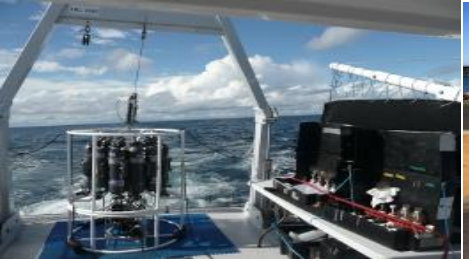


Sub-surface Intensification of Marine Heatwaves off SE Australia: The Role of Stratification and Local Winds.

Moninya Roughan and Amandine Schaeffer

UNSW Coastal and Regional Oceanography Group

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mroughan@unsw.edu.au

Schaeffer and Roughan (2017) Geophysical Research Letters

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What is a Marine Heatwave (MHW) ?

A discrete prolonged anomalously warm water event in a particular location" (Hobday et al., 2016).


Progress in Oceanography 141 (2016) 227–238

Contents lists available at ScienceDirect

Progress in Oceanography

journal homepage: www.elsevier.com/locate/pocean

A hierarchical approach to defining marine heatwaves

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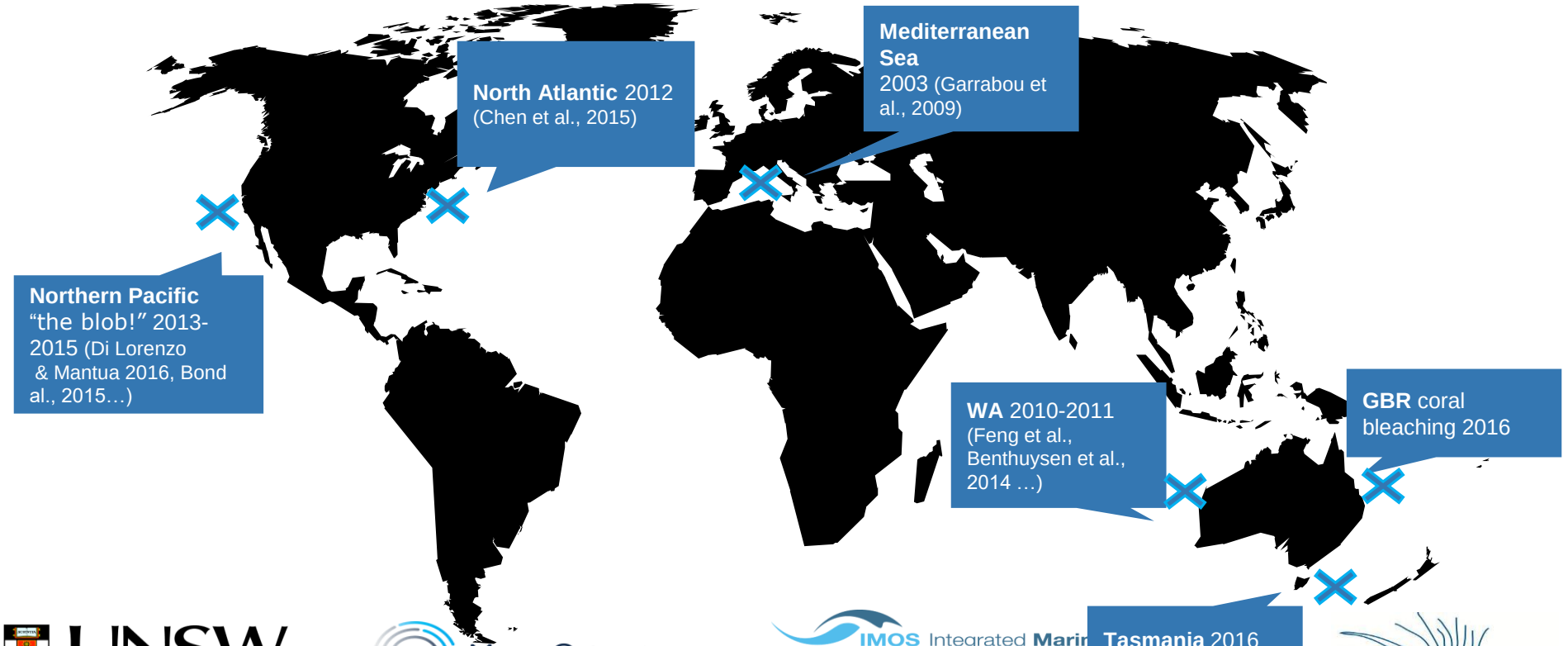
Prolonged: > 5 days

Anomaly: > 90th percentile of daily climatology

Climatology constructed over an extended period, (ideally > 30 yrs)

Extreme Marine Heatwaves are Occurring Globally



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Background

Ocean warming:Western boundary currents (Wu et al., 2012) including the East Australian Current extension (Oliver et al., 2014; Sen Gupta et al., 2015) identified as ocean warming hotspots.

