500 hPa height, surface pressure
2012 Feb 6 06Z

→ Smaller scale features less evident in middle/upper troposphere
Synoptic scale cyclones can develop rapidly (1-2 d.) and move generally eastward
Upper level trough westward of surface frontal low pressure
Jan 500 hPa climatology

Quasi-stationary planetary-scale waves
Jan 850/500/300 hPa climatology

little if any phase shift with height (in the troposphere)
Fig. 6.1  Meridional cross sections of longitudinally and time-averaged zonal wind (solid contours, interval of 1 m s$^{-1}$) and temperature (dashed contours, interval of 5 K) for December–February (DJF) and June–August (JJA). Easterly winds are shaded and 0°C isotherm is darkened. Wind maxima shown in m s$^{-1}$, temperature minima shown in °C. (Based on NCEP/NCAR reanalyses; after Wallace, 2003.)
Fig. 6.1 Meridional cross sections of longitudinally and time-averaged zonal wind (solid contours, interval of m s$^{-1}$) and temperature (dashed contours, interval of 5 K) for December–February (a) and June–August (b). Easterly winds are shaded and 0°C isotherm is darkened. Wind maxima shown in m s$^{-1}$, temperature minima shown in °C. (Based on NCEP/NCAR reanalyses; after Wallace, 2003.)
Observed zonal mean u, T

DJF

cold winter polar stratosphere

high, cold, tropical tropopause

very flat T contours in tropics

JJA

Fig. 6.1 Meridional cross sections of longitudinally and time-averaged zonal wind (solid contours, interval of m s$^{-1}$) and temperature (dashed contours, interval of 5 K) for December–February (a) and June–August (b). Easterly winds are shaded and 0°C isotherm is darkened. Wind maxima shown in m s$^{-1}$, temperature minima shown in °C. (Based on NCEP/NCAR reanalyses; after Wallace, 2003.)
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Observed zonal mean $u$, $T$

Fig. 6.1 Meridional cross sections of longitudinally and time-averaged zonal wind (solid contours, interval of $1 \text{ m s}^{-1}$) and temperature (dashed contours, interval of 5 K) for December–February (a) and June–August (b). Easterly winds are shaded and 0°C isotherm is darkened. Wind maxima shown in $\text{m s}^{-1}$, temperature minima shown in °C. (Based on NCEP/NCAR reanalyses; after Wallace, 2003.)
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Mean meridional circulation DJF

**Fig. 10.7** Streamfunction (units: $10^2$ kg m$^{-1}$ s$^{-1}$) for the observed Eulerian mean meridional circulation for Northern Hemisphere winter, based on the data of Schubert et al. (1990).
Mean meridional circulation DJF

Hadley cells

Ferrell cells

Fig. 10.7  Streamfunction (units: $10^2$ kg m$^{-1}$ s$^{-1}$) for the observed Eulerian mean meridional circulation for Northern Hemisphere winter, based on the data of Schubert et al. (1990).
Seasonal variation of the Hadley circulation
Different averaging approaches
*(Townsend & Johnson, JAS, 1985)*

Average at fixed $\rho$

Average at fixed $\theta$

mass streamfunction
Observed Sea Surface Temperature (°C)

Observed Sea Surface Temperature Anomaly (°C)

7-day Average Centered on 01 February 2012
7-day Average Centered on 26 January 2011

NCEP/EMC/Global Climate & Weather Modeling Branch

Olv2
7-day Average Centered on 20 January 2010