Analysis of long-term trends in global precipitation products

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Purpose

- To evaluate the long-term trend of GSMaP and Ku-band radar (TRMM/PR and GPM/KuPR: Ku Radars) and to understand their characteristics.
  - Precipitation rate (unconditional, conditional)
  - Storm Top Height (TRMM/PR + GPM/KuPR)
    - Thresholds are set and analyzed for TRMM and GPM continuity
  - DSD: epsilon(ε)
  - occurrence of virga/anvil type precipitation
- Comparison of GSMaP and Ku-band radar products with other physical quantities.
  - GRACE (Liquid water equivalent thickness)
  - CERES (net flux at TOA) Loeb et al. (2022)

For the evaluation of the precipitation trend of precipitation radar, appropriate threshold should be set for GPM/KuDPR because of higher sensitivity.

epsilon(ε) is a coefficient to control the relationship between the specific attenuation (k) and radar reflectivity factor (Z)

$$k = \varepsilon \alpha Z^{\beta}$$

where, k in dB/km, Z in $mm^6 m^{-3}$ and α and β are constant.

- $\varepsilon = 1$ default DSD
- $\varepsilon < 1$ larger drops
- $\varepsilon > 1$ smaller drops

Epsilon is sampled according to the Z value, because epsilon changes with Z.

Data (2002 to 2022, 21 years)

- GSMaP-G V8 (Gauge corrected product)
- TRMM/PR V7, GPM/DPR, GPM/KuPR V7 L2
  - Precipitation rate, Storm Top Height, epsilon, virga/anvil type
- GRACE GRCTellus.JPL.200204_202207.GLO.RL06M.MSCNv02CRI.nc)
- CERES (CERES EBAF Ed4.2 2002–2022)
  - netflux@TOA, netflux@surface
- 0.5 deg. grid data, monthly
  - 12x21=252 months
- 2.5 deg. grid data, monthly
  - for precipitation radar product(TRMM/PR and DP/KuPR)
  - 35S to 35N

Analysis

*: Mann-Kendall test (significance level: 5 %)

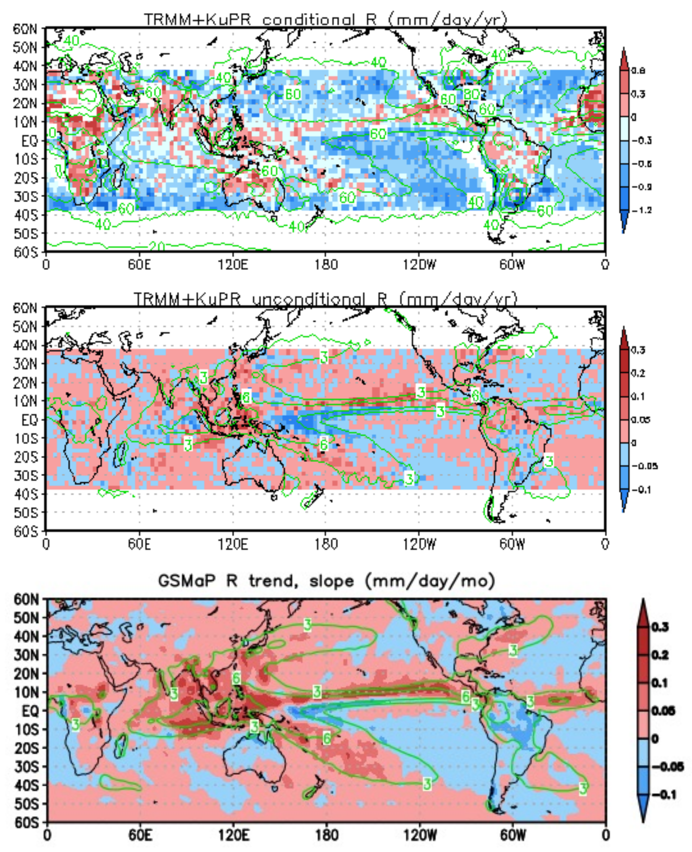
- Precipitation data
  - spatial correlation
  - long term trend (all months of data/monthly)*
  - Correlation coefficient between trend
- Net flux vs. precipitation
  - long term trend (all months of data/monthly)*
  - Correlation coefficient between trend
- GRACE (water equivalent thickness)
  - long term trend (all months of data/monthly)*
  - lag correlation with precipitation (over land)
    - precipitation → under ground water, snow cover : precipitation precedes
    - snow melt and water vapor supply →precipitation : precipitation delays

