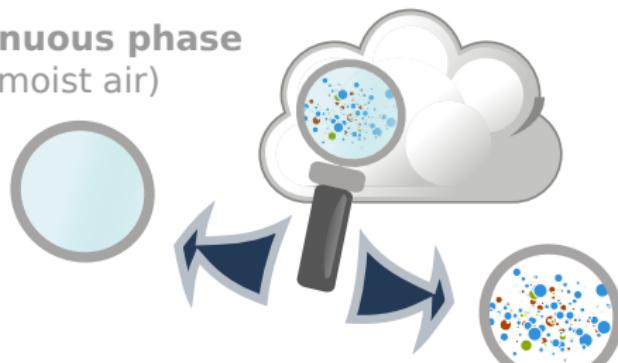
(aerosol particles, cloud droplets, drizzle, rain, snow, ...)



cloud evolution: modelling μ -physics

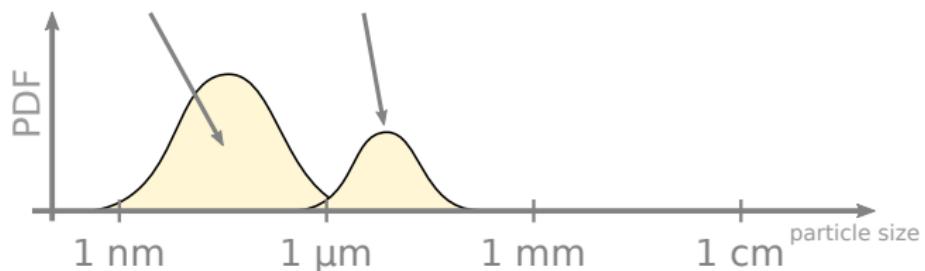
continuous phase

(moist air)



dispersed phase

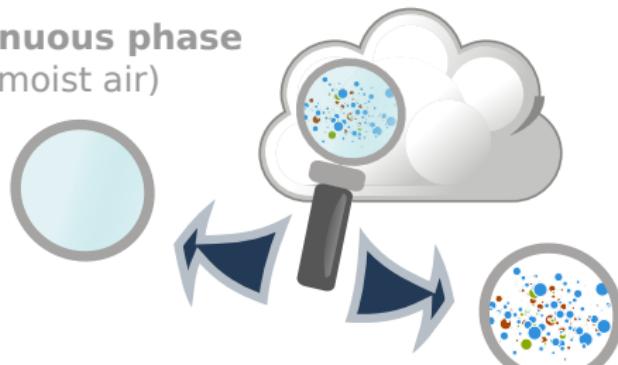
(aerosol particles, cloud droplets, drizzle, rain, snow, ...)



cloud evolution: modelling μ -physics

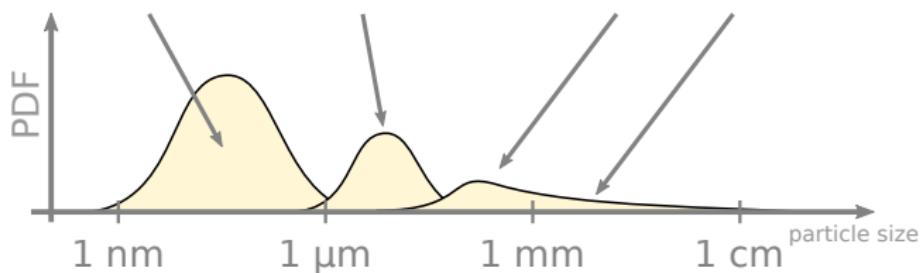
continuous phase

(moist air)



dispersed phase

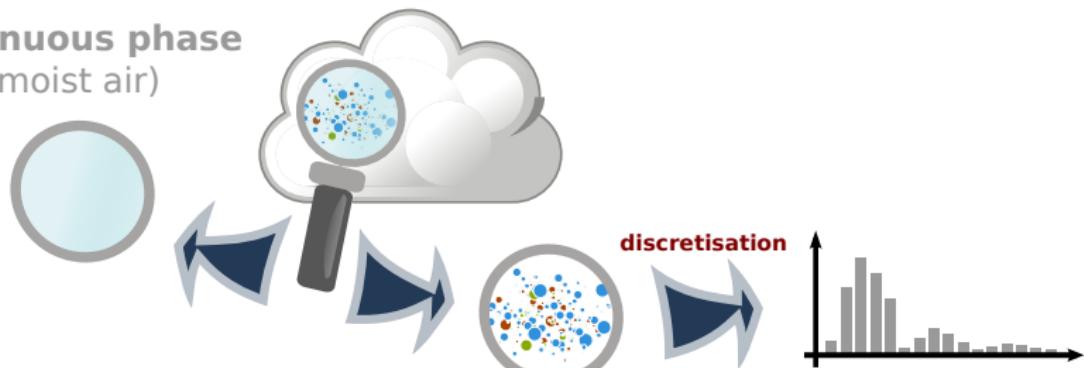
(aerosol particles, cloud droplets, drizzle, rain, snow, ...)



