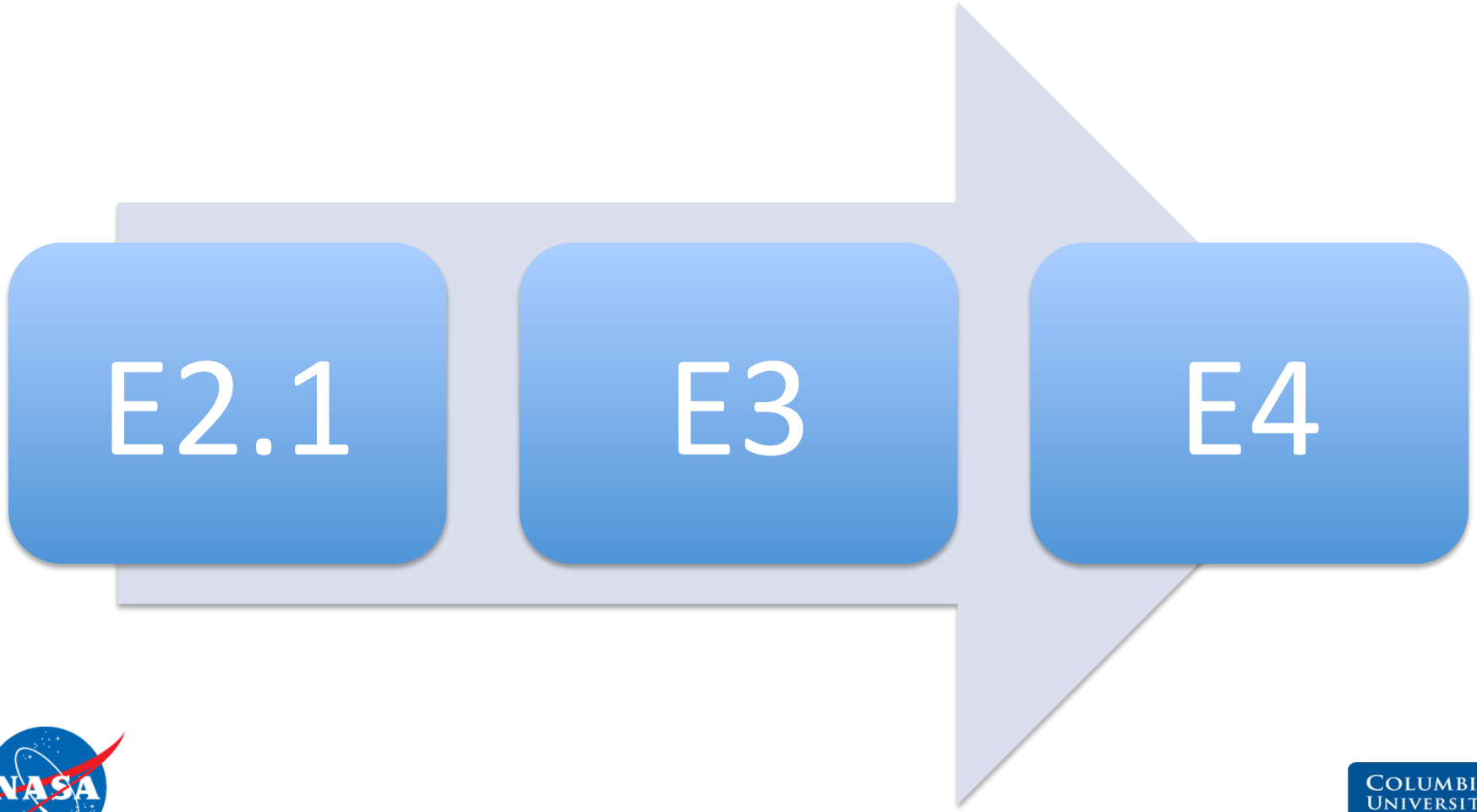
Improvements in the GISS climate model and process based evaluation

A. Romanou
Columbia U. and NASA/GISS

(mostly on behalf of the GISS modeling team)

GISS model evolution after CMIP5



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CMIP5+

E2.1

Southern ocean clouds; clouds convection updates
Ocean mesoscales in E2R; sigma1 in E2H
Atmospheric SW absorbtion
Sea ice thermodynamics (brine pockets code)
Vegetation: 8 PFT -> 13 PFT
Carbon Cycle alkalinity

Newly resolved modes:
- Madden Julian Oscillation (MJO)
- Quasi-Biennial Oscillation (QBO) (2 versions)

Updated and additional forcings:
- Updating volcanoes, solar, ozone/aerosols from E2
- Irrigation as a global forcing

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CMIP6(?)

E3

about same resolution horizontal, higher resolution vertical in both AGCM and OGCM, Fvcore, GISS-mix+tidal dissipation?

Two-moment cloud microphysics, cloud macrophysics (pdf based cloud fractions), virtual mixed-phase clouds, ice nucleation
Moist BL

Land surface: root access to soil moisture, GMAO soil data – extension to 10 layers/20 meters, prognostic albedo
Irrigation forcing updates, new emission datasets, LULC

Chemistry: pH in clouds/sulphate in-cloud chemistry, simple-OMA
Mineral dust in OMA (additional 6(?) tracers)

Ocean-bio: albedo interactions, alkalinity, oxygen, dust fluxes, rivers, fully coupled

Interactive fire
Micro-physics based lightning
Geothermal heat fluxes

Forward models: Calypso, CloudSat, ISCCP, Parasol, MODIS, MISR, MSU

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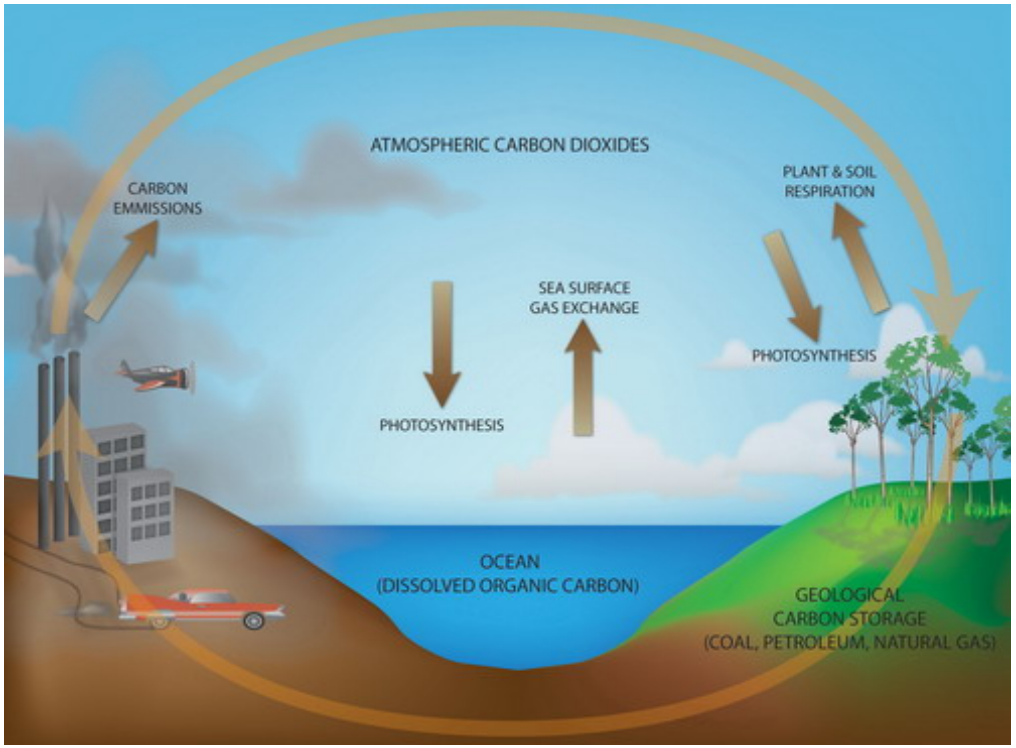
Some cross-cutting processes in ESMs
(from the perspective of the ocean carbon & biology)

