外部評価報告書

2020年5月14日

東京大学大学院

理学系研究科地球惑星科学専攻

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東大地球惑星科学専攻 外部評価委員会 報告書

2020 年 5 月

この報告書は東京大学 大学院理学系研究科 地球惑星科学専攻（以下「専攻」と略記）に 2020 年に設置された外部評価委員会の評価をとりまとめたものである。専攻では自己点検・外部評価を原則として 6 年毎に実施しており，今回は 2013 年の外部評価に続くものである。前回の評価で指摘された課題への対応が適切であったかどうかを含めて，専攻の研究教育活動の現状を評価し，専攻が今後も地球惑星科学の分野で世界を担う知の拠点として活動を続けていくための助けとなることを目的とした。なお専攻と関連の深い宇宙惑星科学機構の評価も合わせて行った。

外部評価の実地委員会の開催に先立って，井出専攻長から評価委員に「自己点検・外部評価資料：専攻資料」（以下「専攻資料」と略記），「同：個人資料」，「同：附属資料」および専攻を説明する冊子やパンフレットが配布された。このうち専攻資料には専攻の沿革や組織，教育と研究の実績，国際化対応，社会貢献，前回評価の指摘事項への対応などが詳しく記述されている。また海外の評価委員による書面評価の結果が実地委員会の開催前に示された。

実地委員会は 2020 年（令和 2 年）2 月 14 日（金）に専攻内で開催された。当日は，専攻長による専攻全体に関する説明の後，五つの研究分野（講座）の代表者から，それぞれの分野の研究教育活動について説明があった。評価委員会の構成や実地委員会の日程など外部評価の実施要領を付録に示す。

外部評価委員会は，海外委員の書面評価を参照したものの，事前の配布資料と実地委員会での説明などに基づき，独自の観点から評価を行った。以下，専攻長から示された「外部評価における評価項目」を参考にして，まず専攻全体の（1）研究体制，（2）学部と大学院の教育，（3）国際性，（4）組織と運営，（5）社会貢献についての評価を示し，次に五つの研究分野（講座）についての評価を記す。

1　専攻全体について

(1) 研究体制

専攻全体として，研究能力の高い教員や大学院生が集まっており，現在の研究レベル，研究成果，学会等での活躍度は，国内で見ても国際的にも非常に高いレベルにある。専攻に求められている研究が地球惑星科学の広範囲にわたるにもかかわらず現在のスタッフは比較的少人数である。これは専攻の設立の当初から地震研究所，大気海洋研究所，先端科学技術研究センターの協力講座などとの連携を前提にしているためであり，協力講座の教員も含めた体制で見ると，その規模においてもカバーする研究領域の広さから見ても，この分野の日本を代表する最大最強の研究教育組織であることは疑う余地がない。これらの協力講座や学外の連携講座・流動講座との強い連携を今後とも続けるべきである。さらに学生に研究の先端状況を体験させるという観点から，関連の研究機関に出向いて講義や実習を受ける機会などをもっと拡充してはどうだろうか。

大学としての重要な使命である人材育成と研究活動を，評価対象期間である最近の7年間（2012～2018年度）について見て気づくことは，まず，修士・博士論文の指導実績が乏しい教授・准教授が存在していることである。個々の教員には様々な理由があると思われるが，日本を代表する大学院大学としては気に掛かる点である。また，一部の教員の論文発表などの研究実績が十分でないように思われる。世界を担う知の拠点を目指している専攻に相応しい活動を期待する。前回の外部評価や専攻資料では，助教へのメンタリングの必要性が指摘されているが，普通は若い教員ほど研究の視野は広くやる気は高いはずなので，それが何に起因するのか気になるところである。助教に関しては，2011年度から公募要領に，採用の5年後に評価を行うと明記し，2014年度から教授による「助教活性化委員会」を設けて，研究活動やキャリアアップに関する助言を行っている。少しずつ成果が現れているようであり今後に期待したい。

講座を越えた連携を進めるために，全専攻の教員・学生・職員が参加する「融合セミナー」を開催していることを評価するが，年1回というのは，あまりにも少ないのではないか。若手教員や大学院生の意識改革や視野の拡大のためにも，彼らが中心となって運営する専攻全体の連携・融合セミナーを，月1回程度，できれば専攻の全分野を統合する役割をもつ地球惑星システム科学講座が音頭を取って開催してはどうだろうか。

理学系研究科の地球惑星科学関係の4専攻（地球惑星物理学，地質学，鉱物学および地理学）が2000年に統合・再編され，地球惑星科学に関する総合的な研究教育組織としてこの専攻が設立された。その頃は，理学系研究科・理学部における研究教育はあくまでも自然が対象であり，人間や人間社会については扱わないとして，例えば地理学ポストの一部を，新たに設立された新領域創成科学研究科に移していた。そして，専攻は，主に地球や惑星系のダイナミクスやプロセスに関する自然科学的な研究を進めてきた。その後，地球環境問題や自然災害問題がクローズアップされるようになり，日本学術会議などでも「地球人間圏科学」という，地球システムと人類活動の関係や相互作用

を扱う研究分野が広がってきた。専攻も理学と社会の接点に注目した研究教育の重要性を認識し，2018 年に「臨象地球科学」分野を立ち上げた。さらに，SDGs（持続可能な開発目標）への貢献を目指して東大が総長主導で全学的に進めている未来社会協創推進本部の登録プロジェクトとして，2019 年に「臨象理学」プロジェクトを立ち上げている。「臨象地球科学」も「臨象理学」も，様々な現象に臨んで，従来の枠に捕らわれない新しい学問を創り出し，地球環境問題などの課題解決を担う人材を養成するとしている。「臨象」の何がこれまでにないポイントなのか，人材育成にどのようにアプローチしようとしているのかが明確ではないが，専攻が人間社会における地球惑星科学の役割や位置を再認識して新たな方向性を示したことを評価する。

評価委員の一人はさらに「東大の未来社会協創推進本部が掲げる『地球と人類社会の未来への貢献』は，専攻全体として真剣に対応すべき課題であり，『人間活動がらみ』を狭くとらえて，『臨象理学（あるいは臨象地球科学)』に押し込めてしまうべきではない。今，問われているのは，人類にとって地球（あるいは宇宙・惑星系）とは何かを，より根源的に考究する契機としての地球惑星科学ではないだろうか。さらに言えば，東大のこの分野が，今後，日本および世界を真にリードできるか否かは，人間不在で自然（あるいは地球）を理解しようとしてきた（デカルト・ニュートン以来の）自然科学パラダイムをどう超克するかという，より高次の問題意識を持って，新たな研究教育を展開できるか否かに掛かっているのではないだろうか。」としている。

後に示すように，天文学と太陽系科学を中心として，化学や生命科学を巻き込んだ新たな学術的連携が国際的に進展している状況で，これらに関する学部・研究科を網羅的に有する東大が，この勃興しつつある学際的分野に戦略的対応ができていないという危惧を抱いている。実際，生命の起源の研究は生物学・化学・惑星科学・天文学・物理学にまたがっており，この分野間の連携は世界的に著しい。例えば，学部で化学や生命科学を学んだ学生が，天文学や宇宙惑星科学で活躍できる状況になっており，その逆もありうる。生命の起源を大テーマとして，専攻をまたがって研究を進めたり大学院生の流動性を高めたりする必要があり，それは異なる専攻間の教員の連携強化にもつながる。今までも個々の学生・教員レベルでこのようなことは行われてきたと思われるが，理学系全体として，より積極的な対応が必要であることを指摘したい。

（2）学部と大学院の教育

＜学部教育の在り方＞

2000 年に専攻が設立された際，理学部の教育課程である従来の地球惑星物理学科と地学科(地質学･鉱物学コースと地理学コース)はそのまま専攻のもとに配置された。地学科は 2006 年に改組されて地球惑星環境学科となり，学部の教育課程が，地球惑星物理学科と合わせた 2 学科体制となって現在に至っている。前回の外部評価で，この 2 学科体制は「学科統合の目的に反するもので，適切ではない」との指摘を受けた。専攻

はこれを重く受け止め，作業部会「教育改革推進 WG」を中心に約 1 年間にわたって慎重に検討した結果，「学部教育では地球惑星科学の基礎学力を系統立てて身につけることが肝要であり，地球惑星科学の多岐にわたる分野やアプローチの基礎を単一学科のカリキュラムで習得させるのは困難である」とし，当面 2 学科体制を続けることとした。そして学科間の垣根を低くするために，新任教員は両学科の教育に携わる，専攻長と副専攻長が両学科長を兼任する，学生が他方の学科の講義などを履修することを奨励する，ガイダンス等の学事暦を共通化する，ランチセミナーなどにより分野間の風通しをよくするなどの取組みを行っている。外部評価委員会は，専攻のこれらの真摯な対応に敬意を表するが，学部教育の在り方は現在でも専攻の最重要検討課題の一つであろう。

東大理学部での学科の変遷の中で，地球惑星物理学科の前身である地球物理学科が物理学科とともに歩んできたのに対して，地球惑星環境学科のルーツである地質学科・鉱物学科・地理学科は博物学の伝統のもとに生まれた学科なので，両学科間の距離はかなり大きい。これは日本に古くからある大学に見られる共通した特徴で，比較的新しく設置された地球科学系の学科では一体として運営されている。地球物理学科と地質・鉱物・地理学科を統合する際の最大の障壁は，必修科目をどの程度に収めるか，言い換えるとそれぞれの学問分野のエッセンシャルミニマムをどの範囲に収めるかに掛かっている。それぞれの大学で過去 20 年余りの間に様々な教育方針で人材育成が行われてきた現在，それぞれの利点と欠点を冷静に評価できる時に来ている。幸い専攻には異なる学部教育を経験した教員が大勢いるので，そのような視点からあるべき地球惑星科学教育についてさらなる議論と検討が行われることを期待する。

ある評価委員の意見は以下の通りである。「そろそろ東大が率先して，学生に『地球と生命』，『地球と人類』あるいは『地球と宇宙』といった包括的理解に興味を持たせることを第一に考えるモードに移行すべきではないか。（米国の有名大学では，学部時代に，初歩的な内容であっても多様なカリキュラムが用意されているようである。）地球と生命（および宇宙）はその時間発展を含めてシームレスにつながっており，その理解が人類存在の基盤になっていることを，学部レベルから理解してもらわなければならない。そのために，19 世紀から変わらないディシプリンによる縦割りは，東大あたりが率先してやめていくべきではないか。◇学部学生には基礎を教え込むという必要性もあるが，一方で，最近の若い人たちは，地球環境問題や太陽系・惑星に関して，古いディシプリンにこだわらない広い興味や視野を持っており，そのモティベーションを大切にした教育を行うことは，研究者の養成のみならず，社会で多様に活躍できる人材の養成としても重要ではないか。また，教員（上から）の指導だけではなく，学生（下から）の選択の自由がないと，学問は発展しない。履修しうる基礎科目は用意しておき，その選択は学生に任せるということも，ある程度はやられているようだが，もっと実質的な統合カリキュラムを考えてはどうか。その中には，例えば『地球哲学』や『地球惑星科学原論』のような基礎科目も必要ではないか。」

