Comments from Public Consultation on ECV Requirements 13/01 – 13/03 2020 for:

# Upper-air temperature

## ECV Product: Atmospheric Temperature in the Upper Troposphere and Lower Stratosphere

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| --- | --- | --- | --- | --- | --- |
| **Name** | Atmospheric Temperature in the Upper Troposphere and Lower Stratosphere | | | | |
| **Definition** | 3D field of the atmospheric temperature in the UTLS | | | | |
| **Unit** | K | | | | |
| **Note** | The following requirements are inferred mainly from the viewpoint of reanalysis and its near-real-time continuation in operational analyses as well as with respect to the magnitude of typical temperature variations at relevant spatial and temporal scales. Some additional considerations are also made, for which explanations are given in notes below respective tables.  For vertical resolution, high vertical resolution is required to diagnose both multiple tropopauses but also trends in tropopause height. | | | | |
| **Requirements** | | | | | |
| **Item needed** | **Unit** | **Metric** | **[1]** | **Value** | **Derivation and References and Standards** |
| **Horizontal Resolution** | km |  | G | 10 | Waller et al. (2016), Thorne et al. (2005)  Roughly corresponds to the current global NWP model resolution, which would be used for next generation reanalyses, ~~and resolves features influenced by local factors such as proximity of water bodies or significant topography.~~ |
| B | 100 | Waller et al. (2016), Thorne et al. (2005).  A  typical horizontal error correlation length in first guess fields and typical scale of mesoscale features that, especially when occurring frequently or with significant amplitude, can affect global climate. ~~For example, Waller et al. (2016) found that error correlations of surface temperature in observation-minus-background and observation-minus-analysis residuals from the Met Office high-resolution model range between 30 km and 80 km. (also for troposphere?\_)~~ |
| T | 500 | Waller et al. (2016), Thorne et al. (2005)  Minimum resolution needed to resolve synoptic-scale waves. Thorne et al., 2005 show typical e-folding correlation distances in radiosonde-measured tropospheric temperatures of at least several 100km and more generally 1000km, with larger values in the tropics. |
| **Vertical Resolution** | m |  | G | 25 | Thorne et al (2005).  This high resolution allows different users the option to subsample or process the data in ways that suit their applications (Ingleby et al. 2016). |
| B | 100 | Roughly corresponds to the assimilating model resolution (Fujiwara et al. 2017) |
| T | 250 | Minimum resolution considering the layer depth |
| **Temporal Resolution** | hr |  | G | 1 | A typical 4D-Var timeslot length, a sub-division into which observations are grouped for processing (ECMWF 2018) |
| B | 12 | A typical time interval between numerical analyses and/or the typical time scale of subsynoptic features |
| T | 24 | Minimum resolution needed to resolve synoptic-scale waves |
| **Timeliness** | hr |  | G | 1 | A typical cut-off time of the operational NWP cycle analysis (JMA 2019), which might also be used for climate monitoring |
| B | 3 | A typical cut-off time for the Climate Data Assimilation System (a near-real time continuation of reanalysis) |
| T | 6 | A typical master decoding cut-off time, beyond which observations are not automatically decoded and incorporated into the operational observation archive |
| **Required Measurement Uncertainty** | K | RMS departures of observed values from first guess field values, in accordance with the practical verification schemes applied by the GUAN Monitoring Centre for upper-air observations. | G | 0.1 | These values are inferred based on the standard deviations of 6-hourly analysis with respect to the monthly climatology. (T) corresponds to regions of high variability, (B) of medium variability and (G) of low variability. |
| B | 0.5 |
| T | 1 |
| **Stability** | K/decade |  | G | 0.01 | These values are based on the need to detect temperature trends such as those observed in recent decades (IPCC 2013; Lübken et al. 2013). (T) corresponds to regions of large trend or 50% of observed global-mean trend, (B) regions of medium trend or 20% of global-mean trend, and (G) regions of small trend or 10% of global-mean trend. |
| B | 0.02 |
| T | 0.05 |
| **Standards and References** | ECMWF, 2018: IFS documentation – Cy45r1, Part I: Observations. ECMWF, UK, 82p. Available at <https://www.ecmwf.int/en/elibrary/18711-part-i-observations>.    Fujiwara, M., 2017: Introduction to the SPARC Reanalysis Intercomparison Project (S-RIP) and overview of the reanalysis systems, Atmos. Chem. Phys., 17, 1417–1452, <https://doi.org/10.5194/acp-17-1417-2017>, 2017.    Ingleby et al., 2016: Progress toward high-resolution, real-time radiosonde reports. Bull. Amer. Meteor. Soc., 97, 2149-2161. <https://doi.org/10.1175/BAMS-D-15-00169.1>.    IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.    JMA, 2019: Outline of the operational numerical weather prediction at the Japan Meteorological Agency, Appendix to WMO Technical Progress Report on the Global Data-processing and Forecasting System (GDPFS) and Numerical Weather Prediction (NWP) Research. Japan Meteorological Agency, Tokyo, Japan. Available at <http://www.jma.go.jp/jma/jma-eng/jma-center/nwp/outline2019-nwp/index.htm>.    Lübken, F.‐J., Berger, U., and Baumgarten, G. ( 2013), Temperature trends in the midlatitude summer mesosphere, J. Geophys. Res. Atmos., 118, 13,347-13,360, doi:10.1002/2013JD020576.    Thorne, P. W., D. E. Parker, et al. (2005). "Revisiting radiosonde upper air temperatures from 1958 to 2002." Journal of Geophysical Research-Atmospheres 110(D18), doi:10.1029/2004JD005753    Thorne, P.W. et al. (2018), Towards a global land surface climate fiducial reference measurements network. IJOC, <http://onlinelibrary.wiley.com/doi/10.1002/joc.5458/full>    Waller, J. E.,\* S. P. Ballard, S. L. Dance, G. Kelly, N. K. Nichols, and David Simonin, 2016: Diagnosing horizontal and inter-channel observation error correlations for SEVIRI observations using observation-minus-background and observation-minus-analysis statistics. Remote Sens. 2016, 8(7), 581, doi:10.3390/rs8070581 | | | | |
| **Adaptation and Extremes** | | | | | |
|  | Relevant? (Yes/No) | Sugg. Req. sufficient? (Yes/No) | Explanation | | |
| **Adaptation[2]** |  |  | Reviewers are invited to suggest answers for these fields | | |
| **Extremes[3]** |  |  | Reviewers are invited to suggest answers for these fields | | |

