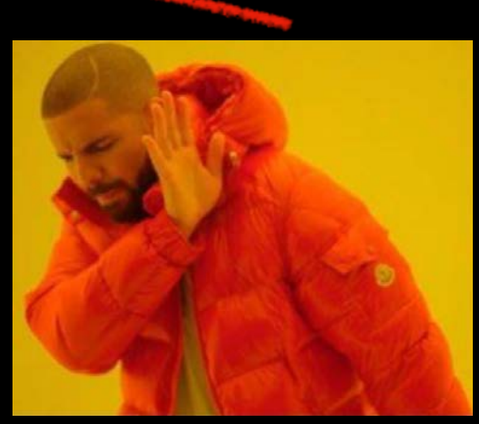
The transport and dynamics of wave-driven reef jets under the influence of rotation and stratification

-Walter Torres
Ph.D Candidate (Year III)| Duke University
Advisor: Jim Hench

“I use Blue Waters to model circulation in the coastal ocean”

The transport and dynamics of wave-driven reef jets under the influence of rotation and stratification



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The transport and dynamics of wave-driven reef jets under the influence of rotation and bottom friction

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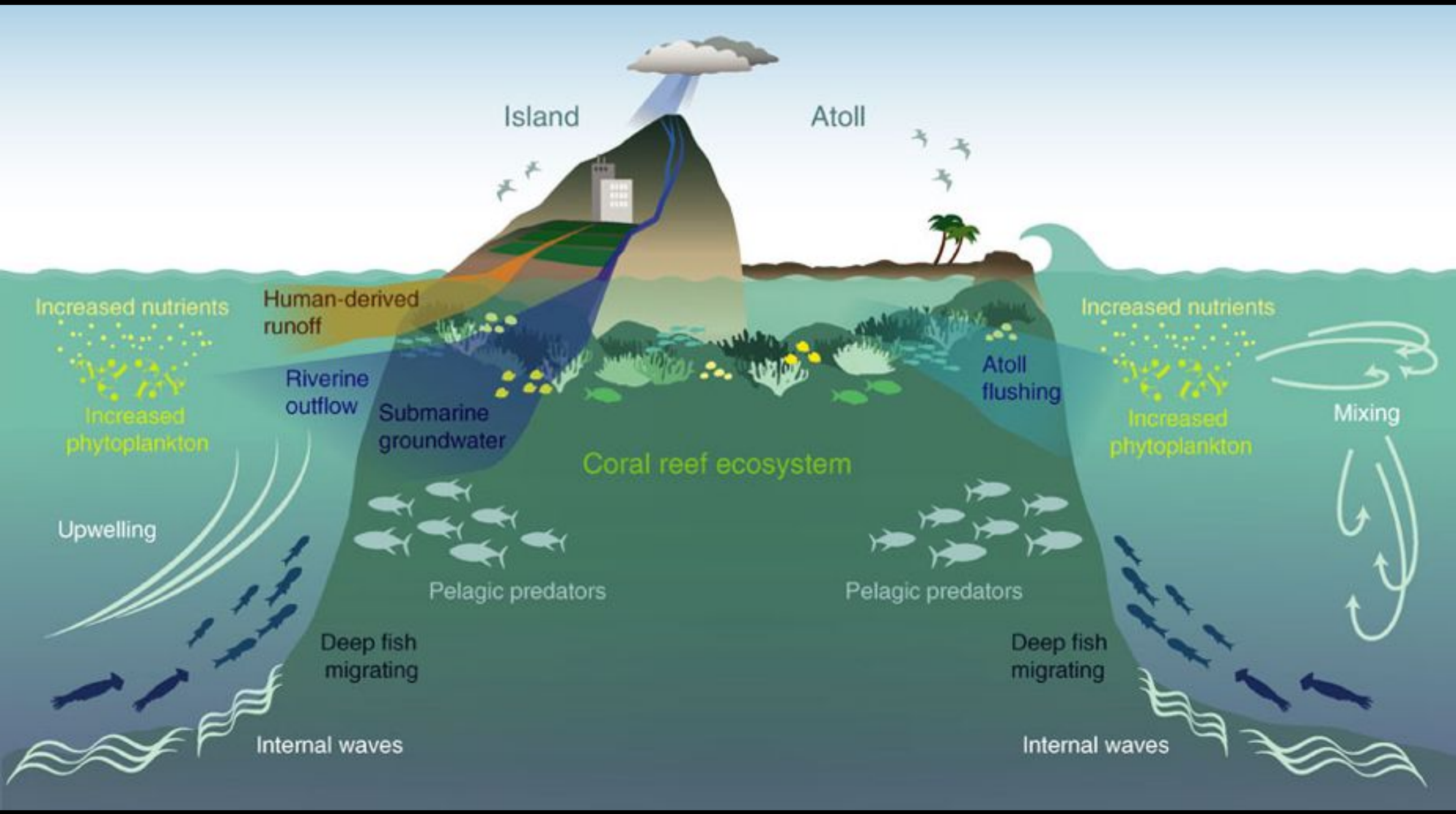
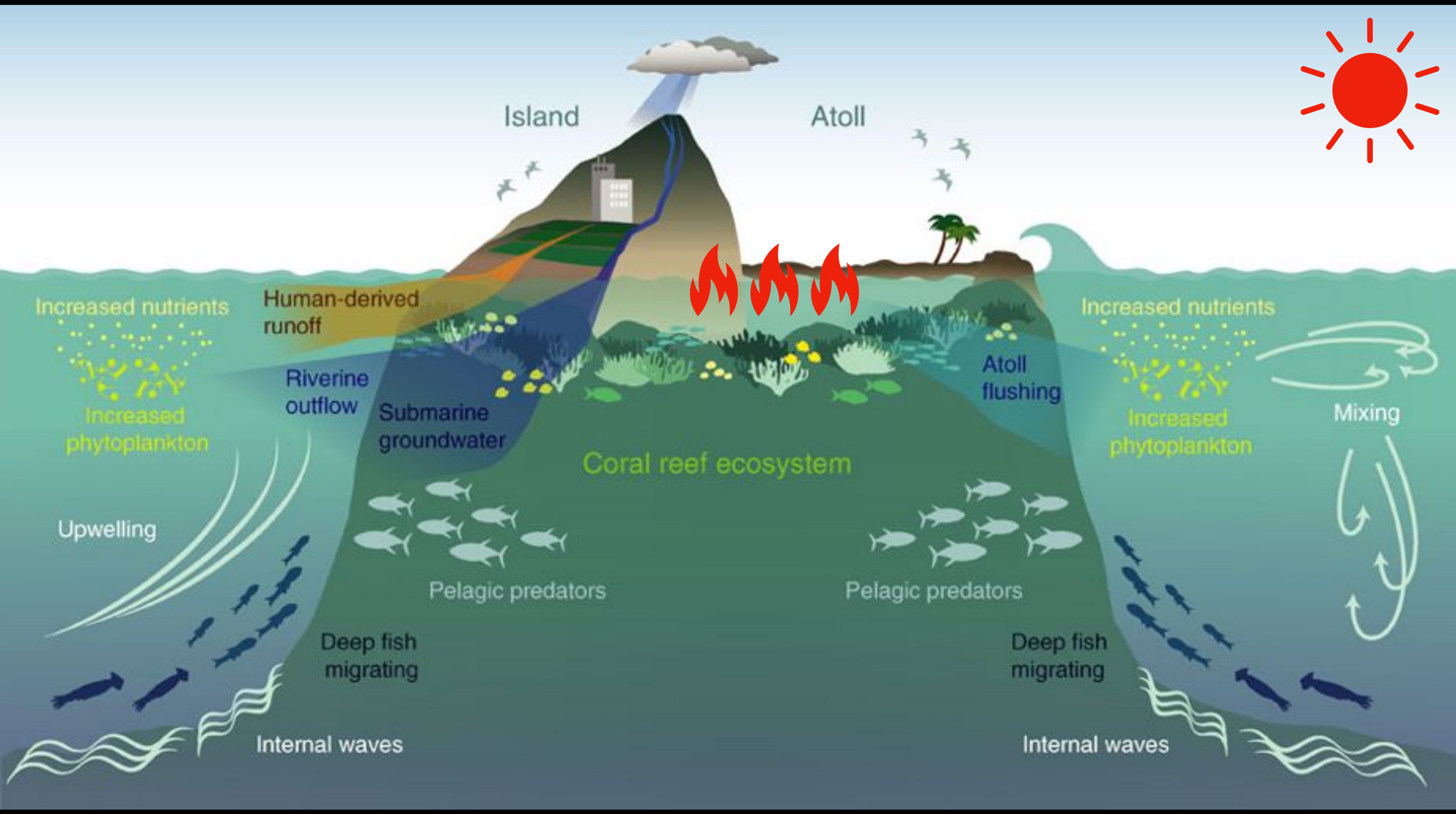


Gove, J. M. et al. Near-island biological hotspots in barren ocean basins. Nat. Commun. (2016)



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THE WORLD
ON
MERCATOR'S PROJECTION
SHEWING THE VOYAGES OF
CAPTAIN COOK ROUND THE WORLD.

Explanation of the Tracks.
First Voyage
Second do
Third do
The direction is shown by the Arrows.

