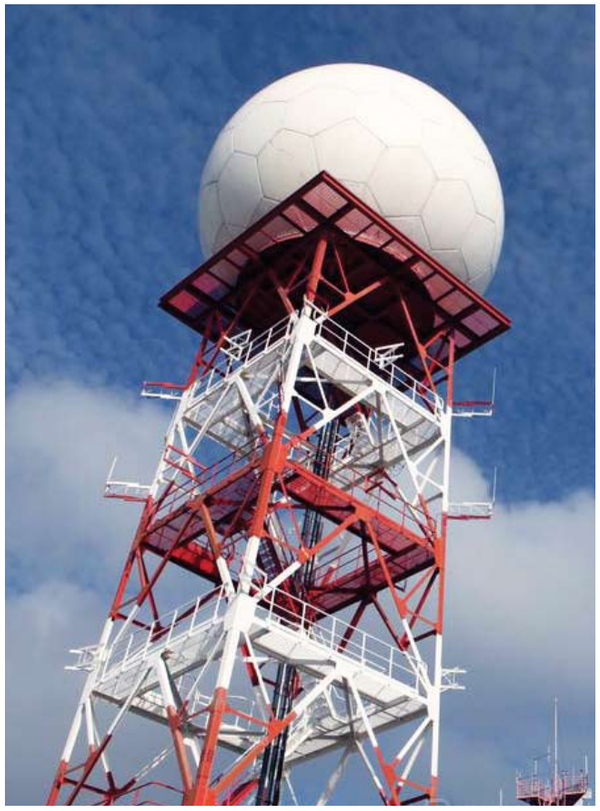

and the
Weather tomorrow is...

*"Within a city, the weather still plays a crucial role. It affects our daily life, it affects the vitality and business prospects of a city. It can disrupt transport, whether you're flying in on a plane, or in a car driving through a flash flood. Over the last two decades, the focus of the Meteorological Service Singapore has widened. Now it's not just about temperature and wind direction and rain but indeed multi-hazard monitoring and early warning services for trans-boundary smoke haze, volcanic ash, earthquakes and recently, even extremely unlikely tsunamis, or radioactive fallout. Today, meteorological services are also widely used by the larger community. It's no longer just scientists or administrators, but indeed, ordinary people, literally the man and the woman in the streets, and people running businesses and schools. Now with rapid advances in IT and in communication technologies, accurate weather forecasts and real-time weather alerts have also become the norm."*

*— Dr Vivian Balakrishnan, Minister for the Environment and Water Resources*



Meteorological Doppler Weather Radar

It's a familiar announcement at the end of the daily news – "And the forecast for tomorrow's weather is ..." In the papers, on the radio and even on the web and mobile phone, these forecasts shape our lives and schedules constantly.

Sunny days during the school break – family picnics at the beach. Overcast skies anticipated for the weekend – postpone that photography outing. Thundery showers in the late afternoon? Remember the umbrella, book your taxi in advance.

Behind these forecasts is a dedicated team of meteorologists, climate scientists and technicians at the Meteorological Service Singapore (MSS). They scan the skies, monitor radar and satellite images, analyse complex weather models and pore over esoteric charts to churn out some 500 forecasts and briefings a day, complete with readings of rainfall, wind, temperature and relative humidity. This information enables a diverse range of users to make better decisions on their activities and improve their safety and comfort.

But weather forecasting is not the only thing MSS does. It also conducts scientific research on our climate, strengthens Singapore's emergency response plans in case of natural or environmental hazards and provides scientific data and risk assessment for uses ranging from governance and policy-making to business operations. It actively collaborates with regional and international climate research institutes and experts in the field to share research findings and weather data. Today, MSS is not just the national meteorological authority of Singapore but also a leading centre in the region.


