

Submesoscale Dynamical Balance from Drifter Observations (and SWOT)

Andrey Shcherbina

& S-MODE team



Lagrangian dynamical balance – at submesoscale?

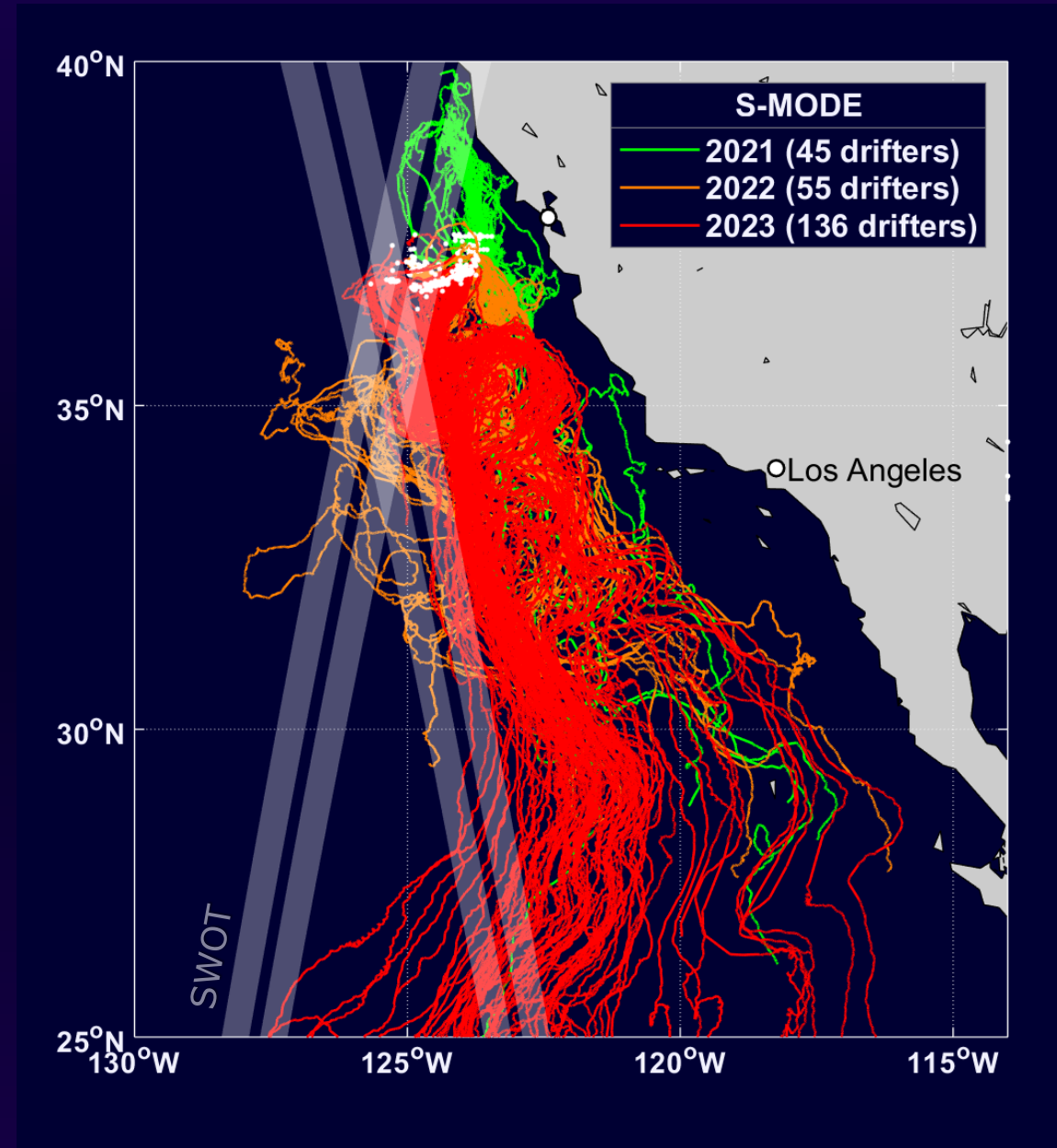
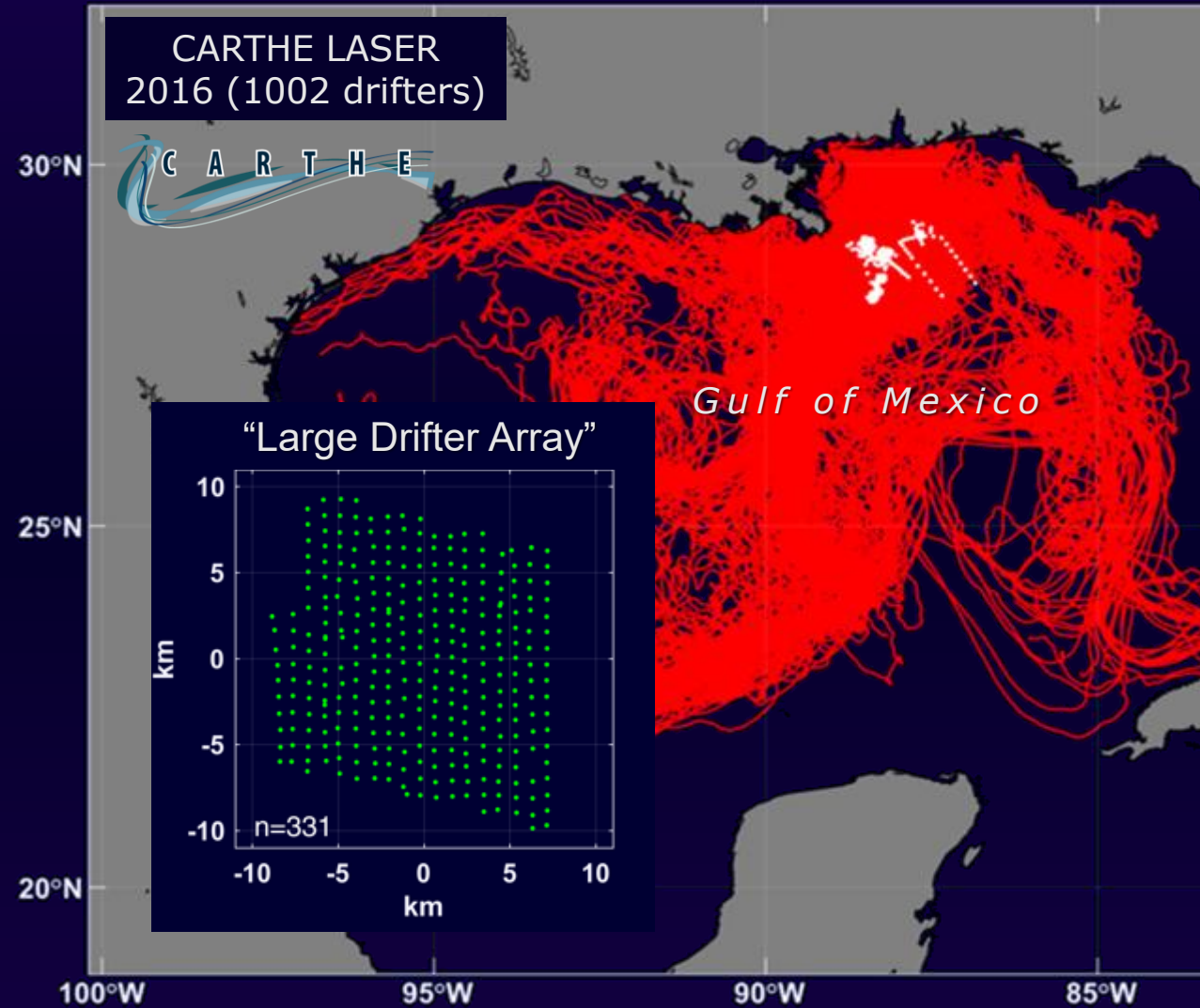
Lagrangian particle momentum equation:

$$\frac{d}{dt}\vec{V} + \vec{f} \times \vec{V} = -g\nabla\eta + \frac{\vec{\tau}}{\rho_0 H} - r\vec{V}$$

Acceleration Coriolis Pressure gradient Wind & waves Friction

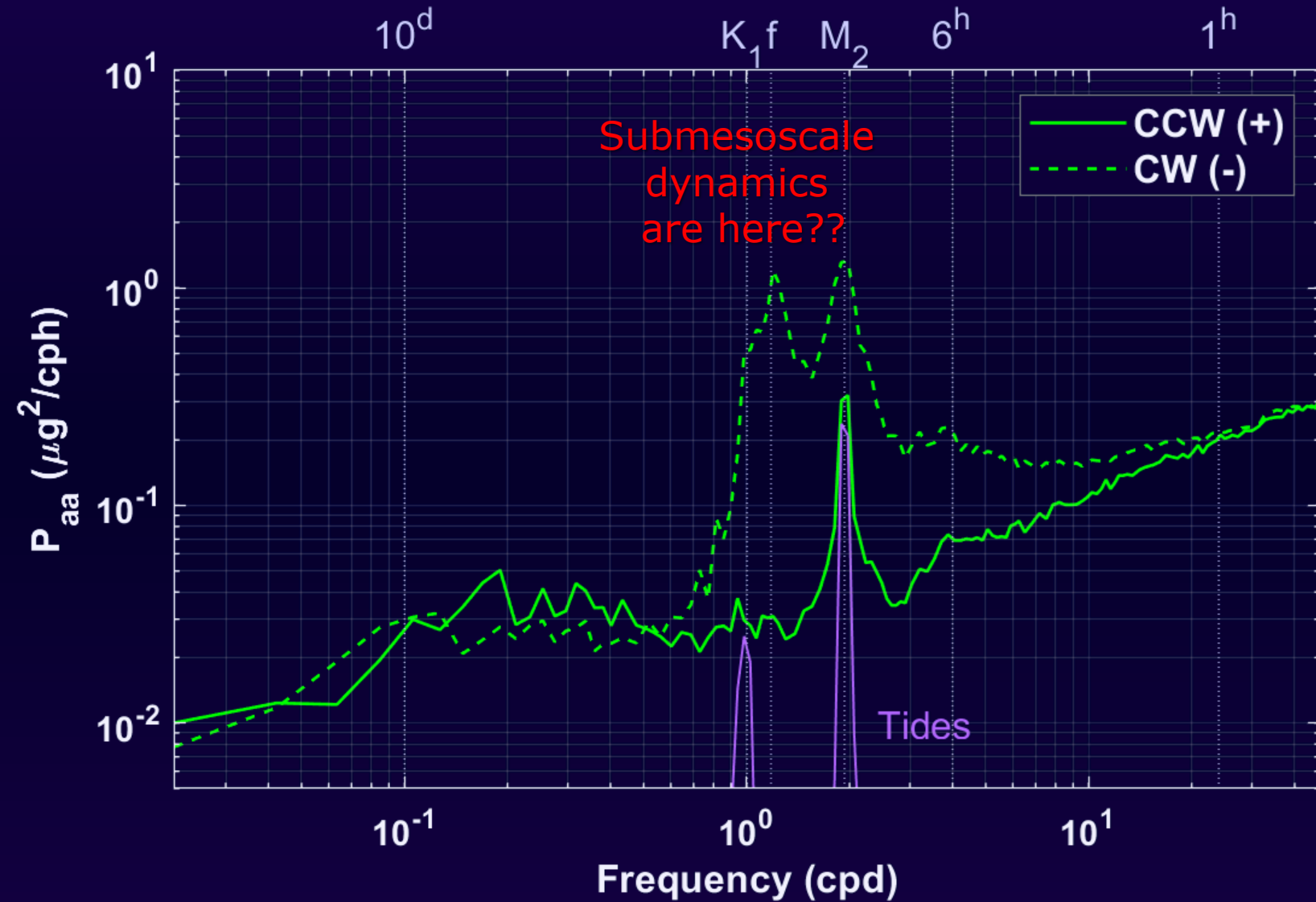
- Different from Geostrophic-Ekman decomposition
- No non-linearity
- No spatial differentiation on LHS → scale-free

Dense drifter deployment experiments



Lagrangian acceleration is dominated by “fast” processes

Lagrangian acceleration frequency spectra from 2023 S-MODE drifter release



- Strong near-inertial, tidal internal wave forcing
- Strong anticyclonic polarization
- Otherwise, \sim flat

A trick: Lagrangian geoacceleration

Introduce “geoacceleration” \overrightarrow{GA} :

$$\overrightarrow{GA} = \frac{d}{dt} \overrightarrow{V} + \vec{f} \times \overrightarrow{V}$$

Then:

$$\overrightarrow{GA} = -g \nabla \eta + \frac{\vec{\tau}}{\rho_0 H} - r \overrightarrow{V}$$

