TWPICE Stratospheric Gravity Waves and the Diurnal Tide measured with Radiosondes

Preliminary Results

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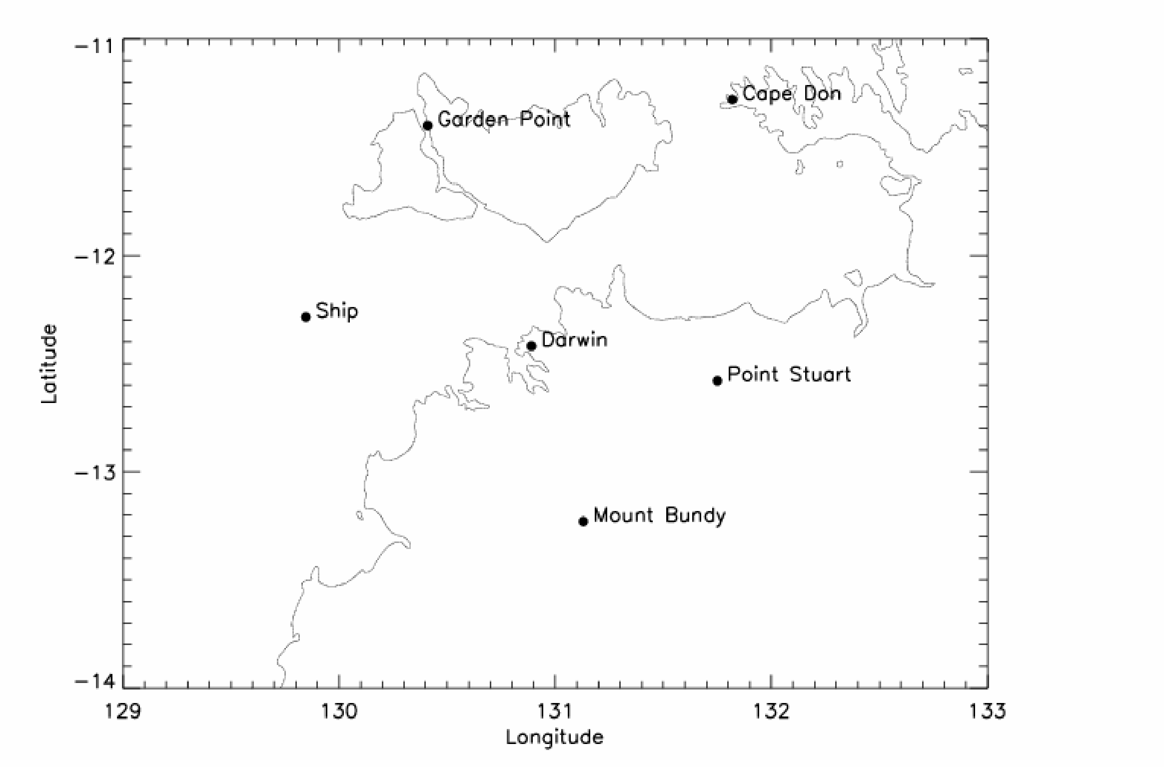
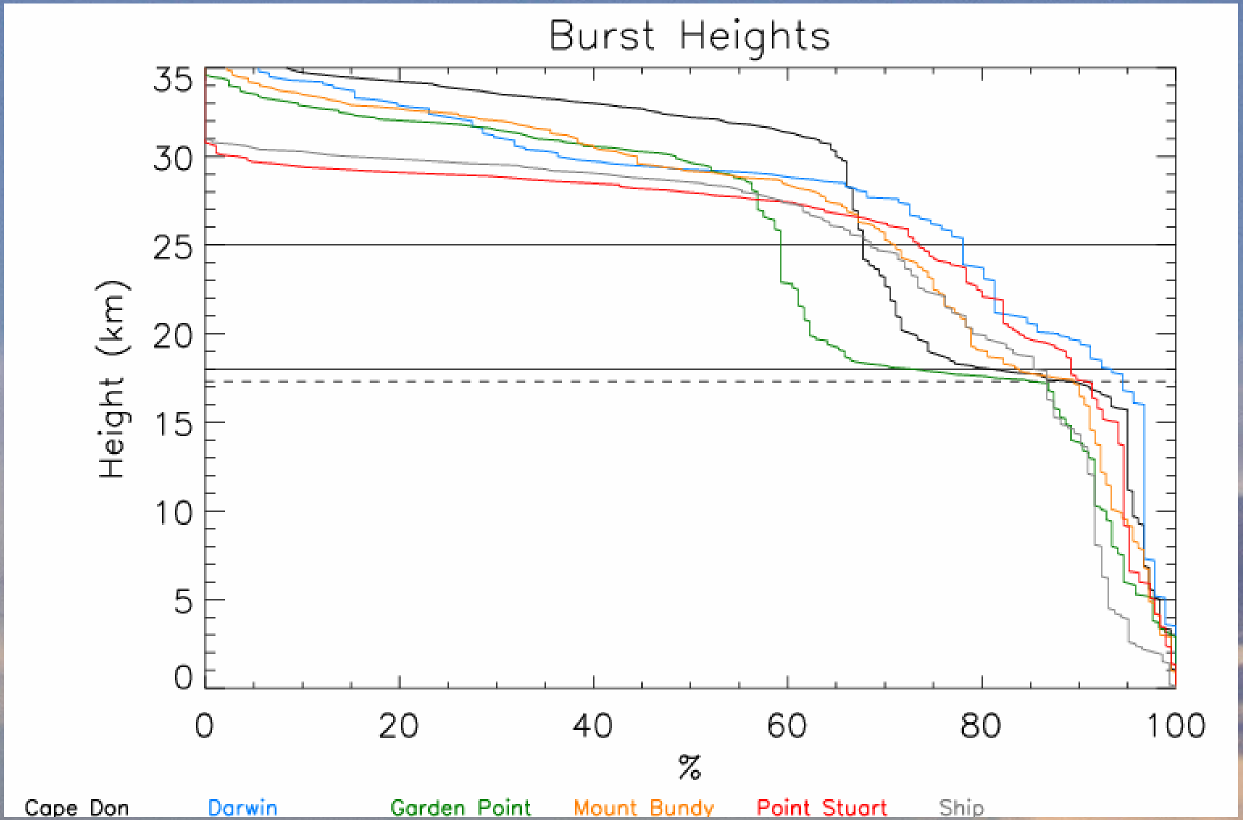
Radiosonde Launch Sites



