250213 Weekly Lab meeting

Weekly Lab Meeting

Juseong Kim

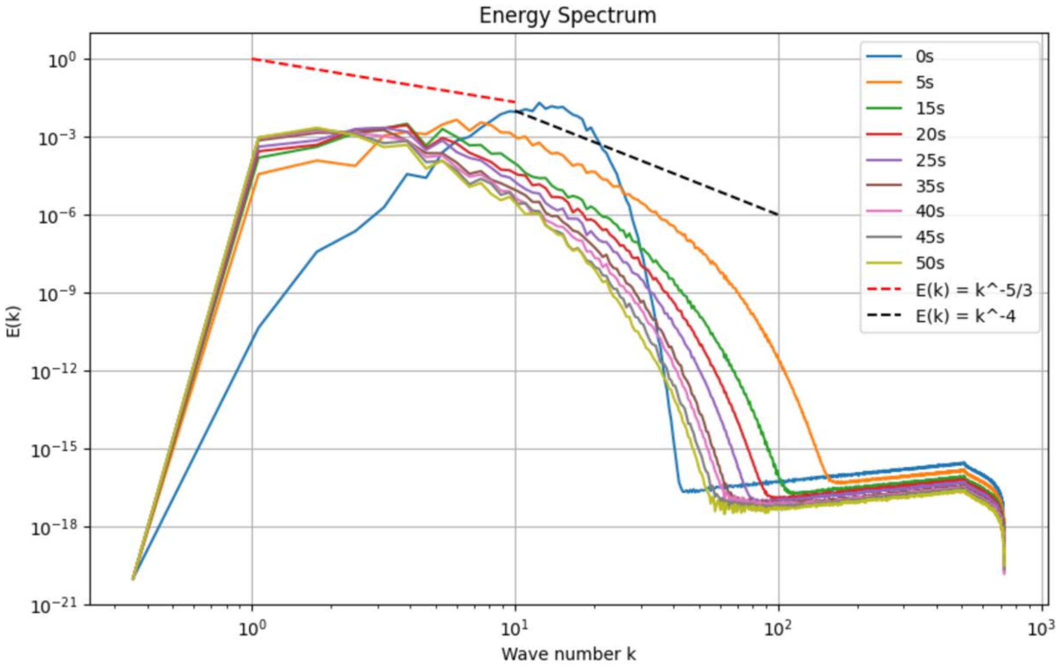
Flow Physics & Computational Engineering Innovation Lab

