DOWNLOAD PDF TRANSPORT ON EARTH

Chapter 1 : Transportation on Earth (24th century) : DaystromInstitute

*Transport on Earth (World of Tomorrow Series) [Neil Ardley] on calendrierdelascience.com *FREE* shipping on qualifying offers. Hardcover, no dust jacket. Minor wear to cover, otherwise a very nice copy.*

Cars[edit] Unleaded gasoline has 8. The target is that by the average emissions for all new cars is 0. Trains contain many different parts that have the potential to be thundering. Wheels, engines and non-aerodynamic cargo that actually vibrate the tracks can cause resounding sounds. Noise caused from directly neighboring railways has the potential to actually lessen value to property because of the inconveniences that railroads provide because of a close proximity. In order to combat unbearable volumes resulting from railways, US diesel locomotives are required to be quieter than 90 decibels at 25 meters away since This noise, however, has been shown to be harmless to animals, except for horses who will become skittish, that live near it [20]. Railroads can make the environment contaminated and unnatural because of what trains carry. Railway pollution exists in all three states of matter: Air pollution can occur from boxcars carrying materials such as iron ore, coal, soil, or aggregates and exposing these materials to the air. This can release nitrogen oxide, carbon monoxide, sulphur dioxide, or hydrocarbons into the air. Liquid pollution can come from railways contributing to a runoff into water supplies, like groundwater or rivers and can result from spillage of fuels like oil into water supplies or onto land or discharge of human waste in an unhealthy manner [22]. Visual Disruption of railroads is defined as a railway changing the way that a previously undisturbed, pristine sight of nature looks. When man chooses to build a railway into the wilderness, he is forever changing the environment firstly by mere sight alone; a viewer will never be able to see the original scene again, and the builders of the railway often alter the landscape around the railway to allow it to ride. Frequent cuttings, embankments, dikes, and stilts are built which will change the way that landscape will look forever. This bridge stands feet above the Arkansas River and stretches 1, feet across [24]. This bridge that now uses aerial trams is an unforgettable part of this Colorado landscape See also: Environmental impact of shipping The fleet emission average for delivery vans, trucks and big rigs is Delivery vans and trucks average about 7. Discharges of sewage into our water bodies can come from many sources, including wastewater treatment facilities, runoff from livestock operations, and vessels. These discharges have the potential to impair water quality, adversely affecting aquatic environments and increasing the risks to human health. While sewage discharges have potentially wide-ranging impacts on all aquatic environments, the impacts may be especially problematic in marinas, slow-moving rivers, lakes and other bodies of water with low flushing rates. Environmentally this creates invasive species that often drive other species to their extinction and cause harm to the environment and local businesses. Emission of greenhouse gases displaces the amount of gas that allows for UV-rays through the ozone. Sulfur and nitrogen compounds emitted from ship will oxidize in the atmosphere to form sulfate and nitrate. Emissions of nitrogen oxides, carbon monoxide, and volatile organic compounds VOC will lead to enhanced surface ozone formation and methane oxidation, depleting the ozone. In particular, the large-scale distribution and diurnal variation of the oxidants and sulfur compounds are studied interactively. Meteorological data winds, temperature, precipitation, clouds, etc.

Chapter 2 : The Environmental Impacts of Transportation | The Geography of Transport Systems

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Chapter 3 : CHAPTER ATMOSPHERIC TRANSPORT

Mars missions require the transport of equipment, material and people from Earth to Mars, and possibly back to Earth. This page wants to clarify the needed transportation volume and the proposed technology.

