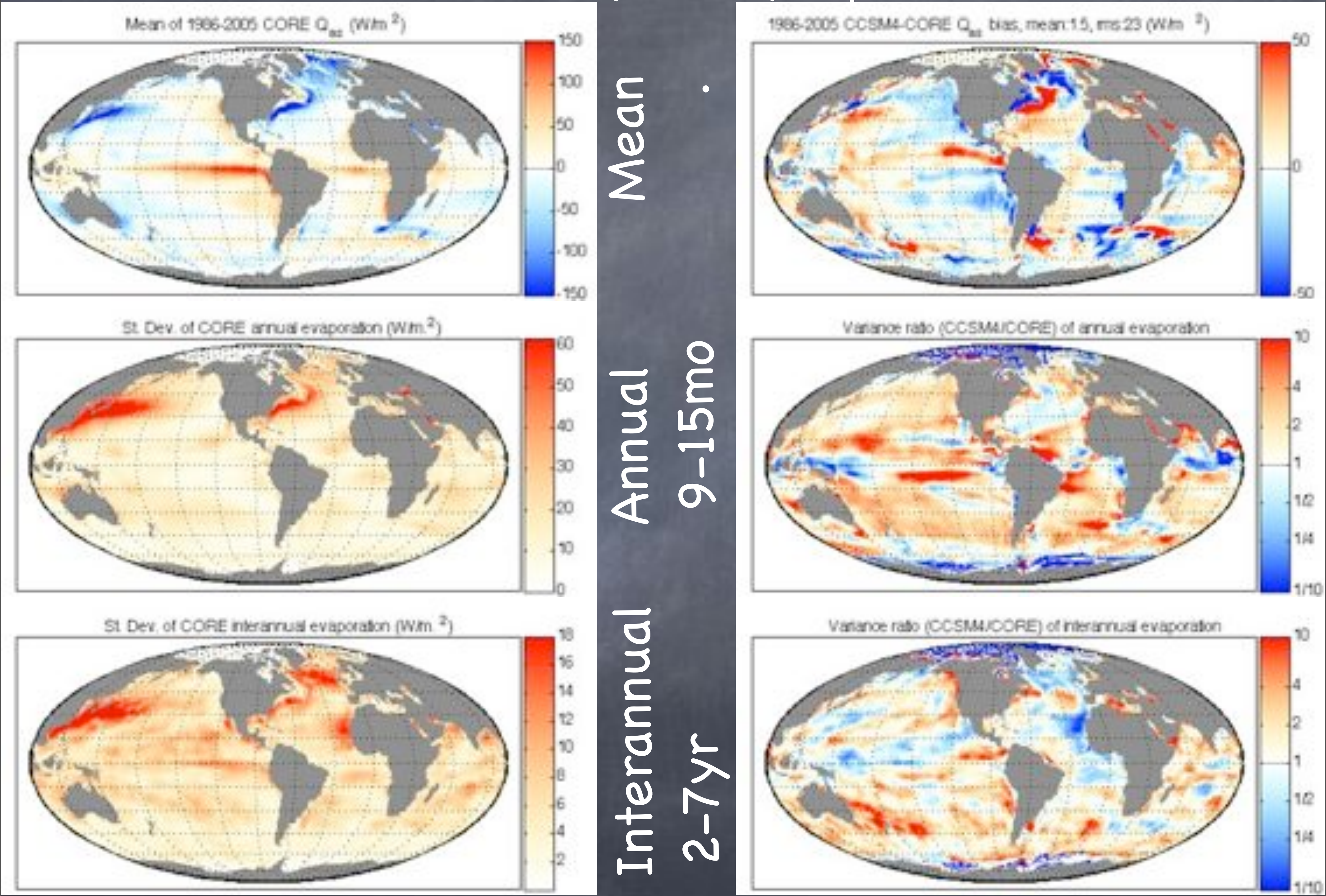
Overview of Parameterizations for Short- to Medium-Range Coupled Forecasts...

- Solutions in Play
  - Scale-Aware Parameterization?
  - Seamless Prediction?
  - Unified Atmosphere-Ocean Parameterization?
  - Stochastic Parameterizations for Ensembles?
- Questions
  - Coupled Model Errors--Differ by Timescale?
  - Processes to parameterize: same or different, studied or new?
  - Predictability & Computational Cost: payoff?

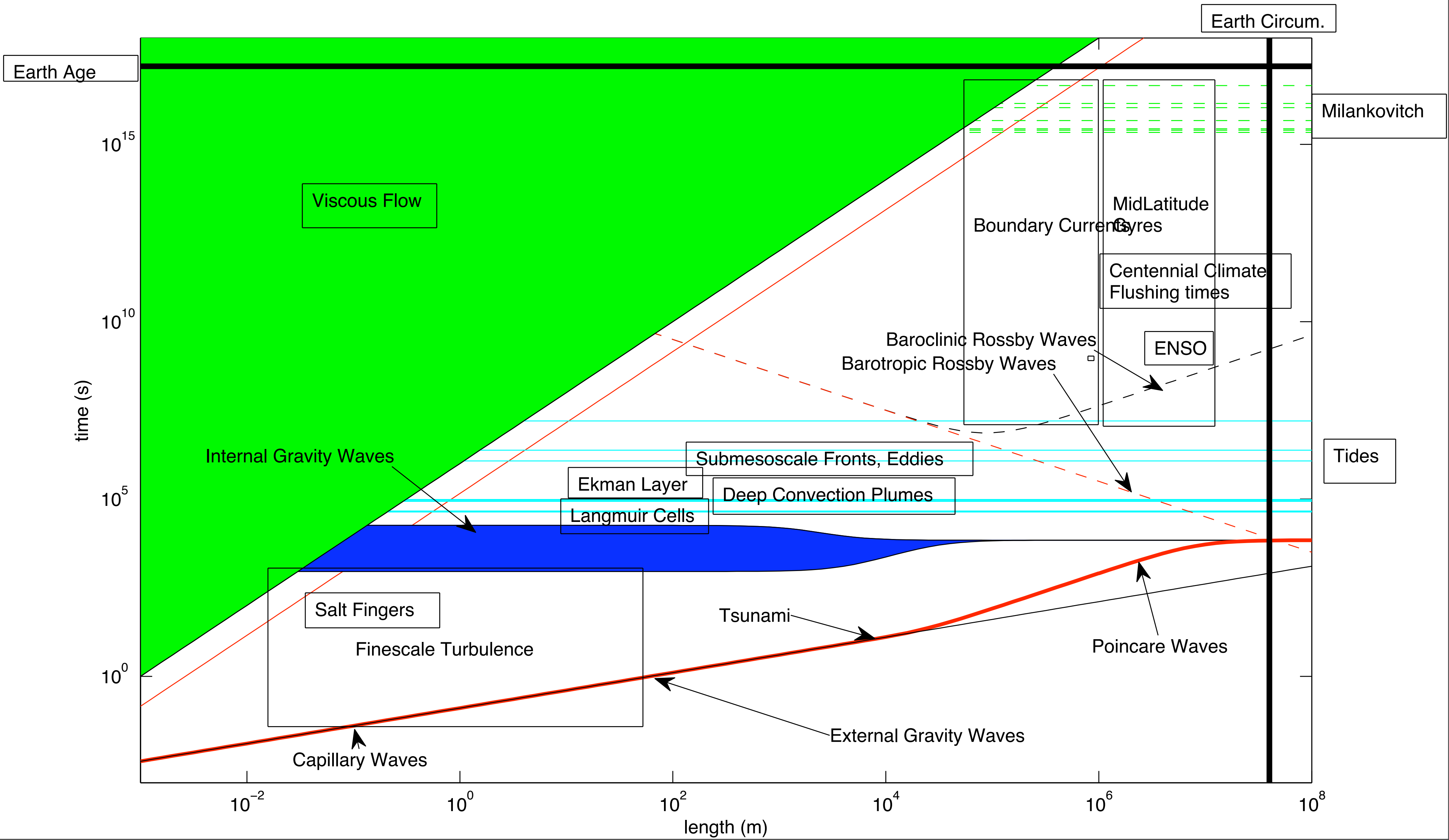
Air-Sea Errors vs. Data (L&Y 09) depend on timescale



S. C. Bates, B. Fox-Kemper, S. R. Jayne, W. G. Large, S. Stevenson, and S. G. Yeager. Mean biases, variability, and trends in air-sea fluxes and SST in the CCSM4. Journal of Climate, 25(22):7781-7801, November 2012.