Result (1) Precipitation trend (2002–2022): GSMaP and Ku Radars

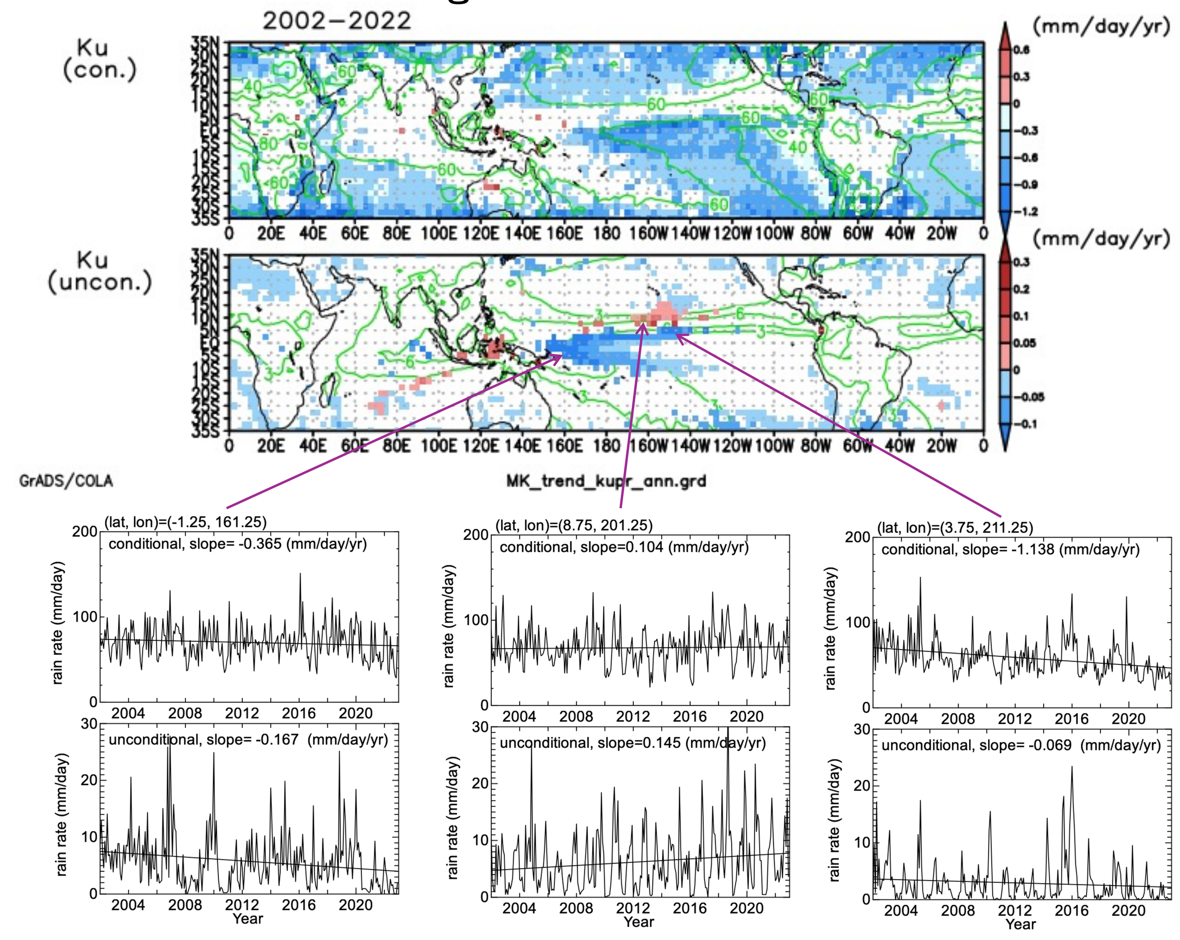
Conditional R (Ku-band radar)

Unconditional R (Ku-band radar)