Extremely hot sea surface temperatures (SSTs) have become more common in 1/3rd of the world's coastline (Lima and Wethey, 2012)

Impact on the ocean ecosystems: Benthic communities, corals, seagrass, fish and invertebrate mortality (Garrabou et al, 2009, Pearce and Feng, 2013); observed poleward shift of seaweeds and tropical fish (Last et al., 2011, Wernberg et al., 2016; Verges et al. 2014); Huge impact on Aquaculture (e.g. Salmon farming)

Drivers: With relative importance varying in different regions: anomalous air-sea flux (increase in air temperature, decrease in wind stress) and ocean advection, superimposed on inter-annual climate variability (e.g ENSO/PDO).

Study Site: Off Sydney 34S

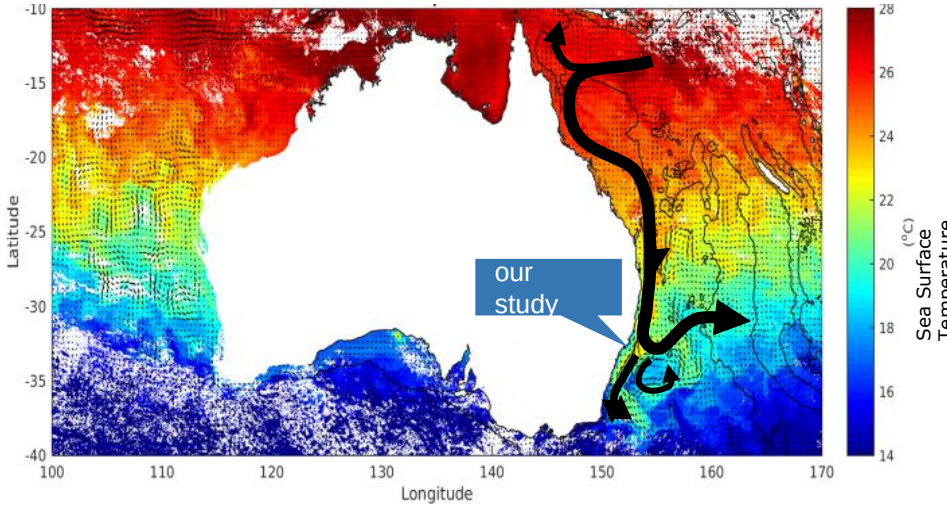
Continental shelf 60-100m deep

Influenced by

- East Australian Current,
- Eddy encroachment,
- Local wind forcing

Known hotspot of ocean warming

- SST has increased nearly 1^{o}C /100yrs at 34S



Research Questions

MHWs have mostly been studied from sea **surface** temperature (SST) records, or identified in the surface mixed layer, little information is available on the depth extent…

- What is the Sub-Surface structure of MHWs?
  - How deep to MHWs extend?
  - What controls their depth structure?
  - Are the characteristics (frequency, intensity, duration) of MHWs similar over the water column?
- Is SST a good proxy for understanding the subsurface / benthic impact of MHWs?

