Evaluation Summary

1. Outline of the Project	
Country: the Republic of South Africa	Project Title: the Project for Establishment of an Early-Warning System for Infectious Diseases in Southern Africa incorporating Climate Predictions
Issue/Sector: Healthcare and medical treatment	Cooperation Scheme: Technical Cooperation Project (Science and Technology Research Partnership for Sustainable Development: SATREPS)
Division in charge: Health Team 2, Health Group 1, Human Development Department	Total Cost：Approx. 250 million JPY

Period of Cooperation	(R/D): 12/May/2014 – 11/May/2019	Partner Country's Implementing Organization: the Department of Science and Technology (DST); the National Department of Health (NDOH); the Applied Centre for Climate and Earth Systems Science (ACCESS); the South African Medical Research Council (SAMRC); the Council for Scientific and Industrial Research (CSIR); the National Institute for Communicable Diseases (NICD); the South African Weather Service (SAWS); the Department of Health-Limpopo (DOHL); the Department of Health-Limpopo, Malaria Control (DOHL-Malaria); the University of Cape Town (UCT); the University of Limpopo (UL); the University of Pretoria (UP); the University of Venda (UV); and the University of the Western Cape (UWC)
		Supporting Organization in Japan: the Nagasaki University Institute of Tropical Medicine; and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
		Other Related Projects: None in particular

1-1 Background of the Project

It is suggested that the epidemic of certain infectious diseases such as malaria, diarrhea and pneumonia can be affected by climate variability, in particular, air-sea interactions such as La Niña effect, seasonal variability of ambient temperature and precipitation. Southern African countries including the Republic of South Africa (hereinafter referred to as "*South Africa*") are being subject to danger of the said infectious diseases. In particular, diarrhoea and pneumonia were the top two causes of deaths of children younger than 5 years of age (21.4% and 16.2% respectively in 2007)[1] in South Africa at the time of project designing (in 2013). Malaria is well controlled in comparison to other Southern African countries. However, the Northeast regions of South Africa sharing the borders with malaria endemic countries such as Mozambique and Zimbabwe including the Limpopo province, which is the target region of the Project, are especially exposed to malaria infection risks[2]. Actually, more than 10,000 malaria incidences were reported in South Africa in 2014 when the Project was commenced. As was just described, the relationship between climate variability and the incidence

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[1] UNDER-5 MORTALITY STATISTICS IN SOUTH AFRICA: Shedding some light on the trend and causes 1997-2007; April 2012, the Burden of Disease Research Unit, the South African Medical Research Council
[2] World Malaria Report 2015, WHO

of infectious diseases is strongly suggested; nevertheless, its concrete correlative relationship has not been scientifically proven. For this reason, climate-based infectious disease epidemic prediction has not been used for practical measures for infectious diseases control to this date.

On the other hand, a climate variability prediction system with high prediction accuracy (SINTEX-F) was developed through the collaborative research of the South African and Japanese research institutes with the support of a former JICA's technical cooperation entitled "*the Project for Prediction of Climate Variations and its Application in the Southern African Region*" (2010–2013), which was implemented under the scheme of the Science and Technology Research Partnership for Sustainable Development (hereinafter referred to as "*SATREPS*"). On the basis of the said project, "*the Project for Establishment of an Early-Warning System for Infectious Diseases in Southern Africa incorporating Climate Predictions*" (hereinafter referred to as "*the Project*") is launched in May 2014 under the scheme of SATREPS, aiming to further improve the prediction skill of the existing seasonal climate forecasting system, followed by the establishment and subsequent operability verification of climate forecast-based infectious disease early-warning systems (hereinafter referred to as "*iDEWS*"), especially for malaria, diarrheal diseases and pneumonia.

1-2 Project Overview

（1）Project Purpose

A climate-based early-warning system model for infectious diseases control is established as a precursor for further application across southern Africa.

（2）Outputs

1) Climate-based infectious disease epidemic prediction models are developed especially for malaria, pneumonia and diarrhoea.
2) Operational guidelines of iDEWS are developed in the Limpopo Province.
3) Prediction performance and operability of the iDEWS are verified.

