

IGCP 663 : 沿海城市地面沉降 的影响、机理与监测

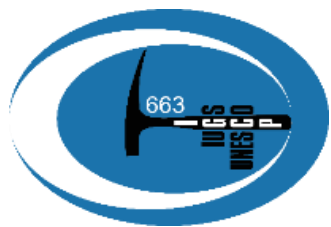


上海市地质调查研究院

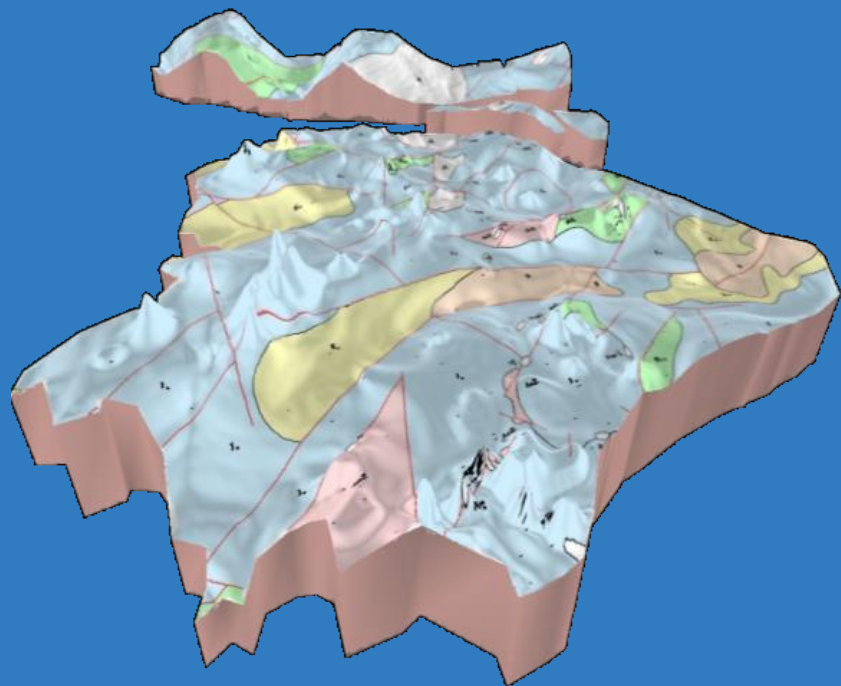
Shanghai Institute of Geological Survey

自然资源部地面沉降监测与防治重点实验室

Key Laboratory of Land Subsidence Monitoring and Prevention, Ministry of Natural Resources



报告内容



1

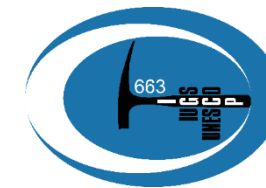
项目基本概况

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主要工作进展

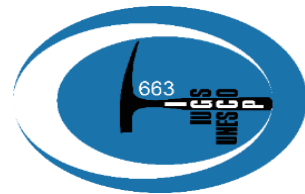
3

2022年项目工作计划



一、项目基本情况





1. 项目简介

1.1 英文标题

Impact, Mechanism, Monitoring of Land Subsidence
in Coastal cities (IM2LSC)

1.2 中文标题

沿海城市地面沉降的影响因素、机理与监测

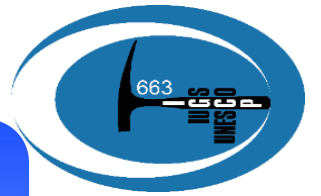
1.3 项目周期

2018~2022年

1.4 项目目标

- 推动地面沉降科学技术进步
- 提升全球地面沉降防治与研究能力





1. 项目简介

**总负责人
首席科学家**

中国

严学新，教授级高级工程师
上海市地质调查研究院 总工程师
自然资源部地面沉降监测与防治重点实验室 主任



意大利

Luigi Tosi，意大利国家研究委员会，资深科学家



**联合
负责人**

荷兰

Esther Stouthamer，荷兰乌特勒支大学，副教授

印尼

Heri Andreas，印度尼西亚万隆理工大学，研究员



埃及

Mahmoud Bakr，埃及国家水资源研究中心，教授

项目组

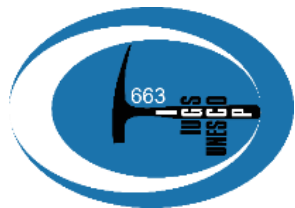
全球30多个国家，160余名国际专家





二、主要工作进展





2. 2020~2021年项目工作报告



2.1 年度工作

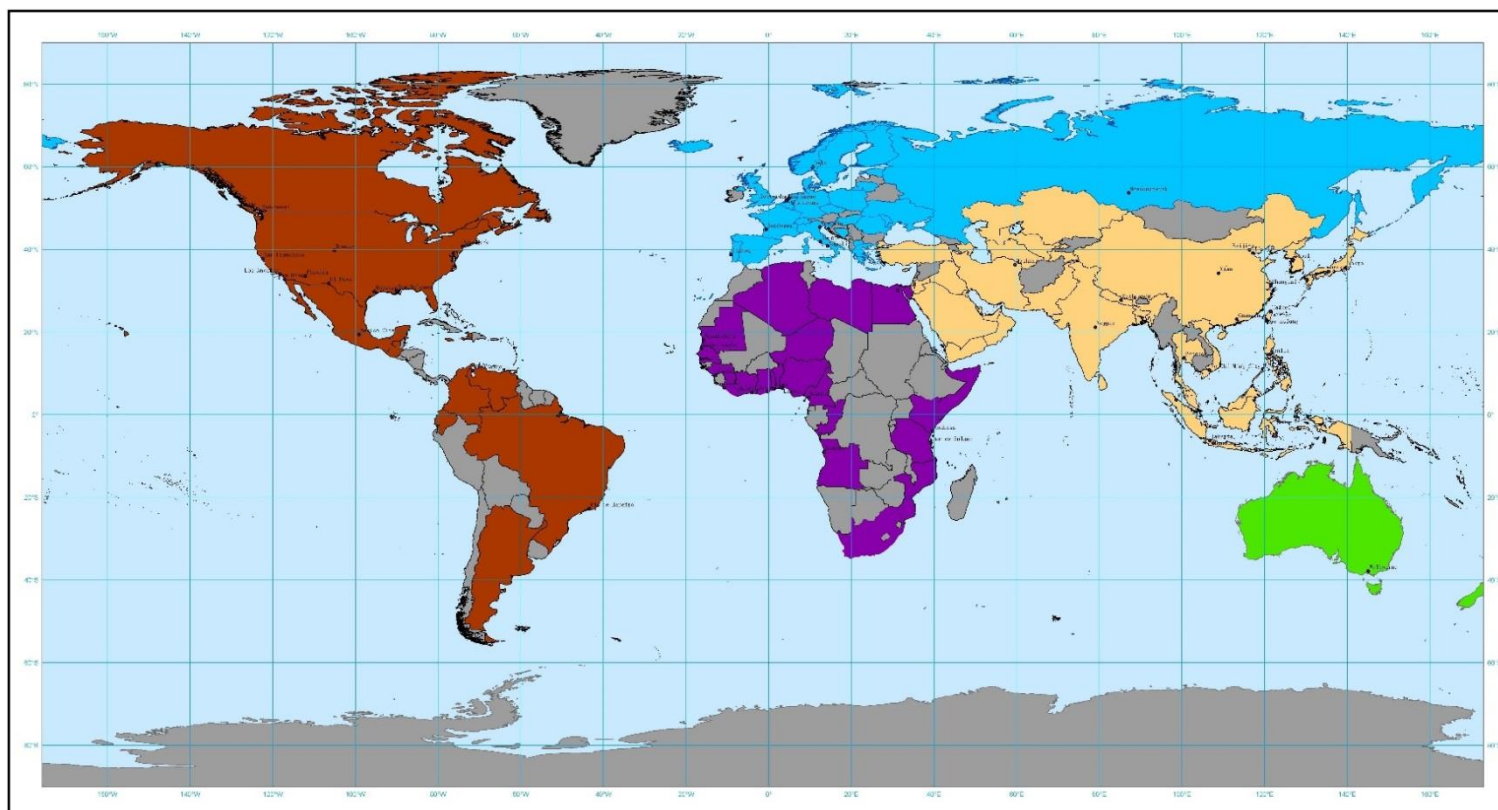
2.2 科研成果

2.3 科学推广

2.1 联合编绘全球地面沉降三张图



■图1 全球地面沉降发育分布图（IGCP 663）



◆地面沉降是全球性地质灾害，广泛分布于亚洲、欧洲、北美洲、南美洲、非洲、大洋洲等六大洲的100多个国家，是威胁地区和城市生存和可持续发展的突出灾害。

Legend

- Land Subsidence in Europe
- Land Subsidence in Asia
- Land Subsidence in Africa
- Land Subsidence in America
- Land Subsidence in Oceania
- No Land Subsidence Recorded
- Typical Cities with Recorded Land Subsidence

Scale: 1:50,000,000



Coordinate System: World Plate Carree
Central Meridian: 00° 00' 00"



<http://igcp.sigs.cn>

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2.1 联合编绘全球地面沉降三张图



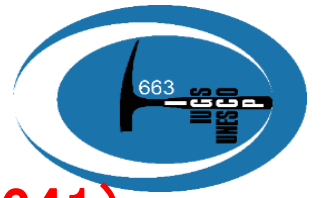
■图1 全球地面沉降发育分布图（IGCP 663）

- 典型城市：中国（上海、北京、天津、西安）、美国（休斯顿）、意大利（威尼斯）、墨西哥（墨西哥城）、荷兰（海牙）、日本（东京、大阪）、印度尼西亚（雅加达）、泰国（曼谷）、越南（河内）等

No.	Country	Location	Causes
1	China	Yangtze River Delta (Shanghai)	Groundwater pumping, Engineering
		North China Plain (Beijing)	Groundwater pumping
		Fen-wei Basin (Xi'an)	Groundwater pumping, Natural
2	Indonesia	Jakarta	Groundwater pumping
		Bandung	Groundwater pumping
3	Italy	Po delta	Groundwater pumping, Natural
		Venice	Natural
4	Japan	Tokyo	Groundwater pumping
		Osaka	Groundwater pumping
5	Mexico	Mexico City	Groundwater pumping, Natural
6	Netherlands	The Hague	Peat oxidation
7	USA	California (San Joaquin Valley)	Groundwater pumping
		Texas (Houston - Galveston)	Nearby urbanization
		New Orleans	Excessive extraction of oil
8	Vietnam	Mekong delta	Natural, Groundwater pumping
...