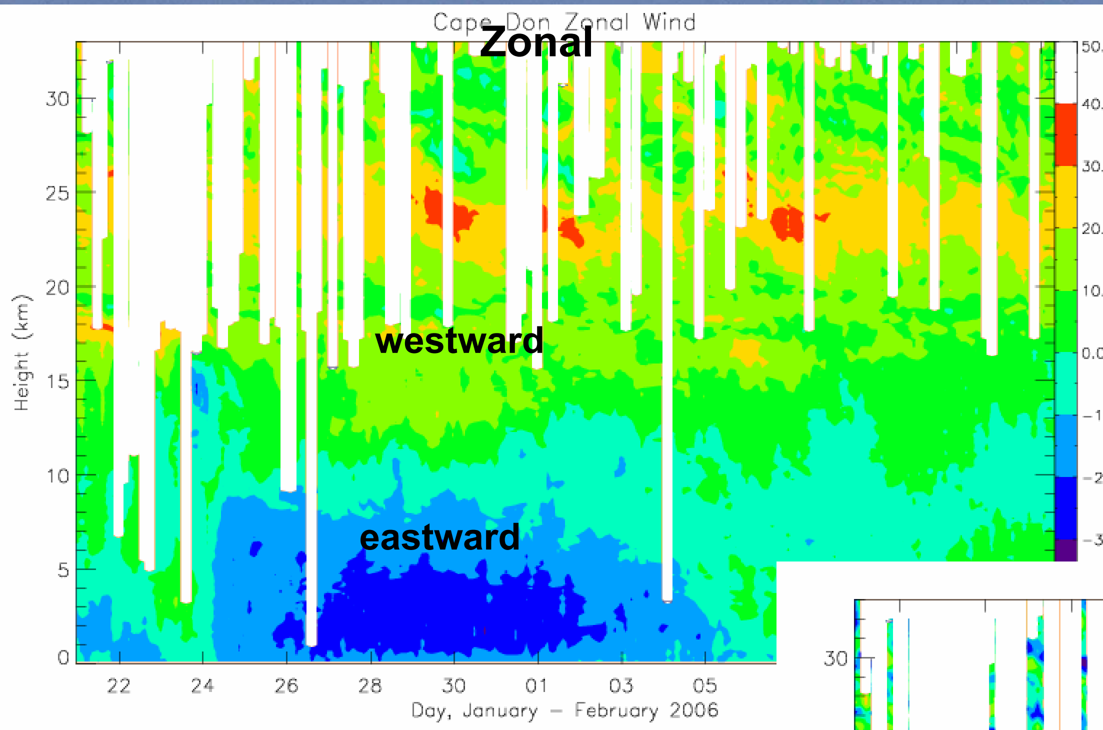
- Radiosondes launched every three hours except Darwin (six hourly)
- Ship not in a constant location
- Sites ~100km from Darwin provides opportunity to study small scale wave field features and variability

