Impact of Subsonic Aviation on Nonmelanoma Skin Cancer Incidence Due to Atmospheric Ozone Variation

Elza Brunelle-Yeung
Master's Student
PARTNER Lab
Department of Aeronautics and Astronautics
MIT

Prof. Ian Waitz
Research Advisor
Department of Aeronautics and Astronautics
MIT

Submitted to
The Fourth Annual Joseph A. Hartman
Student Paper Competition

January 31st 2008
Massachusetts Institute of Technology
Cambridge, Massachusetts, USA

Table of Contents

IMPACT OF SUBSONIC AVIATION ON NONMELANOMA SKIN CANCER INCIDENCE DUE TO ATMOSPHERIC OZONE VARIATION

Elza Brunelle-Yeung
Massachusetts Institute of Technology, Cambridge, MA, USA

Abstract

NO_x emissions from the worldwide subsonic fleet contribute to a net increase in total atmospheric ozone column. Although an ozone increase can cause respiratory ailments, it can be beneficial in reducing the number of skin cancer incidences and associated mortalities. Variations of column ozone due to aircraft emissions are used to approximate decreases in nonmelanoma skin cancer (NMSC) incidences and mortalities in the U.S. and Australia for 1992 and 2015. Valuation of these benefits is also presented. In 1992, subsonic aviation has decreased the number basal cell carcinoma (BCC) mortalities by an estimated 1.2 to 2.3 cases in the USA. The decrease in the number of squamous cell carcinoma (SCC) deaths is estimated to be between 8.1 and 14.0 in the USA in 1992. The valuation of these lives saved is greater than the valuation of direct medical costs associated with the decrease in total number of NMSC cases. This is explained by the relative simplicity of treatment for NMSC.

Introduction

Aircraft emissions impact both the global atmosphere and local air quality. In terms of health impacts, increased ambient concentrations of particulate matter produced by aircraft lead to respiratory and cardiac ailments, as well as premature mortality. While aviation emissions clearly have associated health costs, they may also yield certain health benefits as they react in a complex atmospheric chemistry. An account of all health costs and benefits constitutes an important tool in policymaking. Therefore, a solid understanding of all aviation health impacts will aid in assessing different aviation-related policies. This study was conducted as part of PARTNER's Aviation Portfolio Management Tool (APMT) development effort, specifically, the Benefits Valuation Block – Local Air Quality module (BVB-LAQ).

Subsonic aircraft flying at altitudes between 9 and 13 km emit NO_x, an ozone precursor, in the upper troposphere. The net resulting increase in ozone leads to a decrease in UV radiation (UVR), namely of the UV-B type, reaching the surface of the Earth and hence potentially decreasing the incidence of skin cancer. Biological effects of UV radiation on humans include skin cancer and ocular damage. There exist two types of skin cancer in which UVR plays a role: cutaneous malignant melanoma (CMM) and nonmelanoma skin cancer (NMSC).

At present, the exact action spectrum of UV-B and UV-A on CMM is not completely understood.[22], [30] Some reports even conclude that ozone has a very minor effect on CMM, since UV-A, which is not filtered by ozone, was found to be the main risk factor.[13], [28] However, other reports refer to two different studies on newborn mice to suggest that UV-B also plays a part in human melanoma formation.[23], [26] Due to the lack of consensus on the issue, it is difficult to estimate the impact of a change in ozone on melanoma incidence. Therefore, this report does not include an estimate for changes in melanoma skin cancer incidence and mortality.

Unlike CMM, the relationship between UV-B and NMSC is well understood. It has been studied in numerous reports, based on animal experiments and epidemiological data. [30] NMSC can be divided into basal cell carcinomas (BCC) and squamous cell carcinomas (SCC). As per UNEP 1994, BCC cases represent 80% of all NMSC cases while most mortality is due to SCC.