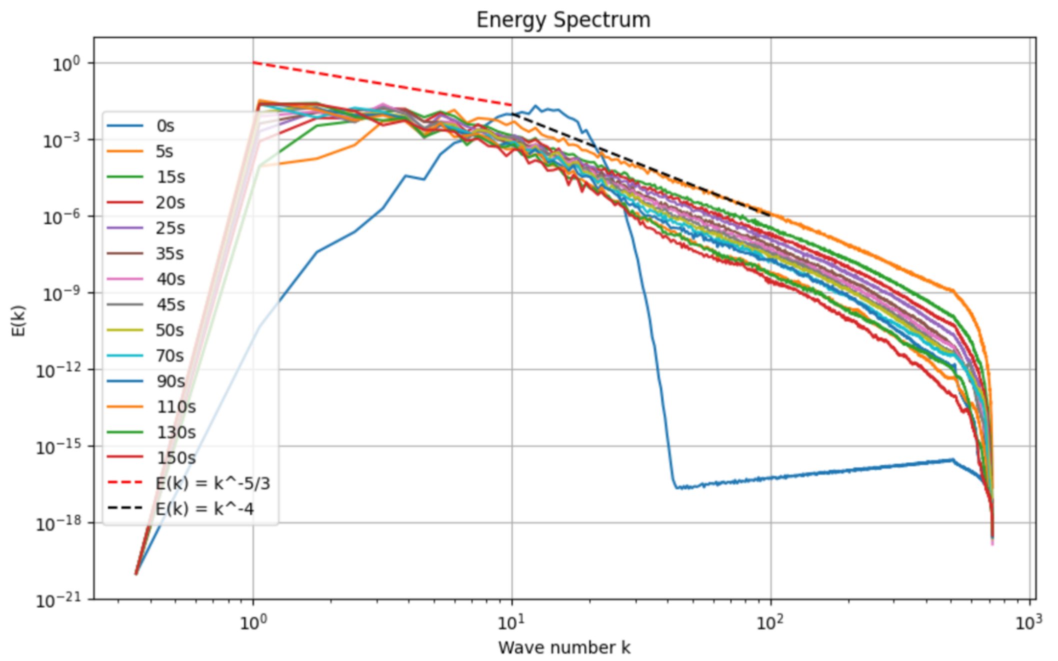
Contents

01 Energy Spectrum

02 Statistics Analysis

Background1 – Fitting 구간 선정



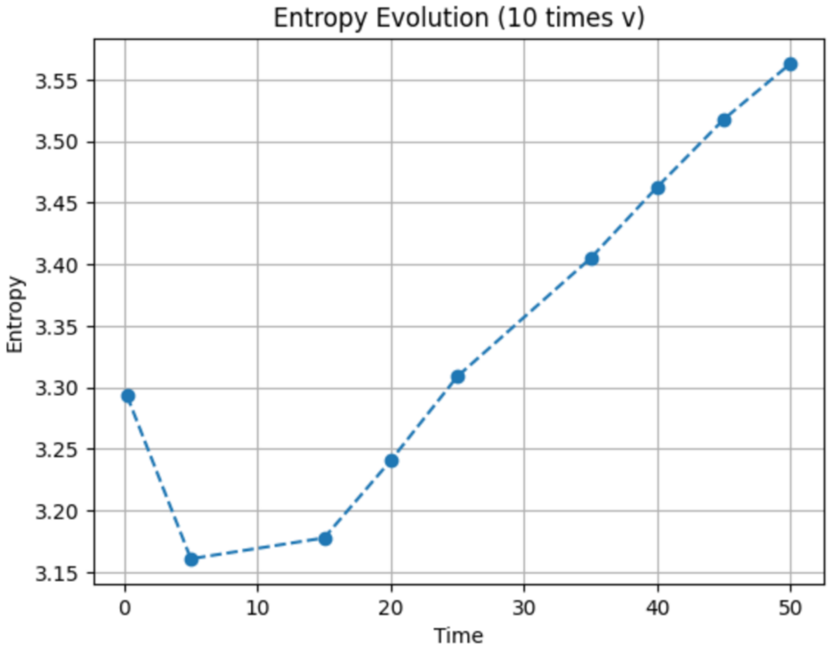


시각적으로 곡선 구간 존재

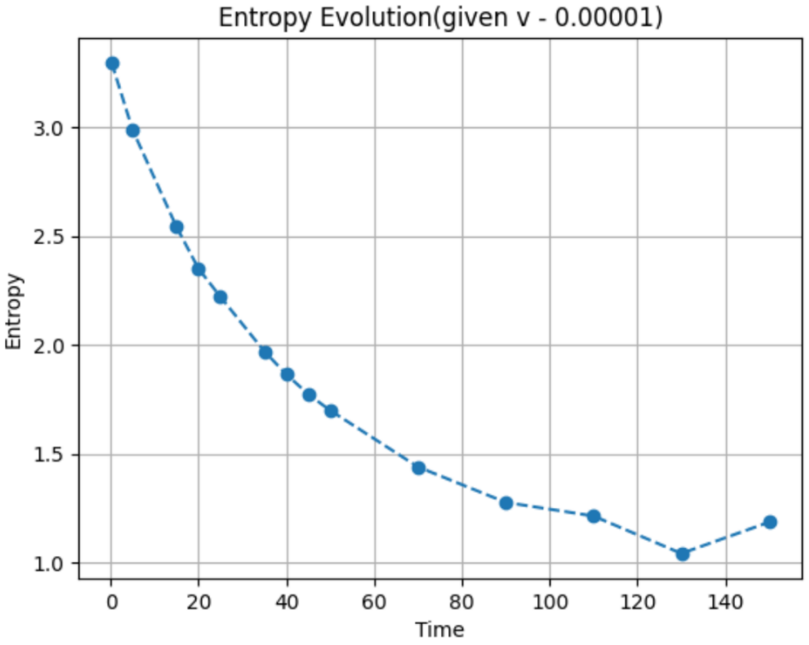
초반에 진동 발생 구간 존재
E(k)가 급감하는 구간 존재

Background2 – Inverse cascade

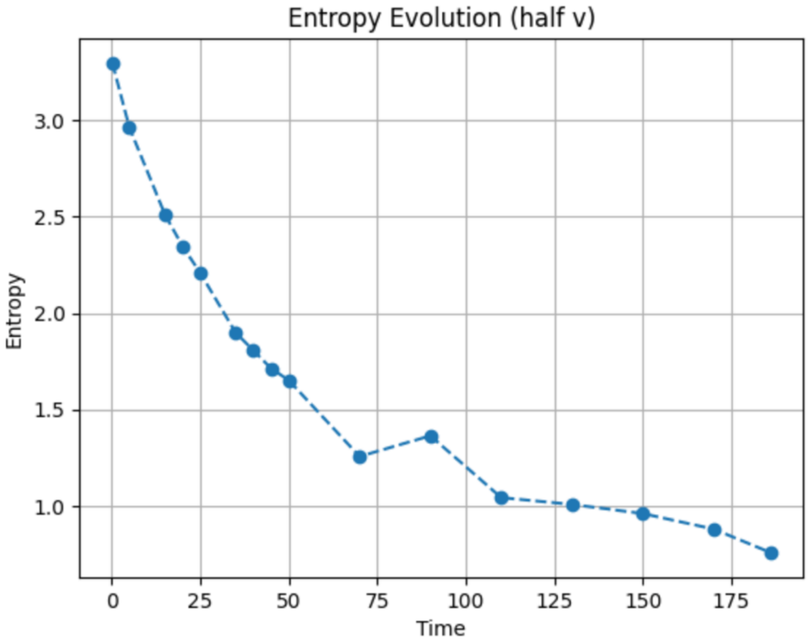
Entropy graph Over time



엔트로피 증가
Inverse cascade 없다고 가정



엔트로피 감소
Inverse cascade 있다고 가정



엔트로피 감소
Inverse cascade 있다고 가정

Background3 – Case

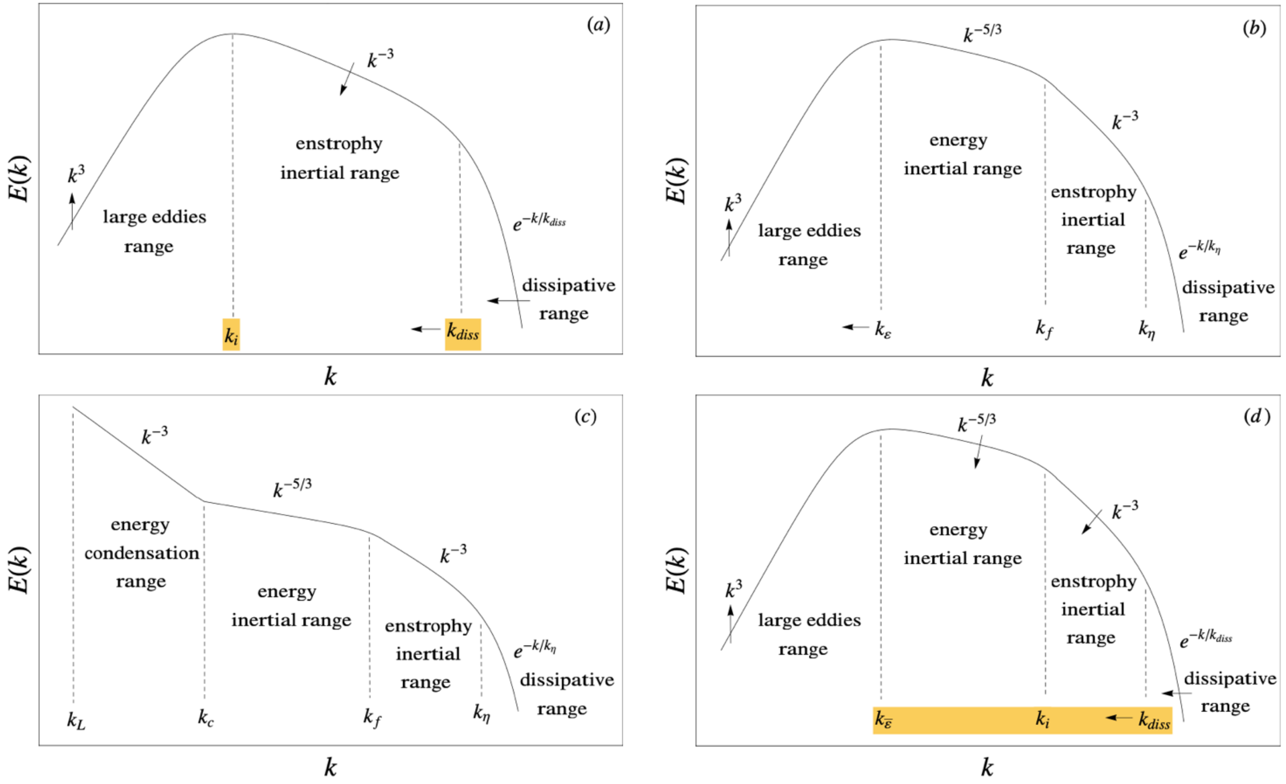


FIG. 1: Picture (log-log scale) of the expected kinetic spectrum in freely decaying (*a*) and forced (*b*) two-dimensional turbulence as a function of the wavenumber. Full spectrum in the presence of energy condensation (*c*) and inverse cascade in freely decaying turbulence (*d*). Arrows indicate displacements in time. In (*a*), (*b*), and (*c*), a time-dependent Saffman spectrum is shown at large scales ($k \to 0$).

Leonardo Campanelli <Dimensional analysis of two-dimensional turbulence>

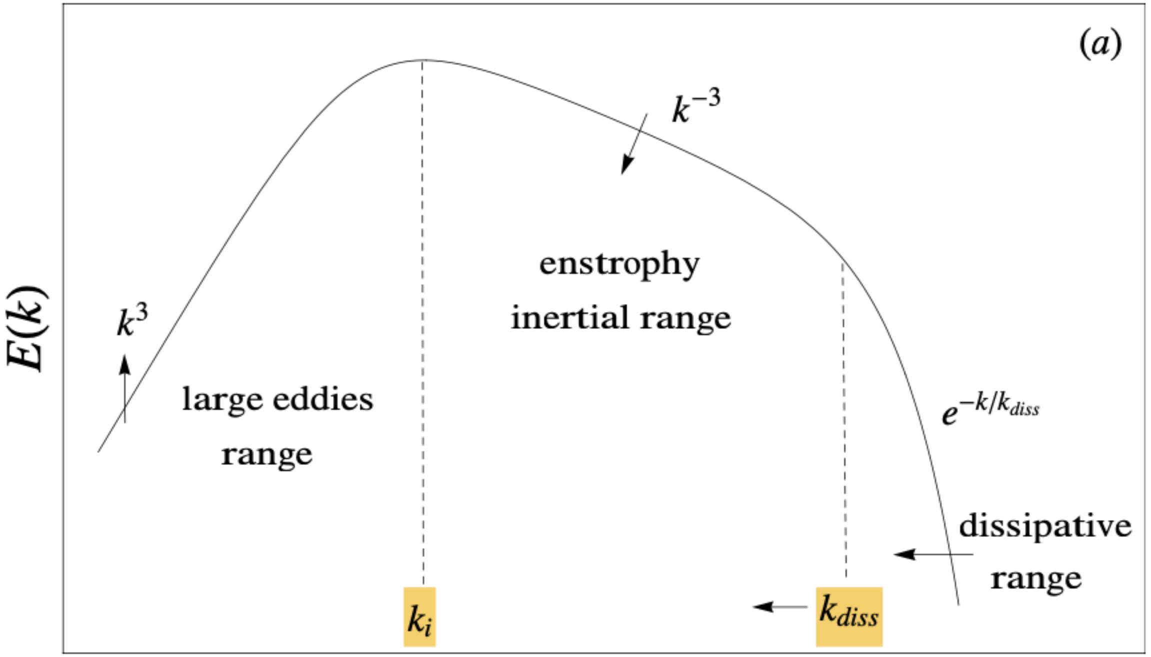
(a): 2d HIT freely decay w/o inverse cascade
-> 10 times v(0.0001) case

(b): 2d HIT Forced

(c): 2d Energy condensation

(d): 2d HIT freely decay with inverse cascade
-> given v(0.00001) case
-> Half v(0.000005) case

Background4 – inertial range of case (a)

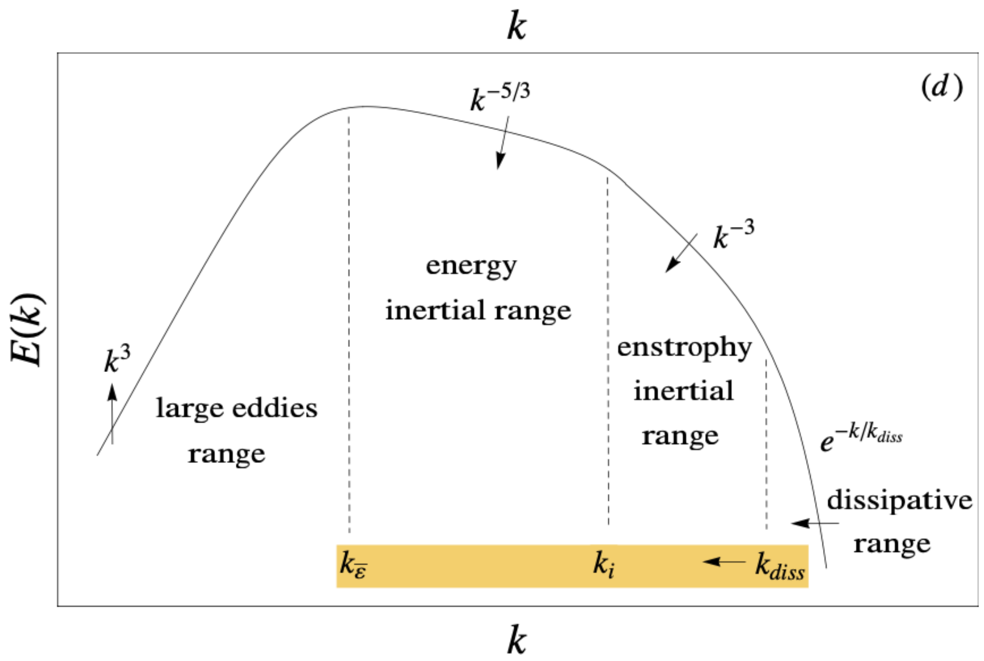


$$E(k,t) = \nu^{3/2} t^{-1/2} \psi(k\sqrt{\nu t}), \quad (1)$$

where ψ is an arbitrary function of its argument. The only scale in the model is the dissipation length $L_{diss}(t) = \sqrt{\nu t}$, to which it corresponds the wavenumber $k_{diss}(t) = 1/L_{diss}$.

1. k_i: E(k)가 max일 때 k 값이라 가정
2. k_diss = 1/ root(nu * t)

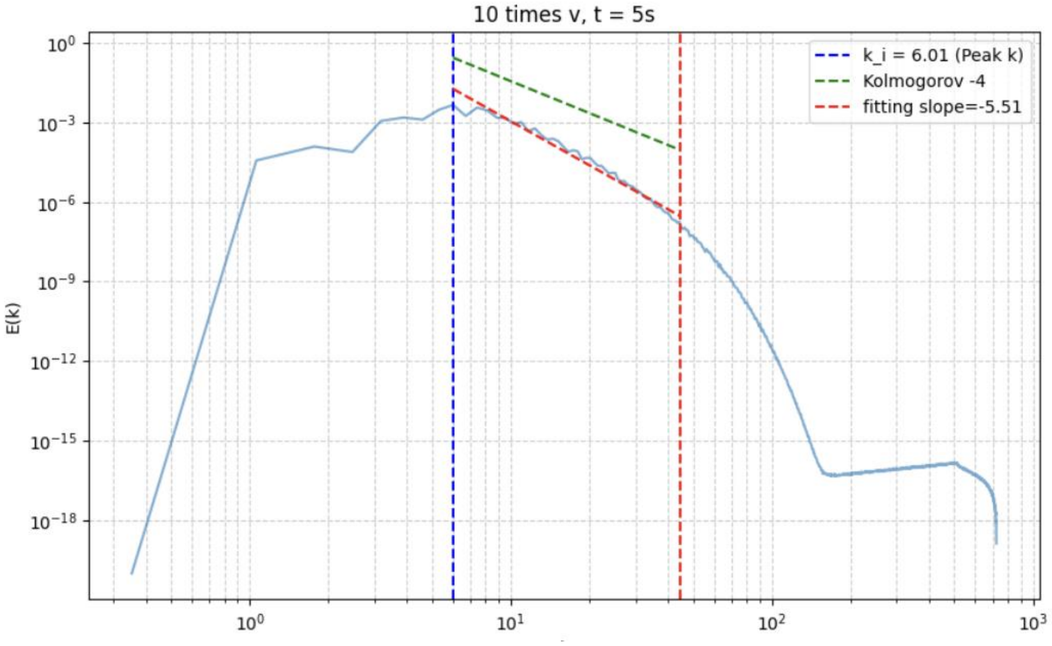
Background4 – inertial range of case (a)

