Length scale of the turbulent heat fluxes in the Southern Ocean

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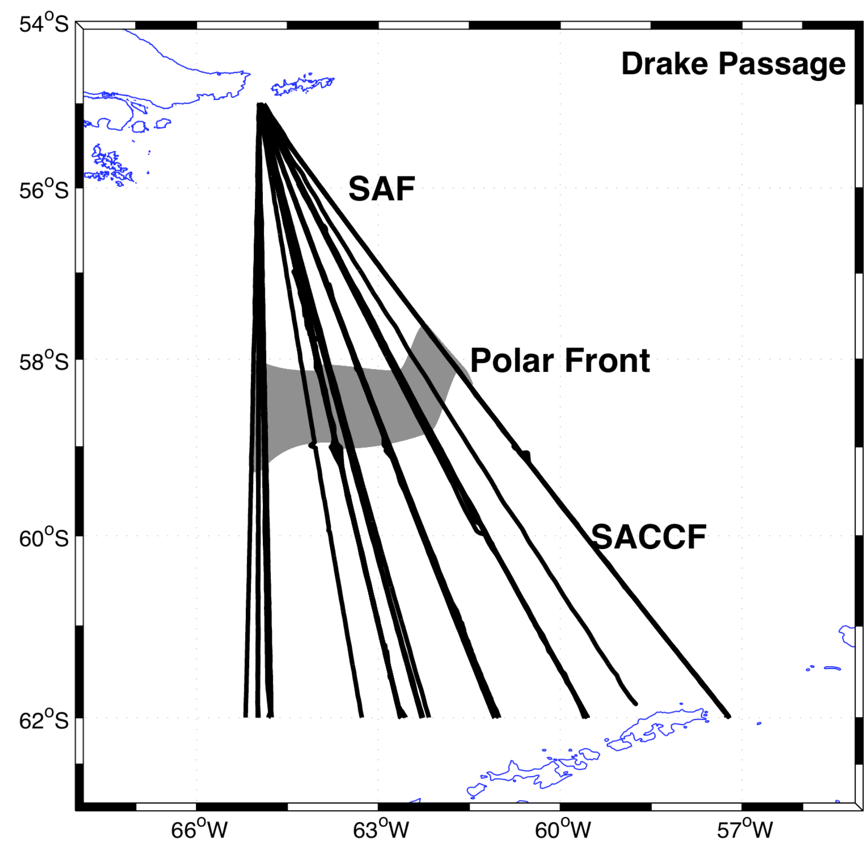
Eddy-resolving air-sea heat fluxes



- **Scale of meso-scale eddies is about 30 km** **(Williams et al., 2007)**
- **Air-sea interactions**: linear relation between SST & windspeed in Agulhas (O'Neill et al., 2005, 2009), air-sea heat fluxes controlled by small-scale SST variations
- **Water mass formation** is sensitive to the small-scale air-sea heat fluxes (Cerovecki et al., 2010)

Existing NWP products: coarse

Products	Resolution
ERA-40	1.125 degree
ERA-INTERIM	1.5 degree
ERA-15	2.5 degree
NCEP-2	2.5 degree
NCEP-NCAR	2.5 degree

Resolutions of existing NWP products are much larger than scale of eddies, 30km.

Recent NWP efforts

Products	Resolution	Period
ECMWF-YOTC	0.5 degree 3hourly	May 2008-Apr 2009
ERA-INTERIM	1.5 degree 6hourly	Jan 2000-Aug 2009
DPRD10	10km hourly	May 2008-Apr 2009