Long Term Data Sets 1 – PH100 / PHB

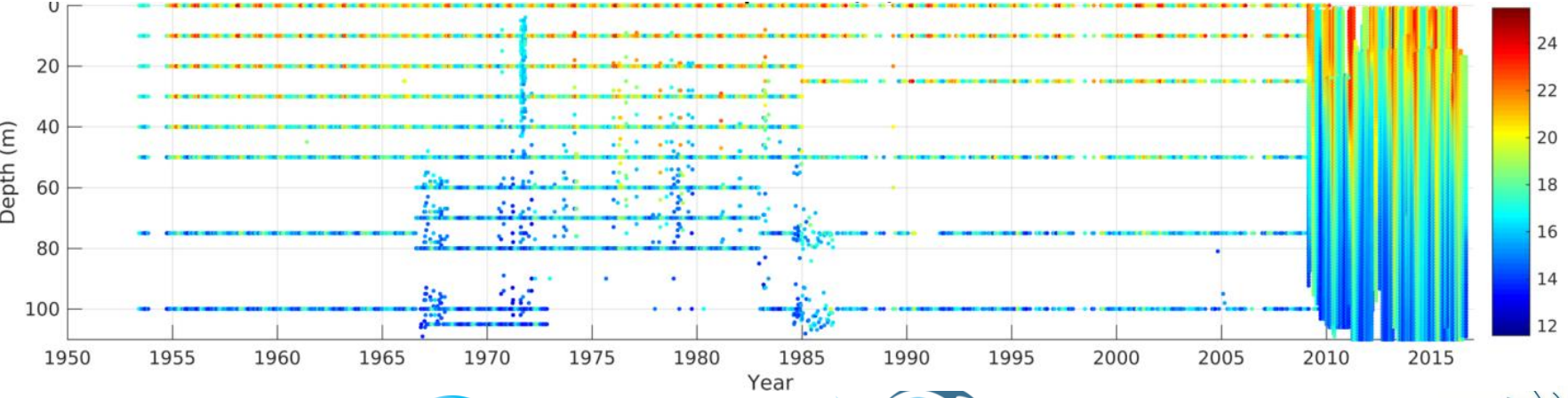
Port Hacking NRS

Local depth: 100 m (6 km from the coast)

Historical samples / CTD: 1953 – now (weekly / monthly)

Mooring (IMOS): 2008 – now

(Δt = 5 min, Δz = 8 m, z =20 – 100 m)



Long Term Data Sets 2 – ORS065


Image credit: Sydney Water

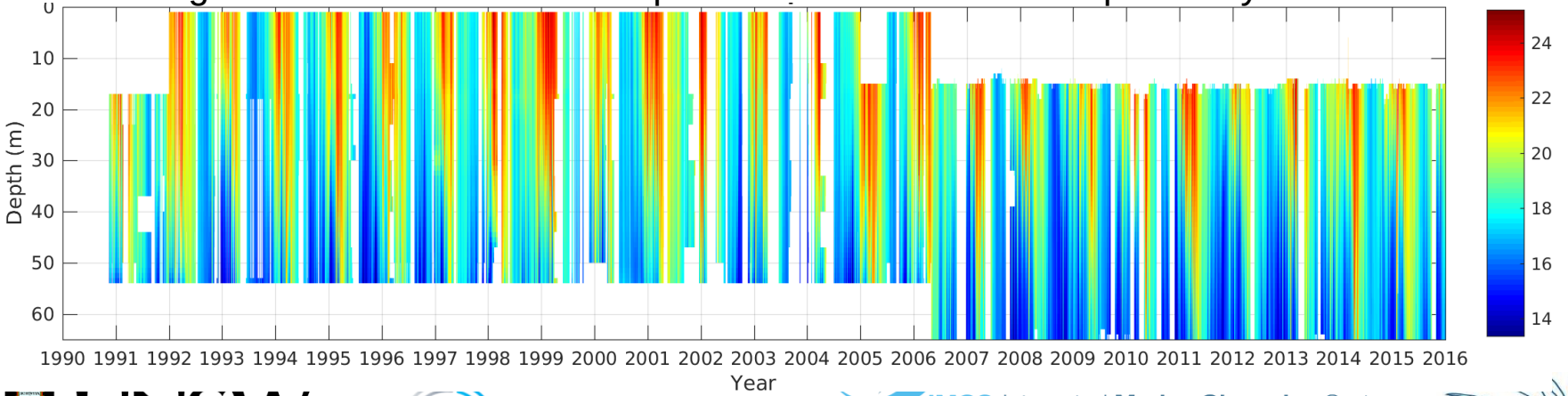
Funded since 1990 by Sydney Water Corporation- Significant contribution to knowledge base

Local depth: 65 m (2 km from the coast)