The Environmental Impacts of Transportation Author: Jean-Paul Rodrigue Transportation systems, from infrastructures to vehicle operations, have environmental impacts ranging from noise, the emission of pollutants to climate change. From one side, transportation activities support increasing mobility demands for passengers and freight, while on the other, transport activities are associated with growing levels of environmental externalities. Further, environmental conditions have an impact on transportation systems in terms of operating conditions and infrastructure requirements such as construction and maintenance see Transportation and Space for a review of such constraints. The growth of personal and freight mobility in recent decades have expanded the role of transportation as a source of emission of pollutants and their multiple impacts on the environment. These impacts fall within three categories: The immediate consequence of transport activities on the environment where the cause and effect relationship is generally clear and well understood. For instance, noise and carbon monoxide emissions are known to have direct harmful effects. The secondary or tertiary effects of transport activities on environmental systems. They are often of higher consequence than direct impacts, but the involved relationships are often misunderstood and more difficult to establish. For instance, particulates which are mostly the outcome of incomplete combustion in an internal combustion engine are indirectly linked with respiratory and cardiovascular problems since they contribute among other factors to such conditions. The additive, multiplicative or synergetic consequences of transport activities. They take into account of the varied effects of direct and indirect impacts on an ecosystem, which are often unpredicted. Climate change, with complex causes and consequences, is the cumulative impact of several natural and anthropogenic factors, in which transportation plays a role. The complexities of the impacts have led to much controversy in environmental policy, the role of transportation and mitigation strategies. This is made even more complex by the fact that priorities between environmental and economic considerations shift in time. The transportation sector is often subsidized by the public sector, especially through the construction and maintenance of road infrastructure, which tend to be free of access. Sometimes, public stakes in transport modes, terminals and infrastructure can be at odd with environmental issues. If the owner and the regulator are the same different branches of the government , then there is a risk that regulations will not be effectively complied to. Total costs incurred by transportation activities, notably environmental damage, are generally not fully assumed by the users. The lack of consideration of the real costs of transportation could explain several environmental problems. Yet, a complex hierarchy of costs is involved, ranging from internal mostly operations , compliance abiding to regulations , contingent risk of an event such as a spill to external assumed by the society. If environmental costs are not included in this appraisal, the usage of the car is consequently subsidized by the society and costs accumulate as environmental pollution. This requires due consideration as the number of vehicles, especially automobiles, is steadily increasing. The Transport â€" Environment Link The relationships between transport and the environment are multidimensional. Some aspects are unknown and some new findings may lead to drastic changes in environmental policies. Historically, transportation was associated with a few negative environmental impacts. For instance, the setting of large navies of sailships was responsible for a level of deforestation in Western Europe and North America from the 16th to the 19th centuries. Urbanization in the 19th century and the reliance on horses created problems concerning the disposal of manure. Further, industrialization and the development of steam engines lead to pollution e. It is however only in the 20th century that a comprehensive perspective about the links between transportation and the environment emerged, particularly with the massive diffusion of transportation modes such as the automobile and the airplane. The s and s were crucial decades in the realization of the negative environmental impacts of human activities and the need for regulations. From an infrastructure perspective, the first comprehensive environmental regulation, the National Environmental Policy Act NEPA , was set in and required all federal agencies of the US government to make environmental impact assessments of their actions. Since an agency such as the Department of Transportation is an important provider and manager of transportation infrastructure, this legislation had substantial impacts on how transportation is assessed to be linked with environmental issues. One clear consequence was the growth in the length and the complexity of approving transport infrastructure projects to insure they meet environmental standards. Opponents of a project could also use the regulatory framework to delay, or even cancel its construction and on occasion change its design parameters e. An unintended consequence was that the complexity of environmental regulations tend to impair innovations and incite current providers to keep existing infrastructure and facilities for the concern to trigger an uncertain environmental review with a new project. From an operational perspective, the Clean Air Act of set clear air quality standards and expectations for both stationary e. For transportation, it immediately set emissions standards from a list of acknowledged pollutants such as carbon dioxide, volatile organic compounds and nitrogen oxide. The outcome was a rapid decline of air pollutant emissions by the transportation sector. The Clear Water Act of provided a similar regulatory environment concerning water pollution and the ability to build infrastructures over wetlands. The s were characterized by a realization of global environmental issues, epitomized by the growing concerns between anthropogenic effects and climate change. These impending developments require a deep understanding of the reciprocal influence between the physical environment and transport infrastructures and yet this understanding is often lacking. The main factors considered in the physical environment are geographical location, topography, geological structure, climate, hydrology, soil, natural vegetation and animal life. The environmental dimensions of transportation are related to the causes, the activities , the outputs and the results of transport systems. Establishing linkages between environmental dimensions is a difficult undertaking. For instance, to what extent carbon dioxide emissions are linked to land use patterns? Furthermore, transportation is embedded in environmental cycles, notably over the carbon cycle where carbon flows from one element of the biosphere, like the atmosphere, to another like the ecosphere, where it can be accumulated permanently of temporarily or passed on. The relationships between transport and the environment are also complicated