A 0-100 km Global Atmospheric Reanalysis of the 2014 Austral Winter in Support of DEEPWAVE Science

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- The National Science Foundation
- The Oceanographer of the Navy through PMW-120/SPAWAR 6.4 transition contracts
- NASA through the Heliophysics Division SR&T and GI programs.

Motivation

- DEEPWAVE acquired gravity wave observations from 0-100 km altitude, with a concentration of MLT observations from ~80-95 km (AMTM, Na lidar, NZ airglow imagers)
- Modeling of these deep wave observations requires (*inter alia*) knowledge of the background environment for wave generation and propagation from 0-100 km
  - Backgrounds for linear ray models and parameterizations
  - Lateral boundary conditions for regional models (COAMPS®, WRF)
  - Diagnostics of wave propagation (critical levels, ducting, etc.)
- Such fields are provided by atmospheric reanalyses
- Existing centers (ECMWF, NASA GMAO, NOAA, FNMOC, Met Office, NIWA) issue reanalyses up to 65-80 km only.
- **There is a "reanalysis gap" from ~70-100 km**

NRL Has Pioneered Research in 0-100 km Atmospheric Analysis

- NRL developed first 0-100 km prototype NWP reanalysis system – “NOGAPS-ALPHA” (Eckermann et al. 2009)
- NOGAPS-ALPHA provided reanalyses of the summer MLT in support of NASA’s Aeronomy of Ice in the Mesosphere (AIM) mission (see Eckermann et al. 2009)
- In 2012/13 NRL retired NOGAPS to develop a next-generation Navy Global Environmental Model (NAVGEM)
- Here we leverage our NOGAPS-ALPHA experience to develop a prototype high-altitude NAVGEM system extending to ~110 km.

Eckermann, S. D., K. W. Hoppel, L. Coy, J. P. McCormack, D. E. Siskind, K. Nielsen, A. Kochenash, M. H. Stevens, C. R. Englert, and M. Hervig (2009), High-altitude data assimilation system experiments for the northern summer mesosphere season of 2007, J. Atmos. Sol.-Terr. Phys., 71, 531-551.

NAVGEM

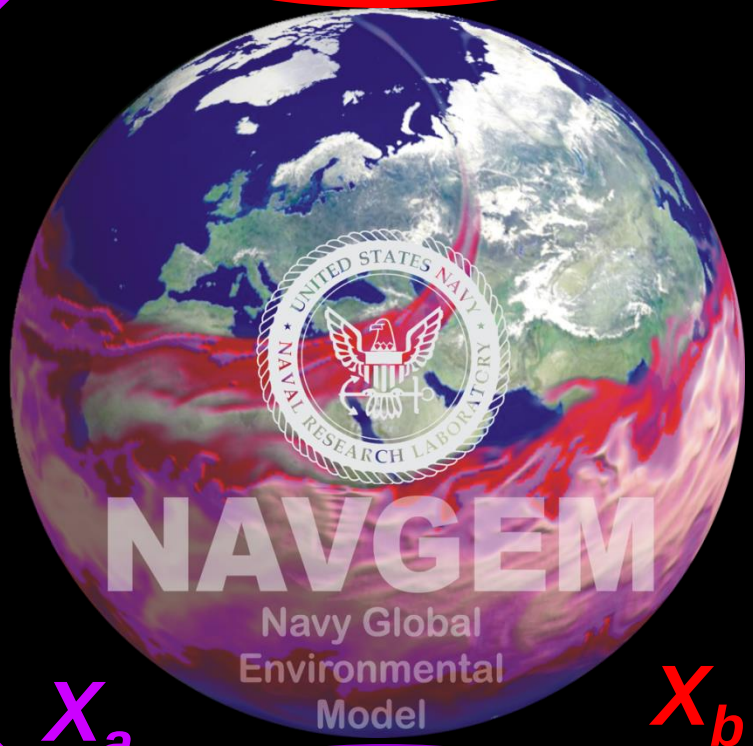
Navy Global Environmental Model

Global SLSI Forecast Model

0-10 Day Forecasts

0-9 Hour Forecasts

Global observations over next 0-6 hours



X_a

X_b

y

Data Assimilation System
NAVDAS-AR 4DVAR

6 hourly global analysis fields

NAVGEM Satellite Assimilation

Radiances Imagers/Sounders

DMSP F16 SSMIS ~~LAS, UAS~~, Imager
DMSP F17 SSMIS LAS, UAS, Imager
DMSP F18 SSMIS LAS, UAS, Imager
DMSP F19 SSMIS LAS, UAS, Imager
METOP-A AMSU-A, IASI, MHS
METOP-B AMSU-A, IASI, MHS
NASA EOS Aqua AIRS, AMSU-A
NOAA 15 AMSU-A
NOAA 16 AMSU-A
NOAA 18 AMSU-A, MHS
NOAA 19 AMSU-A, MHS
NOAA NPP ATMS, CrIS, VIIRS
GCOM-W1 AMSR-2
Megha-Tropiques MADRAS, SAPHIR
OceanSat-2
MSG Severi
MSG-II HIR
Jason-1 (SSH, SWH)
Jason-2 (SSH, SWH)
Cryosat2 (SSH, SWH)
Aquarius (Salinity)
Geo Clear-sky: GOES, MTSAT, GMS

FY-3A,B,C,D,E,F MWTS,MWHS,MAIRS
MERSI
FY-RM 1,2
Meteor 3M MTVZA

Satellite Derived Polar and Geostationary Winds

Coriolis WindSat Ocean Wind Vector
DMSP F16 SSMIS Ocean Wind speed
DMSP F17 SSMIS Ocean Wind speed
DMSP F18 SSMIS Ocean Wind speed
METOP-A AVHRR, ASCAT
METOP-B AVHRR, ASCAT
NASA EOS Aqua MODIS
NASA EOS Terra MODIS, MISR
NOAA NPP VIIRS

Meteosat 9
Meteosat 10
MTSAT
NOAA GOES E
NOAA GOES W
NOAA GOES-R
KMA COMS

FY-2E,F,G,H (Geo Winds)
FY-4A,B,C (Geo Winds)
FY-4A,B,C IR Spectrometer, MW??

GPS Radio Occultation

C/NOFS CORISS
COSMIC FM1-6
GRACE-A
MetOp-A GRAS
MetOp-B GRAS
SAC-C
TerraSAR-X
TanDEM-X
COMS

Other Satellite Products

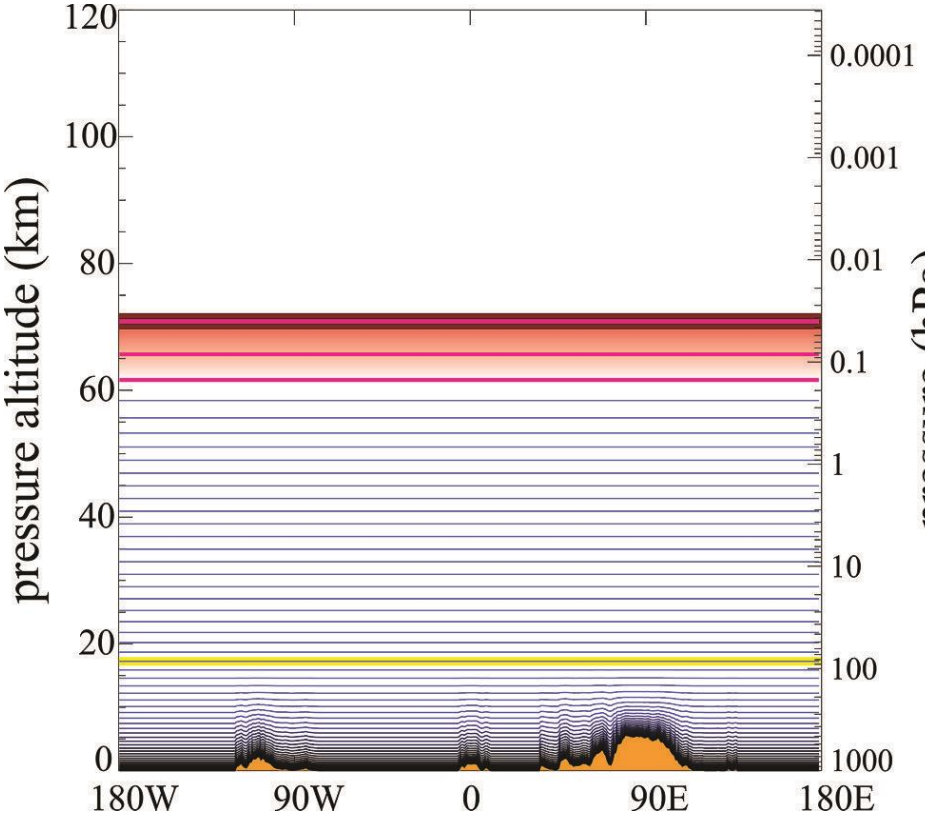
NASA EOS Aura MLS, HRDLS, OMI
NASA TIMED SABER
NOAA SBUV
JPSS NPP OMPS
SMOS
SMAP
FY-3A,B,C,D,E,F TOU

Coriolis WindSat TPW
DMSP F16 SSMIS TPW
DMSP F17 SSMIS TPW
DMSP F18 SSMIS TPW

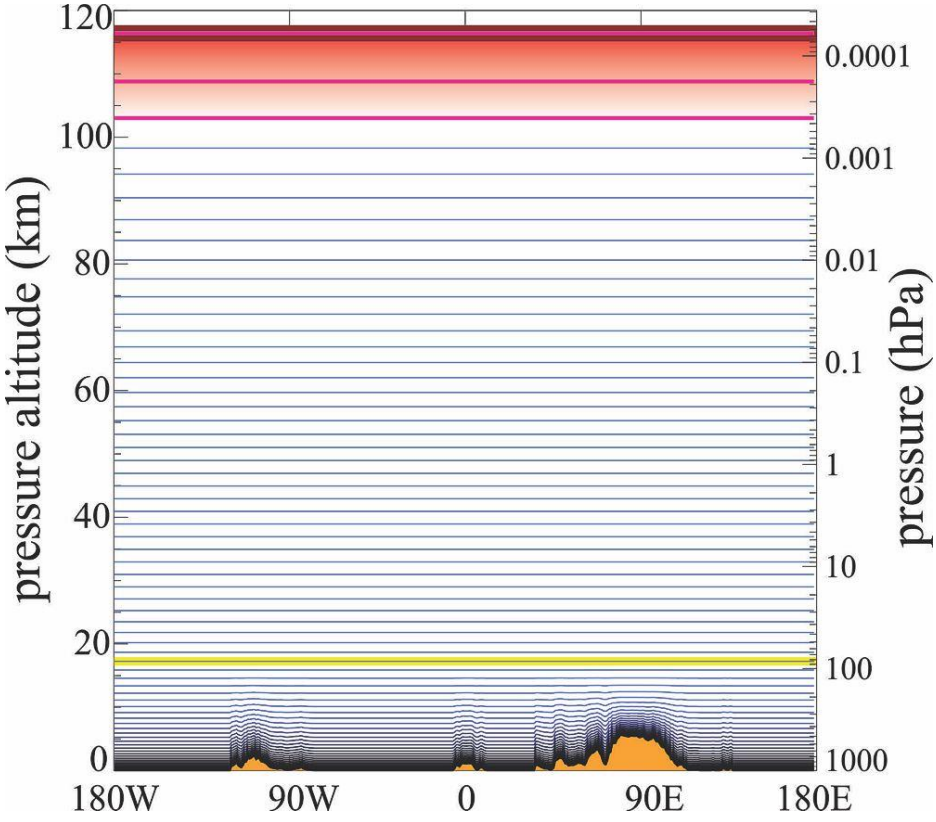
Operational Research Only Planned Restricted Use

