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Space for climate action(13-15 September, 2022)

中国矿业大学
CHINA UNIVERSITY OF MINING AND TECHNOLOGY

资源与地球科学学院
School of Resources and Geosciences

OpenGCS (Geological CO_2 Sequestration) Online Monitoring Platform

Hui Yang[1,*], Yina Qiao[1], Xiang Ru[1], Gefei Feng[2], Bing Zhang[3], Hui Xu[4], Hui Ci[1], Ran Wang[1], Zhaojin Yan[1]

[1]China University of Mining and Technology, Xuzhou, China

[2]Jiangsu Normal University, Xuzhou, China

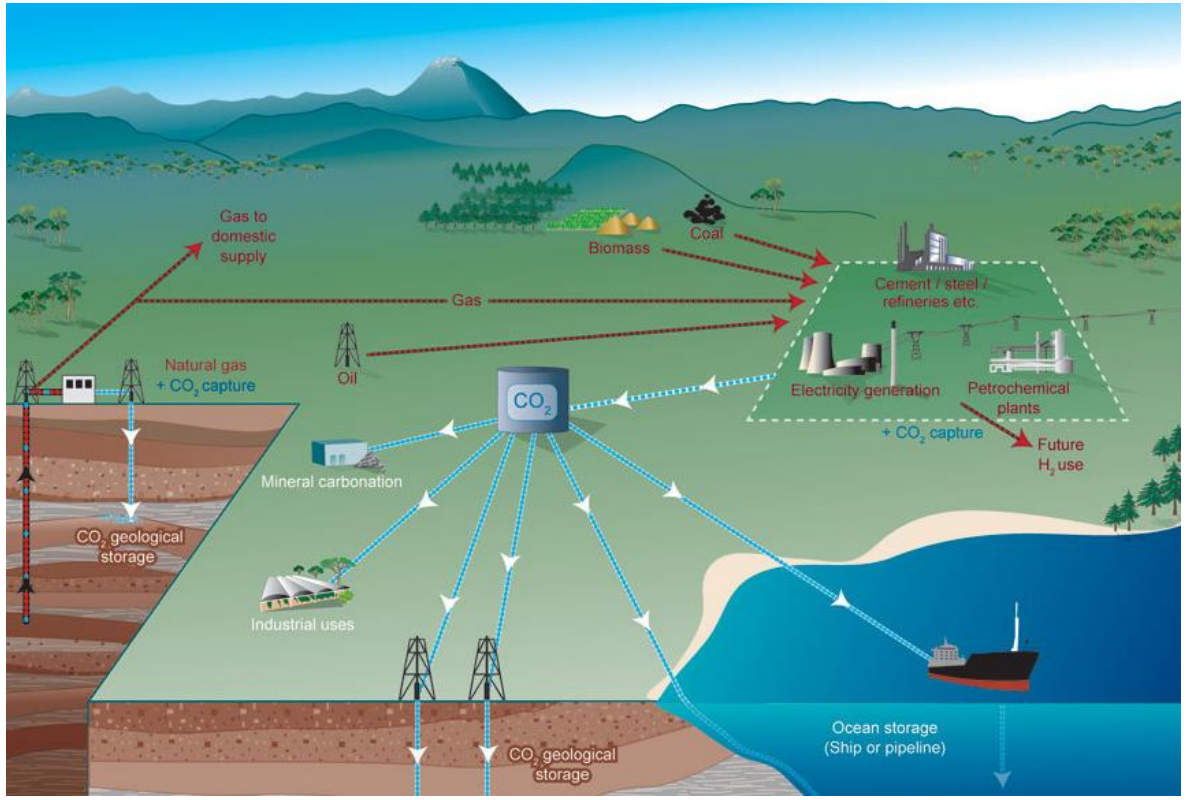
[3]China United Coalbed Methane Co., Ltd, Beijing, China

[4]Jiangsu Institute of Geology and Mineral Resources Design, Xuzhou, China

[*]Correspondence: huiyang@cumt.edu.cn; +8615162138990, https://orcid.org/0000-0001-9421-3573

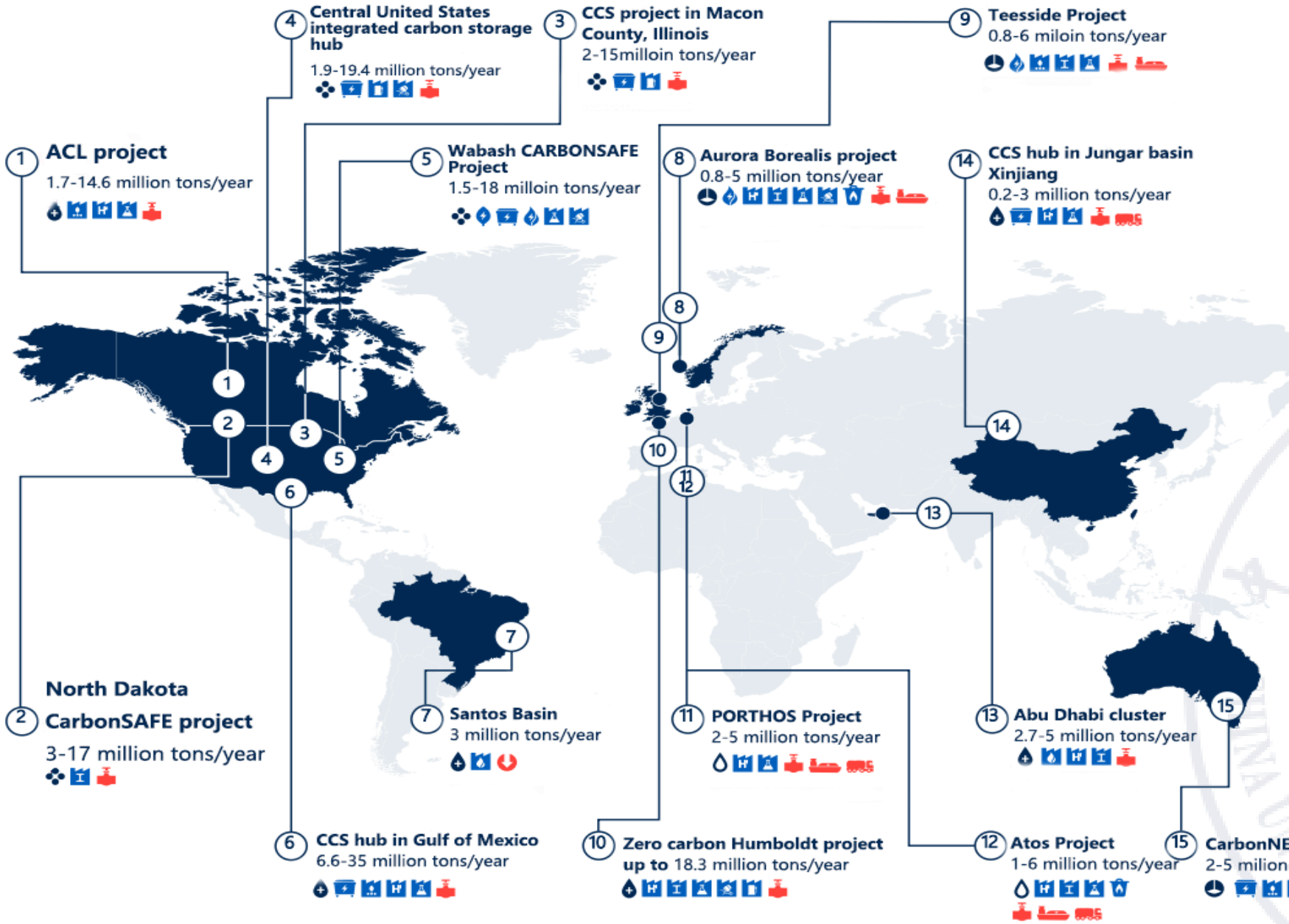
Introduction

- **Geologic Carbon Sequestration (GCS)** is on the one hand an effective way to realize the GHG storage, and on the other to improve oil and gas production.



