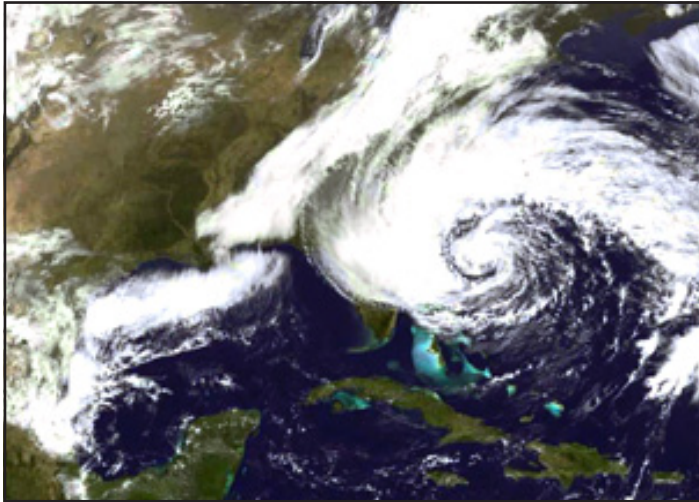




Superstorm Sandy

Sandy has been described as the 'storm of a lifetime' just as the Great Appalachian storm was in the 1950s. It was designated a superstorm not because of the strength of its winds (it began in life in Cuba as a category 3 hurricane on the Saffir-Simpson scale, but was downgraded to a category 2 tropical storm when it reached the Eastern Seaboard of the USA), but because of its extraordinary size (it spanned over 1800 km).

Figure 1 satellite image of Superstorm Sandy



It was also a superstorm in terms of its damage, second only to Hurricane Katrina (Figure 2) in terms of its economic impacts on the USA.

Figure 2. Source: National Hurricane Centre

Rank	Hurricane	Season	Damages
1	Katrina	2005	\$108 billion
2	Sandy	2012	\$75 billion
3	Ike	2008	\$29.5 billion
4	Andrew	1992	\$26.5 billion
5	Wilma	2005	\$20 billion
6	Ivan	2004	\$18.8 billion
7	Irene	2011	\$15.6 billion
8	Charley	2004	\$15.1 billion
9	Rita	2005	\$12 billion
10	Francis	2004	\$9.51 billion

Whilst the winds were both high and dangerous even more damaging was the associated storm surge of water pushed on to land ahead of storm. This flooded many kilometres of the East Coast of the USA Sandy was nicknamed 'Frankenstorm' as it ravaged the mid-Atlantic, North East and Ohio Valley regions (all very densely populated and industrialised) leaving a landscape of post-storm devastation.

Figure 3 shows a series of photos of this



Flooded New York



Snow damage in the Appalachians



Coastal destruction in New Jersey

Figure 4 profile of Sandy

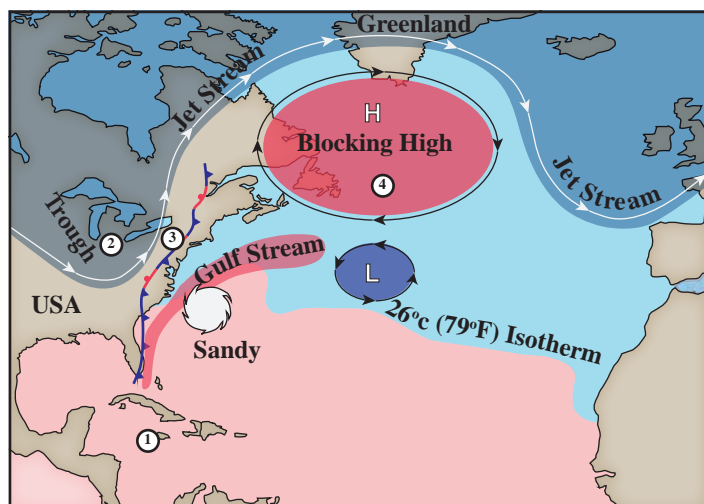
Hurricane Sandy near peak intensity on October 25 th 2012	
Formed	October 22 nd 2012
Dissipated	October 31 st 2012 (extratropical after October 29 th)
Highest winds	115mph (185 km/h) <i>1 minute sustained</i>
Lowest pressure	40 mbar (hPa); 27.76 inHg
Fatalities	147 direct, 138 indirect (285 total)
Damage	\$75 billion (2012 USD) (<i>Second costly hurricane in US history</i>)
Areas affected	Greater Antilles (Cuba), Bahamas, most of the eastern United States (especially the coastal mid-Atlantic states), Bermuda, eastern Canada

