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COPENHAGEN

Spectral correction

to recover full 10min variability from hourly mesoscale data

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Motivation

Mesoscale models play increasing role in resource assessment

But mesoscale data are NOT measured 10min data

Can mesoscale data be used as is directly in energy assessments?

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Contents

- Intro - Spectrum of wind variability
- Problem - too smooth mesoscale data
- Solution - correct and extrapolate spectrum
- Results
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- **Intro - Spectrum of wind variability**
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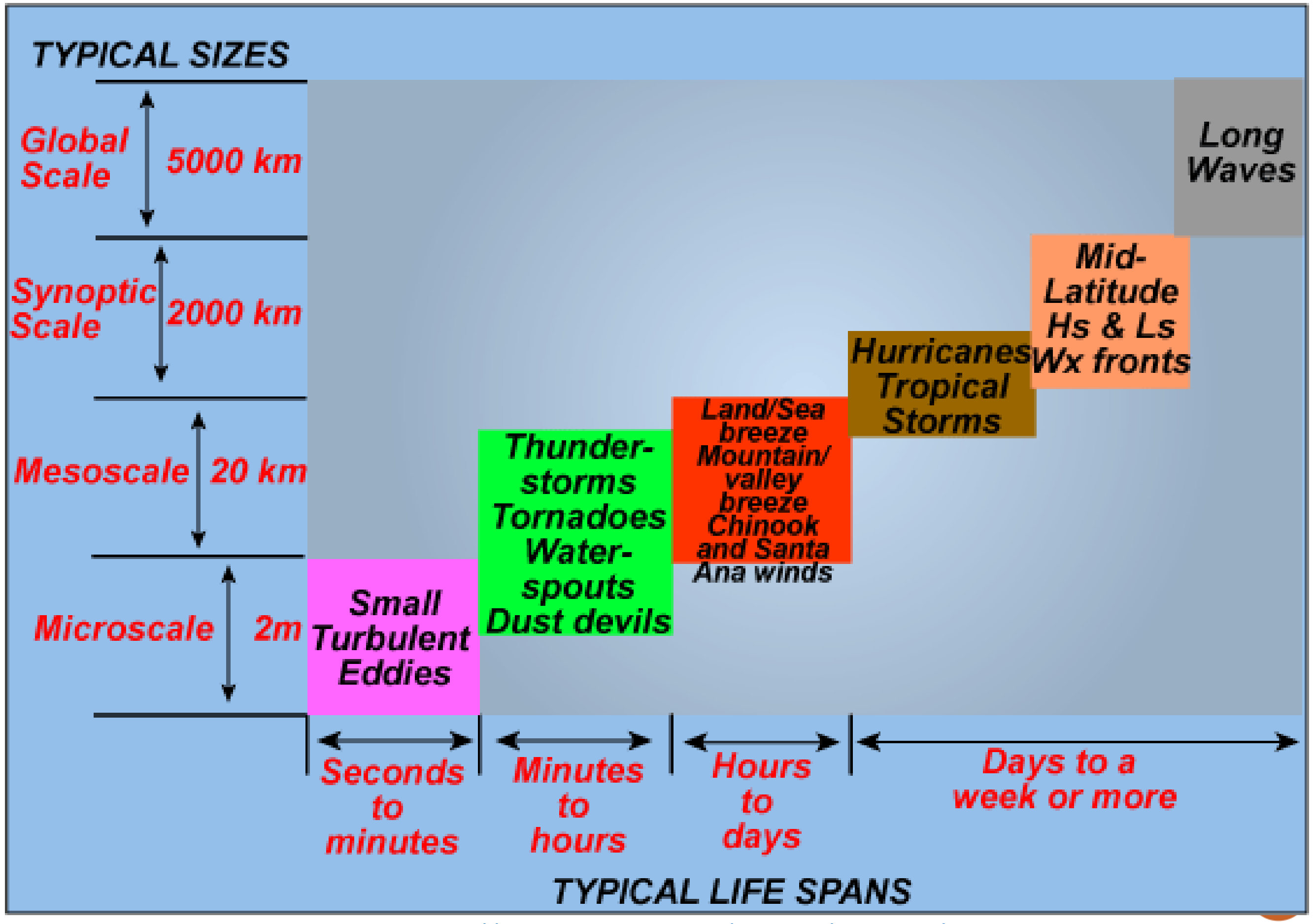
Spectrum of wind variability

Wind varies on a wide range of spatial and temporal scales

- Wind data: 10min averages



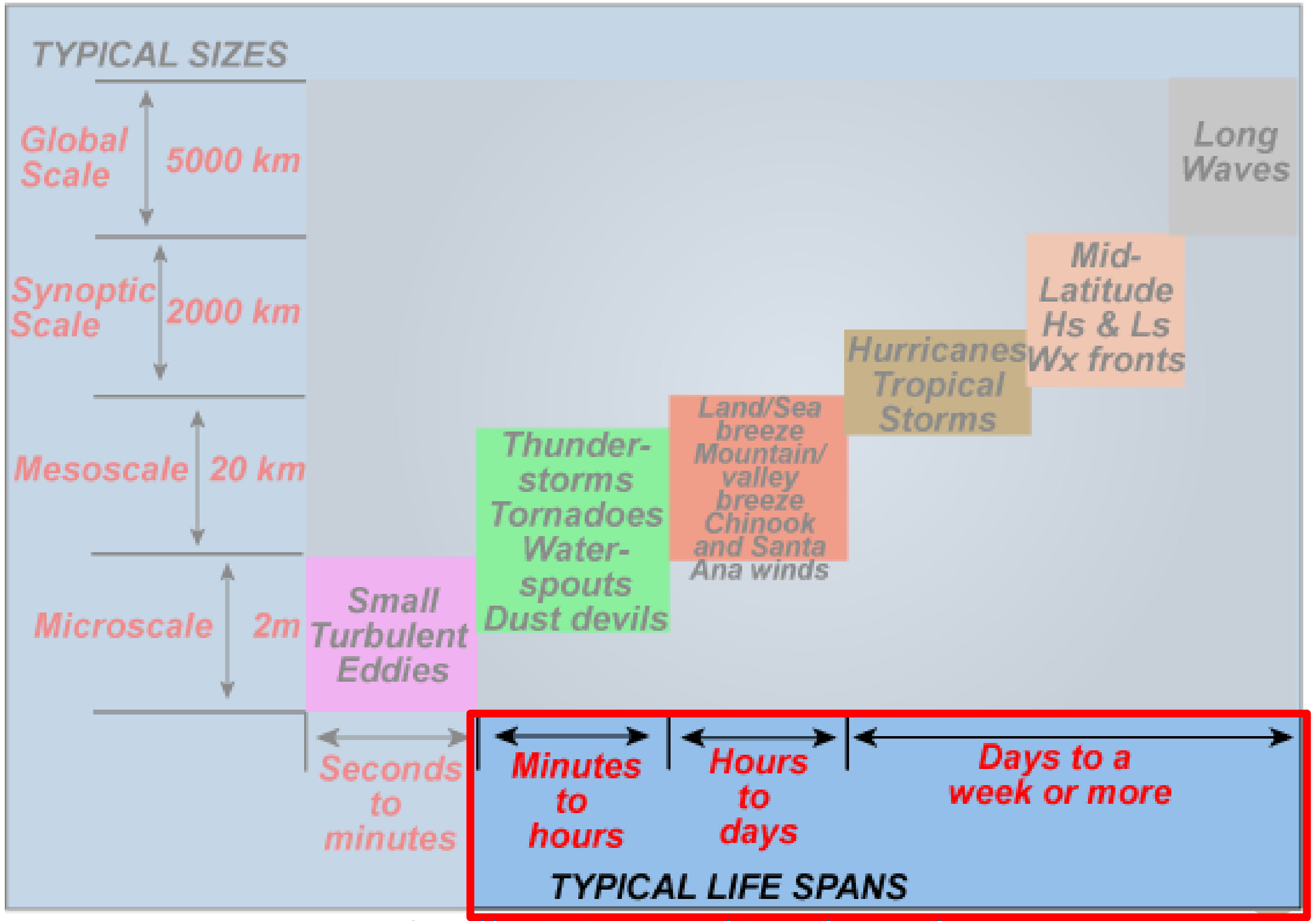
From: http://apollo.lsc.vsc.edu/classes/met130/

Spectrum of wind variability

Wind varies on a wide range of spatial and temporal scales

- Wind data: 10min averages
- Main scales 10min - 1 year:
  - Global scale (7 - 365 days)
  - Synoptic scale (2 - 7 days)
  - Mesoscale ($\frac{1}{24}$ - 2 days)
  - (Microscale) (< $\frac{1}{24}$ days)

Stull (2000) and Fiedler (1970)



From: http://apollo.lsc.vsc.edu/classes/met130/

Spectrum of wind variability

Why is the wind variance important?

