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NP0 – L.F. Richardson's 1922 centennial

Global view of oceanic cascades from the Global Circulation Model

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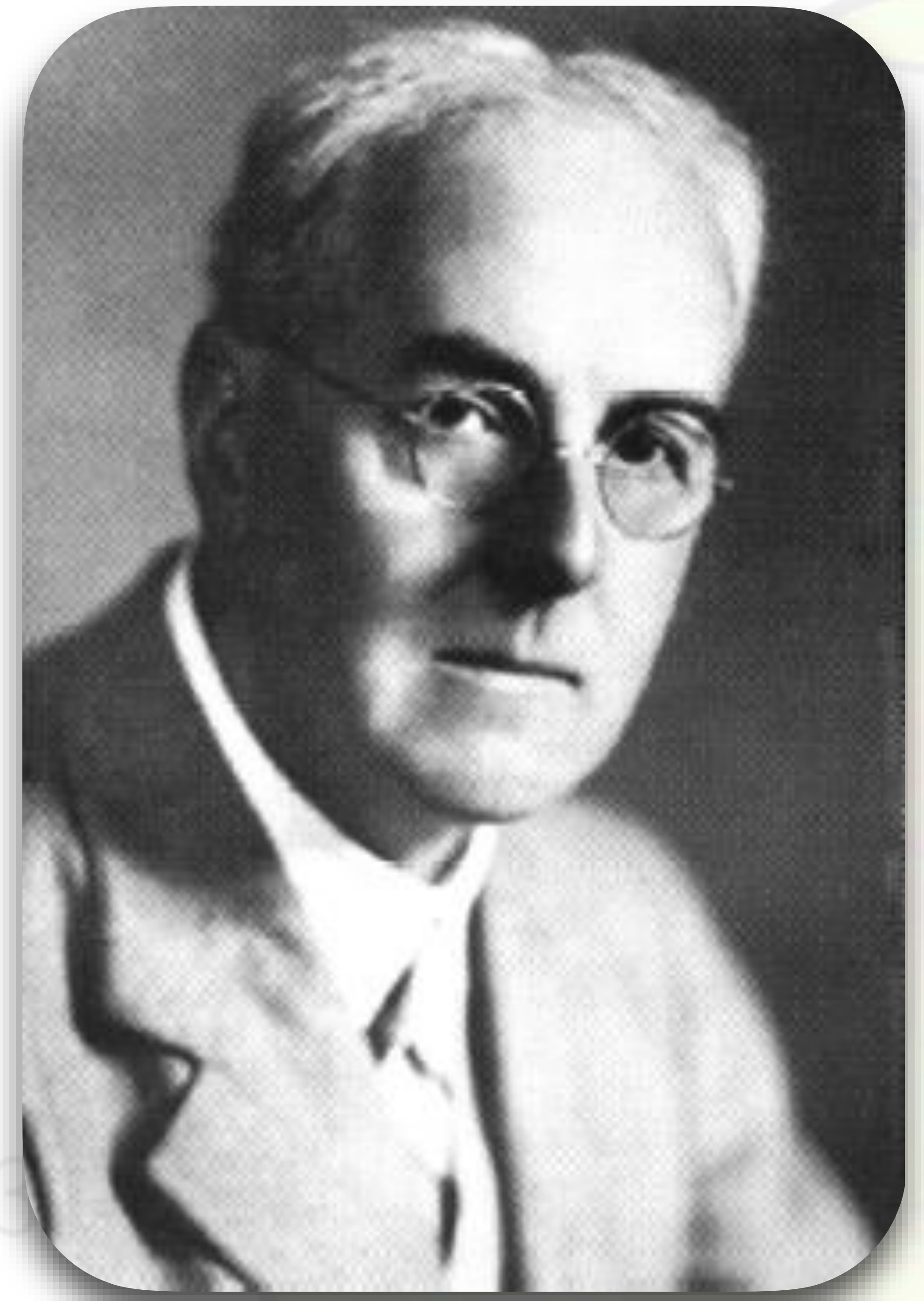


Lewis F. Richardson
1881-1953

Exceptionally low diffusivities have been measured at night by L. F. Richardson (32) in the cold air near the earth. Airmen are very familiar with the increased bumpiness of the wind caused by sun shining on the ground below them. All these facts show that the production of eddies in the wind is greatly facilitated when the thermal equilibrium becomes less stable, although we may not suppose that actual thermal instability is reached in the majority of cases, because such an event is unusual among the collected observations made either by registering balloons or from aeroplanes.