（3）Inputs

The Japanese side:

– **Dispatch of JICA experts:** a total of 3 Long-term Experts (1 for Epidemiology/medical entomology research and a total of 2 Project Coordinators), a total of 101 M/M (Man/Month) / Short-term Experts: a total of 16 Experts, 71.7 M/M

– **Counterpart Researchers' visit to Japan:** A total of 35 counterpart personnel for sharing the research progress and outcomes, discussing on the research plan of operation, participating in symposia and so on. (a total of 347 days);

– **Training in Japan:** A total of 7 counterpart personnel for the training of statistical analyses, data management, etc. in the research of climatology and/or infectious disease control;

– **Provision of Equipment:** Automatic Weather Observation System, research / laboratory instrument and related equipment such as microscopies, artificial environment test system, personal computers for data processing and analyses, software for data analyses, etc.; and

– Overseas Activities Costs: Travel cost, Consumables for research activities, Communication cost, etc.

The South Africa side:

	–	**Allocation of Counterpart Personnel:** A total of 57 counterparts such as Project Director, Project Manager, researchers, administrative and technical officers;
	–	**Facilities, Equipment and Materials:** Facilities, Equipment and Materials: Project office spaces in CSIR and DOHL-Malaria; Laboratory space un DOHL-Malaria; Existing research instruments, equipment and/or devices in the South African counterpart organizations; Available data, information and/or specimens related to the Project; and Availability of teleconference system in CSIR;
	–	**Local Costs:** A total of ZAR 5,700,000 (approx. 419,000 USD) for field survey in the Limpopo province, the development of database for hospital inpatients information, domestic transportation of the South African counterpart personnel, utilities for the project office, consumables used for the project activities, custom clearance of the materials procured in Japan such as research instruments and reagents, etc.

2. Final Evaluation Team

Members	Dr. Kaname KANAI	Leader	Executive Technical Advisor to the Director General, Human Development Department, JICA
	Ms. KAWAGUCHI Misaki	Cooperation Planning	Assistant Director, Health Team 2, Health Group 1, Human Development Department, JICA
	Dr. Yoichi INOUE	Evaluation Analysis	Senior Consultant, Consulting Division, Japan Development Service Co., Ltd.
	Prof. Dr. WATANABE Haruo (Observing member)	Infectious Diseases Control Research	Program Supervisor, International Collaborative Research Program, Department of International Affairs, AMED Professor, the Graduate School of the International University of Health and Welfare
	Mr. Katsumi ISHII (Observing member)	Planning and Evaluation	Deputy Manager, Division of International Collaboration, Department of International Affairs, AMED (Observing member)
Period of Evaluation	7/Jan/2019 – 23/Jan/2019		Study Type: Final Evaluation[3]

3. Summary of Evaluation Results

3-1 Achievements

（1）Output 1: Achieved in general.

JAMSTEC, with the support of the CSIR, had succeeded in developing a novel seasonal prediction system based on an ocean-atmosphere coupled general circulation model called SINTEX-F2 with higher resolution. The SINTEX-F2 improved its prediction accuracy in southern Africa significantly. Moreover, The JAMSTEC had succeeded in downscaling of global seasonal forecasting into local-scale prediction covering as narrow as approx. 10km2. Meanwhile, the UP had succeeded in developing an individualistic ensemble climate forecast model and subsequent downscaling. These climate forecasting and downscaling technologies are combined with infectious disease epidemic prediction models as described below.

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[3] The expression of the "Terminal Evaluation" is used in the "JICA Guidelines for Project Evaluation" (2nd edition) officially; however, an expression of "Final Evaluation" is used in this evaluation report in accordance of a recommendation from the JICA South Africa Office in consideration of local protocol.

Concerning malaria, the Project has developed two epidemic prediction models on the basis of the non-linear statistical model and the machine-learning-based model, and both of which have demonstrated sufficient prediction performance enough to apply the prediction results to practical malaria prevention and control measures. Those models have succeeded in predicting relatively large malaria epidemic for the first time in 20 years in the 2016/2017 season retrospectively; subsequently, have also succeeded in predicting the magnitude of malaria epidemic in the 2017/2018 season, same as that in the previous season, prospectively. The UP also has developed a statistical malaria epidemic prediction model, based on an ensemble climate forecast, with sufficient prediction performance for practical use, i.e., the correlation coefficient between the predicted value and the practically-observed values are 0.7 or higher. Each model has each characteristics of prediction performances such as prediction lead-time and prediction duration; thus, it is anticipated that the planning of countermeasures for the prevention and control of malaria epidemic can be done in an effective and efficient manner by providing prediction information by combining these different models in consideration of its characteristics.