- GCS captures the CO_2 emissions from large point sources and transports and stores it in relatively geological structures or oceans for a long time.
- It is one of the effective technologies to significantly reduce global emissions into the climate system.

Distribution of GCS projects in the world

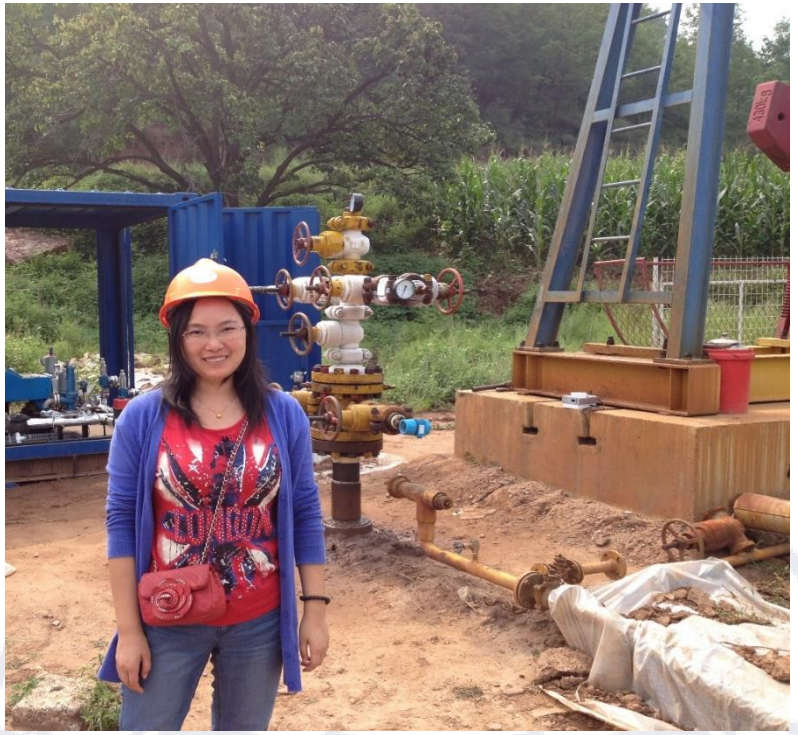


- 135 commercial CCS facilities in the project pipeline worldlide, with 27 fully operational.

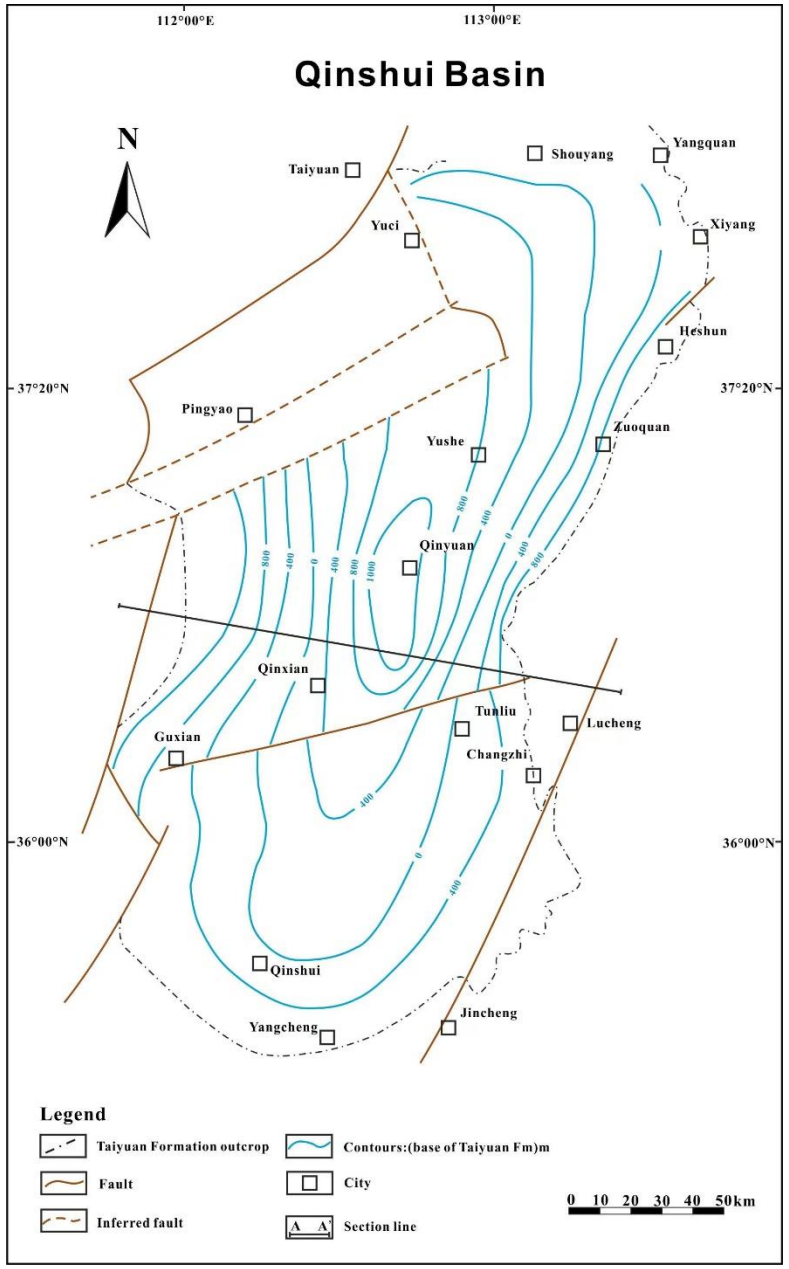
• International	
Sleipner gas field project	Norway
Weyburn oil field project	Canada
In Salah gas field project	Algiers
West Pearl Queen	U.S.
Nagaoka,	Janpan
.....	
• China	
Jilin oil field project	China
Qinshui Baisn project	China

Pilot Test of CO2 Injection

- China's GCS projects started late, and there are few typical CO_2 geological storage demonstration projects in operation at this stage.
- Since 2011, the pilot test of CO_2 injection in Shizhuang North Block in Southern Qinshui Basin has been carried out by China United Coalbed Methane Co., Ltd.
- The goal is to provide free and open access to real-time monitoring data and long-term observations of GCS.

