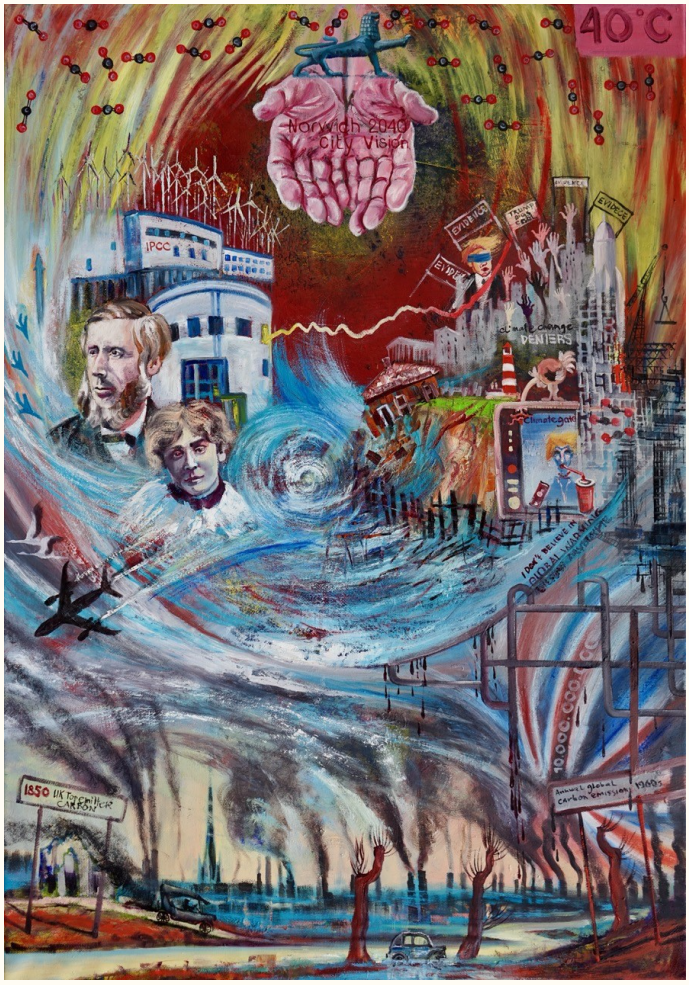
A climate mural for our times

The Stories behind the Painted Scenes



Many of the impacts of climate depicted in the Climate Mural For Our Times, and the free-standing paintings which elaborate on these stories, are based on the information in this account. It is hoped that it will help the viewers of the mural and associated paintings understand the details which are portrayed and, at the same time, aid their understanding of the visual art.

*Elements mentioned here that are depicted in the mural are highlighted in **gold**; those depicted in the elements paintings are highlighted in **blue**.*

The Touches of Climates; Distant, Recent, Now and the Future

Humanity has depended on resources bequeathed by past climates. Building materials are hewn from rock deposited many millions of years ago, or scooped from more recent glacial debris. Soils are related to geological processes. Fossil fuel laid down hundreds of millions of years ago provided an astonishing, if ultimately unsustainable, bounty for many societies.

Human societies developed in relatively recent climates, growing particularly in the benign climates since the Ice Ages. But even in these relatively equable times, even relatively modest climate changes posed threats, as well as presenting opportunities.

We have been, in some part, products of climate and its changes. But, in the blink of an eye – on the geological timescale - we have over-exploited the Earth's resources. Now we find that, rather than climatic conditions fashioning us though rhythyms which are primarily natural, we are corrupting the atmosphere, altering the planet's surface, and pushing our climate into states which will threaten us.

The threats are driven, in particular, by carbon dioxide emitted into the atmosphere from the burning of fossil fuel. Over the next 200 years we may see atmospheric carbon dioxide levels not seen for tens of millions of years. In turn, global temperatures could also rise to levels not seen for a similar period.

If temperatures do rise to such levels, the associated extremes of weather will pose unprecedented threats to humanity. If we act decisively we could still avoid the very worst. There is much talk about climate "tipping points". We must look for one in our own behaviour.

The Times Depicted in the Mural

The mural is formed of six panels (a sextych) joined to span the period from 66 million years ago to the present day, and then forward to 2200. It was 66 million years ago when the **Chicxulub Asteroid** collided with Earth, marking the end of the Cretaceous geological period, and wiping out most of the dinosaurs.

The telling, in art, of the history of climate change and its impacts on our part of the world is told against the background of the Norfolk coastline providing a horizon. Above this, the **sky** is portrayed in hues which represent the temperature of the times, inspired by the **Climate Stripes** made popular by Professor Ed Hawkins (University of Reading).

The panels vary in time-scale to accommodate geological and human time-scales, and the increasing resolution of climatic and human history as we move forward in time.

If we imagine the whole length of the **Norfolk coastline** (around 145 km) to be the distance equivalent of the period 66 million years ago to 2200, the first panel (66 million years ago to 3 million years ago) would represent the whole coastline except for around 7km (the distance between Sheringham and Cromer), which is the distance equivalence of the second panel (3 million years ago to 500). The year 500 was the approximate date of the founding of the settlement which became Norwich. The third panel (501 to 1400) would be a little longer than the length of an average bicycle. The fourth panel (1401 to 1850) would be as wide as a typical television screen (43-inch diagonal); and the fifth panel (1851 to present) and sixth panel (present to 2200) would both be not much wider than a typical laptop.

Impacts of Climate Variations on Norfolk and its Settlers and Citizens

There are “cues” in the mural, which offer links to **free-standing (easel-sized) paintings** which elaborate on, and expand, the stories which are shown in mural panels. The free-standing works are called Elements Paintings. Not all cues and elements are described in detail here. The mural, and the companion Elements Paintings, are intended to invite close scrutiny, to raise questions, to provoke imaginations, and to spark interpretations in the minds of the viewer. It is hoped that the mural will continue to provide cues for thoughts and ideas about climate change. Some may remain in the mind; some may transform into actions; other may be turned into further Elements Paintings.

There is one panel which does not yet have a linked easel-sized Elements Painting. It is a blank canvas. It has still to be painted. It is the Elements Painting for the future; from the present to 2200. It is intended that this painting, or several versions of the painting, will be co-produced with community groupings (schools, colleges, businesses, and so on). It is people in our community who will have the imagination, the ideas, the enthusiasm to visualise what our future could be; what technologies we might adopt and develop, how we should *do* things. Our future demands our buy-in. It should not be left only to politicians or scientists.

It is hoped that the viewer will look at the mural long enough to, for example, notice the **skull of the earliest known hominid** in the cliffs of the 66 million years to 3 million years ago panel, or wonder why **Neptune** is holding an upward-pointing trident in one hand and a downward-pointing trident in the other.

Some cues are more obvious than others, and so are their explanations. The significance of the face which we now commonly attribute to **Frankenstein** in the cliffs, and his association (through the author Mary Shelley) to the 1816 "year with no summer" in the 1401-1850 panel is well known to many. Shelley wrote her novel in this cold and dismal year, which followed the enormous eruption of the **volcano Tambora in 1815**. The resulting shroud of volcanic dust worsened the already disastrous effects of the Little Ice Age climate. Shelley's story matched her mood.

Lord Byron, who was with Shelley at this time, composed his own reaction in *Darkness*:

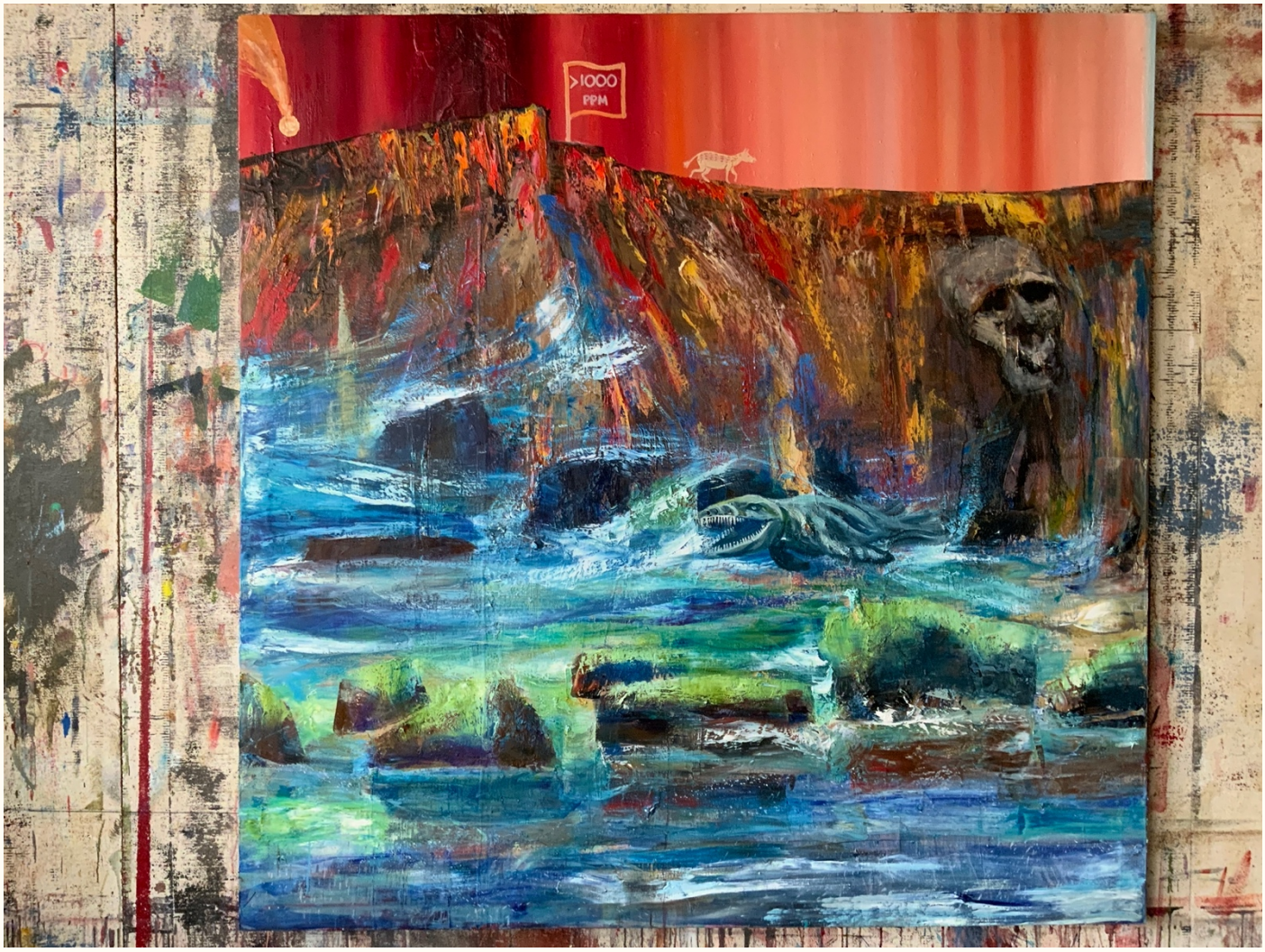
> *I had a dream, which was not all a dream*
> *The bright sun was extinguish'd, and the stars*
> *Did wander darkling in the eternal space*
> *Rayless, and pathless, and the icy earth*
> *Swung blind and blackening in the moonless air.*

He went on to write about famines, and huddling around fires.

Less obvious to see, and perhaps harder to assign significance to, is the shape of the turnip in the same panel. The Elements Painting linked to this panel shows the face of Norfolk's own **"Turnip" Townshend**, who was at the forefront of an agricultural revolution without which Norfolk, and the country, would have suffered even more disastrously in the Little Ice Age.

The impacts of other climate-related extreme events on society are less clear. They interacted with other factors: social, economic and political changes; or disease. Sometimes they exacerbated or amplified other stresses; or they set the pre-conditions for social change, sometimes decades or even centuries before. Writers such as Parker, Behringer and Fagan (see references) pick out these intricate and often little-understood feedback loops. For example, Fagan (page 150) argues that links such as these "connected the diverse strands of the new agricultural economy, the deteriorating climate at the height of the Little Ice Age, and the economic and social conditions that pre-adapted Britain for the **Industrial Revolution**".

Whether obvious and direct, or less perceptible and indirect, climate change – and the weather events associated with it – have helped fashion human activity over very many millennia in Norfolk. It will continue to do so.



Panel 1: 66 million years ago to 3 million years ago

For many millions of years, up to the date of the start of the mural, the thick layers of chalk which underlie Norfolk had been forming from the deposition of marine calcium carbonate microfossils. Sea-level was much higher than today's. The Poles were ice-free because the Earth was in a super-greenhouse climatic phase, much warmer and more humid than the present.

These thick layers of **chalk bedrock** contribute to the current character of our local region. **Chalk streams** are an important ecological habitat: there are only 210 in the entire world of which 160 are in England and many of these are in Norfolk. The biggest and most important is the **River Wensum** – the "most protected river in Europe". So the character of the river which so attracted the early founders of Norwich is governed by climate conditions prevailing at the time of the **dinosaurs**. Since that time, climate has varied enormously, also influencing the nature of our landscape home. Again using the chalk streams as an example, their distinctive gravel beds were created by the huge flows of meltwaters at the end of subsequent Ice Ages.

This climate tens of millions of years ago also touched the early peoples of Norfolk. The chalk contains flints, which were mined at Grimes Graves 5000 years ago – for axes, arrowheads, and other tools. This was one of the very early industries, and important on a European scale.

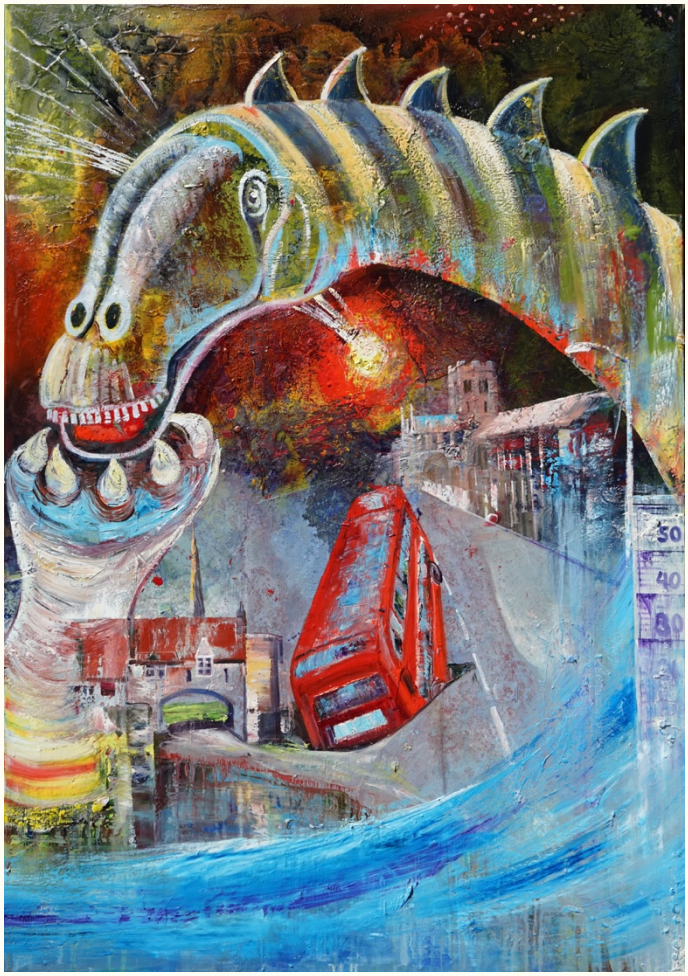
This legacy from a super-greenhouse climate also provides an ideal habitat for the Cromer Crab and the Sheringham Lobster.The Cromer Chalk "Reef", stretching between Happisburgh and Weybourne is the

longest in Europe and is now a Marine Conservation Zone. It formed around 7000 years ago from marine erosion when the southern North Sea flooded again following the end of the last Ice Age.

The chalk which underlies Norwich was mined for building materials, and the collapse of the old tunnels/mines are responsible for the appearance of many sinkholes in the city, the most famous being the one at the top end of Earlham Road which partially swallowed a **double-decker bus** in 1988.

It was before the date of the start of the mural that the bulk of the world's fossil fuel deposits were laid down, over tens of millions of years. We have been extracting and burning these deposits for only a few hundred years. If we carry on as we have been, we will have returned much of the carbon deposited in known fossil fuel reserves back to the atmosphere by around 2200.

The Cretaceous period came to an end when the **Chicxulub Asteroid** collided with Earth – the start of the mural - causing the demise of the vast majority of dinosaurs and many other species. It, together with large volcanic eruptions around the same time, also contributed to a marked change in the Earth's climate.



But some dinosaurs did survive; bird-type and **crocodile type creatures**. No dinosaur fossils have been found in Norfolk because, at that time, the area which is now Norfolk was beneath a shallow sea. However, **Dippy was a celebrated visitor to Norwich in 2021** and is keen on providing his perspective on the world he sees the descendants of dinosaur survivors inhabiting. A world rapidly changing because of human activity. He sees a car-crash, or rather (because dinosaurs think big), a **bus-crash**.

Some small mammals (e.g. rat-like mammals) survived the asteroid. The Eocene period (56-34 million years ago) was when mammals flourished. Eocene means "dawn" (of the mammals); one such was **eohippus** – ancestor of the horse, which gave us a unit (horsepower) for how fast energy is exchanged.

During the period of this panel there were no icecaps. This means **sea level would have been 70m higher than today**; it would have come close to topping today's **Norwich Cathedral**.

The first hominid, Sahelanthropus tchadensis, appeared 6-7 million years ago (in Kenya). His, or her, **skull** is incorporated into the cliff.

Throughout much of the period of this first panel **global temperatures were 8-12°C above today's** and **carbon dioxide levels were around 1000 ppm**, more than twice as high as today's.

As the mural moves forwards through the geological ages, from the Eocene through the Oligocene, the Miocene and into the Pliocene (5.3-2.6 million years ago), the **carbon dioxide levels slowly fell and the Earth's climate cooled**.

