

Eddy-Mean Flow Energetics of the Gulf Stream and Kuroshio Current

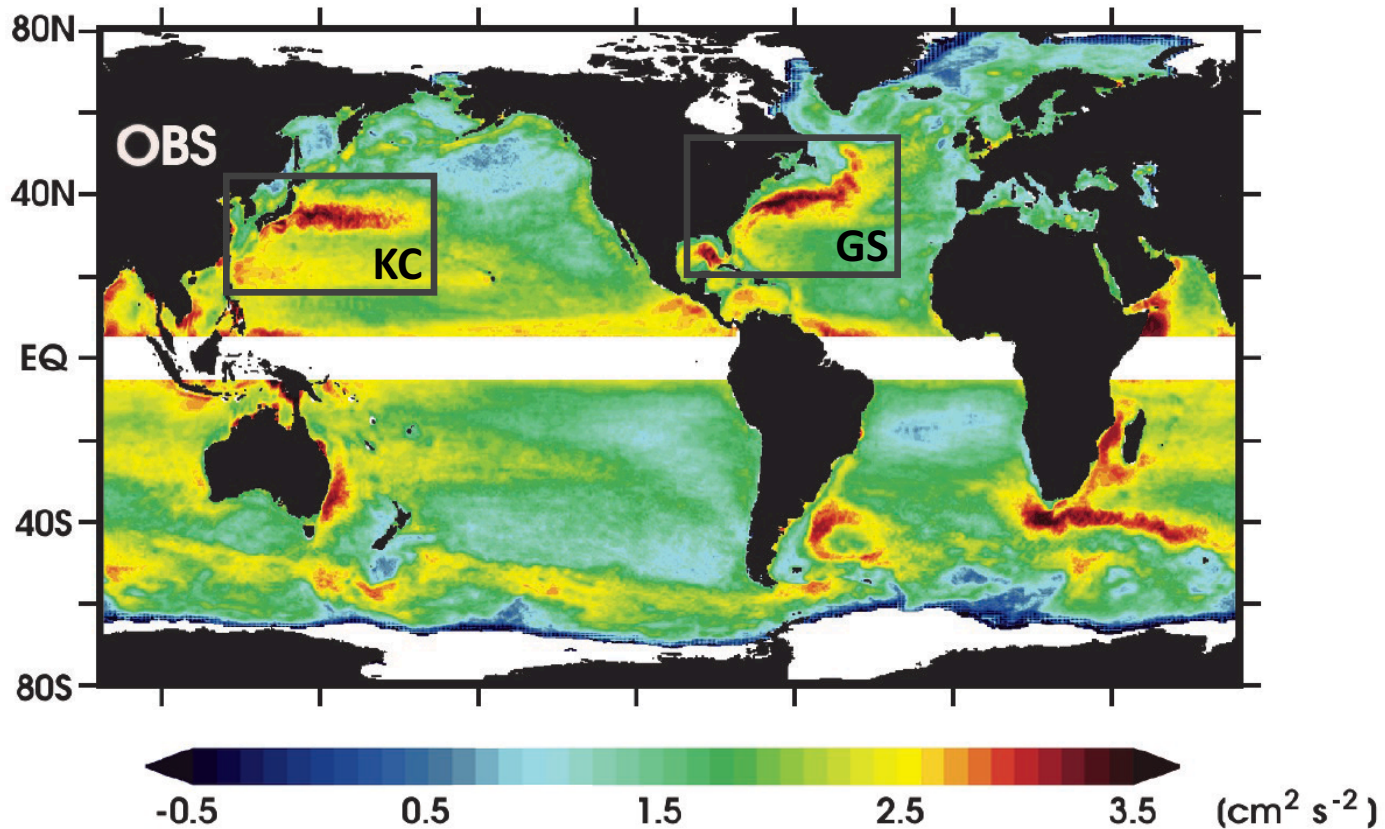
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CLIVAR Ocean Eddy Energy Workshop
12 March 2019

Background & Motivation

- **Logarithm of Eddy Kinetic Energy derived from Satellite Altimetry**



(Figure from Dixon et al., 2011)

ROMS Simulation of the Gulf Stream

- **50-year (1958-2007) high-resolution ROMS simulation**

- **Grid**

- Horizontal: ~7 km
- Vertical: 40 σ -layers

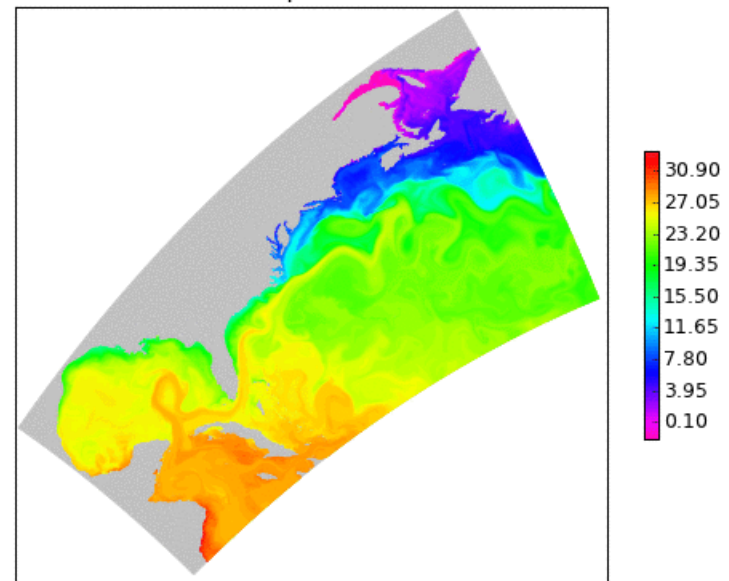
- **Forcing**

- Ocean boundaries: SODA
- Atmospheric forcing: e.g. CORE
- Runoff: river discharge
- Tides: 10 tidal components

- **Ecosystem Model**

- CoSiNE model (U Maine)
- Cobalt model (GFDL)
 - >30 biogeochemical variables

Sea Surface Temperature 01/01/1960



- Kang & Curchitser, 2013
- Kang & Curchitser, 2015; 2017
- Kang *et al.*, 2016
- Zhang *et al.*, 2018
- Chen *et al.*, 2018; 2019 (*in rev.*)
- Alexander *et al.*, 2019 (*in rev.*)

