EMeRGe - the Effect of Megacities on the transport and transformation of pollutants on the Regional and Global scales

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1 Introduction

At the industrial revolution (1750-1800), the population of the earth was around 1 Billion and less than 5% of population lived in urban areas. In 1950, when the population reached about 2.9 billion, there were two megacities New York/Newark and Tokyo. In 2020, the earth's population is around 7.8 Billion, more than 50% live in urban areas, and there are now approximately 38 around the world. Since 2007, more than 50% of the population live in urban areas and the earth's population has now reached 7.8 Billion. Anthropogenic activity to sustain and feed MPC is now one of the most important sources of pollution, modifying atmospheric chemistry, air quality, and climate. To assess the impact of MPC emissions locally and regionally requires knowledge of the transport and transformation of the MPC plumes. The EMeRGe project was proposed to address this need and investigate the transport and transformation of the chemical composition of MPC plumes. Secondary objectives include the improvement of our understanding of the impact of biomass burning, which mixes with the plumes from MPC. EMeRGe selected European and Asian MPC as targets, where the regulations on emissions are significantly different.

EMeRGe assumes that the nature of the local emissions, the meteorology and photochemical oxidation mechanisms in air masses determine the transport and transformation of the plumes from MPCs. To test this hypothesis, the following scientific questions are addressed:

a) which transport and dispersion processes dominate the MPC outflows in Europe and Asia during the selected measurement periods?
b) which oxidation or other processes determine the chemical transformation of MPC emissions?
c) what are the regional impacts of the emission by the selected European and Asian MPCs?
d) what is the relevance of emission from European and Asian MPCs for radiative forcing and climate change?
e) do our chemical models adequately simulate of transport and transformation processes of European and Asian MPC outflows?

2 EMeRGe Scientific Objectives

Investigation of regional and hemispheric impact of the outflow of MPC (major population centres) on atmospheric composition using as field of studies in July 2017 in Europe and in March and April in East Asia in 2018. Some the key of objectives were to investigate examples of:
i) the dispersion and transport patterns of MPC outflows;
ii) the impact of topography and meteorology;
iii) Chemical transformation during transport.
The data set is used to test the accuracy of chemical models to account for the transport and transformation of air masses in the MPC outflows from Europe and East Asia.

3. The EMeRGe HALO Payload

The HALO research aircraft measurement payload during the EMeRGe campaigns comprised in situ gas phase measurements, remote sensing and cloud condensation nuclei and aerosol shown in figures 1, 2 and 3.

Institution	PI	Gas/Parameter	Instrument
Institute for Environmental Physics-University of Bremen (UB-IUP)	J.P. Burrows / M.D Andrés Hernández	HO_2+RO_2	PeRCEAS
University of Wuppertal (BUW-IAU)	R. Koppmann / M. Krebsbach	VOC / carbon isotope ratios	MIRAH
Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology (KIT-IMK)	A. Zahn	O_3, 5-10 VOCs	FAIRO / HKMS
Institute of Atmospheric Physics, Deutsches Zentrum für Luft und Raumfahrt (DLR-IPA)	H.Schlager /H.Ziereis/ Y. Ren	O_3, CO, CO_2, CH_4 isotopes, PFC tracer	AMTEX / CATS / PERTRAS
		SO_2, HNO_3,HONO, organic acids	CI-ITMS
		NO, NO_2, NOy	AENEAS
		PAN	IPAN

Figure 1. The in situ trace gas and free radical measurements made aboard HALO during EMeRGe

Institution	PI	Gas/Parameter	Instrument
Institute for Environmental Physics-University of Heidelberg (UH-IUP)	K. Pfeilsticker	O_3, NO_2, HONO, CH_2O, $C_2H_2O_2$, O_4, BrO, ClO, IO	mini-DOAS
	U. Platt / D. Pöhler	NO_2, CH_2O, $C_2H_2O_2$, H_2O, O_4, SO_2, IO, BrO, O_3	2D/3D HAIDI
Forschungszentrum Jülich (FZJ-IEK-8)	B. Bohn	UV radiation, $J(O_3)$, $J(NO_2)$	HALO-SR

Figure 2. the remote sensing measurements made on board HALO during EMeRGe

Institution	PI	Gas/Parameter	Instrument
Particle Chemistry - Department MPIC/ University of Mainz (JGU-IPA)	S. Borrmann / J. Schneider	Aerosol particle composition	C-ToF-AMS
Multiphase Chemistry Department MPIC- Mainz (MPIC)	U. Pöschl / M.O. Andreae	CCN, soot, aerosol microscopic properties	HALO-CCN
Institute of Atmospheric Physics, Deutsches Zentrum für Luft und Raumfahrt (DLR-IPA)	H.Schlager /D.Sauer	Fine aerosol	AMETYST

Figure 3 the Cloud Condensation Nuclei, CCN, and Aerosol measurements made during EMeRGe.

