برنامج الإمارات لبحوث علوم الاستمطار
UAE Research Program for Rain Enhancement Science

OPTIMIZING CLOUD SEEDING BY ADVANCED REMOTE SENSING AND LAND COVER MODIFICATION (OCAL)

Final Report

UAE Research Program for Rain Enhancement Science

Reporting Period (Interim January Report)	
Start Date	***16.09.2018***
End Date	**07.02.2019**
Submittal Date	**07.02.2019**
University of Hohenheim - Institute of Physics and Meteorology	
Principal Investigator	**Prof. Dr. Volker Wulfmeyer**

EXECUTIVE SUMMARY

The OCAL project proceeded and nearly finished its studies on the detection and forecasting of convergence zones as well as convection initiation. The measurements at the OCAL mountain site were continued and further unique data on the evolution of wind fields and clouds were collected.

It is proposed and supported by the other UAEREP awardees to continue the OCAL mountain site and Al Ain eddy balance closure measurements for another two years to cover the next field campaigns and to develop joint operation and observation modes.

The design of the ensemble forecast model and the model chain down to scales of 300 m is completed and subject of several publications. The main challenge is the outstanding performance of another case study together with other awardee teams. The selection of this case is in preparation and we are planning to complete this during the neutral extension period of OCAL. It is planned to support strongly the integration project with the experience of the UHOH team with WRF-NOAHMP on land-surface processes, land-atmosphere (L-A) interaction, and convection initiation (CI). The implementation of the WRF-NOAHMP system at NCM has been started. First test simulations are planned in comparison with COSMO. **We propose to establish WRF-NOAHMP as Cloud Seeding Alert System (CSAS) for supporting future cloud seeding studies of NCM and UAEREP.**

The OCAL team demonstrated a very powerful approach for rain enhancement, particularly during the dry summer season. The Cloud and Precipitation Reactor (CPR) is based on a large-scale reduction of the surface albedo leading to a strong increase of the power uptake of the land surface. This power is partly converted in the development of convergence zones over and downstream of the land-surface modification area eventually leading to deep convection. The impact of the land-surface modification can be estimated and prediction by a new CPR index developed by the OCAL team. Current estimates lead to the conclusion that the impact of the CPR is approx. 50 times larger than that of cloud seeding. A rain amount of > 15 mm in the region of the CPR can be expected and there is the potential to produce an amount of 1,000,000 m^3 of water during summer. The CPR will also substantially support cloud seeding efforts and can be combined very efficiently with these.

The land-surface modification can be realized by the operation of large-scale photo-voltaic (PV) power plants or large-scale plantations or a combination of these. Therefore, the CPR does not only contribute to rain enhancement but also to the nexus between water-energy-food production. **We strongly recommend to start a pilot project to design and to realize the CPR in the UAE.**

SCIENTIFIC AND TECHNICAL PROCESS

Overall Project Overview:

Within the OCAL project, three main results were achieved:

1. **Set up and operation of a new observations critical for the understanding and modeling of land-atmosphere interaction, convection initiation (CI) as well as clouds and precipitation:**
    a. **The new OCAL mountain observatory with the UHOH Doppler wind lidar, the UHOH Doppler cloud radar, and the NCM weather station. Continuous observations are available since December 2017.**
    b. **The UHOH energy balance station at the Al Ain Airport. Continuous observations are available since April 5, 2017.**
2. **Design and operation of a new forecast system based on the WRF-NOAHMP model system with the following features:**
    a. **ensemble design for the forecasting of uncertainties**
    b. **high resolution down to 300 m**
    c. **data assimilation system with the ingestion of new global navigation satellite system (GNSS) data**
3. **The development and demonstration of the Cloud and Precipitation Reactor (CPR) with the potential to produce significant amounts of rain at least in the precipitation-spare summer season and to combine it with cloud seeding efforts**

We consider it as a particular highlight that the basic scientific idea, the modification of land-surface processes leads to a substantial increase of rain in summer also over the UAE.
We call this approach the Cloud and Precipitation Reactor (CPR).
A case study demonstrated that a single net water gain of > 150,000 m^3 can be expected during > 5-10 day in summer. This corresponds to an amount of approx. 1,000,000 m^3 or 15 mm rain out of the blue sky. This amount is much larger than the natural rain amount (< 2 mm) and also substantially larger than that to be expected by cloud seeding (approx. 10 % rain enhancement of already existing precipitable clouds).
Therefore, we recommend to realize the CPR in the UAE.

Individual Tasks/Projects

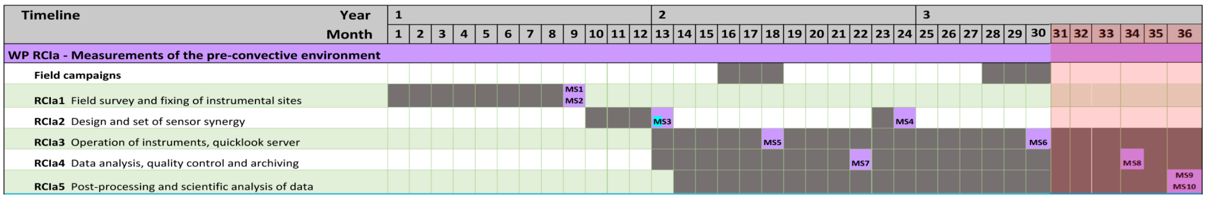
RCIa: Measurements of the pre-convective environment

Staff/Lead person: Dr. Andreas Behrendt

The time schedule and the milestones (MS) are presented in Table 1.

Within OCAL, the first observatory for studying aerosol particles, wind fields, and clouds in 3D was established. It is located at Al Farfar mountain and has the coordinates 25.166452°N, 56.175619°E, 725 m above sea level.

Table RCIa-1: Proposed time schedule and milestones for RCIa.



The quicklook server to study the results is reached with the OCAL website (https://ocal.uni-hohenheim.de) from https://ocal.uni-hohenheim.de/en/rc1:

http://guest.metek.de/mbc2/scan/domescan.html for the DCR data and

http://guest.metek.de/mbc2/scan/domescan_lidar.html for the DL data.

The DCR and DL were running almost continuously during the summer field campaign 2018 and continued to collect data until the date of this report. The scanning modes remained continuously the same with coordinated 15-minute scan patterns of both instruments comprising six full-sky elevation scans and two 360-degree horizontal scans (in 0- and 45-degree elevation).

In addition to the interesting days already reported in the previous report, further interesting days with rain events in October and November 2018 are the following:

October 2018: 15, 19, 24, 28

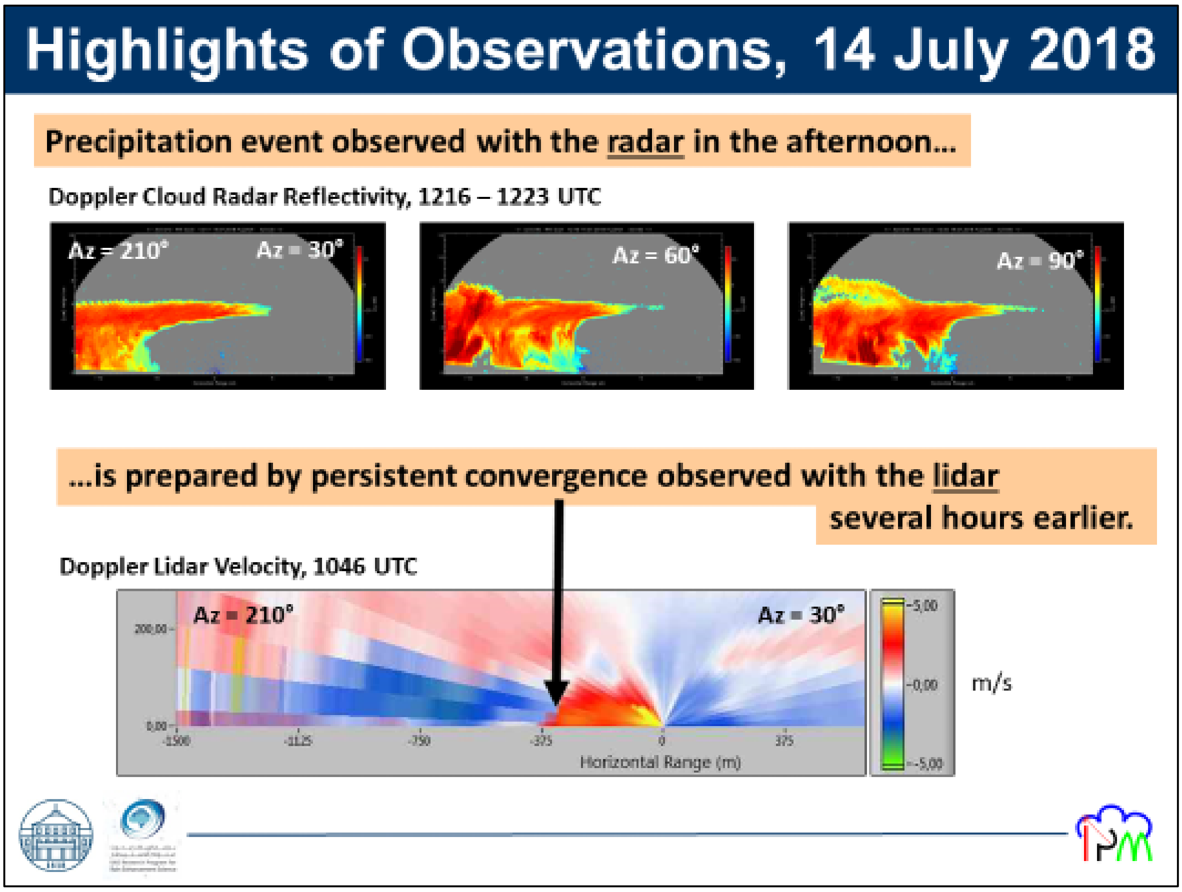
November 2018: 6, 11, 21, 25, 26

While the instruments are still collecting further data with outstanding quality, we started with the detailed analysis of the data collected in summer and the interpretation of the measurements.

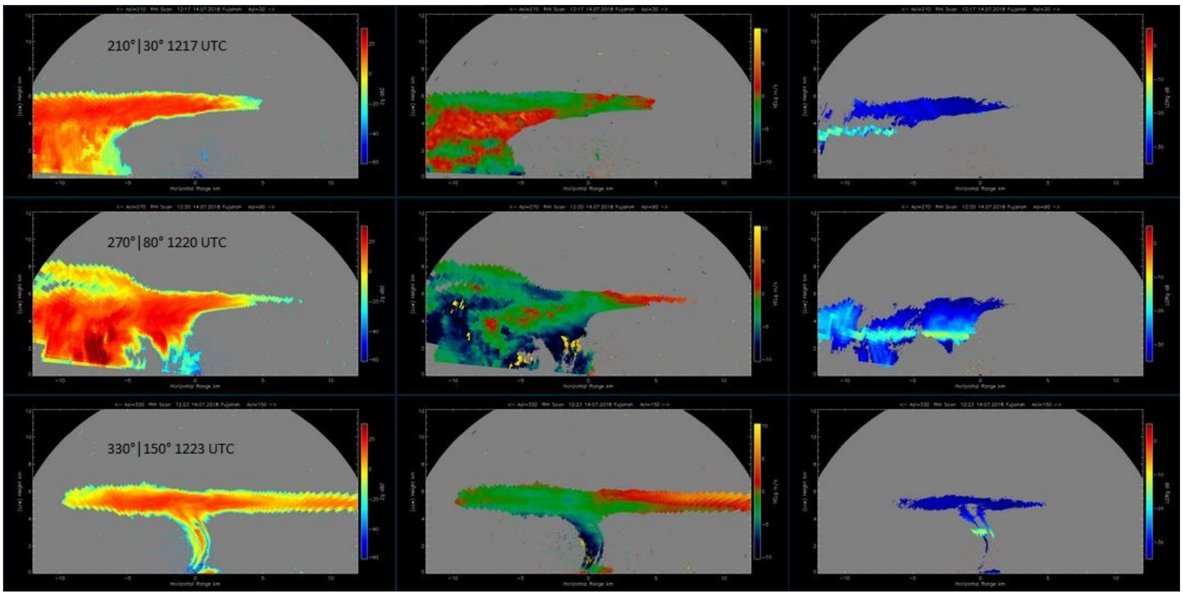
Highlights of the measurements in summer 2018

