Advanced ROMS near real-time **atmosphere-ocean** two-way nested **system for west coast of Australia**

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UWA / IOMRC

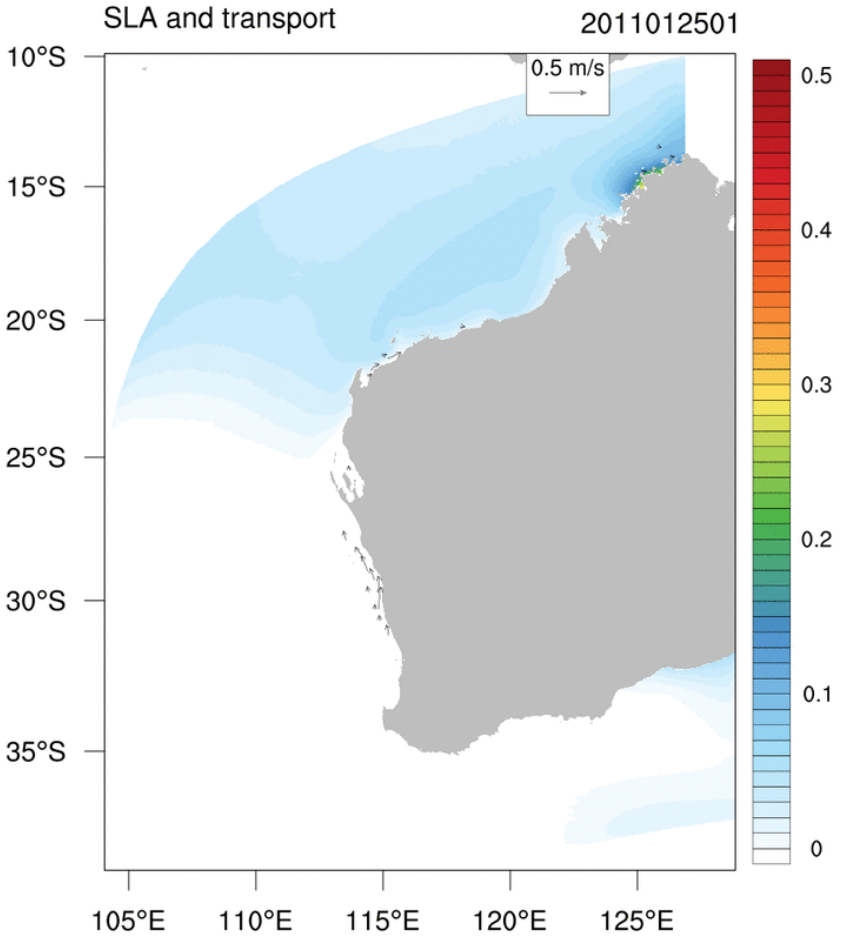
Government of **Western Australia**
Department of **Fisheries**

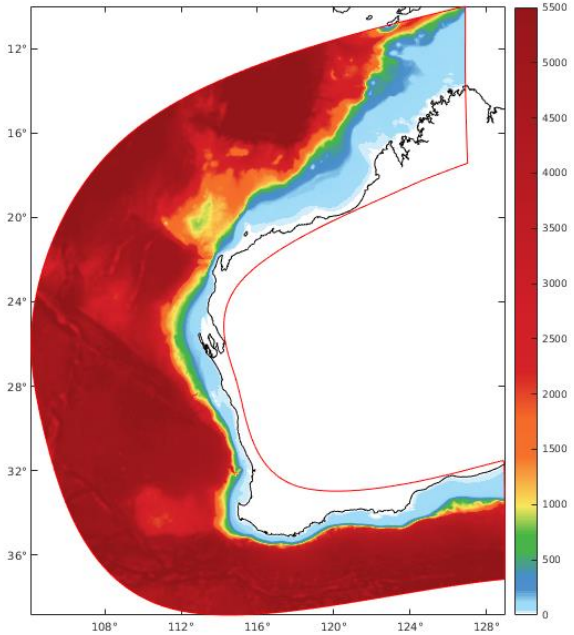
AUSTRALIAN INSTITUTE OF MARINE SCIENCE

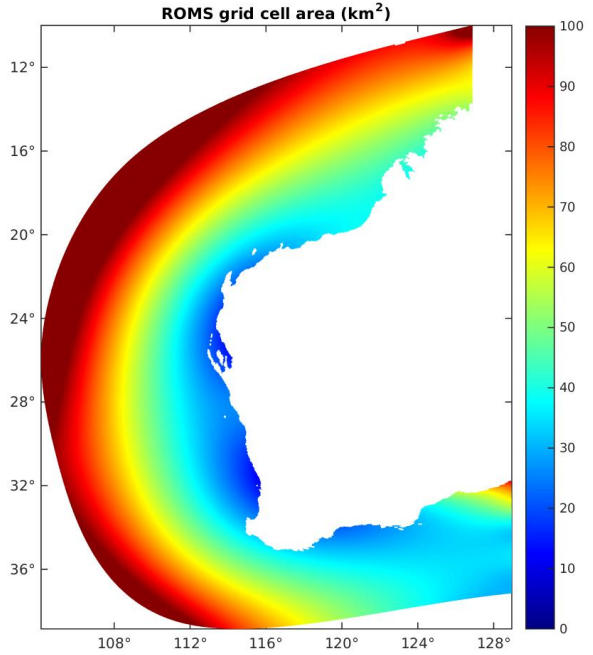
IMOS

CSIRO

WA ROMS modelling

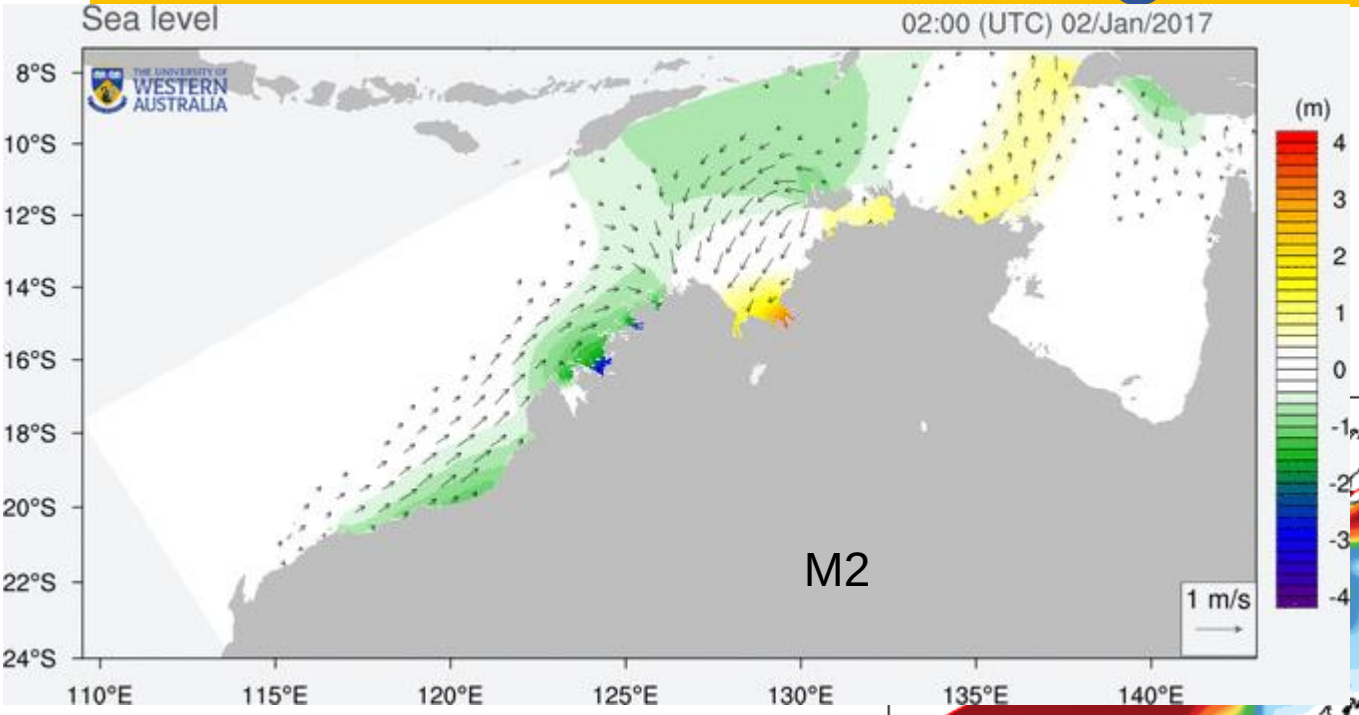




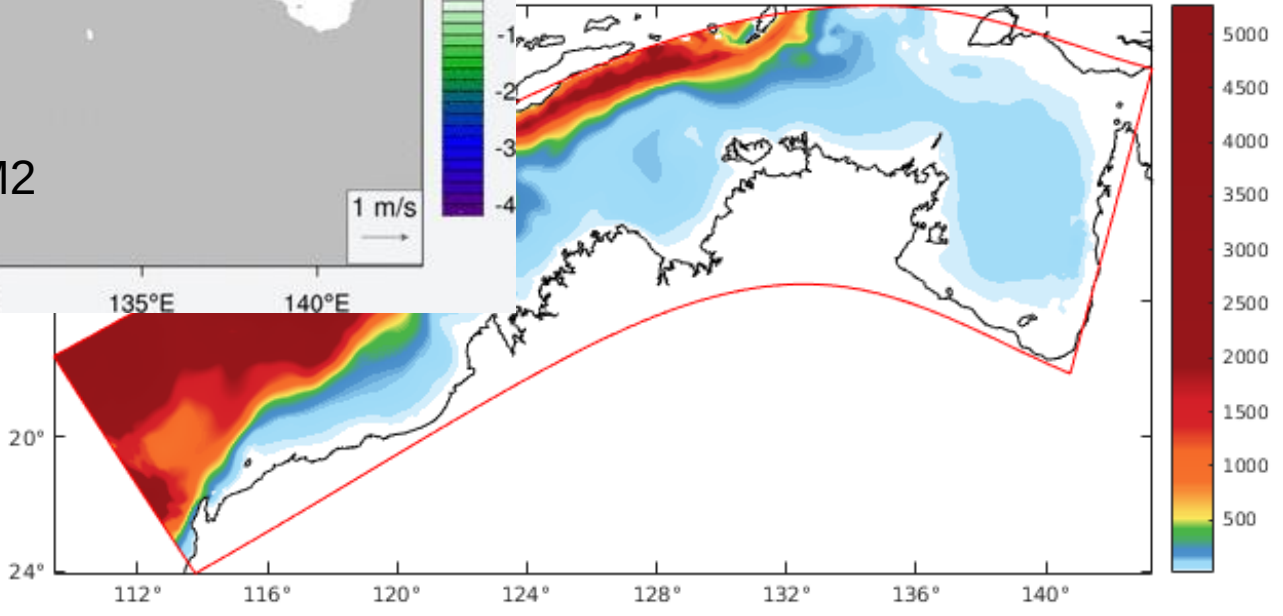


Bianca 2011 case, fast grid, near-realtime candidate

WA ROMS modelling



3D, 35 levels < 2 km
Realistic bathymetry
Internal tides/waves

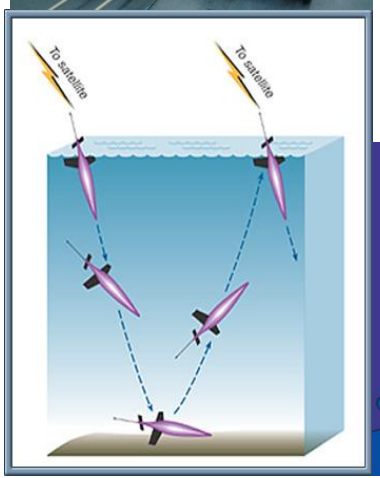


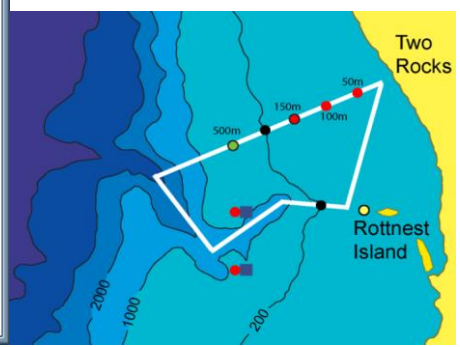
Observations

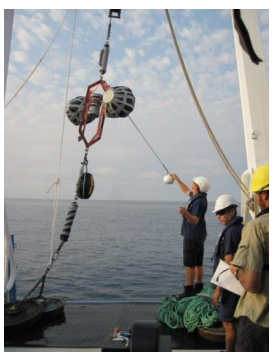
Ocean will always be under-sampled and unconstrained

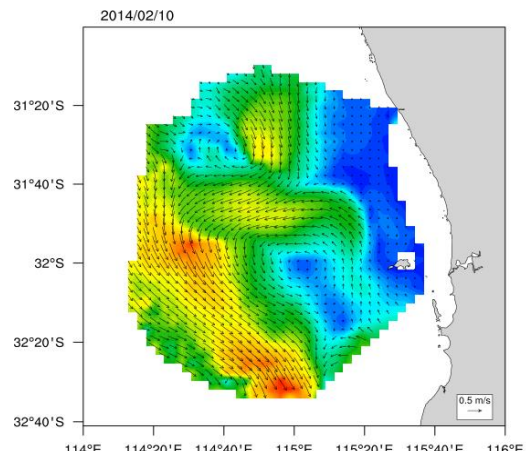
IMOS - providing glider, HF radar, ADCP/CTD moorings, ships, SST …

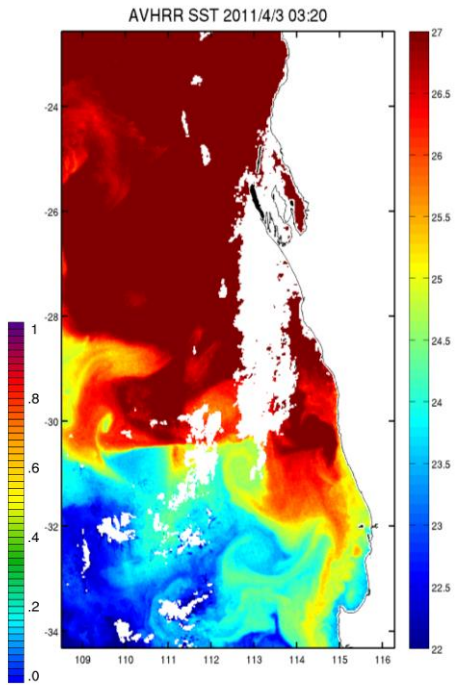
Global - satellite (SST, SSH, SSS) products, ARGO











Global models

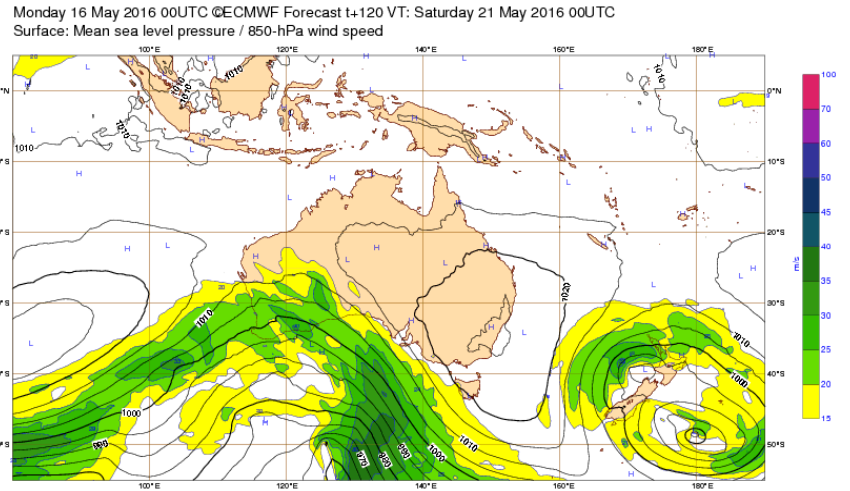
Atmosphere, global-regional scale:

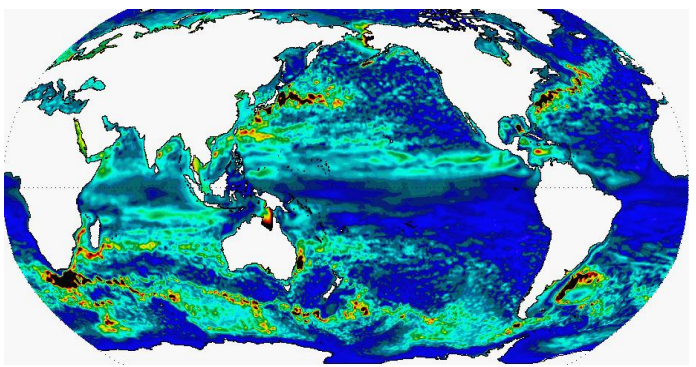
- ECMWF IFS (137 sigma, ~16 km ->9km)
  - Restricted access for real-time
- US GFS (~13 km), 0.25º ~25 km
  - Free access via openDAP
- Australia ACCESS (R~12 km, C~4 km)
  - Restricted

Ocean

- US Hycom (1/12º) with nesting (1/25º)
- France Mercator (1/12º) with nesting (1/36º)
- Australia BLUElink (OCEANmaps) 0.1º

Provide forcing and/or local nesting brys and init





Global Sea Level variability simulated by the Mercator high resolution global ocean model.

