

Part II

The Magnifying Prefixes

Chapter 3

Kiloworld

1000 (1.0×10^3) K

3.1 Kiloworld Length

1 – 1000 Kilometers (Km) 1×10^3 m

Colorado is the only US state where every square millimeter of its land area is above one Kilometer in elevation. This makes Colorado the “Kilometer-High State.”

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On July 2, 1982, Larry Walters of San Pedro California, flew a homemade airship, constructed using an ordinary patio lawn chair, tethered with 43 helium filled, 2.4 meter wide, weather balloons. Larry had dreamed of flying, but was rejected by the US Air Force because of his poor eyesight. Walters and his girlfriend, Carol Van Deusen, purchased the balloons using a forged requisition from his employer FilmFair studios, stating the balloons were to be used in a television commercial. Walters attached water bottles to the lawn chair for ballast. Once released, the lawn chair airship ascended rapidly to about 4.9 Km, and was spotted by two commercial airliners.

After 45 minutes aloft, Larry shot several balloons with a pellet gun he had along for the purpose. He took care to shoot them so they would not unbalance the load. He then accidentally dropped

Distance in Kilometers

Example	Distance
Elevation of Colorado	> 1 Km
Visible Horizon	4 Km
Lawnchair Larry Maximum Altitude	4.9 Km
Distance I. M. Chisov Fell & Survived	7.0 Km
Bar Headed Goose Maximum Altitude	7.3 Km
Mount Everest	8.9 Km
Maximum Depth of Earth's Ocean	11 Km
Highest Commercial Flight Altitude	12 Km
Olympus Mons	21.23 Km
SR-71 Blackbird Altitude Record	24.4 Km
Apollo 17 Lunar Rover Driving Distance	35.74 Km
Mars Opportunity Rover Driving Distance	45.16 Km
Height of Tsar Bomba Mushroom Cloud	64 Km
Noctilucent Clouds	75 Km
Karman Line	100 Km
Length of the <i>Appian Way</i>	212 Km
Maximum Visible Distance on Earth	336 Km
Length of Mason-Dixon Line	375 Km
Length of Grand Canyon	446 Km
Distance from Los Angeles to San Francisco	614 Km
Width of Montana	1015 Km

Table 3.1: Example Kilometer Distances

his pellet gun, which reportedly slid from his lap, then plummeted toward the Earth below. Fortunately, he eliminated just the right number of balloons to slowly descend toward the ground, where some of his dangling cables were caught in a power line in Long Beach, which broke, and caused a 20 minute blackout. Walters landed on the ground unscathed. The lawn chair was exhibited at the San Diego Air and Space Museum through 2014.

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During a battle with the German Luftwaffe, Lieutenant Ivan Chisov (1916-1986) was forced to bail out of his damaged plane. Chisov, exited the plane at an altitude of about 7000 meters (7 Km). The battle was still in full force, so Chisov did not open

his parachute intentionally, preferring to wait until plummeting to an altitude where he believed he was no longer readily apparent to the German fighter planes. Had he opened it just after departing his plane, Chisov was concerned he would be an easy target in his parachute harness, as he gently floated downward. Unfortunately, the air was so thin when he bailed out, that he quickly lost consciousness, and did not pull the rip cord. He fell on the steep side of a snow covered mountain, sliding to the bottom. When found, Chisov was still alive, and wearing his unopened parachute. Chisov regained consciousness a short time later. He broke his pelvis and damaged his spine, but was able to fly again in a few months.

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Bar Headed Geese migrate over the Himalayas. They are the highest-flying bird known. (See Figure 3.1) They fly through air that contains just 30 to 50 percent of the oxygen found at sea level. They are able to lower their metabolism while maintaining their heart rates. The blood of the Bar Headed Goose also appears to cool, which allows for more oxygen transfer.^[1] The highest scientifically recorded altitude of a Bar Headed Goose is 7.29 Km.

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The highest allowed altitude for a commercial airliner is approximately 12 Km. The SR-71 Blackbird holds the altitude record for an aircraft. Its maximum recorded altitude is 24.39 Kilometers, or about twice the maximum altitude of a commercial airliner.

The SR-71 is also the fastest aircraft ever developed. In July of 1976, it reached a speed of 3529.5 Kilometers per hour. At this rate it could cross the 1015 Kilometer length of Montana in just over 17 minutes. The solar terminator, or twilight zone, is the location on Earth of the division between night and day. The Earth's terminator travels at a speed of 1668 Km per hour, so an SR-71 could slow down to about half of its maximum speed, and remain perpetually in the Earth's twilight zone.

The terminator on the Moon's surface moves at a rate of 15.4

Kilometers per hour. The Lunar Rover used by the Apollo Astronauts, could only travel at a maximum of 13 Km/hr and would slowly see the terminator recede at about 2.4 Km per hour if they tried to keep up with it.



Figure 3.1: Bar Headed Goose – Wikimedia Commons

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The tallest mountain on any planet in the solar system is Olympus Mons on Mars. This shield volcano, similar to those found in Hawaii, rises 21.3 Kilometers above the martian surface. Olympus Mons overshadows Mount Everest's height which is only 8.848 Kilometers tall.

The height of mountains on Earth are generally referenced with respect to sea level. A difficulty encountered with this baseline, is that sea level depends on which country has defined it. The UK's mapping agency measures altitude on Earth with respect to mean sea level using a value determined during World War I at Newlyn in Cornwall.^[2] Today this figure has increased by 200 millimeters.