2012 was a very busy Atlantic hurricane season 'breeding' nineteen named storms of which Sandy was number eighteen. The preliminary estimate of damage across all the affected countries was \$75 billion, a total which has subsequently risen. What is remarkable is that the imprint of Sandy's damage can still be seen in the most devastated areas one year on. Largely because of huge legal battles over compensation claims and the concentration of devastation on the Jersey shore.

How Sandy formed

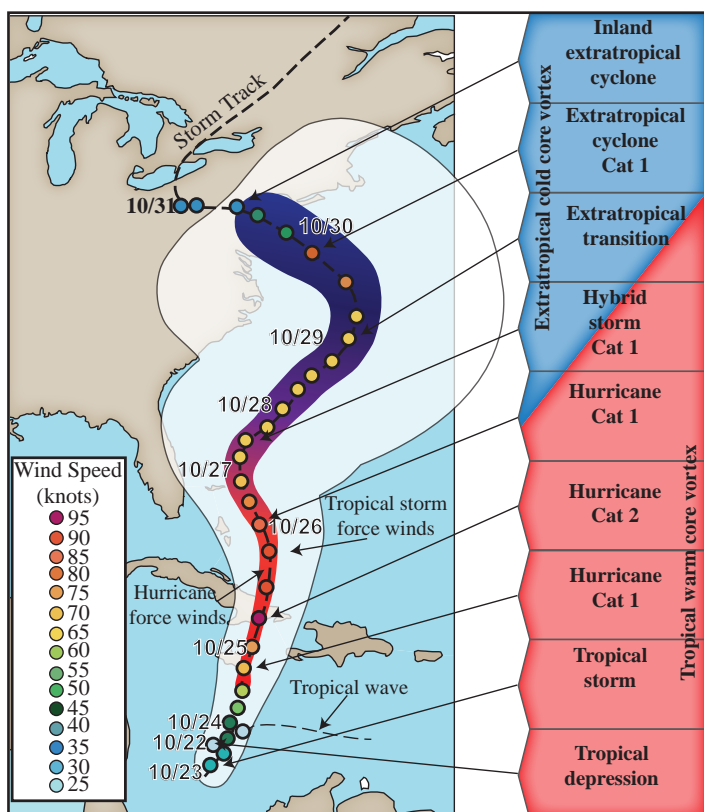
Sandy was described in 'Weather Wise' (April 2013 issue) as a 'freakish occurrence', a confluence of a tropical storm and the vortex of an extra tropical storm.

The storm began (in the classic hurricane belt) as an unusually intense late-season hurricane spawned in the warm tropical waters of the Caribbean south of Cuba ((1) on Figure 5). It rapidly intensified to Category 3 status as it made landfall in Cuba, a country well used to very damaging hurricanes.

Figure 5 Major atmospheric and oceanic elements

Whilst the frictional drag of the highlands of Cuba weakened Sandy to a category 1 storm, it began to grow in size to become the largest tropical cyclone in Atlantic basin history. Unusually for a hurricane Sandy developed a system of weak fronts (3). A large intense trough (2) in the Upper Air and its surface cold front contributed to Sandy's status as a hybrid storm (elements of a winter depression but with the destructive tropical core of a hurricane). A ridge of blocking high pressure (4) spreading south from Greenland and the jet stream trough (2) interacted to divert the path of Sandy towards the USA coastline (an area with 65 million inhabitants), so laying the foundation for an unusual hazard event to become a very costly disaster.

The 10 day life cycle of Superstorm Sandy

Figure 6 summary of the complex ten day life history of Superstorm Sandy.