Talley and Co. 1851 General Atlas

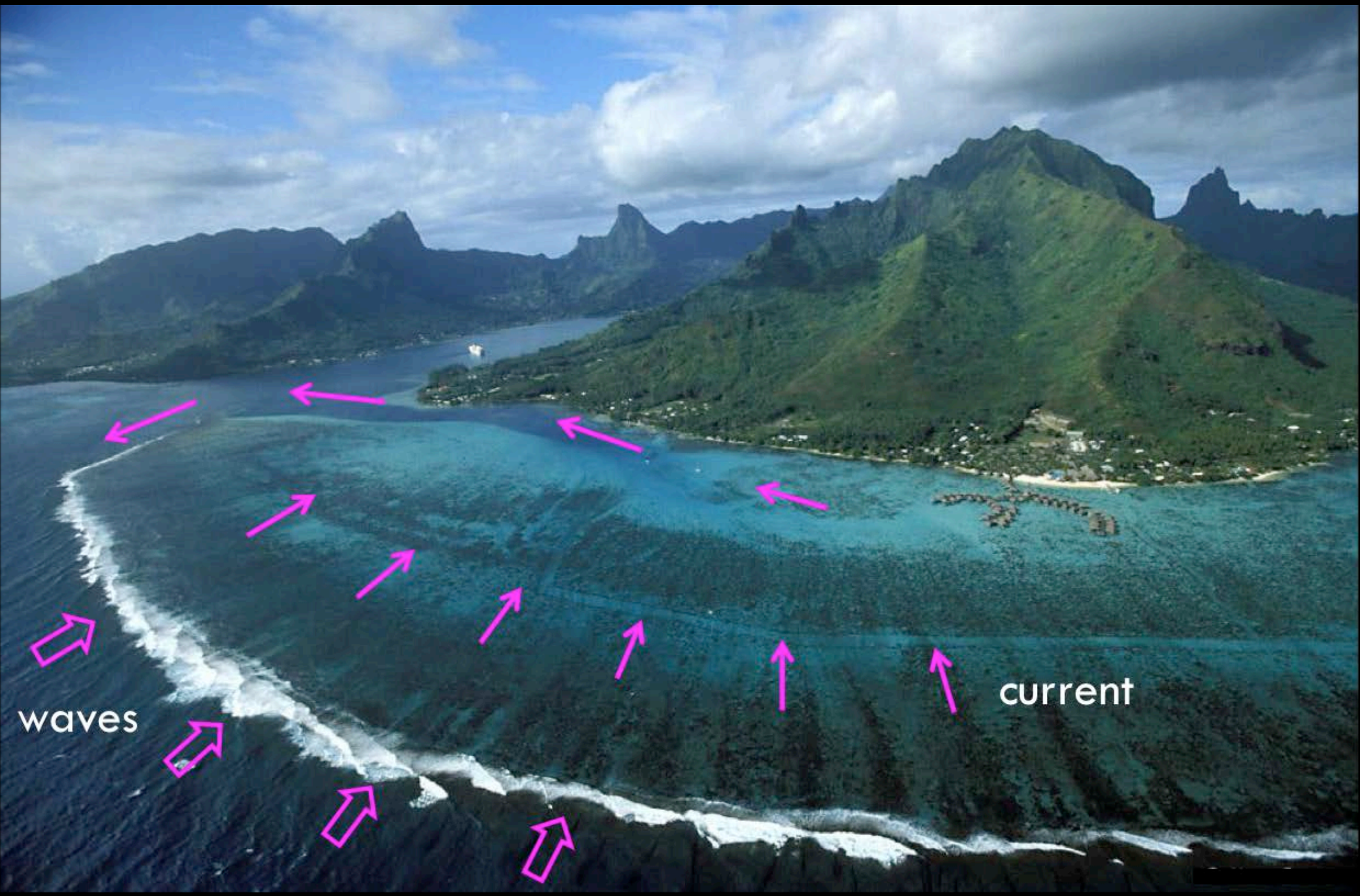
Mo’orea, French Polynesia

Mo’orea, French Polynesia

100
90
80
70
60
50
40
30
20
10
0

1 km

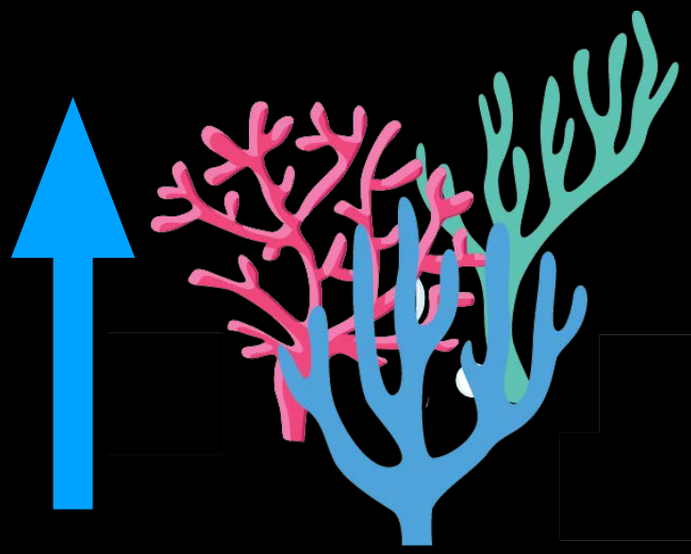
Mo’orea, French Polynesia



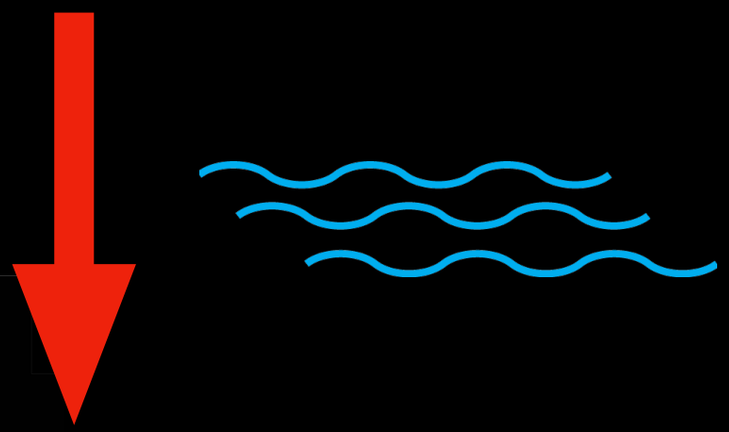
Question: What is the effect of rotation and bottom friction on the behavior of wave-driven reef jets?

Hypothesis: At given latitude, simulations with higher bottom roughness will experience attenuated waves and currents. This will produce weaker jets that are more affected by the Coriolis force and will deflect more prominently

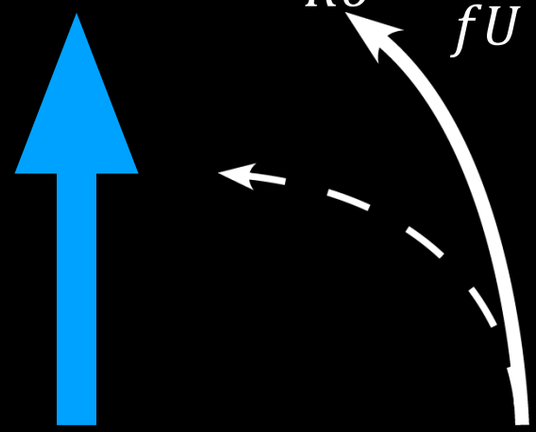
$$Ro = \frac{\frac{U^2}{L}}{fU} = \frac{nonlinear}{coriolis}$$



Bottom Friction



Wave+Current Magnitude



Jet deflection via Coriolis

Methods: Idealized coupled wave-circulation numerical modeling (COAWST) - suite of runs varying latitude (Φ) and bottom friction (via z0)

Annulus Domain

Grid configuration

Wave BC's

- Height = 1m
- Period = 10s
- Direction = Radial-inward

Δx, Δy 5m-150m

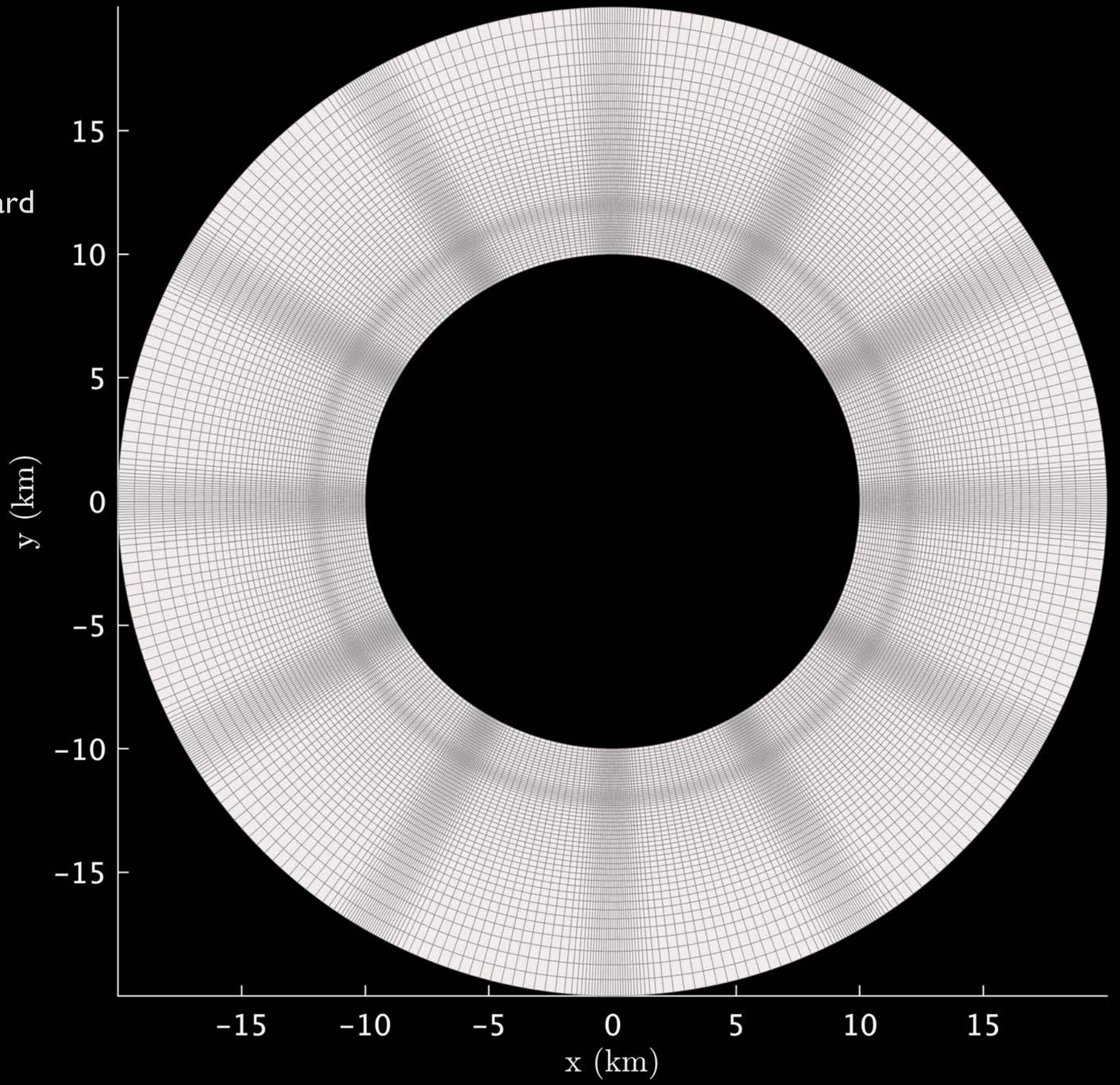
Proposed runs

Parameter	Values
vertical levels	20
Latitude: Φ	0°,
Nθ, Nr	2048, 256
	5°,10°,15°,
dt	0.5 s
	20°, 25°, 30°
Roughness: z0 (m)	0.001, 0.01, 0.1