＜大学院教育＞

修士課程，博士課程ともに入学者の定員割れが常態化していることは看過できない。この専攻（大学院）の大きな特徴の一つは，修士課程の定員（2015 年度から 99 名）が学部定員（52 名）の 2 倍に及ぶため，必然的にほぼ半数の大学院生が他大学出身者で占められていることである。前回の外部評価以降，変動はあるものの学外からの修士課程入学者には減少の傾向が認められる。この傾向は強くなることはあっても，以下の理由から改善するとは思えない。他大学出身者の有意な部分を占める主に地方の国立大学では，文部科学省から求められた大学の機能別分化において，多くが地域との連携を強めるようにミッションを選んでいる。そのような大学では基礎科学の研究に向ける時間や予算が一層厳しくなってきている。その影響で，志高く先端的な基礎科学を学ぼうとする学生も自ずと減少することが強く危惧される。魅力ある地球惑星科学の裾野がこれ以上狭まらないように，東大にあっては教育研究の様々なレベルで他大学との抜本的な連携を行うなどの行動が強く望まれる。

また他大学からの入学者の多く（都内私立大学の物理系学科の卒業生など）は，地球惑星科学とは異なる専門分野の教育を受けているので，修士課程での地球科学の基礎教育をどの程度効率的に実施できるかが研究者養成の観点で極めて重要と思われる。専攻（大学院）のさらなる発展のための一つの鍵は，他大学出身者の基礎教育を充実し彼らのモティベーションを高めて多くの優秀な研究者を生み出すことだと思われる。専攻ではすでにそのための様々な方策を立てて実行しているが，さらなる工夫を期待する。

修士課程では定員に近い学生が確保できているものの，博士課程では入学者の大幅な定員割れを起こしており，さらに近年は博士課程に進学しても中途で会社等に就職する学生が多いことから博士号取得者は一層絞られている。2009 年度から学位審査のルールを改め，論文提出の条件を，申請者が第一著者である論文が国際誌に受理されていることとし，審査の主査は指導教員以外が務めることとした。この改訂の主旨は適切であったと評価するが，その結果，博士号取得者が大幅に減少した。その数は毎年 20 人前後で，基幹講座と協力講座を合わせた教授・准教授の総数の 2 割程度であり，将来を担う研究者の養成機関として十分とはとても言えない。国内の優秀な学生の確保と養成に一層努めるとともに，優秀な留学生を積極的にリクルートするなど思い切った対策を講ずる必要がある。

主に博士課程の学生の表現力の向上を計るために，英語教育の経験を積んだネイティブスピーカーを非常勤講師として雇用し，英語によるディベートやプレゼンテーションのクラスを設けたり，英語論文の執筆を支援したりしているのは有意義な試みであると評価する。

＜その他＞

学生の女性比率は，学部学生が 15%，修士課程が 22%，博士課程が 17%にとどまっている。この比率は理学部・理学系研究科のそれと同程度である（それぞれ 10%，

20%，18%)。女子学生を増やすための特効薬はなく，短期的には解決できないが，引き続き長期的な視点に立った改善に向けた努力を期待する。

新しい教育の試みとして高く評価できると思われるのは，宇宙惑星科学機構で試み始められている理学と工学をつなぐ取組みである。このような従来の縦割りの構造を越えていく試みをぜひ発展させていただきたい。例えば，科学コミュニケーションの重要性がますます高まっていることを考えると，文系の学生が一層関心を持つような新しい試みは考えられないだろうか（数学や物理学のハードルが高いのは確かであるが)。

(3) 国際性

外国人留学生は前回の評価時と同様にわずかであり（その比率は修士課程で 3%，博士課程で 8%)，日本の他大学の現状とは大きく異なる（多くの大学院では博士課程において外国人留学生の占める割合が 2〜5 割に達する)。これは他大学と比べて比較的多数の優秀な国内の学部卒業生をこれまでは獲得できたことが背景にある。しかしながら，博士課程入学者は大幅な定員割れを起こしており，専攻の研究力を飛躍的に高めるためにも，アジアはもとより欧米からも優秀な留学生を多数リクルートすることが必要であろう。そのためには各種の制度による経済支援を充実するだけではなく，個々の教員が研究費の一部を留学生支援に充てるなどの覚悟が必要であろう。さらには優秀な大学院生を育てている諸外国の大学等との密接な連携を専攻として図ることも必要である。優秀な留学生が大学院レベルで増加することは，日本人学生の視野を国際化し研究に対するモティベーションを高めることにも役立つであろう。

大学院生の海外研修のアクティビティは十分に高く，教育的な配慮が十分なされている。前回の外部評価でも強く指摘され，また今回の海外委員の書面評価でも強く指摘されている外国人教員が少ないという問題については，やはり言葉の問題（特に事務処理や読み書き）が大きいのではないだろうか。このことも踏まえ，また前回の評価でも指摘されている「長期的な意味での海外進出が少ないこと」にも関連して，個人レベルでの国際交流から，講座あるいは専攻という組織レベルでの国際連携へと戦略的展開を進めることが課題解決の一つの突破口になるのではないだろうか。

専攻の教員が受け入れて指導した外国人学生は最近の 7 年間で合計 85 名であり，前回評価での 35 名から倍増している。特に理学系研究科が実施している，海外の学部学生を夏季に 6 週間受け入れて研究させるインターンシップ（UTRIP）は，応募者が 30 倍近くになるほどの人気で，専攻では毎年 3〜6 名を受け入れている。東大と専攻が世界の若い人に知られるよい制度・機会であり今後も盛り立てていただきたい。

(4) 組織と運営

組織と管理運営を考える上では，人事，予算，設備環境がその要素と考えられるが，後半の二者については大きな問題はないように見受けられる。一つ挙げるとすれば科学

研究費の獲得状況である。平均すると潤沢に見えるが，教員によるばらつきが大きく，個人レベルで見ると明らかに十分ではない教員が散見される。人事については，外国人教員が少ないことと並んで，やはり女性教員が少ないことが指摘される。この問題に取り組む姿勢も見られるが，この課題は女子学生が少ないこととも連動していて，裾野をどのようにして広げていくかという実社会まで関わる大きな問題であり，研究科あるいは大学レベルで本格的に取り組むことが求められる。

印象として講座間の連携よりも講座ごとの独立性が強いと感じられる。専攻資料でも，専攻は地球惑星科学関連の国内最大の大学院であると自負されており，研究教育におけるこの分野の日本の牽引者として，講座間の意見交換がさらに活発に行われることを期待する。今回の指摘への対応についても，講座内での完結を目指すよりは，講座間の意見調整などを図りながら専攻全体がまとまって進めていくことが望ましい。

日本の大学の専攻長は，欧米の大学の“Department Chairman”と異なり，多分に持回りの要素が強く，（任期が 1 年であれ 2 年であれ）強力なリーダーシップを発揮することは難しいと思われる。合議制の教授懇談会で専攻を運営するのも一つの方法であるが，その反対に教授の役割を制限し，若手教員と職員の専攻運営への参加を促すと，専攻長がリーダーシップを発揮しやすくなる。専攻の将来を企画するような場へ若手教員を積極的に参加させることは，彼らのモティベーションを高めることにもなり，選択肢の一つではないだろうか。

今回の海外の書面評価委員は 5 人すべてが北米の研究者である。前回も 5 人中 4 人が米国の研究者であった。図らずもそのようになったと思われるが，今後は，欧州やアジア・オセアニアの研究者も含めた，異なる国々からの多様な意見が聞けるよう努力していただきたい。

(5) 社会貢献

専攻は，その規模においても影響力においても日本の地球惑星科学を支える最も重要な柱である。歴史的に見ても日本のこの分野の研究教育を支える人材を最も多く輩出してきた。以前は専攻における東大出身者の占める割合が極めて高かったが，最近の 7 年間にスタッフの半数が入れ替わり，今では純粋な東大出身者の割合は 5 割を下回る。その反面，日本の多くの大学や研究機関から傑出した人材を集めてきたことになる。これは，良くも悪しくも「東大ブランド」によって全国から優秀な研究者を集めやすい有利な条件（研究の蓄積，伝統，優秀な学生，豊富な外部資金など）を考えると，ある意味で当然の帰結と言える。それゆえ専攻には，自らの発展を図るだけではなく，日本および世界の地球惑星科学コミュニティの発展のためにリーダーシップを発揮し大いに貢献する責任がある。

国内の学協会や公的機関でのプレゼンス，講演会などのアウトリーチ活動には積極的な取組みが見られる。特に専攻のスタッフが日本地球惑星科学連合などを通じて日本

の地球惑星科学の発展に貢献してきた実績は非常に大きく，今後もそれが継続されることを期待する。さらに全国地球惑星科学系専攻長・学科長懇談会などを通じて，関連学科等をもつ全国の大学の実情を常に把握し，研究を通した連携の模索など適切な対策を講ずることをお願いしたい。

この学問分野の裾野を広げることは，単に国民の科学的好奇心を高めるばかりではなく，災害を含む広い意味での地球環境問題への理解を深め広げることにも資すると思われる。そのために研究成果を社会や市民に分かりやすく解説しアピールするサイエンス・カフェなどをもっと積極的に開くべきではないか。また，専攻がカバーする研究内容は，高校の地学にほぼ相当するが，地球環境問題や災害問題のみならず，宇宙・地球論も含めて，地学は若い人の関心をあまり引いていない。この分野の重要性や必要性を積極的にアピールしないと，人材や研究は先細りしてしまうことを肝に銘ずべきである。

2　各研究分野について

（1）大気海洋科学講座

大気海洋科学講座は，地球の表層環境である大気と海洋における様々な時空間スケールの現象を解明し，その変動予測の基礎を構築することを目指して研究教育を行っている。具体的には，理論，現場観測，データ解析，数値モデルを駆使して，大気と海洋の流れと乱れを深く理解し，大気海洋相互作用のメカニズムを解明し，大気海洋中の物質の動態を把握することを目指している。

大気物理学グループは，対流圏から下部熱圏までの大気大循環と大気波動や不安定現象，乱流などの擾乱との相互作用，雲の組織化メカニズムなどを研究対象としている。佐藤教授が国立極地研究所と連携して建設を進めてきた南極昭和基地の大型大気レーダーPANSY は 2015 年 10 月にフルシステム稼働を開始した。PANSY は南極で最大の大気レーダーで，対流圏，成層圏，中間圏の風速を精密に観測することができ，例えば，夏季の中間圏の観測から，長周期の重力波が運動量輸送を担っているという，これまでの理論的予想を覆す結果を得ている。数少ない女性教員のロールモデルになるよう同教授の活躍を期待する。その他，このグループは，放射対流平衡シミュレーションによる台風強度の長周期振動に関する研究などでも成果を挙げている。

海洋力学グループは，深層海洋大循環に決定的に重要な鉛直乱流混合に関して，中・深層や深海底凹凸地形上での乱流パラメタリゼーションの研究を精力的に進めている。特に超深海乱流計による海底地形直上までの乱流観測を世界に先駆けて実施し，海底凹凸地形上に形成される乱流混合域の鉛直減衰スケールが潮流や地形にどのように依存するかを明らかにした。さらに，キーエリアでありながらこれまで乱流が観測されていなかった南大洋やインドネシア多島海などで乱流混合強度の分布を測定するなど，世界トップレベルの研究を行っている。その他，沿岸エル・ニーニョ現象のメカニズムの解明や，海洋の中緯度水温前線域での大気海洋相互作用に関する研究も進めている。

気候力学グループは，気候変動のメカニズムを解明し，その影響や予測可能性に関する研究を行っている。特に，低緯度域の大気海洋相互作用とそれに関連する海洋変動の理解を進めようとしている。高解像度海洋モデルによって，鉛直混合を加えるとインドネシア通過流が増加することを示した。また，短周期の赤道波の変調によって平均的な湧昇が励起されるなどの興味深い成果を得ている。ただし大気側から気候力学を研究するスタッフは現在はいない。

