EGU22-7715

EGU General Assembly 2022 NP0 – L.F. Richardson's 1922 centennial

Turbulent Energy Cascade in the Gulf of Mexico

Yinxiang Ma[1], Jianyu Hu[1,2], and Yongxiang Huang[1,2,3]

[1] State Key Laboratory of Marine Environmental Science, College of Ocean and Earth Sciences, Xiamen University, Xiamen 361102, China
[2] Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai), Zhuhai 519000, China
[3] SJTU SMSE-Mingguang Joint Research Center for Advanced Palygorskite Materials, Mingguang 239400, China

Date: 2022.5.25

Background

1922 Richardson: energy cascade from large to small scales

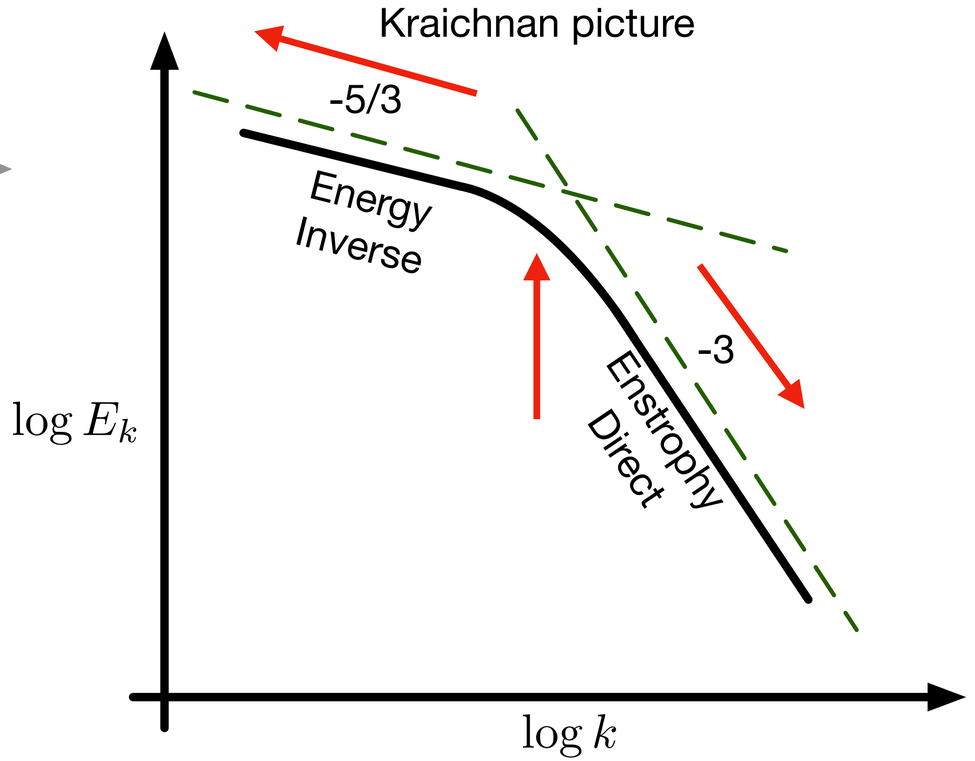
L. F. Richardson, Cambridge Univ. Press. (1922).