4 The EMeRGe HALO Campaigns

An integrating focus of EMeRGe were the measurement campaigns exploiting the capabilities of the German HALO research were undertaken during EMeRGe, which investigated the outflow from: i) European MPCs in July 2017; ii) MPCs in East and South East Asia during March and April 2018. In addition to the HALO aircraft measurements, the EMeRGe International scientists contributed studies of the measurement from instrumentation from ground based, airborne and satellite platforms. For example in EMeRGe in Europe the UK NERC FAAM (https://nerc.ukri.org/research/sites/facilities/aircraft/) "ERA - CNR - ISAFOM" (https://www.eufar.net/aircrafts/44) were deployed to make measurements around London and Rome respectively. Scientists from CNR Rome Italy, Imperial College, the University of York and the University of Leeds in the UK and CNRS in Paris participated in the campaign. In EMeRGe in Asia, measurement were made ground based and Lidar measurements were made by EMeRGe partners from Taiwan, Japan, the Philippines, Thailand, South Korea and China. EMeRGe benefited from the support by iCACGP (international Commission on Atmospheric Chemistry and Global Pollution).

Figure 4. A significant part of the EMeRGe in Europe HALO and FAAM teams of scientists and crews July 2020.

During EMeRGE in Europe, the HALO Aircraft was based at the DLR in Oberpfaffenhofen, Germany. Figure 5 shows the flight tracks for the 7 research flights made in EMeRGe in Europe.

