



Supplement of

Sea level reconstruction reveals improved separation of regional climate and trend patterns over the last seven decades

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Fig. S1: Comparisons of tide gauge data gap-filling statistical methods (Autoregressive (AR) Modelling, Probabilistic Principal Component Analysis (PPCA), and Regularized Expectation Maximization (EM)). Addressing short (12 months), medium (36 months), and large (108 months) data gaps in tide gauge records (Group-1, 10-tide gauge simulation case). Each record has been randomly placed with three types of gaps to mimic realistic tide gauge data missing scenarios. The red line in the time series represents the “true” observations. Additionally, the PPCA method reconstructs the entire time series rather than just filling gaps, allowing a full reconstruction visualization. In contrast, the results from the other two methods only visualize the filled gaps.

Fig. S2: Comparisons of 10-tide gauge data gap-filling statistical methods for the Group-2 simulation case, addressing data gaps of 12, 36, and 108 months, and with an additional 120 random missing months, to assess the respective performance of the three data gap-filling methods. Each record has been randomly placed with the above-described simulated data gaps to mimic realistic tide gauge data missing scenarios.

Fig. S3: Comparisons of 28-tide gauge data gap-filling statistical methods for the Group-3 simulation case, with 120 months of randomly distributed missing data points.

Fig. S4: Spatial maps of the correlation coefficient (r) and root-mean-square error (RMSE, mm) between gap-filled tide-gauge records via three gap-filling methods and their corresponding complete (“true”) records: Regularized EM (panels a, b), Probabilistic Principal Component Analysis (PPCA; panels c, d), and autoregressive (AR) modeling (panels e, f). The assessment uses 198 tide gauges with near-complete monthly records spanning January 1980–December 2021. Circles, stars, and triangles denote Group 1, Group 2, and Group 3, respectively. Group 1 (40 gauges) is assigned random gaps of 12, 36, and 108 months; Group 2 (another 40 gauges) is assigned the same random gaps plus an additional 120 random missing months; Group 3 (118 gauges) is assigned 120 random missing months.

Table. S1: Performance of the three gap-filling methods based on the average Pearson correlation coefficient (r) and root-mean-square error (RMSE, mm) between the 198 gap-filled records (January 1980–December 2021) and their complete counterparts, evaluated separately for Group 1, Group 2, and Group 3, and for the overall mean.

Fig. S5: Spatial distribution of 287 tide gauge stations from January 1950 to January 2022, improved via gap-filling using the Regularized Expectation-Maximization (EM) method (red circles). 225 stations (yellow squares) were selected for the final reconstruction. A subset of 48 near-complete stations (blue triangles, average gap rate at 1.1%) was used to evaluate and compare different statistical methods for tide gauge data gap-filling. Base map image: NASA (National Aeronautics and Space Administration) Blue Marble.

Fig. S6: Schematic flowchart of the modified sea-level reconstruction procedure. Inputs are monthly PSMSL tide-gauge records (January 1950–January 2022) and AVISO gridded sea-level anomalies (SLA, January 1993–December 2021). Outputs are 72 years (January 1950–January 2022) of monthly sea-level grids and a global mean sea-level (GMSL) time series, each with corresponding error estimates.