Local models / operational

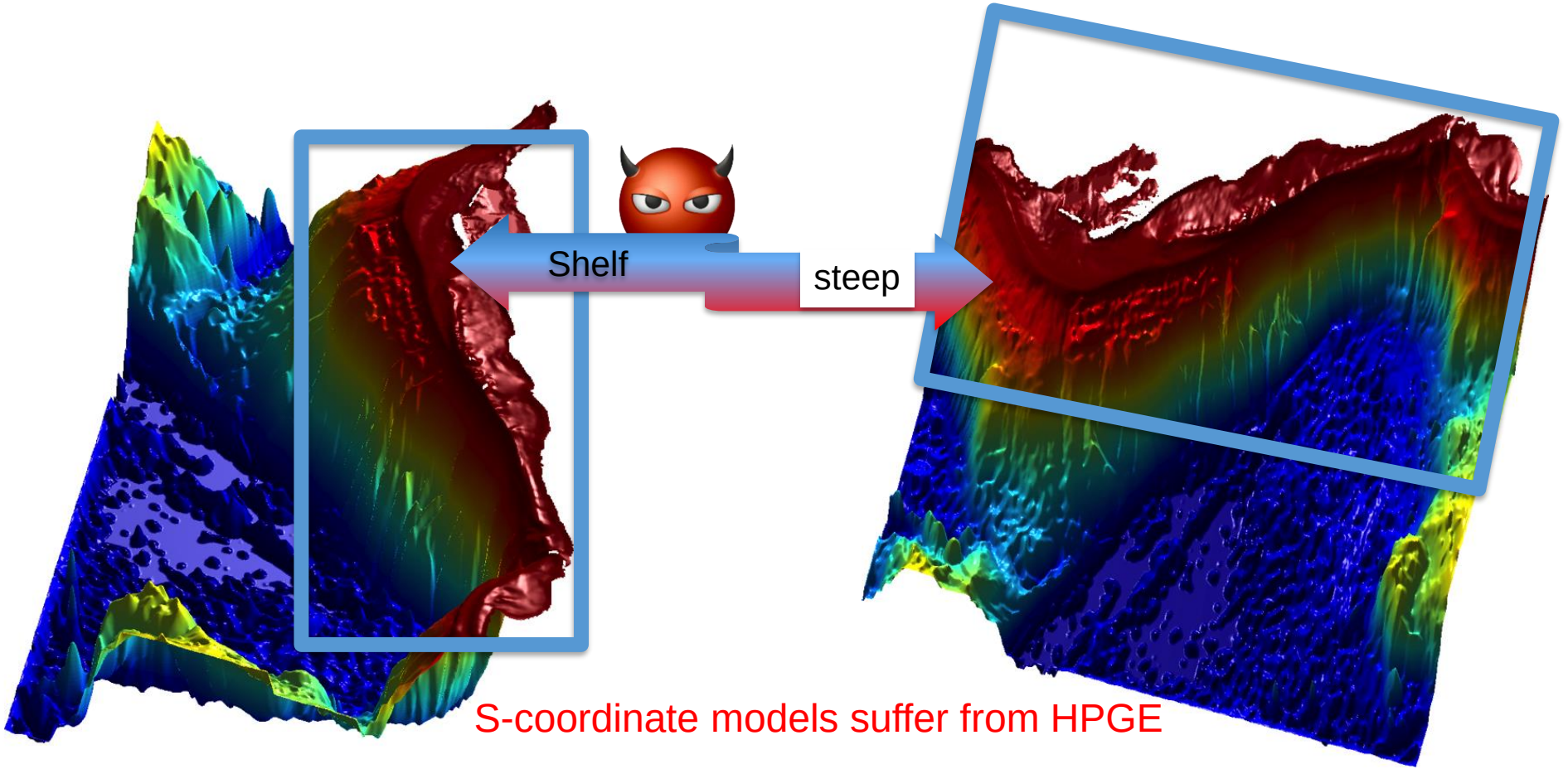
- ROMS model is the (only) “serious” ocean model today
  - MIT licenced, ocean community model, used by many, supported/documented
  - time split, finite difference, parallelized (MPI), small to global scale
  - **2-way coupling with atmosphere/waves, MCT**
  - assimilation comparable to the atmosphere **4DVar IS/PSAS/EKF**

- WRF-ARW – modern NWP model
  - Used to downscale global models at local high res
  - 2-way nesting, vortex moving grids, non-hydrostatic, etc…

- Wave models – spectral models
  - WWM III & SWAN implicit time scheme, WW3 global and local WAM …

1) Janeković et al., 2013. **4D-Var Data Assimilation in a Nested, Coastal Ocean Model: A Hawaiian Case Study**. *Journal of geophysical research*. **118**
2) Matthews, D., Powell, B., Janeković, I. 2012. **Analysis of Four-dimensional Variational State Estimation of the Hawaiian Waters**. *Journal of geophysical research*. **117**
3) Dutour Sikirić et al., 2012. **Hindcasting the Adriatic Sea near-surface motions with a coupled wave-current model**. *Journal of geophysical research* **117**

Western coast of Australia



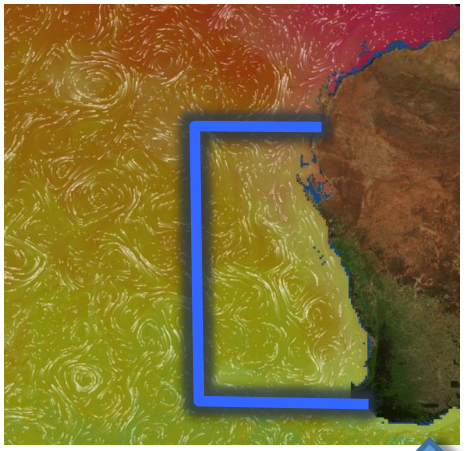
S-coordinate models suffer from HPGE

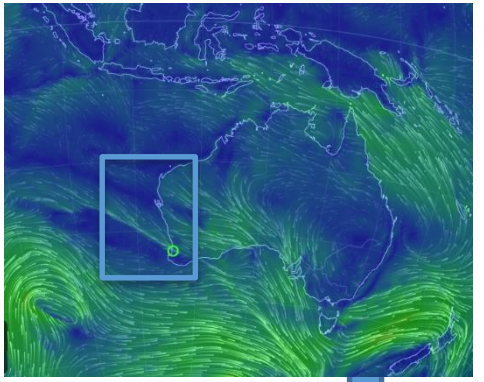
Dutour-Sikirić, M. Janeković, I., Kuzmić, M. 2009. **A new approach to bathymetry smoothing in sigma-coordinate ocean models**. *Ocean Modelling*. 29

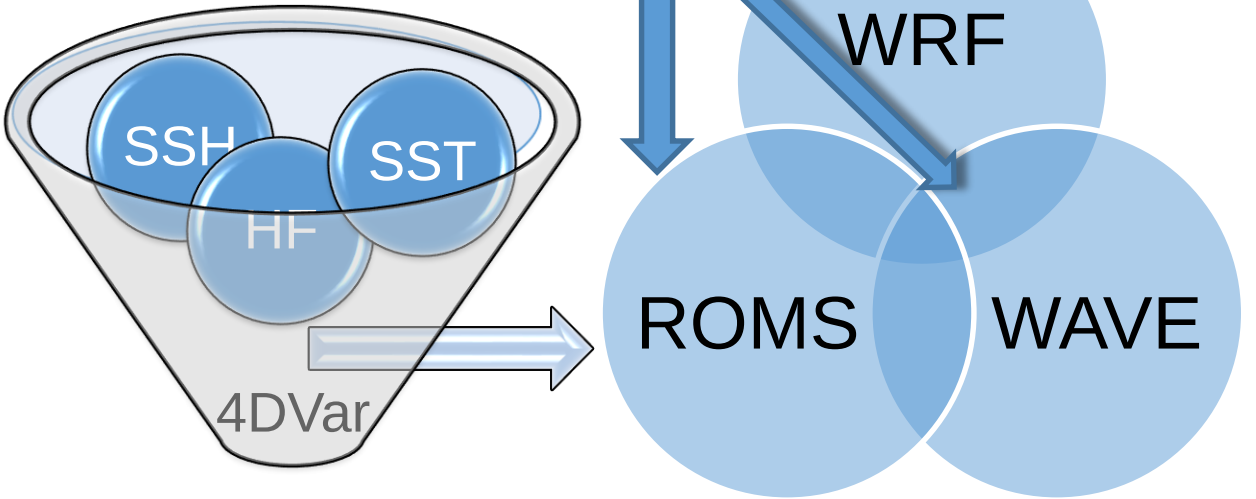
Near real-time system

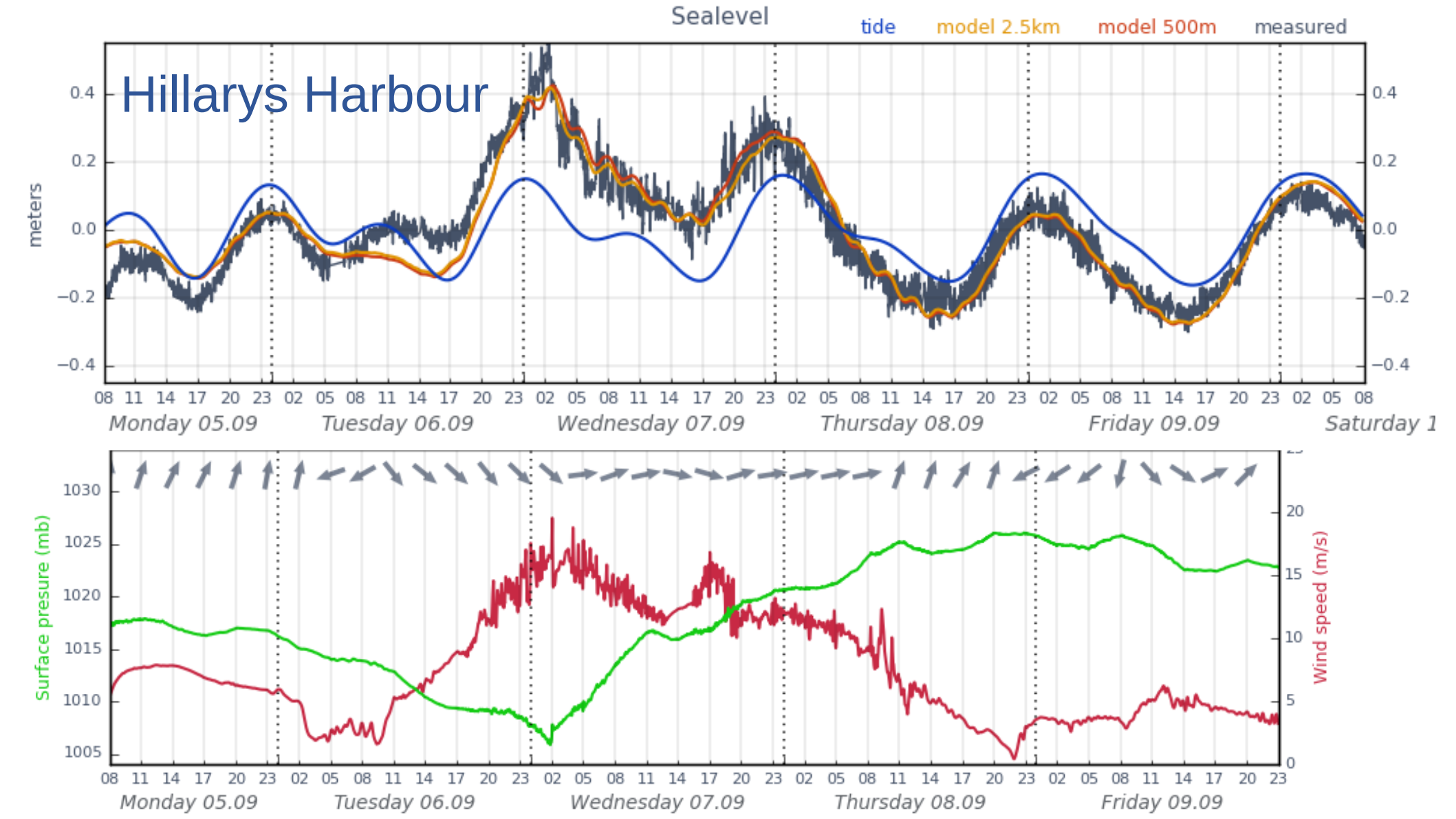
- Open source system
- Linux /shell scripts from scratch
- Modular design
- Python/php/js
- Tomcat/openDAP (TB)

- CPU 48 ->192
- All modules are here
- Need users/project








Sealevel
tide
model 2.5km
model 500m
measured
Hillarys Harbour
meters
0.4
0.2
0.0
−0.2
−0.4
08 11 14 17 20 23 02 05 08 11 14 17 20 23 02 05 08 11 14 17 20 23 02 05 08 11 14 17 20 23 02 05 08 11 14 17 20 23 02 05 08
Monday 05.09
Tuesday 06.09
Wednesday 07.09
Thursday 08.09
Friday 09.09
Saturday 1
Surface presure (mb)
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1010
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Wind speed (m/s)
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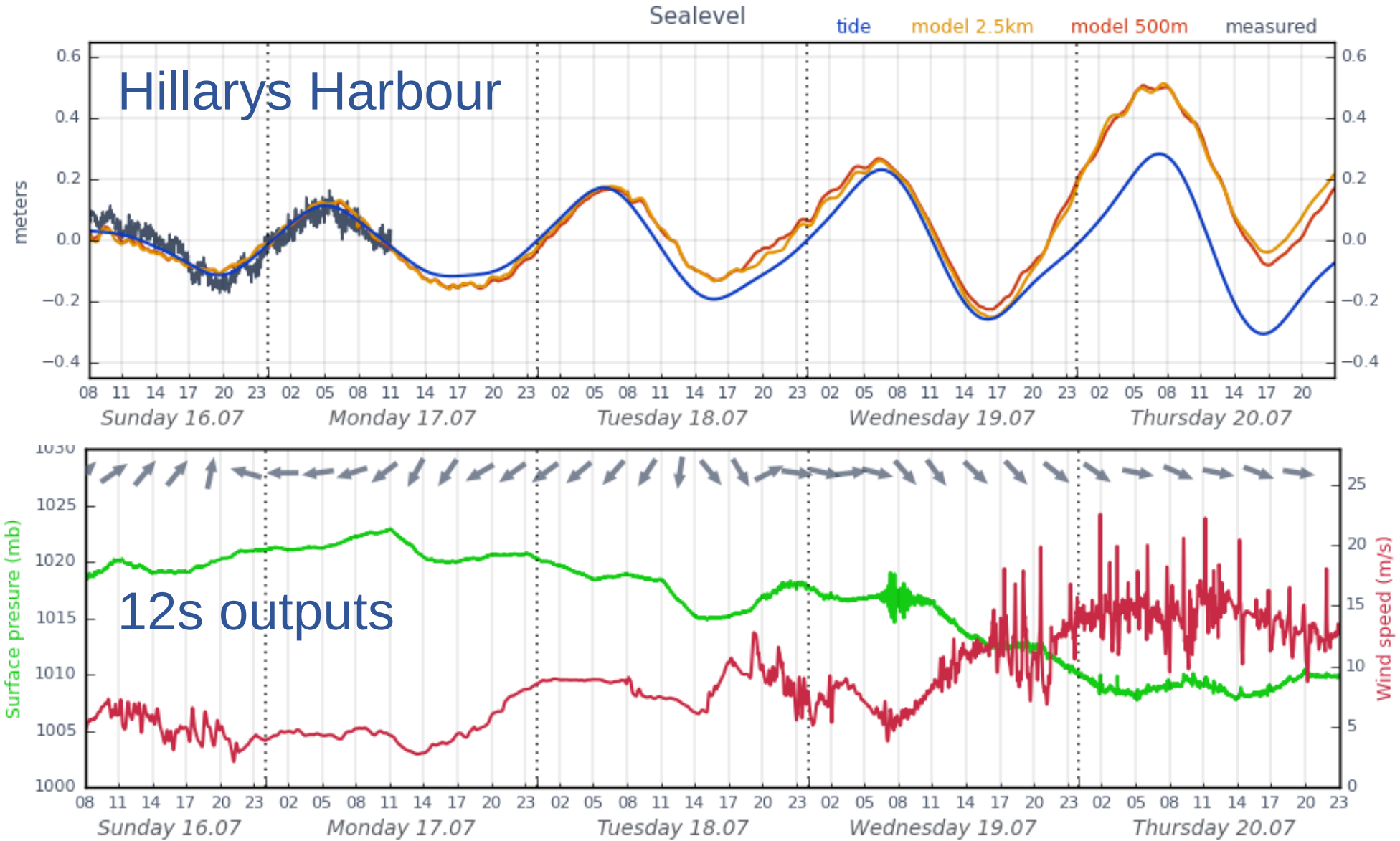
Monday 05.09
Tuesday 06.09
Wednesday 07.09
Thursday 08.09
Friday 09.09