The Ocean is Vast and Diverse

CESM=NCAR Community Earth System Model



The Ocean is Vast and Diverse

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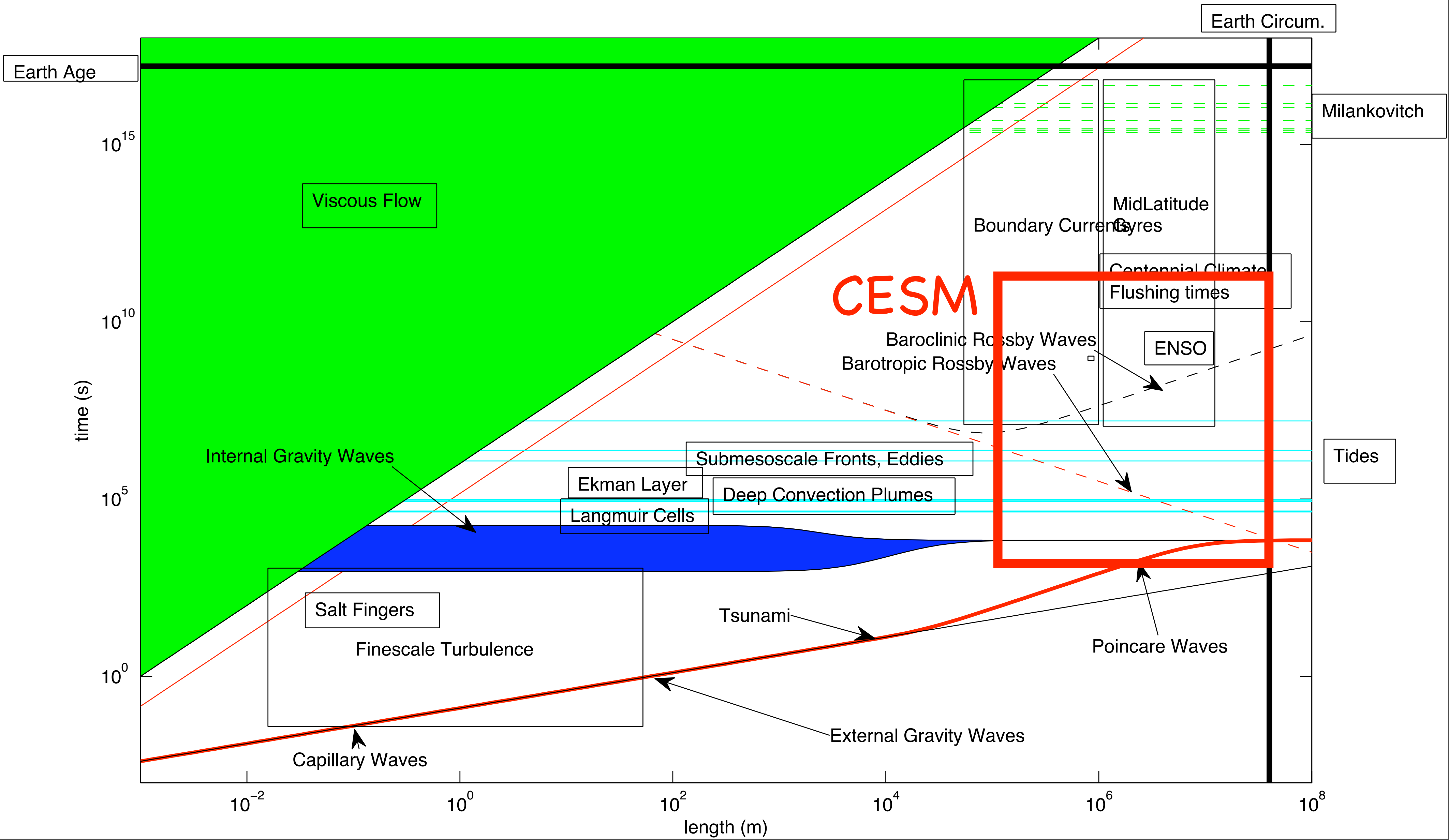
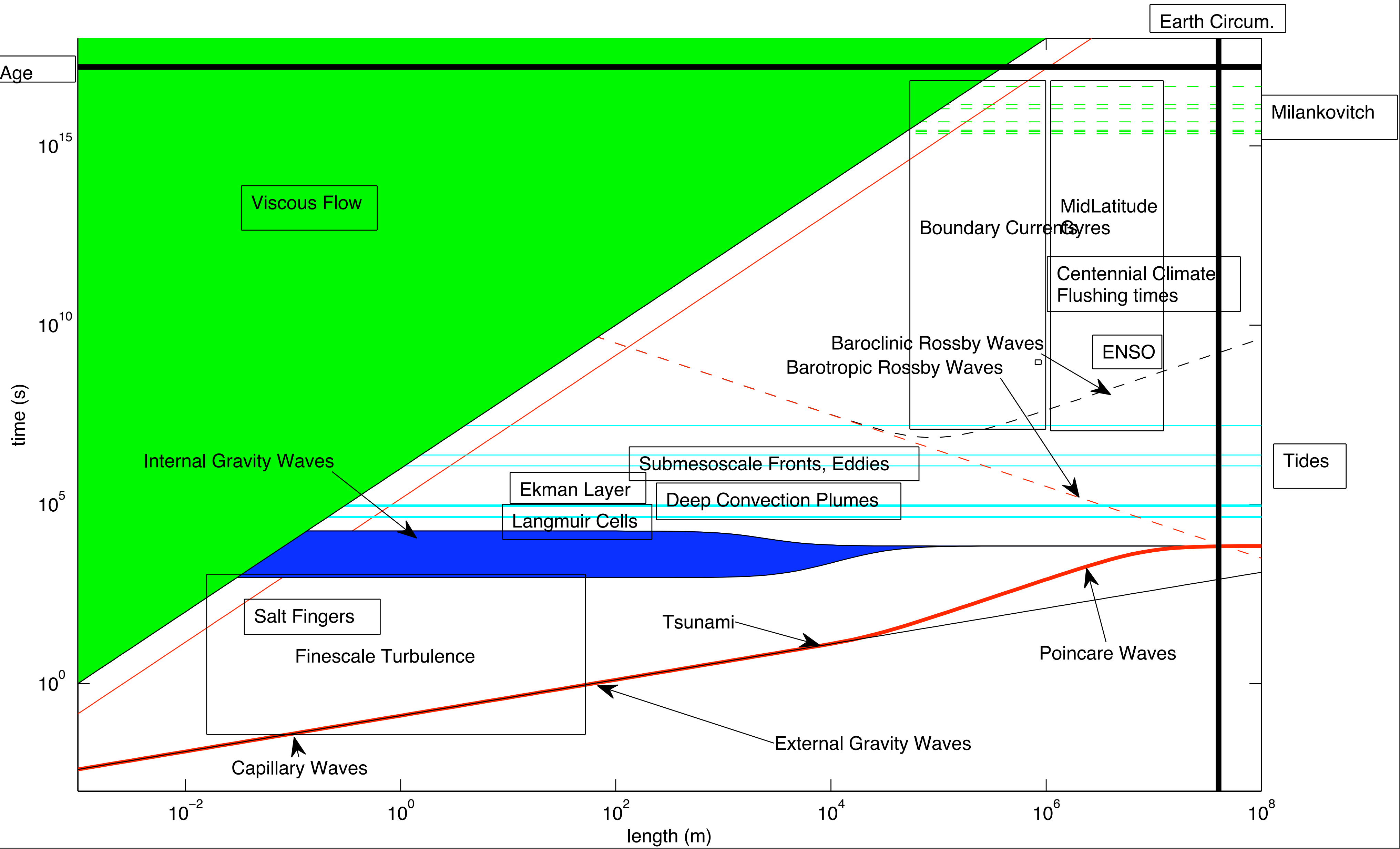


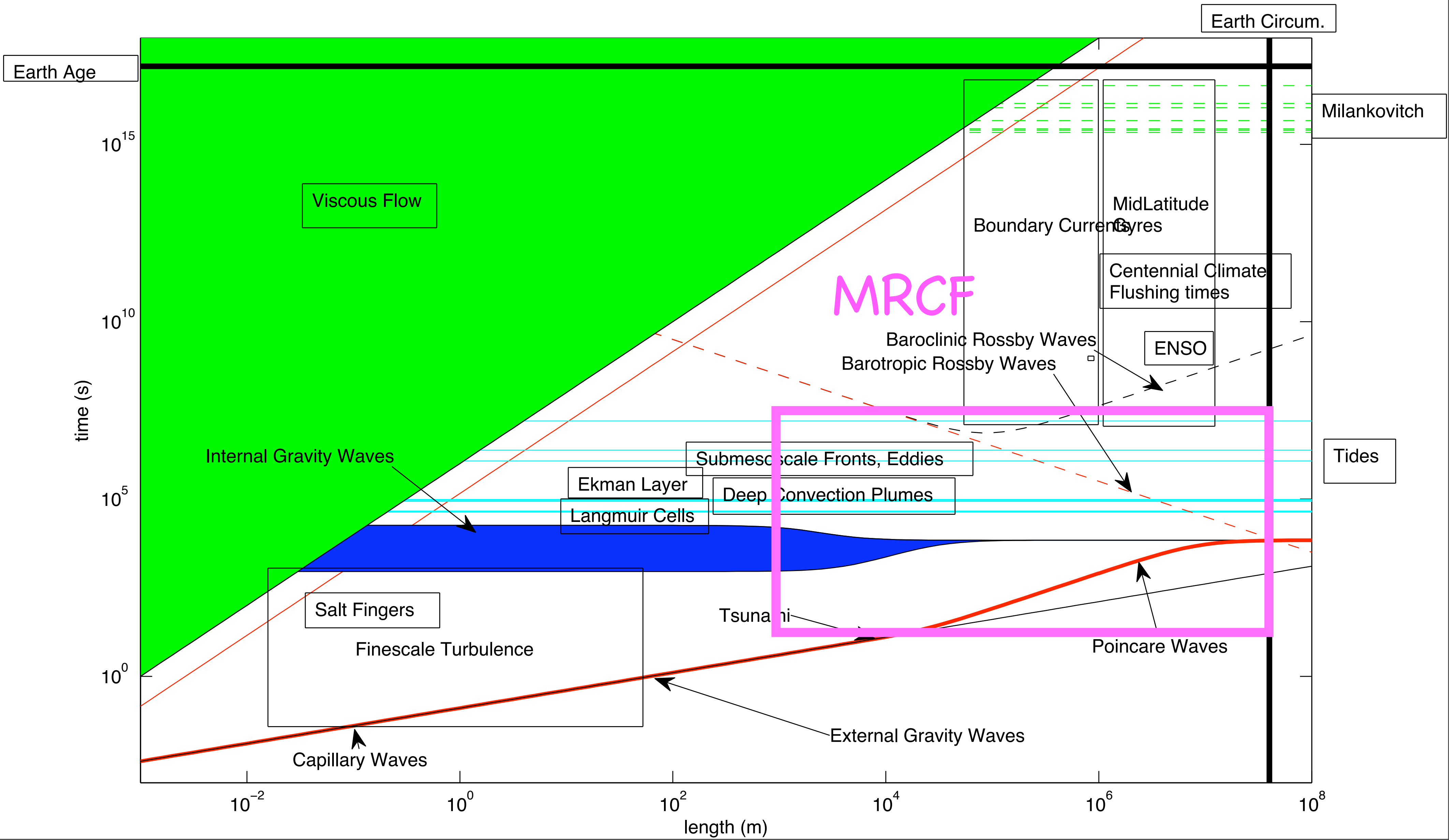
The Ocean is Vast and Diverse

MRCF=Medium-Range Coupled Forecast



The Ocean is Vast and Diverse

MRCF=Medium-Range Coupled Forecast



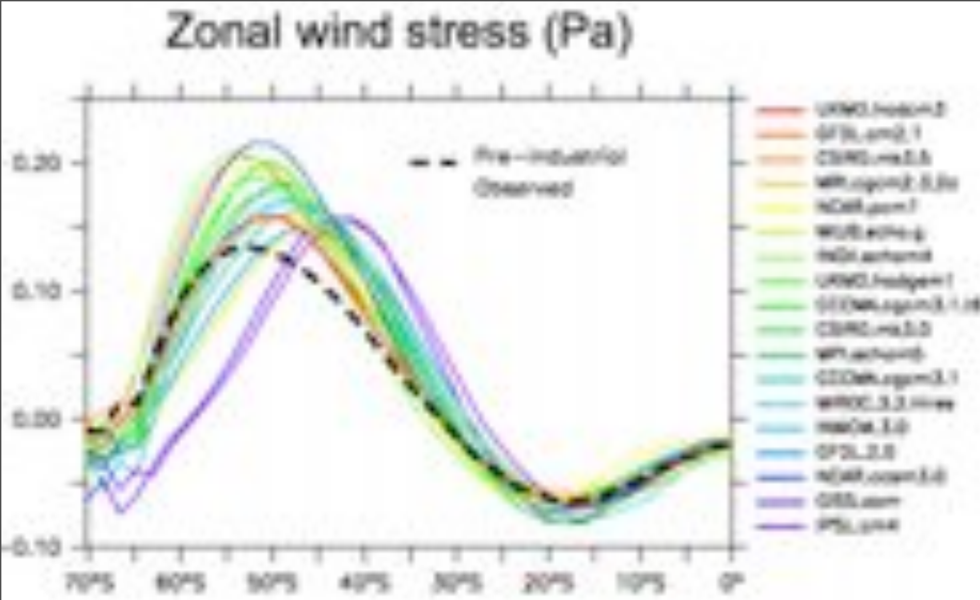
Estimates of the Contribution of Wind-Waves in the Coupled Ocean-Atmosphere Climate System.

