An Approach to Integrate Ground- and Satellite-based Products for Multivariate Hydrometeorological Network Design to Monitor Dry and Wet conditions

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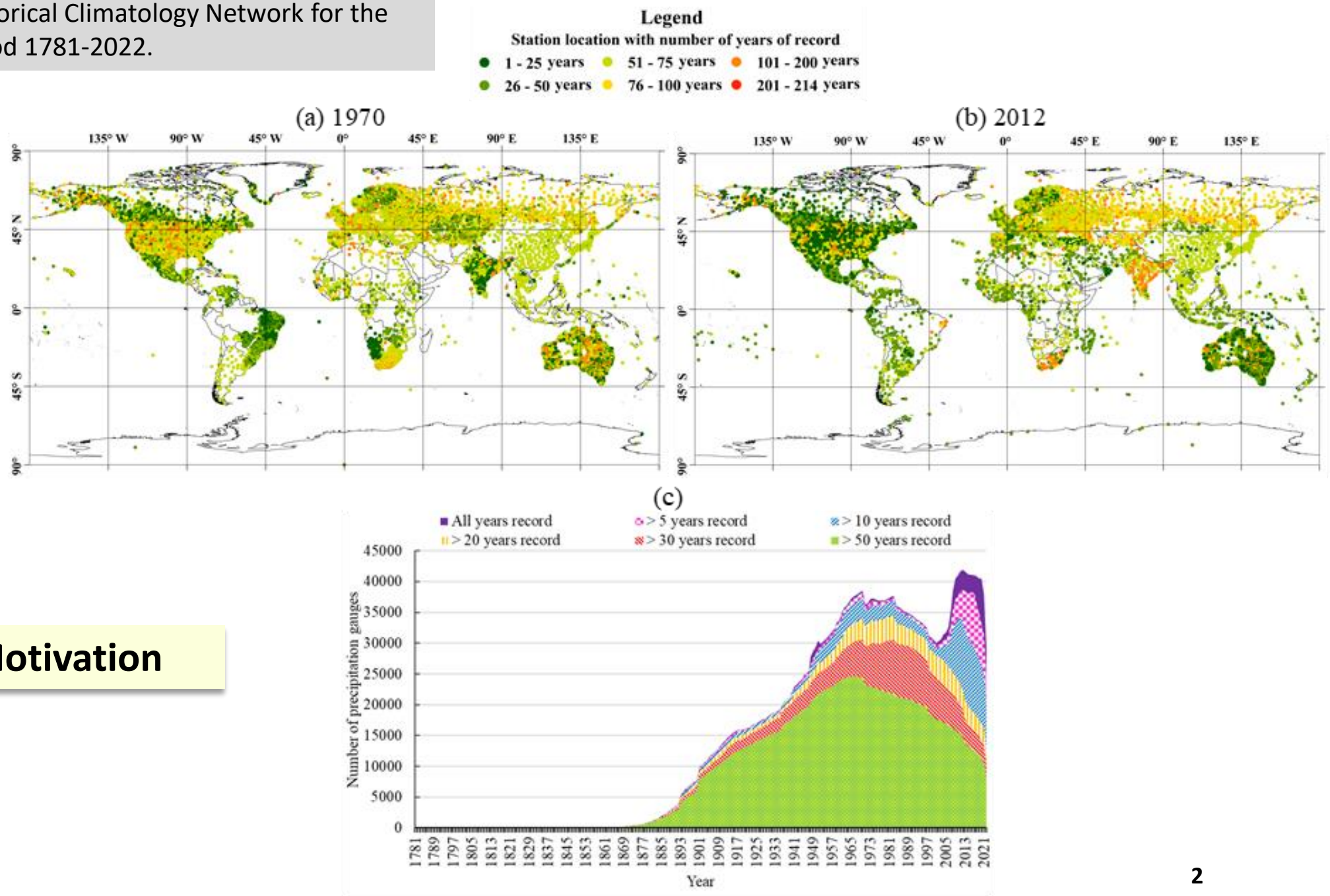
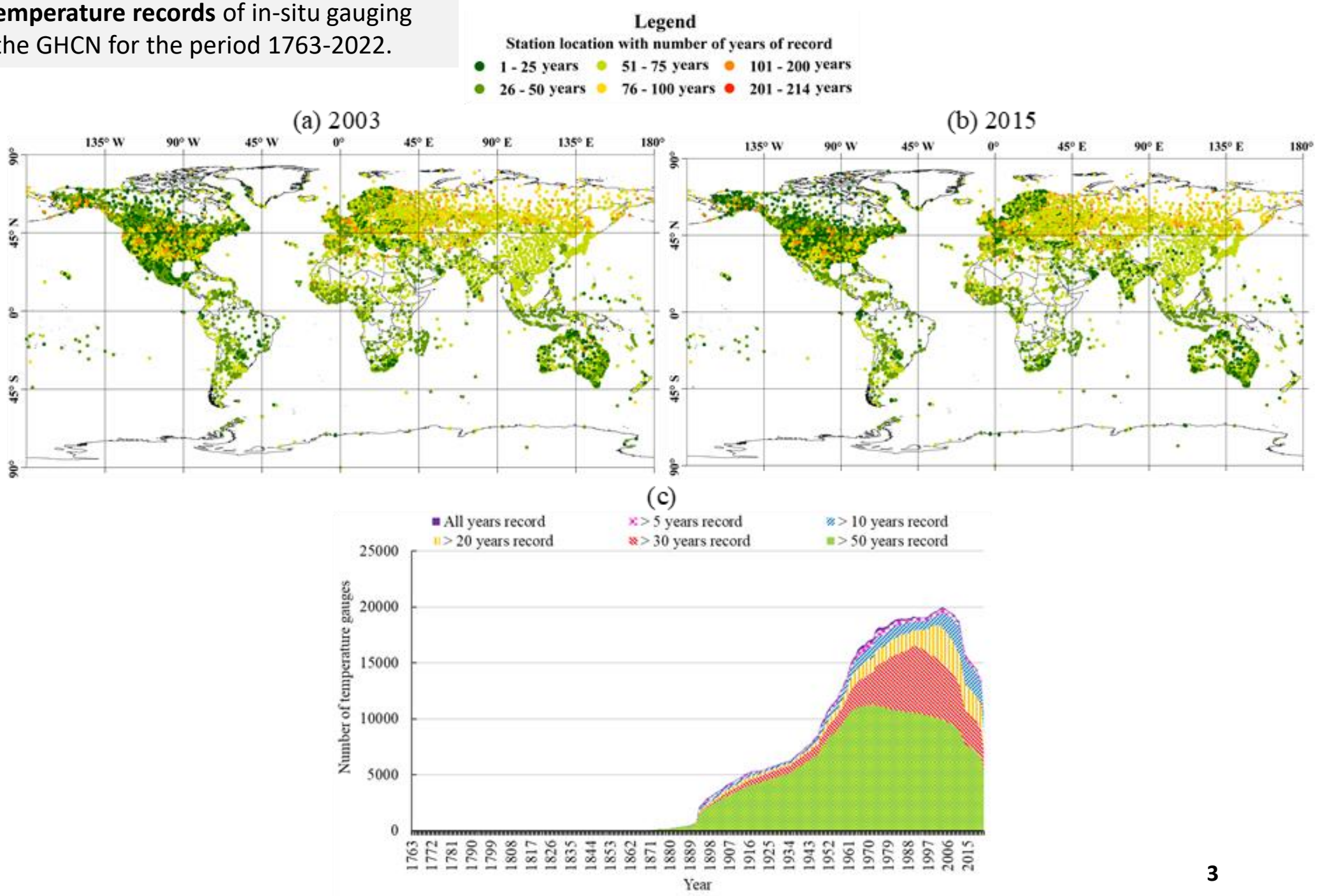
Global statistics of **precipitation records** of in-situ gauging station data from the Global Historical Climatology Network for the period 1781-2022.