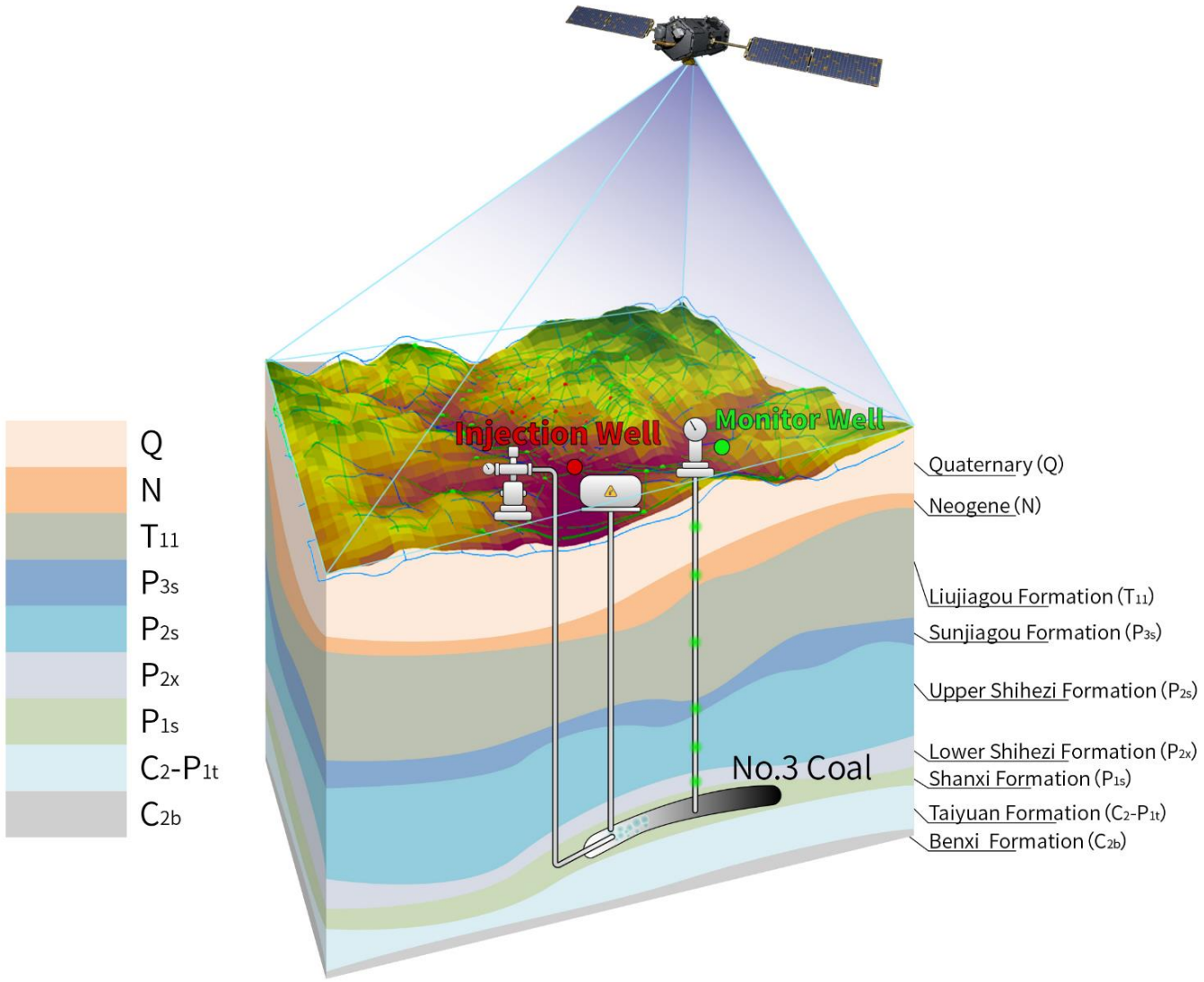


Southern Qinshui Basin-China



- Qinshui Basin is located in Qinshui County, Jincheng City, Southeast of Shanxi Province.
- It is west of Taihang mountain, east of Huo mountain, south of Xiakou Town, and south of Shanxi and Henan Province.
- Qinshui Basin is an important coalbed methane exploration area in China which is a compound syncline.
- In order to assure project performance , monitoring techniques need to be deployed to track CO_2 plume migration, assess leakage risk, and guard against environmental hazards.

Key technologies of GCS Online Monitoring



The Spatio-temperal Distribution of CO_2 in Geological Storage Area

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Analyze Spatio-temporal Factors in Geological Storage Area

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Develop CO_2 Monitoring Instrument based on WSN

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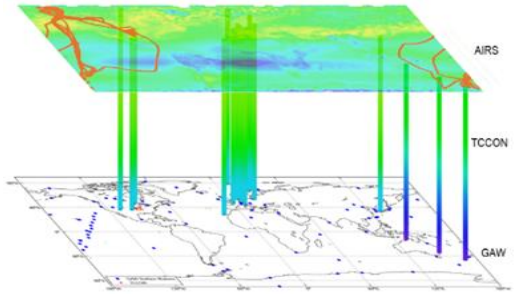
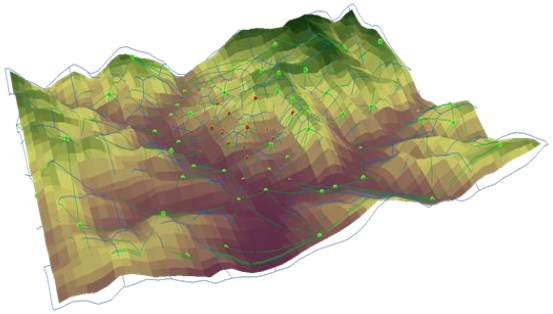
Optimizing Sensor Network Node Location in Geological Storage Area

Key technologies of GCS Online Monitoring





1 Global Monitoring

Spatio-temperal distribution of CO_2 concentrations

Online aggregation of real-time monitoring data and diffusion migration model

- To study the potential of the combination of high-resolution in situ surface and aircraft measurements for validating AIRS observations.
- To inter-compare with GAW, HIPPO, with reference to the TCCON from near surface level to mid-to-high troposphere.
- To analyze the spatial distribution, rising trend and seasonal variation using monthly averaged AIRS observations.

3 Regine Monitoring

Optimization design of near-surface monitoring network

Optimizing Sensor Network Node Location in Geological CO_2 Storage Area

- To analyze geological, geographical and meteorological data in GSC area.
- To design different coverage control schemes of monitoring sensor network nodes.
- To intensively or sparsely arrange sensor nodes based on Delaunay triangulation.

2 Local Monitoring

Surface environmental information monitoring

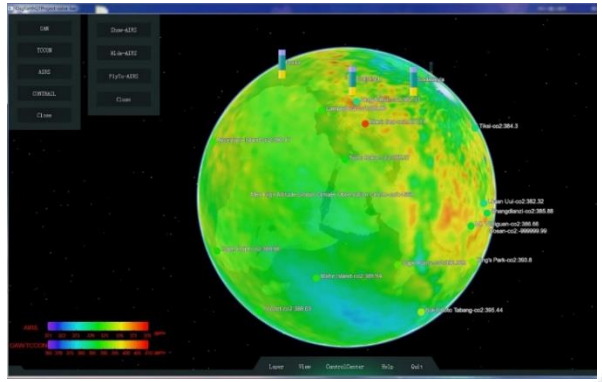
Develop CO_2 monitoring instrument based on WSN

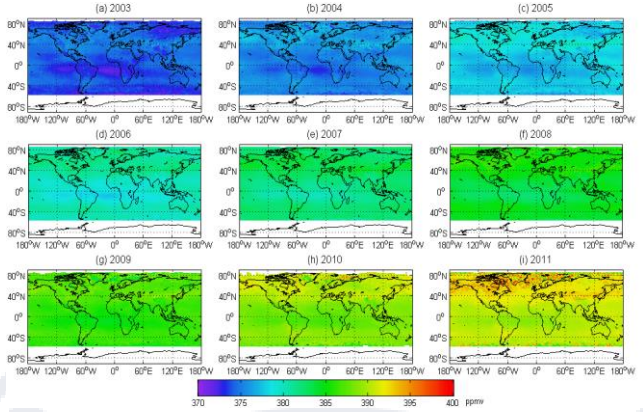
- To develop a remote real-time online surface environmental information monitoring instrument for surface CO_2 concentrations based on the Internet of Things technology.
- To design and develop a visual monitoring platform for GCS leakage based on cloud computing.

