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China’s Natural Hazards: An Introduction

September 2014

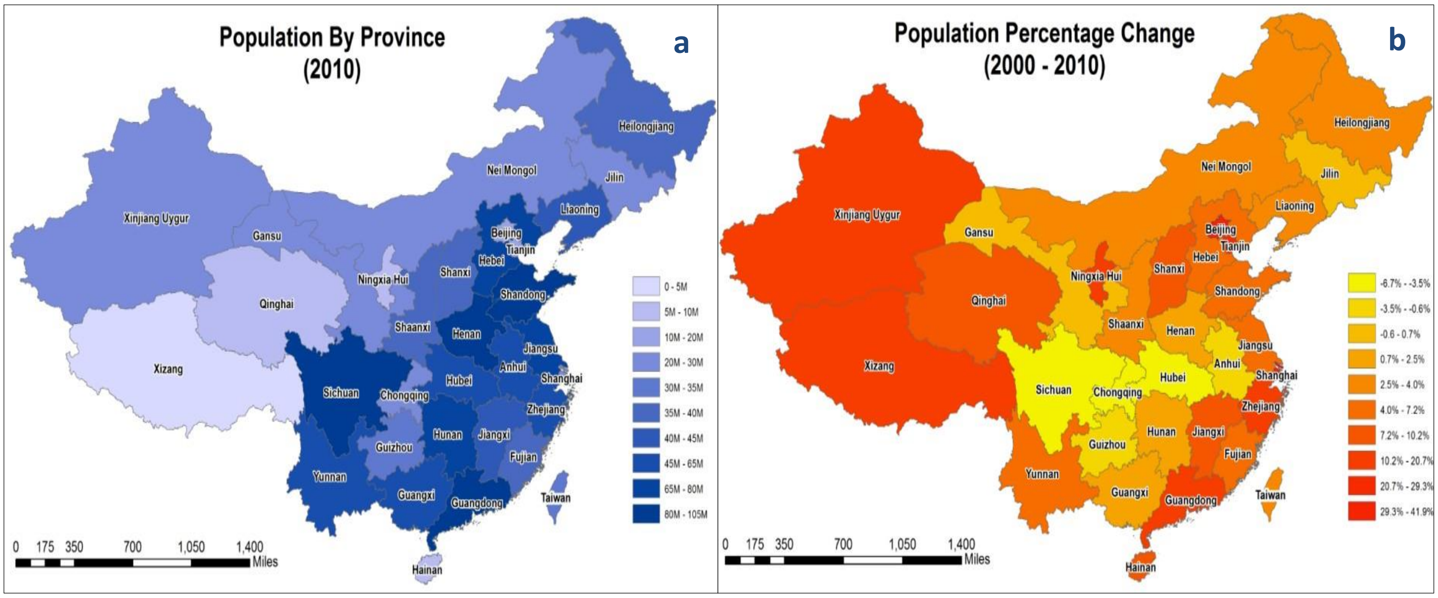

Figure 1. a) China's population by province, given data in the 2010 Chinese Census. b) Percentage population change, from 2000 to 2010, given census data.

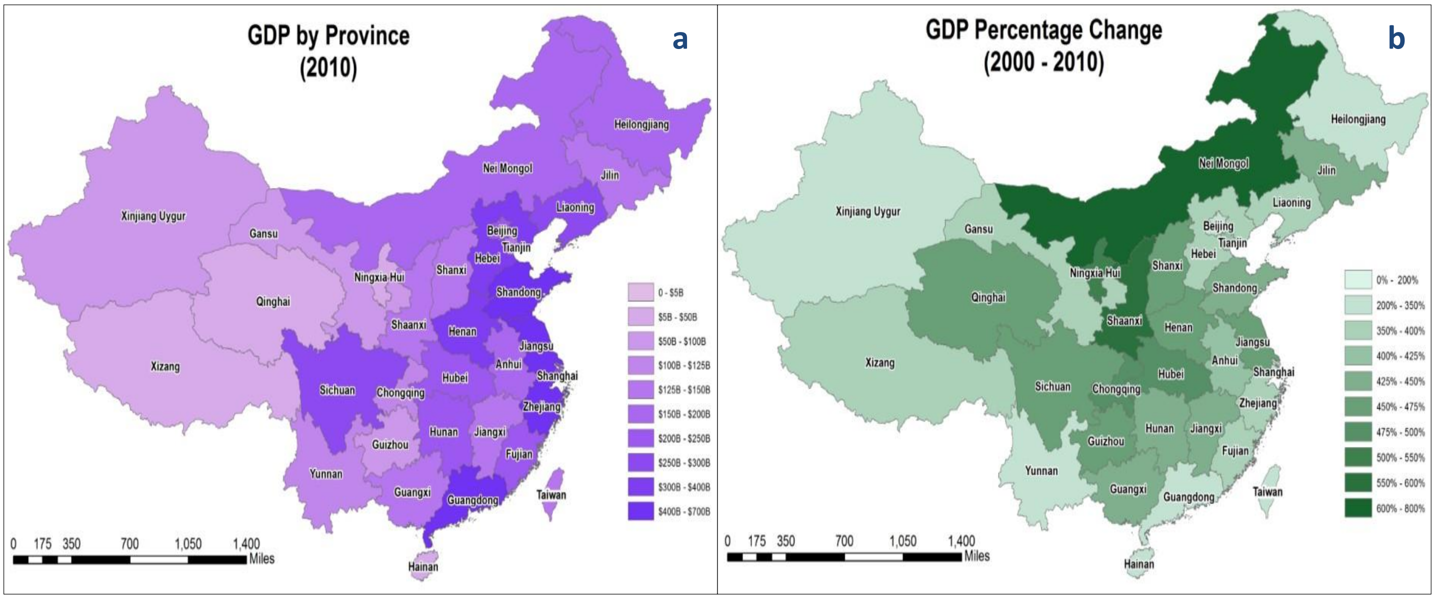

Figure 2. a) China's GDP by province, given data in the 2010 Chinese Census. b) Percentage GDP change, from 2000 to 2010, given Census data.