OFES Simulation of the Kuroshio Current

- 22-year (1993-2014) data from the global OFES simulation

- **OFES**

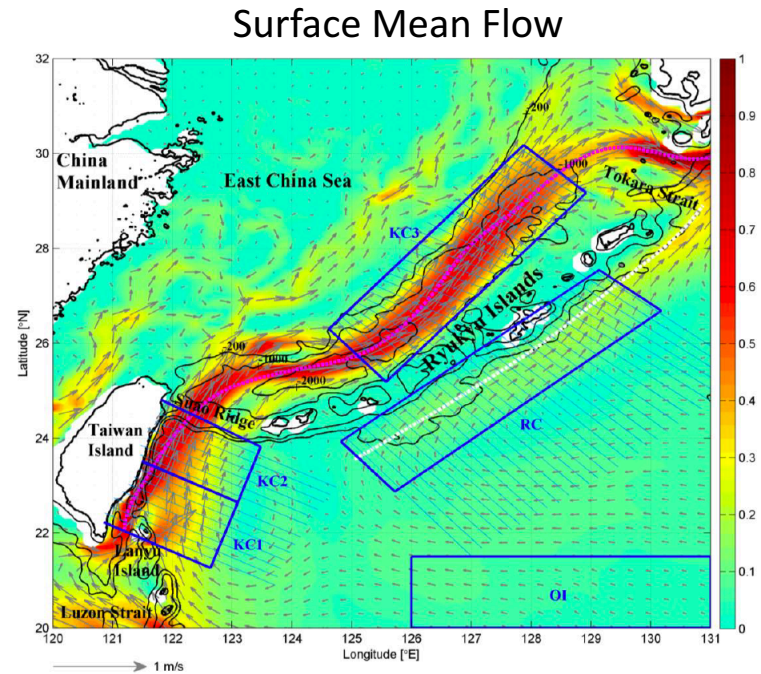
OGCM for the Earth Simulator

- **Grid**

- Horizontal: 0.1°
- Vertical: 54 z-levels

- **Forcing**

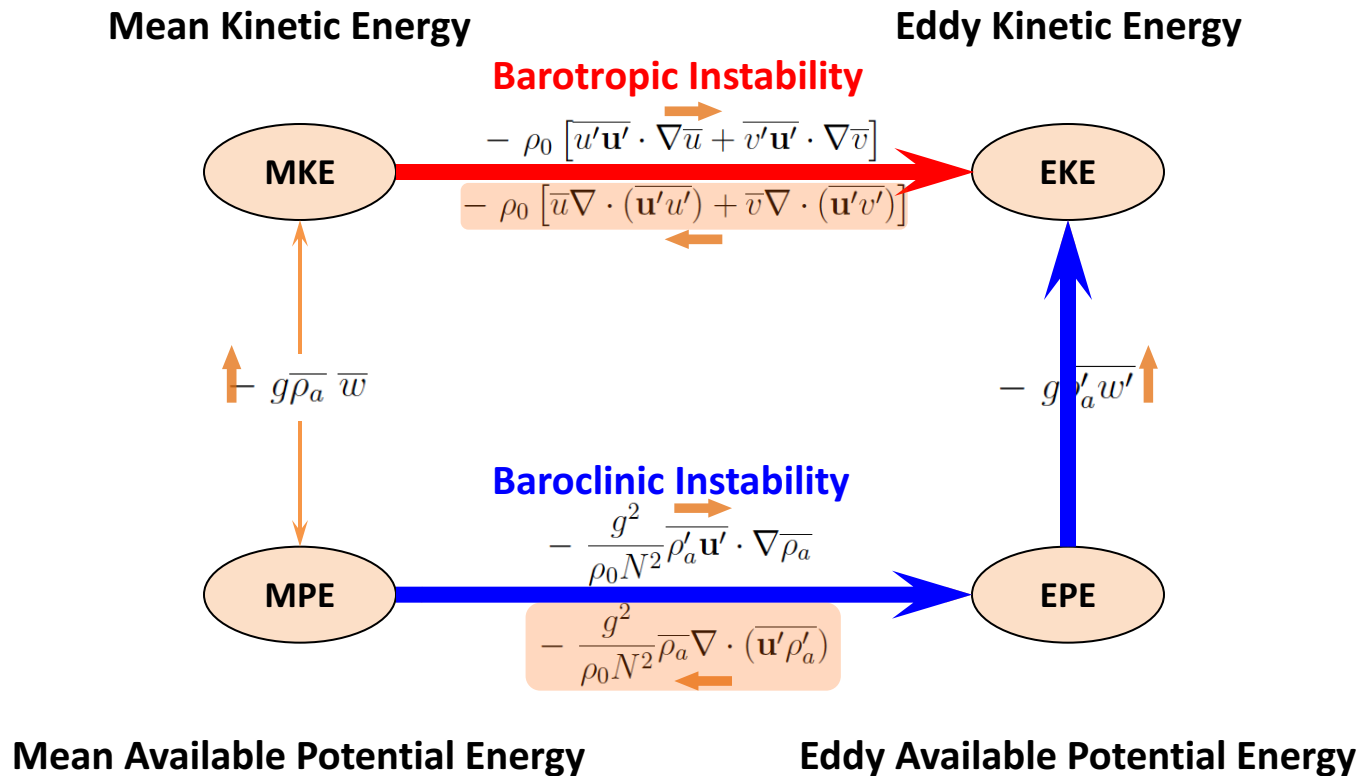
- Atmospheric forcing: NCEP/NCAR
- Precipitation
- River runoff
- WOA98 surface S & T