Thus, as for malaria, two epidemic prediction models based on climate forecasting demonstrated sufficient epidemic prediction performance enough to apply them to practical prevention and control measures. The prospect of developing models for diarrhoea is also obtained; to be more specific, the development work can be completed within 2 to 3 years' time since the development work will be surely continued under the iDEWS Bureau. Though it became clear that the model development was technically difficult on pneumonia, it can be said that important experience and knowledge were given for the future research activity. Further, the Project had published as much as 44 research articles in peer-reviewed international journals as of the time of the Terminal Evaluation. For these reasons, the Output 1 seemed to have generally achieved its objective from the viewpoint of the collaborative research cooperation.

（2）Output 2: Achieved in general.
Concerning the standards for disseminating forecast information, it was initially assumed to implement outbreak prevention through the issuance of alert information based on the early detection of a malaria outbreak and early containment response measures. However, when considering the characteristics of the malaria epidemic prediction models and its operation in the Limpopo province, where the number of malaria cases is rather small, compared with malaria high invasive countries such as Mozambique, the parties concerned agree not to issue individual outbreak alert information but to regularly announce epidemic prediction information and to take actions in accordance with operational guidelines, etc. The Project has succeeded in developing two malaria epidemic prediction models based on the non-linear statistical model and the machine-learning-based model, and is being examining the method for constructing malaria epidemic forecast information in consideration of its characteristics of prediction performance.

In addition, the preparatory committee for iDEWS operation, which was launched in January 2017, is not limited to research institutions, but involves national-level organisations such as NDOH, the SAWS and the NICD, which are key for future institutionalization, as well as the LDOH which are regarded as an actual user of prediction information on infectious disease epidemics. Under this preparatory committee, operational investigations were made, including validation of the predictive performance of malaria epidemics in the Limpopo province and the response (intervention) based on prediction results in advance of the 2017/2018 malaria epidemic season (during the 4th quarter in

2017). As a result, all member organisations evaluated the predictive performance of climate forecast-based epidemic prediction models as practical levels, leading to consensus among the relevant organisations towards the establishment of the iDEWS Bureau. Since the abovementioned pilot study confirmed the need for further experience in order to develop operational guidelines, its developing work cannot be completed within the project period; nevertheless, the verification of ideal operation is likely to be carried out steadily under the iDEWS Bureau.

In conclusion, the objectives of the Output 2 are considered to have been met, as well as well-experienced and evidence-based iDEWS operation guidelines are expected to be completed steadily within the first few years after the completion of the project period.

（3）Output 3: Achieved in general.

As mentioned above, the Project confirmed that the epidemic prediction models could predict the number of malaria cases in the 2016/2017 epidemic season when a large epidemic occurred for the first time in 20 years with high accuracy; based on this result, the prediction information from the models was practically applied to malaria prevention and control measures in the Limpopo province in the following season of 2017/2018. The results showed that the intervention may have affected the reduction of malaria mortality as well as slight decrease in the number of reported cases. However, it is considered that further detailed analyses should be needed for verifying the effect of prediction information based preventive measures (interventions) by taking various alternative factors such as the migration of malaria carriers from neighbouring countries and so on into consideration.

The correlation between the epidemic and climatic variables and climatic events was also confirmed for diarrhoea, and at the time of the Final Evaluation, the Project has just commenced the examination and discussions for the development of prediction models practically. Therefore, it is not possible to assess the predictive performance and operability in diarrhoea control within the project period, but it is likely that the developing work will be continued under the iDEWS Bureau once the model is developed.

In conclusion, the model's predictive performance and operability are expected to be verified under the iDEWS Bureau and the development work of iDEWS is steadily completed within a few years after the end of the project period; thus, it is deemed that the objectives of the Output 3 are generally considered to have been met.

（4）Project Purpose: Achieved in general.

