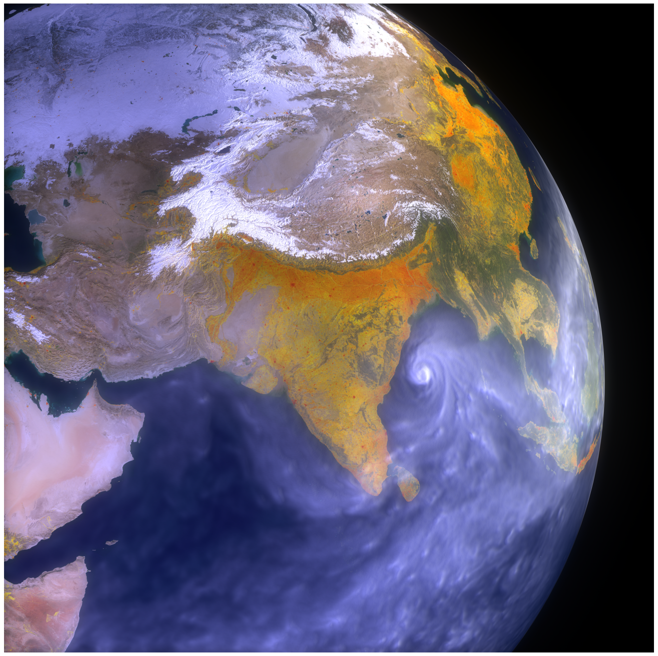
Configuration and assessment of a high-resolution spectral and spectral element CAM4 (AKA " As the world tunes")



Presented by Kate Evans, ORNL

Major Collaborators: Mark Taylor, Pat Worley, John Truesdale, Julie Caron, Mariana Vertenstein

A truly joint effort with help from many others!

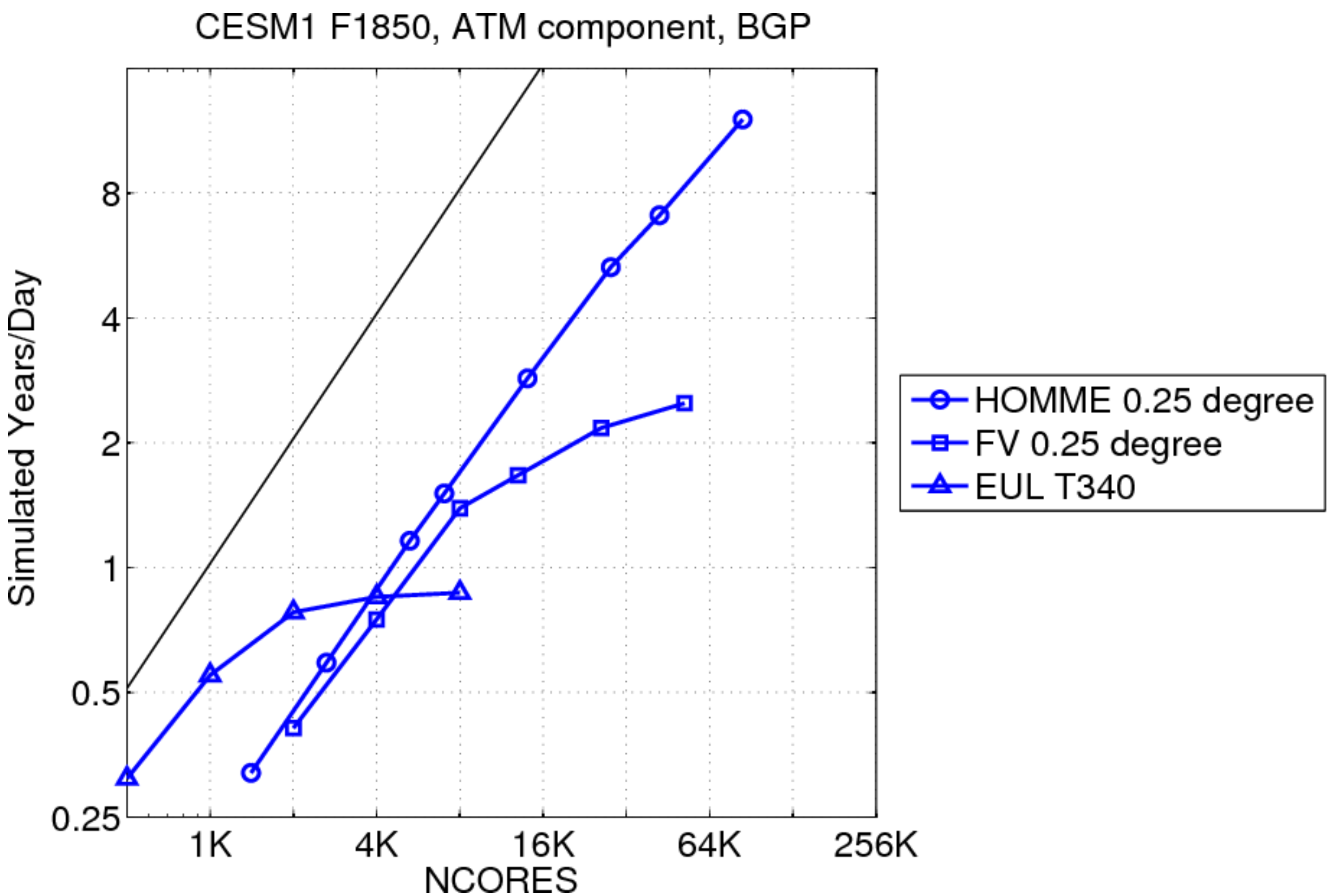
Webpages with data presented today:
http://users.nccs.gov/~4ue and
http://users.nccs.gov/~taylorm

Thanks for support from DOE BER through:
"Ultra High Resolution Global Climate Simulation to Explore and Quantify Predictive Skill for Climate Means, Variability and Extremes," PI Jim Hack
and
"A Scalable and Extensible Earth System Model," PI Dave Bader

Alternative dycore options, CAM-EUL and CAM-SE, are configured to perform high-resolution simulation with the following attributes:

- **Reasonable throughput**
- **Couples well with rest of CESM, e.g. use FV land model, so no new spin up required with dycore switch**
- **New Datasets - many new, improved datasets have been developed**
- **KEY: Good representation of present day global and sub-global climate features**