Mark Hemer (CSIRO, CAWCR)
Baylor Fox-Kemper (Brown U.)
Ramsey Harcourt (UW, APL)

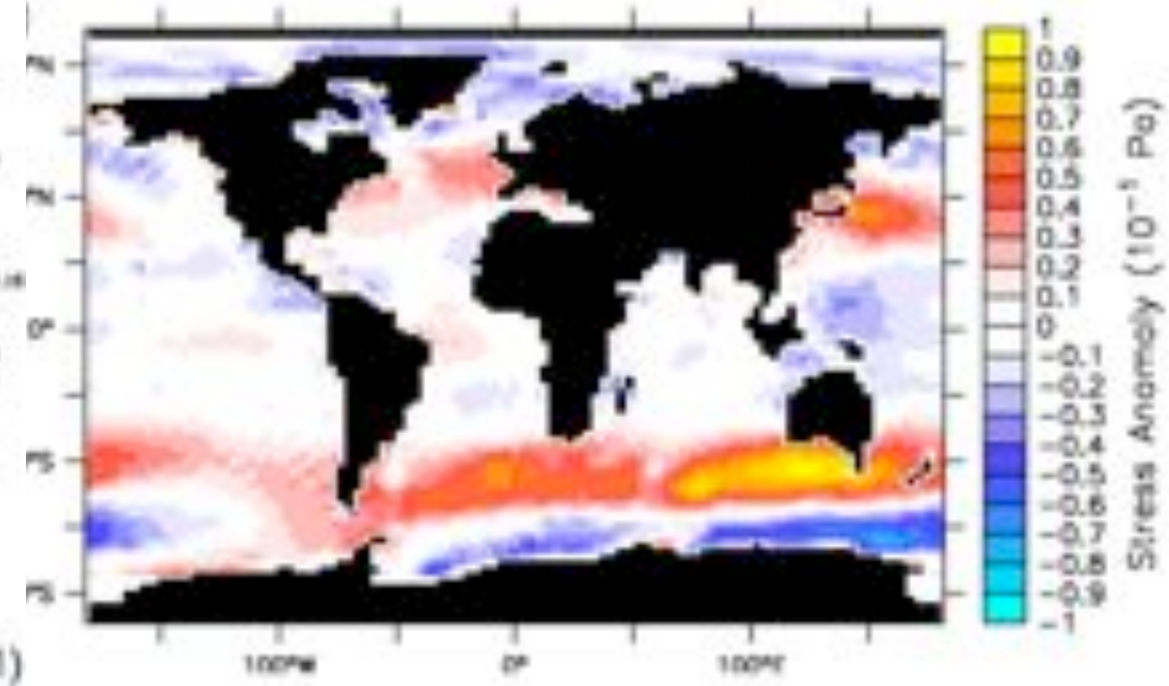
with Input from
Students: Adrean Webb (CIRES/APPM), Erik Baldwin-Stevens (CIRES/ASEN MA)
Luke Van Roekel, Peter Hamlington, Keith Julien, Peter Sullivan, Jim McWilliams, Bill Large, S.E. Belcher

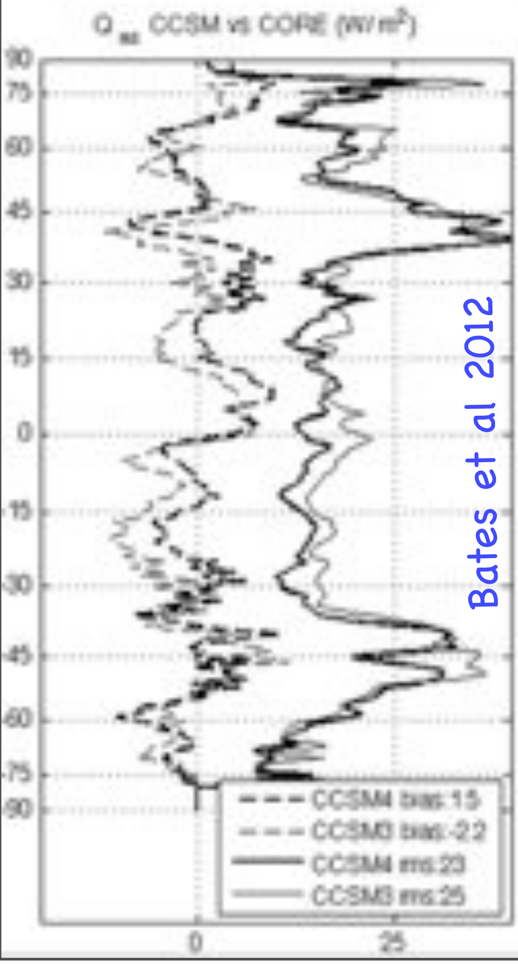
Joint GODAE OceanView/WGNE Workshop, 3/20/13

Sponsors: NSF 0934737, NASA NNX09AF38G, NSF #TBD, CIRES

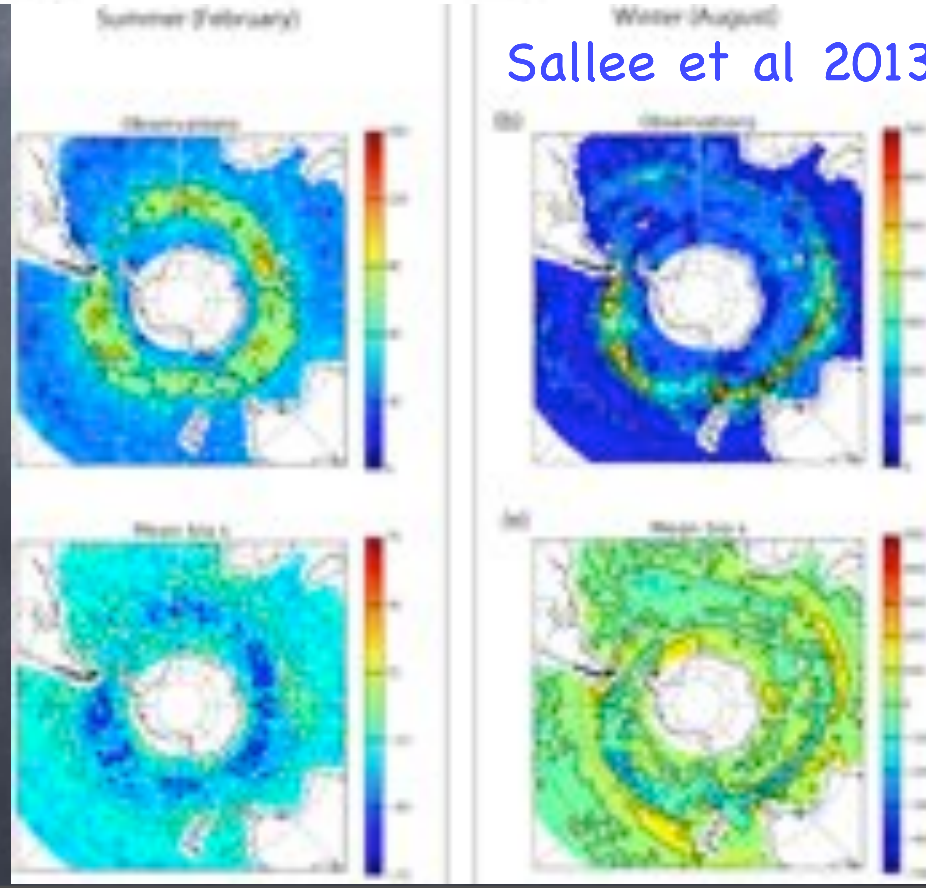


Swart and Fyfe (2011)





Bates et al 2012



Sallee et al 2013

Southern Ocean:

Wind too strong by about 5N/m^2

AND

MLD too shallow by about 50%

< 10W/m^2 net flux errors

Waves?

Southern Ocean Storm Belt Position is Sensitive to Roughness Parameterisation

Janssen and Viterbo (1996)
Sea-state dependent drag in
Seasonal prediction model

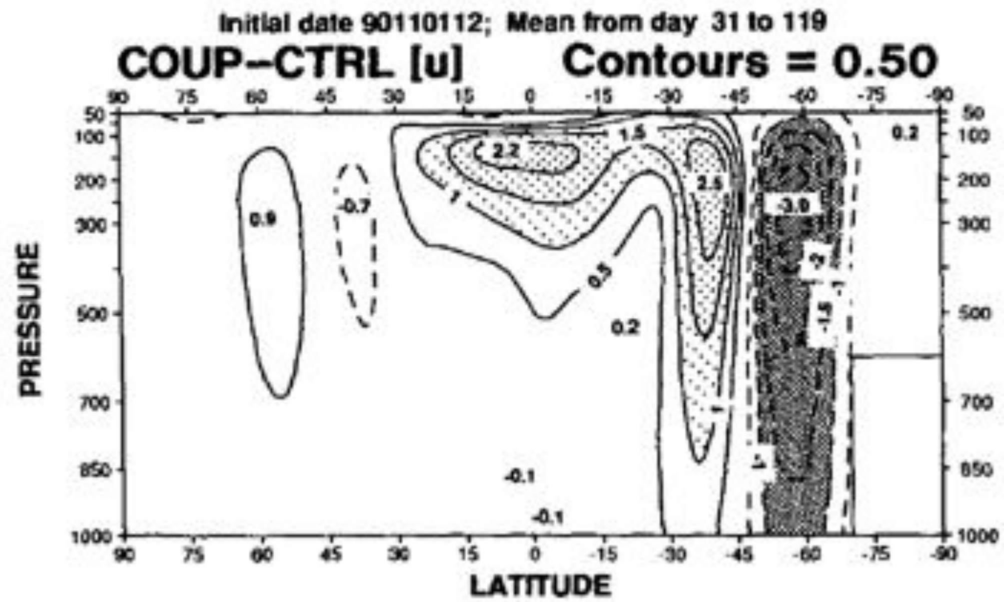
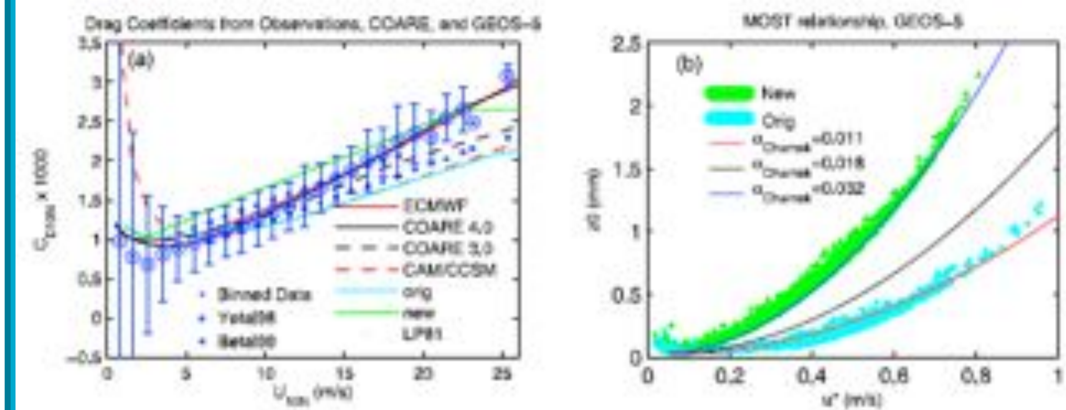
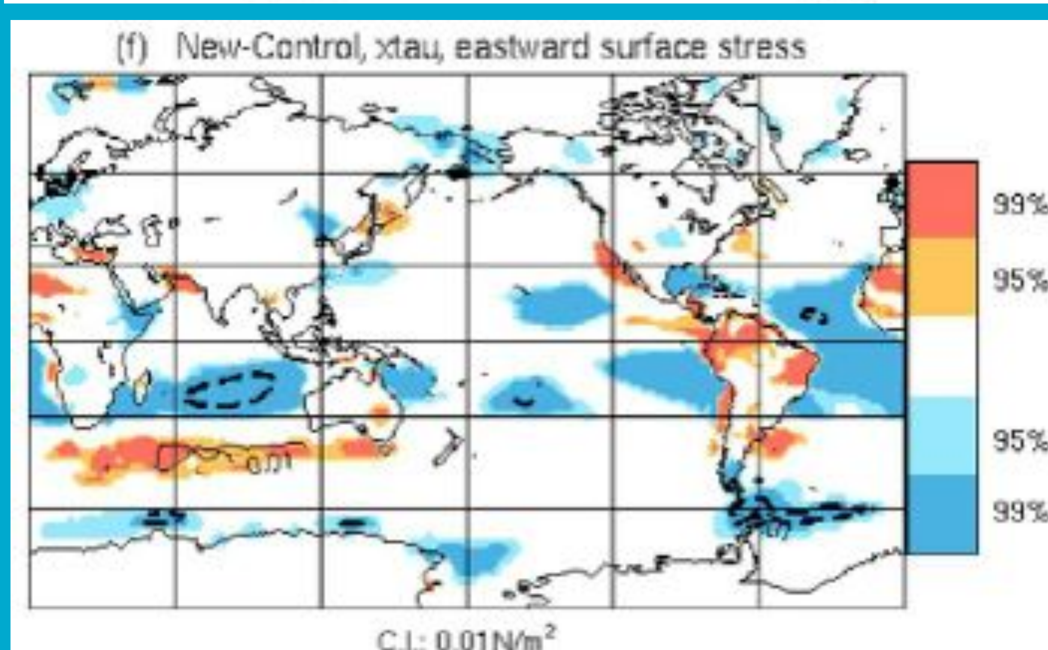