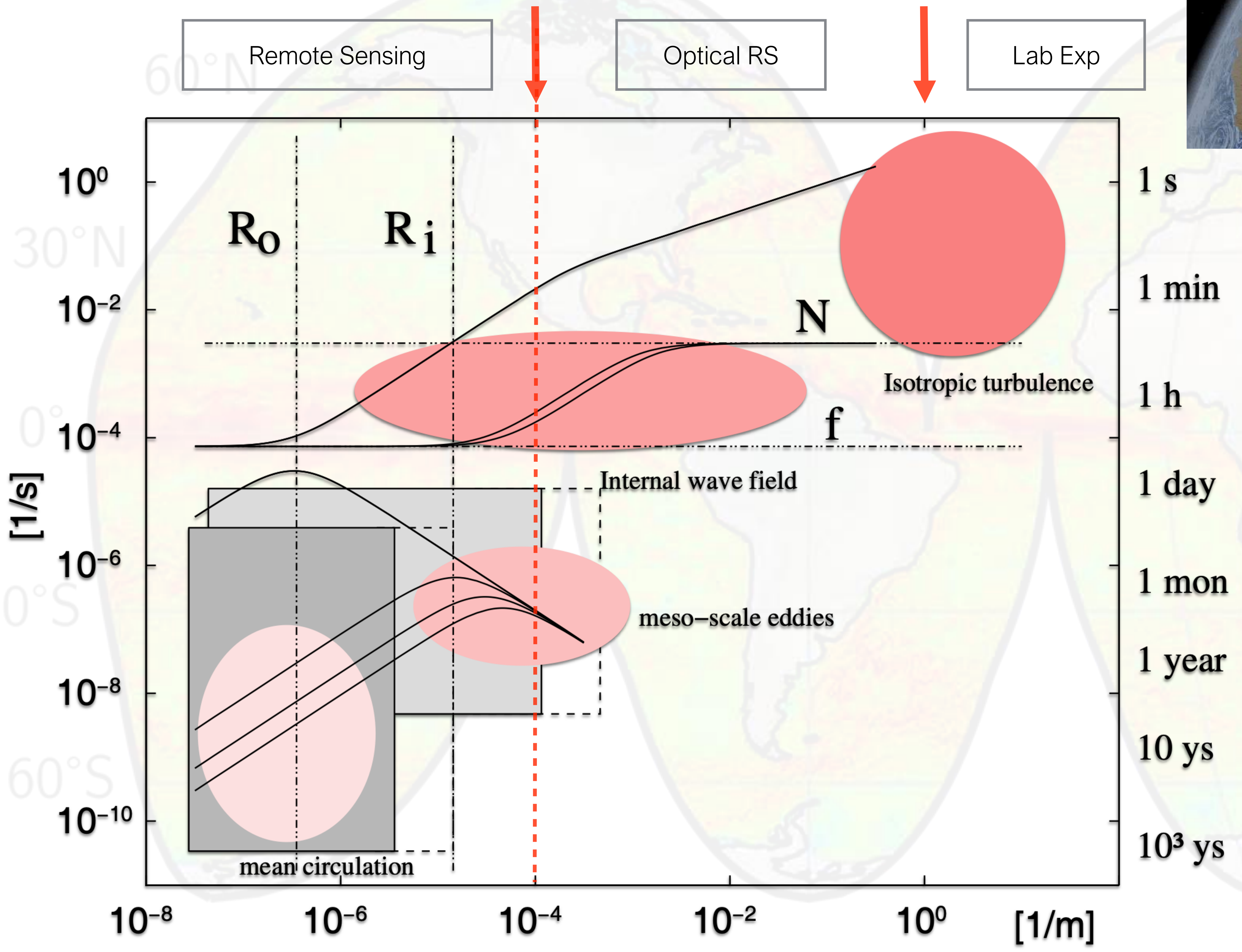
A quantitative theory of the criterion of turbulence has been given by L. F. Richardson (32).

