Idealized Tropical Cyclone(TC) Simulation with FV3GFS

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/ufs-weather-model/FV3/atmos_cubed_sphere/tools/test_cases.F90

(I) test_case=-55 in West Pacific with TC center (10N;180E)

(II) test_case= 55 in West Pacific with TC center (10N;180E)

(III) test_case= 57 in West Pacific with TC center (10N;180E) and f-plane (Coriolis parameter is constant)

(IV) test_case=57a in West Pacific with TC center (10N; 180E), f-plane and aqua-planet

(V) test_case= 4a/b Two-vortices interaction in Atlantic (shallow water model)

https://github.com/ClimateGlobalChange/DCMIP2016/blob/master/DCMIP2016-TestCaseDocument_v1.pdf

Jordan CL. Mean soundings for the west indies area. Journal of Meteorology 1958; 15(1):91–97.

subroutine DCMIP16_TC ----- test_case=-55 (./FV3/atmos_cubed_sphere/tools/test_cases.F90)

```
real, parameter :: zt = 15000 !< m
real, parameter :: q0 = 0.021 !< kg/kg
real, parameter :: qt = 1.e-11 !< kg/kg
real, parameter :: T0 = 302.15 !< K
real, parameter :: Tv0 = 302.15*(1.+0.608*q0) !< K
real, parameter :: Ts = 302.15 !< K
real, parameter :: zq1 = 3000. !< m
real, parameter :: zq2 = 8000. !< m
real, parameter :: lapse = 7.e-3 !< K/m
real, parameter :: Tvt = Tv0 - lapse*zt !< K
real, parameter :: pb = 101500. !< Pa
real, parameter :: ptt = pb*(TvT/Tv0)**(grav/Rdgas/lapse)
real(kind=R_GRID), parameter :: lamp = pi
real(kind=R_GRID), parameter :: phip = pi/18.
real(kind=R_GRID), parameter :: ppcenter(2) = (/ lamp, phip /)
real, parameter :: dp = 1115. !< Pa
real, parameter :: rp = 282000. !< m
real, parameter :: zp = 7000. !< m
real, parameter :: fc = 2.*OMEGA*sin(phip)
real, parameter :: zconv = 1.e-6
```

```
!PS
  do j=js,je
  do i=is,ie
    ps(i,j) = pb - dp*exp( -sqrt((rc(i,j)/rp)**3) )
  enddo
  enddo
```

zs=0 ….no orography

Initial TC in West Pacific (Test No.I /test_case=-55)

(Coriolis parameter is not constant)

pb=1015.0hPa, dp=11.15hPa, rp=282.0km

SLP: max=1015.00000000000 min=1004.44141134051

Surface wind:

U max = 19.4412681540063 min = -19.6647631637477

V max = 19.5408656635388 min = -19.8586152022006

Initial surface temperature /SST: 2016/10/03 00Z GFS analysis

```
!PS
  do j=js,je
  do i=is,ie
    ps(i,j) = pb - dp*exp( -sqrt((rc(i,j)/rp)**3) )
  enddo
  enddo
```

Physics(fv3_ccpp_gfs_v15p2):

NSSTM is active (2, 1, 0, 0, 0)

scale & aerosol-aware mass-flux deep conv scheme

scale-aware hybrid edmf PBL scheme used

scale- & aerosol-aware mass-flux shallow conv scheme (2017)

Original mountain blocking and oragraphic gravity wave drag parameterization used

non-statioary gravity wave drag parameterization used (do_gwd= T)

Radiative heating calculated at 64 layers

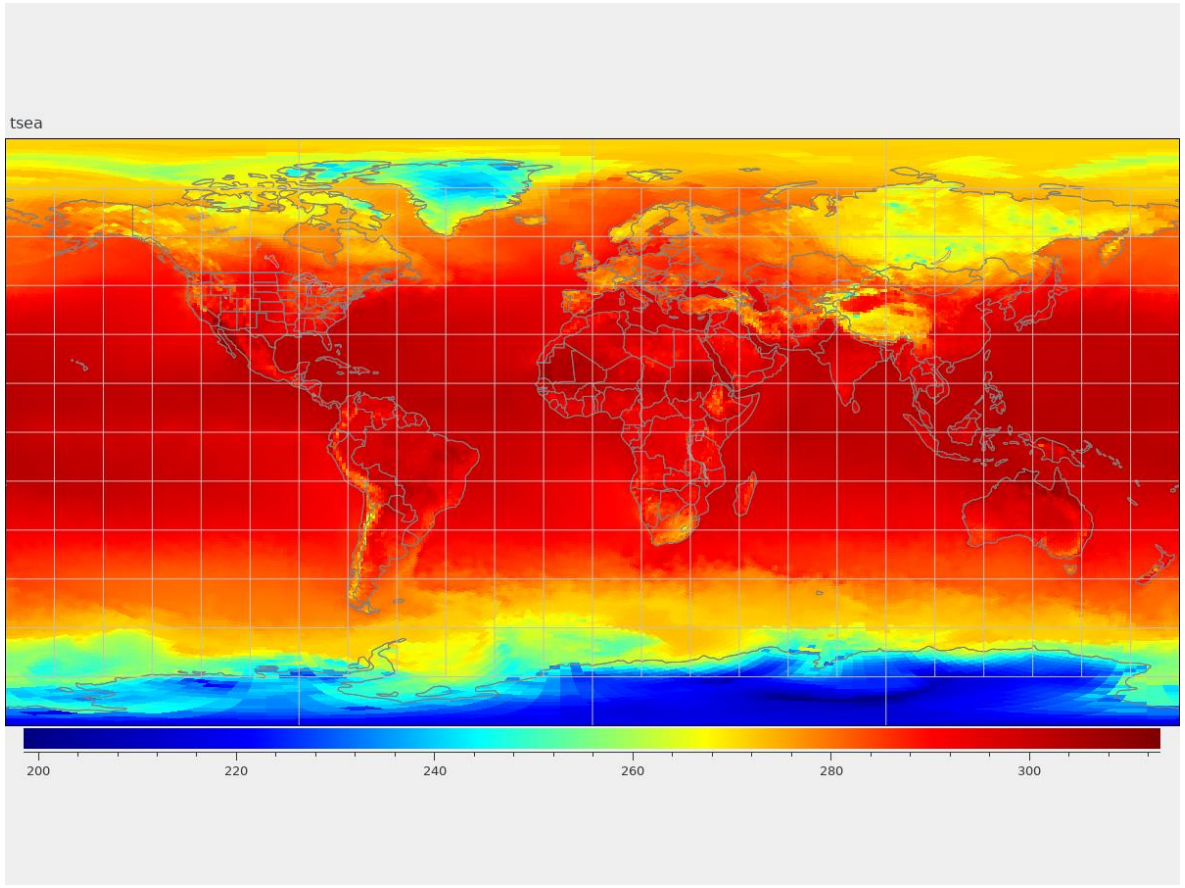
max-random cloud overlap for Shortwave IOVR_SW= 1

max-random cloud overlap for Longwave IOVR_LW= 1

sub-grid cloud for Shortwave ISUBC_SW= 2

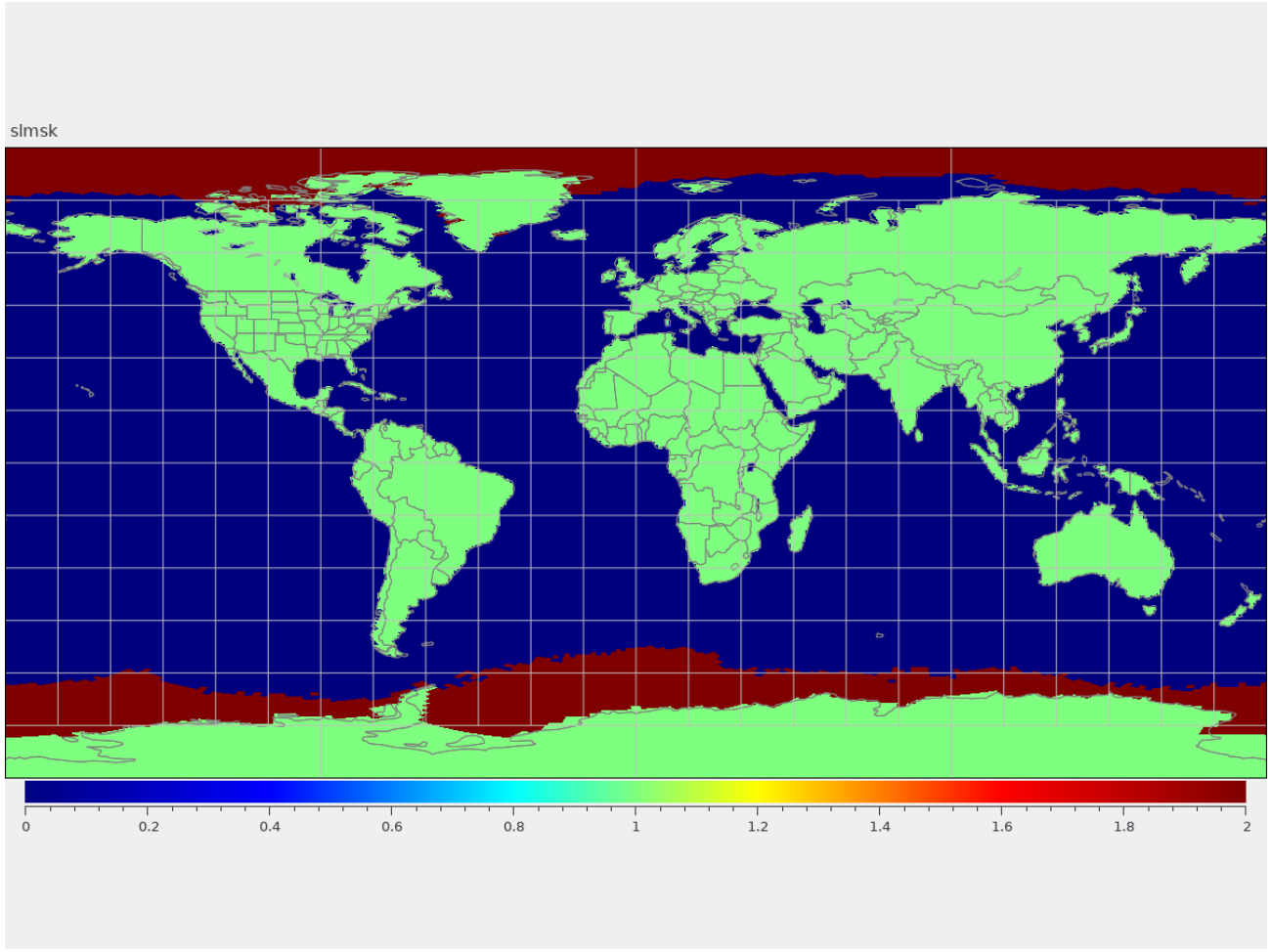
sub-grid cloud for Longwave ISUBC_LW= 2

Using GFDL Cloud Microphysics



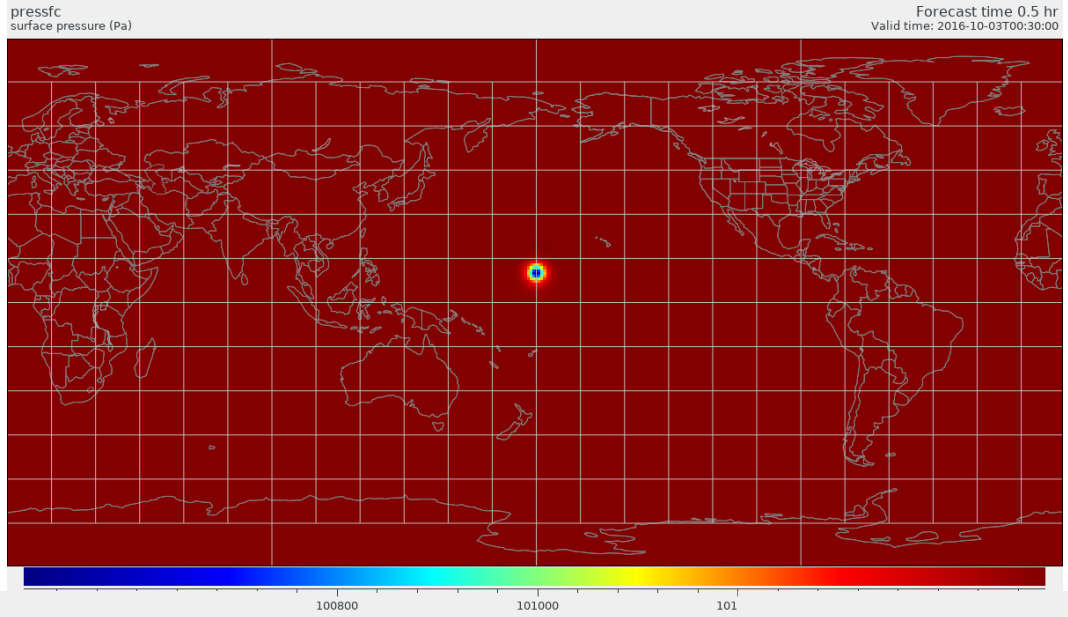
TSEA in sfc_data.tile*.nc
2016/10/03 00Z GFS analysis

