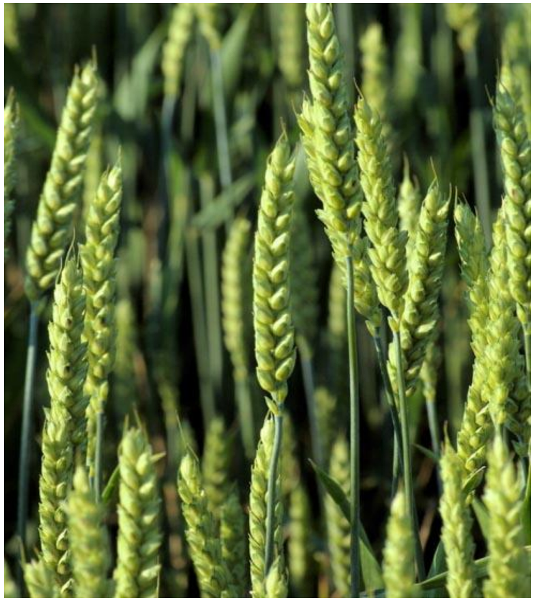
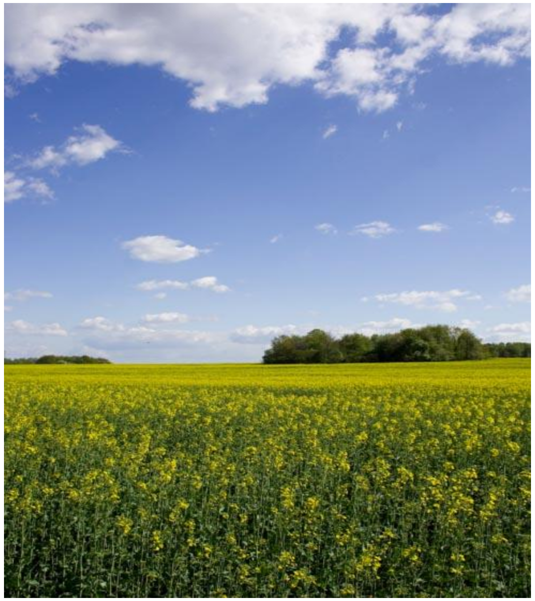
Australian Government
Bureau of Meteorology

The Bureau of Meteorology Coupled Data Assimilation System for ACCESS-S

Yonghong Yin, Angus Gray-Weale, Oscar Alves, Pavel Sakov, Debra Hudson, Xiaobing Zhou, Hailing Yan, Mei Zhao

Research and Development Branch, Bureau of Meteorology, Australia





Outline

- Background: sub-seasonal to seasonal prediction
- Summary of the operational POAMA data assimilation and initialisation scheme at the BOM
- ACCESS-S1: issues and improvements
- Coupled data assimilation plans for ACCESS-S2 and ACCESS-S3
- Some preliminary results

Background

- Need to support a sub-seasonal to seasonal prediction system
- Have made substantial improvements to forecast skill and reliability in the past by modifying the DA and ensemble generation.
- A key innovation was a coupled-model breeding method which produces an ensemble of perturbed atmosphere and ocean states. The new scheme impacted favourably on the sub-seasonal and seasonal forecast skill compared to an ensemble generated using lagged atmospheric initial conditions.

Australian Government
Bureau of Meteorology

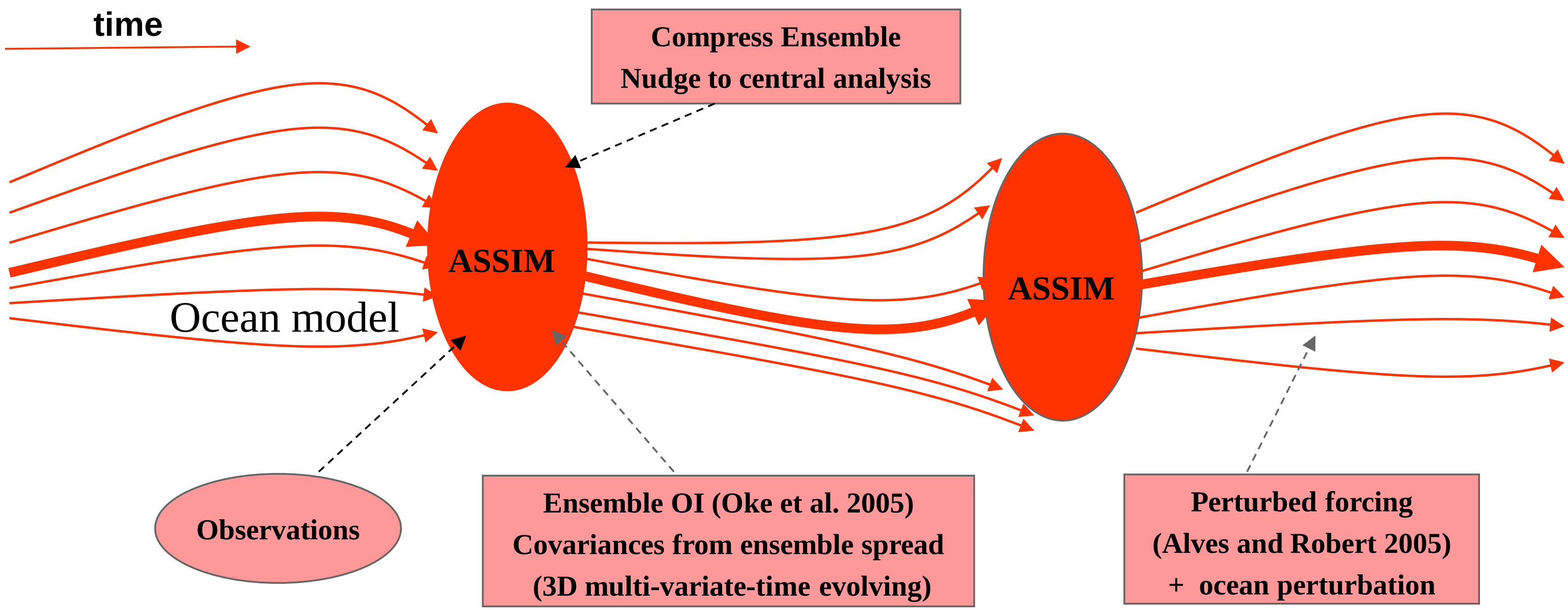
Data assimilation at BoM for POAMA2

ALI: Atmosphere Land Initialisation scheme	• Offline POAMA atmospheric GCM forced by observed sea-surface temperatures is nudged (u,v,T,q) every 6 hours towards an analysis (ERA for hindcasts; NWP for real-time) • Land surface is initialised indirectly through the nudged atmosphere
PEODAS: POAMA Ensemble Ocean Data Assimilation System	• Similar to Ensemble Kalman Filter • Includes state-dependent estimate of the background error covariance • Provides an ensemble of initial ocean states • Assimilates in situ ocean temperature and salinity

Australian Government
Bureau of Meteorology

Ocean data assimilation: PEODAS

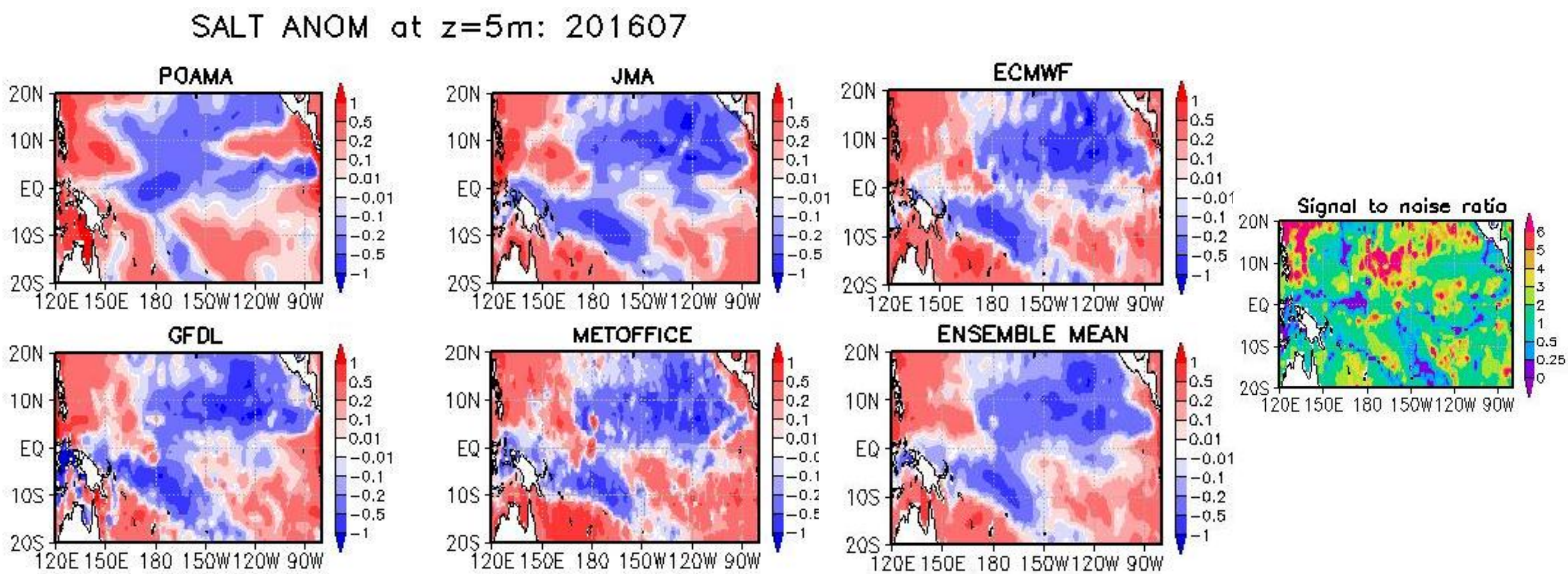
POAMA Ensemble Ocean Data Assimilation System used in POAMA-2 (Yin et al. 2011, MWR)