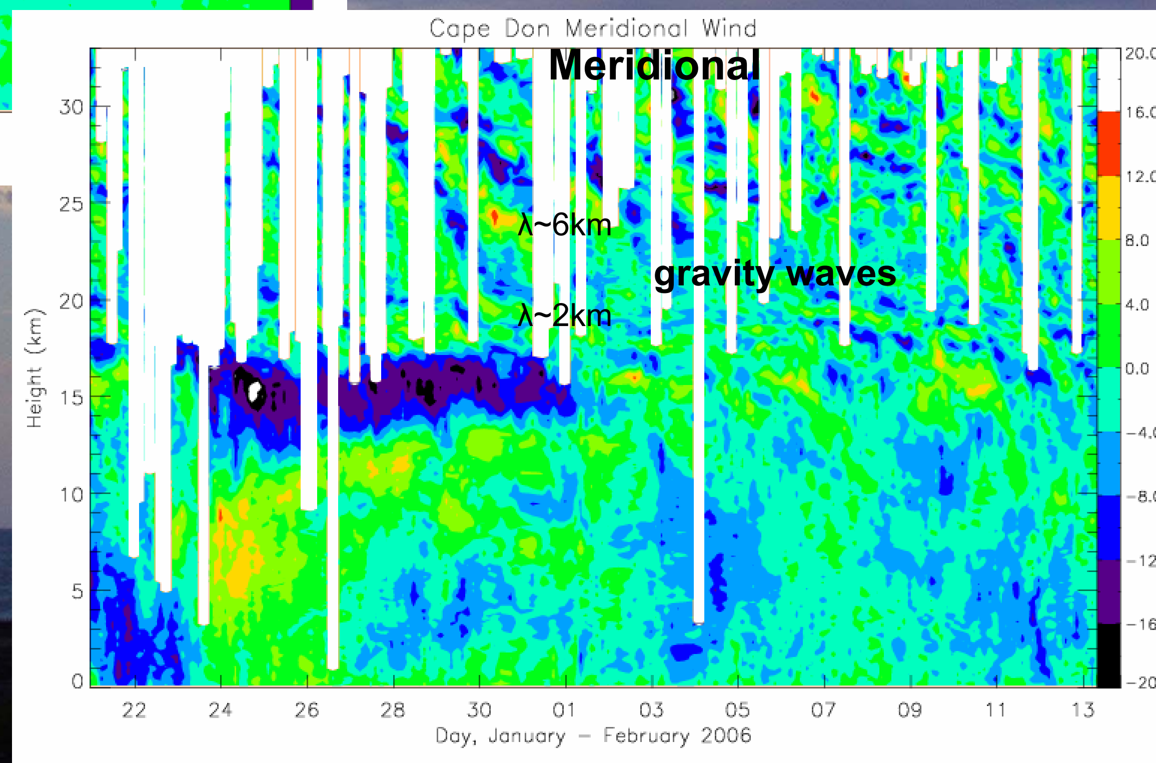
Balloon Burst Height



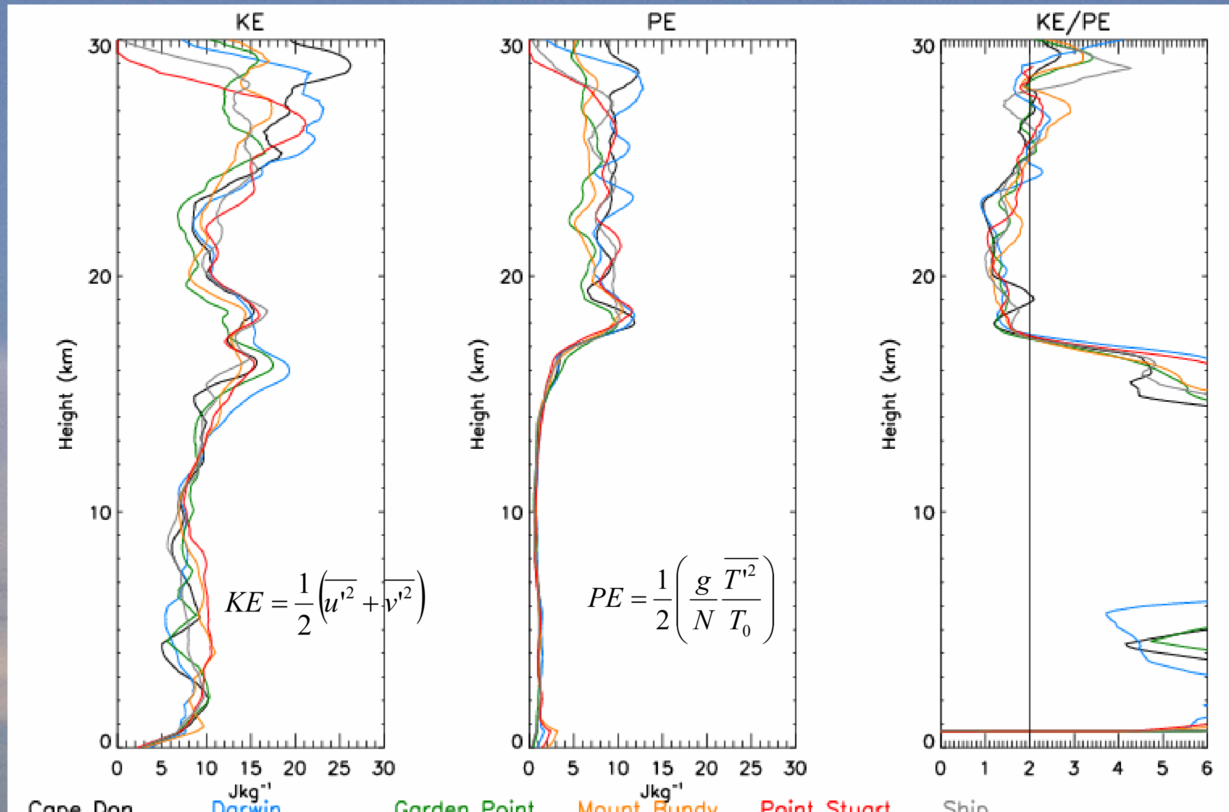
- Mean tropopause height marked by dashed line, ~17.5km
- Many bursts occurred at tropopause or first few km of stratosphere
  - note that Garden Point (green) has only 60% of radiosondes above 20km
  - many of these bursts at the tropopause occurred during the first half of TWPICE
- Solid lines show region of interest for gravity waves (later)