by two observations: Transport activities contribute among other anthropogenic and natural causes, directly, indirectly and cumulatively to environmental problems. In some cases, they may be a dominant factor, while in others their role is marginal and difficult to establish. Establishing environmental policies for transportation thus have to take account of the level of contribution and the geographical scale, otherwise some policies may just move the problems elsewhere and have unintended consequences. A noted example are environmental policies in advanced economies inciting the relocation of some activities with high environmental externalities e. This transfer the problem from one location to another. Still, such as transfer usually involves new equipment and technologies that are usually less impacting. Even if an administrative division municipality, county, state has adequate environmental enforcement policies, the geographical scale of an environmental impact notably air pollutants goes beyond established jurisdictions. The structure of the transport network, the modes used and traffic levels are the main factors of environmental impact of transportation. Networks influence the spatial distribution of emissions e. In addition to these environmental impacts, economic and industrial processes sustaining the transport system must be considered. These include the extraction and production of fuels, vehicles and construction materials, some of which are very energy intensive e. They all have a life cycle timing their production, utilization and disposal. Thus, the evaluation of the link between transport and the environment without the consideration of cycles in the environment and in the product life alike is likely to convey a limited overview of the situation and may even lead to incorrect appraisal, policies and mitigation strategies. Environmental Dimensions Transportation activities support increasing mobility demands for passengers and freight, notably in urban areas. But transport activities have resulted in growing levels of motorization and congestion. As a result, the transportation sector is becoming increasingly linked to environmental problems. The most important impacts include: These gases accumulate in the atmosphere long enough to reach an homogeneous composition across the world. Thus, irrespective of the location their concentration is similar. The quantity of conventional greenhouse gases released into the atmosphere has increased substantially since the industrial revolution and particularly over the last 25 years. The respective impacts of greenhouse gases is further complicated by differences in their atmospheric lifetime or residence time , which is the time they spend in the atmosphere before decaying or being absorbed by biological or chemical processes. For CO_2, it can range between 5 and years, while it is about 12 years for methane and years for N_2O. For halocarbons, such as Chlorofluorocarbons, it is at least 45 years. There is an ongoing debate to what extent these emissions are linked to climate change, but the debate relates more to the extent of these impacts than their nature. In addition to be a contributor to climate change, transportation is also impacted by it , particularly over infrastructure e. Air quality Highway vehicles, marine engines, locomotives and aircraft are the sources of pollution in the form of gas and particulate matters emissions that affects air quality causing damage to human health. The most common include lead Pb , carbon monoxide CO , nitrogen oxides NO_x , silicon tetraflouride SF_6 , benzene and volatile components BTX , heavy metals zinc, chrome, copper and cadmium and particulate matters ash, dust. Lead emissions have declined substantially in the last decades as its use as an anti-knock agent for gasoline was banned in the majority of countries from the s. Toxic air pollutants are associated with cancer, cardiovascular, respiratory and neurological diseases. Carbon monoxide CO when inhaled reduces the availability of oxygen in the circulatory system and can be extremely harmful. Nitrogen dioxide NO_2 emissions from transportation sources reduces lung function, affect the respiratory immune defense system and increases the risk of respiratory problems. The emissions of sulfur dioxide SO_2 and nitrogen oxides NO_x in the atmosphere form various acidic compounds that when mixed in cloud water creates acid rain. Acid precipitation has detrimental effects on the built environment, reduces agricultural crop yields and causes forest decline. Smog is a mixture of solid and liquid fog and smoke particles formed through the accumulation of carbon monoxide, ozone, hydrocarbons, volatile organic compounds, nitrogen oxides, sulfur oxide, water, particulates, and other chemical pollutants. The reduction of visibility caused by smog has a number of adverse impacts on the quality of life and the attractiveness of tourist sites. Particulate emissions in the form of dust emanating from vehicle exhaust as well as from non-exhaust sources such as vehicle and road abrasion have an impact on air quality. The physical and chemical properties of particulates are associated with health risks such as respiratory problems, skin irritations, eyes inflammations, blood clotting and various types of allergies. Smog is often exacerbated by local physical and meteorological conditions which can create periods of high smog concentration and public responses to temporarily mitigate them, such as restricting automobile use. While air quality issues have been comprehensively addressed in advanced economies, with substantial declines in the emissions of a wide range of pollutants. In developing economies, rapid motorization has shifted the concern to the large cities of China and India among those the most impacted by the deterioration of air quality. Noise Noise represents the general effect of irregular and chaotic sounds on people as well as animal life. Basically, noise is an undesirable sound. The acoustic measure of the intensity of noise is expressed in decibel, db, with a scale ranging from 1 db to db. Long term exposure to noise levels above 75 decibels dB seriously hampers hearing and affects human physical and psychological wellbeing. Noise emanating from the movement of transport vehicles and the operations of ports, airports and railyards affects human health, through an increase in the risk of cardiovascular diseases. Ambient noise is a frequent result of road transportation in urban areas, which is the cumulative outcome of all the noise generated by vehicles ranging from 45 to 65 db , which impairs the quality of life and thus property values. Falling land values nearby acute noise sources such as airports are often noted. Many noise regulations impose mitigation if noise reach a defined level, such as sound walls and other soundproofing techniques. Fuel, chemical and other hazardous particulates discarded from aircraft, cars, trucks and trains or from port and airport terminal operations can contaminate hydrographic systems. Because demand for maritime shipping has increased, marine transport emissions represent the most important segment of water quality impact of the transportation sector.