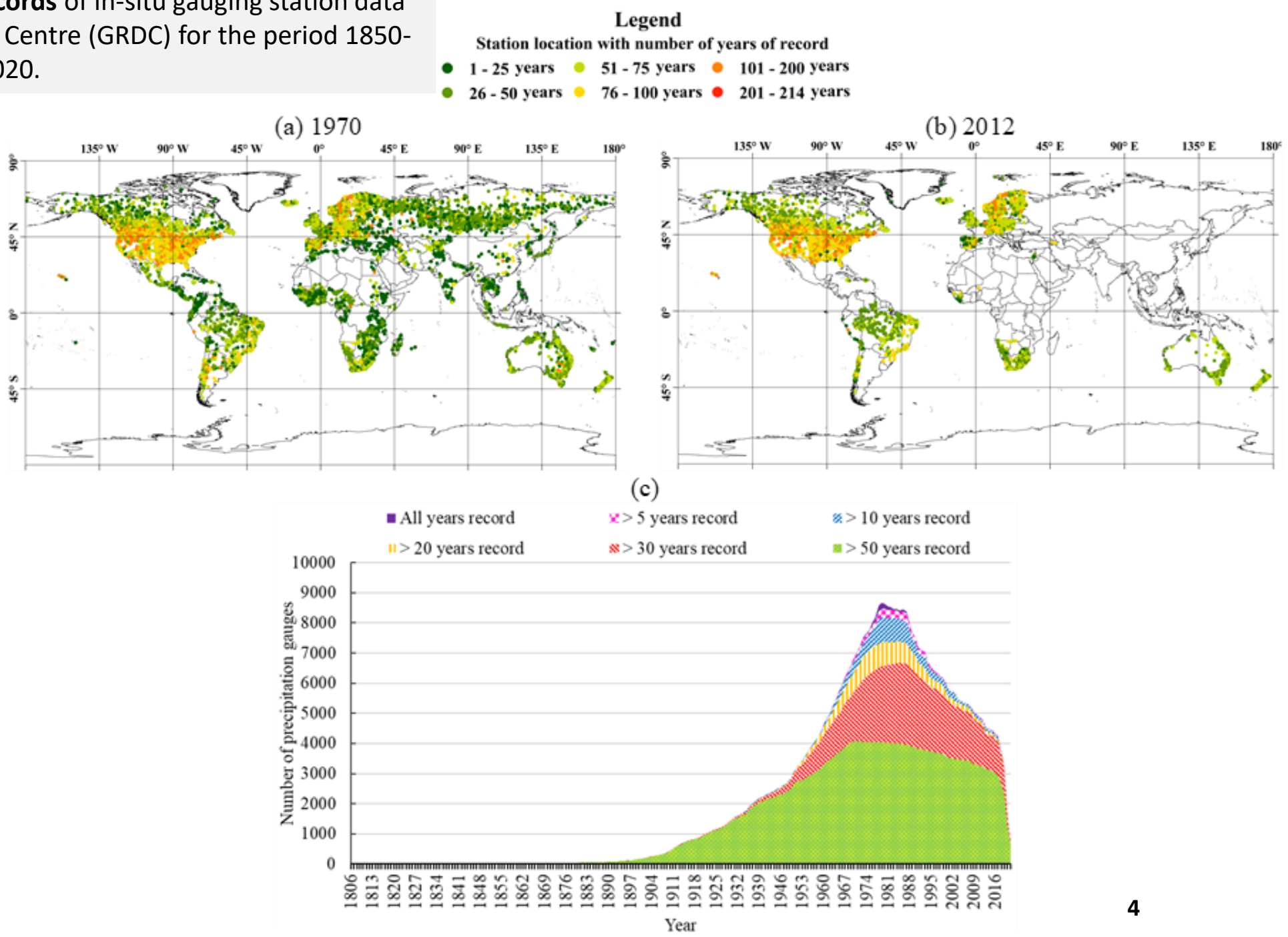


Research Motivation

Global statistics of **temperature records** of in-situ gauging station data from the GHCN for the period 1763-2022.



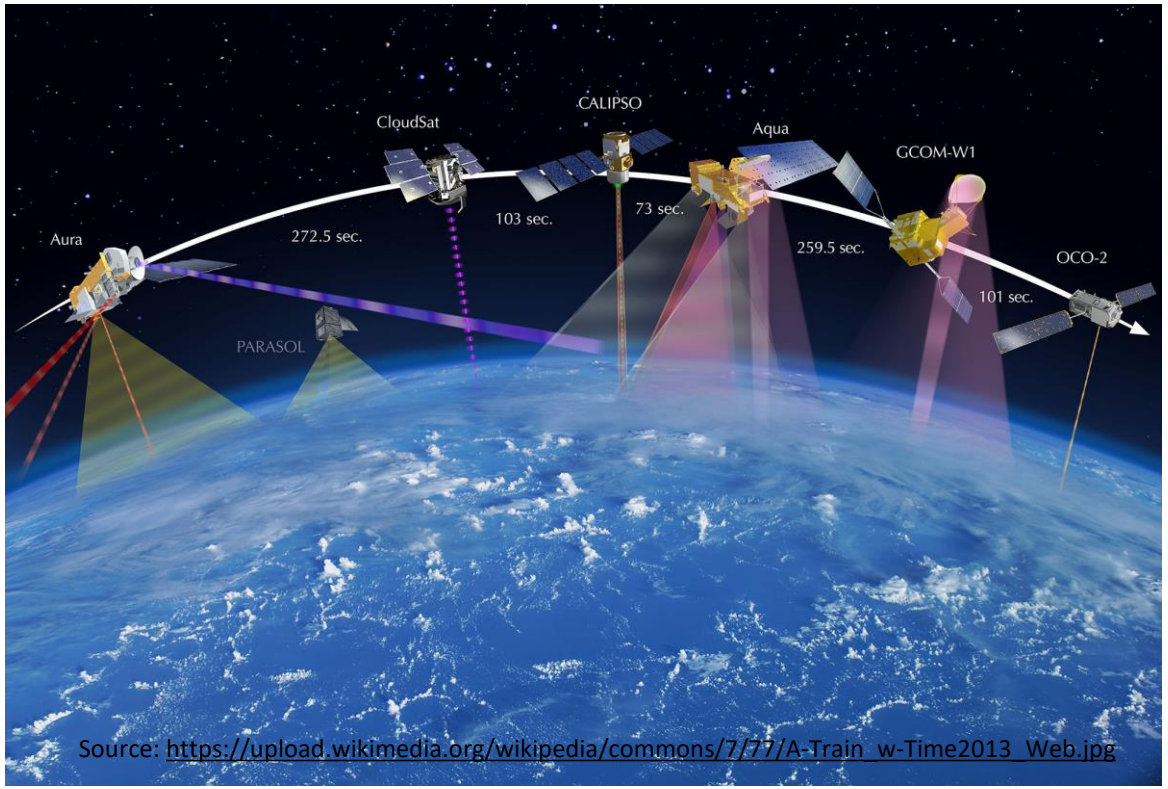
Global statistics of **streamflow records** of in-situ gauging station data collected from Global Runoff Data Centre (GRDC) for the period 1850-2020.



- Effective monitoring and assessment of the associated hydrometeorological variables are essential
  - accurate prediction/forecasting
  - early warnings
  - mitigation of extreme events.

