

## Ocean forecasting - status and outlook

Brassington, Freeman, Sakov, Colberg, Divakaran, Zhong, Huang et al., Oke, Jones, Fiedler, Herzfeld, Chamberlain Bluelink partnership

## Workshop observations

## Science

Annual forcing results indicated Kuroshio separation issues Antarctic extent, timing issues Encourage a debate more effort vs move on? Ice concentration/extent, biases?

Are we ready to move to full JRA run? Exploit ENKF-C model-observation tools Can we exploit tendency methodology a trace for the leading sources of bias

## Computational

CICE scaling MOM5 scaling issue - support Marshall's proposal Overall performance looking fit for purpose

# **Global Ocean forecasting**

Status

Applications driving toward high resolutions Tides and internal tides Conflicting evidence, US Navy vs Sandery and Sakov Observing system step change - SWOT (2021-2022) Moving to optimal DA and ensemble forecasting

### Next target

Ensemble 0.1° Higher resolution through regional and coastal modelling Sea-ice and wave coupling Non explicit tide resolving? Adoption of ACCESS-OM2-01 Has a shelf life until 2022 (Post SWOT R&D)

Target in 2022? Unstructured mesh is making progress MPAS encouraging results, Adoption of core in CSIRO Nesting strategy is feasible but will require evidence science/computation Is there convergence of MOM6, HYCOM, MPAS?

# OceanMAPS v3.1

#### Ocean model

MOM 4p1 (Griffies et al., 2008) Hydrostatic primitive equation model B-grid, regular, spherical coordinates 0-360, 75S-75N ( $0.1^{\circ} \times 0.1^{\circ}$ ) Bathymetry, Smith and Sandwell, v11.1 z\* vertical coordinate - 51 levels 0-200m ( $\Delta z \le 10$  m) GOTM, K-eps mixed layer scheme

#### Forcing

ACCESS-G APS2 (fluxes) Climatological river discharge

#### **Data Assimilation**

ENKF-C (Sakov, 2014) Ensemble optimal interpolation Multi-variate (eta, T, S, u, v) Restart initialisation

#### Observations

Satellite altimetry (Jason2, SARAL, Cryosat2, Sentinal-3A) Satellite SST (AMSR2, NAVO, VIIRS) CTD (Argo, GTS), XBT (GTS)





## OceanMAPS - status

## OceanMAPSv3.2 - Q4 2017 => Q2 2018?

Observations Forcing Ocean model

Forecast cycle

- Sentinel-3A, VIIRS
- Bulk formulae
- MOM5 (OFAM3 grid) (Restart strategy)
- K-Epsilon (Buoyancy production)
- 6-cycle Add 0Z with 12Z

## OceanMAPSv3.3 - Q4 2018/Q1 2019

Data assimilation Bias correction Forcing

- New FGAT SST strategy (ready)
- Inflated spread, Assimilate synthetics
  ACCESS-G3

