Nudging to reanalyses: a tool to evaluate model process realism (and study predictability issues)

Brian Mapes, Patrick Kelly
University of Miami

Observed

time rate of change of ψ

= model tendencies

at observed states

+ model errors

$\psi = \{u, v, T, q_v, \ldots\}$

Observed

time rate of change of ψ

$= \text{model\_errors}$

$+ d\psi dt\_dyn$

$+ d\psi dt\_phy$

$\psi = \{u, v, T, q_v, \ldots\}$

In nudged run (close to Observed...):

time rate of change of ψ

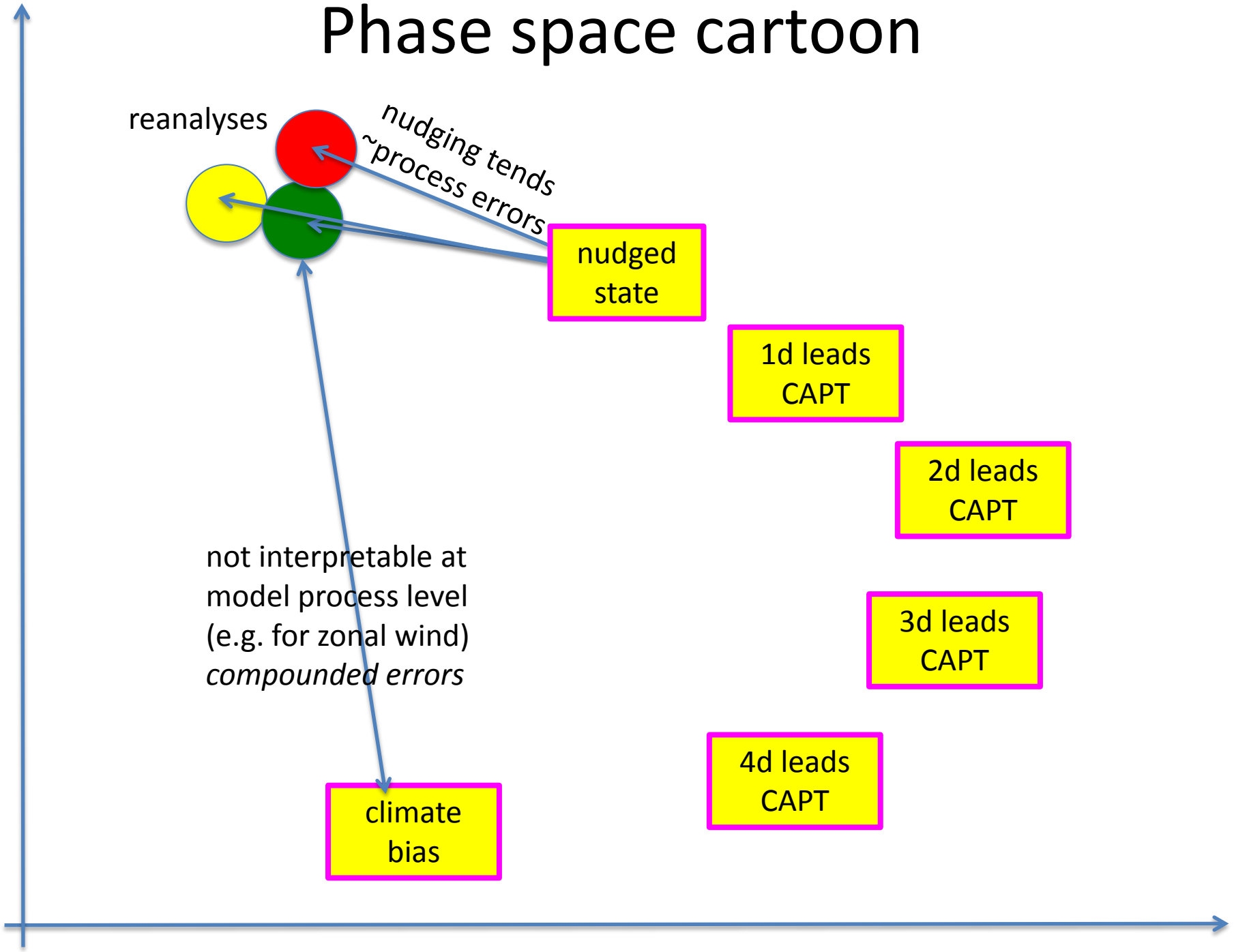
$= d\psi dt\_nudging$

$+ d\psi dt\_dyn$

$+ d\psi dt\_phy$

$\psi = \{u, v, T, q_v, \ldots\}$

Phase space cartoon



The dream: INTERPRETATION

= dTdt_nud

+ dTdt_dyn

+ (dTdt_swr + dTdt_lwr)

+ (dTdt_cnv + dTdt_lsc) +

+ dψdt_trb + …

etc… *breaking down a sensible whole*

resemblance tests, for (hoped-for) process **interpretation**. Then try to reduce **nud** by adjusting ("improving") model physics.

Home page: collection of model outputs from nudging experiments

The idea is to nudge the model to analyzed states, then diagnose the nudging tendency. Since the observed sequence of states really happened, the nudging tendency equals model tendency *error*. Since reanalyses aren't perfect (just very good), we repeat the exercise using multiple reanalyses to get an *ensemble* of estimates of model tendency (or process) errors. Interpreting these tendencies could lead to model process improvements. Statistically fitting them as a time-mean forcing + state-dependent forcing + noise source + ... could improve model performance more agnostically.

Later, nudging to observed sequences will be applied selectively - masked in space, time, variable, and scale, to inject signals - to probe the model's pathways and rates of information flow across these four subdomains of model state space. This is the essential knowledge behind predictability, the fundamental limit of possible prediction.

More nudging project plan details are in this ppt and this PDF proposal text (with bibliography), while more conceptual framework considerations (cartoons about model manifolds, shock & drift, etc.) are in this ppt.

For the moment we are using JJA 2008 (part of the well-observed YOTC period).

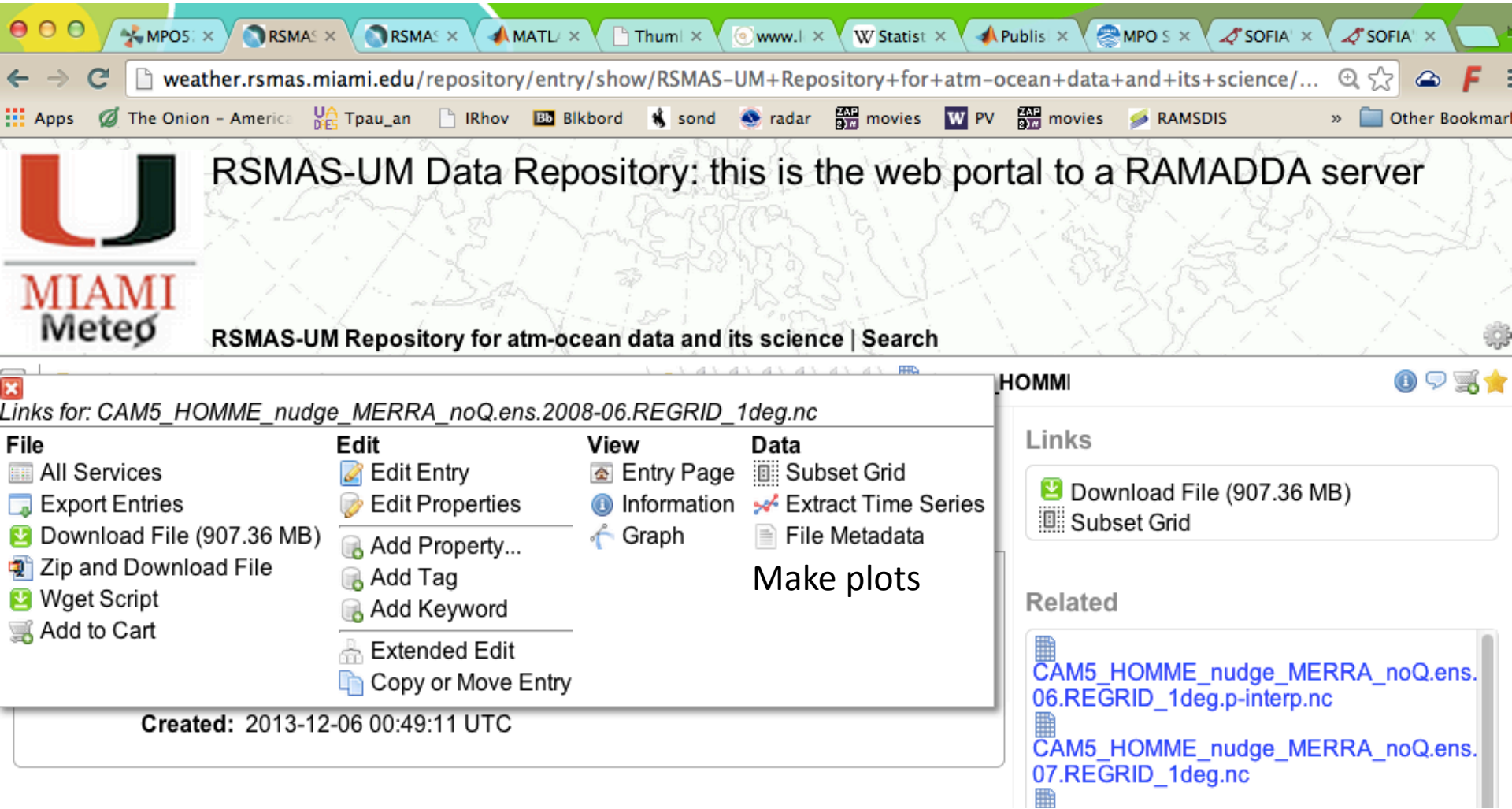
GCMs (rows) nudged to reanalyses (columns)