Chapter 4 : Environmental impact of transport - Wikipedia

Transportation System. If we are used to the ever increasing dependence on transport for our terrestrial endeavors, the colonists will find it even more crucial, for it will become the only physical link between a far off, isolated world in outer space and its home planet, the Earth.

In all geologic time, the responsibilities are on our generation To get from the surface of the Earth or the Moon into orbit around Earth where space products providing valuable space services will reside requires energy in two forms: Energy to rise above the surface, i. In a circular orbit, gravity is countered by the centrifugal force constantly. The total amount of energy kinetic plus potential required is often expressed in terms of an analogy -- an "energy well", as pictured here, as if each gravitational body represented a hole in the ground like a water well which a cargo must crawl out of. The bigger the planet, the deeper the equivalent well. In the picture below, the vertical "height" represents the energy required to move from one point to the other, whereby the horizontal length represents the physical distances to scale. Note on the graph that the energy required to go into "geostationary earth orbit GEO ", i. It will later be shown that the energy required to get material from many asteroids near Earth into geosynchronous orbit is even less than from the Moon. Communications satellite orbit is at 36, kilometers. Roughly half the energy to get to geosynchronous orbit is consumed in just getting to an orbital speed. When the Space Shuttle carries a communications satellite up, it brings it only above the atmosphere to the kilometer orbit. From there, the satellite is removed from the cargo bay and then launches to geosynchronous orbit 36, kilometers up using its own fuel propellant, which mades up most of the cargo in the Shuttle bay, not the satellite. But this is another issue for another place. What orbital speeds are we talking about? For low Earth orbit, we are looking at a little over 7 kilometers per second i. At this speed, the Shuttle orbits the Earth in about one and a half hours. However, it takes much more energy to lift it up to that orbit. An orbit used by communications satellites is a high Earth orbit called "geostationary" or "geosynchronous" orbit, where it takes exactly 24 hours for one orbit. Since the Earth rotates once per 24 hours, each satellite stays "stationary" or "synchronized" above one point on Earth. It takes more than 10 times more energy, theoretically, to get into geosynchrous Earth orbit from the surface of the Earth than from the surface of the Moon that is, a circular orbit. Adding in the heavy vehicle and complexity associated with Earth launch, and launching the fuel for later in the flight, getting materials off of the Moon and especially from asteroids is much easier than from Earth. Hence, the energy difference between GEO and other bodies besides Earth is often much less. One item often quoted by others it that it takes about 22 times more energy to launch from Earth and "escape" to infinity without going into orbit than to likewise launch from the Moon and escape to infinity. That is a simple comparison for laymen to illustrate the point, and differs somewhat from the more detailed comparison given here which accounts for getting into various useful circular orbits. Coming "downhill" takes just as much energy and fuel in space because there is no friction -- you must spend fuel to lower yourself into a circular orbit. An exception could be "aerobraking", i. Aerobraking is discussed in the vehicles section. To stay at the bottom of the orbit requires that you circularize your orbit when you arrive there by spending more fuel. Higher orbits have more potential energy but less kinetic energy. In fact, mathematically, to move from a lower orbit to a higher orbit requires spending two parts potential energy for every one part kinetic energy reduced. However, in practical terms, there are differences between trajectories to get into a circular high orbit so that you can spend significantly more than the theoretical minimum. In general, haste makes waste, in terms of energy and fuel spent. However, this is rarely followed due to economic factors other than fuel launched e. The Moon also has a "sea level orbit", or since it has "Mares" instead of "Seas", it has a corresponding "Mare Level Orbit". The entire graph represents the theoretical minimum amount of energy required. However, the more energy required, the more fuel must be lifted for use later. Thus, the rocket size and complexity increase well out of proportion to the theoretical minimum energy required. Asteroids have no significant escape velocity or "sea level orbital energy", and can be seen as objects already in orbital space. On the chart, they would be located beyond the dashed line above high Earth orbit, energy-wise. Some near Earth asteroids are just a tiny bit above the the dashed line, though most asteroids are significantly above the line. However, an analysis of retrieving asteroidal materials does not lend itself well to the above analysis, largely due to a concept called a "lunar gravity assist", which saves energy by trading orbital energy with the Moon, as discussed below. Reasons to do something yourself: It will help save life on our special planet -- be part of the solution in your generation. It will create and secure a better future for your children and grandchildren. It could be an interesting, cool, and a fun adventure for your life! You can join us and volunteer to help out, If you would like to make a quick donation to our humanistic cause, then please click on one of the buttons below which go to PayPal.