The forecasts we get every day are the result of intensive efforts by teams of meteorologists and technicians working round the clock every day. At the Main Meteorological Office at Changi, the meteorologist's day shift starts at 7.30 am. By 9 am, the first weather forecasts for the next three and 12 hours are released. Forecasts will continue to be churned out every three hours and as and when they are needed. Warnings will also be sent whenever severe weather is expected to affect the island. At 5 pm and 5 am, the weather outlook for the next three days will be issued to the broadcast and print media. The work progresses through the night and the cycle goes on.

# Behind The Forecasts

*"MSS' societal mission has been achieved through the professional expertise and dedication of MSS staff, who deliver reliable and timely services 24 hours a day, every day of the year. For many of us, including myself, our meteorological professions have turned out to be lifelong careers. With the growing demand for meteorological services, along with the increasing threat of climate change to our sustainable development, MSS will have many opportunities to contribute, as never before, to the social and economic well-being of Singapore. By expanding our research collaborations, leveraging on technology and deepening staff expertise, I am confident MSS can meet these challenges and opportunities."*
*— Wong Chin Ling, Director-General, Meteorological Service Singapore*

Barometers, anemometers, rain gauges, thermometers, and such – these make up the basic set of instruments for capturing weather information. But weather science requires much more than that. To provide timely and reliable weather forecasts, MSS relies on a system of weather monitoring, analysis and research.

One of the biggest challenges in forecasting the weather is having up-to-date, precise data on atmospheric conditions. Across the island, weather data collection takes place at MSS' network of over 60 automated weather stations and five manned meteorological stations. Up-to-date information on parameters such as rainfall, wind, temperature, cloud cover and height, solar radiation and visibility are collated every day. With that, more precise forecasts can be provided for Singapore.

Next, technology is a key tool in the weathermen's trade. Images from both geostationary and polar-orbiting satellites are used for observation of clouds and weather systems. A wind profiler radar measures wind conditions at different altitudes in the atmosphere, up to a height of about 5 km.

In 2010, MSS added a more powerful tool to its array — the Meteorological Doppler Weather Radar (MDWR) system. A similar system was first commissioned in 1997. This latest system, however, gives much more information. The MDWR uses the Doppler Effect to gather wind velocity information and also enables MSS to detect and track the movement and intensity of precipitation within a radius of 480 km. MSS can thus better estimate accumulated precipitation, and provide stronger support to the authorities in water resource and flood management.

The weather knows no boundary, and Singapore's weather system is part of a larger regional weather pattern. Hence, MSS also compiles weather data from national meteorological services in the region.

Analysis is done after the data is collected. To do so, MSS employs an advanced meteorological data processing system to handle the sheer volume of information generated daily. Complex mathematical models of the atmosphere, known as numerical weather prediction models, are then run using the processed data. The outputs from these models are analysed to produce a forecast.

The forecasts then benefit a wide range of users, from airlines and ships to the military, businesses and the public.

## A RICH ARCHIVE

**In the archives of MSS, the earliest weather statistics go back as far as 1820. The first full-scale meteorological station with more elaborate equipment and detailed schedule of observations was set up at Mount Faber in 1929. This rich archive of information enables MSS to better understand historical weather trends and how our climate has changed since the 1820s. It is also a valuable resource in research relating to the climate.**

*The automated weather station at Kim Chuan Road provides continuous real-time measurement of rainfall, wind, temperature, relative humidity and pressure.*

*"Before meteorological services were transferred to NEA, the major users were from the civil and military aviation sectors. Our earlier efforts focused on developing our aviation support services to provide better forecasts of flight-path weather conditions and warnings of adverse meteorological situations. In the later years, when our aviation and marine meteorological services, were well developed, we were able to divert more resources to enhance our environmental support and public weather services. Joining NEA enabled us to achieve better synergy to expand and strengthen our public, environmental and climate-change related services, such as addressing the public's need for timely update of weather conditions, frequent occurrences of smoke haze in the region, climate change and its impact."*

*— Woon Shih Lai, Director-General, Meteorological Service Singapore (1991 – 2003)*

## BON VOYAGE!

In 2010, over 301,700 aeroplanes took off from Changi Airport. Ensuring that every flight takes off in safe conditions is no mean feat. MSS plays a critical role by providing essential weather information to airline operators and the Civil Aviation Authority of Singapore.