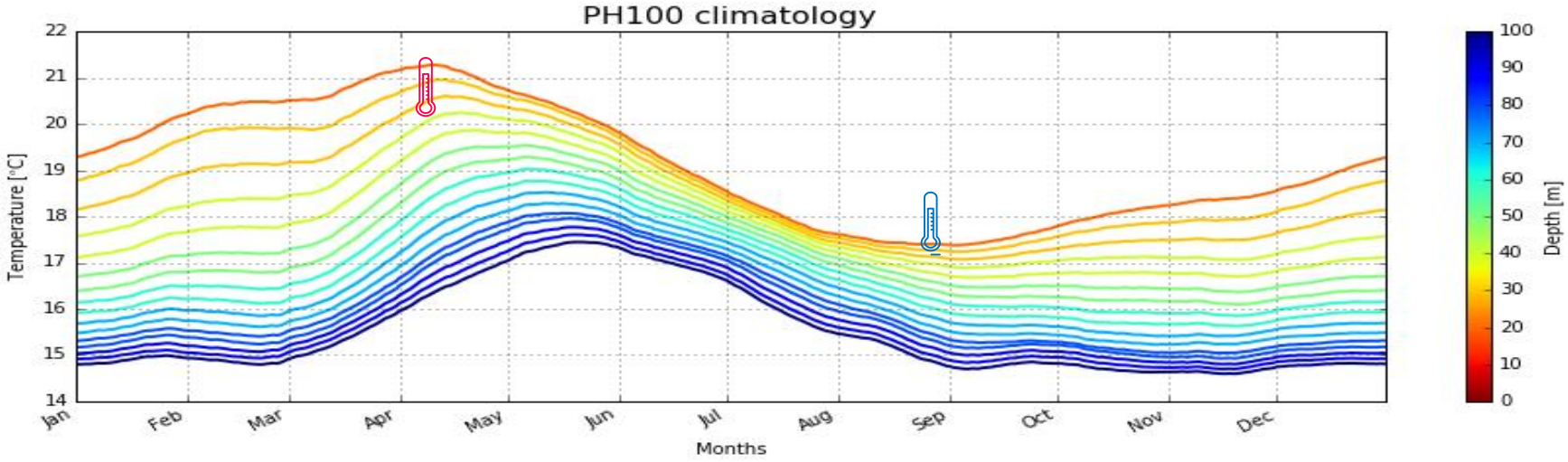
Mooring measurements: 1992– now

(Δt = 5 min – 1 h, Δz = 4 m), z =20 - 53 m (+ 0 – 20 m until 2006)

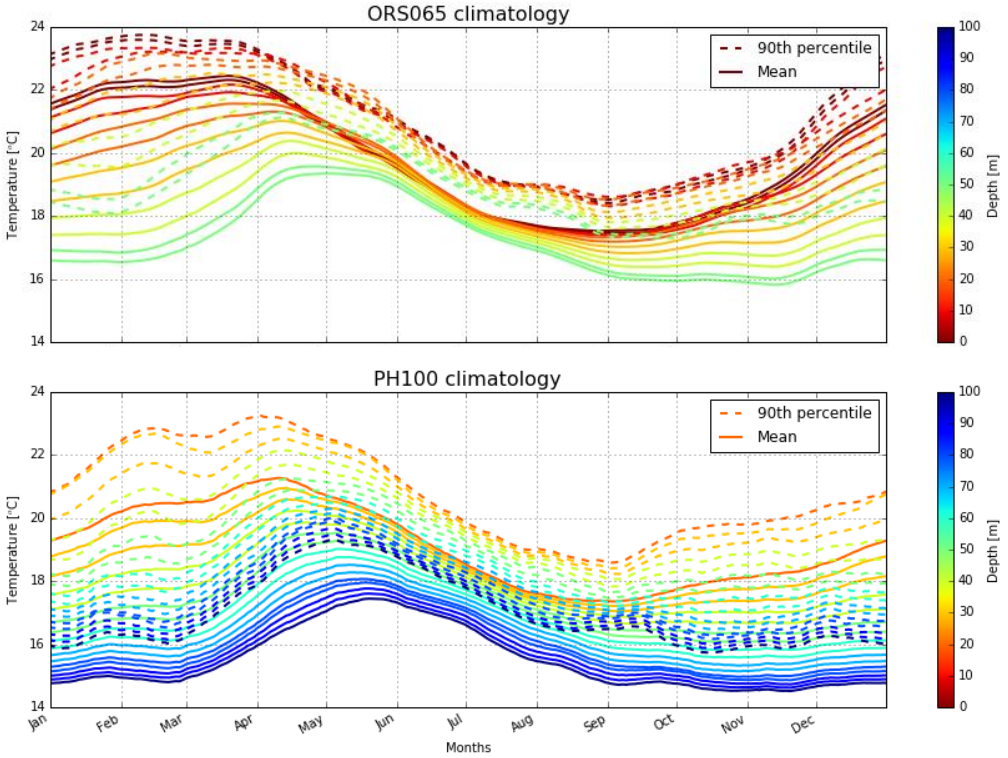
One of longest in situ sub-surface temperature records available publically.



