

THE BRITANNIA GROUP WHITE PAPER
CLIMATE CHANGE
IMPACT ON SOLID BULK AND
GRAIN CARGOES



CLIMATE CHANGE

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OUR PARTNER FOR THE ISSUE



Triglav Maritime provides bespoke, comprehensive consultancy services focusing on risk management, loss prevention, as well as marine vetting and assurance matters.

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Capt. Ostrowicki provides expert advice on risk management and safety management processes. In addition to marine incident and claim investigations, he performs management reviews, ISM and TMSA audits and in-depth risk assessments through data analysis. He has also authored several publications.

RISING TEMPERATURES, SHIFTING RAINFALL PATTERNS, AND MORE FREQUENT EXTREME WEATHER EVENTS AFFECT NOT ONLY SHIPS, PORTS AND MARITIME INFRASTRUCTURE, BUT MAY ALSO IMPACT THE QUALITY AND BEHAVIOUR OF CARGOES WHEN TRANSPORTED ACROSS THE WORLD'S OCEANS.

This means a change in risk exposure to cargo claims, with new challenges in both frequency and severity of claims.

This publication focuses on the impact of climate change on the risks associated with solid bulk and grain cargoes. It also points out the practical steps which may be taken and provides recommendations on mitigation strategies.

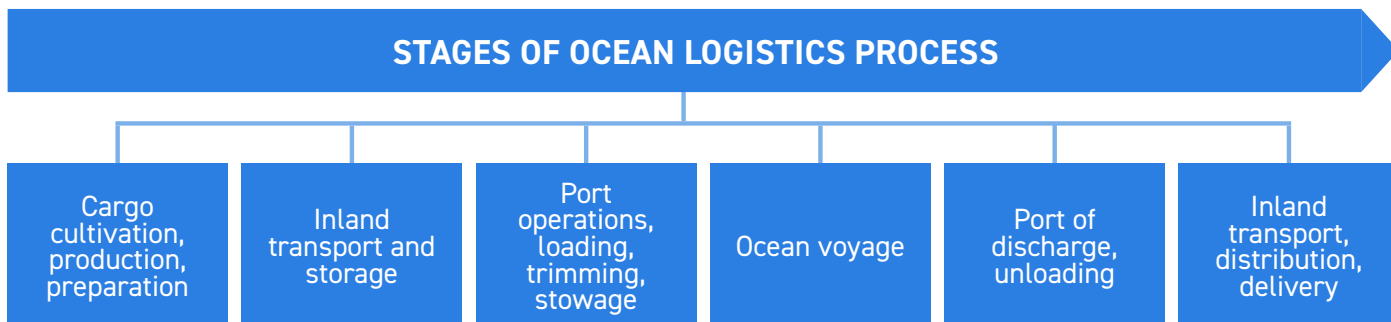
Among the cargoes likely to be affected are grains and solid bulk. Many of these cargoes are highly sensitive to moisture, temperature, and stowage conditions. Climate variability is altering harvest quality, increasing the likelihood of cargo being loaded with elevated moisture or latent damage. Once at sea, prolonged voyages, more humid environments, and unpredictable weather patterns heighten the risk of mould growth, fermentation, and caking, potentially leading to deterioration, cargo rejection, and disputes over liability.

To better understand the phenomena associated with climate change and their impact on the shipping industry, please also refer to the previous two parts of the Britannia climate change series:

- Climate Change: [Severe Weather and its Impact on Shipping Risks](#)
- Climate Change: [Impact of Droughts and Flooding on Shipping Risks](#)

ON THE RIGHT IS A SIMPLIFIED SUMMARY OF THE FORESEEABLE IMPACT OF CLIMATE CHANGE ON GRAIN AND SOLID BULK CARGO.

It should not be treated as exhaustive due to the complexity and extent of climate change phenomena. However, it can assist in developing a structured outlook on the likely disruption scenarios, which will be discussed further in more detail.



CLIMATE CHANGE EXAMPLES OF DISRUPTION FACTORS, EFFECTS, RISK IMPLICATIONS

<p>Increasing temperatures, more frequent droughts, floods, and storms affect yield, quality, and moisture content of commodities.</p> <p>Higher likelihood of latent cargo defects at loading (e.g. high moisture – leading to caking, or heat stress leading to spoilage).</p> <p>Disputes over pre-shipment condition.</p>	<p>Floods and heatwaves disrupt inland transport, damage cargo or delay shipment.</p> <p>Hot, humid conditions promote mould, fermentation, or cargo infestation whilst in storage.</p> <p>Delay and deterioration claims; contamination or infestation claims where cargo storage is compromised.</p>	<p>Extreme weather, storms, and flooding can halt or delay port operations, damage port infrastructure, expose cargo to rain or heat.</p> <p>Increased wet damage, contamination, delays.</p> <p>Misdeclared moisture content and rushed loading under weather pressure increase risk of cargo deterioration or liquefaction issues.</p>	<p>Shifting weather patterns increase the likelihood of water ingress, excessive hull stress.</p> <p>Increased challenges to ventilate effectively.</p> <p>Higher risk of spoilage, wet damage, cargo shifting, or stow collapse.</p> <p>Increase in extreme weather events potentially leading to grounding, collision, or loss of stability incidents, etc.</p>	<p>Extreme weather events result in port delays, congestion, cause prolonged waiting times at anchorage, exposing cargo to additional heat, humidity, and deterioration.</p> <p>Flooding may damage storage facilities.</p> <p>Claims for discolouration, mould, short weight, or rejection. Liability disputes over whether damage occurred prior to, or during carriage.</p>	<p>Infrastructure damage or flooding affects delivery schedules and cargo condition.</p> <p>Spoiled or degraded cargo may not meet buyer's quality specifications.</p> <p>Increase in rejection claims, demurrage, and loss of market cases.</p> <p>Claim causation complexity when multiple disruptions occur.</p>
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EMERGING CLAIM PATTERNS