2.1 联合编绘全球地面沉降三张图



■图2 全球地面沉降发育地区交互式地图(UNESCO LaSII、IGCP663、IGCP641)

- ◆ 基于全球地面沉降研究成果，地面沉降诱发因素划分为**自然因素、抽取地下水、泥炭氧化作用、碳水化合物提取、采矿、城市化、土地改良**等六大类。
- ◆ 按照地面沉降诱发因素分类，**编绘了全球地面沉降发育地区交互式地图**，可实现典型地区地面沉降发育状况及相关成果的查询与分析。



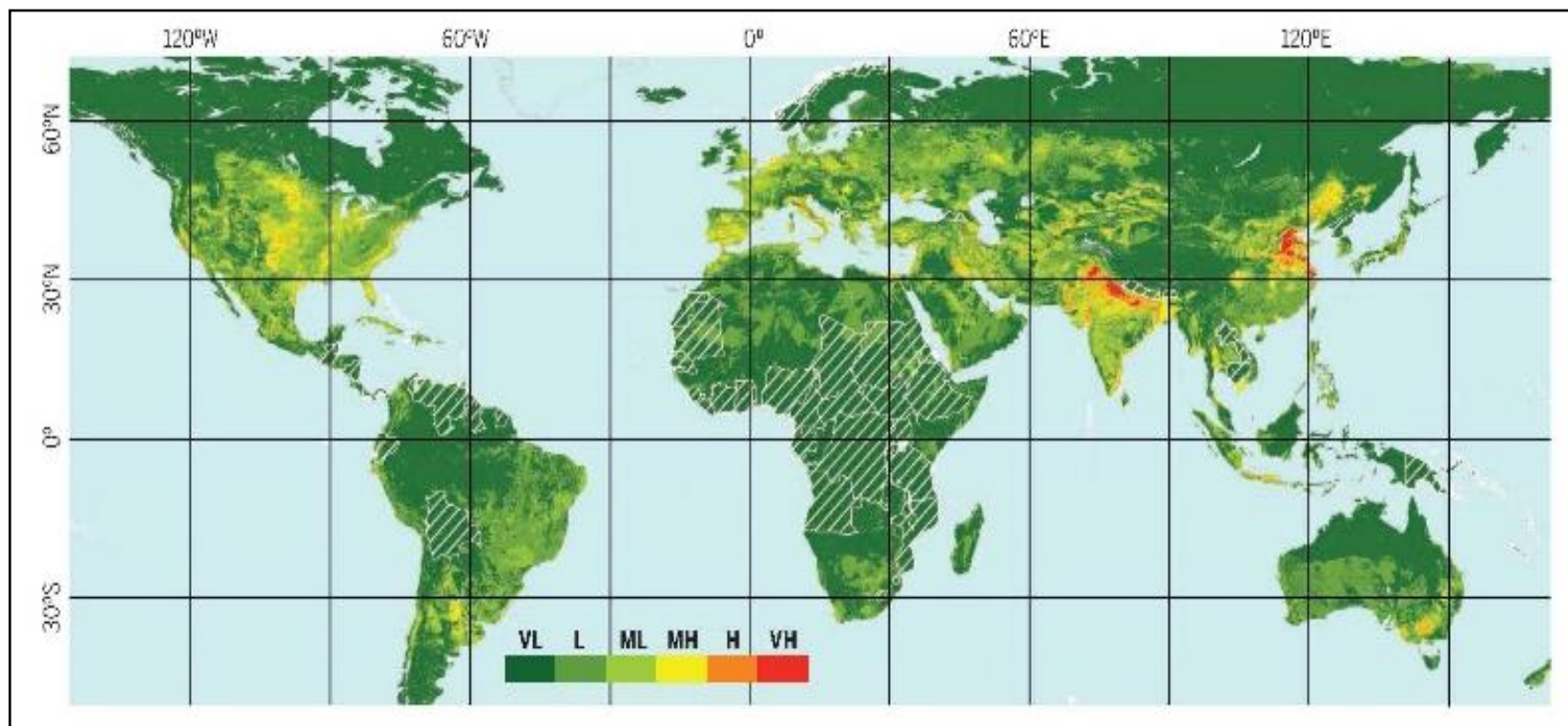
图件发布于UNESCO LASII 官网 <https://www.landsubsidence-unesco.org/maps/>



2.1 联合编绘全球地面沉降三张图



■图3 全球地面沉降易发性分区图(UNESCO LaSII、IGCP663、IGCP641)



- ◆ 汇聚全球地面沉降大数据，开展了全球地面沉降发育情况调查研究，编绘了全球地面沉降易发性分区图。
- ◆ 地面沉降发育区与人口聚集区高度重合，全球约90%的人口将面临地面沉降的威胁。

图件发布于UNESCO LASII 官网 <https://www.landsubsidence-unesco.org/maps/>



2.1 联合编绘全球地面沉降三张图



图3 全球地面沉降易发性分区图(UNESCO LaSII、IGCP663、IGCP641)

- 合作成果发表于顶级期刊《Science》“Policy Forum”栏目
- 被全球主流媒体广泛关注，国内《中国科学报》第一时间进行了报道

INSIGHTS

POLICY FORUM

GEOSCIENCE

Mapping the global threat of land subsidence

Nineteen percent of the global population may face a high probability of subsidence

By Gerardo Herrera-García, Pablo Ezquerro, Roberto Tomás, Marta Béjar-Pizarro, Juan López-Vinuales, Mauro Rossi, Rosa M. Mateos, Dora Carreón-Freyre, John Lambert, Pietro Teatini, Enrique Cabral-Cano, Gilles Erlens, Devin Galloway, Wei-Chia Hung, Najeebullah Kakar, Michelle Sneed, Luigi Tosi, Hamel Wang, Shujun Ye

Subsidence, the lowering of Earth's land surface, is a potentially destructive hazard that can be caused by a wide range of natural or anthropogenic triggers but mainly results from solid or fluid mobilization underground. Subsidence due to groundwater depletion (1) is a slow and gradual process that develops on large time scales (months to years), producing progressive loss of land elevation (centimeters to decimeters per year) typically over very large areas (tens to thousands of square kilometers) and variably affects urban and agricultural areas worldwide. Subsidence permanently reduces aquifer-system storage capacity, causes earth fissures, damages buildings and civil infrastructure, and increases flood susceptibility and risk. During the next decades, global population and economic growth will continue to increase groundwater demand and accompanying groundwater depletion (2) and, when exacerbated by droughts (3), will probably increase land subsidence occurrence and related damages or impacts. To raise awareness and inform decision-making, we evaluate potential global subsidence due to groundwater depletion, a key first step toward formulating effective land-subsidence policies that are lacking in most countries worldwide.

A largescale systematic literature review reveals that during the past century land subsidence due to groundwater depletion occurred at 200 locations in 34 countries [see supplementary materials (SM)]. However, subsidence extent is only known for one-third of these records, information on the impacts is scarce, and mitigation measures were implemented only in a few locations. In China, widespread subsidence affects cities developed in the main sedimentary basins. In Indonesia, coastal subsidence in Jakarta is so severe that government authorities are planning to move the capital to the island of

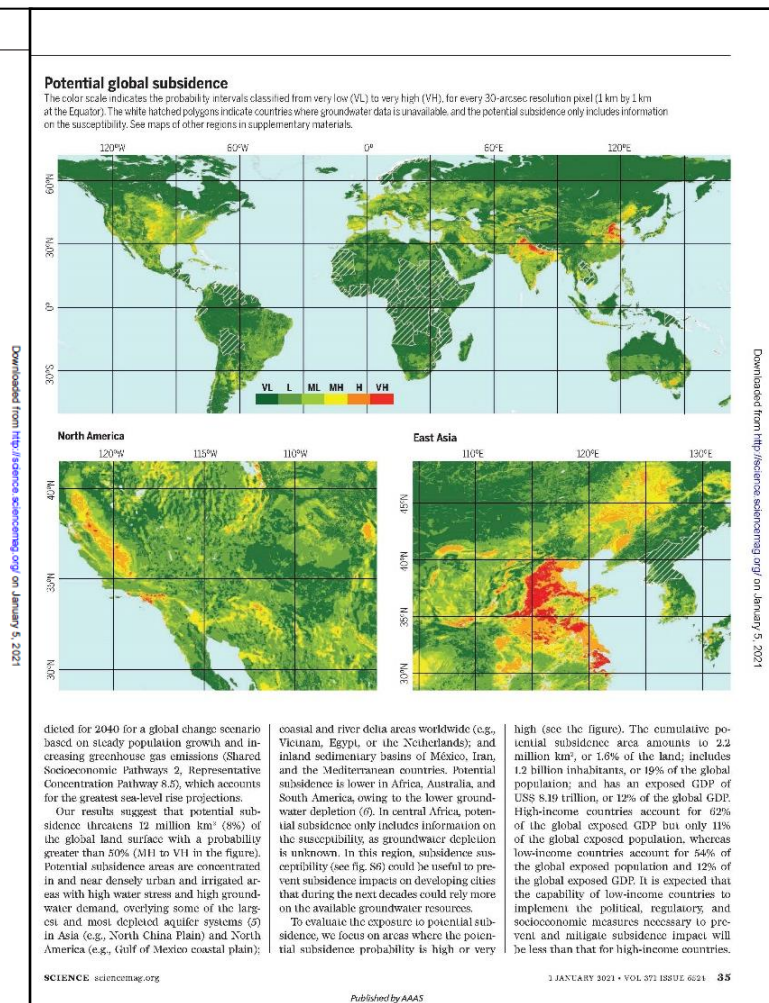
Borneo. In Japan, subsidence affected several cities during the 20th century, including more than 4 m of subsidence in Tokyo, before groundwater management practices mitigated further subsidence. Iran currently hosts some of the fastest-sinking cities in the world (25 cm year⁻¹) because of unregulated groundwater pumping. In Europe, the greatest impact of subsidence occurs in the Netherlands, where subsidence is primarily linked to the mean sea level and increasing the flooding risk. Subsidence in the Po River Plain in Italy started during the second half of the 20th century and currently threatens 30% of the Italian population, contributing to recurrent coastal flooding during extreme high tides in Venice. In North America, intense groundwater depletion triggers subsidence along from California's Central Valley, with as much as 9 m of subsidence in the past century to the Atlantic and Gulf of Mexico coastal plains in the United States, and the probability of subsidence is increasing. In Mexico, subsidence rates are among the highest worldwide (as much as 30 cm year⁻¹), affecting small structurally controlled intramontane basins where the main urban centers developed, causing an important but unaccounted economic impact.

Spatial analysis of subsidence locations identified in our global database (see SM) reveals that subsidence has preferentially occurred in very flat areas where unconsolidated sediments accumulated in alluvial basins or coastal plains, and where urban or agricultural areas developed in temperate or arid climates characterized by prolonged dry periods. Land subsidence has generally occurred in water-stressed basins, when the combination of groundwater withdrawal and natural groundwater discharge outpaced groundwater recharge, resulting in groundwater storage losses, groundwater depletion, and compaction of susceptible aquifer systems. In the affected basins, land subsidence mainly occurred in highly populated areas with half of documented occurrences in ar-

reas susceptible to flooding. In coastal zones, the combined effects of absolute sea-level rise and land subsidence contribute to relative sea-level rise (4). The contribution from land subsidence may exceed the contribution from absolute sea-level rise by a factor of 10 or more and could be especially critical for 21% of the geographic locations identified in our database, where land elevation is less than 1 m above the mean sea level.

On the basis of the spatial analysis findings, a global model is proposed to combine the main variables influencing subsidence to identify environmental settings favoring land subsidence and the anthropogenic factors leading to groundwater depletion (see SM). Statistical analyses of lithology, land-surface slope, land cover, and Koppen-Geiger climate classes are used to predict global subsidence susceptibility at a spatial resolution of 1 km². The probability of groundwater depletion is estimated by identifying urban and irrigated areas suffering water stress and where groundwater demand is high.