Land_sea_ice mask
SLMSK in sfc_data.tile*.nc

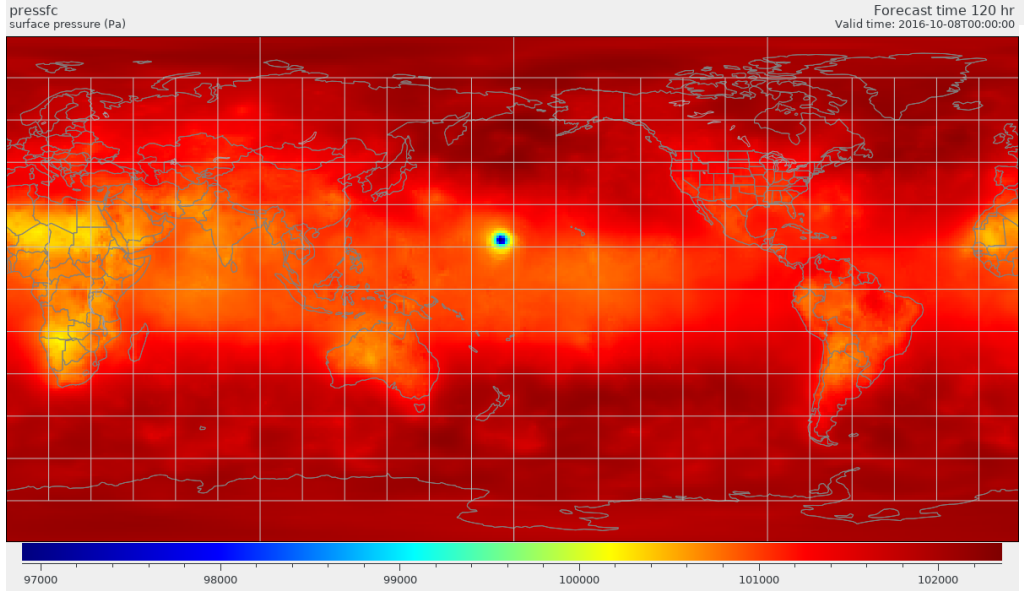


Test No.I /-55
Surface Pressure

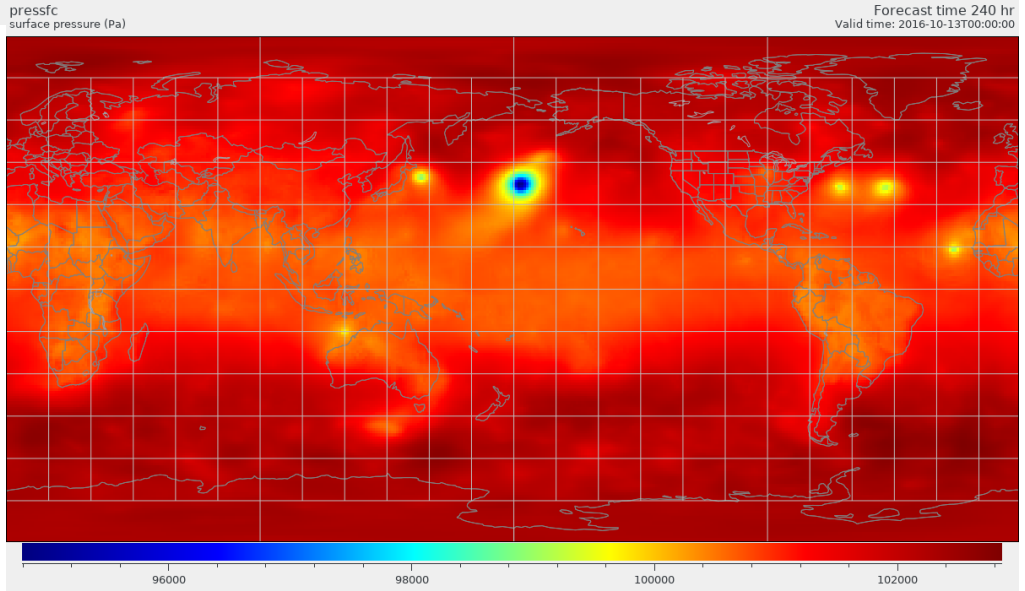
@0.5 hrs



@120 hrs

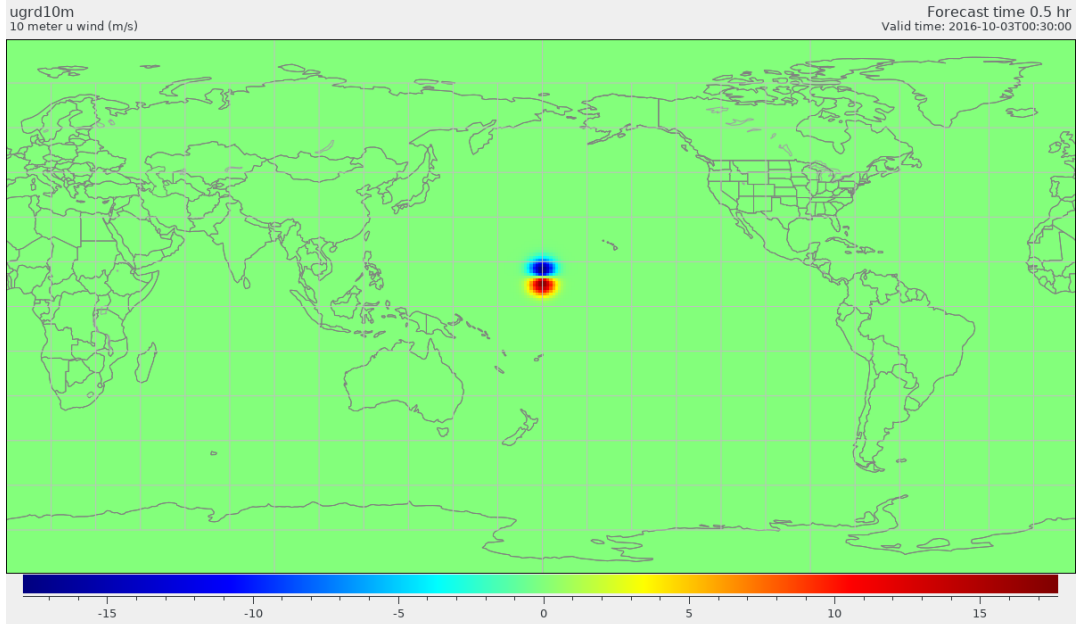


@240 hrs

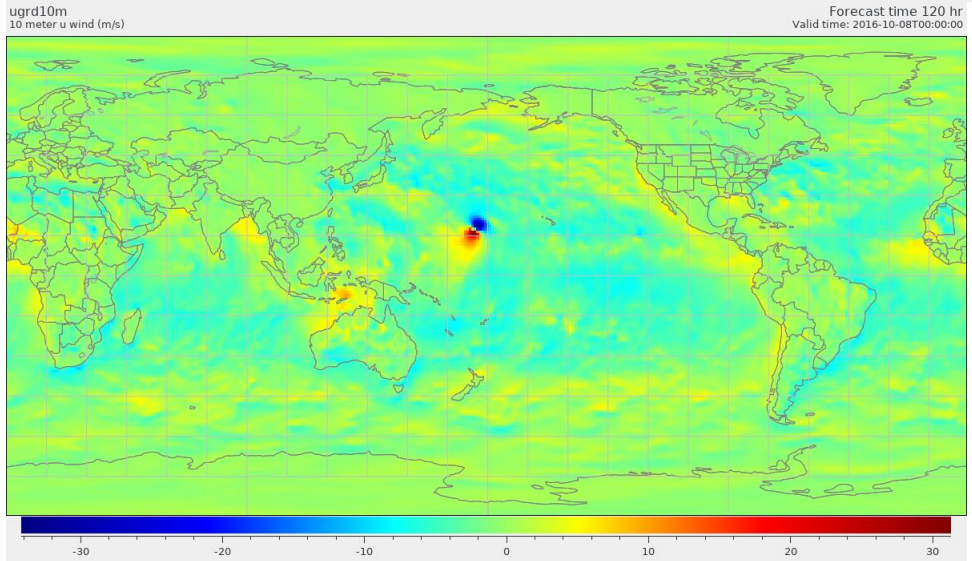


Test No.I /-55
U at 10m

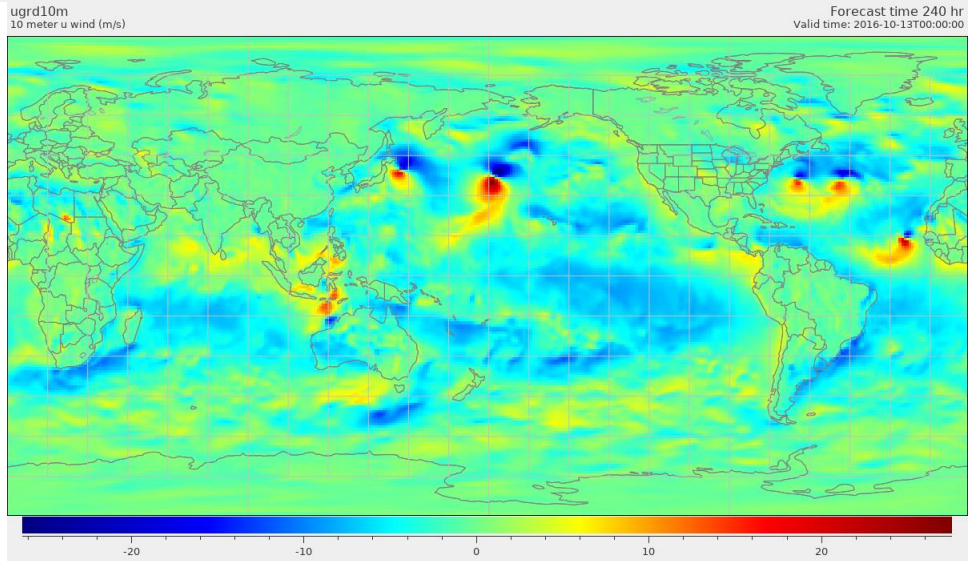
@0.5 hrs



@120 hrs



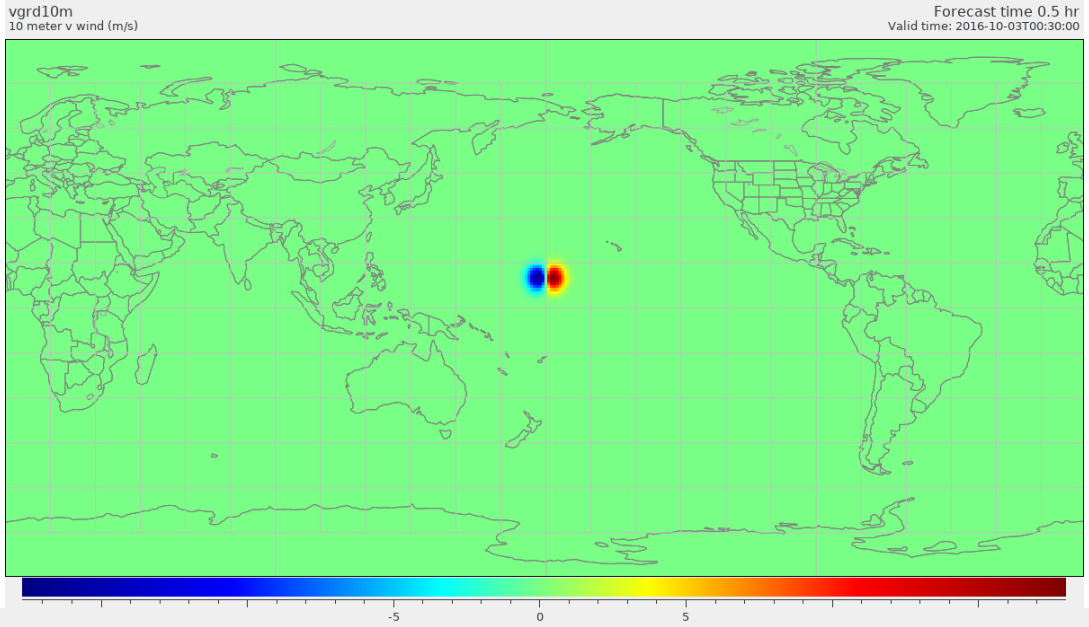
@240 hrs



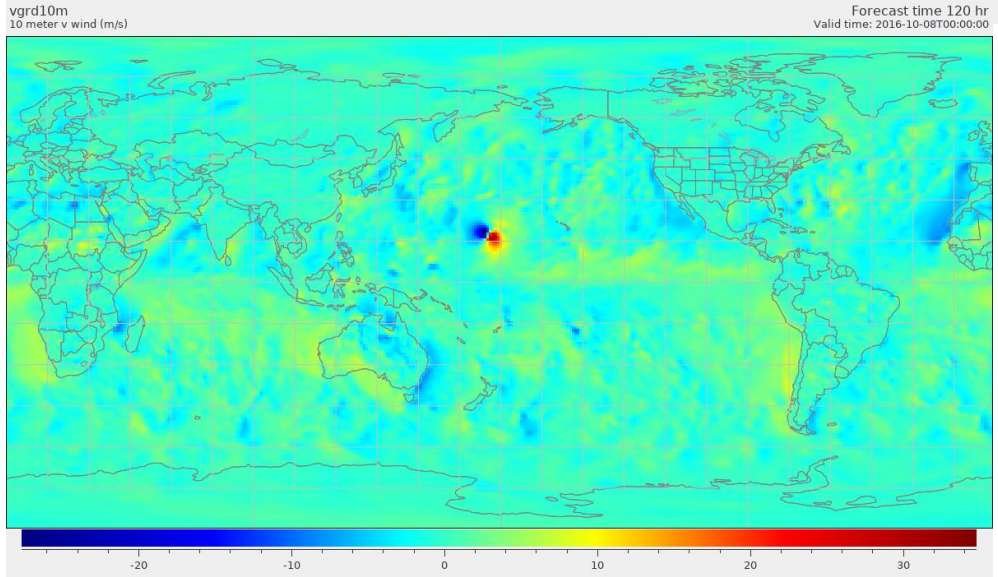
Test No.I /-55

V at 10m

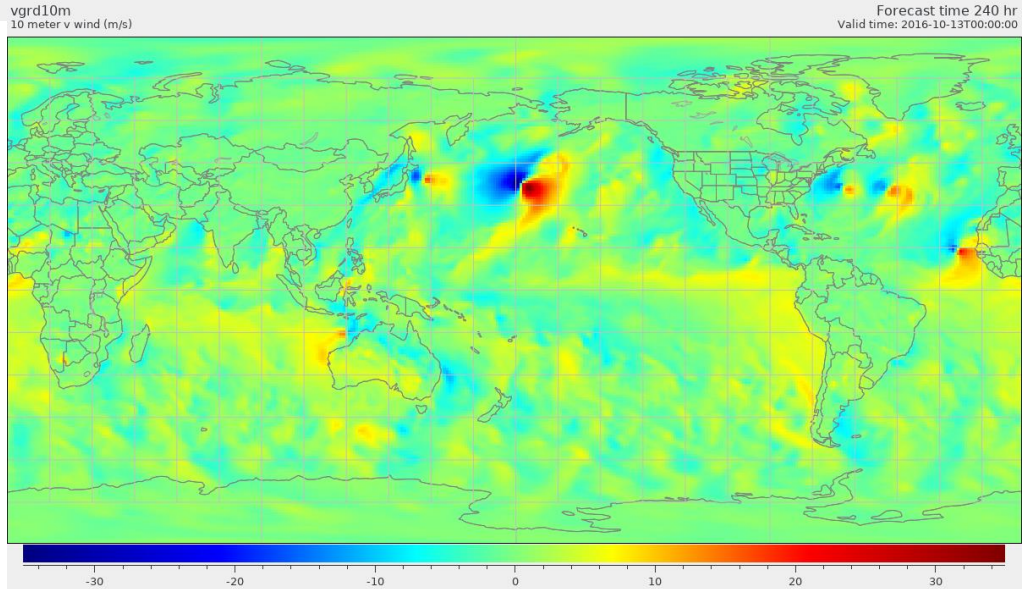
@0.5 hrs



@120 hrs



@240 hrs



Test No.II /test_case= 55

(Coriolis parameter is not constant)

p00=1015.0hPa, dp=11.15hPa, rp=282.0km

The initial TC of Test No.II (test_case=55) is similar to Test No.I (test_case=-55), there may be some difference in thermal structure.

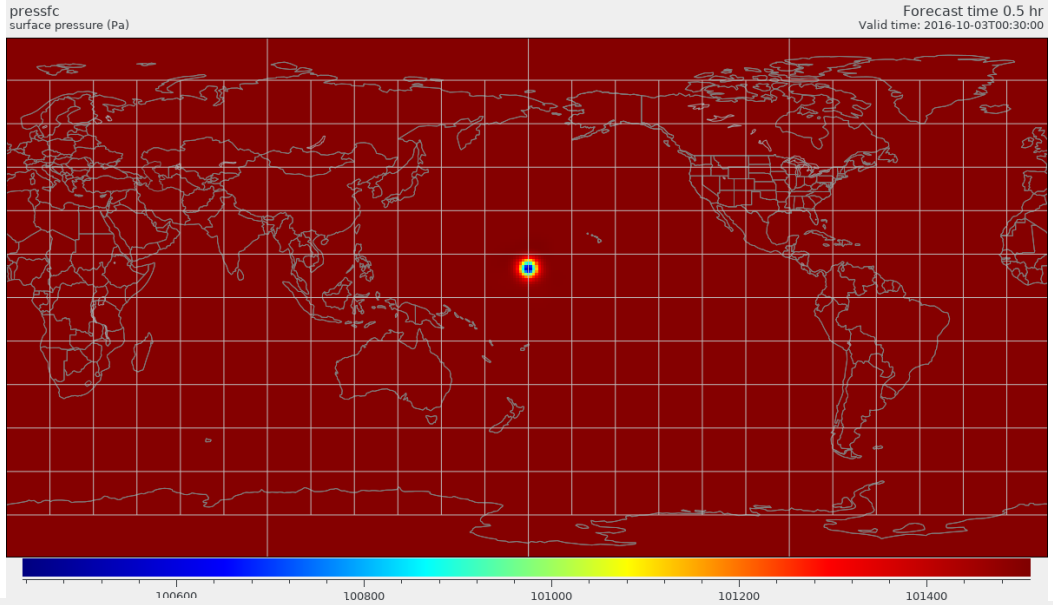
Surface pressure (PS) max=1015.00000000000 min=1004.44141134051
U max = 19.4412681540063 min = -19.6647631637477
V max = 19.5408656635388 min = -19.8586152022006

```
! Initialize surface Pressure
      !Vortex perturbation
      do j=js,je
      do i=is,ie
        p2(:) = agrid(i,j,1:2)
        r = great_circle_dist( p0, p2, radius )
        ps(i,j) = p00 - dp*exp(-(r/rp)**1.5)
        phis(i,j) = 0.
      enddo
      enddo
```