On the other hand we find that convectional motions are hindered by the formation of small eddies resembling those due to dynamical instability. Thus C. K. M. Douglas writing of observations from aeroplanes remarks: "The upward currents of large cumuli give rise to much turbulence within, below, and around the clouds, and the structure of the clouds is often very complex." One gets a similar impression when making a drawing of a rising cumulus from a fixed point; the details change before the sketch can be completed. We realize thus that: big whirls have little whirls that feed on their velocity, and little whirls have lesser whirls and so on to viscosity—in the molecular sense.

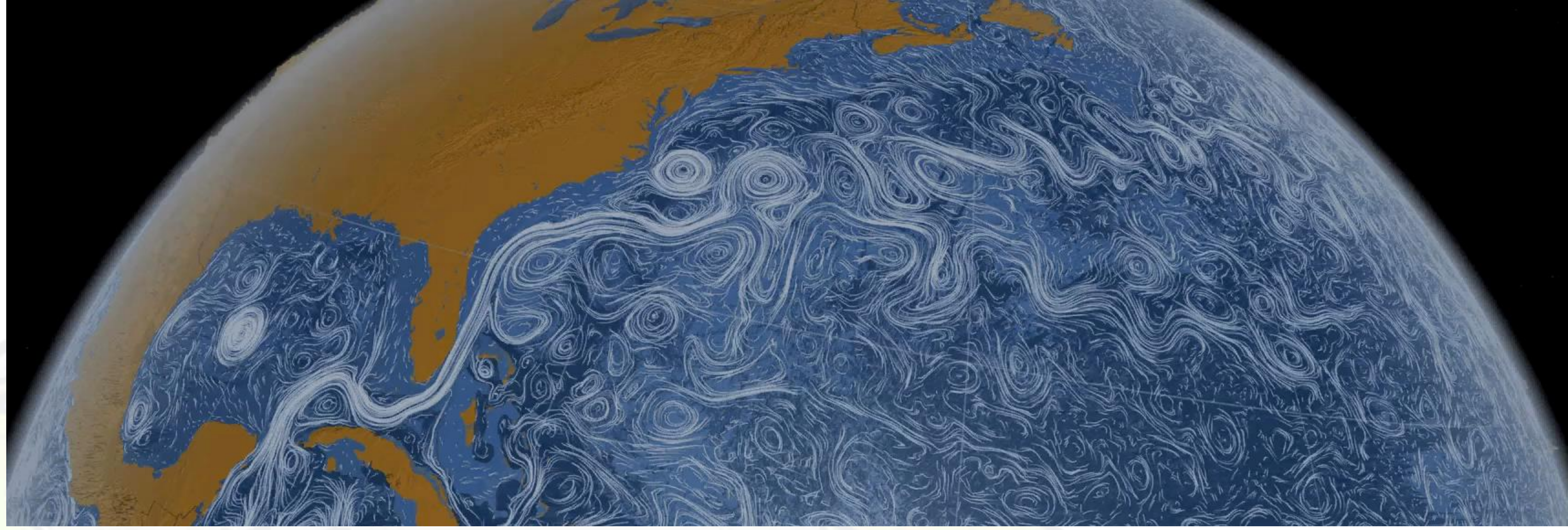
Thus, because it is not possible to separate eddies into clearly defined classes according to the source of their energy; and as there is no object, for present purposes, in making a distinction based on size between cumulus eddies and eddies a [redacted]
in diameter (since both are small compared with our coordinate chequer), the [redacted]
single coefficient is used to represent the effect produced by eddies of all [redacted]
descriptions. We have then to study the variations of this coefficient. But [redacted]
must consider the differential equation. In doing so the aim has been to [redacted]
theoretically only so much as can be determined with strictness, leaving [redacted]
certainties to be decided by observation.

Computational Fluid Dynamics

Colorful Fluid Dynamics



Olbers, et al., Ocean Dynamics, 2012



http://svs.gsfc.nasa.gov/vis/a000000/a003800/a003827/

Real ocean is much complex than ideally model.

- Waves, tidal
- Air-sea interactions
- Stratification
- Rotation
- Large-scale circulation

Models are established based on cascade picture with a lot of parameterizations.

Diagnosing Cascade

3rd structure-functions Kolmogorov 1941		Spectral Method Inverse-cascade is found for all scales.		Filter-Space-Technique Large-Eddy-Simulation	
Derived from NS Eqs	✓	Derived from NS Eqs	✓	Derived from NS Eqs	✓
Easy to implement.	✓	FFT-based/fast	✓	Heavy comput. cost	✓
Local	✓	Global	✓	Local	✓
Knowning balance	✗	Regular domains.	✗	Partially continued data	✓

Each method has its owner advantages and disadvantages.