- Different hydrometeorological variables are interconnected within the hydrologic cycle.
- Rather than designing networks monitoring each variable individually, it is always optimal & cost-effective to design multivariate networks that simultaneously monitor various hydrometeorological variables

- In recent decades, satellite-based data products have been used widely as surrogates to the in-situ gauge measurements for monitoring extreme events due to their advantages
- However, long-term observations from in-situ gauges are essential for efficient prediction as quantitative uncertainties and biases are associated with these satellite/model-based data products

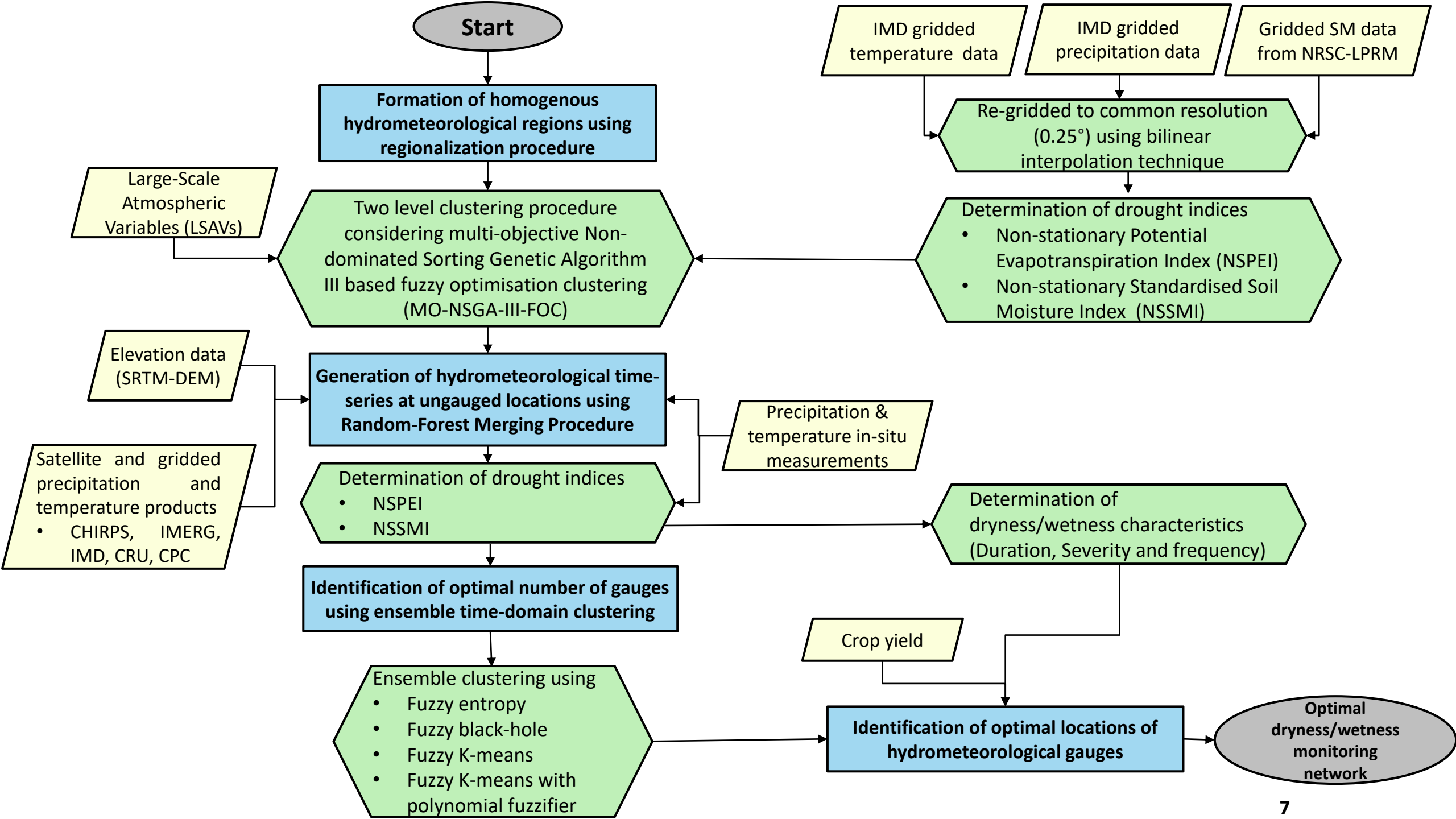


Source: https://upload.wikimedia.org/wikipedia/commons/7/77/A-Train_w-Time2013_Web.jpg

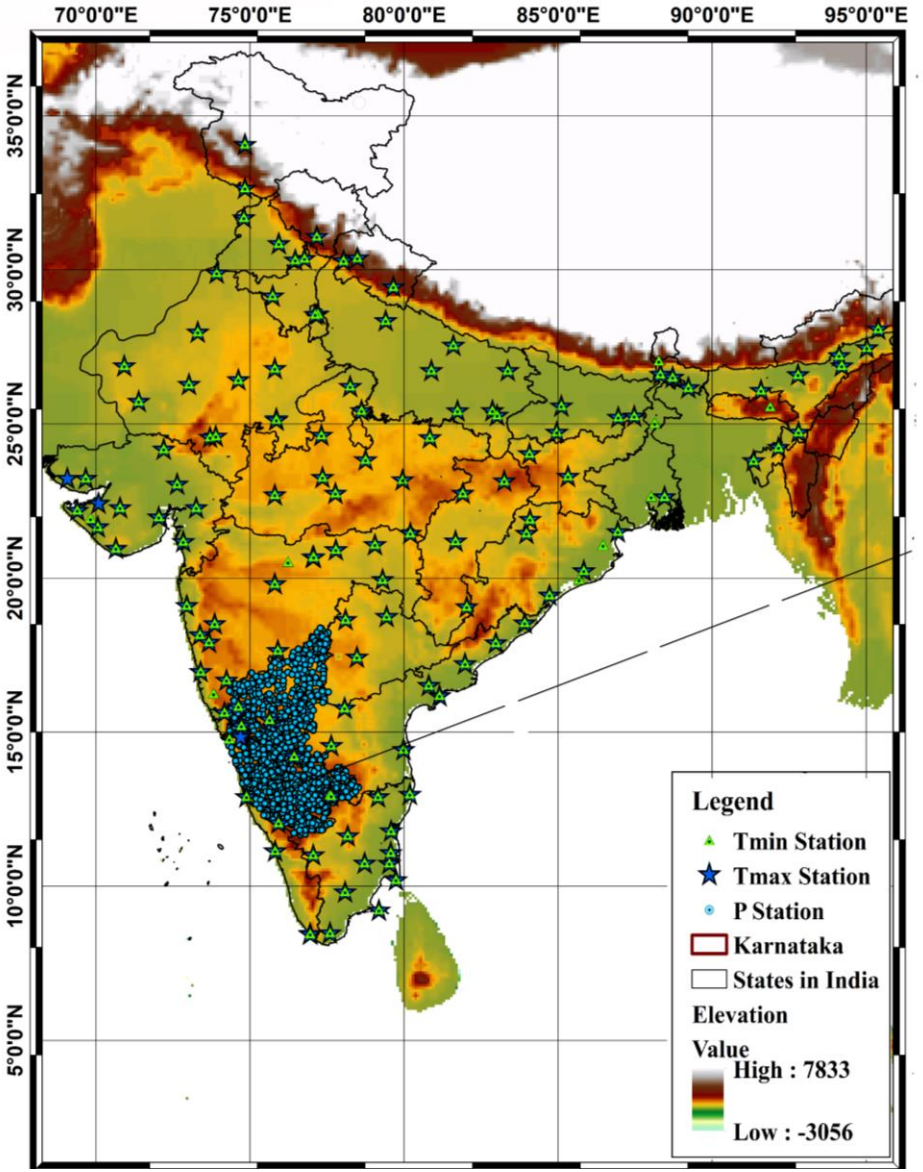
- The proposed network design methodology could be applied to areas having both small and large spatial extent, as it assesses the homogeneity of the study area and delineates it into homogeneous dryness/wetness zones (wherever necessary) using a two-level clustering-based procedure.
- To the best of our knowledge, this is the first study of its kind that proposes a multivariate design procedure for **integrated monitoring of dry and wet conditions using a multi-level clustering procedure.**
- **It also harnesses the advantages of multiple ground- and satellite-based measurements by utilizing the advantages of multi-objective optimization and fuzzy concepts.**