Weather conditions are a significant factor in flight planning, shaping decisions such as the computation of fuel requirements, navigation and routes. The information supplied by MSS helps organisations make better decisions.

MSS undertakes weather surveillance over Changi Airport and the airspace controlled by Singapore. The continuous monitoring allows it to prepare detailed en-route weather forecasts for flights as well as issue advisories and warnings of severe weather. MSS also conducts training on meteorology to air traffic personnel.

On top of this, MSS provides round-the-clock broadcasts of regional weather information to aircraft in flight. Airlines which subscribe to MSS' services are supplied with regional weather information, latest satellite and radar images, direction and speed of upper level winds, upper level temperature and weather prognoses. As the Operational Meteorological Databank in the region, a responsibility MSS has taken on since its designation by the International Civil Aviation Organisation in 1995, MSS also facilitates the exchange of operational meteorological data between Asia Pacific and Europe.

## PLAIN SAILING

Just as weather affects flight, it, too, impacts travel by sea.

Storm warnings, sea state and wind forecasts, marine weather assessments and advisories. Such are just some of the services MSS provides to shipping companies and port operators to help them improve on safety and efficiency at sea.

MSS issues weather bulletins for shipping twice daily, as well as warnings of rough sea states and strong winds. It also collects and distributes weather reports made by ships at sea and assists vessels in the calibration and installation of onboard weather instruments.



## FROM NOWCASTS TO LIGHTNING ALERTS

Need to plan an outdoor event? The first thing to do is probably to check the weather forecast for the day.

Besides meeting the needs of specialised users, MSS also caters to the public, its largest group of users. Over the years, MSS has improved its services and products to serve the public better.

For example, local weather forecasts are provided not just for the next 24 hours, but for the next 12, and even the next three hours. Taking convenience a step further, location-specific, three-hour forecasts (Nowcast) are made readily available via the Internet and smart phone applications. In 2009, the service was further enhanced with the launch of Weather@SG, which allows the public to access weather information and forecasts via their mobile phones. Today, the data is also made available to smart phone users through NEA's mobile application, myENV.

Lightning risk alerts are also an important service offered by MSS. Singapore has one of the highest rates of lightning activities in the world. For more effective monitoring, MSS has in place a system to detect lightning activities in Singapore. The lightning detection system and the Meteorological Doppler Weather Radar are the key tools used to assess such risks within an area. MSS issues lightning risk alerts via SMS to registered users such as the military, schools, golf clubs and construction companies so that they can plan and take precautionary measures while carrying out outdoor activities.

Aside from these, MSS also offers a whole range of relevant services and products for businesses, including weather assessments and data for planning the design of buildings and structures, and for legal and insurance purposes.


## TAKE THAT UMBRELLA ALONG!

Remember those mornings when you wake up to torrential rains which seem to last forever? Well, they are usually caused by "Sumatra" squalls. Squalls are organised lines of intense thunderstorms which are often accompanied by gusty surface winds and low clouds. After they pass, light rain usually persists for some time. These squalls generally build up over the Straits of Malacca at night and move over Singapore before dawn and in the early morning.

Throughout the year, Singapore's weather is marked by uniform temperature and pressure, high humidity, abundant rainfall and no distinct wet or dry season. Rainy days happen once every two or three days. Between mid-November and end January, the northeast monsoon brings surges of heavy rains. The southwest monsoon between June and September is characterised by more frequent "Sumatra" squalls.