Efforts made by both Japanese and South African research institutes and administrative bodies have improved the accuracy of the seasonal climate prediction systems in the southern African region and led to successful downscaling. Based on this result, the Project has developed three malaria epidemic prediction models with practical-level prediction performance, and actual preventive measures based on prediction information are piloted, and the effects and problems (e.g., the necessity of developing the operational guidelines for the implementation of prevention and control measures against malaria epidemics and subsequent its optimization in consideration of available human and financial resources, packaging those elements of iDEWS practical operation in light of dissemination to neighbouring countries in future, etc.) are confirmed. South African research institutes and administrative agencies highly appreciated project's achievements and have agreed the intention to establish the iDEWS Bureau to make a climate-forecast-based infectious disease epidemic prediction service, especially for malaria, as a part of administrative services in future. In addition, the climatological and

infectious disease research groups of the project's research institutes have started the joint research with the Mozambican authorities concerned as of the time of the Final Evaluation, and the prediction performance of the models will further be improved hereafter. In addition, the cooperation with the "*Southern African Elimination 8 Initiative*", which was established under the Southern African Development Community for the elimination of malaria with a consorted effort by eight southern African counties, is becoming concrete on the malaria, and the expansion to the southern African region is also greatly expected. Although the modelling of diarrhoea has not been achieved due to the delay in the first half of the project period, the development work is supposed to continue under the iDEWS Bureau. Although it has been confirmed that it is technically difficult to develop epidemic prediction models based on climate variation prediction for pneumonia, the process to judge it may have provided an important basis for consideration of its application to other diseases.

Thus, the establishment of an early warning system model based on climate forecasting for controlling infectious diseases as the first step towards its application to southern Africa countries (the Project Purpose) is likely to be steadily achievable within a few years. As mentioned above, significant achievements were confirmed both from the academic perspective and from the perspective of ODA technical cooperation. Besides, the current-observable issues have been appropriately organized. For these reasons, it is deemed that the Project can be regarded as largely achieving its objectives as of the time of the Final Evaluation.

3-2 Summary of Evaluation Results

（1）Relevance

The relevance of the Project has been highly maintained hitherto.

In Southern African countries including South Africa, infectious diseases are major threats. Though under-5 mortality of diarrhoea and pneumonia are being reduced in recent years, those two diseases are still being regarded as major under-5 causes of death in South Africa (8.7% and 16.9%, respectively in 2015) in South Africa.

Malaria is well controlled in comparison to other Southern African countries. However, the Northeast regions of South Africa sharing the borders with malaria endemic countries such as Mozambique and Zimbabwe including the Limpopo province, which is the target region of the Project, are especially exposed to malaria infection risks. Actually, the number of reported malaria cases was thought to be at a level close to elimination with 4,323 cases and 34 deaths in 2016, while in 2017, a large malaria epidemic had occurred; in particular, the number of reported cases and deaths were 22,517 (more than 5 times higher than that in the previous year) and 264 (approximately 5 times higher), respectively. The following year of 2018 saw a similar magnitude of the epidemic; therefore, it is obvious that South Africa is still at risk for malaria. Under such conditions, the national DOH of South Africa positioned the reinforcement of infectious disease countermeasures as the "*Primary Medical Service*" of the national program in the "*Strategic Plan 2015-2020*". It promotes the strengthening of the infectious disease surveillance system, strengthening preparedness and core response capacities for public health emergencies in line with the International Health Regulations and promoting the development of science and technology.

Meanwhile, in the ODA policy in Japan also, infectious disease countermeasures are stressed and the "*Yokohama Action Plan 2013-2017*" that is the basis of the specific policy of the "*Yokohama Declaration 2013*" that was agreed in the 5th Tokyo International Conference on African Development (TICAD V) in June 2013 reviewed the importance of infectious diseases

countermeasures and also indicates the importance of the approach towards climate change issues by many sectors. The "*Nairobi Declaration*" that was adopted in TICAD VI that was implemented in August 2016 confirmed that the "*Yokohama Declaration*" and "*Yokohama Action Plan*" are effective until the next TICAD in 2019.Further, WHO clarifies the necessity for the countermeasures for the impact of climate change such as global warming on the health of people. In particular, "*WHO Global Programme on Climate Change & Health*"（2016）indicates the importance of obtaining the scientific basis relating to climate change and health. Therefore, the development of infectious disease epidemic prediction models based on the correlation between climate change and malaria, pneumonia, and diarrhoea and scientific analysis relating to the administrative handling based on the prediction information are also considered to meet such international demands.