Cape Don Detailed Wind Structure



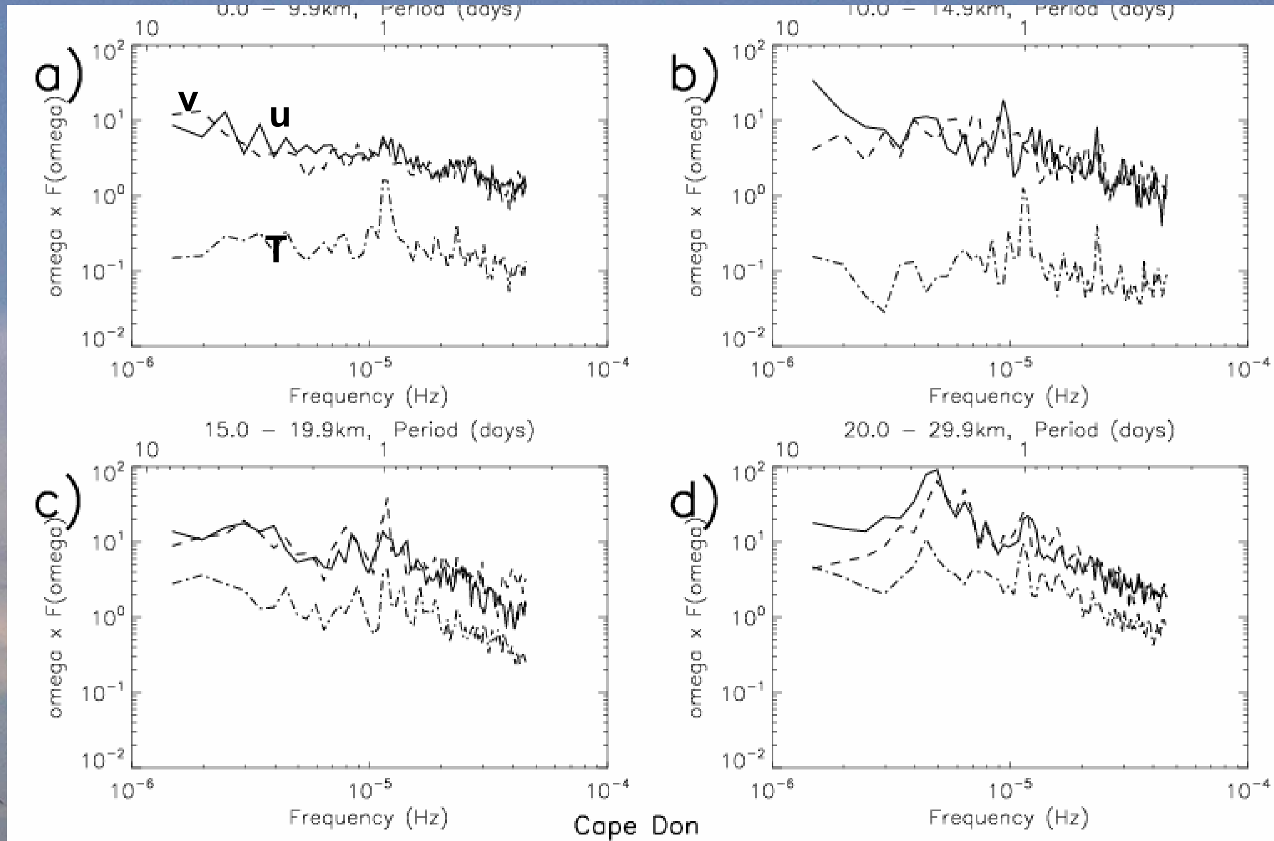


Kinetic & Potential Energy



- Daily wind and temperature variances calculated, from which KE, PE obtained
- Peak in KE at ~18km (15 J/kg) and 26 -27km (~20 J/kg)
- PE constant in stratosphere, ~10 J/kg at all heights
- KE / PE ratio ~1.6 in the lower stratosphere (18 – 25km) suggests wave field dominated by inertial gravity waves.

Radiosonde Spectra – Cape Don



0 – 10km

10 – 15km

15 – 20km

20 – 30km

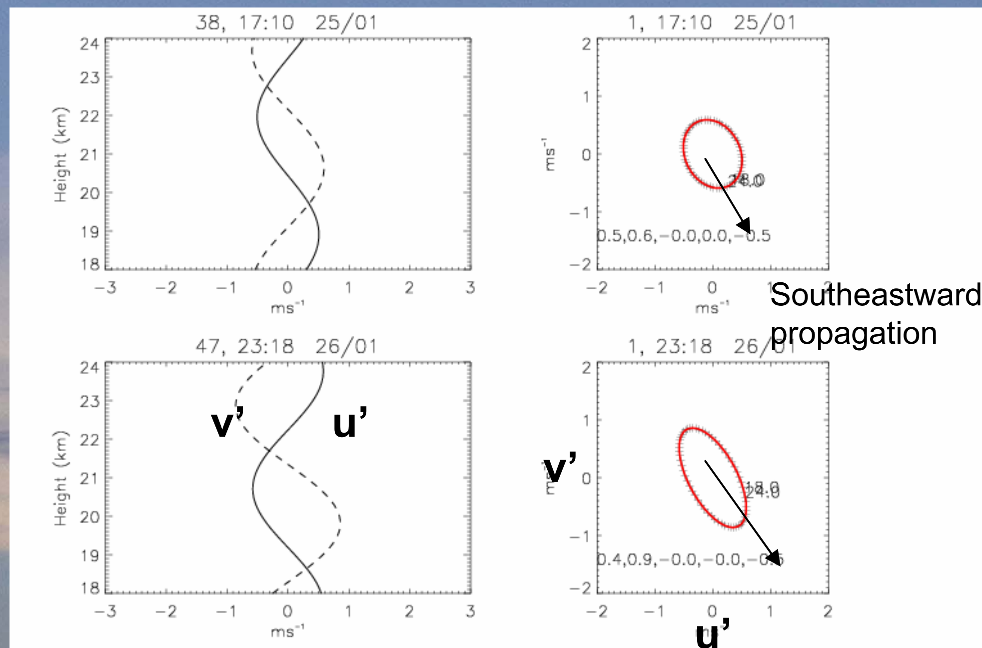
- Strong diurnal peak in *T* at all altitudes
- Diurnal *u, v* components also clear in UTLS and stratosphere
- Also strong 2.5 day wave in stratosphere

Inertial Gravity Waves

- Previous tropical campaign based or climatological standard (12-hourly) radiosonde analyses have shown preferential eastward wave propagation, vertical wavelengths ~ few km
- TWP-ICE IGW results also show similar characteristics
  - Focused on 18 – 25km region since KE/PE ~1.6 (indicative of IGW presence) and data quantity higher
- With TWP-ICE, we also have access to 4~km horizontal resolution MTSAT cloud top temperature data
  - eventually will use to determine wave sources if possible
  - study the temporal variability of these waves and relate to convection / monsoon