GSMaP

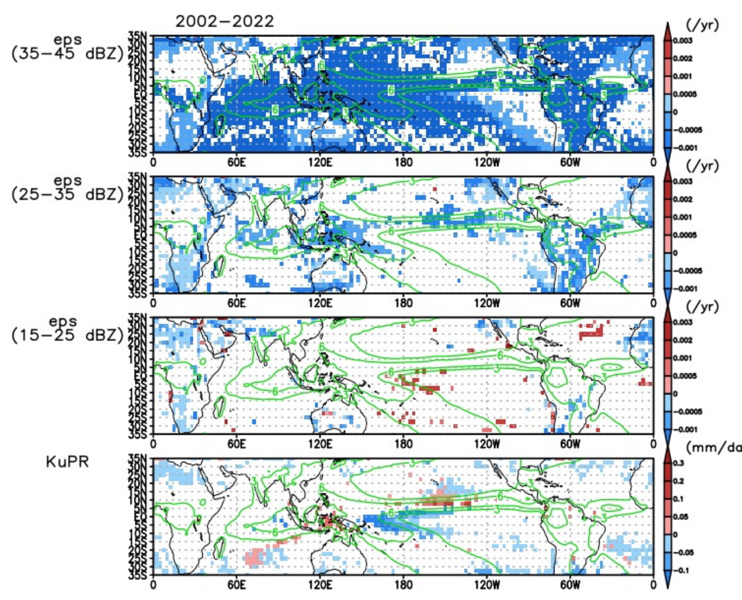


Significant trend area



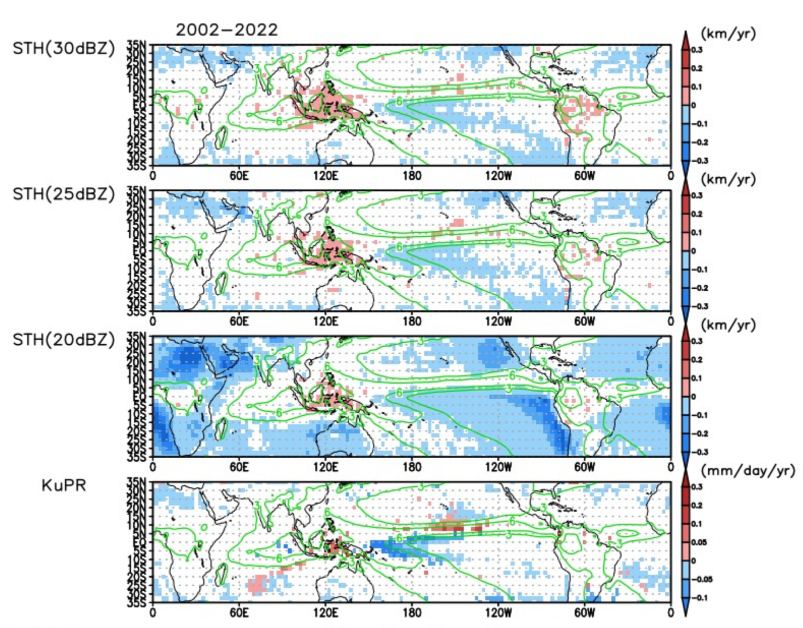
Result (2) DSD trend (2002–2022): Ku Radars

epsilon trend



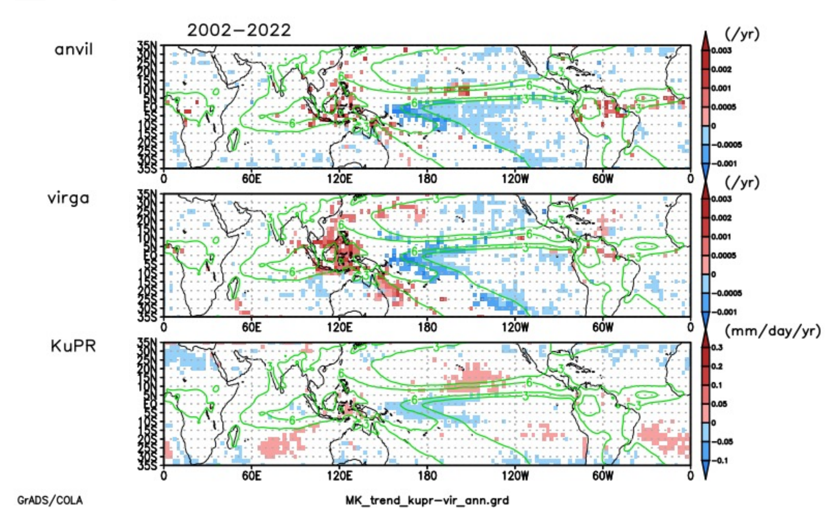
- For smaller Z (15-25 dBZ)
  - increasing trend over **tropical pacific**, corresponding to the decreasing trend of rain rate (**decreasing trend of D**)
  - decreasing trend over African continent except for rain forest
- For medium Z (25-35 dBZ)
  - decreasing trend over ITCZ and SPCZ (**increasing trend of D**)
  - decreasing trend over amazon and African continent (**increasing trend of D**)
- For higher Z (35-45 dBZ)
  - most of the area shows decreasing trend (**increasing trend of D**)

