Performance results with the Total Energy - Mass Flux PBL scheme

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What is TEMF and what is it good for?

Level 2.5 scheme

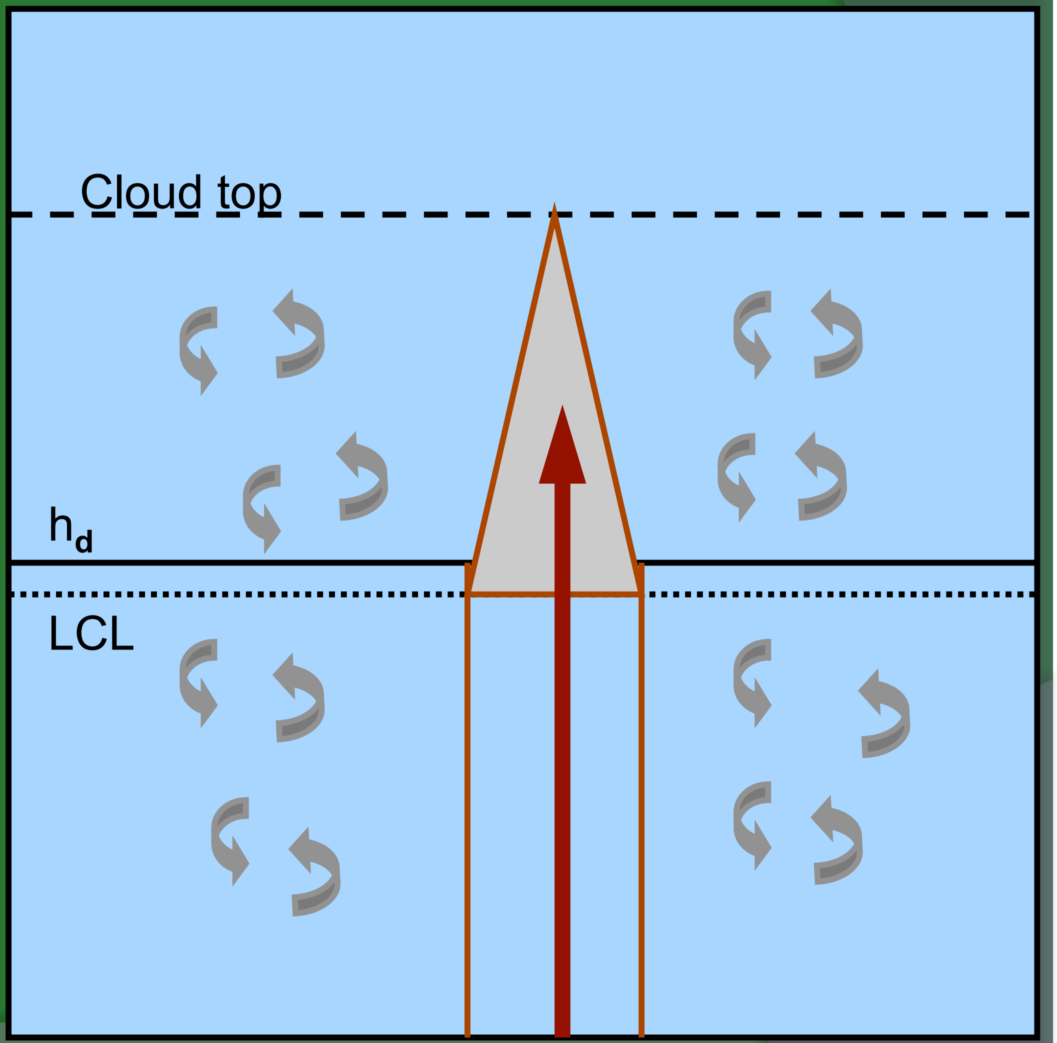
Total turbulent energy as prognostic variable

Mass flux for non-local transport in convective BL

Integrated shallow cloud

Available in WRF since v3.3

Intended to improve simulations with shallow cloud and/or stable boundary layers



CalNex cases

Two-month runs

WRF REF configuration:
36/12/4 km horizontal grid, inner grid covers all of California
ERA-Interim initialization
60 vertical levels, 18 below 1 km, lowest level ~15 m
Eta microphysics
RRTM-G radiation (LW & SW)
Grell-Devenyi cumulus, outer domain only
MYJ boundary layer & surface layer
Navy GODAE high-resolution SST (6-hourly)

WRF TEMF configuration:
Same as REF except for TEMF boundary layer and surface layer on domains 2 and 3

COAMPS:
Navy operational mesoscale model run at Pt. Mugu by Lee Eddington
NOGAPS initialization, warm start mode, no data assimilation

Profiles over water near Catalina Island

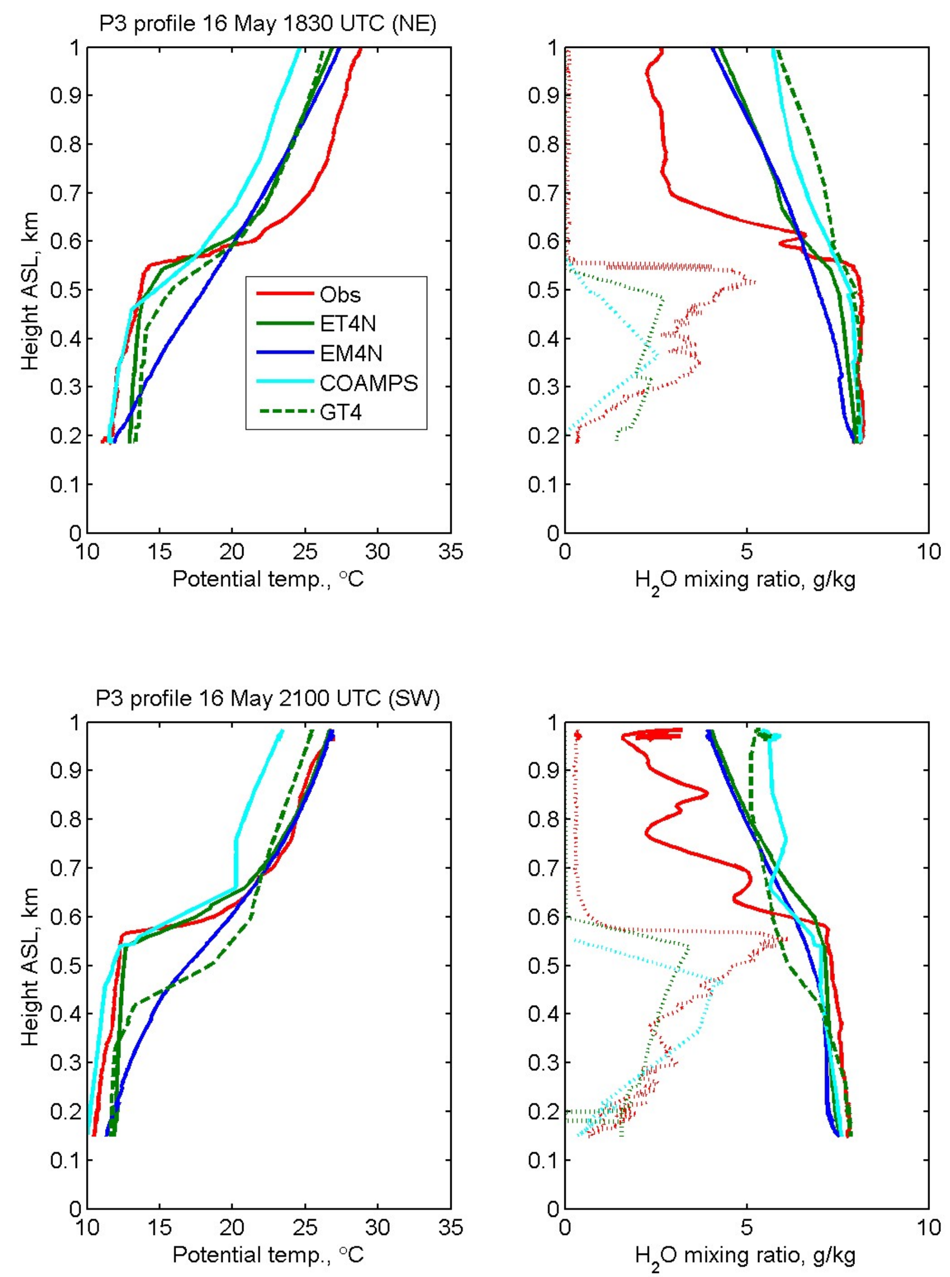
Obs have ~550 m roughly well-mixed cloudy BL with strong, sharp inversion and dry layer above

