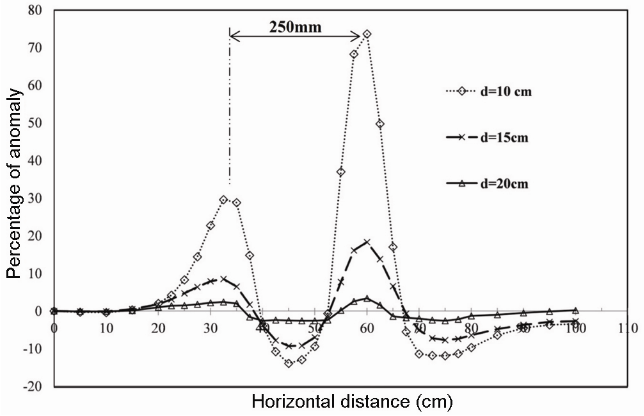

Figure 8. Percentage of anomaly observed over a thin horizontal aluminium sheet (l = 600 mm, b = 250 mm, t = 2 mm, f = 40 kHz and Tx–Rx separation L = 75 mm) for target depths d = 100, 150 and 200 mm.

possible because of the repulsion between the magnetic lines of force. The depth of investigation is 1.8 times the Tx–Rx separation, and the strength of the anomaly is eight times more compared to the VPDCc system.

We have designed and developed a new frequency domain electromagnetic system for geophysical exploration of subsurface conductive bodies. The physical model laboratory studies over conducting bodies with different transition parameters show that this configuration is efficient compared to the conventional frequency domain systems. The system facilitates accurate boundary detection between geological formations with different electrical properties. The proposed system can be operated over a wide range of frequencies to scan the subsurface with high resolution. The main features of the system are as follows: (i) depth of investigation of the system is around ~1.8 times the transmitter–receiver separation and the strength of the anomaly is eight times more compared to the VPDCc system. (ii) As the receiver is placed in the magnetic null plane, the observed anomaly is directly proportional to the difference in the magnetic properties between the subsurface lateral extents and provides accurate boundary detection. (iii) The exact estimation of the target length/breadth is possible as the boundaries between the different formations are clearly indicated by peaks in the anomaly curve.

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Overestimated groundwater ^{14}C ages triggered an inexpediency of water policy in China

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Northern China has been facing a serious problem of groundwater scarcity. The government developed restrictive policies on groundwater extraction, and designed the South–North Water Transfer Project (SNWTP) to transfer water from the Yangtze River in southern China to the arid region in the north. However, contrary to expectation, groundwater levels in northern China have been rising significantly before completion of the project. Due to misapplication of the ^{14}C dating method, the age of deep confined groundwater in arid northern China has been overestimated. This classifies the groundwater as palaeo-groundwater with little recharge, which results in the prohibition of groundwater extraction and SNWTP. Significant tritium concentrations recently reported in the so-called palaeo-groundwater, along with rising groundwater levels, imply recent groundwater recharge in arid northern China.

Keywords: Groundwater, ^{14}C dating method, northern China, South–North Water Transfer Project.

THE problem of groundwater scarcity in northern China is very severe than any other parts of the world[1–3]. In the 1980s and 1990s, long-term over-exploitation of groundwater resulted in sustained lowering of groundwater