Result (3) Storm top height trend (2002–2022): Ku Radars



- Strom top height trend pattern is similar to precipitation trend for higher threshold.
  - storm top height with higher threshold reflects the **convective activity** (e.g. updraft)
- Storm top height **increases** over **maritime continent**, subtropical pacific in northern hemisphere and amazon.
  - increasing trend for all threshold

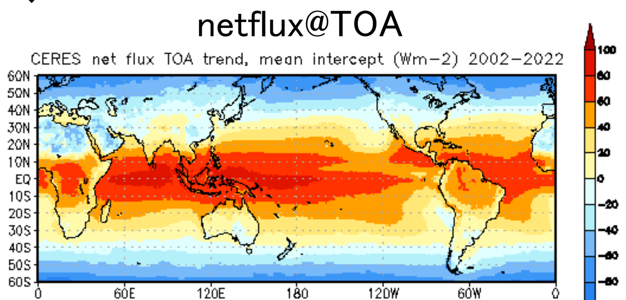
Result (4) Anvil/Virga occurrence trend (2002–2022): Ku



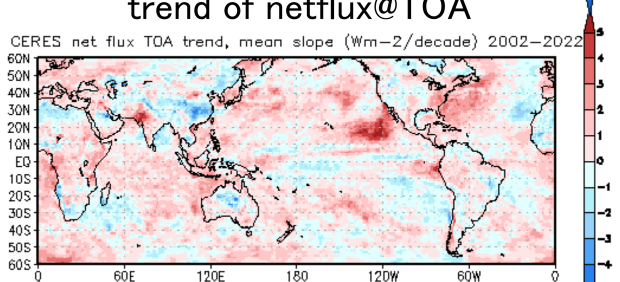
- area of significant change is similar to that of R, except for maritime continent
- Anvil type fraction trend is similar to the R trend
  - decreasing R and decreasing anvil fraction
  - increasing R and increasing anvil fraction
- Virga fraction also decrease →more humidity lower altitude?
- Maritime continent
  - increase R
  - increase virga
  - increase anvil
  - drier lower level but active convection, or
  - virga type reflect the tilting precipitation?

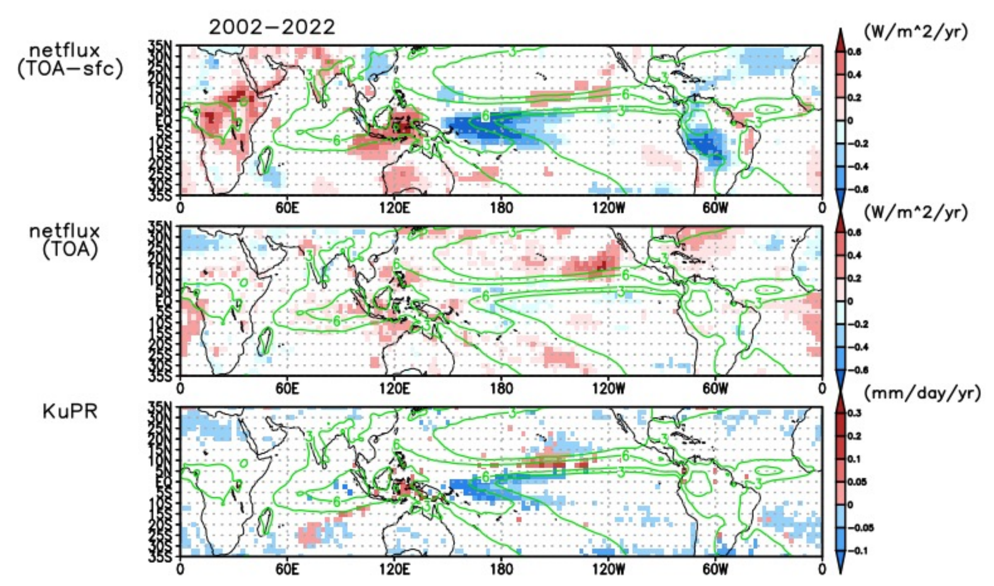
Result (5) CERES trend vs Ku radar trend(2002–2022)

