

Contrail-free flying could help the climate

没有凝结尾迹的飞行，或可帮助应对变暖

A trial over the Atlantic aims to show how

大西洋上空的一项试验，试图验证如何做到

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飞机身后留下细长白色尾迹，附近另有已经扩散的云带。

难度 73 / 100

建议85–110分钟；选做作文另计。

适用读者：能阅读一般英语新闻，希望读准长句、搭配与作者语气的学习者。

入门准备：能辨认基本主谓结构和常见从句，愿意结合语境查词。

About this lesson 本课导读

减少飞机尾迹，看似只是微调高度，却涉及高空水汽、卫星观测、航路安排和气候收益核算。本篇沿着“为何会增暖—能否避开—怎样验证—代价是什么”展开，并用原文中的不同百分比训练分母意识与数量级核对。

- 读懂冰晶、辐射与持续性尾迹的形成机制
- 拆解长主语、嵌入从句与条件表达
- 区分航班数、航程、覆盖率和增暖份额
- 核对数量级，并说明短期收益不能替代长期减排

Before you read 读前思考

What would you need to know before deciding whether a small flight-path change helps the climate?

拓展例句与练习情境用于说明用法。

书末答案 (p.18)

Text 课文

[P01] THE 40M scheduled passenger flights which took place in 2019 added up to about 61bn kilometres of travel—exceeding the distance from Earth to the Sun every day of the year.^{V01V02} More than 40% of those flights left contrails behind them for at least some of the journey as water vapour in the exhaust from their engines froze into tiny particles of ice.^{V03}



飞机身后留下细长白色尾迹，附近另有已经扩散的云带。

5 [P02] Many of these trails were ephemeral.^{V04} They streamed out behind their progenitor planes before fading quickly away.^{V05} But over about 5% of the total distance flown—comfortably enough for ten round-trips a day to the Moon—they persisted and widened as water vapour already in the atmosphere joined in the freezing.^{V06} Thin white lines became broad translucent stripes of cirrus cloud.^{V07} Wind those stripes around Earth like yarn around a ball and you will
10 find that, at any one time, persistent contrails cover maybe a thousandth of the sky.^{V08V09K01} In doing so they warm the planet.

[P03] Contrails are white because their constituent ice crystals reflect sunlight.^{V10} That can have a cooling effect during daytime. But the crystals also absorb infrared radiation and re-emit it, rather as greenhouse gases do.^{V11} Some is thus radiated into space, but the rest travels back
15 towards Earth. This produces 24-hour warming that, overall, handily outweighs the cooling (something which is true for non-contrail cirrus, too).^{V12} The exact amount of net warming is hard to calculate, but current evidence suggests aircrafts' contrails and the cirrus clouds they induce may do more to raise the planet's temperature than carbon dioxide emitted by the aircrafts' engines.^{V13}

20 [P04] This warming is, though, to some extent, optional.^{V14} For contrails to persist the air they are in must be well below freezing point and yet contain a significant amount of not-yet-frozen water vapour.^{K02} The thing which stops this water vapour freezing is a lack of particles that might "seed" the process by acting as nuclei around which crystals can form.^{V15V16K03} A contrail provides such seeds by the trillion, and so creates cloud where there was none.

25 [P05] Such ice-supersaturated regions (ISSRs) tend to be found at altitudes of 8-13km. They are a few hundred kilometres across, but only a few hundred metres deep. Keep aircraft out of them and you should get rid of a lot of persistent contrails—which means getting rid of some warming, too.

[P06] On August 18th a consortium based in Britain announced Operation Blue Skies, the most
 30 important trial of this approach to cooling the climate so far undertaken. It will take place in Shanwick, a piece of airspace that covers 1.8m square kilometres of the North Atlantic west of the British Isles (see map).



北大西洋洋区管制空域示意图；阴影标出Shanwick，邻接Gander、Reykjavik与Santa Maria等空域。

[P07] There have been smaller trials of the idea. One was run by Germany's aerospace agency in 2021 and another, in 2025, by American Airlines and Contrails.org, a not-for-profit research
 35 organisation largely funded by Breakthrough Energy, a network of investors founded by Bill Gates. The results were promising. Blue Skies, which is considerably bigger, should show whether ways to predict and route around ISSRs are both effective and suitable for operational use.

[P08] Shanwick is a bit of airspace well suited to such a project. It is prone to the right sort of
 40 damp chilliness at airliners' cruising altitudes, and it is used by a lot of planes.^{V17V18} In combination, those factors mean that, although it covers just 0.4% of Earth's surface, models suggest Shanwick is responsible for about 5% of contrail-associated warming. What is more, European and American weather satellites monitor the area day and night in both visible-light frequencies and infrared, making it easy to see what is going on.

45 [P09] The plan is that on between 20 and 40 days over the coming winter and again the one after

that air-traffic controllers at NATS, the company which looks after British airspace, will alter the flight paths of aircraft passing through Shanwick to keep them out of suspected ISSRs.^{K04} These changes will route the planes a few hundred metres below their filed flight plans when conditions suggest it and when there is no reason not to (such as turbulence).^{V19V20}

