Reanalysis data – the latest news

With focus on alignment between MetOcean and Wind Resource Assessment studies!!!

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This presentation is prepared for Wind Energy Denmark 2019 on October 1st 2019.

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Agenda

- Brief intro to Reanalysis data and what's been used in the market!

- The challenge of "mean wind speed & design"!!

- Is ERA5 really the new champion of wind power modelling?

- How to best align the MetOcean & Wind Resource Assessment Studies!

Basics…

- Focus is on offshore wind projects…

- Material is based on real life commercial offshore wind projects…

- We discuss the global data sets only!

- Aim is to highlight the challenges and suggest an alternative!

What is reanalysis wind data?

✓ a comprehensive record of how weather and climate are changing over time

✓ observations and a numerical model that simulates one or more aspects of the Earth system are combined

✓ extends over several decades or longer

✓ Covers the globe or regional areas or even local areas…

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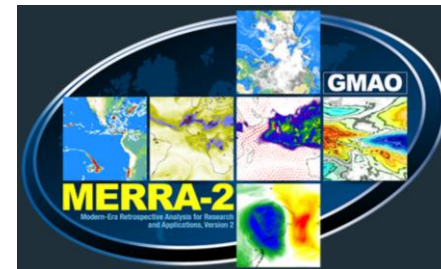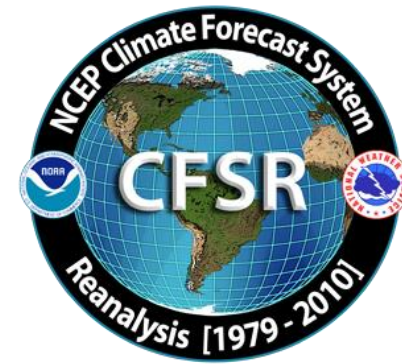
What do we use today as meteorological input?

	MERRA-2	CFSR & CFSv2	ERA5
Temporal Resolution	1 hour	1 hour	1 hour
Spatial Resolution	0.5° × 0.625°	0.3° x 0.3° (CFSR) 0.2° x 0.2° (CFSv2)	0.28° x 0.28°
Coverage	1980-now	1979- 2010 (CFSR) 2011-now (CFSv2)	1979-now
Wind speed height	2m, 10m & 50m	10m	10m & 100m
Other	Atmospheric model	Climate model, Coupled	Climate model, Coupled

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What does a MetOcean Study cover?

- High resolution atmospheric (?), hydrodynamic and wave modelling
- ~40 years of wind, waves, water levels & currents

- Normal conditions
  - weather-windows
  - mis-alignment
  - scatter tables etc.

- Extreme conditions
  - 50-year 10-minute wind speed at hub height
  - 10,000 year crest height
  - Joint probabilities
  - Turbulence intensity

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How is it nowadays delivered? Web-based Database

- ✓ Access to time series and spectral data
- ✓ Instant access to Extreme conditions and NSS tables
- ✓ Map of normal and extreme conditions
- ✓ On-the-fly analysis such as Weather-windows, scatter tables, altimeter comparison, rose plots etc.
- ✓ Following GDPR regulations
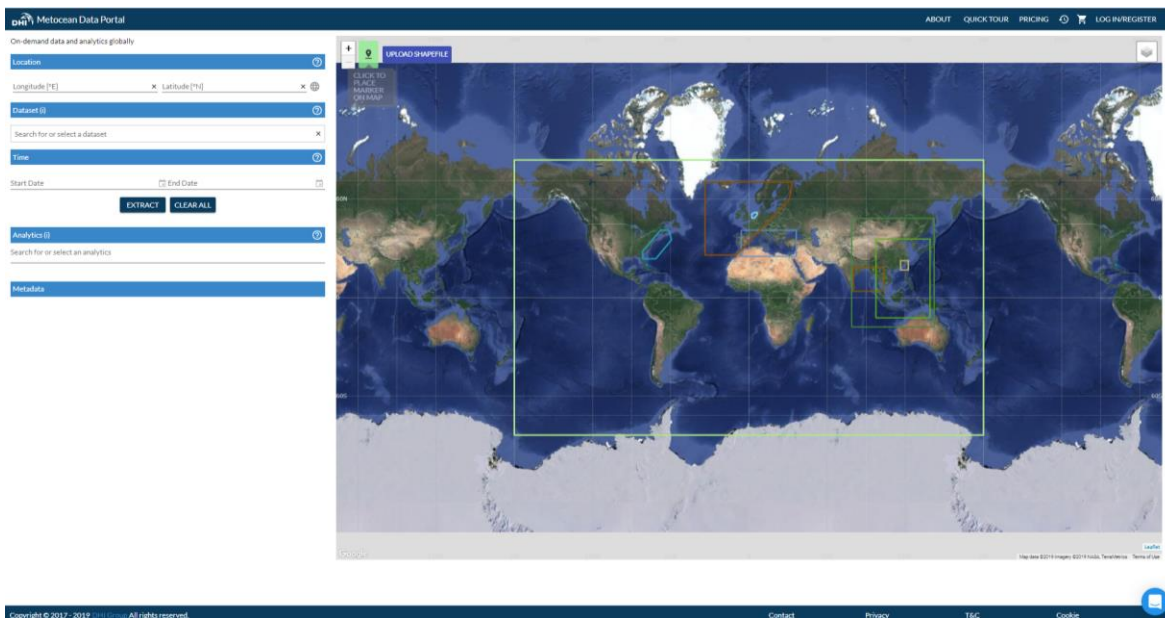
MetOcean-On-Demand Data Portal
https://www.metocean-on-demand.com