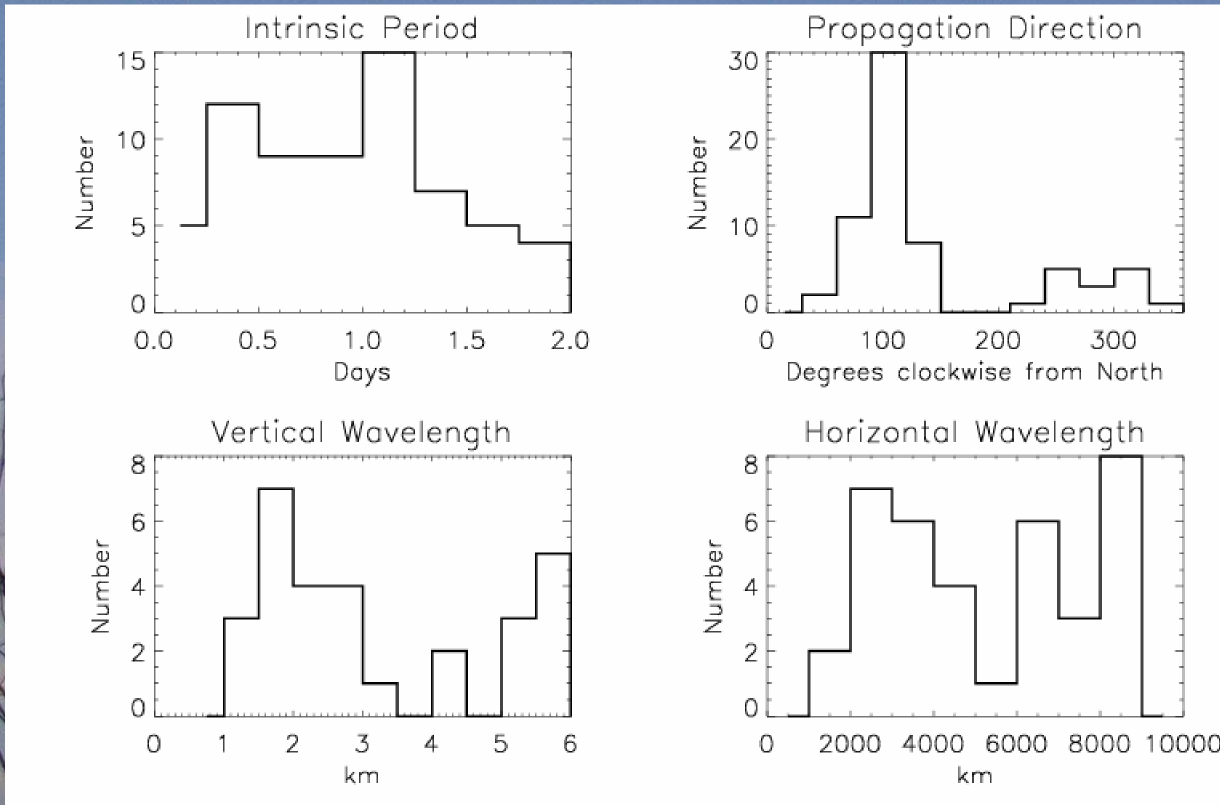
Hodograph Example – Cape Don

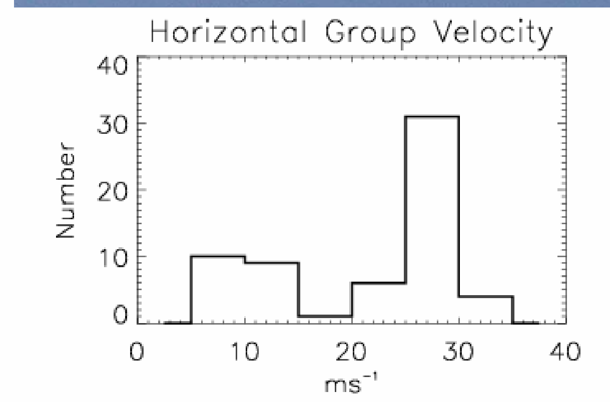
Lower stratosphere dominant wave



- Can determine propagation direction & other parameters from hodographs but waves must be monochromatic
- Extract dominant wave component for each radiosonde profile and bandpass that component
- Fit ellipse to obtain wave parameters: propagation direction, amplitude, vertical wavelength, period etc.
- Note that the MTSAT data is for the troposphere
  - Not directly related → cloud propagation directions different
  - Stratospheric waves may be from distant sources (mostly from the west & equatorial region as it turns out)

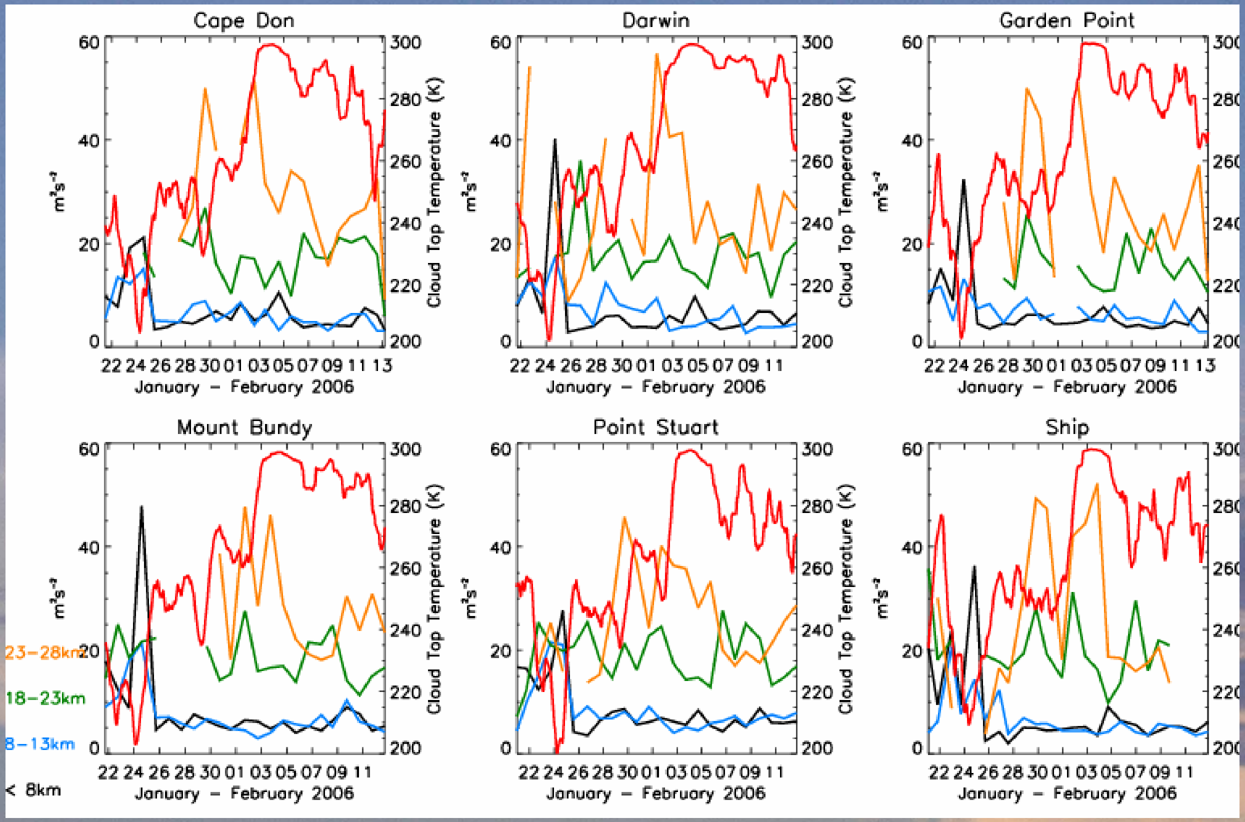
Gravity Wave Parameters – Cape Don





- Dominant wave component periods of 0.5 – 1.5 days
- Mostly propagate eastwards or southeastwards, with a few westward
- ~2km vertical wavelength, or 5 – 6km
- Horizontal wavelengths large compared with previous analyses
  - waves propagated close to the horizontal → may have come from distant sources
- Group velocities either ~10m/s or ~25m/s
- Other sites are similar to Cape Don