1941 Kolmogorov-Obukhov: $E_k \propto \epsilon^{2/3} k^{-5/3}$

A. N. Kolmogorov, Dokl. Akad. Nauk SSSR 30, 299. (1941)
A. M Obukhov, Dokl. Akad. Nauk SSSR, 5, 453–466. (1941)

1967 Kraichnan: $E_k \propto \begin{cases} k^{-5/3} \\ k^{-3} \end{cases}$

R. H. Kraichnan, *Phys. Fluids*, *10*(7), 1417-1423. (1967)

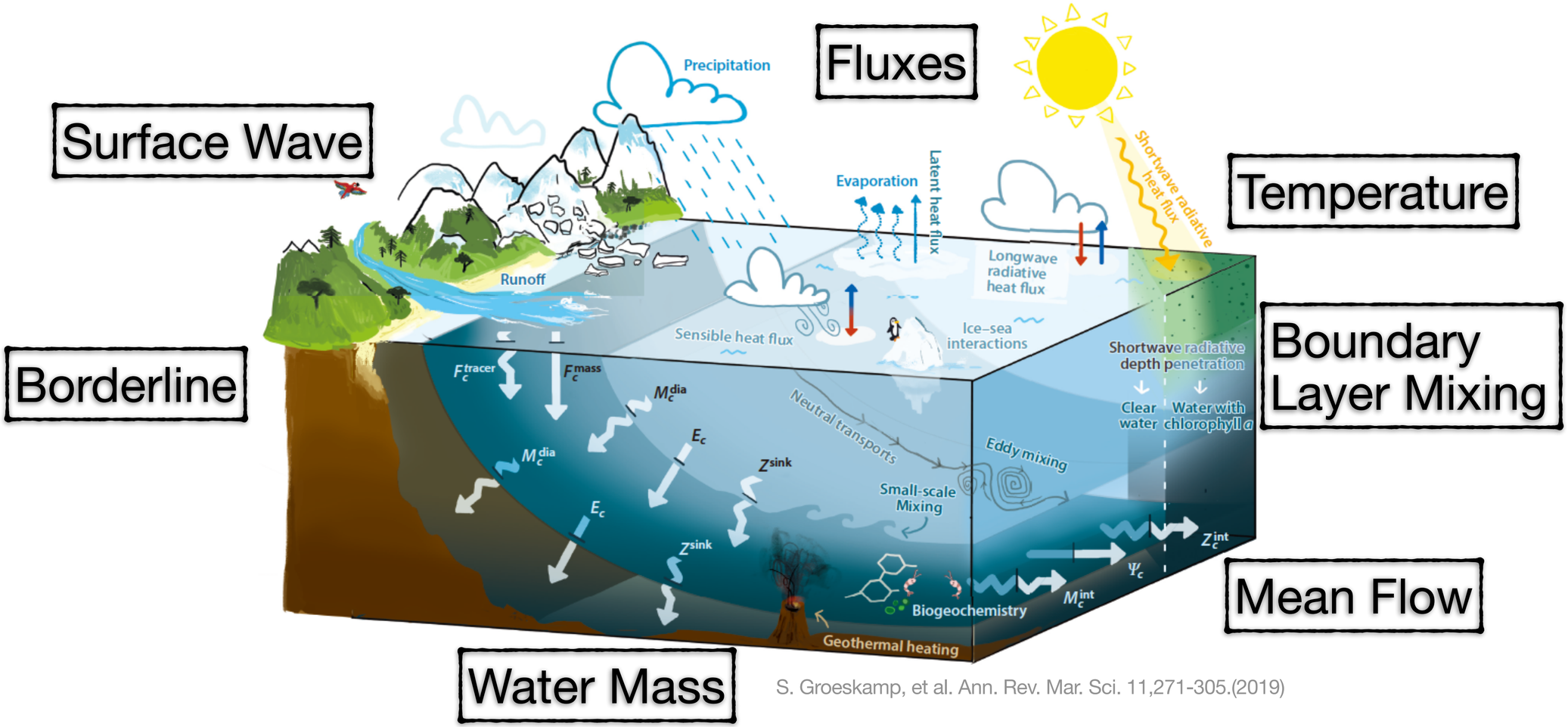


1971 Charney: Geostrophic Turbulence

J. G. Charney, J. Atoms. Sci., *28*(6), 1087-1095.(1971)

Background

— complexity of oceanic flow



S. Groeskamp, et al. Ann. Rev. Mar. Sci. 11,271-305.(2019)

Theories

—Under different hypotheses

Kolmogorov's 4/5th law of 3D, HIT $\langle \Delta u_L^3(r) \rangle = -\frac{4}{5}\varepsilon r$

Extension to d-dimension

$$\langle \Delta u_L^3(r) \rangle = -\frac{12}{d(d+2)}\varepsilon r$$

(Falkovich et al. 2001)

$$\langle \Delta u_L^3(r) \rangle + 2\langle \Delta u_L(r) \Delta u_T^2(r) \rangle = -\frac{4}{3}\varepsilon r$$

(Lindborg 1996; Antonia et al. 1997)

Batchelor–Kraichnan theory

$$\langle \Delta u_L^3(r) \rangle = \begin{cases} \frac{1}{8}\eta r^3 & \text{for } r \ll l_f \\ \frac{3}{2}\varepsilon r & \text{for } l_f \ll r \end{cases}$$