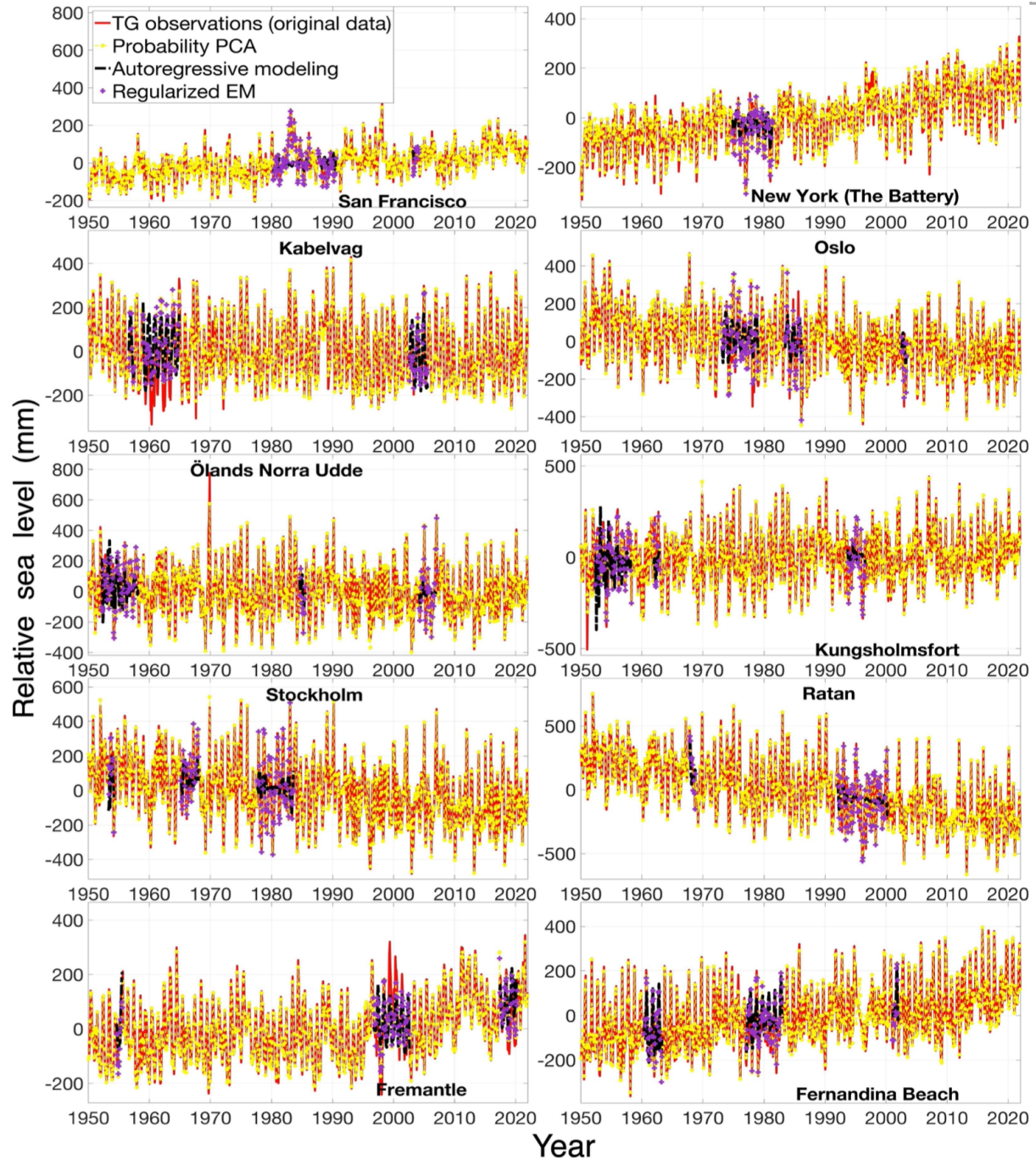


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