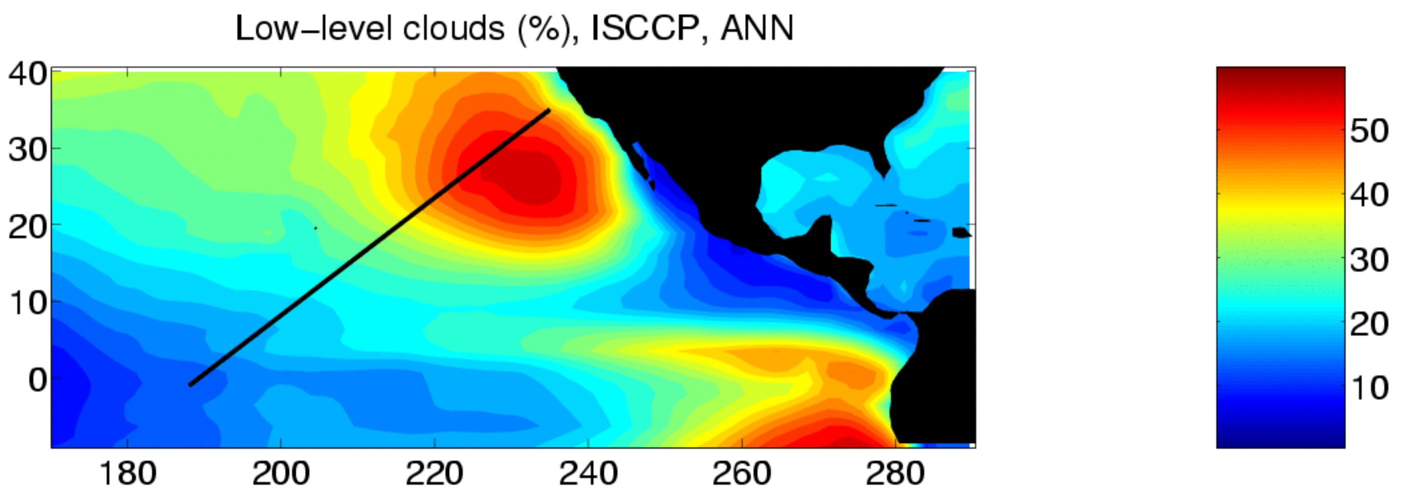
Sc-Cu transition CPT

Goal: Improve the representation of the cloudy boundary layer in global weather/climate models with a focus on the subtropical stratocumulus to cumulus (Sc-Cu) transition



NOAA funded, 1 August 2010 - 31 July 2013

(with additional internal JPL and DOE funds)