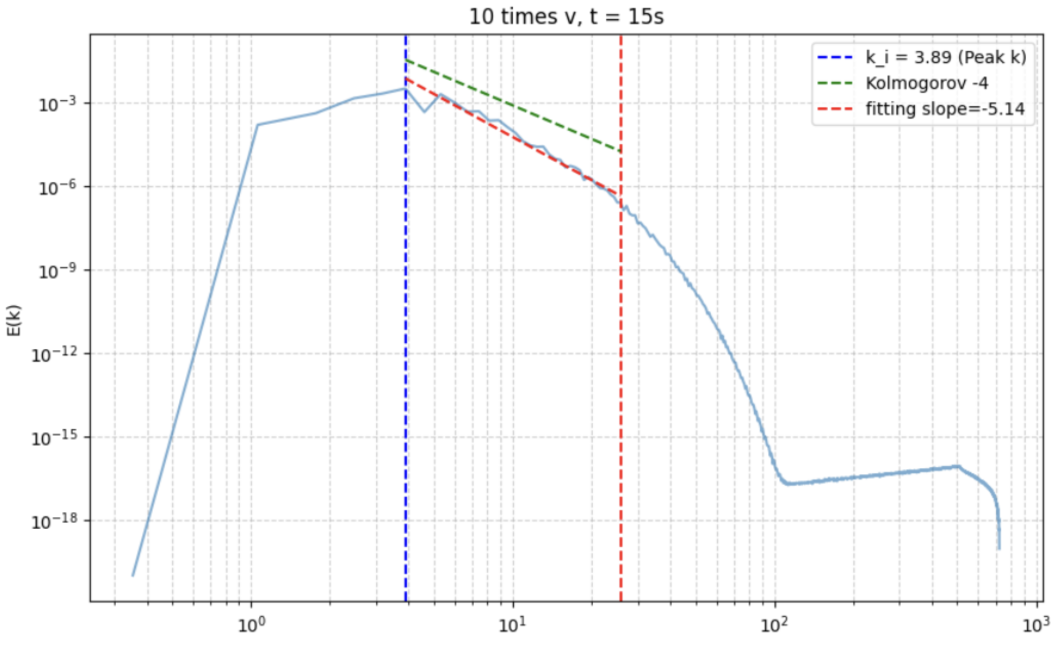


1. k_eps_bar: E(k)가 max일 때 k 값이라 가정
2. k_i: 초기조건인 k_p = 12를 k_i라 가정
3. k_diss = 1/ root(nu * t)

Energy Spectrum

10 times v(0.0001)



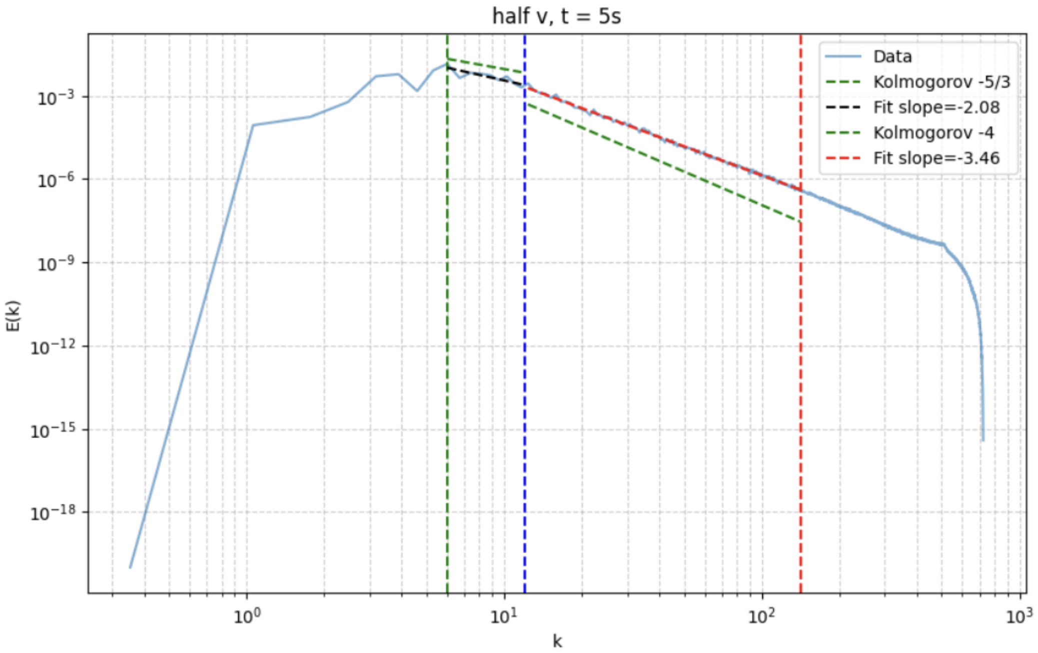


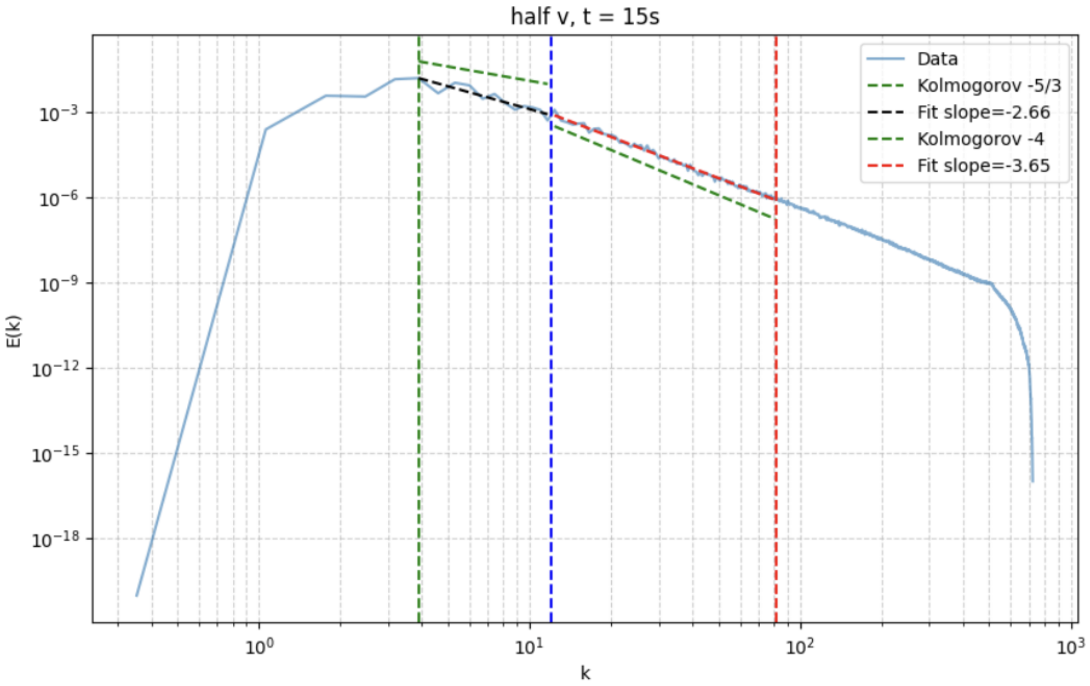
k_i (Peak k): 6.010
fitting slope: -5.511
deviation: 37.77%
R^2: 0.974

k_i (Peak k): 3.889
fitting slope: -5.137
deviation: 28.42%
R^2: 0.966

Energy Spectrum

Half v (0.000005)



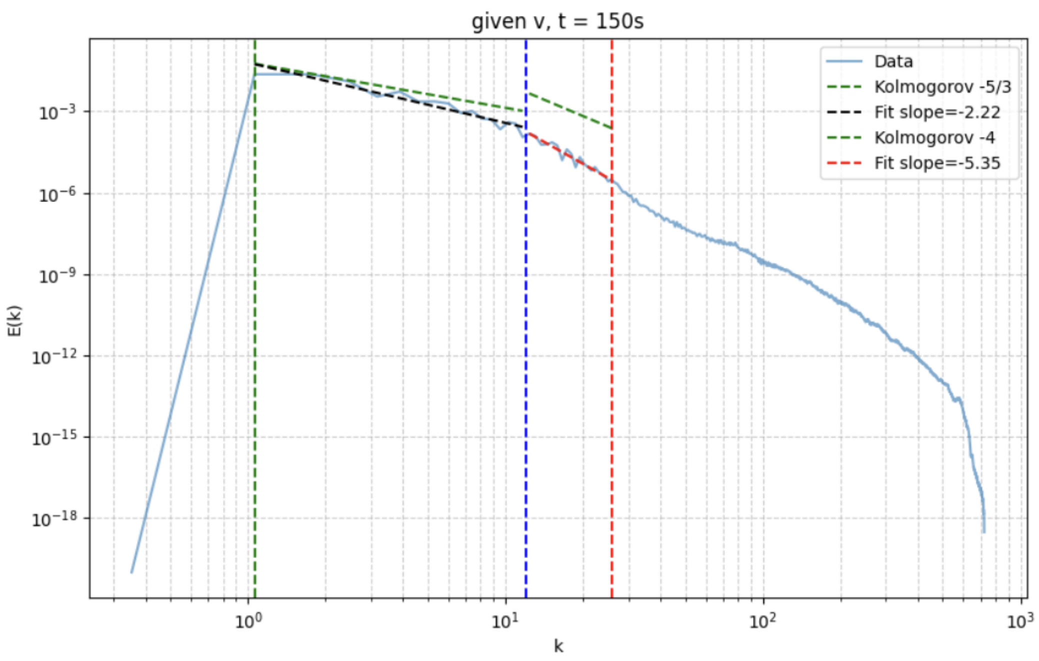



```
-------------------------
Energy(ENG) inertial range Slope: -2.077
Deviation from -5/3: 24.63%
R² for Inverse Cascade: 0.699
-------------------------
Enstophy(EST) inertial range Slope: -3.463
Deviation from -4: 13.41%
R² for EST: 0.997
```

```
-------------------------
Energy(ENG) inertial range Slope: -2.663
Deviation from -5/3: 59.81%
R² for Inverse Cascade: 0.840
-------------------------
Enstophy(EST) inertial range Slope: -3.647
Deviation from -4: 8.82%
R² for EST: 0.992
```