Furthermore, the Project' achievements is supposed to disseminate the technologies or infectious disease control measures to neighbouring countries as a concept of the Project from the beginning, and it was obvious that only South Africa is capable of doing highly-advanced research with Japanese research institutes. Therefore, the rationale for selecting South Africa as a partner and the target site is considered to be secured.

Based on the above, the consistency of the purpose of the Project that implements infectious disease countermeasures based on the technical enhancement of South African – Japan research institutes with the South African health policies, science and technology policies, and the needs from community residents in South Africa are enhanced further.

（2）Effectiveness

The effectiveness of the Project is considered to be high.

During the project period, a number of scientific papers on climatological research (mainly, that related to the development or improvement of the seasonal climate prediction system and subsequent downscaling) have been published in frontline peer-reviewed international journals as of the time of the Final Evaluation. Although only a few studies have been conducted on models for predicting epidemics of infectious diseases based on climate forecasts in other research groups, three models for predicting epidemics of malaria with different characteristics have been developed and confirmed to be at the practical level. Since the application of prediction information by these models to actual malaria prevention measures will be carried out followed by the verification of intervention effects from the scientific viewpoint, it is anticipated that many related research findings and outcomes are anticipated to be published in international journals even following the completion of the project period. On the other hand, unlike international joint research with other developing countries, the Project has been continuing technological cooperation and exchanges at a very high level as equal partners, challenging frontier sciences such as development of a model for predicting epidemics of infectious diseases based on climate forecasting, and practical application to the prevention and control of malaria epidemics. The Project commenced such a cross-cutting research with no experience and even record; however, gained many research findings and outcomes with high possibility to apply them to the society as of the time of the Final Evaluation. This is thought to have greatly improved the capabilities of relevant organisations such as research institutes in both South Africa and Japan, central and local administrative agencies and even health facilities in South Africa; thus, the Project could have produced significant achievements from the perspective of ODA assistance.

Though the Project could not complete to establish iDEWS for each of three target diseases, the

achievement level of the Project from both academic and ODA points of view is significantly high; thus, it is deemed that the "*Effectiveness*" of the Project is high in general.

（3）Efficiency

The efficiency of the Project is moderate for following reasons.

Two (2) long-term JICA experts arrived at their positions in South Africa in October 2014, five (5) months after the commencement of the Project, which resulted in delays in the installation of research instruments as well as the commencement of data collection activities. Aside from this, it took longer-than-expected time for the South African project member organisations to enter into the Memorandum of Understanding (MOU) among them, which resulted in some delay in the acquisition of the terrestrial climate data. Furthermore, the budget allocated by the South African side for the construction of the database of hospital inpatient information became available eventually in 2016, resulted that the modelling work has lagged behind the schedule by 6-12 months; for this reason, the Project could not complete the epidemic prediction modelling for diarrhoea as of the time of the Final Evaluation.

Having said that, the South African and Japanese research institutes have continuously and frequently been communication each other through various channels such as JCC meetings, symposia held both in South Africa and Japan, day-to-day emailing and teleconferences as of the time of the Final Evaluation; for these reason, it is deemed that the management of the progress as well as the generation of research outcomes has generally been appropriate. This can be explained by the significant achievement of research outcomes of the Project as of the time of the Final Evaluation. Further, the causes of the delays are seemed to be external factors, and the South African side had been putting best effort to the Project by allocating their own budget for the project activities as well as working on the orchestrating the iDEWS preparatory committee. Other inputs of the Project such as the Provision of Equipment as well as the Training in Japan were seemed to be done effectively. Therefore, it is considered that the project management itself has been appropriate in general throughout the project period.

（4）Impact

The following positive impacts are confirmed and/or expected by the implementation of the Project.

The climate forecasting models improved by the Project are already capable of forecasting climate in Mozambique, consequently, it is technically possible to perform malaria epidemic prediction using current climate forecast-based epidemic prediction models even now. Moreover, the Project, both the climatology and infectious disease control groups, had already commenced operational and research collaboration with the Mozambican authorities concerned; thus, the benefits derived from the achievements of the Project can be anticipated in Mozambique in future. On the other hand, the Elimination 8 has shown great interest in the application of climate-based malaria epidemic prediction to its member countries, and consultations on specific ways of collaboration have been initiated as of the time of the Final Evaluation. If cooperation with other Southern African countries can be initiated through Elimination 8, it is likely that the said models can be disseminated to those countries by fine-tuning them using malaria epidemic data in each country.