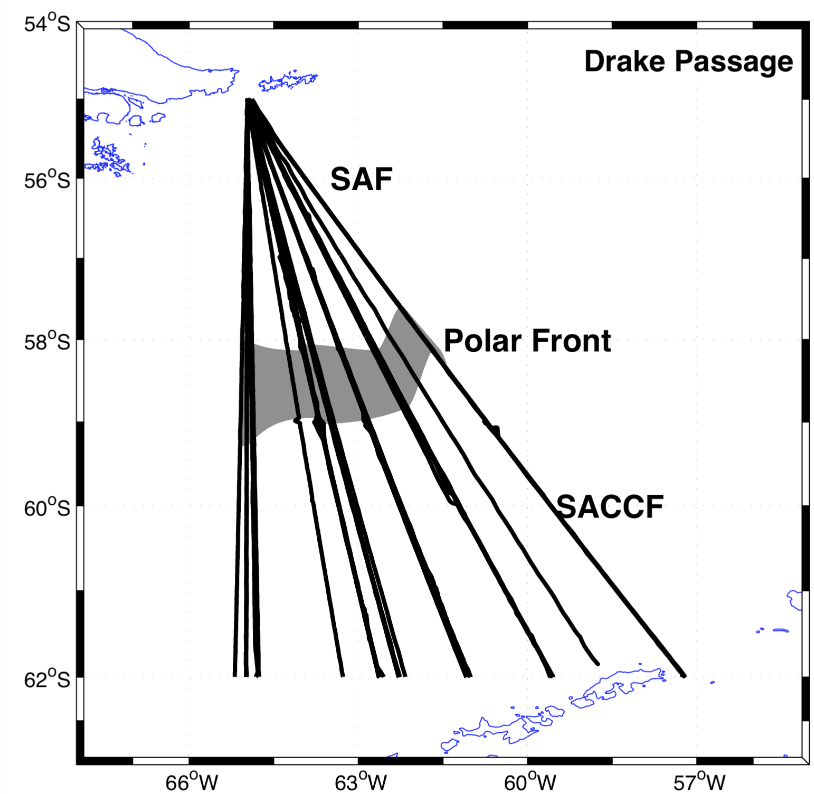
DPRD10: Drake Passage Reanalysis Downscaling at 10km, atmospheric regional spectral model, forced by GHRSST NCDC 0.25 degree daily field, similar to Kanamitsu & Kanamaru 2007.

Gould ship measurements

http://photolibrary.usap.gov

Lawrence M. Gould provides:
- **all season, 1 minute interval.**
- **Jan 2000 - present.**

This analysis:
- **Drake Passage triangle.**
- **Constant ship speed.**
- **95 transects.**
- **Jan 2000 – Aug 2009.**



Observed state variables & derived fluxes

Variables	Symbol	Depth	Mean± σ	Range
Sea surface temperature ^{o}C	SST	-4m	2.7±0.2	[-1.8,10.0]
Air temperature ^{o}C	Tair	10m	2.9±0.3	[-7.7,15.9]
Air-sea T difference ^{o}C	ΔT		-0.2±0.2	[-6.4,9.9]
Air specific humidity g/kg	qair	10m	4.1±0.1	[1.4,7.3]
Wind speed m/s	Uw	10m	9.7±0.5	[0.5,27.0]
Latent heat flux W/m2	LHF		-17.7±3.3	[-268.5,93.2]
Sensible heat flux W/m2	SHF		1.4±3.2	[-289.9,154]

