



Enhancing Coverage and Confidence of HF Radar Current and Wave Level-3 Products through Multi-Station Integration

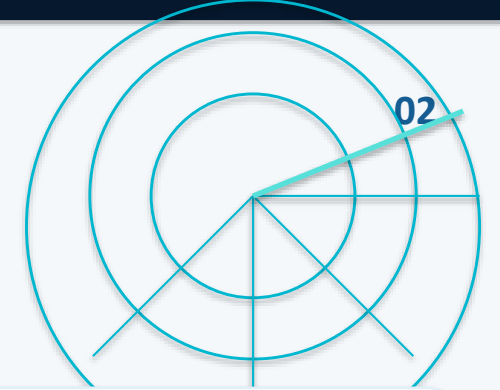
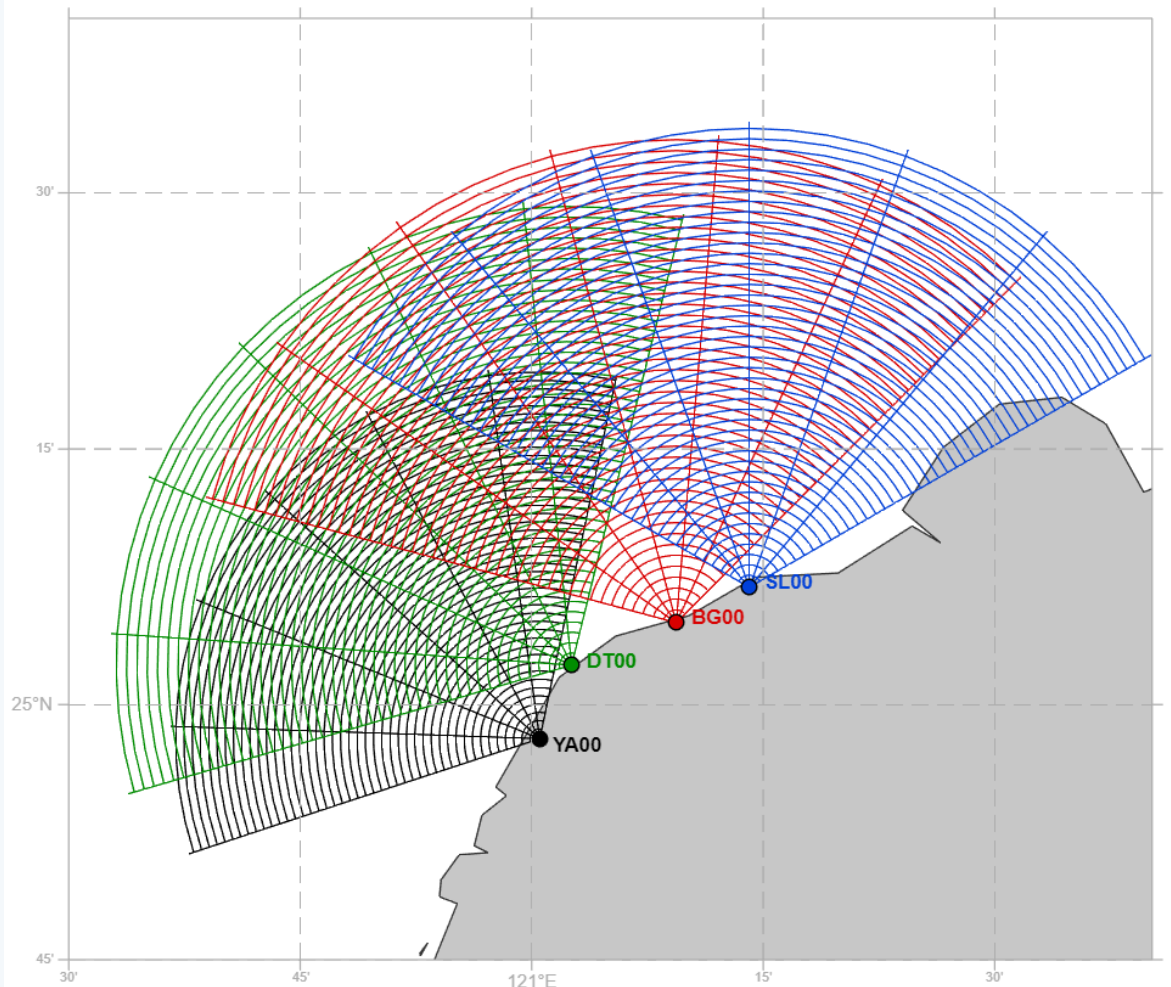
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MOTIVATION

Overlap is not redundancy to discard it is information to use



01 Single-station limitation

Different sectors, signal quality, geometry, and missing observations.

02 Multi-station opportunity

Overlapping L2 observations provide independent views of the same ocean region.

03 Research objective

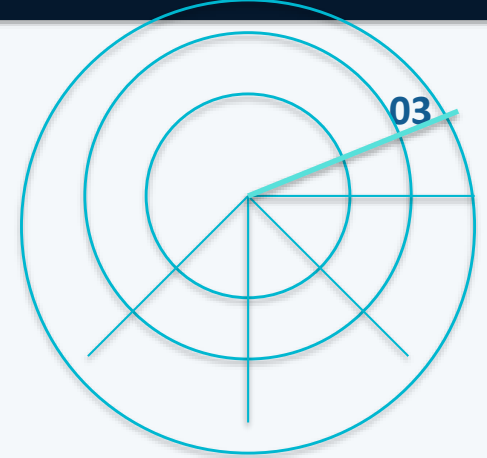
Convert overlap into larger usable Level-3 coverage without sacrificing physical reliability.