- Wind power is proportional to wind speed cubed: $P \propto u^3$
- Increased variance means more power (at same average wind speed)
- Mean wind speed is also important – but not the focus of this study

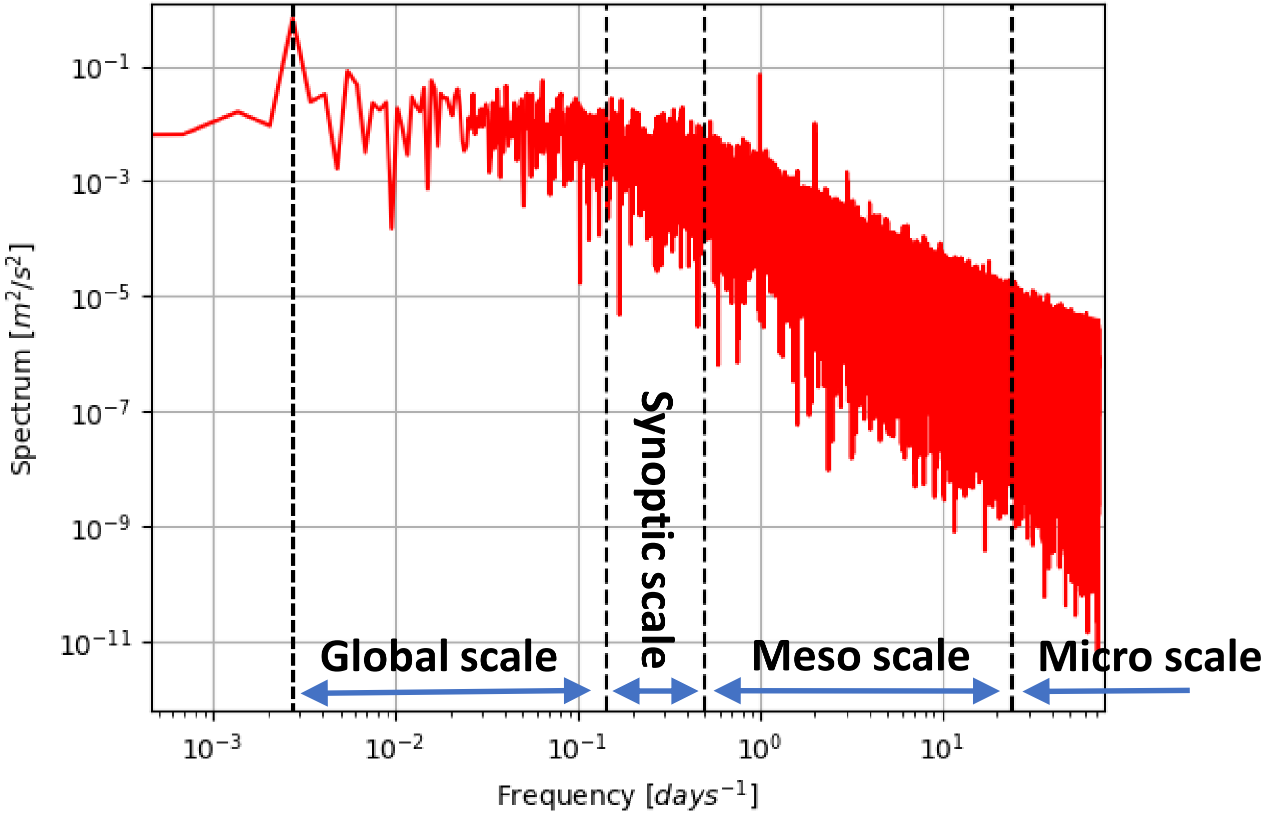
Spectrum of wind variability

What does a wind speed spectrum look like?

Spectrum of wind variability

What does a wind speed spectrum look like?

- Wind measurements - Cabauw mast (3 years, 80m agl):
- “Raw” FFT (variance contribution of each frequency bin)



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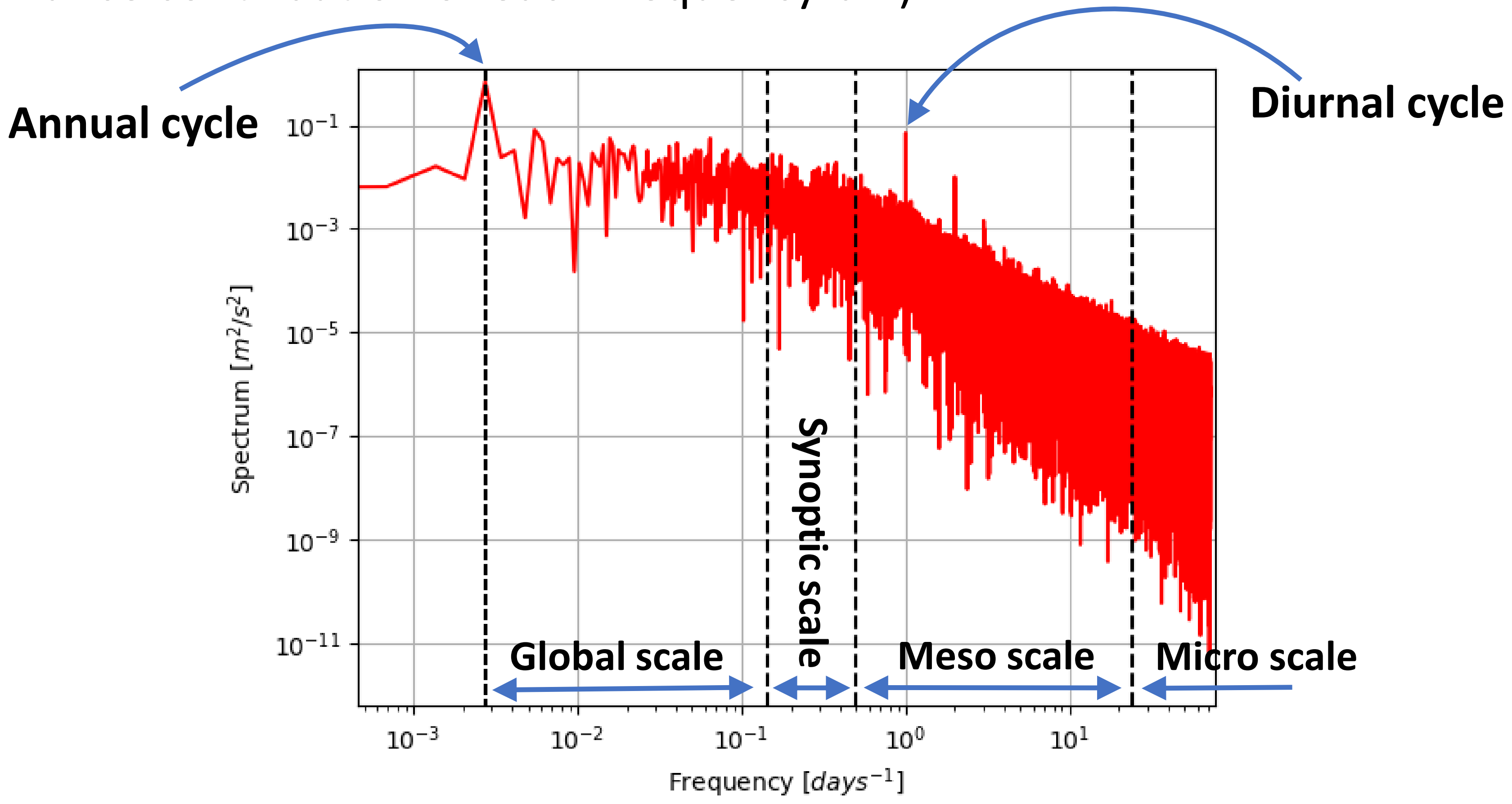
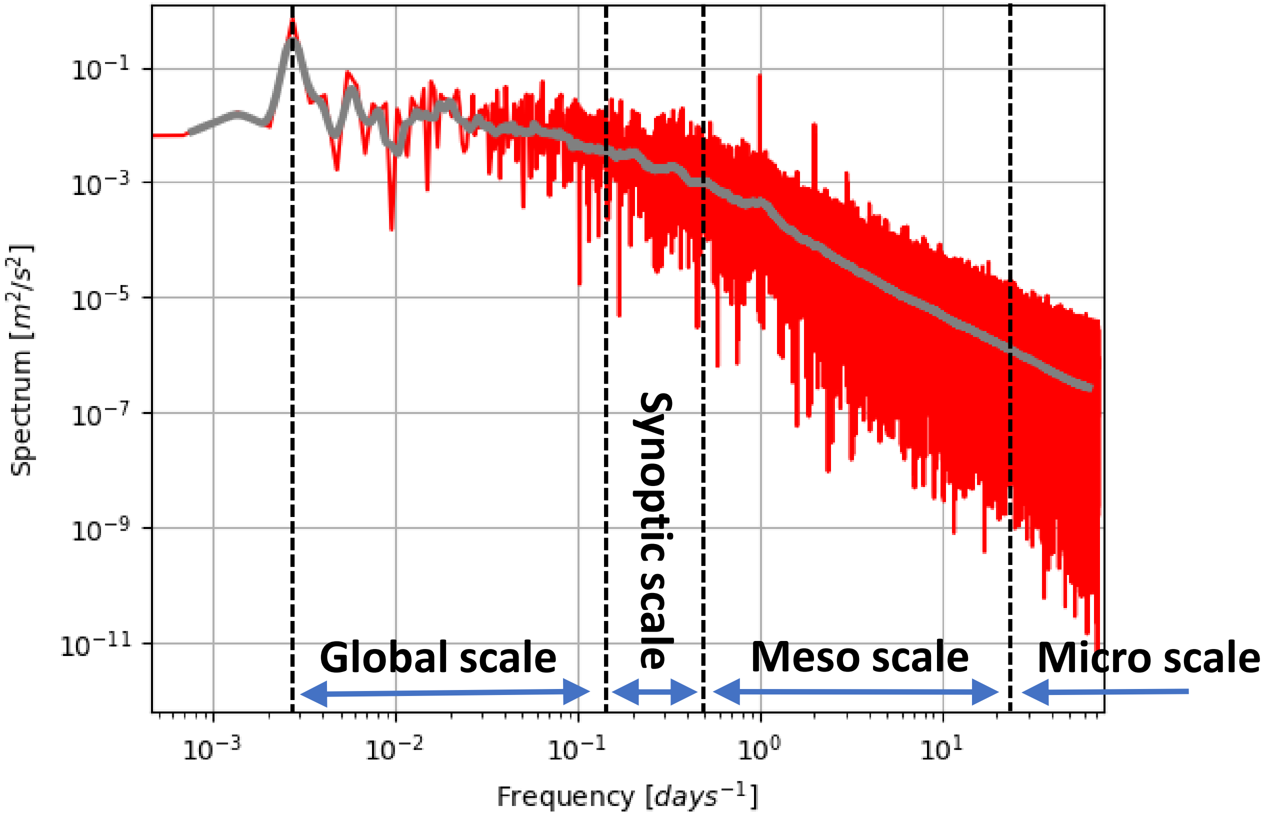


Spectrum of wind variability

What does a wind speed spectrum look like?