[1]Goal (G); Breakthrough (B) (not mandatory, more as one possible); Threshold (T), for definitions see [Guidelines](http://tiny.cc/ecv-review)

[2] Is the ECV Product directly relevant to support Climate Adaptation?

[3] Can the ECV Product be used to monitor climate extremes or aspects of extremes?

### Comment 1

|  |  |
| --- | --- |
| Author: Shinya Kobayashi | Email: shn.kobayashi@gmail.com |
| \* Horizontal Resolution  Same as Atmos Temp in the FT.  \* Timeliness  Same as Atmos Temp in the BL. | |

### Comment 2

|  |  |
| --- | --- |
| Author: ECMWF | Email: ecresgcosreqs@gmail.com |
| Regarding reanalysis and NWP ativities at ECMWF, the stated requirements look adequate.  We agree with the post made by Shinya Kobayashi on horizontal correlation lengths.  Progress in estimating multi-annual variability and trends in atmospheric temperature through use of reanalysis has been documented in:  Simmons et al. (2014): Estimating low-frequency variability and trends in atmospheric temperature using ERA-Interim https://doi.org/10.1002/qj.2317 | |

## ECV Product: Atmospheric Temperature in the Middle and Upper Stratosphere

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Name** | Atmospheric Temperature in the Middle and Upper Stratosphere | | | | |
| **Definition** | 3D field of the atmospheric temperature in the middle and upper stratosphere | | | | |
| **Unit** | K | | | | |
| **Note** | The following requirements are inferred mainly from the viewpoint of reanalysis and its near-real-time continuation in operational analyses as well as with respect to the magnitude of typical temperature variations at relevant spatial and temporal scales. Some additional considerations are also made, for which explanations are given in notes below respective tables.  Correlation distances on climate timescales are much larger in the stratosphere than the troposphere. The dynamical processes are distinct as is the degree of stratification which leads to lower requirements for both vertical and spatial resolution. Some large-scale waves are common to the upper stratosphere and lower mesosphere, with horizontal scales of around 2500 km.  Historical and projected future trends are larger so commensurately the stability requirements can be relaxed accordingly. | | | | |
| **Requirements** | | | | | |
| **Item needed** | **Unit** | **Metric** | **[1]** | **Value** | **Derivation and References and Standards** |
| **Horizontal Resolution** | km |  | G | 50 | Thorne et al. (2005), Vincent (2015)  Roughly corresponds to the current global NWP model resolution, which would be used for next generation reanalyses. |
| B | 100 | Thorne et al. (2005), Vincent (2015)  A  typical horizontal error correlation length in first guess fields and typical scale of mesoscale features that, especially when occurring frequently or with significant amplitude, can affect global climate. |
| T | 1500 | Thorne et al. (2005), Vincent (2015)  Minimum resolution needed to resolve synoptic-scale waves. Thorne et al., 2005 show typical e-folding correlation distances in radiosonde-measured tropospheric temperatures of at least several 100km and more generally 1000km, with larger values in the tropics. |
| **Vertical Resolution** | km |  | G | 0.5 | This high resolution allows different users the option to subsample or process the data in ways that suit their applications (Ingleby et al. 2016). |
| B | 1 | Roughly corresponds to the assimilating model resolution (Fujiwara et al. 2017) |
| T | 2 | Minimum resolution considering the layer depth |
| **Temporal Resolution** | hr |  | G | 1 | A typical 4D-Var timeslot length, a sub-division into which observations are grouped for processing (ECMWF 2018) |
| B | 12 | A typical time interval between numerical analyses and/or the typical time scale of subsynoptic features |
| T | 24 | Minimum resolution needed to resolve synoptic-scale waves |
| **Timeliness** | hr |  | G | 1 | A typical cut-off time of the operational NWP cycle analysis (JMA 2019), which might also be used for climate monitoring |
| B | 3 | A typical cut-off time for the Climate Data Assimilation System (a near-real time continuation of reanalysis) |
| T | 6 | A typical master decoding cut-off time, beyond which observations are not automatically decoded and incorporated into the operational observation archive |
| **Required Measurement Uncertainty** | K | RMS departures of observed values from first guess field values, in accordance with the practical verification schemes applied by the GUAN Monitoring Centre for upper-air observations. | G | 0.1 | These values are inferred based on the standard deviations of 6-hourly analysis with respect to the monthly climatology. (T) corresponds to regions of high variability, (B) of medium variability and (G) of low variability. |
| B | 0.5 |
| T | 1 |
| **Stability** | K/decade |  | G | 0.05 | These values are based on the need to detect temperature trends such as those observed in recent decades (IPCC 2013; Lübken et al. 2013). (T) corresponds to regions of large trend or 50% of observed global-mean trend, (B) regions of medium trend or 20% of global-mean trend, and (G) regions of small trend or 10% of global-mean trend.  IPCC(2013) |
| B | 0.1 |
| T | 0.2 |
| **Standards and References** | ECMWF, 2018: IFS documentation – Cy45r1, Part I: Observations. ECMWF, UK, 82p. Available at <https://www.ecmwf.int/en/elibrary/18711-part-i-observations>.    Fujiwara, M., 2017: Introduction to the SPARC Reanalysis Intercomparison Project (S-RIP) and overview of the reanalysis systems, Atmos. Chem. Phys., 17, 1417–1452, <https://doi.org/10.5194/acp-17-1417-2017>, 2017.    Ingleby et al., 2016: Progress toward high-resolution, real-time radiosonde reports. Bull. Amer. Meteor. Soc., 97, 2149-2161. <https://doi.org/10.1175/BAMS-D-15-00169.1>.    IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.    JMA, 2019: Outline of the operational numerical weather prediction at the Japan Meteorological Agency, Appendix to WMO Technical Progress Report on the Global Data-processing and Forecasting System (GDPFS) and Numerical Weather Prediction (NWP) Research. Japan Meteorological Agency, Tokyo, Japan. Available at <http://www.jma.go.jp/jma/jma-eng/jma-center/nwp/outline2019-nwp/index.htm>.    Lübken, F.‐J., Berger, U., and Baumgarten, G. ( 2013), Temperature trends in the midlatitude summer mesosphere, J. Geophys. Res. Atmos., 118, 13,347-13,360, doi:10.1002/2013JD020576.    Thorne, P. W., D. E. Parker, et al. (2005). "Revisiting radiosonde upper air temperatures from 1958 to 2002." Journal of Geophysical Research-Atmospheres 110(D18), doi:10.1029/2004JD005753    Vincent, R. A., 2015: The dynamics of the mesosphere and lower thermosphere: a brief review. | | | | |
| **Adaptation and Extremes** | | | | | |
|  | Relevant? (Yes/No) | Sugg. Req. sufficient? (Yes/No) | Explanation | | |
| **Adaptation[2]** |  |  | Reviewers are invited to suggest answers for these fields | | |
| **Extremes[3]** |  |  | Reviewers are invited to suggest answers for these fields | | |

[1]Goal (G); Breakthrough (B) (not mandatory, more as one possible); Threshold (T), for definitions see [Guidelines](http://tiny.cc/ecv-review)

[2] Is the ECV Product directly relevant to support Climate Adaptation?

[3] Can the ECV Product be used to monitor climate extremes or aspects of extremes?