Geo-
acceleration

Pressure
gradient

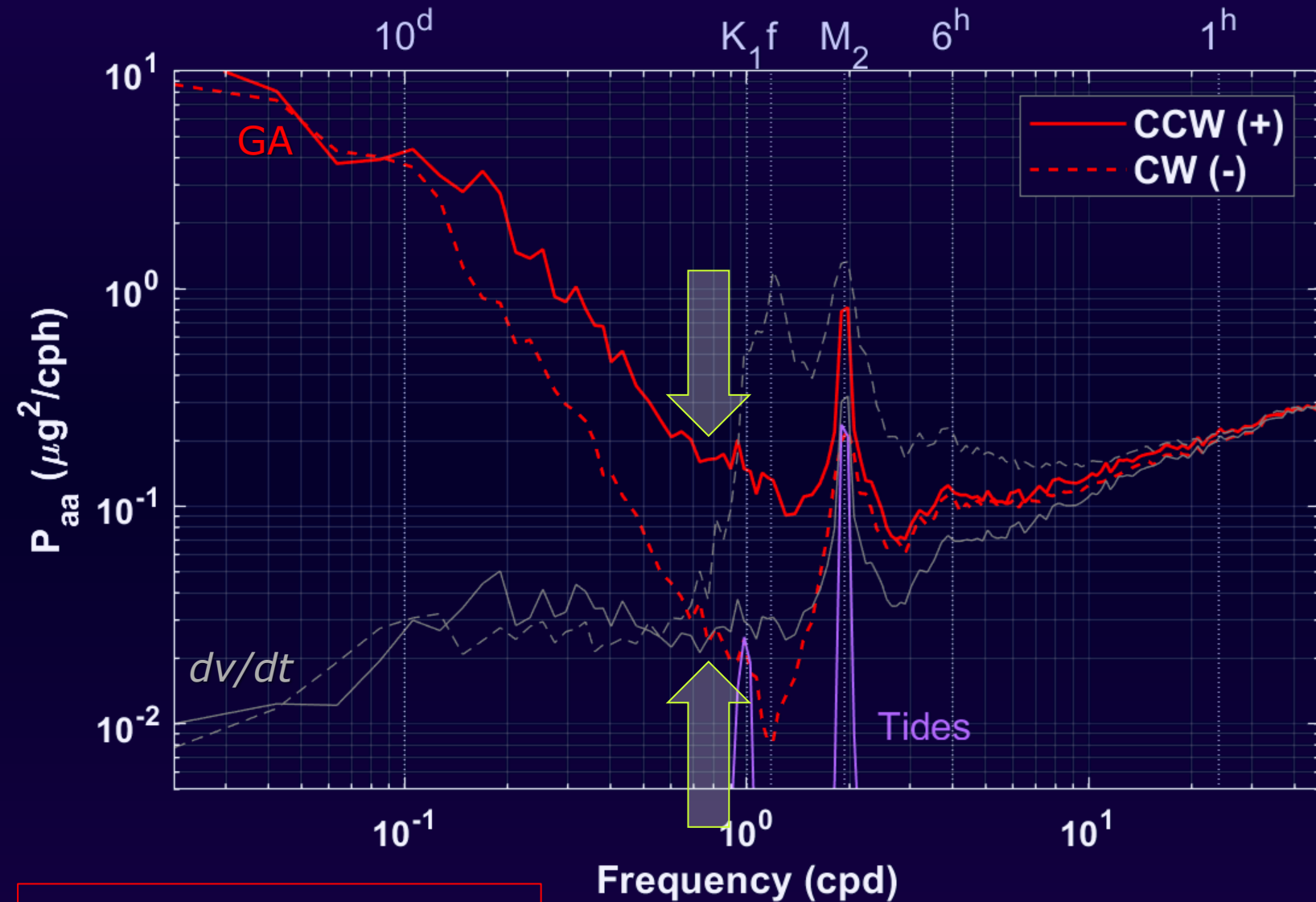
Wind &
waves

Friction

GA “hides” inertial oscillations

Geoacceleration "hides" inertial oscillations

GA shows the structure of external forcing as experienced by the drifters



- NIO are invisible
- Low-frequency component (balanced)