Methodology

Although the IPCC *Aviation and the Global Atmosphere* [25] report uses erythemal dose rate (UV_{eff}) to measure the efficacy of solar radiation, it is not the most appropriate or recent method for studying the potential for skin cancer. Indeed, UV_{eff} is associated with the action spectrum for sunburn, as compared to the action spectrum for skin cancer. Through experiments with hairless mice, an action spectrum for human carcinogenesis of the NMSC type has been derived. This action spectrum is used to relate changes in ozone with changes in UV exposures and ultimately with changes in NMSC incidence. Epidemiological studies have confirmed these findings. [10]

The radiation amplification factor (RAF) gives the percent increase in ambient UV exposure (E_{am}) per percent decrease in O_3.[10]

$$RAF = \frac{-\frac{dE_{am}}{E_{am}}}{\frac{dO_3}{O_3}} \qquad (1)$$

The biological amplification factor (BAF) gives the percent increase in skin cancer incidence (I) per percent increase in ambient UV exposure.[10]

$$BAF = \frac{\frac{dI}{I}}{\frac{dE_{am}}{E_{am}}} \qquad (2)$$

The total amplification factor (AF) is the product of RAF and BAF. It gives the percent increase in skin cancer incidence per percent decrease in column O_3.[10]

$$AF = RAF \times BAF \qquad (3)$$

Amplification factors for NMSC are summarized in Table 1. A distinction between BCC and SCC has been made. As per Kelfkens et al., 1990, RAFs vary of less than 6% from the average for latitudes between 0^o- 65^o. Considering that the AFs given by de Gruijl & van der Leun, 1994 (Table 1) were derived using an RAF of 1.2 for 0^o- 65^oN, we assume that this RAF is also applicable for 0^o- 65^oS. Therefore, the same AFs were used for the USA and Australia.

Table 1: Amplification Factors NMSC

$RAF_{0\text{-}65deg\ N}$	1.2		Radiation Amplification Factor (RAF)
BAF_{SCC}	2.5	± 0.7	Biological Amplification Factor for Squamous Cell Carcinoma (BAF_{SCC})
BAF_{BCC}	1.4	± 0.4	Biological Amplification Factor for Basal Cell Carcinoma (BAF_{BCC})
AF_{SCC}	3	± 0.8	Total Amplification Factor for SCC (AF_{SCC})
AF_{BCC}	1.7	± 0.5	Total Amplification Factor for BCC (AF_{BCC})
AF_{NMSC}	2.0	± 0.4	Total Amplification Factor for Nonmelanoma Skin Cancer (AF_{NMSC})

Source: de Gruijl & van der Leun, 1994

Data for the percent change in O_3 caused by subsonic aviation (Table 2) was extracted from the IPCC *Aviation and the Global Atmosphere* report. Calculated O_3 values for July and October 1992 were obtained from existing emissions data, while values for July and October 2015 were estimated using computerized models.

Percent change in BCC, SCC, and NMSC incidence are computed using data from Table 1 and Table 2. Average percent decrease in NSMSC for the North and South Hemispheres (Table 3) is obtained by averaging values with the North Hemisphere taken as 0^o-65^oN and the South Hemisphere taken as 0^o-65^oS. The same procedure was used to obtain average percent decrease for BCC and SCC.

Table 2: % Change in Ozone Column for Subsonic Fleet Minus Background

	% Change Ozone			
	1992		2015	
Latitude	July	October	July	October
65^{o}S	0.03	0.03	0.09	0.09
60^{o}S	0.03	0.03	0.11	0.11
50^{o}S	0.04	0.04	0.13	0.13
40^{o}S	0.05	0.05	0.16	0.16
30^{o}S	0.06	0.06	0.20	0.18
20^{o}S	0.06	0.06	0.19	0.18
10^{o}S	0.06	0.06	0.19	0.19
0^o	0.06	0.06	0.18	0.19
10^{o}N	0.10	0.14	0.25	0.33
20^{o}N	0.15	0.23	0.26	0.48
30^{o}N	0.19	0.31	0.41	0.63
40^{o}N	0.28	0.41	0.55	0.75
50^{o}N	0.33	0.44	0.63	0.80
60^{o}N	0.36	0.39	0.71	0.74
65^{o}N	0.38	0.38	0.74	

Source: IPCC 1999: *Aviation and the Global Atmosphere*
Data obtained from Figure 5-5, pg. 177

The number of new nonmelanoma skin cancer cases in the USA is estimated to be between 900,000 and 1,200,000.[5], [20] A value of 1,000,000 new cases of NMSC/year was used in this report. This is the estimate made by the American Cancer Society.[3] For Australia, an annual value of 374,000 new NMSC cases per year was used, as reported by the Australian Government Department of Health and Ageing.[4] It should be noted that NMSC is not rigorously reported, which means that these rates are approximate. Most countries do not consider NMSC in their national skin cancer registries. This is mainly explained by the fact that many cases remain undiagnosed and/or untreated. Data for worldwide incidence of NMSC is currently unavailable.

