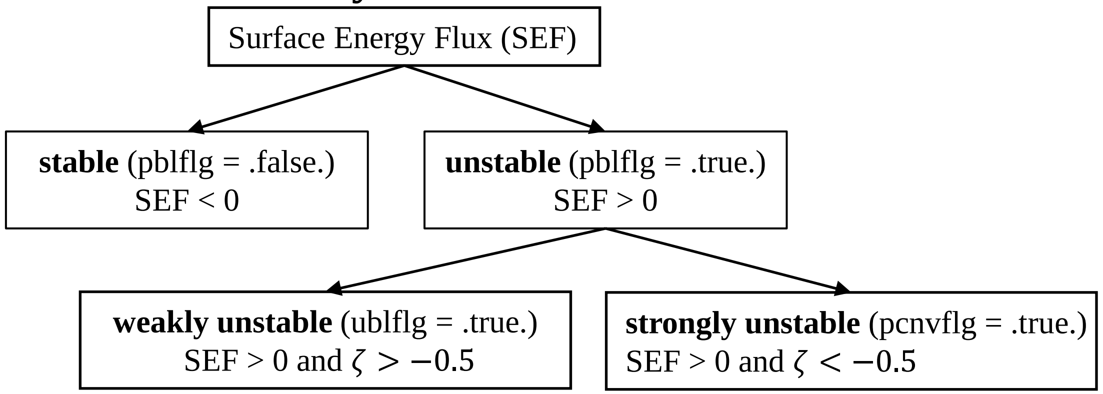
stability conditions



Surface Energy Flux (SEF)

stable (pblflg = .false.)
SEF < 0

unstable (pblflg = .true.)
SEF > 0

weakly unstable (ublflg = .true.)
SEF > 0 and $\zeta > -0.5$

strongly unstable (pcnvflg = .true.)
SEF > 0 and $\zeta < -0.5$

- For unstable BL ($eq. 10\ from\ Han\ and\ Pan\ 1996$):
    - $P_r = \frac{\phi_h}{\phi_m} + b * \kappa * 0.1$
- For stable BL:
    - $P_r = \frac{\phi_h}{\phi_m}$

- Diffusion coefficient for heat K_T and momentum K_M below PBL height (Eq. 2 from Hong and Pan 1996):

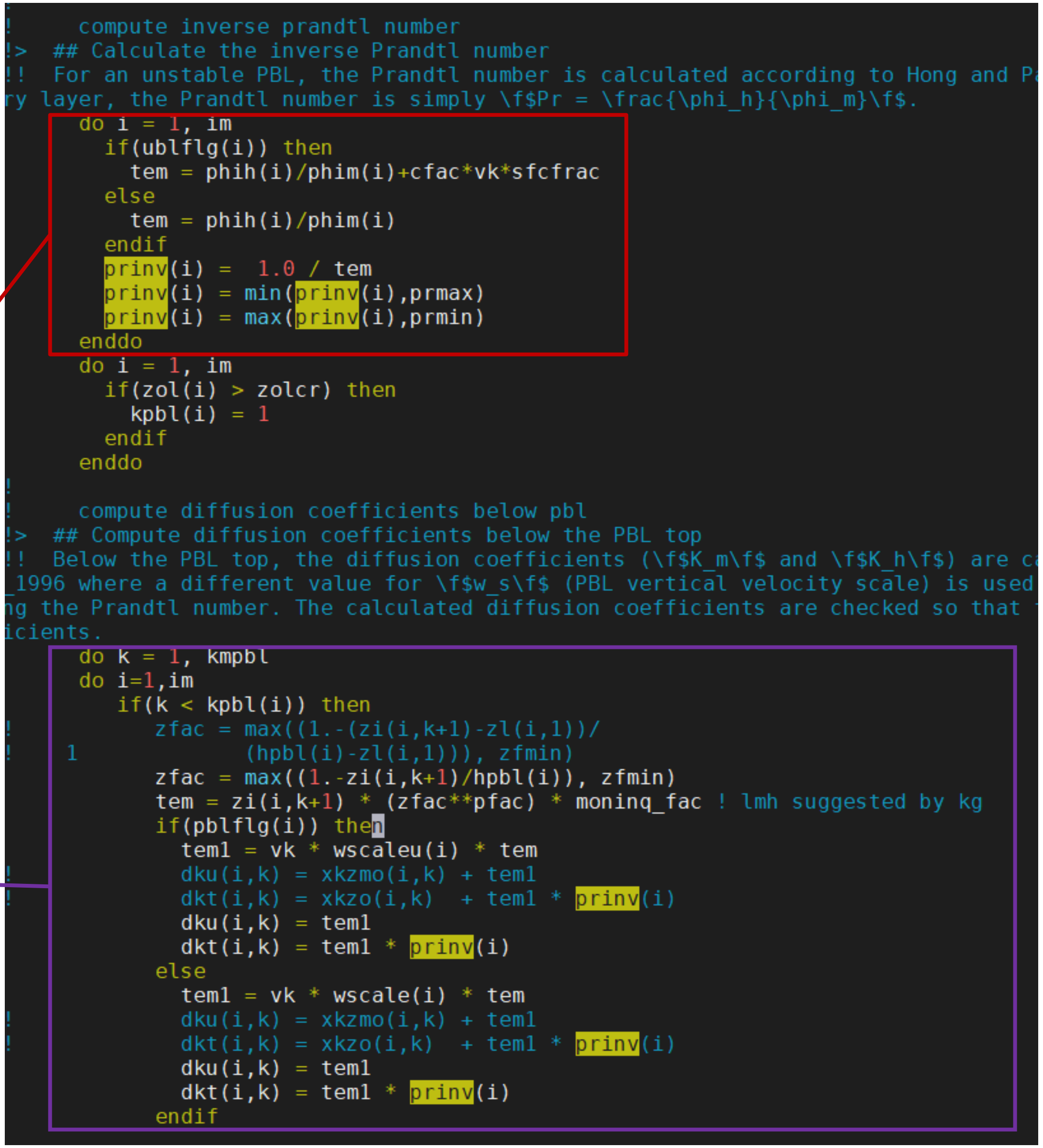
$$K_M = \kappa * w_* * \left(z * \left(1 - \frac{z}{H}\right)^2 \right)$$