Energy Spectrum

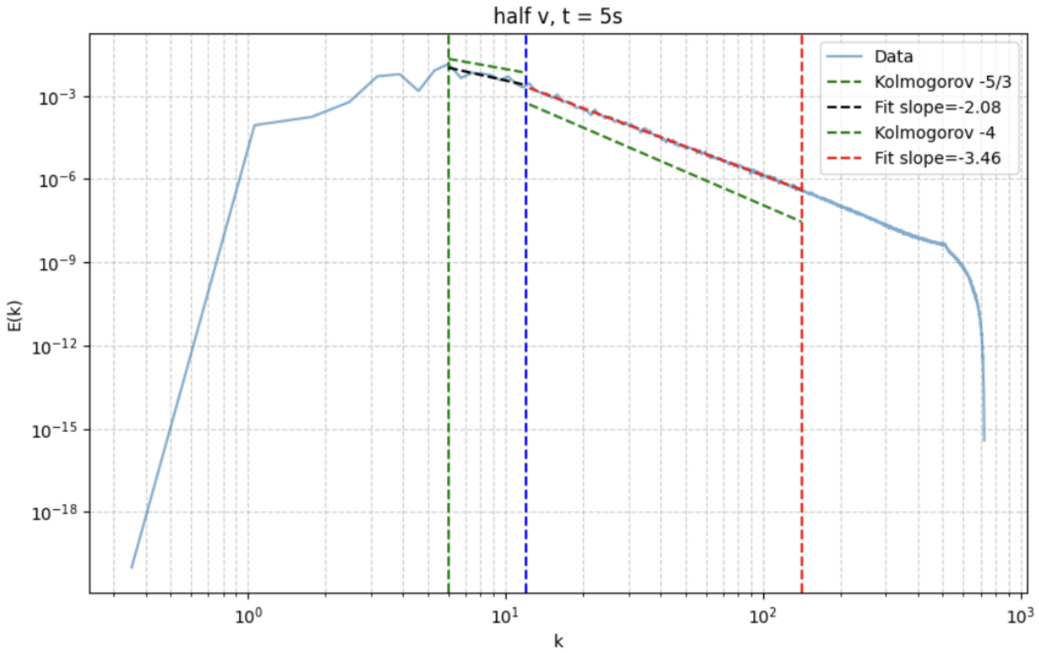
given v(0.00001)

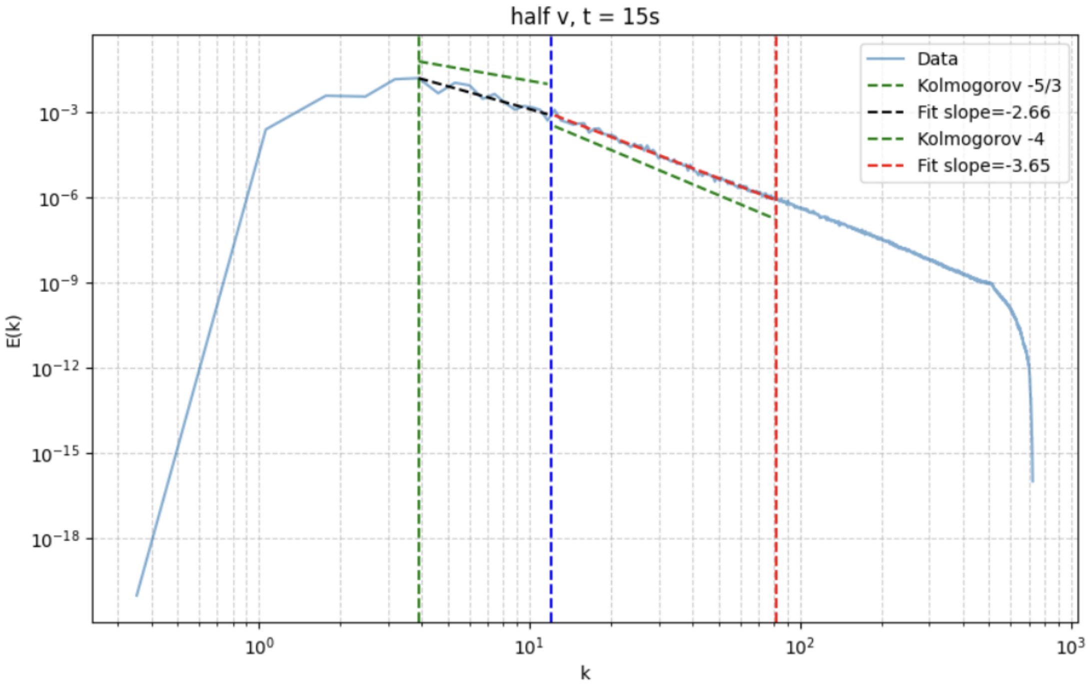



```
------------------------
Energy(ENG) inertial range Slope: -2.223
Deviation from -5/3: 33.40%
R² for Inverse Cascade: 0.919
------------------------
Enstophy(EST) inertial range Slope: -5.352
Deviation from -4: 33.81%
R² for EST: 0.935
```

Energy Spectrum

Half v (0.000005)



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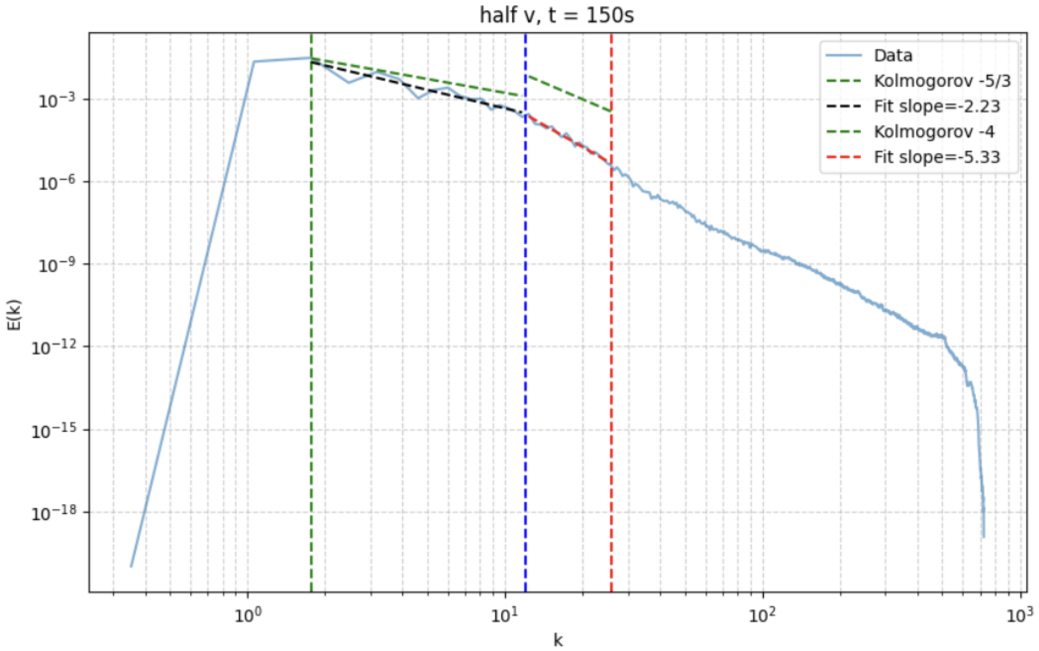
```

Half v (0.000005)

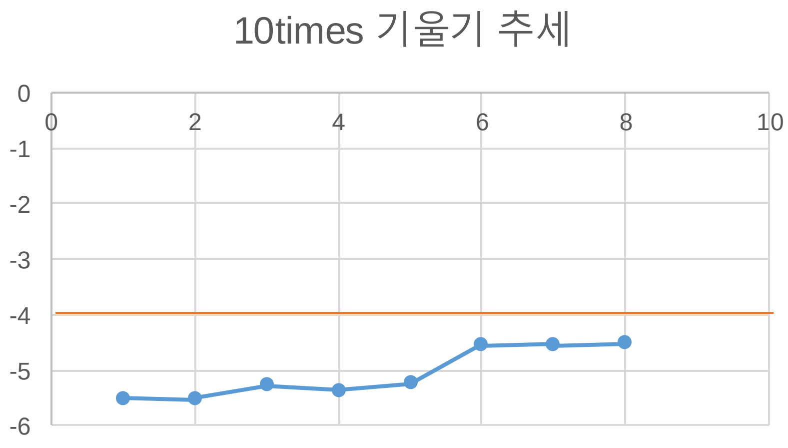


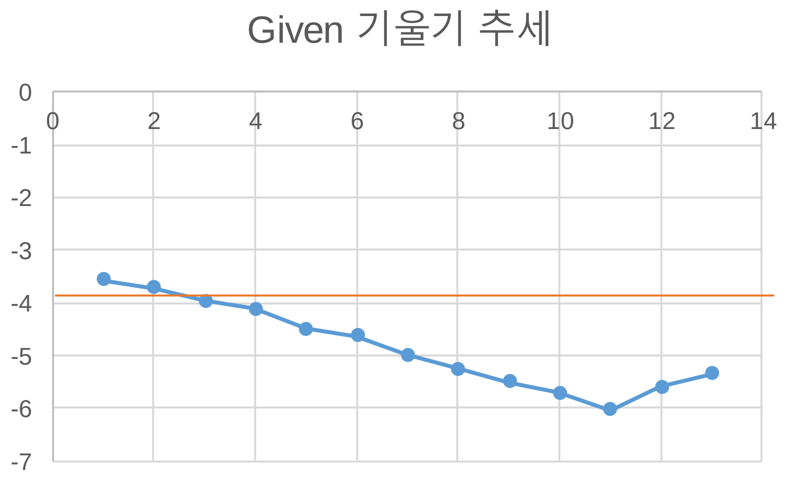