Boffetta and Musacchio, Phys. Rev. E, 82, 016307, (2010)

typical geophysical scaling

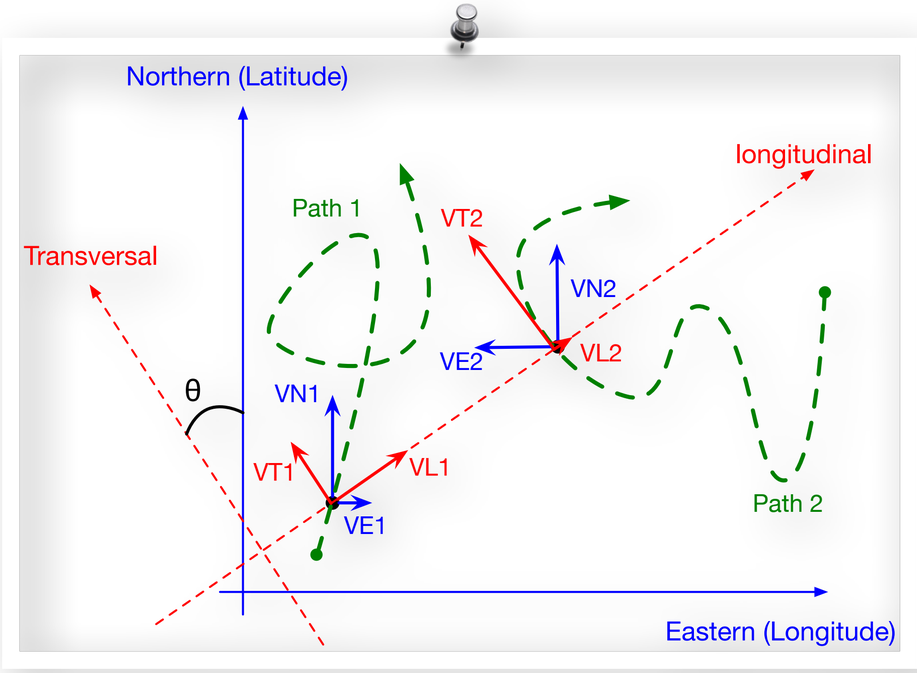
$$\langle \Delta u_L^3(r) \rangle + \langle \Delta u_L(r) \Delta u_T^2(r) \rangle = -2\varepsilon r$$

(Lindborg et al. 2001)

neglect viscous term, local isotropy...

$$\langle \Delta u_L^3(r) \rangle + \langle \Delta u_L(r) \Delta u_T^2(r) \rangle = \frac{1}{4}\varepsilon_\omega r^3$$

(Lindborg 1999)



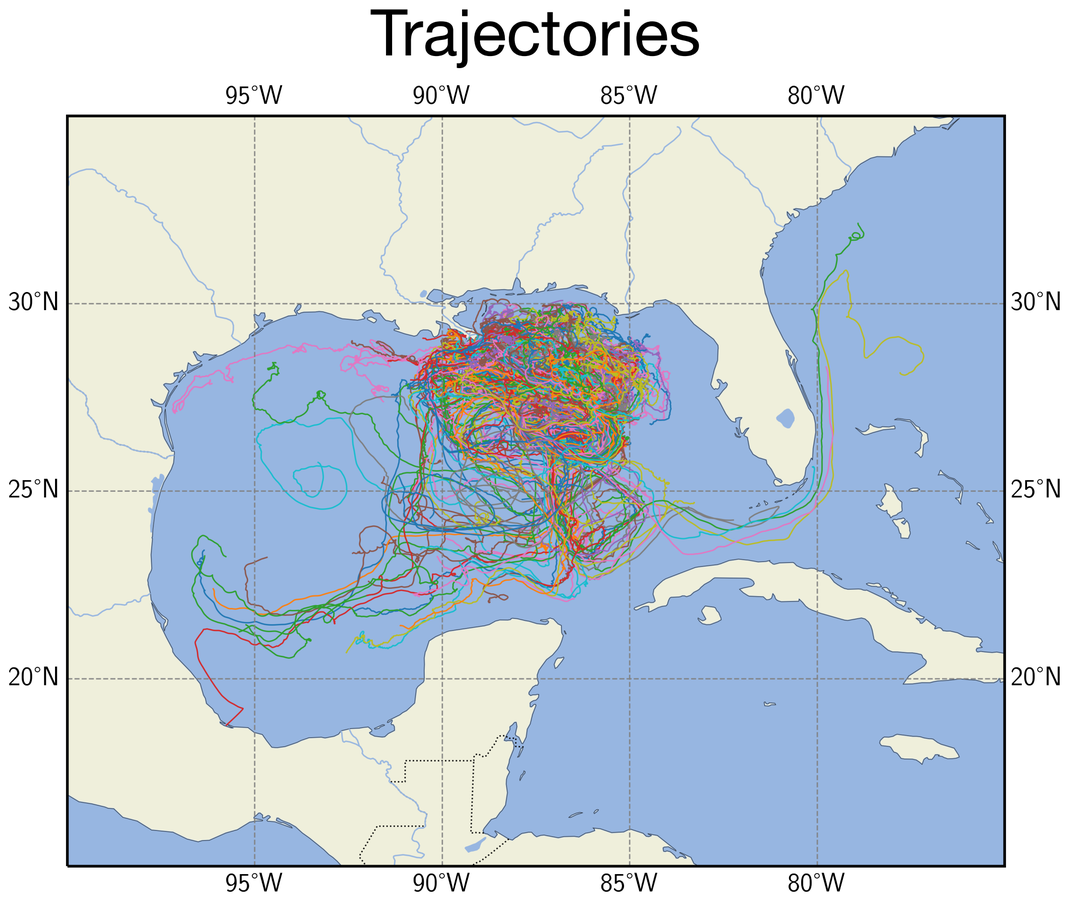
sketch of longitudinal structure-function method