$$K_T = K_M * \frac{1}{P_r}$$

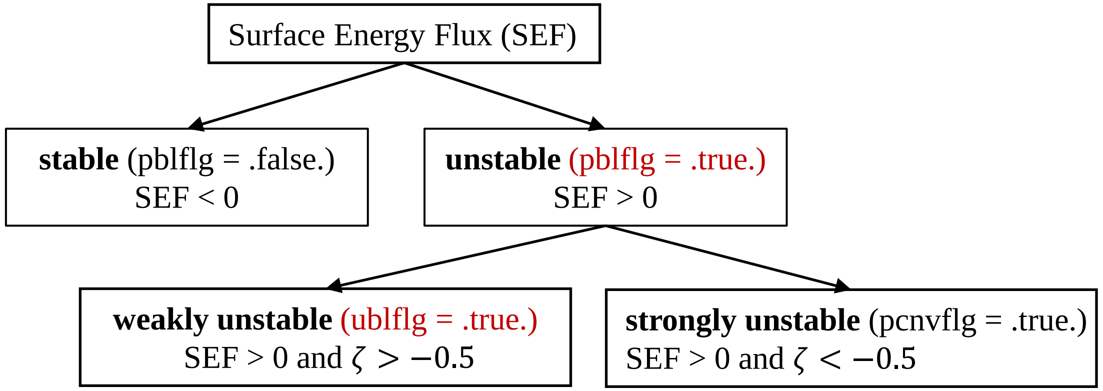
$$w_* = w_{*u}\ for\ unstable\ (SEF > 0\ and\ \zeta > -0.5);$$

$$w_* = \frac{u_*}{\phi_m} for\ stable\ (SEF < 0)$$

Subroutine: moninedmf.f
Lines 725~771



```
!
!     compute inverse prandtl number
!>  ## Calculate the inverse Prandtl number
!!  For an unstable PBL, the Prandtl number is calculated according to Hong and Pa
ry layer, the Prandtl number is simply \f$Pr = \frac{\phi_h}{\phi_m}\f$.
      do i = 1, im
        if(ublflg(i)) then
          tem = phih(i)/phim(i)+cfac*vk*sfcfrac
        else
          tem = phih(i)/phim(i)
        endif
        prinv(i) =  1.0 / tem
        prinv(i) = min(prinv(i),prmax)
        prinv(i) = max(prinv(i),prmin)
      enddo
      do i = 1, im
        if(zol(i) > zolcr) then
          kpbl(i) = 1
        endif
      enddo
!
!     compute diffusion coefficients below pbl
!>  ## Compute diffusion coefficients below the PBL top
!!  Below the PBL top, the diffusion coefficients (\f$K_m\f$ and \f$K_h\f$) are ca
_1996 where a different value for \f$w_s\f$ (PBL vertical velocity scale) is used
ng the Prandtl number. The calculated diffusion coefficients are checked so that t
icients.
      do k = 1, kmpbl
      do i=1,im
         if(k < kpbl(i)) then
!           zfac = max((1.-(zi(i,k+1)-zl(i,1))/
!    1                 (hpbl(i)-zl(i,1))), zfmin)
            zfac = max((1.-zi(i,k+1)/hpbl(i)), zfmin)
            tem = zi(i,k+1) * (zfac**pfac) * moninq_fac ! lmh suggested by kg
            if(pblflg(i)) then
              tem1 = vk * wscaleu(i) * tem
!             dku(i,k) = xkzmo(i,k) + tem1
!             dkt(i,k) = xkzo(i,k)  + tem1 * prinv(i)
              dku(i,k) = tem1
              dkt(i,k) = tem1 * prinv(i)
            else
              tem1 = vk * wscale(i) * tem
!             dku(i,k) = xkzmo(i,k) + tem1
!             dkt(i,k) = xkzo(i,k)  + tem1 * prinv(i)
              dku(i,k) = tem1
              dkt(i,k) = tem1 * prinv(i)
            endif
```