```
-------------------------
Energy(ENG) inertial range Slope: -2.231
Deviation from -5/3: 33.85%
R² for Inverse Cascade: 0.881
-------------------------
Enstophy(EST) inertial range Slope: -5.332
Deviation from -4: 33.30%
R² for EST: 0.972
```

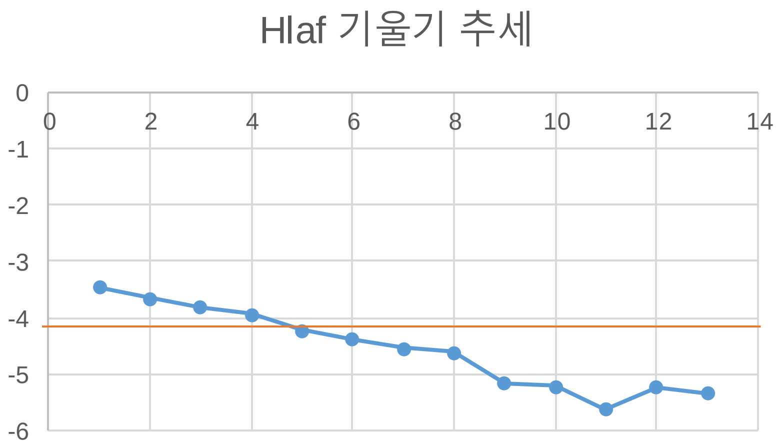
Fitting Summary

Enstrophy Inertial Range (-4)	10 times v (0.0001)	Given v (0.00001)	Half v (0.000005)
Max Slope	-5.511	-6.039	-5.621
Min Slope	-4.519	-3.568	-3.463
Average slope	-5.015	-4.845	-4.552
Energy Inertial Range (-5/3 = -1.667)	-	이론 값: -1.6667	이론 값: -1.6667
Max Slope	-	-2.625	--2.663
Min Slope	-	--1.747	-1.607
Average Slope	-	-2.263	-2.195

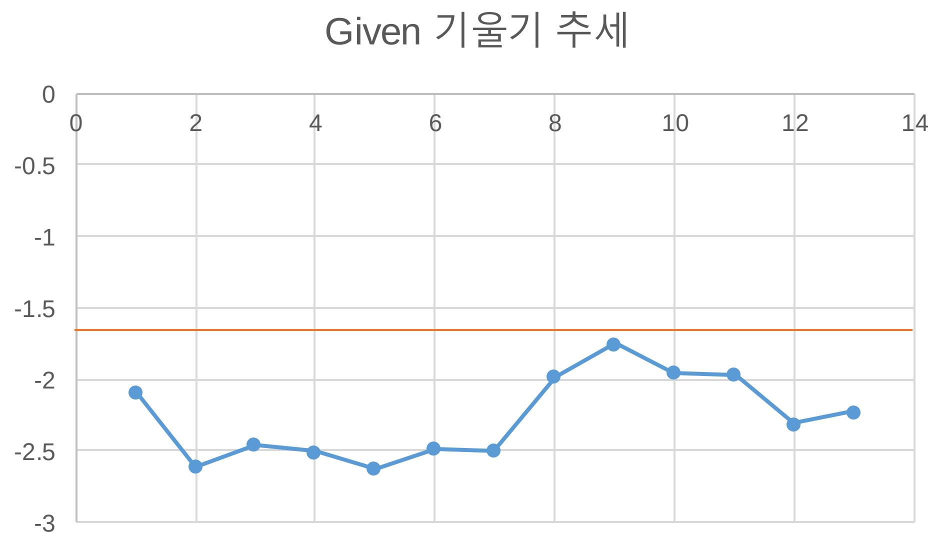
Fitting Summary – Enstrophy Inertial Range (이론값: -4)