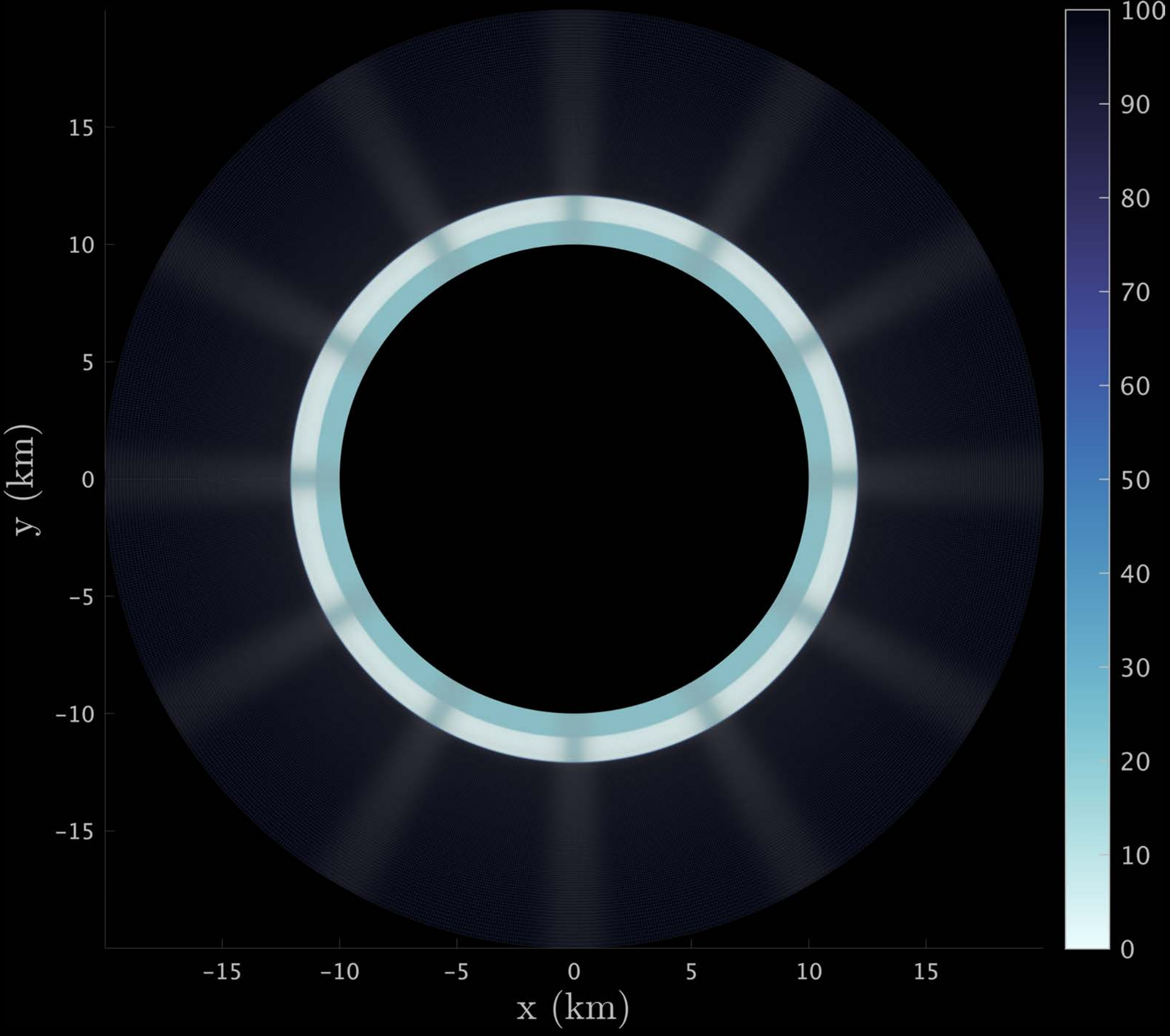
Challenges

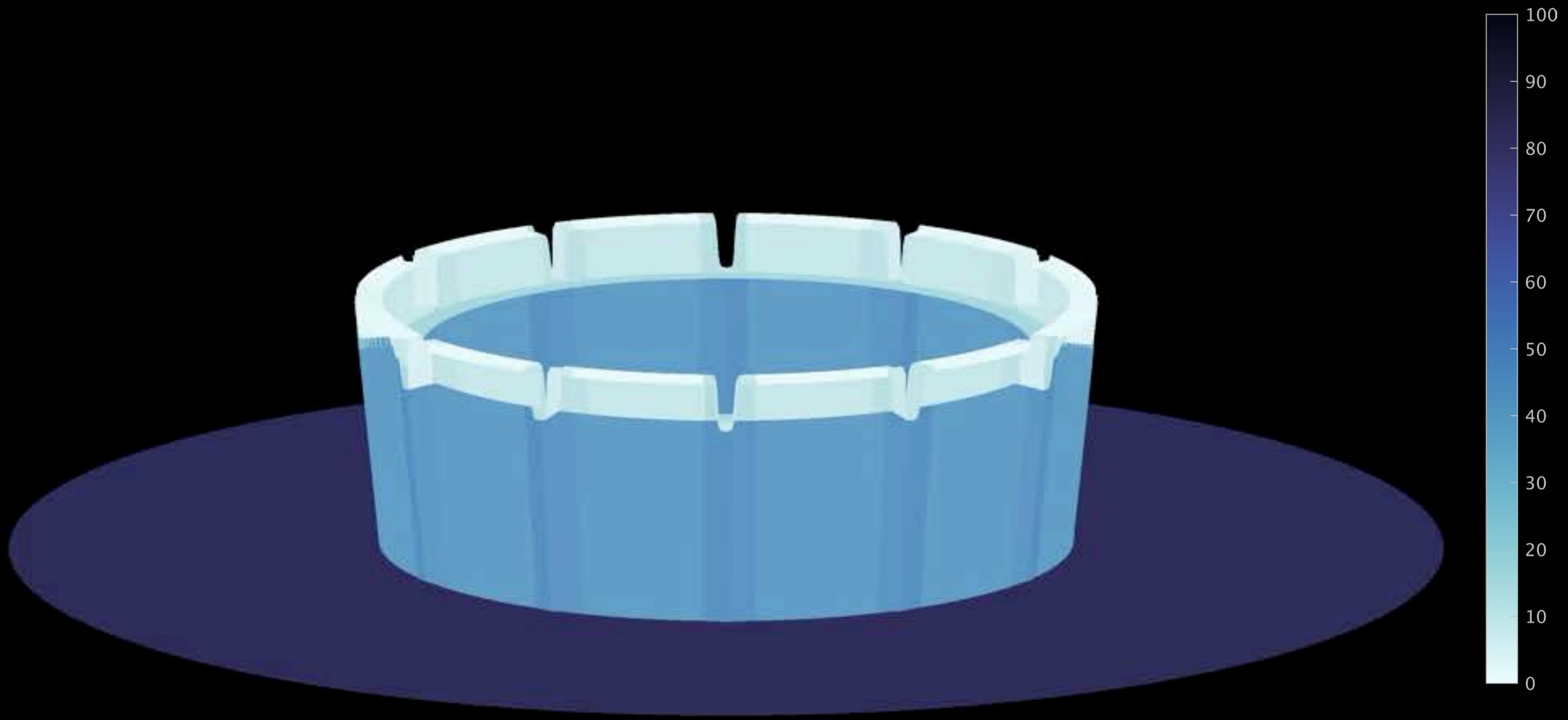
-High resolution required resolve fine-scale processes = short time step (must satisfy CFL) requires HPC.

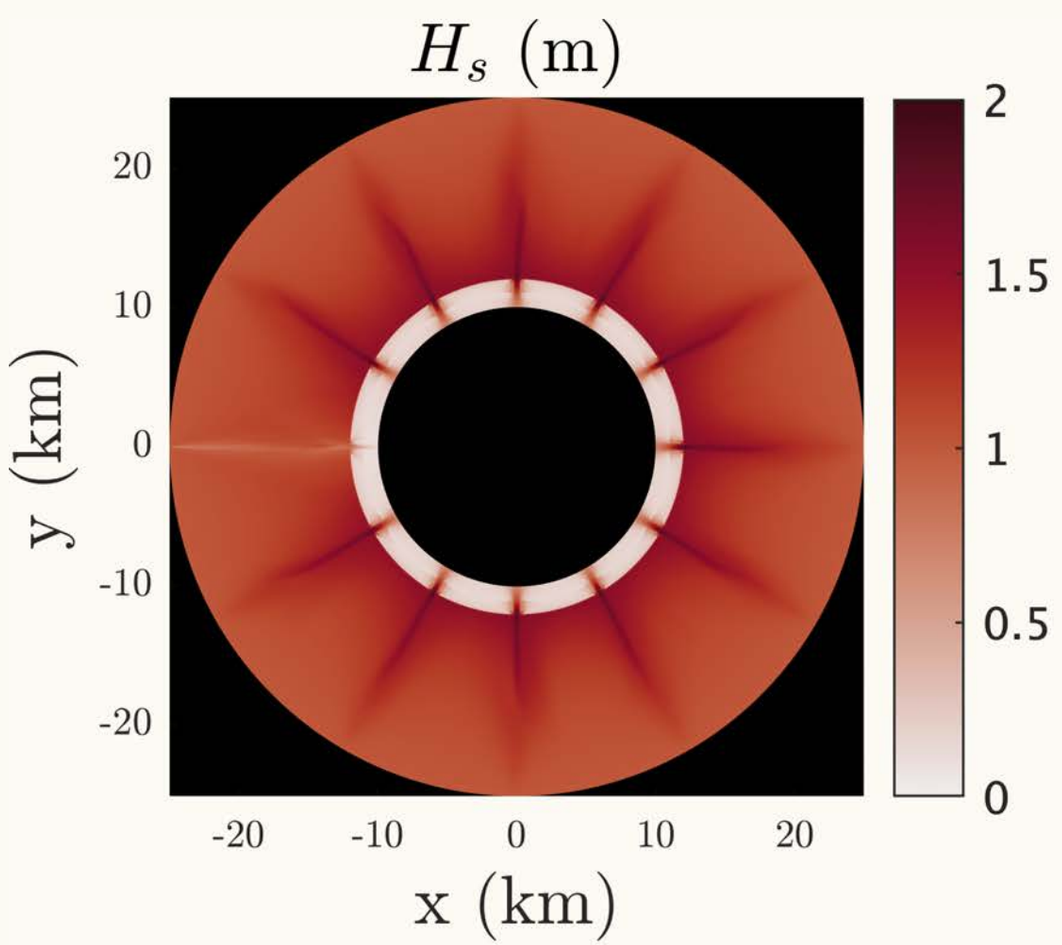
Thank you Blue Waters!