Sealevel
tide
model 2.5km
model 500m
measured
Hillarys Harbour
meters
0.6
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0.2
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−0.2
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Sunday 16.07
Monday 17.07
Tuesday 18.07
Wednesday 19.07
Thursday 20.07
12s outputs
Surface presure (mb)
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1025
1020
1015
1010
1005
1000
Wind speed (m/s)
25
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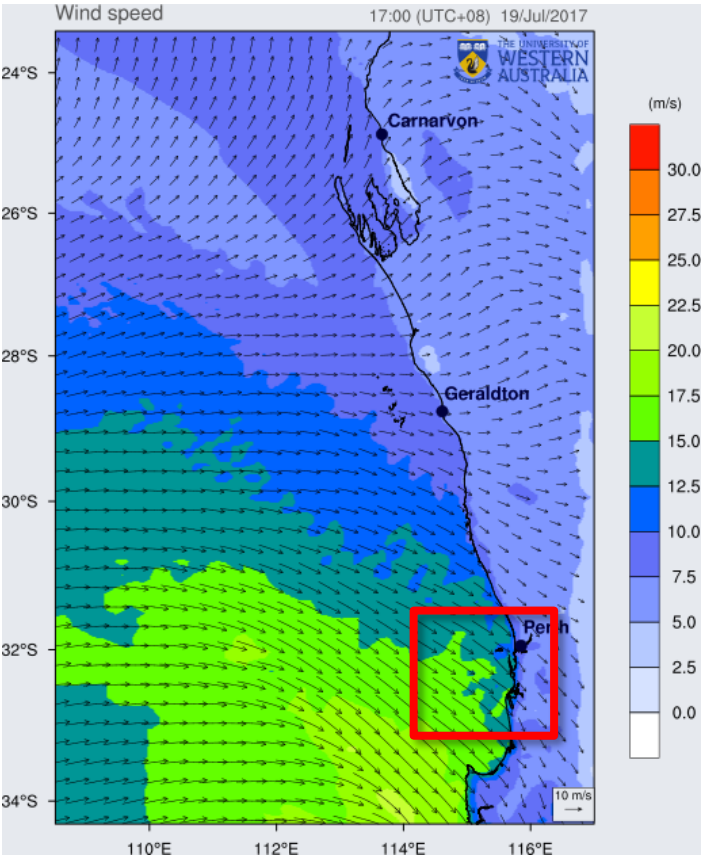
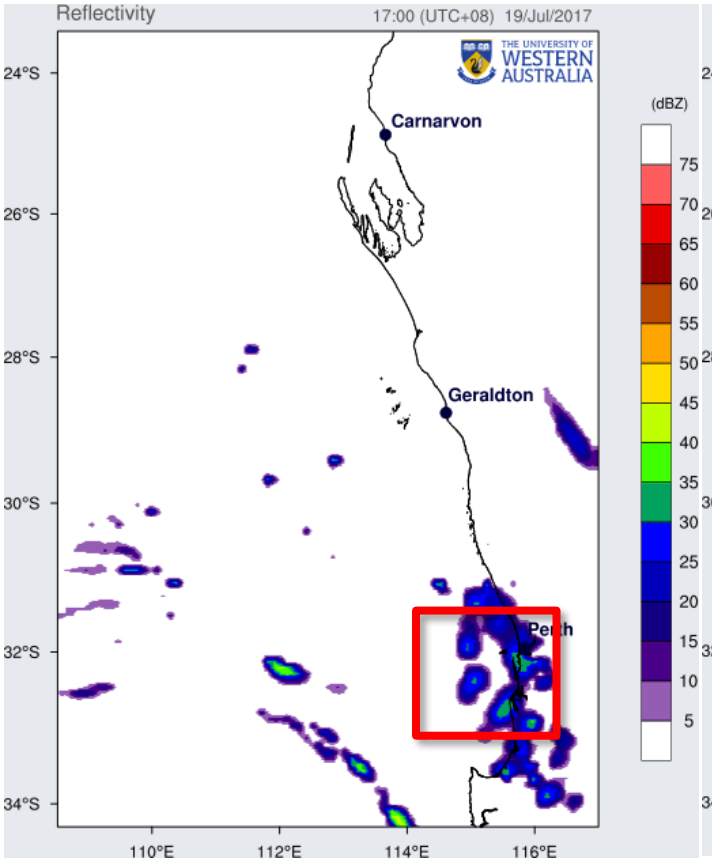
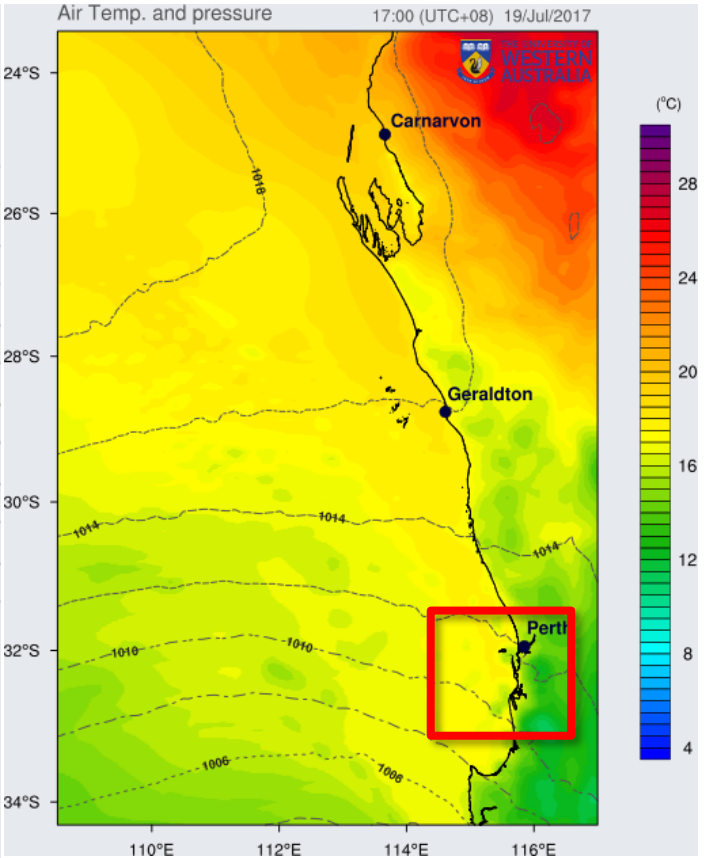
15
10
5
0
08 11 14 17 20 23 02 05 08 11 14 17 20 23 02 05 08 11 14 17 20 23 02 05 08 11 14 17 20 23 02 05 08 11 14 17 20 23
Sunday 16.07
Monday 17.07
Tuesday 18.07
Wednesday 19.07
Thursday 20.07

Atmospheric WRF local model

WRF-ARW, 2-way nesting big domain 10 km, 60s using GFS 0.25º for initial and bry

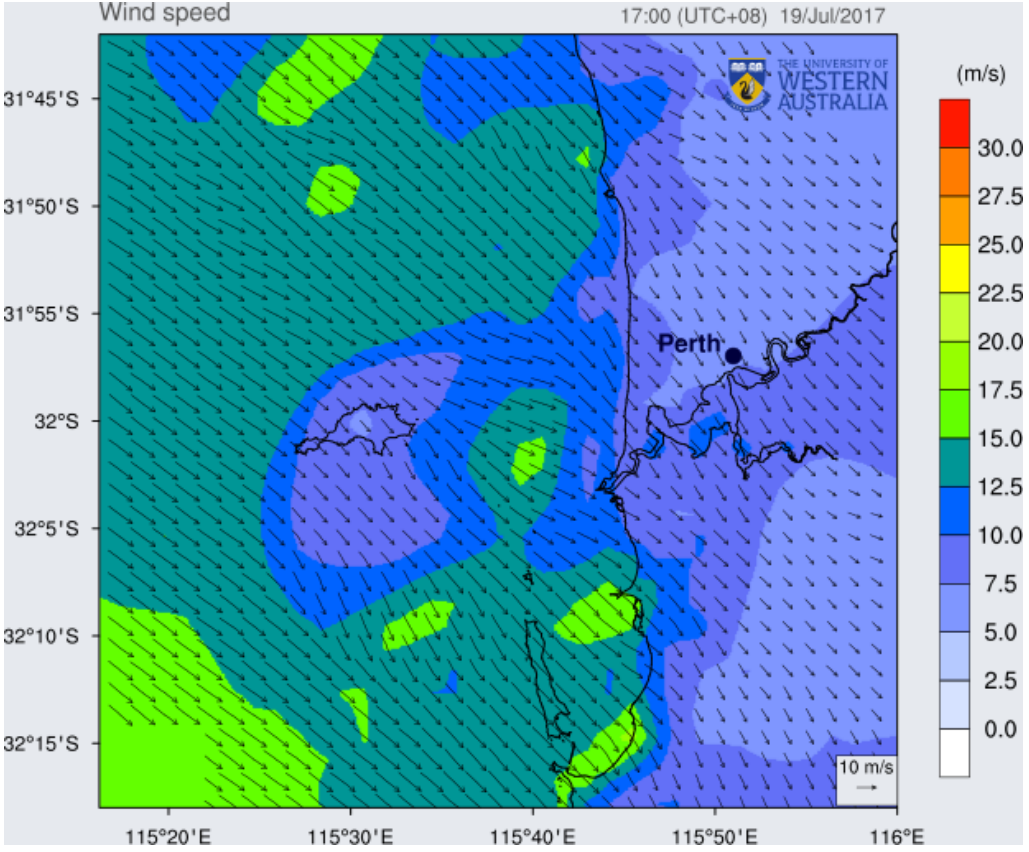


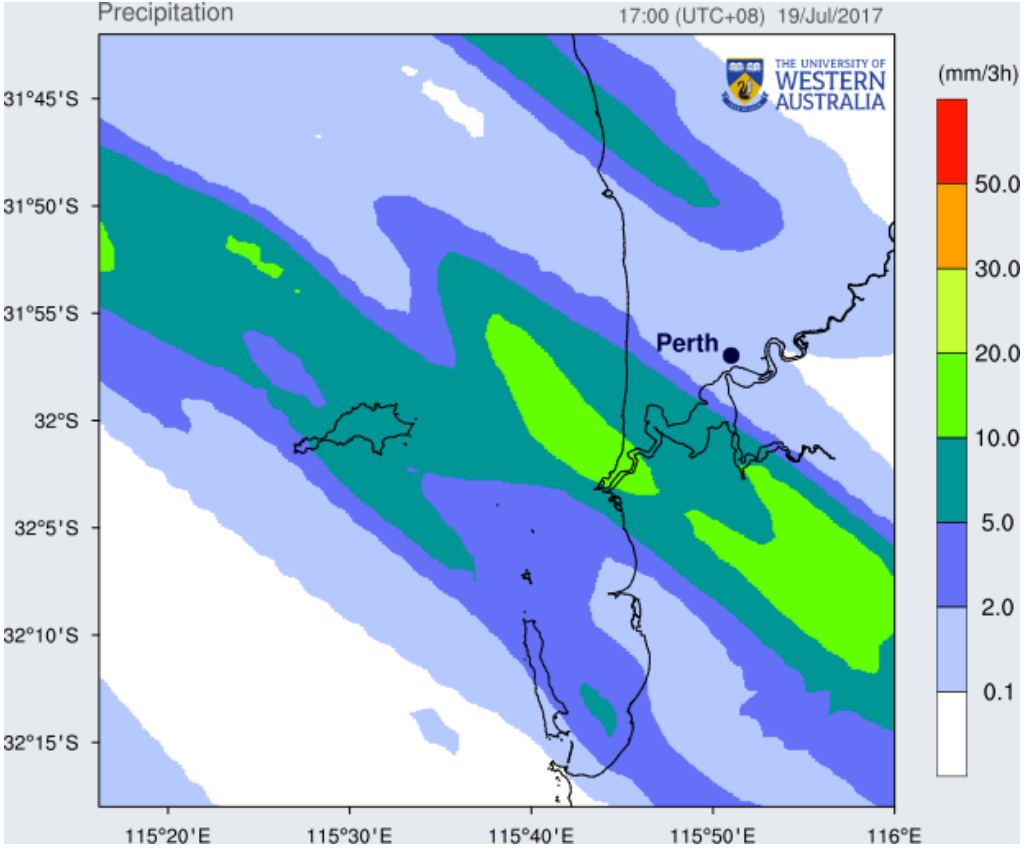




Atmospheric WRF local model

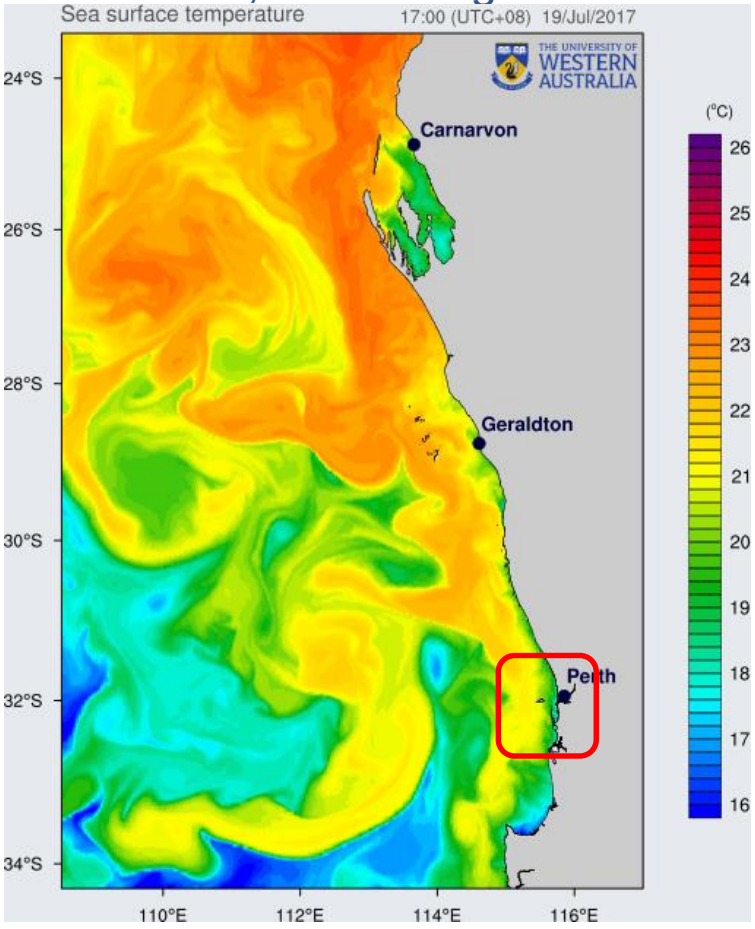
2-way nesting, 2 km res. inside big domain (10km), different physical params (dt 12s)

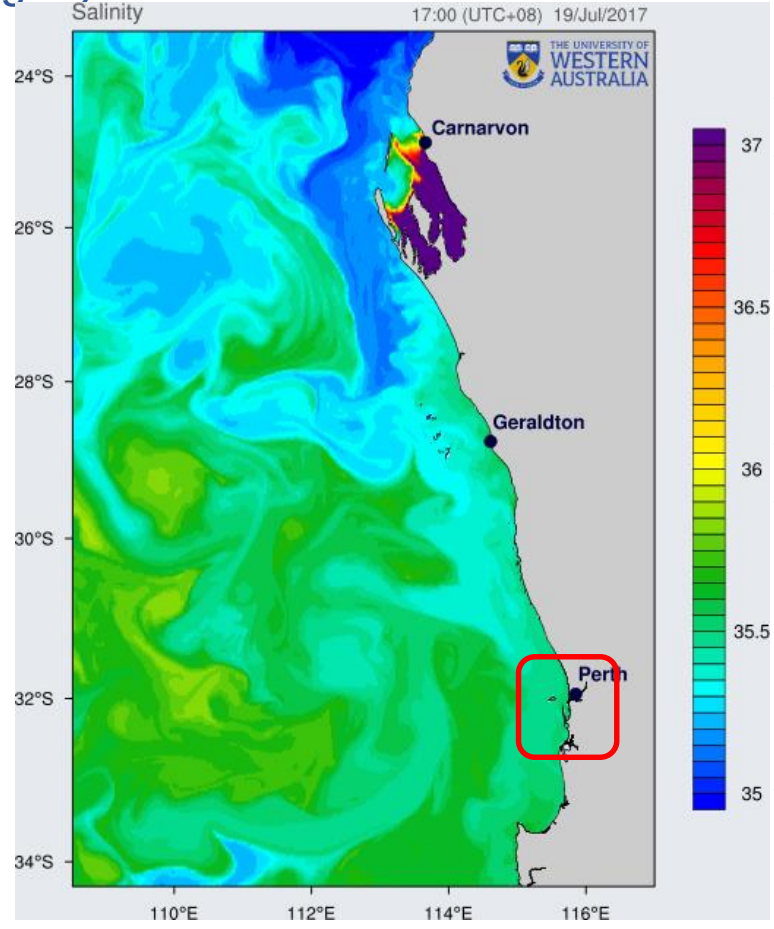




Ocean ROMS local model

ROMS, 2-3 km big domain using Hycom and Mercator boundaries with nested 500m

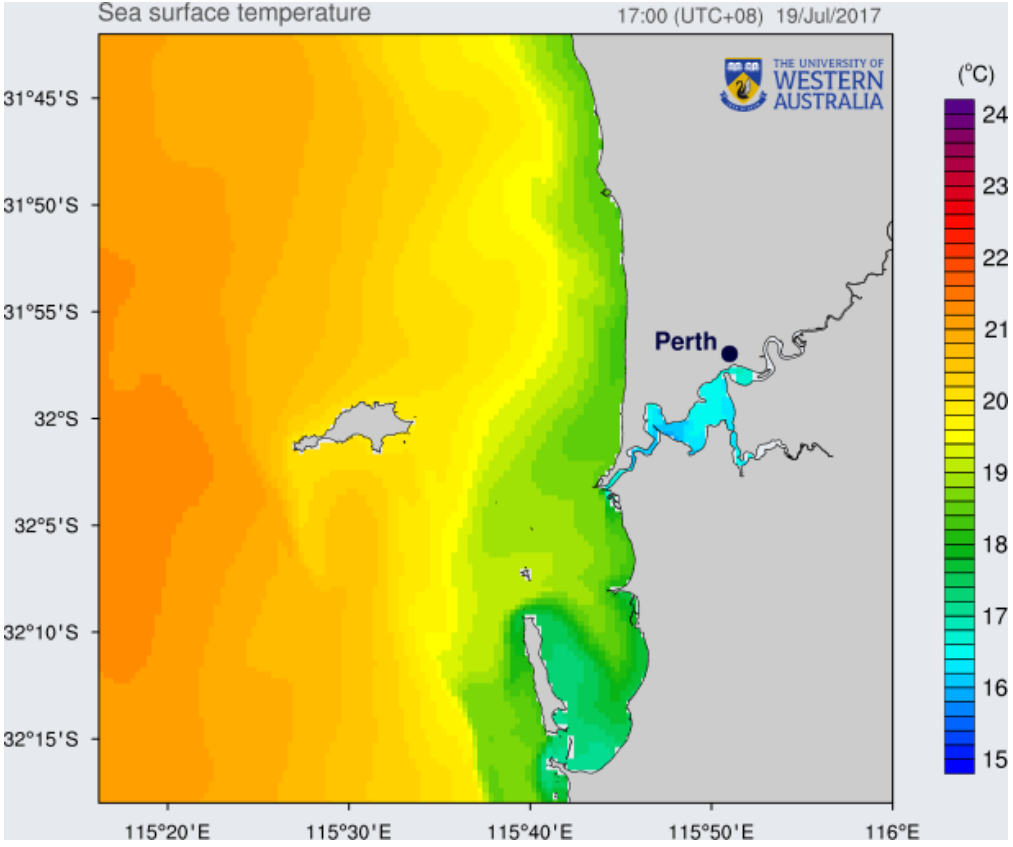


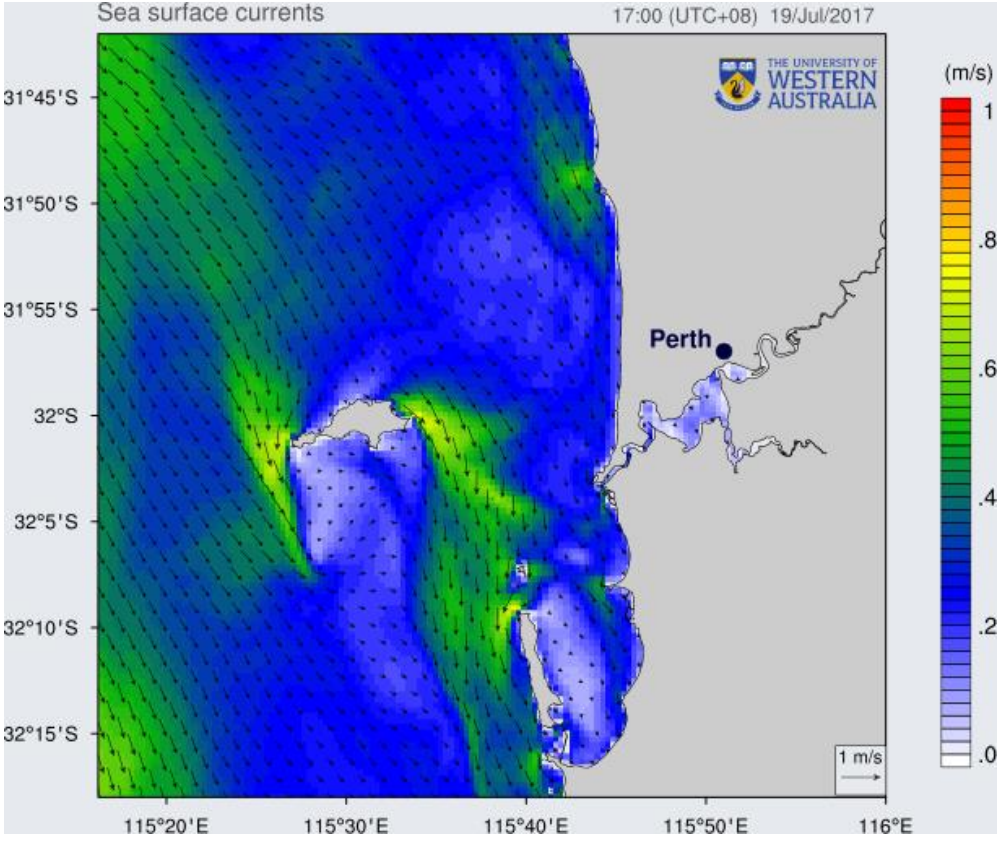


- 25 sigma levels
- 640x480 curved
- LP smoothed bathy
- Resolve shelf
- Dense water
- Tides (8 harm), bulk
- 2011-today
- Data assimilation using SST, SSH, HF, gliders, ADCP, CTD,… currently not operationally used (need project/CPU)
- 2-way coupling (not op.)