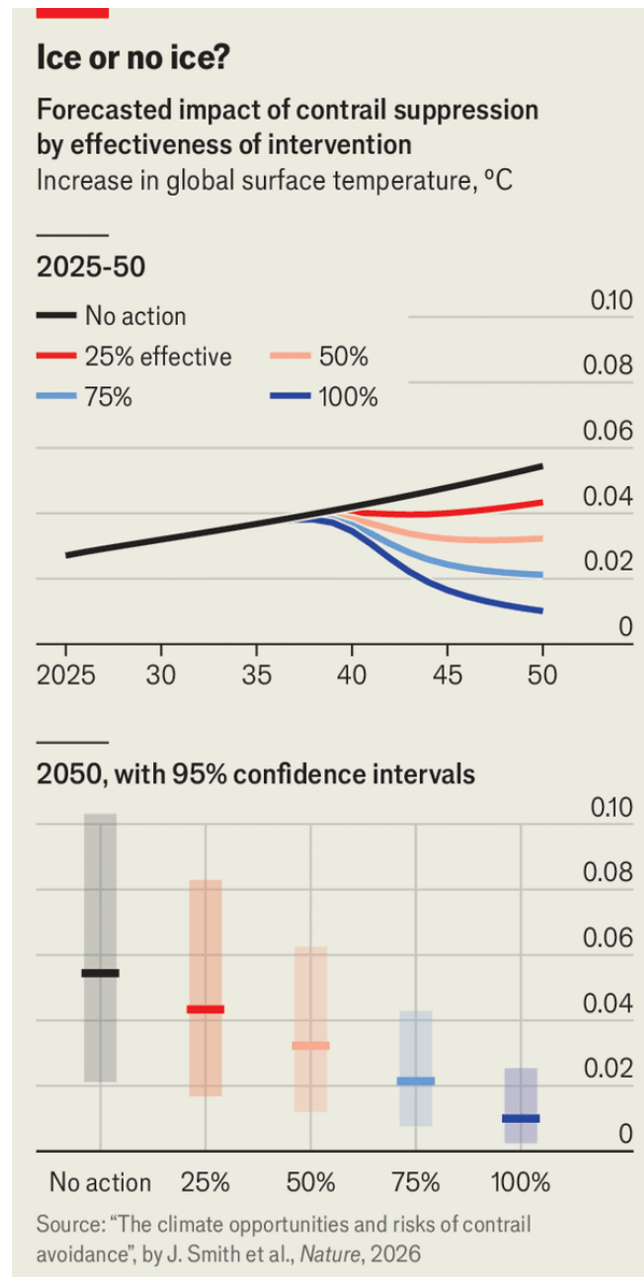
50 [P10] Comparing contrails made during periods when these changes are happening and periods when they are not should provide reliable data on how much the contrails are being reduced.^{K05} “The perfect outcome”, says Sebastian Eastham, part of the team working on Blue Skies at Imperial College, London, “is that a satellite image robustly and reliably has fewer contrails in it, time after time after time.”^{V21}

55 [P11] As well as NATS and Imperial, the consortium behind Blue Skies consists of Contrails.org, Google (which, as well as its software expertise, is chipping £1.4m, or \$1.9m, of hardware and computing time into the £5m budget), the University of Cambridge and Britain’s Met Office.^{V22K06}

[P12] If contrail avoidance is to go mainstream, the Blue Skies trial needs to show not just that 60 days with avoidance measures in place have fewer contrails, but also that integrating the process into normal operations can be done safely and straightforwardly.^{V23V24K07} That would open the way to more widespread, and eventually everyday use.

[P13] Adoption does not have to be universal to be useful.^{V25} The warming attributed to contrails is concentrated. By one estimate 80% of the temperature-raising effect on the climate comes 65 from just 2% of flights. Awkwardly, you cannot know in advance exactly which 2% they are. But Marc Shapiro, who runs Contrails.org, says that a system eliminating 70% of the world’s contrail warming might require changing the flight plans of fewer than 5% of flights.^{V26}

[P14] According to a recent paper by Jessie Smith of Cambridge and colleagues elsewhere, if aviation does not change its ways it will be responsible for about 0.01°C of total warming 70 above preindustrial levels in 2050.^{V27} If the world is seeing about 2°C of warming by then, that contribution comes in at 5%, with more than half of it induced by contrails. A 75%-effective contrail-avoidance programme that began in 2035 would reduce the total by about a third, though there is a lot of uncertainty.



不同尾迹抑制有效率下的温升预测：上图比较2025—2050年路径，下图显示2050年估计及95%置信区间；颜色贯穿两图。

[P15] Fractions of fractions sound small, but Dr Smith and her colleagues argue that the effect is similar in size to that of any other single measure proposed to reduce warming as a result of air transport—and could be realised faster.

[P16] The benefits are not free. Flying at lower altitudes increases the amount of fuel used, which is a cost to airlines, and the amount of carbon dioxide emitted, which is a cost to the planet.^{K08} But neither cost is huge. Estimates from models suggest that avoiding ISSRs makes flights only slightly longer and increases the amount of fuel used by less than 2%.

[P17] Using 2% more fuel on 5% of flights would increase the industry's total fuel bill by a thousandth. In the American Airlines trial the difference in fuel use between the flights that were

diverted and those which were not was undetectable.^{V28V29}

[P18] Similar calculations hold for warming. According to Olivier Boucher, a climate scientist
85 who has worked on the matter for 30 years and now runs Klima, a small French company
dedicated to it, “If you really focus on the most impactful flights, maybe you can save like 100
tonnes of carbon-dioxide equivalent for an extra tonne of carbon dioxide.”^{V30}

[P19] There are also opportunity costs.^{V31} Some worry that focusing on contrails will distract
attention from airlines’ carbon-dioxide emissions and efforts either to reduce them (by using
90 sustainable aviation fuels, or SAFs) or offset them (by removing CO₂ from the atmosphere and
putting it into permanent storage).^{V32} Eliminating contrails without attacking these points—or
reducing the amount of flying—provides a one-off gain but does not change the fundamental
fact that, in the long term, more flying means more warming.^{V33K09}

[P20] Doubters argue as well that SAFs can be designed to produce fewer particles around which
95 ice can form, thus reducing contrails as well as carbon dioxide. This is true. But steering
clear of ISSRs looks like a far more cost-effective approach to contrail reduction.^{V34} The paper
by Dr Smith and her colleagues found that adding SAFs to a system which already practised
avoidance resulted in at most 0.001°C of cooling.

[P21] There is, then, no free lunch. But the idea that giving passengers a minute or two longer to
100 savour the in-flight cuisine that they have paid for on a few of the world’s many many flights
might result in some good is about as appealing as climate interventions get.^{V35K10}

New words and expressions 生词和短语

按原文出现顺序排列；*为优先练习表达。

V01 · P01 **scheduled**

/ˈʃedjuːld/ adj. 定期的；按计划运行的

scheduled passenger flights为定期客运航班，不代表
统计了世界所有军用、私人或货运飞行。

V02 · P01 **add up to***

/æd ʌp tə/ phr. v. 合计为；总计达到

先把全年的航程相加，再按每天作距离比较，不是每一
架飞机都飞到太阳。

V03 · P01 **exhaust**

/ɪgˈzɔːst/ n. 尾气；废气

in the exhaust from their engines指发动机排出的气
体，含水汽而非只有二氧化碳。

V04 · P02 **ephemeral**

/ɪˈfemərəl/ adj. 短暂的；转瞬即逝的

与持续并扩宽的另一类尾迹对照。

V05 · P02 **progenitor**

/prəʊˈdʒenɪtə/ n. 起源者；产生者

将飞机写成尾迹的“祖先”，这里译为产生尾迹的飞机即
可。

V06 · P02 **persist***

/pəˈsɪst/ v. 持续存在

尾迹没有迅速消散；与固执己见这一人的用法不同。

V07 · P02 **translucent**

/trænzˈluːsənt/ adj. 半透明的

能透过部分光，区别于transparent完全透明的通常用
法。

V08 · P02 **wind***

/waɪnd/ v. 缠绕；卷绕

此处读/waɪnd/，不是风/wɪnd/；Wind ... and ...是想象
性操作指令。

Wind the thread around the reel.