Panel 2: 3 million years ago to 500 CE

This panel stretches from a period where conditions were significantly cooler than before, through the grand cycle of Ice Ages to the approximate date of the founding of Norwich.

It was around 2.4 million years ago that there was the pronounced transition from a relatively temperate climate, when there was **mixed oak forest in Norfolk**, to much colder conditions. The Norwich Crag shelly gravels which are exposed at Bramerton Woods End, near Norwich, contain rich fossil deposits of otter, vole, gomphothere (an elephant-like animal), as well as marine fish and **shells** – one such find shown in the mural – showing that sea-level was still higher than today's.

Then, during the cycle of Ice Ages, sea-level fluctuated by around 120m in cycles with period of 41,000 and 100,000 years, with vast amounts of water being locked up in ice sheets during glacial periods and released during the melting in the temperate inter-glacial periods. **Neptune** is pointing one trident upwards, and the other downwards.

The initiating cause of the cycle of Ice Ages was now well-known variations in the Earth's orbit. But they were amplified by feedback processes, which led to large fluctuations in the atmospheric concentrations of greenhouse gases, including carbon dioxide. To represent this, in the sky in the panel, **the orbital variations are combined with the linear molecular structure of carbon doxide** - a carbon atom joined by double bonds to two oxygen atoms.

During one of the Ice Ages – the Anglian – around 450,000 years ago, Norfolk was under a thick layer of ice which extended down to what is now Essex. Evidence of this Ice Age is still apparent in Norfolk; one example being the **chalk raft in the cliffs at Sidestrand**, where once practically horizontal chalk bedrock, around 70 millions years old, was buckled and bulldozed by the ice.

One of our hominid ancestors – Homo antecessor – may have lived in Norfolk around a million years ago. The **oldest-known hominid footprints outside Africa** were discovered on Happisburgh Beach in 2013. They were 800-900,000 years old, and were found in a newly exposed sediment layer of the Cromer Forest Bed which had been exposed by a storm. They lasted just a short two weeks but were recorded using 3D photography before being washed away by the tides.

This remarkable snapshot into our far pre-history chimes with our own short period – yet to be determined by us – on Earth. Like the exposed footprints, we are transient, but we have a choice over to what extent.

The famous **West Runton mammoth** is 650-720,000 years old. **Flint tools**, including the oldest hand axes found in northwest Europe from maybe 6-700,000 years ago, have also been revealed through erosion. Particularly good examples have been found on Happisburgh beach, and would have been used by our ancestors to **hunt mammoths**, as well as other animals.

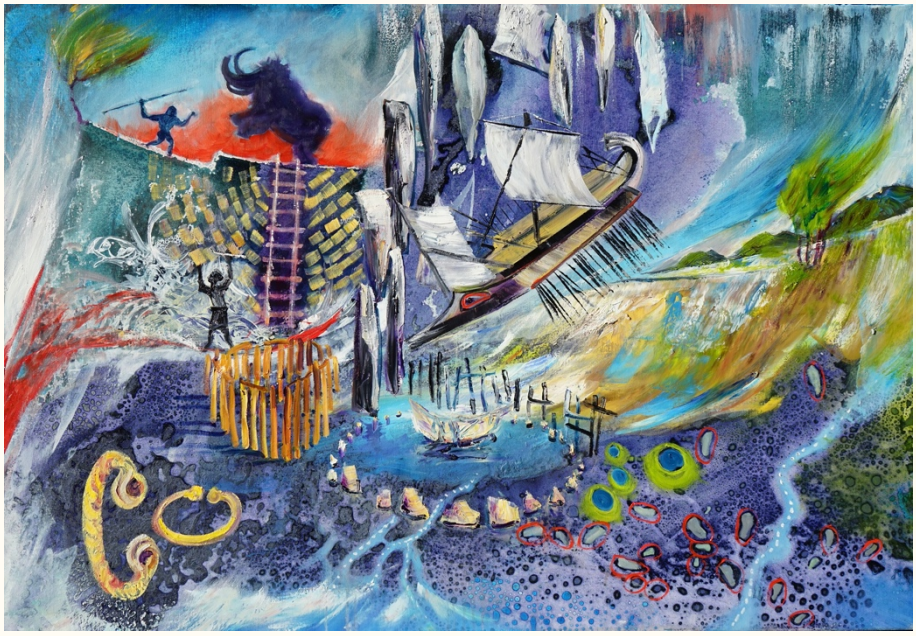
The last Ice Age finished about 12,000 years ago, and as the ice started to retreat it had left behind tundra and permafrost in Norfolk – conditions similar to present-day northern Canada. Breckland was dotted with **pingoes** (pingo is the Inuit word for hill) which formed about 20,000 years ago through pressure causing a lens of ice to push the ground up into a mound. When the ice melted, the mound collapsed leaving a pond. Around 400 of these pingo ponds exist today in Norfolk (mainly in Breckland) – the largest density in the UK.

Even though ice did not cover Norfolk during the more recent Ice Age, it did leave immense amounts of debris. The Cromer Ridge, the location of which had been at the edge of the retreating ice sheet for a long time, is a depositional feature. Meltwater distributed and deposited gravels, sands and clays over much of Norfolk, as had earlier retreating ice sheets, whilst also carving out our modern day river valleys. This deposited material has not been compressed and consolidated by the weight of other deposits above them, and so are “soft” and very prone to erosion; hence the problem of **coastal erosion**.

One of the reasons that Norfolk is such an important agricultural county is because of the rich clay soils developing on the glacial deposits, as well as the sandy sandy soils and gravels of Breckland. Glacial clays (**Norwich brickearth**) from Mousehold was used to make bricks, still visible in the oldest city walls.

Because of the lower sea-level in an icy world, there was still a land connection between Norfolk and the rest of Europe as recently as 12,000 years ago.

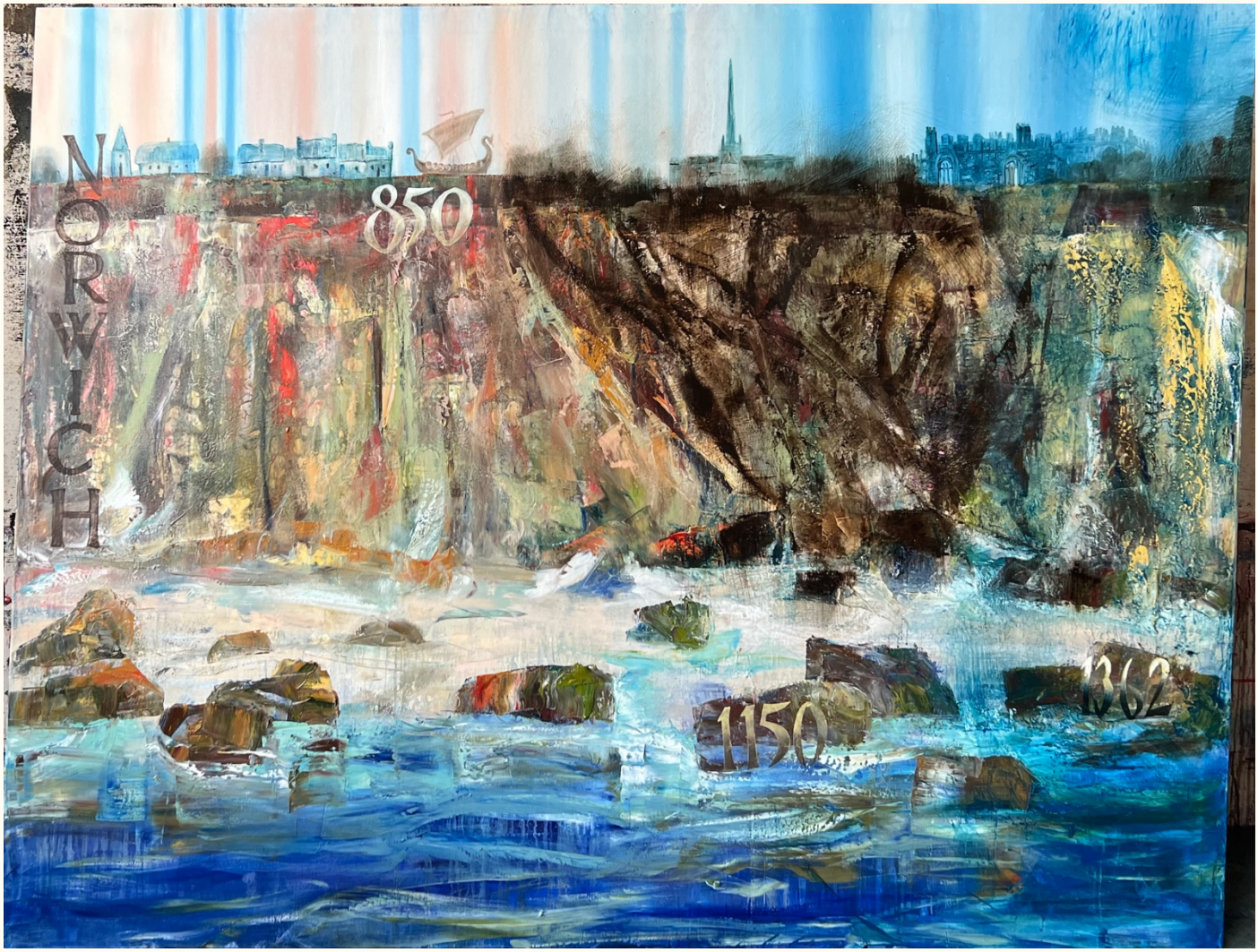
As climatic conditions slowly improved, humans began to develelop more community organisation. **Flints** from the underlying chalk were mined at **Grimes Grave** around 5,000 years ago, in what some have described as the first “industry” in Europe. **Tools and weapons fashioned from Norfolk flints** have been found around Europe.