Chapter 5 : Mode of transport - Wikipedia

About the Book. Discusses future possibilities in transportation based on current research and technology.

Sustainable Transport is sometimes known as Green Transport and it is any form of transport that does not use or rely on dwindling natural resources. Instead it relies on renewable or regenerated energy rather than fossil fuels that have a finite life expectancy. For this reason it is said to have a low or a negative effect on the environment since it makes use of energy sources that are sustainable. Walking, cycling and sailing are excellent examples of sustainable transport. A fuel-hungry world Until relatively recent times very little consideration was given to the sustainable sources of energy for transport , or for the efficient use of clean fuels. In many parts of the developing world this is still the case and high levels of pollution continue to be tolerated. Information about greenhouse gases GHGs. All but a very few are powered by petroleum-based fuel. In there were just a few thousand cars in the world but as numbers increased, so did the demand for oil. It is only relatively recently that people began to be concerned about future oil supplies. A combination of political unrest in major oil producing areas like the Middle East, combined with the fact that reserves are running out in areas such as the US, has heightened this concern and had the combined effect of focusing the mind on seeking alternative energy sources, and pushing up prices. Added to that, during the last few years people have simply become more environmentally conscious. Information about world fossil fuel reserves. What are the alternatives? In many areas there have been moves to encourage people to use public transport networks rather than travelling by car. Cycling has also gained in popularity , both as a means of maintaining fitness, but also because it is a cheap and often swift form of transport. There have been moves to introduce cleaner and more fuel-efficient means of urban transport. Hybrid vehicles have been developed as an alternative to conventional cars. These are gaining in popularity. Generally they are of a hybrid design, combining an internal combustion engine with an electric engine. Other vehicles run on natural gas and some are electrically powered. Hybrid electric vehicle HEV. Biofuels have also become very popular in some areas. Bioethanol is made by fermenting plant materials and biodiesel is made from vegetable oils, animal fats or recycled grease. In biofuels provided 1. One of the problems is that bioethanol production relies on the cultivation of large amounts of plant material often on land that was formally tropical rain forest, or on land that would otherwise have been used to produce food. Solar power is another possible future option, but this will depend on a technical leap in the conversion rates of the photovoltaic PV cells that convert sunlight into electricity. Battery power would be required at nighttime or when there was no sun during daylight periods. More detail on solar powered cars and solar transportation as a method of sustainable transport. Hydrogen can be used to power future transportation. This might in fact be the power of the future because hydrogen is the most common element in the Universe. Power can either be through the use of electric motors powered by fuel cell technology or by improved internal combustion engines. In both cases emissions would be zero. Hydrogen power is currently prohibitively expensive, but progress is being made in the technology to achieve this. A big challenge is to source the hydrogen from renewable resources. Nuclear power was once advocated as the clean alternative to coal, oil and gas for generating electricity and for producing hydrogen through electrolysis. A number of accidents at nuclear plants, together with the inherent problem of dealing with large amounts of radioactive waste, has led many countries to reconsider this method of power generation. Looking to the future Transport is a vital part of our everyday life. The prevailing 20thcentury view was to rely on fossil fuels for most of our transport needs and to ignore any consequences. In the 21stcentury we have woken up to the fact that there is a need for us to care for the world around us.