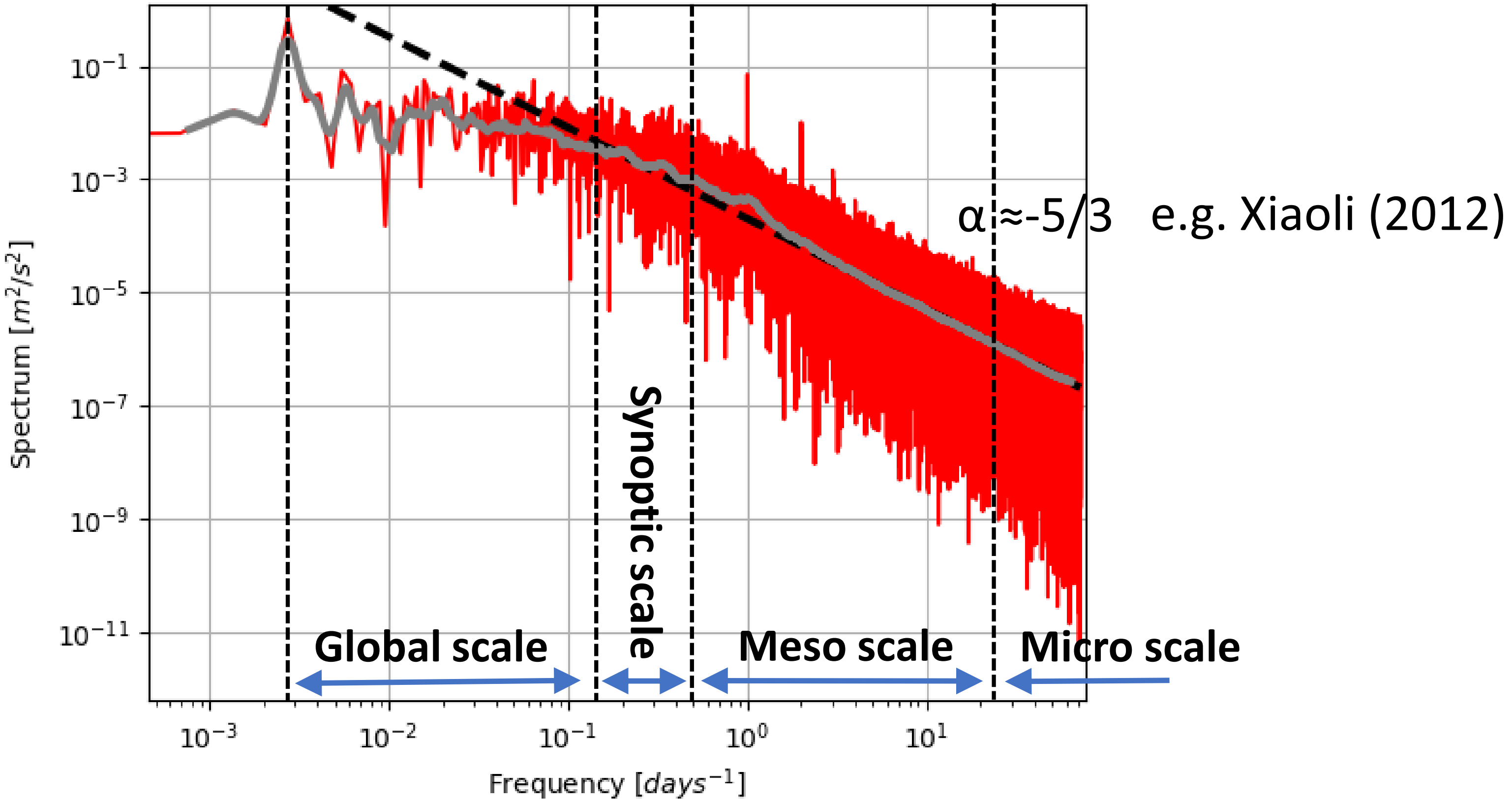
- Wind measurements - Cabauw mast (3 years, 80m agl):
- “Smoothed” FFT



Spectrum of wind variability

What does a wind speed spectrum look like?

- Wind measurements - Cabauw mast (3 years, 80m agl):
- Linear trend (log-log), f > 1 $days^{-1}$



Spectrum of wind variability

Relation between spectrum and variance?

- Variance = integral of S(f) for all f $\longrightarrow$ $$\sigma^2 = \int_{f_{min}}^{f_{max}} S(f)df$$

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Spectrum of wind variability

Relation between spectrum and variance?

- Variance = integral of S(f) for all f
- Cumulative Spectrum = integral of S(f) up to f_0

$$\sigma^2 = \int_{f_{min}}^{f_{max}} S(f)df$$

$$\sigma_{Cum}^2(f_0) = \int_{f_{min}}^{f_0} S(f)df$$

Spectrum of wind variability

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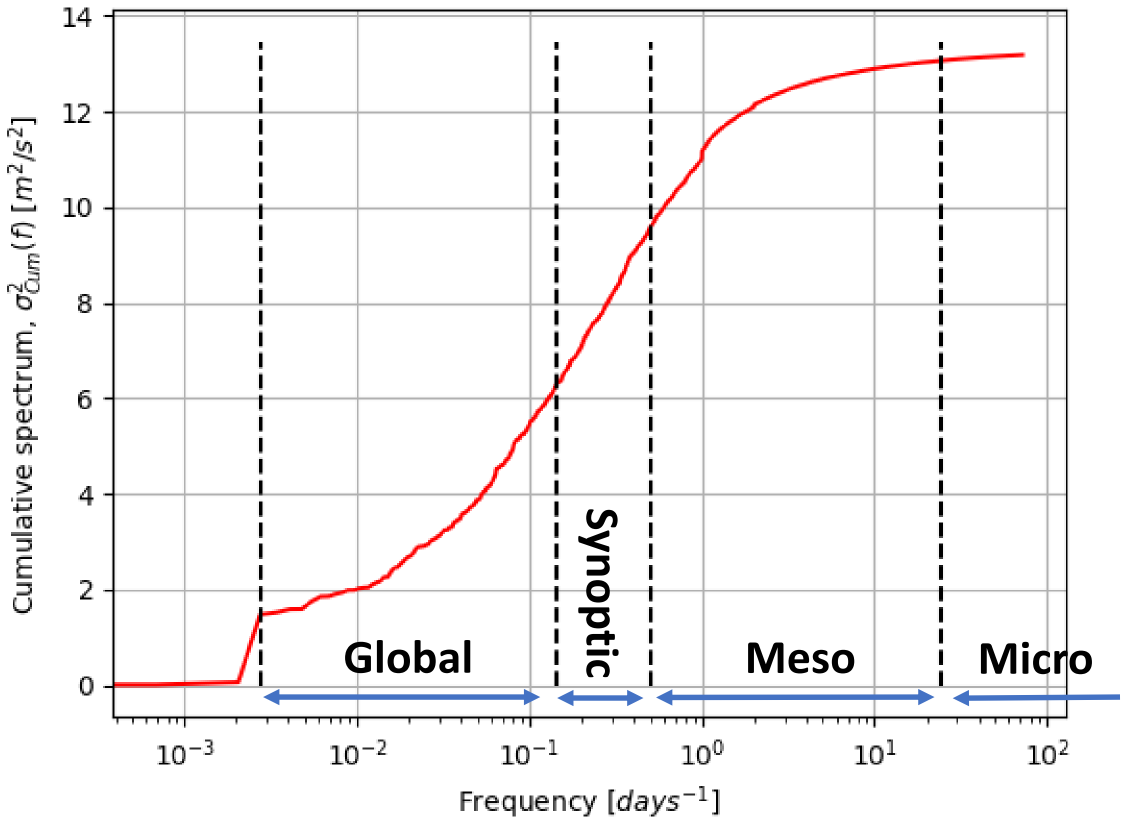

Spectrum of wind variability

Relation between spectrum and variance?

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$$\sigma^2 = \int_{f_{min}}^{f_{max}} S(f)df$$

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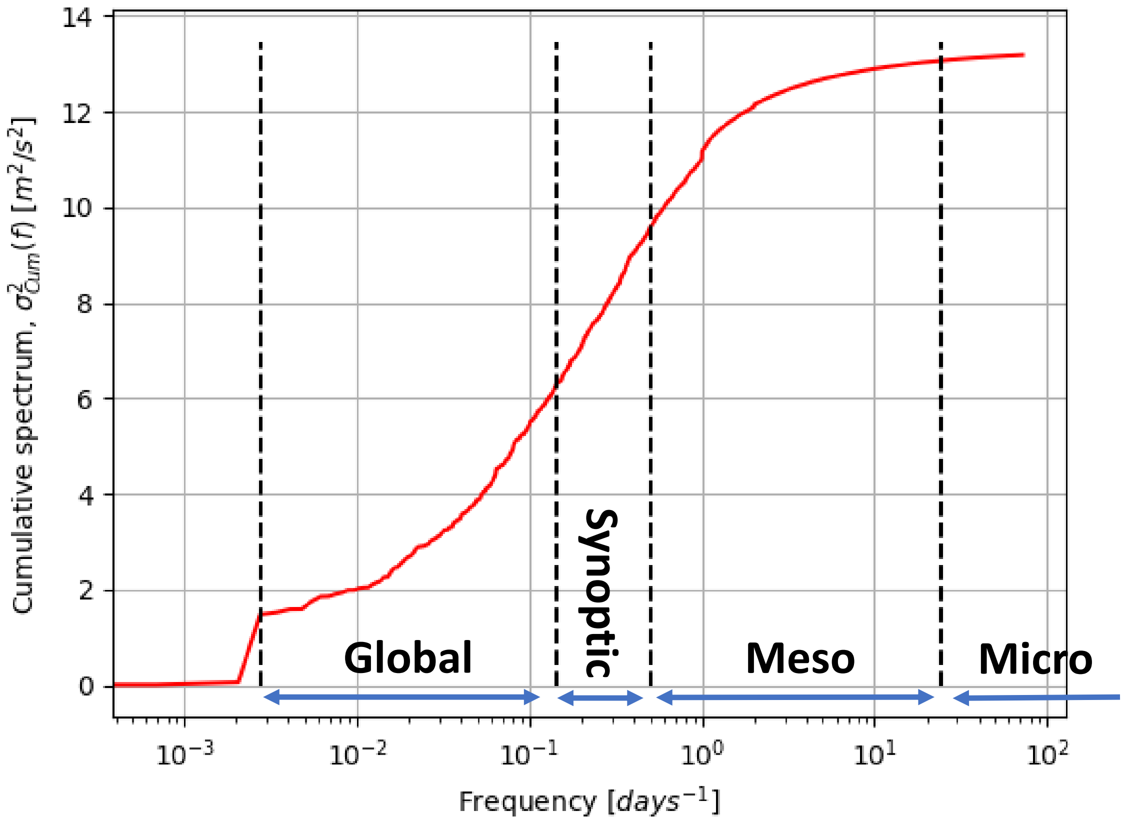
$$\sigma^2_{Cum}(f_0) = \int_{f_{min}}^{f_0} S(f)df$$



