RGC Ref.: E-CityU101/16
(please insert ref. above)

European Commission (EC) / Research Grants Council (RGC) Collaboration Scheme

Completion Report

(Please attach a copy of the completion report submitted to the European Commission by the project coordinator of the concerned Horizon 2020 project)

Part A: The Project and Investigator(s)

1. Project Title

Development of a Regional Prediction System for Seasonal Tropical Cyclone Landfall Prediction and Future Projections under Different Change Scenarios

2. Investigator(s) and Academic Department/Units Involved

	Hong Kong Team	Europe Team
Name of Principal Investigator / Project Coordinator *(with title)*	Professor Johnny Chung-leung Chan	Dr Hattermann, Fred F
Post	Chair Professor of Atmosphere Science	Senior Scientist
Unit / Department / University	School of Energy and Environment City University of Hong Kong	Potsdam Institute for Climate Impact Research
Contact Information		
Co-investigator(s) *(with title and institution)*		

3. Project Duration

	Original	Revised	Date of RGC/ University Approval *(must be quoted)*
Project Start date	1 May 2017	1 May 2017	
Project Completion date	30 April 2020	30 April 2021	7 July 2020
Duration *(in month)*	36	48	
Deadline for Submission of	30 April 2021	30 April 2022	

Completion Report			

Part B: The Completion Report

5. Project Objectives

5.1 Objectives as per original application

1. To develop a regional climate prediction system capable of predicting seasonal tropical cyclone landfalling activity
2. To identify the relative importance of various components of this system in contributing towards a good prediction of seasonal tropical cyclone landfalling activity
3. To identify the optimum configuration of the physical processes within each component of the system for the best prediction of seasonal tropical cyclone landfalling activity
4. To project possible changes in tropical cyclone landfalling activity under different climate change scenarios

5.2 Revised Objectives

Date of approval from the RGC: _____

Reasons for the change: _____

_____

1.
2.
3. ....

6. Research Outcome

Major findings and research outcome
(maximum 1 page; please make reference to Part C where necessary)

This project started out by investigating how best to modify the Coupled-Ocean-Atmosphere-Wave-Sediment Transport modeling system (COAWST) to make it suitable for simulating and predicting tropical cyclone (TC) landfalling activity along the South China coast. The COAWST consists of three models: the Weather Research and Forecasting Model, the

Regional Ocean Modeling System and the Simulating Waves Nearshore model. The three models are connected by the Model Coupling Toolkit (MCT) to exchange information. Because of the complexity of each model, it took tremendous amount of time to test the ability of each model in simulating the track and intensity of the TC. Then, the application of the MCT is far from straightforward. In addition, to verify the simulations, analyses of past data need to be, and have been, carried out. After all the tests, we have developed a configuration (domain and physical processes) that appears to give reasonable predictions of the intensity of TCs as they make landfall along the South China coast. The relative importance of the various physical processes has also been identified.

Based on these results, we have tested the ability of the modeling system to simulate the TC landfalling activity in the current climate with and without the coupling among the three models, and found that the inclusion of the ocean components is essential in producing a much more realistic simulation. We have also made projections of future TC landfalling activity using the coupled model system.

The major results from this study include the following. We have developed the first air-sea coupled system for the prediction of landfall intensity of TCs (Lok and Chan 2021a). Our simulations suggest that the TC size and its cloud cover, as well as the bathymetry of the coast, are important in determining the TC intensity (Zhao and Chan 2017; Pun et al. 2019; Lok et al. 2021). Our analyses of past observations reveal the existence of interdecadal variations in the maximum intensity of landfalling intense typhoons (Liu and Chan 2019, 2020a, Liu et al. 2021), as well as an increase in the intensity of typhoons making landfall over South China in recent years (Liu and Chan 2020b). This latter result is also highlighted in the increase in damage to Hong Kong (Sajjad and Chan 2020). In addition, we have made future projections of the intensity of TCs making landfall over South China (Lok and Chan 2018, 2021b; Choi et al. 2019). All the results point to an increasing likelihood of more intense typhoons making landfall in South China.

Potential for further development of the research and the proposed course of action *(maximum half a page)*

This project represents for the first time an air-sea coupled model system has been developed and implemented in predicting and projecting the seasonal tropical cyclone activity along the South China coast. Now that the system has been developed, it can be modified and applied to perform similar predictions and projections in other locations. We have indeed used some of the project funding to train a researcher in Mainland China to modify the modeling system for such predictions for typhoons threatening the East China coast (Zheng et al. 2021). Thus, one future direction of extending the results of this study is to have a technology transfer to other researchers. In addition, because of the limitations of time and computer resources, the projections made in this study are based on one global model only and on the RCP8.5 scenario. Different models will have different future projections, the CMIP6 projections will soon be available. In other words, projections of future landfalling TC activity (frequency and intensity) should be made using other global model projections and different climate change scenarios.

This modeling system can also be used to perform real-time forecasts of individual tropical cyclones with boundary conditions provided by global model predictions. In addition, numerical simulations can be made using this modeling system to study various physical processes responsible for track, intensity and size changes of tropical cyclones.