把线绕在线轴上。

V09 · P02 **yarn**

/jɑːn/ n. 纱线；线

比喻把云带绕到球体上，用来帮助理解覆盖尺度。

V10 · P03 **constituent**

/kənˈstɪtjuənt/ adj. 组成的；构成的

constituent ice crystals组成尾迹的冰晶，不是选区选
民。

V11 · P03 re-emit

/ri:'mit/ v. 重新发射

吸收辐射后再向不同方向发射，与仅仅反射阳光的过程区分。

V12 · P03 handily

/hændili/ adv. 明显地；轻易地

handily outweighs 强调超过的程度，不是用手操作。

V13 · P03 induce*

/m'dju:s/ v. 引起；诱发

the cirrus clouds they induce 中 they 回指尾迹，后面是省略关系词的定语从句。

V14 · P04 to some extent*

/tə sʌm ik'stent/ phr. 在一定程度上

限定 optional：可以避免部分尾迹增暖，不是任意消除全部气候影响。

The outcome depends on timing to some extent.

结果在一定程度上取决于时机。

V15 · P04 seed

/si:d/ v. 为.....提供形成核心；播种

引号提醒这是比喻，微粒提供冰晶形成所需的核，不是种植农作物。

V16 · P04 nucleus

/nju:kliəs/ n. 核心；凝结核

复数 nuclei；这里是冰晶形成中心，不是讨论原子核裂变。

V17 · P08 prone to*

/prəʊn tə/ phr. 易于；容易出现

prone to damp chilliness 描述容易有潮湿寒冷条件，不等于每天必定如此。

V18 · P08 cruising altitude

/kru:zɪŋ 'æltɪtju:d/ n. phr. 巡航高度

飞机巡航阶段所在高度，区别于起飞或着陆时的全部航迹。

V19 · P09 file*

/faɪl/ v. 正式提交；申报

filed flight plans 为已提交的飞行计划，不是用锉刀修整计划。

V20 · P09 turbulence

/tɜ:bjələns/ n. 湍流；气流扰动

是可能不宜改变高度的因素之一；不能译成有湍流时才去调整。

V21 · P10 robustly

/rəʊ'bʌstli/ adv. 稳健地；经得起检验地

与 reliably、反复出现共同强调结果可重复，不能只凭一张漂亮图片。

V22 · P11 chip in*

/tʃɪp ɪn/ phr. v. 出一份；投入资源

这里投入硬件和计算时间，不能自动改为全部以现金捐款。

V23 · P12 go mainstream*

/gəʊ 'memstri:m/ phr. 进入主流；广泛采用

从试验走向通常运营，需要效果与可执行性两个条件。

V24 · P12 in place*

/ɪn pleɪs/ phr. 已设置好；已实施

measures in place 指措施生效，不是措施在某个物理位置摆着。

V25 · P13 universal

/ju:nɪvɜ:səl/ adj. 普遍的；全面的

does not have to be universal 说无需全部采用，而不是说全面采用被禁止。

V26 · P13 eliminate*

/ɪ'lɪmɪneɪt/ v. 消除；去除

70% 修饰尾迹增暖，不是消除全球全部增暖或70%的航班。

V27 · P14 preindustrial

/pri:m'dʌstriəl/ adj. 工业化前的

温升的比较基准，不能把升温幅度与当天气温混为一谈。

V28 · P17 divert*

/dɑ:vɜ:t/ v. 使改道；改变方向

diverted flights 在本试验语境包括计划航迹调整，不必是紧急备降。

V29 · P17 undetectable

/ʌndrɪ'tektəbəl/ adj. 检测不出的

受检测精度、样本与条件限制，不能直接证明绝对差异为零。

A small difference may be undetectable in a short trial.

在短期试验中，微小差异可能检测不出。

V30 · P18 carbon-dioxide equivalent

/kɑ:bən dɑ:'ɒksaɪd ɪ'kwɪvələnt/ n. phr. 二氧化碳当量

将气候影响换到可比较的尺度，不代表真的从大气取走了该吨数的二氧化碳。

V31 · P19 opportunity cost

/ɒpə'tju:nəti kɒst/ n. phr. 机会成本

把资源和注意力投向一种措施，可能挤占另一种措施，不只是账面燃料费。

V32 · P19 offset*

/ɒfset/ v. 抵消；补偿

原文以移除并永久储存二氧化碳为例，与减少新的排放分开。

V33 · P19 one-off

/ˌwʌn ˈɒf/ adj. 一次性的

收益不能无限随飞行增长而重复扩大，详见长期与短期作用的注释。

V35 · P21 savour*

/ˈseɪvə/ v. 品味；细细享受

与机上餐食构成结尾幽默，额外一两分钟被写成“多享受一会儿”。

V34 · P20 steer clear of*

/stiə ˈkliə əv/ phr. 避开；绕开

与避开特定大气区域对应，不是停止所有飞行。

The team steered clear of the flooded road.