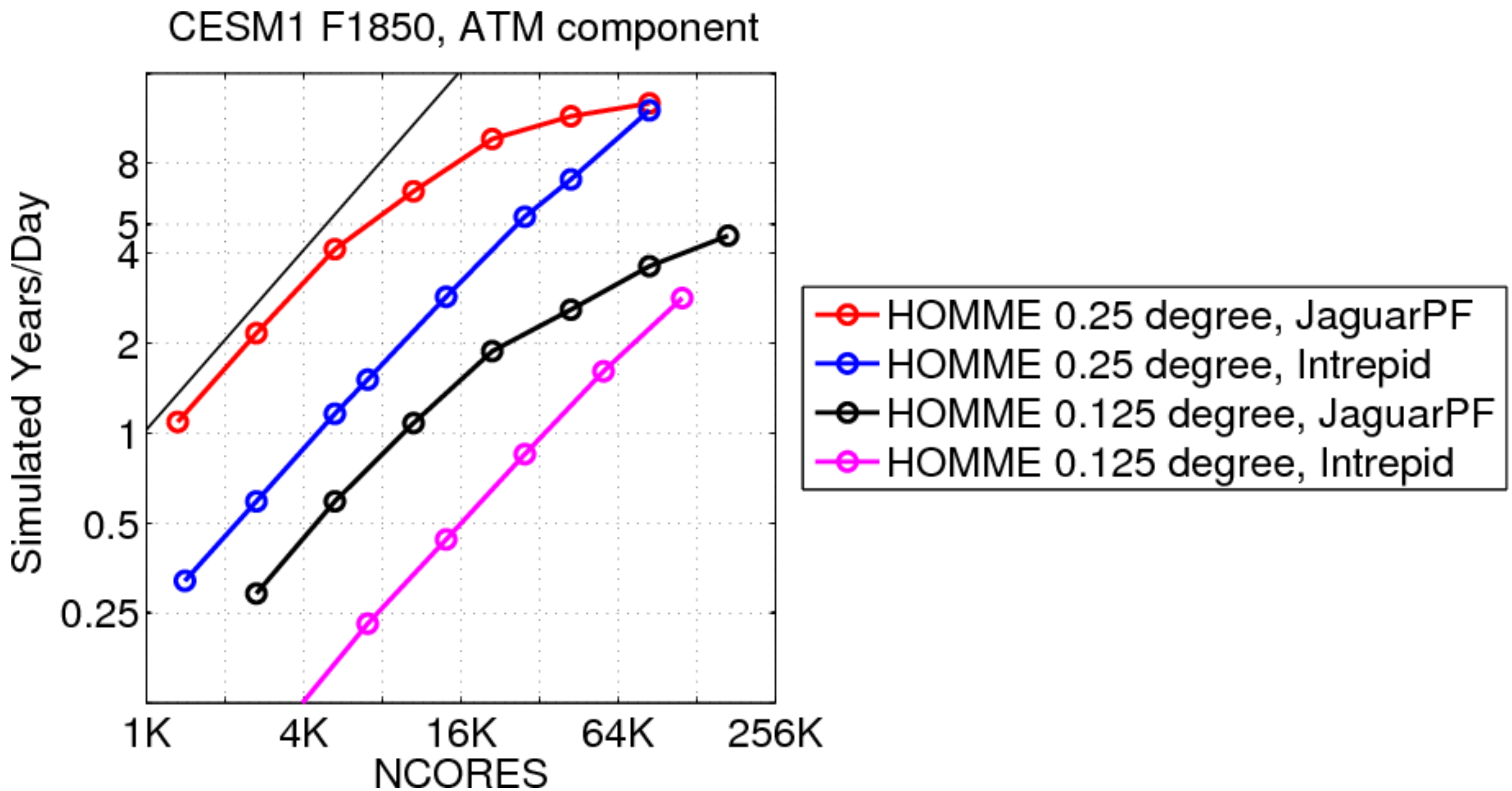
1. Better throughput at scale



Spectral Eulerian is fastest at low processor count*, HOMME provides scaling for faster throughput

*subcycling enbled

Spectral element scaling 1/4° and 1/8°

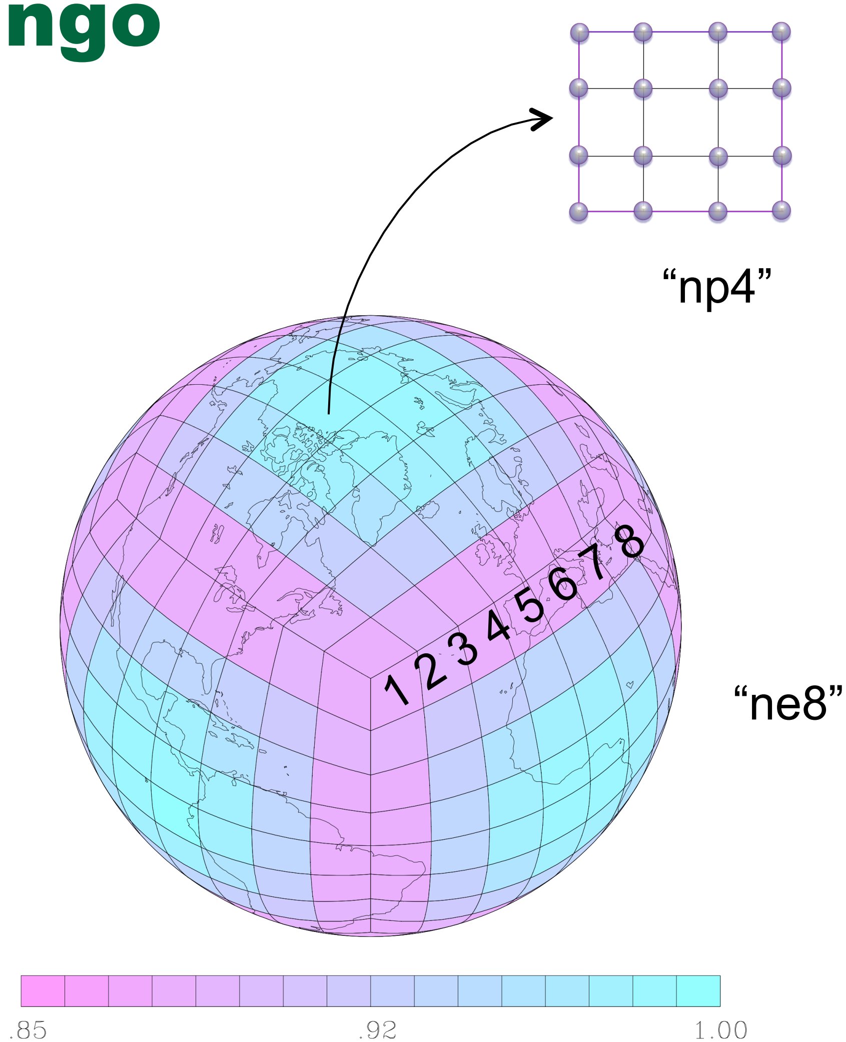


1/8 degree throughput with HOMME CAM4 is now tractable for uncoupled climate runs, but very expensive.

OpenMP enabled, Dennis et al. (2011) IJHPCA

CAM-SE resolution lingo

- **All configured runs in CESM1 use "np4," which refers to the spectral order of discretization within an element**
- **"ne#", where # refers to elements along a cube face**
  - **Ne30 ~ 1 degree**
  - **Ne120 ~ ¼ degree**
- **HOMME-y: someone who performs HOMME runs**



ne8 + np4 is ~4 degree resolution

OAK RIDGE National Laboratory

ne30 and T85 are now tuned for climate experiments:

- **With tri-grid, land model is identical to FV, but there is interpolation**
- **FV1, T85 and ne30 are much closer to each other than observations (i.e. attributes and biases and are similar)**

Next talk: Saroj Mishra presents 1 degree HOMME

Global Annually Averaged Variables of Interest

Variable	ne30	T85	FV1 control	OBS
FSNT(TOA)	243.3	240.3	242.6	240.4*
Surface T	287.6	287.3	287.3	287.7**
U 200mb	15.7	15.9	15.9	15.3**
CLDTOT	48.9	48.5	46.2	66.8@
LWCF	25.1	27.6	26.0	29.9*
SWCF	-48.3	-50.6	-47.1	-47.1*

* CERES2, **NCEP, @ISCCP

High resolution: CAM-EUL (T341)

- CAM4 physics package used
- Subcycling allows choice of physics time step independent of dynamics
- Too few clouds overall affects meridional radiation budget
- Dynamics variables, e.g. surface p, T, zonally avg U, etc. are as similar to obs as 1° dycores
- Improvements at T341 resolution currently limited to short term features

T341 has been tuned for global energy balance.

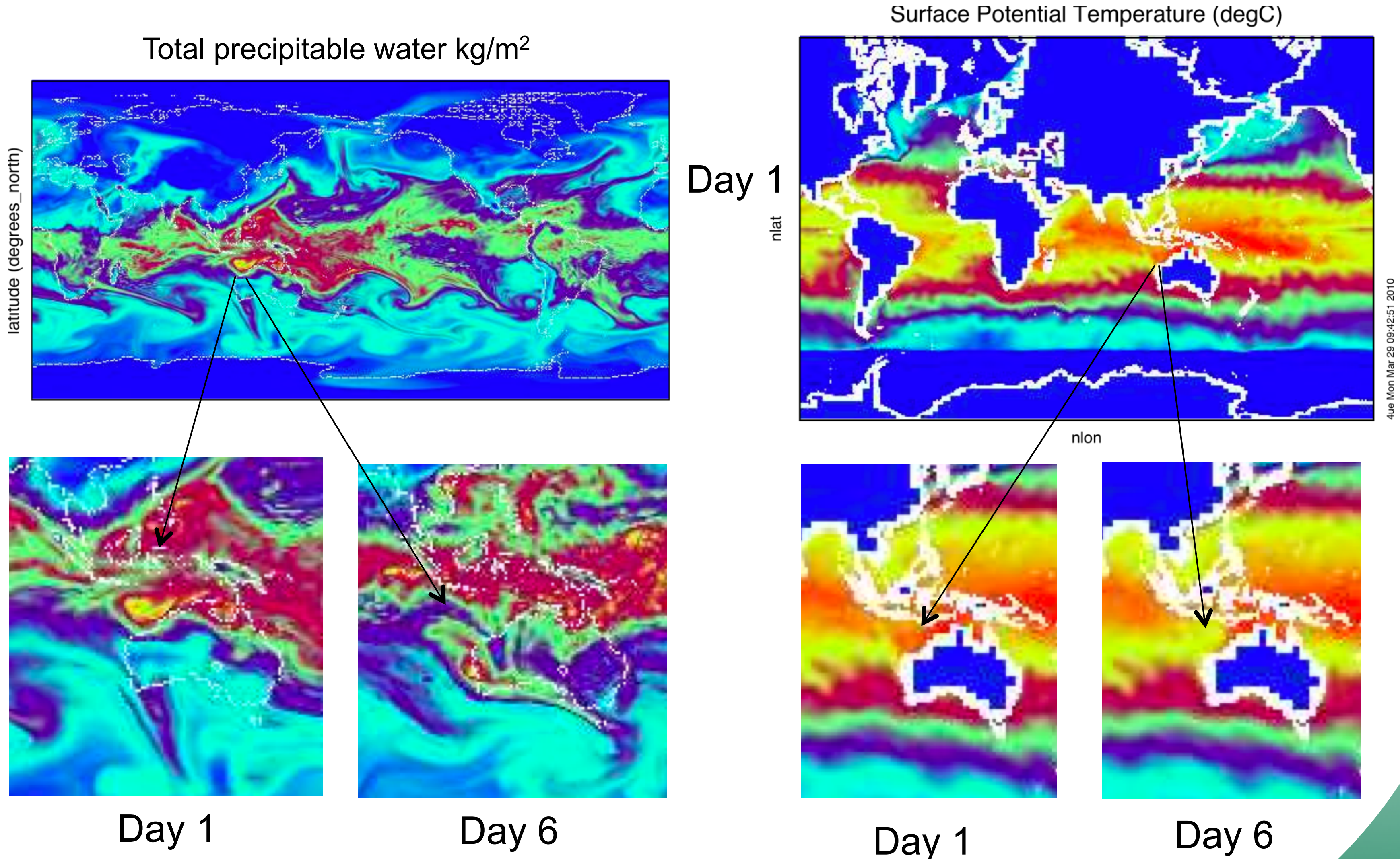
- **Results are sensitive to RH parameters and physics time step size.**
- **Overall, simulations produce a climate that is too dry**