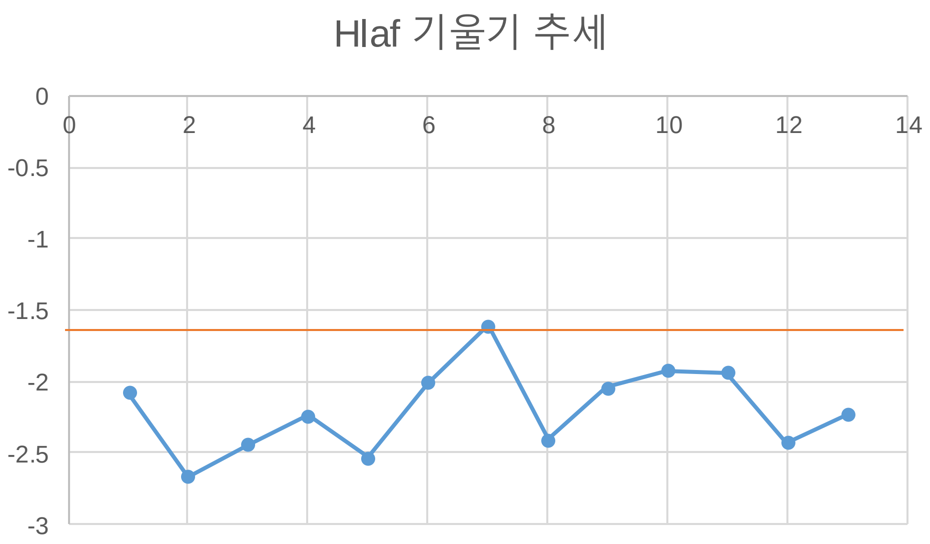






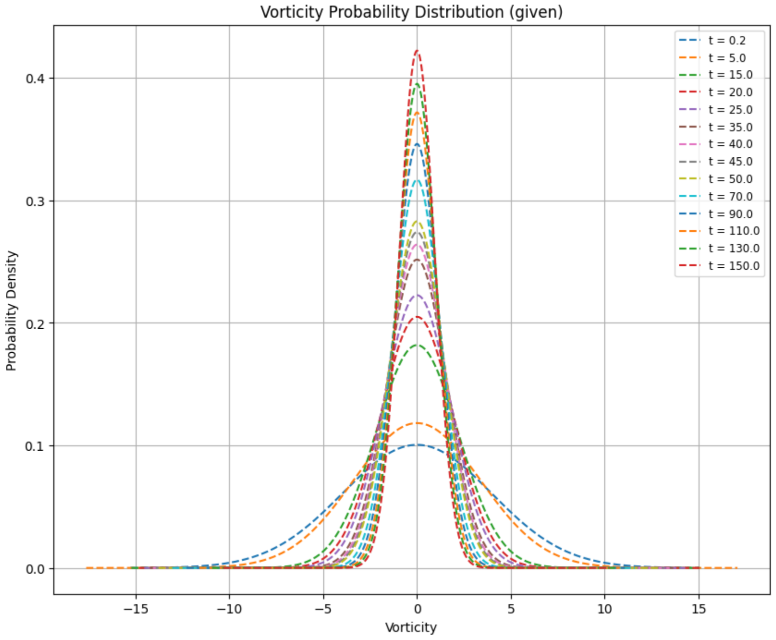
Fitting Summary – Energy Inertial Range (이론값: -1.667)

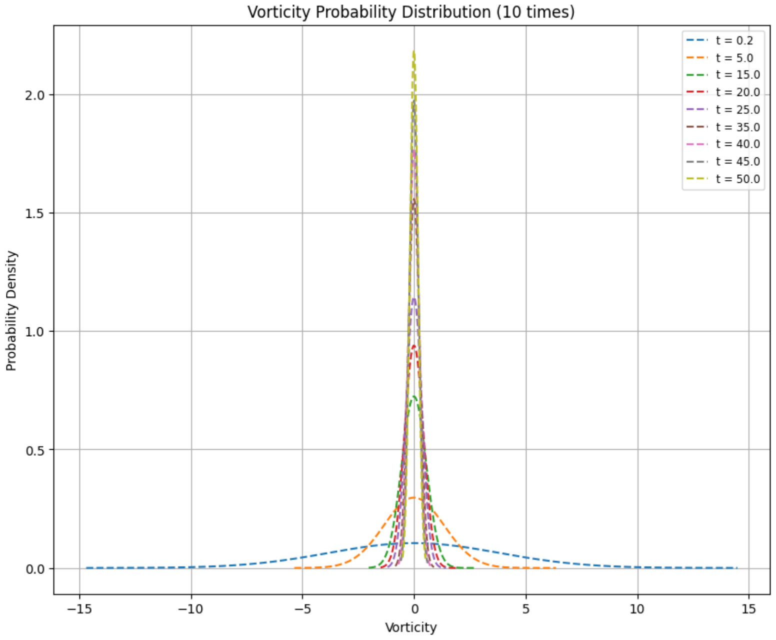


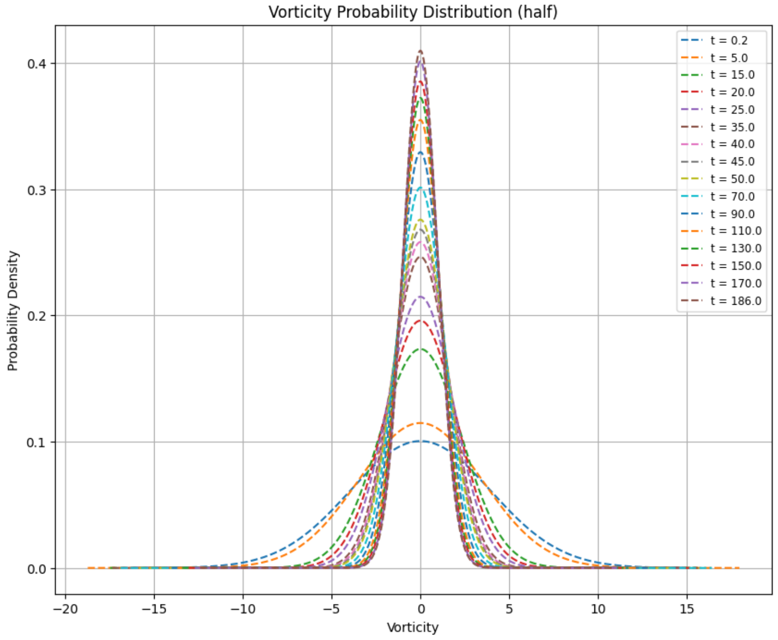


02 Statistics Analysis

Statistics Analysis – Vorticity Probability Distribution





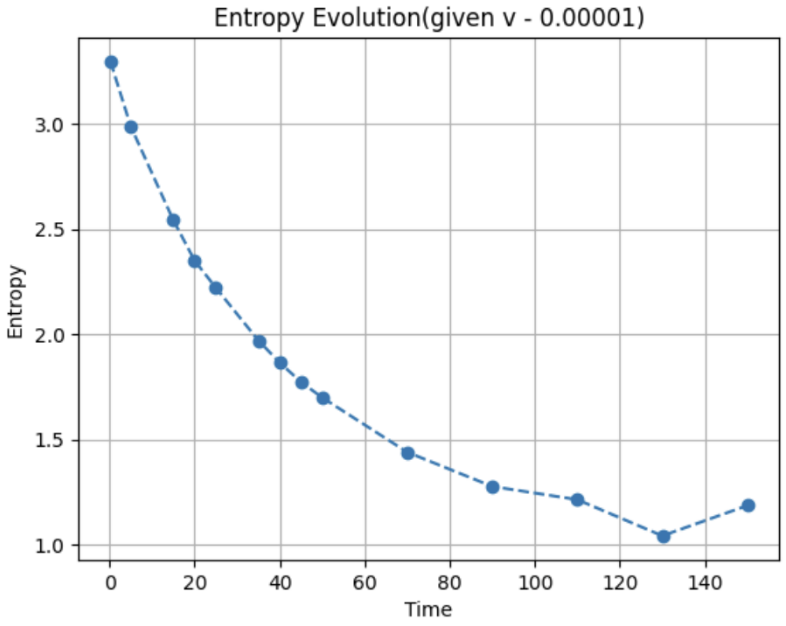


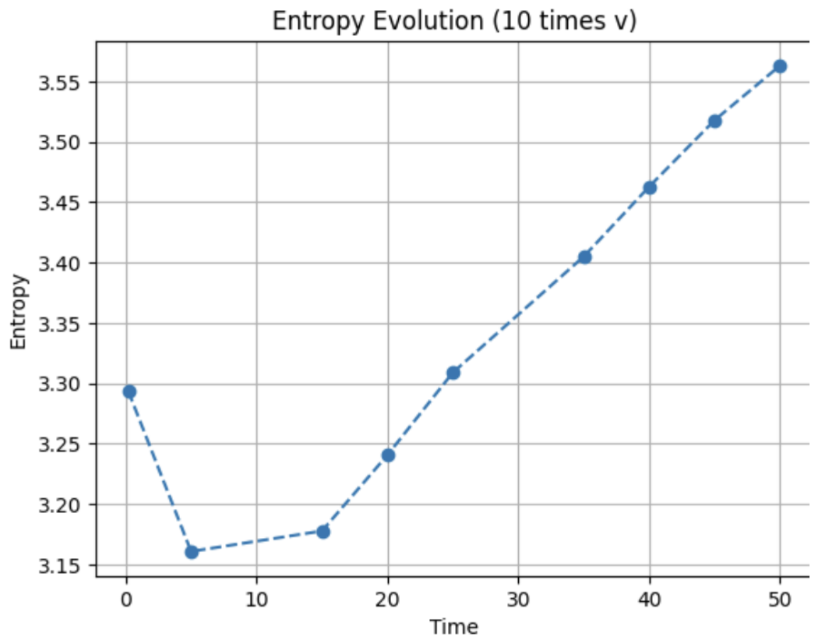
Given v (0.00001)

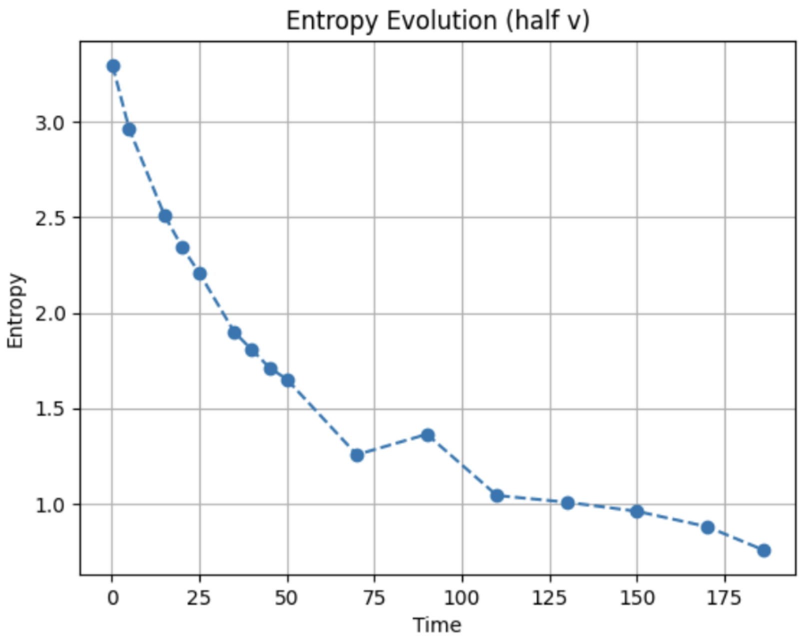
10 times v

Half v

Statistics Analysis – Entropy





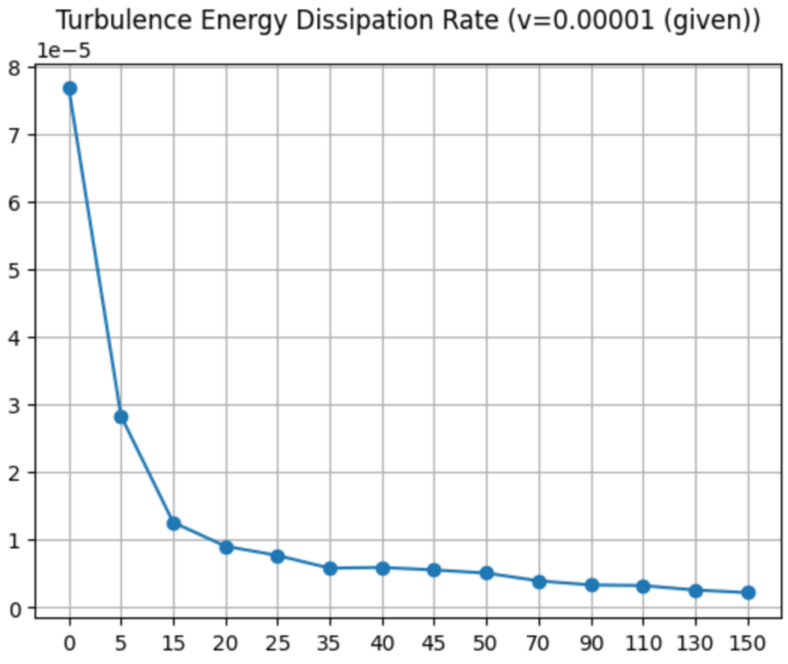


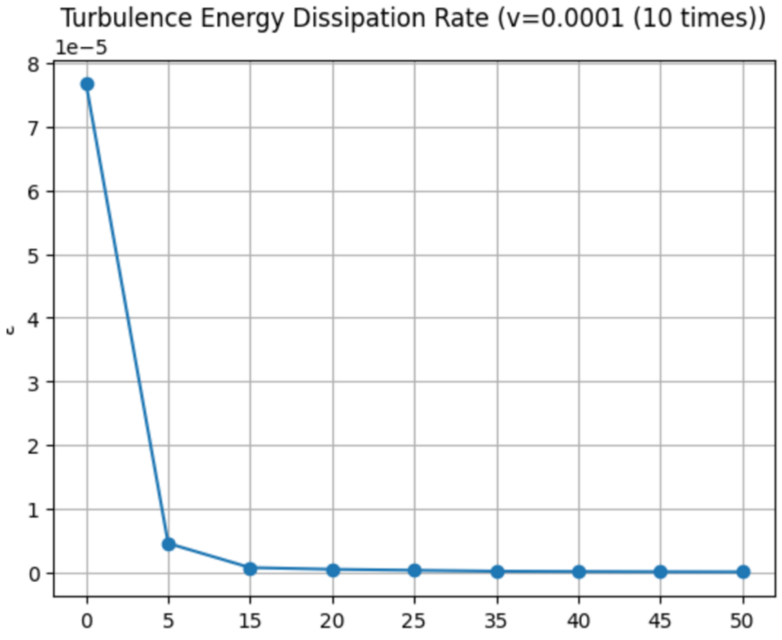
Given v (0.00001)

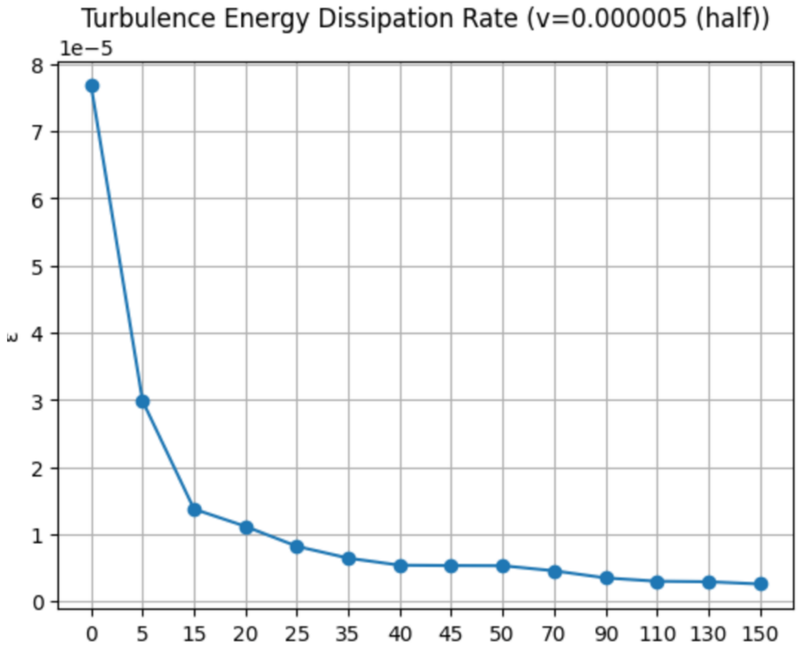
10 times v

Half v

Statistics Analysis – Energy Dissipation Rate





