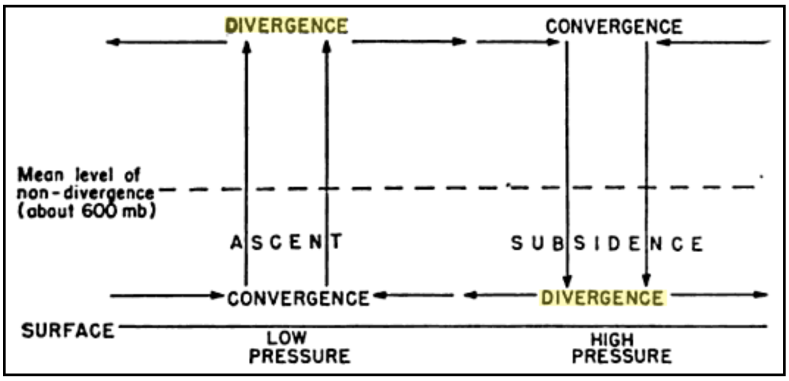
Explain how the principal components of Global Atmospheric Circulation, and their moderation by oceanic & continental-scale topographic features of Earth's surface, determine the climates of Afro-Asian Monsoon regions.

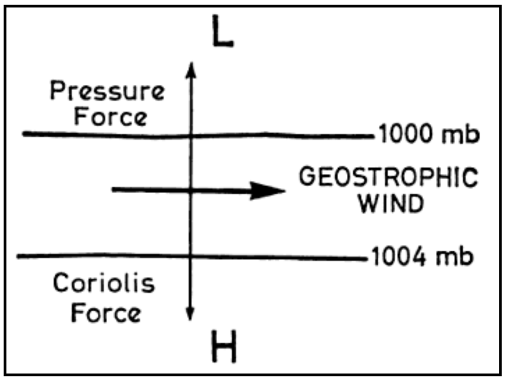
General Atmospheric Circulation refers to the large scale patterns of wind and pressure that persist throughout the year or recur seasonally in order to distribute heat and energy throughout the entirety of the earth and its atmosphere (Barry & Chorley, 2009). This system of energy and heat redistribution arises from the imbalance of radiation receipt between lower and higher latitudes. Unequal heating as such generates mechanisms of energy transfer, most observably through the creation of vertical and horizontal temperature-pressure gradients. Fundamental advances in our understanding of these complex ocean-atmosphere energy mechanisms have been obtained over the past four decades through the development and application of General Circulation Models. These numerical climate and weather models apply the fundamental radiative and mass exchanges of the Earth with their dynamic and thermodynamic processes. As such the GCM is modeled using five basic sets of equations: (i) the three dimensional equations of motion (ii) the equation of continuity (iii) the equation of continuity for atmospheric water vapour (iv) the equation of energy conservation (v) the equation of state for the atmosphere.

Primarily, this paper explores in depth the first two equations of atmospheric motion and continuity. The former involves the laws of horizontal motion and conservation of momentum that enable atmospheric cells to transfer energy down a temperature-pressure gradient. The latter involves the conservation of mass through the coupled vertical and horizontal motions of divergence and convergence. These motions are significant in creating continuity, such that without them air would deplete at the tropics and amass at the poles and there remain static. The remaining three equations, those of water vapour conservation (evaporation-precipitation, latent heat processes); energy conservation (the First Law of Thermodynamics and kintetic-geopotential transfers) and the equation of state for the atmosphere (Boyle's pressure laws) become important in the latter section of this paper. This latter section explores how these components of General Atmospheric Circulation may be moderated and manipulated by oceanic and continental scale topography. With specific reference to the Afro-Asian monsoon region, I suggest that the differing thermal identities of ocean and land and the Coriolis Force - coupled with an ocean basin geometry that facilitates the accumulation of energy - creates a zonal ('west-east, 'along a latitude' dimension) as opposed to a meridional (north-south dimension) system of energy transfer. Finally, this paper explores how these deflected, southwesterly winds of the Summer monsoon interact with Himalayan orography to create the intense updraughts and latent heat releases, inherent within the quasi-stationary rainfall belt.