- Yan *et al.*, 2019
- Yan *et al.*, *in prep.*

Energy Exchange Diagram

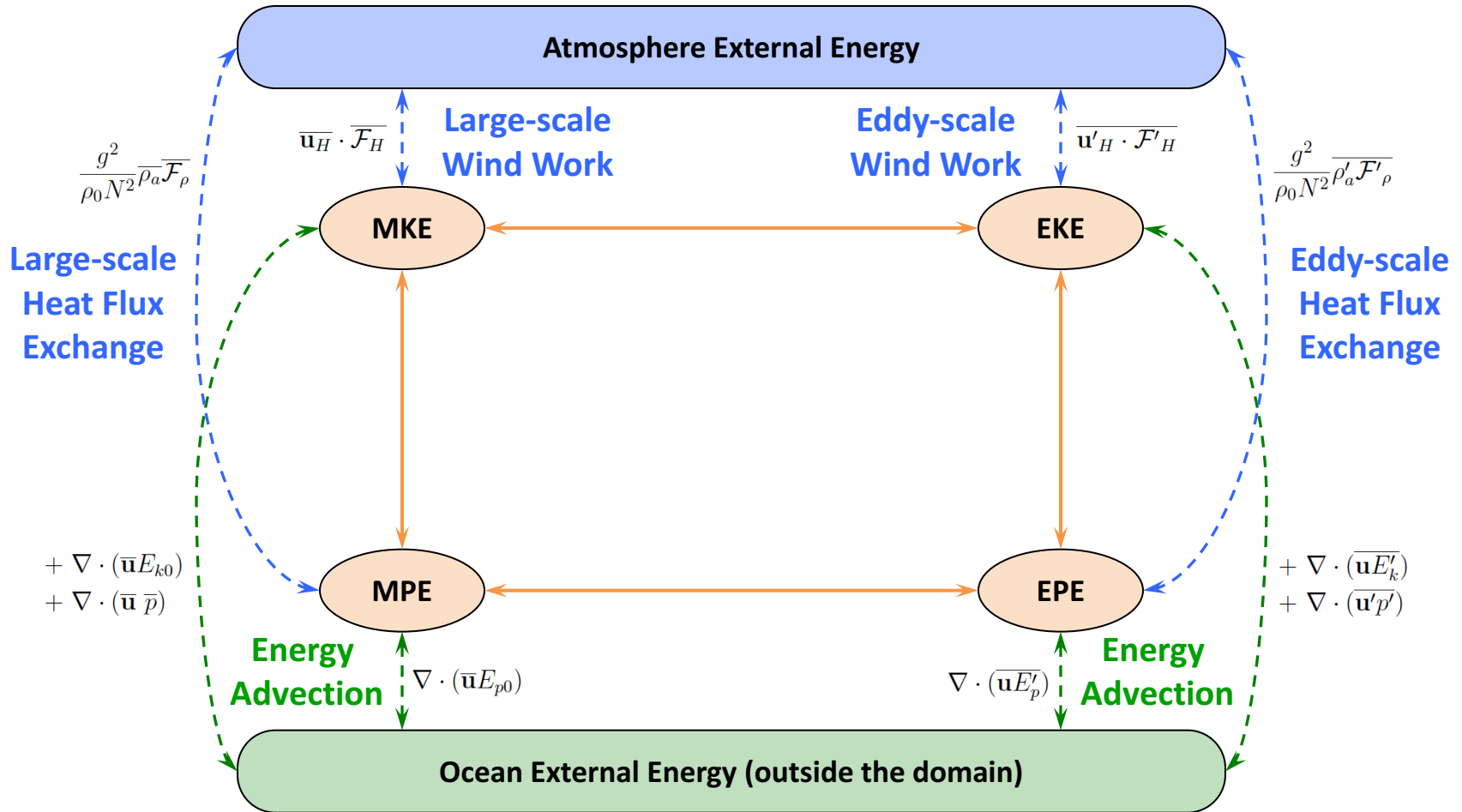
- Energy conversion within a fixed ocean domain



(Kang & Curchitser, 2015)

Energy Exchange Diagram

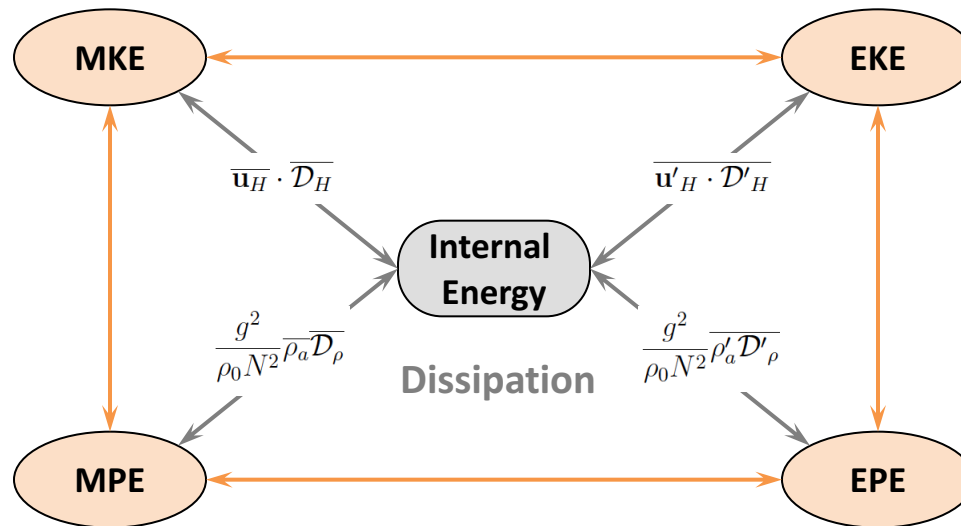
- Energy exchange with external ocean & atmosphere



(Kang & Curchitser, 2015)