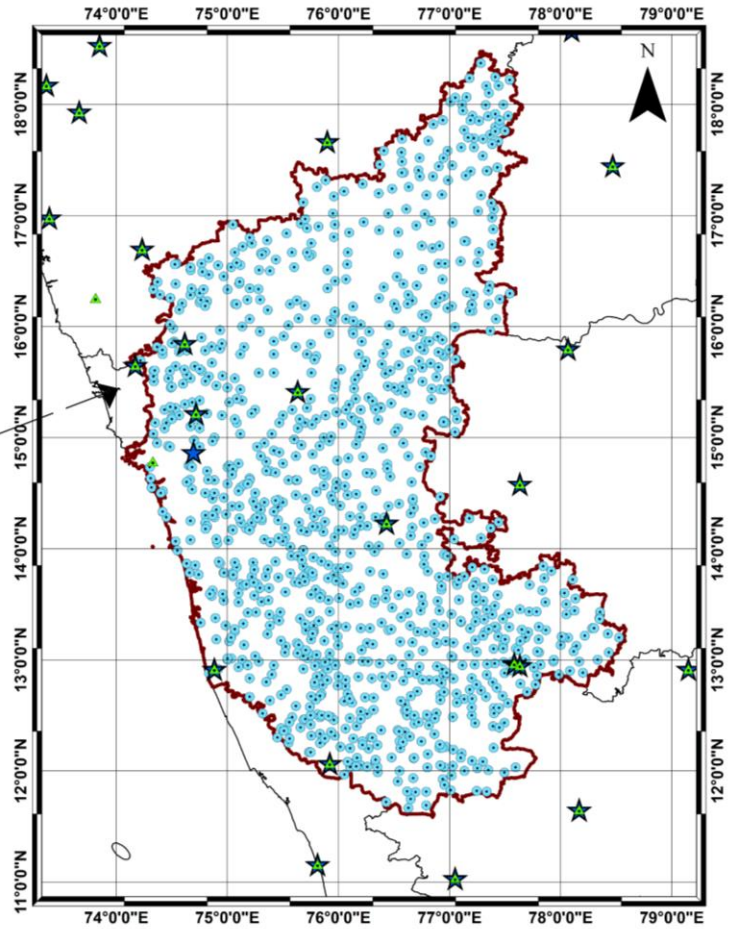
Source: https://www.sstc.org.in/automatic-rain-guage.html

Methodology


Start
Formation of homogenous hydrometeorological regions using regionalization procedure
IMD gridded temperature data
IMD gridded precipitation data
Gridded SM data from NRSC-LPRM
Re-gridded to common resolution (0.25°) using bilinear interpolation technique
Large-Scale Atmospheric Variables (LSAVs)
Two level clustering procedure considering multi-objective Non-dominated Sorting Genetic Algorithm III based fuzzy optimisation clustering (MO-NSGA-III-FOC)
Determination of drought indices
• Non-stationary Potential Evapotranspiration Index (NSPEI)
• Non-stationary Standardised Soil Moisture Index (NSSMI)
Elevation data (SRTM-DEM)
Generation of hydrometeorological time-series at ungauged locations using Random-Forest Merging Procedure
Precipitation & temperature in-situ measurements
Satellite and gridded precipitation and temperature products
• CHIRPS, IMERG, IMD, CRU, CPC
Determination of drought indices
• NSPEI
• NSSMI
Determination of dryness/wetness characteristics (Duration, Severity and frequency)
Identification of optimal number of gauges using ensemble time-domain clustering
Crop yield
Ensemble clustering using
• Fuzzy entropy
• Fuzzy black-hole
• Fuzzy K-means
• Fuzzy K-means with polynomial fuzzifier
Identification of optimal locations of hydrometeorological gauges
Optimal dryness/wetness monitoring network

Study area





In-situ gauge measurements

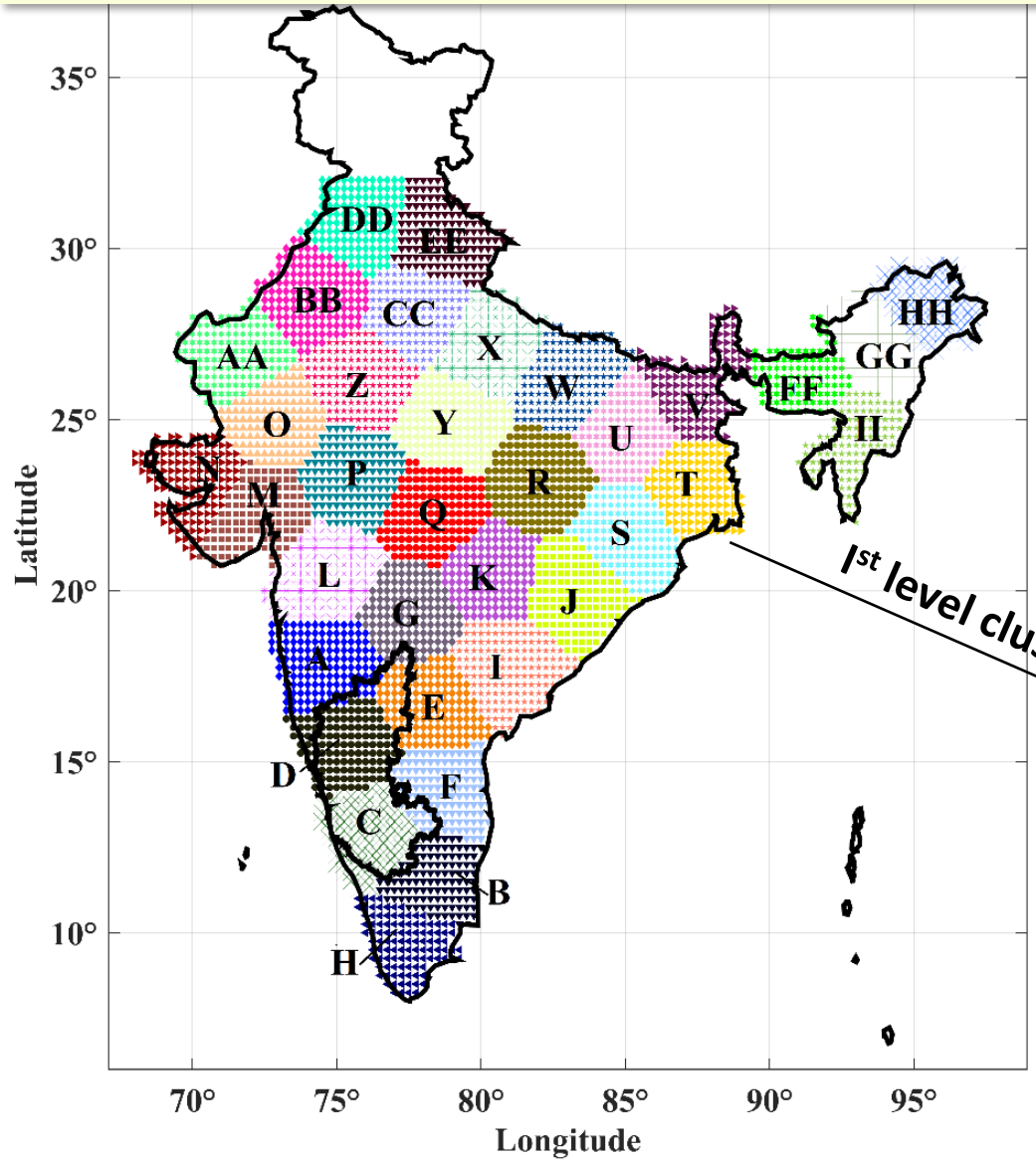
- 1128 precipitation gauges (Directorate of Economics and Statistics, Karnataka)
- 131 Tmin and 137 Tmax stations (NCEI)

