Vision for WMO Integrated Global Observing System (WIGOS) in 2040

世界气象组织全球综合观测系统2020发展远景

--Congratulations to 2018 FY-Sat User Conf.

热烈祝贺首届风云卫星用户大会召开

WORLD METEOROLOGICAL ORGANIZATION

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Assistant Secretary-General
World Meteorological Organization
张文建

Presentation Outline

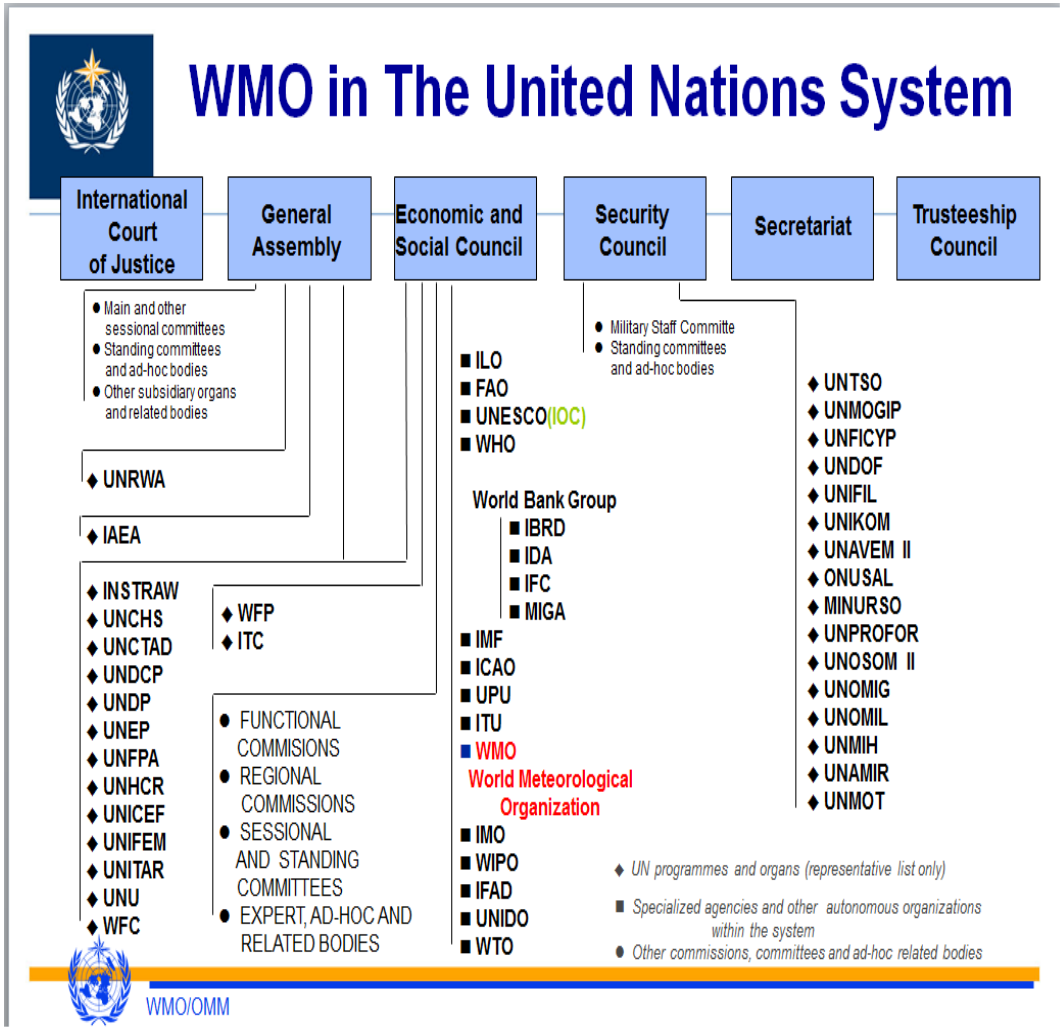
- Introduction of WMO
- WMO Grand Challenges
- Role of WMO Observation Visions
- WMO WIGOS Vision in 2040
- Summary

- WMO简介
- WMO面临的主要挑战
- WMO 观测系统远景的作用
- WMO 综合观测系统2040年远景
- 小结

WMO OMM

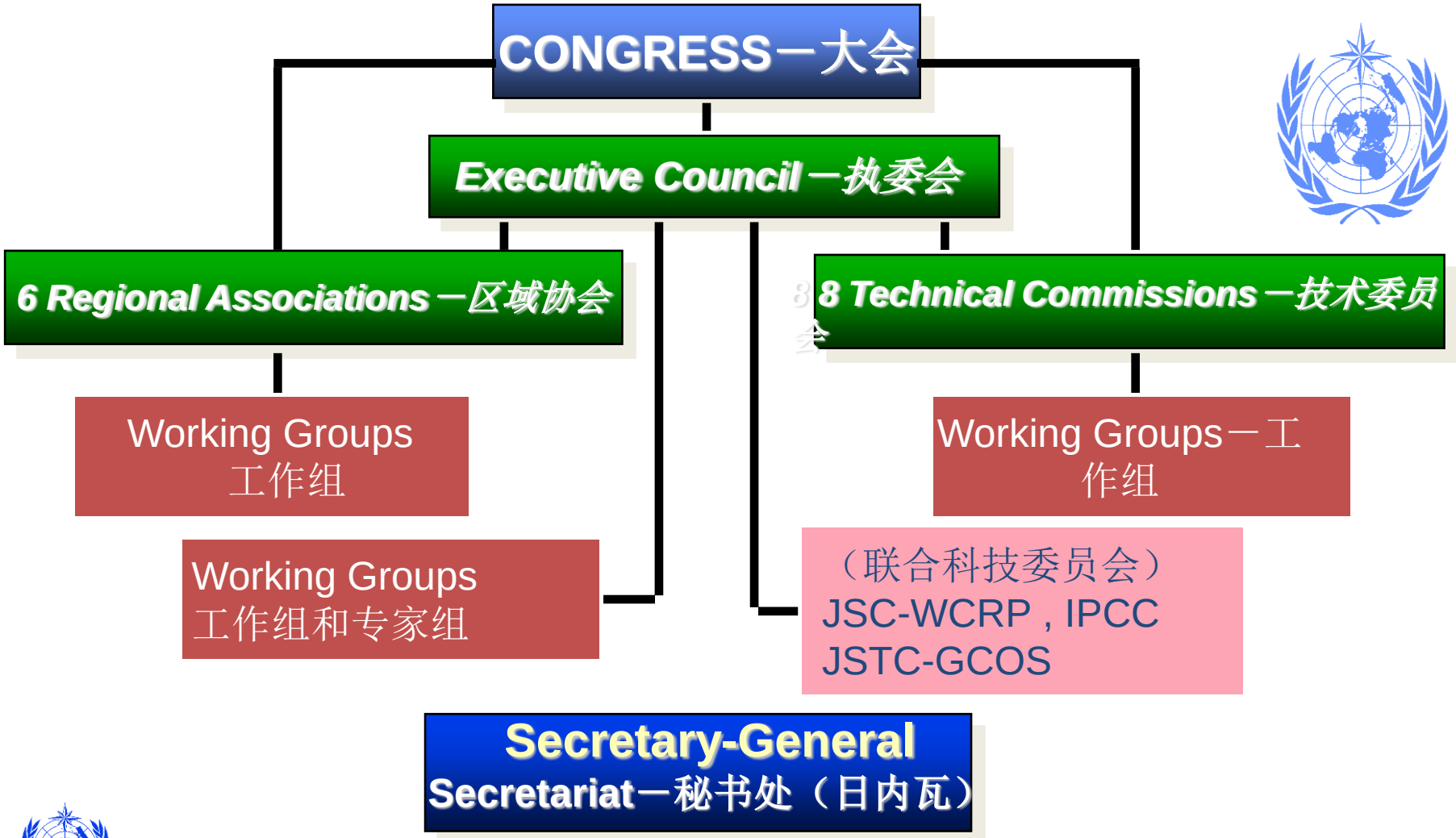
WMO is the UN system's authoritative voice on weather, climate, water & related environmental issues

- UN Specialized Agency on weather, climate & water
- Coordinates 191 Members, 200 000 experts from meteor & hydrological services and academia
- Backbone Programme: World Weather Watch since 1963
- Co-Founder and host agency of IPCC
- Co-Founder of UNFCCC

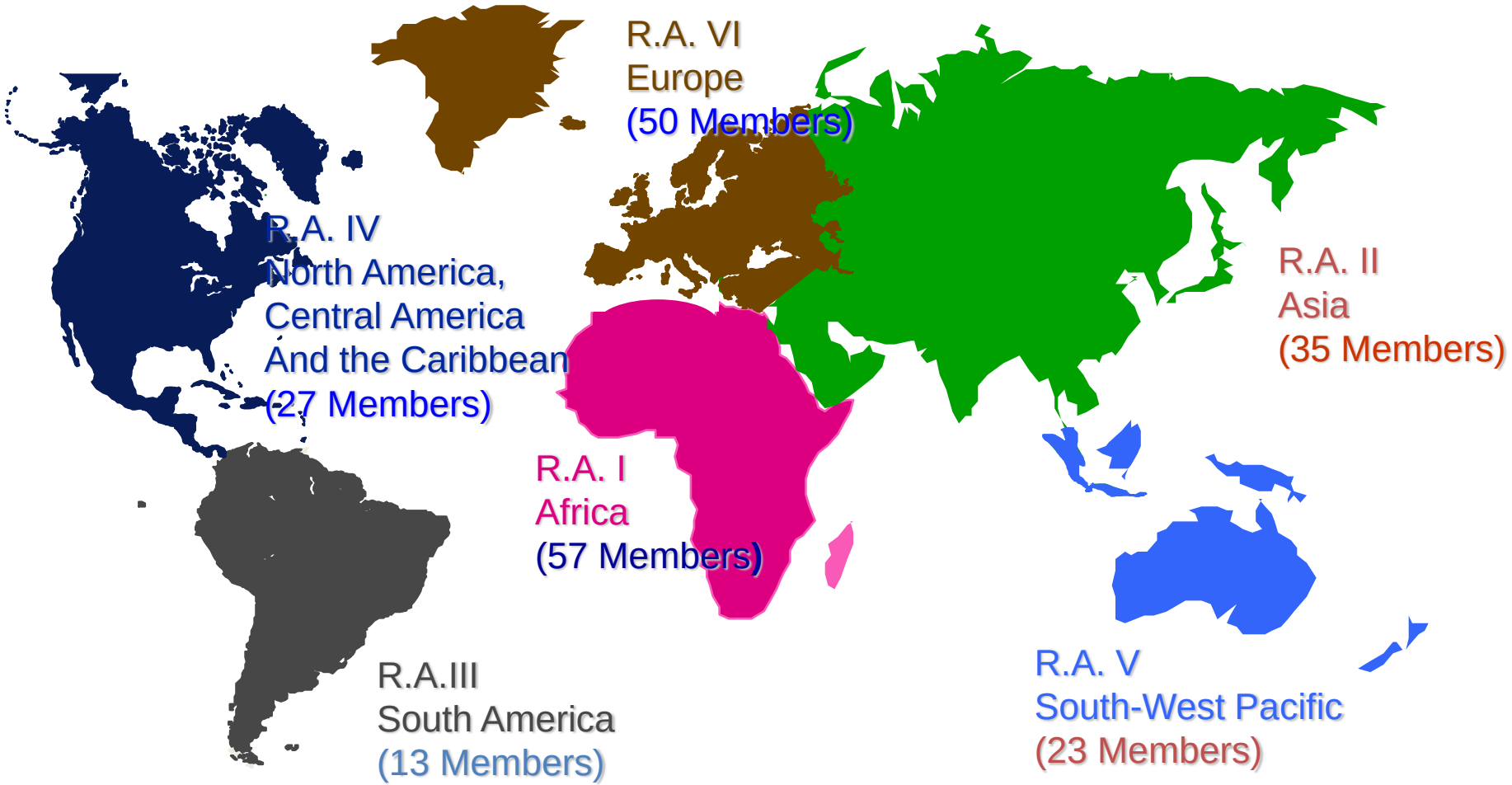


WMO OMM

Current structure of WMO



WMO Regional Associations



WMO is a legal-binding organization !

世界气象组织是一个法律约束的组织：公约，通用规则和技术规范

Since 1951, WMO Cg-I

基 本 文 件

第1号

2015年版

世界气象组织

天气·气候·水

WMO-No. 15

世 界 气 象 组 织
公 约

考虑到可持续发展的需要，减轻自然灾害和其它与天气、气候和水相关的灾难性事件造成的生命和财产损失的需要，以及为人类当代和子孙后代保护环境和全球气候的需要，

认识到一个综合的国际气象、水文和相关资料和产品的观测、收集、加工和分发系统的重要性，

重申国家气象、水文气象和水文部门在观测和认识天气与气候以及提供气象、水文和相关服务以支持相关的国家需求方面的使命至关重要，该使命应包括以下领域：

1、保护生命与财产，

2、保护环境，

3、为可持续发展做出贡献，

4、促进长期观测和气象、水文和气候资料的收集，包括相关环境资料，

5、促进内部能力建设，

6、履行国际义务，

7、为国际合作做出贡献，

还**认识到**会员需要共同致力于协调、统一和改进气象、气候、水文和有关信息的相互交流并鼓励提高这种交流的效率，以助于各项人类活动，

考虑到最好由一个负责的国际组织在国际层面对气象进行协调，

进一步**考虑到**需要与其他同样致力于水文、气候和环境领域的国际组织密切合作，

Purpose of WMO – Convention (1)

(a) To facilitate worldwide **cooperation in the establishment of networks of stations** for the making of meteorological observations;

(b) To promote the establishment and maintenance of systems for the **rapid exchange of meteorological and related information**;

(c) To promote **standardization of meteorological and related observations** and to ensure the uniform publication of observations and statistics;

（a）促进全球合作，建立全球观测网络;

（b）促进建立和维持快速交换气象和相关信息的系统;

（c）促进气象和相关观测的标准化，并确保统一公布观测和统计数据;

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Purpose of WMO – Convention (2)

(d) To further the application of meteorology to aviation, shipping, **water problems, *agriculture* and other human activities;**

(e) To promote activities in **operational hydrology** and to further close cooperation between Meteorological and Hydrological Services; and

(f) To encourage **research** and training in meteorology and, as appropriate, in related fields and to assist in coordinating the international aspects of such research and training.

(d) 推进气象学应用于航空、航海、水利、农业和人类其它活动;

(e) 促进业务水文活动，增进气象与水文部门间的密切合作;

(f) 鼓励气象及有关领域内的研究和培训，帮助协调研究和培训 中的国际性问题。

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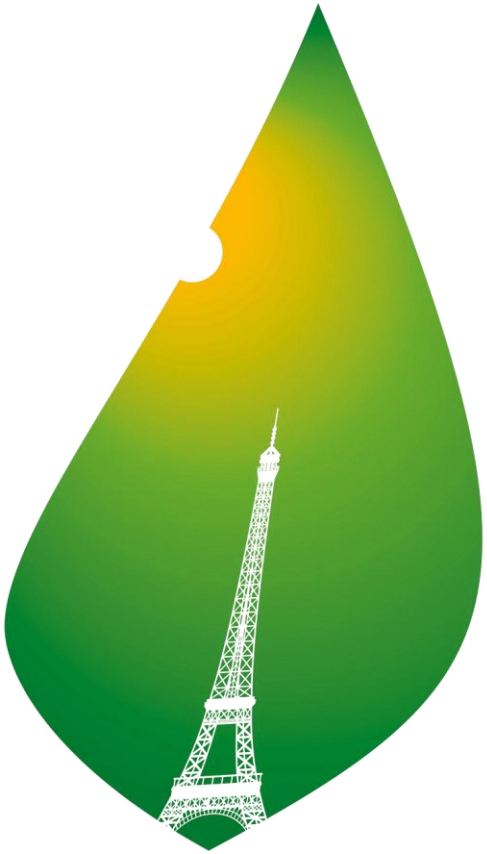
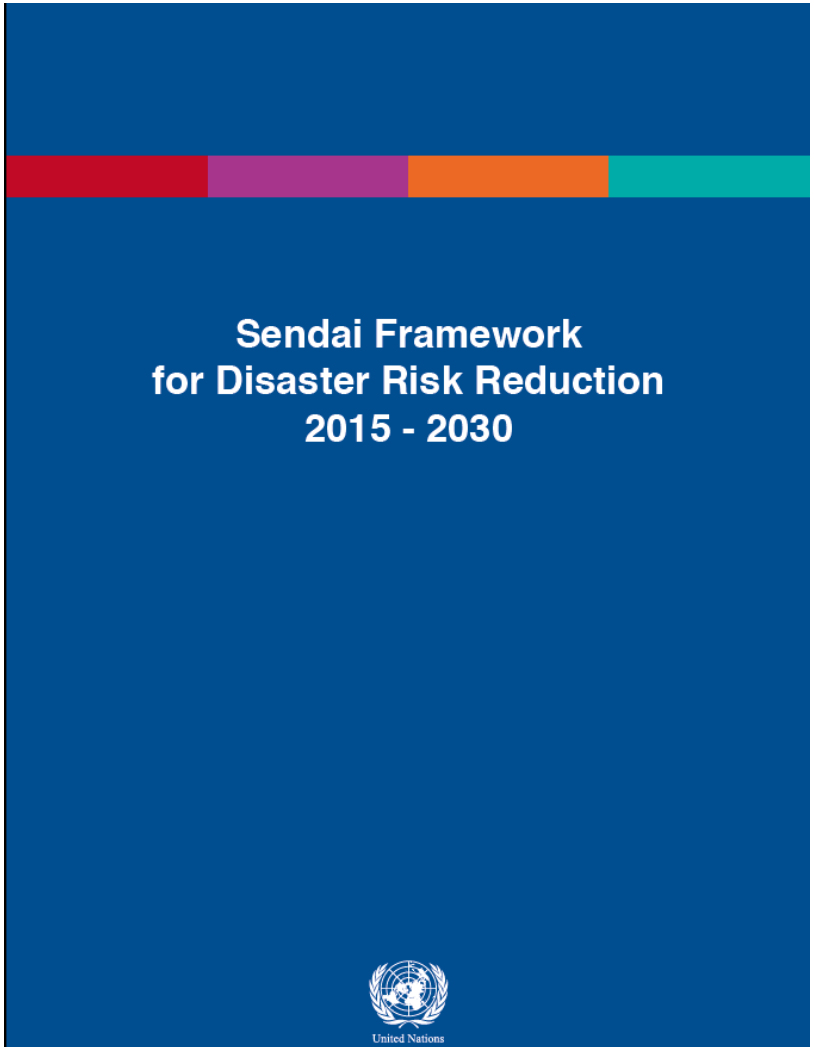
Public Good and Mankind Welfare
全球气象工作-公益事业：避害趋利



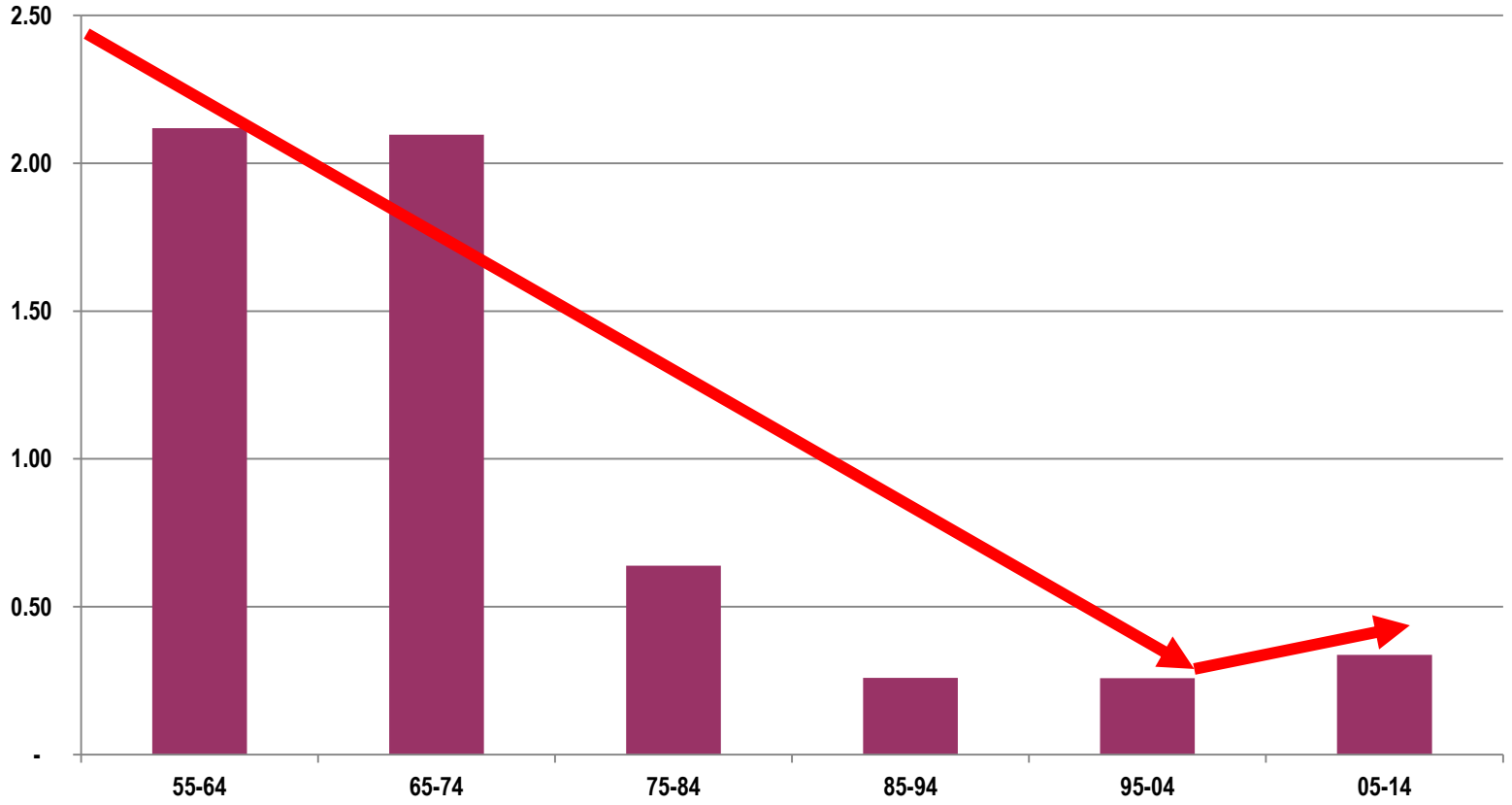
COP21 · CMP11
PARIS 2015

WMO OMM



II: WMO 和会员国取得的成就和面临的挑战-1

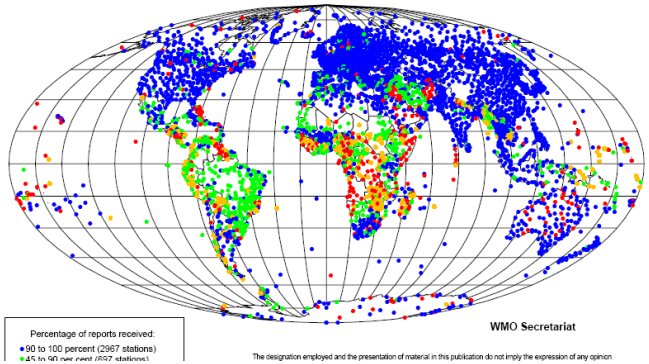
Great Achievement of hydrometeorological services lead to great reduction of human losses (1955–2014)（millions）