MYJ has shallow, stable BL
No cloud water because profile is unsaturated

TEMF BL matches obs well
Not saturated at grid scale

COAMPS has shallow BL with good temp and moisture

Red = P3 obs
Blue = WRF MYJ
Green = TEMF
Cyan = COAMPS



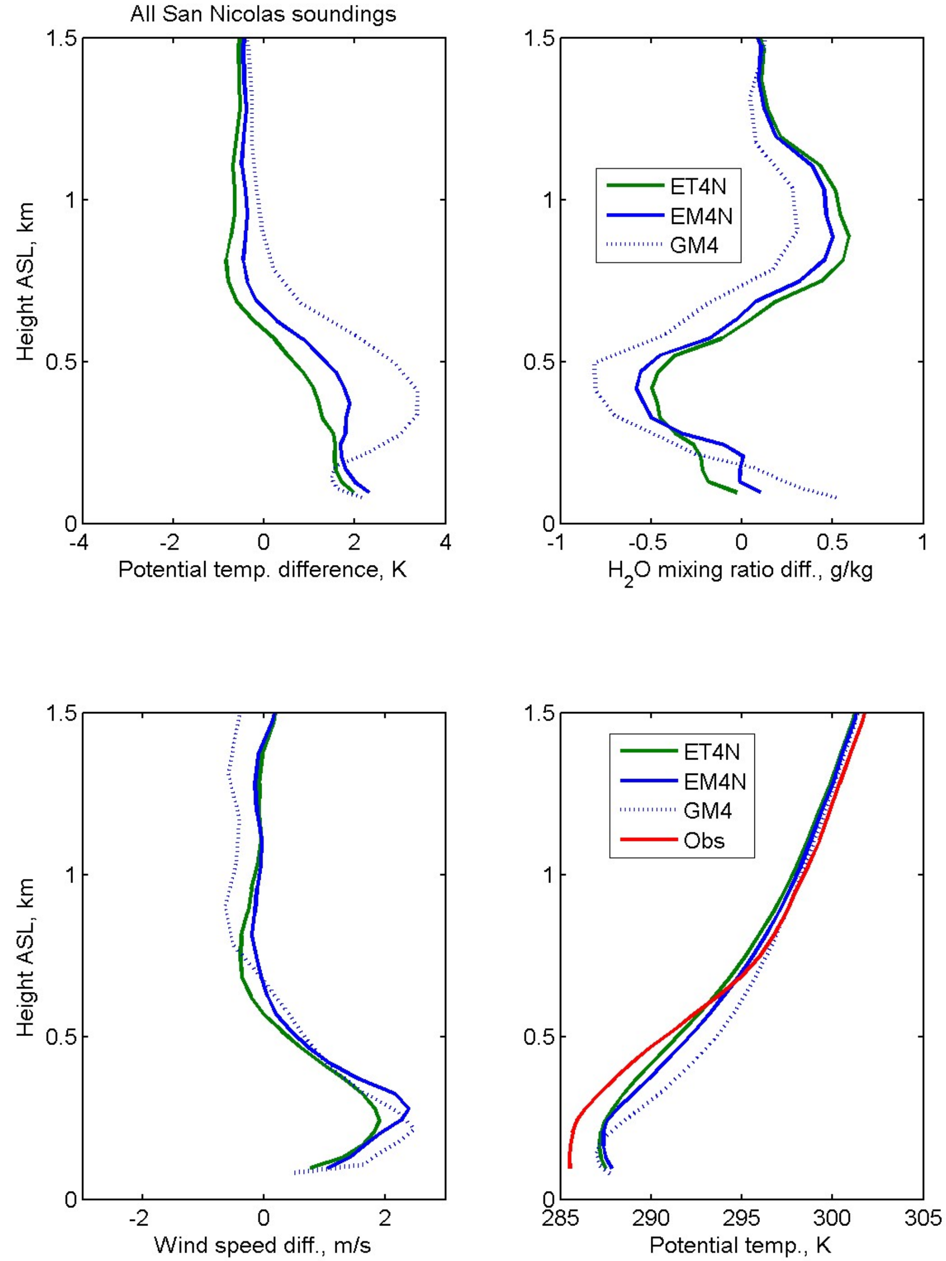
San Nicolas Island soundings

44 soundings during May-June 2010

TEMF has less error in upper BL (~300-500 m) because its BL is deeper

Note difference between MYJ and TEMF initialized with ERA-Interim is less than between MYJ with ERA and with GFS (dashed)