COVERAGE

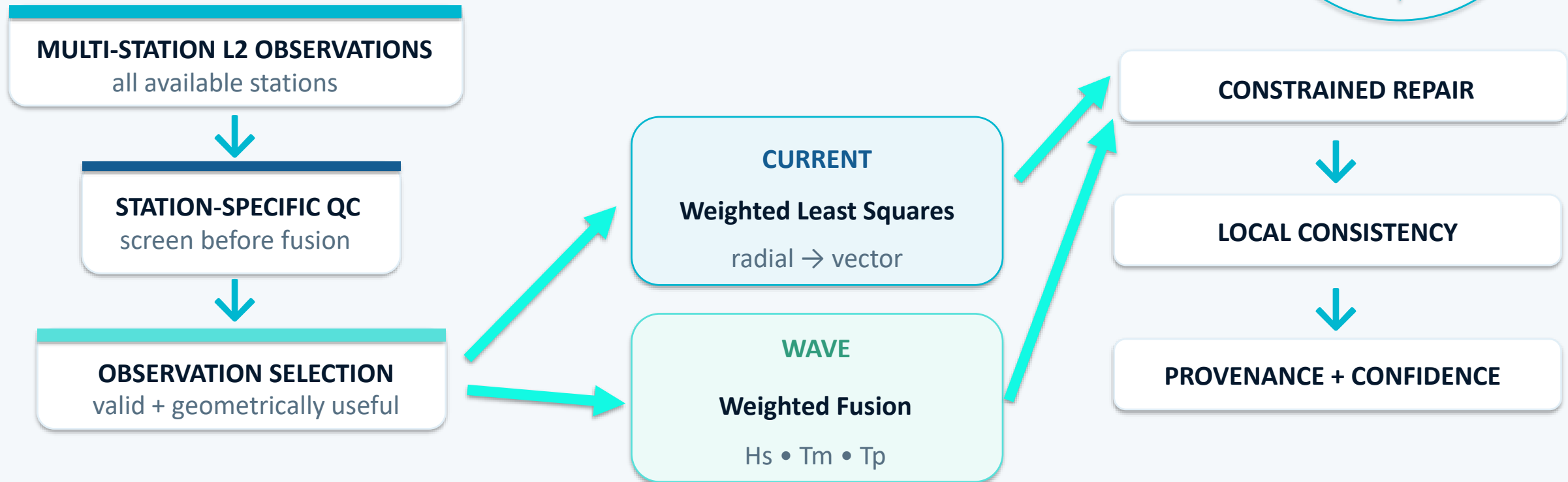
CONFIDENCE

CONTINUITY

The same ocean region can be observed by multiple HF radar stations at the same time.