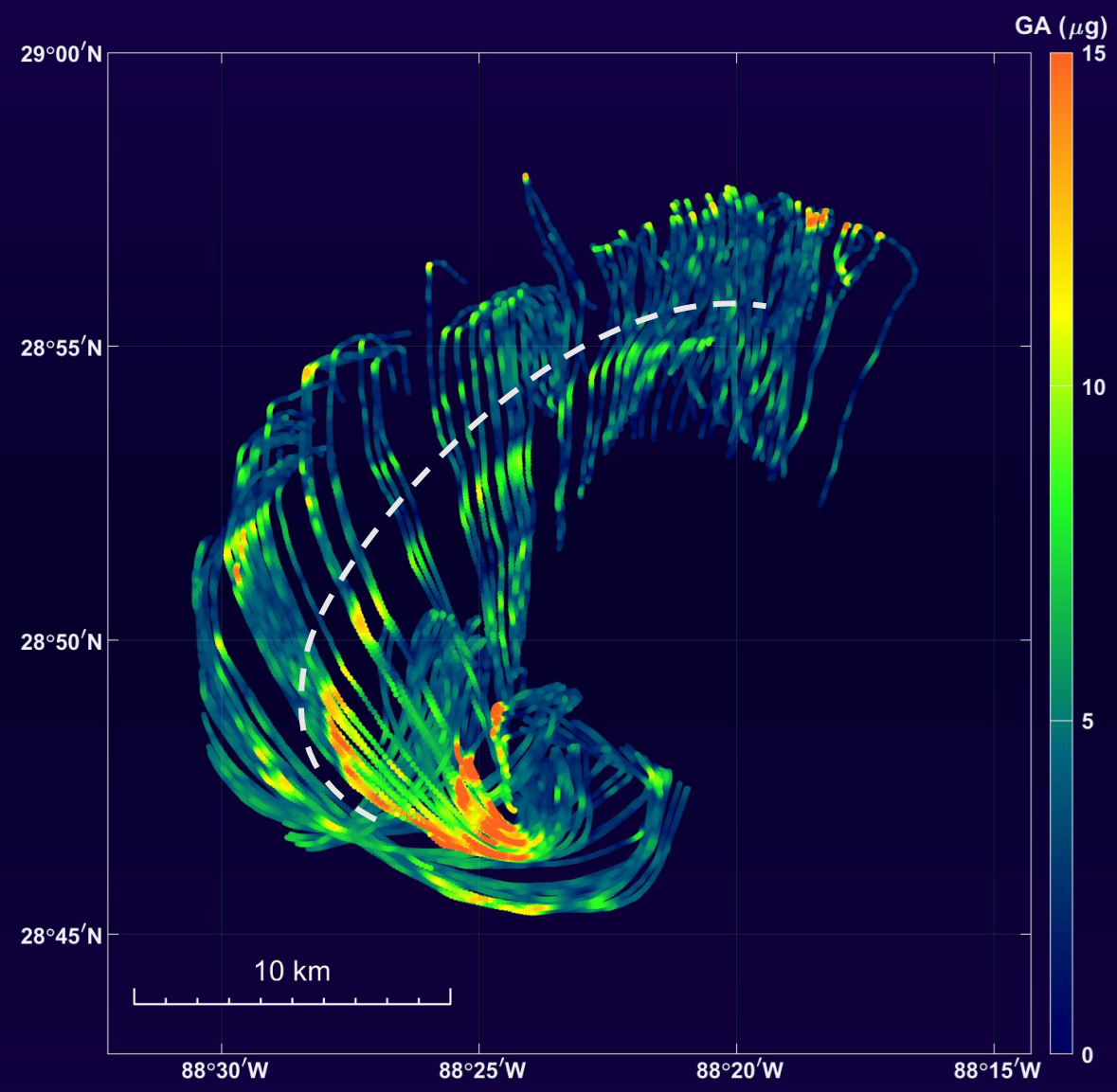
Asymmetry is important!

- Cyclonic dominance
- Maximum @ $\lesssim f$
- Can be due to
 - Cyclogeostrophy
 - SSHa skewness
 - Wind stress polarization (not here)