Global Annually Averaged Variables of Interest

Variable	T341	T85	OBS
FSNT(TOA)	248.1	240.3	240.4*
Surface T	287.6	287.3	287.7**
U 200mb	14.3	15.9	15.3**
CLDTOT	40.2	48.5	66.8@
LWCF	20.4	27.6	29.9*
SWCF	-43.2	-50.6	-47.1*

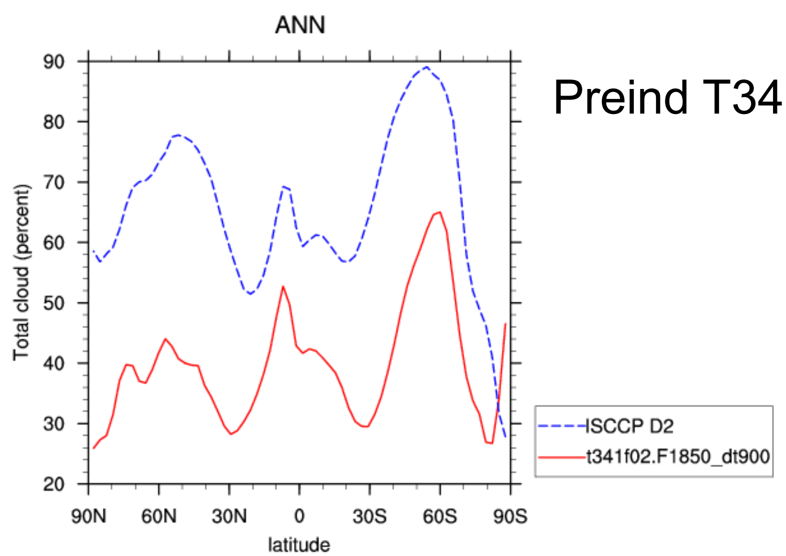
* CERES2, **NCEP, @ISCCP

First days of hi-res coupled model run T341 atm x FV .25° lnd x 0.1° ocn

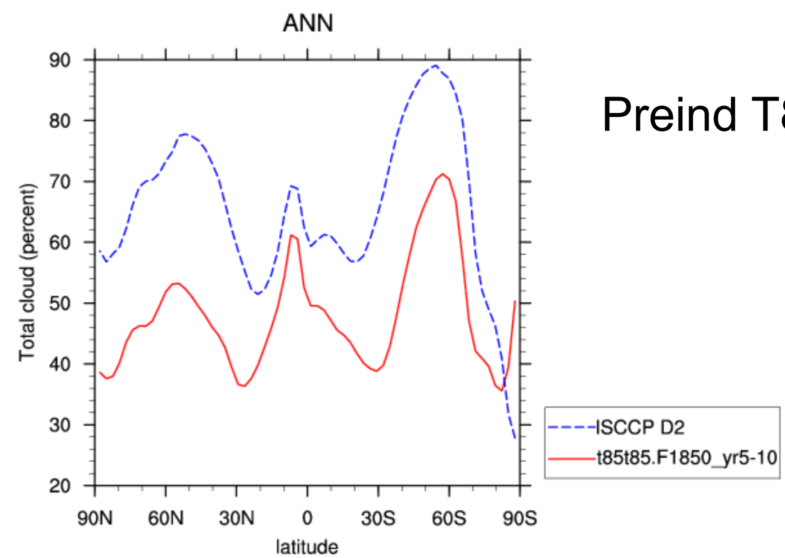


High resolution: CAM-EUL (T341)

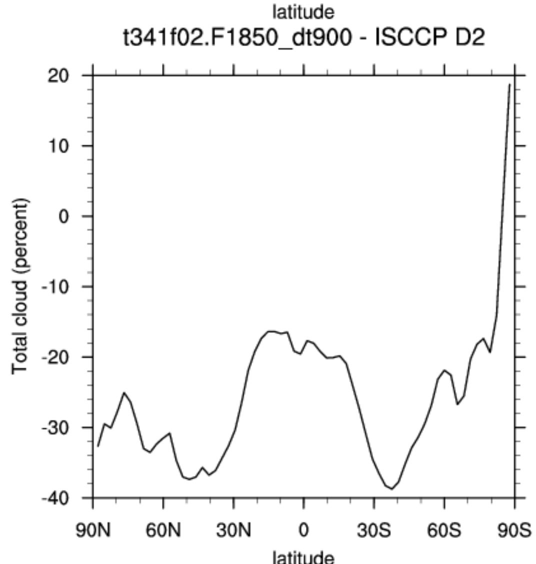
CLOUDTOT, sufficient levels are a challenge. (vs. ISCCP)