Diagnosing Cascade

Filter-Space-Technique

Scale-to-Scale Energy Flux

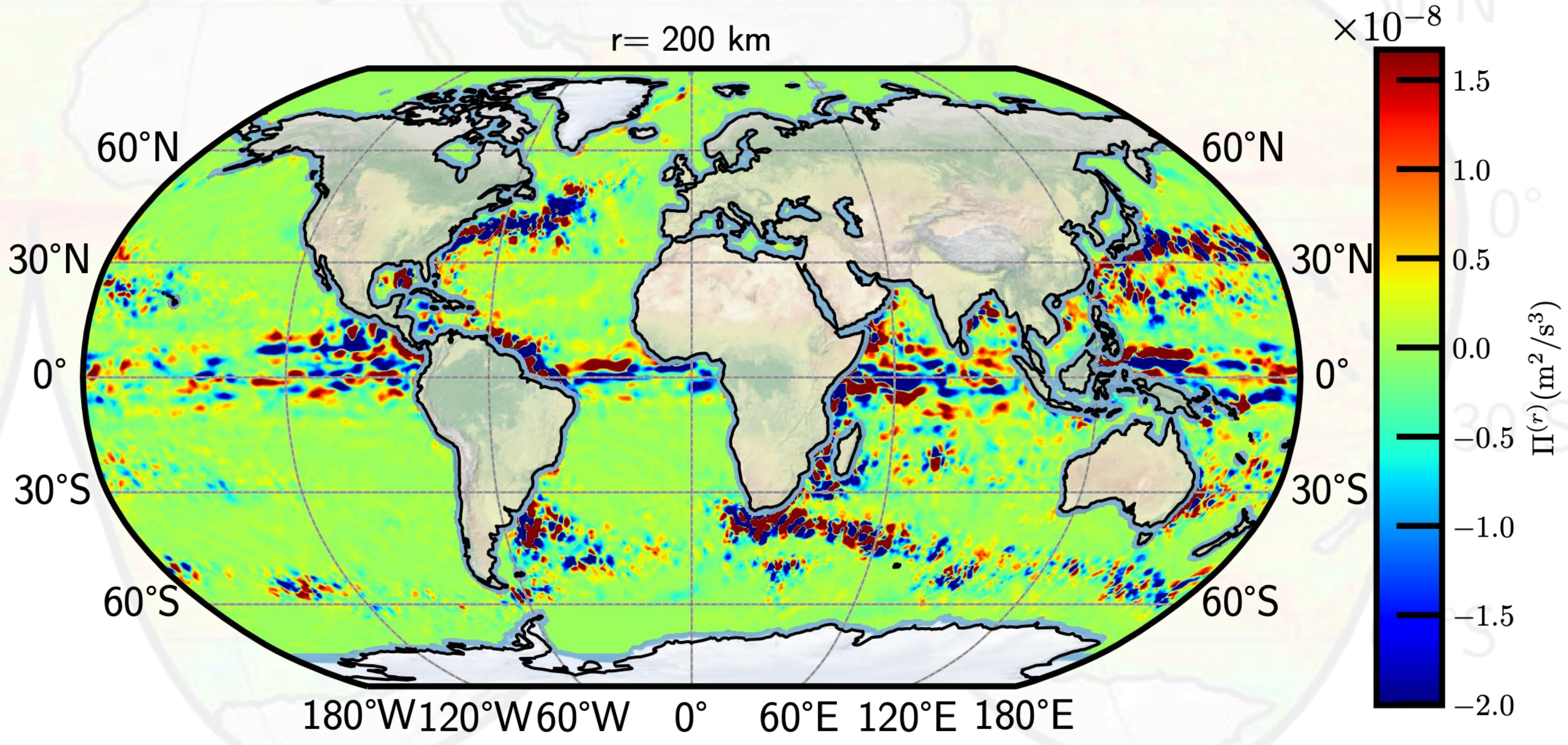
$$\Pi^{(r)}(\vec{x},t) = -\sum \left((u_i u_j)^{(r)} - u_i^{(r)} u_j^{(r)} \right) \frac{\partial u_i^{(r)}}{\partial x_j}$$

Forward cascade

$\Pi^{(r)} > 0$ Energy transfer from large scale to small ones.