### Comment 1

|  |  |
| --- | --- |
| Author: Shinya Kobayashi | Email: shn.kobayashi@gmail.com |
| \* Timeliness  Same as Atmos Temp in the BL. | |

### Comment 2

|  |  |
| --- | --- |
| Author: ECMWF | Email: ecresgcosreqs@gmail.com |
| Regarding reanalysis and NWP ativities at ECMWF, the stated requirements look adequate.  In this part of the atmosphere we would argue that the systematic component is the largest component of Uncertainty.  Good bias corrections are available for radiosonde observations (e.g., Haimberger et al. 2012, https://doi.org/10.1175/JCLI-D-11-00668.1) and so are the large amount of GNSS-RO observations from the 2000s onwards. These are typically available up to 5 hPa. Above that the availability of anchored observations (i.e., those that can be taken as is, and don't need bias corrections) is very sparse, and the systematic error of reanalysis products is an interplay between model bias and changes in the observing system (such as the transition from SSU to AMSU-A in 1998).  We agree with the post made by Shinya Kobayashi on horizontal correlation lengths.  Progress in estimating multi-annual variability and trends in atmospheric temperature through use of reanalysis has been documented in:  Simmons et al. (2014): Estimating low-frequency variability and trends in atmospheric temperature using ERA-Interim https://doi.org/10.1002/qj.2317 | |

## ECV Product: Atmospheric Temperature in the Mesosphere

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Name** | Atmospheric Temperature in the Mesosphere | | | | |
| **Definition** | 3D field of the atmospheric temperature in the mesosphere | | | | |
| **Unit** | K | | | | |
| **Note** | The following requirements are inferred mainly from the viewpoint of reanalysis and its near-real-time continuation in operational analyses as well as with respect to the magnitude of typical temperature variations at relevant spatial and temporal scales. Some additional considerations are also made, for which explanations are given in notes below respective tables.  Horizontal resolution, vertical resolution, temporal sampling, and uncertainty thresholds are based on the scales and amplitudes of typical dynamical features of the mesosphere. Trends and current uncertainties are larger than in the troposphere, so stability criteria can also be relaxed. | | | | |
| **Requirements** | | | | | |
| **Item needed** | **Unit** | **Metric** | **[1]** | **Value** | **Derivation and References and Standards** |
| **Horizontal Resolution** | km |  | G | 50 | Garcia (2005), Vincent (2015)  Roughly corresponds to the current global NWP model resolution, which would be used for next generation reanalyses. |
| B | 100 | Garcia (2005), Vincent (2015)  A  typical horizontal error correlation length in first guess fields and typical scale of mesoscale features that, especially when occurring frequently or with significant amplitude, can affect global climate. |
| T | 1500 | Garcia (2005), Vincent (2015)  Minimum resolution needed to resolve synoptic-scale waves. Thorne et al., 2005 show typical e-folding correlation distances in radiosonde-measured tropospheric temperatures of at least several 100km and more generally 1000km, with larger values in the tropics. |
| **Vertical Resolution** | km |  | G | 0.5 | Garcia (2005), Vincent (2015)  This high resolution allows different users the option to subsample or process the data in ways that suit their applications (Ingleby et al. 2016). |
| B | 1 | Garcia (2005), Vincent (2015)  Roughly corresponds to the assimilating model resolution (Fujiwara et al. 2017) |
| T | 2 | Garcia (2005), Vincent (2015)  Minimum resolution considering the layer depth |
| **Temporal Resolution** | hr |  | G | 1 | A typical 4D-Var timeslot length, a sub-division into which observations are grouped for processing (ECMWF 2018) |
| B | 12 | A typical time interval between numerical analyses and/or the typical time scale of subsynoptic features |
| T | 24 | Minimum resolution needed to resolve synoptic-scale waves |
| **Timeliness** | hr |  | G | 1 | A typical cut-off time of the operational NWP cycle analysis (JMA 2019), which might also be used for climate monitoring |
| B | 3 | A typical cut-off time for the Climate Data Assimilation System (a near-real time continuation of reanalysis) |
| T | 6 | A typical master decoding cut-off time, beyond which observations are not automatically decoded and incorporated into the operational observation archive |
| **Required Measurement Uncertainty** | K | RMS departures of observed values from first guess field values, in accordance with the practical verification schemes applied by the GUAN Monitoring Centre for upper-air observations. | G | 0.1 | Garcia (2005), Vincent (2015)  These values are inferred based on the standard deviations of 6-hourly analysis with respect to the monthly climatology. (T) corresponds to regions of high variability, (B) of medium variability and (G) of low variability. |
| B | 0.5 |
| T | 1 |
| **Stability** | K/decade |  | G | 0.05 | Lübken et al. (2013).  These values are based on the need to detect temperature trends such as those observed in recent decades (IPCC 2013; Lübken et al. 2013). (T) corresponds to regions of large trend or 50% of observed global-mean trend, (B) regions of medium trend or 20% of global-mean trend, and (G) regions of small trend or 10% of global-mean trend. |
| B | 0.1 |
| T | 0.2 |
| **Standards and References** | ECMWF, 2018: IFS documentation – Cy45r1, Part I: Observations. ECMWF, UK, 82p. Available at <https://www.ecmwf.int/en/elibrary/18711-part-i-observations>.    Fujiwara, M., 2017: Introduction to the SPARC Reanalysis Intercomparison Project (S-RIP) and overview of the reanalysis systems, Atmos. Chem. Phys., 17, 1417–1452, <https://doi.org/10.5194/acp-17-1417-2017>, 2017.    Garcia, R. A., 2005: Large-Scale waves in the mesosphere and lower thermosphere Observed by SABER. Journal of Atmospheric Sciences, 62, 10.1175/JAS3612.1.    Ingleby et al., 2016: Progress toward high-resolution, real-time radiosonde reports. Bull. Amer. Meteor. Soc., 97, 2149-2161. <https://doi.org/10.1175/BAMS-D-15-00169.1>.    IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.    JMA, 2019: Outline of the operational numerical weather prediction at the Japan Meteorological Agency, Appendix to WMO Technical Progress Report on the Global Data-processing and Forecasting System (GDPFS) and Numerical Weather Prediction (NWP) Research. Japan Meteorological Agency, Tokyo, Japan. Available at <http://www.jma.go.jp/jma/jma-eng/jma-center/nwp/outline2019-nwp/index.htm>.    Lübken, F.‐J., Berger, U., and Baumgarten, G. ( 2013), Temperature trends in the midlatitude summer mesosphere, J. Geophys. Res. Atmos., 118, 13,347-13,360, doi:10.1002/2013JD020576.    Thorne, P. W., D. E. Parker, et al. (2005). "Revisiting radiosonde upper air temperatures from 1958 to 2002." Journal of Geophysical Research-Atmospheres 110(D18), doi:10.1029/2004JD005753    Vincent, R. A., 2015: The dynamics of the mesosphere and lower thermosphere: a brief review. | | | | |
| **Adaptation and Extremes** | | | | | |
|  | Relevant? (Yes/No) | Sugg. Req. sufficient? (Yes/No) | Explanation | | |
| **Adaptation[2]** |  |  | Reviewers are invited to suggest answers for these fields | | |
| **Extremes[3]** |  |  | Reviewers are invited to suggest answers for these fields | | |