7. The Layman's Summary

(describe in layman's language the nature, significance and value of the research project, in no more than 200 words)

This project has developed a coupled numerical model system to represent the interaction between the atmosphere and the ocean to produce reasonable predictions of the intensity of TCs as they make landfall along the South China coast. We have also tested the ability of the modeling system to simulate the TC landfalling activity in the current climate with and without the coupling among the various model components, and found that the inclusion of the ocean components is essential in producing a much more realistic simulation. Using the coupled system, we have made projection of the future TC landfalling activity, achieving all the objectives in the proposal.

Important results from this study include the importance of the TC characteristics as well as the bathymetry of the coast in determining the TC intensity Together with our analyses of past observations, all the results point to an increasing likelihood of more intense typhoons making landfall in South China. This project represents for the first time an air-sea coupled model system being developed and implemented in predicting and projecting the seasonal tropical cyclone activity along the South China coast.

Part C: Research Output

8. Peer-reviewed journal publication(s) arising directly from this research project

(Please attach a copy of each publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				Author(s) *(bold the authors belonging to the project teams and denote the corresponding author with an asterisk*)*	Title and Journal/ Book *(with the volume, pages and other necessary publishing details specified)*	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of this collaboration scheme *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*
Year of publication	Year of Acceptance *(For paper accepted but not yet published)*	Under Review	Under Preparation *(optional)*						
2017				Zhao, X.-H.* and **J. C. L. Chan**	Effect of the initial vortex size on intensity change in the WRF-ROMS coupled model. J. Geophy. Res. – Oceans, 122, 9636-9648	No	Yes	Yes	Yes

2018				Lok, C. C. F.* and **J. C. L. Chan**	Changes of tropical cyclone landfalls in Southern China throughout the twenty-first century. Clim. Dyn., 51, 2467-2483	No	Yes	Yes	Yes
2019				Liu, K. S.* and **J. C. L. Chan**	Interdecadal variability of the location of maximum intensity of category 4-5 typhoons and its implication on landfall intensity in East Asia. Int'l J Climatol. 39, 1839-1852.	No	Yes	Yes	Yes
2019				Choi, W., C.-H. Ho*, J. Kim and **J. C. L. Chan**	Near-future tropical cyclone predictions in the western North Pacific: Fewer tropical storms but more typhoons. Clim. Dyn. doi.org/10.1007/s00382-019-04647-x	No	Yes	Yes	Yes
2019				Pun, I.-F.*, **J. C. L. Chan**, I.-I. Lin, K. T. F. Chan, J. F. Price, D. S. Ko, Y.-L. Wu, and H.-C. Huang	Rapid intensification of Typhoon Hato (2017) over shallow water. Sustainability 11, 3709: doi:10.3390/su11133709	No	Yes	Yes	Yes

2020				Liu. K. S.* and **J. C. L. Chan**	Interdecadal variation of frequencies of tropical cyclones. intense typhoons and their ratio over the western North Pacific. Int'l J Climatol., 40, 3954–3970.	No	Yes	Yes	Yes
2020				Liu, K. S.* and **J. C. L. Chan**	Recent increase in landfall intensity of tropical cyclones making landfall in South China. Clim. Dyn., 55, 1059-1074	No	Yes	Yes	Yes
2020				Sajjad, M.* and **J. C. L. Chan**	Tropical cyclones and cities: A case of Hong Kong. Frontiers in Built Environ. DOI: 10.3389/fbuil. 2020.575534	No	Yes	Yes	Yes
2021				Liu, K. S.*. **J. C. L. Chan** and H. Kubota	Meridional oscillation of tropical cyclone activity in the western North Pacific during the past 110 years. Climatic Change. DOI:10.1007/s 10584-021-02 983-8	No	Yes	Yes	Yes

2021		Yes		Lok, C. C. F., **J. C. L. Chan*** and **R. Toumi**	Self-induced intensification of tropical cyclones near landfall in South China. Submitted to Comm. Earth & Environ.	No	Yes	Yes	Will be
2021a			Yes	Lok, C. C. F.* and **J. C. L. Chan**	Development of an air-sea coupled modeling system for the prediction and projection of tropical cyclone landfall frequency and intensity. To be submitted to J. Adv. Methods in Earth Modeling	No	No	Yes	Will be
2021b			Yes	Lok, C. C. F.* and **J. C. L. Chan**	Projecting tropical cyclone landfalling intensity along the South China coast. To be submitted to Climate Dynamics	No	No	Yes	Will be
2021		Yes		Zheng, Y., J. C. L. Chan, C. C. F. Lok, H. Li, Z. Duan and R. Yu	A regional air-sea-wave coupled model system in the Yellow Sea and East China Sea and its application in Typhoon Lekima (2019). Submitted to J. Meteor. Res.	No	No	Yes	Will be

9. Recognized international conference(s) in which paper(s) related to this research project was/were delivered *(Please attach a copy of each delivered paper. All listed papers must acknowledge RGC's funding support by quoting the specific grant reference.)*

Month/Year/ Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of this collaboration scheme *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*

10. Student(s) trained *(Please attach a copy of the title page of the thesis.)*

Name	Degree registered for	Date of registration	Date of thesis submission/ graduation

11. Other impact *(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, etc.)*

As mentioned,

12. Statistics on Research Outputs

(Please ensure the summary statistics below are consistent with the information presented in other parts of this report.)

	Peer-reviewed journal publications	Conference papers	Scholarly books, monographs and chapters	Patents awarded	Other research outputs (Please specify)
No. of outputs arising directly from this research project	13				