Climate change may impact the following claim trends:

- Increased frequency of “wet damage” and “heat damage” claims in grain and solid bulk cargoes
- Longer voyage durations (due to slow steaming or weather avoidance) leading to mould, fermentation, or caking
- More frequent disputes over where and when damage occurred (pre-shipment vs. in-transit vs. discharge port)
- Increasing complexity of causation – combining environmental, operational, technical, and commercial factors
- Increased delays in mitigating cargo damage (for example, by offloading) may aggravate relatively minor claims.

VARIABILITY IN CARGO AVAILABILITY, COMPOSITION AND QUALITY

GRAIN AND SOLID BULK COMMODITIES HAVE ALWAYS VARIED IN QUALITY DUE TO ORIGIN, WEATHER, HARVEST OR PRODUCTION CONDITIONS, AND TREATMENT PRIOR TO CARRIAGE.

However, climate change is making that variability more pronounced. The impact is particularly visible in grain and agricultural cargoes, more than in commodities where the variability in raw material can often be compensated at the time of production.

SHIPOWNER’S LIABILITY AND CARGO QUALITY ISSUES EXISTING BEFORE LOADING

Although quality issues, such as cargo deterioration or contamination typically occur before loading, such pre-existing defects may still become the source of claims against the shipowner during or after the voyage. Therefore, understanding and managing these risks is as critical, as the risks which remain under shipowner’s direct control.

The shipowner’s legal responsibility under the Bill of Lading (B/L) means that the liability can still arise even if the cargo had been of poor quality before it was loaded, unless that fact is properly documented at the time of loading. In simple terms, once the cargo is loaded and B/Ls are issued, the shipowner (or the carrier) is deemed to have received the cargo in apparent good order and condition.

If the cargo is found damaged upon discharge, the burden of proof then lies with the carrier to show that the damage was not caused during the voyage, or that it resulted from inherent vice or pre-existing defect of the cargo. Unless there is clear documentary or physical evidence to prove that the cargo was defective before shipment, the shipowner may still be held liable.

Typical examples of such claims:

- Cargo loaded slightly damp (unknown to crew), deteriorates during voyage; cargo interests allege improper ventilation
- Grain or soya beans loaded with high impurity or broken content develops mould or self-heating; claim against shipowner for poor stowage or lack of ventilation
- Iron ore fines loaded with excessive moisture liquefy during voyage; claim for unseaworthiness and unsafe loading supervision.

Each of the above claim scenarios creates liability exposure for the shipowner, despite the root cause occurring before shipment.

In practice, proving that cargo was defective at loading is difficult unless:

- Independent, joint cargo sampling was performed
- Pre-loading condition reports were properly documented
- Appropriate photographic and documentary evidence was retained.

In case of a claim, significant financial exposure also exists due to investigation and legal costs. Examples of such exposure include the appointment of surveyors and correspondents at the discharge port, laboratory testing and cargo analysis, defence costs in arbitration or court, as well as settlement costs to avoid prolonged disputes.

Climate change amplifies these issues. More cargoes are loaded after exposure to extreme weather, moisture, or heat, leading to a higher risk of a latent defect. Such conditions create ambiguity between “cargo issues” and “carriage issues” and can potentially be used to shift liability to the shipowner.

Risk mitigation measures against such liabilities include:

- Maintaining risk awareness by monitoring climate-linked risk origins more closely, and using this input to assess the risk prior to accepting a cargo for carriage
- Ensuring a robust pre-loading survey, and sampling policy, especially for cargoes presenting high risk
- Clausing the B/L when required
- Retaining cargo samples and laboratory results.

KEY POINTS

- Members and ship masters should understand the implications of issuing a clean Bill of Lading
- Cargo defects may be hard to prove, which increases defence costs and likelihood of liability
- Where quality variability leads to damage during the voyage, it creates disputes over handling, ventilation and stowage
- Poor evidence and documentation weaken defence based on shipowner’s due diligence.

CLIMATE CHANGE AND PRE-LOADING CARGO QUALITY ISSUES

Less predictable harvest yields, shifts in nutrient composition, moisture content, impurities, and contaminant risks can all affect the performance and marketability of bulk shipments of agricultural commodities.

CHANGES IN CARGO COMPOSITION

Under heat or drought stress, cereals may show lower starch accumulation, altered protein content, and changes in mineral content. Cargo may fail to meet specific quality specifications (e.g. protein, starch, oil content, moisture), which in turn may prompt buyers to reject or discount shipments. This creates an incentive to seek shipowner's liability for the loss.