The analyses do not consider subsidence magnitude and rate, owing to the lack of this information at a global scale. Hence, the combination of subsidence susceptibility and the probability of groundwater depletion is used to predict a "proxy" of subsidence hazard, which permits identification of exposed areas where the probability of land subsidence occurrence is high or very high. Even though these results do not necessarily translate to direct impacts or damages, they are useful for identifying potential subsidence areas where further local-scale analysis is necessary. The comparison of our model predictions with an independent validation dataset reveals a 94% capability to distinguish between subsidence and nonsubsidence areas, according to the value of the area under the receiver operating characteristic curve (see SM). The global exposure to potential subsidence is evaluated by calculating the number of inhabitants living in potential subsidence areas, i.e., subsidence hazard proxy, and the equivalent gross domestic product (GDP). This "proxy" of exposed assets is calculated assuming that GDP per capita is homogeneous within each country. Finally, the evolution of potential global subsidence and the related exposure is pre-



2.2 中国-越南三角洲地面沉降监测对比研究（中国牵头）



项目名称：长江三角洲与红河三角洲地面沉降监测对比研究

项目来源：外交部亚洲合作资金项目

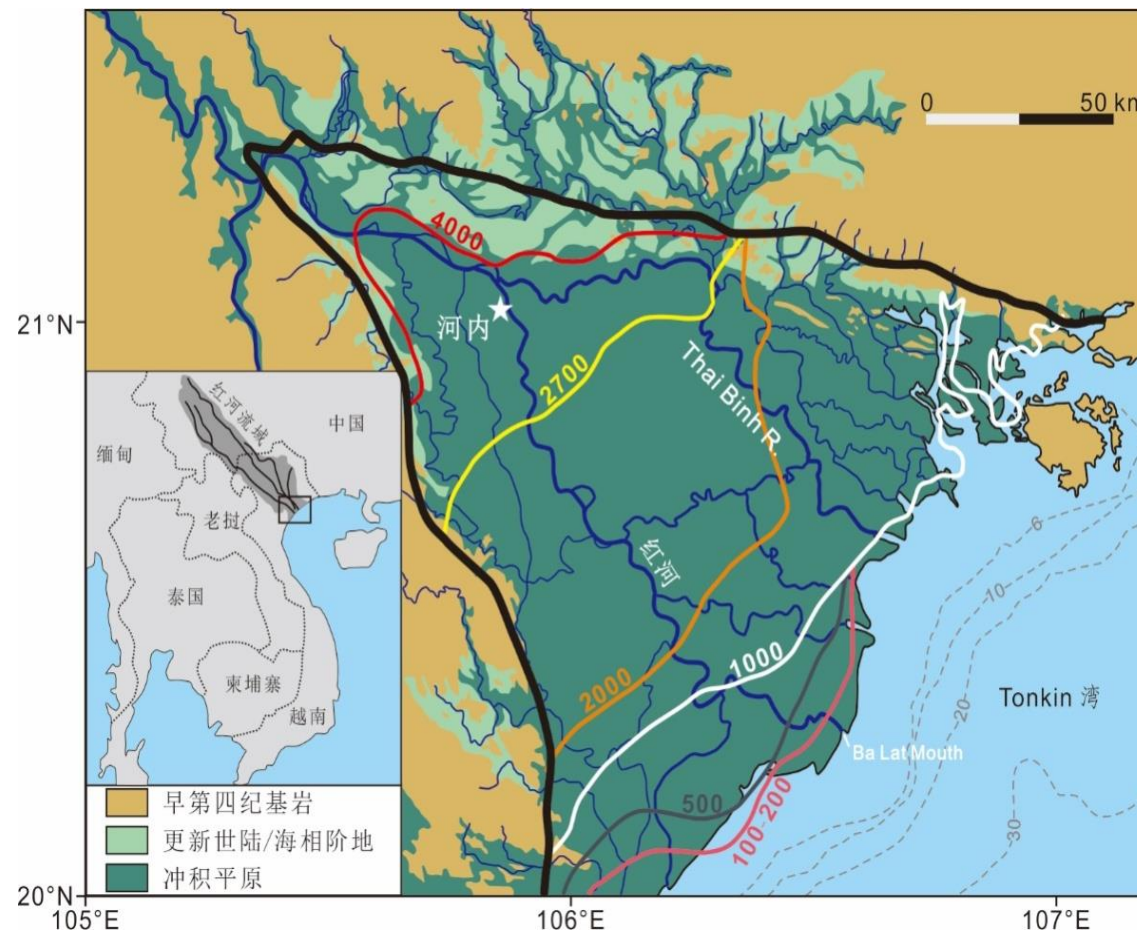
合作成员：

上海市地质调查研究院

中国地质调查局青岛海洋地质研究所

越南翰林科学研究院

IGCP 663项目组



2.2 中国-越南三角洲地面沉降监测对比研究（中国牵头）



□ 目标任务

聚焦中国、越南两国共同应对的海洋地质灾害问题，围绕长江三角洲和红河三角洲地区的地面沉降灾害现状、致灾因素、监测体系等，开展地面沉降监测对比分析研究：

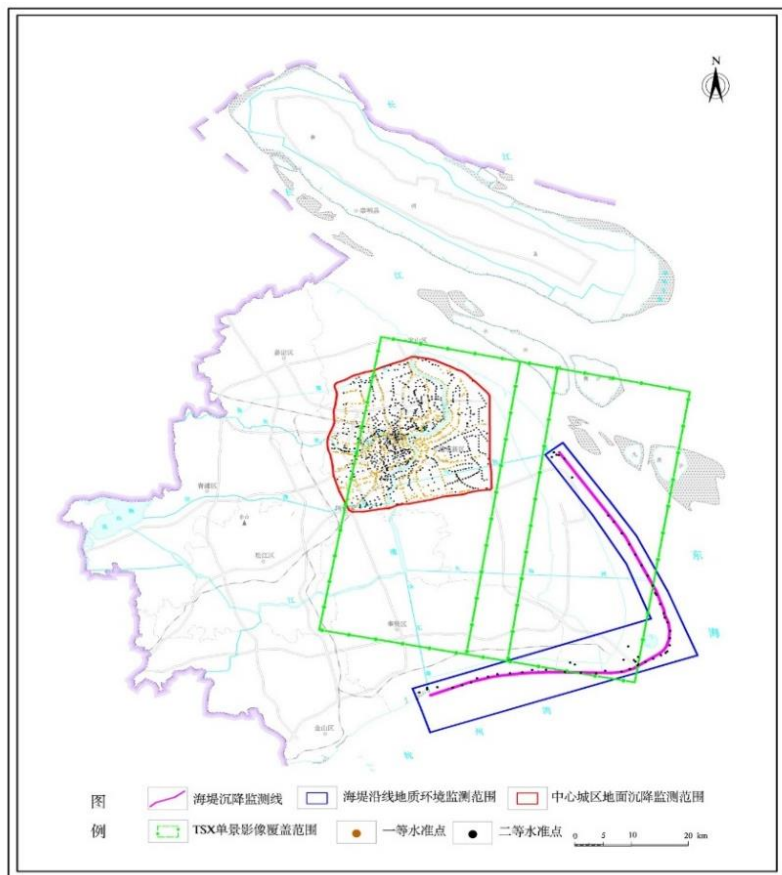
- ◆ **总结分析**：系统总结长江三角洲地面沉降监测与防治研究成果，综合分析红河三角洲地面沉降发育背景、致灾因素、动态特征；
- ◆ **专项监测**：开展以遥感解译、水准为主要手段的两个三角洲重点区域地面沉降监测；
- ◆ **综合对比**：综合对比分析两个三角洲地面沉降发育背景、基本特征等，研究提出红河三角洲地面沉降防治对策建议；
- ◆ **指导培训**：指导越方开展地面沉降调查、监测体系规划，开展地面沉降调查监测技术培训。



2.2 中国-越南三角洲地面沉降监测对比研究 (中国牵头)