Constructing a Daily Temperature Climatology



90th Percentiles



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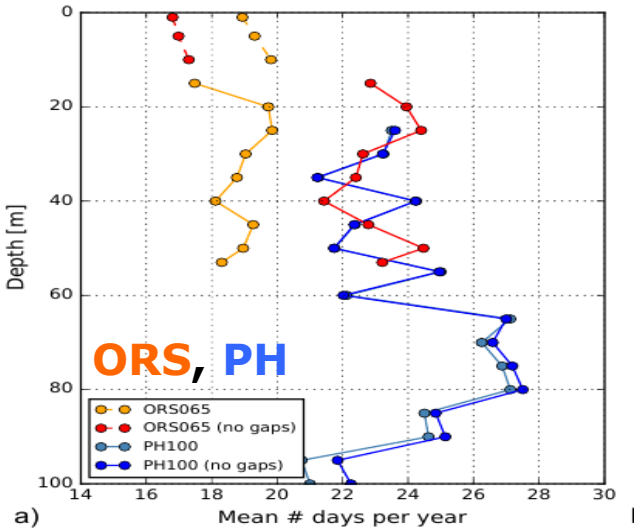
Characteristics of MHWs



~20 events at PH100 over 2010– 2016

~45 events at ORS
Average of 20-25 days / yr, maximum of 100 days /yr

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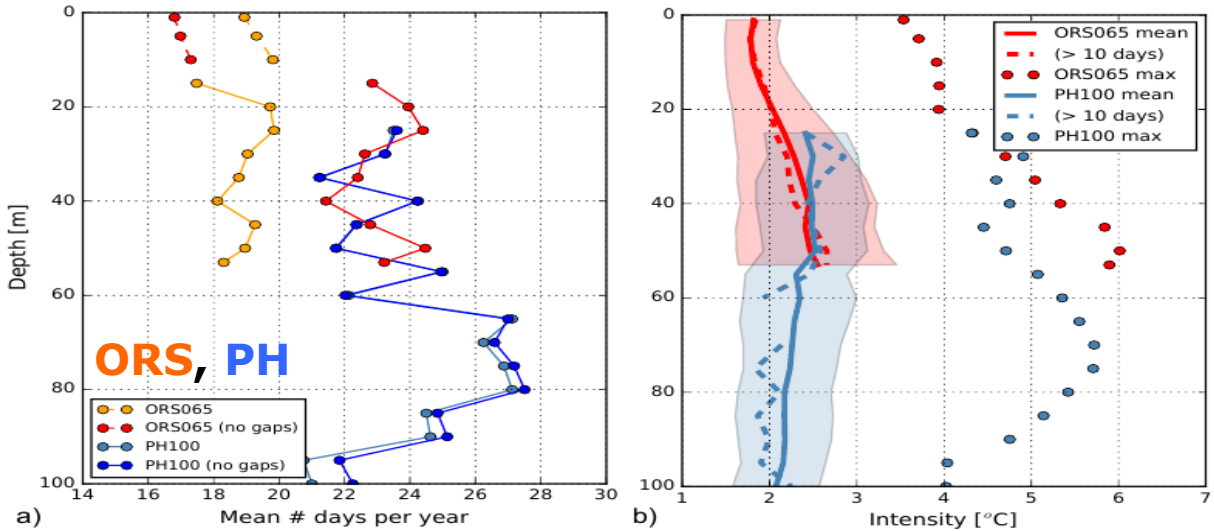