Inverse cascade

$\Pi^{(r)} < 0$ Energy transfer from small scale to larger ones.



Diagnosing Cascade

Song et al., 2022, under preparation

Diagnosing Cascade

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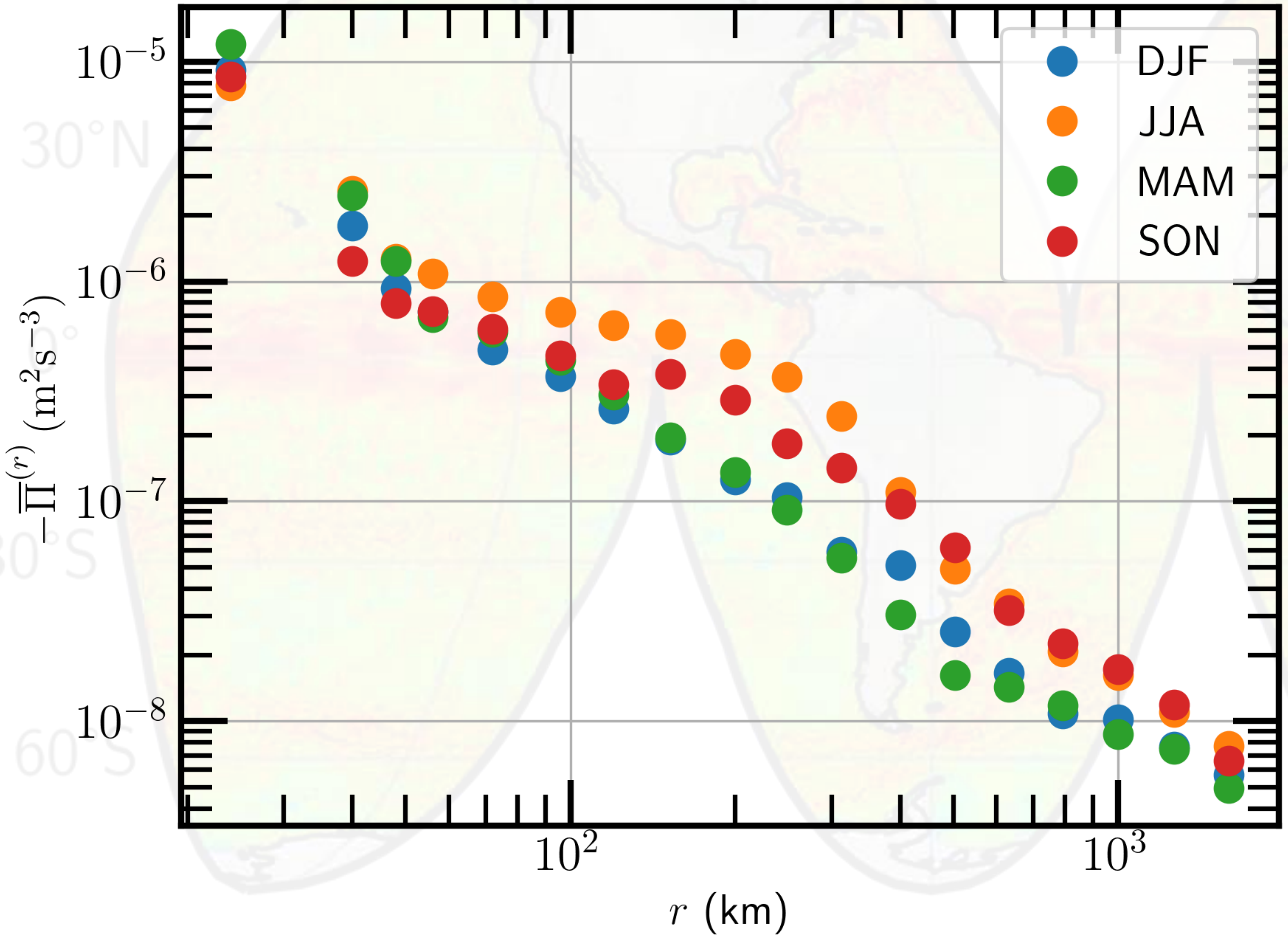

Global average energy flux

Summary

- Scale-to-Scale energy flux is extracted.
- An extremely rich dynamics is visible.
- Seasonable variation is evident.
- Inverse-cascade is found for all scales.

Song et al., 2022, under preparation