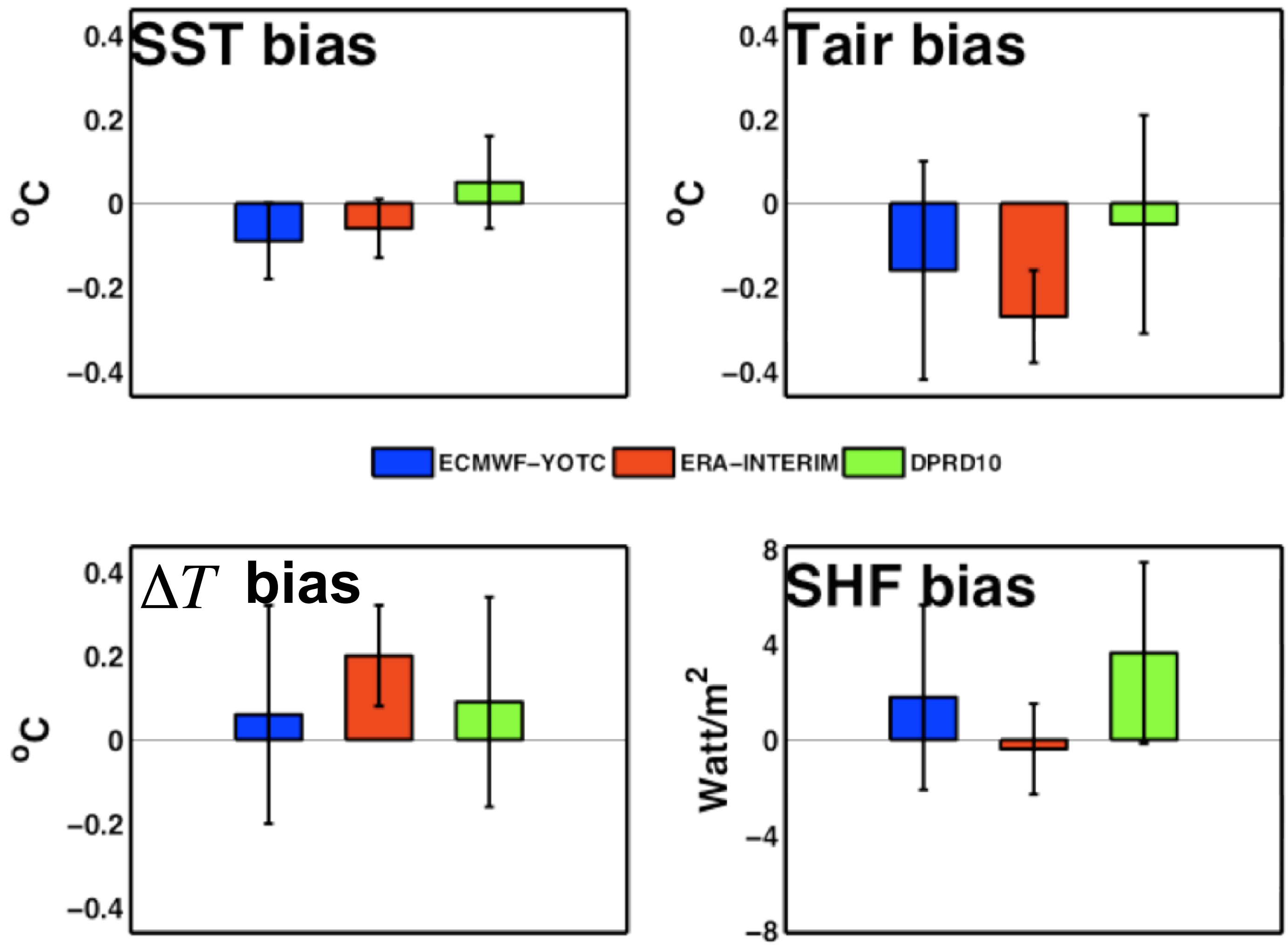
COARE3.0 algorithm:
(Fairall et al., 2003)