团队避开了被水淹的道路。

Notes on the text 课文注释

1 航班数、航程和天空覆盖率是三种分母

[P01 / P02]

P1的40%以2019年航班数为分母，且只要求至少一段航程留下尾迹；P2的5%以总飞行距离为分母，说持久尾迹出现的路径；千分之一则是任一时刻的天空覆盖估计。三个数字不能相减来求“剩余尾迹”。

日地、月地距离与缠线球是尺度比喻：把全年航程平均分到每天，再与太空距离相比，并不表示飞机实际上飞向太阳或月球。maybe与about也提醒读者这些是帮助理解量级的估计，而非对任一秒天空的精确测量。

2 从排气到持久云带：环境水汽加入才会扩展

[P03 / P04 / P05]

尾气带来水汽与形成冰晶的条件，周围空气中的水汽继续加入，尾迹才可能维持并扩宽。原文用seed解释颗粒作为冰晶形成核心的作用：很冷不等于所有水汽会立刻自动变成冰块，具体温湿度与形成过程仍重要。

反射阳光的一面只在有日照时发挥作用，吸收再发射红外辐射则不依赖日照。24-hour warming强调该增暖机制可昼夜发生，并不是说每条尾迹的寿命恰好24小时。净效果仍要把冷暖两面合起来。

ISSR横向很宽、垂直较薄，给小幅改高度提供了可能。tend to与should保留条件，不能从8—13公里这一常见范围推出“全部飞机飞到8公里以下就已解决气候问题”。

3 为何选这片空域：形成条件、航班密度与可观察性

[P06 / P07 / P08]

寒冷潮湿有利于持久尾迹，大量航班提供作用机会，卫星又能反复观察。0.4%是地表面积份额，5%是模型估计的尾迹增暖份额；两者并列说明影响集中，而不是说那里有5%的世界人口或飞行里程。

smaller trials与promising先给已有线索，considerably bigger与operational use再提出更高要求：小规模试验有希望，不等于在繁忙空域已经证明普遍可行。

4 好结果需要反复出现，也要进得了日常程序

[P09 / P10 / P11 / P12]

P9是两个冬季各选20—40天，而不是连续两个冬季每天都调整。suspected ISSRs承认预测性质；when conditions suggest it与没有湍流等不宜调整理由共同限定执行。

P10比较实施与未实施调整两类时段中形成的尾迹，time after time强调重复观察。P12又加上not just ... but also：不仅图像里的尾迹减少，还需安全、简便地嵌入日常运营。单一漂亮案例不能同时回答所有问题。

P11的140万英镑投入是硬件和计算时间的价值，是500万英镑预算中的一部分；不能把两者相加说预算640万，也不能把资源投入自动写成同额现金。英国气象局项目介绍将试验冬季明确为2026/27与2027/28。

5 影响高度集中，不代表事先知道该挑哪几班

[P13]

80%的增暖集中在2%的航班，是一种分布估计。紧接Awkwardly指出，事先并不能精确识别这2%；不能把集中性直接当作可无误执行的名单。

Shapiro的另一个判断是，减少70%的尾迹增暖或许需要改不到5%的航班计划。70%与80%、2%与5%来自不同表述，不要拼成“只改2%航班就必定消除80%全球变暖”。may/might的条件必须随数字保留。

6 P14数字辨误：先核数量级，再谈比例

[P14 / P15]

原文写0.01°C，并说在2°C总温升中占5%。直接计算 $0.01 \div 2 \times 100\% = 0.5\%$ ，二者不一致。本课保留原文及对应译文，不能把这一组数当作正确百分比范例。

Smith等人在《Nature Communications》论文摘要中，列出2050年未采用规避时的航空二氧化碳增暖0.040 K与尾迹增暖0.054 K，合计0.094 K，约0.1°C；按2°C比较约为4.7%。这是对论文数值的算术核对，并非报刊官方勘误，也不证明所有航空影响或所有未来情景都等于此数。

P14的75%有效率、2035年开始和约减三分之一仍按报道自身情景阅读，不能因核对了数量级，就声称已逐一验证其全部模型设定。P15的could与不确定性提示，规模和实施速度都是带条件的论证。

the total接回航空业造成的增暖贡献，减少约三分之一并非将全球总温升减少三分之一。图中颜色对应不同干预有效率，上半图看时间路径，下半图看2050年的点估计与95%置信区间；区间呈现模型估计的不确定性，不要只取一条线当作确定的未来。

7 千分之一、检测不出与100吨当量，各自说明什么？

[P16 / P17 / P18]

$2\% \times 5\% = 0.1\%$ = 千分之一，是P17使用的简化计算。它把受影响航班在基准燃油成本中的权重近似成航班数量占比；若这些航班原来耗油特别高或低，就需按耗油或成本加权。不能只凭数量占比精确核算全行业账单。

试验中undetectable表示没有检测出差异，不等于已证明所有航班都零成本。模型的不到2%、试验未检出差异和受访者的100吨当量比喻是三类证据，不能合并成同一项已实现保证。

P18比较的是避免的气候影响与额外二氧化碳排放；当量不是物理移除量。maybe与like使受访者的表达保留近似和条件，不能转成每多烧一吨燃料必定赚到100吨碳信用。

8 一次性改善不是永远不用再减排

[P19 / P20 / P21]

opportunity costs把注意力从燃料账单转向资源分配：如果尾迹工作挤走了减排、移除与永久储存方面的努力，也有代价。原文的reduce与offset给出不同路径，不能把所有措施都叫“少形成一点尾迹”。

P20的0.001°C是已经采用规避之后，再增加可持续燃料的模型增量，不是可持续燃料在所有场景的总价值上限。也不能据此认定新燃料完全没有其他收益。

结尾no free lunch承认代价，再用in-flight cuisine把小幅延时写成“多品味一会儿餐食”。这是带轻松语气的有条件支持，不能把作者的话改成飞机餐很好吃、所有措施都免费的字面结论。

Special difficulties 难点辨析**1 aircraft的复数通常仍写aircraft**

[P03]

P3原句有aircrafts'的写法，本课按供稿保留。通常aircraft单复数同形，仿写可用contrails from aircraft或carbon dioxide emitted by aircraft engines，避免照搬这个复数形式。

同句中the cirrus clouds they induce含省略关系词的定语从句；they指尾迹。than后比较的是航空二氧化碳的升温作用，不能扩大成全世界所有二氧化碳排放。

2 do not have to与do not : 无需普遍, 不是否定有用

[P12 / P13]

Adoption does not have to be universal to be useful意为不必全部采用也能有效; 若译成“普遍采用没有用”, 就把必要条件的否定误写成效果的否定。

P12 If ... is to go mainstream则从目标出发提出前提: 若要广泛采用, 就需要证明效果和安全整合。这两段合看, 是有选择地推广仍要过验证门槛。

Background 背景与延伸**1 短寿命云迹与长期二氧化碳: 时间维度不同**

[P03 / P19]

一条尾迹会消散, 航空活动又不断产生新尾迹; 减少形成可较快改变这部分影响。二氧化碳的累积与长期作用则是另一条路径。因此同样使用“增暖”一词, 不代表两种作用的持续时间、响应速度和比较尺度都相同。

这里的one-off gain不是说一次改航路后便可永远停止规避, 而是这种措施带来的是一项可避免影响的改善, 不能无限抵消长期增加的排放。理解这一点, 才不会把减少尾迹当作对其他减排工作的替代。

2 温度差、百分比和模型情景怎样对应?