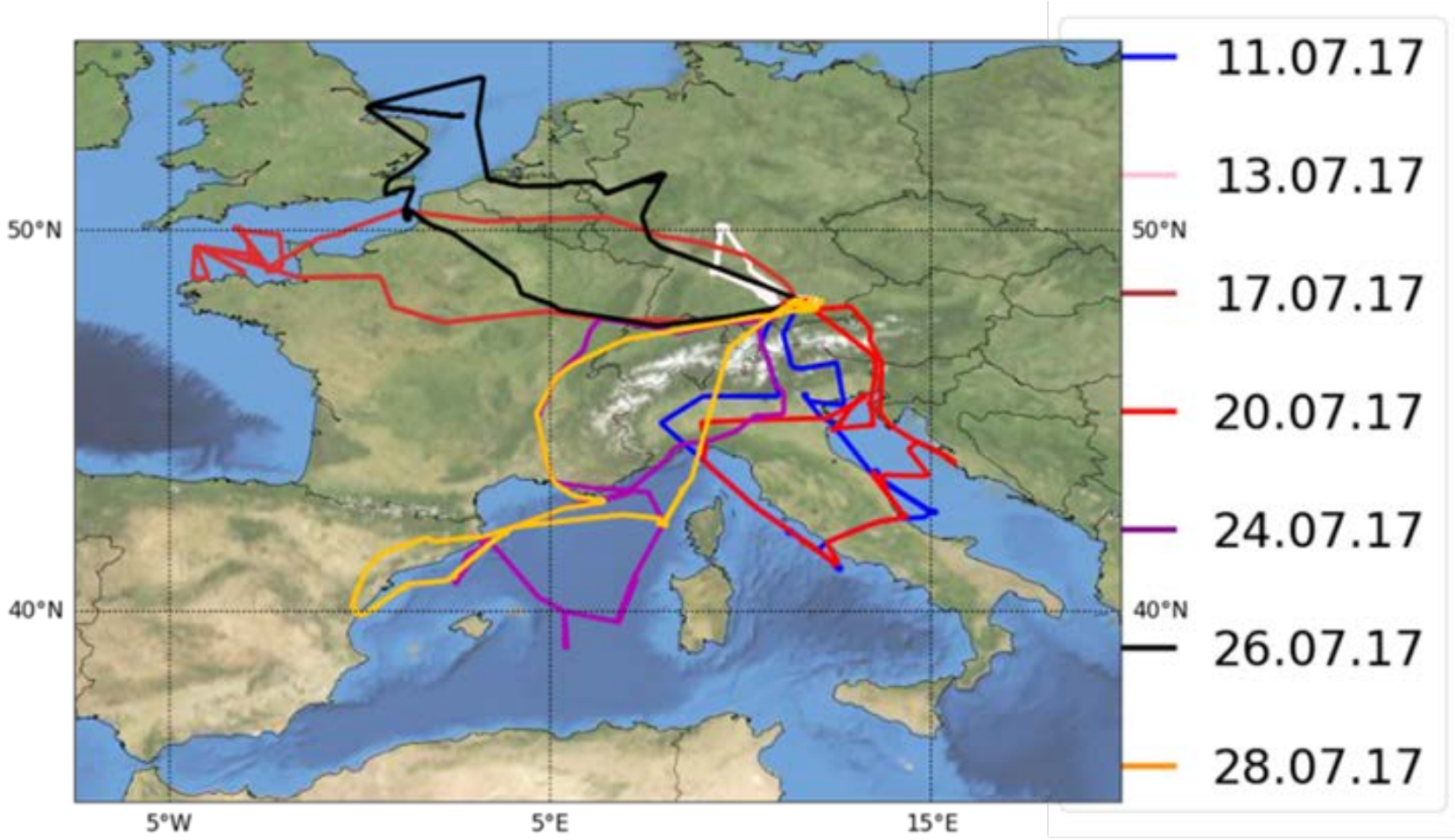

Figure 5.

The 7 research flights made as part of the EMeRGe in Europe

During the EMeRGe the meteorological situation north of Alps was very different from that south of the alps. North the Alps a series of low-pressure systems dominated the weather in July 2017. South of the Alps high-pressure systems led to dry and warm conditions. There was significant amount of biomass burning taking place in southern Europe. The research flights typically lasted about 8 hours. North of the Alps the targeted MPC were: London, Benelux, Paris, the Ruhr and Munich. South of the Alps the targets were: the Po valley, Rome, the French Mediterranean cities, Madrid and Barcelona. In addition, at high altitudes long-range transport was observed coming from North American Fires and dust from the Sahara. Polyfluororcarbon PFC were released in London and Wuppertal in the Ruhr and intercepted downwind by HALO. This enabled the transport and transformation processes to be uniquely constrained.

The flights tracks made during EMeRGe in Asia in March and April 2018 are shown in figure 6.