NAVGEM Changes

NAVGEM 1.3 Operational
T425L60



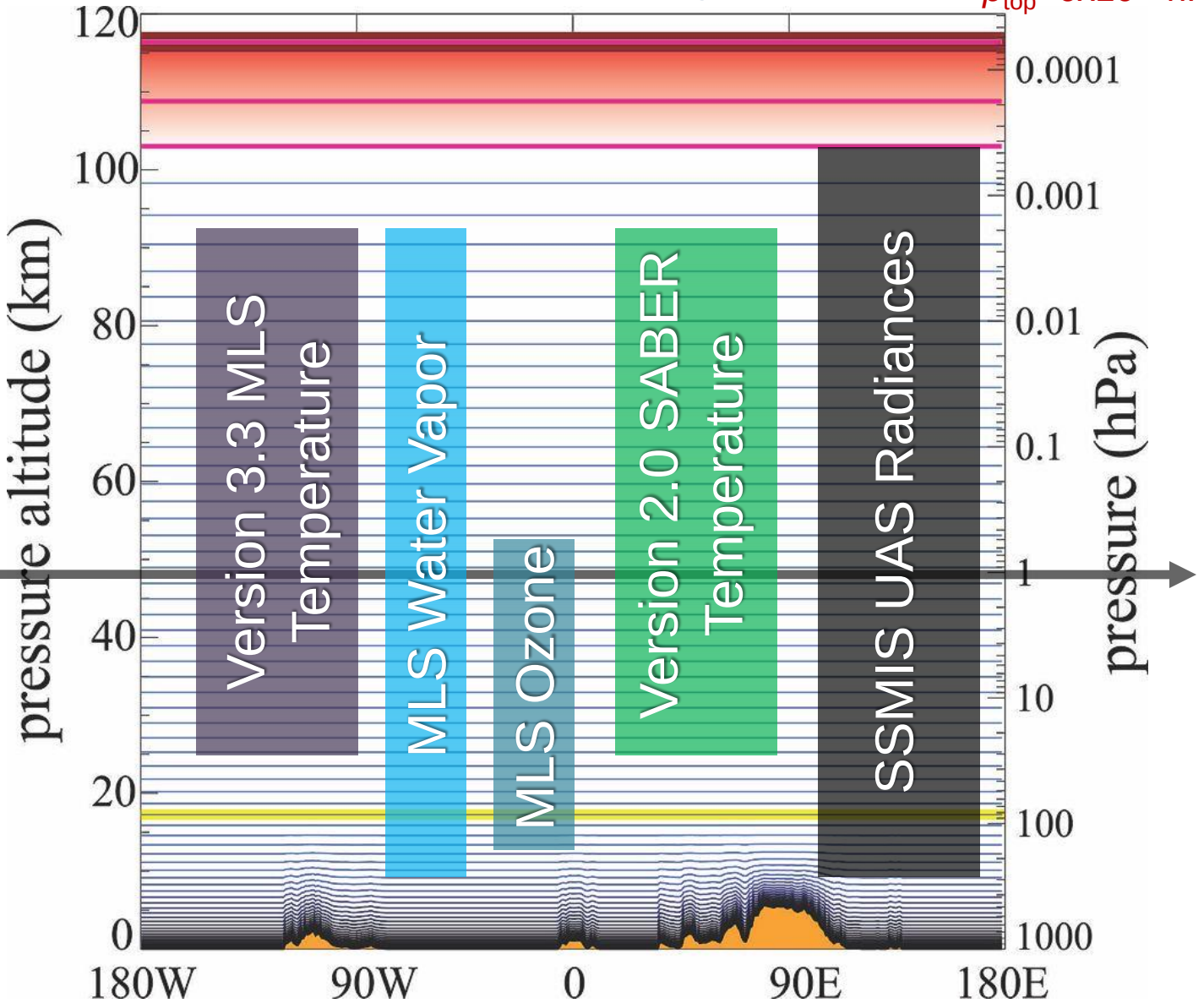
High-Altitude NAVGEM
T119L74



NAVGEM T119L74

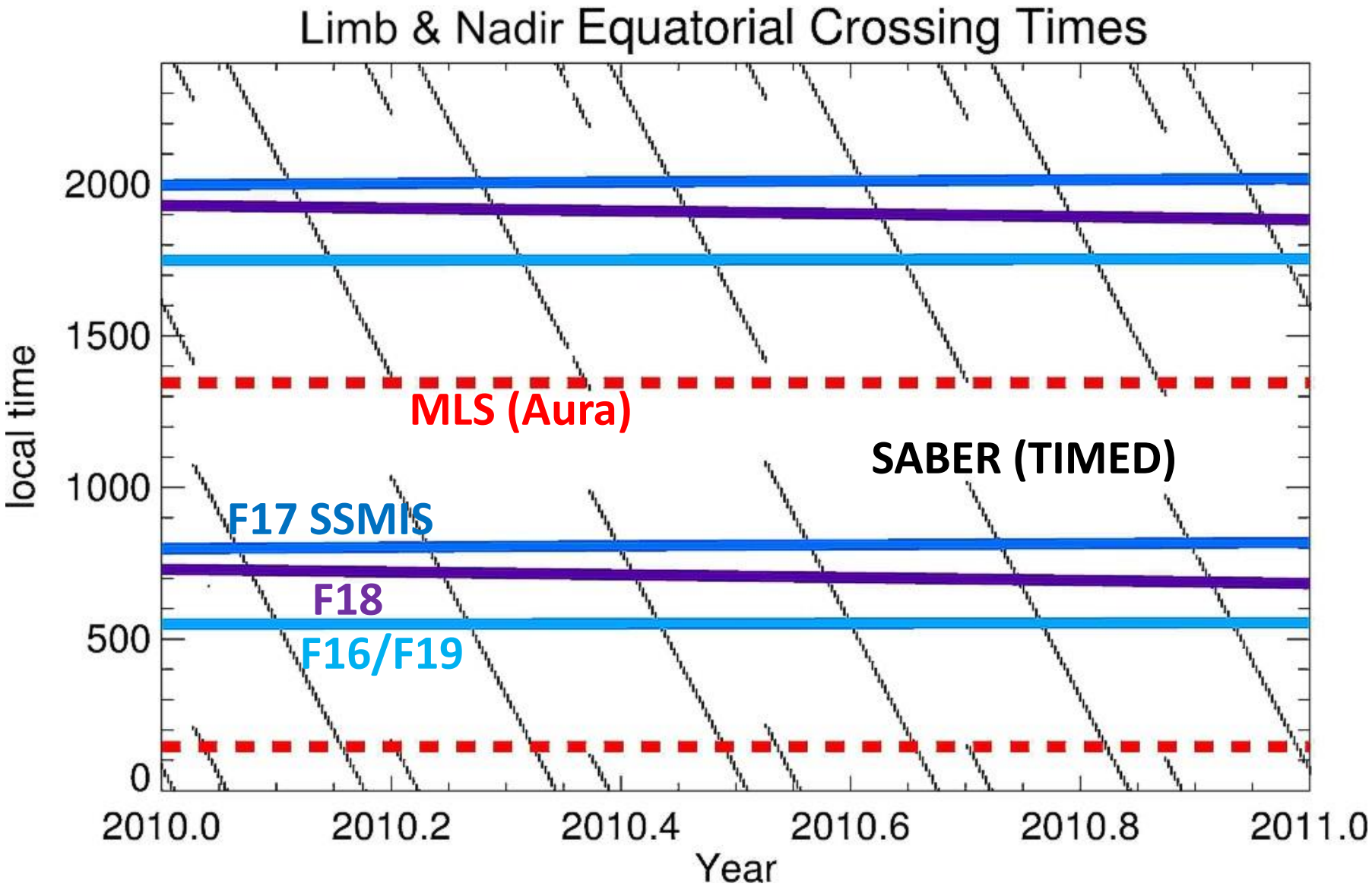
DEEPWAVE Reanalysis Runs

p_{top}=6x10^{-5} hPa

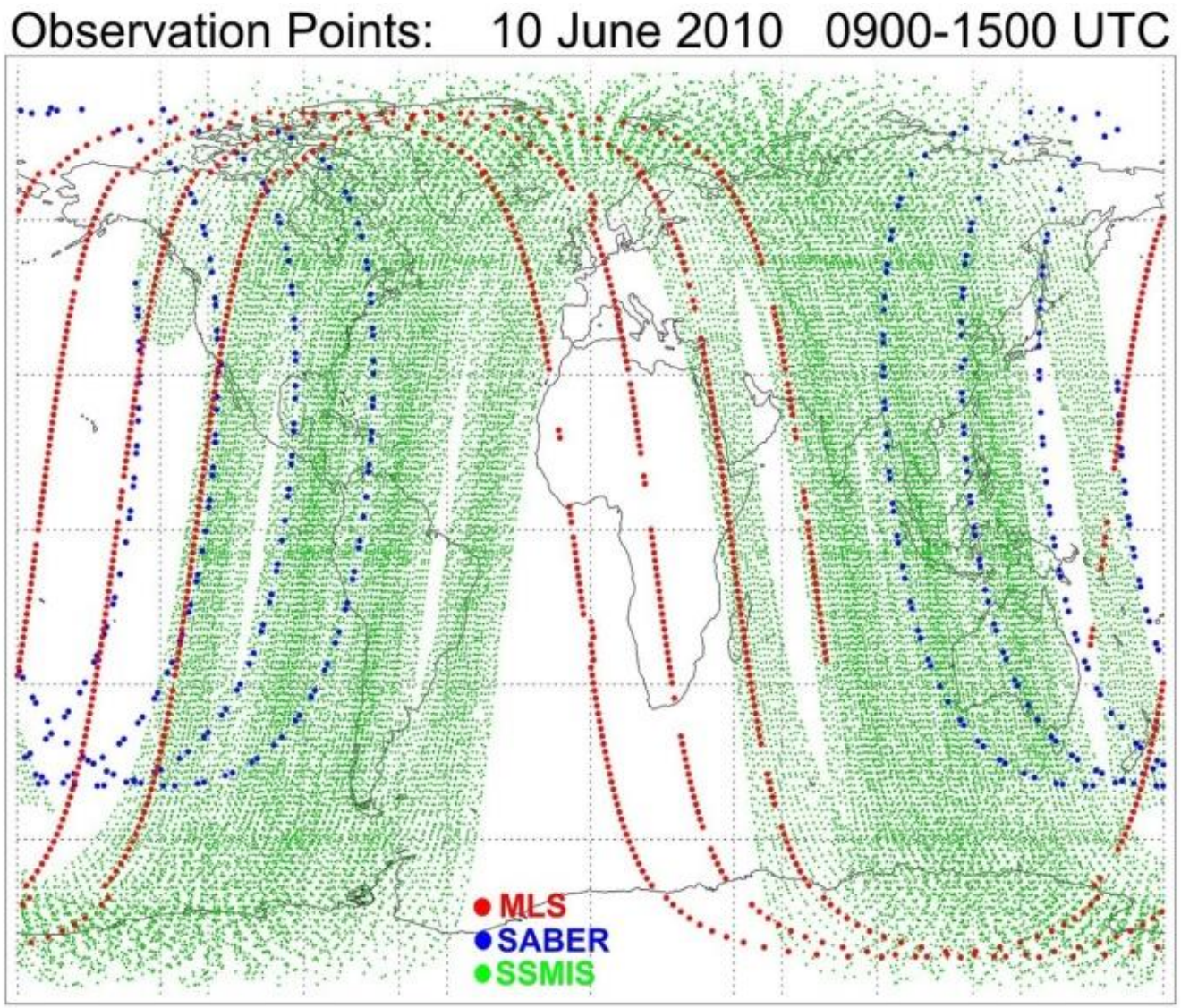


Top Data Insertion Operationally

Local Time Coverage in MLT



Spatial Coverage in 6 Hours



Global Model Physics Modules Needed for Upper Levels

- Heating due to UV O_2 and O_3 photolysis
- Non-LTE CO_2 longwave cooling to space
- Downward Diffusion of Thermospheric Heat
- Parameterization of Net Exothermic Chemical Heating
- **Gravity-Wave Drag** (Momentum Deposition)
  - Orographic Sources of Gravity Wave Drag (OGWD)
  - Nonorographic Sources of Gravity Wave Drag (NGWD)
  - Frictional Heating (KE Dissipation)
  - Momentum/Heat Mixing due to GW-Induced Turbulence
  - NGWD not carefully tuned as yet