[P14 / P15 / P20]

对温度变化而言, 1 K的差与1°C的差大小相同, 因此0.094 K温升可写为0.094°C温升; 这不意味着0 K绝对温度等于0°C。计算占比前, 须让分子分母都是温升幅度。

温升模型还依赖未来飞行需求、措施采用时期及效果等设定。已采用规避后的额外改善, 与未采用规避的基准总影响, 是不同的比较问题; 引用一个小数时必须连同情景一起读。

Key structures 关键句型**K01 · P02 Wind ... and you will find ... : 用动作带出推想**

Wind those stripes around Earth like yarn around a ball and you will find that, at any one time, persistent contrails cover maybe a thousandth of the sky.

把这些云带像纱线绕球那样缠在地球上, 你会发现, 在任一时刻, 持续性尾迹或许覆盖了天空的千分之一。

Wind是祈使句的动词, 读/waɪnd/, 意思是缠绕; and后接you will find ..., 可理解为“如果把这些痕迹想象成缠起来的线球, 就会发现……”。不是wind风作主语后省略了谓语。

that引导find的宾语从句, 内部主干为persistent contrails cover ...; at any one time是插入的时间状语, maybe保留覆盖量的估计。祈使句 + and + 陈述句把想象条件写得具体; 缠线球是尺度比喻, 并非真实测量实验。

Add the same amount to both sides and you get an equivalent equation.

在两边加上相同的量, 就得到一个等价的方程。

K02 · P04 For ... to ... , the air they are in must ... : 先抓主句再补修饰

For contrails to persist the air they are in must be well below freezing point and yet contain a significant amount of not-yet-frozen water vapour.

尾迹若要持续存在, 它所在的空气必须远低于冰点, 同时仍含有相当数量尚未冻结的水汽。

For contrails to persist说明持续存在所需的条件, 可译为“要让尾迹维持下去”。主句主语为the air, must后面的条件描述空气状态; 不能把contrails当作must的主语。

they are in修饰air, 省略了关系词that/which; 还原为the contrails are in the air, they指尾迹。介词in留在修饰从句末尾, 读到它时要接回air, 而不是把air they当作两个并列主语。

For the seedlings to survive, the soil they are in must stay moist.

要让幼苗存活, 它们所在的土壤必须保持湿润。

K03 · P04 The thing which ... is a lack of ... : 三层关系从句

The thing which stops this water vapour freezing is a lack of particles that might “seed” the process by acting as nuclei around which crystals can form.

阻止这些水汽冻结的，是缺少能够充当冰晶形成核心、为冻结过程“播种”的颗粒。

先取主干：The thing ... is a lack of particles. which stops ... 修饰thing，回答阻止云形成的究竟是什么；主句is一直要读到后面才出现。lack of说缺少颗粒，不能遗漏lack而误读成颗粒阻止结冰。

that might seed ... 修饰particles，说明颗粒可能起的作用；around which ... 再修饰nuclei，意为冰晶围绕这些核心形成。两层关系从句中的先行词不同，which不能都指回开头thing。seed在此作动词，用播种比喻引发形成。

The feature which attracts readers is a set of examples that act as anchors around which the argument develops.

吸引读者的是一组例子；这些例子像锚点，论证围绕它们展开。

K04 · P09 The plan is that ... will alter ... : 长时间状语中别丢主语

The plan is that on between 20 and 40 days over the coming winter and again the one after that air-traffic controllers at NATS, the company which looks after British airspace, will alter the flight paths of aircraft passing through Shanwick to keep them out of suspected ISSRs.

计划是在即将到来的冬季选取20至40天，并在下一个冬季再次这样做，由负责英国空域的NATS公司的空管人员，调整经过Shanwick的飞机的飞行路径，让它们避开疑似冰面过饱和区。

The plan is that ... 中that引出计划的具体内容。内部从句的主干为controllers ... will alter the flight paths ...，不是看到winter就结束整个句子。on 20–40 days ... and again ... 给出两季各选若干天的安排。

NATS后的插入说明介绍机构身份，passing ... 后置说明相关航空器，to keep ... out of ... 解释调整目的。suspected限定ISSRs，保留预测尚待验证的性质；future will表示计划，不应译成已经完成。

The plan is that on selected days next month the guides will change the routes used by visitors to keep them away from fragile paths.

计划是，下个月选定的日子里，导游将改变游客使用的路线，让他们避开脆弱的步道。

K05 · P10 Comparing A and B should provide ... : 长主语与省略

Comparing contrails made during periods when these changes are happening and periods when they are not should provide reliable data on how much the contrails are being reduced.

比较实施这些调整的时段与未实施调整的时段中形成的尾迹，应能可靠地反映尾迹究竟减少了多少。

主语是Comparing ... 这一整个动名词结构，主句谓语为should provide。Comparing的宾语为contrails，made during ... 后置修饰尾迹；during后并列两个periods，各带一个when从句。比较的是调整发生与不发生两类时段中形成的尾迹，不是把时段本身当作尾迹。第二个when中的they指these changes，are not后省略happening。

should保留预期：这种比较应能提供关于减少了多少的证据，不是说研究人员已经拿到了结论。读长句时可先把两个时段分别标成A、B，再回到比较提供什么信息。

Comparing readings taken when the pump is running and when it is not should reveal how much noise it adds.

比较水泵运转时与不运转时的读数，应能显示它增加了多少噪声。

K06 · P11 As well as ... , consists of ... : 名单与插入说明分层

As well as NATS and Imperial, the consortium behind Blue Skies consists of Contrails.org, Google (which, as well as its software expertise, is chipping £1.4m, or \$1.9m, of hardware and computing time into the £5m budget), the University of Cambridge and Britain's Met Office.