大気海洋物質科学グループは，地球惑星システム科学講座と連携しながら，大気中の気体成分やエアロゾルなどの大気物質の動態を把握し，その放射や雲物理過程への影響などを解明しようとしている。特に北極におけるブラックカーボン・エアロゾルの動態や，北極下層雲の微物理特性とエアロゾルの影響に関する研究で注目される成果を挙げている。ただし海洋の物質の動態を研究するスタッフは現在はいない。

前回の外部評価で指摘された空席ポストの人事を慎重に行い,総勢8名(教授3名,准教授3名，助教2名）の体制が整った。気候力学グループと大気海洋物質科学グループの教員がそれぞれ1名というのは寂しいし,講座全体の教員数が少ないことが海外の評価委員などから指摘されているが，東大のこの分野の研究教育体制は，(前述のように)この基幹講座に加えて大気海洋研究所や先端科学技術研究センターの協力講座を含めて構築されている。従って，今後も協力講座との強い連携を継続することが重要である。また講座・専攻の研究実績や戦略などを議論する場合は，その分野の東大全体での業績や戦略を示した後で，その中での講座・専攻の貢献や役割を示すべきであろう。そうしないと，実情をよく知らない海外の評価委員の誤解を招くことになりかねない。

(2) 宇宙惑星科学講座および宇宙惑星科学機構

宇宙惑星科学講座は，太陽系内の惑星とその磁気圏・小惑星，および擾乱の源である太陽自身についての研究で成果を挙げている。

小惑星の水や有機物の探索を主要目的とする「はやぶさ２」計画の中で,装置開発,探査機や観測装置等の運用,プロジェクトの科学面の取りまとめなどに複数の教員が参画しており，同ミッションの成功に不可欠な貢献をしている。

磁気圏プラズマ等の理論・シミュレーションを行うグループは，磁気リコネクション，衝撃波，無衝突プラズマ，部分電離プラズマ，粒子加速，ダイナモなどの宇宙の磁気プラズマ等について活発な研究を行っている。このグループは，地球磁気圏・太陽だけでなく天体プラズマ全般の研究も活発に行っているが，ここで，専攻で天体プラズマの研究を行う意義を指摘しておきたい。すなわち，天体プラズマの天文学的手法による研究は,リモートセンシングのもつ制約が大きいのに対して,太陽系プラズマ分野では,直接観測と理論・数値シミュレーションの連携により宇宙プラズマの諸性質について重要な知見が得られており,世界的に見てもそれらの知見を天体プラズマに適用する研究が活発に行われている。

この講座の教員が関わっている宇宙科学研究所（JAXA）の衛星や探査機は，「はやぶさ２」に加えて，惑星分光観測衛星「ひさき」(SPRINT-A)，ジオスペース探査衛星「あらせ」(ERG)，太陽観測衛星「ひので」，磁気圏尾部観測衛星「GEOTAIL」と多岐にわたるが，その関わり方（開発・観測・解析や関連する理論的研究）は，ミッションごとに異なっている。「ひので」や「GEOTAIL」では衛星データに関連した理論・シミュレーション研究が中心であるが,「ひさき」や「あらせ」ではデータ解析だけでなく装置開発や運用に貢献しており（昇格人事で前職での関与を継続している場合が多い),「はやぶさ２」ではプロジェクトの中枢で貢献している。

この講座では教員の実験，開発，観測，理論のバランスを取りつつ，その陣容が次第に増強されている。宇宙科学研究所のミッションとの連携を積極的に進めており，学術面や装置開発面で貢献している。講座の運営に当たり，宇宙科学研究所の衛星や探査

機による研究に積極的に関与する方針を取っていることを高く評価する。今後もこの方向性を継続的に発展させるべきである。

一方，これらの衛星計画は，大学共同利用機関である宇宙科学研究所を中心とした全国の大学の協力のもとで実施されているが，いずれも規模が大きくなり，国家プロジェクトの性格を帯びてきている。今後のミッションについて，東大の関わり方や規模について，衛星や探査機ごとの多様なアプローチを是とするものの，大学としての一定の戦略が必要かもしれない。また，ミッションの開発と運用の現場を活用した高度な人材育成に，東大がより積極的な役割を果たすように，宇宙科学研究所と連携した施策的アプローチが求められる。

2017 年に設置された宇宙惑星科学機構は，この講座の教員に加えて天文学や工学の教員を擁している。この機構の構成員である天文学の教員が総力を結集して取り組んでいる TAO 望遠鏡は，その観測適地（南米の標高 5,000 m の山頂）と大口径とが相まって，「宇宙に一番近い地上望遠鏡」として，国際的に注目されており，その完成と運用開始が待たれる。

また，工学部・工学系研究科の宇宙工学分野は，宇宙科学研究所との連携による，重量 60 kg の超小型衛星「プロキオン」の開発・運用によるジオコロナの撮像などで，超小型衛星がすぐれた科学的価値を生み出しうることを初めて示し，世界的にも注目を浴びた。これは，現在開発中の NASA の大型ロケット SLS 試験機に搭載予定の超小型衛星「EQUULEUS（エクレウス）」の開発につながっている。

このような状況で，この機構は，天文学と太陽系科学の学術的連携強化，そのための多様な手段（地上望遠鏡，宇宙望遠鏡技術・センサー技術，望遠鏡・超小型探査機システム技術）の横断的な連携強化を目指していると思われる。この機構のスタッフが，手段である探査機や搭載観測装置の開発と，目的である観測からシミュレーション研究までをパッケージとして取り組んだことが，この度設立された東大の全学組織「宇宙理工学連携研究機構」につながったことを評価する。

（3）地球惑星システム科学講座

地球惑星システム科学講座は，前回の外部評価で，研究対象別に構成されている他の四つの講座に比べて所属教員間の連携が薄く，実際の連携は研究対象が近い他の講座の教員となされているようであり，研究手法で特徴づけられた同講座を別に設ける意義に関して疑問が呈された。しかしながらこの点は，その後の人事異動・採用や田近教授などの努力の結果，四つの分野を統合するシステム科学の方向性がかなりはっきりしてきたことが，研究成果からもうかがえ，現在ではこの講座の意義が発揮できる陣容を整えていると言える。一方で評価委員の一人は「やはり他分野の集まりであるとの感は否めないことに鑑み，この講座は専攻内の流動部門というスタイルを取り，構成メンバー

を一定期間の所属にとどめ，共通テーマの変更に伴って入れ替えることも考えられるのではないだろうか」としている。

この講座は，地球や惑星をシステム的に捉えて，システムとしての挙動特性（安定性・変動性）やシステムとしての形成・進化を明らかにしようとする新たな学術分野であり，惑星科学（系外惑星や惑星形成論を含む）から地球環境学（地球温暖化から地球環境変動史や地球・生命共進化史などを含む）までを含む幅広い講座となっている。その研究教育は，システム全体の挙動を捉えるための独自の考え方や方法論によっており，単なる複数の領域間の相互作用研究のような既存の研究とは異なっていると理解する。この講座の設立は，今後の学術の流れを先駆的に捉えた戦略的なものであり，今後の発展を期待したい。

特に，太陽系惑星探査は，天文学分野の系外惑星研究と並んで，現在，世界的に急速に進展している分野であり，惑星系をシステムとして捉え総合的に研究することが必要である。例えば，地球における生命の起源・維持の研究一つをとっても，地球史，地球における水や有機物の起源だけでなく，磁気圏の存在と太陽からの擾乱も関連しており，極めて学際的な取組みが必要である。これらの成果は，系外惑星の生命探査にも直結する重要性を持っている。

実際，生命の起源の研究につながる惑星科学と，天文学における系外惑星の研究の連携は，世界的に著しい。ALMA・すばる望遠鏡により，多様な原始惑星系円盤や有機物の発見が続いており，惑星科学と天文学が接近しつつある現況に鑑み，天文学専攻や国立天文台との連携の強化も期待したい。例えば，橘教授の太陽系科学における専門性を生かした（天文学用の）ALMA 望遠鏡を使った研究は国際的に評価されている。また同教授が天文学分野の研究会に積極的に出向いて，惑星科学と天文学の連携に向けた問題提起をしていることも注目される。瀧川晶准教授の着任（2020 年 3 月）にも上記の講座の戦略を読み取ることができ，更なる惑星科学と天文学（星惑星形成・銀河物質循環学）の連携を期待したい。

ただし「エアロゾルの動態と気候影響評価」グループは，やや浮いている感が否めない。大気海洋科学講座に移るか，協力講座である大気海洋研究所の気候モデルグループや先端科学技術研究センターのグループなどとの連携により，新たな研究分野を創っていくのも選択肢の一つであろう。

専攻が設立された際，この講座の当時のスタッフが企画・執筆・編集して教科書「進化する地球惑星システム」を 2004 年に出版した。15 年経って講座のスタッフが一新された今，その第 2 弾を出版する計画が進んでいる。書籍の企画・編集過程は，講座全体あるいは専攻全体での研究の連携・統合を促進するための非常に良い機会になると期待する。

この講座の重要な役割は，大気海洋研究所や地震研究所などの協力講座も含めて，例えば，地球の進化や地球史あるいは表層環境も含む地球システムとその変化のダイナ

ミクスのような分野で，（やや大げさに言えば，人類として）今後何が大きな課題なのかを，講座あるいは専攻全体で，融合セミナーなどの機会を作ってブレーンストーミングを行い，専攻の新しい共同研究課題と，そのための研究教育体制を，10 年程度の時間を掛けて作っていくことではないだろうか。このような活動は，新学術領域のような大型の科学研究費や外部資金の獲得にもつながるはずである。この新分野や新しい研究課題の創出には，臨象科学的分野も当然入るべきで，例えば，長い地球史の中で，現在の人類活動による「人新世（人類世）」をどう理解すべきかなどのテーマは，地球惑星システム科学における臨象科学的研究になるのではないか。

（4）固体地球科学講座

固体地球科学講座は，地震学，地質学，岩石鉱物学，同位体地球化学，高圧地球科学などの研究者が一体となって構成する研究分野で，研究者間の相互協力と分野を越えた研究協力が進んでいる。基幹講座の教員 13 名に加えて，地震研究所 42 名，大気海洋研究所 3 名の協力講座の教員を数えると，固体地球科学に関する巨大研究グループである。この講座ではスタッフの大半が最近 7 年間に新たに任用されていることから，その研究活動は従来の継続とみるべきではなく，新たなスタッフの力量によって今後大いに発展するものと期待される。

地震科学研究グループでは，巨大地震からスロースリップまでの様々な規模の地震活動を視野に入れ，地震発生過程を考慮した研究を展開してきた。地震活動を精密な断層破壊モデルを用いてシミュレーションすることにより，地震学とテクトニクスを融合することを目指している。また波形インバージョンを用いたグローバルトモグラフィーにより，精度の高い地球内部構造の推定を目指している。このように地震学グループはそれぞれ特色ある手法を生かして，単に地震学にとどまらず，テクトニクス，固体地球進化，地球内部ダイナミクスにも研究対象を広げている。

テクトニクス研究グループでは，三波川変成帯やチベットなどの岩石に残された情報を用いて沈み込み帯ならびに大陸衝突帯深部で起こったプロセスを復元し，現在の地球で起こっている変動現象を解明している。現在および過去の変形集中帯における観察・観測によって推定された天然岩石の物性に関する情報を最大限生かすため，専攻の他の教員と連携し，構造地質学・岩石学と地震学とのリンクの強化に努めている。