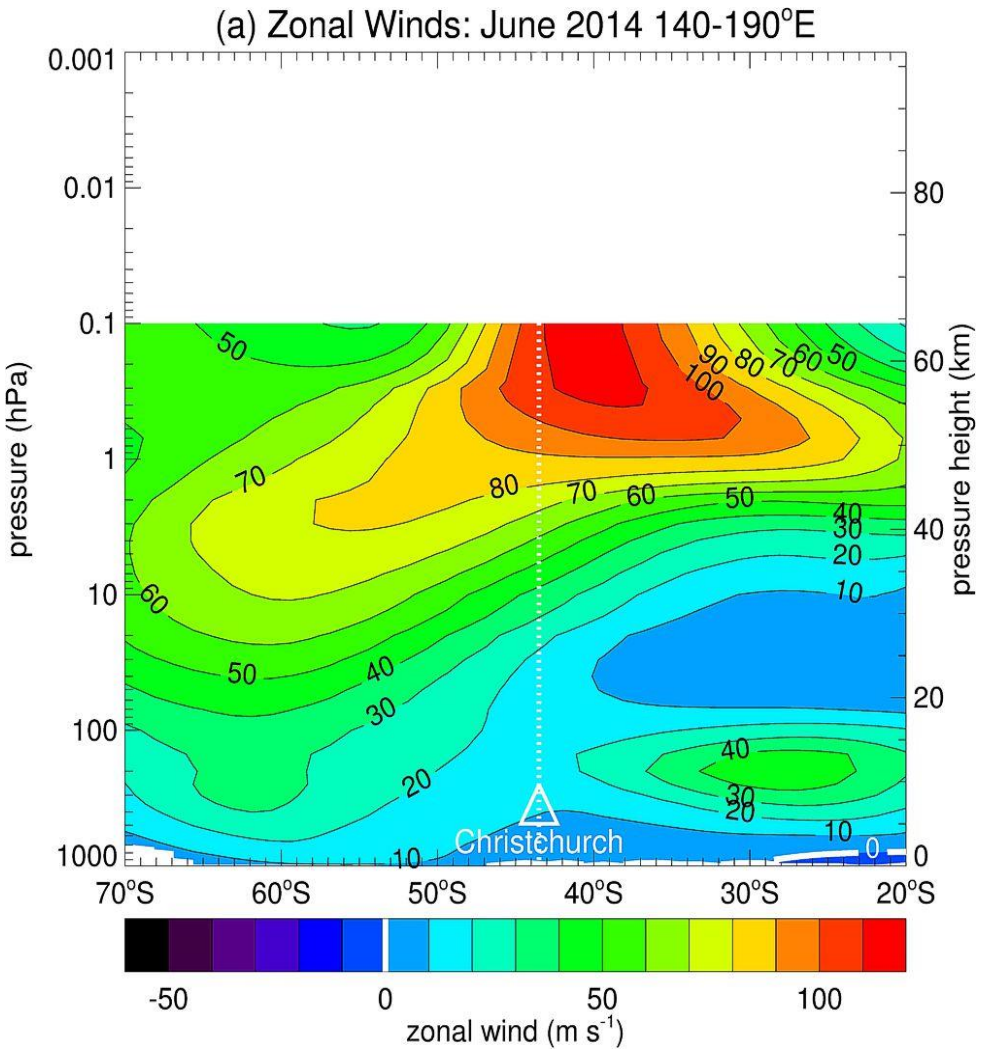
Initial NAVGEM DEEPWAVE Reanalysis Test Runs

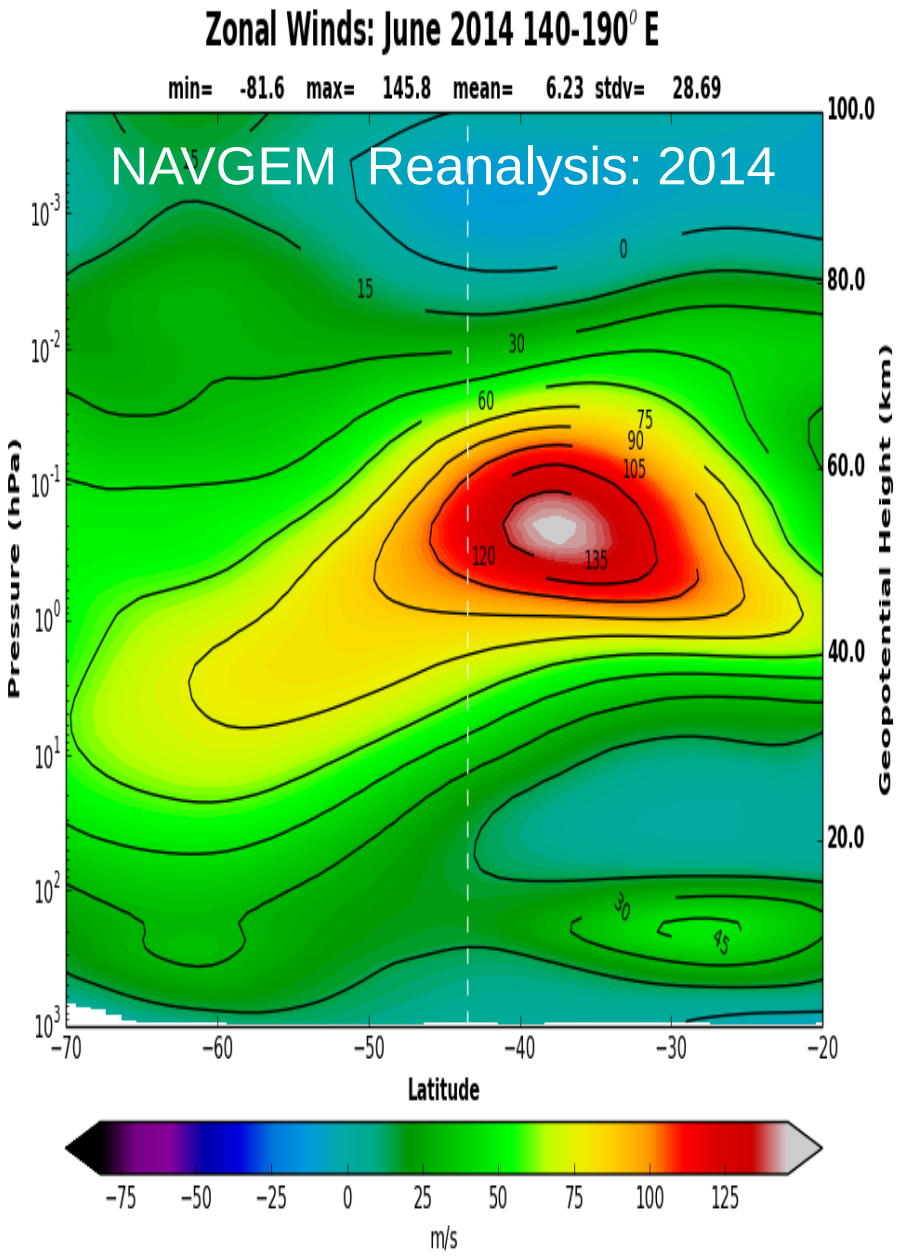
Name:	D3007DM2	L74T47	R3301C	T119L74	D3007DM
DSRC Machine:	KILRAIN	COPPER	COPPER	COPPER	KILRAIN
Outer Loop Resolution:	T119L74	T119L74	T425L60	T119L74	T119L74
Inner Loop Resolution	T119L74	T47L74	T119L60	T119L74	T119L74
2014 Reanalysis Period:	23 Mar-8 Sep	23 Mar-3 Aug	23 Mar-29 Jul	23 Mar-1 Aug	23 Mar-31 Oct
DIGFILT:	F	F	F	T	F
UAS:	T	T	T	T	T
UAS_REGTYPE	varBC	varBC	varBC	varBC	varBC
SBUV O3	F	F	T	F	F
ATMS	T	T	T	T	T
MLS (Aura)	T	T	F	T	T
SABER (TIMED)	T	T	F	T	T

- All experiments have AMSU-A, MHS, GPS, SSMIS (non-UAS), Aqua (AIRS) and IASI activated
- D3007DM2 rerun of D3007DM with updated varBC