[1]Goal (G); Breakthrough (B) (not mandatory, more as one possible); Threshold (T), for definitions see [Guidelines](http://tiny.cc/ecv-review)

[2] Is the ECV Product directly relevant to support Climate Adaptation?

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### Comment 1

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| --- | --- |
| Author: Shinya Kobayashi | Email: shn.kobayashi@gmail.com |
| \* Timeliness  Same as Atmos Temp in the BL. | |

### Comment 2

|  |  |
| --- | --- |
| Author: ECMWF | Email: ecresgcosreqs@gmail.com |
| Regarding reanalysis and NWP ativities at ECMWF, the stated requirements look adequate.  In this part of the atmosphere we would argue that the systematic component is the largest component of Uncertainty.  The availability of anchored observations (i.e., those that can be taken as is, and don't need bias corrections) is very sparse, and the systematic error of reanalysis products is an interplay between model bias and changes in the observing system.  We agree with the post made by Shinya Kobayashi on horizontal correlation lengths.  Progress in estimating multi-annual variability and trends in atmospheric temperature through use of reanalysis has been documented in:  Simmons et al. (2014): Estimating low-frequency variability and trends in atmospheric temperature using ERA-Interim https://doi.org/10.1002/qj.2317 | |

## ECV Product: Atmospheric Temperature in the Free Troposphere

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Name** | Atmospheric Temperature in the Free Troposphere | | | | |
| **Definition** | 3D field of the atmospheric temperature in the troposphere | | | | |
| **Unit** | K | | | | |
| **Note** | The following requirements are inferred mainly from the viewpoint of reanalysis and its near-real-time continuation in operational analyses as well as with respect to the magnitude of typical temperature variations at relevant spatial and temporal scales. Some additional considerations are also made, for which explanations are given in notes below respective tables. | | | | |
| **Requirements** | | | | | |
| **Item needed** | **Unit** | **Metric** | **[1]** | **Value** | **Derivation and References and Standards** |
| **Horizontal Resolution** | km |  | G | 10 | Waller et al. (2016), Thorne et al. (2005)  Roughly corresponds to the current global NWP model resolution, which would be used for next generation reanalyses, and resolves features influenced by local factors such as proximity of water bodies or significant topography. |
| B | 100 | Waller et al. (2016), Thorne et al. (2005).  A  typical horizontal error correlation length in first guess fields and typical scale of mesoscale features that, especially when occurring frequently or with significant amplitude, can affect global climate. For example, Waller et al. (2016) found that error correlations of surface temperature in observation-minus-background and observation-minus-analysis residuals from the Met Office high-resolution model range between 30 km and 80 km. (also for troposphere?) |
| T | 1000 | Waller et al. (2016), Thorne et al. (2005)  Minimum resolution needed to resolve synoptic-scale waves. Thorne et al., 2005 show typical e-folding correlation distances in radiosonde-measured tropospheric temperatures of at least several 100km and more generally 1000km, with larger values in the tropics. |
| **Vertical Resolution** | km |  | G | 0.01 | This high resolution allows different users the option to subsample or process the data in ways that suit their applications (Ingleby et al. 2016).  Determining fluxes requires high vertical fidelity. |
| B | 0.1 | Roughly corresponds to the assimilating model resolution (Fujiwara et al. 2017) |
| T | 1 | Minimum resolution considering the layer depth |
| **Temporal Resolution** | hr |  | G | 1 | A typical 4D-Var timeslot length, a sub-division into which observations are grouped for processing (ECMWF 2018) |