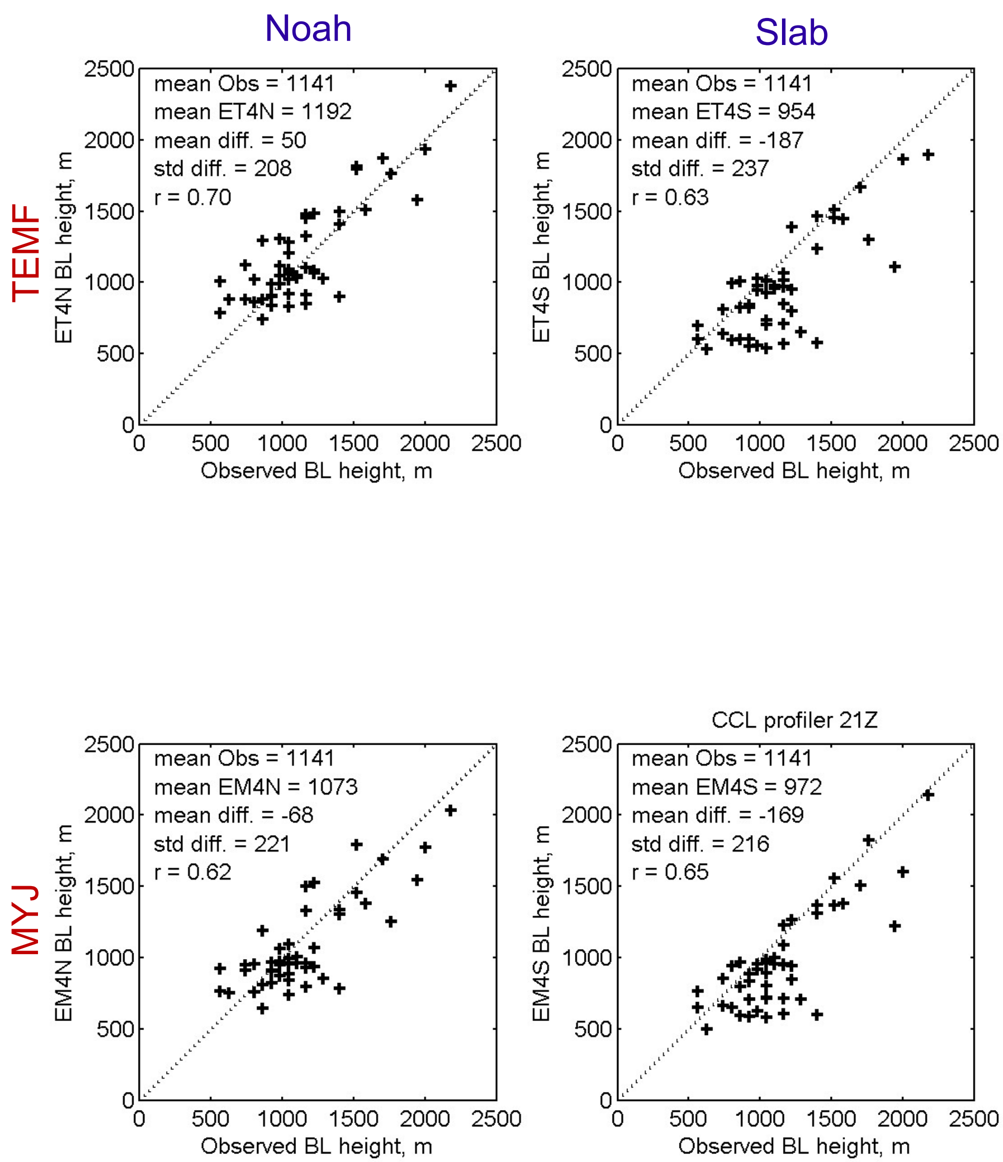
Red = obs
Blue = WRF MYJ
Green = TEMF
Cyan = COAMPS



Chowchilla PBL heights

San Joaquin Valley site
2100 UTC = 1300 LST

TEMF with Noah LSM is least biased and best correlated,
BUT
difference between LSMs is greater than difference between PBL schemes



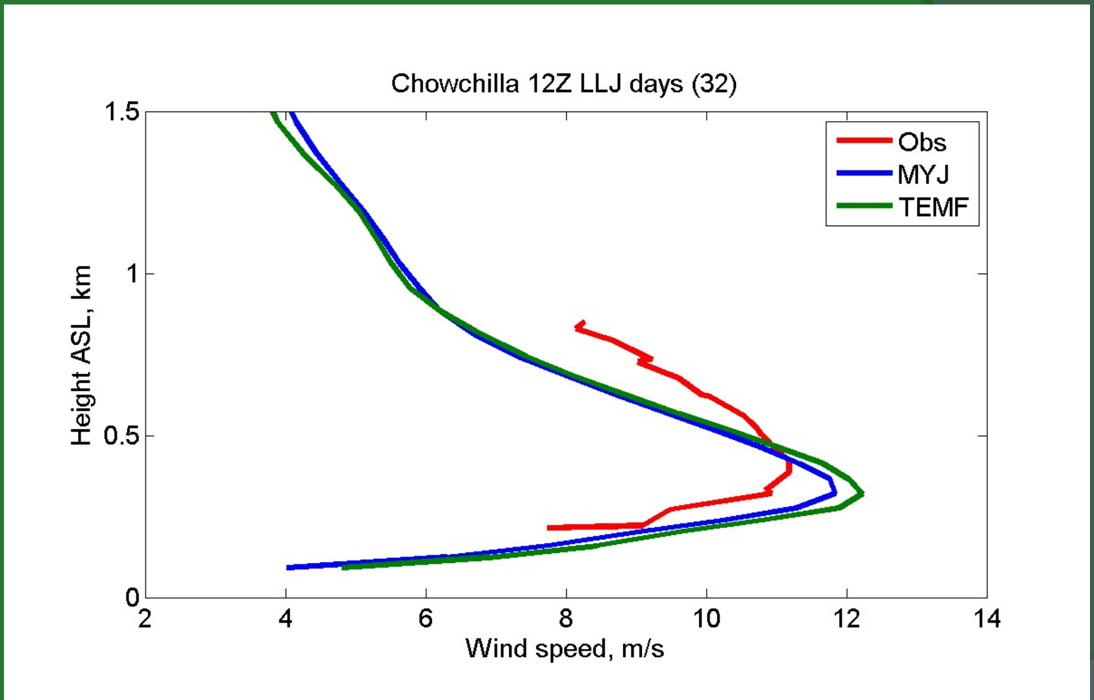
Chowchilla low-level jets

San Joaquin Valley site
1200 UTC = 0400 LST

Averaged over 32 nights with "reasonable" LLJs, no normalization

No significant difference between PBL schemes

Both slightly overestimate strength and sharpness of jet compared to observations (which are also uncertain)