固体地球進化研究グループでは，マグマ生成過程に関する精密な化学反応モデルを構築し，中央海嶺や沈み込み帯の分化過程を解明した。マントル由来捕獲岩の精密な岩石学研究から日本列島下のリソスフィア/アセノスフィア境界（LAB）の実態を初めて明らかにした。また，各種の半減期を持つ同位体元素に着目して太陽系形成から地球コア形成までのタイムスケールを制約し，地球形成後の大陸地殻成長史を解明するなど，同位体地球化学の手法を用いた固体地球進化の研究も盛んに行っている。

地球内部ダイナミクス研究グループでは，ダイヤモンドアンビルを用いた超高圧実験により，地球深部物質の相転移・物性測定，下部マントル・コアの構造の成因の解明，地球の初期進化に関する研究を進めてきた。地球中心の条件を超える超高圧高温状態の発生に，静的圧縮実験として世界で初めて成功するとともに，コアの熱伝導率が高いことから，コアを熱対流させることは困難であること，代りに二酸化ケイ素の結晶化によって，コアの対流と地球磁場が維持されてきたことを提案した。さらに，コアの化学組成（軽元素）の特定に向け，鉄合金の融解実験に基づく状態図の作成，液体鉄や合金の密度・音速などに関する研究を精力的に進めている。

この講座の研究者はいずれも世界第一線で活躍中であり，異なる研究手法を用いたグループをまたぐ共同研究が盛んである。例えば，地震学，地質学，岩石学を組み合わせた沈み込み帯のテクトニクス研究，グローバルトモグラフィーと高圧地球科学の連携による地球深部ダイナミクス研究，同位体地球化学と超高圧実験による初期地球進化研究などがそれである。「地球進化という大きな枠組み」を専攻全体で共有することにより，宇宙惑星科学講座や地球惑星システム科学講座との共同研究が活発に行われることが期待できる。さらに，大気海洋科学講座や地球生命圏科学講座とも連携した専攻全体の大研究プロジェクトに発展させることを期待したい。

（5）地球生命圏科学講座

地球生命圏科学は，安定同位体分析や DNA 解析などのめざましい発展に後押しされ，従来の進化学や地球化学から脱皮し，新しい生命圏としての地球科学の研究領域として，この 20 年間，世界的にめざましい展開を遂げている。それゆえ，多分野からの研究者の参画が可能であり，また求められるので，限られた人員の中で，また大学という人材育成機関において，どのように研究の的を絞り世界をリードしていくかは難しい課題である。そのような背景のもとで，地球生命圏科学講座は，総勢 9 名の教員（教授 5 名，准教授 2 名，助教 2 名；分野別では，古生物学系 1 名，鉱物学系 2 名，堆積学系 2 名，地球化学系 2 名，微生物学系 2 名；2020 年 2 月現在）が，生命誕生と進化という魅力あるテーマに，生命科学，古生物学，物質科学などの多角的な視点から取り組んでいる，日本の地球科学系で最も充実した研究教育組織である。

時代の要求に沿った特色ある活動の一つとして，地球化学系教員が，福島第一原発事故由来の放射性セシウムの河川水中での挙動に関する重要な知見を報告すると同時に，鉱物系教員が，セシウムの粘土鉱物への吸着現象に関する基礎的な研究を発表した。分子地球化学が新分野形成の一つの候補に挙げられている中で，このように分野の異なるメンバーによる協働を踏まえた新たな研究が展開できることを示した。またバイオミネラリゼーションをキーワードとした連携や，地下圏あるいは深海底を対象とした極限環境から地球と生命の相互作用を明らかにしようとする研究が推進されており，この講

座の研究対象に相応しい選択がなされている。さらに学内および他大学や他機関との連携が今後一層広がることを期待したい。

極めて多様な研究テーマに対して講座としてのまとまりを求めるならば，前回の外部評価でも指摘されたように（報告書 p. 15）「大講座全体に共通する目標を立てる」ことが考えられる。しかしながら目標の設定は，研究対象があまりにも広く容易ではないと思われる。教員が，研究対象を時空間的に広くカバーするよう配置されていることからも，対象を一つに絞り込むことは容易ではないであろう。ある目標設定に向けて徐々に講座の内容を変化させるという手法も考えられ，専攻資料には，講座としての人事や個々の研究内容においての努力が記されている（p. 88）。しかし同時に考えなければならないのは，研究領域の変動と人材育成の兼合いをどのように見据えるかであろう。目標設定に際しては，全体を一つに集約するのではなく，すでに試みられているような共通目標の絞込みで小さなグループを作り，数年間走らせるという手法も有効であると思われる。そのような活動の中から地球環境と生命現象をしっかりつなぐ新しい地球生命科学が誕生し，人材が育成されることを期待したい。

新しく設けられた臨象地球科学分野は，フィールドと分析および数値計算を組み合わせて地球環境の変化に向き合うことを目指していると紹介されている。外部からのサポートも得ながら，現象を対象に絞り込んだ中でのみ理解するのではなく，大きな舞台の中で現象を捉える新しい地球科学を期待したい。一方，それと並行して，この講座の研究分野の基盤となるクラシカルとも言える分野をしっかり残すことも東大の役割ではないだろうか。科学研究におけるパラダイムシフトの時間スケールと人材育成の時間スケールをしっかりと見極める作業が求められよう。

今後の展望として掲げている「地球と生命の共進化」は，まさに地球科学と生命科学双方の大問題であり，ぜひその方向に向けて，地球惑星システム科学講座などとの連携・協働を進めて欲しい。また，世界的にもあまり進んでいない生物科学のコミュニティとの協働をぜひ進めていただきたい。

付録：外部評価の実施要領

外部評価委員会の構成

委員長

今脇資郎（九州大学・名誉教授）

委員

常田佐久（国立天文台・台長）：実地委員会は都合により欠席

安成哲三（人間文化研究機構総合地球環境学研究所・所長）

髙橋栄一（中国科学院広州地球化学研究所・教授）

加藤憲二（静岡大学・名誉教授）

書面評価委員

Kevin Hamilton (University of Hawaii, USA; Emeritus Professor)

Timothy D. Swindle (University of Arizona, USA; Professor)

James F. Kasting (Pennsylvania State University, USA; Professor)

Gregory C. Beroza (Stanford University, USA; Professor)

Danielle Fortin (University of Ottawa, Canada; Professor)

実地委員会の日程

日時：2020 年 2 月 14 日（金）9:00-17:00

場所：理学部 1 号館 710 号室

9:00- 9:30	専攻全体について，説明者：井出 哲
9:30-10:15	大気海洋科学講座：日比谷 紀之
10:25-11:25	宇宙惑星科学講座および宇宙惑星科学機構：星野真弘，橘 省吾
11:35-12:20	地球システム科学講座：田近英一
12:20-13:30	昼食（843 号室）
13:30-14:15	固体地球科学講座：小澤一仁，廣瀬 敬
14:20-15:05	地球生命圏科学講座：遠藤一佳
15:10-16:00	質疑応答
16:00-16:45	審議
16:45-17:00	講評
18:00-20:00	懇親会（フォーレスト本郷）

Kevin Hamilton's comments for the external evaluation review of the Department of Earth and Planetary Science and University of Tokyo Organization for Planetary Space Science, Graduate School of Science, the University of Tokyo

My Comments on the Review Process

First I would like to thank the department faculty and personnel for their effort in producing the very extensive and organized materials for the review. I actually found some of the background description of the history and organization of the department to be very interesting reading!

Note that, given my expertise and background, I have confined my comments to the Atmospheric and Oceanic Science Group. I am aware, of course, that the space and earth and biosphere science components have strong international reputations, and the review materials provide ample evidence of this and of high productivity from those components of the department, but I will leave the detailed judgements on these other groups to other members of the review committee with more appropriate expertise.

The very nice review materials the department prepared have helped me greatly to write my comments and assess the efforts and outcomes of the research, education and service activities of the department, but the lack of a visit by the review committee makes it more difficult for me to offer guidance on questions of department management, budget and organization. I think typically such concerns arise for a review committee when talking directly to the faculty, staff and students during a review. In addition, on such topics as the departmental budget, I am at a disadvantage in not knowing the usual procedures and parameters that are prevalent in Japanese universities. So I will have very little comment to offer on such topics here. Hopefully other members of the review committee may be more familiar with the situation in the department and may be able to comment on these topics and particularly the department's response (discussed on pages 79-88) to the organizational issues that were raised in the 2013 eternal review. Also the absence of a visit means that the review committee lacks the perspective of the graduate students themselves on their experience in the M.S. and Ph.D. programs, so my comments on the educational programs mainly reflect my perception of the outcomes of the programs.

My comments are based on the view that the department, as part of one of the world's great universities, is aiming for the very highest standards and expecting to match, or exceed, the accomplishments of the world's top university departments in the atmospheric and oceanic sciences. At least in my mind, I looked at the material provided by the department for the review in a comparison with the atmospheric and oceanic sciences programs at MIT/Woods Hole, University of Washington, University of Reading, University of California San Diego/Scripps Institute of Oceanography – of course bearing in mind the University of Tokyo group is smaller than these American and European programs.

Summary of My Overall Conclusions

The current state of the research and educational activities in the atmospheric and oceanic sciences group is very strong and certainly comparable to the top institutions in the world. The overall high level of attainment of the faculty is attested to by the impressive list of awards since 2013 received from scientific societies (Meteorological Society of Japan, Oceanographic Society of Japan, JpGU, AOGS, AGU) and the Japanese government, including some awards for younger faculty. It is also great to see that graduate students are winning awards virtually every year for their presentations from JpGU as well as awards from other societies and the university itself, which I think is a useful indication of the timeliness of the research projects being undertaken as well as the vitality of the graduate education program.

I assess the research accomplishments and productivity in more detail in response to 1.1 below, but let me summarize by noting that all the faculty are quite active in publishing their research results in leading journals and that generally the contributions of each paper are substantial and significant. The standard of productivity and quality of the research published in the atmospheric and oceanic sciences group is quite high. In addition I should mention a singular achievement of the atmospheric and oceanic sciences group in leading the conception, development, deployment and now application of a unique and major research facility, namely the PANSY radar in Antarctica. This a very impressive contribution to the global atmospheric research from a university.

The department has had a long and distinguished history of producing Ph.D. graduates who go on to important careers. *This graduate education activity has maintained a high level in recent years and the University of Tokyo continues to be a uniquely important source of high level atmospheric and oceanic science talent for Japan.* I expect the department would like to have even more Ph.D. students, but the current enrollment of strong students is actually impressive in a situation (at least in America and Europe) of unfortunately declining numbers of young people wanting to pursue graduate studies and the Ph.D. in particular. I think most departments of atmospheric and oceanic science would envy the vitality of the graduate program at the University of Tokyo.

Focusing on my own subfield of atmospheric dynamics, the University of Tokyo contributions in research and education have been, and continue to be, extremely important. If I imagine doing a "thought experiment" where the research activities, publications, service activities and the Ph.D. graduates from U Tokyo don't exist, I know it would leave a big void in the field of atmospheric dynamics.