However, in order to realize the application of the iDEWS for malaria to other provinces in South Africa and even other countries, the Project should create individual evidence of the effect of each possible intervention based on the epidemic prediction for the prevention and control of malaria;

subsequently, on the basis of those evidences, the Project is required to realize an optimization of operational guidelines in consideration of available resources such as human resources and budget. Furthermore, the Project should perform a scientific verification on the effect of interventions for the prevention and control of malaria taken in accordance with the optimised operational guidelines on the number of malaria cases and related casualties, and consequently, demonstrate a comprehensive evidence of the effectiveness of the malaria iDEWS. If these are all realized, the dissemination of the malaria iDEWS can be disseminated to other regions in South Africa and even neighbouring countries eventually.

On top of that, several positive impacts of the Project have been observed or expected as follows: 1) Discovery of the relationship between the decadal change in the precipitation in southern Africa and the malaria incidence[4]; 2) Functional enhancement of the Tzaneen Malaria Institute; and 3) Collaboration amongst crosscutting stakeholders on the development of iDEWS as a platform.

（5）Sustainability
A self-sustainability as well as a self-deployment of the benefits provided by the Project can be expected to some extent.

<u>Political and Institutional Aspects:</u> the political importance of the implementation of the infectious disease countermeasures based on the results of the relevant research (based on the reason) while enhancing the technological capability of the development of climate change prediction models and infectious disease prediction models in South Africa is expected to be strongly maintained up to and also beyond the end of the Project. Meanwhile, the relevant organisations of the South African side highly evaluated the climate forecasting-based malaria epidemic prediction models as achieving the sufficient level for the practical application of the forecast information to the prevention and control of malaria, and took practical actions to establish the iDEWS Bureau as of the time of the Final Evaluation. For the meantime, it is anticipated that the iDEWS bureau will work on the optimisation of the operational guidelines within two years following the completion of the Project, and evidence on the effects of iDEWS on malaria prevention measures will be created. By presenting the evidences that has been developed to the relevant authorities concerned, the member organisations is aiming to position the iDEWS Bureau as part of the national administrative body. The political sustainability of the Project is expected to some extent at the time of the Final Evaluation.

<u>Financial Aspect:</u> the research institutes in both South Africa and Japan have a high research capacity, and it is considered that the Project is leading the world with regard to the research on the development of climate forecast-based infectious disease epidemic prediction model with sufficient prediction performance for practical application to epidemic control measures and subsequent interventions based on prediction information. For these reasons, each research institute is considered to have a high capability of research enough to acquire external competitive research funds toward this research topic. On the other hand, as mentioned above, given that the iDEWS is included as a part of the infectious disease control system in South Africa, the budget for the continuous operation is expected to be secured as an Administrative system. Since future adaptation of the iDEWS in other provinces and neighbouring countries of South Africa is considered, it is desired that a consorted effort by the member organisation of the iDEWS Bureau should continuously be done for packaging the epidemic prediction models, operational guideline, cost analyses for introducing and running the

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[4] As a consequence of the development of the SINTEX-F2, the Project found the decadal change in precipitation in the South African region and that decadal change also correlated with the number of malaria incidences in that area.

iDEWS.

Technical Aspect: the research capacity of both South African and Japanese research institutes is high, and it is strongly expected that novel research capabilities acquired through the Project will be improved even after the end of the project period. Besides, both NEKKEN and JAMSTED have demonstrated a willingness to continue joint research and related technical cooperation with the South African project member organisations following the termination of the Project, and also are supposed to participate or technically-support the operation of the iDEWS Bureau by any means. Meanwhile, the Project has succeeded in developing three (3) climate forecast-based malaria epidemic prediction models with sufficient prediction performance for practical use; in particular, the machine-learning-bases model by JAMSTEC, the non-linear statistical model by NEKKEN and the linear statistical model by the UP). In parallel, JAMSTEC and the UWC have been working on the development of mathematical model-based malaria epidemic prediction models individually on the basis of the VECTRI model and the compartmental model, respectively. Though those two mathematical models have not reached a sufficient level for practical application to countermeasures at this point, both JAMSTEC and the UWC are anticipated to continue the development work even following the completion of the Project, since mathematical model-based infectious disease epidemic prediction models have a potential to demonstrate high applicability to other regions. Having said that, though the verification of intervention effects of prediction information-based malaria epidemic prevention and control measures as well as the optimisation of its operational guidelines based on the verification results are supposed to be continued at the initiative of the iDEWS Bureau, it is suggested that the Project should seek a technical support from some persons with public health research and/or professional practice to do such activities.