# OceanMAPS – roadmap (slipping)

	2017 (Q4) OceanMAPSv3.2	2018 (Q2) OceanMAPSv3.3	2019 OceanMAPSv4.0	2020 OceanMAPSv4.1	2021 OceanMAPSv5.0
COSIMA (ANU/UNSW/CoE/ Bureau/AAD/CSIRO)		>	Models (OFAM4) MOM5 (75 levels) CICE OASIS-MCT	Models (OFAM4) MOM5 (75 levels) CICE WWIII OASIS-MCT	Models (OFAM5) MOM6 (ALE) (1/30) SIS2 WWIII
MSA Bluelink/ASSET (RAN/Bureau/CSIRO)	Models MOM5 (51 levels) (K-Epsilon, optimised) Data assimilation ENKF-C (EnOI) Fluxes APS2 Bulk fluxes Observations Jason3, AltiKa, Cryosat-2, Sentinel-3A NAVO, AMSR2, VIIRS GTS TESAC/BATHY Argo GDAC Duplicate checker Forecast cycle 10 day forecasts	Models MOM5 (51 levels) Data assimilation ENKF-C (EnOI) <b>FGAT (SST)</b> Bias correction (?) <u>Fluxes</u> <b>APS3G</b> Bulk fluxes <u>Observations</u> Jason3, AltiKa, Cryosat- 2, Sentinel-3A/ <b>3B</b> NAVO, AMSR2, VIIRS, <b>Himawari-8</b> GTS TESAC/BATHY Argo GDAC, IMOS gliders Duplicate checker	Data assimilation ENKF-C (EnKF) (ocean, 100 member) Fluxes APS3G (ACCESS-GE perturbations) Bulk fluxes Observations Jason3, AltiKa, Cryosat- 2, Sentinel-3A/3B, ? NAVO, AMSR2, VIIRS, Himawari-8, ? GTS TESAC/BATHY Argo GDAC, IMOS gliders Duplicate checker Forecast cycle	Data assimilation EnKF (ocean, 100 member) Fluxes APS4G/GE Bulk fluxes Observations Jason3, AltiKa, Cryosat- 2, Sentinel-3A/3B, NAVO, AMSR2, VIIRS, Himawari-8, ? GTS TESAC/BATHY Argo GDAC, IMOS gliders Forecast cycle 10+(?) day forecast 25 member ensemble (100 member lagged	Data assimilation EnKF (ocean, 100 member) Fluxes APS4G/GE Bulk fluxes Observations Jason3, AltiKa, Cryosat- 2, Sentinel-3C/3D, SWOT, NAVO, AMSR2, VIIRS, Himawari-8, ? GTS TESAC/BATHY Argo GDAC, IMOS gliders Forecast cycle 10+(?) day forecast 25 member ensemble
	12Z <u>Compute</u> <u>Data volume</u>	<u>Forecast cycle</u> 10 day forecasts <b>00Z</b> / 12Z <b>6-cycle</b> <u>Compute</u> <u>Data volume</u>	10 day forecast Single deterministic (closest to ensemble mean) <u>Compute</u> <u>Data volume</u>	ensemble) Compute Data volume	(100 member lagged ensemble) <u>Compute</u> <u>Data volume</u>

		6-cycle	moury		<u>o cinputo</u>
	Data volume	U UYUIC	Compute	Data volume	
		Compute	Compute		Data volume
<u>Icean</u> M					
			Data volume		
		Data volume			
	2017 (04)		0010	2000	0004
	2017 (Q4)	2018 (Q2)			
	OceaniviAPSV3.2	OceaniviAPSV3.3	OceaniviAPSV4.0	OceaniwiAPSV4.1	OceaniwiAPSv5.0
COSIMA			Models (OFAM4)	Models (OFAM4)	Models (OFAM5)
Ξ/			MOM5 (75 levels)	MOM5 (75 levels)	MOM6 (ALE) (1/30)
RO)			CICE	CICE	SIS2
			OASIS-MCT	wwiii	WWIII
				OASIS-MCT	
			lessest 0. Continui		lassest 0
			iceasat-2, Sentinel-		iceasat-2
MSA Bluelink/ASSET	Models	Models	Data assimilation	Data assimilation	Data assimilation
(RAN/Bureau/CSIRO)	MOM5 (51 levels)	MOM5 (51 levels)	ENKF-C (EnKF)	EnKF (ocean, 100	EnKF (ocean, 100
,	(K-Epsilon, optimised)	, ,	(ocean, 100 member)	member)	member)
		Data assimilation	,	,	,
	Data assimilation	ENKF-C (EnOI)	Fluxes	Fluxes	Fluxes
	ENKF-C (EnOI)	FGAT (SST)	APS3G	APS4G/GE	APS4G/GE
	, ,	Bias correction (?)	(ACCESS-GE	Bulk fluxes	Bulk fluxes
	Fluxes	. ,	perturbations)		
	APS2	Fluxes	Bulk fluxes	Observations	Observations
	Bulk fluxes	APS3G		Jason3, AltiKa, Cryosat-	Jason3, AltiKa, Cryosat-
		Bulk fluxes	Observations	2, Sentinel-3A/3B,	2, Sentinel-3C/3D
	Observations	<b>_</b>	Jason3, AltiKa, Cryosat-	NAVO, AMSR2, VIIRS,	SWOT,
	Jason3, AltiKa,	Observations	2, Sentinel-3A/3B, ?	Himawari-8, ?	NAVO, AMSR2, VIIRS,
	Cryosat-2, Sentinel-3A	Jason3, AltiKa, Cryosat-	NAVO, AMSR2, VIIRS,	GTS TESAC/BATHY	Himawari-8, ?
	NAVO, AMSR2, VIIRS	2, Sentinel-3A/3B	Himawari-8, ?	Argo GDAC, IMOS	GIS IESAC/BATHY
BGC forecasting	GTS TESAC/BATHY	NAVO, AMSR2, VIIRS,	GTS TESAC/BATHY		AND GDAC, MOS
	Argo GDAC	Himawari-8	Argo GDAC, IMOS		gliders
	Duplicate checker	GTS TESAC/BATHY	gliders	Forecast cycle	
		Argo GDAC, IMOS	Duplicate checker	LOSE Validis	Egrecast GVCB(OCLI)
	Forecast cycle	gliders		25 member ensemble	10+(?) day forecast
	10 day forecasts	Duplicate checker	Forecast cycle	(100 member lagged	25 member ensemble
				Analysis	25 member ensemble
					forecast
				Compute (additive)	(100 member lagged
					ensemble)
				Data volume (additive)	Compute (additive)
					Data volume (additive)