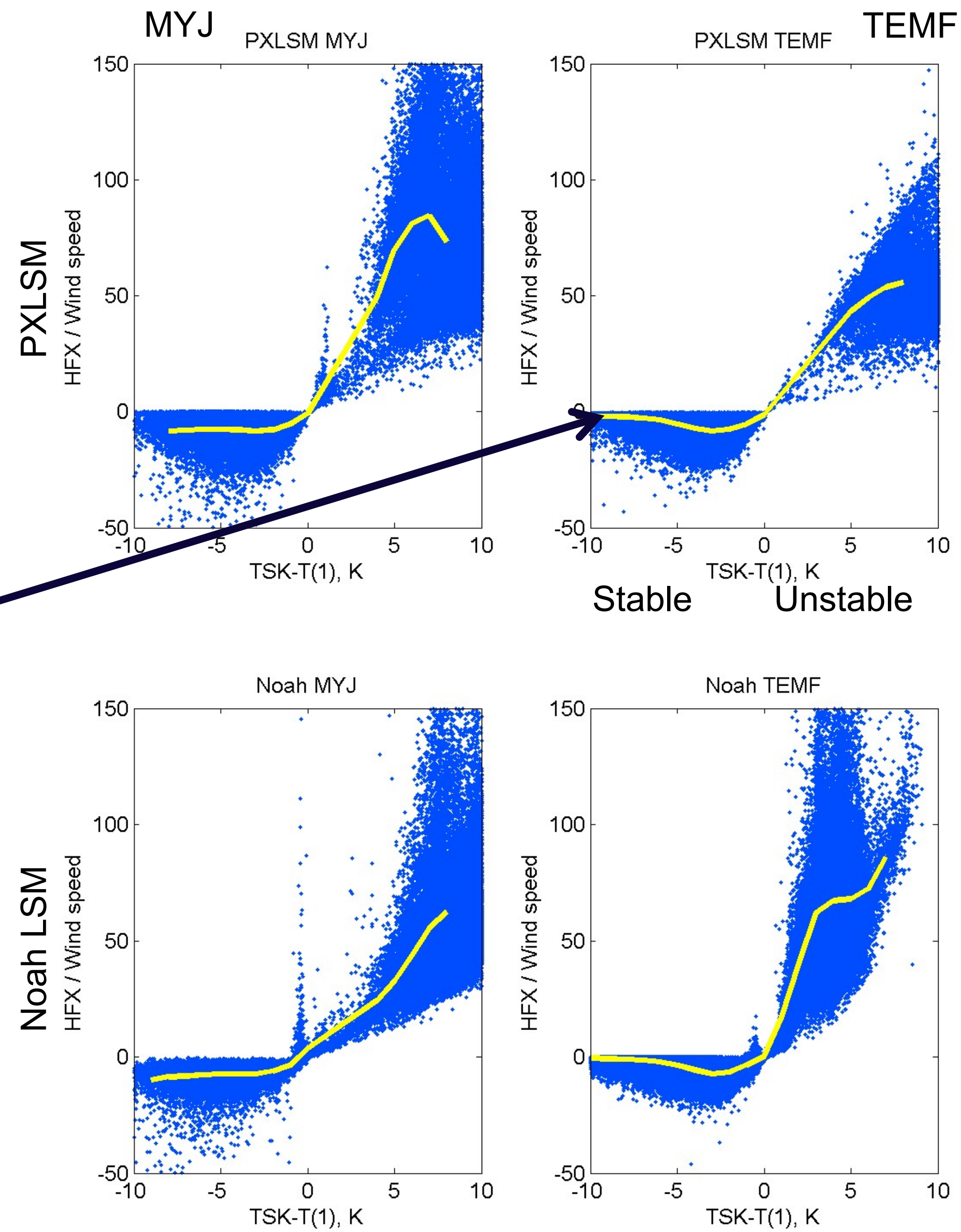


Effective bulk transfer coefficient for heat (C_H)

(Normalized) heat transfer decreases at strong stability in TEMF, not in MYJ

Unstable behavior depends on LSM

Thanks to
Michael Tjernström
for the idea

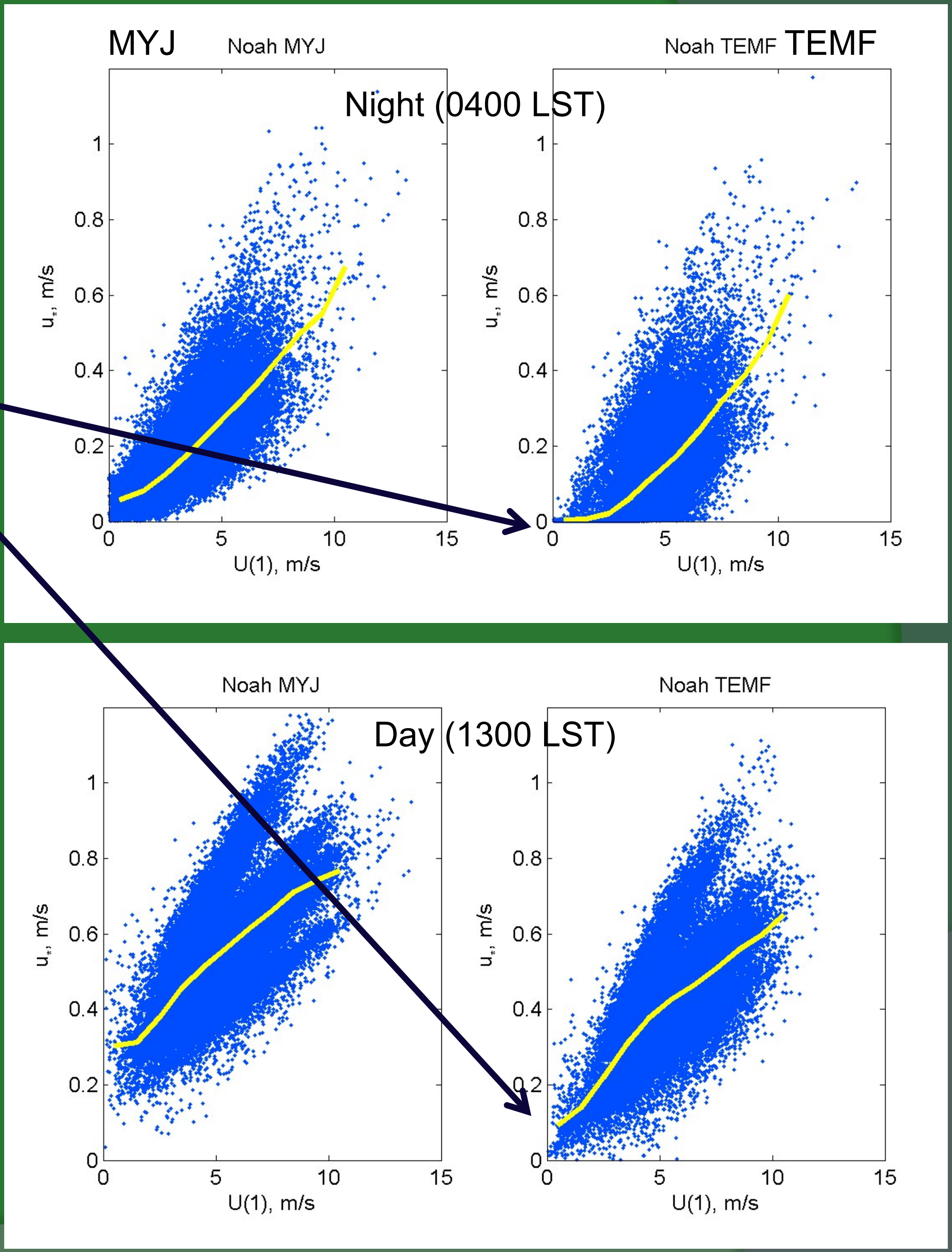


Drag relationship

TEMF has less stress at small speed

TEMF has fewer very small speeds at night

Little LSM dependence at any time (not shown)