Temporal Variability of Gravity Wave Energy & Convection

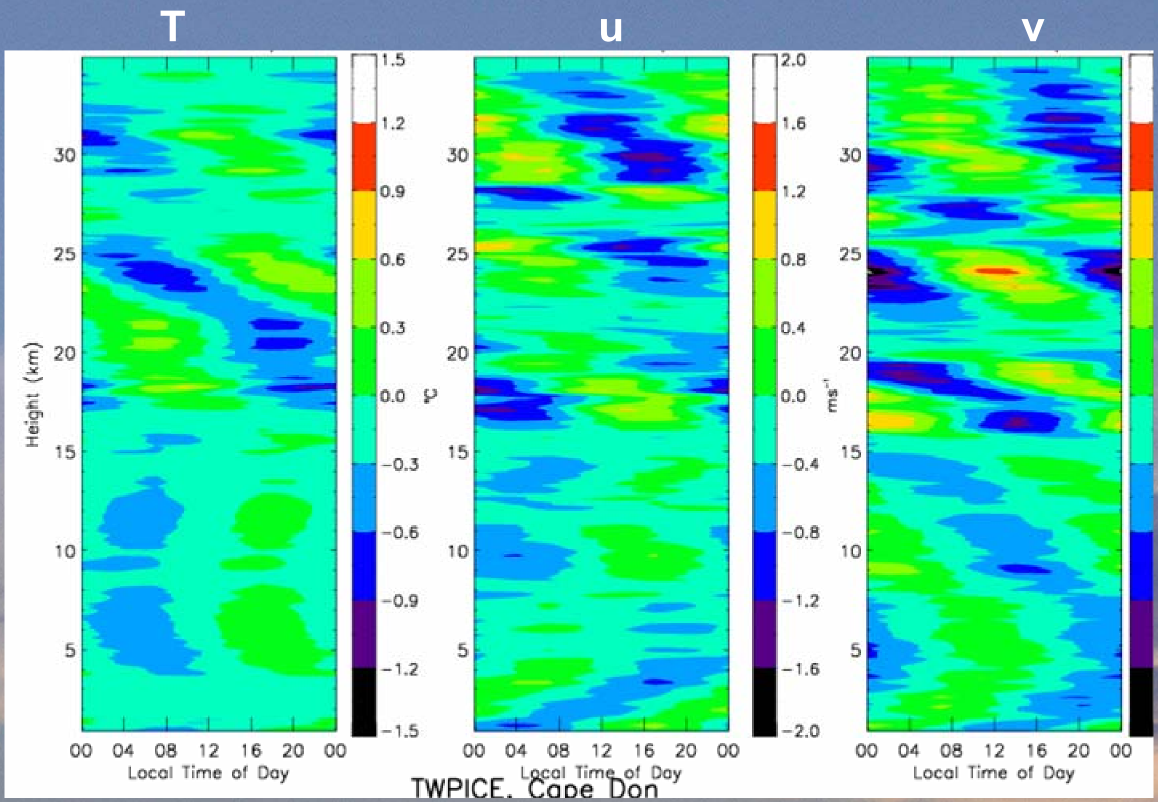


- Total Energy, i.e. KE + PE
- Red shows MTSAT cloud top temperature above each station
- Daily energy calculations are averaged in troposphere (black, blue), lower stratosphere (green) and mid-stratosphere (orange)
- Tropospheric energy increased during strong convection (~24 Jan)
- Large stratospheric energy after ~30 Jan, but datagaps prior to this preclude observations
- General decrease in energy apparent during TWPICE as monsoon returns in Feb

Diurnal Tides

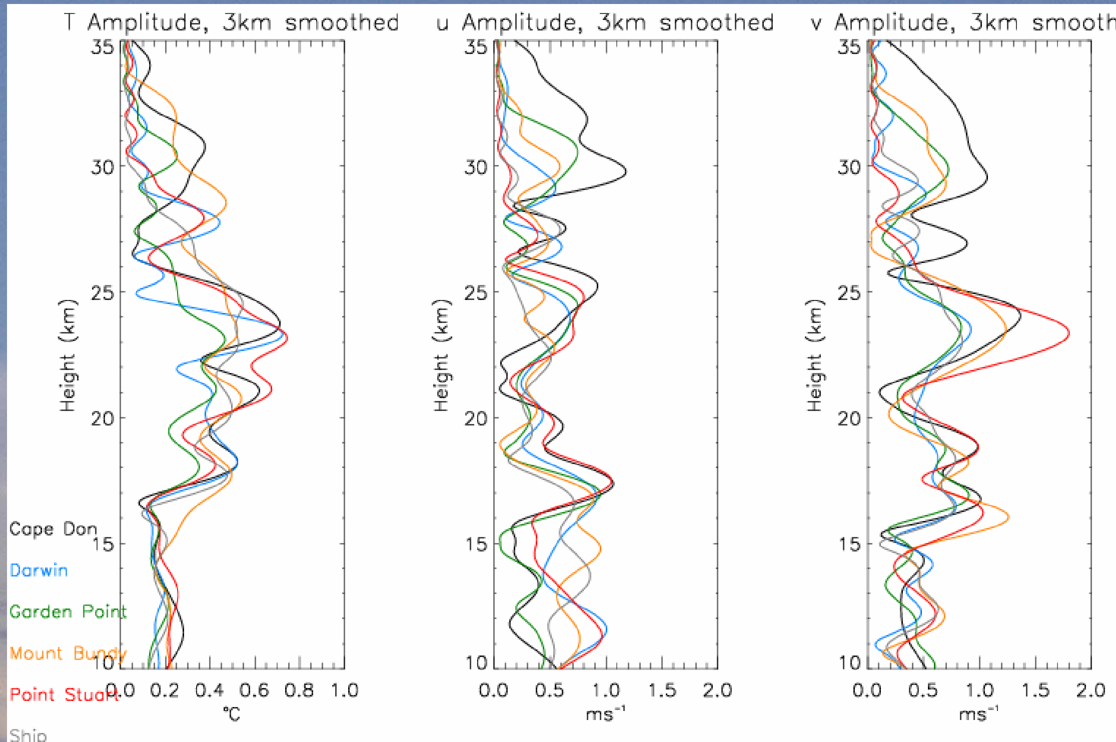
- Migrating (Sun-synchronous) component well modelled and is due to daily heating of water vapour in the troposphere
- But also have local effects, e.g. convection which often occurs on a diurnal cycle
- Convection believed to be partially responsible for *non-migrating* tide
- Inhomogeneous nature of water vapour an diurnal heating also responsible
  - More water vapour & diurnal heating over W Pacific than E Pacific
- non-migrating component not so well understood
- TWPICE three / six hour radiosondes can study the *non-migrating* tide below 30km