The sun's radiation is the energy that sets the atmosphere in motion, both horizontally and vertically. The rising and expanding of the air when it is warmed, or the descending and contracting of the air when it is cooled causes the vertical motion. The horizontal motion is caused by differences of atmospheric pressure; air moves down a pressure gradient from areas of high pressure toward areas of low pressure. Globally, these motions are necessitated by the uneven receipt of solar energy between the tropics and poles. Several factors - the large spheroidal body, 23.5% axial tilt and elliptical orbit - have considerable influence on the distribution of radiation. The low latitude equatorial and subtropical regions receive a surplus of solar energy over earth radiation loss. Conversely, the high latitudes have greater loss of energy by earth radiation to space than the gain from solar radiation. In specific terms the surplus of energy is often exhibited between 38ºN and 38ºS, and the deficit in the polar regions. The thermal equator (the zone of maximum temperature) receives on average 2.5 times as much annual solar energy as the poles (Barry & Chorley, 2009).



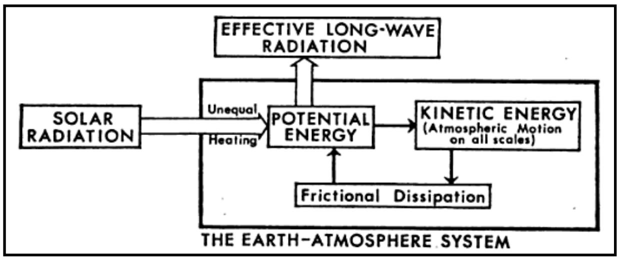
Vertical motions associated with (mass) divergence and convergence in the troposphere. An illustration of mass continuity (Barry & Chorley, 2010, p152)



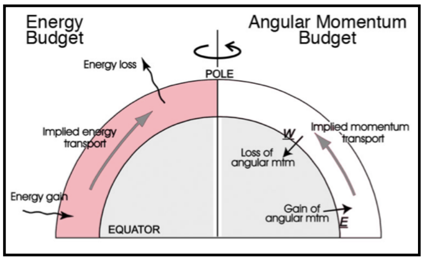
Geostrophic wind Formation, parallel to Isobars. In reality, within the planetary boundary layer the geostrophic wind is slightly skewed. (Addison et. al, 2008)

The primary cause of this imbalance is that the higher latitudes receive solar radiation at a less direct angle than the tropics which have an overhead, intense sun for much of the year. Furthermore, the intensity of radiation at the polar latitudes is less because of the increased scattering and absorption associated with a longer temporal path through the atmosphere. A secondary cause for the high latitude deficit, and one which strongly exacerbates the primary cause, is the high surface albedo of polar snow and ice which reflect much more incoming radiation than the tropics. Solar receipt is further affected on a diurnal and seasonal basis. The summer 'migration' of the Inter-tropical Convergence Zone northwards represents a shifting of the thermal equator caused by the increased intensity of daytime solar heating. Such a spatial shift with the seasons in solar receipt becomes significant in terms of the onset of the Afro-Asian monsoon. If this unequal latitudinal distribution of solar energy were not rectified by the ocean-atmosphere system, there would be a massive accumulation of heat within the tropics and a corresponding deficiency at the poles. As Ruddiman postulates, in 'the absolute absence of this meridional interchange of heat, a radiation balance at each latitude would only be achieved if the equator were 14ºC warmer and the North pole 25ºC colder than at present. In order to rectify this imbalance and reach a steady state equilibrium of 15ºC, the transport of energy and heat is achieved by the fluid components of the system - the atmosphere and oceans; their net poleward transfers essentially draining the lowers and feeding the higher latitudes. The generation of temperature and pressure gradients by unequal solar heating facilitates these meridional transfers of potential energy.