Estimated changes in total NMSC, BCC and SCC incidence for increases of O_3 produced by the worldwide subsonic fleet were obtained for 1992 and 2015 using the average percent change for July and October estimated for each year. The typical BCC to SCC ratio is 4:1. Consequently, the number of annual new cases of BCC and SCC were taken as 4/5 and 1/5 of the total new NMSC cases, respectively, to which were applied lower and upper bound % changes in BCC and SCC incidence. The case-fatality rates for BCC and SCC were taken as 0.05% and 0.7%, respectively.[32]

The valuation section of this report was done based on the value of a statistical life (VSL) obtained from BenMAP documentation,[1] as well as the mean cost per episode of NMSC measured by allowable charges as determined by Chen et al., 2006. The mean cost is estimated at $665 per episode, with a standard deviation of $1067. Such a large deviation comes from the variation in cost between treatment settings: hospital ($4939/episode), ambulatory surgical center ($935/episode), and physician's office ($500/episode).[7] Similar values were obtained from a previous study conducted in 2001.[6] The Environmental Protection Agency (EPA) is currently studying the cost of nonmelanoma skin cancer, which will be published in the "Cost of Illness Handbook."[12] A study done by Murdoch and Thayer, 1990, estimated the willingness to pay (WTP) to avoid skin cancer to be $30,000 (1985 dollars) based on sunscreen expenditures. ExternE approximates the value of lost welfare due to general non-fatal cancers at $450,000. Several reports caution, however, that this value is probably not applicable to skin cancer.[24], [27] Due to the scarcity of WTP studies for nonmelanoma skin cancers, the valuation in this report only includes direct costs associated with the treatment. Monetization of the decrease in number of skin cancer mortalities is based on a VSL value of $6.3 million, the same value used in BenMAP analyses. [1]

Results

NMSC

Estimates of the average percent decrease of NMSC cases in the Northern Hemisphere and the Southern Hemisphere are presented in Table 3 for July and October 1992 and 2015. Table 4 contains lower and upper bound estimates for decrease in new NMSC cases due to subsonic aviation.

Table 3: Average % Decrease NMSC

	Northern Hemisphere	Southern Hemisphere
Jul-92	0.37 – 0.55	0.08 – 0.12
Oct-92	0.47 – 0.71	0.08 – 0.12
Jul-15	0.74 – 1.12	0.25 – 0.37
Oct-15	0.89 – 1.34	0.24 – 0.36

Table 4: Change in NMSC Incidence for Subsonic Fleet

	New NMSC Rates per year	Decrease new NMSC cases due to subsonic fleet in 1992	Decrease new NMSC cases due to subsonic fleet in 2015
USA	1000000	4200 - 6300	8200 - 12000
Australia	374000	300 - 450	900 - 1400

BCC

Estimates for the average percent decrease in BCC incidence are presented in Table 5 for the Northern and Southern Hemispheres for years 1992 and 2015. Table 6 presents lower and upper bound estimates for the decrease in new cases of BCC due to the presence of ozone attributable to aviation activity, as well as the associated decrease in deaths.

Table 5: Average % Decrease BCC

	Northern Hemisphere	Southern Hemisphere
Jul-92	0.27 – 0.50	0.06 – 0.11
Oct-92	0.35 – 0.64	0.06 – 0.11
Jul-15	0.55 – 1.01	0.18 – 0.34
Oct-15	0.66 – 1.21	0.18 – 0.33

Table 6: Change BCC Incidence for Subsonic Fleet

	New NMSC Rates per year	Decrease new BCC cases due to subsonic fleet in 1992	Decrease in BCC Deaths 1992	Decrease new BCC cases due to subsonic fleet in 2015	Decrease in BCC Deaths 2015
USA	1000000	2500 - 4600	1.2 – 2.3	4800 - 8900	2.4 – 4.5
Australia	374000	170 - 320	0.1 – 0.2	540 - 1000	0.3 – 0.5

SCC

Estimates of the average percent decrease in SCC incidence due to subsonic aircraft emissions are presented in Table 7 for the Northern and Southern Hemispheres for years 1992 and 2015. Table 8 presents lower and upper bound estimates for the decrease in new cases of SCC, as well as the associated decrease in deaths.