Fantastical monuments were built. **Seahenge**, exposed by erosion on Holme Beach, was constructed around 4,000 years ago. It consists of a turned oak tree in a **circle of timbers**. At around the same time the Norwich (Arminghall) **woodhenge** was built. In some respects it was as important as Stonehenge. There is barely a trace of it now; the main circle lies beneath two high voltage pylons and there is a very large electicity sub-station covering some of the smaller circles and burial chambers. It is overlooked by an enormous solar energy farm. Perhaps a metaphor for our generation of energy (some of it very progressive) – subsuming so much of our human heritage – risking subsuming our future.

Circles continued to be a feature of the increasingly refined human activity in Norfolk. The **Iceni gold jewellery** of the Snettisham Treasures was fashioned about 2,100 years ago.

At this time, the site of present day Norwich was near the head of an estuary – so sea-level was much higher than when first the **hominid footprints** were found at Happisburgh. This was probably important for the Iceni Tribe who were the local people before the **Roman invasion**. There was a substantial Iceni settlement near Caistor St Edmund, and this location was certainly important for the Romans who built a large garrison after battling with Boudicca, the warrior queen of the Iceni. The Romans had an important wharf at Whitlingham, on the outskirts of Norwich.



Panel 3: 501 CE to 1400 CE

The Anglo-Saxons established **Northwic**, on the banks of the River Wensum, in the area which is now the centre of Norwich. It was constructed mainly of timber. **Cross-sections of trees**, revealing tree-rings, are an important source of scientific information about climate from this period.

Over the next centuries, Norwich grew to become a very significant settlement, eventually accommodating – despite a few skirmishes – the incursions of **Vikings** (Danes). There are many examples in Norwich of **Viking activity**. One is on the **west doorway of St Laurence's Church** in St Benedicts Street, which shows a carving of the **martyrdom of St Edmund**, King of the East Angles; he is tied to a tree, shot full of arrows. His **head was cut off** afterwards and, when found by his followers, it was protected by a wolf.

Many Vikings had settled permanently in Norwich by about 880. Their expansion into Norfolk, and other parts of Britain, had been facilitated by a period of relatively stable and mild climate popularly known as the **Medieval Warm Period** (MWP), which lasted from about 575 to around 1100 in this region, with its warmest portion being around 750 to 790.

By around 1000 Norwich had become one of the important settlements in the kingdom. The **market**, then on Tombland, was thriving with local produce/products, also furs from Scandinavia and Russia, woollen cloth from Flanders, and North Sea herring. The building of the **Norman castle**, replacing a wooden structure, started in 1067. The booming market moved to its current site, in front of the City Hall, about

1080. The building of **Norwich Cathedral** started around 1096. This was a heyday of English cathedral building, when the country enjoyed a relatively favourable climate.

The climate started to deteriorate rapidly in the early 1100s, the start of the decline into the **Little Ice Age** but still with some short relatively mild periods. Perhaps Norwich Cathedral would never have been started if the climate had been like this when the first foundation stones were laid, but it was finished around 1145; then the largest building in East Anglia.

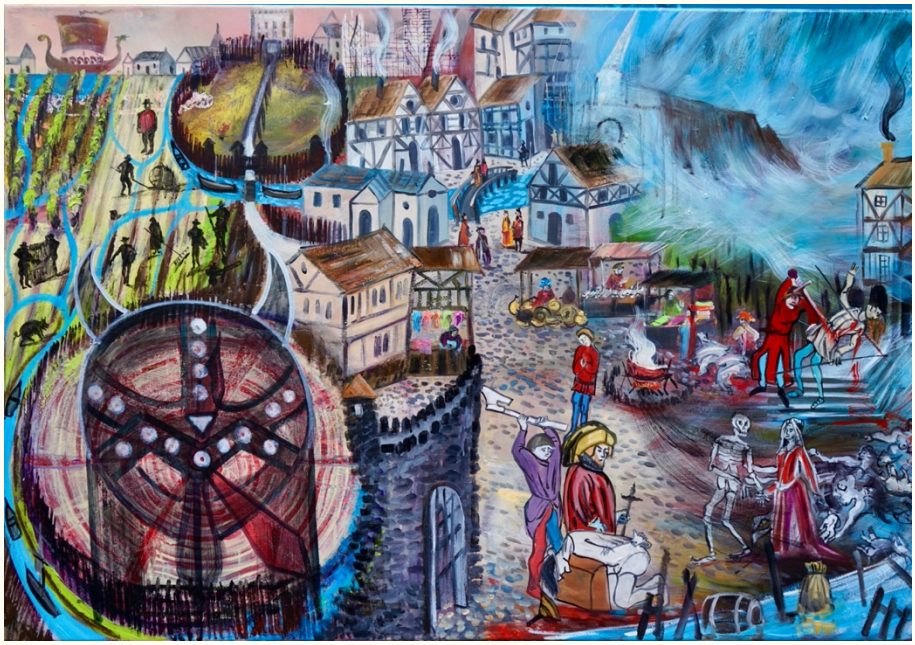
Even during the period of declining climate Norwich continued to grow, becoming the largest walled town in medieval England. The main **wall-building** activity occurred in a 50-year period from about 1290, perhaps reflecting the insecurity of the times. The walls, of course, were constructed of flint stones, as were so many of Norwich's significant buildings – yielded from the underlying chalk deposited during a distant, far different, climate.

One of the most distinctive present-day features of Norfolk started in the 1100's; by the 1300s it had taken a form that would be recognisable today. **Digging for peat** in eastern Norfolk started in the 1100s and continued for 200 years. The peat was burned for fuel. Peat extraction from what we now call **The Broads** was, possibly, the first significant extraction of 'fossil' fuel in Britain. It pre-dated the widespread use of coal in UK. By the 1200s there were records of sea-coal being traded in England and Scotland, and by the end of the 1200s many of the UK coalfields were being worked on a small scale.

Peat extraction from the Broads was an enormous industry for Medieval times. Around 25 million cubic metres were extracted and burned. That would have meant about 3.4 million tonnes of carbon dioxide emitted into the atmosphere (making reasonable assumptions based on data commissioned by the Broads Authority; see references). It seems an enormous amount but represents only about 75% of the annual emission of the population of present-day Norfolk.

The enormous pits left from the extraction of peat filled with water and were abandoned in the 1300s, forming many of the lakes of the **Norfolk Broads**. The flooding was a consequence of gradually rising sea-level (from continuing melting of global ice) and a process called isostatic rebound, which is causing the south and east of England to subside and northern Britain to rise, as a continuing adjustment to the north being relieved of the weight of greater thicknesses of ice during the Ice Ages. The **flooding** was also a result of an increasing frequency of storms, leading to occasional incursions from the North Sea (the **sea broke through Waxham Gap** in 1287), and torrential rainfall.