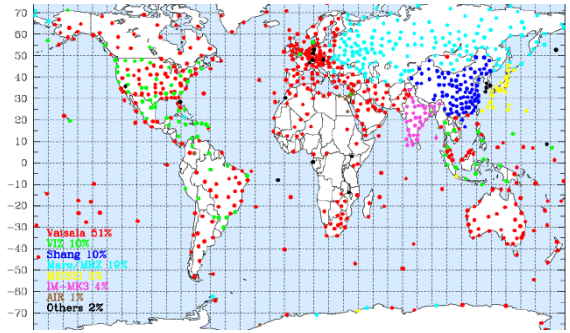


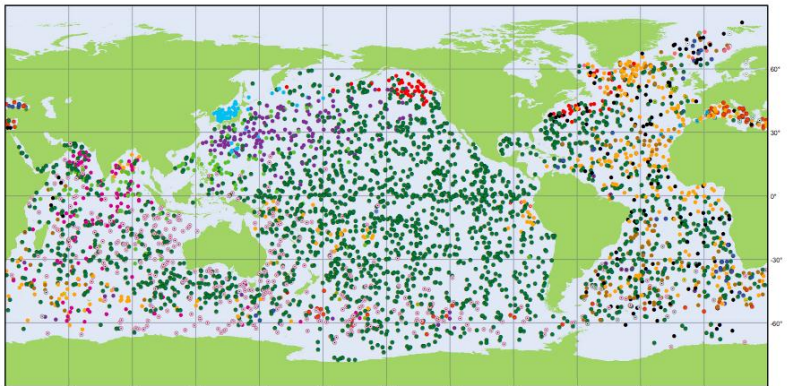
Due to greater progress of WMO for better forecasting, early warning systems and national prevention measures

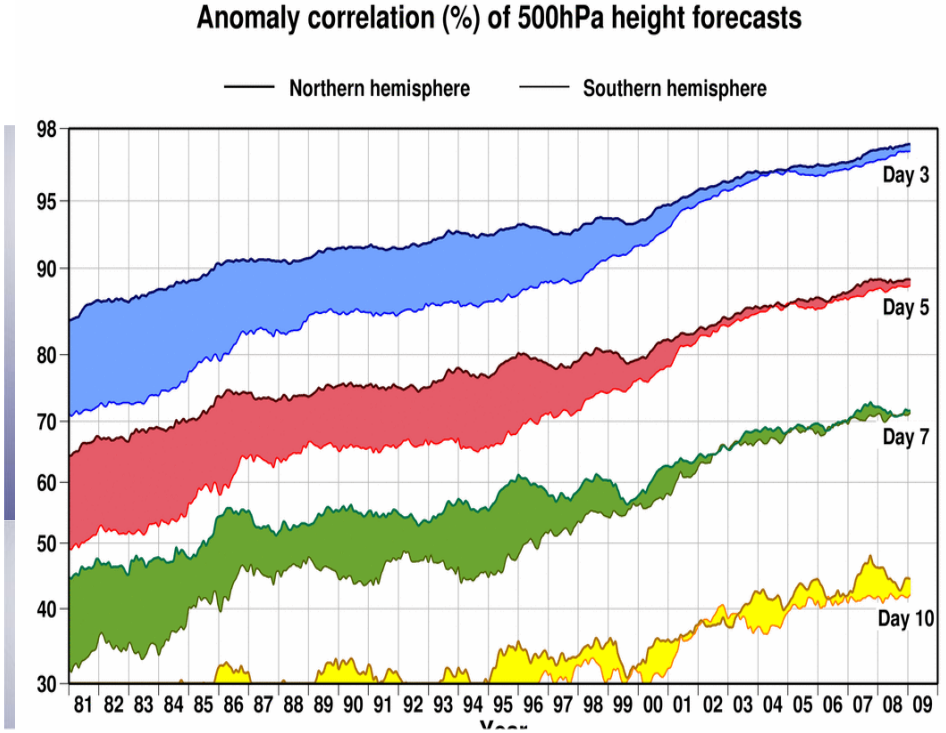
主要归功于日益精准的预报、及时预警和国家的救灾和防范措施

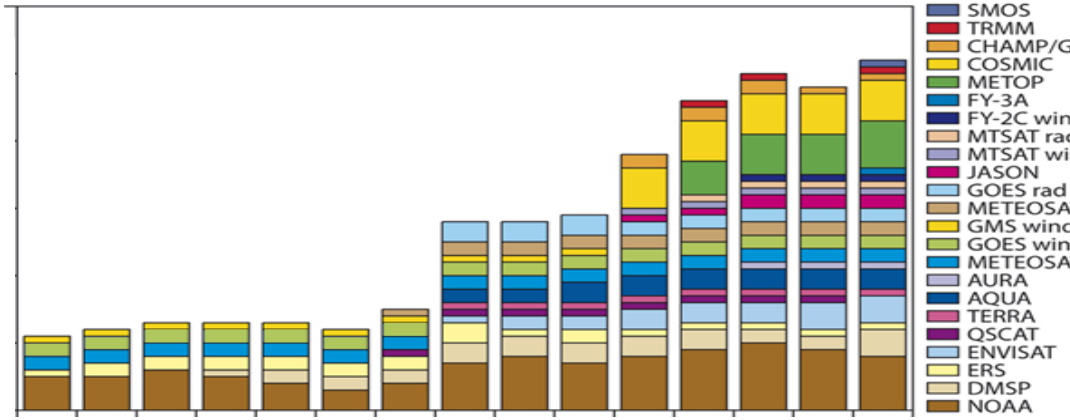
In the past 60+ years, WMO effectively coordinated global Earth System observations & collaboration on Earth System Predictions – Global Foundation for all service provisions





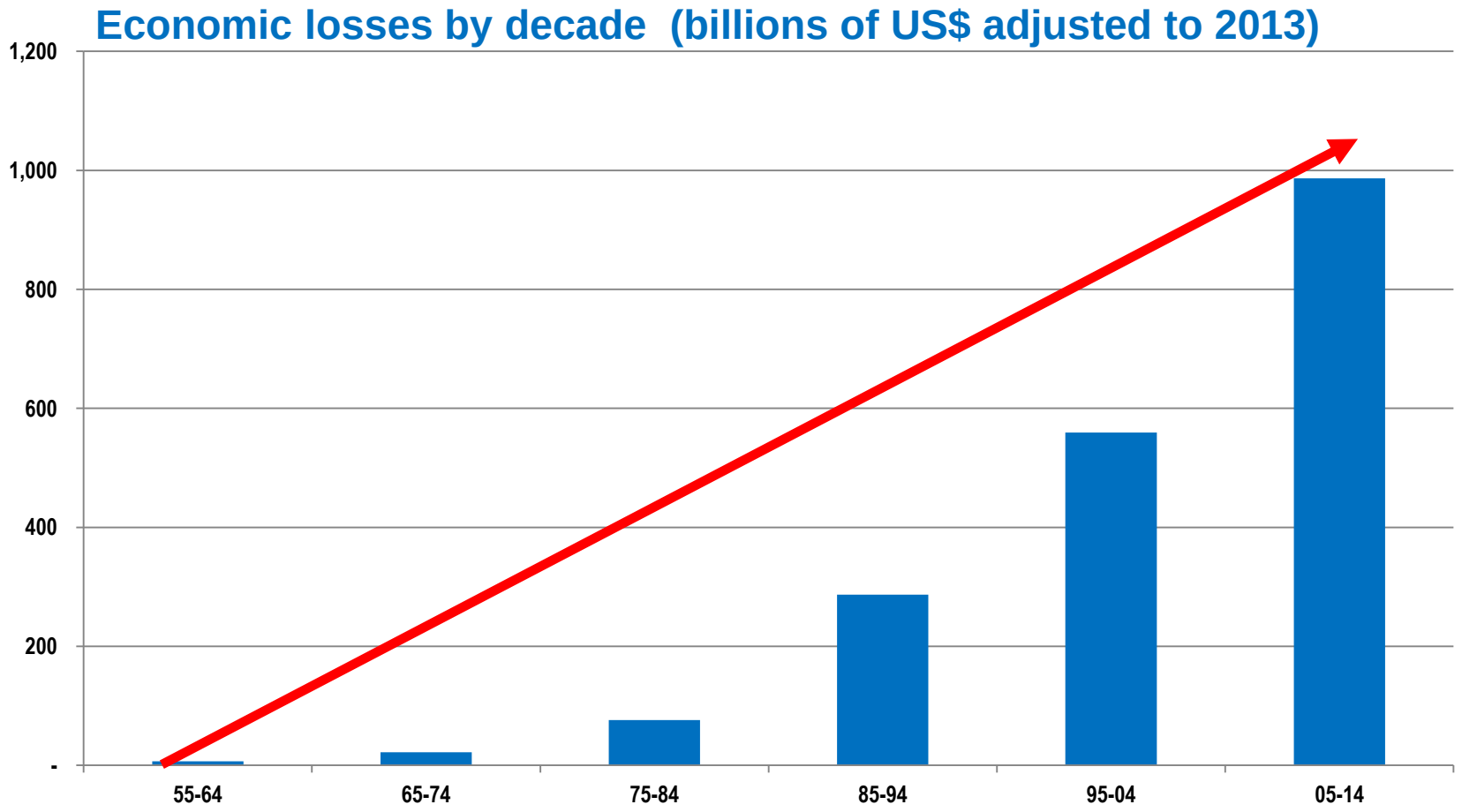






WMO 和会员国取得的成就和面临的挑战-2

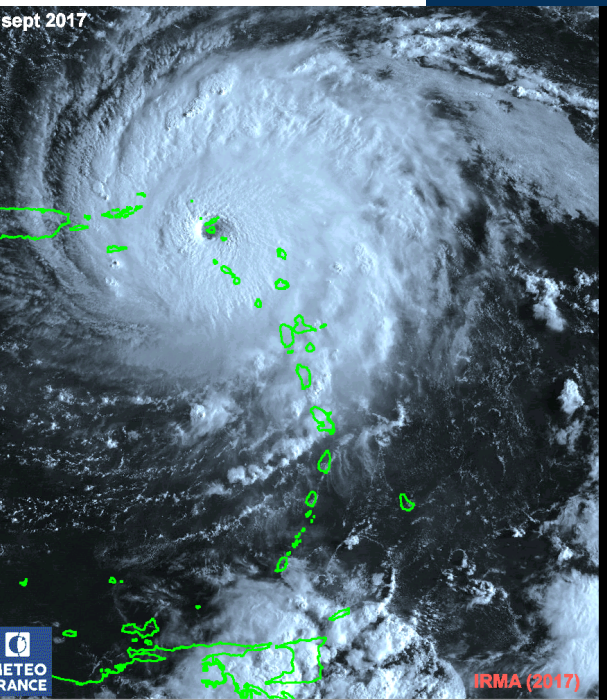
Impacts of hydrometeorological hazards to the global economy (1955–2014) 气象灾害造成的经济损失持续增加

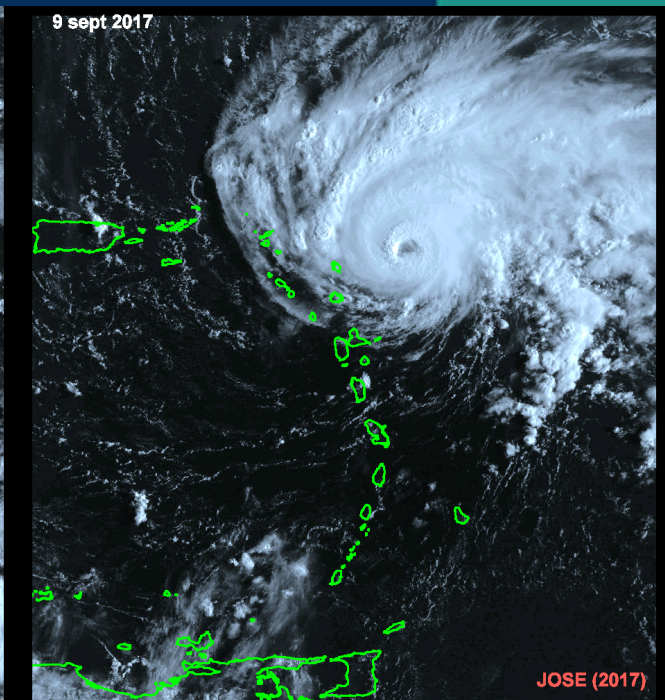


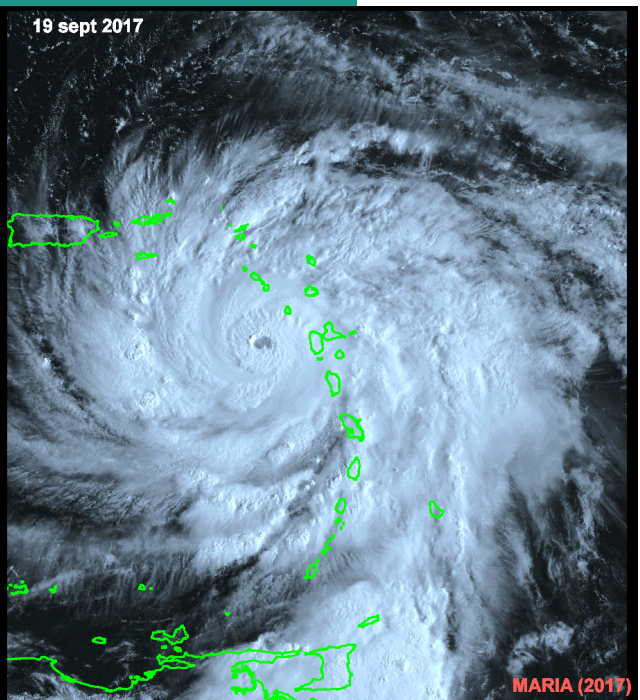
Global economic losses are rocket high due to the rich and volunerable costal megacities vs increase of extreme events

2017 Record breaking economic losses
2017一年的全球经济损失再创新高-3300亿美元

Losses from natural catastrophes 2017	Less than half of the losses insured
US$ 330bn	**US$ 135bn (41%)**



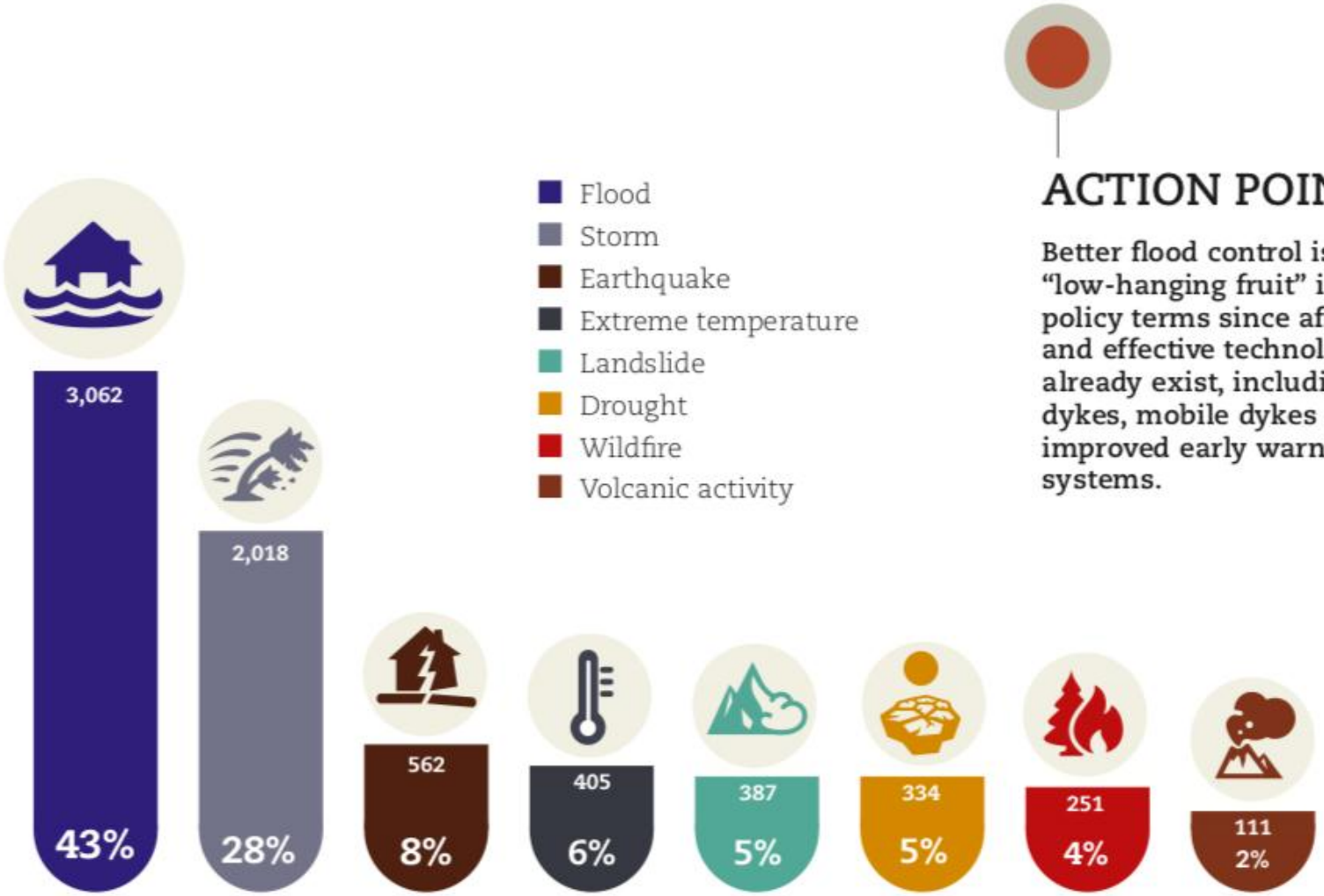




气象气候灾害占全部自然灾害的90%

Figure 4

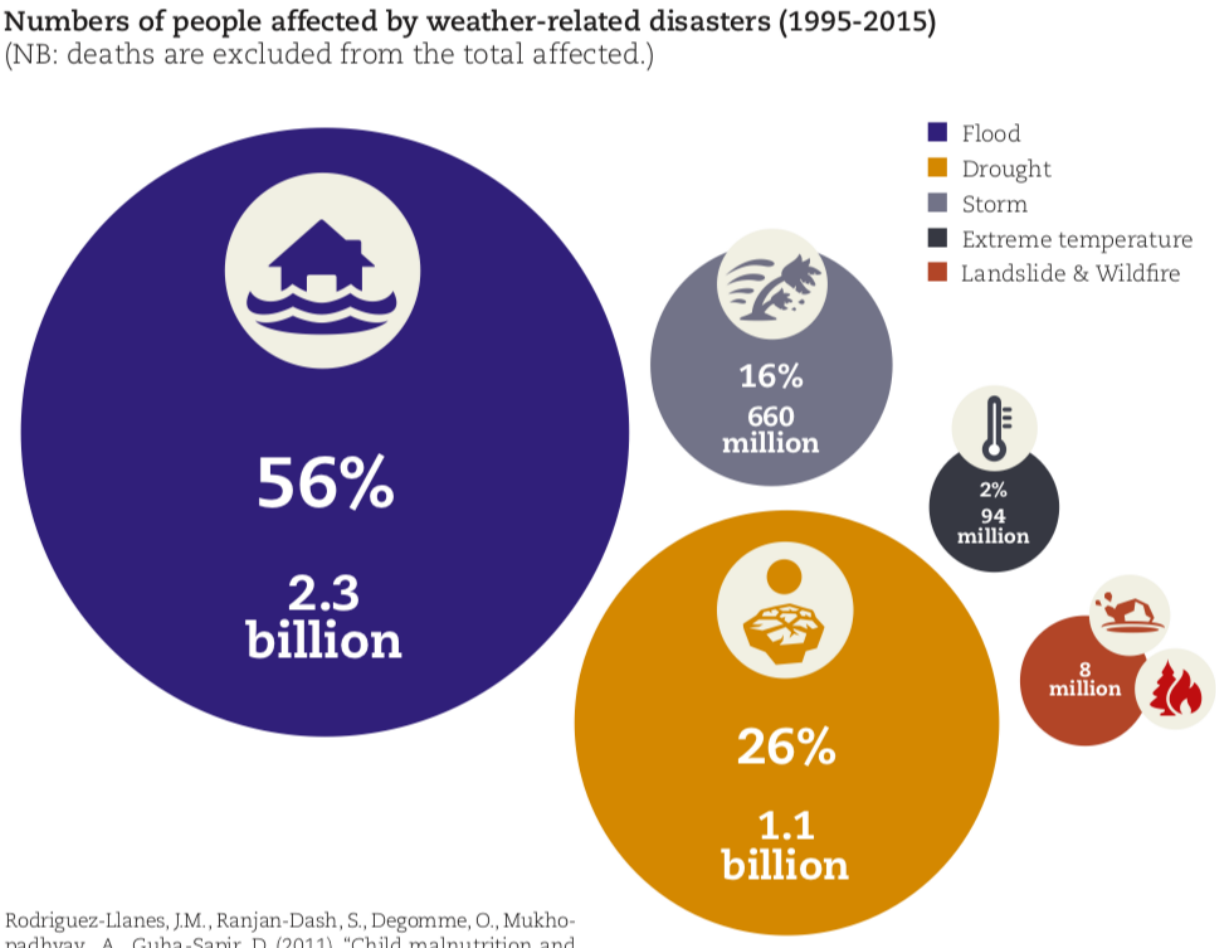
Percentage of occurrences of natural disasters by disaster type (1995-2015)



ACTION POINT

Better flood control is one "low-hanging fruit" in DRR policy terms since affordable and effective technologies already exist, including dams, dykes, mobile dykes and improved early warning systems.