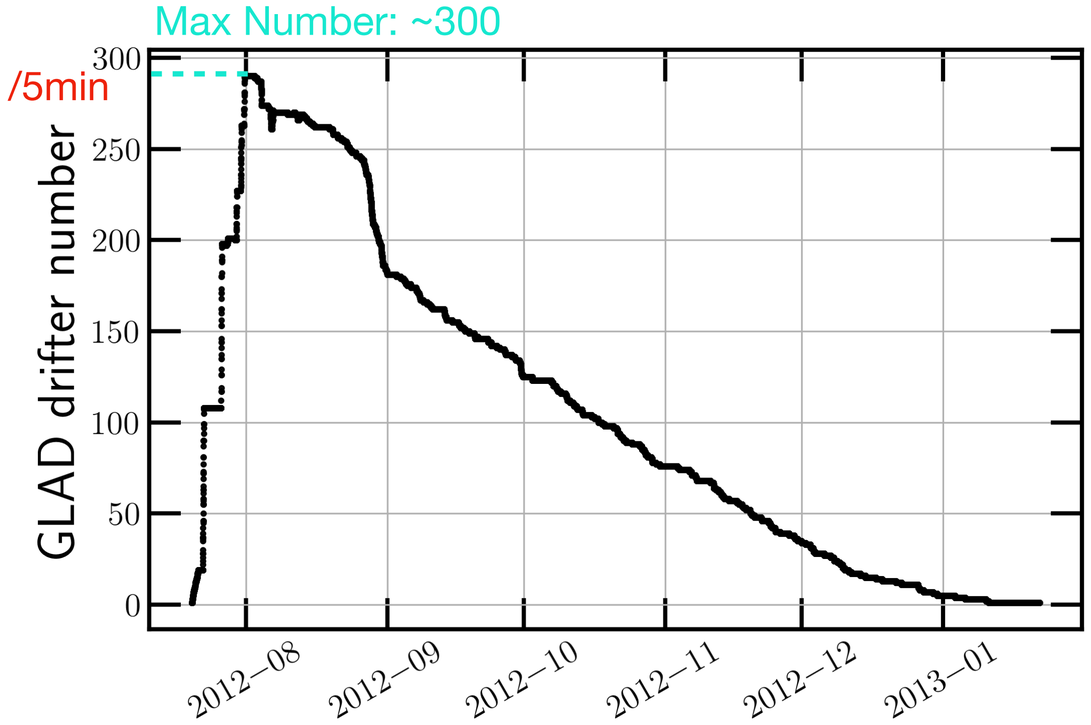
See details in review by Alexakis A and Biferale L. on Physics Reports. 2018

Data

— Grand LAgrangian Deployment (GLAD)