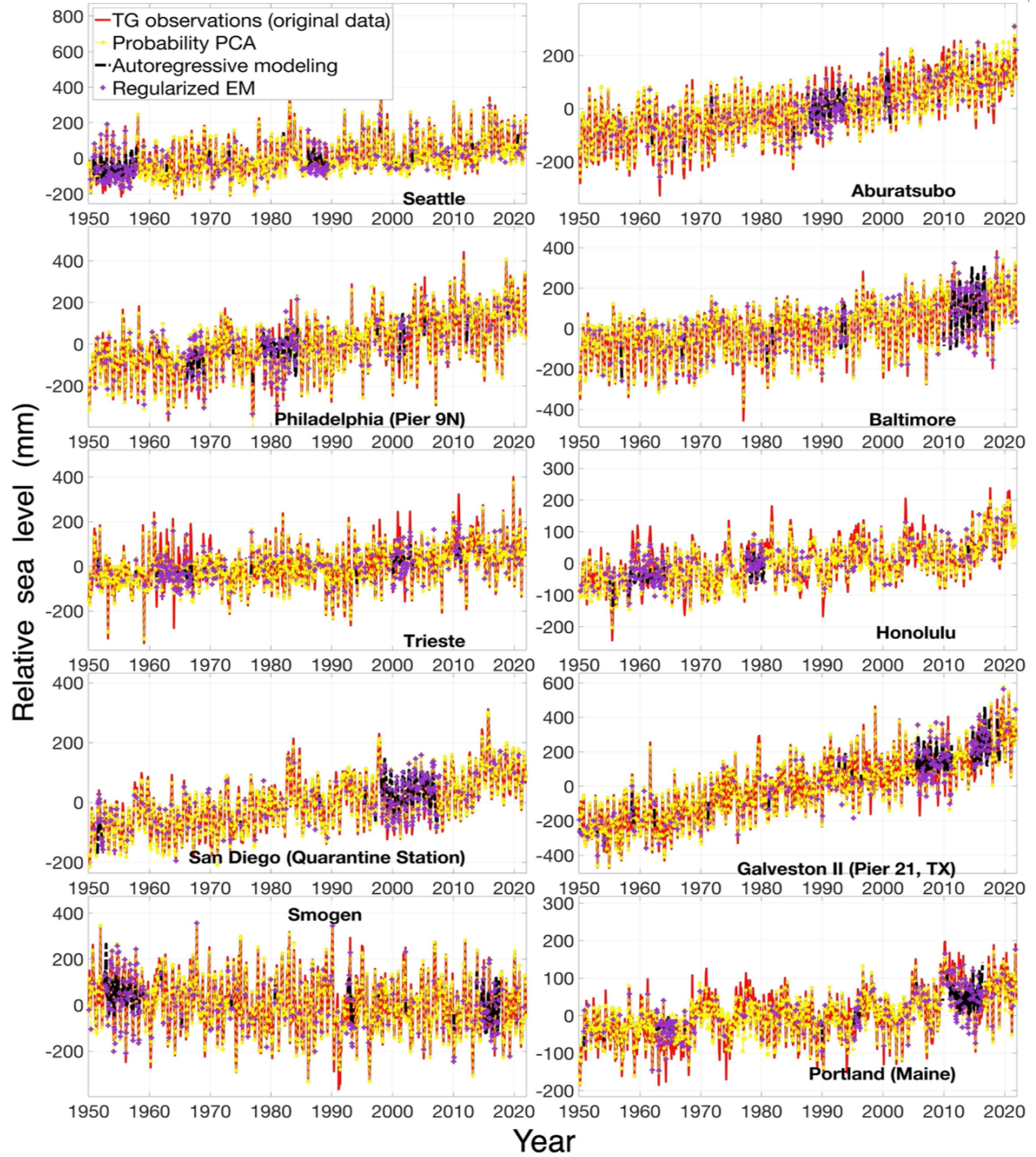