Satellite/gridded data products

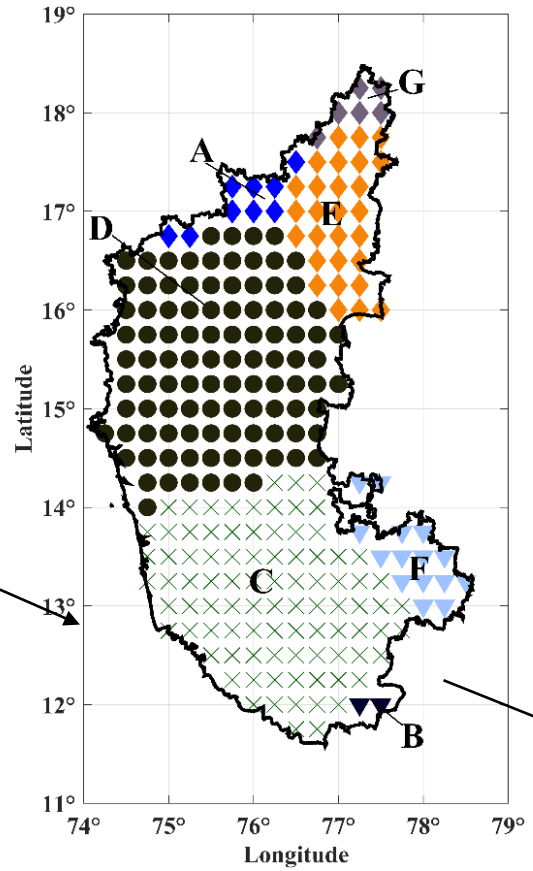
- Soil moisture (SM) data from LPRM, NRSC
- Precipitation data from CHIRPS, IMERG and IMD
- Tmax and Tmin data from CRU, CPC and IMD

Record length: Monthly scale data from 2000-2017

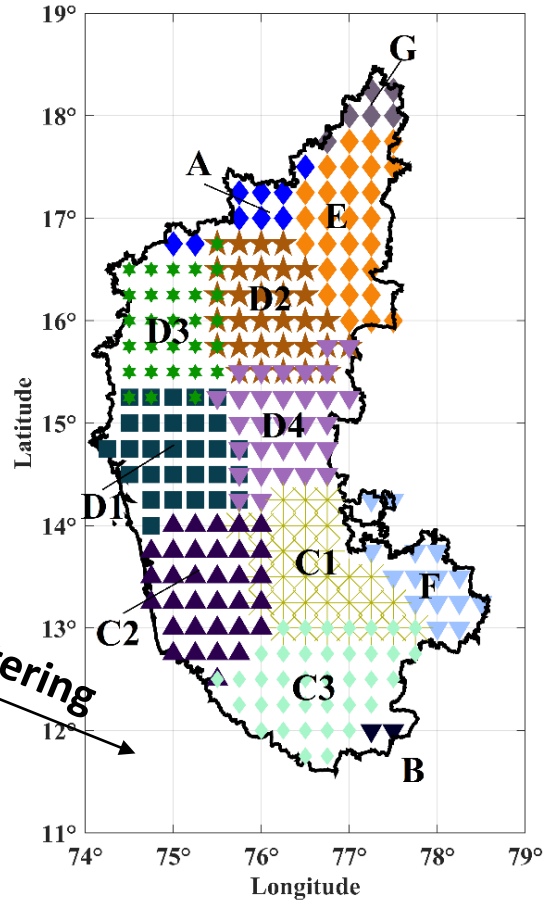
Multi-Objective Non-dominated Sorting Genetic Algorithm III based fuzzy optimisation clustering (MO-NSGA-III-FOC)



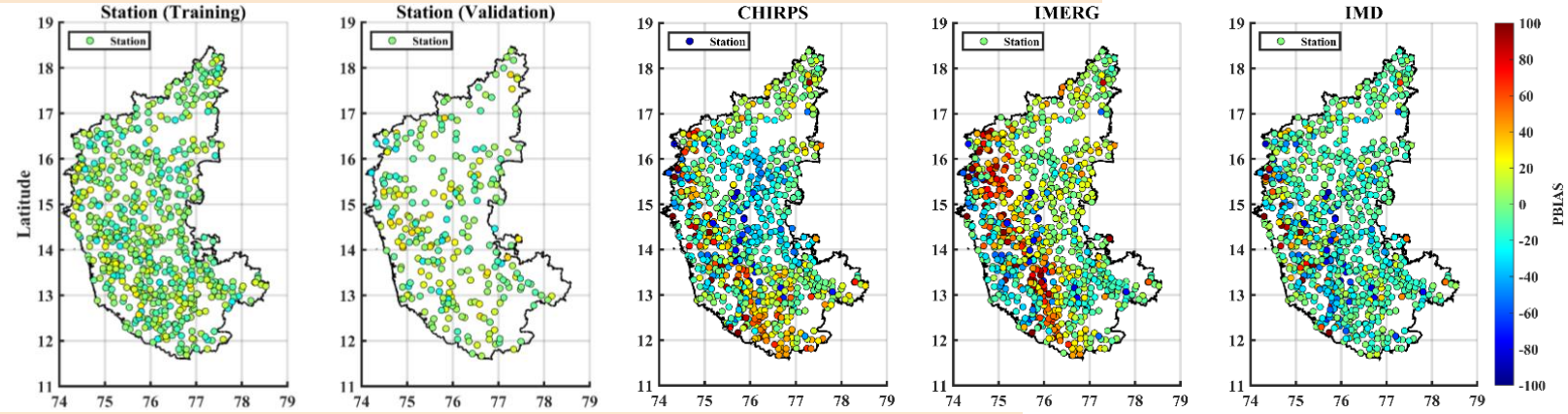
I^st level clustering



II^nd level clustering



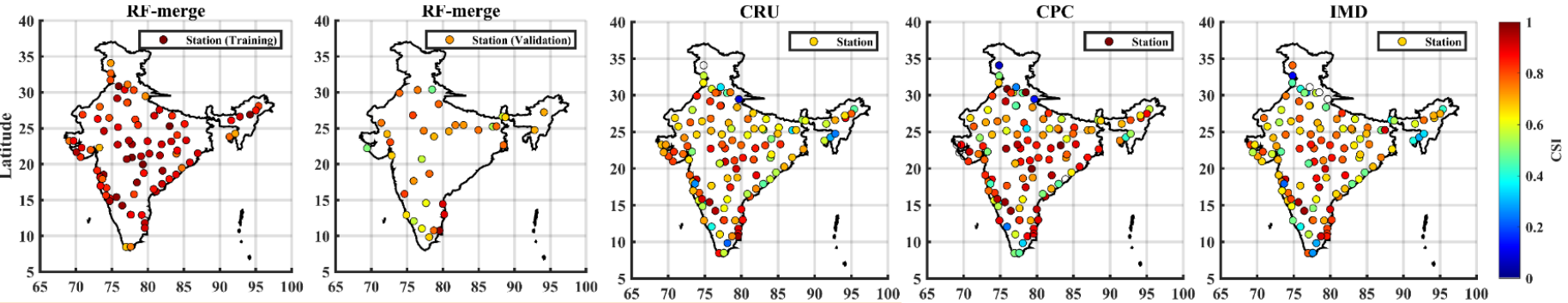
PBIAS in predicting precipitation at in-situ stations