“Zonal Mean” (140-190E) for June

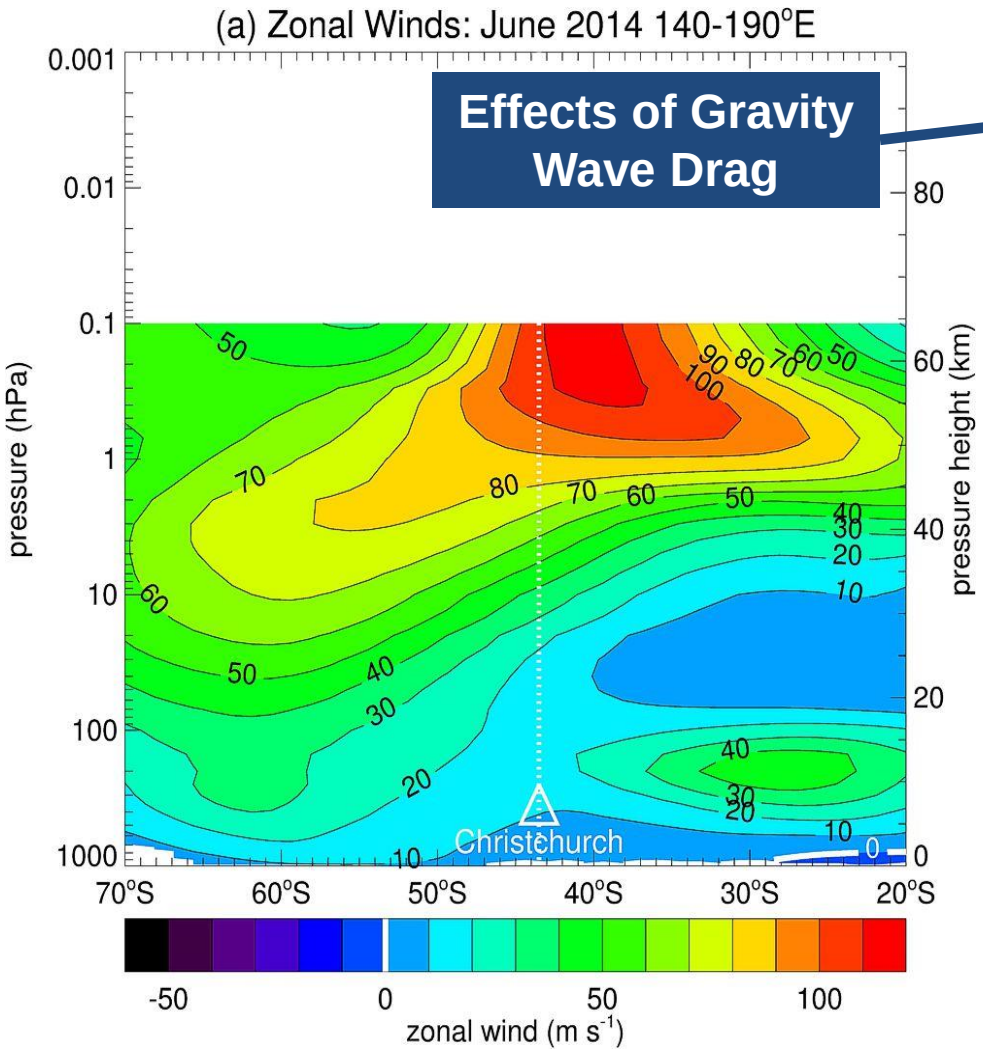
NASA MERRA Reanalysis: 2014





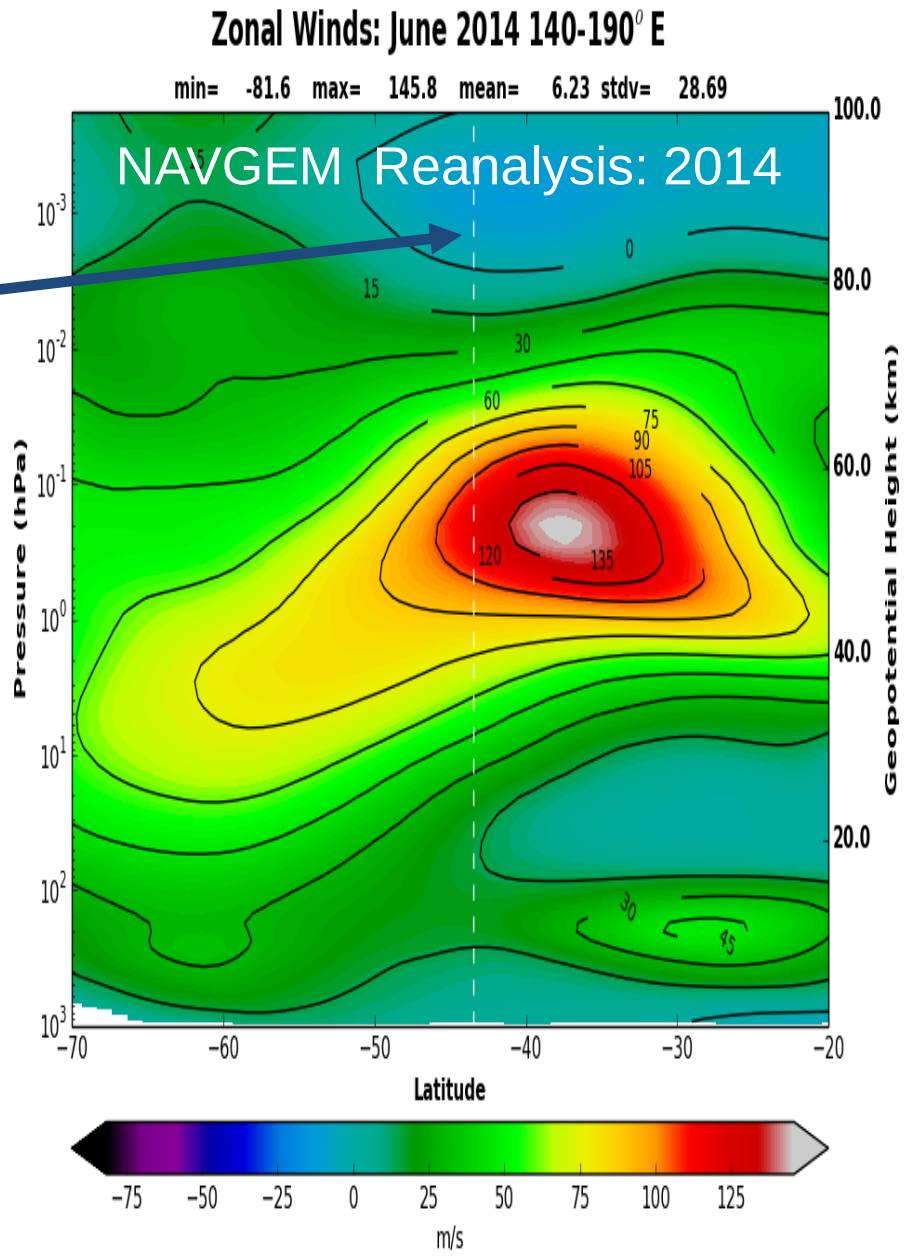
“Zonal Mean” (140-190E) for June

NASA MERRA Reanalysis: 2014

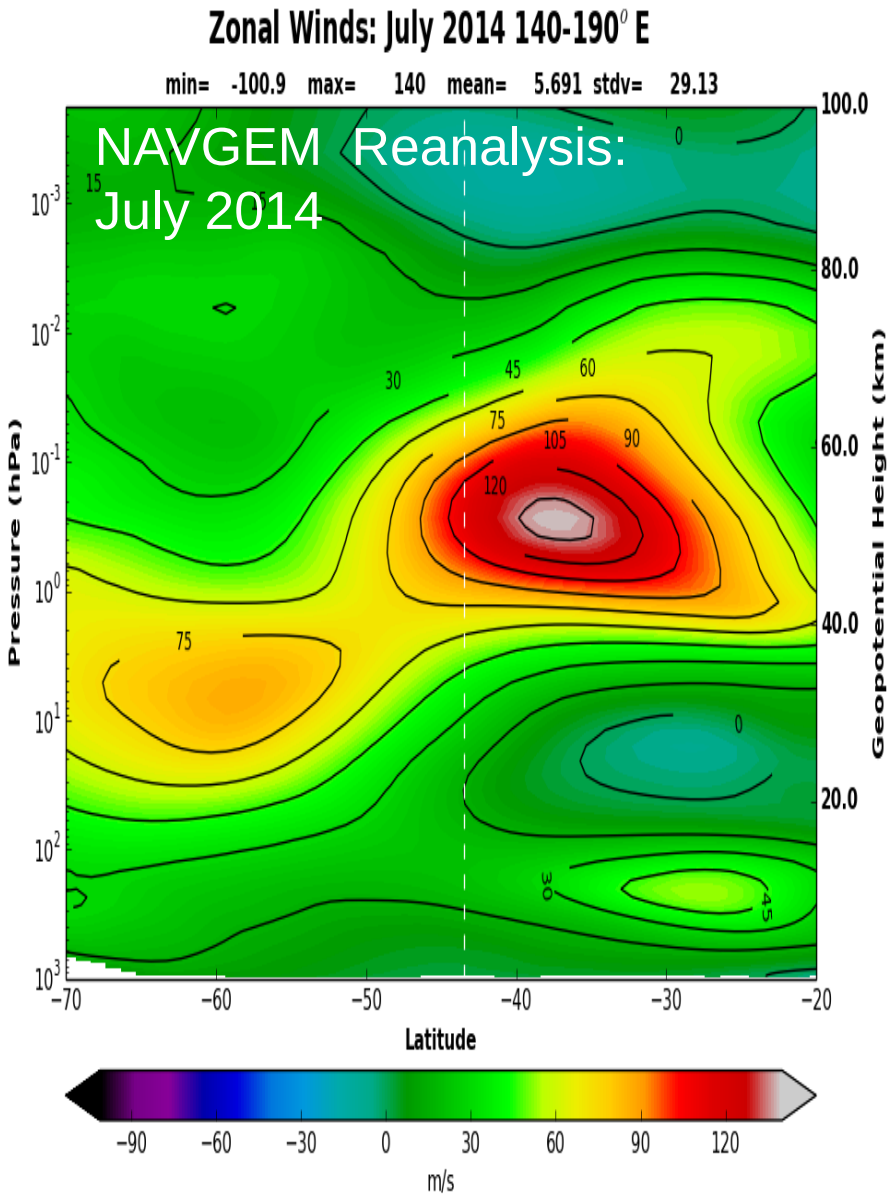


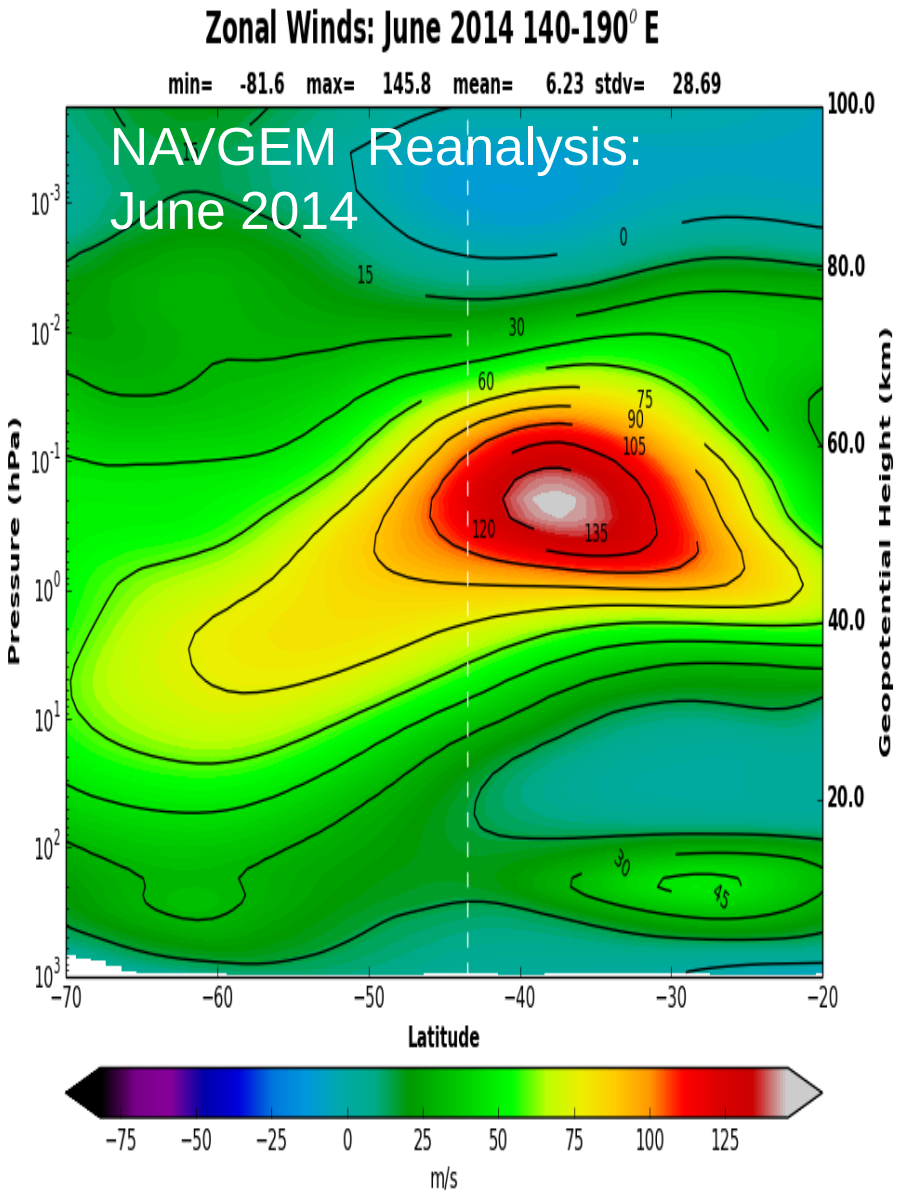
Effects of Gravity Wave Drag

NAVGEM Reanalysis: 2014

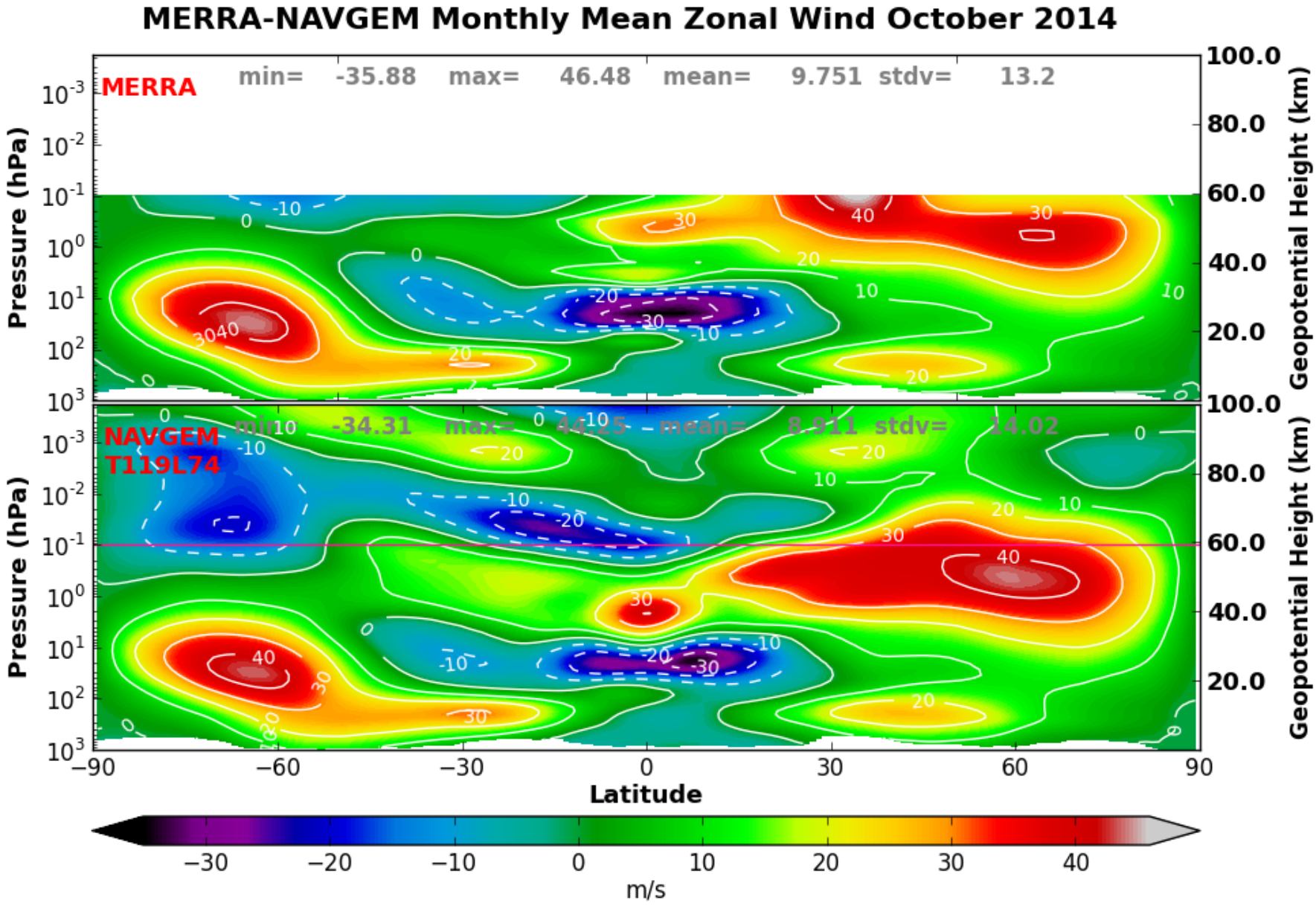


NAVGEM: June vs. July 2014

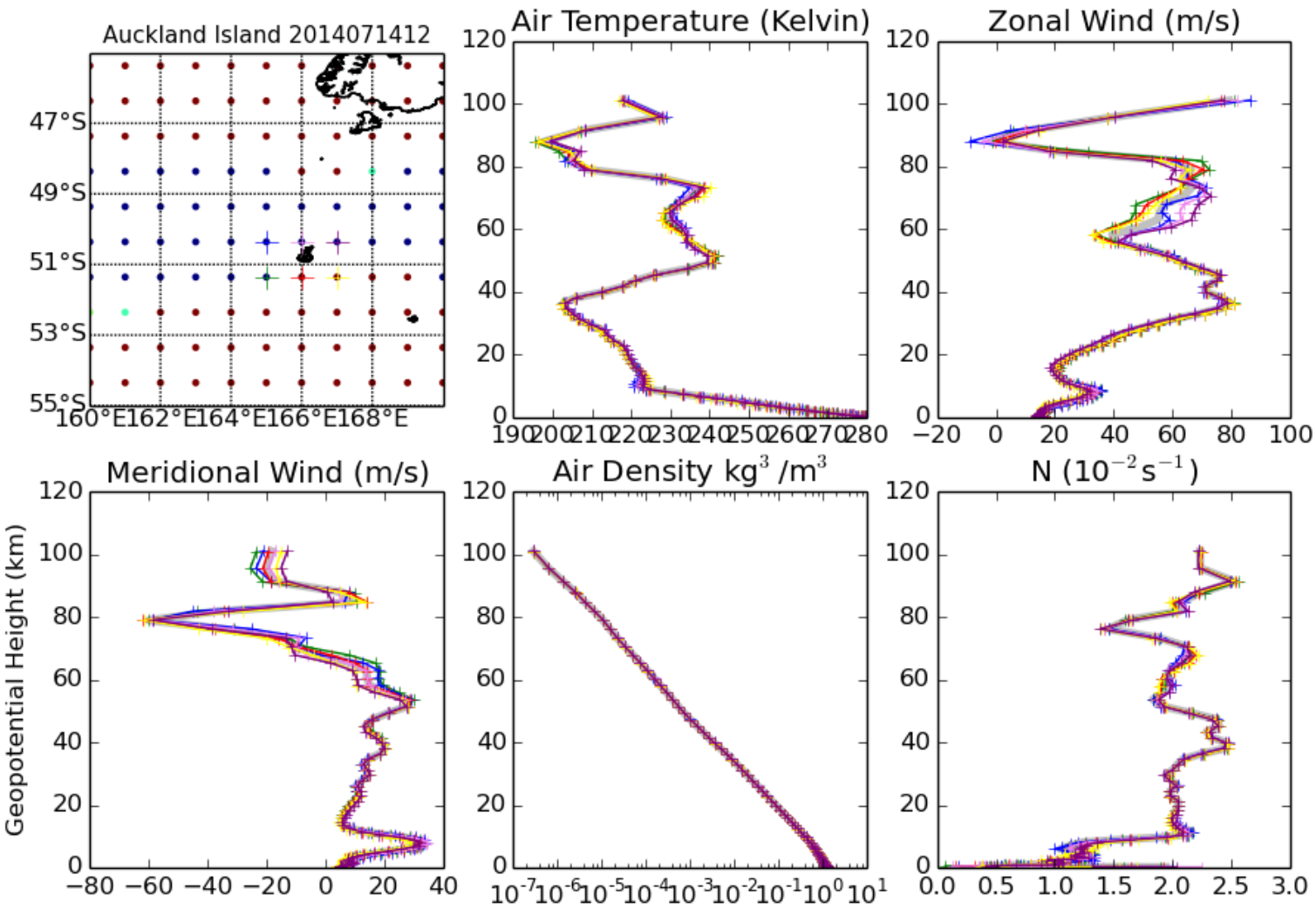




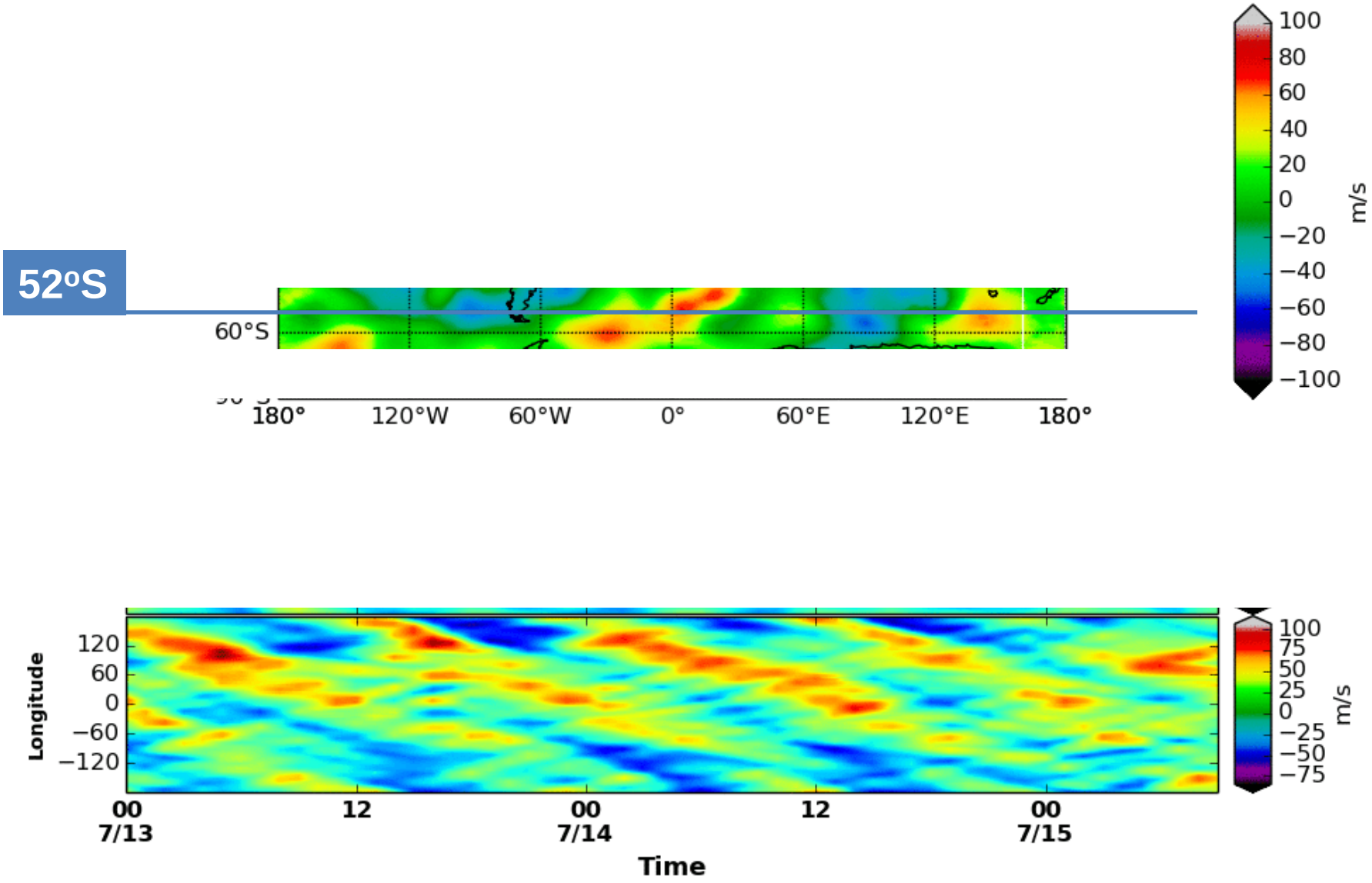
Zonal Winds: NAVGEM v. MERRA