Ocean ROMS local model

ROMS 500m nested domain, 20 lev, boundaries 1-way @ 10min, Swan river, 1h outputs





Ocean ROMS local model

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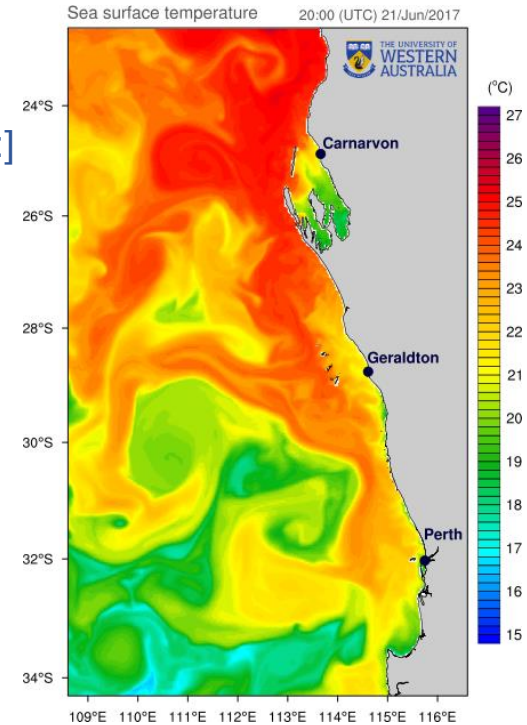
Catalog http://130.95.29.59:8080/thredds/catalog.html

Dataset

- ROMS CWA model grid file
- ROMS CWA 2011 - 2014 model outputs/
- ROMS CWA 2015 and relatime model outputs/
- ECMWF 2011-2015 model outputs/
- NCEP GFS 0.25deg model outputs/
- WRF model outputs for CWA/
- AU GRID SCHISM-WWM FEM 1981 winter storms surge model outputs/
- AU GRID SCHISM-WWM FEM 2007 winter storms surge model outputs/
- AU GRID SCHISM-WWM FEM tidal model outputs/
- QLD GRID SCHISM-WWM FEM Yasi full coupling model outputs/
- QLD GRID SCHISM-WWM FEM Yasi Sxx_out coupling model outputs/

The UWA TDS server at The UWA OI see Info
THREDDS Data Server [Version 4.6.2 - 2015-06-09T15:16:47-0600] Documentation

```
url='http://130.95.29.59:8080/thredds/dodsC/realtime/agg_avg.ncml'
nc = netCDF4.Dataset(url)
lon_rho = nc.variables['lon_rho'][:]
lat_rho = nc.variables['lat_rho'][:]
temp= nc.variables['temp'][itime, -1, :, :]
```



Coastal Ocea

Region West Coast

Date 06.10

Wind
Air Temperature
Precipitation
Reflectivity
MCAPE
Surface Currents
Sea Temperature
Salinity

Coastal Oceanography

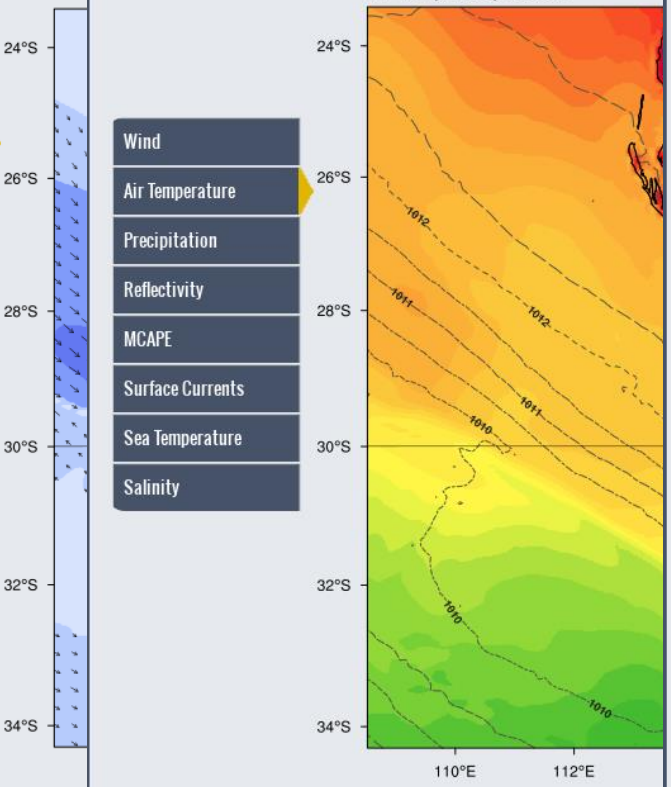
Region West Coast

Date 06.10.2016

Time (UT 02 05 08

WRF-ARW Model Results

Air Temp. and pressure



Wind
Air Temperature
Precipitation
Reflectivity
MCAPE
Surface Currents
Sea Temperature
Salinity

Coastal Oceanography

Home Time series Info Contact

Region West Coast

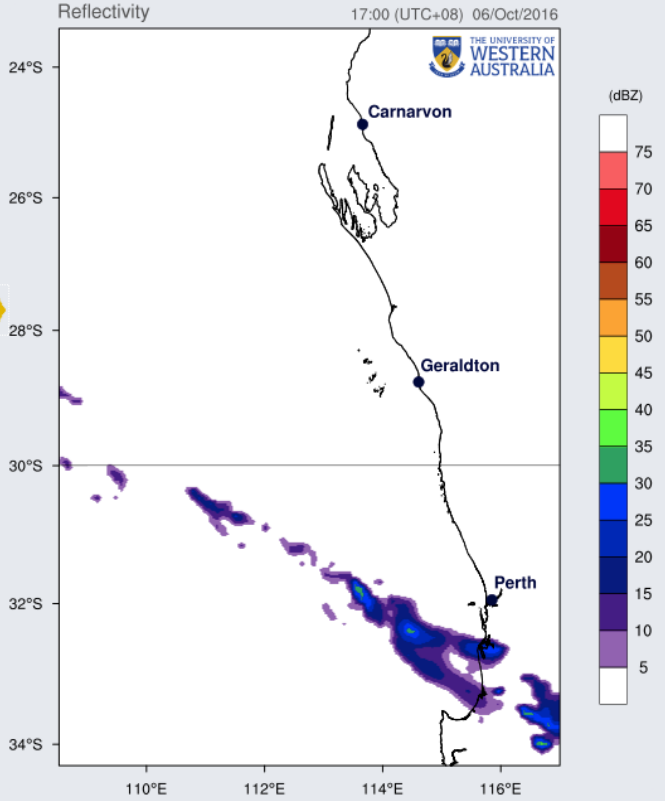
Date 06.10.2016

Time (UTC+8:00) 02 05 08 11 14 17 20 23

animation

WRF-ARW Model Results

Reflectivity 17:00 (UTC+08) 06/Oct/2016



Wind
Air Temperature
Precipitation
Reflectivity
MCAPE
Surface Currents
Sea Temperature
Salinity

Coastal O Coastal Oc Coastal Oceanogr Coastal Oceanography

Region: West Coast

- Wind
- Air Temperature
- Precipitation
- Reflectivity
- MCAPE
- Surface Currents
- Sea Temperature
- Salinity

Region: West Coast

- Wind
- Air Temperature
- Precipitation
- Reflectivity
- MCAPE
- Surface Currents
- Sea Temperature
- Salinity

Region: Perth | Date: 07.10.2016

- Wind
- Air Temperature
- Precipitation
- Reflectivity
- MCAPE
- Surface Currents
- Sea Temperature
- Salinity

ROMS Mo

Salinity

31°45'S
31°50'S
31°55'S
32°S
32°5'S
32°10'S
32°15'S
115°20'E

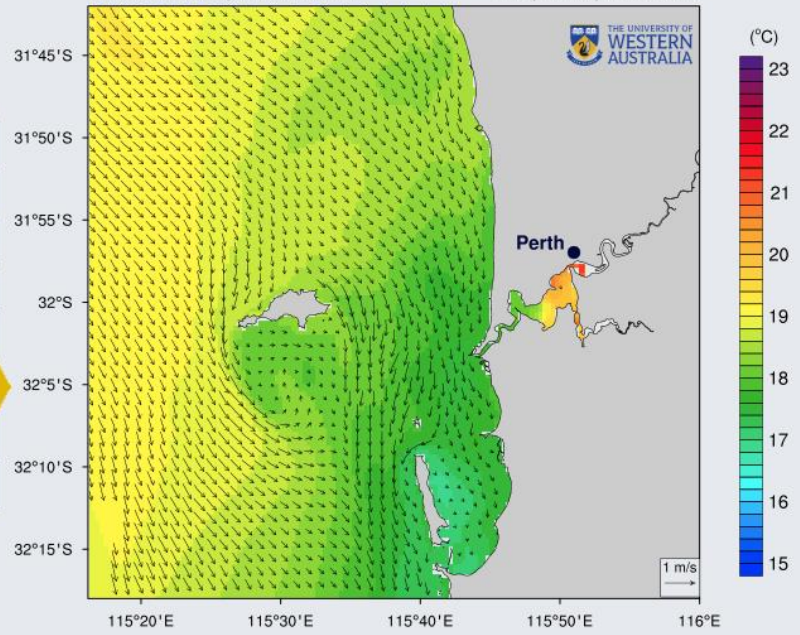
Region: Perth | Date: 06.10.2016 | Time (UTC+8:00): 02 05 08 11 14 17 20 23 | animation

- Wind
- Air Temperature
- Precipitation
- Reflectivity
- MCAPE
- Surface Currents
- Sea Temperature
- Salinity

ROMS Model Results

Sea surface temp. and currents

17:00 (UTC+08) 06/Oct/2016



Coastal Oceanography

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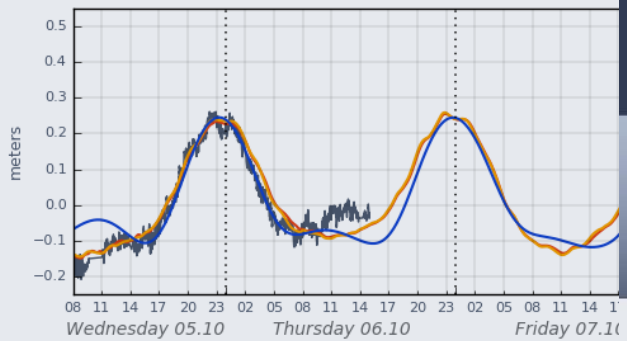
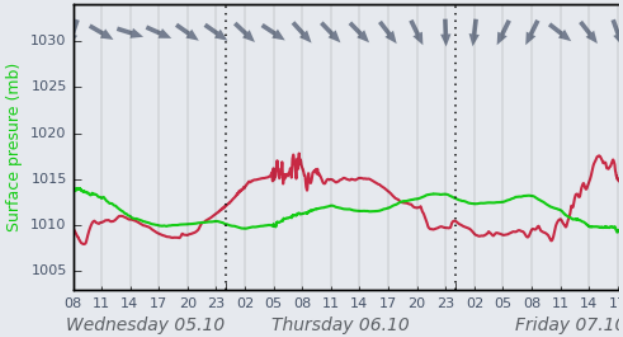
Stations

Hillarys Harbour

Sealev



Wind speed and



Coastal Oceanography

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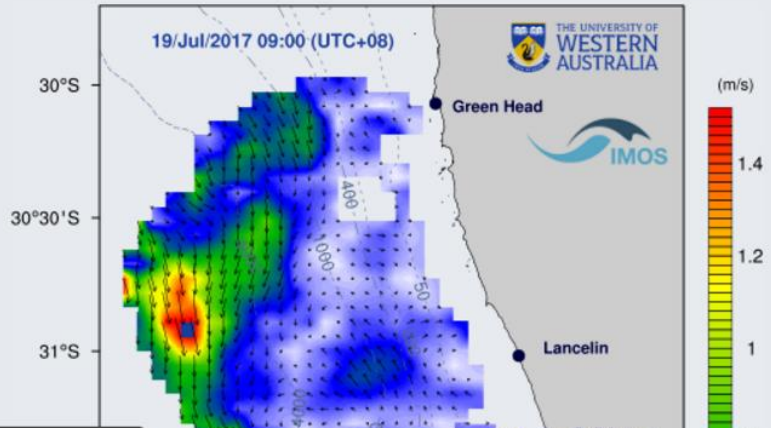
Date: 19.07.2017

Time (UTC+8:00): 00 01 02 03 04 05 06 07 08 **09** 10 11 12 13 14 15 16 17 18 19 20 21 22 23