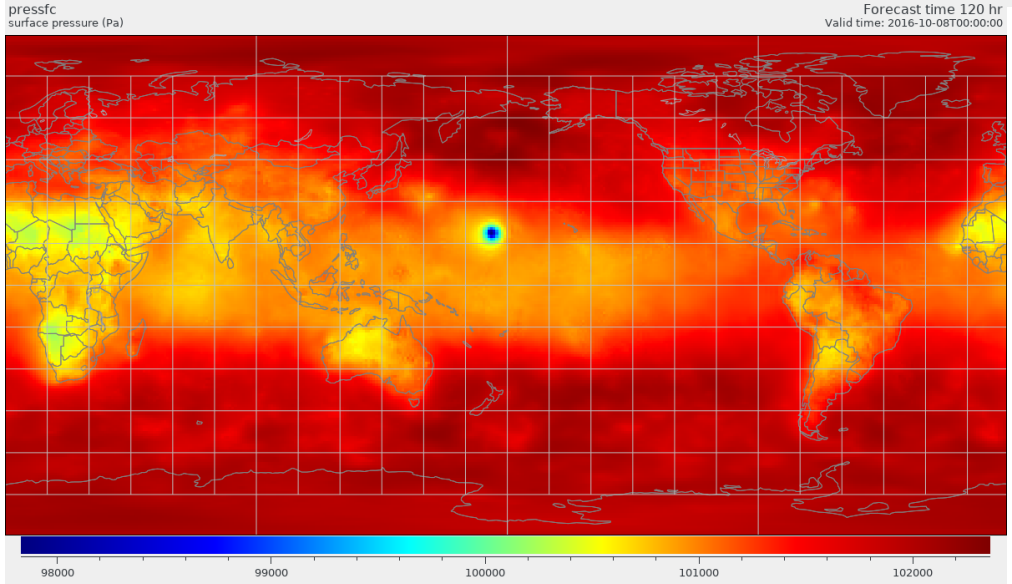
Test No.II/ 55

Surface Pressure

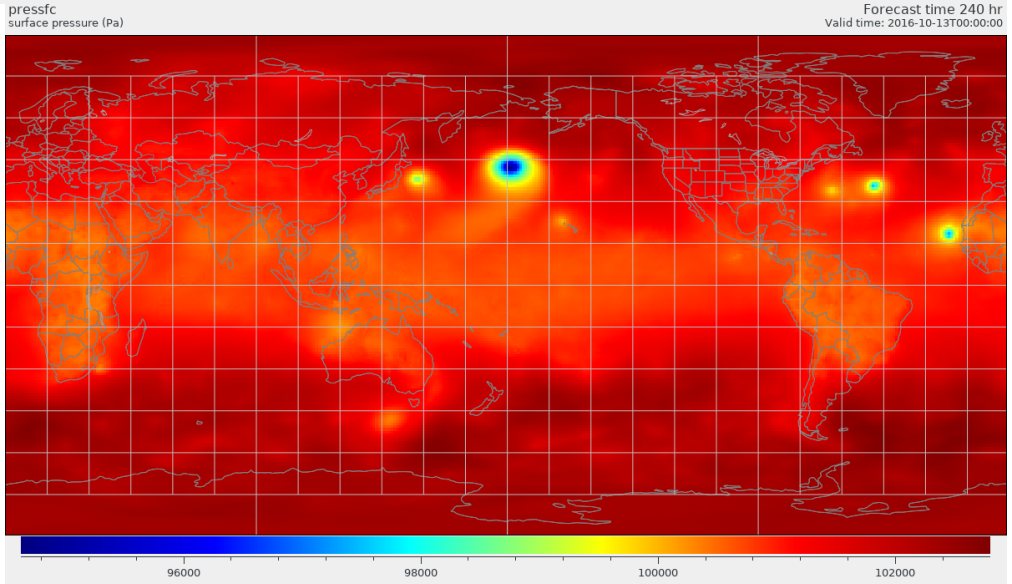
@0.5 hrs



@120 hrs



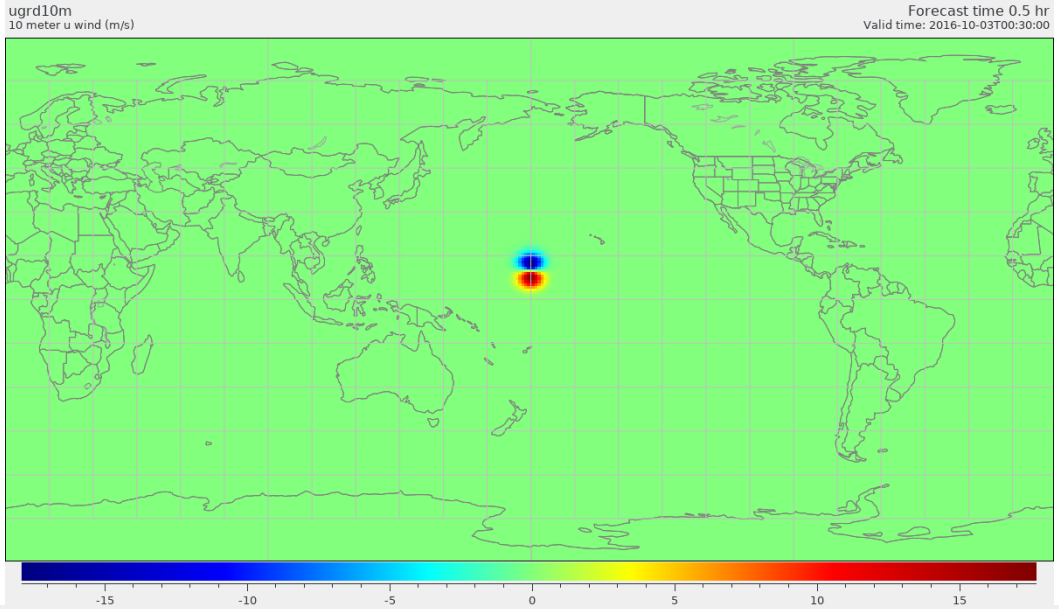
@240 hrs



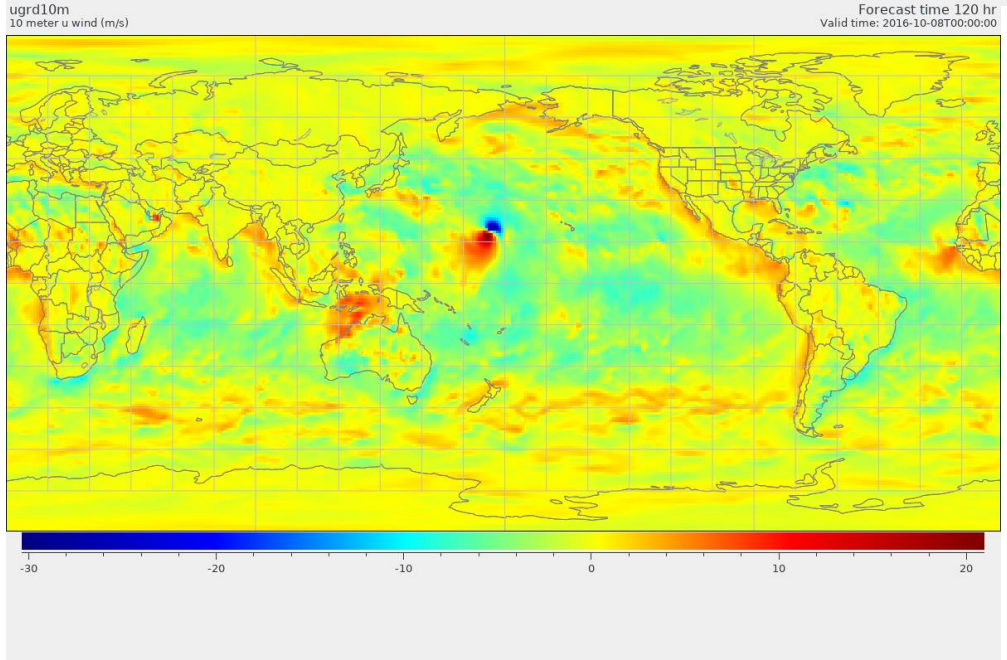
Test No.II/ 55

U at 10m

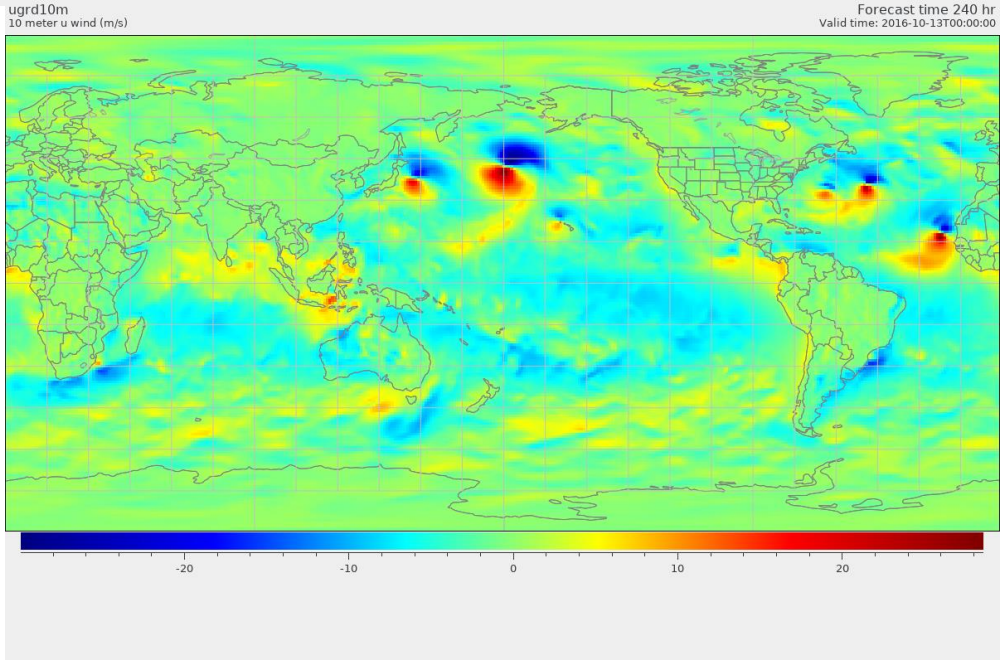
@0.5 hrs



@120 hrs



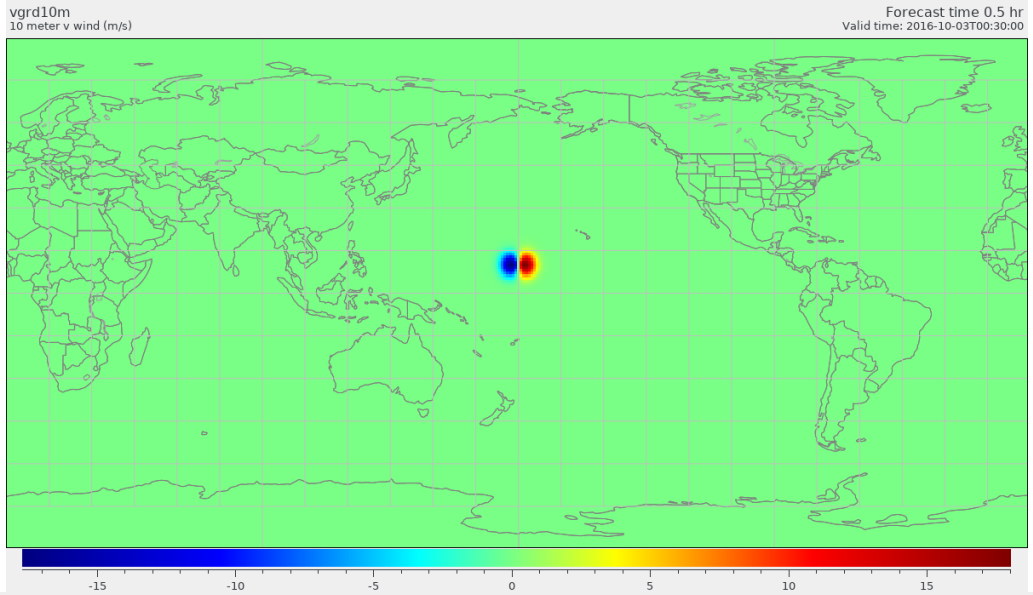
@240 hrs



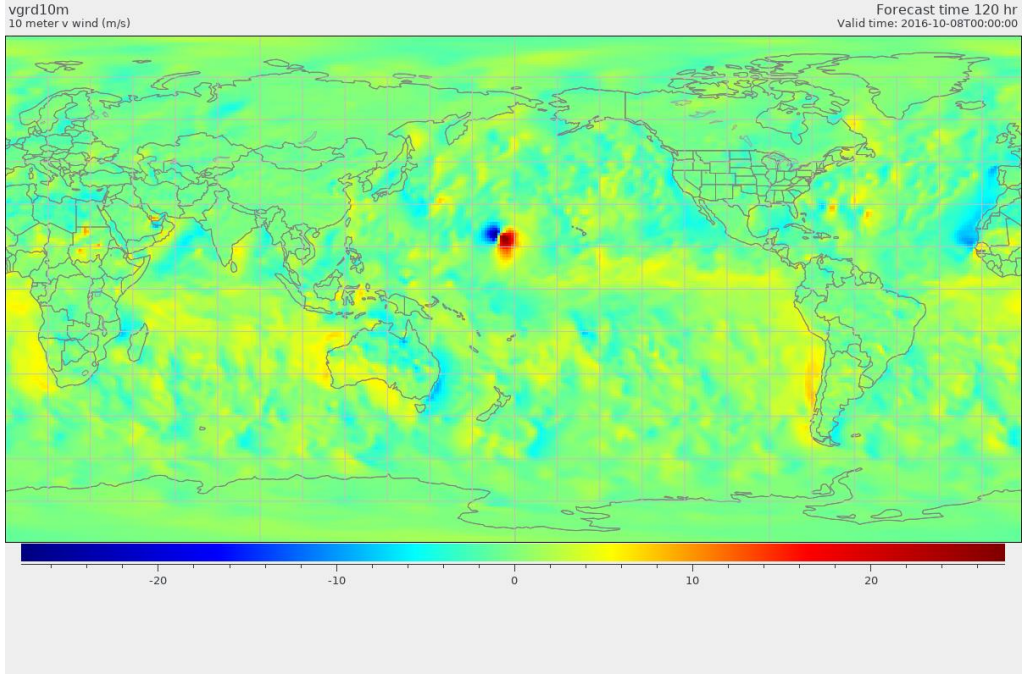
Test No.II/ 55

V at 10m

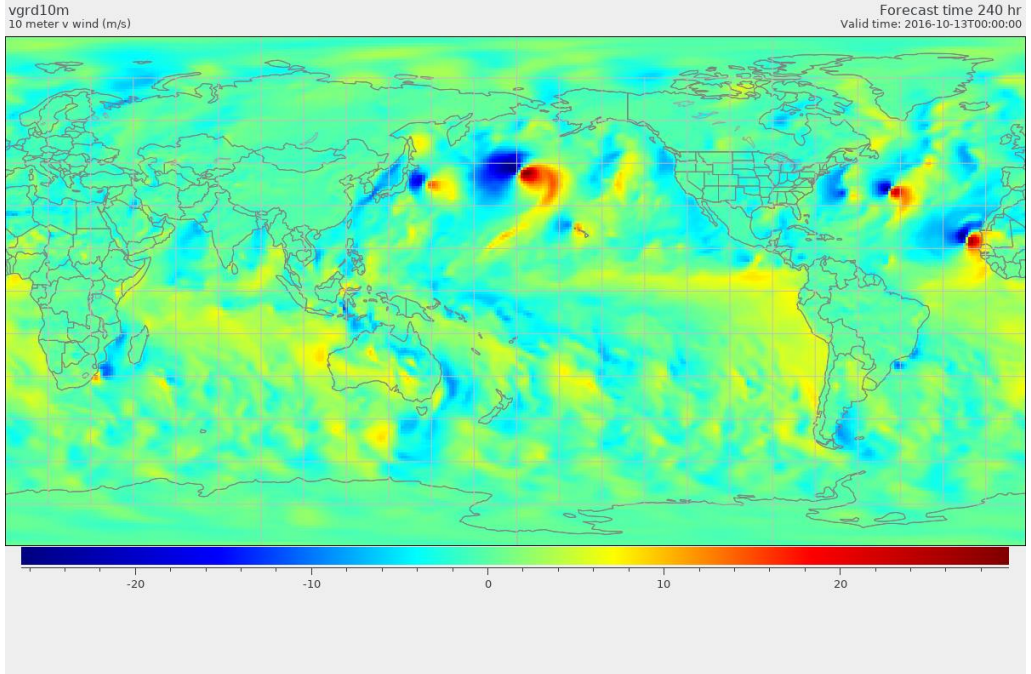
@0.5 hrs



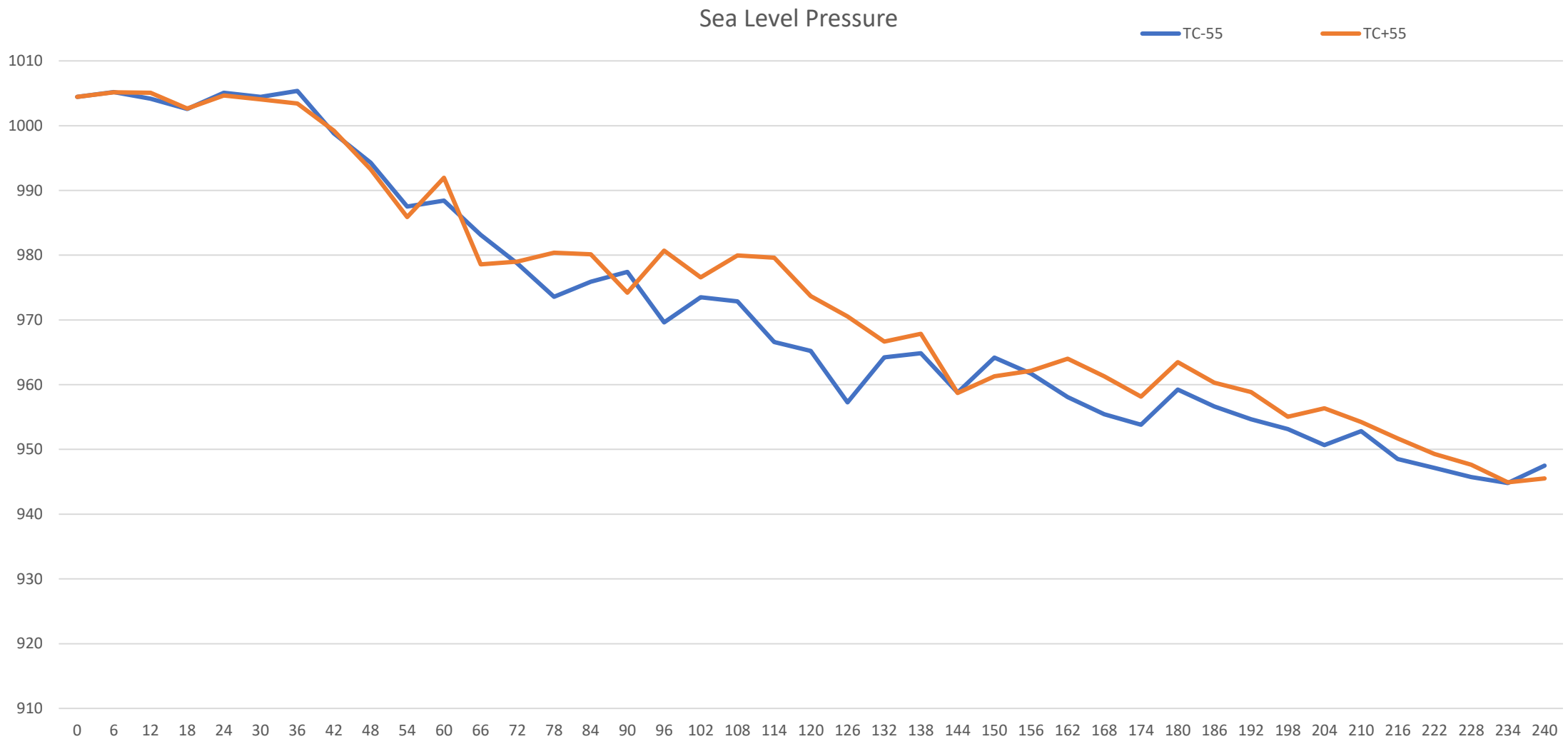
@120 hrs



@240 hrs



Test NO.I/II SLP forecast



Forecast hours

Test No.III (test_case= 57) on f-plane

(Coriolis parameter is constant)

p00=1015.0hPa, dp=11.15hPa, rp=282.0km

```
! Initialize surface Pressure
!Vortex perturbation
do j=js,je
do i=is,ie
   p2(:) = agrid(i,j,1:2)
   r = great_circle_dist( p0, p2, radius )
   ps(i,j) = p00 - dp*exp(-(r/rp)**1.5)
   phis(i,j) = 0.
enddo
enddo
```