GA = Σ External forcing

Geoacceleration reveals pressure gradient features

2016 CARTHE LASER drifter release

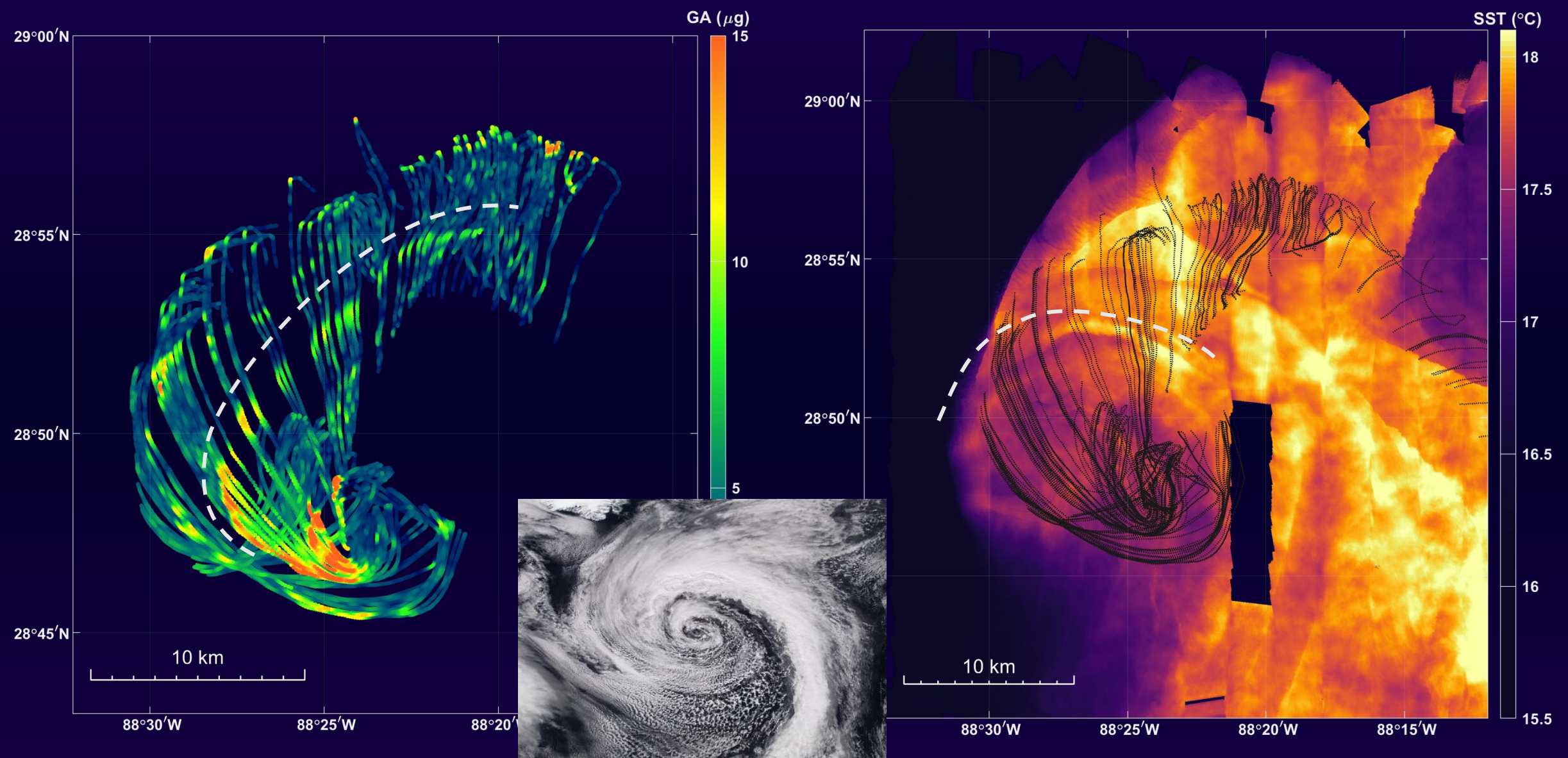


- Cyclonic eddy, ζ up to 5–10 f
- Spiral “arms” of high GA ($>10\mu g$)
- Sub-km width, coherent over 10s km
- Non-material (drifters go through)

$10 \mu g = 10 \cdot 9.8 \times 10^{-6} m^2/s \sim 1 \text{ cm/km } \nabla SSH \sim V_g = 1.4 \text{ m/s}$