## World leading capability - ensemble ocean forecasting



### 50m ocean temperature uncertainty

Largest uncertainty associated with boundary currents and equator Note the seasonal change in confidence in the sub-tropical gyre Results obtained from ensemble Kalman Filter data assimilation, Pavel Sakov

# Regional/coastal forecasting

Status

Bureau - ROMS (eReefs, eSAMarine) CSIRO - SHOC (eReefs, Derwent, …), R&D COMPAS

Next targets

- Bureau Large regional forecast tiles (ACCESS-C scale)
  - Interim solution to higher resolution global
  - Tide/Internal tide resolving
  - Full mesoscale resolving (1/50)
- CSIRO Unstructured modelling COMPAS/BGC

GOAL

Encouraging COMPAS development Critical that we benchmark COMPAS against SHOC, ROMS/Nested and other options Converge on a common platform when COMPAS matured

### Regional Ocean (ROMS, 1/50)



Animation of 3hrly changes to northward velocity Large coherent change over Northern Australia Fine scale changes related to internal tides through Indonesia

## Regional Wave (WavewatchIII, 1/50)

## TC Marcus basetime 2018/03/15 00Z



- Indonesian Throughflow is more focussed and wave groups refract and disperse stronger compared to AUSWAVE-R
- More detail and structure with local wind wave generated between islands
- AUSWAVE-R shows larger values of significant wave height, which may be expected due to insufficient blocking of islands and reefs and coarse resolution of the bathymetry

## Regional Wave (ACCESS, 1/50)



15th February 2018 Iralian Bureau of Meteoro

## **Other Bureau**

Infrastructure resilience

**Operational compliance testing** 

Continuing to grow super-computing infrastructure Moving to ensemble everything Moving to high resolutions Moving to coupled models Moving to flexible mesh (LFRic)

### Resolution <1/10°

- Mesoscale
- Submesoscale
- Tide/internal tides

MODEL

FORECASTING

STATE ESTIMATION

#### Vertical resolution

- 75 layers
- ALE

#### Closure Biases

### Flexible mesh

- Unstructured
- Nesting

### Coupling

- Ocean-wave-ice
- Atmosphere-ocean
- Ocean-BGC

Multi-cycle forecasting Consensus/multi-model Ensemble ocean forecasting

• ACCESS-GE

### Extended range prediction

- ACCESS-S1
- Coupled ACCESS

#### **Observation platforms**

- Himawari-8
- SWOT
- EnKF Bias correction

Coupled DA