So what's the problem?!

Wind Resource Assessment Study	MetOcean Study
Aimed towards **yield analysis**	Aimed towards **design**

Mean wind speed @100m = 9.0 m/s $\neq$ Mean wind speed @100m = 9.8 m/s

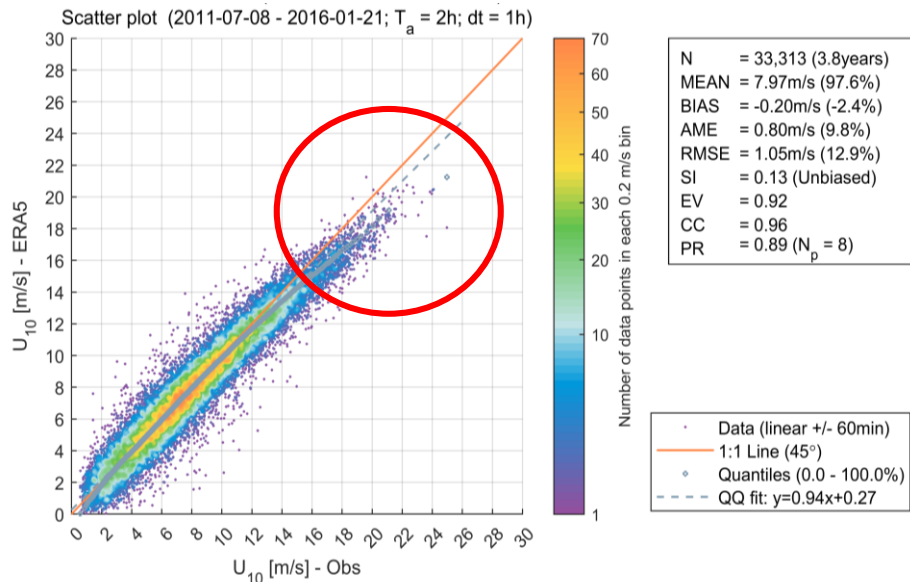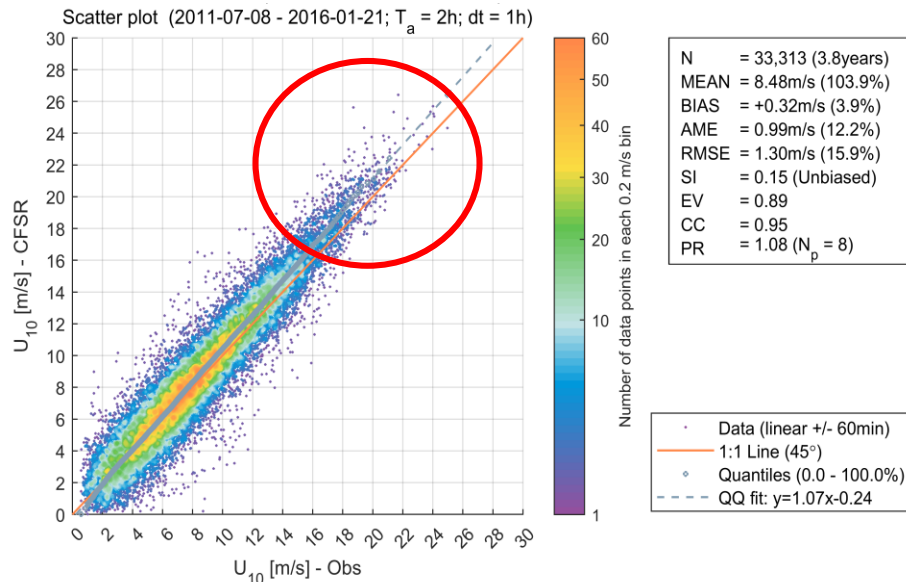| What about turbulence intensity?	What about extreme events and design?	What about wind-wave mis-alignment?	What about power?