3-3 Factors that promoted the attainment of the Project
（1）Concerning the project design
None in particular.

（2）Concerning the implementation process of the Project
Many institutes including the implementation institutes participated in the Project. Frequent communications and discussions were held via e-mail and telephone within both the research groups that are engaged in the development of climate change prediction models and the groups that are engaged in the development of infectious disease epidemic prediction models. These are the factors for achieving smooth implementation of joint research in remote mode between South Africa and Japan and for acquiring the research results as described above. In addition, the Project strategically included two national organisations, which leads to the reinforcement of the project implementation system for the practical application of project's achievements. It is considered that these enhanced the effectiveness of the Project.

3-4 Factors that impeded the attainment of the Project
（1）Concerning the project design
At the time of the Mid-term Review, the Joint Review Team provided a recommendation to allocate a JICA expert with related expertise in order to conduct the prevention and control of malaria epidemics on the basis of the evidences in an effective and efficient manner; however, it was not realized. As a result, this might cause that ad hoc countermeasures with less evidences or discussions

were taken for preventing epidemic of malaria in 2017/2018 season when a large-scale outbreak of malaria is predicted.

Though many factors might affect the unsuccess of effective allocation of a JICA expert based on the recommendation, it can be considered that this unsuccess hindered from maximizing activity results by effective allocation of necessary human resources. Therefore, this can be regarded as a hindering factor against the "*Efficiency*" of the Project.

（2）Concerning the implementation process of the Project

It was agreed that the computerization of paper-based inpatient hospital information followed by the construction of database would be done by the input from the South African side. The said works require a lot of labour force; thus, it was required for the South African side to allocate some budget to outsource. Unfortunately, the budget took longer-than-expected time to become available of the budget on the South African side. This caused a certain delay in the project activities especially for the development of infectious disease epidemic prediction modelling for pneumonia and diarrhoea. The Project found, eventually, that pneumonia is technically inapplicable for the development of a climate forecast-based epidemic prediction model; however, the said delay has affected for the Project to develop a model for diarrhoea; consequently, the Project had just commenced the development work for it at the time of the Final Evaluation. For this reason, this can be recognized as a hindering factor to the effectiveness of the Project.

3-5 Conclusions

The Project has achieved the improvement of the climate prediction skill on the JAMSTEC SINTEX-F2 and the CSIR Variable Resolution Earth Systems Model (VrESM) and the development of downscaling techniques, especially in the Southern African Region. By utilising the improved climate prediction products, the Project also successfully developed three (3) climate-based epidemic prediction models for malaria. These three (3) models, which have different characteristics, can predict the likelihood of epidemic per season, at different, interoperable, time scales, within target range of accuracy, and the potential extent of said epidemic in once instance. The Project provided a prediction of malaria outbreak in the 2017/2018 season, which led to timeous intervention for malaria control. However, it is necessary to make further scientific evidence to clarify the effectiveness of the intervention. On the initiative of South Africa, the iDEWS Bureau is expected to produce evidence for the optimization of operational guidelines (including countermeasures required based on predictions of outbreaks) after the Project's completion. The iDEWS Bureau is expected to disseminate the prediction results, affected areas in South Africa and even in neighbouring countries. In addition, the iDEWS Bureau is expected to further develop the prediction models, and to explore expanding the application to other regions and other fields such as agriculture, disaster preparedness, etc. in future. The Project's outcome has the potential to make a significant impact if climate forecasting information can be applied to other sectors.

Many academic papers have been published in international journals through collaborative research work under the auspices of the Project with mutual capacity development. Even after the Project's completion, it is expected that research outcomes will continue to be created as a result of the update of the malaria epidemic prediction model based on the climate forecast and the effect of measures based on the forecast information, with a number of research papers expected to be published.