INCREASED MOISTURE AT HARVEST/LOADING

Changing and less predictable rainfall patterns (heavy rain, delayed harvests, humid conditions) lead to crops harvested with higher moisture content. Elevated atmospheric humidity can also affect the drying process and storage. Cargoes loaded with marginal or excess moisture are more susceptible to spoilage, mould, fermentation, or quality loss in transit. In cargoes liable to undergo liquefaction or dynamic separation, this means a higher likelihood of marginal or non-compliant cargoes being offered for shipment.

YIELD VARIABILITY AND GRAIN SIZE/WEIGHT INSTABILITY

Heat, drought, and extreme weather reduce yields and introduce variation in grain size and weight due to interrupted grain filling. Grain size often declines under heat/drought. Apart from the seller's contractual obligations, this may result in increased variation of cargo, such as the stowage factor, which in turn may result in operational challenges due to grain stowage requirements.

INCREASED IMPURITIES AND CONTAMINANTS

Shifts in pest populations, fungal growth (mycotoxins), or field contamination (by weeds or foreign material) may increase due to stress caused by the effects of climate change. Unstable weather can lead to field flooding, bringing soils, sediments or contaminants into grain. Impurities may cause discolouration, rejection, additional cleaning/processing costs, or outright rejection. Mycotoxin or other contamination may lead to food safety issues, or regulatory non-compliance.

As an example of a related claim, a bulk shipment of broad beans was rejected by receivers when laboratory testing on discharge revealed the entire cargo was microbially contaminated and in result was unsuitable for the intended use. Without cargo samples, the shipowner had no way of proving this was a pre-existing issue.

MECHANISM/PATHWAY	EFFECT ON CARGO IMPURITIES	CLAIM IMPLICATIONS
ALTERED GROWING CONDITIONS & STRESS ON CROPS	Heat, drought, excessive rainfall, or other environmental stress can reduce crop health. Crops under stress may accumulate more foreign matter (broken grains, weed seeds), have more impurities, or have lower uniformity.	More frequent claims for cargo quality disputes, rejections, or discount on value based on impurity levels.
SOIL EROSION, FLOODING, AND WASH-IN OF CONTAMINANTS	Heavy rainfall and flooding can erode topsoil, wash in silt, clay, or debris into harvested areas, or carry pollutants into fields.	Grain or bulk cargo could carry higher levels of mineral matter, clay, silt, or other unwanted materials, triggering rejection or cleaning costs.
PEST PRESSURE AND DISEASE	Climate change may expand the range and incidence of pests, fungal diseases, or mycotoxins. Damage from pests may result in broken kernels, foreign matter, or "insect frass" content in cargo. The creation of new ecological niches for pests, extending pest ranges and an increase in pest population sizes will likely result in the revision of pest management strategies in agriculture and biosecurity.	Contamination claims, regulatory rejections, or cargo being declared unfit depending on loading vs. carriage responsibility. The increased risk of biological invasion is likely to result in enhanced border biosecurity measures to manage economic and environmental losses from these pests. Some countries, such as Australia, already have strict biosecurity measures in place – it is likely that such measures will expand and evolve in time.
INADEQUATE POST-HARVEST HANDLING	More unpredictable weather can hinder drying, cleaning, or storage operations in producing regions. That means more grain shipped with residual moisture, foreign matter, or improper grading.	Increased risk that cargo is shipped with latent defects or impurities, putting liability pressure on carriers/owners.

DETERIORATION OF CARGO QUALITY AND PRE-EXISTING QUALITY ISSUES

UNDERSTANDING THE DIFFERENCE BETWEEN A PRE-EXISTING QUALITY ISSUE AND DETERIORATION OF CARGO QUALITY DURING THE VOYAGE IS IMPORTANT FROM THE MARINE INSURANCE PERSPECTIVE.

The distinction is fundamental; under the Hague-Visby Rules (Article IV, Rule 2), shipowners are not responsible for *“loss or damage arising or resulting from inherent defect, quality or vice of the goods.”* However, deterioration during the voyage may give rise to a valid claim. Many disputes arise where it is unclear when or why the cargo condition changed, leading to expensive investigations and defence costs.

DIFFERENCE BETWEEN DETERIORATION OF CARGO QUALITY AND PRE-EXISTING QUALITY ISSUES

ASPECT	PRE-EXISTING QUALITY ISSUE	DETERIORATION OF CARGO QUALITY
DEFINITION	Cargo is already damaged, contaminated, or substandard before it is loaded on board	Cargo was sound and in good order when loaded but became damaged or degraded during carriage
TIMING	Defect or poor condition exists prior to shipment, usually due to harvest, processing, storage, or loading practices	Damage occurs after loading, during sea voyage or discharge operations
CAUSE	External to the ship: weather at origin, poor handling ashore, inadequate drying, infestation, or contamination before loading.	Ship-related or voyage-related factors: improper stowage, poor ventilation, ingress of seawater, temperature fluctuation, cargo shifting, prolonged voyage, etc.
EVIDENCE NEEDED	Pre-loading inspection, sampling, laboratory analysis, photographs, cloused B/Ls	Logbook records, ventilation logs, temperature records, weather reports, surveyor evidence at discharge
CARRIER'S LEGAL POSITION	If properly documented, the carrier can defend liability by proving the cargo was already defective at loading	Carrier may be liable if deterioration results from lack of due diligence or improper care of cargo during the voyage
EXAMPLE	Grain loaded with moisture content above limit, starts fermenting at sea. The problem existed before loading.	Grain loaded dry and clean becomes mouldy due to inadequate ventilation during the voyage.