FIG. 8. Latitude–height cross sections of the differences in the zonal mean wind.

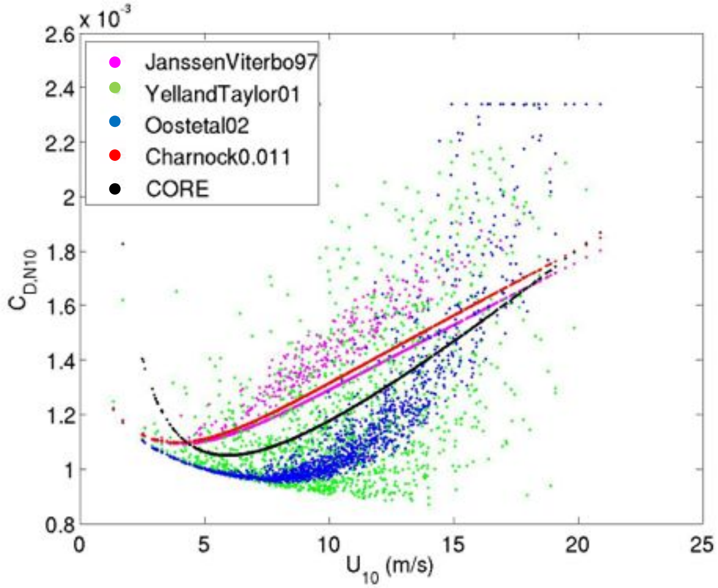
Garfinkel et al. (2011)
Increased ocean roughness in GEOS-5
GCM improved SO wind bias.



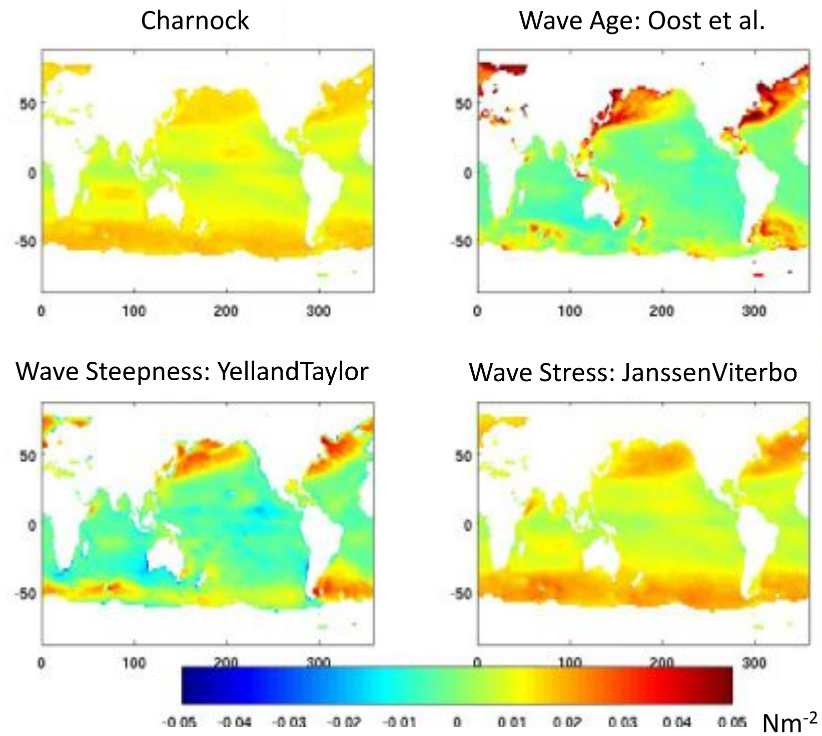


Friday, March 15, 13

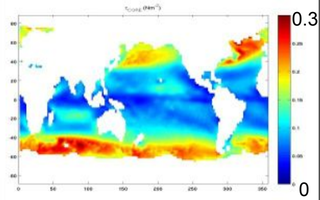
Drag Coefficient vs Wind Speed (SOFS, 47S, 142E)



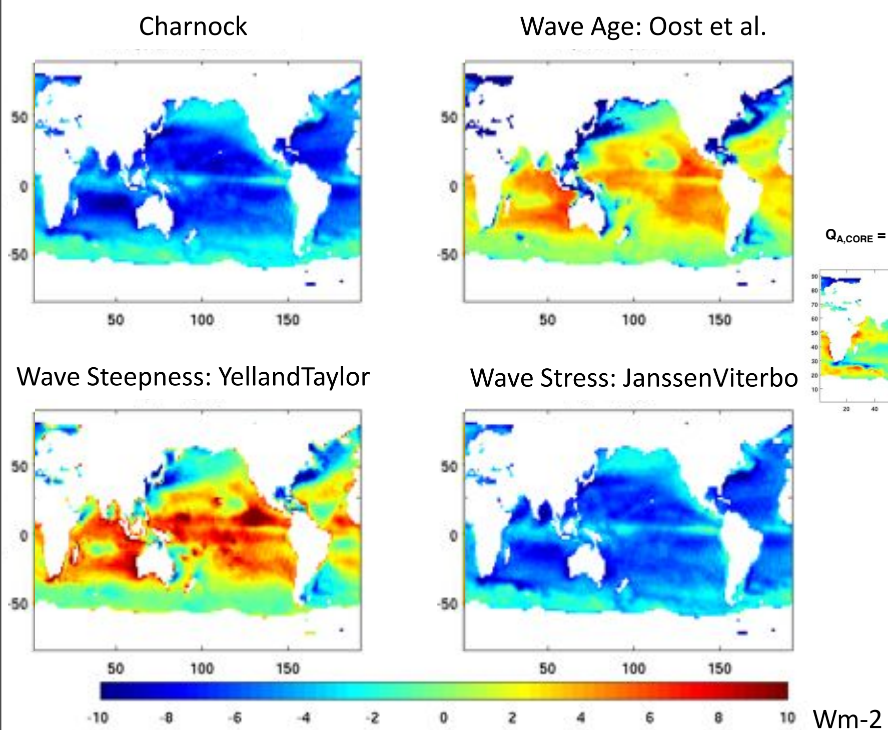
Momentum Flux Mean (Param - CORE)



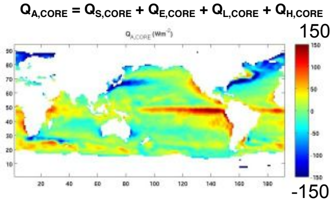
$$\overline{\tau_{CORE}} = \overline{\rho C_{D,CORE} u^2}$$



Total Heat Flux Mean $\overline{\left(Q_{A,param} - Q_{A,core}\right)}$



$Q_{A,CORE} = Q_{S,CORE} + Q_{E,CORE} + Q_{L,CORE} + Q_{H,CORE}$



Note:

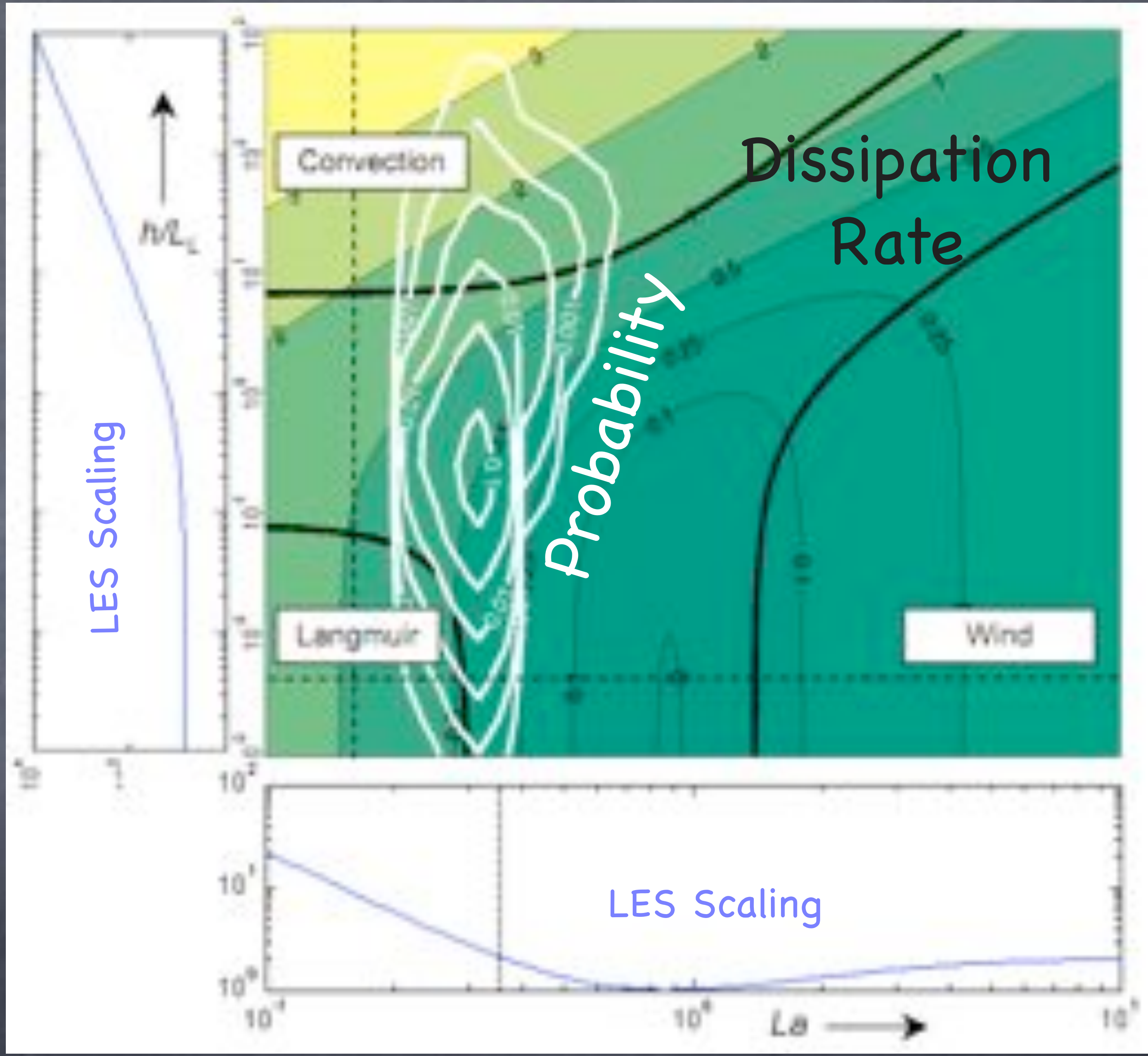
S. Ocean wind effects in about the right size (0.03 N/m²)