- MJO
- Cloud microphysics
- Land carbon
- Dust fluxes



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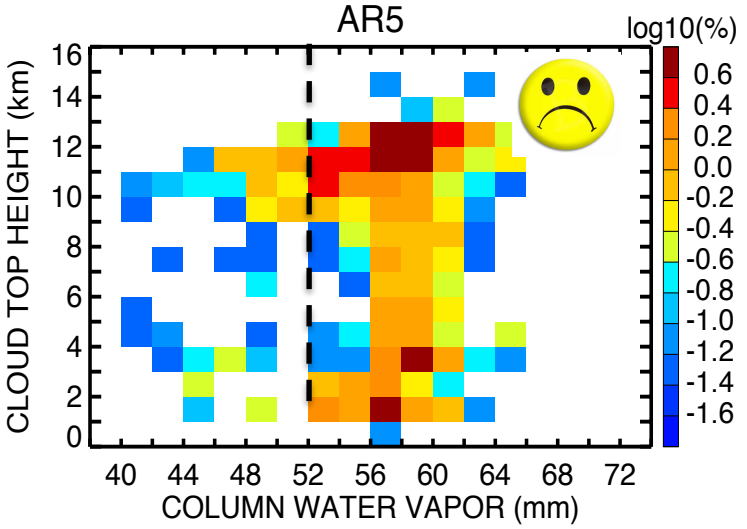
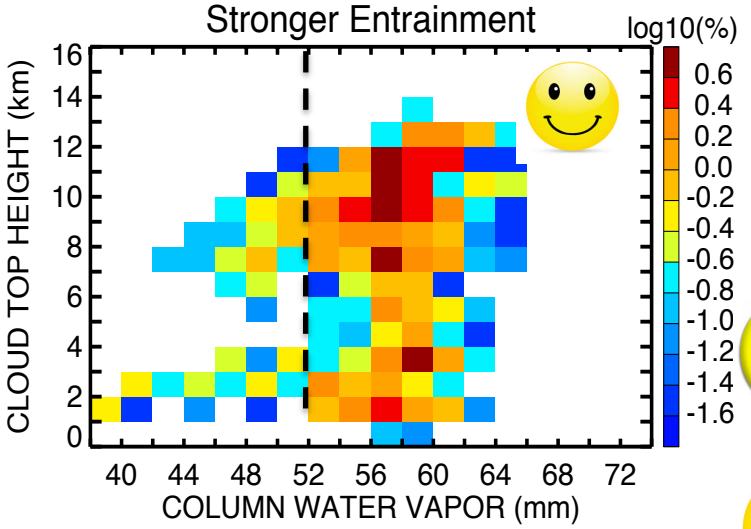
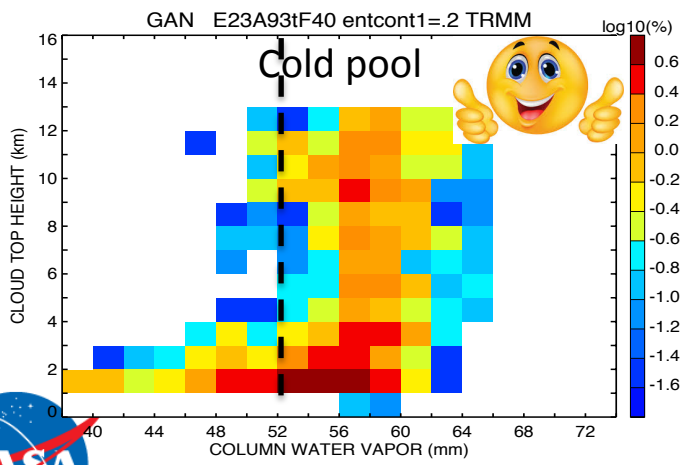
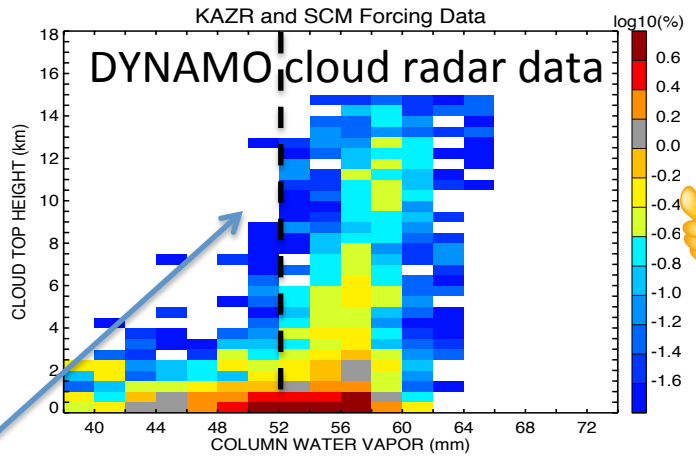
Entrainment & Cold pool parameterization -> MJO improvements









Legend:

No MJO

OK MJO

Best MJO

Transition from shallow to deep convection

Del Genio et al. (J Clim, 2015)

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Bio-physical feedbacks and the MJO