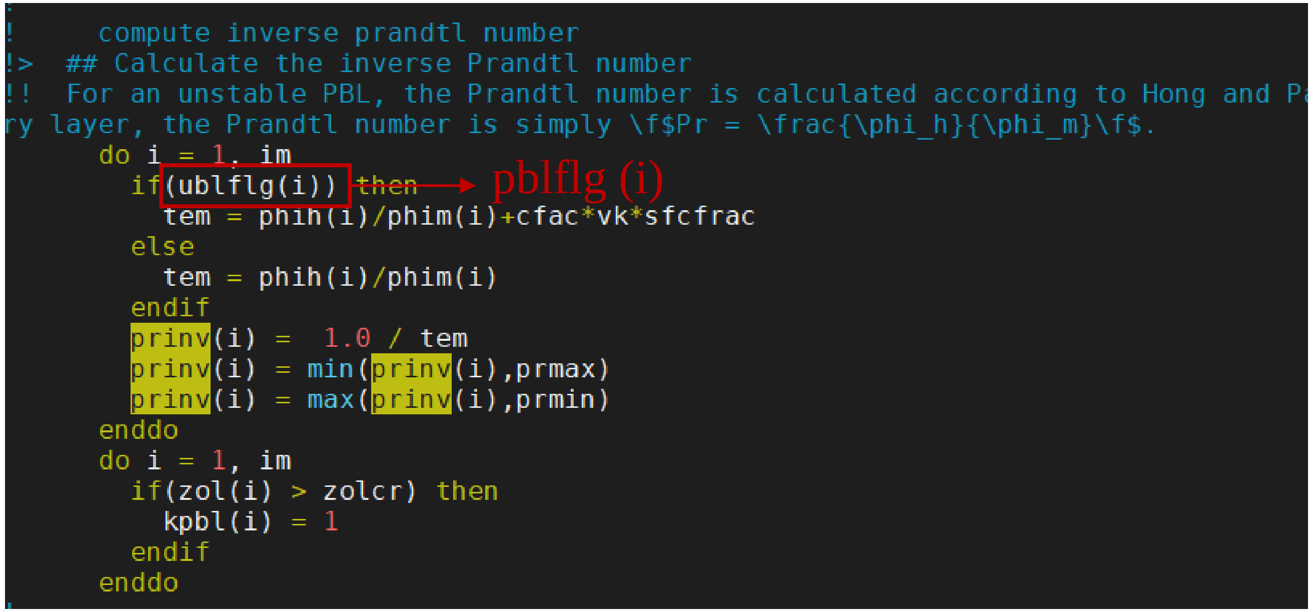
Surface Energy Flux (SEF)