Note: No smoothing applied!
Just integration

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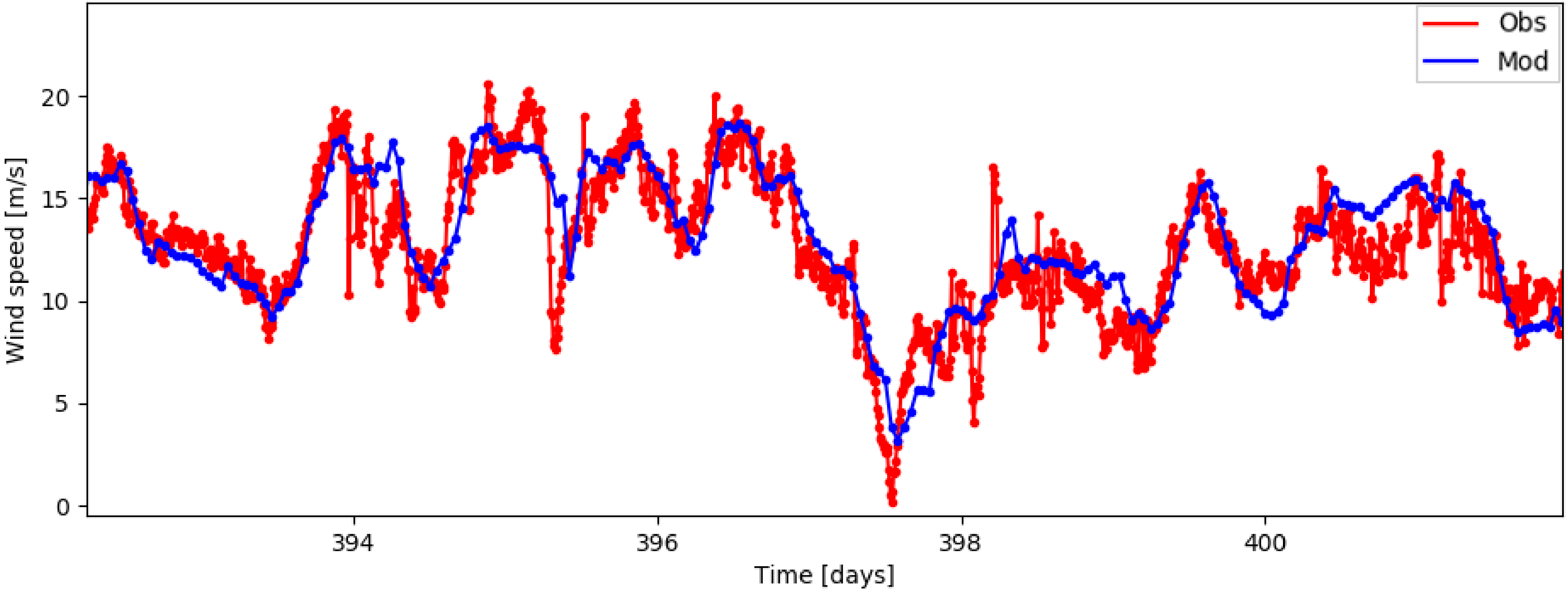
The problem

Mesoscale model problems – time domain

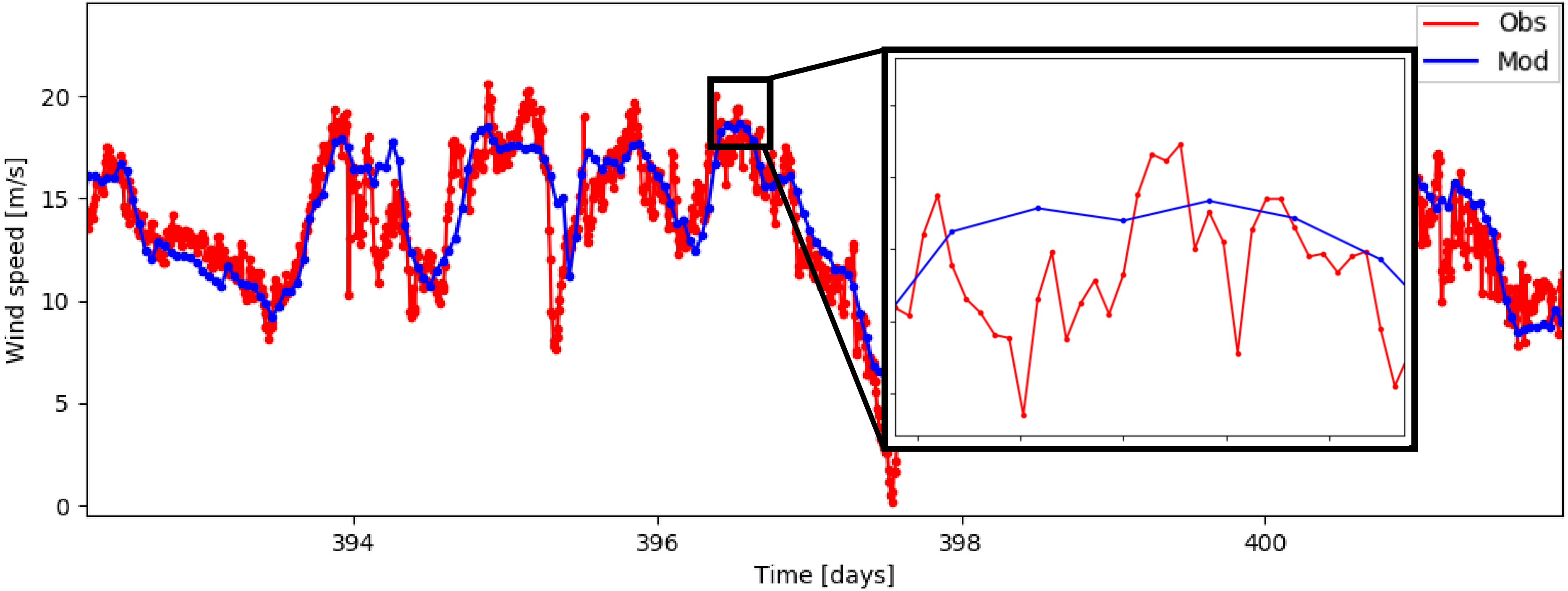
- Model data too smooth compared to measurements



The problem

Mesoscale model problems – time domain

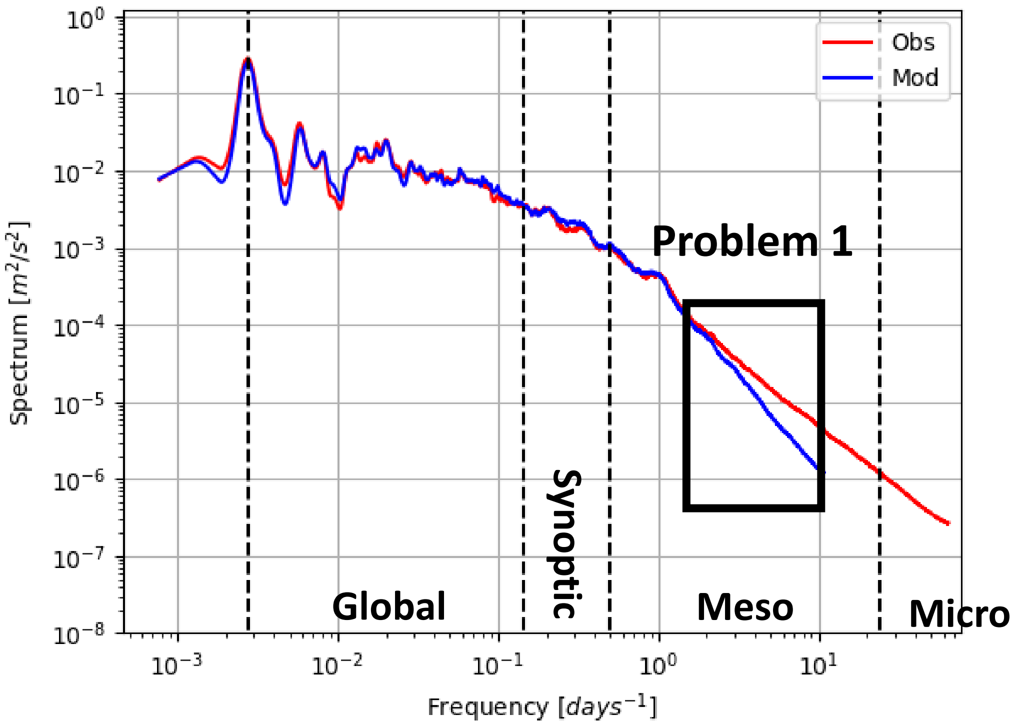
- Model data too smooth compared to measurements
- Model data (often) sampled hourly, but measurements 10min



The problem

Mesoscale model problems – frequency domain (spectrum)