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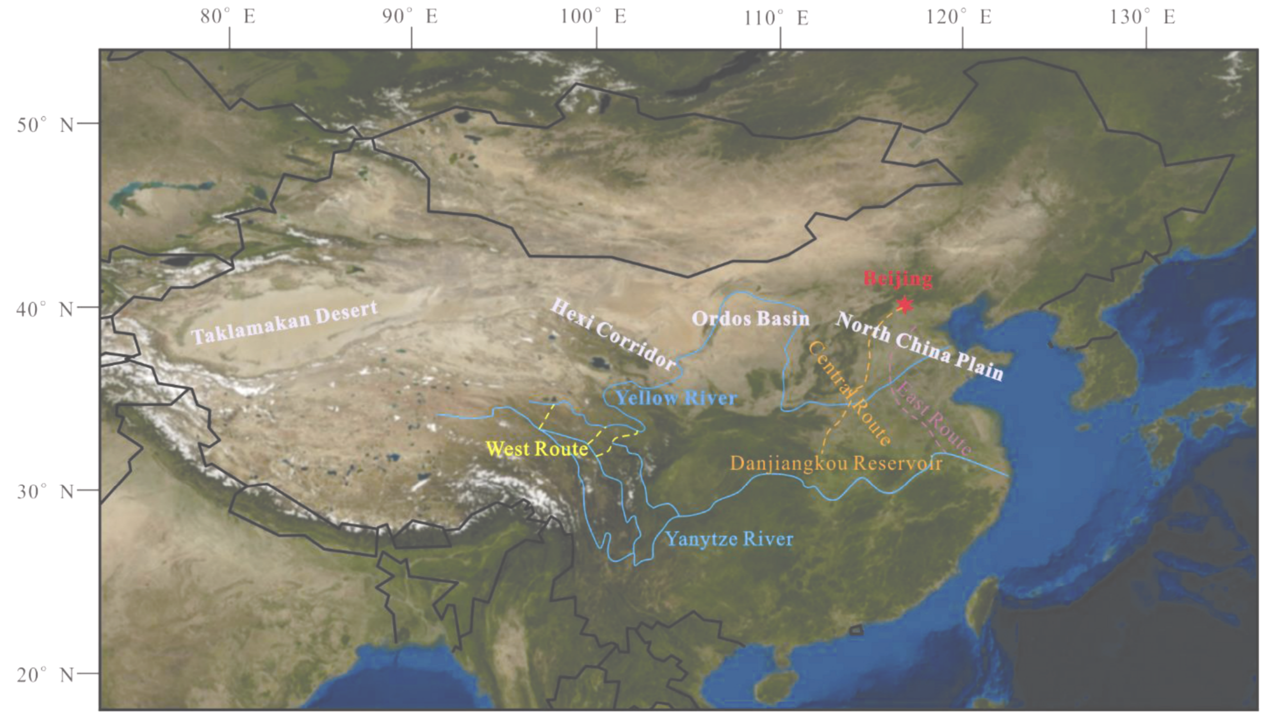

Figure 1. China mainland geography map showing the South–North Water Transfer Project.

levels, with associated land subsidence[4-5]. If left uncontrolled, severe water shortage was predicted in the northern China by the 21st century[5,6]. In order to alleviate the water shortage, restrictions on groundwater extraction were imposed, and a huge infrastructure project, i.e. the South–North Water Transfer Project (SNWTP), was implemented to transfer water from the humid south to the arid north along three canal routes, i.e. the east, central and west (Figure 1)[5,7–9]. After ten years of survey and analysis, construction began in 2002, and the east and central routes were completed in 2013 and 2014 respectively. The project is expected to achieve a water transfer to the north of 40–50 billion cubic metres per year[5,7].

However, there are serious questions whether the huge infrastructure investment is achieving the planned objectives. Since 2003, about 10 years before the project completion, most arid northern regions (Figure 1), such as the Hexi Corridor, Tarim Basin, Ordos Basin, North China Plain, etc., have experienced groundwater levels rising[10], which is contrary to expectation. The groundwater level rose by about 8 m from 2003 to 2006 in the Zhangye region, Hexi Corridor[11]. At the beginning of the 21st century, lakes recharged by groundwater are reappearing in the Taklamakan Desert, Tarim Basin – one of the largest and driest deserts in the world[12]. In the northwestern Ordos Basin, groundwater has overflown to the surface around 2010 (refs 13, 14). Data from 885 observational wells shows that for the first time since 1999, the average groundwater level in Beijing City, North China Plain, rose to 15 cm from 30 June to 31 July 2015, even during the peak usage of groundwater[15]. SNWTP has consumed not only a large amount of money for construction, operation, management and maintenance, but has also occupied considerable areas of arable land[5,7]. Moreover, studies suggest that the benefits of the project, including enhanced water supply, have not actually materialized. Studies show that from December 2014 to May 2016, the total amount of water transferred to Hebei Province, North China Plain, was only 300 million cubic metres, which is less than one-tenth of the predicted amount of 3,500 million cubic metres per year. Additionally, there are issues of pollution, as water flowing in the east route has been shown to have excessive concentrations of NH_3-N, COD_{Mn}, NO_2-N, BOD_5, DO, volatile phenol and petroleum[16], while many water source districts (e.g. Danjiangkou Reservior in Figure 1) along the central route have reported nitrogen and phosphorus contamination[17,18].