Table 7: Average % Decrease SCC

	Northern Hemisphere	Southern Hemisphere
Jul-92	0.51 – 0.88	0.11 – 0.19
Oct-92	0.65 – 1.12	0.11 – 0.19
Jul-15	1.02 – 1.77	0.34 – 0.58
Oct-15	1.23 – 2.12	0.33 – 0.58

Table 8: Change SCC Incidence for Subsonic Fleet

	New NMSC Rates per year	Decrease new SCC cases due to subsonic fleet in 1992	Decrease in SCC Deaths 1992	Decrease new SCC cases due to subsonic fleet in 2015	Decrease in SCC Deaths 2015
USA	1000000	1200 - 2000	8.1 – 14.0	2200 - 3900	16.0 – 27.0
Australia	374000	82 - 140	0.6 – 1.0	250 - 430	1.8 – 3.0

Health Benefits Valuation

1) BCC

Table 9: Valuation of Decrease in New BCC Cases

	1992	2015
USA	$ 1,700,000 - $ 3,000,000	$ 3,200,000 - $ 5,900,000
Australia	$ 120,000 - $ 200,000	$ 360,000 - $ 660,000

Table 10: Valuation of Decrease in BCC Deaths

	1992	2015
USA	$ 7,800,000 - $ 14,000,000	$ 15,000,000 - $ 28,000,000
Australia	$ 550,000 - $ 1,000,000	$ 1,7000,000 - $ 3,100,000

2) SCC

Table 11: Valuation of Decrease in New SCC Cases

	1992	2015
USA	$ 770,000 - $1,300,000	$ 1,5000,000 - $ 2,6000,000
Australia	$ 54,000 - $ 94,000	$ 170,000 - $ 290,000

Table 12: Valuation of Decrease in SCC Deaths

	1992	2015
USA	$ 51,000,000 - $ 88,000,000	$ 99,000,000 - $ 170,000,000
Australia	$ 3,600,000 - $ 6,200,000	$ 11,000,000 - $ 19,000,000

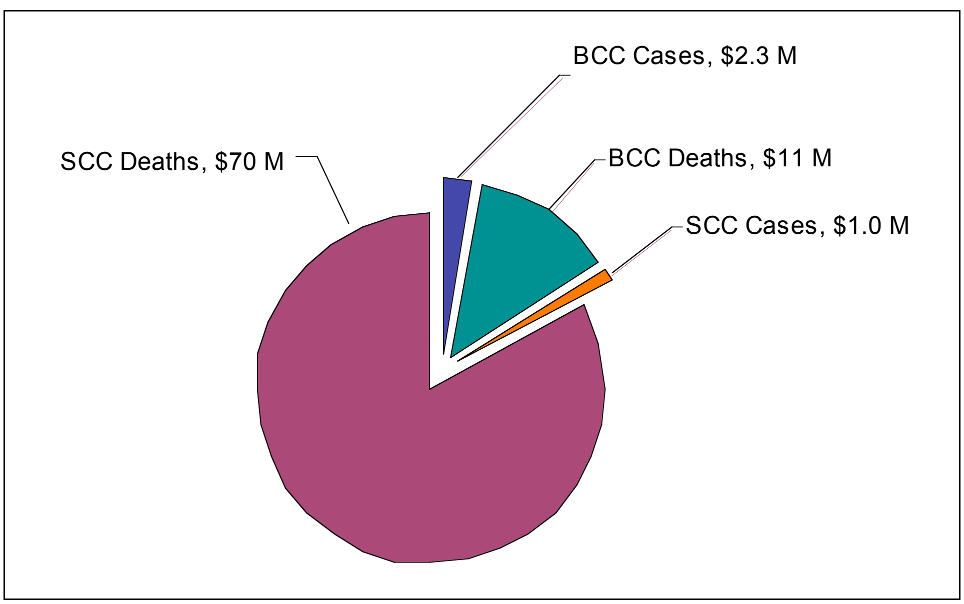

Figure 1: Cost benefits from decrease of NMSC in the USA due to subsonic aviation in 1992

Discussion

As mentioned previously, it was assumed that AFs derived from the RAF for 0^o- 65^oN were also applicable for Australia, located in the Southern Hemisphere. This assumption may lead to a bias in the estimated decrease of nonmelanoma skin cancer cases in Australia.