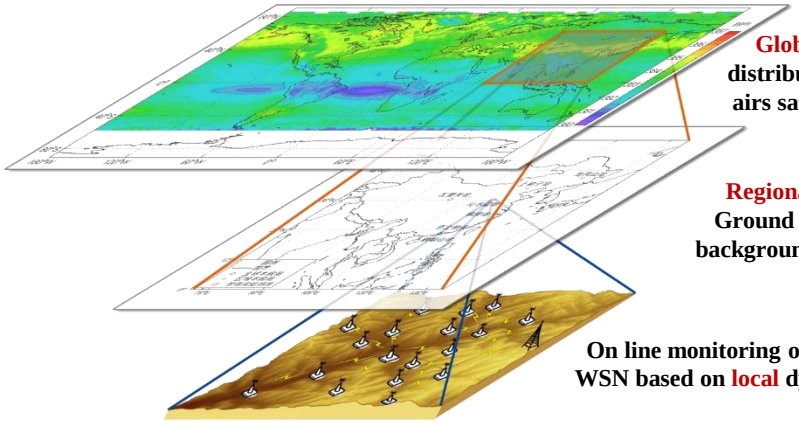
OpenGCS Online Monitoring - Global Monitoring

Spatial distribution and temporal variation of global CO_2 observations

CO_2 observations retrieved by Atmospheric Infrared Sounder (AIRS) were inter-compared with Global Atmosphere Watch Programme (GAW) and HIAPER Pole-to-Pole Observations (HIPPO), with reference to the calibration data obtained using the high-resolution ground based Fourier Transform Spectrometers (g-b FTS) in the Total Carbon Column Observing Network (TCCON) from near surface level to mid-to-high troposphere.