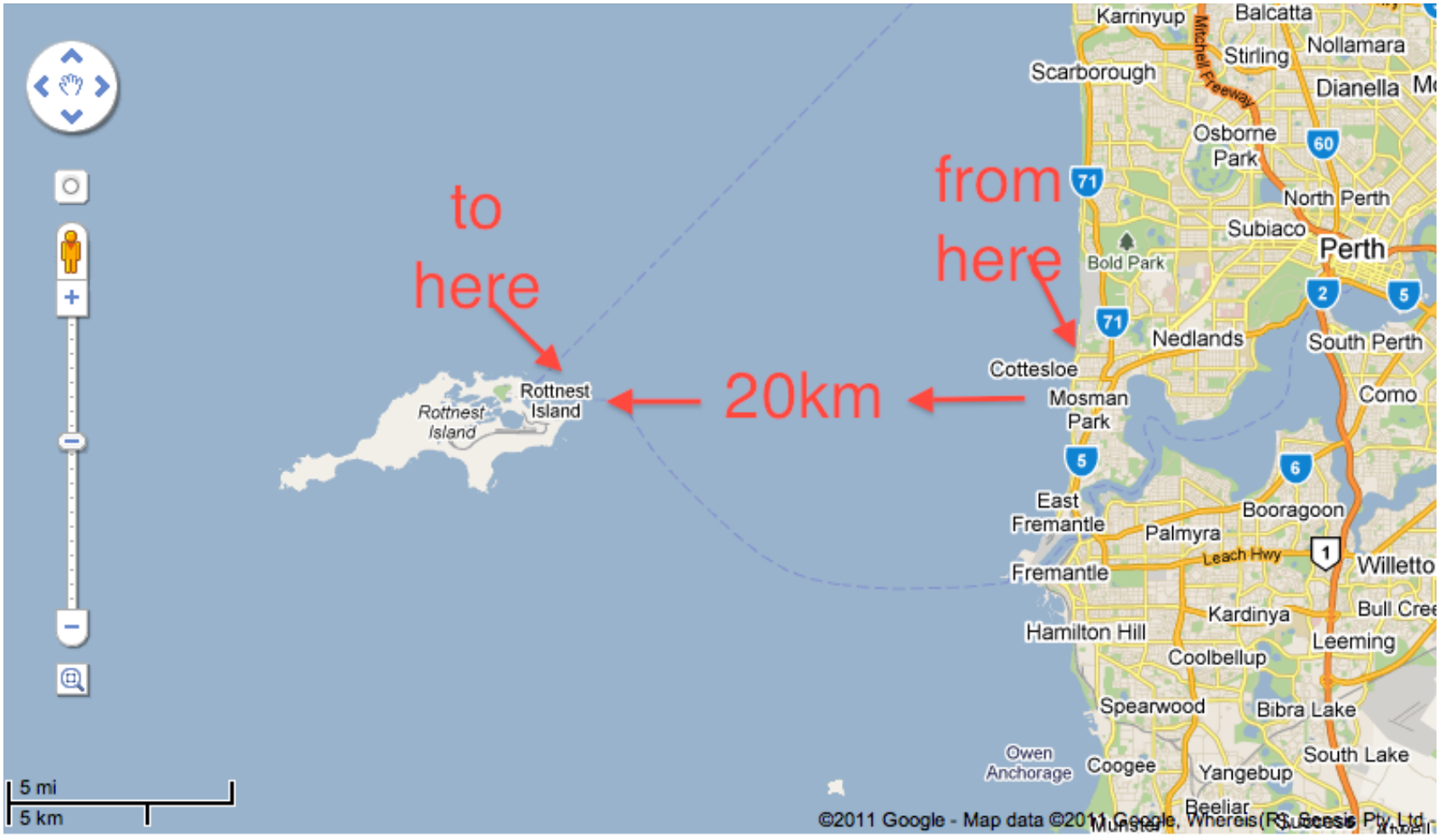
animation

Surface current map for 19.07.2017



Rottnest swim

Rottnest swim



IMOS Integrated Marine Observing System

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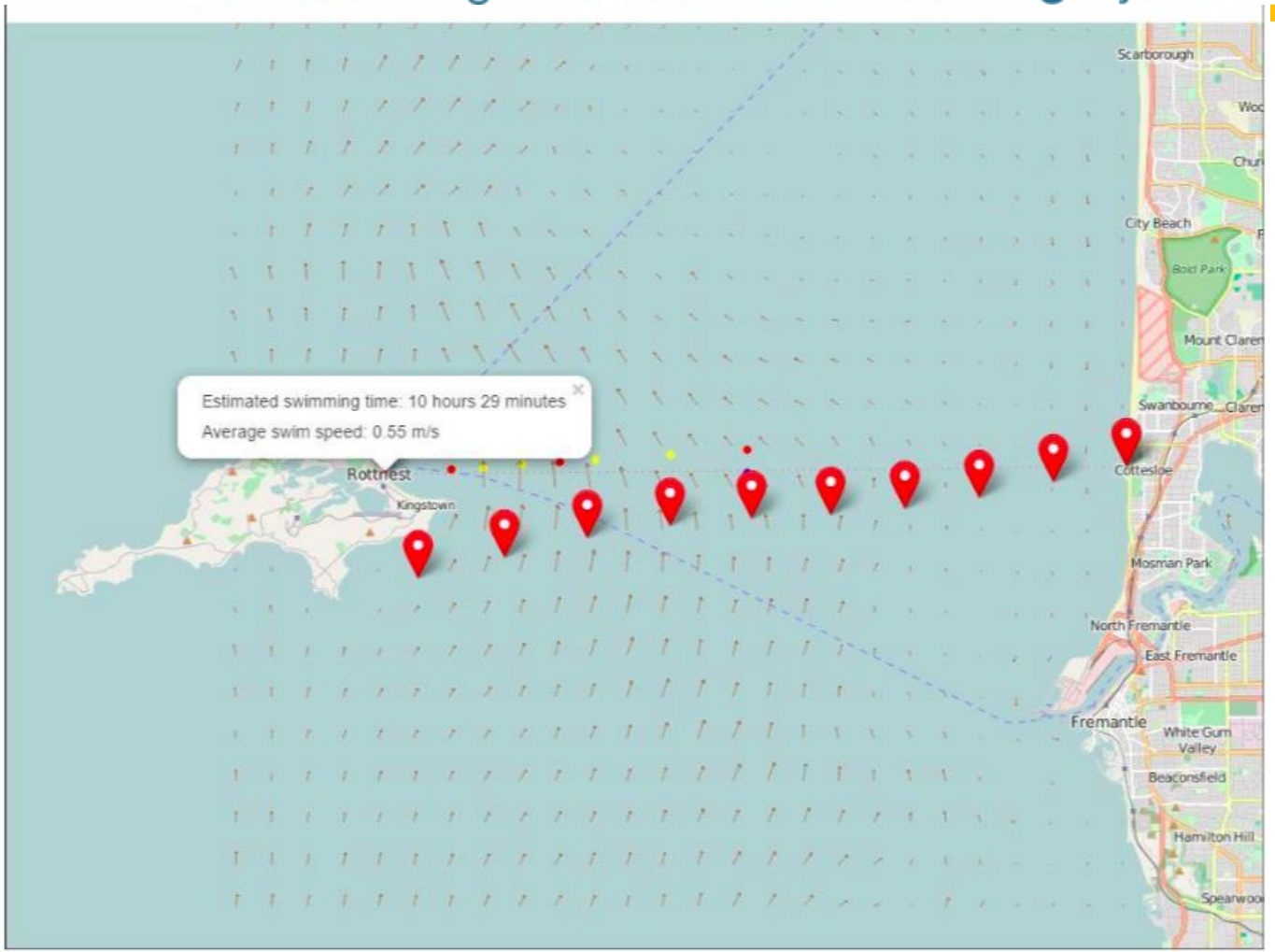
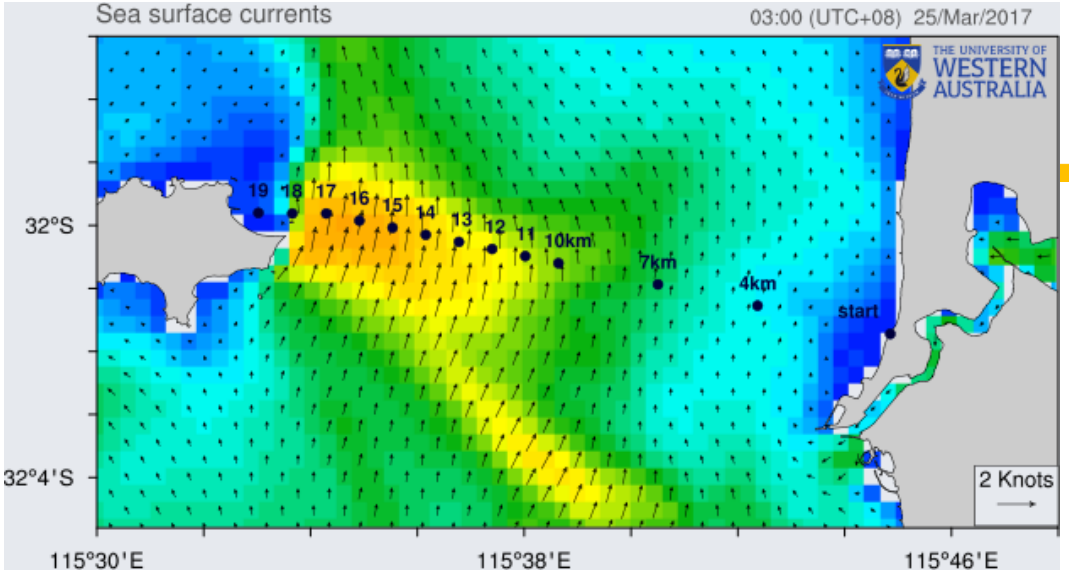
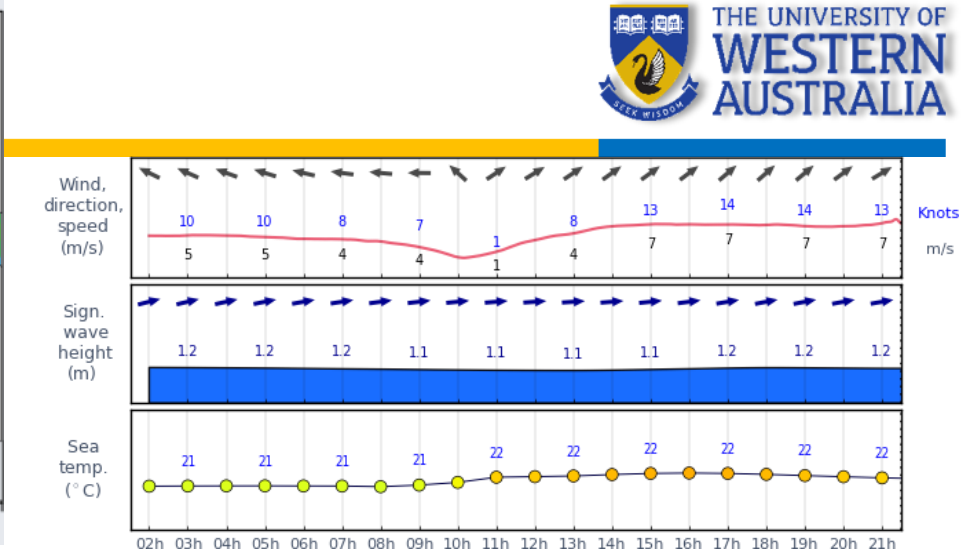
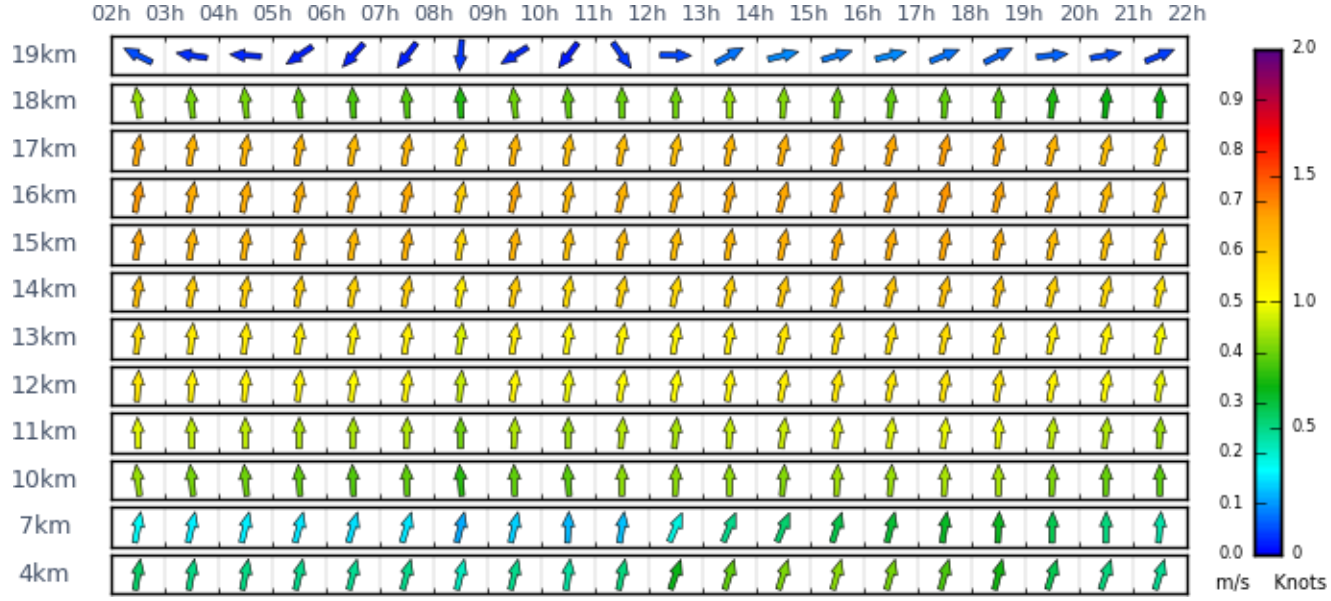


Using hourly UWA ROMS

CSIRO Optimizing route tool


Sea surface currents
03:00 (UTC+08) 25/Mar/2017
THE UNIVERSITY OF WESTERN AUSTRALIA
32°S
32°4'S
115°30'E
115°38'E
115°46'E
19
18
17
16
15
14
13
12
11
10km
7km
4km
start
2 Knots


THE UNIVERSITY OF WESTERN AUSTRALIA
Wind, direction, speed (m/s)
Knots
m/s
Sign. wave height (m)
Sea temp. (°C)
02h 03h 04h 05h 06h 07h 08h 09h 10h 11h 12h 13h 14h 15h 16h 17h 18h 19h 20h 21h


02h 03h 04h 05h 06h 07h 08h 09h 10h 11h 12h 13h 14h 15h 16h 17h 18h 19h 20h 21h 22h
19km
18km
17km
16km
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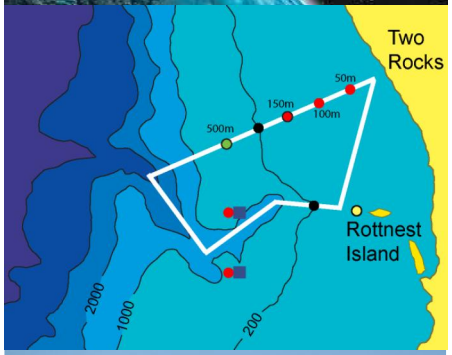
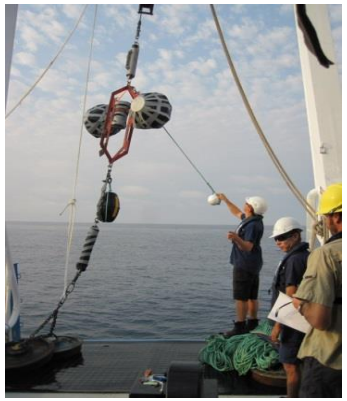
13km
12km
11km
10km
7km
4km
m/s
Knots

Data Assimilation: Observations



~ 2,5 million observations (4 day window from 21/Jan)

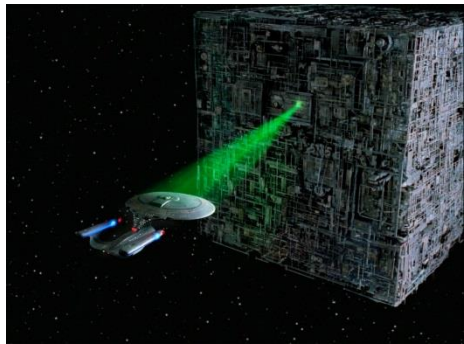
PLATFORM	OBS
NOAA_15	297420
NOAA_16	588766
NOAA_18	734152
NOAA_19	699573
ROT_HF	**117618**
AVISO	4768
ADCP_WATR10	1536
ADCP_WATR20	2880
ADCP_WATR50	2880
ADCP_WACA20	2880
TZ_WACA20	3591
TZ_WACASO	5433
TZ_WATR10	3586
TZ_WATR20	3753
CTD_WATR20	1026
ARGO_R59	160