An approximate form of the EnKF so as to be efficient for operational implementation
(it is more similar to a ESRF than to an EnKF)

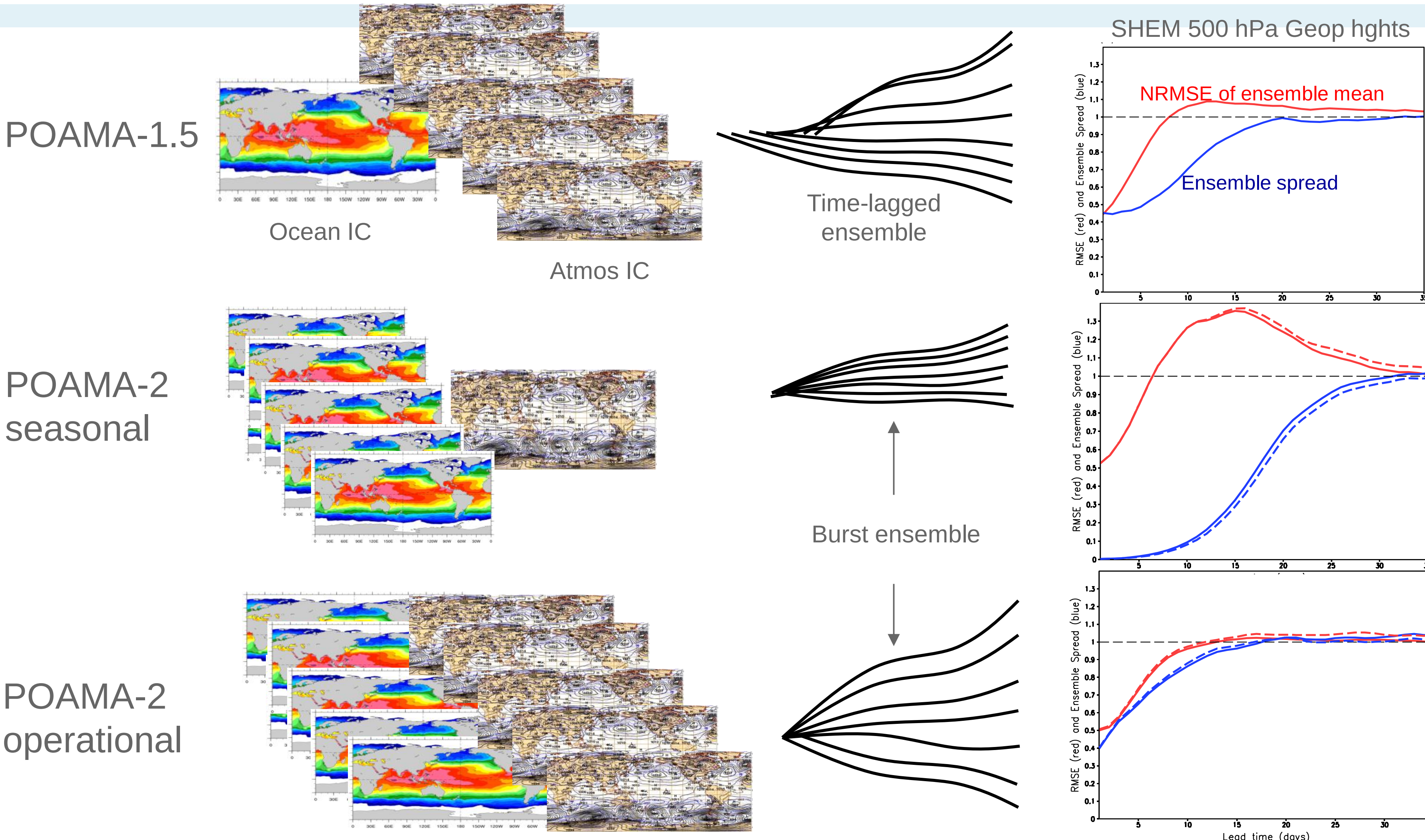
Real-Time Ocean Reanalysis Intercomparison

Salinity: http://poama.bom.gov.au/project/salinity/
Temperature: http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html