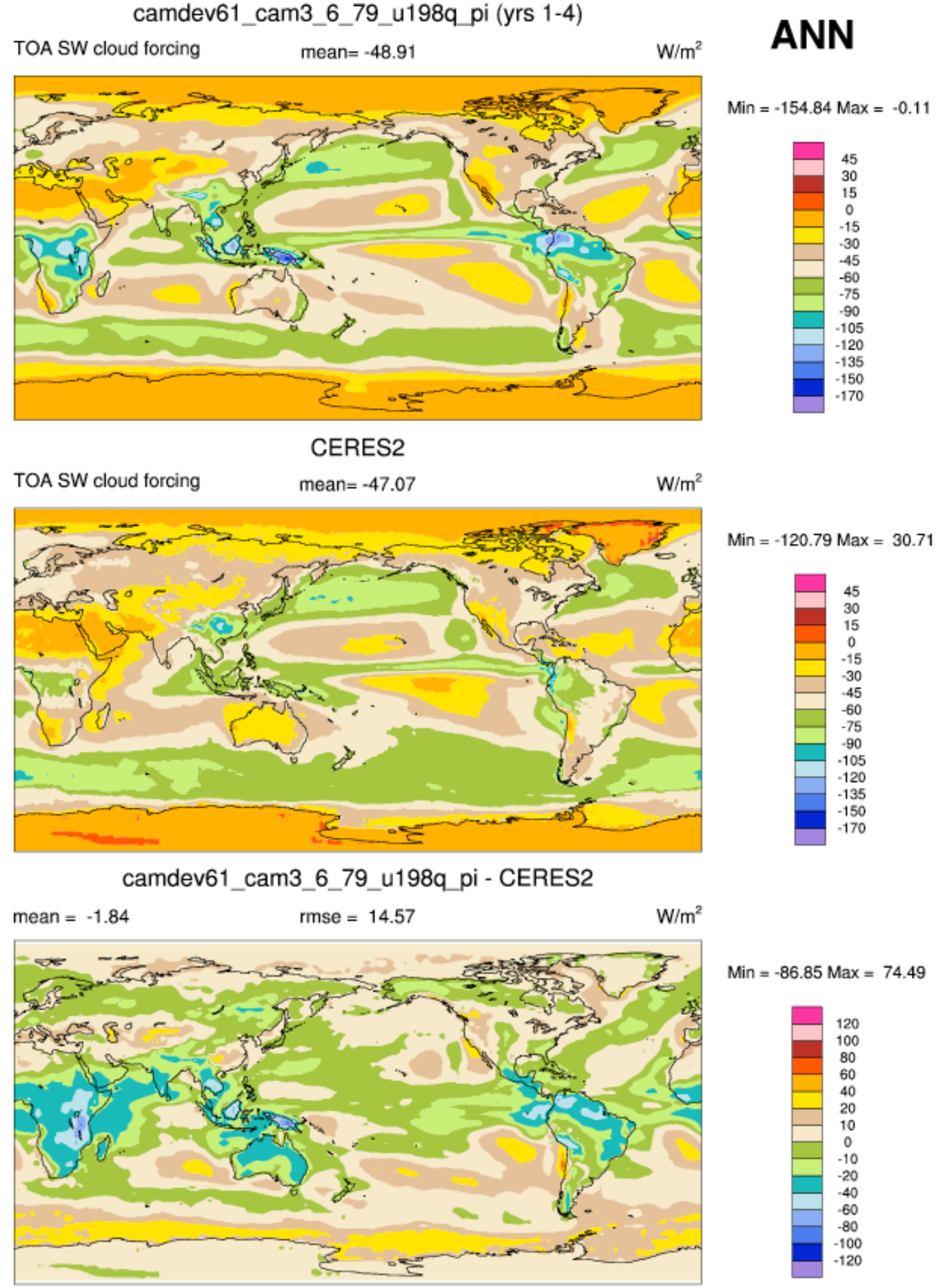
Motivation: CPT-related issues at NCEP

- Operational GFS/CFS struggles with too little subtropical Sc:
  - NCEP is currently developing/testing new parameterizations for Sc and Cu processes separately
  - NCEP showed that CFS Sc-Cu transition could be improved by reducing penetrative Cu entrainment in Sc regions
- Moist physical parameterization suite has been inadequately tested in controlled single-column settings.
- GFS/CFS needs to update its suite of climate bias metrics and use them more rigorously for model evaluation.

Motivation: CAM5 SWCRF biases

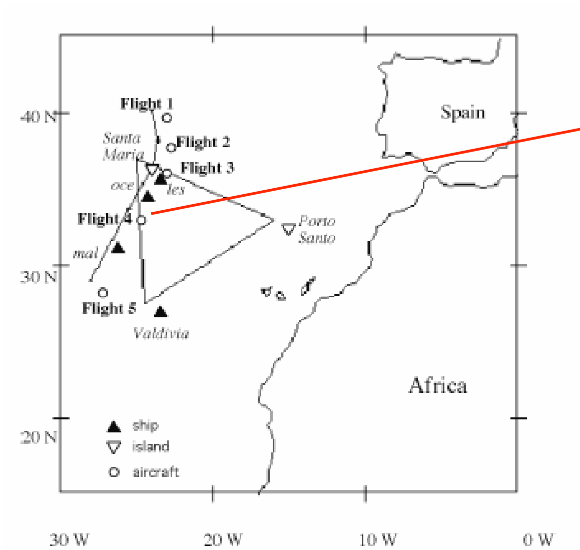
- CAM5 has improved Sc-Cu transitions, but still far from perfect and excess cloud near equator / tropical land.

- CPT aims to cross-fertilize NCEP and NCAR model development and evaluation efforts