Currently, European countries each use their own definition of



Figure 3.2: Mount Everest – Tallest mountain by sea level (Left) Chiborazo – Tallest mountain from the center of the Earth (Right) – Wikimedia Commons

sea level. New data shows how much sea level variation there is across European countries. Amsterdam’s vertical benchmark will be about 10 mm above the proposed European Vertical Reference System, Helsinki is 210 mm higher, and Ostend is 2320 mm lower than the new benchmark. Tregde happens to be very close to zero offset from the new standard.

This farrago of vertical measurement references can have engineering consequences.^[3] In 2003, a bridge was constructed to span the Rhine River, and connect Laufenburg, Germany and Laufenburg Switzerland. Each country began construction on its respective side, and were to meet in the middle. The German reference for sea level used the North Sea. The Swiss reference for sea level used the Mediterranean Sea. The two reference values differ by 270 millimeters. The two cities have always seen themselves as a single metropolis, and so they communicated this difference to one another so that it could be taken into account. A problem occurred when the simple conversion had a sign error, and the German side of the bridge was 540 millimeters higher than that constructed by the Swiss. The German side was lowered, and eventually the two sides connected.

GPS has a spherical “Earth model,” but alas the Earth is not a sphere. It is a lumpy and in-homogeneous solid that looks much like a sphere. Satellites were launched, and have provided enough

new data to create an accurate geometric model of the Earth—warts and all. The model developed will be accurate within a few tens of millimeters. Combined with ground based measurements, the new model should provide millimeter accuracy. The value of altitude on Earth will no longer be expressed in terms of sea level, but with respect to the Earth’s center.

With a costly error like the Laufenburg Bridge, it would seem obvious that the world should embrace the new single model of our Earth developed using the latest satellite data. The US, Canada and Mexico have all agreed to use a unified geoid-based height system in 2022. The International Union of Geodesy and Geophysics passed a resolution in 2015 to support the adoption of a single global model.

Mount Everest is proverbially known as the tallest mountain in the world. Its height has been an academic and political football. China and Nepal argue over whether the height of Everest should be measured in terms of its rock height, or snow height. The National Geographic Society has its own ideas of how to measure the peak and in 1999 argued it is 8850 meters high.

When one starts to use the Earth’s center as a reference, considerable change can occur. The peak of Ecuador’s Chimborazo is a mere 6310 meters above the local sea level, but because of the Earth’s deviation from a sphere, this peak is much farther from the Earth’s center. When using the Earth’s center as a reference point, Chimborazo is over 2 Kilometers taller than Mount Everest. Which is the tallest mountain on the planet? Mount Everest or Chimborazo? This question could become a brouhaha that makes the US converting to metric system seem a tame discussion. One can only hope the political creatures that inhabit our planet can look past “who’s is bigger,” and all agree on a single standard for elevation. Independent of political desires, the summit of Chimborazo is the location on the Earth’s surface that is farthest from its center.

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The visible horizon is the line seen at the boundary between

Earth and sky. The distance to the visible horizon, when standing on flat ground, is about four to five Kilometers. A circular area of about 20 Km² is the maximum extent one can experience when standing on an unobscured flat patch of earth or at sea and turning around. When remaining stationary, the maximum area one can view is about 10 Km² or half of the area. The distance to the visible horizon was of paramount importance when human communication was limited to the maximum available visual distance.

A person can expand their visual horizon by increasing their height above the ground. Standing on a hill 100 meters above the firmament, a person can see for a distance of about 36 Kilometers. This is the reason for the crow's nest at the top of a sailing ship's mast.

In 1792, French engineer Claude Chappe (1763-1805) demonstrated an optical telegraph. It utilized a configurable mechanical semaphore system, which would present messages in semaphore code. The semaphore display was placed upon the top of a semaphore tower. It was configured with a symbol, which was viewed optically, using a telescope, by a person at the next tower.

Lines of towers were constructed within line-of-site of one another, forming a communication chain. These chains had separations from 8–32 Km. Each tower would pass each message it received to the next tower, which was much faster than moving a paper message overland. At its greatest extent, the system consisted of 556 semaphore stations, spanning a total distance of 4800 Kilometers. This communication system was in use from the late 18th century to the 1850s, when they were replaced with the electrical telegraph, which was cheaper, faster, and more private.

If one ascends the 3432 meter (3.4 Km) high summit of Mount Iزارu, an active volcano in Costa Rica, it is possible, on an ideally clear day, to see both the Atlantic and Pacific Ocean from this location. It is thought to be the only location in the Americas for which this is true.*

*The distance between the two oceans in the narrowest part of Costa Rica is 120 Km

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The maximum depth of the world's oceans is estimated to be almost exactly 11 Kilometers. This maximum is located at the bottom of the Mariana Trench in the western Pacific. Fish exist from the surface of the ocean to a depth of 7.7 Km, and then abruptly disappear. No true fish are thought to exist below 8 Kilometers, but sea cucumbers, shrimp, and polychaete worms do.

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In 2014, the Mars Opportunity Rover set the record for the longest driving distance on another planet by traversing 45.16 Kilometers. The longest distance driven with humans behind the wheel on another planet is still the 35.74 Kilometer distance traversed by the Apollo 17 astronauts in the Lunar Roving Vehicle (LRV), in December of 1972.

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If a person is 300 meters above the Earth, about the height of the Eiffel Tower in Paris, the visible horizon becomes approximately 62 Kilometers.

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The largest nuclear weapon ever detonated was the Tsar Bomba. It was detonated on October 30, 1961. Its mushroom cloud extended upward about 64 Kilometers. This is over two and a half times as high in altitude as the SR-71 Blackbird's altitude record. It is the most powerful explosive ever detonated by human kind.