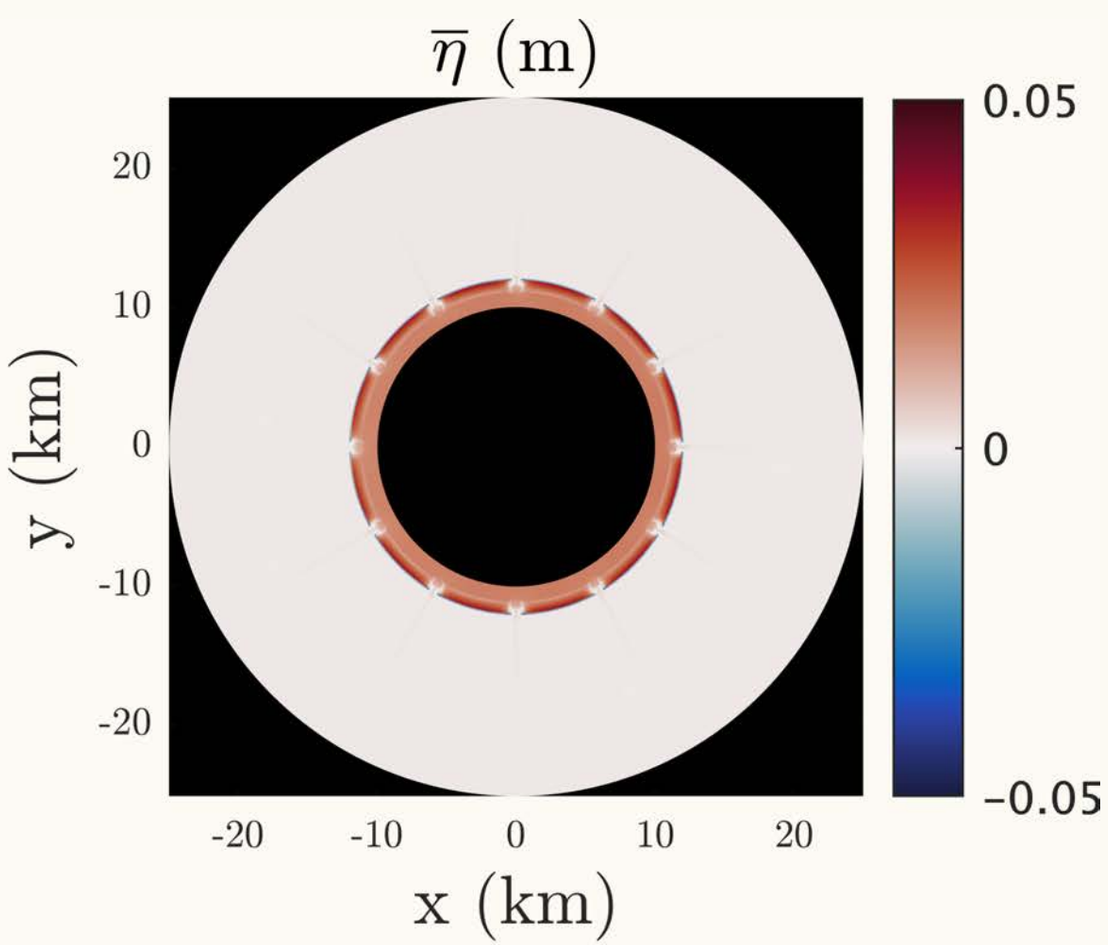


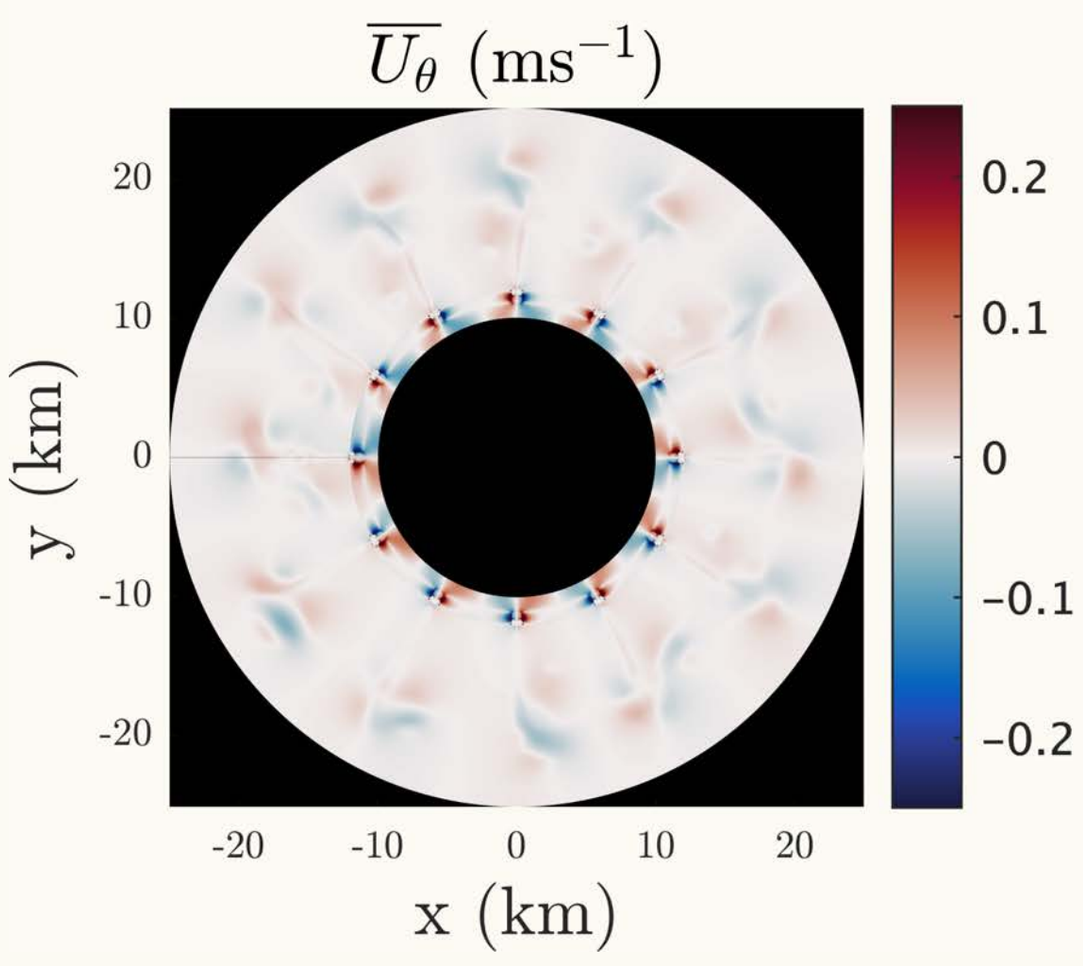
Annulus Domain

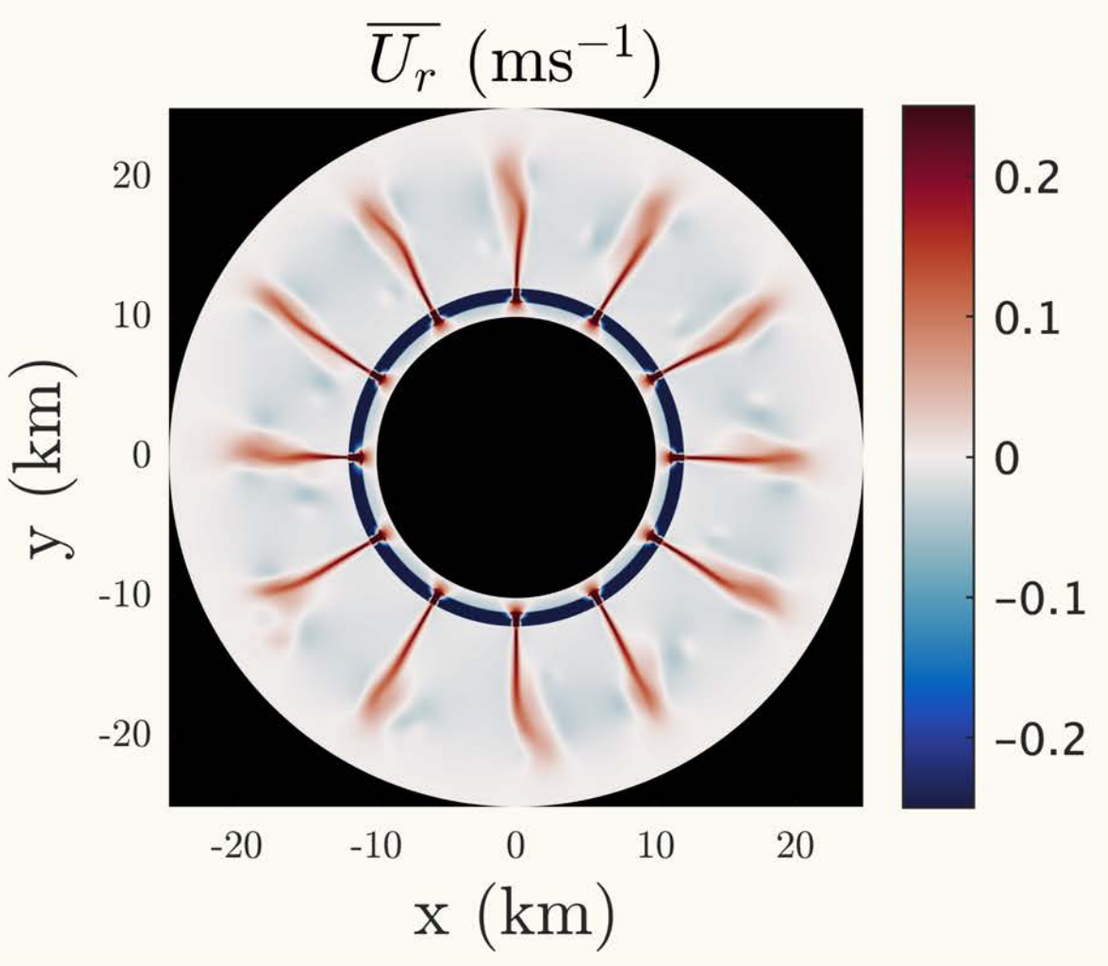


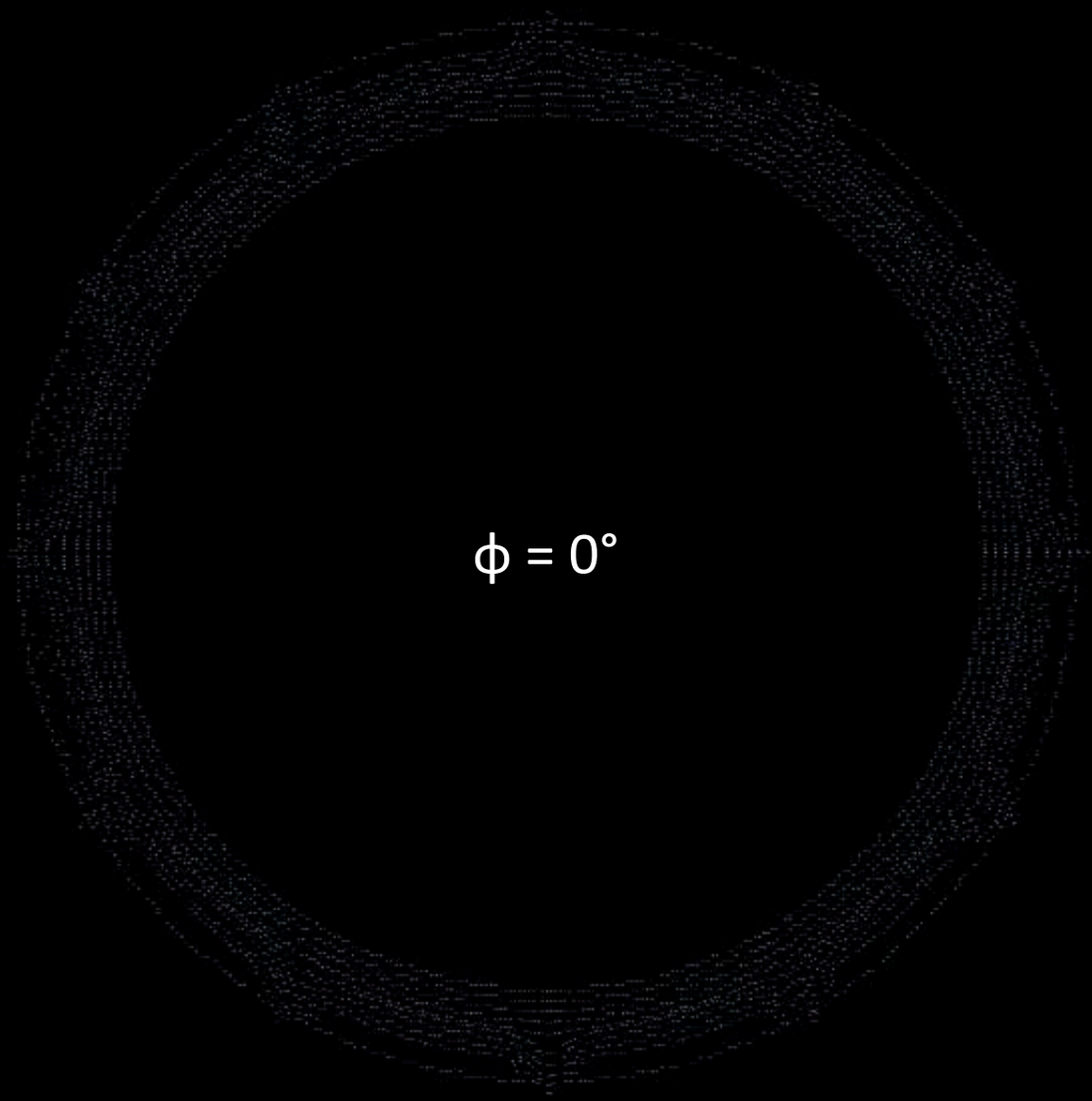