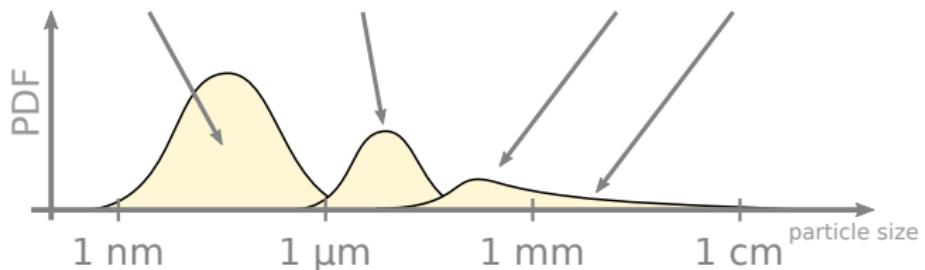
cloud evolution: modelling μ -physics

continuous phase

(moist air)



dispersed phase
(aerosol particles, cloud droplets, drizzle, rain, snow, ...)



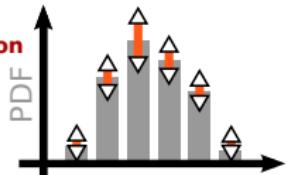
cloud evolution: modelling μ -physics

continuous phase

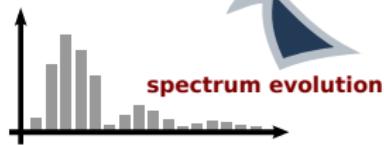
(moist air)



Eulerian representation

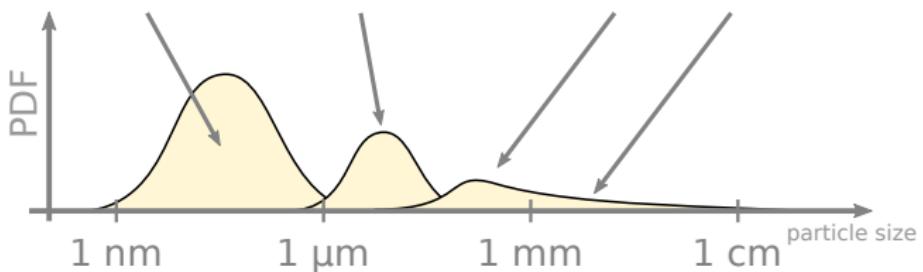


discretisation



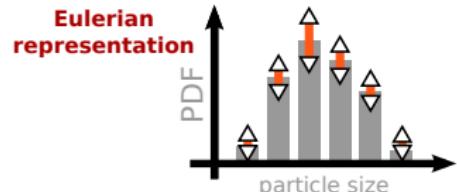
dispersed phase

(aerosol particles, cloud droplets, drizzle, rain, snow, ...)

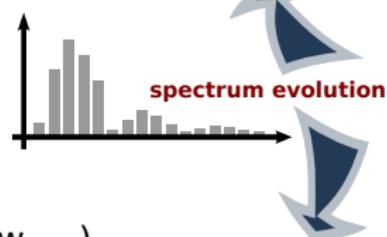


cloud evolution: modelling μ -physics

continuous phase
(moist air)

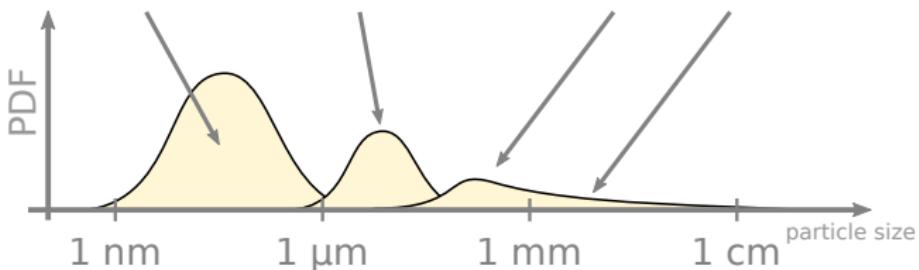


discretisation

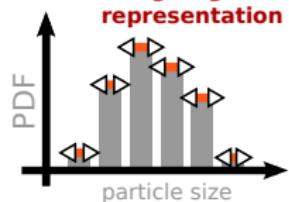


dispersed phase

(aerosol particles, cloud droplets, drizzle, rain, snow, ...)