Energy Exchange Diagram

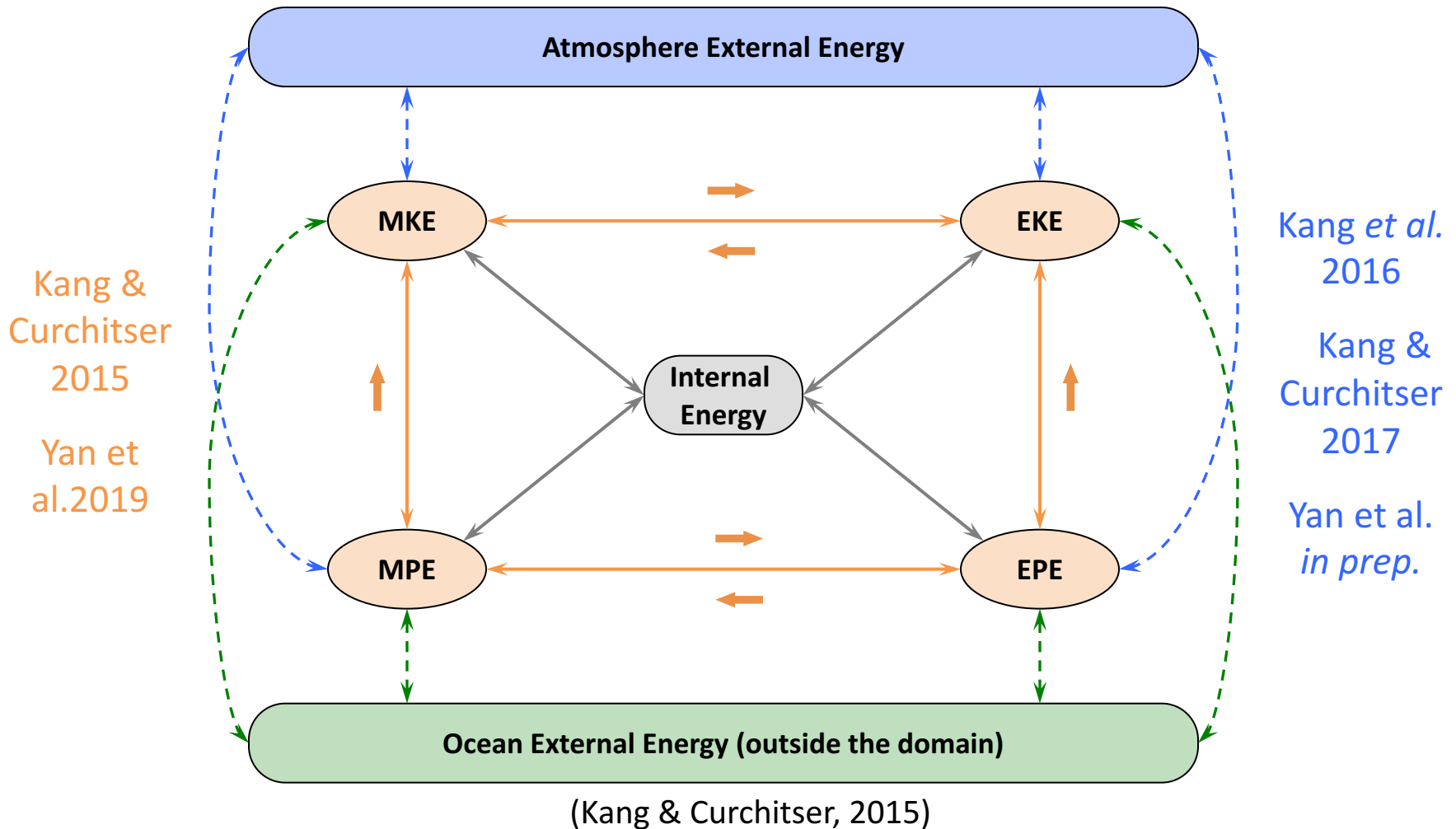
- Energy dissipation within the domain



(Kang & Curchitser, 2015)

Energy Exchange Diagram

- Energy exchange for a fixed ocean domain



GS Eddy-Mean Flow Energetics

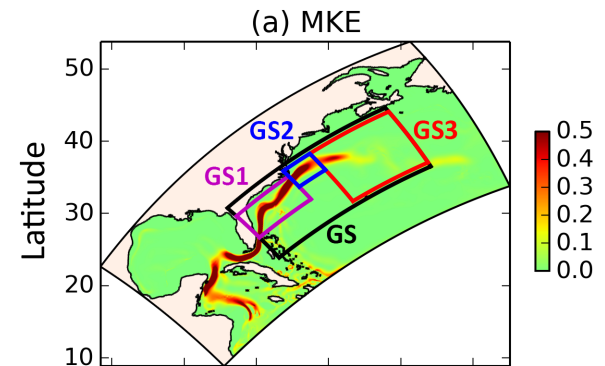
- Study domains

GS : Gulf Stream domain

GS1: along-coast

GS2: upon-separation

GS3: off-coast

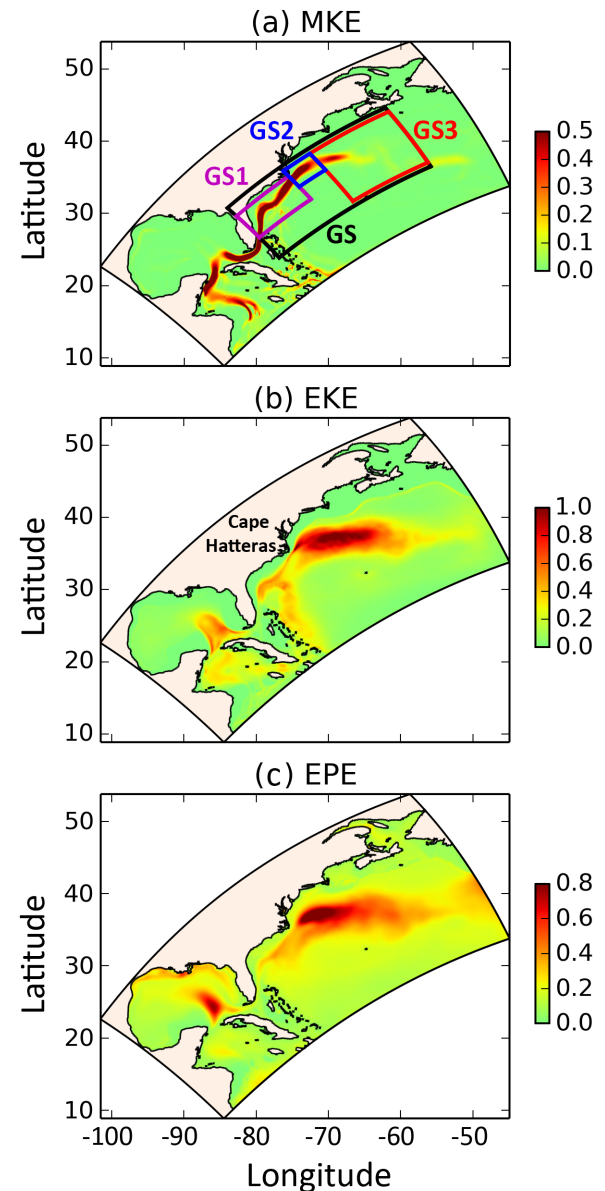


GS Horizontal Energy Distribution

- Depth-integrated energy components (10^5 J m^{-2})