$$q_{sea} = 0.98 q_{sat}(SST)$$

$$LHF = \rho_a L_v C_E U_r (q_{air} - q_{sea})$$

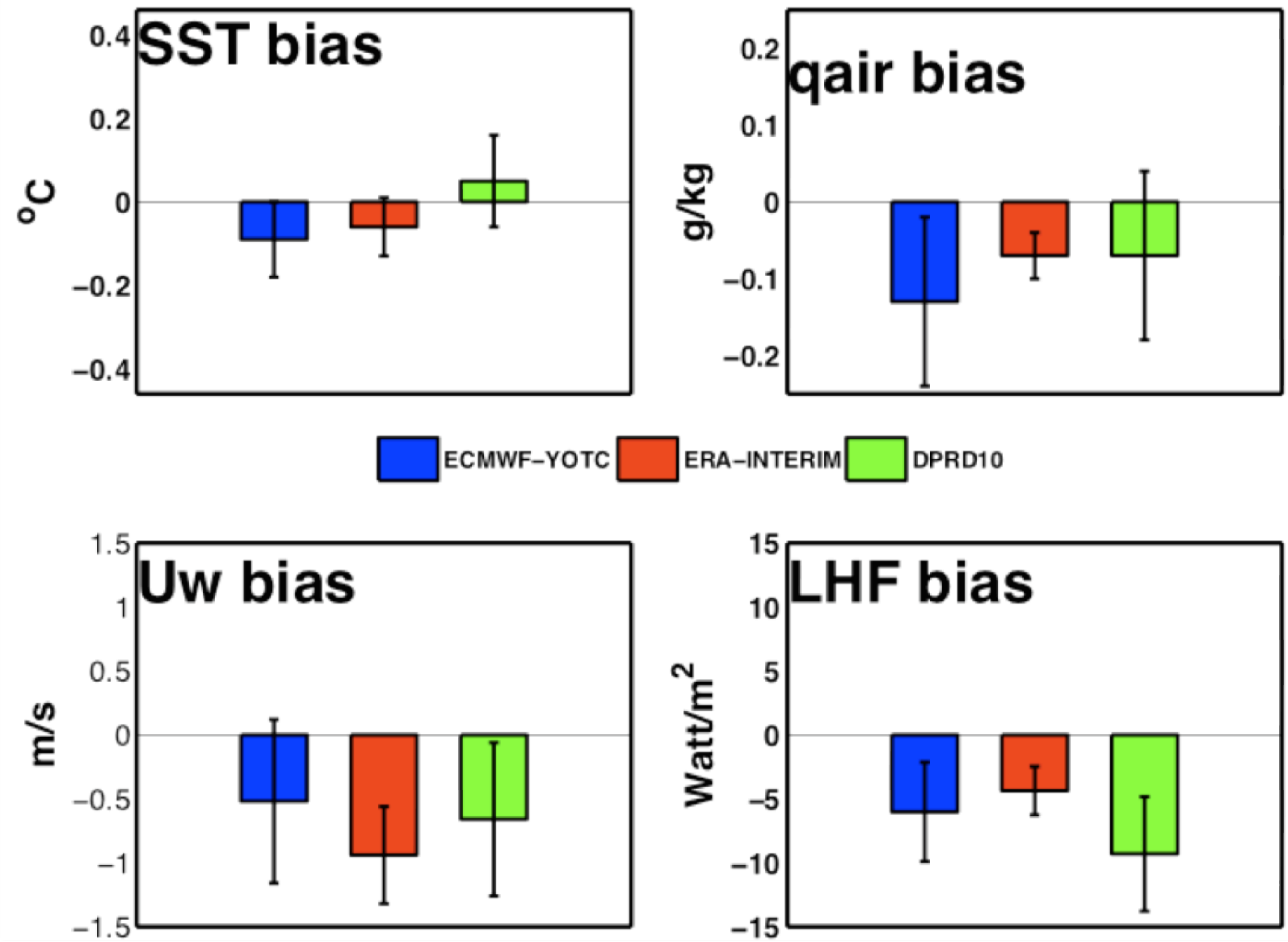
$$SHF = \rho_a c_p C_H U_r (T_{air} - SST)$$