除了NATS和帝国理工学院，“蓝天行动”的联合团队还包括Contrails.org、谷歌、剑桥大学和英国气象局；谷歌除提供软件专长外，还向500万英镑的预算投入了价值140万英镑（190万美元）的硬件和计算时间。

句首As well as把NATS和Imperial纳入团队，后面的consists of继续列出其余成员，不能误读成“除了两家机构以外，它们不参加”。名单中的and连接成员，而括号里的which只引出对Google的补充。括号内部又有as well as，表示除软件专长之外的另一项投入。is chipping ... into the budget中的into把硬件和计算时间的投入接入总预算；140万与500万是部分与整体的关系，而不是两个待相加的总成本。

As well as the library and the school, the group consists of a museum and a local firm, which is contributing equipment towards the project.

除图书馆和学校外，团队还包括一家博物馆和一家为项目提供设备的本地企业。

K07 · P12 If ... is to ... , needs to show not just that ... but also that ...

If contrail avoidance is to go mainstream, the Blue Skies trial needs to show not just that days with avoidance measures in place have fewer contrails, but also that integrating the process into normal operations can be done safely and straightforwardly.

尾迹规避若要进入主流，“蓝天行动”就不仅需要证明实施规避措施的日子尾迹更少，还必须证明这一流程能够安全、简便地融入日常运行。

is to go mainstream在if条件中从目标提出必要前提，可译“若要进入日常广泛使用”。它不是预测必然会成功，也不是说某条命令要求试验已经完成。

show后面not just that ... but also that ...并列两项需要证明的内容：效果，以及进入日常程序时的安全和便利。第二个that内部的integrating ...是动名词主语，不应与主句的show混作同一层谓语。

If the scheme is to expand, it needs to show not just that it saves time but also that using it is straightforward.

若要扩大这项方案，就需要证明它不仅节省时间，而且使用起来简便。

K08 · P16 Flying ... increases A, which ... , and B, which ... : 两类成本

Flying at lower altitudes increases the amount of fuel used, which is a cost to airlines, and the amount of carbon dioxide emitted, which is a cost to the planet.

降低飞行高度会增加耗油量，给航空公司带来成本，也会增加二氧化碳排放，给地球带来代价。

Flying ...整体作主语，increases为主句谓语；它带两个并列宾语：燃料用量与排放的二氧化碳量。used与emitted分别后置修饰fuel和carbon dioxide，不是两个新的主句谓语。

两个which补充各自增加量造成的成本，分别落在航空公司与地球。作者用平行结构把账面成本与气候代价并排，不能只取第一组就说全文没有考虑额外排放。

Running the machines longer increases the electricity used, which raises costs, and the heat released, which warms the room.

机器运转更久会增加用电，从而提高成本，也会增加放热，从而使房间升温。

K09 · P19 Eliminating ... provides ... but does not change the fact that ...

Eliminating contrails without attacking these points—or reducing the amount of flying—provides a one-off gain but does not change the fundamental fact that, in the long term, more flying means more warming.

如果不处理这些问题，也不减少飞行量，单独消除尾迹只会带来一次性收益，而不会改变一个根本事实：长期而言，更多飞行意味着更多增暖。

Eliminating ...构成完整主语，without ...说明未同时采取哪些措施；同一个主语支配provides和does not change两个并列谓语。but把短期可得收益与长期仍存问题接起来。

the fact that ...中的that解释fact的内容，在内部不充当主语或宾语，因此不是像the fact that we discussed那样修饰fact的关系代词。文意承认规避有收益，同时指出它未改变更多飞行带来更多长期增暖的关系。

Removing the backlog provides immediate relief but does not change the fact that new requests arrive every day.

清掉积压任务能立即缓解压力，但并未改变每天都有新请求到来的事实。

K10 · P21 The idea that ... might ... is ... : 从长主语走到结尾幽默

But the idea that giving passengers a minute or two longer to savour the in-flight cuisine that they have paid for on a few of the world's many many flights might result in some good is about as appealing as climate interventions get.

不过，在全世界众多航班中的少数几班上，让乘客多花一两分钟品味他们已经付钱的机上餐食，或许就能带来一点好处——作为气候干预措施，这几乎已是最诱人的想法了。

最外层是The idea ... is about as appealing as ...。第一个that解释idea的内容；其中giving passengers ...作主语，might result ...作谓语，所以不能把giving错当作idea的谓语。

cuisine后另一个that修饰餐食，指出这是乘客付钱购买的东西；它与解释idea的第一个that分工不同。about as ... as ... get表示差不多已达到这类干预最吸引人的程度，带有夸张；“多品味一两分钟机上餐食”是把细小不便反写成享受的幽默。

The idea that giving visitors more time to examine the objects that they came to see might improve learning is highly appealing.

让游客多花时间查看他们专程来看之物，或许能改善学习效果；这个想法很有吸引力。

Exercises 练习与写作

Listening 听力 (选做)

选做：听开头两段，辨认每个比例对应的对象。

02 What do more than 40%, about 5% and about a thousandth describe?

Comprehension 理解

回答时保留时间、条件、估计性质及分母。

03 Why can a contrail cool and warm, and why does 24-hour warming not specify its lifetime?

04 Why is Shanwick useful for the trial?

05 What must the trial demonstrate before wider operational use?

06 Why does the concentration of warming in 2% of flights not provide a ready-made list of flights to change?

07 Check the statement that 0.01°C is 5% of 2°C.

08 Under what simplifying assumption does 2% extra fuel on 5% of flights imply a 0.1% increase overall?

09 Why does contrail avoidance not remove the need to address aviation's carbon-dioxide emissions?

Words in use 词汇

用词库填空，每项一次。

词库：in place / chip in / undetectable / steer clear of / one-off

10 The safety checks must be ____ before the opening.

11 Each partner agreed to ____ with equipment or advice.

12 The change was ____ with this instrument, though it might still exist.

13 Drivers were told to ____ the flooded streets.

14 The grant was a ____ payment, not a yearly subsidy.

Key structures 句型

先辨识真实层级，再将结构用于新情境。

15 Use an imperative and and: "If you add ten, you get fifty."

- 16 Restore the omitted relative word in “the soil they are in”.
- 17 In P4, what does around which refer back to?
- 18 Find the main subject and verb inside the that clause of P9’s opening sentence.
- 19 What is omitted after is not in “when the pump is running and when it is not”?
- 20 Does the £1.4m contribution in P11 add to the £5m budget to make £6.4m? Explain into.
- 21 Use not just that ... but also that ...: “The team must show that the method works and that it is safe.”
- 22 Name the two quantities that Flying ... increases in P16.
- 23 Is that a relative pronoun in “the fact that new requests arrive every day”? Why?
- 24 Identify the outer subject and main verb in P21’s final sentence.