遥感监测工作部署

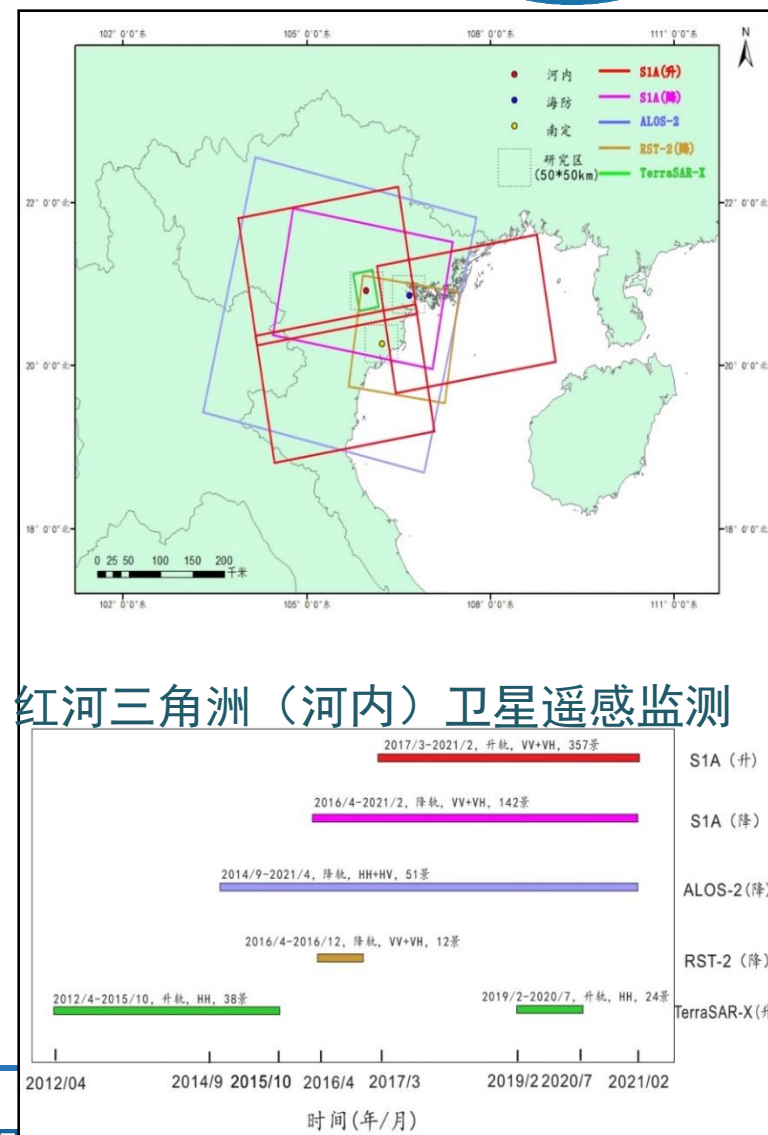


长江三角洲（上海）地面沉降
InSAR监测部署图

监测区：上海、河内为重点，并覆盖主要沉降漏斗区；

卫星数据源：sentinel 1 (2016年以来的升轨、降轨各240景、142景)、TerraSAR、Landsat、GPS。

监测方法：MT-InSAR

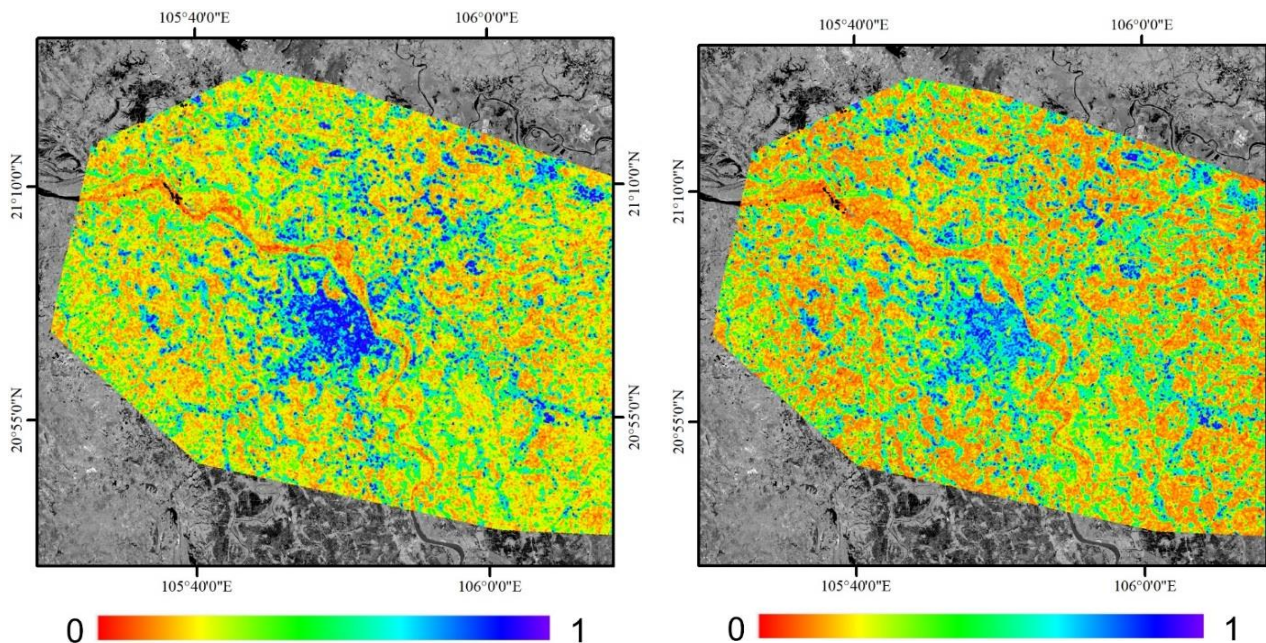


2.2 中国-越南三角洲地面沉降监测对比研究（中国牵头）

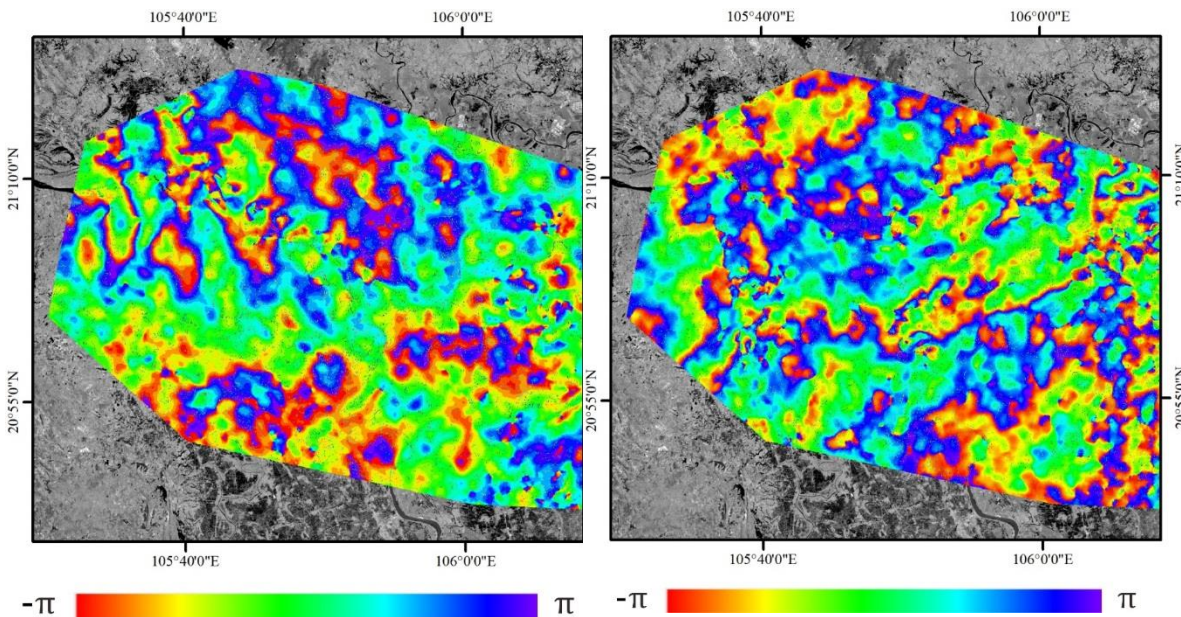


□ 河内Sentinel-1A降轨数据遥感解译（2016.4-2021.2）

➤ 数据处理方法：SBAS方法



2016年（左）、2019年（右）相干图



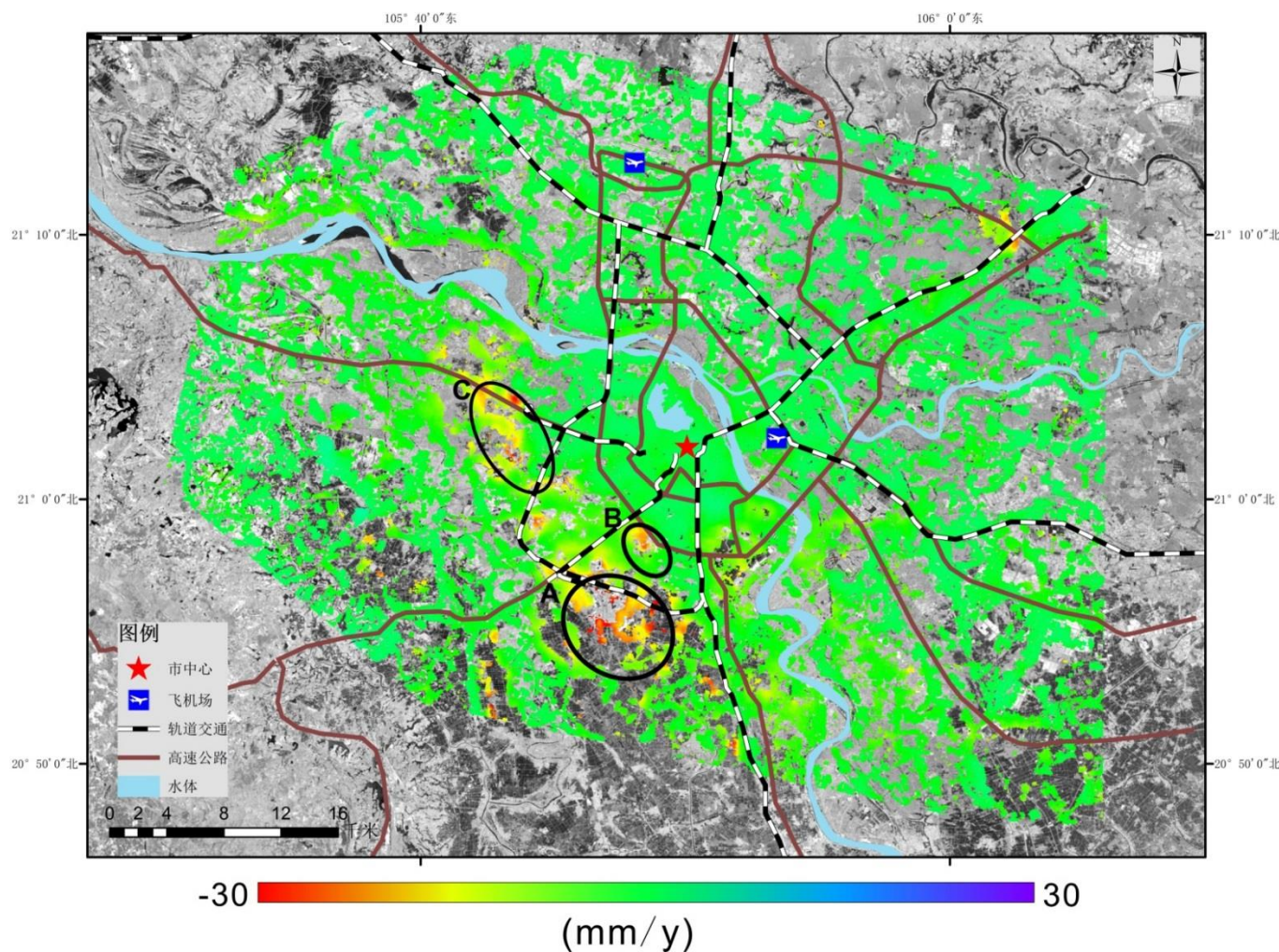
2016年（左）、2019年（右）干涉图



2.2 中国-越南三角洲地面沉降监测对比研究（中国牵头）



□河内Sentinel-1A降轨数据遥感解译结果（2016.4-2021.2）



□3个主要沉降区

➤A区

- 面积约为17.3km²
- 最大沉降速率为-65mm/年
- 平均沉降速率为-14.2 mm/年

➤B区

- 面积约为4.3 km²
- 最大沉降速率为-24.6 mm/年
- 平均沉降速率为-9.7 mm/年

•C区

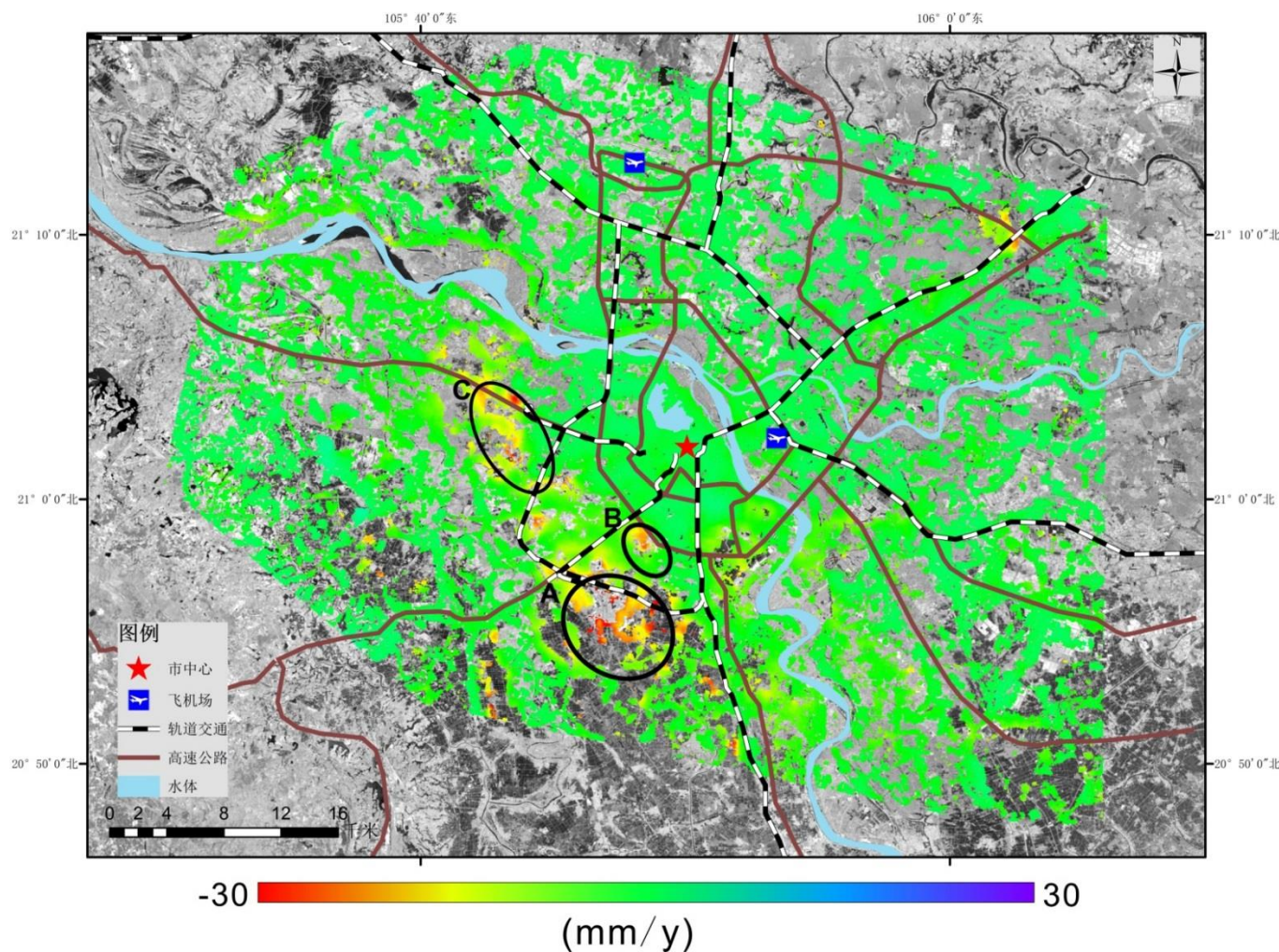
- 面积约为19.4 km²
- 其最大沉降速率为-29 mm/年
- 平均沉降速率为-10 mm/年