Australian Government
Bureau of Meteorology

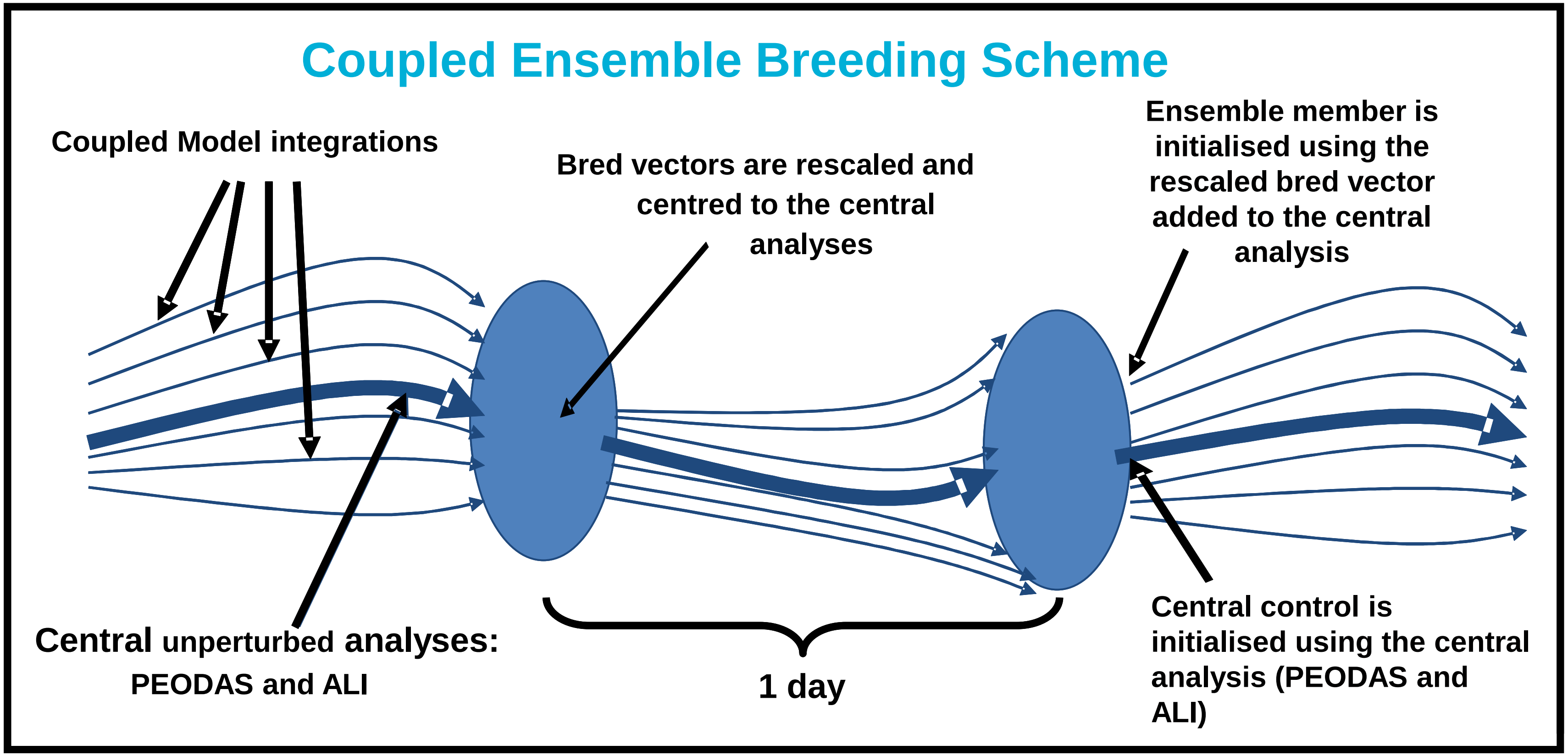
Moving to sub-seasonal prediction



Ensemble generation at BoM for POAMA2

Australian Government
Bureau of Meteorology

Towards Coupled Assimilation: Based on the PEODAS infrastructure



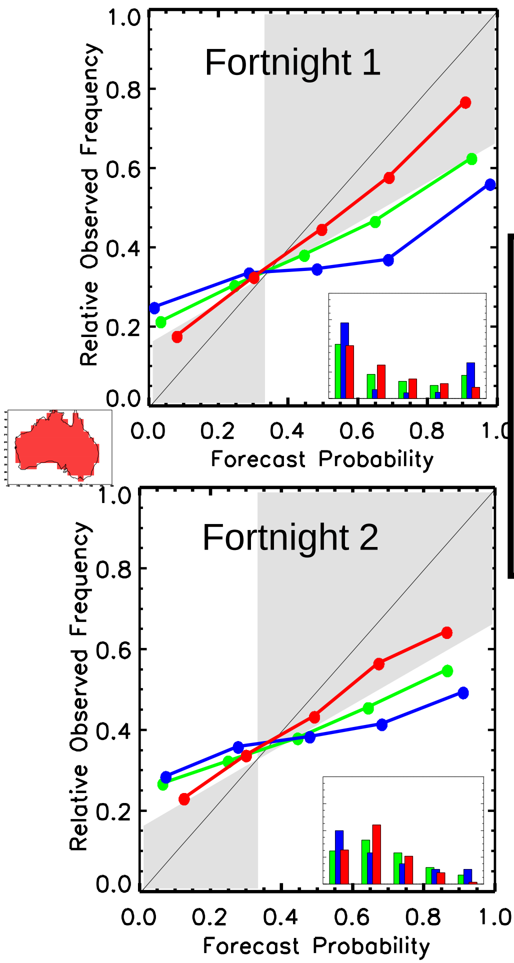
Generates coupled bred perturbations of the atmosphere and ocean based on a breeding method

(Hudson et al. 2013, MWR)

Australian Government
Bureau of Meteorology

Improved forecast reliability and skill

Reliability: Upper tercile rainfall



POAMA-1.5 (lagged atmos)

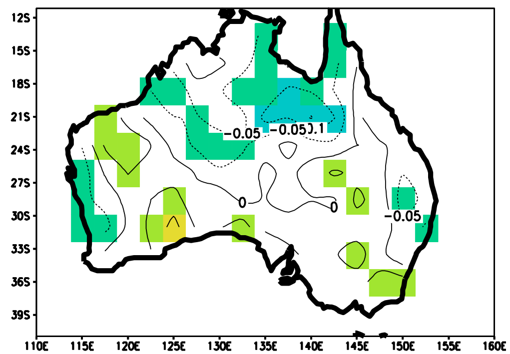
POAMA-2 (ocean perts)

POAMA-2 (atmos+ocean perts)

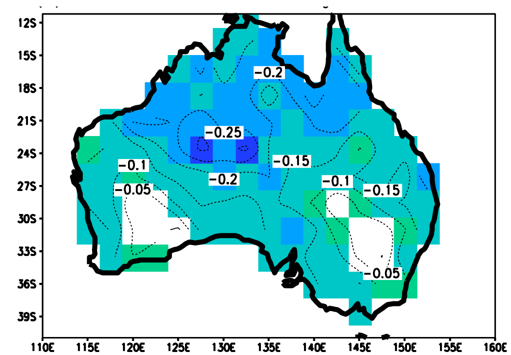
Brier Skill Score: Fortnight 2

Upper tercile Tmax

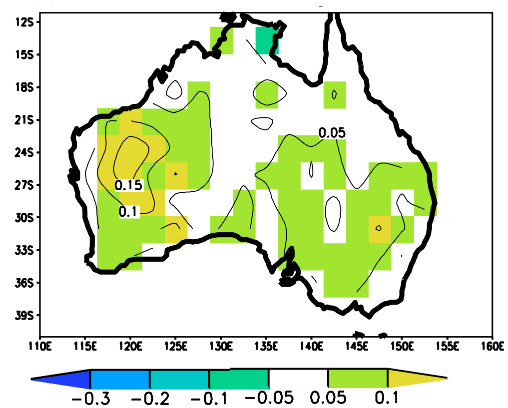
POAMA-1.5 (lagged atmos)



POAMA-2 (ocean perts)

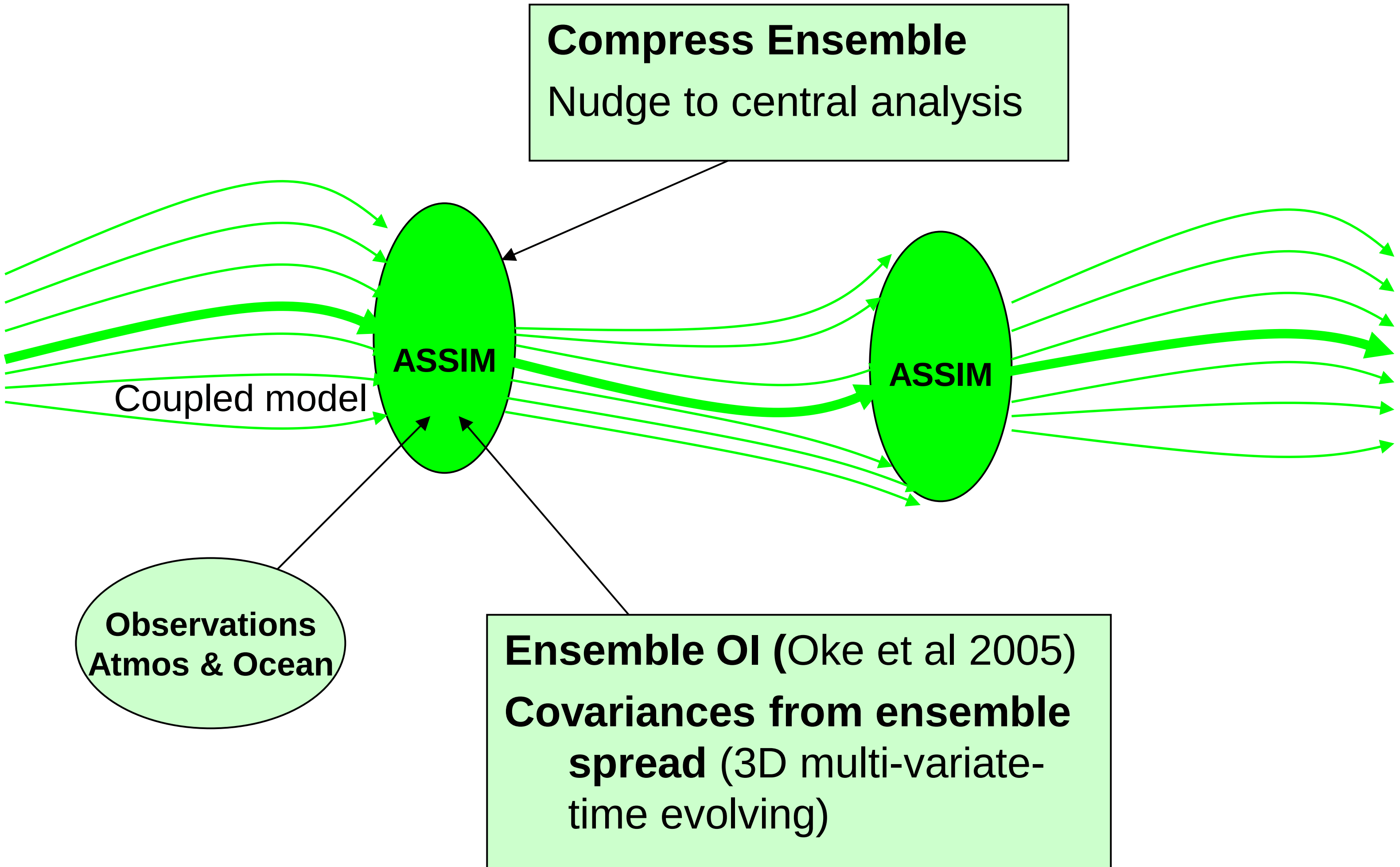


POAMA-2 (atmos + ocean perts)