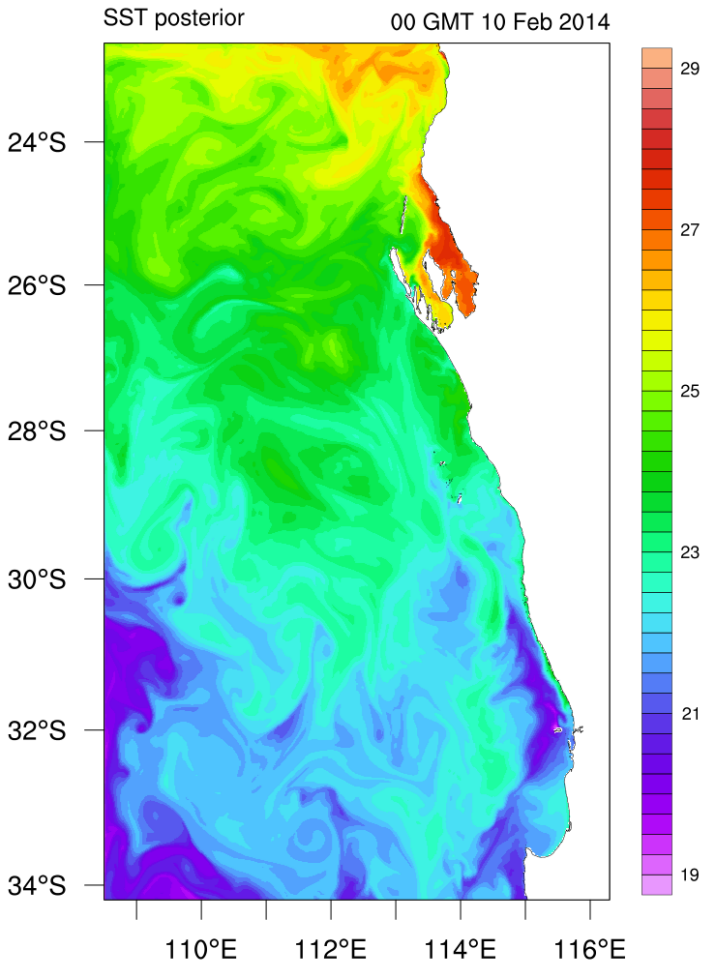
~ 5 hours @ 192 CPU IS4D

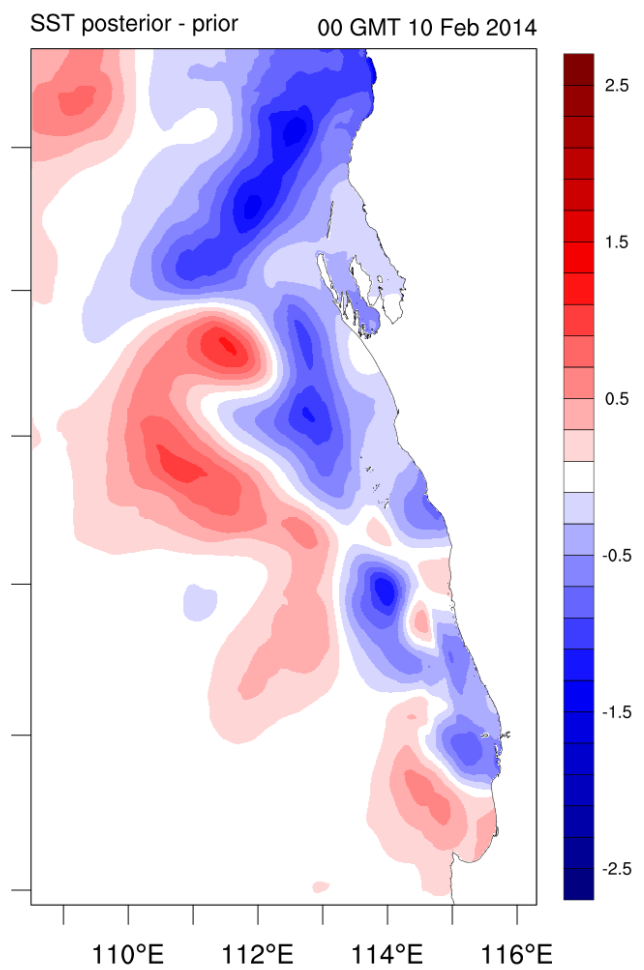
Combination of obs & model

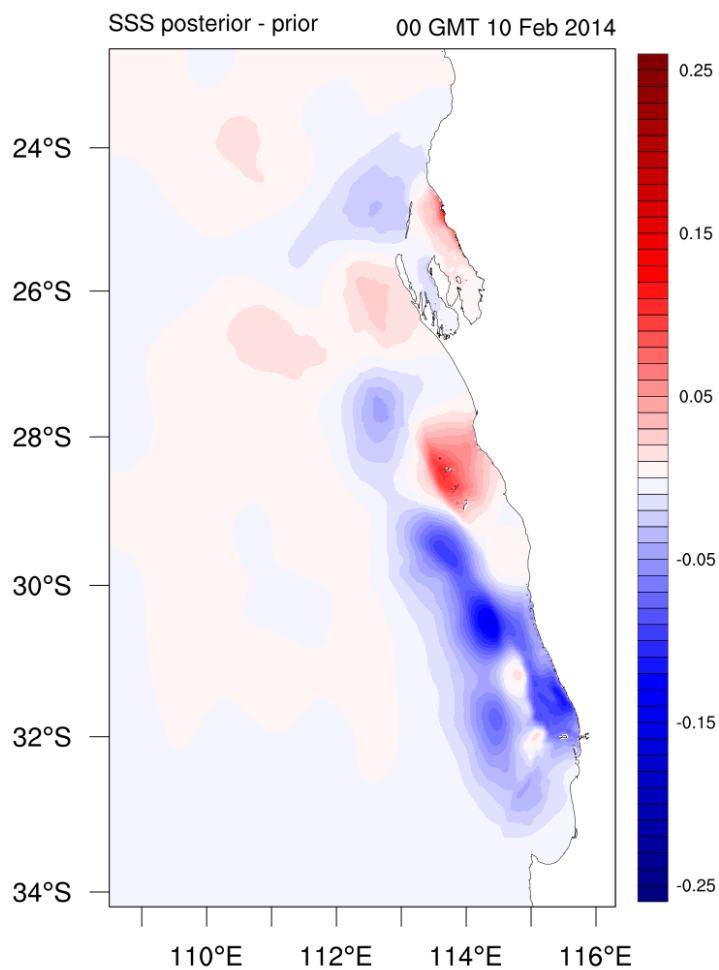
PSAS ~ IS4DVar, mem/node



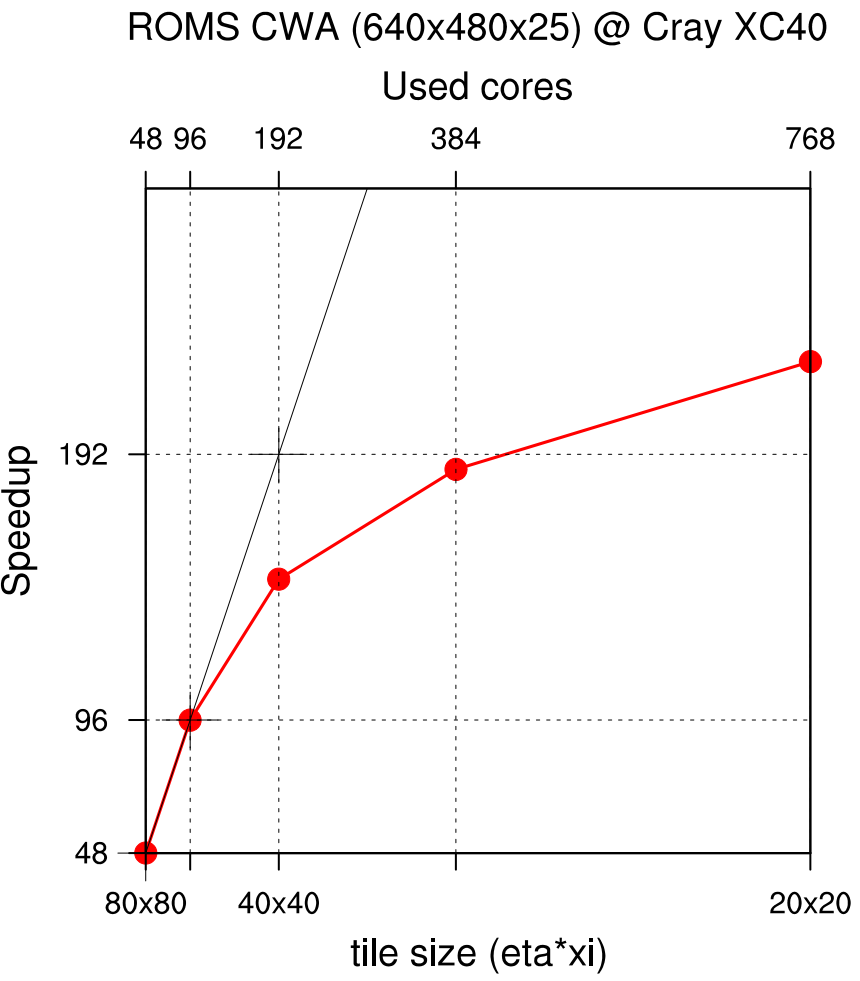
Data Assimilation: WA (4 days)







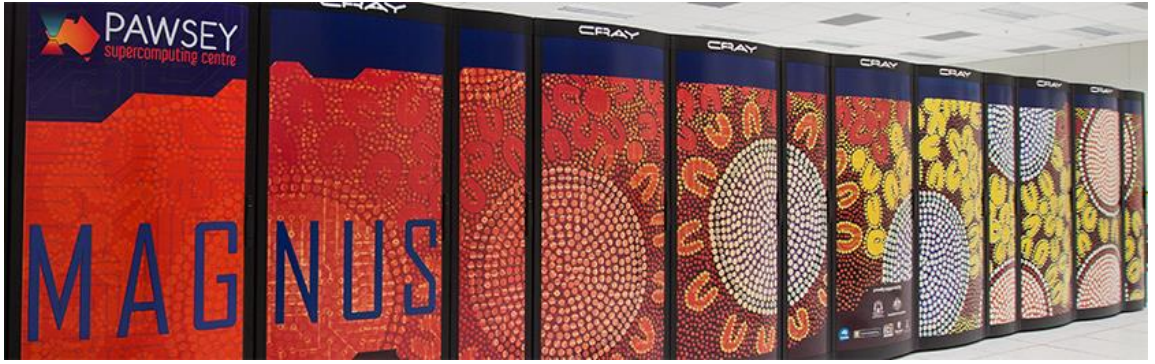
Magnus Pawsey HPC



Magnus Cray XC40

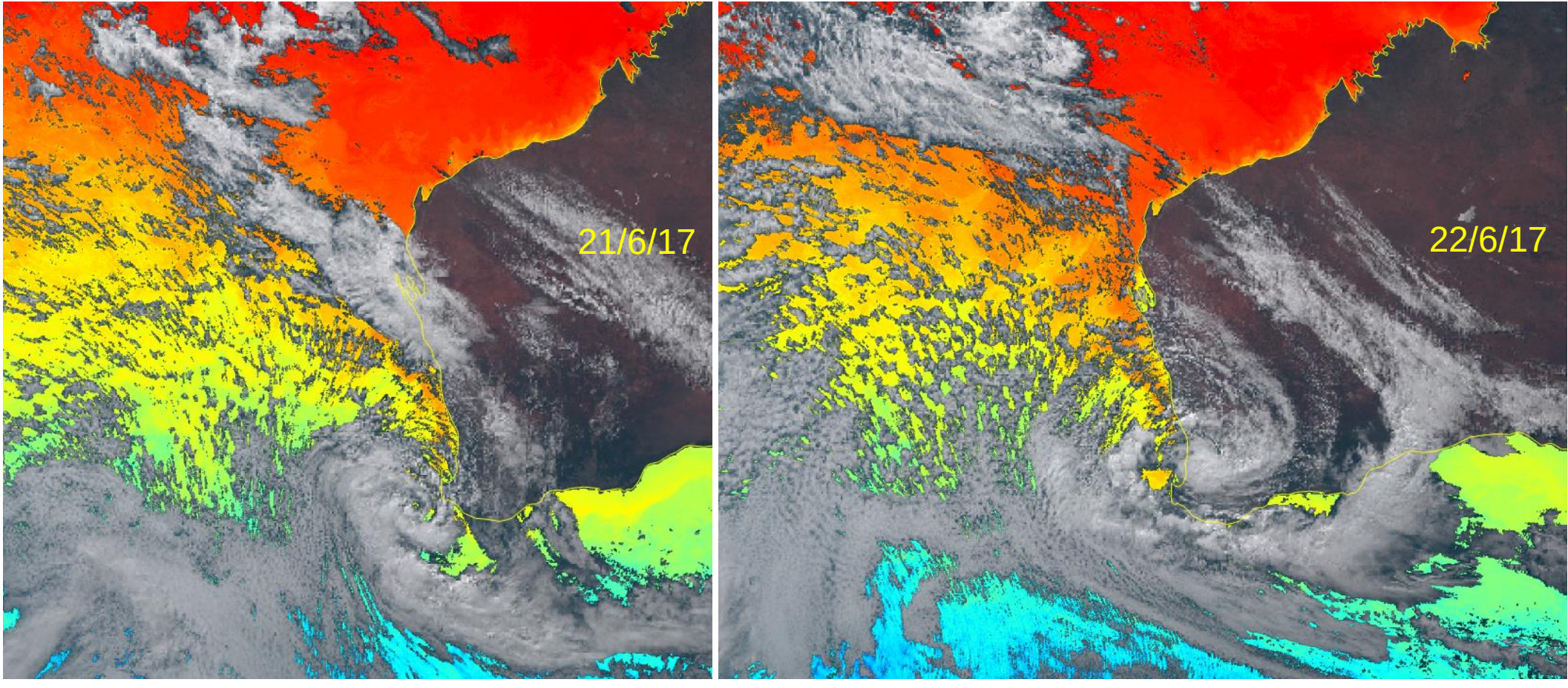
ranked number 78 in the world - the fastest supercomputer in the southern hemisphere

1488 nodes (35,712 cores)

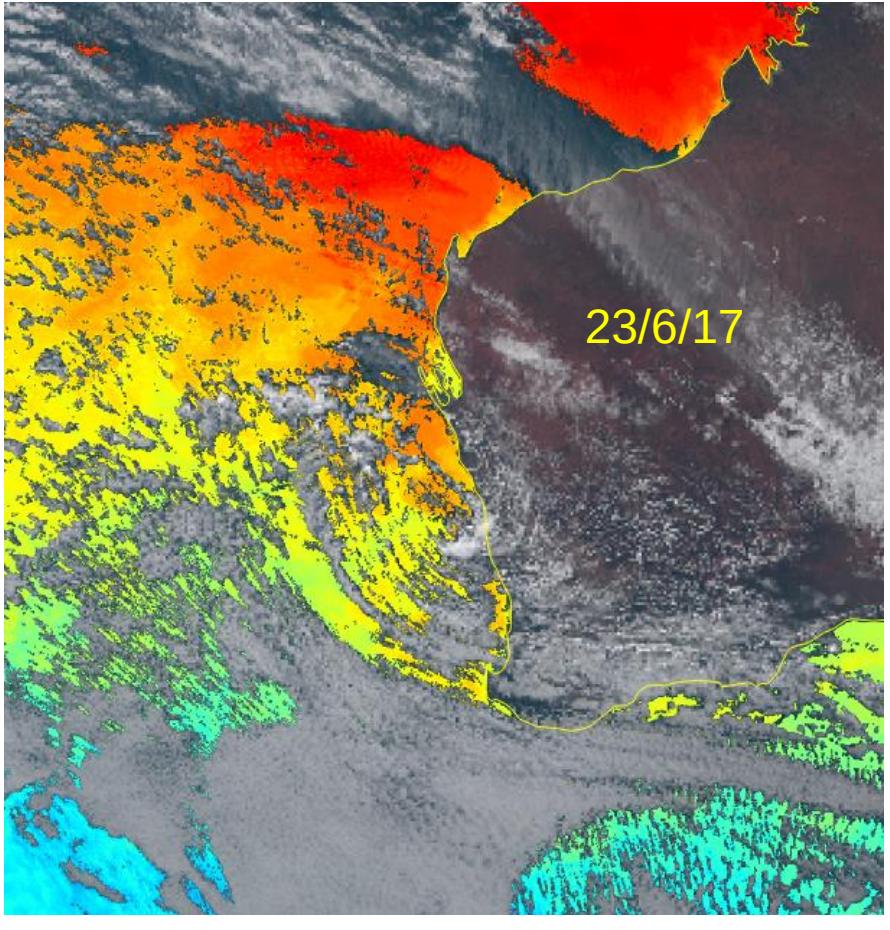


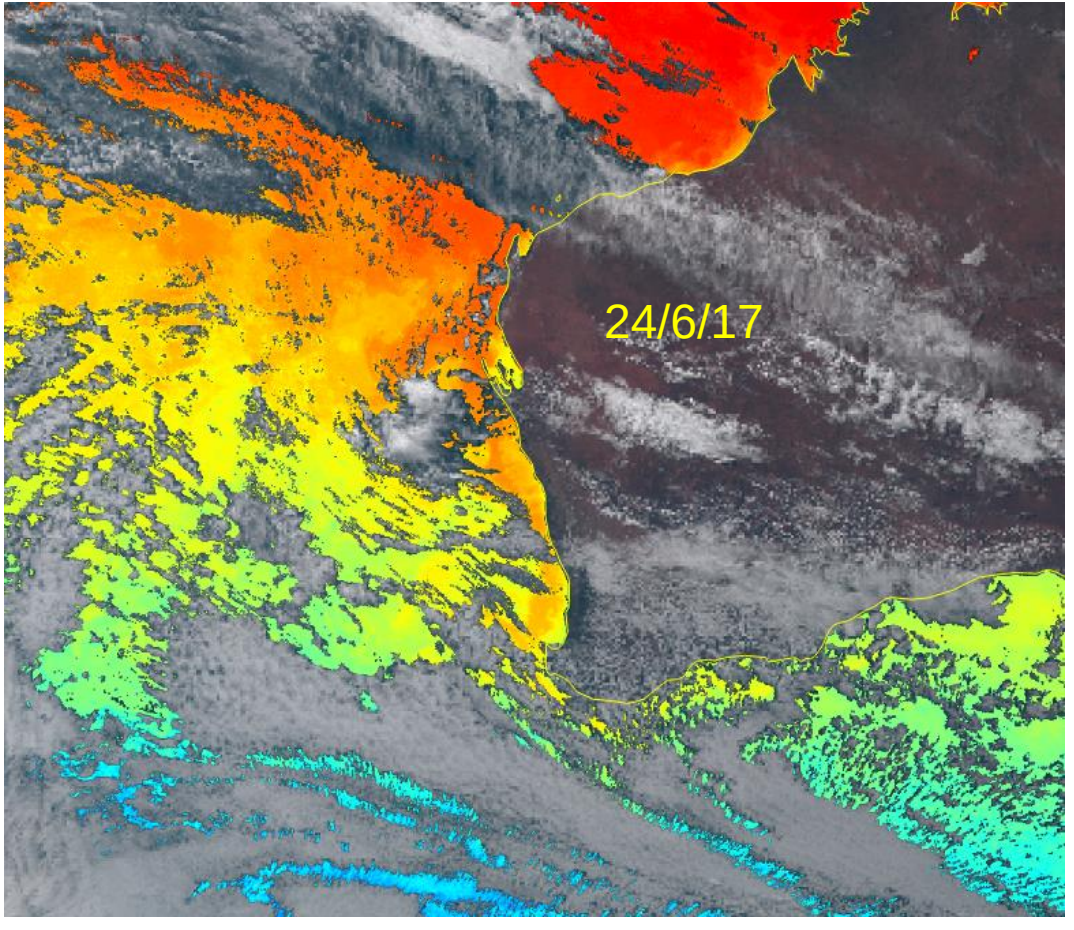
1) Data Assimilation for the Western Australia using ROMS @ Pawsey
2) Optimizing ROMS data assimilation model for CRAY XC40 supercomputer system