The inappropriateness of the national water policy may be attributed to uncertainties over the status of confined groundwater supply. Groundwater age is a significant parameter, which in recent years has been the subject of numerous studies in China and all over the world. Research on confined groundwater in arid North China Plain has reported ^{14}C ages of between several thousand to thirty thousand years, which classifies it as palaeogroundwater with little recharge[19–23]. These age estimations provide the underlying rationale for SNWTP. However, due to the misapplication of ^{14}C dating method, the age of confined groundwater has been overestimated.

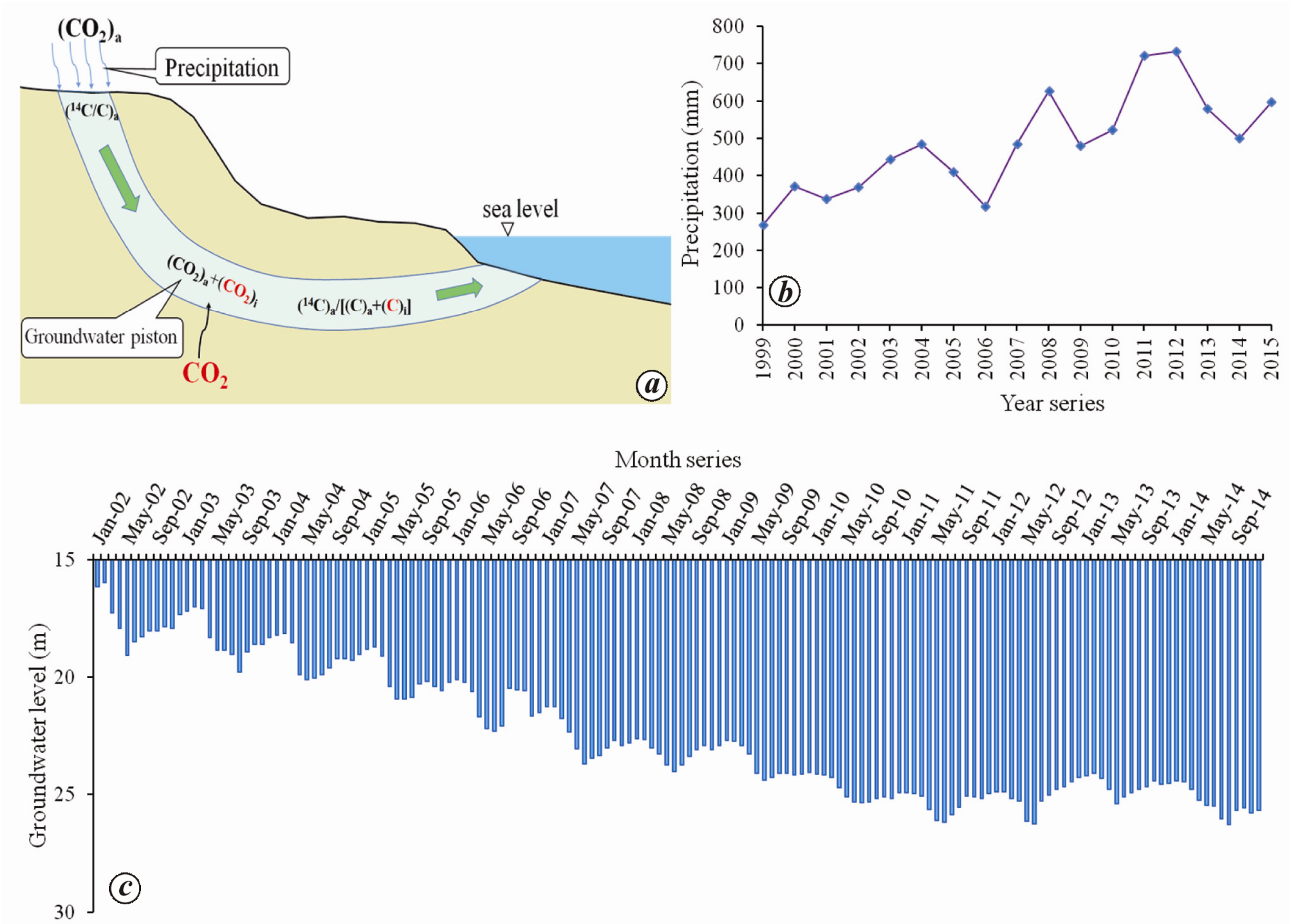

Figure 2. ***a***, Schematic illustration showing how the incursion of CO_2 gas into groundwater may cause ^{14}C activity distortion and overestimation of downstream groundwater ages. The subscripts of *a* and *i* indicate C from air and incursion respectively. Ideally, the initial ^{14}C activity in groundwater is derived from air through precipitation. Assuming groundwater piston flow (green arrow) in a closed system, it is apparent that age can be determined by the ^{14}C decay over time. However, the large amount of CO_2 gas with depleted ^{14}C (red font) derived from extensive mineral deposits represents an incursion into groundwater through widely developed faults, which will decrease the ^{14}C activity to a large extent, resulting in a much older apparent age of groundwater. ***b***, Annual variation of precipitation in Beijing City. Precipitation data are from the China Meteorological Administration. ***c***, Monthly variation of groundwater level in Beijing Plain area from 2002 to 2014. Groundwater level data are from Beijing Water Resources Bulletin[31].

Generally, groundwater flow from the recharge area to the position downstream, where it is sampled for ^{14}C age dating, is assumed as piston flow in a closed system for carbon (Figure 2 *a*)[24–26]. Besides the radioactive decay in the aquifer, the decrease in ^{14}C activity can also be distorted by the mixture of 'dead' (i.e. ^{14}C depleted) carbon caused by the influence of hydrochemical reactions and/or physical processes. Therefore, stable isotope composition ($\delta^{13}C$) is employed to estimate the proportion of admixed 'dead' carbon[19–23]. It is reasonable for the correction of the contribution from dissolving carbonate, as the $\delta^{13}C$ value of carbonate is known. However, many other factors are neglected, such as sulphate dissolution, dolomite