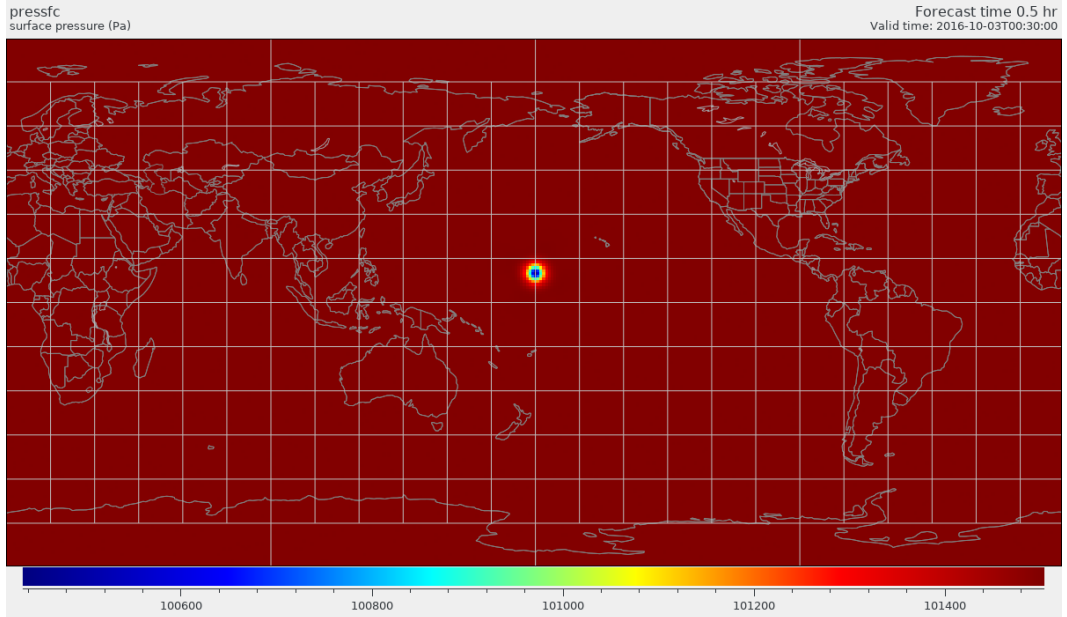
Surface pressure (PS) max= 1015.00000000000 min=1004.44141134051

U max = 19.4412124264969 min = -19.6647077418568

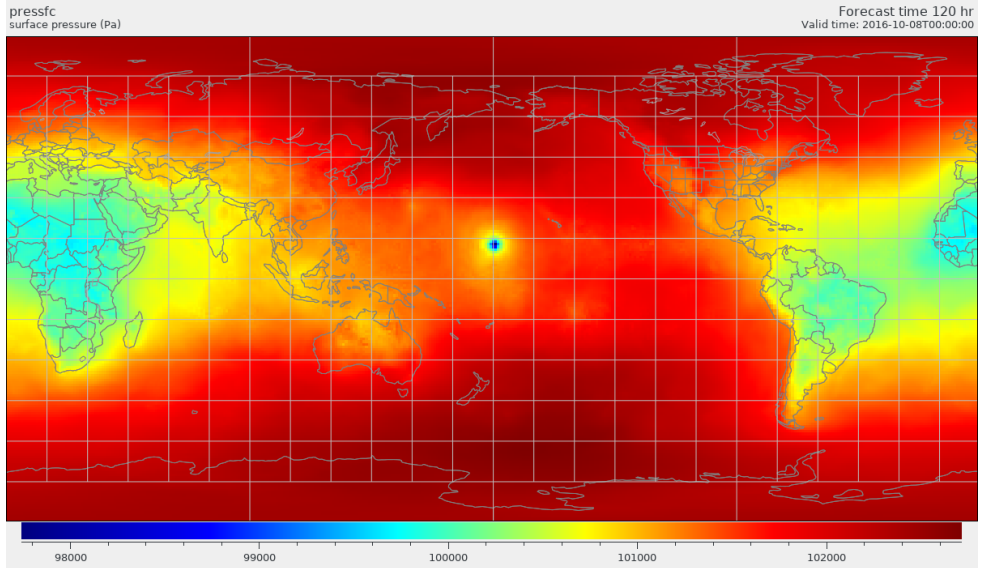
V max = 19.5408117630522 min = -19.8585596483430