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Dogger Bank Example – no land effects

Scatter plot (2011-07-08 - 2016-01-21; T_a = 2h; dt = 1h)

N	= 33,313 (3.8years)
MEAN	= 7.97m/s (97.6%)
BIAS	= -0.20m/s (-2.4%)
AME	= 0.80m/s (9.8%)
RMSE	= 1.05m/s (12.9%)
SI	= 0.13 (Unbiased)
EV	= 0.92
CC	= 0.96
PR	= 0.89 (N_p = 8)

Data (linear +/- 60min)
1:1 Line (45°)
Quantiles (0.0 - 100.0%)
QQ fit: y=0.94x+0.27

Scatter plot (2011-07-08 - 2016-01-21; T_a = 2h; dt = 1h)

N	= 33,313 (3.8years)
MEAN	= 8.48m/s (103.9%)
BIAS	= +0.32m/s (3.9%)
AME	= 0.99m/s (12.2%)
RMSE	= 1.30m/s (15.9%)
SI	= 0.15 (Unbiased)
EV	= 0.89
CC	= 0.95
PR	= 1.08 (N_p = 8)

Data (linear +/- 60min)
1:1 Line (45°)
Quantiles (0.0 - 100.0%)
QQ fit: y=1.07x-0.24

ERA5 Bias = -0.2 m/s
ERA5 PR= 0.9

CFSR Bias = +0.3 m/s
ERA5 PR=1.1

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Hollandse Kust Example – with land effects

HKNB (4.24E;52.68N;10.00mMSL)
Scatter plot (2017-04-10 - 2019-01-10; T_a = 2h; dt = 1h)

N	= 13,932 (580.5days)
MEAN	= 6.85m/s (86.7%)
BIAS	= -1.05m/s (-13.3%)
AME	= 1.36m/s (17.2%)
RMSE	= 1.70m/s (21.6%)
SI	= 0.17 (Unbiased)
EV	= 0.86
CC	= 0.93
PR	= 0.85 (N_p = 3)

Data (linear +/- 60min)
1:1 Line (45°)
Quantiles (0.0 - 100.0%)
QQ fit: y=0.87x-0.01

HKNB (4.24E;52.68N;10.00mMSL)
Scatter plot (2017-04-10 - 2019-01-10; T_a = 2h; dt = 1h)

N	= 13,933 (580.5days)
MEAN	= 7.22m/s (91.5%)
BIAS	= -0.67m/s (-8.5%)
AME	= 1.30m/s (16.5%)
RMSE	= 1.66m/s (21.1%)
SI	= 0.19 (Unbiased)
EV	= 0.82
CC	= 0.91
PR	= 1.02 (N_p = 3)

Data (linear +/- 60min)
1:1 Line (45°)
Quantiles (0.0 - 100.0%)
QQ fit: y=0.98x-0.55

ERA5 Bias = -1.0 m/s
ERA5 PR= 0.85
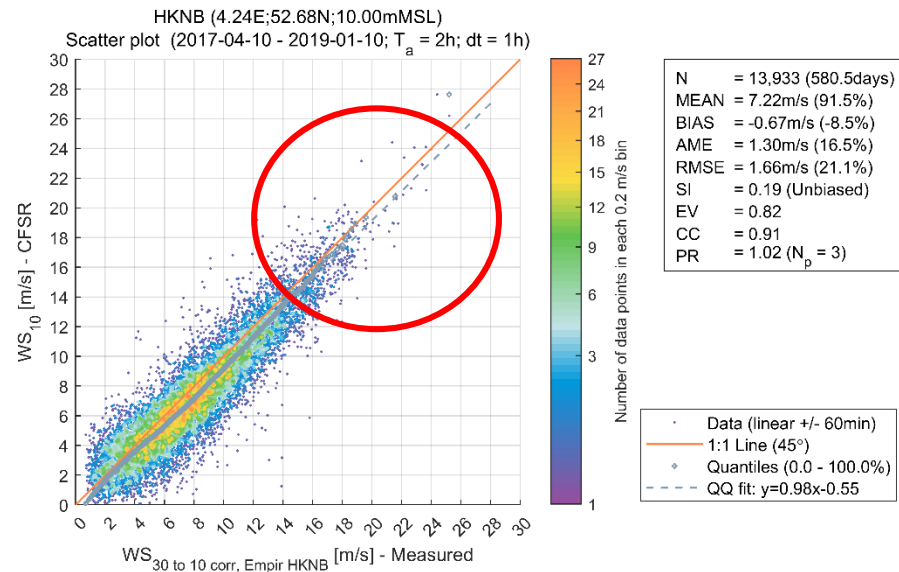
CFSR Bias = -0.7 m/s
ERA5 PR=1.02