Mean bias: SHF & related variables



Bias = product - ship

Mean bias: LHF & related variables



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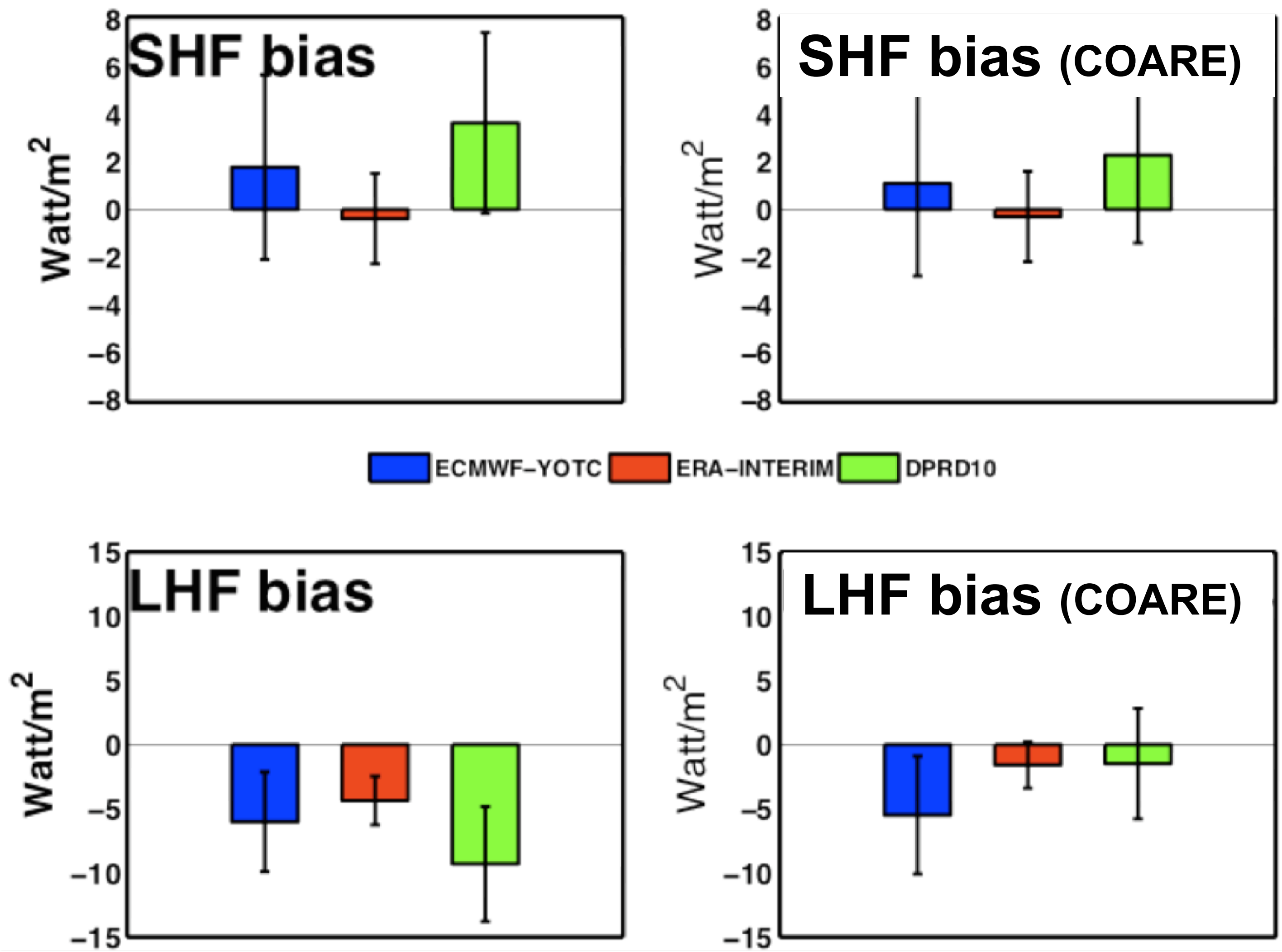
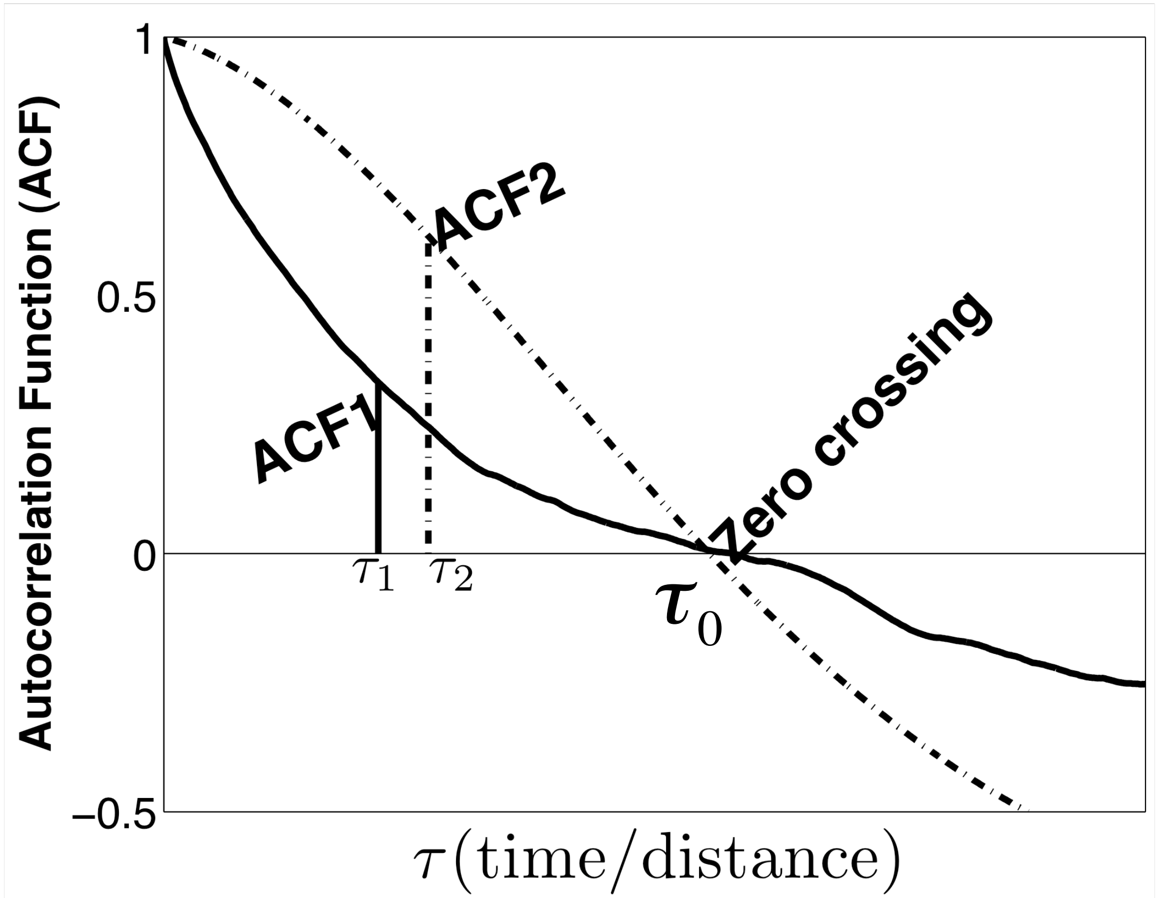
Mean bias: effect of COARE