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Chapter 6 : What is the fastest mode of transportation

I was wondering about how people get around on Earth in the TNG/DS9/VOY era. I was trying to remember episodes that take place on Earth and had.

Car ferry in Split, Croatia Water transport is the process of transport that a watercraft , such as a barge , boat, ship or sailboat , makes over a body of water, such as a sea, ocean, lake, canal or river. If a boat or other vessel can successfully pass through a waterway it is known as a navigable waterway. The need for buoyancy unites watercraft, and makes the hull a dominant aspect of its construction, maintenance and appearance. When a boat is floating on the water the hull of the boat is pushing aside water where the hull now is, this is known as displacement. In the s, the first steamboats were developed, using a steam engine to drive a paddle wheel or propeller to move the ship. The steam was produced using wood or coal. Now, most ships have an engine using a slightly refined type of petroleum called bunker fuel. Some ships, such as submarines , use nucler power to produce the steam. Recreational or educational craft still use wind power, while some smaller craft use internal combustion engines to drive one or more propellers, or in the case of jet boats, an inboard water jet. In shallow draft areas, hovercraft are propelled by large pusher-prop fans. Although slow, modern sea transport is a highly effective method of transporting large quantities of non-perishable goods. Commercial vessels, nearly 35, in number, carried 7. Short-distance systems exist for sewage, slurry water and beer, while long-distance networks are used for petroleum and natural gas. Cable transport is a broad mode where vehicles are pulled by cables instead of an internal power source. It is most commonly used at steep gradient. Typical solutions include aerial tramway , elevators , escalator and ski lifts ; some of these are also categorized as conveyor transport. While large amounts of research have gone into technology, it is rarely used except to put satellites into orbit, and conduct scientific experiments. However, man has landed on the moon, and probes have been sent to all the planets of the Solar System. Unmanned aerial vehicle transport drone transport is currently being tested by Amazon. This method will allow short-range small-parcel delivery in a short time frame. Components of a mode of transport[edit] A transport mode is a combination of the following:

Chapter 7 : Sustainable Transport | The Earth Times | Encyclopaedia

The idea is to combine some of the best features of private cars and collective tracked transit into one package. The concept here is to make electric cars, but with a slit down the middle that allows the cars to ride on, and charge from a triangular cross-section elevated rail for longer hauls.