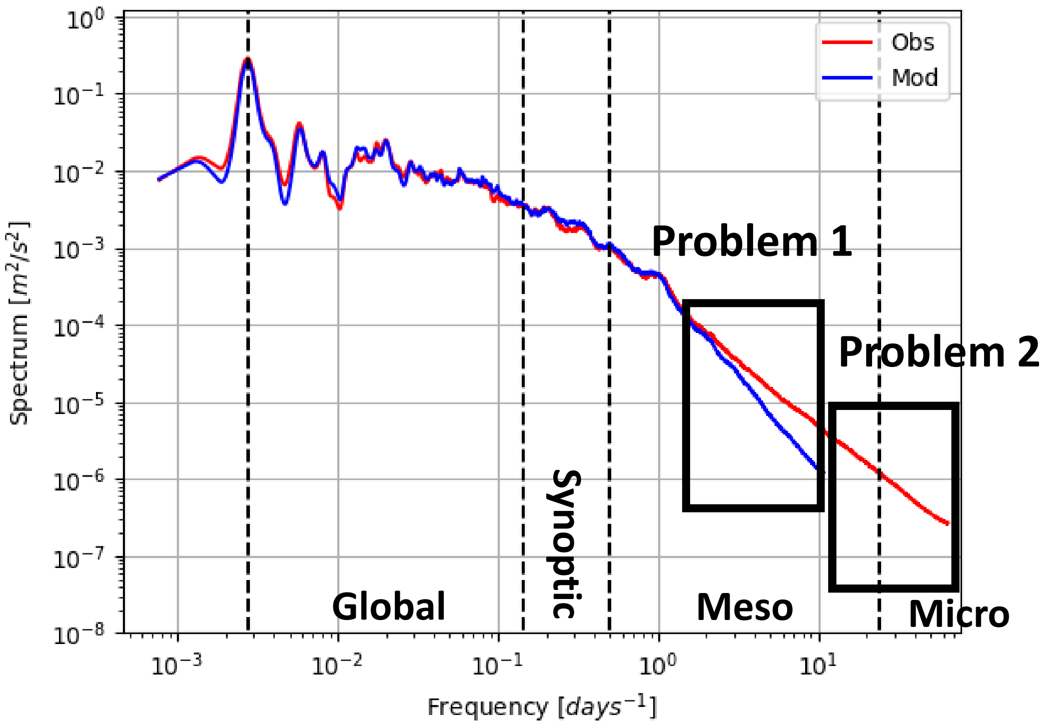
- Problem 1: Spectrum may have too high damping at high frequencies



The problem

Mesoscale model problems – frequency domain (spectrum)

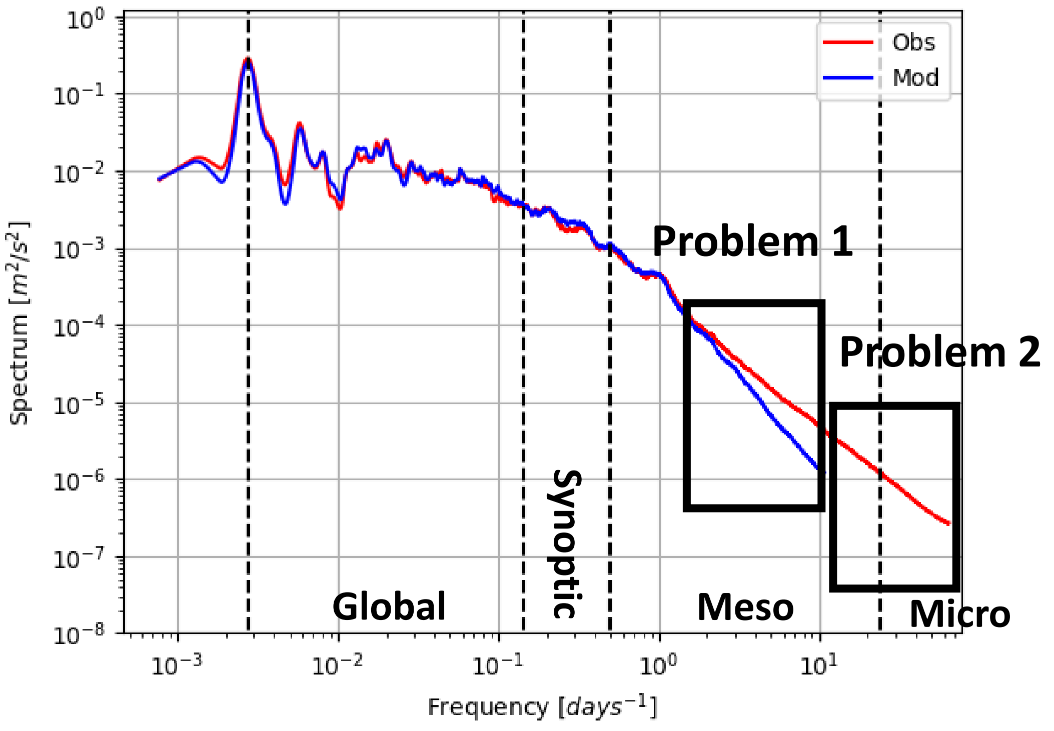
- Problem 1: Spectrum may have too high damping at high frequencies
- Problem 2: Spectrum does not cover highest frequencies (if hourly sampled)

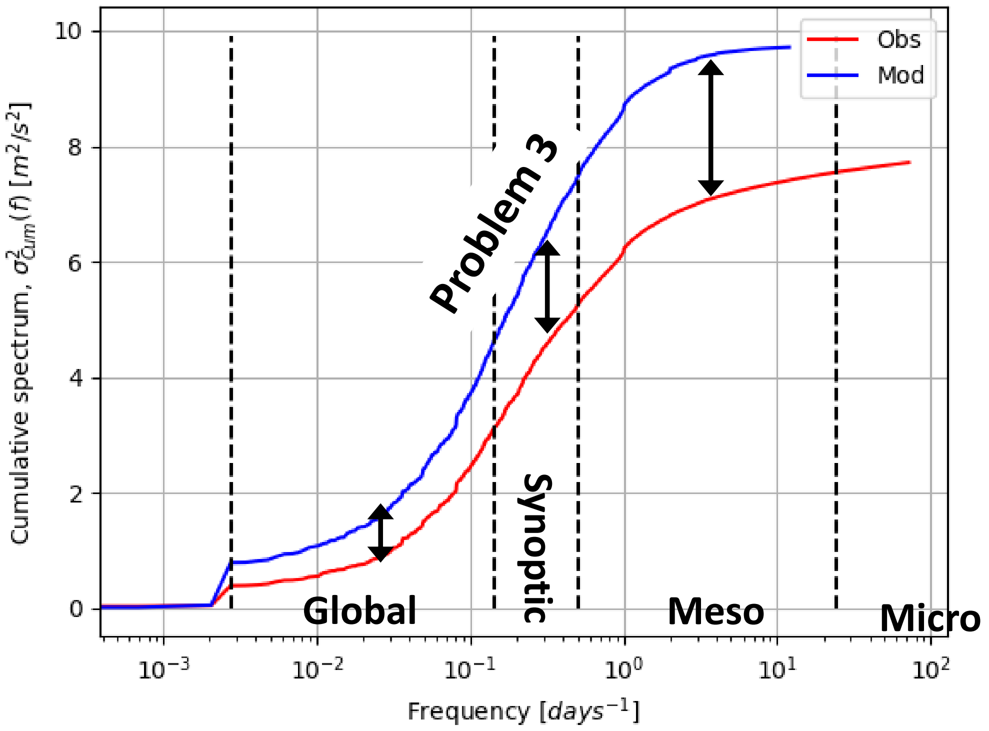


The problem

Mesoscale model problems – frequency domain (spectrum)

- Problem 1: Spectrum may have too high damping at high frequencies
- Problem 2: Spectrum does not cover highest frequencies (if hourly sampled)
- Problem 3: Spectrum may have errors in ‘main ranges’ (meso, synoptic, global)





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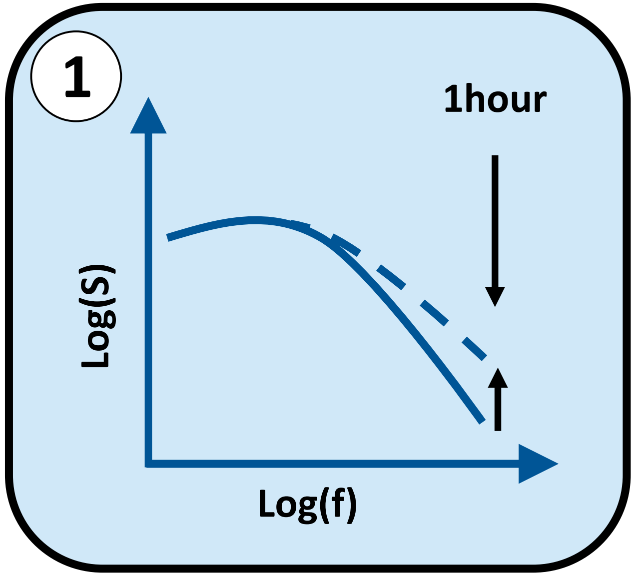
The solution

Solution 1: Correct damping of highest frequencies

- Apply ‘inverse’ damping filter’

(Note: not required for all mesoscale data/models, e.g. ‘EMD-WRF EUR+ (ERA5)’)