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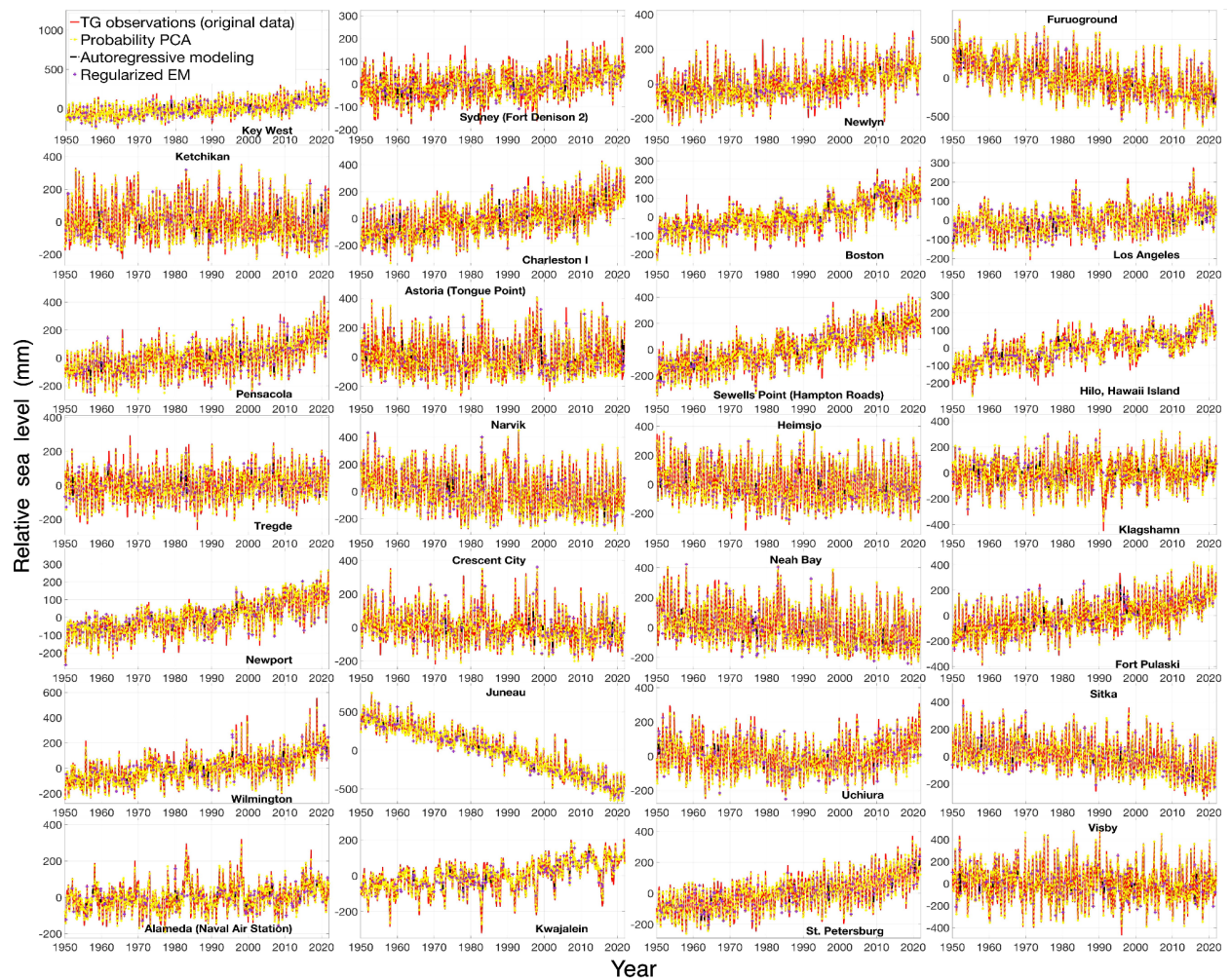