Reanalyses (datasets)--> GCMs	ERA-I	ERA-YOTC	JRA-25	MERRA	CFSR
CAM5-SE (Mapes convection)	outputs	outputs	outputs	outputs	easy
CAM5-SE (Control)	outputs	easy	easy	easy	easy
CAM5 (Scripps)	test upload	easy	easy	easy	easy
GFDL AM	easy	easy	easy	easy	easy
ECHAM	collab	collab	collab	collab	collab
CFSv2	India	India	India	India	India NATIVE ANALYSIS
WRF-global	Tulich	easy	easy	easy	easy
Dry PE	outputs	easy	easy	easy	easy

Please Join Intercomparison! I have data repository

OpenDAP, subset, interactively plot…

any CDM files (NetCDF, HDF, grib…)



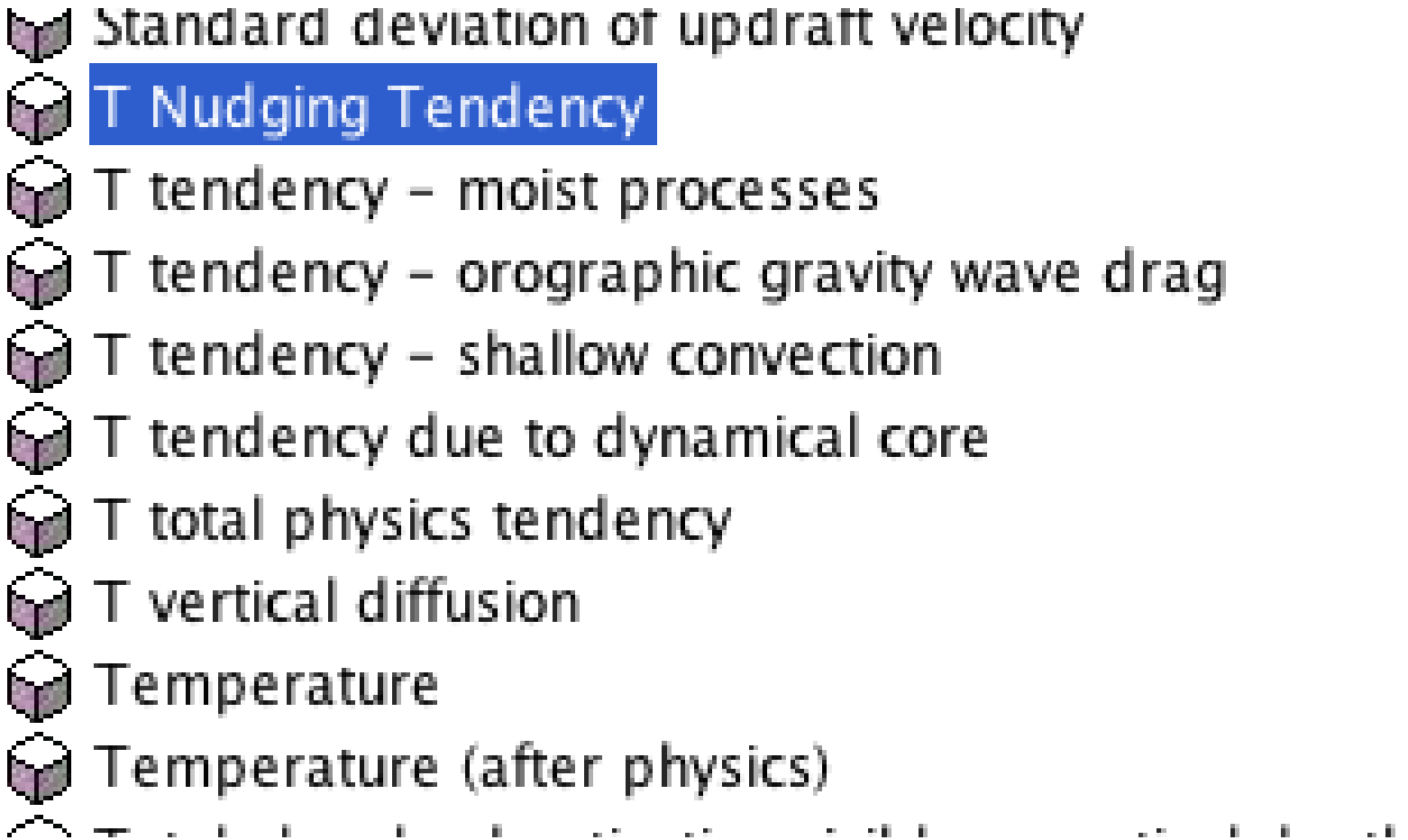
First tries: nudging CAM5-SE

- Nudged (relaxed) to Various Reanalyses
  - (MERRA, JRA, ERAI)
- U, V, and T*relaxation tendencies added
  - with time scale = 6 hrs

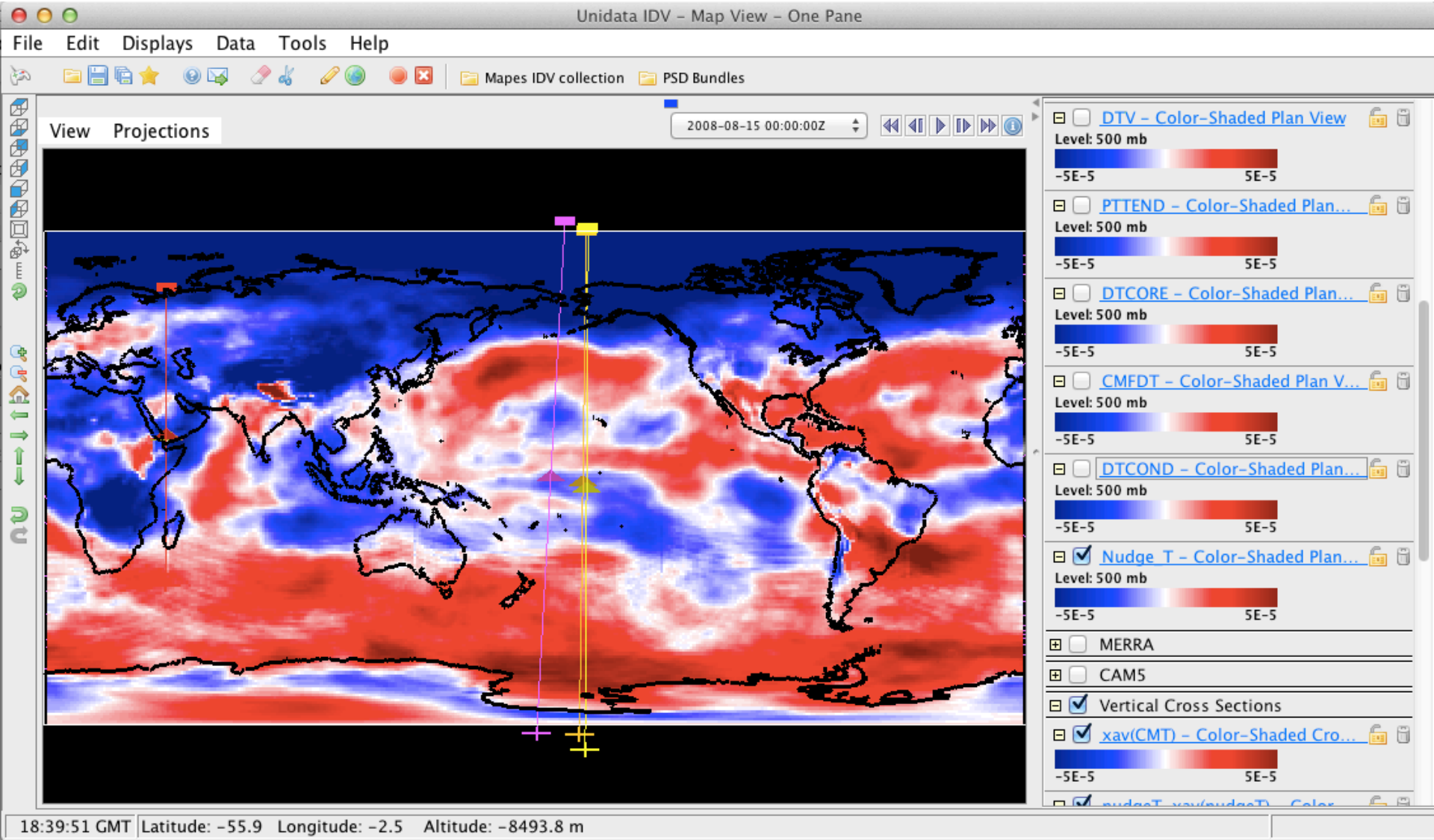
- ***BUG learned yesterday. 6000h not 6h for T!**