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Noctilucent, or "night shining" clouds form around 80 Kilometers above the Earth. They are composed of water ice crystals around 100 nanometers in diameter. Noctilucent clouds form at a higher altitude than any other clouds in the Earth's atmosphere. There is no authenticated observation of them prior to 1885. Noctilucent clouds are typically colorless or a pale blue, but infrequently red and green coloration have also been observed. They



Figure 3.3: Noctilucent Cloud visible over Orlando Florida formed by a Falcon 9 about 90 minutes after lifting off - Wikimedia Commons - Space Exploration Technologies Corporation

are dim and ephemeral, and only seen during twilight near sunrise and sunset, when the clouds of the lower atmosphere are in shadow, and only the noctilucent clouds are illuminated by sunlight.

It appears very cold temperatures are required for the formation of noctilucent clouds. Water vapor released by Space Shuttle exhaust was observed to precipitate small noctilucent clouds. The launch of a SpaceX Falcon 9 rocket produced noctilucent clouds above Orlando Florida in August of 2014. (See Figure 3.3)

In 2006, researchers with the Mars Express mission discovered clouds composed of carbon dioxide crystals, that formed up to 100 Kilometers above the surface of Mars. These clouds are the highest clouds ever observed above the surface of a planet. As with noctilucent clouds on Earth, they can be seen only when the Sun is below the horizon.

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The Karman Line is used to define the boundary between our atmosphere and space. The line is defined as 100 Kilometers above sea level.[†] The Karman Line is named after Hungarian-American engineer and physicist Theodore von Karman (1885-1963). Karman was the first to compute the altitude where the atmosphere becomes so rarefied, that conventional aircraft cannot support themselves. This altitude was computed by Karman as 83.6 Kilometers. A vehicle at this altitude would have to travel faster than the the speed required to obtain Earth orbit in order to provide the lift required to sustainably fly within this vacuum air.

100 Km above the Earth is where ultraviolet radiation causes the ionization and dissociation of molecules, and the approximate region in which Auroras occur. The legal regulations of aircraft and spacecraft are under different jurisdictions. The Karman Line is used as a legal demarcation altitude. This is a heuristic, as there is no international agreement as to what constitutes a country's air space, and outer space. The Iridium satellite constellation chose an altitude which was well above the Karman Line, but far enough below the Van Allen Belt, so as not to degrade satellite avionics, which affects reliability.^[4]

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Pike's Peak protrudes 1679 meters (1.7 Km) above the onset of the Great Plains. The visual horizon for a person standing on Pike's Peak in Colorado, and looking toward Kansas, is 146 Km.

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In 312 BC, Appius Claudius Caecus (340 BC–273 BC), a Roman official, constructed one of the most famous of Roman roads, the *Appian Way*. It was the most soundly-constructed road of its time, and stretched 212 Kilometers from Rome to Brindisi, Italy.

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[†]Considering the problematic nature of defining sea level, perhaps this distance may be defined in terms of a distance from the center of the Earth in the future.

The tallest mountain on Earth is Mount Everest, which is 8.848 Km. The maximum distance one can view directly to the horizon at this height is 336 Kilometers. This distance is approximately the span across Iowa from north to south (320 Km). The height of Mount Everest sets a limit on the distance one can personally experience while directly positioned on the Earth's surface. It is the maximum limit for an Earth-bound human gaze and falls far short of 1000 kilometers, the official, but pliable, boundary of Kiloworld lengths.

Beyond 336 Km, one must rely on roads and signs with distance values on them to travel from one location on Earth to another.

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One hundred Kilometers per hour is the approximate average speed of a car on a long trip. The original Volkswagen Beetle was designed to maintain 100 Kilometers per hour with a fuel efficiency under seven liters per 100 Kilometers.^[5] At this rate of speed, it would take about 3.4 hours to drive the 336 Kilometer length of the maximum possible visible horizon seen from the highest point on the Earth.

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The distance from San Francisco, California to New York, New York is about 4000 Km. When discussing distances across continents, a person will soon cross the border which separates Kiloworld and Megaworld. The Kilometer is still a distance most people experience and use in their everyday lives. Modern travel allows people to cross distances unimaginable in prior centuries, and to personally experience planetary dimensions.

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Electromagnetic (EM) waves with wavelengths longer than 1 Kilometer are historically called longwaves. Longwaves are only of practical use for communicating with submarines. The corresponding frequency range of the electromagnetic wavelengths encompassed by Kiloworld (1-1000 Km) is from 300 Hz to 300 KHz.

3.2 Kiloworld Area

1 – 1 000 000 Square Kilometers (Km^2) $1 \times 10^6 \text{ m}^2$

New York's Central Park is approximately 4 Kilometers long and 800 meters wide covering an area of about 3.4 Km^2 . Meteor Crater in Arizona has an area very close to that of New York's Central Park at 3.6 square Kilometers.

Areas in Square Kilometers

Example	Area
New York's Central Park	3.4 Km^2
Meteor Crater Arizona	3.6 Km^2
Armillaria Solidipes (Fungus)	8.4 Km^2
Palmyra Atoll	12 Km^2
Easter Island	164 Km^2
Mille Lacs Lake (Minnesota)	536 Km^2
Salton Sea (California)	889 Km^2
Lake of the Woods (Minnesota)	4 350 Km^2
Lake Vostok (Antarctica)	15 690 Km^2
Chicxulub Meteor Crater	32 400 Km^2
Lake Victoria (Africa)	69 485 Km^2
Vredefort Meteor Crater (Africa)	70 686 Km^2
Black Dragon Fire Burn Area	72 884 Km^2
Lake Michigan-Huron	117 400 Km^2
Ligeia Mare (Titan)	126 000 Km^2
Deep Water Horizon Oil Spill Area	180 000 Km^2
Lake Agassiz	400 000 Km^2
Kraken Mare (Titan)	400 000 Km^2
California	423 970 Km^2
Black Sea	436 400 Km^2
Rocky Mountain Locust Swarm (1877)	510 000 Km^2
Hudson Bay	1 230 000 Km^2
Alaska	1 718 000 Km^2
Siberian Traps	7 000 000 Km^2
Lower 48 US States	8 080 000 Km^2

Table 3.2: Example Square Kilometer Areas

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One of the largest living organisms on Earth, *Armillaria solidipes*, is a fungus. A specimen found in Oregon's Malheur National Forest is believed to have been growing for about 2400 years, and extends over an area of about 8.4 square Kilometers. This is about 2.5 times the area of Central Park. The majority of the fungus grows underground and is therefore not readily visible. The Oregon specimen has been dubbed the "Humongous Fungus."