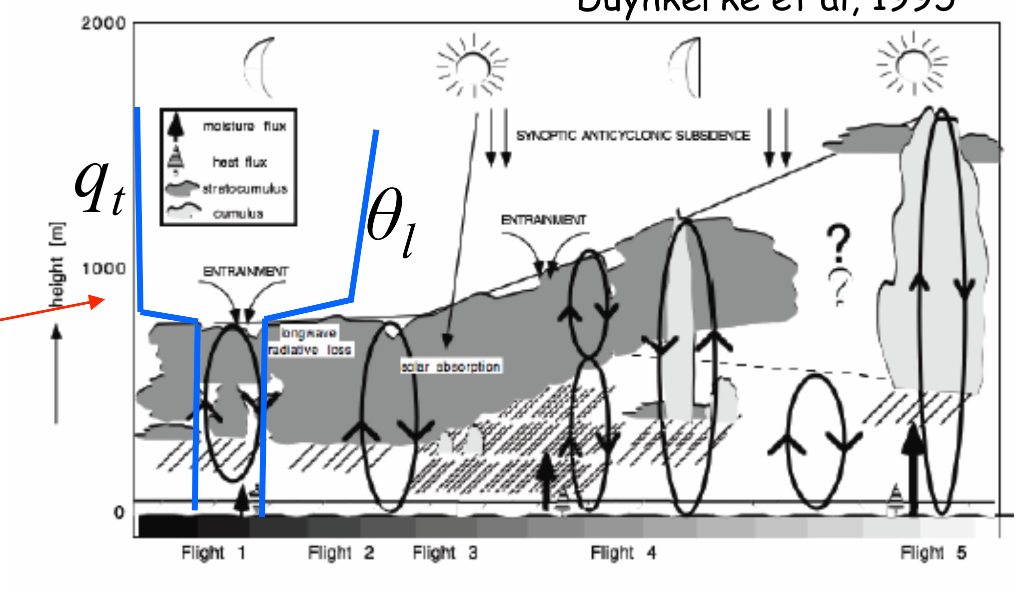


GEWEX Cloud Systems Study (GCSS): Two new Sc-Cu transition case-studies

ASTEX
Lagrangian 1992



Duynkerke et al, 1995



SST=290K	SST=293K	SST=295K
CA =100%	CA = 100%	CA = 60%
LWP=50 gm^{-2}	LWP=140 gm^{-2}	LWP=40 gm^{-2}

GCSS Working Group 1 will spend next 3 years evaluating LES and SCMs for two new Sc-Cu transition case-studies

Optimal period to develop and test new parameterizations for Sc-Cu transition in NCEP and NCAR models

Eddy-Diffusivity/Mass-Flux (EDMF)

Dividing a grid square in two regions (updraft and environment) and using Reynolds decomposition and averaging leads to

$$\overline{w'\varphi'} = a_u \overline{w'\varphi'}_u + (1-a_u)\overline{w'\varphi'}_e + a_u(1-a_u)(w_u - w_e)(\varphi_u - \varphi_e)$$

where a_u is the updraft area. Assuming $a_u \ll 1$ and $w_e \sim 0$ leads to

$$\overline{w'\varphi'} = \overline{w'\varphi'}_e + a_u w_u(\varphi_u - \bar{\varphi})$$

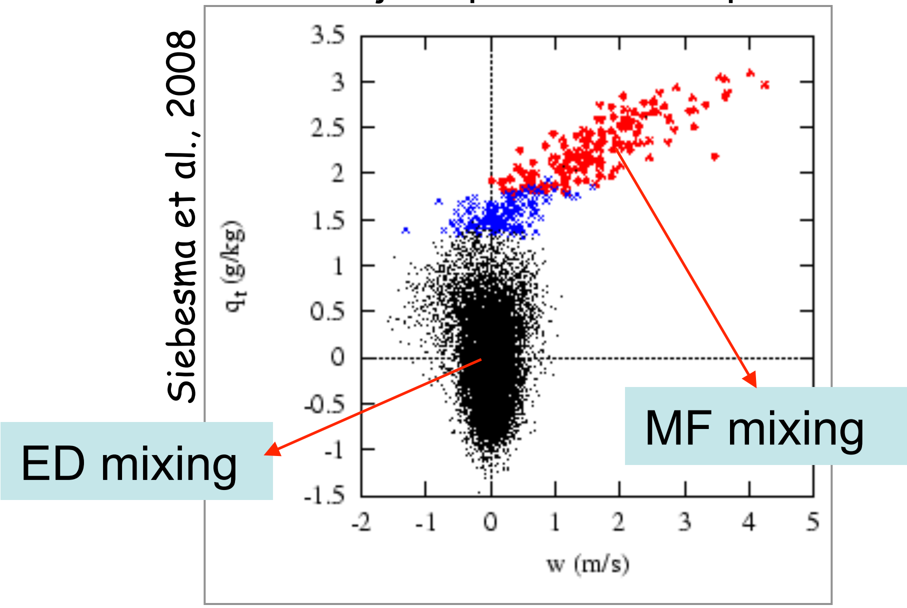
ED closure: assuming ED for 1st term and neglecting 2nd term