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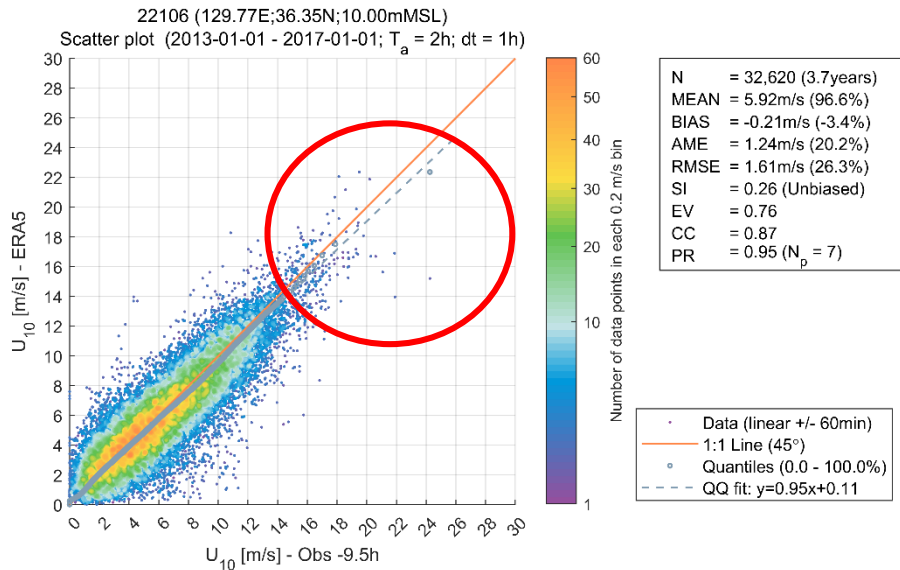# Hollandse Kust project – https://offshorewind.rvo.nl/windwaternh
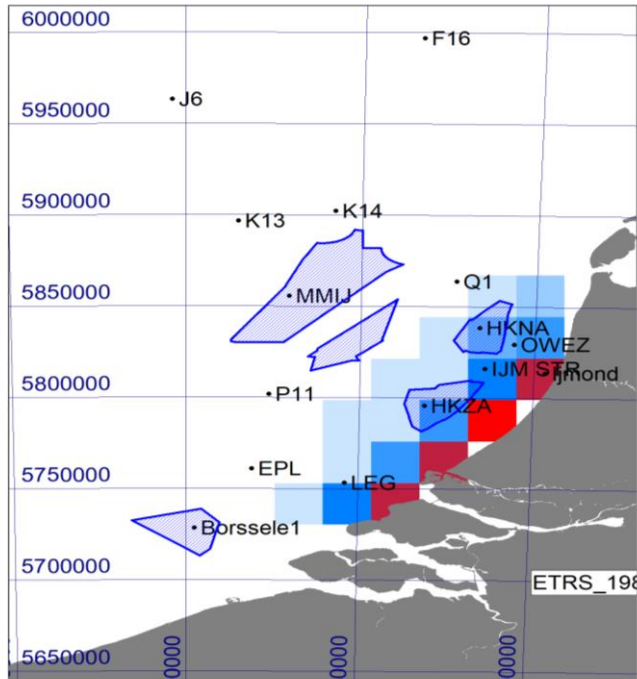
Map showing the difference of wind speed between corrected and original CFSR (2017)
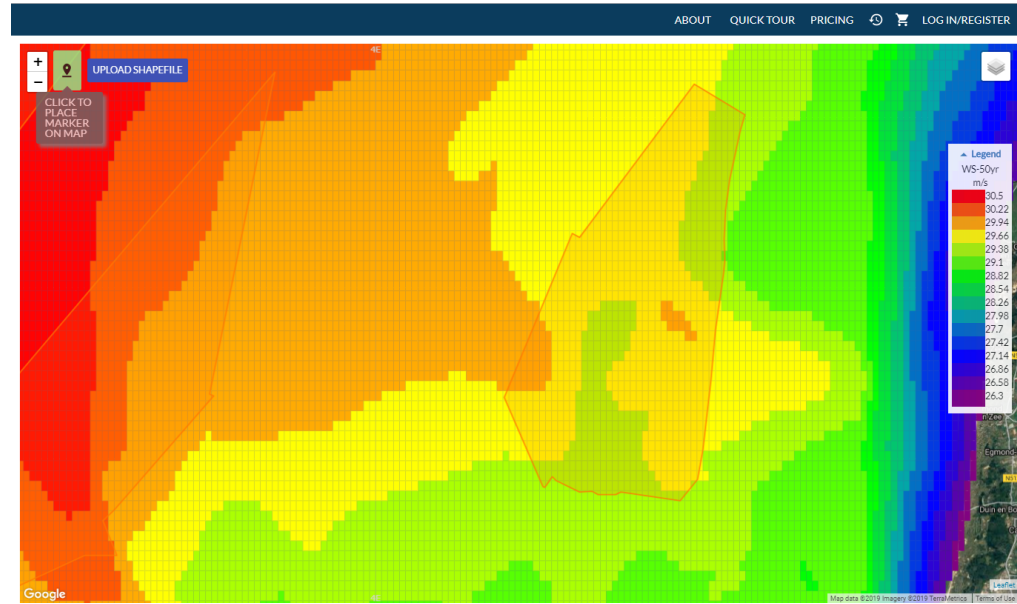
Map of 50-year Wind speed [m/s] @10m values around Hollandse Kust (noord)