dissolution, oxidation of organic matter, and the admixture of geogenic or magmatic CO_2 from deep crustal or mantle sources and subsequent carbonate dissolution, all of which contribute significantly to distort the ^{14}C activity decay. Since the $\delta^{13}C$ value of these sources is unknown, it is impossible to use the models to correct the measured age of groundwater. This is the case in the arid North China Plain, where extensive mineral deposits exist and contain lots of CO_2 gas with depleted ^{14}C. It will enter deep confined groundwater through widely developed faults, resulting in a significant decrease in the ^{14}C activity[27]. The reduction of ^{14}C activity in previous studies was ascribed to ^{14}C decay[19–23], leading to overestimation of groundwater age and the erroneous conclusion of palaeo-groundwater[28].

Beijing city is located in the north of the North China Plain, and the terrain changes from mountains in the northwest to a lowland plain in the southeast. It covers an area of 16,400 km^2, containing a mountainous area of 10,200 km^2 and a plain area of 6,200 km^2. The groundwater level in Beijing had dropped sharply by an average value of 1 m per year from 1999 to 2014 (ref. 14), even with increasing amounts of annual precipitation (Figure

2 *b*). Every year, the groundwater level decreases during summer, when large amounts of water are extracted for agricultural irrigation, while the levels rise during winter (Figure 2 *c*), which cannot be attributed to local precipitation recharge. Conservatively, assuming that most observation wells are mainly distributed in the plain area, and the effective porosity[29] of the aquifer is approximately equal to 0.2, the average 1 m decline of water level per year is approximately equal to 1,240 million cubic metres of groundwater over-extraction. However, at the end of July 2016, instead of decreasing the average 1 m, the groundwater level in the Beijing plain area rose on an average by 62 cm above that in the same period last year, the equivalent to groundwater augmentation of ~769 million cubic metres[30]. By the end of 26 August 2016, the SNWTP had only transferred 1,573 million cubic metres in total to Beijing[30], which could not meet the requirement of groundwater augmentation of ~2,009 million cubic metres (1,240 million + 769 million). Additionally, most of the transferred water is used to fill rivers and reservoirs, and only a little recharges the groundwater[30]. Therefore, the transferred water could not account for the rising groundwater level in Beijing.