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Introduction

Worldwide economic losses from natural catastrophes were $140 billion in 2013 (events including Australia Drought, US Wildfire and Egyptian Snow), of which 68% was uninsured. These figures are down from 2011 (Texas Drought, Thailand Floods, Hurricane Irene), when 72% of the $380 billion economic losses were uninsured. While recent total losses from natural catastrophes are below average ($190 billion), they represent major losses for insurers, and significant opportunities for global insurance growth.

This growth potential is most apparent in Asia, which contributed 58% of 2013's uninsured losses, with events such as Typhoon Haiyan and the Indian cold wave. More specifically, within Asia, China has the world's largest population, one of the world's largest and most vibrant economies, and is exposed to a plethora of natural catastrophes. It is extremely important that further research is performed to improve the ability of the government planners, (re)insurers, businesses and citizens to better understand the impact of natural disasters, and to calibrate mitigation plans.

> Historically, only 5% of economic loss from natural catastrophes has been recovered from insurers in China, whereas 20-40% is recovered in more established markets.

China is experiencing rapid industrialization and urbanization of the population. A number of these major population centers are coastal cities; exposing them to potential events such as rising sea levels, flooding and increasingly frequent and severe windstorms.

At the same time, these developing urban areas are benefiting from significant investments in infrastructure and other projects in transport (high speed rail, highways and airports), power (generation and transmission) and water (storage, treatment and distribution). Such capital investments are exposed to complicated delays and damage from natural catastrophes.

As the cities have expanded, so has the need to feed them. Creating conservative water management systems and diversification away from flood plains are two of the significant farming and agricultural challenges that China faces.

As public perceptions of risk and insurance change, and as insurance penetration increases in developing markets, understanding the base elements of accurate risk assessment and price adequacy becomes ever more important.

One paper cannot cover all aspects of natural catastrophes. Instead we offer a general overview of the major risks in China: an introduction to the science behind **typhoons, monsoons, winter storms, drought and earthquakes,** and introduce some of the implications for local insurers.

These are not the only disasters that may strike – China is also exposed to brushfires, hail, landslides and volcanoes, many of which will be covered in subsequent papers.

FAIRCO is in the business of evaluating and managing risk. Our task is to understand the links between natural disasters, to weigh their correlations and to pass our analysis and experience to our customers.

Typhoons – The Science

Unlike any other ocean basin, the Western North Pacific Basin is vulnerable to tropical cyclone genesis throughout all 12 months of the year. Tropical cyclone genesis is, therefore, higher in the Western North Pacific Basin than any other ocean basin.

Storms that develop and strengthen to tropical storm or typhoon strength are more likely to occur from June to November, when the six main requirements for typhoon formation are more prone to align: warm sea surface temperatures (SSTs), enough Coriolis force to develop a low pressure center, atmospheric instability, low vertical wind shear, high humidity in the lower-to-middle troposphere, and a pre-existing low level disturbance.

As with tropical cyclones in every ocean basin, Western North Pacific typhoon frequency, intensity and path are dictated by large-scale climate oscillations, namely the El Niño Southern Oscillation (ENSO) and the Quasi-Biennial Oscillation (QBO).

El Niño/La Niña and Typhoons

ENSO oscillates between two phases: the anomalously warm El Niño phase, and the anomalously cold La Niña phase.

Countless studies have found that in El Niño years, tropical cyclones have longer life cycles and become more intense storms, with a greater chance of category 3-5 storms and lower chance of smaller storms

Conversely, in La Niña years, tropical cyclones have shorter life cycles and tend to be less intense storms.

Over the past 50 years, the average number of named storms in El Niño years is 150% of the average in La Niña years. Landfall typhoons also occur more frequently in El Niño years. This may be because tropical cyclones form east of 150^0 E during El Niño years, giving them more time to develop, while La Niña storms tend to develop west of 150^0E.

Quasi-Biennial Oscillation and Typhoons

QBO also has two phases: the westerly and easterly phase, corresponding to changes in tropical cyclone frequency.

When QBO is in its westerly phase, tropical cyclones are more frequent, and are prone to be stronger storms. This is due to a decrease in the vertical wind shear over the Tropics during the westerly QBO phase.

Conversely, during the easterly QBO phase there are fewer formed and they are less strong.

For typhoons that impact China, ENSO has a stronger influence than QBO.

What is ENSO?

The El Niño Southern Oscillation (ENSO) is the 3-5 year oscillation between anomalously warm (El Niño) and cold (La Niña) bands of ocean water dominating the Pacific Ocean. The pools of cold and warm water act as energy stores that influence weather on a global scale, particularly near the Western Pacific.

What is QBO?

The quasi-biennial oscillation (QBO) is a slow moving pattern (average cycle period is 28.5 months) of atmospheric waves. These waves start in the tropical troposphere and travel higher before being dissipated in the stratosphere, and cause successive waves of easterly and westerly wind anomalies.