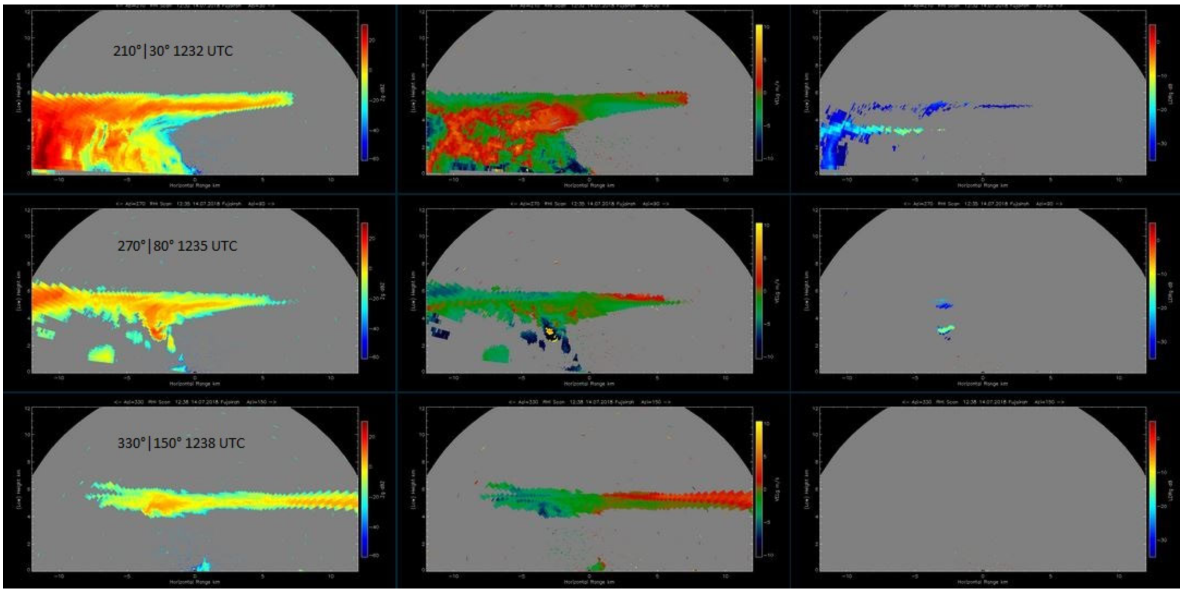
14 July 2018

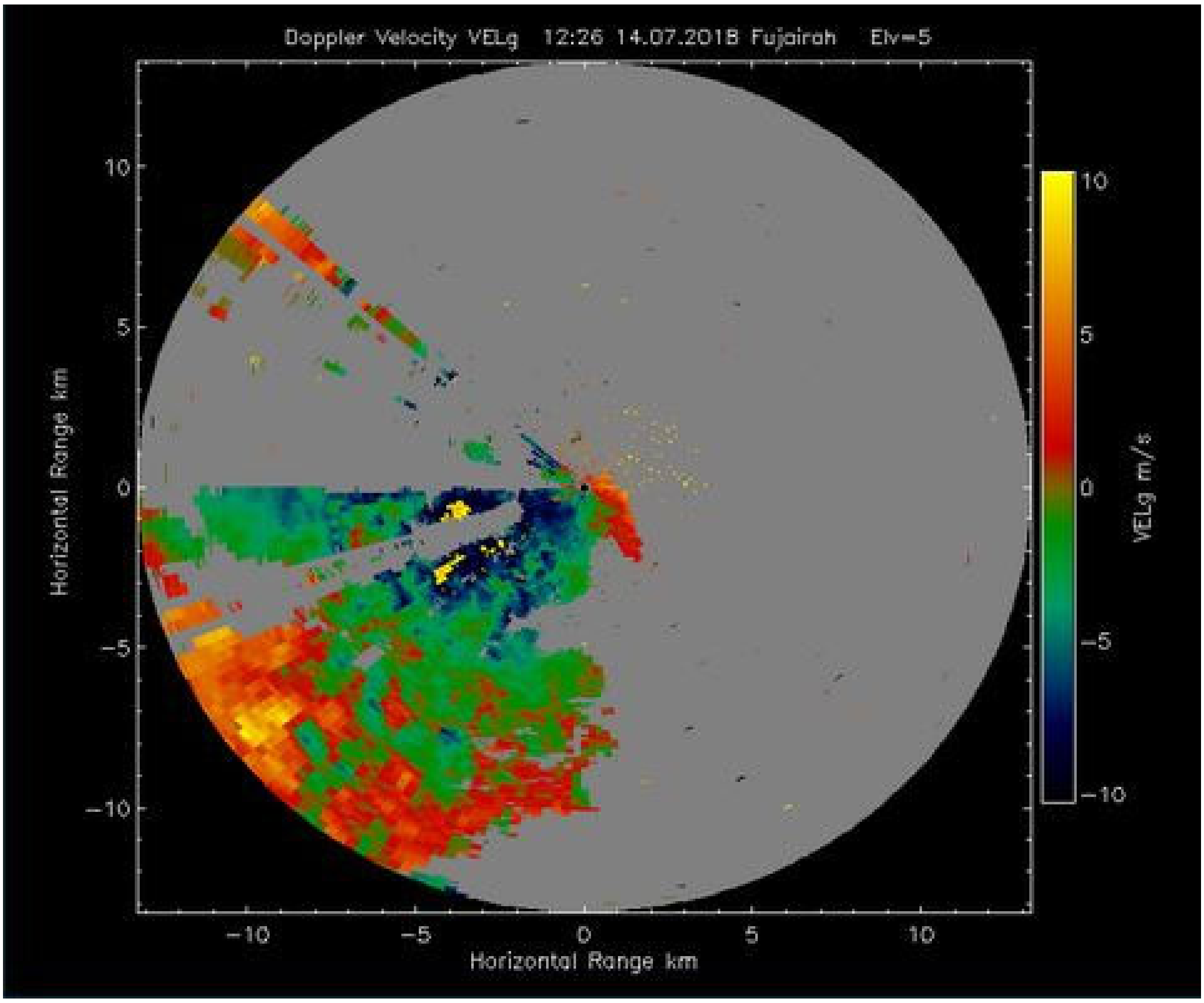
On this day, a convective cell formed above the OCAL mountain site shortly after 12 UTC. Several hours before the cell was detected by the cloud radar which is sensitive to cloud particles and hydrometeors, the DL which uses dust and other aerosol particles as scatters observed a persistent convergence zone several hours earlier. This observation proofs the concept that DL and DCR are capable of determining those atmospheric conditions which will later result in the initiation of convection. Consequently, the data of DL and DCR may be used for early alarms of cloud-seeding activities – much earlier than the currently used weather radar data which detect precipitation as end-result of the chain of processes leading to rain.



Further observations of this rain event with the DCR are shown here:

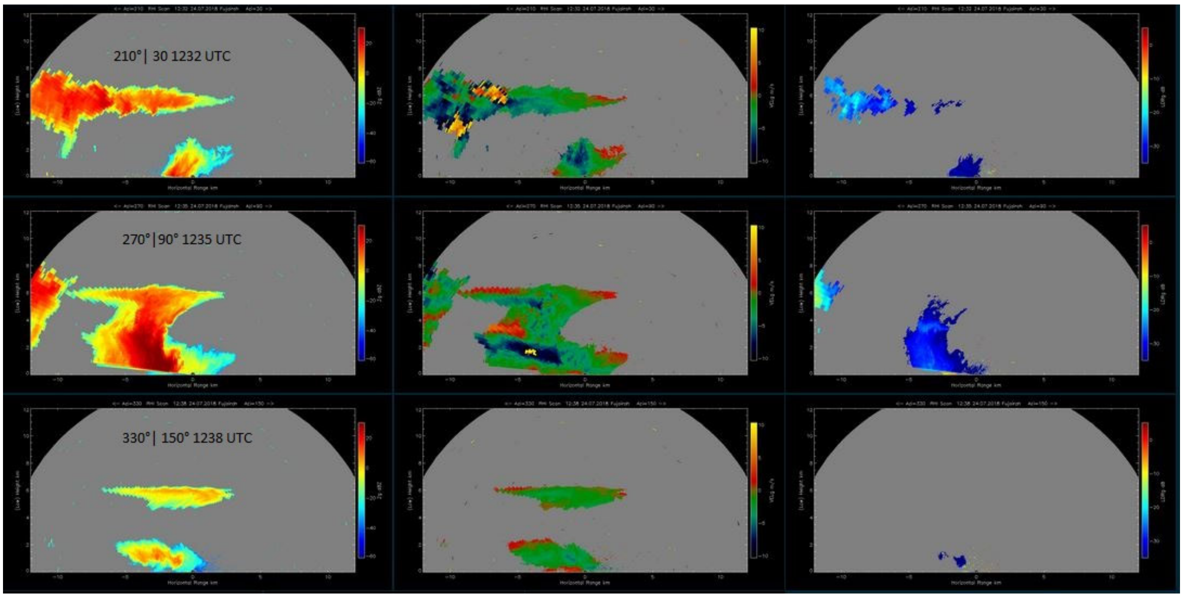


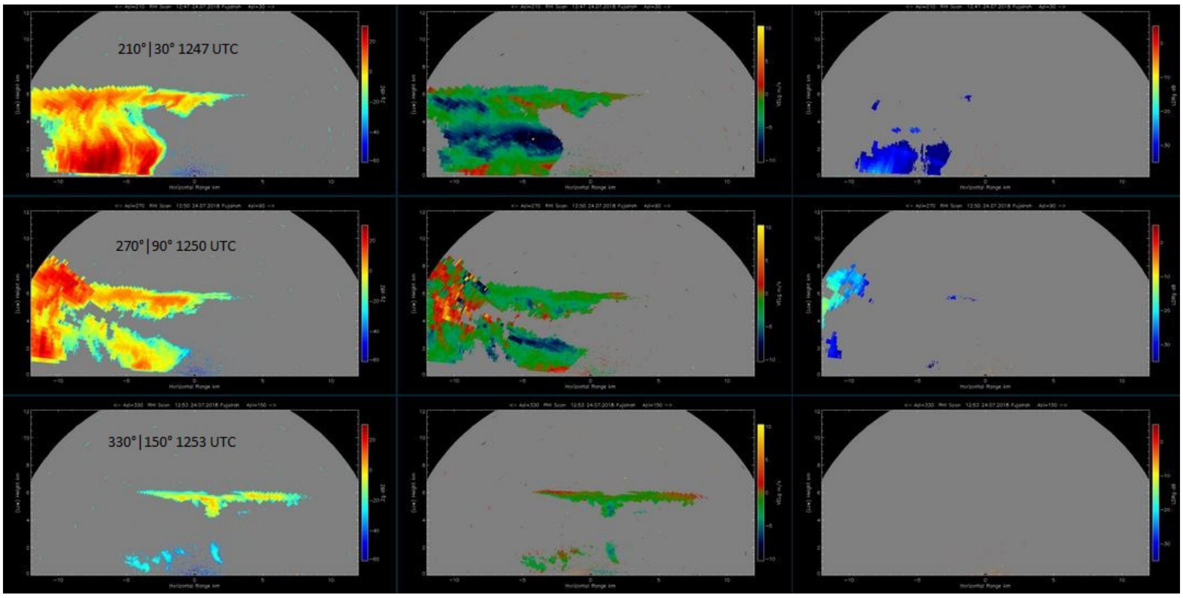

210°|30° 1232 UTC
270°|80° 1235 UTC
330°|150° 1238 UTC

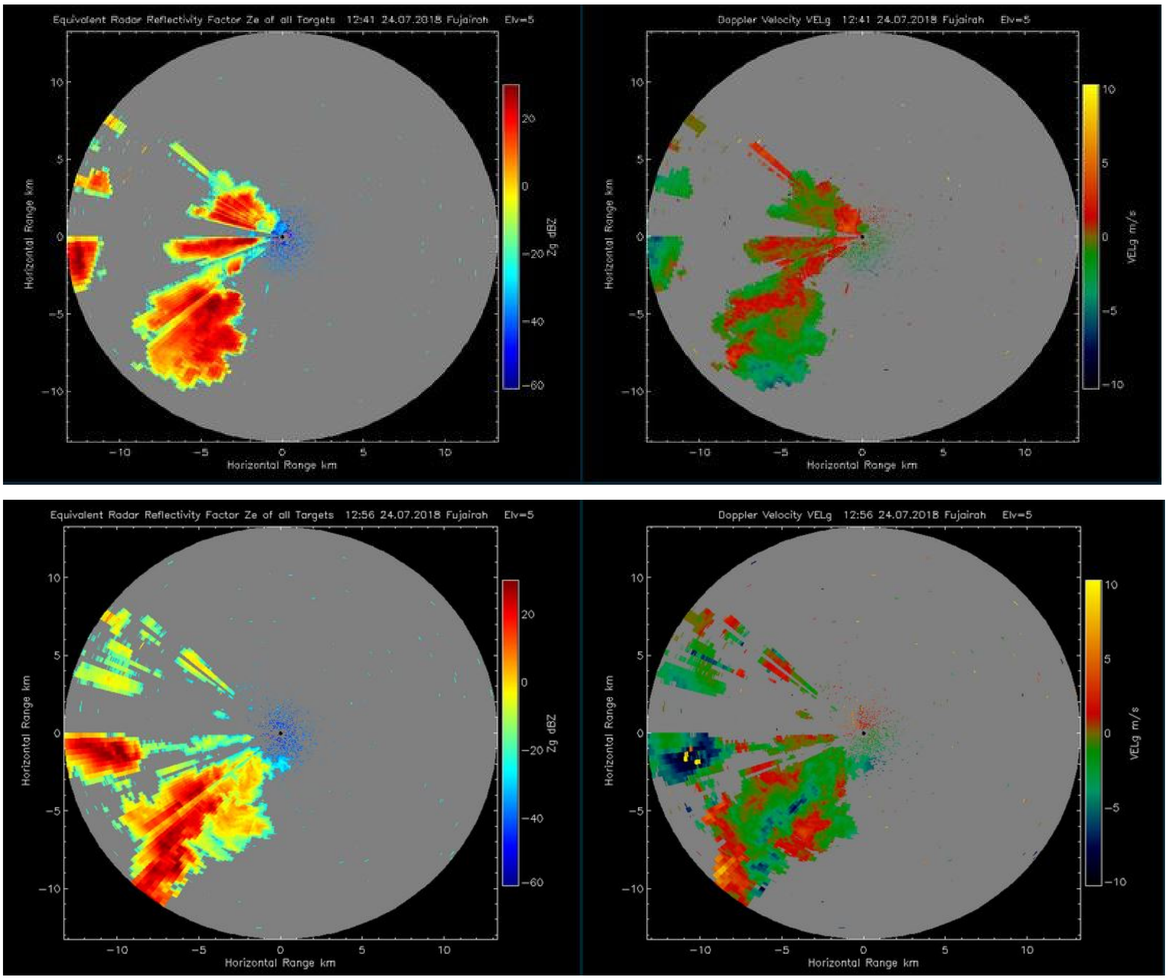

Doppler Velocity VELg 12:26 14.07.2018 Fujairah Elv=5
Horizontal Range km
Horizontal Range km
VELg m/s
10
5
0
-5
-10

24 July 2018

Also on this day, a convective cell formed above the OCAL mountain site shortly after 12 UTC. Observations of this rain event with the DCR are shown here:

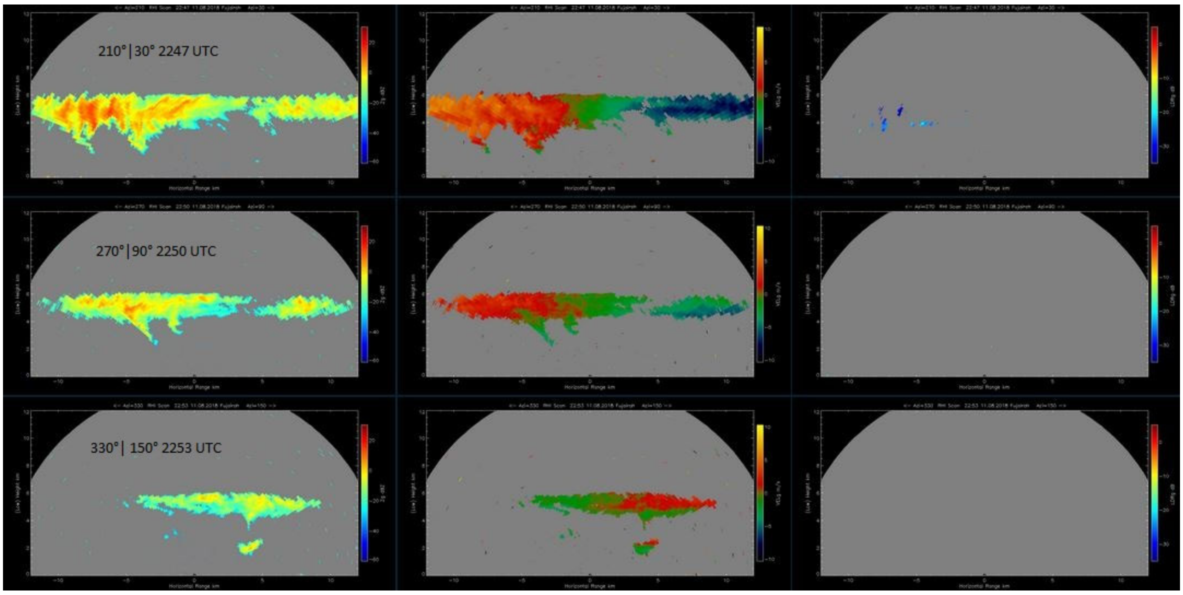


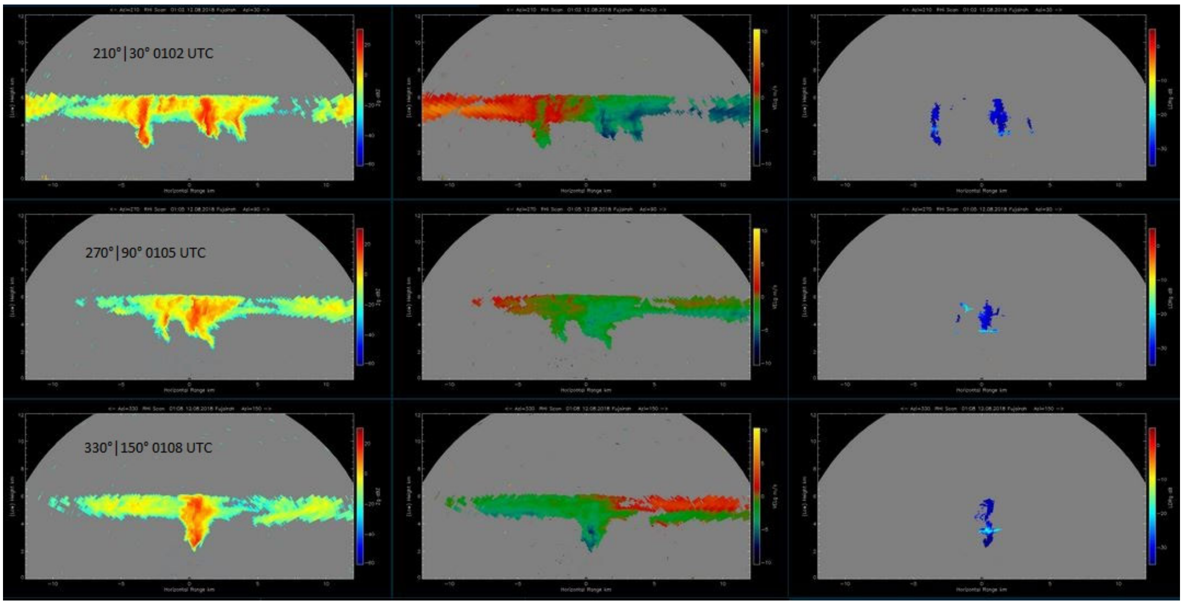


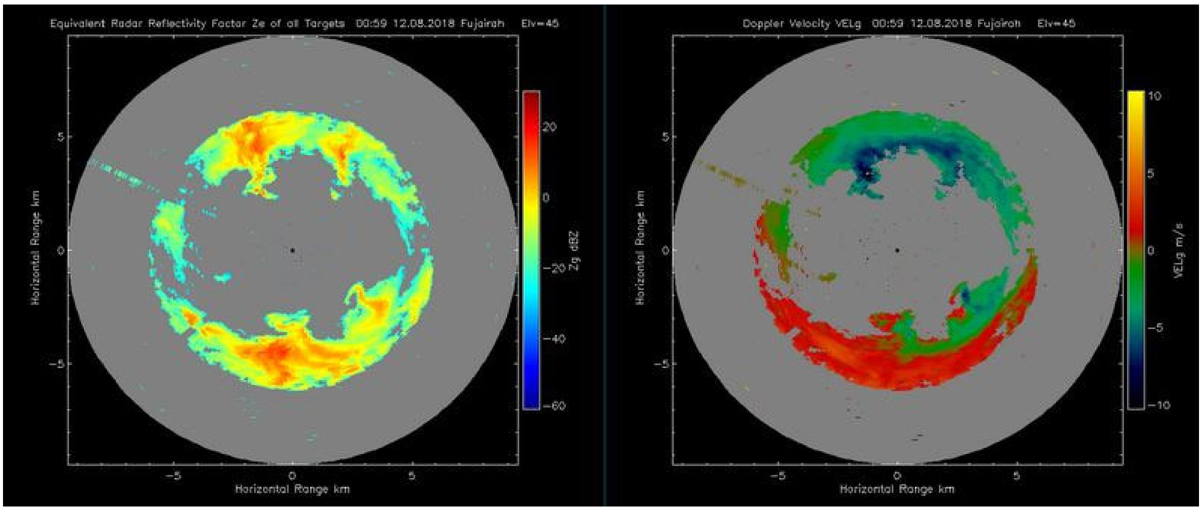

Equivalent Radar Reflectivity Factor Ze of all Targets 12:41 24.07.2018 Fujairah Elv=5
Doppler Velocity VELg 12:41 24.07.2018 Fujairah Elv=5
Equivalent Radar Reflectivity Factor Ze of all Targets 12:56 24.07.2018 Fujairah Elv=5
Doppler Velocity VELg 12:56 24.07.2018 Fujairah Elv=5
Horizontal Range km
Zg dBZ
VELg m/s

11/12 August 2018

On this day, rain cells were present above the OCAL mountain site at night. Observations of this rain event with the DCR are shown here:

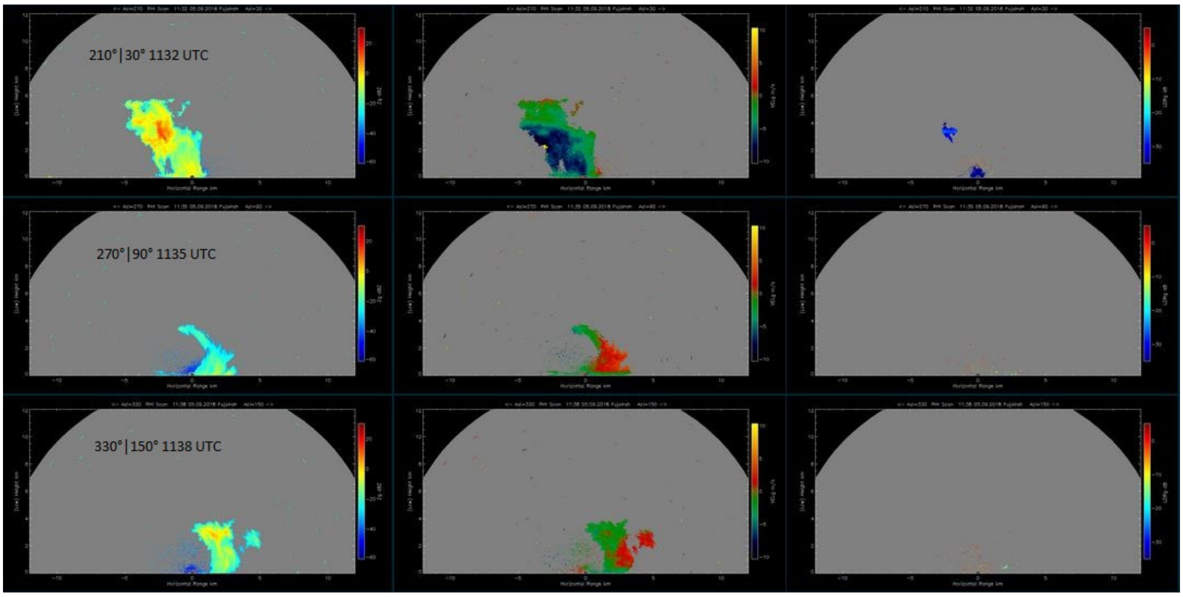


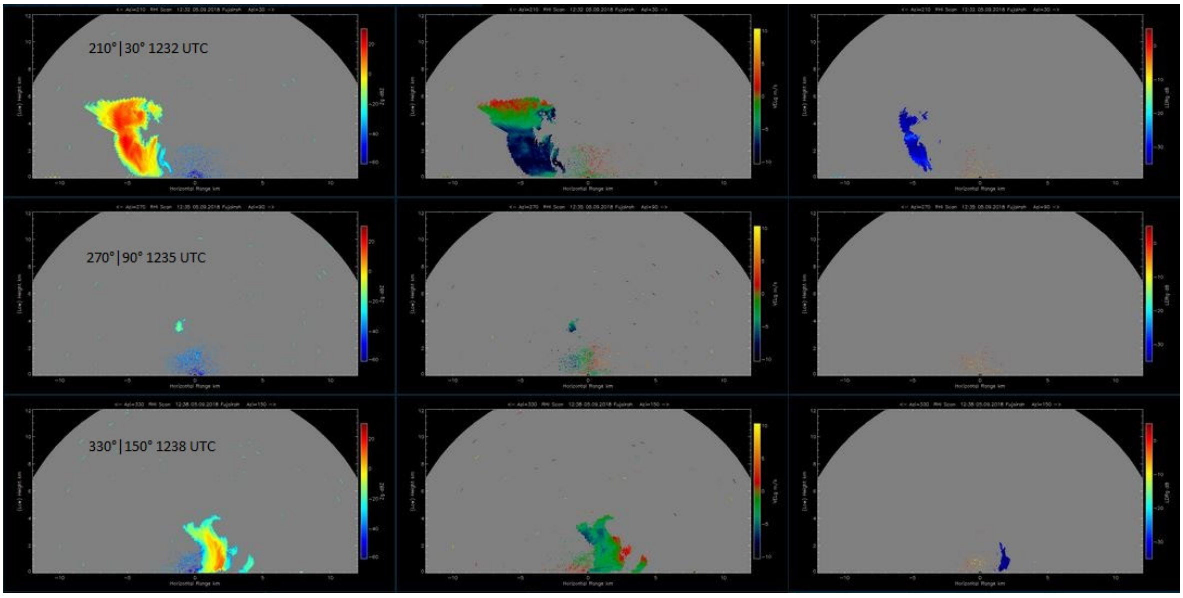


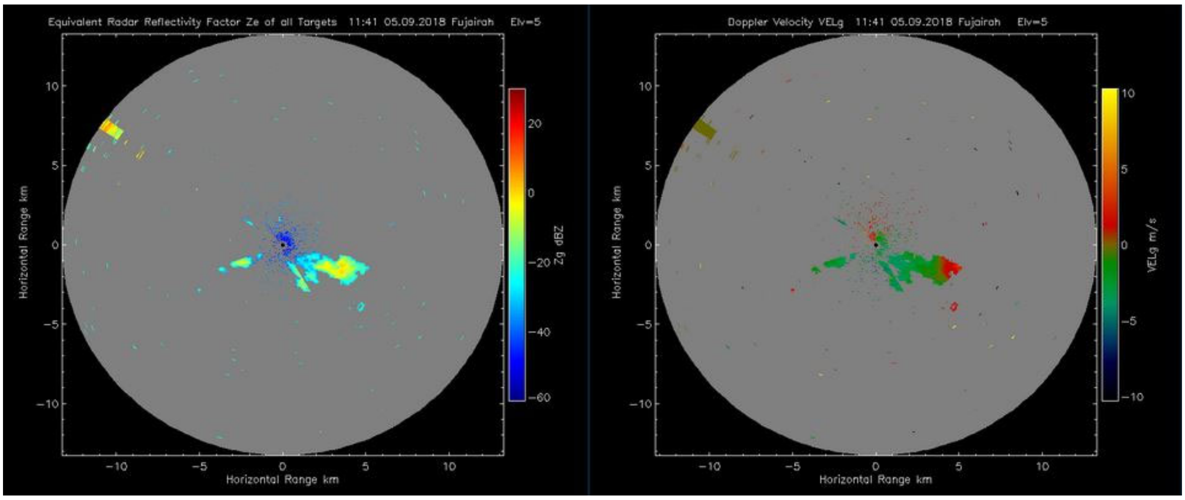


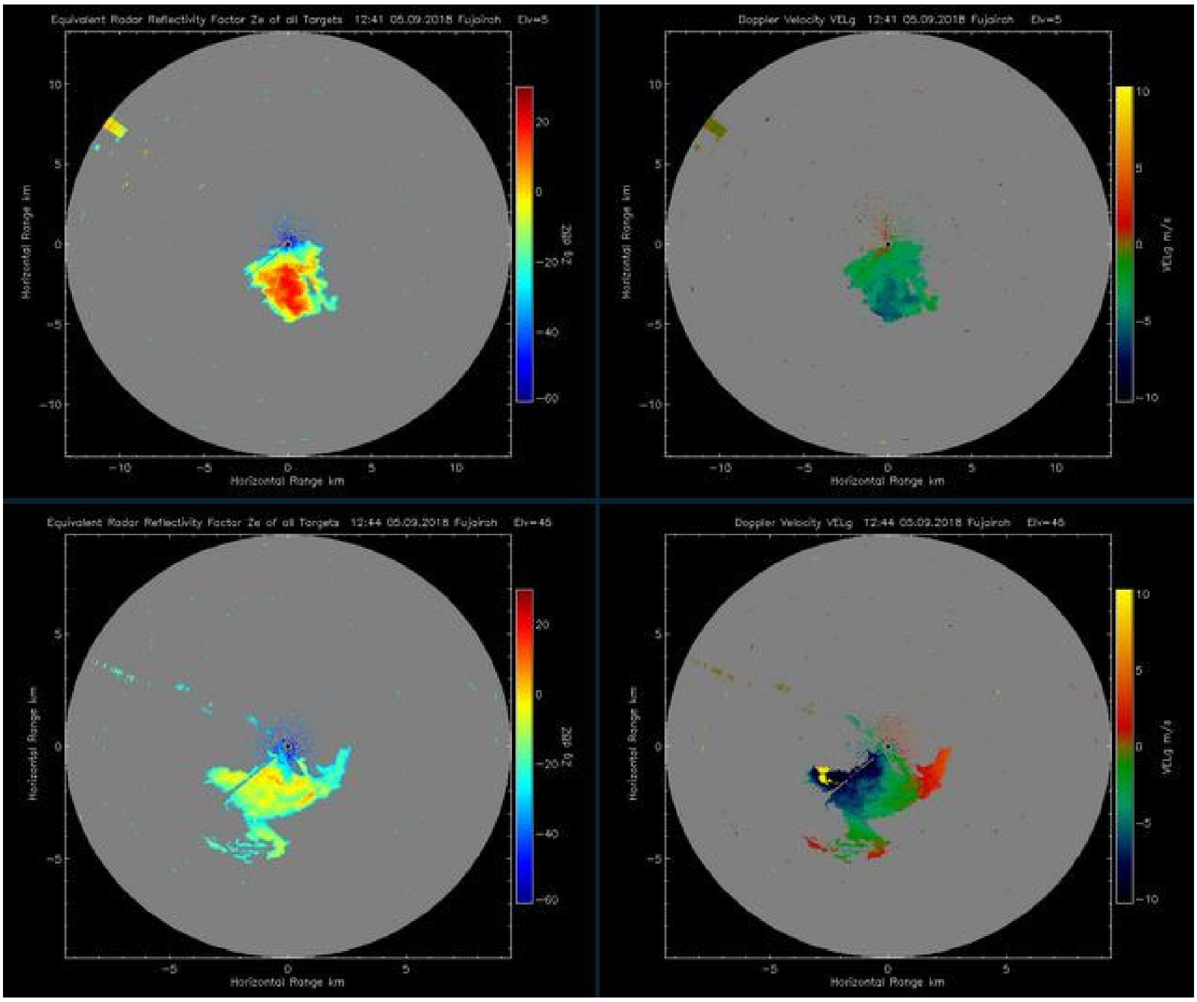
5 September 2018

Originally, it was not planned to extend the intensive observations at the OCAL mountain site beyond the summer months of June to August. However, we decided to keep the instruments running and collected further interesting convective events in September 2018. On 5 September 2018, a convective cell formed above the OCAL mountain site at around 1130 UTC. Observations of this rain event with the DCR are shown here:



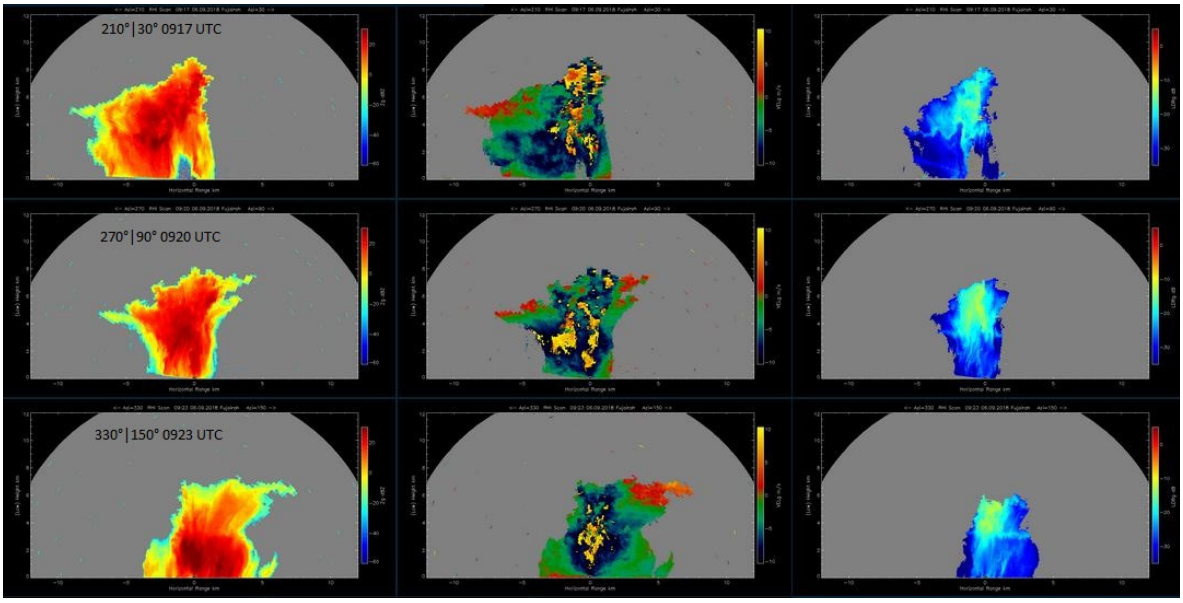

210°|30° 1232 UTC
270°|90° 1235 UTC
330°|150° 1238 UTC

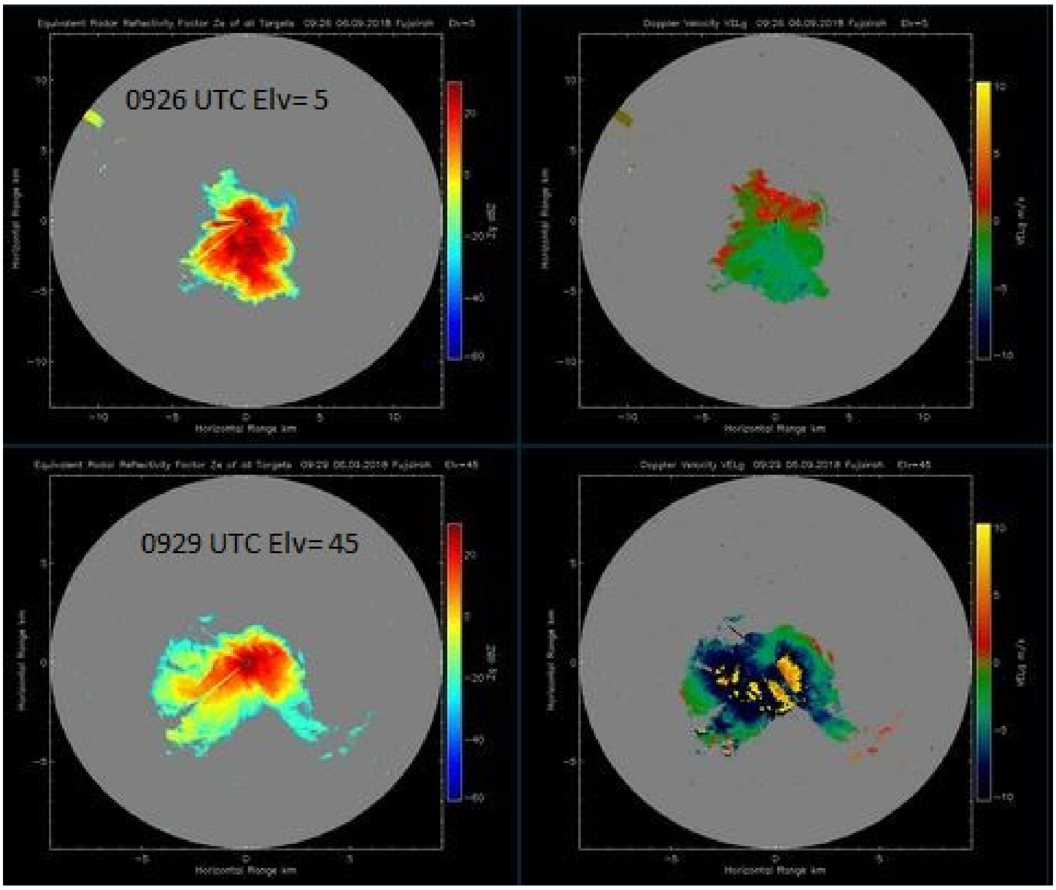

Equivalent Radar Reflectivity Factor Ze of all Targets 11:41 05.09.2018 Fujairah Elv=5
Horizontal Range km
Zg dBZ
Doppler Velocity VELg 11:41 05.09.2018 Fujairah Elv=5
VELg m/s