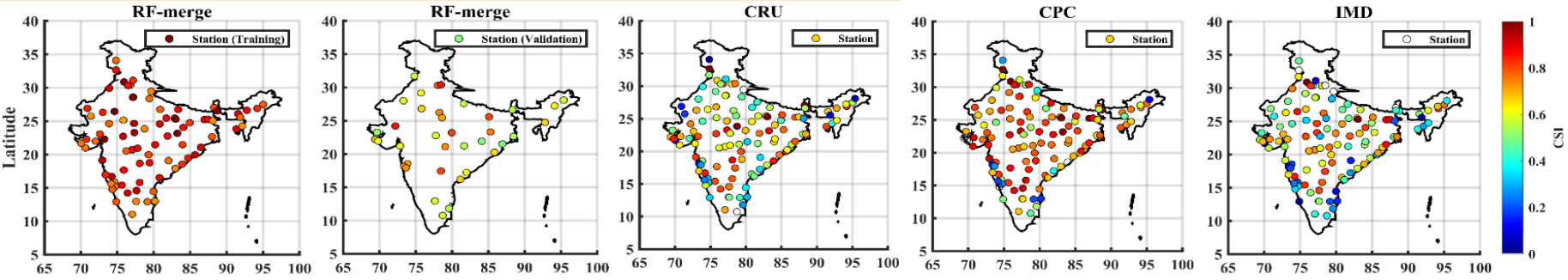
Random-Forest merging procedure to generate hydrometeorological timeseries at ungauged locations

Assessment of RF-merge model's performance: using split-sample validation

CSI for Tmax stations (10-50 percentile Tmax value)



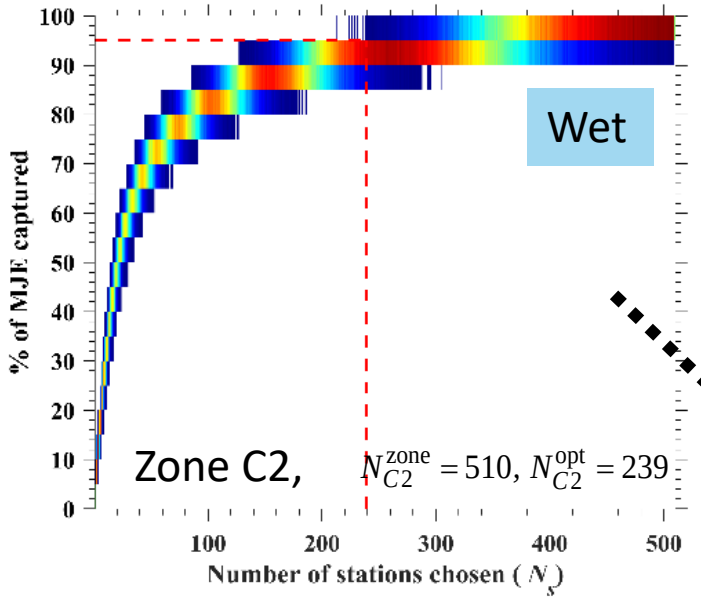
CSI for Tmax stations (20-40 percentile Tmin value)