BLLAST case

Boundary Layer Late Afternoon and Sunset Turbulence study

Lannemezan, France, June-July 2011

Planned mesoscale intercomparison

Presenting preliminary WRF results for 30 June
- At primary measurement site
- 4D, advection very important
- Two PBL schemes (MYJ and TEMF)
- Two land surface models (Noah and Pleim-Xu)

BLLAST profiles

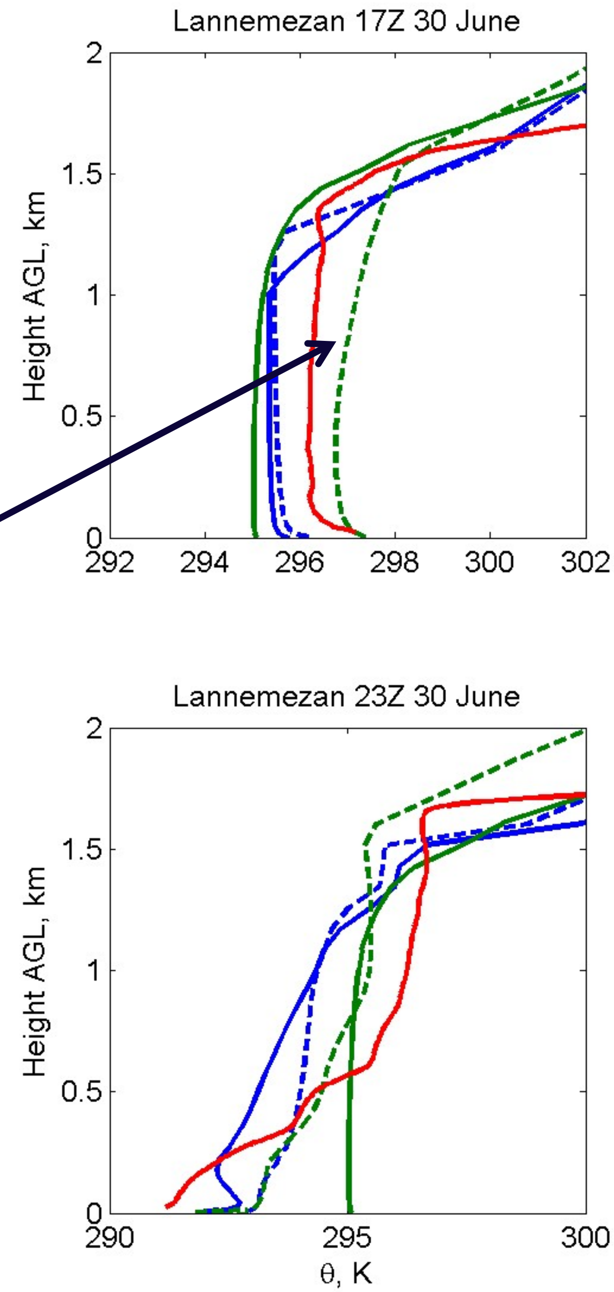
30 June vs. soundings

Temperature and moisture bias depends on PBL scheme and LSM

All too cool & low except TEMF w/ PXLSM (which is too hot & high)

3D case so non-local effects vary/ dominate – not just the local column!

Red = obs
Blue = MYJ
Green = TEMF
Solid = Noah LSM
Dashed = PX LSM



BLLAST profiles

30 June vs. soundings

Wind speed profiles not simple in afternoon

LLJ in evening, too high in all simulations
TEMF/Noah has no LLJ
TEMF/PXLSM LLJ is too strong

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Blue = MYJ
Green = TEMF
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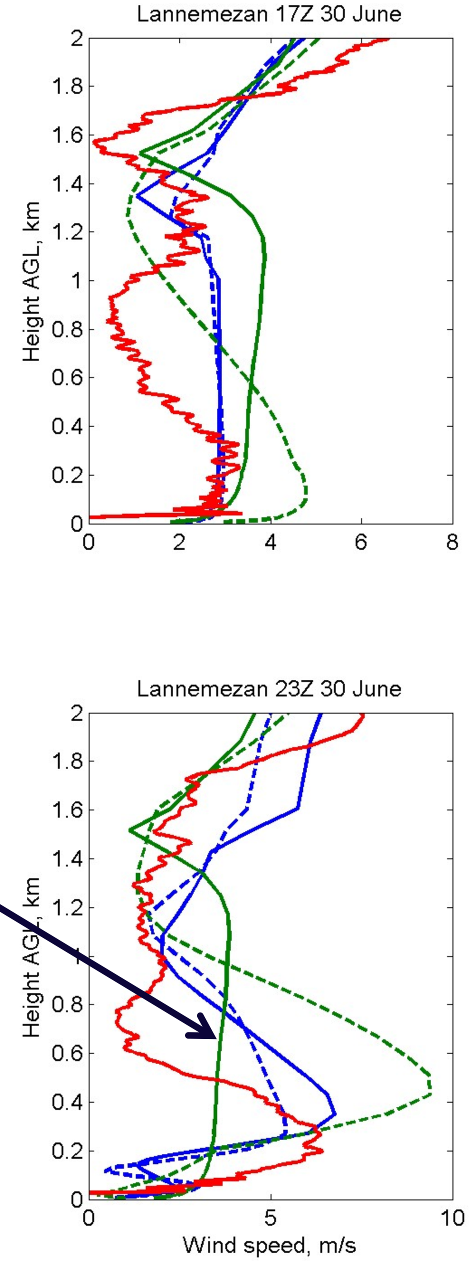
Dashed = PX LSM