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While Coconut Island (Gilligan's Island) may well be one of the most famous in the world, America's last incorporated territory is not. When Alaska and Hawaii became states in 1959, Palmyra Atoll became the last US incorporated territory, and as such is subject to all the provisions of the US Constitution. Palmyra Atoll is a 12 Km² island with a 14 Kilometer coastline. Located about 1600 Km south of Hawaii, the island has no permanent residents and sits at an elevation of about 2 meters.[‡]

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Easter Island was named by Dutch explorer Jacob Roggeveen (1659-1729) when he encountered it on April 5, 1722, which was Easter Sunday. The island is famous for its giant statues, known as moai. The largest erected statue is about 10 meters tall, and has a mass of about 74 Megagrams. The area of the island is 163.6

[‡]The island of Palmyra is also the location of an infamous 1974 double murder. A wealthy couple, Malcolm and Eleanor Graham, sailed to Palmyra, hoping it would be deserted, and allow them a summer of solitude. The pair were disappointed when they encountered two Canadian scientists, who the conservative couple initially mistook for hippies. Two others, Wesley Walker and Stephanie Stearns, were also there. They had sailed a decaying sloop from Hawaii, and hoped to cultivate marijuana and sell it. Around the end of August of that year, the Grahams vanished. Walker and Stearns sank their own boat, and sailed to Hawaii in the Grahams' boat, *The Sea Wind*. After arriving in Hawaii, the pair had *The Sea Wind* repainted and renamed. Locals recognized the boat despite the new paint and alerted authorities. Walker was able to avoid arrest for the theft of the boat and fled. In 1981, a visitor to Palmyra discovered the skull and remains of Eleanor Graham. Walker was convicted of murdering Mrs. Graham, and incarcerated. Wesley Walker was paroled in 2007 and died in 2010.

square Kilometers.

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In 1905, engineers working for the California Development Company made a number of cuts into the bank of the Colorado River to increase water flow for Imperial Valley farming. An irrigation system developed to supply the area had been silted up by the Colorado River, and it was hoped the extra water flow would provide relief. This outflow overwhelmed the irrigation system after the water volume substantially increased following a heavy rainfall and snow melt. Water from the river began to flow into a dry lake bed, known as the Salton Basin, for two years, producing the largest lake in the state of California. Over this period, the entire output of the Colorado River flowed into the Salton Basin, submerging the town of Salton. With nowhere else to go, the water formed an inland lake.

The Salton Sea currently has a surface area of approximately 889 Km², and is located directly on the San Andreas Fault. In the 1950s, the Salton Sea had considerable success as a tourist destination, but subsequent environmental difficulties caused the hotels and recreational areas to be abandoned. The Salton Sea was central to the plot of the 1957 film *The Monster That Challenged the World*. The deserted structures, abandoned after the heyday of the Salton Sea, have become a destination for tourists.

Mudpots and mud volcanos are seen on the eastern side of the lake, and bear witness to local geothermal activity. Eleven electricity generating geothermal plants are located near the shores of the Salton Sea, with a potential to produce 2400 Megawatts of power.

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Minnesota is the land of 10 000 lakes. They range in area from Ham Lake's 0.0016 Km² (1620 square meters) to 4350 square Kilometers for Lake of The Woods.

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Lake Rostock is the largest lake in Antarctica and the largest

subglacial lake in the world. A subglacial lake is one beneath a glacier or other ice sheet. Lake Rostock has an area of 15 690 Km².

The sixty-five million-year-old Chicxulub Crater, buried beneath the Yucatan Peninsula in Mexico, was left behind by the meteor impact which led to the extinction of the dinosaurs. It has an area of approximately 32 400 Km². The energy released by the impact of the Chicxulub meteor was 2 000 000 times (two Mega-times) larger than the energy produced by the largest thermonuclear fusion explosive device ever detonated, the Russian Tsar Bomba.

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Lake Victoria, the largest lake in Africa, has a surface area of 69 485 square Kilometers.

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The largest verified meteor crater on Earth is the Vredford Crater in South Africa. It was formed about two billion years ago. The original impact crater, which long ago eroded away, is thought to have been 300 Kilometers in diameter, and covered an area of 70 686 square Kilometers. This makes it about the size of Lake Victoria, and slightly larger than the area of West Virginia. The meteor which created the Vredford Crater is thought to have been approximately 5-10 Km in extent.

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The Black Dragon fire, which straddled the border of Siberia and China, left the largest known burn scar. The burn area is 72 884 square Kilometers. The fire began in May of 1987. The Chinese sent two armies of regular troops, and thousands of forestry workers to fight the fire. The Russian government decided to let the fire burn uncontrolled on their side of the border. Not until June was the blaze finally contained.