The faculty in the atmospheric and oceanic sciences group are understandably in great demand on editorial boards, national and international science committees. The faculty generously give their time to these demands and are very active and prominent in their service to the scientific community (including taking the initiative in organizing scientific meetings). Indeed it is clear (pages 68-78) that this outstanding devotion to service to the community is a strong feature of the entire department. I note that the service component of departmental activities extends beyond the scientific community to the community at large with a notable and impressive number of public lectures. I think most university departments throughout the world would be quite envious of the level of community interest and interaction this implies.

My overall opinion is that the present state of the department's atmospheric and oceanic sciences is very strong and continues to uphold the important tradition and high standards of the University of Tokyo in these fields. If I have a concern it is whether – in a very rapidly changing world - the department is on track to continue this level of success and prominence in the years and decades ahead. I have a couple of specific issues which I am sure the department faculty already appreciate (and which have been called out in the earlier external review from 2013), but here I will add my view of the current situation and prospects.

The overall size of the atmospheric and oceanic sciences group is quite small with 8 faculty including the 3 full professors. This is quite significantly smaller than the top atmospheric/oceanic sciences departments and programs in western countries (such as at MIT/Woods Hole, University of Washington, University of Reading, University of California San Diego/Scripps Institute of Oceanography). The size of the University of Tokyo group is also dwarfed by many university departments and science centers in other Asian countries, which are becoming more and more prominent in the science. The most concerning aspect of the small size is potentially missing out on important opportunities. In particular, research into aspects of global climate change benefit from contributions from a range of specialties and some of the important outstanding challenges will relate to the chemical and biological interactions with the atmospheric and oceanic dynamics and physics. The 2013 external review noted an overall modest representation of the geochemical sciences in the department and that point applies to the atmospheric and oceanic sciences group (not forgetting the excellent work of Prof. Koike, of course). Other key expertise that should be strengthened in the atmospheric and oceanic sciences are comprehensive global coupled ocean-atmosphere modeling and the study of predictability of the climate system on various scales. Also there apparently is not much activity connecting to some now emerging subjects such as geoscience applications of machine learning/artificial intelligence. Obviously it is difficult to expand any group as the university policy now seems to be to reduce total faculty numbers, but *the atmospheric and oceanic sciences stand at the center of so much exciting and critically important research these days that it would be very desirable for the university to increase the commitment to this area and allow at least some expansion with additional faculty in key climate-related specialties*.

The second concern relates to the degree of internationalization in the department. This issue was also raised in the 2013 external review. Clearly there have been some admirable recent efforts to improve international connections (page 63-68; although I note that the specific programs aimed at expanding international involvement - GSGC, UTRIP, UCEAP, STEPS - seem to involve the other groups in the department with little engagement from the atmospheric and oceanic sciences group). However, despite these efforts, the current level of international faculty, students and researchers remains very low compared to standards at major western universities these days. The trend to more globalization of the scientific research community can be expected to continue and the most flexible and welcoming organizations will have the best chance to tap into the global pool of talented students and researchers. In such a rapidly changing landscape it may be easy for more conservative organizations to be left behind. *I strongly encourage continuing efforts to make the department and its educational programs as international as possible.*

My Response to Some Specific Queries for the Review Panel

1. Research

1-1 Quality and quantity of researches compared with the global standard

The overall numbers of journal publications in oceanic and atmospheric science are quite reasonable for a group with 8 total faculty members: 220 papers in peer-reviewed journals over 6 years. The papers published are almost all in high ranking journals with strong international reputations. Most importantly, generally each paper represents a substantial contribution and, while I have not examined all the publications, obviously, it is clear that there is a culture of publishing substantial and innovative work. The quality is also attested by the many awards the faculty (both senior and junior) have won for their research achievements.

1-2 Diversity of research topics expected from the size of the department

On the positive side I think the faculty members in the atmospheric and oceanic sciences generally display a fairly broad set of interests and approaches in their published research. So, for example, the contributions to atmospheric dynamics have involved experimental work (including the development and deployment of a major new observational facility – the PANSY radar), innovative theoretical work and the interesting application of comprehensive global simulation models. On the negative side, the overall small size of the group (8 faculty members) does limit the range of topics investigated (and available for graduate student projects). With just one chemist, the focus of the group's research leans strongly towards atmospheric and oceanic dynamics. As I argued earlier, given the centrality of the basic physical climatology in understanding urgent global environmental change issues, I believe a case can be made for expanding the size of the faculty and hence the range of expertise and interests in the atmospheric and oceanic sciences group at University of Tokyo.

1-3 Management of research projects

I feel I do not have useful input on this issue.

1-4 Perspectives of researches in each group and the department

I have limited my comments mainly to the atmospheric and oceanic sciences group, where I have some level of expertise. As I mention in my summary comments above, I do have a general impression of a very strong research and educational reputation for all parts of the department, and this is supported by the extensive review materials provided to the committee.

２．Education

2-1 Educational system for graduate students

With outstanding faculty and quite extensive curriculum of courses the graduate students certainly should be provided a world class opportunity for their education. There are excellent features now built into the program such as a mandatory class on research ethics. The requirement of an accepted first author paper in an international journal for the student to proceed to completing their Ph.D. thesis is another great aspect. As I mention below, the achievement of the graduate program is very strong and world class. My one concern is whether the curriculum is being kept completely up to date – for example there seem to be no offerings related to machine learning/artificial intelligence.

2-2 Educational achievements of graduate students

The results for the number of Ph.D. graduates each year (page 46) are reasonably strong. The department as a whole has seen a decrease in total numbers from 2006-2008 to the present, but overall the production of Ph.D. graduates is reasonably high for a department of this size. For the atmospheric and oceanic sciences there have been roughly 4-5 Ph.D. graduates per year recently, which is impressive for a group of only 8 faculty, particularly in these days with fewer young people generally interested in graduate studies. More importantly the Ph.D. graduates have a very strong reputation and the expectation of the international science community is that a University of Tokyo Ph.D. graduate is on his/her way to a productive career in science. The high quality of the students and the high regard in which they are held is evident from the large number of publications in important journals and the awards they win each years at conferences etc. (pages 47-50). In the current tough time for science graduate education, almost any atmospheric or oceanic science department in the world would be envious of the overall track record in the graduate program at University of Tokyo.

The review material provides a nice summary (page 52) of the initial career path for the Master's and Ph.D. graduates. Particularly for the Ph.D. graduates it would be very nice to have tracking of the careers over a longer time period. The figure on page 52 shows that – as expected – almost all the Ph.D. graduates go one to temporary postdoctoral positions. More relevant to judging the success of the Ph.D. program are the career paths at say 5 and 10 years after graduation. I appreciate it is sometimes difficult to track alumni over such extended periods, but this is one of the most useful metrics in evaluating the success of a Ph.D. program.

2-3 Educational system for undergraduate students

I do not have much to say on this. I note the external review committee in 2013 recommended combining the two undergraduate programs. In response this recommendation, the department over the next several years discussed this and considered (rather than merging the programs) various initiatives to coordinate the two programs. It is not clear to me how successful these initiatives have

and if they have substantially improved the undergraduate student experience. Perhaps other members of this year's review committee who understand the situation in the department may have useful input on this issue. The review material (pages 53-54) does provide a useful summary of undergraduate student course evaluations for each of the two programs. These course evaluations suggest most of the students are reasonably content with their education program.

2-4 Educational achievements of undergraduate students

Once again other members of the review committee may have a better perspective on this issue. The review material provided (page 51) does have a summary of the initial career path for graduates of the two programs. It seems the main path is to private companies. The small (and declining) numbers of graduates who choose graduate school is a bit discouraging, but follows trends in many other countries of reduced interest in graduate (particularly Ph.D.) studies.

2-5 International activities in education

The 2013 review raised a concern with the lack of progress in internationalization (including declining numbers of foreign students) in the department. The material provided to this year's review committee includes information on a number of worthwhile initiatives to increase international exchange, but not much evidence of improving numbers of foreign students (or foreign faculty for that matter). These initiatives show that the University and the department are both focused on this concern and looking for solutions. However, given the trend to a more globalized research community I think this issue needs to be addressed even more vigorously and urgently, in order to position the department's research and education enterprise to meet the challenges clear lying ahead.

3. Organizational Operation

3-1 Organization of the department

I feel I do not have useful input on this issue.

3-2 Policy and system for the appointment of faculty members

I feel I do not have useful input on this issue.

3-3 Budget and external funds

I feel I do not have useful input on this issue.

4. Public partnership, contribution for societies, and outreach

The material provided for review provides ample evidence of outstanding contributions of the department's faculty to the scientific community and the broader society. The engagement with the general community shown by the many public lectures presented by faculty is really quite impressive and something that almost any other science department in the world would envy.

Review comments by Timothy D. Swindle (University of Arizona, USA; Professor)

Let me group my comments in four categories. First are responses to the provided evaluation points – most of the important points I wish to make are raised here. Second are comments on the "Specific responses" to the January 2013 external review, although I found that I had already commented on the ones where I felt I had enough information to comment. Third are some comments about the department's performance in my area of expertise, planetary science. Finally, I will comment about what seems to me, from the information provided, to be the major areas in which the department can improve.

I will preface these comments by saying that I assume that the largest Geosciences department in Japan aspires to be one of the premier Geosciences departments in the world, so I am comparing with the standards of the best in the world in mind. In general, the department meets those standards, although there are areas where improvement is possible.

1) Evaluation points:

1. Research

1-1 Quality and quantity of researches compared with the global standard

The most obvious measure of quality and quantity of research is the citation rate for publications, and in that respect, the numbers are what I would expect for an internationally prominent department.

1-2 Diversity of research topics expected from the size of the department

To be the leading geosciences department in Japan, the research topics should be broad, but should include topics that are of particular interest to the nation, topics that are at the forefront of international research, and/or topics that are likely to be of increasing importance nationally or internationally. Although these do not encompass every faculty member, four topics that I see prominently featured that meet those criteria are the study of earthquakes (a nationally-important topic), global climate change (a topic of growing importance internationally, and also one that is likely to affect a nation of islands as sea levels rise), extrasolar planets (a topic that is rapidly developing internationally), and planetary exploration (a topic in which Japanese spacecraft missions are becoming increasingly important internationally). Earthquakes and planetary exploration are clearly areas of expertise. Climate change and extrasolar planets are not mentioned much in the descriptions of the research areas, but do seem more prominent when reading through the activities of the individual faculty. I don't know whether this is because there is some difference in opinion within the department about the importance of these, whether the research group descriptions are slightly out of date, or some other reason, but this is work that should be highlighted.

1-3 Management of research projects

I am sure not what is meant by this question.

1-4 Perspectives of researches in each group and the department

See the comments for 1-2.

2. Education

I found it difficult to find quantitative measures of the effectiveness of the educational program. I did not find numbers on retention rates of students, either undergraduate or graduate, or time to completion of degree. It would be interesting to know those, both for the department as a whole and, for the graduate students, for the individual research groups. Also, there is very little information on the diversity of students, for instance, by nationality, ethnicity, socioeconomic status, or any other measure other than gender. Females are ~20% of the students at every level, which is lower than in many American universities. I would be interested to see a comparison with other Japanese universities. Also, what fraction of the applicants for admission are female, both at the undergraduate and graduate level?

Although there were lists of Master's and PhD graduates by advisor, I did not find information on the success rates for the various research groups.

2-4 Educational achievements of undergraduate students

I find this difficult to judge, but the fact that virtually all of the graduates go on to graduate school (p. 51) is very impressive. However, it appears that no one has gone to graduate school in a program other than University of Tokyo in the last two years. This might be a place to encourage international exposure.