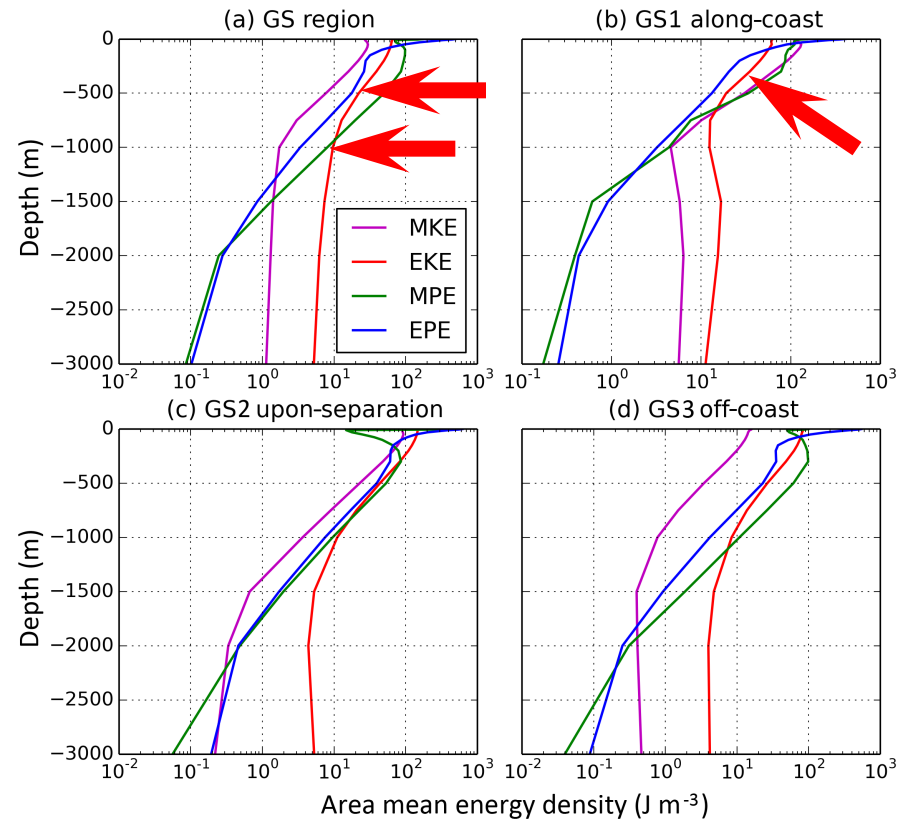
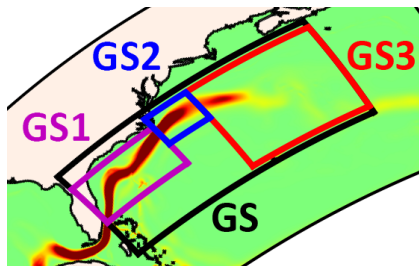
- Inhomogeneous distribution
- Along-stream variation
- Peak MKE along the shelf edge
- Peak EKE in the off-coast region
- EPE resembles EKE

(Kang & Curchitser, 2015)



GS Vertical Energy Distribution

- Density of energy components (J m^{-3})
 - Energy drops quickly with depth
 - EKE drops a half at 500 m, and drops to $\sim 1/10$ at 1000 m
 - EKE > MKE except for upper 700 m in GS1



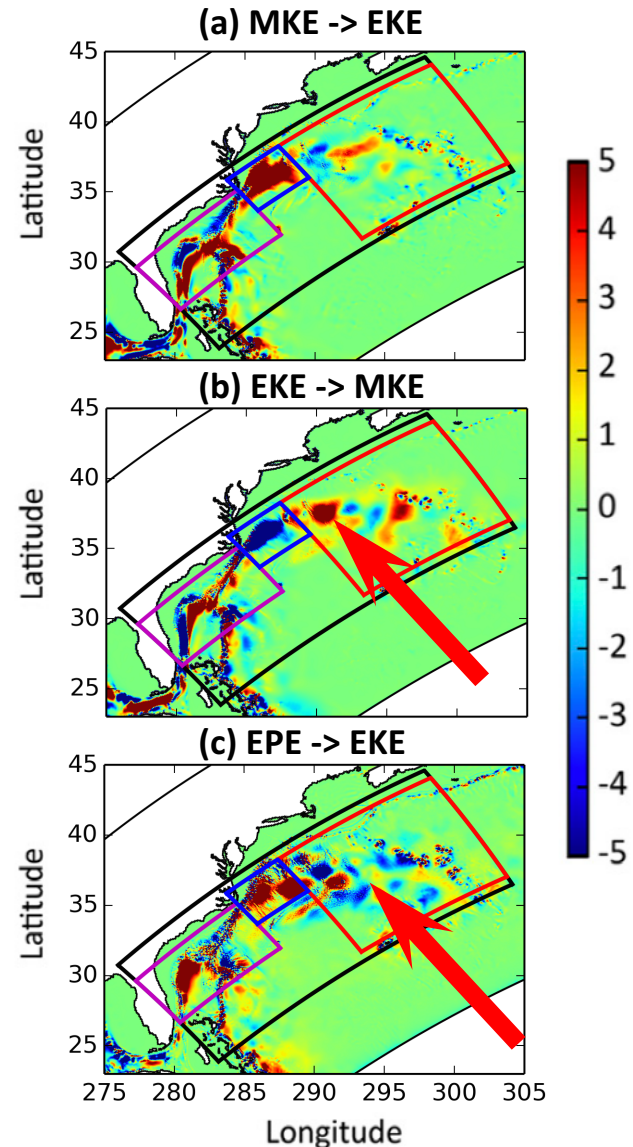
(Kang & Curchitser, 2015)

GS Horizontal Energy Conversion Distribution

- Depth-integrated energy conversions (10^{-2} W m^{-2})

- Inhomogeneous distribution
- Along-stream variation
- MKE \rightarrow EKE & EPE \rightarrow EKE
in along-coast (GS1) & upon-separation (GS2) regions
- MKE \leftarrow EKE & EPE \leftarrow EKE
in off-coast (GS3) region

(Kang & Curchitser, 2015)

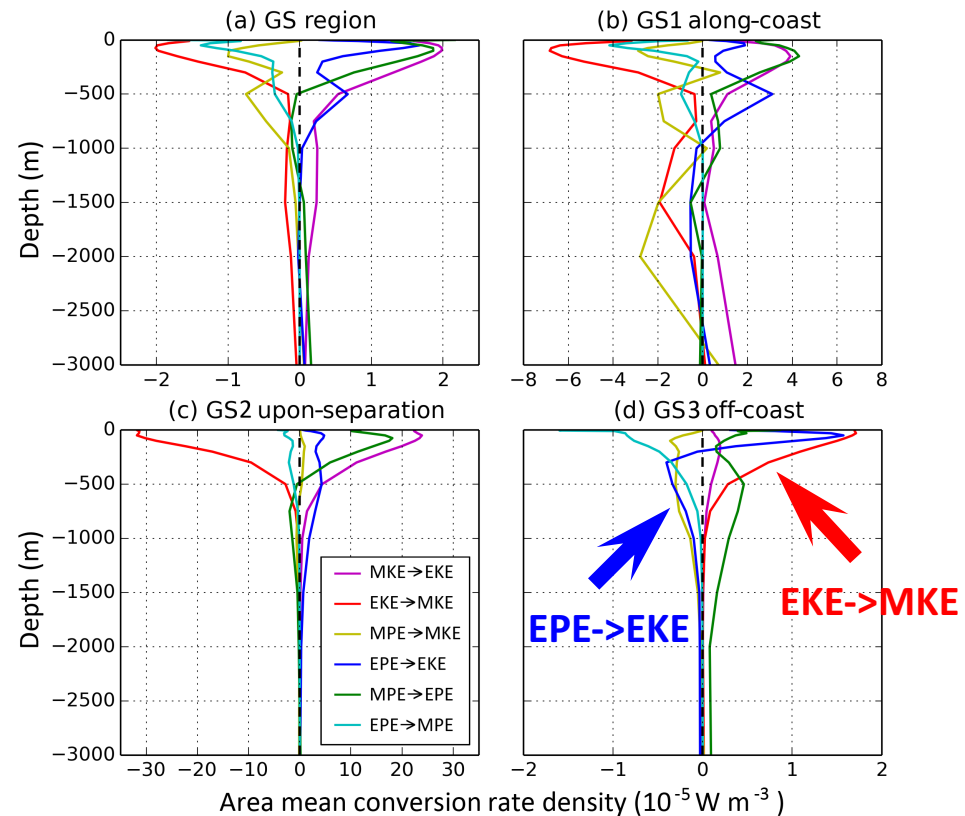
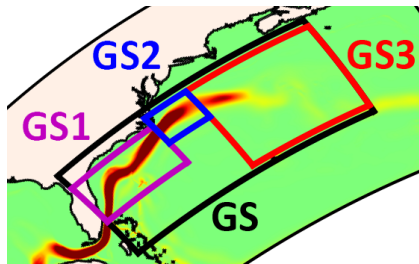