This is really just a measure of –Tbias

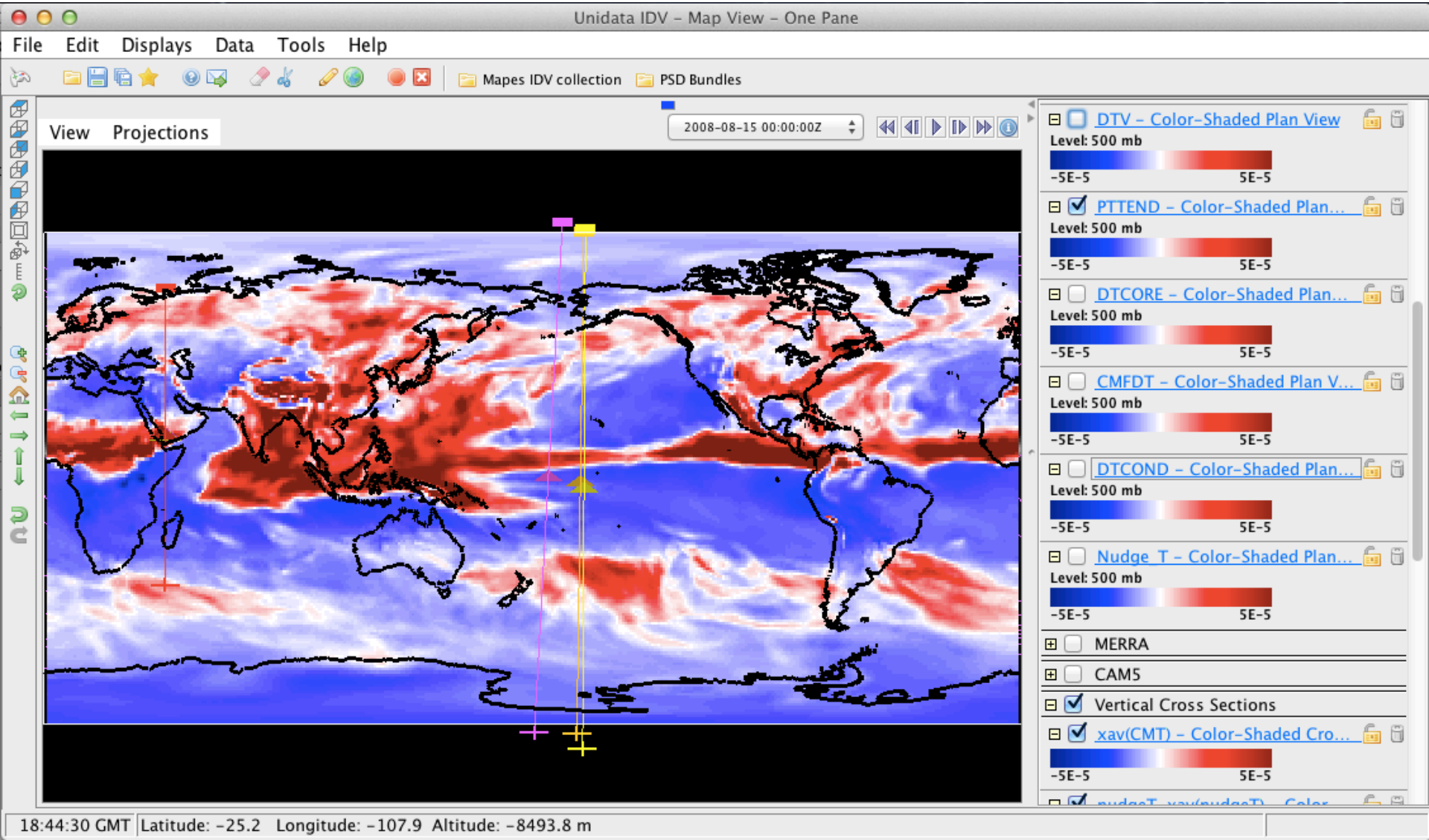
- **in presence of nudged *horiz. winds only***



NudgeT = (-Tbias)/6h due to bug
500mb (Aug 2008 monthly mean)