Estimates for percent change in ozone column given in Table 2 are said to be "fair" for 2015.[25] This means that estimates for number of reduced cases of skin cancer in 2015 should be considered with caution. Also, it should be noted that ozone column change data (Table 2) was read point by point from Figure 5-5 (pg. 177) of the IPCC 1999 *Aviation and the Global Atmosphere* report.

The methodology for NMSC applies to the number of newly diagnosed cases of NMSC. The results presented in Table 4 for the decrease in new NMSC cases are obtained considering that without the positive subsonic fleet contribution, the ozone depletion (caused by other effects) would yield the given number of new cases of skin cancer. Rates of decrease in incidence of NMSC are higher in the Northern Hemisphere than in the Southern Hemisphere, since aviation activity is predominantly in the North. The greatest changes in ozone column effectively occur in the Northern Hemisphere (Table 1).

Although the typical BCC to SCC ratio is 4:1, there are other nonmelanoma skin cancer types, which represent less than 5% of all NMSC cases. The slight discrepancy between the sum of the estimates for decrease of new BCC and SCC cases, and the approximated total NMSC decrease is due to the rounding of the AF values (Table 2), which are also based on the 4:1 ratio.

Calculations for the decrease in deaths are strictly based on the new NMSC cases, considering a case-fatality rate of 0.05% for BCC and of 0.7% for SCC. The number of deaths depends on various factors, such as the moment of detection and the treatment provided. Incidences and fatalities mainly occur in persons over 65 years of age.

Monetization of benefits from the decrease in skin cancer incidence presented here only accounts for the direct costs of treatment. The cost of illness (COI) for skin cancer which is forthcoming as part of the "Cost of Illness Handbook" (EPA) may be used in the future to better approximate the health benefits from subsonic aviation. COI considers direct costs, welfare loss, and production loss.

From Figure 1, it is apparent that the number of lives saved from NMSC has a higher valuation than that of the decrease in total number of new cases. This is due to the fact that NMSC is usually easily treated and therefore, not very costly to treat. It can be expected that with future medical breakthroughs and earlier detection, case-fatality rates will decrease.

Conclusion

The decrease in number of BCC deaths due to subsonic aviation is estimated to have been between 1.2 and 2.3 in the USA in 1992. The decrease in the number of SCC deaths is estimated to have been between 8.1 and 14.0 in the USA in 1992. The decrease in number of deaths in Australia in 1992 is estimated to have been between 0.1 and 0.2 for BCC and between 0.6 and 1.0 for SCC. Further research is required before the number of lives saved from CMM can be given within reasonable accuracy.

The valuation of the number of lives saved in the USA in 1992 by the increase in atmospheric ozone is estimated to be between $7.8 M and $14 M for BCC and between $51 M and $88 M for SCC. These amounts surpass the cost savings associated with the decrease in number of new cases.

Ozone increases from subsonic aviation have proven to be beneficial in reducing the number of skin cancer cases. However, consideration should also be given to the fact that ground-level ozone is associated with various negative health impacts such as lung damage and other respiratory illnesses and that tropospheric ozone is considered to be a strong greenhouse gas.

Future Research

Work will be done to implement these findings into the BVB-LAQ module. The APMT health impacts analysis will therefore account for changes of nonmelanoma skin cancer incidence in addition to local air quality health impacts. Further research is needed to compute net changes in ozone column depending on global aviation emissions. Currently, complex 3D-grid-based climate models are required. These models are computationally intensive and are ill-suited for policy assessment work. Future efforts may involve the development of a reduced-order model to estimate global ozone column changes using emissions inventories as input.

Acknowledgments

Special thanks to Prof. Ian Waitz and Dr. Stuart Jacobson (PARTNER Lab, MIT) for their continuous guidance and counsel.

The US FAA through PARTNER funded this work.

Bibliography

[1] Abt, *Environmental Benefits Mapping and Analysis Program (BenMAP) User's Manual*, 2003, Bethesda, MD, Abt Associates, Inc. Prepared for the U.S. Environmental Protection Agency Office of Air Quality and Standards.