Equivalent Radar Reflectivity Factor Ze of all Targets 12:41 05.09.2018 Fujairah Elv=5
Doppler Velocity VELg 12:41 05.09.2018 Fujairah Elv=5
Equivalent Radar Reflectivity Factor Ze of all Targets 12:44 05.09.2018 Fujairah Elv=45
Doppler Velocity VELg 12:44 05.09.2018 Fujairah Elv=45
Horizontal Range km
Zg dBZ
VELg m/s

6 September 2018

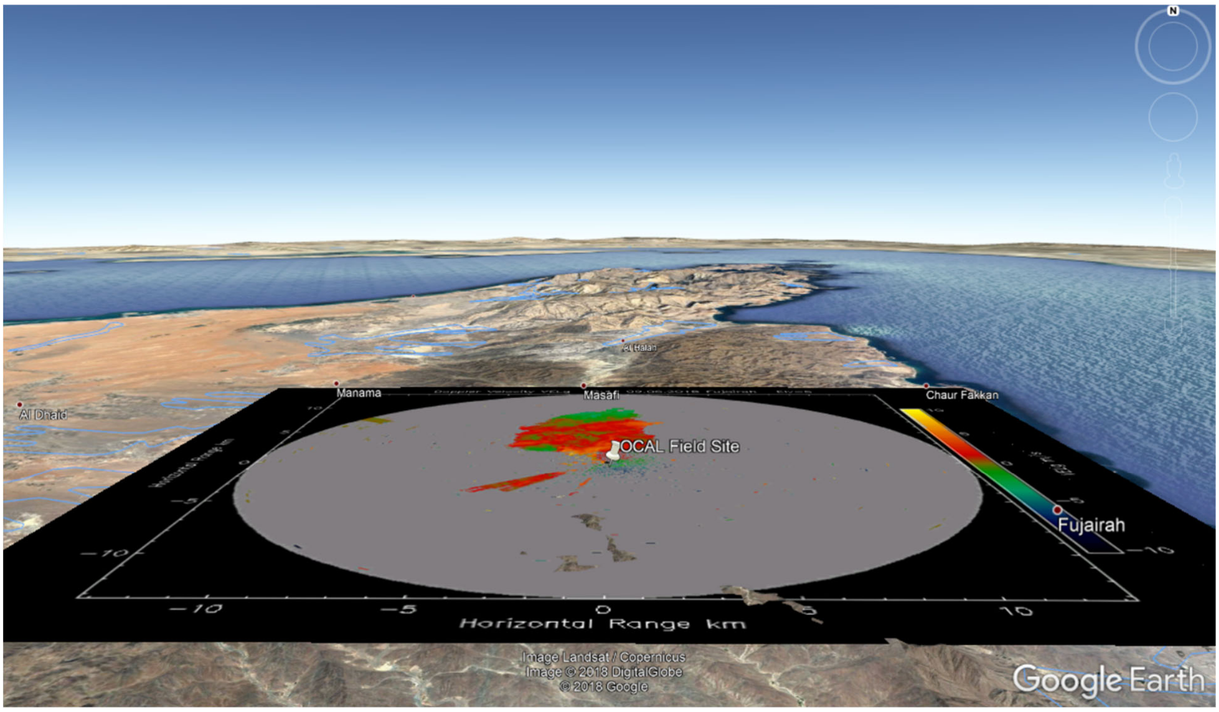
On 6 September 2018, a convective precipitation event was observed in the morning from about 9 UTC. Observations of this rain event with the DCR are shown here:

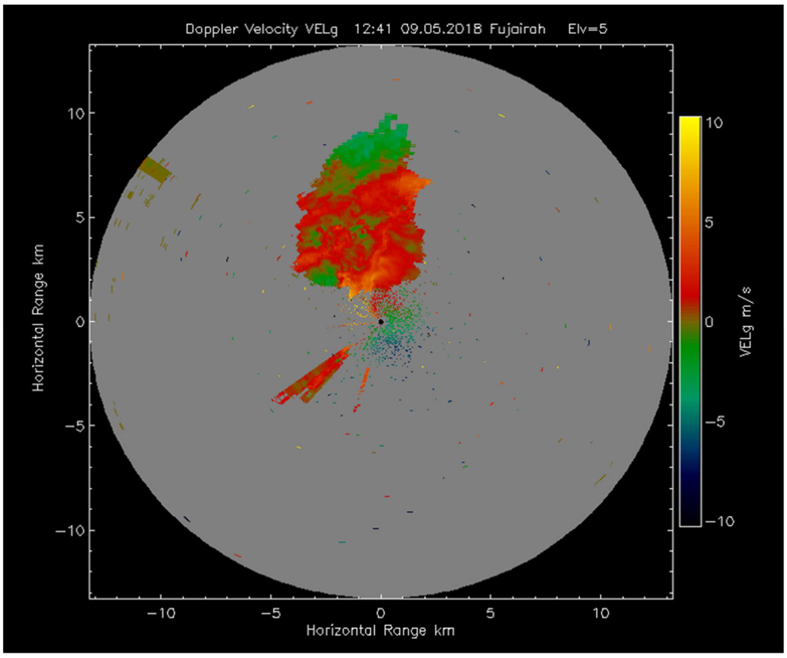




Visualization of the Measurements

We are currently also working on implementing the OCAL measurements into Google Earth so that the observation can easily be related to orographic features as well as the 3-dimensional nature of the scans can easily be seen. Please find in the following an example of the implementation of a horizontal scan of the DCR. This image was also used for public outreach and posted to social media.





RCIb: Development and application of model chain

Staff/Lead person: Dr. Thomas Schwitalla

The time schedule and the milestones (MS) are presented in Table 2.

Within this RC, the first ensemble forecast system on the convection-permitting scale as well as the first turbulence permitting simulation were realized for the UAE.

Table RCIb-1: Proposed time schedule and milestones for RCIb.

WP RCIb - Development and application of model chain	Milestones	
RCIb1 Analysis of previous precipitation cloud seeding events and selection of case studies	MS1, MS2	Synthesis
RCIb2 Set up of model system down to the LES scale	MS3, MS4	
RCIb3 Selection of EPS members, post-processing of boundaries and initial fields	MS5	
RCIb4 Post-processing of satellite and radar data for DA	MS6, MS7	
RCIb5 En3DVAR simulations and forecasts for case studies	MS8, MS9, MS10, MS11	

WP RCIb4 (M1-30): Post-processing of satellite and radar data for DA

Milestones:

RCIb.MS7 (M30): Corresponding observations available, post-processed, and ready to use for the cases occurring during the mountain measurement campaign. Data available from IPM server.

The OCAL data were collected and are ready to use so that these parts of the milestones were realized. Further case studies for the mountain campaigns are currently being defined between IPM, NCM as well as the Finnish and the Chinese research teams. As soon as a case study is defined, further data processing procedures can be initiated. Post-processing of NCM radar data was not possible yet, as quality control and corrections of the data for data assimilation purposes could not be applied. In the future, the radar data quality should be good enough for data assimilation purposes, as the radar data processing is further enhanced by NCM.

WP RCIb5 (M16-36): En3DVAR simulations and forecasts for the case studies

Milestones:

RCIb.MS9 and RCIb.MS10 (M28 and M36): Simulations of cases during the mountain campaigns and their evaluation. Model data, analyses, figures, and skill scores will be made available on an IPM server.

The first milestone was not accomplished yet due to the lack of decision of a suitable case for the mountain campaigns and challenges encountered for the LES (see below). Therefore, we could not fulfill milestones MS9 and MS10 yet. However, we will strive for this during the cost-neutral extension of this project. Data for the LES simulation can be made available upon request.

RCIb.MS11 and RCIb.D9 (M36): Based on the model simulations, scientific analyses of overarching research goal I, OI.1 and OI.2 as well the HI.1 and HI.2.

The results concerning the HI.1 will be published soon as the evaluation of the five member ensemble is close to be finished. The scientific analysis with respect to HI.2 will be subject of another publication.

FIRST RESULTS CONCERNING MODEL DOWNSCALING TO THE 300-M SCALE

The initial set up with a nesting ratio of 1:5 ending at 111 m grid increment, which was reported in the second intermediate report, led to difficulties in simulating the cloud development over the Al Hajar Mountains because the steep gradient leads to an unstable behavior. WRF is based on a terrain following coordinate system and a true horizontal diffusion scheme is applied. According to the WRF developers, this pushes the applied numeric to its limits as the slope at this particular resolution exceeds 40°. A suggestion by the WRF developers is to heavily smooth terrain but this is not our intention on the turbulence permitting scale.

Therefore, it was necessary to revise our setup and applied a nesting ratio of 1:3 so that currently the finest grid increment is 309 m with an intermediate nest of 926 m grid increment. We also tested a fourth domain with 103 m grid increment but we could not generate results due to numerical instability. The following Table RC1b-2 summarizes the grid dimensions and resolutions.

Table RC1b-2: Model domain configurations and resolutions.

Domain	*# Grid Cells*	*# Vertical Levels*	*Grid Increment*	*Time step*	*Approx. Domain Size*
D01	900*700	100	0.025° (2.8 km)	10s	2500 km x 2000 km
D02	790*790	100	0.0083° (926 m)	3s	732 km x 732 km
D03	826*772	100	0.0027° (309 m)	1s	255 km x 239 km

Domains D01 and D02 are running concurrently by applying a one-way nesting approach while D03 is forced by the 5 min output of D02 using the NDOWN approach. The turbulence permitting simulation was conducted for 24 hours forecast time and is initialized at 00 UTC on 14 July, 2015. The computation requires 7200 compute cores on the Cray XC40 system for about 300 min resulting in an output data volume of 10 TB assuming 1 min output on D03 for process studies. Due to the large amount of data, the files are stored on the HLRS tape library but can be made available upon request.

The applied physics options of WRF 3.8.1 are summarized in Table RC1b-3 in the previous report.

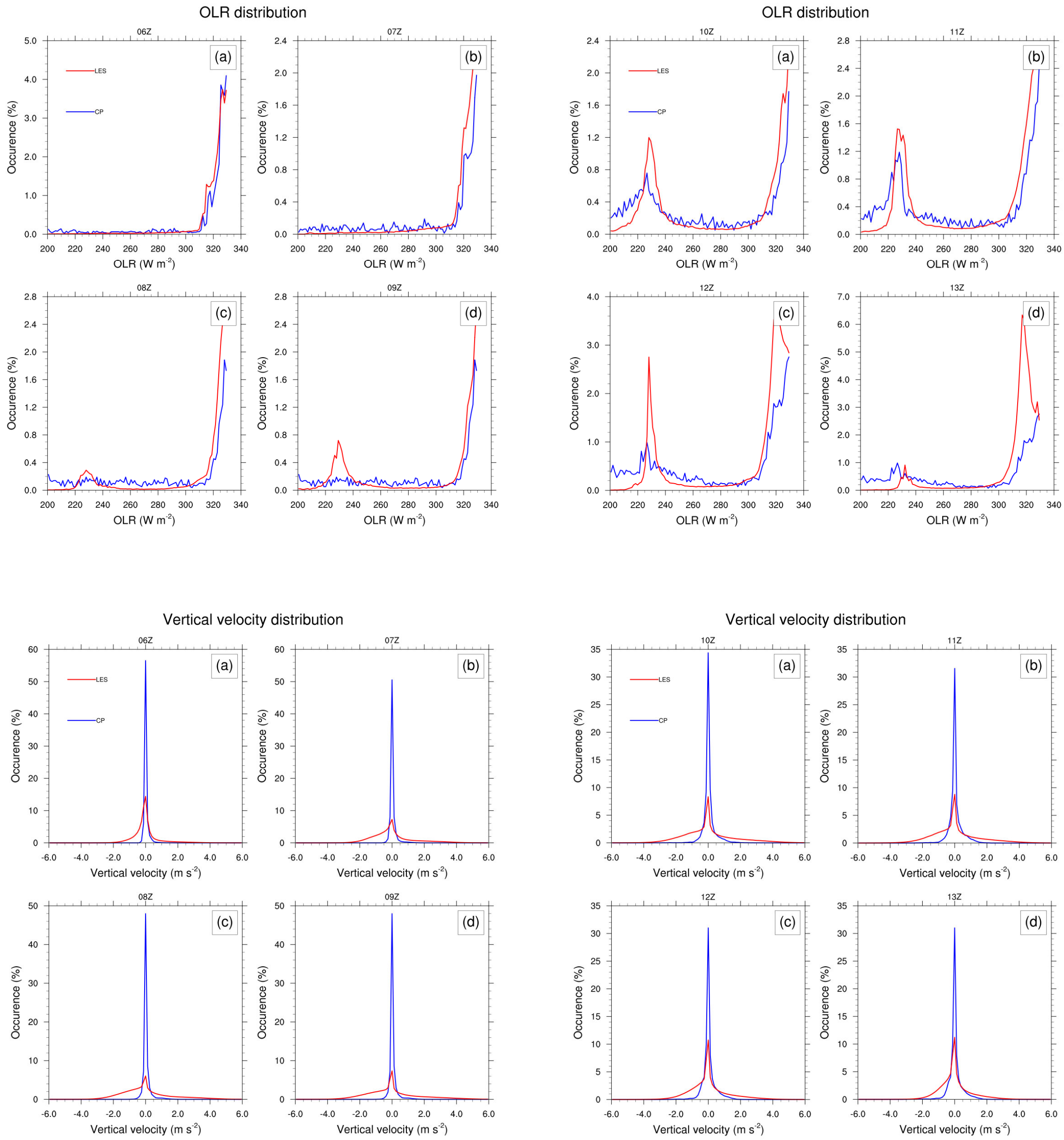


Fig. RC1b-1: Upper row: Outgoing longwave radiation (OLR) distribution of the convection permitting simulation and the LES simulation between 06 UTC and 13 UTC at 14. July 2015. The blue line denotes the convection permitting simulation (CP) and the red line denote the turbulence permitting simulation (LES). Lower row: distribution of the vertical velocities averaged between 1400 m and 1900 above ground level (AGL) for the same time period.