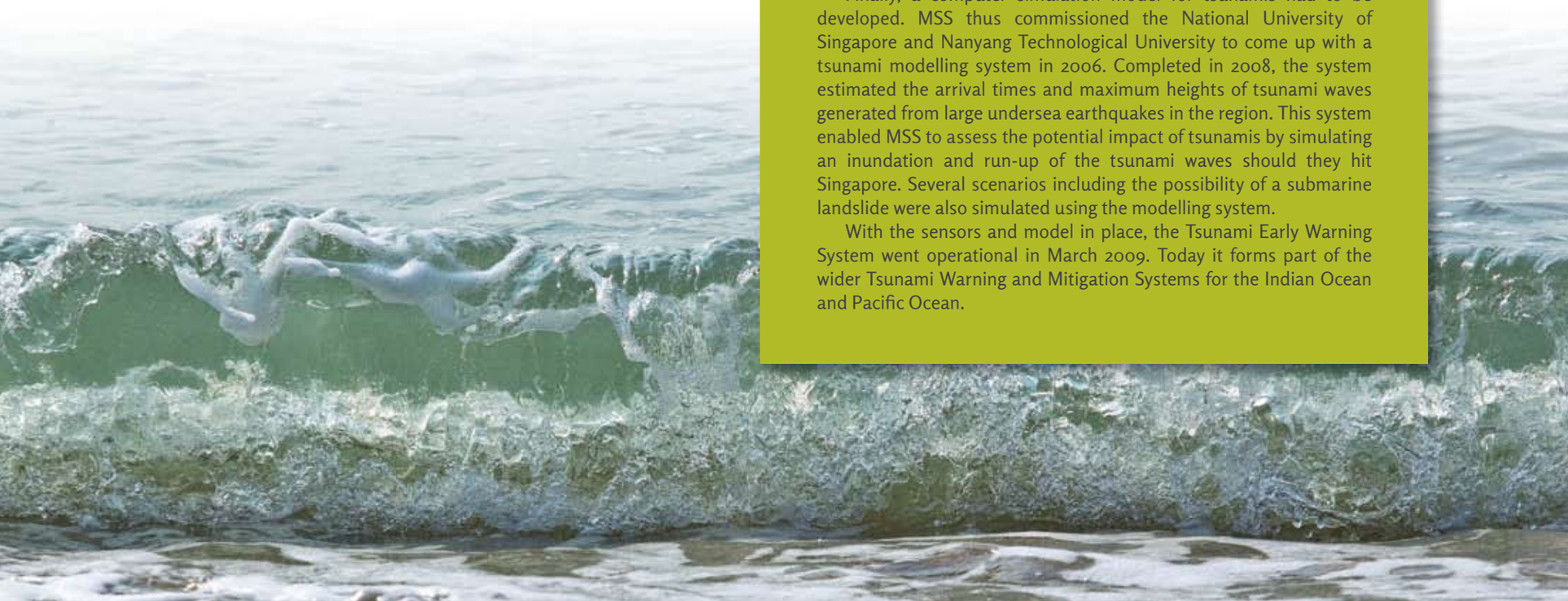
In between the heavy downpours and storms, light rains generally fill in the gap. Take note though, the term "drizzle" does not really apply to Singapore. Precipitation is classified as drizzle when the diameter of the water drop is less than 0.5 mm. Any bigger and it is termed "rain". In Singapore, we usually experience either rain or showers. Rain generally forms from layer clouds and is steadier in nature. Showers are short-lived, begin and end suddenly, and usually fall in small localised spots instead of over large areas. So the next time you hear someone talking about drizzle in parts of Singapore, it is actually light rain.

## MANAGING EMERGENCIES

You may ask, what does the weather have to do with emergency planning? Well, take one example. During the Fukushima Daiichi radiation crisis in 2010, MSS undertook modelling studies to assess if radioactive plumes would hit Singapore, and to gauge the level of threat posed by these plumes.

When it comes to natural hazards and environmental incidents with trans-boundary effects, MSS' robust weather monitoring and research regime provides critical data and expertise in assessing their impact on Singapore.