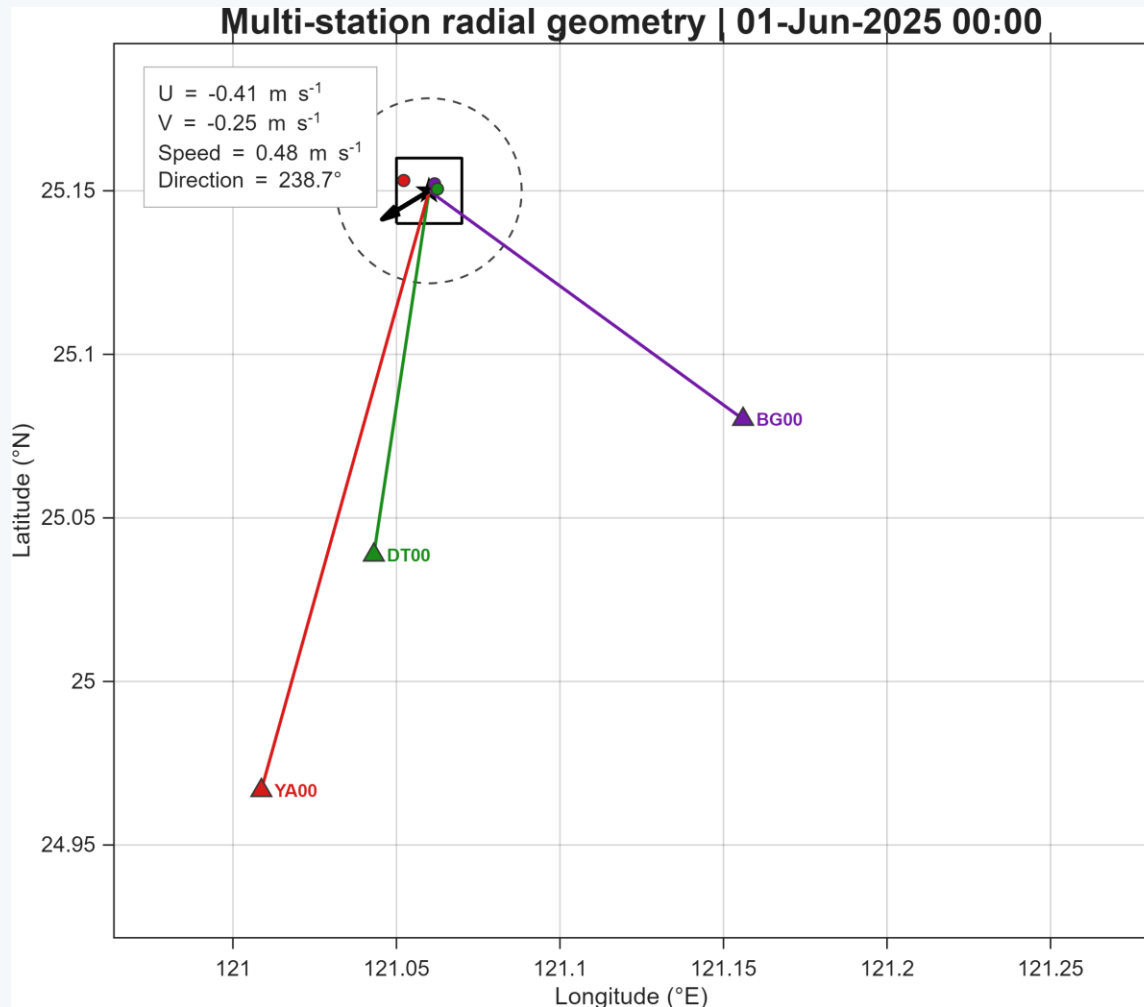
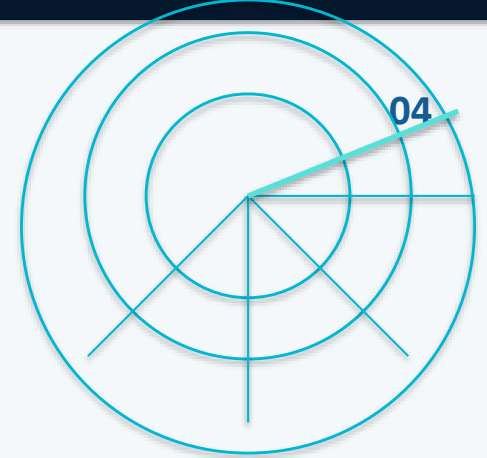
A unified multi-station Level-3 framework