THERE ARE SEVERAL WAYS IN WHICH A CARGO CAN DETERIORATE IN QUALITY DURING THE VOYAGE:

MOULD AND FERMENTATION

Rising global temperatures and increased humidity can create more favourable conditions for microbial growth in organic cargoes such as grains and oilseeds, as well as other bulk commodities of organic origin. Global climate change is likely to affect all stages of the logistical/supply chain, especially where the existing infrastructure has no capacity to deal with the challenges resulting from weather disruption.

If the cargo is not correctly processed, a heavier rainfall during harvest or storage may lead to higher moisture content at loading, even if the cargo visually appears sound. In case of supply chain disruption, the time between harvest and shipment will increase, which may allow time for spoilage to begin even before the voyage.

Cargo spoilage occurs through mould and fermentation, which are similar processes ultimately leading to the deterioration of cargo quality.

Mould is a fungal growth which appears on cargo as visible spots or patches. Fungal spores naturally occur in agricultural cargoes; in the presence of moisture, oxygen and in suitable temperature, the spores germinate. Cargo mould develops when cargo moisture content and temperature rise above safe limits during storage or carriage. Fungal growth may result in discolouration, odour, and contamination with mycotoxins and spores. P&I risks due to fungal growth involve reduction of commercial value and ultimately rejection of cargo.

Fermentation is a microbiological or enzymatic process where microorganisms (bacteria, yeasts), or the cargo's own enzymes, convert sugars or carbohydrates into alcohol, acids, and gases. Fermentation is triggered by high moisture content and warm temperatures that promote microbial activity or biochemical reactions within the cargo. Like mould, fermentation occurs when moisture content is above the cargo's safe threshold.

Both processes can accelerate cargo degradation and pose safety hazards through oxygen depletion or spontaneous heating. Poor or insufficient ventilation during sea passage exacerbates the risk, especially when holds are sealed in heavy weather or due to fumigation requirements.

Typical P&I claim scenarios have been outlined in the table below, along with loss prevention measures, defence documents likely to be required and the probable claim outcome.

CASE SCENARIOS

Mould & fermentation in grain and solid bulk cargoes

CARGO ARRIVES WITH VISIBLE MOULD PATCHES

Likely cause	Excessive moisture content at loading; microbial spores present
Influence of climate change	More wet harvests, higher humidity in ports, unseasonal rains during loading
Liability considerations	Defence possible if pre-loading condition can be proven. Otherwise, liability likely
Loss prevention measures	Prudent approach to independent pre-loading cargo surveys, sampling and testing
Documents supporting defence	Survey reports, moisture analysis reports; photographic evidence; sampling records
Likely claim outcome	Claim may be defensible if it can be demonstrated that damage existed before loading

FERMENTATION AND HEATING MID-VOYAGE

Likely cause	High moisture content and poor/insufficient ventilation
Influence of climate change	Higher cargo and air temperatures accelerate microbial activity; longer voyages due to slow steaming
Liability considerations	Liability likely if crew failed to ventilate or cannot present evidence of sufficient ventilation
Loss prevention measures	Ventilation whenever possible. Consistent temperature/ dewpoint measurements
Documents supporting defence	Comprehensive ventilation records; weather reports; logbook entries; temperature logs
Likely claim outcome	Possible liability if lack of ventilation records, or records erroneous/inconsistent with good practice

CONDENSATION DAMAGE CAUSING MOULD

Likely cause	Condensation of moist air on cooler surfaces
Influence of climate change	Increased port temperature differentials; erratic seasonal shifts
Liability considerations	Defence possible if ventilation carried out correctly; liability if logs absent or questionable
Loss prevention measures	Ventilate as per appropriate rule and in line with good practice; ensure ventilation logs are complete and correct
Documents supporting defence	Ventilation logs; weather data; officer statements
Likely claim outcome	Defensible with good logs; otherwise, may be liable for poor cargo care

LOCALISED SPOILAGE INSIDE THE CARGO HOLD

Likely cause	Water ingress from hatch covers or via defective hull structure
Influence of climate change	Increased frequency and severity of extreme weather events which may result in hatch cover failure or structural defects
Liability considerations	Strong liability if ingress proven
Loss prevention measures	Hatch cover maintenance; ultrasonic testing; systematic inspections; weather routing
Documents supporting defence	Hatch cover test certificates; repair logs; weather routing data; surveyor reports
Likely claim outcome	Liability likely if ingress proven; defensible if ingress from peril of the sea and due diligence shown