Figure RC1b-1 shows an example for the PDF of the outgoing longwave radiation, which can be used as a proxy for deep convection, averaged over the area of D03. It is seen, that the timing of the cloud development between CP and LES is very similar. During the further course of the day, the LES simulation shows more deep convection as indicated by lower values of OLR starting at 08 UTC. Especially during the early afternoon, the LES simulates stronger convection as compared to the CP simulation. This is also reflected in the vertical velocity distribution shown in the lower panel of Fig. RC1b-1. While the CP simulation only shows weak updraft velocities, the LES clearly shows moderate updrafts leading to more intense convection over the al Hajar Mountains.

Figure RC1b-2 shows every minute model time series of water vapor mixing ratio at one grid point northeast of Al Ain where the convection occurs at 309 m resolution.

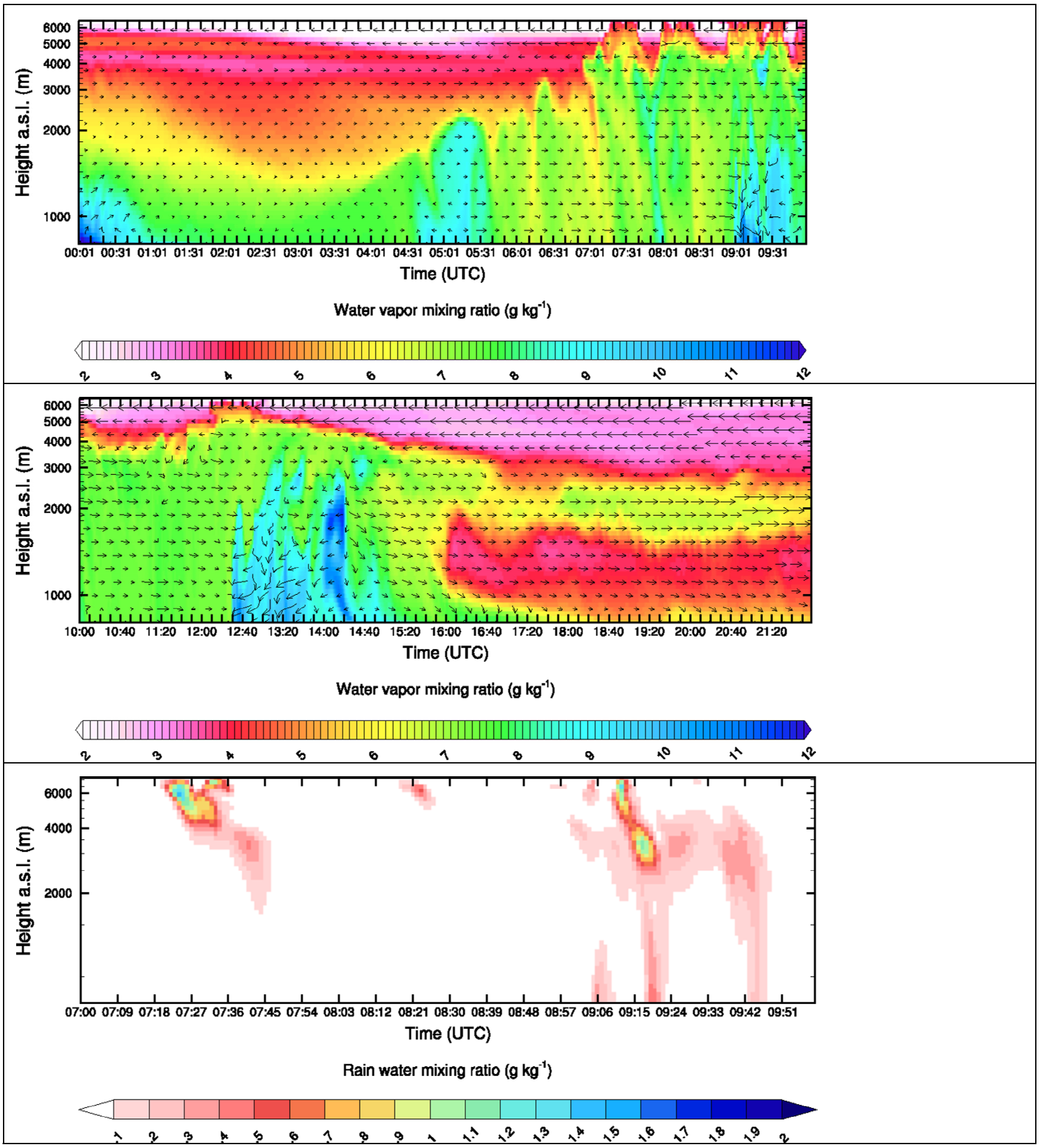


Fig. RC1b-2: Top rows: 2-m water vapor mixing ratio time series of the model grid point 24.47°N 56.14° E. Bottom row: Rainwater mixing ratio time series at 24.47°N 56.14° E.

The initiation of convection can be seen in the transport of moist air to higher altitudes at around 8:40 UTC associated with rain reaching the ground. A second and stronger convective period evolved around 12:30 UTC (16:30 LT). It is also very interesting to see that the boundary layer height reaches around 5000 m above sea level as indicated by the strong moisture gradient.

Ensemble Design

As mentioned in last progress report, we decided to set up a five member physics ensemble replacing the coarse resolution ECMWF EPS in order to achieve a sufficient spread among the simulations at this particular high resolution. Table RC1b-3 of the previous report summarizes the applied configurations. More details will be presented in a publication which is currently under preparation.

In summary, we developed a new ensemble-based forecast system for the UAE on the convection permitting scale. This ensemble demonstrated excellent performance for the prediction of the evolution and properties of clouds. However, due to challenges in the design of the LES, the definition and simulation of further cases for the mountain campaigns are delayed.

Apart from these issues, it is now possible to elaborate further details of convection initiation and cloud development with our LES (300 m) simulations as these allow for simulating further details of the orography in the Al Hajar mountain range, the region of the highest likelihood of cloud development.

For the first time, it was possible to assimilate GNSS-ZTD data into the WRF data assimilation system with the support of the GFZ Potsdam and NCM. These data help to improve the distribution of water vapor over the UAE. Having said this, it is extremely important to get more GNSS observations from the neighboring countries, especially from OMAN.

Additional OCAL effort in original proposal not considered and provided as an additional contribution of the UHOH: Eddy-Covariance Measurements at Al Ain Airport

Leadperson: Dr. Hans-Dieter Wizemann

In the frame of the UAEREP project an eddy-covariance station for surface flux measurements was installed at Al Ain Intl. Airport on 5th April 2017. The station is in operation until today. Routine maintenance, bi-weekly sensor cleaning and data collection, is performed by Mark Newman and Steven Williams. The collected raw data are uploaded to the NCM server from where they are picked up by the IPM member Hans-Dieter Wizemann for further processing. The processed data are stored in the OCAL_UHOH folder on the NCM server.

Due to an unexpected early battery capacity loss with subsequent data logger failure, a flux and weather data gap between October 2017 and 1st February 2018 occurred. Since the latter date, a continuous time series without data gaps is available for the first time. Thus, insight to the energy balance closure and all four radiation components is now possible.

The results are now used by scientists at UHOH and KU for process studies and model verification.

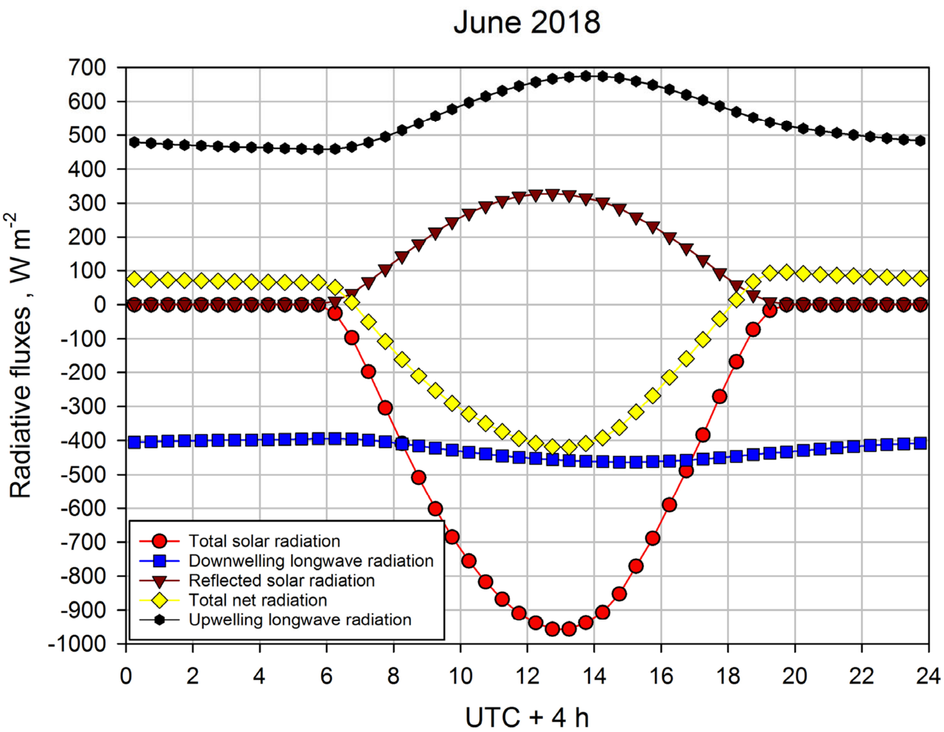


Fig. RC1+1: Typical diurnal cycle of all shortwave and longwave radiation components and the derivation of the resulting incoming net radiation.

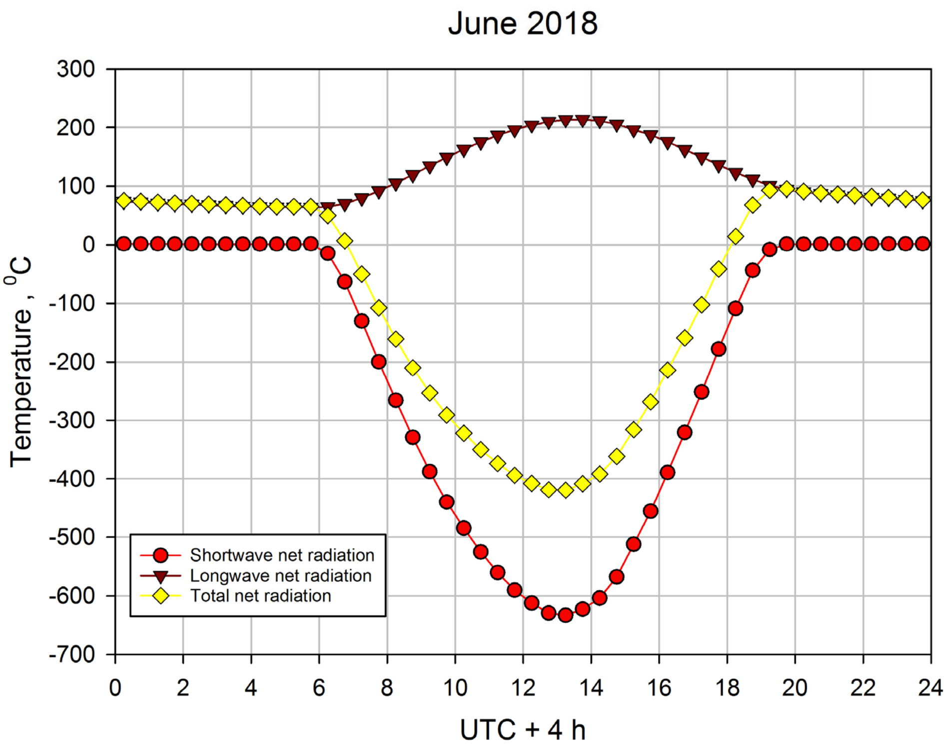


Fig. RC1+2: Resulting shortwave and longwave net radiation.