stable (pblflg = .false.)
SEF < 0

unstable (pblflg = .true.)
SEF > 0

weakly unstable (ublflg = .true.)
SEF > 0 and $\zeta > -0.5$

strongly unstable (pcnvflg = .true.)
SEF > 0 and $\zeta < -0.5$



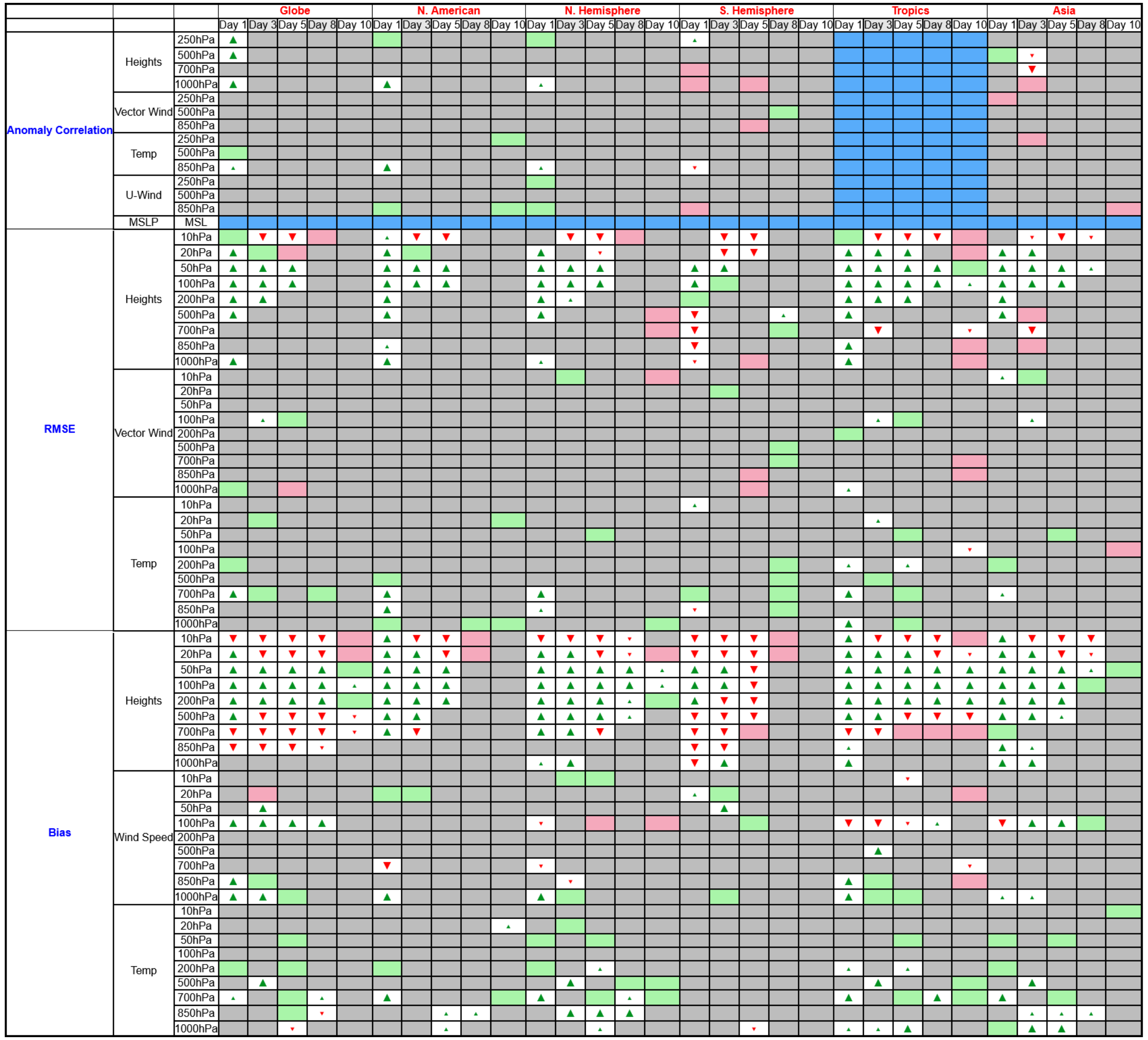
```
!     compute inverse prandtl number
!>  ## Calculate the inverse Prandtl number
!!  For an unstable PBL, the Prandtl number is calculated according to Hong and Pa
ry layer, the Prandtl number is simply \f$Pr = \frac{\phi_h}{\phi_m}\f$.
      do i = 1, im
        if(ublflg(i)) then
          tem = phih(i)/phim(i)+cfac*vk*sfcfrac
        else
          tem = phih(i)/phim(i)
        endif
        prinv(i) =  1.0 / tem
        prinv(i) = min(prinv(i),prmax)
        prinv(i) = max(prinv(i),prmin)
      enddo
      do i = 1, im
        if(zol(i) > zolcr) then
          kpbl(i) = 1
        endif
      enddo
```

pblflg (i)