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South Korea Example – Offshore Ulsan

22106 (129.77E;36.35N;10.00mMSL)
Scatter plot (2013-01-01 - 2017-01-01; T_a = 2h; dt = 1h)

N	= 32,620 (3.7years)
MEAN	= 5.92m/s (96.6%)
BIAS	= -0.21m/s (-3.4%)
AME	= 1.24m/s (20.2%)
RMSE	= 1.61m/s (26.3%)
SI	= 0.26 (Unbiased)
EV	= 0.76
CC	= 0.87
PR	= 0.95 (N_p = 7)

Data (linear +/- 60min)
1:1 Line (45°)
Quantiles (0.0 - 100.0%)
QQ fit: y=0.95x+0.11

22106 (129.77E;36.35N;10.00mMSL)
Scatter plot (2013-01-01 - 2017-01-01; T_a = 2h; dt = 1h)

N	= 32,564 (3.7years)
MEAN	= 6.04m/s (98.5%)
BIAS	= -0.09m/s (-1.5%)
AME	= 1.44m/s (23.5%)
RMSE	= 1.86m/s (30.3%)
SI	= 0.30 (Unbiased)
EV	= 0.68
CC	= 0.84
PR	= 1.10 (N_p = 7)

Data (linear +/- 60min)
1:1 Line (45°)
Quantiles (0.0 - 100.0%)
QQ fit: y=0.98x+0.01

ERA5 Bias = -0.2 m/s

ERA5 PR= 0.95

CFSR Bias = -0.1 m/s

ERA5 PR=1.10

Why does ERA5 under-estimates storms?

- It all starts from two-way coupling…specially during unstable conditions (winter)

  - Big storms generate high waves
  - High waves increase the drag
  - Increase the drag reduces the wind speeds