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People generally see Lake Michigan and Lake Huron as separate lakes, but technically they are considered a single body of

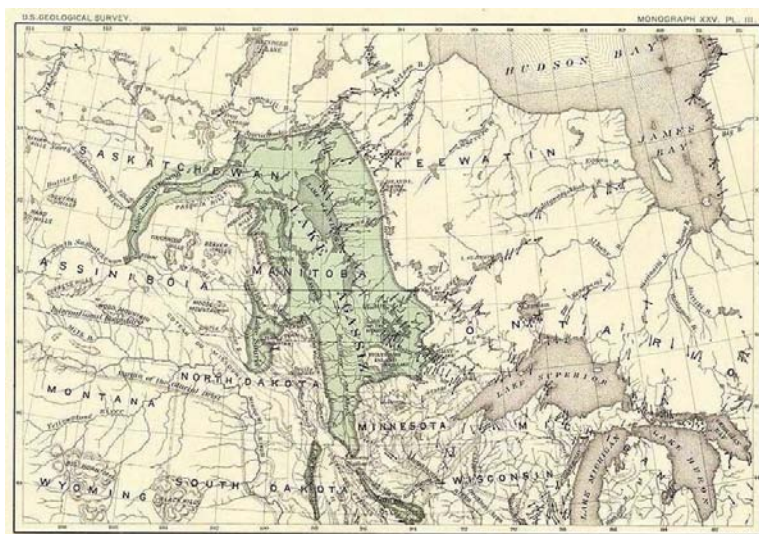


Figure 3.4: An early map of Lake Agassiz (Wikimedia Commons)

water. The surface area of Lake Michigan-Huron is 117 400 square Kilometers.

The Deepwater Horizon oil release affected an area of about 180 000 square Kilometers. This area is larger than Lake Michigan-Huron and is about the size of Missouri.

Hydrocarbon lakes have been detected on Titan, which is a moon of Saturn. One of these lakes, Ligeia Mare, is thought to be liquid ethane, methane, or a mixture of both. This body of surface liquid has an area of 126 000 square Kilometers, slightly larger than Lake Michigan-Huron. Kraken Mare is the largest hydrocarbon lake on Titan with an area of about 400 000 square Kilometers, similar in area to the Black Sea.

If we reach back into the Earth's history, the largest lake known to have existed was Lake Agassiz, which is illustrated in Figure 3.4. Approximately 13 000 years ago, Lake Agassiz spread over most of Manitoba, northwestern Ontario, northern Minnesota, and eastern North Dakota. At its greatest extent, it is thought to have

possessed a surface area of over 400 000 square Kilometers.

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In 1877, the largest known swarm of Rocky Mountain Locusts began to flow across the Midwestern United States. This tsunami of insects cascaded across the Great Plains where recent settlers had not previously experienced them. From 1873 to 1877 flying oceans of locusts descended upon farmers, ate their crops, and laid untold numbers of eggs below the ground as they passed. One Iowa farmer related that as a swarm passed between himself and the sun, daylight vanished, the air cooled, and stars became visible. Other witnesses described the sound of the descending grasshoppers like a multitude of cutting scissors. When they landed, the locusts began to feed on anything and everything available. They denuded the leaves on the trees as well as the surrounding prairie grass. Lettuce and cabbages quickly disappeared. Onions were eaten by consuming their tops, and then devouring the onion from the inside outward, leaving only a thin outer husk behind. They consumed paper, bark, window blinds, paint and wool from the backs of sheep.

During the swarm of 1877, Dr. Albert Child used telegraphic reports of the extent of the locusts, and telescopic observations, to estimate the size of the swarm which passed by for over five days.^[6] The area of the swarm is estimated at around 510 000 square Kilometers, which is larger than the state of California, which is 423 970 Km². The number of insects was estimated in the 12.5 Tera-count (Trillion) range. Their estimated mass is 27.5 Teragrams. In 1876, Congress stated that the Rocky Mountain Locust was the single greatest impediment to the settlement of the country.

Then, within a couple of decades, the Rocky Mountain Locusts vanished. It took sometime for people to notice the absence of the locusts. On July 19th of 1902, entomologist Norman Criddle (1875-1933) collected a male and female locust on his father's estate. He preserved them to the standards of museum specimens, and labeled the container *Melanoplus spretus*. The

specimens eventually made their way into the insect collection at the Smithsonian Institution. These specimens testify that Norman Criddle is the last person known to have seen a living Rocky Mountain Locust. The locust was so ubiquitous, very few contemporary samples were collected, and only in the special situation where specimens were serendipitously preserved in Grasshopper Glacier Montana have any new samples emerged. The disappearance of the Rocky Mountain Locusts is still debated. The locusts may have congregated in a single small area of the West, not unlike how Monarch Butterflies do in Mexico, where introduced agricultural practices disrupted the locust's specialized breeding area. The Terra-forming of the prairie for agricultural use may have also punctuated the demise of the Rocky Mountain Locust. Entomologist Jeffrey Lockwood states:

The most spectacular “success” in the history of economic entomology—the only complete elimination of an agricultural pest species—was the result of unplanned, uncoordinated and unintentional human activity. The agriculturalists who arrived in the river valleys of the West, managed to drive their most severe competitor to extinction in the matter of a few years, leaving North America as the only inhabited continent without a locust species.^[7]

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The surface area of Hudson Bay finally reaches just past the Kiloworld area boundary at 1 230 000 square Kilometers. This area is impressive, but the state of Alaska contains an area of 1 717 856 Km². It is the largest US state by far. The state of Texas is the second largest at 696 200 Km² but even if one adds California's 423 970 Km² and Montana's 380 800 Km² to the area of Texas, Alaska still has a larger surface area. Texas, California and Montana have a combined area of 1 500 970 Km².