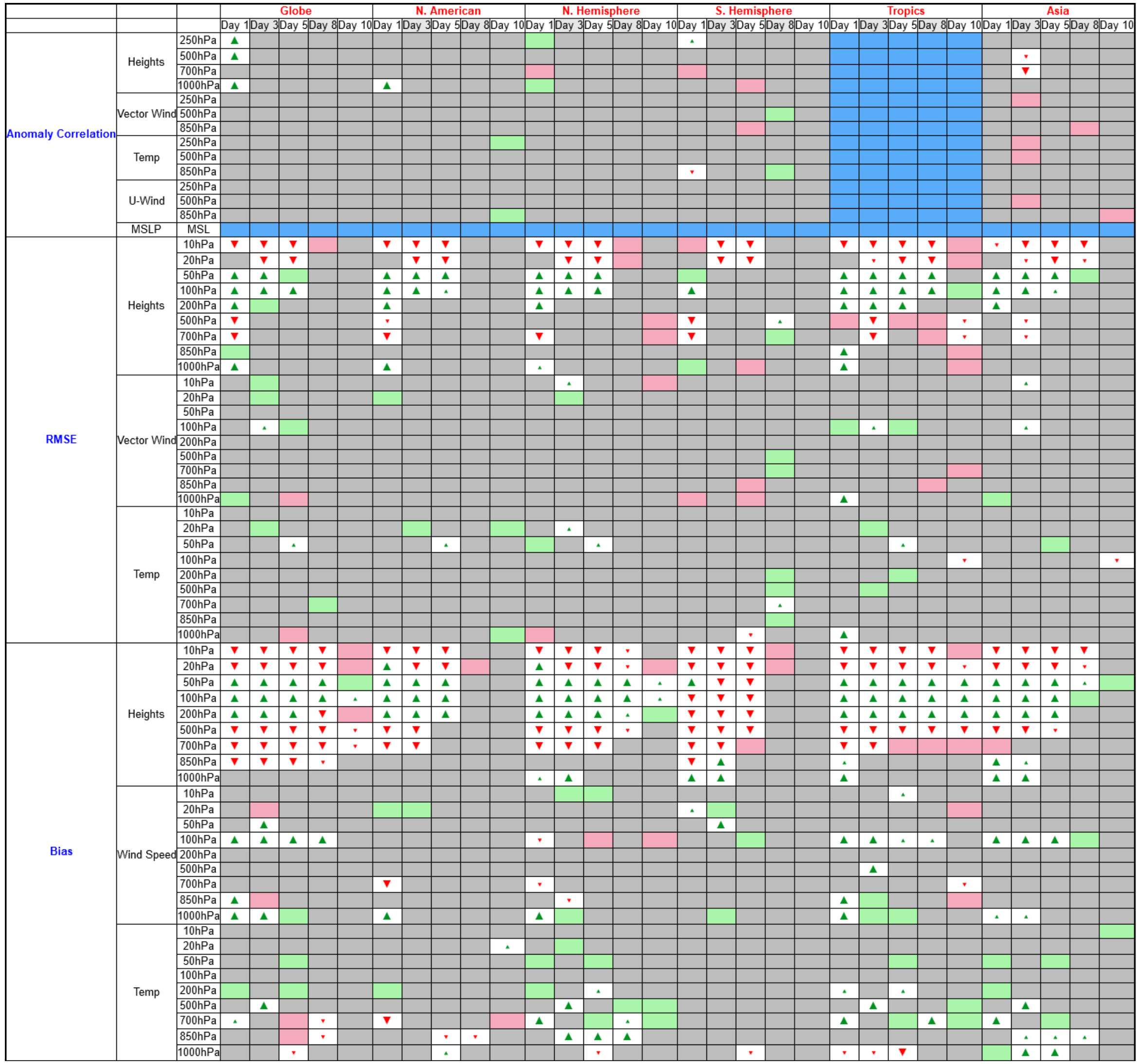
- Model: CWB FV3GFS (C384T), 64 layers
- Initialized at 0000 UTC each day from 01 Jun 2021 to 30 Jun 2021 (30 cases total)
- The experiments are integrated for 240 h
- **UNFG**: modified the conditional statement when the Prandtl number was calculated

EMC Verification Scorecard	
Symbol Legend	
▲	UNFG is better than CTRL at the 99.9% significance level
▴	UNFG is better than CTRL at the 99% significance level
🟩	UNFG is better than CTRL at the 95% significance level
▨	No statistically significant difference between UNFG and CTRL
🟥	UNFG is worse than CTRL at the 95% significance level
▾	UNFG is worse than CTRL at the 99% significance level
▼	UNFG is worse than CTRL at the 99.9% significance level
🟦	Not statistically relevant
Start Date: 20210531	
End Date: 20210710	