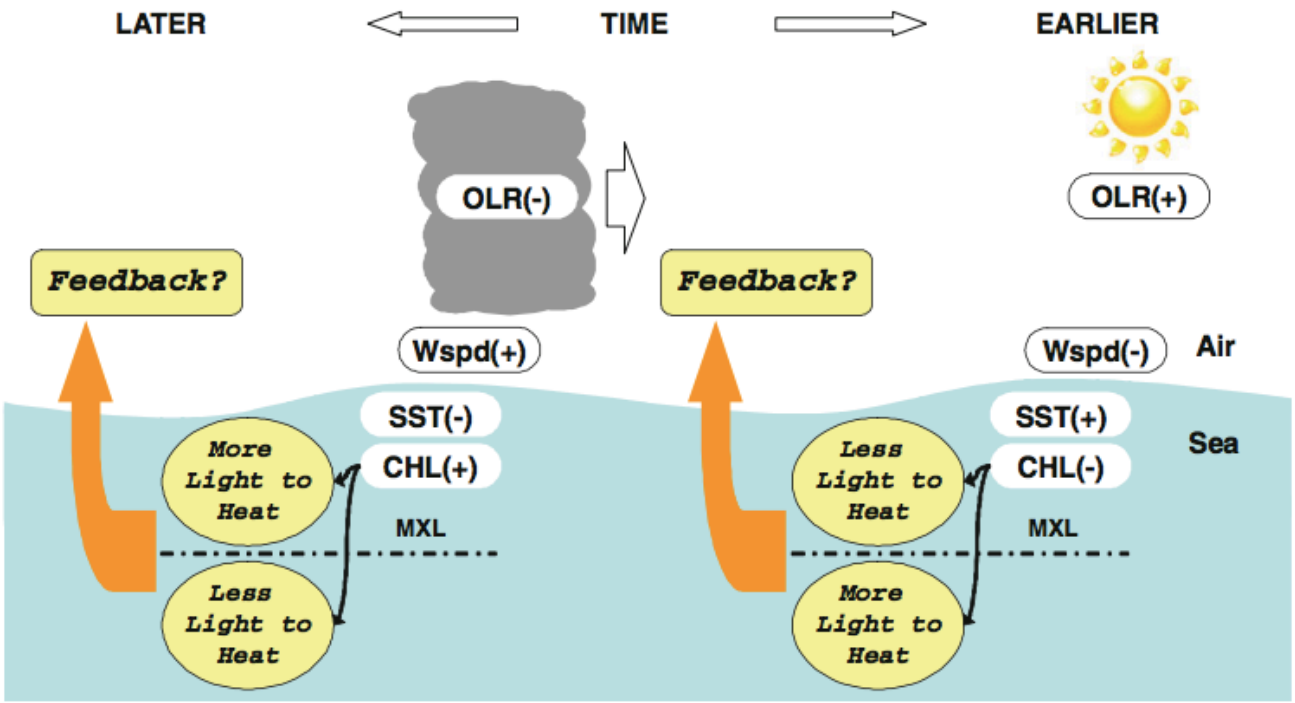

Fig. 9 A schematic representation of the MJO and bio-physical feedback, shown as a cross-section along the path of the MJO convection. (+) or (−) indicate sign of anomalies, and "Wspd" indicates wind speed

Jin et al, (2013). Clim Dyn

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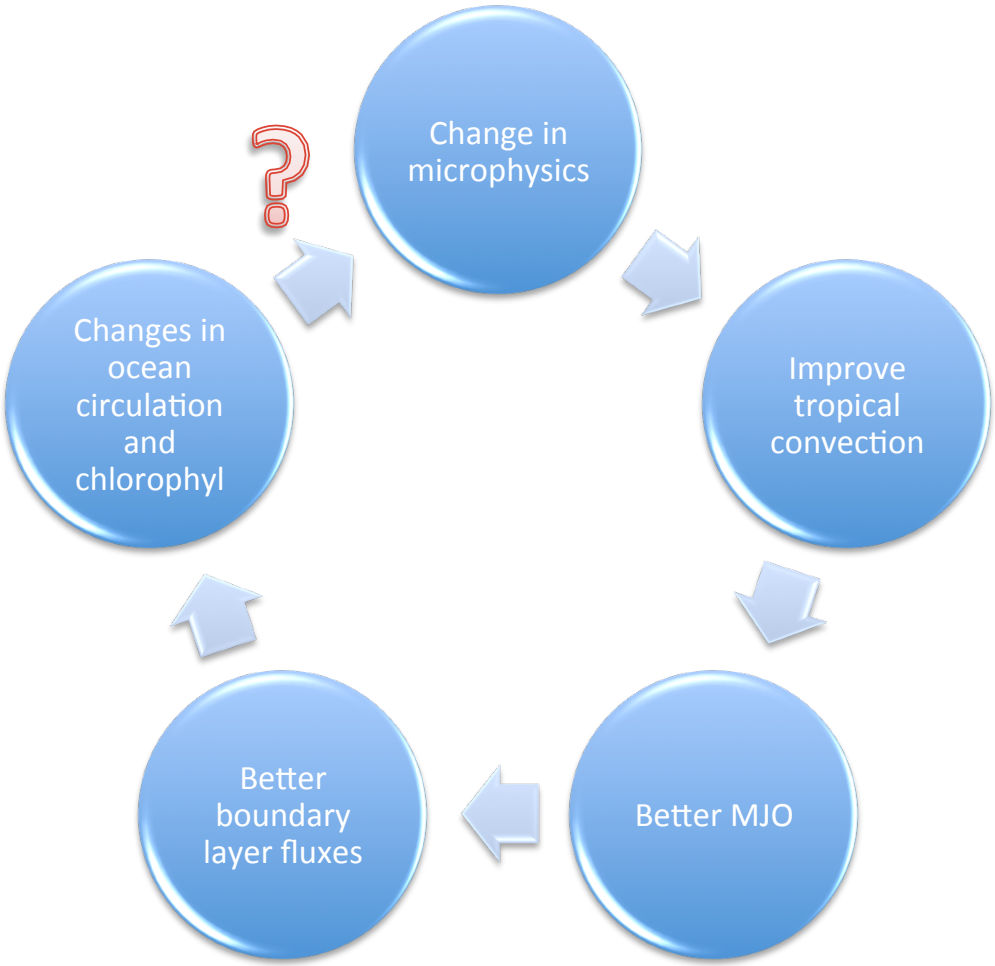
MJO in Earth System Models