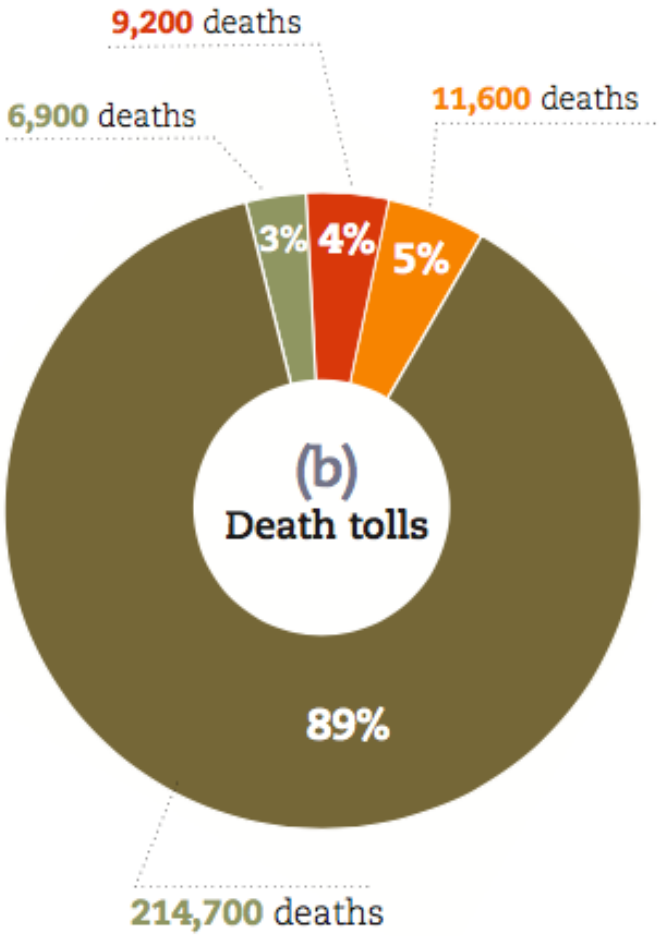
human costs of weather-related disasters - 不同灾害类型造成的人员死亡比例

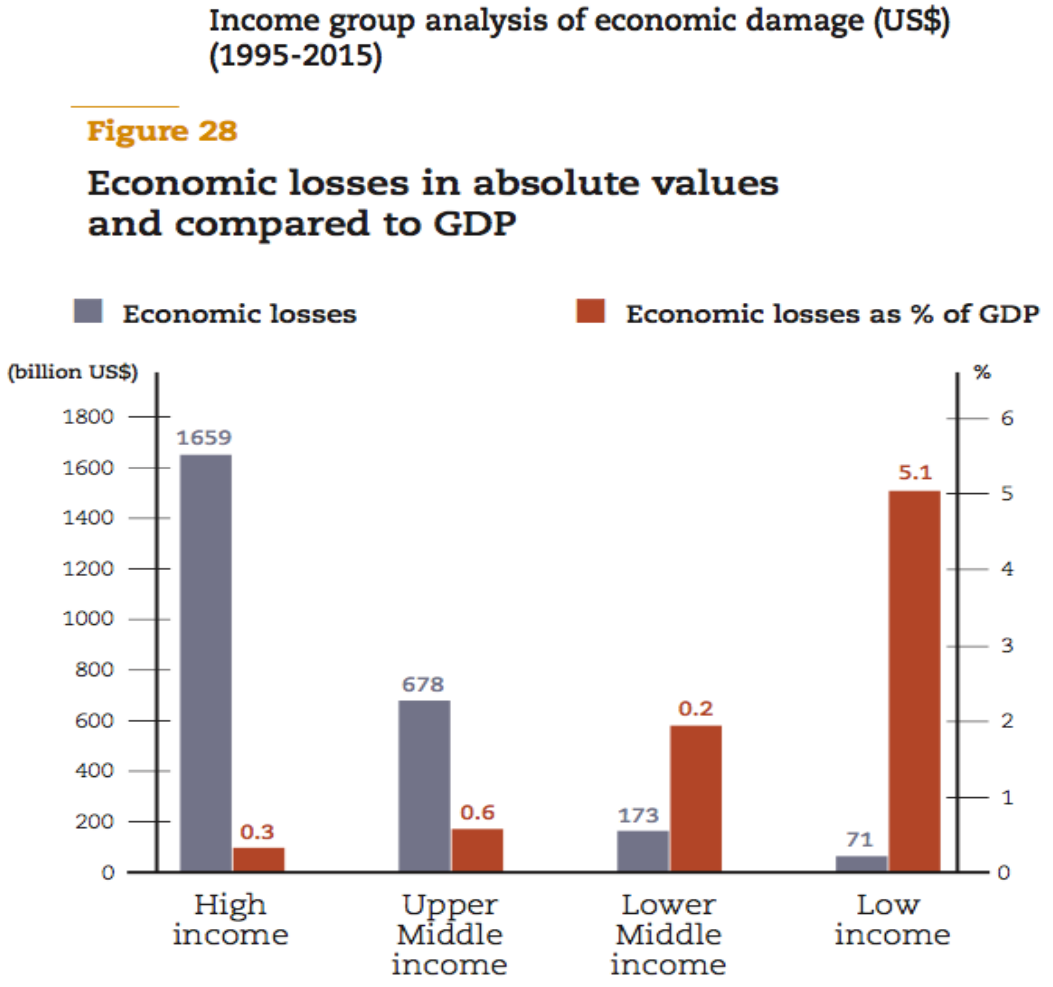


[3] Rodriguez-Llanes, J.M., Ranjan-Dash, S., Degomme, O., Mukhopadhyay, A., Guha-Sapir, D. (2011). "Child malnutrition and

Pay special attention to the lower-middle income countries on DRR

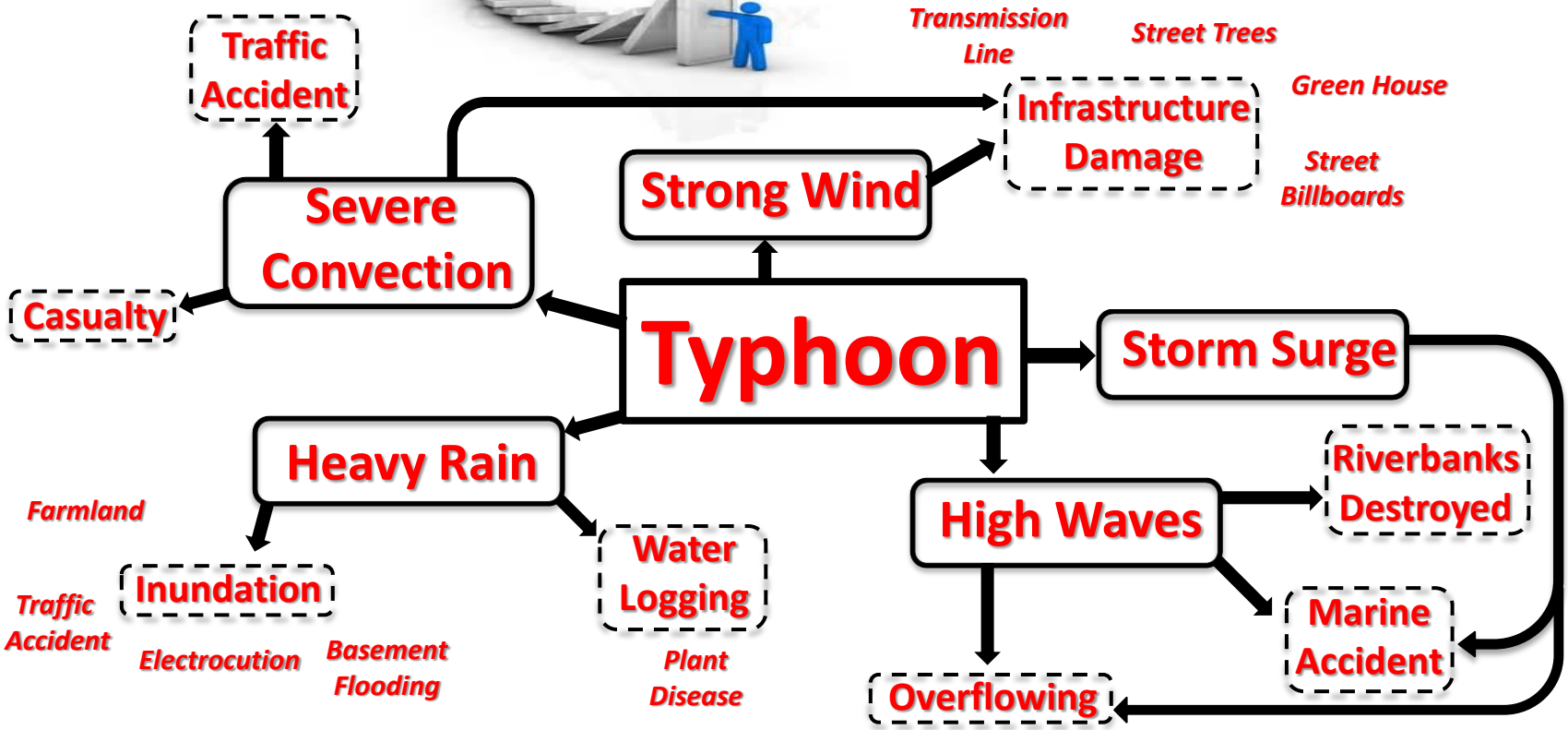
发展中国家和不发达国家灾害死亡人数和经济损失占GDP比重高





Through a domino effect, a single extreme event can lead to a broad breakdown of a city's infrastructure:

Example of Hazard Domino Effect (Typhoon)



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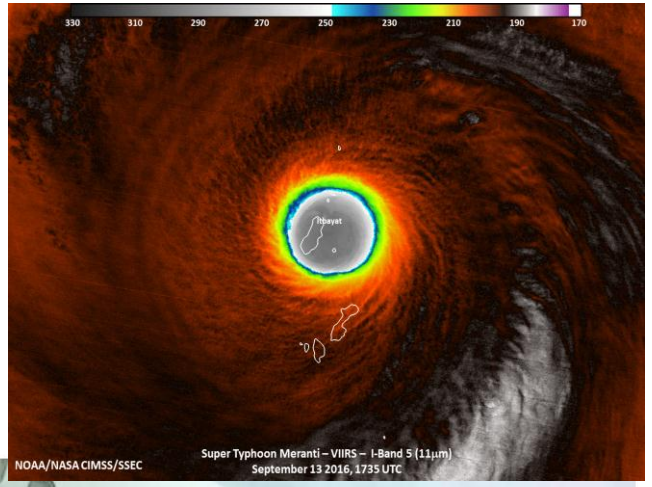
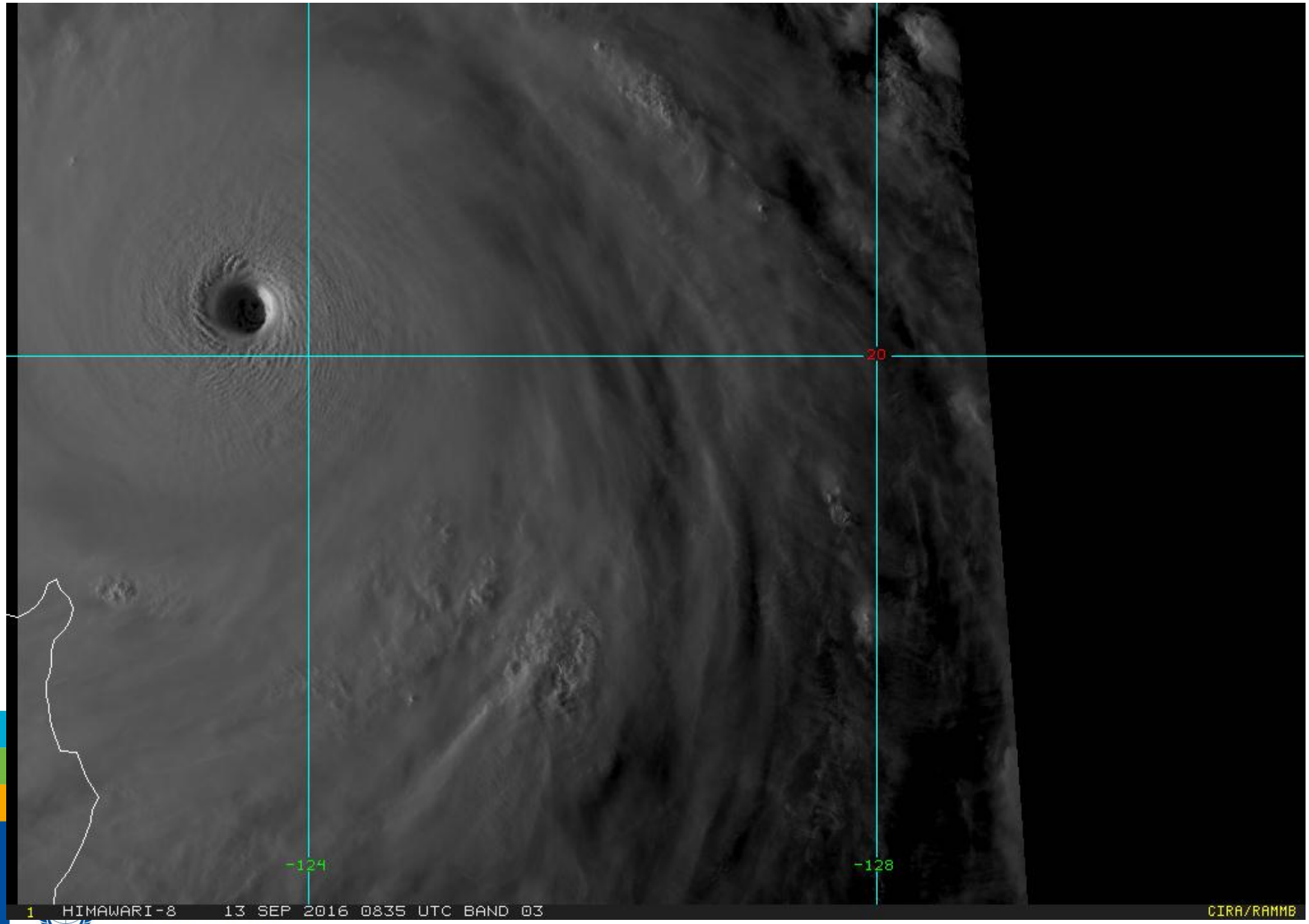
Typhoon Meranti, one of the most intense Typhoone (landing China on Sept. 15, 2016)

- Basic Data:



WMO OMM


20
-124
-128
1 HIMAWARI-8 13 SEP 2016 0835 UTC BAND 03
CIRA/RAMMB

WMO Observation Vision based on the Rolling Review of Requirements (RRR) Process
-远景规划来自于对多个领域的未来需求和差距分析

14 application areas

Requirements

Requirements

Requirements

Long-term vision of WIGOS

Critical review-Gaps

Statements of guidance

1) Implementation Plan for Evolution

2) Update of WMO Regulations

Observing capabilities (space & surface)-database

Members' surface and space observation programmes

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The history of WMO Observation Visions
远景规划 - 实施计划

- **The Global Observing System Vision in 2015 was adopted in 2002**
  - **The Implementation Plan for Evolution of Global Observing System (2015 EGOS-IP)** was approved in 2005
- **The Global Observing System Vision in 2025 was adopted in 2009**
  - **The Implementation Plan (2025 EGOS-IP) was** approved in 2012 (A 120 pages document and with 115 actions)
- **The WIGOS Vision 2040, targeted to be approved by Cg-18 (2019) -** Then WMO will follow up working together with space agencies for drafting the WIGOS Implementation Plan 2040 (with the hope be approved by 2021)

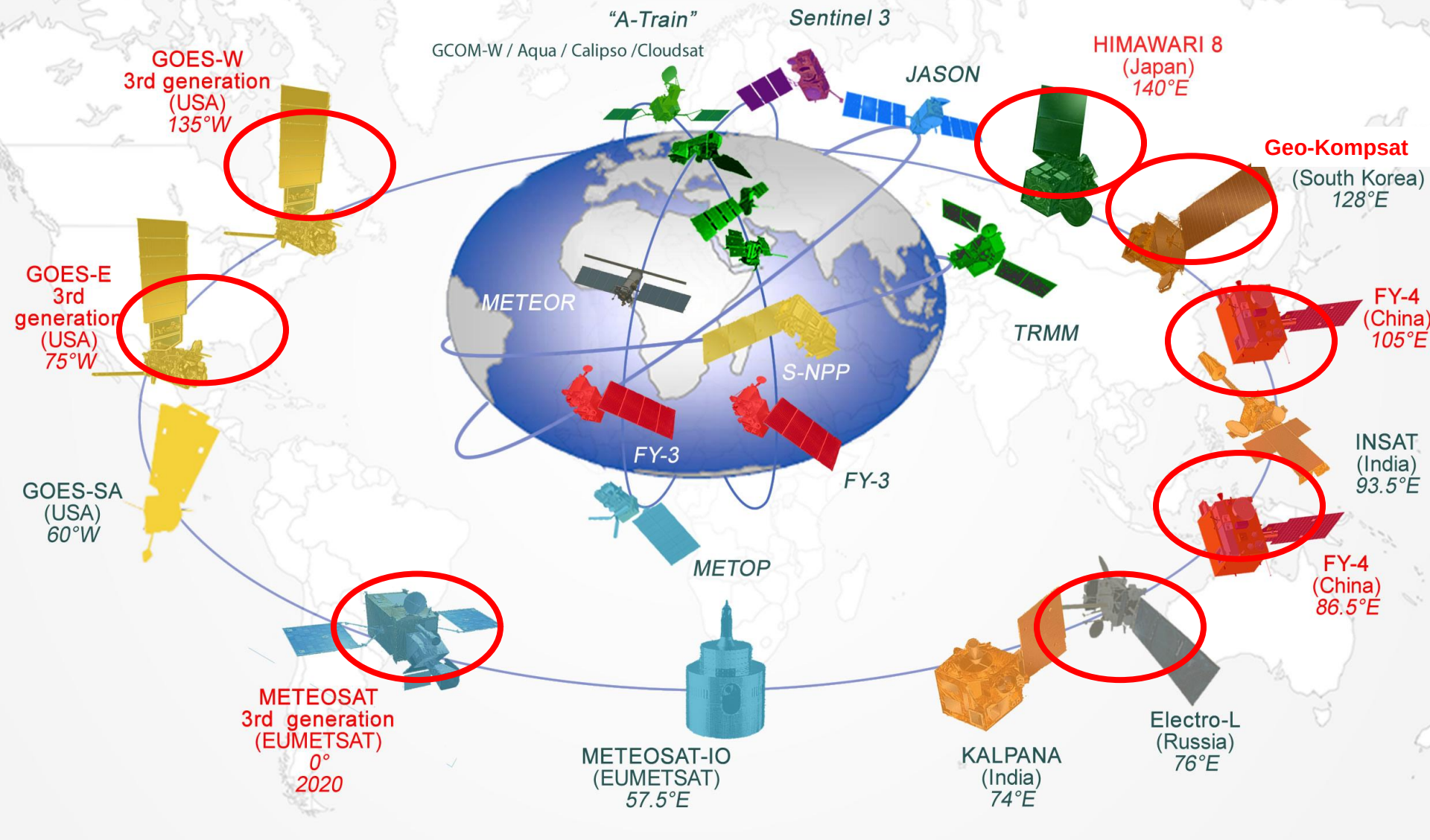
Operational GEO satellites in 2025 vs Vision
2025年远景规划与实施的比较

	Vis/IR imager 成像仪	Hyperspectral IR sounder 高光谱探测器	Lighting imager 闪电成像仪
E.Pacific	**YES**	**no**	**YES**
W.Atlantic	**YES**	**no**	**YES**
E.Atlantic	**YES**	**YES**	**YES**
Indian Ocean	**YES**	**YES**	**YES**
W.Pacific	**YES**	**Partly**	**no**