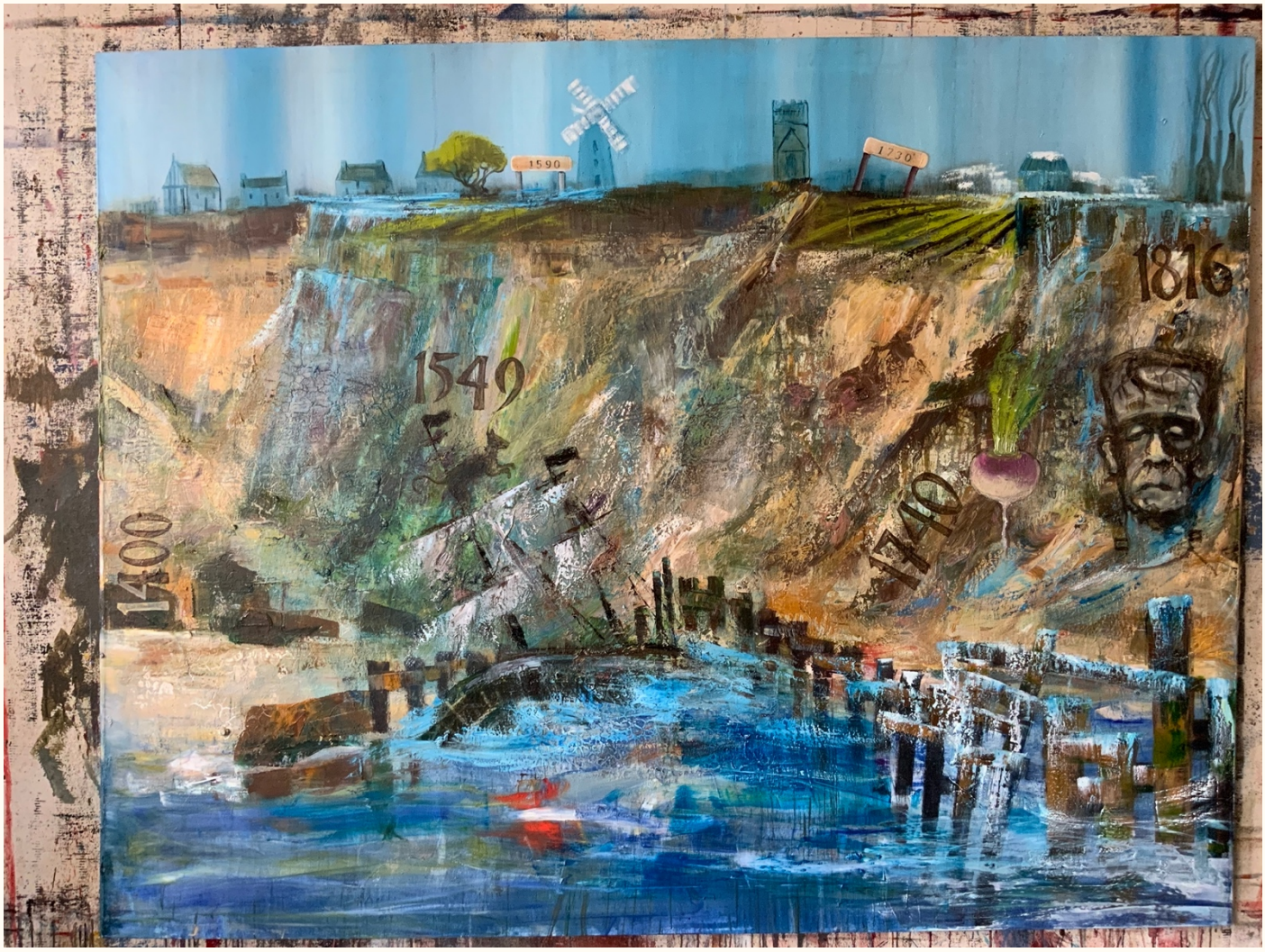
The growing inclemency of the climate started to have a big impact on people's lives, often exacerbating other social and economic factors. The year 1316 produced the "Great Famine", when Norfolk's richer farmers bought out their poorer neigbours. There was a **"Great Dying of Beasts"** in the bitterly cold winter of 1317/18. This was followed by a very wet summer which impacted harvests. Such weather continued into the 1320s, and people became desperate – illustrated by an upsurge in **grave robbing** when jewellery and other items were stolen.



Catastrophe hit Norwich two decades later. Between 1346 and 1352, 40% of the population (then 6000) died of the **Black Death**. Historians have made the link between the scale of the impact of the disease and poor nourishment following a string of bad harvests, with some connecting the devastation to particulary inadequate harvests in a seven-year period around the 1316 Great Famine: childhood hunger creating a life-long susceptibility to disease.

The second half of the 1300s and the beginning of the 1400s saw many **great storms**, with many thousands of people dying on the coastlines of the North Sea. A notable storm hit Norwich in January 1362, collapsing church towers, and even the spire of Norwich Cathedral (which was then wooden). There was also further damage to the important coastal town of Dunwich in Suffolk which had taken batterings from storms earlier in the century, and would continue to do so throughout the Little Ice Age until it was effectively completely destroyed in the 1700s.

What turned out to be the last major event of the **English Peasants Revolt** occurred as the **Battle of North Walsham in 1381**, when a large group of rebelling peasants fought the heavily-armed forces of the Bishop of Norwich. The rebels had previously taken Norwich and Yarmouth. The Peasants Revolt had various causes, included tensions caused by famines, the Black Death, and the trigger of an attempt to collect poll taxes in Essex: an example of how stresses produced by climate change interact with social and political disruptions.



Panel 4: 1401 CE to 1850 CE

The most severe conditions (low temperature, storms) of the **Little Ice Age** occurred in the late 1400s, from about 1580 to about 1715, and the first half of 1800s. Very bad conditions have been associated with a period of low sunspot activity (known as the Maunder Minimum, 1645-1715; sunpsots were particularly rare 1672-1699). Low sunspot numbers are associated with a decline in energy emitted from the Sun. Sightings of the Aurora Borealis became rare. Another factor in the initiation and persistence of the very poor climate conditions were large **volcanic eruptions**; there were particularly large eruptions in 1257, 1458, 1600, 1640, 1809, 1815, and 1883.

Ice fairs on frozen rivers and lakes became common from the 1300s onwards, when the tradition of **skating on the frozen fens** began

Norfolk has around 200 **"lost villages"**, which had been thriving in medieval times and abandoned since then – mainly in the 1600s, 1700s and 1800s. There were a number of reasons – including the enclosure of common land and disease – but deteriorating climate played a part.

Vineyards, which had flourished in England in the Medieval Warm Period, had mostly died out by the 1440s, although a vineyard at Ely persisted until 1469.

The extreme cold was a subject in one of the famous Paston letters; this time from John Paston who remarked on the cold weather in September 1465 when requesting Margaret Paston to send him some cloth from Worstead.

It wasn't unremittingly bad weather. In the 1520s there were five **exceptionally good harvests, but followed by cold and very poor harvests** in 1527-29. In the Mayor of Norwich's Register in 1527 is the entry "there was so great scarceness of corne that about Christmas the commons of the cyttye were ready to rise upon the ryche men". This is a common theme of historical accounts from this period onwards – that climate change may not have been the single cause of an event, or series of events, but that it was often a contributory (sometimes the critical) factor working with others, such as economic, social and political change.

One such example was **Kett's Rebellion in 1549**. Kett held a famous meeting at **Kett's Oak**, which still stands by the side of the road between Norwich and Wymondham. He was **hung from the walls of Norwich**. There were a number of factors contributing to the rebellion: common land being enclosed; bad local government in Norfolk; and protestant demands. But a string of bad harvests was also a factor.

This rebellion divided the City of Norwich, and linked protestantism with the urban poor. This link was strengthened by the Dutch and Flemish "strangers" fleeing Catholicism and settling in Norwich. These strangers brought canaries to Norwich. Norwich was developing a tendency towards protestant radicalism, strengthened by the City becoming a hotbed of Lollardy.

Norwich became the first city to adopt a civic scheme of poor relief. There were social, political, and economic factors at play in shaping the special character of Norwich but bad harvests contributed to the particular cut of its cloth.

The second half of the 1500s saw famine upon famine, with food riots widespread across England in the 1590s. Scapegoats were sought; one of the many accusations against **witches** was that they caused bad weather. This persecution, overwhelmingly of women, reached a peak in England in the very severe weather years of 1587 and 1588. **Fye Bridge in Norwich was the location of a witches' ducking stool.** Another Norwich site of persecution of witches, especially in the 1600s, was the Lollards Pit; not only were "religious heretics" burned at the stake, but also witches. **Cats** were buried under the thresholds of many homes to repel witches.

The societal storms were matched by meterological storms. Some of these, undoubtedly, set the course of history. The **Spanish Armada was decimated by a storm in July 1588**, some of the wreckage being wreaked in the North Sea. The storm destroyed more Spanish ships than did the English Navy. A famous, recently-discovered, **wreck off the Norfolk coast** is HMS Gloucester. A survivor of that wreck in 1688 was future King James II (see later references to Norwich as the Jacobin City).

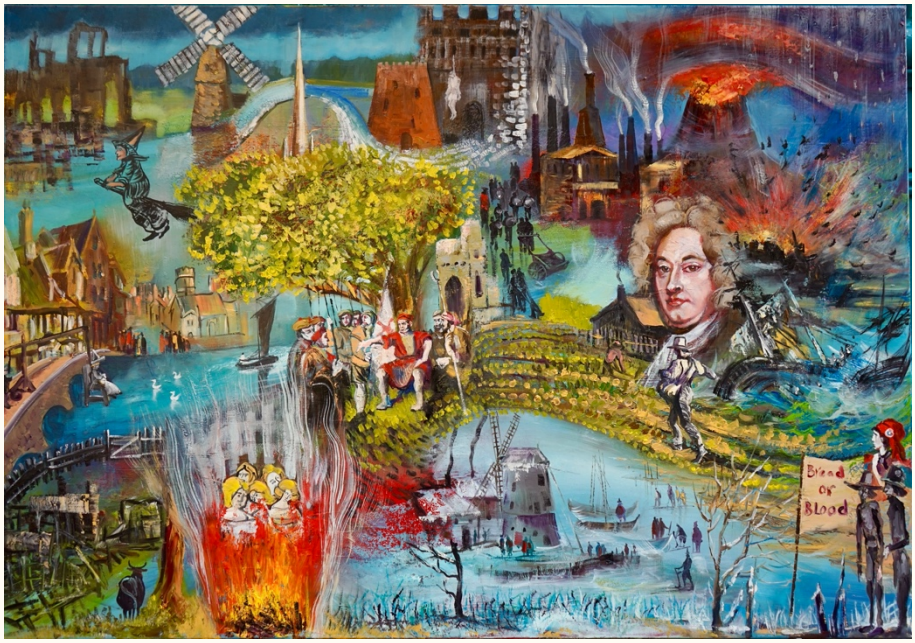
By the end of the 1500s, **windmills** were being built to drain the marshes of present-day Broadland of the flooding which had occurred over the previous 200-400 years. Reputedly, there was a greater density of **windmills in the Norfolk marshes** than anywhere in Europe.