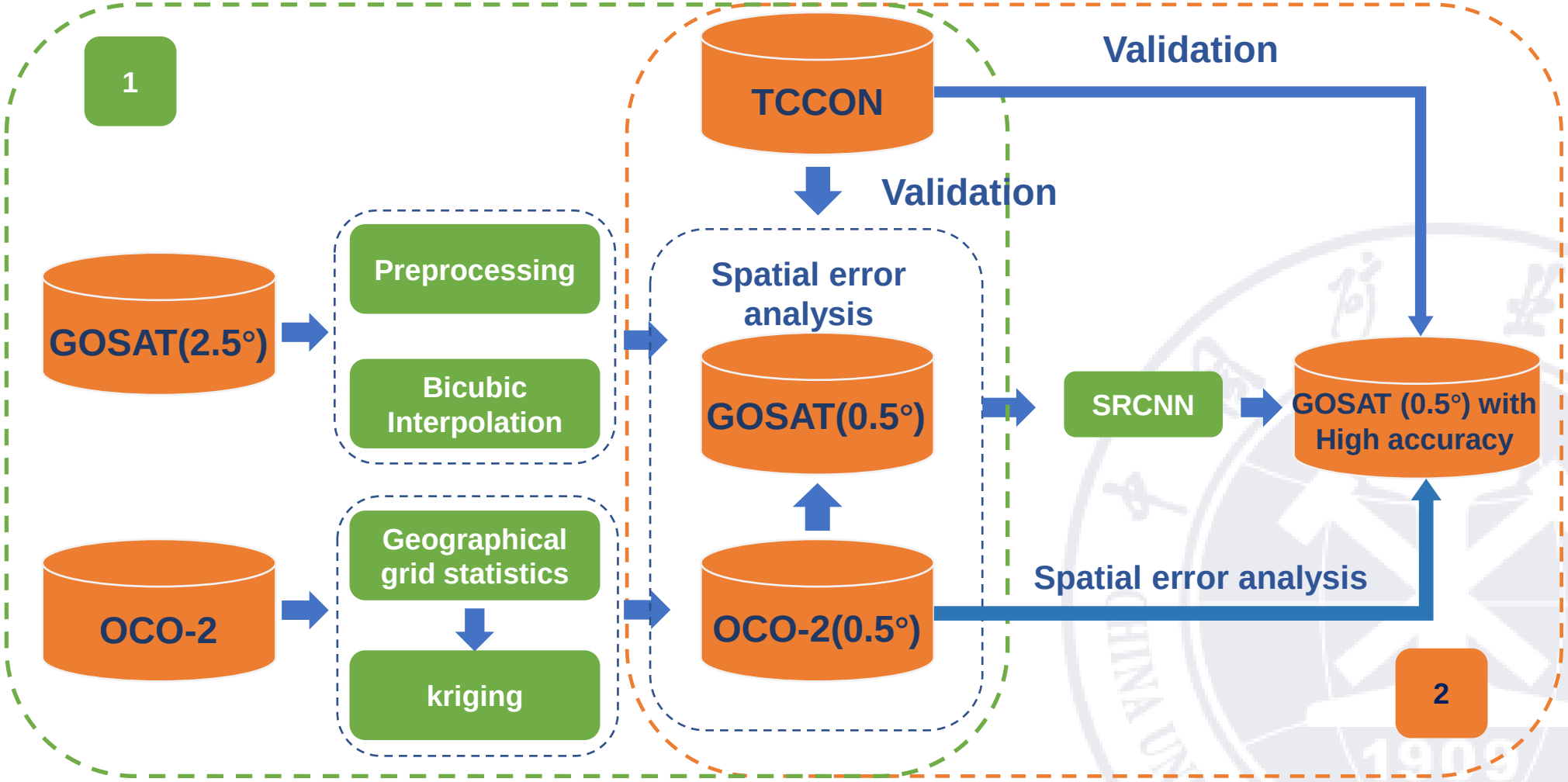




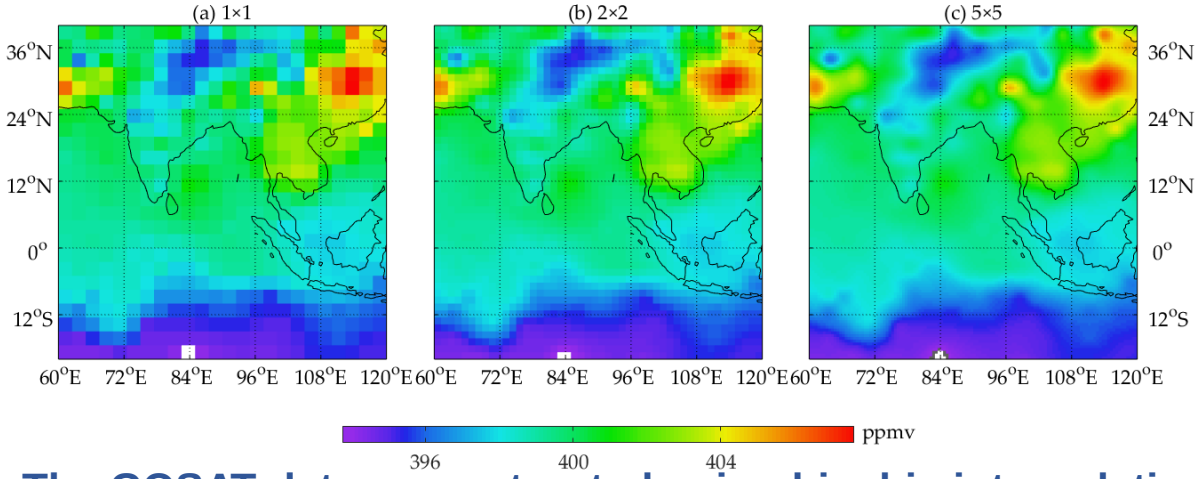
Technical connotation： To evaluate the long-term trends of the total CO_2 column concentrations, we inter-compared the mid-to-upper tropospheric CO_2 data from AIRS, TCCON and GAW of high accuracy for the period from January 2007 to December 2013. The study results prove the potential of AIRS satellite observations for monitoring and analyzing mid-tropospheric CO_2 concentration at global scales, which will provide new insights into more accurate, sufficient, stable and continuous XCO_2 observations.

OpenGCS Online Monitoring - Global Monitoring

➢ Super-resolution reconstruction of GOSAT using SRCNN



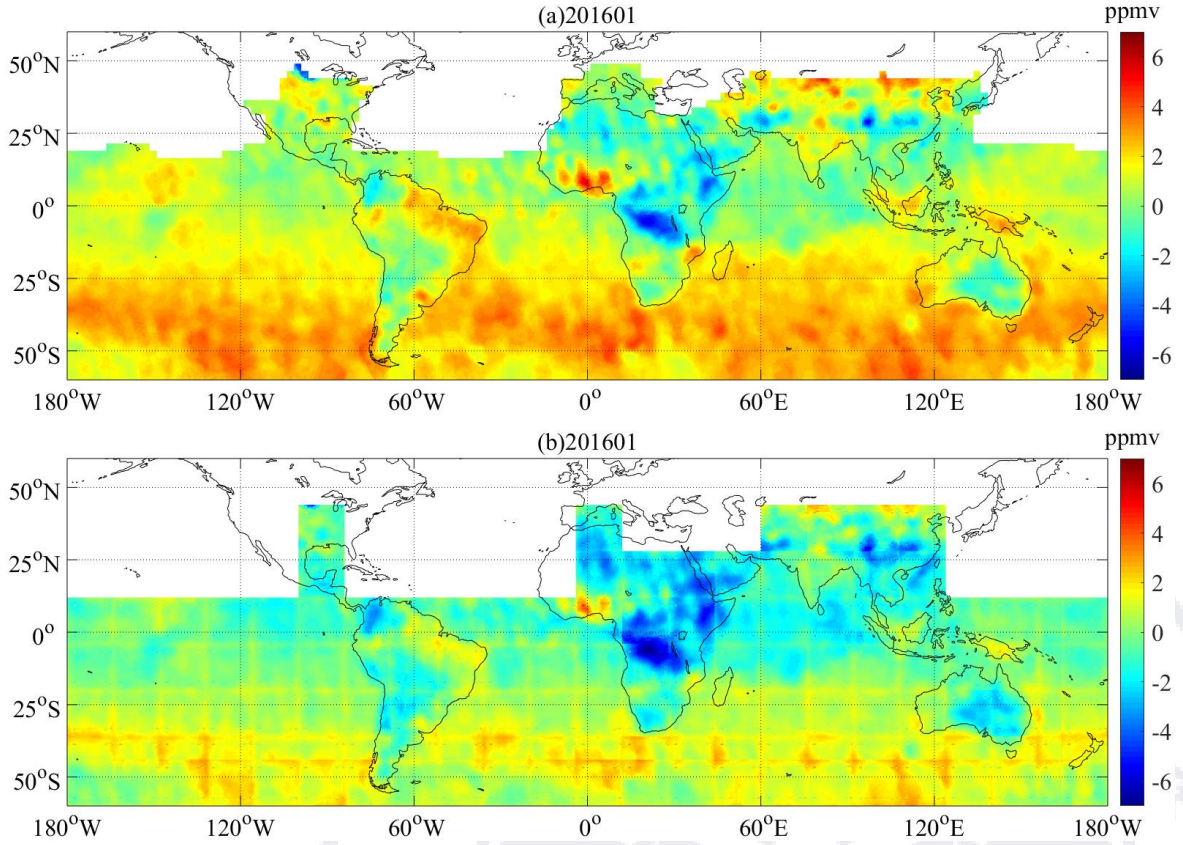
OpenGCS Online Monitoring - Global Monitoring



The GOSAT data reconstructed using bicubic interpolation (5×5 scale) results in better spatial continuity and is more suitable for mapping.

Data type	Effective pixels	ME	MAE	RMSE
GOSAT raw data (2.5°)	5616	1.274	1.574	1.864
Bicubic interpolation reconstruction results (0.5°)	131185	1.335	1.608	1.892
SRCNN reconstruction results (0.5°)	119905	0.041	1.082	1.357