CARGO REJECTION FOR QUALITY AT DISCHARGE

Likely cause	Pre-shipment borderline condition worsened in voyage
Influence of climate change	Supply disruptions mean marginal cargo shipped
Liability considerations	Defence possible if condition at loading documented
Loss prevention measures	Pre-loading sampling; independent surveyor attendance
Documents supporting defence	Loading survey reports; sample analysis; signed surveyor certificates
Likely claim outcome	Strong defence if pre-load condition

For further reference, please refer to the following Britannia publications:

- [Essential Guide to Understanding Cargo Ventilation](#)
- [Carriage of Grain and Oilseed Cargoes](#)
- [Heat Damage to Agricultural Cargoes on Board and How to Avoid It](#)

KEY POINTS

- **Burden of proof:** The shipowner may be required to demonstrate that the cargo was either damaged before loading, or that proper care was taken during the voyage

CAKING

Caking is the unwanted agglomeration of fine particles of cargo into lumps (pieces of solidified cargo), making the cargo difficult to discharge and sometimes reducing its commercial value. In some cases, the formation of lumps may affect the suitability of cargo for a particular end use (e.g. when it is intended for direct industrial application). In severe cases the cargo may solidify/ cake to a point where it cannot be discharged with usual means and requires additional machinery and time/resources to handle.

- **Operational Discipline:** Loss prevention is heavily dependent on adherence to correct operational procedures and disciplined documentation
- **Evidence-based defence:** The absence of clear and consistent records (such as the ventilation log) significantly increases exposure in case of a claim
- **Climate change factor:** Higher moisture variability at origin, longer voyages, and more extreme weather will make borderline cargoes more common, increasing disputes.

Main causes of caking include:

- Excessive moisture content at loading,
- Temperature fluctuations causing condensation, moisture absorption and recrystallisation,
- Compaction from prolonged storage or due to the ship's vibration,
- Chemical or hygroscopic properties of cargoes such as fertilisers, salt, sugar, cement, and mineral concentrates.

Some hygroscopic cargoes such as fertilisers, shipped with very low inherent moisture content, have the property called critical relative humidity (CRH). If relative humidity of the surrounding air reaches CRH, the cargo may begin to rapidly absorb moisture and in result sustain caking, clumping, or similar forms of deterioration. Loading hot cargo may exacerbate the risk of subsequent caking (as CRH decreases with temperature). It is therefore important to be aware of the CRH specific for the cargo/temperature and ensure these cargoes are loaded in suitable conditions.

Climate change may influence the likelihood of cargo caking due to:

- Increased variability of moisture content at origin. For example, unseasonal rainfall during harvest (or extraction of components from the crop) may unexpectedly increase moisture content before loading,
- Higher temperatures during the carriage (e.g. occurrence of heat waves whilst enroute),
- Operational or commercial pressures leading to the cargo being loaded in unsuitable conditions (e.g. fertilisers such as urea being loaded too hot, at a temperature in which ambient humidity exceeds the cargo's critical relative humidity),
- Longer voyages due to slow steaming, port congestion or re-routing, allowing more time for moisture migration and compaction of cargo,
- Temperature differentials between load and discharge ports being greater than anticipated/usual, which may result e.g. in the formation of cargo or ship sweat,
- Extreme rainfall events in ports, resulting in a greater risk of wetting damage whilst handling cargo.

INSECT INFESTATION

Likely claim types associated with cargo caking include:

- Loss of value (cargo discounted or refused by receivers),
- Discharge delays (additional time and/or cost to handle cargo or to mechanically break the lumps), as well as the associated charter party disputes resulting from extra handling costs,
- Contamination (cargo damaged or contaminated due to attempts to break lumps). Broken lumps may also be spread to otherwise unaffected cargo because of negligent handling and not separating the affected cargo right away.

Climate change increases risk of insect infestation through the following factors:

- **Expanding geographic range and seasonality of pests**

Warmer average temperatures allow insect species to survive in regions where they were previously absent; longer warm seasons reduce insect mortality and extend the window for breeding.

- **Increased infestation pressure on stored products**

Bulk agricultural cargoes like grains and oilseeds are particularly vulnerable. Insect pests may adapt or shift their host preferences and life cycles in response to changing conditions, potentially affecting cargoes not previously at high risk.

- Cargoes with elevated moisture and temperature (e.g. due to wet weather during harvest) are more susceptible to infestation, because insects thrive under such conditions.

- **Longer transit periods and delays**

Weather diversions, slower passage speeds, port congestion and delays mean more time for insects to act on cargo during the voyage.

As a result, we may see more frequent claims for infested cargo requiring fumigation, segregation or destruction, as well as higher liabilities for additional costs (storage, transshipment, delays).

Attempts to apportion liability to the carrier may lead to disputes over causation, by questioning whether the infestation had been present at loading, or did it develop in transit due to inadequate ventilation or pest control.

This highlights the need for thorough documentation of onboard measures (ventilation, fumigation, monitoring, pest control), demonstrating compliance with good industry practice to defend against claims. As with other types of claims, effective loss prevention requires pre-loading diligence, such as stricter pre-loading inspections and sampling.