Typhoons – Insurance Implications

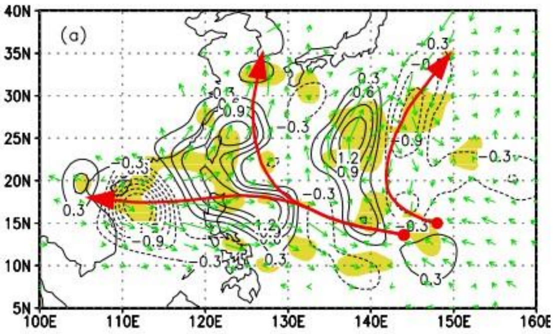

Figure 3. The June-October mean frequency of TC occurrence, and the prevailing winds and motion vectors. The thick solid lines represent the prevailing typhoon tracks.

CAR/EAR represents 10.5% of insured business in China.

The top five provinces for CAR/EAR insured exposure are:

1. Guangdong
2. Jiangsu
3. Shanghai
4. Zhejiang
5. Fujian

When considering where and when to underwrite contracts, insurers should seek the most up-to-date knowledge of and information about the dynamics of all Western North Pacific typhoons.

Recent studies show a westward shift over the past four decades in the two prevailing typhoon tracks in the Western North Pacific. Any westward move in typhoon track will increase typhoon landfall over all of coastal China, from subtropical southeastern China (including Hong Kong and Guangzhou) to northeastern China, as far as Qingdao. These significant metropolitan areas can expect increasing frequency of typhoons hitting their cities.

The shift in prevailing typhoon tracks has a profound influence on China, as regions like the Yangtze River Valley experience more flooding from tropical cyclones, while major cities along the coastline are more prone to be struck by heavy wind and rain.

This shift is significant for risk managers, catastrophe modelers, and particularly underwriters of construction projects where the risks change and evolve as the construction progresses, from foundation to completion.

To correctly price Construction All Risk/ Erection All Risks (CAR/EAR), typhoon risk, underwriters should analyze not just the wind and flood vulnerability of a structure in its various phases of construction, but also keep an eye on future trends of Western North Pacific typhoons. The trends can be partially understood by following the movement of ENSO, QBO and various climate change effects.

In El Niño years, impacts of typhoons in China are more pronounced due to the more westerly tropical cyclone track. This allows for greater longevity of storms and greater percentage of landfall. El Niño years also result in above-normal tropical cyclone activity during September and October, but below-normal activity in the South China Sea.

In post-El Niño years, when a La Niña is developing, tropical cyclone formation is below normal for the entire Western North Pacific Basin.

Given these facts, underwriters are well advised to understand the predictive methodology for El Niño/La Niña and the QBO. The National Weather Service's Climate Prediction Center, based out of Maryland, USA, sends out weekly and monthly diagnostics on the state of ENSO, and the oscillation's strongest signals can be predicted up to 6-8 months in advance. This is also true of the phases of QBO which enhance the track of typhoons and reduces wind shear.

Interested stakeholders should consider every approach angle, including partnering with private companies, public organizations and universities to create more in-depth and long range prediction services. FAIRCO will continue to monitor developments on behalf of our customers.

East Asia Monsoons - The Science

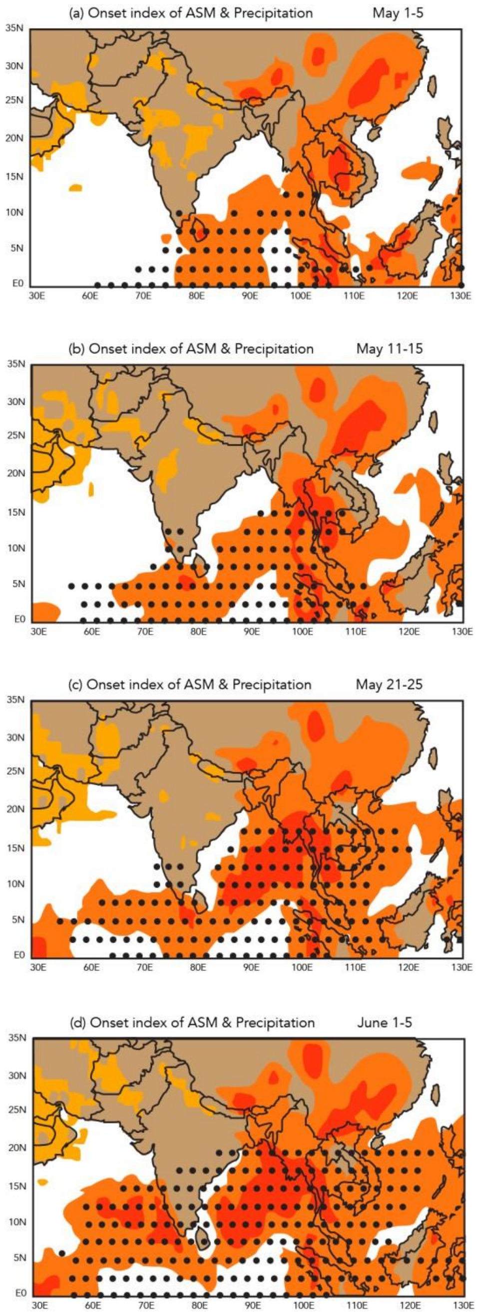

Figure 4. Climatological precipitation rates in sequence from early May to early June. Light and dark shadings represent rainfall regions greater than 5 mm/day and 10 mm/day, respectively. Black dots show the onset of the summer monsoon.