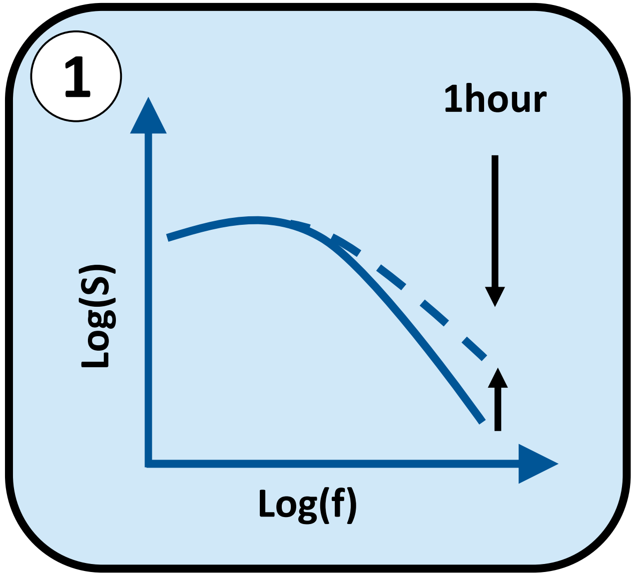


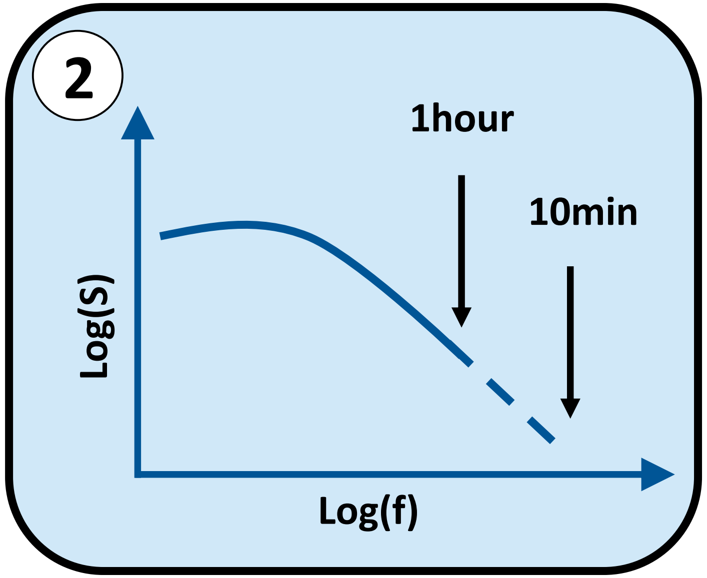
The solution

Solution 1: Correct damping of highest frequencies

Solution 2: Extrapolate spectrum to recover high frequencies

- Utilize linear nature (in log-log) to extrapolate to 10min





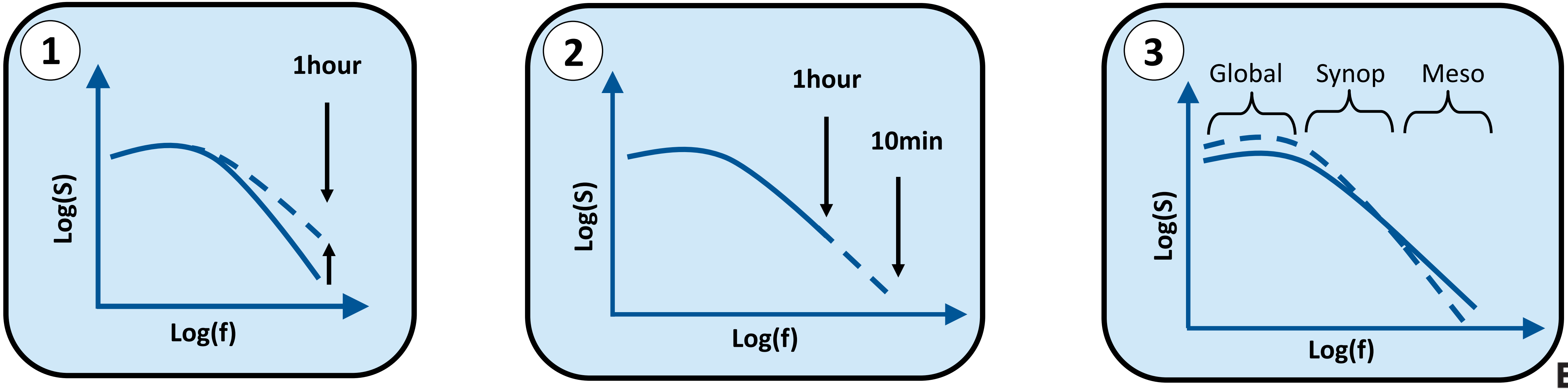
The solution

Solution 1: Correct damping of highest frequencies

Solution 2: Extrapolate spectrum to recover high frequencies

Solution 3: Correct shape of spectrum in main ranges

- Correct the amount of variance in each main range



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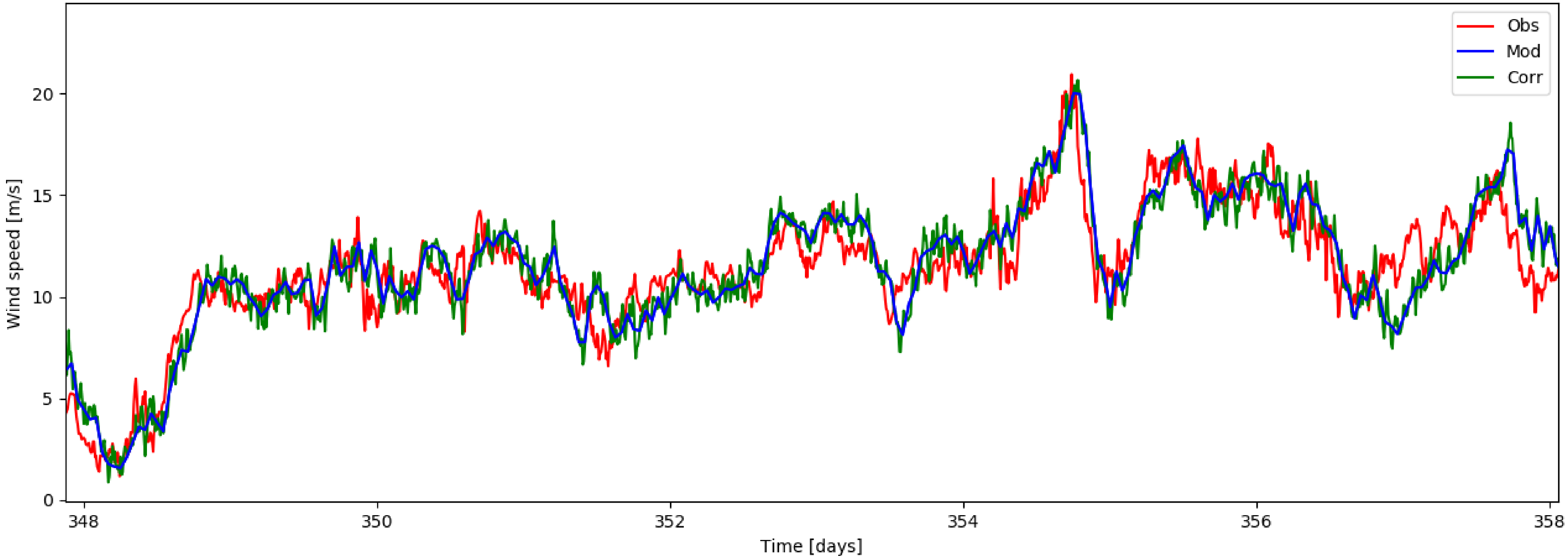
The solution

Example (time domain)

- Obs: Cabauw Vs Mod: EMD-WRF Europe+ Vs Mod+Cor. 2+3 (cor. 1 not needed)



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The solution

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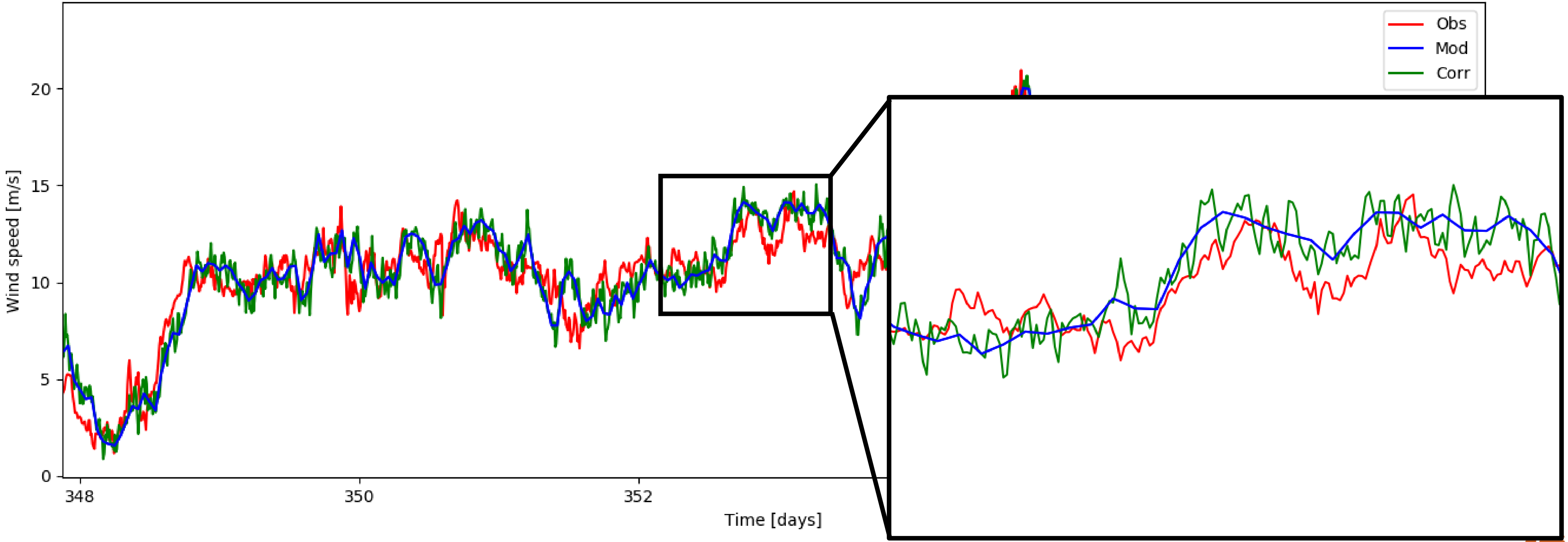