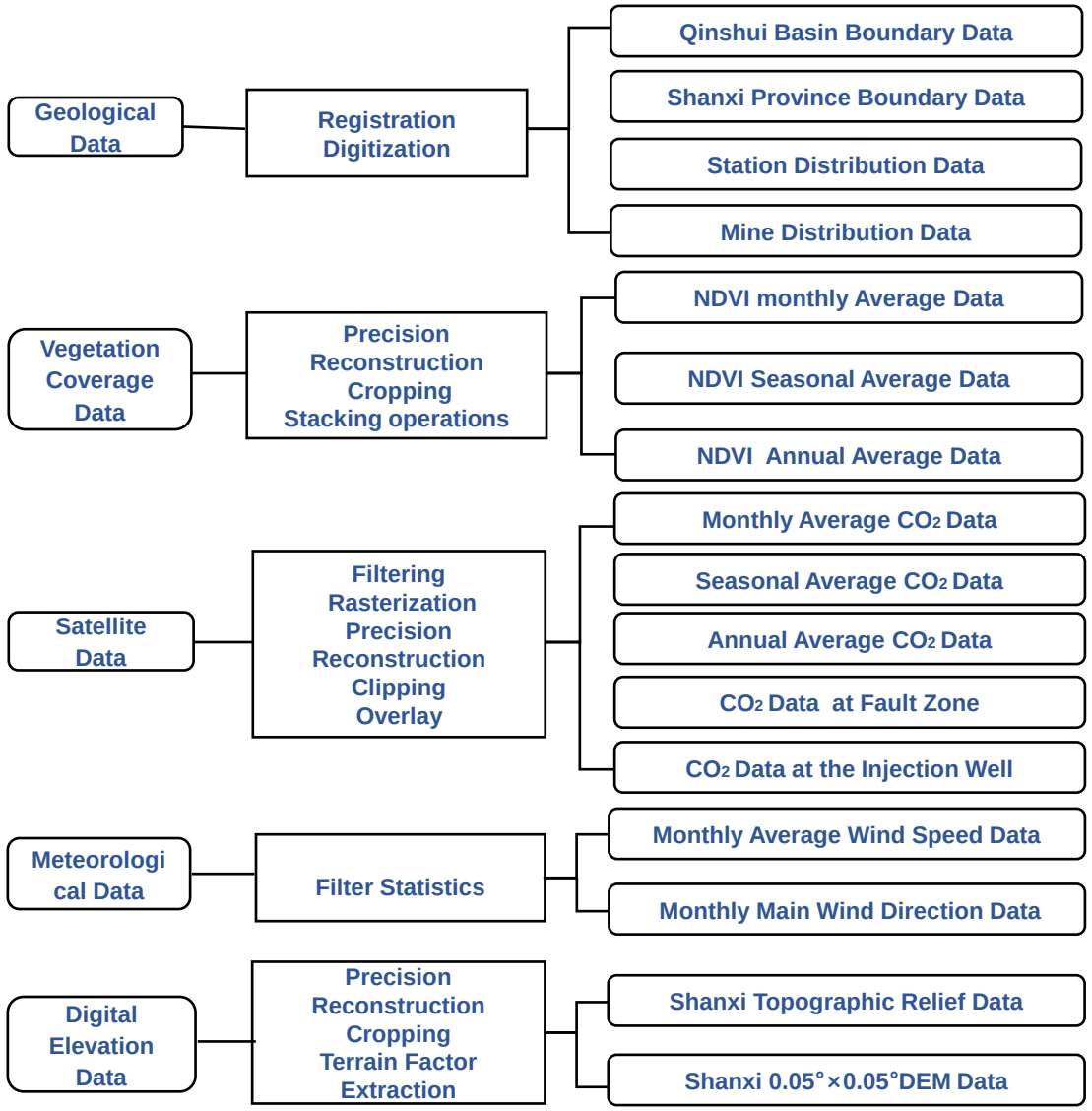
The reconstruction results of bicubic interpolation can maintain the average accuracy of the original data, and the reconstruction results of SRCNN have a high accuracy, with 0.5 PPMV accuracy improvement.



In January, the error spatial distribution of SRCNN reconstruction results is shown in Figure B, where the improved CO_2 accuracy is mainly distributed in the southern hemisphere, while the improved accuracy is less in the Northern hemisphere, which may be caused by sample imbalance.

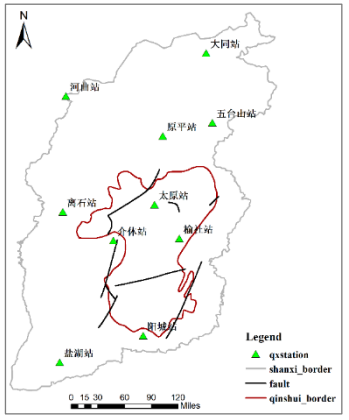
OpenGCS Online Monitoring – Regional Monitoring

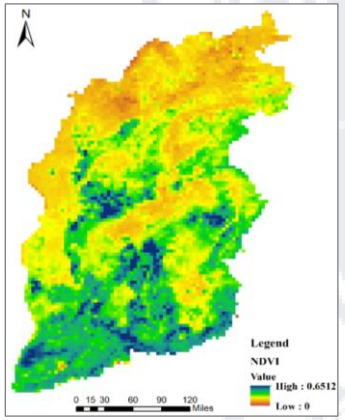
Spatio-temporal factors of CO_2 distribution in Shanxi Province

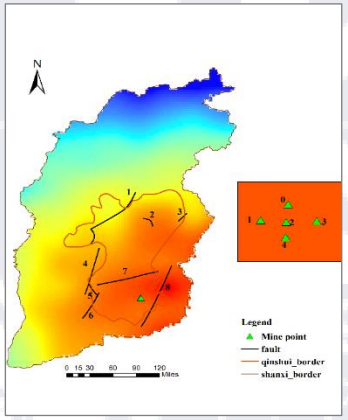


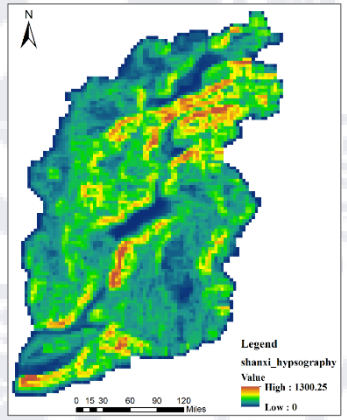
Survey and observation data preprocessing

- Digitization of geological data, Extraction of boundary and fault zone data
- Extraction of topographic relief from elevation data
- OCO-2 data gridding and accuracy reconstruction
- Accuracy reconstruction and cropping of NDVI data
- Extraction of wind speed and direction from meteorological data and digitisation of meteorological stations









OpenGCS Online Monitoring – Regional Monitoring

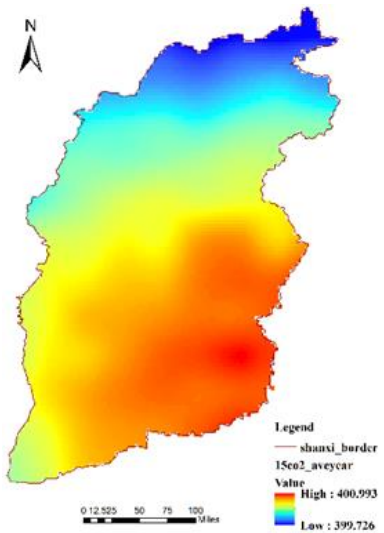
Spatio-temporal Variation of Atmospheric CO_2 in Shanxi Province

- Spatio-temperal Distribution of CO_2
  - Temporal Distribution of CO_2
    - Annual variation of CO_2
    - Seasonal variation of CO_2
    - Monthly variation of CO_2
  - Spatial Distribution of CO_2
    - Annual Variation Pattern of CO_2
    - Seasonal Variation Pattern of CO_2
    - Monthly Variation Pattern of CO_2

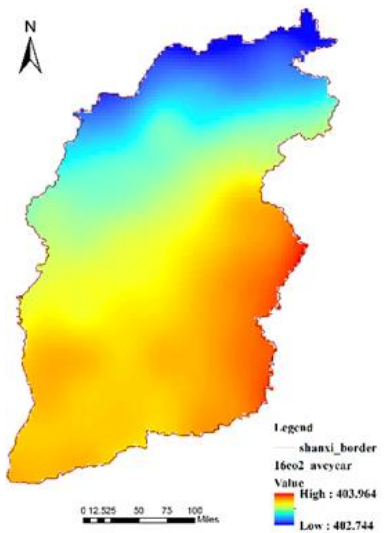
Driving Factors Analysis of Atmospheric CO_2 based on GWR model

- Driving Factors of Spatio-temporal Distribution of CO_2
  - Distribution of Fault Zone in Qinshui Basin
  - Distribution of Injection Wells in Qinshui Basin
  - Wind Speed and Direction
  - NDVI
  - Relief Amplitude
- CO_2 Satellite Data