The East Asian Summer Monsoon (EASM) is a seasonal pattern of southeasterly winds that carry warm, moist air from the Indian and Pacific Oceans into East Asia. Each year, summer monsoons first appear in the central and southern Indochina Peninsula and the South China Sea, as seen in Figure 4a. The onset is abrupt and dramatic and is preceded by distinct circulation patterns over the tropical East Indian Ocean and Bay of Bengal.

The East Asian summer monsoon advances in a distinct stepwise march, with northward and northeastward movements. The monsoon forges ahead with two abrupt northward jumps and three completely stationary periods.

After commencing over the Indochina Peninsula and the South China Sea in early to mid-May, the monsoon jumps to the Yangtze River Basin, western and southern Japan and the Philippine Sea in early to mid-June, as in Figure 4b. The final step is into North China, Korea and central Japan by early to mid-July, like in Figure 4d.

With the reliable precipitation spike in July and August, a significant amount of moisture is transported from the South China Sea and leads to a dramatic change in climate regime in East Asia. After the Northern Hemisphere's summer, winds change to northeasterly and monsoonal bands retreat back to the south. Heavy rainfall in the winter season is confined to South China.

It is important to note that Pacific and Indian Ocean sea surface temperatures and Eurasia and Tibetan Plateau snowmelt are also contributing factors to processes and mechanisms related to EASM.

The EASM, like Asian typhoons, are distinctly affected by ENSO and QBO.

ENSO and Summer Monsoons

As El Niño develops, droughts tend to occur more often in North China, as El Niño prevents summer monsoons from migrating far to the north. This is due to the effect of El Niño on the location of Western Pacific Subtropical High.

Conversely, during the decaying stages of El Niño, floods tend to occur in the Yangtze River Valley, especially in the regions just south of the river.

QBO and Summer Monsoons

China's summer rainfall clearly oscillates with a period of two or three years, most notably in eastern and southern China, including the Yangtze River Valley and the Huiahe River Valley, and is also seen in Northern China.

The variation in rainfall can be attributed to the oscillation of water vapor transfer from the South China Sea to the Asian continent. Monsoonal winds are intensified during QBO westerly phases and bring more moisture to mainland China.

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Monsoons – Insurance Implications

Each year, economic losses in China due to drought and floods average 200 billion Yuan (~US $24 billion). The 1998 summer floods in the Yangtze River Basin and the Songhua and Nen River Valley created losses of approximately 260 billion Yuan (~US $31 billion). All values above are represented in 1998 currency exchange rates.

Climactic model recreations of the 1998 summer floods show that six major components came together in a ‘perfect storm’ to create the severe floods in the Yangtze and Huiahe River Valleys.

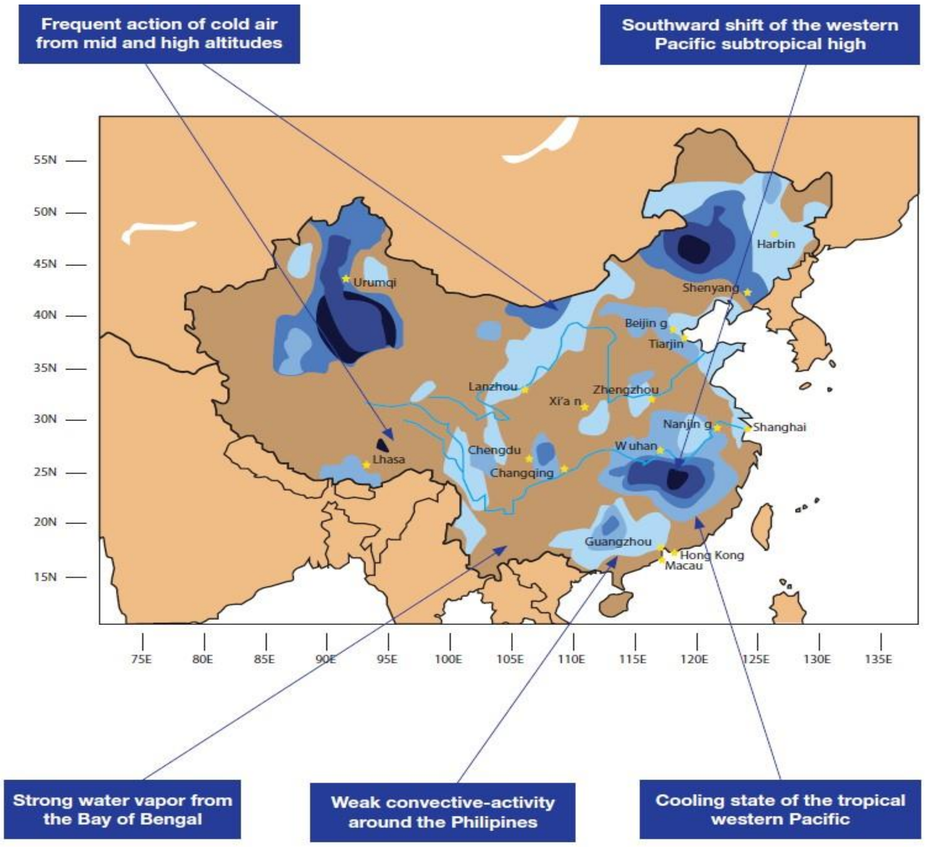

Figure 5. Diagram of the components that came together to create the 1998 severe floods in China. Shaded areas show precipitation anomalies over 80%.