2-5 International activities in education

The Self-Study lists many activities and programs designed to increase the international exposure of the students, and the number of students taking advantage of those is increasing, for which the department should be commended. I think that finding a way to encourage more students to attend international conferences would be beneficial.

3. Organizational Operation

3-1 Organization of the department

The length of time for the appointment of the department head still seems to be short. It appears that this was only increased to two years after the last review. For an organization as large as this, I would think that a term of at least three years, preferably five, would be more appropriate. Alternatively, a tradition of multiple reappointments, so that the department head remains in the position for several years, should be encouraged. Adding a discretionary fund for the department head is a definite improvement.

The organizational structure seems designed to ensure communication with faculty and staff on decisions, which I think is very positive. However, it appears that the individual groups have a considerable amount of power compared to the department as a whole. Without knowing what the working relationships of the various groups and individuals are, this structure could make it difficult to

make changes. The discussion about the considerations about reducing the undergraduate education program from two threads to one seems like it could be an example of this, although I will not comment on whether that was the correct decision or not.

3-2 Policy and system for the appointment of faculty members

Faculty are the heart of an academic department. Rather than commenting on the details of the process, I would like to comment on the results. In the recent hirings, I wish to comment on several things, some positive, some negative.

There has clearly been an effort in the last decade to hire faculty who have not spent their entire careers at the University of Tokyo. I believe this is a good thing. Having some faculty who are graduates makes sense for a premier program like this. However, by hiring faculty who have spent time elsewhere, the department can attract some of the best scientists who a) didn't choose the University of Tokyo at the start of their career, or b) who did not appear to be of the caliber expected of University of Tokyo students when they were initially evaluated, but then demonstrated their abilities elsewhere.

The department's capabilities in geochemistry have been strengthened significantly in response to the last review, which is also very positive.

The most obvious negative item is that there are only two female faculty members out of approximately 50. Yet there has been a turnover of approximately half of the faculty since 2012. I find this disturbing. I find it even more disturbing that the number of female faculty members is decreasing, according to the table on p. 18. Increasing diversity is always difficult, but with that many hiring opportunities, it should have been possible to do better than that. One problem may be that while all of us would like to hire based solely on merit, research has shown that, in the U.S. at least, our judgment of merit is clouded by unconscious bias, so we (both males and females) underestimate the merit of female applicants. The personnel committee, and the hiring committees, should be made aware of that research. In addition, the department needs to understand whether there are particular attitudes or policies that are causing female faculty members to leave.

The department's efforts at globalization have had mixed success, as far as I can tell. In the tables in Section V.3. (and on pp. 69 and 70 of the Self-Study) for international leadership, only about half the faculty appear anywhere in leadership activities. While there are some excellent journals and programs represented for those who do appear in the tables, the number of faculty involved is lower than I would have expected for an internationally important department. Furthermore, in looking through the biographical information on the faculty, I found only six who had any degrees outside of Japan. I think the department should encourage participation in international leadership activities. The efforts to fund young faculty spending extended periods of time in other countries is a good start, and hiring two faculty with international post-doctoral experience does send a message that such experience is valued, as suggested in the Self-Study. Finding ways to encourage more students and young faculty to attend international meetings would also help.

Also, on p. 7 of the Self-Study, there is a comment that 30% of the applicants in the last seven years have been foreign nationals, but only one has been hired. That suggests that there is some unstated barrier to hiring foreign nationals. If the department wishes to become more international in nature, there is a need to determine what that barrier is and figure out how to address it.

Finally, systems for promotion vary from nation to nation, and I found it difficult to understand what the process is for promotion of faculty through the ranks. Although the Self-Study report said that Assistant Professors are evaluated after five years, and mentioned that some had been promoted, it did not discuss what the further outcome was for those who were not promoted. Furthermore, p. 18 of the Self-Study commented that only 6 faculty members were promoted internally in this period, and expressed some concern about the number who have remained Assistant or Associate Professors for more than 10 years. Have those faculty members been given goals to meet to achieve promotion?

3-3 Budget and external funds

It is difficult to tell whether the budget is adequate from just reading about the department. It does appear that the vast majority of faculty have external grants to support their research, which is good. Whether there is adequate support for graduate students is impossible to tell without knowing what the experiences of those students are. Similarly, there are references to changes in the way the university is funded by the government, which is apparently responsible for the overall decrease in the number of faculty. That is concerning, particularly for a world-class department, but without understanding the details of the system, I cannot comment on whether the current situation is adequate, or whether there are things that can be done to address inadequacies.

4. Public partnership, contribution for societies, and outreach

Many faculty in the department appears to be very active in Japanese scientific societies (particularly the Japan Geoscience Union) and in working with government groups, as they should be. As mentioned above, I think an organization with this department's strength nationally should be more active internationally.

Most faculty list at least one public lecture, several list 10 or more. This is very good, what I would expect from a department in a national leadership role. I am a little concerned about some faculty who list no outreach activity, although some of them are very recent additions to the faculty, so they would not have had time to build up this activity.

2) Response to previous review

1) The department has made some attempts to increase synergy with things like seminars. It might be possible to determine whether more faculty are collaborating with faculty in other areas by searching through the details of the author lists of papers, but I have not done that.

2) I cannot tell how the Earth and Planetary System Science Group interacts with the rest of the department, but it is the group that contains the expertise in exoplanet studies, and the members have good publication records. The group may not be fulfilling the original intent, but it does seem to be productive.

3) The department has greatly increased its strength in chemistry-oriented subfields.

4) The department has made some attempts to better unify the two threads, but there is clearly strong support for the existing threads. As long as the students graduate with a basic understanding of geosciences, I trust the department's collective judgment.

5) The department appears to have made progress on getting experts from the related research institutes to contribute to the educational mission.

6) I don't know enough about the department to know whether there truly was a problem, and if so, whether the steps taken have corrected it.

7) Mentoring of young faculty is crucial. It appears that positive steps have been taken. Assigning individual mentors to individual faculty members is another approach that might be taken in addition.

8) As I have stated elsewhere, there appears to be a major problem in recruiting and retaining female faculty members, and the situation with international students is not good, though there appears to have been some improvement in the latter.

9) The appointment of two new Assistant Professors with international postdoctoral experience is commendable.

10) The department needs to have the ability to switch faculty positions between groups as fields increase or decrease in importance. The steps taken appear to be a start at that.

11) Major progress was made on this.

12) This is a large enough department that it needs strong leadership. While I would recommend that the term of the head be increased, if the head can be reappointed, that could serve the same purpose. Adding a discretionary fund for the head is a very good thing.

13, 14) I do not have enough information to be able to comment or make recommendations.

3) Some comments about planetary science

My expertise is in planetary science, so I think it is appropriate for me to comment on the department's programs in that area. Simply put, the department is strong, and seems to be getting stronger. The interaction with JAXA is very good, and the plans for UTOPSS are also very positive. Finally, the study of exoplanets has often been done by astronomy departments, but as the amount and quality of the data increases, I think that it is appropriate for departments of Earth and planetary sciences to become leaders in interpretation of that data, and the department seems positioned to do that.

4) Major areas for improvement

The biggest area for improvement, from my perspective, is that the department needs to increase its diversity. At the time of the last review, it appears that the faculty were almost entirely Japanese males who were educated in the department, a situation that cuts the department off from many voices that could provide fresh ideas and ways of doing things.

There has been considerable improvement in bringing in faculty who have not spent their entire careers in the University of Tokyo system, which is very good.

The efforts at globalization have not been as successful, but there has been progress in the number of faculty with international postdocs or visiting professorships. The fact that, according to the self-study, only 1 foreign faculty member has been hired, despite having 30% of the applicants be foreign, suggests a problem there.

The most obvious area for improvement, though, is the gender balance. The percentage of the faculty that is female has decreased, during a time where it is increasing in most of the world's major departments. Whether it is a problem with the hiring procedures or with a department culture that is making it difficult to retain female faculty (or both), I do not know, but it is an area that clearly needs to improve.

Review of the Department of Earth and Planetary Sciences, University of Tokyo

Reviewer: James Kasting, Penn State University (USA)

December 2019

Let me preface my remarks by saying that, as an external reviewer from the USA, my knowledge of the Department of Earth and Planetary Sciences at U. Tokyo is limited. I had the privilege of being invited by Yutaka Abe to give a series of lectures there in 2013. One of your current faculty members, Eiichi Tajika, served as a gracious co-host during my visit. Other than that, my contact with your Department and its faculty has been limited. Thus, my comments will be mostly general in nature. I will first briefly address the topics that you have listed for us, then I will provide some more general comments on the problems, as I see them, that are unique to your fine institution.

Below, I've highlighted your suggested topics in blue. My responses are in black.

1. Research

1-1 Quality and quantity of researches compared with the global standard

The faculty as a whole are quite productive. Numbers of scientific papers and books are comparable to those at a prestigious university in the U.S. There is only so much time in the day, and only so many days in a year. What really matters in science is not so much the numbers of papers produced, as their impact on their respective fields. I did not try to evaluate all 52 faculty member's impact, but my overall impression is that they are quite an elite group.

1-2 Diversity of research topics expected from the size of the department

The research topics are all over the map, as would be expected from a Department of Earth and Planetary Sciences. That is what makes this field entertaining to many of us who are engaged in it. There is almost no area of science that is excluded from this broad title.

1-3 Management of research projects

No comment. I am not close enough to those involved to judge the effectiveness of project management.

1-4 Perspectives of researches in each group and the department

Oh, this is a tough question! There are five different general areas, and I am expert in only one of them: Earth and Planetary System Science. Even there, I am only really familiar with one of the faculty, Prof. Tajika. Prof. Tajika has written several papers in the past 15 years that have inspired interest from within my own group. In particular, he was the first person to point out the concept of climate limit cycling, through his work with EBMs back in the early- to mid-2000's. Limit cycling is now a well-accepted concept that may apply to some exoplanets and that very likely applied to early Mars in our own Solar System.

Of the other main areas, Solid Earth Science appears very strong, although I am not the best person to judge this. To my knowledge, Japan has always been at the forefront of research in seismology and earthquakes, for obvious reasons. You experience a lot of them.

Evaluators from the previous external review pointed out that the Atmospheric and Oceanic Science group is rather small. It currently has only 8 members. By comparison, our Meteorology and Atmospheric Science department here at Penn State has ~25 members. The 8 members in the U. Tokyo group appear to be mostly focused on dynamics, including atmosphere, ocean, and climate. One group member is an atmospheric chemist. Other important areas (e.g., clouds, radiation, boundary layer processes) are not covered, unless I missed something. And, although climate dynamics is covered, I didn't identify anyone who is focused on what I consider to be the outstanding problem in this research area, namely, anthopogenic global warming. I'm guessing that this topic is covered in the Graduate School of Environmental Science. If that is correct, then I hope that you facilitate interactions with them. This problem is one that is common to all societies, and one that all universities should be doing their best to help solve.

Space and Planetary Science seems to be in good shape because of coordination with JAXA. That is a very solid and useful cooperation. The Geosphere and Biosphere Science group may also be quite good. I just don't have the time right now to evaluate each of the 9 faculty members individually. Even so, they cover a large amount of academic territory. Here at Penn State, we have roughly 25 faculty members covering this same territory within our Geosciences department. (The other 10 faculty members in Geosciences overlap with your Solid Earth group.)