100
90
80
70
60
50
40
30
20
10
0

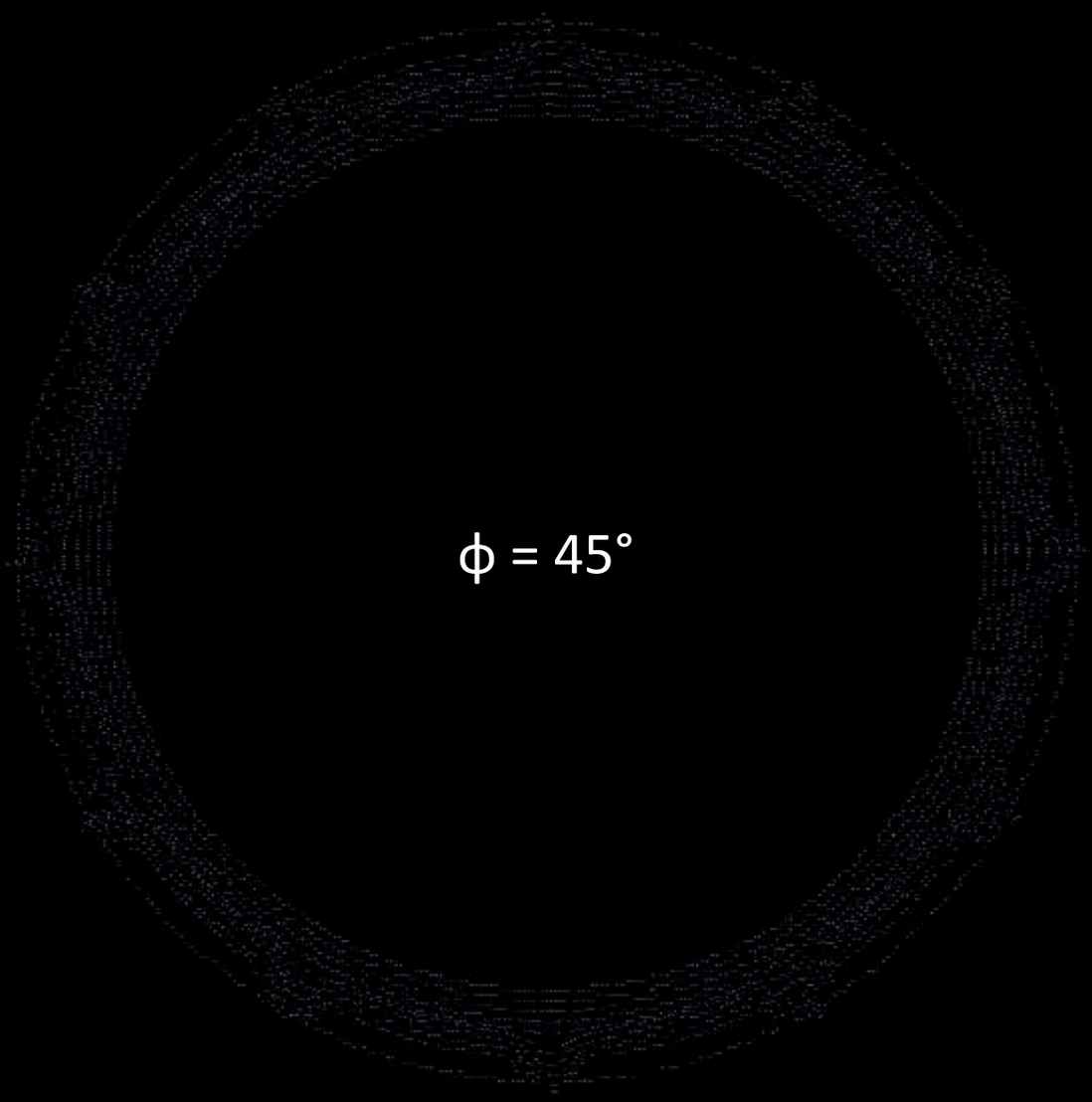

H_s (m)
2
1.5
1
0.5
0
20
10
0
-10
-20
y (km)
-20
-10
0
10
20
x (km)

