Applied Remote Sensing Training (ARSET) Program

Advanced Monitoring Groundwater Changes for Water Resources Management

Homework Questions

Question 1

GRACE/GRACE-FO measurements are used to infer what parameter?

Answers: (bold correct)

a. Groundwater amount change
b. Total terrestrial water storage change
c. Surface displacement rate

Feedback:
GRACE/FO missions measure gravitational changes occurring due to movement of total terrestrial water (i.e. surface and ground water, and not just groundwater). The gravitational changes are used to infer Total Terrestrial Water storage change. GRACE/FO measurements cannot detect surface displacement; they only detect mass changes (gravitational changes).

Question 2

GLDAS 2.2 assimilates both GRACE and Sentinel-1 SAR data in Land Data Assimilation System (LDAS) to get high resolution groundwater estimates.

Answers: (bold correct)

a. True
b. False

GLDAS 2.2 assimilates only GRACE/GRACE-FO terrestrial water thickness data in LDAS to derive soil moisture and groundwater components. Sentinel-1 data are used to derive a surface displacement product (DISP) using SAR interferometry, which are not assimilated in LDAS.

Question 3

When monitoring dry/wet conditions in a watershed, which measurements provide indication of ground water changes at the highest spatial resolution?

Answers: (bold correct)

a. GRACE/GRACE-FO JPL mascon
b. GLDAS 2.2 groundwater
c. OPERA DISP

Feedback:
OPERA DISP is derived from Sentinel-1 SAR data and has 30m resolution whereas GLDAS provides groundwater estimates at 0.25x0.25 degree resolution, and GRACE/GRACE-FO JPL mascon provides terrestrial water storage at 3x3 degree or at 0.5x0.5 degree. Therefore, OPERA DISP data would provide dry/wet conditions monitoring at highest spatial resolution.

Question 4

If you are interested in monitoring drought in Africa, which datasets would you use?

Answers: (bold correct)

a. GRACE/GRACE-FO and GLDAS 2.2
b. GLDAS 2.2 and OPERA-DISP
c. OPERA-DISP and GRACE/GRACE-FO

Feedback:
For monitoring drought in Africa, GRACE/GRACE-FO and GLDAS 2.2 should be used as these are global datasets whereas OPERA-DISP are currently available only for North America.

Part 1 Exercise

Please refer to the Part 1 Exercise with [JPL Interactive Data Browser & Analysis Tool] to answer the next 4 questions.

Question 5

Based on the Part-1 Exercise (Step 3): Examine the global groundwater map from 2021–2025 for the month of January. Which two years have relatively higher (less water deficit) Terrestrial Water Thickness (TWT) over California?

Answers: (bold correct)

a. 2021 and 2025
b. 2021 and 2022
c. 2023 and 2024

Feedback:

Examination of Terrestrial Water Thickness maps for January of 2021 to 2025 shows that in 2023 and 2024 the water thickness is much larger than -30 cm (close to approximately -15 cm as depicted by yellow color over most of the state). In other years the values are closer to -30 cm (orange/red colors). Larger TWT indicates smaller anomaly and less water deficit.

Question 6

Based on the Part-1 Exercise (Step 3): Examine the global groundwater map from 2021–2025 for the month of January. In January 2023 the TWT anomaly was ________ in central India and _______ in northern India.

Answers: (bold correct)

a. Positive and Positive
b. Negative and Positive
c. Positive and Negative
d. Negative and Negative

Feedback:

Examination of Terrestrial Water Thickness maps for January of 2023 over India shows that in central India the TWT anomalies were positive indicating terrestrial water surplus whereas they were negative in northern India suggesting deficit of terrestrial water.

Question 7

Based on the Part-1 Exercise (Step 4): Terrestrial Water Storage Time Series for Amazon River Basin. Review the time series in the GRACE tool and the .csv file that you downloaded. Which year and month had the least TWT – or maximum deficit of TWT?

Answers: (bold correct)

a. October 2005
b. November 2020
c. November 2023
d. October 2024

Feedback:
Examination of Terrestrial Water Thickness times series for the Amazon basin, and based on the values in corresponding csv file, the least TWT was noted in October 2024 with the negative TWT anomalies of -32.4091 cm.

Question 8

Based on the Part-1 Exercise (Step 4): Terrestrial Water Storage Time Series for Amazon River Basin. The TWT anomaly in May 2009 indicated a deficit or surplus of terrestrial water? What was the amplitude of the TWT anomaly?

Answers: (bold correct)

a. Surplus, 26.2114 cm
b. Surplus, 26.0934 cm
c. Deficit, -171263 cm
d. Deficit, 1.1538 cm

Feedback:
Examination of Terrestrial Water Thickness times series for the Amazon basin, and based on the values in corresponding csv file, May 2009 had the maximum surplus of TWT at 26.2114 cm.

Part 2 Exercise

Please refer to the Part-2 Exercise on Access, Analysis and Visualization of GLDAS groundwater using Giovanni and QGIS.

Question 9

Based on the Part-2 Exercise (Step 7): Refer to the area-averaged time series of GLDAS groundwater storage in Colorado River Basin .png and corresponding .csv file that you downloaded from Giovanni. After which year did groundwater in the North America Colorado watershed remained **less than 600 mm:**

Answers: (bold correct)

a. 2005
b. 2010
c. 2011
d. 2020

Feedback:

Examination of GLDAS groundwater timeseries and corresponding csv file from Giovanni—after 2011 though there is interannual variability, but peak groundwater values are decreasing and never went above 600 mm.

Question 10

Based on the Part-2 Exercise (Step 14): Examine inter-decadal changes in groundwater using QGIS. Use the legend for the layer GLDAS-GW_Change to interpret the map. In which time period was the groundwater amount across most of the watershed larger between these two decades, 2003 to 2013 & 2014 to 2025?

Answers: (bold correct)

a. 2003 to 2013
b. 2014 to 2025

Feedback:

The groundwater change map shows that the difference between averaged groundwater from (2014–2025) minus (2003–2013) was negative in most of the watershed with values ranging from approximately -1 to -68 mm (except for a small portion in the northern most part of the watershed). This indicates a decrease in groundwater during 2014–2025 compared to 2003–2013.

Part 2 Exercise

Please refer to the Part 3 Exercise on time series and map of OPERA Displacement Product using the Alaska SAR Facility Displacement Portal and QGIS to answer the next 2 questions.

Question 11

Based on the Part-3 Exercise (Steps 2 & 3): Based on the two, time series of the displacement, the slope of time series 1 is ____ and that of time series 2 is ________

Answers: (bold correct)

a. **Negative and Positive**
b. Negative and Negative
c. Positive and Positive
d. Positive and Negative

Feedback:
The first time series has negative slope (~-0.088 m/year) depicting subsidence, most likely due to groundwater decrease, while time series 2 has a positive slope (0.03 m/year) depicting rebound of surface. These time series are based on the shortwave (filtered) displacement data from the Displacement Portal, showing local changes in displacement velocity.

Question 12

Based on the Part-3 Exercise (Step 11): Based on the displacement map viewed in the QGIS, what is the range of minimum and maximum values of displacement for the MexicoCity-DISP_S1 layer?

Answers: (bold correct)

a. 173 to 152 m
b. -173 to 152 m
c. -0.017 to 0.015 m
d. **-0.173 to 0.152 m**

Feedback:

Based on the map, the displacement velocity range was -0.173 to 0.152 m in the period of 03/27/2022 to 10/05/2022 for the Sentinel-1 frame in the map covering Mexico City, with majority of the Mexico City area experiencing subsidence (negative displacement).