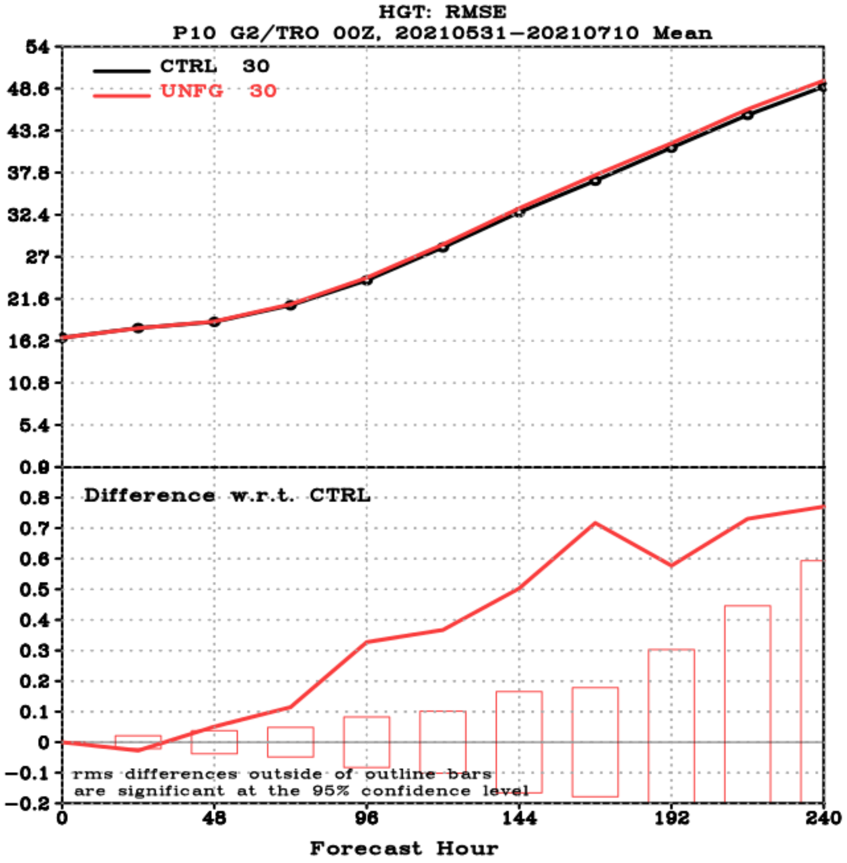
Verification data: NCEP


Globe
N. American
N. Hemisphere
S. Hemisphere
Tropics
Asia
Day 1
Day 3
Day 5
Day 8
Day 10
Anomaly Correlation
Heights
Vector Wind
Temp
U-Wind
MSLP
MSL
RMSE
Bias
Wind Speed
10hPa
20hPa
50hPa
100hPa
200hPa
250hPa
500hPa
700hPa
850hPa
1000hPa