LEVEL-3 PRODUCT TARGET

Higher usable coverage • explicit confidence • traceable source history

WLS are the solution of multi-station current reconstruction



Radial to vector projection formula

$$V_r = u \sin \theta + v \cos \theta$$

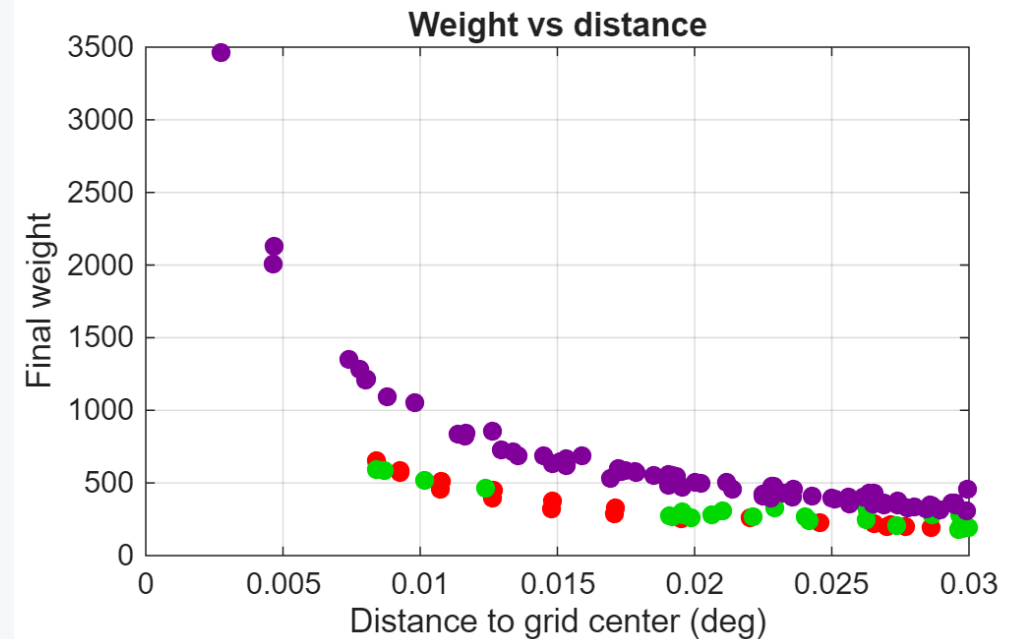
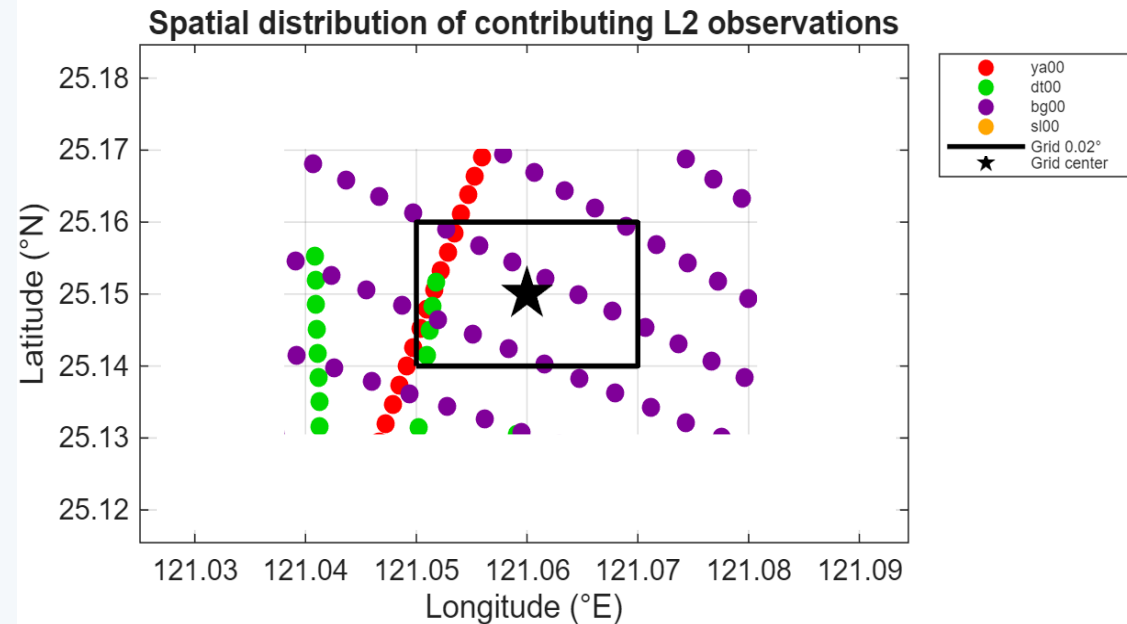
WEIGHTED LEAST SQUARES