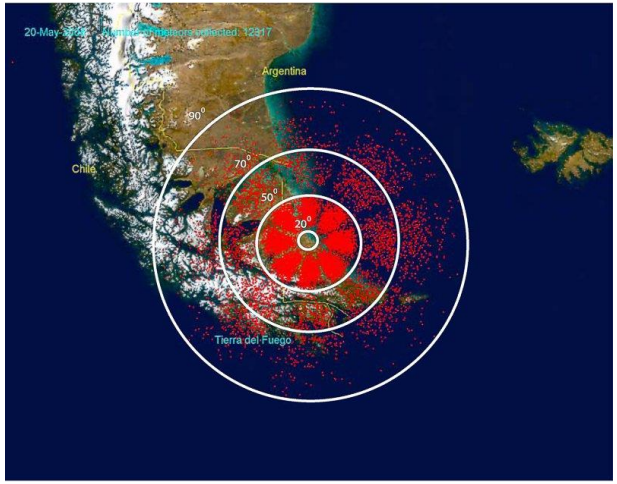
RF23: Winds over Auckland Island



Large Semidiurnal Tides ~90 km

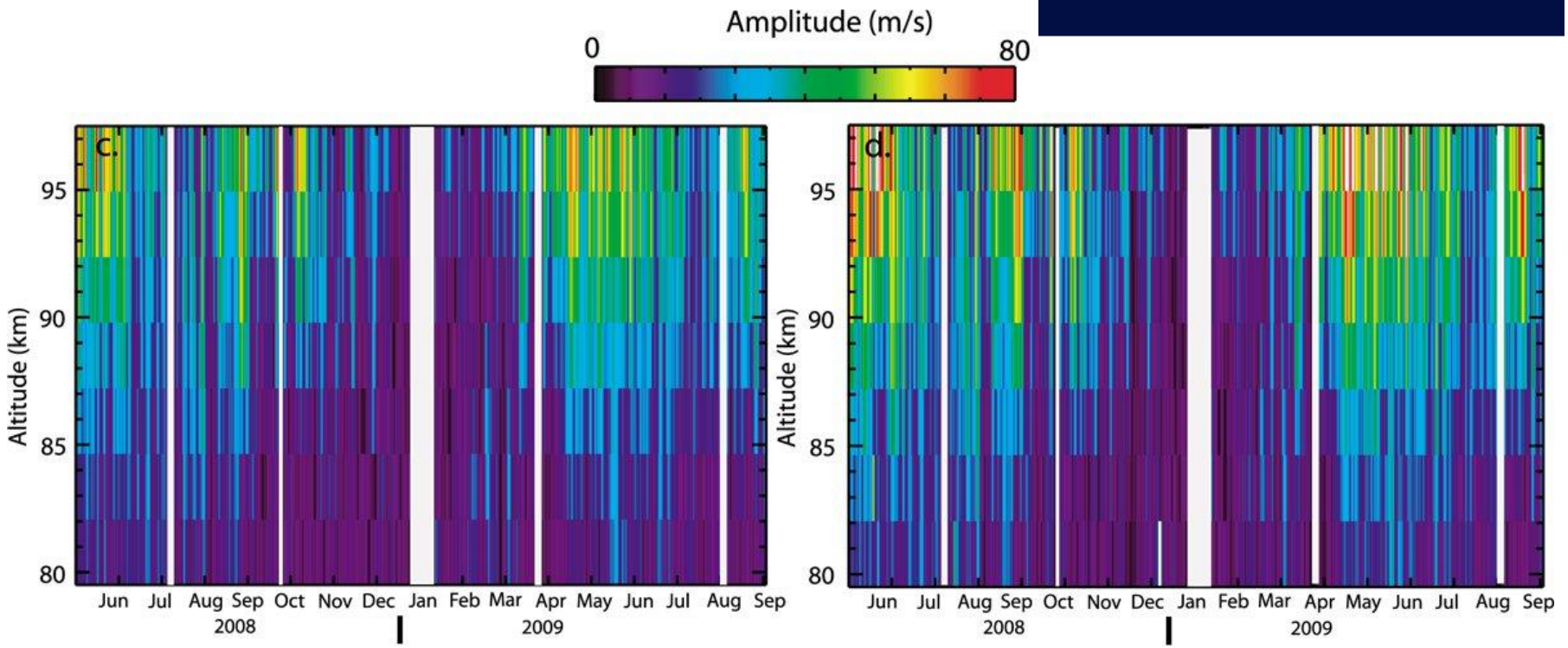


Semidiurnal Tidal Amplitudes at ~90 km & 53.8°S

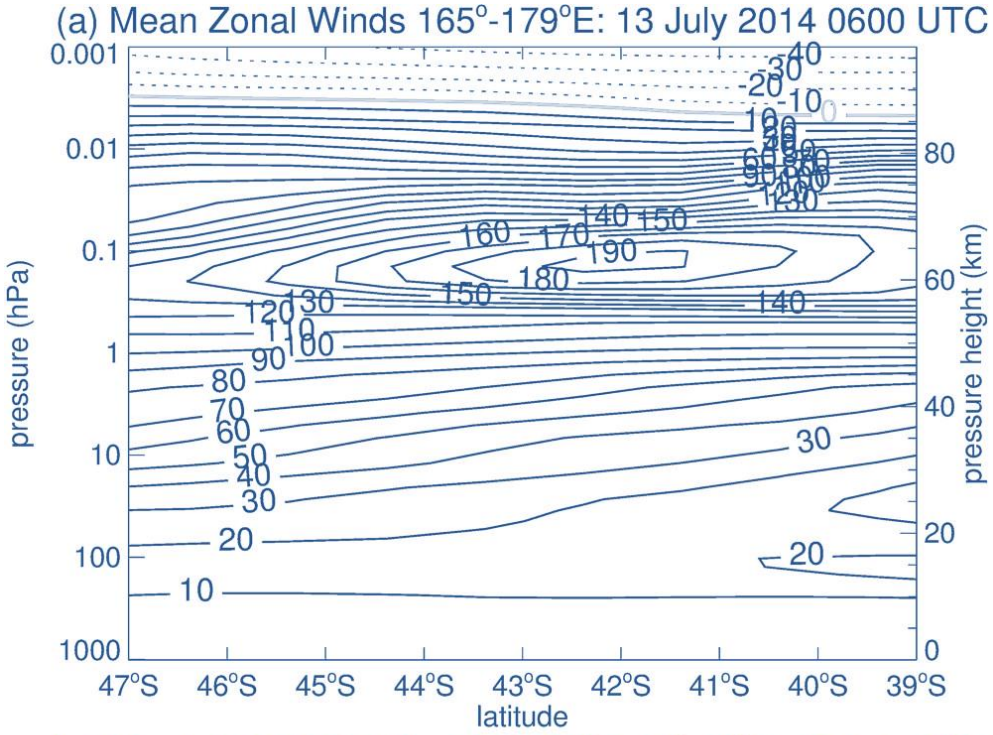


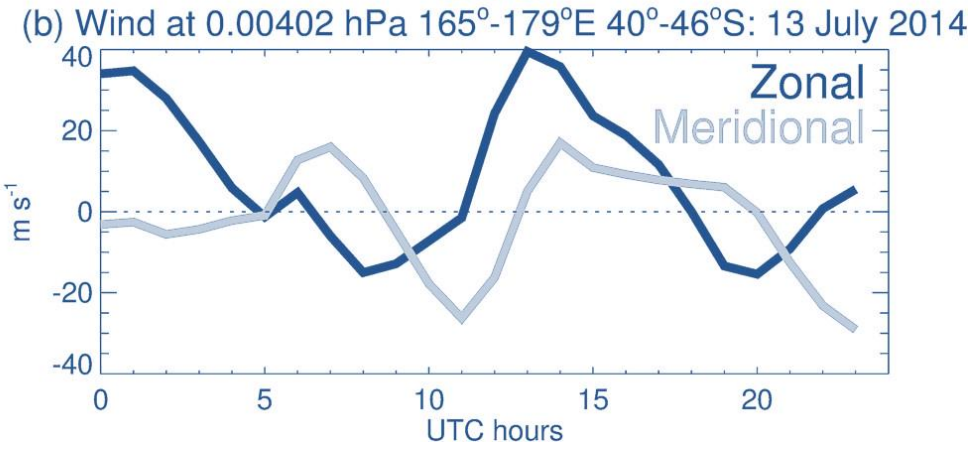
Winds at 80-95 km measured by Southern Argentina Agile Meteor Radar (SAAMER)

Fritts, D. C., et al. (2010), Southern Argentina Agile Meteor Radar: System design and initial measurements of large-scale winds and tides, J. Geophys. Res., 115, D18112, doi:10.1029/2010JD013850.