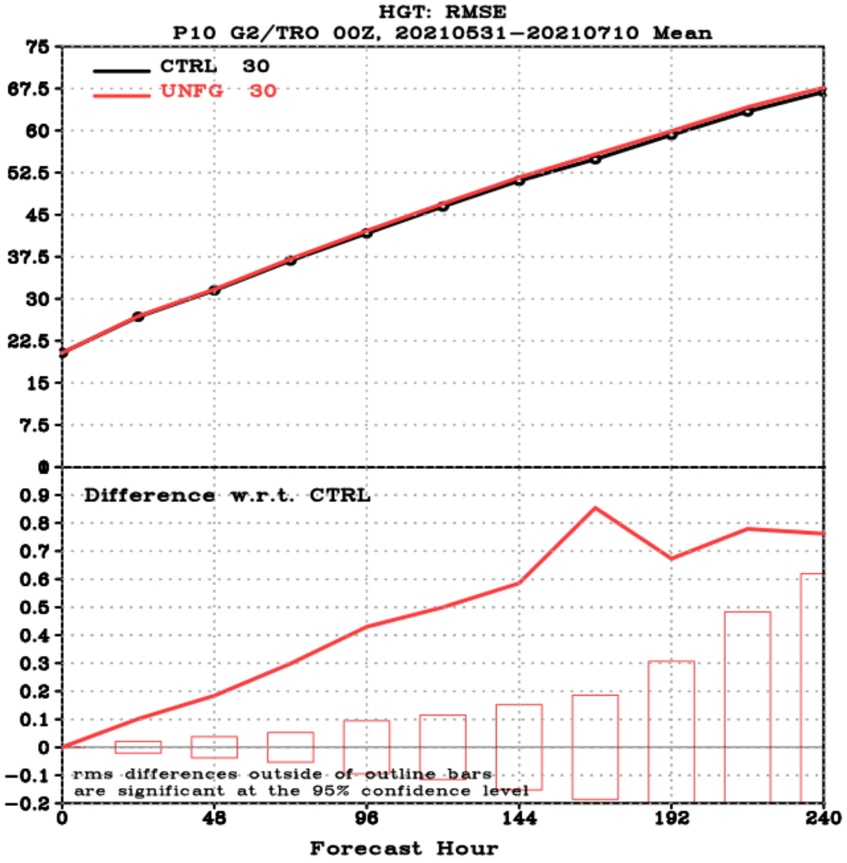
Verification data: ERA5


Globe
N. American
N. Hemisphere
S. Hemisphere
Tropics
Asia
Day 1
Day 3
Day 5
Day 8
Day 10
Anomaly Correlation
Heights
Vector Wind
Temp
U-Wind
MSLP
MSL
RMSE
Bias
Wind Speed
10hPa
20hPa
50hPa
100hPa
200hPa
250hPa
500hPa
700hPa
850hPa
1000hPa

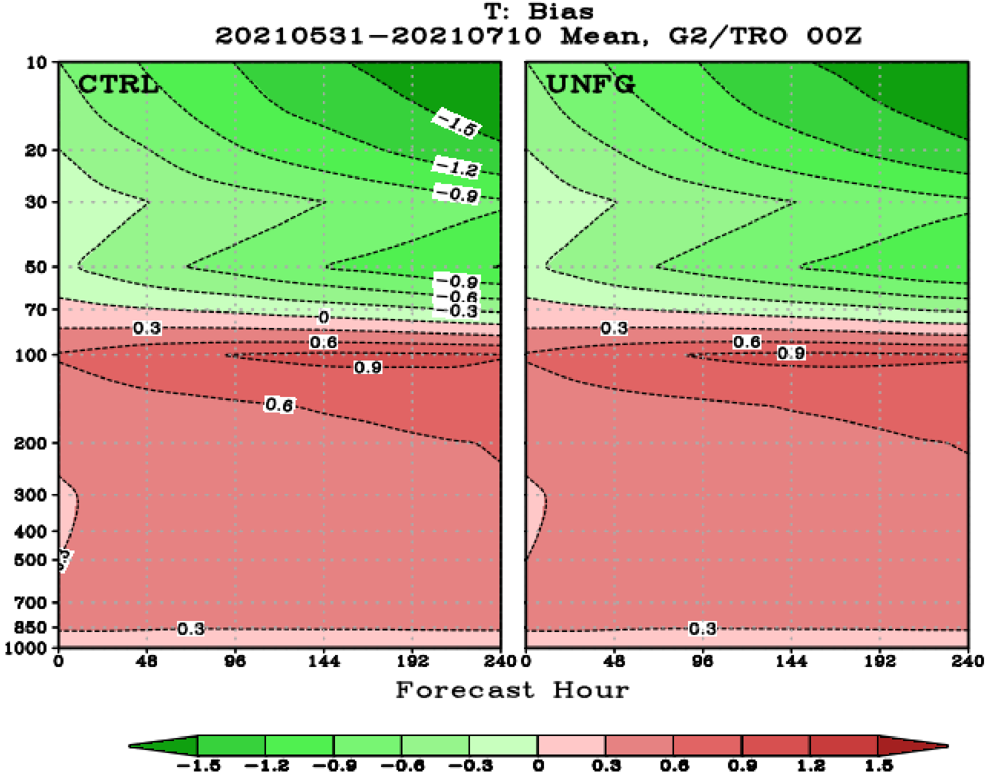
NCEP


HGT: RMSE
P10 G2/TRO 00Z, 20210531–20210710 Mean
CTRL 30
UNFG 30
54
48.6
43.2
37.8
32.4
27
21.6
16.2
10.8
5.4
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
Difference w.r.t. CTRL
rms differences outside of outline bars
are significant at the 95% confidence level
0
48
96
144
192
240
Forecast Hour