Bias = product - ship

Decorrelation scale definition



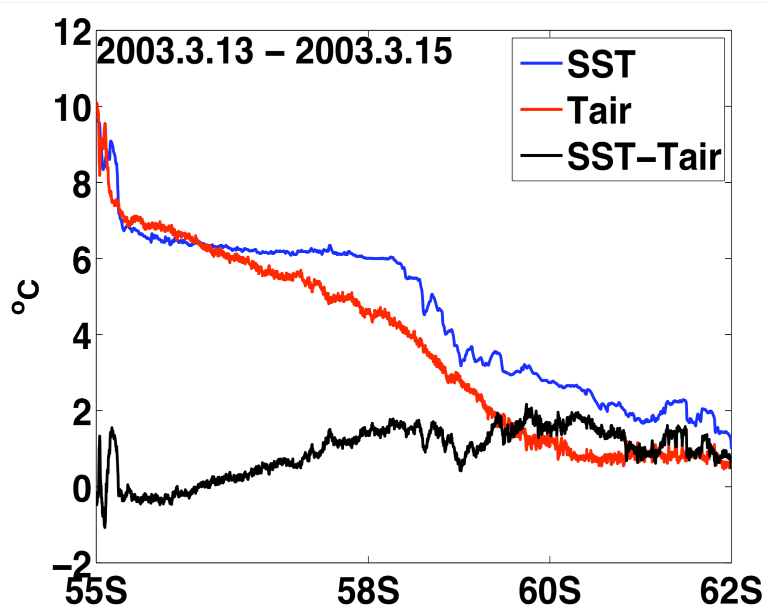
ACF1: ship SHF
ACF2: INTERIM

$$\tau_1 = \int_0^{\tau_0} ACF1(\tau)d\tau$$

$$\tau_2 = \int_0^{\tau_0} ACF2(\tau)d\tau$$

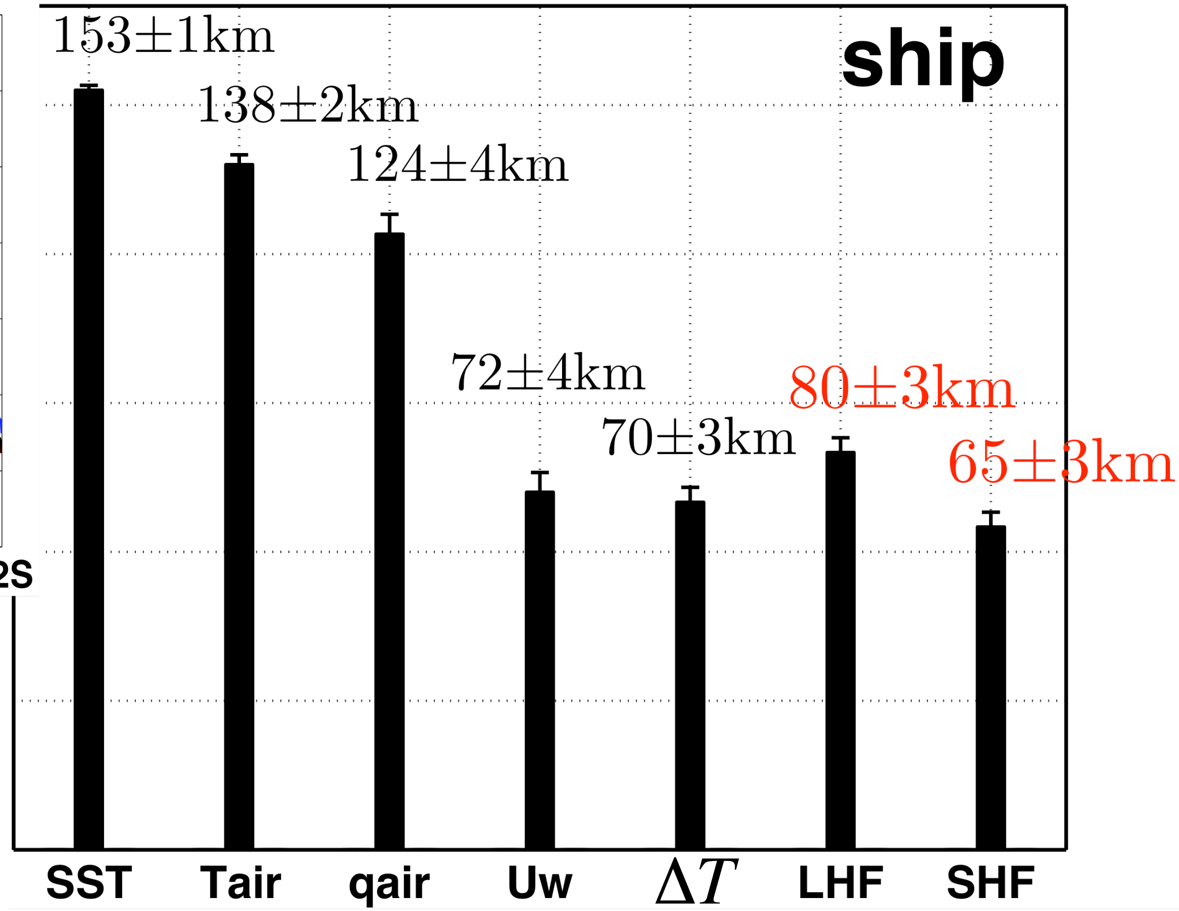
Integral scales precisely measure their small-scale decorrelation scales.