For instance, MSS uses satellite images and other meteorological information to monitor the development and spread of fires and smoke haze in the region, particularly during the dry season. When necessary, advisories on occurrence of haze are provided to the public and the relevant agencies in Singapore. On the regional front, the Association of Southeast Asian Nations (ASEAN) Specialised Meteorological Centre, hosted by MSS, monitors land and forest fires to assess and predict the occurrence of trans-boundary smoke haze affecting the region. It also provides regular weather and haze outlooks to ASEAN members and advises them when significant trans-boundary haze is likely to occur.



### SENSING THE TREMORS

It was one of the most destructive natural disasters in the 20th century. On 26 December 2004, an earthquake of magnitude 9.2 struck off the west coast of Sumatra, triggering a destructive tsunami in the Indian Ocean which took more than 200,000 lives. The sheer scale of the disaster prompted governments worldwide to develop emergency response plans for tsunamis.

Singapore is located about 400 km from the nearest earthquake source in Sumatra. No earthquakes are known to have been recorded here. Studies show that the shallow and narrow Straits of Malacca also make it unlikely for a tsunami to affect us. However, the government decided on a prudent course, and set about putting an emergency response plan in place. The plan required a tsunami early warning system and MSS was tasked to develop it.

Tsunamis are generally caused by earthquakes under the oceans. Hence, having a seismic monitoring network to detect the earthquakes is an important part of a tsunami warning system. MSS has had in place a network of sensors to detect seismic waves since 1996. The sensors were linked to a central data processing system at the meteorological office in Changi. This system was upgraded in 2006 so that Singapore could exchange real-time earthquake data with seismic networks in other countries. This improved the speed and accuracy of seismic detection. Next, MSS installed three new seismic sensors and upgraded existing components to enhance the system's reliability. MSS also worked with the Maritime and Port Authority of Singapore (MPA) to share real-time sea level data. Such data was important to confirm if a tsunami had formed after an earthquake.

Finally, a computer simulation model for tsunamis had to be developed. MSS thus commissioned the National University of Singapore and Nanyang Technological University to come up with a tsunami modelling system in 2006. Completed in 2008, the system estimated the arrival times and maximum heights of tsunami waves generated from large undersea earthquakes in the region. This system enabled MSS to assess the potential impact of tsunamis by simulating an inundation and run-up of the tsunami waves should they hit Singapore. Several scenarios including the possibility of a submarine landslide were also simulated using the modelling system.

With the sensors and model in place, the Tsunami Early Warning System went operational in March 2009. Today it forms part of the wider Tsunami Warning and Mitigation Systems for the Indian Ocean and Pacific Ocean.

*"First of all, I need to see if officers are making proper entries to the programme and that our observations are correct. Then, we have to send timely weather data to meteorological centres ashore. Based on data received from the ships and other sources, the forecaster prepares weather charts, which are available for the ships within two to three hours. Most importantly, more data from the ships gives possibility for more accurate predictions, so that we have better weather charts and better forecasts for our voyage. This way, we can expect more accurate surface analysis and weather forecasts for the next 24 hours, 48 hours and more and this can help us to plan our voyage more efficiently. This is very important for captains and officers and can make us more aware of what is around, so that we can make faster decisions. Thanks to correct weather forecasts we can avoid storms, typhoons, improve safety of our ship and save time and fuel."*

*– Captain Andrzej Gomulski, Master of the vessel NYK Olympus, on the VOS scheme*

# FRIENDSHIP ACROSS THE HIGH SEAS

Ong Chin Hong holds the one and only job of its kind in Singapore.

He gets on board ships, whether docked in our ports or anchored out at sea. There, he meticulously checks and maintains the ship's weather instruments, from barometer to anemometer, making sure that they are performing accurately. Where necessary, he also shows crew members how to use and log in weather observation data into a standardised system.