Other basins O(5W/m²) flux effect

Parameterization dependent

NO STORM TRACK FEEDBACK HERE!

Data + LES, Southern Ocean mixing energy: Langmuir (Stokes-drift-driven) and Convective

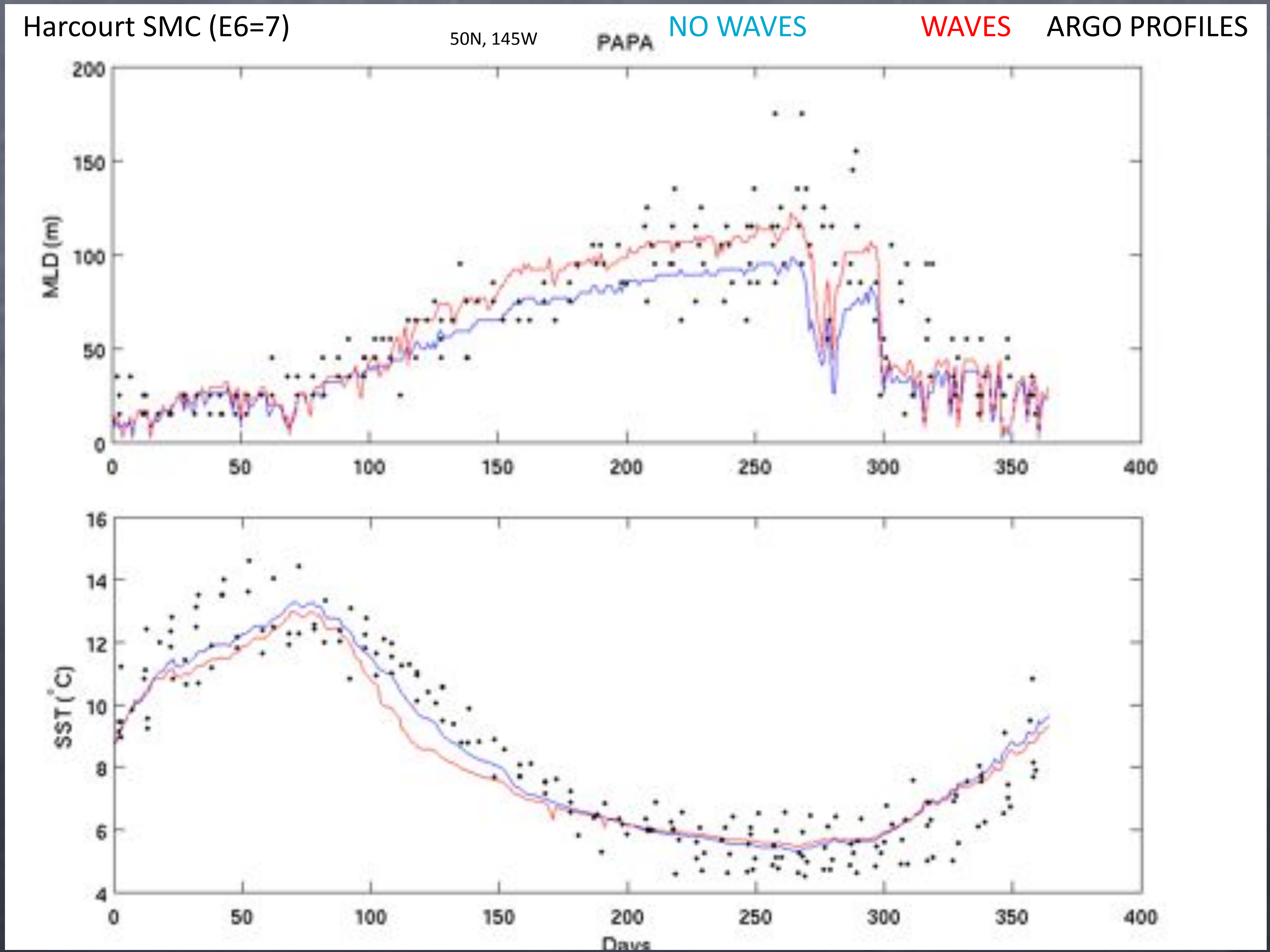


S. E. Belcher, A. A. L. M. Grant, K. E. Hanley, B. Fox-Kemper, L. Van Roekel, P. P. Sullivan, W. G. Large, A. Brown, A. Hines, D. Calvert, A. Rutgersson, H. Petterson, J. Bidlot, P. A. E. M. Janssen, and J. A. Polton. A global perspective on Langmuir turbulence in the ocean surface boundary layer. Geophysical Research Letters, 39(18):L18605, 9pp, 2012.

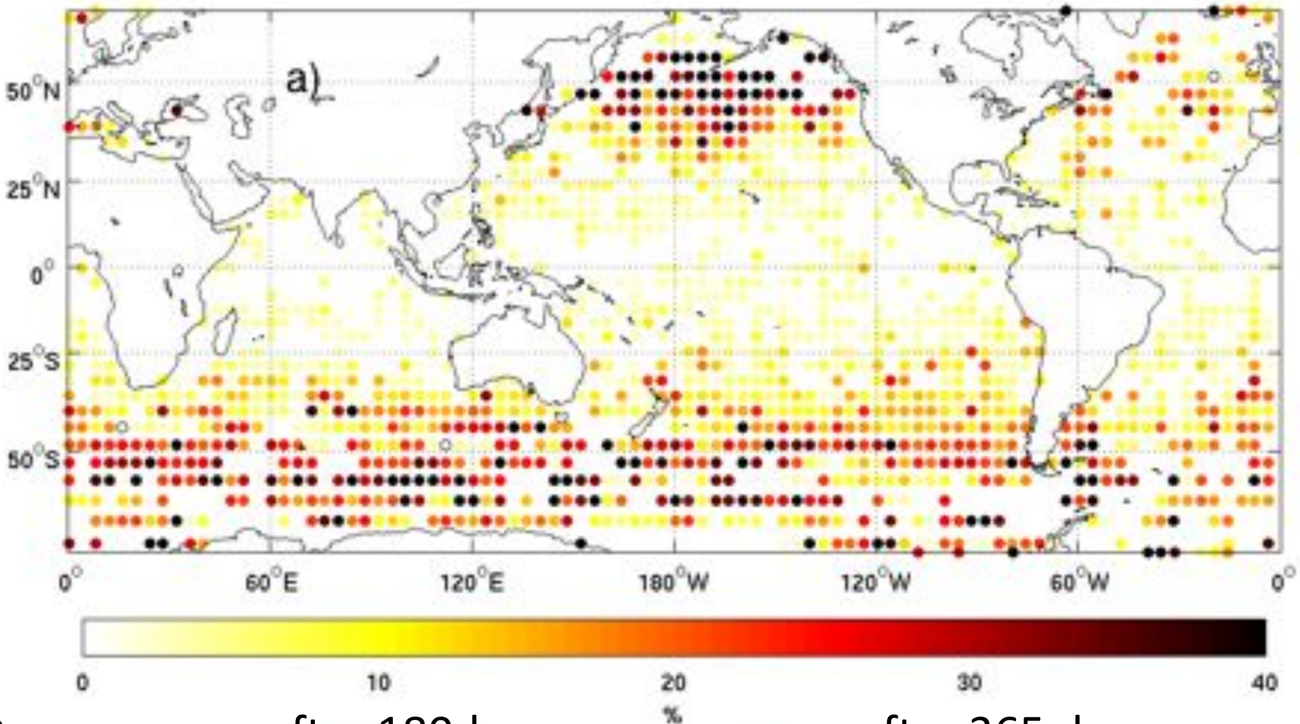
R.R. Harcourt. A second moment closure model of Langmuir turbulence. In press, JPO, 2013. doi: 10.1175/JPO-D-12-0105.1
M.A. Hemer, B. Fox-Kemper, R.R. Harcourt. Quantifying Wind-Wave Effects on Climate. In prep., 2013.

- 1) Estimate Langmuir effect based on Harcourt (2013)
- 2) Initialize with ARGO profile, run for 1 year with Large & Yeager (04) forcing (neglect oceanic flux divergence)

One example location shown at right, near OWS-PAPA



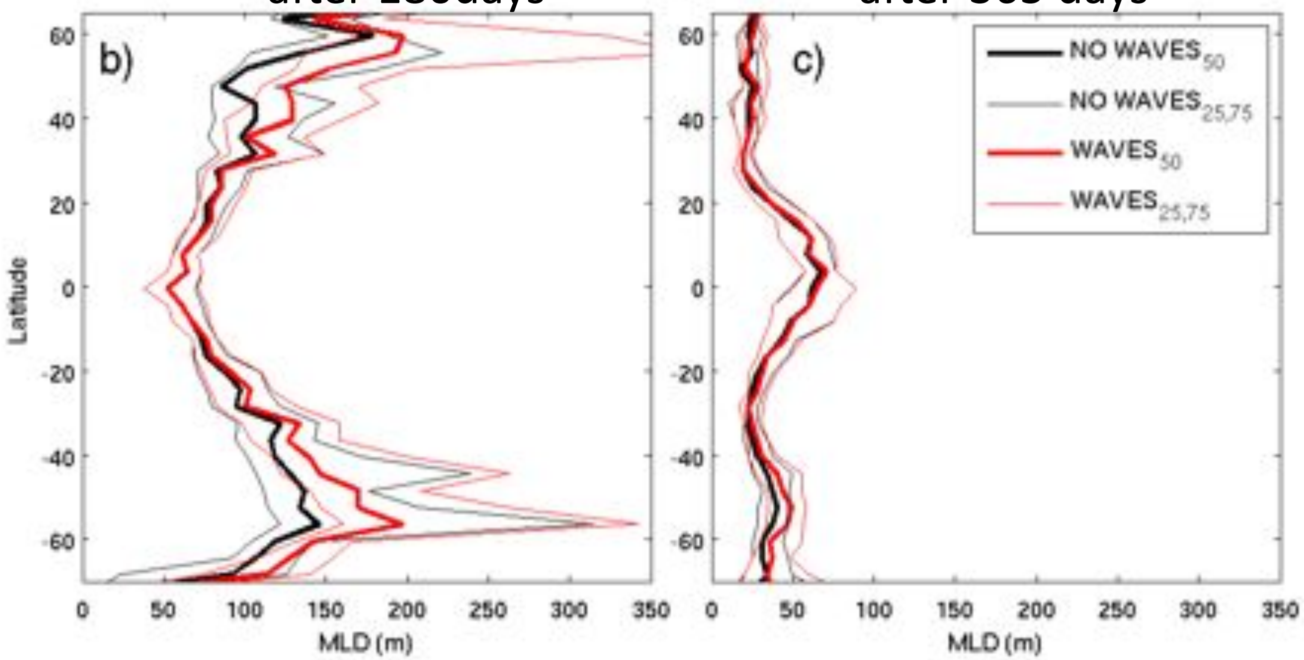
Percentage increase in MLD with introduction of SMC (E6=7) langmuir mixing ~180 days after Summer Solstice