The constant motion of the atmosphere is governed predominantly by the laws of horizontal, and less so vertical, motion. Average horizontal wind speeds are of the order of 100 times greater than average vertical movement, with the exceptions in turbulent, convective storm cells. The reason for these differing influences on the atmosphere originate in the fact that the general stability of the atmosphere, coupled with hydrostatic equilibrium, greatly limits vertical air motion. Hydrostatic equilibrium refers to the mutual balance between the force of gravity and the vertical pressure gradient. The vertical distribution of atmospheric mass is thus, on average, relatively stable. Horizontal motions are less so however. There are four controls on the horizontal movement of air near the earth's surface: the pressure-gradient force, the Coriolis force, centripetal acceleration, and frictional forces. The interactions between these parameters determine the wind and pressure patterns of the global climate. The primary cause of air movement is the development of a horizontal pressure gradient through spatial differences in surface heating or mechanical causes such as orographic barriers. The consequent changes in air density and pressure facilitate the creation of a pressure-gradient force (Barry & Chorley, 2009). This motivating force causes air to move from regions of high pressure to regions of relatively lower pressures. Differences in air pressure are mapped by defining lines of equal pressure known as isobars. Movement



Changes of Energy within the Earth Atmosphere System
The 1st Law of Thermodynamics - Energy can not be destroyed but it may change form and location. The Equation of Energy Conservation (Barry & Chorley, 2009)



Latitudinal transport of heat and angular momentum. In the angular momentum budget, the atmosphere gains angular momentum in low latitudes (where the surface winds are easterly) and loses it in the mid-latitudes (where the surface winds are westerly. There is thus a poleward atmospheric flux of angular momentum. (Ruddiman, 2010)

occurs down the pressure gradient at right-angles to these isobars. As Addison et. al posit, 'the magnitude of the force causes movement, [thus] the speed of the wind is inversely proportional to the distance between the isobars.' The closer the isobars are together and therefore the more rapidly pressure falls with distance, the stronger the wind. Whilst ideally, air would flow along the latitudinal pressure gradient - transferring energy aloft from the tropics to the poles - in actuality, other forces complicate the process by preventing such a direct movement.

The Coriolis force arises due to Earth's constant rotation from west to east at 15° longitude per hour. This rotational force acts deflects winds into taking a more parallel path to the isobars as opposed to the more direct path through the isobars that the pressure gradient force alone would have. There is an observable deflection of wind to the right of its line of motion in the Northern Hemisphere and to the left in the Southern Hemisphere. The magnitude of this deflection is directly proportional to the sine of the latitude and horizontal velocity of the air (such that, air moving at 10m/s has half the deflective force operating on it as with air moving at 20m/s). This latitudinal signature of the Coriolis parameter underlies why the effect is greatest at the poles - where Earth's surface is at right-angles to the axis of rotation - and zero at the equator - where there is no component of the deflection in a plane parallel to the surface. Furthemore, whilst the Coriolis acts at right-angles to the direction of the air motion, its deflective influence does not affect the speed because this would involve changing the kinetic energy. Rather, the Coriolis force purely affects direction, giving rise to the westerlies in the mid-latitudes. Its importance in deflecting the Southeast trade winds to take a southwesterly path becomes significant in the Monsoon cycle as will be explored later.

The interactions between the pressure-gradient force and the Coriolis deflection form a geostrophic wind that blows more or less parallel to the pressure gradients (at right-angles to the isobars). The creation of this steady motion wind occurs once the pressure gradient force is exactly balanced by the Coriolis deflection acting in the diametrically opposite direction. These geostrophic winds are common in the free atmosphere (500-1000m height) where the effects of surface friction are minimal. As will be explored later, this surface friction has a directional effect of its own upon an air parcel by affecting the velocity profile and thus the Coriolis force. Predominating in the free atmosphere however, the velocity of the geostrophic wind is inversely dependent on latitude such that 'the same pressure gradient associated with a wind speed of 15m/s at latitude 43° will produce a velocity of only 10m/s at latitude 90°' (Barry & Chorley, 2009). Thus, in the low latitudes, where the Coriolis parameter approaches its minimal, the geostrophic wind is less observable. The geostrophic wind strictly should only operate when isobars are straight. Normally however, isobars are more random, being curved and unevenly spaced. Stable air movements are however maintained even in this seemingly less accommodating system by the addition of a further parameter of air motion. The centripetal acceleration, a force which acts towards the centre of rotation, serves to maintain a parallel, yet curved path along the isobars. Within a

Northern Hemisphere low pressure system, balanced flow as such is maintained in a curved path by the Coriolis force being weaker than the pressure force. The resultant wind, known as the gradient wind, is closer to the observed flow in the upper atmosphere (Addison et. al, 2008). The net centripetal acceleration inward is calculated by the difference between the stronger Coriolis force and the weaker pressure gradient force. Conversely, in high pressure systems, regions of strong convergence, the inward acceleration exists because the Coriolis force closely related to velocity, exceeds the pressure force. In the equatorial regions where the Coriolis force is negligible, the magnitude of this centripetal acceleration becomes significant.