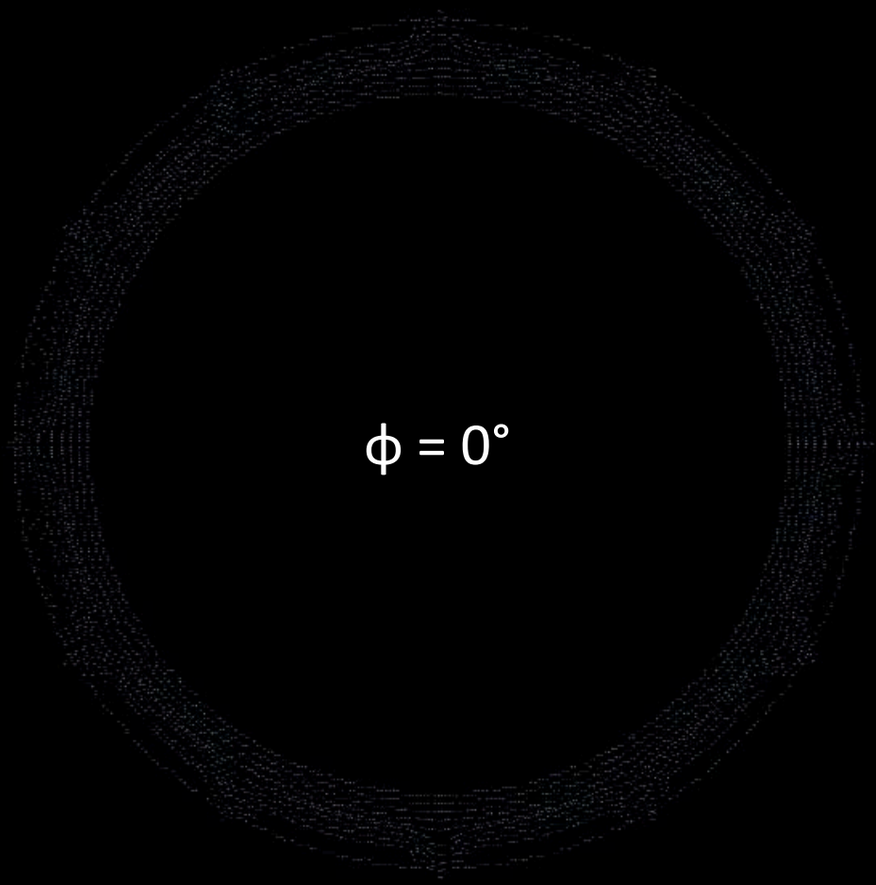

$\overline{\eta}$ (m)
0.05
0
-0.05
20
10
0
-10
-20
y (km)
-20
-10
0
10
20
x (km)

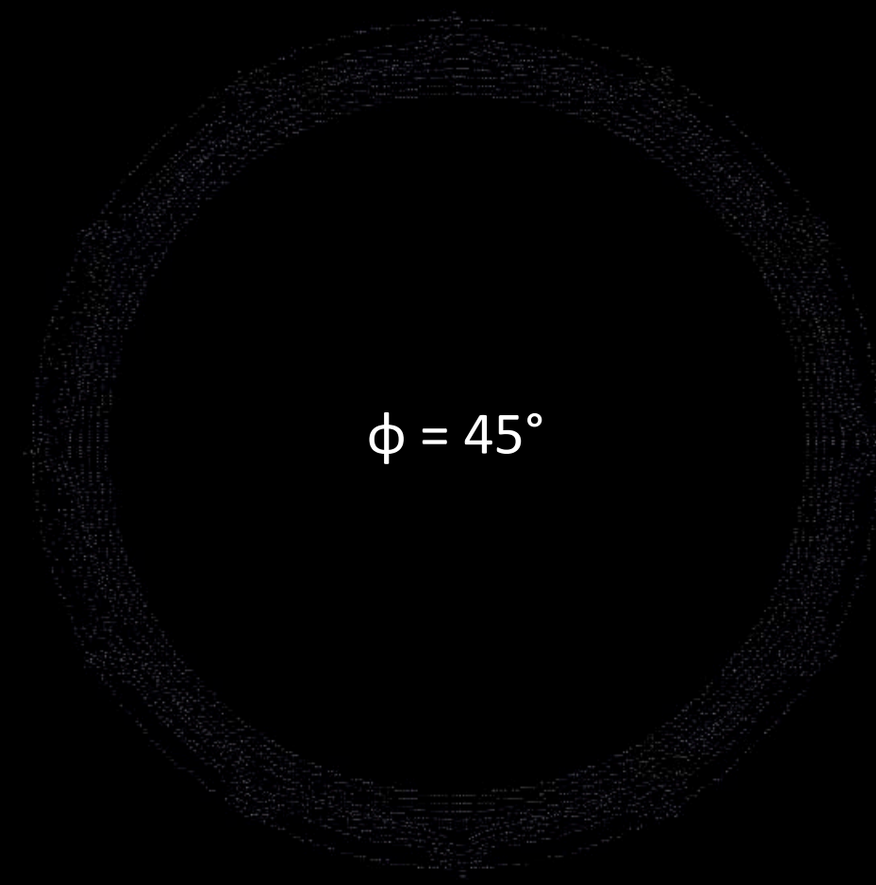

$\overline{U_\theta}$ (ms^{-1})
0.2
0.1
0
−0.1
−0.2
20
10
0
-10
-20
y (km)
-20
-10
0
10
20
x (km)

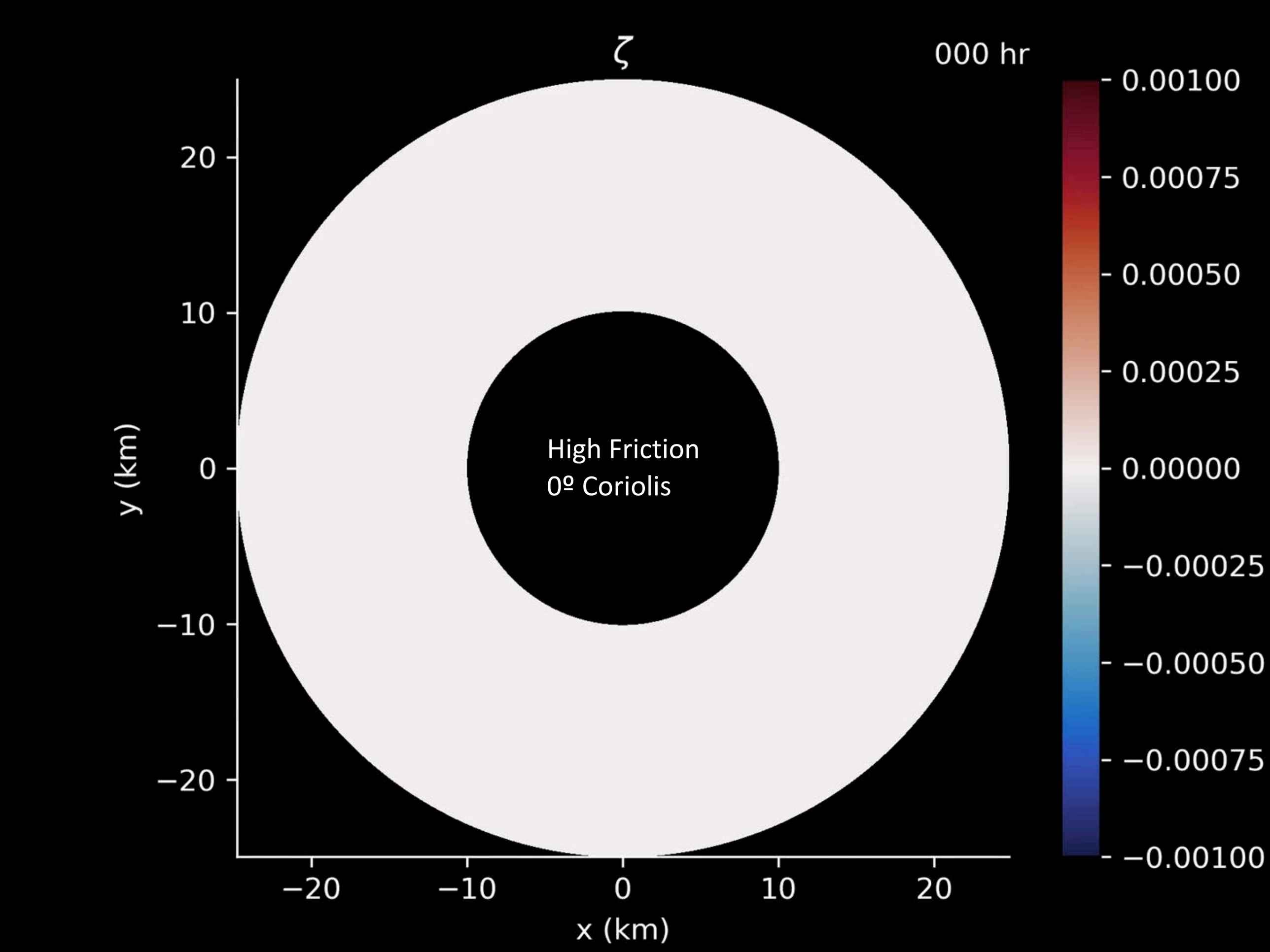

$\overline{U_r}$ (ms^{-1})
0.2
0.1
0
−0.1
−0.2
20
10
0
-10
-20
y (km)
-20
-10
0
10
20
x (km)