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Around 251 to 250 million years ago, volcanic eruptions took place over a one million year period which formed the Siberian Traps. The word “traps” is from Swedish words meaning stairs, because the volcanic rock formed steps which look similar to a staircase.

Immense amounts of lava flowed across a massive area of Siberia, coating its surface with basalt. The original area of coverage is estimated at about 7 000 000 square Kilometers. For comparison, the area of the lower 48 US states is approximately 8 080 464 Km².

3.3 Kiloworld Volume

1 – 1 000 000 000 Cubic Kilometers (Km³) 1 x 10⁹ m³

(1 Teraliter (TL) → Zettaliter (ZL))

1 – 1000 Kiloliters (KL) 1 x 10³ L

A cubic meter volume is equal to 1000 liters or 1 Kiloliter.[§] There has been a distinction between liquid and solid measurements in the minds of people since antiquity. This distinction is essentially a psychological one and has no physical basis. When a person thinks of a liter, they often visualize a one or two liter bottle of soda, which is liquid.

The liter was originally defined as the volume contained by a cube with 100 mm (0.1 meter) sides. Most people encounter the liter when measuring liquids, and its well defined cubic volume can be obscured by the fact it was given a name.

A common Kiloliter volume most people encounter frequently is the interior of an elevator. A standard elevator floor size is 1016 mm x 1372 mm with a height of about 2200 mm. Despite the seemingly small dimensions of an elevator car, its volume is about 3 Kiloliters (3000 liters), which is well outside of Uniworld’s boundary.

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[§]Kiloliter sounds like Cubic Meter and they are the same volume.

Volumes in Kiloliters

Example	Volume
Common Elevator Interior	3 KL
Hoba Meteorite	6-7 KL
Wärtsilä-Sulzer RTA96-C Diesel Engine	25.5 KL
Baobab Tree	100 KL
Annual Water Use Per Person (US)	130 KL
Railroad Oil Car (DOT-111)	131 KL
World's Littlest Skyscraper	200 KL
Marston Water Tower	613 KL
Largest Spheroidal Water Tower	1900 KL
Meteor Crater Meteorite	8000 KL

Table 3.3: Examples of Kiloliter Quantities

The largest known meteorite is the Hoba meteorite in Namibia in southwestern Africa. It was discovered in 1920 by a farmer plowing his field. The meteorite remains where it fell because of its large mass, 60 Megagrams. It has been excavated and its volume is estimated at around 6-7 cubic meters, which is 6-7 Kiloliters. Its approximate dimensions are 2700 mm x 2700 mm x 900 mm. The meteorite is unusual in that it is flat on two sides and believed to have fallen to Earth at terminal velocity.[¶] This in turn caused it to impact the earth in a manner which produced no identifiable crater and preserved it as a single intact object.

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The total displacement of the cylinders in the largest diesel engine manufactured, the Wärtsilä-Sulzer RTA96-C Diesel Engine, is just over 25 Kiloliters (25 cubic meters).

...

[¶]Terminal velocity is when the drag from the air through which an object is falling equals the force of gravity on it. As an object passes through air, the air “pushes back” producing drag. When this force of air resistance is equal to the force of gravity the object no longer accelerates and falls at a constant velocity or *terminal velocity*. A skydiver with their belly facing the earth has a terminal velocity of approximately 54 m/s.

The Baobab tree stores up to 100 Kiloliters of water in its trunk, which it uses to survive droughts. The volume of water stored is about four times the displacement of the diesel engine. A hollow Baobab tree in Derby, Western Australia, was used as prison in the 1890s.

...

The ubiquitous railroad oil tanker car is seen all over the United States. The common unpressurized DOT-111 tank car has a capacity of 131 Kiloliters.

The US Geological Survey estimates each person in the United States uses between 300–375 liters of water per day. This is approximately 130 Kiloliters per person per year, or about the amount that could be held in a single DOT-111 railroad tank car.

...

The World's Littlest Skyscraper, located in the town of Wichita Falls Texas, has an internal volume of almost exactly 200 Kiloliters.

...

In the mid twentieth century, small town water towers were ubiquitous on the Great Plains of the United States. They were often decorated and painted to reflect the heritage of each of the small hamlets they served. The town of Stanton Iowa is the birthplace of Virginia Christine (1920–1996) who played Mrs. Olson in numerous Folgers Coffee commercials of the era. She was in *Invasion of the Body Snatchers* (1961) and also appeared in a large number of films and television series. The town of Stanton morphed its water tower into a giant coffee percolator in 1971 to honor her.

Most water towers of this era have a form similar to the Marston Water Tower, located on the campus of Iowa State University. (See Figure 3.5) The Marston Water tower was constructed in 1897 and holds about 613 Kiloliters of water, or about six times the capacity of a Baobab Tree.^{||}

^{||}Water is pumped upward into the tank of a water tower. For each 102

Many of these water towers have been replaced with spheroidal water towers. Spheroidal water towers have a single bulb upheld with a single central post. The largest of these water towers is said to hold around 1900 Kiloliters of water. It would take more than four of these to equal the volume of Meteor Crater.

...

In Arizona, about 50 000 years ago, a meteorite created a very large crater, which is appropriately called "Meteor Crater." This designation is only a coincidence, as it is common to assign the names of land features based on the name of the nearest post office, which in this case was Meteor. This meteorite excavation is also called Barringer Crater, after Daniel Barringer (1860-1929). He was the first person to suggest the crater was created by a meteor impact.

Meteor crater is about 1200 meters in diameter, and 170 meters deep. The meteor which produced Meteor Crater is believed to have been about 50 meters across. It descended with an estimated energy of 42 Petajoules (42×10^{15} joules) and was vaporized on impact. The volume of the meteorite is thought to have been perhaps 8000 Kiloliters in volume.