PTTEND ("total physics") at 500mb



T Nudging Tendency

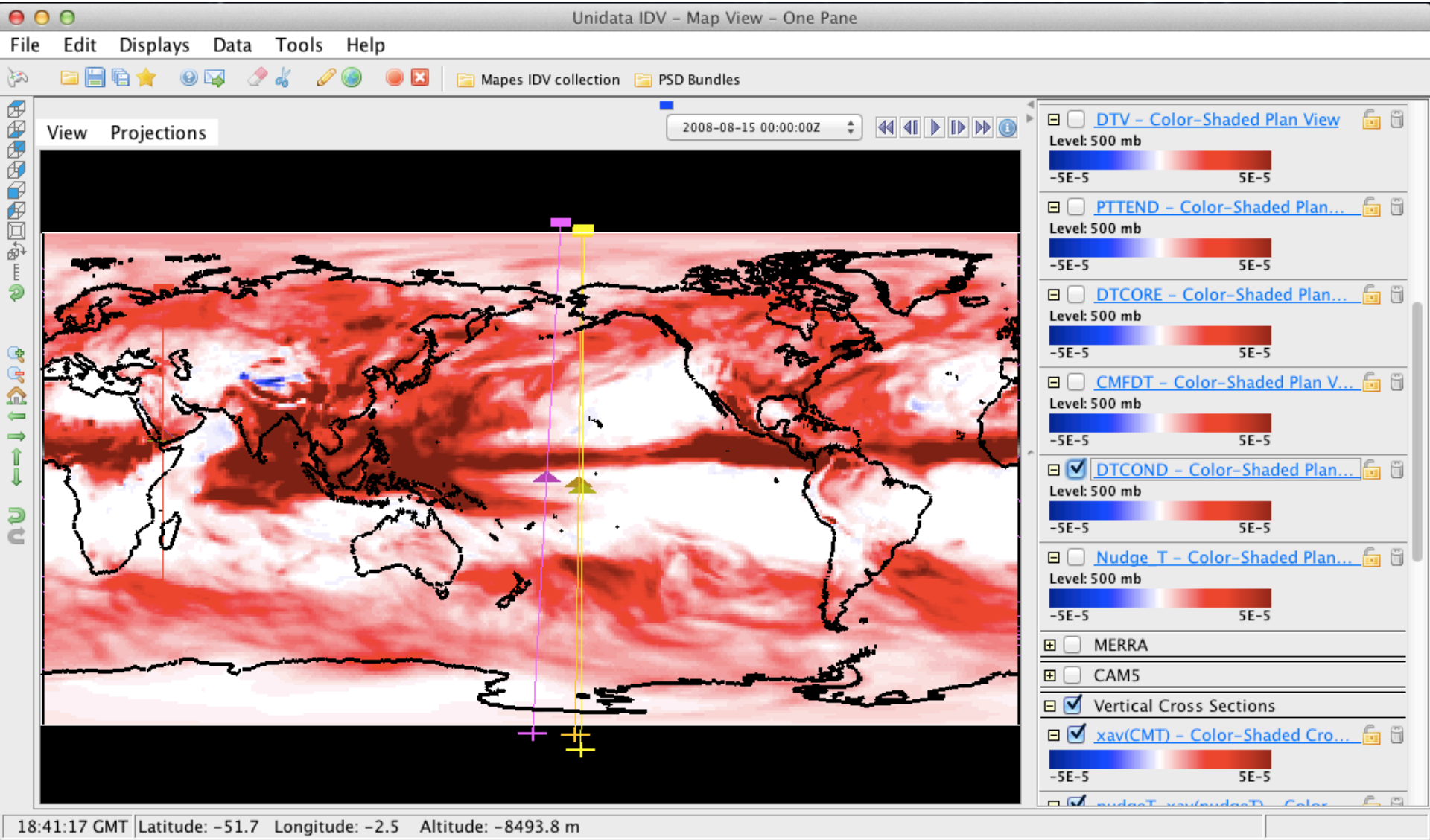
T tendency – moist processes

T tendency – orographic gravity wave drag

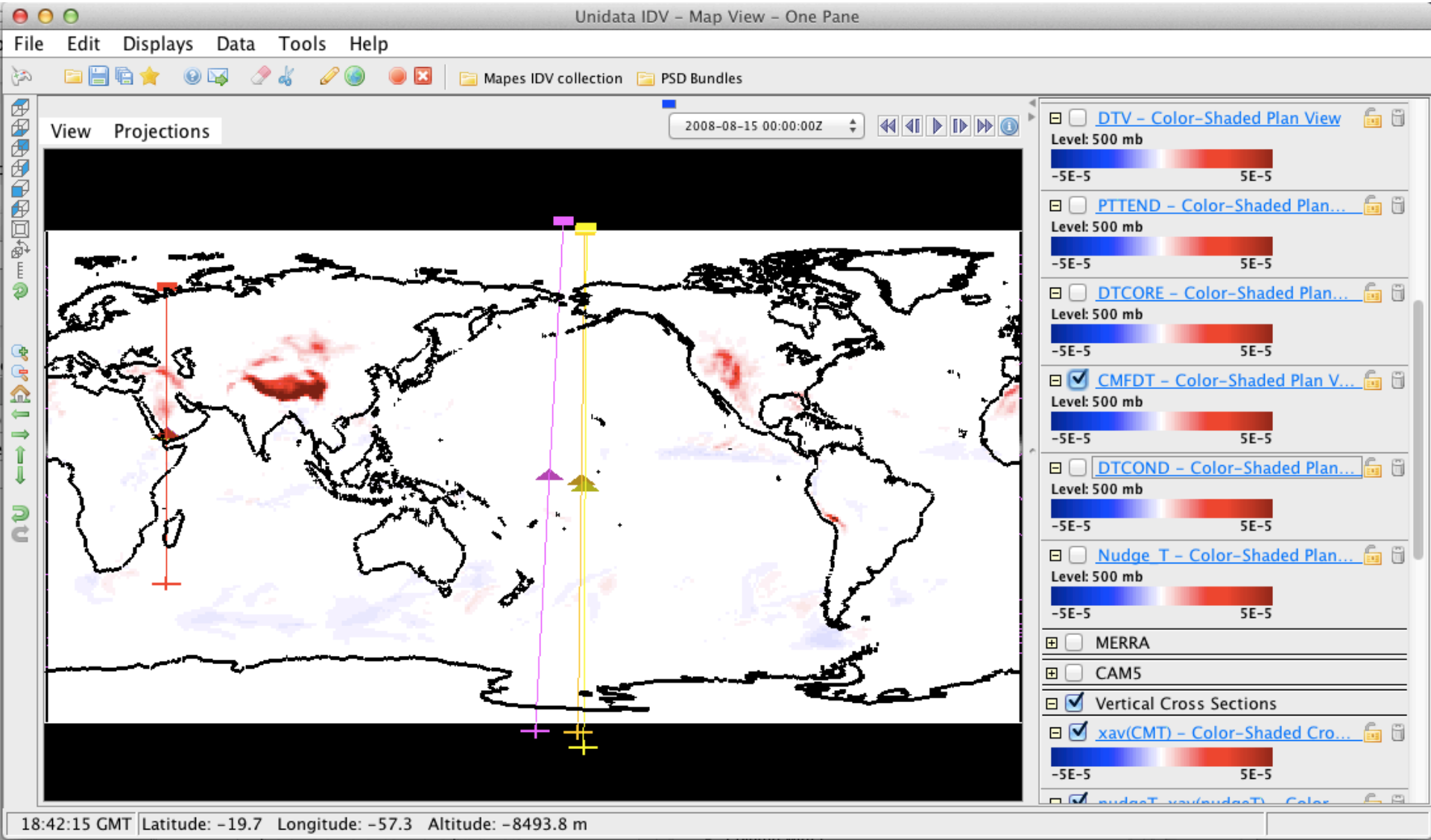
DTCOND
T tendency – moist processes

T total physics tendency