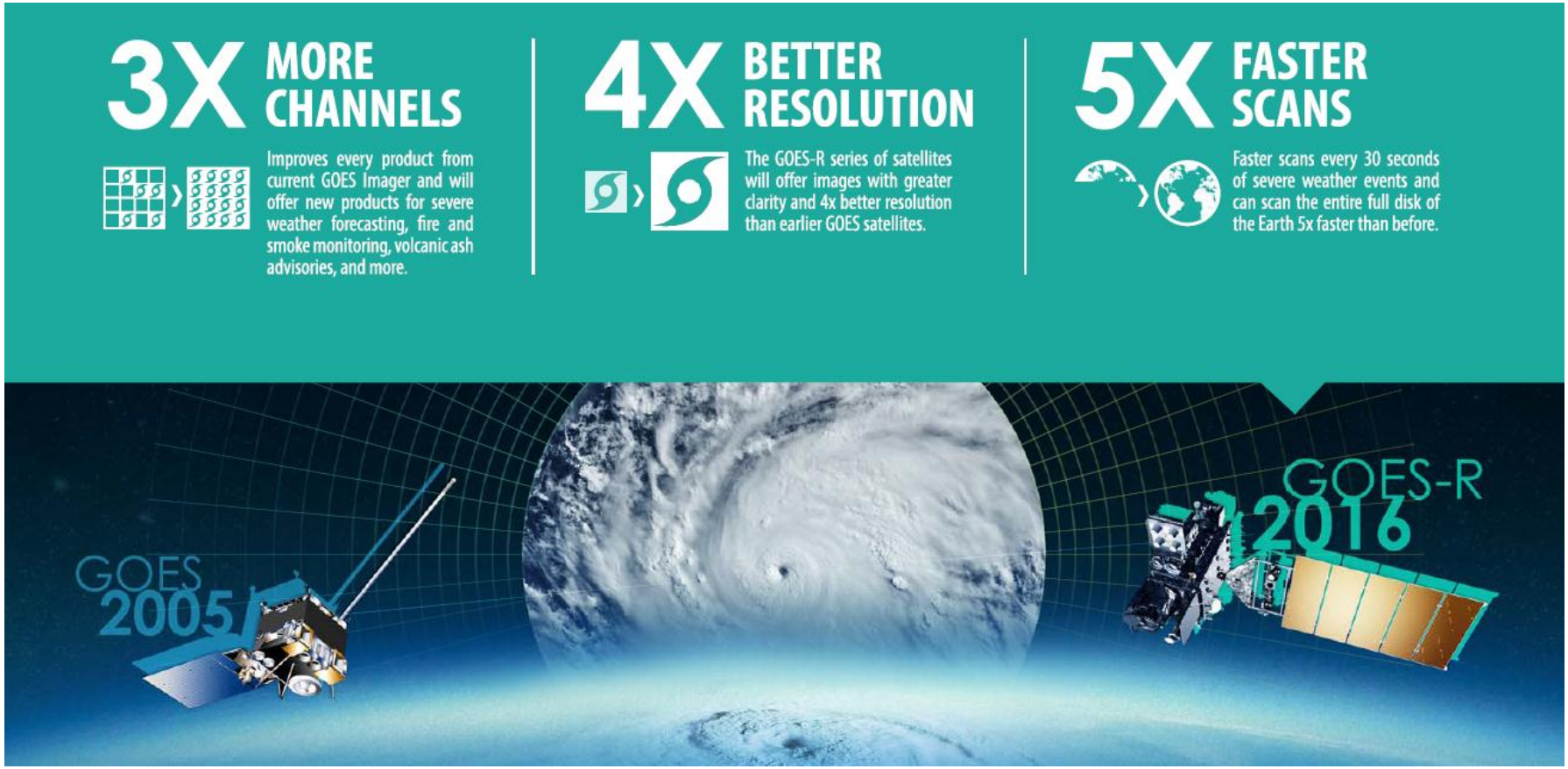
Gaps in Operational GEO satellites vs Vision in 2025-主要差距

satellite series	Vis/IR imager	Hyperspectral IR sounder	Lighting imager
MSG	**SEVIRI (12 ch)**	**no**	**no**
MTG	**FCI (16 ch)**	**IRS**	**LI**
GOES-R	**ABI (16 ch)**	**no**	**GLM**
Himawari	**AHI (16 ch)**	**no**	**no**
FY-4	**AGRI (14 ch)**	**GIIRS**	**LMI**
INSAT-3DS	**IMAGER (6 ch)**	**no (low-res SOUNDER)**	**no**
GEO-KOMSAT-2	**AMI (16 ch)**	**no**	**no**
Electro-M	**MSU-GSM (20 ch)**	**IRFS-GS**	**LM**

WMO Space Programme with New-Generation of Geostationary Constellation



The New Generation of GEO Meteorological Satellites for DRR: Himawari, FY-4, GOES-R, etc



WMO OMM

MTG – Overall system configuration-MTG发射大大增强欧洲和非洲观测能力

Search and Rescue Beacons

Search and Rescue Mission Control Centres

Data Collection Platforms

TELEMETRY, TELECOMMAND AND CONTROL
GROUND STATION SITES

MISSION DATA ACQUISITION
GROUND STATION SITES

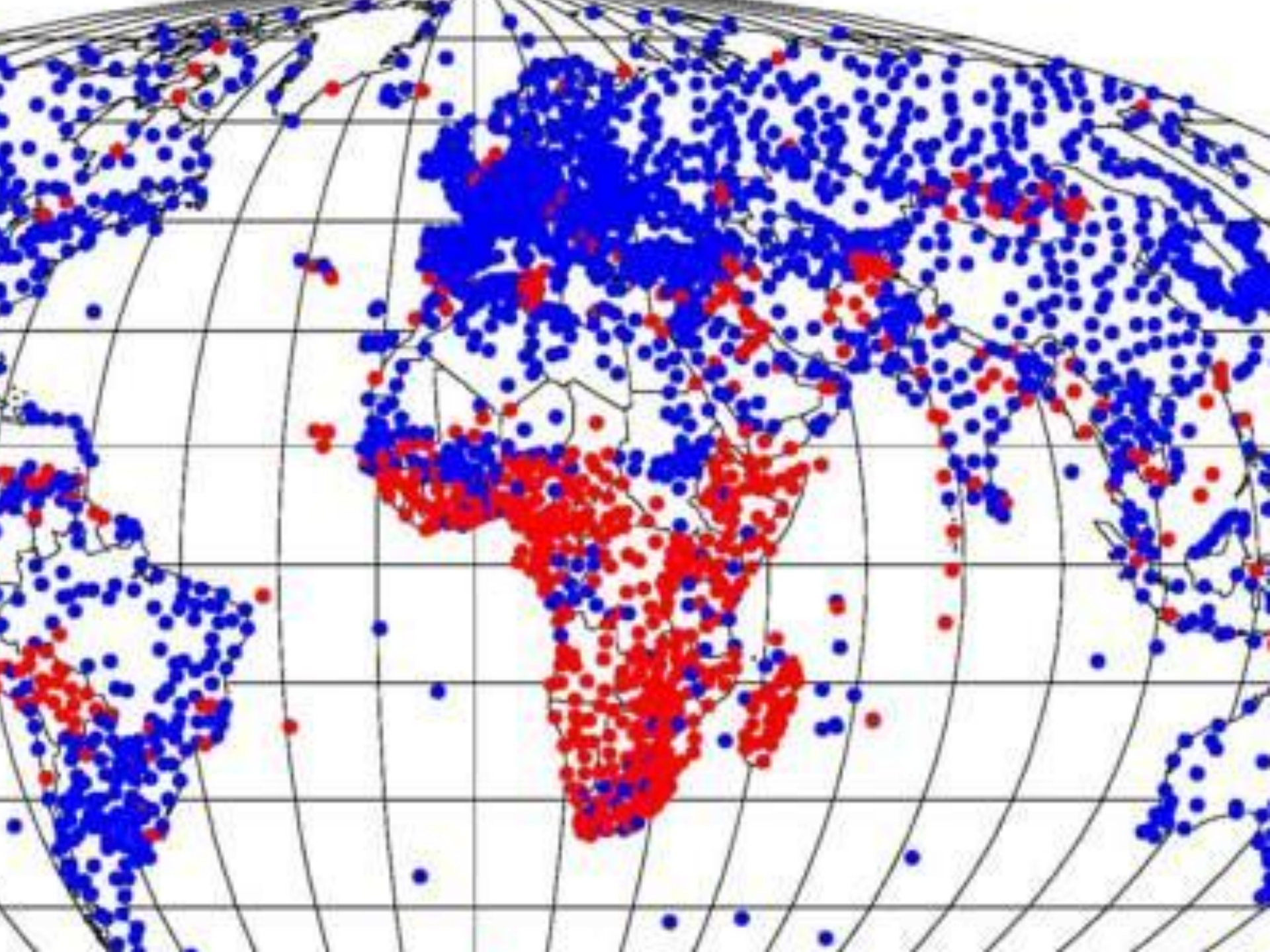
EUMETSAT
CORE GROUND SEGMENT

- Satellite Control Centre
- Mission Control Centre
- Product Processing Facilities
- Data Centre Archive
- Data Dissemination via EUMETCast

Direct reception by users in all countries

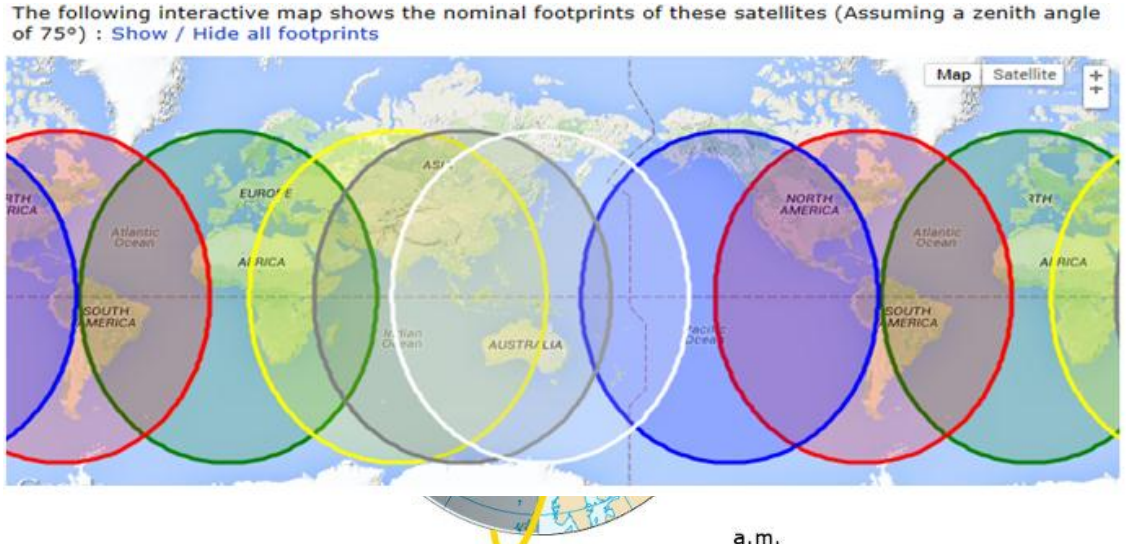
EUMETSAT Network of Satellite Application Facilities (SAFs)

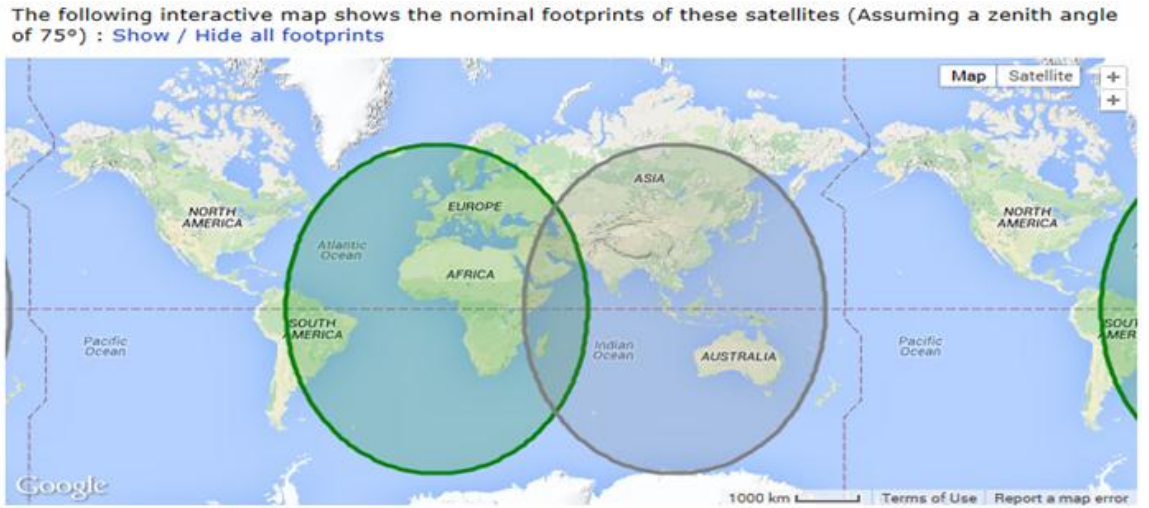
External data sources

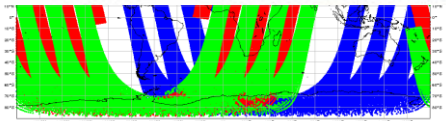


WMO Appreciates greatly to the space agency response to the GOS Vision 2025-感谢全球航天对于WMO2025远景规划实施的鼎力支持

- Space agencies' plans provide a good response to the "WMO GOS Vision for 2025", for example, China's commitment to the early morning orbit
- With some key gaps for operational meteorology
    - – GEO: Hyperspectral IR sounder and lightning mapper
    - -- LEO Doppler Wind Lider, low-freq. MW, GPS/RO
    - -- more gaps for climate monitoring and other applications
- System vulnerabilities to early failure
- Way Forward -- Towards new "WIGOS Vision for 2040"







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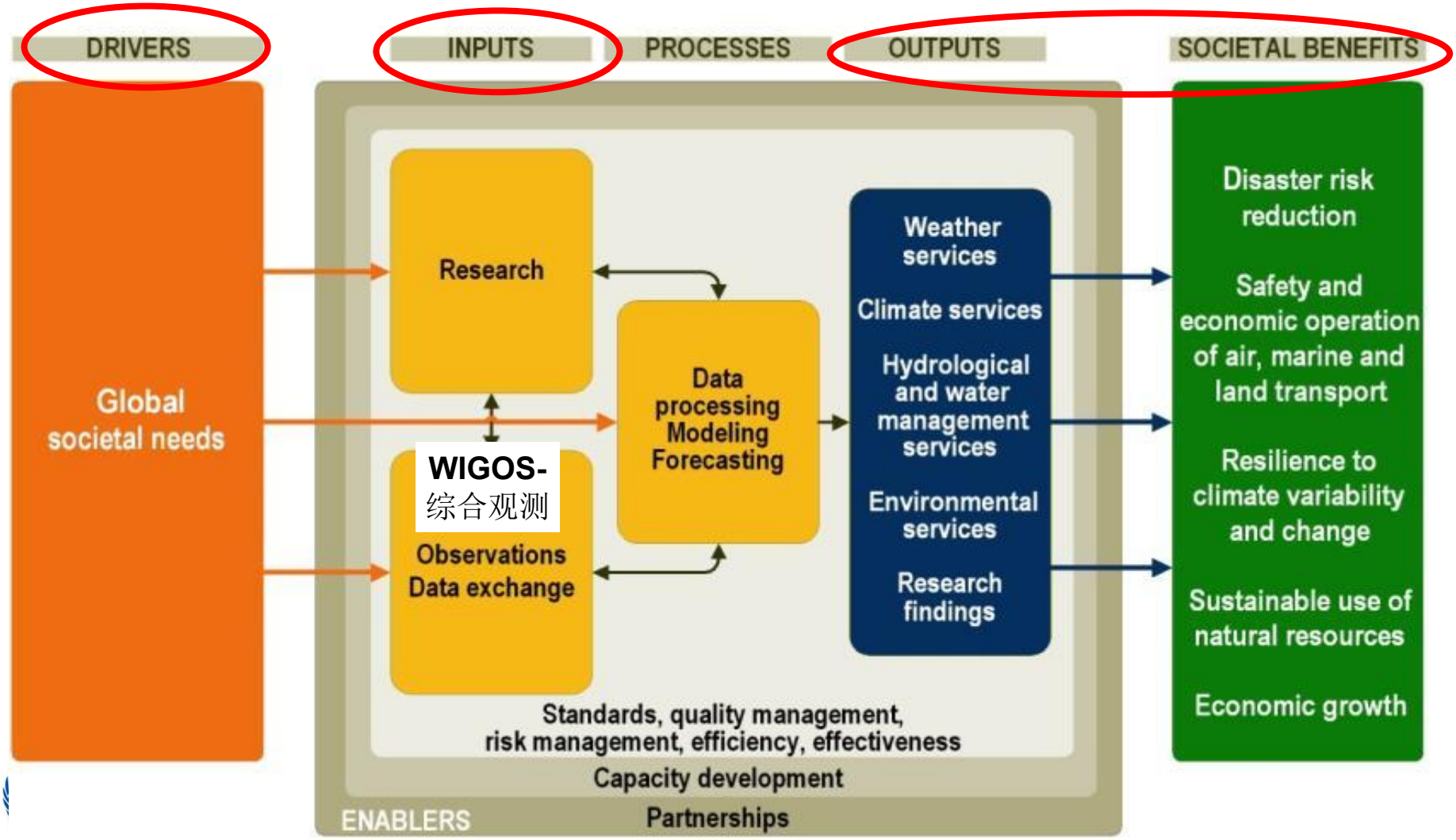
DRIVING FORCE FOR WIGOS VISION 2040

III:为什么需要2040年观测发展远景规划-需求牵引

WMO STRATEGIC PLAN – Global Societal Needs

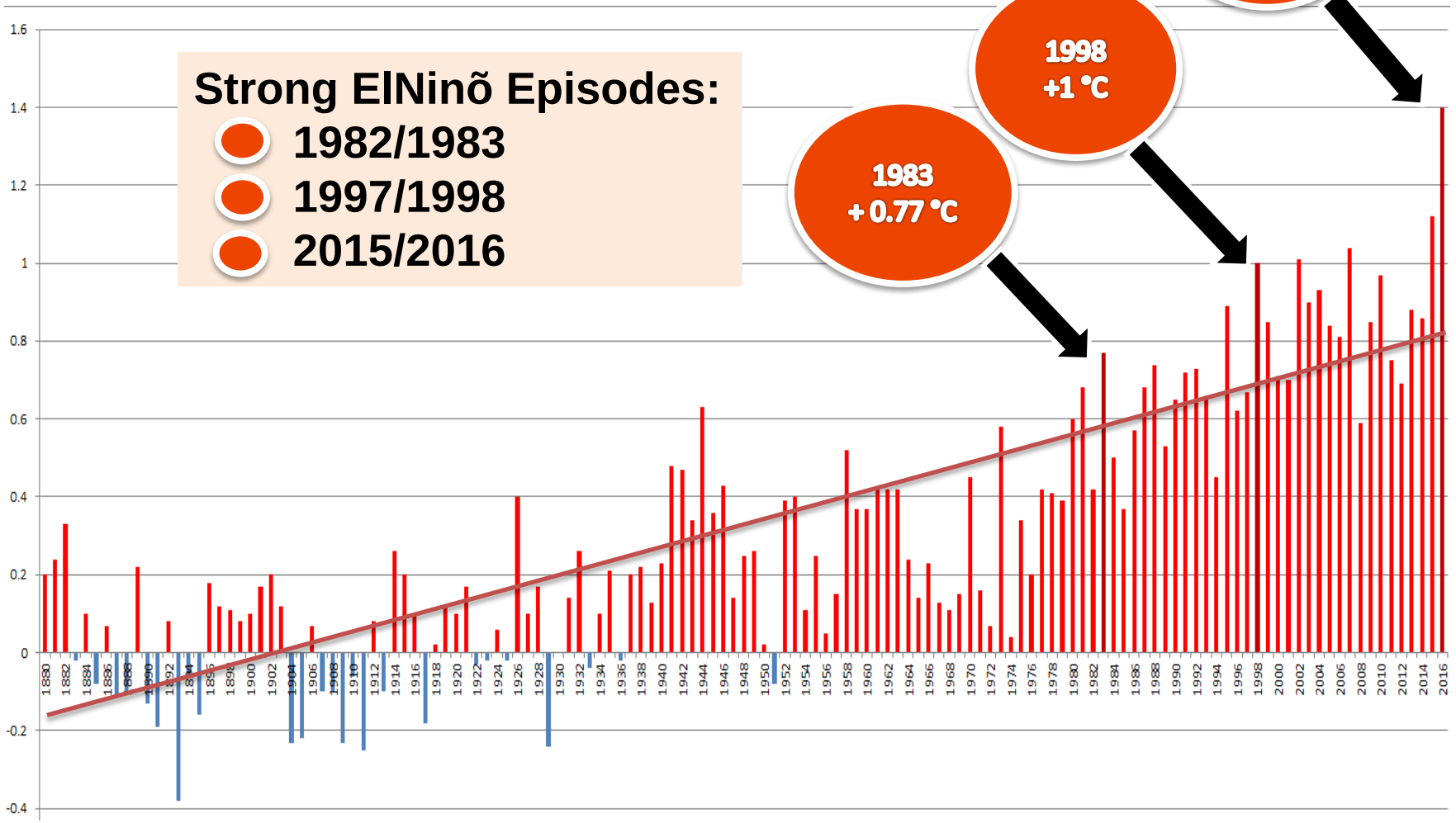


WMO Vision on Obs in 2040 -观测远景规划2040

- **The Vision: 人无远虑必有近忧(A man who does not plan long ahead (foresignt) will find trouble at his door)**
- The role of WMO Visions
  - Consolidating WMO Requirements supporting the justification of space agencies long-term plans -综合WMO需求，为航天长期规划提供需求依据
  - Provides high-level goals to guide the evolution of the Global Observing System in the coming decades. Goals are challenging but achievable. –用高层目标牵引未来20年发展，目标具有挑战性但是有实现可能
  - Meet the needs of long lead times for planning of new observing systems development (esp. space systems). 满足航天新技术和新体系发展需要长期规划和发展周期的要求