| B | 12 | A typical time interval between numerical analyses and/or the typical time scale of subsynoptic features |
| T | 24 | Minimum resolution needed to resolve synoptic-scale waves |
| **Timeliness** | hr |  | G | 1 | A typical cut-off time of the operational NWP cycle analysis (JMA 2019), which might also be used for climate monitoring |
| B | 3 | A typical cut-off time for the Climate Data Assimilation System (a near-real time continuation of reanalysis) |
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| **Required Measurement Uncertainty** | K | RMS departures of observed values from first guess field values, in accordance with the practical verification schemes applied by the GUAN Monitoring Centre for upper-air observations. | G | 0.1 | These values are inferred based on the standard deviations of 6-hourly analysis with respect to the monthly climatology. (T) corresponds to regions of high variability, (B) of medium variability and (G) of low variability. |
| B | 0.5 |
| T | 1 |
| **Stability** | K/decade |  | G | 0.01 | IPCC(2013)  These values are based on the need to detect temperature trends such as those observed in recent decades (IPCC 2013; Lübken et al. 2013). (T) corresponds to regions of large trend or 50% of observed global-mean trend, (B) regions of medium trend or 20% of global-mean trend, and (G) regions of small trend or 10% of global-mean trend. |
| B | 0.02 |
| T | 0.05 |
| **Standards and References** | ECMWF, 2018: IFS documentation – Cy45r1, Part I: Observations. ECMWF, UK, 82p. Available at <https://www.ecmwf.int/en/elibrary/18711-part-i-observations>.    Fujiwara, M., 2017: Introduction to the SPARC Reanalysis Intercomparison Project (S-RIP) and overview of the reanalysis systems, Atmos. Chem. Phys., 17, 1417–1452, <https://doi.org/10.5194/acp-17-1417-2017>, 2017.    Ingleby et al., 2016: Progress toward high-resolution, real-time radiosonde reports. Bull. Amer. Meteor. Soc., 97, 2149-2161. <https://doi.org/10.1175/BAMS-D-15-00169.1>.    IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.    JMA, 2019: Outline of the operational numerical weather prediction at the Japan Meteorological Agency, Appendix to WMO Technical Progress Report on the Global Data-processing and Forecasting System (GDPFS) and Numerical Weather Prediction (NWP) Research. Japan Meteorological Agency, Tokyo, Japan. Available at <http://www.jma.go.jp/jma/jma-eng/jma-center/nwp/outline2019-nwp/index.htm>.    Lübken, F.‐J., Berger, U., and Baumgarten, G. ( 2013), Temperature trends in the midlatitude summer mesosphere, J. Geophys. Res. Atmos., 118, 13,347-13,360, doi:10.1002/2013JD020576.    Thorne, P. W., D. E. Parker, et al. (2005). "Revisiting radiosonde upper air temperatures from 1958 to 2002." Journal of Geophysical Research-Atmospheres 110(D18), doi:10.1029/2004JD005753    Thorne, P.W. et al. (2018), Towards a global land surface climate fiducial reference measurements network. IJOC, <http://onlinelibrary.wiley.com/doi/10.1002/joc.5458/full>    Waller, J. E.,\* S. P. Ballard, S. L. Dance, G. Kelly, N. K. Nichols, and David Simonin, 2016: Diagnosing horizontal and inter-channel observation error correlations for SEVIRI observations using observation-minus-background and observation-minus-analysis statistics. Remote Sens. 2016, 8(7), 581, doi:10.3390/rs8070581 | | | | |
| **Adaptation and Extremes** | | | | | |
|  | Relevant? (Yes/No) | Sugg. Req. sufficient? (Yes/No) | Explanation | | |
| **Adaptation[2]** |  |  | Reviewers are invited to suggest answers for these fields | | |
| **Extremes[3]** |  |  | Reviewers are invited to suggest answers for these fields | | |

[1]Goal (G); Breakthrough (B) (not mandatory, more as one possible); Threshold (T), for definitions see [Guidelines](http://tiny.cc/ecv-review)

[2] Is the ECV Product directly relevant to support Climate Adaptation?