Singapore's only Port Meteorological Officer, Ong provides these services to ships taking part in the Voluntary Observing Ships (VOS) scheme. The VOS scheme is an international programme launched by the World Meteorological Organization (WMO). Under the scheme, ships are recruited to observe weather conditions while on the high seas, encode the observations and transmit the data every six hours to the national meteorological services agencies in the WMO network. Singapore supports the scheme too. VOS ships benefit from the goodwill services and support given by the member countries as well.

Says Ong, "Once a ship is recruited, it is my duty to take care of it. I see to the ships recruited in other countries as well. It's like one whole big family. When ships come in, and they need our services, they will send us an email, or the port meteorological officers from the respective countries will send us emails requesting visits. We'll then see to their needs, such as comparing the ships' instruments with ours for calibration and providing weather charts."

This scheme is of particular importance to the provision of meteorological services worldwide because of the data collected. The oceans play a significant role in our global climate system, and data on weather conditions at sea can greatly enhance the development of climate research. At the same time, the real-time data also supports more accurate weather forecasting, climate analysis and provides validation for satellite observations. However, meteorological data over the oceans is sparse, so these ships constitute an important source.

Every participating country in the scheme has at least one Port Meteorological Officer to tend to these ships. These officers also help to recruit ships for the scheme. "For new ships, we will go on board to see what equipment may be lacking. Most of the ships have the necessary meteorological instruments to conduct observation, like dry and wet bulb thermometers, anemometers, sensors for measuring sea surface temperatures and barographs. At the same time I brief them on how to use the electronic log book. We also provide reference books and materials to refresh the seamen's knowledge of meteorology," Ong explains.

For Ong, who understudied the work for a few years before he officially became a Port Meteorological Officer in 2011, the work he does is meaningful and interesting. "In a way, I'm honoured to represent Singapore in this scheme. On land we have stations to collect weather observation data. But two-thirds of the world is covered by oceans, and apart from satellite remote sensing, the only way to get observations from the oceans is through these ships."


DELL

# THE SCIENCE OF WEATHER FORECASTING

If you think that predicting the weather is merely a question of looking at the skies, you are pretty far off the mark.

Weather forecasting starts with collecting data – loads of it. Looking at the skies is the first step. Hazman Bin Mohani, Technical Officer, supervises one of the teams tracking weather. These technicians are specially trained to conduct weather observation. "We observe the clouds and check the visibility around the aerodrome using physical markers such as landmark buildings and structures such as the Swissotel," describes Hazman. "Certain clouds are associated with precipitation. In the day, the blue sky acts as the background for us to survey the clouds. At night, we use light sources in the sky, such as stars and the moon, to estimate the cloud cover. When city lights are reflected on the clouds, we know that these are low-lying. To conduct observation at night, one must be a good observer by day. Generally, one needs about three years to be good at reading the skies."

A plethora of weather instruments is maintained by these teams as well. The data collected, including temperatures, dew point and barometric pressure, is submitted hourly. Reports are produced whenever there is a change in weather conditions, such as the start or end of a thunderstorm.

This ground data is only part of what a weather forecaster has to analyse. Goh Wee Poh, Executive Meteorological Officer, elaborates, "To do a weather forecast, we need to analyse a lot of data. For shorter-term forecasts for up to several hours ahead, observation data from the meteorological stations, upper-air sounding data, satellite and radar images are used." For longer-term forecasts beyond twelve hours, an important tool is the numerical weather prediction model, which is a computer model to simulate the future state of the atmosphere. These models provide useful guidance in predicting large-scale weather features, such as the Northeast Monsoon surges, up to several days ahead.

Despite the latest technology, predicting the weather is never a breeze. Firstly, weather dynamics is a complex science which has yet to be fully understood. Secondly, a good forecast requires reliable information about the current state of the atmosphere while there are large observation data gaps over oceans and remote land areas. Thirdly, while the numerical weather prediction models are generally useful in predicting large-scale weather features, they are less skillful in predicting smaller-scale systems.