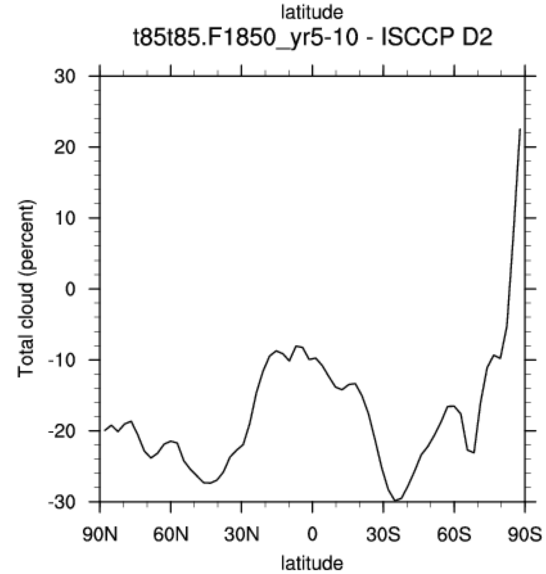


Preind T341

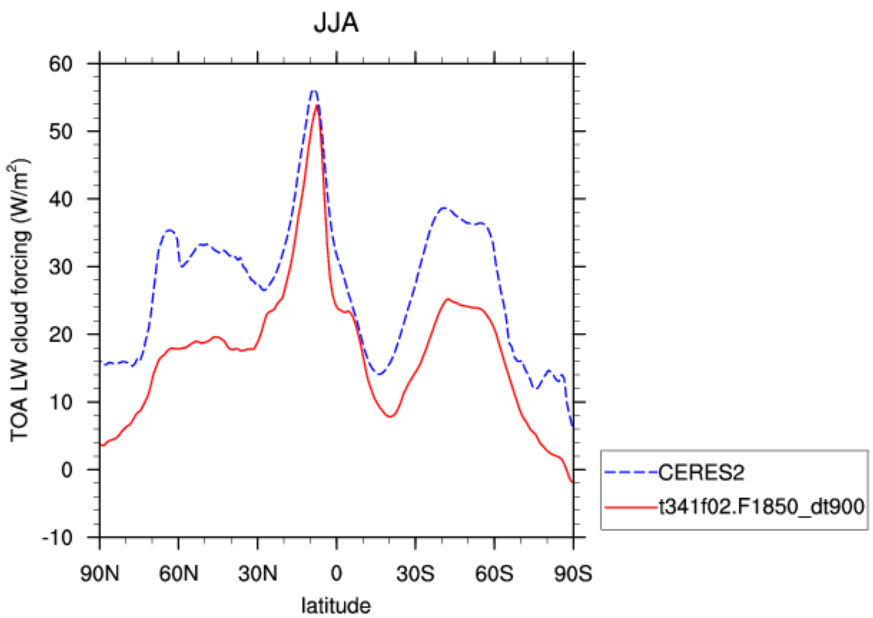


Preind T85





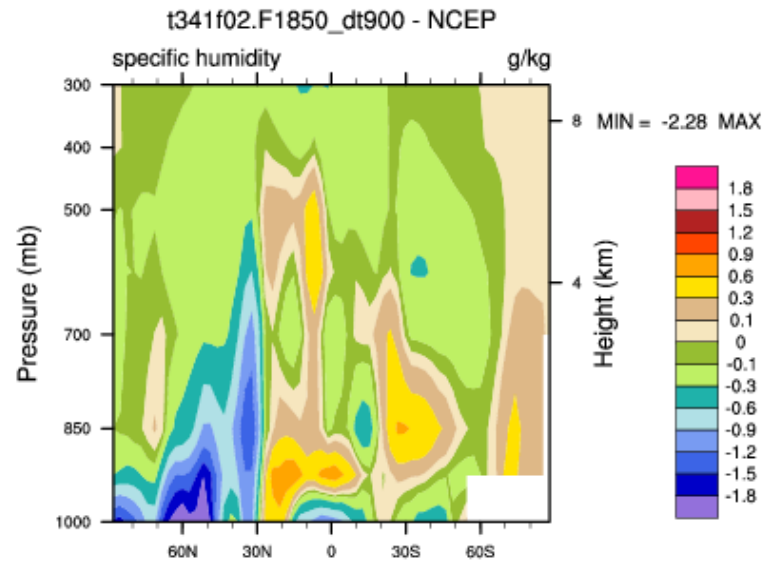
Details regarding model moisture. Does it affect dynamics? Or vice versa?

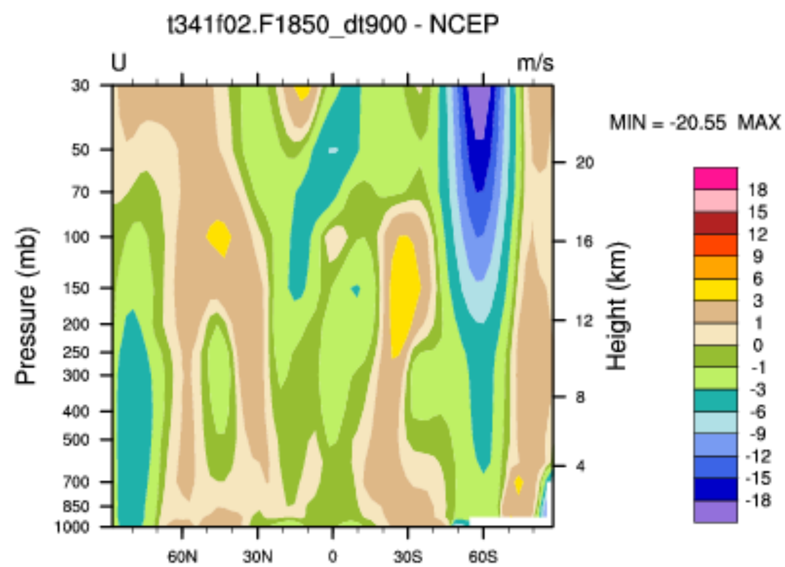


SH Winter (JJA) LW cloud forcing

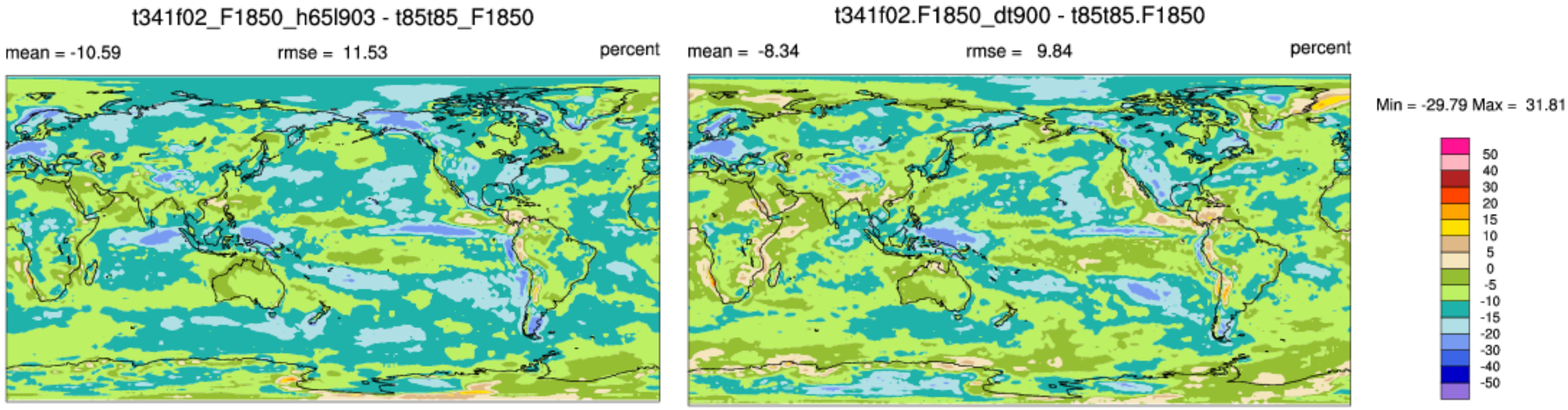
SH Winter Stratosphere Jet deficiencies (right) →

SH Winter Specific Humidity (top right)





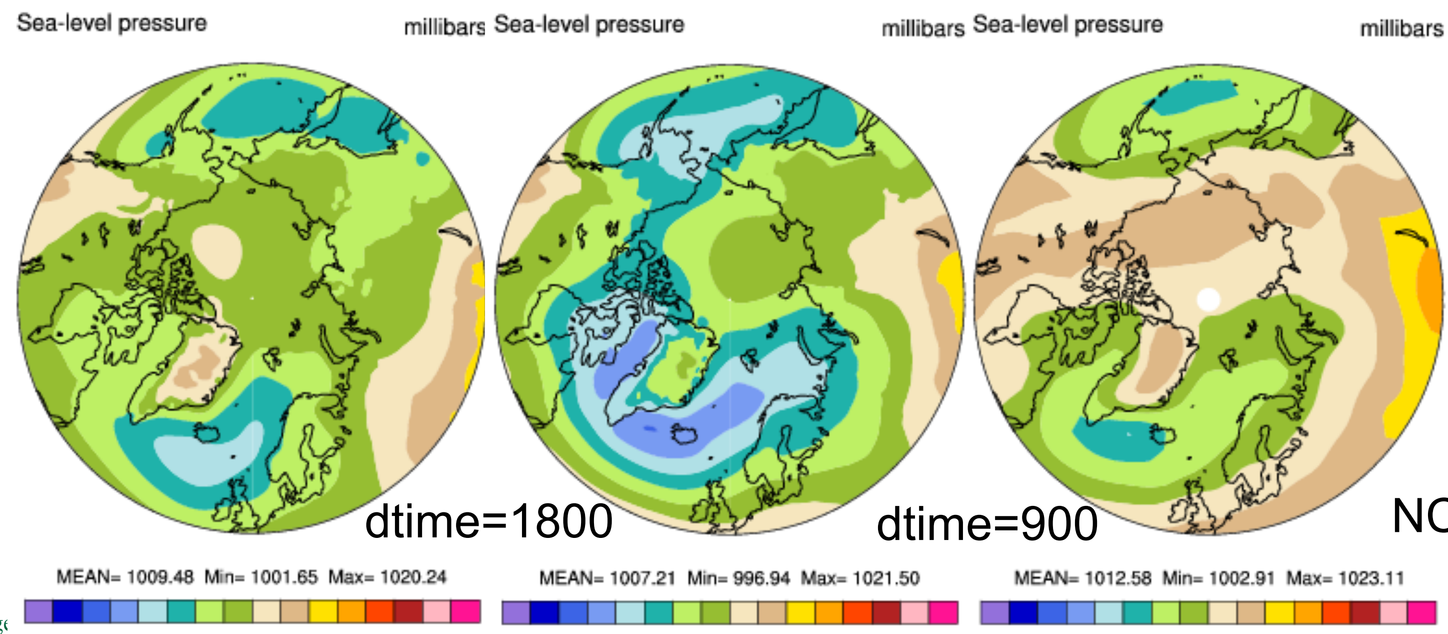
*T341 model balance is sensitive to the physics time step size



dtime=1800

dtime=900

Total Cloud



dtime=1800

dtime=900

NCEP

Sea Level Pressure

OAK RIDGE National Laboratory

HOMME ¼° (ne120) has been tuned for global energy balance.