Decorrelation scales: ship



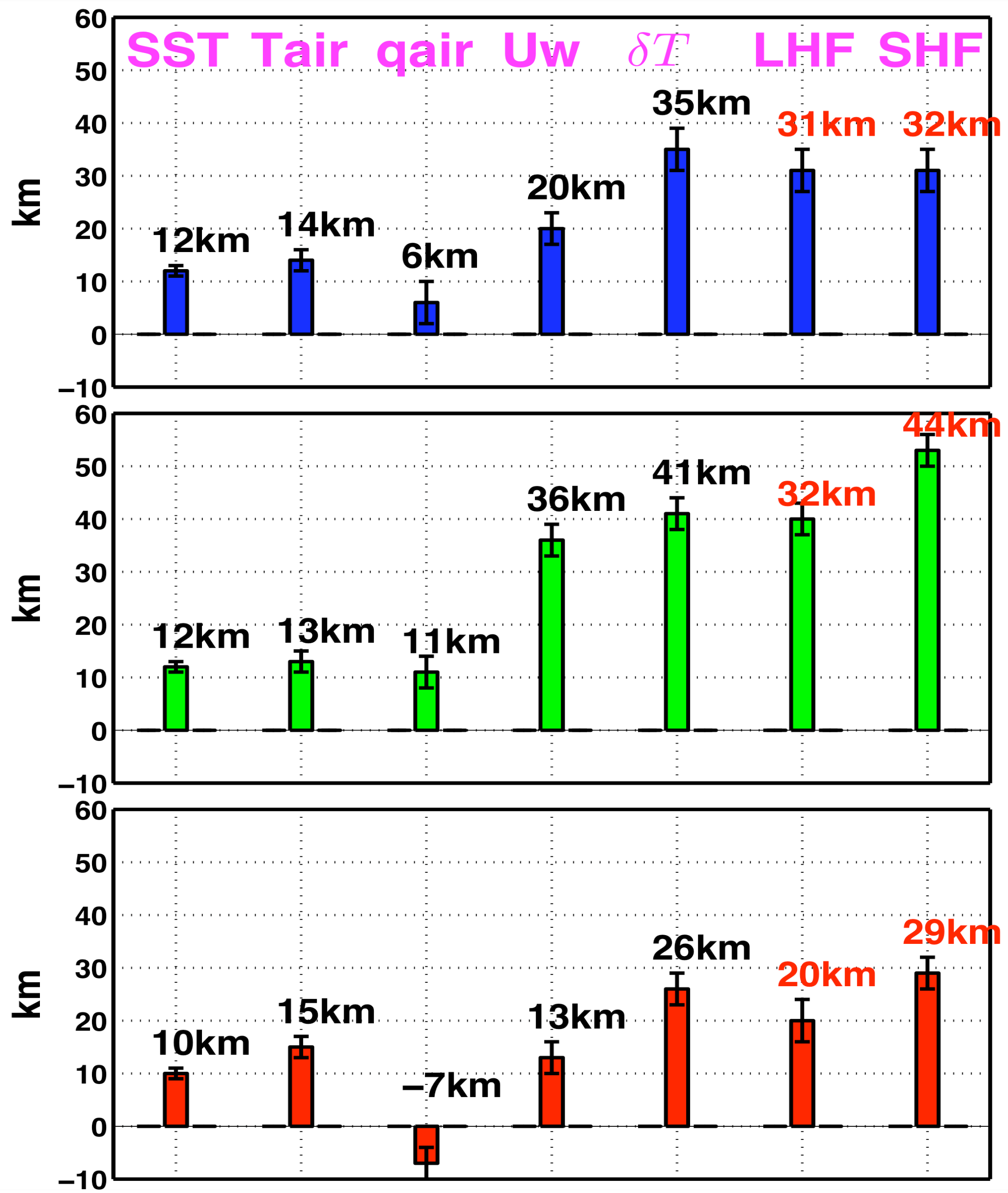
$$LHF = \rho_a L_v C_E U_r (q_{air} - q_{sea})$$

$$SHF = \rho_a c_p C_H U_r (T_{air} - SST)$$



- Length scale of LHF sensitive to every variable.
- Length scale of SHF sensitive to ΔT .

Decorrelation scales bias: recent NWP



[ECMWF-YOTC] – [ship]

[ERA-INTERIM] – [ship]

[DPRD10] – [ship]

Conclusions & implications

- **Conclusions:**
  - **Length scale of LHF is 80±3km**
    SHF is 65±3km.
  - **Existing NWP > 20km for LHF**
    > 29km for SHF.

- **Implications: to improve resolution of**
  - **LHF: need improve every related variable.**
  - **SHF: need improve ΔT.**

$$LHF = \rho_a L_v C_E U_r (q_{air} - q_{sea})$$
$$SHF = \rho_a c_p C_H U_r (T_{air} - SST)$$

$$q_{sea} = 0.98 q_{sat}(SST)$$

Wish list

Eddy-resolving turbulent heat fluxes need:

- ❖ **High resolution Tair, qair;**
- ❖ **High wind speed appropriate algorithm;**
- ❖ **Direct flux measurements as ground data;**
  - ➢ **Gould onboard flux measurements.**
  - ➢ **TAO-like moorings.**

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