2.2 中国-越南三角洲地面沉降监测对比研究（中国牵头）



□河内Sentinel-1A降轨数据遥感解译结果（2016.4-2021.2）



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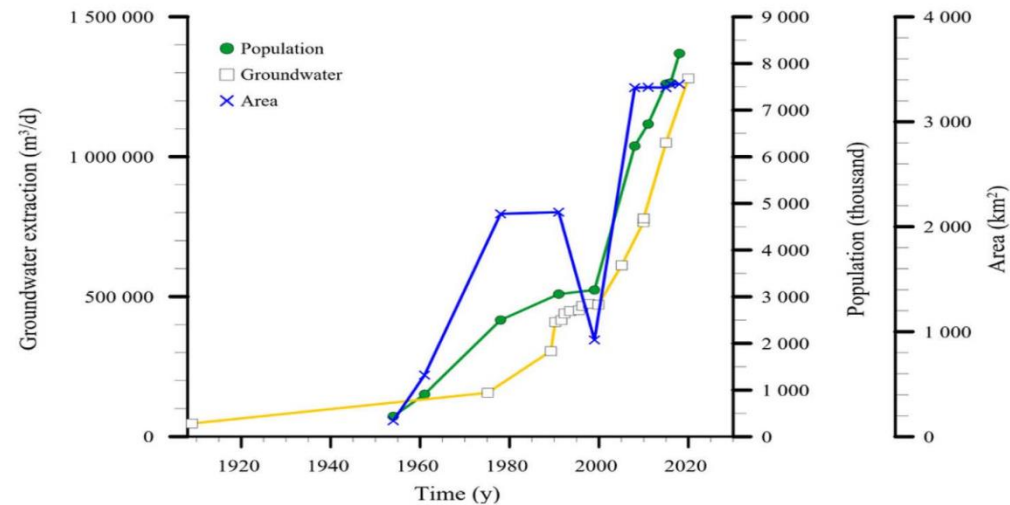
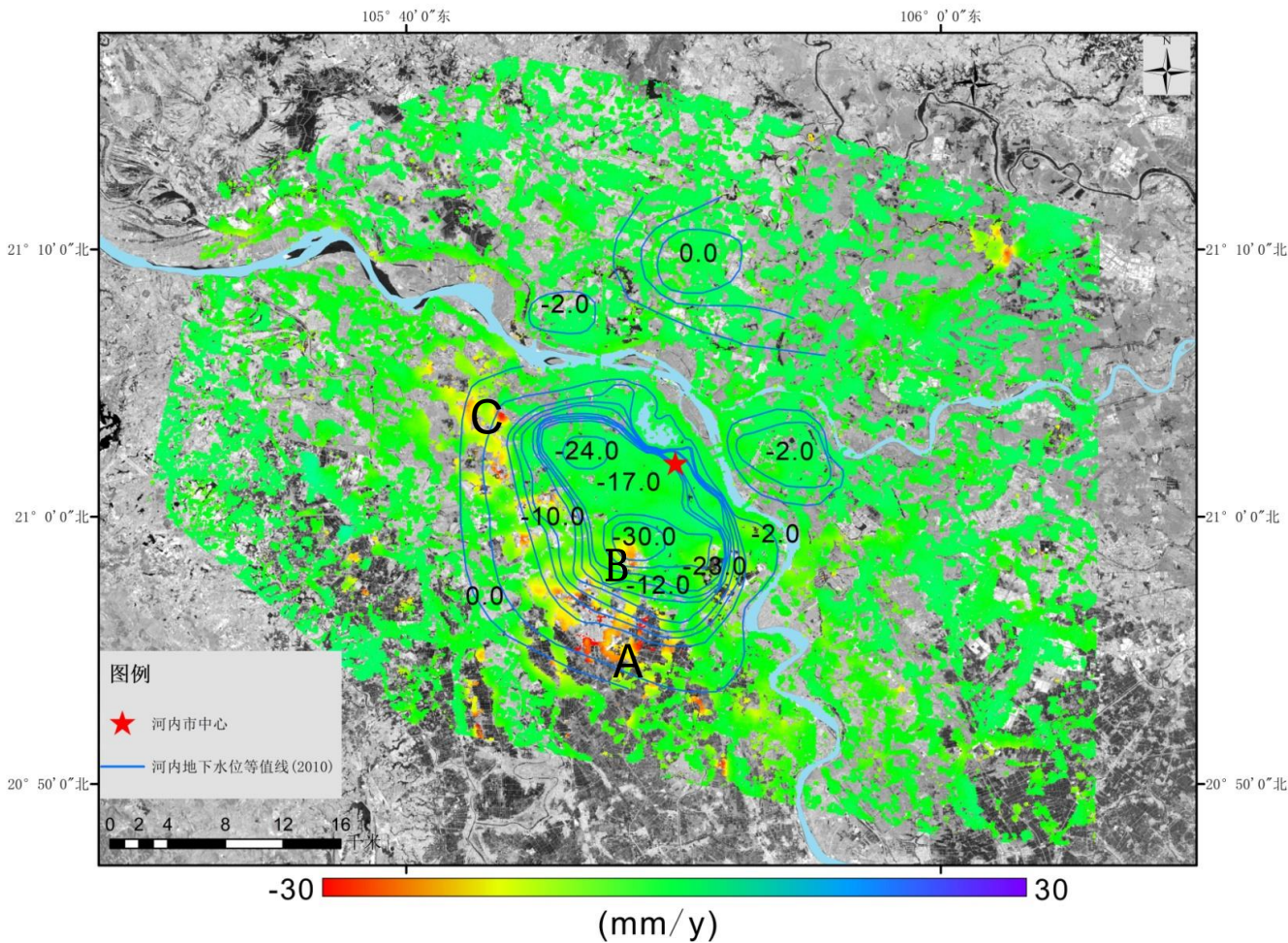
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2.2 中国-越南三角洲地面沉降监测对比研究 (中国牵头)



河内Sentinel-1A降轨数据遥感解译结果 (2016.4-2021.2)



河内市地下水监测 (2010年) 与地面沉降监测 (2021年) 对比分析:

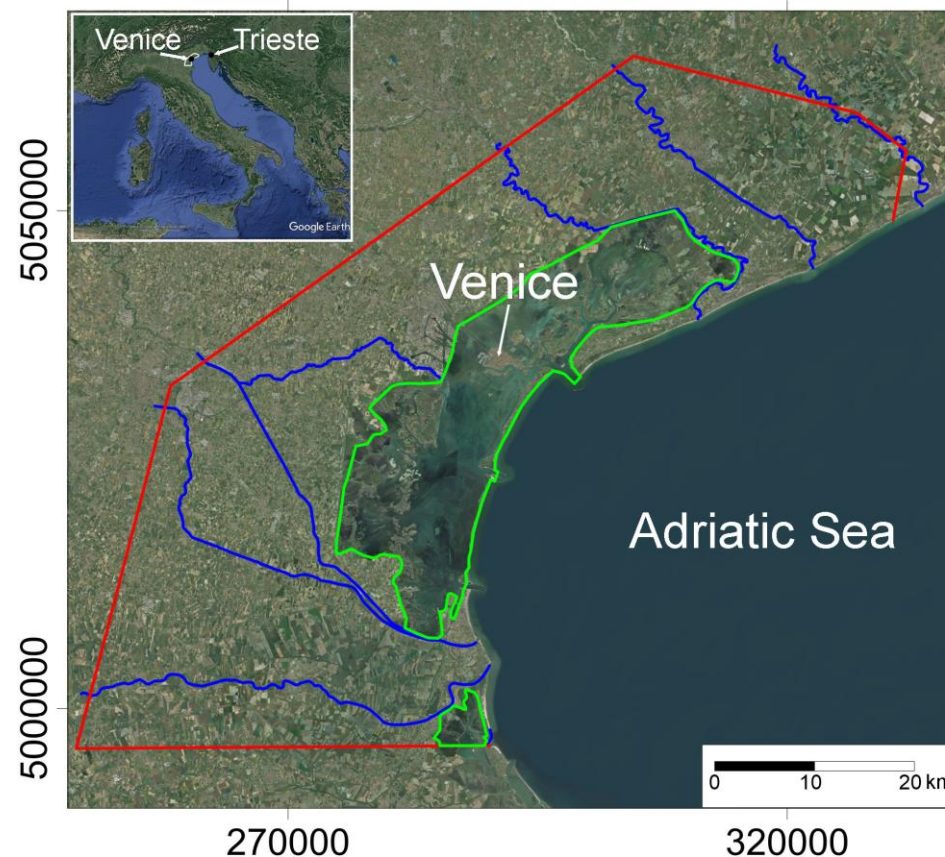
- 河内市地下水日开采量达100万，地面沉降主要诱发因素为地下水过量开采。
- 地面沉降漏斗区与地下水位漏斗区不一致，发生了西南部迁移，这与地下水开采区域向西南部转变是一致的。



2.3 威尼斯沿海地区海平面上升的脆弱性研究（意大利牵头）



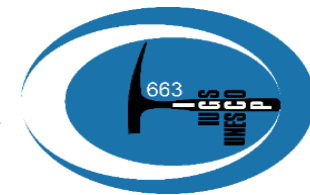
- 威尼斯是全球著名的水域，大部分地区低于或接近平均海平面，受地面沉降危害严重，其海岸地区形成了意大利主要的低洼地区，**相对海平面上升** (Relative sea level rise, RSLR)是目前世界上对海岸系统威胁最严重的过程之一。
- 地面沉降、海平面上升是威胁威尼斯城市生存和发展的双重因素，全球气候变化背景下的海平面上升对沿海地区的脆弱性分析研究非常必要。