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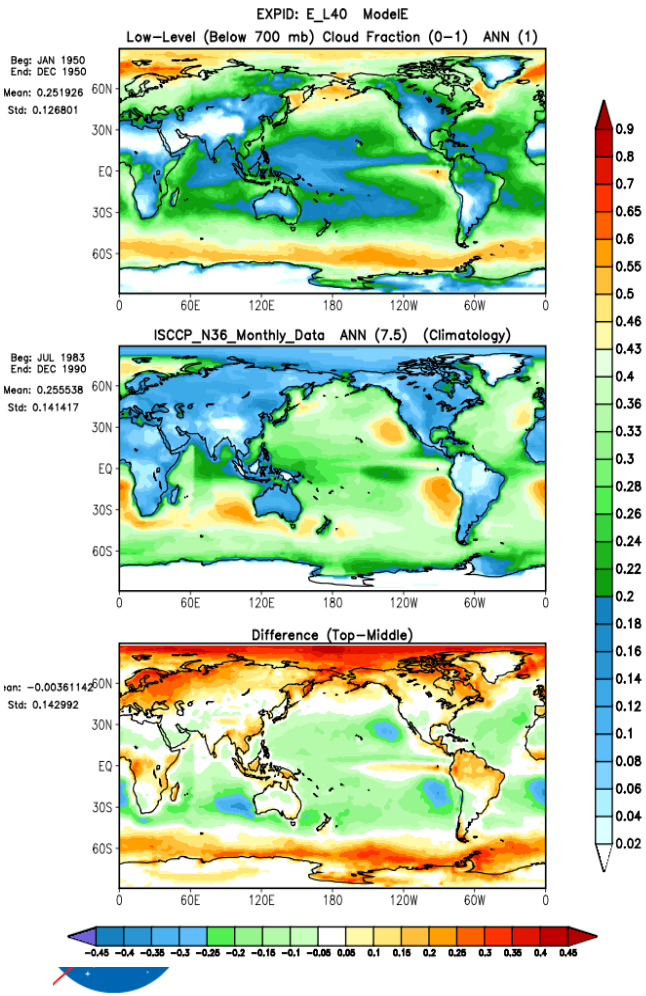
Multi-scale, process based cloud evaluation

Andy Ackerman, Ann Fridlind, George Tselioudis

Global scales
GCM – Satellite data



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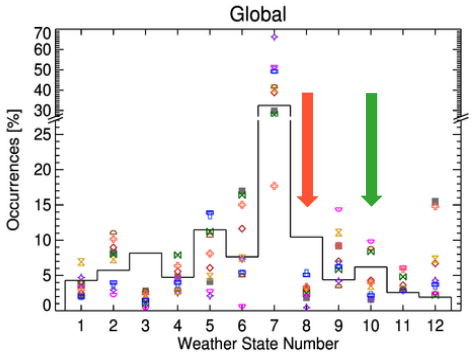
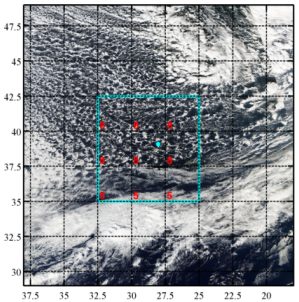
Synoptic scales
Weather State (cluster) analysis

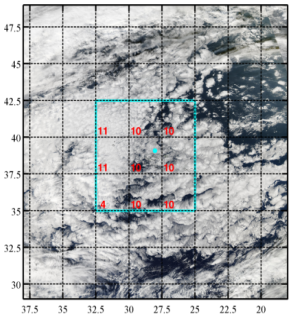


Case studies

Cu: WS8 post-frontal cold-air outbreak

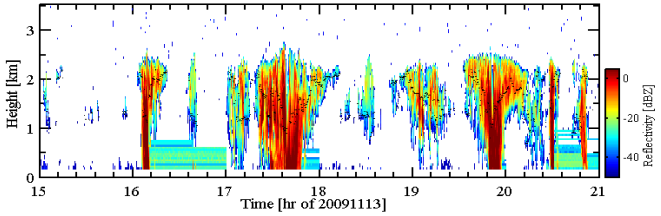


Sc: WS10, Azores high

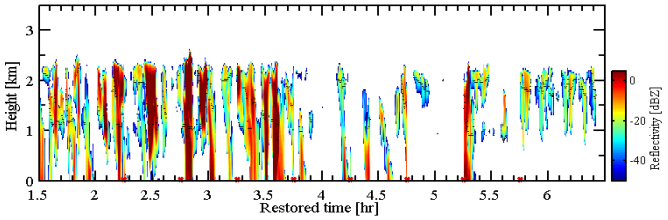


Microphysical scales
LES – SCM simulations
In-situ observations

ARM radar



DHARMA LES



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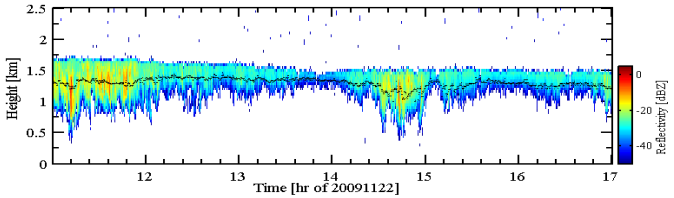

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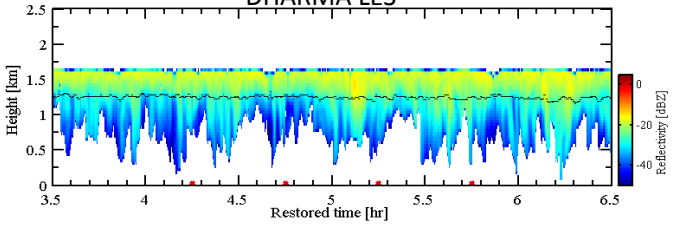

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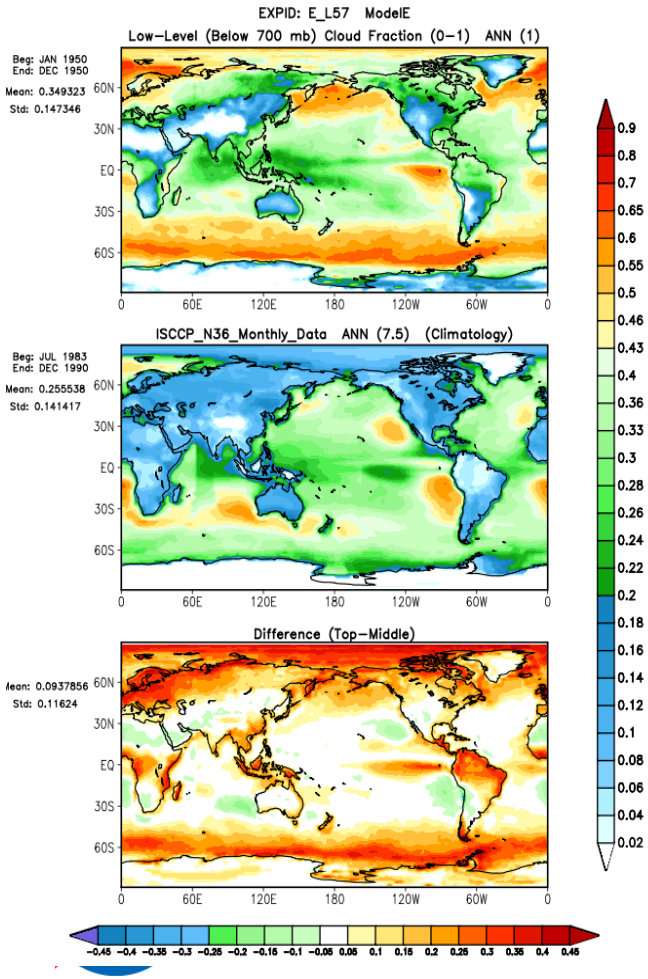