Zonal mean MLD

after 180days

after 365 days



R.R. Harcourt. A second moment closure model of Langmuir turbulence. In press, JPO, 2013. doi: 10.1175/JPO-D-12-0105.1

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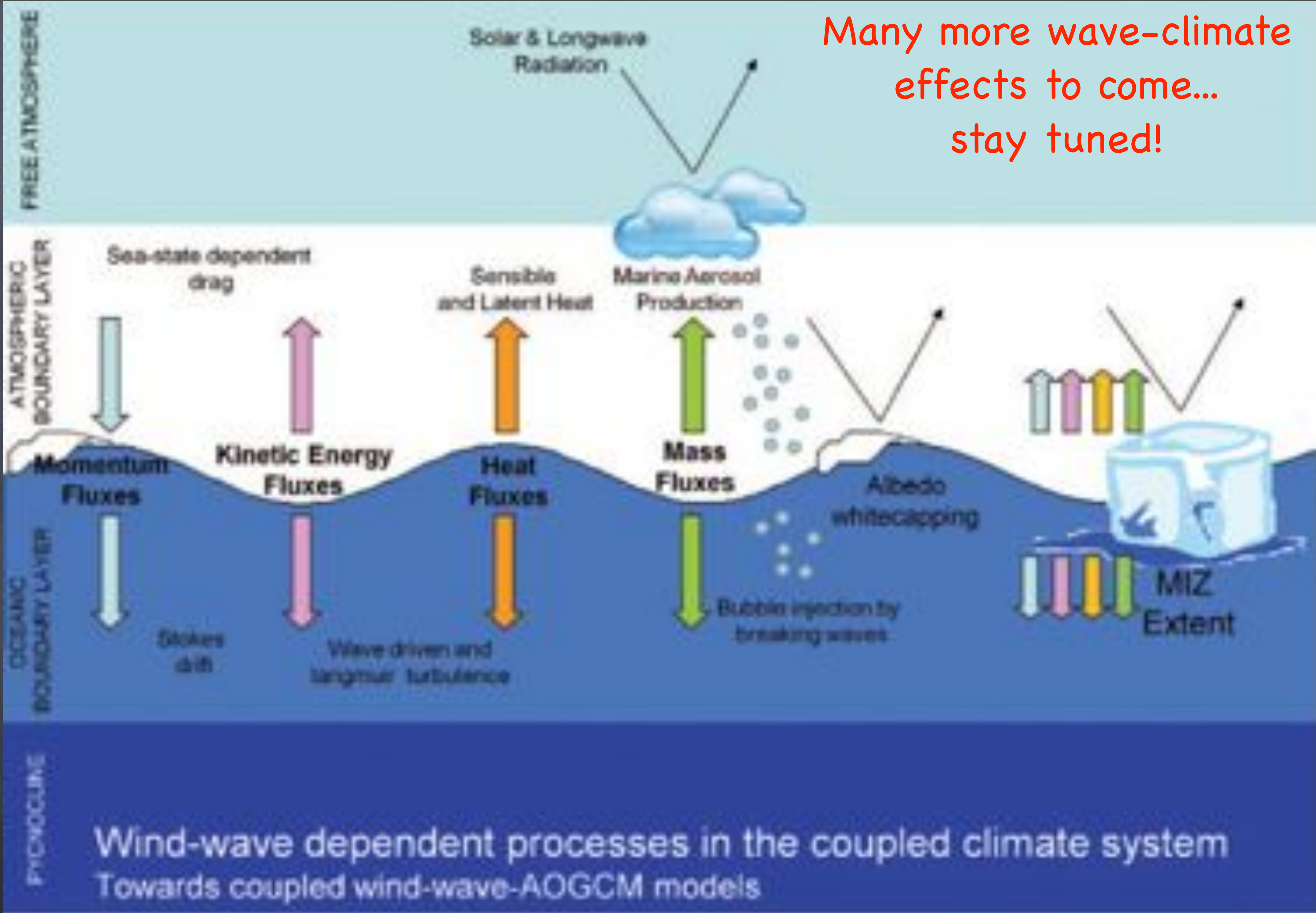

Many more wave-climate effects to come... stay tuned!

L. Cavaleri, B. Fox-Kemper, and M. Hemer. Wind waves in the coupled climate system. Bulletin of the American Meteorological Society, 93(11):1651-1661, 2012.

Results

- Errors in climate model on annual to decadal timescales can be attributed (partly) to neglect of
  - Waves -> Wind stresses, air-sea fluxes
  - Waves -> Langmuir turbulence
- These phenomena are the right size and active in the right places, but difficulties remain:
  - Prognostic waves in Coupled Models needed
  - Parameterizations need coding, evaluation, generalization
- Along the way, we found negligible/erroneous effects with
  - Whitecaps->radiation, PWP-based Langmuir and Babanin non-breaking wave turbulence
- Hypothesis: Improving Seasonality will Improve Forecasts & Trends

All papers at: fox-kemper.com/research

L. Cavaleri, B. Fox-Kemper, and M. Hemer. Wind waves in the coupled climate system. Bulletin of the American Meteorological Society, 93(11):1651-1661, 2012.

A. Webb and B. Fox-Kemper. Wave spectral moments and Stokes drift estimation. *Ocean Modelling*, 40(3-4): 273-288, 2011

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E. C. Baldwin Stevens. Remote Sensing, Modeling, and Synthesis: On the Development of a Global Ocean Wind/Wave Climatology and Its Application to Sensitive Climate Parameters. Master's thesis, University of Colorado Boulder, 2010.

B. Fox-Kemper, G. Danabasoglu, R. Ferrari, S. M. Griffies, R. W. Hallberg, M. M. Holland, M. E. Maltrud, S. Peacock, and B. L. Samuels. Parameterization of mixed layer eddies. III: Implementation and impact in global ocean climate simulations. *Ocean Modelling*, 39:61-78, 2011.

CORE (Large and Yeager, 2004, 2009)

Standard air-sea flux dataset of WGOMD

Atmospheric Fields

- NCEP/NCAR
  - Near surface winds, U
  - Near surface atmospheric temperature, θ
  - Near surface specific humidity, q

Radiation

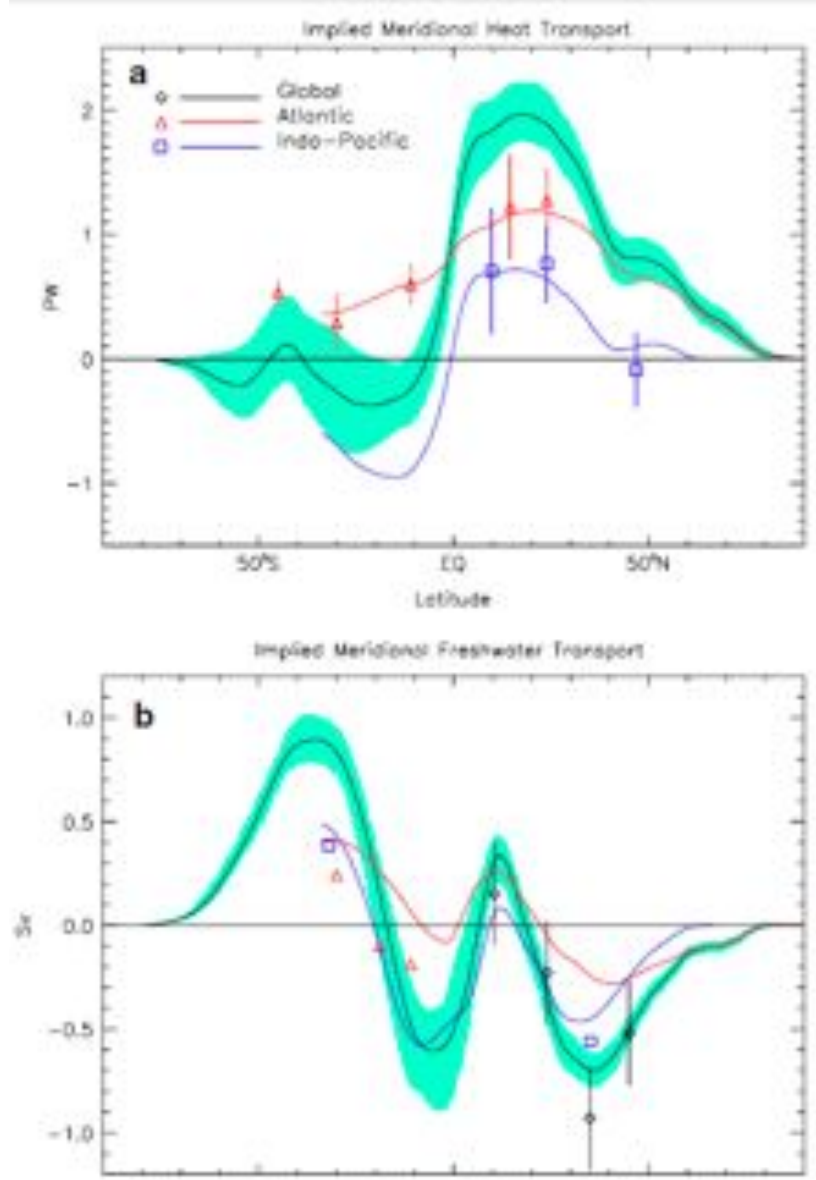
- International Satellite Cloud Climatology Experiment
  - Short wave insolation, Q_I
  - Downwelling Long wave Radiation, QA