威尼斯海岸地区卫星影像图

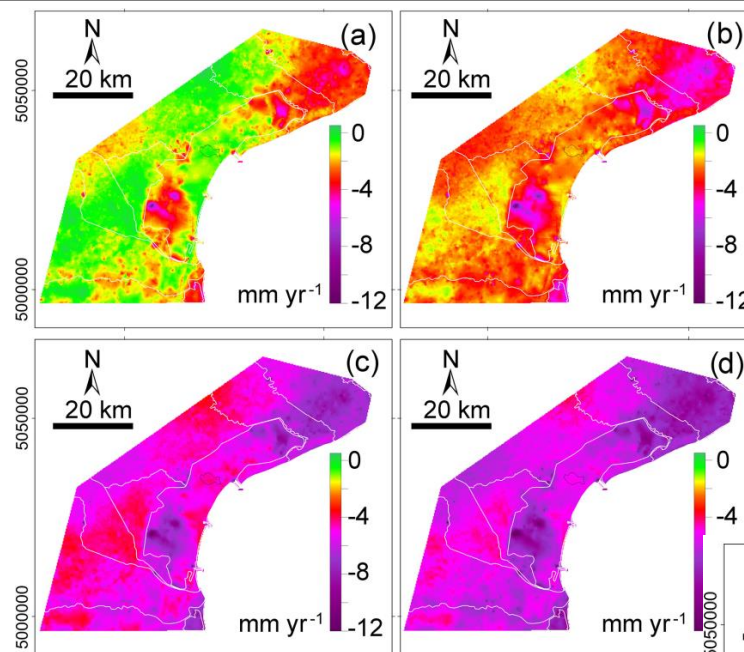


2.3 威尼斯沿海地区海平面上升的脆弱性研究（意大利牵头）

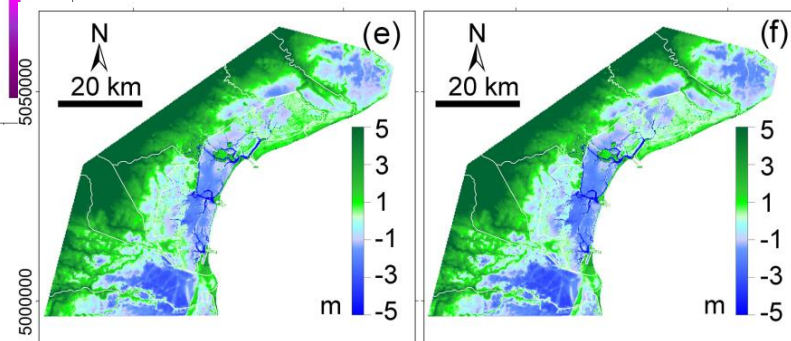


◆ 基于指数模型和不同工况的适当耦合，采用高分辨率SAR影像卫星数据解译，并根据里雅斯特(北亚得里亚海)潮汐测量站数据计算，获得了长时序(1875-2018年)和短时序(1992 - 2018年)条件下的海平面上升速率分别为1.3和3.8 mm/yr。

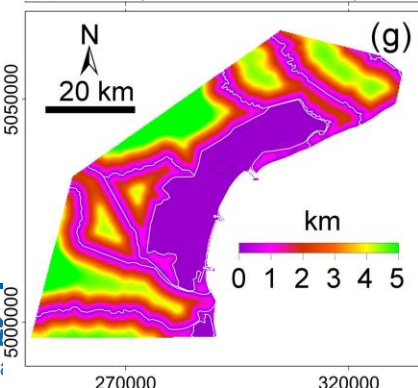
◆ 采用联合国发布的全球平均海平面上升的最不利情况预估，远期预测2100年海平面将上升0.74米，到2050年平均速率为5 mm/yr。



不同工况下的RSLR速率
a.现状条件； b.长时序条件(1875-2018)； c.短时序条件(1992 - 2018)； d.远期预测(2018 - 2050)。



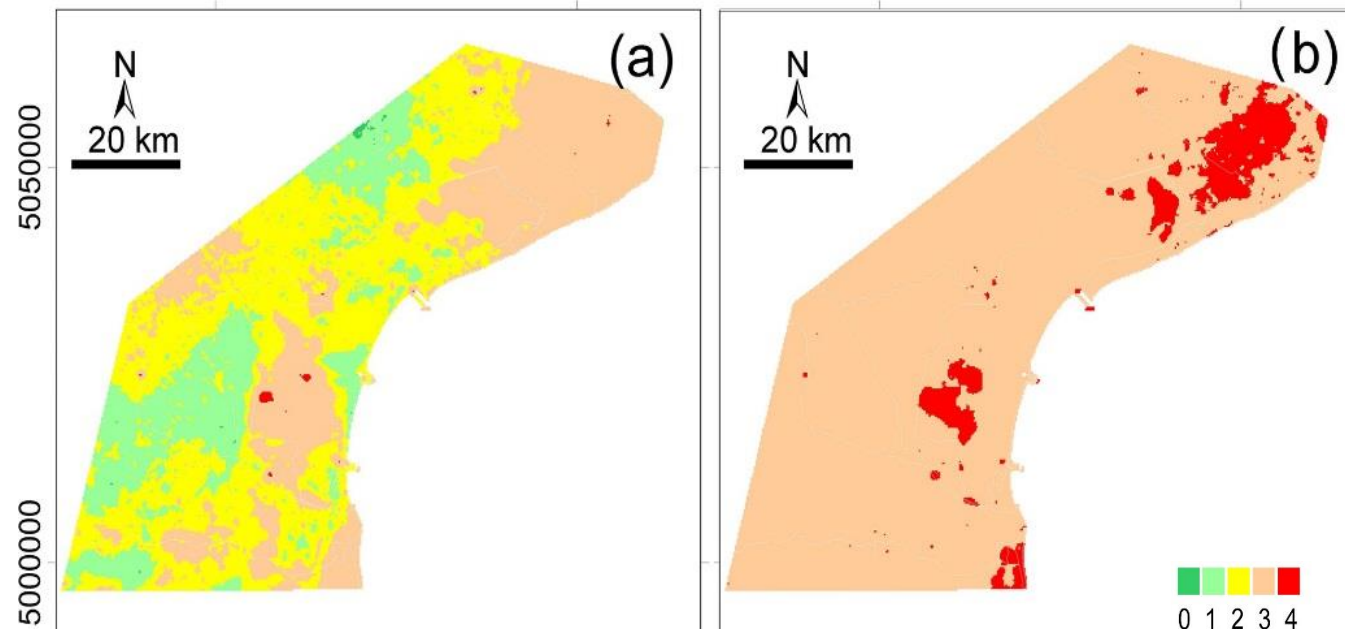
威尼斯海岸地面高程
e.2019年高程； f.2050年高程； g.与海岸线距离



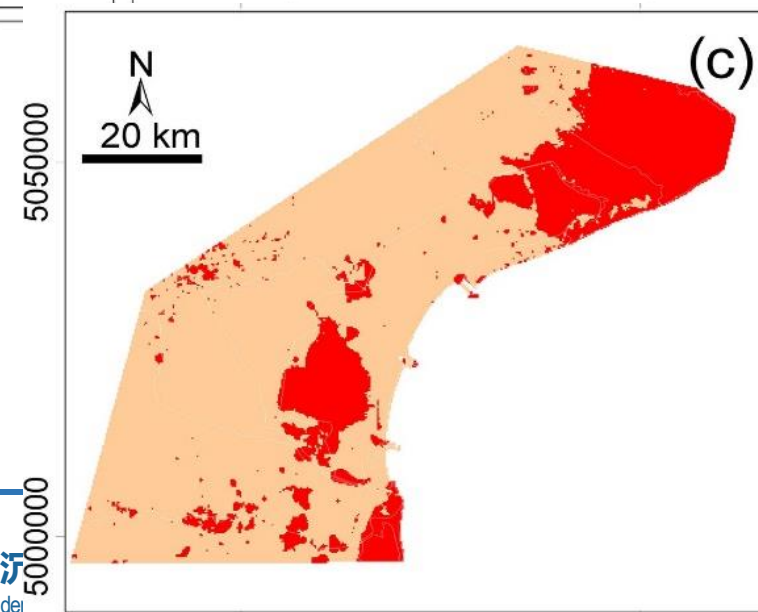
2.3 威尼斯沿海地区海平面上升的脆弱性研究（意大利牵头）



- 威尼斯沿海地区RSLR危险性分级：0-4表示危险性由低到高
- 考虑到威尼斯地区的特殊性，地面高程越低，其危险性越高。



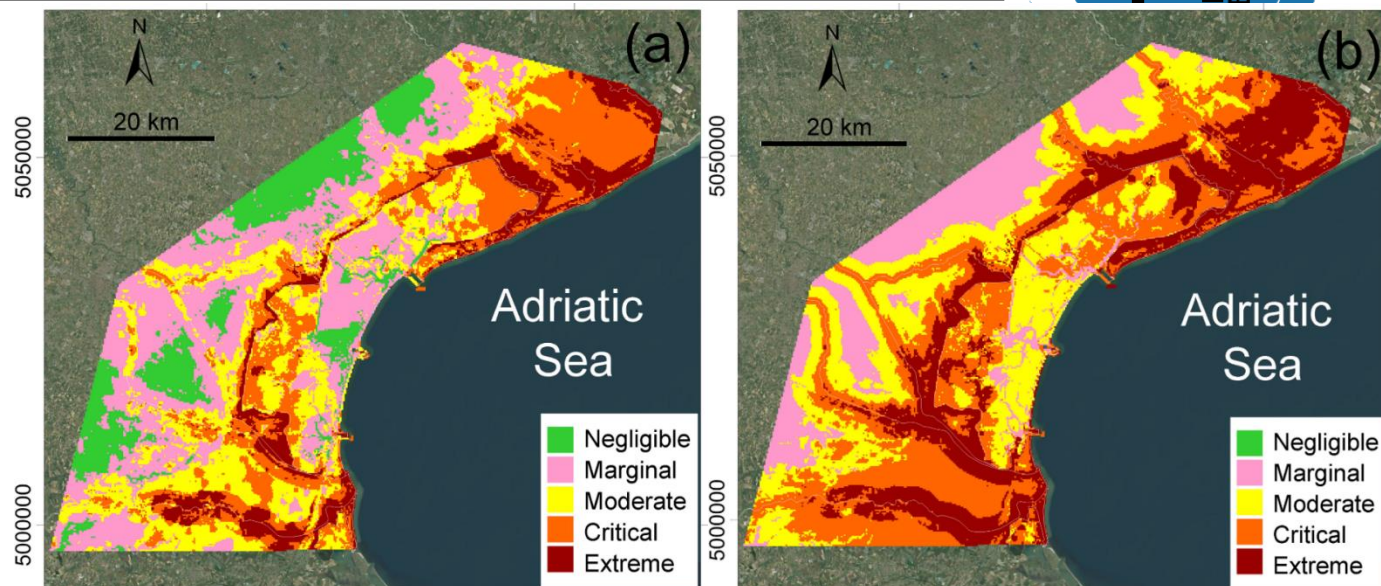
RSLR危险性分级：a. 长时序条件；b. 短时序条件；c. 远期预测



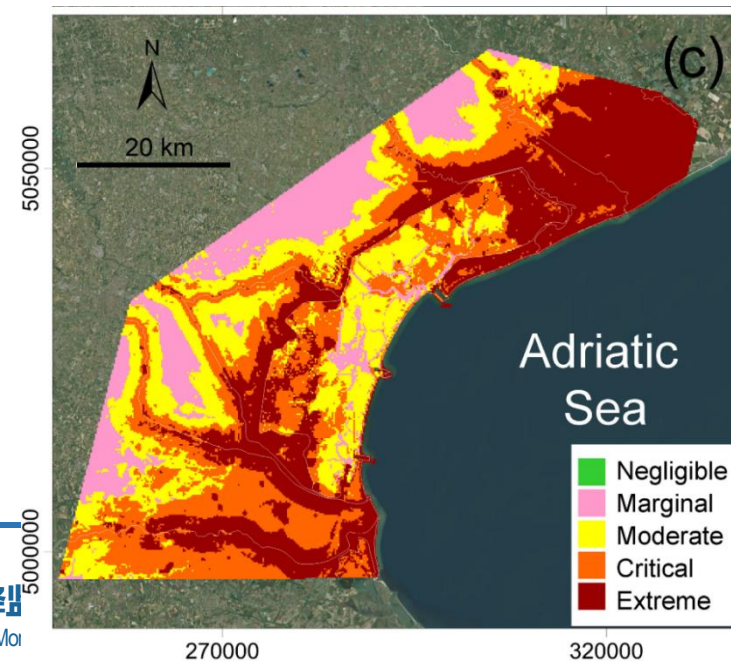
2.3 威尼斯沿海地区海平面上升的脆弱性研究（意大利牵头）



- 评估表明RSLR脆弱性在不同区域间表现出显著的差异性，反映了地面沉降和水文环境的异质性。
- 区域地面沉降速率（1-5mm/yr），是影响相对海平面上升脆弱性的关键，威尼斯沿海地区脆弱性评估中的地面沉降与海平面上升的贡献权重相当。
- 基于长时序条件下，30.5%、23.5%和10%的沿海地区被划分为**较低脆弱**、**中度脆弱**和**极端脆弱**状态，中度脆弱以上地区占比达**56%**。