RF 22 Zonal Winds: 13 July 0600Z





For RF22 and RF23 NAVGEM MLT reanalysis over South Island yields:

1. weakening or reversal to mean easterlies
2. Strong semidiurnal tides

MLT MW observations suggest westerlies persist to ~90 km

Untuned NGWD with large phase speeds may be responsible

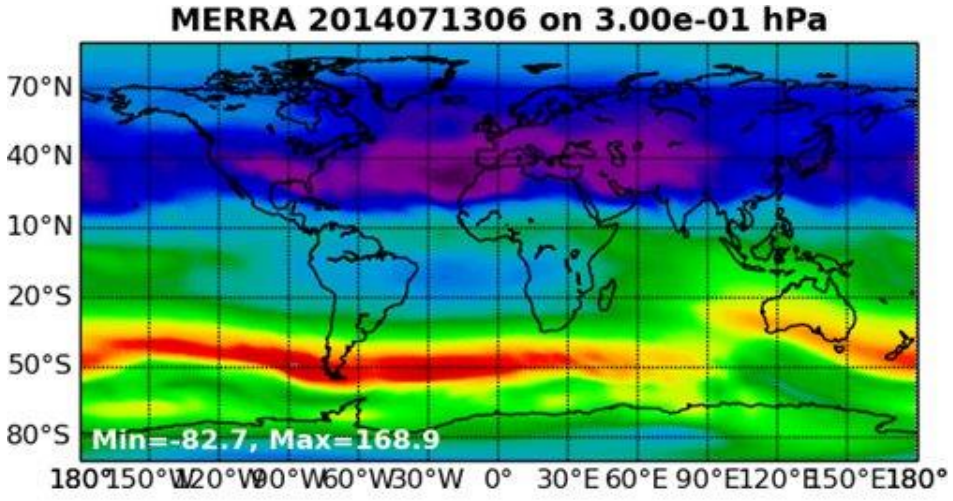
Limited radar observations suggest semidiurnal tides ~10 ms^{-1} amplitude in winter MLT over New Zealand (Stening et al. JASTP 1995)

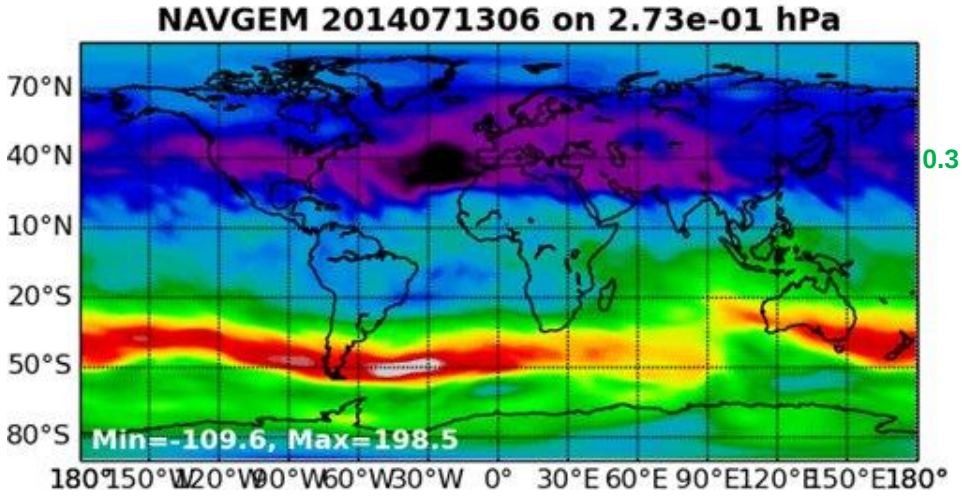
Really want to compare to Kingston meteor radar winds