GS Vertical Energy Conversion Distribution

- Density of energy conversions (10^{-5} W m^{-3})

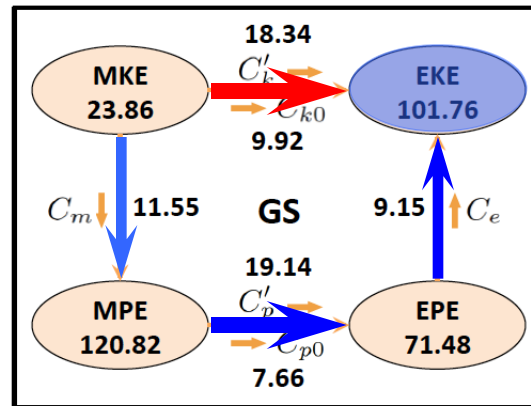
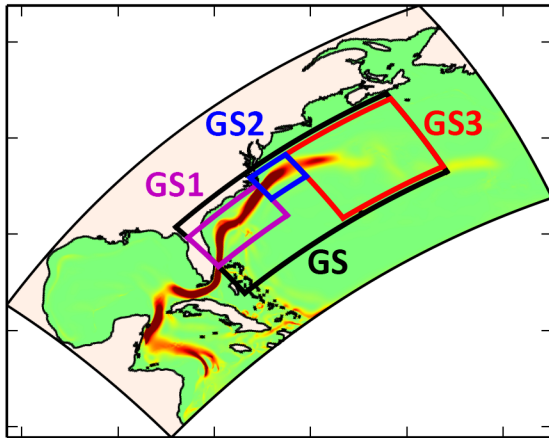
- Peak conversions in upper 500m

- Inverse conversion from EKE to MKE & EPE in GS3



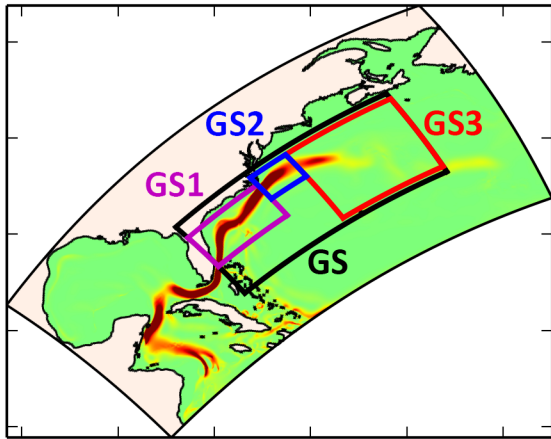
(Kang & Curchitser, 2015)

GS Eddy-Mean Flow Energy Budget

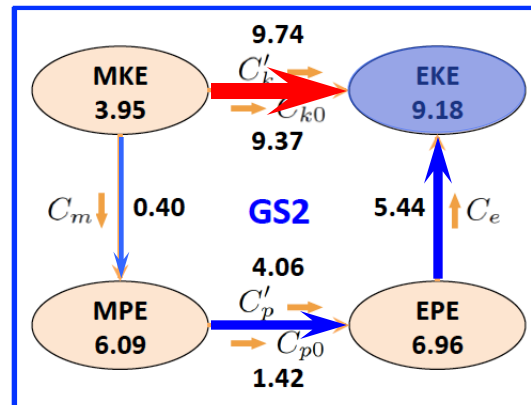
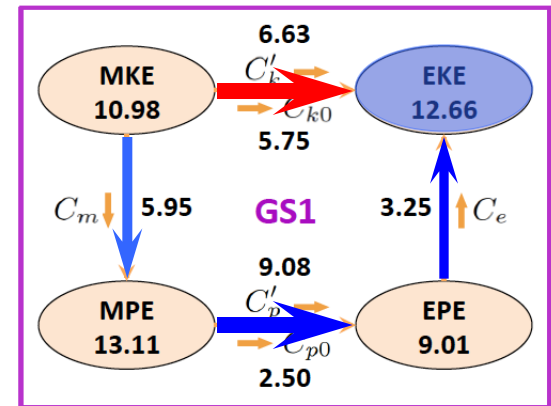
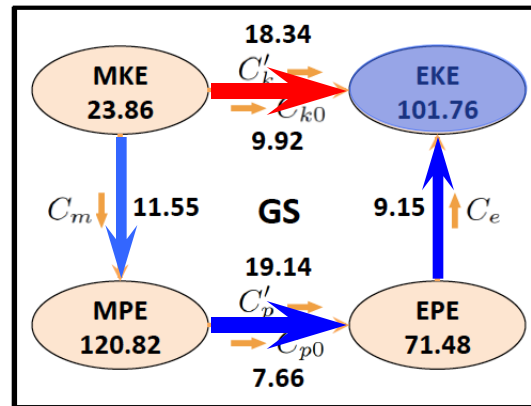


- Power transfer: mean flow \rightarrow eddy field
- EKE generation through two pathways
Barotropic: MKE \rightarrow EKE
Baroclinic: MPE \rightarrow EPE \rightarrow EKE
- MKE also supplies the baroclinic pathway