远虑: 极端天气气候事件频次更高强度更强 ！

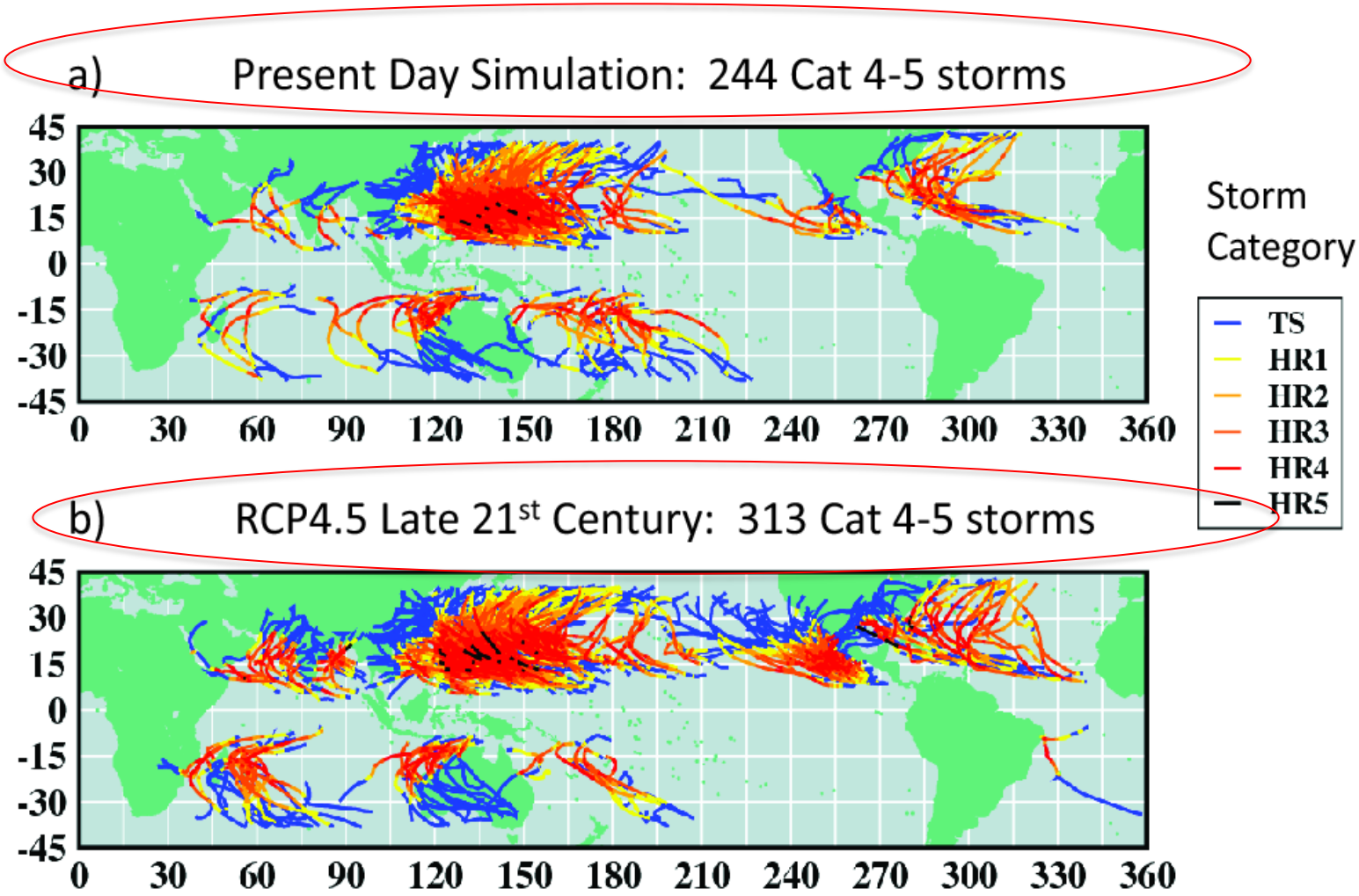
January-February 2016 global Temperature increase
reference :1881-1910

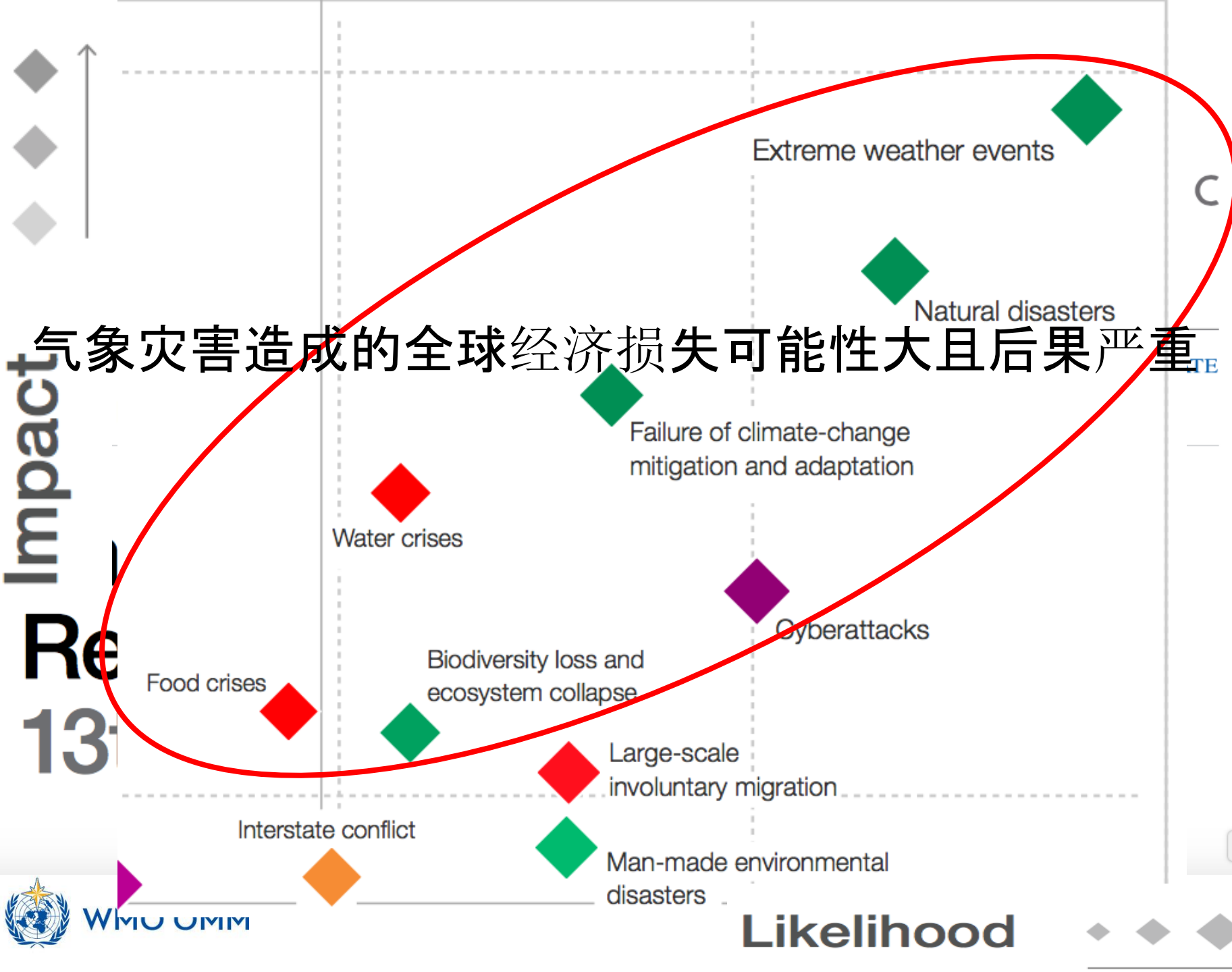


WMO OMM

Model simulations indicate **hurricanes in a warmer climate are likely to become more intense – 全球变暖强风暴更多更强！**

Tropical storms today and in 3 C warmed climate

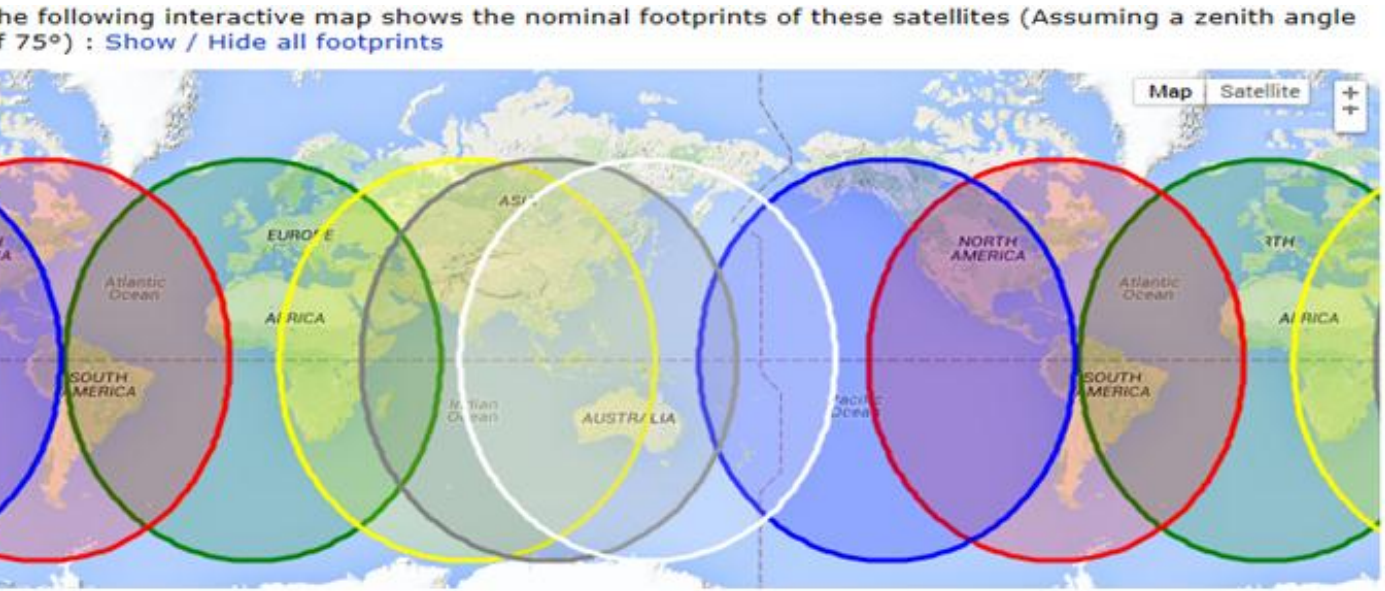




气象灾害造成的全球经济损失可能性大且后果严重

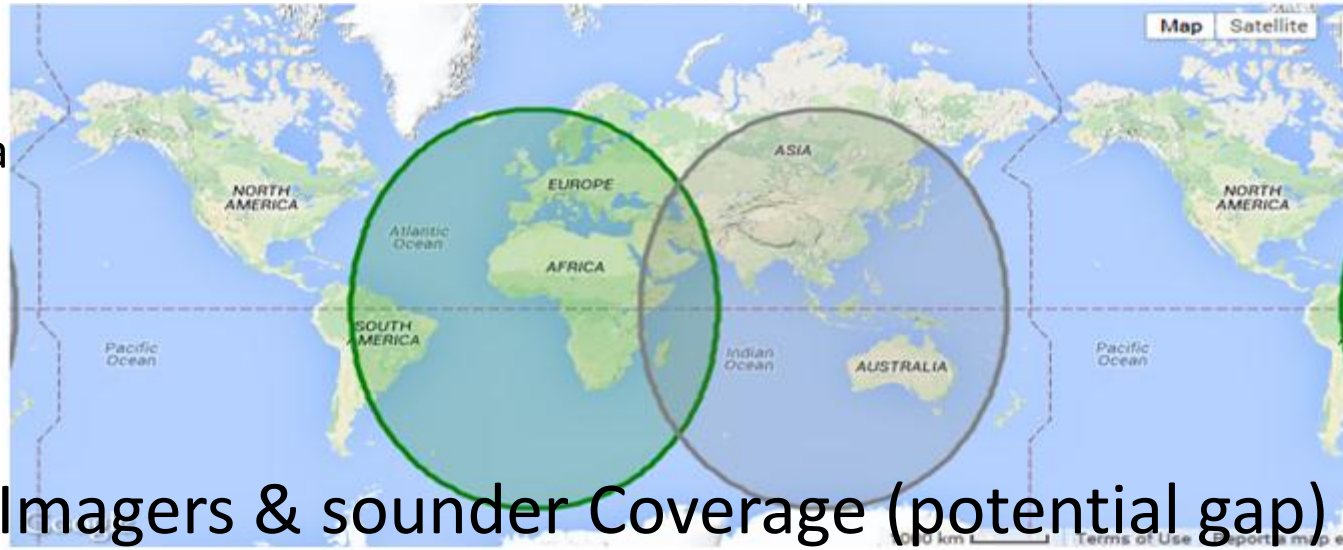
Challenges of space observing capability for meeting severe **Weather** monitoring Requirements in 2040 – DRR

Direct monitoring storm/hurriance genesis, intensify & moving



- Biggest forecast challenge is rapid intensity change

- Geostationary satellites are critical with better hurricane structure data (wind, temperature and moisture data) for improving monitoring and forecasting



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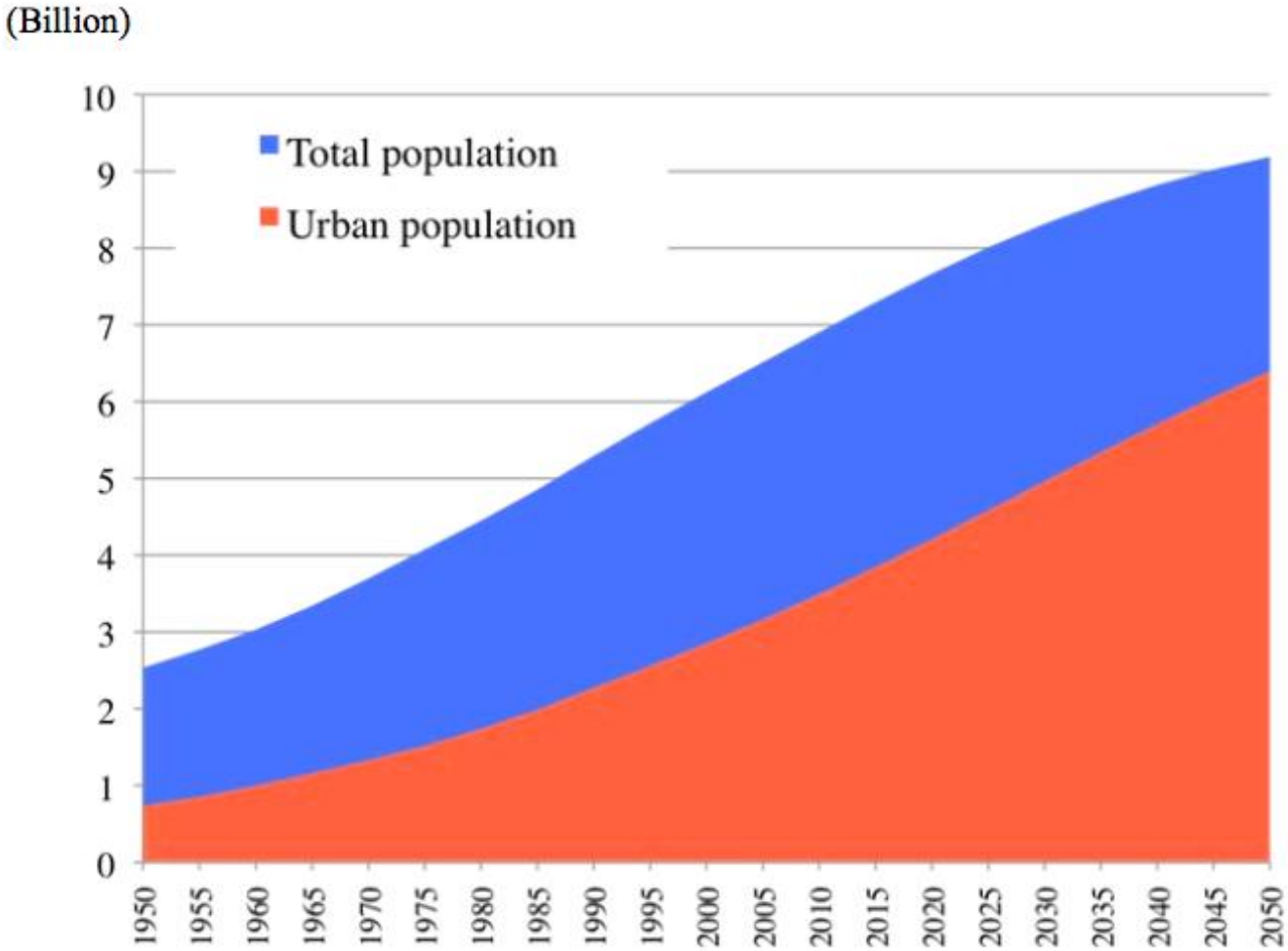
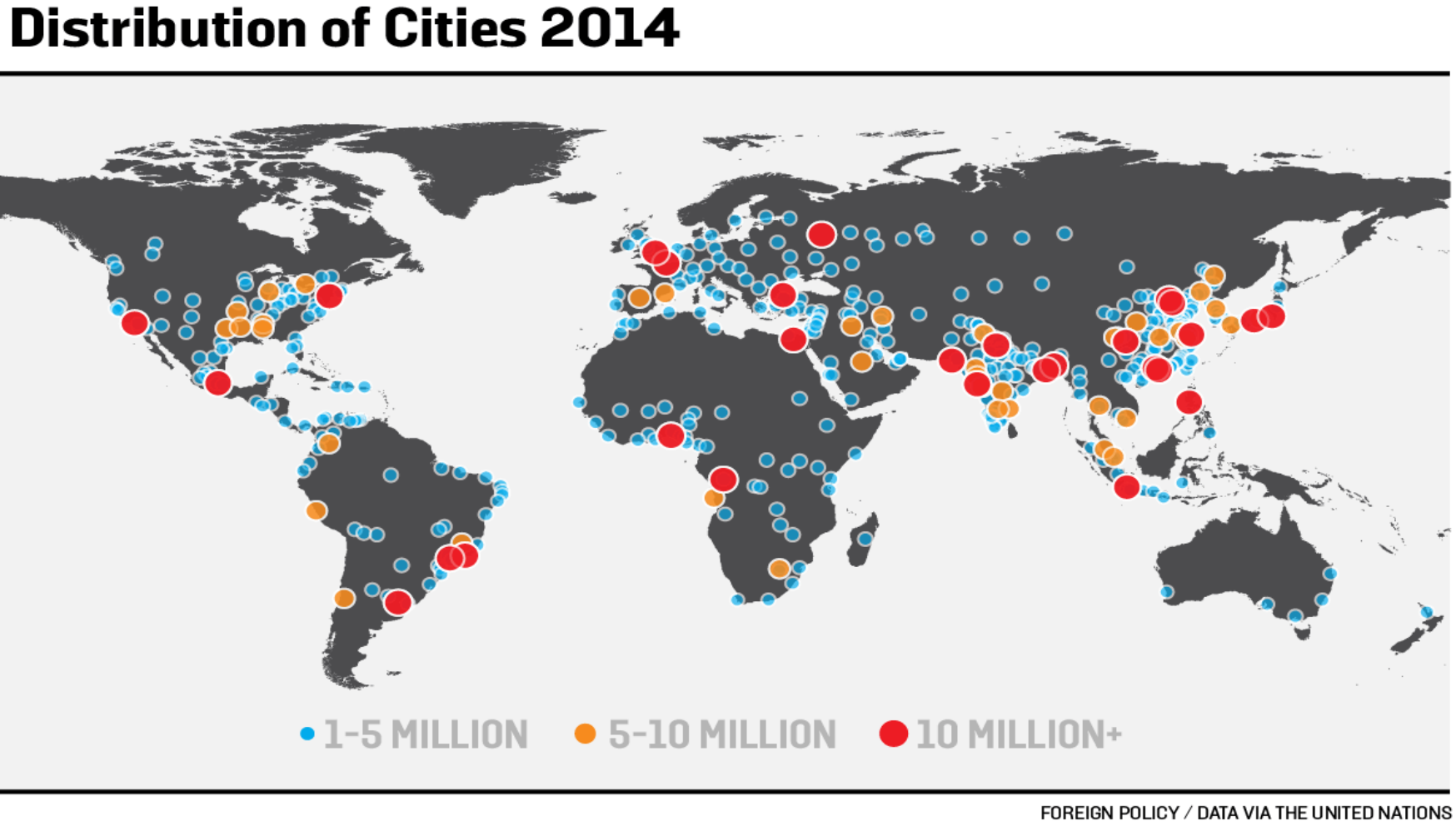
GEO Imagers & sounder Coverage (potential gap)

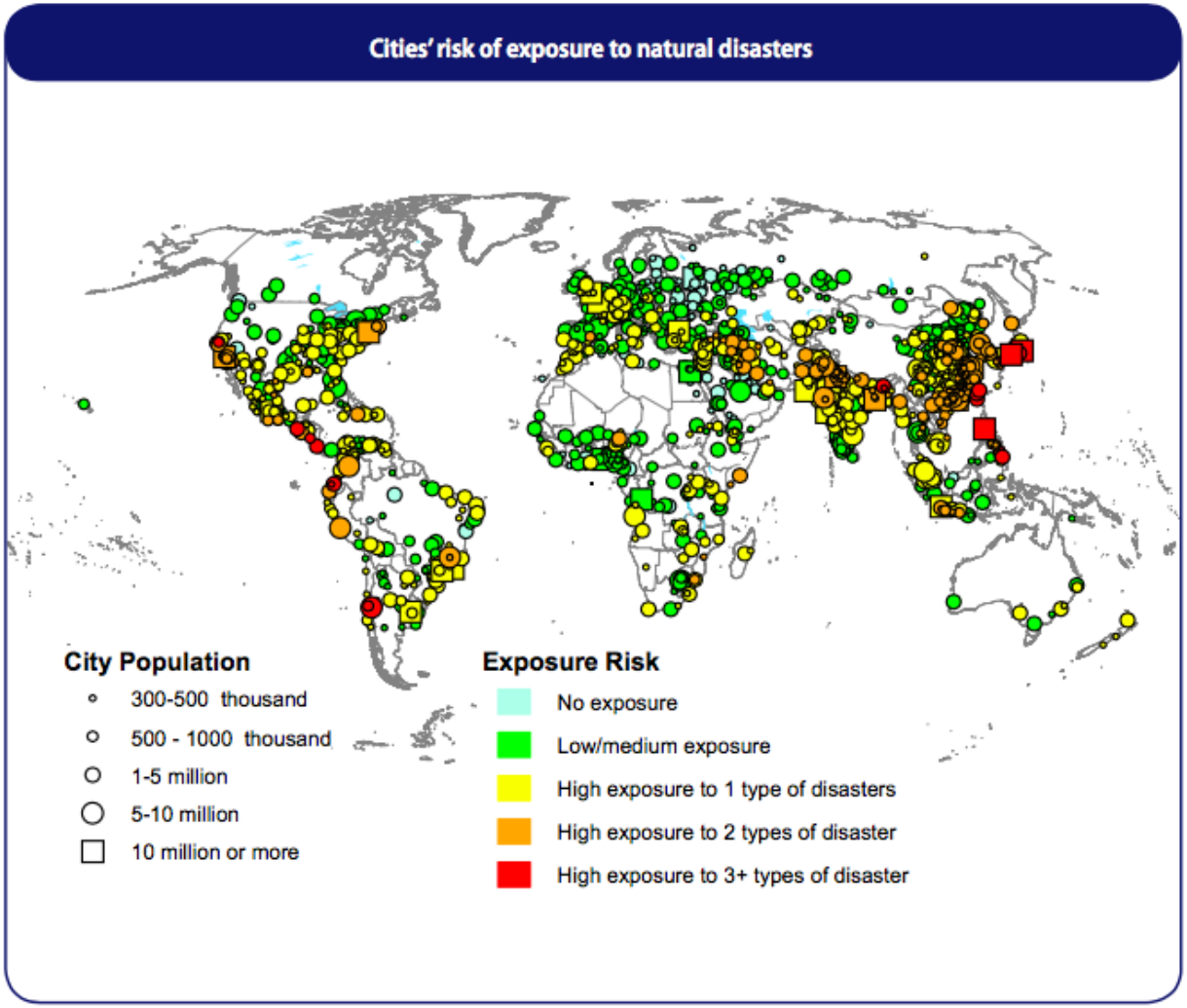
Growing Urban Population



Climate & climate change –extreme weather and climate events impact to costal Megacities !!!!
全球超大城市将成为减灾防灾的重点难点 ！