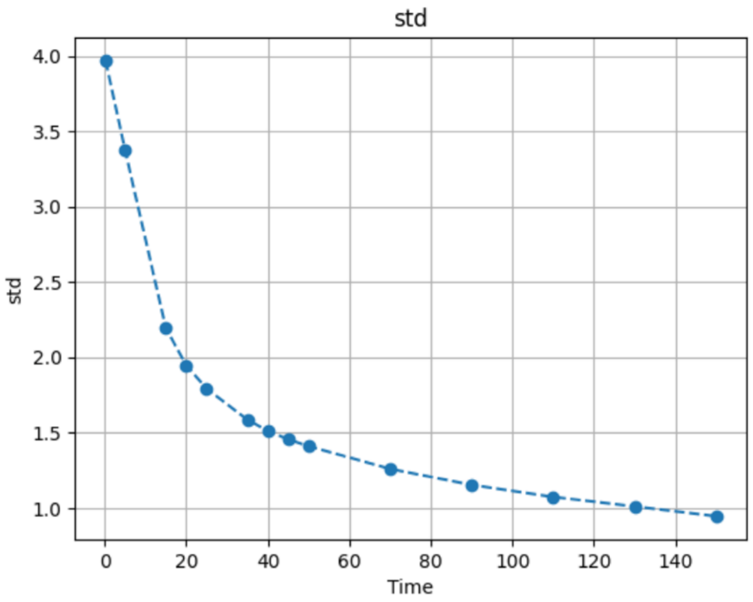


Given v (0.00001)
최소값: 2.161404e-06 m^2/s^3

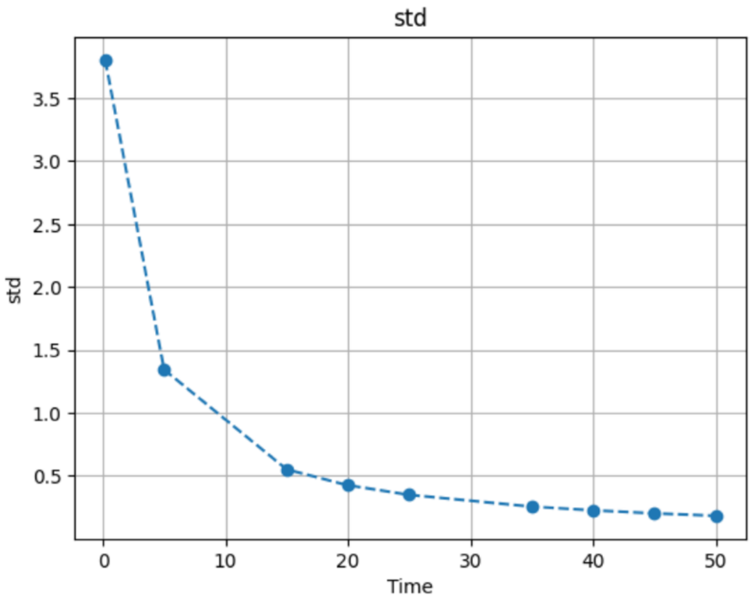
10 times v
최소값: 6.822461e-08 m^2/s^3

Half v
최소값: 2.572554e-06 m^2/s^3

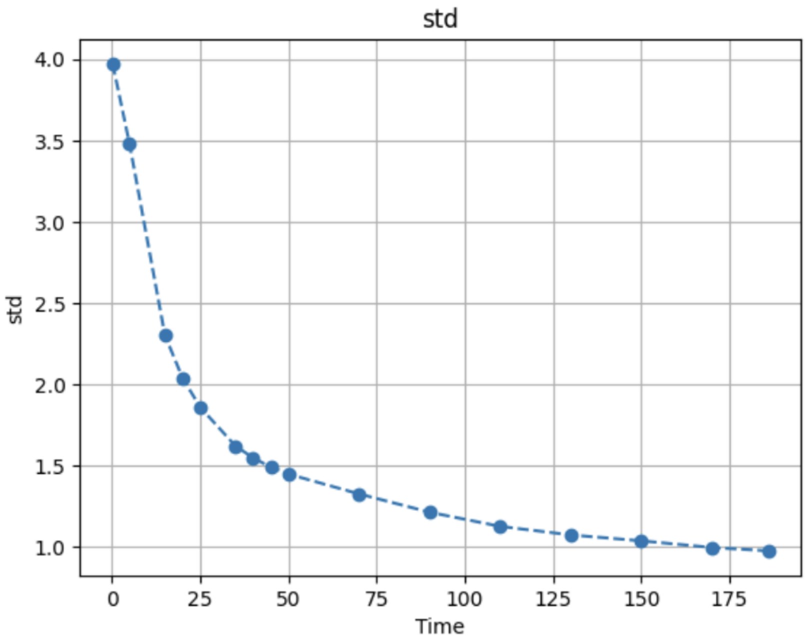
Statistics Analysis – STD



Given v (0.00001)

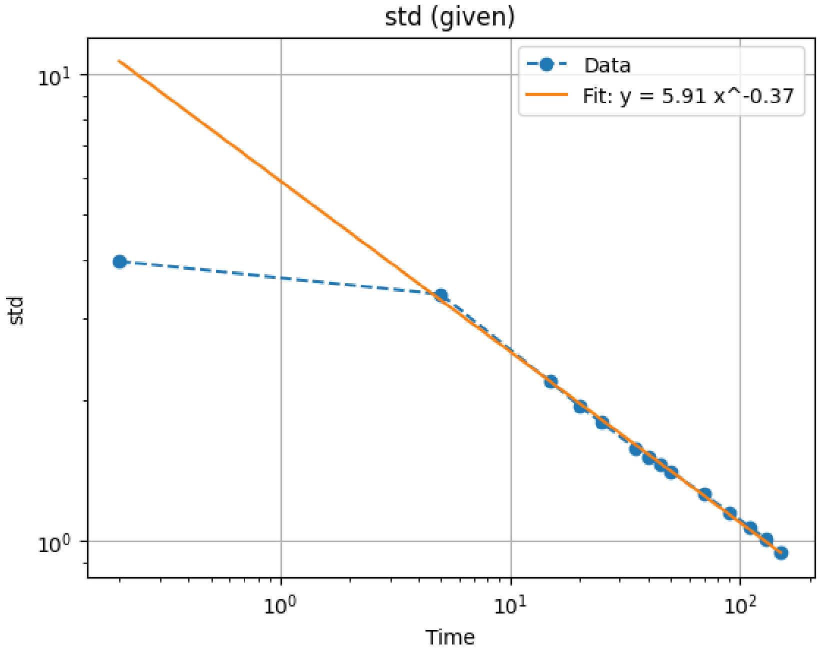


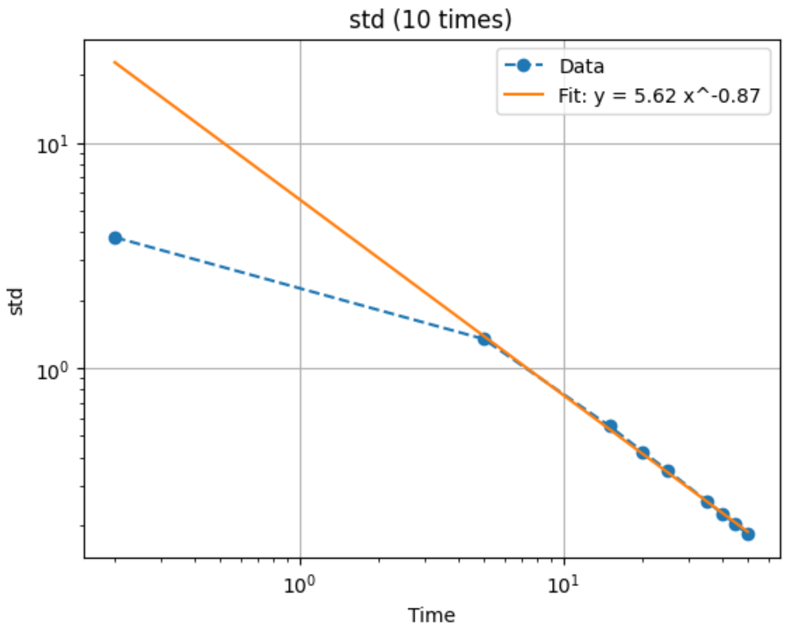
10 times v

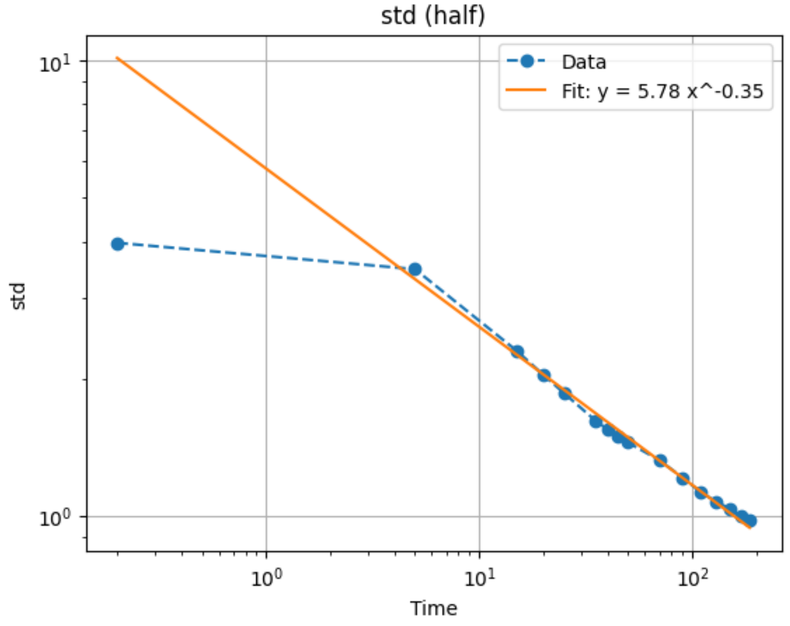


Half v

Statistics Analysis – STD log scale





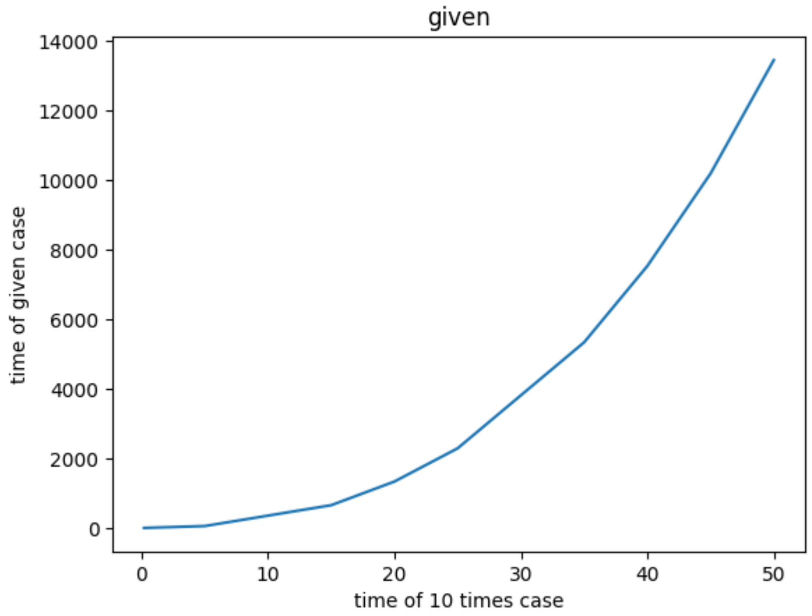


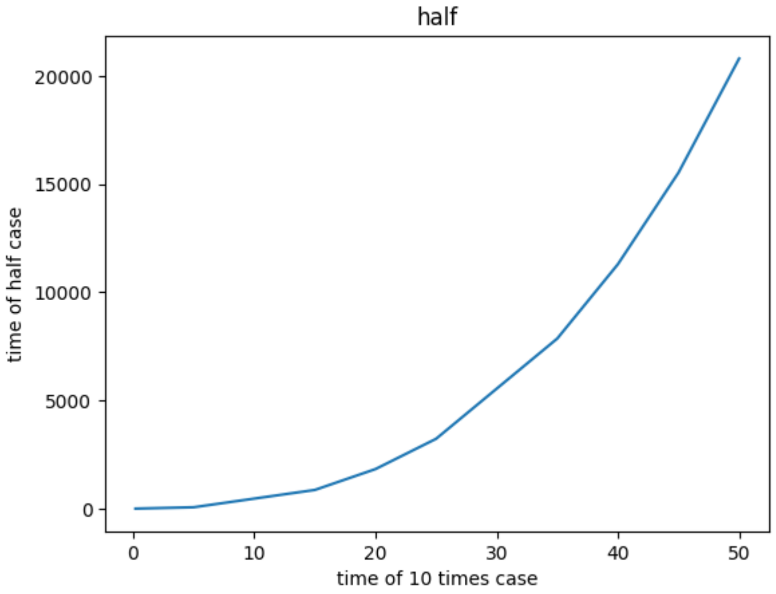
Given v (0.00001)

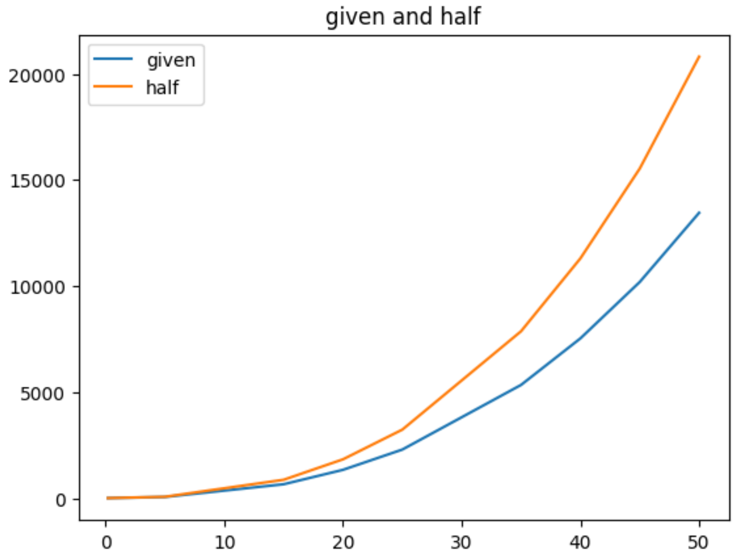
10 times v

Half v

Statistics Analysis – STD log scale



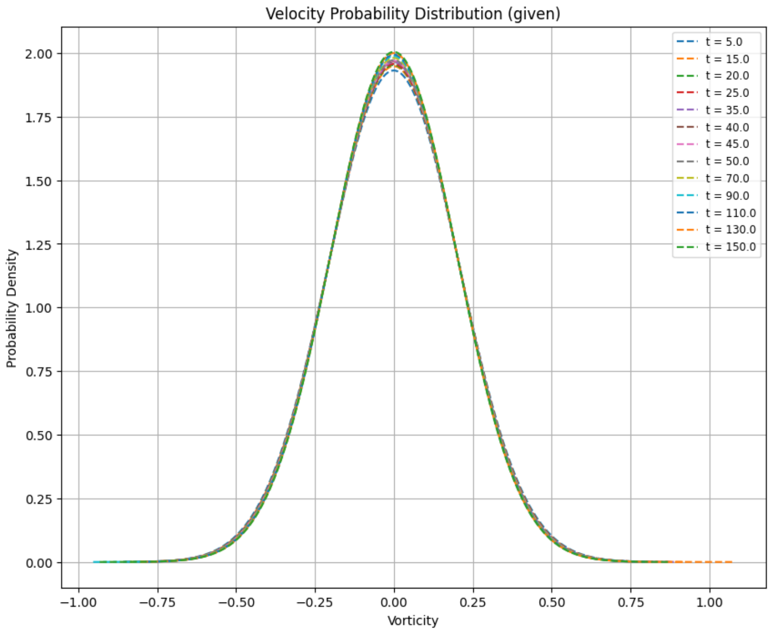