China’s urban planners now have an opportunity to develop sustainable infrastructure that is capable of adapting to changes in local climate, sea levels and post-disaster recovery needs.

In doing so, they and the insurers who protect such investments can learn lessons from older infrastructure around the world that was not designed with climactic changes in mind, and to garner best practice lessons from the experiences of others.

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Drought – The Science

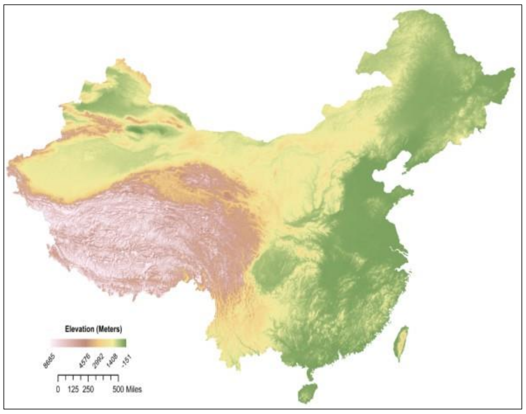

Figure 6. Elevation map of China, in meters.

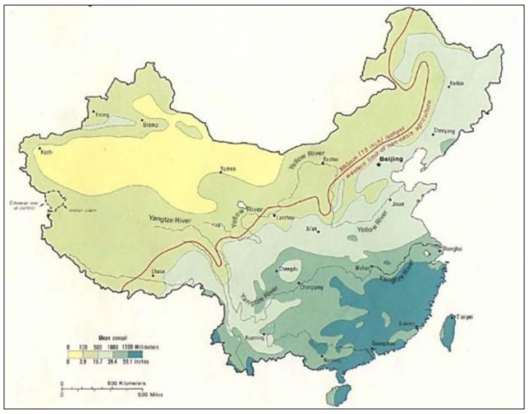

Figure 7. Annual mean rainfall in China. The orange line represents a 350 millimeter/year isohyet, delineating the western extent of rainfall-fed and irrigated agriculture.

China's diverse climate is dominated by a monsoonal system. The warm and wet summer monsoon is followed by a cool and dry winter monsoon that brings a completely different weather system to China. Despite being in the 'temperate' latitudes, China's climactic patterns are far more complex than other temperate regions.

The yearly advance and retreat of the monsoons accounts for the timing and quantity of rainfall across the country. Conversely, this also means the monsoon's movement dictates when and where droughts hit China.

Geographically, rainfall regions are bisected by the Qin Mountain Range. Regions to the south and east receive upwards of 1000 millimeters of rain per year, most coming over spring and summer. Areas to the north and west of the Qin Mountains receive less rain, and rainfall events become less reliable, increasing the chances of a drought occurring.

China has suffered large-scale droughts for thousands of years. The trend has recently been on the upswing - 17 widespread droughts have hit China since 1949. Droughts are most common in the northern provinces of Jilin, Liaoning, Hebei, Shanxi, Henan, Shandong, Inner Mongolia, Gansu and Qinghai, where wheat and corn are the most commonly grown crops.

Historically, droughts were confined to Northern and Northwest China, but over the past 30 years, the impact has become more widespread, affecting areas in the Northeast and South, which were previously very moist regions.

Due to large annual variations in rainfall, drought in Huanghuai occurs more often. The Yangtze River Basin and the Henan and Anhui Provinces, which were previously unaffected by drought, have been hit hard multiple times since 2000.

The 2006 drought in Sichuan and Chongqing was the worst since 1950, while the drought in 2008-9 severely affected 12 Northern provinces.

The drought that began in late 2010 and ended in March 2011 was even worse than 2006. It started in the central and northern Yangtze River Basin and eventually limited water supplies to 3.5 million people, simultaneously halting cargo shipping along the river. Rainfall was 25% less than normal. The suppressed summer monsoon and heightened winter monsoon were influenced by an El Niño phase, while an extremely negative Arctic Oscillation contributed to the persistence of the drought once it had already begun.

These 1-in-50 year and 1-in-60 year events have been heavily influenced by climate change. Senior meteorologists at China's National Climate Central suggested that the light rain and high temperatures were results of anomalous atmospheric currents, and that the droughts in China are part of a larger phenomenon felt worldwide.

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Drought – Insurance Implications

Only about 1/8th of China's land mass is capable of being cultivated for arable crops. Despite having less arable cropland than the USA, China's agriculture output is twice the US total. This is due to intensive farming of the available land to maximize food growth to feed the much larger population of China. Agriculture represents just under 10% of China's GDP.

Intensive farming and water usage leaves China exposed to chronic food and water shortages in times of drought. The persistent droughts in North China since the late 1970's have brought huge losses to agriculture and affected the region's water sources and ecology.

Efforts to expand farming land north and west have been met with limited success, as minimum rainfall requirements and nutrient content in soils are not favorable to rice, wheat, corn and millet production.

Droughts account for 52% of agricultural loss. It is no surprise, therefore, that maps of overall agricultural loss and drought distribution match up seamlessly.