netflux@TOA



trend of netflux@TOA

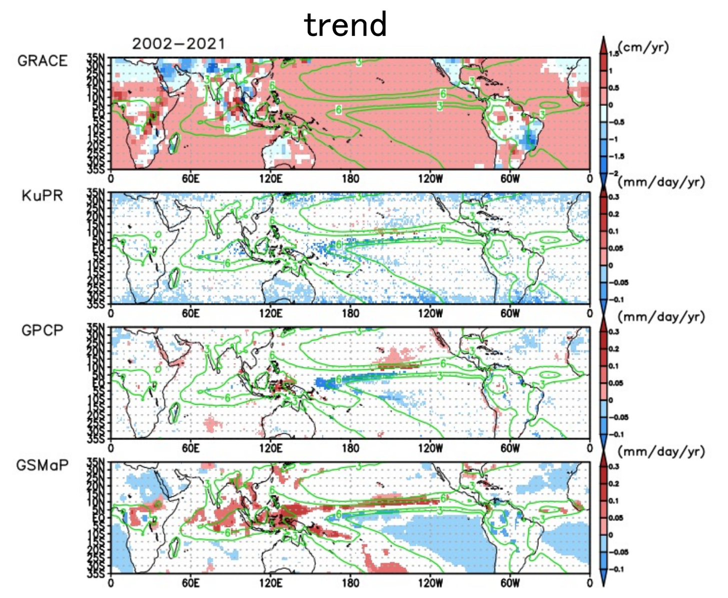




Long term trend of "netflux(TOA – surface)" corresponds well with Ku radar trend over pacific and maritime continent. It can be explained that netflux (@TOA-@surface) represents the latent heating (then, precipitation).

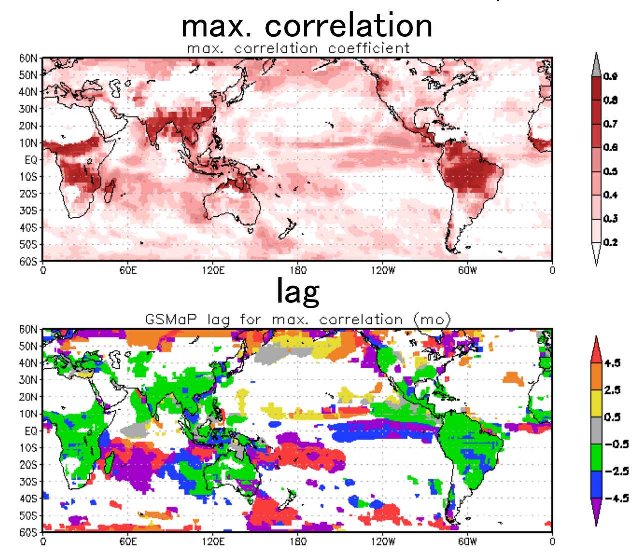
Result (6) GRACE trend vs GSMaP trend(2002–2022)