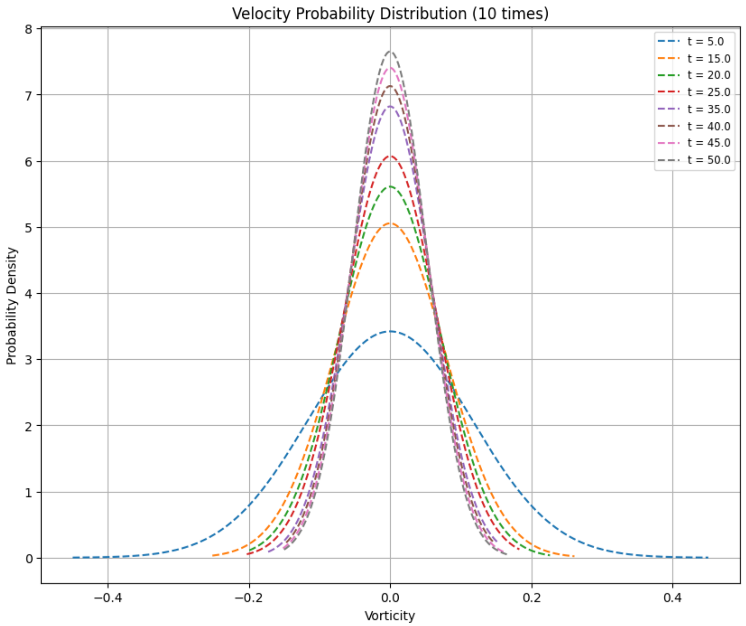
t = 5.0 | Sigma = 1.3441899424 | 57.3495s
t = 15.0 | Sigma = 0.5512383245 | 656.7063s

t = 5.0 | Sigma = 1.3441899424 | 66.6392s
t = 15.0 | Sigma = 0.5512383245 | 867.1453s

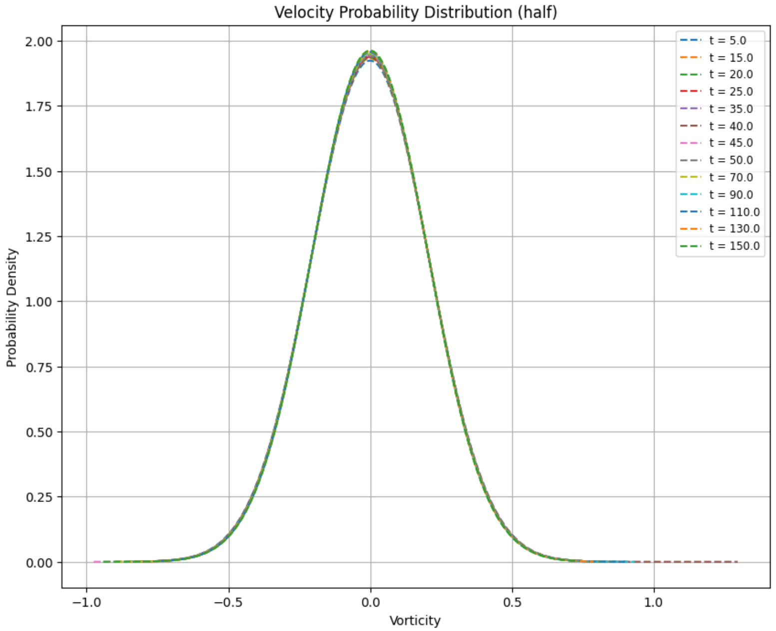
Statistics Analysis – STD



Given v (0.00001)

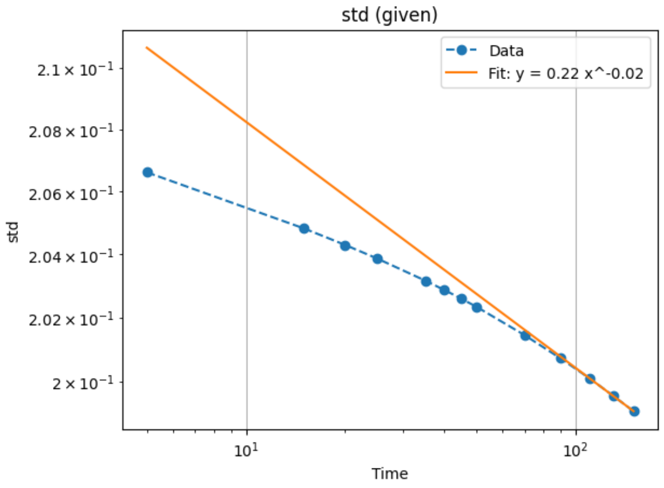


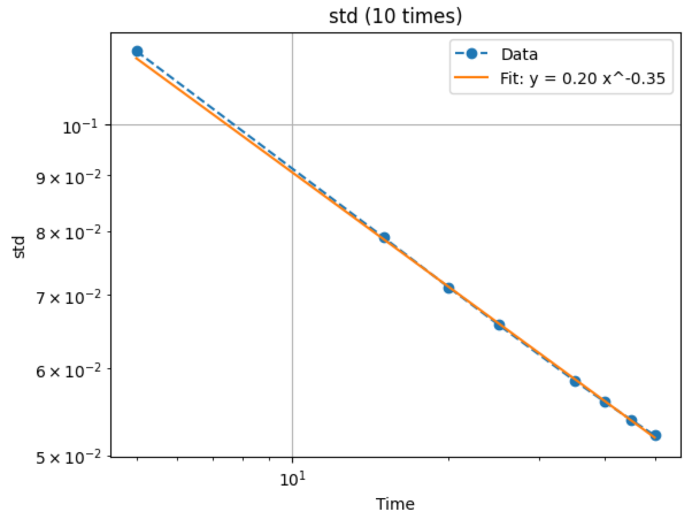
10 times v

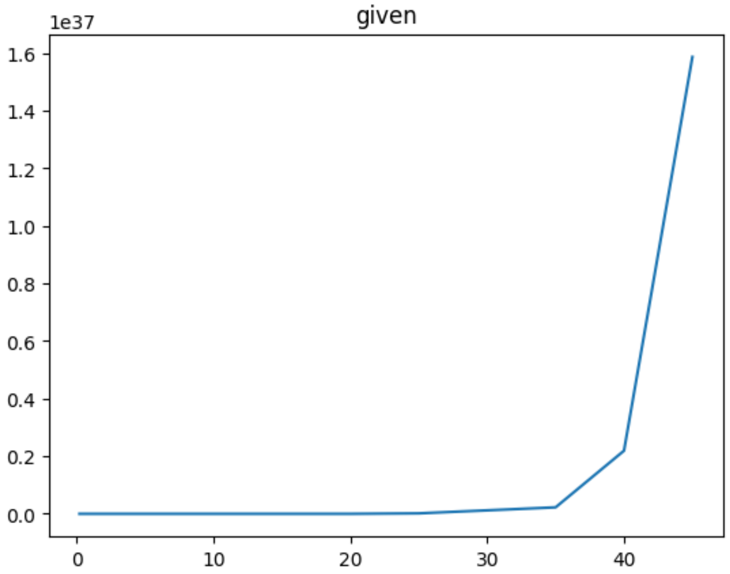


Half v

Statistics Analysis – STD







t = 5.0 | Sigma = 0.1166312320 | 14253061707512166s

t = 15.0 | Sigma = 0.0789406084 | 228103155817964468504100864s

250213 Weekly Lab meeting

Thank you for your attention!

Flow Physics & Computational Engineering Innovation Lab