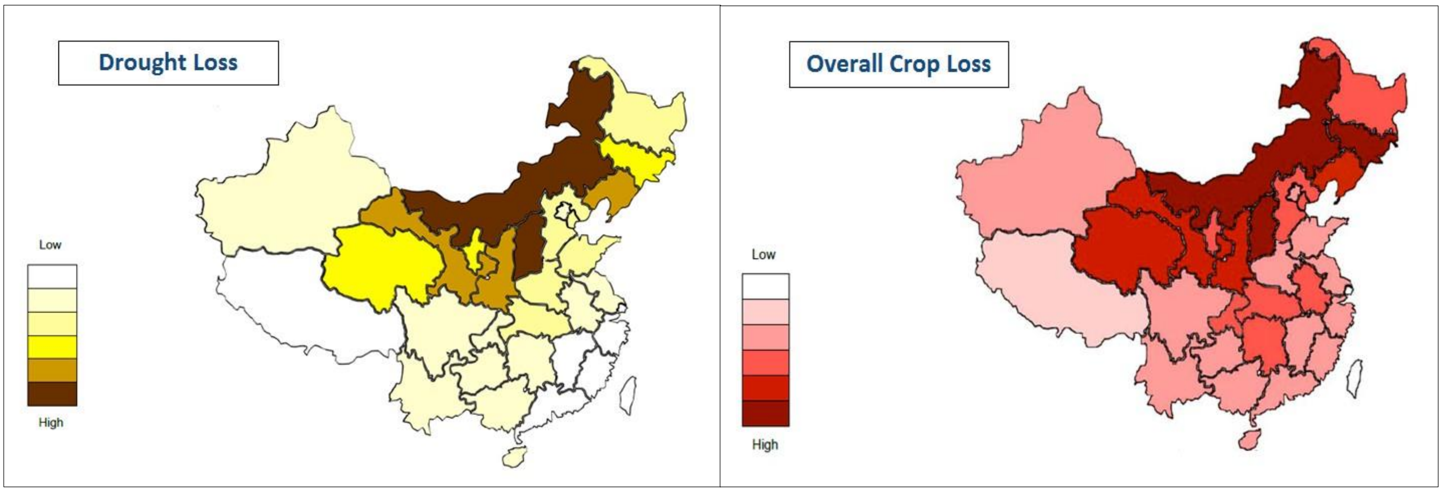

Figure 8. The left image shows average severity of drought from 1987-2008, on the right it shows overall crop loss.

China's crop insurance market is growing rapidly, at a time when pricing cannot rely on historic data while projecting future trends. The Chinese agricultural market is currently the second largest in the world, behind the United States.

Risk managers in China and abroad should take note to manage their systemic risk, looking at correlations of loss between and within provinces.

FAIRCO intends to produce further papers that will delve into the science of flood, hail, typhoon and cold temperatures, and their effects on crop insurance in China.

Winter Storms – The Science

Extratropical Cyclones (ETC) are mid-latitude cyclones that derive their energy from the horizontal temperature differential between warm, subtropical air masses and cold, Arctic air masses.

ETCs differ in structure, shape and size from Northwest Pacific typhoons. The latter are warm core tropical cyclones, deriving their energy from a vertical temperature differential between the upper and lower atmosphere.

Because ETCs are fueled by a horizontal temperature differential and not warm sea surface temperatures, they can form over land masses and will not dissipate as they track over land.

Phase I- A perturbation forms along a baroclinic zone between low and high pressure systems.

Phase II- The wave amplifies, scale contracts and the fronts of the storm form.

Phase III-The fronts 'T-bone' and waves amplify. Storm force winds form between the warm and occluded fronts.

Phase IV-Full seclusion of the warm front. Storm and hurricane force winds found on cold side of the occluded front.

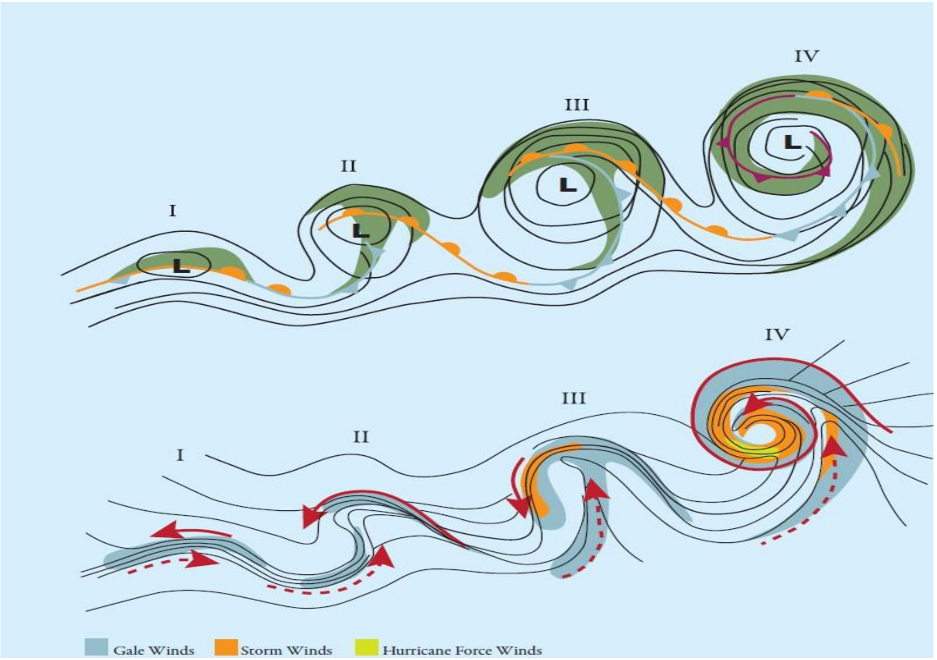

Figure 9. The Shapiro-Keyser Extratropical Cyclone Model, developed in 1990, shows the life-cycle of an ETC.