Time Span: 2012.7 - 2013.1



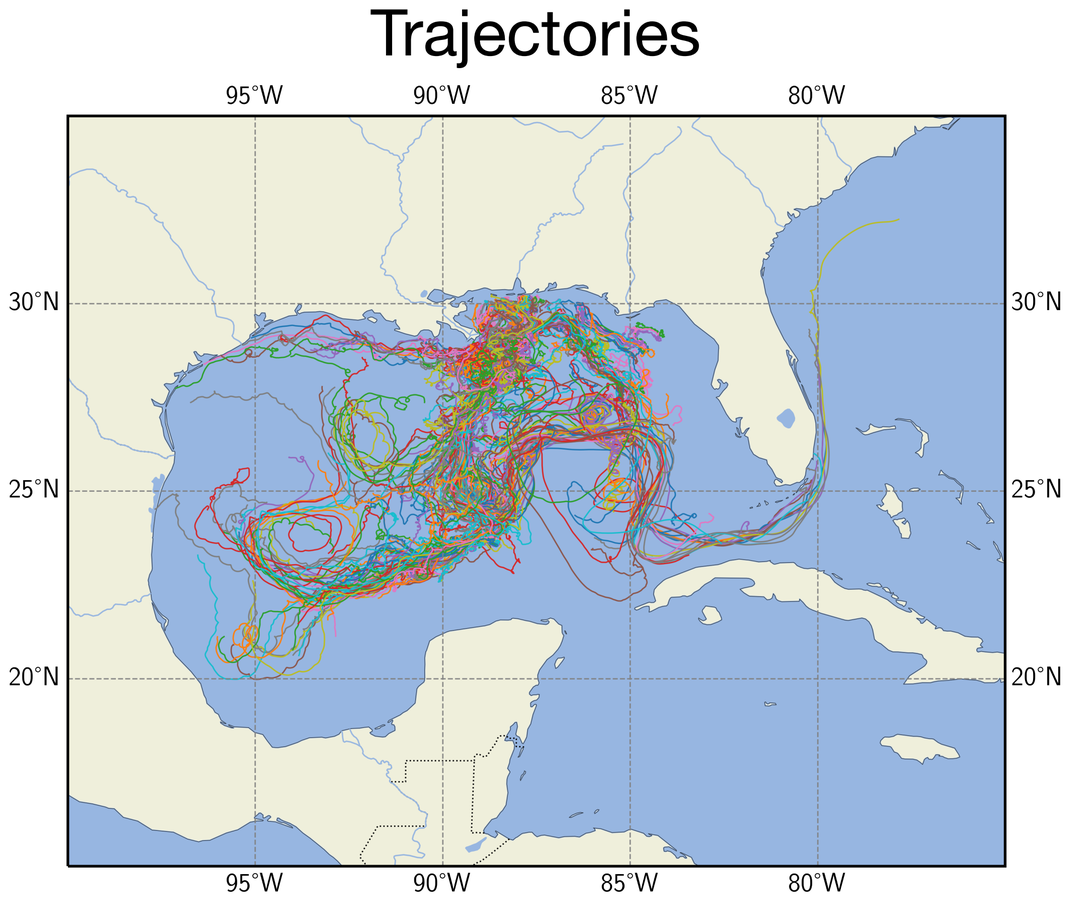


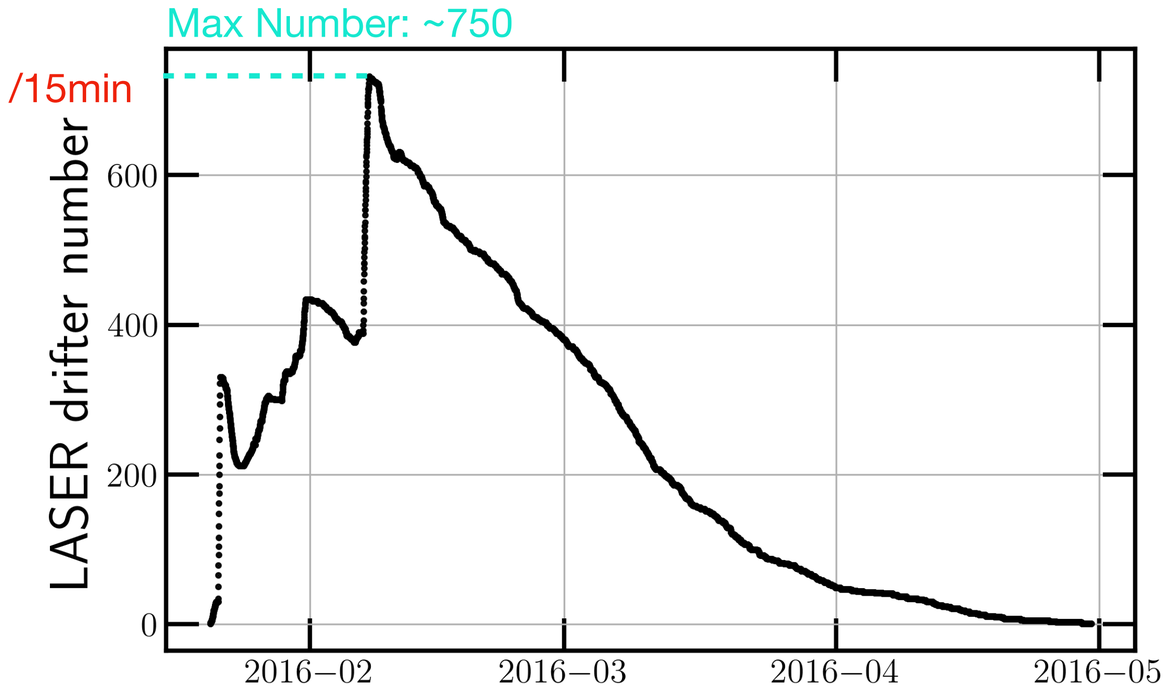
http://carthe.org/glad/

Data

— LAgrangian Submesoscale ExpeRiment (LASER)