Australian Government
Bureau of Meteorology

Further development: Weakly coupled DA with implicit bred vectors



Australian Government
Bureau of Meteorology

POAMA-2 vs ACCESS-S

	POAMA-2	ACCESS-S
Atmospheric model	Bureau Atmospheric Model (BAM) ~10 years old	Latest UK MetOffice atmospheric model which is part of the UK MetOffice coupled model GC2
Atmospheric resolution	Horizontal: 250 km (T47) Vertical: 17 levels (does not extend into the stratosphere)	Horizontal: ~60 km in the midlatitudes (N216) Vertical: 85 levels (extending into the stratosphere)
Land surface model	Simple bucket model for soil moisture and 3-layers for soil temperature.	State-of-the-art land surface model (JULES) with 4 soil levels. Sophisticated representation of soil and surface hydrology and of fluxes of heat and moisture within the soil and to the atmosphere. Land cover heterogeneity is represented.
Ocean model	Modular Ocean Model (MOM version 2). ~13 years old	Latest NEMO model from France which is part of the UK MetOffice coupled model GC2
Ocean resolution	Horizontal: ~200 km x 100 km Vertical: 25 levels; level thicknesses range from 15 m near the surface to almost 1000 m near the bottom	Horizontal: ~25 km Vertical: 75 levels; level thicknesses range from 1 m near the surface to about 200 m near the bottom (6000m depth)
Model Physics	>10 years old	Latest from UK MetOffice and France

ACCESS-S1

Australian Government
Bureau of Meteorology

ACCESS-S1: An intermediate system dependent on UKMO

UKMO GC2 (stochastic physics, greenhouse gases, etc.)

UKMO initial conditions + locally developed ensemble generation

Hindcasts increased from 15 to 23 years

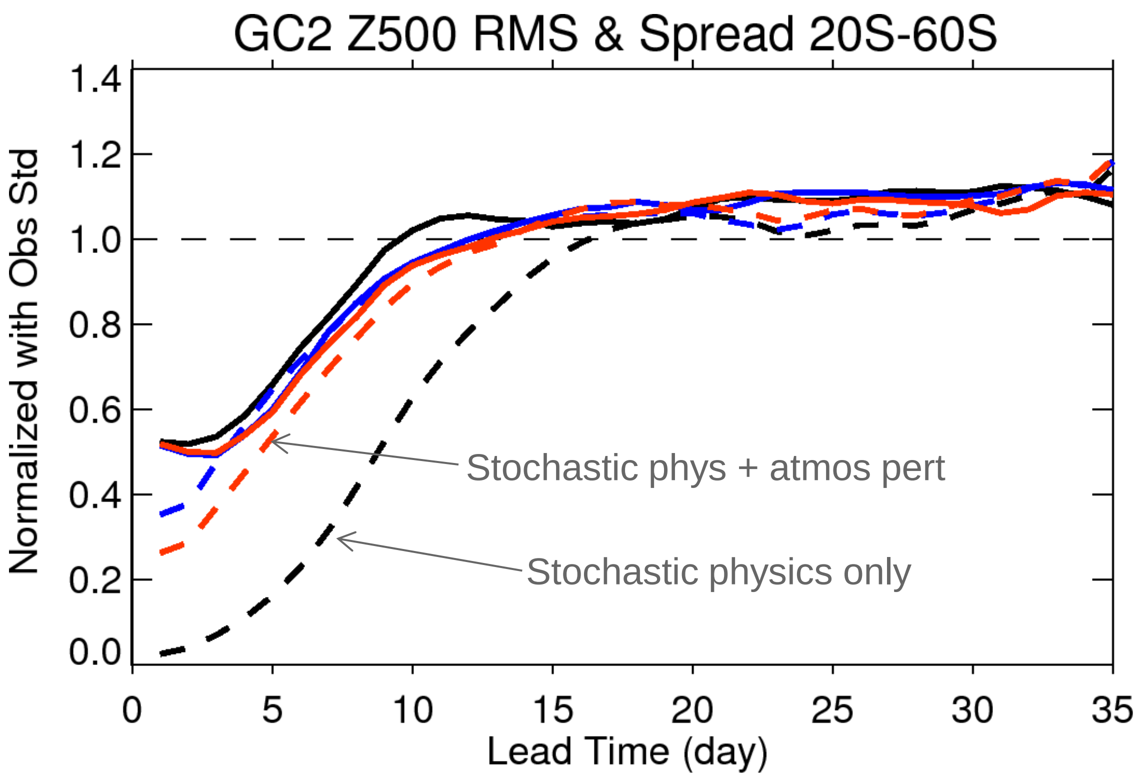
Hindcasts ensemble members increased from 3 to 11 per start date

Real-time forecasts: 11 ensembles per day, 6 months lead

Australian Government

Bureau of Meteorology

Atmospheric perturbations produce a more reliable ensemble for sub-seasonal



Test hindcasts:

1 May 1990-2012

ACCESS-S1

5 member ensemble

RMSE	SPREAD	
		Control
		Trial 1
		Trial 2

Control: Stochastic physics only

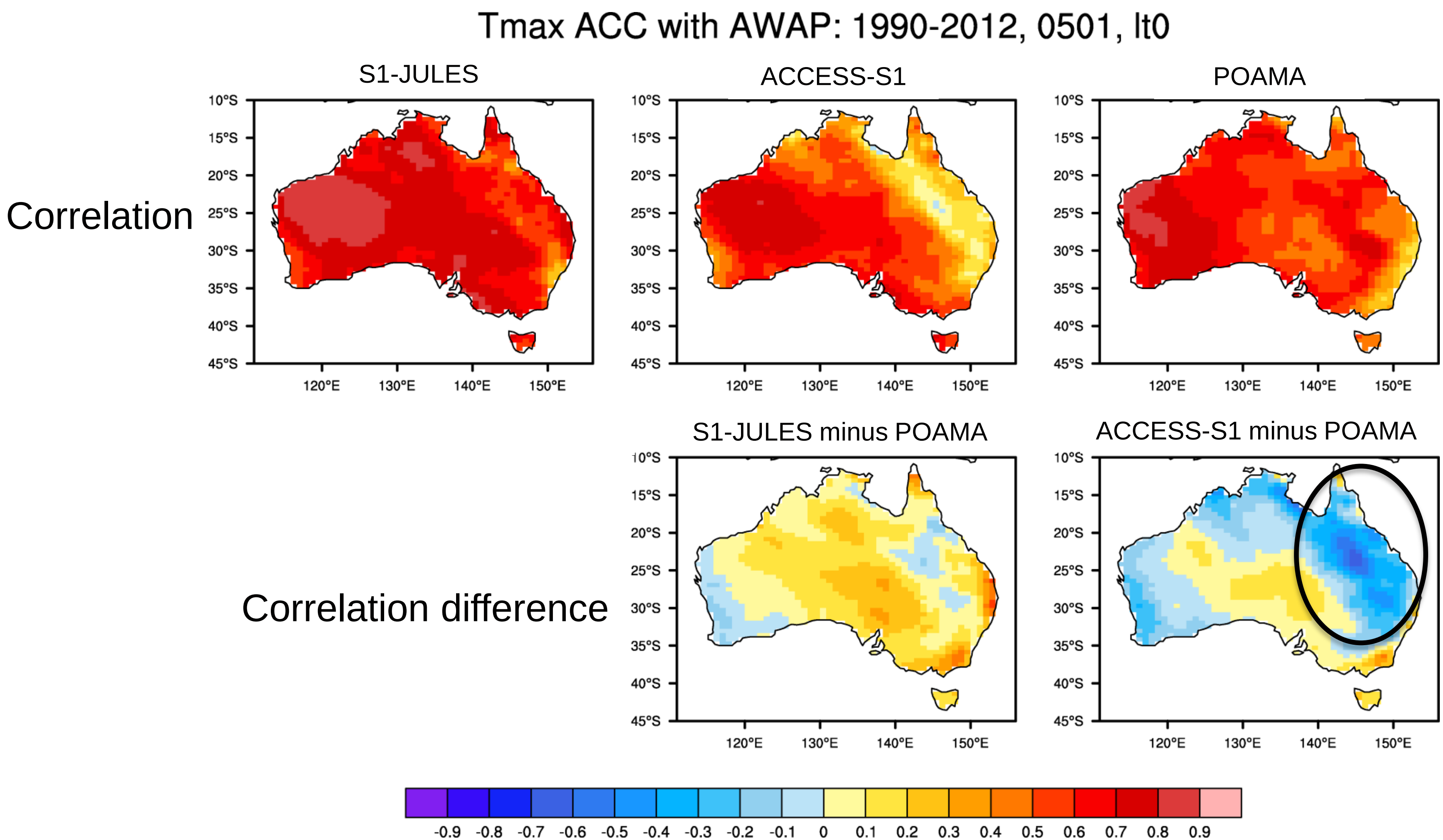
Trial 1: Stochastic phys + atmos pert

perturbations scaled to have obs uncertainty=rmsd(ERA-NCEP)