Test No.III / 57
Surface Pressure

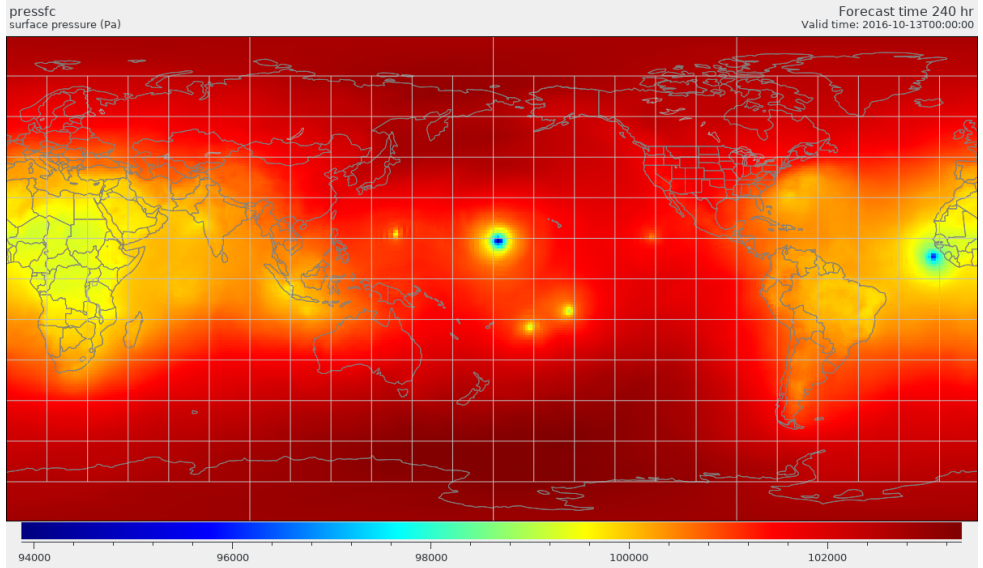
@0.5 hrs



@120 hrs



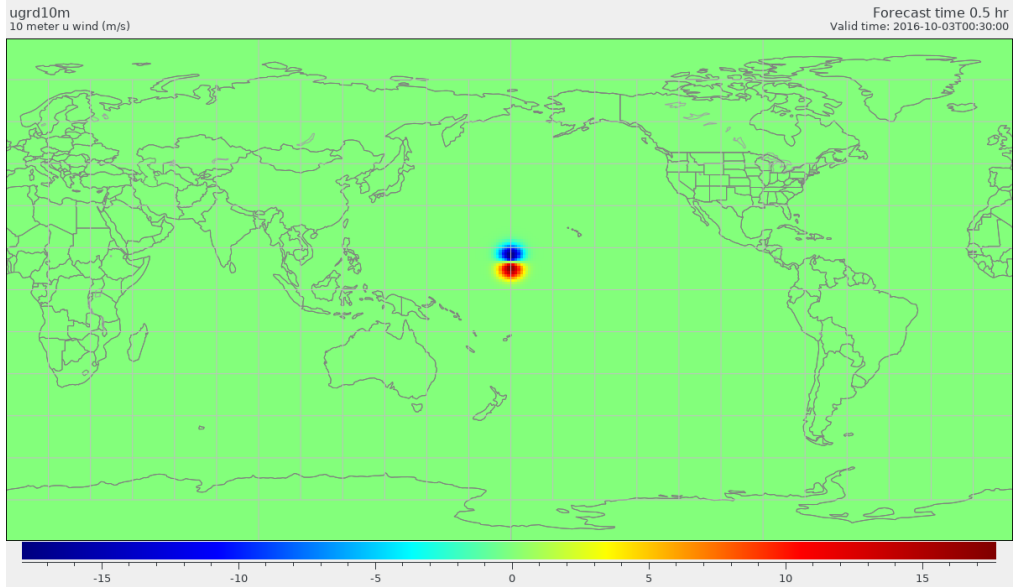
@240 hrs



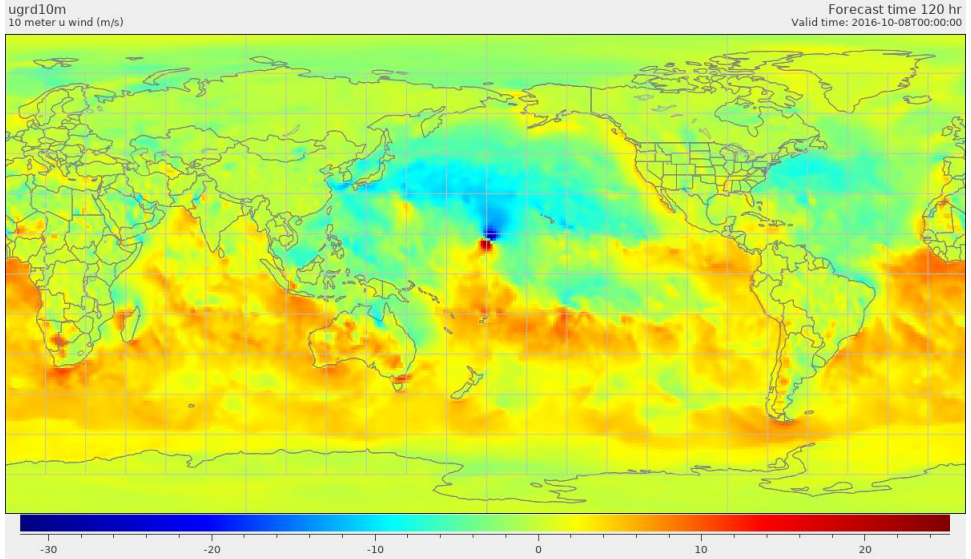
Test No.III / 57

U at 10m

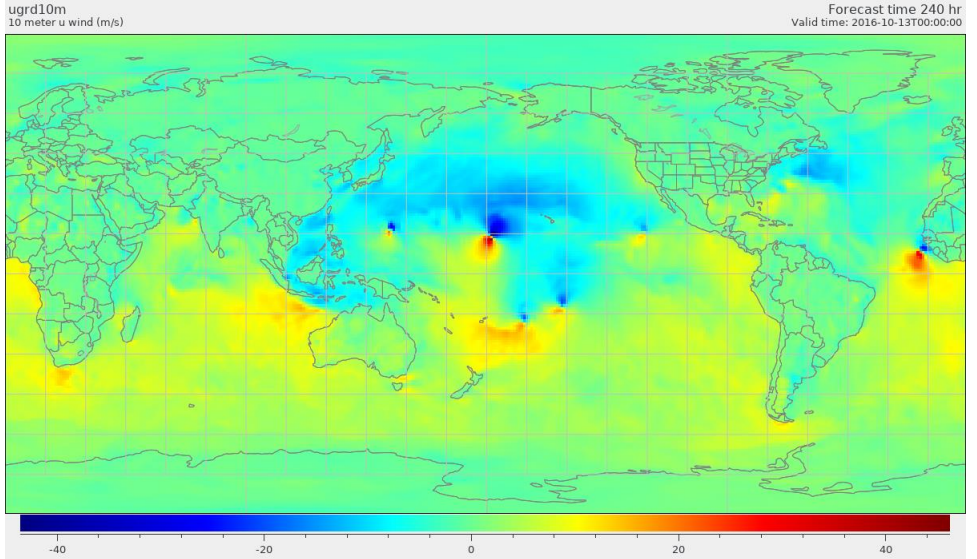
@0.5 hrs



@120 hrs



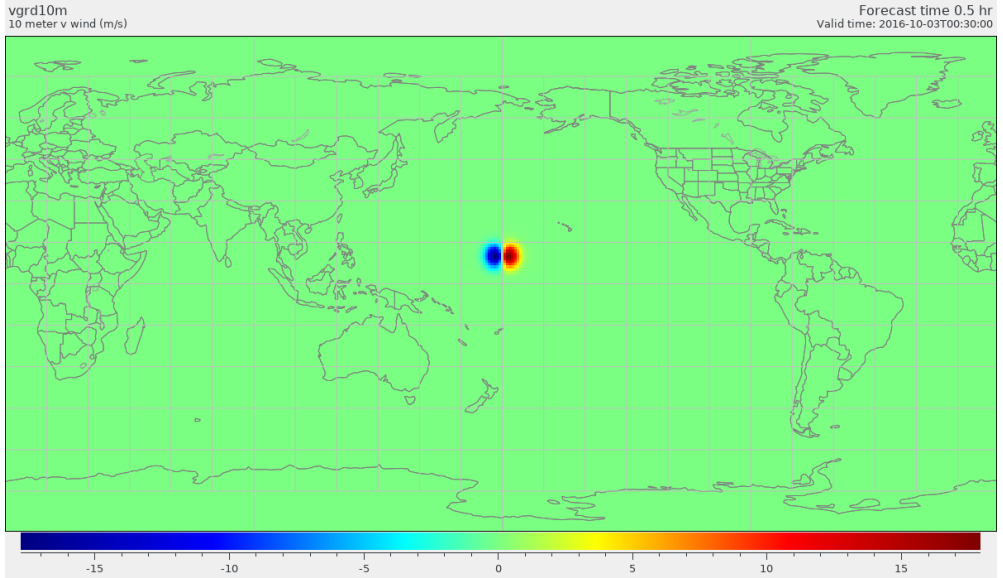
@240 hrs



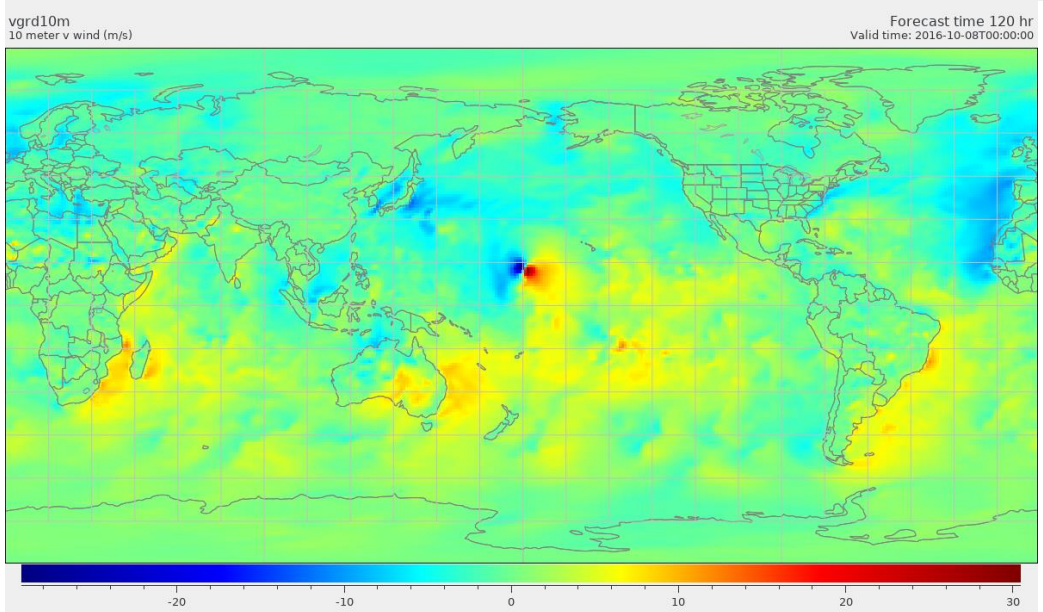
Test No.III / 57

V at 10m

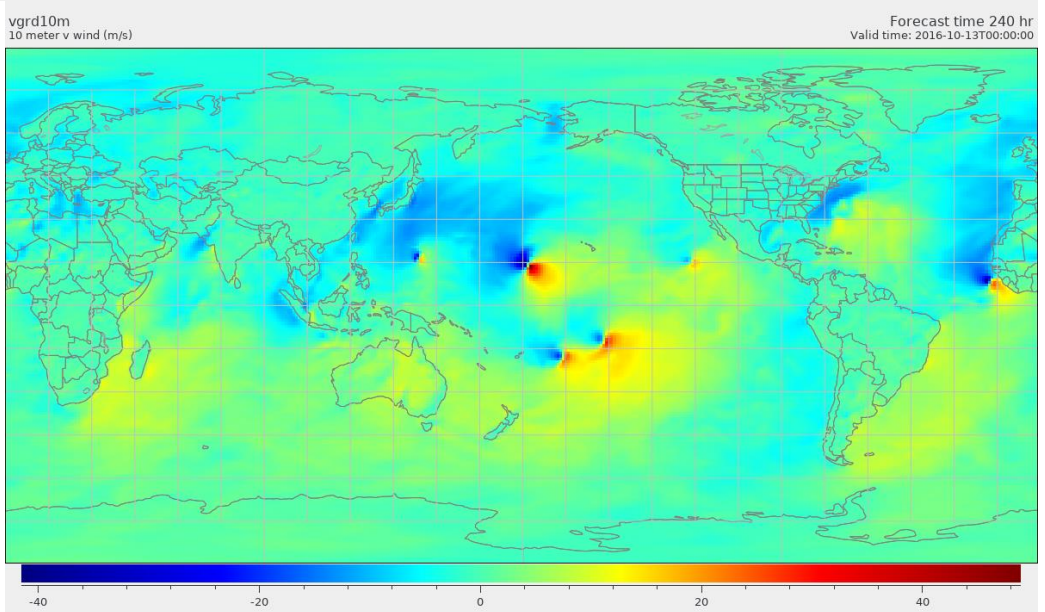
@0.5 hrs



@120 hrs



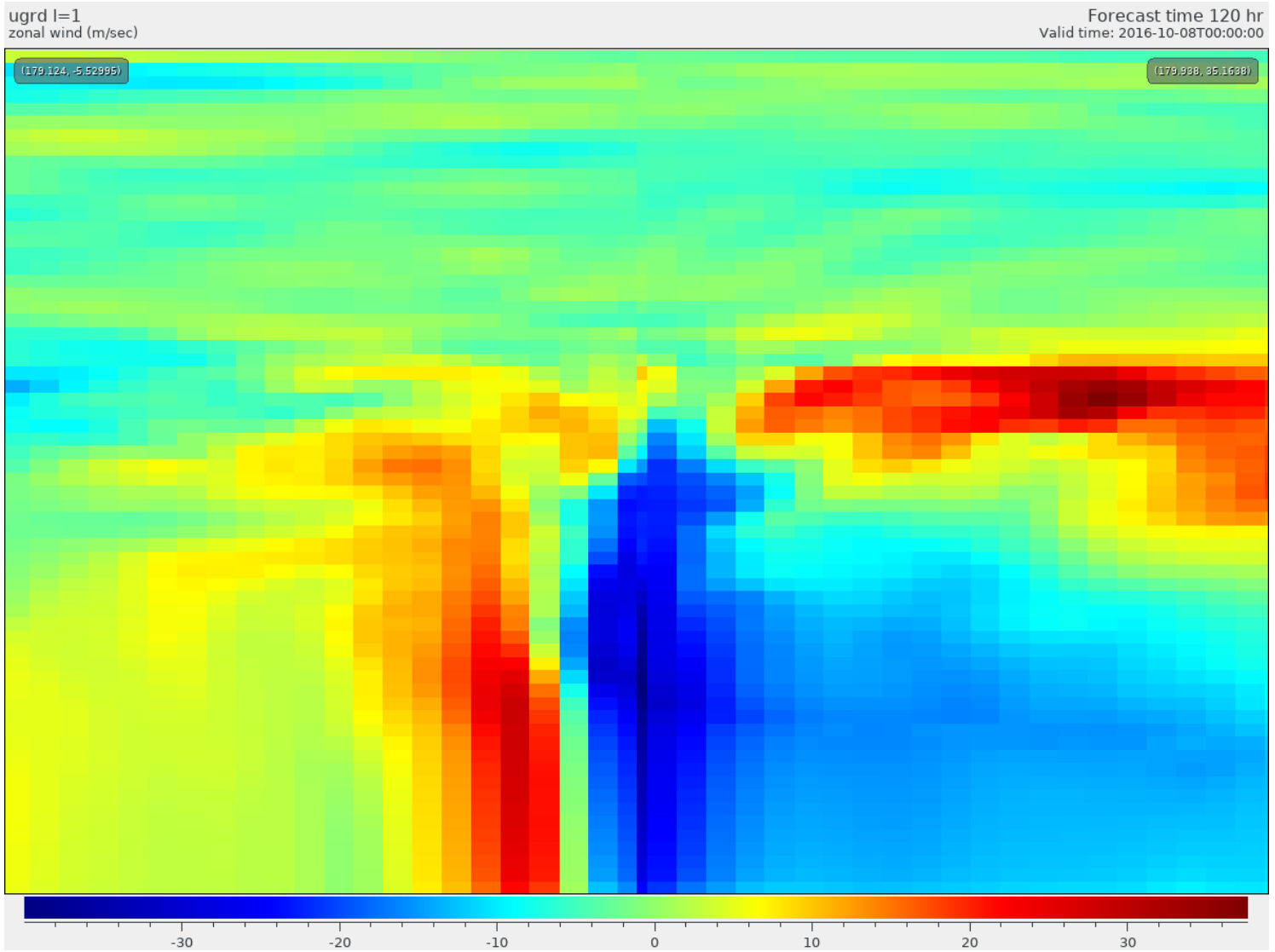
@240 hrs



Test No.III / 57

Zonal wind (U)

Cross-section @180E



@120 hrs

South

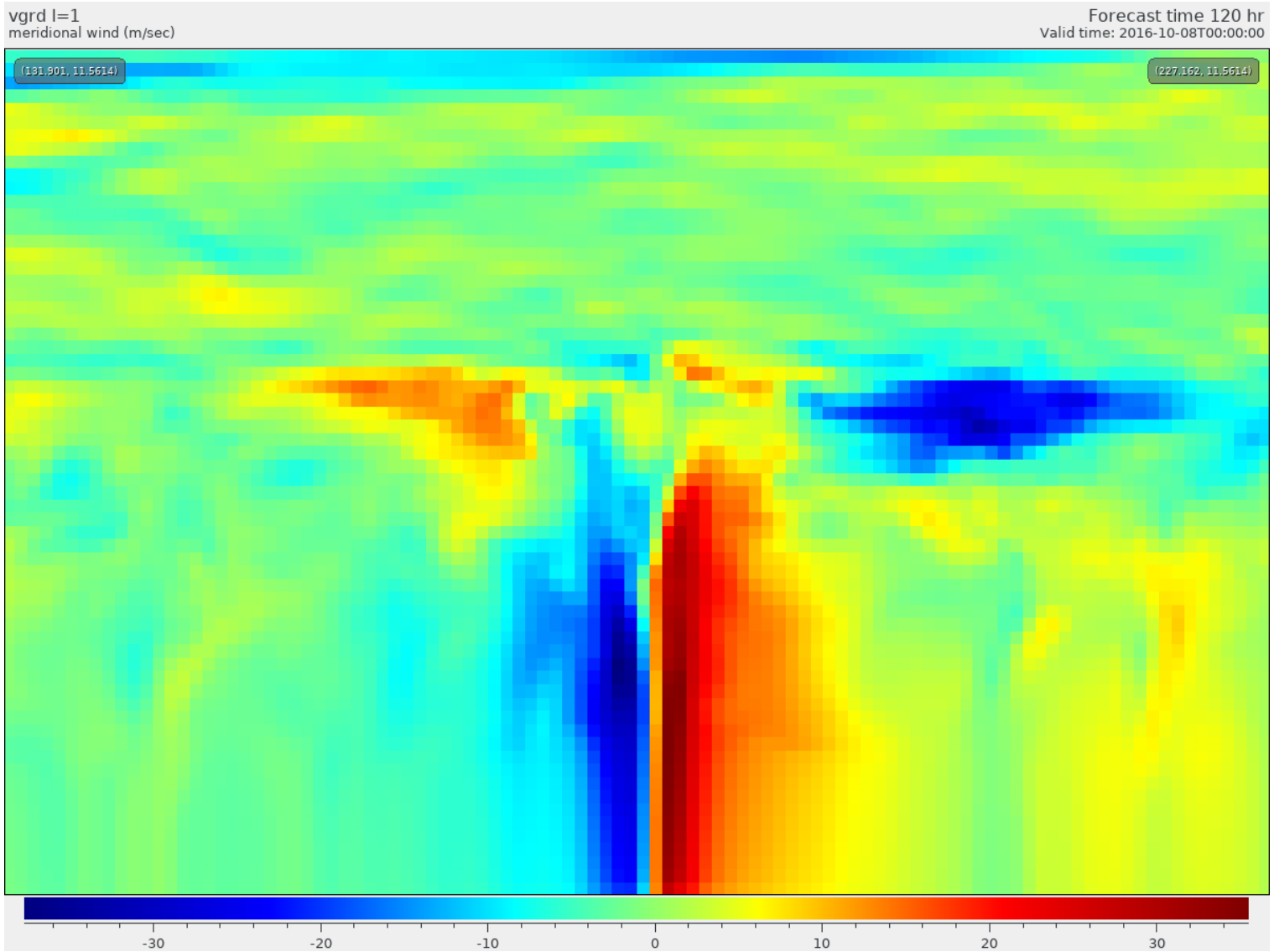
North

Test No.III / 57

Meridional wind (V)

Cross-section @12N

@120 hrs



West

East

Test No.IV (test_case= 57a) on f-plane, aqua-planet

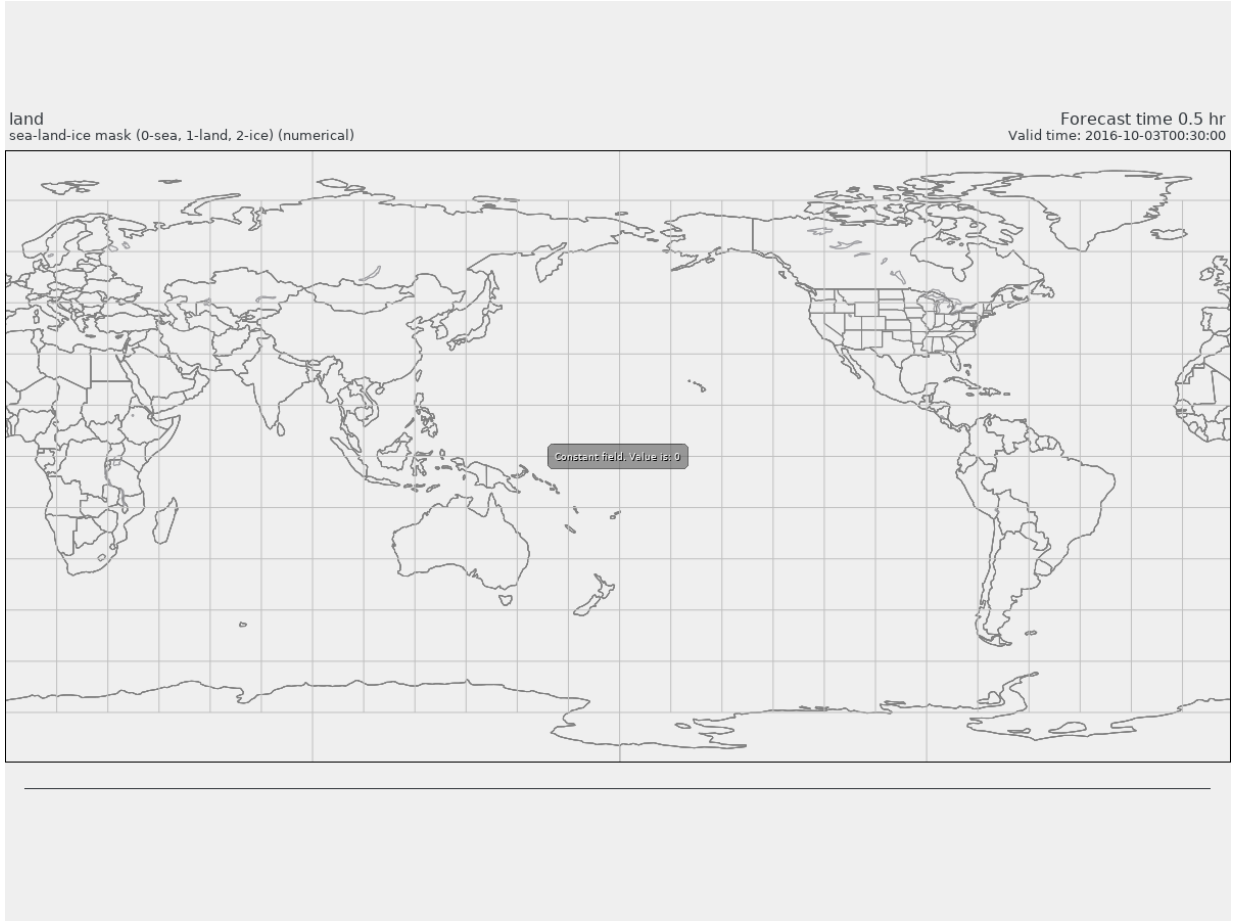
p00=1015.0hPa, dp=11.15hPa, rp=282.0km

Surface pressure (PS) max= 1015.00000000000 min=1004.44141134051
U max = 19.4412124264969 min = -19.6647077418568
V max = 19.5408117630522 min = -19.8585596483430

NSSTM is active (1, 1, 0, 0, 0)

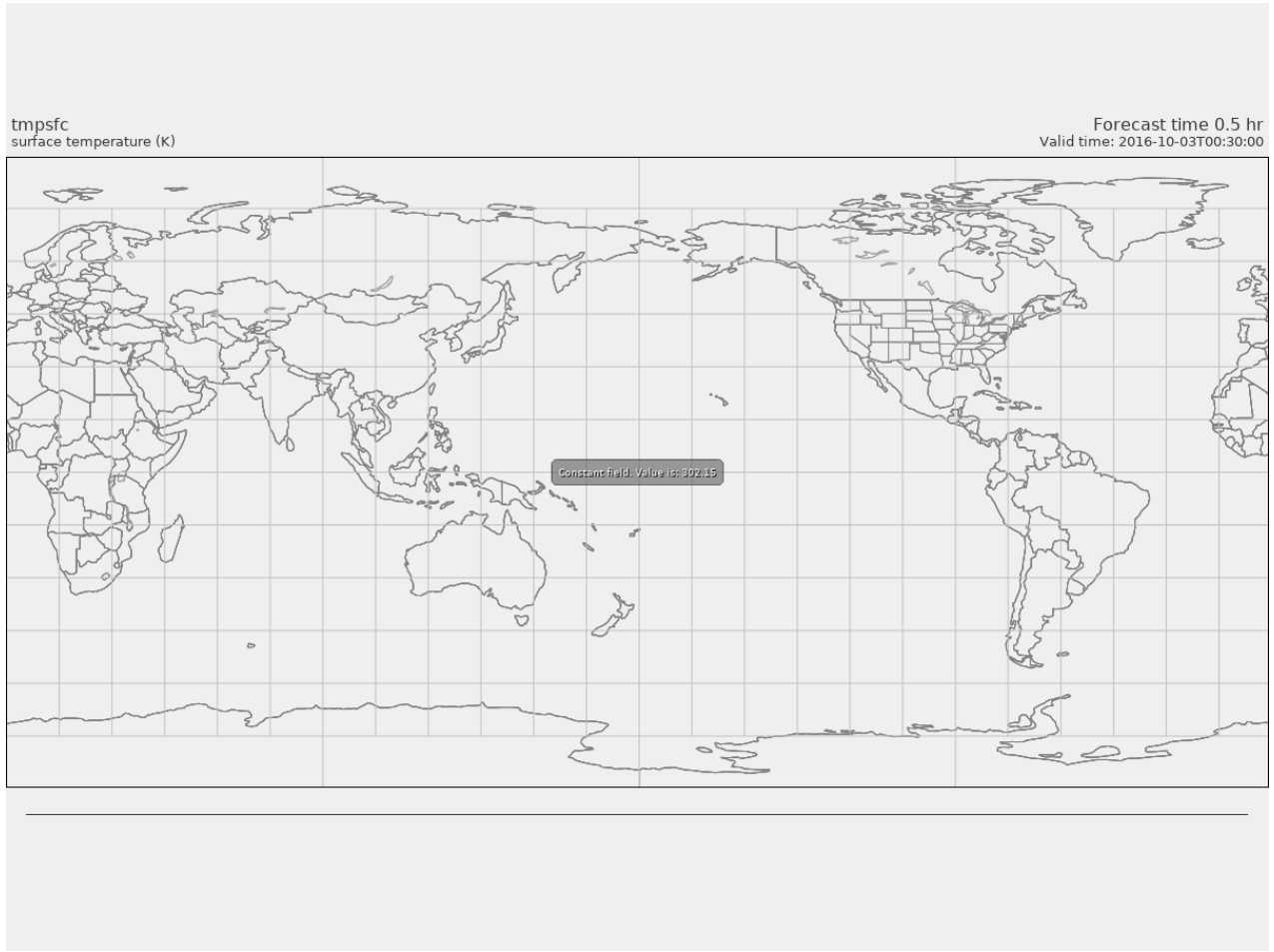
!< nstf_name(1) : 0 = NSSTM off, 1 = NSSTM on but uncoupled
!< 2 = NSSTM on and coupled
!< nstf_name(2) : 1 = NSSTM spin up on, 0 = NSSTM spin up off
!< nstf_name(3) : 1 = NSST analysis on, 0 = NSSTM analysis off
!< nstf_name(4) : zsea1 in mm
!< nstf_name(5) : zsea2 in mm