$$\mathbf{x} = [u \ v]^T = (A^T W A)^{-1} A^T W \mathbf{v}_r$$

$$W = \text{diag}(w_i)$$

$$w_i = \max \left(0.1, \min \left(1.0, 10^{\frac{SNR_{dB,i} - 15}{10}} \right) \right)$$

Hs, Tm, and Tp are fused at the Level-3 grid using contribution weights.



FUSION

$$H_{S, \text{fusion}} = \frac{\sum_i w_i H_{S, i}}{\sum_i w_i}$$

Nearby / better-supported observations receive larger weights.



**Quality control is applied before integration;
repair and provenance are applied after
reconstruction.**

01**Current QC**

- signal / SNR QC
- physical radial velocity
- temporal consistency
- directional / geometric consistency
- station-specific masking

02**Wave QC**

- finite H_s , T_m , T_p
- physical ranges
- $SNR_{2nd_mean} \geq 7$ dB
- WavesOverallQc
- $T_p - T_m$ consistency
- station-specific masking

03**Constrained repair**

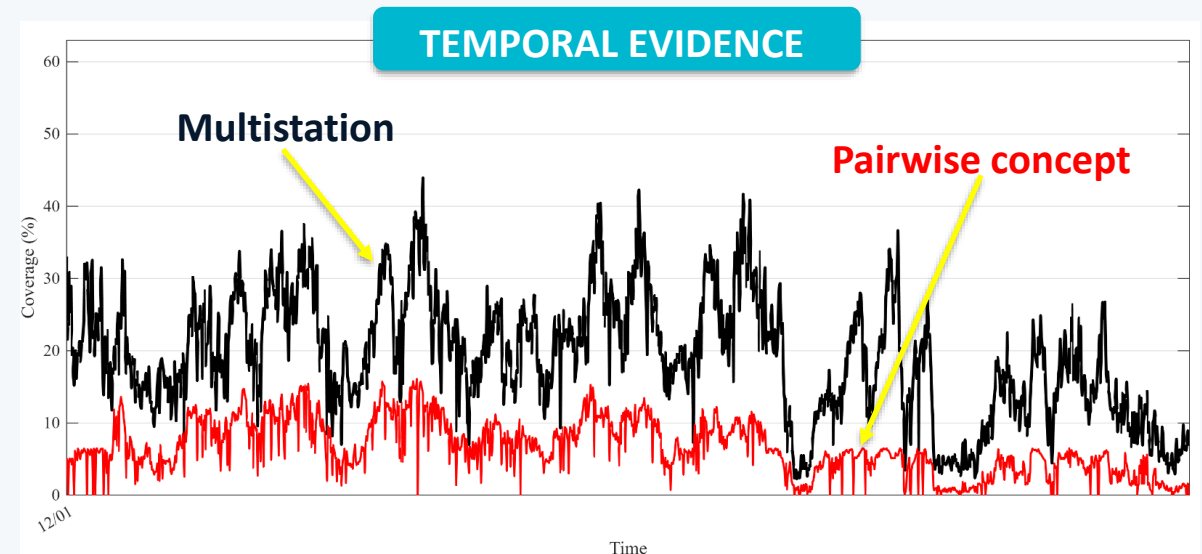
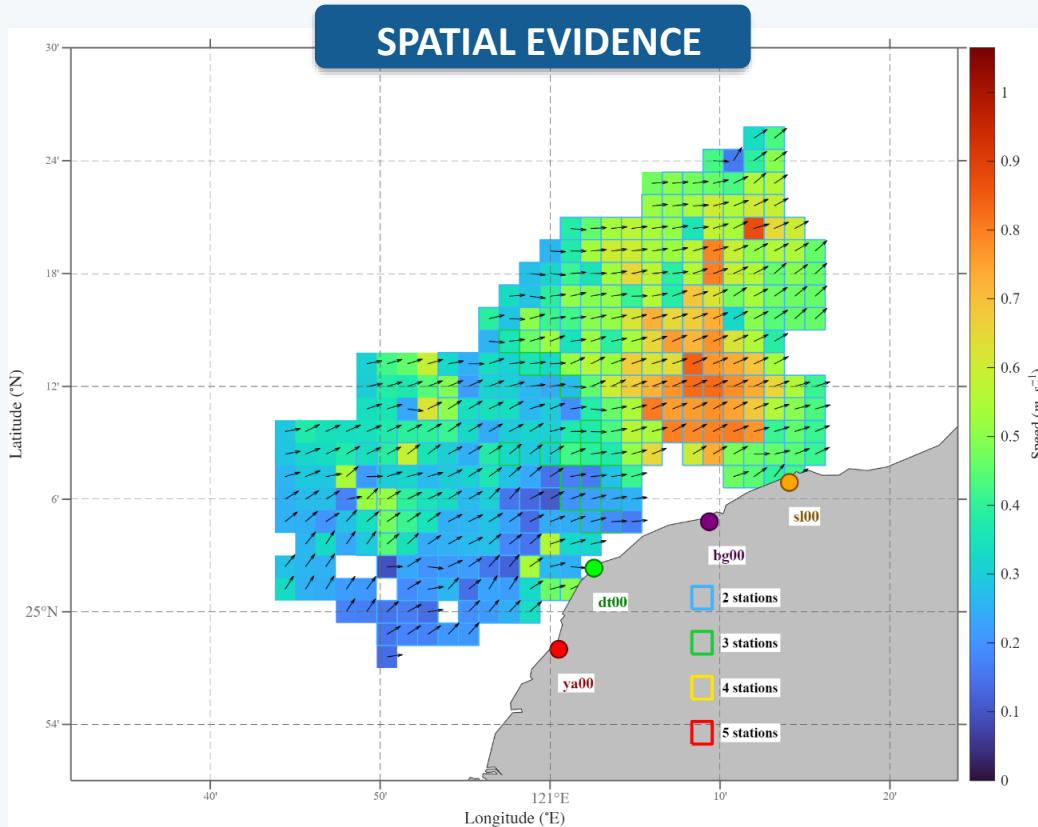
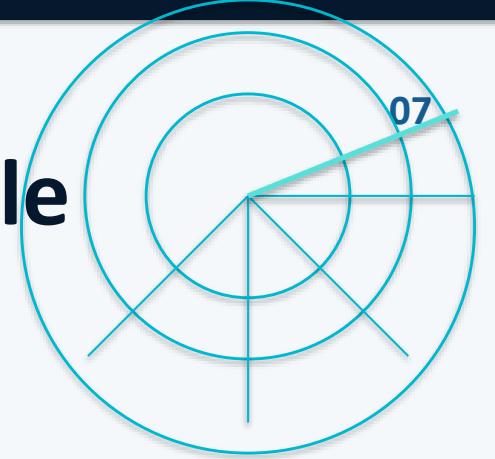
Only eligible gaps are repaired. The goal is to recover usable observations, not to manufacture coverage.

04**Provenance**

Every Level-3 cell retains its source class: direct multi, direct single, spatial / temporal repair, or rejected.