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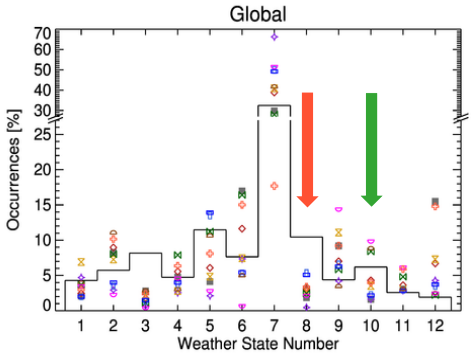

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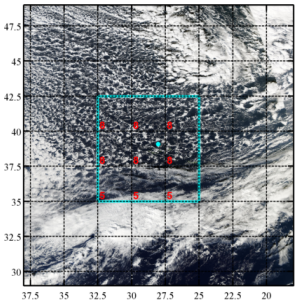

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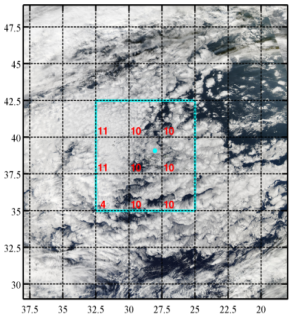

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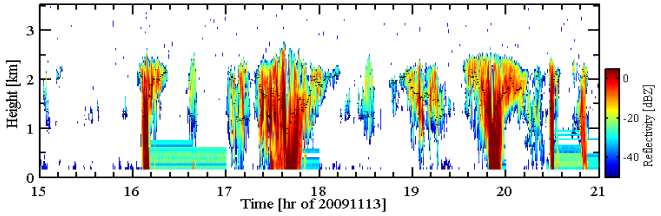

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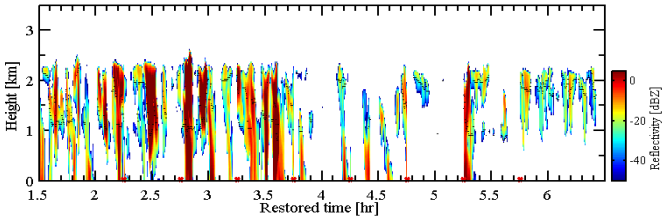

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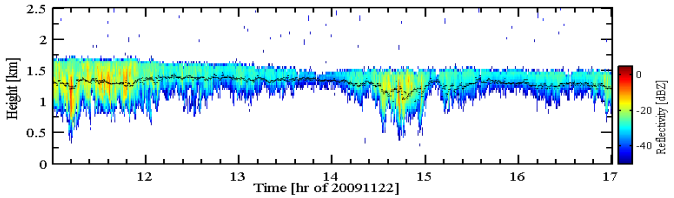

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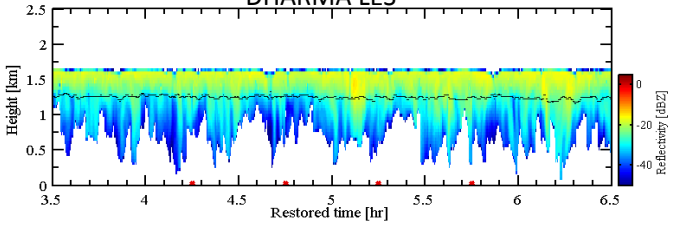


GISS GCM ModelE2 Ent Terrestrial Biosphere Model:

Land-Atmosphere Coupled Carbon

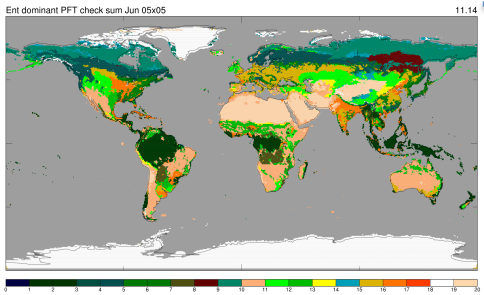
Nancy Kiang, Igor Aleinov

Ent Global Vegetation Structure Dataset (Ent GVSD) 1.0

13 Plant Functional Types Cover:

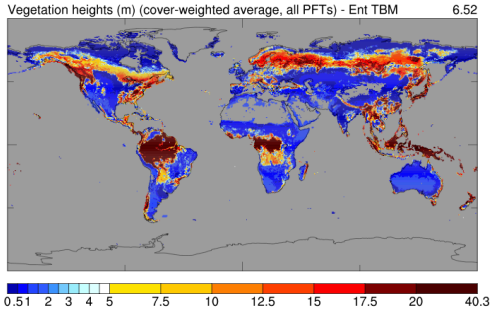
MODIS + SAGE
+ Monfreda et al. (2008)
+ Sheffield et al. (2006)
1951-2006 climate

Leaf Area Index: MODIS



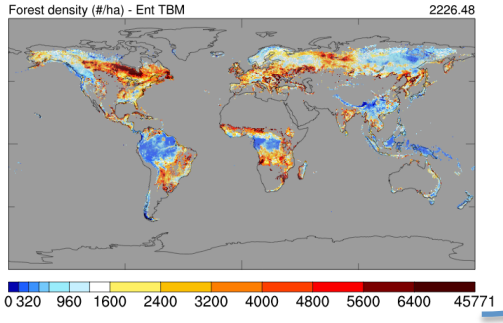
Forest heights:

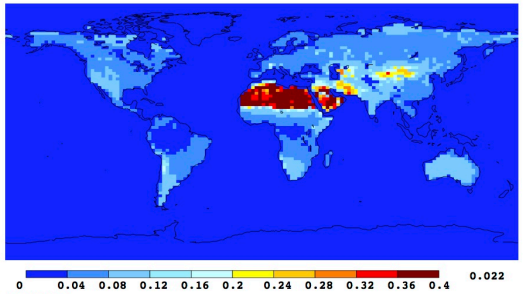
ICESat/GLAS (Simard et al., 2011)



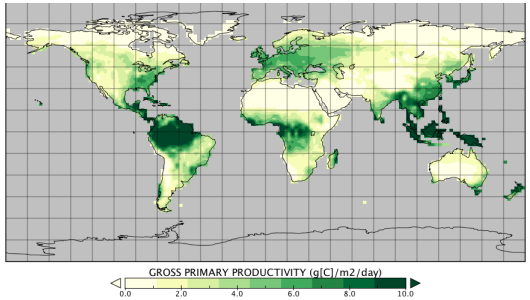
Plant densities:

Via Ent allometry

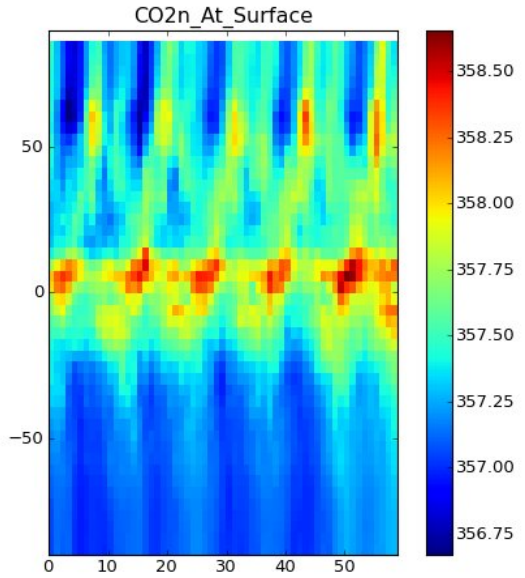




ALBEDO (tbd: soil albedo by Carrer et al.2014)



GROSS PRIMARY PRODUCTIVITY ~ 104-142 PgC/yr



PROGNOSTIC ATMOSPHERIC CO2

-Faster to equilibrium with new veg data structure

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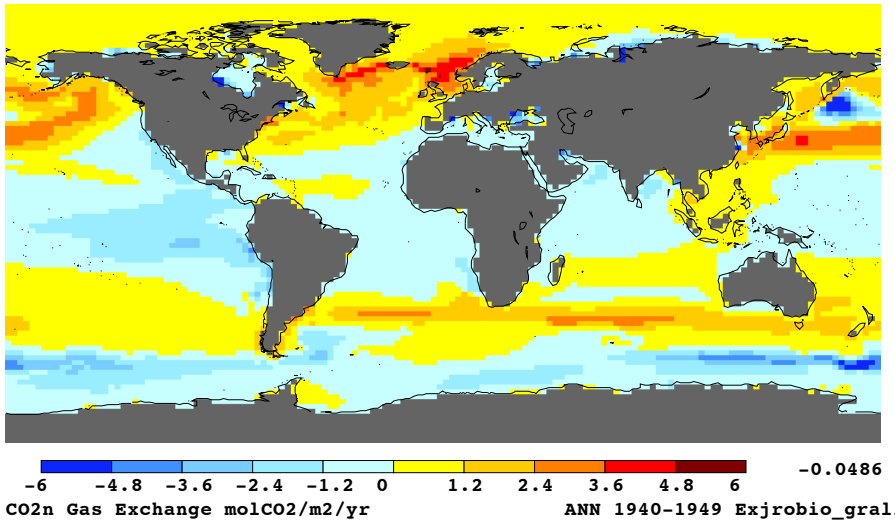
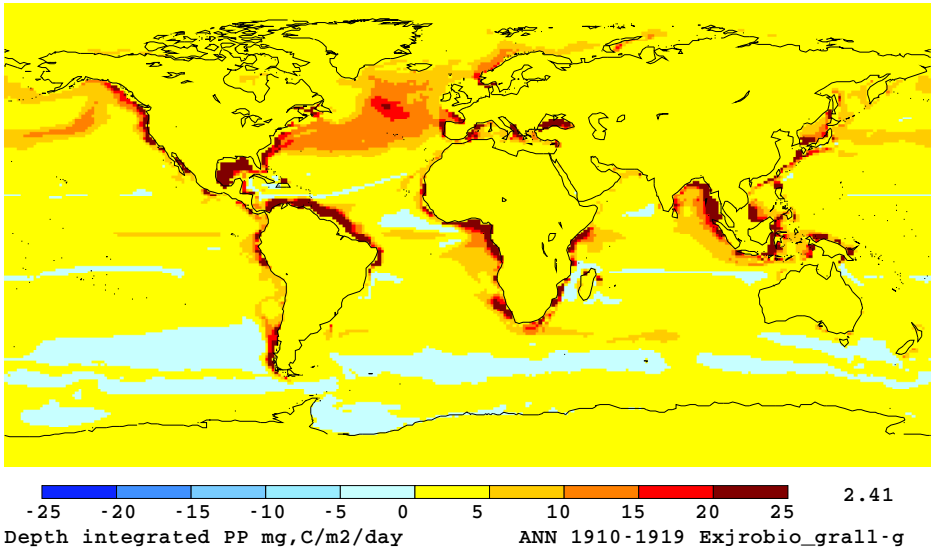
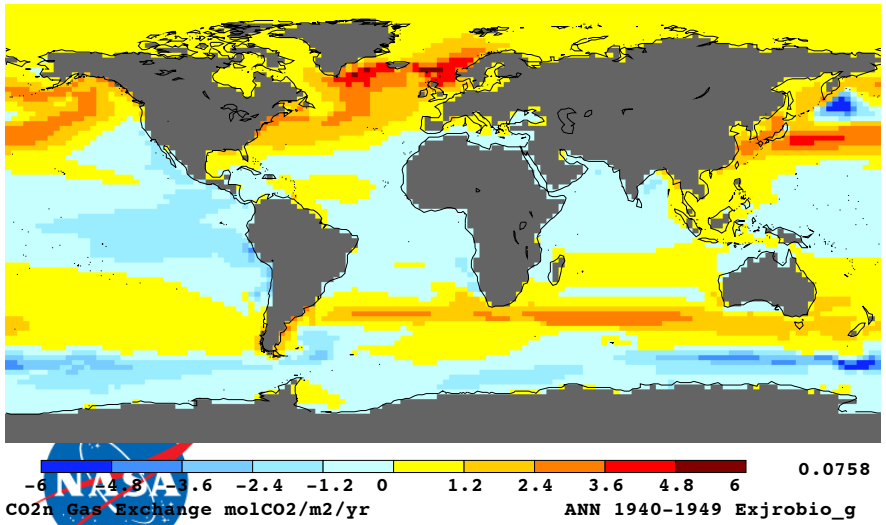
Riverine/continental runoff *(Romanou et al, 2015, in prep)*







- potential impact of river N, Si, Fe, and organic carbon (OC) fluxes on the global and coastal ocean biogeochemistry
- Data from Cotrim daCuhna et al (2007)
- Interactive freshwater fluxes and constant concentrations of organic and inorganic elements