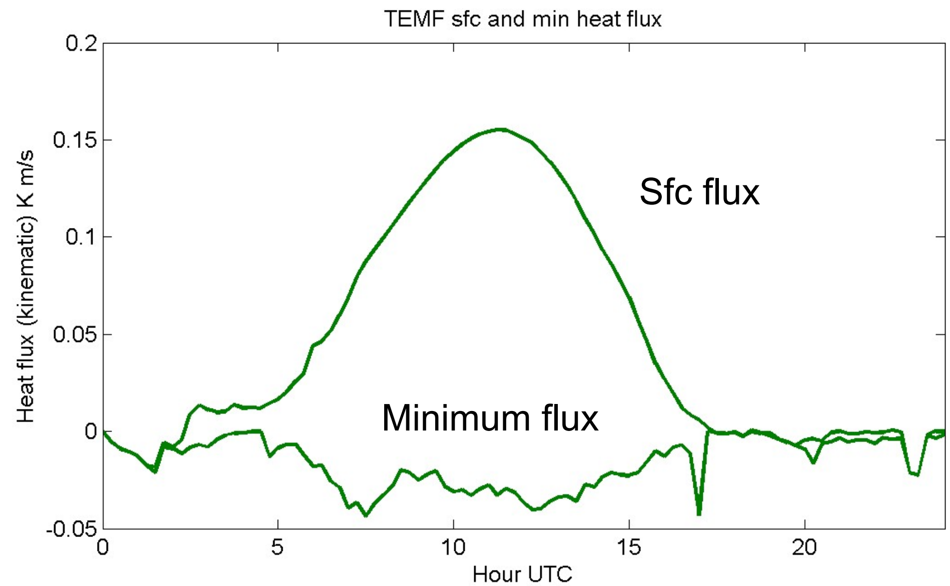


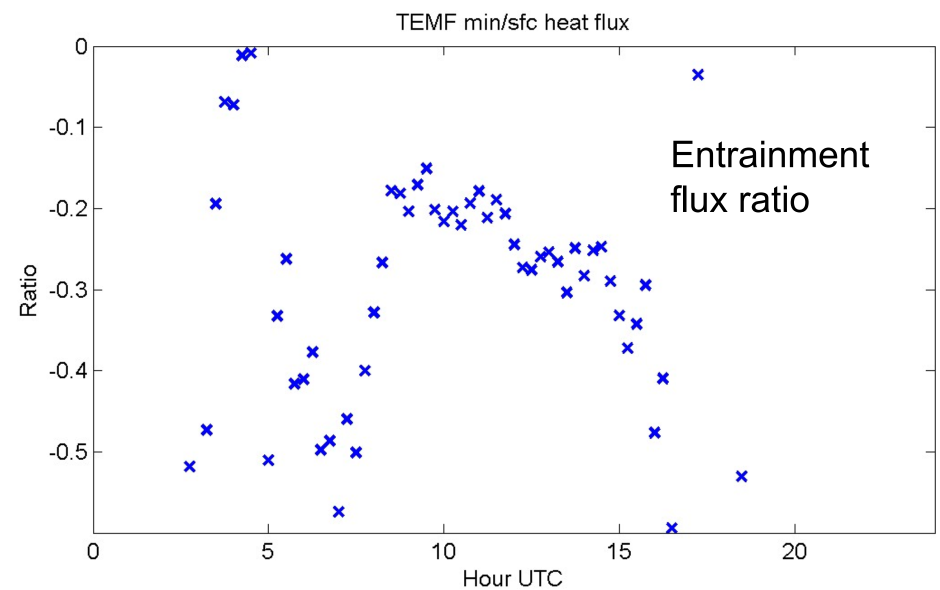
BLLAST Entrainment

Entrainment flux ratio is about 0.2 midday but larger early and late

Reinforces hypothesis that entrainment depends on various processes, which are more important when surface flux is less

Only TEMF shown



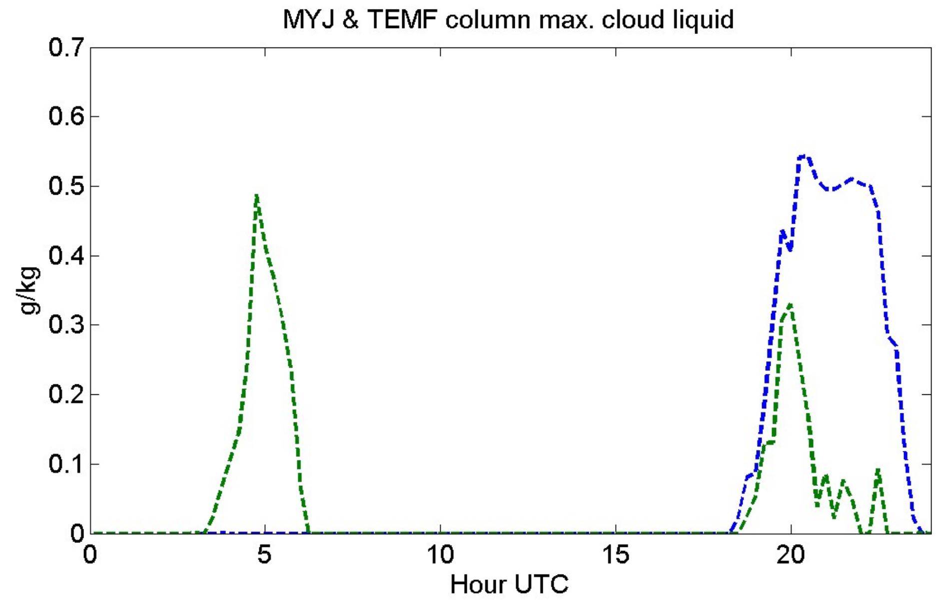


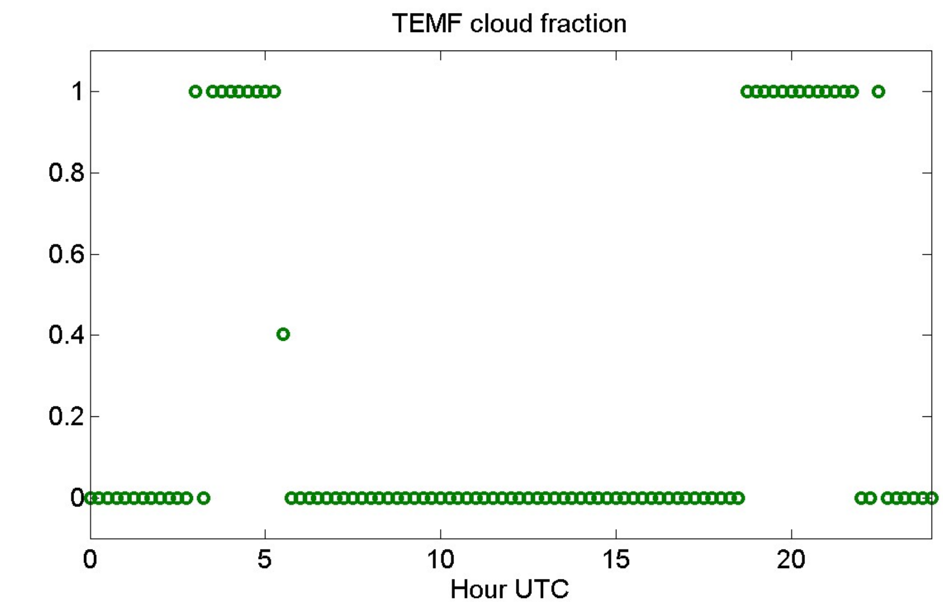
BLLAST cloud

30 June at main site

Reality was mostly cloudy all day

No simulation has midday cloud





TEMF Status

Released in WRF v3.3

Documented: Angevine et al. (2012) MWR, Angevine et al. (2010) JAMC, release notes