Test No.IV / 57a



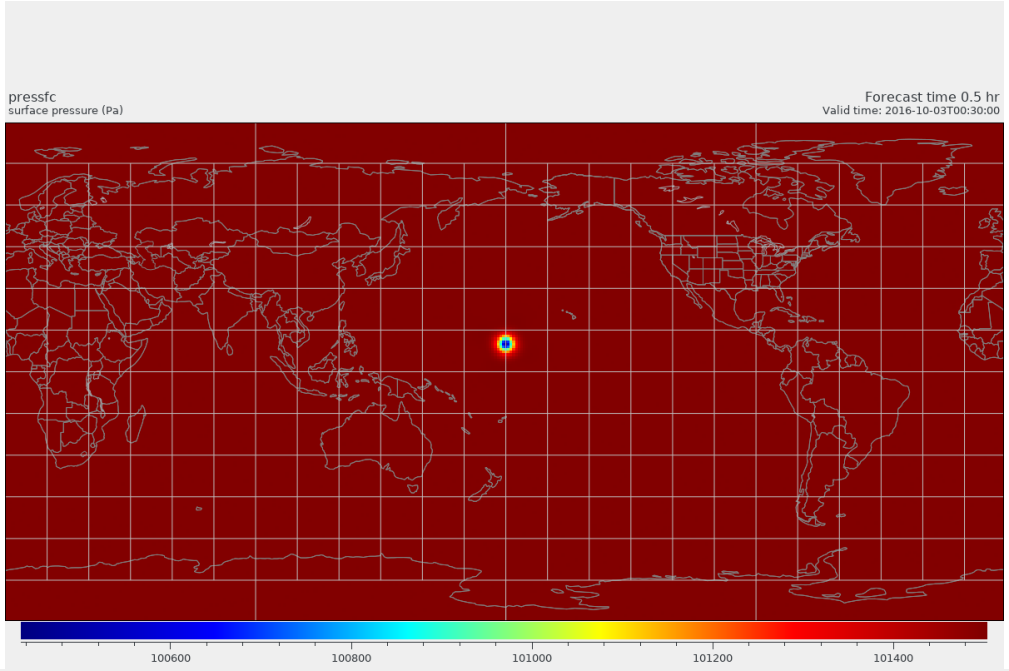
Land_Sea_Ice_mask=0 @ hour 0.5

Surface temperature=302.15 K @ hour 0.5

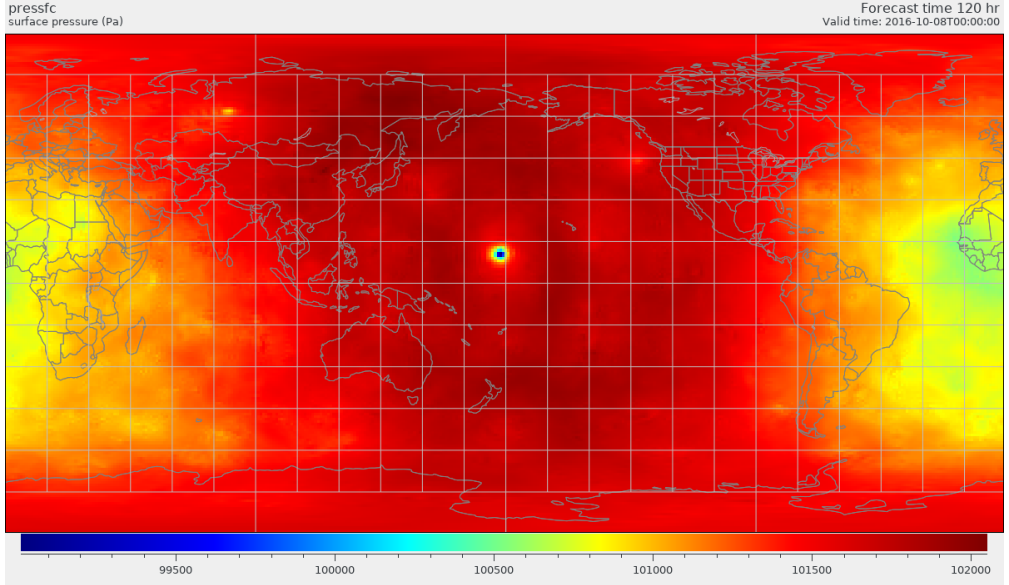


Test No.IV / 57a
Surface Pressure

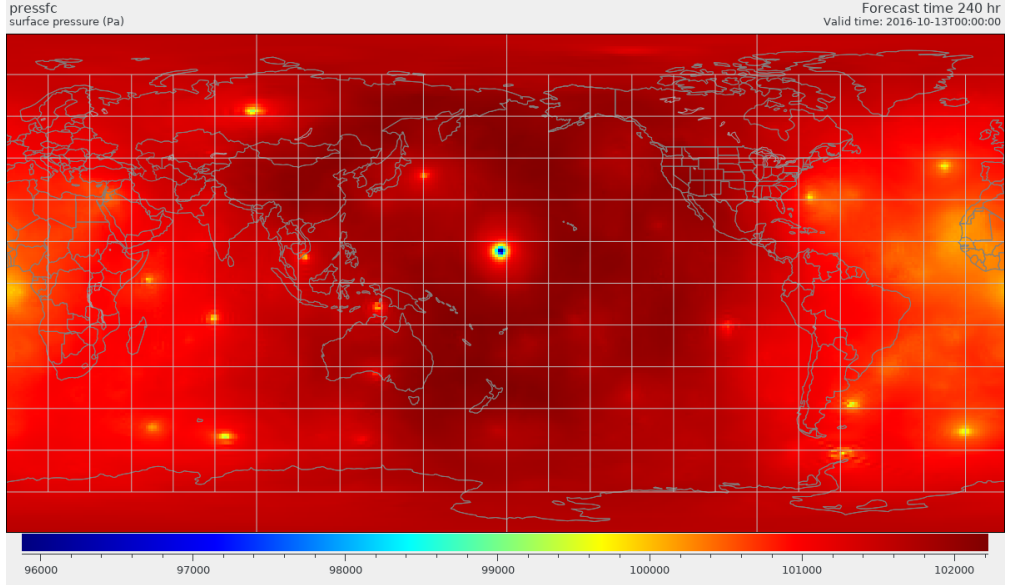
@0.5 hrs



@120 hrs



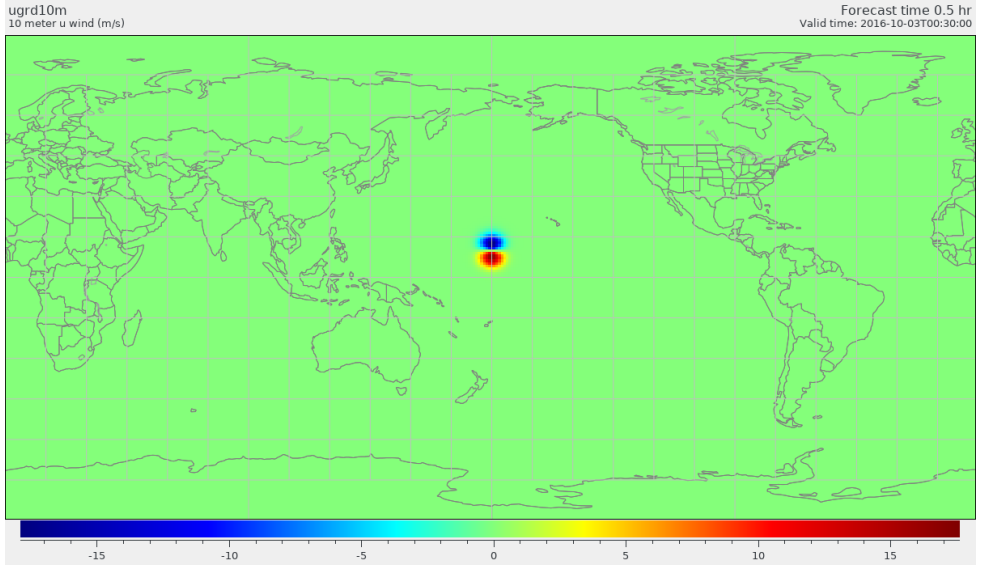
@240 hrs



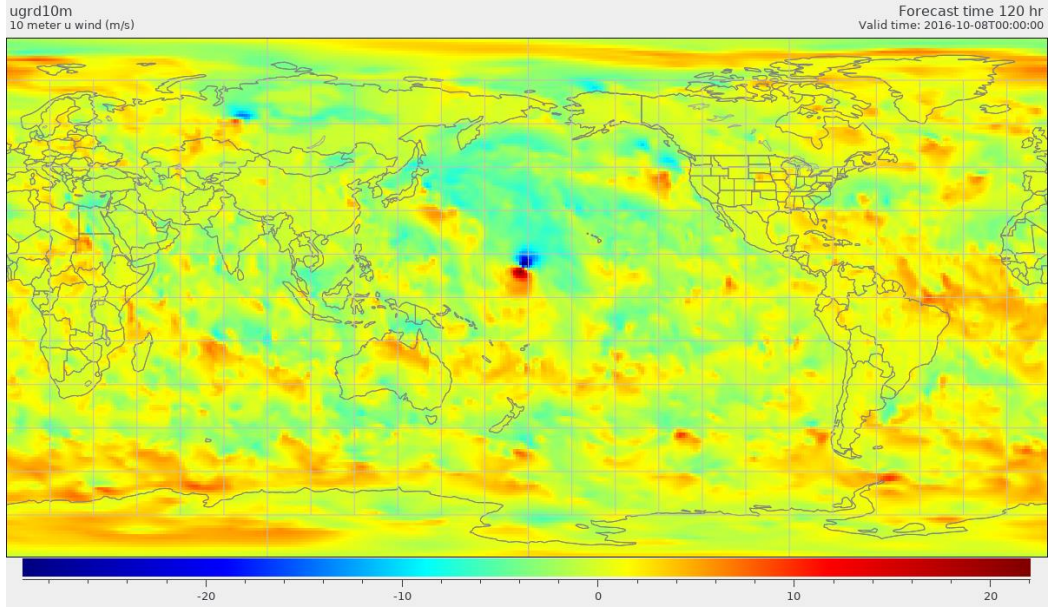
Test No.IV / 57a

U at 10m

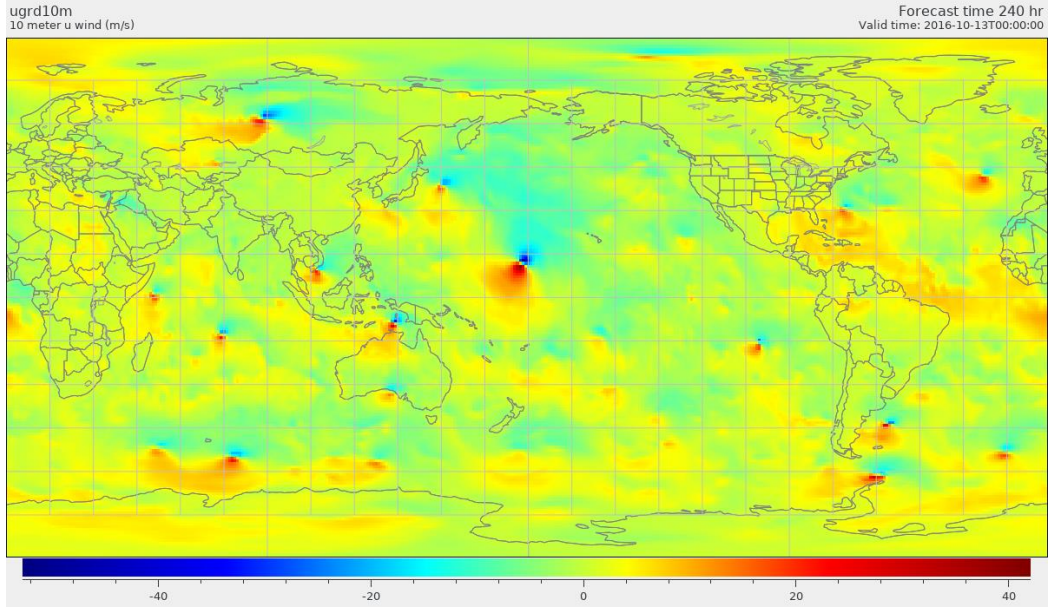
@0.5 hrs



@120 hrs



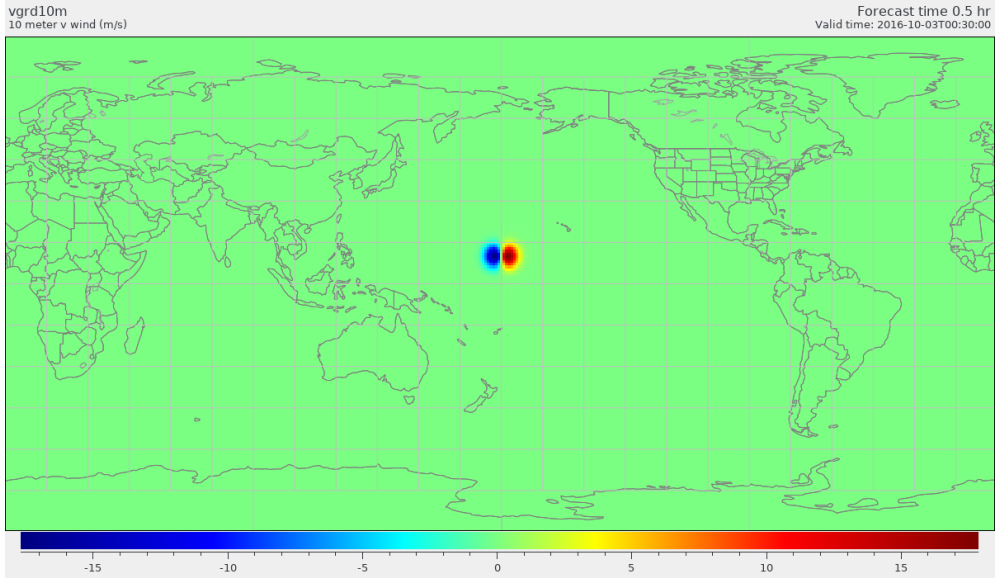
@240 hrs



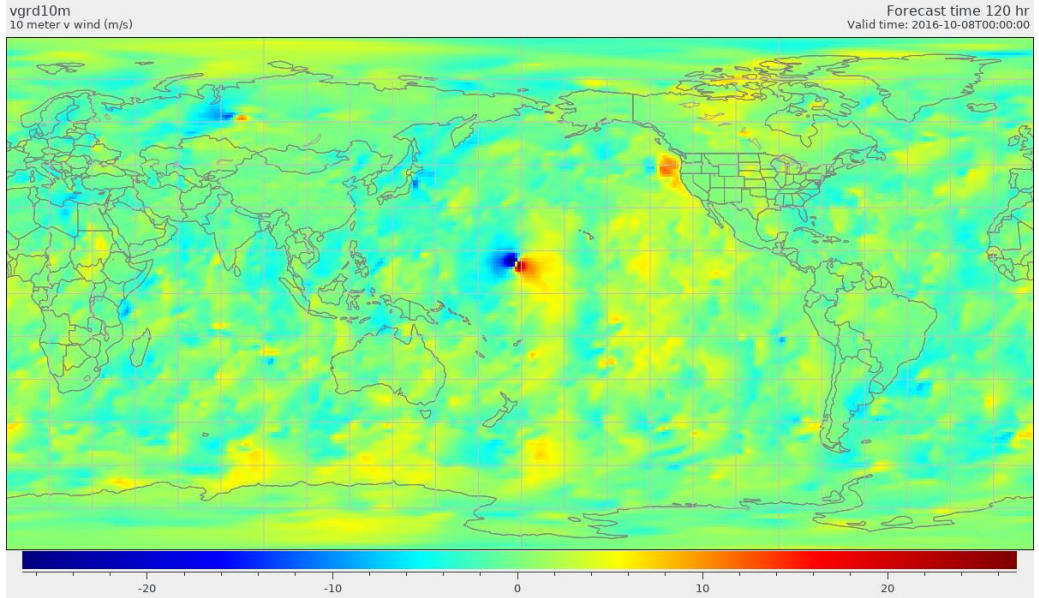
Test No.IV / 57a

V at 10m

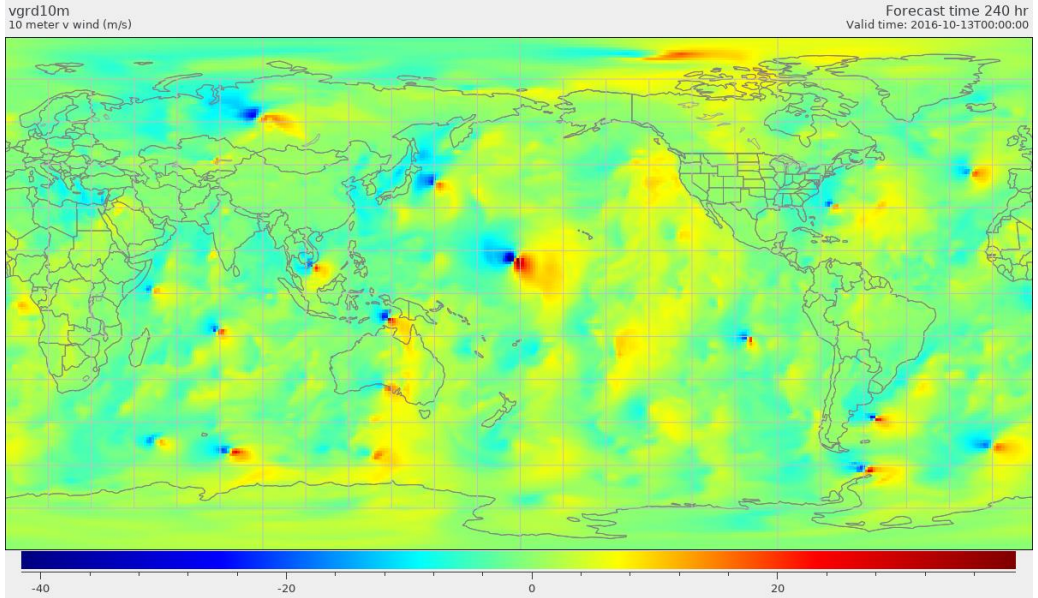
@0.5 hrs



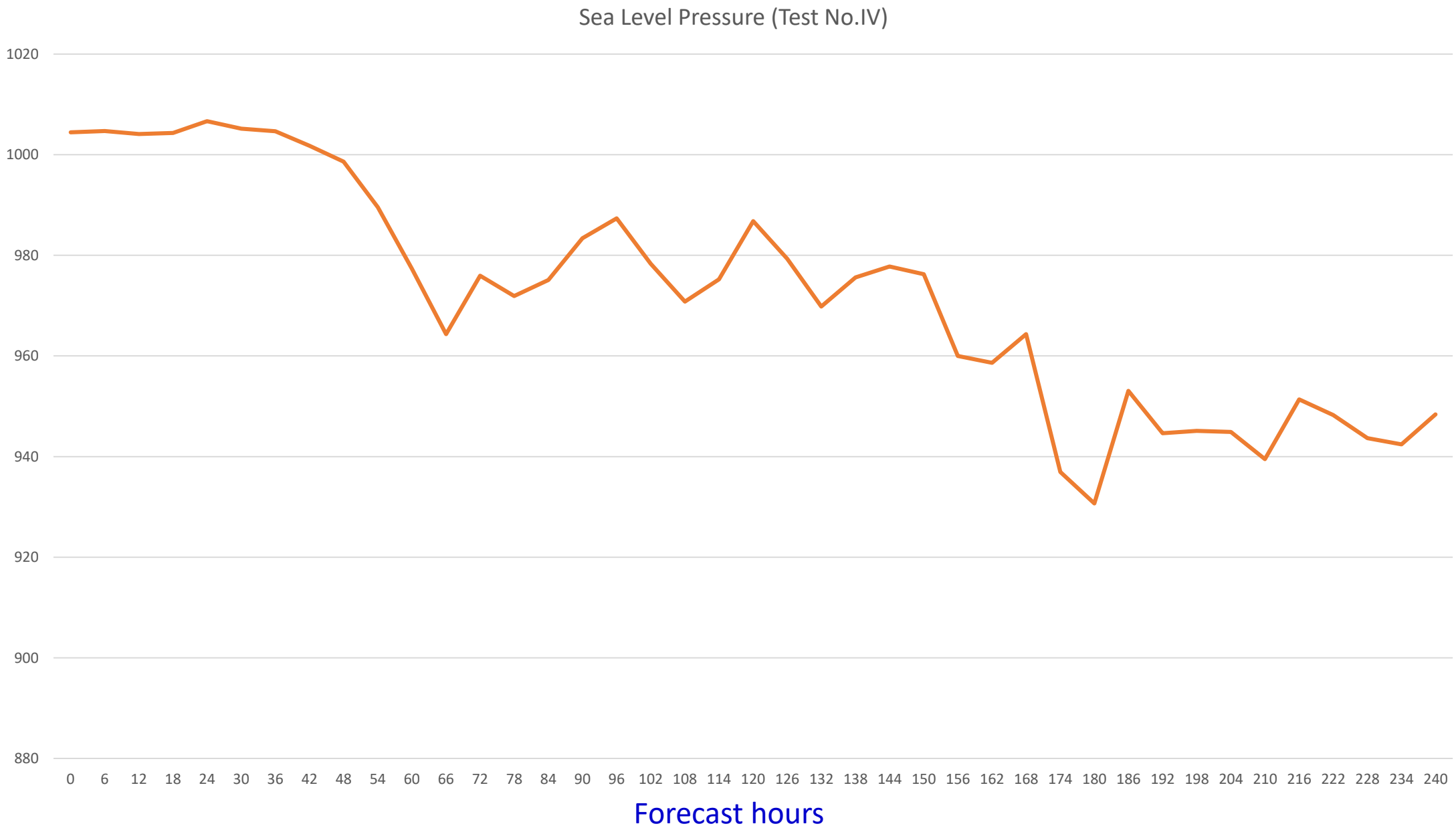
@120 hrs



@240 hrs



Test No.IV / 57a SLP forecast



HOW TO RUN

(1) Download the code

https://github.com/ufs-community/ufs-weather-model/wiki

% git clone https://github.com/ufs-community/ufs-weather-model

(2) Build

https://ufs-weather-model.readthedocs.io/en/ufs-v1.0.0/ContributingDevelopment.html (3.3.1 /3.3.3)

cd ./modulefiles/hera.intel

module use . ---- module load fv3 ---- ./build.sh

(3) simple-test-case

https://github.com/ufs-community/ufs-weather-model/wiki/Getting-Started (3 /4)

% wget https://ftp.emc.ncep.noaa.gov/EIB/UFS/simple-test-case.tar.gz

(4) input.nml .... changed

```
&test_case_nml      ----  added ------
     test_case = -55
     bubble_do = .false.
     alpha = 0.
     Nsolitons = 1
     soliton_size = 750.e3,
     soliton_Umax = 50.  /
  external_ic = .false.   ----  changed as "false"
  external_eta = .false.
```

(5) Submit your job and relax

0: NOTE from PE 0: reading surface properties data from INPUT/sfc_data.tile*.nc

./ufs-weather-model/FV3/io/FV3GFS_io.F90

```
!--- 2D variables
!   ------------
      Sfcprop(nb)%slmsk(ix)  = sfc_var2(i,j,1)    !--- slmsk
      Sfcprop(nb)%tsfco(ix)  = sfc_var2(i,j,2)    !--- tsfc (tsea in sfc
file)
      Sfcprop(nb)%weasd(ix)  = sfc_var2(i,j,3)    !--- weasd
(sheleg in sfc file)
      Sfcprop(nb)%tg3(ix)    = sfc_var2(i,j,4)    !--- tg3
      Sfcprop(nb)%zorlo(ix)  = sfc_var2(i,j,5)    !--- zorl on ocean
      Sfcprop(nb)%alvsf(ix)  = sfc_var2(i,j,6)    !--- alvsf
      Sfcprop(nb)%alvwf(ix)  = sfc_var2(i,j,7)    !--- alvwf
      Sfcprop(nb)%alnsf(ix)  = sfc_var2(i,j,8)    !--- alnsf
      Sfcprop(nb)%alnwf(ix)  = sfc_var2(i,j,9)    !--- alnwf
      Sfcprop(nb)%facsf(ix)  = sfc_var2(i,j,10)   !--- facsf
      Sfcprop(nb)%facwf(ix)  = sfc_var2(i,j,11)   !--- facwf
      Sfcprop(nb)%vfrac(ix)  = sfc_var2(i,j,12)   !--- vfrac
      Sfcprop(nb)%canopy(ix) = sfc_var2(i,j,13)   !--- canopy
      Sfcprop(nb)%f10m(ix)   = sfc_var2(i,j,14)   !--- f10m
      Sfcprop(nb)%t2m(ix)    = sfc_var2(i,j,15)   !--- t2m
```

Code modification

```