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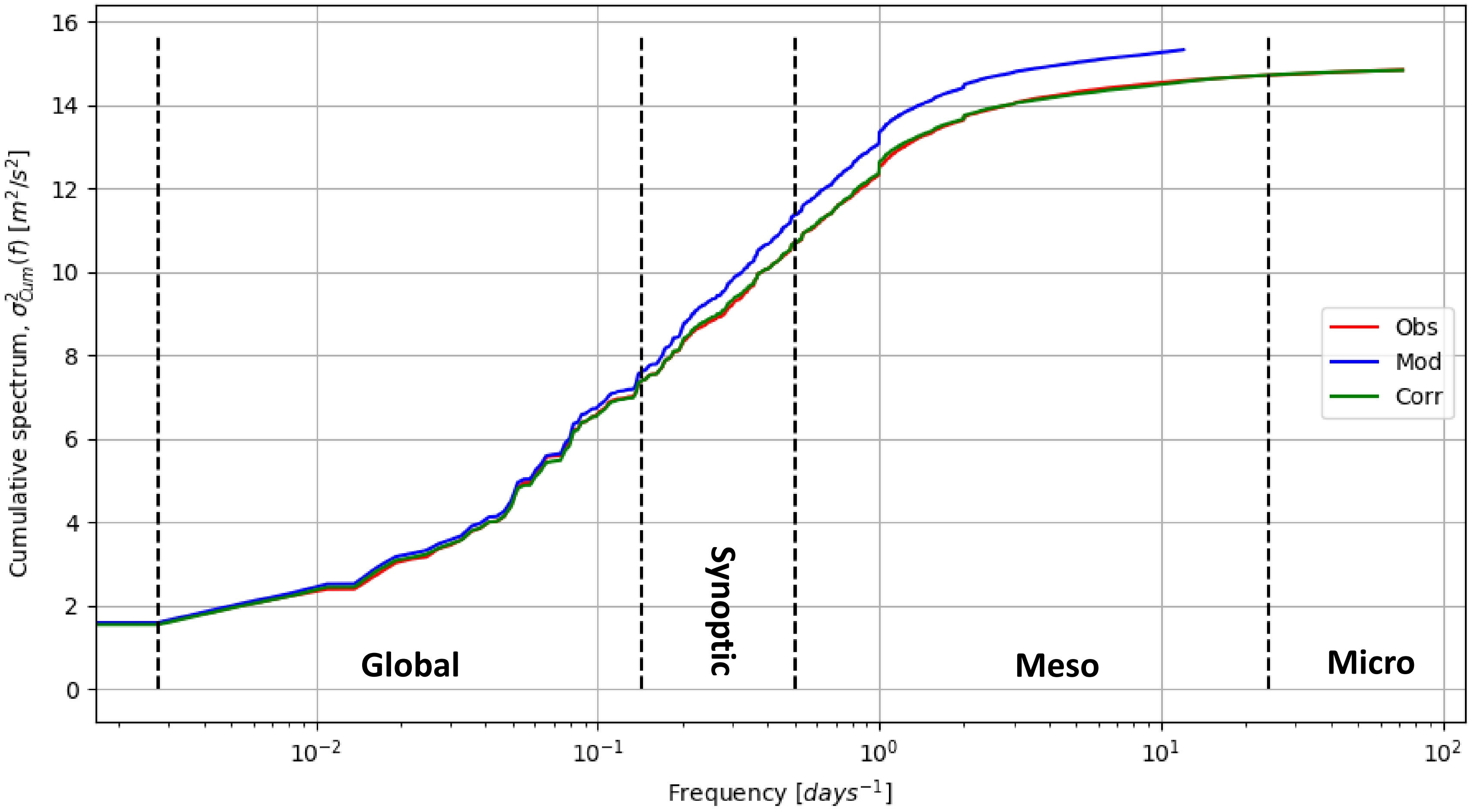
The solution

Example (cumulative spectrum)

- Obs: Cabauw Vs Mod: EMD-WRF Europe+ Vs Mod+Cor. 2+3 (cor. 1 not needed)



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Results

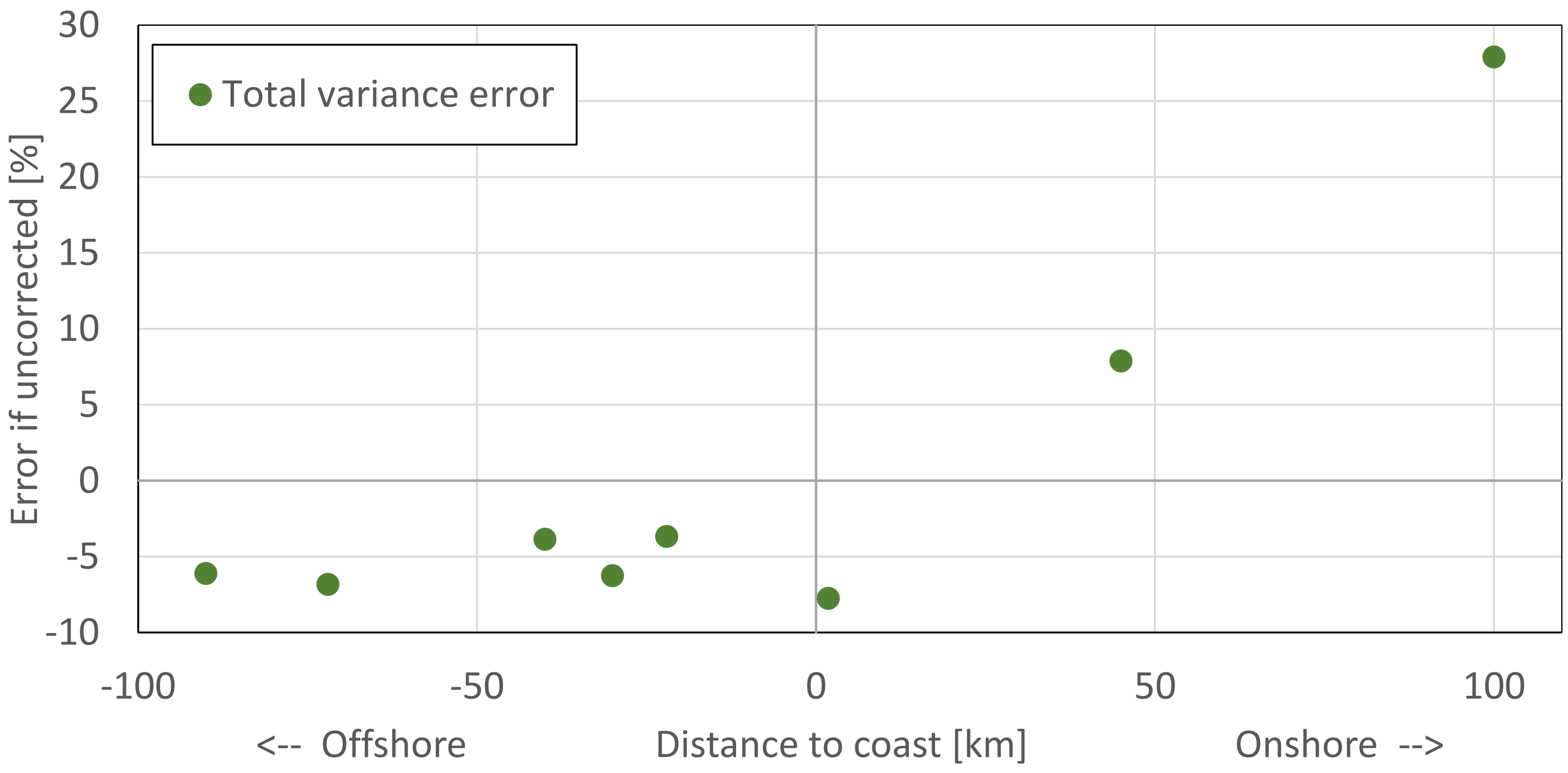
What is the effect of spectral correction?

- 8 masts from 100km offshore to 100km onshore (2-8 years)
- Errors quantified relative to corrected data to focus on spectral effects
- Hence, errors on mean wind speed are avoided

Results

What is the effect of spectral correction?

- Error on total variance (if uncorrected):



Results

What is the effect of spectral correction?

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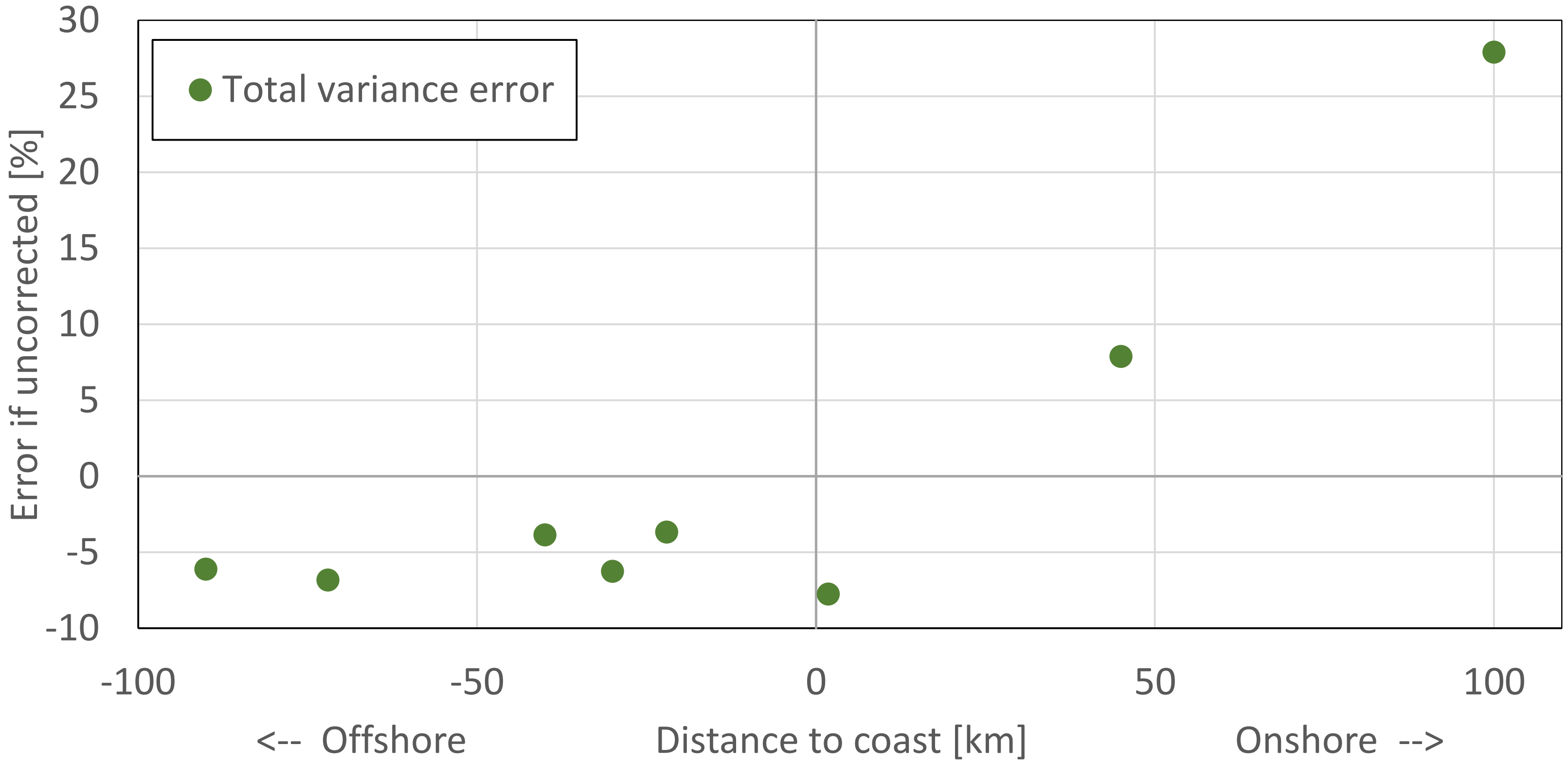