Known deficiencies:

- Sometimes crashes when thunderstorms are present
- No ice phase
- Interface to radiation not in released version
- Several limits and tweaks for numerical stability
- Handling of water surface in WRF is crude

Further evaluation, comparison, and development needed

Conclusions(?) and prospects

- TEMF shows more “ideal” behavior in heat transfer and drag relationships
  - More “sensitive”, fewer empirical limits – good or bad?
- TEMF performs better for stratocumulus off California
- Low-level jets are OK with either TEMF or MYJ PBL
- For BLLAST, PBL scheme and land surface model make about equal differences
- Cloud in BLLAST case is poor in all simulations

The whole system matters:

- Initialization, land surface, etc.
- PBL scheme is constrained above, below, and on all sides
- Differences are not bigger because (numerical) stability and other constraints don’t allow it

Thanks to:

Thorsten Mauritsen (TEMF development)

Lee Eddington (COAMPS)

NOAA ESRL High-Performance Computing Program

Stephan de Roode (help with cloud fraction parameterization)

James Cummings, Naval Research Lab (SST data)

Michael Trainer, Sara Lance, NOAA ESRL, and NOAA AOC (WP3 data)

NOAA ESRL PSD (CCL wind profiler data)

Marie Lothon, Fabienne Louhou, David Pino, Fleur Couvreux (BLLAST experiment and intercomparison setup)

Effective bulk transfer coefficient for heat (C_H)

(Normalized) heat transfer decreases at strong stability in TEMF, not in MYJ

Zoomed in on stable branch

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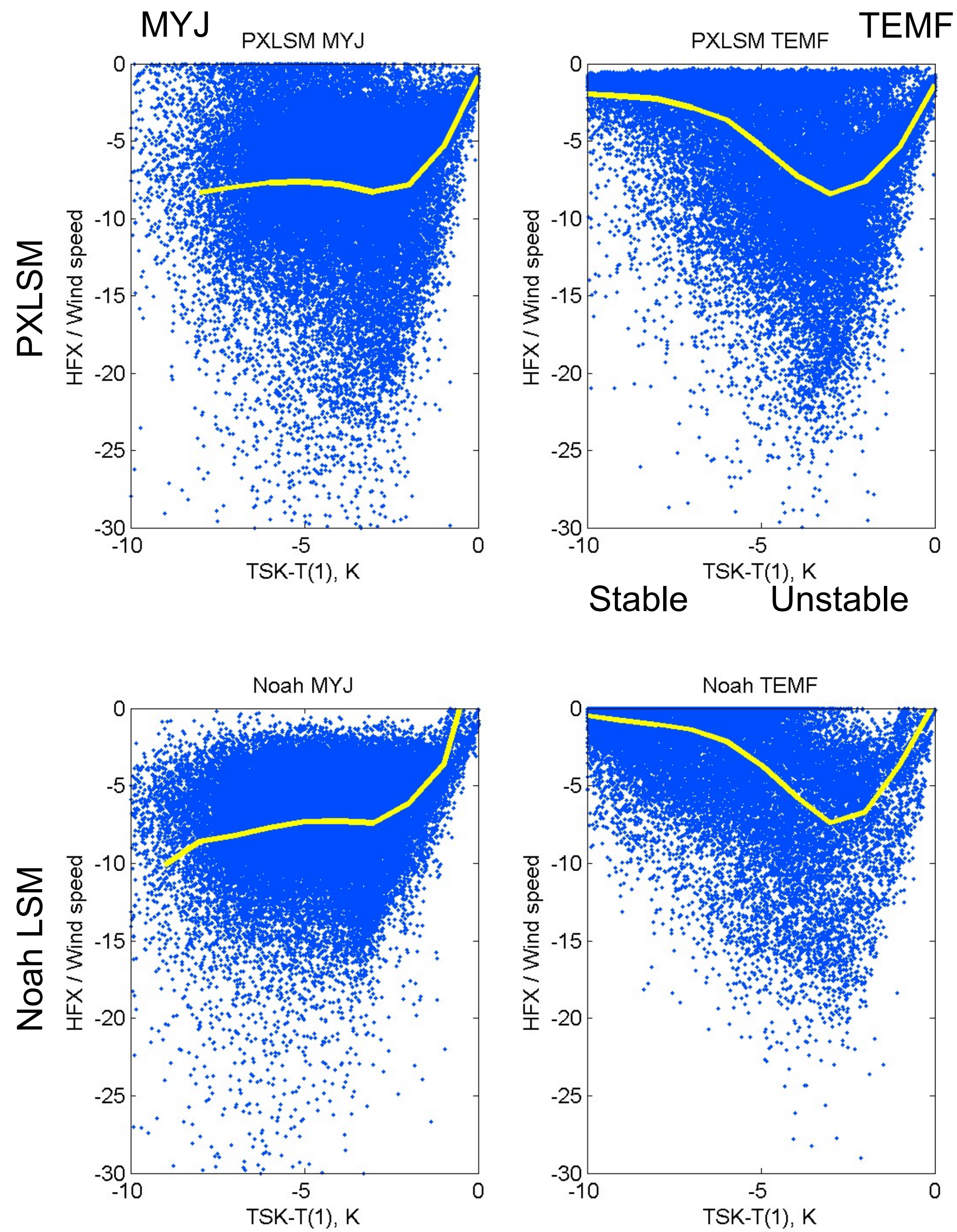