RSLR脆弱性评估：(a)基于长时间序列条件(1875-2018)；(b)基于短时间序列条件(1992 - 2018) (c)基于远期预测(2018 - 2050)



■2.4 沿海地区地面沉降防治“6M”方法研究（荷兰牵头）



- 基于地面沉降缓变性、累积性、长期性、系统性、不可逆等特点，项目组联合UNESCO LASII共同研究提出了三角洲地区地面沉降防治“6M”方法，也是完整闭环的六步法。
- **6M方法**：M1沉降测量、M2沉降机理、M3预测模型、M4资金保障、M5措施实施、M6监测评价



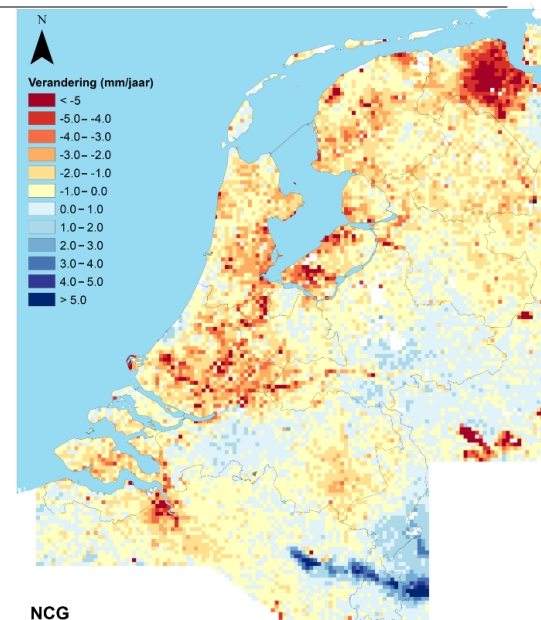
■2.4 沿海地区地面沉降防治“6M”方法研究（荷兰牵头）



□ **M1地面沉降测量**：发现地面沉降现象，掌握地面沉降发育历史与现状。

➤ **实例1：印尼雅加达**（1926年发现地面沉降现象，1978年发布首次测量报告，1990年以后开始专项地面沉降测量工作。）

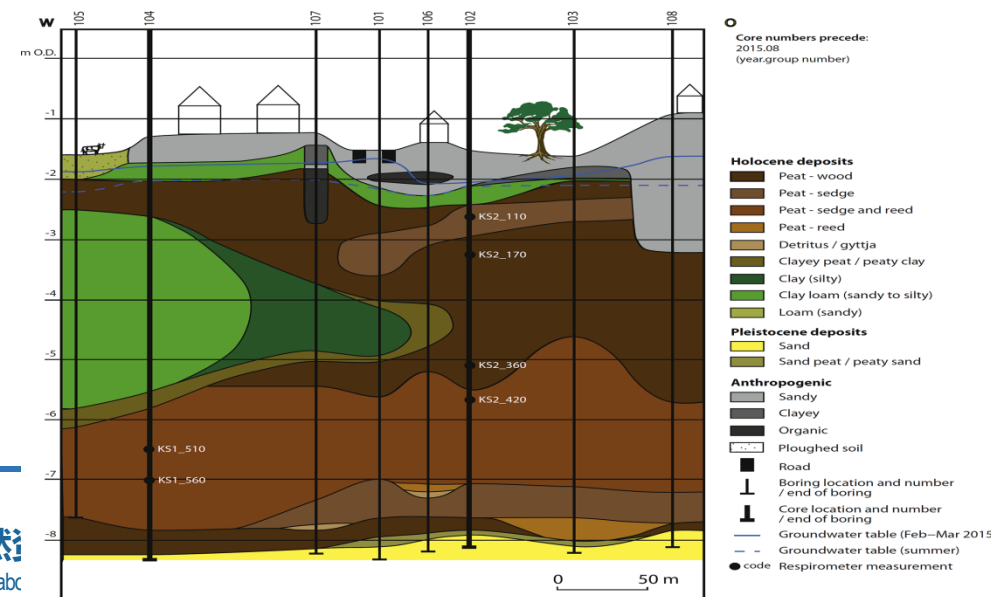
➤ **实例2：荷兰**2019年发布第一张基于PS InSAR、GNSS和重力联合测量的的全国范围的绝对变形矢量图，测量结果表明荷兰大部分地区在持续下沉。



荷兰地区地面沉降速率（2015~2018）

□ **M2地面沉降机理**：调查不同地区地面沉降的成因（自然因素、人类工程活动），揭示地面沉降发育规律。

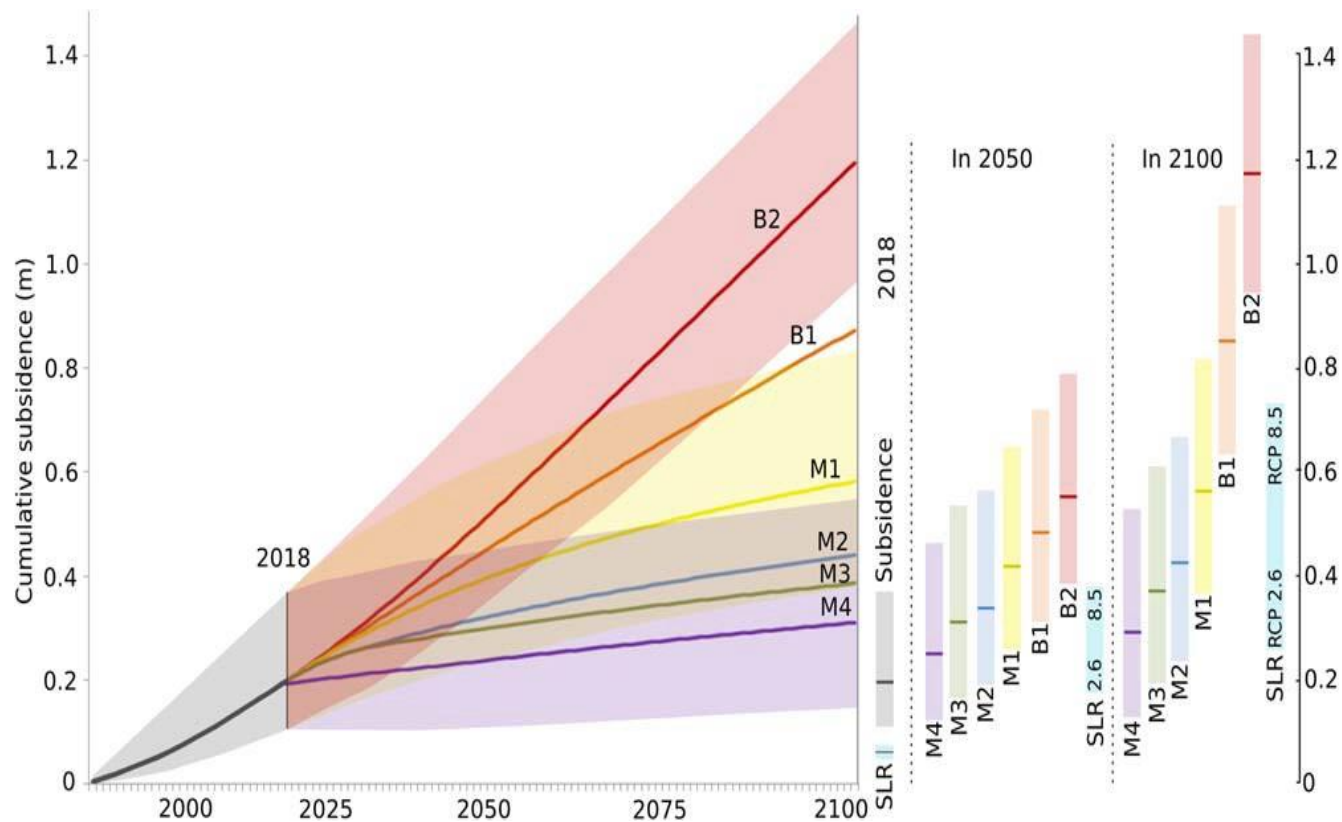
➤ **实例：荷兰**泥炭土(棕色)广分布泛，当地下水位低于泥炭土层顶时，泥炭氧化是诱发地面沉降主因，通过岩土力学特性分析，揭示地面沉降致灾机理。



■2.4 沿海地区地面沉降防治“6M”方法研究（荷兰牵头）



- **M3地面沉降预测模型**：应用建模技术方法判断地面沉降发展趋势，但目前多应用场景的综合预测模型仍是难点。
- **实例：越南湄公河三角洲**，采用数值模型预测未来80年湄公河三角洲地面沉降，模拟了六种地下水开采场景下的地下水位和地面沉降动态，揭示了通过限制地下水开采来减少地面沉降措施的作用和潜力。



湄公河三角洲不同地下水开采路径的平均累积沉降量
(Minderhoud et al., 2020)



■2.4 沿海地区地面沉降防治“6M”方法研究（荷兰牵头）



- **M4资金保障**：需要进行成本-效益分析，帮助决策者定量深入了解地面沉降管控措施的隐性成本和潜在效益；
- **M5措施实施**：需要根据M1~M4的分析，制定出适应性的地面沉降防治规划，并依托主管机构长期开展地面沉降防治工作；
- **M6监测评价**：重点是对M1~M5的有效性验证，监测评价的结果将有助于适时调整已采取的地面沉降防治措施。



■2.4 沿海地区地面沉降防治“6M”方法研究（荷兰牵头）



□ 6M方法：适用于全球沿海城市地面沉降防治

- 指导决策者通过基于全球任意地方的最佳实践案例（如中国上海），进行适用于当地的科学有效的地面沉降防治
- 为科学研究提供了一个适用的、统一的背景。通过将地面沉降研究确定为6个步骤中的一个或多个步骤的组成部分，研究成果可以更有效地分享、交流和推广。



2.5 项目主要科研成果统计



■ 论文发表：

➤ 本年度项目组累计发表

论文 30 余篇，其中

SCI/EI检索论文 10 余篇

Acta Geologica Sinica (English Edition), 2020, 94(1): 162–175

Advances and Practices on the Research, Prevention and Control of Land Subsidence in Coastal Cities

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Abstract: Land subsidence severely threatens most of the coastal plains around the world where high productive industrial and agricultural activities and urban centers are concentrated. Coastal subsidence damages infrastructures and exacerbates the effect of the sea-level rise at regional scale. Although it is a well-known process, there is still much more to be improved on the monitoring, mapping and modeling of ground movements, as well as the understanding of controlling mechanisms. The International Geoscience Programme recently approved an international project (IGCP 663) aiming to bring together worldwide researchers to share expertise on subsidence processes typically occurring in coastal areas and cities, including basic research, monitoring and observation, modelling and management. In this paper, we provide the research communities and potential stakeholders with the basic information on the participating teams in developing this project. Specifically, major advances on coastal subsidence studies and information on well-known and new case studies of land subsidence in China, Italy, The Netherlands, Indonesia, Vietnam and Thailand are highlighted and summarized. Meanwhile, the networking, dissemination, annual meeting and field trip are briefly introduced.