- **Start with ne30 setup, then lower RH mins until RESTOM/SURF ~0**
- **Alternatively, try out Julio's suggestion of using a high RH threshold for high and low clouds. Also, reduced physics time step size.**

Global Annually Averaged Variables of Interest
ne120 1: rhmin_h=.60, rhmin_l=.85, dtime=900
ne120 2: rhmin_h=.95, rhmin_l=.89, dtime=450

Variable	ne120 1	ne120 2	Ne30 1°	OBS
FSNT(TOA)	252.5	250.8	243.3	240.4*
Surface T	287.7	287.3	287.6	287.7**
U 200mb	14.7	13.4	15.7	15.3**
CLDTOT	34.2	46.6	49.0	66.7@
LWCF	18.6	17.4	25.1	29.9*
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•CERES2, **NCEP, @ISCCP

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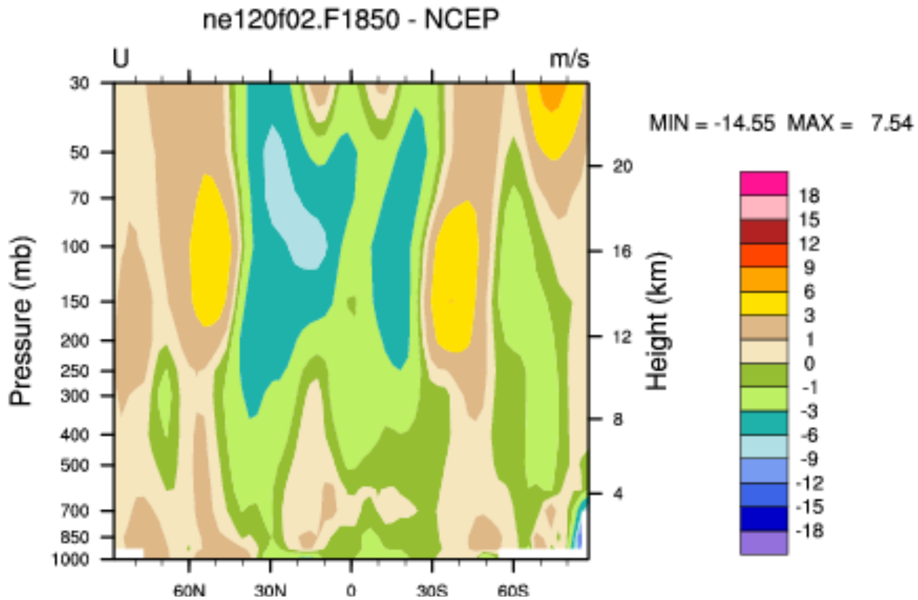
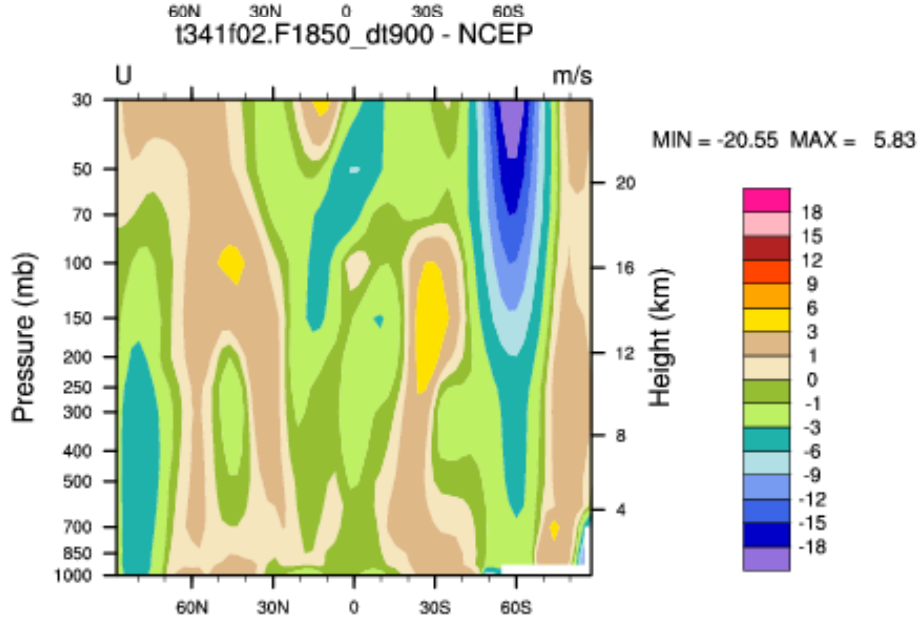
T341 vs ne120 SH winter jets



ne120



T341

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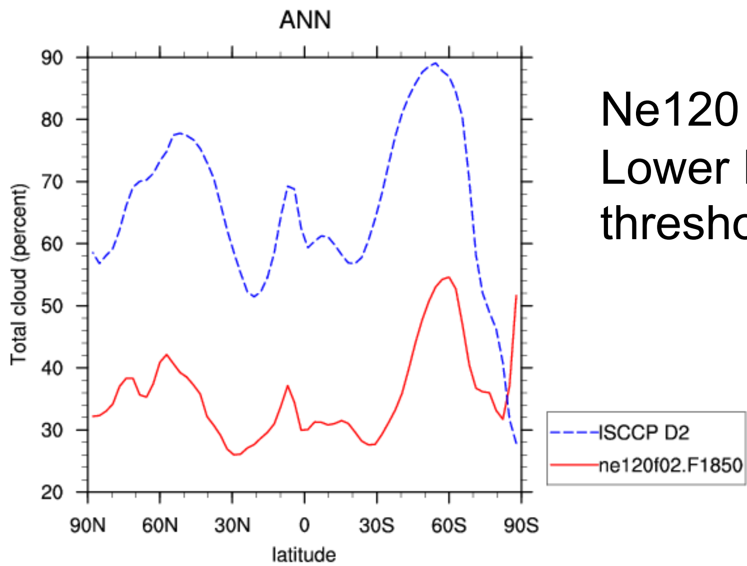
LWCF	18.6	17.4	25.1	29.9*
SWCF	-39.1	-40.3	-48.3	-47.1*

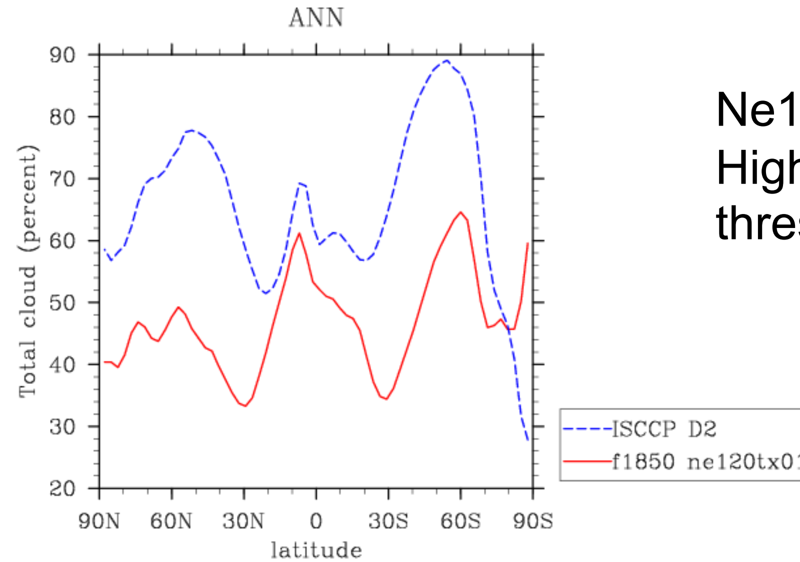
•CERES2, **NCEP, @ISCCP

High resolution: CAM-SE (ne120) 1850

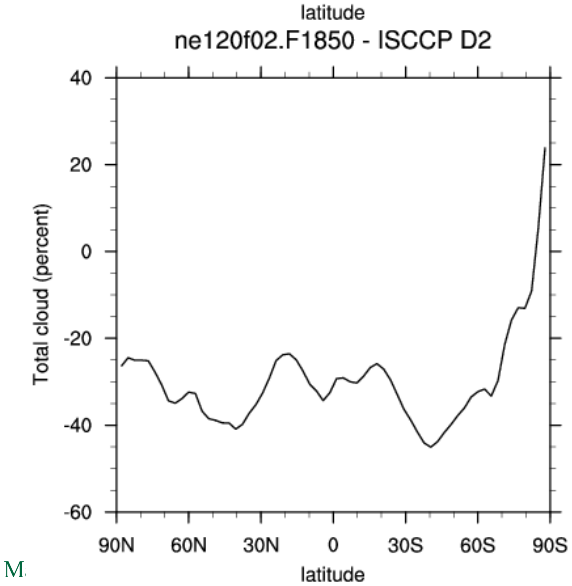
CLOUDTOT (vs. ISCCP)