$\text{Km}^3 \bullet \bullet \bullet \text{Km}^3$

1000 cubic Kilometers approaches the limit of volume which is expressible in terms of liters. One thousand cubic Kilometers is a Zettaliter. The last magnifying prefix is Yotta. A Yottaliter is very close to the exact volume of the Earth. From this point on, volume in cubic meters will be used to describe astronomical volumes, and liters will only describe terrestrial volumes.

On May 18, 1980, after two months of rumbling and bulging, Mount St. Helens in Washington state exploded. The north face of the volcano slid away, producing the largest landslide in recorded history. Over more than nine hours, an energetic plume of ash

millimeters of increased elevation, a pressure of one Kilopascal of pressure is generated. A water tower with a height of 30 meters produces about 300 Kilopascals of pressure, which is generally sufficient to service most small mid-western towns. Atmospheric pressure is about 100 Kilopascals.



Figure 3.5: **The Marston Water Tower** This water tower was constructed in 1897. It is 51 meters in height, and rests on an octagonal base. The tank holds approximately 613 Kiloliters

Volumes in Cubic Kilometers

Example	Volume
Mount St. Helens Eruption	2.8 Km ³
Mount Tambora 1815 Eruption	41 Km ³
Volume of Crude Oil on Earth	300 Km ³
Chicxulub Meteorite	523 Km ³
Toba Supereruption	2 800 Km ³
Volume of Lake Superior	12 232 Km ³
Annual Rain Falling on the Earth's Continents	107 000 Km ³
Water Evaporated from the Oceans into Atmosphere	505 000 Km ³
Planetary Volume Needed to Create a Sphere	1 000 000 Km ³
Greenland Ice Cap	2 600 000 Km ³
Volume of Water in the Earth's Oceans	1 400 000 000 Km ³
Eris	6 589 000 000 Km ³
Pluto	6 990 000 000 Km ³

Table 3.4: Examples of Cubic Kilometer Quantities

snaked upward into the sky. The volcano expelled at least 2.79 cubic Kilometers of material into the atmosphere. The eruption column extended upward 24 Km. About 1.5 Petagrams of sulfur dioxide were released into the atmosphere. The cloud of ash moved across the United States in three days, circled the Earth, and seventeen days later, arrived from the west, and passed over the mountain which originally belched it.

The largest volcanic eruption in recorded history began on April 5, 1815 in what is now Indonesia. Mount Tambora on the island of Sumbawa ejected approximately 41 cubic Kilometers of material into the atmosphere. This is almost 15 times larger than the amount of material expelled by Mount St. Helens. Pumice stones 200 mm in diameter rained down from the sky. The total mass ejected is estimated at 10 000 Petagrams! This eruption produced the “Year Without a Summer” around the globe.

The sound made by the Tambora eruption was heard over 1500 Kilometers away. This distance is longer than the length of California. Temperatures dropped in every country in the world fol-

lowing the eruption. Large crop failures occurred in China because of summer frosts. India's monsoon did not arrive, instead, drought replaced the summer rains. In the Northeastern United States and Europe, 1816 was known as the "Year Without a Summer." Snow fell in New York State in June of 1816. By July, summer had still not arrived.

A migration from the Northeastern US occurred, as tens of thousands of people left for opportunities in the West. Crop failures in Europe precipitated migration to the US. Subsistence farming was the global norm, this produced three years where almost everyone on Earth was hungry. Crop failure became worldwide. Famine swept across the globe as people searched for anything edible, such as moss. In China, people wandered fields eating white clay. Sickness followed.

No contemporary connection was made between the eruption of Mount Tambora, global cooling, and the inclimate weather. In 1783, Benjamin Franklin speculated that a link might exist between volcanic eruptions and cooling of the planet, but his was a singular view. Suggestions for the arrival of the intense pestilence included immorality, low church attendance, sun spots, or icebergs in the North Atlantic. The sulfate aerosols in the upper atmosphere produced a "dry fog" which allowed citizens to see sun spots with the naked eye in New York. The upper atmosphere had cleared enough by 1818, that summer crops were grown that produced excellent harvests.

...

The total volume of oil which existed within the Earth, prior to the beginning of human extraction, is estimated to have been about 300 Km³.

...

The sizes of asteroids are often expressed in terms of their length, rather than volume. If we assume an asteroid is approximately spherical, then those with a diameter of 12.41 Kilometers contain 1000 cubic Kilometers of volume.

The Chicxulub asteroid, which impacted the Earth 66 million

years ago, and is thought to be responsible for the extinction of the dinosaurs, is estimated to have been approximately 10 Kilometers in diameter. The meteor is thought to have been about 523 cubic Kilometers in volume (523 TL). The Chicxulub asteroid impacted the Earth with an energy of approximately 420 Zettajoules (420×10^{21} J).

The largest human-created explosion was the Russian Tsar Bomba detonated on October 30, 1961. This thermonuclear fusion bomb had an energy estimated at 210 Petajoules. The Chicxulub asteroid had a kinetic energy two metric prefixes larger in magnitude. This means the largest hydrogen bomb ever exploded, produced about 2 000 000 times *less* energy than that released by the asteroid thought responsible for the demise of the dinosaurs. This asteroid created one of the largest verified impact artifacts on Earth. The Chicxulub crater is about 180 Kilometers in diameter and 20 Km deep.

The Tsar Bomba had a mushroom cloud that extended 64 Kilometers into the atmosphere. It was had the potential to produce third degree burns as a distance of 100 Km. Observers felt heat from the explosion at a distance of 270 Km from the explosion. The flash from the Tsar Bomba was seen by people, through bad weather, at a distance of 1000 Kilometers. This is the length of Montana.