2-way WRF<->ROMS<->SWAN

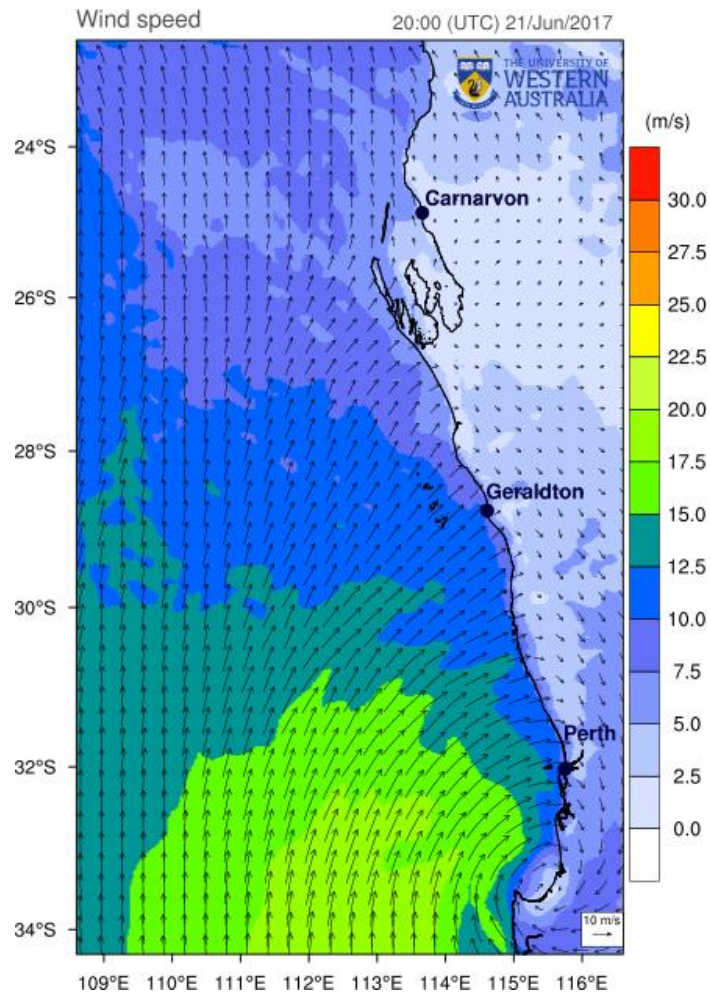


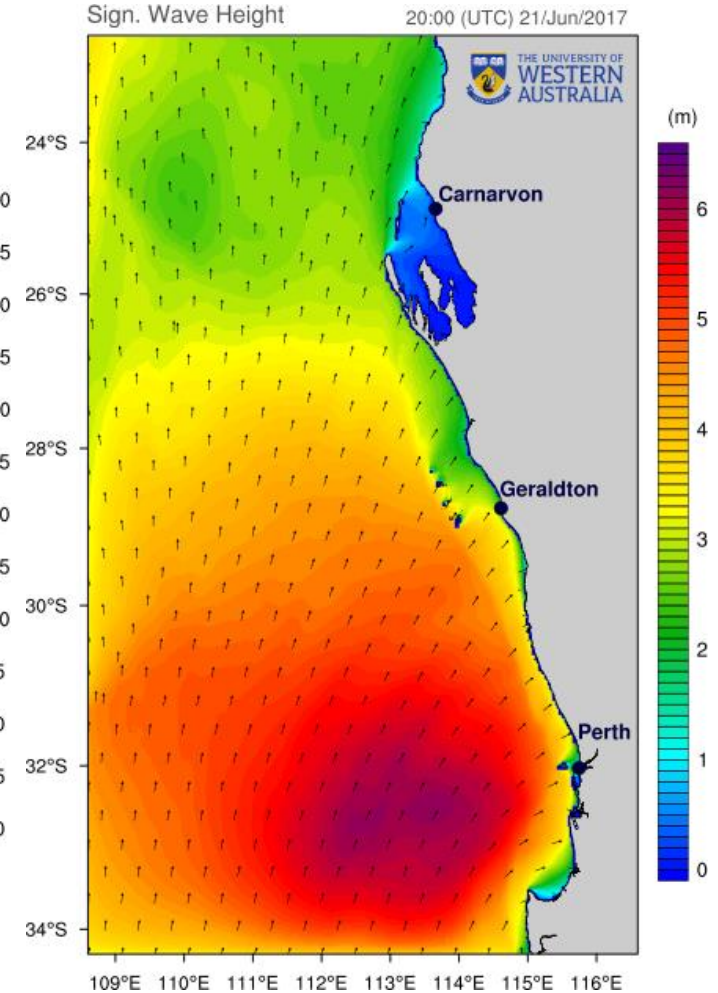
2-way WRF<->ROMS<->SWAN

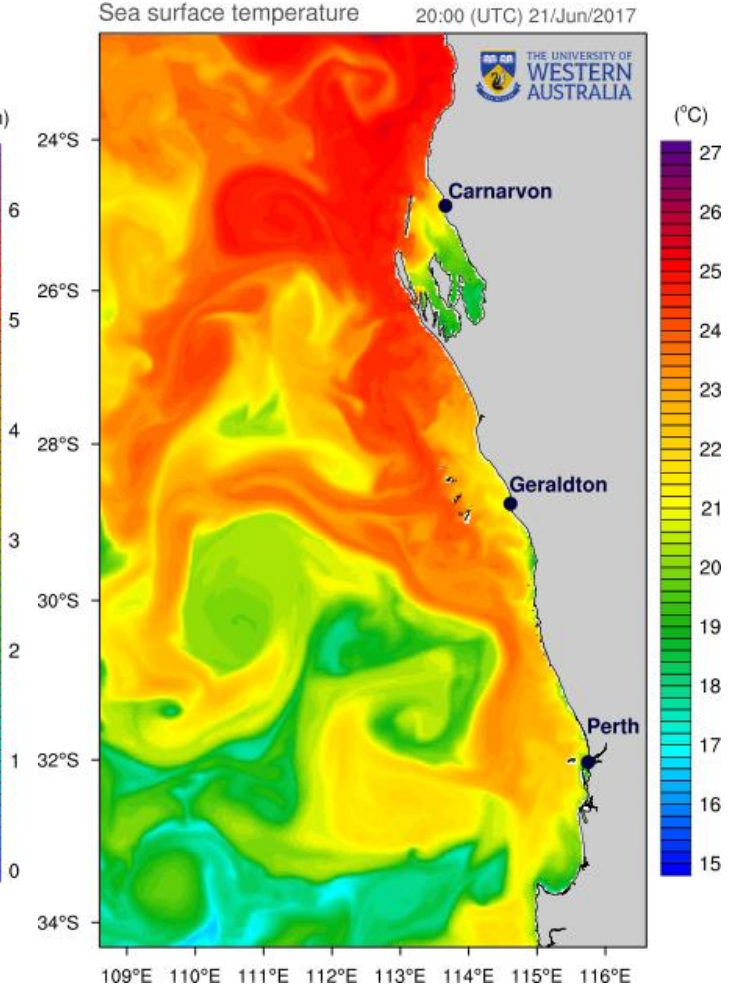




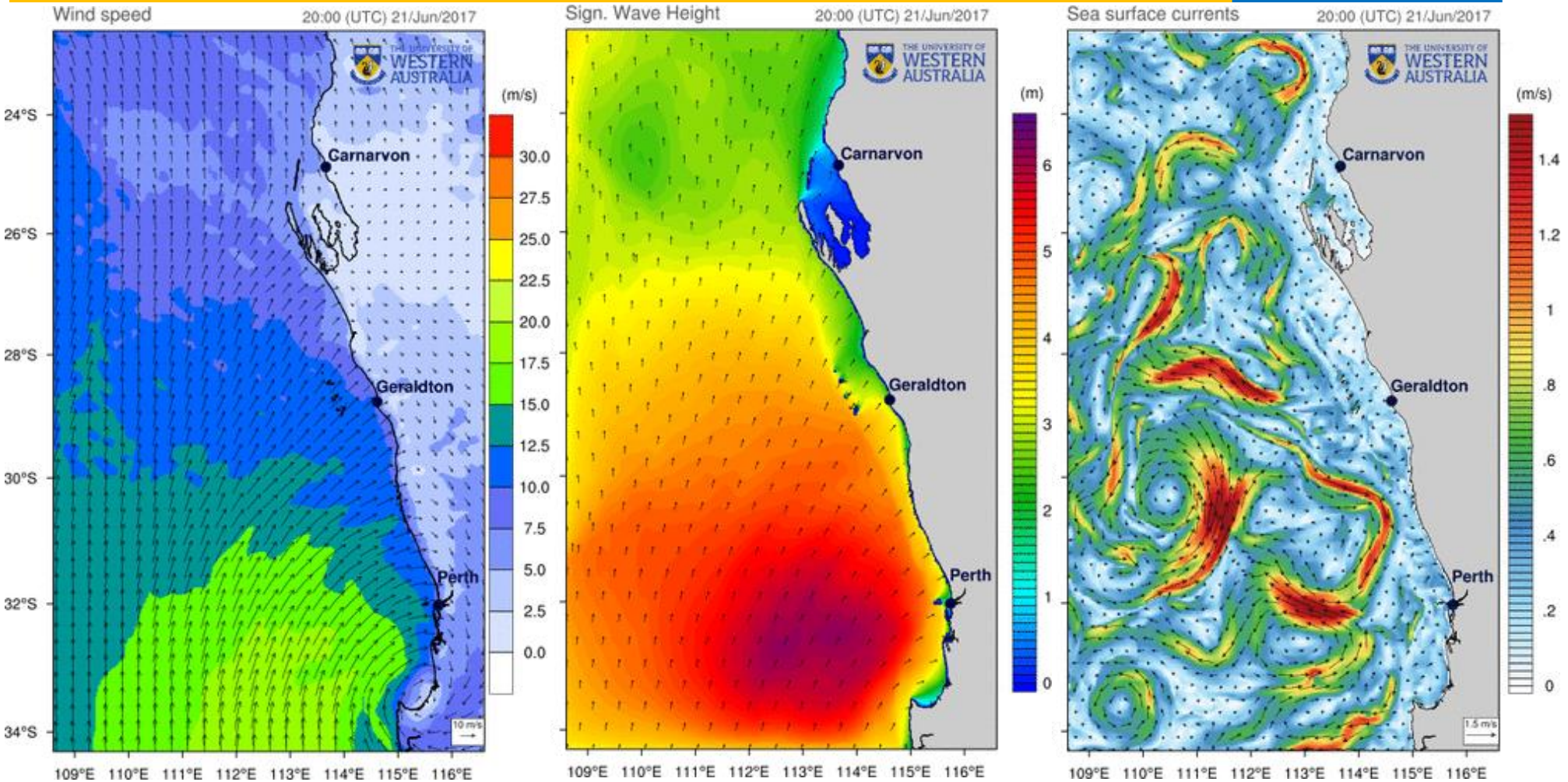
2-way WRF<->ROMS<->SWAN

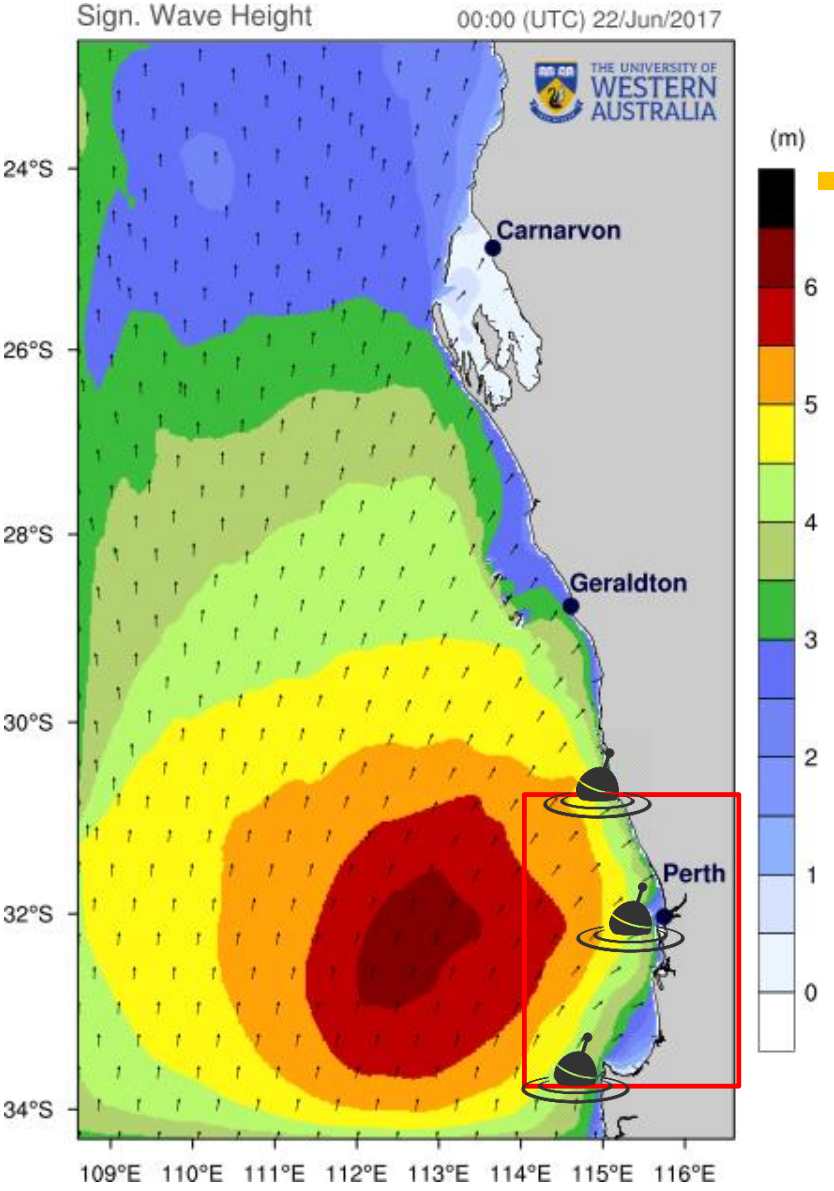


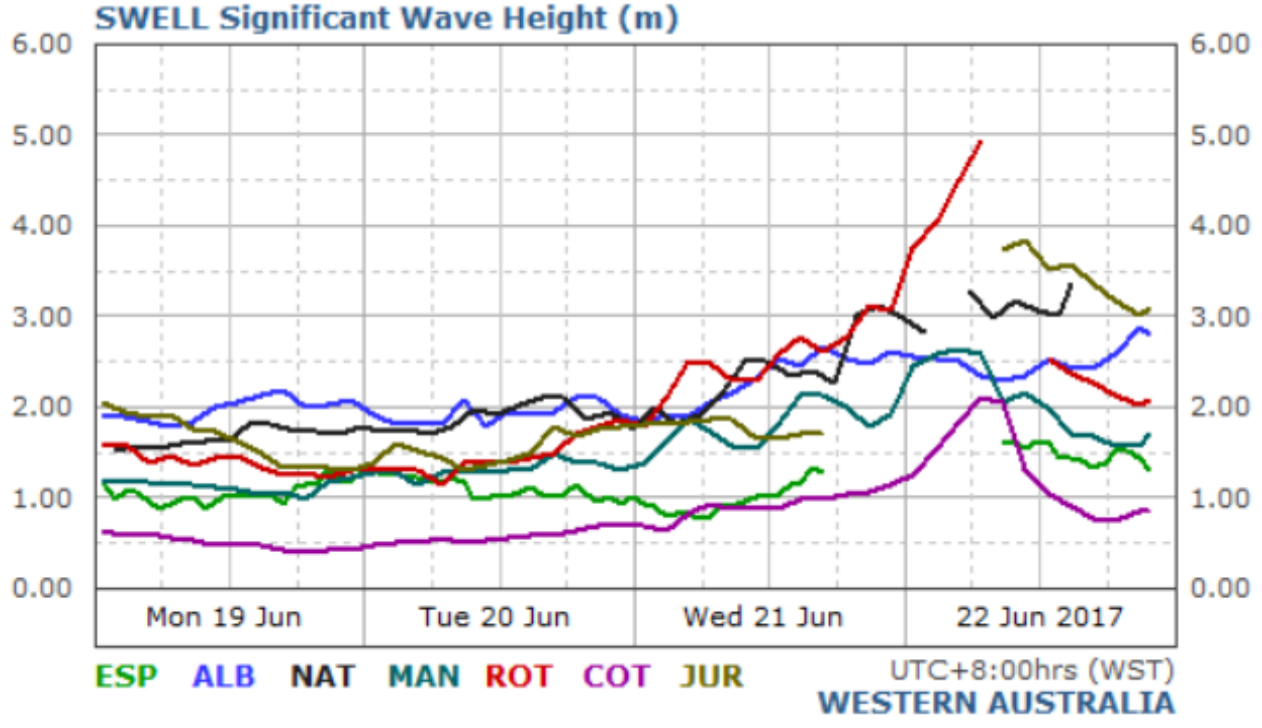


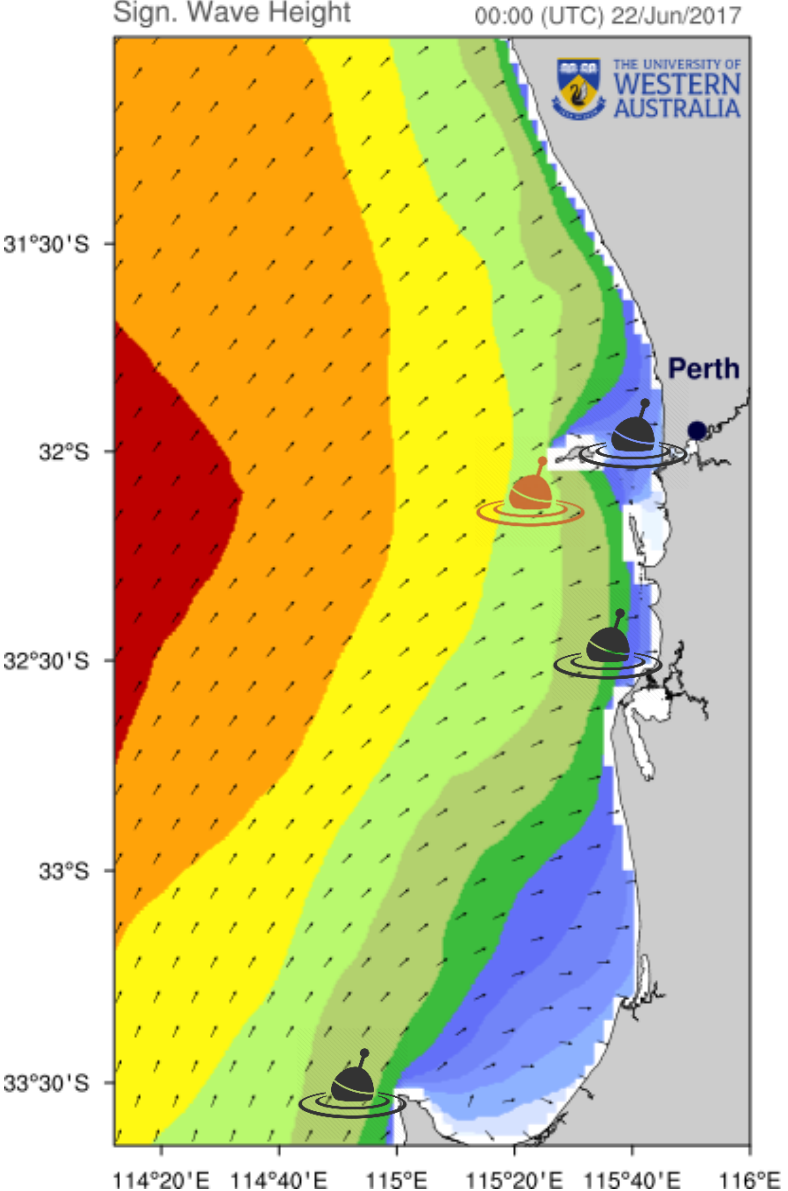


2-way WRF<->ROMS<->SWAN

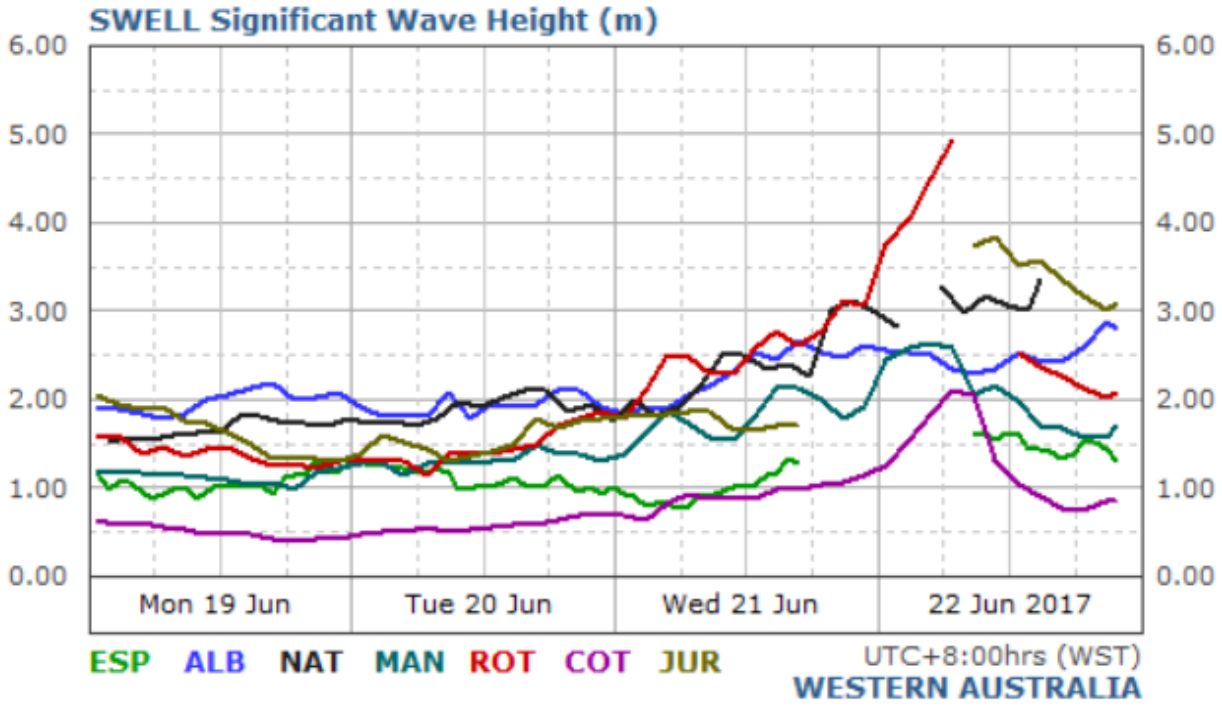



Sign. Wave Height
00:00 (UTC) 22/Jun/2017
THE UNIVERSITY OF WESTERN AUSTRALIA
Carnarvon
Geraldton
Perth
24°S
26°S
28°S
30°S
32°S
34°S
109°E
110°E
111°E
112°E
113°E
114°E
115°E
116°E
(m)
6
5
4
3
2
1
0