HEAT-SENSITIVE BULK CARGOES

Heat-sensitive bulk cargoes are solid bulk goods which degrade, self-heat, or deteriorate in quality when exposed to elevated temperatures, heat transfer from ship structures, or long exposure to warm conditions. These cargoes may contain residual oils, moisture, and/or microbiological agents which under elevated temperature can accelerate biological or chemical activity, ultimately leading to deterioration and self-heating. They are typically agricultural or feed-type cargoes of organic origin. However, there are other solid bulk cargoes which are heat-sensitive; in these cases, deterioration may occur due to chemical reactivity or physical changes – such as caking/agglomeration (discussed in one of the sections above), softening or melting, release of fumes, or even noxious or flammable gases.

Examples include soya beans, wheat, maize, sunflower pellets, canola, fish meal, soya bean meal, raw sugar, barley (in particular malting barley), also certain coals, fertilisers (urea, NPK blends), etc. For solid bulk cargoes other than grain, attention should be paid to the provisions of the International Maritime Solid Bulk Cargoes (IMSBC) Code, particularly hazards outlined in the cargo schedule and where cargoes are to be stowed “separated from” sources of heat.

Due to the great variety of cargoes which are heat-sensitive and the individual nature of the sensitivity, we provide general guidance only. For detailed guidance, please refer to cargo information and the regulatory requirements (such as the IMSBC Code). Flag administrations, competent authorities, P&I clubs may provide further advice on specific cargoes if required. As an example, Britannia published [guidance on the safe carriage of coal](#).

The impact of climate change on potential deterioration of heat-sensitive cargoes may occur through the following factors:

- **Higher ambient and cargo hold temperatures**

Rising sea, air, and atmospheric temperatures increase the baseline heat to which cargo is exposed. Exposure of cargo adjacent to heated fuel tanks may also increase due to the heating requirements of new fuel blends, such as VLSFO – which may require relatively high storage and transfer temperature to prevent solidification due to waxing.

- **Increased moisture content**

Due to more intense or even extreme rainfall, the cargo may be offered for shipment with excessive moisture content. When cargo moisture content is already marginally high, even a moderate increase in temperature or contact with heated surfaces can bring reactions occurring in the cargo over the safe threshold.

- **Longer exposure times**

Delays, slow steaming, rerouting, congestion in ports or canal passages lead to longer voyages. Consequently, this increases exposure to heat whilst on board and the extent of potential damage from heat and associated effects.

- **Greater risk of self-heating**

As mentioned above in the section on mould and fermentation, organic cargoes may be more susceptible to self-heating due to the increased presence of mould spores and microorganisms, leading to the potential deterioration, spoilage and ultimately self-heating.

Causation disputes are likely to become more common (i.e. whether damage was due to pre-shipment factors rather than improper care or exposure to heat during the voyage). As with other claim types, for successful defence this will place a stronger burden of proof requirement on ship owners, as well as increase the need for adequate inspection and sampling of cargo prior to loading.

From recent cases related to heat damage of sensitive cargoes, typically soya beans, several implications and trends are apparent:

- Increasing frequency and volume of claims – such as the surge of Brazilian soya bean heat damage in Chinese ports, connected with more weather disruptions at cargo origin increasing moisture content at loading.

LIQUEFACTION AND DYNAMIC SEPARATION ISSUES

Liquefaction occurs when a solid bulk cargo (typically fine mineral concentrates or ores) containing too much moisture compacts and behaves like a liquid, so that it can flow and create a free-surface that severely affects ship stability.

Dynamic separation takes place when due to compaction and vibration, fine solids and free moisture separate and form a liquid slurry on top of a denser consolidated bed of cargo, producing a free liquid surface effect similar to liquefaction but caused by internal segregation rather than full bulk liquefaction.

- Stricter judicial attitudes toward carrier liability; courts are less likely to accept that damage is purely inherent vice in cases where the carrier did not document and was unable to demonstrate sufficient care. Local courts in the country of destination may find carriers primarily liable even in cases where origin issues existed.
- Critical importance of documentation and frequency of monitoring. Time ventilating cargo and frequency of temperature recording is coming under scrutiny.
- Weather conditions at the origin of cargo matter more in causation – e.g. heavy rains in Brazil and cargo being shipped with higher moisture content are frequently cited as contributing causes.
- Highlighted operational and ship design risks, particularly the proximity of heated tanks to cargo; conversely, insulation and heat separation becoming a defence factor.

These phenomena may lead to uncontrollable shifting of cargo, loss of stability and even ship capsizing, and are considered to be the greatest contributor to the loss of life at sea in recent years. For further reference, see [Understanding Liquefaction and Dynamic Separation in Solid Bulk Cargoes](#).

Climate change increases the risk through the following factors:

- Weather seasonality becoming less predictable due to the disruption of rainfall patterns and the increasing frequency and severity of extreme weather events.²
- More frequent port disruption due to extreme weather – the combination of stockpile exposure to rain and port delays may make proper drying/conditioning of the cargo at origin harder. This may in turn raise the likelihood of non-compliant or marginally compliant cargo being offered for shipment. It is also likely that we will more often see disputes over failures of cargo testing at load port, access to the stockpile, or over sampling methodology.
- Longer exposure of cargo to ship movement and vibration due to slow steaming, re-routing, more frequent extreme weather events – which will in turn increase the time for moisture migration, cargo compaction or separation to develop.