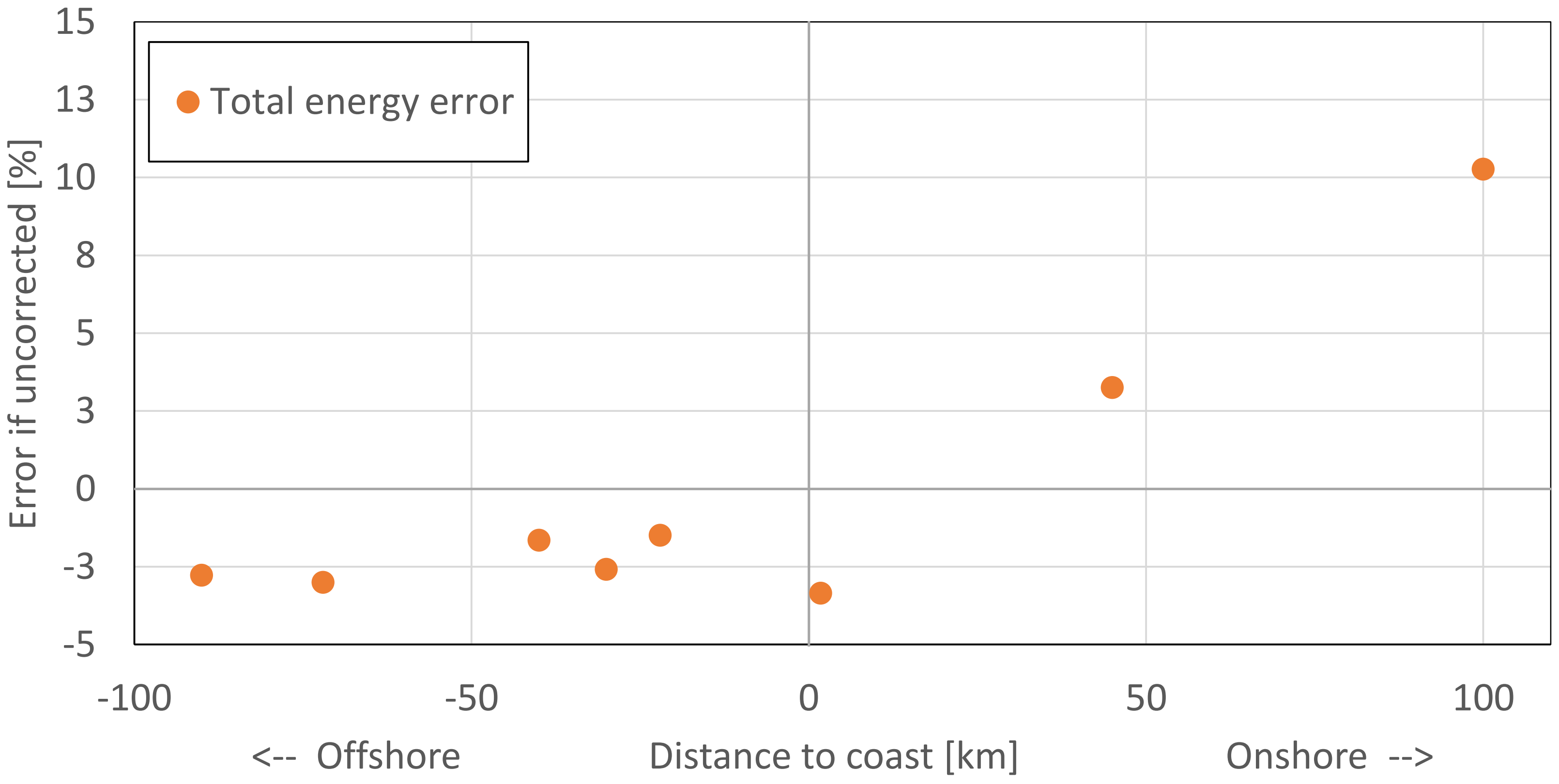
Total Variance error:

- Ca. -5% offshore
- Up to +28% onshore

Results

What is the effect of spectral correction?

- Error on total energy $\langle u^3 \rangle$ (if uncorrected):

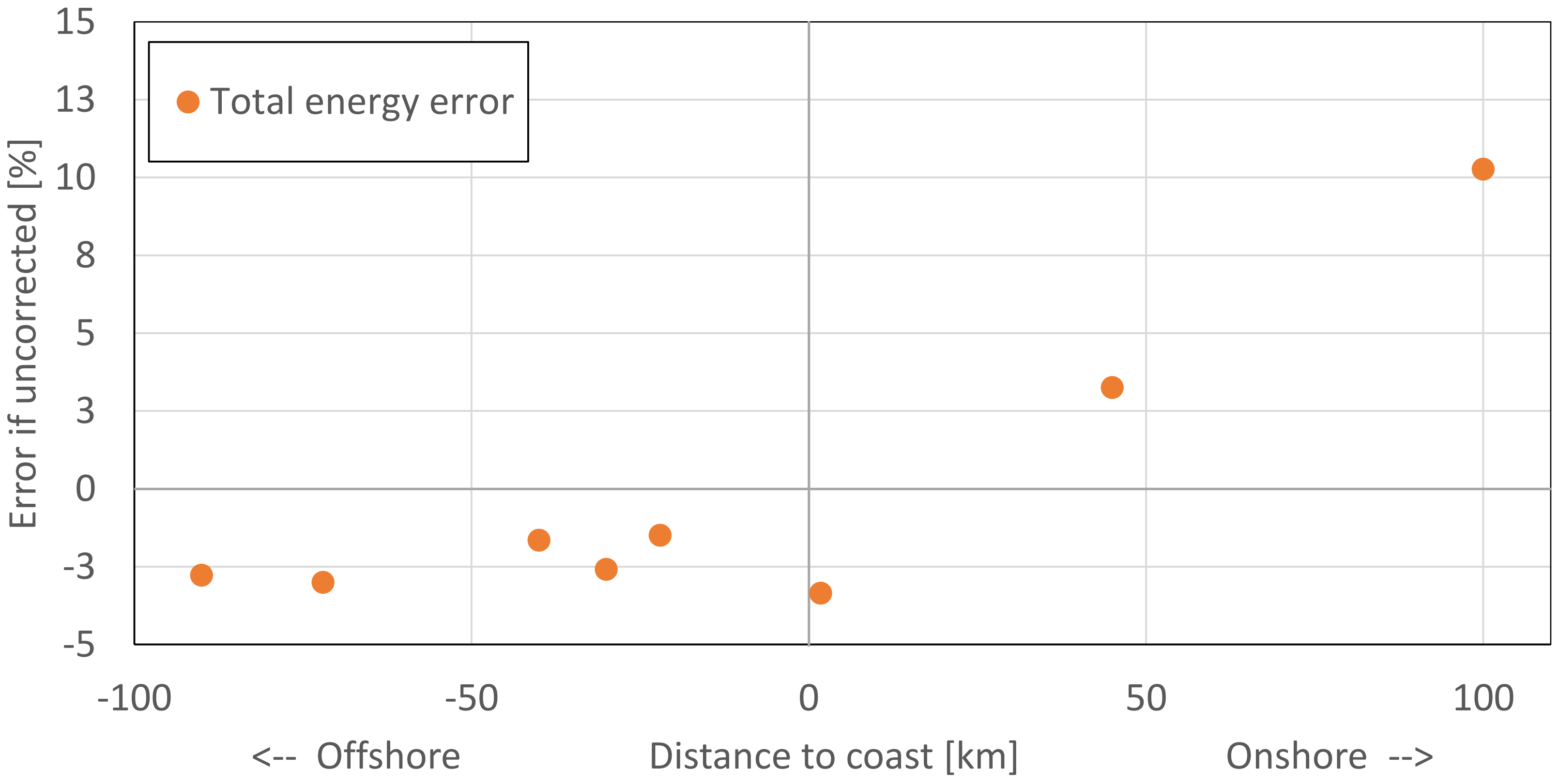


Results

What is the effect of spectral correction?

- Error on total energy $\langle u^3 \rangle$ (if uncorrected):

  AEP error ca. 20-50% of total energy error



Total energy $\langle u^3 \rangle$ error:

- Ca. -3% offshore
- Up to +10% onshore

AEP error:

- Ca. 1% offshore
- Up to 5% onshore

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Conclusion

Spectrum of mesoscale data - summary

Problems:

- 1) Mesoscale data may be dampened too much for $f > 1$ day^{-1}
- 2) Mesoscale data mostly sampled hourly
- 3) Mesoscale data may have erroneous variance in ‘main ranges’

Conclusion

Spectrum of mesoscale data - summary

Problems:

- 1) Mesoscale data may be dampened too much for f > 1 day^{-1}
- 2) Mesoscale data mostly sampled hourly
- 3) Mesoscale data may have erroneous variance in ‘main ranges’

Presented solutions:

- 1) Correct damping by an applying ‘inverse damping filter’
- 2) 10min samples recovered by extrapolating spectrum (linear in log-log)
- 3) Re-shape amount of variance in main ranges

Conclusion

So can mesoscale model data be used as is for AEP?

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- **onshore:**
  - **No** - spectral errors result in up to 28% error on variance and up to 5% on AEP
  - Full spectral correction recommended

Conclusion

So can mesoscale model data be used as is for AEP?

- **onshore:**
  - **No** - spectral errors result in up to 28% error on variance and up to 5% on AEP
  - Full spectral correction recommended

- **offshore:**
  - **Yes** – spectral errors result in up to 5% error on variance and up to 1% on AEP
  - **But** solution 2 is recommended to recover 10min data
    for consistency with 10min measurements

The End

Thanks for the attention!

Title: **Spectral correction**
to recover full 10min variability from hourly mesoscale data

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