GS Eddy-Mean Flow Energy Budget

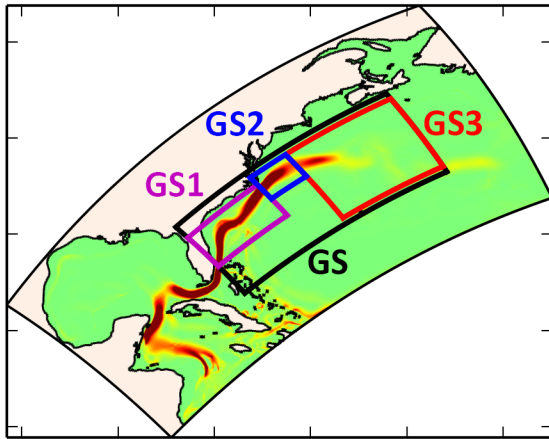


GS : Gulf Stream
GS1: along-coast
GS2: upon-separation
GS3: off-coast

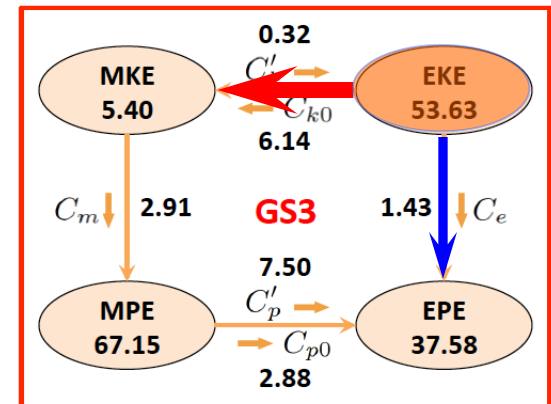
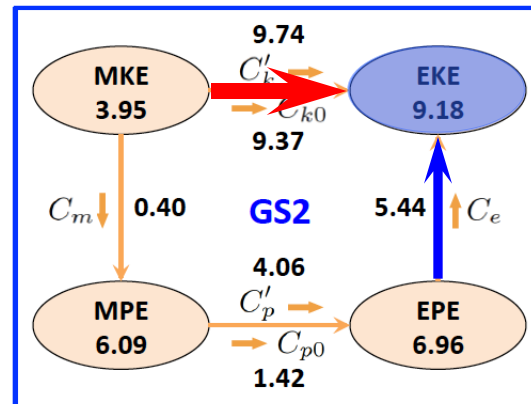
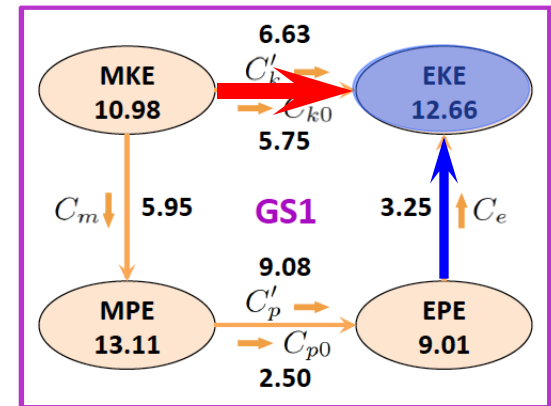
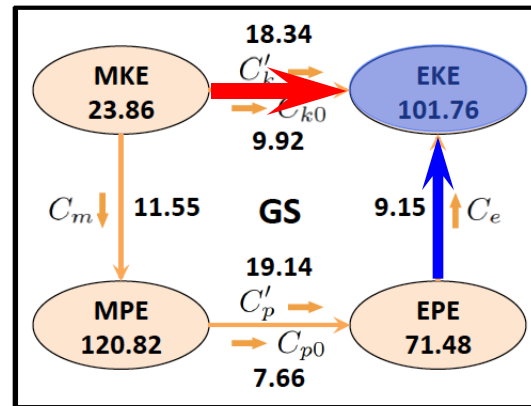


(Kang & Curchitser, 2015)

GS Eddy-Mean Flow Energy Budget



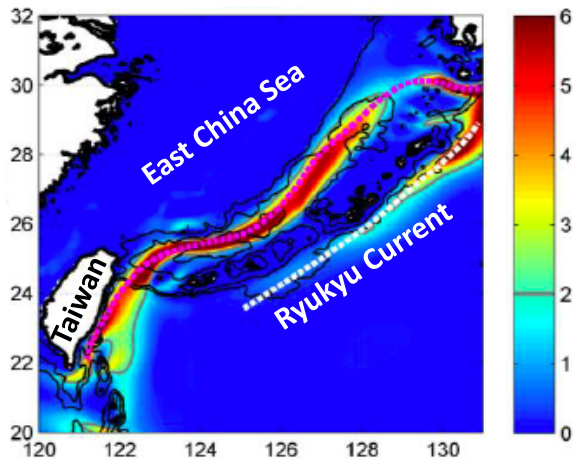
GS : Gulf Stream
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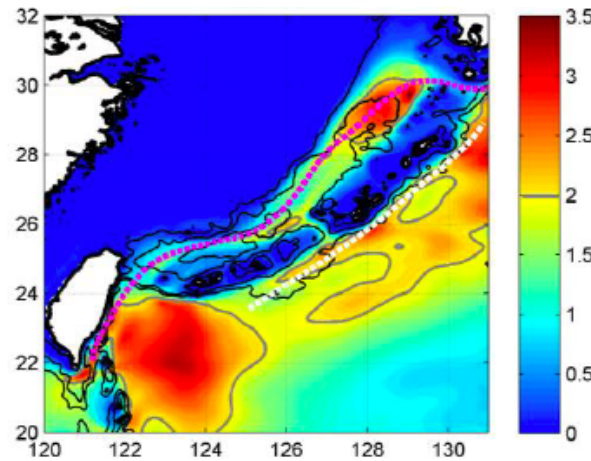
KC Eddy-Mean Flow Energetics

- Depth-integrated energy components (10^4 J m^{-2})