Time Span: 2016.1 - 2016.4



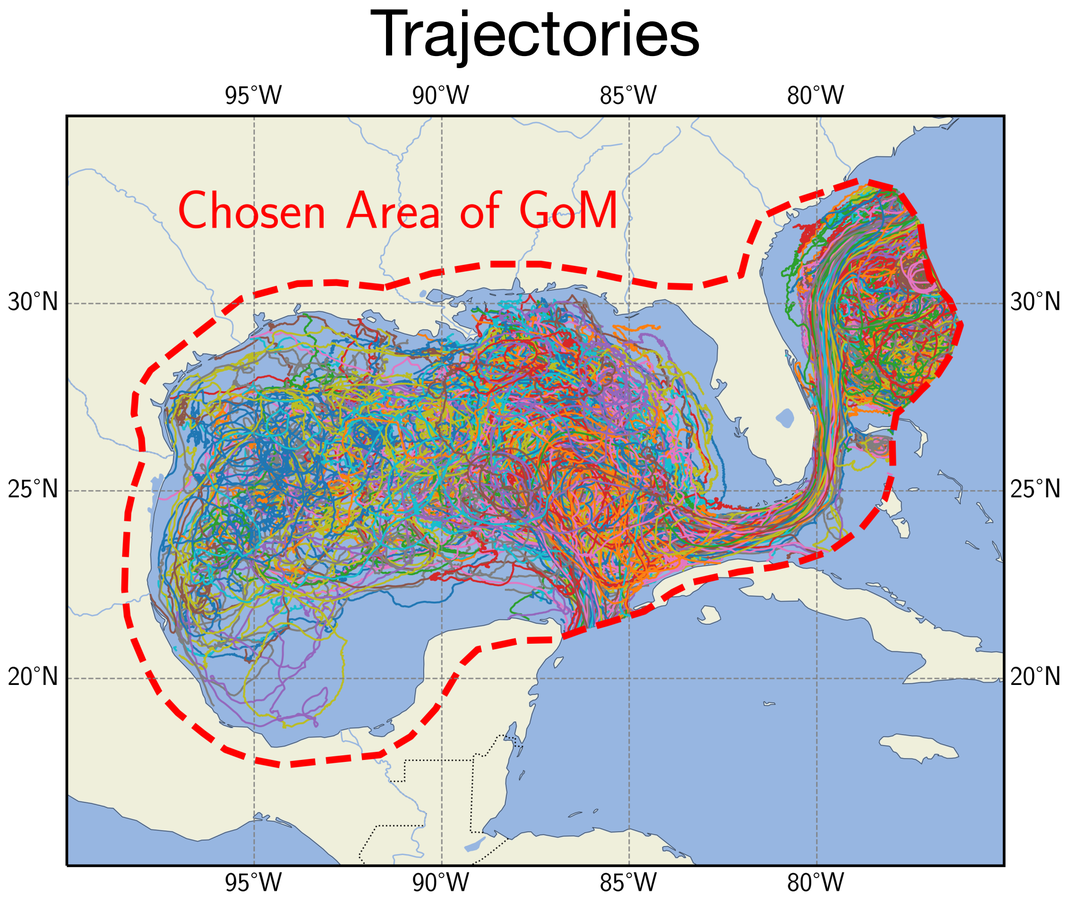


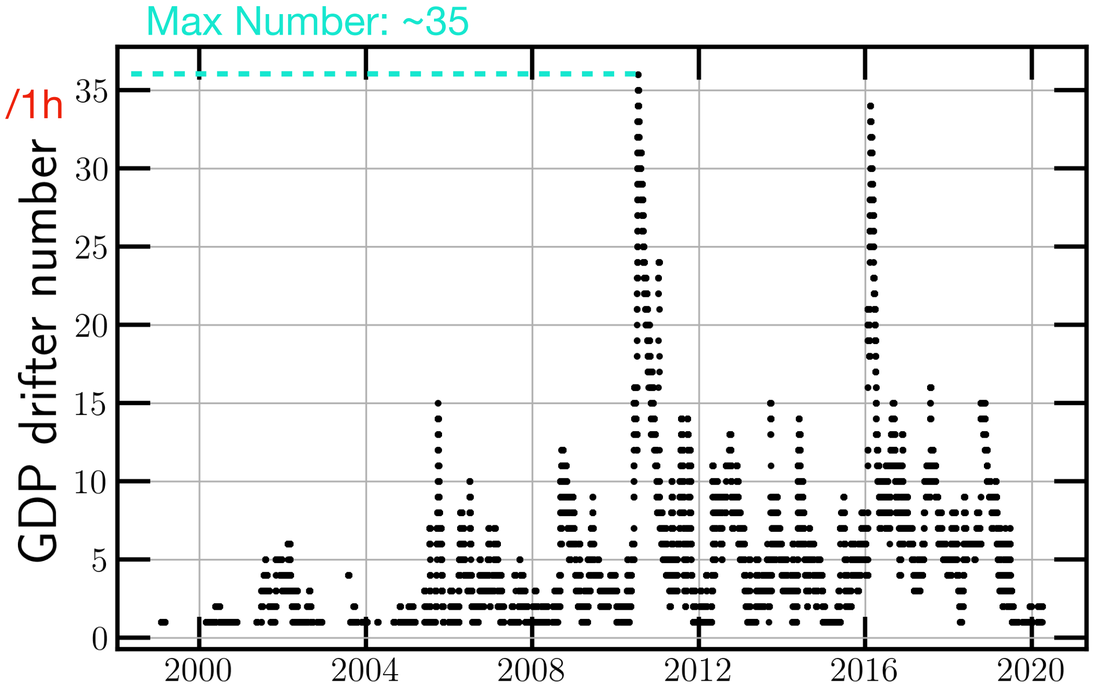
http://carthe.org/laser/

Data

— Global Drifter Program (GDP)

Time Span: 1999.2 - 2020.4



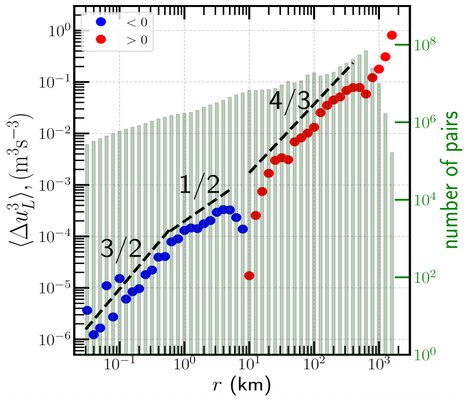


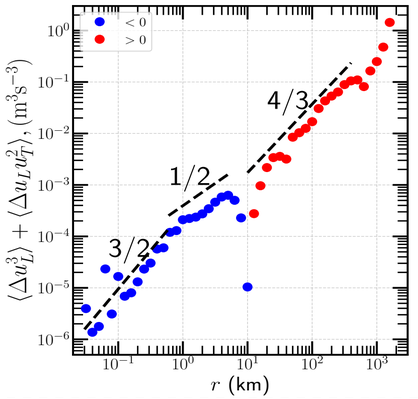
https://www.aoml.noaa.gov/phod/gdp/

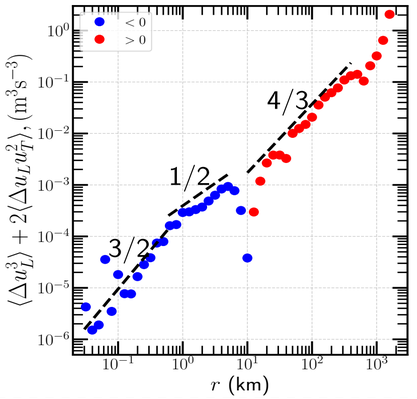
Results

$\langle \Delta u_L^3(r) \rangle \propto r^?$ $\langle \Delta u_L^3(r) \rangle + \langle \Delta u_L(r) \Delta u_T^2(r) \rangle \propto r^?$ $\langle \Delta u_L^3(r) \rangle + 2\langle \Delta u_L(r) \Delta u_T^2(r) \rangle \propto r^?$