Sfcprop(nb)%q2m(ix)    = sfc_var2(i,j,16)   !--- q2m
  Sfcprop(nb)%vtype(ix)  = sfc_var2(i,j,17)   !--- vtype
  Sfcprop(nb)%stype(ix)  = sfc_var2(i,j,18)   !--- stype
  Sfcprop(nb)%uustar(ix) = sfc_var2(i,j,19)   !--- uustar
  Sfcprop(nb)%ffmm(ix)   = sfc_var2(i,j,20)   !--- ffmm
  Sfcprop(nb)%ffhh(ix)   = sfc_var2(i,j,21)   !--- ffhh
  Sfcprop(nb)%hice(ix)   = sfc_var2(i,j,22)   !--- hice
  Sfcprop(nb)%fice(ix)   = sfc_var2(i,j,23)   !--- fice
  Sfcprop(nb)%tisfc(ix)  = sfc_var2(i,j,24)   !--- tisfc
  Sfcprop(nb)%tprcp(ix)  = sfc_var2(i,j,25)   !--- tprcp
  Sfcprop(nb)%srflag(ix) = sfc_var2(i,j,26)   !--- srflag
  Sfcprop(nb)%snowd(ix)  = sfc_var2(i,j,27)   !--- snowd (snwdph in the file)
  Sfcprop(nb)%shdmin(ix) = sfc_var2(i,j,28)   !--- shdmin
  Sfcprop(nb)%shdmax(ix) = sfc_var2(i,j,29)   !--- shdmax
  Sfcprop(nb)%slope(ix)  = sfc_var2(i,j,30)   !--- slope
  Sfcprop(nb)%snoalb(ix) = sfc_var2(i,j,31)   !--- snoalb
  Sfcprop(nb)%sncovr(ix) = sfc_var2(i,j,32)   !--- sncovr
  if(Model%cplflx) then
    Sfcprop(nb)%tsfcl(ix)  = sfc_var2(i,j,33) !--- sfcl  (temp on land portion of a cell)
    Sfcprop(nb)%zorll(ix)  = sfc_var2(i,j,34) !--- zorll (zorl on land portion of a cell)
  end if
```

Code modification

So far, two codes need to be modified for TC_AQUA, and more changes for FV3GFS shallow water model.

./ufs-weather-model/FV3/io/FV3GFS_io.F90

./ufs-weather-model/FV3/gfsphysics/physics/sfcsub.F

```
#ifdef TC_AQUA
      ----------------------------------------
#else
      ----------------------------------------
#endif

#ifndef TC_AQUA
      ----------------------------------------
#else
      ----------------------------------------
#endif
```

```
#ifdef SW_DYNAMICS
      ----------------------------------------
#else
      ----------------------------------------
#endif

#ifndef SW_DYNAMICS
      ----------------------------------------
#else
      ----------------------------------------
#endif
```

Test No.V (test_case= 4a/b) with FV3GFS shallow-water model

```
ubar = 50.     (m/s)          ! maxmium wind speed
 r0 = 250.e3     (m)          ! RADIUS of the maximum wind of the Rankine vortex
```

(4b)ddeg = 3.*r0/radius ! Distance between the Two-vortices (6.7 degree*2.0)

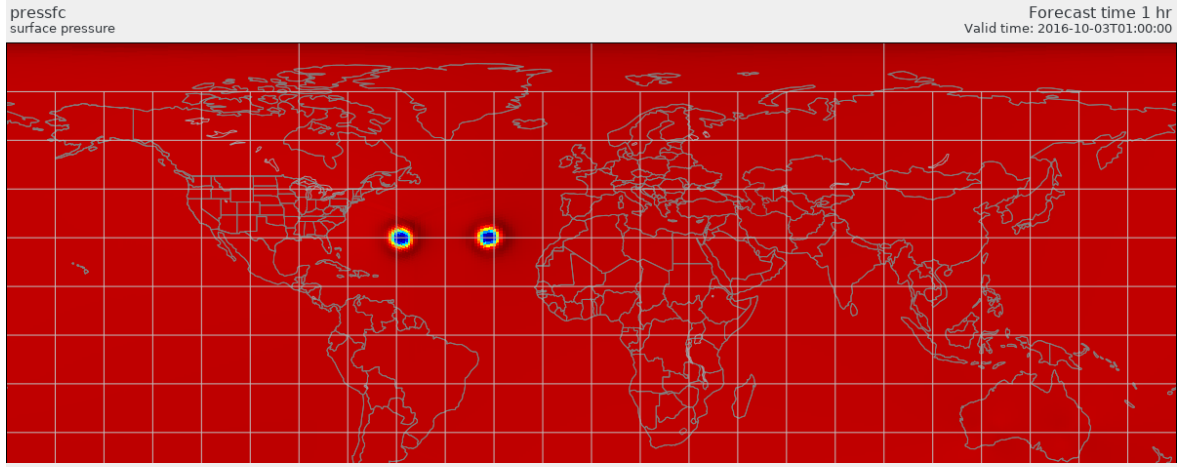
```
    p1(1) = pi*1.75 – ddeg          ! 45W -ddeg
    p1(2) = pi/6.                   ! 30 N
    call rankine_vortex(ubar, r0, p1, u, v, grid, bd)

    p2(1) = pi*1.75 + ddeg          ! 45W +ddeg
    p2(2) = pi/6.                   ! 30 N
    call rankine_vortex(ubar, r0, p2, u, v, grid, bd)
```

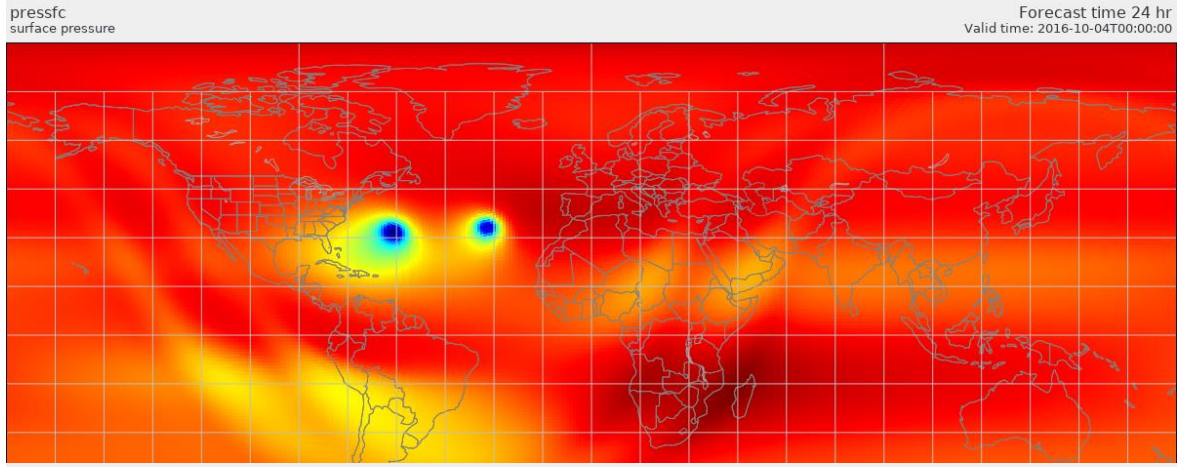
```
if( r<r0 ) then
      vr = ubar*r/r0
   else
      vr = ubar*r0/r
   endif
```

(4a)ddeg = 6.*r0/radius ! Distance between the Two-vortices (13.4 degree*2.0)