Precipitation

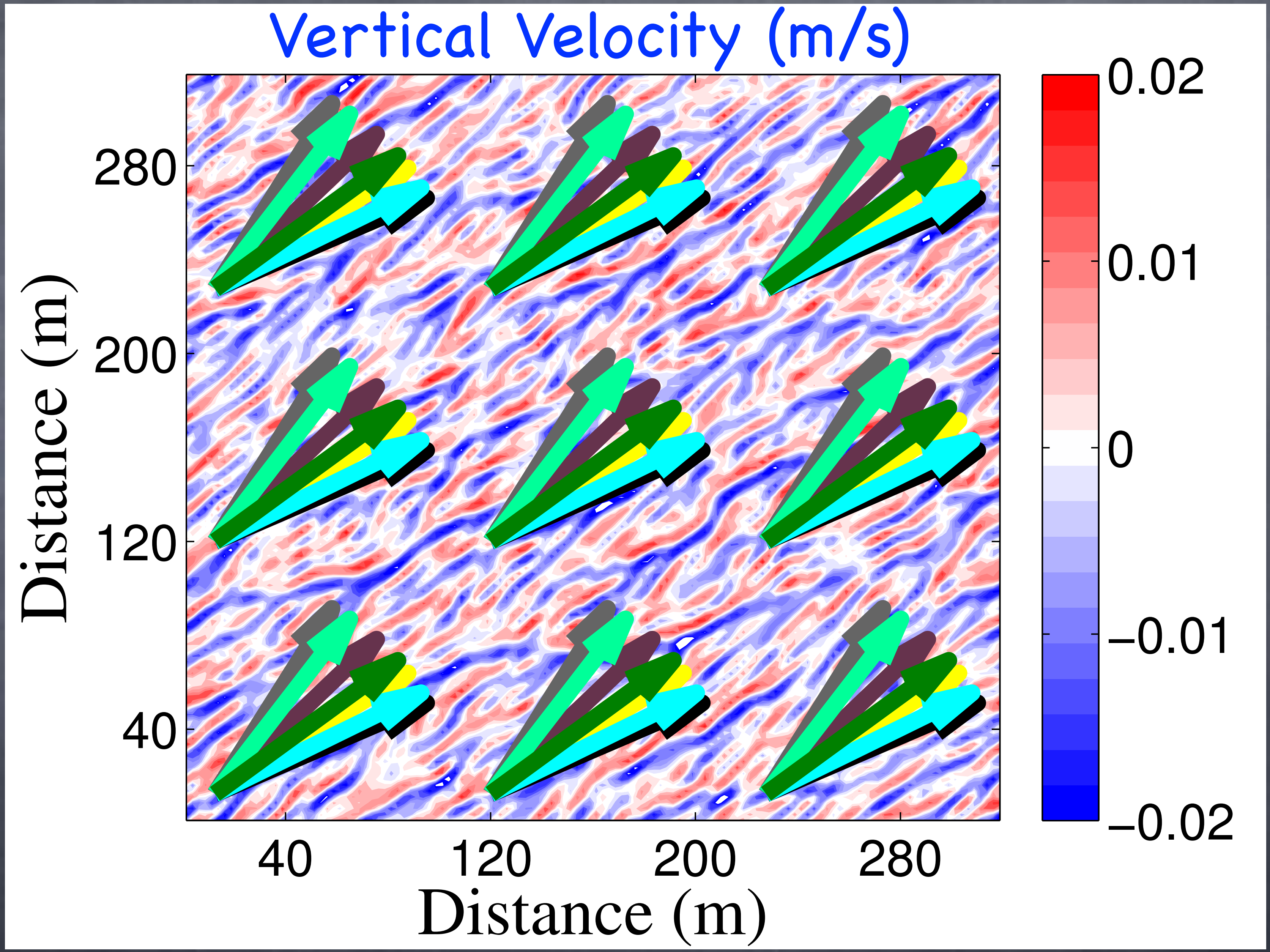
- GCGCS (Merged GPCP, CMAP, S-H-Y data)

SST

- Hadley Centre sea Ice and SST dataset version 1 (HadISST1)



Real World Forcing: Misaligned Wind & Waves



L. Van Roekel, B. Fox-Kemper, P. P. Sullivan, P. E. Hamlington, and S. R. Haney. The form and orientation of Langmuir cells for misaligned winds and waves. *Journal of Geophysical Research-Oceans*, 2012. In press.

How well do we know Stokes Drift?

Reanalysis vs wave model

Altimetry vs wave model

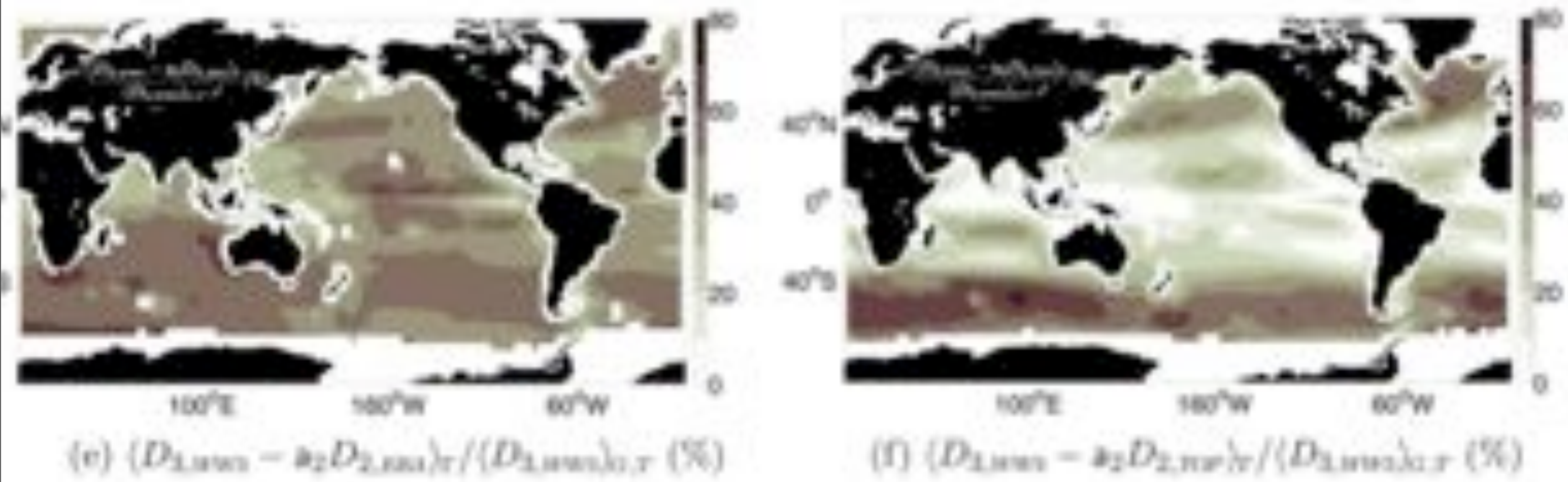


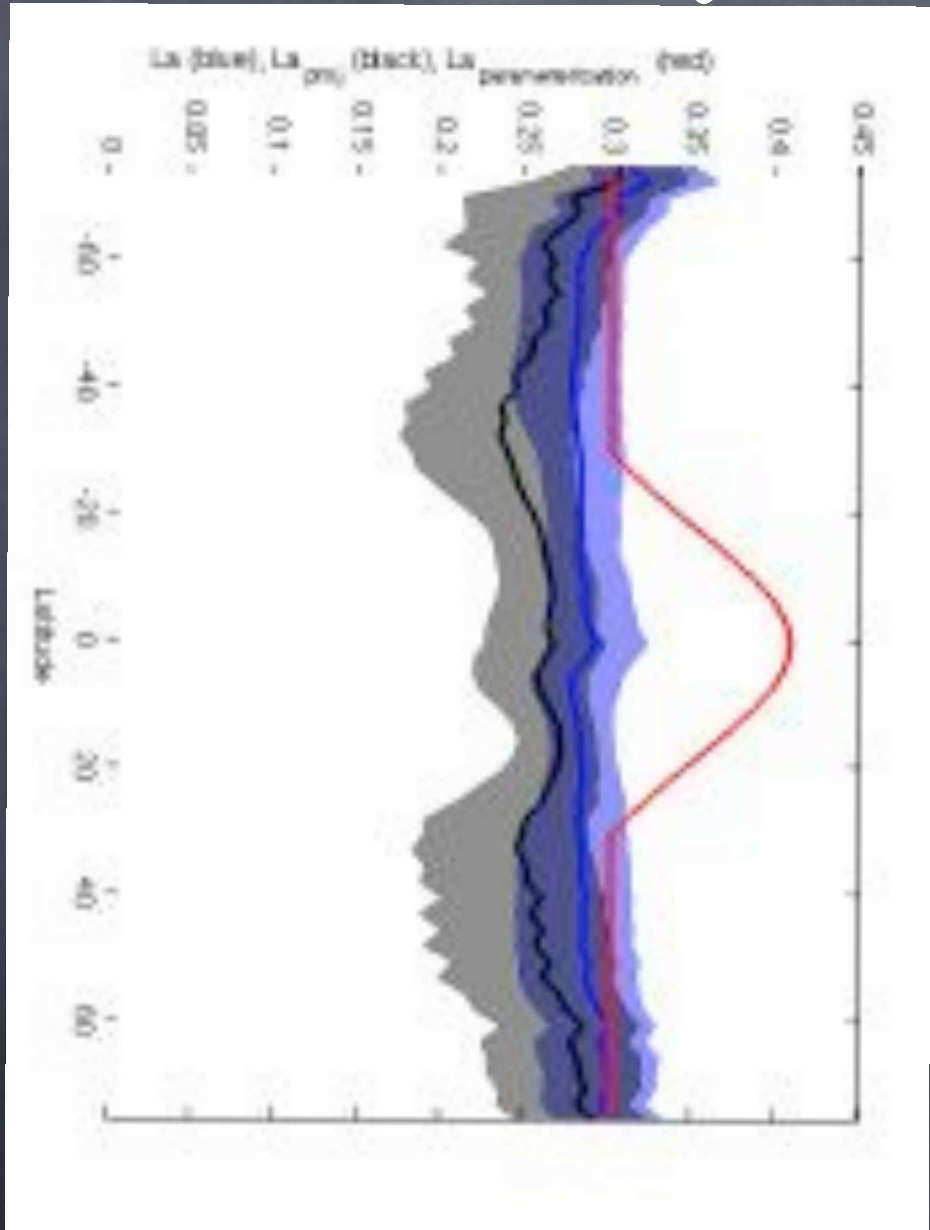
Fig. 4. D3 Comparison of ERA40 reanalysis and TOPEX satellite data with WW3 using eight year means (1994–2001).

Within a factor of 2.