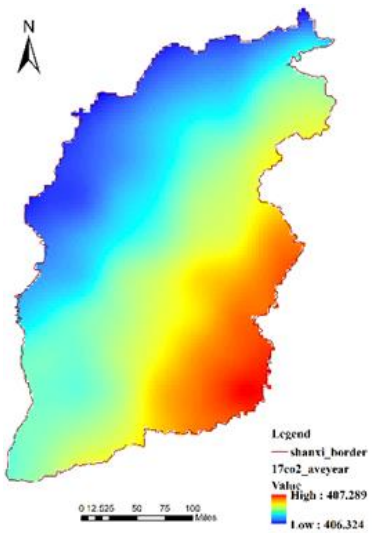
Model Contrast
- Generalized Linear Regression
- Geographic Weighted Regression



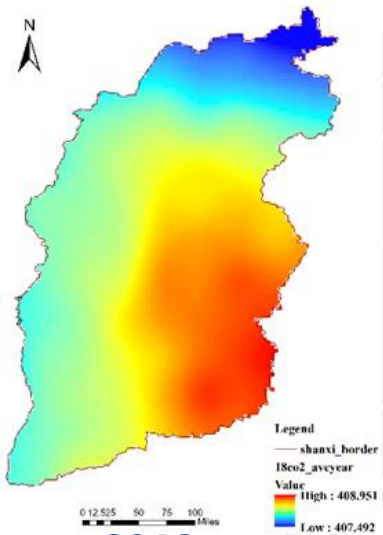
2015



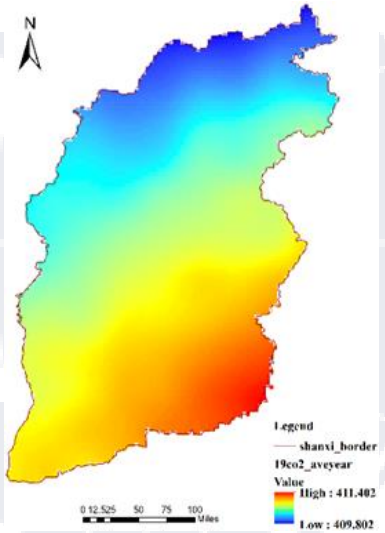
2016



2017

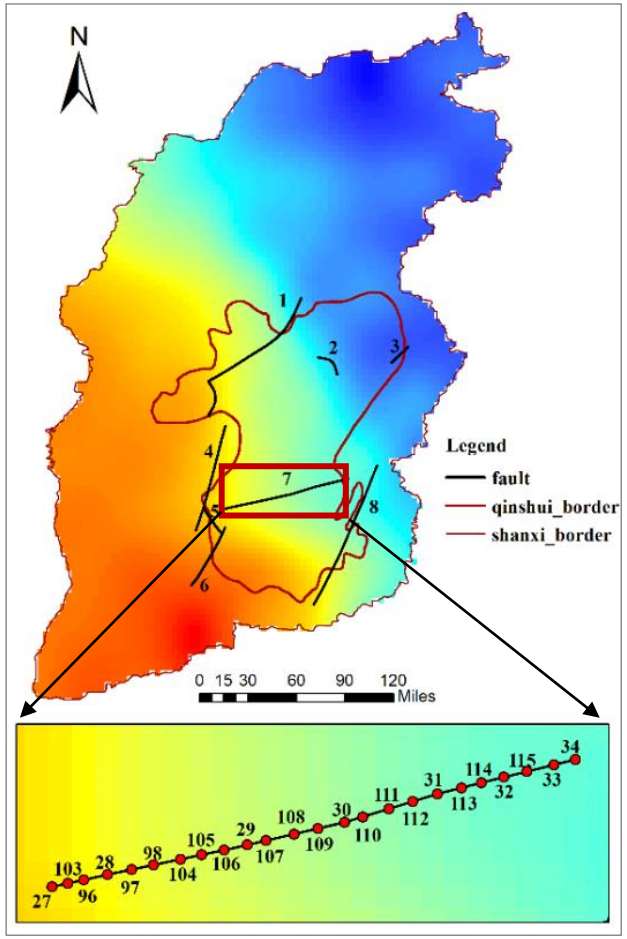


2018



2019

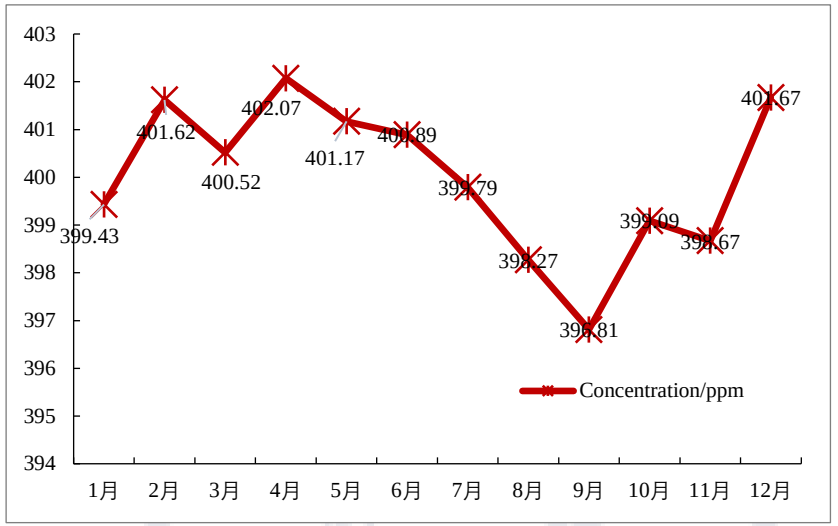
OpenGCS Online Monitoring – Regional Monitoring



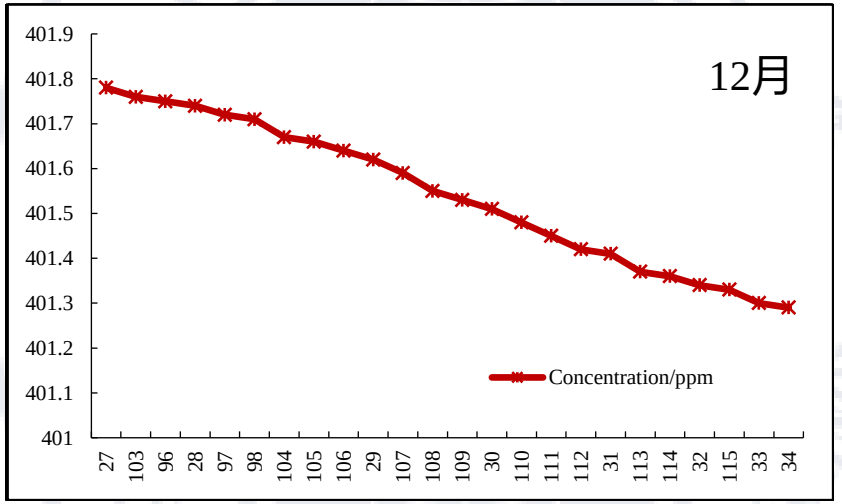
Distribution of Fracture Zone in Qinshui Basin, Shanxi Province

- There are 8 large and small fracture zones, FID is the point number of the cell through which the fracture zone passes

- CO_2 concentrations show an "increasing-decreasing-increasing" trend throughout the year, but there is a sudden drop in March and November
- Reasons: Fewer real values and anomalies caused by interpolation pre-processing
- CO_2 concentration in the fracture zone reaches its lowest value in September
- Reasons: Probably due to the slow temperature drop near the fracture zone, when the vegetation photosynthesis is relatively strong
- Comparing the annual and monthly variations and spatial patterns at the Qinshui Basin and the fracture zone, we found that the distribution of CO_2 at fracture zone has no obvious regularity, which is consistent with the spatio-temporal distribution of CO_2 in Qinshui Basin.