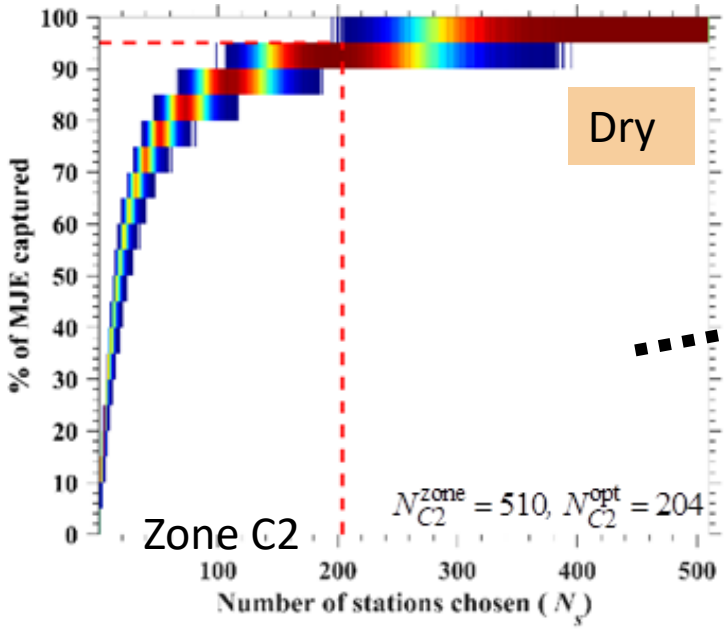


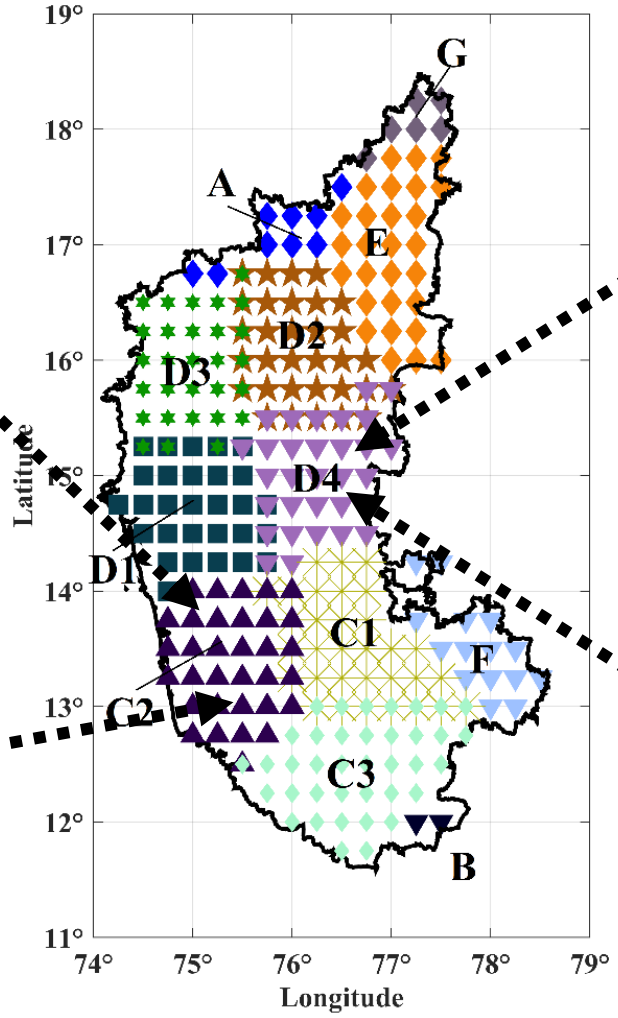
Performance measures

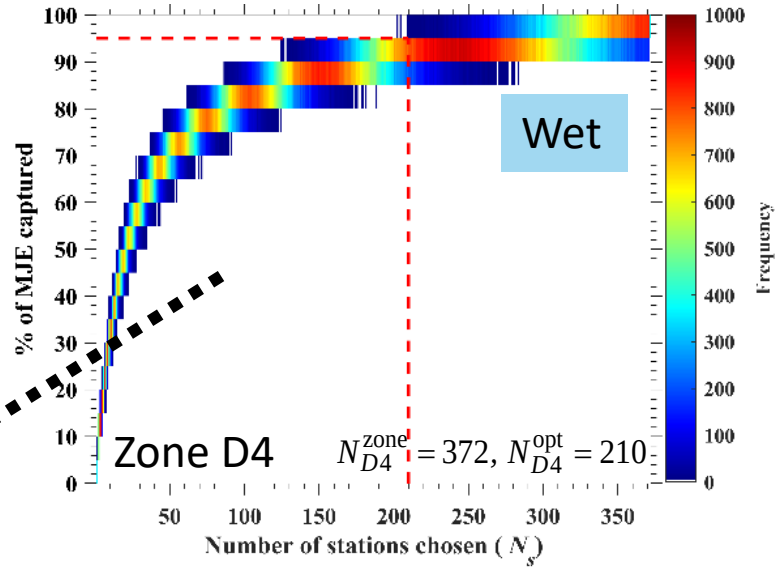
- Kling-Gupta Efficiency (KGE)
- Critical Success Index (CSI) analysed at different quantiles
- Percentage bias (PBIAS)
- Kullback-Leibler Divergence (KLD)

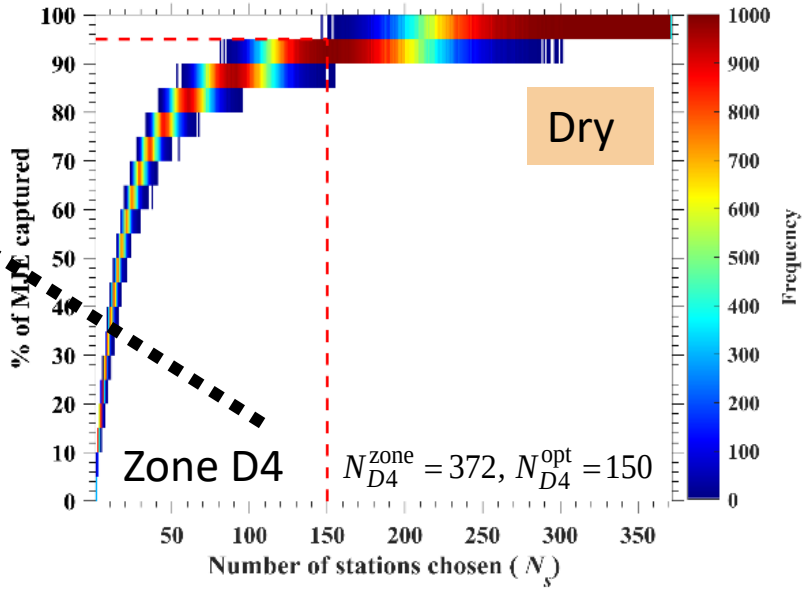
Identification of optimal number of gauges using ensemble time-domain clustering