Diurnal Tides – Cape Don diurnal composite example



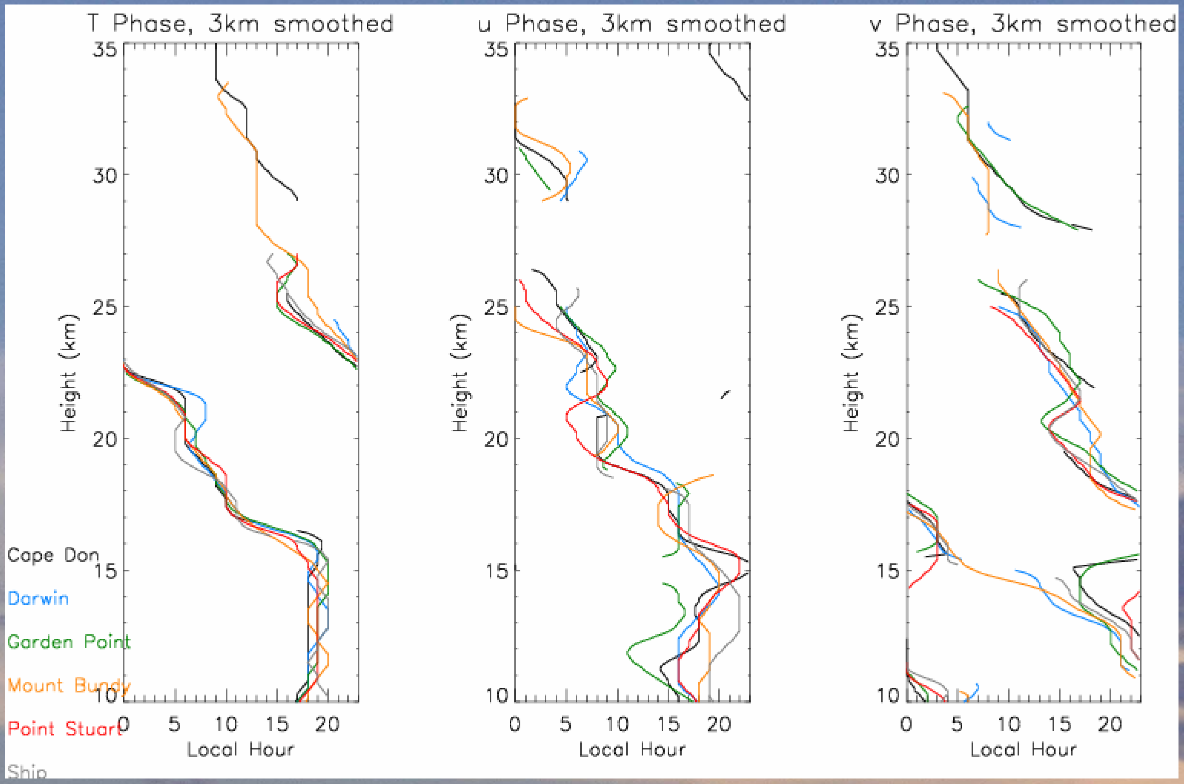
- Form daily composite from this filtered data, for each campaign
- Fit 24hr sine wave to data to obtain amplitude, phase of *T, u, v*
- Daily diurnal tide composite at Cape Don, but other sites similar
- Note downward phase propagation in stratosphere (upward energy)
- Mixture of upward *(v)*, downward *(u, v)*, standing *(T)* phases in the troposphere
- Weak amplitudes ~27km in all components

Diurnal Tides – Amplitudes



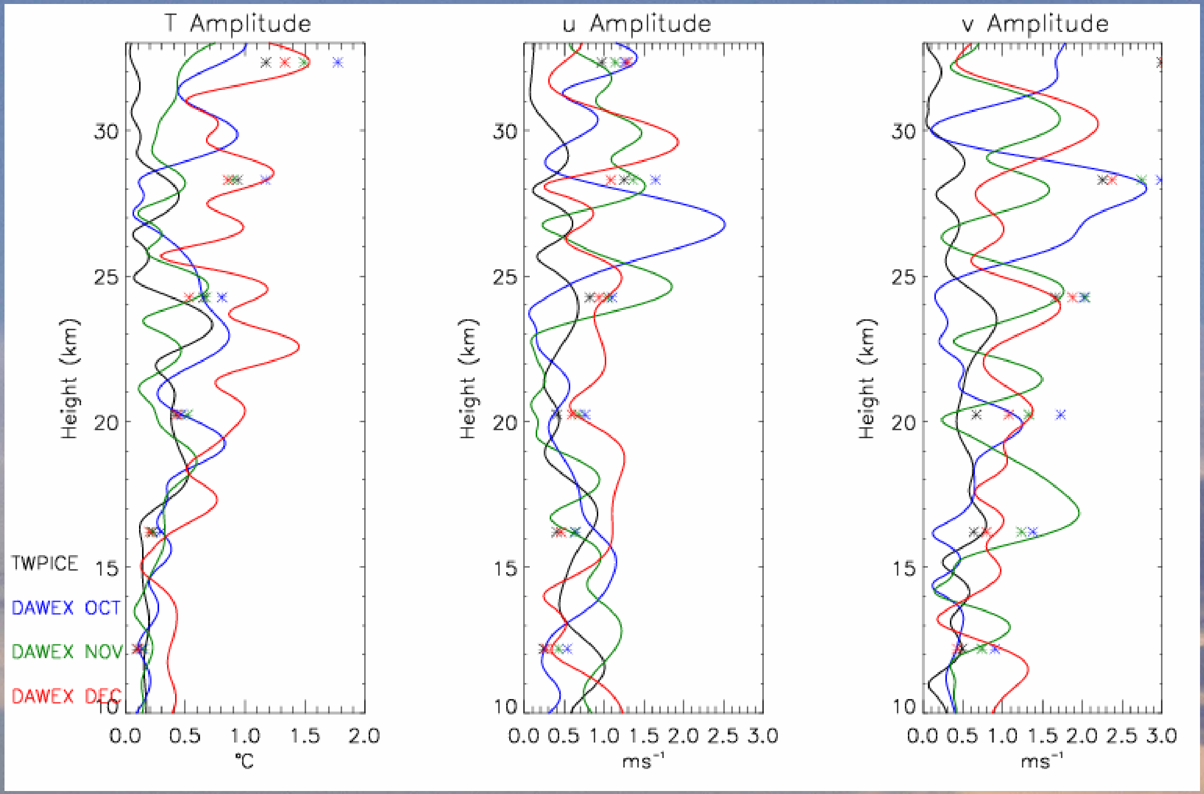
- Large *T'* 18 – 25km of 0.5C, decreases above 25km
- *u'* large at 18km, 25km, up to 1m/s. Very small 20 – 22km
- *v'* similar structure to *u'* but slightly larger amplitudes
- Note the large variations in amplitude between stations
  - Little data above 30km, except at Cape Don