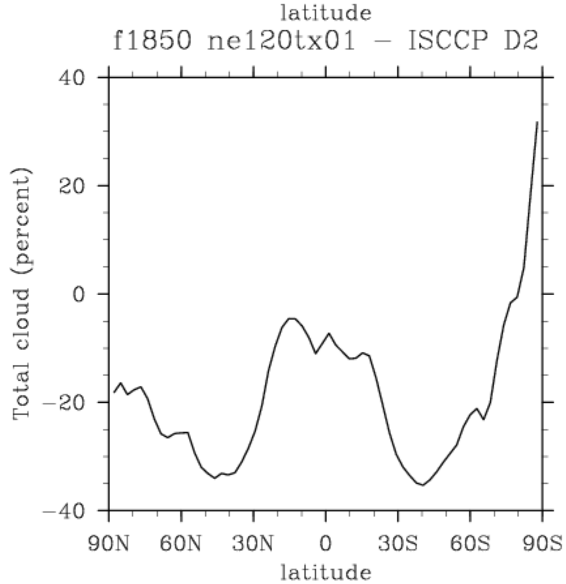


Ne120 1:
Lower RH
thresholds



Ne120 2:
Higher RH
thresholds





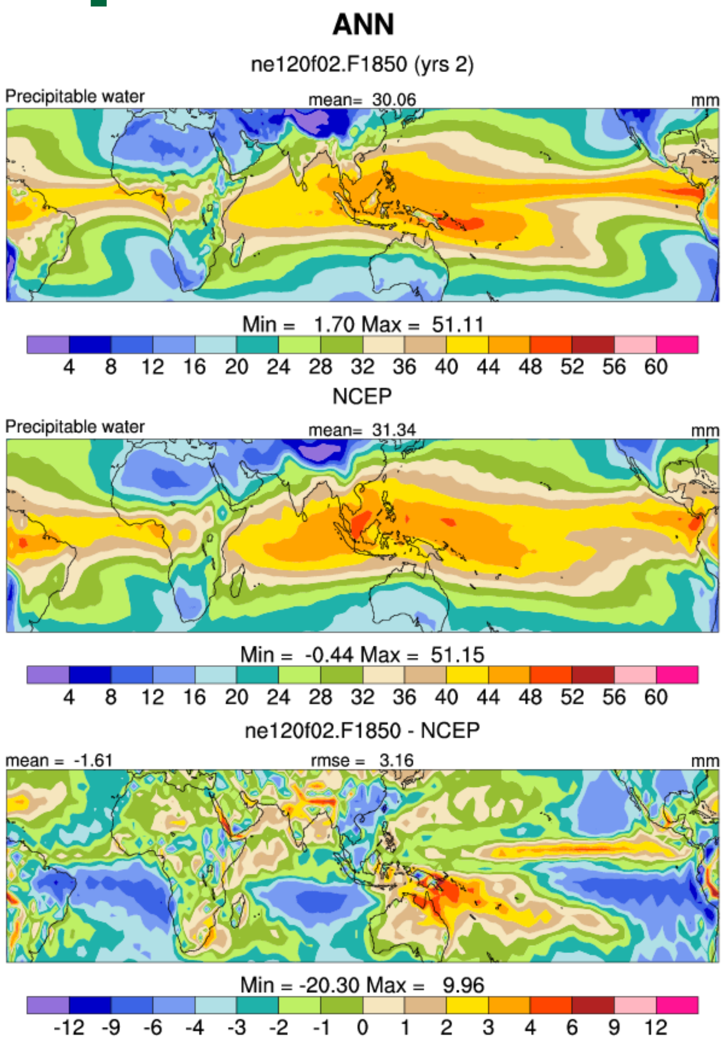
Why are clouds increased with higher RH thresholds?

- **Physical reasons include**
  - Smaller grid spacing means that different threshold applies, > 100% needed in real world
  - Localized higher vertical velocities (closer to obs but still low)
  - Localized dynamics means smaller area of precip, so more moisture/clouds are retained

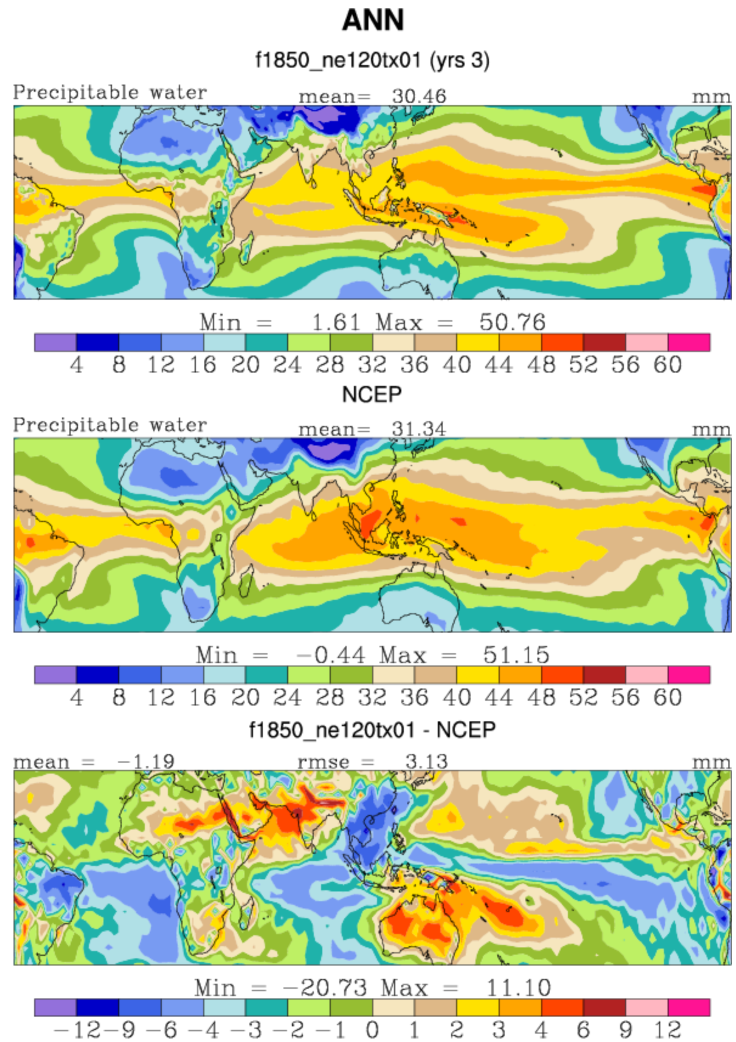
Variable	ne120 1	ne120 2	ne30	OBS
CLDTOT	34.2	46.6	49.0	66.7@
CLDHGH	16.8	27.3	23.8	21.3@
CLDMED	10.5	10.2	15.4	19.1@
CLDLOW	24.6	28.2	35.4	26.4@