Summary

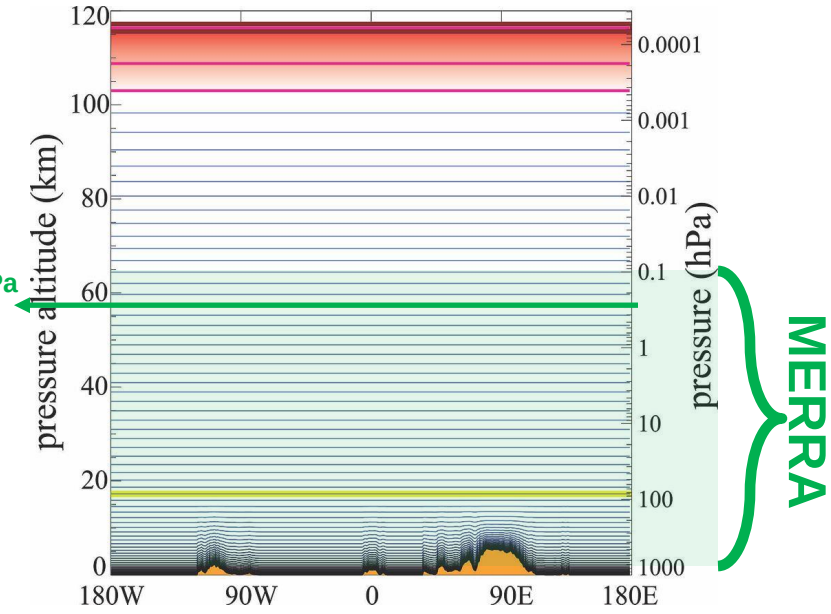
- NAVGEM reanalyses are being generated to support DEEPWAVE GW science from 0-100 km
- Good comparisons with other low-altitude reanalyses
- Somewhat realistic closure of jets in MLT
- Strong semidiurnal tidal winds in MLT
- Fields available for DEEPWAVE scientific use
- New runs will add/tune physics and hopefully improve final MLT analysis
- Need validation against independent MLT obs
- Why are our resolved gravity waves so weak?

MERRA v. NAVGEM for RF22
0.3 hPa: 13 July 2014 0600 UTC



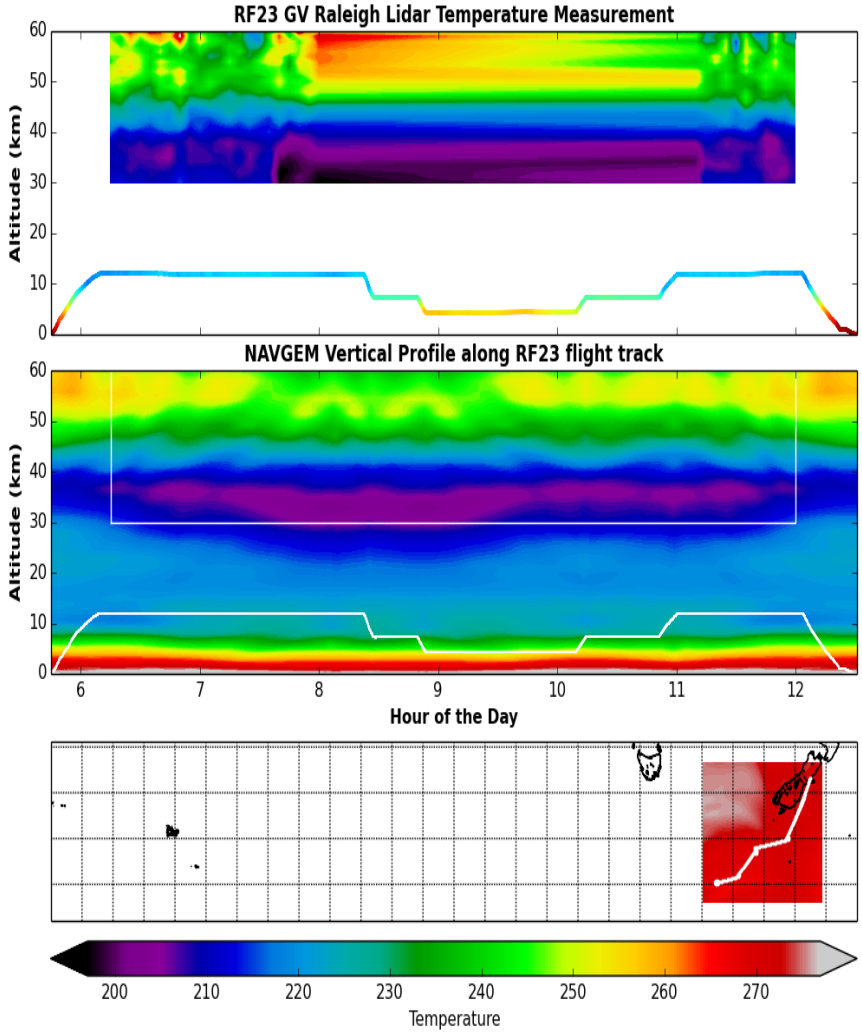


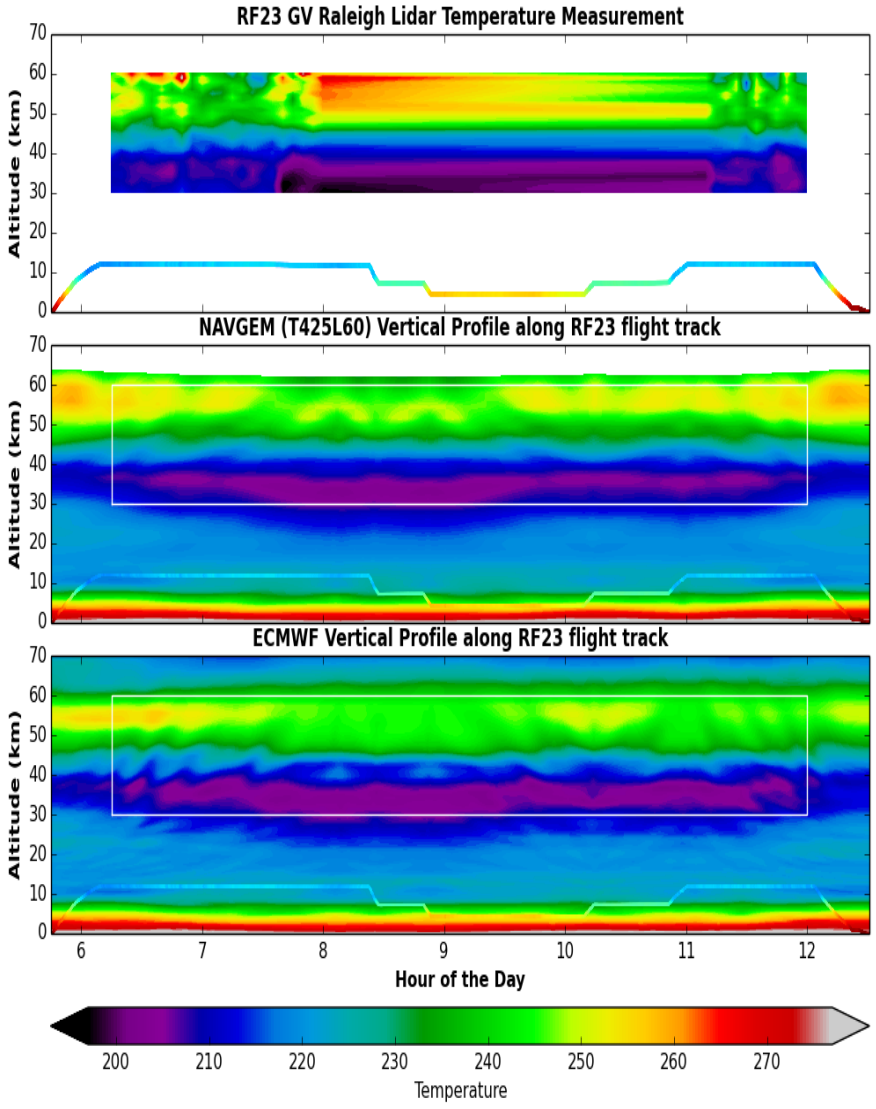
Strong deformed stratopause jet over New Zealand agrees well with MERRA