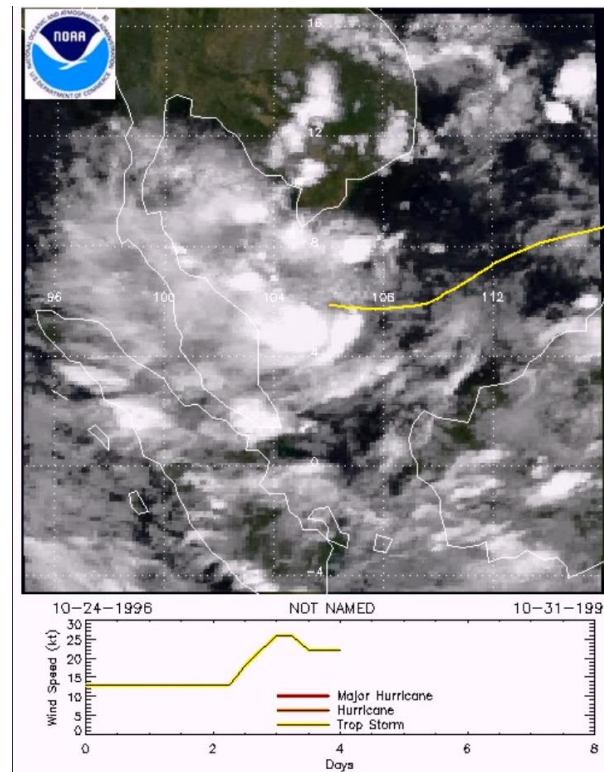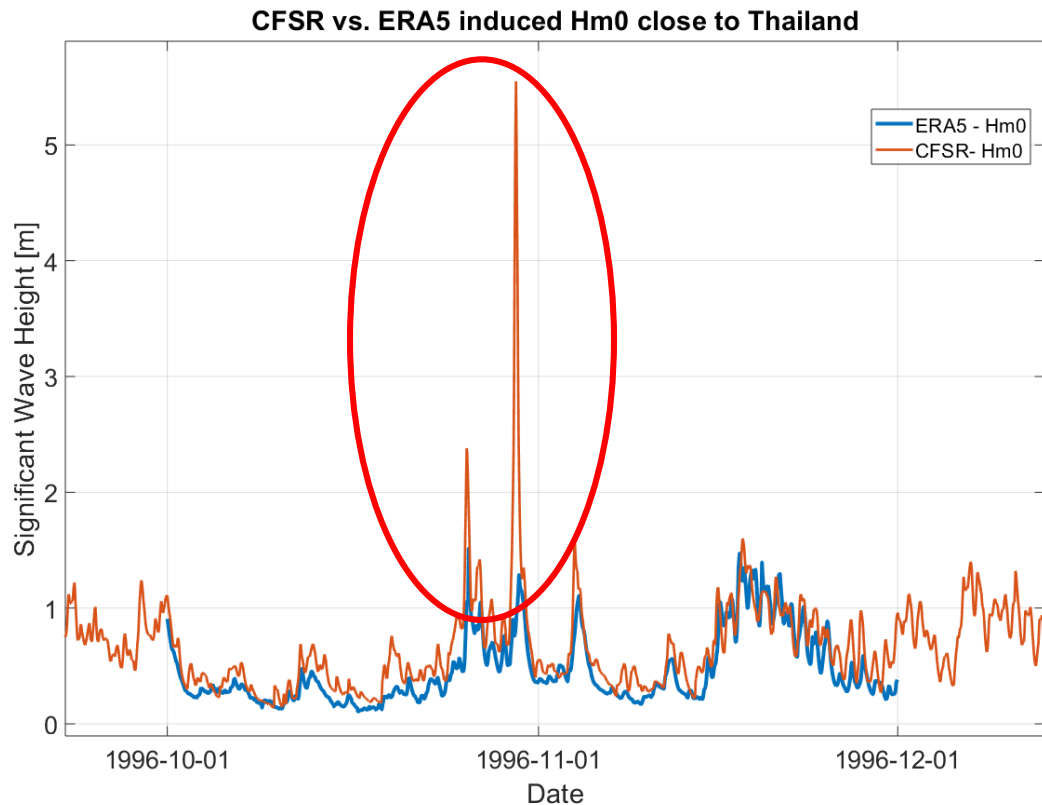- The shear is too high for strong wind speeds!
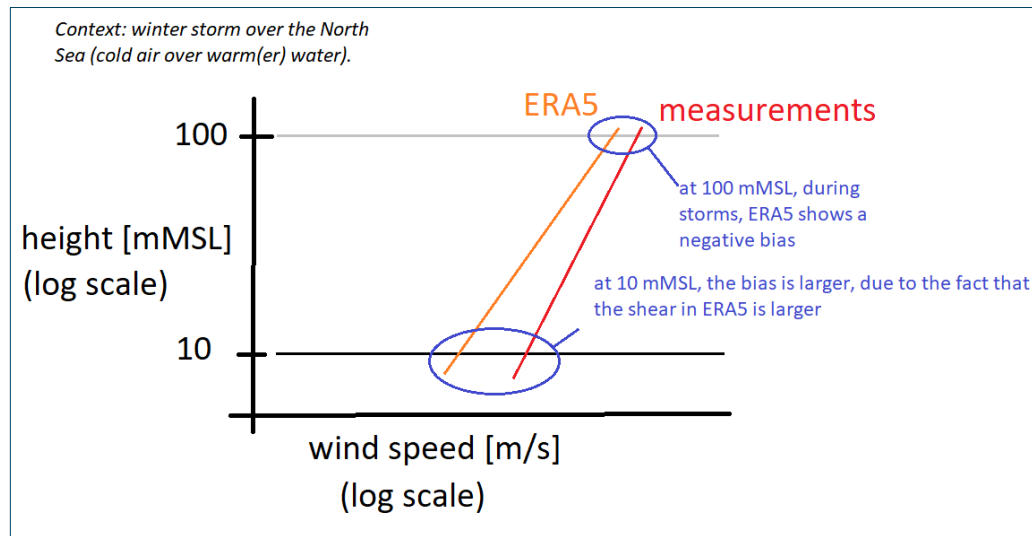
Courtesy of Rémi Gandoin, C2Wind