But high clouds are what goes up …

There are local variations with altered RH parameters

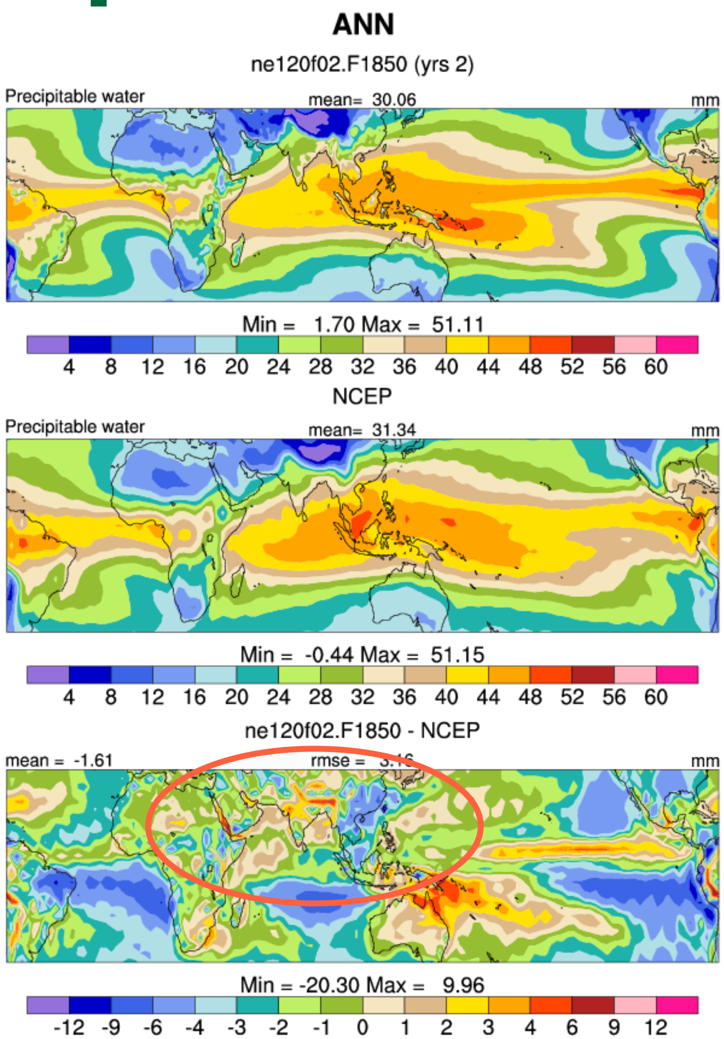


Ne120 1

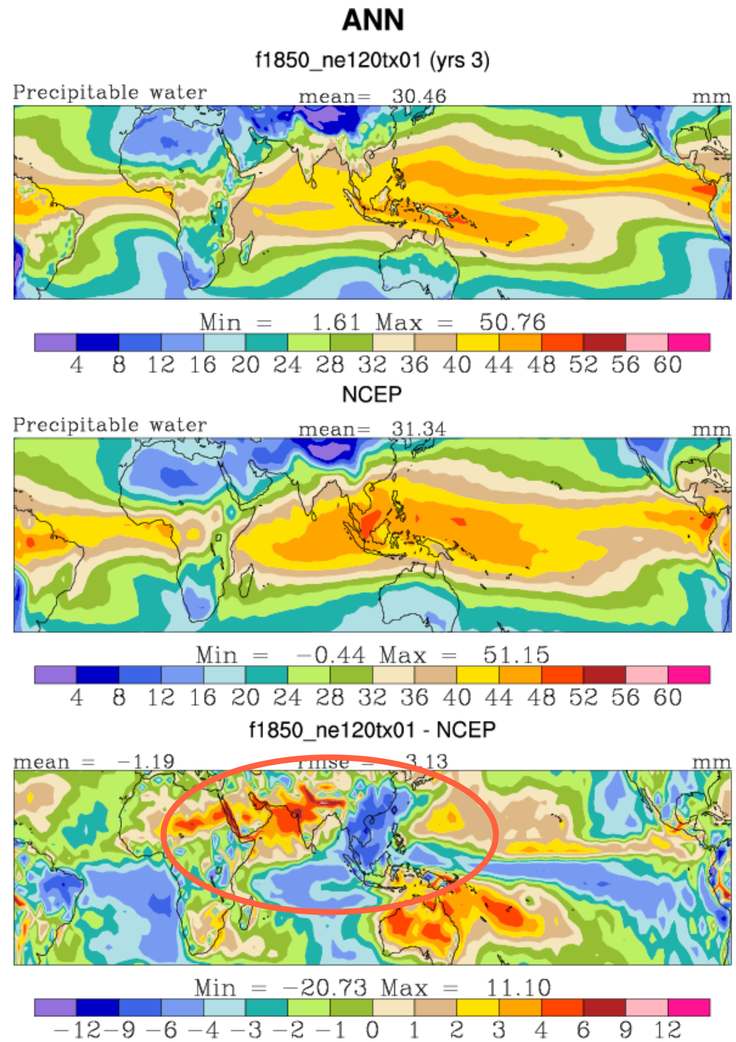


Ne 120 2

There are local variations with altered RH parameters



Ne120 1



Ne 120 2

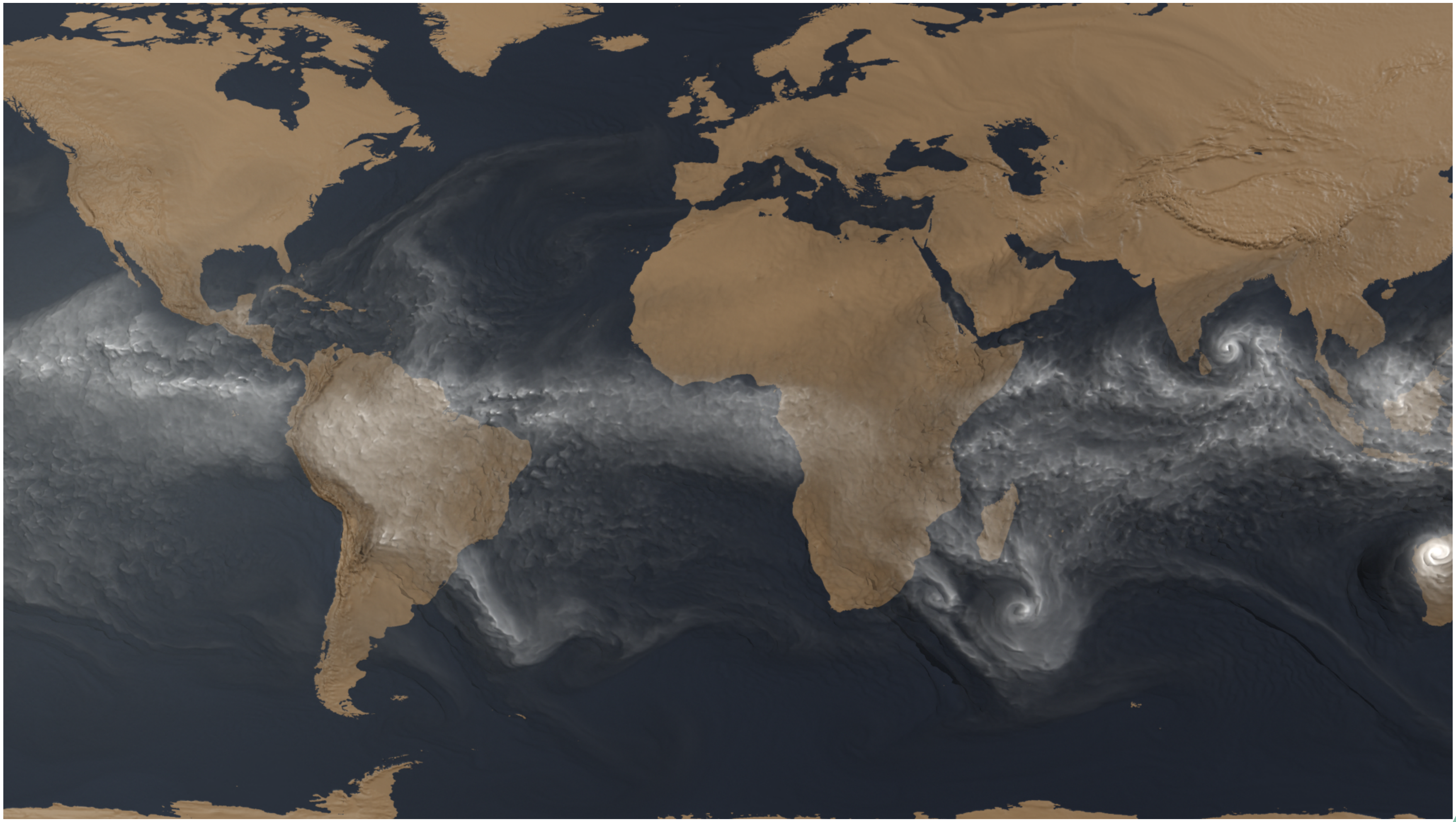
How do we translate this into better long term climate simulations at high resolution?