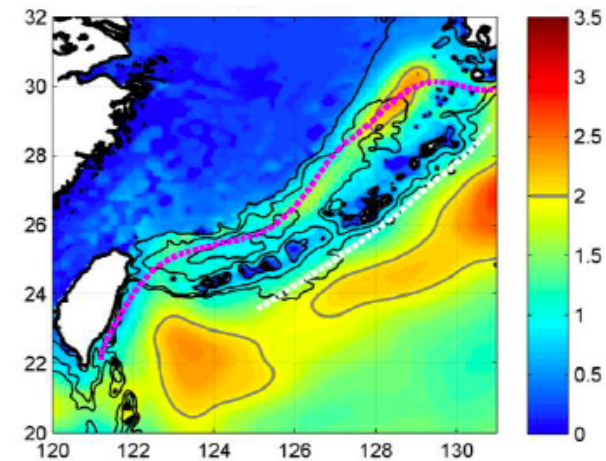
MKE



EKE

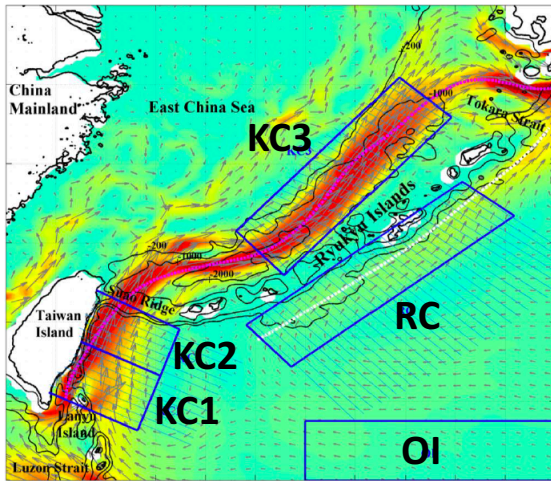


EPE

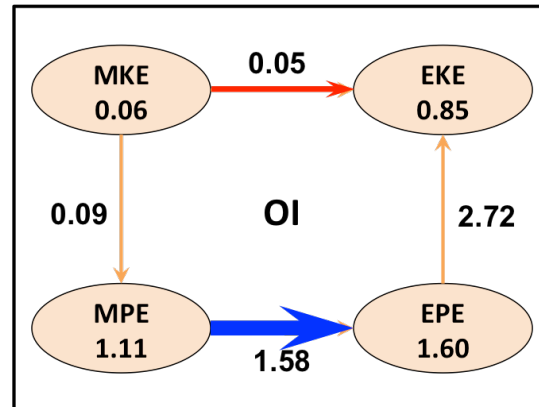
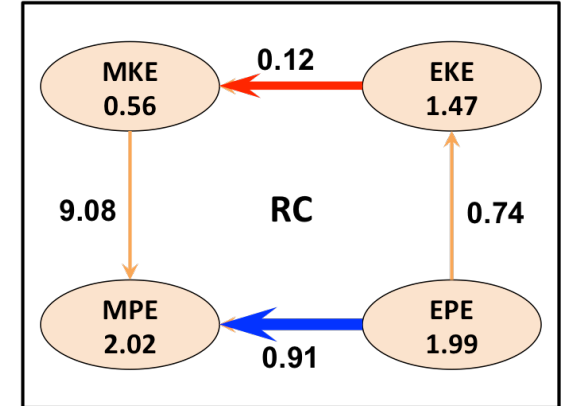
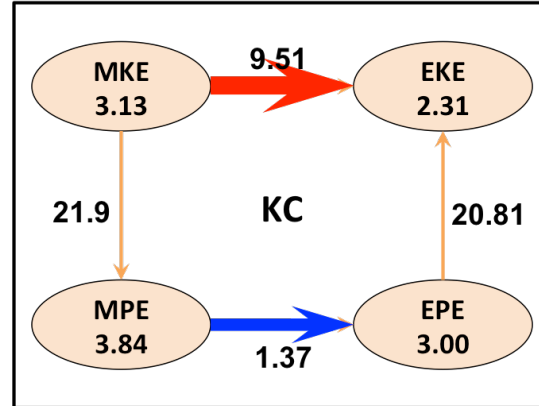


(Yan et al., 2019)

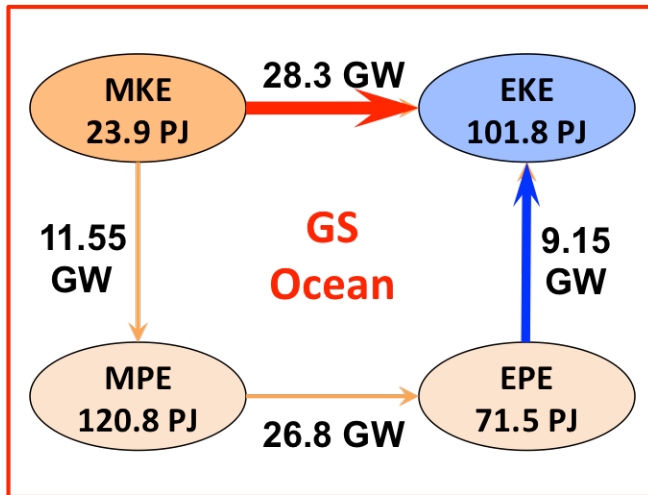
KC Eddy-Mean Flow Energy Budget



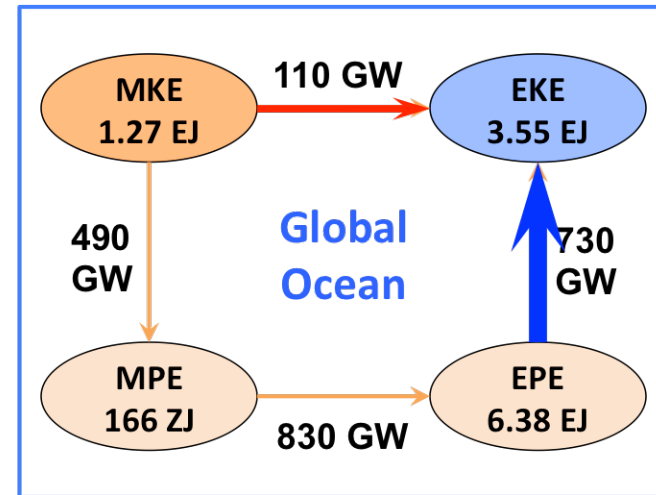
- KC1:** SE of Taiwan
- KC2:** NE of Taiwan
- KC3:** East China Sea
- RC :** Ryukyu Current
- OI :** ocean interior



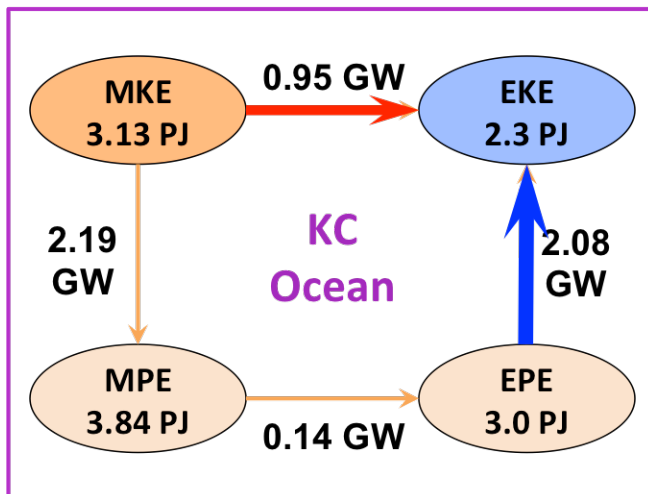
Lorenz Energy Cycles: GS – KC – Global Ocean



(Kang & Curchitser, 2015)



(Von Storch et al., 2012)



(Yan *et al.*, 2019)

Thank You !