The period just before the middle of the seventeenth century was a period of political instability across the country because of tension between Scotland and England, initiated by the Scottish Rebellion. This instability, which was amplified by disease and poor harvests, eventually led to the **Civil War** of 1642-1660 during which hundreds of thousands were killed. A dramatic episode in this war occurred in Norwich in 1648, known as the **Great Blow**, when ammunition exploded as Parliamentary forces tried to quell Royalist supporters, reputedly the biggest explosion seen in the country up to that point.

The weather was not to be outdone in its direct effect. In the same year as the Great Blow, Parliament banned maypoles, the celebration of Christmas, and actors and audiences of plays because they "provoked God's wrath and displeasure" (i.e. poor weather, bad harvests, disease).

The Catholic King James II of England was deposed in 1688 and replaced by his protestant daughter Mary II and William III, Prince of Orange. A change in wind direction enabled the invasion to take place. At the time, references to "Popish Winds" and "Protestant Winds" were common. This time became to be

known as the "Glorious Revolution". Norwich's response was not unified; it still had something of a split personality. It became known as the Jacobin City – long after it had ceased to be a significant movement in Scotland – and started to build its **reputation as a revolutionary city**.



Skipping forward in time, the Norwich Revolution Society was formed in 1788 to mark the centenary of the Glorious Revolution, but also in response to the French Revolution which was to become epitomised by the storming of the Bastille in 1789. Hunger was one of the factors in the French Revolution; a severe drought in 1788/9, combined with the harshest of harsh winters, was a trigger. The Society had 4000 members and delegates met at The Bluebell Inn (now The Bell). The **French liberty cap** was a symbol used by the Norwich Society. The Jacobin tendency within part of the City community undoubtedly contributed to Norwich's reputation of being politically more diverse than most other cities in the country, and more democratically governed than many other large boroughs. This shaped the City's political complexion in the following centuries.

The heydays of Norwich's textile industry (Norwich cloths were famous as "Norwich Stuffs") lasted from the 1650s to the 1740s. Perhaps it was just a coincidence that this was also a period when – for climatic reasons – the demand for warm clothing would have been high.

The impact of the poor weather would have been far worse had it not been for dramatic improvements in agricultural practices. In the 1650s papers began to be published on **new methods of tillage and crop rotations** – historians described this period as the **Agricultural Revolution**. In fact, the revolution had been a long time coming. Even during the Little Ice Age, there had been some relatively good summers. A run of these in the 1550s produced exceptional harvests, which led to **agricultural innovation** in the Low Countries, which eventually made its way over to Norfolk. In the 1660s **Dutch immigrants** introduced the cold-resistant **turnip** to England, which was planted in September, after the corn harvest, on what would otherwise be fallow ground. In 1661, the church warden at Hingham noted that "the want of hay was supplied by the growing of turnips". Such innovations improved the resilience of people, and their stock, to climate change, but there were still disasters caused by food shortages.

Another "great blow", but of very different character to the 1648 version, occurred in south Norfolk in October 1669. Formerly stable sand dunes (glacial deposits from the major ice ages) were shifted by a ferocious north-easterly gale. Several villages, including Santon Downham, were buried by sand several metres deep. Villagers built sand breaks behind which sand piled up 20m high. These sands had shifted a number of times, when the stability provided by overlying soil and vegetation was overcome, and cornfields were buried and rivers blocked, but this was the most dramatic recorded event. Much of Thetford Forest, which was planted in the 1920s, is on sand.Today, agriculture in this part of Norfolk often requires irrigation because the sands are free-draining.

Ice-skating, which had started more than 300 years earlier, became very fashionable in the early 1700s, although more variable climate later in the eighteenth century meant its popularity waned, before some

very harsh winters in the early 1800s brought it into vogue again. This fashionable trend took off first in the Fens and then on the Norfolk Broads.

By the 1730s Norfolk had commandeered the **Agricultural Revolution**, primarily through the figure of **Viscount (Turnip) Townshend**. His promotion of turnips, as part of the Norfolk four-course rotation system (turnips, barley, clover, wheat), provided winter feed for animals so peasants did not have to slaughter livestock in poor harvests. **Commercial farming** started to take hold in lighter soiled areas like Norfolk, with Norwich being a sufficiently large city to provide a market.

Although the agricultural revolution had increased resilience to the poor climate, it could not completely prevent its worst impacts. The period 1739-1742 was particularly cold, with a **Great Famine in 1740-41**. Across the country many tens of thousands of people died from hunger, exacerbated by disease which itself was worsened by malnutrition; moreover people huddling together for warmth increased infection rates. Norwich saw riots over the price of bread and fish in 1740. **Rural workers** became devastatingly poor through the 1700s, as common land continued to be lost through enclosures. By the end of the 1700s more and more rural poor were moving into urban areas, where they were one of the important fuels for industrialisation; the other being fossil hydrocarbons.

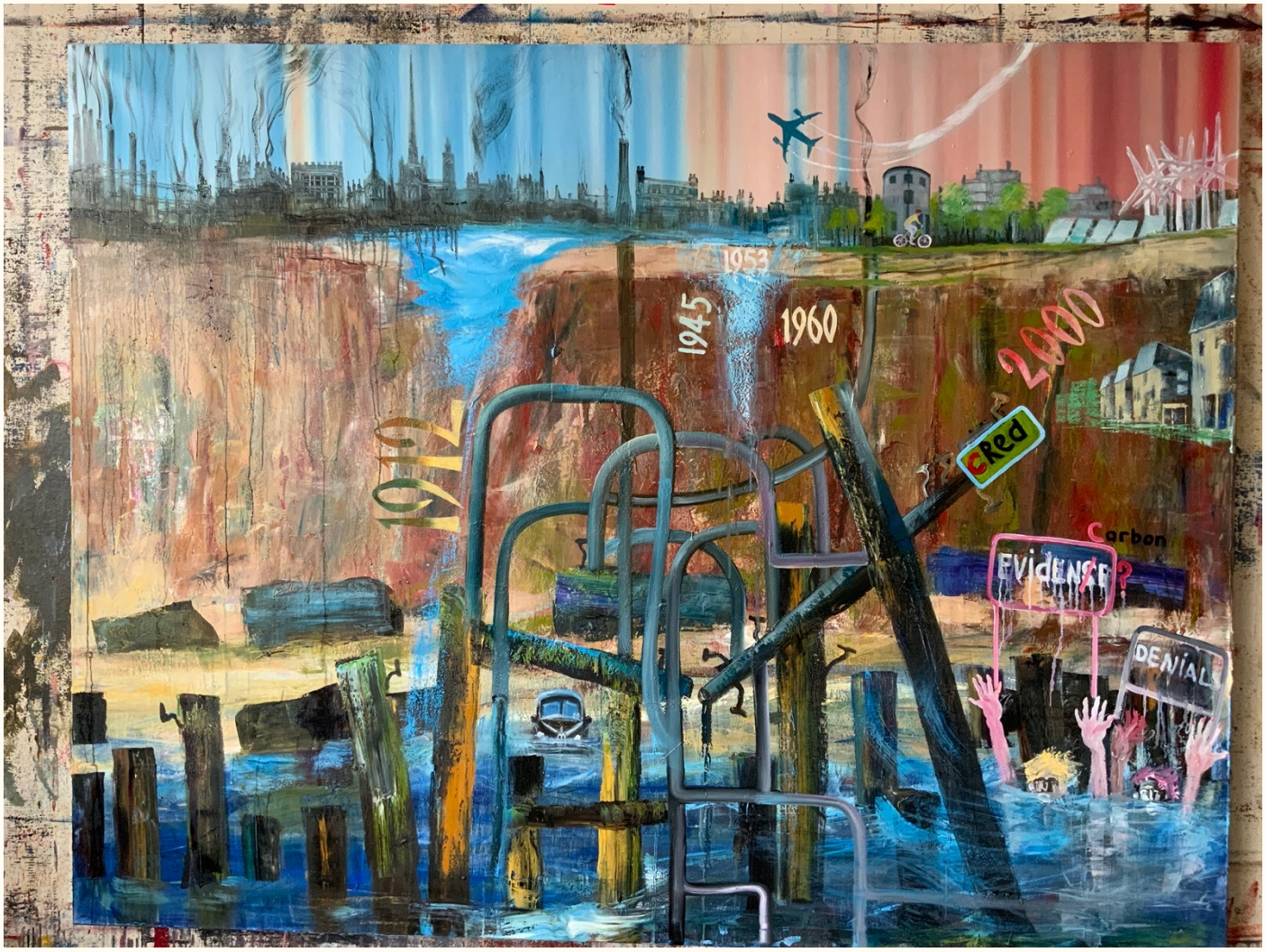
Had it not been for agricultural innovation the suffering in the 1700s would have been even worse. Other countries, such as France, suffered more, because of the absence of such innovation. Another factor was important for Britain. It had become part of an increasingly well-organised trade network, which included grain imports from the Baltic.