Approximately 74 000 years ago, a supervolcano erupted in Indonesia. An immense volcanic crater known as Toba was left in its aftermath. An estimated 2800 cubic Kilometers of material were ejected. The Toba catastrophe hypothesis asserts this event produced a global volcanic winter lasting 6-10 years and produced atmospheric cooling for another 1000 years. Stratospheric dust clouds are thought to have lowered the global temperature by 3-5 degrees Celsius.

The ejected mass from the prehistoric Toba event is believed to be at least 100 times larger than the 1815 eruption of Mount Tambora, also in Indonesia. This much smaller expulsion of material into the atmosphere produced the “Year Without a Summer”

in 1816.

The ancient Toba event is thought to have produced a layer of ash approximately 150 millimeters thick over an area of about 4 400 000 Km². This is about half the area of the lower 48 US states. The amount of ash ejected into the atmosphere is estimated at 800 cubic Kilometers.**

...

The oceans evaporate approximately 505 000 cubic Kilometers of water into the atmosphere each year. Most of this water vapor falls as rain. About 107 000 cubic Kilometers of this rain falls on Earth's landmasses.

...

An astronomical body with a volume above approximately 1 000 000 cubic Kilometers produces a gravitational field with sufficient force to compress the matter it contains into a sphere. A sphere of this volume has a diameter of approximately 124 Kilometers.

In recent years, the definition of the word planet has undergone considerable revision. The word planet is from Greek words which mean "wandering stars," which could apply to many celestial objects. In the early years of the 20th century, the term planet referred to eight objects: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. Pluto was discovered in 1930 by American astronomer Clyde Tombaugh (1907-1997), and designated the ninth planet from the Sun.

However, in the late 1970s, objects with similar characteristics to Pluto were discovered outside of Neptune's orbit. Then in 2005, a trans-Neptunian object was discovered with 27% more mass than Pluto, which is now called Eris.

**Geneticists have found evidence for a "genetic bottleneck" in humans, their parasites, and other primates, thought to have occurred at the same time. It is hypothesized the number of humans decreased to a total of 1000 to 10 000 breeding pairs. It is thought cooling and a severe decrease in sunlight globally decreased the available human food supply. The pre-catastrophe human population is estimated to have been around 1 million.

In response to this discovery, the International Astronomical Union (IAU) decided to create a clearer definition for a planet in our solar system. The new definition is that a planet is a body which orbits the Sun, is massive enough for its own gravity to make it round, and has “cleared its neighborhood” of smaller objects around its orbit. This new definition does not include Pluto or Eris.

Pluto has a volume of 6 990 000 000 Km³ and Eris possesses a volume of 6 590 000 000 cubic Kilometers, well past the rule of thumb for an astronomical body with enough gravitational force to form itself into a sphere.

Pluto and Eris, along with several other trans-Neptunian objects, plus Ceres in the asteroid belt, are now known as dwarf planets. The IAU defines a dwarf planet as a celestial body in direct orbit of the Sun, massive enough for its shape to be controlled by gravity, but unlike a planet, has not cleared its orbit of other objects. The definition of planet is controversial within the scientific community, and some have outright rejected the new designations.

3.4 Kiloworld Mass

1 – 1000 Kilograms (Kg) 1×10^3 g

The original standard for mass in the metric system was the gram. It was defined as the mass of water at four degrees Celsius contained within a cube with 10 millimeter sides,^{††} or equivalently, one milliliter of water. As there are 1000 mL in a liter of water, it has a mass of 1000 grams or 1 Kilogram.

A Kilogram is the mass which describes the larger objects found in the human world. A human being has a mass of about 70 Kilograms. We all have an idea of how much objects around us weigh in proportion to ourselves. Cats weigh less than a human, and horses weigh more. In the US, the almost complete absence of approximate numbers for common objects in grams or Kilograms

^{††}This volume is atavistically known as a cubic centimeter.

Mass in Kilograms

Example	Mass
Domestic Cat	5 Kg
Apollo 11 Moon Rocks	22 Kg
Thumbelina (smallest horse)	26 Kg
Human	70 Kg
Sputnik 1	84 Kg
Largest Gold Nugget	97 Kg
Total Apollo Mission Moon Rocks	382 Kg
Horse	450 Kg
Yugo (car)	875 Kg

Table 3.5: Mass of Example Objects in Kilograms

prevents Americans from intuitively understanding mass magnitude in the metric system. The reason for this unfamiliarity is simple. It is because the metric system has not been adopted as the exclusive set of weights and measures in the United States. A large cat is around 5 Kilograms, and a horse is about 450 Kg. The world’s smallest horse is Thumbelina. She is 430 mm in height, and masses-in at only 26 Kilograms. Thumbelina was born in Saint Louis, Missouri in 2001.

...

The original artificial satellite, Sputnik 1, masses just more than a human at 84 Kilograms. The total mass of moon rocks retrieved by all the Apollo moon missions is over four times more than Sputnik 1.

...

The “Welcome Stranger” is the largest alluvial gold nugget ever found. Its refined mass was 97.14 Kilograms and it was 610 mm x 310 mm in extent. When the nugget was discovered, there was no scale capable of measuring its mass, so it was broken up into three pieces. The nugget was happened upon on February 5, 1869 at Moliagul, Victoria, Australia.

...

While the total amount of moon rocks brought back to Earth by all the Apollo missions may be impressive when compared with Sputnik 1, they have a mass less than an average horse. The Yugo, a subcompact car from the former nation of Yugoslavia, is not quite twice the mass of an average horse.

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