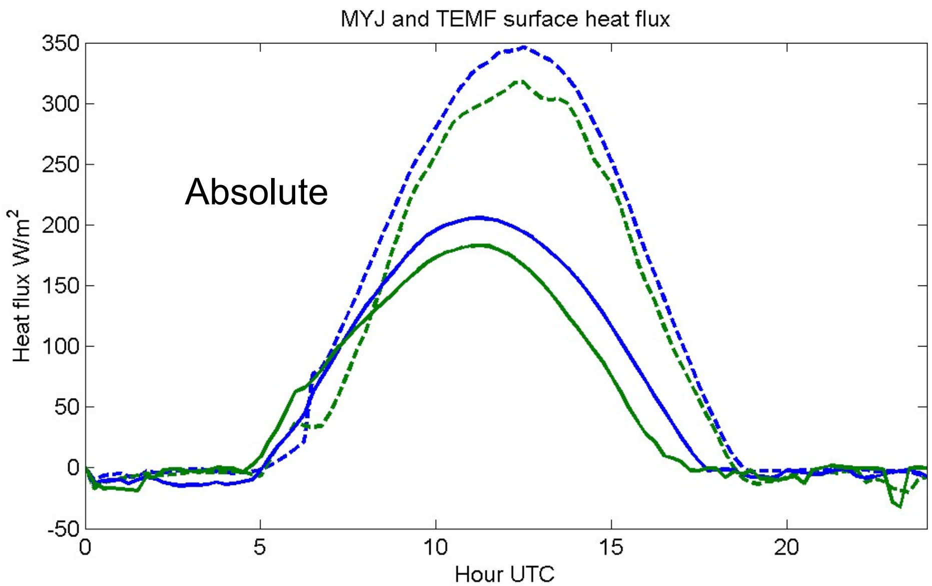
BLLAST sensible heat flux

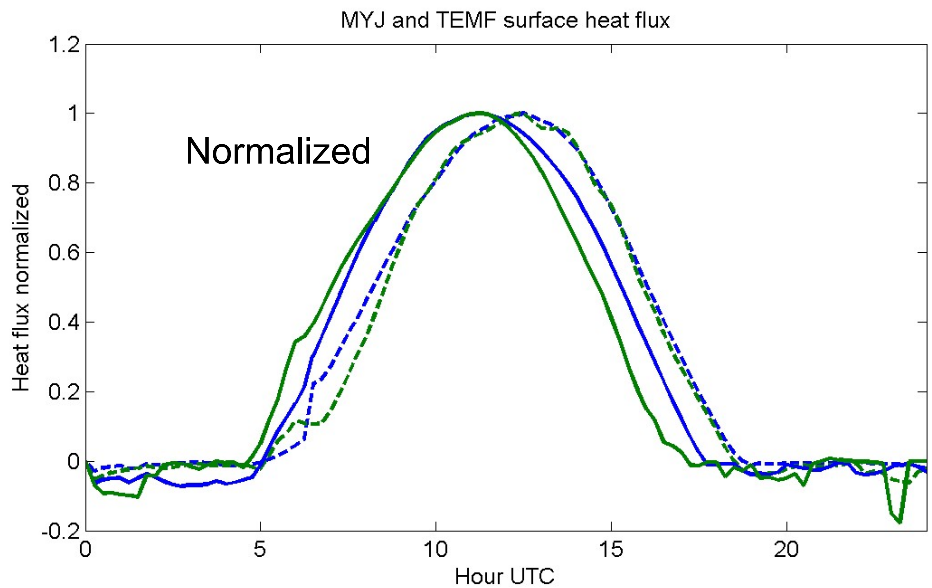
Afternoon timing related to maximum magnitude (larger peak happens later)

NOAH LSM rises and falls earlier (less ground heat storage or greater resistance?)

TEMF makes less heat flux than MYJ (contrary to expectations, due to 3D effects?)

Blue = MYJ
Green = TEMF
Solid = Noah
Dashed = PXLSM





BLLAST Energy variables

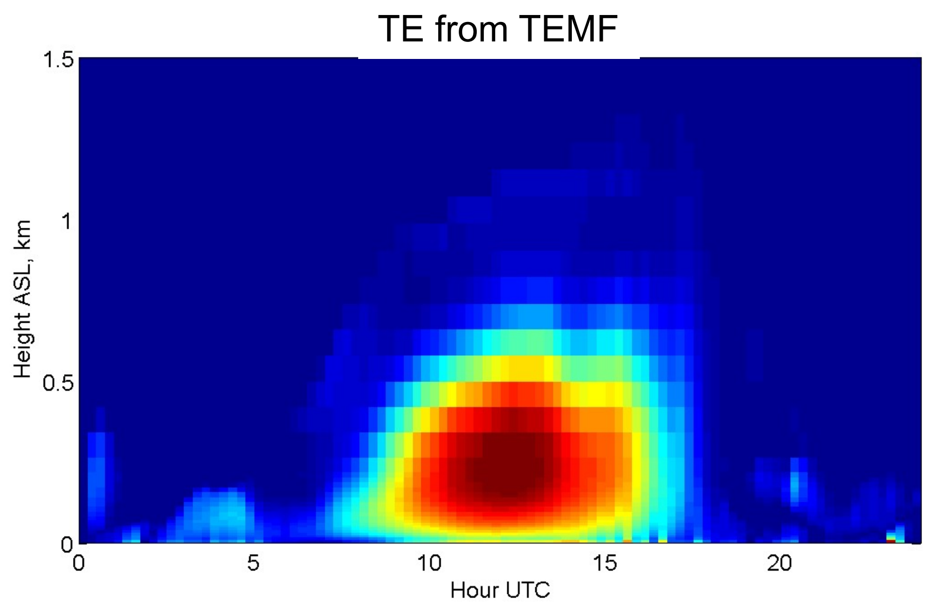
Diurnal cycle on 30 June

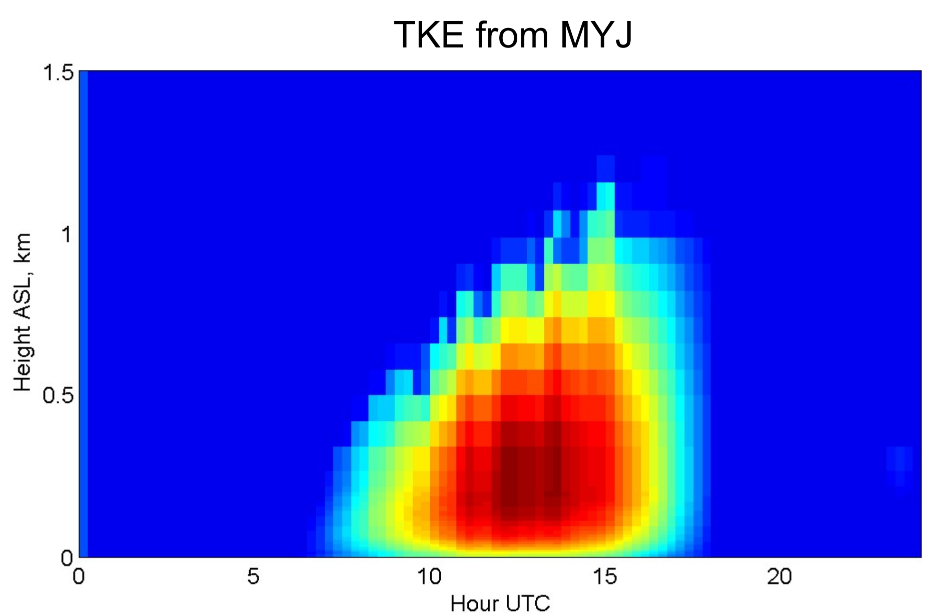
Scaled to maximum in each plot, same zero

Min. TKE in MYJ is 0.1

TEMF TE shows some response to intermittent nocturnal events (some support in data)

(with Noah LSM)





BLLAST cloud impact

14Z 30 June

Some cloud present over site, what height?