[3] Can the ECV Product be used to monitor climate extremes or aspects of extremes?

### Comment 1

|  |  |
| --- | --- |
| Author: Shinya Kobayashi | Email: shn.kobayashi@gmail.com |
| \* Horizontal Resolution  I think that the reference cited here (Waller et al. 2016) is about the horizontal error correlation estimated for the SEVERI observations, but the background error covariances would be more relevant for this requirement. Hersbach et al. (2018) shows examples of the background error covariances prescribed for the latest-generation reanalysis, where the horizontal correlation decreases below 1/e within the length of 500 km or less in the troposphere. It should be noted that the correlation length depends on the data assimilation system used as well as the observing system assimilated for making initial conditions. In general, the correlation length tends to be shorter when the data assimilation system has a higer resolution and is more advanced as well as the observations assimilated have a higher density. In order to produce reanalysis data with accuracy comparable to NWP, the requirements needs to be similar to those for NWP, as already proposed in the table.  Hersbach et al. (2018): Operational global reanalysis: progress, future directions and synergies with NWP. ERA Report Series, 27. http://dx.doi.org/10.21957/tkic6g3wm.  \* Timeliness  Same as Atmos Temp in the BL. | |

### Comment 2

|  |  |
| --- | --- |
| Author: ECMWF | Email: ecresgcosreqs@gmail.com |
| Regarding reanalysis and NWP ativities at ECMWF, the stated requirements look adequate.  We agree with the post made by Shinya Kobayashi on horizontal correlation lengths.  Progress in estimating multi-annual variability and trends in atmospheric temperature through use of reanalysis has been documented in:  Simmons et al. (2014): Estimating low-frequency variability and trends in atmospheric temperature using ERA-Interim https://doi.org/10.1002/qj.2317 | |