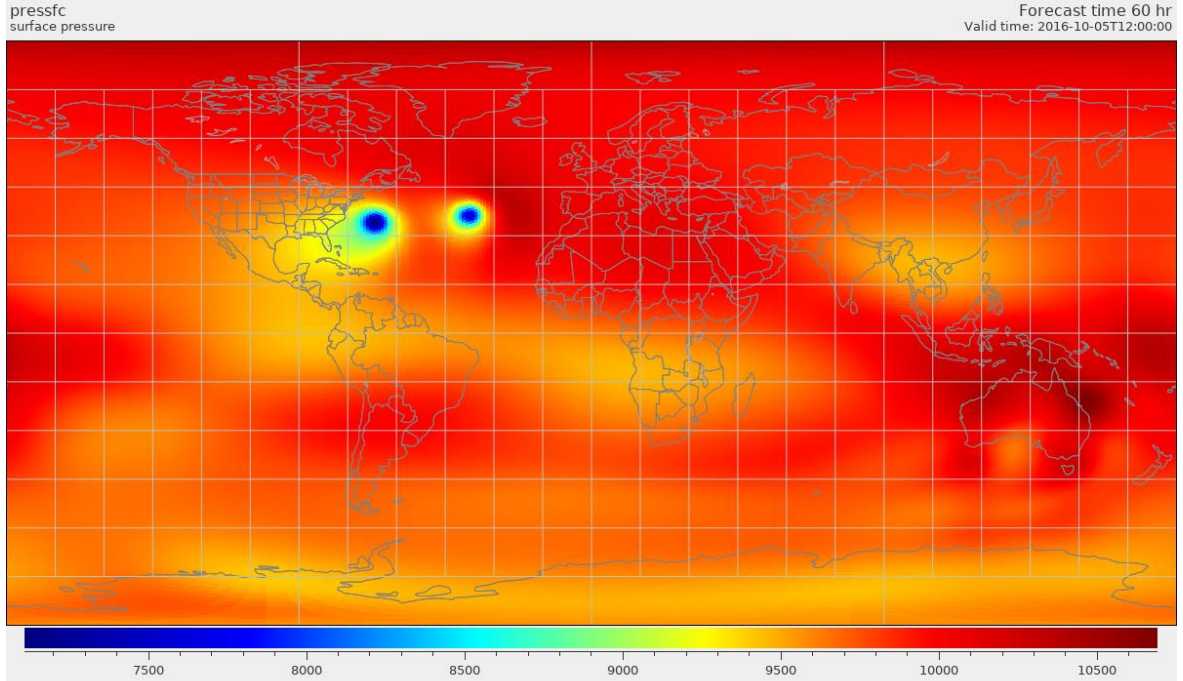
@001 hr



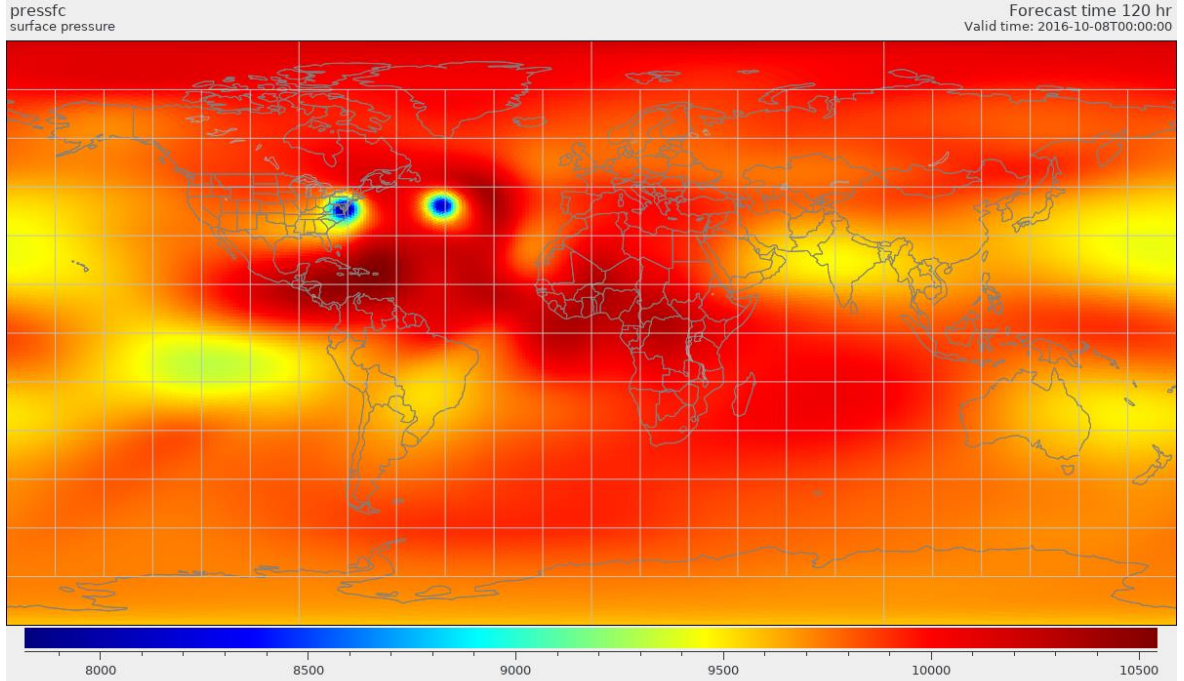
@024 hrs



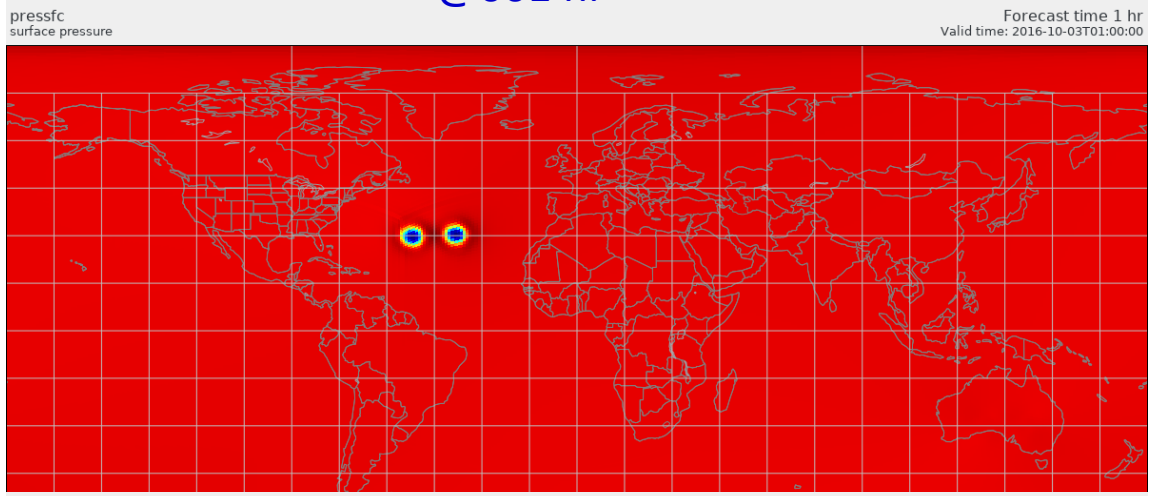
@060 hrs



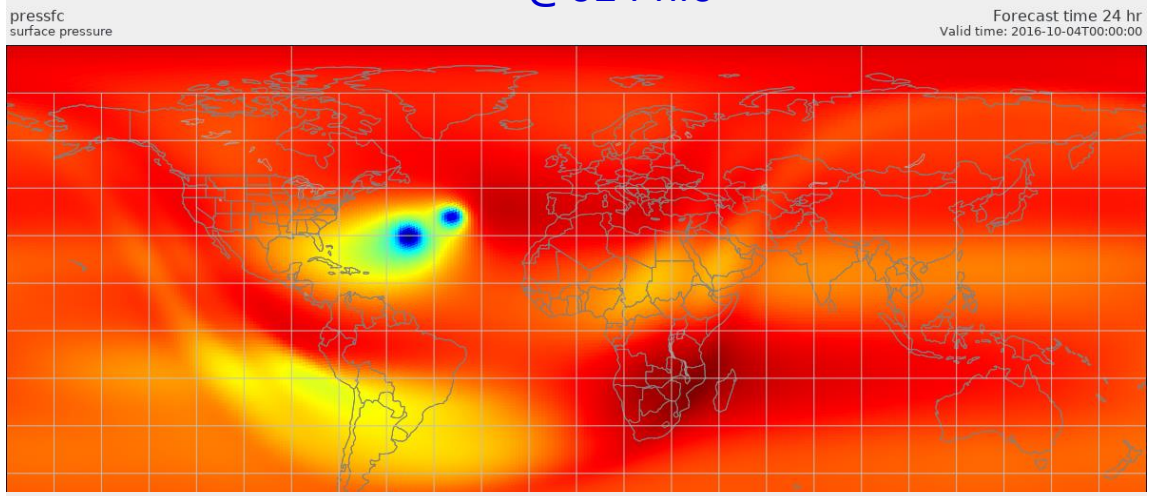
@120 hrs



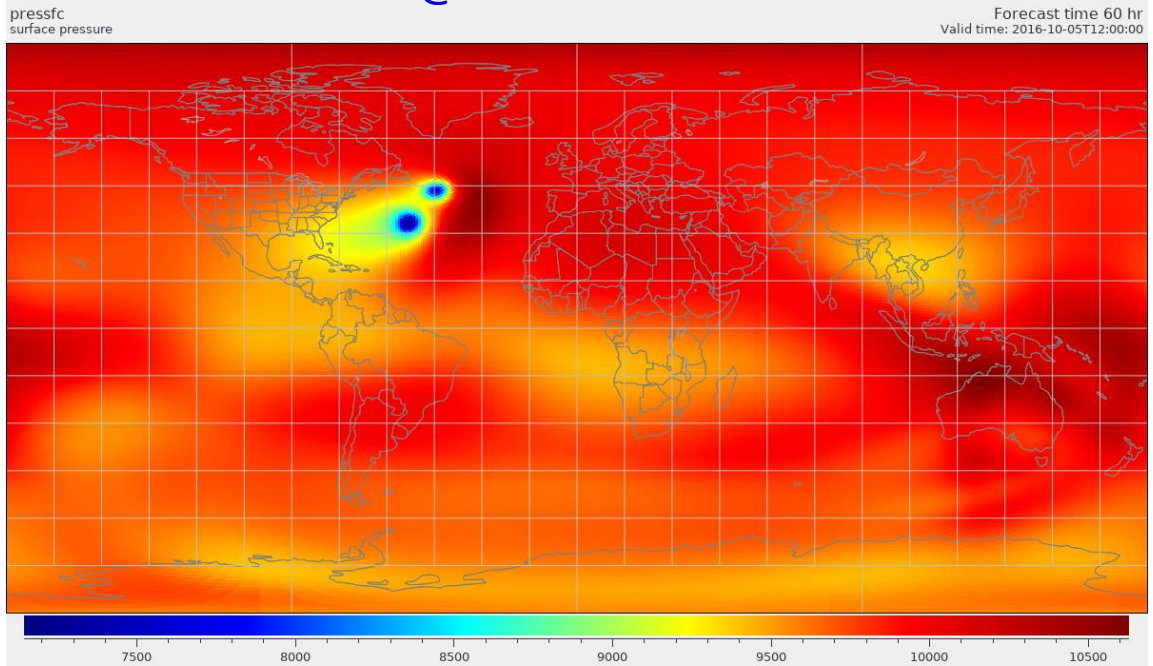
@001 hr



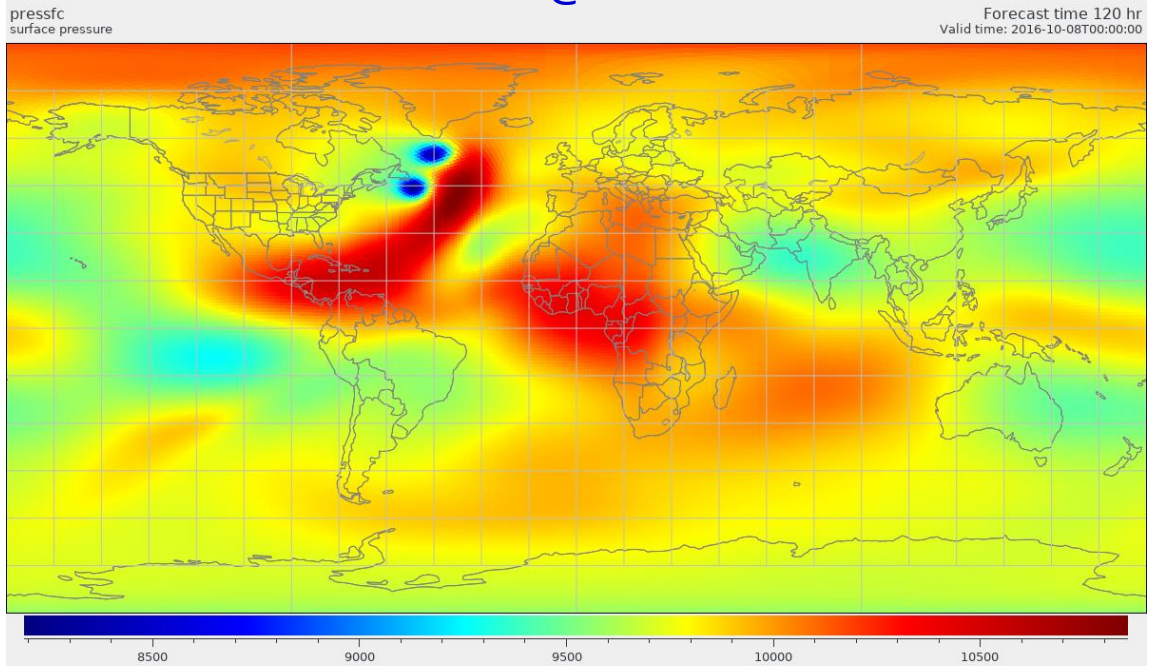
@024 hrs



@060 hrs



@120 hrs



Summary:

the 2D/3D idealized TC could be run under FV3-GFS V15/16 framework.

Applications:

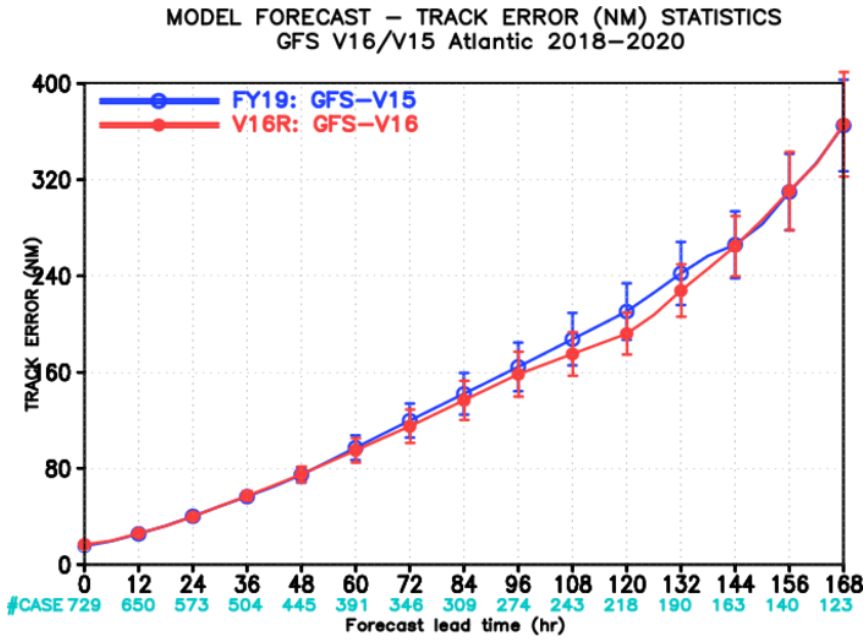
it could be a platform for the investigation of TC basic dynamics and physics as well.

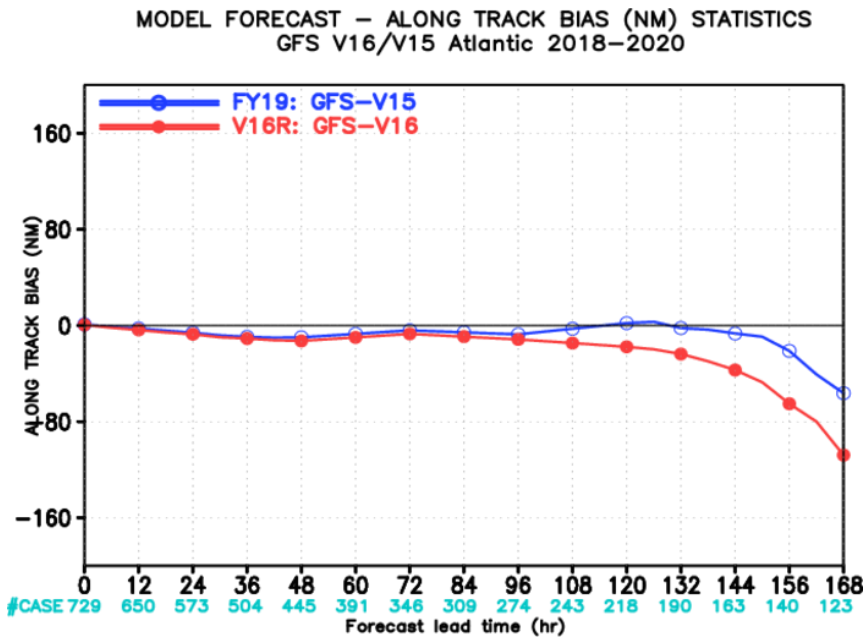
Goal: this platform will be built on global 9Km/3Km resolution.

Hope: quantum computer is on the way!

C48 = 2degree, C96=1degree, C192 = 0.5degree ≈ 50km, C384 = 0.25degree ≈ 25km, C2560 ≈ 3.5km)

Questions and suggestions ????





Questions and discussion:
GFS-V15/16 has large cross-track bias, why?