Trial 2: Stochastic phys + atmos pert

max perturbation limited to 20% of observed standard deviation

Issue: Initialising the land



CDA plans for ACCESS-S

- Preliminary version of BoM EnKF/EnOI weakly-coupled data assimilation + ensemble generation for ACCESS-S2
- Ocean observations (temperature, salinity) assimilated (altimeter for ACCESS-S3?)
- Static background ocean error covariance fields (EnOI) (time-varying EnKF for ACCESS-S3)
- Atmosphere nudged to a pre-existing analysis (direct assimilation for ACCESS-S3)
- Includes land surface initialisation
- Breeding scheme creates ensemble of perturbed atmos, land, ocean
- Sea-ice???
- EnKF-C written in C and efficient on massively parallel systems (DEnKF/ETKF/EnOI)
- Progress: preliminary version of the ACCESS-S2 DA has been set up and a two year reanalyses is being performed to evaluate the system and measure the impact on the forecasts

EnOI ensemble

$X(n) - (X(n-1) + X(n) + X(n+1))/3$

n: for month

X: T, S, U, V

23 years (1990-2012) of ICs for day 01/09/17/25 every month for GC2 run in MetOffice

Ensemble size:

Standard: 92 (23x4) for each month

Augmented: 184

(92+46(last half of last month)+46(first half of next month))

Obs error estimation and tunning

Measurement + representiveness + …

Adaptive moderation of observations (Sakov et al. 2012)

$$\sigma_{obs}{}^{2} \leftarrow \left[\left(\sigma_f{}^{2} + \sigma_{obs}{}^{2}\right)^{2} + \sigma_f{}^{2} d^{2}/K^{2}\right]^{1/2} \text{-} \sigma_f{}^{2}$$

R-factor: shift the balance between fitting to model and observations: rf=1/alpha

PH^T/(HPH^T + rf R) = alpha PH^T/(alpha HPH^T + R)

Exps of CDA for ACCESS-S2

Atmosphere: ALI nudging towards ERA-Interim

Ocean: EnOI scheme (T,S,U,V incs)

Assim: every 1 day with 1 day time window

Obs: EN4 Temp. & Sali. profiles, including CTD, XBT, Argo

Model: UKMO GC2 (with strongly SST relaxation to daily obs)

Observation errors: uncorrelated in space

Localisation radius: horizontally 1000km

EXP1: Orig_obs_error: 0.05° C(T), 0.01psu(S), Kf=1,Rf=6

EXP2: Orig_obs_error: 0.05° C(T), 0.01psu(S), Kf=3,Rf=6

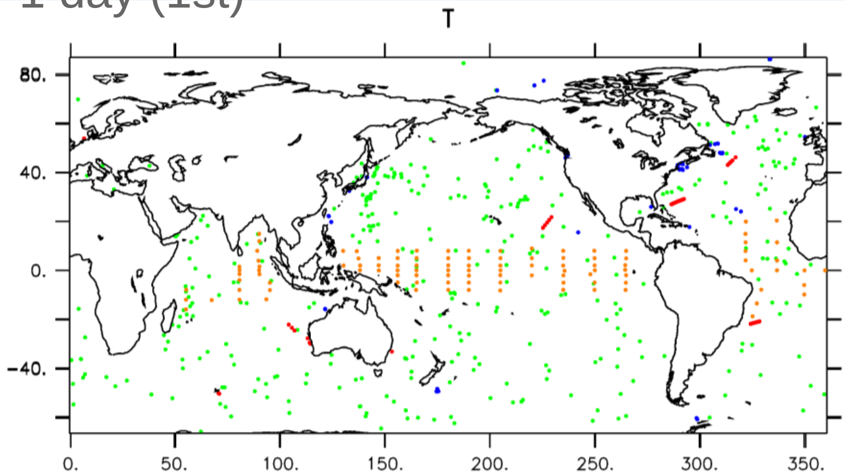
EXP3: Orig_obs_error: 0.5° C(T), 0.1psu(S), Kf=999,Rf=2

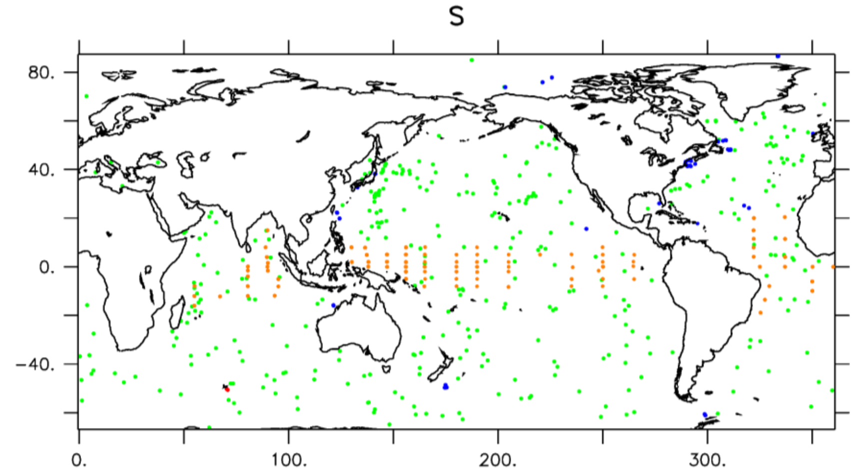
CTL: same run without ocean assimilation

Spatial distribution of the assimilated ocean observation (EN4 T/S) for December 2011

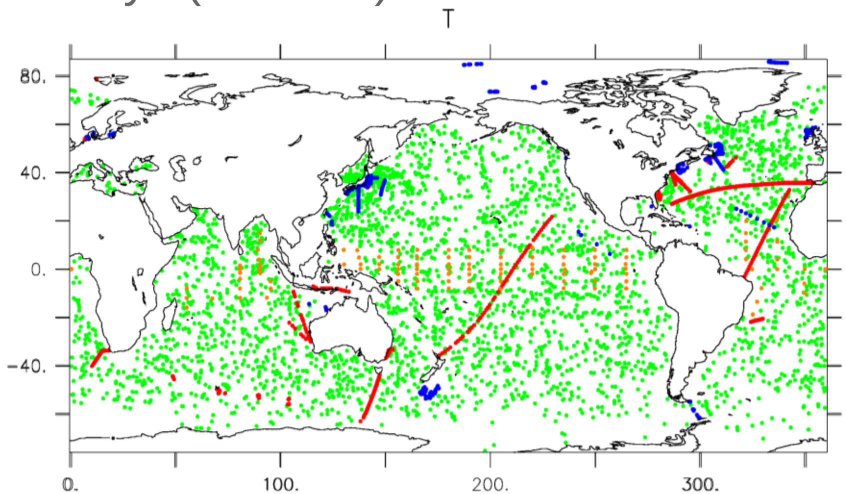
Australian Government
Bureau of Meteorology

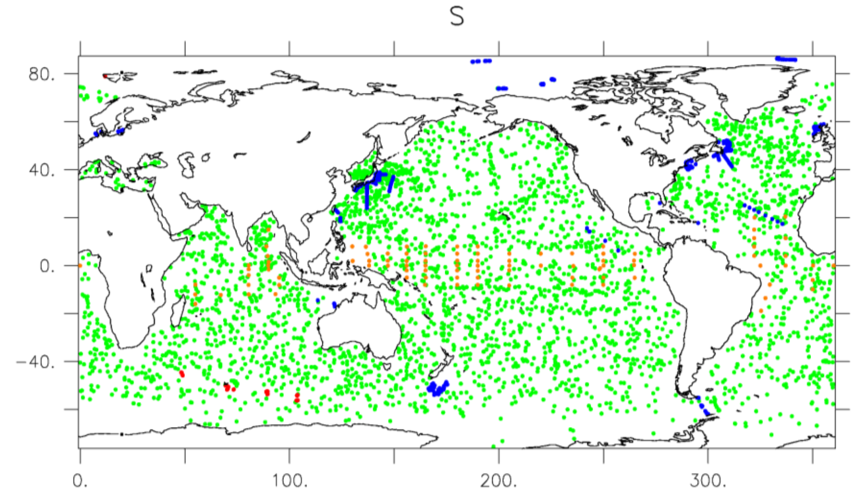
1 day (1st)