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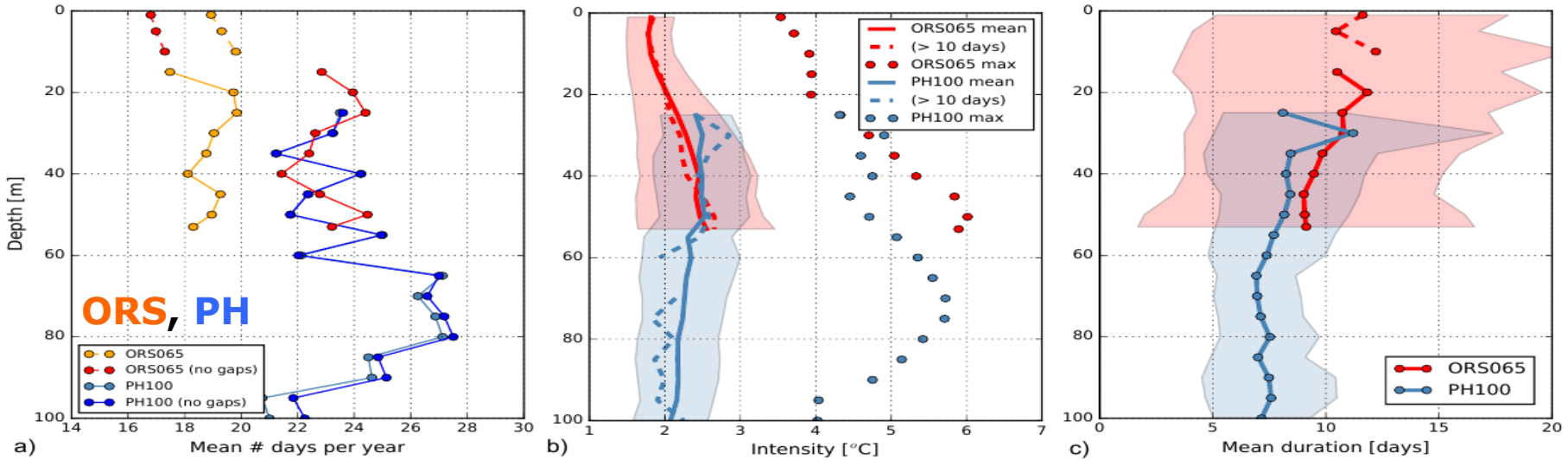
Intensity
Average ~2°C,
Maximum 5-6°C
Long events are not less intense

Characteristics of MHWs



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Average of 20-25 days / yr, maximum of 100 days /yr

Intensity
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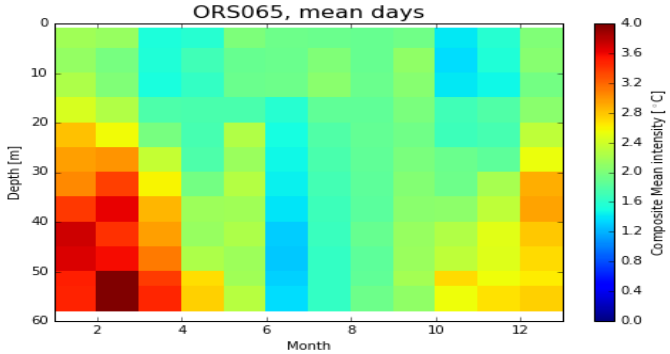
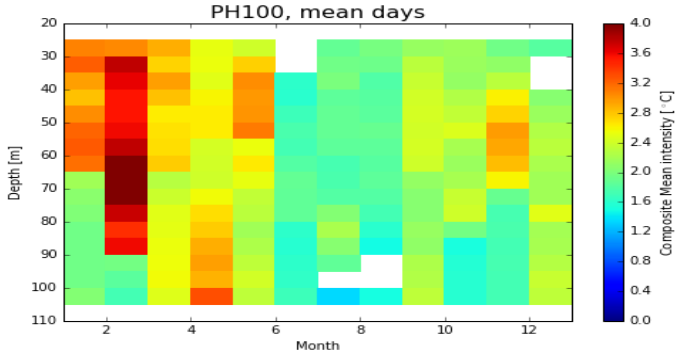
Long events are not less intense

Duration
Mean 7-10 days

Intensity





Depth Extent: 1/3 of events reach the bottom

The most intense MHWs happen at depth and not at the surface!

Mean intensities up to 4 ^{o}C above the climatology occur around 30-70 m in late summer, while anomalies in the surface layers (0 – 20 m) are on average < 2.5 ^{o}C

Matches the depth of the thermocline (just below), where the temperature variability is the greatest

Great impact on benthic species and phytoplankton productivity!