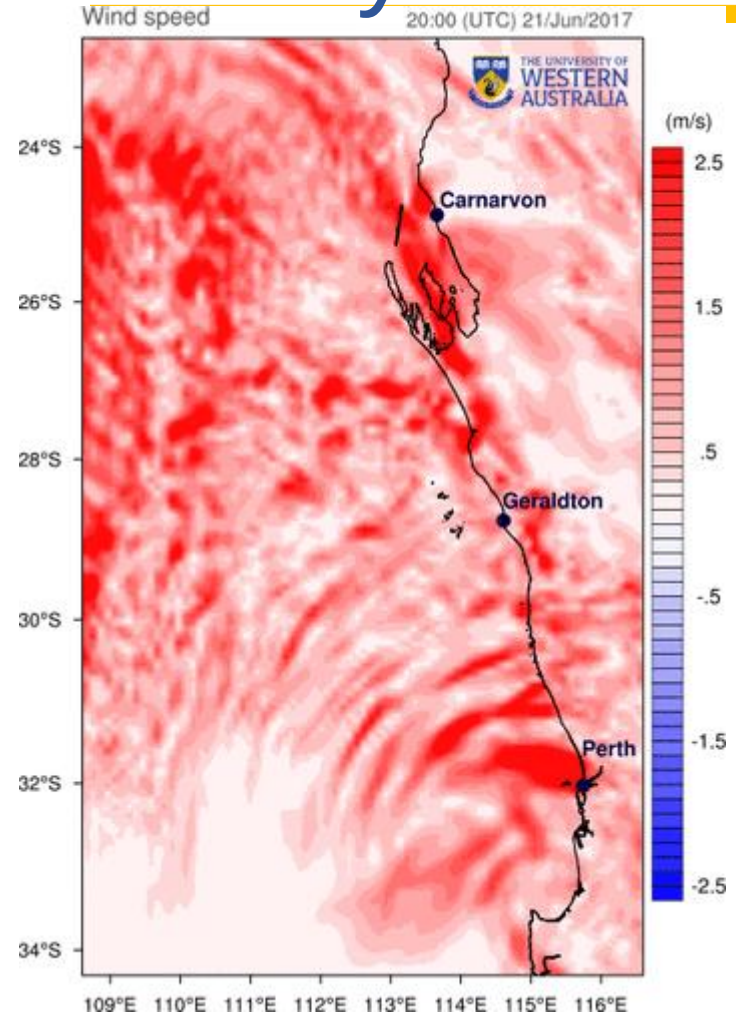

SWELL Significant Wave Height (m)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Mon 19 Jun
Tue 20 Jun
Wed 21 Jun
22 Jun 2017
ESP
ALB
NAT
MAN
ROT
COT
JUR
UTC+8:00hrs (WST)
WESTERN AUSTRALIA

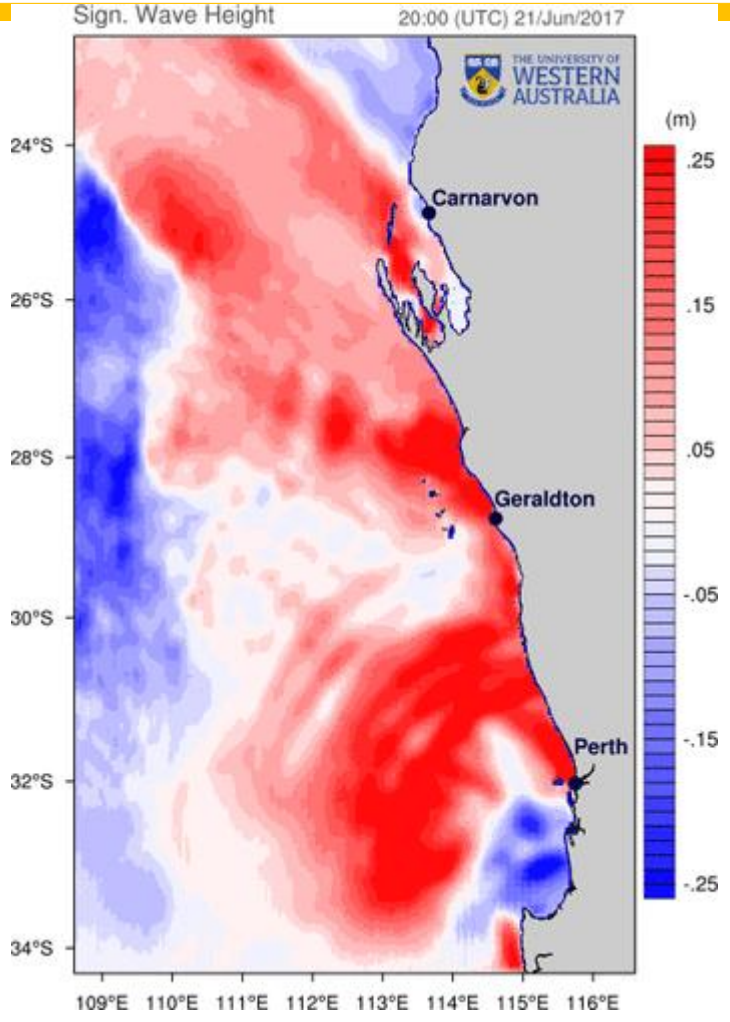

Sign. Wave Height
00:00 (UTC) 22/Jun/2017
THE UNIVERSITY OF WESTERN AUSTRALIA
Perth
31°30'S
32°S
32°30'S
33°S
33°30'S
114°20'E
114°40'E
115°E
115°20'E
115°40'E
116°E


(m)
6
5
4
3
2
1
0


SWELL Significant Wave Height (m)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Mon 19 Jun
Tue 20 Jun
Wed 21 Jun
22 Jun 2017
ESP
ALB
NAT
MAN
ROT
COT
JUR
UTC+8:00hrs (WST)
WESTERN AUSTRALIA

• 2-way WRF<->ROMS<->SWAN



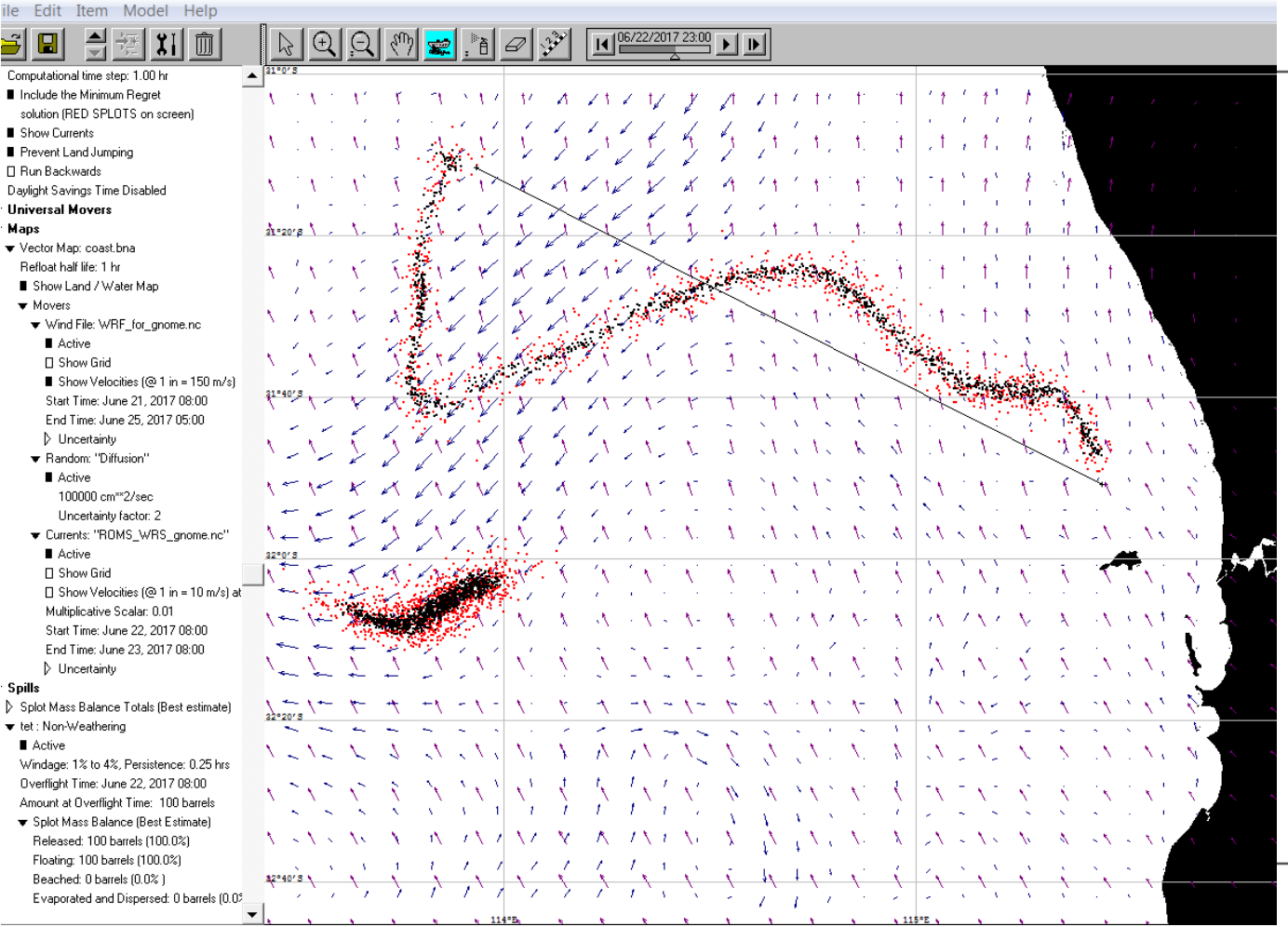


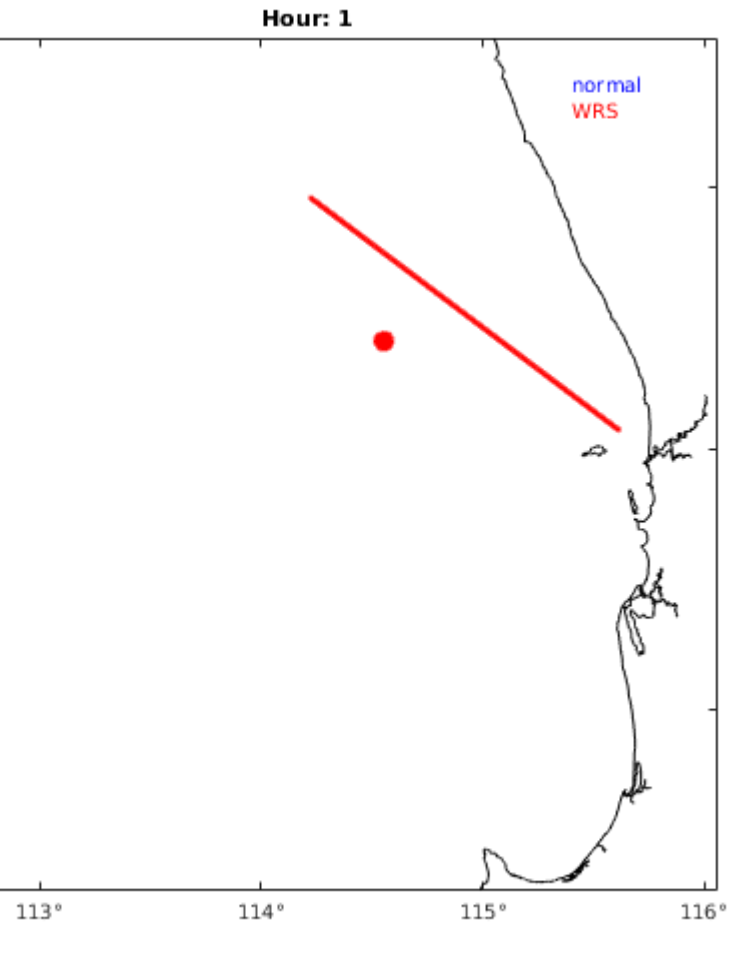
Normal - 2way coupled

-> reducing wind/hsig

-> surf. currents ?

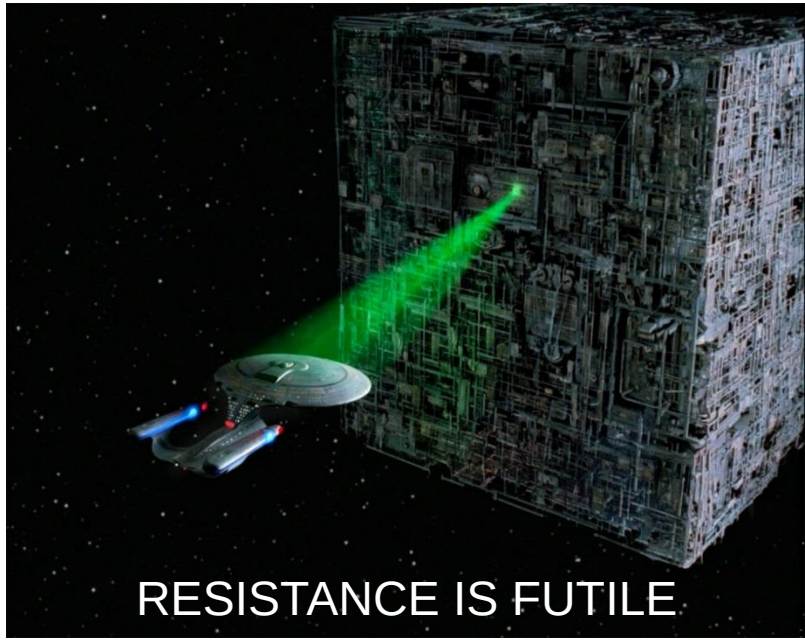
2-way coupled WRF-ROMS-SWAN diff

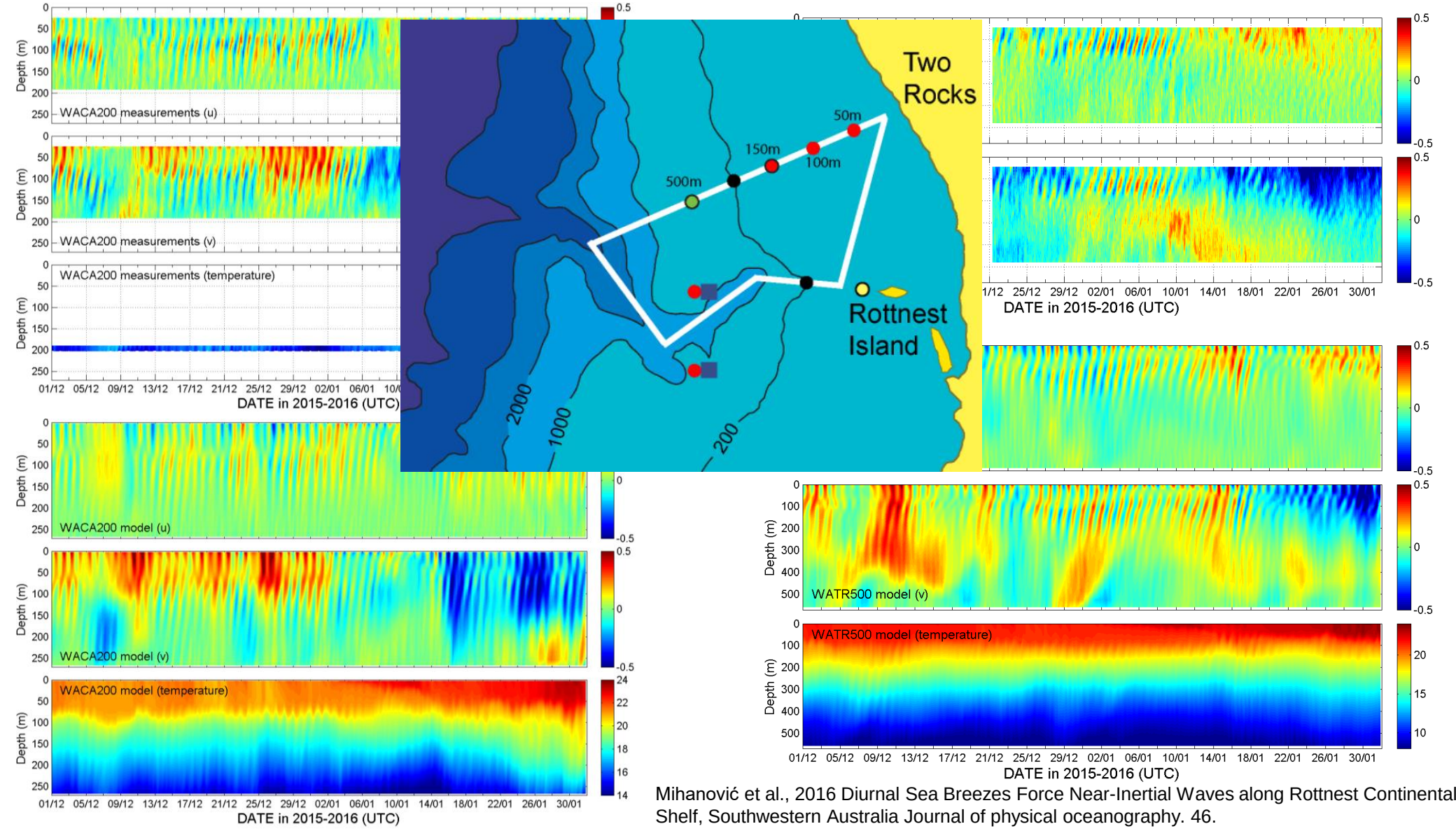




Conclusion

- ~ 2 years of near-real-time ROMS/WRF
- Online, data (!) & web
- Relocatable engine (modular)
- Many studies, validations
- New developments (where to go?)
  - **Data assimilation** (model vs. obs space)
  - 2-way coupled system (atmo/ocean)
    - Vortex formulation, 3D Stokes, TKE modified
    - Atmo. drag modified with waves -> reduce U10
    - Coastal application affected, open ocean?
- Specific requests/users
  - Specific outputs/levels/variables?





Mihanović et al., 2016 Diurnal Sea Breezes Force Near-Inertial Waves along Rottnest Continental Shelf, Southwestern Australia Journal of physical oceanography. 46.