Summary writing 摘要

用100–120词概括尾迹机制、试验设计与主要权衡；避开原文有算术疑点的数字。

- 25 Write a 100–120-word summary.

Composition 作文（选做）

选做：用100–120词，说明一个小规模试验走向日常使用还需证明什么。

- 26 Discuss why a successful demonstration is only one step towards routine use.

Reference translation 参考译文

P01 2019年执行的4000万班定期客运航班，飞行总里程约为610亿公里——平均到一年中的每一天，都超过地球到太阳的距离。其中超过40%的航班，在至少部分航程中留下了凝结尾迹，这是因为发动机尾气中的水汽冻结成了微小冰粒。

P02 许多尾迹转瞬即逝。它们在产生自己的飞机身后延伸，随后迅速消散。但在约占总飞行距离5%的航程上——换算成每天往返月球十次还绰绰有余——大气中原有的水汽也加入冻结过程，使尾迹持续存在并不断扩宽。纤细白线变成了宽阔、半透明的卷云带。把这些云带像纱线绕球那样缠在地球上，你会发现，在任一时刻，持续性尾迹或许覆盖了天空的千分之一。它们在这个过程中使地球变暖。

P03 尾迹呈白色，是因为组成它们的冰晶会反射阳光。这在白天可能产生降温效果。但冰晶也会吸收红外辐射并重新发射，颇像温室气体的作用。其中一部分因而辐射到太空，其余则返回地球方向。这带来全天候的增暖作用，总体上明显超过降温作用（非尾迹形成的卷云也如此）。净增暖的确切大小很难计算，但现有证据表明，飞机的尾迹及其诱发的卷云，对地球升温的作用可能超过飞机发动机排放的二氧化碳。

P04 不过，这种增暖在一定程度上是可以选择避免的。尾迹若要持续存在，它所在的空气必须远低于冰点，同时仍含有相当数量尚未冻结的水汽。阻止这些水汽冻结的，是缺少能够充当冰晶形成核心、为冻结过程“播种”的颗粒。一条尾迹能提供数以万亿计的这类“种子”，从而在原本无云的地方制造出云。

P05 这样的冰面过饱和区（ISSR），通常位于8至13公里的高空。它们横向延伸几百公里，垂直厚度却只有几百米。让飞机避开这些区域，就应该能去掉大量持续性尾迹，也就意味着避免一部分增暖。

P06 8月18日，一个设在英国的联合团队宣布开展“蓝天行动”，这是迄今针对这一气候降温思路最重要的试验。试验将位于Shanwick空域：不列颠群岛以西、覆盖北大西洋180万平方公里的一片空域（见地图）。

P07 这一想法此前已有较小规模的试验。其中一项由德国航空航天机构于2021年开展；另一项于2025年由美国航空与非营利研究机构Contrails.org开展，后者主要由比尔·盖茨创立的投资者网络Breakthrough Energy资助。结果令人鼓舞。规模大得多的“蓝天行动”应能检验，预测并绕开冰面过饱和区的方法，是否既有效又适合实际运行。

P08 Shanwick空域很适合这样的项目。在客机巡航高度，它容易出现所需的那种潮湿寒冷天气，而且有很多飞机经过。这些因素结合起来，意味着虽然它只覆盖地球表面的0.4%，模型却认为它产生了约5%的尾迹相关增暖。此外，欧洲和美国的气象卫星使用可见光波段与红外线，昼夜监测这一区域，使人们容易看清发生了什么。

P09 计划是在即将到来的冬季选取20至40天，并在下一个冬季再次这样做，由负责英国空域的NATS公司的空管人员，调整经过Shanwick的飞机的飞行路径，让它们避开疑似冰面过饱和区。当气象条件提示应当调整、且没有湍流等不宜调整的理由时，这些改变会使飞机比已申报飞行计划中的高度低几百米飞行。

P10 比较实施这些调整的时段与未实施调整的时段中形成的尾迹，应能可靠地反映尾迹究竟减少了多少。伦敦帝国理工学院参与“蓝天行动”的Sebastian Eastham说，“最理想的结果”，就是“一次又一次，卫星图像都以稳健、可靠的方式显示更少的尾迹”。

P11 除了NATS和帝国理工学院，“蓝天行动”的联合团队还包括Contrails.org、谷歌、剑桥大学和英国气象局；谷歌除提供软件专长外，还向500万英镑的预算投入了价值140万英镑（190万美元）的硬件

和计算时间。

P12 尾迹规避若要进入主流，“蓝天行动”就不仅需要证明实施规避措施的日子尾迹更少，还必须证明这一流程能够安全、简便地融入日常运行。这将为更广泛、最终成为日常做法的应用铺平道路。

P13 不必所有航班都采用，这种方法也能有用。尾迹造成的增暖高度集中。一项估计认为，气候升温效果的80%，仅来自2%的航班。棘手的是，你无法事先确切知道是哪2%。不过，Contrails.org负责人Marc Shapiro说，一个消除全球70%尾迹增暖的系统，或许只需要改变不到5%航班的飞行计划。

P14 根据剑桥大学的Jessie Smith与其他机构同事最近的一篇文章，如果航空业不改变现有做法，到2050年，它造成的相对于工业化前水平的总增暖将约为0.01°C。如果届时全球升温约为2°C，那么这项贡献就占5%，其中超过一半由尾迹造成。如果一项有效率为75%的尾迹规避计划在2035年开始实施，就会将航空业造成的总增暖减少约三分之一，不过其中有很大不确定性。

P15 小比例中的小比例听起来不多，但Smith博士及同事认为，这种效果与任何其他单项降低航空运输增暖的提议相比，规模相近，而且能更快实现。

P16 收益并非没有代价。降低飞行高度会增加耗油量，给航空公司带来成本，也会增加二氧化碳排放，给地球带来代价。但两种代价都不算大。模型估计认为，避开冰面过饱和区只会让飞行稍微变长，耗油量增加不到2%。