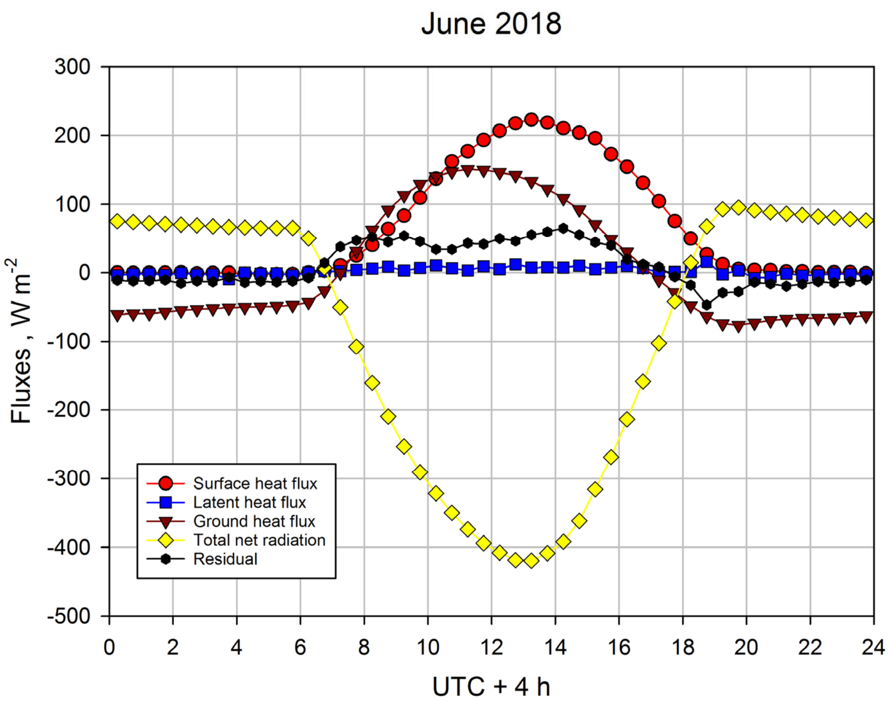


Fig. RC1+3: Resulting energy balance closure with the partitioning between the soil and the sensible heat flux

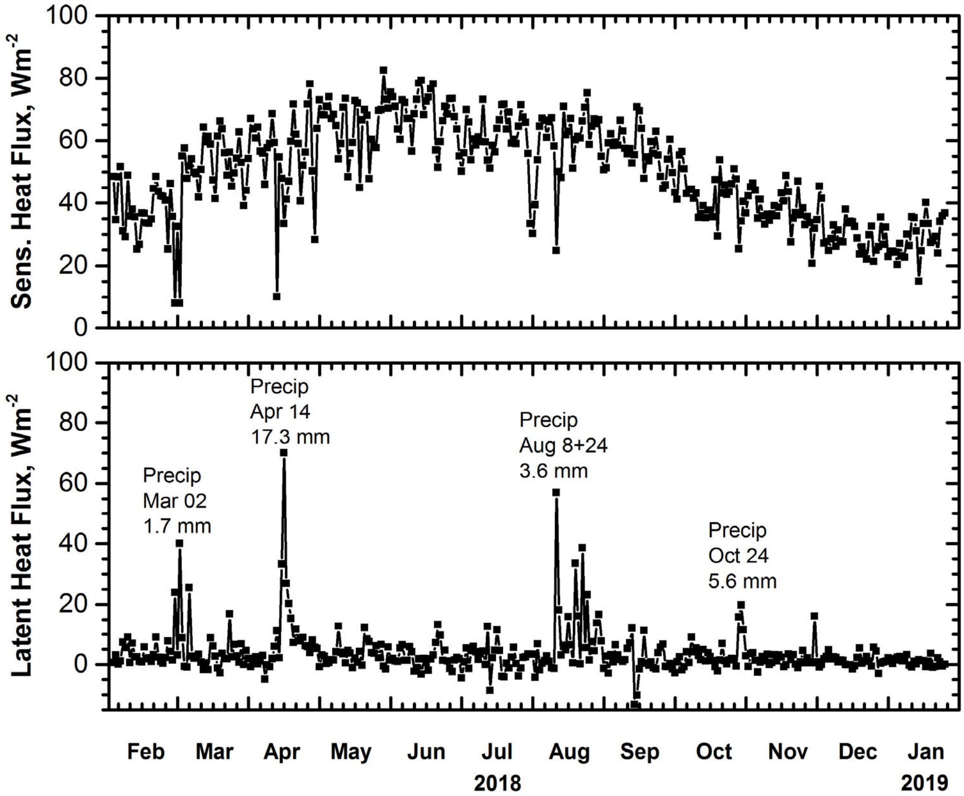


Fig. RC1+4: Annual cycle of daily mean sensible (upper panel) and latent heat flux (lower panel). Rain events are indicated.

A highlight of the measurements is the disclosure of the behavior of latent heat in combination with rain events. After a spontaneous large peak of latent heat flux, water stored in the upper soil supplies a decreasing latent heat flux at daytime for several days (Fig. 5).

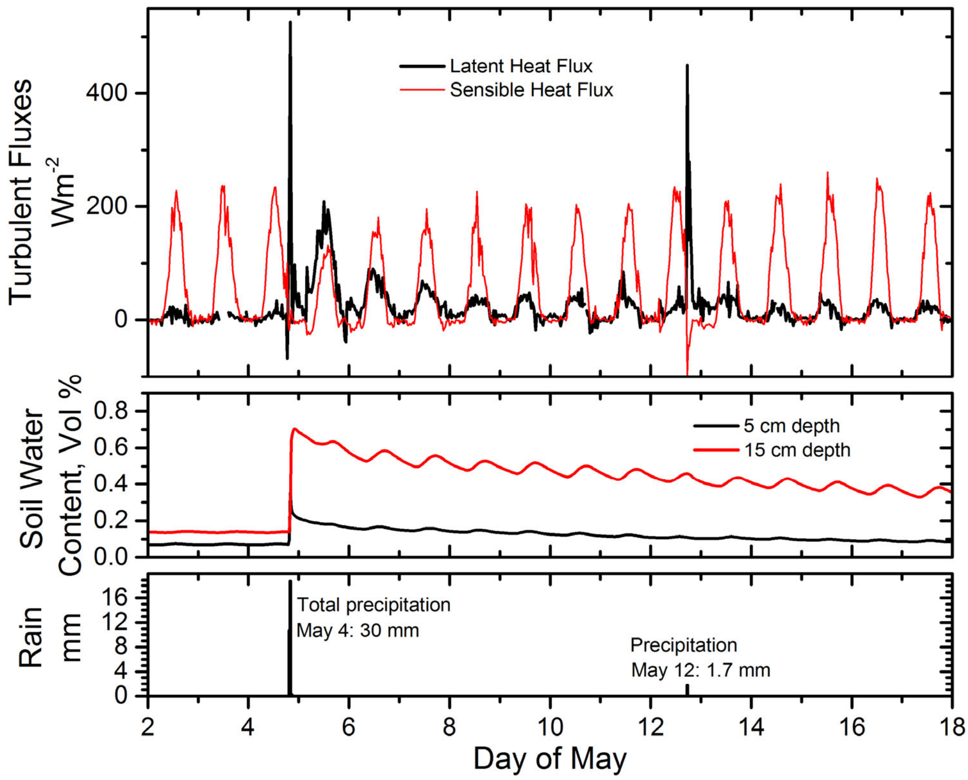


Fig. RC1+5: Latent heat flux after the rain events in May 2017. Upper panel: turbulent fluxes; middle: soil water content in 5 and 15 cm depth; lower panel: precipitation.

The results obtained from the initial installation date until October 2017 were presented during the OCAL Review Panel Meeting at Hohenheim in November 2017. Within a B.Sc. thesis (in German) the source area (footprint) of the fluxes was analyzed in dependence of the wind sector. The corresponding results of this thesis were also presented at the meeting.

RCII: Sustainable land cover and terrain modification to enhance convection and precipitation

Staff/Lead person: Dr. Oliver Branch

New results from RCII since 3rd Annual Report

In 2018 and 2019, many different land use and terrain modification scenarios were developed and run for one day cases, selected based on atmospheric conditions (RCII1.MS3, MS4, MS9). The emphasis was on modification of the land use within the flat desert areas of the UAE.

A concept was also developed for maximizing the impact on the atmosphere by heating the surfaces and/or minimizing the albedo by using dark surfaces – the Cloud Precipitation Reactor (CPR). New results from these later CPR simulations (27 July 2015) show a strong impact on wind flows and an increase in cloud development in comparison with control simulations without modifications (Figure RCII.-1).

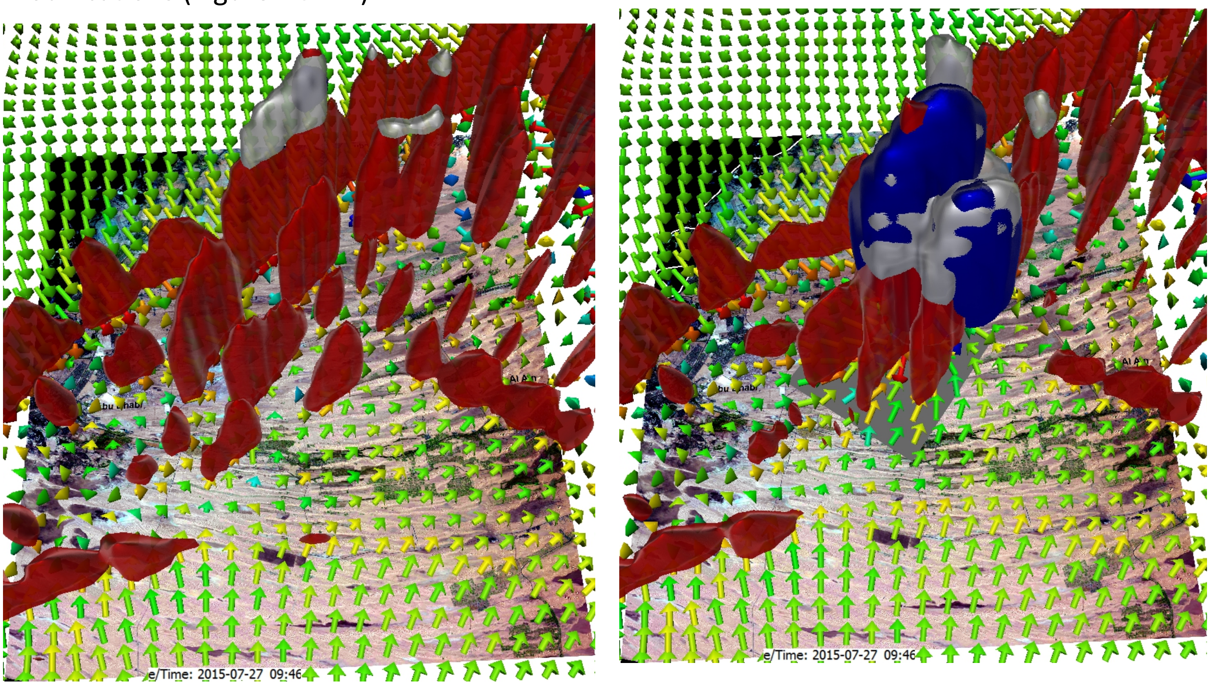


Figure RCII-1: Impact of a 30 by 30 km black surface on clouds and vertical winds on 27 July 2015. Left is control, right is impact. Shown are the landscape (Landsat satellite image), the surface wind field as well as isosurfaces of vertical wind (red), cloud liquid water (grey), and rain (blue).

Significant increases in total rainwater amounts was modeled with a larger ensemble of model runs and with a strong dependency on the scale of the artificial surfaces, and on the level of heating was observed. Figure RCII. 2).