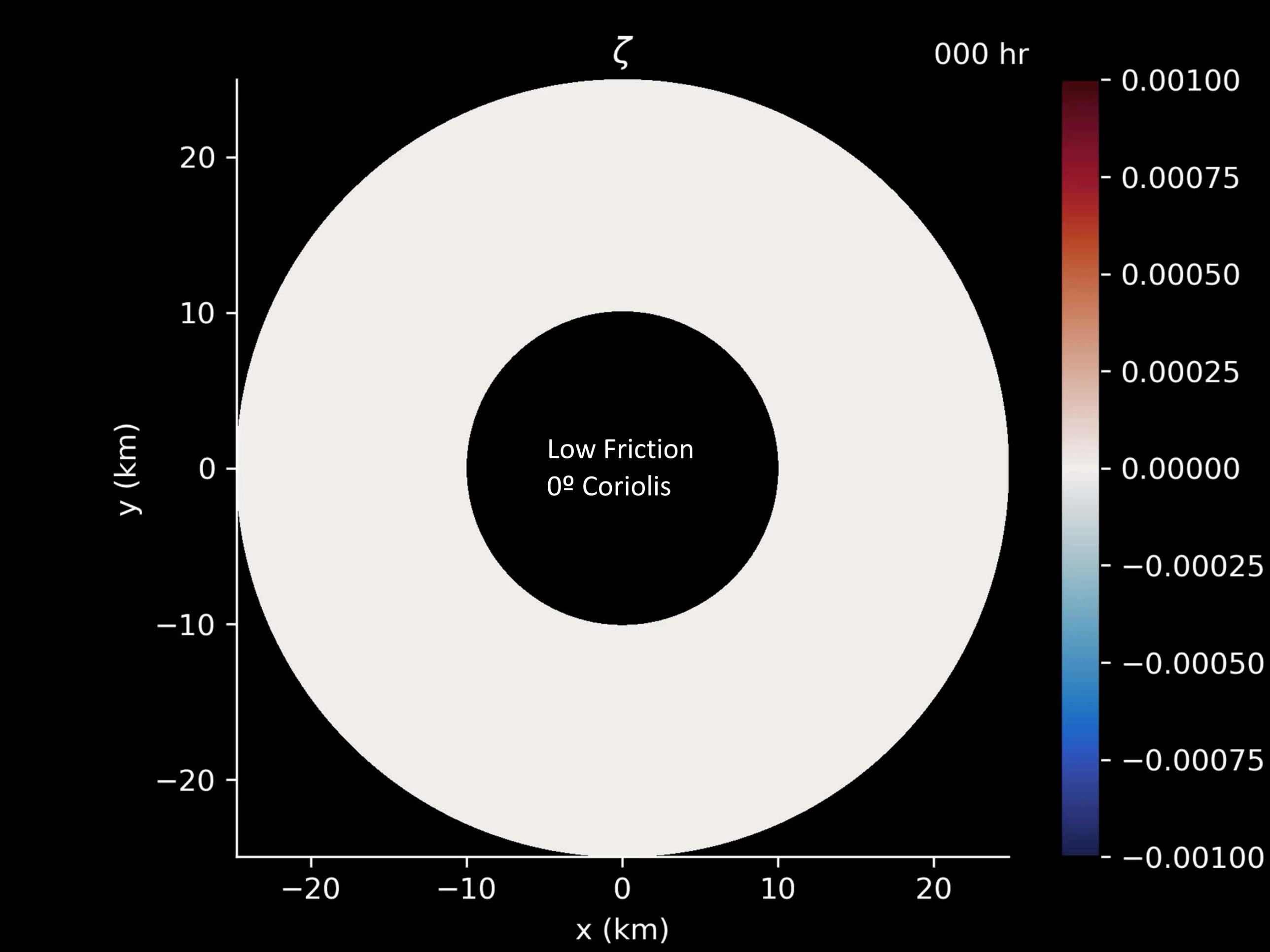

ϕ = 0°

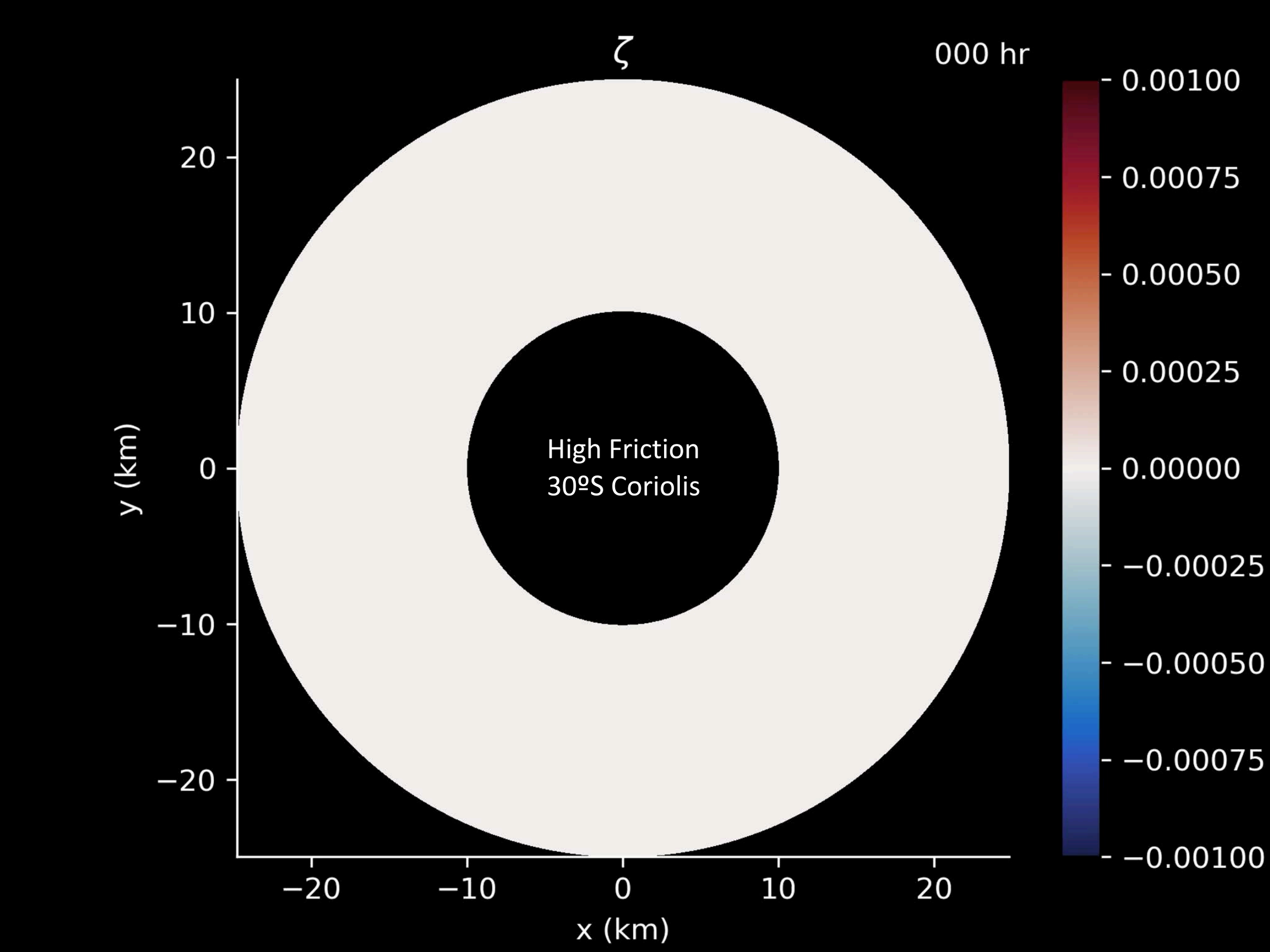

ϕ = 45°

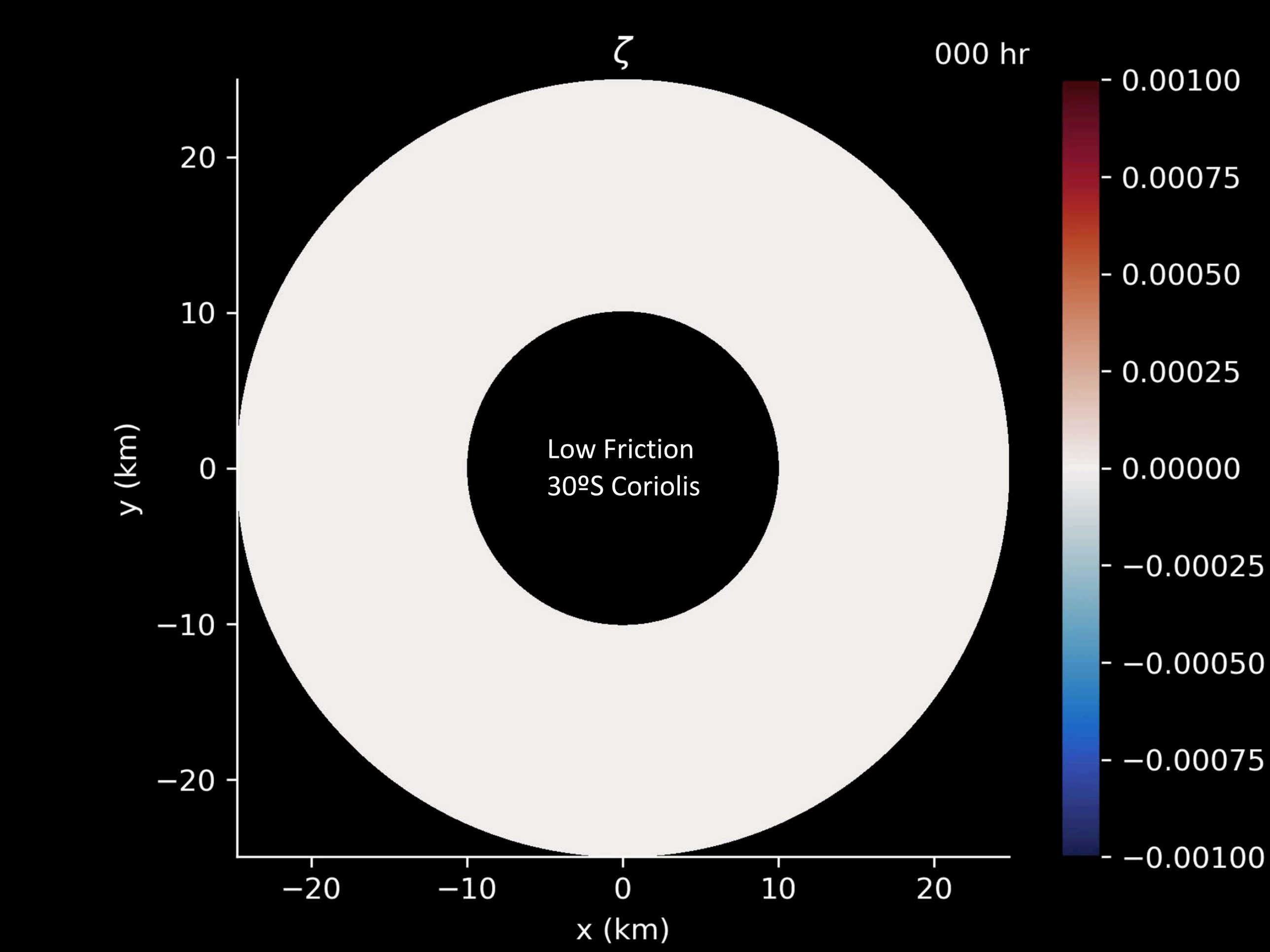

ϕ = 0°


ϕ = 45°


ζ
000 hr
High Friction
0º Coriolis
y (km)
x (km)
20
10
0
−10
−20
−20
−10
0
10
20
0.00100
0.00075
0.00050
0.00025
0.00000
−0.00025
−0.00050
−0.00075
−0.00100