[2] Ambach W. and Blumthaler M., Biological effectiveness of solar UV radiation in humans, *Experientia*, 1993 Sep 15; 49(9):747-53.

[3] American Cancer Society, *Cancer Facts and Figures: 2006*, http://www.cancer.org/downloads/STT/CAFF2006PWSecured.pdf, [online], viewed Oct. 2007.

[4] Australian government Department of health and ageing, National Skin Cancer Awareness Campaign, *Key Facts*, http://www.skincancer.gov.au/internet/skincancer/ publishing.nsf/ Content/fact-2#1, [online], viewed Oct. 2007.

[5] Buckman S.Y., Gresham A., Hale P., Hruza G., Anast J., Masferrer J., Pentland A.P., COX-2 expression is induced by UVB exposure in human skin: implications for the development of skin cancer, *Carcinogenesis*, 1998 May; 19(5):723-9.

[6] Chen J.G., et al., Cost of Nonmelanoma Skin Cancer Treatment in the United States, *Dermatologic Surgery*, 2001, 27 (12), 1035–1038.

[7] Chen J.G., et al., Treatment Patterns and Cost of Nonmelanoma Skin Cancer Management, *Dermatologic Surgery*, 2006, 32 (10): 1266–1271.

[8] CIESIN, The Relationship of Skin Cancer Prevalence and the Increase in Ultraviolet-B Exposure due to Ozone Depletion, *CIESIN Thematic Guides, 2007*, http://www.ciesin.org/TG/HH/ozskin1.html, [online], viewed Sept. 2007.

[9] Dahlback A., Henriksen T., Larsen S.H., Moan J., Ultraviolet-radiation and skin cancer. Effect of an ozone layer depletion, *Photochem Photobiol.*, 1990 May; 51(5):579-82.

[10] de Gruijl F.R., Van der Leun J.C., Estimate of the wavelength dependency of ultraviolet carcinogenesis in humans and its relevance to the risk assessment of a stratospheric ozone depletion, *Health Phys*., 1994 Oct; 67(4):319-25.

[11] de Gruijl F.R., Van der Leun J.C., Climate change and skin cancer, *Photochem Photobiol Sci.*, 2002 May;1(5):324-6.

[12] EPA, *Cost of Illness Handbook: Chapter II.6: Cost of Skin Cancer*, pending, http://www.epa.gov/oppt/coi/pubs/toc.html, [online], viewed Oct. 2007.

[13] Grant W.B., Moan J., Reichrath J., Comment on "the effects on human health from stratospheric ozone depletion and its interactions with climate change" by M. Norval, A. P. Cullen, F. R. de Gruijl, J. Longstreth, Y. Takizawa, R. M. Lucas, F. P. Noonan and J. C. van der Leun, Photochem. Photobiol. Sci., 2007, 6, 232., *Photochem Photobiol Sci*., 2007 Aug; 6(8):912-5; discussion 916-8.

[14] Kelfkens G, de Gruijl FR, and van der Leun J.C., Ozone depletion and increase in annual carcinogenic ultraviolet dose, *Photochem Photobiol*, 1990 Oct; 52(4):819-23.

[15] Lewis K. G. and Weinstock M. A., Nonmelanoma Skin Cancer Mortality (1988-2000) The Rhode Island Follow-Back Study, *Arch Dermatol*., 2004; 140:837-842.

[16] Longstreth J., Cutaneous malignant melanoma and ultraviolet radiation: a review, *Cancer Metastasis Rev.*, 1988 Dec; 7(4):321-33.

[17] Longstreth J. D., de Gruijl F. R., Kripke M. L., Takizawa Y., and van der Leun J. C., 1994. *Environmental effects of ozone depletion: 1994 Assessment, Chapter 2 Effects of Increased Solar Ultraviolet Radiation on Human Health*, United Nations Environmental Programme, Nairobi.

[18] Lucas R., Global Burden of Disease of Solar Ultraviolet Radiation, *Environmental Burden of Disease Series*, July 25, 2006; No. 13. News release, World Health Organization.

[19] Marks R., Selwood T.S., Solar keratoses. The association with erythemal ultraviolet radiation in Australia, *Cancer*, 1985 Nov 1;56(9):2332-6.