trend



max. correlation

lag

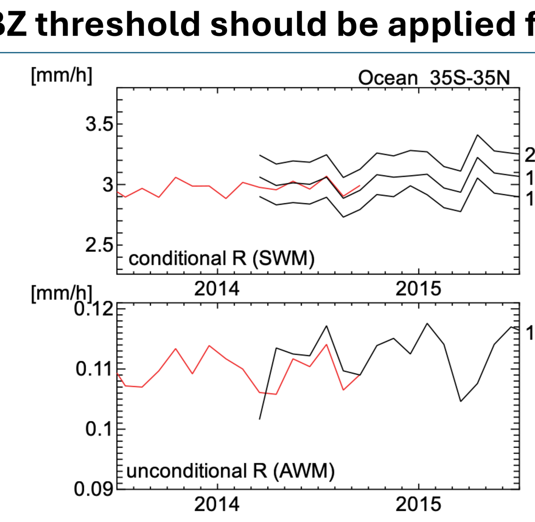


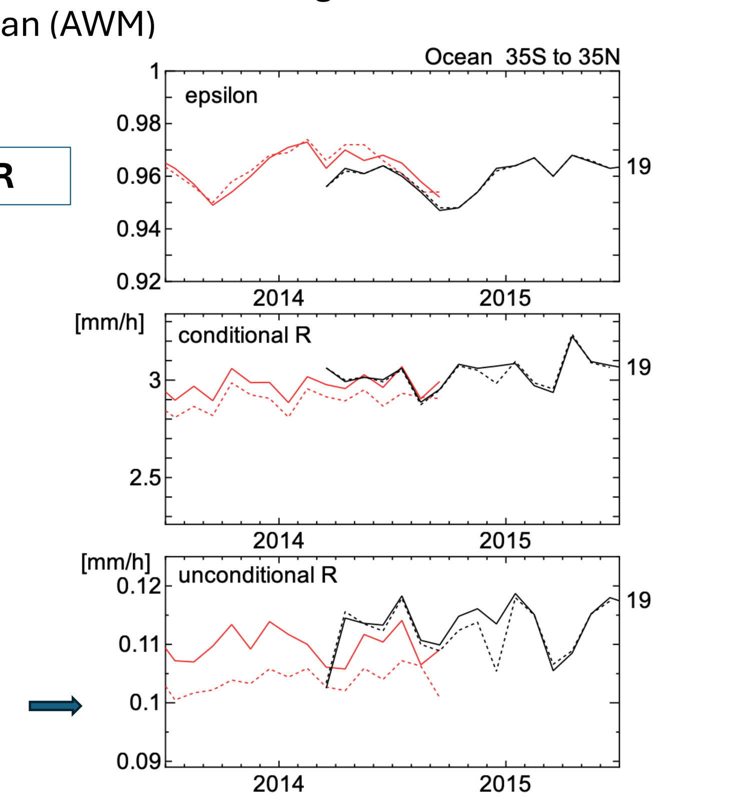
- High correlation region:
  - Africa, Southeast Asia, Amazon
  - precipitation precedes 1-2 months
- Correlation coefficient of 0.5 over Siberia.
  - GRACE precedes 3-4 months

Continuity between TRMM/PR and GPM/KuPR

- compare the precipitation overlapping period
  - Mar. to Oct. 2014
- need to consider (1): sensitivity of radar
  - find the appropriate threshold Z for GPM/KuPR
  - conditional rain rate is compared
- need to consider (2): different inclination
  - sampling frequency against latitude is weighted for conditional rain rate and epsilon (sample weighted mean: SWM)
  - unconditional rain rate is calculated in each latitude and global mean is calculated with the area weighted mean (AWM)

19 dBZ threshold should be applied for KuPR





AWM for unconditional R and SWM for conditional R shows better continuity between TRMM and GPM

Slight bias between TRMM/PR and GPM/KuPR in unconditional R can be explained small bias of KuPR's Z (about 0.1 dB)

Summary

- Comparison of precipitation trends
  - GSMaP matched well with the KuPR (2.5 deg. grid) trend
  - On the other hand, near 30ºS, GSMaP shows an increasing trend while KuPR shows no trend
- Comparison of precipitation trend with other precipitation parameters
  - Near ITCZ, the trend matches the 20 dBZ Storm Top Height, but the KuPR increasing trend south of Hawaii matches the 25 dBZ and 30 dBZ Storm Top Height trends.
  - Drop size (ε) of weaker echo decreasing at decreasing area of precipitation, whereas drop size of stronger echo increases at increasing area of precipitation.
  - Anvil occurrence trend correlates well with precipitation trend
- Comparison of the precipitation trend with the flux trend
  - In the eastern Pacific, there appears to be an inverse trend, but the pattern is slightly off. Note that inverse correlation between flux and precipitation trends is consistent
  - The KuPR precipitation trend is clearer.
- In comparison to GRACE on land, precipitation is 1-2 months ahead of GRACE in the tropics, while in Siberia, precipitation is delayed by 3-4 months.
  - Tropics: precipitation → increasing groundwater
  - Siberia: melting snow → increasing water vapor and then precipitation