Where the pressure-gradient force is able to greatly exceed a non-existent Coriolis force, a centripetal acceleration is provided to give balance flow parallel to the isobars, a motion called cyclostrophic. Intense, equatorial cyclones thrive through such cyclostrophic motions. The final governing law of horizontal motion refers to frictional forces of the earth surface and the planetary boundary layer. Below the free atmosphere level, friction due to form drag over orography begins to reduce the wind velocity below its geostrophic value. Through slowing of the wind, the deflective force, a component dependent upon velocity, is decreased. This dampening of the Coriolis force causes winds to blow obliquely across the isobars in the direction of the pressure gradient. As Ruddiman posits, 'the angle of obliqueness increases with the growing effect of frictional drag due to the earth's surface averaging about 10-20° at the surface of the sea and 25-35° over land' (Ruddiman, 2000). Frictional effects thus tend to manipulate lower, surface winds directionally and furthermore in terms of velocity because friction decreases wind velocity exponentially. This layer of frictional influence, beneath the geostrophic-wind dominated free atmosphere, is known as the planetary boundary layer. The winds within this layer represent a balance between the pressure gradient force and the Coriolis force perpendicular to the air motion, and friction, that occurs subsequently, and parallel yet opposite to the air motion. As such the oblique North Atlantic winds experienced throughout Southern Ireland result from the coalescence of these four parameters of horizontal atmospheric motion.

The equation of continuity, involving air divergence and convergence models, progresses naturally from a discussion of the laws of motion. As Addison et. al posit, where flows travel obliquely across the isobars in the direction of lower pressure, there is a transfer of air towards the low-pressure centre, leading to convergence and a net accumulation of air. Conversely, where flow is away from a high-pressure centre, there is a divergence of air away from the surface anticyclone, leading to a net outflow of air. Furthermore the acceleration of air leads to velocity divergence; the deceleration of air, to velocity convergence. These changes in velocity are significant in large-scale tropical disturbances within easterly waves. As air enters a trough, it must decelerate to maintain the balance between the pressure- gradient force and the Coriolis force. This deceleration causes convergence behind and across the trough axis. However, air accelerates and diverges ahead of the trough where curvature becomes anticyclonic. Convergence or divergence may also result from the interactions of the atmosphere with the ocean-land surface. When an onshore wind slows down on crossing into the rougher, more frictional coastline, low-level convergence occurs. The dimensions of these air movements are three-dimensional, such that horizontal inflow or outflow near the surface has to be compensated by vertical motion. Without this mechanism global high to low pressure wind patterns would not occur and air would amass in the low pressure regions with no return flow. The vertical motions thus allow for the conservation of mass within the system. Air rises above a low pressure cell and subsides over high pressure, with compensating divergence and convergence, respectively, in the upper troposphere. Surface convergence often produces cloud and precipitation, whilst divergence is usually associated with clear skies and dry weather. Vorticity exists with these columns because the individual air parcels have a tendency to rotate cyclonically or anti-cyclonically around an axis vertical to the earth's surface. Such vorticity plays a significant role in turbulence and the creation of high-velocity vertical tunnels within cumulonimbus clouds. The potential vorticity of the mean monsoon zonal flow over western India has extreme values in the mid-troposphere, and is accompanied by strong westerly shear.