Geoacceleration reveals pressure gradient features

2016 CARTHE LASER drifter release

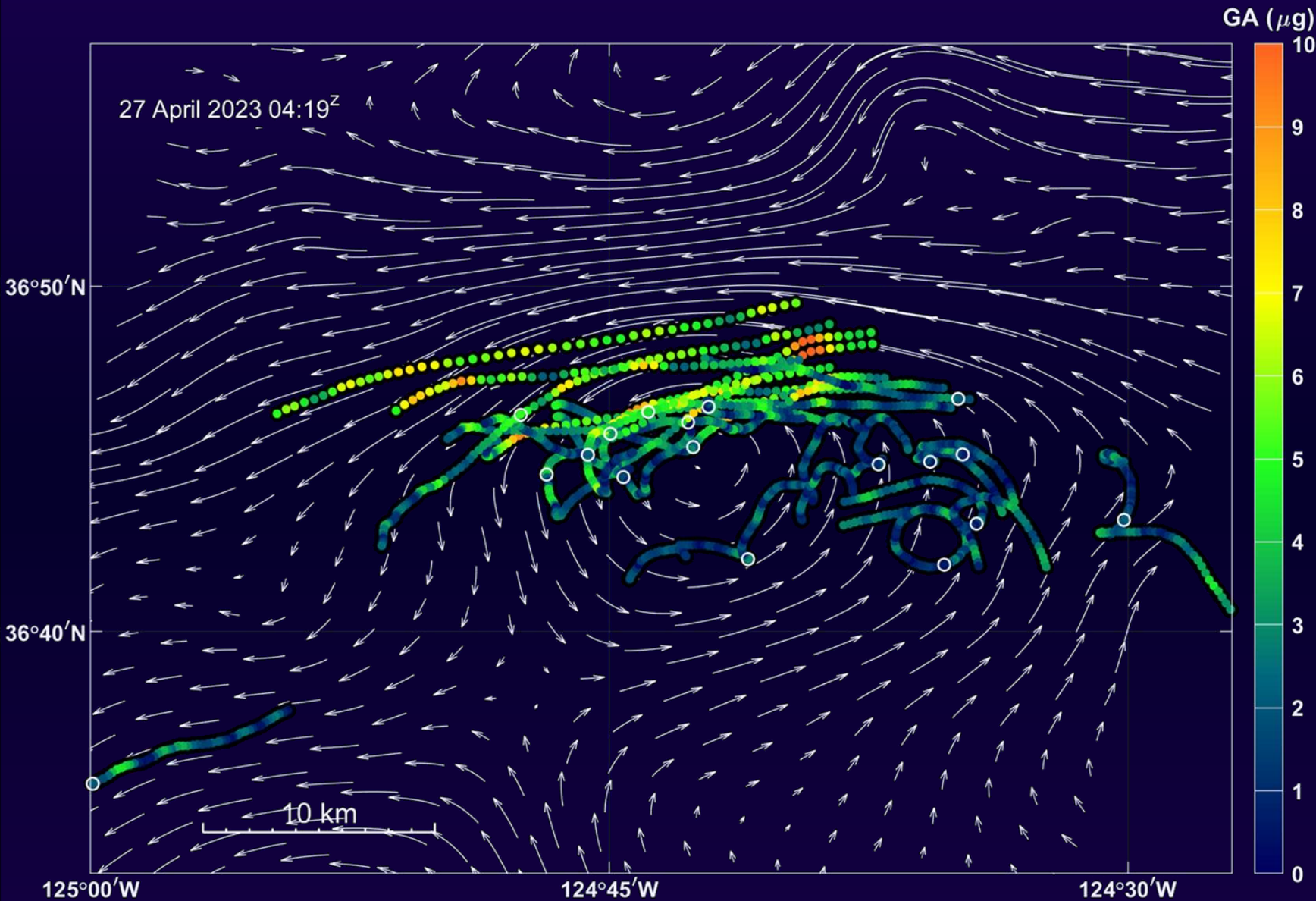


$10 \mu\text{g} = 10 \cdot 9.8 \times 10^{-6} \text{ m}^2/\text{s} \sim 1 \text{ cm}/\text{km} \nabla\text{SSH} \sim V_g = 1.4 \text{ m}/\text{s}$

Aerial SST: Jeroen Molemaker / UCLA

Geoacceleration features vs. SWOT velocities

2023 S-MODE drifter release



- Cyclonic eddy, $\zeta \sim 2f$
- Patches of high GA
- Associated with the front
- Little coherence
- Too small for SWOT?

Lagrangian dynamical balance @submesoscale

- Drifters offer direct, scale-free diagnosis of the forces acting on near-surface parcels
- Geoacceleration reveals patterns in the forcing – temporal and spatial
- Physics behind these patterns is under investigation
- It remains to be seen if these patterns can be found in SWOT data