P17 如果5%的航班多用2%的燃料，整个行业的燃油账单就会增加千分之一。在美国航空的试验中，改道航班与未改道航班之间的耗油差异未能被检测出来。

P18 类似的计算也适用于增暖。Olivier Boucher是一名研究这一问题已有30年的气候科学家，如今经营专注于此的法国小公司Klima；他说：“如果你真正聚焦影响最大的航班，或许每多排放一吨二氧化碳，就能避免大约100吨二氧化碳当量的气候影响。”

P19 此外还有机会成本。有人担心，把注意力集中在尾迹上，会分散人们对航空公司二氧化碳排放的关注，以及对减排或抵消排放工作的关注：前者可使用可持续航空燃料（SAF），后者可从大气中移除二氧化碳并将其永久封存。如果不处理这些问题，也不减少飞行量，单独消除尾迹只会带来一次性收益，而不会改变一个根本事实：长期而言，更多飞行意味着更多增暖。

P20 质疑者还指出，可持续航空燃料可以通过设计减少供冰晶形成的颗粒，因而在减少二氧化碳的同时减少尾迹。这确实如此。但就减少尾迹而言，避开冰面过饱和区看起来是一种成本效益高得多的方法。Smith博士及同事的论文发现，在已经实行规避的系统中加入可持续航空燃料，最多只多带来0.001°C的降温。

P21 所以，天下没有免费的午餐。不过，在全世界众多航班中的少数几班上，让乘客多花一两分钟品味他们已经付钱的机上餐食，或许就能带来一点好处——作为气候干预措施，这几乎已是最诱人的想法了。

Reference answers 参考答案与解析

开放题不要求与参考答案逐字一致；先检查信息和意思，再修改表达。

Before you read 读前思考

01 读前思考

Whether it reduces warming from contrails, how much extra fuel it uses, and whether the change can be made safely and reliably.

这是评估问题，不能从改道幅度小直接推定总效果一定好。

Listening 听力

02

Flights that left a contrail for some of the journey, total distance associated with persistent contrails, and estimated sky coverage at any moment, respectively.

航班数、航程与天空覆盖不是同一分母；只写三个数字不足以作答。

Comprehension 理解

03

It reflects sunlight but also absorbs and re-emits infrared radiation. The warming mechanism can operate by day and night; the phrase does not say that every contrail lasts exactly a day.

从作用发生时段区分云迹存在时长。

04

It combines conditions favourable to persistent contrails with heavy traffic and satellite coverage, making a concentrated source of warming observable.

面积与增暖份额可作补充；不是只因为面积大。

05

Repeated reductions in contrails and the ability to integrate the changes safely and easily into normal operations.

效果与实施能力缺一不可；试验仍是计划。

06

The flights responsible cannot be identified precisely in advance. Concentration estimated across flights does not guarantee perfect prediction for each future flight.

集中分布与事前识别是两件事。

07

0.01 divided by 2 is 0.005, or 0.5%, so the two figures in the article are inconsistent.

论文约0.094 K的合计可帮助核数量级，但不能把算术核对写成报刊正式勘误。

08

The affected flights are assumed to account for about 5% of baseline fuel use or cost as well as 5% of flight numbers.

航班数量占比不必等于耗油占比；undetectable也不能证明绝对为零。

09

It can reduce one source of warming but does not remove the longer-term effect of continued and growing carbon-dioxide emissions.

承认一项收益不等于认定它解决所有影响；P20的0.001°C是先规避后的额外比较。

Words in use 词汇**10**

in place

表示已经设置并能实施。

11

chip in

to后用原形，投入不限于现金。

12

undetectable

没有检测出不自动等于不存在。

13

steer clear of

to后接动词词组，意为避开。

14

one-off

一次性与每年重复相对。

Key structures 句型**15**

Add ten and you get fifty.

可接受表达：

- Add ten and you will get fifty.
- Add ten and you'll get fifty.

此处用祈使动作带出结果，不必改成疑问句。

16

The soil that they are in; or the soil which they are in.

that/which作in的宾语；也可写the soil in which they are.

17

Nuclei.

冰晶围绕核心形成，不是围绕开头的the thing。

18

Controllers at NATS; will alter.

时间状语、机构介绍与目的不替代这一主谓关系。

19

Running.

重复的进行时内容可省略，否定仍指水泵不运转的时段。

20

No. The contribution is being put into the £5m budget and forms part of that total.

另须保留硬件和计算时间，不自动改为现金。

21

The team must show not just that the method works but also that it is safe.

两个that从句都作show的宾语，内容各自完整。

22

The amount of fuel used and the amount of carbon dioxide emitted.

used与emitted修饰名词；两组成本由后面的which说明。

23

No. It introduces the content of the fact; the clause new requests arrive every day is complete without a missing noun role.

与the fact that we discussed中discussed缺宾语的结构作区别。

24

The idea followed by its that clause; is.

giving ... might result位于idea的内容从句中，不是最外层主谓。

Summary writing 摘要

25

Persistent aircraft contrails can reflect sunlight but cause net warming by trapping outgoing heat. Operation Blue Skies will test whether small altitude changes over the North Atlantic can prevent their formation. It must demonstrate repeated reductions as well as safe integration into normal operations. Since warming is concentrated in a small share of flights, widespread benefits may not require changing every route, although identifying the right flights in advance remains difficult. Extra fuel use could be limited, but costs and climate gains require careful comparison. Avoiding contrails may offer a relatively quick improvement; it does not remove the need to reduce aviation's longer-term carbon-dioxide impact.

参考摘要105词左右；核心链条是机制、可验证操作、选择性干预与未消失的长期问题。

Composition 作文**26**

A school tests a new system that adjusts classroom lighting automatically. In one room it saves electricity, but this result alone does not justify installing it everywhere. The school needs repeated measurements across different rooms and seasons. It must also check whether the system is easy to operate and whether occasional faults interrupt lessons. Equipment, maintenance and training costs should be compared with the likely savings. A sensible next step would be a larger trial with clear success criteria. The original demonstration can establish that the idea is promising, while the wider trial shows whether it remains useful under ordinary working conditions.

原创情境；从可重复性、操作负担与净收益推进，而不是只重述第一次节电成功。