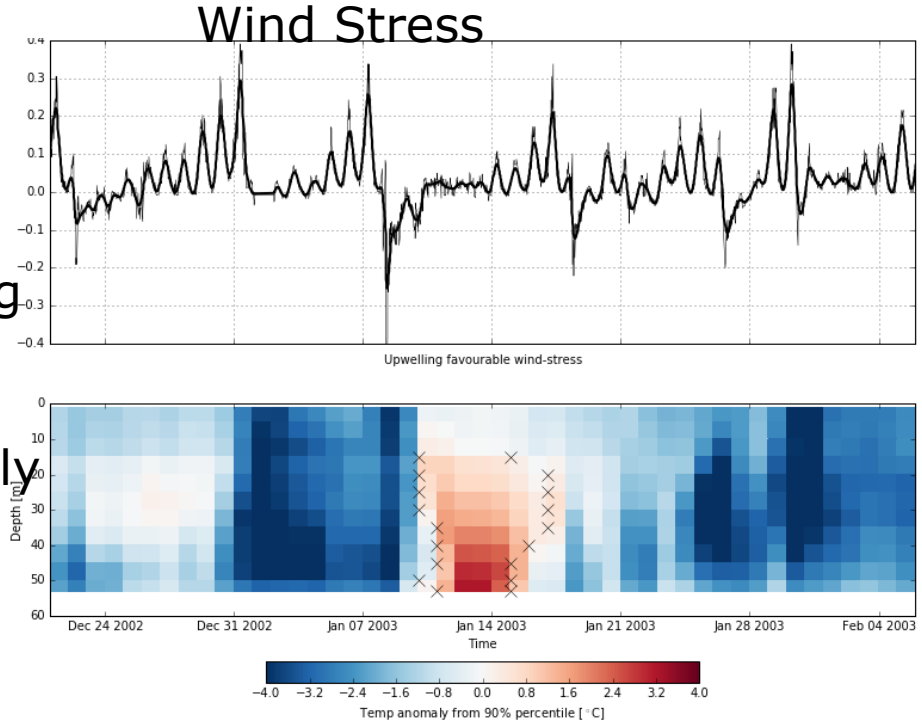
Drivers of MHWs at PH

Local wind drives temperature response in the coastal ocean

Upwelling

Downwelling

Temp Anomaly



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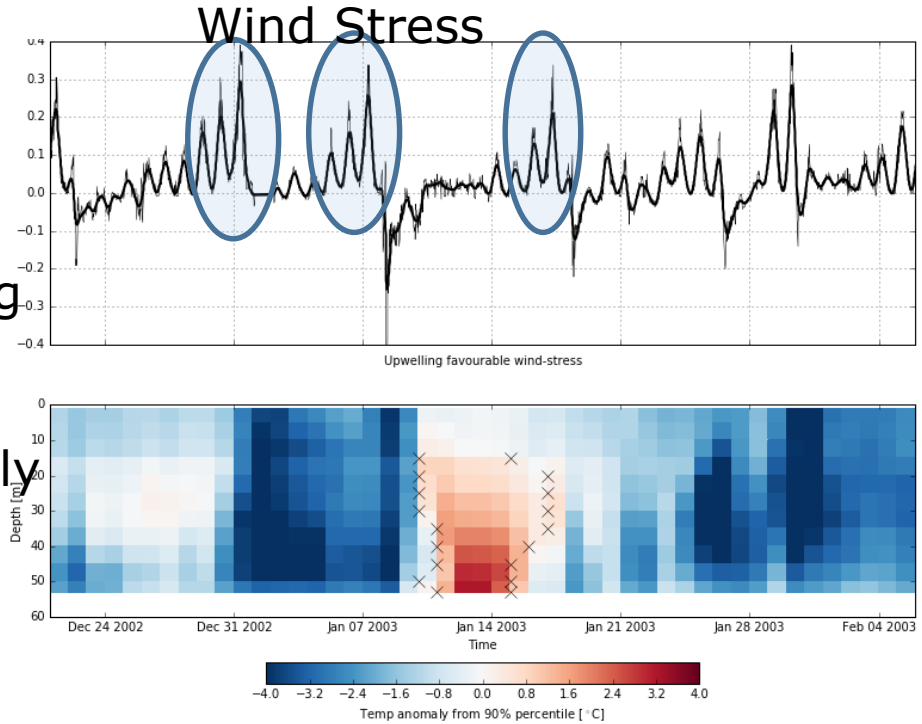