Lagrangian representation





- „.... simulation of 40 days and 40 nights, beginning at 0Z, 1 August 2016, using global models with a grid spacing of 5 km or less”

- ▶ „.... simulation of 40 days and 40 nights, beginning at 0Z, 1 August 2016, using global models with a grid spacing of 5 km or less”
- ▶ „The images are constructed from the output at 0400 UTC on 4 August 2016... the models still are on trajectories that are well constrained by the atmospheric state from which they were initialized, 76 h previously”

- ▶ „.... simulation of 40 days and 40 nights, beginning at 0Z, 1 August 2016, using global models with a grid spacing of 5 km or less”
- ▶ „The images are constructed from the output at 0400 UTC on 4 August 2016... the models still are on trajectories that are well constrained by the atmospheric state from which they were initialized, 76 h previously”
- ▶ „The images suggest that despite capturing the patterning of large-scale circulation features on the distribution of condensate... substantial differences become apparent when looked at quantitatively”

- ▶ „.... simulation of 40 days and 40 nights, beginning at 0Z, 1 August 2016, using global models with a grid spacing of 5 km or less”
- ▶ „The images are constructed from the output at 0400 UTC on 4 August 2016... the models still are on trajectories that are well constrained by the atmospheric state from which they were initialized, 76 h previously”
- ▶ „The images suggest that despite capturing the patterning of large-scale circulation features on the distribution of condensate... substantial differences become apparent when looked at quantitatively”
- ▶ „These differences are likely sensitive to the representation of both cloud microphysics and shallow convection, whose treatment differs across the models”

- ▶ „.... simulation of 40 days and 40 nights, beginning at 0Z, 1 August 2016, using global models with a grid spacing of 5 km or less”
- ▶ „The images are constructed from the output at 0400 UTC on 4 August 2016... the models still are on trajectories that are well constrained by the atmospheric state from which they were initialized, 76 h previously”
- ▶ „The images suggest that despite capturing the patterning of large-scale circulation features on the distribution of condensate... substantial differences become apparent when looked at quantitatively”
- ▶ „These differences are likely sensitive to the representation of both cloud microphysics and shallow convection, whose treatment differs across the models”
- ▶ „.... state vector of 11 variables (5 microphysical variables, 3 components of the velocity vector, and 3 thermodynamic coordinates) with 84×10^6 horizontal and 90 vertical degrees of freedom comprises nearly a terabyte of information per sample”

- ▶ „.... simulation of 40 days and 40 nights, beginning at 0Z, 1 August 2016, using global models with a grid spacing of 5 km or less”
- ▶ „The images are constructed from the output at 0400 UTC on 4 August 2016... the models still are on trajectories that are well constrained by the atmospheric state from which they were initialized, 76 h previously”
- ▶ „The images suggest that despite capturing the patterning of large-scale circulation features on the distribution of condensate... substantial differences become apparent when looked at quantitatively”
- ▶ „These differences are likely sensitive to the representation of both cloud microphysics and shallow convection, whose treatment differs across the models”
- ▶ „.... state vector of 11 variables (5 microphysical variables, 3 components of the velocity vector, and 3 thermodynamic coordinates) with 84×10^6 horizontal and 90 vertical degrees of freedom comprises nearly a terabyte of information per sample”
- ▶ „Hourly output for 40 days inflates this by a factor of a thousand.”

- ▶ „.... simulation of 40 days and 40 nights, beginning at 0Z, 1 August 2016, using global models with a grid spacing of 5 km or less”
- ▶ „The images are constructed from the output at 0400 UTC on 4 August 2016... the models still are on trajectories that are well constrained by the atmospheric state from which they were initialized, 76 h previously”
- ▶ „The images suggest that despite capturing the patterning of large-scale circulation features on the distribution of condensate... substantial differences become apparent when looked at quantitatively”
- ▶ „These differences are likely sensitive to the representation of both cloud microphysics and shallow convection, whose treatment differs across the models”
- ▶ „.... state vector of 11 variables (5 microphysical variables, 3 components of the velocity vector, and 3 thermodynamic coordinates) with 84×10^6 horizontal and 90 vertical degrees of freedom comprises nearly a terabyte of information per sample”
- ▶ „Hourly output for 40 days inflates this by a factor of a thousand.”
- ▶ „guide future developments ... by focusing efforts on non-trivial problems, for instance the representation of turbulent mixing and cloud microphysical processes, or managing and efficiently analyzing output”

and a smaller-scale higher-detail example

<https://www.youtube.com/playlist?list=PLupuoB0sASq6gZ2ryszf4JzB98JglpAfI>



【VR180 3D 4K】微速度撮影された雲の様子を観察してみよう：「京」コンピュータを使ったシミュレーション編2 【2019年度R-CCS一般公開】

attendance list!!!