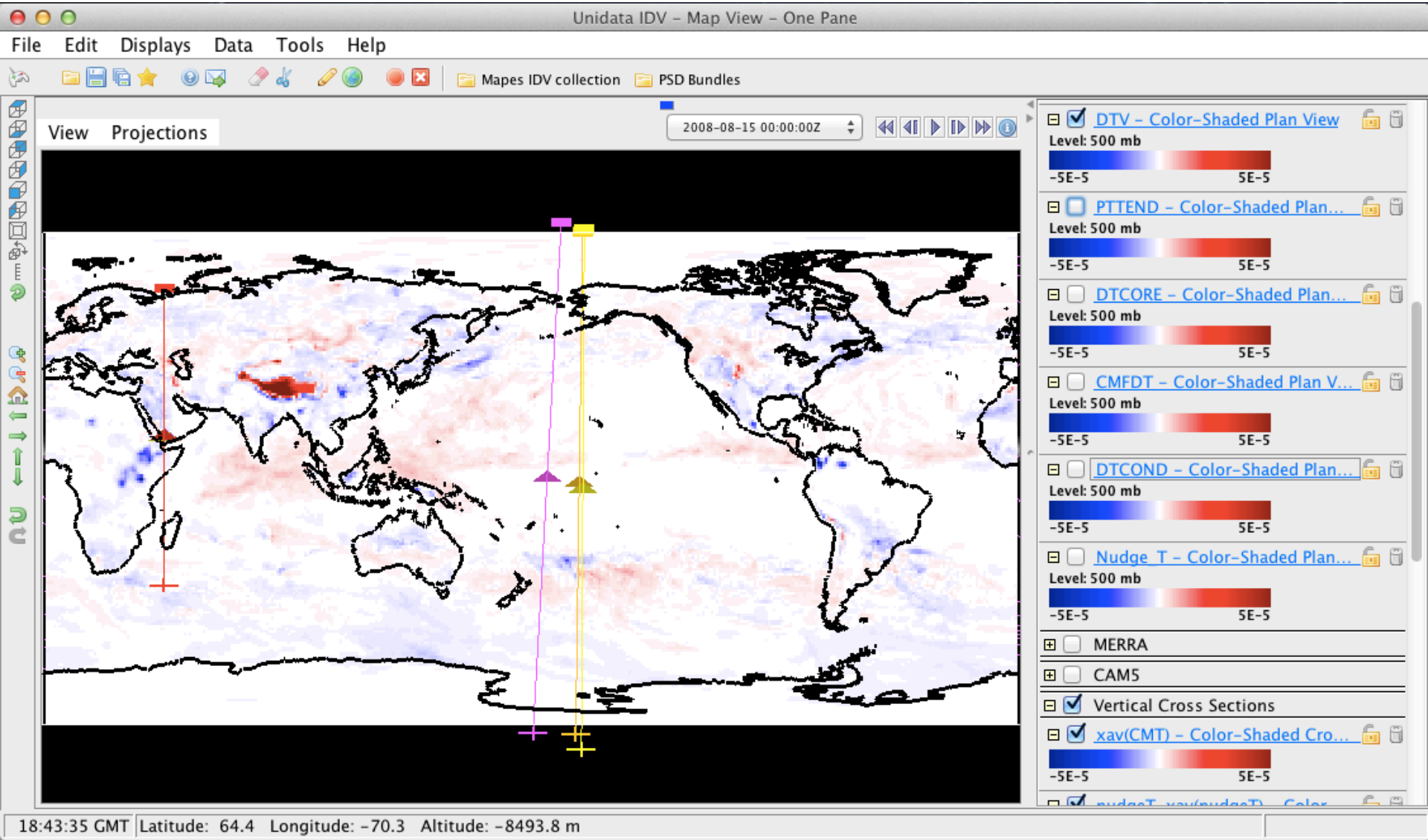
at 500mb



CMFDT ("shallow conv") at 500mb

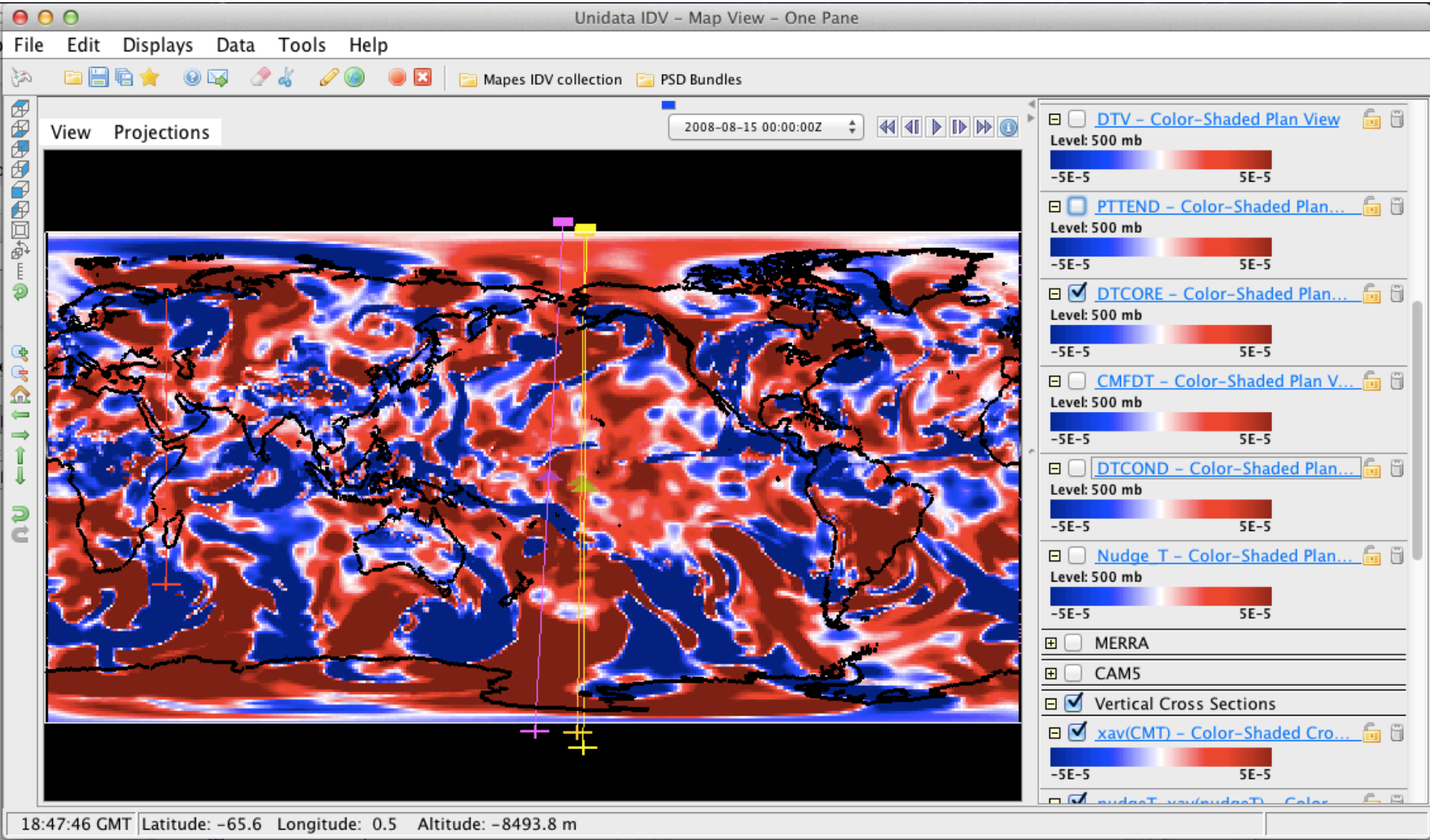


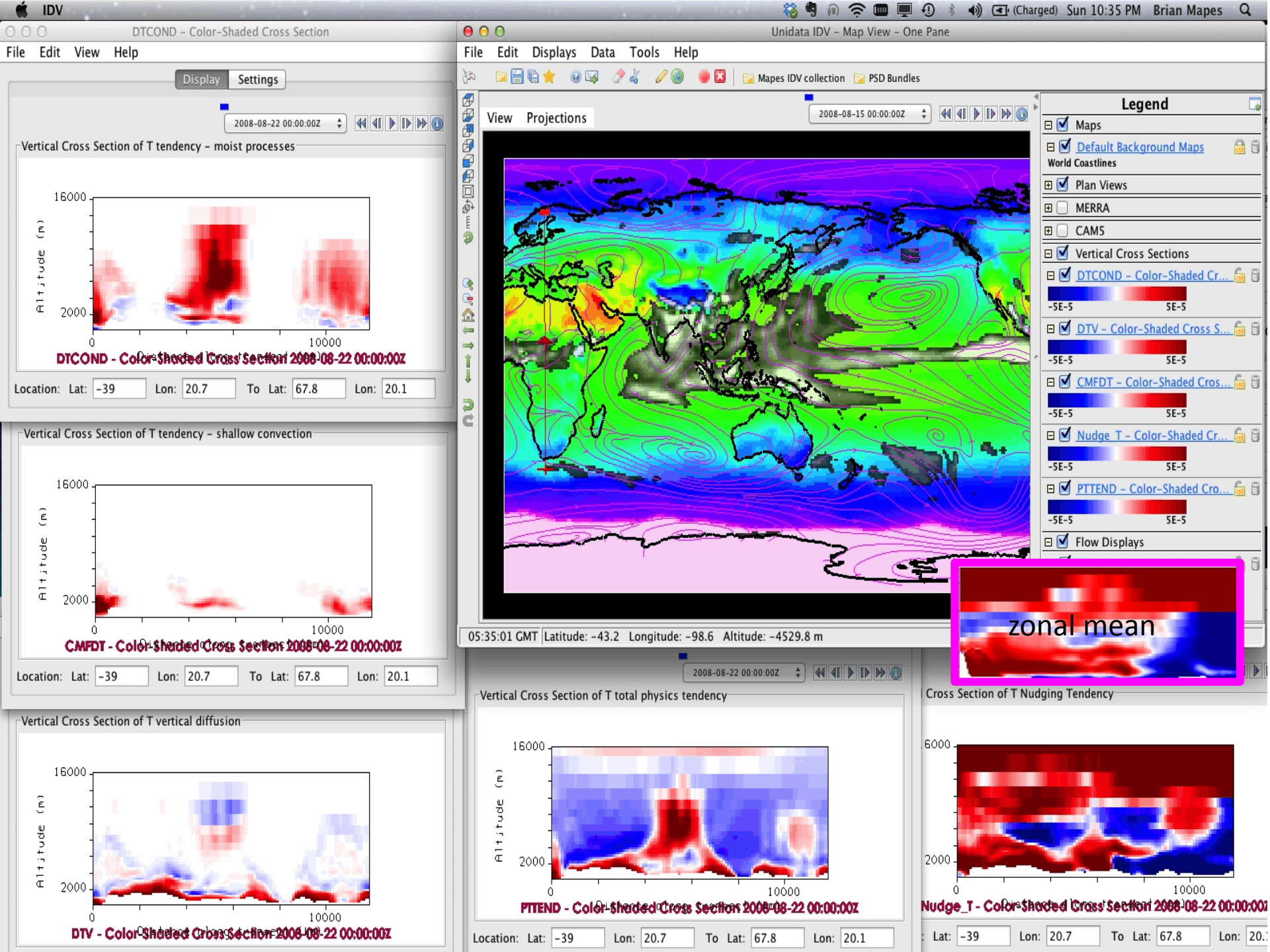
DTV ("vert. diff.") at 500mb



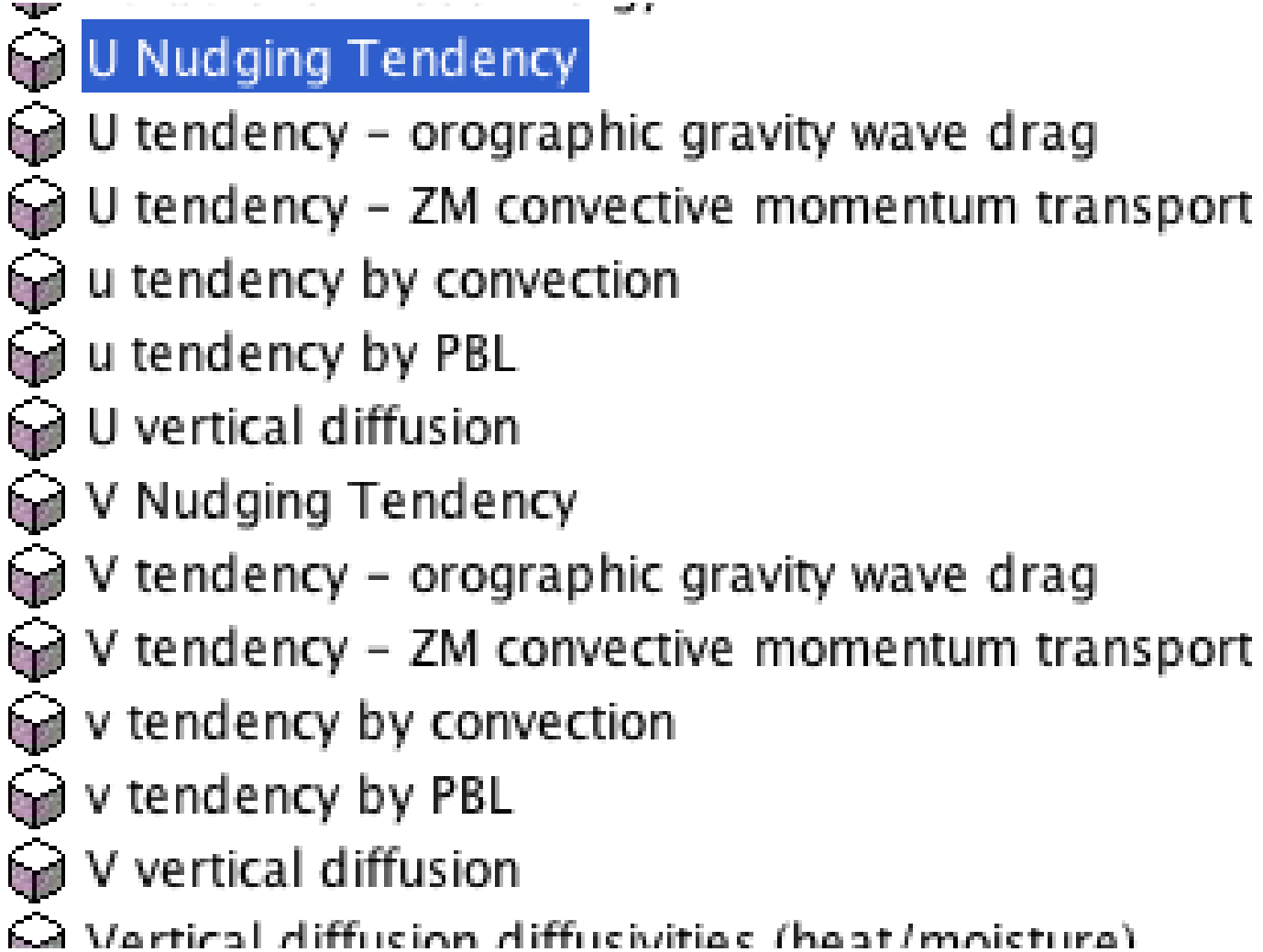
DTCORE at 500mb

(*bug, not monthly mean output?*)