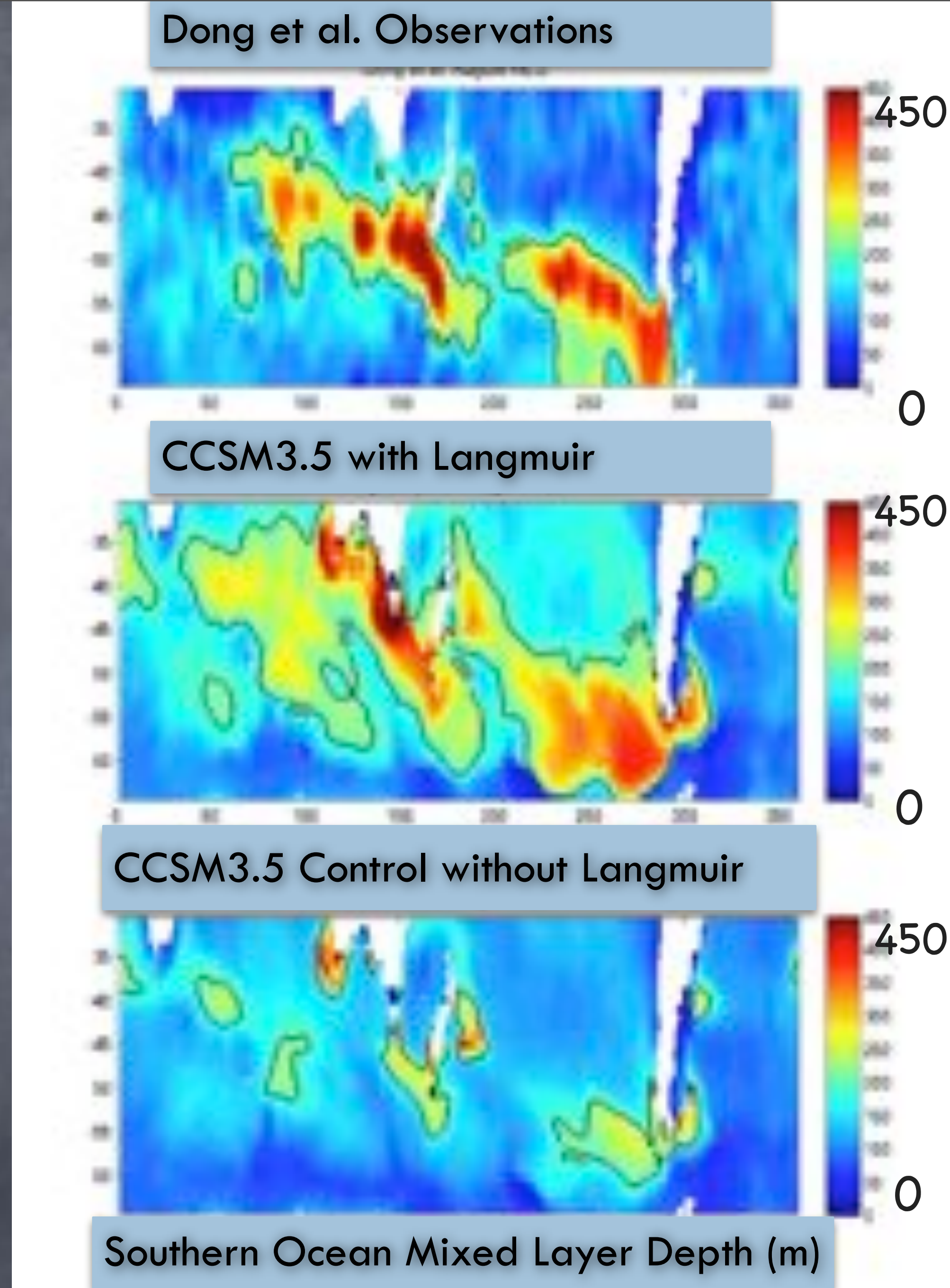
Assuming full-development (e.g., McWilliams & Restrepo, 1999) is worse

A. Webb and B. Fox-Kemper. Wave spectral moments and Stokes drift estimation. *Ocean Modelling*, 40(3-4): 273-288, 2011

Langmuir Mixing Estimate from WW3 & Projection



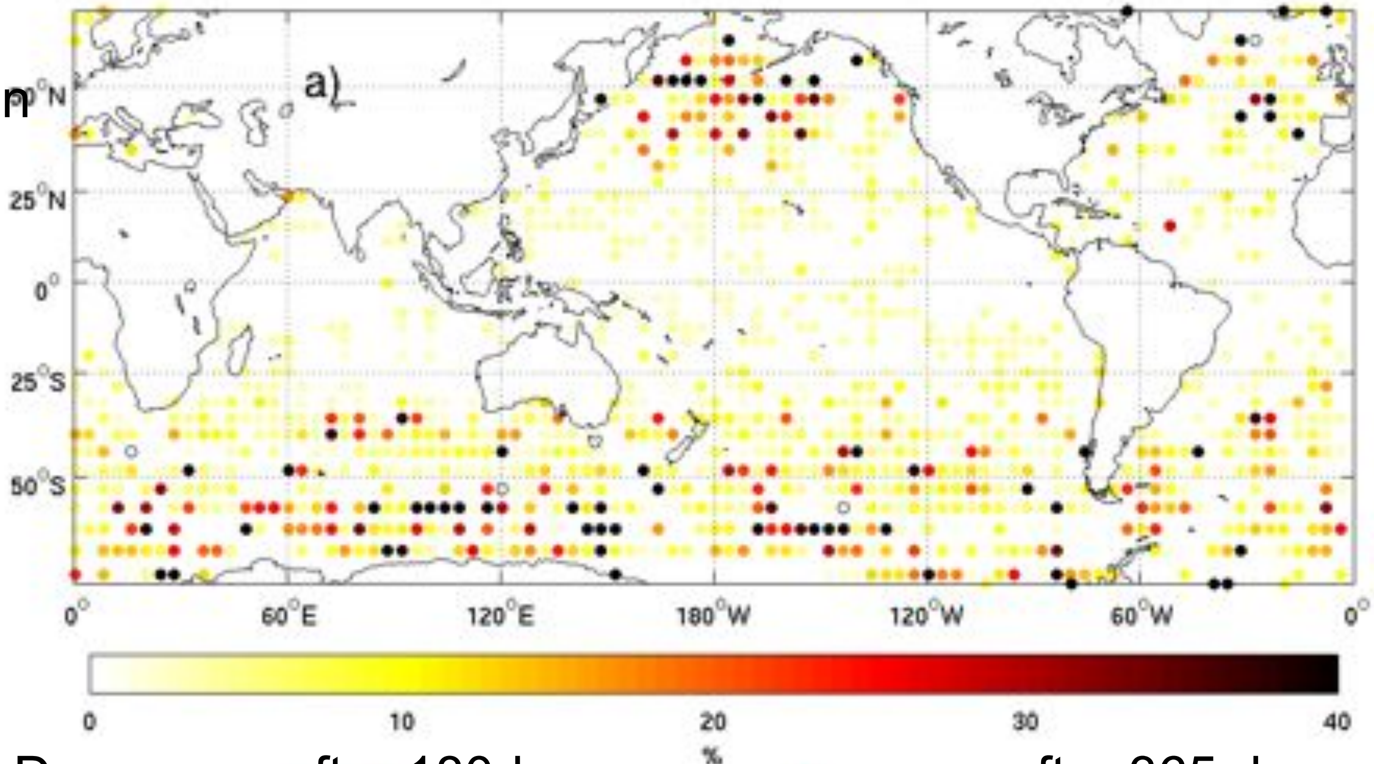
Underestimates WAVE IMPACT



ESTIMATES WAVE IMPACT
on MLD

Percentage increase in MLD with introduction of SMC (E6=7) langmuir mixing ~180 days after Summ

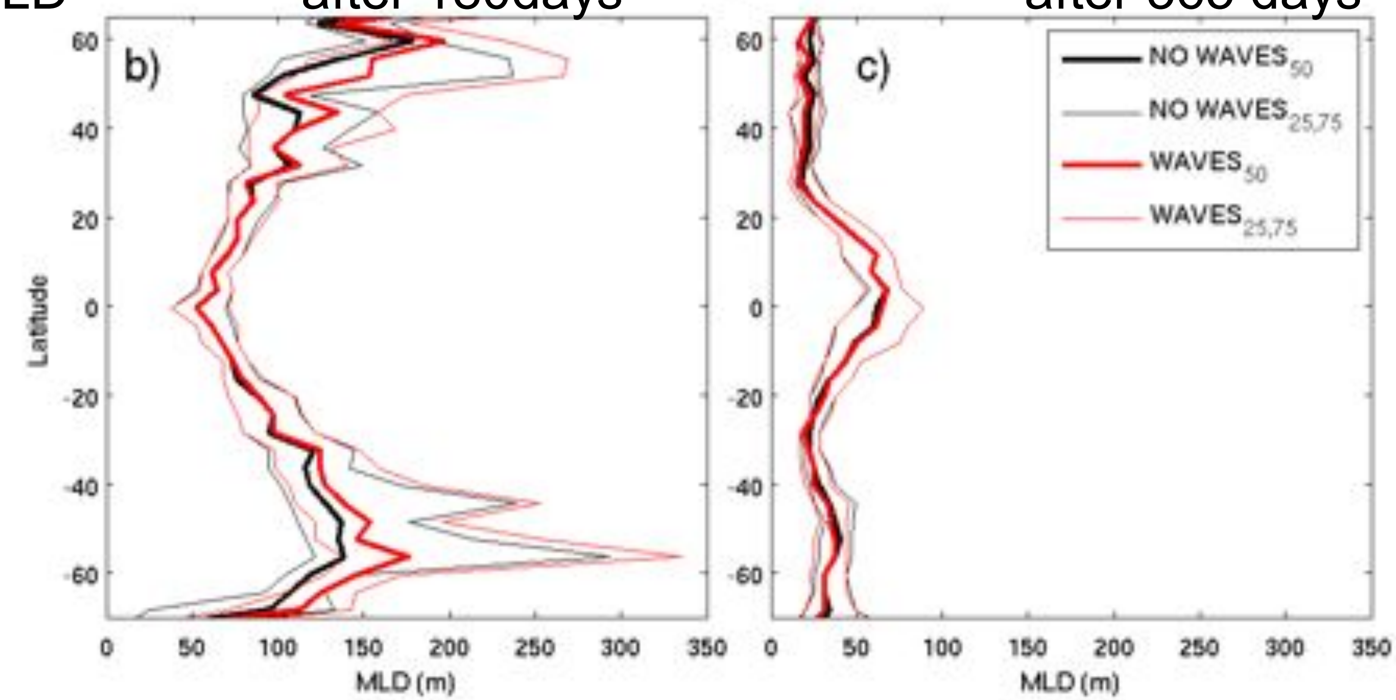
Reduced to Kantha&Clayson Approximation GV=GS=0



Zonal mean MLD

after 180days

after 365 days



Global mean air-sea fluxes (Wm^{-2})

Corrected 2007 CORE data. C.f., Table 3 Large and Yeager, 2009, but note different masking area defined by wave model.

Flux	CORE	Charn	Oost et al	Taylor-Yelland	Janssen
Qh	-12.8	-13.4	-12.9	-12.7	-13.4
Qs*	178.4[1]	178.3[2]	178.3[3]	178.3[3]	178.3
Ql	-53.9	-53.9	-53.9	-53.9	-53.9
Qe	-107.4	-112.0	-106.5	-105.3	-111.9
Qa	4.3	-1.0	4.9	6.4	-0.8

- 1 no consideration of whitecapping.
- 2 whitecapping parameterised using wind-dependent method of Frouin et al., 2001.
- 3 whitecapping parameterisation is sea-state dependent, following Zhao et al. 2003.
    - This is a function of u*, thus dependent on zo parameterisation.
- No wave dependent long-wave radiation flux is implemented. Note surface emissivity has a sea-state dependent component
- 4 rms (spatial) of annual mean relative to CORE calculation annual mean.