2. Education

2-1 Educational system for graduate students

The Department has averaged about 90 Masters students and 31 doctoral students per year for the last several years. That's a little over two Masters students per faculty member, but less than one doctoral student. We're tilted the other way in our Department: We have more Ph.D. students than Masters students. This may reflect different job markets in Japan versus the U.S. In the U.S., academia has been expanding – at least until quite recently. As the academic job market tightens up, our ratio of Ph.D.'s to Master's students may become lower, as well.

The students within your graduate program seem to be getting an excellent education. I was impressed with the interdisciplinary seminars that have been set up and with the emphasis on speaking and writing English. Although it sounds parochial for a native English-speaker to say this, English is clearly the international language of science. Japan has many bright, motivated researchers, but it is more important than ever to be able to communicate well with scientists from other nations. It appears that this idea is not news to you and that you have been working hard on this for many years.

That said, there is a *big* difference between our graduate education system and yours. According to the charts on pages 43 and 44 of your self-assessment document, about half of your

Master's students, and nearly all of your Ph.D. students, are drawn from your own undergraduates. That is quite different from the situation here in the U.S. Here, nearly all of our graduate students, both Master's and Ph.D., come from other universities. Indeed, we actively discourage undergrads from doing their graduate work at the same institution (although there are, of course, exceptions). The philosophy here is that scientists, especially young ones, are like butterflies who flit from academic flower to flower helping to transmit and receive knowledge and information.

Whether this same strategy of switching institutions between undergraduate and graduate education would work in Japan is not clear to me. I understand that your undergraduate students are quite elite. That is different from a place like Penn State, where we have some excellent undergraduates but where the average student is just that – average. I also don't know enough about the university system in Japan to know whether switching institutions is a realistic possibility. Are there any other universities at the same level as Univ. of Tokyo? The U.S. is bigger, of course, and so we can support more high-level universities. But Japan has about 40% of the U.S. population, according to Wikipedia. That seems big enough to support several top-notch universities. Would the same type of academic cross-fertilization work there? This might be something to think about, although it is more of a national-level problem than a Univ. of Tokyo one.

2-2 Educational achievements of graduate students

As far as I could tell, your graduate students are doing quite well. I cannot evaluate their theses, but they appear to be going to national and international conferences and presenting talks and posters. You are clearly doing a good job of educating the next generation of professors.

2-3 Educational system for undergraduate students

I also see no problems here. The previous external review raised questions as to whether there should be two distinct tracks for undergraduates: Earth and Planetary Physics, and Earth and Planetary Environmental Science. I myself do not see this as serious concern. Some students are naturally more mathematically inclined than others. This statement is supported by my own observations here in the U.S., and I presume it is true in Japan and elsewhere, as well. The students in each program are encouraged to participate in cross-program courses, notably a fieldwork course that I recall being mentioned. So, I see no problems here.

2-4 Educational achievements of undergraduate students

Your undergraduate students are clearly outstanding. I read that 90% of them go on to graduate school, and 40% will receive a Ph.D. This is certainly a much higher level of achievement than we see here at Penn State, and I suspect it is at least as good as the success record of undergraduates at elite private U.S. universities like Harvard, Yale, Princeton, and Stanford (although I have to admit that I do not know the statistics from those schools).

2-5 International activities in education

Opportunities to travel abroad are evidently offered for graduate students. It was less clear that many students were taking advantage of them. My guess is that the encouragement of international travel would be more effective at the postdoc level than at the graduate student level. Postdocs have more experience and fewer educational responsibilities.

3. Organizational Operation

3-1 Organization of the department

The current designation of programs, with five major research areas, seems fine to me. The previous external review expressed some qualms about whether the Earth and Planetary System Science group had enough internal cohesion to constitute an effective group. I see their point, but I am less concerned about it than they were, for the following reason: This group is where the *exoplanet* researchers appear to reside. In case you haven't noticed, the field of exoplanet research appears to be the next big wave in astronomy. I looked up the structure of the University of Tokyo on the Web, and I see that Astronomy is its own (highly respected) department within the Graduate School of Science. The astronomers in the U.S., and in Japan also, I suspect, are very smart, and they are engaged in big projects, both ground- and space-based. Within the next few years, they may obtain transit spectra of rocky exoplanets from NASA's James Webb Space Telecope. Within the next 20-30 years, they will hopefully obtain reflectance (or emission) spectra of rocky exoplanets via direct imaging. Some of this can be done from the ground; more of it can eventually be done from space. When these direct imaging spectra become available, our understanding of planetary systems and of the possibility of life on other planets will increase enormously. The astronomers will *need* the expertise on planetary atmospheres and planetary evolution that exists within your Department in order to interpret what they see. So, I would encourage you to expand this group, rather than getting rid of it, and I would also encourage you to make as many contacts as possible with your Astronomy department. This may already be being done through cooperation with the UTOPS (Univ. of Tokyo Organization for Planetary and Space Science) that is described near the end of your self-assessment report. Exoplanets, and the associated search for extraterrestrial life, is almost certain to remain a hot topic for the next several decades. Make sure that your Department is positioned to take advantage of these discoveries as they occur.

3-2 Policy and system for the appointment of faculty members

I was surprised to see that the rate of turnover in your Department has been quite high during the past 6 or 7 years. Evidently, almost half the faculty has been replaced since 2012. That seems like an awfully high turnover rate to me. Some of this turnover has evidently resulted from other universities that hire away your junior faculty members.

So, I asked myself whether there might be a structural reason for this. Then I read that some of the members have remained as Assistant or Associate professors for more than 10 years. That could not happen here in the U.S. Assistant professors must achieve tenure within 6 years;

otherwise, they are required to leave. This is a good policy. Associate professors with tenure can remain at the Associate level forever if they are not productive. So, we are no different in that respect than you are. But it seems that the policy at the Associate Professor level may be different. Question: Do you have the same type of tenure system in Japan that we have in the U.S.? Having been part of academia now for more than 30 years, I continue to think that our U.S. tenure system basically works. You might want to emulate it if yours is any different.

3-3 Budget and external funds

These items are mostly beyond your control, as they depend on how much money your government wants to devote to scientific research. It looked like you are holding your own, or perhaps gradually increasing in funding. Whatever problems may exist here are probably largely beyond your control.

4. Public partnership, contribution for societies, and outreach

I was quite impressed to read all the things that you are doing for public outreach and for service to various professional societies and journals. Academic service is evidently valued there at Univ. of Tokyo. I encourage you to keep doing what you are doing. It's important to bring the general public along with us as we work on our science.

General comments:

Two other points struck me that I have not mentioned above. Both come from reading the comments from the previous external review.

1) The percentage of female faculty members is still very small compared to that in the U.S. (and I suspect in Europe, as well). Evidently, only 2 of 46 teaching faculty members at the present time are women. The percentage varies a lot between different fields in the U.S., but in our own Department of Geosciences, 9 of 35 faculty members are female, and we are always looking to recruit more of them.

   Some of the difference is likely cultural. We have been encouraging women to enter technical fields for at least 30 or 40 years. It sounds as if you are trying to do the same, but evidently you are somewhat behind us. The problem is not easy to solve, as you have only ~50 faculty positions in the Department, and it must be difficult to offer these up to women who might not be as qualified as their male counterparts. But you can start with undergraduate and graduate education. Make sure you are admitting as many qualified female applicants as you can. These students will be the recruiting grounds for the next generation of professors. The goal is useful in the end. I'm guessing that there are a lot of smart women in Japan, as there are in the U.S., who will take advantage of such opportunities as they become more readily available.

2) I read also that about 80% of the faculty members in your Department are graduates of the University of Tokyo. This, again, is quite different from the U.S. Here, we rarely hire graduates from our own universities. The philosophy is similar to the one I described above regarding undergraduate and graduate institutions. We feel that science is best served if students end up teaching at some place other than where they received their education (especially their graduate education). This also helps to reduce favoritism. It is easy to favor people that you know over those who are strangers. This problem is not unique to academia; it exists in all forms of public and private enterprise. But one can minimize its effects by trying to recruit many, or most, faculty from other universities. This, of course, requires that other strong universities exist. Again, I don't know to what extent this is true in Japan.

   I could go on, I suppose, but I think I have said most of what I have to say. I hope you find at least some of these comments useful. You have a strong Department there in what is also a very strong university. It's nice to see that you are always working to make it even better.

Department of Earth and Planetary Science and UTokyo Organization for Planetary Space Science, Graduate School of Science, the University of Tokyo

External Evaluation by Professor Gregory C. Beroza

Thank you for the opportunity to offer advice to the Department of Earth and Planetary Science and UTokyo Organization for Planetary Space Science. For simplicity I will refer to this as "the department" or "the Department of Earth and Planetary Science" below. I offer my suggestions based on the material provided in the *Data for Self-Assessment and External Review* documents, which represents an exceptionally detailed and comprehensive reporting on the many activities of the department. I provide my remarks coming from the perspective of a solid-Earth geoscience background in seismology, and as a faculty member, and former Chair, of the Department of Geophysics in the School of Earth Sciences at Stanford University. Under each of the topics I provide my thoughts on your situation, and for some of them I make recommendations that the Department and the University may wish to consider. I highlight these with italics. With that as prelude, I offer my comments, organized according to the specific points indicated in your cover letter.

1. Research

The University of Tokyo is internationally renown, as is the Department of Earth and Planetary Science. The department maintains strong and highly regarded research and education programs, and it does so across a very broad spectrum of research topics. Maintaining this excellence and effectively working across this breadth of research scope, particularly in an era where the department is required to shrink the size of its faculty, will be very challenging.

The solid Earth, oceans, atmosphere, the space around Earth, and the bodies of the solar system together form a complex interacting system. Processes that matter to understanding it range in scale from the atomic to the planetary, and in temporal scale from milliseconds to billions of years. Physical, chemical, and biological processes have substantial influence on this complex geosystem and they all interact. People interact with it too, and in impactful ways that are consequential to the future – both for the natural world and for civilization.

The research and teaching of the Department of Earth and Planetary Sciences are important to the need to develop the best possible predictive understanding of how this system works and how its components interact. That understanding needs to be informed not just by the present, but also by events from the deep past.

1-1 Quality and quantity of research compared with the global standard. The 410-page document detailing the accomplishments of individual faculty members is impressive both for its completeness, and for the research productivity it represents. There is considerable variability in the productivity of individual research programs, but the integrated accomplishments are consistent with peer, top-tier research institutions across the globe.

1-2 Diversity of research topics expected from the size of the department. The diversity of research addressed by the department is very high. The University of Tokyo is competing with institutions around the world who have larger faculty in each of these areas. For ~50 faculty to address research on the solid Earth, oceans, atmosphere, space, and planets is exceptionally ambitious. It means that in many sub-fields there will be only one expert in the department. This thinness of coverage presents a challenge for collaborations, and also for students, who benefit from hearing diverse perspectives and approaches to problem solving. I'll comment on the challenges for students in the education section below. For faculty, the thin coverage of a wide range of topics may make it difficult to achieve deep collaborations within the department. It's apparent from the CVs of the individual investigators that many of your faculty successfully collaborate with national and international partners, which is one way to address that challenge.

1-3 Management of research projects. This is a topic on which I have no comments.

1-4 Perspectives of research in each group and the department. Within the five groups in the departments there is again considerable variability across individual research programs, but the integrated accomplishments within each are approximately subequal. That is, each seems to be making important contributions.

2. Education

The educational goals of the department include developing the observational skills, understanding of physical processes, and carrying out systematic integration.