Most cities are vulnerable to at least one type of natural disaster

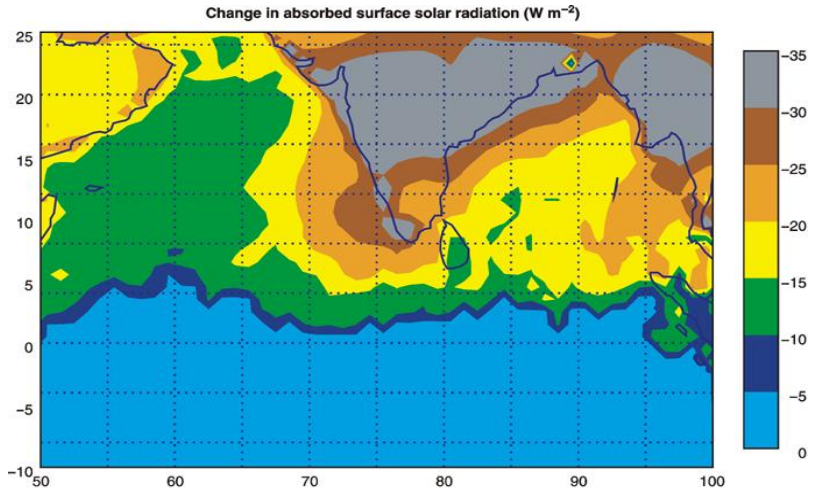


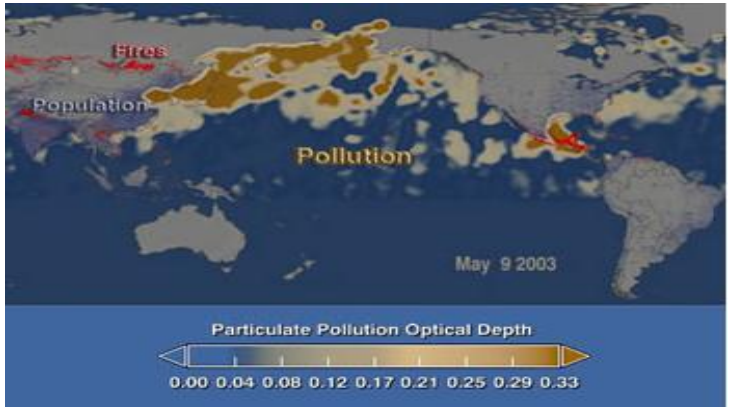
Of the 1,692 cities with at least 300,000 inhabitants in 2014, 944 (56 per cent) were at high risk of exposure to at least one of six types of natural disaster (cyclones, floods, droughts, earthquakes, landslides and volcano eruptions), based on evidence on the occurrence of natural disasters over the late twentieth century.* Taken together, cities facing high risk of exposure to a natural disaster were home to 1.4 billion people in 2014.

Around 15 per cent of cities—most located along coastlines—were at high risk of exposure to two or more types of natural disaster; 27 cities—including the megacities Tokyo, Osaka and Manila—faced high risk of exposure to three or more types of disaster.

* Results summarised here are from a 2015 United Nations technical paper that analysed city population estimates from the 2014 revision of World Urbanization Prospects together with spatial hotspot data on the risks of exposure and vulnerability to natural disasters produced by research institutes at Columbia University and the World Bank. The natural disaster data used in this analysis included historical information on

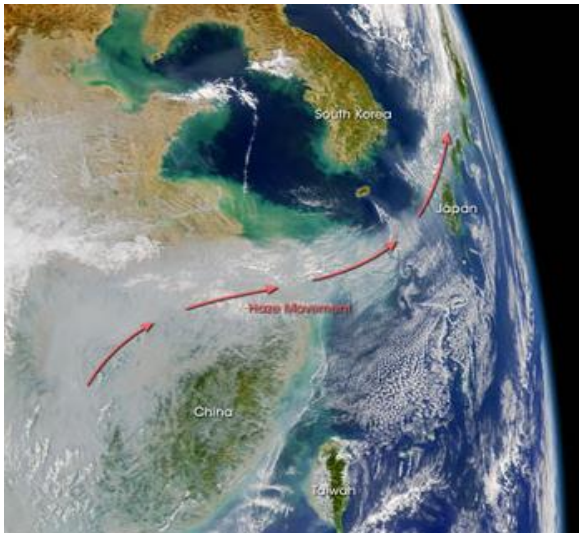
AEROSOLS AND ASIAN POLLUTION AFFECTING THE ENTIRE NORTHERN HEMISPHERE - 空气污染也是一种严重灾害！





Optical depth of particles pollution. Much of this pollution is industrial but some is caused by fires. NASA image.

Reduction in surface solar radiation absorption due to the Indo-Asian haze effects (measured January to April from 1996-1999) (Ramanathan et al. 2001a) Steffen at al., 2004



GLOBAL CHANGE IGBP International Geosphere-Biosphere Programme

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WMO Strategic Plan – expecting greater contribution to the global DRR efforts：WMO发展战略强调防灾减灾

Vision

Guiding principles: Cost effectiveness • Influence and inform the global agenda • Alliances and partnerships • Relationships and cooperation • Interactive approach to science and services

We envision a world in 2030 where all WMO Members, especially the most vulnerable, are more resilient to the socioeconomic consequences of extreme weather, water, climate and other environmental events; and support their sustainable development through the best possible services, whether over land, at sea or in the air.

Overarching Priorities

- **Reducing losses of life and property** from hydrometeorological hazards.
- Supporting climate action to build **resilience and adaptation to climate risk.**
- **Enhancing socioeconomic value** from hydrometeorological and climate services.

Long-Term Goals

- **1- Better serve societal needs: Delivering actionable, authoritative, accessible, user-oriented and fit-for-purpose services**
- **2- Enhance Earth system observations and predictions: Strengthening the technical foundation for the future**
- **3- Advance targeted research: Leveraging leadership in science**
- **LTG 4 Close the gap on services: Enhancing and leveraging existing capabilities among all WMO Members to bring capability to all**
- **LTG 5 Work smarter: Supporting effective policy- and decision-making and implementation in WMO**

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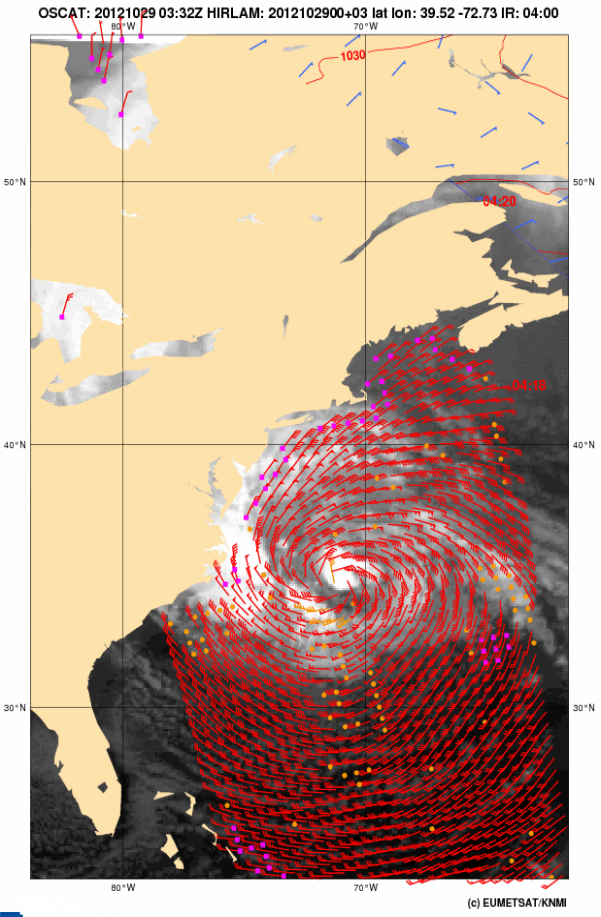
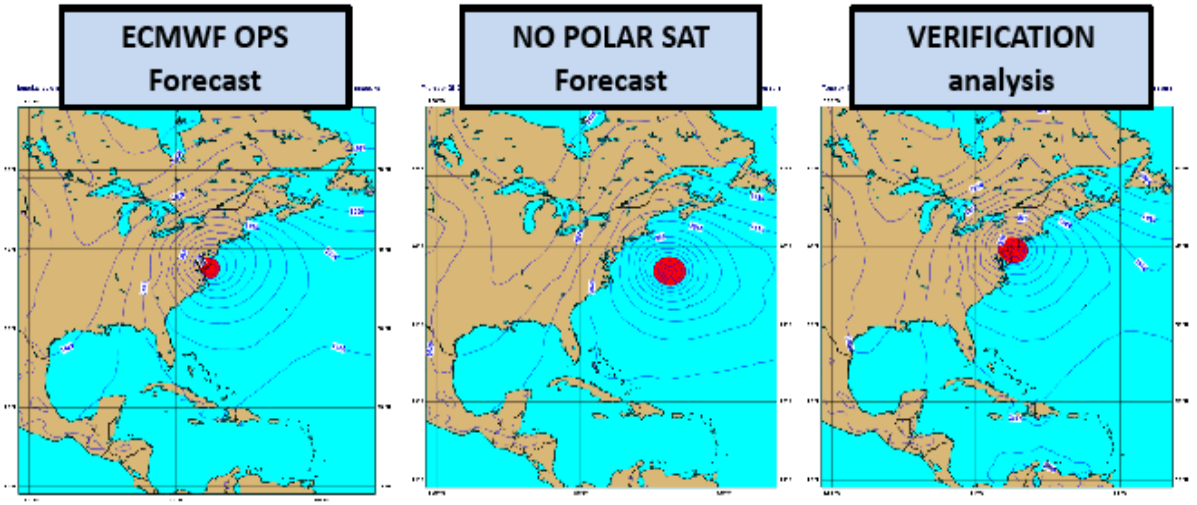
Challenges of space observing capability for meeting severe **Weather** monitoring & forecast Requirements in 2040 - DRR

卫星减灾防灾的两大贡献：实时监测预警/早期预报



Forecasts of Hurricane Sandy without polar satellites

ECMWF forecasts of Mean Sea Level Pressure, **5 days in advance** of the 30th October 2012 for the landfall of Hurricane Sandy. Forecasts from an assimilation system **with no polar satellites** fail to predict the landfall of the storm on the US east coast.



5 day forecast: Base time 2012-10-25-00z **Valid Time: 2012-10-30-00z**

European Center for Medium-Range Weather Forecasts (ECMWF) strategy: GOALS BY 2025

- **EARTH SYSTEM** PREDICTION & SERVICES, Goals By 2025 :
  - Skilful predictions of **high-impact weather** up **to two weeks** (2016: one week) ahead **with a horizontal resolution of 5 km-高影响天气预报：全球五公里分辨率提前两周预报**
  - To improved predictions in the medium range as well as at **monthly and seasonal timescales**. -月到季度预报
  - **To produce forecasts with increasing fidelity on time ranges up to one year ahead. -年际预报**
- This will meet the international community DRR requirements on severe weather and climate events:
  - **Where ?, When ?, How strong ?（何时何地何等强度）**
- **The Earth System Prediction need a truly Earth System Observations to provide INPUT ! Grand Challenges to WMO**

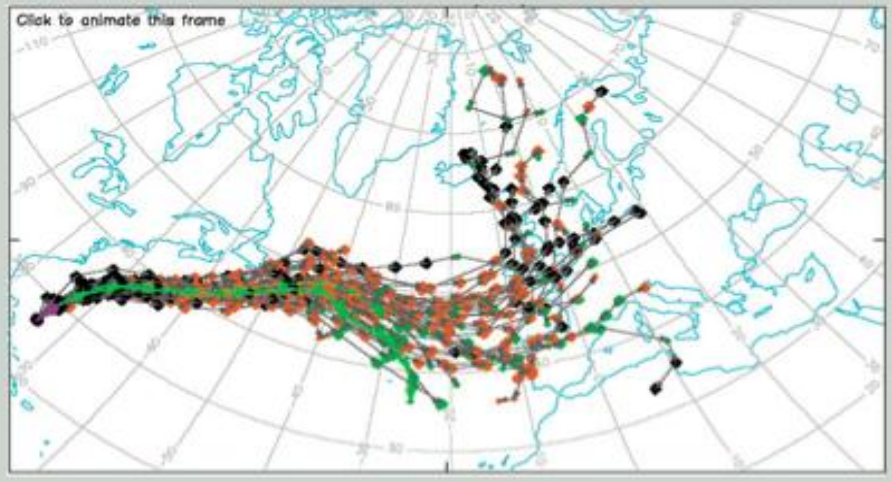


Figure 1. *Tracks of Bertha into the extra-tropics, as forecast by ENS (grey lines), Control (thin green) and HRES (thick green). Western Europe is reached around day 6.*

- The Extreme Forecast Index (EFI) in *Figure 2* indicated a potential windstorm over northwest Europe more than one week before the event, but the location and high values of probabilities became accurate only a few days ahead of the event.
- By 2025 the EFI can be issued two weeks ahead with higher accuracy

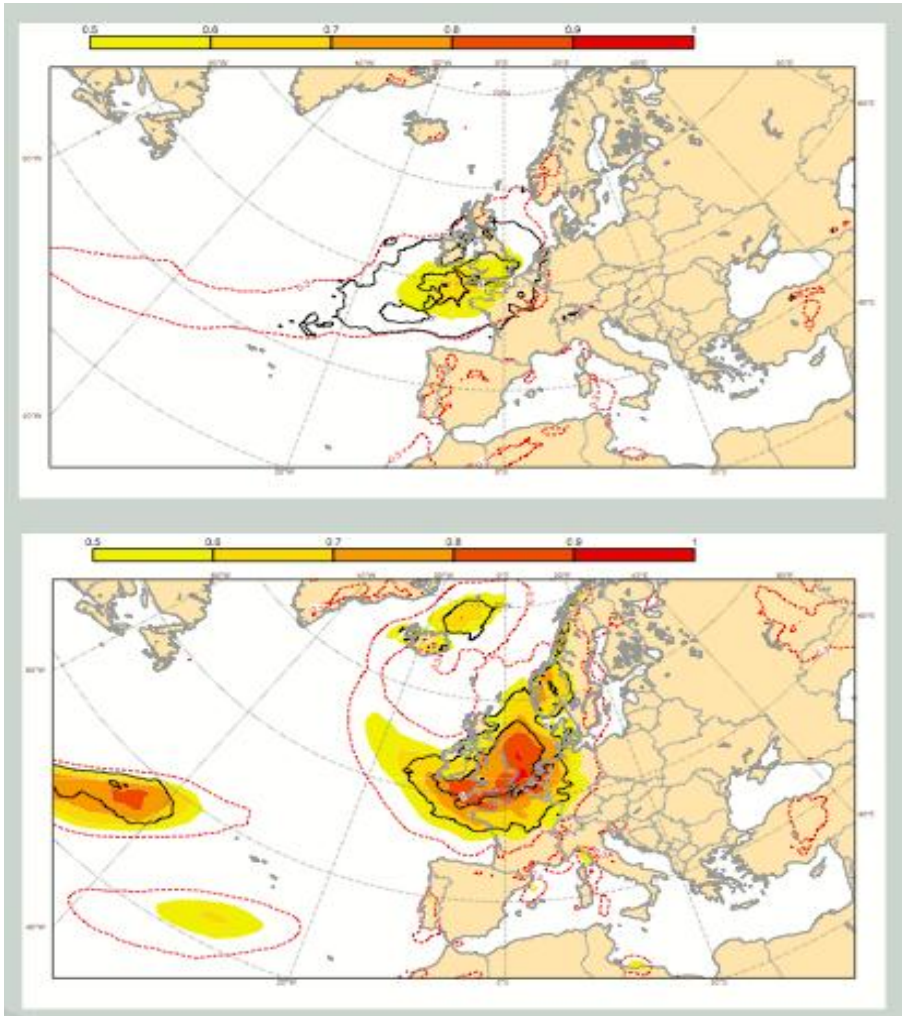


Figure 2. *Extreme Forecast Index of wind speed for the period 10–12 August 2014, at ranges 6 to 9 days (top) and 2 to 5 days (bottom).*

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VISION for WIGOS in 2040
WMO综合观测系统2040远景规划

CHAPTER I. INTRODUCTION, PURPOSE AND SCOPE-导论和宗旨

- Key drivers for meteorological services
- Trends in capabilities and requirements for meteorological service delivery
- WIGOS principles and design drivers
- Integration in WIGOS

- **CHAPTER II: THE SPACE-BASED OBSERVING SYSTEM COMPONENTS OF WIGOS IN 2040-空间系统的2040远景规划**
  - Introduction & General trends and issues
  - Trends in system capabilities
  - Sensor technology
  - Orbital scenarios
  - Evolution of satellite programmes
  - Approach to developing the space-based component of the Vision
- **CHAPTER III: THE SURFACE-BASED OBSERVING SYSTEM COMPONENTS OF WIGOS IN 2040-地面系统的2040远景规划**

Main Drivers for the 2040 Vision-2040远景规划的驱动力

- Evolving and emerging user requirements-用户需求的演进
  - Earth system prediction & Services need higher resolutions (spatial, temporal, spectral, radiance..)-更高的时间/空间/光谱和辐射分辨率
  - Consistent data records (calibration & traceability)-长期连续稳定精准
  - Breakthrough to severe weather, air quality, cryosphere, hydrology, space weather observations –灾害天气，温室气体空气质量，冰冻圈，水文等方面的突破性进展
- Anticipated advances in technology enabling new capabilities
  - New Sensor technology-新探测器技术
  - Orbital & Satellite programme concepts (small satellites, constellations)-新轨道和卫星组网技术
  - Data system architecture-新数据系统构架
- Changes in the provision of satellite systems
  - More space faring nations – Vision should promote various cooperation models-更多航天国家开展地球观测
  - Enhanced pressure to provide cost/benefit justification - 更高的效费比
  - Increased interest from private sector- 私营航天的兴趣增加

Approach to the new vision 2040

- **Consists of 4 systems,** Three of them would fulfil the Vision for 2040. The fourth includes additional capacities and capabilities that may emerge in the future: 提出四大框架体系

1. **Backbone system with specified orbital configuration and measurement approaches - 框架体系一：轨道和观测技术具体化的骨干体系**
   - Basis for Members' commitments, should respond to the vital data needs
   - Similar to the current CGMS baseline with addition of newly mature capabilities
2. **Backbone system with open orbit configuration and flexibility to optimize the implementation-框架体系二：轨道和观测技术具有灵活型的骨干体系，用于进一步优化和完善骨干观测星座系统**
   - Basis for open contributions of WMO Members, responding to target data goals
3. **Operational pathfinders, and technology and science demonstrators-框架体系三：未来业务先导和科学技术验证体系**
   - Responding to R&D needs-
4. **Additional capabilities- 框架体系四：附加增发能力体系** contributed by WMO Members and third parties including governmental, academic or commercial initiatives.