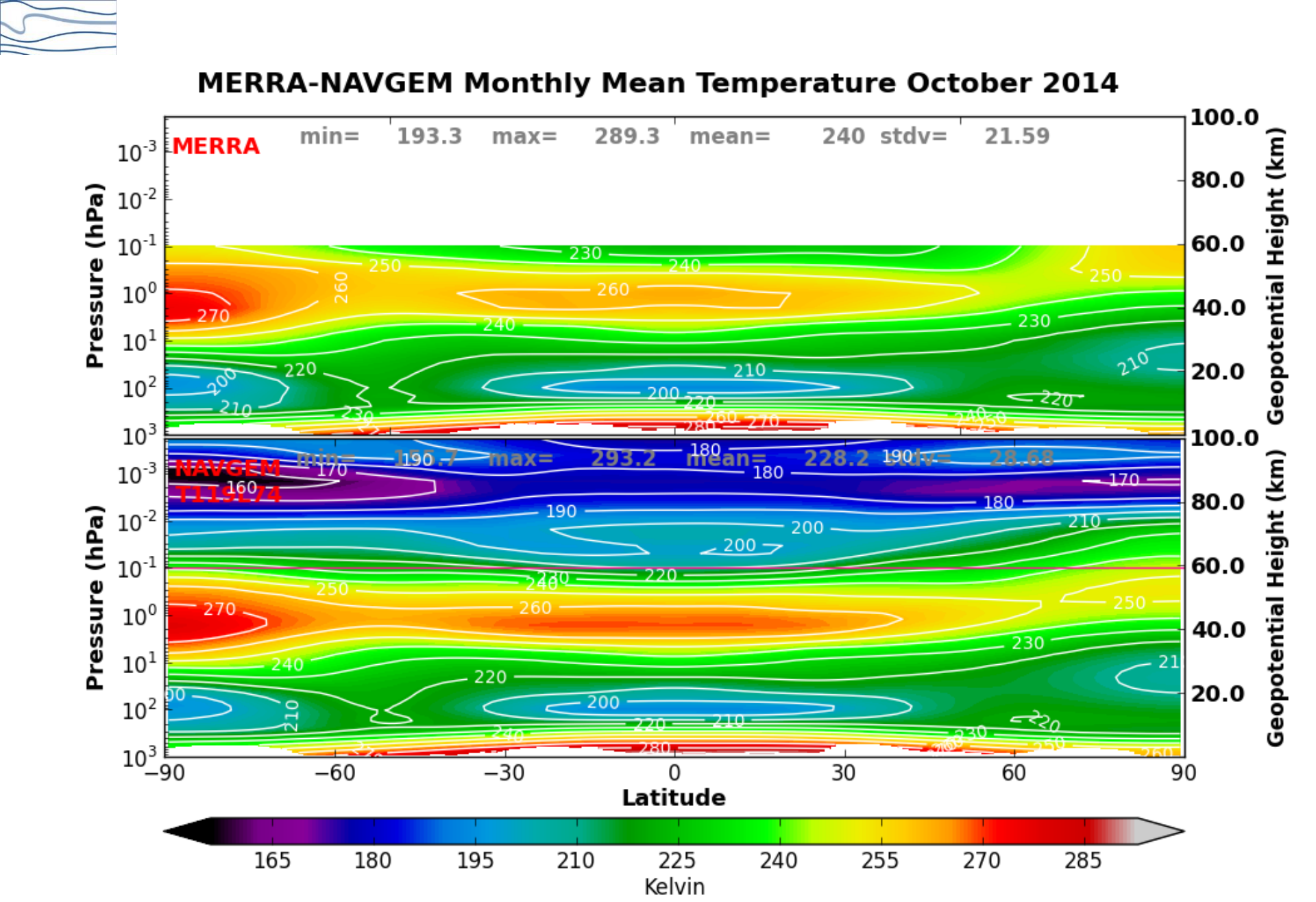


BACKUP SLIDES

Sections Along RF23 Flight Track

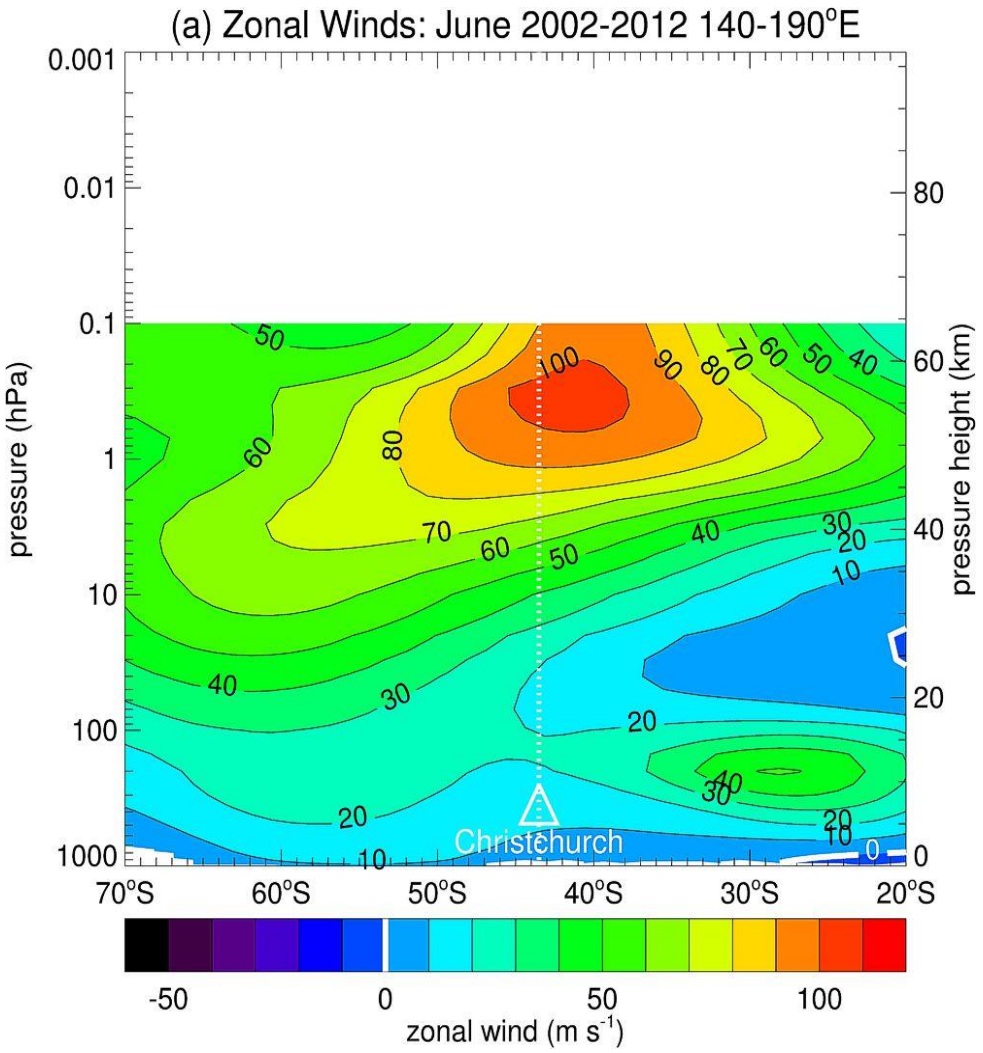




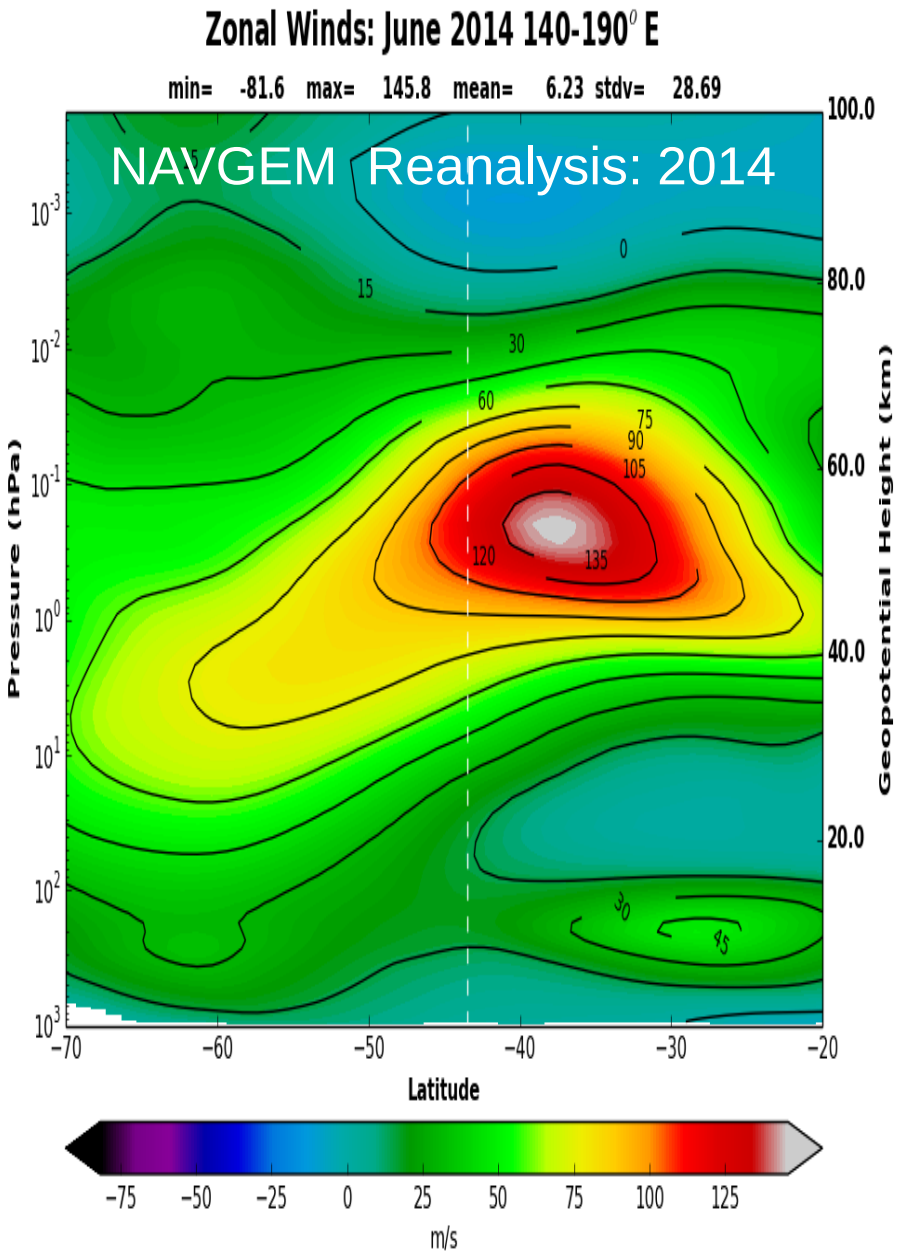

MERRA-NAVGEM Monthly Mean Temperature October 2014
MERRA
min= 193.3 max= 289.3 mean= 240 stdv= 21.59
NAVGEM
T119L74
min= 165.7 max= 293.2 mean= 228.2 stdv= 28.68
Pressure (hPa)
Geopotential Height (km)
Latitude
−90
−60
−30
0
30
60
90
Kelvin
165
180
195
210
225
240
255
270
285

Zonal Mean Winds for June

NASA MERRA Reanalysis: 2002-2012

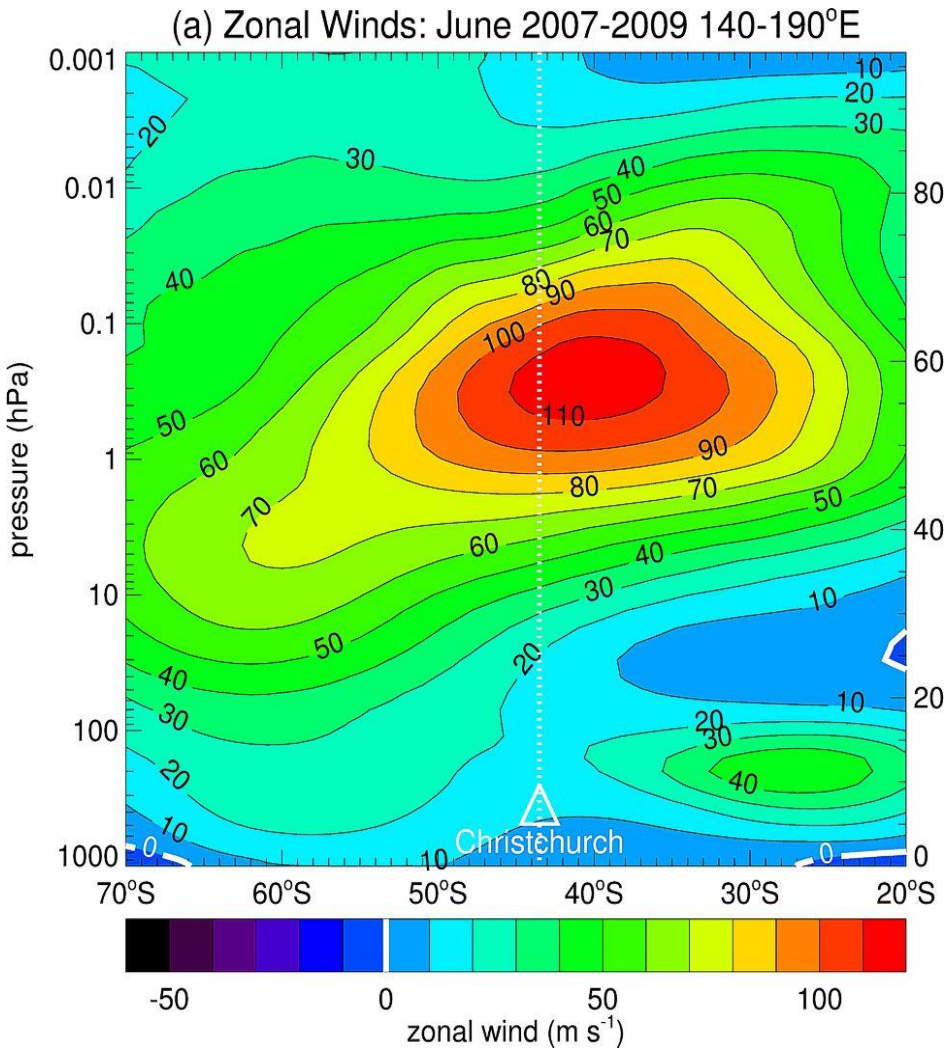


NAVGEM Reanalysis: 2014



"Zonal Mean" (140-190E) Zonal Winds for June

NOGAPS-ALPHA Reanalysis: 2007-2009



NAVGEM Reanalysis: 2014