Current studies of Chinese ETCs cover the tracking, climatic characteristics, intensity, movement and areas of explosively-deepening cyclones. The findings show that there are three main areas of ETC development in and around East Asia.

Cyclogenesis- The development or strengthening of cyclonic circulation in the atmosphere (an area of low pressure).

1. The western area of cyclogenesis refers to the western Siberian Plain (55°N-75°N, 60°E)
2. The central area refers to Mongolia, more specifically to the south of Lake Baikal
3. The eastern area refers to the east coast of the China-Northwest Pacific Ocean border

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Winter Storms – Insurance Implications

Knowing the area of potential ETC development, insurers in China should be able to assist in loss mitigation, while better knowledge will also encourage socioeconomic development in areas less affected by the conditions.

ETCs are generated more in central and eastern areas than in the west. For affected areas, more storms are generated in spring (there is no ETC genesis in the West in summer at all). With the end of summer/beginning of autumn, genesis increases dramatically in each area.

In the eastern area, there is a southward shift of ETC genesis and track in the winter. This means a greater chance of storms tracking into Shanghai and Qingdao, where insurance penetration is above average.

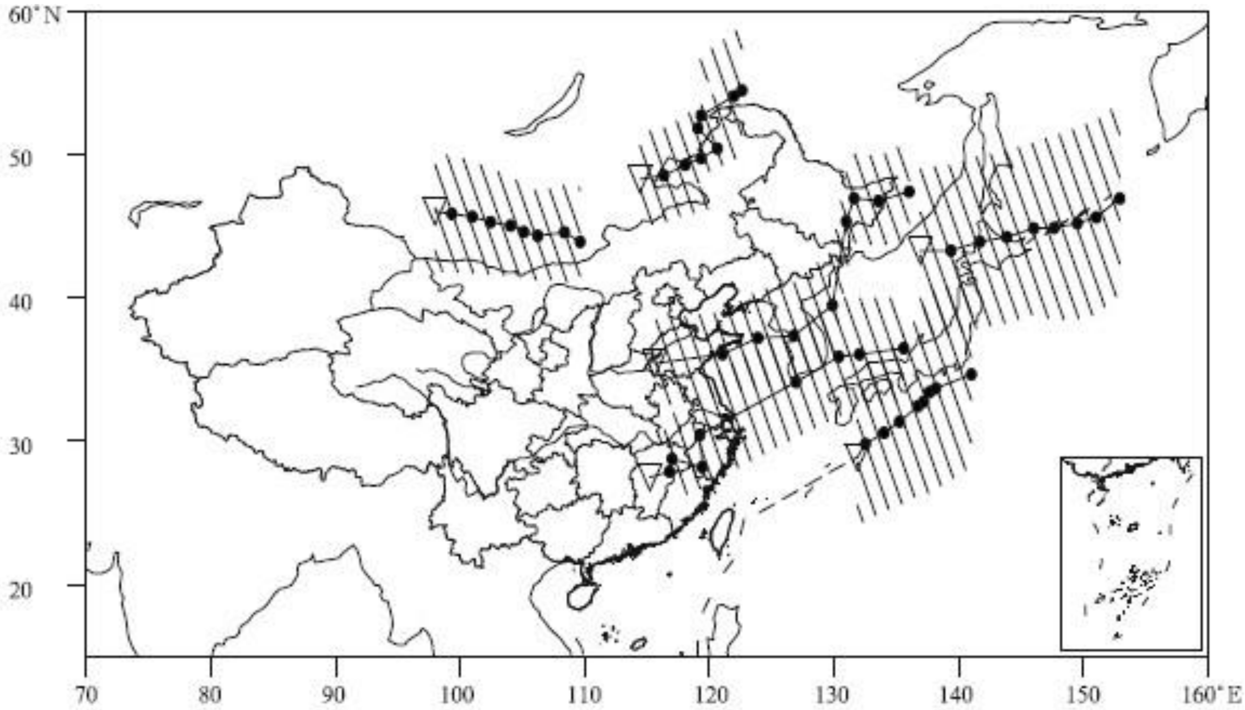

Figure 10. Starting position of cyclone tracks in East Asia. Inverted triangles represent the starting point of each track; slashed lines represent areas of influence.

Many of the storm tracks go right through some of the most heavily populated provinces in China, along the East China Sea. Additionally, these tracks match up with locations of areas where explosively-deepening cyclones occur most frequently, and where ETCs track the furthest over land.

All these findings correspond to the potential for greater insured loss per storm, as insurance penetration continues to grow. Risk managers and underwriters should take such facts into account as part of their overall risk assessment.

Earthquakes – The Science

Island Arc – Known as the First Island Chain, the island arcs are a series of major archipelagos that extend from the East Asian continental mainland coast.

China's highly active tectonic regime makes the country one of the most earthquake-prone in the world. The continental margins that represent China's tectonic borders are not a single boundary line, rather than a complicated amalgamation of transitional crusts, composed of continental and transitional plates of different widths. The island arcs further complicate Chinese tectonic architecture.

The various rifts and margins create a complex collage of subduction-related zones. The principal geotectonic provinces are: The North China Craton, Yangtze Craton, Cathaysia Block (South China Block), Tarim Craton, Altay-Tianshan-Hinggan oregens (Altaids), Kunlung-Qinlang fold belt, South China Fold Belt, the Himalayan, Qingai-Yunnan and Gandise fold belts. Together, the interaction of these tectonic zones accounts for millions of years of tumultuous geologic history.