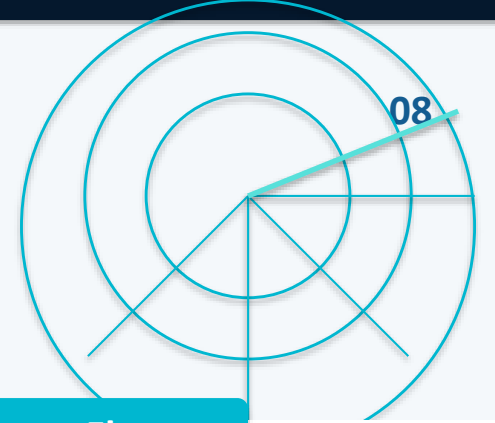
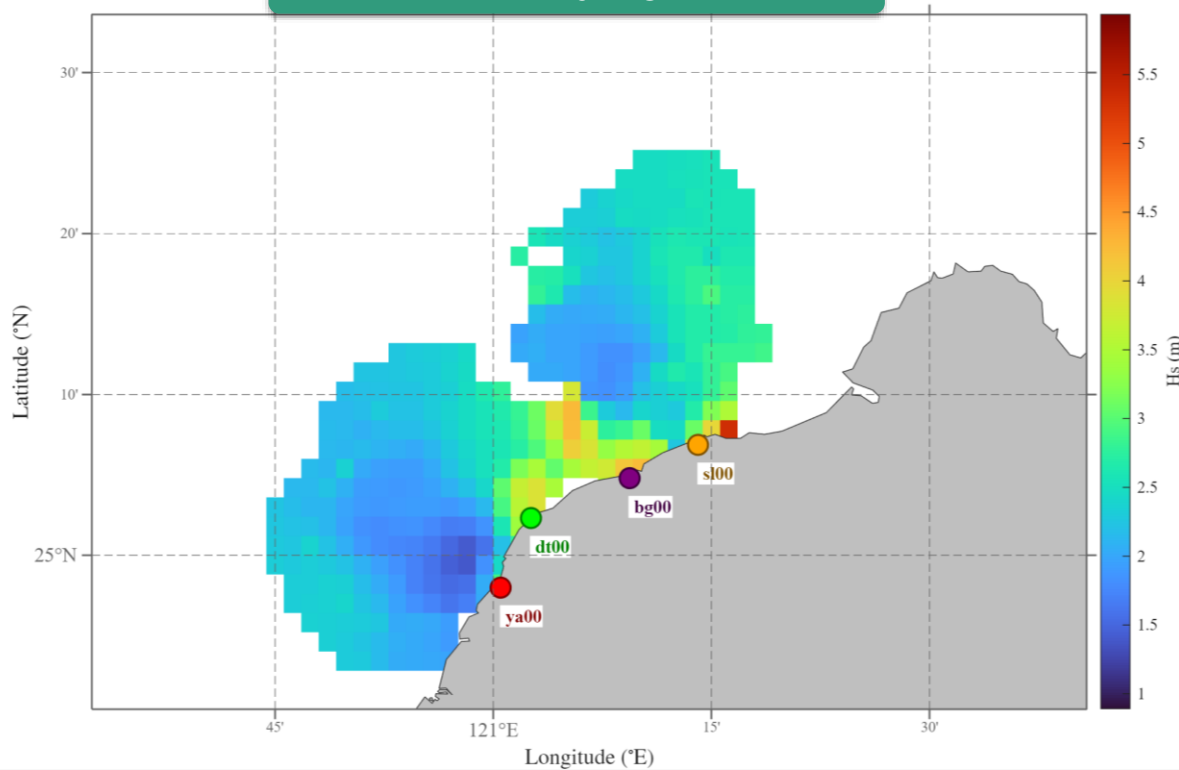
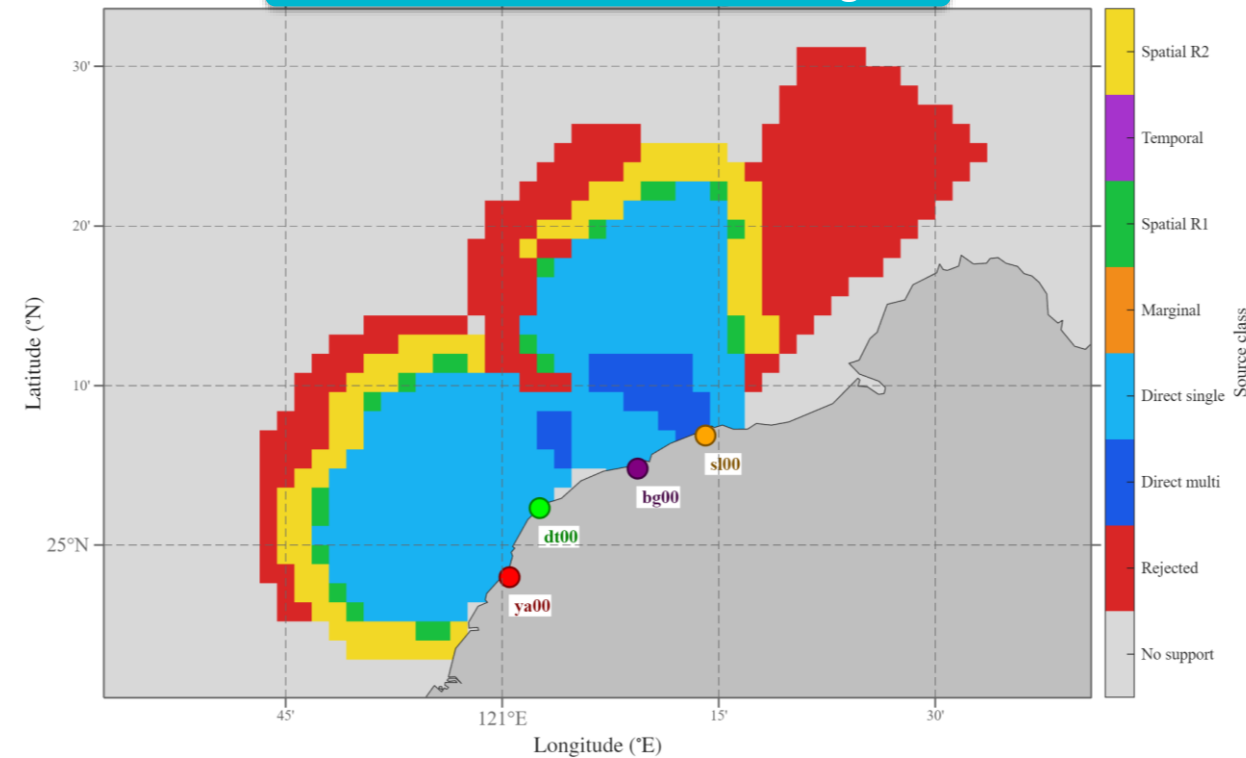
Final QC after all procedure