On top of that, Singapore's weather is often characterised by small-scale thunderstorms. Rain-bearing clouds can form quickly, bringing showers to an area. They can also dissipate as fast as they develop, at times within 10 minutes. Hence, it is highly challenging to detect weather trends or predict in advance when the storms are building up. Says Goh, "Every day is different. We don't have a day where weather conditions are exactly the same. But throughout the year, the temperature variation is small and showers commonly occur, so to many people, it seems that our weather is the same all the time."

Technical officer looking out for physical markers such as landmark buildings and structures to determine visibility.

The constant scrutiny of weather has an unexpected toll on those working behind the scenes. Hazman for example, recalls, "When there are thunderstorms, we have to immediately report on it. So in my first few years here, even when I was off-duty and asleep at home, I would wake up at the first sounds of thunder or rain!" The same goes for Goh, who used to have the added anxiety of putting out inaccurate forecasts. "Especially for the first one or two years, I would keep monitoring my forecast to see whether it was accurate or not! It was hard to get a good sleep during those years and sometimes my friends would ask me why the forecasts were not accurate. But the thing is, people tend to remember the few times when the forecasts were not accurate, and not when they were accurate."

With advances in weather prediction and computer technology, the accuracy of weather forecasts has gradually improved over the years. In 2011, the accuracy of Nowcasts (three-hour forecasts) was around 89%. The occasional inaccurate forecast is something that forecasters have to contend with. "Predicting the weather accurately is a challenge," says Goh. "We strive to produce accurate forecasts, based on the data available and our best assessment of the weather situation. By giving accurate forecasts, we can impact the lives of many people in a positive way."

# A Leading Centre For Research

*"I am delighted to have signed this agreement between the UK Met Office and the Singapore National Environment Agency. We have a mutual interest in continually improving the scientific understanding and modelling of climate in order to inform decision making around our changing climate. This partnership will enable us to advance climate research, modelling and prediction in Singapore, the wider Southeast Asian region and across the globe."*

*— John Hirst, Chief Executive, UK Met Office*


The effects of climate change are increasingly felt throughout the world. In order to adapt to these changes, governments are seeking answers from science to develop the appropriate response. MSS is establishing the Centre for Climate Research Singapore (CCRS) to respond to the need for better understanding and improved prediction of tropical weather and climate systems affecting Singapore and the wider Southeast Asia region.

The tropical weather and climate systems in the region are poorly understood and less well-researched than mid-latitude weather systems. The broad areas of research in CCRS include improved understanding of tropical weather and climate systems (e.g. El Niño and La Niña, the Asian Monsoon), assessment of local climate change and variability (e.g. droughts and intense rainfall) and improved weather prediction techniques.

CCRS will build up its capability by developing research partnerships with leading climate centres. In May 2011, MSS inked an MOU with the UK Met Office for a multi-year programme involving the joint development and implementation of climate models, exchange of scientists and regional research. The models will be used to generate robust long-term projections of Singapore's climate for various time scales up to 2100. Government agencies will use these projections to develop measures to strengthen the resilience of Singapore's infrastructure to withstand climate change.

Recognising that climate science demands a wide range of inter-disciplinary skills, the Climate Science Experts Network was launched in January 2012 as a platform to engage local and international researchers. For a start, MSS is collaborating with the Earth Observatory of Singapore in Nanyang Technological University and the Centre for Environmental Sensing and Monitoring in National University of Singapore on relevant climate projects.

Past long-term trends of temperature and rainfall are key indicators of changes in Singapore's climate. In 2011, MSS conducted a study of heavy rainfall events in the last 30 years and found that the intensity and frequency of such events have increased across Singapore during the period. The trend is in line with observations of more extreme weather in many parts of the world.