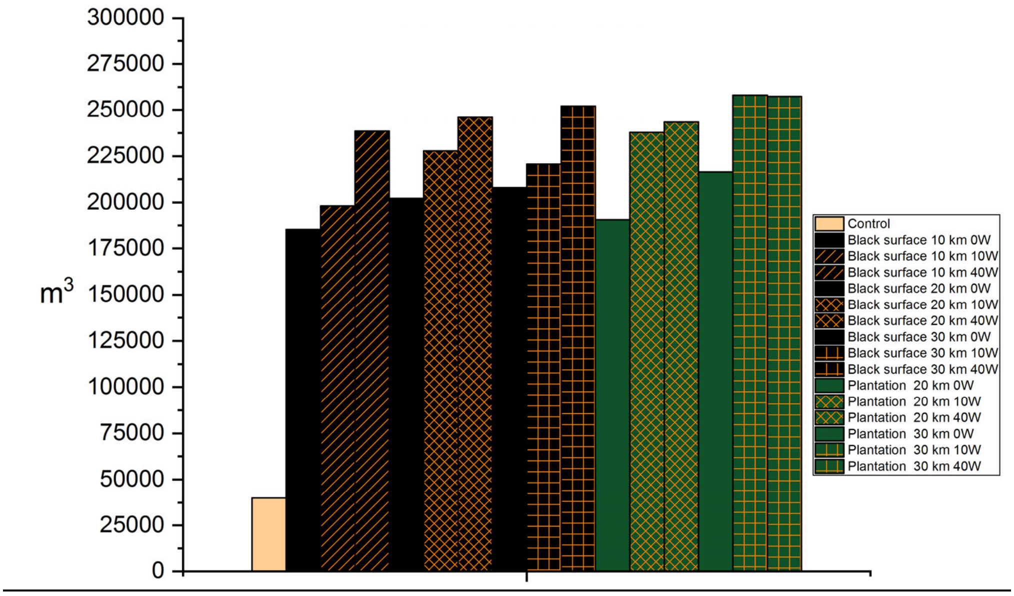


Figure RCII-2: Total rainfall amounts within a 80 by 80 km search area around various scenarios

It is a significant result that there is a strong impact from 10 km by 10 km dark surfaces and plantations, which was originally judged unlikely to be an sufficient size (Fig RCII. 3). Also clear is that adding heating does increase water amounts somewhat, but unheated surfaces are also effective in increasing rainfall.

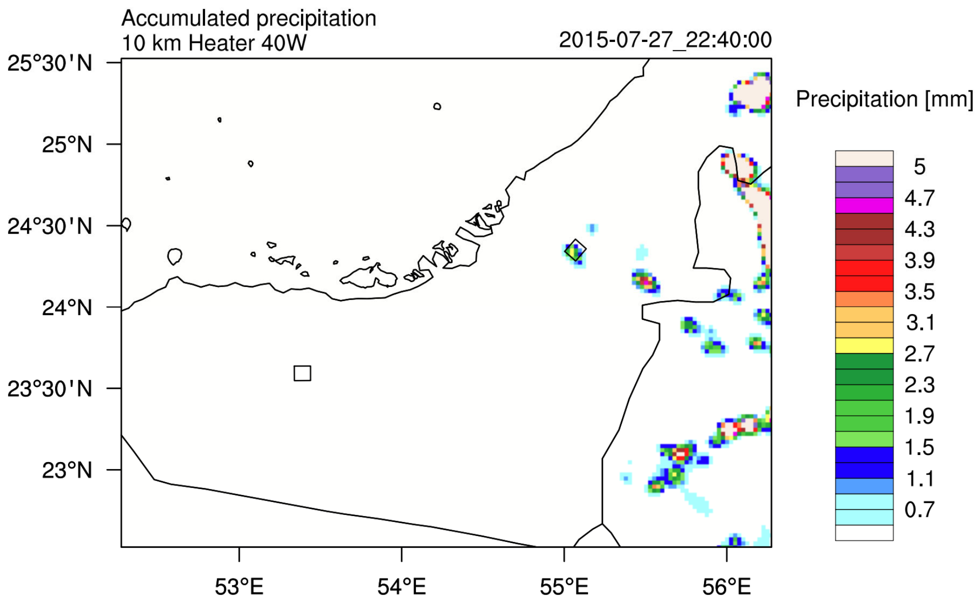
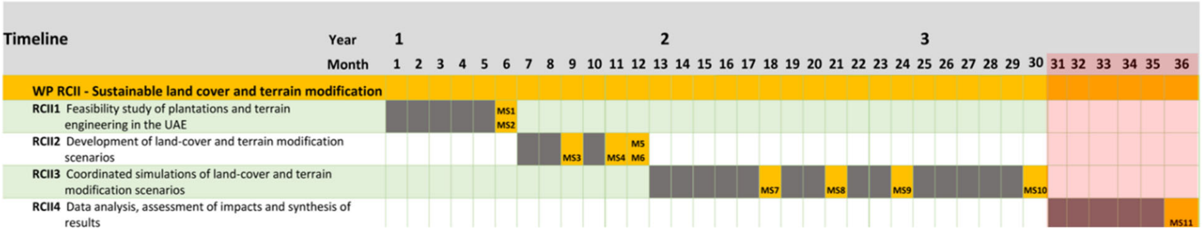


Figure RCII-3: Impact of a heated 10 by 10 km black surface on ground precipitation over a single day. Virtually no precipitation was seen in control in the vicinity of the surfaces.

Summary of achievements for RCII

Table RCII 1: Proposed time schedule and milestones for RCII.



- A feasibility study was conducted and published in collaboration with the Masdar Institute and NCM
- The WRF model was verified over one year using data from 50 NCM stations with good model performance
- The WRF model was verified for 30 min intervals over JJA 2015 against cloud liquid water path from METEOSAT 8 (Figure RCII. 4) with good results
- New land use and soil datasets were collated, merged for the UAE and ingested into WRF and archived on the NCM server
- Many terrain and land use modification scenarios were developed and run for cases at 2.7km and later down to 300m resolutions
- Interesting cases were selected based on a newly developed stability index
- Significant positive impacts on rainfall were observed from all sizes (10 by 10km to 30 by 30km) and for vegetated and non-vegetated surfaces
- All milestones were achieved to a high standard within the agreed timeframes set out in Table RCII 1

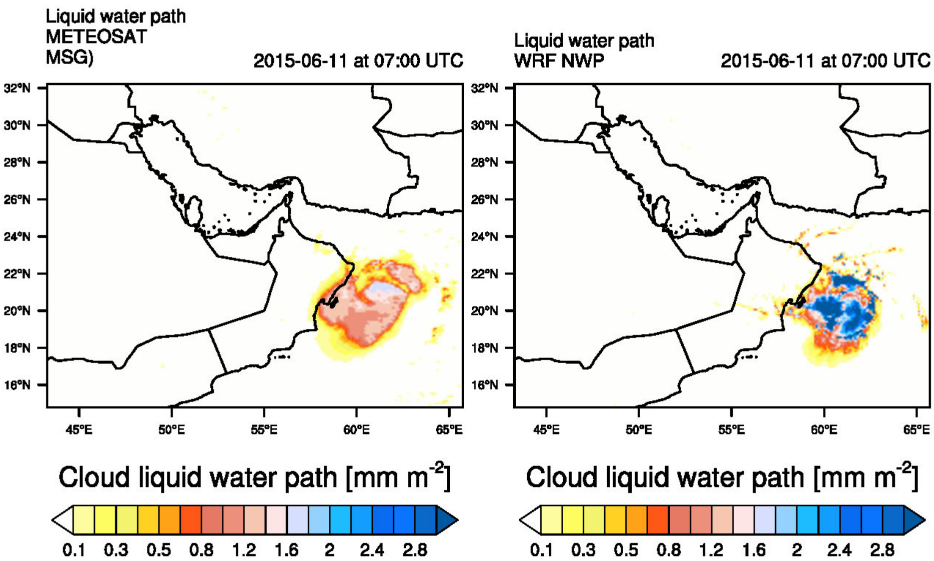


Figure RCII-4: Verification of WRF-NOAHMP against METEOSAT 8 liquid water path data at 30 min intervals

PUBLICATIONS/PRESENTATIONS

Published

Aldababseh, A., Temimi, M., Maghelal, P., Branch, O., Wulfmeyer, V. (2018). Multi-Criteria Evaluation of Irrigated Agriculture Suitability to Achieve Food Security in an Arid Environment. Sustainability. 10. 803. 10.3390/su10030803.

B.Sc. and M.Sc. Theses

Neumann, A., B.Sc. Thesis University of Hohenheim, 2017: Footprint-Analyse der Eddy-Kovarianz-Messungen während SABLE, CAOS und in den Vereinigten Arabischen Emiraten.

Negar Masserat, M.Sc. Thesis University of Hohenheim, 2017: Investigation of dynamics in the atmospheric boundary layer with a scanning Doppler lidar.

Gong, Zhecheng, M.Sc. Thesis University of Hohenheim, 2017: Investigation of Convection Initiation Over the Eastern Arabian Peninsula With Meteosat Data.

Adesina, Nurudeen Abiodun, M.Sc. Thesis University of Hohenheim, 2018: Analysis of atmospheric convection in Germany and the United Arab Emirates with scanning Doppler lidar.

Jens Strohbach, M.Sc. Thesis University of Hohenheim, 2018: Analysis of four months of Doppler lidar measurements on Al Farfar Mountain, UAE, within the OCAL project.

Späth, F., et al., 2019: The new Wind and Cloud Mountain Observatory in the UAE, in preparation.

Branch, O., 2019: A new Satellite Climatology for the Arabian Peninsula, in preparation.

Submitted

Wehbe, Y., M. Temimi, M. Weston, N. Chaouch, O. Branch, T. Schwitalla, V. Wulfmeyer, and A. Al Mandous, 2018: Analysis of an Extreme Weather Event in a Hyper Arid Region Using WRF-Hydro Coupling, Station, and Satellite data, submitted for publication in Natural Hazards and Earth System Science, https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2018-226.

Branch, O & Wulfmeyer, V. Sustainable desert plantations will enhance rainfall and mitigate climate change

In preparation

Review paper on the UAEREP status and results, Prof. Wulfmeyer lead author

Identification of convection initiation events over the United Arab Emirates and Oman with Meteosat 7 MFG data

Performance of the WRF-NOAHMP model over the United Arab Emirates using in-situ station measurements

Seasonal verification of WRF-NOAH MP cloud liquid water path with Meteosat 8 MSG data

Publication about the performance of the five member WRF model ensemble

Conferences

Wulfmeyer, V., Abu Dhabi Sustainability Week: IREF 3rd International Rain Enhancement Forum, 2019: Presentation - *Land-Atmosphere Interaction: The Key to Predicting and Creating Clouds and Rainfall*

Branch, O., Wulfmeyer, V., Abu Dhabi Sustainability Week: IREF 3rd International Rain Enhancement Forum, 2019: Presentation - *Increasing Rainfall with the Cloud and Precipitation Reactor – A Drop in the Bucket or a Breakthrough Concept to Reclaim the Desert?*

Branch, O., Wulfmeyer, V., Adebabseh, A., Temimi, M., 2018*: Sustainable land cover and terrain modification to enhance precipitation in the United Arab Emirates*. 21st Conference on Planned and Inadvertant Weather Modification. Oral presentation at AMS Austin, Texas. https://ams.confex.com/ams/98Annual/webprogram/Paper335164.html

Prof. Volker Wulfmeyer provided two presentations for the 2nd International Forum on Rain Enhancement in Abu Dhabi, January 2018.

Branch, O., Wulfmeyer, V., Adebabseh, A., Temimi, M., 2017: *Sustainable Land Cover and Terrain Modification To Enhance Precipitation in the UAE*. Poster at AGU American Geophysical Union, New Orleans, Louisiana.

Prof. Dr. Volker Wulfmeyer, Dr. Hannele Korhonen, and Dr. Lulin Xue organized a new session at EGU 2019 entitled: The Nexus between Weather Modification and Limited-Area Geoengineering

Other Information

We propose to continue the OCAL measurements at the mountain site and the Al Ain airport, to realize the Cloud Seeding Alert System (CSAS) at NCM. Particularly, we recommend to start a pilot project to design and to operate the CPR over the UAE and to combine its operation with cloud seeding efforts. We recommend a strong participation of the UAEREP at the EGU 2019 in connection with a specially designed Townhall Meeting, press activities, and the high visibility of the UAEREP Awardees at the dedicated EGU session.

References

Aldababseh, A., Temimi, M., Maghelal, P., Branch, O., Wulfmeyer, V. (2018). Multi-Criteria Evaluation of Irrigated Agriculture Suitability to Achieve Food Security in an Arid Environment. Sustainability. 10. 803. 10.3390/su10030803.