Key words: land subsidence, coastal cities, case studies, International Geoscience Programme

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1 Introduction

Land subsidence, the lowering of ground surface due to natural and human-induced processes occurring in the shallow and deep subsurface, is a worldwide geohazard. Land subsidence causes damages and has widespread impacts on a variety of infrastructures, e.g., sewer systems, roads, buildings, subway tunnels and in coastal low-lying areas. In the cities in proximity to shorelines, such as Shanghai, Jakarta and Venice, it is particularly alarming as it reduces the ground elevation with respect to the sea level.

Nowadays the majority of coastal areas affected by land subsidence are characterized by a limited surface elevation

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《Acta Geologica Sinica (English Edition)》发表论文

Report

by Xuexin Yan^{1,2}, Yan Xu^{1,2,*}, Tianliang Yang^{1,2,3}, Luigi Tosi⁴, Esther Stouthamer⁴, Philip Minderhoud^{1,5,6}, Pietro Teatini^{5,6}, Henk Kooij⁷, Heri Andreas⁷, Dhota Pradipta⁸, Sandra Donnici⁹, and Roberta Boni⁸

Sustainable development of coastal cities through control of land subsidence: activities of IGCP Project 663 in Jakarta

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<https://doi.org/10.18814/epings/2021.02.1014>

The awareness on the importance that land subsidence plays on coastal processes at the regional scale is increased over the last two decades, and it clearly appears that land subsidence can contribute primarily to the relative sea level rise affecting coastal zones. Jakarta is one of the cities mostly affected by the combination of sea-level rise and land subsidence. In this paper, the activities carried out in Jakarta under the umbrella of the IGCP Project 663 were presented, and the possible measures and best practices mitigating land subsidence for the research associates and potential stakeholders were provided, with which can serve as inspiration for authorities and communities facing land subsidence. Meanwhile, major achievements of IGCP 663 in Jakarta were summarized and introduced, including dissemination session, scientific session and field trips. Specifically, major advances on coastal subsidence studies regarding the effect of relative sea level rise, subsidence mapping, monitoring and simulation, as well as the support of policy making are highlighted and summarized.

Vietnam and Pakistan attended the workshop, among which over 90% were from developing countries.

This workshop arranged a roundtable meeting, annual work report, keynote lectures, oral and poster presentations by young professionals, technical teaching and training, field trips, etc. The Indonesian government held an official ceremony for the release of the "Road map for prevention and control of land subsidence in the coastal lowland of Indonesia". The vice-president of the UNESCO LASII, Pietro Teatini, addressed the conference and gave a keynote lecture.

After the meeting, a field trip was organized in Jakarta, and four sites seriously affected by land subsidence were investigated.

Dissemination Session

Low-lying coastal areas generally encompass a variety of environments, such as farmlands, estuaries, deltas, lagoons and urbanized areas including valuable ecosystems, historical heritages and economic activities, which are severely jeopardized by land subsidence combined with sea-level rise. Within IGCP 663 we developed an analysis of the vulnerability of these environments to relative sea level rise (RSLR) considering an uneven land subsidence distribution that improved the assessment of vulnerability to RSLR at the regional scale. The outcomes of the analysis are available to the authorities responsible for water resources and coastal protection (Wang et al., 2012; Irksana and Stouthamer, 2020; Yang et al., 2020).

Jakarta is one of the cities mostly affected by the combination of sea-level rise and land subsidence. It has been calculated that if necessary measures are not taken, around 27% of Jakarta may be below the sea level in 2025 (Andreas et al., 2018). The project team promoted the development and launch of a "Road map for prevention and control of land subsidence in the coastal lowland of Indonesia" (Fig. 1), and co-hosted an official ceremony with the Indonesian government

《Episodes》发表论文



<http://igcp.sigs.cn>

上海市地质调查研究院
Shanghai Institute of Geological Survey

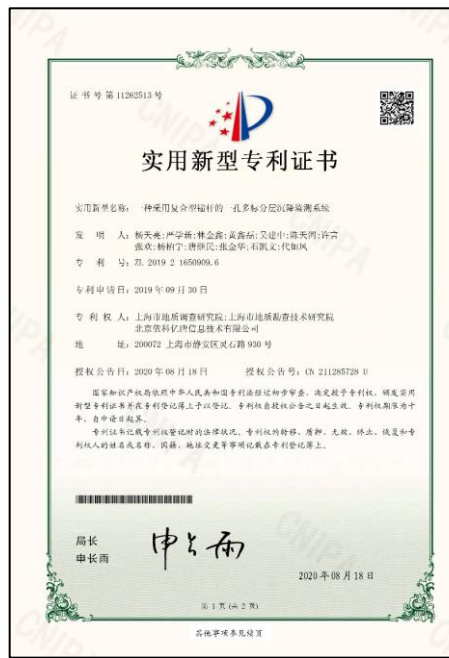
自然资源部地面沉降监测与防治重点实验室
Key Laboratory of Land Subsidence Monitoring and Prevention, Ministry of Natural Resources

2.5 项目主要科研成果统计



■ 国家专利2项，软件著作权1项

- 一种采用复合型锚杆的一孔多标分层沉降监测系统(ZL201921650909.6)
- 一种用于地下水人工回灌深井的修复装置(ZL201921650908.1)
- 地下水流-地面沉降三维可视化模型软件(GW-LS 3DVM, 2021SR0876182)

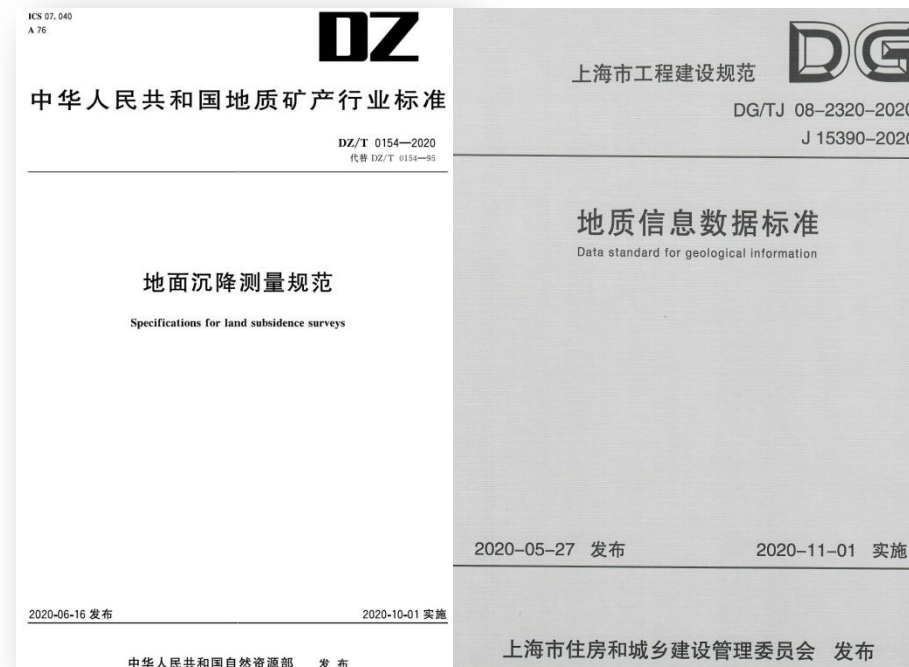


2.5 项目主要科研成果统计

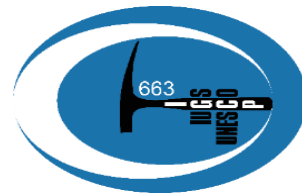


■ 主编行业和地方标准/指南4部，参编国际指南1部

序号	标准名称	类型	进展
1	地面沉降监测与防治技术标准 (DG/TJ08-2051-2021)	上海市标准	已发布
2	地质信息数据规范 (DG/TJ 08-2320-2020)	上海市标准	已发布
3	地面沉降测量规范 (DZ/T 0154-2020)	行业标准	已发布
4	中国地质灾害防治指南 (地面沉降)	行业指南	在编
5	地面沉降减灾指南(Guidelines for Mitigation of Land Subsidence)	美国土木工程师协会 (ASCE)	在编



2.6 国内外学术交流研讨



■ 国际学术交流



2.6 国内外学术交流研讨



国内学术交流：主/承办大型学术会议5次



2020年长三角地区地面沉降联防联控年会



地质环境与城市安全专题学术研讨会



城市病害专题学术研讨会



2.6 国内外学术交流研讨

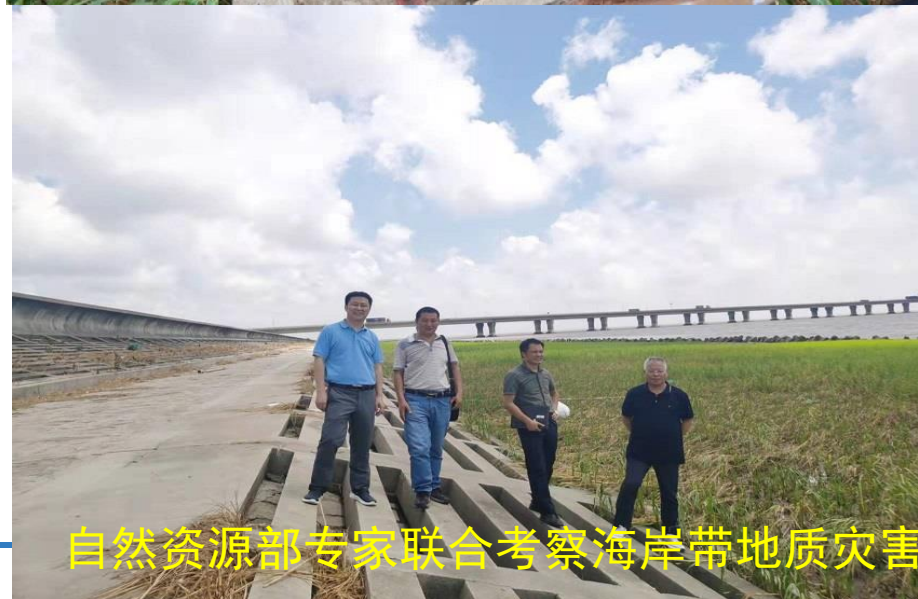
■ 长三角地区地面沉降防治考察交流



自然资源部与长三角地区领导专家考察长三角一体化发展示范区



考察上海地面沉降监测设施



自然资源部专家联合考察海岸带地质灾害



2.7 科技讲座与科普宣传



科技讲座：线上线下专题讲座7次



世界地球日上海科普高端论坛



上海市地面沉降“前世今生”



上海市地面沉降历史及防控



2.7 科技讲座与科普宣传

■ 科学普及

- 研究团队开展地学科普讲座进社区、进校园活动6场
- 累计为1000余名大中小學生和社会公众提供地学科普讲座

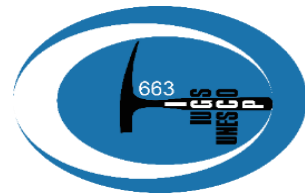




三、2022年工作计划



2022年度工作计划



项目	工作内容
基础研究	<ul style="list-style-type: none">· 编制地面沉降防治指南/地面沉降减灾指南· 深入推进中越、中墨地面沉降监测与防治技术合作· 联合发表科技成果
成果推广与能力建设	<ul style="list-style-type: none">· 持续拓展地面沉降国际研究网络· 参加第10届国际地面沉降研讨会（TISOLS）· 开展科普教育活动
项目会议	<ul style="list-style-type: none">· 2022年学术年会，2022年4月，荷兰代尔夫特
其他计划	<ul style="list-style-type: none">· IGCP项目延续申报





请指正，谢谢！



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Key Laboratory of Land Subsidence Monitoring and Prevention, Ministry of Natural Resources