Multi-station reconstruction expands the usable current field

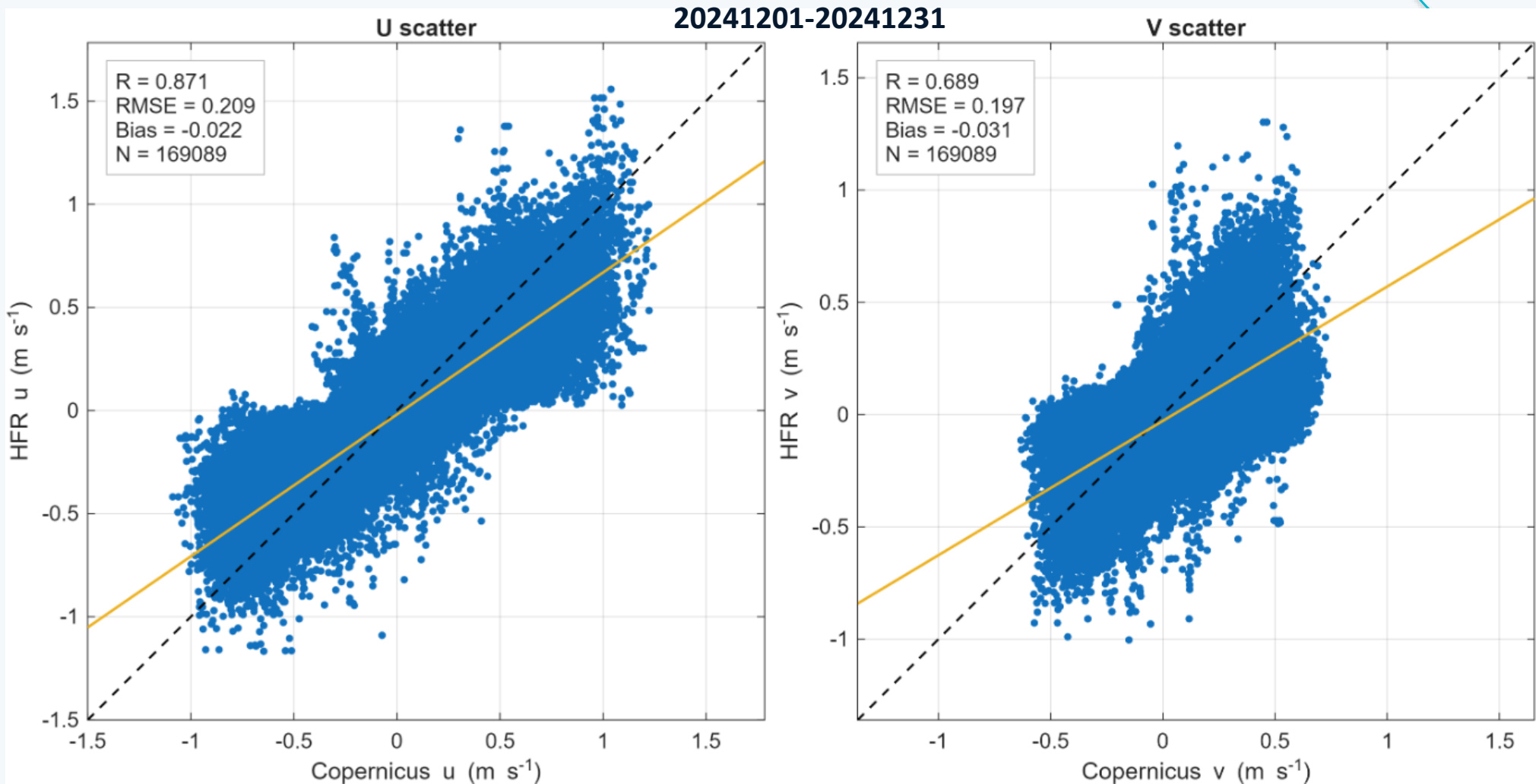


Multistation maintained higher valid coverage compared to the pairwise benchmark across most of that period.

Wave integration extends the spatial product while retaining source provenance

**Final Hs****Hs Source / Provenance Flag**

The multi-station WLS product preserves good agreement with Copernicus while extending usable spatial coverage.



Multi-station HFR turns observational overlap into usable information

01

COVERAGE

More observations become usable

02

CONFIDENCE

Redundancy becomes observational support

03

CONTINUITY

Missing does not automatically mean fillable

MULTI-STATION = observation opportunity | WLS = current reconstruction mechanism | Weight Fusion = Wave mechanism