Having defined the governing laws of horizontal motion and the equation of continuity, this paper briefly outlines the global atmospheric circulation in terms of the energy transfers involved. Furthermore the 'conservation of angular momentum' is discussed in order to understand why meridional energy transfer is not undergone by a single, thermal cell but rather by a dominant three; the Hadley, Ferrel, and polar cells respectively. As Barry et al. postulate, 'unequal heating of the earth and its atmosphere by solar radiation generates gradients in potential energy, some of which is converted into kinetic energy by the rising of warm air and the sinking of cold air' (Barry et. Chorley, 2009). This kinetic energy of atmospheric motion is eventually dissipated by friction and turbulent eddies. However in order to maintain the general circulation, the rate of generation of kinetic energy must balance its rate of dissipation. These rates, at about 1% of the average global solar radiation receipt suggest that the atmosphere is a highly inefficient heat engine. A second controlling factor of the general circulation of the atmosphere is the angular momentum of the earth and its atmosphere. This is the tendency for the atmosphere to move with the earth, around the axis of rotation. With a uniformly rotating earth and atmosphere, the total angular momentum must remain constant, there must be a conservation of angular momentum, just as there is a conservation of energy. Thus if a large air mass shifts northwards from the equator, decreasing its radial distance from the axis, then its speed of rotation increases to compensate. Thus air moving polewards tends to acquire progressively higher eastward velocities.

These increasing velocities in order to maintain angular momentum are manifest in the occurrence of fast-moving poleward jet streams in the upper troposphere. One such jet stream, the westerly subtropical jet is an important, atmospheric component of the South Asian summer monsoon with its high wind speed of up to 135m/s transporting vast amounts of moist air. It originates from the poleward drift of air in the Hadley circulation and the conservation of angular momentum. Furthermore, the westerly element of the monsoon winds is manufactured through the exchange of angular momentum between equatorial air and higher latitude air. It is significant to note that this transport of heat and momentum occurs in both vertical and horizontal planes. In the low latitudes, transport is predominantly in a vertical, meridional plane. The Hadley cell occurs with mean upwelling near the equator, poleward flow aloft, subsidence in the subtropics and equatorward return flow near the surface. Heat and momentum exchanges within the midlatitudes, however, occur more in the horizontal planes as standing waves and transient eddies. This midlatitude air flows, increasingly deflected with latitude, constitute the westerly winds in both hemispheres. Furthermore the global meridional heat transfer is often represented as containing two thermally direct Hadley cells (the Hadley and the Polar) - where warm air rises and cool air sinks, governed by differential heating - separated by a weak, thermally indirect Ferrell cell in the mid-latitudes, governed by eddy (weather systems) forcing as opposed to thermal forcing. Following an engagement with the principal components of General Atmospheric Circulation, atmospheric behaviour in the Afro-Asian monsoon region will now be explored. The monsoon regime typifies the logic that meridional energy transfer may be disrupted and moderated by oceanic and continental-scale topographic features of the Earth's surface. As such, this paper progresses from a season breakdown of the monsoon to discussing the three distinct topographic features of the Afro-Asian monsoon region that contribute to its zonal pressure gradient and subsequent west-east energy transfer: (i) ocean-land differences in specific heat capacities; (ii) ocean basin geometry creating energy supply and (iii)

Himalayan mountains forming a quasi-stationary system of intense and localised precipitation. The latter orographic influence is significant, illuminating the fact that orography, coupled with moisture processes, can create conditionally unstable and buoyant parcels of intense rainfall.

Monsoons are generally viewed as regionally concentrated, thermally direct overturning circulations in the latitude–height plane, with ascending motion in the summer hemisphere subtropics and descending motion in the winter hemisphere. Specifically, the Asian monsoon refers to the large-scale seasonal reversals of the wind regime. The monsoon as such is seen as 'a consequence of the interaction of planetary and regional factors, both at the surface and in the upper troposphere' (Ruddiman, 2000). Based on observations of seasonal surface-pressure persistence and wind reversal, the climatological monsoon region is generally defined to be contained within the subtropics and tropics of the eastern hemisphere, dominated by the Hadley Cell circulation. The overturning cell involved in the monsoon involves deep and complex interactions between the easterly trade winds and the westerly compartments of the monsoon flow. The essential features of the circulation are that; (i) the lower-tropospheric monsoon air comes from the southern hemisphere; (ii) the monsoon air-stream with a westerly component has greater thickness and northward spread in the eastern region than in the west; (iii) there is general ascending motion north of the Equator in the lower troposphere; (iv) the easterlies in the upper troposphere are primarily subsiding and are associated with a northerly component; (v) most of the upper tropospheric air crosses the Equator and subsides to low levels in the southern hemisphere; and (vi) there is exchange of air between the upper easterlies and the subtropical westerlies in the eastern and western flanks of the Tibetan and Middle East anticyclones. These interactions are underlain by the convergence-divergence model of mass conservation, wherein behaviours of air at the surface are reversed within the troposphere. As such, an upper level anticyclone accompanies a continental heat low-pressure region at surface level. The reverse pattern is often seen over adjacent oceans. Large momentum transports occur in the meridional circulation and strongly influence the subtropical jet streams. the area of surface low pressure over the Asian continent is within the troposphere a region of high pressure and air divergence.