CO_2 concentration variation at Point 104 from January to December 2015

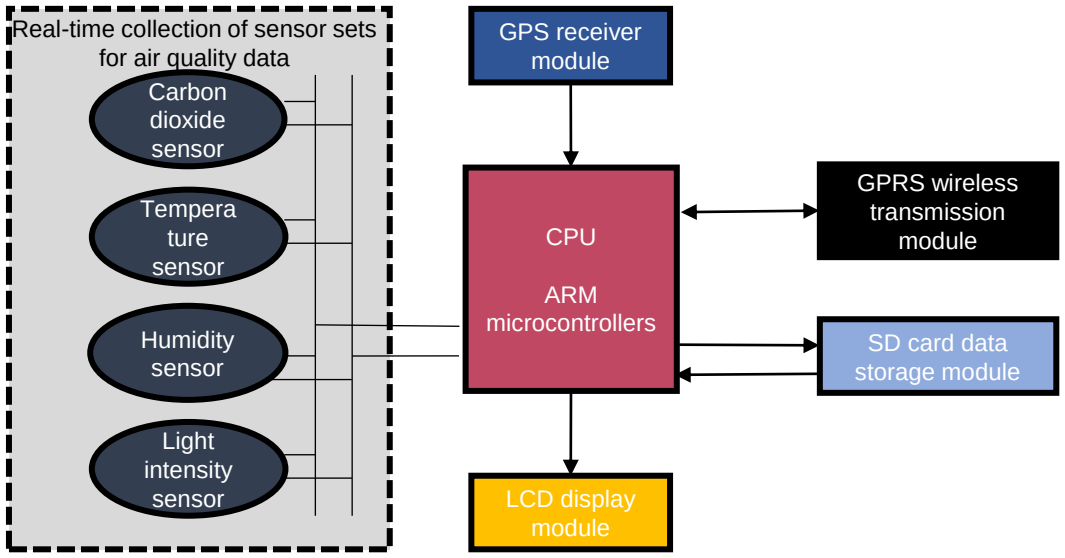


CO_2 concentration variation at Fracture Zone 7 from January to December 2015

OpenGCS Online Monitoring – Local Monitoring

Online Monitoring of Geological CO_2 Storage and Leakage based on Wireless Sensor Networks

Monitoring of CO_2 leakage from geological storage is the key to check and verify the effectiveness, persistence and safety of CO_2 geological storage, which has important theoretical and practical significance for promoting the in-depth study of safety assessment and risk control of CCS.

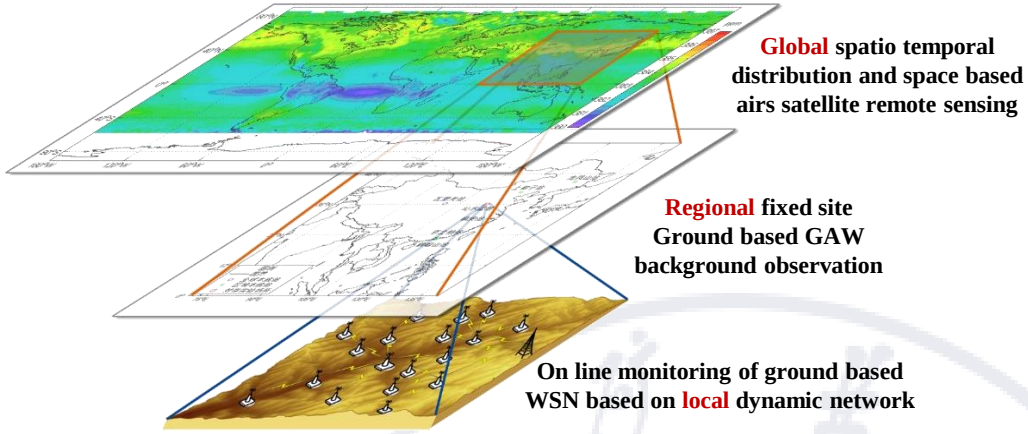


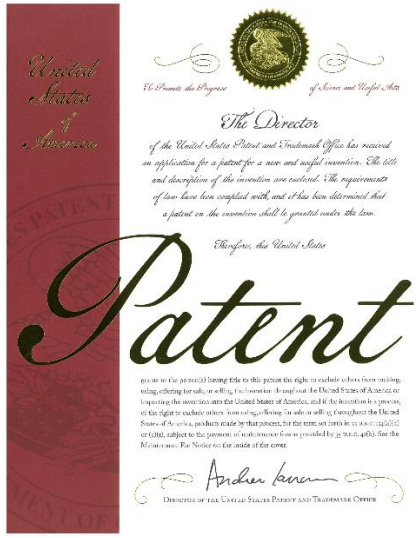
Technical connotation: Advance the research progress of CO_2 capture and storage monitoring technology from the perspective of geo-information science and technology and promote the research of surface real-time monitoring technology for CO_2 geological storage leakage. Using the Internet of Things technology to develop a remote real-time monitoring instrument for CO_2 surface concentration , using cloud computing designed and developed a visual monitoring platform for CO_2 geological storage leakage.

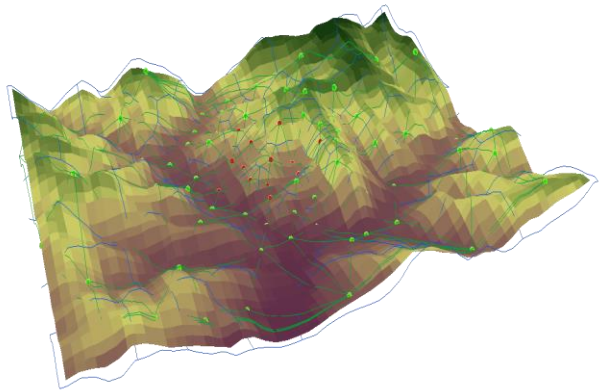
OpenGCS Online Monitoring – Local Monitoring

Optimizing Location of Sensor Nodes in Geological CO_2 Storage Area

By analyzing data in a monitoring area, such as geological, geographical and meteorological data, analyzing an influence factors of a CO_2 leakage event and determining a sensitivity partition, designing different coverage control schemes of monitoring sensor network nodes, or intensively or sparsely arranging sensor monitoring nodes, a coverage network is described and optimally expressed on the basis of Delaunay triangulation.







Technical connotation: In the method for optimizing sensor network node location in a geological carbon storage area, the arrangement density of wireless sensor network nodes can be dynamically adjusted according to geological and geographical features, and the optimization of a dynamic monitoring sensor network for carbon dioxide injection area can be realized. The method reduces node redundancy and communication overheads as much as possible and has strong network coverage and connectivity.

About this presentation

Researched by

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- Jiangsu Institute of Geology and Mineral Resources Design (Testing center of China Coal Geology Administration)

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- Science and Technology Innovation Project of Jiangsu Provincial Department of Natural Resources (2022004,2022008)
- Special Project of Carbon Neutralization Institute of China Coal Geology Administration (ZMKJ-2021-ZX02)

Further Reading/References

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Thanks