Despite the trials and tribulations of the climate, Norwich had a **rich cultural life** in the 1700s – it was the golden age of the cloth industry and a time of growing **urbanisation**. Norwich became the wealthiest town in England. It had published the first provincial newspaper in country at the beginning of century. It was regarded as a cultured and – with 75% of males able to read – a literate place. But the dead-hand of the poor climate was a persistent backdrop; there were more bread riots in 1766. Perhaps culture, climate, and deprivation were components of the catalytic mix encouraging an openness to radical and revolutionary thought.

The period 1805 to 1820 saw years which were amongst the coldest of the Little Ice Age. This was epitomised by the **"year without a summer" of 1816**, with heavy rain. Grain prices soared and the rioters across the country unfurled flags reading **"Bread or Blood"**.

Emigration – not, this time, from rural areas to city but from the British Isles to other countries – increased in the 1830s (although it was probably most popular 1870-1880). There were a number of factors, including the Napoleonic Wars at the beginning of the century, the collapse of the cloth industry (which greatly affected Norfolk), Norwich's lack of the natural resources which stoked the industrial revolution in other cities, and growing mechanisation in agriculture leading to rural unemployment. But the stresses imposed by a vicious phase of the Little Ice Age would have contributed to many making such daunting journeys. From June 1835 to July 1837, 3354 people emigrated from Norfolk, encouraged by a number of poor law emigration schemes.

The **Industrial Revolution** started in Britain from around 1760. The most obvious sign – **industrial chimneys** – started to appear in Norwich. Although Norwich's industrialisation was never as extensive as in other cities across the country, industrialisation did change the face of Norwich, as well as towns and villages across Norfolk.



Panel 5: 1851 CE to present

There are good global instrumental observations available for this period, allowing the **Climatic Research Unit** at UEA and other organisations to accurately compile detailed records. The trend in these records has become increasingly influenced by atmospheric carbon dioxide (and other greenhouse gas) concentrations. At the start of the period, the **United Kingdom was the largest emitter of carbon dioxide**, with six times more emissions than the second-placed emitter (the USA).

Eunice Newton Foote (in 1856) discovered the warming effect of atmospheric gases and then **John Tyndall** (in 1859) discovered the "greenhouse" effect of carbon dioxide. The Tyndall Centre for Climate Change Research at UEA is named after the latter. In the mid-1960s, the annual global emissions of the gas reached **10 billion tonnes**. By 1999, the cumulated global emissions of carbon dioxide from the burning of fossil fuel was 1 trillion tonnes.

Norfolk did not play a significant role in the fossil fuel industry in the most active phase of the UK's industrial revolution, but that changed in the 1960s and 1970s with the development of the **North Sea oil and gas industry**. This was also the time when UK emissions of carbon dioxide peaked. In the 2000s, Norfolk is playing an increasingly important role in the more sustainable offshore wind energy industry.

Extreme weather events have had severe local impacts. In **1912 Norwich suffered what many regard to be its "biggest ever" flood** because of very heavy rainfall. There was devastation along the Norfolk coast in **1953, when more than 300 people died in a storm surge** along the combined coastlines of Norfolk,

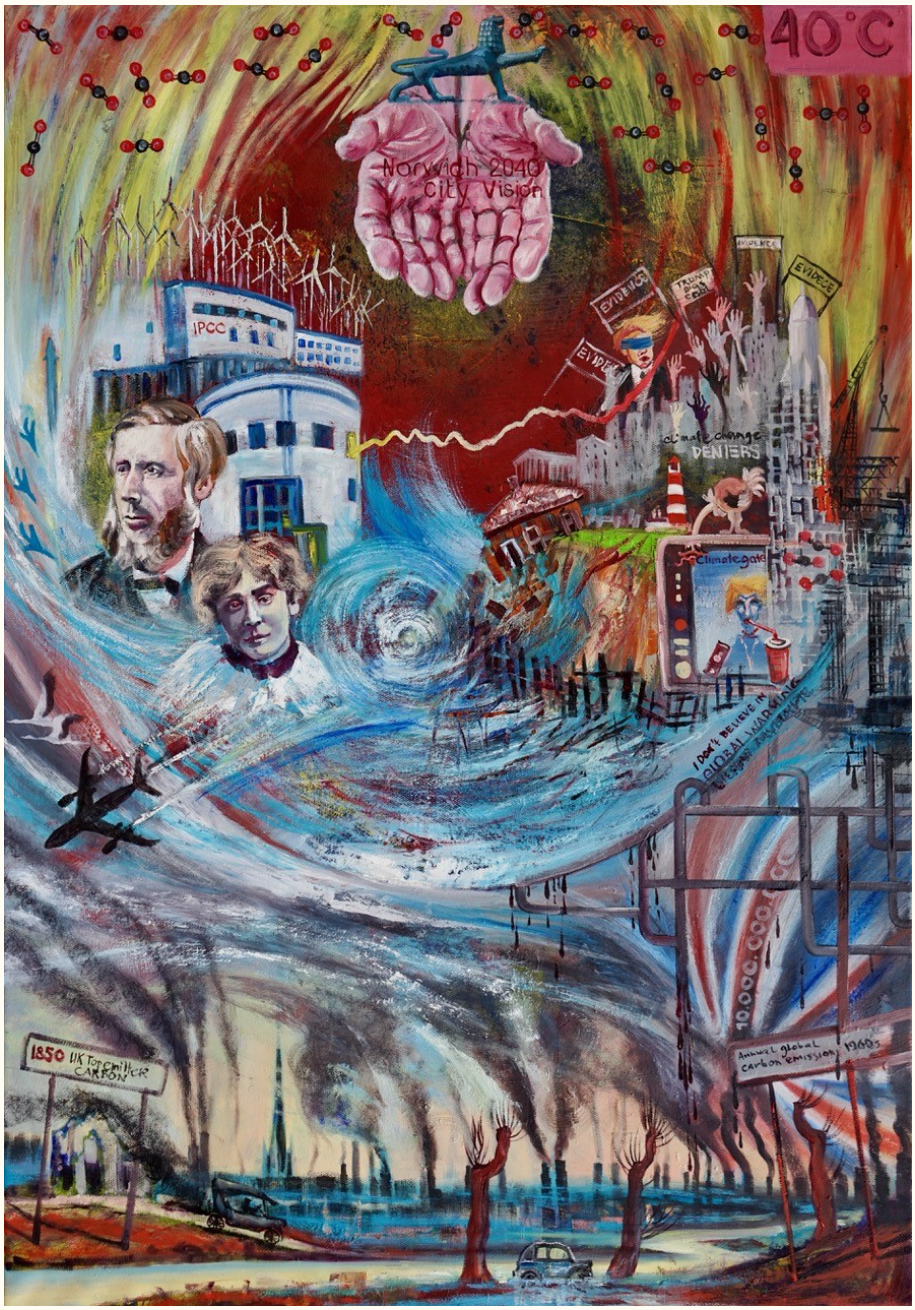
Lincolnshire, Suffolk, and Essex. Many more died in the Low Countries. A particularly severe breach in the coastine occurred near Sea Palling; it is this part of the coastline, and a little further south, where future inundations of the sea may be particularly problematic.

Such severe events have always been part of the natural variability within all states of our climate. The colder climate of the Little Ice Age produced particularly severe cold, wet and stormy events, but it also produced occasional relatively hot and dry events.

However, towards the end of the last century, and into the current one, we are experiencing extreme events within a rapidly warming climate. An increasing intensity of severe events such as heatwaves, very intense rainfall, and drought are now convincingly linked to our warming climate. The year 2022 saw "1-in-500 years" droughts in Europe, **40°C in England** and an astonishing number of wildfires.

Norwich has played a significant role in the move towards sustainable solutions for climate change. As early as the 1920s, it had a reputation as a green city, with the planting of many trees and the establishment of parks, some of which are now listed.

In 1945 the first large scale water source heat pump in the UK was installed in Duke Street; and a modern-day version is now being installed in the same location.



The **Climatic Research Unit** (CRU) was established in 1972 at the University of East Anglia in Norwich and has spearheaded study of climate change around the world ever since. In the 1980s it compiled the first **global record of temperature** from instrumental observations across both land and oceans. This research has, and still does, provide the basis of much of what we know about the course of global temperatures over the last 150-200 years. The Unit's work on the variations in tree rings has also made significant contributions to reconstructions of climate over longer periods. Such temperature reconstructions have proved crucial is assessing and improving the performance of computer models which project future climates.

CRU hosted the first international conference on climate and history in Norwich in 1979, representing a direct link

over more than 40 years to the vivid portrayals of the interactions between climate and social history in the mural and the easel paintings.

CRU and its sister research centre The Tyndall Centre for Climate Change Research (established in 2000) together have provided a large number of contributors to successive reports by the UN **Intergovernmental Panel on Climate Change** (IPCC) which, in 1995, issued a landmark statement that "the balance of evidence suggests a discernable human influence on global climate". That evidence has grown even stronger every year since then.