## ECV Product: Atmospheric Temperature in the Boundary Layer

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Name** | Atmospheric Temperature in the Boundary Layer | | | | |
| **Definition** | 3D field of the atmospheric temperature in the Boundary Layer | | | | |
| **Unit** | K | | | | |
| **Note** | The following requirements are inferred mainly from the viewpoint of reanalysis and its near-real-time continuation in operational analyses as well as with respect to the magnitude of typical temperature variations at relevant spatial and temporal scales. Some additional considerations are also made, for which explanations are given in notes below respective tables.  The requirements for temperature in the boundary layer  are mainly driven by needs for monitoring of fluxes for the goal threshold. Stability assumes independence of measurements between instruments permitting partial cancellation and is based upon need to be able to detect current trends which are c.0.2 K/decade.  Boundary layer temperature is assumed to share spatial characteristics with surface temperature for which this has been characterized in e.g. Thorne et al., 2018 | | | | |
| **Requirements** | | | | | |
| **Item needed** | **Unit** | **Metric** | **[1]** | **Value** | **Derivation and References and Standards** |
| **Horizontal Resolution** | km |  | G | 10 | Waller et al. (2016), Thorne et al. (2018).    Roughly corresponds to the current global NWP model resolution, which would be used for next generation reanalyses, and resolves features influenced by local factors such as proximity of water bodies or significant topography. |
| B | 100 | Waller et al. (2016), Thorne et al. (2018).    A  typical horizontal error correlation length in first guess fields and typical scale of mesoscale features that, especially when occurring frequently or with significant amplitude, can affect global climate. For example, Waller et al. (2016) found that error correlations of surface temperature in observation-minus-background and observation-minus-analysis residuals from the Met Office high-resolution model range between 30 km and 80 km. |
| T | 500 | Waller et al. (2016), Thorne et al. (2018).  Minimum resolution needed to resolve synoptic-scale waves. Thorne et al., 2005 show typical e-folding correlation distances in radiosonde-measured tropospheric temperatures of at least several 100km and more generally 1000km, with larger values in the tropics. |
| **Vertical Resolution** | m |  | G | 1 | This high resolution allows different users the option to subsample or process the data in ways that suit their applications (Ingleby et al. 2016).  Determining fluxes requires high vertical fidelity. |
| B | 10 | Roughly corresponds to the assimilating model resolution (Fujiwara et al. 2017) |
| T | 250 | Minimum resolution considering the layer depth |
| **Temporal Resolution** | hr |  | G | Sub-hourly | A typical 4D-Var timeslot length, a sub-division into which observations are grouped for processing (ECMWF 2018) |
| B | 6 | A typical time interval between numerical analyses and/or the typical time scale of subsynoptic features |
| T | 12 | Minimum resolution needed to resolve synoptic-scale waves |
| **Timeliness** | hr |  | G | 1 | A typical cut-off time of the operational NWP cycle analysis (JMA 2019), which might also be used for climate monitoring |
| B | 3 | A typical cut-off time for the Climate Data Assimilation System (a near-real time continuation of reanalysis) |
| T | 24 | A typical master decoding cut-off time, beyond which observations are not automatically decoded and incorporated into the operational observation archive |
| **Required Measurement Uncertainty** | K | RMS departures of observed values from first guess field values, in accordance with the practical verification schemes applied by the GUAN Monitoring Centre for upper-air observations. | G | 0.1 | These values are inferred based on the standard deviations of 6-hourly analysis with respect to the monthly climatology. (T) corresponds to regions of high variability, (B) of medium variability and (G) of low variability. |