[20] Miller DL, Weinstock MA., Nonmelanoma skin cancer in the United States: incidence, *J Am Acad Dermatol*, 1994 May; 30(5 Pt 1):774-8.

[21] Moan J., Dahlback A., The relationship between skin cancers, solar radiation and ozone depletion, *Br J Cancer*, 1992 Jun; 65(6):916-21.

[22] Norval M., Cullen A.P., de Gruijl F.R., Longstreth J., Takizawa Y., Lucas R.M., Noonan F.P., van der Leun J.C., The effects on human health from stratospheric ozone depletion and its interactions with climate change, *Photochem Photobiol Sci.*, 2007 Mar; 6(3):232-51.
[23] Norval M., de Gruijl FR., Reply to the 'Comment on "The effects on human health from stratospheric ozone depletion and its interactions with climate change"' by W. B. Grant, J. Moan and J. Reichrath, Photochem. Photobiol. Sci., 2007, 6, DOI: 10.1039/b705482c., *Photochem Photobiol Sci.*, 2007 Aug; 6(8):916-8.
[24] Pearce, D., *Valuing Risks to Life and Health: Towards Consistent Transfer Estimates in the European Union and Accession States*, 2000, Paper prepared for the European Commission (DGXI) Workshop on Valuing Mortality and Valuing Morbidity, University College London.
[25] Penner, Joyce E., et al., *Aviation and the global atmosphere : a special report of IPCC Working Groups I and III in collaboration with the Scientific Assessment Panel to the Montreal Protocol on Substances that Deplete the Ozone Layer*, Intergovernmental Panel on Climate Change, Cambridge, New York, Cambridge University Press, 1999.
[26] Perlis C., Herlyn M., Recent advances in melanoma biology, *Oncologist*, 2004; 9(2):182-7.
[27] Serup-Hansen N., et al., *Valuation of Chemical Related Health Impacts: Estimation of direct and indirect costs for asthma bronchiale, headache, contact allergy, lung cancer and skin cancer*, 2004, Danish Ministry of the Environment Environmental Protection Agency.
[28] Setlow R.B., Spectral regions contributing to melanoma: a personal view, *J Investig Dermatol Symp Proc.,* 1999 Sep; 4(1):46-9.
[29] Urbach F., Ultraviolet radiation and skin cancer of humans, *J Photochem Photobiol B.*, 1997 Aug; 40(1):3-7.
[30] van der Leun J. C., Longstreth J. D., de Gruijl F. R., Kripke M. L., Abseck S., Arnold F., Slaper H.I., Velders G., and Takizawa Y., *Environmental effects of ozone depletion: 1998 Assessment, Chapter 2 Health Risks*, 1998, United Nations Environmental Programme, Nairobi.
[31] Wang L.E., Xiong P., Strom S.S., Goldberg L.H., Lee J.E., Ross M.I., Mansfield P.F., Gershenwald J.E., Prieto V.G., Cormier J.N., Duvic M., Clayman G.L., Weber R.S., Lippman S.M., Amos C.I., Spitz M.R., Wei Q., In vitro sensitivity to ultraviolet B light and skin cancer risk: a case-control analysis, *J Natl Cancer Inst.* 2005 Dec 21; 97(24):1822-31.
[32] Weinstock M.A., Bogaars H.A., Ashley M., et al., Nonmelanoma skin cancer mortality: A population-based study, *Arch Dermatol*, 1991;127:1194 –1197.

Student Biography

Elza Brunelle-Yeung is currently an S.M. student at the Massachusetts Institute of Technology in the Aeronautics and Astronautics department. She holds a Bachelor's degree in Mechanical Engineering from McGill University, Montreal, Canada. She serves as a research assistant at MIT's PARTNER Lab. Her work thus far has been on the Aviation Portfolio Management Tool's Benefits Valuation Block for Local Air Quality (APMT BVB-LAQ). She studies the health impacts related to aviation.

Throughout her university studies, Elza has utilized her leadership skills to contribute to her community. She is the founder and organizer of the annual "*YOUths! Find the Leader in YOU!*" Conference (2004-2007) held at McGill University. The conference is aimed at motivation high school students from across the province of Quebec to develop and apply their leadership skills, both on the local and international fronts. Recently, she was elected as Co-President of the Graduate Association of Aeronautics and Astronautics of MIT for 2008.