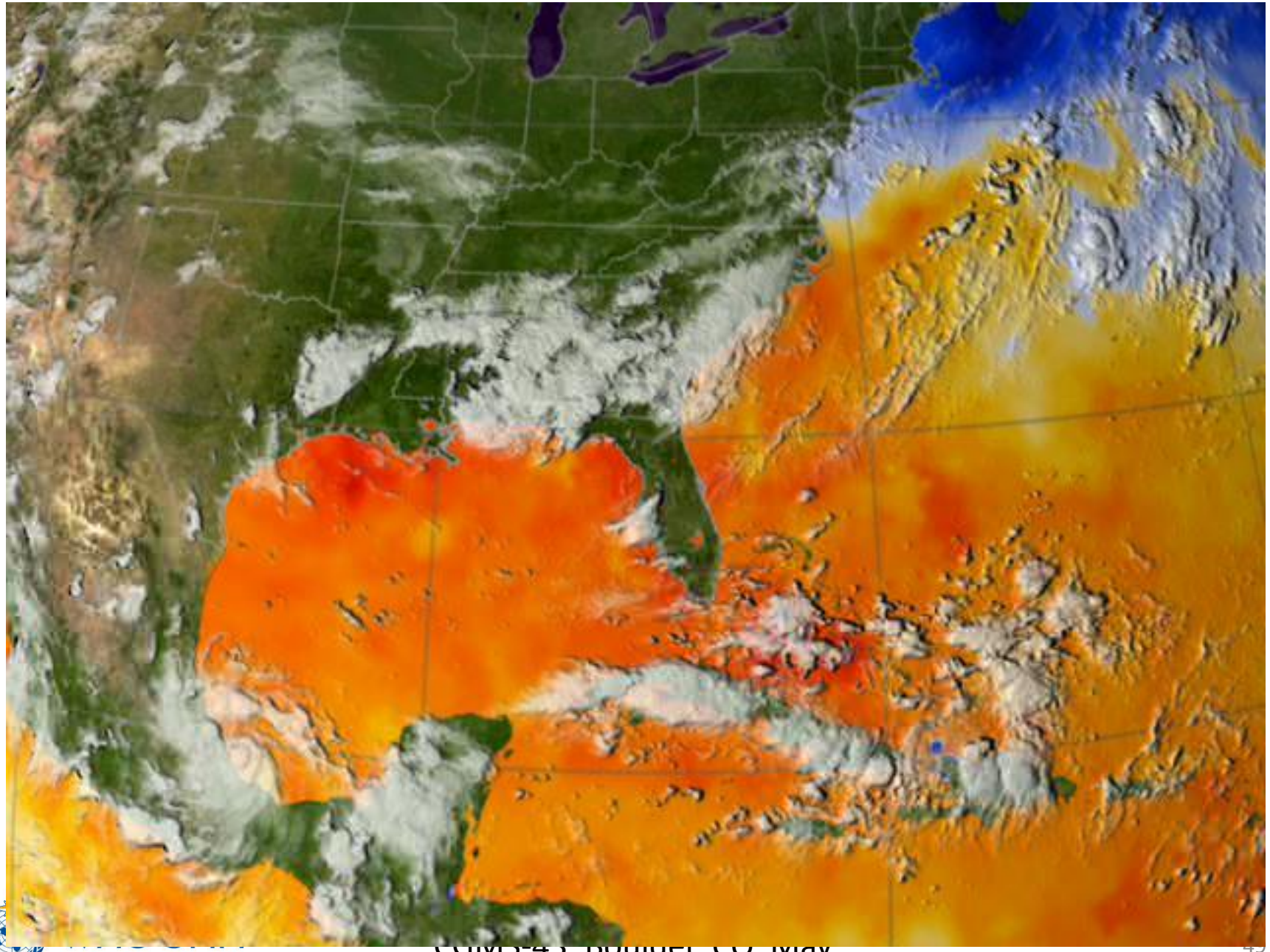
1. Backbone system with specified orbital configuration and measurement approaches

框架体系一：轨道和观测技术具体化的骨干体系

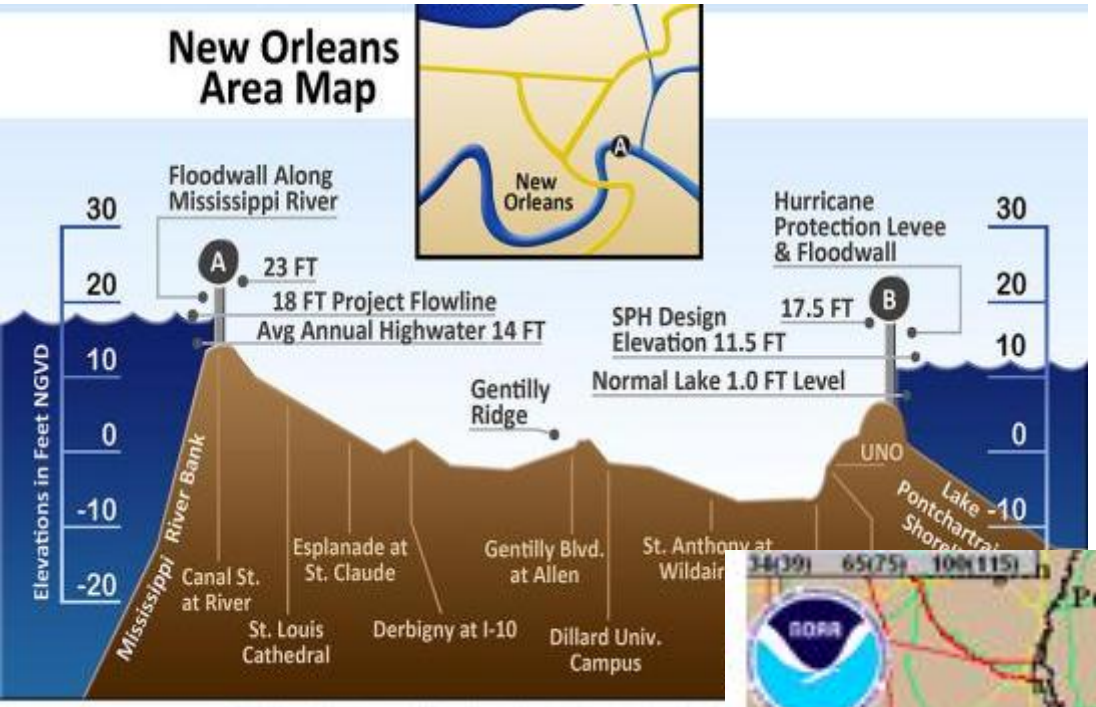
- Basis for Members' commitments, should respond to the vital data needs （成员国确保的最基本的观测骨干卫星星座，以满足最核心数据需求）
- Similar to the current CGMS baseline with addition of newly mature capabilities （和目前全球气象卫星协调委员会的基线卫星骨干星座类似，但是使用更多成熟的技术和能力）

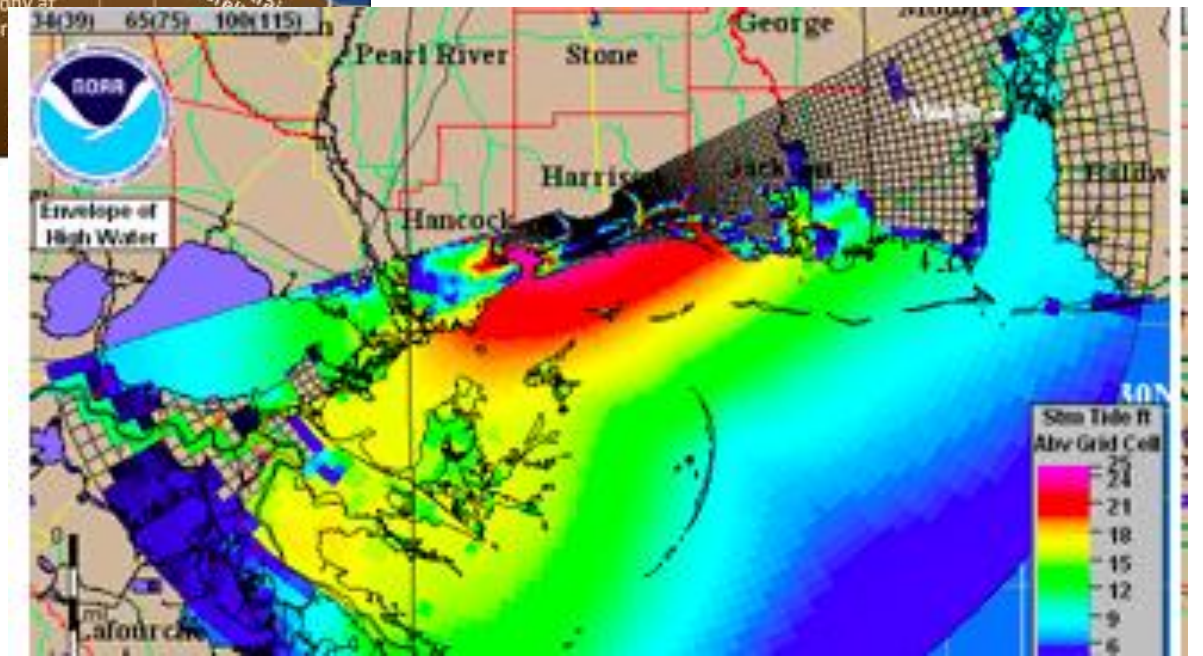
1. Backbone system - with specified orbital configuration and measurement approaches (1/2)

- **Geostationary** ring providing frequent multispectral VIS/IR imagery
  - with IR hyperspectral, Lightning mapper, UV/VIS/NIR sounder（静止卫星星座：高光谱可见光红外成像，探测，闪电监测，紫外/可见光/近红外探测）
- **LEO sun-sync. core constellation** in 3 orbit planes (am/pm/earlymorning)
  - hyperspectral IR sounder, VIS/IR imager including Day/Night band
  - MW imager, MW sounder, Scatterometer
- **LEO sun-sync. at 3 additional ECT** for improved robustness and improved time sampling particularly for monitoring precipitation （全球3+3极轨卫星）
- **Wide-swath radar altimeter, and high-altitude, inclined, high-precision orbit altimeter （宽幅度雷达高度计）**
- IR dual-angle view imager (for SST)
- MW imagery at 6.7 GHz (for all-weather SST)
- Low-frequency MW (for soil moisture and ocean salinity)
- MW cross-track upper stratospheric and mesospheric temperature sounder
- UV/VIS/NIR sounder , nadir and limb (for atmospheric composition, incl H2O)



Storm Surge wave heights higher than 20 feet !





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Great losses: 1000 death & 100 Billion $

How the space observations can help the Hurricane intensity forecasting ?

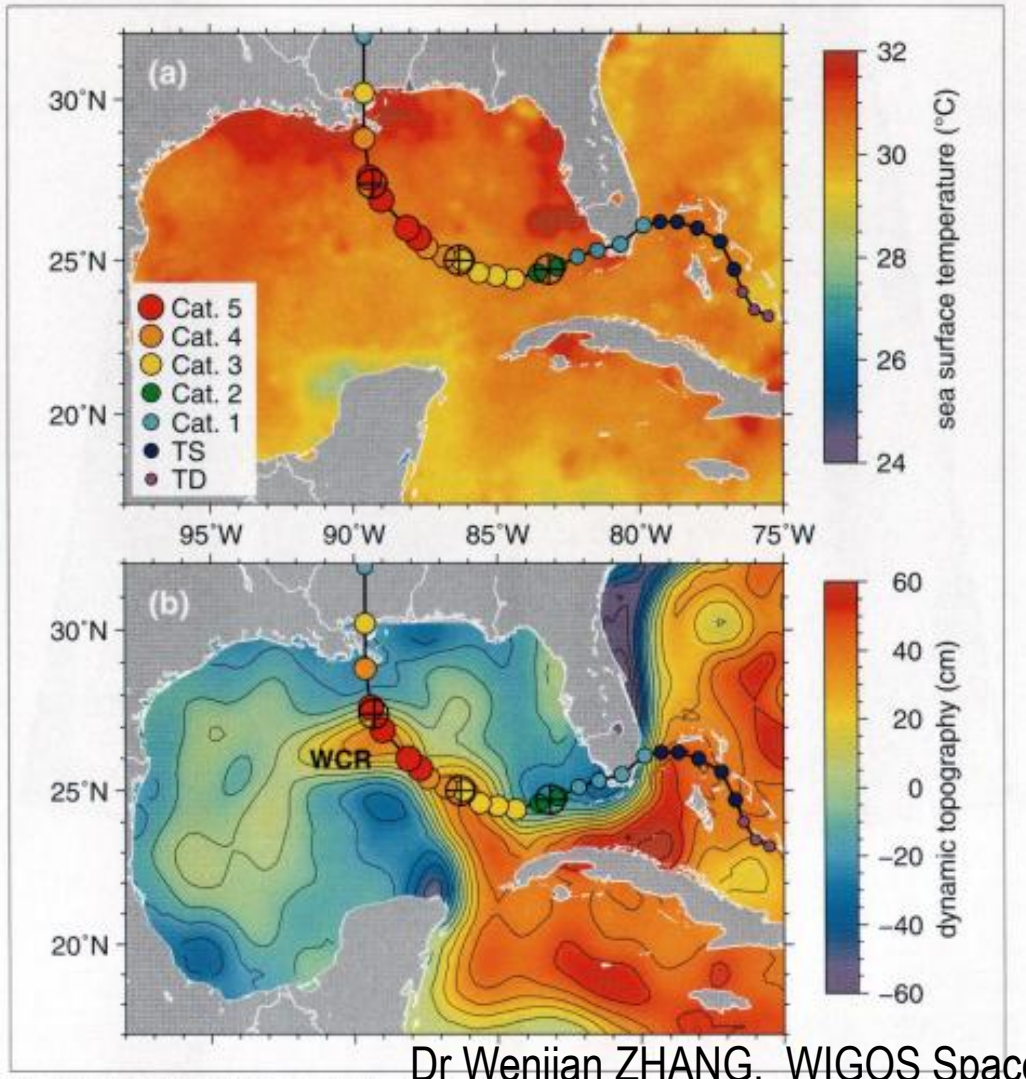


Fig. 2. The location and intensity of Katrina at intervals of six hours (circles indicate data from National Hurricane Center advisories) show two intensification events. (a) Intensification is not

Since SSTs can change rapidly due to mixing processes and correspond to only about the top 10 metres, SST by itself does not provide sufficient information about the heat content stored in the upper ocean to accurately forecast tropical cyclone intensity.

We get far more reliable data from altimeters, since sea surface height anomalies are strongly correlated with the internal thermal structure of the ocean.卫星观测的海洋表面温度不能提供台风强度预报所需要的海洋上层（100-300米）热含量信息。利用海洋高度计可以测量出由于海洋内部热膨胀导致海表高度异常-海洋暖池

1. Backbone system - with specified orbital configuration and measurement approaches (2/2)

- **Precipitation and cloud radars and MW sounder and imager on inclined orbits**
- Absolutely calibrated broadband radiometer and TSI and SSI radiometer
- GNSS radio-occultation (basic constellation) for temperature, humidity and electron density
- Narrow-band or hyperspectral imagery (ocean colour, vegetation)
- High-resolution multispectral VIS/IR imagers (land use, vegetation, flood monitoring)
- SAR imagery (sea state and sea-ice observations, soil moisture)
- Gravimetry mission (ground water, oceanography)
- Solar wind in situ plasma and energetic particles, magnetic field, at L1
- Solar coronagraph and radio-spectrograph, at L1
- In situ plasma, energetic particles at GEO and LEO, and magnetic field at GEO

- On-orbit measurement reference standards for VIS/NIR, IR, MW absolute calibration

2. Backbone system with open orbit configuration & flexibility to optimize the implementation

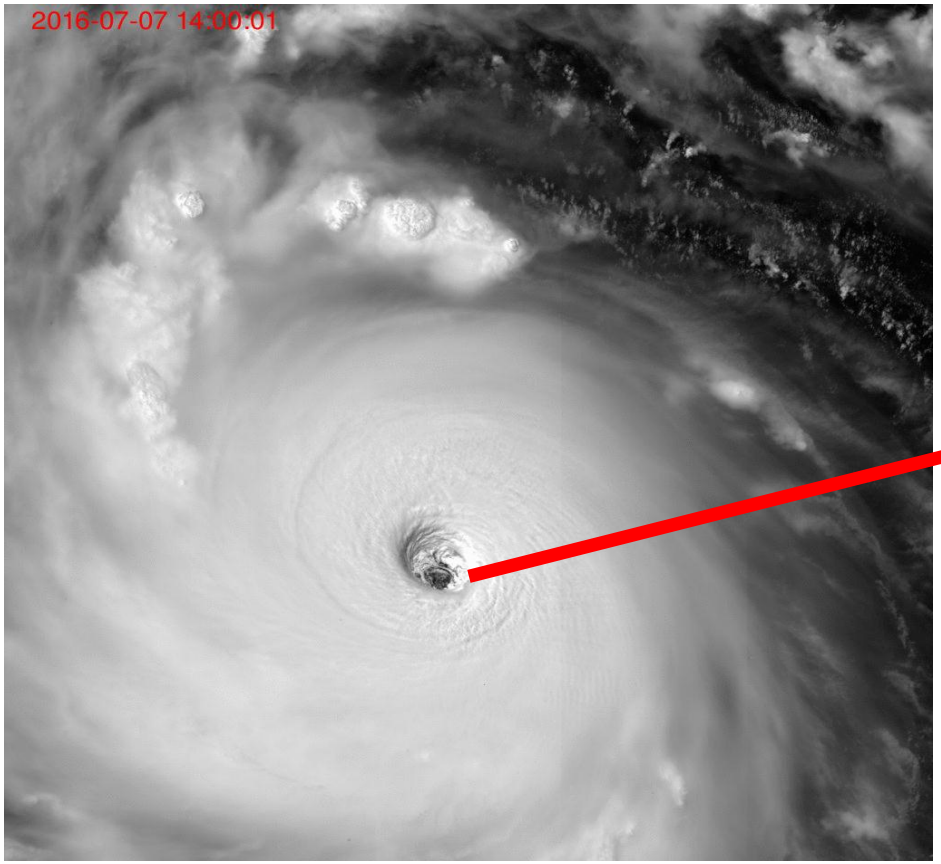
框架体系二：轨道和观测技术具有灵活型的骨干体系，用于进一步优化和完善骨干观测星座系统

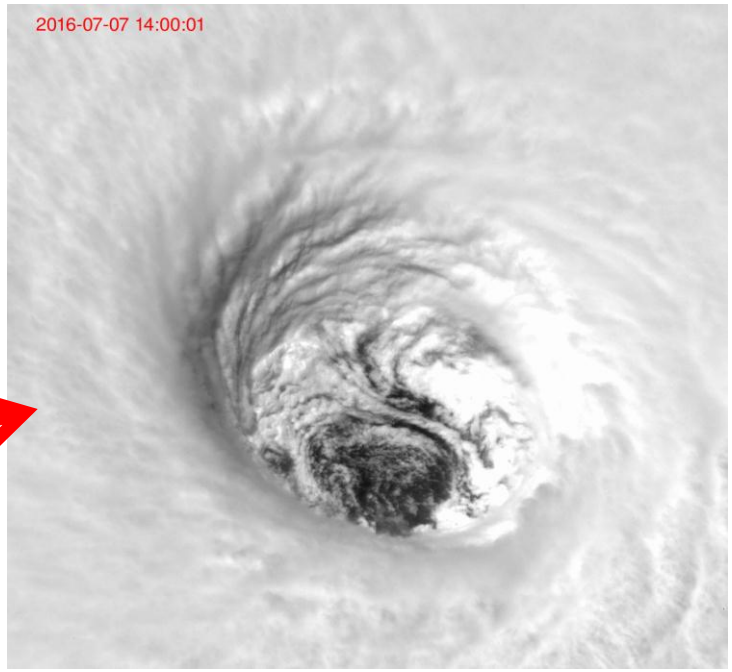
-- Basis for open contributions of WMO Members, responding to target data goals （主要针对WMO成员国对于特定数据目标作出贡献的系统）

2. Backbone system – Open measurement

- Surface wind and sea state, e.g. by GNSS reflectometry missions, passive MW, SAR
- **High temporal frequency MW sounding (GEO or LEO constellation)**
- Stratosphere monitoring by UV–VIS–NIR–IR-MW limb sounders
- Wind and aerosol profiling by lidar (Doppler and dual/triple-frequency backscatter)
- Atmospheric moisture profiling by lidar (DIAL)
- Sea-ice thickness by lidar (in addition to radars mentioned in Tier 1)
- Cloud phase detection, e.g. by sub-mm imagery
- Carbon Dioxyde and Methane by NIR imagery
- Aerosol and radiation budget by multi-angle, multi-polarization radiometers
- High-resolution land or ocean observation (multi-polarization SAR, hyperspectral VIS)

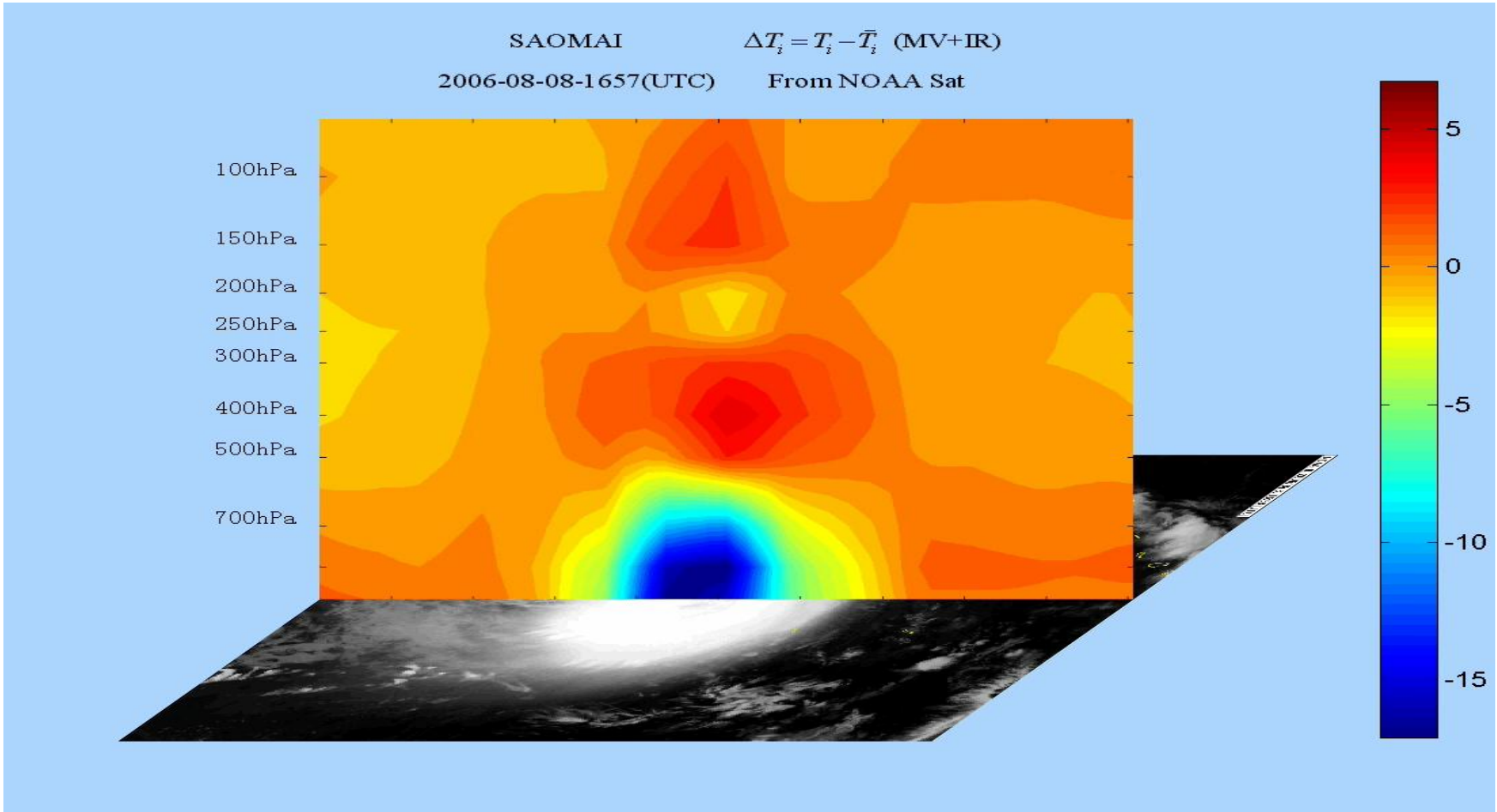
New GEO satellite technologies reached 50meters Resolution, /every 9 seconds for monitoring extreme weather events