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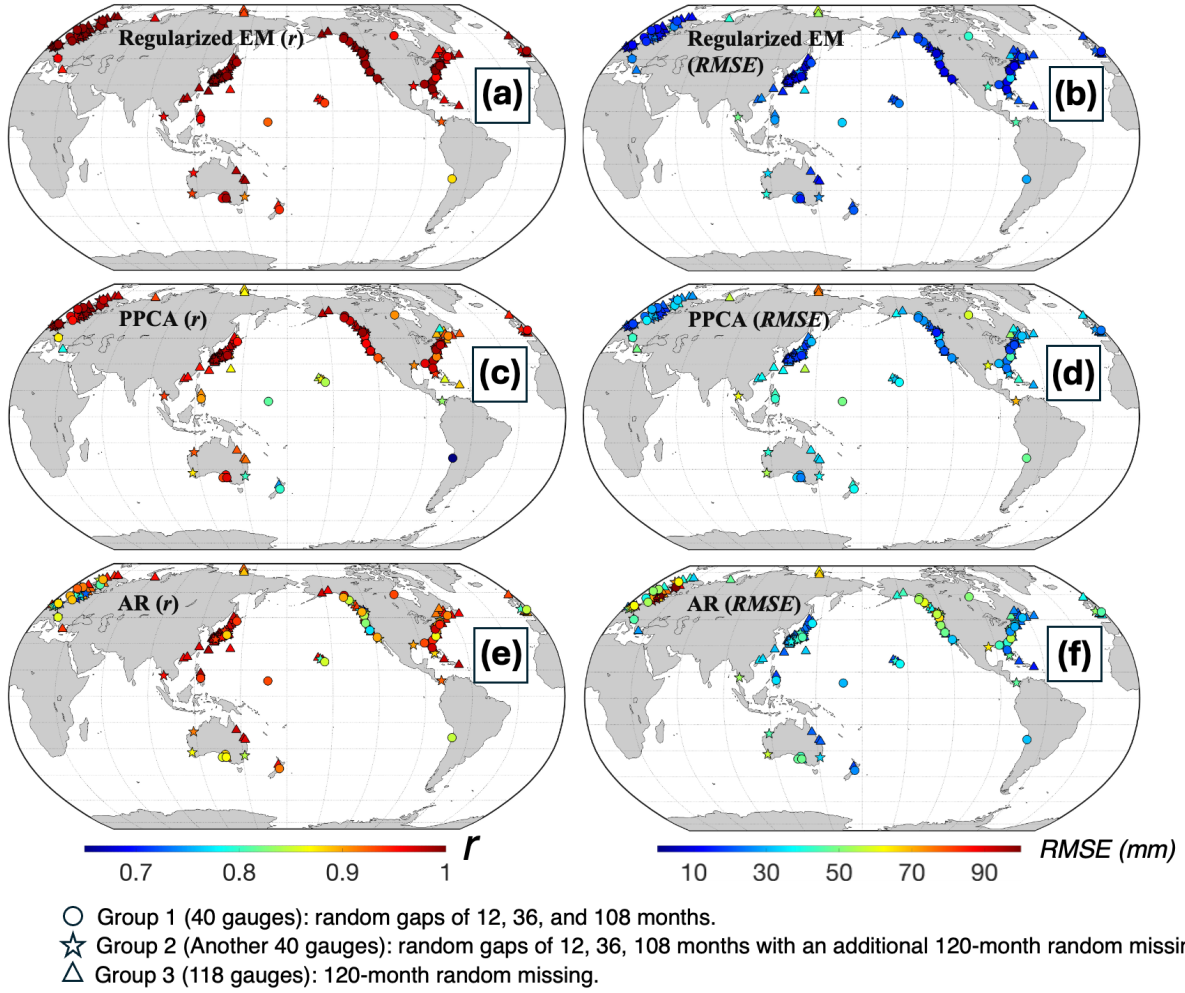