Preventative measures that should be considered and implemented include:

- Higher risk awareness; vigilance in known risk trades and points of cargo origin
- Strict enforcement of sampling and testing methodology prescribed by the IMSBC Code
- Increased scrutiny of cargo documentation and raising the bar on documentary evidence (cargo certificates, independent sampling and testing, loading surveys) – as essential in preventing incidents but also in claim defence or prosecution
- Improved operational controls on board (cargo monitoring, record-keeping, etc.)
- Appropriate training to masters, officers and the responsible crew
- Route and voyage planning to avoid severe weather windows where possible, reduce anchor waiting time in exposed conditions, minimise voyage extensions/delays which increase compaction time.

DAMAGE FROM HEAVY/EXTREME WEATHER

One of the known effects of climate change is the increase in frequency and severity of extreme weather events.

Heavy or extreme weather can trigger cargo damage in several ways:

WATER INGRESS/WET DAMAGE

- Wet damage is one of the most common and costly cargo claims in bulk carriers. Hatch covers, panel joints, cross-joints, rubber seals, and drain channels may leak during heavy seas or spray from green water. Once water enters, the cargo gets wetted and is likely to develop mould, spoilage, or caking.
- Prolonged and repeated ship exposure to heavy motion increases stress and wear on hatch cover securing, seals/gaskets and drainage systems, making future water ingress more likely unless adequately maintained.
- Heavy/extreme weather subjects the ship to mechanical stress which may result in a structural failure or exacerbate pre-existing structural issues. Water ingress may occur via defective hull plating, ballast pipes, bilge wells, or other defective structural parts, which may result in severe damage to cargo, among other safety issues.

CHALLENGING OPERATIONAL CONDITIONS

- Extreme weather often forces route changes, slows the ship, leads to more deck exposure to waves and spray. This increases the risk that cargo gets exposed, even if covers are well maintained.
- Maintenance of gear (hatch seals, bilge lines, drain channels, etc.) becomes more critical; poorly maintained equipment is more likely to develop a leak.

CLIMATE CHANGE MAY CAUSE MORE FREQUENT AND PROLONGED DELAYS IN GLOBAL SHIPPING DUE TO:

Extreme weather increasing in frequency and severity (storms, cyclones, heavy rainfall, droughts, fog, heatwaves).

Port congestion after weather-related shutdowns or infrastructure damage.

Route diversions due to abnormal water levels in canals or rivers (e.g. Panama Canal, Mississippi River) or high-risk zones (e.g. storms in the Indian Ocean).

Slow steaming and extended waiting times for safe anchorage or cargo operations.

These factors combine to create longer voyage durations and less predictable transit times, directly affecting the risks associated with cargo condition:

- **Deterioration of perishable or hygroscopic cargo**
For time- and condition-sensitive cargoes, longer voyage times increase the risk of mould growth, fermentation or caking. Also, higher average temperatures of cargoes accelerate biological or chemical reactions in cargo.
- **Delay-related deterioration**
Cargoes which would normally remain stable for a standard voyage period may deteriorate when voyages extend unexpectedly. For example, soya beans that could remain sound for 20 days may spoil after 40 days, despite being properly ventilated, due to the limitations of ventilation whilst on board.
- **Damage during port waiting**
The ability to avoid extreme weather events is limited whilst awaiting port access. Prolonged rolling or pitching may contribute to cargo shifting in holds. Heavy rainfall and rough seas restrict the ability to ventilate, leading to a further cargo deterioration, especially if the interruption in ventilation is prolonged.
- **Limited salvage opportunities during port waiting**
It may also be difficult or impossible to offload and salvage the affected cargo whilst awaiting berth, which may result in a continued deterioration and further exacerbate developing claims.

OPERATIONAL AND TECHNICAL FACTORS TO CONSIDER

CREW COMPETENCE & COMPLIANCE

Climate change is introducing new variables and uncertainties into ship operations. More frequent extreme weather, longer and less predictable voyages, wider variability in cargo quality all increase the potential for cargo deterioration, contamination or instability.

In these circumstances, the competence and diligence of crew has become critical to claim prevention and defence.

Human factors tend to contribute to most claims. Poor understanding of cargo behaviour, failure to follow cargo care procedures (such as ventilation), inadequate documentation and record-keeping may all play a role.

If the crew cannot demonstrate that all reasonable care was taken, liability may still arise, even if the physical cause was climate-related. To quote the Hague-Visby Rules, the carrier must “properly and carefully load, handle, stow, carry, keep, care for, and discharge the goods”. This obligation applies even when weather or voyage conditions are extreme.

Several key competence areas influence the risk of cargo claims:

- Cargo knowledge
- Ventilation management
- Weather routeing awareness
- Record keeping and reporting
- Safety Management System (SMS) compliance
- Emergency procedures.

(continued)

TECHNICAL/OPERATIONAL ASPECTS AND SHIP DESIGN LIMITS

Climate change increasingly tests the technical resilience of ships and their cargo systems.