The variation of groundwater level in recent decades in north China indicates that it is impossible for the confined groundwater to be palaeo-groundwater. Recent studies on the so-called palaeo-groundwater in North China Plain, the age of which was determined by ^{14}C in the 1980s, report significant tritium concentrations[13,20–23,28]. Tritium input in groundwater is the product of nuclear testing in the 1950s–60s, and is thus an indicator of young water. If it is palaeo-groundwater, the groundwater level will not go up, even though extraction is prohibited. It is contrary to the observed groundwater level rising. Therefore, the presence of tritium, along with rising groundwater levels, implies recent confined groundwater recharge in arid northern China. Although the mistake in ^{14}C dating of groundwater is not in itself momentous, it has triggered adoption of an inappropriate national water policy. As confined groundwater is presently being actively recharged by modern water, we suggest that it should be explored as a source of drinking water in part of regions, in order to alleviate the water crisis as a complement. Additionally, since the completed east and central routes of SNWTP have not achieved their planned objectives, the government may need to reconsider the ongoing west route.

Conflicts of interest: Both authors declare no conflict of interest.

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Inbound tourism in Uttarakhand, India, before and after the 2013 Kedarnath disaster – evidence derived from social networking sites using GIS

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Tourism is an important industry for the developing nations. The Indian Himalayan region attracts a multitude of tourists, but is highly prone to natural disasters that affect tourism. The 2013 Kedarnath disaster in Uttarakhand caused by the torrential downpour and subsequent flooding is one such example. In the present study, visitation rates were assessed with regard to the Kedarnath disaster using geo-tagged photographs posted on Flickr as proxy. Continued decrease in photo-user days from 2012 to 2014 was witnessed and the effectiveness of GIS in the spatio-temporal analysis of inbound tourism using big data available on social networking sites has been demonstrated.

Keywords: Big data, natural disasters, social networking sites, tourism, visitation rates.

TOURISM is one of the world's largest industries having significant potential to drive the world economic growth. The World Travel and Tourism Council (WTTC) estimates that tourism generates about 10% of the global GDP and contributes to 284 million jobs. The revenue generated by tourism in India was Rs 8.31 lakh crores (US$ 120 billion), equal to 6.3% of the nation's GDP in 2015 and supported 37.315 million jobs, 8.7% of its total employment[1]. It is of major national economic importance for many developing countries that provide many natural attractions such as ecotourism, adventure tourism, extractive tourism, wildlife tourism, wilderness and nature retreats, which in turn succour livelihood of the local people. Globally, tourism is a US$ 625 billion industry, the single largest non-Government economic sector in the world[2]. Though negative aspects of tourism in terms of its impact on the environment have been often raised by conservationists, it plays a significant role in creating a sense of solidarity among people across the globe, as reflected by the affinity between tourists and their families and friends, and individuals and communities in various destinations.

Tourism constitutes a wide variety of sectors that provide diverse products and services to visitors. Some consider leisure, recreation, entertainment and hospitality as the main concepts related to tourism[3], whereas there are several other dimensions as well, e.g. education, natural disaster, research, business, etc.[4–7]. According to the United Nations World Tourism Organization (UNWTO), activities comprising persons travelling to and staying in places outside their usual environment for not more than one consecutive year for leisure, business and other purposes are considered as tourism. Thus, there are various classes of tourism based on motives, locations, type of visitors, etc. Depending upon the origin of visitors, tourism may be classified as inbound, outbound and domestic. Activities of non-resident foreign tourists visiting a country are known as inbound tourism (foreign tourism), whereas outbound tourism comprises activities of a resident visitor outside the country of reference, and domestic tourism involves residents of a country travelling only within it. India holds tremendous potential tourist destinations in the form of both inbound and domestic tourism. This potential is evidently palpable in terms of overall development and growth of our economy. India's total foreign tourist arrivals in 2013 stood at 6.84 million. Foreign exchange earnings from tourism in 2013 grew to US$ 18.44 billion, showing an annual growth rate of 4% (ref. 8).

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