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	Pearson correlation coefficient (r)				RMSE (mm)			
	Group 1	Group 2	Group 3	Mean	Group 1	Group 2	Group 3	Mean
PPCA	94.14%	95.48%	95.97%	95.49%	29.13	29.33	25.88	27.25
Regularized EM	97.94%	97.98%	98.91%	98.50%	17.76	20.87	13.11	15.64
AR modeling	89.50%	83.38%	95.70%	91.92%	46.50	61.42	31.89	40.88

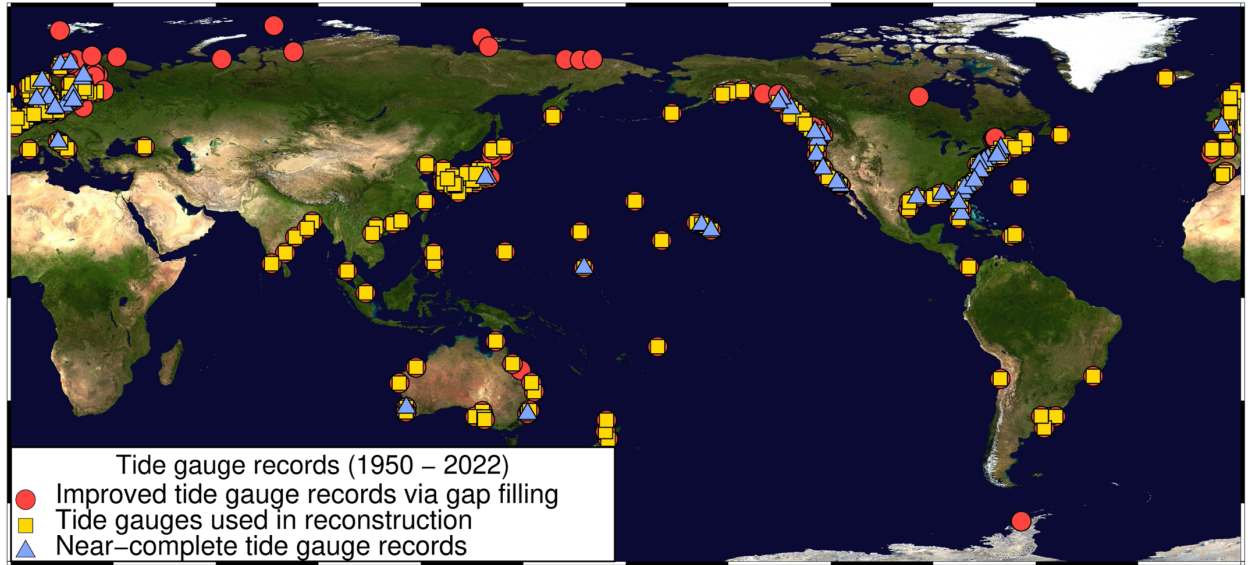


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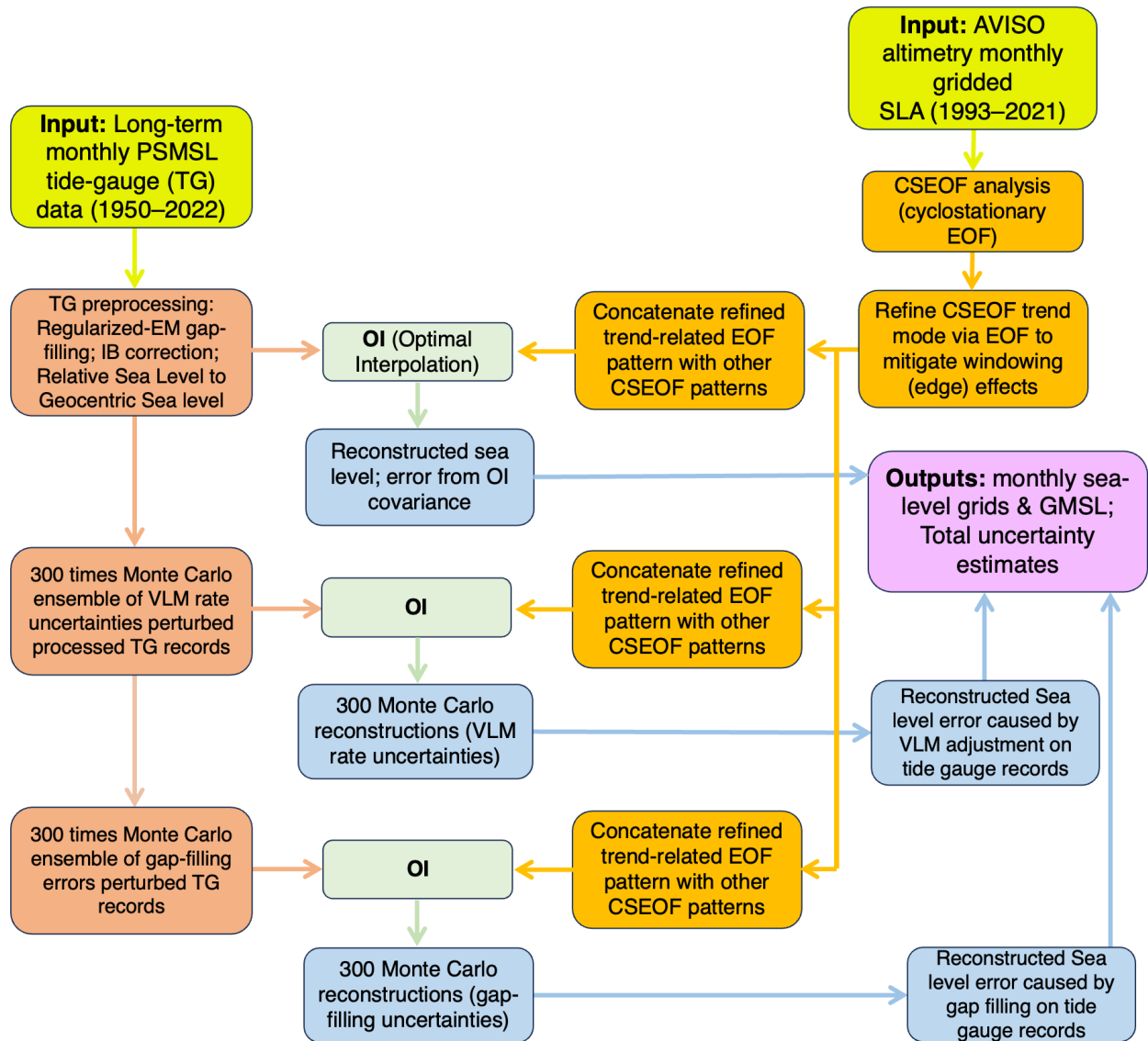


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