Condensation of water vapor is an exothermic process, meaning that it releases heat in meteorological jargon this is called latent heat release. Cloud formation in a rising air parcel provides an internal source of heat that partly compensates for the cooling due to expansion of the air parcel Figure and therefore increases its buoyancy. Figure Effect of cloud formation on the adiabatic lapse rate We refer to buoyant motions in cloud as wet convection. The lapse rate of a cloudy air parcel is called the wet adiabatic lapse rate GW and ranges typically from 2 to 7 K km-1 depending on the water condensation rate. Figure Formation of a subsidence inversion. Temperature profiles on the right panel are shown for the upwelling region A thin line and the subsiding region B bold line. It is assumed for purposes of this illustration that regions A and B have the same surface temperature To. The air column extending up to the subsidence inversion is commonly called the planetary boundary layer PBL. Although cloud formation increases the buoyancy of the air parcel in which it forms, it increases the stability of the surrounding atmosphere by providing a source of heat at high altitude. This effect is illustrated in Figure Consider an air parcel rising from the surface in an unstable atmosphere over region A. This air parcel cools following the dry adiabatic lapse rate G up to a certain altitude zc at which the saturation point of water is reached and a cloud forms. As the air parcel rises further it cools following a wet adiabatic lapse rate GW; for simplicity we assume in Figure that GW is constant with altitude, although GW would be expected to vary as the condensation rate of water changes. Eventually, precipitation forms, removing the condensed water from the air parcel. Ultimately, the air parcel reaches an altitude zt where it is stable with respect to the surrounding atmosphere. This altitude which could be the tropopause or the base of some other stable region defines the top of the cloud. As the air parcel flows out of the cloud at altitude zt, it has lost most of its water to precipitation. The outflowing air is then carried by the winds at high altitude and must eventually subside for mass conservation of air to be satisfied. As the air subsides, its temperature increases following the dry adiabatic lapse rate G. Let us assume that the subsidence takes place over a region B that has the same surface temperature To as region A. For any given altitude over region B, the air subsiding from zt is warmer than the air rising from the surface; this situation leads to stable conditions, often manifested by a subsidence inversion typically at km altitude where the subsiding air meets the air convecting from the surface. The stability induced by subsidence is a strong barrier to buoyant motions over region B. Vertical mixing of surface air above region B is limited to the atmospheric column below the subsidence inversion; this column is commonly called the planetary boundary layer PBL. Strong and persistent subsidence inversions can lead to accumulation of pollutants in the PBL over several days, resulting in air pollution episodes. Subsidence inversions are ubiquitous in the troposphere. In their absence, air parcels heated at the surface during daytime would rise unimpeded to the tropopause, precipitating in the process. The scales involved in the upwelling and subsidence of air in Figure i. In the Hadley cell, air rising at the ITCZ eventually subsides in the subtropical high-pressure belts at about 30o latitude. Persistent subsidence inversions lead to severe air pollution problems in the large subtropical cities of the world for example Los Angeles, Mexico City, Athens, in the northern hemisphere; Sao Paulo in the southern hemisphere. However, external sources and sinks of heat prevent this equilibrium from being achieved. Major sources of heat in the atmosphere include the condensation of water vapor, discussed in the previous section, and the absorption of UV radiation by ozone. The mean lapse rate observed in the troposphere is 6. A major reason for this stability is the release of latent heat by cloud formation, as illustrated in Figure Another reason is the vertical gradient of radiative cooling in the atmosphere, which will be discussed in chapter 7. Absorption of solar UV radiation by the ozone layer in the stratosphere generates a temperature inversion Figure Because of this inversion, vertical motions in the stratosphere are strongly suppressed the stratosphere is stratified, hence its name. The temperature inversion in the stratosphere also provides a cap for unstable motions initiated in the troposphere, and more generally suppresses the exchange of air between the troposphere and the stratosphere. This restriction of stratosphere-troposphere exchange limits the potential of many pollutants emitted at the surface to affect the stratospheric ozone layer problem 3. Figure Diurnal cycle of temperature above a land surface Heating and cooling of the surface also affect the stability of the atmosphere. During daytime, heating of the surface increases air temperatures close to the surface, resulting in an unstable atmosphere. In this unstable atmosphere the air moves freely up and down, following the adiabatic lapse rate, so that the atmospheric lapse rate continually adjusts to G; unstable lapse rates are almost never actually observed in the atmosphere except in the lowest few meters above the surface, and the observation of an adiabatic lapse rate is in fact a sure indication of an unstable atmosphere. At sunset the land surface begins to cool, setting up stable conditions near the surface. Upward transport of the cold surface air is then hindered by the stable conditions. If winds are low, a temperature inversion typically develops near the surface as shown in Figure If winds are strong, the cold surface air is forced upward by mechanical turbulence and moderately stable conditions extend to some depth in the atmosphere. After sunrise, heating of the surface gradually erodes the stable atmosphere from below until the unstable daytime profile is reestablished. We call the unstable layer in direct contact with the surface the mixed layer, and the top of the mixed layer the mixing depth; the mixing depth zi for the morning profile is indicated in Figure The mixing depth does not usually extend to more than about 