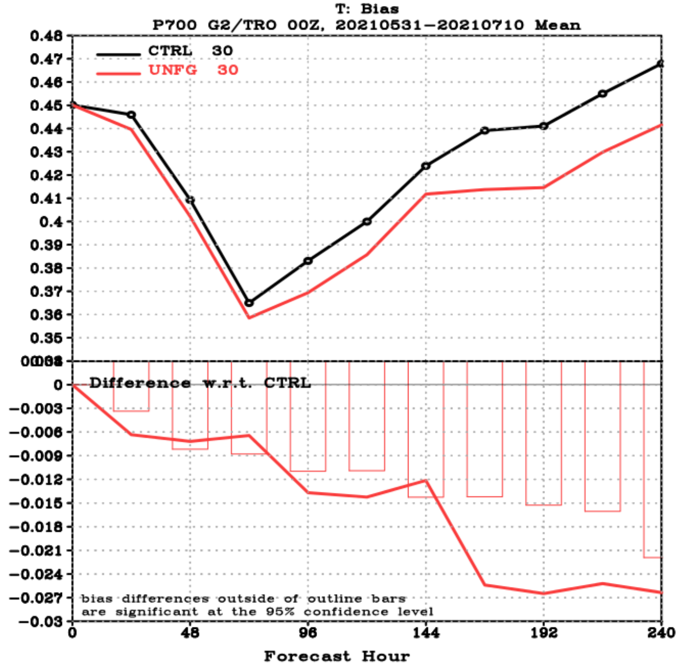
ERA5


HGT: RMSE
P10 G2/TRO 00Z, 20210531–20210710 Mean
CTRL 30
UNFG 30
75
67.5
60
52.5
45
37.5
30
22.5
15
7.5
0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
Difference w.r.t. CTRL
rms differences outside of outline bars
are significant at the 95% confidence level
0
48
96
144
192
240
Forecast Hour

T: Bias
20210531–20210710 Mean, G2/TRO 00Z

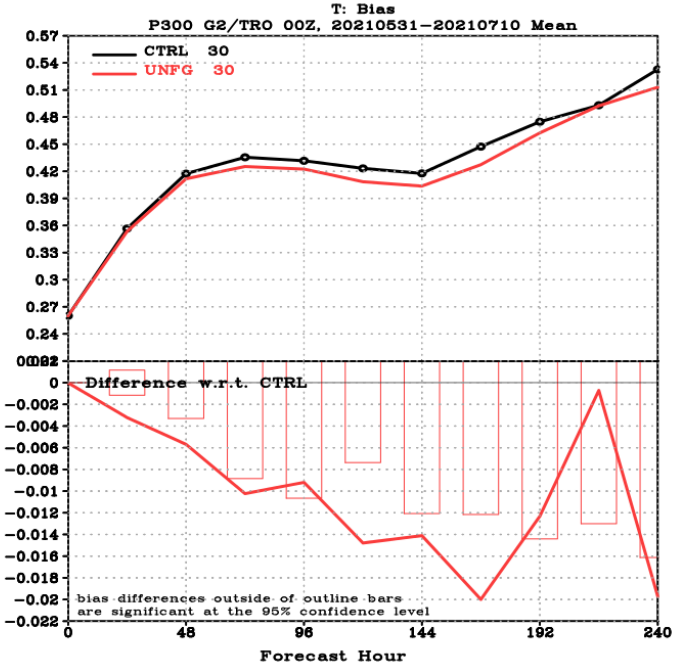


T: Bias
P700 G2/TRO 00Z, 20210531–20210710 Mean



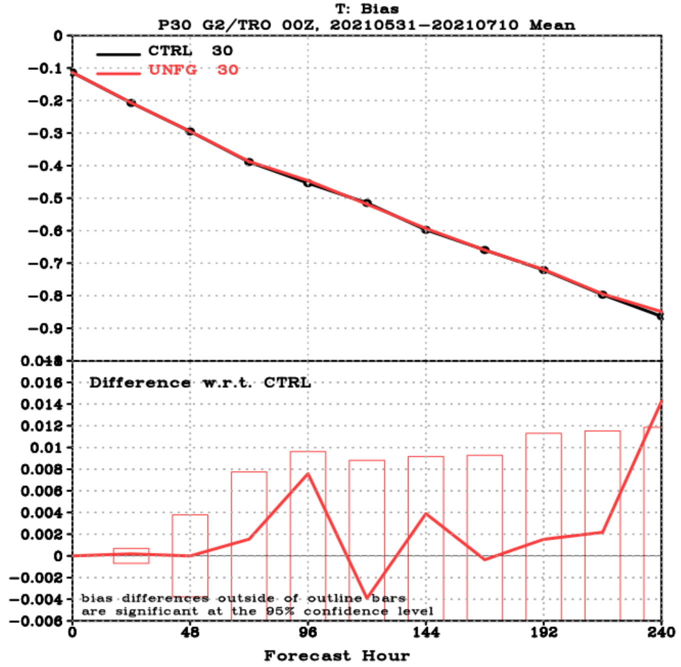
bias differences outside of outline bars are significant at the 95% confidence level

T: Bias
P300 G2/TRO 00Z, 20210531–20210710 Mean



bias differences outside of outline bars are significant at the 95% confidence level

T: Bias
P30 G2/TRO 00Z, 20210531–20210710 Mean



bias differences outside of outline bars are significant at the 95% confidence level