job offer @ ETH

► https://www.jobs.ethz.ch/job/view/JOPG_ethz_j2n0fDTzkSj9ektI0k

Scientific Software Developers (Python)

100%, Zurich, temporary

The **Swiss National Supercomputing Centre (CSCS)** is operated by ETH Zurich and its headquarters are located in Lugano, Switzerland. CSCS develops and provides key supercomputing capabilities for solving important problems in science and society. CSCS is leading an effort to develop scientific software and libraries for HPC platforms. This work involves close collaboration with domain scientists and working on cutting edge HPC technologies, to ensure that scientists will be able to fully utilize modern HPC systems. To this end, CSCS has open position at our office in Zurich.

job offer @ ETH

- ▶ https://www.jobs.ethz.ch/job/view/JOPG_ethz_j2n0fDTzkSj9ektI0k

Scientific Software Developers (Python)

100%, Zurich, temporary

The **Swiss National Supercomputing Centre (CSCS)** is operated by ETH Zurich and its headquarters are located in Lugano, Switzerland. CSCS develops and provides key supercomputing capabilities for solving important problems in science and society. CSCS is leading an effort to develop scientific software and libraries for HPC platforms. This work involves close collaboration with domain scientists and working on cutting edge HPC technologies, to ensure that scientists will be able to fully utilize modern HPC systems. To this end, CSCS has open position at our office in Zurich.

- ▶ „*The main role of this position is to develop tools and libraries for scientific computing.*”

- ▶ https://www.jobs.ethz.ch/job/view/JOPG_ethz_j2n0fDTzkSj9ektI0k

Scientific Software Developers (Python)

100%, Zurich, temporary

The **Swiss National Supercomputing Centre (CSCS)** is operated by ETH Zurich and its headquarters are located in Lugano, Switzerland. CSCS develops and provides key supercomputing capabilities for solving important problems in science and society. CSCS is leading an effort to develop scientific software and libraries for HPC platforms. This work involves close collaboration with domain scientists and working on cutting edge HPC technologies, to ensure that scientists will be able to fully utilize modern HPC systems. To this end, CSCS has open position at our office in Zurich.

- ▶ „*The main role of this position is to develop tools and libraries for scientific computing.*”
- ▶ „*She or he should have a Master or Ph.D. in computer science, computational science, mathematics or natural sciences.*”

- ▶ https://www.jobs.ethz.ch/job/view/JOPG_ethz_j2n0fDTzkSj9ektI0k

Scientific Software Developers (Python)

100%, Zurich, temporary

The **Swiss National Supercomputing Centre (CSCS)** is operated by ETH Zurich and its headquarters are located in Lugano, Switzerland. CSCS develops and provides key supercomputing capabilities for solving important problems in science and society. CSCS is leading an effort to develop scientific software and libraries for HPC platforms. This work involves close collaboration with domain scientists and working on cutting edge HPC technologies, to ensure that scientists will be able to fully utilize modern HPC systems. To this end, CSCS has open position at our office in Zurich.

- ▶ „*The main role of this position is to develop tools and libraries for scientific computing.*”
- ▶ „*She or he should have a Master or Ph.D. in computer science, computational science, mathematics or natural sciences.*”
- ▶ „*As part of an interdisciplinary team, you will contribute to the Exascale goal of CSCS, with the domain of weather and climate modeling.*”

LAB: github.com/atmos-cloud-sim-uj/MoAC-2020

[atmos-cloud-sim-uj / MoAC-2020](#)

Code Issues Pull requests Actions Projects Security Insights

Materials accompanying the "Modelling of Atmospheric Clouds" lecture series

2 commits 1 branch 0 packages 0 releases 1 contributor

Branch: [master](#) [New pull request](#) [Find file](#) [Clone or download](#)

slayoo initial commit	Latest commit 46e05511 1 hour ago
notebooks	Initial commit
README.md	Initial commit
requirements.txt	Initial commit

[README.md](#)

MoAC-2020

Materials accompanying the "Modelling of Atmospheric Clouds" lecture series

[launch](#) [binder](#)

please clone or launch on binder and open notebooks/01....

atmospheric soundings (<http://weather.uwyo.edu/>)



Region	Type of plot	Year	Month	From	To	Station Number
Europe	Text: List	2020	Feb	23/12Z	23/12Z	72672

Click on the image to request a sounding at that location or enter the station number above.



Thank you for your attention!