| B | 0.5 |
| T | 1 |
| **Stability** | K/decade |  | G | 0.01 | These values are based on the need to detect temperature trends such as those observed in recent decades (IPCC 2013). (T) corresponds to regions of large trend or 50% of observed global-mean trend, (B) regions of medium trend or 20% of global-mean trend, and (G) regions of small trend or 10% of global-mean trend. |
| B | 0.05 |
| T | 0.1 |
| **Standards and References** | ECMWF, 2018: IFS documentation – Cy45r1, Part I: Observations. ECMWF, UK, 82p. Available at <https://www.ecmwf.int/en/elibrary/18711-part-i-observations>.    Fujiwara, M., 2017: Introduction to the SPARC Reanalysis Intercomparison Project (S-RIP) and overview of the reanalysis systems, Atmos. Chem. Phys., 17, 1417–1452, <https://doi.org/10.5194/acp-17-1417-2017>, 2017.    Ingleby et al., 2016: Progress toward high-resolution, real-time radiosonde reports. Bull. Amer. Meteor. Soc., 97, 2149-2161. <https://doi.org/10.1175/BAMS-D-15-00169.1>.    IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.    JMA, 2019: Outline of the operational numerical weather prediction at the Japan Meteorological Agency, Appendix to WMO Technical Progress Report on the Global Data-processing and Forecasting System (GDPFS) and Numerical Weather Prediction (NWP) Research. Japan Meteorological Agency, Tokyo, Japan. Available at <http://www.jma.go.jp/jma/jma-eng/jma-center/nwp/outline2019-nwp/index.htm>.    Thorne, P. W., D. E. Parker, et al. (2005). "Revisiting radiosonde upper air temperatures from 1958 to 2002." Journal of Geophysical Research-Atmospheres 110(D18), doi:10.1029/2004JD005753    Thorne, P.W. et al. (2018), Towards a global land surface climate fiducial reference measurements network. IJOC, <http://onlinelibrary.wiley.com/doi/10.1002/joc.5458/full>    Waller, J. E.,\* S. P. Ballard, S. L. Dance, G. Kelly, N. K. Nichols, and David Simonin, 2016: Diagnosing horizontal and inter-channel observation error correlations for SEVIRI observations using observation-minus-background and observation-minus-analysis statistics. Remote Sens. 2016, 8(7), 581, doi:10.3390/rs8070581 | | | | |
| **Adaptation and Extremes** | | | | | |
|  | Relevant? (Yes/No) | Sugg. Req. sufficient? (Yes/No) | Explanation | | |
| **Adaptation[2]** |  |  | Reviewers are invited to suggest answers for these fields | | |
| **Extremes[3]** |  |  | Reviewers are invited to suggest answers for these fields | | |

[1]Goal (G); Breakthrough (B) (not mandatory, more as one possible); Threshold (T), for definitions see [Guidelines](http://tiny.cc/ecv-review)

[2] Is the ECV Product directly relevant to support Climate Adaptation?

[3] Can the ECV Product be used to monitor climate extremes or aspects of extremes?

### Comment 1

|  |  |
| --- | --- |
| Author: Shinya Kobayashi | Email: shn.kobayashi@gmail.com |
| \* Horizontal Resolution  Same as Atmos Temp in the FT.  \* Timeliness  Given a longer cut-off-time for near-real-time continuation of reanalysis than that for NWP, the timeliness requirements could be relaxed, for example, to 6 hr (Goal), 12 to 24 hr (Breakthrough) and 2 day (Threshold) respectively. | |

### Comment 2

|  |  |
| --- | --- |
| Author: ECMWF | Email: ecresgcosreqs@gmail.com |
| Regarding reanalysis and NWP ativities at ECMWF, the stated requirements look adequate.  We agree with the post made by Shinya Kobayashi on horizontal correlation lengths.  Progress in estimating multi-annual variability and trends in atmospheric temperature through use of reanalysis has been documented in:  Simmons et al. (2014): Estimating low-frequency variability and trends in atmospheric temperature using ERA-Interim https://doi.org/10.1002/qj.2317 | |