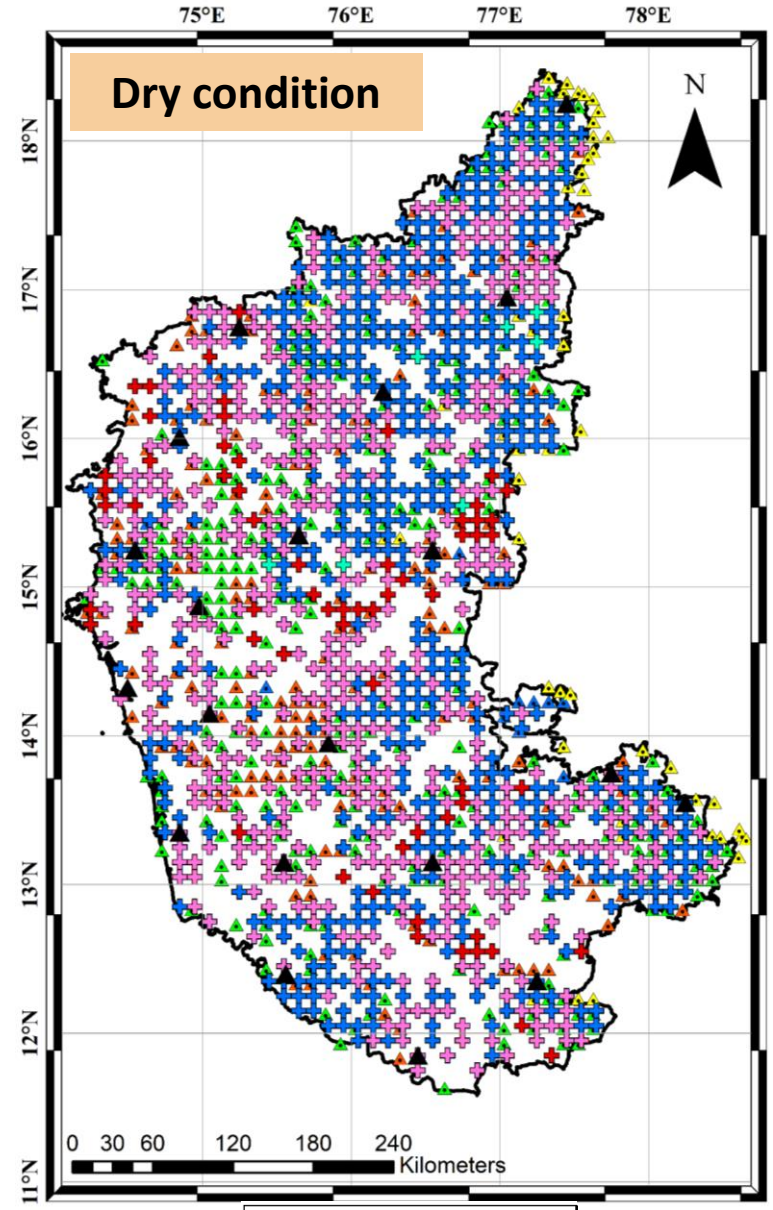


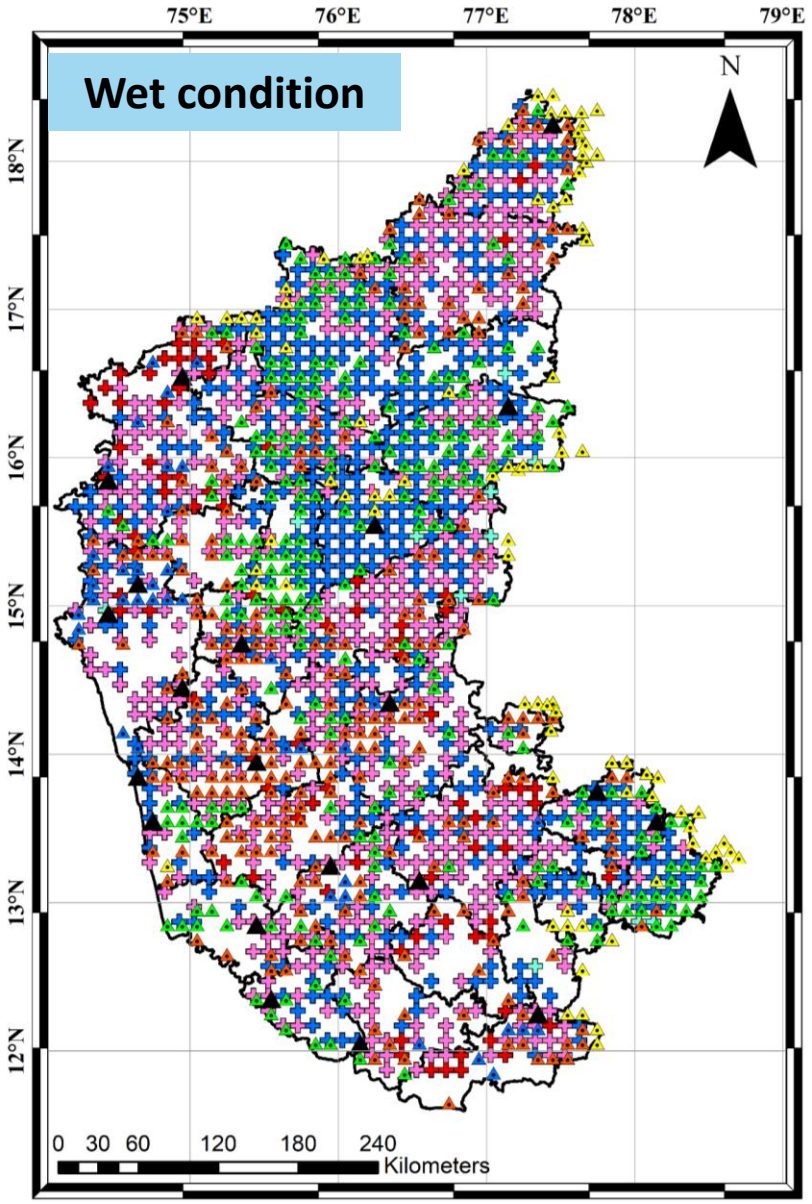


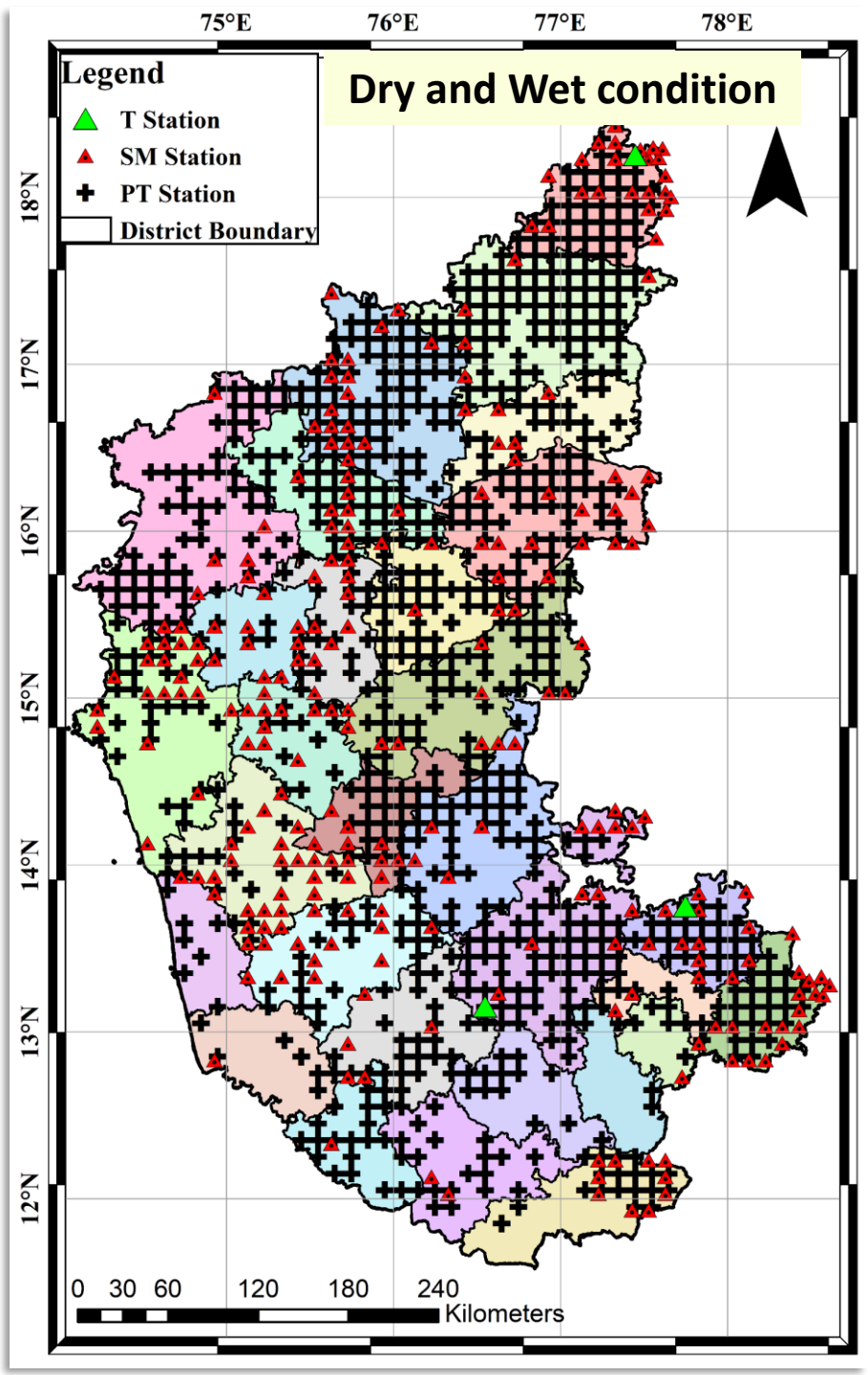







Dry condition
75°E
76°E
77°E
78°E
18°N
17°N
16°N
15°N
14°N
13°N
12°N
11°N
N
0 30 60 120 180 240
Kilometers
Legend
T Station
SM Station
P Station
0-25%
25-50%
50-75%
75-100%
District Boundary


Wet condition
75°E
76°E
77°E
78°E
79°E
18°N
17°N
16°N
15°N
14°N
13°N
12°N
N
0 30 60 120 180 240
Kilometers
Legend
T Station
SM Station
P Station
0-25%
25-50%
50-75%
75-100%
District Boundary


Dry and Wet condition
75°E
76°E
77°E
78°E
18°N
17°N
16°N
15°N
14°N
13°N
12°N
Legend
T Station
SM Station
PT Station
District Boundary
0 30 60 120 180 240
Kilometers

INFERENCES

- A total of
  - (i) 1059 precipitation (P), 552 SM and 20 temperature (T) stations formed the integrated ground-based dryness monitoring network (IGDMN).
  - (ii) 1144 P, 664 SM and 21 T stations formed the integrated ground-based wetness monitoring network (IGWMN).

- Out of the total precipitation key stations identified
  - i. In IGDMN,
    - 578 locations have an existing P stations
  - ii. the rest are P-ungauged. In IGWMN,
    - 540 locations have an existing P stations (P-gauged)
    - the rest 604 grids are potential location where new gauges needs to be installed (P-ungauged)

- Out of the total P , T and SM stations chosen in IGDMN and IGWMN, 848 P, 3 T and 268 SM stations were found to be shared in both networks

- None of the identified Tmax and Tmin key station locations in IGDMN and IGWMN is gauged. The four existing stations could be relocated to 4 of the identified key station locations. As 3 T monitoring stations are common to IGDMN and IGWMN, additional 34 (=20+21-3-4) stations are desirable.

- There are no existing SM gauges. Hence all the key SM gauges identified need to be newly installed.


Thank
you!