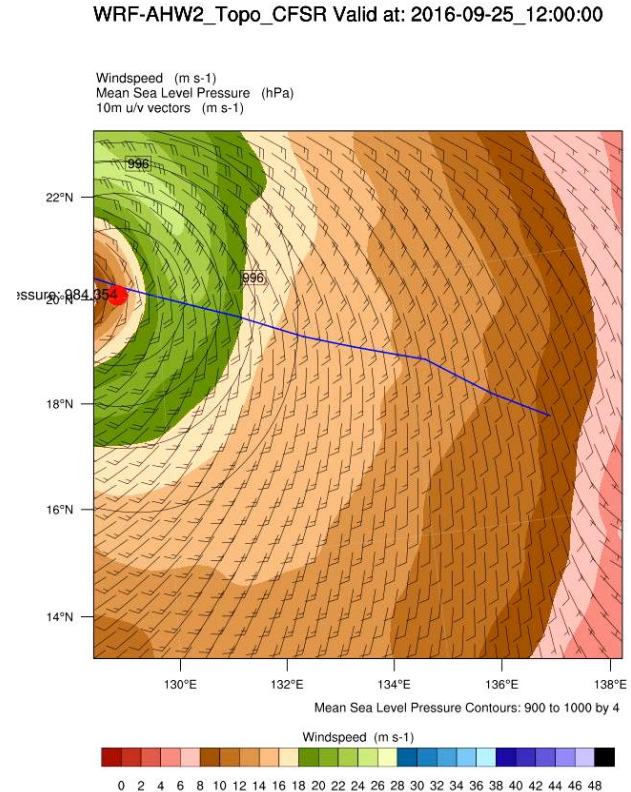# What about cyclones, typhoons & tropical storms?

What about cyclones, typhoons & tropical storms?
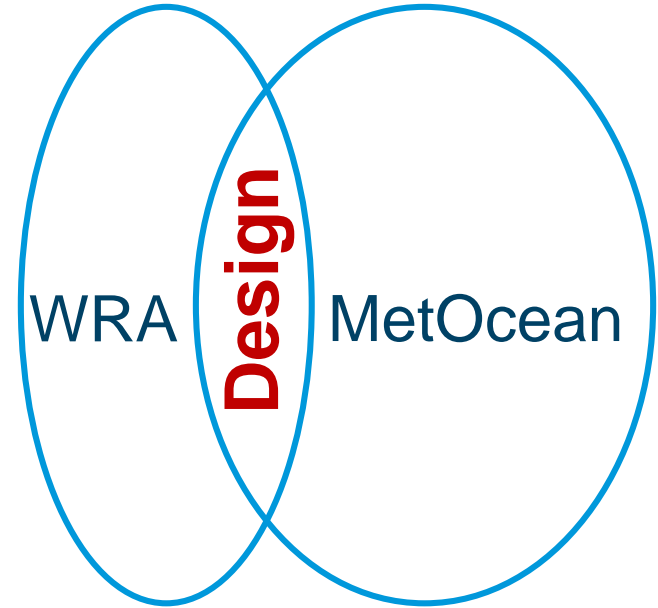