10 days (1st-10th)





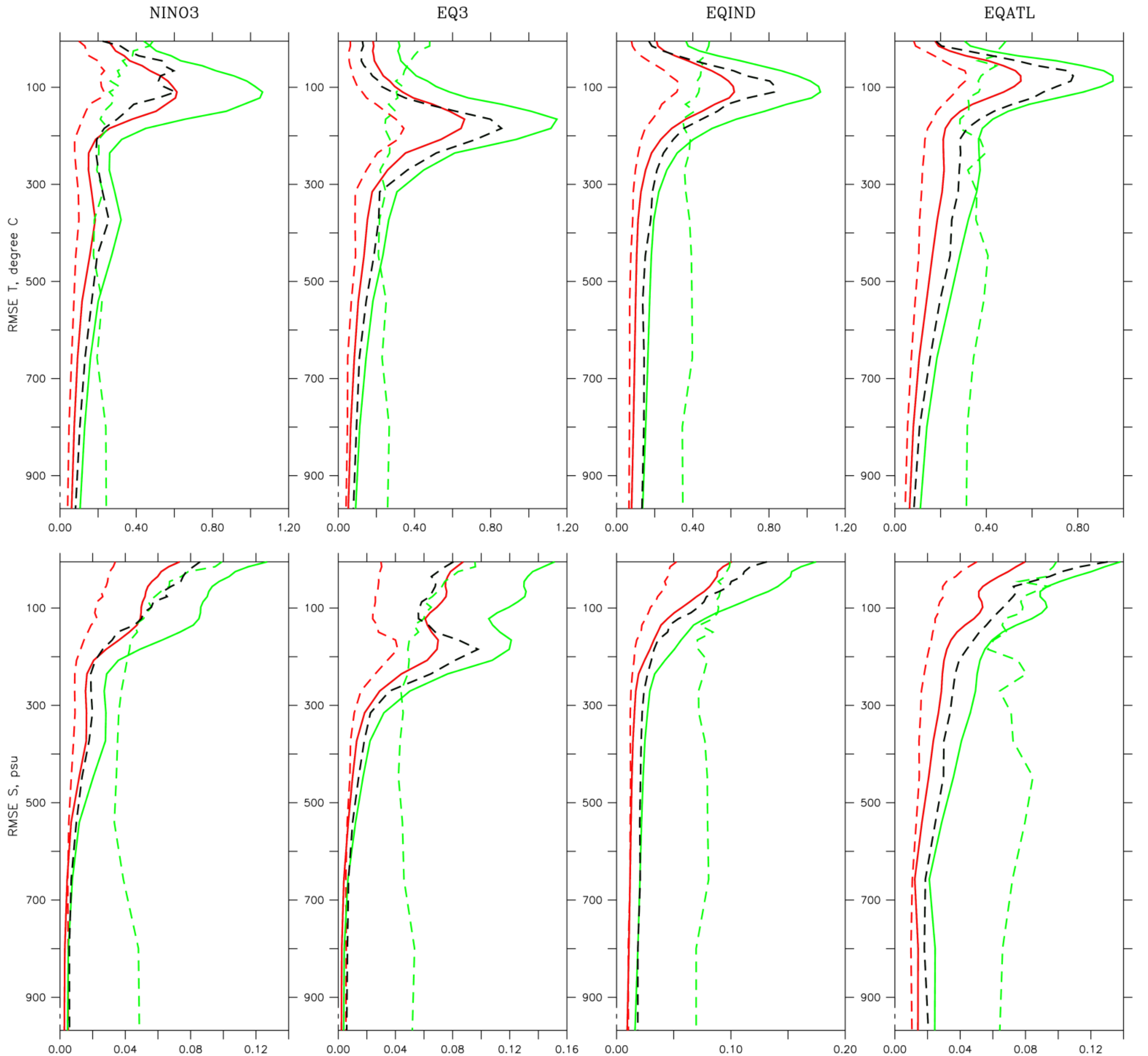
Background error(solid) vs Observation error(dashed) 201112 for EXP1, EXP2 and EXP3

Note: Solid black and red line overlapped due to the same Rfactor used

T

S

Kfactor=1,3,999
Rfactor=6,6,2
Ali_alpha=0.85
σT=0.05,0.05,0.5° C
σS=0.01,0.01,0.1psu

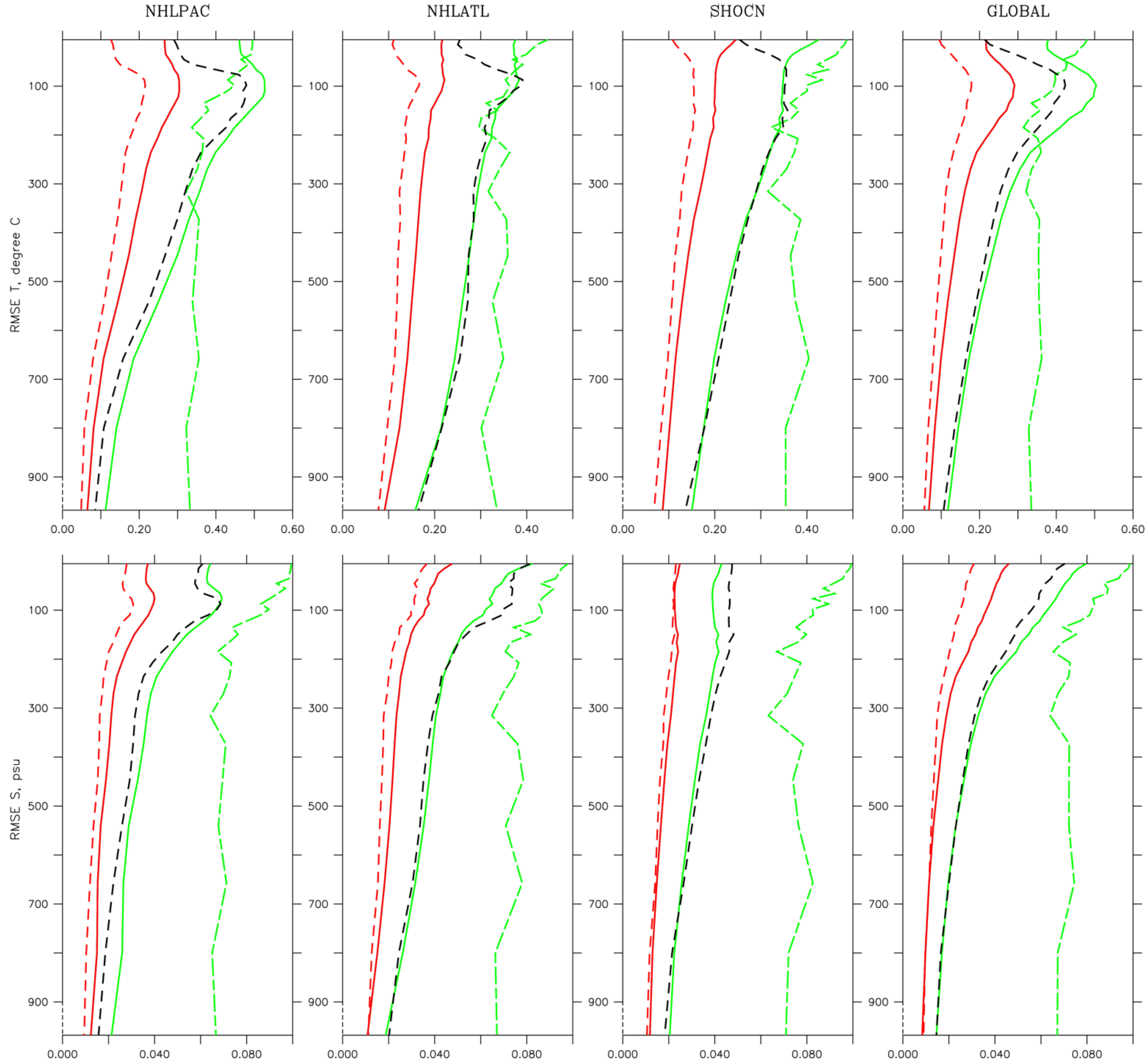


Background error(solid) vs Observation error(dashed) 201112 for EXP1, EXP2 and EXP3