THANK YOU

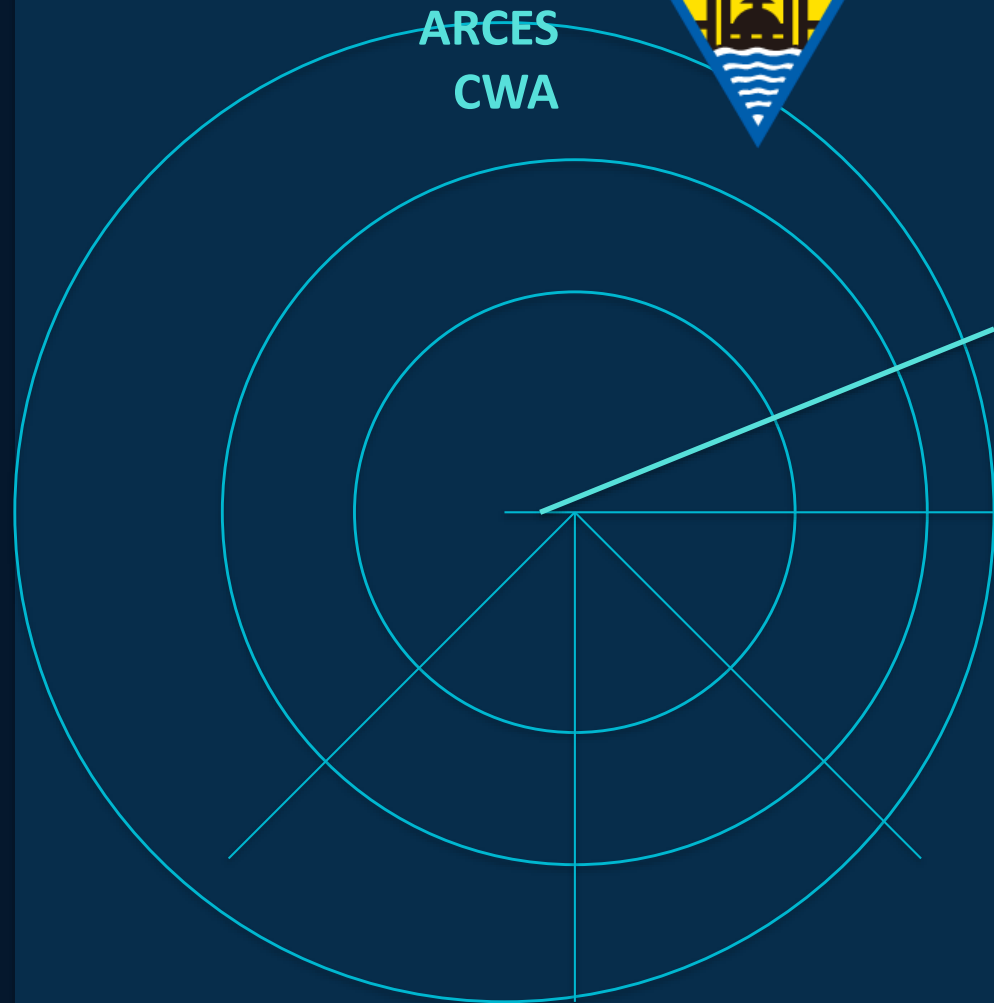
MPORG LAB
ARCES
CWA

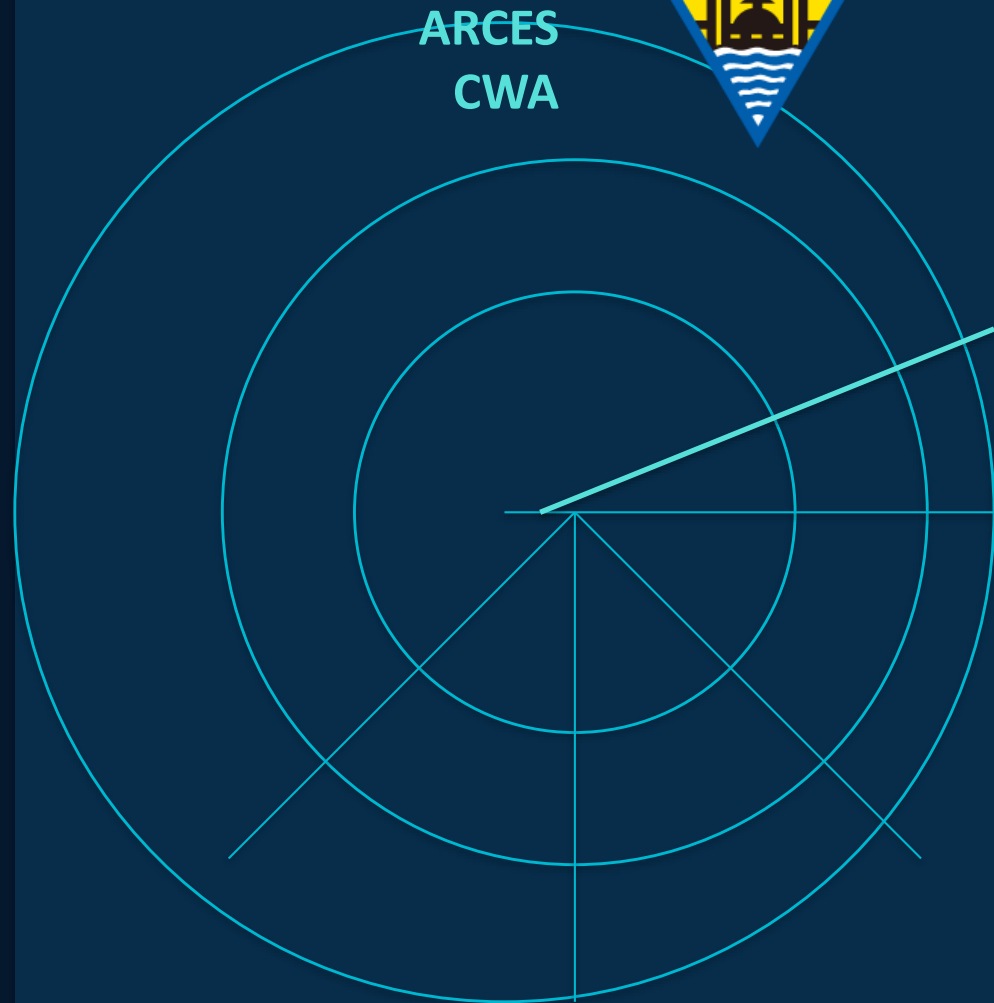


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Back up slide
Validation part