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Romanou et al, 2015

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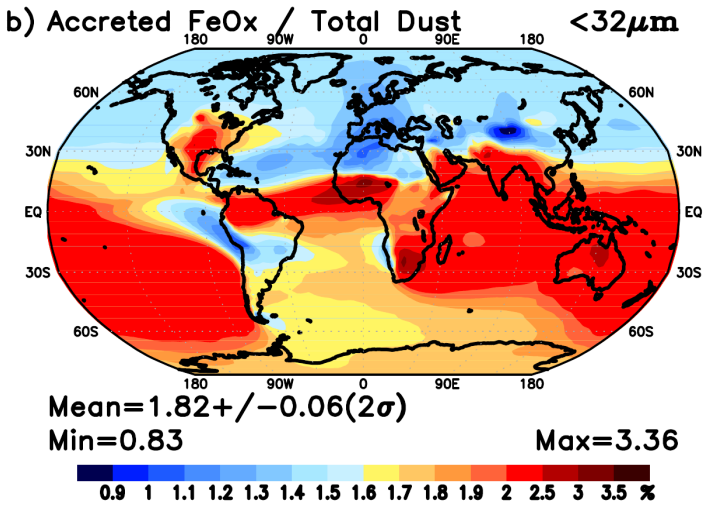
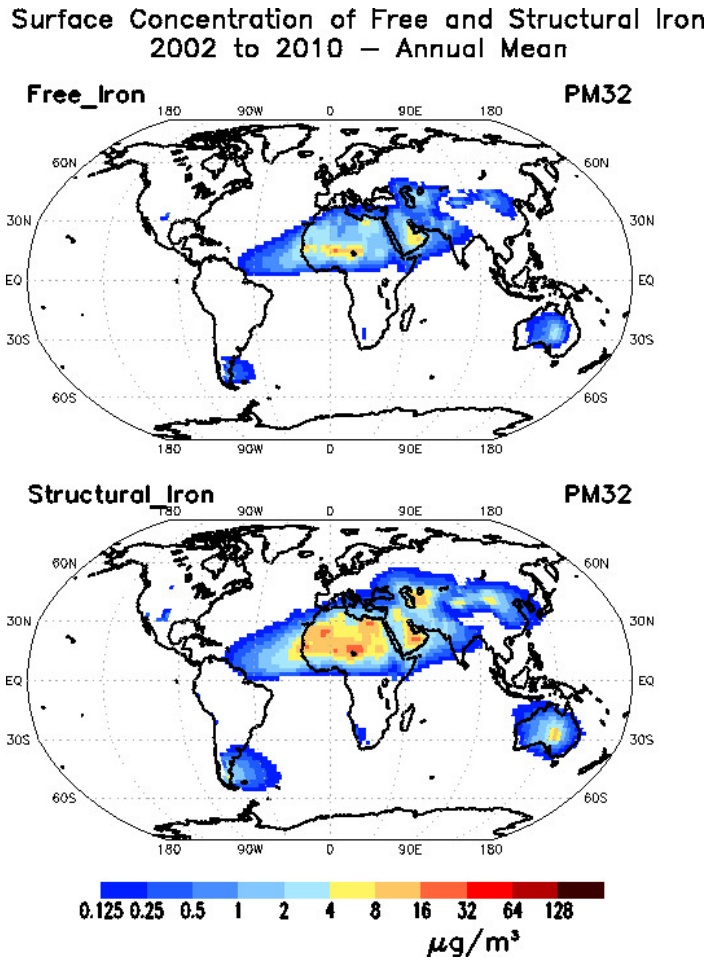
Dust & Iron Cycle in ModelE2.1

(Dust group at NASA GISS: Ron. L. Miller, Carlos Pérez García-Pando, Jan P. Perlwitz)





Eight externally mixed minerals (illite, kaolinite, smectite, carbonates, quartz, feldspar, iron oxides, gypsum) plus internal mixtures between seven minerals and iron oxides.

Perlwitz et al, 2015a,b

The mass of free iron and structural iron and their fractions of total iron are evaluated using measurements for location at Izaña Observatory. *Pérez García-Pando et al. (2015).*

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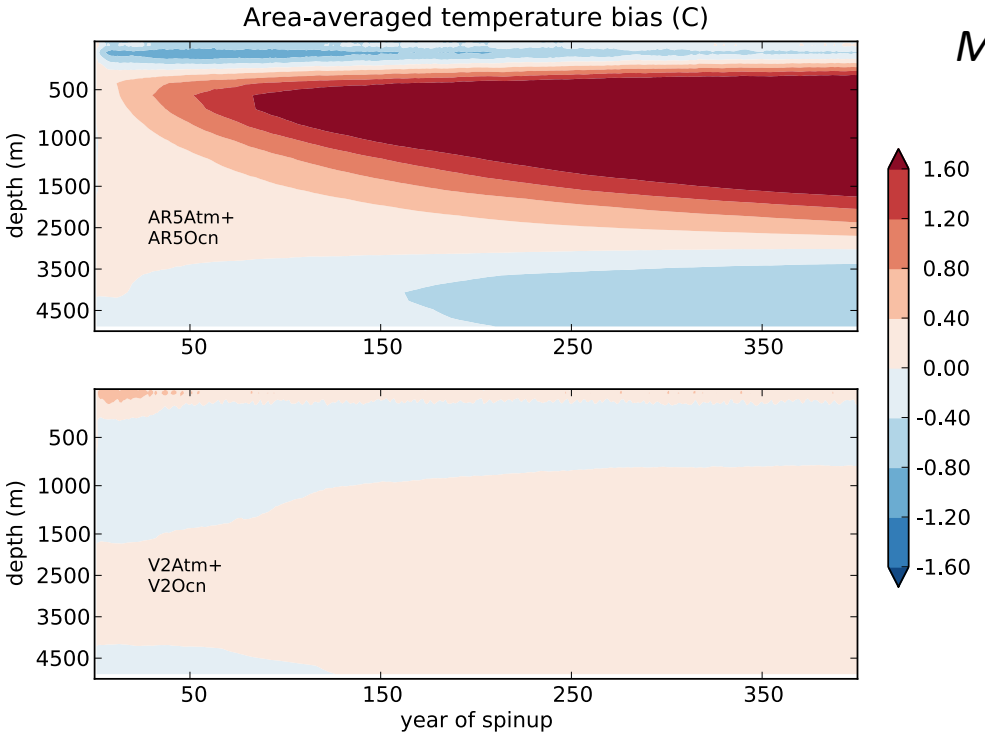
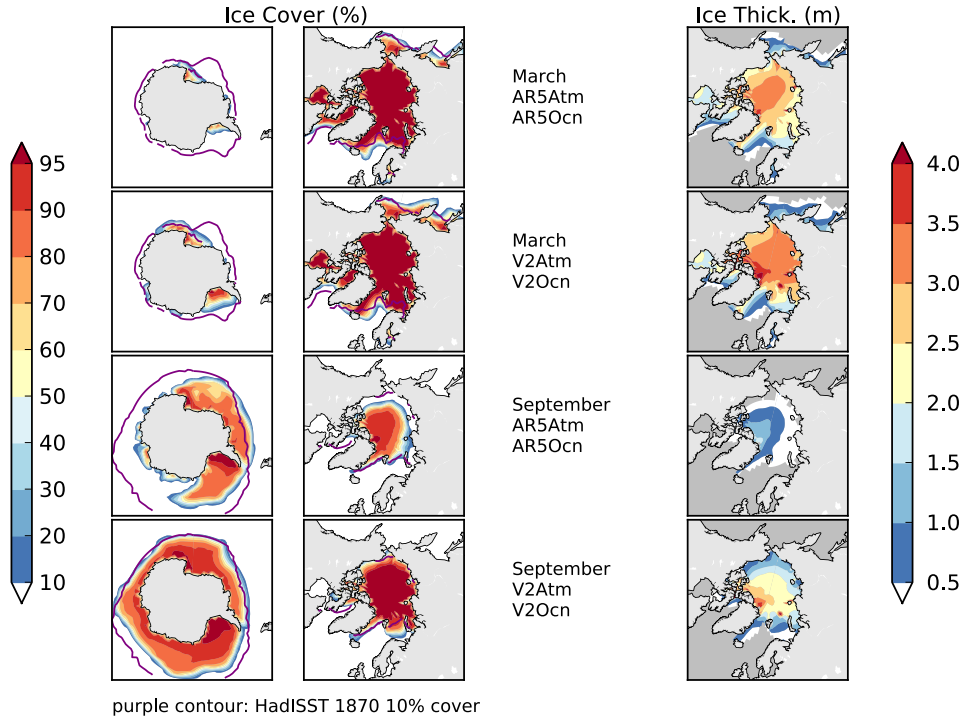