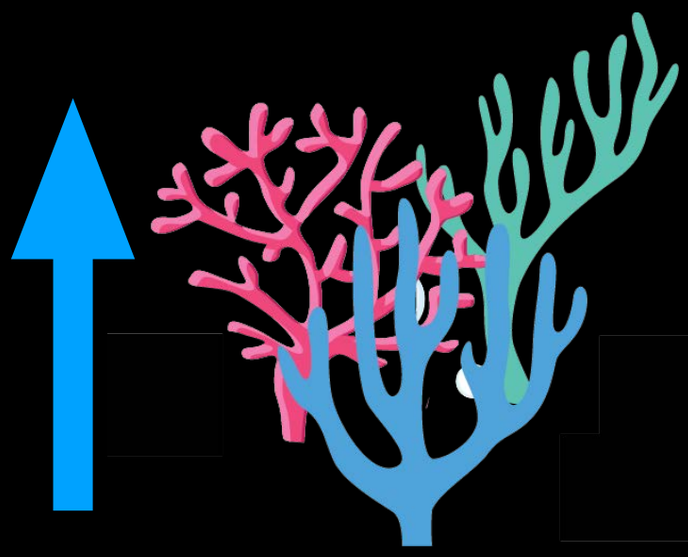

ζ
000 hr
Low Friction
0º Coriolis
y (km)
x (km)
20
10
0
−10
−20
−20
−10
0
10
20
0.00100
0.00075
0.00050
0.00025
0.00000
−0.00025
−0.00050
−0.00075
−0.00100


ζ
000 hr
High Friction
30ºS Coriolis
y (km)
x (km)
20
10
0
−10
−20
−20
−10
0
10
20
0.00100
0.00075
0.00050
0.00025
0.00000
−0.00025
−0.00050
−0.00075
−0.00100


ζ
000 hr
Low Friction
30ºS Coriolis
y (km)
x (km)
20
10
0
−10
−20
−20
−10
0
10
20
0.00100
0.00075
0.00050
0.00025
0.00000
−0.00025
−0.00050
−0.00075
−0.00100

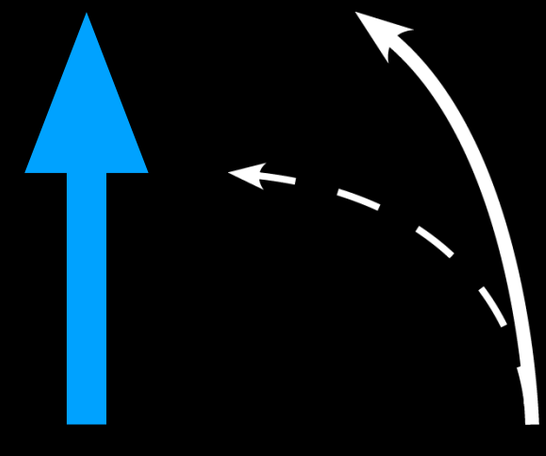
Summary

- Interaction of eddy shedding from jets, Coriolis, and stokes drift from waves as possible retention mechanism, which is modulated by frictional processes in the back reef



Bottom Friction

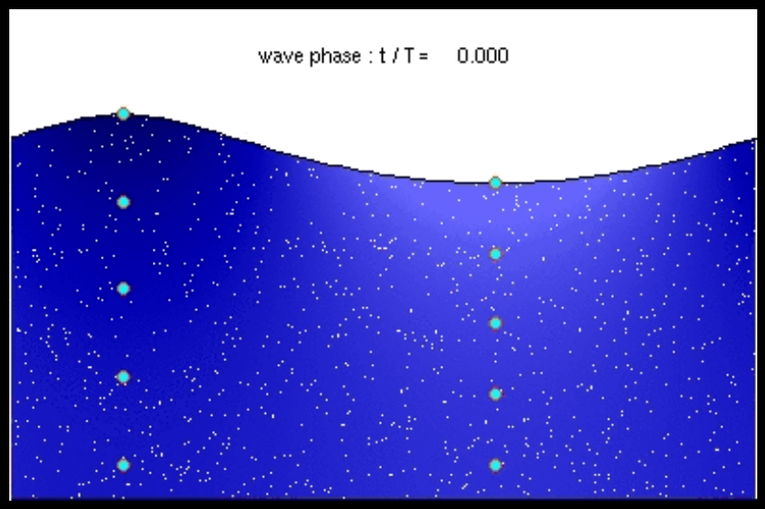
Wave+Current Magnitude



Jet deflection via Coriolis

Eddies

+



Stokes drift

=

Retention?

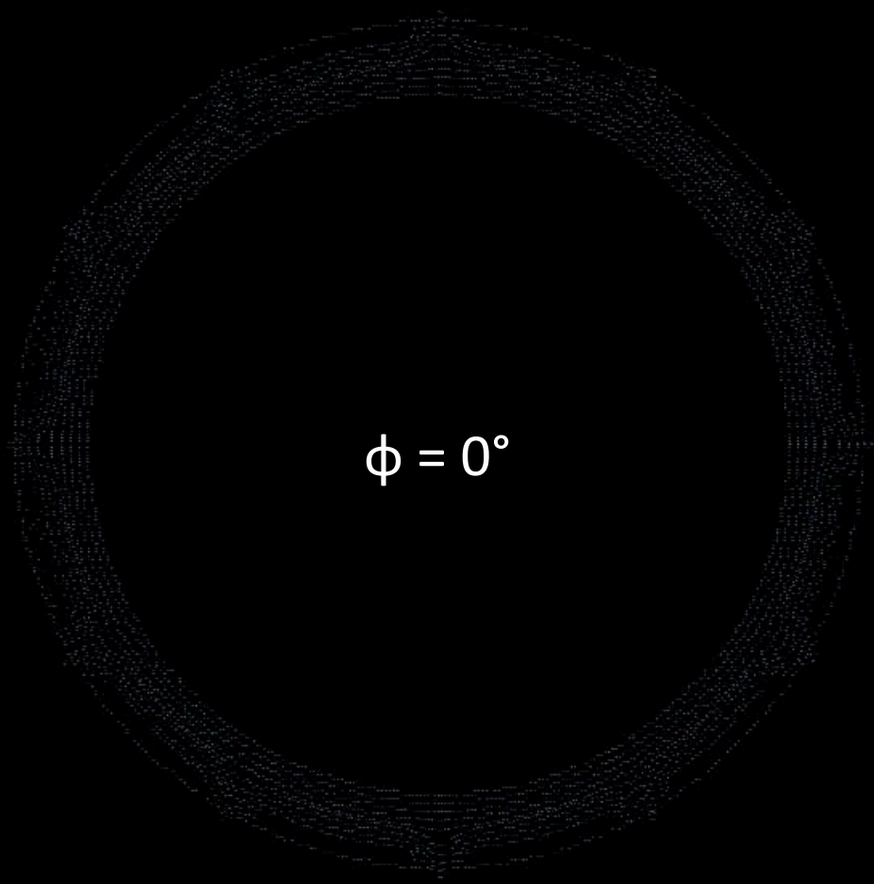
Future Work

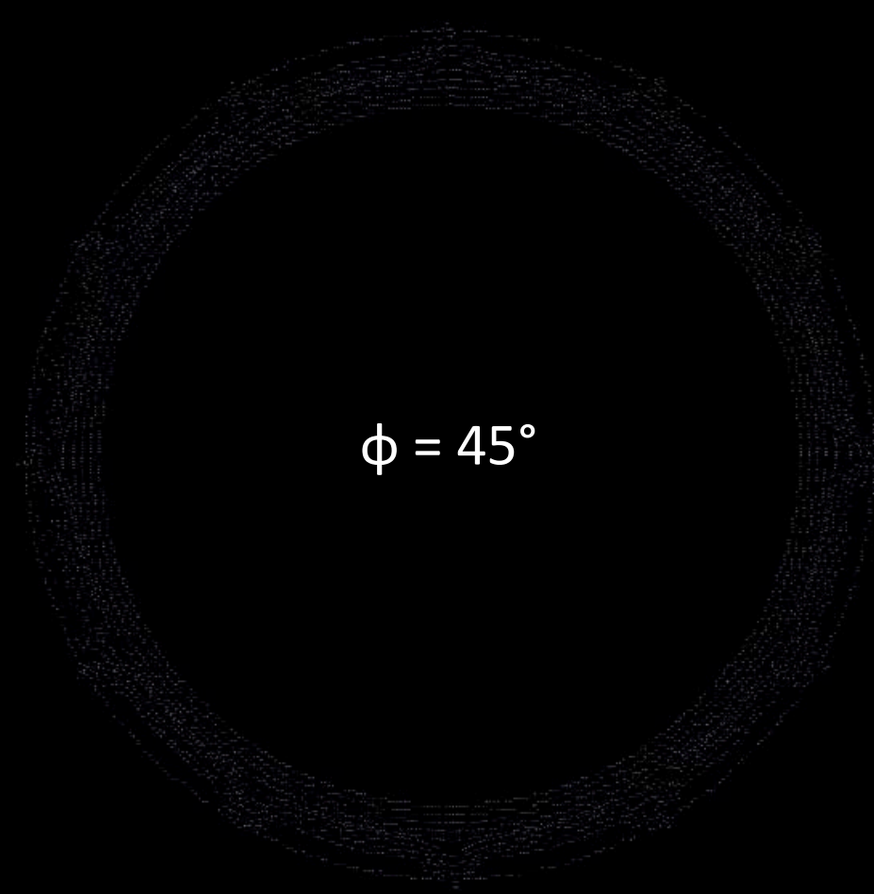
- Longer model integration times to allow for recirculation and eddy interaction with other jets
- Preferential sign of vorticity due to centrifugal instability
- More model runs to span (z0,ϕ) parameter space
- Next project: include stratification and diurnal heating forcing for more realistic conditions capturing combined plume+jet dynamics

Duke
UNIVERSITY

BLUE WATERS
SUSTAINED PETASCALE COMPUTING

MCR
MOOREA CORAL REEF
LONG TERM ECOLOGICAL RESEARCH





“Winterfell”, Game of Thrones S08E01
Dave Hill et al., *HBO* (2019)