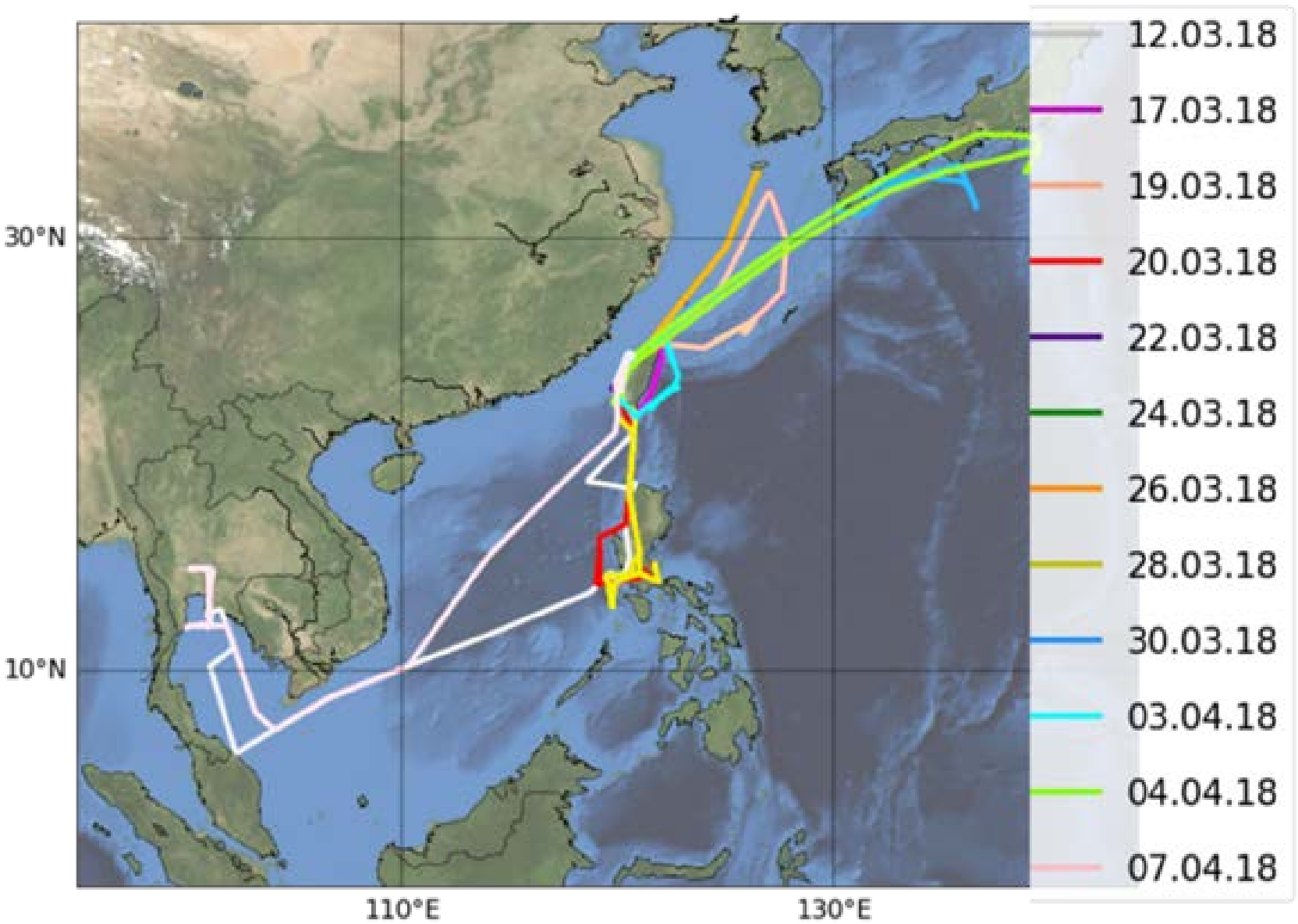

Figure 6: The HALO research flights made during the EMeRGe in Asia campaign in March and April 2018.

The HALO research aircraft was based at the Air Asia Hangar at the Tainan Airport in Taiwan during EMeRGe in Asia in Mach and April 2018. During EMeRGe in Asia from the 10th March to the 7th April 2018 the weather conditions were typical for the East Asian inter monsoon season. There were large amounts of biomass burning in south East Asia and southern China, whereas MPC pollution dominated the East China, Taiwan, China and South Korea. A Typhoon brought pacific air into the Taiwan, South Korean and Japanese region for a period of 4 to 5 days in the middle of the campaign.

The transfer and research flghts of EMeRge in Asia are shown in figure 5. During the twelve research flights and two transfer flights successful measurements were made. The outflow from the following MPC were successfully sampled: Beijing, Shanghai, Pearl River Delta, Yangtze River Delta, Taipei, Manila, Tokyo, Seoul, Bangkok Taipei.

In addition, the EMeRGe International partners organised the following research activities during the HAO Campaign period:

i) ProACT[3] Taiwanese Research Project including drone measurements coordinated with HALO overpasses in Taiwan and EPA ground based measurement
ii) Japan EMeRGe ground based in situ and remote sensing measurements
iii) South Korea EMeRGE ground based and aircraft measurement campaigns
iv) Thailand and Philippines EMeRGe ground based and remote sensing campaign

In addition to the main targets of the campaign, the following were also scientific highlights:

i) HALO participated in a validation exercise for the TCCON FTIR Greenhouse gas measurements in the Philippine
ii) the PFC tracer releases: Taiwan (3 sites), Manila (Philippines), Nanjing (Yangtze area, China). All these releases were successfully intercepted by HALO downwind.

Figure 6 Members of the EMeRGe Team and HALO in Tainan, Taiwan March and April 2018

5 Results and Discussion

The first scientific paper describing the measurements and their interpretation are currently being prepared. Many new results will be presented in this session. New findings about the production of short lived climate pollutants (aerosol, ozone and their precursors) and long lived greenhouse gases (CO_2 and CH_4) in both EMeRGe in Eurpe and EMERGe o Asia will be presented. Notable highlights are the daytime observations of peroxy free radicals, HONO, NOx and VOC.

6. Acknowledgements

The EMeRGe mission would not have been possible without the dedication and efforts of the DLR HALO engineers, and pilots, the entire EMeRGe Halo and EMeRGe International Science teams. We thank the DFG (HALO SPP), RCEC Academia Sinica and all the Universities and research centres for funding EMeRGe. This contribution is dedicated to our late colleague Dr. Andreas Hilboll of the University of Bremen.