MF closure: neglecting 1st term and assuming $M = a_u w_u$

EDMF: $$\overline{w'\varphi'} = -k\frac{\partial\bar{\varphi}}{\partial z} + M(\varphi_u - \bar{\varphi})$$

Siebesma & Teixeira, 2000

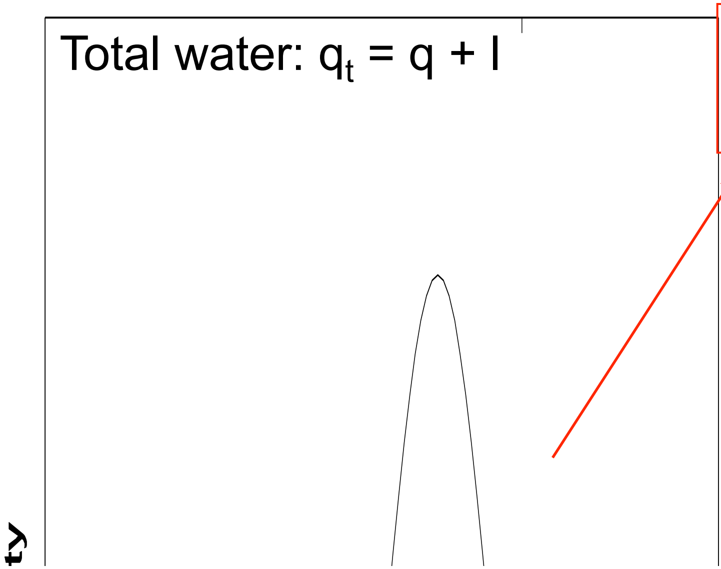
Bimodal joint pdf of w and qt



EDMF may be able to reproduce the mixing for the entire Sc-Cu transition

PDF-based Cloud Parameterization

PDF cloud parameterizations are based on the pdf of q_t (in this simple example) or on the joint pdf of q_t and θ_l



Mellor, 77; Sommeria & Deardorff, 77

Values larger than saturation are cloudy

$$a = \int_{q_s}^{+\infty} p(q_t)\,dq_t$$

$$\bar{l} = \int_{q_s}^{+\infty} (q_t - \overline{q_s})\,p(q_t)\,dq_t$$

a = cloud fraction

With Gaussian distribution we obtain cloud fraction and liquid water as a function of Q:

$$a = \frac{1}{2} + \frac{1}{2} erf\left(\frac{Q}{\sqrt{2}}\right)$$

$$\frac{l}{\sigma} = aQ + \frac{1}{\sqrt{2\pi}} e^{-Q^2/2}$$

$$Q = \frac{q_t - q_s}{\sigma}$$

CPT Lead PI: Joao Teixeira

NCEP

Hua-Lu Pan (PI): GFS/CFS moist physics development

Jongil Han (res sci): Shallow Cu and cloudy PBL

Ruiyu Sun (res sci): GFS/CFS evaluation; parameterization of Cu-Sc interaction.

NCAR

Sungsu Park (PI): CAM5 turbulence/Cu/microphysics development

Cecile Hannay (res sci): CAM5 climate/forecast mode model runs and diagnostics

JPL

Joao Teixeira (PI): EDMF, CPT spokesman, outreach

Marcin Witek (postdoc) : EDMF implementation in GFS

U. Washington

Chris Bretherton (PI): NCEP and NCAR parameterization development advisor

Jennifer Fletcher (grad student): NCEP SCM testing/improvement - GCSS cases

Peter Blossey (res sci): LES of GCSS Sc-Cu and other cases in support of SCM

Matt Wyant (res sci): Metrics; Evaluate GFS/CAM forecasts for Azores, VOCALS

UCLA

Roberto Mechoso (PI): Sc-Cu impact on ENSO, ocean coupling

Heng Xiao (postdoc: 50% at NCEP): “ “ “

LLNL

Steve Klein (PI): PDF-based cloud parameterization for CAM5

Peter Caldwell (res sci): “ “

CPT Main Tasks

a) GCSS Sc-Cu cases with NCAR and NCEP SCMs, and LES

b) NCAR and NCEP simulations of VOCA cloud assessment

c) Development/testing of PDF cloud schemes in NCAR, NCEP

d) Development/testing of EDMF approach in NCAR, NCEP

e) Detailed coupled/uncoupled diagnostics (e.g. ENSO)