M. Kelley et al. (2015)

Key AR5 -> V2 ocean+ice drivers:
(1) Low cloud distribution, sea ice albedo
(2) Ocean mesoscales: 3D K, numerics
(3) Tidally induced ocean diapycnal mixing

Effects of (1)-(3):
(1) Mid/hi-lat SW reduction -> icier
(2) Cooler ocean interior, better S.O.
(3) Reduced NH ice extent

Other improvements: ENSO amplitude, CO2 and CFC fluxes *(Romanou et al, 2015, in prep)*



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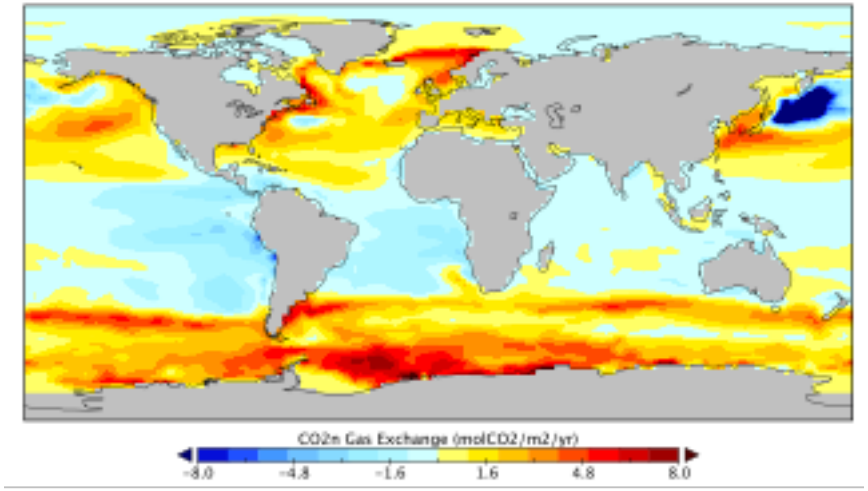
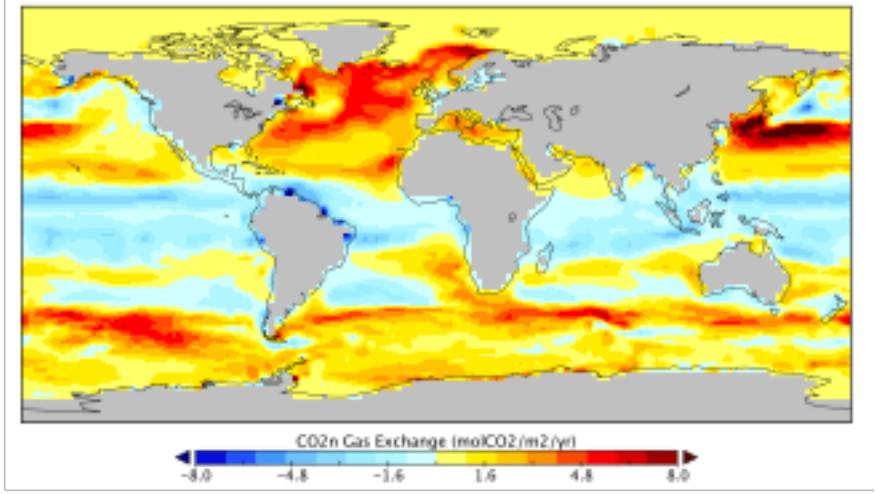
Oceanic Carbon-Cycle: Surf CO_2 flux

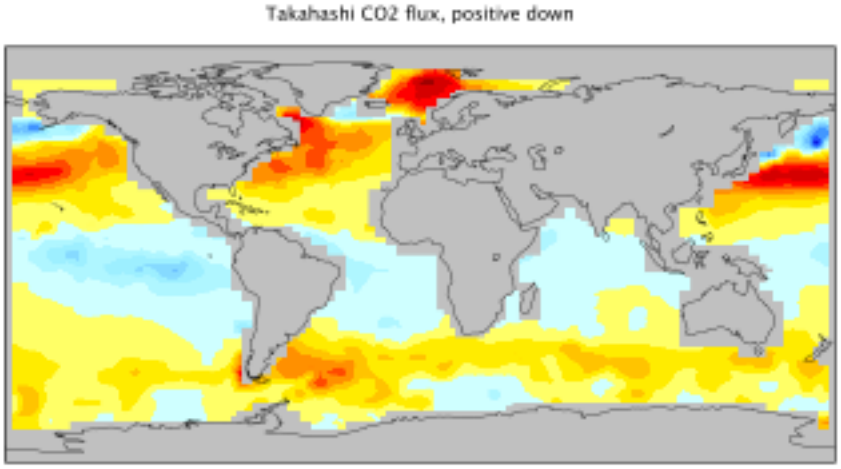
Modified NOBM in GISS-E2-R and -H *(Romanou et al, 2012;2013)*



GISS-E2-R



GISS-E2-H



Observations (Takahashi)

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A take home message

- Process evaluation studies should cut across systems, eg. Ocean, atmosphere, carbon cycle, ecosystems etc -> Truly coupled

- Develop methodology/tools/a culture (?) to simultaneously assess changes in different parts of the model

- Cross-cutting evaluation is a more holistic approach appropriate for the complexity of the ESMs

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