Note: Solid black and red line overlapped due to the same Rfactor used

T

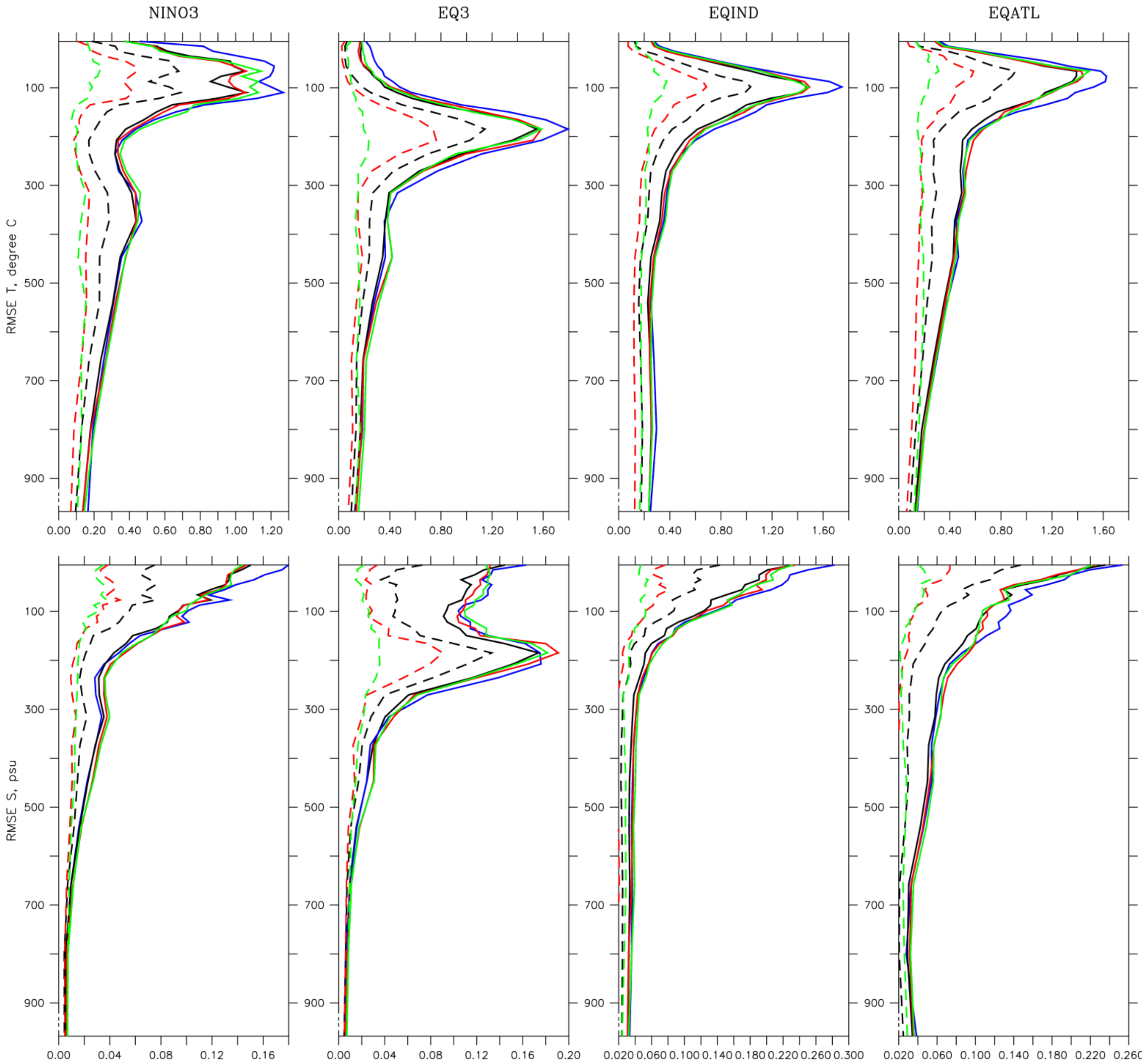
S



Kfactor=1,3,999
Rfactor=6,6,2
Ali_alpha=0.85
σT=0.05,0.05,0.5° C
σS=0.01,0.01,0.1psu

RMS O-B(solid), O-A(dashed) 201112
for EXP1, EXP2, EXP3 and CTL

T



S

Kfactor=1,3,999

Rfactor=6,6,2

Ali_alpha=0.85

σT=0.05,0.05,0.5° C

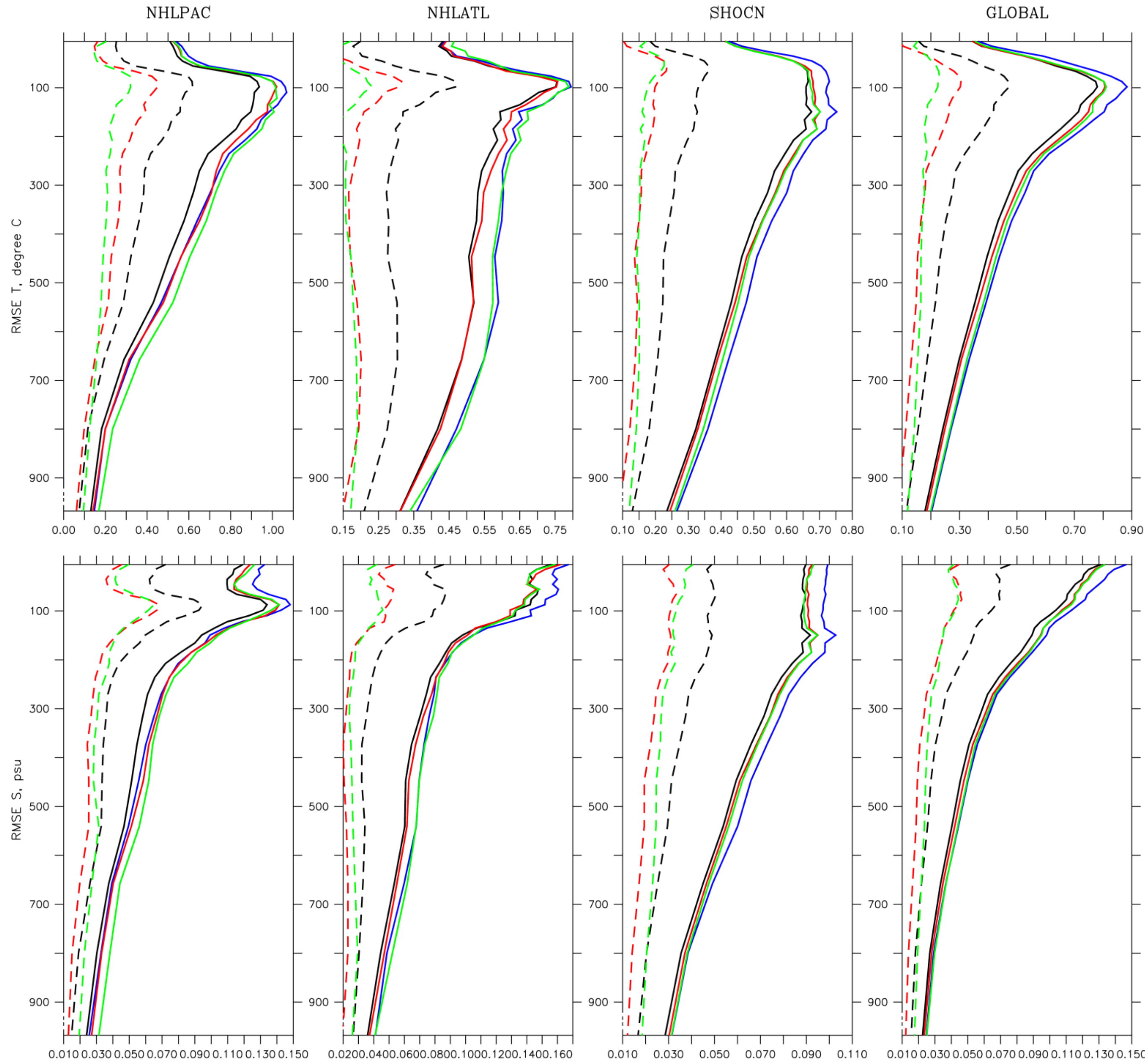
σS=0.01,0.01,0.1psu

RMS O-B(solid), O-A(dashed) 201112
for EXP1, EXP2, EXP3 and CTL

T

S

Kfactor=1,3,999
Rfactor=6,6,2
Ali_alpha=0.85
σT=0.05,0.05,0.5° C
σS=0.01,0.01,0.1psu