The recommended risk management approach may include the following:

- Integrating climate-related cargo risk awareness into SMS procedures
- Conducting crew briefings before loading high-risk or climate-sensitive cargoes
- Including cargo care and documentation training in familiarisation programmes
- Participating in P&I Club training initiatives and circulating loss prevention bulletins/material as required.

Competent, well-trained crews who understand both cargo behaviour and the legal burden of due diligence can make the difference between a defensible claim and a costly settlement.

Cargo claims are not only caused by human factors or cargo quality issues, but often by technical or design limitations of a ship that are exceeded during extreme weather, high temperatures, or prolonged voyages.

As climate change intensifies adverse sea conditions and thermal variation, ships may be exposed to stresses and environments beyond their original design assumptions, such as:

- More frequent heavy/extreme weather encounters
- Higher ambient and sea temperatures
- Increased humidity
- Delayed port operations caused by storms, floods, or heatwaves.

The role of extreme weather events highlights the need for **weather routing practices** to evolve due to climate change. For example, more advanced forecasting methods, such as probabilistic forecasting allow for more reliable predictions⁵. Route optimisation algorithms tuned to probabilistic forecasting and accurate, real-time data allow better route optimisation.

During cargo handling whilst in port, **weather forecasting** must also become more reliable to help prevent cargo damage. This is being achieved through more precise, high-resolution and hyper-local weather models, along with real time radar and satellite monitoring of storm cells – combined with “nowcasting” of imminent weather and improved predictive alerts.

Technical suitability of the vessel for the intended trade and cargo is a form of due diligence. A carrier who knowingly accepts moisture-sensitive cargo on a ship without adequate ventilation, or a ship with hatch cover issues on a route prone to tropical storms, may be deemed negligent if damage occurs, even if the weather was unusually severe. If cargo damage results from foreseeable deficiencies in ship design, equipment, or maintenance, the defence of “perils of the sea” may not apply. Therefore, ship design limits are directly tied to liability, not just to operational performance.

Critical technical systems, which may reach design limits due to the climate change impact, include:

- Ventilation systems and hold design
- Insulation and temperature control
- Structural strength and hatch cover integrity
- Drainage and bilge systems

(continued)

- Cargo securing arrangements
- Power and propulsion systems
- Ballast and stability systems.

Risk mitigation through technical and operational measures may include design adaptation and upgrading/retrofitting of the above systems, but also technical and operational controls such as strengthened preventive maintenance, voyage planning adjusted for climate anomalies, pre-loading cargo suitability assessments, improved monitoring of predominant weather/hydrological conditions for the potential to exceed the design limits. Also, several class societies have issued guidelines for extreme weather resilience and structural integrity.

MANAGING THE RISK

THE RISKS ASSOCIATED WITH CARGO SHOULD ALREADY BE COVERED IN GUIDANCE AND PROCEDURES PROVIDED BY THE SHIP'S SAFETY MANAGEMENT SYSTEM (SMS).

Whilst the underlying causes of cargo claims are not new, their complexity is evolving due to climate change.

A structured continuous approach is recommended to maintain appropriate risk awareness, as well as to formulate suitable risk mitigation measures. The systematic review of a company's operations and activities, and the required risk controls, should be kept up to date.

Core areas of risk management which should be subject to such review include:

- Technical resilience: ensure the ship's design, equipment, and maintenance standards can withstand changing climatic and voyage conditions
- Operational competence and compliance: crew knowledge and procedural discipline are critical in adapting to volatile conditions
- Enhanced cargo awareness and due diligence: identify high-risk cargoes early, ensure a robust sampling and cargo survey policy, apply the regulatory requirements strictly, refuse to load non-compliant cargoes
- Long-term climate resilience achieved through strategic planning and technical preparedness: strengthened fleet management, predictive maintenance systems, use of the available digital tools to assist cargo monitoring and knowledge sharing.
- Improved weather forecasting and weather routing/route optimisation.

KEY POINTS

- Climate change is increasing the variability in quality of solid bulk and grain cargoes, with higher moisture, impurities, heat exposure, and latent defects at loading
- Cargo condition at origin is becoming less reliable, leading to more disputes over whether damage arose before shipment or during carriage. Proper pre-loading surveys, sampling, testing, and documentation are now critical
- Extreme weather events, port disruption, and longer voyages increase the risk of mould, fermentation, caking, contamination, self-heating, insect infestation, and other forms of deterioration

- Mould, fermentation, heat damage, and wet damage claims are likely to become more frequent, especially where ventilation is restricted, weather is volatile, or cargo is already marginal at loading
- Liquefaction and dynamic separation risks may further increase due to unpredictable rainfall, stockpile exposure, and delays that may lead to marginally compliant cargoes being offered for shipment
- Heavy/extreme weather events increase the risk of water ingress, cargo shifting, and structural failures, highlighting the need for robust maintenance and effective weather routing
- Human factors remain a key contributor to claims and require careful consideration for effective loss prevention
- Technical resilience and ship design limits are increasingly tested by heat, humidity, and extreme weather. Ventilation capacity and hatch cover condition are critical
- Effective risk management requires a structured, climate-aware approach, including enhanced cargo due diligence, improved operational discipline, reinforced crew training, and stronger maintenance and planning.

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