In the area of weather research, MSS has implemented the United States National Center for Atmospheric Research (NCAR) Weather and Research Forecasting model to produce forecasts for up to three days ahead. This model is widely used by many meteorological services in the world to produce operational forecasts for their region and for studies. Research is ongoing to improve the model to better predict weather conditions in Singapore and the region.

## FORGING INTERNATIONAL TIES

The World Meteorological Organization (WMO) is the United Nations system's authoritative voice on weather, climate and water. It comprises membership from 189 countries around the world. Singapore became a member of WMO in 1966. A key programme of WMO is the World Weather Watch Programme which coordinates the daily exchange of meteorological observations from about 11,000 land, sea and upper-air stations around the world, including Singapore's. The data is essential to the operations of all national meteorological services. In addition to data exchange, MSS participates in other WMO programmes, conferences, seminars and workshops to keep abreast of international developments in meteorology and to enhance its capabilities in weather and climate prediction. The platforms provided by WMO also enable MSS to develop close working relationships with its international counterparts.

At the regional level, MSS is host to the ASEAN Specialised Meteorological Centre (ASMC), which was established in January 1993. ASMC was set up as a regional collaboration programme among the national meteorological services of ASEAN member countries to enhance regional capacity in weather and climate prediction. Over the years, ASMC has also played a leading role in developing a number of technical capacity-building projects involving the participation of ASEAN national meteorological services.

# TRANSLATING SCIENCE INTO POLICY

The global climate system is extremely complex, and our current understanding of the physical processes is rudimentary at best. As it is impossible to perform climate experiments in the laboratory, we are reliant on model simulations of the climate system to provide basic understanding of atmospheric processes. Early climate models were only able to represent key features of the climate system such as incoming solar radiation, rainfall and carbon dioxide concentration. Over the years, such models have become more sophisticated, in part due to greater computing power and better understanding of the atmosphere. The current generation of models also includes cloud processes, a broad range of atmospheric constituents such as sulphates, aerosols and land use etc.

Generally, global climate models are able to represent large-scale features of the global climate fairly well but are less able to do so on a regional and local scale. Such information, however, is needed by decision makers to develop strategies to combat the impact of climate change. The CCRS is set to develop new competencies in climate modelling and research. "Currently, global climate models run by established centres worldwide simulate the climate of the whole globe. These models are based on the best understanding of the science, using mathematical equations," shares John Low, Director, Climate Science Department. "We need to downscale these models to get very fine-scale information of Singapore's climate. These results will be more useful to us. Research on tropical weather is still somewhat lacking in the world, so our centre will develop niche research in this area."

This scientific research is undertaken to further understanding of the climate of Singapore and the region and how it will impact our lives in the future. But most importantly, it will support the translation of climate science into important public policies.

Low elucidates, "Of particular interest now is how Singapore will be affected by climate change in the long term, in 50 years' time, in 100 years' time. And how the weather is going to be like for this region. We want to help develop climate resilience for the country by providing the government with the best science available to develop the policies for Singapore to adapt to climate change. And based on these long-term projections, the government can take decisions on future infrastructural development and economic policies, for example. We recognise that climate science is evolving and new research is being conducted every day around the world, and new information on ice-caps melting, sea levels rising or aerosols will affect our projections. There is a need for MSS to have this capability to look at all this research and assess how it is going to affect our region."

*"Of particular interest now is how Singapore will be affected by climate change in the long term, in 50 years' time, in 100 years' time. And how the weather is going to be like for this region. We want to help develop climate resilience for the country by providing the government with the best science available to develop the policies for Singapore to adapt to climate change."*

*— John Low, Director, Climate Science Department, NEA*

*Opposite:* Weather balloons carrying sensors are released twice a day at the Upper Air Observatory to collect wind, temperature and humidity data of the atmosphere.

The Meteorological Service Singapore is the national authority on weather and climate. It provides forecast and information services to the public, government agencies and industry.