Atmospheric motions are strongly affected by zonally-asymmetric distribution of heating and cooling. In summer, strong solar radiation causes rapid warming of the land, relative to the ocean. This is due to the differing specific heat capacities of land and water, a difference exacerbated by the ocean's capacity to turbulently mix and absorb solar energy between its vertical layers. This rapid heating of the Asian continent causes air parcels to warm adiabatically, expand and rise into the atmosphere. This vertical motion of air creates a thermal low-pressure system at the surface. Conversely, the oceans, which are cooler than the continent, become zones of relative high pressure. Zonal fluxes of heat begin to occur down the temperature gradient, transporting heat to the cooler domain in an attempt to reduce the zonal temperature gradient. The pressure gradient force involved facilitates a steady in-breeze from the Indian Ocean. However due to the Coriolis effect, these winds do not flow directly onto land but instead low-level westerlies form parallel to the strong pressure gradient along the boundary between the Asian-Indian continent and the ocean areas to the south. These horizontal wind motions down the pressure gradient are facilitated by a constant energy source within the ocean.

Intense vertical fluxes of water vapour, heat and momentum within the Indian Ocean are determined by the interactions of ocean basin geometry/continental topography and the meridional polewards energy transfer of the Hadley Cell.1 The net energy accumulated over the tropics is transported to higher latitudes by the atmospheric and oceanic circulations in maintaining the thermal equilibrium of the earth-atmosphere system. Yet because the Indian Ocean is surrounded on three sides by the African, Asian and Australian continents, its efficiency in transporting the surplus net heat gain from the equatorial region towards the north pole is very much restricted. This restriction leads to an accumulation of energy on its northern boundary. The southeast trades of the southern hemisphere continually contribute to this accumulation of energy in the north Indian Ocean from March onwards. Furthermore in summer the Equatorial Trough and subtropical anticyclones are displaced northward in response to the increased latitudinal solar heating of longer daytimes and more direct sunlight. These energy-rich, tropical belts of the Indian Ocean and the western Pacific ocean, have a large influence on the summer monsoon of India for two reasons. Firstly, the atmosphere over this belt is in its average state close to the threshold of latent vertical instability, so that even a small positive anomaly of heating and evaporation can release vast amounts of atmospheric potential energy. Secondly, the mass of air near the Equator has a vast amount of absolute angular momentum about the axis of the earth, so that its exchange with air at higher latitudes leads to a large transport of westerly angular momentum essential for the maintenance of the extra-tropical westerlies.

The southwesterlies are pivotal in the transport of moisture during the Asian monsoon and often originate from within the Southeast trades of the southern hemisphere, that, having crossed the equator become deflected by the Coriolis force towards their more westerly paths. The importance of the ocean is further explored by Shukla. Utilising a general circulation model specific to the Indian Ocean, he noted that a decrease in ocean temperature led to a decrease in precipitation over India and the surrounding region. His hypothesis was that cold temperatures result in a decrease in evaporation and thus a decrease in the moisture available for downstream precipitation. Furthermore an equatorial teleconnection was uncovered between the upward motion over the central Indian Ocean and that over Malaysia and the western Pacific, with the strength of the Somali jet increasing. The cross-equatorial flow which carries water vapour across the Arabian Sea and affects India, is very close to the east African coast and is concentrated into this low-level jet flowing off the Somali coast. The Somali jet thus operates as a dynamic component in the low-level circulation of the southwest monsoon.