<http://weatherwarfare.worldatwar.info/author/killemwithscience/#>

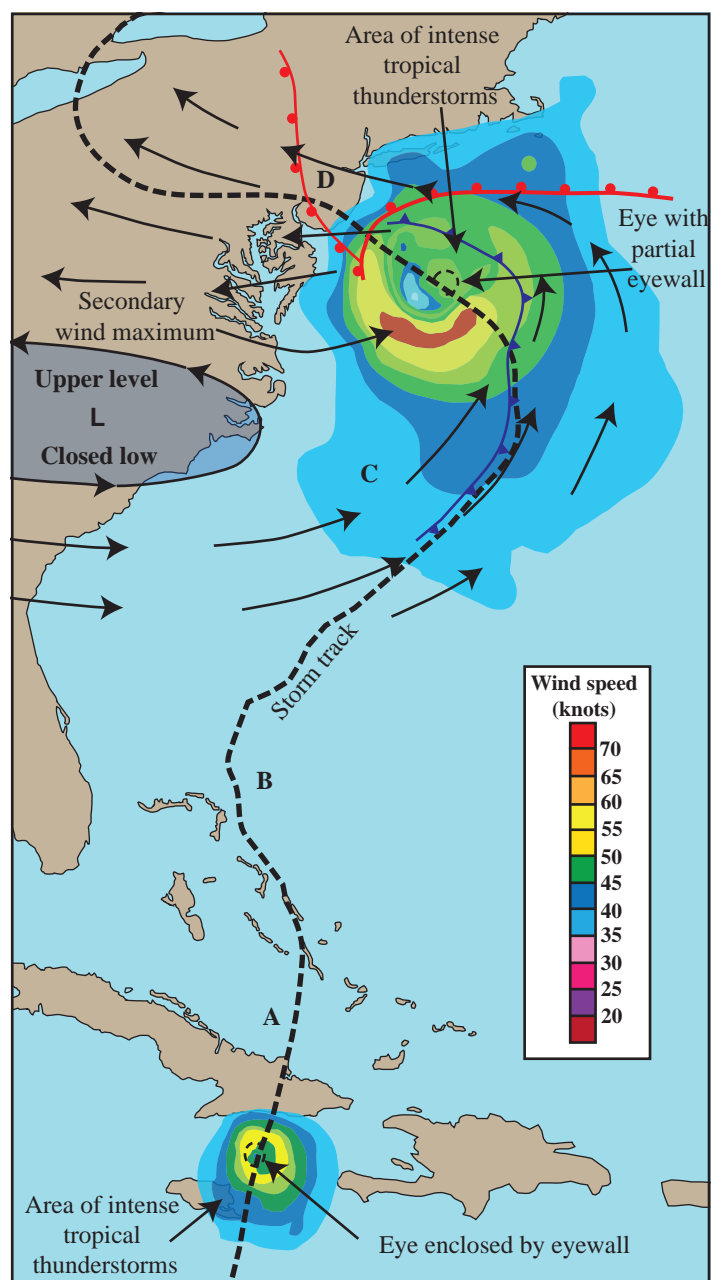
Note the following:-

- The curved track
- The variations in wind speed
- The broadening width of impact the transition from a classic hurricane (hot core) to an extra tropical storm (cold core).

As Figure 7 (table) shows, Sandy's ten day journey can be divided into four main phases:

- (A) Tropical phases
- (B) Transition to hybrid storm
- (C) Extra Tropical Transition
- (D) Inland Extra Tropical Cyclone

Note there were major structural differences between (A) and (D) in terms of areal coverage, intensity of surface winds, weather fronts, core temperature and pattern of wind vortex driven by contrasting upper flow features.

Figure 7 The Chronology of Superstorm Sandy

http://www.washingtonpost.com/blogs/capital-weather-gang/files/2013/10/sandy_composite.jpg