3 km altitude, even in the afternoon, because of capping by subsidence inversions. This diurnal variation in atmospheric stability over land surfaces has important implications for urban air pollution; ventilation of cities tends to be suppressed at night and facilitated in the daytime problem 4. In winter when solar heating is weak, breaking of the inversion is difficult and accumulation of pollutants may result in severe air pollution episodes problem 4. Figure Vertical profiles of temperature T, potential temperature q, water vapor dew point , and ozone measured by aircraft in early afternoon in August over eastern Canada. Figure illustrates how solar heating generates an unstable mixed layer in the lower troposphere. The Figure shows vertical profiles of temperature, water vapor, and ozone measured in early afternoon in summer during an aircraft mission over eastern Canada. Also shown in Figure is the potential temperature q, defined as the temperature that an air parcel would assume if it were brought adiabatically to hPa. Inspection of Figure shows that solar heating of the surface results in an unstable mixed layer extending from the surface up to 1. Water vapor and ozone are nearly uniform in the mixed layer, reflecting the intensity of vertical mixing associated with the unstability of the atmosphere. Although small, this inversion produces sharp gradients in water vapor and ozone reflecting the strong barrier to vertical transport. A second weak inversion at 3 km altitude is associated with amother sharp drop in water vapor. An important message from Figure is that the vertical structure of atmospheric composition is highly dependent on atmospheric stability. As pointed out in section 4. One observes considerable irregularity in the vertical flow field, a characteristic known as turbulence. In this section we describe the turbulent nature of atmospheric flow, obtain general expressions for calculating turbulent transport rates, and infer characteristic times for vertical transport in the atmosphere. Laminar flow is smooth and steady; turbulent flow is irregular and fluctuating. One finds empirically and can justify to some extent theoretically that whether a flow is laminar or turbulent depends on its dimensionless Reynolds number Re: The transition from laminar to turbulent flow takes place at Reynolds numbers in the range , Flows in the atmosphere are generally turbulent because the relevant values of U and L are large. This turbulence is evident when one observes the dispersion of a combustion plume emanating from a cigarette, a barbecue, or a smokestack. We wish to determine the vertical flux F of X at some point M downwind of the stack. The number of molecules of X crossing an horizontal surface area dA centered on M during time dt is equal to the number nXwdtdA of molecules in the volume element wdtdA, where w is the vertical wind velocity measured at point M and nX is the number concentration of X. The flux F molecules cm-2 s-1 at point M is obtained by normalizing to unit area and unit time: We will drop the subscript X in what follows. Due to the turbulent nature of the flow, both C and w show large fluctuations with time, as illustrated schematically in Figure Figure Instantaneous smokestack plume Figure Time series of C and w measured at a fixed point M. C and w are the time-averaged values. Since C and w are fluctuating quantities, so is F. Let C and w represent the mean values of C and w over Dt. We decompose C t and w t as the sums of mean and fluctuating components: In the troposphere, FT usually dominates over FA in determining rates of vertical transport. One can apply the same distinction between mean advective flux and turbulent flux to horizontal motions. You should appreciate that the distinction between mean advective flux and turbulent flux depends on the choice of Dt; the larger Dt, the greater the relative importance of the turbulent flux. To understand the physical meaning of the turbulent flux, consider our point M located above the centerline of the smokestack plume. Air parcels moving upward through M contain higher pollutant concentrations than air parcels moving downward; therefore, even with zero mean vertical motion of air, there is a net upward flux of pollutants. An analogy can be drawn to a train commuting back and forth between the suburbs and the city during the morning rush hour. The train is full traveling from the suburbs to the city, and empty traveling from the city to the suburbs. Even though there is no net motion of the train when averaged over a number of trips the train is just moving back and forth , there is a net flow of commuters from the suburbs to the city. The use of collocated, high-frequency measurements of C and w to obtain the vertical flux of a species, as described above, is called the eddy correlation technique. It is so called because it involves determination of the covariance, or correlation, between the "eddy" fluctuating components of C and w. Eddy correlation measurements from towers represent the standard approach for determining biosphere-atmosphere exchange fluxes of CO_2 and many other gases Figure Figure Eddy correlation measurements of CO_2 and heat fluxes made 5 m above a forest canopy in central Massachusetts. A sample s time series for a summer day is shown. The canopy is a source of heat and a sink of CO_2. Figure courtesy of M. In fact, no satisfactory theory exists to describe the characteristics of turbulent flow in a fundamental manner. In atmospheric chemistry models one must resort to empirical parameterizations to estimate turbulent fluxes. We present here the simplest and most widely used of these parameterizations. Let us consider the smokestack plume described previously. The instantaneous plume shows large fluctuations but a time-averaged photograph would show a smoother structure Figure Figure Time-averaged smokestack plume In this time-averaged, smoothed plume there is a well-defined plume centerline, and a decrease of pollutant mixing ratios on both sides of this centerline that can be approximated as Gaussian. Molecular diffusion is far too slow to contribute significantly to atmospheric transport See Role of molecular diffusion in atmospheric transport , but the dispersion process resulting from turbulent air motions resembles that from molecular diffusion.

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