The moderation of atmospheric general circulation by topography is most observable in the Himalayan mountain belt, a zone of intense updraught of the westerly, moisture-laden monsoon winds in Summer. Conversely in Winter, a phenomenon of dry out-blowing northerly winds predominate, being sourced from the thermally cool, subtropical anticyclone over northwest India and Pakistan. The Tibetan highlands acts as a heat engine with an enormous convective activity in the southeastern sector where giant cumulonimbus cells play a major role in continuously carrying heat upwards into the upper troposphere. In similar vein to much of the tropics the monsoon's primary thermal source is the release of latent heat in convective clouds along the inter-tropical convergence zone (ITCZ). These releases of latent heat occurs primarily in hot cumulus towers penetrating from the surface boundary layer through the stable middle layers into the upper-tropospheric layers. The Himalayan mountains however serve to intensify and localise these updraughts. Experiments on the effect of mountains on the Asian monsoon circulation revealed that

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[1] Heating of the tropical atmosphere with particular reference to monsoonal upper tropospheric maximum heating is often equated in creating general circulation models of the monsoon. Neglecting horizontal advection, the total heating in a unit column of the atmosphere may be represented as:
QT = QR + QS + QL where
QR = radiational heating, including absorption of solar short-wave radiation and long-wave emission in the column,
QS = heating or cooling by the turbulent transfer of sensible heat between the atmosphere and its lower boundary, and
QL = Heating or cooling due to condensation or evaporation of water vapour.

without mountains, the low-pressure monsoon system moves far to the north and east of the Himalayas with moist air penetrating farther north into India. In the mountain simulation, the onset of the monsoon occurred rather abruptly so that the jet stream quickly moved north of the Himalayas into its summertime position. In the simulation without mountains, the transition from spring to summer, rather than exhibiting a similar abruptness, was gradual. The mechanical and thermodynamical effects of the Tibetan plateau are thus pivotal in the formation of the monsoon. Shukla further suggests that the resultant convective clouds account for a large percentage (greater than 80%) of the total cloudiness over the Tibetan and adjoining Himalayan region. The subsequent release of latent heat in condensation within such clouds, with a marked degree of persistency over India, contributes towards the occurrence of a quasi-stationary heat centre during the summer monsoon season in the middle and upper troposphere. There are also cloud feedback effects. As the monsoon sets in over the extreme south of peninsular India by the beginning of June and then steadily advances northwards, the resulting cloudiness cuts off the solar heating and so the phases in the lower-tropospheric levels over India lag by about 30 to 45 days those over the corresponding latitudes in the remaining parts of the northern hemisphere. Within these general circulation models of the monsoon, the interplay between the five basic equations begins to solidify.

Primarily, this paper has explores the equations of atmospheric motion and continuity. It is these laws of horizontal motion and conservation of momentum that enable atmospheric cells to transfer energy down a temperature-pressure gradient. The latter in particular is significant in creating continuity, such that without convergence and divergence, air would deplete at the tropics and amass at the poles and there remain static. The remaining three equations, those of water vapour conservation (evaporation-precipitation, latent heat processes); energy conservation (the First Law of Thermodynamics and kintetic-geopotential transfers) and the equation of state for the atmosphere (Boyle's pressure laws) have been applied in less depth but are nevertheless intrinsic to the formation of global climate. The latter part of this paper has attempted to flesh out the interactions of these General Circulation parameters with particular topographic features of the Earth Surface.

Observing the Afro-Asian monsoon region, we can identify a zonal west-east dimension that serves against the traditional north-south dimensions of meridional transfer. This is due to solar heating having different effects on regions of differing specific heat capacities, most manifestly between the ocean and continent. Furthermore the subsequent winds created down the temperature-pressure gradient interact with Himalayan orography to create intense updraughts and latent heat release. Finally, within the monsoon, we can see the five basic equations of General circulation being represented; the horizontal motions of westerly winds; the divergence of surface oceanic air and convergence at the continent; the conservation of water vapour through latent heat processes; energy conservation through conversions from kinetic wind energy to geopotential by orographic uplift; and the equation of state for the atmosphere manifest in the constant vertical fluxes of air in accordance with Boyle's and Charles' laws. Most fundamentally, the Afro-Asian monsoon reveals how the principal components of global atmospheric circulation can be moderated and modified by oceanic and continental-scale topographic features, both oceanic and continental.

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