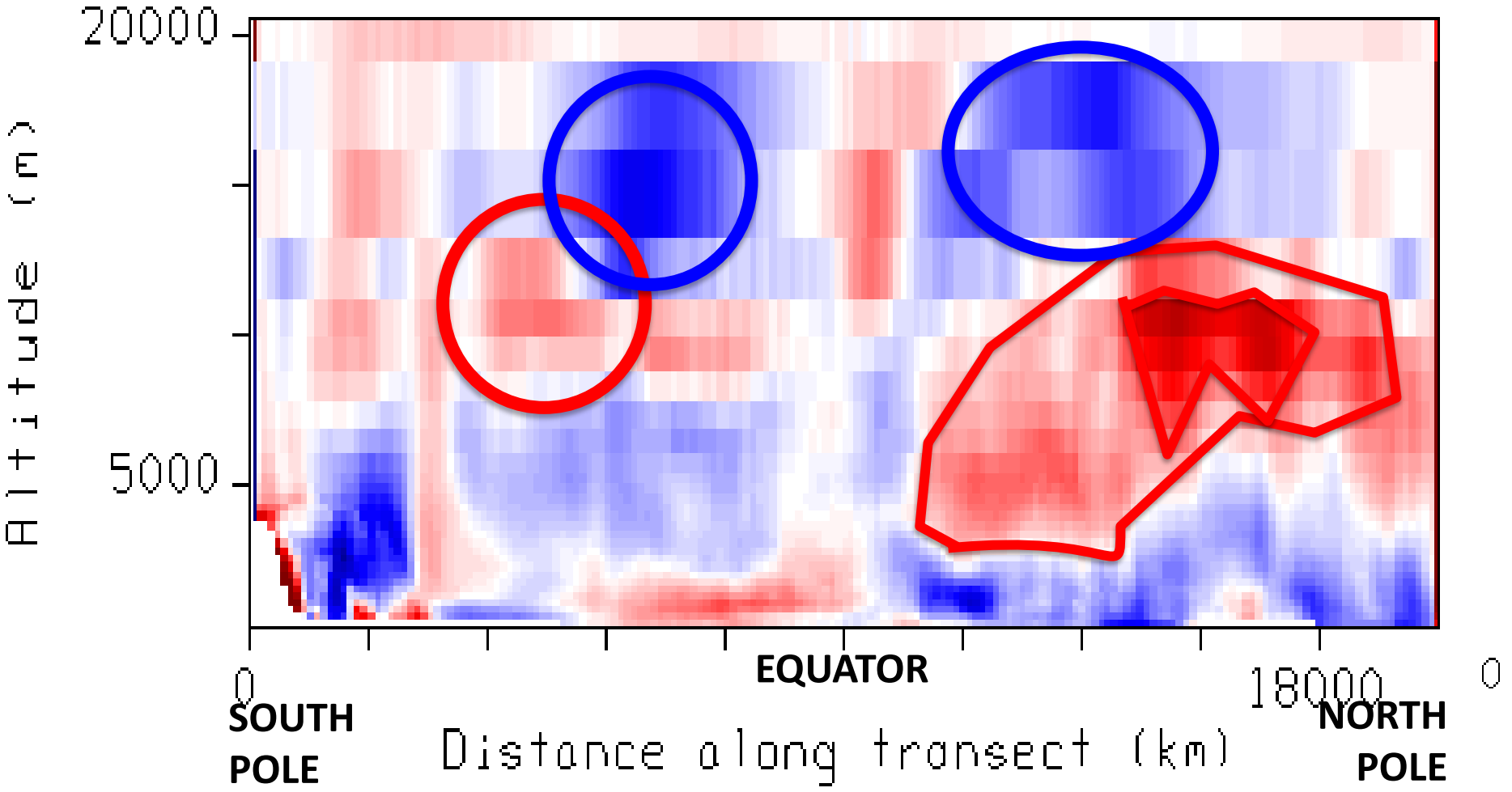



IDV
(Charged) Sun 10:35 PM Brian Mapes
DTCOND - Color-Shaded Cross Section
File Edit View Help
Display Settings
2008-08-22 00:00:00Z
Vertical Cross Section of T tendency - moist processes
16000
2000
Altitude (m)
0
10000
DTCOND - Color-Shaded Cross Section 2008-08-22 00:00:00Z
Location: Lat: -39 Lon: 20.7 To Lat: 67.8 Lon: 20.1
Vertical Cross Section of T tendency - shallow convection
16000
2000
Altitude (m)
0
10000
CMFDT - Color-Shaded Cross Section 2008-08-22 00:00:00Z
Location: Lat: -39 Lon: 20.7 To Lat: 67.8 Lon: 20.1
Vertical Cross Section of T vertical diffusion
16000
2000
Altitude (m)
0
10000
DTV - Color-Shaded Cross Section 2008-08-22 00:00:00Z
Unidata IDV - Map View - One Pane
File Edit Displays Data Tools Help
Mapes IDV collection
PSD Bundles
View Projections
2008-08-15 00:00:00Z
Legend
Maps
Default Background Maps
World Coastlines
Plan Views
MERRA
CAM5
Vertical Cross Sections
DTCOND - Color-Shaded Cr...
-5E-5
5E-5
DTV - Color-Shaded Cross S...
-5E-5
5E-5
CMFDT - Color-Shaded Cros...
-5E-5
5E-5
Nudge_T - Color-Shaded Cr...
-5E-5
5E-5
PTTEND - Color-Shaded Cro...
-5E-5
5E-5
Flow Displays
05:35:01 GMT Latitude: -43.2 Longitude: -98.6 Altitude: -4529.8 m
zonal mean
2008-08-22 00:00:00Z
Vertical Cross Section of T total physics tendency
16000
2000
Altitude (m)
0
10000
PTTEND - Color-Shaded Cross Section 2008-08-22 00:00:00Z
Location: Lat: -39 Lon: 20.7 To Lat: 67.8 Lon: 20.1
Cross Section of T Nudging Tendency
6000
2000
0
10000
Nudge_T - Color-Shaded Cross Section 2008-08-22 00:00:00Z
Lat: -39 Lon: 20.7 To Lat: 67.8 Lon:

Wind budgets

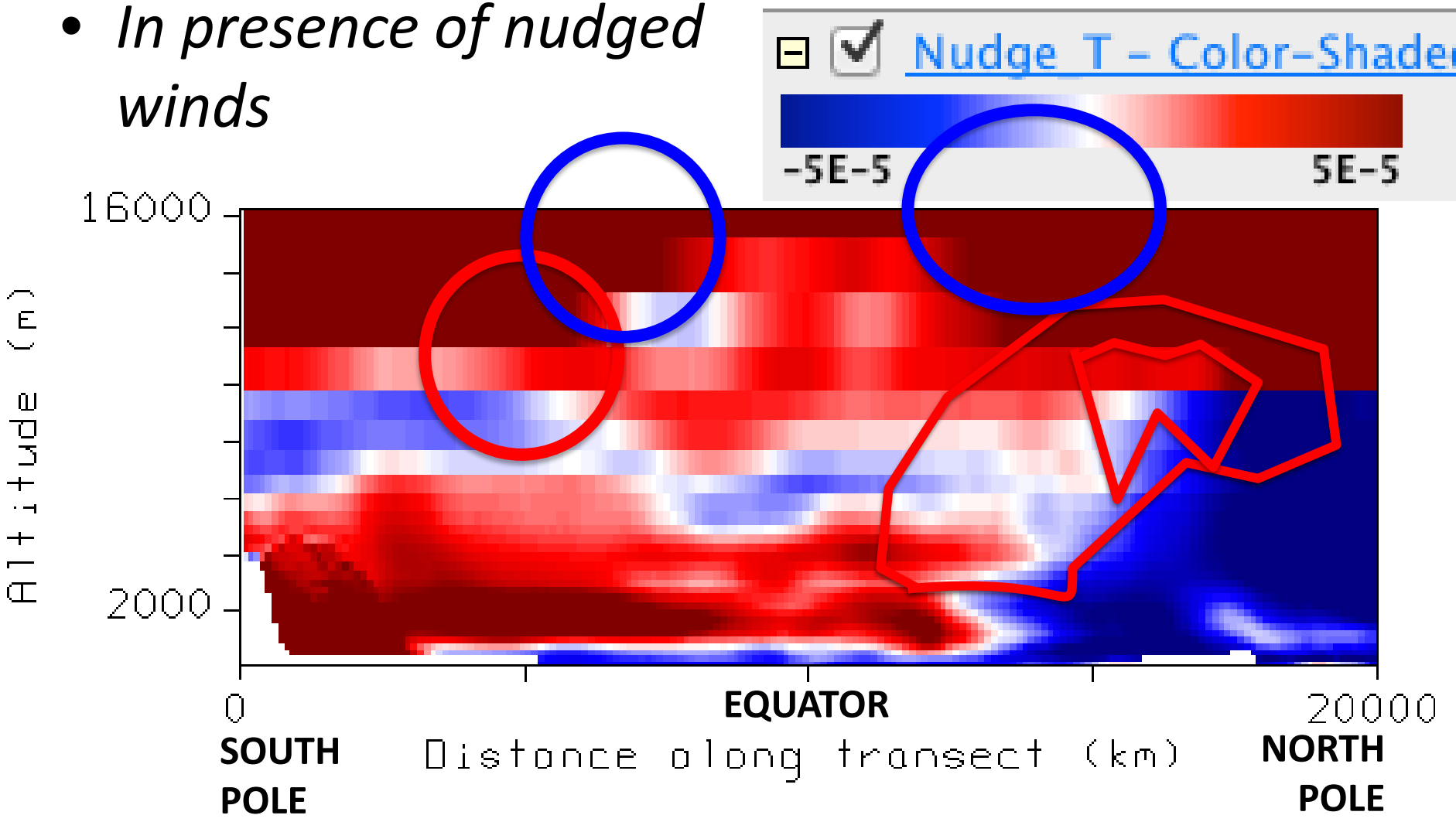


Zonal average of dudt_nud



Zonal average of (-Tbias/6h)

- *In presence of nudged winds*



Want to build a balanced diagnosis

- Thermal nudging → PV source
- Curl of wind nudging → PV source

Conclusions

- Nudging escorts model through realistic states
  - albeit pulled a bit off its attractor/manifold
- After the run, nudging tendencies are essentially a data set on model process (tendency) errors
- Leap: ***Interpret*** errors as process shortcomings...?
  - *exploratory* data analysis initially... IDV my new fave...

- Multi-model, multi-reanal intercomparisons.
  - Data please? RAMADDA repository is all set up...
    - Standardize, then we can develop standard diagnostics.
- Better CAM budget outputs?
  - *Dani inquired last week...thanks!*

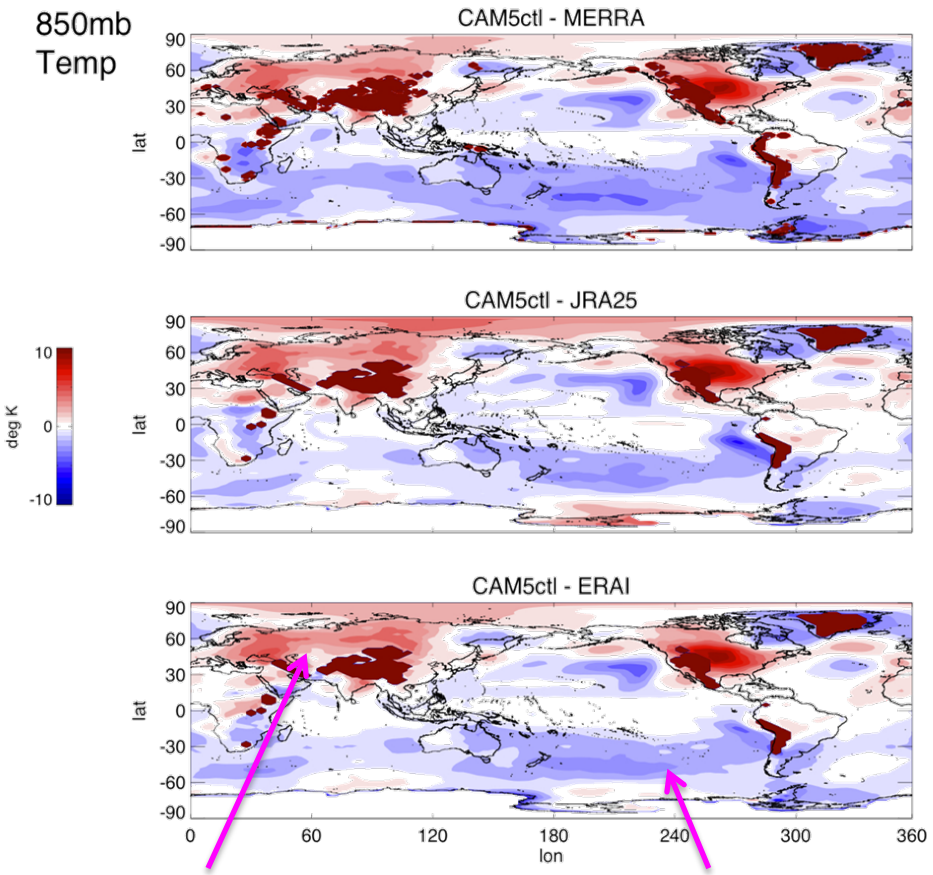
- extra slides

T nudging "Cp bug" (6000h not 6h relaxation timescale)

- makes 2013 June Breckenridge result more understandable (next 2 slides)