In terms of the evaluation results of the Project, the "*Relevance*", the "*Effectiveness*", and the

"*Sustainability*" of the Project are all high, although "*Efficiency*" is moderate due to the delay of the data collection activity and the dispatch of an expert. On the other hand, there are positive "*Impacts*" which will be expected in future practical application of the research findings and outcomes to society, at the time of the Final Evaluation. Therefore, it is considered that the Project's achievement is very high, both academically and as technical cooperation.

3-6 Recommendations
 (1) Establishment and Development of iDEWS Bureau
    The proposed iDEWS Bureau should clarify its roles and functions and commence the actual operations by May 2019 when the Project officially ends.

 (2) Verification of the effectiveness of the predication information-based interventions for the prevention and control of malaria epidemics
    The iDEWS Bureau is required to verify the effectiveness of the intervention from the aspects of prevention, diagnosis and treatment of malaria, which had been taken based on the malaria epidemic prediction information, even after the end of the project period. The iDEWS Bureau is also expected to optimize the operational guidelines for measures against malaria epidemics based on the evidences and to provide information to WHO etc. to sublimate the evidences and experiences to global activities.

 (3) Dissemination of the experience to the neighbouring countries
    The iDEWS Bureau should take initiative for the dissemination of the Project's experience and outcomes not only to Mozambique, which shares the border with the Limpopo province, but also the member countries of the Elimination 8. The iDEWS Bureau and Japanese research institutes are expected to maintain their continuous cooperation and joint research on a long-term basis.

 (4) Operationalisation of diarrhoeal disease research
    The project partners, in collaboration with the iDEWS Bureau, should pursue research on the diarrhoea disease toward further development of climate-based models for the prediction of diarrhoea disease prevalence and incidence variability. The work should consider the utilisation of pathogen data from the laboratory-based surveillance system when available in future.

3-7 Lessons Learnt
    Strategic involvement of envisaged user organisations of research findings and outcomes at both local and national levels
    The Project is an international collaborative research implemented in a framework of JICA's technical cooperation under the scheme of SATREPS; consequently, developed climate forecast-based infectious disease epidemic prediction models through the international and crosscutting collaborative research between South Africa and Japan. The Project is aiming to create evidences of the effectiveness of climate forecast-based countermeasures for the prevention and control of infectious disease epidemics and subsequent development of optimal and feasible operational guidelines, followed by its application to both domestic and international affected areas as one of public services under the iDEWS Bureau. In order to realize that, it was necessary for the Project to gain supports not only from the provincial

administration body as a direct user organisation of the epidemic prediction information (i.e., LDOH) but also from the NICD of the national policy and strategy-making bodies for infectious disease control as well as the SAWS of the national agency bearing weather and climate-related services, research and development. For this reason, the Project had incorporated them into the member organizations in the initial phase of the project period, and advanced the project activities with the support of both local users and national policy-makers in consideration of the practical application of research findings and outcomes to the society, which is an objective of SATREPS. Consequently, the establishment of the iDEWS Bureau is planned at the initiative of the South African side at the time of the Final Evaluation; therefore, it is anticipated that the said multidisciplinary approach for realising the epidemic prediction-based countermeasures for the prevention and control of infectious disease sustains hereafter. This is deemed to enhance the "*Sustainability*" and the "*Impact*" of the Project significantly.

As was described above, the Project has commenced efforts for the establishment of an implementation system for "*the practical application of the research findings and outcomes*" in the early stage of the project period, and enhanced the "*Sustainability*" and the "*Impact*" by taking the crosscutting collaboration amongst research institutes and by incorporating local and national, practical users and policy/strategy-making bodies into the project implementing system. Thus, in other JICA's technical cooperation implemented under the scheme of SATREPS, it can be effective to construct a project implementation system not just by counterpart research institutes and its supervisory agencies but also envisaged user organisations as well as related policy/strategy-making bodies at national level. In this regard, however, such multidisciplinary approach can cause am extra efforts for liaison and coordination both domestically and internationally. Therefore, the preparation and operational management should carefully be done, especially for domestic and international liaison and coordination amongst the multidisciplinary project implementing agencies.

3-8 State of the follow-up
    None in particular.