The five major tectonic principalities in China (North China, South China, Godwana, which are continental, Siberian-Mongolian and the Western Pacific, which are continental margins) create the most earthly stresses through subduction and convergent crustal zones.

One tectonic domain consists of the North China continental margin in the south and the Siberian-Mongolian continental margin in the north. These run from the western Aibi-Juyan zone to the northern slope of North TIanshan to Beishan, and the eastern Suolun-Xilamulun zone crossing the border line on the Tumen River in eastern Jilin.

Other domains, such as the convergent zone between North China and South China continental boundary run along the Kunlun-Qinling line. The Sahngyang-Tongcheng convergent zone of increased tectonic activity runs from southern-Shaanxi and enters the Yellow Sea near Lianyun Harbor, and is divided by the Tancheng-Lujiang transcurrent fault in eastern Anhui.

The East China Continental Margin Domain is a part of the giant, trans-Pacific volcanic belt. The dominant section comprises the 450 million year old South China Mountains and fold belts stretching from the southeastern coastal region to the Nadanhada Mountains in Northeast China.

Each of these tectonic lines is intimately intertwined with the geologic evolution of China. Almost every major recorded earthquake in China, in both ancient and modern times, has been a result of changes in tectonic architecture.

The major earthquakes have occurred over subduction zones and convergent zones. Crustal development in China is very active; geothermal events and tectonics movements have caused earthquakes numerous times in the past ten years, just as socioeconomic development has burgeoned.

Convergent - Boundary where two or more tectonic plates of the lithosphere collide.

Subduction- Area at convergent boundaries where one plate moves below another tectonic plate.

Geothermal - Thermal energy generated and stored in the earth.

Lithosphere - The crust and upper mantle of the earth.

Fold Belt - Series of mountainous foothills that form due to tectonic interactions.

Earthquakes – Insurance Implications

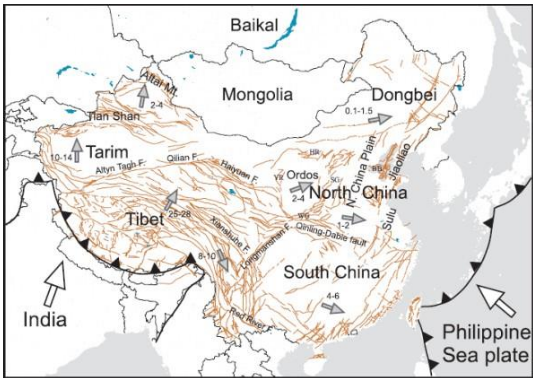

Figure 11. Major geological units and their relative motion (mm/yr) with respect to stable regions nearby. Thin lines represent active faults.

Looking at the historical catalog of catastrophic Chinese earthquakes, some major trends come to light. Almost all earthquakes occur along known, active fault lines. However, this data does not provide insurers with the most important information: predictions of long-term seismic hazards in China.

Since high-risk areas with significant exposures have not experienced major earthquakes in recent history, underwriters must combat buyer complacency and disbelief in applied science.

Combining knowledge of lithospheric strain rate with high resolution soil maps is one way to determine areas most prone to earthquake risk. Factoring tectonic strain and soil composition into risk equations will determine the intensity of ground shaking given strength of earthquake.

Earthquakes of all magnitudes can destroy structures, whether finished or under construction. Once again, CAR/EAR differs from other lines, in that structures are at different susceptibilities to quake through the phases of construction.

Much of the CAR/EAR business involves mid-rise masonry or mid-to high-rise reinforced concrete buildings. Yet the most prevalent structures in many small towns across China are unreinforced masonry (URM) structures. URM structures are the most vulnerable to ground motion, and were the principal type of structure lost in the 2008 Sichuan earthquake.

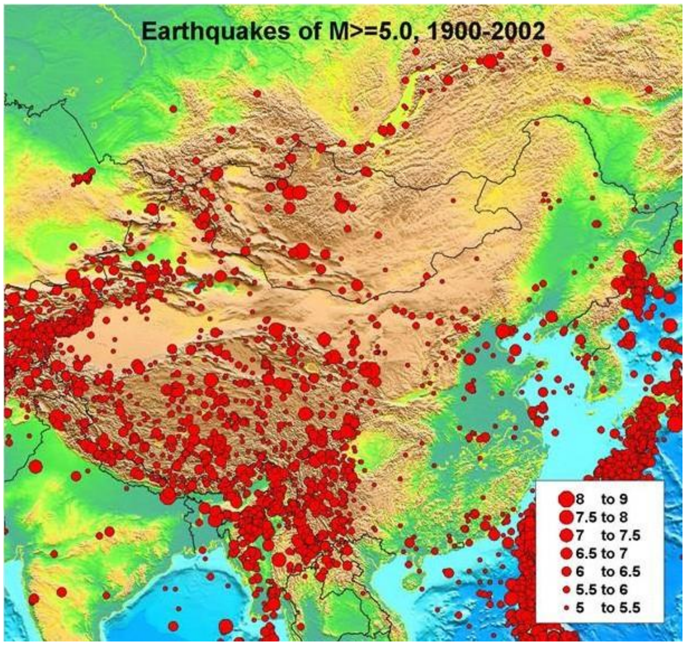

Figure 12. Earthquakes of magnitude 5.0 or greater, from 1990 to 2002.

Utilizing earthquake maps is the best way to comprehend how complex plate tectonic schematics might act in future years. Geotectonic science is among the most difficult to fathom and predict, but is one area where understanding the history does help in predicting future scenarios.

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