CFSR vs. ERA5 induced Hm0 close to Thailand
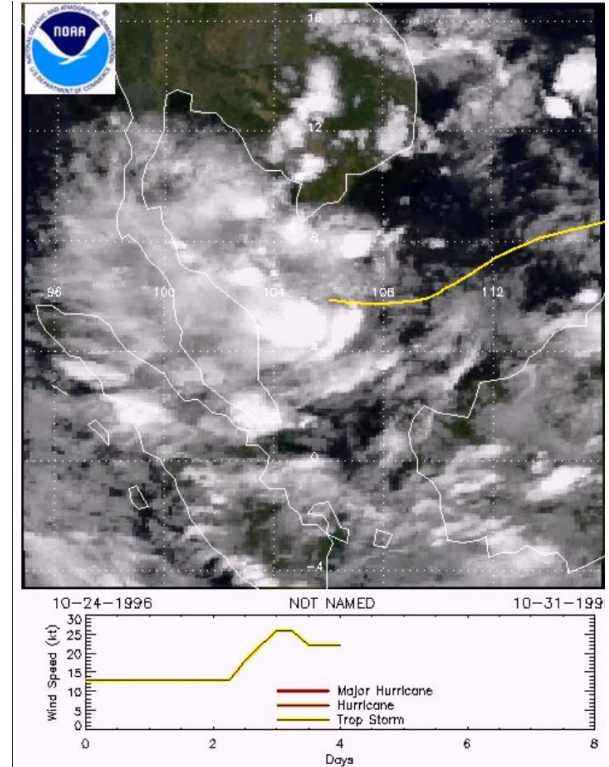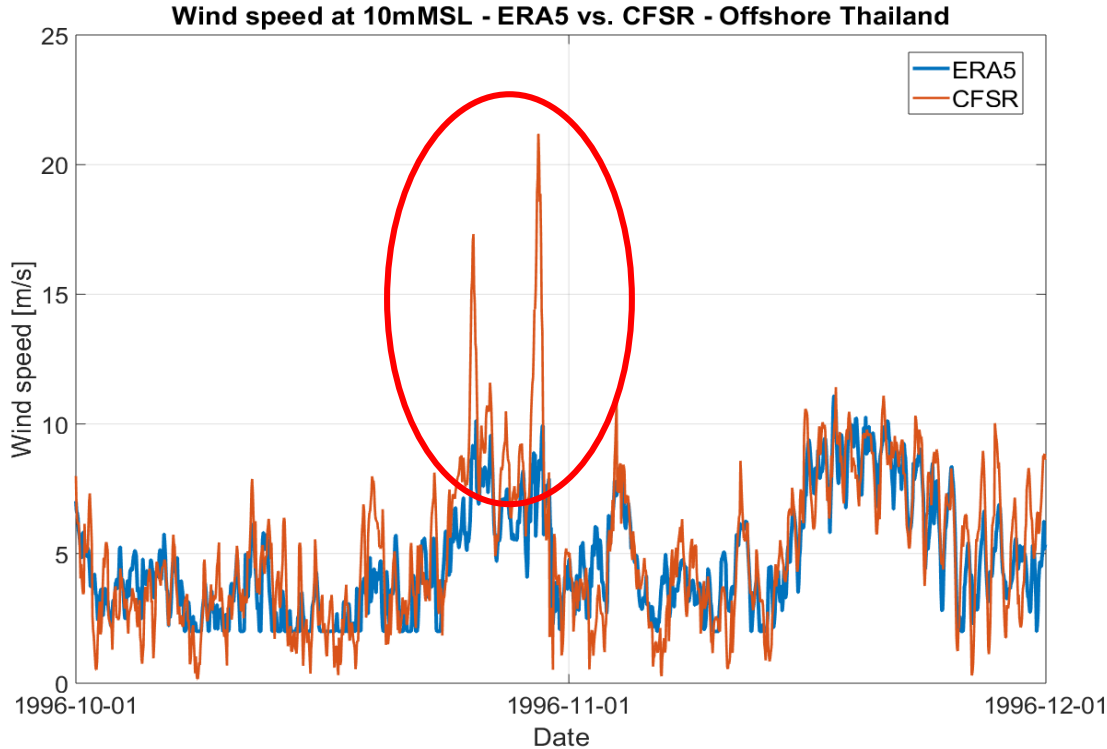
What to do instead of using ERA5 or CFSR?

✓ Use WRF model rather than HOLLAND model

✓ Preferably use CFSR as boundary conditions for WRF

✓ Use data assimilation (if possible) to get the best quality extremes

WRF-AHW2_Topo_CFSR Valid at: 2016-09-25_12:00:00

Windspeed (m s-1)
Mean Sea Level Pressure (hPa)
10m u/v vectors (m s-1)

Mean Sea Level Pressure Contours: 900 to 1000 by 4

Windspeed (m s-1)

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48

Conclusion

- Start the WRA first and then keep two-way contact with MetOcean study
- No need to use the same wind fields for WRA and MetOcean studies
- Use Scatterometers to validate

- Design
  - For normal conditions, ERA5 and CFSR would provide very similar results!
  - ERA5 is better than CFSR for hub height wind speed, so using ERA5 would give more accurate wind-wave mis-alignment
  - For extreme conditions, CFSR is superior to ERA5!
  - Perform the HD and Wave modelling using ERA5 (**for normal conditions**) and CFSR (**for extreme conditions**)

WRA Design MetOcean

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Thank you ☺ Questions?

Web-based MetOcean Database

https://www.metocean-on-demand.com/