JJA Temp 850mb

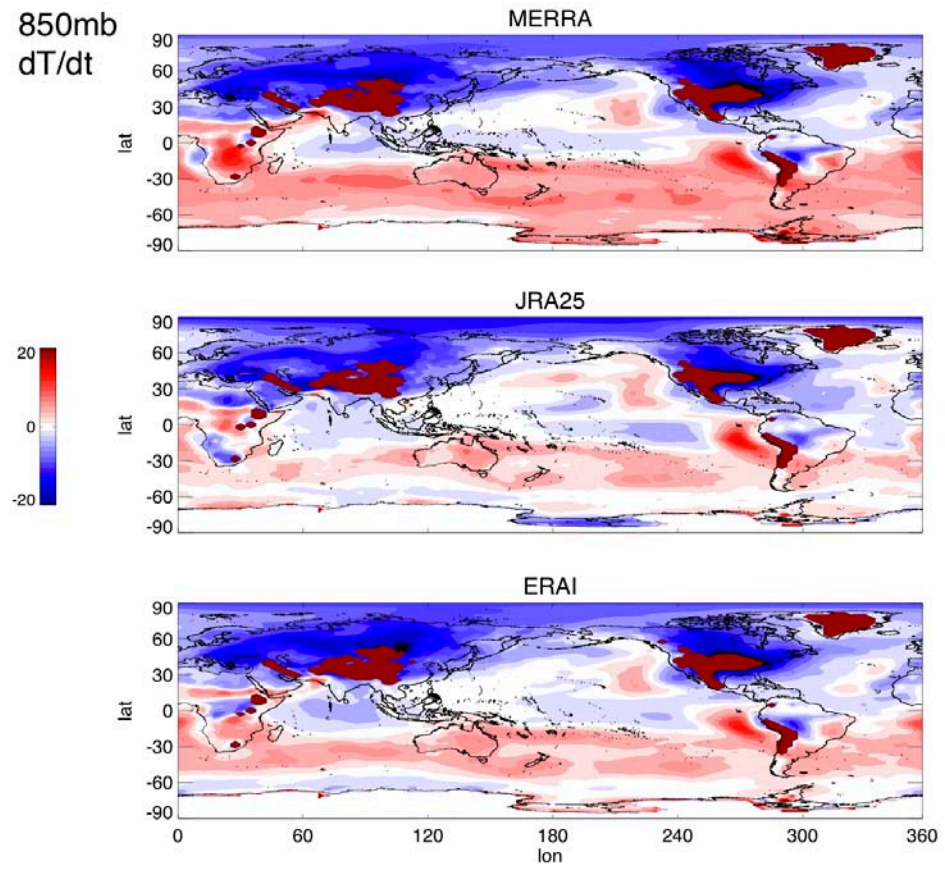
Mean Bias CTL



NH land too Hot

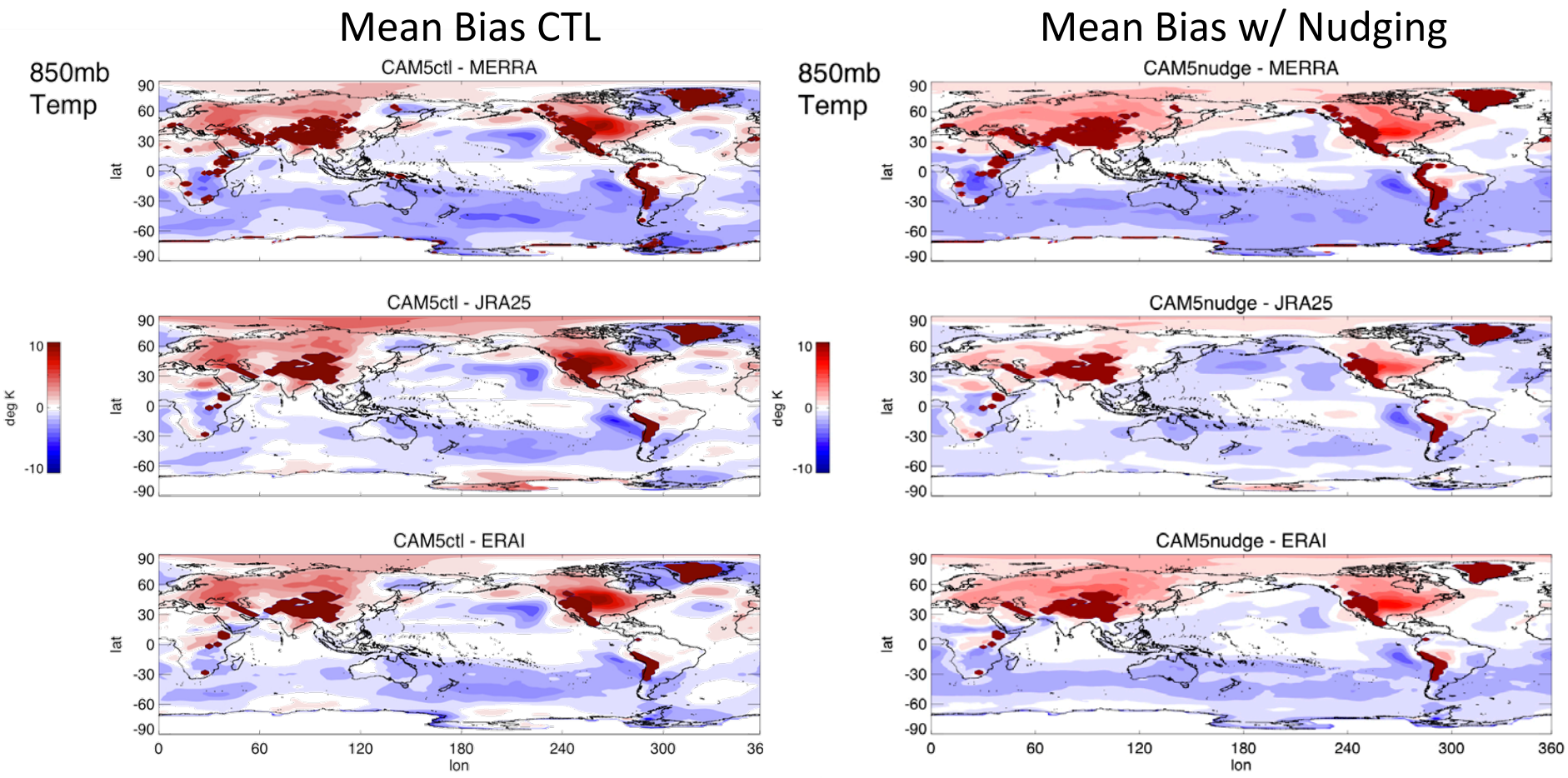
SH ocean too Cold

Nudging DT/Dt

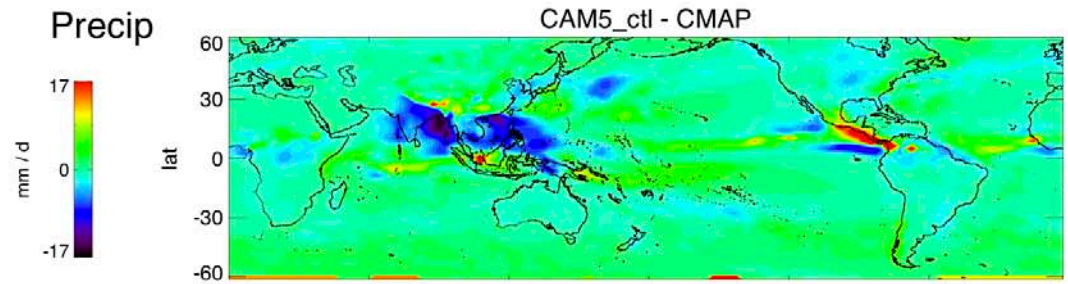


Nudging directly opposes the pattern of errors

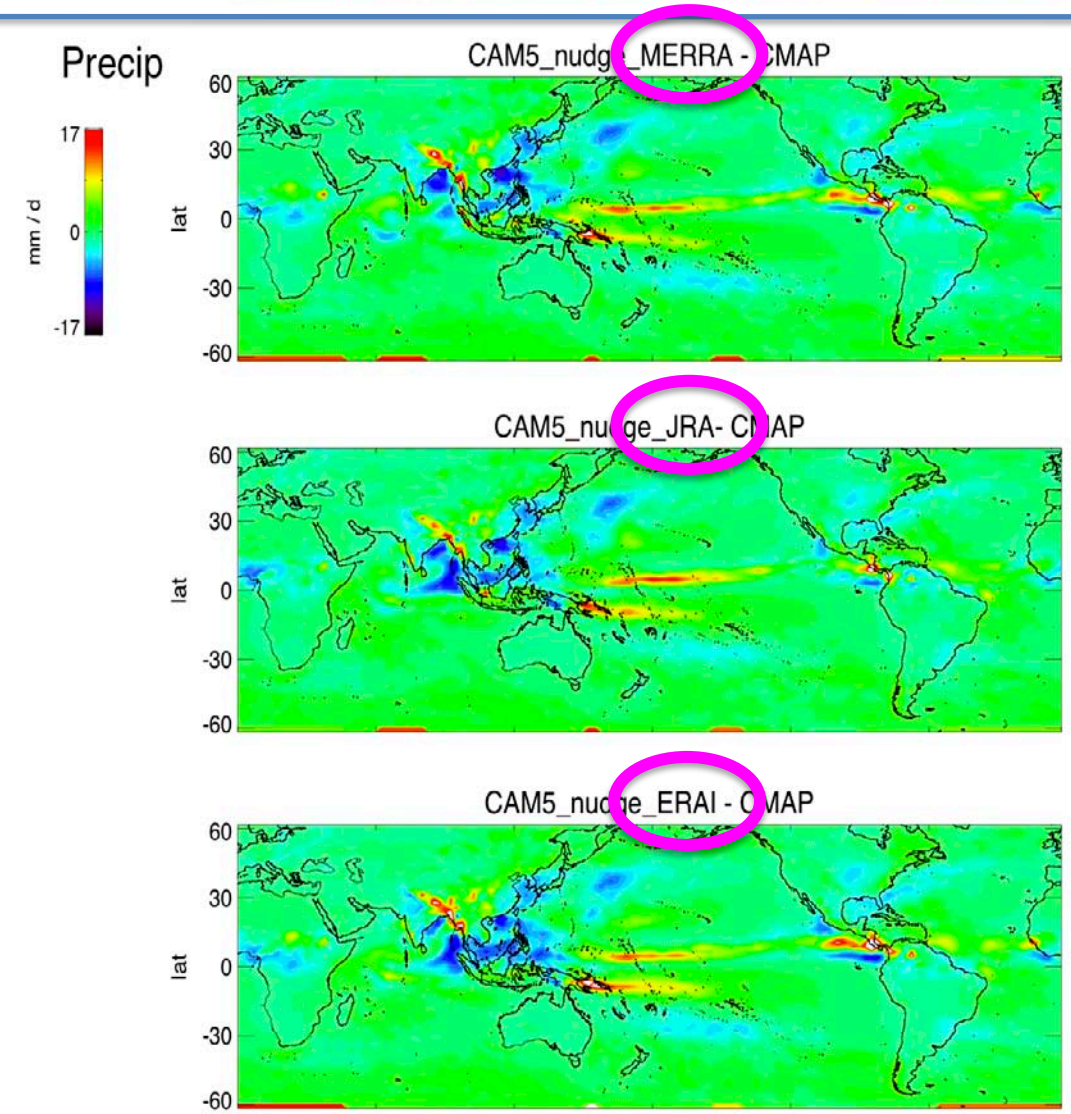
But Marginal improvement of T_{850mb} errors



Some stronger tendencies overpower nudging:
(*from surface? from imbalance like in v wind?*)



←Control error in precipitation



All 3 Nudgings of {u,v} only reduce precip errors

<u>All 3 similar</u>

Special thanks

- NCAR/CISL for computing resources
- Julio Bacmeister
- Patrick Callaghan
- Jerry Olson