- **Assess quality of smaller term climate features in high-resolution models (frequency and magnitude)**
- **Look at local fluxes (NCAR efforts)**
- **Sources of moisture from land model are mostly ½^o resolution**

Discussion points:

- Connect more with high resolution observed datasets to compare high resolution model results.
- Playing with RH thresholds and physics time steps cannot be the long term solution.
  - Resolution (space and time) independent physics, or at least resolution specific physics
  - What about increasing both physics and dynamics time step size to 30 minutes for all resolutions?

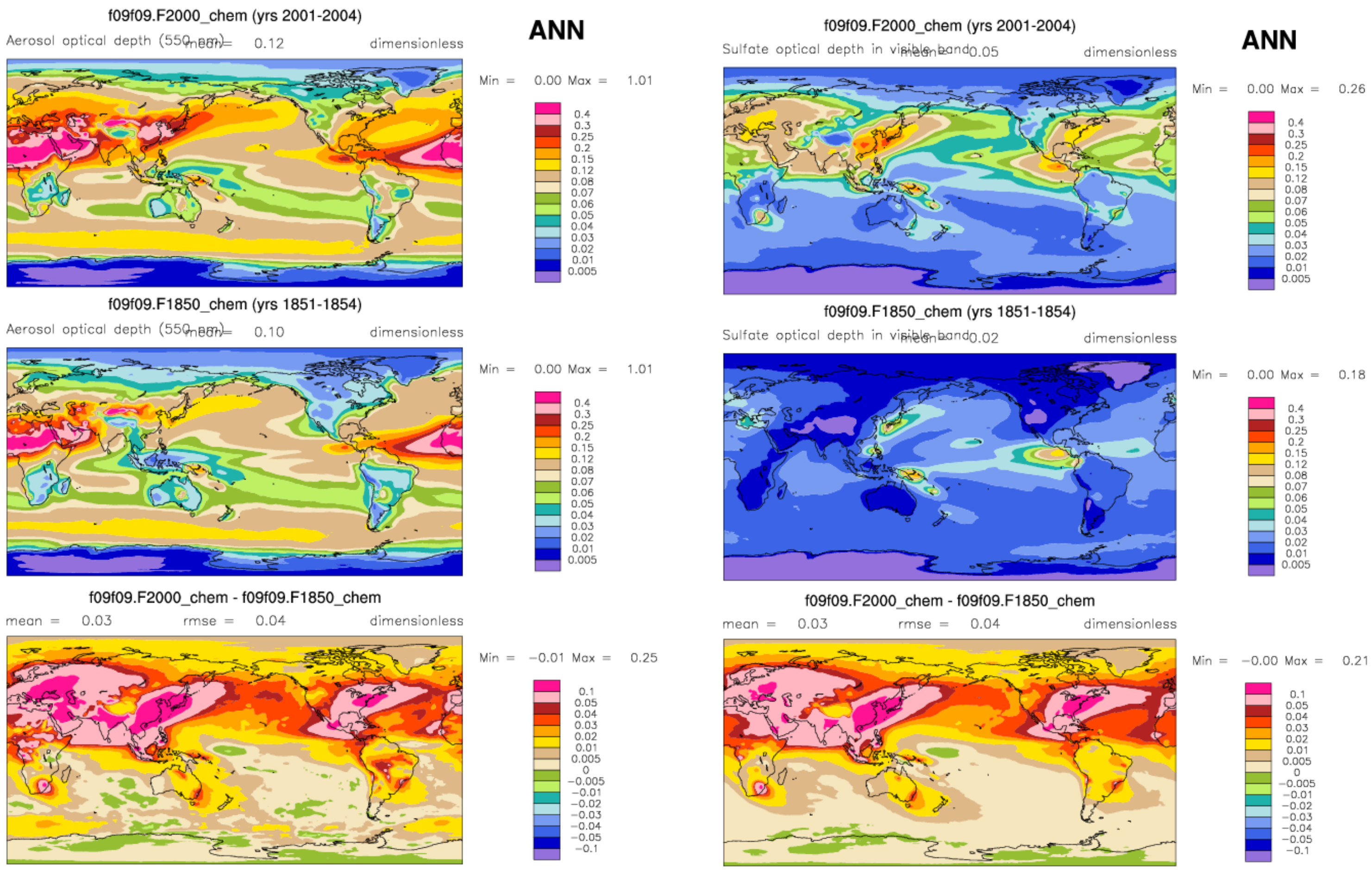
Questions?



$1/8^o$ CAM-SE simulation run on Intrepid (Mark Taylor)

Visualization by Jamison Daniel, ORNL

New monthly varying BAM aerosol dataset: additional emissions, resolution, and temporal variability

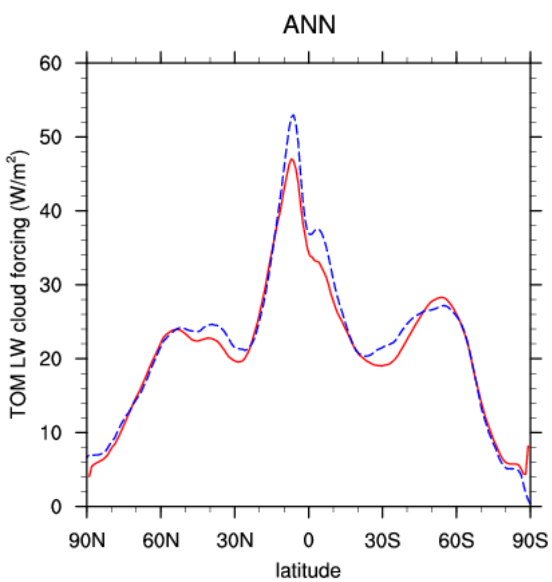


Project with S. Mahajan, J-F. Lamarque, J. Truesdale

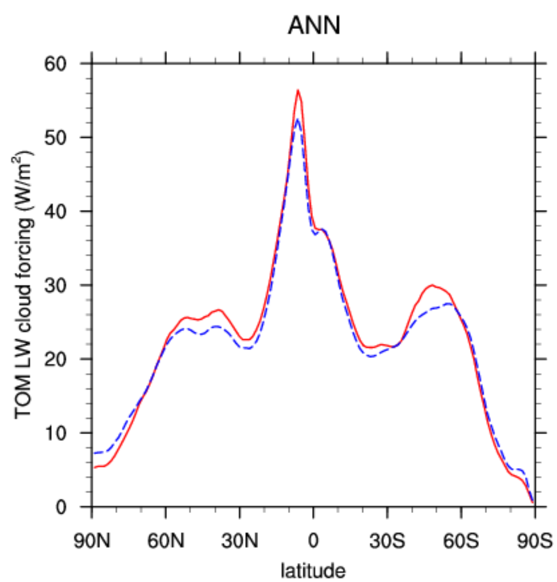
ne30 and T85 are tuned for climate experiments:

- **Ne30 climate will be presented in detail in the next talk**
- **Both ne30 and T85 dycores produce a climate similar to FV**

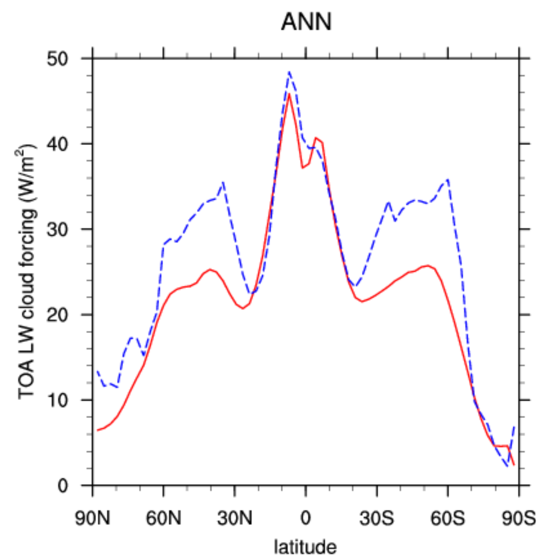
Total Cloud Forcing



ne30 vs. FV1



T85 vs. FV1



FV control vs. obs (ERBE)

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•CERES2, **NCEP, @ISCCP

*What is going on radiatively? Is ne120 2 better?

- **The net SW and LW radiation at the model top are reduced because there is more cloud cover.**
- **FSNT bias is more localized to strong precip regions**
- **FLUT bias (LW flux upward model top) is reduced. Mean difference 16.7 -> 9.7 from observations (chg values to match CERES)**
- **Surface net SW and LW are relatively unchanged even with additional clouds**