Norwich and UEA have been ever-mindful to implement solutions to climate change. **UEA boasts a number of award-winning low carbon buildings**, first started in the 1990s. The city's **highly energy efficient social housing in Goldsmith Street** won a national Royal Institute of British Architects award in 2019. Norwich City Council intends to build on successful initiatives such as Goldsmith Street, within the framework of its **Norwich Vision 2040**, in which the need to address climate change is a central plank. The Climate Mural For Our Times will be a constant reminder of the prime imperative that climate change remains at the forefront of local policy and decision making.

Despite the wealth of scientific evidence, building over decades, that the main reason for our rapidly warming world was emissions of greenhouse gases from human activity, **climate denialism** became more active around the turn of the century. This erupted in late 2009, and the main impact was initially felt in Norwich. Climate deniers used emails hacked from CRU to spread false allegations that research on climate change was a hoax. These scurrilous claims produced lurid headlines around the world. By mid-2010 a number of independent inquiries had exposed the allegations and associated international furore for what they were – a campaign to mislead which had taken in the more gullible parts of the media. Unfortunately the episode – which became known as **"Climategate"** – did sow doubts in the minds of some at the time, and has sometimes been blamed for weakening the resolve of politicians around the world to implement the necessary robust actions needed to address climate change.

Politicians such as Donald Trump, years later, were still referring to Climategate when continuing their own – real – hoax that climate change was a hoax.

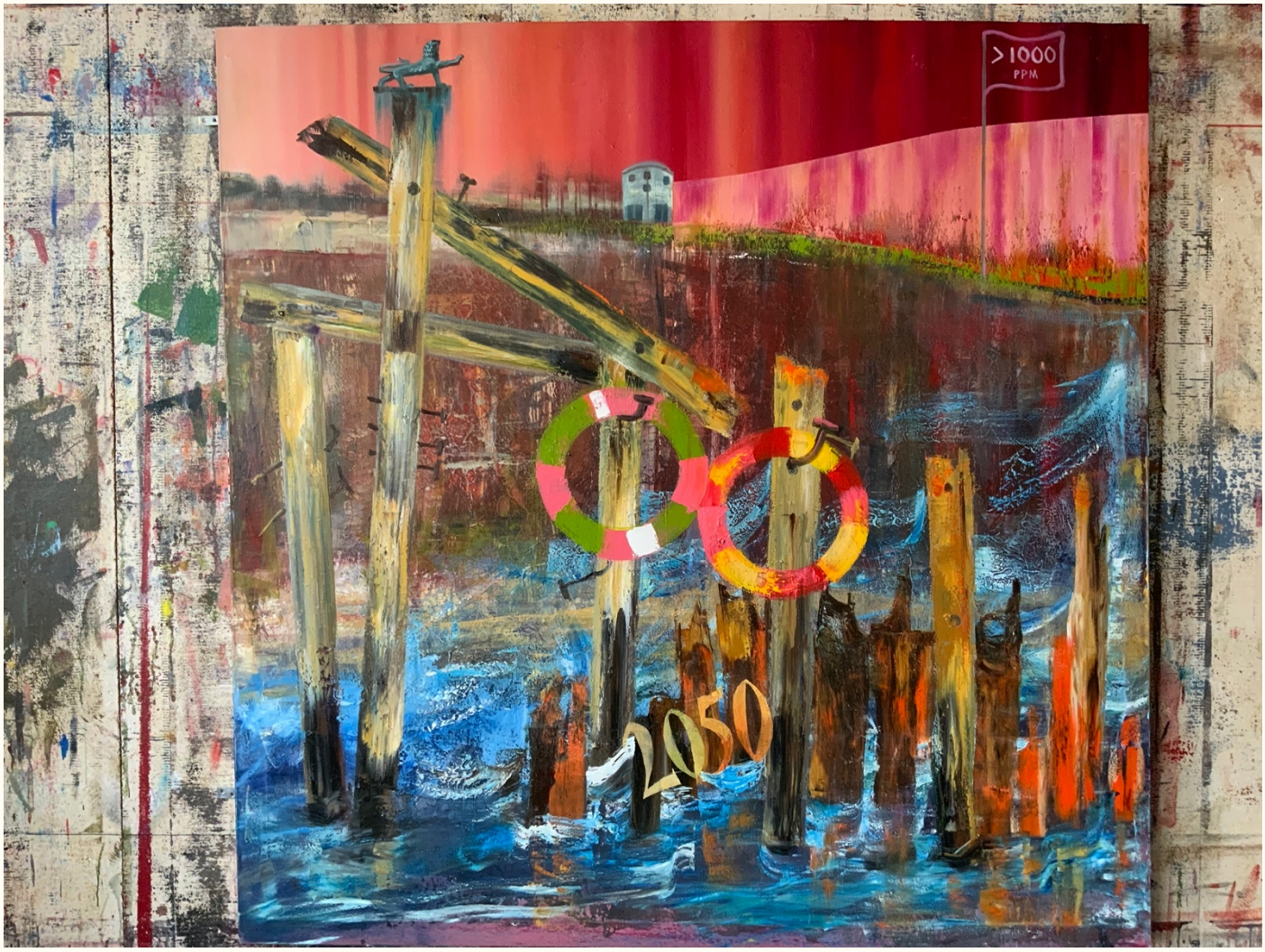
Years before Climategate, in 2002, an innovative c**ommunity carbon reduction project** started in Norwich. UEA was the lead partner and it included Norwich City Council and a large number of other community partners (businesses, streets, local authorities, towns, etc.) in the UK and, eventually, in other countries. It was called CRed and its objective was for all participating communities to reduce their carbon dioxide emissions, in specified sectors, by 60% by 2025. It was financially supported by big business and had considerable success until the double blow of the global financial crisis of 2008 and Climategate in 2009.

A prescient feature of the CRed project was that Keith Tovey (CRed Energy Director), in 2003/04 as Norwich was taking its lead in **carbon reduction**, was arguing that one of the significant benefits of adopting more green energy was that Euorpean reliance on Russian gas would be much lower (Sir Lancelot Flemming Lecture, Norwich Cathedral 2004).

Staggeringly, at least to those who are prepared to listen to science and accept rationality, at the time of writing (December 2022) the views that we cannot afford greenhouse gas reductions because of the current global financial climate, and doubts spread by denialist lobbies about the inevitable conclusions from climate research, have started to gain traction again.

The reality is that, whatever current global financial conditions, the economic cost now of a rapid mobilisation of effort to achieve **"Net Zero"** will be dwarfed by the costs to come of allowing unsustainable climate change. Surely, the present-day version of denialism can be seen for the nonsense it is.

If CRed (and related projects) had not been derailed by an economic recession, and deniers' plots, valuable time would not have been lost. If widespread moves towards significant carbon reduction had been made in 2002, or 2012, the world would not now be facing such catastrophic consequences from climate change.



Panel 6: Present to 2200 CE

The sky above the cliffs repesents **two possible climate futures**. One is the course we are currently set on, where atmospheric **carbon dioxide concentrations rise** back towards those seen early in the Age of Mammals, after the impact of the asteroid 66 million years ago. **Temperatures are predicted to climb** towards those seen at a similar distant time. Weather events would become more extreme. We would eventually approach an **ice-free world**.

The **other course is towards a climate which will still be challenging but, with human imagination and ingenuity, will be broadly manageable**. It will require a global detemination to drastically reduce carbon dioxide emissions, to adopt sustainable practices and technologies – many of which are already available. But it will also require innovation. Most of all, it will require community buy-in. Local authorities and community groups will have crucial roles to play. We must learn to listen to young people better. We must recognise the arguments, and distortions, of vested interests for what they are. We must listen to climate, and other, scientists when they provide the objective assessments which should guide policy and decisions.

Norwich, represented by a **city hall lion**, has embedded its **2040 Vision** into the city's Corporate Plan. In his introduction the Chief Executive stresses that the "focus is now on developing a … plan to become a net-zero city".

In this panel, there are **two lifebelts**. One has the colours of a broadly sustainable world – green, some colours representing aridity and difficult habitability, white representing ice at the poles. The other has the colours of a hotter, less habitable world. Which one shall we choose?

If we choose the one which represents a more sustainable world, we need policies and decisions to match that Vision. Quickly. We need our communities to help paint the stories of the future to buttress that Vision, and to make that world attainable.

Professor Trevor Davies, Dr Michael Taylor and Professor Tim Osborn

Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, UK

November 2022

Images

Website

For further information about the mural: https://crudata.uea.ac.uk/cru/climate-mural/

References

Behringer W. *A Cultural History of Climate*, 2020. Polity Press, Cambridge, 295pp.

Broads Authority. *Assessing carbon stocks within the peat of the Broads National Park*, 2020, Norwich. 52pp (https://www.broads-authority.gov.uk/__data/assets/pdf_file/0029/393365/Carbon-stocks-within-the-peat-of-the-Broads-National-Park.pdf).

Fagan B. *The Little Ice Age*, 2019. Basic Books, New York, 258pp.

Parker G. *Global Crisis*, 2014. Yale University Press, London, 871pp.