Phase	Date		Locational damage summary
A	22 nd Oct.	Incubation from a tropical easterly wave off Africa. Identified as a tropical depression in southern Caribbean	Widespread disruption of transport and utilities in Jamaica. Haiti badly affected by flooding and landslides. Sandy was the deadliest hurricane to hit Cuba since Hurricane Dennis 2005. Nine deaths from collapsed buildings and trees
	23 rd Oct.	Storm static, but continued to strengthen (very warm ocean, weak wind shear, huge quantities of moisture). Winds increase to 60mph	
	24 th Oct.	Sandy declared to be a hurricane. Winds 74mph. Sandy reaches Jamaica	
	25 th Oct.	Landfall on S. Cuban coast. Winds 105mph. Category 3 status – falls to Category 1 when leaving Cuba	
B	26 th Oct.	Sandy finds new energy source – a trough of low pressure → hybrid storm.	Some damage in the Bahamas Damage as far east as Bermuda – high winds and heavy rains. Minor damage only in Florida
	27 th Oct.	Sandy becomes an extra tropical cyclone. Winds 75mph	
	28 th Oct.	Sandy grows in size and heads towards the eastern coast of USA driven by its position between a strong trough and a blocking ridge of high pressure	
C	29 th Oct.	Storm invaded by more cold area from west. Created a system of weather fronts. Sandy moved over Gulf Stream, gathering strength.	State of emergency in Carolinas Major disaster in Virginia
D	30 th Oct.	New eye developed. Winds increased to 90mph. Makes landfall off New Jersey	Major impacts in Mid Atlantic. Huge damage from storm surges which led to flooding especially in Atlantic City and New York. Widespread disruption of subway, power outages.
		Super storm of huge size moves into New York area	West Virginia and Pennsylvania experience snow blizzards Wind gusts up to 70 mph Remnants of Sandy lead to high winds in Great Lakes.
		Storm moves inland. Course due westward to Ohio, Pennsylvania	
		Storm declines and turns north across Lake Erie	

Why was Sandy so damaging?

Superstorm Sandy revealed a plethora of destructive weather, spread across a huge area of Eastern USA. The precise type and intensity of the weather depended not only on the geographical location, but also on the distance from the storm core (centre) and which side of the storm track the area was located.

- Distribution of peak wind gusts, the highest occurring at over 90mph along the New Jersey shore and New York City. These areas were nearest to the storm centre at landfall and also to the right (seawards) of its track – not slowed by the frictional drag of the relief of the land.
- The height of the storm surge is closely linked to the wind field. Peak storm surge was up to 3 metres, amplified by spring tides to 4.5 metres. There was even a raised pattern in the Great Lakes which did considerable damage to cities such as Cleveland, Ohio.
- Total precipitation was concentrated around the vortex – often up to 20 cm over two days. There was very different distribution for snowfall whose effects were concentrated in West Virginia where over 1m of very wet, heavy snow fell causing huge damage and disruption.
- There was a huge variation in temperature across the region. The configuration of Sandy meant that the coldest air came from the south west and the warm air arrived from the northeast so causing the marked anomalies.
- To conclude, Sandy caused huge disruption - 20,000 airline flights cancelled over the period October 27th-November 1st, 8.6 million power outages. Only 125 people died but nearly 600,000 businesses and homes were destroyed.

Some issues to think about

- Overall, the predictions concerning Sandy's track and intensity were sound as a result of satellite surveillance but will they be so reliable in the future as equipment ages?
- Many discussions occurred as to whether global warming could be the cause for the superstorm. The evidence here is both complex and conflicting.
- Whilst global warming was not a direct trigger, there had been a marked rise in ocean temperature and this can impact on both frequency and intensity of hurricane formation. Warmer oceans increase the atmospheric carrying capacity of water vapour leading to heavier rainfall.
- Sandy derived a large part of its total energy from the mid-Atlantic jet stream and the jet stream is sustained by the size of the temperature gradient between the equator and the Poles.
- However, prior to Sandy there have been other superstorms such as the 1950 Great Appalachian Storm – but this formed in a period of global cooling.
- One year after Superstorm Sandy, the UK and Western Europe had its own superstorm, Jude, again driven and stoked by a very strong jet stream.

Further Reading and Research

www.weatherwise.org Article on Super Sandy March-April 2013. www.nasa.gov/missionpages/hurricanes/archives/2012 for satellite images

www.nha.noaa.gov/archive 2012 This is the US National Hurricane Centre with full details on Sandy

www.fema.gov/blog for full details of preparation/responses. www.bloomberg.com discussion on damage and possible link to global warming

www.weather.com/weather/hurricane/central/storms/2012/SANDY Detail from this weather channel. <http://www.youtube.com/watch?v=91ldZZiOq>

Acknowledgements: This Geo Factsheet was researched and written by Sue Warn, a well known author