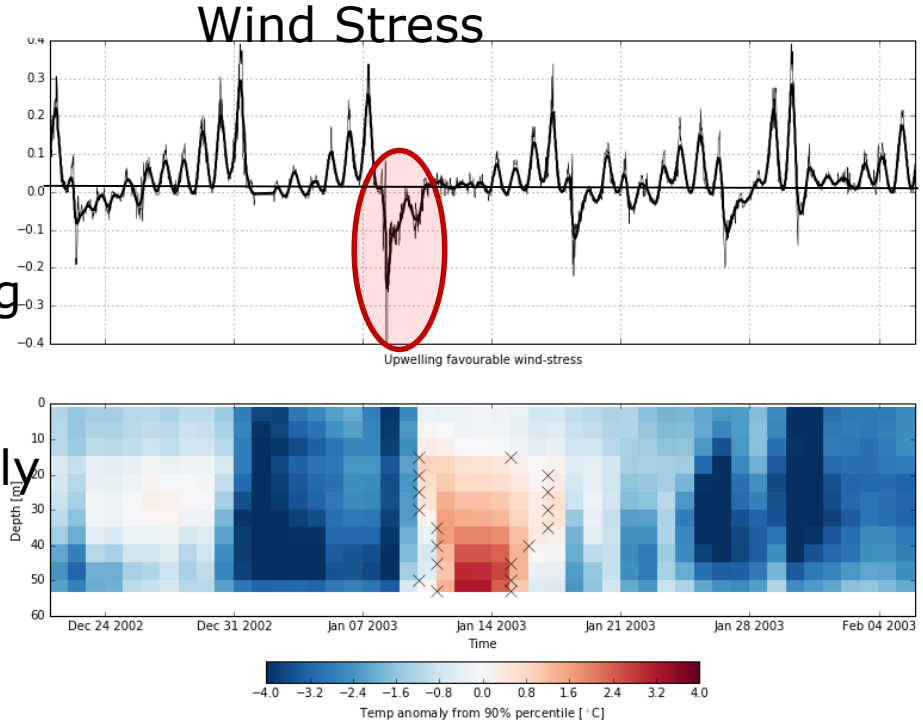
Drivers of MHWs at PH

Along-shelf (upwelling and downwelling favourable) winds can control the onset and decline of MHWs.

Upwelling

Downwelling

Temp Anomaly



Operational Considerations – Salmon Aquaculture

Tasmanian Salmon farming

- Industry is worth ~$550 million per year,
- Projected to be a billion-dollar industry within 20 years.
- Rapidly surpassing other fisheries

Chile: 2nd largest exporter of Salmon $4.5B

NZ Aquaculture represented $500M (2011), and King Salmon is 10-15% of that.

NZ is one of the few places globally to farm king salmon (considered superior!)

Operational Considerations – Salmon Aquaculture

Salmon cannot regulate their body temperature.

King Salmon need water temperatures 12-17^{o}C

Pens extend through the water column (24m)

NZ - Summer 2015 water temperatures stayed above 18^{o}C for three months

Cardiovascular capacity is lowered, when temps increase, fish become more vulnerable to disease and predators. If the temperature gets too high, it can be fatal.

Large numbers of salmon died in the Marlborough Sounds creating a "multimillion-dollar problem" for New Zealand King Salmon

Chile - March 2016 $800M in losses (100,000Tonnes lost) with sea temps 2-4 deg above average and HABS.

MHWs and Ocean Warming - Operational Considerations

Temperatures regularly exceeding 18 degrees in summer.

Long term temperature trends?

Trends in MHWs?

- Are MHWs increasing in frequency / duration / intensity

What is the implication of sub surface intensification?

- Pen Depth ?

How long is too long?

- Off Sydney MHWs last 7-10 days, but could be longer further south.

Needs and Recommendations

Long term sub-surface temperature data to further assess trends, impacts and drivers

[Access to existing data!]

Real time data for ongoing monitoring

Short term ocean forecasting (Weather timescale 1-7days)

Seasonal forecasts (2 weeks – 9 months)

minimise impacts

maximise opportunities.

Climate Forecasts – Long term planning

Conclusions

60+ years of temperature data through the water column used to identify MHWs

- Occur **all year long**, for approx.1-2 weeks on average, with mean temperature anomalies of ~2-2.5^{o}C.
- Regularly extend to the bottom the shelf, and are **most intense at depth**, around the thermocline (~30-70m) and in the end of summer.
- Local wind forcing influences their onset and decline, with predominantly downwelling favourable winds at the onset, while upwelling can halt the temperature anomaly.

Operational Considerations

Aquaculture Industry is being heavily impacted by sustained warming and MHWs.

What got us here, won't get us there….

Acknowledgements

Our thanks to the NSW-IMOS moorings, glider and radar teams, the broader IMOS community, Clive Holden OFS, Sydney Water, SIMS and UNSW.

The UNSW Coastal and Regional Oceanography Group is online at: www.oceanography.unsw.edu.au

All papers: http://www.oceanography.unsw.edu.au/publications.html

All Data freely available: http://imos.aodn.org.au/imos/

Integrated Marine Observing System (IMOS) – IMOS is a national collaborative research infrastructure supported by Australian Government.

“marineHeatWaves” module for python was written by E. Oliver.

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