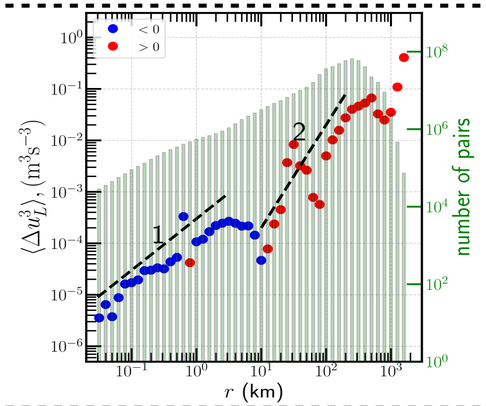
GLAD
Jun. - Jan.
2012

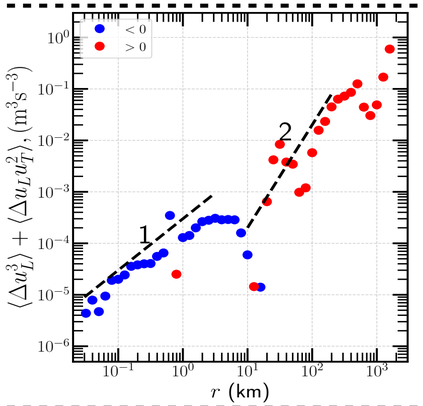


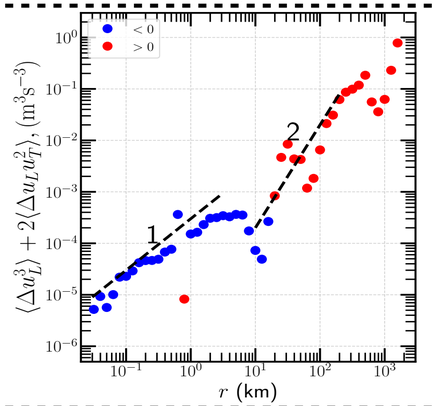




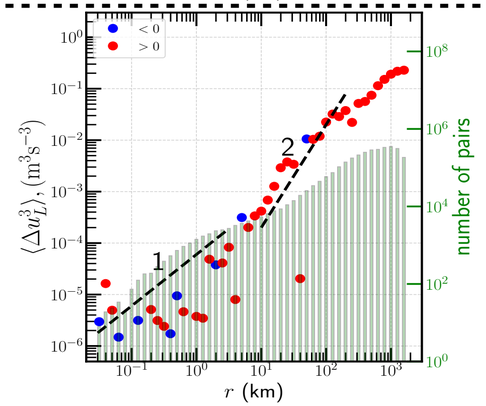
LASER
Jan. - Apr.
2016

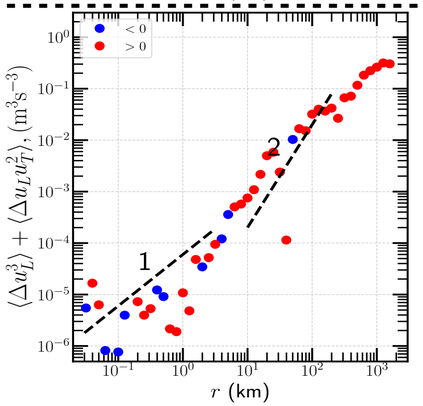


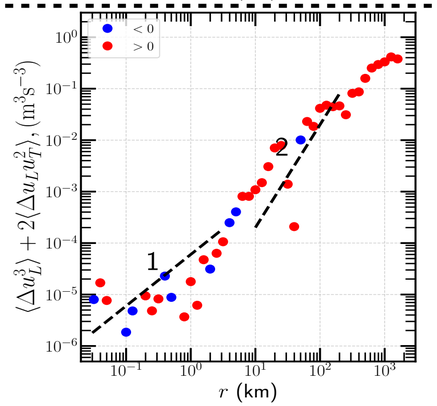




GDP
1999-2020







Conclusion

- Sign change of $\langle \Delta u_L^3(r) \rangle$ in the scale of ~10km in Golf of Mexico
- The oceanic cascade is confirmed by r-dependent 3rd SFs.
- Either Kraichnan or Charney theory cannot be excluded.

Thank you !