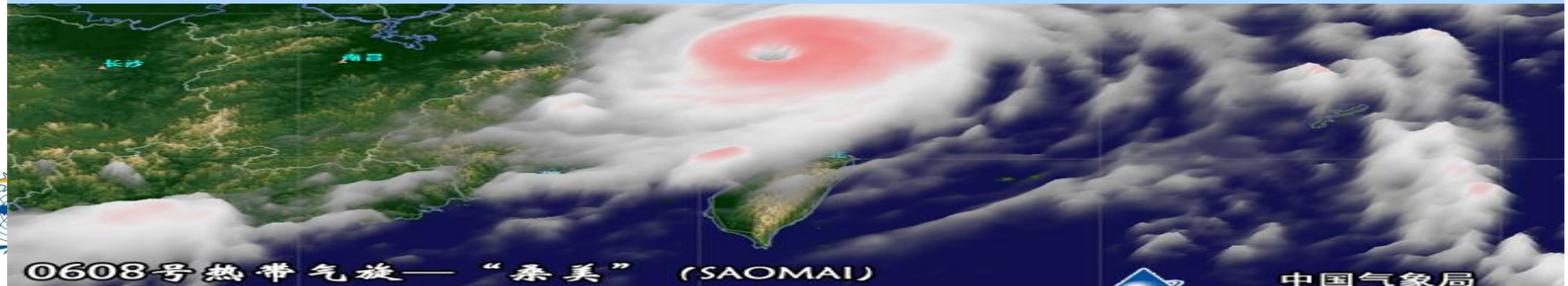




Typhoon Nepartak
(7 July, 2016)

Potential GEO Microwave Sensor

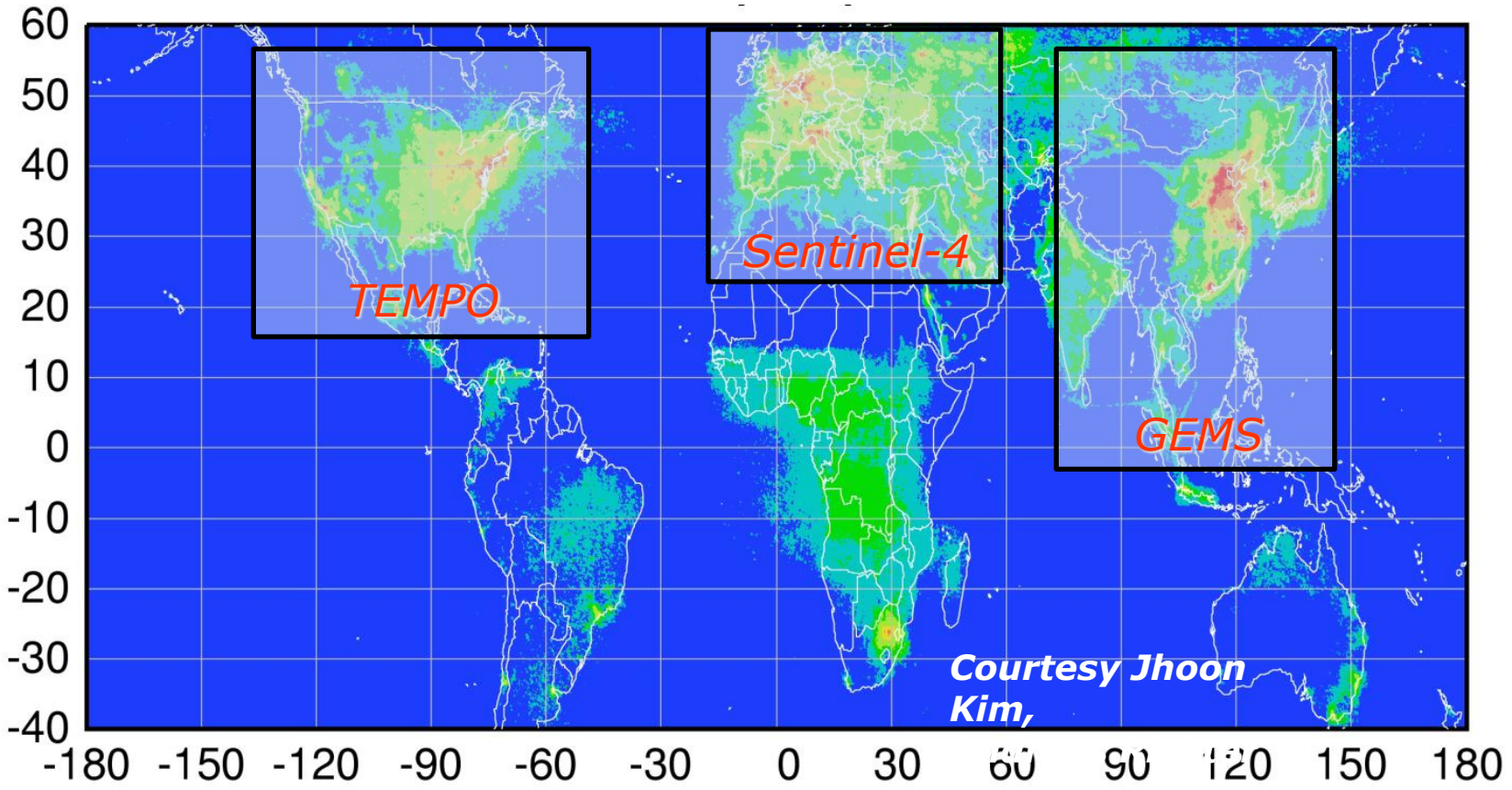




Example: Geostationary pollution monitoring

Hourly atmospheric pollution observations from geostationary Earth orbit

Spatial coverage of funded spectrometers 2018-2020



Policy-relevant science and environmental services enabled by common observations

- Improved air quality forecasts and assimilation systems
- Improved assessment, e.g., observations to support United Nations Convention on Long Range Transboundary Air Pollution

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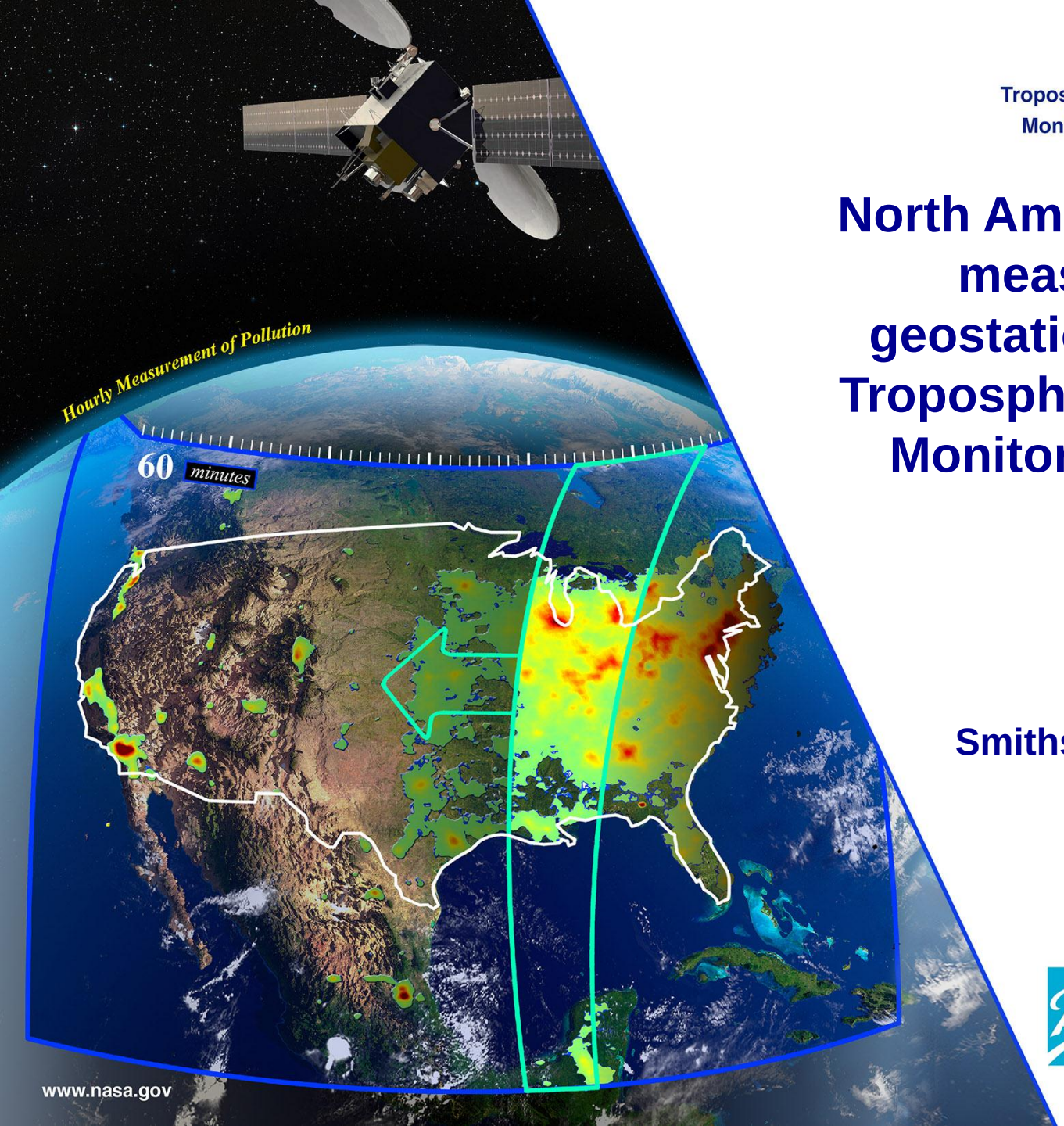


Tropospheric Emissions:
Monitoring of Pollution

TEMPO

North American pollution measurements from geostationary orbit with Tropospheric Emissions: Monitoring of Pollution (TEMPO)

tempo.si.edu

Kelly Chance
Smithsonian Astrophysical Observatory

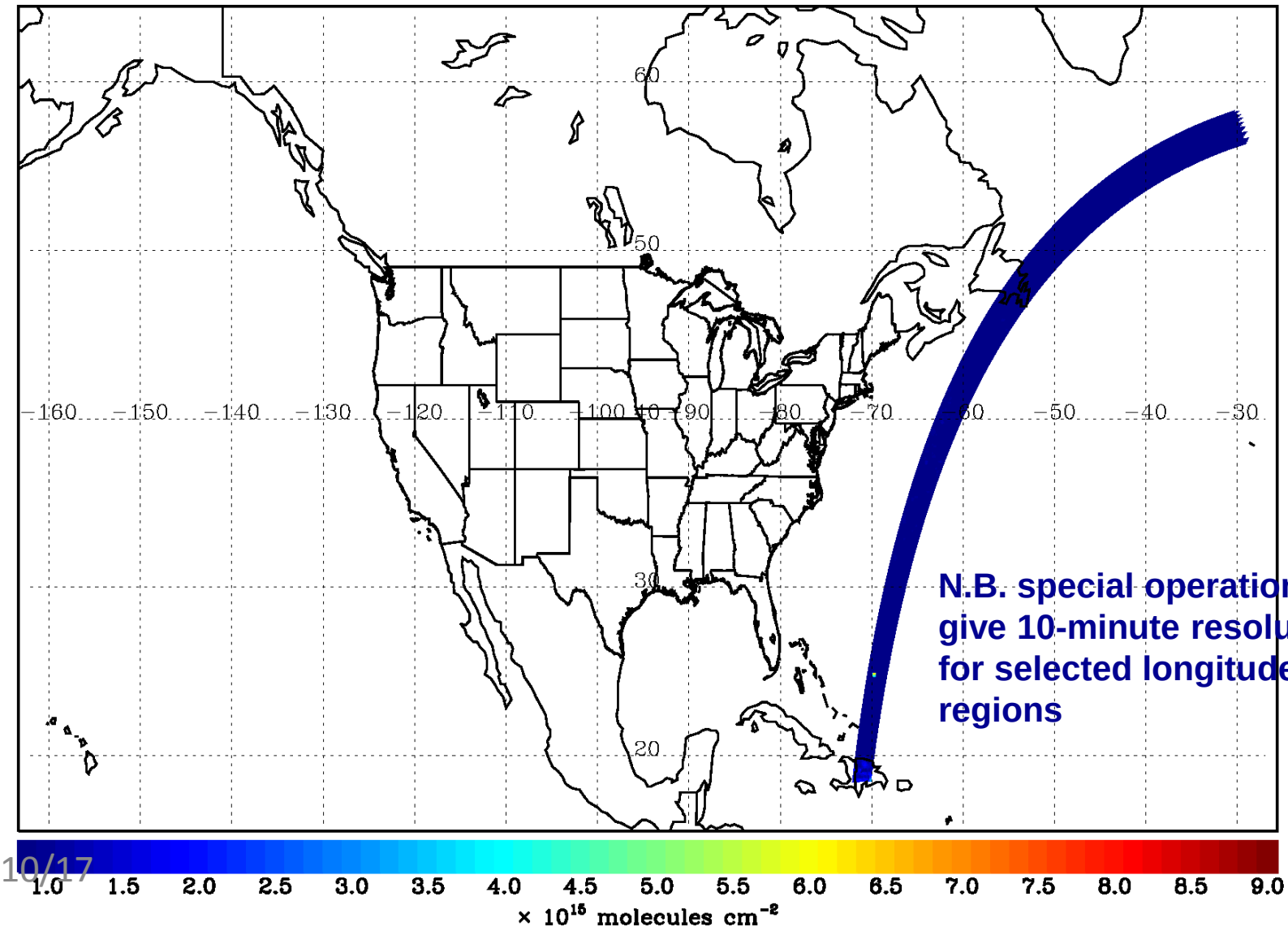
Smithsonian Institution
July 10, 2017

Ball

Smithsonian

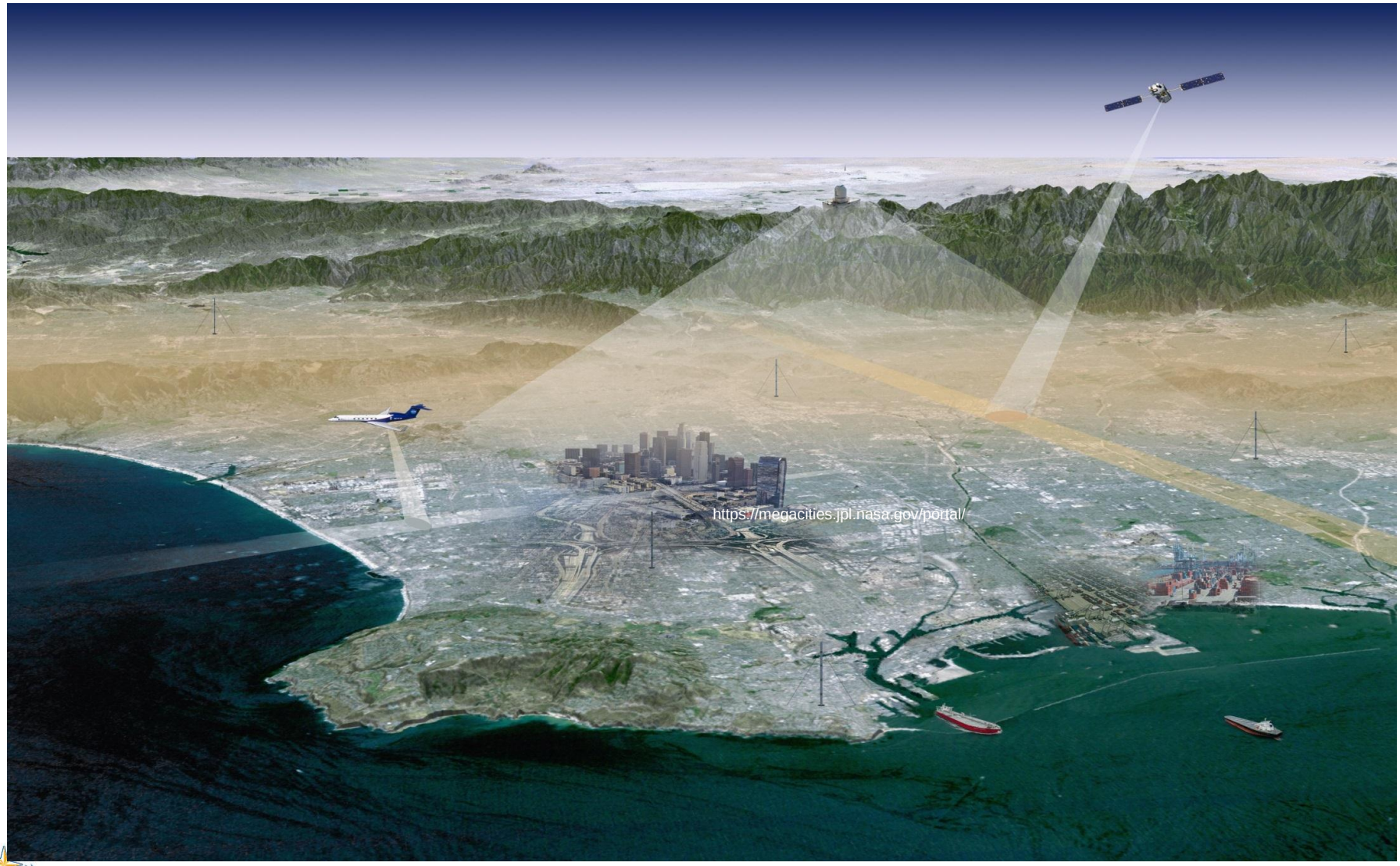
NASA

TEMPO hourly NO_2 sweep



N.B. special operations give 10-minute resolution for selected longitude regions

Toward an Integrated Global Greenhouse Gas Information System (IG^{3}IS)



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Critical role of satellites+In situ observations -

3. Operational pathfinders, and technology and science demonstrators

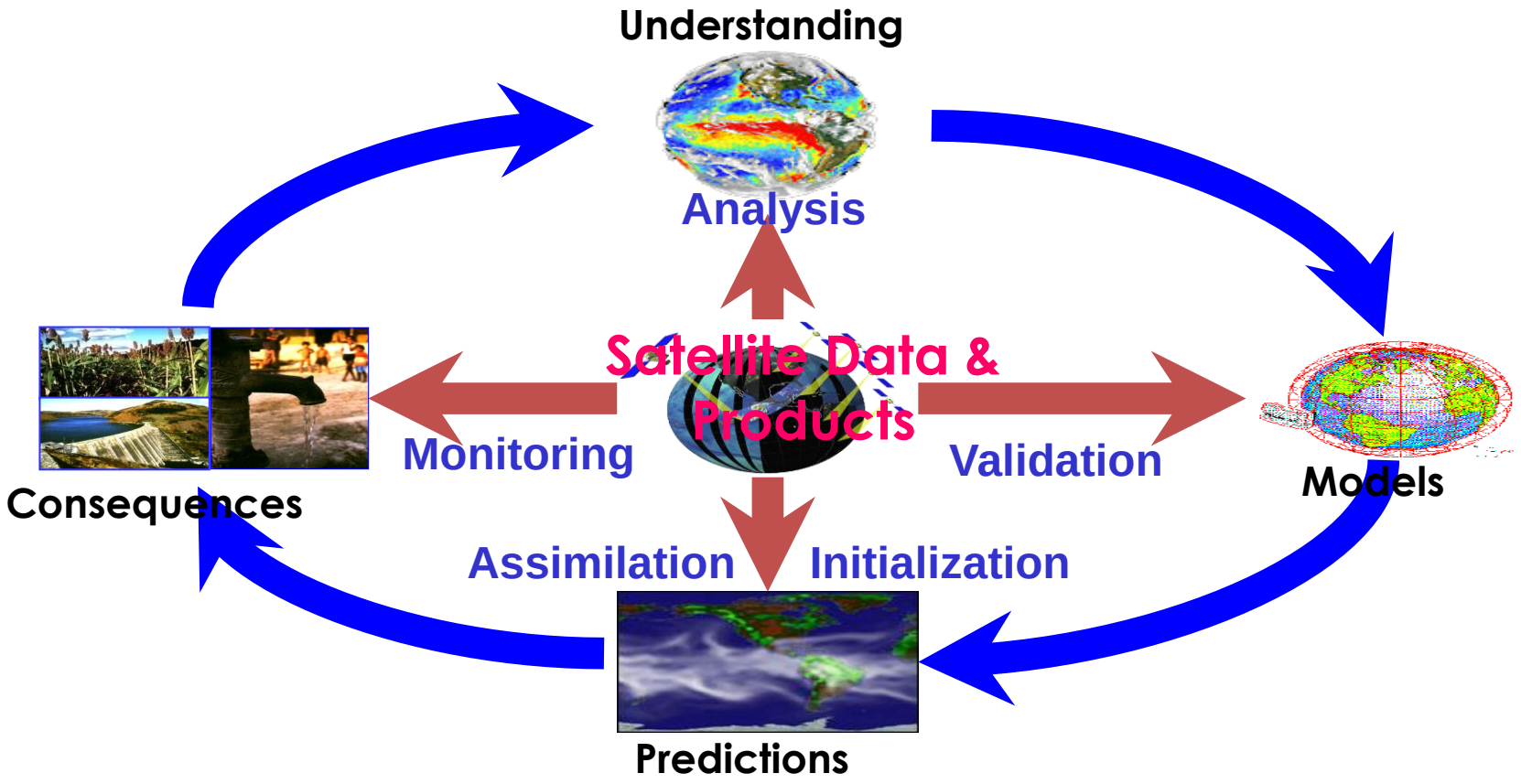
- 框架体系三：未来业务先导和科学技术验证体系

Responding to R&D needs- （应对于研发项目需求）

Summary： Dialogues between Observation Users and Providers：总结-用户和航天交流

- Difficulty to anticipate the user needs & Technical progress 20 years ahead-提前20年预测需求和技术进步都很困难
- Space agencies need to better understand the user needs – Service driven approach-航天需要进一步理解用户需求
- Users need to aware of potential future capabilities- Technological driven-用户需要深入了解潜在的新技术能力
- EC-70 recommended the WIGOS Vision 2040 draft to Cg 18 (2019) – 2019世界气象大会批准2040规划文件

Satellite data and products are required by a broader application areas and research
加大投入建立机制全面深度开展风云卫星应用！



The availability of satellite data and value-added products strongly motivates advances in understanding, prediction, and application in all Earth system components.

Thank you

WEATHER CLIMATE WA
TEMPS CLIMAT EAU

WMO OMM

World Meteorologi
Organisation mété