2-1 Educational system for graduate students and 2-2 Educational achievements of graduate students. Students within the program seem well educated and perform well; however, enrollment in the graduate program is highly variable and seems smaller than would be optimal for such an important program. There ought to be more students interested in your research. The Computational Alliance and the UTokyo Ocean Alliance might provide opportunities to reach more students.

Recommendation: The Department should work proactively to recruit students who might not otherwise consider Earth and Space Sciences for their education. Emphasizing and raising the prominence of subfields that could lead to multiple career choices, such as computational geosciences, might be one strategy to accomplish this.

2-3 Educational system for undergraduate students and 2-4 Educational achievements of undergraduate students. The department appears to be primarily focused on the education and development of graduate students, but that doesn't mean that undergraduate education can be ignored. Undergraduates have to learn the fundamentals, and hence the emphasis is necessarily on coursework. Recent additions to the curriculum are responsive to need, and in the case of chemistry and biology, are important to the field. The research ethics is an interesting new addition.

2-5 International activities in education. Compared to many other countries, relatively few Japanese students obtain their degrees from universities outside Japan; yet, science is increasingly internationalized, and it is important that early career scientists form collaborative research networks with other early career scientists around the world. Thus, Japanese students need to get that exposure. The department has been pro-active in pursuing international opportunities for students – both for international students to visit Tokyo, and for students at the University of Tokyo to do internships abroad. The document lists an impressive number of programs that students can take advantage of to do this. You are to be commended for this, and I think it is important that these programs can continue. I know that students in the US are excited about and motivated by the possibility of carrying out research in Tokyo, and I hope the feeling is mutual.

The same benefits hold for undergraduates, though because the undergraduate curriculum is focused more on coursework than research, that international interaction is less essential. Still, the degree to which the STEPS and UTRIP program for hosting international undergraduate students are over-subscribed – by a factor of 30 times – indicates that the demand for these programs is tremendous.

Recommendation: The Department should continue to promote international opportunities, particularly for graduate students.

3. Organizational Operation

3-1 Organization of the department. The organization of the department into four theme-focused group and one group focused on integration reflects the reality that each of the four themes is itself complex and demands focused attention, while also recognizing that these complex systems interact, and that those interactions are important to understand. The theme-focused departments are natural divisions. A natural question to ask is: to what extent does the integrative department carry out integration across other fields?

The research of the individual faculty in the integrated department cover topics as diverse as paleoenvironments, cosmochemistry, comparative planetology, exoplanets, paleontology, and atmospheric chemistry. Scientists with these specialties are only likely to carry out integrative science that concerns a fraction of that represented by the other four focus groups. How are students in the integrated department are educated?

That said, the history of the department indicates that it took extended effort and multiple reorganizations to arrive at the current structure. Such reorganizations require a lot of work, can be extremely disruptive, and so must be considered carefully and with that in mind.

Departmental operations within this organizational framework might be described as a federation, with each of the five groups having some autonomy, but with a central, consultative process for decision making. The process appears to work well, though it inevitably requires a lot of committee participation by the faculty.

3-2 Policy and system for the appointment of faculty members. The decision to reduce the number of faculty from 58 to the current 48 must create substantial pressure on the appointment system because each decision is critical and leaves little margin for error. The department has been creative and resourceful in seeking ways to effectively increase that number to 52.

The number of members across the five groups ranges from 8-12, yet each of those groups cover very broad research areas that involve multiple disciplines. This requires that many research areas be only "one-deep" in faculty expertise. This too must put pressure on faculty and their research groups because they have to be effectively self-sufficient with minimal overlap. The lack of overlap, in turn, makes research collaborations challenging, raising concerns that research groups may work somewhat in isolation.

Finally, the gradual reduction in staff support is, unfortunately, a trend in the same direction. The only area of increased support is for TA positions, which can be extremely (though indirectly) helpful to the continued funding of research through the support of graduate students.

Nearly all the universities in the US that I am familiar with have grown their geoscience departments in the last several decades, with one notable exception. The California Institute of Technology decided many decades ago that they would not grow their faculty – not only in the geosciences, but across all fields. Instead, they choose to keep the size of their faculty fixed, but make sure that the faculty are very well supported such that those faculty they do have are exceptionally effective. Given the modest and declining number of billets in the department at Tokyo, this might be an effective strategy for the university to pursue.

Recommendation: Reversing the trend of reducing management and staff support (as detailed in the budget section below) could be a cost-effective way of ensuring that faculty are as effective as they can be in fulfilling their research and teaching mission.

The document mentions several efforts to achieve better gender balance among the faculty cohort. This can be a difficult issue to overcome in that female students who might otherwise consider careers in academia may be discouraged by the lack of role models – i.e., female faculty who are happy and successful in their careers. For that reason it can be difficult to affect such changes. The more positive aspect is that once such changes occur, they help sustain themselves as more female students will be encouraged to pursue careers in academia.

Recommendation: Despite slow progress, continuing efforts to increase diversity in the department should be pursued. These may include pipeline programs to ensure that promising female students receive effective mentoring and encouragement, as well as programs to support early career professors once they are hired.

The current framework has decisions on faculty hiring carried out based on initiatives within the five groups, but with oversight and consultation at the departmental level. Although this appears to work smoothly, this approach has the potential to limit the flexibility of each of the groups to pursue new research areas, which will in any case be difficult due to the limitations on faculty hiring.

3-3 Budget and external funds. The budget situation appears challenging. Management expenses are variable but show a gradual declining trend. External funding is also somewhat variable but shows a clear increasing trend – at least when integrated over the department and considered over the evaluation period. This indicates that faculty are working hard to make up internal funding shortfalls – essentially doing more with less.

The document notes that indirect expenses included in external funds can be used for purposes not directly related to the research project. It goes on to say that these are "important to support

the finances of the department." This strongly suggests that there is a structural deficit in the departmental operating budget. That is, it appears that the management expenses provided to the department may not be sufficient to cover the true management expenses occurred. If so, and if it is possible, these funds would be better spent as seed funding for exploratory research, or as contingency funding to meet unanticipated budgetary shortfalls, rather than to support ongoing management expenses. There is a hidden opportunity cost to having faculty spend time on administration and fundraising rather than spending that time on the research and teaching they were trained and hired to carry out.

Recommendation: The university should work with the department to eliminate any structural deficit related to ongoing department expenses.

4. Public partnership, contribution for societies, and outreach.

The department is clearly making important contributions to national and international societies. This is important community service and is also important to keeping a high profile for the University. I think it would be helpful for these contributions and the contributions to research to be more widely recognized by the international community.

Recommendation: The Department should consider a canvassing committee to identify accomplished faculty members who are competitive for international recognition and awards, and promote their nomination.

The 21st century is going to be the time during which the finiteness of the Earth becomes apparent and during which boundary conditions strongly impact the human condition. So we need to learn all we can about Earth, and the Department of Earth and Planetary Sciences has an important role to play. The impact of the department's research will depend on interactions with the public and private sectors, where critical policymaking and decisions will be made. These will be best supported by a motivated public that understands the science behind these decisions. This interaction and outreach can not be assumed, but must be actively pursued, such as through the public lectures that you engage in.

It is easy for the public to understand that strategic research, aimed at pressing societal problems is important. To take one example, the fact that Japan is threatened by earthquakes, volcanoes, and tsunami, should make engagement with a motivated public on these topics relatively straightforward It is more difficult to convince the public that curiosity driven research is of value, yet it is critical that the case for pure research be made because the results can have unanticipated impacts. To cite a specific example, attempts to determine the age of the Earth were driven by curiosity rather than strategic considerations. The fact that lead isotope dating was needed for the task, and that it requires extremely clean laboratory conditions, led to the recognition of widespread lead contamination. This recognition led to an awareness of the adverse health effects of environmental lead, and culminated in the banning of lead from household paint, gasoline, and food containers, which was completely unanticipated, but has been of tremendous benefit to societal health. Examples like these can help make the case for continued support for a broad research portfolio.

Recommendation: The Department should pro-actively develop opportunities for public outreach and outreach to policymakers by making the case for a combination of basic research and strategic research.

I saw little mention of social media in your report. Social media, particularly in the teachable moment after significant events or for new and unexpected research findings, provides an effective way to reach a very large audience – particularly young people – and to help convince them that your research is relevant, useful, and worth supporting.

Recommendation: The department should explore the development of social media for public outreach.

I hope you find these recommendations useful. Thank you once again for the privilege of offering them to you.

Sincerely,

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Auckland, January 20th 2020

Dr. Satoshi IDE
Head of the Department of Earth and Planetary Science,
Graduate School of Science,
The University of Tokyo

Dear Dr. IDE

Please find below my evaluation of the Department of Earth and Planetary Science. My evaluation is based on the criteria you provided.

Sincerely

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Research

The department of Earth and Planetary Science comprises 5 major areas of research along with research carried out by affiliated groups and collaborators. Research performed within and outside of the department encompasses a broad range of topics related to Earth and Planetary science. Most researchers within the department are known internationally for their contribution to their field of research. Several researchers have published their work in highly ranked peer-reviewed journals, including Science, Nature and PNAS. There is no doubt that the department of Earth and Planetary Science at the University of Tokyo is one of the best in Japan and that it has a research caliber comparable to other departments in top universities around the world. Based on the self-assessment document, there also appears to be a very good collaboration

between the various groups in the department (when compared to the comments from the last evaluation).

Efforts have been made over the years to recruit outside of the University of Tokyo in order to broaden the scientific vision of the department but it is not as diversified as it should be since several active professors are still former graduates of the University of Tokyo. Having said that, the hiring of T. Takahashi has tremendously help broaden the research activity of the department in fields related to chemistry/ low-temperature geochemistry and biogeosciences.

In addition, despite efforts to recruit more female professors, the department still lacks behind when it comes to gender equality. National and international recruitment of female professors should be a priority for the department in the coming years. The presence of female professors in the department would also act as a recruitment tool for female undergraduate students as female professors are often seen as "role models" for young female students.

Education

The department offers an undergraduate program divided into 2 major programs: Earth and Planetary Physics and Earth and Planetary Environment. It is nice to see that newly hired professors are now members of both programs in order to promote collaboration and that undergraduate students are encouraged to take courses in both programs. Low enrolment in Earth and Planetary sciences is not unique to the University of Tokyo, it is a common problem world-wide. North American initiatives to tackle the problem of low enrollment at the undergraduate level include outreach activities involving high school students (sometimes as young as grade-8th students). The results have been very promising and have generated a genuine interest in how planet Earth works and evolves and how future generations will need to adapt to the ongoing changes we are currently experiencing, including climate change. I would strongly encourage the department to create outreach activities that will engage young brilliant minds eager to learn and be involved in our society.

The department offers 2 healthy graduate programs, i.e., M.Sc. and Ph.D. which appear to be well run and populated. Students are encouraged to present at national and international conferences. The department has also put in place English communication activities in order to ensure that the graduate students can easily express themselves at conferences and convey their scientific findings. I also applaud that creation of the mandatory research ethics course for graduate students. I would recommend extending it to undergraduate students since they do not always know what scientific integrity is all about.

Organizational operation

Despite financial cuts, the department appears to function appropriately. I would only recommend that that the mandate of the Chair of the department be extended to 3 years and be renewed once. Some people make outstanding administrators and they need to be kept in place for a sufficient period of time in order to see growth and positive changes within the department. I am certain that there are such people in the department of Earth and Planetary Science at the University of Tokyo.

Public partnership, contribution for societies and outreach

The department has put in place a series of public partnerships and outreach activities over the years. The outcome of such activities is however not clearly stated in the self-assessment document. What worked and what did not work?