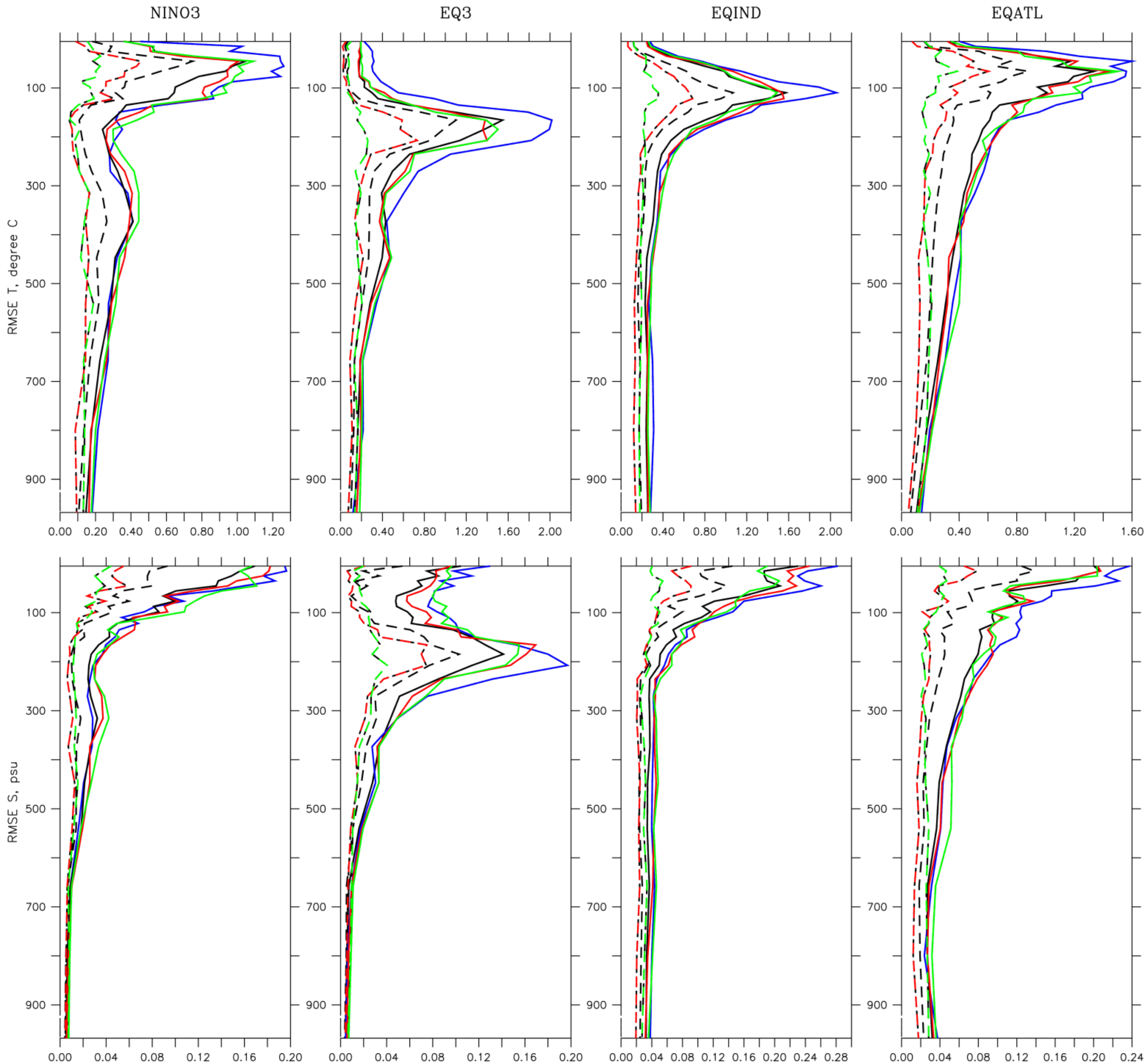


RMS O-B(solid), O-A(dashed) 201112 (24-30 mean)
for EXP1, EXP2, EXP3 and CTL

T

Kfactor=1,3,999
Rfactor=6,6,2
Ali_alpha=0.85
σT=0.05,0.05,0.5° C
σS=0.01,0.01,0.1psu

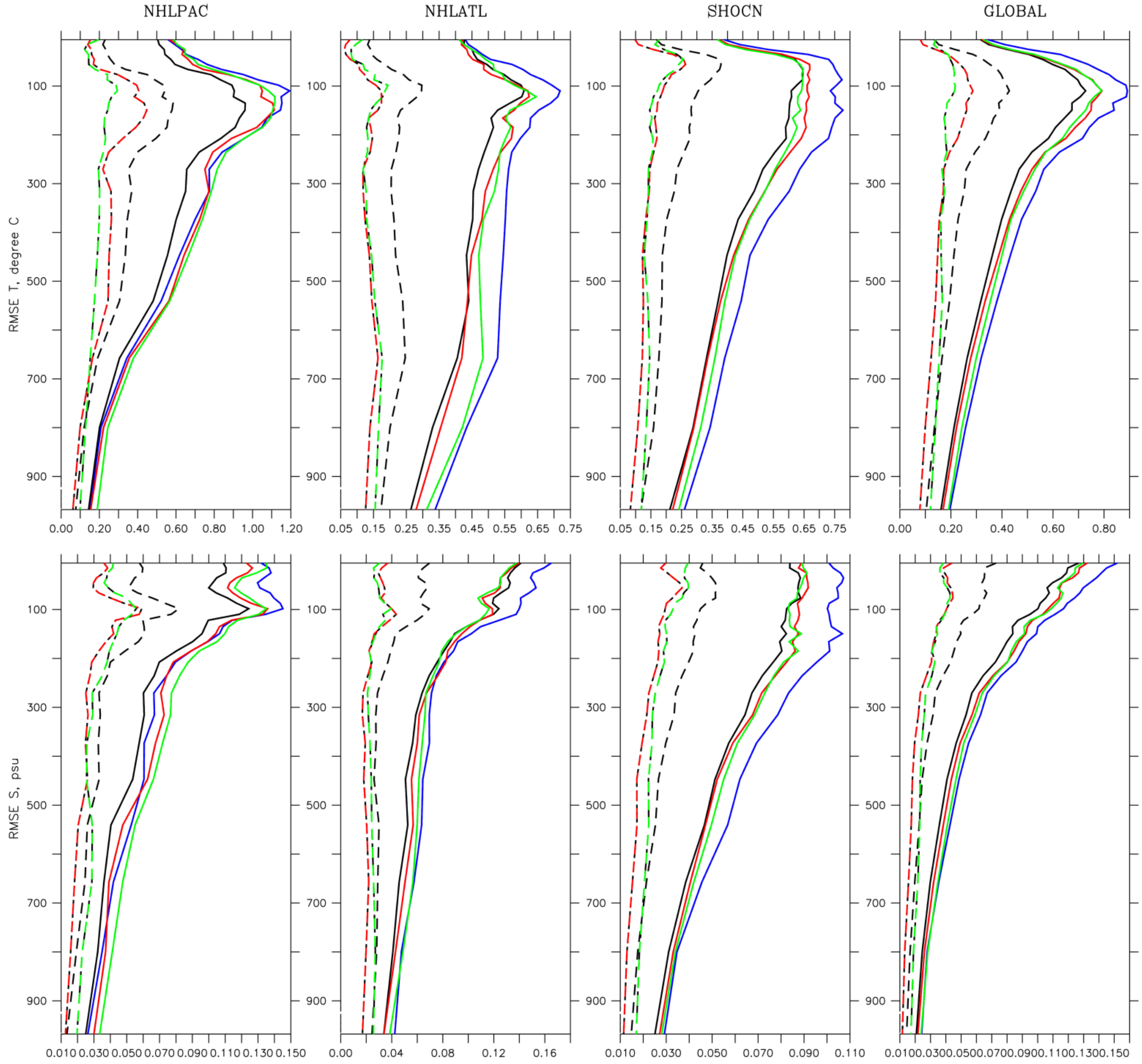
S



RMS O-B(solid), O-A(dashed) 201112 (24-30 mean)
for EXP1, EXP2, EXP3 and CTL

T

S



Kfactor=1,3,999
Rfactor=6,6,2
Ali_alpha=0.85
σT=0.05,0.05,0.5° C
σS=0.01,0.01,0.1psu

Australian Government
Bureau of Meteorology

Summary

- Need to support a sub-seasonal to seasonal prediction system
- Implementing EnKF weakly coupled DA and ensemble generation with ACCESS-S2 and S3
- Ensemble of perturbations to the atmosphere, land and ocean for initialising forecasts

Australian Government
Bureau of Meteorology

Thank you…