Diurnal Tides – Phases



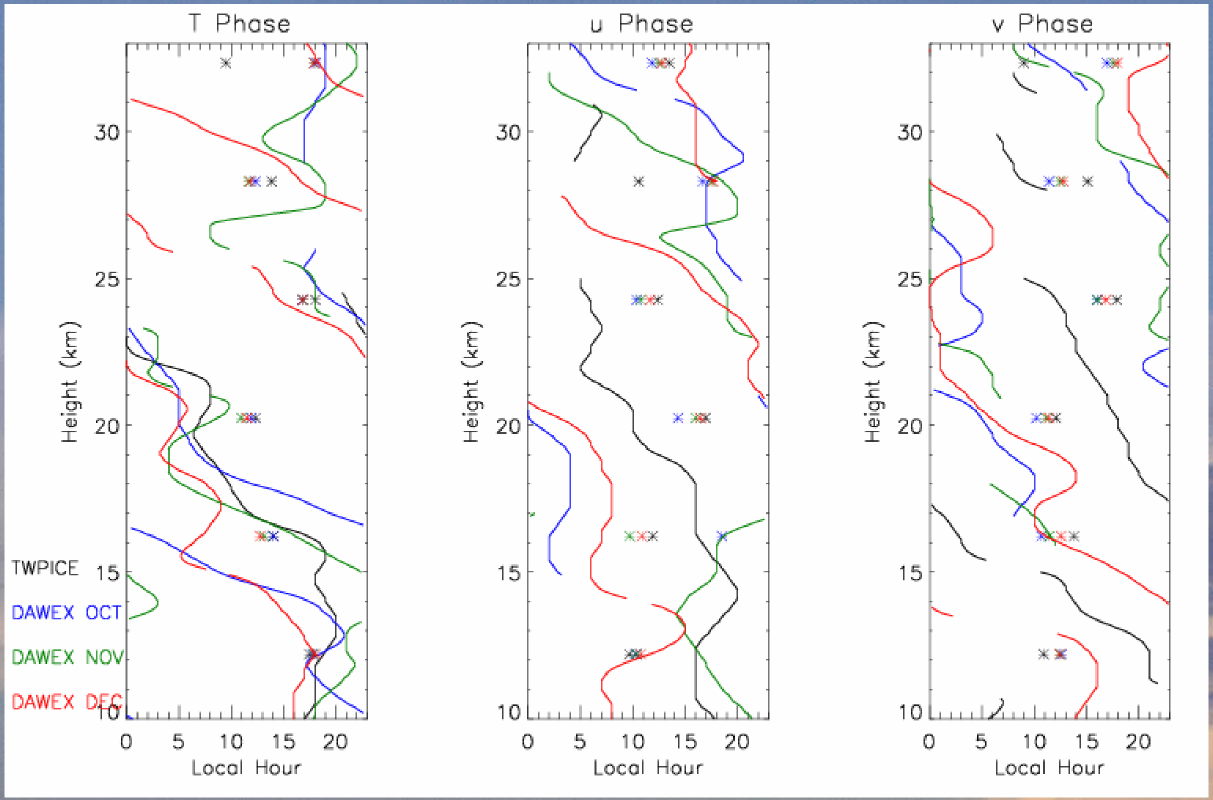
- Phases plotted in Local Time with clear consistency between stations
- *T'* wavelength ~8km in LS below 25km
- *u'* wavelength ~10km, *v'* also ~10km
- Note that *migrating* diurnal tides have a vertical wavelength ~30km so these are *non-migrating* components

TWPICE & DAWEX Darwin Diurnal Amplitude Comparison



- DAWEX: three campaigns of five days duration each in Oct, Nov, Dec 2001
- Large diurnal amplitudes during DAWEX – although these campaigns were only a few days duration
  - But DAWEX was during the build-up, so large convection
- Asterisks mark Hagan & Forbes GSWM *migrating* tidal amplitude at Darwin

TWPICE & DAWEX Darwin Diurnal Phase Comparison



- *T* consistent below 25km (except DAWEX OCT around 17km tropopause)
- Note DAWEX DEC very strong *T* component, wavelength ~5km in stratosphere
- DAWEX *u, v* tides are about 12hrs different from TWPICE in stratosphere
- *T* wavelength ~10km, while wavelengths of *u* and *v* at least 10km, hard to quantify
- Asterisks mark Hagan & Forbes GSWM *migrating* tidal phase at Darwin

Ongoing and Future Work

- Do a full comparison of GW activity between all stations
  - spatial & temporal variability
- Try to identify convective GW sources using MTSAT cloud top temperature data
  - although waves have propagated substantial horizontal distances
- Compare and contrast Darwin (TWPICE, DAWEX) diurnal tides with three equatorial month-long campaigns centred on Indonesia (Nov 2002, CPEA1, CPEA2)